



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project.*

**EST-FRAME DELIVERABLE 4.1: BIOFUELS
TECHNOLOGY, GOVERNANCE CONTEXT AND ASSESSMENTS**

[Philip Boucher¹², Kate Millar¹, Robert Smith¹]

¹ Centre for Applied Bioethics, University of Nottingham, Sutton Bonington Campus, LE12 5RD, UK.

² Institute for Protection and Security of the Citizen, Joint Research Centre, Via Enrico Fermi 2749,
21027 Ispra (VA), Italy.

May 31st 2013

EST-Frame

G.A. no: 288981





Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

TABLE OF CONTENTS

PREFACE	4
1. SUMMARY	5
2. BIOFUELS: SCIENCE AND TECHNOLOGY	5
2.1 INTRODUCTION TO BIOFUELS.....	5
2.2 RELEVANCE OF THIS CASE TO EST-FRAME	7
3 THE GOVERNANCE CONTEXT	8
3.1 INTRODUCTION.....	8
3.2 EUROPEAN BIOFUEL POLICIES.....	8
3.3 UK BIOFUEL POLICIES	10
4 THE BODY OF ASSESSEMENTS	12
4.1 SELECTION METHOD.....	12
4.2 PROFILING KEY ASSESSMENTS.....	13
4.2.1 <i>Hart et al., 2003</i>	15
4.2.2 <i>Biofuelwatch et al., 2007</i>	15
4.2.3 <i>Evans (NNFCC), 2007</i>	15
4.2.4 <i>Round Table on Sustainable Development, 2007</i>	15
4.2.5 <i>United Nations-Energy, 2007</i>	16
4.2.6 <i>Wuppertal, 2007</i>	16
4.2.7 <i>AEA Technology, 2008</i>	16
4.2.8 <i>RFA, 2008</i>	16
4.2.9 <i>Royal Society, 2008</i>	17
4.2.10 <i>SAC Consulting, 2009</i>	17
4.2.11 <i>SNV/WWF, 2009</i>	17
4.2.12 <i>United Nations Environment Programme, 2009;</i>	18
4.2.13 <i>United Nations Conference on Trade and Development, 2009</i>	18
4.2.14 <i>Action Aid, 2010</i>	18
4.2.15 <i>International Energy Agency, 2010</i>	18
4.2.16 <i>BirdLife Europe, 2011</i>	18
4.2.17 <i>CIFOR 2011</i>	19
4.2.18 <i>Committee on Climate Change, 2011</i>	19
4.2.19 <i>Nuffield Council on Bioethics, 2011</i>	19
4.2.20 <i>Slade et al., 2011</i>	20
4.3 ANALYSIS	20
4.3.1 <i>Purpose Analysis</i>	20
4.3.2 <i>Core Process Characteristics</i>	23
4.3.3 <i>Core Substantial Characteristics</i>	23
4.3.4 <i>Core Practical Characteristics</i>	25
4.3.5 <i>Core Contextual Characteristics</i>	25
4.3.6 <i>Features in Common</i>	27
4.4 INSIGHTS FROM WORKSHOP ON BIOFUEL ASSESSMENT	27
4.4.1 <i>Identifying and Evaluating Assessments</i>	27
4.4.2 <i>Changes in Assessments</i>	27
4.4.3 <i>Strengths and Weaknesses of Body of Assessments</i>	28
4.4.5 <i>Away from 'Biofuels under the Spotlight' towards Integrated Assessment</i>	28
4.5 INSIGHTS FROM INTERVIEWS WITH ASSESSMENT PRACTITIONERS.....	29
4.5.1 <i>Experience of Assessments</i>	29



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

4.5.2 *Missing Dimensions of Biofuel Assessment*..... 30
4.5.2 *Integration through Holistic Research Funding* 30
4.5.3 *Summary of Interview Findings*..... 31

5 RECOMMENDATIONS32

5.1 SUMMARY OF FINDINGS 32
5.2 MEASURES TO IMPROVE INTEGRATION 32
 5.2.1 *Covering Topic Areas* 33
 5.2.2 *Including Values*..... 33
 5.2.3 *Including Narratives* 33
 5.2.4 *Not isolating one topic at the expense of the whole* 33
 5.2.5 *Identifying the Framing*..... 33
 5.2.6 *Including Necessary Elements*..... 33
 5.2.7 *Targeting the application of methods* 34
 5.2.8 *Integrating Broader Experts, Stakeholders and/or Publics*..... 34
 5.2.9 *Integrating the Findings of Assessments* 34
 5.2.10 *Integrating Governance Concerns*..... 34
 5.2.11 *Integrating Assessments into Governance* 34
5.3 RECOMMENDATIONS 34
 5.3.1 *Recommendations for Assessment Practitioners* 35
 5.3.2 *Recommendations for Research Councils*..... 36
 5.3.3 *Recommendations for Policymakers* 36

REFERENCES37



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project.*

Preface

This report is a deliverable in the European research project Integrated EST Framework (EST-Frame), reporting on the case study on biofuels. Similar reports are published from the case studies on nanotechnology in food and agriculture, synthetic biology and cloud computing. The case studies feed into the cross case study comparison in Work Package 1 and the development work in Work Package 6.



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

1. SUMMARY

Biofuel technology has developed significantly in the past decade, largely due to regulatory support at a European level. A proliferation of assessments has accompanied the intensification of research, although the body of assessments is very diverse and, often, poorly coordinated. Here, a set of UK, European and international reports are analysed in a desk-study, interviews and workshop to consider the state of biofuel assessment and the potential for a more integrated approach. It is found that assessments tend to focus upon environmental and, to a lesser extent, economic impacts with social impacts often overlooked. Most assessments position biofuel technology in an 'opening' stage and demand more knowledge and broader understandings of potential impacts. The assessments exhibit high scientific literacy and impartiality. Transparency varies amongst assessments and both participation and self-reflection are low. The workshop findings confirmed that many practitioners consider the embedded and implicit assumptions to be a major problem for the body of biofuel assessments.

2. BIOFUELS: SCIENCE AND TECHNOLOGY

The aim of this report is to analyse assessments of biofuels, drawing upon a documentary analysis of secondary data comprised of a set of 'key' assessments. The analytical structure of this desk study was designed as part of the broader EST-Frame project. Additional insights on the body of biofuel assessments were collected in interviews and a workshop, the details of which are presented in a separate report (EST-Frame Deliverable 4.2).

2.1 Introduction to biofuels¹

Several definitions of the terms 'biofuel' and 'bioenergy' are found in the literature. In this project, 'bioenergy' refers broadly to energy for any application from any biological source (i.e. biomass, rather than fossil fuels). Bioenergy can be used for heat, electricity and transportation fuel and is unique amongst renewable energies in this respect. A dominant definition of 'biofuels' has emerged as bioenergy (as defined above) for use in transport applications as a liquid fuel. This definition is adopted here.

We may also refer to biofuels more specifically as bioethanol which is biofuel from sugary products for use in petrol engines, and biodiesel which is biofuel from oily products for use in diesel engines. The commercially established and most abundant sources of biofuel today are soy and palm oil for biodiesel, and sugar cane and corn for bioethanol. These are often referred to as 'first-generation' or 'conventional' biofuels. 'Second-generation' or 'advanced' biofuels are produced from lignocellulosic biomass derived from non-food or food crop co-products such as straw. Further technological and commercial development is required in order to make these viable on a commercial scale. This distinction between first and second generation (or conventional and advanced) biofuels is

¹ Derived from the publication Gamborg, Millar et al. (2012) and Boucher (2012)



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

important in current policy and debate, which often focuses upon biofuels' impact upon the demand for, and price of, food and agricultural services.

Since biofuels are generally compatible with existing motor engines, they are usually blended with conventional fuels in transport applications. The International Energy Agency (IEA 2008) estimate that this blending could reduce current fossil-fuel related carbon dioxide emissions from cars by 30–50%. Reductions may also be expected in other applications, for example if biofuels are used in air transport. Demonstration flights have been conducted but barriers remain, including technical problems with low-temperature operation.

The main drivers of European policies to promote biofuels are energy security, a commitment to economic development and the mitigation of climate change (Boucher 2012). The Renewable Energy Directive (RED, 2009/28/EC) and Fuel Quality Directive (FQD, 2009/30/EC) have the following policy objectives: (i) to improve energy security through reduced dependency on crude oil and transport fuels; (ii) to improve security of agricultural productivity and quality of life in rural areas; and (iii) to reduce GHG emissions through the use of sustainably produced biofuels.

These policies have already led to increases in the area of European land cultivated with non-food rapeseed feedstocks, as well as increased imports of biofuels and their feedstocks. An increasing number of studies have pointed to the potentially negative effects of land conversion for biofuels. This land-use change (LUC) issue has cast doubt upon biofuels' role in responding to global warming (e.g. Searchinger et al. 2008; Fargione et al. 2008). It has been claimed that, to the extent that the production of crop-based biofuels involves deforestation or other types of LUC, any carbon saving benefits achieved through the displacement of fossil fuels with biofuels will be compromised. The debate surrounding biofuels has increasingly focussed upon this issue of LUC (Boucher, 2012). While appreciating the potential benefits of global biofuel production, many proponents have recognised that these opportunities must be balanced against potential risks. This has been framed as a 'food, energy and environment trilemma' (Tilman et al. 2009).

