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La dimensión social en la evaluación de tecnologías: el caso del etanol utilizado como biocombustible

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Für meinen lieben Opa

(A mi querido abuelito)

"(...) the resistance to the machine was quite consciously resistance to the machine in the hands of the capitalist."

Eric Hobsbawn, 1952, a respecto del
movimiento ludita en Inglaterra del siglo XIX

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La presente tesis doctoral corresponde a un compendio de trabajos previamente publicados, aceptados para publicación o enviados para publicación, que se especifican a continuación:

1. Ribeiro, B. E. [1] (2012). From first to second generation biofuels: putting social aspects on the scale. En A. Agustoni y M. Maretti (Eds.), *Energy Issues and Social Sciences: Theories and Applications* (pp. 79-94). Milan: McGraw-Hill. ISBN: 9788838673627.

2. Ribeiro, B. E. [1] (en prensa). El desarrollo de una matriz social para la evaluación de impacto de los biocombustibles. *ArtefaCToS*. ISSN-e: 1989-3612.

3. Ribeiro, B. E. [1] (2013). Beyond commonplace biofuels: social aspects of ethanol. *Energy Policy, 57*, 355-362. ISSN: 0301-4215. DOI: 10.1016/j.enpol.2013.02.004.

4. Ribeiro, B. E. [1] y Quintanilla, M. A. [2] (2014). *Transitions in biofuel technologies: an appraisal of the social impacts of cellulosic ethanol using the Delphi method*. Enviado a Technological Forecasting and Social Change (TFSC-14-193).

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CERTIFICAN:

Que el trabajo doctoral por compendio de artículos o publicaciones realizado bajo su dirección por Dª Barbara Esteves Ribeiro, titulado *"La dimensión social en la evaluación de tecnologías: el caso del etanol utilizado como biocombustible"*, reúne las condiciones de originalidad requeridas para optar al grado de Doctor en Estudios Sociales de la Ciencia y la Tecnología por la Universidad de Salamanca.

Y para que así conste, firman la presente certificación en Salamanca, a 17 de junio de 2014

Fdo. Prof. Miguel Ángel Quintanilla Fisac Fdo. Profª. Ana Cuevas Badallo

Resumen

Los biocombustibles constituyen una de las mayores apuestas políticas en materia de alternativas energéticas para el sector de transporte bajo el paradigma del cambio climático y frente al pico en la producción de petróleo. Estados Unidos y Brasil lideran la producción de etanol de primera generación a partir del maíz y de la caña de azúcar, actualmente el biocombustible más producido en el mundo. La Unión Europea igualmente representa un importante mercado para la exportación de etanol y, aunque en menores cantidades, produce el biocombustible desde distintas materias primas como el trigo, la remolacha azucarera y también desde el maíz. Paralelamente a su ascensión como alternativa 'más sostenible' al uso de petróleo en motores de combustión interna, los biocombustibles han sido foco de escrutinio público y científico en función de sus impactos ambientales y sociales. Tales críticas han motivado el apoyo a tecnologías emergentes para la producción de etanol. Concretamente, a procesos que permiten la utilización de materia prima no-alimentaria proveniente de cultivos energéticos específicos o de residuos y desechos para la producción del etanol de segunda generación, o celulósico. Sin embargo, a pesar de la demanda de análisis científicos más robustos sobre la sostenibilidad de los biocombustibles, la literatura dedicada a la evaluación de la dimensión social de sus impactos, en concreto la del etanol de primera generación y el etanol celulósico es todavía escasa y suele tratar el tema de manera superficial. De lo que se ocupa esta tesis doctoral y los artículos incluidos en ella, es de investigar la dimensión social de los impactos del etanol utilizado como biocombustible y de las tecnologías emergentes relacionadas con el etanol celulósico. Además de contribuir a llenar este importante hueco en la literatura, la investigación ha procurado sobre todo arrojar luz sobre la complejidad de los impactos sociales del etanol y explorar algunas de las consecuencias de sus tecnologías emergentes. Las principales conclusiones de esta tesis indican que la dimensión social de los impactos del etanol es muchas veces inseparable de la ambiental, por lo que evaluaciones integradas de desarrollos como estos son muy útiles. Para ello, se necesitan enfoques interdisciplinares capaces de articular las dos dimensiones, algo que es poco frecuente en los estudios de la sostenibilidad de los biocombustibles. Asimismo, los contextos socioeconómicos y ambientales específicos dónde se implementan los proyectos son decisivos en los

tipos de impactos –positivos o negativos– de estas tecnologías, los cuales varían también según los grupos sociales afectados. Se sugiere que puede haber diferencias significativas entre países pobres y ricos, con distintas implicaciones para países exportadores e importadores de etanol. Se enfatiza, por tanto, la importancia de involucrar distintos actores en los procesos de evaluación de estas tecnologías, sobre todo porque una identificación y valoración más robusta de estos impactos para informar los procesos de toma de decisiones depende de una consulta con agricultores, comunidades rurales, representantes de la industria y poblaciones urbanas. Los trabajos desarrollados en esta tesis también indican que las innovaciones tecnológicas en la producción de etanol no garantizan necesariamente una superación de los impactos sociales de este biocombustible. Sin embargo, los estudios apuntan hacia determinadas rutas tecnológicas para la producción de etanol celulósico que parecen ser más "aceptables" que otras desde la perspectiva de su sostenibilidad social. Se subraya, no obstante, que el análisis de los distintos factores que influyen en la producción de los impactos es una tarea compleja. Por último, se concluye que las evaluaciones de tecnologías emergentes como las del etanol celulósico deben, por tanto, atender a cuatro criterios principales: intentar influir en las trayectorias tecnológicas todavía en fase inicial de desarrollo del sistema técnico, cuando este es más reversible; definir los objetivos de la tecnología evaluada y considerar alternativas anticipadamente; clarificar la interacción entre los factores contextuales y el sistema técnico para evaluar su desempeño; e involucrar distintos actores en el proceso de evaluación.

Índice

1 Introducción

La historia de las civilizaciones se sostiene en la de la relación entre el ser humano y su entorno biofísico. Dicha relación se ha mediado, frecuentemente, a través del uso de artefactos más o menos complejos, lo cual ha posibilitado una rápida expansión de la especie y ha asegurado su supervivencia frente a las adversidades medioambientales. A lo largo de miles de años, la transmisión y evolución de los conocimientos asociados al uso de los recursos naturales y al desarrollo de los artefactos ha dado lugar a la ciencia y a las tecnologías que hoy permiten la realización de un proyecto humano muy distinto al de los demás animales. Para algunos, en este proyecto no solo se busca garantizar necesidades básicas como alimento y abrigo, sino que se buscan igualmente objetivos de orden secundario, relacionados con la movilidad, el confort o el entretenimiento. No cabe duda que el proyecto científico-tecnológico de las sociedades humanas ha tenido como resultado unos beneficios invaluables de los que hoy una parte considerable de la población mundial disfruta. Sin embargo, como es bien sabido, más allá de una desigualdad en la distribución de esos beneficios, los desarrollos científico-tecnológicos también conllevan unos impactos ambientales y sociales que no han pasado desapercibidos en el curso de la historia. Tales impactos no solo desfavorecen la supervivencia de los más vulnerables, sino que profundizan las desigualdades ya existentes.

Coincidiendo con los primeros pasos de los estudios sobre la ciencia, la tecnología y la sociedad (CTS) - “nacidos” de la guerra y alimentados por la desilusión respecto a las promesas y la supuesta infalibilidad de la ciencia (Spiegel-Rosing 1977), a partir de la segunda guerra mundial y sobre todo a lo largo últimas décadas del siglo XX, distintos grupos, dentro y fuera de la academia, empiezan a investigar más a fondo y a denunciar los riesgos y consecuencias negativas de las tecnologías y actividades industriales. La formación del Club de Roma y la publicación de su primer informe en el inicio de la década de los 70, alertando sobre los límites del crecimiento económico, sus impactos en el medioambiente y en la sociedad y la finitud de los recursos naturales es un marco en este movimiento de contestación, que desde entonces solo ha ganado fuerzas (Lipietz 2003, García 2006). Paralelamente a él, aumentaba por parte de los gobiernos el interés por el “control” de los riesgos y consecuencias de las tecnologías. De cara a responder a dicha demanda, se planificaron instituciones ligadas a los gobiernos dedicadas a asesorar a los tomadores de decisión en materia de impactos de la ciencia y tecnología y se desarrollan regulaciones específicas para la gestión de impactos de proyectos (Quintanilla 2005). Algunos ejemplos son la pionera OTA (*Office of Technology Assessment*), fundada en los años 70 en Estados Unidos, distintas oficinas creadas en los años 80 en Europa, como la NOTA en Holanda (*Netherlands Office for Technology Assessment*) o el POST (*Parliamentary Office of Science and Technology*) en Reino Unido (Van Eijndhoven 1997) y la Evaluación de Impacto Ambiental (EIA), institucionalizada por primera vez en 1970 a través del Acta Nacional de Política del Medio Ambiente (NEPA, por su sigla en inglés), en Estados Unidos (Vanclay 2006).

Mientras algunas de estas oficinas se extinguieron o se modificaron, otras se han creado – y el papel y las características de las evaluaciones de los desarrollos científico-tecnológicos han sido revisados y han evolucionado considerablemente hasta la actualidad. Se destaca, en este sentido, una creciente crítica hacia los modelos de evaluación poco inclusivos y reflexivos, que adoptan una visión determinista y lineal del desarrollo tecnológico, acompañada de un giro hacia modelos más constructivos y participativos (López-Cerezo y González-García 2002). En todo caso, el universo de las evaluaciones de impacto es muy amplio en la actualidad y distintos actores investigan y emplean un sin número de métodos y metodologías para atender a objetivos académicos, empresariales o institucionales, dentro y fuera de gobiernos. Algunos factores que suelen influir en el diseño y los objetivos de una evaluación se relacionan con la determinación del sistema socio-técnico a estudiar; la definición del problema; la dimensión que se desea evaluar, e.g. económica, social, ambiental o técnica; la disponibilidad de recursos y tiempo para llevar a cabo el proyecto; los intereses de los promotores del estudio o las capacidades y decisiones tomadas por los propios evaluadores. Aunque haya cuerpos metodológicos más o menos establecidos, cabe decir que existen tantas maneras de evaluar como las hay de hacer políticas o proyectos científicos y tecnológicos. Naturalmente, como la propia ciencia, y como todo y cualquier emprendimiento social, las evaluaciones de impacto y de tecnologías no están libres de problemas y limitaciones. No obstante, como herramienta útil en el proceso de toma de decisiones, es preferible trabajar hacia su perfeccionamiento que elegir la inacción ante los riesgos del desarrollo científico-tecnológico.

El presente documento sigue la estructura recomendada por la Comisión de Doctorado y Posgrado de la Universidad de Salamanca de 15 de febrero de 2013 según su "Procedimiento para la presentación de la tesis doctoral en la Universidad de Salamanca en el formato de compendio de artículos/publicaciones". En él se incluyen, además de los artículos correspondientes, un apartado en castellano que refleja la coherencia y relación directa entre los artículos presentados. Dicho apartado, que se recoge en la sección 1 de esta tesis y sus subsecciones, incluye los antecedentes de los temas objeto de estudio (1.1 a 1.3), la hipótesis de trabajo y los objetivos de la investigación doctoral (1.4) y sus conclusiones (1.5). Los objetivos específicos de cada artículo y las metodologías utilizadas se describen en las secciones correspondientes a cada uno de ellos (secciones 2 a 5). Las copias completas de las publicaciones originales (PDFs) se encuentran recogidas después de las referencias bibliográficas, en el anexo incluido al final de este documento.

1.1 La bioenergía y los biocombustibles

El dominio del fuego para luz y calor y su posterior utilización en la producción de herramientas más complejas (Brown et al. 2009), además de la domesticación de animales y plantas, con la consecuente densificación de las sociedades humanas (Diamond 2008), son capítulos decisivos de la historia del ser humano moderno. El uso de distintos recursos naturales para la transformación de energía y generación de trabajo a lo largo de la historia ha demarcado momentos importantes de cambios en las sociedades. La energía hidráulica, por ejemplo, aprovechada a través de los molinos de agua, tenía muchas funciones en la ciudades europeas entre los siglos XII y XV como moler granos, elevar el agua, mover máquinas trefiladoras o posibilitar la trituración de minerales (Sánchez-Ron 2012). Las ciudades que no disponían de un río cerca de ellas utilizaban molinos de viento aprovechando la energía eólica para desempeñar actividades similares (Sánchez-Ron 2012). A pesar de que distintas fuentes de energía hayan apoyado el desarrollo de sociedades cada vez más complejas, antes de la revolución industrial el uso de la biomasa era dominante comparado con el de otras fuentes hoy disponibles (Field et al. 2007).

Según una moderna definición del término – ya aplicada a fines energéticos y biocombustibles recientes, la biomasa corresponde a "la fracción biodegradable de los productos, desechos y residuos de origen biológico procedentes de actividades agrarias (incluidas las sustancias de origen vegetal y animal), de la silvicultura y de las industrias conexas, incluidas la pesca y la acuicultura, así como la fracción biodegradable de los residuos industriales y municipales" (Dir. 2009/28/CE del Parlamento Europeo y del Consejo, de 23 de abril de 2009, pp. 27). Los flujos o transformaciones de energía que son útiles para los seres humanos lo son porque permiten la realización de trabajo, sea mecánico o no (Odum 2007). El uso de la biomasa como fuente de energía para fines humanos se denomina bioenergía. Esta bioenergía corresponde a la transformación de la energía química almacenada en las plantas durante el proceso de fotosíntesis, obtenida a partir de la energía solar.

Los biocombustibles, a su vez, se refieren a la biomasa de origen reciente en su forma sólida, líquida o gaseosa que se utiliza como material combustible (Granda et al. 2007). Esta definición es útil porque diferencia a los biocombustibles de los combustibles fósiles, los cuales, en última instancia, también constituyen un tipo de biomasa, pero de origen muy antiguo (Sobrino y Monroy 2009). Así, el carbón, el petróleo y el gas natural son productos de procesos biológicos de producción de materia orgánica y, posteriormente, procesos geológicos y geotérmicos que remontan al periodo Silúrico (400-1,5 millones de años) (Brown et al. 2010). Entre los distintos tipos de uso de los biocombustibles figuran su quema directa para la obtención de energía térmica (calor) o generación de electricidad, su conversión en biocombustibles líquidos como el biodiesel o el etanol a través de procesos físicos y químicos o su digestión anaerobia para la obtención del biogás, una mezcla de gases en la que predomina el metano. Además de los productos anteriores, en los procesos de obtención de bioenergía se puede generar una serie de coproductos químicos de utilidad industrial y alto valor económico (Singhania 2009).

1.1.1 Bioenergía tradicional y moderna

Aproximadamente el 10% del total de energía primaria consumida por el ser humano hoy en el planeta se obtiene de la biomasa (IEA 2009). Su uso puede variar entre el llamado "tradicional", i.e. de pequeña escala, usualmente a nivel rural, y el "moderno", i.e. de carácter industrial y comercial (Spiertz and Ewert 2009:286). El uso tradicional es el más frecuente. En él, se quema la biomasa directamente en hornos para cocinar alimentos o para la calefacción en residencias (Bringenzu et al. 2009). En la actualidad, más de 2 mil millones de personas en el mundo dependen de la bioenergía tradicional para atender a necesidades básicas diarias, especialmente en las zonas rurales de los países pobres (Spiertz y Ewert 2009). En África, por ejemplo, se atiende a un 90% de las necesidades energéticas a través del uso de la biomasa con fines no-comerciales. Sin embargo, su uso directo suele presentar bajos valores de eficiencia energética y, como consecuencia de su quema en hogueras abiertas o fogones, se generan impactos negativos especialmente en la salud de los niños, mujeres y personas mayores, además de contribuir a la deforestación de bosques y provocar la erosión del suelo debido a la explotación del carbón vegetal (Goldemberg y Coelho 2004; Kammen 2006).

Aunque muchos autores consideran la biomasa como una fuente de energía renovable, i.e. aquella que proviene de recursos naturales considerados inagotables, Goldemberg y Coelho (2004) llaman la atención sobre el uso del adjetivo "renovable". Según los autores, se debe atribuir tal característica únicamente a aquellos procesos relacionados con el uso moderno de la bioenergía como, por ejemplo, la producción de biocombustibles líquidos o gaseosos para el transporte y la generación de calor y electricidad a partir de residuos forestales o desechos industriales y municipales. De esa manera, quedarían excluidos del grupo de las renovables los modos tradicionales de obtención de bioenergía, que a día de hoy representan un 80% del uso mundial de la biomasa con fines energéticos (IEA 2009). Entre los 20% restantes se encuentra el biocombustible líquido más producido en la actualidad, el etanol.

1.1.2 Los biocarburantes: biocombustibles para el transporte

Los biocarburantes son una forma específica y líquida de biocombustibles destinada a la utilización por el sector de transportes como alternativa a los combustibles fósiles en motores de combustión interna, sea en su forma pura o, más comúnmente, mezclados en porcentajes variables a la gasolina y al diésel. El etanol y el biodiesel son los dos principales biocarburantes de los que se dispone actualmente para uso. El primero se obtiene a partir de la conversión del almidón o la sacarosa presente en el maíz, sorgo, trigo, caña de azúcar, remolacha o residuos lignocelulósicos, entre otros. El biodiesel, por su parte, se obtiene a partir de semillas oleaginosas como la soja, el girasol, la colza, la palma o el algodón, pero también de grasas animales o de microalgas (Medina 2008). Entre los demás biocarburantes figuran el aceite vegetal puro, el biogás (biocarburante gaseoso), biometanol, biodimetiléter (DME), BioETBE (Etil ter-butil éter), BioMTBE (Metil ter-butil éter) y el biohidrógeno (Sánchez-Macias 2006). Uno de los primeros motores de combustión interna de la historia salió de las manos del ingeniero e inventor alemán Nikolaus August Otto en el siglo XIX, quien utilizó etanol como combustible para el funcionamiento del motor (Luque et al. 2008). Durante la Segunda Guerra Mundial, debido a la escasez de crudo, los Aliados y Alemania alimentaban los vehículos con biocarburantes, normalmente una mezcla de gasolina y etanol (Luque et al. 2008).

1.1.3 Biocarburantes de primera generación

Para el análisis de las tecnologías involucradas en el proceso de producción, distribución y uso de los biocarburantes es útil diferenciarlos en "generaciones". Esta clasificación los distingue temporalmente en función de su escala de producción y comercialización y según el nivel de desarrollo de las tecnologías involucradas en el proceso de conversión de la materia prima. Además, tal distinción sirve para la identificación de los tipos de insumos o materia prima utilizados para su producción.

La siguiente tabla (Tabla 1) presenta, de manera resumida, los principales tipos de biocarburantes de primera generación según los procesos de conversión utilizados para su producción, su uso y el tipo de materia prima utilizada.

	Proceso de conversión	**Uso**	**Materia prima**
Etanol	Fermentación del azúcar; hidrólisis y fermentación del almidón	Utilizado como sustituto de la gasolina o mezclado a ella en motores tipo *Flex fuel*	Azúcar, almidón de insumos agrícolas
Biodiesel	Transesterificación de triglicéridos	Utilizado como sustituto del diésel o mezclado a él en motores a diésel	Semillas oleaginosas, aceites vegetales y residuos de aceites y grasas animales

	Proceso de conversión	Uso	Materia prima
Biogás	Fermentación anaerobia de la materia orgánica	Utilizado en motores de vehículos adaptados (puro o mezclado al gas natural)	Todo tipo de materia orgánica, incluyendo a los desechos industriales o municipales
Aceite vegetal puro (SVO - *Straight Vegetable Oil*)		Utilizado directamente en el motor modificado de los vehículos movidos a diésel o mezclado con él	Aceites vegetales, incluyendo a los desechos de aceites de cocina usados

Tabla 1. Principales tipos de biocarburantes de primera generación. Fuente: compilación propia.

Producidos a partir de insumos agrícolas, el etanol y el biodiesel de primera generación son los dos biocarburantes más producidos y comercializados actualmente. El biogás, también conocido por biometano, se comercializa en menor escala que el etanol y el biodiesel debido a que son pocos los vehículos cuyos motores están adaptados a su uso, además de no haber todavía una infraestructura bien establecida para su comercialización y distribución (Sims et al. 2008; Naik et al. 2010). El aceite vegetal puro (SVO), por su parte, puede ocasionar problemas en los motores de vehículos a largo-plazo en tanto que el aceite puro es mucho más viscoso que el diésel y su punto de ebullición mayor, generando mayores costes de mantenimiento y reduciendo la vida útil del motor. Aunque éste se encuentre adaptado para el uso del SVO directamente, el uso del biodiesel, fabricado a partir de la transesterificación del SVO es más recomendable, no supone tantos problemas y no requiere adaptación previa del motor (Peterson y Auld 1991; NREL 2010).

1.1.4 Biocarburantes de segunda generación

Se espera en los próximos años una sustitución paulatina de los biocarburantes de primera generación por los de segunda (Sims et al. 2008; Naik et al. 2010). De ese modo, en un primer momento habría un escenario de participación de los dos tipos y la experiencia en la producción de los primeros serviría de apoyo para el avance de las tecnologías de producción de los de segunda generación. Éstos se enfrentan todavía a barreras técnicas y económicas para su producción y comercialización a gran escala, aunque especialmente desde el sector privado programas de I+D+i reciben financiaciones considerables para fomentar su desarrollo. Sus principales representantes son el etanol celulósico, los biocarburantes sintéticos[1] y el gas natural sintético, conocido por Bio-SNG[2], todos producidos a partir de la biomasa lignocelulósica de los vegetales (Bacovsky et al. 2010).

La biomasa lignocelulósica utilizada en la producción de los biocarburantes de segunda generación está presente en los residuos agrícolas como la paja de los cereales o el bagazo de la caña de azúcar, en los residuos forestales, en los componentes orgánicos de los desechos municipales o en la materia orgánica vegetal proveniente de la silvicultura de corta rotación, entre otras plantaciones (Sims et al. 2010). La lignocelulosa es un complejo compuesto orgánico que caracteriza la biomasa lignocelulósica. Está formado por una mezcla de celulosa (20-50%), hemicelulosa (20-35%), lignina (10-35%) y otros componentes en menor porcentaje (Kumar et al. 2009). La celulosa es la molécula orgánica más abundante en el planeta y constituye un polímero de alto peso molecular y buena resistencia. La hemicelulosa, a su vez, posee bajo peso molecular y está constituida por unidades de azúcar en proporciones y tipos variables. Normalmente está formada por polisacáridos de xilosa o manosa y sus cadenas son mucho menores que las de la celulosa, además de estar más asociada a la lignina que la última (Nag 2010). Después de la celulosa, la lignina es el segundo compuesto más abundante del planeta y es un componente importante para el transporte de agua en las plantas vasculares, confiriéndoles también resistencia mecánica y contribuyendo a la defensa de la planta contra patógenos (Campbell and Sederoff 1996; Nag 2010). Se trata de un polímero de composición variable en términos de tipos de unidades constituyentes y enlaces intermoleculares, además de variar también en cantidad de acuerdo con el tipo de célula, tejido y estrés medioambiental al que está sometida la planta. Esta variación se da no solo entre especies distintas y dentro de una misma población, sino también entre células y partes diferentes de una misma planta (Campbell and Sederoff 1996).

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[1] Corresponden a los biocarburantes obtenidos a partir de un proceso de conversión conocido como BtL, *biomass-to-liquids*, en el cual se produce un gas de síntesis llamado *syngas* que, sometido a una técnica de conversión denominada *Fischer-Tropsch* se convierte en diesel sintético, combustible de avión o etanol (Sims et al. 2010).

[2] El gas natural sintético (Bio-SNG) se diferencia del biogás porque se obtiene a partir de un proceso de gasificación directa de material lignocelulósico, mientras el segundo se produce a partir de la digestión anaerobia de la materia orgánica.

Conocer tales características de la biomasa lignocelulósica, con algo de detalle, es esencial para entender el proceso de transición tecnológica por el que actualmente pasan los biocombustibles, en especial, el etanol. Mientras que el etanol de primera generación se obtiene desde azúcares cuyo acceso es relativamente fácil, la obtención de esos mismos azúcares y otros desde otras partes de la planta representa un desafío. Tal como se explica anteriormente, la lignocelulosa que se encuentra en las partes duras de las plantas no solo es un componente muy complejo, sino que también muy resistente. De esta manera, los mismos procesos de conversión utilizados en la producción del etanol de primera generación no son suficientes para obtener el etanol celulósico. Para la producción del último, se necesitan distintas rutas de conversión basadas en tecnologías más avanzadas.

Actualmente, existen dos principales rutas de conversión para la obtención de etanol a partir de material lignocelulósico. La producción de etanol a partir de ambas rutas se encuentra en fase piloto o de demostración. La primera, denominada ruta bioquímica, está basada en el uso de enzimas y microorganismos para la conversión de la celulosa y la hemicelulosa en azúcares para su subsecuente fermentación. La segunda se denomina termoquímica (o *biomass-to-liquids*, BTL, por su sigla en inglés) y consiste básicamente en la transformación de la biomasa en un gas de síntesis que es finalmente convertido en etanol (u otros biocarburantes como el biodiesel sintético o combustible para aviones) mediante un proceso específico conocido como Fischer-Tropsch. A largo plazo se espera que las posibilidades de reducción en los costes de producción del etanol celulósico sean mayores en el caso de la ruta bioquímica que en el de la ruta termoquímica, ya que la segunda es una tecnología mucho más madura que la primera (Carroll y Somerville 2009; Sims et al. 2010).

Respecto a las plantas de producción de biocarburantes de segunda generación, se puede diferenciar entre planta piloto, de demostración y comercial de acuerdo con la continuidad de la operación, su incorporación a la cadena logística completa y el nivel de comercialización del producto (Tabla 2).

	Operación	Cadena logística	Mercado
Planta piloto	No continuada	No incorporada	Normalmente no comercial
Planta de demostración	Normalmente continuada	Incorporada	Comercial (normalmente sin intereses económicos)
Planta comercial	Continuada con alto nivel de disponibilidad del producto	Incorporada	Comercial con intereses económicos

Tabla 2. Tipos de planta de producción de biocombustibles de segunda generación. Fuente: adaptado de Bacovsky (2010).

Hoy, la mayor parte de las plantas que se dedican a producir etanol celulósico son de tipo piloto o demonstración como, por ejemplo, la planta de etanol administrada por la empresa Abengoa y ubicada en el municipio de Babilafuente, Salamanca. En octubre de 2013, un grupo empresarial liderado por Biochemtex celebró la inauguración de la primera planta de etanol celulósico de tipo comercial en la provincia de Vercelli, Italia.[3] Sin embargo, se sigue invirtiendo en I+D+i en el área de los biocombustibles celulósicos para lograr una disminución más radical en los costes. Muchas veces tal inversión constituye una iniciativa mixta entre la industria y los fondos públicos como, por ejemplo, proyectos financiados bajo los Programas Marco de la Unión Europea.[4] Para conseguirse mejores rendimientos y más eficiencia en las distintas fases del ciclo de vida del etanol, se proponen algunas estrategias desde el campo de la biotecnología. Según Carroll y Somerville (2009), la investigación dedicada a la optimización del proceso de conversión de la lignocelulosa en etanol se enfoca o se debe enfocar principalmente en: a) la identificación de especies más prometedoras; b) el conocimiento acerca de cómo producir dichas especies y cuáles son los aspectos medioambientales y ecológicos de la producción de la lignocelulosa; c) el diseño de mejores catalizadores para la hidrolisis de la biomasa y la modificación genética de

[3] European Biofuels Technology Platform. http://www.biofuelstp.eu/cell_ethanol.html#crescentino. Último acceso en 17 de febrero de 2014.

[4] Para un listado de proyectos financiados por la UE, ver: http://www.biofuelstp.eu/cell_ethanol.html#ce2. Último acceso en 17 de febrero de 2014.

los cultivos bioenergéticos respecto a sus rasgos agronómicos y la composición de la biomasa.[5]

1.2 Las evaluaciones de impacto y de tecnologías

La Asociación Internacional para la Evaluación de Impacto (AIEI) define la evaluación de impacto (EI) de proyectos, planes y programas como el "proceso de identificación de las consecuencias futuras de una acción en curso o propuesta".[6] En algunos casos, el término *consecuencia* es sustituido por *externalidad*[7] o *coste*, especialmente en aquellos trabajos cuyo análisis es de carácter económico. El Portal de Evaluación de Tecnologías (ET), por su parte, define la ET como "práctica análitica y democrática para ampliar la base de conocimientos de las decisiones políticas analizando las condiciones socioeconómicas así como los posibles impactos sociales, económicos y ambientales de la implementación de nuevas tecnologías".[8] Aunque compartan algunos objetivos, como se verá a continuación las comunidades de teoría y práctica que se han desarrollado en torno a las EI y las ET también guardan diferencias. Probablemente lo que más les diferencia es la función que han cumplido junto a los gobiernos: las EI enfocadas en el ámbito de la implementación de proyectos concretos y las ET en el del análisis y asesoramiento en torno a las políticas científico-tecnológicas. Asimismo, mientras las ET no suelen diferenciarse según la dimensión analizada, e.g. económica, ambiental o social, los teóricos y profesionales que se ocupan de la EI han tratado de especializarse en este sentido.

A modo de sistematización, Becker (2001:316) diferencia a las evaluaciones de impacto según la naturaleza del principal tipo de impacto evaluado por ellas. El autor

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[5] Debido a que el estudio de la composición de la biomasa no ha sido una prioridad en el desarrollo de la mayor parte de los cultivos alimentarios, hay una carencia de conocimiento respecto a este tópico en la actualidad (Carroll y Somerville 2009).

[6] IAIA, "What is Impact Assessment". Disponible en: www.iaia.org. Último acceso en 20 de marzo de 2014.

[7] Para Lenk et al. (2007), las *externalidades* se refieren a los costes o beneficios de una transacción económica que resulta, por ejemplo, en la generación de un subproducto no esperado capaz de afectar a partes que no participan directamente en la transacción (Lenk et al. 2007:1500).

[8] TA Portal, "About TA", Disponible en: technology-assessment.info. Último acceso en 11 de junio de 2014.

identifica, así, las siguientes categorías: la evaluación de impacto ambiental (EIA), evaluación de impacto económico (EIE), evaluación de impacto social (EIS) y, separadamente, la evaluación de tecnologías (ET). También en el intento de establecer el estado del arte de las EI y refinar su categorización, Bond y Pope (2012) proponen una tipología general que incluye seis principales cuerpos de teoría y práctica: la evaluación de impacto ambiental, la evaluación estratégica ambiental, la evaluación de políticas, la evaluación de impacto social, la evaluación de impacto en la salud y la evaluación de la sostenibilidad. Si no todos, muchos de los tópicos de los que se ocupan las distintas EI también son abordados por las ET. No obstante, la especialización de las últimas se ha dado sobre todo a nivel de proceso, hacia modelos más participativos y de caráter anticipatorio, más que en relación con el tópico de la evaluación.

Los métodos utilizados por las EI y ET son tan distintos como lo son los temas de los que la evaluación se puede ocupar. Así, aunque se puedan definir tipos más genéricos y bien establecidos como los que señalan los últimos autores, también se pueden encontrar tipos más específicos de EI como, por ejemplo, las evaluaciones de impacto en los derechos humanos o evaluaciones de los impactos cumulativos de proyectos, entre otros. Una tipología de las EI no tiene porque ser definitiva y no debería limitar los ámbitos de actuación e investigación de las evaluaciones en general. De hecho, los distintos tipos de evaluación integran, en mayor o menor grado, análisis de aspectos que normalmente se evalúan en las demás. Así, una evaluación de impacto en la salud humana, por ejemplo, no deja de ser una parte importante y más específica de una evaluación de impacto social de algunos desarrollos científico-tecnológicos, algo de que también se ocupan las ET. En definitiva, el campo de las evaluaciones de los desarrollos científico-tecnológicos es dinámico. En él, los procesos de evaluación se ajustan a los diferentes contextos y objetivos propuestos por el analista.

En la actualidad, hay una tendencia hacia la integración de las distintas dimensiones de las EI. Hay muchas razones para tal tendencia, entre las cuales se destacan la creciente importancia del tema de la sostenibilidad asociada al paradigma del cambio climático (y la articulación de sus tres pilares, económico, ambiental y social) en la agenda política; la complejidad de los sistemas sociotécnicos ligados a desarrollos científico-tecnológicos cuyos mercados y sistemas de producción tienen carácter global y se regulan entre si; y el hecho de que mientras las evaluaciones técnicas, económicas y ambientales abundan, los aspectos sociales y éticos de los desarrollos científico-tecnológicos se ven muchas veces ignorados o pobremente evaluados.

Ambas corrientes ofrecen aproximaciones teóricas que ayudan a comprender las distintas dimensiones, económica, ambiental y social de los impactos de los desarrollos científico-tecnológicos. Sin embargo, es en el campo de las EI que se da una mayor distinción conceptual entre impacto económico, ambiental y social de los desarrollos científico-tecnológicos. En este contexto, se consolida la disciplina de la evaluación de impacto social de planes, políticas, programas y proyectos (EIS), que se presenta en la sección 1.2.2. La definición de impacto social adoptada en esta tesis se articula en la sección 1.2.1 a partir de las contribuciones de autores que forman parte de la disciplina de EIS y de las aportaciones teóricas de Quintanilla (2005). Con un enfoque en la evaluación de tecnologías emergentes y de las políticas científico-tecnológicas, se presenta el campo de las ET en la sección 1.2.3. Mientras la corriente de las EI informa el concepto de impacto social que se aplica al caso del etanol en la presente tesis, las aportaciones de los teóricos y profesionales relacionados con las ET apoyan el análisis de los potenciales impactos de las tecnologías emergentes involucradas en la producción del etanol celulósico.

1.2.1 La dimensión social de los impactos de los desarrollos científico-tecnológicos

La evaluación de las consecuencias sociales de las tecnologías adquiere cada vez más importancia (Quintanilla 2005:150). Para dar cabida al análisis de la dimensión social de los impactos o consecuencias de los desarrollos científico-tecnológicos, desde el punto de vista teórico Quintanilla (2005) diferencia entre evaluación *interna* y *externa* de las tecnologías. Mientras en la evaluación interna las variables a considerar se limitan a aquellas relacionadas sobre todo con medidas de la eficiencia del diseño tecnológico, la evaluación externa abarca "la utilidad o el valor que el diseño tiene para el usuario o la sociedad en su conjunto" (Quintanilla 2005:126). En la última se enmarca la EIS de los desarrollos científico-tecnológicos. Para el autor, la evaluación externa se divide en evaluación de la idoneidad y evaluación del impacto o consecuencias de la *aplicación del diseño tecnológico* (Quintanilla 2005:146). Según él, la idoneidad de un proyecto puede cambiar según se avanza en el conocimiento. Esto ocurre porque los niveles de utilidad y adecuación del diseño, que caracterizan la idoneidad del proyecto, pueden verse modificados en el tiempo tras la consideración y el conocimiento de nuevas variables (e.g. disponibilidad de recursos naturales) que condicionan la viabilidad de la implementación y uso de la tecnología. Por otra parte, la evaluación de los impactos o consecuencias sociales, entendidos aquí como sinónimos, se refieren a la evaluación de sus riesgos, impactos ambientales e impactos sociales derivados de su aplicación (Quintanilla 2005).

Los impactos sociales se pueden materializar a partir de cambios directos en el medio social, e.g. en la oferta de empleo, en efectos sobre el ocio o la cultura y en la organización industrial (Quintanilla 2005:150). De hecho, ya durante la construcción de Roma entre los años 69 y 79, el emperador Vespasiano se preocupaba por los impactos sociales que podría conllevar la construcción de una gran rueda hidráulica en la ciudad. Decidió prohibir su implementación por temer, en aquel entonces, que esto resultara en una pérdida considerable de puestos de trabajo entre la población (Sánchez-Ron 2012). Asimismo, los impactos sociales de los desarrollos científico-tecnológicos pueden darse de forma indirecta a partir de cambios en las funciones o servicios ecosistémicos que son útiles para las sociedades humanas (Slootweg et al. 2003). Para Odum (2007), de acuerdo con una concepción ecosistémica de la naturaleza, en la que los organismos vivos (medio biótico, incluyendo al ser humano) se relacionan entre sí y con el medio abiótico, y que dependen de los recursos del último y de dichas relaciones para su supervivencia, parece lógico que cualquier impacto a nivel biofísico tenga una implicación social (i.e. a nivel de las sociedades humanas), directa o indirectamente identificable. En esta línea, Pardo (1994) también indica que la conexión entre los impactos biofísicos (en sus palabras "ecológicos") y los sociales "es inmediata en la medida que la regulación del impacto ecológico deviene social en sus consecuencias y es la sociedad, en definitiva, quien interpreta ambos y les da contenido" (Pardo 1994:146).

En la presente tesis, se define impacto social de la implementación o aplicación de desarrollos científico-tecnológicos como los *procesos de cambio social y las consecuencias, directas o indirectas, positivas o negativas, experimentadas por actores o grupos de actores sociales directa o indirectamente relacionados con tales* *desarrollos*. Tal definición se ha articulado a partir de los trabajos de Quintanilla (2005), Vanclay (2002a) y van Schooten et al. (2003). Mientras Quintanilla (2005) explora al tema de la EIS sobre todo en el marco de los programas de I+D y de manera más teórica, las definiciones propuestas por los últimos autores se incluyen en una corriente teórico-metodológica de fuerte dimensión práctica ligada a los estudios de evaluación de impacto, la cual se presentará brevemente en la siguiente sección. En ella, diversos especialistas se dedican a evaluar los impactos sociales de políticas y proyectos normalmente en un contexto de aplicación de la legislación, de manera análoga a las EIA o incluidas como una parte de estas.

1.2.2 La evaluación de impacto social de planes, políticas, programas y proyectos

La evaluación de impacto social (EIS) como cuerpo metodológico definido es más conocida como *social impact assessment* (SIA) en inglés. El término inglés es importante a modo de desambiguación, ya que que el impacto social de planes, políticas, programas y proyectos se puede evaluar de distintas maneras, desde diferentes perspectivas disciplinares y utilizándose distintos métodos. Esta corriente teórico-metodológica de reconocida dimensión práctica se apoya sobre todo en métodos de investigación sociológica y se desarrolla no solo en el seno de universidades y a nivel académico, sino que se encuentra institucionalizado en las legislaciones de algunos países como Canadá y Australia y es comúnmente aplicado por empresas especializadas en forma de consultoría en la implementación de proyectos.

Surgió formalmente en los años 70 en Estados Unidos debido a la necesidad de incluir las consecuencias sociales derivadas de la implementación de proyectos y programas del gobierno estadounidense, especialmente aquellos relacionados con los proyectos energéticos de gran escala, en las evaluaciones de impacto ambiental (EIA) desarrolladas en aquellos momentos (Vanclay 2006). De hecho, la evolución del análisis de los aspectos sociales de los desarrollos científico-tecnológicos está ligada a la idea de que los cambios en el medio biofísico pueden producir cambios en la esfera social (Burdge 2003). En Europa, la EIS se ha desarrollado como un tipo de análisis de las políticas, como las evaluaciones de los impactos o riesgos para la salud (Becker 2001:318).

Las EIS se encuentran institucionalmente subdesarrolladas en comparación con las EIA, incluyéndose en las legislaciones de unos pocos países (Burge 2002). Aunque muchas legislaciones incluyan elementos de base para el desarrollo de la EIS, pocos presentaban hace una década un marco procedimental para realizar las evaluaciones. En este ámbito destacan Canadá, Estados Unidos, Australia y Nueva Zelanda (véase Burdge 2003). Las definiciones tradicionales de la EIS entienden la misma como un proceso necesariamente vinculado al plan legislativo, muchas veces relacionada únicamente con la predicción de los impactos negativos de los proyectos (Vanclay 2003). No obstante, en la actualidad, su definición incluye pero excede el ámbito legal. En este contexto, se considera la EIS como un *proceso de análisis y gestión de las consecuencias y cambios sociales, i.e. en el medio humano, producidos a partir de cualquier intervención planificada* (Vanclay 2003b:2).

Hoy, se puede considerar que el principal objetivo de la EIS es garantizar la maximización de los beneficios o impactos positivos de los planes, políticas, programas y proyectos, mientras se minimizan los costes o impactos negativos de los mismos (Vanclay 2003b). En resumen, se trata de un proceso de carácter iterativo que sirve para comprender y responder a los problemas sociales asociados con el desarrollo (Franks 2012:6). Los profesionales que se ocupan del estudio académico de la EIS la consideran una filosofía sobre el desarrollo y la democracia; en ella, se desarrolla el análisis de las patologías o impactos negativos y objetivos o impactos positivos del desarrollo, además de los procesos asociados a este (e.g. la participación pública en la toma de decisiones) (Vanclay 2002b:388 citado en Vanclay 2003a:2). Como proceso de carácter interdisciplinar, busca comprender la dimensión social del desarrollo en un sentido amplio y en su aplicación se verifica la incorporación de agencias de los sectores público y privado (Esteves et al. 2012), además de la ciudadanía (Burdge 2003). Actualmente, se utilizan sus métodos en la gestión de recursos naturales, resolución de conflictos, proyectos de cooperación internacional en materia de desarrollo o en planes de preparación para desastres naturales, entre otros (Esteves et al. 2012).

Sin embargo, los métodos, principios y criterios utilizados en la EIS no son universales y se señalan importantes diferencias entre experiencias desarrolladas en el occidente y oriente o entre países ricos y pobres (Becker 2001; Tang et al. 2008). Desde el ámbito empresarial, hoy más que nunca se reconoce el valor de la EIS en tanto que la consideración de sus aspectos sociales puede significar el ahorro de una cantidad considerable de tiempo y dinero en el desarrollo de un emprendimiento. Sus ventajas incluyen la reducción de los riesgos económicos de los proyectos desde el punto de vista de los inversionistas, gobierno y sociedad o de los riesgos de paralizaciones o cierre de proyectos, hasta el incremento de las ventajas competitivas y reputación empresarial, entre otros (Franks 2012). También se reconocen sus potencialidades en la mediación de conflictos durante los estudios de evaluación de impacto e implementación de proyectos y en la promoción de la sostenibilidad social de comunidades (Aucamp et al. 2011).

1.2.3 La evaluación de tecnologías

La evaluación de tecnologías (ET), o *technology assessment* (TA, por su sigla en inglés) como proceso y cuerpo de teoría y práctica surgió formalmente en el seno de la Oficina de Evaluación de Tecnologías (OET), o Office of Technology Assessment (OTA, por su sigla en inglés) en el principio de los años 70 en Estados Unidos (van den Ende et al. 1998). Su principal función era asesorar al Congreso en materia de política tecnológica, informando a los congresistas de los impactos de las nuevas tecnologías (Quintanilla 1989; Quintanilla 2005). Surgieron, por tanto, de manera paralela a las EIS anteriormente presentadas, y con estas comparten características como el análisis de los impactos sociales de los desarrollos científico-tecnológicos. Sin embargo, son corrientes con enfoques distintos. Las EIS priorizan el análisis de los impactos sociales a través del uso de métodos de investigación sociológica, diferenciándolos de aquellos de orden económico o ambiental. Las ET pueden abarcar, además de los anteriores, distintas dimensiones del desarrollo científico-tecnológico, como sus aspectos éticos o políticos (Tran y Daim 2008). Sin embargo, no han sido concebidas como un conjunto de métodos para la realización de las distintas partes de la evaluación, sino que tienen la función de manejar e integrar los análisis producidos por distintas disciplinas (van den Ende et al. 1998). Aunque haya surgido en Estados Unidos, la ET se ha establecido y popularizado sobre todo en

Europa, donde surgió a mediados de los años 80, a través de agencias para la ET ligadas a los parlamentos de Francia, Holanda, Dinamarca, Reino Unido, Alemania y al Parlamento Europeo (van Eijndhoven 1997). Mientras el cuerpo teórico-metodológico de las EIS se ha desarrollado y perfeccionado especialmente en el seno de procesos obligatorios, previstos en la legislación, y aplicados en la fase de planificación o implementación de proyectos concretos para la obtención de una licencia, la ET ha adoptado tradicionalmente un carácter más "predictivo" a nivel de políticas científico-tecnológicas y en diálogo con los parlamentos, con el objetivo de analizar los riesgos e impactos de distintas opciones tecnológicas futuras.

La ET es a la vez producto de la tecnocracia y respuesta crítica a la misma, en tanto que involucra la esperanza de resolver problemas sociales a través de la ciencia y la tecnología, mientras reconoce que la ciencia y la tecnología son fuentes de nuevos problemas (Hennen 1999:304; Quintanilla 2005). En la actualidad, agencias evaluadoras institucionalizadas como, por ejemplo, la Agencia de Evaluación de Opciones Científicas y Tecnológicas (STOA, por su sigla en inglés) ligada al Parlamento Europeo o el Instituto Rathenau ligado al Ministerio de Educación, Cultura y Ciencia de Holanda, entre otras, vienen sufriendo un proceso de "apertura a la pluralidad" y de "borrosidad de los límites" (Delvenne et al. 2011). En ello, se busca una mayor inclusión de diferentes actores sociales en el proceso de evaluación y un aprendizaje social en el seno de la agencia, cuya estructura analítica se vuelve más plástica en el proceso de evaluación, dejando de segregar ámbitos que han sido históricamente tratados como dicotómicos e inmiscibles, como el conocimiento científico (formal, disciplinar) y el no-científico, por ejemplo (Delvene et al. 2011). Dicho proceso se ha caracterizado como un movimiento hacia una concepción más constructiva y menos reactiva de la ET. En él, una tradición economicista y exclusivamente experta, basada en análisis cuantitativos y en un modelo de cálculos de riesgo que contrapone la sociedad y la naturaleza a la ciencia y la tecnología ha sido criticada frente a la necesidad de democratizar el proceso de evaluación y entender el desarrollo científico-tecnológico como producto interno y disociable de la sociedad (López 1997).

El campo de las ET es diverso en términos de los objetivos específicos y métodos de los estudios. Es posible distinguir tres tipos principales de evaluación: ET para el incremento del conocimento, la ET estratégica y la evaluación constructiva de tecnologías (Schot y Rip 1997; van den Ende et al. 1998). La última es el reflejo del proceso de apertura en los procesos de ET anteriormente mencionados. La evaluación constructiva de tecnologías, o *constructive technology assessment* (CTA, por su sigla en inglés) nació de la búsqueda por incluir la participación de una variedad de actores sociales en los procesos de evaluación y por influir en el desarrollo de las tecnologías y posibles trayectorias tecnológicas (van Eijndhoven 1997; Joss 1999), en lugar de limitarse a la evaluación de sus potenciales consecuencias. En este sentido, la metodología cobra especial importancia cuando es aplicada en la fase de diseño de la tecnología, en el seno de las instituciones promotoras de I+D+i (Franks y Cohen 2012). La principal diferencia entre el enfoque tradicional y el constructivo en la ET es que, mientras el primero considera la tecnología como una entidad estática, el segundo ve la producción de impactos de la tecnología en el seno de un proceso dinámico entre el cambio tecnológico y factores contextuales, en el que actores sociales promueven o evitan la ocurrencia de estos impactos (Schot y Rip 1997). De hecho, la evaluación constructiva de tecnologías parece tener sus orígenes en los estudios CTS, donde se asume la innegable influencia de procesos sociales en el desarrollo tecnológico (van den Ende et al. 1998).

En el caso de la evaluación social de políticas de I+D+i, muchas contribuciones se enfocan sobre todo en la evaluación de "los resultados de los esfuerzos hechos" en la política científica y tecnológica de una nación (Albornoz et al. 2005:74). Se dedican por tanto a analizar los niveles de producción, diseminación y apropiación del conocimiento científico y tecnológico en la sociedad. Esto les caracteriza más bien como estudios generales del impacto social del conocimiento, entre cuyos fenómenos a analizar se incluyen, por ejemplo, en el nivel macro, la aplicación del conocimiento a la actividad productiva (i.e. innovación) en un país o la influencia de la oferta científica brindada por los diversos grupos de investigación en una determinada región (Albornoz et al. 2005:87). También se evalúa el impacto de la producción de conocimiento científico y tecnológico en la sociedad desde la perspectiva del desarrollo social y humano (véase Estebánez y Vogt 2005). En este caso, se analiza el papel del conocimiento en la generación de beneficios sociales como, por ejemplo, el incremento de la esperanza de vida o de lo niveles de bienestar en la sociedad. Desde el punto de vista metodológico, el análisis del impacto social de las políticas de I+D+i enfatiza la medición precisa (cualitativa y cuantitativa) de los resultados tangibles, o los productos obtenidos como consecuencia de la actividad científica promocionada por las políticas públicas (Villaveces et al. 2005).

De manera más aplicada, propuestas importantes de marcos metodológicos sugieren el uso de amplias checklists o listas de control para una valoración robusta de los aspectos sociales, socioecónomicos e incluso medioambientales de los proyectos de I+D+i desarrollados en centros tecnológicos (véase Moñux-Chércoles et al. 2003). Propuestas como estas contribuyen a establecer la conexión entre los procesos de evaluación exante (i.e. anterior a la implementación de los proyectos) y expost (i.e. posterior a la implementación de los proyectos), donde los aspectos asociados a los potenciales impactos de determinadas tecnologías se evalúan ya en la fase de I+D+i de los desarrollos científico-tecnológicos. De este modo, sus objetivos se conectan en parte a aquellos de algunas evaluaciones constructivas de tecnologías.

1.3 Los impactos sociales del etanol utilizado como biocombustible

En la búsqueda de fuentes de energía potencialmente menos contaminantes que los combustibles fósiles[9], y que se puedan obtener desde países distintos a aquellos que hoy dominan la producción de crudo, la producción de biocombustibles ganó considerable apoyo en la última década en distintos países dentro y fuera de Europa. Sin embargo, como cualquier desarrollo científico-tecnológico, los biocombustibles pueden conllevar impactos de orden ambiental y social. Desde hace algunos años, se ha generado una notable controversia política y en diversos sectores de la sociedad y de la comunidad científica respecto a algunos aspectos de su sostenibilidad. La mayor parte de ellos se refieren a los efectos negativos en el medio ambiente de la producción a gran escala de los principales tipos de biocombustibles comercializados en la actualidad, el etanol y el biodiesel. Aunque en menos profundidad, la controversia en torno a la sostenibilidad de los biocombustibles también se ha ocupado de temas sociales, como los impactos de su producción en comunidades rurales, las malas condiciones de trabajo de las personas involucradas en el proceso de

[9] En términos de gases de efecto de invernadero, sobre todo el dióxido de carbono (CO_2).

cultivo de materias primas y la incertidumbre respecto a los efectos de estos cultivos en la seguridad alimentaria, entre otros.

Basada en los trabajos de Mol (2007) y Boucher (2012), que se dedican a analizar a fondo la controversia en torno a los biocombustibles, la siguiente tabla (Tabla 3) resume los principales temas relacionados con el debate.

Temas	Encuadre
Biodiversidad	Cambios en el uso de la tierra para la producción de biocombustibles puede conllevar a la deforestación de zonas de bosque y a pérdidas en los niveles de biodiversidad.
Economía rural	Hay incertidumbre respecto al potencial de los biocombustibles de generar beneficios económicos a zonas rurales, por ejemplo, en la forma de generación de puestos de trabajo.
Emisiones de gases de efecto invernadero (GEI)	La reducción de los biocombustibles en GEI es considerada costosa, i.e. es menos eficiente desde el punto de vista económico que otras estrategias que buscan la reducción de los GEI. Además, hay incertidumbre respecto a las emisiones de GEI tras el uso de fertilizantes, teniendo en cuenta el uso de combustibles fósiles para el transporte en la fase de producción de materia prima y distribución del biocombustible. También hay incertidumbre respecto a las emisiones de GEI que derivan de los cambios directos e indirectos en el uso de la tierra y en el rendimiento de diferentes tipos de cultivos utilizados como materia prima, que suelen resultar en mayores reducciones de GEI que otros (e.g. caña de azúcar versus maíz).
Prácticas agrícolas	La producción de materia prima para biocombustibles suele basarse en modelos de monocultivos que pueden conducir a la degradación de los suelos y contaminación del agua.
Seguridad alimentaria	La utilización de ciertos cultivos en la producción de biocombustibles que también se utilizan como alimentos parece interferir en los precios de los últimos. También una mayor demanda de insumos agrícolas, mano de obra y tierra puede llevar a un aumento de los precios de los productos agrícolas en general. El aumento de precios afecta negativamente a la seguridad alimentaria sobre todo de los sectores más empobrecidos y vulnerables de la sociedad.
Tenencia de la tierra	Pequeños agricultores pueden verse afectados negativamente por la presión ejercida por productores de gran-escala, sobre todo en

	aquellos países donde conflictos en torno a la tenencia de tierra son más comunes.

Tabla 3. Principales temas discutidos en la controversia en torno a los biocombustibles. Basado en: Mol (2007) y Boucher (2012).

Aunque estos dos autores se han dedicado al análisis de la controversia en torno a los biocombustibles, otros han tratado de analizar los varios impactos de su producción en el medio ambiente y en la sociedad. Especialmente en algunos trabajos se nota el carácter dicotómico que se les ha atribuido a los biocombustibles – promocionados por un lado como estrategia en la lucha contra el cambio climático y por otro como una fuente de nuevos problemas (e.g. Doornbosch y Steenblik 2007; Sharlemann y Laurance 2008; Ajanovic 2011; Selfa et al. 2011; Wright y Reid 2011). Sin embargo, como se sostiene en los distintos artículos que componen esta tesis, la mayor parte de los estudios acerca de la sostenibilidad de los biocombustibles y más específicamente del etanol, se han enfocado en el análisis de sus aspectos económicos y ambientales. Esta tendencia no es exclusiva de los biocombustibles, sino que se aplica igualmente a estudios de los impactos de otros desarrollos energéticos (Carrera y Mack 2010; Hall et al. 2011). En el caso de los biocombustibles, dicho desequilibrio entre el análisis de las dimensiones económica y ambiental frente a la social ha sido verificada en los artículos que se presentan a continuación y ha sido también destacada anteriormente por otros autores (véase Sheehan 2009; Uriarte et al. 2009; German et al. 2011 y Lehtonen 2011).

1.3.1 Primera exploración: principales temas

Los enfoques de los distintos estudios que se han ocupado en mayor o menor grado del análisis de los impactos sociales de los biocombustibles se ven reflejados en las siguientes secciones de esta tesis. El trabajo de Buchholz et al. (2009) ha servido de punto de partida en la identificación y sistematización de estos impactos(véase Artículo I). En él, los autores seleccionan unos criterios para la evaluación de la sostenibilidad los sistemas bioenergéticos, entre los cuales quince se clasifican como de orden social. Agrupándo dichos criterios temáticamente, emergen cinco temas principales (Tabla 4).

Temas principales	Criterios sociales identificados por Buchholz et al. (2009)	Criterios de aplicabilidad ‘general’[1]
Cambios en el uso de la tierra	Derecho de propiedad y uso de la tierra	Cumplimiento de las leyes Monitoreo del rendimiento de los criterios Planificación Respeto por los derechos humanos
	Disponibilidad de tierra para otros fines de interés humano (que no la producción de alimentos)	
Seguridad del agua[2]	*No informado*	
Seguridad alimentaria	Seguridad alimentaria	
Desarrollo rural	Condiciones de trabajo	
	Respeto a las minorías	
	Cohesión social	
	Calidad de vida	
	Impactos de los ruidos	
	Impactos visuales	
Aceptación social y participación pública	Aceptación cultural	
	Participación	

Tabla 4. Temas y criterios sociales relacionados con la producción de biocombustibles. [1]Criterios de aplicabilidad general son aquellos que se aplican a más de un tema. [2]El tema de la seguridad del agua no se incluye en el trabajo de Buchholz et al. (2009) pero es relevante en la literatura analizada.

Sin embargo, como se verifica en los artículos que se presentan a continuación, los criterios destacados por Buchholz et al. (2009) son capaces de ‘capturar’ la dimensión social de los impactos de los biocombustibles de manera parcial. Esta parcialidad también se aplica a los principales temas que se han identificado a partir de estos criterios. Un estudio más profundo y exhaustivo, como el que se presenta en los Artículos II y III de esta tesis indica una realidad bastante más compleja. Igualmente, estos artículos revelan que en la mayoría de los trabajos que abordan la dimensión social de los biocombustibles – en concreto, del etanol – dicha complejidad se ha tratado de manera superficial o poco sistemática, haciendo que la información ofrecida por ellos sea difícil de trasladar a estudios concretos de evaluaciones de impacto.

1.3.2 Hacia la sistematización de los impactos sociales del etanol

Una manera de sistematizar los impactos sociales del etanol utilizado como biocombustible – con el fin de ser de utilidad no solo a la comunidad académica que se dedica a investigar al tema, sino también a aquellos interesados en llevar a cabo evaluaciones concretas – es tratar dichos impactos desde la perspectiva del ciclo de vida de este producto. Los análisis del ciclo de vida (ACV) se utilizan sobre todo como metodología en estudios de los impactos ambientales de los biocombustibles (veáse Larson 2006). No obstante, su enfoque se aprovecha en los artículos de esta tesis como un marco de apoyo para la sistematización de la dimensión social de los impactos del etanol. En este caso, se pueden distinguir entre las distintas fases de producción, distribución y uso de este biocombustible, así como entre los distintos grupos de actores sociales que pueden verse involucrados o relacionados con su ciclo de vida. La estrategia de búsqueda, la identificación y sistematización de los aspectos que componen la dimensión social del etanol utilizado como biocombustible, tal y como se presentan en los trabajos disponibles en la literatura académica, se ilustra a través de una matriz social que se desarrolló como base para la investigación presentada en los Artículos II y III de esta tesis (véase Artículo II, Apéndice A). La matriz recoge varios aspectos relacionados con los impactos sociales del etanol y los agrupa y organiza en la forma de criterios e indicadores. En este sentido, puede servir como un complemento en estudios de evaluación de impactos del etanol. Su carácter general, sin embargo, hace con que sea necesario verificar la relevancia de los distintos aspectos reflejados en ella contra contextos específicos de aplicación. La publicación de los principales resultados de la construcción de esta matriz consiste en el primer intento, en la literatura académica especializada, de sistematización de la dimensión social del etanol utilizado como biocombustible, con el propósito de ser de utilidad a evaluaciones de impacto social del mismo.

La matriz social abarca distintos criterios que podrían formar parte de un análisis de tipo *macro* de los impactos sociales del etanol, como los efectos de sistemas de producción centralizados o descentralizados; o más específicos como los efectos de los cambios en el tráfico en carreteras regionales. De esa manera, la matriz, que representa un esfuerzo hacia la recopilación y sistematización del máximo de información posible obtenida en la literatura seleccionada, puede atender a los objetivos de evaluaciones de los impactos sociales del etanol con distintos enfoques y escalas. Para probar su utilidad y profundizar en el análisis de los impactos sociales del etanol, se ha llevado a cabo un estudio de evaluación basado en opinión experta, el cual se presenta en el artículo IV de esta tesis. Dicho estudio se enfoca en la transición tecnológica entre los biocombustibles de primera y segunda generación y cuenta con la contribución de reconocidos expertos en el tema de la sostenibilidad del etanol, de distintos países e instituciones. Los resultados de la evaluación de algunos de los potenciales impactos del etanol de segunda generación, o etanol celulósico, señalan la complejidad de cada uno de ellos. Mientras la matriz sugiere el uso de una lista de chequeo en los procesos de evaluación, el último artículo recogido en esta tesis destaca los retos a los que se pueden enfrentar tales procesos – sobre todo en el caso de estudios prospectivos que se dedican a analizar tecnologías de tipo emergente, como el etanol celulósico.

