Desk Study on Indirect GHG Emissions from Fossil Fuels

Final Report

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Table of Contents

Executive Summary

Through the legislative amendment of Directive 2009/30/EC[1], the Fuel Quality Directive ('FQD', 98/70/EC) became a low carbon fuel standard. Among the possible methodologies for fuel suppliers to calculate their fossil fuels' GHG intensities are policy options[2] that distinguish quantitatively between GHG intensities of different fuels (e.g. by feedstock). Such differentiation implies the need for sufficient accuracy in the GHG intensities of those fuels, as well as the need to take into account significant indirect effects, to avoid drawing false conclusions. To date, the evaluation of indirect GHG emissions has been limited to indirect land use change (ILUC) emissions for biofuels; ILUC GHG emission intensities were proposed by the Commission in the October 2012 ILUC proposal (COM(2012) 595 final) to be used in addition to biofuel direct GHG emission intensities.

The objective of this report is to provide an overview that enables the European Commission to be in a position to objectively evaluate the indirect GHG emissions from fossil fuel origin. This study has identified five possible sources of indirect emissions**:**

1. **Induced land development**,
2. **Military involvement**,
3. **Accidents**,
4. **Marginal effects** (comprising: effects on fossil fuel sources; effects on operation of refineries; and effects on electricity generation) and
5. **Market-mediated effects** (comprising: export of co-products to other markets; and price effects).

ICF has mapped each identified indirect source on to the fossil fuel life cycle (Figure E–1). Table ES-1 provides the sources, applicable fossil fuel types, quantitative estimates for their potential scale of contribution to GHG emissions intensity, and the main conclusions drawn on the sources in this study.

Overall, ICF found that the life cycle literature does not apply uniform definitions to direct and indirect emission sources and that there is no consensus about which fossil fuel emissions sources constitute direct or indirect sources. There is a lack of established methodologies and guidance for accounting for them. This report is structured as follows:

- Section 1 describes the objectives of the study and the context;
- Section 2 outlines the methodology followed to complete the study;
- Section 3 summarises the indirect emission sources identified by a literature review and interviews.
- Section 4 defines direct and indirect emissions, and maps each onto the fossil fuel life cycle. It establishes criteria for evaluating the appropriateness of including or excluding possible indirect emissions sources in the fossil fuel life cycle.
- Section 5 synthesises from the relevant literature each indirect GHG emission source as a separate subsection. Each source is evaluated in terms of the appropriateness of including or excluding each source from the GHG life cycle.

[1] The 2009 FQD amendment introduced, among other requirements for transport fuel suppliers, a target for the reduction in GHG intensity of fuels supplied on the EU market. The FQD applies to all petrol, diesel and biofuels used in road transport, and to gasoil used in non-road-mobile machinery.

[2] The Article 7a implementing measure has not been published at the time of writing.

Figure E-1: Fossil fuel life cycle with indirect emission sources shown alongside direct emission sources that are generally well-characterised in life cycle studies, and direct emissions that are inconsistently-characterised

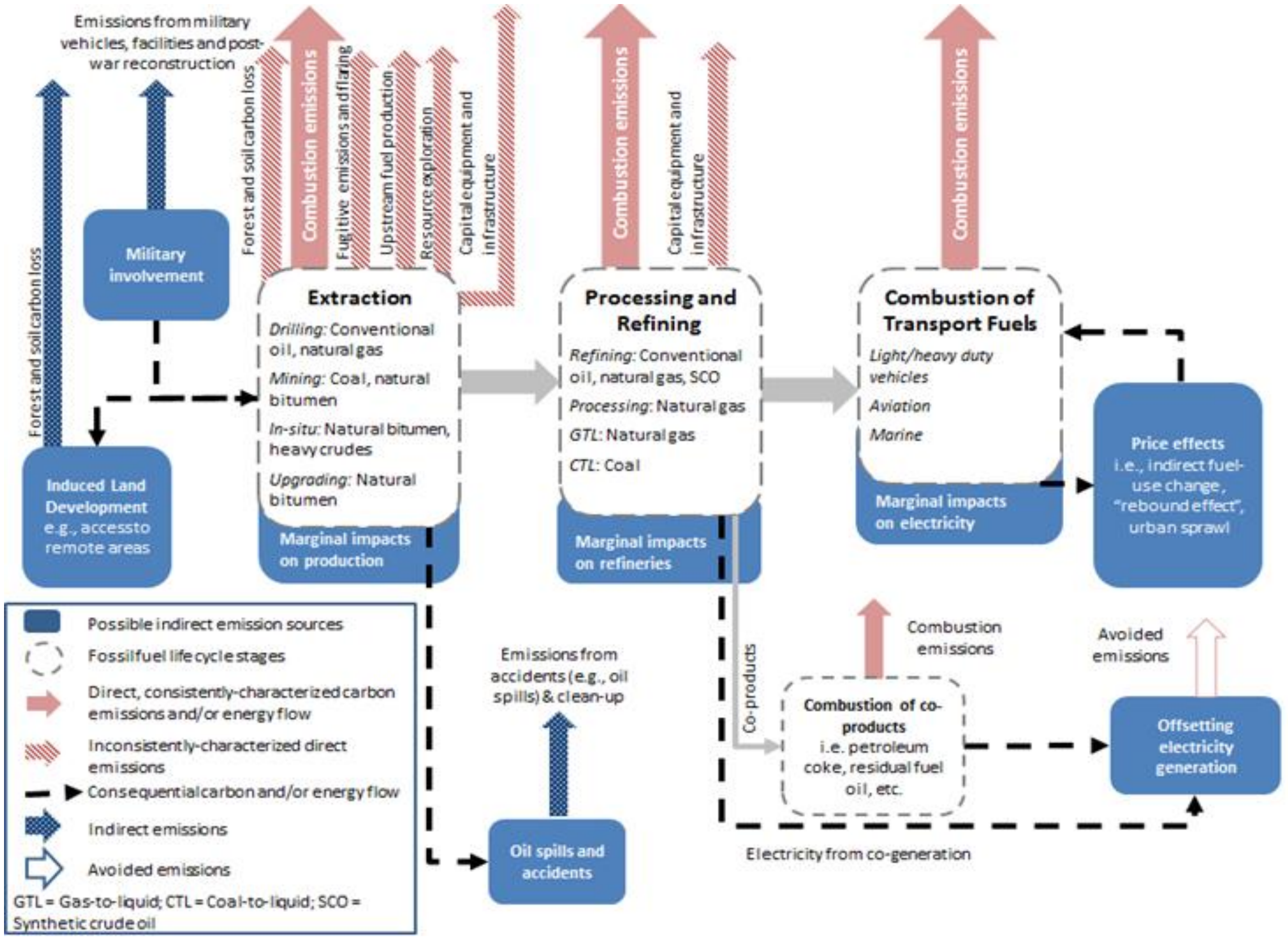

Table ES-1: Summary of estimated scale of GHG Emissions relevant to EU fuel consumption based on literature review

Indirect Emission Source	GHG Emissions Estimate		Applicable Fossil Fuel Type(s)	Main conclusions
	g CO_2e/ MJ of Fuel	% of WTW GHG emissions[3]		
Induced land development	0.6 - 1.0 For relevant fuel	0.7 - 1.1%	Fossil fuels extracted in remote, forested areas	• Potential contribution to life cycle emissions of fossil fuels is likely small. • Quantitative estimate only relevant for oil produced in forested regions; may not be necessarily representative of all conditions. • No widely accepted models have estimated the this effect.
Military involvement[4]			Conventional oil supplied through the Persian Gulf, extracted from Iraq, Libya, and other conflict or unstable areas	• Methods for allocating GHG emissions are subjective: require arbitrary decisions for time period, allocation to fuels, sources of emissions. • Exclusion of this source is consistent with other jurisdictions, notably within the EPA's Renewable Fuel Standard. • No study explicitly discusses petroleum exported from the Persian Gulf into the EU and the degree to which emissions (primarily from the U.S. military) are attributable to petroleum in the EU.
Military protection	0.18 - 1.1	0.2 - 1.3%		
War-related emissions	1.2 For relevant fuel	1.4%		
Accidents	Negligible (i.e.,<0.00003)	Negligible	Fossil fuels[5]	• Environmental impact assessments of accidents primarily focus on local ecosystem impacts rather than GHG emissions. This source is not included in other existing LCAs of fossil fuels in the literature surveyed • Exclusion of accidents is consistent with European guidance on the development of life cycle inventory data for the International Reference Life Cycle Database data network. • Accidents are fundamentally different from normal operating conditions and methods for including GHG emissions from infrequent accidents and oil spills into LCA studies are still under development. • Large-scale accidental releases of oil are rare and have been decreasing since 1973; they represent a small portion of the oil produced and transported worldwide and may thus constitute a very small source of emissions. Marine accidents and oil spills add a negligible amount of GHG emissions to the total fossil fuel life cycle.

[3] Expressed as a percentage of the life cycle GHG intensity of petrol from conventional crude (87.5 gCO_2/MJ) in EC (2011).

[4] Note that these estimates are based on U.S. military activities and allocated on the basis of U.S. oil imports and transportation fuel use. Military activity emission estimates for the EU would be different and would need to differentiate by EU military activities and activities in other countries based on crude oil origin; e.g., refined fuels imported from the U.S. Gulf Coast that may have been refined from Persian Gulf crude oil imports.

[5] "Fossil fuels" refers to transportation fuels produced from crude oil, natural gas, and coal fuel sources, including both conventional and unconventional extraction methods.

Indirect Emission Source	GHG Emissions Estimate		Applicable Fossil Fuel Type(s)	Main conclusions
	g CO_2e/ MJ of Fuel	% of WTW GHG emissions[3]		
Market-mediated effects				
Export of co-products to other markets	2 - 4	2.2 - 4.5%	Crude oil-derived fuels	• Did not locate quantification at a sufficient level of detail to allow inclusion within an LCA. • Available quantitative estimate is for illustrative purposes and makes several market assumptions such as fuel mix, market share, and supply and demand elasticity. • No accepted macro-economic models have demonstrated the European or global impact on energy system supply and demand related to co-product consumption, production, and GHG emissions.
Price effects	0.25	0.28%	Fossil fuels[5]	• Scarce data regarding fuel use changes in response to policy shifts • No currently accepted modelling for behavioural responses in European markets related to oil price, consumption, production, and GHG emissions across all the economic sectors that are affected by petroleum. • Any modelling work is complicated by political factors such OPEC targets.
Marginal effects				
On fossil fuel sources	Not available	Not available	Crude oil-derived fuels, natural gas	• The information currently available on marginal changes in the fossil fuel resource consumed is insufficient to include these effects as an indirect emissions source in the scope of the FQD. • No quantitative estimates of this effect are available in the literature surveyed, and there is still a great deal of uncertainty over the timing, magnitude, and direction of these effects.
On operation of refineries	Not available	Not available	Crude oil-derived fuels	
On electricity generation	Not available	Not available	Natural gas	• There is currently a paucity of data available on changes in electricity generation that may result from increased demand for natural gas as a transportation fuel. • Literature shows GHG-intensity of electricity sector is sensitive to changes in demand, but did has not assessed this effect explicitly. • Current level of information on this effect is insufficient to determine the significance of its inclusion in the boundaries of the FQD.

Note: for full details of the notes applicable to this table, please see Section 6.

1. Introduction

1.1. Objective

This desk study seeks to provide an overview that enables the European Commission to objectively evaluate the indirect GHG emissions from fossil fuel origin. It is intended to provide an evidence base summarising the possible indirect greenhouse gas (GHG) emission sources of fossil transport fuels that will allow the Commission to better characterise the theoretical basis for including or excluding these emissions in GHG life cycle assessments (LCA) and react to claims about the consistency of the Commission's treatment of fossil fuels relative to biofuels within the context of the implementation of the Fuel Quality Directive (FQD).

The objectives of this study are to:

- Conduct an assessment of sources of indirect GHG emissions from fossil transport fuels as identified in literature, studies, and other regulatory low-carbon fuel initiatives;
- Evaluate where such claimed indirect GHG emission sources sit in relation to the fuel life cycle;
- Evaluate the definitions of, and boundaries for direct and indirect GHG emissions from fossil transport fuels, including classification of direct and indirect emissions from fossil fuels as being either attributional or consequential (see Section 4.1 for details);
- Provide guidance (based on accepted LCA standards, guidance, and literature) on where appropriate boundaries may be drawn and which indirect GHG emissions sources are most appropriate to include or exclude from the boundary;
- Analyse the numerical values of indirect GHG emissions from fossil transport fuels in the existing literature; and
- Provide indications of the approximate scale of indirect GHG emission sources to the extent they have been evaluated in literature.

This study focuses on a near-term timescale relevant to the FQD (i.e., a 2020 timescale). Its geographic scope includes emission sources both in the European Union and other regions that would be affected by implementation of the FQD.

1.2. Context

For the purpose of mitigating GHG emissions from transportation fuels, the European Commission has updated the FQD (Directive 98/70/EC, 'FQD') via the amendment Directive 2009/30/EC. This legislative amendment introduced a series of environmental requirements and binding targets for fuels sold in the European Union in relation to GHG emissions:

- Article 7a 'greenhouse gas emission reductions' requires a reduction in GHG emissions from fossil fuel pathways, including through encouraging the use of lower GHG intensity fuels.
- Article 7b establishes sustainability criteria for the sale of biofuels as a means of reducing carbon intensity of supplier fuels, supported by a verification process in Article 7c; and

- Article 7d establishes a methodology for calculating the life cycle GHG emissions from biofuels.

The FQD is implemented using the principles of LCA – or well-to-wheels analysis – for the GHG emissions attributable to transport fuels. Article 2(6) of the FQD defines 'life cycle greenhouse gas emissions' as "*all net emissions of* CO_2*,* CH_4 *and* N_2O *that can be assigned to the fuel (including any blended components) or energy supplied. This includes all relevant stages from extraction or cultivation, including land-use changes, transport and distribution, processing and combustion, irrespective of where those emissions occur*".

Article 7a(2) of the FQD requires fossil fuel suppliers to achieve a 6% reduction in the GHG intensity of their transport fuels placed on the EU market from a 2010 baseline by 31 December 2020. The Commission proposed that the 2010 baseline GHG intensity was 88.3 g CO2e/MJ. The FQD allows suppliers to meet the 6% reduction from this baseline by utilising fuels with lower life cycle carbon intensities (e.g., by replacing natural bitumen or oil shale feedstocks-derived fuels with conventional crudes), through using biofuels or electrical energy in place of fossil fuels, through achieving upstream emission reduction credits or through other fuel lifecycle GHG emission reduction measures. The development of the baseline for fossil fuel GHG intensity has been supported by a series of contributing life cycle assessments (LCAs) and studies. A leading contributor is the JEC, a research collaboration between the Joint-Research Centre of the European Union, the European Council for Automotive Research & Development (EUCAR) and the oil companies' European association for environment, health and safety in refining and distribution (CONCAWE). JEC (2011) produced the *Well-to-wheels Analysis of Future Automotive Fuels and Powertrains in the European Context*, which characterises the process of producing, transporting, manufacturing and distributing various transportation fuels. Other supporting information for the FQD's characterisation of baseline fossil fuel emissions includes LCA studies focused on the European market, such as Jacobs (2012) *EU Pathway Study: Life Cycle Assessment of Crude Oils in a European Context* and Brandt (2011) *Upstream Greenhouse Gas (GHG) Emissions from Canadian Oil Sands as a Feedstock for European Refineries*.

LCAs for fossil fuels typically include two types of GHG emissions: "direct" and "indirect" (see Section 4 for a more detailed overview). For the purposes of this study, direct emissions are emitted from the processes used to produce, transport and combust the fuel along the full life cycle. "Indirect" emissions are those that are influenced or induced by economic, geopolitical, or behavioural factors, but which are not directly related to extraction, processing, distribution, or final combustion of the fuels

Relevant LCA Standards and Guidance

A variety of international LCA standards and guidance documents provide guidelines for the characterisation of life cycle fossil fuel emissions to support the FQD. The primary source for guidance on LCA methodology comes from the International Organisation for Standardisation (ISO) 14040-series of standards, which establish principles, requirements, and guidelines for conducting LCAs. To provide more specific guidance alongside the 14040-series of standards, the European Commission's Joint Research Centre (JRC) issued its International Reference Life Cycle Data System (ILCD) Handbook – General guide for Life Cycle Assessment –

themselves.[6] The proposed FQD Article 7a implementing measure distinguishes quantitatively between GHG intensities of different fuels and their lifecycle pathways. The need for these estimates of GHG intensities is to determine which fuels have a lower intensity than others. In order for these determinations to be accurate, GHG intensity estimates need to include significant sources of indirect emissions to avoid drawing false conclusions on the basis of only direct effects.

There is, however, limited practical guidance on how indirect effects should be considered in LCAs and GHG emission factors. Although LCA standards do not specifically refer to indirect emissions or consequential analyses, ISO 14044 recommends using system expansion—whereby the product system assessed in the LCA is expanded to include the impacts of co-products produced by that system. The proposed FQD Article 7a implementing measure methodology for calculating GHG intensities from fossil fuels does not include indirect impacts in the calculation, and only makes reference to indirect emissions by specifically excluding from the calculation "*emissions from the manufacture of machinery and equipment utilised in extraction, production, refining and consumption of fossil fuels*". The proposed implementing measure includes a review clause in Article 6, which would mandate the Commission to review the implementing measure by the end of 2015 to consider, among other topics, "*how to address (…) any significant impacts from any potential indirect emissions of fossil fuels*". It is understood that this desk study is the first step for the Commission to study and potentially address indirect emissions of fossil fuels in the context of the FQD.

As the European Commission has worked to characterise the indirect emissions associated with biofuels production within the context of the FQD, stakeholder input during the Article 7a proposal development has highlighted the need for biofuels and fossil fuels to be evaluated consistently. The FQD addresses aspects related to the sustainability criteria for biofuels but does not address the indirect impacts of biofuels. The cultivation of biofuels can conceivably contribute to changing land use from forests or wetlands to agricultural land, especially in the case of food-based biofuels. This indirect land use change (ILUC) can lead to increased GHG emissions for example through the removal of existing carbon sinks, which could undermine the direct emissions savings attributable to biofuels compared to fossil fuels.

In November 2010, the European Commission's Joint Research Commission hosted an expert consultation on ILUC effects caused by increased use of biofuels. The discussions at this consultation included a focus on land use change and GHG emissions (methodologies, datasets and uncertainties to locate ILUC and calculate GHG emissions). The experts concluded that the ILUC effect is significant and crop-specific, suggesting use of a factor that attributes a quantity of GHG emissions to crop-specific biofuels as well as incentivising good agricultural practices, land management, carbon mitigation strategies, and intensification on pasture lands. A wide variety of recent literature has attempted to quantify the impact of ILUC and allocate it to the life cycle emissions from biofuels. These studies seek to determine the extent to which applying a credit for GHG uptake from growing biofuels is justified, and to correct for potential indirect GHG emissions effects that are induced by

[6] See Figure 4-3 for an overview of direct and indirect emission sources along the life cycle. These definitions have been developed based on a review of the relevant literature on indirect emission sources from fossil fuels. For more detail on the different defintions applied in the available literature, refer to Section 4).

increases in biofuel production worldwide. Consequently, the European Commission proposed a further amendment in October 2012 to the FQD in order to include ILUC factors for the purposes of reporting the life cycle GHG emission savings from biofuels under Article 7a of the FQD.[7]

[7] Proposal for a directive of the European Parliament and of the Council amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources. COM (2012) 595. http://ec.europa.eu/clima/policies/transport/fuel/docs/com_2012_595_en.pdf

2. Approach

ICF undertook three tasks to meet the objectives in Section 1.1 above:

1. Literature review of indirect emission sources
2. Assessment of boundaries and definitions of indirect emission sources
3. Estimation of the range of indirect emission estimates and uncertainties and evaluation of appropriateness of including or excluding indirect emissions sources

Each task is described below to demonstrate our approach and the steps we took to ensure the review was as comprehensive as possible within the available resources, incorporated the latest information, consulted with a diverse mix of interested parties, and consistently applied accepted LCA standards and principles. This section also describes the rationale and criteria for determining appropriate boundaries on the life cycle of GHG emission sources.

2.1. Task 1: Summary of Potential Indirect Emissions Sources Identified by the Literature Review

The first task involved a review of the literature available on indirect emissions from fossil fuels. Building on ICF's existing understanding of approaches for quantifying emissions from fossil fuels production, ICF gathered and assessed information through a comprehensive literature review in order to develop proposals for definitions and boundaries of fossil fuel production emissions to be included in this study. This literature search was conducted using two methods: a targeted online literature search and through outreach to stakeholders and sector experts.

- ICF conducted a targeted online literature search to locate recent literature that discussed or attempted to characterise the fossil fuel life cycle. ICF's literature search utilised ICF's existing knowledge of LCA literature and a targeted Internet search of peer-reviewed journal articles and presentations.
- ICF also made enquiries to both fossil fuel and biofuels industry stakeholders and sector experts to identify relevant studies. The stakeholders were provided with a brief overview of the FQD and a working definition of indirect emissions (see Section 4.1). To acquire a representative cross-section of sectoral expertise and relevant studies across fossil fuel types and throughout the life cycle, ICF contacted a variety of organisations in industry, government and NGOs within the EU and North America (for a complete list of stakeholders contacted, see Table 2-1).

A full list of sources considered is included in Section 7. After studies were identified via the online search or provided by stakeholders, ICF evaluated and then categorised each source based on how it met the following criteria:

- The goal, scope, and purpose of the study and whether the evaluation of indirect emission sources was a specific focus of the study, or whether it specifically acknowledged potential indirect emission sources;
- How direct or indirect sources were defined;
- The types of fossil fuels included;

- The pathway of the emission source;
- Approaches used for multi-function processes (i.e., processes which produce more than one product, such as lower-value petroleum coke and sulphur produced at refineries alongside premium fuels) and the effects that these other products (referred to as co-products) have when sold to other markets (e.g., petroleum coke's effects on the electric power sector when sold as a fuel for electricity generation); and
- Gaps or inclusions identified by the study.

ICF developed a database in Microsoft Excel to sort each study reviewed using a set of selection criteria. The primary criterion in assessing the literature was whether or not it acknowledged the potential for indirect emissions from fossil fuels. If a study indicated the existence of indirect emissions and then attempted to quantify them, ICF then assessed the representativeness, completeness, and overall quality of the estimates according to the following criteria: time horizon of the study, transparency and documentation of data and methods, representativeness of the data and technologies modelled, approaches or quantification methods used to quantity indirect emission estimates, uncertainty information, limitations or data gaps, and whether a peer or critical review was performed on the study.

Table 2-1: Stakeholders contacted to identify literature on indirect emission sources

Location	Stakeholder	Description
Europe	CONCAWE	European oil company association researching environmental issues relevant to the oil industry
	Copa Cogeca	Group representing European farmers and agricultural cooperatives in the EU
	ePure	Group representing and supporting companies that produce renewable ethanol
	European Biodiesel Board	Non-profit group promoting use of biodiesel and representing major biodiesel producers in the EU
	Greenpeace*	Global environmental lobbying and activism organisation
	International Council on Clean Transportation (ICCT)	A non-profit organisation researching environmental performance and energy efficiency in transportation
	Energy Research Architecture (ERA)	Energy consultancy focused on the development of sustainable and efficient use of resources.
	Transport & Environment (T&E)	Non-governmental organisation advocating environmentally sound transport policies
	Union zur Foerderung von Oel- und Proteinpflanzen e.V. (UFOP)	German association that represents the processing and marketing of domestic oil and protein crops.
North America	Government of British Columbia	Province-level government of British Columbia, Canada
	California Air Resources Board (CARB)	State-level air quality regulatory body for California
	Don O'Connor (S&T^2 Consultants)	Independent consultant specialising in fuel LCAs and ILUC. S&T^2 Consultants support Natural Resource Canada's GHGenius model for lifecycle assessment of transportation fuels.