Increased demand for land for the production of biofuels may lead to the transformation of other land that was not previously used for agriculture, such as forests or grasslands. This may also affect the ecological and social systems that were in place before. This kind of change in land-use is described as *direct* LUC. However, simply restricting biofuels produced on converted land (e.g. banning biofuels associated with direct LUC) could lead to the displacement of other agricultural activities which are not restricted, such as food and feed production. These activities could be moved to make way for biofuel production which would not, therefore, be associated with *direct* LUC. Under this scenario, other land may be converted to make way for the displaced activity, so the demand for land for biofuel production still causes LUC but of an *indirect* character (ILUC). To take an example, if farmers in the EU switch production from soy for fodder to maize for biofuels, soy imports may increase to meet the



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

fodder demand. This could lead to deforestation outside the EU, raise food prices in both regions, impair food access, increase food poverty, visit insecurity on rural and urban communities and affect GHG emissions and biodiversity (Bouët et al. 2010; Cushion et al. 2010).

Direct LUC associated with biofuel production is often readily traceable but ILUC is much more difficult to associate with a specific practice because of the complex weave of international markets involved. Even where there is general acknowledgement that a case of LUC is indirectly associated with biofuels (e.g. the displacement of fodder production), there is no clear means of calculating and allocating the associated GHG emissions. This means that ILUC is very difficult to measure and manage. The success of biofuel policies against their stated aims may depend upon a robust response to the broad range of social, environmental and economic impacts implicated by ILUC. There have been disputes regarding whether, and to what extent, indirect impacts should be included in biofuel assessments. The choice of data, boundaries and framing all make important differences in the results and, as such, the specifics of biofuel assessment is important for developing policies to ensure that biofuel developments deliver results against stated policy objectives.

2.2 Relevance of this case to EST-Frame

In some senses, biofuels might not always be considered an emerging technology. Indeed, their use is as old as the engine itself. Yet in other senses, the technologies to produce and consume biofuels on a large scale are emerging. Certainly, biofuels currently hold many of the characteristics of early-stage technologies including market expansion, rapid technical development, public debate, frequent policy changes and the risk of unknowns, both known and unknown. In the UK and across Europe there has been significant public investment in bioenergy research. For example, approximately 10 million Euros has been invested through the Biotechnology and Biological Sciences Research Council (BBSRC- <http://www.bbsrc.ac.uk>). Alongside increased science and technology research, increases are also observed in the quantity of biofuel assessments. These assessments emerge from a diverse range of literatures and vary in their approach, methods, assumptions and scope. Most assessments focus upon the measurement of material flows (most often GHG emissions and potential yields) and economic impacts (most often on prices of food and fuel). Nonetheless, the use of biofuels raises a number of notable and complex social and ethical issues, with the potential to substantially change current energy, agricultural and land use practices and policies. These issues are exemplified by the increasing controversy surrounding the use of arable land and the resultant impact that this may have upon the material and economic availability of food. Proposals for GM biofuels may raise further social and ethical issues, particularly regarding the under-analysed subject of public acceptability. A minority of assessments are designed to account for such societal implications through stakeholder engagement, national ethical committee appraisals and other tools for ethical, social and legal analysis, most suggesting that more attention to these issues is required.



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

This proliferation of assessments makes biofuels a productive case study for exploring the assessment of emerging technologies in general. The pertinence of this work can also be detected from within the biofuels literature, with debate about the utility of the body of combined assessments and discussion of how the insights of assessments can be unified (e.g. Gasparatos, Lehtonen and Stromberg, 2012). This study, therefore, may contribute to understandings of the assessment of emerging science and technology in general while offering a timely contribution to debates about how biofuel assessment can move forward.

3 THE GOVERNANCE CONTEXT

3.1 Introduction

Within the EU, bioenergy has been promoted as an essential component of sustainable energy-use. The Union's 'Europe 2020' strategy requires 20% of total energy consumption to be based on renewables by the year 2020. This requirement is set out in the RED which all member states must implement. The specific approach to national implementation is governed by member states, and they can achieve their targets through a combination of renewable energy developments including solid biomass for heat and electricity, wind, solar, hydropower and biofuels. Biofuels, as the only current technology capable of introducing renewable energy to the existing motor infrastructure, is expected to be developed significantly as part of the 2020 strategy. The UK has a further national obligation to reduce its carbon emissions by 80% in 2050, with bioenergy expected to play a significant role. Other member states have different physical resources, political priorities and regulatory frameworks, and adopt different approaches to the implementation of European Directives. As such, member states' biofuel development is shaped at the intersection of European and national interests. In the following sections, we provide brief chronological summaries of biofuel policies at European and UK levels.

3.2 European Biofuel Policies

In 2001, the EC identified biofuels as a key future energy source for the first time, with a dual motivation to reduce the dependency on oil and make better progress in reducing GHG emissions. The European Climate Change Programme (ECCP) recommended a Directive on biofuels as one of several cost-efficient measures for EU to meet the GHG emission reduction targets in the Kyoto protocol, leading to the European Commission adopting the Biofuels Directive (2003/30/EC) to promote the use of biofuels and other renewable fuels in the transport sector (Afionis and Stringer 2012). This marked the first important step in the development of a common EU policy for biofuels. The Directive aimed to reduce GHG emissions, improve energy security and promote rural development (Boucher, 2012).

The Biofuels Directive set overall targets for biofuels to constitute 5.75% of the fuel mix by 2010, with individual member states free to implement measures themselves. Ten types of biofuels were acknowledged: bioethanol, biodiesel, biogas, biomethanol, biodimetyler, bio-ETBE, bio-MTBE, synthetic biofuels,



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

biohydrogen and pure plant oil. A number of further incentives were meant to promote and stimulate biofuels use and production, including subsidization, a common agricultural policy (CAP) to promote feedstock production and funding for R&D on biofuels (Afionis and Stringer 2012). Minimum levels of tax and duties were set for transport fuels, with a full or partial exception granted for biofuels (SFT 2006). The implementation of Directive 2003/30/EC progressed slowly, and by 2005 biofuel consumption had only grown to just above 1% (Afionis and Stringer 2012). Few member states met the targets and others were actually producing less than they were before the Directive (Boucher, 2012).

At the end of 2005, the EU adopted a Biomass Action Plan (COM/2005/628). This drew upon some scientific literature as well as the input of experts, stakeholders and a public consultation to deliver its recommendations, more analysis than some of the biofuel assessments considered here can reasonably claim. The aim was to set out market based methods to promote bioenergy research development. The plan is explicitly positioned towards more integrated transport and renewable energy policies; "It is in this wider context of an integrated and coherent energy policy and, in particular, of the promotion of renewable energy sources that the Commission is presenting this action plan". In February 2006, the EU Strategy for Biofuels (COM/2006/0034) was published, presenting the Commission's view of a coherent approach to the reduction of the EU's dependency on imported oil and gas.

In 2009, the EU made the Biofuels Directive obsolete with the introduction of the Renewable Energy Directive (2009/28/EC; RED) which incorporated biofuels into a broader renewable energy strategy with the aim of improving energy efficiency and reducing GHG emissions across all energy sectors. Article 4 of the RED requires all Member states to develop National Renewable Energy Action Plans (NREAPs), describing their strategies for meeting the European targets, followed by regular progress reports. In order to contribute to meeting the RED's targets, locally produced and imported biofuels should comply with a set of sustainability criteria. These state that biofuels produced from feedstocks from primary forest, lands with high biodiversity value, protected territories and carbon-rich areas could not contribute to the meeting of targets. To be eligible for compliance certificates, biofuels must offer a 35% GHG emission reduction against fossil fuels (60% for installations built after 2017). Biofuel feedstocks from other specific areas were encouraged, e.g. those produced on brownfield/degraded land would receive twice the number of compliance certificates. 2nd generation biofuels were encouraged by doubling the certificates awarded to biofuels from non-food feedstocks. The Parliament also recognised the problem of ILUC, promising an investigation into its mechanisms and management.

In late 2012 the EC proposed an amendment (2012/0288) to the RED and FQD which would take action against ILUC associated with biofuel development resulting from previous European legislation. If accepted, member states will be required to implement the amendment within a year. The document makes a case for action in response to ILUC, for the reasons discussed above, and



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

proposes setting factors for specific biofuels to take account of the GHG emissions associated with the ILUC they caused. Those biofuels which already account for direct LUC or are derived from waste or oceanic feedstocks would not be given a factor. In an earlier draft of the proposal (leaked before the official publication), these factors would be applied to calculation of GHG emissions associated with biofuels. Recalling that the targets for biofuel consumption require a minimum GHG emissions savings against fossil fuels, this would mean that the amendment would restrict biofuels associated with high levels of ILUC. Following industry lobbying, the ILUC factors were reduced to reportage status, seriously weakening the proposed amendment so that even biofuels with the highest ILUC factors could still be used to meet mandatory targets (Kretschmer and Baldock, 2013). The final proposal maintained that the minimum 35% emissions reduction would rise to 60% in 2014 instead of 2017 and that biofuels from edible crops could only contribute to 5% of targets. The proposal suggests that the factors and the methodology for their calculation should be reviewed and updated on the basis of the latest scientific evidence. It is unclear whether the EC would propose that ILUC factors are strengthened beyond the 'reporting status' in future, given the evidence they have accepted for the need to managed ILUC.