1.4 Hipótesis de trabajo y objetivos

Las secciones anteriores han adelantado la hipótesis de trabajo y los objetivos de la presente tesis y de los artículos que la componen. De lo que se ocupa esta tesis doctoral y, por tanto, los artículos incluidos en ella, es de investigar la dimensión social de los impactos del etanol utilizado como biocombustible, una alternativa a los combustibles fósiles utilizados en vehículos, y de sus tecnologías emergentes, concretamente aquellas relacionadas con el etanol celulósico (segunda generación), considerado a su vez una alternativa al etanol actualmente comercializado (primera generación). Conviene indicar que el proyecto inicial que ha dado lugar a la investigación que aquí se presenta originalmente pretendía estudiar los límites y oportunidades de una evaluación 'integrada' del etanol, enfocándose en la articulación entre las dimensiones social y ambiental de sus impactos. No obstante, a lo largo del primer año de investigación, se comprobó que los impactos sociales del etanol – y de los biocombustibles, en general – se trataban muy marginalmente en los estudios que se ocupan de analizar sus sostenibilidad. Las dimensiones ambiental y económica de su sostenibilidad, además de los análisis de sus aspectos técnicos, abundaban (y todavía abundan) en la literatura dedicada a la evaluación de los impactos de este biocombustible. Por este motivo, la investigación que se ha realizado en los últimos años ha tenido como principal objetivo el de contribuir a llenar este hueco en la literatura y a arrojar luz sobre la complejidad de estos impactos, además de anticipar los impactos de las tecnologías emergentes relacionadas con el etanol.

Uno de los artículos que se presenta en esta tesis constituye el único estudio sistemático de los impactos sociales del etanol disponible en la literatura científica (véase Artículo III). Los otros dos tienen como objetivo dar un paso más allá, analizando los potenciales impactos sociales del etanol obtenido desde procesos y tecnologías más avanzados, los cuales a día de hoy se encuentran todavía en fase experimental o de demostración industrial (véase Artículos I y IV). Son igualmente novedosos en tanto que son pioneros en el análisis de los aspectos sociales de una nueva generación de etanol y se dedican a abrir la 'caja negra' relacionada con la dimensión social de estas tecnologías – una dimensión que muchos autores tratan, pero que sin embargo en pocas ocasiones se ocupan de trabajar de manera más profundizada. Un último trabajo de investigación, que no se recoge en esta tesis, ha tratado de analizar la percepción pública de los impactos de una planta de etanol ubicada en el municipio de Babilafuente, Salamanca. Este estudio indica la orientación de futuros trabajos relacionados con el tema y dará continuidad al proyecto de comprehender con profundidad la dimensión social de los impactos de desarrollos científico-tecnológicos como los biocombustibles. De cara a atender sus objetivos, los artículos que conforman esta tesis se caracterizan por estudios empíricos, de orientación inductiva y carácter exploratorio (proyección de impactos) y evaluativo (valoración de los procesos de cambio social y sus impactos relacionados) de los impactos reales y potenciales del etanol desde distintas fuentes y utilizando distintos métodos. Los objetivos específicos de cada uno de los estudios que forman parte de esta tesis se presentan en castellano en los resúmenes de los artículos correspondientes.

1.5 Conclusiones

Las distintas investigaciones que componen esta tesis doctoral contribuyen a un mismo objetivo general, el de comprender y analizar la dimensión social de los impactos de los desarrollos científico-tecnológicos. Para tal, se ha tomado como estudio de caso el del etanol utilizado como biocombustible, también conocido como bioetanol. La elección de este caso específico no ha sido accidental ni mucho menos desinteresada – los biocombustibles se han transformado en una de las mayores apuestas políticas en los últimos tiempos en materia de alternativas energéticas para el sector de transporte frente al aumento de los precios del petróleo y en el contexto de la lucha contra el cambio climático. Paralelamente, en los últimos años, han sido foco de escrutinio público y científico en función de sus impactos ambientales y sociales.

La producción de biocombustibles guarda una interesante diferencia en comparación con otras fuentes de energía que no debe pasar desapercibida. Se trata de un desarrollo científico-tecnológico de carácter descentralizado geográficamente y que aprovecha unas infraestructuras ya existentes en el sector de transportes para su distribución y uso. Diferentemente de los combustibles fósiles – que dependen de la disponibilidad de reservas explotables en determinados territorios, o de otras energías renovables como la solar, eólica o hidroeléctrica – que dependen de ciertos recursos cuya disponibilidad se concentra en determinadas regiones, los biocombustibles solo dependen de que haya suelo agrícola para la producción de su materia prima. Aunque se pueda argumentar que la disponibilidad de suelo agrícola es finita y hasta cierto punto centralizada, se trata de un recurso mucho más extendido en el planeta que los anteriores. Por este motivo, el fenómeno de apoyo a la producción y al consumo de los biocombustibles es sin duda mundial. El soporte político a los biocombustibles en países como Estados Unidos y Brasil, además de en países europeos, africanos y asiáticos, ha venido acompañado del soporte industrial y económico. Asimismo, su producción ha fomentado un mercado global de *commodities* agrícolas y otros mercados que han surgido paralelamente, como el de la importación y exportación de los propios biocombustibles, en especial el etanol, o de los distintos insumos necesarios para su producción. También se ha generado en torno a su desarrollo un sin número de proyectos de I+D+i en varias partes del mundo dedicados a incrementar la eficiencia y calidad de los procesos de conversión, reducir los costes del producto final y mejorar el rendimiento de estos combustibles respecto a su sostenibilidad ambiental y social.

Pese a que los biocombustibles hayan sido blanco de críticas negativas, su producción no se ha frenado, sino que dichas críticas han motivado el desarrollo de innovaciones y un cambio en el discurso político, que ha adoptado una postura de precaución frente a las posibles consecuencias de estos desarrollos en el medio ambiente y en la sociedad. Sin embargo, a pesar de la demanda de análisis científicos más robustos sobre la sostenibilidad de los biocombustibles, la literatura dedicada a la evaluación de la dimensión social de esta sostenibilidad, en concreto la del etanol de primera generación y el etanol celulósico es todavía escasa y suele tratar el tema de manera superficial. Las investigaciones que se han desarrollado en el marco de esta tesis doctoral llenan parte del hueco en la literatura especializada, sistematizando lo que se ha recogido en gran parte de los trabajos que tratan del tópico y profundizando en algunos de sus aspectos. Los resultados, discusiones y conclusiones de cada una de ellas sostienen a los de las demás, aunque es importante tener en cuenta el orden en el que se han desarrollado. Empezando por un estudio narrativo y exploratorio de la sostenibilidad social del etanol de primera y segunda generación en el que se revela que el tema se ha tratado marginalmente en la literatura especializada (Artículo I), seguido de un estudio sistemático dedicado a establecer el estado del arte en el tema en la literatura especializada y definir la dimensión social de los impactos de estos desarrollos (Artículos II y III), y finalmente, una evaluación profundizada de algunos de los potenciales impactos sociales del etanol celulósico (Artículo IV). Las siguientes secciones resumen las conclusiones de estas investigaciones de manera integrada.

1.5.1 La integración entre las dimensiones ambiental y social de los impactos de los desarrollos científico-tecnológicos

El estudio de caso del etanol utilizado como biocombustible indica que varios de los impactos de este desarrollo científico-tecnológico no se relacionan de manera exclusiva con la dimensión ambiental o social de su sostenibilidad, sino que revelan la conexión entre ambas. De hecho, la comprensión de la interdependencia entre los impactos ambientales y sociales de los proyectos científico-tecnológicos, especialmente aquellos relacionados con la energía, ha motivado el desarrollo de las evaluaciones de impacto social hace algunas décadas (Burdge 2003). En el caso de la cadena de producción de los biocombustibles, los impactos provocados por los cambios en el uso de la tierra sirven de ejemplo de la relación entre estas dos dimensiones. Debido a su efecto directo en los servicios ecosistémicos, cambios en el uso de la tierra pueden conllevar una pérdida en la fertilidad de los suelos o en los niveles de biodiversidad, con efectos indirectos en la seguridad alimentaria y la conservación de especies útiles o valoradas por las sociedades humanas. Asimismo, la seguridad y salud de las poblaciones depende de que se garanticen servicios ecosistémicos como agua limpia para el consumo en suficiente cantidad – la conversión de áreas al modelo de agricultura intensiva y de gran escala basada en monocultivos puede poner en peligro dichos servicios.

No obstante, las comunidades responsables del desarrollo de la teoría y práctica de evaluaciones integradas se enfrentan todavía a barreras institucionales, epistémicas y metodológicas. Bajo el paradigma del 'desarrollo sostenible', aunque se reconozca la necesidad de un diálogo integrado entre las dimensiones ambiental, social y económica de los impactos de los desarrollos científico-tecnológicos (Eggenberger y Partidario 2000), académicos, expertos y evaluadores siguen desarrollando sus investigaciones de manera fragmentada en el caso de los biocombustibles. Esta fragmentación puede estar en última instancia relacionada con la histórica percepción de que los análisis derivados de las ciencias naturales y las sociales son inconmensurables; de que los análisis desarrollados por las naturales priorizan los números, mientras las sociales priorizan el sentido – y que estas dos maneras de entender el mundo son opuestas (Bryman 2012). La histórica falta de diálogo entre las dos comunidades ha dado lugar a estructuras institucionales rígidas, que en la actualidad siguen resistiéndose a la integración. Esta tendencia se ve reflejada en un campo tan específico como el de las evaluaciones de impacto de los desarrollos científico-tecnológicos.

1.5.2 La dependencia del contexto y la complejidad de las evaluaciones

Aunque un análisis genérico tomando como punto de referencia el ciclo de vida del producto sea posible y produzca resultados útiles para evaluaciones específicas, una definición precisa de los impactos sociales positivos y negativos del etanol dependen en última instancia de los contextos sociopolíticos y ambientales en los que se inserta su cadena productiva. Peculiaridades como condiciones geoclimáticas, patrones de ocupación del territorio, disponibilidad de recursos naturales, niveles socioeconómicos de las poblaciones o aceptación social de estas tecnologías son algunos de los factores que influyen en las consecuencias de la producción y uso del etanol como biocombustible. Por ejemplo, distintos tipos de materia prima presentan distintas demandas de agua, de manera que dicha demanda se debe sopesar frente a la disponibilidad de agua para irrigación o régimen pluvial de una determinada región para una evaluación más precisa de la seguridad del agua para determinadas poblaciones. Por otra parte, la generación de empleo en zonas rurales, comparada con la relacionada con la producción de etanol de primera generación, debe ser menor y caracterizada por una demanda de mano de obra especializada. En regiones más pobres los beneficios de la industria del etanol celulósico dependerán tanto de las características de los proyectos (por ejemplo, su escala y tipo de cadena de producción) como de las políticas específicas de la empresa que desarrolla el proyecto, o de la adopción de principios de responsabilidad social corporativa. Aunque la importancia del contexto en la evaluación de impactos sea reconocida en la literatura (Vanclay 2003b; Bond y Pope 2012; Esteves et al. 2012) y evidente en el estudio de caso desarrollado en esta tesis, una parte importante de los procesos de evaluación se refiere a la posibilidad de análisis comparativos con estudios ya realizados (Taylor et al. 2003). Si bien sus resultados no son necesariamente generalizables, las variables consideradas o desarrolladas a partir de evaluaciones específicas pueden servir como parámetros para futuras evaluaciones. En el caso del etanol utilizado como biocombustible, la carencia de estudios empíricos acerca de sus impactos sociales desafortunadamente no contribuye a este objetivo y revela la falta de robustez de muchos análisis que se han publicado en la literatura especializada sobre el tema.

El carácter descentralizado y globalizado de la cadena productiva del etanol también complica la tarea de identificación, definición y valoración de sus impactos sociales positivos y negativos. No solo la tarea de llevar a cabo evaluaciones que tienen una dimensión global es extremadamente compleja, sino que las distintas culturas políticas y condiciones socioeconómicas de las regiones a investigar contribuyen al aumento de esta complejidad. Esto se revela sobre todo en una percepción acerca de la dicotomía norte-sur o países ricos versus países pobres, según la cual las capacidades de los últimos para evitar, mitigar o monitorear los impactos negativos de desarrollos como, por ejemplo, el etanol celulósico son consideradas como inferiores en comparación con los primeros.

1.5.3 La importancia de la participación de distintos actores en el proceso

La configuración de los actuales sistemas energéticos no es algo sobre lo que se ha decidido de manera democrática en la historia. Si bien hoy hay estructuras que permiten un diálogo más inclusivo a este respecto, la participación de los diversos actores en este ámbito parece ser todavía insuficiente, no solo a nivel de estudios específicos de sus impactos, sino además desde una perspectiva política más amplia. Teniendo en cuenta los resultados de las investigaciones desarrolladas en esta tesis, la variedad de actores sociales que participan en la evaluación de los impactos de los desarrollos científico-tecnológicos es considerada importante por varios motivos.

En primer lugar, porque se espera que los desarrollos científico-tecnológicos contribuyan a unos objetivos sociales que se deben definir mediante consulta con distintos actores. En el caso del etanol utilizado como biocombustible se deben discutir con los actores interesados y afectados, no solo los objetivos relacionados con su uso final (como servir de alternativa a los combustibles fósiles en los motores de combustión interna), sino también los relacionados con su producción (como contribuir al desarrollo de zonas rurales, entre otros). En segundo lugar, teniendo en cuenta la subjetividad inherente a cualquier proceso de evaluación y las limitaciones y sesgo de los análisis expertos (Wynne 1992; Mostert 1996), los impactos sociales positivos y negativos del desarrollo y la implementación de las tecnologías solo se podrán identificar, definir y, sobre todo, valorar a través de la consulta con estos actores (Mostert 1996). En los procesos de evaluación de impacto, estos actores contribuyen sobre todo a la definición de los límites del sistema a evaluar y a la identificación, definición y valoración de las variables. Un ejemplo ampliamente discutido en el caso del etanol utilizado como biocombustible se refiere al disputado concepto de tierras marginales, cuyo significado no es consensuado y depende del contexto y de los actores consultados. Lo mismo se aplica a la valoración de otros servicios ecosistémicos, incluyendo cuestiones como preferencias sobre determinados paisajes y los impactos visuales de estos desarrollos. Debido al carácter descentralizado y complejo de la cadena productiva del etanol, para cada fase de su ciclo de vida es necesario involucrar a distintos grupo de actores – desde agricultores y comunidades rurales, hasta representantes de la industria y poblaciones urbanas.

Finalmente, y en tercer lugar, porque si los resultados de las evaluaciones específicas llegan a influir en el diseño de las políticas científico-tecnológicas y de las regulaciones relativas a determinadas tecnologías, el proceso de evaluación puede contribuir al diálogo entre la sociedad y la toma de decisiones en este ámbito.

Desafortunadamente, el número de estudios que se han dedicado a explorar la percepción pública de los biocombustibles es escaso y en su mayoría tratan del tema de manera superficial. Asimismo, la existencia de un mercado global de etanol y de materia prima para su producción es uno de los desafíos a los que se enfrentan aquellos procesos que busquen la inclusión de distintas voces en la evaluación. Se destaca en esta tesis la necesidad de se desarrollen estudios más inclusivos para informar la evaluación de los biocombustibles, sobre todo los análisis *ex ante* de los impactos de los biocombustibles avanzados.

1.5.4 ¿El "mejor" de los casos? La producción de etanol a partir de residuos y desechos

Los resultados de las distintas investigaciones que componen esta tesis apuntan hacia una misma dirección respecto a la configuración de un escenario más "aceptable" para el futuro desarrollo del etanol desde el punto de vista de su sostenibilidad social y ambiental. El etanol celulósico obtenido desde cultivos no-alimentarios, residuos agrícolas y forestales o desechos urbanos se considera un sustituto más sostenible que el etanol de primera generación. Esta conclusión no solo coincide con la literatura y la percepción experta, sino también con las últimas regulaciones europeas e internacionales en materia de la sostenibilidad de los biocombustibles, como se indica en esta tesis. No obstante, las investigaciones que se han llevado a cabo igualmente revelan que es necesario tener en cuenta las peculiaridades de cada ruta tecnológica para la producción de biocombustibles de segunda generación como el etanol celulósico. Además, se destaca la necesidad de considerar los contextos ambientales y sociales específicos en los que se insertan distintas cadenas de producción, ya que estos influyen en sus consecuencias positivas y negativas.

La producción a gran escala de etanol celulósico dependerá de un suministro considerable de materia prima. En el caso de que esta materia prima derive de nuevos cultivos – de manera análoga a la producción de materia prima desde cultivos alimentarios para el etanol de primera generación – es posible que sus impactos sociales sean similares a aquellos ya evidenciados para el último. Esto se aplica sobre todo a materia prima obtenida desde los bosques de rotación corta o gramíneas perenes, conocidos como cultivos para fines energéticos. En cambio, se entiende que el uso de residuos agrícolas o forestales y los desechos urbanos no suponen una demanda de nuevas áreas, evitando cambios radicales en el uso de la tierra. Sin embargo, también la diferenciación entre residuos y desechos es importante tener en cuenta en la evaluación de los impactos de cada cadena productiva. Entre los factores que se deben considerar a la hora de evaluar los impactos del etanol celulósico producido a partir de residuos agrícolas y forestales están desde los niveles máximos de extracción de residuos del suelo para evitar su deterioro hasta los efectos de tal extracción en otras cadenas productivas como la del pienso o los efectos indirectos en la seguridad alimentaria. El alto coste de la recolección y transporte de residuos también se deben tener en cuenta en un análisis de coste y beneficio. En este sentido, se verifica en esta tesis que la utilización de desechos municipales orgánicos como materia prima para la producción de etanol es considerada menos controvertida que las demás. No por casualidad, a diferencia de otras, el uso de esta materia prima no debería involucrar cambios en el uso de tierra – transcendiendo el paradigma agrícola en que las demás se insertan. Sin embargo, esta ruta tecnológica se encuentra todavía menos desarrollada que las demás, de manera que aún queda por entender en profundidad sus implicaciones económicas, ambientales y sociales.

1.5.6 Consideraciones finales: hacia la anticipación, reflexión e inclusión en la evaluación de tecnologías

La complejidad de cadenas de producción como las del etanol celulósico aumenta con el tiempo, de manera que el sistema técnico tiende a volverse más resistente a cambios. De forma análoga, sus impactos también tienden a volverse menos reversibles. Como se verifica en esta tesis, los niveles de reversibilidad de estos impactos y la posibilidad de identificarlos y monitorearlos dependen doblemente de las características del sistema técnico y de los contextos ambientales y sociopolíticos en los que se desarrollan. Asimismo, los resultados de las investigaciones que aquí se presentan sugieren que pueden ser considerables los costes sociales de la continuación de ciertos modelos de producción de etanol de primera generación y la implementación en gran escala del etanol celulósico. Por otra parte, también se verifica que su desarrollo puede generar beneficios sociales. No obstante, lo que queda por comprender, tomando cada caso en su particularidad y conectándolo con experiencias anteriores, es exactamente qué modelos de producción y en qué contextos se consiguen estos beneficios. Más importante, qué alternativas pueden atender a los mismos objetivos del sistema técnico, quiénes son los actores que deben tener sus intereses y opiniones reflejados en la valoración de los impactos positivos y quiénes son aquellos que se verán afectados por los impactos negativos del etanol utilizado como biocombustible.

Tales consideraciones, entendidas como un desenlace del estudio de caso de la dimensión social del etanol, se entienden como válidas para otros desarrollos científico-tecnológicos y tienen relevancia para los procesos de evaluación de tecnologías en general. Además de la necesidad de internalizar la dimensión social de los impactos de las tecnologías en los procesos de evaluación, los puntos que se destacan a partir de las conclusiones de las investigaciones llevadas a cabo en esta tesis son: a) la necesidad de que las evaluaciones adopten un carácter anticipatorio para que puedan influir en las trayectorias tecnológicas todavía en las fases iniciales de desarrollo del sistema técnico; b) la necesidad de que se definan los objetivos del sistema técnico y de que se consideren alternativas disponibles anticipadamente; c) la necesidad de que se investigue la interacción entre los factores contextuales y el sistema técnico para que se clarifiquen los efectos de estos factores en el desempeño del mismo y viceversa y d) la necesidad de que se involucren distintos actores sociales en la identificación, definición y valoración de las consecuencias positivas y negativas de las tecnologías. Estos puntos constituyen a la vez prioridades y desafíos para la evaluación de tecnologías. Aunque no necesariamente novedosos, se han corroborado y reforzado a partir de la investigación de un estudio de caso prominente en la actualidad, como lo es el del etanol utilizado como biocombustible.

Nuestra capacidad de identificar las consecuencias de las tecnologías antes de su implementación es, si no nula, limitada, de manera que solemos darnos cuenta de sus impactos cuando los experimentamos (Collingridge 1980). El ejemplo de los ya comprobados impactos ambientales y sociales de los biocombustibles de primera generación es tan paradigmático cuanto el ofrecido por Collingridge (1980) respecto a los impactos negativos del plomo en la salud humana, utilizado ampliamente por la industria en el pasado en medio al desconocimiento acerca de sus riesgos. De esta manera, si la necesidad de cambio del diseño tecnológico emerge de la identificación y comprensión de los impactos de las tecnologías – y estos se identifican solamente tras su implementación, es probable que el sistema técnico haya evolucionado hasta un nivel de complejidad en el que la posibilidad de cambio sea muy pequeña o tienda a cero (Collingridge 1980). Es decir, los sistemas técnicos se vuelven menos flexibles y reversibles con el tiempo. Un ejemplo ofrecido por Collingridge (1980) es el de los automóviles y la infraestructura relacionada con ellos. Naturalmente, la popularidad de los biocombustibles como alternativa a los combustibles fósiles en el sector de transportes tiene relación con este ejemplo. El rápido y extendido desarrollo de los biocombustibles se debe a la existencia (y resistencia) de unas infraestructuras de proporciones extraordinarias y de un sistema social, político y económico asociado al sistema técnico que es de igual o mayor proporción y que se encuentra bien establecido. Aunque el concepto de sistemas sociotécnicos no es nuevo (véase Trist 1981), trabajos más recientes han profundizado en la comprensión de sistemas sociotécnicos complejos. Se argumenta que estos constan de artefactos, conocimiento, capital, trabajo y cultura, e involucran la producción, difusión y uso de las tecnologías. Además, se vuelven más resistentes a cambios según se hacen más complejas las relaciones entre actores y organizaciones y su estructura material (Hughes 1993; Geels 2004).

Sin embargo, aunque la predicción del futuro sea un logro imposible y el aumento de la complejidad de los sistemas sociotécnicos inevitable, los métodos y herramientas para la comprensión de escenarios y futuros tecnológicos han evolucionado teniendo en cuenta las limitaciones de los estudios tradicionales. Los últimos, basados casi exclusivamente en la opinión experta, priorizaban análisis cuantitativos y suponían que la identificación de un escenario único era posible respecto al desenlace del desarrollo tecnológico (Cuhls 2003). Reconociendo las desventajas y problemas de análisis lineales y deterministas, un cambio en la orientación de estos estudios ha dado lugar, no obstante, a la investigación de escenarios múltiples que incluyen alternativas tecnológicas, la priorización de análisis cualitativos y la inclusión de métodos participativos en los procesos (Cuhls 2003; Haegeman et al. 2013). Esta tendencia supone la posibilidad de influir en las trayectorias tecnológicas sobre todo en el inicio de su desarrollo y es análoga a propuestas como las de las evaluaciones constructivas de tecnologías (véase Schot y Rip 2007 y Franks y Cohen 2012).

Los resultados de esta investigación doctoral igualmente sugieren que cada desarrollo científico-tecnológico, con sus distintos elementos técnicos y contextuales constituye 'un universo en sí mismo'. En este sentido, es necesario que se juzguen los beneficios e impactos negativos de las tecnologías no solo anticipadamente, sino que además se tenga en cuenta su desempeño en situaciones concretas. Como ilustra Quintanilla (2005):

> "(…) no es lo mismo el riesgo de una central nuclear en un paraje desértico que en una zona densamente poblada, ni es igual el impacto ambiental de los efluentes contaminantes de una central térmica en una zona seca que en una húmeda, y las consecuencias del uso de pesticida agrícolas pueden ser inocuas o desastrosas si se produce una acumulación de contaminantes a lo largo de la cadena trófica, etcétera" (Quintanilla 2005:148).

Asimismo, los resultados del estudio de caso del etanol corroboran y destacan la importancia que cobra el contexto cultural y político en la gobernanza de las tecnologías y su desempeño. En última instancia, un mismo sistema técnico puede conllevar unos impactos positivos y negativos completamente dispares según la manera como esté regulado y controlado. La responsabilidad por estos impactos igualmente se extiende a la responsabilidad por elecciones acerca de la configuración del sistema. La cadena de producción del etanol utilizado como biocombustible comprende varias rutas tecnológicas posibles y, por tanto, presenta múltiples opciones cuya elección dependerá de ciertas preferencias. Esta elección de alternativas es un proceso multidireccional, como en el caso de muchas otras tecnologías, aparentemente menos complejas (véase Pinch y Bijker 1993). De este modo, lo esencial en la evaluación de tecnologías es ampliar y clarificar los distintos caminos posibles en el proceso, no reducirlos (Winner 2001).

A su vez, el diálogo acerca de alternativas y preferencias supone la necesidad de que la evaluación de tecnologías constituya un proceso participativo. Por 'participativo' se entienden los procesos que incluyen ciudadanos en la evaluación, además de expertos y científicos, *stakeholders* y tomadores de decisión. La inclusión de la ciudadanía en debates en torno al desarrollo científico y tecnológico se puede dar en distintos niveles, desde evaluaciones específicas para la regulación e implementación de proyectos, hasta discusiones acerca de programas y políticas más amplias. En el contexto de las democracias liberales, la premisa básica de esta 'práctica' es que los ciudadanos son agentes capaces y con derecho de opinar acerca del desarrollo de manera general (Hickey y Mohan 2004). En el caso de los procesos formales de evaluación de tecnologías, a pesar de sus limitaciones, un ejemplo de procedimiento institucionalizado de apoyo a la participación de diversos actores son las evaluaciones participativas de tecnologías, en las cuales se utilizan métodos que involucran ciudadanos, tomadores de decisión, científicos y expertos (Joss y Bellucci 2002).

Se sostiene en esta tesis que en casos como el del ciclo de vida del etanol utilizado como biocombustible una variedad de grupos sociales son afectados por su producción, distribución y uso. Sin embargo, uno de los desafíos de las evaluaciones participativas – o de cualquier instrumento que busque ser inclusivo, es identificar tales grupos y 'calibrar' su participación. Asimismo, el hecho de que una misma cadena de producción involucre distintos grupos dispersos geográficamente a nivel regional, nacional o internacional incrementa la complejidad de esta tarea. Pero la cuestión de la representatividad es solo uno de los factores por los que ejercicios de inclusión del público en el debate acerca del desarrollo de la ciencia y la tecnología han sido criticados en los últimos años (Irwin et al. 2012). Otros temas críticos a los que se enfrentan se refieren al hecho de que los ejercicios de participación presentan a priori un diseño y enmarcan el problema de manera que llegan a determinar el desenlace del proceso; que a menudo sus resultados no tienen impacto en los procesos de toma de decisión y que su relación con principios democráticos no es clara, sirviendo muchas veces para legitimar decisiones que en realidad ya han sido tomadas (Irwin et al. 2012). Es cierto que los mecanismos de participación pública en materia de ciencia y tecnología urgen mejoría en distintos aspectos. No obstante, aunque no exenta de críticas, la inclusión de distintas voces en el proceso de evaluación no solo contribuye a su legitimación social, sino que puede llegar a constituir el único medio para definir los objetivos sociales a los que deben atender los diseños tecnológicos, identificar las variables que formarán parte del estudio y, sobre todo, valorar estas variables.

Teniendo en cuenta lo que se ha discutido anteriormente, las evaluaciones de impacto y de tecnologías pueden insertarse en un contexto más amplio que aquel del aparato político-regulatorio, en el que procesos de evaluación sirven exclusivamente para informar, por ejemplo, procesos de obtención de licencia de ciertos proyectos. Dependiendo de su escala y objetivos, estas evaluaciones pueden contribuir con el diálogo entre la ciudadanía, la industria, los gobiernos y los científicos y expertos. Este es su propósito principal en la actualidad, sobre todo en relación con tecnologías de carácter emergente, como los biocombustibles avanzados, la nanotecnología, la biología sintética o las nuevas tecnologías de la información y comunicación. Sin embargo, aunque se haya avanzado considerablemente en la comprensión de la transcendencia social de los desarrollos científico-tecnológicos, parece ser que la concrección de un proyecto de evaluación de tecnologías más reflexivo e inclusivo depende de cambios institucionales que todavía quedan por forjar.

2 Artículo I: “From first to second generation biofuels: putting social aspects on the scale”

Referencia[10]

Ribeiro, B. E. (2012). From first to second generation biofuels: putting social aspects on the scale. En A. Agustoni y M. Maretti (Eds.), *Energy Issues and Social Sciences: Theories and Applications* (pp. 79-94). Milan: McGraw-Hill.

Abstract

Albeit it is well known by the scientific community that the adoption of new technologies and innovation processes can entail societal changes within global and community scales, little effort has been paid so far to the development of research and policy tools that allow us to effectively assess social consequences of novel energy sources deployment and use. Available scientific literature on biofuels assessment and analysis of its sustainability aspects illustrates these evidences: technical, environmental and economic approaches abound while social aspects are pushed aside or superficially discussed. Amongst different types of biofuel technologies, and particularly regarding concerns over social and environmental impact issues, second generation lignocellulosic bioethanol produced from agriculture and wood residues, short-rotation forests and prairie grasses or municipal waste is thought to be a promising option in the near future when compared to current first generation large-scale bioethanol made from sugar and starch crops, which technology and market, whereas well established, still cope with the lack of consensus surrounding its sustainability. Main reasons for such statement are related to scientific expectations regarding lignocellulosic bioethanol lower levels of CO_2 emissions along its life cycle and reduced risk of competing with food production. Bioethanol produced from lignocellulosic biomass might therefore represent an attractive alternative when it comes to energy options aimed at tackling climate change, while at the same time it

[10] El manuscrito incluido en este documento representa una versión extendida del artículo publicado como capítulo de libro.

could ensure important social sustainability criteria such as food security. Nonetheless, we should not dismiss assessing potential social consequences of its adoption as an alternative to first generation bioethanol like effects on land use, water security or rural development, for example. Moreover, issues such as public participation on the biofuels sustainability debate or evaluation of the social acceptance of these technologies are also of great relevance. Based on a literature review, this workraises the question of what differences, in terms of social aspects, are identified when comparing first generation and lignocellulosic bioethanol as alternative bioenergy sources. Main findings indicate that lignocellulosic bioethanol could face several social drawbacks if attention in depth is not given to aspects like the choice of feedstock type and socio-environmental particularities of producing regions. There is also an urgent need for more empirical research in this field in order to accompany the rapid development of biofuel policy worldwide.

2.1 Resumen de la investigación

Aunque la comunidad científica es consciente de que la adopción de nuevas tecnologías y procesos de innovación puede conllevar cambios sociales en escalas globales o locales, poco esfuerzo ha sido dedicado al desarrollo de herramientas a nivel político y científico que nos permita evaluar de manera efectiva las consecuencias sociales del desarrollo y uso de nuevas fuentes de energía. La literatura académica que trata del tema de la evaluación de los biocombustibles y de los distintos aspectos de su sostenibilidad ilustra dicho argumento: los análisis de sus dimensiones técnica, medioambiental y económica abundan, mientras los aspectos sociales se discuten superficialmente. Entre los distintos tipos de tecnologías biocombustibles, y particularmente en relación con preocupaciones acerca de sus impactos sociales y medioambientales, se considera el etanol celulósico o de segunda generación producido a partir de residuos agrícolas o forestales, bosques de rotación corta y gramíneas perennes o residuo sólido urbano, una opción más sostenible al etanol de primera generación hecho a partir de cultivos agrícolas. El último, aunque ampliamente comercializado, todavía se enfrenta a críticas relacionadas con su sostenibilidad. Las principales razones para el apoyo al etanol celulósico son expectativas acerca de reducciones en los niveles de emisiones de CO_2 y una reducción en el riesgo de competir con la producción de alimentos. El etanol producido a partir de biomasa celulósica parece representar, por tanto, una alternativa atractiva en términos de opciones energéticas alternativas a los combustibles fósiles en la lucha contra el cambio climático, a la vez que podría garantizar aspectos importantes de la sostenibilidad social como la seguridad alimentaria. Sin embargo, las potenciales consecuencias de su producción en el uso de la tierra, la seguridad del agua o el desarrollo rural no deben ser ignoradas. Además, temas como el de la participación pública en el debate sobre la sostenibilidad de los biocombustibles o la evaluación de la aceptación social de estas tecnologías son también de gran importancia.

En este sentido, el presente artículo explora las diferencias, en términos de los aspectos sociales y potenciales impactos del etanol de primera y segunda generación. Para ello, identifica y analiza distintos temas ligados a su dimensión social: los efectos de los cambios en el uso de la tierra, la seguridad del agua, la seguridad alimentaria, el desarrollo rural y la aceptación y participación pública en el debate acerca de su sostenibilidad. El estudio consiste en un análisis de información obtenida desde fuentes secundarias, concretamente la literatura especializada disponible, recogida de manera no-sistemática. Dicho análisis ha sido orientado por un grupo de criterios basados en el trabajo de Buchholz et al. (2009).

Los principales resultados de esta investigación indican que:

- Un aumento en la producción a gran escala de etanol de primera generación conlleva la diseminación de monocultivos y una reorganización espacial de los distintos tipos de uso de la tierra ya que nuevas áreas serían necesarias para tal expansión. Sin embargo, mientras el etanol de primera generación utiliza partes específicas de cultivos agrícolas, la materia prima celulósica se obtiene de cualquier parte de la planta. Una vez que la tecnología sea económicamente viable, y en el caso de que no hayan regulaciones adecuadas en la materia, un aumento en el cultivo de materia prima celulósica de tipo bosques de rotación corta o gramíneas perennes podría tener los mismos efectos que tuvo la expansión de cultivos para el etanol de primera generación. Por otra parte, el uso de residuos agrícolas o forestales podría evitar la demanda de nuevas áreas y procesos extremos de cambios en el uso de la tierra.

- La producción de materia prima para el etanol de primera y segunda generación presenta una demanda de agua variable que depende de las características específicas de los cultivos y de las zonas productoras en términos de irrigación, condiciones geo-climáticas, tecnologías disponibles para el proceso de conversión y de la capacidad de reciclaje del agua y mecanismos de gestión para evitar la contaminación del agua. Sitios en los que la materia prima para el etanol celulósico se produce en la ausencia de irrigación o procesos que utilizan residuos y desechos serían, por tanto, más favorables a garantizar la seguridad del agua.

- De manera similar a los resultados relacionados con los cambios en el uso de la tierra, el uso de residuos agrícolas o forestales, o desechos urbanos como materia prima para la producción de etanol celulósico debería ser menos perjudicial a la seguridad alimentaria que el cultivo de materia prima para el etanol de primera generación y bosques de corta rotación o gramíneas perennes utilizados en la producción de etanol celulósico. Además, las características específicas de determinadas áreas juegan un rol importante en los posibles efectos sobre la seguridad alimentaria. En este caso, la producción de materia prima celulósica en zonas en las cuales la producción de alimento no es posible porque presentan altos niveles de degradación, por ejemplo, serian más deseables a aquellas que actualmente – o en el futuro – se podría utilizar para fines alimentarios.

- En materia de desarrollo rural, las tecnologías involucradas en el proceso de producción de etanol celulósico deberían conllevar una reducción en el número de empleos generados por esta industria, además de una mayor demanda de mano de obra especializada. Así como en el caso del etanol de primera generación, una expansión de su producción hacia nuevas áreas, especialmente en países más pobres, también puede conllevar conflictos de interés entre comunidades rurales e inversores. Los beneficios a las comunidades rurales dependen de las características específicas de los determinados proyectos y de las políticas de las empresas.

- Existen pocos estudios disponibles en la literatura especializada que se hayan ocupado de evaluar la percepción pública respecto al etanol utilizado como biocombustible y las diferencias entre los de primera y segunda generación apenas se exploran en estos estudios. No es posible comparar la aceptación o participación pública en esta materia a partir de los estudios seleccionados, lo que indica la necesidad de que se lleven a cabo más investigaciones de este tipo, especialmente en países más pobres, donde muy posiblemente se concentrará la producción de materia prima para el etanol celulósico en el futuro.

Este artículo concluye que el etanol celulósico puede enfrentar varios desafíos en términos de su sostenibilidad en el futuro si no se investigan con más profundidad los efectos de la elección de determinados tipos de materia prima y el rol de las particularidades sociales y medioambientales de las regiones productoras en sus impactos. Se ha comprobado también que temas que normalmente se tratan en las evaluaciones de impacto de tipo ambiental pueden tener una importante relevancia social. Además, hay una carencia de investigaciones empíricas en este campo que necesita ser atendida de manera urgente para que pueda acompañar e informar las políticas de apoyo a los biocombustibles y regulaciones desarrolladas para la gestión de su sostenibilidad. Tales investigaciones deberían priorizar el análisis de la percepción y aceptación pública de estas tecnologías. Entre las distintas opciones de materia prima para la producción de etanol celulósico, el uso de residuos o desechos parece ser más favorable a otras y a aquellas actualmente utilizadas en la producción de etanol de primera generación. Sin embargo, su sostenibilidad dependerá de procesos menos costosos, más eficientes y menos contaminantes.

2.2 Introduction

The transport sector is responsible for approximately 60% of today's world oil consumption (IEA 2010). Moreover, 'business as usual' could make vehicle fleet and driving distances among OCDE countries grow 200% by 2030, with also an increase in the frequency of flights (Hoogma et al. 2002). If such a prediction is true, considerable amounts of biofuels -presented as one of today's strongest alternative to diminish transport sector dependence on oil- would be needed in the short-term whereas political and economic pressure continue to rise to meet demand of the energy sector for a) energy security reasons or b) to comply with renewable energy targets for environmental reasons. Among biofuel options, bioethanol is expected to be one of the most used in the transport sector within the next two decades (Hahn-Hägerdal et al. 2006). Largest world producers are United States, which uses maize as main feedstock, and Brazil, whose bioethanol is produced from sugarcane. These two countries are, together, responsible for 90% of the total bioethanol produced presently in the planet (Rajagopal et al. 2007). In Brazil, more than 80% of the vehicle fleet run on bioethanol (Soccol et al. 2010), which can be used as neat alcohol or, more often, blended with gasoline in flex-fuel hybrid vehicles.

Currently commercialised bioethanol is referred to as a first (1st) generation biofuel, while second generation (2nd) or lignocellulosic bioethanol is obtained through different conversion processes using different types of feedstock with respect to its predecessor and is still not commercially deployed due to economic constraints, with technologies in pilot or demonstration stages. To obtain the former, starch and sugar crops such as maize, wheat, sugarcane or sugar beet are fermented to bioethanol, while production of the latter, lignocellulosic biomass (composed mainly of cellulose, hemicellulose and lignin) from agriculture and forest residues, short-rotation forests and prairie grasses or municipal solid wastes provides the raw material to bioethanol production (Figure 1).

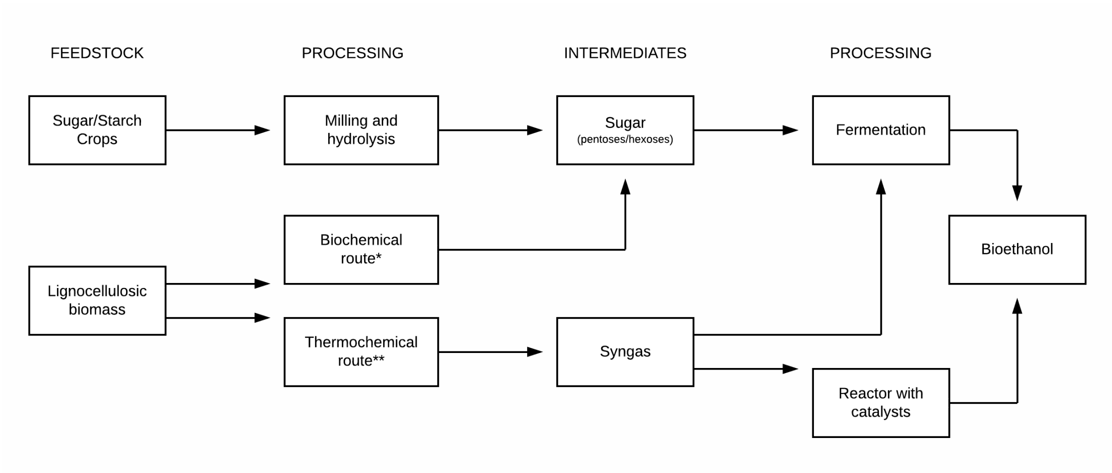


Figure 1. Overview of bioethanol conversion routes from sugar/starch crops (1st-generation bioethanol) and lignocelullosic biomass (lignocellulosic bioethanol). *Enzymes or micro-organisms convert cellulose and hemicellulose to sugars. **Heat and/or physical catalysts convert biomass to intermediate gas. By thermochemical route is possible to obtain other fuels than bioethanol. Sources: Badger (2002), Foust et al. (2009), Sims et al. (2010), Chum et al. (2011) and dos Santos et al. (2011).

Expectations are that 1st-generation will be gradually replaced by 2nd-generation bioethanol within the next years (Sims et al. 2008; Naik et al. 2010). This is mainly due to a lack of scientific consensus surrounding social and environmental sustainability of 1st-generation bioethanol (e.g. Rajagopal et al. 2007; Fargione et al. 2008; Ojima et al. 2009; Bureau et al. 2010 and Lapola et al. 2010) and promises of lignocellulosic bioethanol (i) lower levels of CO_2 emissions (Farrell et al. 2006; González-García et al. 2010) and (ii) reduced risk of competing with food production (Hahn-Hägerdal et al. 2006; Solomon et al. 2007) when compared to the former. Currently there is no clear cost advantage between the biochemical and thermochemical routes for conversion of lignocellulosic biomass into bioethanol (Foust et al. 2009; Sims et al. 2010), although is thought that in the longer term higher cost reductions should be achieved on the first case since thermochemical conversion is a much more mature technology (Sims et al. 2010). Besides, the biochemical route seems to be receiving more attention from investors due to the considerable number of precommercial plants being constructed or already in operation (dos Santos et al. 2011).

From an ethical point of view, similar to the use of fossil fuels which charted the fastest way to climate change (Gardiner 2004), and thus to the emergence of a number of new environmental and social challenges, biofuels rapid and widespread adoption could also entail intergenerational burdens given to its short to medium-term benefits versus possible negative consequences in the future. The point is that no forecasting is capable of being absolutely sure about what kind of environmental conditions we will face, for example, four decades from now. Neither those directly produced from the adoption of a technology (e.g. more nuclear accidents as consequence of a increase in number of power plants and in levels of seismic activity; or faster processes of deforestation of rainforest biomes as a consequence of the construction of large dams) nor those indirectly related to human interference in the world (e.g. higher sea levels as consequence of increased greenhouse effect). In this sense, sustainability criteria today used for different impact assessments could lose its validity through time as global warming may induce changes in, for example, vegetation cover, soil quality or water availability with ensuing societal and economic effects. Moreover, besides the appraisal of intergenerational aspects, assessment of intragenerational consequences is needed to insure equity among different social groups within society, avoiding social impacts to fall particularly in women, children, disabled people or populations of vulnerable regions (Vanclay 2003a). Nonetheless, albeit is well known by the scientific community that the adoption of new technologies and innovation processes can entail societal changes within global and community scales, little effort has been paid so far to the development of research and policy tools that allow us to effectively assess social consequences of novel energy sources deployment and use (Carrera and Mack 2010; Hall et al. 2011). Available scientific literature on biofuels assessment and its sustainability aspects illustrates these evidences: technical, environmental and economic approaches abound while social aspects are pushed aside or superficially discussed.

Due to the lack of work on this subject, particularly of analysis that explicitly addresses possible differences among first-generation and lignocellulosic bioethanol in terms of their social performances[11], the objective of the present paper is to compare social aspects involved in the production and use of these fuel options based on literature review. The idea here is neither to offer a finished and defined set of social criteria for the reader nor to present an analytical framework for bioethanol social assessment, but to discuss main issues pointed out by different authors and

[11] Social consequences of 1st-generation bioethanol should be found within available literature while expected social consequences of lignocellulosic bioethanol could be inferred in their majority from technical, economic or environmental ex-ante evaluations within available literature or studies dedicated to appraise this specific question.

contribute to the definition of critical issues for the assessment of social consequences comparing these two alternative energy sources.

As such, this work is divided into three parts: firstly, the author provides a brief description of methodological trends in different Impact Assessments in order to explore the definition of social impacts (equal to social consequences) and how the assessment of such impacts is currently addressed; secondly, social consequences of 1st-generation and lignocellulosic bioethanol, related to their present or expected social performances respectively, are discussed and compared under a tentative set of social issues and related criteria; finally, conclusions and recommendations are presented.

2.2.1 Impact Assessments

Impact Assessment (IA) is defined by the International Association for Impact Assessment (IAIA) as the "process of identifying the future consequences of a current or proposed action"[12]. Occasionally, the word *consequences* is replaced by *externalities* or *costs* in some works. Probably the best known IA type or sub-field is the Environmental Impact Assessment (EIA), which became part of the United States legislation through the National Environmental Policy Act (NEPA) in 1970 and today is embedded in a legal framework in most countries. Social Impact Assessment (SIA)[13] followed EIA establishment short after due to the need for appraisal of social consequences implicated in a number of projects and programs, especially those related to large-scale energy projects in the U.S. in the 70's (Vanclay 2006). Formal definition of guidelines and principles for SIA was first materialised on work by the Interorganizational Committee on Guidelines and Principles for SIA, that defined *social impacts* as "the consequences to human populations of any public or private actions that alter the ways in which people live, work, play, relate to one another, organise to meet their needs and generally cope as members of society", including changes in societies' norms, values and beliefs, defined as *cultural impacts* (Interorganizational Committee 1995:11).

[12] IAIA, "What is Impact Assessment". Retrieved from www.iaia.org (last visited on 14th may 2011).

[13] Alternatively, other authors prefer the Social Assessment (SA) terminology to avoid any negative connotation that may derive from the word impact (e.g. Taylor et al. 1995 apud Seebohm 1997).

This definition is used also in other works related to the study of social consequences of projects or policy actions (e.g. Burdge and Vanclay, 1996 and van der Horst and Vermeylen, 2011). However, as noticed by Taylor et al. (2003), SIA practice is still limited by a poor research base with a lack of reliable empirical data available, crippling comparative analysis, which are key players in SIA developing. Social impact assessments have existed since the late 18th century (Becker 2001). Today, they give shape to a major discipline (SIA), defined in general terms as the analysis, monitoring and management of the social consequences of planned interventions, including public participation within the process (Vanclay 2003). Life-cycle assessments (LCA) have also incorporated social appraisal through Social LCA (S-LCA), with emphasis on products' life cycle (Benoît et al. 2010). Other assessment methodologies, such as Technology Assessments (TA), also provide tools for social evaluations of technological development. Traditional TAs were focused on prediction of future consequences of technological developments and what could be done in terms of policy options based on an expert team for consultancy (van den Ende et al. 1998). Nonetheless, unforeseen events (e.g. oil crises) made lots of assessments become valueless, forcing a change in the way TA was conceived and planned. As examples of new TA types, post-traditional ones, there is the Strategic TA and the Constructive Technology Assessment (CTA). The latter was brought by approaches from Science and Technology Studies and emphasises the influence of society in technological development, giving priority to participatory methods (van den Ende et al. 1998). Another interesting example of more recent TA approaches is found in the work by Guston y Sarewitz (2002), where the authors propose a real-time TA (RTTA) to be applied to those technologies that were not yet implemented in society and rely on the idea of gathering natural scientists, engineers, social scientists, stakeholders and lay public for working together. The importance of assessments of this kind is given to the fulfilment of the need to 'adjust' IA methods -at least in theory- to today's technology particularities, such as development rapidity, geographic scope and number of direct and indirect effects. Many of these aspects remain unknown since what is being assessed is a set of truly novel technologies, some of them still under research and laboratory testing phase, like in the case of lignocellulosic bioethanol. Recent integrated approaches propose the use of multi-criteria methods for sustainability assessment (e.g. Giampietro et al. 2006 and Elghali et al. 2007) and application of complex frameworks aiming at participatory social evaluation of technologies or projects (e.g. Munda 2004).

It should be noted that any description or 'design' of a system that is going to be assessed, including components such as structures and actors, besides the definition of its boundaries, is never 'perfect' or complete. The same is true for problem structuring within decision-making analysis where 'representations of the reality' instead of 'reality' itself are the guidelines for criteria selection within discussions related to sustainability of energy options (Giampietro et al. 2006). In the latter, objectives of other social groups or appraisal of other relevant dynamics and constraints associated to scale or space definitions, for example, will always be left out. This is one of the main reasons why the plurality of representations and thus the inclusion of a variety of stakeholders in decision-making processes is so important from the beginning in the assessment of technology options, programs or projects. Moreover, assessment of bioenergy projects that are carried out locally and include gathering of *in situ* data and direct community consultation, for example, should be more reliable than other based on model analysis and expert consultation only.

2.3 Social consequences of bioethanol

An *energy technology,* as defined by Gallagher et al. (2006), refers to "the means of locating, assessing, harvesting, transporting, processing and transforming the primary energy forms found in nature" in order to deliver energy services (e.g. heat) or secondary forms (e.g. gasoline, electricity or biofuels) to end users, besides the means of distributing this secondary forms or converting them to energy services (Gallagher et al. 2006:194). Here, *energy technologies* are broadly understood as the technological set and processes involved in the life cycle[14] of an energy product such as bioethanol (Figure 2). So, building a bridge between the definition for social impacts and the proposed broad definition of energy technologies, social consequences of bioethanol are represented by alterations in the way in which people

[14] "A life cycle refers to the life span of a product, from resource extraction, to manufacture, use and final disposal. The cycle aspects reflect that materials extracted from the environment are followed until they are ultimately returned to the environment" (Nieuwlaar, 2004).

live, work, play, relate to one another, organise to meet their needs and generally cope as members of society that are driven -directly or indirectly- by actions implicated in bioethanol's technological set and related processes involved in its life cycle.

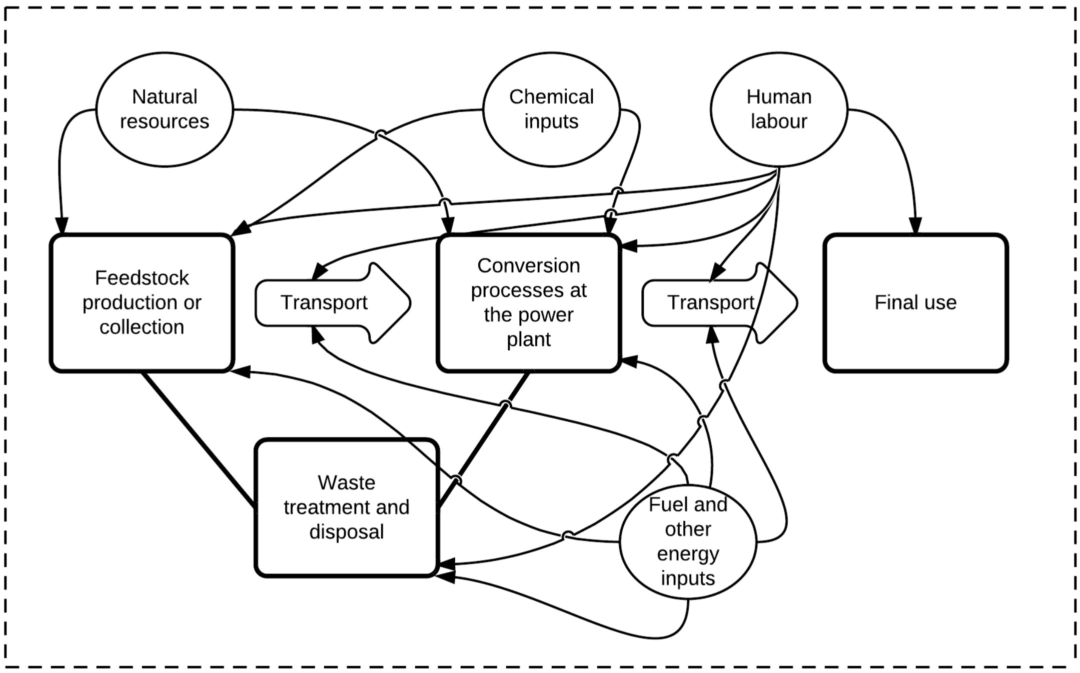


Figure 2. Simplified systems diagram of bioethanol life cycle. Rectangles indicate the four main processes involved, while circles refer to external inputs required for processes development. The main dashed rectangle indicates that the system is not closed in terms of geographical localisation of each process and land availability, for example. Besides, it illustrates the possibility of generating externalities at all times and in different localities. Economic aspects are involved in all phases.

Social consequences emerge at some point of the product's life cycle as a result of a given action within the system, even if they do not seem to be directly related to it (e.g. indirect effects on communities that are geographically distant from harvesting or production areas derived from migration of crop activities or changes in food or fuel prices). Indirect effects are specially important on sustainability assessment of bioenergy technologies and are still a sore point for scientific analysis due to the difficulty of 'tracking them down' through production and commercialisation phases since some of the product life cycle steps are likely to be spread geographically.

To first compare first-generation and lignocellulosic bioethanol in terms of the social consequences implicated in their life cycle, the next sections will take core sustainability criteria previously explored by different authors as ‘battlegrounds’. Drawing on work by Buchholz et al. (2009), on which 35 sustainability criteria for bioenergy systems were identified, grouped and assessed, aspects that emerge from social criteria identified by the authors will be highlighted and analysed through literature comparison. In their work, among all identified criteria, 15 were classified as of social nature. The next sections explore these criteria within 5 main social-related issues of bioethanol life cycle, namely land use aspects; water security; food security; rural development; and social acceptance and public participation (Table 1).

<table>
<tr><th>Main social issues</th><th>Social criterion identified by Buchholz et al. (2009)</th><th>Social criterion of general applicability*</th></tr>
<tr><td rowspan="2">Land use aspects</td><td>Property rights and rights of use</td><td rowspan="13">Compliance with laws
Monitoring of criteria performance
Planning
Respect for human rights</td></tr>
<tr><td>Land availability for other human activities than food production</td></tr>
<tr><td>Water security</td><td>Not informed</td></tr>
<tr><td>Food security</td><td>Food security</td></tr>
<tr><td rowspan="6">Rural development</td><td>Working conditions</td></tr>
<tr><td>Respecting minorities</td></tr>
<tr><td>Social cohesion</td></tr>
<tr><td>Standard of living</td></tr>
<tr><td>Noise impacts</td></tr>
<tr><td>Visual impacts</td></tr>
<tr><td rowspan="2">Social acceptance and public participation</td><td>Cultural acceptability</td></tr>
<tr><td>Participation</td></tr>
</table>

Table 1. Social issues and related social criteria of bioethanol life cycle. *Compliance with laws, monitoring, planning and respect for human rights are considered as overall criteria since they are applicable to more than one issue as relevant social criteria.

The water security issue, although not identified by Buchholz et al. (2009) as a social criterion for bioenergy sustainability evaluation, is included in this work as a major issue due to its relevance within the biofuels sustainability debate. Employment generation – considered by the authors as an economic criterion – will be explored here within the issue of rural development. Naturally, other criteria that might be considered to be relevant, but that were not identified in literature review of already explored issues surrounding bioethanol externalities, will not be considered. Considering the purpose and dimension restrictions of the present work, definition of possible social indicators and measurements methods are not given. It is worth noting that Buchholz et al. (2009) research is based purely on literature review and expert advisement, which means that for criteria selection and appraisal no public 'input' was included, although the authors recognise the importance of participatory methods embedding on the process. On an attempt to partially 'fill' this gap and make sure that major criteria are not left behind in the analysis, case studies on public acceptance of biofuels are also examined.

2.4 Land use aspects

Two different 'types' of land use change (LUC) that may derive from biofuels production and social effects of LUC could be linked to the emergence of monocultures for large-scale production of biofuels feedstocks and spatial reorganisation of land use types. Both situations could be embedded in these two types which are called direct (DLUC) or indirect land use change (ILUC). While DLUC makes reference to *in situ* consequences of land use change (i.e. those produced within biofuel production area or not very distant from it), ILUC refers to any *ex situ* consequences produced as a result of LUC, for example, biofuel feedstock plantations replace rangelands, which replace forests in other places, distant from the production site. Worrisome environmental impacts may also be involved in LUC, like increasing in greenhouse gases emissions or deforestation (Kim et al. 2009; Lapola et al. 2010). Social implications of LUC related to biofuels production are barely explored in the literature, which gives priority to assessing environmental aspects (e.g. Searchinger et al. 2008, Kim et al. 2009 and Havlík et al. 2011).

The ILUC issue is especially problematic since occupation by biofuels feedstock of areas previously dedicated to cattle raising, other cropping or any other kind of use can lead to indirect or "displacement" effects that are difficult to track (Lapola et al. 2010; van der Horst and Vermeylen 2011). Difficulty is due to the lack of a scientific reliable methodology for the assessment of such a complex criterium (RFA 2008). For example, ILUC may entail social impacts related to land access that are not directly linked to feedstock cultivation for biofuel production, but to other factors related rather to their expansion, such as increase in land prices of those now elected to grow energy crops and that were undervalued before (Cotula et al. 2008). Indirect effects of LUC still face deep methodological problems in regards to its prediction and allocation issues (Gallardo and Bond 2011). Havlík et al. (2011) states that proper assessment of this issue -just as any other related to biofuels impacts- should integrate a variety of scales. For the author, overall trade is the fundamental driver of indirect land use changes, for which a global representation of agricultural and forest commodity market is needed.

Large-scale production suggests large companies as land owners. Authors like van Wey (2009) and van der Horst and Vermeylen (2011) argue that positive social effects on the rural context are disconnected with agribusiness objectives, while small-scale initiatives are more likely to result in benefits for rural communities. National or private interests may directly affect social access to land on the rural context (e.g. biofuel production programs and biofuel producing companies). There are cases on which government itself uses expropriation strategies to expel people from land to provide biofuel investors with crop areas, characterised as a social consequence of DLUC. This is possible when the person, family or community that occupies a certain area is not its legal owner (Cotula et al. 2008). Land tenure versus biofuel expansion is a problem, for example, in Indonesia, where indigenous people were expropriated from forest lands for oil palm cultivation (Phalan 2009), a popular biodiesel feedstock in tropical regions. Other social implication of the implementation of bioenergy large-scale monocultures is the displacement of rural workers and communities to cities. In this case, swelling cities entails problems for both rural immigrants and city dwellers, like higher levels of unemployment and Social Security expenses for the State. Apart of the type of LUC, social consequences are expected to emerge from changes in the way land is used, as discussed above. To discuss social implications of land use for each type of bioethanol, possible scenarios of production of 1st-generation and lignocellulosic bioethanol and their relation with LUC are explored below.