Location	Stakeholder	Description
	Environmental Law and Policy Center (ELPC)*	Midwestern environmental advocacy organisation
	Fred Ghatala (Waterfall Group)	Private consultancy active on clean energy and natural resource issues in the Canadian biofuel sector. On the International Organization for Standardization's TC 248 Project Committee Working Group 4, Mr. Ghatala worked on standard-setting for ILUC from biofuels.
	Northeast States for Coordinated Air Use Management (NESCAUM)	Non-profit association of air quality agencies in the Northeast to provide scientific, technical, analytical, and policy support
	Oregon State Department of Environmental Quality	State-level environmental regulatory body for Oregon
	Washington State Department of Ecology	State-level environmental regulatory body for Washington

* These organisations were contacted but did not suggest additional resources for inclusion in this report.

2.2. Task 2: Assessment of Definitions and Boundaries of Indirect Emissions Sources

Prior to the characterisation of indirect emission sources from fossil fuels, ICF used the literature review phase of this study to synthesise possible boundaries between direct and indirect emissions sources and a final list of indirect emissions sources. The boundary definitions were informed by the overall goal, scope and definitions of the FQD, as well as our existing understanding of the indirect GHG emission boundaries or GHG accounting methodologies that have been established for biofuel production and use pathways. As part of this effort, ICF summarised how various emissions sources are treated within the literature and assessed the studies' definitions of direct and indirect emissions. Indirect emissions sources identified in this task were included in the final desk study based upon their alignment with the following criteria:

- Availability of peer-reviewed scientific literature describing that emission source;
- The degree of scientific consensus;
- Feasibility of accurately estimating emissions;
- Treatment of the source in other high-quality and peer-reviewed LCA studies (e.g., was it factored into the final analysis?); and
- Data availability.

2.3. Task 3: Estimation of the range of indirect emission estimates and uncertainties and evaluation of appropriateness of including or excluding indirect emissions sources

For studies that provided quantitative estimates of potential indirect emissions sources, ICF extracted information on the direction and magnitude of the source, and (if available) the range or level of uncertainty in the estimates. For studies where uncertainty information was not provided, ICF used the evaluation of literature in Task 1 to qualitatively assess uncertainty according to model imprecision, input uncertainty, and data variability.

ICF applied the criteria developed in Task 2 and the quantitative estimates developed in this Task to develop recommendations for each indirect emission sources, namely:

- Sources where there may be a basis for inclusion or for further study,
- Sources that are most appropriately excluded from the boundary, and
- Sources where a determination on inclusion or exclusion is not currently feasible to evaluate due to the lack of vetted scientific information, data and estimates representative of the context in Europe, and of accepted methods for evaluation.

3. Task 1: Summary of Potential Indirect Emissions Sources Identified by the Literature Review

ICF's literature review identified several potential indirect emissions sources that may warrant consideration as components of the fossil fuel life cycle for the purposes of implementing the amended FQD. Table 3-1 indicates which studies were assessed in the literature review process and assigns them to three categories: (i) studies that included quantitative estimates of possible indirect emission sources, (ii) studies that only discussed possible indirect sources qualitatively, and (iii) studies that did not discuss possible sources of indirect emissions along the fossil fuel life cycle.

Table 3-1: Overview of Literature Assessed in the Literature Review Process

Studies that included quantitative estimates of possible indirect emissions sources	Studies that discussed possible indirect emissions sources qualitatively	Studies that did not discuss possible sources of indirect emissions
AEA 2012	Brander et al. 2009	Abbott and Worhach 2003
Arvesen et al. 2011	Copulos 2003	Baynard 2007
Brandt 2011	Delucchi 2011	Bergerson et al. 2012
CARB 2010, 2011	ERA 2009, 2010	Charpentier et al. 2011
Chen and Khanna 2011	Rajagopal and Zilberman (undated)	Ecofys 2013
IHS CERA 2010, 2011	TIAX 2007	Ernst and Young 2011
Jacobs 2009, 2012	Yeh et al. 2012	European Commission 2010
JEC 2011		Howarth et al. 2011
Lattanzio 2012	Personal correspondence with stakeholders	ISO PC 248 Working Group 4 2012
Liska and Perrin 2010		Jordaan et al. 2009
NETL 2008, 2009		Liska and Perrin 2009
Oil Change International 2008, 2013		McCann and Associates 2001
Rajagopal et al. 2011		NRDC 2010
Ryerson et al. 2011		O'Hare 2009
$(S\&T)^2$ Consultants 2012		PwC 2003
TIAX 2009		Rajagopal and Plevin 2013
Unnasch et al. 2009		Sanchez et al. 2012
		Santoro et al. 2011
		Schneider and Dyer 2006
		Schremp 2011
		TIAX 2010
		USFWS 2001
		Yeh et al. 2010
		York 2012

Studies which did not discuss possible indirect sources for fossil fuels—i.e., those studies that focused on only direct emissions or on indirect emissions associated with biofuels—were not evaluated in detail in our literature survey. Table 3-2 provides a summary of the studies that did discuss possible indirect emission sources along the fossil fuel life cycle. The type of study distinguishes between LCAs and reports that focused on a specific indirect emissions source (i.e., source-specific studies).

Table 3-2: Summary of studies that discussed possible indirect emissions sources in the fossil fuel life cycle either quantitatively or qualitatively

Author	Title	Publisher	Type of study[1]	Fossil fuel types addressed
Studies with quantitative estimates of possible indirect emission sources				
AEA 2012	Climate impact of potential shale gas production in the EU.	Self-published	LCA	Natural gas, shale gas
Arvesen et al. 2011	Considering only first-order effects? How simplifications lead to unrealistic technology optimism in climate change mitigation	Energy Policy	Source-specific	All fossil fuels[2]
Brandt 2011	Upstream greenhouse gas (GHG) Emissions from Canadian Oil Sands as a Feedstock for European Refineries	Self-Published	LCA	Oil sands petroleum
CARB 2010	Indirect Effects of Other Fuels	Presentation	Source-Specific	Petroleum
CARB 2011	Low Carbon Fuel Standard -- Indirect Effects	Self-Published	Source-specific	All fossil fuels[2]
Chen and Khanna 2011	The Market-Mediated Effects of Low Carbon Fuel Policies	Ag Bio Forum	Source-Specific	All fossil fuels[2]
IHS CERA 2010	Oil Sands, Greenhouse Gases, and US Oil Supply: Getting the Numbers Right	Self-Published	LCA	Oil sands petroleum
IHS CERA 2011	Oil Sands, Greenhouse Gases, and European Oil Supply: Getting the Numbers Right	Self-Published	LCA	Oil Sands Petroleum
Jacobs 2009	Life Cycle Assessment Comparison of North American and Imported Crudes	Self-Published	LCA	Petroleum
Jacobs 2012	EU Pathway Study: Life Cycle Assessment of Crude Oils in a European Context	Self-Published	LCA	Petroleum
JEC 2011	Well-to-wheels Analysis of Future Automotive Fuels and Powertrains in the European Context	Self-Published	LCA	All fossil fuels[2]
Liska and Perrin 2010	Securing Foreign Oil: A Case for Including Military Operations in the Climate Change Impact of Fuels	Environment Magazine	Source-Specific	Petroleum
NETL 2008	Development of Baseline Data and Analysis of Life Cycle Greenhouse Gas Emissions of Petroleum-Based Fuels	Self-Published	LCA	Petroleum

NETL 2009	An Evaluation of the Extraction, Transport and Refining of Imported Crude Oils and the Impact of Life Cycle Greenhouse Gas Emissions	Self-Published	LCA	Petroleum
Oil Change International 2008	A Climate of War	Self-Published	Source-Specific	Petroleum
Oil Change International 2013	Petroleum Coke: The Coal Hiding in the Tar Sands	Self-Published	Source-Specific	Oil sands petroleum
Rajagopal et al. 2011	Indirect Fuel Use Change (IFUC) and the Lifecycle Environmental Impact of Biofuel Policies	Energy Policy	Source-Specific	All fossil fuels[2]
Ryerson et al. 2011	Atmospheric Emissions from the Deepwater Horizon Spill Constrain Air Water Partitioning, Hydrocarbon Fate, and Leak Rate	Geophysical Research Letters	Source-Specific	Petroleum
(S&T)[2] Consultants	Biorefinery Conference 2012: Indirect Effects Petroleum	Presentation	Source-Specific	Petroleum
TIAX 2009	Comparison of North American and Imported Crude Oil Lifecycle GHG Emissions	Self-Published	LCA	Petroleum
Unnasch et al. 2009	Assessment of Direct and Indirect GHG Emissions Associated with Petroleum Fuels	Self-Published	LCA	Petroleum
Studies that discussed possible indirect emission sources qualitatively				
Brander et al. 2009	Consequential and Attributional Approaches to LCA: a Guide to Policy Makers with Specific Ref erence to Greenhouse Gas LCA of Biofuels	Ecometrica Press	LCA	All fossil fuels[2]
Copulos 2003	America's Achilles Heel: The Hidden Costs of Imported Oil	National Defense Council Foundation	Source-Specific	Petroleum
Delucchi 2011	Beyond Life-Cycle Analysis: Developing a Better Tool for Simulating Policy Impacts	UC Davis Institute for Transportation Studies	LCA	All fossil fuels[2]
ERA 2009	The Impact of Fossil Fuels: Greenhouse Gas Emissions, Environmental Consequences and Socio-economic Effects	Self-Published	Literature review	All fossil fuels[2]
ERA 2010	Substitution of biofuels for fossil fuels	Self-Published	Source-specific	All fossil fuels[2]
Rajagopal and Zilberman	On Market-Mediated Emissions and Regulations on Life Cycle Emissions	Working paper	LCA	All fossil fuels[2]
TIAX 2007	Full Fuel Cycle Assessment: Well to Tank Energy Inputs, Emissions, and Water Impacts	California Energy Commission	LCA	Petroleum
Yeh et al. 2012	National Low Carbon Fuel Standard: Policy Design Recommendations	Self-Published	(Neither)	All fossil fuels[2]

Notes: [1] The type of study distinguishes between LCAs and reports that focused on a specific indirect emissions source (i.e., source-specific studies). [2] "All fossil fuels" refers to applies to transportation fuels produced from crude oil, natural gas, and coal fuel sources, including both conventional and unconventional extraction methods.

For studies that included quantitative estimates of GHG emissions from possible indirect emission sources, we evaluated that data quality in terms of: the functional units used to express GHG emissions[8]; (ii) the representativeness of the study in terms of time horizon and geographic applicability; and (iii) whether the study had undergone a peer review or critical review[9]. Table 3-3 provides a summary of the quantitative sources and their characteristics.

Table 3-3: Overview of Quantitative Literature Addressing Indirect Emission Sources

Author and year	Functional unit(s) (if applicable)	Time horizon	Geographic applicability	Peer review*
AEA 2012	MJ of shale gas	Varies[10]	Europe; with U.S. studies	No, but includes peer-reviewed studies
Arvesen et al. 2011	N/A	N/A	Global	Yes
Brandt 2011	MJ of refined fuel, on a lower heating value basis	Varies[10]	Europe	Yes
CARB 2010	MJ of fuel	2002-2010	Global	No
CARB 2011	MJ of fuel	2000-2030	California	No
Chen and Khanna 2011	N/A	2007-2030	United States	Yes
IHS CERA 2010	barrel of refined product	2005-2030	United States	No[11]
IHS CERA 2011	barrel of refined product	2005-2030	Europe	No
Jacobs 2009	MJ of fuel	2000's	United States	No[12]
Jacobs 2012	MJ of fuel	2000's	Europe	No
JEC 2011	MJ of fuel	2015-2020	Europe	Yes
Liska and Perrin 2010	MJ of fuel	2003-2009	United States	Yes
NETL 2008	MMBtu LHV of fuel consumed	2005	United States	Yes

[8] The functional unit of a study was evaluated to ensure that qualitative estimates, where provided, were on a consistent basis with other estimates from the literature. For example, whether results were expressed in higher or lower heating values, or as per MJ of a finished fuel, such as gasoline, versus raw crude oil inputs.

[9] As per ISO 14044 requirements.

[10] Varies by the individual LCA studies included in the assessment; generally representative of current practices.

[11] A multi-stakeholder forum was held and several participants also reviewed a draft of the report; the report notes that participation in peer review does not reflect endorsement of the report.

[12] A stakeholder workshop was held and comments are provided in a separate report. Work was performed under a Technical Steering Committee and Stakeholder Committee.

Author and year	Functional unit(s) (if applicable)	Time horizon	Geographic applicability	Peer review*
NETL 2009	MMBtu LHV of fuel consumed	2005	United States	Yes
Oil Change International 2008	N/A	2003-2008	Iraq	No
Oil Change International 2013	N/A	Current conditions	Canada, United States	No
Rajagopal et al. 2011	N/A	2015-2030	Global	Yes
Ryerson et al. 2011	N/A	2010	U.S.	Yes
$(S\&T)^2$ Consultants	N/A	Not stated	Not stated	No
TIAX 2009	N/A	2007-2009	United States	No[13]
Unnasch et al. 2009	MJ of fuel	Not stated	Global	No

Notes: N/A = Not applicable or not provided by the study.
* Studies marked as “no” were not published in peer-reviewed articles and did not otherwise indicate that a peer review had been performed. Stakeholder workshops to present or share results were not considered peer reviews.

Based on the literature sources reviewed in Table 3-2 and Table 3-3 above and discussions with stakeholders, we developed a list of possible sources of indirect emissions along the fossil fuel life cycle. The sources are listed in Table 3-4. The following is a brief description of the possible indirect emission pathways; each potential indirect emission source is described in more detail and quantified in Section 5.

- **Induced Land Development:** This refers to land use change that is induced by, but not directly attributable to, fossil fuel extraction. For example, the construction of access roads for oil and gas extraction in remote areas may induce land use change for other purposes, such as logging or human settlements; oil and gas development or these induced activities may also trigger forest fires that emit GHGs. This is sometimes referred to as “ILUC” for fossil fuels. For the purposes of this report, we have used an alternative term to distinguish this emission source from ILUC caused by the cultivation of crops for biofuels, as the two effects are different: Biofuel ILUC is triggered by the displacement of agricultural activity, whereas induced land development is cause by adjacent developments that are facilitated by oil and gas production in remote areas.
- **Military Involvement:** Emissions from military activities and reconstruction efforts to protect and stabilise the supply of oil to global markets. This includes direct emissions from military vehicles utilised for war in oil-supplying countries and protecting supply routes, as well as the materials and energy used to construct military infrastructure and rebuild nations affected by war.

[13] A stakeholder workshop was held, and comments were provided in appendices G and H of that report. The report states that it has not undergone an independent technical review.

- **Accidents:** Emissions from accidents (e.g., oil spills) including emissions from the accident itself, emergency response, and clean-up or remediation efforts. These activities are unrelated to the process of extracting fossil fuel sources and lie outside of normal operation conditions. They are induced by the supply of fossil fuels globally and are therefore treated as an indirect emission source in this study.[14]
- **Marginal Impacts:** Changes in demand for fossil fuels will affect the marginal fossil fuel resource consumed, such as either increasing or reducing the demand for unconventional sources of fossil fuels based on global demand. Likewise, changes in demand can affect refinery operations, as well as influence the availability of fossil fuels for use in the electricity generation sector due to fuel switching. This source is influenced by prices in energy markets (e.g., crude oil supply and demand, the marginal cost of fossil fuel production), and relates to the incremental change in the type of fossil fuel extracted, produced and refined. We have distinguished these from market-mediated effects (discussed below), which relate to changes in overall end-use consumption of fossil transportation fuels.[15]
- **Market-Mediated Effects:** Changes in transportation fuel prices from increased use of alternatives to petroleum-based fuels will change the overall consumption of fuels in Europe and abroad. These effects are related to price-induced changes in the aggregate end-use consumption of refined fossil fuels or co-products. For example, this could cause a “rebound” effect wherein reduced demand lowers prices and increases consumption of those fuels. Likewise, changes in demand for fossil fuels will affect the supply of co-products (e.g., residual fuel oil, petroleum coke) to other markets (e.g., electricity generation). A specific market-mediated effect that was identified in stakeholder interviews is that the availability and relatively low price of fossil fuels affects personal transportation choices, potentially resulting in longer travel distances that increase fuel consumption and in turn, transportation emissions.

[14] An important exception for fossil fuel LCAs is fugitive emissions from sources such as sealings, well completions, and workovers (i.e., retrofitting a well), which constitute “engineered losses” that occur during normal operations; these are considered a direct emission source and are often included in LCAs.

[15] In a simplistic, first-order sense, the distinction can be thought of marginal effects largely influencing the GHG-intensity of the production of fossil fuels, whereas market-mediate effects largely influence overall GHG emissions through changes in overall consumption of transportation fuels.

Table 3-4: Summary of potential indirect emission sources

Source of GHG Emissions	Life Cycle Stage(s)	Applicable Fossil Fuel Type(s)	Literature References
Induced land development	Extraction	Fossil fuels extracted in remote, forested areas	Unnasch et al. 2009
Military involvement	Extraction	Conventional oil supplied through the Persian Gulf, extracted from Iraq, Libya, and other conflict or unstable areas	Copulos 2003; Unnasch et al. 2009; Liska and Perrin 2010; Oil Change International 2008
Accidents	Extraction	Fossil fuels[16]	Ryerson et al. 2011; TIAX 2007
Marginal impacts:			
on fossil fuel sources	Extraction	Crude oil-derived fuels, natural gas	CARB 2011
on operation of refineries	Processing	Crude oil-derived fuels	CARB 2011; JEC 2011; TIAX 2009
on electricity generation	Use/Combustion	Natural gas	CARB 2011
Market-mediated effects:			
Price effects: indirect fuel use change, rebound effects, urban sprawl	Use/Combustion	Fossil fuels[17]	Arvesen et al. 2011; Chen and Khanna 2011; Yeh et al. 2012; Rajagopal et al. 2011
Exports of co-products to other markets	Use/Combustion	Crude oil-derived fuels	Brandt 2011; Jacobs 2009; Lattanzio 2012; Oil Change International 2013; TIAX 2009

[16] "Fossil fuels" refers to transportation fuels produced from crude oil, natural gas, and coal fuel sources, including both conventional and unconventional extraction methods.

[17] "Fossil fuels" refers to transportation fuels produced from crude oil, natural gas, and coal fuel sources, including both conventional and unconventional extraction methods.

4. Task 2: Assessment of Definitions and Boundaries of Indirect Emissions Sources

To evaluate the possible sources of indirect emissions identified in Table 3-4, it is necessary to determine each source's relationship with the fossil fuel life cycle and establish criteria for assessing the appropriateness of including or excluding these sources in the fossil fuel life cycle boundary. This section first describes two different perspectives for evaluating emission sources: attributional and consequential. A consequential approach provides information about the consequences of changes in the level of output of a product, including effects both inside and outside the life cycle of the product. Second, this section evaluates how direct and indirect emissions sources are defined in the literature and, finding a high level of inconsistency in the use of these terms, establishes definitions of direct and indirect emissions that are consistent with the objectives of this report. Based on these definitions, the indirect emission sources are "mapped" onto the fossil fuel life cycle to establish the boundaries between direct and indirect emissions sources. Finally, this section identifies a series of "guideposts", or criteria, for evaluating the appropriateness of inclusion or exclusion of possible indirect emissions sources in the fossil fuel life cycle.

4.1. Defining Attributional and Consequential Approaches

LCAs can adopt two approaches for quantifying GHG emissions: attributional life cycle assessment (ALCA) or consequential life cycle assessment (CLCA) (JRC-IES 2012). An attributional approach focuses on emissions resulting from the processes used to produce the fuel, whereas a consequential approach quantifies emissions resulting from changes in the level of output of a fuel.

Brander et al. (2009) describes the difference between these attributional and consequential approaches as "ALCAs are generally based on stoichiometric relationships between inputs and outputs, and the results may be produced with known levels of accuracy and precision, [whereas] CLCAs are highly dependent upon economic models representing relationships between demand for inputs, prices, elasticities, supply, and market effects of co-products."

The conceptual differences in these approaches can be represented graphically, as shown in Figure 4-1:

- Attributional methods, represented by the circle on the left, specify the slice of total environmental burdens (i.e., GHG emissions) attributable to a given product system. Emissions in this case are represented by the slice of the overall circle, and are static, representing a "snapshot" of emissions attributed to a product system based on a certain technology at a given level of production.
- Consequential methods, represented by the circle on the right, specify how the burdens change as a result of a change or shock to the system. Emissions here are represented by the shaded area between the curves. They are dynamic and vary over time, changing in response to effects from other systems, changes in supply or demand, changes in technology or methods of production, or in response to policies or regulations.

A consequential analysis therefore may provide a more complete estimate of life cycle emissions for fossil fuels with regards to predicting the impact of policy changes on fossil fuel production.

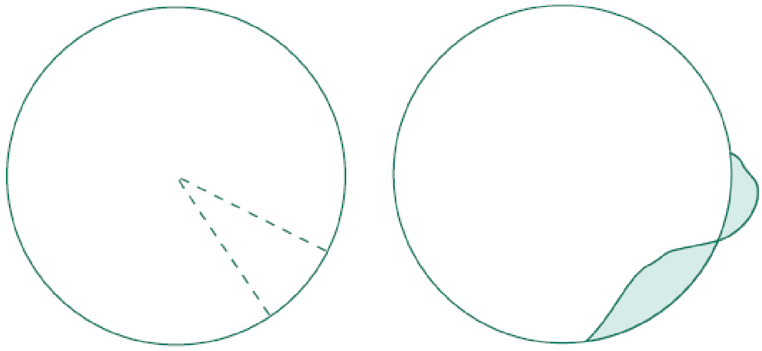

Figure 4-1: A graphical representation of attributional (left) and consequential (right) approaches (UNEP/SETAC 2011, citing Weidema 2003)

Attributional and consequential approaches are both relevant to the FQD. An attributional approach is used to determine the impacts of a specific product or system, but does not consider the indirect effects arising from changes in the output of a product. Thus, an attributional approach is necessary for evaluating GHG emissions attributable to the production, distribution, and consumption of specific transportation fuels in the FQD. A consequential LCA, on the other hand, assesses impacts on a macro-level, where decisions will have effects outside of a specific production system; a consequential approach factors into its analysis the economic and behavioural impacts of a policy's introduction and translates them into its impact assessment. Consequently, a consequential approach may be an appropriate perspective for examining how the FQD may affect GHG emissions in other systems and markets.

