The Implications of Life Cycle Assessment in Biofuel Policy:

Assessing the Influence of Life Cycle Assessment on Sweden's Biofuel Industry

Michael Martin[a], David Lazarevic,[b,c] Frida Røyne[d] and Tomas Ekvall[a]

a-IVL-Swedish Environmental Research Institute (michael.martin@ivl.se)
b-KTH-Royal Institute of Technology
c- SYKE-Finnish Environmental Research Institute
d-SP Technical Research Institute of Sweden

1 Aims and objectives

This projects **aims** at understanding the implications of the increased importance of life cycle thinking (LCT) and life cycle assessment (LCA) in European and national policies on Sweden's biofuel industry. This will be accomplished by analyzing how, and in what forms, LCA and LCT practices have responded to European and national biofuel policies and the influence of LCA and LCT on business practices and decision-making.

This project is interdisciplinary in nature, as it assesses the impact of European and national level policies in terms of a) practices and decision-making at the company level, b) institutionalization of life cycle approaches at the industry level and c) environmental performance of biofuel production.

The **objectives** of this project are to:

- **O1**: Understand and analyze the institutionalization and legitimacy of LCA in Sweden's biofuel industry
- **O2**: Facilitate the development of more coherent environmental performance indicators for biofuel production.

This **project is unique** as it is, to the best of our knowledge, the first research to look at the influence of LCT and LCA in the biofuel industry in Sweden in terms of LCT and LCA practices in businesses and the institutionalization of the life cycle approach in the industry.

2 Overview of the research area

LCT is visible in several European thematic strategies and directives (e.g., the Waste Framework Directive 2008/98/EC and the EcoDesign Directive 2009/125/EC). However, the Renewable Energy Directive (2009/28/EC) (RED), which has a significant influence on biofuel production, is the only directive that requires LCA-based assessments to justify the 'sustainability' of biofuels (see EC, 2009). This has created a unique situation which mandates that the minimum greenhouse gas (GHG) reduction targets for biofuels should be based upon LCA; the only industry facing such requirements although e.g. energy producers using biomass may also need to produce LCAs in the near future.

2.1 Institutionalization of LCA

In European policy-making, LCT and LCA have become vital when addressing the environmental sustainability of products and services throughout their life cycles (i.e. from a cradle-to-grave perspective). LCT can be described as a way of "understanding human-nature interactions, and responsibility for them, in terms of a system of materials, energy, information and management flows" (Heiskanen 2000:56), whereas LCA is an analytical tool defined as the "compilation and

evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" (ISO 2006:2).

According to the European Environmental Agency (EEA) (1997), the use of LCA was originally primarily advocated as a voluntary measure for producers. EEA was at first less optimistic about its use as a mandatory measure, suggesting it could "lower the quality of tools" and "impose excessive costs for industry." Indeed, European waste policy has steered away from mandating the use of LCA to promoting the use of LCT (see Lazarevic et al. 2010). Today, however, LCA has acquired the position as the principal tool to assess environmental impacts of product systems.

In addition, Heiskanen (2000) claims that life cycle approaches have become institutionalized (see Tolbert & Zucker 1994 &1999) among many societal actors. Institutionalization refers to the process in which rules, norms and typifications are derived from a cumulative history into shared rules, norms and typifications that govern action and interaction (Barley & Tolbert 1997). Studies have been conducted on the institutionalization of LCA in businesses (Frankl & Rubik 1999; Baumann 1998,2000), market actors (Heiskanen 2000) and the waste management sector (Lazarevic 2012). However, to our knowledge, no studies have investigated the institutionalization of LCA in a field where its application is legally mandated, nor the actors' positions and controversies surrounding such an approach.

LCA is the principal tool used to assess the environmental impacts of biofuel systems. In the biofuel industry, LCA has been addressed in many earlier studies to understand and compare biofuels to fossil alternatives, obtain information about the main environmental impacts related to biofuels and to identify the main hotspots in the product/service life cycle; see e.g. Cherubini et al. (2009) and Van der Voet et al. (2010) for reviews of LCAs on biofuels.

