REPORT f3 2016:09A

# SYSTEMIC CONSTRAINTS AND DRIVERS FOR PRODUCTION OF FOREST-DERIVED TRANSPORT BIOFUELS IN SWEDEN

# PART A: REPORT

Report from a project within the collaborative research program *Renewable transportation fuels and systems*

September 2016

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THE SWEDISH KNOWLEDGE CENTRE
FOR RENEWABLE TRANSPORTATION FUELS

# PREFACE

This project is financed and carried out within the f3 and Swedish Energy Agency collaborative research program *Renewable transportation fuels and systems* (Förnybara drivmedel och system).

f3 Swedish Knowledge Centre for Renewable Transportation Fuels is a networking organization which focuses on development of environmentally, economically and socially sustainable renewable fuels, and

- Provides a broad, scientifically based and trustworthy source of knowledge for industry, governments and public authorities
- Carries through system oriented research related to the entire renewable fuels value chain
- Acts as national platform stimulating interaction nationally and internationally.

f3 partners include Sweden's most active universities and research institutes within the field, as well as a broad range of industry companies with high relevance. f3 has no political agenda and does not conduct lobbying activities for specific fuels or systems, nor for the f3 partners' respective areas of interest.

The f3 centre is financed jointly by the centre partners and the region of Västra Götaland. f3 also receives funding from Vinnova (Sweden's innovation agency) as a Swedish advocacy platform towards Horizon 2020. Chalmers Industriteknik (CIT) functions as the host of the f3 organization (see www.f3centre.se).

Partners engaged in this project are IIIEE at Lund University, KTH Energy Processes, and IVL Swedish Environmental Research Institute.

**Acknowledgement**

This study would not have been possible without the financial support supplied by f3 and the Swedish Energy Agency. Nor would it have been possible without the generous contribution of time and effort from study informants. The project team wish to thank both these actor groups for their support.

**This report should be cited as:**

Philip Peck, Grönkvist, S., Hansson, J., Lönnqvist, T. and Voytenko, Y. (2016) *Systemic constraints and drivers for production of forest-derived transport biofuels in Sweden – Part A: Report.* Report No 2016:09A, f3 The Swedish Knowledge Centre for Renewable Transportation Fuels, Sweden. Available at www.f3centre.se.

# EXECUTIVE SUMMARY

## BACKGROUND

Diversification of forest industry activites into transport fuels is important for Swedish climate and energy policy goal achievement, and biofuel proponents also claim that it is important for Swedish forest industry competitiveness. There is significant ongoing research effort on biofuels for road transport and extensive experimentation on several technical platforms has been conducted. These different platforms each inter-relate in different ways with the forest sector and transportation fuel processing/value-adding industries. As of 2016, it remains unclear how many of these will emerge from niche applications or experimentation into the market mainstream.

Decisions regarding which particular forest-derived transport biofuels to pursue, and how best to pursue them, are complex and are influenced by many factors. On the technology side, such can include competition between technology development pathways; requirements for new distribution infrastructure; commitments to existing “locked in” fuel infrastructure; overall efficiencies of fuel production systems; relative engine efficiencies; rates of engine technology advances; and the progress in the development, or demonstration, of key technologies for fuel production. Consideration of socio-economics on the other hand, brings issues such as energy security; environmental quality; rural development potentials; consumer and political beliefs and preferences; media focus; vested industry interests; and logistics and spatial distribution. Misalignment among these many criteria has the potential to pose very real constraints upon the pursuit of any fuel pathway.

A constraining factor of particular relevance in the Nordic context is found within tensions that exist within the forest industries sector itself and is linked to ‘vested interests’. The forest industry is a critical sector for both biomass supply, and for technology system hosting. This study observes conflicting opinions regarding large-scale forest-derived tranport fuel production. Depending how initiatives are framed, they can be seen as a new source of competition for limited biomass feedstock supplies; a threat to the operation, or longevity, of important infrastructural items within a pulp mill; or as a complication for supply chains (e.g. with potential to increase transportation costs). Other issues that have been highlighted in recent years include differing views regarding the importance of cooperation between the forest industries and the petrochemical sector; which types of transportation fuels should or could be produced from the sector (e.g. syn-biogas, ethanol, methanol, DME, FT-diesel, etc.); and disparate opinions whether the main focus should be placed on biofuels or upon the inherent functions that exist in wood mechanical characteristics or chemicals.

This analysis demonstrates that Sweden hosts a very significant suite of advanced forest-derived transportation fuel initiatives despite the potential constraints or ‘complicating factors’ listed above. The technical function of a number of fuel platforms have been demonstrated at various scales, and biofuels are delivered to commercial transportation markets. However, the initial production cost for renewable transportation fuels is higher than that for fuels from the deeply entrenched fossil sector. This cost differential essentially precludes spontaneous development of the industry and significant support has been required. A variety of policy support mechanisms have helped the development of biofuel technologies and the creation of protected ‘spaces’ for experimentation. Policy support has also helped them to create spaces in the market.

This study has worked from the position that due to the inherently lower production costs for fossil based fuel systems (that are directly related to policy support and technical learning over many decades), it remains difficult to see the industry for renewable transportation fuels achieving independence from policy support in the short or medium term. This analysis is thus framed with the view that the need for ongoing support of 'protected spaces' for renewable fuels is a logical reality. An important portion of this work thus examines issues that affect delivery of efficient and effective support that can help to sustain such spaces.

## AIMS AND OBJECTIVES OF STUDY

This study is built from the premise that a number of the issues constraining the expansion of Swedish forest-derived transport biofuels have not been studied adequately. A need for a structured consideration of the degree of alignment of the technology systems with incumbent industries was identified. Thus, the analysis maps overlap and synergies (or competitive issues) between varying technology platforms, and seeks clearer insights into the preferences (or beliefs) of key 'supply chain' and 'user chain' actors regarding the future of a potential industry delivering modern transportation biofuels derived from forest-based feedstocks.

The assumption that the emergence of an advanced forest-derived biofuel system (an area of 'innovation') requires that the proponents of these new socio-technical systems for biofuels production must better account for incumbent actors, their strategies, existing infrastructure and markets is important for this analysis. The work also assumes that the technology systems themselves must evolve to fit with established socio-technical systems as they transition from isolated and protected niche applications into the mainstream. Or, alternatively that they force changes, or fill an opportunistic place, in the established regime by other mechanisms. To reflect this, the work was framed using insights and frameworks from technology transitions literature and institutional studies.

The **overall purpose** of this work is to provide input to the shaping of policy and research activities in Sweden that can promote the emergence of forest derived biofuels in coming years. It aims to contribute to a more updated and detailed understanding of the positions and views among existing, and potential, producers of transportation biofuels from forest-based feedstock in Sweden via work delivering against three objectives.

**Objective 1.** Provide understanding of the positions and views among existing and potential transportation biofuel producers in the important areas of:

- synergy, or rivalry, or direct competition for important resources or political support;
- key strategies pursued by leading actors in the forest-derived transport fuel initiatives and the incumbent petrochemical sector;
- general 'viability perceptions' regarding leading fuel-engine pathways.

**Objective 2.** To describe and delineate notable differences between strategies and perceptions of need in the field and the scientific work undertaken and knowledge yielded by the research community (principally those of the broader *f3* community).

**Objective 3.** To provide recommendations to policy makers, government, industry and other actors for decisions about the production of forest-derived transport fuels, particularly regarding:

- areas where policy is helping or hindering progress towards fossil fuel independence;
- the structural function of important drivers and barriers to progress – particularly related to intra-industry, inter-industry or institutional barriers issues.

## CONDUCT OF THE STUDY

This project gathered information directly from actors involved in a range of forest derived forest-biofuel project initiatives. These views and experiences, along with a broad range of supporting materials, have been documented in detailed case studies and then subjected to cross case analysis. The analysis is structured with insights from two inter-related fields of theoretical work. The first has a strong focus on the examination of strategies to pursue collective action, and strengthen institutionalisation and/or legitimation, so as to help overcome the difficulties of emergent technology systems. The second approach (the multi-level perspective, MLP) analyses both actors and the technology system itself within the broader socio-technical environment. It builds on the central idea that the establishment of new socio-technical systems comes about via transitions through, and interactions between, three different levels. Of special interest for this work was the pursuit, or emergence, of activities that help create 'protected spaces' within the market. The case studies are summarised below.

**Table: Summary of Case Study Projects.**

| Cases | Technology, Feedstock & Output | Plant capacity (MW capacity and approx. production) |
|---|---|---|
| Chemrec and Domsjö Fabriker, Örnsköldsvik Chemrec | Entrained flow biomass gasification, black liquor, Output: DME or methanol | 100 MW<br>≈ 1000 GWh/yr |
| LTU Green Fuels, Piteå<br>Luleå University of Technology | Entrained flow biomass gasification, black liquor & pyrolysis oil, Output: DME and methanol | 3MW |
| Bioraff (biorefinery) Norrtorp<br>SAKAB et al., Kumla | Gasification, forest residues & waste, OP: methanol and/or methane | 250MW<br>≈ 1800 GWh/yr |
| Värmlands Metanol, Hagfors<br>Värmlandsmetanol AB | CFB gasifier, wood chips, OP: methanol, heat | 110MW<br>≈ 600 GWh/yr |
| GoBiGas, Göteborg<br>Göteborg Energi (municipally owned energy company) | Indirect gasification, solid biomass (pellets at first), Output: methane, heat | 20MW (≈100 GWh/yr)<br>100MW (≈800-1000 GWh/yr) |
| Bio2G<br>E.ON Sverige AB (E.ON Sweden) | Gasification, wood chips, forest residues, Output: methane | 325$MW_{th}$ feedstock<br>200MW biogas<br>≈ 1600 GWh/yr |
| Renfuel | Catalytic conversion of lignin into lignin oil | >3000tonnes/yr<br>>20 GWh/yr |
| Preem | Diverse:<br>HVO from bio-diesel<br>Biooils to diesel<br>Solid biomass to diesel (future?) | 160 000 $m^3$/year<br>≈ 1600 GWh/yr |
| SunPine, Piteå<br>Södra (other owners: Preem, Sveaskog, Kiram, and Lawter) | Raw tall diesel separated from raw tall oil | 100 000 $m^3$/year<br>≈1000 GWh/yr |

## A PRINCIPAL FINDING FROM THE STUDY

We have chosen to highlight one particular area as a central finding immediately relevant to the shaping of policy and research activities in Sweden that can promote the emergence of forest derived biofuels in coming years.

While all proposed projects shared a common set of challenging political and institutional conditions, of the seven larger (>500GWh/yr) fuel projects studied, only two (the Sunpine and Preem) initiatives (which also happen to be directly linked) have moved forward into commercial production. This analysis indicates that the nature of their project approach and how it allows development within the existing institutional conditions is central to their success. Difficult conditions are summarised in the study as:

- low 'predictability' among policy instruments that affect biofuels – the suite of policy instruments have been surrounded by dynamic uncertainty;
- short policy time horizons – in order to underpin investment decisions, a time horizon that is several times longer than the current best situation is required;
- significantly reduced project proponent and investor levels of trust and confidence – related to the manner in which policymakers have managed the preceding two items, and the related series of project cancellations (or 'mothballing'), trust in the Swedish and EU political processes required to underpin biofuels investments is now very much lower than in the past and perceptions of political risk are higher.