4.2. Defining Direct and Indirect Emissions Sources

The existing body of life cycle literature does not apply uniform definitions to direct and indirect emission sources. In fact, we found there was no consensus in the literature or among stakeholders about which fossil fuel emissions sources constituted "direct" or "indirect" sources. Many studies did not explicitly define direct or indirect emission sources. Of those that specifically addressed "indirect" emissions from fossil fuels, however, studies treated indirect emissions in three different ways as follows[18]:

1. Studies considered upstream extraction, transportation, and production of fossil fuels to be "indirect" emission sources; emissions from final combustion of fossil fuels were considered "direct" emission sources. Examples include: Santoro et al. (2011), Howarth et al. (2011), Ecofys (2012), Bergerson et al. (2012), AEA (2012).
2. Studies defined indirect emissions as those occurring from sources that are not directly related to the fossil fuel life cycle (i.e., extraction, processing, distribution, and combustion of fossil fuels), but which are induced by the use of fossil fuels, either by economic, geopolitical, or behavioural factors. Examples include: Unnasch et al. (2009), Rajagopal et al. (2011), Yeh et al. (2012),

[18] Not all of the studies explicitly defined indirect or direct emissinos sources; where definitions were not provided, they were inferred from the treatment of emissions sources within the life cycle boundaries of the study. These three distinctions encompass all of the studies reviewed.

3. CARB's Subgroup on Indirect Effects of Other Fuels focused on indirect emissions sources relevant to fossil fuels and defined direct and indirect emissions in the following three categories (CARB 2011):
    a. Direct effects are all significant effects within the primary production chain or life cycle (cradle to grave);
    b. Co-product effects are significant effects caused by co-products from the production chain, and
    c. Indirect effects are other market-mediated effects caused by changes in economic markets (e.g., induced land development, or changes affecting marginal electricity or fossil fuel supply).

These definitions are represented graphically in Figure 4-2, with definitions i, ii, and iii corresponding to definitions 1, 2, and 3 described above.

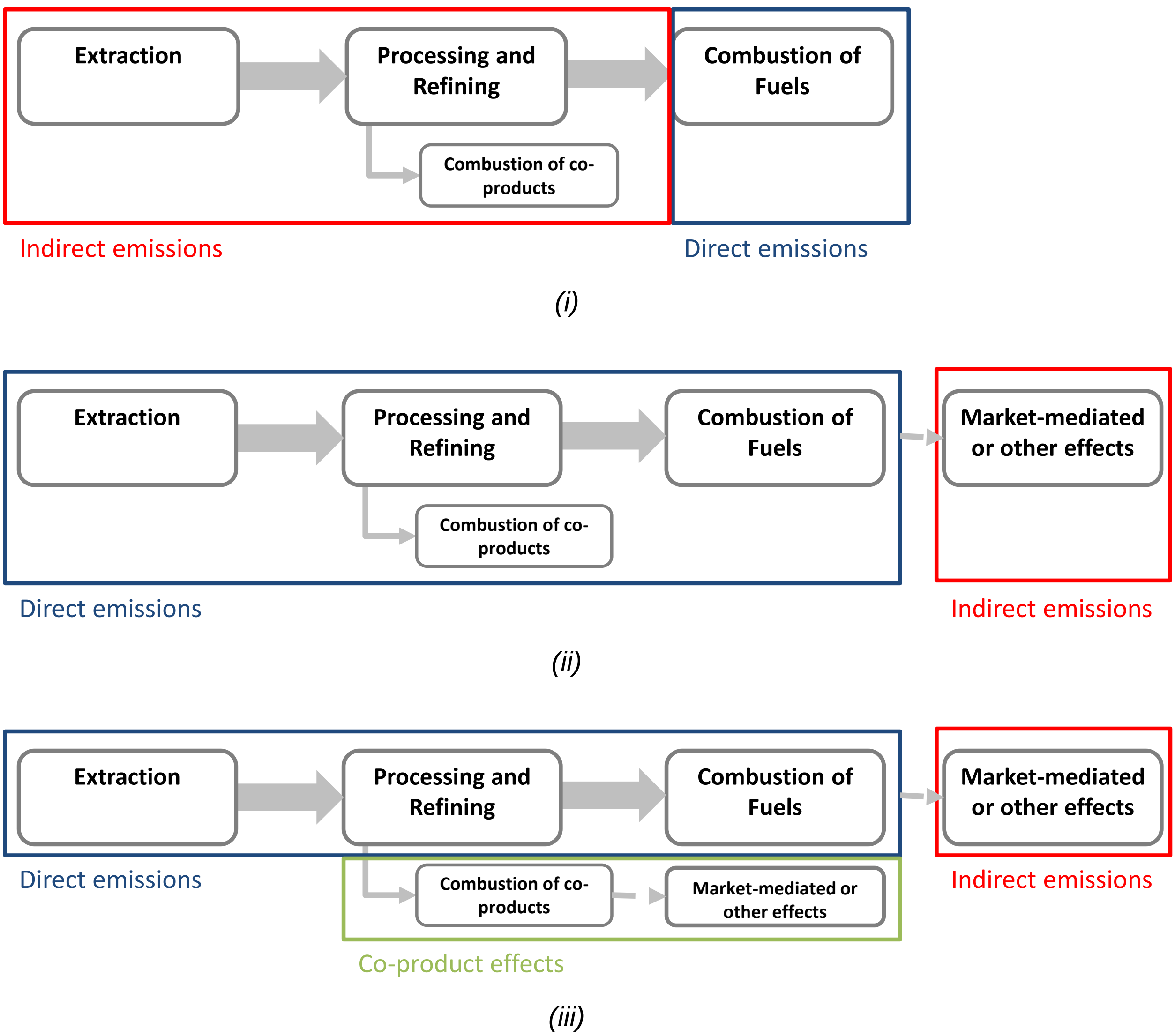

Figure 4-2: Definitions of direct and indirect emission sources along the fossil fuel life cycle: (i) treats fuel combustion emissions as direct, and upstream stages as indirect; (ii) treats all emissions along the fuel cycle as direct, and effects from market-mediated or other responses as indirect; (iii) represents the definition developed by CARB (2011), which defined co-product effects separately from indirect emissions.

The second and third definitions of indirect emissions are the most relevant to the emissions sources that are the focus of this report. To resolve these different interpretations among studies and highlight the specific indirect emissions relevant to this study, we classified emission sources along the fossil fuel life cycle in three categories:

- **Direct emissions** are emissions from processes or materials that directly relate to the extraction, processing, and combustion of fuels at any point along the fossil fuel life cycle. Direct fuel production impacts typically include emissions from the upstream production of fuels used during production, refinery emissions, venting and flaring, fugitive leaks, local induced land development, and other emissions that can be directly attributed to steps needed to produce the primary fuel considered. For the purposes of this report, we consider emissions from the production and combustion of co-products as direct emissions associated with the fossil fuel cycle.

- **Inconsistently-characterised direct emissions** are emission sources that are frequently excluded or inconsistently evaluated in the literature due to data gaps, high levels of uncertainty in emission estimates, or disagreement in appropriate categorisation or impact assessment methods for evaluating these emissions sources.
- **Indirect emissions** are emissions that are not directly related to the extraction, processing, distribution, or combustion of fossil fuels, but which are influenced or induced by economic, geopolitical, or behavioural factors related to fossil fuel use and changes in their supply or demand. Indirect impacts include emissions that are beyond the production system of the primary fuel considered, including the effects of exporting co-products from fuel refining to other markets and other market-mediated effects.

The purpose of distinguishing *inconsistently-characterised* direct emission sources is to clearly delineate the full range of direct emission sources from indirect emission sources—as defined in this report—as there is sometimes some confusion between the two. For example, direct emissions from oil well flaring are commonly mis-characterised as an “indirect” source due to the wide variation in emissions, resulting both from different crude oil sources as well as differences in methods of calculating or estimating emissions. Venting and flaring emissions are treated as direct emissions sources in NETL (2008, 2009), Jacobs (2009, 2012), and TIAX (2009). Similarly, direct emissions from deforestation caused by building an oil well pad or other extraction sites and facilities are often conflated with indirect emissions from land clearing for purposes unrelated to oil extraction that are facilitated by oil industry expansion into remote areas.

Defining Direct and Indirect Emissions in Terms of Attributional and Consequential Perspectives

Indirect emissions are not exclusively consequential, and direct emissions are not exclusively attributional: indirect emissions can, for example, be included in attributional LCAs through system expansion, where the LCA boundary is expanded to include the effects that the fuel cycle may have on other markets or sectors.[19] However, as the consequential LCAs include effects outside of the attributional LCA, indirect emissions are more likely to be factored into a consequential analysis. For example, some of the possible indirect emissions sources identified in Task 1 (e.g., marginal impacts on fossil fuel production, refineries, and electricity) are predominantly effects that can only be evaluated through a consequential perspective: i.e., by looking at the consequences of a policy, shock, or change imposed on the fuel life cycle. Other sources, such as emissions from military activities may also be understood as attributional emissions.

The distinguishing characteristic of consequential effects is that they occur in response to changes imposed on the system (e.g., changes in supply, demand, technology, laws and regulations) and relate to changes in production rather than the production of a given product itself. This includes all processes and material flows which are directly or indirectly

[19] System expansion in attributional LCAs is commonly applied to co-products that are produced alongside the main (desired) product (e.g., lower-value refinery products such as sulfur, petroleum coke, asphaltenes, etc.). These co-products displace the production and use of other products that would have otherwise been produced by another means. This indirect effect can be included in an attributional perspective by expanding the system boundary to include the production and end-use of co-products and applying a substitution credit for the products that they offset in the marketplace.

affected by a change in the output of a product (e.g., through market effects, substitution, use of constrained resources, etc.). Table 4-1 provides a summary of how attributional and consequential perspectives apply to the possible sources of indirect emission sources identified in Section 3.

Table 4-1: Attributional and consequential perspectives of possible indirect emission sources

Source of GHG Emissions	Applicability of Attributional and Consequential Perspectives for Assessing GHG Emissions
Induced land development	An attributional perspective would involve land use impacts from a specific production site or operation; a consequential perspective would investigate how changes in the consumption of fossil fuels would impact land use change by inducing land development in other sectors.
Military involvement	Attributional and consequential; for example, Liska and Perrin (2010) develop both attributional and consequential estimates of GHG emissions from military involvement.
Accidents	An attributional perspective would involve emissions from accidents based on current levels of fossil fuel consumption; a consequential perspective would involve the change in emissions from accidents given a change in fossil fuel consumption.
Marginal effects on: fossil fuel sources, operation of refineries, and on electricity generation	These effects result from changes in the consumption of fossil fuels; as a result, they are a consequential source and would not be captured in an attributional perspective.
Market-mediated effects: price effects and exports of co-products to other markets	These effects result from market responses to changes in the production of fossil fuels; as a result, they are consequential and would not be captured in a strictly attributional perspective.

The methodologies for attributional and consequential LCA are distinct and separate, but in the case of biofuels, they are added together to capture significant indirect emissions such as ILUC. ILUC emissions are consequential in that they are triggered by expansion of demand for agricultural land in response to increased biofuel production. Including ILUC emissions in the life cycle essentially accounts for the displacement of food crops by biofuel development and that land use may change. ILUC GHG emissions represent one-off emissions from the conversion of land, and they can be evaluated as a shock to the system over a specified timeframe. These factors have enabled ILUC—essentially an indirect, consequential source—to be evaluated alongside attributional biofuel emissions factors, although great care is required to avoid double-counting and ensure assessments are made consistently.

4.3. Mapping Possible Indirect Emissions Sources to the Fossil Fuel Life Cycle

Based on the above definitions of direct and indirect emission sources, and of attributional and consequential emissions, Figure 4-3 shows these emission sources mapped onto the fossil fuel life cycle. The diagram distinguishes between direct emissions that are well-characterised in LCA studies, direct emissions that are inconsistently-characterised, and possible sources of indirect emissions.

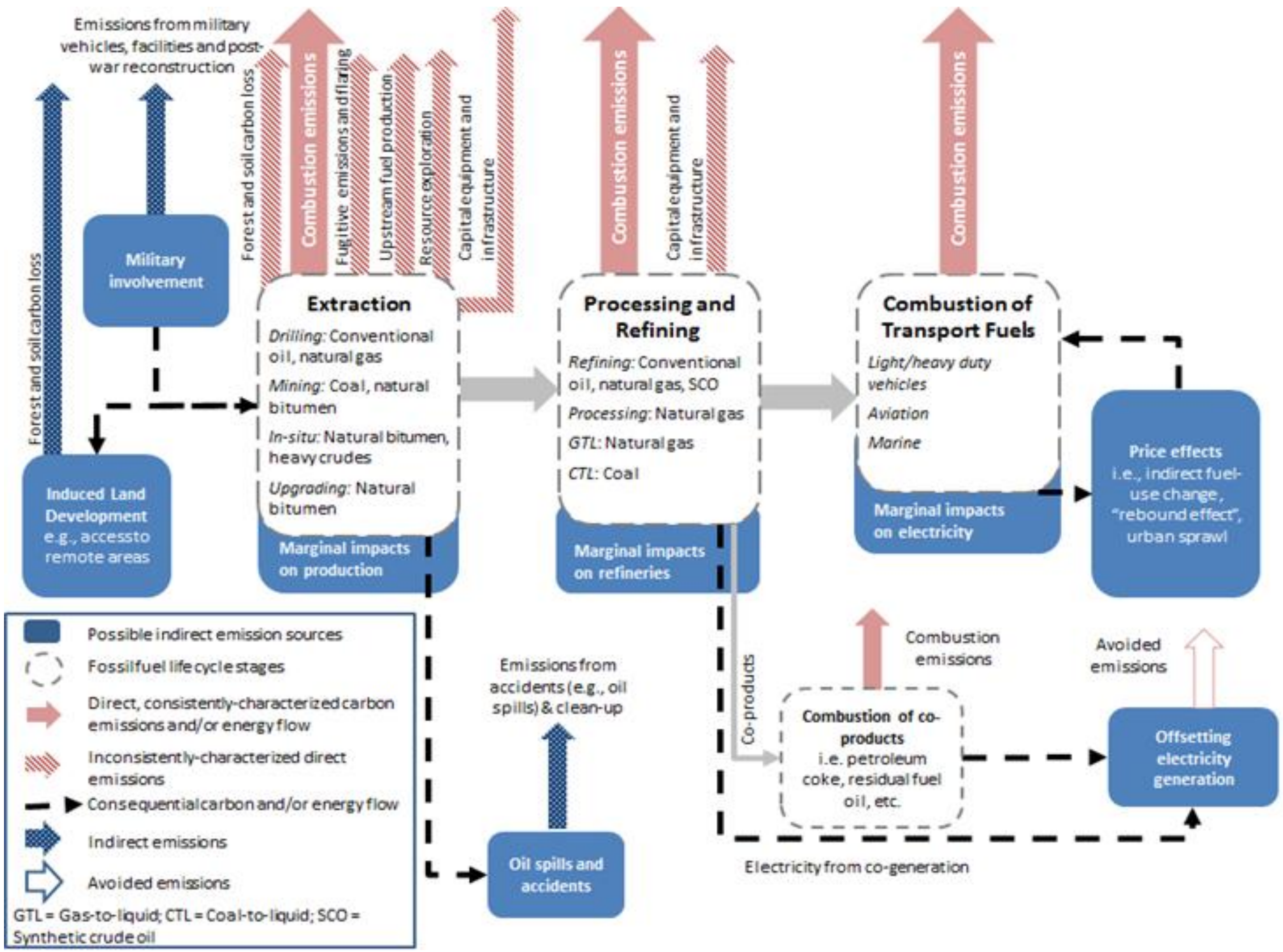

Figure 4-3: Fossil fuel life cycle with indirect emission sources shown alongside direct emission sources that are generally well-characterised in life cycle studies, and direct emissions that are inconsistently-characterised

4.4. Criteria for Establishing Boundaries for Indirect Emission Sources

Indirect emissions sources are particularly challenging to account for in life cycle approaches—these sources lie on the periphery of LCA state of the art and there is a lack of established methodologies and guidance for accounting for them. Due to the lack of standardisation within the scientific literature reviewed, evaluation of indirect sources requires “judgment calls” to be made by the life cycle practitioner.

In making these judgment calls, however, there are “guideposts” that can be used to guide decisions, ensure consistency in the analysis, and defend modelling choices and assumptions. These include the following:

- Consistency of established boundaries with accepted life cycle principles and guidance, primarily the ISO 14040 family of standards related to LCA;
- Consistency of established boundaries with the overall goal and scope of the FQD;
- The degree of consensus in the literature on the indirect emission source pathway, and the indirect impact of emissions to the fossil fuel life cycle;
- Treatment of the source in other high-quality and peer-reviewed LCA studies; and
- The quantification of the magnitude of the effect and whether it would make a material difference on GHG emissions from fossil fuels relative to other fuels, or on emissions within and outside of the European Union.

In Section 5, we have applied these criteria to each of the indirect emissions sources in Table 3-4.

5. Task 3: Estimation of the range of indirect emission estimates and uncertainties and evaluation of appropriateness of including or excluding indirect emissions sources

5.1. Induced land development

Description

GHG emissions result from the disturbance in land, such as clearing vegetation, removing the top soil to prepare the land, and also lost CO_2 sequestration potential resulting from removal of vegetation. Emissions from land use changes due to fossil fuel production, transport, and refining are considered direct land development[20], whereas the land-use changes that are induced by development or extraction of fossil fuel sources are indirect. The latter are distinct from biofuel ILUC—which applies to biofuels—and as these indirect effects are for fossil fuels, we refer to this type of land use change as induced land development (EC 2012a).

ILUC for biofuels has been examined in several studies (Searchinger 2008, Fargione 2008, DG ENERGY 2011) and this relates to releasing more carbon emissions due to land-use changes across the world due to displacement of croplands by the expansion of cultivation of crops for ethanol or biodiesel production. The mechanism of ILUC, as it relates to biofuels, does not apply to fossil fuels: instead, indirect GHG emissions arise from land development that is induced by fossil fuel development, such as road building in forested areas that encourages other forms of development (Unnasch et al. 2009). This fossil fuel induced land development can include additional deforestation or other land use changes following initial road construction from subsequent activities such farming or logging. The mechanism of induced land development from fossil fuel production is shown in Figure 5-1.

Several LCAs for fossil fuels have included direct LUC for surface mining of oil sands (Jordaan et al. 2009, Yeh et al. 2010, Brandt et al. 2011, Jacobs 2012):

- Jordaan et al. (2009) investigated "direct" and "peripheral" land disturbance in Canadian oil sands developments. The authors did not develop GHG emission estimates, but focused on the area of land disturbed. They defined "direct" disturbance as land directly affected by oil sands developments, and "peripheral" disturbance as land affected by fragmentation and the upstream production of natural gas used at oil sands development. The study found that total land disturbance for *in situ* technologies (that involve a small direct footprint) were comparable to surface mining (which involves a large direct footprint) when considering land disturbance from fragmentation and natural gas production.
- Yeh et al. (2010) acknowledged that GHG emissions from land use were poorly quantified for oil and gas production. The authors developed estimates of GHG

[20] See, for example, Jordaan et al. (2009), which classified "direct" land disturbance as the area directly affected by oil sand developments.

emissions from direct land use change for fossil fuels for oil wells in California, Alberta, and the Canadian oil sands. The study found that the net contribution of direct land use change to life-cycle GHG emissions from crude oil development ranges from less than 0.4 to 4 percent of WTW life-cycle GHG emissions over a 150-year modelling period.

- Brandt et al. (2011) describes direct land use change emissions as resulting from land clearing, soil disturbance, and peat disturbance. Jacobs (2012) included direct land use GHG emissions from oil sands mining, resulting from the removal of top soil during preparation of land for bitumen mining and upgrading, fugitive emissions from the mine face and tailings ponds, and loss of potential CO_2 sequestration due to deforestation.[21]

As the level of information available on direct land use changes from fossil fuel developments has improved, LCA studies have been able to include direct land use change in their analysis. For example Jacobs (2012) incorporates direct land use change estimates from Yeh et al. (2010). However—apart from one study by Unnasch et al. (2009), which is described below—none of the studies reviewed for this report specifically quantified the impact of fossil fuel induced land development.

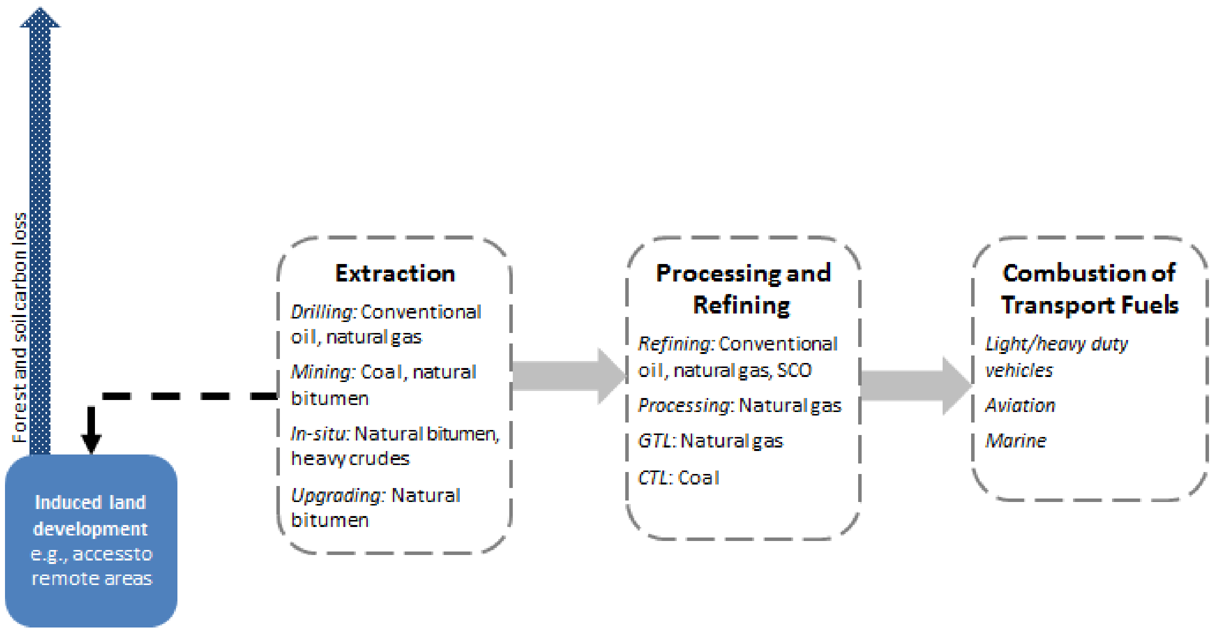

Figure 5-1: Placement of Induced Land Development within Fossil Fuel Life Cycle

Treatment of this source in studies that support the FQD and fossil fuel LCAs

Although emissions from ILUC from biofuels are not part of the current FQD, they are under consideration for potential inclusion (see Section 1). Studies supporting the FQD and the proposed emission intensities of fossil fuels for the FQD Article 7a do not include induced land development for fossil fuels. As explained above, recent LCAs have begun to

[21] Using estimates from Yeh et al. (2010). See Jacobs (2012), p. ES-8.

incorporate direct LUC GHG emissions from fossil fuels, but—apart from Unnasch et al. (2009)—none of the fossil fuel LCAs in the literature review included induced land development emissions from fossil fuels. For example, Jacobs (2009, p. 5; 2012, p. 4-18) noted that land use GHG emissions from other sources, such as resource exploration, the building of infrastructure and facilities, manufacturing and disposal of heavy equipment were beyond the scope of the analysis. Apart from Unnasch et al. (2009), the identified studies merely discuss the indirect GHG emissions on a qualitative basis and not as a quantitative value of lifecycle GHG intensity in gCO2e/MJ of fuel product. In addition, this source was not included in the boundaries of the other high-quality LCA studies included in our review, shown in Table 3-3.