3.3 UK Biofuel Policies

The current legislative push for biofuels in the UK started with the Department for Trade and Industry's Energy White Paper (DTI, 2003). This government report was very positive about biofuel development as "a potential route for achieving the goal of zero-carbon transport, creating new opportunities for agriculture" (p. 69). Biodiesel already enjoyed tax cut (at 20 pence per litre) at this time, which was rolled out for bioethanol soon after, in 2005, the same year in which the UK announced the Renewable Transport Fuel Obligation (RTFO). The RTFO implemented the EU Biofuels Directive described above, and came into effect in 2008. By 2010, 5% of the mainstream fuel mix was to be produced from biofuels. A market mechanism was introduced, allowing suppliers which do not meet their supply obligations to purchase excess compliance certificates earned by other suppliers by exceeding their own obligations. Suppliers failing to comply by either supplying sufficient biofuels or purchasing excess certificates were fined.

In the year the RTFO was to come into force, the government commissioned a report on the indirect effects of biofuel production, commonly referred to as the Gallagher Review (RFA, 2008). This highlighted the scale of the problem of indirect land-use change and the barriers to the development and use of advanced biofuel technologies that could respond to it. The Review was a landmark biofuels technology assessment and is considered in greater detail below.

The following year, as discussed, the Biofuels Directive was made obsolete by the RED. As discussed, this softened the biofuel targets and made more specific demands for their GHG emissions reductions. It also restricted those biofuels that are produced on more sensitive land, such as biodiversity hotspots. The UK



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project.*

targets set by the RTFO were adjusted to reflect these changes in a 2009 amendment (Secretary of State, 2009). This reduced the 2010 target from 5% to 3.6%, although the 5% rate was expected to be met in 2013 and maintained thereafter. A voluntary sustainability certification scheme was introduced whereby biofuel suppliers submitted monthly performance reports which stated those standards that their biofuels complied with (RFA, 2010). There was no obligation to comply with any standards, although the reports could be made public, providing a soft incentive for suppliers to ensure the sustainability of their products.

4 THE BODY OF ASSESSEMENTS

4.1 Selection Method

In order to ensure full coverage of the relevant biofuels literature, a database was created using Mendeley software. Excel spreadsheets were used to help manage the process. The library was produced from research staffs' existing databases and a further comprehensive literature search conducted on Web of Science and Scopus in order to extend this literature set with a specific focus on assessment. In addition, searches were conducted using internet search engine resources. The literature collected from a number of systematic literature searches using terms relating to biofuel and bioenergy was complemented by the collation of reports, news stories, position papers and policies using the snowball technique based on the contacts and knowledge of the researchers involved in this work package. In total 1348 published sources were identified. Almost half of these are public domain reports published by individuals, organisations, companies and governing bodies, and most of the remainder are peer-reviewed articles published in national and international academic journals. The other publications were comprised of web material, position statements, newspaper reports, pamphlets and letters. The breakdown is shown in Table 1 below.

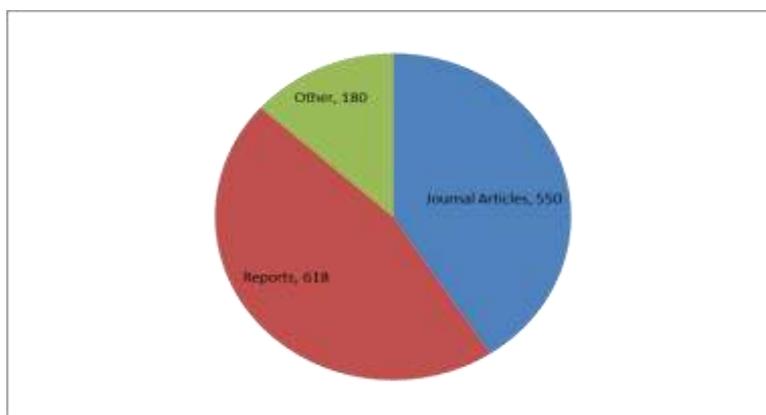


Table 1: Profile of broad biofuel literature

Clearly, this group of publications is too large to evaluate in depth considering the timeframe of the project. Furthermore, many are not appropriate in a study focussed upon assessments. In identifying a more manageable subset of these assessments for analysis, we cut those that did not fit the project's definition of assessment as a *strategy and/or standardised procedure for gathering, prioritising and communicating information about the assessment topic, involving analysis and judgement, and meant to support decision making or policy forming*. At this stage, other publications were also rejected as they were not sufficiently focussed on biofuels, did not involve any analysis or did not suggest how biofuels could, should or would be used, developed or controlled. This left 65 publications as candidates for in-depth analysis.



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

From these 65, we identified a smaller group of 'key assessments' for detailed analysis. The aim of this selection phase was to capture a broadly representative array of assessments. Selection was also designed to capture those assessments which had achieved greater prominence in the field, e.g. through breadth of scope, comprehensiveness or relevance in policy development. This is important because the project group as a whole wishes to consider not only how assessments are constructed, but also how they are used and how they gain influence. Assessments commissioned by state actors, for example, are particularly interesting in this regard. This process resulted in 20 assessments, some pitched at a UK level, others of European scope and others international. These are considered in greater detail in the following section.

Clearly, this overarching selection rationale introduces an intrinsic subjectivity as our requirements codify the assumptions of the research team regarding what makes an assessment 'key'. Of course, any selection criteria will reflect the purpose of making a selection. Further subjectivity is introduced in the research team's application of the selection criteria, because there are no absolute markers for inclusion or exclusion. While the research team is confident that a broadly representative and appropriate set of assessments has been identified, others with different interests may have selected differently. For this reason, it is important that both modes of subjectivity are recognised and reflected upon. This question was revisited during primary data collection, as members of research team asked participants in the case study workshop and interviewees what their key assessments were and what attributes they would expect to find in a useful assessment.

4.2 Profiling Key Assessments

In this section, each assessment is introduced with details on who produced the work, who paid for it and who the intended audience is. It also includes a brief discussion of the ambitions, objectives and methods of assessment, as well as any particular features that may have justified their selection as a key assessment. The key details of each assessment are presented in Table 2 below with further discussion presented in the subsequent subsections.

#	Authors	Title	Year
1	Hart, Bauen, Chase and Howes (E4Tech)	Liquid Biofuels and Hydrogen from Renewable Resources in the UK to 2050: A Technical Analysis	2003
2	Biofuelwatch, Carbon Trade Watch/TNI, Corporate Europe Observatory, Econexus, Ecoropa, Grupo de Reflexión Rural, Munlochy Vigil, NOAH, Rettet Den Regenwald, Watch Indonesia	Agrofuels: Towards a Reality Check in Nine Key Areas	2007
3	Evans (NNFCC)	International Biofuels Strategy Project	2007
4	Round Table on Sustainable Development	Biofuels: Is the Cure Worse than the Disease?	2007
5	United Nations - Energy	Sustainable Bioenergy: A Framework for Decision Makers	2007
6	Wuppertal	Recent Developments of Biofuels/Bioenergy Sustainability Certification: A Global Overview	2007
7	AEA Technology	Review of Work on the Environmental Sustainability of International Biofuels Production and Use	2008
8	Renewable Fuel Agency	The Gallagher Review of the Indirect Effects of Biofuels Production	2008
9	Royal Society	Sustainable Biofuels: Prospects and Challenges	2008
10	SAC Consulting	An Assessment of the Potential Impact on UK Agriculture and the Environment of Meeting Renewable Feedstock Demands	2009
11	SNV and WWF	Developing Sustainable Pro-poor Biofuels in the Mekong Region and Nepal	2009
12	United Nations Environment Programme	Assessing Biofuels: Towards Sustainable Production and Use of Resources	2009
13	United Nations Conference on Trade and Development	The Biofuels Market: Current Situation and Alternative Scenarios	2009
14	Action Aid	Meals per Gallon	2010
15	International Energy Agency	Sustainable Production of Second Generation Biofuels	2010
16	BirdLife Europe	Meeting Europe's Renewable Energy Targets in Harmony with Nature	2011
17	CIFOR	Social Sustainability of EU-Approved Voluntary Schemes for Biofuels	2011
18	Committee on Climate Change	Bioenergy Review	2011
19	Nuffield Council on Bioethics	Biofuels: Ethical Issues	2011
20	Slade, Saunders, Gross and Bauen	Energy from Biomass: the Size of the Global Resource	2011

Table 2: List of Key Assessments



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

4.2.1 Hart et al., 2003

The Department for Transport commissioned E4Tech (UK) Ltd, an energy-environment consultancy, to produce this research as part of a broader study of UK renewable fuels. The report was led by David Hart. The research was quite technical, and considered both hydrogen and biofuels under various scenarios towards 2050, in line with the Energy White Paper. In doing so, it assesses various technical options in the context of different policies and objectives. The report was written for the Departmental commissioners, although its publication made it available for other decision makers too.