An increase in production of large-scale 1st-generation bioethanol would lead to both emergence of monocultures and spatial reorganisation of land use types unavoidably since new areas would be required for crop expansion (e.g. maize in the U.S., sugarcane in Brazil, wheat and sugar beet in EU or cassava in Indonesia)[15]. On the other hand, while 1st-generation bioethanol uses parts of specific starch or sugar crops as feedstock, lignocellulosic feedstock can be obtained from almost any source of plant biomass (Byrt et al. 2011). Once the conversion technology become cost-effective, it seems reasonable to think that -in the absence of regulations on the matter- increase in cultivation of bioenergy crops or lignocellulosic dedicated feedstocks such as short-rotation wood forests or grasses could be encouraged. This could also entail DLUC and ILUC, transforming areas originally used for growing of other agronomic crops or those occupied by family farming or other rural communities. Although these short-rotation coppices (SRC), which are high-density plantations of woody crops such as willow and poplar (Pistocchi et al. 2009) or vegetative grasses, like switchgrass (Sims et al. 2010) show a limited range of distribution[16], lignocellulosic bioethanol could also be obtained to a lesser extent from *Pinus sp.* (Mercker 2007), which is cultivated in other regions around the world, so LUC could be spread globally.

Another possible scenario is the one where the land is used for planting food crops or is already occupied by existing SRC, and agricultural and forest residues -only- are used for lignocellulosic bioethanol production. Production of lignocellulosic bioethanol made from agricultural residues like wheat straw, corn stover or sugarcane bagasse, for example, or wood residues should not enter in competition for land with other types of production (Havlík et al. 2011). This way, and apparently, while increase in feedstock cropping for both 1st-generation and lignocellulosic bioethanol are likely to produce LUC and implicate social impacts, lignocellulosic bioethanol

[15] In the locality of Lampung, Indonesia, for example, poor farmers who previously grew coffee or oil palm in their lands, replaced their crops with more-lucrative cassava in 2008 due to the implementation of bioethanol power plants in the area. The Jakarta Post, Wed 07/07/2008. Available at: http://www.thejakartapost.com/news/2008/07/02/poor-farmers-boosted-bioethanol-boom.html. Last visited on 19 may 2011.

[16] Distributional range data for native *Salix burjatica*, *Populus deltoides* and *Panicum virgatum* retrieved from the Germplasm Resources Information Network (GRIN Taxonomy for Plants) of United States Department of Agriculture database. Available at http://www.ars-grin.gov. Last visited on 19 may 2011.

produced exclusively from agricultural or forest residues (of already existing plantations) should minimise negative social consequences surrounding this issue.

2.5 Water security

Biofuels feedstock plantations can compete with water resources -especially in those areas of arid and semi-arid climates and increasing population- an issue that has been poorly explored to date in the literature (Havlík et al. 2011). Increased biofuel production could have a significant impact over water availability and quality. Water could become less available on the community level, but the effects of its scarcity could also be felt regionally regarding water prices (Gopalakrishnan et al. 2009). Implications of bioethanol production in water security depends not only on feedstock characteristics, but also on the region where it is being cultivated and what processing technologies are being used (Wu et al. 2009). This means that water requirements for bioethanol feedstocks need to be assessed on specific local contexts where plantations are to be grown and power plants implemented.

Fraiture et al. (2007) argue that monocultures of biofuel crops lead to water scarcity and water pollution. Also, competition for limited water resources between biofuel crops and food crops could raise agricultural commodity prices. In their study, in 2005, South Africa allocated 9,8% of its total irrigation withdrawals for bioethanol production from sugarcane, while Brazil needed only 3,5% of its total to produce much more bioethanol from the same feedstock. These numbers reflect differences in yielding and technology conversion efficiency between both countries. In countries like China or India, where massive agricultural production are very dependent on irrigation, negative impacts on water resources, food and feed production would be unavoidable if both countries increase their land for biofuel cropping substantially.

Water resources have a naturally unequal distribution around the world. As more populous is the country, worse are its chances of supplying population's water needs. China and India, the world's two more populous nations, have very low rates of water resources per capita (WRpc) when compared with the U.S. or Brazil, besides more than half of their population lives in rural regions. Their rates of water resources per capita are very similar to African countries such as South Africa and Uganda (Figure 3).

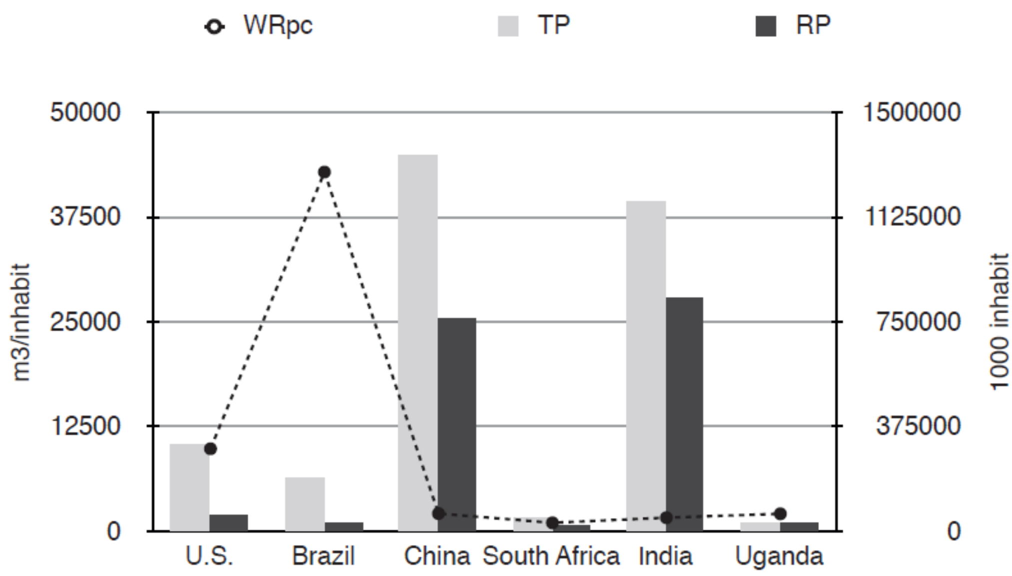


Figure 3. Relation between Total Population (TP), Rural Population (RP) and Water Resources per capita (WRpc) among different countries in 2008. Data retrieved from FAO/AQUASTAT database.

In regards to water security issues, bioethanol production is thus likely to affect these six countries in very different ways. The United States and Brazil show not only the higher WRpc rates among the group, but also the higher percentage of urban population and higher Human Development Index values (HDI, not shown in the figure). These two world's top producers of bioethanol should be more able to cope with water shortages in the long-term, while all the other four could face harder challenges due to water scarcity.

Plants invariably need water to grow. The amount of water needed for potential biofuel crop species is highly variable though, as well as their response to water stress. Havlík et al. (2011) estimates for a 2010/2030 comparison scenario on irrigation water use that the better performance in the long-term among different feedstocks for first and second generation bioethanol should be expected from woody crops obtained from existing forests to lignocellulosic bioethanol production, followed by both traditional and lignocellulosic crop grown or marginal lands[17]. White et al. (2011), on the other hand, reports higher water use efficiency for grain maize or sugarcane than for short-rotation woody crops. Additionally, accordingly to the author, perennial grasses should perform better than the latter in terms of drought tolerance, although both are widely adaptable and could be produced on marginal land. For Gopalakrishnan et al. (2009), the best option in terms of water optimisation use by bioethanol feedstock is that where short-rotation wood energy crops are grown from degraded water irrigation, such as municipal wastewater, on marginal lands. This case does not apply for the majority of plant species used for biofuel production, but should be considered as an effective mitigation tool for a more sustainable lignocellulosic bioethanol production. Non-irrigated switchgrass and wood residues are also potential less water-intensive options since water is needed for conversion process only. Among the two main routes explored today to lignocellulosic bioethanol production, biochemical or thermochemical, the first one shows much higher levels of water consumption, surpassing numbers for 1st-generation bioethanol conversion process in the case of the U.S. corn bioethanol and even for gasoline production under a complete life cycle analysis (Wu et al. 2009). In this case, feedstock production would show higher weight in water consumption quantification.

Increasing 1st-generation or lignocellulosic bioethanol production implies increasing in water consumption in both cases, but probably in different levels. Differences between performances depend on feedstock irrigation needs, the region's geoclimatic conditions, available conversion technologies and capacity of recycling water and avoiding water contamination. Poorer countries could show limited access to cutting-edge technology, depending on foreign investment to overcome this problem, while semi-arid regions could be more affected in terms of water security due to bioethanol's production expansion. Places where bioethanol feedstock is grown in the absence of irrigation, or where for irrigation degraded water is used; or where feedstock derives exclusively from agriculture or forest residues should present lower water demand for bioethanol production. Lignocellulosic biomass would thus present us with the best odds from a water security point of view. On the other hand, conversion technologies -which play an important role in water use efficiency in

[17] The concept of marginal land is discussed in a further section.

conversion processes for lignocellulosic bioethanol production via biochemical route- need to be optimised in terms of water saving.

2.6 Food security

During 2008, food prices rose sharply, accompanied by a boom of discussions among experts, politics, public and the media surrounding biofuels level of 'culpability' on the subject. For the last three years the issue have been being debated and many other factors have been put in the dock. Accordingly to Rathmann et al. (2010), biofuel feedstocks occupation of lands traditionally used for food crops contributed to increasing in food prices in the short-term, but with little impact individually. Other factors could be higher demand for crops from China and India, droughts in Australia, low crop yields in the EU and Ukraine in 2006 and 2007, crude oil price and speculation, which were much less explored within last years debate (Ajanovic 2011). Besides, food commodity prices have been declining since then, despite of no reduction in biofuel production in the world (Sims et al. 2010). The complexity that characterised food commodity prices fluctuation globally in the past years could not be fully explained by biofuels production hike solely. A good part of the problem could be explained by higher crude oil prices (one of the reasons by which biofuels production was encouraged) leading to rising of energy prices for farming, processing and distribution of food, associated to augmentation of food demand and adverse climate conditions. Moreover, trade measures such as subsidies and trade protection can also affect agricultural commodities prices directly (Dewbre et al. 2008). In any case, increase in currently commercial biofuels production can interfere, although in debatable levels, with agricultural commodities prices. Increase of food prices worldwide is certainly a direct social threat to rural and poor people which incomes are dedicated almost in its totality to buy food.

The question of food prices rising -as the ultimate consequence of a series of actions within biofuels life cycle- take us again to land use issues. In fact, there are two key arguments related to the food security controversy that are generally used for defending lignocellulosic instead of 1st-generation bioethanol. Firstly, one of the most quoted advantage of lignocellulosic over 1st-generation bioethanol is its reduced risk of competing with food production (Hahn-Hägerdal et al. 2006; Solomon et al. 2007) once bioethanol produced from starch and sugar crops such as maize, wheat, sugarcane or cassava could compete with food for land and influence global commodities prices (OECD/FAO 2008) while lignocellulosic biomass obtained from residues would not, as discussed previously. The second argument is that some lignocellulosic feedstocks could grow on lands that are not used for growing food crops nor dedicated to other agriculture and livestock activities (Tilman et al. 2006; Gopalakrishnan et al. 2009). These kinds of lands are commonly called 'marginal' lands. Notwithstanding, the concept of marginal land is a controversial one. While the adjective conveys the idea of a valueless space, abandoned or low quality one, such appraisal will depend largely on whom or what institution issuedthe opinion, falling on a relativistic discussion surrounding differences on points of view.

Ojima et al. (2009) argues that the concept is poorly defined, leaving room for a variety of interpretations on the extent or viability of exploitation of the land. 'Marginal' is a term usually defined from an economic standpoint (i.e. marginal lands are cheap lands or lands that are not profitable), however, lands that are not valuable for one group (e.g. company investors) can be valuable for another (e.g. indigenous communities) due to its biodiversity or other environmental characteristics (Gressel 2008; van der Horst and Vermeylen 2011). Bustamante et al. (2009), seeks to clarify the concept by changing the term marginal lands to "lands of low competition". These would be lands with low potential for food production; not desirable to food production expansion in the future; that do not store a lot of carbon today and are not likely to be good carbon sinks in the future; and that presents low levels of biodiversity. Besides, those lands should not depend on irrigation. Again, conceptualisation falls on relativism since other criteria are missed like previous occupation by poor minority or indigenous groups with no formal title to the land (the land tenure issue) or seasonal occupation by nomadic people (Phalan 2009; van der Horst and Vermeylen 2011).

First-generation and lignocellulosic bioethanol feedstocks are likely to be grown on both land today used for crop grow and livestock purpose, and low competition land (Sims et al. 2010; van der Horst and Vermeylen 2011). Nonetheless, lands with characteristics pointed out by Bustamante et al. (2009) and that complies with aforementioned criteria proposed by van der Horst and Vermeley (2010), are probably less available. In effect, Field et al. (2007) reports that approximately only 5% of world primary energy consumption could be delivered by biofuels produced from plants cultivated in these kinds of lands. These would be concentrated mainly in countries from South-America and Africa, which show higher potentials for energy crops production (Campbell et al. 2008). Furthermore, popular bioenergy feedstocks used in production of 1st-generation and lignocellulosic bioethanol such as corn or wheat, have high water and nutrients needs and may require good soil quality (Table 3), involving higher economic and water security risks.

Type of crop	**Soil**	**Water**	**Nutrients**
Corn	Well-aerated and well-drained	Efficient use of water	High fertility
Sugarcane	Preferable well-aired with good amount of water	High precipitation equally along the seasons	High amount of nitrogen and potassium
Wheat	Average texture	High	High

Table 2. Agro-climatic requirement of some bioethanol feedstocks. Adapted from Escobar et al. (2009)

Notwithstanding, while growing certain 1st-generation bioethanol crops on marginal lands could increase erosion and pollution, low-input perennial grasses (e.g. sugarcane, elephant grass or switchgrass) could reduce such impacts (Campbell et al. 2008). These plants are capable of growing, and presenting considerable yielding rates, within minimal input conditions (i.e. no or low-irrigated, low fertility soil) in some regions in the short-term (3-4 years). Each specie, however, require specific management to guarantee its sustainability over time and its viability will depend on specific economic, environmental and social assessment (Knoll et al. 2012).

An optimistic hypothetical scenario such as the one presented by Rajagopal et al. (2007), argues that when lignocellulosic bioethanol technology is finally deployel, only 14% of todays's global cropland - plus crop residues - would be needed to replace 91% of current global demand for gasoline with bioethanol. A more moderated scenario, although also optimistic, is presented by Kim and Dale (2004). The authors point out that a good quantity of biomass is wasted during logistic processes (handling, storage and transport) of dry grains such as rice, maize and wheat. If sugarcane bagasse is included in the accounting, a large amount of lignocellulosic residue would be available for bioethanol production, coming especially from Asia (around 60% of total wasted biomass). This quantity of bioethanol would be precisely of 491GL, a value 16 times higher than 2004 bioethanol's world production, and that could replace about 32% of the total gasoline used in that year.

On the other hand, in the long-term, climate change consequences such as higher temperatures and changes in rainfall regimes could have considerable effects over agriculture yielding and thus impact also residues availability and price. Those effects could be either positive or negative depending on the type of feedstock. Non-cereal plantations like switchgrass fields, for instance, could show increase in yielding in warmer conditions (Field et al. 2007) and cropping of other bioethanol feedstocks, like sugarcane, could even result in benefits to cope with climate change. Loarie et al. (2011), for example, reports that conversion of crop or pastureland in the Brazilian *cerrado* (a large savanna area) to sugarcane fields for bioethanol production as a land-use option has a cooling effect over local climate. Instead of basing their assumptions on model simulations, the authors collected data from satellite images to measure historical climate effects and found out that the temperature and evapotranspiration budget of sugarcane was closer to those of natural vegetation than to crop and pasture cover. In any case, further research on interaction between feedstocks for biofuel production and climate change is needed.

Again, grain crops for 1st-generation bioethanol production as well as prairie grasses and short-rotation forests for lignocellulosic bioethanol could both be grown on land in competition with food, fibre and feed. As discussed previously, if lignocellulosic feedstocks are to be grown in ("truly") marginal lands with null direct competition with food crops, then maybe this could be an alternative, although a limited one. The use of forest and agriculture residues or the organic fraction of municipal solid waste as feedstocks could also one more time be more effective in minimisation of social impacts of bioethanol production. A good option in the short-term for guaranteeing food security could be combine growing of feedstocks in marginal lands with the use of residues and wastes for lignocellulosic bioethanol production (Sims et al. 2010). In any case, proven sustainability of presented options depend largely on the existence of a previous consensus on what is understood by marginal land among a variety of actors, what increases complexity of social assessment of this issue.

2.7 Rural development

In 2010, 51,4% of the world population was living in rural areas. Splitting numbers with respect to "more-developed" and "less- developed" regions, we obtain 25% and 54,7%, respectively, of rural population as percentage of the total population for each region. For 2030, forecasting does not show a very different picture: 44% of people in less-developed regions would be living in rural areas while 19,4% of people would be in the same situation in more-developed regions[18]. It is worth noting that, accordingly to International Energy Agency (IEA) scenarios, 2nd-generation biofuels (lignocellulosic bioethanol included) commercial deployment is not likely to happen before 2020-2025 (Eisentraut 2010), what means that biofuels production until then will depend pretty much on 1st-generation technologies. Reflecting on these last considerations, low-income to upper-middle-income economies [19] (i.e. poorer countries or countries where social inequality is high) would feel more intensively social consequences on rural regions implicated in biofuel production. Additionally, 1st-generation biofuels feedstocks are obtained from crops that require more lands to accomplish production goals for the next decade. A good part of these lands is located in poorer countries given to their higher availability of potential areas for growing energy crops (Field et al. 2007; Arndt et al. 2011). This factor have serious implications in guaranteeing respect for minorities since most part of world's poorest communities are situated in those countries, where violation of human rights are often 'everyday' events and control over human rights compliance are looser. The same pattern is valid for lignocellulosic bioethanol if, for its production, lands for large-scale feedstock grow such as new short-rotation forests or prairie grasses is needed.

[18] Data retrieved from United Nations World Urbanization Prospects: The 2007 Revision Population Database. Available at: http://esa.un.org/unup/. Last visited on 20 may 2011.

[19] According to country classification by the World Bank based in the gross national income (GNI) per capita. Examples of low-income economies are Afghanistan, Haiti or Ghana; lower-middle-income economies are represented by India, China, Indonesia or Bolivia, and examples of middle-upper economies are Brazil, Peru, Cuba and Mexico.

Moreover, agricultural mechanisation of large-scale production of energy crops could force rural displacement to cities. While a mass of unemployed and unskilled workers may be generated, mechanical harvesting and product processing would create fewer jobs to absorb semi-skilled and skilled workers[20]. This way, implementation of feedstock cultivation and bioethanol power plants could make rural labour force experiment a pattern change while a high number of low-qualification workers might be "replaced" by fewer medium or high-qualification ones (La Rovere et al. 2011). In the U.S. biofuel industry, for example, less than 20 jobs would be created from the implementation of a small bioethanol plant (Koshel and McAllister 2010), although job creation impacts of bioenergy projects extrapolate direct employment at the power plant (Thornley et al. 2007). Small-scale bioenergy facilities generate more rural jobs than large-scale ones (Berndes and Hansson 2007) and rural communities should benefit more from unskilled labour demand than generation of some semi-skilled or skilled job opportunities and land rents to smallholders instead of large-plantations owners, especially in poorer countries (Arndt et al. 2009). In any case, precise quantification of unemployment rates and workers absorption derived from such dynamic, as well as rural immigration levels is needed for grounded assertions.

Rural regions of poor countries with a resource-extractive industrial base like Mozambique, for example, could profit from biofuel production in the sense that this last model, differently from the extractive one, tend to be more labour intensive and embed investments in local infrastructure -although paying sometimes substandard wages and employing capital-intensive technologies not accessible to small farmers (Arndt et al. 2009). Nonetheless, Schut et al. (2010), also analysing Mozambique's biofuel developments, argues that projects are concentrated in those areas where semi-skilled to skilled labour and good infrastructure are available, so most of remote rural areas remain excluded from potential socioeconomic benefits derived from biofuel production. Habib-Mintz (2010), studying the case of 1st-generation large-scale biofuels production in Tanzania, argues that unplanned agro-industrialization associated to problems of land tenure issues, inefficient infrastructures and poor

[20] Unskilled workers are those employed in the manual-agricultural phase of bioethanol production while semi-skilled workers refers to machine operators such as tractor drivers; skilled workers are those operating more complexes machines or working in the conversion stage and administration area.

connectivity with rural areas only leads to prolongation and intensification of rural poverty.

Regional inequalities within biofuel producing countries are also a problem. In Brazil, the sugarcane sector is historically linked with the concentration of large-scale farmers in the southeast and central regions, which today concentrates almost the totality of the country's bioethanol production (Hall et al. 2009). Similarly to African cases, benefits in the form of better health services, accessibility to education, specially in the case of women and children, would depend on local investments brought by biofuel production. Those, in turn, are directly dependent on project's objectives, which should be connected to communities longing for higher levels of quality of life. Further, uncontrolled migration from poorer regions (e.g brazilian states from north and northeast to southeastern producing states) could entail effects such as unemployment or lower accessibility to health and education services in determined areas, not prepared to a sudden demographic pressure. In this sense, regulation and planned public policy play an important role in social impacts alleviation. To van Dam et al. (2010), certification systems could also work as an effective tool for monitoring and mitigating regional social impacts of bioenergy.

With regard to health impacts, most studies explore issues related to changes in air quality (i.e. level of toxic gases emissions) derived from switching from vehicle fossil fuel burning to biofuel use in engines. Naturally, air pollution effects on human health are likely to be most concentrated in urban instead of rural areas when looking at combustion of liquid biofuels such as biodiesel or bioethanol. Liaquat et al. (2010) shows greater concern on levels of air pollution in developing countries since emissions are increasing sharply due to a each time higher number of vehicles per capita, specially passenger cars, which is proportional to levels of income per capita. In their study, cities of China, India, Pakistan, Thailand and Bangladesh, for example, could benefit from bioethanol combustion instead of petrol-based fuels and thus lower levels of carbon monoxide (CO) and hydrocarbon (HC) emissions. Nonetheless, production of potentially carcinogenic aldehyde compounds during bioethanol combustion should be considered as an important drawback for substitution of non-oxygenated by alcohol fuel, as well as a slight increase in NO_x emissions verified in a

10% blending of ethanol in gasoline and impacts on regional ozone production (Gaffney and Marley 2009).

Kusiima and Powers (2010) monetized environmental and health externalities of bioethanol's life cycle obtained from four different feedstocks, presenting estimation of impacts cost. In their analysis, not only air pollutants were assessed, but also pesticide use was taken as a potential impact on human health for accounting. Results showed that average external costs for bioethanol production are much higher for corn (1st-generation bioethanol) than for lignocellulosic biomass. Also, costs for corn stover surpass the ones for switchgrass and forest residue, being the last one the less 'expensive' one in terms of human health impacts linked to its complete life cycle. Costs of externalities are mainly related to intensity of fossil fuel use, use of nitrogen fertiliser and, in the case of lignocellulosic bioethanol, emissions throughout the conversion process at the power plant -which could also result in health impacts in the vicinity, although credits associated with co-products generation and biogenic carbon contributes to reduction of overall costs. In a previous and similar study undertaken by Hill et al. (2009), production and use of lignocellulosic bioethanol have the lowest health costs related to air pollution while 1st-generation bioethanol made from corn has higher costs than gasoline in terms of fine particulate matter. In any case, estimations like these present a certain level of uncertainty due to a lack of consensus on economic values of human health, factors not yet identified that may miss in the analysis and depend largely on the study's established boundaries.

Cereal cropping for 1st-generation bioethanol and conventional technologies require more direct agricultural input than cultivation of wood and perennial energy crops and its related technologies for lignocellulosic bioethanol production. This implies that the former present higher labour demand than the latter, so the switching from one to another should result in negative impacts on jobs generation locally (Berndes and Hansson 2007; Thornley et al. 2007). Expansion of feedstock cultivation for large-scale production of both 1st-generation and lignocellulosic bioethanol, especially in developing countries, are likely to derive in conflict of interests between rural communities and company investors (van der Horst and Vermeylen 2011). Exclusion of remote rural areas characterised by majority of unskilled labour force can also happen in both cases. If it is assumed that rural development depends basically on employment generation or absorption of the rural labour force, increasing the level of income per capita, improvement in quality and accessibility of health and education services and inclusion of women labour in the rural community, then the feedstock production phase within bioethanol's life cycle is the one most directly related to these aspects. While power plants implementation may result in overall improvements in infrastructure, capital attraction and creation of a limited number of more semi-skilled and skilled jobs, working in feedstock cultivation is the most 'extended' option among rural dwellers. Moreover, any rural benefit will only come out from carefully planned projects, preferably small-scale ones and well distributed geographically, independently of bioethanol type. Taking this into account, it seems difficult to appraise what differences within rural communities should be expected from moving from 1st-generation bioethanol production to lignocellulosic bioethanol beyond changes in labour demand and workers qualification needs, which should be felt more negatively in rural communities -especially poorer ones- with the increasing of mechanisation and technological innovation.

2.8 Social acceptance and public participation surrounding biofuels

Although frequently present in the public debate over renewable energies and climate change, there are few academic studies that explore the issue of social acceptance of biofuels (Savvanidou et al. 2010). Besides, those which have explored this issue were focused on assessing a general and simplified question on whether or not citizens support biofuels, with no attention given to the differences among specific technologies or on what information the public base its opinion (Delshad et al. 2010). Even more noticeable is the absence of works on public participation[21] experiences - taking citizens as stakeholders aside from experts and other interested parties such as industry or NGOs- surrounding discussions over biofuels issues specifically. Whereas some academicians point out the necessity of promoting participatory processes

[21] Citizen or public participation in science and technology is the inclusion of public opinion (i.e. civil society as one of consulted stakeholders) within a specific debate over techno-scientific projects, programs or policies viability and desirability. The participatory debate seeks having a political significance with social and scientific value. Public participation is generally fostered through the organisation of workshops, consensus conferences, citizens' panels or public hearings, among other types of consultation processes.

within -and specifically- the biofuels sustainability debate, sustainability assessments and decision-making processes (e.g. Haywood et al. 2009, Carrera and Mack, 2010 and Raghu 2010), academic contributions dedicated to analyse initiatives or experiences of this kind surrounding biofuels[22] as main and only subject are inexistent, restricted to grey literature to date. This section builds on prior studies undertaken in the field of social acceptance and social perception of biofuels. Special attention is given if whether or not social aspects are discussed within studies and if their approach differentiates among biofuel types.

On research undertook by Savvanidou et al. (2010), 571 persons (randomly chosen) from the North-Easthern part of Greece, a potential area for biofuels feedstocks cultivation, were asked about their opinion surrounding biofuels as an alternative source of energy. Main conclusions points out to a significant lack of information about biofuels among respondents and their preference for other renewable energy sources over biofuels. However, half of participants considered biofuels as an effective solution for the energy problem and the majority of car owners are willing to pay more for it at the gas station. Their work did not explore issues such as the differences among biofuel options nor the reasons why people were supportive or not of biofuels.

Conversely, Delshad et al. (2010) investigated public understanding of and attitudes toward specific bioethanol technologies, distinguishing between 1st-generation and lignocellulosic bioethanol. They conducted a small but representative public consultation in the midwestern U.S. state of Indiana, in a major bioethanol producer region that uses maize as feedstock. They found that participants preferred lignocellulosic instead of 1st-generation bioethanol mainly due to perceived differences in environmental and economic performances of both options, although 40% of participants were not supportive of biofuels. It is interesting that, albeit living in a major producing region, people were not much supportive of bioethanol as an energy option. Also, no social aspects beyond a few economic issues (e.g. subsidies or fuel prices) seemed to have been brought about on their discussion exercise, similarly to interviewing carried-out by Savvanidou et al. (2010), where market price was the

[22] Examples of public consultations on sustainability of biofuels are governmental initiatives such as those promoted by the Department for Transport of the UK or by the European Commission.

only socioeconomic factor explored. While an average of 80% of participants from both studies are supportive of energy saving, in the Greek study 76,1% believe that such practice should precede the adoption of alternative energy sources like biofuels.

Also within the U.S. midwestern, Selfa et al. (2011) undertook community-level research to examine public perceptions of bioethanol in three locations of Iowa and Kansas, which are defined by the author as “national biofuels regions” (i.e. those where the State has strong involvement, making them part of a globally integrated network of production, distribution and consumption of biofuels). Around 660 households participated in the survey, conducted by post. Besides, semi-structured interviews were used to evaluate the opinion of other stakeholder groups such as farmers, power plant workers and government and institutional representatives. Their study explored a wide range of social aspects such as power plant’s level of importance to local economy, generation of new jobs and salary levels, provision of jobs for local workers, reduction of local poverty, security of water resources, generation of odours, effects on traffic congestion, air pollution, health problems among local population and local food prices, among others. No differentiation was made between bioethanol types since the study’s objective was to examine local perception related to 1st-generation bioethanol production from corn within the vicinities of specific power plants, but uncertainties related to its potential as an energy option in the long run were revealed by respondents in face of deployment of newer technologies or second generation feedstocks. Overall, residents were concerned about water security and traffic congestion, and most of them declared that new jobs were created but those were not well-paid jobs. Within costs vs. benefits analysis, most of participants perceived benefits as being equal to costs. Among other stakeholders, local business leaders and other investors were very positive about economic benefits while farmers seemed to be more sceptical.

Public perception of biofuels was also evaluated in Fayetteville, U.S. and Ghent, Belgium, through a mail survey and personal approach, respectively (Skipper et al. 2009). Food security was brought up as a variable for analysis. The study found that in both localities respondents preferred low food prices to low fuel prices. Differences between localities were related to how achieve low food prices; while Belgian argued that lower food prices would implicate in higher fuel prices, U.S. participants declared their hopes on domestic agriculture to provide low-cost and environmentally friendly alternatives with lower impact of food prices. Moreover, Belgians gave more importance to food price decreases due to the fact that public transportation -as an strategy for fuel saving- is a much more accessible option for them than for North-Americans.

Wegener and Kelly (2008) offer a wide theoretical appraisal of social change and acceptance from a more psychological level for biofuel development and use. Within the empirical part of their study, a total of 1.059 U.S. citizens were randomly contacted by telephone to respond to a survey dedicated to examine attitudes -positive or negative- surrounding bioenergy. The majority agreed that using corn and switchgrass to produce bioethanol "is a good idea", with a little smaller percentage in agreement on the use of wood or wood chips as feedstock. Respondents were also very positive to the use of genetically modified plants. Nonetheless, participants admitted to being "not at all informed" about biofuels and an even higher percentage is lack of knowledge surrounding lignocellulosic feedstocks such as switchgrass and wood. The authors argue that past research in social psychology demonstrates that the higher the knowledge, the less is the level of acceptance to change. From their analysis it is also possible to identify some topics for further research that can be applied to the bioethanol case such as the possibility of emergence of public opposition to use of genetically modified (GM) crops for biofuel production and the evaluation of the level of adoption of flexible fuel vehicles by consumers.

In the line of consumer behaviour analysis, Van de Velde et al. (2009) examined perceptions of Belgian fuel consumers respect to biofuels. The majority of 363 consumers interviewed in fuel stations in the locality of Ghent were almost completely unaware of bioethanol characteristics due to the fact that most of them normally drive diesel-run vehicles. Similarly to the tendency of other studies, respondents overall were very supportive of biofuels due to its environmental performance, although not familiar with it. The only social aspects explored in the research were safety to drive and prices, which were worse perceived by consumers than environmental performance.

Table 3 summarises main features and findings of studies analysed in this section.

Study	Social aspects examined	Differentiation between bioethanol generations	Respondents' level of knowledge over the subject	Geographic localisation	Main findings
Savvanidou et al. (2010)	Price at the gas station	No	Very low	Greece (NE): biofuel feedstock cultivation area	Lack of information surrounding biofuels among respondents; Respondents support biofuels
Delshad et al. (2010)	Price at the gas station; Subsidies	Yes	Sufficient	U.S. (WE): major bioethanol producing region	Respondents prefer lignocellulosic bioethanol; 40% of respondents don't support biofuels
Selfa et al. (2011)	Effects on local economy; jobs; salaries; reduction of poverty; water security; air pollution; food prices; traffic congestion; generation of odours	No	(Not evaluated)	U.S. (WE): major bioethanol producing region	Lignocellulosic will probably replace 1st-generation in the long-term; water security and traffic congestion are big concerns; plants create new jobs, but not well-paid ones; benefits are equal to costs
Skipper et al. (2009)	Food security	No	(Not evaluated)	U.S. and Belgium	Respondents prefer low food prices to low fuel prices, specially in regions with higher access to public transportation
Wegener and Kelly (2008)	(Not specified)	No	Gets notably lower from fossil fuels to pure biofuel and new biofuel generations	U.S.	Respondents support the use of corn and switchgrass more than wood as feedstock for bioethanol production; respondents are positive to the use of GM crops;

Study	**Social aspects examined**	**Differentiation between bioethanol generations**	**Respondents' level of knowledge over the subject**	**Geographic localisation**	**Main findings**
Van de Velde et al. (2009)	Price at the gas station; Safety to drive	No	Very low	Belgium	Respondents support biofuels due to its environmental performance

Table 3. Studies on the social acceptance and public perception of biofuels.

Within studies, overall social aspects were examined poorly or not at all (except for the work of Selfa et al. 2011). This could be a direct consequence of the lack of an accepted and scientifically grounded framework on biofuel social sustainability criteria and indicators. Differences among biofuel types and between bioethanol generations are also practically not addressed, which is very negative considering that a transition between technologies is expected within the next decade. Citizens' lack of knowledge surrounding widespread energy options such as biofuels is worrisome and could hinder public participation initiatives. Moreover, studies were concentrated in the U.S. or Europe. Other research on public acceptance or perception of biofuels conducted in producing countries characterised by more socially unequal contexts or realities (e.g. from other regions that already produce or might produce biofuels, where capital is concentrated in a few national elites like countries from Latin-America, Asia or Africa) should present contrasting results. Also, among regions of the same country factors as gender, education and income levels, for example, might influence the results. This topic is a vast field of research yet to be explored.

In this line, and in light of the limited number of studies available and their constrained scope of analysis, it is not possible to compare 1st-generation and lignocellulosic bioethanol in terms of social acceptance. If something can be said it is that this field of research should receive far more attention from scholars if social acceptance is to become a social criterion on sustainability assessment of technologies.

2.9 Economic feasibility of lignocellulosic bioethanol

Any considerations on the social benefits or drawbacks of a transition from 1st-generation to lignocellulosic bioethanol depend obviously on the availability of the latter, which presently faces two main constraints for its commercial deployment: technology improvement and costs reduction. Economic constraints of lignocellulosic bioethanol production hinder its commercial viability while fully deployed 1st-generation bioethanol is already globally commercialised, competing with fossil fuel prices -although highly dependent on government subsidies.

Biofuels prices depend, among other factors, on feedstock market price, which vary along with crop-yield fluctuations. Since plant growth is directly dependent on environmental conditions such as rainfall regime or soil conditions, this kind of economic 'risk' applies to all types of biofuels whose raw material comes from agricultural crop (food and non-food ones), forest and its residues, or dedicated feedstock (e.g. prairie grasses or short-rotation forests). A recent example of such fluctuation was the rise in Brazilian bioethanol prices since the end of 2009. As a result of 2008 world financial crisis combined with a large period of drought in mid-2010 that seriously affected sugarcane yields, from August 2009 to May 2011, hydrated bioethanol almost doubled its price at the gas station[23]. Moreover, lignocellulosic conversion to bioethanol is still an expensive process. This is mainly due to feedstock costs, biochemical pretreatment and cost of enzymes used to break down cellulose into sugar, as well as the cost of fermentation of glucose (Kumar et al. 2009). Costs of raw material and enzymes have been major costs for lignocellulosic bioethanol production for the last two decades (e.g. Hahn-Hägerdal et al. 1988) and economic feasibility is thought to be one of the main barriers for its large-scale production and commercial deployment (Chen and Qiu 2010). Costs could be diminished through increased crop productivity, energy efficiency increase of the integral conversion process and production of valuable by-products and co-products[24] generated through production chain (Chen and Qiu 2010). From the review of various

[23] Data retrieved for comparison from brazilian Sugarcane Industry Union (UNICA) statistics (www.unica.com.br) and the Brazil's National Agency of Oil, Natural Gas and Biofuels (www.anp.gov.br).

[24] While co-products have similar revenues respect to the main product, by-products are wastes that present little or no revenue (Singh et al. 2009).

works, Singh et al. (2010) quote pentose sugars and lignin -by-products of lignocellulosic bioethanol life cycle- in the production of animal feed molasses, as substrate for yeast production or feedstock for methane-rich biogas, besides production of electricity in the case of lignin burn. Wheat straw can also be used for electricity generation and sugars could also be used to manufacture organic acids and other organic alcohols, besides aromatic chemicals.

Lignocellulosic bioethanol could become more competitive with gasoline through technological advancements and higher valued co-products obtained from its production. Feedstock specific composition also plays a major role in its economic feasibility. Hemi-cellulose, cellulose and lignin, the three main components of the lignocellulosic plant cell wall, show different values once the first can be used to produce furfural, the second is converted to ethanol and the last, because of its high energy content, is burned as an energy source (Kaylen et al. 2000). Not only production processes, but the whole supply-chain (from production to consumption) can interfere with the economic viability of lignocellulosic bioethanol. In Europe, for example, cost of feedstocks (determined by location and markets) and the value obtained for bioethanol (determined by oil price and policy incentives) were identified as being cost determinants in the whole chain, although these are highly uncertain factors (Slade et al. 2009).

2.10 Conclusions

Odds are that lignocellulosic bioethanol will break out of its technological and economic barriers, replacing 1st-generation bioethanol within the next decade and environmental sustainability of lignocellulosic systems will depend on three basic issues: the choice of crops, management practices and crops location (Koshel and McAllister 2010). As shown in this work, social issues are closely related to these criteria, so they should not be assessed exclusively under environmental ‘lenses’. Although no scientifically sounded social impact assessment for both bioethanol generations has yet been carried out, social assessment of 1st-generation bioethanol should have a noticeable ex-post component once case studies reporting on various social and environmental sustainability criteria can be found in literature. These criteria, some of them already assessed by previous works, could assist the development of social assessment of lignocellulosic bioethanol since "(…) prediction of social impacts are formulated as a result of combining understandings from previous comparative cases with knowledge about new circumstances of the case at hand" (Baines et al. 2003). Major challenges of overall energy assessments, such as the definition of study scope in order to appraise the maximum of aspects for analysis, remains valid to the assessment of biofuels technologies. It is also highly necessary to carry out more fieldwork in order to 'adjust' theoretical and methodological frameworks to different geographic contexts and realities. Bioethanol production-chain in the U.S., for instance, is different from the Brazilian or Mozambican one for a number of reasons related to social, economic and environmental peculiarities of each country, like for instance land occupation patterns, natural resources availability, labour conditions and incomes or social acceptance of technology.

In terms of expected differences between 1st-generation and lignocellulosic bioethanol social performances, the analysis presented in this work suggests that production of the latter from agricultural and forest residues only, as well as other residues containing lignocellulosic biomass like those found in municipal waste, could present minimised social impacts when compared to other lignocellulosic feedstock such as purpose grown species (e.g. poplar, willow, switchgrass) or starch/sugar crops used in the production of 1st-generation bioethanol (e.g. corn, wheat or sugarcane). At least within three major social issues, land use change and food and water security, social consequences could also be minimised through the use of marginal lands for feedstock expansion. However, it is very important to stress that this last option is completely dependent on the existence of scientific and public consensus surrounding marginal land's concept and the evaluation methodology used for definition of these kind of land. More sustainable lignocellulosic bioethanol also needs to be highly efficient, to use low-contaminant conversion processes and to present low costs throughoutits life cycle. Moreover, if rural development is to remain as one of the principal arguments for supporting biofuels policies, availability of technology and feedstock among different regions of the world, especially poorer ones, is needed. Possible benefits are also dependent on well-established management policies and well-planned programs focused at benefiting rural regions in terms of infrastructure improvements and labour integration.

Social assessments of bioethanol need to rely on a much broader set of empirical data. For such, fieldworks should be carried-out within a wide range of contexts and regions including, whenever possible, participatory methods in order to provide expertise with new and important lay or community-based knowledge, besides respecting rights of minorities. This is a critical topic, as it has been shown that there is a considerable lack of efforts toward public-opinion appraisal surrounding biofuels worldwide and that public engagement experiences on this matter are limited.

This essay pondered overall differences between the social consequences of first-generation and lignocellulosic bioethanol production. The discussion presented is an attempt to draw attention to the necessity of addressing priority social issues of new bioenergy technologies such as lignocellulosic bioethanol before its full deployment. Otherwise, social drawbacks could undermine the technology's viability in the future.

3 Artículo II: “El desarrollo de una matriz social para la evaluación de impacto de los biocombustibles”

Referencia

Ribeiro, B. E. (en prensa). El desarrollo de una matriz social para la evaluación de impacto de los biocombustibles. *ArtefaCToS*.

Resumen

Aunque un gran número de trabajos se dedique a la evaluación de los impactos de los biocombustibles, los aspectos sociales de su sostenibilidad permanecen todavía muy poco conocidos y estudiados. El presente artículo se dedica a presentar un novedoso método de recogida sistemática de los aspectos sociales relacionados con la sostenibilidad de políticas y proyectos científico-tecnológicos, utilizando el etanol como estudio de caso. Se concluye que la matriz social, desarrollada a partir de una revisión sistemática de la literatura disponible, constituye una valiosa herramienta de recogida de información en un campo de investigación como el de la sostenibilidad de los biocombustibles, marcado por una carencia de datos primarios y ausencia de consenso y homogeneidad científica en el trato del tema.

3.1 Introducción

Entre el 2011 y el 2012, la Comisión Europea aprobó un total de doce esquemas de certificación voluntarios para los biocombustibles en el intento de regular su producción e importación respecto a unos criterios sociales y sobre todo medioambientales de sostenibilidad[25]. Esta maniobra en la política energética a nivel europeo afecta al comercio internacional de una popular fuente de energía alternativa al petróleo, denotando la preocupación que hay en torno a su sostenibilidad. Entre otros motivos, este hecho indica la necesidad de que la esfera académica también se ocupe del tema. En efecto, a lo largo de los últimos años el número de publicaciones científicas dedicadas al análisis de los costes y beneficios económicos, medioambientales y sociales de los biocombustibles ha aumentado considerablemente. Una búsqueda sencilla en Google Scholar, por ejemplo, demuestra que en los últimos cinco años la publicación de trabajos relacionados con los biocombustibles ha sido tres veces mayor que entre 2003 y 2007.

No obstante, y tal como apuntan varios autores como Sheehan (2009), Uriarte et al. (2009), German et al. (2011), Lehtonen (2011), Ribeiro (2012) y Ribeiro (2013), aunque un gran número de trabajos se dedique a la evaluación de los impactos de los biocombustibles, los aspectos sociales[26] de su sostenibilidad permanecen todavía muy poco conocidos y estudiados. Desafortunadamente, este hecho no se restringe a las evaluaciones de nuevas tecnologías energéticas, sino que se aplica a la mayoría de los estudios y evaluaciones de la sostenibilidad de políticas o proyectos (PPs) científico-tecnológicos. En ellos, la dimensión social se ve a menudo eclipsada por los análisis de su viabilidad técnica y económica o de sus impactos medioambientales (Burdge 2002; Casula-Vifell y Soneryd 2012), siendo la ausencia de un marco institucional para la Evaluación de Impacto Social (EIS) una de las principales razones que explica la insuficiencia de estudios dedicados a evaluar la viabilidad social de los desarrollos científico-tecnológicos.

[25] Criterios fijados por la Directiva 2009/28/CE y Directiva 2009/30/CE.

[26] En este trabajo, se consideran como “aspectos” sociales los criterios, indicadores o verificadores de sostenibilidad social, además de medidas de mitigación y otras variables relacionadas con los impactos sociales directos e indirectos de los planes, programas o proyectos relacionados con los biocombustibles.

Utilizando el etanol como estudio de caso (el biocombustible de mayor producción mundial en la actualidad), el presente artículo se dedica a presentar el desarrollo de un novedoso método de recogida sistemática de aspectos sociales relacionados con PPs científico-tecnológicos, a través de la literatura revisada por pares. Dicho método consiste en el desarrollo de una matriz social compuesta de dos ejes: el ciclo de vida del producto[27] y los actores sociales relacionados con el último (véase ApéndiceA). Mientras las etapas del ciclo de vida y los determinados grupos de actores sociales sirven de guía para el análisis de contenido de la literatura, el cuerpo de la matriz refleja los resultados del análisis de los artículos seleccionados tras la búsqueda sistemática, i.e. sus celdas contienen los aspectos sociales relacionados según actores y fase del ciclo de vida del etanol. El desarrollo de la matriz tiene como objetivos el de contribuir con nuevos métodos de apoyo a las evaluaciones impacto social de PPs científico-tecnológicos y con el conocimiento de los impactos relacionados con el etanol, informando a las futuras evaluaciones sociales de su sostenibilidad.

3.2 La Evaluación de Impacto (EI) de PPs

La Asociación Internacional para la Evaluación de Impacto (AIEI) define de manera general a la Evaluación de Impacto (EI) como "el proceso de identificación de las consecuencias futuras de una acción en curso o propuesta"[28]. Ocasionalmente, el término *consecuencia* es sustituido por *externalidad* o *coste* en algunos trabajos, especialmente en aquellos del ámbito de la economía. Para Lenk et al. (2007), las externalidades se refieren a los costes o beneficios de una transacción económica que resulta, por ejemplo, en la generación de un subproducto no esperado capaz de afectar a partes que no participan directamente en la transacción (Lenk et al. 2007:1500). Mientras la identificación y análisis de los efectos no esperados de los desarrollos sea esencial en la evaluación de la viabilidad y sostenibilidad de PPs, es importante señalar que también a los resultados esperados los podemos denominar externalidades o consecuencias en el caso de la EIS. En efecto, la generación de empleos en una zona

[27] El ciclo de vida de un producto se refiere a su vida útil desde el proceso de extracción de recursos para su producción, los procesos de fabricación, su uso y desecho (Nieuwlaar, 2004).

[28] IAIA, "What is impact assessment". Disponible en: http://iaia.org/publicdocuments/special-publications/What%20is%20IA_web.pdf (visitado el 6 de abril de 2013).

empobrecida, por ejemplo, puede constituir uno de los objetivos de la implementación de determinadas políticas y proyectos. Aunque la generación de empleos se considera una consecuencia de las PPs, o una externalidad, no se trata de un subproducto no esperado, ni afecta a partes que no participan directamente en el PP científico-tecnológico.

Bond y Pope (2012) proponen una tipología general que incluye a seis principales cuerpos de teoría y práctica en las EI: la evaluación de impacto ambiental, la evaluación estratégica ambiental, la evaluación de políticas, la evaluación de impacto social, la evaluación de impacto en la salud y la evaluación de la sostenibilidad. Sin embargo, esta tipología de las EI no tiene por qué ser definitiva y no debería limitar los ámbitos de actuación e investigación de las evaluaciones en general. De hecho, los distintos tipos de evaluación integran, en mayor o menor grado, análisis de aspectos que normalmente se evalúan en las demás. Una evaluación de impacto en la salud humana, por ejemplo, no deja de ser una parte importante de una evaluación de impacto social de PPs. El campo de las EI de PPs es, por tanto, un campo muy dinámico en el que los procedimientos de evaluación se ajustan a los diferentes contextos y objetivos propuestos por el analista. Asimismo, muchas evaluaciones de impacto se enfocarán en la evaluación de la *sostenibilidad* de PPs, fomentando la generación de impactos positivos, enfatizando el análisis de impactos intergeneracionales e integrando las dimensiones social, medioambiental y económica de políticas y proyectos (Bond et al. 2012).

3.2.1 La EIS de PPs y el concepto de impacto social

"Todo es social" fueron las palabras proferidas por Frank Vanclay en junio de 2012 al empezar su curso sobre Evaluación de Impacto Social en el marco de la conferencia anual de la AIEI. Vanclay no se preocupó, entonces, en ofrecer una explicación exhaustiva sobre su afirmación, pero no es difícil entenderla y la reflexión acerca de su significado da lugar a interesantes consideraciones. Al afirmar que *todo* es social, Vanclay indica que cualquier impacto, incluyendo aquellos considerados de naturaleza ambiental, tienen en última instancia una consecuencia social. Se puede pensar que cambios, por ejemplo, en la calidad del agua afectan a las poblaciones humanas que dependen directamente de los ríos como fuente de alimento o como vía de transporte. Cambios de orden económico, socialmente construidos y producidos, pero siempre relacionados con flujos de energía y materiales, también producen consecuencias directas a nivel social, afectando a la supervivencia y al bienestar de los seres humanos. Para Pardo (1994), la conexión entre los impactos biofísicos (en sus palabras, "ecológicos") y los sociales "es inmediata en la medida que la regulación del impacto ecológico deviene social en sus consecuencias y es la sociedad, en definitiva, quien interpreta ambos y les da contenido" (Pardo 1994:146).

Aunque la EIS haya existido desde hace más de dos siglos (Becker 2001), surgió formalmente en los años 70 en los EEUU debido a la necesidad de incluir las consecuencias sociales derivadas de la implementación de proyectos y programas políticos del gobierno estadounidense, especialmente los relacionados con proyectos energéticos de gran escala, en las evaluaciones de impacto ambiental desarrolladas en aquellos momentos (Vanclay 2006). Sin embargo, desde el punto de vista social es posible evaluar a virtualmente todo: desde políticas científico-tecnológicas, a políticas económicas, ambientales y sociales; pero también proyectos científico-tecnológicos específicos, como desarrollos industriales, los relacionados con la extracción de recursos naturales o con la transformación de estos en productos. Igualmente, es posible asignar cualquier escala a la evaluación, en términos de tiempo, lugares geográficos y grupos sociales involucrados; pero también a nivel de plan o proyecto, en su fase de diseño o tras su implementación. Precisamente por esas razones, cuando se habla de EIS es imposible hablar de un marco metodológico o conceptual único para su desarrollo.

No obstante, y de manera general, la siguiente definición de EIS propuesta por Vanclay (2003a) es bastante aceptable:

"La EIS es el proceso de análisis (predecir, evaluar y reflexionar) y gestión de las consecuencias intencionales y no-intencionales en el medio humano de las intervenciones planificadas (políticas, programas, planes y proyectos) y cualesquiera procesos de cambio social producidos a partir de tales intervenciones para que de éstas resulten medios humanos y biofísicos más equitativos y sostenibles " (Vanclay 2003a:2).

Así como no hay una única definición de EIS, el concepto de impacto social (y qué es exactamente lo que se considera como impacto social) varía enormemente en la literatura. La definición formal de las directrices de la EIS se materializó por primera vez en un trabajo del *Interorganizational Committee on Guidelines and Principles for SIA*, que definió a los impactos sociales como

"Las consecuencias para las poblaciones humanas ocasionadas por cualesquiera acciones públicas o privadas que alteran las maneras en que las personas viven, trabajan, juegan, se relacionan, se organizan para satisfacer sus necesidades y ejercer su ciudadanía" (Interorganizational Committee 1995:11).

En la literatura especializada, normalmente no se diferencian procesos de cambio social e impactos sociales, aunque algunos defiendan que dicho ejercicio es imprescindible a la hora de llevar a cabo la EIS de PPs (véase Vanclay 2002a). Para Vanclay (2002a), mientras un proceso de cambio social puede llegar a producir impactos sociales positivos o negativos a nivel individual o del grupo social, estos impactos se refieren a la sensación "real", corporal (e.g. dolor, muerte) o cognitiva (e.g. miedo, alegría), que el ser humano experimenta tras determinado cambio. Al mismo tiempo que Vanclay critica la utilización de listas de chequeo (*checklists*, en inglés) predefinidas en la EIS, también critica otras propuestas o esfuerzos en la categorización de impactos sociales señalando que estos confunden muchas veces las variables de impacto social (e.g. cambios en la densidad poblacional) con lo que sería un impacto social (e.g. posibles pérdidas de cohesión social). Aunque parezca válida desde el punto de vista operacional, esta discusión es compleja y puede dar lugar a equivocaciones. Por ejemplo, el mismo Vanclay (2002a), al agrupar o categorizar una serie de impactos sociales de PPPs, identifica al "cambio en los valores culturales, tales como las normas morales, creencias, rituales, lenguaje e indumentaria" como un posible impacto (Vanclay 2002a:205). Lo mismo sucede a la hora de agrupar impactos a nivel de la familia y la comunidad, dado que el autor incluye las "alteraciones en las estructuras familiares", o los "cambios en la estructura demográfica de la comunidad" en la categoría de impactos (Vanclay 2002a:206). No obstante, estos constituirían, según el autor, procesos de cambio social que pueden producir impactos una vez que, según su propia definición, una alteración en la estructura familiar (e.g. pérdida de uno de los miembros responsables por la mayoría de los ingresos económicos en la unidad) no significa *per se* una sensación física o psicológica, lo que, por su parte, caracterizaría un impacto social. Por otro lado, se podría decir que la ocurrencia de desnutrición entre los miembros de una unidad familiar, debido a la disminución total de los ingresos por muerte de un individuo, es con seguridad un impacto social.

En el presente artículo, se considera el impacto social de PPs como una consecuencia de la intervención humana en el medioambiente o en la sociedad cuyos efectos son experimentados por seres humanos, directa o indirectamente y a lo largo del tiempo. Sus características y niveles de complejidad varían de acuerdo con el contexto y especificidades del sistema técnico estudiado. Asimismo, se pueden identificar tres dimensiones de un impacto social: los procesos de cambio social, e.g. un aumento en la exposición humana a sustancias tóxicas; la experiencia humana del cambio, e.g. el desarrollo de patologías, y la respuesta o adaptación humana al cambio, e.g. búsqueda de tratamiento. La principal diferencia entre esta definición y la propuesta por Vanclay (2002a) es que, mientras el autor aboga por la equivalencia entre impacto social y experiencia humana, separándolos de los procesos de cambio social, aquí se considera el impacto social como el conjunto de los procesos de cambio social y las experiencias y respuestas humanas asociadas a los últimos. Lo que caracteriza a un impacto como positivo o negativo es la calidad de la experiencia humana, es decir, el impacto social, en cuanto impacto experimentado por seres humanos, es valorado por los humanos como positivo o negativo, o no se valora. Las respuestas humanas dependen, a su vez, de los valores individuales o compartidos por un grupo social, de manera que la valoración positiva o negativa de un impacto puede variar entre individuos y grupos distintos. Además, y tal como ha sido defendido por van Schooten et al. (2003), distintos grupos presentan distintas capacidades de adaptación a los cambios haciendo que los impactos sean siempre y necesariamente dependientes de los contextos sociales.

3.3 La matriz social: bases y objetivos

La matriz que sirve de base para la recogida de los aspectos sociales del etanol está inspirada en aportaciones provenientes del campo de la ética en la agricultura y sistemas alimentarios, especialmente en el trabajo desarrollado por Kaiser y Forsberg (2001). Las matrices éticas sirven de herramienta conceptual de apoyo en los procesos de toma de decisión, sobre todo a nivel de la regulación de desarrollos científico-tecnológicos en esos campos (Mepham et al. 2006). Se trata de una herramienta polifacética que se puede aplicar a diversos casos, pero cuyo principal objetivo es proporcionar un análisis sistematizado de la dimensión ética del caso elegido teniendo en cuenta, por un lado, los actores sociales involucrados y, por el otro, determinados principios éticos que pueden variar según autores y tipo de estudio.

Kaiser y Forsberg (2001), por ejemplo, evalúan la situación de las pesquerías en Noruega y los aspectos éticos involucrados en el sector pesquero a través de un proceso participativo de construcción de una matriz ética relativa al tema. En su matriz, cada celda representa un aspecto ético relevante para determinado grupo de actores sociales interesados en la cuestión (e.g. pescadores, la industria pesquera, consumidores etc.) y se relaciona, a la vez, con uno de los principios éticos fundamentales que se eligieron para el estudio, en su caso, justicia, dignidad o bienestar. Los aspectos reflejados en la matriz, i.e. consideraciones éticas acerca del sector pesquero en Noruega desde la perspectiva de los impactos experimentados por los diferentes actores sociales involucrados, sirven para informar procesos de toma de decisión relacionados con este sector en el país. Los autores señalan, no obstante, que la matriz sola no sirve de instrumento decisorio definitivo, sino que su mayor objetivo es hacer que se vuelvan más transparentes los intereses y valores de los distintos grupos y apoyar la evaluación de desarrollos alternativos a una determinada opción científico-tecnológica (Kaiser y Forsberg 2001). Otro ejemplo, todavía en el ámbito de la evaluación ética en el sector pesquero, es el estudio de Lam y Pitcher (2012), en el que los autores también proponen una matriz ética, pero esta vez basada en la literatura, para el análisis de la sostenibilidad de las pesquerías. Por último, Schroeder y Palmer (2003), al analizar la utilidad de la matriz ética en la evaluación de tecnologías emergentes, argumentan que la matriz puede ser especialmente útil como herramienta de identificación y registro de información, más que de ponderación de los aspectos éticos relacionados con el caso en estudio. Sobre este último punto, los autores defienden que el desarrollo de un proceso participativo podría incrementar la utilidad y calidad de la matriz como instrumento de ponderación para la toma de decisiones.

Mientras en las matrices éticas se eligen primeramente a los principios éticos básicos, que constituyen el *input* teórico que caracterizará al estudio, la matriz social aquí desarrollada para recoger los aspectos sociales del etanol no selecciona de antemano ningún tipo de directriz teórica; en realidad, lo que trata de hacer es garantizar que su pluralidad esté justamente en la recogida dirigida de esos aspectos. De ese modo, aunque uno de los ejes sea común a ambos tipos de matrices, i.e. el eje de los grupos de actores sociales involucrados (con sus diferencias)[29], el eje de los principios en la matriz ética se sustituye por el de las etapas del ciclo de vida del etanol[30] en la matriz social (veáse Apéndice A). Esta adaptación en el diseño y metodología de desarrollo de la matriz es debida al objetivo de la misma, que es recoger la mayor cantidad y variedad posible de aspectos sociales del etanol presentes en la literatura especializada. La construcción de la matriz consiste, por tanto, en un ejercicio de naturaleza arriba-abajo, pero cuya intención es servir de base para un proyecto posterior de carácter participativo, o abajo-arriba, en el que se discutirán y se definirán los criterios e indicadores de impacto social que se pueden utilizar en las evaluaciones de la dimensión social de la sostenibilidad del etanol. No se debe entender la matriz social como inalterable, ni tampoco como una *checklist* de los impactos verificados y potenciales del etanol, sino que debe ser entendida como una guía básica para la consideración de los posibles impactos sociales de la planificación y la implementación de PPs relacionados con el etanol de manera general. No obstante, es necesario percatarse de que los procesos de cambio social dependen de los contextos en el seno de los cuales se producen y sus diferentes escalas, que pueden variar de local a mundial. Asimismo, es virtualmente imposible describir todas las dimensiones de los cambios sociales provocados por PPs, una vez que los propios cambios se retroalimentan (van Schooten et al. 2003). Por eso, cualquier guía siempre será más o menos incompleta y se espera que muchas variables que uno considera como posibles no estén presentes en la matriz, la cual, en definitiva, refleja simplemente lo que se ha recogido en la literatura analizada. De manera análoga, otras variables propuestas en la matriz pueden no "encajar" en determinados contextos. En cualquier caso, y a pesar de dichos inconvenientes, el valor de esta novedosa matriz

[29] Basado en la categorización utilizada por Benoît et al. (2010) en su metodología de evaluación social del ciclo de vida de productos.