The projects (and their technology platforms) that are either cancelled or on hold are Chemrec and Domsjö Fabriker; Bioraff Norrtorp; Värmlands Metanol; GoBiGas Phase 2; and Bio2G (case study descriptions are provided in the report). This work indicates that these projects – each in their different ways – aimed to achieve a substantial substitution of incumbent technologies in the established socio-technical system for transport fuels. Such degrees of ambition, and the strategies pursued, were not feasible under the prevailing political and institutional conditions.

In contrast, significant progress by Preem and Sunpine has apparently been achieved via pursuit of more stepwise processes. These have required reconfiguration of only parts of the incumbent technological fuel-transport system. Here, a modular innovation or innovations within the biofuel supply chain is seen to replace a part of the fossil system – or even fit in parallel with it – without substantially changing the rest of the system. These more successful endeavours have been able to develop within the existing and difficult institutional conditions as they have been formulated to more or less match the fossil (regime) infrastructure – and then it appears – to gradually change it.

As a result of this work, it is first concluded that pursuit of stepwise reconfiguration strategies, in part or whole, appear more likely to succeed in Sweden than more radical transition strategies unless there are significant improvements in the stability of policy support. While progress forward is being made by the successful platform, this may not be all positive. The longer the time that elapses before improved policy conditions emerge, the more 'entrenched' the new (emerging) system resulting from the Preem/Sunpine stepwise approach may be – this in itself may increasingly pose a barrier to the emergence of other platforms. On the other hand, if the institutional and political barriers detailed within this analysis ease, then the viability of all pathways can be expected to improve.

Despite a degree of concern that the Swedish renewable fuel system may be entering a form of ‘lock-in’ to a certain form of renewable fuel production, following the logic outlined above it is secondly proposed that pursuit of such modular and less ’bold’ strategies never-the-less also show promise to offer potential for more radical change should the substantial institutional and political constraints be reduced, and drivers and support mechanism be strengthened, or made more stable, or both. Indications are that they have clear potential to expand their feedstock base to a variety of bio-oils and then even solid biomass.

Thus, thirdly, we conclude that policy efforts, research activities, and future attempts to upscale or mainstream innovative biofuel production systems in Sweden can learn from such ‘more modular’ strategies and seek to exploit them wherever possible. However, decision-makers should not lose sight of the complex interplay of the broad palette of (potential) fuel production technology systems that have been developed on the one hand, with the likely need for multiple solutions to meet social and political goals for the transportation sector on the other hand. At this point in time, it remains uncertain which of the potential pathways studied here will function at large scale. However in the short-term at least, it appears advantageous that Sweden retain its capabilities to pursue a range of transportation biofuel solutions.

## OTHER FINDINGS AND CONCLUSIONS OF THE STUDY

More detailed commentary that directly relates to the three objectives of the study is briefly provided here.

Firstly regarding **synergies and/or competition for important markets and resources**, a central conclusion of this work is that the initiatives, or portions of initiatives, that have been successful thus far have built substantially upon synergies and complementarities. The Preem-SunPine system provides numerous examples in this regard. These include *inter alia*: synergistic incorporation of Preem’s HVO system within its refinery structures; the Sunpine/Preem value chain has combined two separate projects to complement each other (e.g. HVO/tall oil diesel refining); SunPine redefines market conditions for the tall oil by-product streams thus complementing core business areas among the ownership consortium; and HVO fuels seamlessly mesh with the existing diesel fuel infrastructure that Preem utilises within its mainstream business. While synergetic or complementary aspects were found in all cases, this particular case stands out due to the breadth and depth of ‘fit’ with other portions of the technical and institutional systems. Thus an important lesson for future efforts should be that the pursuit of cross industry and multi-faceted synergies will improve the strength of an initiative – and may be crucial to success.

A subsidiary conclusion is that Sweden has a suite of proponents for different forest-derived fuel platforms: (e.g. methanol, tall oil HVO, DME, and Bio-SNG) rather than a common ‘forest-derived fuel’ field or ‘sector’. Evidence suggests that this ‘constellation’ of actors do not effectively work in a synergistic fashion to further their common interests. Rather there is evidence that they compete in different ways for important resources such as media attention, social and political attention and support, research funding, policy sphere support, market space and so forth. A common platform to address common barriers to progress was not observed.

Competition for physical resources was also raised as an important issue within this study but primarily as an intra-sectorial issue for the forest industries. In short, engagement with forest-derived transport biofuels is perceived to have potential to increase industry costs. As such, it was concluded that the forest sector is indeed still partially divided regarding the engagement with forest-derived transport fuels activities, and that this apparent 'divide' likely undermines the efforts of biofuel proponents to secure support from various social and political constellations.

Secondly regarding **key strategies pursued in forest-derived fuel initiatives**, this study concludes that the key strategies being pursued in the initiatives can be described using variations of two concepts from the transitions literature. The first being substitution and the second being stepwise reconfiguration. The principle differences in strategies is that some require fundamental changes to large portions of the existing system – and also require changes in systems upstream, or downstream, or both. Other initiatives however, require more modest changes, and may barely affect other items upstream and downstream. Clear evidence was found that reconfiguration strategies have been more successful thus far.

The most successful case involved Preem and SunPine in a linked value chain, with HVO production from mainly crude tall oil. As noted, this is seen as an example of 'systemic innovation through stepwise reconfiguration' in which the project proponent has adopted modular innovations – with each new step enabling additional innovations. The whole chain is part of the same market, it utilizes a distribution infrastructure that already is aligned with the core business of Preem, and only specific modules of the fuel production system that have been modified. This study concludes that this is a major contributory factor to why this initiative has been realized commercially.

In contrast, other projects such as the commercial size gasifiers GoBiGas Phase 2, and Bio2G can be used as an example of other strategies assessed within the study. These were planned to be of a size that would demand a very large increase in size of the relatively small market for vehicle gas. With no small portion of the market to fit within, this required a strategy where significant portions of the diesel and petrol market needed to be substituted. This in turn required very considerable efforts – from the project proponent side – to grow the market for the fuel via fleet change *ex ante*. On the technology side, such projects are also strongly substitutional – new gasification plants are in essence substitutes for traditional petroleum fuel infrastructure.

Thirdly, regarding **the role of fuel-engine systems**, cases highlighted how substitution or reconfiguration strategies mentioned above create different engine platform and fleet requirements. Cases show how reconfiguration strategies, particularly those with drop-in fuels have many advantages, but the case for substation of specific fleets can also be made in specific situations. The situation is more challenging for all substitution pathways however.

Regarding the second work area – namely **where the research community can better serve forest-derived transport fuel activities**, this study finds considerable evidence that supports the guiding hypotheses made at the very outset of the project. These were that:

- there remains insufficient knowledge regarding the degree of alignment of (proposed) fuel production technology systems with incumbent industries;

- better understanding is required of the overlap of synergies (or competitive issues) between varying technology platforms;
- clearer insights are required into the preferences (or beliefs) of key ‘supply chain’ and ‘user chain’ actors regarding the future of a sector,
- there is insufficient delineation of ‘trade-off areas’ that the advanced transport fuels community must recognize and resolve in coming years, and finally
- the form and function of biofuel policy instruments in Sweden, and their relationship with EU rules and processes remains unresolved, the need for further assessment (and guidance) remains in this area.

One notable area for immediate work is assessment of the views of the broader industrial portion of the forest industries – as distinct from the actors in the forest industries that are engaged in transport fuel initiatives – accounting for this actor grouping will be vital for progress forward. In a broader perspective, the items above provide an outline for an important research agenda towards realisation of Swedish biofuels initiatives.

Regarding the third work area – namely **areas for action to improve conditions for the production of forest-derived transport fuels**, it was chosen to focus on two key audiences; namely, the policy sphere and the forest sector actors hosting initiatives relevant to this study. Comments seek to direct attention to where and why target audiences should direct efforts if they wish to improve conditions for the production of forest-derived transport fuels in Sweden.

Regarding **the policy-sphere**, a number of general conclusions regarding policy frameworks enfolding the development of domestic forest-derived biofuel production are listed here.

- There is a clear mood of dissatisfaction among the industrial actors engaged in fuel initiatives. In general, this study indicates that the levels of trust that such actors have in the Swedish and EU political processes is now low.
- Factors representing the themes of eroded confidence, trust, and faith in policy support, have already and will continue to affect investment hurdle rates. Further, it is judged that investment hurdles are now significantly higher than they were in past years, both because of escalated perceptions of political risk exposure and because of the current low oil price levels.
- If Sweden truly desires large fuel production initiatives in place, more stable long-term investment conditions will have to be provided via policy instruments. This points clearly in the direction of moving from tax exemptions and towards quota obligations, or instruments directed towards certain investments in production capacity, such as the price premium model. A general time horizon for the investments addressed in this work is predictability over ten to twelve years.
- If one of the key outcomes sought is to develop domestic biofuel processing industries that utilise domestic forest feedstock, then general policy instruments should be combined with more specific policy instruments on the market side.

- If the vision is to keep the current distributions infrastructure and vehicle fleet relatively intact while still striving towards a transport sector that is independent of fossil fuels, more directed support towards developing the industry for the production of feedstock that is possible to use within Sweden's existing refinery infrastructure is required. This and other studies have revealed that single pilot or demonstration plants cannot automatically generate commercial size production units. If forthcoming initiatives such as the Renfuel project, to utilise lignin, are to be developed to serve the refineries with large amounts of bio-oil feedstock, a clear strategy supported by directed policy instruments will be required.

Regarding **Forest-derived fuel proponents** a number of general conclusions regarding areas where effort is required are indicated by this work.

- The forest sector is partially divided regarding the value of engagement with forest-derived transport fuels activities. Some parts of the industry believe it is a valuable addition to the forest industries portfolio, some believe it is a risk. Such a potential 'divide' in the industry could undermine the efforts of transportation biofuel proponents to secure support from various social and political constellations.
- If forest-derived transportation fuels industry is truly a valuable addition to the forest sector portfolio, as many believe, then the case for this needs to be made in a more convincing manner to a broader suite of social and political actors. The more unified the forest sector appears to external stakeholders, then the higher the legitimacy of messages from fuel initiative proponents would presumably also be. Increased efforts to pursue such alliances and unity by the forest sector thus appear to be a requirement.
- An immediate knowledge gap appears to be of priority is the pursuit of a clearer picture of the 'ambivalence' or 'opposition' to transportation fuels initiatives from within the forest sector.
- As issues such as continuing policy instability and short-termism are those that have been found to pose the most significant barriers to initiatives moving forward, then again the more unified the "forest-derived fuel sector" appears to external stakeholders, then the higher the legitimacy of messages from fuel initiative proponents would also be. Increased efforts to pursue alliances and unity among forest-derived fuel initiatives thus appear worthy of deeper consideration.

**Concluding comments -** This study has uncovered a rich tapestry of phenomena and views within the forest-derived fuels field. While evidence of significant advances in knowledge and experience for advanced fuel production systems has been found, the fact of the matter is that a number of initiatives where very large resources have been invested have not moved forward. There is a clear sense of disappointment and frustration present among many actors in the field. Despite such experiences, most informants to this study were reluctant to rule out the possibility that projects will be realised at some stage in the mid-term.

As a further positive note, this work has also documented significant progress forward by some (i.e. Preem and Sunpine). The success initiatives in the Swedish system have been able to develop within the existing difficult conditions as they have been shaped to more or less match the fossil (regime) infrastructure – to then gradually change it. We perceive such strategies to have the highest likelihood of success for future developments.