The European Commission (EC, 2009) has addressed LCA and LCT in the Renewable Energy Directive for assessing the environmental sustainability of biofuels. The directive includes qualitative assessments such as changes in land use with high biodiversity and outlines quantitative LCA methodologies to assess the emissions of greenhouse gases from biofuel production and the benefits provided by the replacement of fossil fuels with biofuel alternatives (EC, 2009).

Apart from institutionalization, another important issue concerning LCA in biofuel decision-making and policy-making is legitimacy, which is especially relevant considering the controversy surrounding the environmental performance of biofuels. The legitimacy surrounding the role of LCA in waste policy has been previously studied (Lazarevic 2015) in context of plural systems of legitimacy in the construction of collective agreements (Boltanski and Thévenot, 2006). Whilst some studies have investigate the controversies surrounding biofuels from such perspectives (e.g. Lehtonen 2014; Gouveia & Lehtonen 2015), the role of sustainability assessment in these controversies has yet to be fully explored.

There is currently a push from political and academic spheres to improve LCA methodologies for biofuels. Recently, there have been a large number of studies calling for policies to review e.g., indirect emissions from land use changes and to show the adverse effects that biofuel production may have (see Plevin et al., 2014). However, disagreements among researchers on the applicability, exhaustive nature, and complete coverage of impacts produced when using different methodological approaches (consequential LCA vs. attributional LCA) is occurring in the scientific community. For

example, Plevin et al.'s (2014) critique of attributional LCA attracted four letters to the editor and led to an editorial outlining the controversy (see Anex and Lifset, 2014). Furthermore, the use of carbon dioxide (CO_2) emissions as a sustainability indicator has been questioned (Laurent et al. 2012; Parajuli et al. 2015; Martin et al. 2015a), suggesting that environmental impacts categories other than Global Warming Potential (GWP) and land use should be taken into account (e.g. biodiversity, resource depletion, acidification potential, loss of nutrients, etc.).

2.2 Implications of LCA applied to Biofuel systems

While academics and policy makers have addressed the shortcomings of LCA for biofuels in policies, the implication of LCA is not entirely apparent regarding LCA practices in industry and its influence on the innovation and development of products and management practices of biofuel producers' operations.

Some biofuel producers have suggested that policies and regulations have hindered development and investments (Martin, 2015; Lantmännen, 2014). This has been primarily due to limits on biofuels produced from "food crops" and the possible introduction of indirect land use factors of e.g., rapeseed, which would reduce the number of biodiesel producers which could meet life cycle emissions reductions (Börjesson et al, 2013). Recent debate articles highlight the effects that these LCA-based decisions may have on both socio-economic and environmental spheres (see e.g. Börjesson, 2012 and Eklund & Frankelius, 2014).

2.3 Research questions

The project will address the following research questions, connected to the project objectives:

- ***RQ1: What influence has European and national biofuel policy had on life cycle practices in companies and at the industry as a whole in Sweden? (addressing O1)***
    - *RQ1.1: How is LCA practiced in biofuel companies in Sweden?*
    - *RQ1.2: What are the main factors in the institutionalization process of LCA in Sweden's biofuel industry?*
    - *RQ1.3: How is the legitimacy of LCA perceived by different actors in the biofuel industry and what are the controversies surrounding its implementation?*
    - *RQ1.4: Has the use of LCA influenced the environmental performance of biofuels and other products?*
- ***RQ2: Does current LCA methodology address the environmental sustainability of biofuels in a holistic manner? (addressing O2)***
    - *RQ2.1: Are the impact categories (e.g. GWP) currently covered by LCA in policies adequate to address environmental sustainability?*
    - *RQ2.2: What are the implications of introducing environmental impact categories other than* GWP *on biofuel policies, production and environmental sustainability?*

3 Project description and structure

The project will analyze the influence of LCA on the biofuel industry and environmental sustainability with regard to the product development and organization at biofuel producers. This will take place in 3 concurrent work packages using a combination of qualitative and quantitative methods. The project will run for a period of 11 months, commencing in late November 2016 and run through

September 2017 (with results presented in the summer or Fall of 2017). See Table 1 for a breakdown of different activities in each work package (WP) and the responsible researchers for the activities.