[30] Según descripción de von Blottnitz y Curran (2007).

reside en su esfuerzo por incrementar la profundidad y calidad de las evaluaciones de impacto social del etanol a las que les sea útil la herramienta.

3.4 El proceso de revisión sistemática de la literatura

Se aplicó la metodología de revisión sistemática a aquellos trabajos revisados por los pares, es decir, solamente artículos publicados en revistas científicas han sido considerados en el presente estudio. La elección de un análisis restringido a la literatura científica se justifica por tres motivos principales. Primero, se espera que una importante parte de la literatura gris que trata del tema esté recogida en los artículos; segundo, lo que se publica en medios no-científicos relacionado con los biocombustibles es de una extensión tal que un trabajo exhaustivo de revisión y evaluación de esta literatura demandaría un equipo de trabajo igualmente extenso y una cantidad de tiempo de la que no se dispondría al realizar este estudio; tercero, se espera que a través de la revisión de la literatura científica se llegue a otras fuentes bibliográficas no-científicas claves para el futuro trabajo de determinación de criterios e indicadores de sostenibilidad social tal como informes de ONGs, esquemas de certificación o estándares internacionales etc.

Una revisión sistemática consiste en una revisión guiada por una pregunta de naturaleza clara y objetiva, anteriormente formulada, que utiliza métodos sistemáticos y explícitos para la identificación, selección y evaluación de investigación relevante, además de servir para la recolección y análisis de datos de los estudios incluidos en dicha revisión (Moher et al. 2009:1). Las revisiones sistemáticas son especialmente comunes en el ámbito de la medicina (e.g., Glinianaia et al. 2004; Lundh et al. 2009) y deberían cobrar más importancia en los campos de investigación en ciencias sociales.

3.4.1 Estrategia de búsqueda

Se utilizó una estrategia de búsqueda basada en las directrices de las revisiones Cochrane (véase Higgins y Green 2011), que consiste en la revisión de estudios que atienden a unos criterios de inclusión preestablecidos, es decir, una revisión sistemática cuyo objetivo es identificar el mayor número de estudios relevantes que se ajustan al dominio del asunto elegido (Budimir et al. 2011). Se siguieron los siguientes pasos:

1. Definición de la pregunta de la revisión (relacionada con el objetivo del estudio).
2. Determinación de los criterios de inclusión para selección de los artículos relevantes.
3. Búsqueda de los artículos en las bases de datos científicas utilizando un listado de términos de búsqueda.
4. Selección de los artículos a través de la aplicación de los criterios anteriormente determinados.
5. Análisis cualitativo del contenido de los artículos seleccionados.
6. Presentación de los resultados y conclusiones.

3.4.2 Pregunta de la revisión

Se definió la siguiente pregunta como guía para la revisión: ¿qué aspectos del etanol utilizado como biocombustible se pueden identificar en la literatura revisada por los pares hasta la fecha?

3.4.3 Determinación de los criterios de inclusión

Se han definido dos amplios criterios de inclusión para la selección de artículos relevantes: a) artículos revisados por pares publicados en revistas científicas, en el idioma inglés y en cualquier fecha y b) artículos que analizan o mencionan como mínimo un tipo de aspecto social relacionado con el etanol usado como biocombustible. Al último se le considera el criterio de elegibilidad temática, es decir, el criterio responsable de garantizar la relevancia del contenido del artículo respecto al objetivo y pregunta de la revisión sistemática propuesta.

3.4.4 Bases de datos y términos de búsqueda

Se utilizaron la Web of Science, Science Direct y Google Scholar como bases de datos para la búsqueda de los artículos. Se insertaron en el campo "tema" (*topic*, en inglés, referente al título, resumen o palabras clave) para las dos primeras bases de datos los siguientes términos de búsqueda: *biofuel* and (bioethanol or ethanol) and (social or ethic* or cultural)*. La búsqueda en Google Scholar se basó en los mismos términos, pero con ocurrencia en todo el texto, es decir, sin restricción a áreas específicas del artículo tales como el título, resumen o palabras clave. Para restringir el número de resultados (una vez que la ocurrencia de los término no se limita a ciertas áreas del texto), y basándose en una revisión narrativa de los aspectos sociales del etanol previa a este trabajo (véase Ribeiro 2012), se construyó la búsqueda de la siguiente forma: en el campo "con todas las palabras" (*with all the words*, en inglés) se usaron *biofuel* *ethanol social*; en el campo "con al menos una de las palabras" (*with at least one of the words*, en inglés) se usaron *cultural ethic* health right* work* education wage employment communit* minorit* quality participation law* gender safety noise "human rights" "land use" "water security" "food security" "social acceptance" "public participation"*.

3.4.5 Selección y análisis de los artículos

Para la gestión de citas se utilizó EndNote Web versión 3.1 y EndNote X2 para Macintosh. Para el análisis de contenido, se leyeron los textos completos de los artículos seleccionados tras la aplicación de los criterios de inclusión presentados anteriormente. Se empleó una adaptación del diagrama de cuatro fases propuesto por la declaración PRISMA (Moher et al. 2009) para incrementar la calidad del proceso de búsqueda, identificación y selección de los estudios (Tabla 1).

Búsqueda e Identificación	# de registros identificados a través de la búsqueda en las bases de datos
Cribado **(Aplicación del criterio "a")**	# de registros seleccionados; # de registros excluidos y # de registros restantes tras eliminación de duplicados
Chequeo de elegibilidad **(Aplicación del criterio "b")**	# de resúmenes y artículos completos analizados para elegibilidad y # de artículos (texto completo) excluidos, con razones
Incluidos	# de artículos seleccionados para análisis cualitativo final

Tabla 1. Identificación y selección de artículos en la revisión sistemática. Adaptado de Moher et al. (2009)

La alteración más significativa en términos metodológicos ha ocurrido en la fase de "cribado", en la cual se removieron los duplicados (entre bases de datos distintas) tras haber aplicado el criterio de inclusión "a". La razón para dicha alteración ha sido el altísimo número de registros identificados en la búsqueda en Google Scholar, comparado con las demás bases de datos. La exclusión de los artículos que no cumplían con el criterio "a" antes de la identificación de duplicados facilitaría el trabajo enormemente sin comprometer la calidad del proceso. La fase de elegibilidad consistió en la aplicación del criterio de elegibilidad "b" en los estudios seleccionados tras el proceso de cribado. No se realizó meta-análisis (análisis estadístico para evaluación cuantitativa) de los artículos seleccionados debido a la naturaleza cualitativa del estudio. El análisis de contenido de los artículos incluidos se apoyó en el marco de la matriz social (Apéndice A) y en un formulario para recuperación de información (Apéndice B), ambos desarrollados de manera iterativa, permitiendo que la información recogida contribuyera al diseño de los instrumentos.

3.5 Resultados de la búsqueda sistemática

La búsqueda en las bases de datos se realizó el día 14 de octubre del 2011. La búsqueda en la Web of Knowledge resultó en 59 referencias (registros), mientras Science Direct produjo 28 referencias. Se obtuvieron 646 resultados tras la búsqueda en Google Scholar.

3.5.1 Cribado (aplicación del criterio "a")

Entre los 59 resultados de Web of Knowledge, 55 consistían en publicaciones revisadas por pares en revistas científicas, en el idioma inglés. De los 28 resultados de Science Direct, 27 eran artículos de revistas científicas, mientras se excluyó el único capítulo de libro que aparecía entre los registros. Debido a que la ocurrencia de los términos de búsqueda usados en Google Scholar se aplicaba a todo el texto, se esperaba un número significativo de entradas irrelevantes. Por este motivo, se modificó el proceso de cribado y se leyeron los títulos y resúmenes de los registros identificados para un chequeo inicial de su relevancia antes de seleccionar las referencias para aplicación del criterio “b”. Solamente 47 artículos atendían a los requisitos. Estos, entonces, fueron seleccionados para la siguiente fase de la evaluación.

Antes de la aplicación del criterio “b” se realizó un chequeo cruzado de las referencias para eliminación de resultados duplicados. Entre las referencias de Web of Knowledge y Science Direct se identificaron 20 estudios duplicados. Se formó un nuevo grupo de registros, consistente en la suma de los estudios no-duplicados, 62 en total. A este nuevo grupo se añadieron los resultados de Google Scholar (109, en total) y se identificaron 2 artículos duplicados. La muestra final para aplicación del criterio “b” consistía entonces en 107 referencias.

3.5.2 Chequeo de la elegibilidad (aplicación del criterio “b”)

Los artículos seleccionados tras aplicación del criterio “a” deberían atender al siguiente criterio de inclusión “b”: artículos que analizan o mencionan como mínimo un tipo de aspecto social relacionado con el etanol usado como biocombustible. Se leyeron los resúmenes de los 107 artículos seleccionados. Finalmente, 90 atendían al criterio “b” de inclusión y pasaron a la fase de análisis cualitativo de contenido.

3.5.3 Análisis de contenido de los artículos seleccionados

Tras la aplicación de los dos criterios de inclusión, se leyeron los textos completos de los estudios seleccionados. La matriz social (Apéndice A) y la tabla presentada en el Apéndice B sirvieron de guía para el análisis cualitativo de los contenidos de los artículos. Dicho análisis transcurrió entre el mes de noviembre del 2011 y mediados de marzo del 2012.

3.6 Características de la matriz social

La introducción de los aspectos sociales en la matriz se dio en dos pasos básicos: primeramente, se incluyó cualquier aspecto social mencionado o analizado en los artículos seleccionados; posteriormente, se eliminaron los elementos repetidos, y se agruparon los aspectos similares. Un gran número de aspectos sociales consistía en criterios o indicadores de cambios sociales, lo que demuestra el énfasis en los procesos de cambio social cuando se habla de la sostenibilidad social o impacto social de los desarrollos científico-tecnológicos (veáse Apéndice C).

Una vez introducidas en la matriz, se interpretaron las variables, buscando refinar el agrupamiento de éstas. Los ejes de la matriz, i.e. actores sociales y fases del ciclo de vida, eran flexibles en la medida que se obtenía información derivada del análisis de contenido de la literatura. De hecho, el análisis de los artículos contribuyó a que se expandiera la definición de algunos elementos de la matriz, y la matriz misma. En el caso de los actores, "trabajadores" (*workers*) incluían a los agricultores y también a los empleados; "sociedad" (*society*) incluía también a las instituciones públicas y privadas; "actores de la cadena de valor" (*value chain actors*) se refería a los distribuidores de insumos de manera general. Durante el análisis, se añadió a un nuevo actor, el "medio ambiente" (*environment*), definido como los servicios o funciones medioambientales valiosas para el ser humano, i.e. funciones ecológicas de las cuales las personas obtienen beneficios. Respecto a las fases del ciclo de vida del etanol, "producción de insumos" (*production of inputs*) incluía a los fertilizantes, herbicidas, pesticidas, equipamiento, combustible y construcciones; la fase de "producción de materia prima" (*feedstock production*) se limitaba a la fase agrícola, en el medio rural; "transporte" (*transport*) se refería al transporte de materia prima e insumos (e.g. carbón) a la planta de producción y de etanol desde la planta a la gasolinera, además de transporte de los últimos a los almacenes; "planta de producción" (*producing plant)* incluía a todos los procesos de conversión, ocurriendo la mayor parte de ellos a nivel industrial; "uso final" (*final use*) se definió como la fase en la que el etanol llega al consumidor final, desde su compra hasta su combustión en los vehículos públicos o privados.

3.7 Discusión

La casi totalidad de los estudios seleccionados (95%) se publicaron después del 2007, con una gran concentración de artículos en los años de 2010 y 2011. La mitad de los trabajos se enfocaban en la cadena de producción del etanol en los EEUU y Brasil, los dos mayores productores de etanol en el mundo. La gran mayoría se publicó en revistas científicas de carácter multidisciplinar (67%) y no contribuían con datos primarios (76%), i.e. no se trataba de estudios pioneros en el tema. El aumento en los precios de los alimentos entre el 2007 y el 2008 puede explicar parcialmente la "explosión" en las publicaciones relacionadas con los aspectos sociales de los biocombustibles a partir del 2007. Se acusó a los biocombustibles denominados de "primera generación" (aquellos que utilizan como materia-prima cultivos alimentarios) como una de las causas del aumento en los precios de algunos tipos de alimentos - entre ellos el maíz, a partir del cual se produce gran parte del etanol en EEUU. Este hecho les hizo muy populares entre los medios de comunicación y el público, lo que podrá haber llamado también la atención de la academia respecto a los impactos sociales del etanol, en especial aquellos relacionados con la seguridad alimentaria.

No había consenso entre los autores de los trabajos seleccionados respecto a cuáles son los impactos o grupos de impacto sociales del etanol, a qué fases del ciclo de vida se relacionan o cuáles son los actores involucrados. Mientras muchos autores ponían énfasis y se limitaban a discutir o apuntar la cuestión de la seguridad alimentaria, pocos se ocupaban de temas menos "populares", como los impactos sociales derivados de cambios infraestructurales, o los relacionados con los cambios en los modos de producción en el campo, entre otros. De manera general, los artículos seleccionados no profundizaban en el análisis de la sostenibilidad social del etanol, pasando por alto muchas de las fases del ciclo de vida, como la de transporte y uso final, y actores sociales como la sociedad en general, los consumidores y otros actores de la cadena de valor.

Gran parte analizaba la cuestión de la sostenibilidad de los biocombustibles de manera general, dejando de diferenciar los tipos de biocombustibles sobre los que se discutían, i.e. etanol o biodiesel. De hecho, un 30% de los artículos seleccionados se dedicaban exclusivamente a trabajar el etanol como biocombustible. Asimismo, es muy preocupante que solamente un 24% de los estudios contribuyera con resultados empíricos, es decir, datos primarios que pueden servir de base empírica en el análisis de la sostenibilidad del etanol. Aunque haya un creciente interés académico por los aspectos sociales del etanol, la mayor parte de los estudios debatió el tema con base en los resultados o afirmaciones de otros autores. Este hecho definitivamente influye de manera negativa en el desarrollo de evaluaciones robustas del impacto social de este biocombustible.

3.8 Conclusiones

El presente artículo se ha ocupado de presentar el proceso de desarrollo de una matriz destinada a identificar y sistematizar la recogida de los aspectos sociales del etanol desde el marco de las evaluaciones de impacto social de PPs científico-tecnológicos. No es objetivo del artículo presentar o discutir el contenido de dicha matriz, pero en el caso de que le interese al lector, su análisis detallado se ha publicado recientemente en otro trabajo (véase Ribeiro 2013).Se concluye que la matriz social desarrollada a partir de una revisión sistemática, explícita y cuidadosa de la literatura disponible constituye una valiosa herramienta de recogida de información en un campo de investigación como el de la sostenibilidad de los biocombustibles, marcado por una carencia de datos primarios y ausencia de consenso y homogeneidad científica en el trato del tema. No obstante, es importante señalar que, como en el caso de las matrices éticas, no se debe considerar la matriz social como único instrumento en un proceso de evaluación. Mientras se espera que su inclusión aumente el rigor y la calidad de las evaluaciones, se recomienda que a ella se añadan estrategias de participación ciudadana.

Apéndice A. Matriz social (inicial)

	Production of inputs	Feedstock production	Transport	Producing plant	Final use
Workers					
Local community					
Society					
Value chain actors					
Environment (ecological services valuable for human society)					

Apéndice B. Artículos seleccionados e incluidos (final)

	Reference	Journal	Journal research area*	Authors' institutional affiliation (country)	Main geographic scope of analysis	Primary data offered? Original research article?	Ethanol generation addressed. Differentiates among ethanol generations regarding social aspects?	Addresses ethanol exclusively?
1	**Aerni (2008)**	ATDF Journal	SS	Switzerland	African countries and New Zealand	No	1st. No	No
2	**Amigun et al. (2011)**	Renewable and Sustainable Energy Reviews	EE (M)	South Africa	African countries	No	1st mainly. Yes	No
3	**Bailis and Baka (2011)**	Annals of the Association of American Geographers	GS (M)	United States	Not defined (Brazil, US, EU, India, Tanzania)	No	1st. No	No
4	**Banerjee (2011)**	Development and Change	SS	India	United States	No. Yes	1st mainly. Yes	Yes
5	**Bell et al. (2011)**	Energy Policy	SS	US, Thailand	Thailand	No. Yes	1st mainly. Yes	No
6	**Bodgan et al. (2010)**	Bulletin UASVM Animal Science and Biotechnologies	AE	Romania	Not defined	No	1st. No	No
7	**Bush (2007)**	Biofuels, Bioproducts and Biorefining	CC (M)	The Netherlands	Southeast Asia	No	1st mainly. Yes	No
8	**Carioca et al. (2009)**	Biotechnology Advances	BS (M)	Brazil	Brazil	No	2nd mainly. Yes	No
9	**Chavez et al (2009)**	Journal of Biobased Materials and Bioenergy	BS (M)	England, China	China	No	Both. Yes	No
10	**Coelho et al. (2006)**	Energy for Sustainable Development	EE (M)	Brazil	Brazil	No	1st. No	Yes
11	**Conejero et al. (2010)**	Future SRJ	SS	Brazil	Not defined (Brazil as a common point for comparison)	No. Yes	1st mainly. Yes	No
12	**Corbière-Nicollier et al. (2011)**	Ecological Indicators	ES (M)	Switzerland, France	Switzerland and Brazil (Comparison)	No. Yes	1st mainly. Yes	Yes
13	**Dale et al. (2010)**	Ecology and Society	ES (M)	United States	United States	No	2nd mainly. Yes	Yes

	Reference	Journal	Journal research area*	Authors' institutional affiliation (country)	Main geographic scope of analysis	Primary data offered? Original research article?	Ethanol generation addressed. Differentiates among ethanol generations regarding social aspects?	Addresses ethanol exclusively?
14	**Davis et al. (2011)**	GCB Bioenergy	BS	United States	Not defined (Mexican, Brazilian, African and Australian cases highlighted)	No	1st. No	Yes
15	**de Gorter and Just (2010)**	Applied Economic Perspectives and Policy	SS	United States	United States	No. Yes	1st. No	No
16	**Demirbas and Demirbas (2007)**	Energy Conversion and Management	EE (M)	Turkey	Not defined (Emphasis on "developing countries")	No	Both. No	No
17	**Di Lucia (2010)**	Energy Policy	SS	Sweden	Mozambique	No. Yes	1st. No	No
18	**Dodic et al. (2010)**	Renewable and Sustainable Energy Reviews	EE (M)	Serbia	Serbia	No	1st mainly. No	No
19	**Fabiosa et al. (2009)**	Land Economics	SS	United States	Not defined (U.S. and Brazil are highlighted, China, EU and India)	No. Yes	1st mainly. No	Yes
20	**Fischer et al. (2010)**	Biomass and Bioenergy	BS (M)	Austria, The Netherlands	Europe	No. Yes	Both. Yes	No
21	**Furtado et al. (2011)**	Energy Policy	SS	Brazil	Brazil	No. Yes	1st mainly. No	Yes
22	**Gallardo and Bond (2011)**	Environmental Impact Assessment Review	AE (M)	Brazil, UK	Brazil	No	1st. No	Yes
23	**Gao et al. (2011)**	Applied Geography	GS	México, Italy, Indonesia	Not defined (Latin America, Asia and Africa, but emphasises on the Brazilian case)	No. Yes	Both. Yes	No

	Reference	Journal	Journal research area*	Authors' institutional affiliation (country)	Main geographic scope of analysis	Primary data offered? Original research article?	Ethanol generation addressed. Differentiates among ethanol generations regarding social aspects?	Addresses ethanol exclusively?
24	**Gasparatos et al. (2011)**	Agriculture, Ecosystems and Environment	AE	Japan	Not defined (Brazil, US, China, India)	No	1st. No	No
25	**German et al. (2011)**	Ecology and Society	ES (M)	Indonesia	Asia, Africa and Latin America	No	1st. No	No
26	**Gielen et al. (2003)**	Biomass and Bioenergy	BS (M)	Japan	Not defined (global application of model)	No. Yes	Both. No	No
27	**Gillon (2010)**	Journal of Peasant Studies	SS	United States	United States	Yes. Yes	1st. No	Yes
28	**Goldemberg and Guardabassi (2009)**	Biofuels, Bioproducts and Biorefining	CC (M)	Brazil	Brazil (and sugarcane producing countries from tropical zones)	No	1st. No	Yes
29	**Gomiero et al. (2010)**	Journal of Agricultural and Environmental Ethics	SS	Italy, United States	Not defined (presents US and Brazil's case)	No	Both. Yes	No
30	**Hall and Matos (2010)**	International Journal of Physical Distribution & Logistics Management	SS	Canada	Brazil	Yes. Yes	1st. No	No
31	**Hall et al. (2009)**	Journal of Cleaner Production	EE (M)	Canada, Brazil	Brazil	Yes (SAME DATA AS ABOVE). Yes	1st. No	No
32	**Hall et al. (2011)**	Technological Forecasting & Social Change	SS	Canada, UK	Brazil	Yes (SAME DATA AS ABOVE). Yes	1st. No	No
33	**Harvey and Pilgrim (2011)**	Food Policy	AE (M)	UK	Brazil, US and Europe	No	Both. Yes	No
34	**Hattori and Morita (2010)**	Plant Production Science	AE	Japan	Not defined	No	Both. Yes	Yes

	Reference	Journal	Journal research area*	Authors' institutional affiliation (country)	Main geographic scope of analysis	Primary data offered? Original research article?	Ethanol generation addressed. Differentiates among ethanol generations regarding social aspects?	Addresses ethanol exclusively?
35	**Janssen and Rutz (2011)**	Energy Policy	SS	Germany	Latin America	No	1st. No	No
36	**Jordaan (2007)**	Ethics in Science and Environmental Politics	SS	Canada	Not defined	No	1st. No	No
37	**Jordan and Warner (2010)**	BioScience	BS (M)	United States	United States	No	Both. No	No
38	**Koh and Ghazoul (2008)**	Biological Conservation	BS (M)	Switzerlan d	Not defined (main producing countries)	No	Both. Yes	No
39	**Koizumi (2011)**	Journal of Cleaner Production	EE (M)	Japan	Japan	No	Both. Yes	No
40	**Koning et al. (2008)**	Wageningen Journal of Life Sciences	AE (M)	The Netherland s	Not defined	No	Both. Yes	No
41	**Lal (2009)**	European Journal of Soil Science	AE	United States	Not defined	No	2nd. No	No
42	**Lehtonen (2011)**	Biomass and Bioenergy	BS (M)	UK	Brazil	Yes. Yes	1st mainly. Yes	Yes
43	**Lenk et al. (2007)**	Biotechnology Journal	BS (M)	Germany	Not defined (emphasis on Germany)	No	1st mainly. Yes	No
44	**Luk et al. (2010)**	Biofuels, Bioproducts and Biorefining	CC (M)	Canada	Canada	No. Yes	1st mainly. Yes	Yes
45	**Luque et al. (2008)**	Energy and Environmental Science	AE (M)	Spain, UK	Not defined	No	Both. Yes	No
46	**Malik et al. (2009)**	Applied Energy	EE	Philippines	Greater Mekong Subregion (Asia: Cambodia, Laos, Myanmar, Thailand, Vietnam and China)	No	1st. No	No
47	**Martinelli and Filoso (2008)**	Ecological Applications	AE (M)	Brazil, United States	Brazil	No	1st. No	Yes

	Reference	Journal	Journal research area*	Authors' institutional affiliation (country)	Main geographic scope of analysis	Primary data offered? Original research article?	Ethanol generation addressed. Differentiates among ethanol generations regarding social aspects?	Addresses ethanol exclusively?
48	**Martinelli et al. (2011)**	Agricultural Systems	ES (M)	United States, Brazil	Brazil	No. Yes	1st. No	Yes
49	**Milder et al. (2008)**	International Journal of Agricultural Sustainability	AE (M)	United States, Switzerlan d	Not defined	No	1st mainly. Yes	No
50	**Mohamadabadi et al. (2009)**	Energy	EE (M)	Canada	United States	Yes. Yes	1st. No	No
51	**Naylor (2011)**	Food Security	ES (M)	United States	Not defined	No	Both. Yes	No
52	**Naylor et al. (2007)**	Environment	ES (M)	United States	United States, Brazil, China and Indonesia (main world producers)	No	Both. Yes	No
53	**Neves (2010)**	China Agricultural Economic Review	SS	Brazil	China and Brazil (implemen tation of Brazilian experience in China)	No	1st mainly. Yes	Yes
54	**Ng et al. (2011)**	Biofuels, Bioproducts and Biorefining	CC (M)	United States	United States	No	Both. Yes	Yes
55	**Nigam and Singh (2011)**	Progress in Energy and Combustion Science	EE	UK, Ireland	Not defined	No	Both. Yes	No
56	**Novo et al. (2010)**	Journal of Peasant Studies	SS	The Netherland s	Brazil	No	1st. No	Yes
57	**Paustian and Cole (1998)**	Climatic Change	AE (M)	United States, Germany	Not defined	No	Both. Yes	No
58	**Phalan (2009)**	Applied Energy	EE	UK	Asia	No	Both. Yes	No
59	**Pilgrim and Harvey (2010)**	Sociological Research Online	SS	UK	Europe	Yes. Yes	1st mainly. Yes	No
60	**Pimentel et al. (2008)**	Energies	EE (M)	United States	Not defined (emphasis on the US, used as an example several times)	No	Both. Yes	No

	Reference	Journal	Journal research area*	Authors' institutional affiliation (country)	Main geographic scope of analysis	Primary data offered? Original research article?	Ethanol generation addressed. Differentiates among ethanol generations regarding social aspects?	Addresses ethanol exclusively?
61	**Pimentel et al. (2009)**	Human Ecology	ES (M)	United States	Not defined (emphasis on the US, used as an example several times)	No	Both. Yes	No
62	**Randelli (2009)**	Regional Environmental Change	ES (M)	Italy	Not defined (emphasis on Europe and presentation of a brief case-study in Italy)	No	1st mainly. Yes	No
63	**Rinne et al. (2011)**	Biomass and Bioenergy	BS (M)	Finland	Not defined (Finland as case-study)	No. Yes	1st. No	Yes
64	**Rossi and Hinrichs (2011)**	Biomass and Bioenergy	BS (M)	United States	United States	Yes. Yes	2nd mainly. Yes	Yes
65	**Sathaye et al. (2009)**	Energy Efficiency	EE (M)	United States, France, Brazil, The Netherlands and South Africa	Not defined	No	1st. No	No
66	**Savvanidou et al. (2010)**	Energy Policy	SS	Greece	Greece	Yes. Yes	Both. No	No
67	**Sawyer (2008)**	Philosophical Transactions of the Royal Society	BS (M)	Brazil	Brazil	No	Both. Yes	No
68	**Schaffel and La Rovere (2010)**	Journal of Cleaner Production	EE (M)	Brazil	Brazil	No	1st mainly. No	No
69	**Schuurbiers et al. (2007)**	Biotechnology Journal	BS (M)	The Netherlands	Europe	Yes. Yes	Both. Yes	No
70	**Selfa (2010)**	Renewable Agriculture and Food Systems	AE (M)	United States	United States	Yes. Yes	1st mainly. No	Yes
71	**Selfa et al. (2011)**	Biomass and Bioenergy	BS (M)	United States	United States	Yes. Yes	1st mainly. Yes	Yes

	Reference	Journal	Journal research area*	Authors' institutional affiliation (country)	Main geographic scope of analysis	Primary data offered? Original research article?	Ethanol generation addressed. Differentiates among ethanol generations regarding social aspects?	Addresses ethanol exclusively?
72	**Sheehan (2009)**	Current Opinion in Biotechnology	BS	United States	Not defined (emphasis on United States)	No	1st mainly. No	No
73	**Smeets et al. (2008)**	Biomass and Bioenergy	BS (M)	The Netherlands, Brazil	Brazil	Yes. Yes	1st mainly. No	Yes
74	**Sobrino and Monroy (2009)**	Renewable and Sustainable Energy Reviews	EE (M)	Spain	Spain	No	Both. No	No
75	**Sobrino et al. (2010)**	Renewable and Sustainable Energy Reviews	EE (M)	Spain	Europe (emphasis on the Spanish case)	No	1st. No	No
76	**Solomon (2010)**	Annals of the New York Academy of Sciences	BS (M)	United States	Not defined (emphasis on the US, used as an example several times)	No	Both. Yes	No
77	**Sosovele (2010)**	Africa Spectrum	SS	Tanzania	Tanzania	No	1st. No	No
78	**Spiertz and Ewert (2009)**	NJAS Wageningen Journal of Life Sciences	ES (M)	The Netherlands, Germany	Not defined	No	Both. Yes	No
79	**Tan et al. (2010)**	Biotechnology Advances	BS (M)	People's Republic of China	China	No	1st mainly. Yes	No
80	**Timilsina and Shrestha (2011)**	Energy	EE (M)	United States	Not defined	No	Both. Yes	No
81	**Uriarte et al. (2009)**	Agriculture, Ecosystems and Environment	AE	United States	Brazil	No. Yes	1st. No	Yes
82	**van der Horst and Vermeylen (2011)**	Biomass and Bioenergy	BS (M)	UK	Not defined	No	1st mainly. Yes	No
83	**Vasudevan et al. (2005)**	Journal of Scientific & Industrial Research	EE (M)	India	Not defined	No	Both. No	No
84	**Walter et al. (2008)**	Biomass and Bioenergy	BS (M)	Brazil, UK	Not defined	No	Both. Yes	Yes

	Reference	Journal	Journal research area*	Authors' institutional affiliation (country)	Main geographic scope of analysis	Primary data offered? Original research article?	Ethanol generation addressed. Differentiates among ethanol generations regarding social aspects?	Addresses ethanol exclusively?
85	**Wetzstein (2010)**	Journal of Agricultural and Applied Economics	SS	United States	Not defined (emphasis on the US, used as an example several times)	No	Both. No	No
86	**Wilkinson and Herrera (2010)**	Journal of Peasant Studies	SS	Brazil	Brazil	No	Both. Yes	No
87	**Wright and Reid (2011)**	Biomass and Bioenergy	BS (M)	United States	United States	Yes. Yes	1st mainly. Yes	Yes
88	**Zanin et al. (2000)**	Applied Biochemistry and Biotechnology	BS	Brazil	Brazil	No	1st. No	Yes
89	**Zapata and Nieuwenhuis (2009)**	Business Strategy and the Environment	SS	UK	Brazil	Yes. Yes	1st. No	No
90	**Zinoviev et al. (2010)**	ChemSusChem	CC (M)	Italy, Germany, India, Argentina	Not defined	No	2nd. Yes	No

*Basado en la categorización de Glänzel y Schubert (2003).

AE = Agriculture & Environment
BS = Biological Sciences
CC = Chemistry
EE = Engineering
GS = Geosciences
SS = Social Sciences
(M) = Multidisciplinary

Apéndice C. Matriz final[31] de criterios e indicadores involucrados en la dimensión social de los impactos del etanol y recogidos en la literatura académica según las distintas fases del ciclo de vida del producto y grupos de actores sociales potencialmente relacionados con él.

Production of inputs
Workers
Not defined
Local community
1. Dependence on external inputs a. Cost and availability of inputs 2. Employment generation a. Number of jobs created
Society
Implementation of a regulatory framework for production of inputs
Consumer
Not defined
Value chain actors
1. Employment generation a. Number of jobs created
Environment
Not defined

[31] La matriz se presenta aquí en forma de tabla para que se pueda incluir en éste documento. La versión original se encuentra en formato de plantilla (Excel).

Feedstock production

Workers

1. Farmers subsidising
2. Stabilisation of crop prices for farmers
3. Farmers access to land
    a. Land acquisition
    b. Rent prices
    c. Sale or rental of land to producing companies
        i. Benefits and drawbacks to land owners
        ii. Strengthening of agricultural contracts
            1. Contract conditions (characteristics of the formal agreement with the company)
4. Farmers inclusion, especially small-scale impoverished ones, in the ethanol supply chain
    a. Guaranteed market for their crops
    b. Inclusion of independent small-scale farmers in the sector
    c. Basic business education to impoverished farmers
    d. Dislocation, marginalisation and impoverishment of farmers (small to medium-scale ones)
5. Farmers income generation (wages)
    a. Increase in farmers revenues
    b. Effects on the revenues of farmers from other sectors
6. Dependence of farmers on pesticides, herbicides and other inputs for feedstock production
7. Employment generation
    a. Number of jobs created
        i. Number of jobs created per tons of feedstock produced
        ii. Geographical origin of workers (in-migration monitoring)
        iii. Demand for more qualified workers
8. Workers income generation
    a. Comparison with minimum wage
    b. Analysis of capacity of paying for the cost of living in the region
    c. Concentration of income between producers and workers
9. Workers benefits
    a. Non-wages benefits such as housing, transport, food and other goods, dental, health, pharmaceutical care, loan etc.
10. Workers' unions political influence
11. Workers life quality
    a. Increment in literacy rate

Feedstock production

Changes in farmers perception and acceptance of ethanol and new ethanol technologies
 	
1. Willingness to grow ethanol feedstock
    a. Willingness to grow cellulosic feedstock despite the not yet stable and sustained demand of this feedstock for second-generation ethanol production
        i. Adaptation of farm technology and infrastructure (planning horizons)
        ii. Costs to return to conventional cropping systems
    b. Impoverished farmers' level of mistrust in industry and government
    c. Impoverished farmers' engagement in early stages of policy development
    d. Farmers perception of risk regarding ethanol economic tradeoffs (e.g. feedstock prices' volatility)

Changes in the type of farming
 	
1. Introduction of mechanisation
    a. Professional re-qualification of rural workers who use to harvest
    b. Reduction in demand for unskilled labour (exclusion of poorest workers)
    c. Reduction in the number of jobs
2. Reduction in the use of fuel and associated costs
3. Increment or reduction in the efficiency in the use/need of inputs
4. Diversification of agricultural activity
5. Comparison of wages between sectors (e.g. ethanol compared to classical plantations)
6. Capacity of adoption and availability of new farming techniques and technology (changes in farm management)
    a. Level of farm adaptation needed (level of integration with previous cropping systems)
    b. Level of small-scale farmers business knowledge
    c. Assistance services for farmers on the aspects of production from planting to harvesting
7. Access of small-scale farmers to agricultural inputs (e.g. water for irrigation, fertilisers, improved seeds)
    a. Cost of seeds

Feedstock production

Working conditions and job quality (workers rights)

1. Workers health and job safety
    a. Respiratory problems
        i. Open-air burning on cultivation fields
    b. Accidents and number of deaths
        i. Protective equipment
2. Workload (Labour intensity)
3. Job stability
    a. Seasonal or formal and annual
4. Integration (hiring) of migrant workers
5. Infrastructural and other working conditions and benefits
    a. Clean water, restrooms, food storage facilities etc.
    b. Transportation of workers to rural work areas
    c. Meals
    d. Healthcare
6. Forced labour (slavery)
7. Child labour
    a. Attention to the ILO convention guidelines
8. Work legality
    a. Number of illegal workers
    b. Existence and conditions of work contract
    c. Elimination of intermediaries through direct hiring
    d. Compliance with standards of the ILO convention
9. Compliance with national labour laws
    a. How solid is the legislation?
    b. Further law enforcement is needed?

Local community

Feedstock production

1. Public acceptance of the project
    a. Public resentment towards modern agriculture (nostalgic attitude)
    b. Public acceptance of biotechnology (use of GMOs)
    c. Public acceptance of changes in infrastructure
    d. Public protest related to the project implementation
2. Public participation on planning and design
3. Public perception regarding the project or technology
    a. Public expectations and aspirations
        i. Comparison with current or previous reality (improved image of agriculture, expectations on life quality improvement etc.)
        ii. Project compliance with local needs
        iii. Perception of gains by indigenous people (preservation of ecological services may be regarded as more valuable than compensation payments, for example)
4. Capacity building

Food security

1. Food prices
    a. Changes in food prices at the local level
        i. Changes in the % of family budget spent on food
    b. Changes in food prices in the international market
2. Food distribution
    a. Access to food
3. Hunger and malnutrition
    a. Number of undernourished people
4. Competition with food crops
    a. Use of edible crops as ethanol feedstock
    b. Competition with arable land and natural resources
    c. Destruction of natural habitat and displacement of customary land uses (risk of diminishing forest resources for the livelihood of ethnic communities)

Feedstock production

Social cohesion and stability

1. Demographic changes
    a. Rural-urban migration
    b. Overpopulation
2. Changes in social relations
    a. Solidarity
    b. Sufficient and accessible nutritious food
    c. Sufficient and equitable supply of ecosystem services
3. Increment of social exclusion
    a. Increment of violent crime by a wider gap between rich and poor
4. Relocation of local community (resettlement)

Community sovereignty

1. Protection of the interests of locals and small landowners
    a. Proportion of large producers / small producers (concentration of rural properties)
    b. Percentage of land belonging to local structures (whom owns the land)
    c. Coexistence of high-tech plantation with family agriculture integration models
    d. Access of ethnic groups to used of land and forest resources
2. Effects on culture and tradition
    a. Changes in aesthetics and cultural amenities
        i. Interference in natural landscapes with significant value for cultural heritage
        ii. Interference in the historical, archaeological and palaeontological heritage
3. Energy security at the local level
    a. Access of village households to ethanol and other energy services

Health and safety

1. Overall human health depreciation
    a. DALY (Disability Adjusted Life Years) and qualitative estimation
2. Health burdens produced by on-farm wastes and residues
    a. Pollution of waterways by nitrate, atrazine etc. (generally linked to large feedstock monocultures)
3. Air pollution due to harvest burning practices
4. Health improvements
5. Preservation of quality services of food and water
6. Increase of noise levels
7. Increase of odour levels
8. Risk of car accidents due to smoke from harvest burning
9. Risk of reduction in the access to land and water by local population (e.g. water shortages)

Feedstock production

Rural development and empowerment of rural communities

1. Engagement of local people as producers and processor of ethanol
    a. Entrepreneurship and business run by local people
    b. Development of support industries
2. Access to inputs
    a. Access to machinery and industrial equipment
    b. Access to modern technologies (more efficient and reliable ones)
    c. Access to affordable (cheap) energy
3. Access to cheaper locally manufactured ethanol by local residents
4. Access to efficient transportation systems
5. Generation of valuable co-products for replacement of fertilisers, herbicides etc.
6. Use of local bioenergy crops
7. Organisation of small producers cooperatives
    a. Level of negotiation power
    b. Support from industry
    c. Diffusion of technical and basic business knowledge
8. Inclusion of remote rural areas as production sites
9. Presence of companies
    a. Technology transfer
    b. Local people training
10. Rural infrastructure and availability of services
    a. Improvement of irrigation systems
    b. Electrification of rural areas
    c. New energy services to rural people
    d. Improvement of domestic energy infrastructure
    e. Improvement of infrastructure for ethanol distribution at the local level
    f. Housing for migrants (e.g. those that will fill new job placements)
    g. Revitalisation of rural areas
    h. Attraction of research institutes and universities
    i. Company investments in health services
11. Employment generation
    a. Number of jobs created
        i. Number of jobs/ ton of feedstock
        ii. Hiring of local workers
12. Corporate social responsibility and benefits
    a. Support of schools, nursery centres, day care units etc.
    b. Company transparency and communication
        i. Access to knowledge and information
        ii. Combination of traditional and new knowledge
        iii. Improvement in educational levels

Feedstock production

Land governance

1. Land tenure and property rights
    a. Status of the land acquired or rented by the company or state (i.e. formal or informal land tenure)
    b. Concentration of land tenure by few large owners
    c. Occurrence of land grab
    d. Conflict or struggles over land (land dispute)
        i. Illegal acquisitions
        ii. Land seizure (involuntary) from smallholder farmers by large companies
        iii. Killing, expropriation of peasant
        iv. Emergence of organised social movements
2. Differences on the perception of land "status" used for feedstock production ("marginal land" and its variations)
    a. Shift of feedstock production towards "marginal" lands occupied by natives
3. Regulatory framework
    a. Definition of the conditions for the suitability of the land so it can be used for feedstock production

Gender issues

1. Empowerment of women
    a. Reduction in workload in the field
    b. Access to and productive control of the land (including land ownership)
    c. Access to resources and input (food, water, fertilisers, pesticides)
    d. Engagement in decision-making
    e. Employment opportunities
    f. Decent working conditions
    g. Access to formal credit schemes

Society

Feedstock production

1. Decentralisation versus centralisation of production
    a. Ocurrence of regional inequalities within the country
        i. Effects on employment
            1. Comparison of workers wages from different regions
        ii. Effects on migration (in direction to or away from harvest areas)
            1. Overpopulation
            2. Increase in the number of urban slum dwellers
2. Contribution to national employment
    a. Increment in the national number of jobs attributed to the ethanol sector in comparison to other sectors
    b. Direct and indirect employment
    c. Loss of jobs because of mechanisation
3. Public participation on planning, design and policies
4. Public acceptance of projects, plans or programs
    a. Public acceptance of imported feedstock
5. Public perception of the project or technology
    a. Knowledge level surrounding ethanol as a biofuel
    b. Perception of pros and cons
    c. Source of information

Food security

1. Effects of ethanol production on food prices
2. Land use change
    a. Quality of soil occupied by energy crops (potential for food production)
    b. Land distribution and demand for feedstock production
        i. Increment of land areas because of mechanisation (rows must be wide enough for tractors)
        ii. Replacement of food crops plantation or livestock production by energy crops
        iii. Increment of yields instead of expanding plantation areas (e.g. through genetic improvements)
3. Use of agricultural wastes
4. Use of the excess grain supply

Feedstock production

Governance of biofuels sustainability (institutional changes)

1. Changes on agricultural policies
2. Creation of social inclusion policies alongside ethanol programs (e.g. laws to protect social actors involved in the ethanol supply chain, like workers, for example)
3. Verification and monitoring activities
4. Certification schemes (social sustainability criteria)
    a. Access of small-scale producers to schemes (costs)
    b. Schemes robustness regarding social aspects appraisal
5. Regulatory framework to drive ethanol development strategy
6. Development of new forms and scales of governance of ethanol
    a. External (international) governance through, for example, mandatory directives or the effects in the South from biofuel consumption in the North
    b. NGOs as strong political actors

Consumer

Not defined

Value chain actors

1. Employment generation
    a. Number of jobs created

Environment

Land use change (competition of ethanol feedstock for land and resources)

1. Biodiversity (effects on biological pest control, loss of traditional plant species etc.)
    a. Implementation of large-scale monocultures
    b. Introduction of invasive plant species (e.g. resistant cellulosic feedstock)
    c. Deforestation due to displacement of traditional cultivation or communities
    d. Human occupation of conversion areas
    e. Implementation of best management practices (e.g. agroecological practices like intercropping, polyculture)
2. Protection of soil
    a. Implementation of best management practices (e.g. agroecological practices like conservative tillage, crop rotation)

Feedstock production

Water security

1. Water use (quantity) for irrigation and other activities (water resources diversion from other community needs)
    a. Feedstock needs in terms of irrigation
        i. Comparison with past or current reality (will ethanol feedstock need less water?)
        ii. m3/ton of feedstock
    b. Water re-use practices and recycling wastewater
2. Water quality
    a. Use of untreated liquid waste in the fields
    b. Nutrient runoff from the use of agrochemicals
        i. Comparison with current reality (will ethanol feedstock need less chemical inputs?)
3. Equitable use of water resources
    a. Water availability
4. Respect of formal or customary water rights

Transport
Workers
Adequate channels for transport communication between agricultural and processing phase

Local community

1. Public participation on planning and design
2. Social acceptance of infrastructure change and expansion
3. Changes on traffic flows and congestion patterns
    a. Feedstock bulkiness
    b. Deterioration of local roads due to heavy trucks traffic
    c. Accidents due to increased truck traffic (e.g. children's safety)
4. Employment generation
    a. Demand for more qualified workers
    b. Demand for unskilled workers
    c. Number of jobs created
5. Improvement of rural infrastructure
    a. Improvement of roads
6. Energy security
    a. Improvement of infrastructure for ethanol distribution at the local level

Society

1. Proximity of feedstock plantation and mills/refineries
2. Energy security
    a. Proximity of power plant and cultivation field with major regional or national transportation corridors
    b. Improvement of infrastructure for cross-country ethanol distribution (national level)
3. Pressure on the road system due to increase in the number of vehicles
4. Health and safety
    a. Increment on the level of accidents due to increased truck traffic
    b. Transportation hazards (flammability and leakages)
5. Governance
    a. Regulatory framework for ethanol and feedstock transportation

Value chain actors
Not defined
Environment
Not defined

Producing plant

Workers

1. Working conditions
    a. Compliance with ILO convention
2. Health and safety
    a. Risks of explosion and fire by ethanol storage
3. Employment generation
    a. Skilled workers
        i. Demand for more qualified workers
    b. Unskilled workers
    c. Integration of migrant workers
    d. Number of jobs created
4. Workers income
5. Adoption of social responsibility principles
    a. Training of workers lacking formal education
    b. Workers benefits
        i. Company's investment in education and health for workers' children

Local community

1. Adoption of social responsibility principles
    a. Training local people
2. Health and safety
    a. Control of spills and prevention of other accidents
    b. Potential impact of spills and other accidents (risk management)
    c. Noticeable odours from the ethanol plant
3. Public participation on planning and design
4. Public perception of risks (e.g. risk of shutting down an ethanol plant after investments and taxes paid)
5. Public acceptance of biorefineries location
6. Social benefits or public goods such as long term lower cost energy derived from hosting an ethanol plant
7. Empowerment of women
    a. Employment opportunities
    b. Working conditions

Producing plant

Rural development

1. Empowerment of rural communities
    a. Investments in human capital
    b. Generation of valuable co-products and by-products (e.g. bagasse as energy source, corn meal as animal feed, treated vinasse as fertiliser)
    c. Access of locals to cheap electricity
    d. Inclusion of remote rural areas as power plant hosting sites
2. Access to new technologies (availability and affordability)
    a. Access to machinery and industrial equipment
3. Locally owned and run facilities
4. Corporate social responsibility and benefits
    a. Support of schools, nursery centres, day care units etc.
    b. Company transparency and communication
        i. Access to knowledge and information
        ii. Combination of traditional and new knowledge
        iii. Improvement in educational levels

Society

1. Governance
    a. Regulatory framework
    b. Certification schemes (social sustainability standards)

Consumer

Not defined

Value chain actors

Not defined

Environment

1. Waste management
2. Control of air pollution
3. Water security
    a. Water demand for processing
        i. Efficiency of water use (volume water/volume fuel)
        ii. Quantity of water used (m3/L of ethanol produced)
    b. Treatment of wastewater
    c. Control of liquid effluents

Final use

Workers

Not defined

Local community

1. Fuel access for local consumption
    a. Access to cheaper ethanol by local residents

Society

1. Food security
    a. Increase in the demand for grain-made ethanol due to a increased number of vehicles or vehicles miles running on ethanol
2. Consumption inequalities
    a. Potential ethanol users and income classes
3. Health and safety
    a. Fire safety in urban areas
4. Public acceptance of imported ethanol
5. Use on public transport
6. Employment generation
7. Reduction in the use of non-renewable energy at the national level (energy security)

Consumer

1. Reliability of domestic price of ethanol compared with the price of fossil fuels
2. Changes in consumption patterns (ethical consumption)
    a. Miles traveled
    b. Pressure from consumers on social sustainability guarantees of the product
    c. Increasing of consumption of the cheaper option
3. Changes in the level of consumer choice
4. Public acceptance of ethanol (willingness to use ethanol, perception of pros and cons)
    a. Access to flex-fuel vehicles (FFVs)
        i. Compatibility of existing fleets with ethanol or ethanol-gasoline blended (depends on the vehicle technology, age)
    b. Consumer perception on security of supply
        i. Stability of ethanol prices
        ii. FFVs price
        iii. Risk perception of shortage of fuel
        iv. Convenience of refueling (adaptation of filling stations)
        v. Ethanol price (willingness to pay more at the pump for ethanol)

Value chain actors
Not defined

Environment
Improvement or reduction in urban air quality (metropolitan areas) from vehicle exhausts using ethanol

Cross-cutting issues (apply through the whole lifecycle)
Quality of life
1. Poverty alleviation a. Increase in the income per capita 2. Equity on wealth distribution 3. Equity on rights a. Equal treatment, equal participation
Others
Job creation in R&D

4 Artículo III: “Beyond commonplace biofuels: social aspects of ethanol”

Referencia

Ribeiro, B. E. (2013). Beyond commonplace biofuels: social aspects of ethanol. *Energy Policy, 57*, 355-362.

Abstract

Biofuels policies and projects may lead to environmental, economic and social impacts. A number of studies point out the need to deliver comprehensive sustainability assessments regarding biofuels, with some presenting analytical frameworks that claim to be exhaustive. However, what is often found in the literature is an overexploitation of environmental and economic concerns, by contrast to a limited appraisal of the social aspects of biofuels. Building on a systematic review of the peer-reviewed literature, this paper discusses the social constraints and strengths of ethanol, with regard to the product’s lifecycle stages and the social actors involved. Its objective is to contribute to the development of social frameworks to be used in assessing the impact of ethanol. Main findings indicatethat ethanol developments can increase the levels of social vulnerability, although there is little evidence in the literature regarding the positive and negative social impacts of 1^{st}-generation ethanol and potential impacts of cellulosic ethanol. Further work is needed on the formulation of social criteria and indicators for a comprehensive sustainability assessment of this biofuel. Policy makers need to internalise the social dimension of ethanol in decision-making to prevent public opposition and irreversible social costs in the future.

4.1 Resumen de la investigación

Varios estudios indican la necesidad de que se realicen evaluaciones de la sostenibilidad de los biocombustibles de una manera más integral, articulando sus diferentes dimensiones económica, medioambiental y social. Sin embargo, lo que se encuentra en la literatura especializada disponible es una predominancia de las dos primeras – económica y medioambiental – en comparación con la evaluación de los aspectos sociales de estos desarrollos. Esta tendencia a la subvaloración de la dimensión social frente a la económica y la ambiental de los desarrollos científico-tecnológicos no es exclusiva de este tópico en particular, sino que se verifica en la práctica en los procesos de evaluación en general (Burdge 2002). En el caso de los biocombustibles, sus políticas de apoyo y las regulaciones correspondientes no son informadas por una evaluación robusta de sus impactos sociales. Estos últimos se relacionan con las distintas fases del ciclo de vida del producto, como la producción de insumos, materia prima, transporte, conversión y uso. Igualmente, involucran y afectan positiva y negativamente a distintos actores sociales.

Este artículo identifica y analiza de manera sistemática los impactos sociales negativos y positivos del etanol utilizado como biocombustible desde la perspectiva de las distintas fases de su ciclo de vida y de los actores involucrados. Sus principales objetivos son comprehender de manera más profundizada la dimensión social de los impactos de este biocombustible, presentando y discutiendo los elementos que forman parte de su sostenibilidad social, y contribuir al desarrollo de marcos de evaluación de estos impactos. Para este estudio se ha utilizado un método de revisión sistemática de la literatura para la búsqueda, identificación y selección de trabajos relevantes basada en Moher (2009), lo cual se detalla en el Artículo II de la presente tesis. El análisis de contenido de la literatura seleccionada ha sido guiado por la construcción de una matriz social inspirada en las matrices éticas desarrolladas por Kaiser y Forsberg (2001) y Mepham et al. (2006), la cual también se presenta en el mismo Artículo II.

Los principales resultados del estudio se señalan a continuación:

- Las implicaciones sociales de la fase de producción de insumos como fertilizantes, pesticidas, combustibles fósiles etc. utilizados en la producción de materia prima para el etanol se refieren sobre todo a los niveles de dependencia y acceso de productores y comunidades locales a estos insumos. Comunidades empobrecidas pueden encontrar dificultades en obtenerlos debido a su alto coste o pueden volverse dependientes de suministro externo. Por otra parte, el desarrollo de cadenas de suministro como la del etanol contribuye de manera general a la generación de empleos en distintos sectores que sirven de soporte a la producción de materia prima.

- En comparación con las demás, la fase agrícola de producción de materia prima para el etanol utilizado como biocombustible es ampliamente discutida en los estudios analizados. Los cambios sociales involucrados en esta fase se relacionan, por ejemplo, con los cambios en el uso de la tierra y las escalas de producción. Se considera que los impactos positivos en comunidades locales de la producción de materia prima para el etanol derivan sobre todo de proyectos de pequeña escala o proyectos que incluyen planes de mejora infraestructural en las comunidades y generación de empleo en el campo. Entre otros, los impactos negativos se relacionan con problemas en torno a la tenencia de la tierra en determinadas regiones, potencial degradación ambiental, flujos migratorios descontrolados y contaminación del aire y del agua. El tema de la seguridad alimentaria en el contexto de la sustitución de cultivos alimentarios por cultivos energéticos o del desvío de alimentos hacia la cadena de producción de biocombustibles es uno de los más explorados en esta fase del ciclo de vida del etanol.

- Los impactos relacionados con la fase de transporte de materia prima y producto final en la cadena de producción del etanol son analizados en menor medida en la literatura que la fase de producción de materia prima. Los cambios en el tráfico, la deterioración de carreteras y el incremento del riesgo de explosiones debido a las características del etanol son indicados como impactos negativos de esta fase. Por otro lado, la producción de etanol también puede conllevar una mejora en las infraestructuras para su transporte, fruto de la inversión directa de las compañías que lo producen. En cualquier caso, las características específicas de cada materia prima y las distancias entre plantaciones, refinerías y centros de distribución determinan la gravedad de estos impactos.

- En la fase de conversión en la planta productora, se transforma la materia prima en etanol y se generan varios co-productos y desechos en el proceso. Los principios de responsabilidad social corporativa juegan un rol importante en los impactos positivos y negativos que pueden derivar de estos procesos, tanto a nivel de los beneficios a la comunidad local en la cual se instala la planta productora, como a nivel de sus efectos en los servicios ecosistémicos locales y regionales.

- Respecto a la fase final de su ciclo de vida, una de las ventajas del etanol como alternativa al uso de combustibles fósiles en el sector de transporte es que su distribución y uso no implican cambios drásticos en la actual infraestructura de dicho sector. Su utilización en el transporte público puede contribuir a la seguridad energética de ciertas regiones y países debido a una menor dependencia de la importación de crudo. Asimismo, hay evidencia de que la combustión de etanol libera menos contaminantes en el aire que la gasolina, aunque dicha evidencia es contestada por el argumento de que la combustión de etanol puede liberar otras partículas contaminantes y que una mayor cantidad de etanol que de gasolina es necesaria para viajar una misma distancia debido al menor contenido energético del primero. Otros aspectos sociales del etanol que se deben tener en cuenta a la hora de evaluar su fase de uso final incluyen el coste y opciones de vehículos tipo *flex-fuel* y la disponibilidad de etanol en estaciones de servicio.

- No todos los aspectos sociales del etanol utilizado como biocombustible se aplican exclusivamente a una determinada fase del ciclo de vida del producto, sino que son considerados como transversales. Estos se refieren al tema de la seguridad energética, conformidad con regulaciones, generación de empleo, participación pública en la toma de decisiones relacionadas con políticas y proyectos, y aceptación pública de los biocombustibles.

Lo que se indica en el primer estudio de carácter exploratorio (véase Articulo I), se verifica a través de este estudio sistemático. En la literatura especializada hay una carencia de evaluaciones de los impactos sociales del etanol. Además, se comprueba que los análisis disponibles suelen ser demasiado genéricos, no discriminando los distintos tipos de biocombustibles. Los principales resultados de esta investigación indican que proyectos relacionados con la producción del etanol para su utilización como biocombustible pueden contribuir hacia un incremento de los niveles de vulnerabilidad social, especialmente de aquellos actores que ya se encuentran en contextos más vulnerables, como poblaciones rurales empobrecidas. Es necesario que se formulen criterios e indicadores sociales para un análisis integrado de la sostenibilidad del etanol, así como la inclusión de sus aspectos sociales en las políticas y regulaciones relacionadas con este biocombustible. El desarrollo de marcos de evaluación debe ser informado por un esfuerzo conjunto entre científicos, la industria, tomadores de decisión y el público. El aspecto descentralizado de los impactos del etanol y sus implicaciones globales indican que espectros más amplios de la sociedad pueden verse afectados por sus impactos en temas como, por ejemplo, el de la seguridad alimentaria.

4.2 Introduction

Paraphrasing Rabel Burdge, who characterised social impact assessment as the orphan of assessment processes (see Burdge 2002), the social dimension of the sustainability of biofuels could be considered as the abandoned child of sustainability appraisals for this energy alternative. Studies thus far have instead tended to give priority to in-depth analysis of economic and environmental issues (see German et al. 2011; Lehtonen 2011; Ribeiro 2012; Sheehan 2009; Uriarte et al. 2009). Although this tendency certainly does not contribute to the development of a sound governance of bioenergy, investment in biofuel programs and projects is on the increase, driven primarily by worldwide energy policy mandates (see OECD/FAO 2011). Among biofuels, ethanol is the most produced and commercialised today, obtained mostly from the fermentation of glucose contained in starch and sugar crops such as corn, wheat, sugarcane, and sugar beet. Next-generation or second-generation ethanol, made from cellulosic feedstock such as short-rotation forests, prairie grasses or agricultural and municipal wastes, is thought to be a potential substitute for first-generation ethanol in the coming decades (Naik et al. 2010; Sims et al. 2008).

While “a lifecycle refers to the life span of a product, from resource extraction, to manufacture, use and final disposal” (Nieuwlaar 2004), ethanol’s lifecycle ranges from the phase of raw material or feedstock production and collection to the product’s final use in internal combustion engines. As a complex technological system that interacts with the societal setting (see Russell et al. 2010) – i.e. a socio-technical system – processes related to ethanol’s lifecycle can engender, and be modified by, processes of social change involving various actors, such as farmers, employees, consumers and members of rural communities. This article aims to contribute to the understanding of the social aspects of ethanol, and in so doing, encourage the development of social sustainability frameworks for use in impact assessments. To this end, it draws on a systematic review of the peer-reviewed literature, highlighting and discussing the social trade-offs related to ethanol’s socio-technical system, paying particular attention to the stages of the lifecycle and to the actors involved.

4.3 Systematic search for articles

A systematic review of the available peer-reviewed literature was undertaken. Moher et al. (2009) define systematic reviews as “a review of a clearly formulated question that uses systematic and explicit methods to identify, select and critically appraise relevant research, and to collect and analyze data from the studies that are included in the review” (Moher et al. 2009). Systematic reviews are very popular among medical studies (e.g. Glinianaia et al. 2004; Lundh et al. 2009) and should be given greater significance on the field of social science research.