4.2.2 Biofuelwatch et al., 2007

This report was produced collaboratively by several NGOs critical of biofuel development. They released the report themselves and, in the absence of declared funding sources, presumably financed the project and publication themselves. The report was produced in 2007, which was the peak of the public controversy about biofuels in the UK and a period in which biofuels were being covered in the mainstream media. While its intended audience is not explicitly stated, it is written in an accessible format and was likely intended for the consumption of any interested party. The report focuses upon biofuels, in particular the impacts associated with the development of large-scale systems of biofuels with international trade. The broad critique of such biofuels is based upon their negative environmental impacts (biodiversity, climate change, soil quality, etc.) and social impacts (employment, human rights, poverty, etc.). The report has a particular framing of biofuels' problems and the impartiality and robustness of both data and methods may be questioned. Nonetheless, it is included here as it captures the earlier stages of the critical tide against biofuels towards the peak of the biofuel controversy in the UK. Furthermore, it is relatively well known in the field, certainly amongst the most visible 'grassroots' assessments in the UK.

4.2.3 Evans (NNFCC), 2007

This report was produced by Geraint Evans for the National Non-Food Crops Centre (NNFCC), who are UK based 'bio-based economy' consultants. The financing of the project is not discussed, although it incorporates three previous NNFCC reports produced by AMEC, Nexant and Tamutech, bringing it up to date through a review of secondary data and discussions with the technology providers. The aim was to assess progress in the development of advanced biofuels. It is quite descriptive, assessing technical options and their consequences in the form of a technical and economic SWOT analysis.

4.2.4 Round Table on Sustainable Development, 2007

The Round Table is a forum of the OECD for international ministers considering sustainable development issues. This report was written under the supervision of Brice Lalonde and Simon Upton, with financial support from the United Nations Foundation and International Institute for Sustainable Development. The year of publication, 2007, saw a biofuel controversy emerge around food prices, energy security and lifecycle emissions balances. The report aimed to present "salient



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

facts and figures to shed light on these controversial issues and [ask] whether biofuels offer a cure that is worse than the disease they seek to heal". It did so with a substantial literature review. The audience is decision makers around the world.

4.2.5 United Nations-Energy, 2007

This report by UN-Energy (The UN Inter-Agency Mechanism on Energy) was sponsored by the Food and Agriculture Organisation (FAO), "drawing on important support from the Worldwatch Institute". It has the stated aim to "structure the approach to the current discussion on bioenergy", although the subtitle, *A Framework for Decision-Makers*, indicates that it may be targeting policy and industry figures. It also states its intention to contribute to international discourse and informed decision making. A desk based method was adopted, with expertise brought in from several departments of the UN to identify and summarise nine key sustainability issues. Some are common in the literature, such as climate change and economics, while others are quite novel such as health and gender issues. In highlighting these issues, the report seeks to inform decision makers and, ultimately, develop more sustainable bioenergy policies. The report has received several citations.

4.2.6 Wuppertal, 2007

The report was internally commissioned and produced by the Wuppertal Institute, a German research group with a focus on climate issues. They are an independent non-profit limited company which frequently participates in publicly funded research projects. Their aim in producing this report was to assess the state of knowledge and recommend research priorities. The intended audience is not clear, although it is likely to include the academic and policymaking communities which shape research priorities. The focus is upon environmental issues, with other aspects of sustainability considered in that context. That is to say, economic and social sustainability issues are considered inasmuch as they affect environmental sustainability. The report calls for more integrated analysis.

4.2.7 AEA Technology, 2008

DEFRA's Climate, Energy, Ozone: Science and Analysis Division commissioned AEA Technology to produce this report which aimed to "identify and review published and ongoing work on the greenhouse gas (GHG) emissions and environmental sustainability of biofuels production and use". The intention was to provide policy support information, in the form of a literature review, for UK representatives to draw upon during international negotiations, e.g. in agreeing biofuel targets. These personnel form the target audience although the work is made public for other decision makers.

4.2.8 RFA, 2008

This report by the Renewable Fuel Agency, often cited as the Gallagher Review, remains an important and influential assessment of biofuels. It is frequently cited and may be a major factor in the position of ILUC at the fore of the biofuel debate. The report was commissioned by The Secretary of State for Transport to



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

review the indirect effects of biomass production, particularly on land-use change, which were raised around this time. The research involved a literature review and expert consultation. In producing the report, the RFA commissioned further research from AEA Energy and Environment; The Overseas Development Institute; E4Tech; North Energy Associates; Themba; ADAS; CE Delft and ECOFYS. Their recommendation to slow the pace of biofuel development was adopted in an amendment to the RTFO the following year (Secretary of State, 2009).

4.2.9 Royal Society, 2008

The report was internally commissioned and produced by the Royal Society, a Fellowship of over 1300 high profile academics from science and engineering disciplines. It advocates scientifically advised policy and public debate. In this instance, they appear to be targeting policymakers. Written in 2008, the report takes the controversial issues associated with early biofuel policy as its starting point, and presents a comprehensive consideration of the potential opportunities and challenges of biofuels in a sustainability context.

4.2.10 SAC Consulting, 2009

This report was produced in a project funded by DECC and managed by the NNFFC. It was produced by SAC consulting with partners from Innovation Management (an agricultural marketing consultancy) and Aberdeen University. The aim was to review potential impacts of increased biomass supply (especially bioenergy) on agriculture, the environment and the economy, particularly through changing cropping patterns. Recommendations were intended to minimise environmental costs while maximising economic benefit. Unlike many such reviews, this included a review of knowledge of stakeholder and public perspectives. These were considered in the context of knock-on environmental and economic impacts.

4.2.11 SNV/WWF, 2009

SNV and WWF are both NGOs, the former a Dutch development group and the latter an animal-oriented environmentalist group with a particular interest in wildlife management in developing countries. They commissioned the report, which was produced by a group of seven consultants, led by Stephen Shepley. A desk based review of data is conducted and then fieldwork is undertaken for verification purposes. The aim of the report, from SNV/WWF perspective, was to improve understandings of "the potential for biofuels to contribute to the development" of Lao, Cambodia, Vietnam and Nepal. The focus is on assessing the impacts of biofuels in these four case countries and particularly their potential to "improve the situation of poor smallholders in the target countries without compromising food security and sustainable environmental management". A 'holistic' approach is claimed, looking at economic, social and environmental impacts, and considering the intersection of some policy objectives (e.g. pro-poor development and climate change mitigation). The intended audience is unclear, but it clearly aims to inform policy.



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

4.2.12 United Nations Environment Programme, 2009;

This report is a review of recent literature undertaken by the International Panel for Sustainable Resource Management, commissioned by the United Nations Environment Programme. The aim was to "provide policy relevant information on the assessment of the environmental and social costs and benefits of biofuels". It focusses upon the first generation fuels which dominated that time period and includes a critique of the proliferation of lifecycle analyses.

4.2.13 United Nations Conference on Trade and Development, 2009

The United Nations Conference on Trade and Development produced this report as a contribution to the Global Bioenergy Partnership. It was 'made possible' by a financial contribution from the Italian Ministry of Environment, Land and Sea. Each chapter was produced by different authors who are also affiliated with US universities. The report presents discrete scenario analyses in 5 different domains; blending targets, GHG markets, trade opportunities, intellectual property (in a developing nation context) and the role of jatropha. It is included here as a compendium of assessments of biofuels intended for decision makers that does not present any overarching discussion which could integrate the domains considered. The stated purpose of the report is to present plausible scenarios for the industry and encourage further research. The intended audience appears to be decision makers in different national contexts.

4.2.14 Action Aid, 2010

The commissioning of this report is not discussed, so it is assumed to be internally produced and funded by Action Aid, a pro-poor development NGO. The target audience is likely to be interested publics as well as decision makers as they recommend a moratorium on further development. The report presents Action Aid's reading of the literature, illustrated with reports from individuals affected by biofuel development in developing countries. The report is particularly interesting because it is amongst few which include local perspectives on the global impacts of biofuel development.

4.2.15 International Energy Agency, 2010

The IEA is an autonomous international agency which advises governments on 'sound' energy policy, emphasising security. This information paper was drafted by their Renewable Energy Division in close cooperation with Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), who funded the project on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). The aim was to consider the potential for sustainable production of second-generation biofuels in eight case study reviews. It is of particular interest here because it combines these insights to deliver recommendations aimed at policy makers the world over.

4.2.16 BirdLife Europe, 2011

BirdLife Europe is a group of NGOs with a special interest in birds and wildlife, including the RSPB in the UK. The study was partially funded by a European Climate Foundation grant with the rest, presumably, self-funded with capital



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

raised through member fees. They also coordinated the production of the report. The report considers renewable energy production targets generally, assessing technical options in terms of risk with a particular focus upon ecology, biodiversity and, ultimately, birds. The report includes a risk assessment developed through interviews and literature reviews. It concludes with pan-European policy recommendations. The report is intended for policymakers and, likely, interested members of the public. This assessment is particularly interesting because, unlike many others, it positions the technology in the context of other options for the decarbonisation of the energy system.

4.2.17 CIFOR 2011

The Center for International Forestry Research (CIFOR) is a research based NGO with a focus upon the human and environmental dimensions of wellbeing, conservation and equity, particularly in a development and forestry context. This report was produced by Laura German and George Schoneveld, who also publish in academic outlets. The project was financed through an EU project *Bioenergy, sustainability and trade-offs: Can we avoid deforestation while promoting bioenergy?* The research involved a comparative analysis of seven EU approved sustainability certification schemes. Focussing upon social dimensions of sustainability, they assessed each scheme's substantive content (scope) and likely procedural effectiveness. The aim was then to communicate this policy relevant research to an audience of governmental, industrial and civil society decision makers.