3.1 WP1-Implications of Life Cycle Approaches in the Biofuel Industry (Nov 2016–May 2017)

Contributes to Objectives O1, and answers RQ1

WP1 will investigate the institutionalization of LCA biofuel production companies in Sweden and Europe. It will analyze the role of organizational context on the institutionalization process and LCA practices (organizational processes, role(s) in organizational processes, use(s) in corporate and public discourses, preferred methodological choices and data sources, etc.) and the implications it may have on products in these companies. Furthermore, WP 1 will investigate the legitimacy of LCA in biofuel policy-making and how scientific controversies extend to the public discourse on the sustainability of biofuels.

Methods and data

WP1 will employ qualitative research methodologies. Semi-structured interviews will be conducted with biofuel producers in Sweden and Europe. Swedish companies may include: Biogas - Svensk Biogas, Swedish Biogas International, Göteborg Energi; Ethanol - Lantmännen Agroetanol (Wheat), Sekab (Cellulosic), ST1 (Waste); Biodiesel - Perstorp, Energifabriken; and HVO – PREEM. European companies will include several comparable systems to Swedish systems.

The interviews will serve as a primary source of data in the analysis of the institutionalization of LCA within these companies and how companies organize their LCA related activities, and the legitimacy of LCA in decision-making and policy-making.

3.2 WP2-Applicability of Environmental Sustainability Indicators to Assess Biofuels in Policy (July 2016–April 2017)

Contributes to Objectives O2, and answers RQ2

While WP1 will analyze the implementation of LCA, WP2 will assess the applicability and feasibility of introducing impact categories other than GWP (i.e. CO_2 eq. emissions) which are currently used and regulated. This is done in order to contextualize the environmental sustainability assessment of biofuels and the implications of such an assessment for biofuel producers. This will be done by analyzing the level of methodological development and uncertainty of relevant impact assessment categories, actors' and decision makers' attitudes to these impact assessment categories, and analyzing the legitimacy and potential controversies related to including such indicators in future biofuel policies.

Methods and data

WP2 will employ qualitative research methodologies such as interviews and open-space workshops with biofuel producers in addition to biomass producers, academia, governmental institutions (in order to address policy makers) and non-governmental organizations.

Previous work on the salient impact categories used to assess biofuels in Swedish research, will provide important background input for the study (see Martin et. al, 2015a). Open space workshops have also been used by Tomas Ekvall in previous projects for similar input from users. The project will

also contribute to current research at IVL, SP and KTH on environmental and social sustainability introducing biodiversity, toxicity, social and other impacts to produce more comprehensive life cycle impact assessment methodology for regional applications, i.e. Sweden. A such, there will also be many synergies with current projects by the applicants, which will allow the project to be completed given the allocated budget and timeframe. These will prove important to identify previous reviews of the impact categories assessed, important sustainability criteria and environmental implications of policy during the past years. Such projects include e.g.:

- Increased Biofuel Consumption and Trade in Sweden: Reviewing the Environment and Political Implications (Original Title, Accumulated Impacts of Biofuel Production in Sweden), *Funded by the f3-Swedish Knowledge Center for Renewable Transportation Fuels*
- Life Cycle Sustainability Evaluations of Biomass Chains: Current Practice, Limitations and Recommendations*. Funded by FORMAS*
- Carbon Vision? A Review of biofuel environmental systems analyses research in Sweden, *Funded by the f3-Swedish Knowledge Center for Renewable Transportation Fuels*

3.3 Project team

The project will include a team of researchers with extensive experience in quantitative and qualitative research with strong linkages to current research in order to ensure quality and efficiency in the project execution. Dr. Michael Martin, Dr. David Lazarevic and Dr. Frida Røyne will be the chief researchers in the project with support from Dr. Tomas Ekvall in order to ensure quality, exchange ideas and extend the results and knowledge produced to a broader network of researchers.

Dr. Michael Martin (MM) of IVL-Swedish Environmental Research Institute will act as **project leader**. MM is a senior researcher in the LCA group of the Organisations, Products and Processes Division with experience applying LCAs to biofuel production systems, food system modelling, industrial symbiosis and analyzing conditions to increase biofuel production and utilization. MM has developed a large network of biofuel industry representatives during his previous research, developed and lectured in the course “Biofuels for Transportation” at Linköping University and has been coordinator for the f3-Swedish Knowledge Centre for Renewable Transportation Fuels. MM has led several projects on environmental impacts of bioenergy systems, mapping and valorization of biofuel by-products and has published several papers on LCA method development for integrated systems, reviewing biofuel development pathways and applications of LCA for renewable energy systems. MM is also the project leader for the Formas project “Life Cycle Sustainability Evaluations of Biomass Chains.”