Our research question was what social aspects of ethanol as a biofuel are identified among the peer-reviewed literature on the subject? A comprehensive list of search terms was defined accordingly. The search strategy was partly based on the guidelines of the Cochrane review (Higgins and Green 2011) that consists of a review of studies that meet pre-specified criteria for inclusion, i.e. a systematic review aiming to identify all relevant studies that fit into the chosen issue domain (Budimir et al. 2011). Two inclusion criteria were defined: a) articles from peer-reviewed journals with their full-text in the English language with no time period limit and b) articles addressing or mentioning at least one social impact of ethanol used as a biofuel (following the concept of social impact presented in the next section of this article). The Web of Science, Science Direct and Google Scholar were used as databases for articles search. In total, 90 papers were selected for final qualitative analysis (see Appendix for a summary of selected studies). Meta-analysis (statistical methods for quantitative appraisal) was not performed due to the dominating qualitative approach of our study.

4.4 Social sustainability of ethanol as a socio-technical system

Understanding the social sustainability of ethanol involves tasks of both a conceptual and operational nature (for a detailed discussion of the definition of social sustainability see Boström 2012). One must define, on the one hand, the various aspects which have a bearing on the social sustainability of ethanol’s socio-technical system, i.e. social impacts, and on the other, how those elements are to be operationalised so as to reveal the variables, i.e. criteria and indicators, needed to assess them. The first task in conceptual framing, which is the object of this article, involves considering the potential positive and negative social impacts of planned interventions related to ethanol as a biofuel (see Vanclay 2003b). In our study, we understand the social impact of socio-technical systems as the influence of those systems in the generation of social change processes and the associated human responses to those changes - if identifiable, which may be positive or negative. This vision is slightly different from the one defended by some social impact assessment scholars, for which social change processes and social impacts tend to be seen as separate components, being social impact equal to human response to change (see van Schooten et al. 2003; Vanclay 2002a). Processes of social change can relate to any phase of the development of projects, policies and programs, starting from their planning and continuing throughout the product's lifecycle. The ultimate consequence of a social impact is the experience felt by the person (the human response), e.g. fear or happiness, death or health improvements etc. (see van Schooten et al. 2003). Moreover, these processes can be indirectly related to changes at the economic, institutional and environmental levels. The sphere of the 'social issues' is thus not independent of the one of market, political and biophysical issues.

Evaluating the social impacts of planned interventions is not a straightforward exercise, and given their strongly normative nature, it is one which necessarily involves considering the views of a number of actors concerning what is or is not socially desirable (see Russell et al. 2010). The idea of "desirability" of technological development is linked to that of social sustainability. Due to its politicised nature, the discussion is not limited solely to technical appraisals, and involves public debate. Besides, more than assessing the immediate advantages of devising and implementing a system such as ethanol as a biofuel – e.g. potential reductions in greenhouse gases (GHG) emissions, improvement of energy security at national level etc. – one should reflect upon the socially desired, wider-reaching processes of social change that will shape a new development model or contribute to the upkeep of a current one (see Quintanilla 2005). Thus, in order to ensure the social sustainability of a socio-technical system like ethanol as a biofuel, one must a) avoid damaging what is socially shared as being desirable and b) improve social conditions where current ones are viewed as not being desirable, at every stage from the planning to the implementation of the system. Balancing desirability sometimes entails a conflict of interest between groups with different social goals, which gives rise to a situation of political disagreement. However, decision-making in political dispute is not constrained to the realm of opinions, but must also involve objective appraisal of social outcomes. In this sense, sound social contextualization of planned interventions, by identifying potential social changes and the interests of the various actors involved, is essential in promoting more equitable debates on social and technological futures. This is partially done here, by way of a top-down approach through the analysis of the peer-reviewed literature, and the framework will hopefully be strengthened later by bottom-up input, with public and expert consultation.

4.5 Contextualizing the social aspects of ethanol

As previously stated, this work is a first step toward social framing of ethanol, so it is limited by a finite body of literature, consisting of selected peer-reviewed articles. Our identification and evaluation of social change processes and potential social impacts related to ethanol reflect the opinions or findings presented in the papers under discussion. Later sections summarise the social aspects of ethanol and actors involved from a lifecycle perspective. For the sake of objectivity and due to space constraints, only the main variables are addressed.

4.5.1 Production of inputs

This stage of ethanol's lifecycle refers to the production of fertilisers, herbicides, pesticides, equipment, fuels etc. that are used in the ethanol production chain and is the least explored among the existing studies. Changes at the local community level involve dependence on external inputs such as petroleum-based fertilisers, pesticides and fuels (Amigun et al. 2011) for feedstock production and transport of raw material and ethanol, for example. If inputs are to be purchased from companies for large-scale ethanol production, high costs could diminish their availability for poorer communities and increase farmers' dependence on external supply. On the other hand, cross-cutting issues such as employment generation (Solomon 2010; Vasudevan et al. 2005) could apply to this stage, with ramifications for actors involved in the supply chain, such as fuel distributors or retailers.

4.5.2 Feedstock production

Unlike the production of inputs, the agricultural or feedstock production stage of ethanol is by far the most fully discussed. The ethical and social trade-offs of biofuels are thought to be mostly related to land use (see Jordaan 2007), i.e. changes in terms of land use resulting from the implementation of new biofuel projects or switching from traditional cropping to biofuel feedstock production. At the local community level, ethanol projects could contribute to the empowerment of women – especially in developing countries where they are responsible for securing energy for their households (Amigun et al. 2011). However, this could be limited to small-scale, locally based production (Malik et al. 2009), since large-scale monocultures for export entail a risk of concentration of wealth, and uncertainties surrounding social welfare (Uriarte et al. 2009). Furthermore, any negative impacts on wellbeing are likely to affect men and women disproportionally, the latter being the more affected group (Gasparatos et al. 2011). Overall empowerment of rural communities would come from entrepreneurship and business run by local people (as producers and processors of ethanol) (Hall and Matos 2010). To accomplish this, access to machinery and cheap energy is needed. Ethanol projects that invest locally in education, sport and health could also benefit communities (Neves 2010), and the organisation of small producers in locally-run cooperatives could guarantee a larger share of these benefits (Milder et al. 2008). Profound changes in local rural infrastructure can result from ethanol production and distribution, increasing the availability of services to the community. While social benefits may arise from, e.g., the revitalisation of rural areas (Bush 2007; Koizumi 2011), the assessment must also look at possible increases in the vulnerability of infrastructural systems, relating to, for example, changes in traffic flow or water distribution in the long term (Ng and Yanfeng 2011). Besides, project planning should include remote areas as biofuel production sites, in order to contribute to the alleviation of poverty in those places (Malik et al. 2009).

The choice of production sites poses questions of land governance, related to land tenure conflicts (Gasparatos et al. 2011; Sosovele 2010) – the result of conflicting valuation of the land between investors, governments and local communities. This phenomenon involves the misinterpretation of “marginal” or “degraded lands” – a qualifier that is often used to justify the choice of feedstock production sites. These lands are often perceived as unused, unsuitable for agriculture, unprofitable (see Bailis and Baka 2011; Davis et al. 2011) or contaminated lands (see Hattori and Morita 2010). However, lands which are arguably marginal may be particularly valuable for vulnerable and marginalised populations, serving as support for livelihoods, as well as harbouring important cultural values (German et al. 2011; Van der Horst and Vermeylen 2011). Forest clearing for biofuel cropping, and the resultant deforestation, destroys natural heritage and reduces the environmental services and goods that forests might provide to local populations (Gao et al. 2011). Communities’ sovereignty can be preserved by protecting the interests of locals and small landowners by, for instance, preventing concentration of land – i.e. power – in the rural setting (Schaffel and La Rovere 2010); conservation of aesthetics and cultural, archaeological and paleontological heritage (Dale et al. 2010; Fischer et al. 2010; Gallardo and Bond 2011); guaranteeing ethnic groups’ access to land and forest resources, which could be threatened by environmental degradation due to expansion of biofuel feedstock (Banerjee 2011); and fostering energy security at the local level by offering village households access to cheaper fuel (Van der Horst and Vermeylen 2011). On the other hand, an increase in the levels of rural-to-urban migration, as seen with ethanol development in Brazil (see Lehtonen 2011), and the risk of overpopulation in producing areas (Gallardo and Bond 2011), can have a profound impact on the social cohesion and stability of communities. Concentration of ethanol production could also lead to the emergence of regional inequalities within countries, with implications for employment and migration (Hall et al. 2009).

Changes in the type of farming (e.g. from traditional cropping to ethanol feedstock production) could affect farmers and workers in several ways. For instance, the introduction of mechanisation in sugarcane plantations reduces the number of jobs and causes exclusion of a high number of poor, unskilled workers, although it may increase demand for skilled workers (Wilkinson and Herrera 2010). Professional re-qualification of unskilled workers should help mitigate this problem (Schaffel and La Rovere 2010). Farmers would also need to adapt farm management when adopting new technologies (Malik et al. 2009), and evaluation of farmers’ acceptance of or willingness to change (Selfa et al. 2011) is a crucial issue, as is the necessity of expert assistance for transition (Rossi and Hinrichs 2011). If farmers are willing to produce ethanol feedstock, we have to guarantee their inclusion in the supply chain – especially for impoverished farmers (Hall and Matos 2010) and strengthen agricultural contracts between farmers and companies (Novo et al. 2010) to avoid social exclusion of this vulnerable group.

As regards issues of health and safety (H&S) and working conditions, workers can suffer from respiratory problems if sugarcane is burnt before harvesting (Corbiere-Nicollier et al. 2011) and other problems associated with high workloads (Smeets et al. 2008). Pollution of waterways by farm wastes and residues can cause health afflictions among locals (Chavez et al. 2010) and air pollution due to harvest burning practices may affect not only workers in the field but also nearby communities – mostly children and elderly people – because of the aerosol particles and carcinogenic products released (Martinelli et al. 2011; Uriarte et al. 2009). Others point to the reduction in the levels of emissions of some types of air pollutants in metropolitan areas due to ethanol consumption (Goldemberg and Guardabassi 2009), although this is a controversial issue since there is evidence of an increase in the emissions of other pollutants like nitrous oxide (Pimentelet al. 2008). Increased noise and noticeable odour levels can also affect local dwellers near feedstock production areas in the case of sugarcane ethanol (Gallardo and Bond 2011). Job stability and legality are also important issues, since seasonal or informal employment can increase workers' vulnerability (Gallardo and Bond 2011). To mitigate other issues such as forced or child labour associated with feedstock harvesting, as identified, e.g., in the case of sugarcane in Brazil (Smeets et al. 2008), and guarantee decent working conditions, there must be compliance with national legislation and with international standards (Janssen and Rutz 2011).

A point closely related to the land use issues discussed above, which comes under the broad problem of international security (see Naylor 2011), is that the food security of locals and society overall can be threatened – either directly by competition of food crops with ethanol feedstock (i.e. through the diversion of food crops for ethanol production) or indirectly through competition for limited resources such as land, water, fertiliser and fossil fuels (Bell et al. 2011; Hattori and Morita 2010; Koning et al. 2008; Paustian and Cole 1998; Phalan 2009). The social burdens of food/biofuel competition are mostly felt by poor people, who are more vulnerable to rises in staple food prices since they spend a larger share of their incomes on food (Aerni 2008; Timilsina and Shrestha 2011). The fluctuation of food prices in the international market can threaten food security at a broader societal level, irrespective of the place of feedstock production (Naylor et al. 2007). The use of agricultural and forest wastes and non-edible energy crops for production of cellulosic ethanol could be one measure to mitigate the food/fuel competition (Koh and Ghazoul 2008; Nigam and Singh 2011). In China, the third-largest ethanol producer in the world, availability of land for feedstock production is one of the main barriers to the expansion of ethanol, and given that food security is a major concern for the government, production of ethanol from non-food crops and cellulosic material have been being encouraged in the past few years (Tan et al. 2010). However, the overall sustainability of this option is a matter of some debate, since the large-scale use of agricultural residues for ethanol production could increase feed/biofuel competition (Gomiero et al. 2010). In addition, differences in terms of resources and specific socioeconomic contexts that influence crop yields, land availability and labour costs in feedstock-producing regions can also affect food security levels, which are likely to vary worldwide (Spiertz and Ewert 2009).

Changes in the biophysical setting can affect the availability and quality of environmental products and services, i.e. ecosystem functions, having negative impacts on assets that are valuable for society, and engendering indirect social impacts (Slootweg et al. 2003). In terms of the feedstock production stage, the shift from traditional agriculture to ethanol feedstock cropping, and the resultant diversion of land and resources, can have a damaging effect on biodiversity. Homogenisation of agricultural landscapes by large-scale monocultures has a negative impact on natural pest control, increasing the need for pesticides (Dale et al. 2010; Phalan 2009). Moreover, feedstocks with invasive behaviour, i.e. those that are more tolerant to biophysical constraints, can destroy traditional plant species with high cultural value (Gasparatos et al. 2011). The implementation of agro-ecological practices such as intercropping and polyculture would increase biodiversity on these farms (Amigun et al. 2011) and the adoption of a multifunctional agricultural model could combine preservation of ecological services with rural development (Jordan and Warner2010; Randelli 2009). The water security issue, on the other hand, is mostly linked to the diversion of water resources from human needs (water availability) to ethanol feedstock production and the pollution of waterways (water quality) by disposal or runoff of liquid wastes from the fields. The irrigation needs of ethanol crops may vary, but in the case of cultivation of water-intensive crops, negative impacts on water availability could be expected, like for corn cultivated in the U.S. (Ng and Yanfeng 2011; Pimentel et al. 2009). In the case of sugarcane cultivation, discharge of vinasse into waterways and contamination by nutrients from fertiliser use can lead to eutrophication of surface waters (Martinelli and Filoso 2008). Moreover, developers must ensure existing formal or customary water rights are respected before implementing biofuel projects (Solomon 2010).

4.5.3 Transport

Similarly to the input production stage, changes at the level of transport are poorly addressed. This stage of ethanol's lifecycle comprises the transportation of feedstock, ethanol or other inputs from the fields to the power plant and from plant to pump, as well as storage. An increase in the passage of heavy goods vehicles could cause changes to traffic flows and congestion patterns (Selfa et al. 2011) transporting feedstock to and ethanol from the biorefinery, besides cross-country transportation of ethanol from rural producing areas to major urban areas for consumption (Ng and Yanfeng 2011). Deterioration of roads (Selfa et al. 2011), an increased risk of accidents and a threat to children's safety (Gillon 2010) are possible negative social impacts of these changes. The risk of transportation hazards from flammability and possible leakages should also be considered (Ng and Yanfeng 2011). On the other hand, implementation of ethanol projects could lead to overall improvement of transportation infrastructure – e.g., repairs of railways (Ng and Yanfeng 2011). The physical bulkiness of the feedstock and the proximity of the plantation, biorefineries and the overall supply chain are examples of factors that affect the transportation and storage of goods during ethanol's lifecycle (see Ng and Yanfeng 2011; Rossi and Hinrichs 2011).

4.5.4 Production plant

At the production or processing level, conversion processes transform raw material into ethanol, generating a number of by-products, co-products and waste products. At this stage, but at other levels as well, the adoption of comprehensive corporate social responsibility principles could deliver positive social impacts (Schaffel and La Rovere 2010; Schuurbiers et al. 2007). Of such positive impacts, one might cite the improvement of working conditions (Neves 2010), the generation of services and benefits for local communities such as maintenance of schools, nurseries and day-care units (Gallardo and Bond 2011), education and health for workers' children and training of workers lacking formal education (Hall and Matos 2010). In the state of São Paulo, the major ethanol-producing area in Brazil, the presence of ethanol plants is associated with socioeconomic benefits in terms of rural development, such as job creation and infrastructural development (Martinelli et al. 2011). As regards workers' health and safety at the ethanol plant, risks of explosion and fire due to storage of ethanol should also be taken into account (Gallardo and Bond 2011). Other benefits may arise from agreements between communities hosting ethanol plants and energy companies – on long-term lower-cost energy, for instance (Selfa et al. 2011). Also, the sale of co-products and by-products can provide extra income for producers (Zapata and Nieuwenhuis 2009) and benefit the overall supply chain. These can be used as an energy source for the conversion process, like in the case of the combustion of sugarcane bagasse (Hattori and Morita 2010; Schaffel and La Rovere 2010), or in the production of animal feed (corn meal) (Harvey and Pilgrim, 2011; Koh and Ghazoul 2008), among other valuable products. However, while locally owned and run facilities would benefit more poor rural communities (Milder et al. 2008), ethanol processing is rather expensive (Koizumi 2011) and its costs vary greatly from one producing country to another, depending on subsidisation policies, the level of development of the sector and climatic conditions (Lenk et al. 2007).

Ethanol processing can release liquid and airborne pollutants into the environment, resulting in possible health problems for the local population and jeopardising water safety. In the U.S., ethanol plants have been responsible for excessive release of a number of air pollutants, and have broken the law regarding air pollution due to the lack of emission control equipment, as well as committing water quality violations due to undesirable effluent discharging (Selfa 2010). In the case of sugarcane vinasse, a by-product of ethanol processing in Brazil, accidents during storage or transport are not uncommon and, were the product to reach the waterways, it could compromise the quality of aquatic systems (Martinelli and Filoso 2008). Moreover, the ethanol industry is water-intensive and could be especially dangerous in those areas where water availability is limited, which are more vulnerable to water shortages (Luk et al. 2010; Selfa 2010; Selfa et al. 2011). In any case, social trade-offs involved with the siting and scale of the plant should be studied further (Van der Horst and Vermeylen 2011), since there is a lack of research on social vulnerabilities of communities hosting biofuel production (Selfa et al. 2011).

4.5.5 Final use

At the final use stage, ethanol reaches the final consumer and is burned in the engines of public or private vehicles. One advantage of ethanol is that it can be used in contemporary internal combustion engines and distributed through the existing fuel infrastructure, avoiding the need for major infrastructural rearrangements (Walter et al. 2008). However, existing pipelines used for gasoline distribution are not suitable for transporting ethanol due to its affinity for water (high hygroscopicity), which could lead to corrosion problems (Luque et al. 2008; Ng et al. 2011). This way, the biofuel is rather transported by truck (Luk et al. 2010) or rail, since the costs for the construction of special, ethanol-dedicated pipelines are too high (Ng et al. 2011). On the other hand, its implementation in public transportation could improve energy security at national level (Demirbas and Demirbas 2007). The rural poor could benefit from the reduction of the amount spent on transport if cheaper biofuel is provided, although there is no record of initiatives of this kind (Van der Horst and Vermeylen 2011). Substitution of gasoline by ethanol could deliver health benefits in urban areas through the reduction of emissions of pollutants such as nitrogen oxides, carbon monoxide, particulate matter and volatile organic compounds, with the consequent improvement in air quality (Goldemberg and Guardabassi 2009; Nigam and Singh 2011; Randelli 2009; Walter et al. 2008). However, some consider this a fallacy, as there may be an increase in emissions of other pollutants (Phalan 2009). Moreover, since ethanol combustion delivers less energy than gasoline, more ethanol would be needed to travel the same distance, increasing the overall release of air pollutants

(Pimentel et al. 2008). The same would be true in the case of an increase of miles travelled due to lower ethanol prices forced by government mandates and subsidies (De Gorter and Just 2010), since the demand for ethanol on the part of the final consumer is largely determined by fuel prices at the pump (Banerjee 2011). In addition to lower toxicity, better fire safety and biodegradability are held up as examples of the advantages to ethanol, in support of its suitability for use in urban areas (Randelli 2009). Other aspects at the final use stage are those which affect ethanol consumers directly, like the costs of vehicles and the fuel itself, the distance between refuelling stations, vehicle options available (Mohamadabadi et al. 2009) and flexibility of choosing between fuels at the pump in the case of flex-fuel vehicles (Koh and Ghazoul 2008). These aspects interfere directly with consumption patterns and convenience, affecting consumer behaviour.

4.6 Cross-cutting issues

The category of “cross-cutting issues” encompasses those social aspects that apply to more than one of ethanol’s lifecycle stages or affect more than one group of actors. These issues, which are crucial in the debate surrounding the social sustainability of ethanol, are: energy security, compliance with legal framework and law enforcement, employment and income generation, public participation and public acceptance of biofuels.

4.6.1 Energy security

Energy security constitutes one of the main driving forces behind biofuel development policies worldwide (Rossi and Hinrichs 2011; Selfa et al. 2011; Spiertz and Ewert 2009), since one of the benefits of biofuels would be to reduce dependence on foreign energy at the national level (Sobrino and Monroy 2009; Sobrino et al. 2010; Zanin et al. 2000; Zinoviev et al. 2010), sidestepping the reliance on politically unstable countries for fossil fuels (Luque et al. 2008). However, national energy security goals are likely to correspond more with the interests of governments and large-scale producers than with those of small communities (Van der Horst and Vermeylen 2011), and that could undermine energy independence at the regional level or energy sovereignty of the rural poor. In fact, bioenergy programs aimed at delivering energy to the rural poor are normally limited, since buyers cannot afford the product (Coelho et al. 2006). In spite of that, there is evidence of cases in which biofuel production has increased energy security at the local level through the implementation of small-scale projects and at the household level, contributing indirectly to poverty alleviation (Gasparatos et al. 2011).

4.6.2 Legal framework and law enforcement

While law enforcement is regarded as an important element for mitigating the negative social impacts of ethanol (Janssen and Rutz 2011), socially unequal countries with weak or unenforceable regulatory frameworks are more vulnerable to possible negative outcomes from its production (Uriarte et al. 2009). These are usually biofuel-producing countries in the poor south. Tanzania, for example, suffers from a complete absence of a legal framework to regulate biofuel development (Sosovele 2010). In Brazil, there is a need for firm enforcement of labour and social law, and for strengthening of social justice in the ethanol sector in order to reduce labour violation, poverty, conflicts and social inequality at the local, regional and national levels (see Martinelli and Filoso 2008; Sawyer 2008; Schaffel and La Rovere 2010; Smeets et al. 2008). The cumulative negative social impacts of the ethanol industry could damage its socio-political legitimacy (Hall et al. 2011) if there is not a sturdy legal framework for biofuel development and active law-enforcement mechanisms.

4.6.3 Employment and income generation

The development of biofuel programs can create jobs in rural areas and along the overall productive chain, from research to trade and services (Neves 2010; Vasudevan et al. 2005), although from one type of biofuel – i.e. one type of production process to another, there are noticeable differences in the volume and characteristics of jobs created (Conejero et al. 2010). By contrast to biodiesel, which tends to support the development of small-scale producers, the ethanol industry is usually characterised by centralised, large-scale, export-driven production (see Hall et al. 2009) so as to guarantee its economic feasibility (Conejero et al. 2010). This model is less labour-intensive since it is based on mechanised harvesting and involves higher rates of temporary, unskilled employment at the plantation level (German et al. 2011; Lehtonen 2011). In Brazil, for example, one single machine used in sugarcane harvesting can displace 80 workers (Smeets et al. 2008). However, temporary jobs could be created during the construction of the processing plant, while jobs at the refinery would demand unskilled but also highly skilled labourers, e.g. engineers, chemists and managers (Bell et al. 2011; Solomon 2010). In any case, learning opportunities need to be fostered to avoid social exclusion of unskilled rural workers (Sathaye et al. 2009), but being able to work in complex industrial facilities such as an ethanol refinery also depends on an existing educational background (Luk et al. 2010). Maintenance of ethanol programs is also crucial for avoiding massive job losses and other negative social impacts in countries like Brazil, where more than half of jobs in the sugarcane industry are directly related to the ethanol production chain (Zanin et al. 2000). As regards wages in the ethanol sector, the average wage paid by the trade-union member companies in the ethanol industry in Brazil was shown to be much higher than the federal minimum wage for the same period (Neves 2010) and higher than in other industrial sectors (Novo et al. 2010; Smeets et al. 2008). However, the generation of incomes should be contrasted with living costs, which, if high, can hinder decent standards of existence (Smeets et al. 2008). In Brazil, manual harvesting is still underpaid, leading to higher workloads of cane cutters wishing to earn more (Martinelli and Filoso 2008). Concentration of the larger share of incomes in the hands of producers and processors is also an issue in the Brazilian ethanol sector (Sawyer 2008).

4.6.4 Public acceptance and public participation

Public acceptance of biofuels varies among different geographical contexts, and previous studies do not offer conclusive results on the subject (Savvanidou et al. 2010). Ethanol could face public resistance in the future if technology does not advance as forecasted – i.e. developing cellulosic ethanol with improved cost and environmental efficiency or if it continues to threaten food security by using edible crops for production (Luk et al. 2010). Also, public acceptance of genetically modified crops (GM crops) is an important issue surrounding biofuel developments (see Fischer et al. 2010; Gallardo and Bond 2011; Gielen et al. 2003; Smeets et al.

2008). The levels of acceptance of GM organisms for biofuel production should be higher if dedicated, non-edible energy crops are genetically modified instead of food crops (Koh and Ghazoul 2008) and vary among different regions in the world (Janssen and Rutz 2011). In a study conducted in Greece, few citizens would prioritise biofuels over other renewable energy sources, although an even smaller number know the difference between ethanol and biodiesel (Savvanidou et al. 2010). Consumer acceptance of ethanol depends mainly on the risk perception of supply stability and the price of vehicles, and flex-fuel vehicles are likely to reduce consumer uncertainty concerning the fuel's reliability (Zapata and Nieuwenhuis 2009). Moreover, consumer acceptance of biofuels is increasingly being driven by preference for more socially and environmentally responsible products, including imported biofuels (Phalan 2009). Policy makers and investors normally have an instrumental vision of rural actors as passive suppliers with neutral or absent opinions regarding the trade-offs and social desirability of biofuel production (Rossi and Hinrichs 2011). Yet, farmers are concerned about a number of aspects such as changes on aesthetics, concentration of incomes by large-scale firms, feedstock transportation constraints, among others (Rossi and Hinrichs 2011). For example, local communities from ethanol-producing regions in the U.S. showed low levels of satisfaction regarding economic benefits or poverty reduction resulting from the presence of ethanol plants, as well as concerns about water security, air pollution, traffic problems and risks of instability or decline of the industry in the future (Selfa et al. 2011). On the other hand, residents believed that energy security constitutes a crucial reason for supporting ethanol industry in the U.S., and concern over negative environmental impacts was usually overshadowed by public expectations of job creation and new markets for farm products (Selfa 2010). Changes in and expansion of infrastructure related to ethanol projects also need the appraisal and acceptance of local communities (Ng et al. 2011). Finally, the media's discourse plays a great role in shaping public perception of controversial issues (Wright and Reid 2011), which could influence the level of public awareness and acceptance of biofuels. Public participation in decision-making is considered a way of legitimising biofuel policy and fostering implementation of more sustainable projects from the environmental and social points of view (see Di Lucia, 2010; Schaffel and La Rovere 2010; Schuubiers et al. 2007; Sheehan 2009). Participatory processes are important tools for project planning, so bioenergy can contribute to multiple social goals held by different actors (Milder et al. 2008), including often-marginalised local knowledge, which are especially valuable in the assessment of bioenergy trade-offs (Rossi and Hinrichs 2011). However, effective public engagement and inclusion of non-specialist knowledge in the bio-based economic debate might depend on the redesign of current methods and models (Schuurbiers et al. 2007).

4.7 Conclusions

Impact assessment of alternative energy sources has to be committed to wide-ranging social agreements over desired and realisable energy futures. This is a very complex and novel task, since modes of governance of socio-technical systems have evolved at a different pace than have democratic regulating institutions. Besides, although public criticism of science and technology development is not entirely new, the configuration of energy systems and their use has not been something largely debated or agreed since humans first started to use coal. At the same time, evidence shows that choices on energy sources made in the past, as well as the related consumption patterns adopted in wealthy societies in the last century, are responsible for most of today's environmental and social challenges. Although biofuel sustainability has been a much-debated topic in the past few years, there is still a lack of evidence in the peer-reviewed literature regarding the positive and negative social impacts of 1st-generation ethanol or appraisal of potential social impacts of cellulosic ethanol. Besides, studies tend to discuss aspects of biofuels but disregard the specificities of each kind of fuel. When quoted, social changes or impacts of ethanol are not contextualised as regards the actors affected and the lifecycle stage involved. A range of actors are often overlooked, such as consumers, value-chain actors or even society as a whole, as well as the phases of input production, transport and final use.

Further work is needed on the formulation of social criteria and indicators for a comprehensive sustainability assessment of ethanol. For this,case studies focused on the identification and engagement of relevant actors based on a lifecycle approach can be particularly valuable. Greater availability of primary data should encourage the development of comparative studies. Assessments will have to make it a priority to engage local rural dwellers in order to define the parameters and boundaries of assessment, based on community perception of social and environmental trade-offs. The absence of an agreed definition of marginal land should serve as an example of how values that are in dispute can lead to misinterpretation of crucial sustainability aspects. Consultation should be extended to other interested parties, including the opinion of the wider public. A comprehensive sustainability assessment of ethanol also depends on a robust and integrated body of work from the environmental and social sciences. Greater attention should be paid to frameworks based on the appraisal of ecosystem functions, i.e. the contribution of natural resources to human wellbeing and how that contribution is affected by the implementation of ethanol projects. Researchers and impact assessment practitioners can take advantage of the large body of biophysical appraisals of the impacts of biofuels that are already available. Priority needs to be given to the identification and operationalisation of tailor-made indicators for assessment of major sustainability principles such as guaranteeing food and water security of ethanol developments. Methodologies of assessment must consider the analysis of positive and negative social consequences over time and potential off-site impacts, including those across borders.

Policy makers need to internalise the social dimension of ethanol in decision-making to prevent public opposition and irreversible social costs in the future. Efforts to support or regulate ethanol developments should count withparticipatory and integrated appraisals of ethanol sustainability, with explicit strategies for the management of long-term impacts of the biofuel, prior to the implementation of promotion programs. The academia must collaborate with the industry, and both with governments, on the development of well-informed, evidence-based frameworks for the impact assessment of projects. The emergence of numerous social standards proposed by different institutions, e.g. multi-stakeholder certification schemes can be of value, although a lack of homogeneity among frameworks may hamper an effective governance of the impacts of biofuels. Public awareness of the technology and its potential social drawbacks should be fostered along with spaces for deliberative dialogue between experts, citizens and the industry. Policy makers should endorse the outcomes of these dialogues. It is essential that national and international policies and agreements have a focus on the governance of impacts of ethanol in poorer and more environmentally vulnerable regions.

As stressed by Coelho et al. (2006), “biofuels are energy sources produced in rural areas to primarily service the energy needs of cities that can afford to pay”. Although this assertion might seem obvious for some, it summarises the logic of large-scale biofuel production nowadays. Small-scale producers do not sustain the largest part of the current biofuels global market created and supported by policy mandates. However, a major development of alternative energy sources like biofuels cannot be realised at the expense of rural sovereignty and wellbeing. Besides, any projections of future interventions also need to consider the effects of climate change on top concern issues regarding ethanol development. These are water and food security, which could be threatened by land-use change for feedstock production and raw material processing, among other factors. An increase in the levels of social vulnerability may be felt mostly at the local and regional levels, close to production sites, but indirect consequences can also affect the broad societal level, especially the access of poor people to cheap water, consumer goods and staple food in the near future.

Appendix D. Summary of selected papers

Reference	Year of publication	Main geographic scope of analysis	Is the study based on primary data?	Does the study addresses ethanol exclusively?	Ethanol generation(s) that is/are mainly addressed
Aerni (2008)	2008	African countries and New Zealand	No	No	1st
Amigun et al. (2011)	2011	African countries	No	No	1st
Bailis and Baka (2011)	2011	Brazil, U.S., EU, India and Tanzania	No	No	1st
Banerjee (2011)	2011	United States	No	Yes	1st
Bell et al. (2011)	2011	Thailand	No	No	1st
Bodgan et al. (2010)	2010	Not defined	No	No	1st
Bush (2007)	2007	Southeast Asia	No	No	1st
Carioca et al. (2009)	2009	Brazil	No	No	2nd
Chavez et al (2009)	2009	China	No	No	1st and 2nd
Coelho et al. (2006)	2006	Brazil	No	Yes	1st
Conejero et al. (2010)	2010	Not defined (emphasis on Brazil)	No	No	1st
Corbière-Nicollier et al. (2011)	2011	Switzerland and Brazil	No	Yes	1st
Dale et al. (2010)	2010	United States	No	Yes	2nd
Davis et al. (2011)	2011	Mexico, Brazil, African countries and Australia	No	Yes	2nd
De Gorter and Just (2010)	2010	United States	No	No	1st
Demirbas and Demirbas (2007)	2007	Not defined (emphasis on “developing countries”)	No	No	1st and 2nd
Di Lucia (2010)	2010	Mozambique	No	No	1st
Dodic et al. (2010)	2010	Serbia	No	No	1st
Fabiosa et al. (2009)	2010	U.S., Brazil, China, Europe and India	No	Yes	1st
Fischer et al. (2010)	2010	Europe	No	No	1st and 2nd
Furtado et al. (2011)	2011	Brazil	No	Yes	1st
Gallardo and	2011	Brazil	No	Yes	1st

Bond (2011)					
Gao et al. (2011)	2011	Latin America (emphasis on Brazil), Asia and Africa	No	No	1st and 2nd
Gasparatos et al. (2011)	2011	Brazil, U.S., China and India	No	No	1st
German et al. (2011)	2011	Asia, Africa and Latin America	No	No	1st
Gielen et al. (2003)	2003	Not defined	No	No	1st and 2nd
Gillon (2010)	2010	United States	Yes	Yes	1st
Goldemberg and Guardabassi (2010)	2010	Brazil and sugarcane producing countries	No	Yes	1st
Gomiero et al. (2010)	2010	U.S. and Brazil	No	No	1st and 2nd
Hall and Matos (2010)	2010	Brazil	Yes	No	1st
Hall et al. (2009)	2009	Brazil	Yes	No	1st
Hall et al. (2011)	2011	Brazil	Yes	No	1st
Harvey and Pilgrim (2011)	2011	Brazil, U.S. and Europe	No	No	1st and 2nd
Hattori and Morita (2010)	2010	Not defined	No	Yes	1st and 2nd
Janssen and Rutz (2011)	2011	Latin America	No	No	1st
Jordaan (2007)	2007	Not defined	No	No	1st
Jordan and Warner (2010)	2010	United States	No	No	1st and 2nd
Koh and Ghazoul (2008)	2008	U.S., Brazil and China	No	No	1st and 2nd
Koizumi (2011)	2011	Japan	No	No	1st and 2nd
Koning et al. (2008)	2008	Not defined	No	No	1st and 2nd
Lal (2009)	2009	Not defined	No	No	2nd
Lehtonen (2011)	2011	Brazil	Yes	Yes	1st
Lenk et al. (2007)	2007	Germany	No	No	1st
Luk et al. (2010)	2010	Canada	No	Yes	1st
Luque et al. (2008)	2008	Not defined	No	No	1st and 2nd
Malik et al. (2009)	2009	Countries from the Greater Mekong Subregion	No	No	1st
Martinelli and	2008	Brazil	No	Yes	1st

Filoso (2008)					
Martinelli et al. (2011)	2011	Brazil	No	Yes	1st
Milder et al. (2008)	2008	Not defined	No	No	1st
Mohamadabadi et al. (2009)	2009	United States	Yes	No	1st
Naylor (2011)	2011	Not defined	No	No	1st and 2nd
Naylor et al. (2007)	2007	U.S., Brazil, China and Indonesia	No	No	1st and 2nd
Neves (2010)	2010	China and Brazil	No	Yes	1st
Ng et al. (2011)	2011	United States	No	Yes	1st and 2nd
Nigam and Singh (2011)	2011	Not defined	No	No	1st and 2nd
Novo et al. (2010)	2010	Brazil	No	Yes	1st
Paustian and Cole (1998)	1998	Not defined	No	No	1st and 2nd
Phalan (2009)	2009	Asia	No	No	1st and 2nd
Pilgrim and Harvey (2010)	2010	Europe	Yes	No	1st
Pimentel et al. (2008)	2008	United States	No	No	1st and 2nd
Pimentel et al. (2009)	2009	United States	No	No	1st and 2nd
Randelli (2009)	2009	Italy	No	No	1st
Rinne et al. (2011)	2011	Finland	No	Yes	1st
Rossi and Hinrichs (2011)	2011	United States	Yes	Yes	2nd
Sathaye et al. (2009)	2009	Not defined	No	No	1st
Savvanidou et al. (2010)	2010	Greece	Yes	No	1st and 2nd
Sawyer (2008)	2008	Brazil	No	No	1st and 2nd
Schaffel and La Rovere (2010)	2010	Brazil	No	No	1st
Schuurbiers et al. (2007)	2007	Europe	Yes	No	1st and 2nd
Selfa (2010)	2010	United States	Yes	Yes	1st
Selfa et al. (2011)	2011	United States	Yes	Yes	1st
Sheehan (2009)	2009	United States	No	No	1st
Smeets et al. (2008)	2008	Brazil	Yes	Yes	1st
Sobrino and Monroy (2009)	2009	Spain	No	No	1st and 2nd
Sobrino et al. (2010)	2010	Spain	No	No	1st

Solomon (2010)	2010	United State	No	No	1st and 2nd
Sosovele (2010)	2010	Tanzania	No	No	1st
Spiertz and Ewert (2009)	2009	Not defined	No	No	1st and 2nd
Tan et al. (2010)	2010	China	No	No	1st
Timilsina and Shrestha (2011)	2011	Not defined	No	No	1st and 2nd
Uriarte et al. (2009)	2009	Brazil	No	Yes	1st
Van der Horst and Vermeylen (2011)	2011	Not defined	No	No	1st
Vasudevan et al. (2005)	2005	Not defined	No	No	1st and 2nd
Walter et al. (2008)	2008	Not defined	No	Yes	1st and 2nd
Wetzstein (2010)	2010	United States	No	No	1st and 2nd
Wilkinson and Herrera (2010)	2010	Brazil	No	No	1st and 2nd
Wright and Reid (2011)	2011	United States	Yes	Yes	1st
Zanin et al. (2000)	2000	Brazil	No	Yes	1st
Zapata and Nieuwenhuis (2009)	2009	Brazil	Yes	No	1st
Zinoviev et al. (2010)	2010	Not defined	No	No	2nd

5 Artículo IV: “Transitions in biofuel technologies: An appraisal of the social impacts of cellulosic ethanol using the Delphi method”

Referencia

Ribeiro, B. E. y Quintanilla, M. A. (2014). *Transitions in biofuel technologies: an appraisal of the social impacts of cellulosic ethanol using the Delphi method*. Manuscrito remitido para publicación.

Resumen

The sustainability of biofuels produced from food crops has become a focus of public and scientific scrutiny in the past few years. In the case of ethanol production, advanced technologies aim at avoiding controversy by using instead cellulosic biomass contained in wastes, residues and dedicated energy crops. However, despite the positive expectations that drive the development of the so-called “cellulosic” ethanol, sustainability challenges remain to be elucidated. Expecting to contribute to closing the gap in the field of the social assessment of biofuels, this paper reports and analyses the results of a Delphi survey that explored the perception of biofuel experts from different countries on potential social impacts of cellulosic ethanol. The complexity of appraising impacts emerges as one important conclusion of the study along with the realisation that these will be context-specific. Except for the case of municipal solid waste used as feedstock, such a technological transition might not be able to ameliorate the issues already faced by conventional ethanol, especially when production is based in poorer countries. This is because impacts of cellulosic ethanol depend upon both the technical dimension of its production and the socio-political context of locations where production might take place.

5.1 Resumen de la investigación

En los últimos años la sostenibilidad de los biocombustibles producidos a partir de cultivos alimentarios ha sido blanco de críticas en el ámbito científico y público. Se ha apoyado la producción de biocombustibles de segunda generación en el intento de superar una serie de problemas como la competencia con los alimentos o emisiones de gases de efecto invernadero (GEI) derivados de cambios en el uso de la tierra. En el caso del etanol, su "sustituto" es el etanol celulósico, para el cual se utiliza la biomasa de residuos, desechos o cultivos energéticos no-alimentarios en su producción. Sin embargo, aunque su desarrollo se contextualice por expectativas positivas, algunos estudios indican que su producción no supera necesariamente los retos enfrentados por el etanol de primera generación y que análisis más profundizados de su sostenibilidad son necesarios antes de su implementación a gran escala (véase Artículos I y III de esta tesis).

Esta investigación presenta y analiza los resultados de un estudio Delphi sobre la percepción de expertos en biocombustibles respecto a algunos potenciales impactos sociales del etanol celulósico. Las variables analizadas se han recogido de la matriz social desarrollada en una de las investigaciones que forman parte de la presente tesis (véase Artículo II). Se ha buscado profundizar en la comprensión de estas variables a través de una evaluación que ha explorado tres dimensiones de las mismas: su probabilidad, reversibilidad y monitorabilidad. Para la aplicación del instrumento de evaluación se ha utilizado el método Delphi, una técnica de diálogo estructurado originalmente desarrollada para la anticipación de impactos de desarrollos científico-tecnológicos y ampliamente utilizada en el campo de la evaluación de tecnologías. El estudio ha contado con la participación de 23 expertos provenientes de 7 países distintos e incluye dos rondas de evaluación del conjunto de los impactos de acuerdo con diferentes escenarios y una tercera para la evaluación de la técnica utilizada y diseño del estudio. Los cuestionarios desarrollados para cada ronda se recogen en el Apéndice D de esta tesis.

Los principales resultados de este estudio se presentan a continuación:

- La sustitución de cultivos alimentarios por no-alimentarios para la producción de etanol celulósico puede no garantizar la seguridad alimentaria en el caso de que a) la remoción excesiva de residuos conlleve al deterioro de los suelos o b) que los cultivos para fines energéticos sustituyan cultivos alimentarios o utilicen áreas potenciales para la producción de alimentos en el futuro.

- El consenso respecto a los beneficios de la utilización de desechos municipales, que no involucra cambios en el uso de la tierra, en comparación con los demás escenarios, indica que la producción de materia prima para la producción de etanol celulósico se inserta en el mismo paradigma que el de la producción agrícola en general. En este sentido, los factores que afectan a la sostenibilidad de la agricultura convencional o industrial se aplican igualmente a la producción de ciertos tipos de materia prima celulósica. Dichos factores incluyen la escala de producción, la intensidad en el uso de fertilizantes y herbicidas o la gestión de sus impactos como el control de la erosión etc.

- Desde la perspectiva de la inclusión de pequeños productores de materia prima y de biocombustibles, la contribución del etanol celulósico al desarrollo rural es incierta. Uno de los principales factores que contribuyen a esta incertidumbre es el alto coste de estos procesos. Los casos de la producción de etanol en Estados Unidos y en Brasil, en las cuales muy pocos productores se encuentran involucrados, ilustran dicha tendencia. Por otra parte, sistemas productivos más descentralizados que se enfoquen en la inclusión de pequeños productores pueden generar beneficios a las poblaciones rurales.

- Los impactos del etanol celulósico deben afectar de manera distinta a las poblaciones de los países más ricos y las de los más pobres. Contextos socioeconómicos y políticos dispares implican distintos niveles de severidad en relación con los potenciales impactos del etanol y de los biocombustibles en general. Estos incluyen elementos como los recursos económicos y humanos de los que dependen las actividades de monitoreo o mitigación de impactos, de los niveles de corrupción en sistemas regulatorios y de aspectos contextuales que sirven de línea de base como las condiciones ambientales y sociales iniciales en los sitios de producción.

- La evaluación de los impactos del etanol celulósico es una tarea compleja. Las consecuencias de la producción de los biocombustibles dependen en gran parte del contexto en el que se inserta la misma. Una anticipación de los potenciales impactos de los biocombustibles avanzados involucra, por tanto, altos niveles de incertidumbre. Entre los aspectos que contribuyen con la complejidad de sus evaluaciones están el desarrollo de nuevos mercados asociados a las cadenas productoras, la percepción del riesgo económico por parte de inversores y productores y las dificultades en comprender las dimensiones espaciales y temporales de temas como el de la seguridad alimentaria.

Se concluye que la evaluación de los impactos sociales del etanol celulósico es una tarea compleja ya que múltiples factores juegan un papel importante en la producción de estos impactos. El análisis del peor y mejor de los casos para cada impacto evaluado por los expertos ha revelado que, excepto en el caso del uso de residuos sólidos urbanos como materia prima en la producción de etanol celulósico, una transición entre el etanol de primera generación y el celulósico puede no significar una superación de los retos enfrentados por el primero respecto a su sostenibilidad. Dichos retos incluyen su potencial en contribuir al desarrollo rural y las implicaciones de los cambios en el uso de la tierra, en la seguridad alimentaria y seguridad del agua, por ejemplo. Según la opinión de los participantes en el estudio, los impactos negativos del etanol celulósico pueden ser todavía más severos si la producción de materia prima se da en los países más pobres, como los del África subsahariana. En ese sentido, se ha verificado que las consecuencias positivas y negativas de un desarrollo científico-tecnológico como el etanol celulósico dependen a la vez de los aspectos técnicos involucrados en su ciclo de vida y de los contextos sociopolíticos en el que se inserta dicho ciclo. La complejidad de estos sistemas sociotécnicos tiende a aumentar con el tiempo, lo que contribuye con una disminución de su reversibilidad. Esta consideración tiene mucha relevancia para la evaluación de los impactos de tecnologías emergentes como las involucradas en las cadenas de producción del etanol celulósico. Una de sus principales implicaciones es que se hace necesaria la consideración y evaluación de sistemas técnicos alternativos que puedan atender a los mismos objetivos u objetivos similares antes de su implementación a gran escala.

5.2 Introduction

Alongside the development of a promising international market, in the last decade liquid biofuels have been promoted as strong candidates in the search for alternatives to the use of fossil fuels in the transportation sector. However, the brisk development of a global commodity chain of liquid biofuels (Raikes et al. 2000) did not come without its share of controversy, as it has been facing great challenges regarding the governance of its impacts. In the development of biofuels, two antagonistic narratives have prevailed. On the one hand biofuels have been framed as an important, strategic solution to reduce greenhouse gas (GHG) emissions while increasing the energy security of countries that are dependent on oil imports. On the other however, some biofuel production chains have been coupled to both direct and indirect land use change, leading to increasing GHG emissions and putting pressure on food security. Because of the high levels of uncertainty regarding its potential impacts and already proven detrimental effects on the environment and society, large-scale production of liquid biofuels has become a focus of public and scientific scrutiny (see, for example, Doornbosch and Steenblik 2007; Sharlemann and Laurance 2008; Ajanovic 2011; Selfa et al. 2011; Wright and Reid 2011). As a response to the latter, the European Union and governments around the world have been supporting innovations in biofuels technologies, such as the ones involved in the conversion of non-edible biomass into liquid biofuels (EC 2013). These particularly aim at addressing issues of technical efficiency and the environmental and social sustainability of biofuels by achieving greater reductions in GHG emissions while avoiding negative impacts on food security along their lifecycle.

Ethanol is the world's most produced type of liquid biofuel. Brazil and the United States dominate production, but use in Europe is also increasing (RFA 2012). Technological innovations in ethanol production are focused on bringing "second-generation" biofuels to market. These 'advanced biofuels'[32] commonly make use of the cellulosic components of biomass, which may be obtained from forestry and agricultural residues, municipal solid waste (MSW) and dedicated energy crops, such as grasses and short-rotation coppice (SRC). The so-called cellulosic ethanol is

[32] The term 'advanced' in this work refers to a type of biofuel that is obtained from processes that involves technological innovations in comparison to conventional ones.

commonly considered to offer advantages in comparison to conventional, "first-generation" ethanol made from edible crops rich in sugar or starch. These advantages include further reductions in GHG emissions and reduced competition with food production (Farrell 2006; Hahn-Hagerdal et al. 2006; Solomon et al. 2007; González-García et al. 2010; Vikari et al. 2010; Mabee et al. 2011; Borrion et al. 2012). Based on these benefits, several countries have been encouraging the development and economical scale-up of cellulosic ethanol[33]. Presently, this is generally limited to production at experimental and demonstration scales because of economic and technical barriers (Limayem and Ricke 2012).

Despite the positive expectations that drive the development of cellulosic ethanol, a number of important sustainability challenges have also been highlighted. Many of these derive from consideration of the impacts of conventional ethanol (Mohr and Raman 2013). Moreover, previous research has demonstrated that the social dimensions of ethanol impacts are largely overlooked in the scientific literature; a transition from conventional to cellulosic ethanol may entail negative social impacts, and there is a lack of research dedicated to the appraisal of potential social trade-offs of such a transition (Ribeiro 2012; 2013).

Following up on previous work and expecting to contribute to closing the gap in the field of the social appraisal of advanced biofuels, this paper reports and analyses the main results of a Delphi survey that explored the perception of twenty-four biofuel experts from seven different countries[34] on potential social impacts of cellulosic ethanol. Impacts were assessed against different hypothetical scenarios. These were based on the type and source of raw material for the production of cellulosic ethanol in different regions from the global North and South. Experts appraised impacts with regards to their probability of occurrence and two additional criteria that are less explored in the analysis of the impacts of technological change: reversibility and monitorability. Since ethanol production may take place in different locations across the world, the main objective of the survey was to stimulate reflection around the social sustainability of ethanol under different contexts. We focus the analysis in

[33] In the United States and European Union this support is formulated in the Energy Independence and Security Act of 2007 and in Directive 2009/28/EC, respectively.

[34] Brazil, Canada, India, Spain, Sweden, UK and the US.

terms of ‘best’ and ‘worst-case scenarios’ that stem from quantitative and qualitative data obtained in the mixed methods survey (Bryman 2012). The combination of these different data sets was helpful in unveiling interesting aspects of the variables assessed and supporting the findings of each approach.

The challenge of such an appraisal emerges as one important conclusion of the study along with the realisation that the potential social benefits and drawbacks of cellulosic ethanol will be highly context-specific and complex. In addition to highlighting the difficulty of analysing complex problems, participants revealed the dual, sometimes ambiguous, technical and social nature of their ‘solutions’ (Quintanilla 1993). Main findings indicate that experts are sceptical if a transition to advanced biofuel production will be able to ameliorate the issues faced by the production of conventional ethanol, especially when production is based in poorer countries of the global South. Production from MSW may however be the exception to this rule.

This paper is divided into 6 sections. It starts with an introduction to the Delphi method (section 5.3), followed by a description of the survey process (section 5.4). It then presents a summary of the results (section 5.5) and a discussion on the limitations and strengths of the study (section 5.6). Finally, it offers key considerations on the development of cellulosic ethanol (section 5.7) followed by some concluding remarks (section 5.8).

5.3 The Delphi method: some applications and critiques

The Delphi method is a forecasting technique which elicits expert knowledge from a variety of participants (Scapolo and Miles 2006). The makeup of this expertise is determined by the design of the exercise. Developed in the 1950s in the United States as an experiment aimed at estimating bombing requirements (Dalkey and Helmer 1963), a Delphi traditionally involves an anonymous survey using questionnaires with controlled feedback to allow iteration within a panel of experts (Linstone and Turoff 2011). A key feature of the Delphi technique is its potential to disclose subjective value judgements of a group of individuals assessing complex problems that are characterised by varying levels of uncertainty (Linstone and Turoff 2002). It is also understood as a tool for reaching expert consensus through scientific discourse and helping to solve complex situations in which, while scientific knowledge elements are relatively certain, the relations between variables are very complex (Bijker et al. 2009).

The Delphi method has been employed in social impact assessment (SIA) to gather public opinion through community engagement in SIA studies (Burdge and Robertson 1990); in environmental impact assessment (EIA) to assist in the estimation of impacts (e.g. Green et al. 1990 and Vizayakumar and Mohapatra 1992) and as an instrument for the evaluation of available tools for other types of assessment (e.g. Buytaert et al. 2011). The Delphi technique has also been used as an analytical tool for structured interaction in technology assessment (TA) between experts and other relevant actors (van den Ende et al. 1998). Among other methodologies for foresight and forecasting, such as lifecycle assessment and future-oriented bibliometrics, Delphi studies can serve as tools for decision-making in the context of the development of emerging technologies, helping to increase reflexivity in innovation systems (Barber et al. 2008).

The choice of a specific design and the methodological characteristics of a Delphi process are dependent on the research question defined by the analyst and vary significantly among studies (Hasson and Keeney 2011). Critiques of the method have stemmed from a plethora of analyses, focusing on different dimensions of the process and its potential drawbacks. Landeta (2006) points out several weaknesses of the method: participants' biases, bias in expert selection by the facilitators, the idea of consensus as an approximation to truth, the limitations to participants' interaction in controlled feedback, the weight of the interests of who runs the study in the design of the methodology, and the difficulty in appraising the method's accuracy and reliability are all key concerns (Landeta 2006:469). In another evaluation of the Delphi method, Tichy (2004) addressed the issue of how different levels of expertise (or specialisation) among participants influence their levels of optimism and pessimism regarding proposed scenarios. Finally, Hussler et al. (2011) have demonstrated the importance of panel composition, arguing that non-expert and expert panels will often produce significantly different results.

However, if its pitfalls are acknowledged and methodological rigour is ensured, the Delphi method is able to produce robust long-term forecasts (Parente and Anderson-Parente 2011), with higher levels of accuracy in its results than for those obtained from unstructured group interactions (Rowe and Wright 1999). The method can also be combined with other forecasting techniques and social research methodologies. In technology assessment, for example, it can be used in association with analytic hierarchy process and cross-impact method, among others (Tran and Daim 2008). A key argument in defence of the Delphi method, forwarded by some of its main theorists is that ultimately when making judgements in situations of high uncertainty, one head should be better than none and multiple heads better than one (Linstone and Turoff 2002:234). Importantly in such situations, the method allows overlooked research topics to be raised and discussed where in other group situations they might remain hidden (Cuhls 2003).

This section has briefly laid some applications, challenges and opportunities of the Delphi method. As indicated above, Delphi studies can be useful to help achieving many different objectives and might have different degrees of complexity. The survey presented in this paper corresponds to an exploratory exercise that aimed at eliciting the perception of biofuel experts regarding potential social impacts of cellulosic ethanol. It attempted that by promoting reflection around a set of previously defined variables and against different scenarios and criteria. It does not engage, however, in complex foresight or forecasting activities, nor it attempts at reaching consensus among participants. Providing with structured feedback on experts' responses in questionnaires, eliciting their knowledge on complex issues and revealing some of their assumptions in the process are therefore the main elements of the present study, and so the reasons for structuring it around the Delphi method. Section 5.4 describes the different aspects of the survey in more detail.

5.4 A Delphi study for the social appraisal of cellulosic ethanol

The Delphi study presented here was devised in a structured format in order to assess a list of pre-defined impacts drawn from previous work documented in Ribeiro (2013). Two generic pathways were used to illustrate the main technical differences between the production of conventional and cellulosic ethanol. Participants used three criteria to appraise the potential impacts of ethanol: their probability, reversibility and monitorability. This was done against a range of different hypothetical scenarios where types of land, feedstock and geographical locations for the production of cellulosic ethanol were variables. Sub-sections 5.4.1 to 5.4.4 describe the design of the study and the development of the survey process.

5.4.1 The survey process

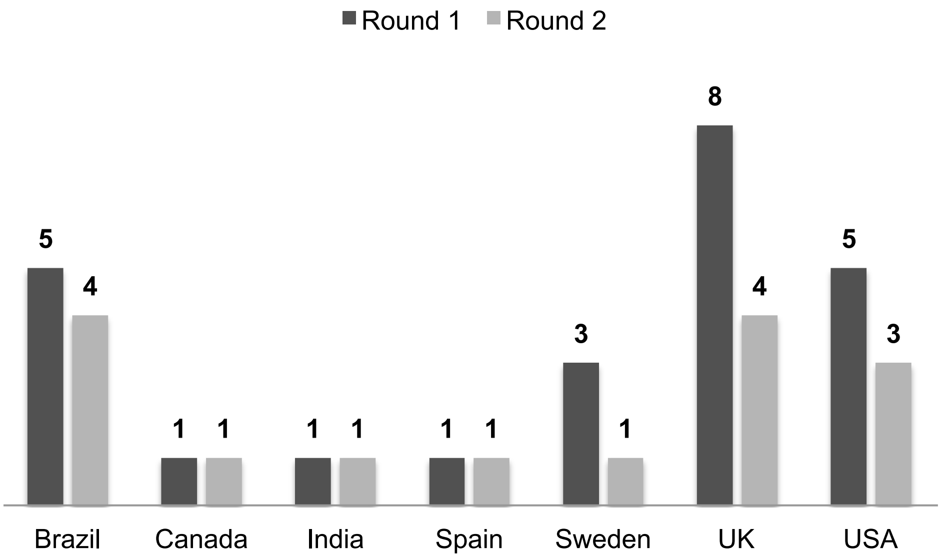
The survey was run online between April and July 2013 using the Adobe Forms Central platform. It was anonymous and divided into three rounds. The last round consisted of an evaluation of the study and the method used. Selection of potential participants was based on their recognised expertise and familiarity with the topic of biofuels' sustainability. Although invited participants were experts in the broad area of biofuels studies, they self-identified as having a range of expertise from different disciplinary backgrounds (Table 1).

Table 1. Main areas of expertise of participants (areas are "biofuels-related", inserted by participants as free text)

Agricultural Economics	Environmental Management
Bioenergy systems	Ethics
Biofuel Supply Chains	Integrated Analysis of Farming Systems
Biofuels Governance	Life Cycle Assessment
Corporate Social Responsibility	Public Opinion
Critical Environmental Social Science	Renewable Energy
Ecosystem Ecology	Rural Sociology
Energy and Environmental Policy	Sociology
Energy and Society	Sociology of Technology
Energy Planning	Sustainability Certification

Participants were identified in the peer-reviewed literature, mainly from the references used in Ribeiro (2013), and through the use of snowball sampling from invited experts. Out of thirty-nine invitations sent (n=39), a total of twenty-four experts (n=24) from seven countries took part in the first round of the survey, indicating a response rate of 61,5%. Fifteen participants (n=15) remained in the study and completed the questionnaire for the second-round. Despite a dropout rate of 37% between the two rounds, panellists were still representative of the geographic diversity of the first round group (Fig. 1).

Figure 1. Number and geographical location of participants



5.4.2 Potential social impacts of cellulosic ethanol

Social impacts might involve large or small communities, groups of people or individuals. They have different dimensions, as they might refer to social change processes (e.g. an increase in human exposure to toxic substances or an increase in wages) or to the human experience related to change (i.e. the actual physical or psychological effects of the change as perceived by people and their response to the experience). Although these dimensions are neither definitive nor linear, they can be useful to understand that social change processes and social responses to change often create subsequent social changes, making it impossible to determine and define all the levels of a social impact (Van Schooten et al. 2003; Vanclay 2002a). Therefore, the depth to which a social impact is described depends on the decisions made by the analyst or other actors that take part in the assessment. Distinguishing between social change processes and the human experience related to change can be helpful as it calls attention to the fact that, while social change processes might be generalizable, the human experience and responses or adaptation to change will likely differ among actors and in different contexts.

Eight potential impacts involved in a transition from the production of conventional to cellulosic ethanol were drawn from Ribeiro (2013). This study developed a comprehensive matrix of social aspects of ethanol used as a support tool for a systematic review of the peer-reviewed literature on the topic. The identification and definition of impacts aimed to generalise a number of social change processes that would be relevant in the transition between two technological pathways for conventional and cellulosic ethanol. These are described in section 5.4.3. The main technical changes of such a transition are related to the type of feedstock or raw material used for ethanol production and the processes to convert that feedstock into ethanol. Variables were derived from these impacts and were framed to focus on changes at two different stages of the lifecycle of ethanol: feedstock production (I) and conversion processes at the refinery (II) (Table 2).