4.2.18 Committee on Climate Change, 2011

The Committee is an independent statutory body set up to advise UK policymakers on issues related to climate change, particularly carbon budgets and how to meet them. The report considers bioenergy in the context of meeting carbon budgets sustainably through an analysis of various supply scenarios, presenting an anticipatory assessment which targets technology policy.

4.2.19 Nuffield Council on Bioethics, 2011

This report was included here as an ethical assessment and a widely regarded benchmark in research into the societal aspects of biofuel development, although the extent of its influence is difficult to trace. The Council commissioned and produced the report with a working group comprised of well-respected academics from various fields, particularly the social sciences and humanities. The audience is policy and decision makers, as the Council aimed to shape biofuel development in an ethically acceptable and socially equitable trajectory. This endeavour includes reference to environmental and economic impacts with knock-on effects. The approach was to consider the technology in terms of predefined ethical principles through literature reviews and case studies in conjunction with the working group. Following the Gallagher review, the report is particularly interested in the analysis of the problem of indirect land-use change.



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

4.2.20 Slade et al., 2011

This report was produced by a group at Imperial College Centre for Energy Policy and Technology, commissioned by the Technology and Policy Assessment Function of the UK Energy Research Centre. The aim was to review current knowledge of biomass resources, taking account of sustainability concerns, delivering accessible and policy relevant findings. It is included here because it reviews integrated assessment models and the differences they make.

4.3 Analysis

A calibration document was produced for the EST Frame project which defined the structure of analysis in all four of the case studies. This structure comprised a purpose analysis and analyses of various process, practical, substantial and contextual characteristics. These analyses are considered in the following sections.

4.3.1 Purpose Analysis

First, we considered the intended role of the assessments. This process drew upon a set of predefined roles described in Table 3, below. These 21 roles, labelled a to u, are drawn from a previous project (see Decker and Ladikas, 2004) and are organised into a two-dimensional matrix with 9 cells. One axis is defined by the 'issue dimension', capturing the intended object of the assessment with three options; technological/scientific aspects, societal aspects and policy aspects. The other axis is defined by the 'impact dimension', capturing the intended role of the assessment with three options; raising knowledge, forming attitudes/opinions and initialising actions. We recorded a set of letters, corresponding to the roles described in this matrix, to capture our interpretation of the intended role(s) of each assessment.

Impact Dimension Issue Dimension	I. Raising Knowledge	II. Forming Attitudes / Opinions	III. Initialising Actions
Technological/ Scientific Aspects	Scientific Assessment a) Technical options assessed and made visible b) Comprehensive overview on consequences given	Agenda Setting f) Setting the agenda in the political debate g) Stimulating public debate h) Introducing visions or scenarios	Deframing of Debate o) New action plan or initiative further scrutinise the problem at stake p) New orientation in policies established
Societal Aspects	Social Mapping c) Structure of conflicts made transparent	Mediation i) Self-reflecting among actors j) Blockade running k) Bridge building	New Decision making Processes q) New ways of governance introduced r) Initiative to intensify public debate taken
Policy Aspects	Policy Analysis d) Policy objectives explored e) Existing policies assessed	Re-Structuring The Policy Debate l) Comprehensive-ness in policies increased m) Policies evaluated through debate n) Democratic legitimisation perceived	Decision Taken s) Policy alternatives filtered t) Innovations implemented u) New legislation is passed

Table 3: Matrix of Intended Roles

In most cases, several intended roles were identified, with an average of 4 codes per assessment. Recognising the interpretive nature of this process, and the problems associated with reducing assessments to predefined roles, we did not place great emphasis on the individual results. Instead, we considered the results more broadly, using patterns and features identified in aggregated results to support our reflections upon the body of assessments. That is to say, the assessments are not reduced to these 'role codes' but, rather, role codes are used to support and illustrate our deep, qualitative consideration of the intended role of the biofuel assessments. The aggregated table of results are presented in Table 4, below, with the letters corresponding to those previously presented in Table 3.

Impact Dimension - Role of Assessment

AGGREGATES		Raising knowledge	Forming attitudes/ opinions	Initialising actions	TOTAL			
		Issue Dimension - Object of Assessment	Technological/ scientific aspects	a) 12		f) 4 g) 3	o) 7	38
b) 8	h) 3			p) 1				
Societal aspects	c) 1		i) 1 j) 0 k) 1	q) 2 r) 2	7			
			Policy aspects	d) 11 e) 13		l) 11 m) 0 n) 0	s) 2 t) 0 u) 0	37
				TOTAL		45	23	

Table 4 Aggregated TAMIs

We recorded a total of 82 tallies, which are distributed amongst the coding categories 'a' to 'u', organised into columns and rows following the structure defined in Table 3. Some clear patterns are visible in the distribution of these tallies. Considering the columns, it is clear that most of the tallies are recorded in the leftmost column- a knowledge raising role. Many of the remaining tallies were in the middle row in an attitude/opinion forming role. There were relatively few tallies in the rightmost column where the intended role was to initialise action. Over 80% of the tallies occupy the leftmost two columns of raising knowledge and forming opinions. This distribution reflects a broad tendency of assessments to report that not enough is yet known about the impacts of biofuel development, and that more knowledge must be created before actions are implemented. This sentiment prevails within various actors' reports such as anti-biofuel NGOs (e.g. Biofuelwatch et al.) pro-biofuel industry groups (e.g. Evans) and governmentally appointed assessors (e.g. the Gallagher Review). In these assessments, the claim that more knowledge is required is often justified by the degree of complexity and the extent or importance of certain types of unknown. This sentiment prevails when considering that half of the 14 tallies in the rightmost column are for 'o', intending to initiate more action to scrutinise the problems at stake. In this sense, it seems that many of the assessments position biofuels in an 'opening' stage of development, where the issues and ideas surrounding the technology are subject to development, change and broadening of scope. The intended roles of assessments are then aligned with this positioning.



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

Considering Table 4 on a row-by-row basis, the issue dimension, it is apparent that the assessments most frequently consider scientific and technological aspects (top row) and policy aspects (bottom row), with relatively little attention to societal aspects (middle row). Where assessments have made substantive efforts to consider societal aspects (e.g. CIFOR, 2011), they tend to confirm that this social pillar of sustainability is not as well developed as the economic and environmental. This trend is further confirmed in other aspects of our analysis and considered in later sections.

Beneath these figures, then, is a tendency for assessments to consider the impacts and uncertainties associated with various technical options and policies and to call for an extended scope of policies and initiatives to further scrutinise the issues. Indeed, these features – captured in the six categories 'a', 'b', 'd', 'e', 'l' and 'o' – attracted more than three quarters of the 82 tallies. The remaining 20 tallies are distributed amongst the other 15 categories without notable clustering.

4.3.2 Core Process Characteristics

Some broad trends are revealed through consideration of the set of process characterisations. Considering the 'core process characteristics', the first thing to note is the low level of participation across the studies. This is particularly the case for lay participation (average score 1.4 out of 5), slightly higher for stakeholder and expert participation (scoring 2.1 and 2.6 out of 5 respectively). This contributes to the broader tendency for assessments to adopt a technocratic, science-led approach to decision making, whereby recommendations are based upon quantitative measures of economic or environmental impacts produced by experts.

Impartiality scored an average of 3.5 and transparency 3.0, although there is some variation amongst the reports. Transparency is particularly varied, with some omitting the description of their approach, scope, methodology and limitations while others provide these with considered reflexivity. Generally, the assessments with more scientific authors scored highly in this regard. These measures of impartiality and transparency exhibit the greatest correlation of all variables applied to the biofuel assessments with a co-efficient of .78 (where 1 is perfect correlation). This correlation may be due to impartiality being demonstrated through the transparent description of analytical contexts and procedures (including finding, methods, assumptions and limitations). Failing to provide such information may give an impression of a partial or partisan assessment.

4.3.3 Core Substantial Characteristics

Analysis of the 'core substantial characteristics' reveals that the assessments of biofuels have a generally strong scientific evidence basis, scoring an average of 3.4 out of 5 in this measure. Most assessments drew upon a respected corpus of peer reviewed literature. Uncertainty scored an average of 2.8 out of 5. While some recognise the presence of uncertainties, for example in anticipating technical and regulatory trajectories, it is seldom a substantive analytical feature

of assessment. As discussed in a report on methodological issues in risk assessment (SCHER, SCENIHR & SCCS, 2011), the basic assertion of uncertainty and need for further research is often vague and unhelpful for risk managers and policymakers. Aside from transparency and impartiality, the strongest correlations in the study were found between the participation of experts (c), scientific evidence basis (f) and treatment of uncertainties (g) (c&f=.64, c&g=.64 and f&g=.66). The causal links between these features, if any, are not clear.

Few studies reflect upon their own normative position, value base or ethical perspective. These tend to be those that consider societal and ethical aspects explicitly, such as the Nuffield report. Instead, most report are technical and adopt a somewhat scientific or technocratic position accompanied by a deficit approach to non-scientific concerns. This may be related to the low level of participation observed across biofuel assessments. It is also noted that some studies do adopt more explicitly normative or, perhaps, partisan position. For example, Action Aid’s ‘pro-poor’ position, while potentially justifiable from a technocratic perspective, is a clearly normative position that does have an effect upon their analysis and recommendations.