Quantitative estimates of this source and uncertainty

Examining the magnitude of induced land development related to fossil fuel production is a relatively recent concept that has come under consideration because of the focus on ILUC emissions from the production and consumption of biofuels. Although both relate to indirect emissions from land use changes, the mechanism by which induced land development occurs is different from biofuel ILUC. The amount of land used in the production of fossil fuels is a very small fraction of the land used to produce biofuels, and as a consequence, issues related to displacement of other land uses do not apply to fossil fuel production, and the overall magnitude of affected land and corresponding GHG emissions are substantially less than ILUC from biofuels.

It is difficult to quantify the emissions from fossil fuel induced land development because we located scant information on the magnitude of induced development that occurs related to oil and gas production around the world. It is also difficult to isolate induced development that is related specifically to oil and gas production in remote areas relative to other drivers of land use change and development.

Unnasch et al. (2009) illustrate that GHG emissions related to direct land use impacts are of a small magnitude when compared to the total fuel production. Several activities are taken into consideration in this report, one being deforestation following road construction. Constructing new roads causes minimal direct land use emissions[22], but this activity may promote further, indirect GHG emissions by providing access to previously inaccessible land for other uses. Different types of fossil fuels result in varying degrees of land disturbance depending on the type and location of land involved in the production of the fuel. Additionally, with regards to the drivers behind induced land development, factors including but not limited to social changes, demographic shifts, political unrest, and economic incentives should be examined. Unnasch et al. (2009), developed an estimate for subsequent deforestation following road building for a case study in Ecuador, and the GHG emissions intensity from induced land development were estimated in this case to be between 0.6 and 1.0 gCO_2e/MJ.

There is significant uncertainty in the assumptions of this case study and the authors noted that they could not find comparable analyses for other regions.

[22] The EU Transport GHG: Routes to 2050 II project found that land use change emissions from road construction contributed to a small fraction—between 0.06 and 6.56 percent—of GHG emissions from road and rail construction, and to 0.01 to 0.83 percent of total life-cycle transportation GHG emissions (Hill et al. 2011, p. 73-76).

Unnasch et al. (2009, p. 60) conclude that oil production activities in tropical forests may result in emissions that are over 0.5 gCO_2/MJ. The emissions from induced land development from fossil fuels are therefore much smaller than ILUC from biofuels; this estimate is 1/24th to 1/110th of the estimated ILUC from biofuel feedstocks in the Comissions's proposed directive on ILUC emissions for biofuels (EC 2012b). As explained above, these two types of land use change involve different mechanisms (displacement of agricultural activity for biofuels vs. adjacent development for fossil fuel production) and consequently trigger emissions on entirely different scales of magnitude. Unnasch et al. (2009) recommend that these effects be further examined, although many of the behavioural factors related to induced land development do not lend themselves to straightforward calculation.

Degree of consensus over whether indirect emissions can be allocated to the fossil fuel life cycle

The studies discuss the importance of including the impact of fossil fuel induced land development when completing the life cycle analysis for fuels. However, lack of available quantifiable data and no consensus on whether the global emissions will decrease or increase as a result of the induced land development implies that this emission source cannot be allocated to the fossil fuel life cycle.

Limitations in evaluating the emissions source

Thus far few quantitative arguments around the emissions from fossil fuel induced land development have been provided; further investigation in this area is necessary to support quantification of this emissions source. Each policy may have a different impact of European and global fuel demand and supply and fossil fuel induced land development.

A key uncertainty is the extent to which oil development contributes to subsequent deforestation by logging and agricultural activities. Unnasch et al. (2009), cite Wunder (1997), who acknowledges the following:

> *It is generally recognized that oil activities 'opened up' new agricultural frontiers in the Northern Amazon region by building penetration roads into primary forest areas. […] However, about 60% of the population in the Ecuadorean Amazon region's active population works in agriculture. In principle, one could therefore question the additional deforestation impact of the oil boom: Maybe road construction directed settlers to specific areas, but in counterfactual terms, the same amount of deforestation might have occurred elsewhere, even without oil production.*

Consistency of the indirect emissions source with the goal and scope of the FQD

In our expert opinion, the level of information available on GHG emissions from induced land development issues from fossil fuels is currently too speculative and difficult to quantify to include in the scope of the FQD for the following reasons:

- First, there are currently no widely acceptable models that have estimated the GHG emissions of induced land development from fossil fuel production. The sole quantitative estimate for this indirect emission source is based on assumptions developed by Unnasch et al. (2009) to derive an order-of-magnitude estimate.

- Second, the current information available on GHG emissions from induced land development from fossil fuels suggests that this emission source is a relatively small contributor that is largely limited to tropical areas where deforestation is an issue. The magnitude of the estimate depends on an assumption of the extent to which oil and gas development in an area triggers other indirect deforestation activities.
- Third, while it is conceivable that a model could be developed to estimate induced land development from fossil fuel production, its usefulness is questionable as unlike biofuels where the ILUC analyses are focused on the food supply system, induced land development for fossil fuels would cross many economic sectors. Deforestation or other land use changes after road building may include activities such as logging, farming, ranching, housing, and it would be difficult to determine which of these activities is attributable to the road built for fossil fuel production, and which happened for other economic reasons.

5.2. Military involvement

Description

Military activities that provide security and stability to oil-producing regions and to protect international oil supply routes may constitute a potential source of indirect GHG emissions from the fossil fuel life cycle. To the extent that military interventions in oil-producing regions have been motivated by efforts to secure petroleum reserves, it can be argued that a portion of GHG emissions from these activities results from demand for fossil fuels in countries without sufficient domestic supplies. GHG emissions from military involvement include emissions from fossil fuels combusted by military vehicles utilized for conflicts or security in oil-producing regions and along supply routes, as well as the materials and energy used to construct military infrastructure and rebuild nations affected by conflict (Liska and Perrin 2010, Unnasch et al. 2009). The relationship between military involvement and the fossil fuel life cycle is illustrated in Figure 5-2

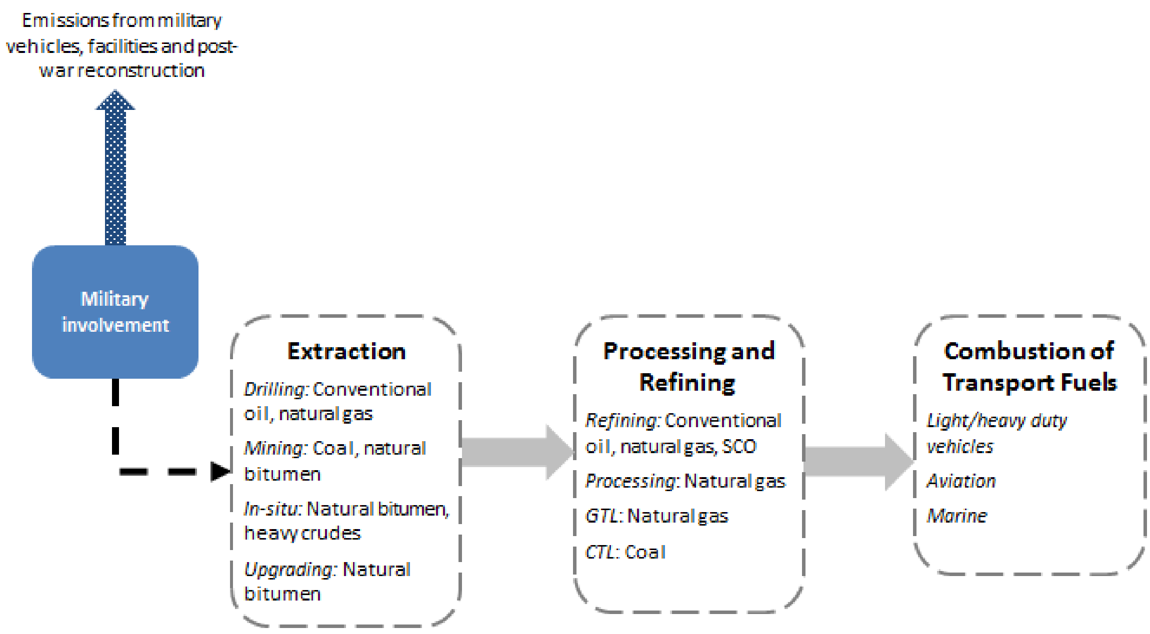

Figure 5-2: Placement of Military Involvement within Fossil Fuel Life Cycle

Studies that have evaluated this indirect emission source classify GHG emissions from military activities into two categories;

- "Security-related" GHG emissions, which result from a long-term, sustained military presence in a geographic area.
- "Conflict-related" operations. Modern wars are large-scale industrial undertakings that require large amounts of fossil fuels and materials to wage. In the Persian Gulf War, oil fires were a significant source of GHG emissions. Post-conflict, GHG emissions result from material-intensive rebuilding of war-torn regions. Finally, the reliance on petroleum may be a factor in continued unrest and military intervention in oil-producing regions.

Since these activities have different relationships with access to fossil fuel resources, these emissions are allocated separately. Assessments of military involvement and the security of supply routes are typically allocated per unit of petroleum (e.g., grams of CO_2e per unit of energy supplied by fossil transportation fuels) whereas military intervention in Iraq and other conflict-related emissions are evaluated as a sum total (e.g., million tons of CO_2e) due to the one-time nature of the events and the uncertainty associated with allocating unique events in a life cycle.

Treatment of this source in studies that support the FQD and fossil fuel LCAs

Indirect emissions from military involvement were not cited in the studies that support the FQD. For example, in the JEC's well-to-wheel analysis of future automotive fuels in the European context, military involvement is not factored into the study's assessment of the extraction or transport stages for crude oil. Similarly, Brandt et al. (2011) does not discuss military involvement in its LCA of unconventional oil sources.

There are, however, several studies that have suggested that GHG emissions from military activities should be included in fossil fuel LCAs, and have attempted to quantify these emissions (Liska and Perrin 2010, Unnasch et al. 2009). Liska and Perrin (2009) is not a full, well-to-wheel LCAs of fossil fuels; instead, it focuses solely on evaluating GHG emissions from military activities. , Unnasch et al. (2009) developed estimates and included these in well-to-wheel results for different fossil fuel sources to show their relative impact as a share of total life cycle emissions.

Studies that have included military-related emissions have evaluated this source from both attributional and consequential perspectives (Liska and Perrin 2010). These studies argue that military activities are an essential component of ensuring fossil fuel supply, which justifies its inclusion within the LCA boundaries. They argue that, to the degree that ILUC is an expected behavioural outcome of biofuel production, military emissions may be considered a behavioural outcome for fossil fuel production in the same manner.

Quantitative estimates of this source and uncertainty

Security and Protection of Supply Routes

Several studies have attempted to quantify the GHG emissions from foreign countries' heavy military presence and conflicts in the Persian Gulf (comprising Bahrain, Iran, Iraq, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates), which holds the world's largest proven reserves of petroleum (see Figure 5-3).

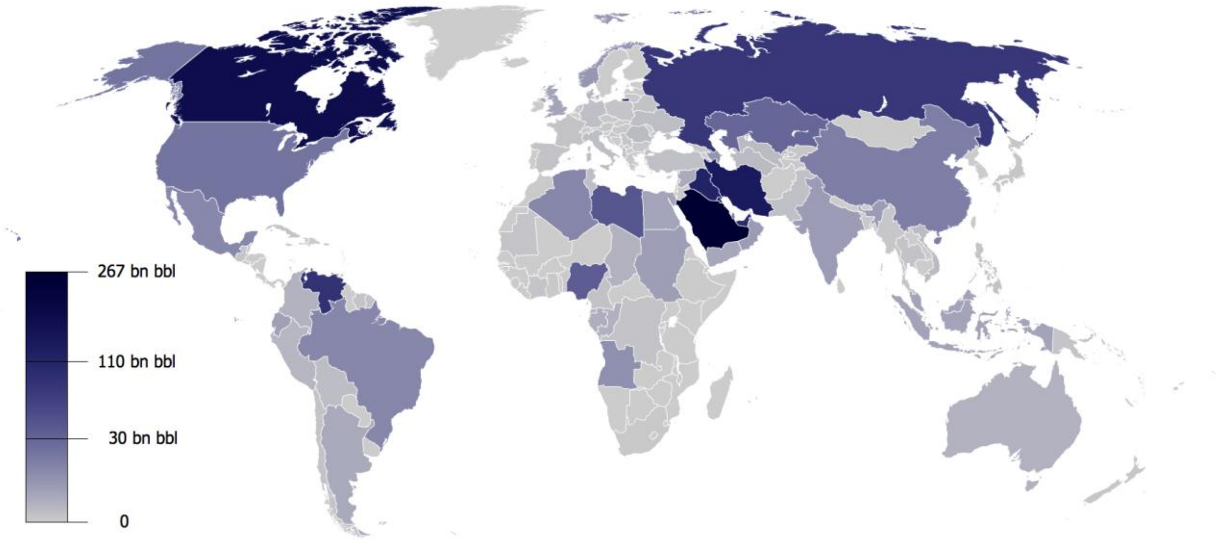

Figure 5-3: Global Distribution of Proven Reserves of Petroleum, 2009

Note: "Proven reserves" refer to petroleum that is highly likely to be recoverable using existing technology under current economic and political conditions.

Source: CIA World Factbook 2009

Liska and Perrin (2010) argue that the United States' military presence in the Middle East generates significant and quantifiable GHG emissions. The U.S. military is responsible for protecting global maritime supply routes for the shipment of petroleum, with a focus on the Persian Gulf region. Liska and Perrin (2010) draw a parallel between the necessity of mechanical combines in the production of biofuels and the necessity of military warships to assure the supply of petroleum. Furthermore, the authors argue that the risk of impacts on the world's economy from supply disruptions motivates the United States to maintain presence in the Gulf to ensure security in the region.

Liska and Perrin calculated the military emissions component of the fossil fuel life cycle by first estimating the share of U.S. military spending devoted to protecting oil supply (estimated to be approximately 20% of a $589 billion USD in 2009) and then scaling that by an emission factor that quantified GHG emissions per unit of U.S. Department of Defence (DoD) spending (approximately 0.289 MMT CO_2e per billion USD)—resulting in a total of 34.4 MMT CO_2e from oil-related military involvement emissions[23]. After accounting for the share of the total exported petroleum volume processed into gasoline (46.1%), the study allocated 8.1 g CO_2e/MJ of gasoline imported from the Persian Gulf (see Table 5-1).

This does not consider the use of other fuels than gasoline, nor global use of transport fuels in the rest of the world outside of the United States. Although Liska and Perrin (2010) do not calculate this result, allocating these GHG emissions across global liquid petroleum consumption would reduce the amount of emissions allocated to these fuels. For example, in a separate calculation, ICF allocated the same annual GHG emissions from U.S. military activities estimated by Liska and Perrin (2010) to global exports of crude oil and condensates from the Persian Gulf in 2010[24] (EIA 2013). We calculate that this decreases emissions intensity by 86% to 1.0 gCO_2e/MJ in the attributional perspective. Table 5-1 provides an overview of the data used to estimate the military GHG emissions for U.S. gasoline and global petroleum consumed globally in 2010.

[23] This emission factor, refered to as an "implied" emission factor for DoD spending, was calculated by summing the petroleum, electricity, natural gas emissions of the DoD and adding it to the upstream emissions associated with the agency's acquisitions and infrastructure, and then dividing it by the agency's 2009 spending.

[24] Taken as 84,759 thousand barrels per day from EIA (2013).

Table 5-1: Attributional GHG Emissions Estimates for Military Involvement in the Persian Gulf

	Units	GHG Emissions Allocated to U.S. Imports from Persian Gulf (Liska and Perrin 2010)	GHG Emissions Allocated to Global Exports from Persian Gulf (estimate by ICF)	% Reduction in GHG Emissions When Allocating to Global Exports
Fuel to which GHG Emissions are Allocated	--	Gasoline derived from crude oil exported from Persian Gulf to U.S.	Global Persian Gulf exports of crude oil and condensate	--
Annual Oil Security-Related Emissions (A)	million $MtCO_2e/yr$	34.4	34.4	--
Fraction of Emissions Allocated to Fuel (B)	%	46.1% [a]	100%	--
Amount of Fuel (C) [b]	Billion litres/yr	58	920	--
GHG Emissions (= A * B / C [c])	gCO_2e/L	262	37.4	
	gCO_2e/MJ[d]	8.1	1.0	86%

Source: Adapted from Liska and Perrin 2010 and ICF estimates.
[a] Based on the volume of gasoline produced from a barrel of crude oil (Liska and Perrin 2010).
[b] Target fuel consumption is based on Liska and Perrin (2010) for the U.S. perspective, and EIA (2013) for global petroleum consumption.
[c] GHG emissions calculated by multiplying U.S. annual oil security emissions by the fraction of emissions allocated to each fuel and dividing by the target fuel consumption, with appropriate unit conversions.
[d] Converted based on a Higher-Heating Value (HHV) of 32.2 MJ/L for gasoline, and 38.5 MJ/L for petroleum (Iowa State University Extension and Outreach 2007).

A 2009 study by Unnasch et al. also quantifies emissions associated with protection of petroleum supply routes through the Persian Gulf, but its approach differs from Liska and Perrin by using the emissions associated with the Iraq War as a proxy for protection. The study draws heavily on the findings from Oil Change International (2008). Unnasch et al. (2009) allocated the war's total emissions to the sum of all transport fuels made from petroleum imported to the United States from the Persian Gulf between 2003 and 2007 (2.89 billion barrels of oil). This time period was chosen arbitrarily as the period from the start of the Iraq War to the publication of the study (Oil Change International 2008).

Using this approach, the additional emissions from military activity in this scenario were found to be 6.0 g CO_2e/MJ of transport fuel exported from the Persian Gulf .If allocated to the 28.3 billion barrels of petroleum exported from the Persian Gulf during the same time period, the magnitude of the military involvement emissions decreases to 0.8 g CO2e/MJ of petroleum[25] (see Table 5-2).

Unnasch et al. (2009) also used an alternative method to estimate military involvement emissions by scaling the sum of total fuel consumed by the U.S. military between 2001 and 2006 assuming that half of it was used for securing petroleum and protecting supply routes

[25] Liska and Perrin (2010) did not calculate this result. We took the author's value for total war-related emissions (141 $MMTCO_2e$), divided by the total volume of Persian Gulf exports between 2003 and 2007 (28.27 billion barrels, according to EIA 2013), and applied the necessary conversions, assuming 159 liters per barrel and a petroleum energy content of 38.5 MJ/L.

(an assertion made by Copulos 2003). Assuming that the average carbon intensity of military fuel consumption is 95 g CO_2e/MJ, and if these emissions were allocated to only transport fuels made from petroleum exported from the Persian Gulf, Unnasch et al. (2009) estimated that the GHG emissions from military activities would be 7.1 g CO_2e/MJ of transport fuel. If allocated to the 32.35 billion barrels of petroleum exported from the Persian Gulf to global markets during the same time period, the military involvement emissions associated with Persian Gulf crude decrease by 84% to 1.1 g CO2e/MJ of petroleum (see Table 5-2).

Table 5-2: GHG Emission Estimates for Military Involvement

Method of Estimating Indirect GHG Emissions from Military Activities	Units	GHG Emissions Allocated to Persian Gulf-Derived Transport Fuels Consumed in the United States (Unnasch et al. 2009)	GHG Emissions Allocated t to All Exported Persian Gulf Petroleum Consumed Globally (estimate by ICF)	% Reduction in GHG Emissions When Allocating to Global Exports
Method 1: Using Iraq War as a Proxy	g CO_2e/MJ	6.0	0.8	86%
Method 2: Military Fuel Use Emissions	g CO_2e/MJ	7.1	1.1	84%

Source: Adapted from Unnasch et al., 2009 and ICF estimates

Conflict-Related Emissions

Liska and Perrin (2010) argue that the Iraq War was motivated primarily by a desire to ensure access to Iraqi oil. The authors allocate the emissions from the war using an attributional approach. The authors calculated the war's emissions by multiplying an implied emission factor (0.289 MMT CO_2e/ billion USD) for the DoD's annual spending on the war from 2005-2009, and then adding that value to the sum of indirect emissions from the conflict, including supply chain fuel, troop deployment, cement production, and flaring. These emissions were then divided by the gasoline produced from the average annual oil imports from the Persian Gulf from 2005-2009 to calculate the war-related emissions allocated directly to that gasoline. Liska and Perrin (2010) do not justify the selection of the 2005 to 2009 time period; the authors do not consider future volumes of oil production from the Persian Gulf in the years and decades following the war Iraq.

Liska and Perrin (2010) estimate the impact of GHG emissions from the Iraq War to be 10.1 g CO_2e/MJ of Persian Gulf-derived gasoline. Liska and Perrin did not consider global consumption of Persian Gulf petroleum. To calculate this result, we used Liska and Perrin's estimate of average annual Iraq War emissions from 2005 to 2009 (43.3 MMt CO_2e/yr) and allocated these emissions on the basis of average Persian Gulf exports of crude oil and condensates from 2005 to 2009, approximately 920 billion litres of crude oil and condensates per year (EIA 2013). Allocating GHG emissions across this amount reduces emissions by 87% to 1.2 gCO_2e/MJ. See Table 5-3 for full details.

Table 5-3 Iraq War GHG Emissions Allocated to Persian Gulf-Derived Gasoline in the United States and Total Persian Gulf Petroleum Exports

	Units	GHG Emissions Allocated to U.S. Imports from Persian Gulf (Liska and Perrin 2010)	GHG Emissions Allocated to Global Exports from Persian Gulf (estimate by ICF)	% Reduction in GHG Emissions When Allocating to Global Exports
Timeframe	--	2005-2009	2005-2009	--
Fuel to which GHG emissions are allocated	--	Gasoline derived from crude oil exported from Persian Gulf to U.S.	Global Persian Gulf exports of crude oil and condensate	--
Annual Oil Security-Related Emissions (A)	Million Mt CO_2e/yr	43.3	43.3	--
Fraction of Emissions Allocated to Fuel (B)	%	46.1% [a]	100.0%	--
Amount of Fuel (C)	Millions of barrels	787	5,784	--
	Billions of litres/yr	60.5	920	--
GHG emissions (= A * B / C [c])	gCO_2e/L	331	47.2	--
	gCO_2e/MJ [d]	10.1	1.2	87%

Source: Adapted from Liska and Perrin 2010 and ICF estimates.
[a] Based on the volume of gasoline produced from a barrel of crude oil (Liska and Perrin 2010).
[b] Target fuel consumption is based on Liska and Perrin (2010) for the U.S. perspective, and the annual average of global Persian Gulf petroleum exports from 2005-2009 (EIA 2013).
[c] GHG emissions calculated by multiplying U.S. annual oil security emissions by the fraction of emissions allocated to each fuel and dividing by the target fuel consumption, with appropriate unit conversions.
[d] Converted based on a Higher-Heating Value (HHV) of 32.2 MJ/L for gasoline, and 38.5 MJ/L for petroleum (Iowa State University Extension and Outreach 2007).