**Keywords:** forest-derived transport biofuels, advanced biofuels, transitions.

# SAMMANFATTNING

I projektet har systemrelaterade begränsningar och drivkrafter för en expansion av skogsbaserade biodrivmedel i Sverige studerats utifrån nio fallstudier av existerande eller planerade produktionsanläggningar för biodrivmedel där storleken varierar från pilot- till kommersiell skala. Genom litteraturstudier och intervjuer har en uppdaterad och nyanserad bild av uppfattningarna hos potentiella och existerande biodrivmedelsproducenter presenterats gällande: (a) synergier och konkurrens kopplat till resurser, marknader och politiskt stöd, (b) strategier hos ledande aktörer inom biodrivmedelsproduktion och petrokemiska industri och (c) uppfattningar om genomförbarheten för olika drivmedel gällande produktion, distributionsinfrastruktur och fordonsflotta. Studien stärker beslutsunderlagen för politiska och industriella beslutsfattare inom områden där: styrmedel stimulerar eller bör stimulera utvecklingen, kunskapen om funktionen hos olika drivkrafter och barriärer behöver förbättras och kunskapsluckor om möjligheter att producera skogsbaserade drivmedel i stor skala behöver täckas. Det sista är betydelsefullt i Sverige som har en historia av utveckling av biodrivmedelsanläggningar upp till pilotstorlek men där övergången till kommersiell skala sällan har skett.

# LIST OF ABBREVIATIONS

| | |
|---|---|
| B100 | 100% biodiesel vehicle fuel |
| CAPEX | Capital expenditure |
| CDM | Clean Development Mechanism |
| CNG | Compressed natural gas |
| $CO_2$ | Carbon dioxide |
| DME | Dimethyl ether |
| E5 | 5% ethanol mix (gasoline) vehicle fuel |
| E85 | 85% ethanol mix (gasoline) vehicle fuel |
| ETBE | Ethyl tetra-butyl ether |
| EU | European Union |
| EU-ETS | European Union – Emissions Trading System |
| EUA | European Union Emission Allowances |
| *f3* | Fossil Free Fuels (*f3* center) |
| FAME | Fatty acid methyl ester |
| GFC | Global financial crisis (2007/8) |
| GROT | Branches and tops (Swedish 'grenar och toppar') |
| GWh | Gigawatt hours |
| HVO | Hydrodtreated vegetable oils |
| IEA | International Energy Agency |
| ILUC | Indirect land-use change |
| KLIMP | Climate investment programme (Swedish - Klimatinvesteringsprogram) |
| LIP | Local investment programme (Swedish - Lokalainvesteringsprogram) |
| LNG | Liquid natural gas |
| LPG | Liquid petroleum gas |
| M100 | 100% methanol vehicle fuel |
| MLP | Multi level perspective |
| NER | New Entrants Reserve |
| RES | Renewable energy sources (Directive) |
| RME | Rape methyl ester |
| SEA | Swedish Energy Agency (Statens Energimyndighet) |
| SNG | Synthetic natural gas |
| SNM | Strategic niche management |
| TWh | Terawatt hours |
| VAT | Value added tax |

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# 1 INTRODUCTION

Sweden has ambitious goals with regards to the reduction of global warming. A goal that the country's transportation sector should be independent of fossil fuels by 2030 is a part of this.[1] These goals were first presented in the climate proposition of 2009 and led to the "Fossilfrihet på väg [Fossil Free Road Transport]. The conclusions of this study were submitted to the government in December 2013;[2,3] while it remains somewhat unclear by what is meant by a number of the ambitions stated in these documents, several milestones were provided in the report. On the demand side, it is judged that pursuant to policy interventions, and technology advancement, that the total energy use in Swedish road traffic in 2030 can be reduced to between 31 and 47 TWh per year. This can be compared to 79 TWh in 2014 (which is already a reduction from a high of 91.1TWh in 2005). On the supply side, it is estimated that a production of transport biofuels of 15-20 TWh can be achieved by 2030. In contrast, the potential for electricity and hydrogen in transport is estimated to be between 1.6 and 4.2 TWh in 2030.

There are several pathways for supply of renewable fuels to the national transport system that can be pursued to reach such goals. Among these, significant research efforts are focusing on biofuels for the road transport sector. Such biofuels interrelate in different ways with the forest and agricultural sectors, and with transportation fuel processing/value-adding industries both inside and outside the country. Decisions regarding which forest-derived transport biofuels to pursue, and how best to pursue them, are however a complex issue, and are influenced by many factors. Among others these include: distribution infrastructure; energy security concerns; environmental quality; rural development issues; consumer beliefs and preferences; engine technology advances; media focus; and rates of progress in the development, or demonstration, of key technologies for fuel production.

Adding to complexity to desires for expansion of production and consumption of advanced biofuels is the fact that shifting from fossil fuels in the transportation sector has long been seen as a more challenging issue for Sweden than removing fossil fuels from other parts of the economy. Indeed, it is now seen as central issue for national infrastructure planning if the national climate goals are to be met.[4] Experiences with biofuels over the past decade have also demonstrated to Swedish actors that social expectations (from Europe and abroad) for the environmental performance of fuel systems continually escalate – and that these issues constrain the pathways forward for the country. In addition to requirements that biofuels must deliver technical performance at similar levels to fossil fuels in existing systems (e.g. driving range, suitability for engines, and availability of distribution points) it has become clear that climate emission and land use issues are now central issues for

[1] Regeringskansliet. (2009). *Climate and energy policy for a sustainable future: INFORMATION SHEET ABOUT THE GOVERNMENT BILLS 2008/09:162 AND 163* (Information sheet No. M2009.10). Stockholm, Sweden: Ministry of the Environment and Ministry of Enterprise, Energy and Communications.

[2] SOU. (2013). *Fossilfrihet på väg [Fossil free road transport] (del 1 och 2)* (Statens offentliga utredningar (SOU) No. SOU 2013:84). Stockholm, Sweden: Näringsdepartmentet. Retrieved from http://www.regeringen.se/sb/d/17075/a/230739

[3] In the investigation, it was delineated that the term 'independent of fossil' means that the transportation fleet can be driven without fossil fuel and that fossil free energy carriers are available at a sufficient scale.

[4] See for example: El och biodrivmedel förs fram som enda framtida bränslealternativen NYHETSBREVET ENERGIMARKNADEN - Drivmedel | 19 april 2016 11:02 http://www.energimarknaden.com/Nyhetsarkivet/Energi-Online/2016/04/19/El-och-biodrivmedel-fors-fram-som-enda-framtida-branslealternativen/

[Electricty and biofuels are presented as the only future transport fuel options] News letter Energy market critics.[5] Despite the fact that biofuels bear benefits with them such as additional economic activity within a country, can be linked into waste management systems to create extra value from waste, and displace fossil oil derived products (with their considerable environmental footprints and energy dependence issues) stakeholders place increasingly stringent environmental demands upon biofuels.[6] Such demands in turn have been translated into EU policy. Already it is required that transportation biofuels must show high levels of performance with regards life cycle $CO_2$ emissions, land use implications, and competition for resources in general.[7]

To meet such demands (and the more stringent forms they may evolve into), and deliver the scale of fuel supply required it now seems even more obvious that advanced fuel production from forest resources is required. Yet, the establishment of production systems for advanced biofuels still seems to progress slowly.

A key focal sector for the development of advanced biofuels, the Swedish forestry industry, overlaps and interlinks with this complex suite of issues. First and foremost the sector is of great socio-economic importance: it constitutes an important pillar for the export economy delivering some 10% of the world's exported sawn timber, while pulp and paper provides net positive export earnings of around 100 billion SEK;[8] Swedish forestry companies are world leaders in technology development and leading actors on the world market, and the forestry sector activities, and forest by-products are integral to the energy balance of Sweden.[9] While the forest sector naturally has a function as a feedstock supplier, it also hosts the technical, financial resources, and strong relational networks that could underpin central involvement in fuel production facilities.

When considering transport biofuels and their production, the Nordic forestry and pulp/paper sectors recognise an imperative for more sophisticated portfolios of specialised products and a shift to the 'bio-economy'.[10] While some analysts describe this as a shift to biofuels, bioenergy, and a lower carbon footprint of production within traditional sector activities,[11] others portray more complex bio-refineries as central to the creation of a 'green economy'.[12] Transportation fuels are often present in such scenarios in the form of high-volume base-products from a refinery, but such visions invariably include a range of different chemicals or material outputs. In the forest sector context, pulp mills are often at the centre of biorefinery related initiatives, and it is typically highlighted that such developments must benefit the profitability of the pulp/paper industry; as the primary goal of converting a (chemical) pulp mill into an integrated bio-refinery is to create more value from forest feedstocks.[13]

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[5] See discussion in Sluka, C., & Peck, P. C. (2015). Stakeholder dynamics in the forest energy sector: key issues to manage and ways forward. Biofuels, Bioproducts and Biorefining, 9(1). Volume 9, Issue 1, pages 51–71, January/February 2015. DOI: 10.1002/bbb.1501
[6] European Biofuels Technology Platform (EBTP), Biofuels and Sustainability Issues, See: http://biofuelstp.eu/sustainability.html
[7] *Ibid*.
[8] KSLA. (2009). *The Swedish Forestry Model*. Stockholm, Sweden: Royal Swedish Academy of Agriculture and Forestry. Retrieved from http://www.skogsstyrelsen.se/Global/myndigheten/Skog%20och%20miljo/ENGLISH/retrieve_file.pdf
[9] Elforsk. (2008). Ökad efterfrågan på biomassa i Sverige – Hur påverkas energi- och skogssektorn? Elforsk AB. Retrieved from http://www.elforsk.se/Documents/Trycksaker%20och%20broschyrer/biokonkurrens_2008.pdf
[10] Rushton, M. (2012, November 15). I have seen the future. Retrieved June 3, 2013, from http://www.risiinfo.com/blogs/I-have-seen-the-future.html
[11] Hawkins Wright. (2008, September). Hawkins Wright - Serving the global forest products industries [Executive summary of Energy from Forests: Bioenergy and Global Forest Products report]. Retrieved June 3, 2013, from http://www.hawkinswright.com/Bioenergy-Multi_client_reports-Energy_from_Forests_Bioenergy_and_Global_Forest_Products
[12] Van Ree, R., & Annevelink, B. (2007). *Status Report Biorefineries 2007* (No. 847). Agrotechnology and Food Sciences Group: Wageningen University. Retrieved from www.biorefinery.nl/publications
[13] Söderholm, P., & Lundmark, R. (2009). Forest-based biorefineries: Implications for market behavior and policy. *Forest Products Journal*, *59*(1-2), 6–16.

However, progress in achieving change in such directions within the Swedish forest sector in general, and pulp/paper sector in particular, has been slow. While high sunk costs related to the capital infrastructure intensive nature of the sector dictate a slow rate of change, [14] other issues also constrain progress. Herein lies the central focus of this study.

Some constraints can be posed in terms of being 'internal' to the forestry sector – often related to issues within organizations, or between sectorial organizations (thus generally organizational or intra-industry).[15] As a first issue, we observe that multiple and conflicting opinions and scenarios about which biorefining strategies to pursue exist. Some biorefinery strategies – and particularly those involving (potential) large-scale fuel production can even be perceived in quite negative terms by some sectorial actors. Depending how initiatives are framed, they can be seen as: a new source of competition for limited biomass feedstock supplies; a threat to the operation, or longevity, of important infrastructural items within a pulp mill; or as a complication for supply chains (e.g. with potential to increase transportation costs). Other issues important to this study that have been highlighted in recent years include:

- differing views regarding the importance or desirability of a deep (or shallow) cooperation between the forest industries and the petrochemical sector;
- conflicting opinions which types of transportation fuels should or could be produced from the sector (e.g. syn-biogas, ethanol, methanol, DME, FT-diesel, etc.); and
- disparate views on whether key focus should be placed on biofuels or upon the inherent functions that exist in wood chemicals such as lignin and extractive substances such as tall oil (pine oil) rather than on transportation fuels.