Dr. David Lazarevic (DL) of KTH-Royal Institute of Technology and SYKE-Finnish Environmental Research Institute will also take part in the project and act as leader in several of the deliverables. DL has experience in studying and analyzing LCT and LCA in waste policy from a Science and Technology Studies perspective. DL’s PhD thesis, entitled “Life cycle thinking and European waste policy: between science and society”, investigated the application, institutionalization and legitimacy of LCA in the waste management sector in the UK and France. DL has published several articles on the application and legitimacy of LCA from perspectives based in the social sciences (i.e., institutional theory, the economies of worth, and the multi-level perspective of system innovation).

Frida Røyne (FR) of SP the Technical Research Institute of Sweden, Division of Energy and Bioeconomy, will have a major role in the project. Her research focus is LCA of forest products, such as chemicals, fuels, building materials and textiles. FR has previously conducted a review of 101 forest product LCAs, with a primary focus on climate impact and biodiversity metrics. FR has participated in projects related the bio-transition of the Stenungsund chemical industry cluster, and environmental assessments of bio-refineries and bioplastics, with associated scientific publications.

Dr. Tomas Ekvall (TE) of IVL-Swedish Environmental Research Institute is a specialist on LCA and other tools and methods for environmental systems analysis with more than 30 scientific papers and more than 100 conference contributions in the area. Previously Associate Professor in Energy Systems Technology, Chalmers University of Technology, he has extensive experience in the development and application of methodology for LCA and energy systems analysis in cooperation with industry and industry associations as well as governments and the European Commission. He contributed to the development of a framework for life cycle sustainability analysis in the EU FP6 project CALCAS. He recently applied this framework in a sustainability assessment of the transfer of residual heat from the industries in Stenungsund to the district heating systems of Kungälv and Gothenburg. He organized two Open-Space workshops in the context of this project.

4 Relevance for Göteborg Energi and Society

The project will generate results that will be useful for Göteborg Energi and other biofuel producers, on a strategic level to develop plans for future development to meet environmental performance targets and develop knowledge of LCA/LCT to be used in other areas of business when expanding renewable energy portfolios. The project will also highlight concerns from biofuel producers on the positive and negative aspects related to the requirement to produce LCAs and aid providing recommendations for future developments at Göteborg Energi in addition to other biofuel producers and authorities.

Knowledge produced in the project will increase knowledge on the implications of environmental policies that mandate the use of LCA; with importance for biofuel producers, policy makers and governing organizations (e.g. Energimyndigheten). It will provide Göteborg Energi and the biofuel industry with indications on the environmental sustainability of their production processes and imported fuels, as well as a depended understanding of how LCA is conducted in the industry.

The results from the project can be directly applied to other areas (besides biofuel production) for Göteborg Energi and other bioenergy producers. The knowledge and results are relevant for reviewing the use of LCA for solid biomass energy production, as many industrial actors have been concerned that mandates to require LCA may be passed in the near future and can learn from the adoption in the biofuel industry, which is similar in many ways.

Furthermore, the production of sustainable biofuels is an important approach to fulfil Sweden's environmental objectives and commitments in many sectors. The production and use of sustainable biofuels for transportation has a positive effect in sectors other than the mobility sector, such as: agriculture, energy, forestry and waste management. A successful biofuel industry in line with this application is of great societal relevance and addresses the European goals for promoting sustainable transportation fuels throughout Europe (EC, 2008 and EC, 2009) in addition to many other strategies for bio-based economies in Sweden, Europe and worldwide (see e.g. Formas, 2012 and EC, 2012).

The project will also engage policy makers to ensure that the results have an impact; this is done through the workshop and interviews. Information from the project can provide decision-makers with the knowledge to increase the efficiency of LCA application in relevant biofuel policies and policy instruments. Again, this knowledge is also transferrable to other sectors (e.g. solid biofuels for energy production) to improve resource efficiency and the use of LCA in other policy arenas.