Unnasch et al. (2009) included Iraq War-related emissions in its assessment of on-going military involvement in the fossil fuel cycle but also incorporated Gulf War oil well fires and Iraq War reconstruction as one-time sources of emissions. Gulf War oil well fires, which were lit by the retreating Iraqi Republican Guard, corresponded to a 1.4 g CO_2e/MJ increase in life cycle emissions when assigned to Middle Eastern oil imports over a 20 year period. This estimate is notable because it applies a longer timeframe than the other estimates, although Unnasch et al. (2009) do not justify why a longer time period was chosen here relative to selecting a four-year time period to evaluate other emission sources from the Iraq War. The impact of Iraq War reconstruction was extrapolated by multiplying the amount of concrete attributable to reconstruction (20 million metric tons) by a general emission factor for concrete production 1.102 metric tons CO_2e/metric ton)—yielding an annual value of 22 million metric tons of CO_2e attributable to post-war reconstruction in Iraq.

Degree of consensus over whether indirect emissions can be allocated to the fossil fuel life cycle

Experts in favour of including emissions from military activities argue that energy security issues are a strong motivator behind military operations and conflicts, particularly in the Persian Gulf. Studies that have quantified GHG emissions from military activities have shown they can be a significant source of GHG emissions (Liska and Perrin 2010; Unnasch et al. 2009). Although there the degree to which these emissions are attributable to the fossil fuel life cycle is highly uncertain, Liska and Perrin (2010) claim the level of uncertainty is similar to GHG emissions from ILUC from biofuels.

The key arguments against including GHG emissions from military activities include the following:

- Military activities serve many different objectives and there is no objective way of allocating GHG emissions to energy security objectives versus other purposes (CARB 2011, p. 40). For example, the Iraq War was waged for a variety of reasons and attributing the entirety of the war's emissions to fossil fuel security overestimates those emissions within the context of a consequential analysis.
- The time period over which emissions are calculated and allocated is arbitrary and difficult to defensibly justify. None of the studies examined provided a detailed discussion of how the results would vary by assuming different time periods. Very few estimates considered the future production from current or recent conflict areas in calculating GHG emissions attributable to war.
- The studies focused primarily on U.S.-military emissions and generally allocated GHG emissions across U.S. imports and consumption of oil. The selection of the total volume of crude over which to allocate emissions has a large impact on the emission result, but is based on arbitrary decisions regarding export volumes, imports, or total consumption of a certain region. When estimates are allocated across global exports or consumption, the GHG emissions per-MJ of fuel are greatly reduced to as little as one fifth of estimates that allocate to U.S. imports or consumption.
- Reductions in oil imports are unlikely to cause a reduction in military activities (since the force size is determined by the likely challenges of the mission rather than any other factor). The relationship between petroleum demand and military involvement is therefore unlikely to be 1:1; for example, a study by the U.S. National Research Council suggested that even a 20% reduction in oil consumption in the U.S. would have little impact on the nation's foreign military presence (CARB 2011, citing NRC 2010).
- Studies on the topic do not reach a consensus on which sources of petroleum have added life cycle emissions from military involvement. It is unclear whether fuels derived from petroleum from outside the Persian Gulf also benefit from military protection as petroleum is a globally-traded commodity and market behaviour may be set to a degree by supplies from the Persian Gulf region. CARB's Subgroup on Indirect Effects of Other Fuels also suggested that "similar considerations would have to be made for biofuels" in the future, such as for ethanol shipments from Brazil (CARB 2011, p. 40).
- All of the studies identified focused on Middle Eastern oil resources, so there is no applicability of these emissions estimates outside of this region to other oil sources.

- As a result of the many conceptual problems with their inclusion, GHG emissions from military have not been included in similar low-carbon fuel policies in other jurisdictions. The U.S. EPA considered the link between military activities and fossil fuel sources, and found insufficient evidence to include these sources. A majority of experts involved in a peer review of the agency's Renewable Fuel Standard agreed that these emissions should not be included (CARB 2011, p. 39).

Limitations in evaluating the emissions source

Evaluating the extent of military involvement emissions is limited by two components: first, the uncertainty with regards to data collection for estimating the magnitude of this emission source, and second, the degree to which these emissions are attributable to fossil fuel demand.

On the first limitation: None of the studies evaluated were able to estimate with certainty the emissions from military action due to data restrictions on military activities and thus had to extrapolate military involvement emissions from other indicators. Liska and Perrin (2010) did not undertake an uncertainty analysis, but qualitatively assess the level of uncertainty in their estimates of GHG emissions from military activities as "comparable" to ILUC estimates for biofuels. Neither Oil Change International (2008) nor Unnasch et al. (2009) assessed the uncertainty in their GHG estimates, but since these approaches largely used first-order approximations and proxies, the level of uncertainty would be similar to, if not greater than, Liska and Perrin's estimates. In addition, it is unclear what time period would be appropriate for an allocation of emissions from one-off events. Military conflicts, though GHG-intensive, are one-time events which cannot be reliably predicted. There are currently no existing standards for the temporal allocation of war-related emissions to the production of production of fossil fuels

On the second limitation, the body of literature assessed did not arrive at a consensus about the degree to which military emissions and wars are attributable to the fossil fuel life cycle. Approaches for allocating GHG emissions are highly subjective and there is no clear method or indicator for determining what fraction of military emissions should be attributed to fossil fuels, and whether the allocation should be based on global supply or only on those regions engaged in energy security-related military activities (CARB 2011).

All of the studies we identified in this review focused primarily on emissions from U.S. military activities in the Persian Gulf. We did not find other sources that have investigated GHG emissions attributable to the military activities of other countries, or estimates that assessed global energy-related conflicts.

Consistency of the indirect emissions source with the goal and scope of the FQD

In our expert opinion, military involvement emissions are unrelated to the scope of the FQD and should not at this time be included in the system boundary for the following reasons:

- The link between military involvement and petroleum production cannot be objectively measured and it is uncertain to what degree military emissions should be attributed to the fossil fuel life cycle. Beyond the security of petroleum supplies, military involvement is tied to many other causes. In addition, similar arguments can be applied broadly to a point where military emissions for safety and security should be applied to a wide range of different human activities, goods, or services, and far beyond the scope of the fossil fuel or product life-cycle.

- Current analyses rely on a number of subjective and arbitrary decisions that have a large impact on the final results. Some of the most sensitive decisions include: the time period over which GHG emissions and crude oil production volumes are evaluated, the volume over which GHG emissions are allocated (e.g., imports to a specific country, global exports, global consumption), and the sources of emissions, whether conflict or security-related.
- Military involvement emissions are difficult to estimate due to restrictions on data regarding military operations and poorly-tracked data regarding wartime operations. Any estimates of military emissions rely on a large amount of extrapolation from other indicators (e.g., using concrete production data as a proxy for post-war reconstruction emissions or using a generalised DoD emission factor to estimate military involvement emissions). Uncertainty over appropriate time period for allocation of one-off emissions.
- The available studies are focused solely on GHG emissions from U.S. military activities and Persian Gulf imports. The selection of the total volume of crude over which to allocate emissions has a large impact on the emission result, but is based on arbitrary decisions regarding export volumes, imports, or total consumption of a certain region. When estimates are allocated across global exports or consumption, the GHG emissions per-MJ of fuel are greatly reduced to as little as one fifth of estimates that allocate to U.S. imports or consumption.
- The exclusion of military GHG emissions from the fossil fuel life cycle is consistent with the treatment of this source in other jurisdictions, notably within the EPA's Renewable Fuel Standard.

As a result, it is our opinion that the linkages between military activities and fossil fuel life-cycle emissions are suitably tenuous that they can be excluded from the life-cycle boundary. Our position is made on the basis that the methodologies examined for estimating and attributing GHG emissions are subject to a large number of arbitrary assumptions that greatly influence the results, and that they do not demonstrate a convincing method for evaluating GHG emissions, nor do they provide sufficient evidence of a valid link between military activities and fossil fuel production. As a result, we recommend that military activities be excluded from consideration in the FQD.

5.3. Accidents

Description

During the processes of fossil fuel extraction and transportation, the accidental release of fuels may pose a risk to the environment and may result in GHG emissions. Accidents and spills can occur during extraction via “blowouts”—uncontrolled bursts or releases of oil—or during transportation of fossil fuels, which primarily occurs via pipeline, rail or marine vessel. Spills may also occur during storage of fossil fuels at tank farms or terminals. Open ocean and marine terminal spills can lead to large-scale releases of crude oil or refined products into the environment, affecting large natural areas and necessitating energy and GHG-intensive clean-up efforts, such as the surface burning of oil. Emissions from spills can also include volatile organic compounds (VOCs) which have an impact on climate via low-level ozone formation (see Figure 5-8). Spills may also occur during vehicle fuelling operations, although this is a different type of spill than large-scale, infrequent accidents and is similar to "engineered losses" from fugitive emissions, such as those from natural gas systems. This source of indirect GHG emissions refers to any GHG emissions associated with accidentally-released fossil fuels as well as from clean-up and remediation efforts. The placement of accidents and spills in the fossil fuel life cycle is illustrated in Figure 5-4.

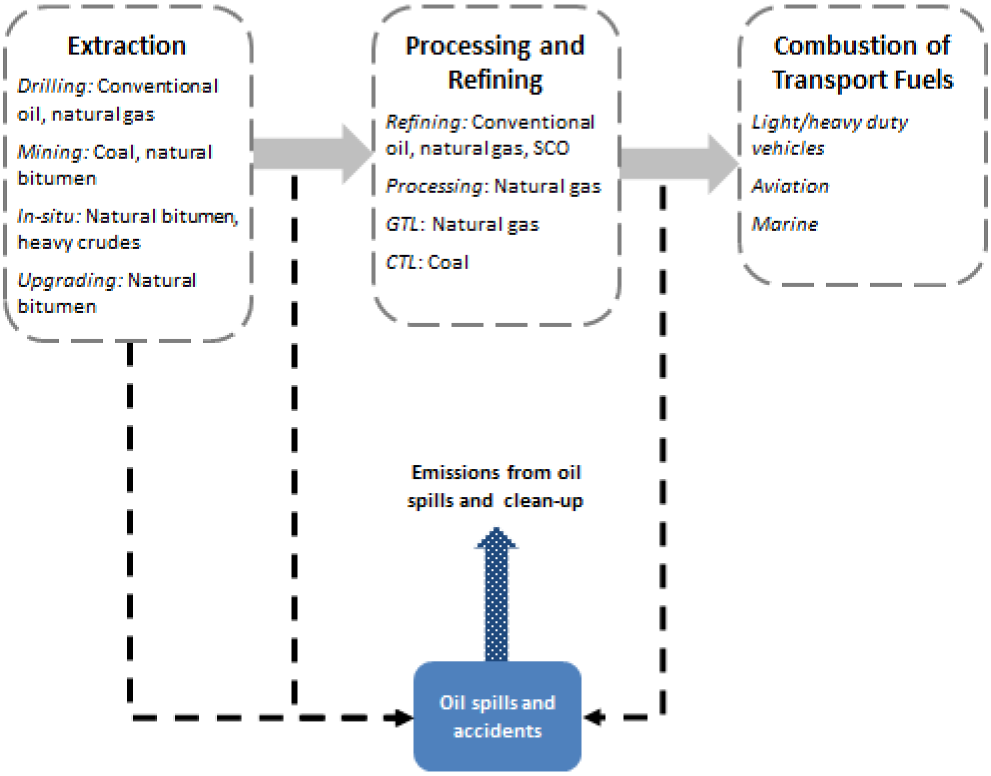

Figure 5-4: Placement of Accidents and Spills within Fossil Fuel Life Cycle

Treatment of this source in studies that support the FQD and fossil fuel LCAs

Accidental releases are not discussed in the studies that support the FQD. The Commission's handbook for the International Reference Life Cycle Data System[26] recommends that accidents should not be included in life cycle inventory (LCI) data because they represent fundamentally different conditions than normal operations, and because methods for integrating cause-effect chains and accident frequencies into LCA are still under development (JRC-IES 2012, p. 95).The FQD's exclusion of GHG emissions from accidents and spills is therefore consistent with current practices for the development of LCI datasets within the ICLD data network. An important exception for fossil fuel LCAs is fugitive emissions from sources such as sealings, well completions, and workovers (i.e., retrofitting a well), which constitute "engineered losses" that occur during normal operations; these are considered a direct emission source and are often included in LCAs.

[26] The EC's International Reference Life Cycle Data System provides a common basis for developing consistent and robust life cycle data and studies. It consists of the EC's handbook on general guidance for LCA and the ILCD data network, which is a repository of LCI information managed by the Joint Research Centre (JRC).

In its LCA approach for calculating carbon intensities of transportation fuels for the state's proposed low-carbon fuel standard, the Department of Environmental Quality (DEQ) in Oregon specifically proposes to not include indirect GHG emissions released from the clean-up of oil spills. The DEQ notes that the current science on these issues is "immature" and recommends a revisiting this topic in future program reviews (DEQ 2011).

Carbon footprint standards developed by the British Standards Institute (BSI 2011) and the World Resources Institute (WRI 2011) do not specifically discuss how accidents, spills, or other "non-standard" operating conditions should be treated in LCA. The majority of outside literature and fossil fuel LCAs do not discuss accidents and spills. Only Energy Research Architecture (2009), Ryerson et al. (2009) and TIAX (2007) addressed accidents and spills but only discussed them in quantitative terms and did not calculate GHG emission rates. This may be due to the fact that the most-severe environmental impacts of accidental releases are local impacts on marine and terrestrial ecosystems (Bengtsson 2011, Epstein 2006), rather than the release of GHG emissions.

Quantitative estimates of this source and uncertainty

GHG emissions from accidents and spills across the fossil fuel life cycle are poorly characterised and difficult to quantify within the literature surveyed. Generally, GHG emissions from accidental releases are not the primary environmental concern associated with spills—toxic components and ecological impacts take precedence. Large releases of oil[27] into the environment have widespread environmental impacts and tend to be high-profile events. However, due to their infrequency and the site-specific characteristics of spills and accidental releases, they are difficult to assess statistically (ITOPF 2012). The vast majority of oil spill incidents (by number) are small-scale (below 7 metric tons); however, inconsistent reporting of smaller incidents worldwide creates data gaps (ITOPF 2012).

In a 2007 life cycle assessment of gasoline, diesel, and other alternative transportation fuels for the California Energy Commission, TIAX (2007) considered environmental impacts from spills and accidents. The study, however did not quantify the GHG emissions from this source; it focused instead on the amounts of fuels accidentally released into the environment, the emissions of toxic components of the fuels, and ecological impacts. The distribution of spills by total volume spilled is illustrated in Figure 5-5 and shows that annual volumes of spills have decreased since 1973 (TIAX 2007, p. 6-9).

[27] E.g. large releases are defined by the International Tanker Owners Pollution Federation Limited, or ITOPF, as releases of greater than 700 metric tons (ITOPF 2012).

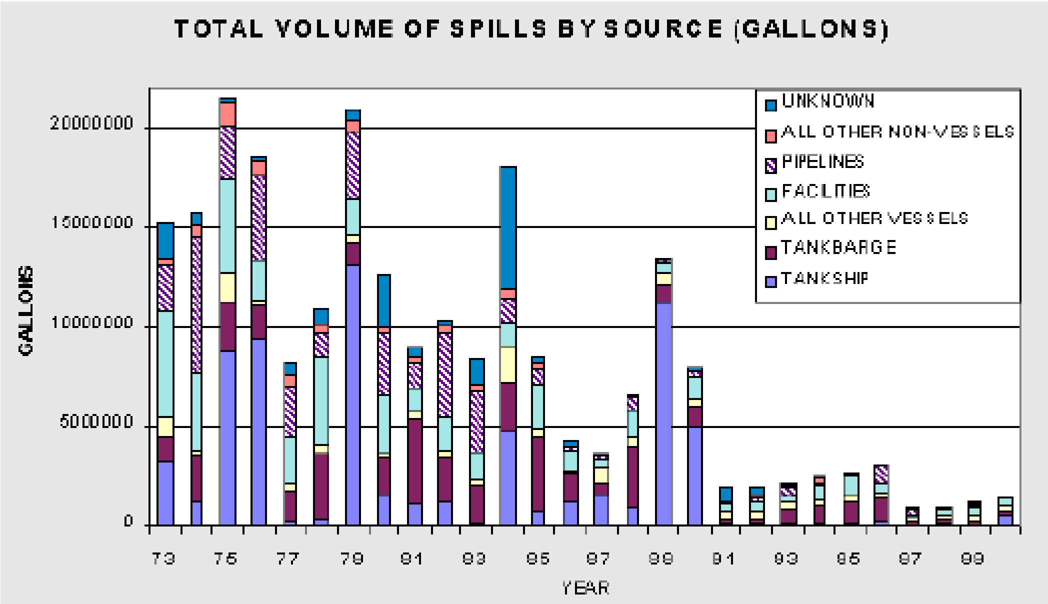

Figure 5-5: Total Volume of Spills by Source in and around U.S. Waters

Source: TIAX 2007

Based on Figure 5-5, spills during marine transport are the largest source of oil spills. The International Tanker Owners Pollution Federation (ITOPF) maintains a database of accidental oil spills from tankers, combined carriers and barges. This database indicates that while petroleum usage and shipping has increased over the past four decades, the absolute numbers of large oil tanker spills (i.e., greater than 7 metric tons) have decreased in frequency from 24.6 spills per year in the 1970s to 3.3 spills per year in the 2000s (see Figure 5-6). Similarly, without factoring small spills into consideration, the total amount of oil spilled over the past four decades has also decreased (see Figure 5-7).

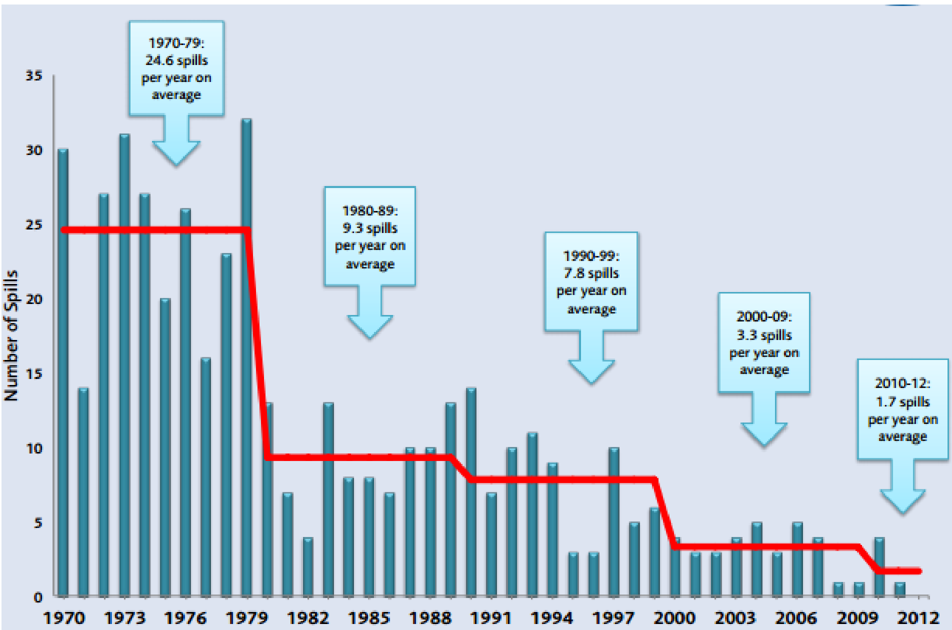

Figure 5-6: Large Oil Tanker Spills (>700 Metric Tons) from 1970-2012

Source: ITOPF 2012

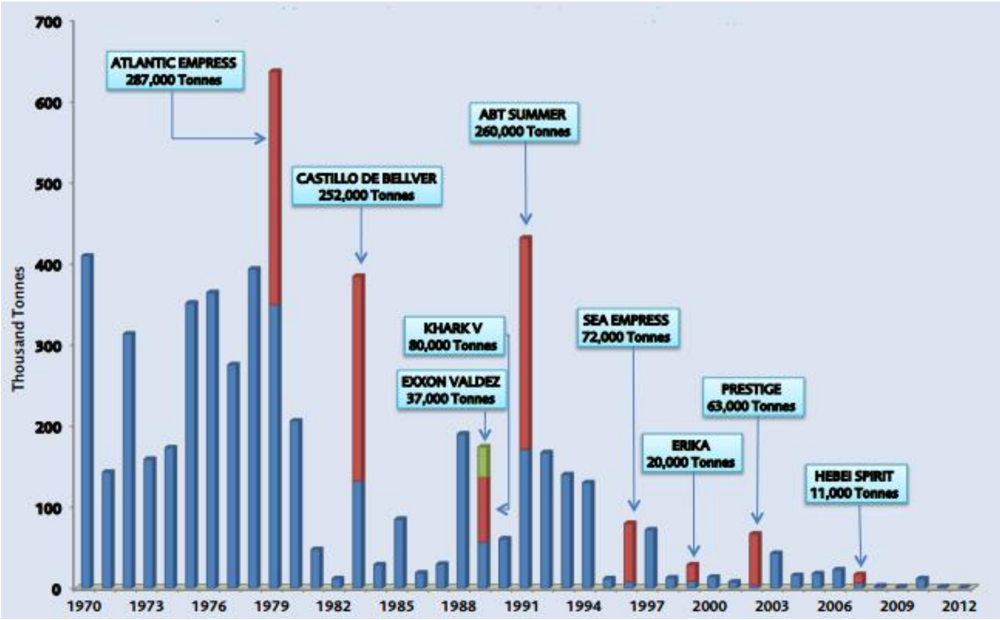

Figure 5-7: Magnitude of Total Oil Spilled from Marine Transport (>7 Metric Tons) Worldwide 1970-2012

Note: Red bars signify large, individual releases (e.g. Exxon Valdez in 1989)

Source: ITOPF 2012

Ryerson et al. (2011) assesses the environmental impact of the Deepwater Horizon oil platform spill and assesses the oil released as well as the airborne release of pollutants. The spill was estimated to release 32,600 to 47,700 barrels of oil (1,369,200 to 2,003,400 gallons) per day until it was capped, with a total of approximately 4.9 million barrels of oil released. Approximately 283 thousand barrels of the oil released was remediated through *in-situ* controlled burns, releasing approximately 135,000 metric tons of CO_2[28], plus additional emissions of black carbon, and soot particles that have climate impacts. After the cap was installed over the blown out oil well, natural gas flaring accounted for an additional $1.3 \pm 0.5 \times 10^6$ kg CO_2e released per day. The release of oil from the Deepwater Horizon spill and associated emissions to the atmosphere from the spill and clean-up effort are illustrated in Figure 5-8. The authors Ryerson et al. (2011) did not calculate a total for GHG emissions released by the Deepwater Horizon accident, so it is not possible to provide an indication of the overall magnitude of these releases.

[28] Calculated assuming an energy density of 6,100 MJ/barrel of crude oil (MIT 2007) and 78.9 gCO_2/MJ of oil (EPA 2011).