Other factors with the potential to act as barriers can be categorised as 'external'. These are often related to pressures from institutions and higher level stakeholder forces that in some way steer or support the sectors involved from the outside. Examples of external constraints affecting the global forest sector include a lack of clear policy directions via a global $CO_2$ tax, increasing social opposition to the sourcing of biomass from forest and field,[16] and the dissipation of 'end of oil fears' and cheap natural gas in some jurisdictions. [17] A number of important issues in this area are also referred to as 'socio-technical landscape' phenomena. This term is intended to capture the idea that they enfold macro-economic and macro-political trends, significant environmental changes, demographic trends and so forth – these in turn define the 'landscape' that a technology system exists within.[18]

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[14] Elforsk. (2008). Ökad efterfrågan på biomassa i Sverige – Hur påverkas energi- och skogssektorn? [Increased biomass demand in Sweden – How is the energy and forest sector affected?] Elforsk AB. Retrieved from http://www.elforsk.se/Documents/Trycksaker%20och%20broschyrer/biokonkurrens_2008.pdf

[15] Intra-industry relationships can be seen as the relationships and interactions that take place between organisations that belong to the same industry.

[16] Sluka, C., & Peck, P. C. (2015). Stakeholder dynamics in the forest energy sector: key issues to manage and ways forward. Biofuels, Bioproducts and Biorefining, 9(1). Volume 9, Issue 1, pages 51–71, January/February 2015. DOI: 10.1002/bbb.1501

[17] Papernet.se. (2013, May 3). Skiffergas v/s skoglig biomassa [shell gas vs forest derived biomass] [Online e-journal]. Retrieved June 3, 2013, from http://www.papernet.se/iuware.aspx?pageid=395&ssoid=165970

[18] F. W. Geels, "The multi-level perspective on sustainability transitions: Responses to seven criticisms," *Environ. Innov. Soc. Transitions*, vol. 1, no. 1, pp. 24–40, 2011.; F. W. Geels, "Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study," *Res. Policy*, vol. 31, no. 8–9, pp. 1257–1274, 2002.; J. W. Schot and F. W. Geels, "Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy," *Technol. Anal. Strat. Manag.*, vol. 20,

Falling generally between these two categories a third area of potential internal/external constraints relevant to forest-derived *fossil free fuels* (*f3*) is also discerned. Often we can consider these in terms of inter-industry interactions.[19] Relevant to this study, internal parts of such 'internal and external' constraints include the already significant involvement that actors from the forest sector have made in some parts of the transportation sector. By such involvement, parts of the sector are thus linked to some engine platforms and vehicle makers (e.g. black liquor gasification efforts have linked to Volvo's DME trials). Important external elements include factors such as transportation fuel policy in general, changes in the makeup and size of the Swedish passenger vehicle fleet, and form and extent of existing fuel logistics infrastructure. It is also relevant that relationships with vehicle producer 'communities' are not traditionally linked to the forest sector. However, all such items can be seen as important components of that which analysts often refer to as the 'deep structure of the socio-technical system' – or socio-technical 'regime'. This term is intended to capture the concept of alignment between technologies, infrastructure, institutions, practices, behavioural patterns, markets, industry structures, and so forth.[20]

Among other things, it can be anticipated that such regime-type issues are related to real or perceived 'need profiles' for the renewable transportation fuels market in Sweden. While measures can be taken at several levels to 'stimulate' market needs (e.g. both policy push and industry pull), this analysis works from the assumption that the fossil free fuel sector will be constrained in a number of ways by trends and changes in regime factors such as the existing market profile, and the roles of established actors.

As in important example of a change trend in the market, is how the Swedish transportation fuel market has quite radically evolved over the past decade or so. In the area of renewable fuels, the market share has grown from around 1TWh (circa 1.2%) of road transport to more than 11TWh (circa 14%) over the period 2003-15. Three fuel types are involved (2014 figures)[21]: first generation ethanol (1,9 TWh and falling from 2011 figures of 2.4TWh), biodiesel[22] (8,1 TWh and climbing rapidly) and biogas derived from (principally) waste digestion (1TWh and climbing slowly as of 2014). In parallel to this, there has been a marked shift in the Swedish fleet makeup, particularly with gasoline driven passenger vehicles being replaced by vehicles with diesel engines. While diesel consumption started to rise rapidly at the end of the 1990s as the road transport freight sector expanded, [23] the proportion of diesel cars in the Swedish fleet has changed drastically from 2004/5 onwards. This is deemed to have been initiated by the combination of (firstly) a change in taxation in 2005 that chose to relate part of the annual vehicle tax to each car model's emission of $CO_2$ per kilometre and (secondly) the market appearance of low consumption, high performance diesel vehicles from leading manufacturers. These changes show up clearly in fuel consumption statistics. In 2003, Sweden's road transport consumed 48.6TWh gasoline, 30.5TWh diesel and 1TWh biofuel

no. 5, pp. 537–554, 2008.; F. W. Geels, "From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory.," *Res. Policy*, vol. 33, no. 6–7, pp. 897–920, 2004.

[19] Inter-industry interactions or relationships are those that involve different industries. For instance, the relationships between agricultural producers and technological equipment producers would classify as an inter-industry relationship.

[20] *Ibid* (Citations from Geels, and Schot & Geels above).

[21] Swedish Energy Agency, 2016. Energy in Sweden – Facts and Figures 2016 [Energiläget i siffror 2015]. Eskilstuna: Statens Energimyndighet.

[22] Unless otherwise noted, the term biodiesel is used to describe both FAME (fatty acid methyl ester) and HVO (hydro-treated vegetable oils).

[23] Swedish Energy Agency, 2016. Energy in Sweden – Facts and Figures 2016 [Energiläget i siffror 2015]. Eskilstuna: Statens Energimyndighet.

(0.9TWh ethanol). By 2014, this had changed to 29.7TWh gasoline, 38,5 TWh diesel and 11TWh biofuels (1.9TWh ethanol, 8.1 TWh biodiesel).

In recent years the trend to diesel cars has been maintained by environmentally motivated policy support for low consumption diesel vehicles.[24] The diesel share of new passenger vehicle sales in 2004 was approximately 10%, this reached the (then) European average of around 45% in 2009, and by 2011 was close to 60% - a level that been maintained.[25, 26] As of 2014, the diesel proportion of the Swedish passenger vehicle fleet had reached some 25%.[27]

Viewed from the perspective of the (historically) superior efficiency of diesel engines over spark-ignition gasoline engines (i.e. Otto engine-types), trends to more diesel platforms appears logical – but a major challenge faces the entire EU transport sector in in this regard – a EU diesel deficit of some 30-40 million $m^3$/yr. exists[28] which in turn can increase the volatility of diesel markets. This analysis has worked from a view that this leaves 'degrees of freedom' open to other fuel platforms (and the *f3* community) as alternative renewable fuels both exist, and have the potential to offer a markedly different range of potential socio-economic benefits as compared to fossil fuels.[29] An escalating diesel deficit can also open mainstream market opportunities for other fuel/engine platforms – particularly as they evolve to better match the efficiency of diesels. Important for this work is that there are several new renewable fuel platforms competing for policy and research attention: methanol/DME and biogas are important - but in the background there is also the potential that traditional fossil producers can produce renewable fuels in new types of fossil plants.[30]

In this regard, a guiding assumption when shaping this project (during mid 2013) was that a major increase of biofuels in petro-refineries should such an increase eventuate, has potential to reduce the imperative for forest sector initiatives pursuing diesel-like renewable alternatives. It was considered necessary to both map activities in the field, and then compares them against the emerging situation described in the preceding text. It was chosen to concentrate on thermochemical fuel production projects associated with the forest sector. An initial mapping of these biofuel-related projects – including planned, existing, notable closed projects – is provided in **Table 1** overleaf.

Of these, a subset of 9 projects was chosen for study. These are detailed in

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[24] Kågeson, Per. "Dieselization in Sweden." *Energy Policy* 54 (2013): 42-46.

[25] *Ibid.*

[26] According to Teknikensvärld [Technologies World] a Swedish magazine, during 2015, diesels continued to dominate new car sales. The proportion of diesel powered passenger vehicles reached 58% (200109 registrations). http://teknikensvarld.se/rekord-for-nybilsforsaljningen-under-2015-239508/

[27] http://www.dn.se/debatt/dieseltrenden-haller-uppe-utslappen-av-kvavedioxid/

[28] Preem. (2012, May 22). From Tall Oil to Diesel. Retrieved from http://evolution.preem.se/assets/upload/documents/From_tall-oil_to_Diesel.pdf

[29] Dale, V. H., Efroymson, R. A., Kline, K. L., Langholtz, M. H., Leiby, P. N., Oladosu, G. A., ... & Hilliard, M. R. (2013). Indicators for assessing socioeconomic sustainability of bioenergy systems: a short list of practical measures. *Ecological Indicators*, *26*, 87-102

[30] Eriksson, S. (2011, November). *Framtidens Förnybara - Fossila drivmedel Inklusive ACP Evolution - från Idé till färdig diesel - En saga om hopp och förtvivlan (eller, det var inte så lätt?)*. Presented at the Välkommen till vårt seminarium Klimatsmarta val av tunga fordon gör ditt företag mer lönsamt! 24 november 2011, Jönköping; Eriksson, S. (2013, May 21). Personal communication: PREEM, 21 May (with P. Peck, IIIEE); Eriksson, S. (2013b, June 11). Personal communication: PREEM, 11 June (with S. Grönkvist, KTH); Erikssson, S. (2013, May). *Towards a Fossile Free Refinery*. Presented at the LU Biofuels Day, Lund.

in Section 3.4. In addition, a case study examining motor platforms (Scania and Volvo trucks) for two heavy transportation biofuels (ethanol and dimethyl ether) were also selected in order to provide context from the user perspective.