5 Communication Plan

The results from this project will be communicated to stakeholders through a variety of media. This includes scientific papers, presentations at conferences, reports, workshops with stakeholders in addition to dialogue; see the table and descriptions below.

Stakeholder	Communication/Information Sharing
Research society	2 Scientific Articles Presentations at Scientific Conferences Scientific reports Workshop
Biofuel companies and other actors within the sector	As above, and: Presentations at National Conferences Meetings and Workshop Personal Dialogue
Policymakers, authorities and the general public	Reports and Scientific Articles Articles in Media (e.g. IVL newsletter, debate articles) Presentations at National and International Conferences Workshops

The project results will be communicated through international and national conference presentations (e.g. International Society for Industrial Ecology Conference, International Conference on Life Cycle Management and important international and national biofuel related conferences).

A workshop will also be conducted in collaboration with the Swedish Life Cycle Centre on the management of LCA in the biofuel industry (for which IVL, SP and KTH are members and have board members) in order to reach policy makers, industry (biofuel and other industries) and other LCA researchers in Sweden and start a dialogue between them.

During the project, 2 scientific articles will be produced in order to reach the scientific community with important information on the implications of LCA in biofuel policy. Results will also be communicated through research reports to allow for the dissemination of results to reach societal actors, industries active in biofuel production, authorities, policy makers and the general public as a successful biofuel industry is of great societal relevance. If required, a final scientific and economic report will also be produced at the end of the project for Göteborg Energi.

MM, DL, FR and TE are members of a number of national and international networks which will be important for gathering data, discussing and disseminating research results and methods. These include the following networks:

- Swedish Life Cycle Network
- SETAC-UNEP Life Cycle Initiative

- International Society for Industrial Ecology
- f3-Swedish Knowledge Centre for Renewable Transportation Fuels
- Centre for Resource Efficiency in Sweden
- Sustainability Transitions Research Network
- Bio4Energy

Furthermore, the applicants work in leading institutes in the development and application of LCAs. Prominent researchers in the field at IVL, SP and KTH include Tomas Rydberg, Johanna Berlin, Göran Finnveden, Miguel Brandão, Åsa Moberg, Martin Erlandsson and Lars-Gunnar Lindfors. The applicants also have collaboration with several prominent LCA research groups in Sweden.

6 References

Anex R. & Lifset R. 2014. Life Cycle Assessment Different Models for Different Purposes. Journal of Industrial Ecology 18(3), 321-323

Barley, S. R., & Tolbert, P. S. 1997. Institutionalization and structuration: Studying the links between action and institution. *Organization studies*, *18*(1), 93-117.

Baumann H. 1998. Life cycle assessment and decision making: theories and practices. Chalmers University of Technology.

Baumann H. 2000. Introduction and organisation of LCA activities in industry.The International Journal of Life Cycle Assessment, 5(6), 363-368.

Boltanski L & Thévenot L. 2006. On justification: economies of worth. Princeton University Press.

Börjesson P., Lundgren J., Ahlgren S., Nyström I. 2013. Dagens och framtidens hållbara biodrivmedel. F3 report 2013:13.

Börjesson P. 2012. ”Tragiskt felbeslut om etanolbilar”. Debattartikel, Ny Teknik 23 januari 2012. Available at: http://www.nyteknik.se/asikter/debatt/article3388756.ece Accessed: 2014- 02-14.

Cherubini F., et al. 2009. Energy- and greenhouse gas-based LCA of biofuel and bioenergy systems: Key issues, ranges and recommendations. Resources, Conservation and Recycling 53(8), 434-447.

Dalhammer C. 2007. An Emerging Product Approach in Environmental Law Incorporating the life cycle perspectivethesis, The International Institute for Industrial Environmental Economics, Lund University, Lund.

EEA 1997. LCA. A guide to approaches, experiences and information sources. European Environmental Agency.

Eklund M. & Frankelius P. 2014. Debattartikel, Ny Teknik. Dynamiska företag hotas av nya regler för biodrivmedel.

European Commission, 2008. 20 20 by 2020: Europe's Climate Change Opportunity. COM (2008) 30. , 1-12.