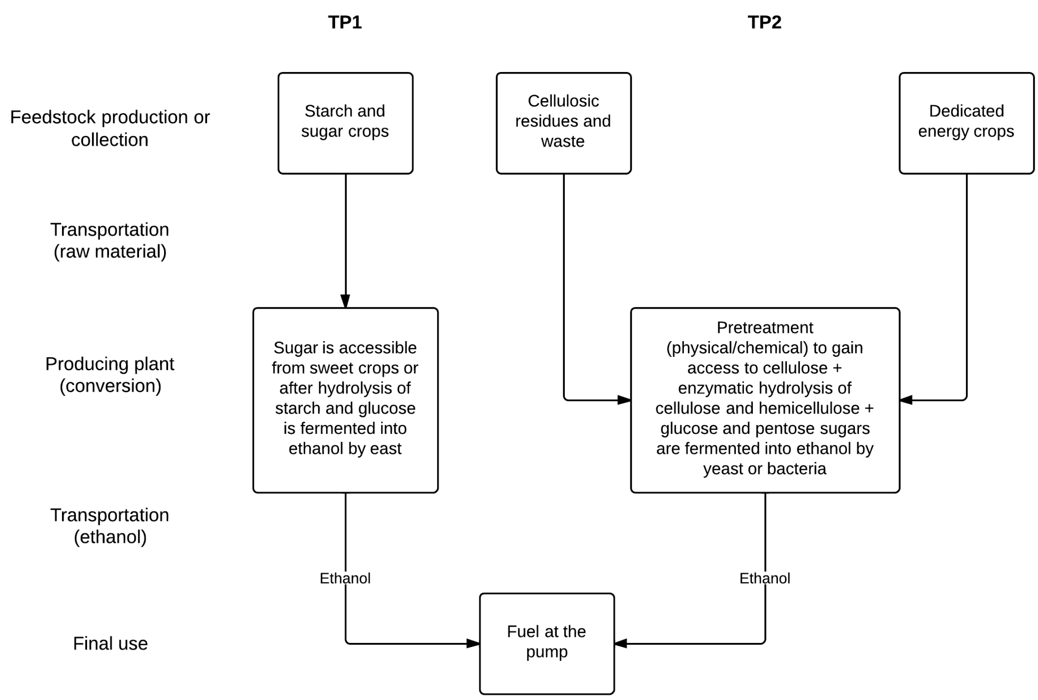
Table 2. Definition of potential social impacts

Variable #	Stage	Definition
1	I	Inclusion of small-scale farmers in the supply chain of cellulosic ethanol, which may be affected by different farming techniques and management needs (e.g. Farm inputs, machinery, logistics etc.).
2	I	On-site food security, defined as the current and future equitable and sufficient access to affordable nutritious food by locals, especially vulnerable groups. It may be affected by the competition for land and other natural resources (on-site ecosystem services) between cellulosic feedstock and food crops, and by impacts of the former on soil fertility.
3	I	Off-site food security, defined as the current and future equitable and sufficient access to affordable nutritious food by people, especially vulnerable groups. It may be affected by direct competition (e.g. replacement of food crops plantations by cellulosic feedstock) or indirect competition (e.g. displacement of livestock production in land that could be used for food production in the future) for land and other natural resources of cellulosic feedstock and food crops, and by impacts of the former on soil fertility.
4	I	Water security (feedstock-related), defined as the current and future equitable and sufficient access to clean (safe) water by people, especially vulnerable groups. It may be affected by changes in the intensity of water-use for feedstock irrigation and by water pollution (e.g. contamination by chemical inputs released in the fields).
5	I	Biodiversity security, defined as the preservation of plant and animal species that are valuable to human societies (e.g. for biological pest control, for traditional uses, or to maintain the flow of other ecosystem services). It may be affected by, e.g., the implementation of monocultures, introduction of invasive plant species or deforestation.
6	II	Employment generation for low-skilled or unskilled workers at the power plant (conversion processes) and other facilities (R&D) due to changes in the demand for workers with lower professional qualification.
7	II	Inclusion of small-scale producers, i.e. locally owned and run facilities in the supply chain of cellulosic regarding the access (availability and affordability) to bioconversion technologies, e.g. machinery and industrial equipment, enzymes, chemical and energy inputs etc.
8	II	Water security (related to conversion processes needs), defined as the current and future equitable and sufficient access to clean (safe) water by people, especially vulnerable groups. It may be affected by changes in the intensity of water-use in the overall conversion process (e.g. hydrolysis and fermentation) and by water pollution.

5.4.3 Technological transitions in ethanol production

A variety of technological pathways exist for ethanol production. In the case of cellulosic ethanol, feedstock pre-treatments and conversion routes can be multiple and complex, involving different combinations of biological, chemical and physical processes (Sanchez and Cardona 2008; Kumar 2009; Menon and Rao 2012). In order to guarantee the feasibility of a survey that addresses a complex technical system, two generic technological pathways (TP1 and TP2) were devised to inform the analysis of the technical aspects of a transition between conventional and cellulosic ethanol (Fig. 2). These technological pathways were designed to represent hypothetical real-world scenarios, based on current technical literature.

Figure 2. Technological pathways for first-generation (TP1) and cellulosic ethanol (TP2) production



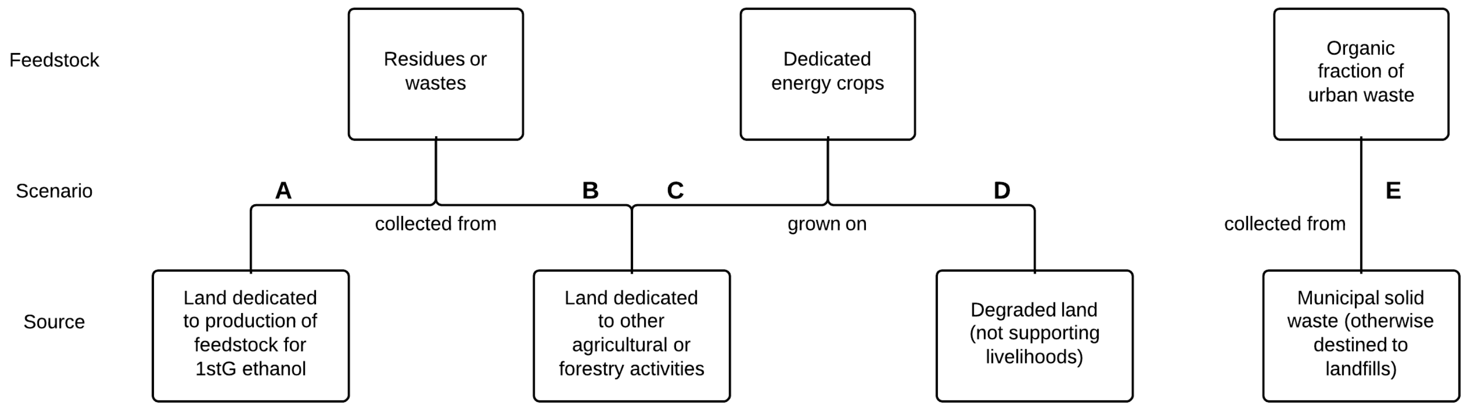
In TP1, conventional ethanol is produced from starchy or sugar crops, such as maize, wheat, sugarcane and sugar beet. Feedstock for TP2 is lignocellulosic material such as woody residues and agricultural residues like corn stover, wheat straw and sugarcane bagasse, dedicated energy crops like switchgrass and SRC and the organic fraction of SMW, which would otherwise be destined to landfills (Naik et al. 2010; Sims et al. 2010). In TP2, these are converted into cellulosic ethanol. The main technical differences between TP1 and TP2 relate to the access to sugar molecules for fermentation and the types of molecules that are fermented into ethanol. Both factors depend on the characteristics of the feedstock or raw material used, i.e. the source of sugar. While in starchy and sweet crops (as in TP1) sugar molecules are more readily accessible and easier to ferment, lignocellulosic material (as in TP2) presents a lignin barrier that hinders the access to cellulose and hemicellulose, complex polymers made of glucose and other types of sugars that are more difficult to ferment into ethanol (Lee 1997; Sun and Cheng 2002).

5.4.4 Criteria and scenarios for appraisal of social impacts

Three criteria were chosen to explore different dimensions of potential social impacts of cellulosic ethanol: their probability of occurrence, their degree of reversibility (dependent, for example, on the geographical scale of an impact and the potential costs to mitigate it) and their degree of monitorability, i.e. the possibility of identifying and measuring an impact so that mitigation strategies can be put in place (dependent, for example, on the complexity and number of indicators needed, levels of pre-existing knowledge and amount of resources needed). Although subject to different interpretations, 'probability' is a common dimension of the analysis of technological change in future-oriented research (Loveridge and Saritas 2012). 'Reversibility' and 'monitorability' are less popular criteria in the field of technology and social change analyses, but were deemed as worth of exploring due to their role in related fields of research. The notion of reversibility is attributed to interpretations of the Precautionary Principle, and is articulated in frameworks for ecological and sustainability analysis at both policy and project levels (Dovers 1995; Matheson et al. 1997; Faruk et al. 2002). It has also been directly explored in environmental analysis of the impacts of biodiesel production (Kaercher et al. 2013) and identified as an important, but overlooked dimension of impact significance in environmental impact assessment practice (Lawrence 1997). Verbruggen (2013) offers a comprehensive review on the usage of the concept by different disciplines in search of a workable definition for policy-making purposes. In attempting to bridge the gap between the use of reversibility and irreversibility in the natural and social sciences, the author proposes a generic definition of reversibility as “the ability to maintain and to restore the functional performance of a system” (Verbruggen 2013:26). Finally, the task of monitoring social change processes in the assessment of policies, programs, plans or projects has been largely acknowledged in the social impact assessment literature as a crucial component of the assessment process (Becker 2001; Vanclay 2003b; Baines et al. 2012; Esteves et al. 2012)

Questionnaires used in the two first rounds included close-ended questions for the appraisal of the probability, reversibility and monitorability of each of the eight impacts against different scenarios, with a space for comments at the end of each section. In round 1, five generic scenarios (A-E) based on the type of feedstock and the type of land for the production of cellulosic ethanol guided the appraisal of impacts related to the stage of feedstock production (Fig. 3). For the stage of conversion processes, scenarios were differentiated in terms of low, middle and high-income countries. Initial scenarios were informed by Ribeiro (2012) and Ribeiro (2013). Close-ended questions consisted of five point Likert-type items, a variation of the Likert scale that is based on the analysis of individual items rather than on the analysis of the summed item scores (Clason and Dormody 1994).

Figure 3. Overview of feedstock-related scenarios for cellulosic ethanol



After completing the first round of the survey, participants received a report on its quantitative and qualitative results, which informed the questionnaire devised for round 2. In round 2, the same criteria were used to explore the same set of impacts of the first round. However, building on the results of the latter, the initial five generic scenarios (used in round 1) were further divided into more specific, hypothetical sub-scenarios regarding different geographical locations and more specific feedstocks (Table 3).

Table 3. Scenarios (round 1) and sub-scenarios (round 2)

Scenario A	
Feedstock: Residues or wastes	
Source: Land dedicated to production of feedstock for 1G ethanol	
A1	**A2**
Region: Centre-South of Brazil	**Region:** Eastern Africa (e.g. Sudan, Tanzania, Kenya)
Type of feedstock: Sugarcane bagasse, straw, leaves	**Type of feedstock:** Sugarcane bagasse, straw, leaves
Scenario B	
Feedstock: Residues or wastes	
Source: Land dedicated to other agricultural or forestry activities	
B1	**B2**
Region: Western Europe (e.g. UK, Germany)	**Region:** South Asia (e.g. India)
Type of feedstock: Wheat straw	**Type of feedstock:** Rice straw
Scenario C	
Feedstock: Dedicated energy crops	
Source: Land dedicated to other agricultural or forestry activities	
C1	**C2**
Region: United States	**Region:** Eastern Africa (e.g. Uganda)
Type of feedstock: Short rotation coppices (e.g. Poplar)	**Type of feedstock:** Short rotation coppices (e.g. Eucalyptus)
Scenario D	
Feedstock: Dedicated energy crops	
Source: Degraded land (land disturbed by human impact)	
D1	**D2**
Region: Eastern Europe (e.g. Poland, Hungary)	**Region:** Western Africa (e.g. Benin, Togo)
Type of feedstock: Pernnial grasses (e.g. Miscanthus, switchgrass)	**Type of feedstock:** Perennial grasses (e.g. Miscanthus, switchgrass)
Scenario E	
Feedstock: Organic fraction of urban waste	
Source: Municipal solid waste (otherwise destined to landfills)	
E1	**E2**
Region: Canada	**Region:** Eastern China (e.g. Shangai)
Type of feedstock: Urban waste	**Type of feedstock:** Urban waste

5.5 Results of the Delphi survey

Quantitative and qualitative analysis of the results were performed. In this paper, we limit the presentation of quantitative results to participants' ratings of variables in the second round (medians, means and standard deviations). Since the questionnaire used in the second round involved different scenarios compared to the first one, no statistically significant correlation was expected between results of different rounds. However, qualitative data, in the form of comments, was collated and coded for both rounds and are also summarised alongside quantitative results in the next sections of this paper. Bryman (2012) argues that although there are epistemological and ontological differences between quantitative and qualitative research, their dichotomies, e.g. empiricist versus constructivist approaches, numbers versus words etc. are often exaggerated. In other words, their analyses should not be regarded as incommensurable. As the questionnaires designed for the present Delphi included both quantitative and qualitative components, the study is characterised as a mixed methods exercise (Bryman 2012).

5.5.1 Inclusion of small-scale farmers in the supply chain of cellulosic ethanol

The inclusion of small-scale farmers as suppliers of raw material in the supply chain of cellulosic ethanol may be affected by various factors, such as costs of adaptation to different farming techniques, technologies and management needs, farmers' perception of investment risk and the existence of support mechanisms offered by governments. For the majority of scenarios, experts considered that the inclusion of small-scale farmers in the supply chain of cellulosic ethanol would be rather unlikely (Table 4). An exception to this might be situations where cellulosic ethanol is produced from residues, (e.g. wheat straw), from land dedicated to agricultural or forestry activities independent of biofuel production in countries such as the UK or Germany. This would be the best-case scenario for small-scale farmers. Conversely, the probability that small scale-farmers would be successfully included in production chains in poorer countries was suggested to be low, irrespective of feedstock.

Panellists indicated that the collection of residues could be costly due to high technological costs and the requirement of qualified labour. Its economic feasibility was also perceived to be dependent on the geographical distribution of ethanol plants (i.e. how close and well-connected these are to locations where the raw material is produced). Another point made by participants is that there is a risk that only large-scale producers would be able to provide great levels of feedstock at lower prices as demanded by the ethanol industry. As pointed out by one individual, “there are almost no small (i.e. peasant) farmers involved in bioenergy feedstock production in the US, although there are efforts to involve non-corporate farmers and private landowners in growing dedicated energy crops on abandoned agricultural land” (participant 22). Moreover, according to another panellist, the ‘lobby power’ held by large landholders might also have a detrimental effect on the inclusion of smallholders in the ethanol supply chain.

Should small-scale farmers begin to grow dedicated energy crops for the production of cellulosic ethanol, they would be likely to face difficulties in returning to their previous cropping systems (Table 4). Important factors that need to be considered in this regard are costs and return on investment, the type of crop being cultivated and the related process of land-use change. An example is the case of perennially rooted crops, which are perceived as being “harder to dislodge than, for example, fodder maize” (participant 15). Experts argued that this was not simply a situation of ‘ploughing up the crop’; reversibility needs to include business considerations, such as investment risk and the development of complex, new markets around products and co-products, which significantly complicate the picture.

In the opinion of participants, monitoring the inclusion of small-scale farmers in the supply chain of cellulosic ethanol would be more difficult in poorer countries because of a lack of resources and potentially corruptive practices (Table 4). Despite this, there may be ways of implementing invoice systems to track the origin of the feedstock and controlling financial transactions or lorry loads to monitor the activities of farmers. Again, the potential for implementing these mechanisms would be likely to correlate to economic development. Others indicated, however, that monitoring this particular variable can be rather complicated due to the complexity of the supply chain and its related markets.

Table 4. Inclusion of small-scale farmers in the supply chain of cellulosic ethanol

Scenario	Probability (1-lower "very unlikely", 5-higher "very likely")			Reversibility (1-lower "very difficult", 5-higher "very easy")		
	Median	Mean	SD	Median	Mean	SD
A1	2	2.43	1.15	3	2.78	1.18
A2	2	2.43	0.85	3	2.77	1.16
B1	4	3.23	1.09	3	3.42	0.99
B2	2.5	2.83	1.19	3	3.08	1.16
C1	2.5	3	1.10	2.5	2.43	0.64
C2	2	2.33	0.98	2	1.93	0.61
D1	3	3	0.96	3	2.92	0.91
D2	2.5	2.5	0.84	2.5	2.71	1.06

	Monitorability (1-lower "very difficult", 5-higher "very easy")		
	Median	Mean	SD
Low-income countries	2	2	0.96
Middle-income countries	3	2.86	0.77
High-income countries	4	3.73	0.79

5.5.2 Impacts on food security

Two dimensions of food security were explored in the study. The first referred to the impacts on local (on-site) food security at the site of production (i.e. equitable and sufficient access to food by locals from communities where feedstock for cellulosic ethanol may be produced). The second aimed to explore the effects of large-scale feedstock production for cellulosic ethanol on food security at a broader scale (off-site) (i.e. equitable and sufficient access to food by people, especially vulnerable groups, from other areas than feedstock hosting communities).

For both local and macro-level food security, the best-case scenarios (i.e. those where food security is perceived as being least threatened) were those in which MSW, otherwise destined to landfills, was used as feedstock for producing cellulosic ethanol, disregard the country of production (Table 5). Following these as second-level best-case scenarios, were those where feedstock is cultivated or collected in countries like the UK and the US. In contrast, scenarios where dedicated energy crops such as SRC and perennial grasses are grown in African countries, such as Uganda and Kenya, were perceived as being potentially detrimental to local food security. In this situation, cultivating these crops in land previously dedicated to other agricultural or forestry activities would likely be more menacing to on-site food security than doing it on degraded land. Indeed, one panellist suggested that growing energy crops on degraded land might "even have a positive impact on productivity due to an increase in the levels of nitrogen in the soil" (Participant 14). There was much less consensus about the worst-case scenarios for macro-level food security than local food security in the expert group. Scenarios that rated slightly worse than others (in terms of frequency of responses) were again those where raw material for cellulosic ethanol is collected or cultivated in African countries.

Many factors play a role in food security levels, regarded by panellists as a complex issue, in which it is difficult to generalise. As one participant puts it, "attribution of food insecurity to biofuel production is contested and contestable, requiring isolation of interacting factors, often spatially and temporally remote from each other" (Participant 15). As indicated by another expert, impacts on local food security will also depend on specific consumption baskets (share of the budget spent on food and consumed types of food), so they are likely to vary from place to place, among different classes or even ethnic groups within the local population. Experts also indicated that governments have an important role in guaranteeing food security by implementing social policies and regulating land-use. Examples offered refer to Brazil's "bolsa família", which provides direct and continued financial help to impoverished families, and the national program of sugarcane zoning that restricts cultivation of such feedstock to specific areas within the country.

In terms of re-establishing food security by mitigating the competition of cellulosic feedstock with food crops, experts considered the case where dedicated energy crops were grown on land dedicated to other activities in African countries as the hardest to manage, (i.e. lower reversibility, both for local and macro food security; Table 5). For residues and wastes the task was perceived as being easier, since farmers could just keep or plough the residues back into soil. However, some argued that it might take time to achieve the same harvest levels again. As for the monitorability of changes in the levels of food security there was clear consensus that local food security would be more difficult to monitor in African, low-income countries than in middle-income countries such as Brazil and high-income countries. In the case of the latter, experts considered monitoring as a relatively easy activity. The majority of experts believed that monitoring food security on a larger-scale to be significantly more difficult task than at the local level (Table 5).

Table 5. Negative impacts on food security

Scenario	Probability (1-lower "very unlikely", 5-"very likely")						Reversibility (1-lower "very difficult", 5-higher "very easy")					
	On-site food security			Off-site food security			On-site food security			Off-site food security		
	Median	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median	Mean	SD
A1	3	2.8	0.94	2.5	2.71	1.2	4	3.38	1.19	3.5	3.14	0.94
A2	3	3	0.78	3	3.07	1.2	3	3.23	1.16	4	3.23	0.92
B1	2	2.47	0.83	2	2.28	0.82	4	3.92	0.86	4	3.71	0.82
B2	3	2.85	0.98	2.5	2.67	1.07	3	3.46	1.05	4	3.61	0.86
C1	2	2.53	0.99	3	2.86	0.77	3	2.75	0.62	3	2.77	0.83
C2	4	3.64	0.84	3	3.14	1.02	2.5	2.43	0.64	2.5	2.43	0.64
D1	3	2.77	1.16	3	2.46	0.87	3	3.31	0.94	3	3.3	0.99
D2	3.5	3.28	1.06	3	2.54	0.87	3	3.25	1.05	3	3.14	1.09
E1	1	1.4	0.63	1	1.36	0.63	4	3.86	1.06	4	3.87	1.12
E2	1	1.5	0.75	1	1.5	0.75	4	3.86	1.06	4	3.78	1.09

	Monitorability (1-lower "very difficult", 5-higher "very easy")					
	On-site food security			Off-site food security		
	Median	Mean	SD	Median	Mean	SD
Low-income countries	2	2.08	0.86	1	1.5	0.74
Middle-income countries	3	2.71	0.99	2	2	0.87
High-income countries	4	3.61	0.96	2	2.4	1.24

5.5.3 Impacts on water security

Water security depends on several factors, including the actual demand for water for growing crops, for converting glucose into ethanol at the refinery and the potential water pollution from both stages. To try to capture this, the issue of water security was analysed in the survey using two variables corresponding to water use at the feedstock production phase and at the producing plant. Of all variables assessed by panellists, impacts on water security were by far the most uncertain (regarding the frequency with which experts would tick the “not sure” box), especially with regards to the stage of conversion processes. As indicated by one participant, “water impacts are considered as unknown by many” (Participant 17).

Despite acknowledging these high levels of uncertainty, the majority of participants went on to rate the variable in each scenario. At the stage of feedstock production, converting land which had previously been devoted to other agricultural or forestry activities to dedicated energy crops in African countries was considered to be the worst-case scenario for water security (Table 6). Conversely, the case of cultivated perennial grasses and collected residues in European countries, were forecasted to perform much more positively. One participant argued that feedstock types for cellulosic ethanol that require irrigation would be unlikely to become commercially viable and that “water quantity and quality will be generally improved by having more perennials on the landscape” (Participant 4). However, as indicated by another panellist, additional irrigation might be needed if dedicated crops are planted in degraded land. For some participants, the amount of water used was seen to be much more dependent on agricultural practices and water management systems than crop feedstock selection; ultimately, any badly managed crop could have negative impacts on water security. For residues and wastes, water demand might be less of an issue, but “minimum amounts of residues must remain on the ground in order to protect it from erosion, loss of nutrients and water” (Participant 14). Moreover, one should also consider that, in the future “climate change may reduce water availability in many regions” (Participant 10).

There was little consensus on how conversion technologies would impact on water security. When converting cellulosic feedstock into ethanol, participants rated the case of low and middle-income countries equally, but below high-income countries (Table 7). Factors raised as important to consider by participants were the size of the conversion plant, the specifics of the pre-treatment processes for the biochemical route, which “might use lots of water” (Participant 4), whether water is recycled or not, and other baseline conditions such as local water availability and the amount of toxic water that is discharged in waterways.

Re-establishing water security was regarded as being moderately difficult to difficult in all scenarios (Tables 6 and 7). Participants indicated that technology improvements could play a decisive role in reducing water demand through improved efficiency, for example. For one of the panellists, if understood as mitigation potential, and from a technical standing point, reversibility would not differ much between scenarios in the stage of feedstock production. However, he added that, “the potential for actually fundamentally modifying the supply chain depends on so many factors that is rather hard to compare the scenarios” (Participant 11).

Monitoring water demand and pollution at the feedstock production stage was considered to be more difficult than for the conversion phase (Tables 6 and 7). It could also vary between countries due to institutional capacity, which is thought to be higher in higher income countries. Experts suggested a range of quantitative and qualitative indicators and tools that could be used to monitor water use efficiency, including m3 of water/ton of ethanol, water footprint and watertable (Participant 23).

Table 6. Negative impacts on water security (feedstock-related)

Scenario	Probability (1-lower "very unlikely", 5-higher "very likely")			Reversibility (1-lower "very difficult", 5-higher "very easy")		
	Median	Mean	SD	Median	Mean	SD
A1	3	2.71	0.91	3	2.83	0.83
A2	3	2.86	0.94	3	2.83	0.83
B1	2.5	2.5	1	3	3	0.85
B2	3	2.9	1.3	3	2.8	0.78
C1	3	3	0.89	3	2.63	0.8
C2	4	3.6	1.07	2	2.42	0.79
D1	2	2.7	1.05	3	2.83	0.93
D2	3	2.9	1.05	3	2.83	0.93
E1	1	1.71	1.06	4	3.75	1.03
E2	1	1.71	1.06	4	4	1.06

	Monitorability (1-lower "very difficult", 5-higher "very easy")		
	Median	Mean	SD
Low-income countries	2	1.73	0.79
Middle-income countries	2	2.33	0.89
High-income countries	3	2.93	0.79

Table 7. Negative impacts on water security (conversion processes)

Scenario	Probability (1-lower "very unlikely", 5-higher "very likely")			Reversibility (1-lower "very difficult", 5-higher "very easy")		
	Median	Mean	SD	Median	Mean	SD
Low-income countries	4	3.44	1.01	2	1.83	0.71
Middle-income countries	4	3.44	1.01	2	2	0.73
High-income countries	3	2.87	0.83	2.5	2.5	0.52

	Monitorability (1-lower "very difficult", 5-higher "very easy")		
	Median	Mean	SD
Low-income countries	2	2.2	0.94
Middle-income countries	3	2.87	0.91
High-income countries	3	3.4	0.5

5.5.4 Impacts on biodiversity security

The potential social consequences that could be related to the impact of cellulosic ethanol production on biodiversity levels were defined in terms of biodiversity security. This is the preservation of plant and animal species that are valuable to human societies, or that could be valuable in the future. Examples of value include biological pest control functions or to maintain the flow of other ecosystem services. Compared to residue collection scenarios, the majority of panellists consider that the cultivation of dedicated energy crops is more likely to have negative impacts on biodiversity levels (Table 8). Here, experts did not differentiate between the country of production or the specific kind of crop being cultivated (e.g. SRC vs. perennial grasses). Several experts pointed out that the cultivation of such crops could favour the expansion of monocultures, inherently decreasing biodiversity levels. Moreover, the risk of negative impacts could be greater in low and middle-income countries, "as laws protecting forests in most developing countries are vague and inadequate" (Participant 2). In contrast, some degree of dissent among experts was observed regarding the effects of collection of sugarcane straw in Brazil and African countries in threatening biodiversity. For example, one participant referred to the necessity of taking into account the intensity with which straw is harvested: "The impacts we perceive are low if the 'take' is moderate (say 30%-50%). […], Overstripping of crop residues will likely lead to soil carbon loss and increased biodiversity risk" (Participant 16). Some experts indicated the importance of establishing a more detailed baseline scenario with which to work to assess the variable. As argued by another participant, "for energy crops, biodiversity impacts and reversibility largely depend on the baseline conditions […] this illustrates one of the main problems with bioenergy impact assessment – so much is site specific" (Participant 15).

Panellists attributed very low reversibility for biodiversity levels for all scenarios[35] (Table 8), suggesting that mitigating a decrease on biodiversity levels would be a difficult or very difficult task. Of all impacts, biodiversity security is the variable that rates the lowest for reversibility, independent of the type of feedstock being collected or cultivated. As one expert puts it, "restoring prior biodiversity levels is not a very realistic scenario" (Participant 10). Although participants rated all scenarios as equally low (i.e. same median value) the effects of the collection of straw in countries like the UK on biodiversity were perceived as being easier to mitigate compared to the rest of scenarios.

[35] Except for collection of urban waste, which does not apply to this variable.

There was consensus on the difficulty of monitoring the loss of biodiversity (Table 8), considered by experts as one of the most difficult impacts to monitor, along with off-site food security. As indicated by a panellist, "it is very difficult to measure and monitor biodiversity, so we will have a difficult time saying anything definite about it" (Participant 4). Additionally, monitoring biodiversity levels was perceived as being a harder task in low and middle-income countries than in high-income countries. Experts stressed that it can be a time-consuming, expensive activity that depends on prior-knowledge of species diversity or abundance and that requires skilled labour, among other factors.

Table 8. Negative impacts on biodiversity security

Scenario	Probability (1-lower "very unlikely", 5-higher "very likely")			Reversibility (1-lower "very difficult", 5-higher "very easy")		
	Median	Mean	SD	Median	Mean	SD
A1	3	3.14	1.09	2	2.27	0.88
A2	3	3.28	1.06	2	2.13	0.83
B1	3	2.71	0.61	3	2.73	0.96
B2	3	2.86	0.77	2	2.43	0.85
C1	4	3.64	0.63	2	2.27	0.79
C2	4	3.93	0.73	2	1.93	0.73
D1	4	3.71	0.82	2	2.28	0.82
D2	4	3.78	0.89	2	2.14	0.86
E1	1	1.4	0.63	4	3.83	0.75
E2	1	1.4	0.63	3.5	3.67	0.81

	Monitorability (1-lower "very difficult", 5-higher "very easy")		
	Median	Mean	SD
Low-income countries	1	1.47	0.74
Middle-income countries	2	1.93	0.79
High-income countries	2	2.33	0.89

5.5.5 Exclusion of low-skilled workers in the stage of conversion processes

The penultimate variable assessed by participants was the potential exclusion of low-skilled workers at the feedstock conversion stage. Despite some variability in responses, the majority of experts hold that low-skilled workers will likely be excluded from the supply chain of cellulosic ethanol (Table 9). Median-values regarding the probability of this potential impact were the same for all three scenarios (i.e. low, middle and high-income countries). However, despite acknowledging the role of technological specialisation and the use of advanced systems, participants perceived the inclusion of low-skilled workers as an issue that is also very much dependent upon specific social circumstances and companies' policies. Accordingly, the existence of, for example, incentives to develop workers' skills and the ability of governments and companies to offer training would likely be decisive factors in determining the outcomes of the variable. As indicated by a panellist, "it depends on the context, there is nothing inherent in these jobs that excludes low-skilled workers if you are going to be putting in place training programs" (Participant 18). In any case, participants seem to consider that this would be an easier process in high-income countries (Table 9). The difficulty of including low-skilled workers at the conversion processes stage shouldn't, however, be regarded an exclusive issue of cellulosic ethanol. As pointed out by another panellist, "both first and second-generation processes are highly technical" (Participant 7).

Monitoring the demand for and the inclusion of low-skilled workers in the supply chain of cellulosic ethanol was, comparatively, rated as being easier than for other impacts (Table 9). The same pattern applies for other variables appraised in the survey, i.e. monitoring of impacts was perceived to be an easier task in high-income countries than in middle and low-income countries due to issues of institutional capacity and availability of resources.

Table 9. Exclusion of low-skilled workers in the stage of conversion processes

Scenario	Probability (1-lower "very unlikely", 5-higher "very likely")			Reversibility (1-lower "very difficult", 5-higher "very easy")		
	Median	Mean	SD	Median	Mean	SD
Low-income countries	3.5	3.43	1.15	2	2.14	1.02
Middle-income countries	3.5	3.36	0.92	2.5	2.36	0.92
High-income countries	3.5	3.21	0.89	3	2.57	0.75

Scenario	Monitorability (1-lower "very difficult", 5-higher "very easy")		
	Median	Mean	SD
Low-income countries	2	2.53	0.83
Middle-income countries	3	2.87	0.63
High-income countries	3	3.53	0.63

5.5.6 Exclusion of small-scale producers in the supply chain of cellulosic ethanol

Similar to the case of small-scale producers of feedstock, panellists considered that small-scale producers of ethanol, i.e. those involved with the conversion of feedstock into biofuel, are likely to be excluded from the supply chain of cellulosic ethanol, especially in low and middle-income countries (Table 10). Many pointed out the problem of unequal market competition with large-scale producers that could be faced by low-volume producers. Technical capability and costs to produce cellulosic ethanol were also identified as important factors that could hinder production at a smaller scale. As one expert illustrated, "the option [of including small-scale producers in the ethanol supply chain] was tested in the beginning of the 'Proalcool' program [in Brazil], but did not stand the competition with large companies. […] In the case of second-generation, a technology more expensive than first-generation *per se*, competition will be even harder" (Participant 14). Others considered that as with the inclusion of low-skilled workers, the exclusion of small producers might also depend on factors like the implementation of incentive structures by governments and the specific behaviour of companies. Rated as the easiest impact to monitor from all variables appraised in the Delphi survey, the task of monitoring is nevertheless considered to be more complicated in poorer countries (Table 10).

Table 10. Exclusion of small-scale producers in the supply chain of cellulosic ethanol

Scenario	**Probability** (1-lower "very unlikely", 5-higher "very likely")			**Reversibility** (1-lower "very difficult", 5-higher "very easy")		
	Median	Mean	SD	Median	Mean	SD
Low-income countries	4	3.67	1.11	2	2	0.78
Middle-income countries	4	3.67	1.17	2	2	0.78
High-income countries	4	3.73	1.09	3	2.43	0.75

	Monitorability (1-lower "very difficult", 5-higher "very easy")		
	Median	Mean	SD
Low-income countries	3.5	3.14	1.02
Middle-income countries	3.5	3.28	0.91
High-income countries	4	3.71	0.72

5.6 Limitations and strengths of the study

Valuable messages regarding the limitations of the study can be drawn from the survey process. One of the most relevant issues in this regard refers to the complexity of the variables assessed. The appraisal of simplified 'versions' of complex concepts – that rely on single instead of multiple indicators, was valuable to unveil the various factors considered and assumptions made by the participants. However, these proved to be hard to work with in the absence of better-defined scenarios, revealing the limitations of Delphi exercises in tapping generalised, yet complex realities. During the design of the survey, a major issue that emerged from the attempt to generalise social aspects related to a technological transition of ethanol was that every variable involves a context-dependent component. A non-exhaustive list would include factors such as a specific company's policies, facilities' characteristics and the environmental and social context of hosting communities. The problem of context-dependency was later corroborated in the exercise through various comments made by participants, regarding the difficulty they had for assessing variables under generic, technology-based scenarios. Feedback from the evaluation questionnaire also indicated that:

- Participants found it difficult to assess variables and support their opinion in the absence of evidence (since cellulosic ethanol is still being produced on an experimental stage), and making judgements under briefly described scenarios;
- The questionnaire was considered to be long and include complex questions, making participation in the survey rather time-demanding;
- The design of the survey didn't allow space for a debate on the positive aspects of cellulosic ethanol and possible configurations of more sustainable biofuel systems.

One should note that the design and content of a Delphi study reflect the culture, bias and knowledge of its formulators (Linstone and Turoff 2002:226). This is valid for both proponents and designers of the study and those who participate in it. Surveys will be always limited in the sense that specific choices made by a group of individuals will shape the exercise and, thus, influence its results. Besides, the study cannot claim to be representative in terms of the experts' community involved in it and the appraisal is constrained by the types of expertise of selected participants.

On the other hand, feedback from experts also indicates important strengths of the Delphi study in which they participated. They considered the results useful to inform other assessments of cellulosic ethanol and to inform decision-making on biofuels policy. Some also indicated that their participation in the Delphi helped them learning more about the topics addressed in the survey and made them feel more interested about the social dimension of the impacts of cellulosic ethanol. Other aspects pointed out by experts as the main strengths of the study include:

- Its strong interdisciplinary character given the broad range of expertise involved;
- The interactive component of the method as a tool for knowledge pooling;
- The opportunity of reflecting upon key issues concerning the social impacts of biofuels through comprehensive questions and interesting scenarios.

5.7 Key considerations on the development of cellulosic ethanol

The analysis of the results of the Delphi survey presented in section 5.5 provides an opportunity to outline some important considerations regarding a transition to cellulosic ethanol with regards to its social sustainability.

5.7.1 Replacing the use of food crops, as feedstock in the production of conventional biofuels, for non-edible raw material to produce advanced biofuels such as cellulosic ethanol might not guarantee overcoming food security risks.

Apart from the case where cellulosic ethanol is produced from the organic fraction of urban waste, there are doubts regarding the effects of its production from other feedstock on food security. Whereas the use of residues and wastes as raw materials for cellulosic ethanol raises less concern among experts (except for potential effects of the removal of residues on worsening soil conditions), growing dedicated energy crops such as SRC and perennial grasses is perceived as a more 'risky' option in terms of a potentially detrimental interference in the food chain. This is mostly related to the substitution of current agricultural activities by energy crops, lower levels of reversibility for such cropping activities and the potential use of land that could otherwise be suitable for food production. With regards to the latter, many advocate instead for the use of land considered to be low-input or 'marginal' as legitimate sites for growing dedicated energy crops for the production of cellulosic ethanol (e.g. Tilman et al. 2006, Gopalakrishnan et al. 2009 and Swinton et al. 2011). However, in-depth analyses of the terminology demonstrate that such definitions are a matter of dispute and should be regarded with scepticism. As social constructs, they are ultimately created or adopted by certain groups of actors in order to defend their particular interests regarding land-use (Baka 2013 and Shortall 2013).

5.7.2 Feedstock production for cellulosic ethanol is inserted in the same agricultural paradigm to that of conventional ethanol.

An important result of the survey that helps to support this statement is the large consensus for scenarios where cellulosic ethanol is produced from urban waste (which should not involve land-use change) as best-case scenarios or as scenarios that wouldn't interfere at all with the variables assessed. Therefore, it seems logical to infer that the impacts of biofuels at the stage of feedstock production are very much related to the use of natural resources and changes in the use of land, irrespective of the type of feedstock being collected or cultivated. This inserts the case of biofuels in the same paradigm of any other agricultural activity, illustrated by the thesis of Beus and Dunlap (1990) as a dichotomy between conventional, industrialised and alternative, ecological agriculture. Issues such as the scale of production, the intensity in the use of fertilizers and herbicides, the expansion of monocultures, good or bad land management in terms of control of erosion - all highlighted by experts in the Delphi survey - are issues that also apply to agriculture overall. It is worth noting that such concerns might not be exclusive to first-generation biofuels. Nor might they be exclusive to growing dedicated energy crops, since bad practices in the collection of residues and wastes from agricultural and forestry activities could also entail negative environmental impacts on the soil and water. As indicated by experts in the survey, the replication of intensive, large-scale models of forestry and agricultural production in cellulosic ethanol production might lead to biodiversity losses and a decrease in the quality of water – impacts that are perceived as being potentially irreversible.

5.7.3 From the perspective of the inclusion of small landholders and small-scale producers in the supply chain, the contribution of cellulosic ethanol to rural development is uncertain.

An important factor to be considered in this regard relates to the potentially high costs of feedstock production, both for collection of residues and wastes and cultivation of dedicated energy crops, and of conversion processes into ethanol. Experts from the US and Brazil that participated in the survey indicate that the supply chain of first-generation ethanol is already dominated by large-scale producers in both countries. Besides technology costs, free market competition could also favour large-scale producers due to demand for lower-price products in the ethanol supply chain. Compared to a highly centralised oil industry, which is controlled by few corporations, biofuel production is characterised by a considerably decentralised system. Experts pointed out at the proximity of processing facilities in relation to the localities where feedstock is produced as an additional and significant factor influencing costs. On the other hand, while decentralisation could represent an opportunity to local empowerment (Bailey et al. 2011), several participants in the Delphi indicated that governments and companies would have a decisive role in guaranteeing that the benefits are effectively extended to rural communities (also stressed by Bailey et al. 2011). As recent research shows, the interests of host communities could end up being at odds with the ones of the industry and of regional and local governments in the absence of specific initiatives and programs aimed at empowering such communities (Ribeiro 2014).

5.7.4 The global South will likely experience the impacts of cellulosic ethanol production differently to the global North.

As previously indicated, the outcomes of social change processes are likely to be experienced differently across different groups of actors and contexts. Such differences may be generalised to nations, due to considerable disparities in regards to their socioeconomic and political contexts. This should be just as true for advanced biofuels as it is for conventional ones. For all variables, scenarios that refer to high-income countries rate better than those involving middle and low-income countries. The trend is especially noticeable in ratings of the monitoring or mitigation capacity of impacts by different nations. For poorer countries, a lack of resources or corruption within the system could compromise the latter, in the opinion of experts. The burden of impacts is likely to also depend on specific baseline conditions. For example, since a larger part of the budget of poor people is spent on food (Aerni 2008; Timilsina and Shrestha 2011), rural communities from African countries might be more vulnerable to changes in food availability and prices. This statement is supported by the opinion of experts in the survey. Different political cultures could also influence outcomes due to both specific regulations to protect the people and the environment, and because of issues of law enforcement and regulatory compliance. Participants particularly acknowledged this point with regards to land-use practices, water management and biodiversity conservation, which could be more controversial in the global South. This has major implications for biofuels governance, especially regarding international markets and novel regulatory mechanisms and initiatives for 'ensuring' sustainability, such as certification schemes.

5.7.5 The appraisal of the impacts of advanced biofuels is a complex task.

Several experts emphasised in the survey that the impacts of cellulosic ethanol production depend largely on the baseline conditions considered in appraisals. Despite the possibility of building on real data of studies on the impacts of conventional ethanol, such context-dependence suggests that the assessment of potential impacts of cellulosic ethanol before its implementation at a commercial scale involves high levels of uncertainty. Not only baseline conditions are unknown, but also the establishment of assumptions and boundaries of the system are steps in the design of the study that have great influence on its results. This is already acknowledged by lifecycle assessments (LCA) of biofuels, especially in regards to the considerable number of competing results for GHG and energy balance of certain supply chains (see Larson 2006; Cherubini et al. 2009; Borrion 2012). In so far as any in-depth analysis of the social dimension of biofuels would depend on the establishment of a series of environmental, social, economic and technical parameters, the same difficulty or higher could be expected. Attempts to translate LCA into the social realm through systematising and accounting for the social impacts of products have resulted in interesting approaches (see e.g. Jorgensen et al. 2008 and Benoît et al. 2010). These studies however do not address other important aspects of the social dimension of technological change such as disputing interests and behaviour of specific actors, the public demand and acceptance of technology and the normative dimension of the appraisal. Further, all LCAs and assessments have embedded assumptions that are hardly ever disclosed (Boucher et al. 2014). These are all relevant points of discussion regarding the variables assessed in the Delphi – such discussion, however, goes beyond the scope of the present study. More specific considerations around the challenges of appraising the social impacts of cellulosic ethanol include the uncertainty regarding the development of new markets around supply chains and their potential complexity; the unpredictable perception of investment risk by producers and difficulty in understanding the spatial and temporal dimensions of factors that interfere with variables such as food security. In this line, "biofuel impact assessment continues to push the limits of impact assessment methods" (Upham and Smith 2014:267).

5.8 Conclusions

The process of reflection and discussion on the different scenarios for cellulosic ethanol production allowed experts that participated in the Delphi survey presented in this paper to disclose some of the main assumptions that would guide their ratings, and important factors that play a role in the social impacts assessed. Their comments support the claim that assessing the social sustainability of a development such as cellulosic ethanol is not a straightforward task, and that outcomes are largely context-dependent. Since cellulosic ethanol is yet to be produced at a commercial level, there are also high levels of uncertainty and ignorance surrounding its potential social and environmental impacts. The occurrence and severity of impacts are associated with different processes of land-use change, types of feedstock used and to the different nations in which production of raw material for cellulosic ethanol or the production of the biofuel itself might take place. In general, the use of waste and residues as feedstock for cellulosic ethanol production is perceived as preferable over the use of dedicated energy crops. Also, low and middle-income countries of the global South are seen as more vulnerable to negative impacts than high-income countries from the global North. However, apart from the case of cellulosic ethanol produced from urban waste, all potential supply chains may face the same societal and environmental challenges faced by conventional ethanol. These are related to doubts regarding their potential to contribute to rural development, possible detrimental effects of land-use change and potentially negative impacts on biodiversity and water.

Although the production of cellulosic ethanol has not yet reached large-scale proportions, it is the intention of the industry to reduce costs and make its commercial deployment viable. Meanwhile, demonstration facilities and policy incentives provide the opportunity for other technologies, markets and social actors to evolve from and get involved with the development of cellulosic ethanol. With reservations concerning potentially deterministic views on technological change, the social control over technologies tends to diminish in face of the continued development and increased complexity of sociotechnical systems. This has been an acknowledged fact for many decades (see e.g. Collingridge 1980) and is relevant for the social appraisal of emerging science and technological developments such as the case of cellulosic ethanol. Participants in the Delphi supported this statement by pointing out at several issues that relate to aspects of reversibility of the technical system and to institutional capacities and political cultures of nations where projects could be implemented. This suggests an extension of the thesis of the social construction of technology to the governance of its potential impacts. Not only our capacity of controlling technological change is diminished in face of complexity, but also our chances of properly governing or avoiding its impacts might be lower. In this sense, negotiating technical options ultimately means governing also their related social change processes. As argued by Winner (2001), boosting, not constraining negotiation possibilities in the appraisal of energy alternatives, should be the tendency here. The development of each alternative, e.g. cellulosic ethanol or other advanced biofuels, should be viewed as a multidirectional process (see Pinch and Bijker 1993). As such, different technologies and technological pathways are seen as being possible and each requires appraisal from a range of relevant actors. It is highly desirable that assessments involve affected or interested actors, beyond disciplinary experts. As it is shown for the case of cellulosic ethanol, specific environmental and social contexts have to be considered in their singularity and real case studies should not obviate this.

From the analysis of some of its potential social impacts, this study does not provide an answer on which is the 'best' way to take regarding the development of cellulosic ethanol. It attempts to offer, instead, a few messages to technology developers and decision-makers. Innovations in biofuel technologies might be motivated by different concerns, such as sustainability issues, the prospect of new markets and consumer demand. The former has taken on a particular political relevance in the EU. However, while much of the 'ability' of innovations in addressing concerns such as sustainability relies on important technical features of developments like, for example, the notion of efficiency or reversibility, it also depends on contextual, societal factors (Quintanilla 1993; 2005). In this sense, behind the positive and negative outcomes of scientific and technological developments are the mechanisms responsible for governing their production, applications and impacts. Such mechanisms are embedded in different scientific and political cultures, which will ultimately influence their consequences on society and on the environment. Therefore, deciding on energy futures is not only a matter of responsibility of technology developers, funders and users, but also of political commitment to more participatory, comprehensive and transparent practices in the appraisal of technological change. It is crucial to evaluate *if* and *how* the production of cellulosic ethanol would help overcoming the various issues that have already been raised and evidenced for the production of conventional biofuels. More adequate regulatory measures and incentive mechanisms would follow. The results of the Delphi study presented in this paper suggest that in this regard important challenges remain. If these are not properly addressed, there is a risk that advanced biofuels such as cellulosic ethanol will not be justifiable from a sustainability standing point – something that would ultimately undermine the legitimacy of its political support.

Apéndice D. Cuestionarios utilizados en el estudio

Primera Ronda

TEG Delphi - Round 1

Please read the "Guidance Document" before starting to complete the survey. If you're completing this form offline as a PDF, please make sure to use the latest version of Adobe Reader, **since it will not work properly using other programs**. The Adobe Reader is available for free at: http://get.adobe.com/reader/

1. Expert's profile *(Your personal information will be kept confidential)*

1.1. First name **1.2. Last name** **1.3. Email** *(please provide only one email address)*

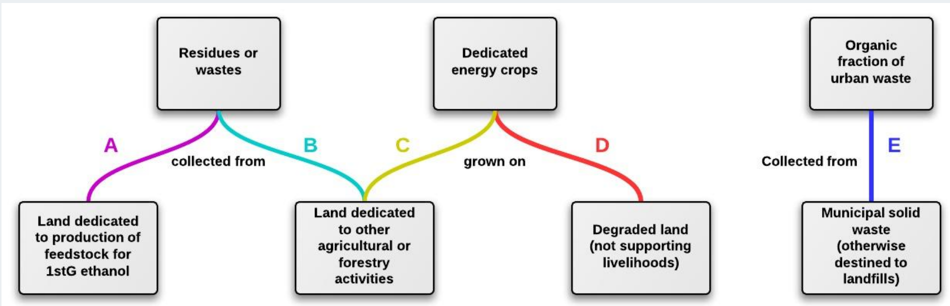
1.4. Institution's name **1.5. Country** **1.6. Area(s) of expertise**

2. Assessment of potential social impacts of TEG

In the next sections, you will be presented with a set of **eight potential impacts** involved in the TEG. You are invited to assess their **probability**, **reversibility** and **degree of monitorability**. Impacts are distributed in two stages of ethanol's lifecycle: the feedstock production (I) and conversion processes (II). For the feedstock production (I), five scenarios apply (A to E). When completing this form online, you will find a description of each impact (variable) by placing the mouse arrow on the interrogation mark on the right side of the related statement. There is a box for inserting comments at the end of each section. Please feel free to comment on any aspect of this questionnaire.

Please refer to the "Guidance Document" while completing the survey.

FEEDSTOCK PRODUCTION (I) - Impact 1



Scenario A. **The collection of cellulosic residues/waste from feedstock used in the production of 1G-ethanol**, to use as feedstock for cellulosic ethanol...

Scenario B. **The collection of cellulosic residues/waste from land dedicated to other agricultural/forestry activities**, to use as feedstock for cellulosic ethanol...

Scenario C. **The cultivation of dedicated energy crops on land dedicated to other agricultural/forestry activities**, to use as feedstock for cellulosic ethanol...

Scenario D. **The cultivation of dedicated energy crops on degraded land (not supporting rural livelihoods)**, to use as feedstock for cellulosic ethanol...

Scenario E. **The collection of the organic fraction of urban waste collected from municipal solid waste**, to use as feedstock for cellulosic ethanol...

2.1. Would **facilitate the inclusion** of small-scale farmers in cellulosic ethanol's supply chain.

	Very Unlikely	Unlikely	About as likely as not	Likely	Very Likely
Scenario A					
Scenario B					
Scenario C					
Scenario D					

Regarding the previous impact, in the hypothetical case of occurrence:

2.1.1. Indicate the reversibility degree (less to more reversible) you would attribute to it, i.e. small-scale farmers returning to their previous cropping systems.

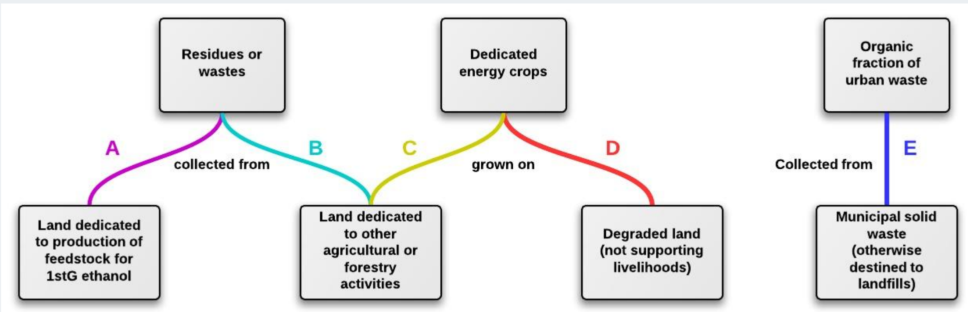
	1	2	3	4	5
Scenario A					
Scenario B					
Scenario C					
Scenario D					

2.1.2. Indicate the degree of monitorability you would attribute to the impact.

	1	2	3	4	5
All scenarios					

Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

FEEDSTOCK PRODUCTION (I) - Impact 2



Scenario A. **The collection of cellulosic residues/waste from feedstock used in the production of 1G-ethanol**, to use as feedstock for cellulosic ethanol...

Scenario B. **The collection of cellulosic residues/waste from land dedicated to other agricultural/forestry activities**, to use as feedstock for cellulosic ethanol...

Scenario C. **The cultivation of dedicated energy crops on land dedicated to other agricultural/forestry activities**, to use as feedstock for cellulosic ethanol...

Scenario D. **The cultivation of dedicated energy crops on degraded land (not supporting rural livelihoods)**, to use as feedstock for cellulosic ethanol...

Scenario E. **The collection of the organic fraction of urban waste collected from municipal solid waste**, to use as feedstock for cellulosic ethanol...

2.2. Will **threaten food security** at the local level (hosting and nearby communities).

	Very unlikely	Unlikely	About as likely as not	Likely	Very likely
Scenario A					
Scenario B					
Scenario C					
Scenario D					
Scenario E					

Regarding the previous impact, in the hypothetical case of occurrence:

2.2.1. Indicate the reversibility degree (less to more reversible) you would attribute to it, i.e. reestablishing on-site food security levels by mitigating competition of cellulosic feedstock with food crops.

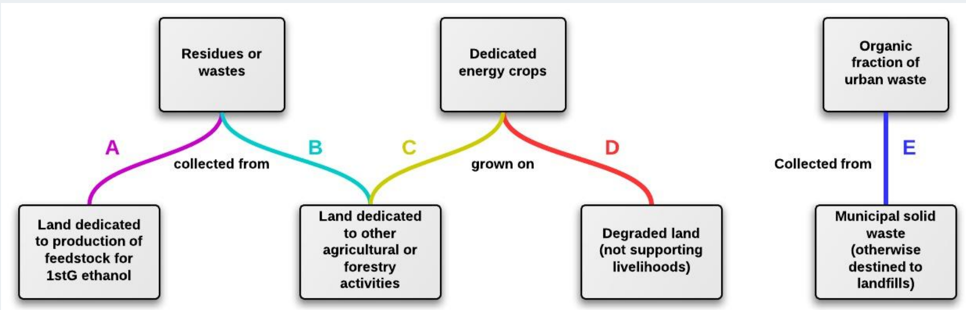
	1	2	3	4	5
Scenario A					
Scenario B					
Scenario C					
Scenario D					
Scenario E					

2.2.2. Indicate the degree of monitorability you would attribute to the impact.

	1	2	3	4	5
All scenarios					

Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

FEEDSTOCK PRODUCTION (I) - Impact 3



Scenario A. **The collection of cellulosic residues/waste from feedstock used in the production of 1G-ethanol**, to use as feedstock for cellulosic ethanol...

Scenario B. **The collection of cellulosic residues/waste from land dedicated to other agricultural/forestry activities**, to use as feedstock for cellulosic ethanol...

Scenario C. **The cultivation of dedicated energy crops on land dedicated to other agricultural/forestry activities**, to use as feedstock for cellulosic ethanol...

Scenario D. **The cultivation of dedicated energy crops on degraded land (not supporting rural livelihoods)**, to use as feedstock for cellulosic ethanol...

Scenario E. **The collection of the organic fraction of urban waste collected from municipal solid waste**, to use as feedstock for cellulosic ethanol...

2.3. Will **threaten food security** at the national or international levels.

	Very unlikely	Unlikely	About as likely as not	Likely	Very likely
Scenario A					
Scenario B					
Scenario C					
Scenario D					
Scenario E					

Regarding the previous impact, in the hypothetical case of occurrence:

2.3.1. Indicate the reversibility degree (less to more reversible) you would attribute to it, i.e. reestablishing off-site food security levels by mitigating competition of cellulosic feedstock with food crops.

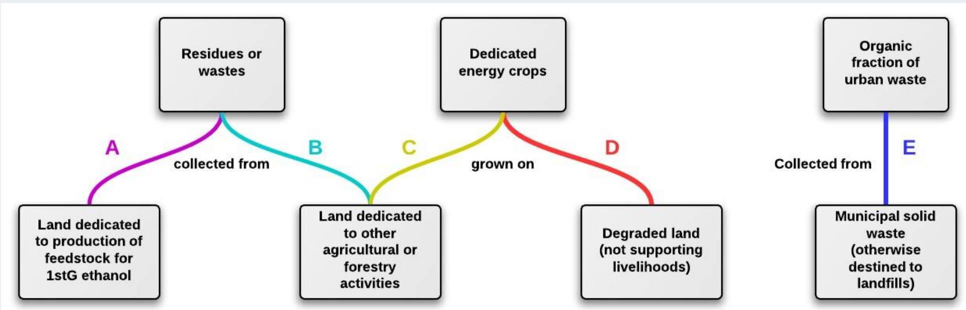
	1	2	3	4	5
Scenario A					
Scenario B					
Scenario C					
Scenario D					
Scenario E					

2.3.2. Indicate the degree of monitorability you would attribute to the impact.

	1	2	3	4	5
All scenarios					

Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

FEEDSTOCK PRODUCTION (I) - Impact 4



Scenario A. **The collection of cellulosic residues/waste from feedstock used in the production of 1G-ethanol**, to use as feedstock for cellulosic ethanol...

Scenario B. **The collection of cellulosic residues/waste from land dedicated to other agricultural/forestry activities**, to use as feedstock for cellulosic ethanol...

Scenario C. **The cultivation of dedicated energy crops on land dedicated to other agricultural/forestry activities**, to use as feedstock for cellulosic ethanol...

Scenario D. **The cultivation of dedicated energy crops on degraded land (not supporting rural livelihoods)**, to use as feedstock for cellulosic ethanol...

Scenario E. **The collection of the organic fraction of urban waste collected from municipal solid waste**, to use as feedstock for cellulosic ethanol...

2.4. Will **threaten water security** at the local and higher levels.

	Very unlikely	Unlikely	About as likely as not	Likely	Very likely
Scenario A					
Scenario B					
Scenario C					
Scenario D					
Scenario E					

Regarding the previous impact, in the hypothetical case of occurrence:

2.4.1. Indicate the reversibility degree (less to more reversible) you would attribute to it, i.e. reestablishing acceptable levels of water security in terms of quantity and quality by mitigating water pollution and reducing the intensity of water use.

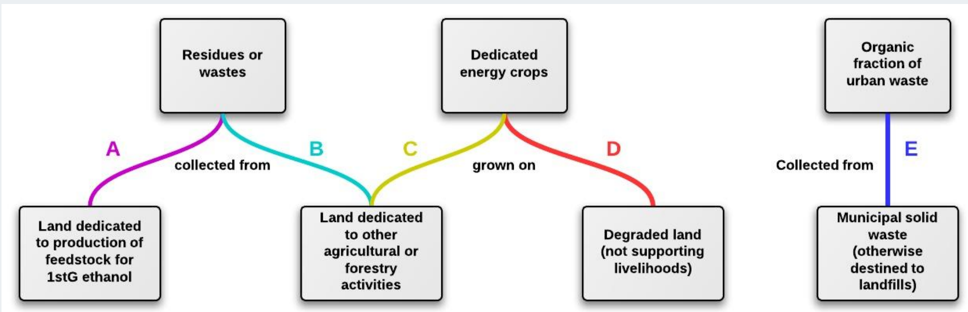
	1	2	3	4	5
Scenario A					
Scenario B					
Scenario C					
Scenario D					
Scenario E					

2.4.2. Indicate the degree of monitorability you would attribute to the impact.

	1	2	3	4	5
All scenarios					

Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

FEEDSTOCK PRODUCTION (I) - Impact 5



Scenario A. **The collection of cellulosic residues/waste from feedstock used in the production of 1G-ethanol**, to use as feedstock for cellulosic ethanol...