**Table 1. Overview of thermochemical biofuel projects in Sweden**

| Plant, Owner & Location | Technology, Feedstock & Output | Capacity & Production | Status & Infrastructure for output |
|---|---|---|---|
| Gobigas Phase 1, Göteborg Energi, Gothenburg | Indirect gasification, solid biomass (pellets at first), OP: methane, heat | 20 MW, 160 GWh fuel/y | Operational (2013). INF: gas, district heating, and electricity grid |
| Gobigas Phase 2, Göteborg Energi, Gothenburg | Indirect gasification, solid biomass (chips, twigs, and tops), OP: methane, heat/electricity | 100 MW, 800 GWh fuel/y | Plans postponed. INF: gas, district heating, and electricity grid |
| Bio2G, E.on, Malmö or Landskrona | Gasification, wood chips, forest residues, OP: methane | 200 MW, ca. 1550 GWh fuel/y | In planning (4 year time horizon). INF: gas and district heating grid |
| LTU Green fuels, Luleå Tech. Uni., Piteå | Entrained flow biomass gasification, black liquor & pyrolysis oil, OP: DME | 3 MW, 6 GWh fuel/y | Operational (2010), Decision to close (2016). INF: 10 trucks, 4 refilling stations |
| Chemrec/ Domsjö, Domsjö Fabriker, Örnsköldsvik | Entrained flow biomass gasification, black liquor, OP: DME or methanol | 200 MW, 960 GWh fuel/y | Project closed |
| Vallvik Biofuel, Rottneros AB, Vallvik (Söderhamn) | Gasification, black liquor, OP: methanol | 200 MW, 750 GWh fuel/y | In planning (4-5 years time horizon). INF: not known |
| Rottneros biorefinery, Rottneros AB, Rottneros (Värmland) | Gasification, lignocellulosic biomass, OP: methanol | 200 MW, 750 GWh fuel/y | In planning (4-5 years time horizon). INF: not known |
| Värmlandsmetanol AB, Hagfors (Värmland) | CFB gasifier, wood chips, OP: methanol, heat | 110 MW, 600 GWh fuel/y | In planning: INF: district heating grid |
| Pyrogrot, BillerudKorsnäs AB, Skärblacka Bruk (Östergötland) | Pyrolysis, twigs, tops & stumps, OP: pyrolysis oil | 100 (?) MW, 750 GWh fuel/y | Project cancelled |
| Biorefinery Norrtorp, SAKAB et al., Kumla | Gasification, forest residues & waste, OP: methanol and/or methane | 250 MW, 1800 GWh fuel/y | Long term planning (2023 or later) |
| Växjö Värnamo Biomass Gasification Center, Linnaues University, Värnamo | Air-fed CFB gasifier, wood chips, OP: electricity | 18 MW | Commissioned in 1996. No longer in use. INF: electricity grid |
| Pilot, SP (formerly ETC), Piteå | Pressurized entrained flow biomass gasification from IVAB, forest residues, torrefied biomass, pyrolysis oil, OP: DME/ methanol | 1 MW | Trials commenced (2013) |
| Woodroll, Köping | Indirect gasification (Cortus), wood chips, OP: not listed | 5 MW (25 MW for stage II) | 150 kW operational. Larger installation in planning. INF: not known |
| Värö bruk, Södra, Värö (south of Gothenburg) | Atmospheric CFB, bark, OP: syngas for use in lime kiln | 28 MW | Operational (1987) for internal use |

## 1.1 AIM AND PROBLEM DEFINITION

While the overall efficiencies of fuel production systems, and the relative efficiency of converting fuel to motive force in vehicle engines are important to the design of a fossil fuel independence strategy for Sweden, these are only two issues among many. As noted, a wide range of parameters such as vested industry interests, consumer preferences, competing technology development pathways in the transport sector, new and existing "locked in" fuel infrastructure, logistics and spatial distribution issues, political beliefs and confidence, and many more issues pose very real constraints upon the pursuit of any pathway.

### *1.1.1 Problem definition*

Portions of all potential fuel supply chains clearly face challenges when viewed from such perspectives. While many research projects are underway in *f3*, and in the broader alternative transport fuels research community, that deal with some individual phenomena listed above, to our knowledge there has been no structured review of activities and stakeholder views within Swedish forest fuel systems that follows technology/innovation and business methodologies for analysis of the emergence of new industrial sectors.

In the context of this sector, we propose that any confidence in recommending 'which fuel pathway(s) to pursue or support', or 'how to support specific technology platforms', or 'how to structure collaboration or cooperation effects' requires much more structured consideration of the degree of alignment of the technology with incumbent industries; it needs better understanding of overlap and synergies (or competitive issues) between varying technology platforms, and it is imperative that there be clearer insights into the preferences (or beliefs) of key 'supply chain' and 'user chain' actors regarding the future of a sector.[31] Further, we hold that to date there is a lack of such consideration within the academic research field in Sweden.

In the light of such gaps in knowledge, this work departs with the guiding assumption that advanced forest-derived biofuel system (the 'innovation') emergence requires that the proponents of these new socio-technical systems for biofuels production must better account for incumbent actors, their strategies, existing infrastructure and markets; these being phenomena that can be studied via sociological, business and institutional lenses.[32] Further, the work assumes that the technology systems themselves must evolve to fit with established socio-technical systems as they transition from isolated niche applications into the mainstream. A perspective that can be used to view such phenomena is the multi-level perspective (MLP) after Geels and others.[33] The principal idea of the MLP is that the establishment of new socio-technical systems comes about via transitions through, and interactions between, three different levels: niche, regime and landscape.[34]

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[31] See the following for discussions enfolding this: Aldrich, H. E., & Fiol, M. C. (1994). Fools Rush in? The Institutional Context of Industry Creation, 645–670; Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis., 407–439; Bergek, A., Jacobsson, S., & Sandén, B. A. (2008). "Legitimation" and "development of positive externalities": two key processes in the formation phase of technological innovation systems, 575–593; Bower, J. L., & Christensen, C. M. (1995). Disruptive technologies: Catching the wave., 43–54.
[32] *Ibid.*
[33] See: Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions*, *1*(1), 24–40. http://doi.org/DOI:10.1016/j.eist.2011.02.002; Geels, Frank W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8-9), 1257–1274. http://doi.org/DOI:10.1016/S0048-7333(02)00062-8; Geels, Frank W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, *33*(6-7), 897–920. http://doi.org/DOI:10.1016/j.respol.2004.01.015; and Schot, J. W., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management*, *20*(5), 537–554.
[34] *Ibid.*

### *1.1.2 Aim*

Pursuant to these considerations, this project was conducted with the overarching purpose to provide input to the shaping of policy and research activities in Sweden that can promote the emergence of forest derived biofuels in coming years. While the spatial boundaries for this work have primarily been set to Sweden, it is intended that the work have relevance and applicability to the broader Nordic context. This project is to draw insights directly from key industrial actors, and then create an analysis that contributes to a more updated and more detailed understanding of the positions and views among existing, and potential, producers of transportation biofuels from forest-based feedstock in Sweden.

In order to contribute to this overall aim, the project was delineated with the following objectives:

**Objective 1.** Provide understanding of the positions and views among existing and potential transportation biofuel producers in the important areas of:

- synergy, or rivalry, or direct competition for important resources[35] or political support;
- key strategies pursued by leading actors in the forest-derived transport fuel initiatives and the incumbent petrochemical sector;[36]
- general ‘viability perceptions’ regarding leading fuel-engine pathways

**Objective 2.** To describe and delineate notable differences between strategies and perceptions of need in the field and the scientific work undertaken and knowledge yielded by the research community (principally those of the broader *f3* community).[37]

**Objective 3.** To provide recommendations to policy makers, government, industry and other actors for decisions about the production of forest-derived transport fuels, particularly regarding:

- areas where policy is helping or hindering progress towards fossil fuel independence;
- the structural function of important drivers and barriers to progress – particularly related to intra-industry, inter-industry or institutional barriers issues.

As this study documents unique information drawn directly from key industrial actors, and provides an updated and more detailed understanding of positions and views among existing and potential producers of transportation biofuels of both 1$^{st}$ and advanced generations, it is expected that this will also deliver increased knowledge and awareness to support dialogue with the current biofuel research community (e.g. *f3* centre actors) and facilitate new collaboration opportunities.

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[35] It is important to note that as the focus is on the relationship of fuel initiatives to each other, the focus of the term ‘resources’ is generally NOT directed towards raw material (biomass) feedstocks competition. Rather the much broader suite of resources required to support a new technology system is referred to. Such can include *inter alia*: finance, political support, production and distribution infrastructure, media support, and so forth. Issues/perceptions of competition for biomass resources are however of central importance within the forest sector itself.

[36] In the original proposal, this was written as “key strategies pursued by leading actors in the forest fuel, incumbent biofuel producers, and the incumbent petrochemical sector”. The alteration was made to better reflect the reality of the study – while incumbent (first generation) actors were included, and their views documented, the topic of ‘forest-derived fuels’ naturally directed nearly all research effort to the cases studied for the report.

[37] In the original project proposal, this was written as “between strategies and perceptions in the field and the scientific results yielded by the research community”. The alteration has been made to better reflect the meaning intended when proposing the work.

The objectives in the original project proposal outlined above, detail work that should provide improved delineation of 'trade-off areas' that *f3* and market actors must recognize and resolve in coming years. By extension, this is to contribute to knowledge collated within the FFF-investigation [Utredningen om FossilFri Fordonstrafik] as that work identified interventions to reduce the transport sector's dependence on fossil fuels in line with Swedish visions for a fossil fuel independent neutral transport by 2050 and an 'independent from fossil fuel fleet' by 2030. A subsidiary aim of the work is that that it will delineate a basis for new research and applied work promoting strategic alliances and collective action in the Swedish (forest-based) transport biofuels sector.

Overall, and in a longer time perspective, the project aims to contribute to the transition outlined in analyses such as the Swedish Government's Commission on fossil-free road transport[38] – particularly the goal to become independent of fossil fuels in transportation. Through such changes, it is also intended to contribute to achievement of the Swedish environmental quality objective (miljömål) of reduced climate impact.

## 1.2 LIMITATIONS

This project was conducted in within a work programme of The Swedish Knowledge Centre for Renewable Transportation Fuels (*f3*) (www.f3centre.se). As such, it has the principal aim to deliver knowledge for the Swedish research community engaged in transportation biofuels, and the policy makers tasked with the shaping of future National policy instruments.

While the *f3* center engages with work across the entire transportation biofuels market, the key focus of this study is on the emergent sector that is developing systems to produce transport fuels with feedstock from, and operations closely aligned with, the forest industries. Further, as there was a broad range of projects focused on chemical or thermochemical pathways, it was chosen to focus there. Advanced fermentation projects where lignocellulose materials are converted to ethanol were thus scoped out of the study.

Further, while electrical vehicles and broader developments in transportation fleets affect all biofuels projects (over time), this analysis has not deeply addressed such issues. These did however come up however in case studies (e.g. fleet descriptions in the Bio2G case as one example) and are discussed in case context only.

Another area of significant relevance that was only superficially examined in this analysis was views of incumbent forestry sector actors NOT involved in biofuels production. These actors lay outside the scope of work for this project. However, while casework investigated forest sector perceptions and preferences regarding how involvement in advanced transportation biofuels production should be pursued, and how this should be linked to the existing petrochemicals sector for those actors involved in fuel initiatives, this misses a significant tension within the forestry sector. That being that the sector itself may be somewhat divided. This topic is addressed briefly in the closing sections, and constitutes an important area for future research. The related topic of broader

[38] SOU. (2013). *Fossilfrihet på väg [Fossil free road transport] (del 1 och 2)* (Statens offentliga utredningar (SOU) No. SOU 2013:84). Stockholm, Sweden: Näringsdepartmentet. Retrieved from http://www.regeringen.se/sb/d/17075/a/230739

competition for forest biomass has largely been delimited from this study as a simple consequence of the limited resources available for the study – it does however appear within specific cases.

Very much related to the limited suite of incumbent forest industry actors involved in the study (mentioned above), it is important to note that as the focus is on the relationship of fuel initiatives to each other, the focus of the term ‘resources’ is generally NOT directed towards raw material (biomass) feedstocks competition. Rather the much broader suite of resources required to support a new technology system is referred to. Such can include *inter alia*: finance, political support, production and distribution infrastructure, media support, and so forth. It is noted that issues/ perceptions of competition for biomass resources are however of central importance within the forest sector itself.