The results of the analysis of impacts considered by the assessments are presented in Table 5, below. Clearly, almost all of the 20 assessments consider environmental impacts, and more than half consider economic impacts. This domination of environmental and economic aspects will not surprise those familiar with the literature. Considering the primary impacts considered (bracketed), however, illustrates a more interesting tendency. Few economic assessments and no security assessments feature as the primary consideration, but most social and environmental impact assessments do hold as the primary consideration. These figures capture a characteristic of assessments to consider economic and security impacts (e.g. prices and security of food and fuel) in order to consider their knock-on environmental or social impacts (e.g. poverty or carbon emissions). Health and safety was seldom considered, but is of greater relevance in other case studies.

Environmental	17 (12)
Economic	11 (3)
Social	8 (5)
Security	4 (0)
Health and Safety	1 (0)

Table 5 Impacts Considered

We considered whether the assessments were anticipatory or retrospective in their analysis, also recording whether they looked 5, 15 or more years into the future or the past. Of course, all assessments have some anticipatory and retrospective elements, if only to describe a situation and suggest developments. Instead of saturating our results in a way that offered little meaning, we only counted the analytical components of the assessments. Thus, mentioning past events is not enough to be considered retrospective analysis. For this, some analytical work must be undertaken. Likewise, suggesting further research or a particular regulatory approach is not considered anticipatory analysis, whereas analytical work such as a foresight study or economic scenario modelling would. The results are presented in Table 6, below.

Timescale	Retrospective	Anticipatory	SUM
1 (0-5 yrs)	17	4	21
2 (0-15 yrs)	0	3	3
3 (15+ yrs)	0	6	6
SUM	17	13	

Table 6 Retrospective and Anticipatory Analysis

Studying the table, it is clear that the retrospective aspects of analysis in biofuel assessments tend to be short term (up to 5 years), focussing on the state of art, whereas anticipatory aspects of analysis are spread across a longer timescale, most often 15 years plus. Many of the anticipatory analyses considered 2030 or 2050 scenarios to link their assessments with scenarios already established in government targets, such as the European 2020 target, or the UK 2050 targets.

4.3.4 Core Practical Characteristics

Cost and self-reported efficacy are not reported upon directly within any of the assessments. This kind of data may have been accessed through contact with each author and commissioning actor but this was not feasible. As such, the analysis of these characteristics is not delivered. Nonetheless, we may speculate that the studies which rely upon secondary data would cost less than those which involve the collection of primary data. Likewise, those that draw upon particular expertise (e.g. modelling or scenario analysis) may result in higher costs.

4.3.5 Core Contextual Characteristics

The contextual characteristics of the assessments are coded according to Table 7, below.

	Unreflexively	Reflexively
Assumes	UY	RY
Does Not Assume	UN	RN
Unclear	U?	R?

Table 7 Coding the Core Contextual Characteristics

These six codes result from two separate codings; one from a choice of positive, negative and unclear assumption of the trend and another from a choice of reflexive or unreflexive, as presented in Table 8, below. The preponderance of '?' codes illustrates that the contextual assumptions are frequently unclear. The preponderance of unreflexive codings reflects a tendency for contextual features to be assumed implicitly.

Assumes / Addresses	Y	N	?	R	U
Liberalisation	8	4	8	2	18
Internationalisation	8	4	8	3	17
Public/private partnerships	2	1	17	1	19
Policy integration	3	4	13	6	14
Consumer acceptance	1	1	18	3	17
Sustainability	20	0	0	20	0

Table 8 Tallies of Core Contextual Assumptions

Beyond this broad reflection, there is some notable detail. Public-private partnerships are not generally recognised in assessments and their role is difficult to perceive. This may reflect a certain distance between the public and private sectors. Likewise, consumer acceptance is rarely considered important, although some refer to the possibility of future technical trajectories (such as the use of GM biofuel feedstocks) impacting upon levels of consumer acceptability. This implies an assumption that consumer perspectives can be important.

Of all the trends, policy integration is the one most often considered reflexively, although it is generally referred to in the context of the need for a more integrated approach to the assessment and management of biofuel development

(e.g. Wuppertal). The mode of integration discussed varies from broader agricultural activities to policies for environment, energy, forestry, development and/or transport. It seems that integration is on the horizon of biofuel assessment practice and may well develop in the coming years.

Importantly, while it may appear from the above table that the assumptions of liberalisation and internationalisation are coupled, it is only the crude proportions that match up. This is an example of why aggregated data such as that presented in Table 8 is not sufficient for explanation without reference to the full data set as a summary which can support qualitative reflection upon the causes of any coding patterns identified.

4.3.6 Features in Common

The introductory material provided as a background for assessments generally assert the significant complexity and heterogeneity of biofuel technology. The overwhelming majority of assessments demand further research, whether the report supports or opposes further development. Indeed, the demands of some stronger critics of biofuels include a moratorium on development to allow more research into the potential impacts (e.g. Biofuelwatch et al.). In particular, many assessments point out the need for further research into the mechanisms and potential controls of indirect land use change (e.g. the Gallagher Review).

4.4 Insights from Workshop on Biofuel Assessment

A workshop was conducted with producers and users of biofuel assessments to consider the body of assessments and the potential for their improvement. The workshop and its findings are discussed in detail in deliverable 4.2. Here, the key insights are summarised and subsequently drawn upon, alongside the desk study described above, to analyse biofuels' integration needs and deliver recommendations.

4.4.1 Identifying and Evaluating Assessments

- The identification of assessments is non-systematic and informal, performed through dialogue with colleagues, wider contacts (e.g. at conferences) and through Google Scholar searches.
- The producer and commissioner of assessments are indicators of legitimacy
- The references cited are indicators of competence
- Assessments do not make their approaches and assumptions explicit enough
 - This is a major problem and it affects their usefulness for policy
- Peer review of assessments is viewed with a degree of suspicion

4.4.2 Changes in Assessments

- The scope of assessments has narrowed from energy balances, rural development and energy security to GHG emissions
 - This is seen as a response to the dominance of the GHG agenda in policy

- ILUC has recently become a focus of assessment
 - This has led to the rejection of the assumption the biofuels always offer GHG emission reductions
- There has been less attention to biofuels' relationship with other sectors and technologies, with biofuels being put under the spotlight to the detriment of assessments' utility
- Changes in biofuels' context (e.g. policies) can make assessments obsolete

4.4.3 Strengths and Weaknesses of Body of Assessments

- Not enough is known about ILUC and the definition of land areas is questionable
- Not enough is known about social aspects of biofuels
- Embedded assumptions are a huge problem, they are not transparent enough and are not well understood by the users of assessments
- Nonetheless, we do know quite a lot about biofuels, enough to make many decisions.
 - This can be improved through better coordination and a quality review of current knowledge with reference to its embedded assumptions
 - Biofuels are complex and there will always be some uncertainty. We should not fear it.
 - We need better coordination and understanding of existing knowledge

4.4.5 Away from 'Biofuels under the Spotlight' towards Integrated Assessment

- Biofuels are examined more closely than many of the alternatives.
- Issues such as land use need to be considered from a broader perspective.
- This may be resolved through more holistic/integrated assessments which focus on problems rather than technologies.
 - Data level integration, e.g. building on ecosystem services literature
 - Findings level integration with an authority reviewing different assessments
 - The authority should be state sponsored but independent (consultants/academics)
 - Access to this authority and its procedural design would be crucial
 - A traffic light system was suggested, but criticised for reductionism
 - Integration should be undertaken at a European level to avoid duplicated work
 - Coordination could be improved through forums, information exchanges, use of social media, incorporation of industry perspectives and cross-fertilisation between research projects.

4.5 Insights from Interviews with Assessment Practitioners

In the UK, the majority of publicly-funded research is directed towards second generation biofuels (i.e. the more 'emerging' technologies). In line with wider trends in research governance, there is a tendency to attempt to instill some form of ethical and social reflection or assessment alongside the actual research. Furthermore, a number of broader assessments, such as economic analysis, ethical assessment, Life Cycle Assessment, have been conducted as part of research programmes in biofuels. Based on these developments, interviews were conducted with researchers working in the field of biofuels to explore:

- Scientists' experience and involvement in conducting assessments of biofuels;
- How their own work was assessed, for example in terms of research assessment;
- How, by whom and at what points it is most valuable to assess biofuel development and any associated ethical or social issues, and;
- What their own responsibility to address ethical issues might be, given current shifts towards more 'upstream' points of consideration and embedded notions of responsibility in research.

Five interviews were conducted between October 2012 and March 2013. A range of career-stage scientists and disciplines were selected from UK universities and were both prominent and active in the field of biofuels, as shown in the anonymised listing presented in below.

Participant identifier	Organisation	Position	Discipline
S6A	University A	Research Fellow	Experimental Biology
S6B	University A	Research Fellow	Botany
S7A	University B	Professor	Plant Biochemistry
S5A	University C	Director of Research	Energy
S8B	University D	Professor	Biochemistry

Table 9: Interviewees

The following section highlights some prominent points from the resulting discussions, primarily focusing on participants' experience of the assessment of biofuels, the current scope of assessment and any gaps, and the potential for integration in assessing biofuels. Where quotes are provided, they are accompanied by the participant identifier and are either illustrative of general points that are either interesting or common across the set of interviewees.