Scenario B. **The collection of cellulosic residues/waste from land dedicated to other agricultural/forestry activities**, to use as feedstock for cellulosic ethanol...

Scenario C. **The cultivation of dedicated energy crops on land dedicated to other agricultural/forestry activities**, to use as feedstock for cellulosic ethanol...

Scenario D. **The cultivation of dedicated energy crops on degraded land (not supporting rural livelihoods)**, to use as feedstock for cellulosic ethanol...

Scenario E. **The collection of the organic fraction of urban waste collected from municipal solid waste**, to use as feedstock for cellulosic ethanol...

2.5. Will **threaten biodiversity security** at the national or international levels.

	Very unlikely	Unlikely	About as likely as not	Likely	Very likely
Scenario A					
Scenario B					
Scenario C					
Scenario D					
Scenario E					

Regarding the previous impact, in the hypothetical case of occurrence:

2.5.1. Indicate the reversibility degree (less to more reversible) you would attribute to it, i.e. restoring biodiversity levels (plant and animal species that are valuable to human societies).

	1	2	3	4	5
Scenario A					
Scenario B					
Scenario C					
Scenario D					
Scenario E					

2.5.2. Indicate the degree of monitorability you would attribute to the impact.

	1	2	3	4	5
All scenarios					

Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

CONVERSION PROCESSES (II) - Impact 6

Scenario. Direct changes in the conversion processes, from the traditional conversion routes for production of first-generation ethanol to the biochemical route for production of cellulosic ethanol at the power plant and related facilities.

2.6. Will **prevent employment generation** among low-skilled or unskilled workers.

	Very unlikely	Unlikely	About as likely as not	Likely	Very likely
All scenarios					

Regarding the previous impact, in the hypothetical case of occurrence:

2.6.1. Indicate the reversibility degree (less to more reversible) you would attribute to it, i.e. including low-skilled or unskilled workers in the workforce.

	1	2	3	4	5
All scenarios					

2.6.2. Indicate the degree of monitorability you would attribute to the impact.

	1	2	3	4	5
All scenarios					

Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

CONVERSION PROCESSES (II) - Impact 7

Scenario. Direct changes in the conversion processes, from the traditional conversion routes for production of first-generation ethanol to the biochemical route for production of cellulosic ethanol at the power plant and related facilities.

2.7. Will **prevent the inclusion** of small-scale producers in the supply chain of cellulosic ethanol.

	Very unlikely	Unlikely	About as likely as not	Likely	Very likely
All scenarios					

Regarding the previous impact, in the hypothetical case of occurrence:

2.7.1. Indicate the reversibility degree (less to more reversible) you would attribute to it, i.e. including small-scale producers in the supply chain of cellulosic ethanol.

	1	2	3	4	5
All scenarios					

2.7.2. Indicate the degree of monitorability you would attribute to the impact.

	1	2	3	4	5
All scenarios					

Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

CONVERSION PROCESSES (II) - Impact 8

Scenario. Direct changes in the conversion processes, from the traditional conversion routes for production of first-generation ethanol to the biochemical route for production of cellulosic ethanol at the power plant and related facilities.

2.8. Will **threaten water security** at the local and higher levels.

	Very unlikely	Unlikely	About as likely as not	Likely	Very likely
All scenarios					

Regarding the previous impact, in the hypothetical case of occurrence:

2.8.1. Indicate the reversibility degree (less to more reversible) you would attribute to it, i.e. restoring water security in terms of quantity and quality.

	1	2	3	4	5
All scenarios					

2.8.2. Indicate the degree of monitorability you would attribute to the impact.

	1	2	3	4	5
All scenarios					

Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

Segunda Ronda

TEG Delphi - Round 2

Introduction to round 2

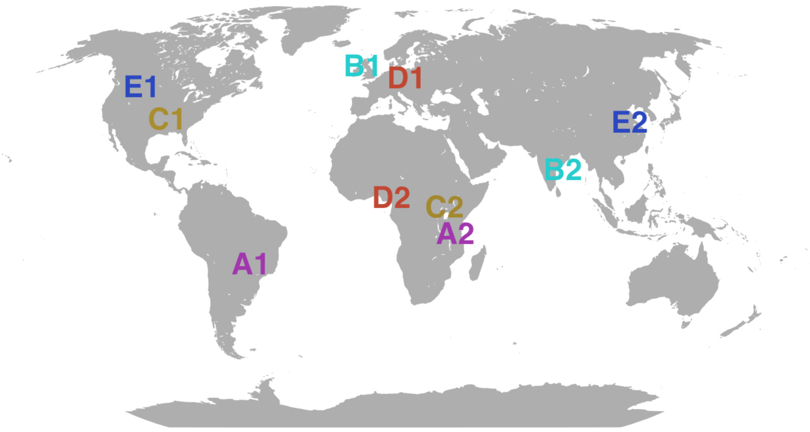
In the previous round of the Delphi you assessed a set of eight potential social impacts involved in the transition to cellulosic ethanol against five generic scenarios (A-E). Many comments on various aspects of the exercise were received. The objectives of this second round is to allow you to review your responses in the light of the comments made by others and elements modified in the framework, as a result of suggestions received. The main difference between the two rounds is that in round 2 we will look at examples based on the generic scenarios of round 1. You will find a compilation of all comments and the average of ratings from round 1 in the document "Summary of results of round 1" that was sent to you by email.

Important note: If you are completing this form offline as a PDF, please make sure to use the **latest version** of Adobe Reader, **since it will not work properly using other programs**. The Adobe Reader is available for free at: http://get.adobe.com/reader/

Before starting to complete the form, please provide your **email** address

Reassessment of potential social impacts

In the next sections, you are invited to reassess the potential impacts involved in the transition to cellulosic ethanol based on different sub-scenarios, or examples (see an overview of their geographical location below). The examples take into account the potential of regions to produce determined types of cellulosic feedstocks, focusing on contrasting socioeconomic and political contexts. In each section of this form, you will find a selected part of the comments received in round 1 to inform the reassessment. Please refer to them while completing the questionnaire and to the "Summary of results of round 1" for a complete compilation of comments.

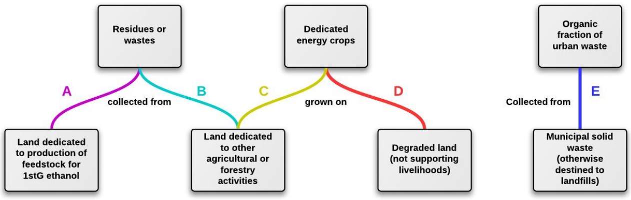


Impact 1. Inclusion of small-scale farmers as feedstock producers and suppliers of raw material in the supply chain of cellulosic ethanol.

1.1. The inclusion of small-scale farmers in the supply chain of cellulosic ethanol may be affected by various factors, such as:

- Costs of adaptation to different farming techniques, technologies and management needs.
- Farmers' perceptions of investment risk.
- Policies and regulations (e.g. support mechanisms by governments).

Considering the following land-use scenarios and sub-scenarios, besides the comments of participants in round 1, please give your opinion on the **likelihood small-scale farmers would be included in the supply chain of cellulosic ethanol**:



*Time frame: 2015-2050 (expected deployment of commercial facilities of cellulosic ethanol and 20 years after an expected integration with 1G-ethanol landscape in 2030).
*Average size of farms: sub-scenarios A1 (55ha), A2-B2-C2-D2 (2-8ha), B1 (25-40ha), C1 (150ha), D1 (3-20ha).
*In A1 and B1 residues were partially left in the field and commercialised; in A2 and B2 residues were left in the field.
*In A1 and B1 farmers are fairly well-connected to processing facilities; in A2 and B2 collection is more decentralised and transport systems are inappropriate and expensive.
*Degraded land: land severely disturbed by human impact, e.g. overexploited by previous agricultural or industrial activities and that is currently not used by formal agriculture or forestry nor is a direct support for rural livelihoods; low levels of biodiversity.

	Very Unlikely	Unlikely	About as likely as not	Likely	Very Likely	Not sure
A1. Region: Brazil (Centre-South) **Feedstock:** Sugarcane bagasse, straw						
A2. Region: Eastern Africa (e.g. Kenya) **Feedstock:** Sugarcane straw						
B1. Region: Western Europe (e.g. UK) **Feedstock:** Wheat straw						
B2. Region: South Asia (e.g. India) **Feedstock:** Rice straw						
C1. Region: United States **Feedstock:** Short Rotation Coppices (Poplar)						
C2. Region: Eastern Africa (e.g. Uganda) **Feedstock:** SRC (Eucalyptus)						
D1. Region: Eastern Europe (e.g. Poland) **Feedstock:** Perennial grasses						
D2. Region: Western Africa (e.g. Benin) **Feedstock:** Perennial grasses						

COMMENTS FROM ROUND 1

P2: Higher costs of production for scenarios C and D may hinder inclusion of small-scale farmers in cellulosic ethanol's supply chain.

P6: While waste biomass left in the field is very cheap, it's actual collection is not economically feasible since it is widely geographically distributed. Unless the collection is carried out for a high value purpose, then this feedstock will not make it to ethanol plants and market. On the other hand, when waste biomass accumulates in processing plants then it becomes much more feasible to collect this biowaste and process it into cellulosic ethanol. So a key question is: to what extent are small scale farmers already involved in growing centrally collected crops, including waste biomass?

P8: Smallholders will only benefit from it if they are involved in processing, i.e. the value added stages of production; In the case they are selling the product to markets/buyers rather than using it for their own energy needs, the terms of their insertion into those end markets is also another factor to take into account. In the case of residues/wastes, what are the other uses for those products? Were the residues left on the land prior to the hypothetical scenarios? If so, what are the environmental consequences (soil fertility etc.) of removing those residues?

P14: Collection of residues tends to be costly for small farmers due to expensive technology and qualified labor. However, the organisation of cooperatives can attenuate such cost. It is worth to understand the model adopted in the mechanical harvesting process.

P17: More dedicated systems (crops or land) are less likely to involve small scale farmers. In the UK, e.g., those are quite innovative and interested in new markets, but find the regulatory system too uncertain to invest.

P18: The whole paradigm of western agriculture is built around notions of economies of scale that inherently undermines the position of small scale farmers. Biofuel production, first or second-generation technologies, are primarily focused on large-scale production because that is where the big profit margin is. This demands greater levels of feedstock for the cheapest price which implicitly favours large-scale, industrial arable farms. As for dedicated energy crops, you are asking a small scale farmer to further undermine their central business enterprise by removing land from that operation to grow a crop with expensive establishment costs and marginal returns. Also when it comes for growing these crops on degraded land the evidence from the recent experiences with Jatropha is that marginal land means marginal crop that isn't commercially viable. Also if degraded land isn't being used to support livelihoods it would suggest that the cost of making that land profitable far outweighs the likely return.

P19: Although biofuels have been suggested as an opportunity to foster and protect the development of small-scale farms, the means to which this will happen are not dependent on the feedstock and production pathway. What seems more likely is that the production system will be dominated by large-scale producers, as is common with many other agricultural commodities. Other factors, such as support mechanisms, will likely have more of an impact on the inclusion of small-scale farmers in the production of biofuels.

P21: Small scale farmers could be included purely as feedstock producers or in a sustainable way, if possible.

P22: There are almost no small (i.e. peasant) farmers involved in bioenergy feedstock production in the US, e.g., although there are efforts to involve non-corporate farmers and private landowners in growing dedicated energy crops on abandon agricultural land. However, this is completely different from peasant farmers in Latin America, Africa or Asia.

1.2. The level of difficulty that **small-scale farmers may face to return to their previous cropping systems** may depend on various factors, such as:

- Costs and return on investment.
- Type of crop and land-use change.
- Countries' regulatory capacity and institutional structures.

Considering the following examples and the comments of participants in round 1, please give your opinion on the **level of difficulty small-scale farmers may face in returning to their previous cropping systems:**

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure/ Not applicable
A1. Region: Brazil (Centre-South) **Feedstock:** Sugarcane bagasse, straw						
A2. Region: Eastern Africa (e.g. Kenya) **Feedstock:** Sugarcane straw						
B1. Region: Western Europe (e.g. UK) **Feedstock:** Wheat straw						
B2. Region: South Asia (e.g. India) **Feedstock:** Rice straw						
C1. Region: United States **Feedstock:** Short Rotation Coppices (Poplar)						
C2. Region: Eastern Africa (e.g. Uganda) **Feedstock:** SRC (Eucalyptus)						
D1. Region: Eastern Europe (e.g. Poland) **Feedstock:** Perennial grasses						
D2. Region: Western Africa (e.g. Benin) **Feedstock:** Perennial grasses						

COMMENTS FROM ROUND 1
P2: Reversibility is low for small-scale producers in all scenarios because of high prices of ethanol feedstock, that is currently linked to oil prices.
P15: Reversibility depends on timescale, political/institutional system and type of crop. Perennially rooted crops will be harder to dislodge than e.g. fodder maize.
P18: Reversibility is context specific. As for the physical crop traditional or perennial, it is easily reversible, you just plough it up. From a business perspective this may have been a significant investment and therefore destroying the crop is irreversible in the sense that economically you have taken a big risk and have no choice but to see it through. Environmentally it depends on the previous land use, changing permanent pasture to energy crop plantations and back again is technically, fairly straight forward, in comparison to a situation where you have cut down some semi-natural ancient woodland and reversibility is most likely impossible to achieve.
P19: All impacts are potentially reversible - the farmer can dig up the crop - but they become much more difficult to reverse as they become embedded and normalised practices (e.g. as 'waste' streams get converted to by-products or commodities and industries develop around them).

1.3. The degree with which the **inclusion/exclusion of small-scale farmers in the supply chain of cellulosic ethanol can be monitored** so political and regulatory strategies can be put in place may depend on various factors, such as:

- The availability of indicators (e.g. financial transactions, lorry loads reaching the plant, farmer invoices).
- Countries' regulatory capacity and institutional structures.

Considering the following categories and the comments of participants in round 1, please give your opinion on the **difficulty for monitoring the inclusion/ exclusion of small-scale farmers in the supply chain of cellulosic ethanol:**

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure / Not applicable
Low-income countries (e.g. Benin, Tanzania, Uganda)						
Middle-income countries (e.g. Brazil, China, Lithuania)						
High-income OECD countries (e.g. US, UK, Polonia)						

COMMENTS FROM ROUND 1
P6: Technologically, monitoring is rather simple, e.g. financial transactions or lorry loads reaching the plant. However, you must consider that the system is open to abuse.
P7: In North-America it would be easy to monitor such impact since farmers would have invoices for the cellulosic feedstock and thus ethanol producers could track where the feedstock is coming from.
P9: Monitoring of degraded land is inherently difficult.

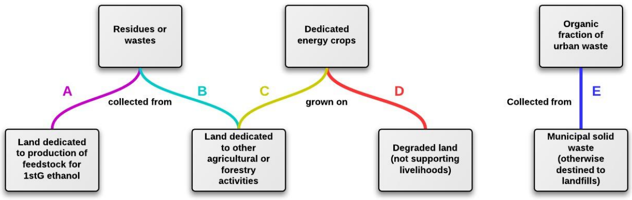
Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

Impact 2. Food security (on-site): equitable and sufficient access to food by locals from communities where feedstock for cellulosic ethanol may be cultivated/collected*.
*In some cases in small-scale farms, others in large-scale ones (see note below).

2.1. The **food security of locals, especially vulnerable groups** may be affected by various factors, such as:

- Direct competition for land and other natural resources between cellulosic feedstock and food crops.
- Behaviour of farmers (dependence on their own food production, profit-oriented market decisions).
- Policies, regulations and institutional capacity of countries.

Considering the following land-use scenarios and sub-scenarios, besides the comments of participants in round 1, please give your opinion on the **likelihood food security of locals would be threatened by production/collection of feedstock for cellulosic ethanol:**



*Time frame: 2015-2050 (expected deployment of commercial facilities of cellulosic ethanol and 20 years after an expected integration with 1G-ethanol landscape in 2030).
*Degraded land: land severely disturbed by human impact, e.g. overexploited by previous agricultural or industrial activities and that is currently not used by formal agriculture or forestry nor is a direct support for rural livelihoods; low levels of biodiversity.
*More vulnerable segments of society are the poor, the elderly, children, women, the unemployed and members of minorities such as indigenous peoples and those who their livelihood depend directly on the biophysical setting. Communities are more impoverished in A2, B2, C2, D2.
Note:
*A2 and B2 take place in small-scale farms where production goals are diverse (subsistence included).
*For all other sub-scenarios, collection/production of feedstock take place in large-scale farms.

	Very Unlikely	Unlikely	About as likely as not	Likely	Very Likely	Not sure
A1. Region: Brazil (Centre-South) **Feedstock:** Sugarcane bagasse, straw						
A2. Region: Eastern Africa (e.g. Kenya) **Feedstock:** Sugarcane straw						
B1. Region: Western Europe (e.g. UK) **Feedstock:** Wheat straw						
B2. Region: South Asia (e.g. India) **Feedstock:** Rice straw						
C1. Region: United States **Feedstock:** Short Rotation Coppices (Poplar)						
C2. Region: Eastern Africa (e.g. Uganda) **Feedstock:** SRC (Eucalyptus)						
D1. Region: Eastern Europe (e.g. Poland) **Feedstock:** Perennial grasses						
D2. Region: Western Africa (e.g. Benin) **Feedstock:** Perennial grasses						
E1. Region: Canada **Feedstock:** Urban waste						
E2. Region: China (e.g. Shangai) **Feedstock:** Urban waste						

COMMENTS FROM ROUND 1
P2: The global food security will get more adversely affected than the local food security. In the local, high incomes from ethanol feedstocks may compensate for high food prices. However, the actual impact (whether food security is hindered or bettered) will depend on the particular consumption baskets of small-scale farmers in terms of the share of food in total consumption expenditure or the types of food. The last factor can vary according to classes and ethnic groups within the local population.
P6: Current market conditions (government interventions not included) suggest that food is more valuable than fuel. Farmers, and especially small scale farmers, would not endanger their food production in order to produce a lower value product.
P7: The danger of food security comes from soil depletion from removing excess carbon thereby exasperating erosion, reducing water and nutrient retention etc. High oil prices and inequitable distribution of food is a much more serious threat to food security than ethanol.
P11: One problem in assessing impacts on food production (or any other social aspect, for that matter!) from biofuel production systems that are in place already is to decide to what extent one should focus on assessing change as opposed to assessing the state of social sustainability. In other words, the question is similar to the distinction between stocks and flows. If a biofuel production system in place already has compromised food security (for centuries in the Brazilian Northeast!), then any minor improvement would appear as positive in an assessment only focusing on change ("flows"). By contrast, if one focuses on the actual situation ("state"), a relevant question would be whether giving up biofuel production would in fact enhance food security much more than any incremental improvement in the existing biofuel production system.
P12: Food security increasingly depends on social policies, e.g. "bolsa família" (Brazil). However, food security may be affected by price increases. These effects haven't been studied enough to make a final statement.
P14: The collections of residues shall not impact food security, however the use of land currently under cultivation of food crops can have an impact. Nevertheless, there is plenty of area under use and governments have tools, such as zoning and licensing process, to regulate land use. It is worth mentioning that the major problems of food security are related to distribution, losses and access. Energy crops could jeopardise food security at local level, but is unlike to have impacts at global scale.
P15: Probability depends on local conditions and behaviour of farmers. If incomes increase this might allow additional food purchase.
P16: Food prices are more elastic than fuel prices - in many instances there is an endogenous price ceiling placed by the price of oil. Planting decisions are made in light of which market will pay best. In the case of small scale farmers, they are often planting to secure their own food supplies, hence it appears less rational to not reverse planting decisions. Our work has indicated that small scale farmers are unlikely to plant coppice crops for the simple reason that they do not have land beyond their 'food security needs' and they have higher risk related sensitivity to changing to non-traditional energy cropping. Plantings of coppice etc. in our experience are more likely to be made by larger scale farmers and economically secure farmers that seek to create a more varied portfolio of products from their land holding.
P18: Food security always seems like an abstract problem, a threat, rather than a issue that clearly materialises in certain localities and is directly attributable to biofuel production per se. Rather, when it comes to issues of food security or local populations becoming more food insecure, this is more attributable to the practices of major agribusiness buying up huge swathes of land for biofuel plantations and, in the process, displacing local people who were using the land for multifunctional subsistence farming. Thereby increasing their food insecurity. In the established scenarios, people aren't losing access to the land, just selling its produce to a different processing chain, which doesn't inherently threaten their food security, plausibly they could always reduce the amount of produce going to biofuel production if they fell on hard times.
P19: Food security is affected by a complex set of interactions, one of which includes biofuel production/pressure for growing non-food crops. I think that attributing changes in food security of the local (i.e. producing) community to biofuel production and crop cultivation would be difficult (except perhaps in specific scenarios such as subsistence farming). In the developed world, it seems sensible that this is much less of a concern because the impacting factors are much more widely distributed than in the developing communities. This makes answering the questions above difficult.
P24: For Scenario D it is hard to imagine how the competition of cellulosic crops with food crops could occur (perhaps for extremely undemanding food crops that could grow anywhere Scenario D is possible). On the other hand, growing cellulosic crops on degraded lands could improve lands' productivity and therefore improve conditions for food security. For Scenario E it is very difficult to imagine the situation of competition.

2.2. The level of difficulty in **reestablishing local food security levels** may depend on various factors, such as:

- Mitigating competition of cellulosic feedstock with food crops (e.g. by switching crops or ploughing residues back into the soil).
- Policies, regulations and institutional capacity of countries.

Considering the following examples and the comments of participants in round 1, please give your opinion on the **level of difficulty of reestablishing food security levels at the local scale:**

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure/ Not applicable
A1. Region: Brazil (Centre-South) **Feedstock:** Sugarcane bagasse, straw						
A2. Region: Eastern Africa (e.g. Kenya) **Feedstock:** Sugarcane straw						
B1. Region: Western Europe (e.g. UK) **Feedstock:** Wheat straw						
B2. Region: South Asia (e.g. India) **Feedstock:** Rice straw						
C1. Region: United States **Feedstock:** Short Rotation Coppices (Poplar)						
C2. Region: Eastern Africa (e.g. Uganda) **Feedstock:** SRC (Eucalyptus)						
D1. Region: Eastern Europe (e.g. Poland) **Feedstock:** Perennial grasses						
D2. Region: Western Africa (e.g. Benin) **Feedstock:** Perennial grasses						
E1. Region: Canada **Feedstock:** Urban waste						
E2. Region: China (e.g. Shangai) **Feedstock:** Urban waste						

COMMENTS FROM ROUND 1
P7: In all cases it is reversible by switching crops.
P16: If there was a food security issue and the plantings are local and smaller scale, then reversibility is high. The planning of coppice crops etc. is a longer time investment and has less reversibility.
P24: In case the impact occurs in Scenario A, it might be rather easy to relocate some or all of the harvest of food crops from first-generation ethanol production to food production. In Scenario B, all residues could be kept on the soil or ploughed back to return the soil's fertility. It might take time though to achieve the same harvest levels again. The latter has a significant degree of uncertainty, so one shouldn't attribute a very high level of reversibility to Scenario B. Growing cellulosic crops on degraded lands (scenario D) could improve lands' productivity and therefore improve conditions for food security (hence high reversibility). For Scenario E it is very difficult to imagine the situation for competition. Therefore there is no reason to provide an answer on reversibility.

2.3. The degree with which **local food security levels can be monitored** so political and regulatory strategies can be put in place may depend on various factors, such as:

- The availability of indicators (e.g. temporal change in prices for locally produced food).
- The complexity of the change due to sectoral interactions and indirect impacts.
- Countries' regulatory capacity and institutional structures.

Considering the following categories and the comments of participants in round 1, please give your opinion on the **difficulty for monitoring local food security levels:**

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure / Not applicable
Low-income countries (e.g. Benin, Tanzania, Uganda)						
Middle-income countries (e.g. Brazil, China, Lithuania)						
High-income OECD countries (e.g. US, UK, Polonia)						

COMMENTS FROM ROUND 1
P7: It is difficult to monitor.
P17: This is more difficult to monitor, due to complex sectoral interactions and indirect impacts.
P23: Soil health can be monitored by a number of indicators: SOM, living biomass, specific taxa, soil structure, water holding capacity, energy efficiency (output/input).
P24: Local food security can be monitored by, for example, comparing the temporal change in prices for locally produced food.

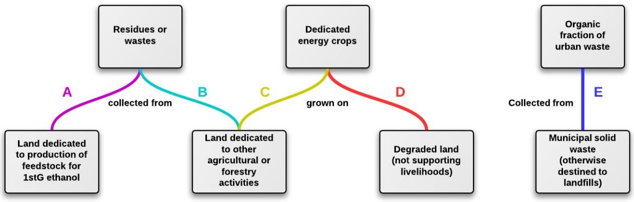
Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

Impact 3. Food security (off-site/indirect): equitable and sufficient access to food by people (especially vulnerable groups) from other areas than feedstock hosting communities.

3.1. The **food security of vulnerable groups** may be affected by various factors, such as:

- Direct and indirect competition for land and other natural resources between cellulosic feedstock and food crops.
- Increase in food prices.
- Policies, regulations and institutional capacity of countries.

Considering the following land-use scenarios and sub-scenarios, besides the comments of participants in round 1, please give your opinion on the **likelihood the following cases* would threaten food security of "off-site" vulnerable groups:**
*See note.



*Time frame: 2015-2050 (expected deployment of commercial facilities of cellulosic ethanol and 20 years after an expected integration with 1G-ethanol landscape in 2030).
*Degraded land: land severely disturbed by human impact, e.g. overexploited by previous agricultural or industrial activities and that is currently not used by formal agriculture or forestry nor is a direct support for rural livelihoods; low levels of biodiversity.
*More vulnerable segments of society are the poor, the elderly, children, women, the unemployed and members of minorities such as indigenous peoples and those who their livelihood depend directly on the biophysical setting.
Note:
*Consider all sub-scenarios as large-scale production.

	Very Unlikely	Unlikely	About as likely as not	Likely	Very Likely	Not sure
A1. Region: Brazil (Centre-South) **Feedstock:** Sugarcane bagasse, straw						
A2. Region: Eastern Africa (e.g. Kenya) **Feedstock:** Sugarcane straw						
B1. Region: Western Europe (e.g. UK) **Feedstock:** Wheat straw						
B2. Region: South Asia (e.g. India) **Feedstock:** Rice straw						
C1. Region: United States **Feedstock:** Short Rotation Coppices (Poplar)						
C2. Region: Eastern Africa (e.g. Uganda) **Feedstock:** SRC (Eucalyptus)						
D1. Region: Eastern Europe (e.g. Poland) **Feedstock:** Perennial grasses						
D2. Region: Western Africa (e.g. Benin) **Feedstock:** Perennial grasses						
E1. Region: Canada **Feedstock:** Urban waste						
E2. Region: China (e.g. Shangai) **Feedstock:** Urban waste						

COMMENTS FROM ROUND 1
P14: (Refers to previous comments): The collections of residues shall not impact food security, however the use of land currently under cultivation of food crops can have an impact. Nevertheless, there is plenty of area under use and governments have tools, such as zoning and licensing process, to regulate land use. It is worth mentioning that the major problems of food security are related to distribution, losses and access. Energy crops could jeopardise food security at local level, but is unlike to have impacts at global scale.
P18: Which nations are we talking about, does food security ever impact on a national level. Rather it impacts certain vulnerable segments of society who rely on key foodstuffs. Hence you get the Tortilla Riots in Mexico, because corn flour became more expensive due to a range of factors of which biofuels was clearly one. However, was this a national food security threat? It certainly impacted one nation, Mexico, but not evenly. I would hardly say that the UK is in the grips of a food security crisis, but rising food prices have squeezed household incomes disproportionately impacting on the poorer segments of society. The implied assumption is also fuel trumps food when it comes to the appropriation of agricultural produce. The recent closure of Ensus due to its failure to secure adequate wheat grain at the right price suggests this isn't the case. Well-established food processing companies have far greater buying power that emergent biofuel producers in many contexts. Also while people can choose alternative forms of transport that do not rely on liquid fuels they are always going to want food.
P19: (Refers to previous comments): food security is complex.
P24: The grading of probability of a threat to food security on the national/international level is based on the assumption that all available land/residues/energy crops etc. are used for ethanol production.

3.2. The level of difficulty in **reestablishing "off-site" food security levels within a country** may depend on various factors, such as:

- Mitigating competition of cellulosic feedstock with food crops (e.g. switching crops, keeping on the soil or ploughing back residues).
- Policies, regulations and institutional capacity of countries.

Considering the following examples and the comments of participants in round 1, please give your opinion on the **level of difficulty of reestablishing off-site food security levels:**

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure/ Not applicable
A1. Region: Brazil (Centre-South) **Feedstock:** Sugarcane bagasse, straw						
A2. Region: Eastern Africa (e.g. Kenya) **Feedstock:** Sugarcane straw						
B1. Region: Western Europe (e.g. UK) **Feedstock:** Wheat straw						
B2. Region: South Asia (e.g. India) **Feedstock:** Rice straw						
C1. Region: United States **Feedstock:** Short Rotation Coppices (Poplar)						
C2. Region: Eastern Africa (e.g. Uganda) **Feedstock:** SRC (Eucalyptus)						
D1. Region: Eastern Europe (e.g. Poland) **Feedstock:** Perennial grasses						
D2. Region: Western Africa (e.g. Benin) **Feedstock:** Perennial grasses						
E1. Region: Canada **Feedstock:** Urban waste						
E2. Region: China (e.g. Shangai) **Feedstock:** Urban waste						

COMMENTS FROM ROUND 1
P2: The only situation in which this can be reversible is when crude oil prices come down to such levels that ethanol production is rendered non-competitive.
P24: (Refers to previous comments): In case the impact occurs in Scenario A, it might be rather easy to relocate some or all of the harvest of food crops from first-generation ethanol production to food production. In Scenario B, all residues could be kept on the soil or ploughed back to return the soil's fertility. It might take time though to achieve the same harvest levels again. The latter has a significant degree of uncertainty, so one shouldn't attribute a very high level of reversibility to Scenario B. Growing cellulosic crops on degraded lands (scenario D) could improve lands' productivity and therefore improve conditions for food security (hence high reversibility). For Scenario E it is very difficult to imagine the situation for competition. Therefore there is no reason to provide an answer on reversibility.

3.3. The degree with which **off-site food security levels can be monitored** so political and regulatory strategies can be put in place may depend on various factors, such as:

- The complexity of the change due to sectoral interactions and indirect impacts.
- Countries' regulatory capacity and institutional structures.

Considering the following categories and the comments of participants in round 1, please give your opinion on the **difficulty for monitoring the levels of off-site/indirect food security** (within the nations concerned)**:**

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure / Not applicable
Low-income countries (e.g. Benin, Tanzania, Uganda)						
Middle-income countries (e.g. Brazil, China, Lithuania)						
High-income OECD countries (e.g. US, UK, Polonia)						

COMMENTS FROM ROUND 1
P17: (Refers to previous comments): indirect impacts and complex market interactions make it difficult to monitor.
P19: (Refers to previous comments): monitoring is difficult.
P24: Monitorability is considered more difficult at the national and even more difficult on the international level.

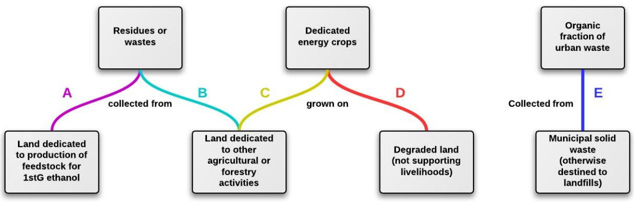
Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

Impact 4. Water security (feedstock-related): equitable and sufficient access to clean and safe water by people, especially vulnerable groups.

4.1. The **water security of vulnerable groups** may be affected by various factors, such as:

- Water demand for feedstock production and water pollution.
- Water availability in certain regions.
- Agricultural practices and water management.

Considering the following land-use scenarios and sub-scenarios, besides the comments of participants in round 1, please give your opinion on the **likelihood water security of vulnerable groups would be threatened by production/collection of feedstock for cellulosic ethanol:**



*Time frame: 2015-2050 (expected deployment of commercial facilities of cellulosic ethanol and 20 years after an expected integration with 1G-ethanol landscape in 2030).
*Degraded land: land severely disturbed by human impact, e.g. overexploited by previous agricultural or industrial activities and that is currently not used by formal agriculture or forestry nor is a direct support for rural livelihoods; low levels of biodiversity.
*More vulnerable segments of society are the poor, the elderly, children, women, the unemployed and members of minorities such as indigenous peoples and those who their livelihood depend directly on the biophysical setting.
Note:
*Unsustainable agricultural practices are more common in A2 and B2, although in all cases for low-income countries the regulatory framework is weaker.
*A2 and B2 take place in small-scale farms.
*For all other sub-scenarios, collection/production of feedstock takes place in large-scale farms.
*Access to water by vulnerable groups is lower for all low-income countries.
*Irrigation is needed in all cases except E1 and E2.

	Very Unlikely	Unlikely	About as likely as not	Likely	Very Likely	Not sure
A1. Region: Brazil (Centre-South) **Feedstock:** Sugarcane bagasse, straw						
A2. Region: Eastern Africa (e.g. Kenya) **Feedstock:** Sugarcane straw						
B1. Region: Western Europe (e.g. UK) **Feedstock:** Wheat straw						
B2. Region: South Asia (e.g. India) **Feedstock:** Rice straw						
C1. Region: United States **Feedstock:** Short Rotation Coppices (Poplar)						
C2. Region: Eastern Africa (e.g. Uganda) **Feedstock:** SRC (Eucalyptus)						
D1. Region: Eastern Europe (e.g. Poland) **Feedstock:** Perennial grasses						
D2. Region: Western Africa (e.g. Benin) **Feedstock:** Perennial grasses						
E1. Region: Canada **Feedstock:** Urban waste						
E2. Region: China (e.g. Shangai) **Feedstock:** Urban waste						

COMMENTS FROM ROUND 1
P7: It is difficult to link cause and effect from crops grown/residues taken and water availability but it is sure to have an impact.
P12: Degraded land (scenario D) is more likely not to offer sufficient water resources. Scenario A might also be likely, but this depends on the edafoclimatic conditions and available water resources in the region.
P14: Water demand is not an issue for the use of residues, unless the collection impacts the moisture contents of the soil, i.e. minimum amounts of residues must remain in the ground in order to protect it from erosion, loss of nutrients and water. In areas covered by forest the impact tends to be more intense.
P15: Probably only scenario E can be answered with much certainty.
P16: In terms of water security, only the case where dedicated energy crops are planted on degraded land appears to infer a potential shift from rain fed agriculture to a state where additional irrigation may be supplied. In areas of water shortage, dedicated energy crops do better with water supply - as do standard crops.
P17: Water impacts are considered as unknown by many.
P18: Water security is already a major issue in certain areas, for instance the US corn belt, due to intensive farming methods. Biofuel feedstock production methods don't challenge these production practices so this is going to be tied into existing problems with the continued sustainability of intensive agriculture in the face of climate change. The only difference is that perennial energy crops are perceived to have a greater water demand over annual food crop varieties and therefore may potentially exacerbate this more if planted in large monocultures. With regards to water pollution, perennial crops, due to reduce chemical input requirements, might improve water quality within an area they are placed, especially if positioned close to rivers and waterways.

4.2. The level of difficulty in **reestablishing water security levels** may depend on various factors, such as:

- Mitigating water pollution or reducing the intensity of water-use in feedstock production (e.g. increasing water efficiency).
- Policies, regulations and institutional capacity of countries.

Considering the following examples and the comments of participants in round 1, please give your opinion on the l**evel of difficulty of reestablishing water security levels**:

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure/ Not applicable
A1. Region: Brazil (Centre-South) **Feedstock:** Sugarcane bagasse, straw						
A2. Region: Eastern Africa (e.g. Kenya) **Feedstock:** Sugarcane straw						
B1. Region: Western Europe (e.g. UK) **Feedstock:** Wheat straw						
B2. Region: South Asia (e.g. India) **Feedstock:** Rice straw						
C1. Region: United States **Feedstock:** Short Rotation Coppices (Poplar)						
C2. Region: Eastern Africa (e.g. Uganda) **Feedstock:** SRC (Eucalyptus)						
D1. Region: Eastern Europe (e.g. Poland) **Feedstock:** Perennial grasses						
D2. Region: Western Africa (e.g. Benin) **Feedstock:** Perennial grasses						
E1. Region: Canada **Feedstock:** Urban waste						
E2. Region: China (e.g. Shangai) **Feedstock:** Urban waste						

COMMENTS FROM ROUND 1
P2: The reversibility really depends on the technology of cultivation 2-G feedstocks that evolves over time. It is a bit difficult to predict this from before.
P11: Understanding reversibility as mitigation potential, technical mitigation potential would not appear to differ much between the scenarios. In principle, production system based on dedicated crop production would appear less reversible than the others, but on the other hand, the dependence of a system on waste and residues as raw material may be just as hard to modify.
P18: The long life of perennial crops may mean it becomes economically difficult to reverse crop choices due to the need to secure a return which make take a number of years.

4.3. The degree with which **water security levels can be monitored** so mitigation strategies can be put in place may depend on various factors, such as:

- Availability of indicators (e.g. at the soil level - SOM, soil structure, water holding capacity; at large scale appropriations of blue/green water; water efficiency - m3 of water/ton of ethanol).
- Methodological difficulties regarding the complexity of linking cause and effect relation of type of feedstock/water use.
- Countries' regulatory capacity and institutional structures.

Considering the following categories and the comments of participants in round 1, please give your opinion on the **difficulty for monitoring the levels of water security:**

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure / Not applicable
Low-income countries (e.g. Benin, Tanzania, Uganda)						
Middle-income countries (e.g. Brazil, China, Lithuania)						
High-income OECD countries (e.g. US, UK, Polonia)						

COMMENTS FROM ROUND 1
P23: Water security can be monitored at different levels. At soil level (SOM, soil structure, water holding capacity), and at large scale by measures of appropriations of blue/green water by ethanol production. It is also important to assess the water efficiency use, e.g. m3 water per ton of ethanol.

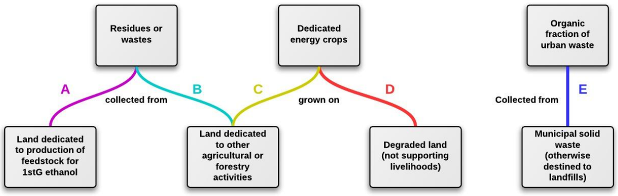
Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

Impact 5. Biodiversity security: preservation of plant and animal species that are valuable to human societies (e.g. for biological pest control, traditional uses or to maintain the flow of other ecosystem services).

5.1. Biodiversity security may be affected by various factors, such as:

- The implementation of monocultures.
- Characteristics of certain types of crops and agricultural practices.
- Policies, regulations and institutional capacity of countries.

Considering the following land-use scenarios and sub-scenarios, besides the comments of participants in round 1, please give your opinion on the **likelihood biodiversity security would be threatened by production/collection of feedstock for cellulosic ethanol:**



*Time frame: 2015-2050 (expected deployment of commercial facilities of cellulosic ethanol and 20 years after an expected integration with 1G-ethanol landscape in 2030).
*Degraded land: land severely disturbed by human impact, e.g. overexploited by previous agricultural or industrial activities and that is currently not used by formal agriculture or forestry nor is a direct support for rural livelihoods; low levels of biodiversity.
*More vulnerable segments of society are the poor, the elderly, children, women, the unemployed and members of minorities such as indigenous peoples and those who their livelihood depend directly on the biophysical setting.
Note:
*All sub-scenarios correspond to large-scale production.
*In C2 there is higher risk of replacing areas with higher levels of biodiversity by monocultures of dedicated energy crops (lower levels of biodiversity).
*Unsustainable agriculture practices are more common in low-income countries.

	Very Unlikely	Unlikely	About as likely as not	Likely	Very Likely	Not sure
A1. Region: Brazil (Centre-South) Feedstock: Sugarcane bagasse, straw						
A2. Region: Eastern Africa (e.g. Kenya) Feedstock: Sugarcane straw						
B1. Region: Western Europe (e.g. UK) Feedstock: Wheat straw						
B2. Region: South Asia (e.g. India) Feedstock: Rice straw						
C1. Region: United States Feedstock: Short Rotation Coppices (Poplar)						
C2. Region: Eastern Africa (e.g. Uganda) Feedstock: SRC (Eucalyptus)						
D1. Region: Eastern Europe (e.g. Poland) Feedstock: Perennial grasses						
D2. Region: Western Africa (e.g. Benin) Feedstock: Perennial grasses						
E1. Region: Canada Feedstock: Urban waste						
E2. Region: China (e.g. Shangai) Feedstock: Urban waste						

COMMENTS FROM ROUND 1

P2: Use of forests for cellulosic feedstocks can seriously threaten biodiversity as laws protecting forests in most developing countries are vague and inadequate.
P14: Collection of residues might not be a threat to biodiversity, unless you consider insects and pests that are used to grow under the piles of crops residues. However, in the case of forest the impact can be more significant. In the case of degraded lands some impact could be observed.
P16: In this case, I am assuming that biodiversity is low in traditional cropping systems. In the example of straw harvesting, the impacts we perceive are low if the 'take' is moderate (say 30%-50%). Overstripping of crop residues will likely lead to soil carbon loss and increased biodiversity risk. In forestry however, the stripping of harvest waste can be expected to negatively impact biodiversity.
P18: Any large monoculture of crops, replacing diverse environments, managed with a high level of chemical inputs, endangers biodiversity. In the UK much of the marginal land (agricultural land grade 4-5) that is mooted as possible sites for future energy crop plantations are important habitats (moorlands, peatlands, heathlands). If those where lost to energy crop plantations then the impact would be significant, however it is largely unlikely due to the high possibility that these lands will produce a commercially unviable crop and are more often than not unsuitable for large machinery making harvest problematic.
P19: Biodiversity impacts are commonly about intensity of production. So for example, removing some waste wood products from managed woodland, or even bringing unmanaged woodland back into use can have positive biodiversity impacts if done in the right way. Likewise, there are studies that show that in some circumstances, growing Miscanthus on land can have positive biodiversity impacts vis-à-vis other crops. It goes the other way as well and there are certainly 'horror stories' that show this, e.g. palm oil, deforestation in Brazil, impact on Brazilian cerrado etc. On the other hand, in terms of the scale considered here, it would be difficult in most cases to attribute biodiversity decline (or benefits) solely to biofuels production. It may be possible to attribute it to something such as new agricultural practices.

5.2. The level of difficulty in **reestablishing biodiversity security** levels may depend on various factors, such as:

- Local biodiversity context for the reestablishment of certain species.
- Complexity of the task.

Considering the following examples and the comments of participants in round 1, please give your opinion on the **level of difficulty of reestablishing biodiversity security levels:**

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure/ Not applicable
A1. Region: Brazil (Centre-South) **Feedstock:** Sugarcane bagasse, straw						
A2. Region: Eastern Africa (e.g. Kenya) **Feedstock:** Sugarcane straw						
B1. Region: Western Europe (e.g. UK) **Feedstock:** Wheat straw						
B2. Region: South Asia (e.g. India) **Feedstock:** Rice straw						
C1. Region: United States **Feedstock:** Short Rotation Coppices (Poplar)						
C2. Region: Eastern Africa (e.g. Uganda) **Feedstock:** SRC (Eucalyptus)						
D1. Region: Eastern Europe (e.g. Poland) **Feedstock:** Perennial grasses						
D2. Region: Western Africa (e.g. Benin) **Feedstock:** Perennial grasses						
E1. Region: Canada **Feedstock:** Urban waste						
E2. Region: China (e.g. Shangai) **Feedstock:** Urban waste						

COMMENTS FROM ROUND 1
P2: The reversibility degree is much lower for biodiversity.
P12: Restoring prior biodiversity levels is not a very realistic scenario.
P19: Not sure, but it might be harder to reverse the decline of biodiversity if the impact is considerable.

5.3. The degree with which **biodiversity security levels can be monitored** so mitigation strategies can be put in place may depend on various factors, such as:

- Prior-knowledge on initial biodiversity level, availability of time series on present species and availability of indicators (e.g. specific/key taxa, population structure and balance etc.).
- Skilled labour and sufficient financial resources.
- Countries' regulatory capacity and institutional structures.

Considering the following categories and the comments of participants in round 1, please give your opinion on the **difficulty for monitoring the levels of biodiversity security:**

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure / Not applicable
Low-income countries (e.g. Benin, Tanzania, Uganda)						
Middle-income countries (e.g. Brazil, China, Lithuania)						
High-income OECD countries (e.g. US, UK, Polonia)						

COMMENTS FROM ROUND 1
P8: Monitoring requires some prior-knowledge of biodiversity (whether species diversity or abundance).
P14: Monitorability of biodiversity is labor intense, skilled, expensive and the impact can only be determined after a long period of observation, because factors as seasonality must be eliminated.
P23: Biodiversity can be monitored by a number of indicators, both concerning the soil (e.g. SOM, living biomass, specific/key taxa, population structure and balance), and landscape (e.g. landscape structure, preservation of natural and semi natural habitats, key taxa).
P24: The impact is difficult to monitor. It requires long time series on present species in a certain area. It might be difficult to attribute biodiversity threat to the activities linked to cellulosic ethanol production.

Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

Impact 6. Exclusion of workers with lower professional qualification at the stage of conversion to ethanol

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6.1. The generation of employment for workers with **lower professional qualification at the stage of conversion to ethanol** may be affected by various factors, such as:

- Higher technological specialisation and use of advanced systems.
- Initiatives of companies and governments in upgrading low-skilled labour force through training.

Considering the following categories and the comments of participants in round 1, please give your opinion on the l**ikelihood workers with lower professional qualification would be EXCLUDED at the stage of conversion to ethanol**:

	Very Unlikely	Unlikely	About as likely as not	Likely	Very LIkely	Not sure
Low-income countries (e.g. Benin, Tanzania, Uganda)						
Middle-income countries (e.g. Brazil, China)						
High-income OECD countries (e.g. US, UK, Polonia)						

COMMENTS FROM ROUND 1

P2: Whether low-skilled workers will be included in the workforce later depends on the up-gradation of their skills. If the demand for ethanol keeps on expanding in the future and the workforce falls short, there may be significant initiatives to upgrade the low-skilled labour force. On the other hand, the labour shortage problem can also be solved through another route, which is to upgrade the technology and reduce the per-unit output's requirement of labour. The outcome depends on what happens in reality.

P7: Both first and second-generation processes are highly technical so if there is a possibility for low-skilled labour with one plant (perhaps doing feedstock handling) then it would also be a possibility for the other process. Moreover, it is unclear that if second-generation becomes possible that first-generation will be phased out.

P14: The ability of companies and governments in providing training to workers will be fundamental in this aspect. In the case of Brazil, e.g., the greatest impacts were observed with the adoption of mechanical harvesting. The education and training programs were relatively successful because the level of education of a significant share of cane cutters was so low that they were not able to learn how to deal with the new technology. Many have been trained and are working in other jobs with lower qualification, such as masons (pedreiros).

P16: For already mechanised systems, extra unskilled jobs will be required for residue collection and logistics. As such, more jobs would be expected. In non-mechanised systems, it might be foreseeable that the advent of more advanced systems will demand greater mechanisation in order to achieve productivity gains. There appears to be a risk for a reduction in low-skilled labouring roles.

P17: Such a specialisation may be likely to exclude low-skilled workers.

P18: There is nothing inherent in these jobs that excludes low-skilled workers if you are going to be putting in place training programs. If not, then you are going to be excluding them in the same way that any skilled or semi-skilled position that requires previous experience or high educational attainment does.

P23: Reducing labor means reducing the cost of energy. Cost is a key issue concerning energy. In fact, subsidies have to be supplied to keep ethanol market alive (that's already an indicator of its economic unsustainability).

6.2. The level of difficulty in **including low-skilled or unskilled workers in the workforce** may depend on various factors, such as financial costs.

Considering the following categories and the comments of participants in round 1, please give your opinion on the **level of difficulty of including low-skilled or unskilled workers in the workforce:**

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure / Not applicable
Low-income countries (e.g. Benin, Tanzania, Uganda)						
Middle-income countries (e.g. Brazil, China)						
High-income OECD countries (e.g. US, UK, Polonia)						

COMMENTS FROM ROUND 1

P7: If there is less of a chance for low-skilled workers as the market evolves to second-generation then it is unlikely to be reversible.

P17: It will be financially difficult to reverse such a situation.

6.3. The degree with which the **inclusion/exclusion levels of low-skilled or unskilled professional in the workforce can be monitored** so political and regulatory strategies can be put in place may depend on various factors, such as the institutional capacity of countries and the availability of indicators.

Considering the following categories and the comments of participants in round 1, please give your opinion on the **difficulty for monitoring the levels of inclusion/exclusion levels of low-skilled or unskilled professional in the workforce at the stage of conversion processes:**

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure / Not applicable
Low-income countries (e.g. Benin, Tanzania, Uganda)						
Middle-income countries (e.g. Brazil, China)						
High-income OECD countries (e.g. US, UK, Polonia)						

COMMENTS FROM ROUND 1

P11: Monitoring these impacts would not be easy, but it would be easier than monitoring the other impacts that are being assessed.

P23: Number of jobs per tons of ethanol as an indicator.

Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

Impact 7. Exclusion of small-scale producers (of ethanol) in the supply chain of cellulosic ethanol.

7.1. The **inclusion of small-scale producers (of ethanol) in the supply chain of cellulosic ethanol** may be affected by various factors, such as:

- Technical capability and financial costs (bioconversion technologies, machinery, enzymes, chemical inputs etc.).
- Market competition.
- Behaviour of farmers (e.g. perceptions of investment risk, choice of specific markerts/products, organisation of 'farmers collectives').
- Countries' regulatory capacity and institutional structures.

Considering the following categories and the comments of participants in round 1, please give your opinion on the **likelihood small-scale producers (of ethanol) will be EXCLUDED from the supply chain of cellulosic ethanol at the stage of conversion to ethanol:**

	Very Unlikely	Unlikely	About as likely as not	Likely	Very LIkely	Not sure
Low-income countries (e.g. Benin, Tanzania, Uganda)						
Middle-income countries (e.g. Brazil, China)						
High-income OECD countries (e.g. US, UK, Polonia)						

COMMENTS FROM ROUND 1
P2: The biochemical route will definitely push the small-scale farmers converting corn to ethanol in their backyards out of the industry.
P14: The problem here is related to technical capability and costs. Scale is fundamental in the ethanol production business. In the case of Brazil, e.g., you can look at the size of first-generation existing facilities and see there is no small-scale units in operation. The option was tested in the beginning of the "Proalcool" program, but did not stand the competition with large companies. In the case of second-generation, a technology more expensive than first-generation "per se", competition will be even harder.
P16: In systems left to the market, it may well occur that low volume small-scale producers will be difficult to include in larger scale second-generation systems.
P17: Smaller producers may be excluded due to risk of venture to specialist crops.
P18: There is nothing that specifically prevents small scale producers from being involved in these supply chains, the problem is they are less likely to compete on price with large producers who have significant economies of scale and due to higher quantities of production, have greater negotiating power.
P23: Since cellulosic ethanol can be obtained from a number of sources, small producers may not represent relevant suppliers of cellulose because of their low-scale economy (better if they specialise on high-value, labor-intensive products).

7.2. The level of difficulty in **including small-scale producers (of ethanol) in the supply chain of cellulosic ethanol** may depend on various factors, such as incentives or guaranteed prices for their products.

Considering the following categories and the comments of participants in round 1, please give your opinion on the **level of difficulty of including small-scale producers (of ethanol) in the supply chain of cellulosic ethanol:**

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure / Not applicable
Low-income countries (e.g. Benin, Tanzania, Uganda)						
Middle-income countries (e.g. Brazil, China)						
High-income OECD countries (e.g. US, UK, Polonia)						

COMMENTS FROM ROUND 1
P17: This may be reversible by guaranteed prices etc. (although e.g. UK farmers are suspicious of these after having been locked in to lower prices after the market price boomed).

7.3. The degree with which the **inclusion/exclusion levels of small-scale producers (of ethanol) in the supply chain of cellulosic ethanol can be monitored** so political and regulatory strategies can be put in place may depend on various factors, such as the institutional capacity of countries and the availability of indicators.

Considering the following categories and the comments of participants in round 1, please give your opinion on the **difficulty for monitoring the levels of inclusion/exclusion levels of small-scale producers (of ethanol) in the supply chain of cellulosic ethanol:**

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure / Not applicable
Low-income countries (e.g. Benin, Tanzania, Uganda)						
Middle-income countries (e.g. Brazil, China)						
High-income OECD countries (e.g. US, UK, Polonia)						

COMMENTS FROM ROUND 1
P17: Should be easy to monitor which kind of producers are providing crops.
P23: Number of small scale producers involved; % of the their income as an indicator.

Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

Impact 8. Water security (conversion processes-related)*: equitable and sufficient access to clean and safe water by people, especially vulnerable groups.
*See note below.

8.1. The **water security at the stage of conversion of cellulosic biomass into ethanol** may be affected by various factors, such as:

- Water demand for conversion processes and water pollution.
- Water management (recycling/reuse).
- Policies, regulations and institutional capacity of countries.

Considering the following categories and the comments of participants in round 1, please give your opinion on the **likelihood water security would be threatened by the conversion of cellulosic feedstock into ethanol:**

***Note:** all cases correspond to the conversion of cellulosic feedstock to ethanol via biochemical route. Although there is a variety of processes being tested within the route for pretreatment, hydrolysis and fermentation, we will assume that the current differences in water demand are not considerable between them. Any estimation should be compared with water demand for conversion to first-generation ethanol from sugar or starchy crops. The principal steps in the biochemical route are pretreatment, enzyme production, hydrolysis and fermentation.

	Very Unlikely	Unlikely	About as likely as not	Likely	Very LIkely	Not sure
Low-income countries (e.g. Benin, Tanzania, Uganda)						
Middle-income countries (e.g. Brazil, China)						
High-income OECD countries (e.g. US, UK, Polonia)						

COMMENTS FROM ROUND 1
P4: Some of the second-generation processes, including some of the pretreatment processes for the biochemical route, as well as most of the thermochemical routes, might use lots of water. So it will depend very much on processes chosen.
P7: Not sure, but second-generation might require less water than fermentation.
P14: Not sure about the water consumption during the second-generation ethanol process. However, considering (1) a new process is being added to the unit and (2) currently the most water demanding process in an ethanol distillery is the cooling of distillation columns and there will be a larger amount of ethanol to distill, then water consumption will increase. On the other hand, it is important to consider the rate of water recycle/reuse within the process, if closed-loop systems are applied etc.
P18: Not sure about the differences in water demands between first and second-generation production pathways to make any claims about how this part of the process impacts on production. However, the bigger problem seems to be what to do with a potentially large amount of toxic waste water after you have extracted the ethanol portion.

8.2. The level of difficulty in **reestablishing water security levels at the stage of conversion of cellulosic biomass into ethanol** may depend on various factors, such as

- Costs and return on investment.
- Mitigating water pollution and reducing the intensity of water-use in conversion processes (increasing water efficiency).
- Policies, regulations and institutional capacity of countries.

Considering the following categories and the comments of participants in round 1, please give your opinion on the **level of difficulty of reestablishing water security levels at the stage of conversion of cellulosic biomass into ethanol:**

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure / Not applicable
Low-income countries (e.g. Benin, Tanzania, Uganda)						
Middle-income countries (e.g. Brazil, China)						
High-income OECD countries (e.g. US, UK, Polonia)						

COMMENTS FROM ROUND 1
P4: Since these are very expensive processes, once the capital investment is in place, it will be difficult to reverse them.
P14: Reversibility depends on technology developments that allow the reduction of water processes. Considering second-generation a technology in its infancy, a significant room for improvements may exist, increasing the reversibility factor.

8.3. The degree with which **water security levels at the stage of conversion of cellulosic biomass into ethanol** can be monitored so mitigation strategies can be put in place may depend on various factors, such as:

- Availability of indicators (e.g. m3 of water per ton of ethanol, water footprint, water table).
- Countries' regulatory capacity and institutional structures.

Considering the following categories and the comments of participants in round 1, please give your opinion on the **difficulty for monitoring the levels of water security at the stage of conversion of cellulosic biomass into ethanol:**

	Very Difficult	Difficult	Moderately Difficult	Easy	Very Easy	Not sure / Not applicable
Low-income countries (e.g. Benin, Tanzania, Uganda)						
Middle-income countries (e.g. Brazil, China)						
High-income OECD countries (e.g. US, UK, Polonia)						

COMMENTS FROM ROUND 1
P23: Monitoring the water use efficiency (e.g. m3 water per ton ethanol, water foot print, water table).

Comments (please share your thoughts on this particular impact, the assessment criteria or any other aspects you like).

Tercera Ronda

TEG Delphi - Evaluation form

Thank you for participating in the Delphi study on the social aspects of a transition from first-generation to cellulosic ethanol. We would appreciate if you could take a few minutes to evaluate the exercise.

Before starting to complete the form, please provide your **email** address

1. Please give your opinion on the following statements:

	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree	NO OPINION
The Delphi is an useful tool for ex-ante impact assessment of cellulosic ethanol.						
The results of the Delphi are useful to inform other assessments of cellulosic ethanol.						
The results of the Delphi are useful to inform decision-making on biofuels.						
My participation in the exercise changed my level of familiarity with the subjects addressed in it, that is to say, I have learned something.						
(For those who participated in round 2) The information regarding the group response and comments made in round 1 was useful when completing the questionnaire in round 2.						

2. Have your **interest** in the discussion around the social sustainability of cellulosic ethanol changed after participating in the Delphi?

Yes, I became much more interested in the topic.
Yes, I became somewhat more interested in the topic.
No, my interest in the topic have not changed.
No, my interest in the topic have actually reduced.
NO OPINION

3. Please indicate your levels of **familiarity with the following subjects before participating in the Delphi** (being **1= Not familiar at all** and **5= Very familiar**)

	1	2	3	4	5	NO OPINION
Small-scale farming and production in biofuel supply chains						
Employment dynamics in biofuel production						
Food security and biofuels						
Water security and biofuels						
Biodiversity and biofuels						

4. For those who did NOT participate in round 2, please rate the following statements regarding possible reasons for not participating in round 2 (you can check as many options as you like):

	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree	NO OPINION
The study **did not** seem useful.						
I **was not happy** with the design of the survey/questionnaires.						
I did not think the content of the questionnaire(s) was adequate.						
I did not have time to fill out the form.						
I did not find I had the adequate levels of expertise to participate in round 2.						