Stepping from limitations posed by choice to those of circumstance, it should be noted that the original research plan involved a stepwise process where preliminary scoping interviews were to be conducted with selected key informants from each sample group in order to build a well grounded questionnaire and survey document. This was to be followed by an online questionnaire/survey targeting many more informants. In practice, the number of potential informants fulfilling criteria (e.g. seniority and access to key information) was too few for each project for this approach to be meaningful. For a small number of projects it was feasible to interview more than one person involved in a project – providing for a crosschecking of views, but several cases would have to be based on information from (in essence) a single informant. Thus, the questionnaire was first developed for the study and then instead used to guide in depth interviews conducted with key informants. The online questionnaire tool was still used to provide a “summary view” of results across the full span of the case studies. The interview base for each case study in turn was then reinforced by desktop study. While these changes affect the number of informants – it is not deemed to significantly affect the validity of this study – not least as the involvement of some informants (to varying degrees) in two or more of the projects studied, provided for a degree of crosschecking.

## 1.3 AUDIENCES

This study has an eventual audience of policy sphere actors tasked with the shaping of policy instruments impacting renewable transportation fuels in Sweden. The first audience in this regard are the actors involved in the f3 centre – this encompassing academic, public and private sector actors with stakes in the renewable transportation fuels industry. As a nationwide knowledge platform and venue for cooperation in the production of renewable fuels and the related system aspects, f3 is tasked with providing guidance to policy makers, government, industry and other organizations as they make decisions related to the production of renewable fuels.

Importantly, the f3 initiative is funded 50% by the Swedish Energy Agency; the Agency thus constitutes both a key partner and a key audience. The Agency is subordinate to the Ministry of the Environment and Energy and is tasked with informing the process of drafting energy policy. The Agency finances research for new and renewable energy technologies, smart grids, and vehicles and transport fuels of the future, and supports the commercialization and growth of energy related cleantech. The results of research funded by the agency, are expected to contribute to development of the Swedish energy system and business in the energy sector, and form a basis for supporting well-founded energy and climate policy decisions.

As noted, the key focus of this research is upon the emergent sector that is likely to produce transport fuels within the large-scale forest industries but works from a point of departure that new routes for fuels production must align significantly with incumbent actors and their strategies – thus encompassing products, infrastructure, and markets. Actors across these categories constitute important potential audiences for this work. Among others the following specific actor groupings are considered relevant:

- Project proponents addressed by the study, and potential proponents for similar endeavours – we perceive that there is significant learning value that can be extracted from the broad suite of case studies provided here – and from the form of analysis that they have been subjected to;
- Local governments – particularly representatives from forest-rich parts of the country that are motivated to host such activities within their jurisdictions as part of their regional development strategies, or local governments motivated to increase the proportion of biofuels in their regional fleets;
- Branch organisations (Industry representative groups) such as Svebio (representing companies and individuals working to promote bioenergy in Sweden) and the World Bioenergy Association (the global organization dedicated to supporting and representing the bioenergy sector).
- Transportation and transportation fuel oriented groups motivated to achieve fossil free fuel systems for transportation (e.g. Gröna Bilister [Green Motorists]; Swedish Petroleum and Biofuels Institute; and the 2030-Sekretariatet).

## 1.4 DISPOSITION

This report has the following format.

This first chapter (Section 1) has presented the nature of the problem addressed in this research, the specific problem(s) addressed and the main gaps in the research field are outlined. The content has identified a number of research limitations, and has delineated the intended audience.

In Section 2, a more thorough analysis of the immediate field of study is presented. This content addresses a number of items: first the utilisation of biofuels in Sweden, second, the major producers and then thirdly, a presentation of the general development of policy frameworks for Swedish biofuels, and their current status. The chapter closes with a short analysis of the dynamics of fossil fuel markets over the past four decades. This last item is intended to help place the timing of the case studies in this analysis in context.

Section 3 presents the methods applied in the study. First the foundation provided in the problem definition is expanded with a description of the key theoretical concepts underpinning the data collection and analysis. Second, a series of research hypotheses are stated – these being the presumptions that supported the work. Third the thematic divisions for the study are presented – this being where explanation of how the different parts of the case studies (e.g. forest sector, petrochemical sector, and distribution/utilisation) are viewed at the outset, Fourth the case study objects are detailed, then fifth the data collection and analysis procedures are described. The chapter closes with a series of tables that delineate the manner in which data (collected for cases) is to be grouped and processed.

Section 4 presents the main findings. For brevity, content is limited to a brief summary for each case. Full detailed versions of the cases for eventual study by the reader are provided in the second volume of this report (Part B).

Section 5 presents the analysis summary (a cross case analysis tabulation) followed by a discussion. This is principally focused on the key issues presented in Section 3.

Section 6 presents the concluding comments for the analysis and then outlines areas for future research.

Following the prescribed *f3* format for reporting, acknowledgements, references and then a numbered section containing appendices follow the conclusions.

# 2 BACKGROUND TO SWEDISH BIOFUELS

This section presents contextual details on the Swedish biofuels market. Four subsections are provided: and overview of biofuels utilisation in the country; a discussion of major producers, an analysis of enfolding policy frameworks and phenomena; and a brief overview of fossil fuel markets and the manner in which they have changed throughout the period addressed by the cases examined in this project.

## 2.1 BIOFUELS UTILISATION

The use of renewable transport fuels in Sweden has increased rapidly; the share of renewables in domestic transport sector reached 14.8 % (as measured by energy content) during 2014.[39] This share includes both biofuels and renewable electricity in rail traffic and is the highest share achieved in EU.[40] When accounting with the procedures outlined in the EU Renewable Energy Sources Directive (RES) the share amounts to as much as 19 %. This mainly because RES double counts the contribution from fuels produced from waste and residues such as biogas and HVO.

Domestic transport in Sweden consumed circa 85 TWh of fuels during 2014, equivalent to nearly one quarter of the domestic final energy use. Of this amount, 8.1 TWh (10 %) was biodiesel, 1.9TWh ethanol (2 %) and 1.0 TWh biogas (1 %). In addition, rail transport used 2.6 TWh of electricity (3 %).[41, 42]

Biofuels for transport increased by 156 % over the period 2008 to 2014. During this period biodiesel increased by 438 %, biogas with 199 %, and ethanol consumption has decreased by some 23 %.[43] The use of electricity as a transport fuel for personal vehicles does not enter into the official statistics by the Swedish Energy Agency, but electrical vehicles are increasing rapidly. By February 2016 there were over 16 000 electrical vehicles in the country.[44]

Biodiesel refers to fuels created as hydrotreated vegetable oils (HVO) or fatty acid methyl esters (FAME). More than half of the biodiesel share was HVO during 2014 and this share is increasing quickly.[45] One advantage is that due its physic-chemical properties being closer to that of diesel, HVO can be blended in diesel to a higher percentage than FAME.[46] Using biodiesel as a blend-in fuel has allowed a quick introduction as no additional or new infrastructure is needed. This stated some 14 % of biodiesel sold was distributed as pure biodiesel, B100. B100 was almost exclusively FAME during 2014.

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[39] Swedish Energy Agency, 2016. Energy in Sweden – Facts and Figures 2016 [Energiläget i siffror 2016]. Eskilstuna: Statens Energimyndighet

[40] Eurostat, 2015. Eurostat. Available at: http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do [Accessed March 31, 2015].

[41] The share of renewables in electricity end-use during 2014 was 63 %.

[42] Swedish Energy Agency, 2016. Energy in Sweden – Facts and Figures 2016 [Energiläget i siffror 2016]. Eskilstuna: Statens Energimyndighet.

[43] Swedish Energy Agency, 2015. Energy in Sweden – Facts and Figures 2015 [Energiläget i siffror 2015]. Eskilstuna: Statens Energimyndighet.

[44] Elbilen i Sverige, 2016. Elbilen i Sverige. [The electrical car in Sweden]Available at: http://elbilsstatistik.se/ [Accessed April 12, 2016].

[45] Swedish Energy Agency, 2015. Use of energy in transport sector 2014 (Transportsektorns energianvändning 2014)

[46] Swedish Energy Agency, 2014. The markets for bio transport fuels 2014 (Marknaderna för biodrivmedel 2014) ER2014 27

Historically, Sweden used significant volumes of ethanol in transportation from the 1920s until at least the 1960s. However, in the post Second World War period fossil gasoline dominated [47] and in the modern period, it was not until 1998 that ethanol surpassed 100GWh/yr consumption (a threshold volume where biofuel use appears in mainstream Swedish Energy Agency statistics in Sweden). After this point, its use grew rapidly and in 2008 the consumption peaked at circa 2.5 TWh.[48] Ethanol is distributed as low blend-in with gasoline (E5), high blend-in with gasoline (E85), and also as high blend-in with diesel (ED95). E5 distribution is essentially a drop in fuel and is managed with the existing infrastructure for gasoline. The infrastructure for E85 is also well developed but requires both dedicated refuelling pumps/tanks and distribution infrastructure. ED95, on the other hand, is distributed through the company SEKAB directly to customers and through one public refuelling station.

Interest in FAME biodiesel appeared among Swedish farmers in the late 1980s and a few small-scale production and trials were set up.[49] However, an official Swedish standard for FAME (also Rape Methyl Ester RME) was only developed in 1996[50] reflecting mainstream utilisation in the country. Usage of biodiesel (in this case, FAME) exceeded 100GWh/yr consumption for the first time in 1998. In Sweden it is permitted to blend up to 7 per cent by volume of FAME in fossil diesel, according to the Swedish Environmental Class 1 standard for diesel. The EU's Fuel Quality Directive also governs the blending level and sets a ceiling of 7 per cent by volume.

HVO appeared on the Swedish market in 2011. Since that time, its use has increased rapidly and by 2013 it was the most widely used transport biofuel in Sweden. [51]

The use of upgraded biogas in transport is supported by the addition of natural gas to meet the demand of vehicle gas.[52] Vehicle gas was introduced in Sweden in the early 90s and was initially solely natural (fossil) gas. Today the majority of vehicle gas contains upgraded biogas at a mixing composition of 74 %.[53] The Swedish natural-gas grid is located in the southwestern part of the country; it stretches from Trelleborg in the south to Stenungssund in the north and Gnosjö in the east. Since 2011 there is a liquefied natural gas (LNG) harbour in Nynäshamn, nearby Stockholm,

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[47] Gunnar Carlquist, red (1947–1955). "Bentyl". *Svensk uppslagsbok* (2:a omarbetade och utvidgade upplagan). Malmö: Baltiska förlaget. Libris 11112

[48] Swedish Energy Agency, 2015. Energy in Sweden – Facts and Figures 2015 [Energiläget i siffror 2015]. Eskilstuna: Statens Energimyndighet.

[49] Sandén BA, Jonasson KM. *Variety creation, growth and selection dynamics in the early phases of a technological transition. The development of alternative transport fuels in Sweden 1974–2004*. Environmental Systems Analysis Department of Energy and Environment. Chalmers University of Technology. Gothenburg, Sweden; 2005.

[50] Rehnlund B, Van Walwijk M. *Assessment of bio-ethanol and biogas initiatives for transport in Sweden.* Background information for the EU-project PREMIA. Atrax Energi; 2005.

[51] Swedish Energy Agency, 2015. Energy in Sweden – Facts and Figures 2015 [Energiläget i siffror 2015]. Eskilstuna: Statens Energimyndighet.

[52] A direct translation of the Swedish word *fordonsgas*.