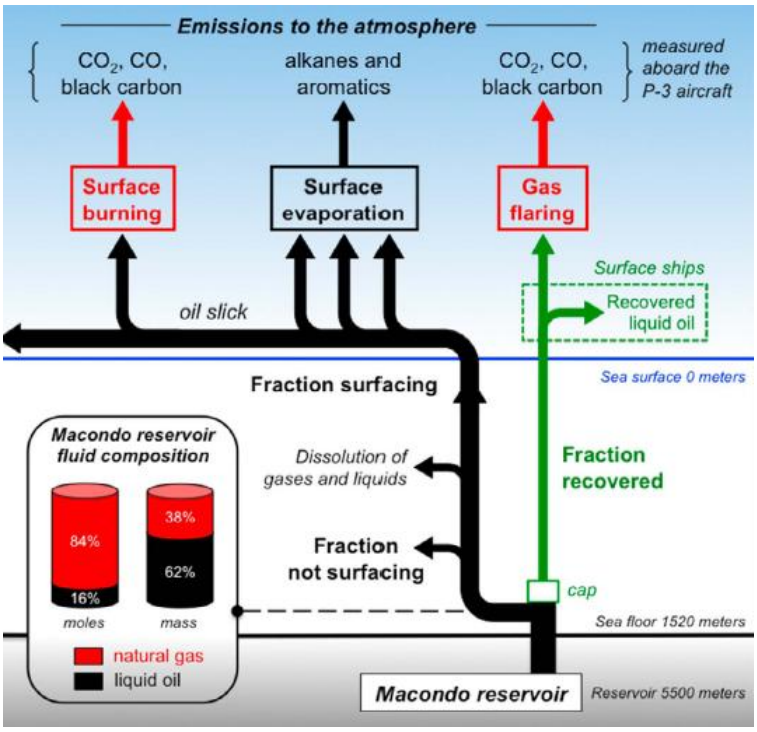

Figure 5-8: Oil, Gas and Carbon Releases to the Environment from the Deepwater Horizon Oil Spill

Source: Ryerson et al. 2011

The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model—a life cycle model created by the U.S. Argonne National Laboratory which evaluates vehicle technologies and fuels—incorporates spillage during vehicle fuelling into its calculations.[29] Spills during vehicle fuelling are different than larger-scale accidents and oil spills from extraction, transportation, and storage of crude oil and refined fuel products—they are similar to "engineered losses" from fugitive emissions in natural gas systems. In GREET, this source is captured primarily for assessing hydrocarbon emissions, as vehicle fuelling spills are a minor GHG emission source (Unnasch et al. 2009). The spillage is estimated to be very small (0.5 g/ gallons fuelled) and has a minimal impact on emissions estimates—totalling only 0.002 g CO_2e/MJ (Unnasch et al. 2009).

To provide an order-of-magnitude estimate of the contribution of oil spills and accidents to GHG emissions, we used information from ITOPF (2012) to compile information on the amount of crude oil spilled from marine transport annually (see Table 5-4). Assuming a density of 7.33 barrels per metric ton of oil, we calculated the total volume spilled in each year[30]. The volume of oil spilled is very small as a fraction of total petroleum consumption: using data from EIA, we determined that the volume spilled has been less than a thousandth of a percent of total consumption over the past 10 years, and often less than a ten-thousandth for the past five years (EIA 2013).

[29] "Spillage" refers to the volume of fuel spilled when fueling a vehicle—it is separate from other fugitive or evaporative emissions at fueling stations.

[30] British Petroleum, 2013, Crude Oil Conversion Factors. Retrieved from: http://www.bp.com/conversionfactors.jsp

Assuming a carbon intensity of 20.4 kg carbon per million BTU[31] and assuming the entire volume of spilled oil was combusted to generate CO_2, the GHG emissions from spilled oil would have averaged 0.066 million Mt CO_2e per year over the past decade, falling to 0.004 in 2012. This is one thousandth to less than one ten thousandth of the EU-27's GHG inventory emissions in 2011, respectively (EEA 2013). According to EIA, global petroleum consumption was 32.5 billion barrels in 2012; dividing spill emissions by this volume and dividing by the energy content of a barrel of oil[32] produces a negligible contribution of 0.00002 gCO_2e/MJ to life-cycle GHG emissions from crude oil as a result of global marine oil spills.

It is also possible to extrapolate the *additional* GHG emissions resulting from oil spills based on the assumption that spilled oil necessitates the production of an equal amount of petroleum to replace it. According to Jacobs (2009), the life cycle emissions of Saudi medium crude, a common crude oil distributed internationally, from extraction through transport, are equivalent to 11 g CO_2e/MJ, or approximately 67.1 kg CO_2e per barrel of oil[33]. ITOPF (2012) provides the total volume for large and medium-scale oil spills occurring worldwide from 1970 through 2010 (see Table 5-4). Scaling the GHG emission factor for petroleum by the volume of oil spilled provides an estimate of the GHG emissions stemming from the replacement of spilled petroleum. As is evident from the table, oil spills have decreased greatly in volume since the 1970s, with the recent period of 2000-2012 comprising approximately 20% of the volume of oil spilled in the 1990s and only 7% of the oil spilled in the 1970s. The GHG emissions generated from replacing spilled oil from 2000 to 2012 are approximately 112,000 metric tons of CO_2e. When allocated to the approximately 62.9 billion litres of petroleum consumed in the same time period[34], these emissions would contribute incremental GHG emissions of only 0.00005 gCO_2e/MJ. Extrapolating further, even if we generously assume that the entire volume of spilled oil from 2000-2012 was combusted, that worst-case scenario would contribute incremental GHG emissions of only 0.00003 g CO_2e/MJ to petroleum consumed in that time period.

[31] From EPA (2011) for residual fuel oil, distillate fuel oil, and unfinished oils.

[32] Taken as 6,100 MJ per barrel of crude oil, based onMIT (2007).

[33] Assuming approximately 6,100 MJ per barrel of crude oil based on MIT (2007). This is not an exact calculation. Emissions estimate from Jacobs (2009), p. 8-5, Table 8-3.

[34] Energy Information Administration, 2013. "International Energy Statistics". Retrieved from: http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm

Table 5-4: Volume of Crude Oil Spilled and GHG Emissions from Replacing Spilled Petroleum, 1970-2012

Year	Volume of Oil Spilled (Barrels)	GHGs Emissions from Replacing Spilled Oil (Metric tons CO2e)
1970s	23,573,280	1,581,767
1980s	8,627,410	578,899
1990s	8,319,550	558,242
2000	102,620	6,886
2001	58,640	3,935
2002	491,110	32,953
2003	315,190	21,149
2004	117,280	7,869
2005	131,940	8,853
2006	168,590	11,312
2007	139,270	9,345
2008	21,990	1,476
2009	14,660	984
2010	87,960	5,902
2011	14,660	984
2012	7,330	492
2000-2012	1,671,240	112,140

Degree of consensus over whether indirect emissions can be allocated to the fossil fuel life cycle

GHG emissions from oil spills were not allocated to the fossil fuel life cycle in the studies ICF has reviewed. This is likely due to two factors: firstly, GHG emissions from accidents and oil spills are typically not quantified as the most-severe impacts of accidents and oil spills tend to be local air, water, or terrestrial pollution and impacts on local ecosystems. Secondly, as oil spills occur outside of normal operations within the fossil fuel life cycle (e.g., due to weather events or human error), these releases are atypical and generally-accepted methods for including these sources in LCA studies are still in development. Based on our calculations, the overall contribution of this source to GHG emissions along the fossil fuel cycle is extremely small and effectively negligible.

Limitations in evaluating the emissions source

No LCAs of fossil fuels reviewed in the literature included accidents and oil spills as a quantified source of GHG emissions.[35] Estimates of this emissions source are limited by the lack of data concerning actual GHG emissions associated with oil spills beyond accounting for the volume of oil spilled. There are also a number of specific characteristics that vary by accident or spill: oil spill responses, for example, use a variety of clean-up methods

[35] The GREET model does include GHG emission estimates from vehicle refueling spills. This emission source, however, is different than infrequent accidents that are outside of normal ooperating conditions; spillage from vehicle refueling is similar to "engineered losses" that occur from fugitive emissions and venting in natural gas systems, which are typically included in fuel LCAs.

depending on the area affected by the spill, and these can affect overall GHG emissions. For example, whether oil is burned for remediation influences GHG emissions from spill response, but this activity is not always applied to oil spills;[36] we also did not locate GHG emissions estimates for oil burning in the literature surveyed (Ryerson et al. 2011). Finally, since accidents and oil spills are outside of normal operations, estimating the likelihood of these impacts requires using accident frequency analyses and cause-and-effect chains; approaches for including these types of analysis within LCA are still under development.

Consistency of the indirect emissions source with the goal and scope of the FQD

In our expert opinion, current life cycle guidance and the level of data available on accident and spill emissions indicate that this emission source is outside of the scope of the FQD and should not be included within the system boundary. We have formed this recommendation on the following evidence:

- Accidental releases and spills of oil are not treated as a source of GHG emissions in the LCAs of fossil fuels within literature surveyed.[37] For the purposes of establishing a standard for GHG intensity in transportation fuels, this category would fall outside the scope of the FQD. This approach is also consistent with European guidance on the development of LCI data within the ILCD data network.
- The data concerning the emissions associated with accidental releases and spills of oil is very limited. Most studies do not treat this as a source of GHG emissions, focusing instead on the volume of oil released into the environment and impacts on the ecosystems affected. Methods for including GHG emissions from infrequent accidents and oil spills into LCA studies are still under development, and face limitations due to lack of information on the GHG emissions from clean-up and accident-specific the variety of remediation methods used, such as oil burning, which influence total GHG emissions.
- Large-scale accidental releases of oil are relatively rare events and have been decreasing annually since 1973. Similarly, the total amount of oil spilled worldwide continues to decrease each year due to improved techniques and technology. These releases are outside the "norm" for fossil fuel production and may consequently be outside the scope of an LCA. Additionally, these accidental releases and spills represent a very small portion of the oil produced and transported worldwide and may thus constitute a very small source of emissions.
- Based on our calculations, the overall contribution of this source to GHG emissions along the fossil fuel cycle is extremely small and effectively negligible.

[36] For example, other techniques may include use of containment "booms", application of dispersants, or manual clean up.

[37] The GREET model does include GHG emission estimates from vehicle refueling spills. This emission source, however, is different than infrequent accidents that are outside of normal ooperating conditions; spillage from vehicle refueling is similar to "engineered losses" that occur from fugitive emissions and venting in natural gas systems, which are typically included in fuel LCAs.

5.4. Marginal Effects

Description

"Marginal effects" refer to consequential impacts to the fossil fuel life cycle that would result from large-scale, economy-wide changes in the supply and demand of fossil fuels and which may not be fully accounted for in looking solely at average conditions from an attributional perspective over time. There are at least two potential effects that have been discussed in the literature and are included in this section:

1. Changes in the demand for fossil fuels will cause changes in the marginal fossil fuel resource consumed, and influence GHG emissions through the following (CARB 2011, ERA 2010, Unnasch et al. 2009):

    a) Marginal changes in the types of fossil fuels that are extracted and produced, and

    b) Marginal changes in the operation of refineries that result in a different GHG emission profile.

    GHG emissions may result from changes in the types of fossil fuels that are extracted and produced globally, and from how and where these different fuels are refined worldwide. The magnitude of this effect on GHG emissions will depend on the GHG-intensity of the marginal fossil fuel resource: for example, if the changes result in a greater supply of fossil fuels with a high GHG-intensity, replacing these marginal fossil fuels with lower-intensity alternatives will yield larger GHG benefits than compared to the EU average fuel mix.

    The FQD itself may cause changes in the types of fossil fuels consumed in the EU and—to the extent that these changes influence global supply and demand for fossil fuels—the rest of the world. These changes will affect direct emission sources, since reducing the GHG-intensity of fuels consumed in the EU is the main objective of the policy, but they may also result in consequential effects—such as increases in the marginal GHG-intensity of fuels consumed in other countries. Potential indirect effects resulting from the FQD are also investigated in this section.

2. Increases in demand for natural gas as a fuel for transportation may reduce its use in the electricity sector, resulting in changes in the mix of fuels used for electricity production (CARB 2011).

An overview of the placement of marginal effects within the fossil fuel life cycle is illustrated in Figure 5-9 below. Marginal effects are entirely a "consequential" emissions source—in other words, they result from changes in the supply and demand of fossil fuels.

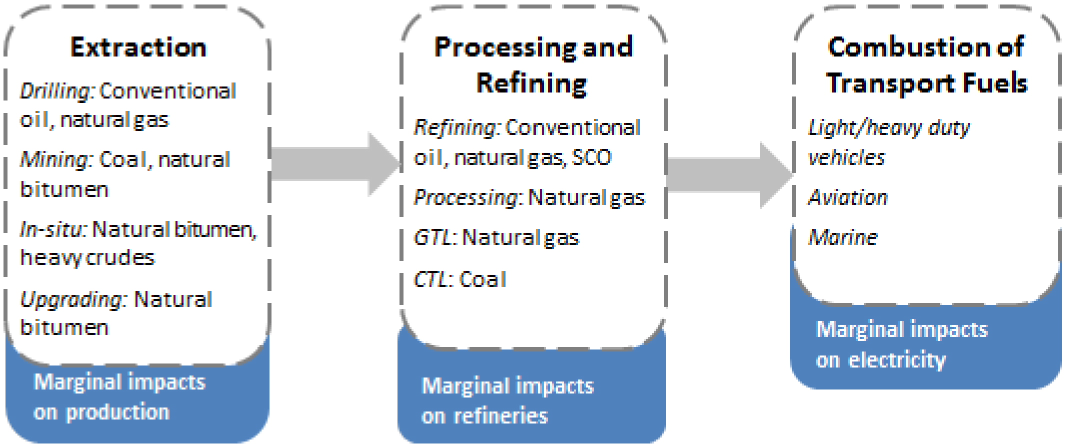

Figure 5-9: Placement of Marginal Effects within the Fossil Fuel Life Cycle

Marginal effects are relevant to this study—and to implementation of the FQD—as an indirect effect to the extent that: (i) they involve short-term changes that are within the time period relevant to the FQD (i.e., a 2020 timescale); (ii) they relate to unintended or unforeseen knock-on consequences on direct emissions. Broader issues, such as the extent to which GHG-intensive fuels will enter the market at longer-term timescales beyond 5 to 10 years are beyond the scope of this study.

Treatment of this source in studies that support the FQD and fossil fuel LCAs

Changes in the marginal fossil fuel resource consumed

The Commission's proposed implementing measure acknowledges that "it would be desirable to attribute a specific greenhouse gas intensity to each fossil fuel feedstock from each and every geographical source globally" (p. 3); this would allow specific emission factors to be applied to each fossil fuel resource consumed to determine the GHG-intensity of fossil fuels supplied to the EU. The proposed implementing measure notes, however, that such an approach "requires a massive amount of information which is currently not readily available on evenly distributed geographical basis" (EC 2011, p. 3). As a result, it establishes several fossil fuel feedstock categories that are "distinguishable" based on average or typical GHG intensities for both conventional and unconventional fossil fuel resources. This enables the GHG intensity calculated to reflect the contribution from some higher-intensity fossil fuel resources that enter the EU market.

The proposed implementing measure does not, however, develop estimates of indirect GHG emissions attributable to changes in the marginal fossil fuel resource consumed globally (i.e., as a result of changes due to implementation of the FQD in the EU, or other broader changes in production of fossil fuels related to resource availability, new extraction technologies, etc.), nor does it develop estimates of how the GHG-intensity of marginal producers differ from the average GHG-intensity. None of the LCA studies included in the literature review developed quantitative estimates of this effect. Three studies (CARB 2011; ERA 2010; Unnasch et al. 2009) discuss the potential implications of this effect qualitatively based on available information. The reports conclude that the marginal fossil fuel resource consumed will depend on the time horizon and will be influenced by a number of factors including cost, OPEC production limits, national energy policies, and other factors.

Marginal changes in electricity sector due to changes in demand for natural gas in transportation

The indirect effect of changes in the demand for natural gas on the electricity sector have not been estimated in the LCA studies supporting the FQD. This is consistent with existing LCA literature: we did not find evidence of other LCAs that have investigated this effect as an indirect source of emissions from fossil fuels.

Quantitative estimates of this source and uncertainty

Changes in the marginal fossil fuel resource consumed

ICF did not locate quantitative estimates in the literature on the relative magnitude or direction of changes in indirect GHG emissions from the marginal fossil fuel resource consumed, or from marginal changes in the operation of refineries. Instead, three studies investigated these indirect emissions sources qualitatively, drawing on recent literature to provide directional assessments of the overall effect (CARB 2011; Unnasch 2009; ERA 2010). They are discussed in the "Degree of consensus" section below.

Marginal changes in electricity sector due to changes in demand for natural gas in transportation

Similarly, ICF did not locate any quantitative estimates of the magnitude, direction, or likelihood of this indirect effect in the existing literature, encompassing high quality, peer-reviewed LCAs, other academic articles, and grey literature. CARB (2011, p. 52) found that, in the United States context, "there is a paucity of data with regard to the potential market-mediated effect of shifting natural gas markets". No information or studies were located that assessed the significance of this effect in European markets.

Degree of consensus over whether indirect emissions can be allocated to the fossil fuel life cycle

Changes in the marginal fossil fuel resource consumed

Low-carbon fuel policies, such as the FQD, have an effect on the marginal production of fossil fuel resources: these policies will result in the displacement of fossil-based transportation fuels with alternative ones. A direct effect of the policy may be to replace high-intensity fuels with lower-intensity ones; however, these changes may result in knock-on effects in the marginal fossil fuel consumed that are not accounted for with emission factors that are based on the average fuel mix. These indirect marginal effects have been likened to ILUC, which addresses the marginal impact that biofuel production has on land use (CARB 2011, p. 11). Some experts have argued that low-carbon fuel policies should include marginal changes in the GHG-intensity of fossil fuels as an indirect effect (CARB 2011; Unnasch et al. 2009).

The most thorough treatment of this issue in the available literature is from CARB's Subgroup on Indirect Effects from Other Fuels (CARB 2011), which presents two perspectives on this issue: one in favour of including marginal changes as an indirect effect, and one in favour of assessing carbon intensities based on "average" production and revisiting the assessment on an as-needed basis. CARB discusses these issues from a California perspective; but we have summarized the issues that are also relevant to the European Union.

The arguments in favour of considering the replacement of marginal fossil fuel consumption as an indirect effect are as follows (CARB 2011):

- Conventional crude is unlikely to be the marginal fossil fuel source displaced by increased demand for biofuels or alternative fuel sources resulting from low-carbon policies like the FQD.
- Although there are a number of factors[38] that will influence the marginal barrel of fossil fuels that are displaced by alternatives, it is likely that the marginal barrel will be more GHG-intensive than the current average GHG intensity of fuels refined in a given market (e.g., the European Union).
- As a result, the displacement of fossil fuels with alternatives, such as biofuels, should account for the fact that these alternatives will be displacing more-intensive fossil fuels than the current average GHG-intensity.

Arguments against treating the replacement of marginal fossil fuel consumption as an indirect effect include (CARB 2011):

- Over a 10-year period (i.e., out to approximately 2020), it is unlikely that low-carbon fuel policies will dramatically influence the types of fossil fuels coming onto the market; it is likely that displaced petroleum will be absorbed in the developing world.
- Even if there is a response, it is likely to come from OPEC production cuts or from high-cost production areas that are close to their end of life, not from new production areas. As a result, marginal production over 5 to 10 years is more likely to be lower GHG-intensity fuels, not heavier oils or natural bitumen produced from Canada.
- Comparing against an average GHG-intensity is consistent with other modelling efforts, such as the EPA’s analysis of the marginal carbon intensity of gasoline and diesel for the U.S. Renewable Fuel Standard. This assessment found that the marginal barrel in 2022 was not significantly more GHG-intensive than the current average (CARB 2011, p. 27).

CARB’s Subgroup on Indirect Effects from Other Fuels (CARB 2011, p. 28) also discussed whether changes in refinery operations should be considered as an indirect effect. The authors in favour of inclusion postulated that a policy-driven demand reduction for gasoline and diesel fuels will reduce refinery throughput for fuels that would have otherwise been produced. This would potentially result in the shutting down of conversion units (e.g. cokers) and thus reduce the GHG intensity of fuels produced. Conversely, the structure of low-carbon fuel policies is such that the fuel life cycle accounts for emissions resulting from extracting, producing, and delivering finished fuel to consumers, so there is no basis for separately assigning a “credit” to other fuels for changes in refinery operations; rather, changes in the GHG intensity are best captured in the life cycle of respective fuels.

The Subgroup also acknowledges that a variety of factors complicate the treatment of marginal effects in refineries—primarily how refineries’ conversion activities respond to changes in demand for fuels. The authors who dissented on modelling the indirect effects

[38] CARB (2011) and ERA (2010) point to several factors that will influence the marginal barrel of fossil fuels displaced (in addition to the cost of production), including the effects of OPEC production cuts, operational decisions in refining of fuels, state energy security and supply priorities, resource nationalism and geopolitical issues, and low-carbon policies. Over the longer term, ERA (2010) argue that it is more likely that the most expensive oil will be the marginal barrel displaced.

from changes in the operation of refineries argued that refinery behaviour is complex and that existing models may not be well-suited to developing estimates of indirect effects. In order to develop defensible and accurate estimates, refinery-specific modelling would be required to estimate how refineries would alter their product slate in response to changes in the supply of crude types and demand for refined products, and how these changes would affect the carbon-intensity of gasoline and diesel. (CARB 2011, pp. 28-30)

Marginal changes in electricity sector due to changes in demand for natural gas in transportation

Although we did not identify quantitative estimates of this indirect effect, CARB (2011) found that it could be significant, based on the results of a separate study on electricity power markets in California conducted by McCarthy et al. (2010).The study did not actually assess how changes in demand for natural gas affects electricity sector emissions; instead, it looked at how electric vehicles could affect the grid. The results, however, demonstrate that the GHG-intensity of electricity generation is very sensitive to changes in demand: The study's results indicated that, over the short- and mid-term, an increase in demand for electricity from electric and hydrogen vehicles could result in much higher marginal carbon-intensity values than current "average" electricity generation in California. This was due to marginal production for electricity occurring from more carbon-intensive natural gas power plants on the grid. The carbon intensity of marginal electricity production was found to be 60-90% higher than gasoline—suggesting that an increase in demand for natural gas in the transportation sector could have similar significant impacts on electricity sector GHG emissions.

Key assumptions in the McCarthy et al. report that introduce uncertainty in the results include the fact that they assumed a very large increase in electric and hydrogen vehicles in 2010, whereas changes in the fleet will occur gradually over time. Also, the authors relied on an electricity power sector model, EDGS-CA, which, among other limitations may not represent the exact mix of power plants operating at a given time.

Limitations in evaluating the emissions source

A few of the key limitations in evaluating these marginal emission sources are as follows:

- From a purely economic perspective, changes in the marginal production of fossil fuels are expected to affect the sources with the highest marginal cost of production first. However, this is complicated by several political and economic factors which may affect which fuel is in fact on the margin. OPEC members may respond to a decrease in demand for petroleum by constraining production and thus supporting high crude prices (CARB 2011). Additionally, as most fossil fuels are globally-traded commodities, any reductions in demand in countries with low-carbon fuel policies may be offset by increased demand by other countries, particularly those whose economies are rapidly growing (Chen and Khanna 2012). New oil fields coming online, such as tight oil in the United States, are displacing conventional crudes, and not higher carbon intensity unconventional crudes. Field- or operation-specific factors will also influence which fuels are displaced: For example, sources with high production costs that involve large, sunk capital costs and low variable, or operating costs may have relatively low marginal production costs once the initial investment is made.