Other reasons (please indicate):

5. Please indicate your level of satisfaction regarding:

	Very Unsatisfied	Unsatisfied	Neutral	Satisfied	Very Satisfied	NO OPINION
The design of questionnaires						
The content of questionnaires						
The length of questionnaires						
The methodology used						
The feedback provided so far						

6. What aspect(s) would you identify as main **weakness(es)** of the study?

7. What aspect(s) would you identify as main **strength(s)** of the study?

8. Do you have any more comments about the study or would like to make any suggestions?

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ANEXO

Publicaciones originales

8

From First to Second Generation Biofuels: Putting Social Aspects on the Scale

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8.1. INTRODUCTION

Bioethanol produced from lignocellulosic biomass is regarded as an attractive alternative when it comes to energy options aimed at tackling climate change—one that could as well ensure important social sustainability criteria such as food security. Nonetheless, we should not dismiss assessing potential social consequences of its adoption as an alternative to first-generation bioethanol, like effects on land use, water security or rural development. Issues such as public participation in the biofuels sustainability debate or evaluation of the social acceptance of these technologies are also of great relevance. Based on a literature review, this article raises the question of what differences, in terms of social aspects, are identified when comparing first-generation and lignocellulosic bioethanol as alternative bioenergy sources. Main findings indicate that lignocellulosic bioethanol could face several social drawbacks if in-depth attention is not given to aspects like the choice of feedstock type and socio-environmental particularities of producing regions. There is also an urgent need for more empirical research in this field in order to accompany the rapid development of biofuel policy worldwide.

The transport sector is responsible for approximately 60% of today's world oil consumption (IEA 2010). Moreover, "business as usual" could make vehicle fleet and driving distances among OCDE countries grow 200% by 2030, with an increase in the frequency of flights, too (Hoogma et al. 2002). Considerable amounts of biofuels would be needed in the short term, while political and economic pressures continue to rise to meet the demand of the energy sector (a) for energy security reasons or (b) to comply with renewable energy targets for environmental reasons. Among biofuel options, bioethanol is expected to be one of the most used in the transport sector within the next two decades (Hahn-Hägerdal et al. 2006).

Currently commercialized bioethanol is referred to as first-generation biofuel, while second-generation or lignocellulosic bioethanol is obtained through different conversion processes using different types of feedstock with respect to its predecessor and is still not commercially deployed due to economic constraints, with technologies in pilot or demonstration stages. To obtain the former, starch and sugar crops such as maize, wheat, sugarcane or sugar beet are fermented to make bioethanol, whereas production of the latter, lignocellulosic biomass (composed mainly of cellulose, hemicellulose and lignin) from agriculture and forest residues, short-rotation forests and prairie grasses or municipal solid wastes provides the raw material made into bioethanol. Expectations are that first-generation will be gradually replaced by second-generation bioethanol within the next few years (Sims et al. 2008 and Naik et al. 2010). This is mainly due to a lack of scientific consensus surrounding the social and environmental sustainability of first-generation bioethanol (see Rajagopal et al. 2007; Fargione et al. 2008; Ojima et al. 2009; Bureau et al. 2010; Lapola et al. 2010) and to the promises of lignocellulosic bioethanol, including (i) lower levels of CO_2 emissions (Farrell et al. 2006 and González-García et al. 2010) and (ii) reduced risk of competing with food production (Hahn-Hägerdal et al. 2006 and Solomon et al. 2007) when compared to first-generation bioethanol.

Little effort has been paid so far to the development of research and policy tools that allow us to effectively assess the social consequences of the deployment and use of novel energy sources (Carrera and Mack 2010 and Hall et al. 2011). Due to the lack of work on this subject, particularly of analyses that explicitly address possible differences among first-generation and lignocellulosic bioethanol in terms of their social performances, the objective of the present essay is to compare main social aspects involved in the production and use of these fuel options on the basis of on a narrative literature review. Firstly, a brief description of methodological trends in impact assessment is provided in order to explore the definition of social impacts and how the assessment of such impacts is currently addressed; secondly, the social consequences of first-generation and lignocellulosic bioethanol are discussed and compared with reference to a tentative set of social issues and related criteria; finally, conclusions and recommendations are presented.

8.2. IMPACT ASSESSMENT

Impact Assessment (IA) is defined as the "process of identifying the future consequences of a current or proposed action,"[1] and social impacts are "the consequences to human populations of any public or private actions that alter the ways in which people live, work,

1 IAIA, "What is Impact Assessment?" Retrieved from http://iaia.org/publicdocuments/special-publications/What%20is%20IA_web.pdf (last visited on 1st November 2012).

play, relate to one another, organize to meet their needs and generally cope as members of society," including changes in societies' norms, values and beliefs, defined as cultural impacts (Interorganizational Committee 1995: 11).

Social impact assessments have existed since the late 18th century (Becker 2001). Today, they give shape to a major discipline (SIA), defined in general terms as the analysis, monitoring and management of the social consequences of planned interventions, including public participation within the process (Vanclay 2003). Life-cycle assessments (LCA) have also incorporated social appraisal through Social LCA (S-LCA), with emphasis on products' life cycle (Benoît et al. 2010). Other assessment methodologies, such as Technology Assessments (TA), provide tools for social evaluations of technological development. Traditional TAs were focused on the prediction of future consequences of technological developments and what could be done in terms of policy options based on an expert team for consultancy (Vandenende et al. 1998). Post-traditional types of TA's emphasize the influence of society in technological development, giving priority to participatory methods (Vandenende et al. 1998) and interdisciplinarity (see Guston and Sarewitz 2002). Recent integrated approaches propose the use of multi-criteria methods for sustainability assessment (see Giampietro et al. 2006 and Elghali et al. 2007) and the application of complex frameworks aiming at participatory social evaluation of technologies or projects (see Munda 2004).

8.3. SOCIAL CONSEQUENCES OF BIOETHANOL

To first compare first-generation and lignocellulosic bioethanol in terms of the social consequences implicated in their life cycle, the next sections will take core sustainability criteria previously explored by different authors as "battlegrounds." Drawing on work by Buchholz et al. (2009), on which 35 sustainability criteria for bioenergy systems were identified, grouped and assessed, aspects that emerge from social criteria identified by the authors will be highlighted and analyzed through literature comparison. In this work, among all identified criteria, 15 were classified as of social nature. The next sections explore these criteria, grouped within 5 main social-related issues of the bioethanol life cycle (Table 8.1.).

The water security issue, although not identified by Buchholz et al. (2009) as a social criterion for bioenergy sustainability evaluation, is included in this work as a major issue due to its relevance within the biofuels sustainability debate. Considering the purpose and the size restrictions of the present work, the definition of possible social indicators and measurement methods are not explored.

Table 8.1. Social issues and related social criteria of the bioethanol life cycle. *Compliance with laws, monitoring, planning and respect for human rights are considered as overall criteria because they are applicable to more than one issue as relevant social criteria.

<table>
<tr><th>Main social issues</th><th>Social criteria (identified by Buchholz et al. 2009)</th><th>Social criteria (identified by Buchholz et al. 2009) considered as of general applicability*</th></tr>
<tr><td rowspan="2">Land use aspects</td><td>Property rights and rights of use</td><td rowspan="12">Compliance with laws

Monitoring of criteria performance

Planning

Respect for human rights</td></tr>
<tr><td>Land availability for human activities other than food production</td></tr>
<tr><td>Water security</td><td>Not identified</td></tr>
<tr><td>Food security</td><td>Food security</td></tr>
<tr><td rowspan="6">Rural development</td><td>Working conditions</td></tr>
<tr><td>Respecting minorities</td></tr>
<tr><td>Social cohesion</td></tr>
<tr><td>Standard of living</td></tr>
<tr><td>Noise impacts</td></tr>
<tr><td>Visual impacts</td></tr>
<tr><td rowspan="2">Social acceptance and public participation</td><td>Cultural acceptability</td></tr>
<tr><td>Participation</td></tr>
</table>

8.3.1. Land-Use Aspects

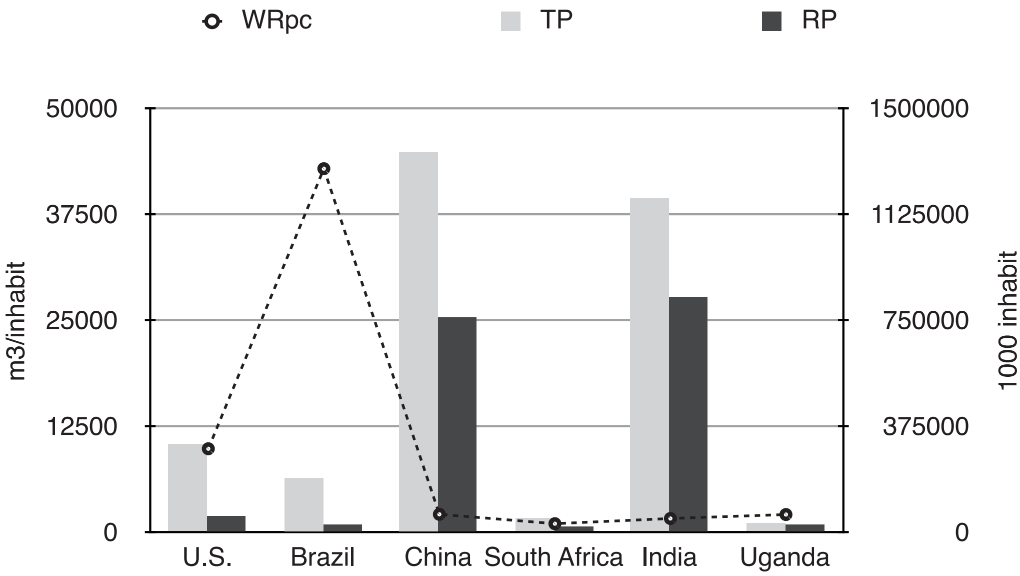
Social implications of land-use change (LUC) related to biofuels production are barely explored in the literature, which gives priority to assessing environmental aspects (e.g. Searchinger et al. 2008, Kim et al. 2009 and Havlík et al. 2010). Indirect land-use changes (ILUC) are difficult to track (Lapola et al. 2010 and van der Horst and Vermeylen 2010) and may entail social impacts related to land access that are not directly linked to feed-stock cultivation for biofuel production, but concern other factors linked rather to their expansion, such as the increase in land prices of those properties that have elected to grow energy crops and that were previously undervalued (Cotula et al. 2008). Large-scale production suggests large companies as land owners. Authors like van Wey (2009) and van der Horst and Vermeylen (2010) argue that positive social effects on the rural context are disconnected with agribusiness objectives, whereas small-scale initiatives are more likely to result in benefits for rural communities. National or private interests may directly affect social access to land in the rural context with expropriation strategies to expel people from land to provide biofuel investors with crop areas (Cotula et al. 2008). Land tenure is a problem, for example, in Indonesia, where forest lands for oil-palm cultivation have been expropriated from indigenous people (Phalan 2009).

An increase in large-scale production of first-generation bioethanol would lead unavoidably to both the emergence of monocultures and the spatial reorganization of land-use types, as new areas would be required for crop expansion. On the other hand, while first-generation bioethanol uses parts of specific starch or sugar crops as feedstock, lignocellulosic feedstock can be obtained from almost any source of plant biomass (Byrt et al. 2011). Once the conversion technology becomes cost-effective, it seems reasonable to think that—in the absence of regulations on the matter—an increase in cultivation of bioenergy crops or lignocellulosic dedicated feedstocks, such as short-rotation wood forests or grasses, could be encouraged. Another possible scenario is the one where agricultural and forest residues only are used for lignocellulosic bioethanol production. Production of lignocellulosic bioethanol made from agricultural residues like wheat straw, corn stover or sugarcane bagasse or wood residues should not enter in competition for land with other types of production (Havlík et al. 2010). Apparently, while an increase in feedstock cropping for both first-generation and lignocellulosic bioethanol are likely to produce LUC and implicate social impacts, lignocellulosic bioethanol produced exclusively from agricultural or forest residues (of already existing plantations) should minimize the negative social consequences surrounding this issue.

8.3.2. Water Security

Biofuels feedstock plantations can compete with water resources (Havlík et al. 2010). Increased biofuel production could have a significant impact on water availability and quality. Water could become less available on the community level, but the effects of its scarcity could also be felt regionally, in water prices (Gopalakrishnan et al. 2009). Implications of bioethanol production on water security depend not only on the characteristics of feedstock, but also on the region where it is being cultivated and the processing technologies being used (Wu et al. 2009). Fraiture et al. (2007) argue that monocultures of biofuel crops lead to water scarcity and water pollution. In countries like China or India, where massive agricultural production is very dependent on irrigation, negative impacts on water resources, food and feed production would be unavoidable if both countries substantially increased their land for biofuel cropping (Fig. 8.1.).

Fig. 8.1. Relation between Total Population (TP), Rural Population (RP) and Water Resources per capita (WRpc) in different countries in 2008. Data retrieved from FAO/AQUASTAT database



Havlík et al. (2010) estimates for a 2010/2030 comparison scenario on irrigation water use that the better performance in the long-term among different feedstocks for first- and second-generation bioethanol should be expected from woody crops obtained from existing forests to lignocellulosic bioethanol production, followed by both traditional and lignocellulosic crops grown on marginal lands.[2] White et al. (2011), on the other hand, report higher water use efficiency for grain maize or sugarcane than for short-rotation woody crops. Perennial grasses should perform better in terms of drought tolerance, although both are widely adaptable and could be produced on marginal land. For Gopalakrishnan et al. (2009), the best option is that where short-rotation wood energy crops are grown from degraded-water irrigation, such as municipal wastewater, on marginal lands. Non-irrigated switchgrass and wood residues are also potentially less water-intensive options, as water is needed for conversion process only. Between the two main routes to lignocellulosic bioethanol production explored today, biochemical and thermochemical, the former shows much higher levels of water consumption (Wu et al. 2009).

Increasing first-generation or lignocellulosic bioethanol production implies increasing water consumption in both cases, but probably at different levels. Semi-arid regions could be more affected in terms of water security due to bioethanol production expansion. Places where bioethanol feedstock is grown in the absence of irrigation, where degraded water is used for irrigation, or where feedstock derives exclusively from agriculture or forest residues, should present lower water demand for lignocellulosic bioethanol production.

2 The concept of marginal land is discussed in a further section.

On the other hand, conversion technologies—which play an important role in water-use efficiency in conversion processes for lignocellulosic bioethanol production via the biochemical route—need to be optimized in terms of water saving.

8.3.3. Food Security

Biofuel feedstocks occupation of lands traditionally used for food crops contributed to increasing in food prices in the short-term, but with little impact individually (Rathmann et al. 2010). Other factors could be higher demand for crops from China and India, droughts in Australia, low crop yields in the EU and Ukraine in 2006 and 2007, crude oil price and speculation, which were much less explored within last years debate (Ajanovic 2011). Trade measures such as subsidies and trade protection can also affect agricultural commodities prices directly (Dewbre et al. 2008). In any case, increase in currently commercial biofuels production can interfere, although in debatable levels, with agricultural commodities prices. Lignocellulosic feedstocks could grow on lands that are not used for growing food crops nor dedicated to other agriculture and livestock activities (Tilman et al. 2006 and Gopalakrishnan et al. 2009). These kinds of lands are commonly called 'marginal' lands, whose concept is a controversial one. While the adjective conveys the idea of a valueless space, abandoned or low quality one, such appraisal will depend largely on whom or what institution issued the opinion, falling on a relativistic discussion surrounding differences on points of view (see Bustamante et al. 2009 and Ojima et al. 2009).

First-generation and lignocellulosic bioethanol feedstocks are likely to be grown on both land today used for crop grow and livestock purpose, and low competition land (Sims et al. 2010 and van der Horst and Vermeylen 2010). These would be concentrated mainly in countries from South-America and Africa (Campbell et al. 2008). While growing certain first-generation bioethanol crops on marginal lands could increase erosion and pollution, low-input perennial grasses could reduce such impacts (Campbell et al. 2008). These plants are capable of growing, and presenting considerable yielding rates, within minimal input conditions in some regions in the short-term. Each species, however, requires specific management to guarantee its sustainability over time and its viability will depend on specific assessments (Knoll et al. 2012). Rajagopal et al. (2007), argues that when lignocellulosic bioethanol technology is finally deployed, only 14% of today's global cropland -plus crop residues- would be needed to replace 91% of current global demand for gasoline with bioethanol. Kim and Dale (2004) report that the use of agricultural wastes in bioethanol production could replace about 32% of the total gasoline used in that year. Grain crops for first-generation bioethanol production as well as prairie grasses and short-rotation forests for lignocellulosic bioethanol could both be grown on land in competition with food, fiber and feed. If lignocellulosic feedstocks are to be grown in marginal lands with null direct competition with food crops, then this could be considered as an alternative, although a limited one. The use of forest and agriculture residues or the organic fraction of municipal solid waste as feedstocks, as well as growing of feedstocks in marginal lands with the use of residues and wastes for lignocellulosic bioethanol production (Sims et al. 2010) could minimize social impacts. In any case, all depends on the existence of a previous consensus on what is understood by marginal land among a variety of actors.

8.3.4. Rural Development

First-generation biofuel feedstocks are obtained from crops that require more lands to accomplish production goals for the next decade, and a good part of these lands is located in poorer countries given their higher availability of potential areas for growing energy crops (Field et al. 2007 and Arndt et al. 2011). This factor has serious implications with regard to guaranteeing respect for minorities, as the greater part of the world's poorest rural communities are situated in those countries. The same pattern is valid for lignocellulosic bioethanol, if for its production lands for large-scale feedstock growth are needed.

Agricultural mechanization of large-scale production of energy crops could force rural displacement to cities, and implementation of feedstock cultivation and bioethanol power plants could make the rural labor force experiment a pattern change, as a high number of low-qualification workers might be "replaced" by fewer medium or high-qualification ones (La Rovere et al. 2011). Small-scale bioenergy facilities generate more rural jobs than large-scale ones (Berndes and Hansson 2007), and rural communities should benefit more from unskilled labor demand than from the generation of a few semi-skilled or skilled job opportunities, as well as from land rents to smallholders instead of large-plantations owners, especially in poorer countries (Arndt et al. 2009). Rural regions of poor countries with a resource-extractive industrial base could profit from biofuel production because the latter tends to be more labor intensive and to embed investments in local infrastructure—although it sometimes pays substandard wages and employs capital-intensive technologies not accessible to small farmers (Arndt et al. 2009). Projects are normally concentrated in those areas where semi-skilled to skilled labor and good infrastructure are available, so most remote rural areas remain excluded from potential socioeconomic benefits derived from biofuel production (Schut et al. 2010). Inefficient infrastructures and poor connectivity with rural areas could lead to a prolongation and intensification of rural poverty (Habib-Mintz, 2010), and regional inequalities within biofuel producing countries are also a problem (Hall et al. 2009). With regard to health impacts, most studies explore issues related to changes in air quality (see Liaquat et al. 2010). Increasing levels of air pollution in developing countries are of great concern. Production of potentially carcinogenic aldehyde compounds during bioethanol combustion is an important drawback, as well as a slight increase in NOx emissions verified in a 10% blending of ethanol in gasoline and impacts on regional ozone production (Gaffney and Marley 2009). Average health external costs for bioethanol production are much higher for corn (first-generation bioethanol) than for lignocellulosic biomass (Hill et al. 2009 and Kusiima and Powers 2010). Production of first-generation bioethanol presents higher labor demand than lignocellulosic bioethanol, so switching from one to another should result in negative impacts on job generation locally (Berndes and Hansson 2007 and Thornley et al. 2007). Expansion of feedstock cultivation for large-scale production of both generations could result in conflicts of interest between rural communities and company investors (van der Horst and Vermeylen 2010). Exclusion of remote rural areas characterized by a majority of unskilled labor forces can also happen. Although power plants implementation may result in overall improvements in infrastructure, capital attraction and creation of a limited number of more semi-skilled and skilled jobs, working in feedstock cultivation is the most "extended" option among rural dwellers. Rural benefits should come from small-scale projects that are well distributed geographically, independently of bioethanol type. It is not easy to appraise what differences within rural communities should be expected from moving from first-generation bioethanol production to lignocellulosic bioethanol, beyond changes in labor demand and workers' qualification needs, which should be felt more negatively in rural communities with the increasing of mechanization and technological innovation.

8.3.5. Social Acceptance and Public Participation Surrounding Biofuels

Although frequently present in the public debate over renewable energies and climate change, there are few academic studies that explore the issue of social acceptance of biofuels (Savvanidou et al. 2010). Besides, those that have explored this issue have focused on assessing the general and simplified question of whether or not citizens support biofuels, with no attention given to the differences among specific technologies or to the information on which the public bases its opinion (Delshad et al. 2010). Even more noticeable is the absence of works on public participation experiences surrounding discussions over biofuels issues specifically.[3] Whereas some academicians point out the necessity of promoting participatory processes within the biofuels sustainability debate, sustainability assessments and decision-making processes (see Haywood et al. 2009, Carrera and Mack 2010 and Raghu 2010), academic contributions dedicated to the analysis of initiatives or experiences of this kind surrounding biofuels as their main and only subject are inexistent, or restricted to grey literature to date.[4] Table 8.2. summarizes the main features and find-

3 Citizen or public participation in science and technology is the inclusion of public opinion (i.e., civil society as one of the consulted stakeholders) within a specific debate over the viability and desirability of projects, programs or policies. The participatory debate seeks to have a political significance with social and scientific value. Public participation is generally fostered through the organisation of workshops, consensus conferences, citizens' panels or public hearings, among other types of consultation processes.

4 Examples of public consultations on sustainability of biofuels are governmental initiatives such as those promoted by the Department for Transport of the UK or by the European Commission.

ings of prior studies undertaken in the field of social acceptance and social perception of biofuels.

Table 8.2. Analyzed studies on social acceptance and perception of biofuels.

	Social aspects	Dif. between bioethanol generations	Respondents' level of knowledge of the subject	Geographic location	Main findings
Savvanidou et al. (2010)	Price at the gas station	No	Very low	Greece (NE): biofuel feedstock cultivation area	Lack of information surrounding biofuels among respondents; Respondents support biofuels
Delshad et al. (2010)	Price at the gas station; Subsidies	Yes	Sufficient	U.S. (WE): major bioethanol producing region	Respondents prefer lignocellulosic bioethanol; 40% of respondents don't support biofuels
Selfa et al. (2011)	Effects on local economy; jobs; salaries; reduction of poverty; water security; air pollution; food prices; traffic congestion; generation of odors	No	(Not evaluated)	U.S. (WE): major bioethanol producing region	Lignocellulosic will probably replace first-generation in the long term; water security and traffic congestion are big concerns; plants create new jobs, but not well-paid ones; benefits are equal to costs
Skipper et al. (2009)	Food security	No	(Not evaluated)	U.S. and Belgium	Respondents prefer low food prices to low fuel prices, specially in regions with higher access to public transportation
Wegener and Kelly (2008)	(Not specified)	No	Gets notably lower from fossil fuels to pure biofuel and new biofuel generations	U.S.	Respondents support the use of corn and switchgrass more than wood as feedstock for bioethanol production; respondents are positive to the use of GM crops;

Within studies, overall social aspects were examined poorly or not at all (except for the work of Selfa et al. 2011). Differences among biofuel types and between bioethanol generation methods were also practically not addressed, which is very negative considering that a transition between technologies is expected within the next decade. Citizens' lack of knowledge surrounding widespread energy options such as biofuels is worrisome and could hinder public participation initiatives. Other research on public acceptance or perception of biofuels conducted in producing countries characterized by more socially unequal contexts or realities should present contrasting results. This topic is a vast field of research yet to be explored.

8.4. CONCLUSIONS

In terms of expected differences between first-generation and lignocellulosic bioethanol social performances, the analysis presented in this work suggests that production of the latter from agricultural and forest residues only—as well as other residues containing lignocellulosic biomass, like those found in municipal waste—could present minimized social impacts when compared to other lignocellulosic feedstock such as purpose-grown species or starch/sugar crops used in the production of first-generation bioethanol. At least within three major social issues—land use change and food and water security—social consequences could also be minimized through the use of marginal lands for feedstock expansion. However, it is very important to stress that this last option is completely dependent on the existence of scientific and public consensus surrounding the concept of marginal land and the evaluation methodology used to define this kind of land. More sustainable lignocellulosic bioethanol also needs to be highly efficient, to use low-contaminant conversion processes and to present low costs throughout its life cycle. Moreover, if rural development is to remain as one of the principal arguments for supporting biofuel policies, availability of technology and feedstock in different regions of the world, especially poorer ones, is needed. Possible benefits are also dependent on well-established management policies and well-planned programs focused on benefiting rural regions in terms of infrastructure improvements and labor integration.

Social assessments of bioethanol need to rely on a much broader set of empirical data. For this, fieldwork should be carried out within a wide range of contexts and regions including, whenever possible, participatory methods in order to provide expertise with new and important lay or community-based knowledge, besides respecting the rights of minorities. This is a critical topic, as it has been shown that there is a considerable lack of efforts toward public-opinion appraisal surrounding biofuels worldwide and that public engagement experiences on this matter are limited.

This essay pondered overall differences between the social consequences of first-generation and lignocellulosic bioethanol production. The discussion presented here is an attempt to draw attention to the necessity of addressing priority social issues of new bioenergy technologies such as lignocellulosic bioethanol before its full deployment. Otherwise, social drawbacks could undermine the technology's viability in the future.

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Beyond commonplace biofuels: Social aspects of ethanol

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H I G H L I G H T S

- The literature lacks evidence on the social impacts of ethanol.
- Further work is needed on social criteria and indicators for assessment.
- Ethanol developments can increase the levels of social vulnerability.
- Decision-making should internalise the social dimension of biofuels sustainability.

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Biofuels policies and projects may lead to environmental, economic and social impacts. A number of studies point out the need to deliver comprehensive sustainability assessments regarding biofuels, with some presenting analytical frameworks that claim to be exhaustive. However, what is often found in the literature is an overexploitation of environmental and economic concerns, by contrast to a limited appraisal of the social aspects of biofuels. Building on a systematic review of the peer-reviewed literature, this paper discusses the social constraints and strengths of ethanol, with regard to the product's lifecycle stages and the actors involved. Its objective is to contribute to the development of social frameworks to be used in assessing the impact of ethanol. Main findings indicate that ethanol developments can increase the levels of social vulnerability, although there is little evidence in the literature regarding the positive and negative social impacts of 1st-generation ethanol and potential impacts of cellulosic ethanol. Further work is needed on the formulation of social criteria and indicators for a comprehensive sustainability assessment of this biofuel. Policy makers need to internalise the social dimension of ethanol in decision-making to prevent public opposition and irreversible social costs in the future.

1. Introduction

Paraphrasing Rabel Burdge, who characterised social impact assessment as the orphan of assessment processes (see Burdge, 2002), the social dimension of the sustainability of biofuels could be considered as the abandoned child of sustainability appraisals for this energy alternative. Studies thus far have instead tended to give priority to in-depth analysis of economic and environmental issues (German et al., 2011; Lehtonen, 2011; Ribeiro, 2012; Sheehan, 2009; Uriarte et al., 2009). Although this tendency certainly does not contribute to the development of a sound governance of bioenergy, investment in biofuel programs and projects is on the increase, driven primarily by worldwide energy policy mandates (see OECD-FAO, 2011). Among biofuels, ethanol is the most produced and commercialised today, obtained mostly from the fermentation of glucose contained in starch and sugar crops such as corn, wheat, sugarcane, and sugar beet. Next-generation or second-generation ethanol, made from cellulosic feedstock such as short-rotation forests, prairie grasses or agricultural and municipal wastes, is thought to be a potential substitute for first-generation ethanol in the coming decades (Naik et al., 2010; Sims et al., 2008).

While "a lifecycle refers to the life span of a product, from resource extraction, to manufacture, use and final disposal" (Nieuwlaar, 2004), ethanol's lifecycle ranges from the phase of raw material or feedstock production and collection to the product's final use in internal combustion engines. As a complex technological system that interacts with the societal setting (see Russell et al., 2010)—i.e. a socio-technical system—processes related to ethanol's lifecycle can engender, and be modified by, processes of social change involving various actors, such as farmers, employees, consumers and members of rural communities. This article aims to contribute to the understanding of the social aspects of ethanol, and in so doing, encourage the development of social sustainability

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frameworks for use in impact assessments. To this end, it draws on a systematic review of the peer-reviewed literature, highlighting and discussing the social trade-offs related to ethanol's socio-technical system, paying particular attention to the stages of the lifecycle and to the actors involved.

2. Systematic search for articles

A systematic review of the available peer-reviewed literature was undertaken. Moher et al. (2009) define systematic reviews as "a review of a clearly formulated question that uses systematic and explicit methods to identify, select and critically appraise relevant research, and to collect and analyze data from the studies that are included in the review" (Moher et al., 2009). Systematic reviews are very popular among medical studies (e.g. Glinianaia et al., 2004; Lundh et al., 2009) and should be given greater significance on the field of social science research.

Our research question was what social aspects of ethanol as a biofuel are identified among the peer-reviewed literature on the subject? A comprehensive list of search terms was defined accordingly. The search strategy was partly based on the guidelines of the Cochrane review (Higgins and Green, 2011) that consists of a review of studies that meet pre-specified criteria for inclusion, i.e. a systematic review aiming to identify all relevant studies that fit into the chosen issue domain (Budimir et al., 2011). Two inclusion criteria were defined: (a) articles from peer-reviewed journals with their full-text in the English language with no time period limit and (b) articles addressing or mentioning at least one social impact of ethanol used as a biofuel (following the concept of social impact presented in the next section of this article). The Web of Science, Science Direct and Google Scholar were used as databases for articles search. In total, 90 papers were selected for final qualitative analysis (see Appendix for a summary of selected studies). Meta-analysis (statistical methods for quantitative appraisal) was not performed due to the dominating qualitative approach of our study.

3. Social sustainability of ethanol as a socio-technical system

Understanding the social sustainability of ethanol involves tasks of both a conceptual and operational nature (for a detailed discussion of the definition of social sustainability see Boström, 2012). One must define, on the one hand, the various aspects which have a bearing on the social sustainability of ethanol's socio-technical system, i.e. social impacts, and on the other, how those elements are to be operationalised so as to reveal the variables, i.e. criteria and indicators, needed to assess them. The first task in conceptual framing, which is the object of this article, involves considering the potential positive and negative social impacts of planned interventions related to ethanol as a biofuel (see Vanclay, 2003). In our study, we understand the social impact of socio-technical systems as the influence of those systems in the generation of social change processes and the associated human responses to those changes—if identifiable, which may be positive or negative. This vision is slightly different from the one defended by some social impact assessment scholars, for which social change processes and social impacts tend to be seen as separate components, being social impact equal to human response to change (see Van Shooten et al., 2003; Vanclay, 2002). Processes of social change can relate to any phase of the development of projects, policies and programs, starting from their planning and continuing throughout the product's lifecycle. The ultimate consequence of a social impact is the experience felt by the person (the human response), e.g. fear or happiness, death or health improvements etc. (see Van Shooten et al., 2003). Moreover, these processes can be indirectly related to changes at the economic, institutional and environmental levels. The sphere of the 'social issues' is thus not independent of the one of market, political and biophysical issues.

Evaluating the social impacts of planned interventions is not a straightforward exercise, and given their strongly normative nature, it is one which necessarily involves considering the views of a number of actors concerning what is or is not socially desirable (see Russell et al., 2010). The idea of "desirability" of technological development is linked to that of social sustainability. Due to its politicised nature, the discussion is not limited solely to technical appraisals, and involves public debate. Besides, more than assessing the immediate advantages of devising and implementing a system such as ethanol as a biofuel—e.g. potential reductions in greenhouse gases (GHG) emissions, improvement of energy security at national level etc.—one should reflect upon the socially desired, wider-reaching processes of social change that will shape a new development model or contribute to the upkeep of a current one (see Quintanilla, 2005). Thus, in order to ensure the social sustainability of a socio-technical system like ethanol as a biofuel, one must (a) avoid damaging what is socially shared as being desirable and (b) improve social conditions where current ones are viewed as not being desirable, at every stage from the planning to the implementation of the system. Balancing desirability sometimes entails a conflict of interest between groups with different social goals, which gives rise to a situation of political disagreement. However, decision-making in political dispute is not constrained to the realm of opinions, but must also involve objective appraisal of social outcomes. In this sense, sound social contextualisation of planned interventions, by identifying potential social changes and the interests of the various actors involved, is essential in promoting more equitable debates on social and technological futures. This is partially done here, by way of a top-down approach through the analysis of the peer-reviewed literature, and the framework will hopefully be strengthened later by bottom-up input, with public and expert consultation.

4. Contextualising the social aspects of ethanol

As previously stated, this work is a first step toward social framing of ethanol, so it is limited by a finite body of literature, consisting of selected peer-reviewed articles. Our identification and evaluation of social change processes and potential social impacts related to ethanol reflect the opinions or findings presented in the papers under discussion. Later sections summarise the social aspects of ethanol and actors involved from a lifecycle perspective. For the sake of objectivity and due to space constraints, only the main variables are addressed.

4.1. Production of inputs

This stage of ethanol's lifecycle refers to the production of fertilisers, herbicides, pesticides, equipment, fuels etc. that are used in the ethanol production chain and is the least explored among the existing studies. Changes at the local community level involve dependence on external inputs such as petroleum-based fertilisers, pesticides and fuels (Amigun et al., 2011) for feedstock production and transport of raw material and ethanol, for example. If inputs are to be purchased from companies for large-scale ethanol production, high costs could diminish their availability for poorer communities and increase farmers′ dependence on external supply. On the other hand, cross-cutting issues such as employment generation (Solomon, 2010; Vasudevan et al., 2005) could apply to this stage, with ramifications for actors involved in the supply chain, such as fuel distributors or retailers.

4.2. Feedstock production

Unlike the production of inputs, the agricultural or feedstock production stage of ethanol is by far the most fully discussed. The ethical and social trade-offs of biofuels are thought to be mostly related to land use (see Jordaan, 2007), i.e. changes in terms of land use resulting from the implementation of new biofuel projects or switching from traditional cropping to biofuel feedstock production. At the local community level, ethanol projects could contribute to the empowerment of women—especially in developing countries where they are responsible for securing energy for their households (Amigun et al., 2011). However, this could be limited to small-scale, locally based production (Malik et al., 2009), since large-scale monocultures for export entail a risk of concentration of wealth, and uncertainties surrounding social welfare (Uriarte et al., 2009). Furthermore, any negative impacts on wellbeing are likely to affect men and women disproportionally, the latter being the more affected group (Gasparatos et al., 2011). Overall empowerment of rural communities would come from entrepreneurship and business run by local people (as producers and processors of ethanol) (Hall and Matos, 2010). To accomplish this, access to machinery and cheap energy is needed. Ethanol projects that invest locally in education, sport and health could also benefit communities (Neves, 2010), and the organisation of small producers in locally-run cooperatives could guarantee a larger share of these benefits (Milder et al., 2008). Profound changes in local rural infrastructure can result from ethanol production and distribution, increasing the availability of services to the community. While social benefits may arise from, e.g., the revitalisation of rural areas (Bush, 2007; Koizumi, 2011), the assessment must also look at possible increases in the vulnerability of infrastructural systems, relating to, for example, changes in traffic flow or water distribution in the long term (Ng et al., 2011). Besides, project planning should include remote areas as biofuel production sites, in order to contribute to the alleviation of poverty in those places (Malik et al., 2009).

The choice of production sites poses questions of land governance, related to land tenure conflicts (Gasparatos et al., 2011; Sosovele, 2010)—the result of conflicting valuation of the land between investors, governments and local communities. This phenomenon involves the misinterpretation of "marginal" or "degraded lands"—a qualifier that is often used to justify the choice of feedstock production sites. These lands are often perceived as unused, unsuitable for agriculture, unprofitable (see Bailis and Baka, 2011; Davis et al., 2011) or contaminated lands (see Hattori and Morita, 2010). However, lands which are arguably marginal may be particularly valuable for vulnerable and marginalised populations, serving as support for livelihoods, as well as harbouring important cultural values (German et al., 2011; Van der Horst and Vermeylen, 2011). Forest clearing for biofuel cropping, and the resultant deforestation, destroys natural heritage and reduces the environmental services and goods that forests might provide to local populations (Gao et al., 2011). Communities′ sovereignty can be preserved by protecting the interests of locals and small landowners by, for instance, preventing concentration of land—i.e. power—in the rural setting (Schaffel and La Rovere, 2010); conservation of aesthetics and cultural, archaeological and palaeontological heritage (Dale et al., 2010; Fischer et al., 2010; Gallardo and Bond, 2011); guaranteeing ethnic groups′ access to land and forest resources, which could be threatened by environmental degradation due to expansion of biofuel feedstock (Banerjee, 2011); and fostering energy security at the local level by offering village households access to cheaper fuel (Van der Horst and Vermeylen, 2011). On the other hand, an increase in the levels of rural-to-urban migration, as seen with ethanol development in Brazil (see Lehtonen, 2011), and the risk of overpopulation in producing areas (Gallardo and Bond, 2011), can have a profound impact on the social cohesion and stability of communities. Concentration of ethanol production could also lead to the emergence of regional inequalities within countries, with implications for employment and migration (Hall et al., 2009).

Changes in the type of farming (e.g. from traditional cropping to ethanol feedstock production) could affect farmers and workers in several ways. For instance, the introduction of mechanisation in sugarcane plantations reduces the number of jobs and causes exclusion of a high number of poor, unskilled workers, although it may increase demand for skilled workers (Wilkinson and Herrera, 2010). Professional re-qualification of unskilled workers should help mitigate this problem (Schaffel and La Rovere, 2010). Farmers would also need to adapt farm management when adopting new technologies (Malik et al., 2009), and evaluation of farmers′ acceptance of or willingness to change (Selfa et al., 2011) is a crucial issue, as is the necessity of expert assistance for transition (Rossi and Hinrichs, 2011). If farmers are willing to produce ethanol feedstock, we have to guarantee their inclusion in the supply chain—especially for impoverished farmers (Hall and Matos, 2010) and strengthen agricultural contracts between farmers and companies (Novo et al., 2010) to avoid social exclusion of this vulnerable group.

As regards issues of health and safety (H&S) and working conditions, workers can suffer from respiratory problems if sugarcane is burnt before harvesting (Corbiere-Nicollier et al., 2011) and other problems associated with high workloads (Smeets et al., 2008). Pollution of waterways by farm wastes and residues can cause health afflictions among locals (Chavez et al., 2010) and air pollution due to harvest burning practices may affect not only workers in the field but also nearby communities—mostly children and elderly people—because of the aerosol particles and carcinogenic products released (Martinelli et al., 2011; Uriarte et al., 2009). Others point to the reduction in the levels of emissions of some types of air pollutants in metropolitan areas due to ethanol consumption (Goldemberg and Guardabassi, 2009), although this is a controversial issue since there is evidence of an increase in the emissions of other pollutants like nitrous oxide (Pimentel et al., 2008). Increased noise and noticeable odour levels can also affect local dwellers near feedstock production areas in the case of sugarcane ethanol (Gallardo and Bond, 2011). Job stability and legality are also important issues, since seasonal or informal employment can increase workers′ vulnerability (Gallardo and Bond, 2011). To mitigate other issues such as forced or child labour associated with feedstock harvesting, as identified, e.g., in the case of sugarcane in Brazil (Smeets et al., 2008), and guarantee decent working conditions, there must be compliance with national legislation and with international standards (Janssen and Rutz, 2011).

A point closely related to the land use issues discussed above, which comes under the broad problem of international security (see Naylor, 2011), is that the food security of locals and society overall can be threatened—either directly by competition of food crops with ethanol feedstock (i.e. through the diversion of food crops for ethanol production) or indirectly through competition for limited resources such as land, water, fertiliser and fossil fuels (Bell et al., 2011; Hattori and Morita, 2010; Koning et al., 2008; Paustian and Cole, 1998; Phalan, 2009). The social burdens of food/biofuel competition are mostly felt by poor people, who are more vulnerable to rises in staple food prices since they spend a larger share of their incomes on food (Aerni, 2008; Timilsina and Shrestha, 2011). The fluctuation of food prices in the international market can threaten food security at a broader societal level, irrespective of the place of feedstock production (Naylor et al., 2007). The use of agricultural and forest wastes and non-edible energy crops for production of cellulosic ethanol could be one measure to mitigate the food/fuel competition (Koh and Ghazoul, 2008; Nigam and Singh, 2011). In China, the third-largest ethanol producer in the world, availability of land for feedstock production is one of the main barriers to the expansion of ethanol, and given that food security is a major concern for the government, production of ethanol from non-food crops and cellulosic material have been being encouraged in the past few years (Tan et al., 2010). However, the overall sustainability of this option is a matter of some debate, since the large-scale use of agricultural residues for ethanol production could increase feed/biofuel competition (Gomiero et al., 2010). In addition, differences in terms of resources and specific socioeconomic contexts that influence crop yields, land availability and labour costs in feedstock-producing regions can also affect food security levels, which are likely to vary worldwide (Spiertz and Ewert, 2009).

Changes in the biophysical setting can affect the availability and quality of environmental products and services, i.e. ecosystem functions, having negative impacts on assets that are valuable for society, and engendering indirect social impacts (Slootweg et al., 2003). In terms of the feedstock production stage, the shift from traditional agriculture to ethanol feedstock cropping, and the resultant diversion of land and resources, can have a damaging effect on biodiversity. Homogenisation of agricultural landscapes by large-scale monocultures has a negative impact on natural pest control, increasing the need for pesticides (Dale et al., 2010; Phalan, 2009). Moreover, feedstocks with invasive behaviour, i.e. those that are more tolerant to biophysical constraints, can destroy traditional plant species with high cultural value (Gasparatos et al., 2011). The implementation of agro-ecological practices such as intercropping and polyculture would increase biodiversity on these farms (Amigun et al., 2011) and the adoption of a multifunctional agricultural model could combine preservation of ecological services with rural development (Jordan and Warner, 2010; Randelli, 2009). The water security issue, on the other hand, is mostly linked to the diversion of water resources from human needs (water availability) to ethanol feedstock production and the pollution of waterways (water quality) by disposal or runoff of liquid wastes from the fields. The irrigation needs of ethanol crops may vary, but in the case of cultivation of water-intensive crops, negative impacts on water availability could be expected, like for corn cultivated in the US (Ng et al., 2011; Pimentel et al., 2009). In the case of sugarcane cultivation, discharge of vinasse into waterways and contamination by nutrients from fertiliser use can lead to eutrophication of surface waters (Martinelli and Filoso, 2008). Moreover, developers must ensure existing formal or customary water rights are respected before implementing biofuel projects (Solomon, 2010).

4.3. Transport

Similarly to the input production stage, changes at the level of transport are poorly addressed. This stage of ethanol's lifecycle comprises the transportation of feedstock, ethanol or other inputs from the fields to the power plant and from plant to pump, as well as storage. An increase in the passage of heavy goods vehicles could cause changes to traffic flows and congestion patterns (Selfa et al., 2011) transporting feedstock to and ethanol from the biorefinery, besides cross-country transportation of ethanol from rural producing areas to major urban areas for consumption (Ng et al., 2011). Deterioration of roads (Selfa et al., 2011), an increased risk of accidents and a threat to children's safety (Gillon, 2010) are possible negative social impacts of these changes. The risk of transportation hazards from flammability and possible leakages should also be considered (Ng et al., 2011). On the other hand, implementation of ethanol projects could lead to overall improvement of transportation infrastructure—e.g., repairs of railways (Ng et al., 2011). The physical bulkiness of the feedstock and the proximity of the plantation, biorefineries and the overall supply chain are examples of factors that affect the transportation and storage of goods during ethanol's lifecycle (see Ng et al., 2011; Rossi and Hinrichs, 2011).

4.4. Production plant

At the production or processing level, conversion processes transform raw material into ethanol, generating a number of by-products, co-products and waste products. At this stage, but at other levels as well, the adoption of comprehensive corporate social responsibility principles could deliver positive social impacts (Schaffel and La Rovere, 2010; Schuurbiers et al., 2007). Of such positive impacts, one might cite the improvement of working conditions (Neves, 2010), the generation of services and benefits for local communities such as maintenance of schools, nurseries and day-care units (Gallardo and Bond, 2011), education and health for workers' children and training of workers lacking formal education (Hall and Matos, 2010). In the state of São Paulo, the major ethanol-producing area in Brazil, the presence of ethanol plants is associated with socioeconomic benefits in terms of rural development, such as job creation and infrastructural development (Martinelli et al., 2011). As regards workers' health and safety at the ethanol plant, risks of explosion and fire due to storage of ethanol should also be taken into account (Gallardo and Bond, 2011). Other benefits may arise from agreements between communities hosting ethanol plants and energy companies—on long-term lower-cost energy, for instance (Selfa et al., 2011). Also, the sale of co-products and by-products can provide extra income for producers (Zapata and Nieuwenhuis, 2009) and benefit the overall supply chain. These can be used as an energy source for the conversion process, like in the case of the combustion of sugarcane bagasse (Hattori and Morita, 2010; Schaffel and La Rovere, 2010), or in the production of animal feed (corn meal) (Harvey and Pilgrim, 2011; Koh and Ghazoul, 2008), among other valuable products. However, while locally owned and run facilities would benefit more poor rural communities (Milder et al., 2008), ethanol processing is rather expensive (Koizumi, 2011) and its costs vary greatly from one producing country to another, depending on subsidisation policies, the level of development of the sector and climatic conditions (Lenk et al., 2007).

Ethanol processing can release liquid and airborne pollutants into the environment, resulting in possible health problems for the local population and jeopardising water safety. In the US, ethanol plants have been responsible for excessive release of a number of air pollutants, and have broken the law regarding air pollution due to the lack of emission control equipment, as well as committing water quality violations due to undesirable effluent discharging (Selfa, 2010). In the case of sugarcane vinasse, a by-product of ethanol processing in Brazil, accidents during storage or transport are not uncommon and, were the product to reach the waterways, it could compromise the quality of aquatic systems (Martinelli and Filoso, 2008). Moreover, the ethanol industry is water-intensive and could be especially dangerous in those areas where water availability is limited, which are more vulnerable to water shortages (Luk et al., 2010; Selfa, 2010; Selfa et al., 2011). In any case, social trade-offs involved with the siting and scale of the plant should be studied further (Van der Horst and Vermeylen, 2011), since there is a lack of research on social vulnerabilities of communities hosting biofuel production (Selfa et al., 2011).

4.5. Final use

At the final use stage, ethanol reaches the final consumer and is burned in the engines of public or private vehicles. One advantage of ethanol is that it can be used in contemporary internal combustion engines and distributed through the existing fuel infrastructure, avoiding the need for major infrastructural rearrangements (Walter et al., 2008). However, existing pipelines used for gasoline distribution are not suitable for transporting ethanol due to its affinity for water (high hygroscopicity), which could lead to corrosion problems (Luque et al., 2008; Ng et al., 2011). This way, the biofuel is rather transported by truck (Luk et al. 2010) or rail, since the costs for the construction of special, ethanol-dedicated pipelines are too high (Ng et al., 2011). On the other hand, its implementation in public transportation could improve energy security at national level (Demirbas and Demirbas, 2007). The rural poor could benefit from the reduction of the amount spent on transport if cheaper biofuel is provided, although there is no record of initiatives of this kind (Van der Horst and Vermeylen, 2011). Substitution of gasoline by ethanol could deliver health benefits in urban areas through the reduction of emissions of pollutants such as nitrogen oxides, carbon monoxide, particulate matter and volatile organic compounds, with the consequent improvement in air quality (Goldemberg and Guardabassi, 2009; Nigam and Singh, 2011; Randelli, 2009; Walter et al., 2008). However, some consider this a fallacy, as there may be an increase in emissions of other pollutants (Phalan, 2009). Moreover, since ethanol combustion delivers less energy than gasoline, more ethanol would be needed to travel the same distance, increasing the overall release of air pollutants (Pimentel et al., 2008). The same would be true in the case of an increase of miles travelled due to lower ethanol prices forced by government mandates and subsidies (De Gorter and Just, 2010), since the demand for ethanol on the part of the final consumer is largely determined by fuel prices at the pump (Banerjee, 2011). In addition to lower toxicity, better fire safety and biodegradability are held up as examples of the advantages to ethanol, in support of its suitability for use in urban areas (Randelli, 2009). Other aspects at the final use stage are those which affect ethanol consumers directly, like the costs of vehicles and the fuel itself, the distance between refuelling stations, vehicle options available (Mohamadabadi et al., 2009) and flexibility of choosing between fuels at the pump in the case of flex-fuel vehicles (Koh and Ghazoul, 2008). These aspects interfere directly with consumption patterns and convenience, affecting consumer behaviour.

4.6. Cross-cutting issues

The category of "cross-cutting issues" encompasses those social aspects that apply to more than one of ethanol's lifecycle stages or affect more than one group of actors. These issues, which are crucial in the debate surrounding the social sustainability of ethanol, are: energy security, compliance with legal framework and law enforcement, employment and income generation, public participation and public acceptance of biofuels.

4.6.1. Energy security

Energy security constitutes one of the main driving forces behind biofuel development policies worldwide (Rossi and Hinrichs, 2011; Selfa et al., 2011; Spiertz and Ewert, 2009), since one of the benefits of biofuels would be to reduce dependence on foreign energy at the national level (Sobrino and Monroy, 2009; Sobrino et al., 2010; Zanin et al., 2000; Zinoviev et al., 2010), sidestepping the reliance on politically unstable countries for fossil fuels (Luque et al., 2008). However, national energy security goals are likely to correspond more with the interests of governments and large-scale producers than with those of small communities (Van der Horst and Vermeylen, 2011), and that could undermine energy independence at the regional level or energy sovereignty of the rural poor. In fact, bioenergy programs aimed at delivering energy to the rural poor are normally limited, since buyers cannot afford the product (Coelho et al., 2006). In spite of that, there is evidence of cases in which biofuel production has increased energy security at the local level through the implementation of small-scale projects and at the household level, contributing indirectly to poverty alleviation (Gasparatos et al., 2011).

4.6.2. Legal framework and law enforcement

While law enforcement is regarded as an important element for mitigating the negative social impacts of ethanol (Janssen and Rutz, 2011), socially unequal countries with weak or unenforceable regulatory frameworks are more vulnerable to possible negative outcomes from its production (Uriarte et al., 2009). These are usually biofuel-producing countries in the poor south. Tanzania, for example, suffers from a complete absence of a legal framework to regulate biofuel development (Sosovele, 2010). In Brazil, there is a need for firm enforcement of labour and social law, and for strengthening of social justice in the ethanol sector in order to reduce labour violation, poverty, conflicts and social inequality at the local, regional and national levels (see Martinelli and Filoso, 2008; Sawyer, 2008; Schaffel and La Rovere, 2010; Smeets et al., 2008). The cumulative negative social impacts of the ethanol industry could damage its socio-political legitimacy (Hall et al., 2011) if there is not a sturdy legal framework for biofuel development and active law-enforcement mechanisms.

4.6.3. Employment and income generation

The development of biofuel programs can create jobs in rural areas and along the overall productive chain, from research to trade and services (Neves, 2010; Vasudevan et al., 2005), although from one type of biofuel—i.e. one type of production process to another, there are noticeable differences in the volume and characteristics of jobs created (Conejero et al., 2010). By contrast to biodiesel, which tends to support the development of small-scale producers, the ethanol industry is usually characterised by centralised, large-scale, export-driven production (see Hall et al., 2009) so as to guarantee its economic feasibility (Conejero et al., 2010). This model is less labour-intensive since it is based on mechanised harvesting and involves higher rates of temporary, unskilled employment at the plantation level (German et al., 2011; Lehtonen, 2011). In Brazil, for example, one single machine used in sugarcane harvesting can displace 80 workers (Smeets et al., 2008). However, temporary jobs could be created during the construction of the processing plant, while jobs at the refinery would demand unskilled but also highly skilled labourers, e.g. engineers, chemists and managers (Bell et al., 2011; Solomon, 2010). In any case, learning opportunities need to be fostered to avoid social exclusion of unskilled rural workers (Sathaye et al., 2009), but being able to work in complex industrial facilities such as an ethanol refinery also depends on an existing educational background (Luk et al., 2010). Maintenance of ethanol programs is also crucial for avoiding massive job losses and other negative social impacts in countries like Brazil, where more than half of jobs in the sugarcane industry are directly related to the ethanol production chain (Zanin et al., 2000). As regards wages in the ethanol sector, the average wage paid by the trade-union member companies in the ethanol industry in Brazil was shown to be much higher than the federal minimum wage for the same period (Neves, 2010) and higher than in other industrial sectors (Novo et al., 2010; Smeets et al., 2008). However, the generation of incomes should be contrasted with living costs, which, if high, can hinder decent standards of existence (Smeets et al., 2008). In Brazil, manual harvesting is still underpaid, leading to higher workloads of cane cutters wishing to earn more (Martinelli and Filoso, 2008). Concentration of the larger share of incomes in the hands of producers and processors is also an issue in the Brazilian ethanol sector (Sawyer, 2008).

4.6.4. Public acceptance and public participation

Public acceptance of biofuels varies among different geographical contexts, and previous studies do not offer conclusive results on the subject (Savvanidou et al., 2010). Ethanol could face public resistance in the future if technology does not advance as forecasted—i.e. developing cellulosic ethanol with improved cost and environmental efficiency or if it continues to threaten food security by using edible crops for production (Luk et al., 2010). Also, public acceptance of genetically modified crops (GM crops) is an important issue surrounding biofuel developments (see Fischer et al., 2010; Gallardo and Bond, 2011; Gielen et al., 2003; Smeets et al., 2008). The levels of acceptance of GM organisms for biofuel production should be higher if dedicated, non-edible energy crops are genetically modified instead of food crops (Koh and Ghazoul, 2008) and vary among different regions in the world (Janssen and Rutz, 2011). In a study conducted in Greece, few citizens would prioritise biofuels over other renewable energy sources, although an even smaller number know the difference between ethanol and biodiesel (Savvanidou et al., 2010). Consumer acceptance of ethanol depends mainly on the risk perception of supply stability and the price of vehicles, and flex-fuel vehicles are likely to reduce consumer uncertainty concerning the fuel's reliability (Zapata and Nieuwenhuis, 2009). Moreover, consumer acceptance of biofuels is increasingly being driven by preference for more socially and environmentally responsible products, including imported biofuels (Phalan, 2009). Policy makers and investors normally have an instrumental vision of rural actors as passive suppliers with neutral or absent opinions regarding the trade-offs and social desirability of biofuel production (Rossi and Hinrichs, 2011). Yet, farmers are concerned about a number of aspects such as changes on aesthetics, concentration of incomes by large-scale firms, feedstock transportation constraints, among others (Rossi and Hinrichs, 2011). For example, local communities from ethanol-producing regions in the US showed low levels of satisfaction regarding economic benefits or poverty reduction resulting from the presence of ethanol plants, as well as concerns about water security, air pollution, traffic problems and risks of instability or decline of the industry in the future (Selfa et al., 2011). On the other hand, residents believed that energy security constitutes a crucial reason for supporting ethanol industry in the US, and concern over negative environmental impacts was usually overshadowed by public expectations of job creation and new markets for farm products (Selfa, 2010). Changes in and expansion of infrastructure related to ethanol projects also need the appraisal and acceptance of local communities (Ng et al., 2011). Finally, the media's discourse plays a great role in shaping public perception of controversial issues (Wright and Reid, 2011), which could influence the level of public awareness and acceptance of biofuels. Public participation in decision-making is considered a way of legitimising biofuel policy and fostering implementation of more sustainable projects from the environmental and social points of view (see Di Lucia, 2010; Schaffel and La Rovere, 2010; Schuurbiers et al., 2007; Sheehan, 2009). Participatory processes are important tools for project planning, so bioenergy can contribute to multiple social goals held by different actors (Milder et al., 2008), including often-marginalised local knowledge, which is especially valuable in the assessment of bioenergy trade-offs (Rossi and Hinrichs, 2011). However, effective public engagement and inclusion of non-specialist knowledge in the bio-based economic debate might depend on the redesign of current methods and models (Schuurbiers et al., 2007).

5. Conclusions

Impact assessment of alternative energy sources has to be committed to wide-ranging social agreements over desired and realisable energy futures. This is a very complex and novel task, since modes of governance of socio-technical systems have evolved at a different pace than have democratic regulating institutions. Besides, although public criticism of science and technology development is not entirely new, the configuration of energy systems and their use has not been something largely debated or agreed since humans first started to use coal. At the same time, evidence shows that choices on energy sources made in the past, as well as the related consumption patterns adopted in wealthy societies in the last century, are responsible for most of today's environmental and social challenges. Although biofuel sustainability has been a much-debated topic in the past few years, there is still a lack of evidence in the peer-reviewed literature regarding the positive and negative social impacts of 1st-generation ethanol or appraisal of potential social impacts of cellulosic ethanol. Besides, studies tend to discuss aspects of biofuels but disregard the specificities of each kind of fuel. When quoted, social changes or impacts of ethanol are not contextualised as regards the actors affected and the lifecycle stage involved. A range of actors are often overlooked, such as consumers, value-chain actors or even society as a whole, as well as the phases of input production, transport and final use.

Further work is needed on the formulation of social criteria and indicators for a comprehensive sustainability assessment of ethanol. For this, case studies focused on the identification and engagement of relevant actors based on a lifecycle approach can be particularly valuable. Greater availability of primary data should encourage the development of comparative studies. Assessments will have to make it a priority to engage local rural dwellers in order to define the parameters and boundaries of assessment, based on community perception of social and environmental trade-offs. The absence of an agreed definition of marginal land should serve as an example of how values that are in dispute can lead to misinterpretation of crucial sustainability aspects. Consultation should be extended to other interested parties, including the opinion of the wider public. A comprehensive sustainability assessment of ethanol also depends on a robust and integrated body of work from the environmental and social sciences. Greater attention should be paid to frameworks based on the appraisal of ecosystem functions, i.e. the contribution of natural resources to human wellbeing and how that contribution is affected by the implementation of ethanol projects. Researchers and impact assessment practitioners can take advantage of the large body of biophysical appraisals of the impacts of biofuels that are already available. Priority needs to be given to the identification and operationalisation of tailor-made indicators for assessment of major sustainability principles such as guaranteeing food and water security of ethanol developments. Methodologies of assessment must consider the analysis of positive and negative social consequences over time and potential off-site impacts, including those across borders.

Policy makers need to internalise the social dimension of ethanol in decision-making to prevent public opposition and irreversible social costs in the future. Efforts to support or regulate ethanol developments should count with participatory and integrated appraisals of ethanol sustainability, with explicit strategies for the management of long-term impacts of the biofuel, prior to the implementation of promotion programs. The academia must collaborate with the industry, and both with governments, on the development of well-informed, evidence-based frameworks for the impact assessment of projects. The emergence of numerous social standards proposed by different institutions, e.g. multi-stakeholder certification schemes can be of value, although a lack of homogeneity among frameworks may hamper an effective governance of the impacts of biofuels. Public awareness of the technology and its potential social drawbacks should be fostered along with spaces for deliberative dialogue between experts, citizens and the industry. Policy makers should endorse the outcomes of these dialogues. It is essential that national and international policies and agreements have a focus on the governance of impacts of ethanol in poorer and more environmentally vulnerable regions.

As stressed by Coelho et al. (2006), "biofuels are energy sources produced in rural areas to primarily service the energy needs of cities that can afford to pay". Although this assertion might seem obvious for some, it summarises the logic of large-scale biofuel production nowadays. Small-scale producers do not sustain the largest part of the current biofuels global market created and supported by policy mandates. However, a major development of alternative energy sources like biofuels cannot be realised at the expense of rural sovereignty and wellbeing. Besides, any projections of future interventions also need to consider the effects of climate change on top concern issues regarding ethanol development. These are water and food security, which could be threatened by land-use change for feedstock production and raw material processing, among other factors. An increase in the levels of social vulnerability may be felt mostly at the local and regional levels, close to production sites, but indirect consequences can also affect the broad societal level, especially the access of poor people to cheap water, consumer goods and staple food in the near future.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.enpol.2013.02.004.

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