[53] Statistics Sweden, 2016. Vehicle gas deliveries. Available at: http://www.scb.se/sv_/Hitta-statistik/Statistik-efter-amne/Energi/Tillforsel-och-anvandning-av-energi/Leveranser-av-fordonsgas/Aktuell-pong/307506/310205/ [Accessed April 8, 2016].

and since 2014 there is a terminal in Lysekil north of Gothenburg.[54] There are also plans to establish LNG harbours in Gothenburg, Helsingborg, and Gävle.[55]

A dominant proportion of the upgraded biogas (circa 79 %) is distributed stored in gas cylinders in compressed form while the remaining 21 % is distributed through the natural gas grid.[56] When biogas is injected to the natural gas grid, this is done at distribution points and not via the transmission grid.[57] Local grids exist in Stockholm, Västerås, and Linköping. Distribution through a gas grid is more cost efficient compared to distribution through gas cylinders, especially for longer distances. Almost no biogas is distributed in liquefied form (LBG). LBG is only produced in Lidköping.[58] The process is expensive and also energy consuming compared to other distribution forms.

Gas is distributed both via the grid and cylinders to refuelling stations. By April 2016 there were 163 public and 63 non-public vehicle gas refuelling stations concentrated in the southern, and most densely populated, part of Sweden.[59] The large number of non-public refuelling stations is related to the use of vehicle gas in public transport, which often utilises dedicated distribution infrastructure, sometimes connected to bus pit lanes. In addition there are five LNG refuelling stations. The use of LNG in the road transport has started relatively recently and it is mostly used for trucks.

## 2.2 MAJOR PRODUCERS OF BIOFUELS

Current biofuel production in Sweden is mainly based on so-called first-generation biofuels. This section will focus on these domestic producers. However, there are also second-generation biofuels producers (also called advanced biofuels) in Sweden, e.g. Göteborg Energi that produces methane from gasification of forest residues. Biodiesel production of HVO may also be referred to as an advanced biofuel as it is can often be based on residues and is thus associated with a very low carbon footprint. These will be presented in more detail in the case studies provided in Section 4 (summaries) and Section 0 (detail cases).

There are two major actors on the Swedish HVO market: Preem with production in Sweden and the Finnish firm Neste. Neste has production facilities in Finland and two other countries. Preem uses raw tall oil[60] as feedstock while Neste uses residues from the palm oil industry, animal fats and a range of other feedstocks.[61] The demand for HVO in Sweden is larger than the domestic production. Fuel is thus imported and all domestically produced HVO can thus be assumed used in

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[54] The Linde Group, 2015. Available at: http://www.the-linde-group.com/en/clean_technology/clean_technology_portfolio/merchant_liquefied_natural_gas_lng/small_midscale_lng_plants/index.html [Accessed June 3, 2015]; Energigas Sverige, 2015. Flytande naturgas. Available at: www.energigas.se/Energigaser/Naturgas/FlytandeNaturgas [Accessed October 27, 2015].

[55] (Energigas Sverige 2015; SwedeGas 2015) Energigas Sverige, 2015. Flytande naturgas. Available at: www.energigas.se/Energigaser/Naturgas/FlytandeNaturgas [Accessed October 27, 2015]. SwedeGas, 2015. No Title. Available at: http://www.swedegas.se/lng_terminal/lng_terminal [Accessed June 3, 2015].

[56] Swedish Energy Agency, 2014. The markets for bio transport fuels 2014 (Marknaderna för biodrivmedel 2014) ER2014 27

[57] Swedish Energy Agency, 2013. Swedish Energy Agency, 2013. Analysis of the bio transport fuel markets (Analys av marknaderna för biodrivmedel) ES2013 08

[58] Swedish Energy Agency, 2014. The markets for bio transport fuels 2014 (Marknaderna för biodrivmedel 2014) ER2014 27

[59] Gasbilen, 2016. Gasbilen. Available at: http://www.gasbilen.se.

[60] Raw tall oil is a by-product/residue from the pulp industry

[61] Neste (Hietala., K.) The renewable biofuel refinery 2020 – Challenges and opportunities, Advanced Biofuels Conference – For Aviation, Maritime and Land Transport, Stockholm Sept. 15-17 2015.

Sweden.[62] The most common feedstocks for HVO sold in Sweden during 2014 were animal fats, raw tall oil, and palm oil. Preem has based their production on raw tall oil along with vegetable oils and animal fats. As of the autumn of 2015 they are working expanding capacity. Raw tall oil is refined to raw tall diesel in Piteå by the company SunPine, of which Preem is a part owner. The raw tall diesel is then transported to Preem’s refinery in Gothenburg. HVO is generally considered as interchangeable with conventional diesel, and has similar molecular properties and physical performance characteristics. This means that the same distribution infrastructure may be used and that the fuel may be used in conventional diesel engines without any adjustments.[63] Preem uses HVO as a blend-in fuel and their product ‘Evolution Diesel’ contains an average of some 25 % HVO.[64] During 2014 Statoil, OKQ8, and St1 also distributed blend-in HVO.[65] More detailed description of Preem’s HVO production can be found in Part B of this report.

The major producers of FAME in Sweden are Perstorp Bioproducts AB and Ecobränsle AB. There are also smaller producers, and FAME fuel is also imported. All FAME produced in Sweden is rape methyl ester (RME) derived from rapeseed oil. This provides the fuel better qualities in cold conditions than other types of FAME. Methanol is also used in RME production and it may be of fossil or renewable origin – the utilization of renewable methanol delivering a reduced carbon footprint for the FAME product. Perstorp, which is the largest RME producer in Sweden, imports a renewable methanol from the Netherlands.[66] FAME may be distributed as B100 or as a low-blend. There were 38 refuelling points for B100 during 2015.[67] B100 is also distributed directly to consumers, e.g. public transport. Practically all diesel in Sweden contains a low blend-in share of FAME. During 2014 it was 5.5 %. It is allowed to increase the share up 7 %.[68] However during 2014 the tax exemption was only granted up to 5 %.[69]

There are three ethanol producers in Sweden: Lantmännen Agroetanol, Domsjö Fabriker, and St1. Lantmännen Agroetanol is the largest domestic producer. The production is based on fermentation of cereal grains and – to a lesser extent – industrial residues. It is thus first-generation ethanol and the majority of the product is exported to Germany. Fodder is obtained as a by-product and biogas is produced from production residues. Domsjö Fabriker has produced ethanol since the 1940’s and the production is based on pulp industry residues. SEKAB buys the ethanol from Domsjö Fabriker and exports the majority of it to Finland. This is because the Finish policy framework permits double counting for this fuel (similar to HVO and biogas in Sweden). Given that the production is based on residues it may be seen as an advanced biofuel. In 2015 the company St1 commissioned ethanol production based on residues from food industry. St1 also exports the product to Finland.[70]

[62] Swedish Energy Agency, 2015. The markets for biofuels in transport 2015 (Marknaderna för biodrivmedel 2015) ER 2015 31.

[63] Allthough an approval form the vehicle manufacturer is still needed.

[64] The concentrations of HVO in diesel at the pump have changed over time with technology advances, and also change according to season – with higher concentrations utilised during the summer. The product was launched in early 2011 with a concentration of (up to) 20% renewable content. In 2012 this was increased to 30%. As of 2016, the product contains up to 50% renewable content. See http://preem.se/om-preem/hallbarhet/evolution-drivmedel/evolution-diesel/

[65] Swedish Energy Agency, 2015. The markets for biofuels in transport 2015 (Marknaderna för biodrivmedel 2015) ER 2015 31,

[66] *Ibid*

[67] Swedish Petroleum and Biofuels Institute, 2016. Sales points renewable transport fuels. Available at: www.spbi.se [Accessed April 18, 2016].

[68] Measured by volume.

[69] Swedish Energy Agency, 2015. The markets for biofuels in transport 2015 (Marknaderna för biodrivmedel 2015) ER 2015 31

[70] Grahn, M. & Hansson, J., 2014. Prospects for domestic biofuels for transport in Sweden 2030 based on current production and future plans. Wiley Interdisciplinary Reviews: Energy and Environment, p.n/a–n/a. Available at: http://doi.wiley.com/10.1002/wene.138

Biogas is produced via anaerobic digestion throughout much of Sweden. There were 277 facilities in Sweden as of 2014. It is thus a rather distributed and small-scale production compared to other biofuels in Sweden. Co-digestion plants represent 40 % of the production and biogas production at sewage treatment plants 38 %. Co-digestion plants combine different feedstocks, e.g. food waste and industrial residues. Anaerobic digestion at sewage treatment plant began as a method to reduce the sludge volume. Today substrates such as food waste are added to increase biogas production and gas is often upgraded to natural gas quality. Other types of production include biogas production in industries, agriculture, and landfill gas extraction. In total 1.8 TWh was produced during 2014. The majority was upgraded and used as transport fuel. There are 59 upgrading facilities in Sweden. There are also 13 injection points where upgraded biogas is injected to the natural gas grid. The largest biogas facility, Jordberga, also injects upgraded biogas to the grid. Upgraded biogas is complemented with natural gas to meet the vehicle gas demand. The vehicle gas demand remained constant during 2015 but the production of upgraded biogas increased. As a result, the average share of biogas in vehicle gas was high at 74 %.[71]

## 2.3 POLICY FRAMEWORKS FOR SWEDISH BIOFUELS

The successful implementation of new production concepts for forest-derived biofuels is heavily dependent on a supportive, stable and foreseeable policy. A policy framework with the potential to positively influence biofuels development rests on two pillars: a political desire to affect change, usually manifested through certain goals or visions, and the tools to achieve this, generally referred to as policy instruments. Two major entry barriers for new biofuels are the established infrastructure for conventional transportation fuels and the relatively low price for the conventional fossil feedstock (see Section 2.4). Such policy tools must also address these issues if new production concepts are to be realised.

The following subsection presents a number of political goals that affect the production of Swedish biofuels at different political levels, a general description of policy instruments for renewable transportation fuels, and a summary of the policy instruments that affect forest-derived transportation fuels.

### *2.3.1 Political goals and visions affecting renewable transportation fuels*

Political visions and goals relevant to transportation biofuels relevant to this analysis have been formulated at European, national and local levels. Goals set at all these levels have affected possibilities to produce forest-derived transportation fuels.

Political goals for biofuels at the EU level have been driven by rural development, energy security and climate mitigation considerations. While energy security was a key driver in the 1990s (see for instance the Green Paper “Towards a European strategy for the security of energy supply”),[72] focus has steadily shifted towards mitigation of climate change as the public discourse regarding climate

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[Accessed December 19, 2014]; Swedish Energy Agency, 2015b. The markets for biofuels in transport 2015 (Marknaderna för biodrivmedel 2015); Rebecka Bergström Swedish Energy Agency, 2016. Personal communication.

[71] Statistics Sweden, 2016. Vehicle gas deliveries. Available at: http://www.scb.se/sv_/Hitta-statistik/Statistik-efter-amne/Energi/Tillforsel-och-anvandning-av-energi/Leveranser-av-fordonsgas/Aktuell-pong/307506/310205/ [Accessed April 8, 2016].

[72] European Commission (2000), *Green Paper - Towards a European strategy for the security of energy supply*, Brussels, 29.11.2000, COM(2000) 769 final.

has intensified. Considerations of rural development have also constituted a substantial driver political driver throughout, but we observe that this topic receives considerably less focus (in the media for example) than climate.

In March 2007 the so-called EU Energy and climate package was passed in the European Council.[73] The package included the following targets:

- 20% reduction of green house gases by 2020
- 20% renewables on average in energy supply by 2020
- 20% energy efficiency improvement by 2020

In 2009, the European Parliament approved the renewable energy sources directive (RES).[74] It specified individual national targets and how these should be calculated, as well as a specific target for the share of biofuels in land-based transport[75] that should be at least 10% in 2020 for all member states. Previous to this there were also specific targets for biofuels in transport specified in the EU biofuels directive from 2003.[76] The targets were set to 2% biofuels in transport for all member states in 2005 and 5.75% in 2010. Only Germany and Sweden managed to reach the target for 2005;[77] the target for 2010 was however replaced by the 2020 RES target before its evaluation.