- The fossil fuel sources with the highest production costs are not necessarily the most GHG-intensive. For example, ERA (2010, p. 5) notes that oil extraction processes using Enhanced Oil Recovery can be less GHG-intensive, but involve higher costs than Coal-to-Liquids (CtL) using low-quality coal feedstocks.
- Estimates of refinery behaviour are highly uncertain due to the complexity of refinery operations and how operators may respond to changes in demand for certain refined fuels. Projections of GHG-intensity changes from policy-driven changes in transport fuel demand are thus uncertain.
- There is limited data and modelling expertise offering predictive insight on how policy-driven changes affect the relative use of different fossil fuels within the marketplace. Consequently, the marginal use rates will remain uncertain.

Consistency of the indirect emissions source with the goal and scope of the FQD

Based on the review above, our recommendations on the treatment of these marginal effects are as follows:

- The information currently available on marginal changes in the fossil fuel resource consumed is insufficient to include these effects as an indirect emissions source in the scope of the FQD. ICF did not locate any quantitative estimates on the magnitude of this effect. There are also a number of uncertainties that would influence the direction of this effect: one on hand, over the short term, the marginal GHG intensity of fossil fuels displaced by new sources may not be that different than the average GHG intensity of fuels consumed; on the other hand, longer term changes may result in displacement of more expensive and possibly more GHG-intensive fossil fuel sources. There is still a great deal of uncertainty over the timing, magnitude, and direction of these effects however, and further study is required to determine how significant they could be in an EU context with respect to the FQD.
- Similarly, there is currently a paucity of data available on changes in electricity generation that may result from increased demand for natural gas as a transportation fuel. The current level of information on this effect is insufficient to make a determination of the significance of its inclusion in the boundaries of the FQD.

5.5. Price effects

This section addresses indirect emission sources from price effects, or those related to price-induced changes in the aggregate end-use consumption of finished fuel products from fossil fuels. This section is split into two sub-sections: the first deals with general price effects; the second section discusses urban sprawl, a specific price effect that was identified in stakeholder interviews.

General price effects

Description

Energy and environmental policies affect crude and petroleum fuel prices. Changes in prices affect consumption and thus production. Changes in consumption and production change both indirect and direct GHG emissions. Therefore, price effects are ubiquitous and often important. They occur in every market and industry affected directly or indirectly by petroleum fuels—the markets for agricultural commodities, fertilizer, oil, steel, electricity, new cars, etc. This indirect feedback loop is shown in Figure 5-10.

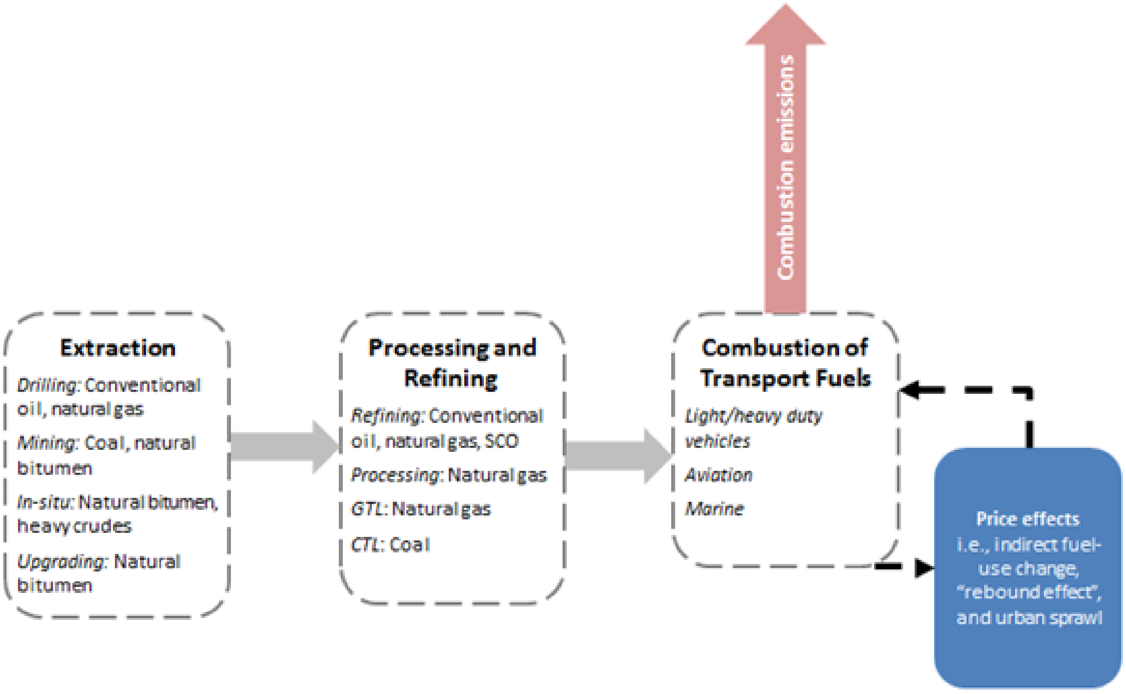

Figure 5-10: Placement of Price Effects within Fossil Fuel Life Cycle

Treatment of this source in studies that support the FQD and fossil fuel LCAs

Indirect emissions from transportation fuel price effects were not estimated in the literature that has informed methods for calculating GHG emissions of fossil fuels under the FQD. In addition, the biofuels under the FQD also did not consider indirect fuel use change (IFUC). This approach is consistent with the existing LCA literature available on life cycle emissions from fossil fuels. We identified studies that have investigated this price effect as an indirect source of emissions from fossil fuels as it relates to the consumption of biofuels and the impact on overall petroleum markets. However the studies relate the GHG emissions on a global basis and not on the basis of lifecycle GHG intensity in gCO2e/MJ of fuel product, nor specifically for the EU. In addition, this source was not included in the boundaries of the other high-quality, peer-reviewed LCA studies included in our review.

Quantitative estimates of this source and uncertainty

Fuel price effects reverberate through the global economy making it a difficult exercise to model them. Higher fuel prices tend to depress a country's GDP and thereby decrease petroleum consumption, and hence lower GHG emissions. In contrast, lower fuel prices reduce the prices of all economic goods, thereby increasing consumption and increasing GHG emissions. Furthermore, lower prices along with improvement in fuel efficiencies will change the type and amount of transportation used by a majority of the population. For example, lower costs associated with operating a personal vehicle will decrease the usage of public transportation or discourage efficient use of the personal vehicle. This is known as the rebound effect where the emission reductions associated with an enacted policy are not fully realized because of changes in consumption habits by the consumers. The impacts are further complicated by subsidies and tax incentives for biofuels and petroleum derived fuels. The consumption of biofuels reduces the demand for petroleum, which tends to reduce the price of crude oil, and lower crude prices can lead to increased petroleum consumption and thus higher GHG emissions.

Arvesen et al (2011) provides qualitative descriptions about the rebound effect by splitting it into micro and macro levels of effects. It argues the micro-level effect of making an energy source more energy efficient for a consumer to be the reduction in price of consumption of that energy source, and the subsequent increase in the demand for that energy source or in the availability of financial resources for other consumption. Whereas, on a macro level, the effect of making an energy source more energy efficient may result in adjustments of demand and supply of several inter-connected products over a period of time. Therefore, the emissions reductions associated with the policy that changed the price of the energy source are not fully utilized because of changes in consumption habits which could result in potentially higher emissions elsewhere. Arvesen et al (2011) describes the total economy-wide rebound effect of changing the price of one product to be the combination of all the micro-level and macro-level effects that are caused by that one change.

Even with these complications, efforts are underway to characterize the price effects associated with the introduction of biofuels. Experts in this area typically use a dynamic computable-general-equilibrium (CGE) model. Although Unnasch et al. (2009) did not quantify price effects, they identified two models that may have the potential to do so. The first is Purdue University's Global Trade Analysis Project (GTAP) as a useful model that has the potential to quantitatively analyse how the global economy will adjust to policy changes. The model has a data base covering 57 commodities/producing industries in 87 countries/regions. Unnasch et al. also identified the Global Emission Model for Integrated Systems (GEMIS) 4.4 developed by Öko-Institut. This model could quantify the environmental impacts of energy, materials, and transport systems and can determine the economic costs associated with in varying economic scenarios. Following a similar economic concept, the Edmonds-Reilly-Barnes (ERB) model is a market equilibrium model of the energy and economic systems originally documented in 1985 wherein major factors such as demand for energy sources and energy source efficiency and indirect factors such as demographics are used to determine total emissions from the energy source. As described in Brenkert et al., since ERB's inception, the model has been updated several times and is currently incorporated as a module in integrated assessment models such as MiniCAM. The fundamental problem the ERB model tries to solve is to equate the supply of each fuel with the demand of each fuel using changes in price of any one or more fuels over a period of time.

Work in this field is relatively recent and the utility of the complex economic models, such as the ones identified by Unnasch et al. and Brenkert et al. for calculating the impact of price effects are still being determined. Nonetheless, several research groups have undertaken their own limited analyses of price effects: Dixon et al. (2007, cited in Delucchi 2011) found that replacing petroleum derived fossil fuels with biomass will reduce the global prices of crude; Hochman et al. (2010, cited in Delucchi 2011) found that fuel prices will decrease by between 1.07 and 1.10 percent causing a global increase in fuel consumption by 1.5 to 1.6 percent; and, Rajagopal et al. (2011) found that world oil prices will decrease by 2.39 to 2.79 percent but global emissions will decrease GHG emissions by -0.08 gigatons carbon dioxide equivalent. The Rajagopal study is the only report that quantifies the price effects of GHG emissions.

The model developed by Rajagopal et al. (2011) simplifies the problem by splitting the world into two regions where only one region implements a biofuel mandate, categorizes all petroleum derived fuels as oil and all non-petroleum derived fuels as biofuel, and assumes that they are perfect substitutes. Rajagopal et al. defined the change in global fuel consumption due to a policy as indirect fuel use change. Rajagopal et al. indicate that a biofuel mandate will increase the price of fuel at home but decrease the price of fuel globally; this decreases oil consumption in the home region, but increases consumption in the rest of the world. The net result is a decrease in GHG emissions globally in Rajagopal et al.'s simulation, provided in Table 5-5. Their work shows that IFUC can be large (i.e., contributing to 50 to 75% of the total GHG reduction benefit from a biofuel mandate policy) compared to direct lifecycle emissions and indirect biofuel ILUC emissions.

Table 5-5: Summary results of simulation of 7.5% US biofuel consumption mandate.

Changes with Respect to Baseline	High Elasticity Case	Medium Elasticity Case	Low Elasticity Case
Home fuel price ($/barrel)	5.15 (6.43%)	4.89 (5.97%)	4.50 (5.35%)
World oil price ($/barrel)	-1.91 (-2.39%)	-2.09 (-2.56%)	-2.35 (-2.79%)
Home oil consumption (mbpd)	-1.92 (-8.99%)	-1.84 (-8.60%)	-1.76 (-8.24%)
Rest of the world oil consumption (mbpd)	0.66 (0.95%)	0.62 (0.89%)	0.58 (0.84%)
Global oil consumption (i.e. home and rest of world combined) (mbpd)	-1.26 (-1.38%)	-1.21 (-1.33%)	-1.18 (-1.29%)
Home GHG emissions (GtCO2) (A)	-0.25 (-6.53%)	-0.23 (-6.14%)	-0.22 (-5.76%)
Rest of the world GHG emissions (GtCO2) (B)	0.12 (0.95%)	0.101 (0.89%)	0.10 (0.84%)
Global GHG emissions (GtCO2) (C=A+B)	-0.13 (-0.84%)	-0.12 (-0.79%)	-0.12 (-0.75%)
Global emission reduction due to replacement of fossil fuel with biofuel (GtCO2) (D)	-0.08	-0.08	-0.08
Global IFUC emissions (GtCO2) (E = C-D)	-0.06	-0.05	-0.04
Global IFUC emissions as a percentage of replacement effect (=E/D)	75%	63%	50%

Note: Figures in parentheses denote percent change with respect to a business-as-usual baseline in which biofuel is used only as oxygenate and not as fuel
Source: Rajagopal et al. 2011

Unnasch et al. (2009) examined the displacement of gasoline by alternatives by first estimating the magnitude of the rebound effect and then allocating emissions based on the relationship of the rebound effect and GHG intensity of fuel substitutes. The authors cite Small and Van Dender (2005), who estimate a rebound effect between 2.2% and 10.7% for consumers' behaviour in response to fuel economy savings. For an example of how this is presented in the study, a 30% increase in fuel efficiency is countered with a rebound effect of 2.2% of that savings value--thus decreasing the total savings by 0.66%. Extrapolating from consumer behaviour in response to fuel economy savings and averaging the results indicates a rebound effect of 0.26%. Averaging this rebound effect value with the expected new fuel supply yields an estimate of 0.25 g CO_2e per MJ of alternative fuels that replace existing fossil fuels on the market.

Degree of consensus over whether indirect emissions can be allocated to the fossil fuel life cycle

The studies agree that the price of crude oil will decrease with a policy such as a biofuel mandate, but there is no consensus on whether the global emissions will decrease or increase as a result of the downward trajectory of crude prices. The authors acknowledge simplification of the problem and indicate areas for further study. Nonetheless, the diverging conclusions still ratify that the impact of price effects on global emissions may not be negligible. However due to lack of quantifiable consensus they cannot be allocated to the fossil fuel life cycle.

Limitations in evaluating the emissions source

Overall, it is difficult to quantify the indirect emissions from fuel price changes as the result of a policy, because the impact will affect the overall global oil market, not just the EU. Changes in transportation fuel prices from increased use of alternatives to petroleum-based fuels will change the overall consumption of petroleum fuels in Europe and abroad. Each unique policy may have a different impact of European and global fuel market prices. We found one study that investigated the impact of a U.S. based biofuel mandate policy, but no studies that evaluated the lower lifecycle GHG intensity mandate of the FQD. The effect of IFUC has not been included in the assessment of GHG emission benefits from renewable energy standards or other low carbon fuel standards. We did not locate any study that allocated GHG emissions from price effects to the fossil fuel life cycle in gCO2e/MJ of fuel product.

Consistency of the indirect emissions source with the goal and scope of the FQD

In our expert opinion, the current level of information available on fuel price effect issues does not support their inclusion within the system boundary of fossil fuels considered under the FQD for the following reasons:

- First, while the price of fuels directly impacts its consumption, there are currently no widely accepted models that have demonstrated the European or global impact on oil markets related to oil price, consumption, production, and GHG emissions across all the economic sectors that are affected by petroleum.
- Second, while it is conceivable that such a model could be developed, its usefulness is questionable as several other significant factors have historically impacted the price and demand for oil that are outside the scope of such modelling, such as OPEC price targets and threats to supply such as wars and political unrest.

Urban sprawl

Description

This section deals with a specific type of price effect; namely, the argument that fossil fuels have enabled affordable personal transportation and opportunities for rapid economic development. To the extent that the price of fossil fuels affects personal transportation choices and development of urban areas and infrastructure, it is possible that fossil fuel use has indirectly led to lower-density, automobile-oriented development, or “urban sprawl”—

primarily in suburban and exurban areas. Urban sprawl, in turn, may contribute to increased consumption of fossil fuels for personal transportation across larger distances than if urban environments were more densely populated.[39] This creates an indirect feedback loop driven by economic considerations, and thus is treated as an indirect effect in this study. The indirect feedback loop is shown in Figure 5-11.

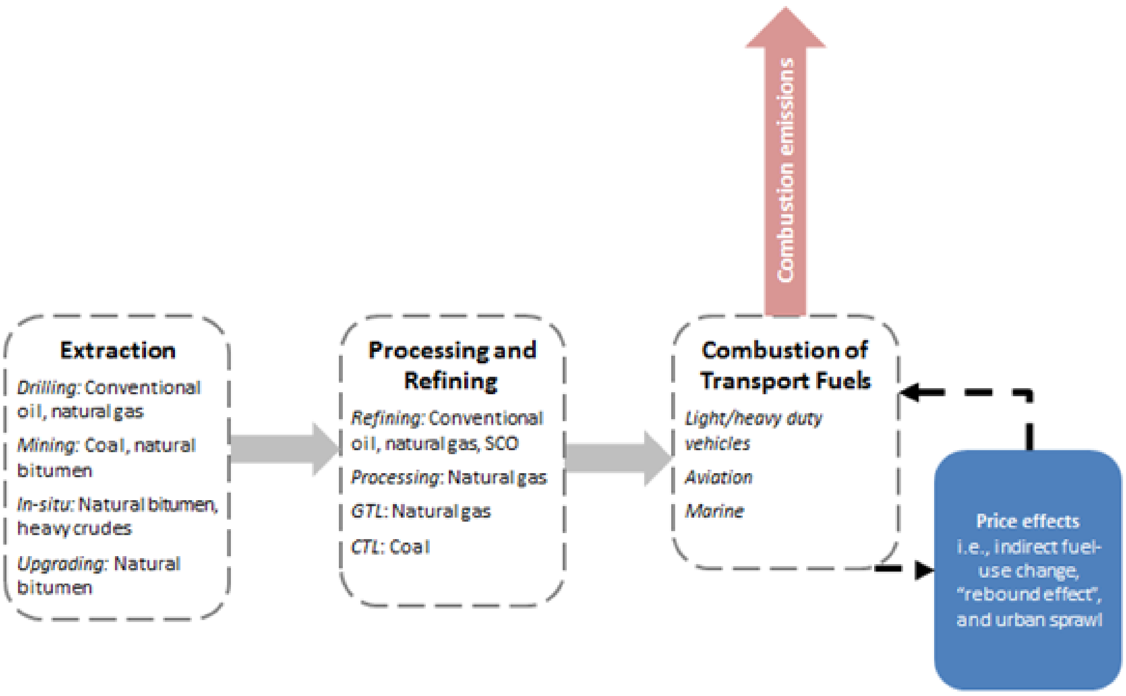

Figure 5-11: Placement of Urban Sprawl within Fossil Fuel Life Cycle

Although this effect was identified in a stakeholder interview, indirect emissions from urban sprawl have not been investigated in the life cycle literature on fossil fuels, nor have they been included in previous LCAs. This source implicates a much broader array of activities related to societal development, economic growth, and consumption that are far removed from the fuel life cycle. For example, the availability of affordable food has increased global population growth, and by a similar line of reasoning, the GHG emission impacts from this additional population growth would be attributed to agriculture. Consequently, although urban sprawl was identified as a possible indirect source and is addressed in this report, it is not well-established and further outside the scope of the fossil fuel cycle than the other emissions sources considered. We have included urban sprawl as a unique price effect to discuss the level of information currently available.

[39] See, for example, Newman and Kenworthy (1999), Puentes and Tomer (2008).

Treatment of this source in studies that support the FQD and fossil fuel LCAs

Indirect emissions from urban sprawl were not estimated in the literature that has informed methods for calculating GHG emissions of fossil fuels under the FQD. This approach is consistent with the existing LCA literature available on life cycle emissions from fossil fuels: we did not find evidence of studies that have investigated this effect as an indirect source of emissions from fossil fuels. This source was not included in the boundaries of the other high-quality; peer-reviewed LCA studies included in our review addressed this emissions source.

Quantitative estimates of this source and uncertainty

Several studies have attempted to quantitatively evaluate the effect of urban sprawl on GHG emissions. All assessments were made on the basis of GHG emissions per capita or per square meter of land area. We did not locate estimates that attributed GHG emissions from urban sprawl to a functional unit of fossil fuel energy (i.e., grams CO_2e per unit of energy supplied by fossil transportation fuels).

Norman et al. 2006 applied two case studies to compare the life cycle GHG emissions associated with high and low-density urban development in North America. This analysis factored in differences in construction materials, transportation distances & modes, as well as building operation. The results of the LCA indicated that low-density suburban development was more energy and GHG intensive by a factor of 2.0–2.5 than high-density urban core development on a per capita basis, as show in Figure 5-12.

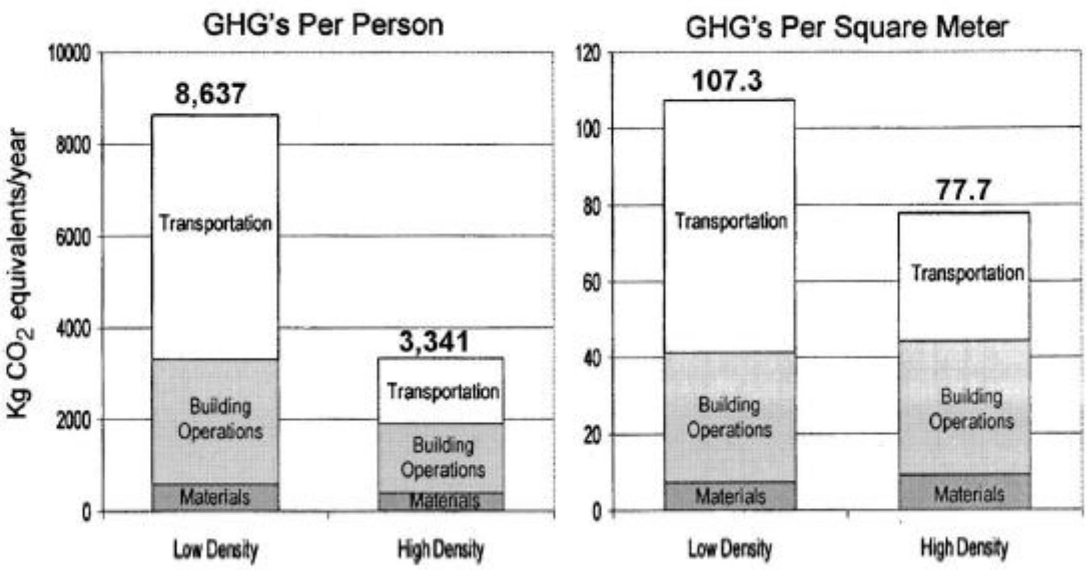

Figure 5-12: Annual Contributions from Various Building Life Cycle Phases in High and Low-Density Developments (source: Norman et al., 2006)

Other studies have identified a similar link to urban sprawl and increased GHG emissions from buildings and transportation, but also found that lifestyle choices and standard of living are also key factors that are independent of location. In case studies of Helsinki, Heinonen and Junnila (2011), Heinonen et al. (2011) have shown that energy production, building energy efficiency, and the consumption of goods and services are key drivers in urban GHG emissions, and that increased density is not necessarily a key factor in determining overall GHG emissions.

Shammin et al. (2010) compared the energy intensity of high and low-density households in the United States by using household patterns of consumption in conjunction with individual energy intensities of goods and services to determine total energy requirements. Though sprawl-related factors[40] accounted for about 83% of the average household energy consumption, the authors found that rural households were only 17–19% more energy intensive than urban households (Shammin et al. 2010). An analysis of uncertainty showed there was an 85% probability that rural households are more energy-intensive than urban households, 67% probability that the difference is greater than 10%, and 50% probability that the difference is at least 17% (Shammin et al. 2010, p. 2372). The difference in energy use between low and high-density areas was lower than indicated in other urban sprawl literature because households in dense areas have not taken advantage of measures to reduce energy consumption, and savings in housing and transportation categories enable households to increase consumption in other areas, which offset the benefits (Shammin et al. 2010, p. 2372).

Degree of consensus over whether indirect emissions can be allocated to the fossil fuel life cycle

Studies have generally found that transportation costs—of which fuel prices are one component alongside other factors such as fuel efficiency and technological improvements—are a factor behind urban sprawl, but there are other important effects and it is difficult to isolate which of these are the key, prevailing factors.