4.5.1 Experience of Assessments

When asked about their experience of biofuel assessments, the participants' sole response was in reference to Life Cycle Assessment (LCA). Generally this was by working alongside LCA practitioners in larger projects or in departments although one individual had co-authored a paper which included an LCA of a biofuel crop. None of the interviewees claimed any expertise in the area,

commenting that they knew it as the primary method for evaluating GHG, energy or economic outputs of biofuels.

On the one hand, this response is unsurprising and confirms work in other parts of the case study that highlights how the debate around biofuels has been narrowed to primarily being one of GHG balance and that in published literature, the majority of assessments focus on environmental and economic aspects of biofuels. On the other hand, many of the participants have had experience working with ethicists, social scientists, economists, or policy academics around biofuels who are likely to be conducting some form of assessment of the technology, its implementation or the wider context surrounding it.

4.5.2 Missing Dimensions of Biofuel Assessment

Although LCA was the only assessment method referred to by the interviewees, each then commented that there were other important issues relevant to biofuels that should be assessed and considered but often struggled to articulate them and how best to assess them in specific terms.

"Well probably like, I mean I'd like to see the you know how a social scientist would deem, well how they would you know what are the impacts at societal level of what we do, you know I'd be interested to see that. Because that would, could potentially change the way that we do our work but not being an expert" (S6B)

To build on this, on more than one occasion, interviewees stated that it was beneficial to include and consider as many issues as possible during the research process. Doing so could produce 'better' research that was better attuned to factors which could affect the 'development pipeline'. For one interviewee, this was especially important when making claims about the sustainability of biofuels. In this way, broader research strands were presented as being complimentary and facilitating in nature for the 'core' scientific research.

"If you say well it's ours, we just, we run it to make a little bit of money on it. And me saying well not only do I want our people to do research but we've got a bunch of other people and we really should be bringing these people in to do research on that as well." (S5A)

"So if I was going to come into biofuels and you say right is the pipeline sustainable, I would say well I can't tell you that until I've researched upstream and downstream and I haven't got the time [...] what I will do is look at, ask the people who are researching that and say well what do you think." (S8B)

4.5.2 Integration through Holistic Research Funding

While the majority of respondents agreed that more integrated or ethical assessments were currently outside the remit of their scientific work (often using limits to their 'workload' as an explanation), two noted that such questions are assumed in science as a result of the language and funding process. Bluntly, you don't get money without the research being within the broad ethical framework of the field.

"you don't really have to make the ethical argument in a scientific argument you don't, if you get a fuel to work really well with a low energy thing it's better than oil on almost everything. It's taken I guess." (S6A)

The final aspect to discuss concerns researchers' positions regarding integrating different assessment strategies during research into biofuels. Most participants spoke very positively about collaborative research and viewed it as the best way to begin to integrate different forms of knowledge about biofuels and their impacts directly into the research system. This collaboration could take a number of forms: from research centers and shared seminars through to directly funded holistic projects that explicitly looked at a range of aspects of biofuel production and use.

"if we're talking about biofuels yeah looking at the whole process chain and having people working alongside and I think it could work really, really well. [...] in an ideal world yes I think it would be, it's really, it's really informative for everybody as well actually and you probably, I think you probably end up with better outputs at the end, but it's a cost, financial cost." (S6B)

"Yes I think it's useful to have an integrated approach rather than to say there's, all the stem cell research is being done there, you over there go and see if it's, because it fosters an understanding of the science and the scientists an understanding of the ethics." (S8B)

In suggesting these forms of collaboration, respondents were wary of a number of pitfalls, including the possibility of 'diluting the research', expense and the importance that projects are designed and structured with an integrated approach from the outset rather than being shoe-horned in and labelled as such at later stages. In this respect, one respondent noted that clear leadership and direction was a fundamental part of successful collaborations.

4.5.3 Summary of Interview Findings

- In line with the prevailing response about experience of assessments and in line with the field, most scientists noted that Life Cycle Analysis had become the dominant way in which biofuels were assessed, and that this has become predominantly in terms of GHG.
- Currently, knowledge of other assessment methodologies for biofuels are relatively low, despite researchers often working alongside or leading, at least in nominal terms, large projects with social scientists, LCA practitioners and other disciplines.
- Despite the relatively shallow experience of assessments, participants unanimously agreed that other aspects beyond those covered by LCA were important to consider when conducting research and development in biofuels.
 - However, they were unsure of how best to do this and some were wary of past experiences where the 'hard science' had been diluted or been less-rigorous as a result of failed integration.

5 RECOMMENDATIONS

5.1 Summary of Findings

The study revealed a number of points about the biofuel assessment literature, summarised as follows:

- A proliferation of assessments is observed as research activity has intensified
- The body of assessments is very diverse and, often, poorly coordinated.
- Assessments tend to focus upon environmental and, to a lesser extent, economic impacts with social impacts often overlooked.
- Biofuels impacts are often reduced to GHG emissions, obscuring a wide range of other impacts.
- Most assessments position biofuel technology in an ‘opening’ stage and recognise the complexity of issues, demanding more knowledge and broader understandings of potential impacts
- The assessments exhibit high scientific literacy and impartiality
- Transparency varies amongst assessments
- Participative methods are infrequently used and reflexivity is low
- Many practitioners consider hidden assumptions and methods to be a major problem for the body of biofuel assessments.

5.2 Measures to Improve Integration

The identification of measures to meet integration needs is a key objective of the EST Frame project. This need for such measures was identified by participants in the workshop, specifically, the need for greater coordination of research activities, a more holistic approach and a mechanism for the integration of findings of the diverse range of assessments. In EST Frame, we build upon Scrase and Sheate (2002) to highlight different aspects of integrated assessment. These are presented in

Integration of assessment topics	1. Covering topic areas
Integration of assessment elements/methods	2. Including values
	3. Including narratives
	4. Not isolating one topic at the expense of the whole
	5. Identifying the framing
6. Including necessary elements	
Integration between assessments	7. Targeting the application of methods
Integration of assessment participants	8. Integrating broader experts, stakeholders and/or publics
Integration between assessments	9. Integrating the findings of assessments
Integration of assessment and governance	10. Integrating governance concerns
	11. Integrating assessments into governance

Table 10, below, and subsequently used to structure a discussion which draws from the desk-based study, interviews and workshop to reflect upon the need and potential for integrated biofuel assessment.

Integration of assessment topics	1. Covering topic areas
Integration of assessment elements/methods	2. Including values
	3. Including narratives
	4. Not isolating one topic at the expense of the whole
	5. Identifying the framing
	6. Including necessary elements
Integration between assessments	7. Targeting the application of methods
Integration of assessment participants	8. Integrating broader experts, stakeholders and/or publics
Integration between assessments	9. Integrating the findings of assessments
Integration of assessment and governance	10. Integrating governance concerns
	11. Integrating assessments into governance

Table 10: Understandings of Integrated Assessment

5.2.1 Covering Topic Areas

While environmental and economic issues are frequently included in assessments, social, security and safety concerns are often left out. The lack of attention to societal aspects is lamented in many reports and also by participants at the workshop. Efforts to broaden biofuel assessments' coverage into these areas may lead to more integrated findings.

5.2.2 Including Values

Assessments were generally quite unreflexive, failing to consider their own value base as well as those of others. Exceptions such as the Nuffield report aside, this reflects a lack of discussion of ethical issues and a failure to position assessments in a normative landscape. The lack of transparency in this regard makes it difficult to understand the assumptions embedded within assessments, leading to the integration challenge identified by the workshop participants.

5.2.3 Including Narratives

As implied in the previous point, the assessments tend to not consider others' values and narratives. This would likely improve if assessments had a more explicit focus upon societal aspects of biofuel development, or had a greater level of non-expert participation.

5.2.4 Not isolating one topic at the expense of the whole

This issue was strongly asserted at the workshop, where participants lamented the focus upon biofuel technology rather than specific challenges, and the failure to analyse alternatives against the same standards. This point is well illustrated in the problem of LUC which, as discussed above, cannot be resolved without taking a broader perspective on agricultural production.

5.2.5 Identifying the Framing

The framing of assessments is crucial in shaping their approach. This is particularly visible in a regulatory context as shifts in assessment foci can be observed as a response to policies in effect at the time of assessment. A simple illustration can be provided in the alignment of scenarios with broader GHG emissions reduction targets; assessments from 2003-2009 referred to the EU Biofuels Directive which was made obsolete in 2009, after which assessments reflected the regulatory context of the Renewable Energy Directive. Such changes can make assessments obsolete, particularly where assumptions and methods are not adequately described. Over the longer term, workshop participants described how GHG emissions have crowded out other issues such as energy balances over the past 10-15 years, and how this reflected the increasing dominance of climate change in policy discourse.

5.2.6 Including Necessary Elements

Opinions differ on the necessary elements of an integrated assessment, but anticipation and plausibility checks have been cited (e.g. von Schomberg 2012). As described above, many biofuel assessments are anticipatory and plausibility of scenarios is often debated (e.g. the potential yields, promise of advanced/GM/synthetic biofuels). These features may present a platform for more integrated assessments.

5.2.7 Targeting the application of methods

A recurring theme in the workshop was the lack of transparency of the assumptions and approaches of assessments. This critique was also extended to the choice of methods. A reflexive discussion of the reasons for method selection, as well as the definition of boundaries and assumptions, would allow the findings of assessments to be more readily integrated with those of others.