European Commission, 2009. DIRECTIVE 2009/28/EC on the promotion of the use of energy from renewable sources, Official Journal of the European Union, Brussels.

European Commission, 2010.Communication from the Commission on the practical implementation of the EU biofuels and bioliquids sustainability scheme and on counting rules for biofuels 2010/C 160/02, Official Journal of the European Union, Brussels.

European Commission, 2012. Innovating for Sustainable Growth: A Bioeconomy for Europe.

EuroObserv’ER. 2014. Biofuel Barometer 2014. Available at: http://www.energies-renouvelables.org/observ-er/stat_baro/observ/baro222_en.pdf.

Formas 2012. Swedish Research and Innovation Strategy for a Bio-based Economy Report: R3:2012.
Frankl P. & Rubik F. 1999. Life-cycle assessment (LCA) in business. An overview on drivers, applications, issues and future perspectives. Glob Nest Int J 1:185–194.
Gouveia, F. and Lehtonen, M. 2015. *Sustainability of ethanol fuel production in Brazil: controversies in a historical perspective.* Biofuels and (ir)responsible innovation: tensions between policy, practice and sustainable development. 13-14 April 2015. Eindhoven University of Technology, Eindhoven, NL
Heiskanen E. 2000. Translations of an Environmental Technique: Institutionaliztion of the Life Cycle Approach in Business, Policy and Research Networks. PhD thesis. Helsinki School of Economics and Business Administration.
ISO, 2006. Environmental Management - Life cycle assessment - Principles and Framework (ISO 14040:2006)
Lantmännen, 2014. Lantmännen Energis remissyttrande avseende ”Utredningen om en fossilfri fordonstrafik (SOU 2013:84)” (Dnr N2014-7434-E)
Laurent A., et al. 2012. Limitations of Carbon Footprint as Indicator of Environmental Sustainability. Environ. Sci. Technol. 46, 4100−4108.
Lazarevic D**.**, et al., 2010.The influence of the waste hierarchy in shaping European waste management: the case of plastic waste. Regional Development Dialogue 31(2): 124-148.
Lazarevic D. 2012. Life Cycle Thinking and Waste Policy: Between Science and Society. PhD thesis. Division of Industrial Ecology, KTH.
Lazarevic D. 2015. The legitimacy of life cycle assessment in the waste management sector. The International Journal of Life Cycle Assessment. DOI: 10.1007/s11367-015-0884-9
Lehtonen, M. 2014. Acceptance of Brazilian ethanol fuel and the role of expertise. *Biofuels*, *5*(3), 261-274
Martin M. 2013. Industrial Symbiosis in the Biofuel Industry: Quantification of the Environmental Performance and Identification of Synergies. PhD Thesis, Linköping University.
Martin M. 2015. Potential of Biogas Expansion in Sweden- Identifying the Gap between Potential Studies and Producer Perspectives. Manuscript. *Submitted to* Biofuels, January 2015.
Martin M. et al. 2015a. Carbon Vision? Reviewing Environmental Systems Analyses of Biofuel Production in Sweden. F3 project research report manuscript, 2015.
Martin M. et al. 2015b. Accumulated Impacts from Increased Biofuel Consumption in Sweden. F3 Project . Research manuscript, 2015.
Parajuli et al. 2015. Biorefining in the prevailing energy and materials crisis: a review of sustainable pathways for biorefinery value chains and sustainability assessment methodologies. Renewable and Sustainable Energy Reviews 43, 244–263
Plevin et al. 2014. Using Attributional Life Cycle Assessment to Estimate Climate-Change Mitigation Benefits Misleads Policy Makers. Journal of Industrial Ecology 18 (1): 73-83.
Tolbert, P. S., & Zucker, L. G. 1994. Institutional analyses of organizations: Legitimate but not institutionalized. *Institute for Social Science Research*.
Tolbert, P. S., & Zucker, L. G. 1999. The institutionalization of institutional theory. *Studying Organization. Theory & Method. London, Thousand Oaks, New Delhi*, 169-184.
van der Voet, E. et al. 2010. Life-cycle assessment of biofuels, convergence and divergence. Biofuels 1(3), 435-449.