For example, Bart (2010) investigated the link between transportation emissions and three factors: population, GDP growth, and “artificial land area”—an indicator of the extent of urban areas.[41] The largest increases in transportation emissions were found in countries that did the least to mitigate expansion of artificial area development through policy measures. Though low prices of fossil fuels may play a role in encouraging sprawl, policies have a much larger impact: countries which strictly restricted the expansion of artificial areas, such as the U.K., experienced economic growth without the same degree of artificial area expansion as Portugal, Spain and Ireland. (Bart 2010)

Christiansen and Loftsgarden (2011) reviewed the key drivers behind urban sprawl in Europe. Alongside transportation costs, they examined a number of factors, including the effects of macro-economic factors affecting migration globally and within the European Union, failures in markets for land, competition between urban centres and surrounding municipalities, land prices, population growth, housing preferences, and land use policies and urban planning. The effect of these factors on urban sprawl is difficult to determine as they are interrelated and vary greatly depending on local or regional socio-economic conditions and policies.

[40] Shammin et al. (2010) define these as housing and transportation expenditures, including residential fuel use, vehicle-related expenditures, and gasoline.

[41] Bart (2010) defined “artificial areas” according to land uses in the CORINE land cover database, which include all buildings and transport infrastructure.

Limitations in evaluating the emissions source

Overall, it is difficult to isolate the most-important drivers and the extent to which each contributes to urban sprawl. We did not locate any studies that attempted to allocate GHG emissions from urban sprawl to the fossil fuel life cycle.

Consistency of the indirect emissions source with the goal and scope of the FQD

In our expert opinion, urban sprawl issues are unrelated to the scope of the FQD and therefore lie outside of the system boundary for the following reasons:

- First, while the availability of fossil fuels has, by lowering transportation costs, likely contributed to urban sprawl, other factors—such as the extent of existing transportation infrastructure, the availability of public transit alternatives, land use policies, land price differentials in urban and suburban or rural areas, failures in the market for land, lifestyle choices, and consumption patterns—play a critical role as well. Consequently, attempts to allocate GHG emissions from urban sprawl to fossil fuel use are highly uncertain, would require arbitrary assumptions on the extent that fuel price drives urban sprawl, and would need to account for a vast array of region- and city-specific considerations that affect urban development.
- Second, while transportation distance does affect GHG emissions, there is evidence that the difference in GHG emissions between high- and in low-density areas is significantly offset by higher levels of other types of consumption in high-density households. This suggests that urban sprawl and GHG emissions may not be as strong as indicated in studies that have only looked vehicle miles travelled.
- Finally, the overall linkages between urban sprawl and the fossil fuel life-cycle implicate a much broader array of activities involving societal development, economic growth, and consumption that are removed from the fossil fuel life cycle. This source is not addressed in currently life cycle literature, is not well-established, and lies further outside of the scope of fossil fuel production and end use than the other emission sources considered in this report

As a result, exclusion of indirect GHG emissions associated with urban sprawl is appropriate and is also consistent with the high-quality, peer-reviewed LCA studies of fossil fuels that were included in the literature review.

5.6. Export of co-products to other markets

Description

During the production of premium refined fossil fuels such as gasoline, diesel, and aviation fuel[42], refineries also produce other lower-value products such as liquefied petroleum gas (LPG), coke, sulphur, residual oil, and asphalt, which are known as co-products. High quality LCA studies include the direct attribution of GHG emissions from co-products, either by substitution, allocation or marginal analysis. However the indirect GHG emissions from the

[42] Aviation fuel is not under the scope of the FQD, but it is generally considered a premium transportation fuel output from refineries.

impact that co-products have on global energy markets or the economy have not been well characterized.

The production of co-products is related to the production of premium fossil fuel products at the refinery. Consequently, changes in the input crude slate at refineries, their operation, or the slate of products produced at the refinery, will impact the types and amount of co-products produced. Co-products are sold to other markets, such as the electric power sector, where they displace other fuels. As a result, changes in the quantity of co-products at European refineries may have an indirect effect on the displacement of fuels in other sectors, and GHG emissions from the production and combustion of these fuels relative to co-products at refineries.

Jacobs (2009) states that when completing life cycle analyses for fossil fuels, determining the impact of the production and usage of co-products is important. In addition, they state it is important to evaluate the corresponding impact on the energy markets wherein these co-products are used and subsequent changes in the demand of other major fuels. These impacts can be segregated into two different approaches described as first (direct) and second order (indirect) approximations in Jacobs (2009). The indirect feedback loop is shown in Figure 5-13.

According to Jacobs (2012), the first order approximation is the distribution of the GHG emissions to products from the production and usage of co-products. Attributing the GHG emissions to products from the production and usage of these co-products is important as refinery configuration and energy intensity can vary significantly due to processing heavy or light crudes, and will result in varying GHG emission LCA intensities. In high quality LCAs, GHG emissions from refinery co-products are attributed to products using several approaches, such as substitution, allocation, and marginal analysis. In substitution, the first order approximation analyses the difference in emissions from producing and consuming a co-product versus its substitution (i.e. petroleum coke for coal). Whereas, in allocation, GHG emissions from the production and usage of co-products are assigned to specific major products based on physical or economic attributes, such as mass, energy content, or value. Finally, in marginal analysis the refinery co-products are kept constant and the gasoline and diesel production is changed.

According to Jacobs (2012), the second order approximation is the indirect emissions from changes in the global energy systems wherein the co-products are used or exported. As an example, co-product petroleum coke produced in oil refineries can be used as a feedstock in power generation where it displaces coal as a feedstock. When considering this scenario in a life cycle analysis, the indirect emissions are determined from the change in the overall global energy market of coal, coke, and power through economic system modelling.

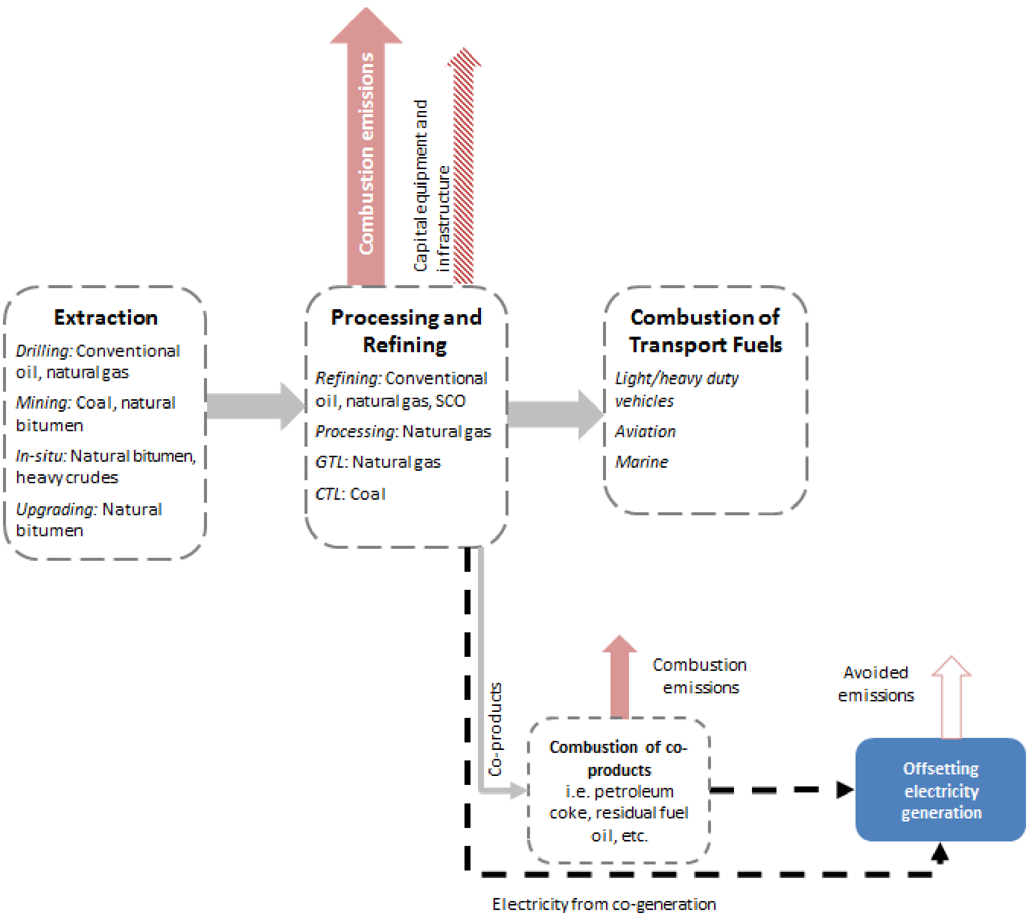

Figure 5-13: Placement of Co-products within Fossil Fuel Life Cycle

Treatment of this source in studies that support the FQD and fossil fuel LCAs

The approach of the study supporting the FQD, JEC (2011), was to determine a change in GHG emissions from the production and use of conventional fuels by marginal analysis, by reducing the demand of gasoline and diesel, and keeping other products and co-products constant. The reasoning for this approach in the JEC (2011) report is as follows:

> *[O]il refineries produce a number of different products simultaneously from a single feedstock. Whereas the total amount of energy (and other resources) used by refineries is well documented, there is no simple, non-controversial way to allocate energy, emissions or cost to a specific product. Distributing the resources used in refining amongst the various products invariably involves the use of arbitrary allocation keys that can have a major influence on the results. More to the point, such a simplistic allocation method ignores the complex interactions, constraints, synergies within a refinery and also between the different refineries in a certain region and is likely to lead to misleading conclusions. From an energy and GHG emissions point of view, this is also likely to give an incomplete picture as it ignores overall changes in energy/carbon content of feeds and products. […] The difference in energy consumption and GHG emissions between the base case and an alternative can be credibly attributed to the single change in gasoline or diesel fuel production.*

In other words, the JEC's approach assumed that the production of co-products would remain constant, and modelled the change in energy and GHG emissions attributable to gasoline and diesel. In this approach, GHG emissions from co-products effectively cancel out between the "business-as-usual" scenario (or base case) and the alternative scenario. This assumes that the changes in input crude slate and operations at refineries will not affect co-products, but shifts in these factors could result in changes in the amount of co-products produced (Unnasch et al., 2009, p. 38). The JEC report does not include a quantitative calculation methodology that would estimate the indirect emissions from the impact of changing co-products in overall energy market systems.

Quantitative estimates of this source and uncertainty

Unnasch et al. (2009) summarises the complex trajectory of changes in the GHG emissions from co-products due to a change in the demand of fossil fuels and argues that these effects are not well demonstrated in life cycle analyses. Refinery economics are driven by the production of highest-value, premium fuels—i.e., gasoline, diesel, and aviation fuel: these are the final products of which refineries seek to maximise production. The study describes a situation wherein displacement of gasoline with alternative fuels, decreases the demand for petroleum gasoline and therefore the consumption of crude oil. Consequently, the production of co-products such as petroleum coke and residual oil decreases, thereby decreasing the GHG emissions related to the combustion of these products. Subsequently, the prices of co-products increase, resulting in either a decrease in the consumption of these products or a shift towards other fuels like coal or natural gas.

Unnasch et al. (2009) discusses the difficulty in predicting the indirect GHG emissions from co-products because of the variety of markets for these co-products; they then examine the effects on GHG emissions from the reduction in co-product use, and increases in coal and natural gas use. The authors provide a scoping-quality estimate of the market mitigated effects of co-products at 2 to 4 gCO_2/MJ. In other words, a reduction in co-product production (in this case, residual fuel oil and petroleum coke) would result in an overall decrease in GHG emissions by 2 to 4 gCO_2/MJ of gasoline produced.

The reduction in GHGs comes from reduced transportation of crude oil, reduced residual oil production at refineries, GHG emission reductions in electricity production from increasing natural gas and renewable power, and reductions in petroleum coke use and in other petroleum co-products (Unnasch et al. 2009, Appendix A, pp. 79-81). This estimate was done for illustrative purposes and made several market assumptions such as fuel mix, market share and supply and demand elasticity.

We investigated several other reports to examine the inclusion of indirect emissions from co-products. Brandt (2011) classifies market considerations as being important but does not include their effects in the analysis. Lattanzio (2012) agrees that comparing GHG emissions from co-products that are used within the refineries versus those that are stored and combusted elsewhere is difficult.

Degree of consensus over whether indirect emissions can be allocated to the fossil fuel life cycle

The studies agree that the indirect GHG emissions from the impact co-products have on global energy systems is an important factor, however this was not included in any of the studies we investigated. The authors acknowledge the significant difficulty in developing a macroeconomic modelling system that can represent supply and demand and the indirect effects across the range of energy systems. However due to current lack of quantifiable estimates this indirect source cannot be allocated to the fossil fuel life cycle.

Limitations in evaluating the emissions source

Overall, it is difficult to quantify the indirect GHG emissions from the impact co-products have on energy systems as a result of a policy. This is because the impact will affect the overall global (and not just the EU) consumption and prices of these co-products and of the other fuels in the markets wherein these co-products are utilised. Additionally, determining this impact on overall global consumption cannot be modelled without allowing simplistic assumptions which inaccurately represent the complex relationships between feedstocks and products or co-products. From the literature reviewed, no studies were identified that allocated indirect GHG emissions from the change of co-products in the energy market to the fossil fuel life cycle in gCO_2e/MJ of fuel product.

Consistency of the indirect emissions source with the goal and scope of the FQD

In our expert opinion, the current level of information available does not support inclusion of indirect emissions from co-product global market impacts within the goal and scope of the FQD for the following reasons:

- First, while all studies discuss the importance of including this indirect emission source, none of them quantified the source at a sufficient level of detail to allow inclusion within an LCA.
- Second the only quantitative estimate located was developed for illustrative purposes and made several market assumptions such as fuel mix, market share, and supply and demand elasticity.
- Third, there are currently no widely acceptable macro-economic models that have demonstrated the European or global impact on energy system supply and demand related to co-product consumption, production, and GHG emissions.

As a result, exclusion of indirect GHG emissions associated with co-products in global energy systems is appropriate. This treatment is also consistent with the high-quality, peer-reviewed LCA studies of fossil fuels that were included in the literature review, see Table 3-3.

6. Conclusion

This section provides an overview of the quantified estimates for indirect emissions on a source-by-source basis and summarises this study's conclusions drawn from the literature review. Quantitative emissions estimates from the studies reviewed in the literature review are provided in Table 6-1.

Table 6-1: Overview of estimated scale of GHG Emissions relevant to EU fuel consumption based on Literature Review

Indirect Emission Source	Applicable Fossil Fuel Type(s)	Emission Estimate: g CO_2e/ MJ of Fuel	Emission Estimate: % of WTW GHG emissions[43]	Notes
Induced land development	Fossil fuels extracted in remote, forested areas	0.6-1.0 (For relevant fuel)	0.7-1.1%	Based on a case study on road-building in Ecuador
Military involvement[44]				
Military protection	Conventional oil supplied through the Persian Gulf, extracted from Iraq, Libya, and other conflict or unstable areas	0.8-1.1	0.9-1.3%	Calculated from data in Unnasch et al. (2009)[45]; high end assumes GHG emissions from military activities are allocated only to transportation fuels derived from Persian Gulf exports to the U.S. Low end allocates GHG emissions to global crude oil and condensate exports from the Persian Gulf.
War-related emissions		1.2 (For relevant fuel)	1.4%	Calculated from data in Liska and Perrin (2010). GHG emissions allocated to global crude oil and condensates exported from the Persian Gulf exports.
Accidents	Fossil fuels[46]	Negligible (i.e.,<0.00003)	Negligible	Calculated from data on marine accidents and oil spills.Evaluations have focused on other toxic emissions and ecosystem impacts rather than quantitative GHG estimates.
Market-mediated effects				
Export of co-products to other markets	Crude oil-derived fuels	2-4	2.2-4.5%	Developed by Unnasch et al. (2009) as an illustrative estimate; made several market assumptions such as fuel mix, market share, and

43 Expressed as a percentage of the life cycle GHG intensity of petrol from conventional crude (87.5 gCO_2/MJ) in EC (2011).

44 Note that these estimates are based on U.S. military activites and allocated on the basis of U.S. oil imports and transportation fuel use. Military activity emission estimates for the EU would be different and would need to differentiate by EU military activites and activities in other countries based on crude oil origin; e.g., refined fuels imported from the U.S. Gulf Coast that may have been refined from Persian Gulf crude oil imports.

45 Liska and Perrin (2010) provided quantitative estimates that fall within this range.

46 "Fossil fuels" refers to transportation fuels produced from crude oil, natural gas, and coal fuel sources, including both conventional and unconventional extraction methods.

Indirect Emission Source	Applicable Fossil Fuel Type(s)	Emission Estimate		Notes
		g CO_2e/ MJ of Fuel	% of WTW GHG emissions[43]	
				supply and demand elasticity.
Price effects	Fossil fuels[46]	0.25	0.28%	Rebound effect emissions are extrapolated from consumer response to fuel economy savings. Emission estimate is derived from rebound effect of 0.26%.
Marginal effects				
On fossil fuel sources	Crude oil-derived fuels, natural gas	Not available	Not available	No quantitative estimates were available in the literature surveyed
On operation of refineries	Crude oil-derived fuels			
On electricity generation	Natural gas			

ICF found that the existing body of life cycle literature does not apply uniform definitions to direct and indirect emission sources and that there is no consensus in the literature or among stakeholders about which fossil fuel emissions sources constituted "direct" or "indirect" sources. Indirect emissions sources are particularly challenging to account for in life cycle approaches—these sources lie on the periphery of LCA state of the art and there is a lack of established methodologies and guidance for accounting for them.

It is our opinion that the level of information currently available in the literature reviewed on these emission sources and methods for quantification and methodological considerations argue against inclusion of these sources within the scope of assessing life cycle GHG emissions for fossil fuels under the FQD. ICF developed the following conclusions on each source based on our survey of LCA standards, guidance documents, the literature reviewed in this report, and conversations with stakeholders:

- **Induced land development:** While GHG emissions associated with ILUC constitute a large source of emissions for biofuels, the potential for induced land development to contribute substantially to life cycle emissions of fossil fuels is likely low, with the only quantitative estimates available for single case studies which may not be necessarily representative and which in any case are only relevant for oil produced in forested regions. Unlike for biofuels, there are no widely accepted models that have estimated the GHG emissions of induced land development from fossil fuel production.
- **Military involvement:** GHG emissions from military involvement are a contested source of indirect emissions. Primarily, the current methodologies for allocating GHG emissions from military activities to fossil fuels are highly subjective, requiring arbitrary decisions in terms of the time period over which GHG emissions and crude oil production volumes are evaluated, the volume over which GHG emissions are allocated (e.g., imports to a specific country, global exports, global consumption), and the sources of emissions, whether conflict or security-related. Exclusion of this source is consistent with other

jurisdictions that have investigated this issue, notably within the EPA's Renewable Fuel Standard. None of the studies explicitly discussed petroleum exported from the Persian Gulf into the EU and the degree to which military involvement emissions (primarily from the U.S. military) was attributable to that petroleum in the EU.

- **Accidents:** Current life cycle guidance and the level of data available on accident and spill emissions indicate that this emission source should not be included within the scope of the FQD. Assessments on the environmental impacts of accidents have focused primarily on local toxic emissions, pollution, and impacts on marine and terrestrial ecosystems rather than GHG emissions. This source is not included in other existing LCAs of fossil fuels in the literature surveyed, and exclusion of accidents is consistent with European guidance on the development of LCI data for the ILCD data network. Accidents are fundamentally different than normal operating conditions and methods for including GHG emissions from infrequent accidents and oil spills into LCA studies are still under development. In terms of overall magnitude, large-scale accidental releases of oil are relatively rare events and have been decreasing since 1973; they represent a small portion of the oil produced and transported worldwide and may thus constitute a very small source of emissions. Our calculations show that marine accidents and oil spills add a negligible amount of GHG emissions to the total fossil fuel life cycle.
- **Export of Co-Products to Other Markets:** None of the studies assessed as part of the literature review quantified this source of emissions at a sufficient level of detail to allow inclusion within an LCA. The only quantitative estimate located was developed for illustrative purposes and made several market assumptions such as fuel mix, market share, and supply and demand elasticity. Furthermore, there are no accepted macro-economic models that have demonstrated the European or global impact on energy system supply and demand related to co-product consumption, production, and GHG emissions.
- **Price Effects:** There are no widely-accepted models for evaluating behavioural responses in European markets related to oil price, consumption, production, and GHG emissions across all the economic sectors that are affected by petroleum. Furthermore, any modelling work is complicated by political factors such OPEC targets.
- **Urban Sprawl.** This specific price-related effect is broadly outside of the system boundary relevant to the scope of the FQD. Fossil fuel use is related to urban sprawl through a vast array of activities related to societal development, economic growth, and consumption that are far removed from the fossil fuel life cycle. Similar activities are excluded from the boundaries of other systems as well; for example, with respect to the availability of affordable food and population growth. Indirect emissions from urban sprawl have not been treated in any of the literature surveyed, and within what secondary literature exists, the contribution of fossil fuels to urban sprawl is mixed, as a host of other factors play a critical role as well. Methods for allocating GHG emissions from urban sprawl indirectly to fossil fuel use would require entirely arbitrary assumptions and would need to account for a vast array of region- and city-specific considerations that affect urban development. There is also recent evidence that the difference in GHG emissions from high- and low-density areas is significantly offset by higher levels of other types of consumption in high-density households. This suggests that urban sprawl and GHG emissions may not be as strong as indicated in studies that have only looked at vehicle miles travelled.

- **Marginal Effects:** This source includes two different types of "marginal" or consequential effects: changes in the marginal fossil fuel resource consumed (including both the type of fossil fuel resource extracted and marginal changes in the operation of refineries), and marginal changes in the electricity sector due to changes in natural gas transportation.
  - The information currently available on marginal changes in the fossil fuel resource consumed is insufficient to include these effects as an indirect emissions source in the scope of the FQD. No quantitative estimates of this effect are available in the literature surveyed, and there is still a great deal of uncertainty over the timing, magnitude, and direction of these effects.
  - There is currently a paucity of data available on changes in electricity generation that may result from increased demand for natural gas as a transportation fuel. In assessing electric power markets in California, McCarthy et al. (2010) found that the GHG intensity of electricity generation is very sensitive to demand, but did not assess how changes in demand for natural gas affects electricity sector emissions. The current level of information on this effect is insufficient to make a determination of the significance of its inclusion in the boundaries of the FQD.

These findings are our expert opinions based on the current state of the literature that exist on indirect GHG emissions sources from fossil fuels. The results of this assessment have shown that there is, in particular, a paucity of research in this area that is specific to a European context—particularly in terms of quantitative estimates of potential GHG emissions sources. Nevertheless, it is clear that when considered at a global level, in a manner which could be relevant to affecting the GHG intensity of fossil fuels, the probable level of these indirect effects would be small. This assessment does not rule out the possibility that further analyses will, in the future, develop better characterisations of these emission categories that enable them to be re-assessed for inclusion within the fossil fuel life cycle. To this end, we recommend that the European Commission continue to monitor the state of the science on potential indirect emission sources from the fossil fuel life cycle. In particular, initiatives currently underway by CARB to undertake analyses may provide further information and analysis on indirect effects of the fossil fuel life cycle.

7. References

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