5.2.8 Integrating Broader Experts, Stakeholders and/or Publics

Participation is quite low in biofuel assessment and is most often limited to experts. Wider participation is widely regarded as beneficial in technology assessment, in particular of emerging technologies, and there is certainly room for greater integration of a wider spectrum of stakeholders and publics as participants in biofuel assessments.

5.2.9 Integrating the Findings of Assessments

The participants in the workshop suggested that a committee should be established to integrate the findings of the broad range of biofuel assessments that have been produced. This would pay particular attention to the differences in the boundaries, limitations and embedded assumptions of assessments and combine their insights to give a balanced overview of the state of knowledge. It was suggested that this should occur at a European level and that selection of committee members would be crucial for its legitimacy.

5.2.10 Integrating Governance Concerns

Many assessments are positioned in the context of European and UK biofuels policies and, in this regard, governance concerns are well integrated to biofuel



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

assessments. Indeed, it has been suggested that other technologies, agricultural activities and motor fuels are not appraised against these contextual features with comparative rigour, so biofuels are unfairly singled out for criticism.

5.2.11 Integrating Assessments into Governance

Biofuel policy documents tend not to refer to their sources but, while it is anecdotally clear that the literature has influenced policy developments (e.g. the rise of ILUC as a biofuel governance issue), our workshop findings suggest that policymakers tend, instead, to make use of assessment consultants to inform their activities. This implies that many assessments are not well integrated into governance processes and that the processes of using knowledge for policy support may not be sufficiently transparent.

5.3 Recommendations

Based upon the findings of the analysis, recommendations are made for (i) assessment practitioners, (ii) research councils and (iii) policymakers. These primarily respond to the following problems identified in the body of biofuel assessments:

- Lack of transparency, affecting the utility of assessments for policymakers or further studies and also making the integration of findings difficult
- Insufficient attention paid to societal aspects
- Focusing upon specific technologies rather than specific problems
- Limited participation, particularly of non-experts, which may affect assessments' sensitivity to different perspectives on technical impacts.

5.3.1 Recommendations for Assessment Practitioners

- The desk study found that biofuel assessments are weak in the areas of transparency and self-reflection. The workshop findings confirmed that this failure to highlight and justify approaches, methods and boundaries negatively affects the utility of assessments, regardless of their scientific integrity (which is considered strong), and presents a serious barrier to the integration of knowledge. As such, we recommend that assessment producers consider the following practical points to improve the transparency and, ultimately, the utility of their work:
 - Explicitly state the methods applied, justify their selection and examine their limitations. The assumptions embedded within these methods should be considered and described.
 - Include as much data as possible (using annexes or on-line resources where necessary), stating any assumptions and clearly describing the analytical steps taken to produce the results.
 - Explicitly state the boundaries of analysis. Consider the geographic scope, specific combinations of feedstocks and process technologies, and different types of impacts (e.g. GHG balances or societal aspects) to which the study is limited. Justifications should be provided where results are extrapolated beyond these boundaries.

- Consider the extent to which results depend upon the context of assessment, and how the results would be affected by, for example, new targets. While such changes are difficult to predict, clearly describing the data and methods applied could prolong the utility of an assessment which may otherwise be made obsolete as contextual features change.
- Reflect upon the limitations of the study and the conditions under which results remain valid.
- Participation, particularly of non-experts, is low in biofuel assessments. Although there are many forms of participation and participation per se may not be appropriate for every study, increased participation may improve the legitimacy of assessments by incorporating the insights of publics and other stakeholders. This may also improve assessments' reflexivity and strengthen their attention to societal aspects, each of which is also considered low.
- Consider how policymakers engage the academic literature and develop strategies to improve visibility, for example publishing targeted policy briefs on open access on-line sites.

5.3.2 Recommendations for Research Councils

- The desk study, workshop and interviews reveal that assessments are insufficiently sensitive to social impacts. This is a difficult problem and is probably not limited to the study of biofuels. The situation may be improved by greater cross-domain or cross-funding council activity relating to biofuels, including grants for the examination of social impacts of biofuel development and support for dialogue across disciplinary boundaries. Some such activities are underway, cross-cutting events organised by the UK bioscience research council, BBSRC.
- Workshop participants find that the focus upon specific technologies such as biofuels, rather than specific problems such as land-use, makes it difficult to produce meaningful assessments which can adequately respond to contemporary challenges. This is exacerbated by the widely reported difficulties of publishing and building careers outside of disciplinary silos. The provision of funding to research the impacts of specific technological developments could discourage assessment practitioners from considering problems holistically. Research councils could respond by providing funding structures which encourage broad research into potential responses to challenges such as land-use change.

5.3.3 Recommendations for Policymakers

- The body of biofuel assessments is diverse and the embedded assumptions often appear incommensurable. This means it is difficult to integrate findings. The workshop participants suggested that a committee should be established to deliver a report summarising the state of current knowledge about biofuels with particular reference to the embedded assumptions and methods. It was suggested that the committee should be independent but state-sanctioned, preferably at a European level. The procedural design and transparency of such a committee would be a crucial factor in its legitimacy and success.



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project.*

- Assessments are framed with reference to policy discourse. As climate change increasingly dominates policy discourse, GHG emissions increasingly dominate assessment spaces. Maintaining alternative discursive arenas such as rural development, energy security and land use may inspire assessments to consider a broader range of impacts. Even indicating a desire to consider more social perspectives on biofuel development, for example, may inspire activity amongst social scientists who are not otherwise not engaged with these issues.
- Policymakers could engage the academic community more systematically. Ad hoc approaches to the literature are not transparent and are unlikely to yield the best results. A closer relationship could be forged, for example, through partnerships with the teams of multi-disciplinary researchers working across topics or directly with research councils. The research community could improve their penetration by releasing policy briefs alongside their academic contributions or by running short policy-focused dissemination events.



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project*

REFERENCES

- Afionis, S. and Stringer, L. (2012) European Union leadership in biofuels regulation: Europe as a normative power? *Journal of Cleaner Production* 32, p114-123
- Boucher, P. (2012). The role of controversy, regulation and engineering in UK biofuel development. *Energy Policy*, 42, p148–154.
- Bouët, A., Dimaranan, B. V., & Valin, H. (2010). Modelling the global trade and environmental impacts of biofuel policies. IFPRI discussion paper 01018. The International Food Policy Research Institute (IFPRI). Available at <http://www.ifpri.org/publication/modeling-global-trade-and-environmental-impacts-biofuel-policies>. Accessed 7 August 2011.
- Cushion, E., Whiteman, A., & Dieterle, G. (2010). Bioenergy development: Issues and impacts for poverty and natural resource management. Washington, DC: The International Bank for Reconstruction and Development/The World Bank. Available at <http://www-wds.worldbank.org/>. Accessed 7 August 2011
- Decker, M. and Ladikas, M. (2004) *Bridges between Science, Society and Policy: Technology Assessment- Methods and Impacts*. Springer, Berlin.
- DTI. (2003). *The Renewables Obligation (Amendment) Order 2003 Statutory Consultation*. London.
- European Commission. (2010). Report from The Commission on indirect land-use change related to biofuels and bioliquids. Brussels.
- Fargione, J., Hill, J., Tilman, D., Polasky, S., & Hawthorne, P. (2008). Land clearing and the biofuel carbon debt. *Science (New York, N.Y.)*, 319(5867), 1235–1238. doi:10.1126/science.1152747
- Gamborg, C., Millar, K., Shotall, O. and Sandøe, P. (2012) Bioenergy and Land Use: Framing the Ethical Debate. *Journal of Agricultural and Environmental Ethics*. 25 (6) p909-925.
- Gasparatos, A, Lehtonen, M and Stromberg, P (2012) Do we need a unified appraisal framework to synthesize biofuel impacts? *Biomass and Bioenergy*. 50. p75-80.
- Kretschmer, B. and Baldock, D. (2013). Addressing ILUC? The European Commission's proposal on Indirect Land Use Change. Institute for European Environmental Policy.
- RFA (2008). *The Gallagher Review of the Indirect Effects of Biofuels Production*. RFA, London, UK.
- RFA (2010). *Year One of the RTFO: Renewable Fuels Agency Report on the Renewable Transport Fuel Obligation 2008/09*. RFA, London, UK.
- Scrase J. I. and Sheate W. R. (2002) Integration and integrated approaches to environmental assessment. What do they mean for the environment? *Journal of Environmental Policy and Planning*, 4, 275-294.
- Secretary of State (2009). *Statutory Implement Number 843: The Renewable Transport Fuel Obligations (Amendment) Order*. Office of Public Sector Information, London.
- Searchinger, T., Heimlich, R., Houghton, R. a, Dong, F., Elobeid, A., Fabiosa, J. and Tokgoz, S. (2008). Use of U.S. croplands for biofuels increases



Integrated EST framework (EST-Frame)

*An FP7, Science in Society, Collaborative Project,
Small or medium-scale focused research project.*

greenhouse gases through emissions from land-use change. *Science* (New York, N.Y.), 319(5867), 1238–1240. doi:10.1126/science.1151861

Tilman, D., Socolow, R., Foley, J. A., Hill, J., Larson, E., Lynd, L. and Pacala, S. (2009). Beneficial Biofuels—The Food, Energy, and Environment Trilemma. *Science*, 325, p270–271.