Sweden has already met the levels stipulated by the RES according to the counting system applied within its system – with the use of renewable transport fuels amounting to 10 % in 2011 and as high as 19% in 2014.[78] Sweden achieved this figure – significantly higher than the actual percentage of fuel measured by energy content – as a result of the RES's double points for fuels produced from waste or residues. This is particularly evident in Sweden where there is a high prevalence of biogas and hydrogenated vegetable oils (HVO) that are double-counted. However, in energy terms, the share of renewables in the transportation sector reached 9.9% in 2012 and, and as noted earlier, the share was 14.8% in 2014. [79] The figures for road transport alone are somewhat lower, with 12.1% biofuels in 2014 and some 14.7% reported for 2015.[80, 81]

The national political ambitions regarding renewable transportation fuels in Sweden have been mentioned (see Section 1). The ambition to have a vehicle fleet that is independent of fossil fuels

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[73] European Commission (2016). *The EU climate and energy package*. http://ec.europa.eu/clima/policies/strategies/2020/index_en.htm (accessed 18 april 2016)

[74] European Union, 2009. Directive 2009/28/EC. Promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. L 140/16 EN(5.6.2009), Brussels: Official Journal of the European Union.

[75] Specifically excluding aviation and sea transport.

[76] DIRECTIVE 2003/30/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport.

[77] European Commission, COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT, Biofuels Progress Report, Report on the progress made in the use of biofuels and other renewable fuels in the Member States of the European Union,Brussels, 10.1.2007, COM(2006) 845 final.

[78] Swedish Energy Agency, 2016. Energy in Sweden – Facts and Figures 2016 [Energiläget i siffror 2016]. Eskilstuna: Statens Energimyndighet.

[79] *Ibid.*

[80] *Ibid.*

[81] Swedish Energy Agency, 2015. Energy in Sweden – Facts and Figures 2015 [Energiläget i siffror 2015] ET 2015 08. Eskilstuna: Statens Energimyndighet.

was expressed in governmental propositions from 2009.[82] Here it became clear that Sweden has a national agenda that is quite dissimilar to most other EU countries – not only for the abatement of greenhouse gases in general – but also for energy supply to the transport sector. The term independent (in Swedish: oberoende) is not defined in the proposition, but should been seen as part of the vision that Sweden not should generate any net emissions of greenhouse gases by 2050 as also expressed in the proposition. A more definitive interpretation of what 'independent of fossil fuels' meant in this context was subsequently clarified in the public inquiry[83] commissioned to investigate the possibilities for Sweden to fulfil the ambition. A vehicle fleet independent of fossil fuels was described here as a vehicle fleet that is predominantly run on biofuels and electricity.

The have also been a range of political visions expressed at local and regional levels that have affected the development of renewable transportation fuels in Sweden. One such example is the five regional climate and energy goals set up by the County Administrative Board of Skåne (Scania), of which four have a direct impact on biofuels in the transport sector.[84] Goal number four explicitly focuses upon biogas production and states that the production of biogas in Skåne should be at least 3 TWh in 2010. A remarkably ambitious and specific goal considering that the total use of biogas in Sweden was 1.3 TWh in 2014, of which 1,0 TWh was used in the transport sector.[85] Another example is the goals set by the Stockholm County Council that the region's public transport should be fuelled by 90 % renewables by 2020 and that it should be free of fossil fuels by 2030.[86,87]

### *2.3.2 Policy instruments for biofuels*

There are several ways by which policy instruments may be categorised, one being the nature of the policy instrument itself as delineated by contents in the categories: administrative; financial; support to research and development; and information. Administrative instruments, also called command and control mechanisms include direct steering effect via legislation. For transportation fuels this might take the form of mandatory quotas, blending standards, and demands on distribution infrastructure and vehicles, or combinations of these. Financial policy instruments in contrast rely on mechanisms such as taxes, tax alleviation or exemptions, investment support, operational support, tradable environmental certificates, loan guarantees, and public procurement. For renewable transportation fuels, support to research and development may be provided to any link in the chain from feedstock to the operation of full-scale conversion plants. When information programmes are used as policy instruments, it is common that the campaigns are performed in combination with a financial instrument, e.g. a tax incentive may be referred to as an environmental tax.

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[82] Ministry of the Environment (2009). *A coherent Swedish policy for climate and energy – Climate (In Swedish, original title: En sammanhållen svensk klimat- och energipolitik - Klimat)*, Proposition 2008/09:162,

[83] Government of Sweden, 2013. Fossil free road transport [Fossilfrihet på väg]. SOU 2013:84, Stockholm: Statens Offentliga Utredningar.

[84] County administrative board of Skåne (Länsstyrelsen i Skåne), Mål för klimat ioch energy, http://www.lansstyrelsen.se/skane/Sv/miljo-och-klimat/klimat-och-energi/klimat-och-energimal/Pages/index.aspx (accessed 19 april 2016).

[85] Swedish Energy Agency, 2016. Energy in Sweden – Facts and Figures 2016 [Energiläget i siffror 2016]. Eskilstuna: Statens Energimyndighet.

[86] Stockholm County Countil [Stockholms läns landsting], 2010. Regional development plan for the Stockholm region [Regional utvecklingsplan för Stockholmsregionen]. ISBN 978-91-85795-43-7.

[87] Stockholm County Council [Stockholms läns landsting], 2012. A regional traffic supply program for Stockholm County [Regionalt trafikförsörjningsprogram för Stockholms län].

Another way of categorizing policy instruments is in accordance with the link in a supply and demand chain to which they are directed. For biofuels this may be towards the supply or the demand side. However, the targeting of interventions may be further divided; for example, to focus on distinct point in the value chain such as domestic production; chemical conversion and upgrading, infrastructure for supply; private or business consumers, vehicle producers, and so forth.

A third way to classify policy instruments is through direct or indirect market interventions. Indirect market interventions can be achieved via mechanisms such as laws and regulation, taxes, subsidies, while direct interventions may be when a public body aids the creation of a market – for instance by acting as a buyer of vehicles or fuels, or even as a supplier of transportation fuels or services that affect renewable fuels in the transportation sector (e.g. by delivering biogas from municipal waste treatment plants). This third way to classify policy instruments was presented in the interview guide used in the studied cases (see Appendix Section 8.3).

The intended outcomes of policy instruments that affect energy carriers have been different at different times and regions. Taxes have been applied to energy carriers for long times, but the intentions have shifted from being purely or predominantly fiscal, towards the achievement of other social or environmental goals such as ‘reduced energy dependence’ or ‘abatement of greenhouse gas emissions’. Other (positive) external effects that may be provided by policy instruments directed at energy carriers can include the development of domestic industries, stimulation of rural economies or development, and poverty alleviation.

For renewable transportation fuels, the initial production costs have been too high (in comparison to the thoroughly established fossil sector) for a spontaneous development of the industry; as a consequence, support has been required. Biofuel support has commonly taken the form of subsidies (also related subsidies, such as tax alleviations) or mandatory targets. Subsidies, in contrast to taxes, are typically costly for the state and if markets grow significantly it may be perceived as a significant burden to state finances.[88, 89] As economically and technically sound biofuel industries develop and evolve, there are hopefully ways to progressively reduce aid from subsidies as the biofuels can increasingly compete freely on the markets for transportation fuels. However, in the European Union, with the deeply entrenched fossil based systems (that have benefited from policy support and technical learning from many decades) it remains difficult to see that the industry for renewable transportation fuels can achieve independence from policy support anywhere in the near future.

There are also financial policy instruments that can remain revenue/cost neutral for the state – at least through the direct effects. Green tax-switching policies, i.e. to decrease the burden on activities that are less environmentally damaging while increasing it on more environmentally harmful is one such system; the Swedish system for the reduction of nitrous oxide emissions is another. In the latter system, polluters with higher specific emissions pay to polluters with lower specific emissions, while the state sets the total ‘cap’ of emissions for the market. Some systems with tradable emission certificates, mandatory blending standards, or mandatory quotas may also have this effect,

[88] Peck, P., McCormick, K., 2008. Dysfunction between policy and industry – important barriers to the uptake of bioenergy in Europe, in: Proceedings of 16th European Biomass Conference & Exhibition: “From Research to Industry and Markets”. Presented at the 16th European Biomass Conference & Exhibition, ETA-Florence Renewable Energies, Valencia, Spain.

[89] Schoepe, Manfred, IFO Institute, 2006. Economic effects of the production of biodiesel for use as fuel [WWW Document]. URL http://www.globalbioenergy.org/uploads/media/0611_IFO_-_Economic_effects_of_the_production_of_biodiesel_for_use_as_fuel.pdf

Nevertheless, indirect effects may have effects on tax revenue in these cases as well. For example, when a higher price may reduce the overall consumption and thus the tax incomes for the state.

One suggested policy instrument that has received significant attention in Sweden (and is mentioned repeatedly in the case studies included in Section 0) is the price premium model presented in the FFF inquiry,[90] is designed so that while the state will lose income from the carbon dioxide tax, it will not lose the income from the energy tax. Specifically, the price premium model would support plants producing transportation fuels from wastes, residues and cellulose using new technologies. A premium would be provided based on a fixed guide price based on diesel equivalents minus the production costs for diesel, and the carbon dioxide tax. The biofuel would receive the premium when it is sold on the market and the energy tax would have to be paid for the biofuel, but not the carbon dioxide tax. The premium would be provided to the producer for twelve years based on the initial guide price, but the initial guide price would decrease with time so that early adopters are encouraged. In this way investors would not have to carry the risk for fluctuations in the crude oil price (affecting the production costs for conventional diesel) and changes of the carbon dioxide tax. In this model, the fuel producers would be paid by the fuel distributors; thereby seeking to avoid involvement of the state; the intent being to (hopefully) eliminate risk that the EU would consider the system as constituting illegal state aid. The support may be seen as a combination of an investment support, because it is only provided for a limited time, and an operational support, because it is provided based on the quantities of the produced fuel sold.

### 2.3.3 *Policy instruments that have an impact on forest-derived transportation fuels in Sweden*

#### ***2.3.3.1 EU policy instruments***

The European Union commonly poses its visions and targets in forms that the member states should meet by choosing their own preferred policy instruments relatively freely. When specific targets are expressed in a directive such as Renewable Energy Sources Directive (RES), the directive is intended to constitute a (binding) push for the implementation of national policy instruments. It thus will have a strong indirect effect on the development of renewable transportation fuels, both generally and specifically. A case in point being where fuels that are counted twice in the fulfilment of the target for the share of renewable fuels. The original text for this was rather unspecific:

*"… the contribution made by biofuels produced from wastes, residues, non-food cellulosic material, and ligno-cellulosic material shall be considered to be twice that made by other biofuels."*[91]

However, in 2012 under pressure from biofuel critics (largely concerning their so-called 'food versus fuel' concerns) the European Commission launched a proposal for an amendment of the RES.[92]

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[90] Government of Sweden, 2013. A vehicle fleet independent of fossil fuels [Fossilfrihet på väg]. SOU 2013:84, Stockholm: Statens Offentliga Utredningar. Basis report 24 [Underlagsrapport 24].

[91] European Union, 2009. Directive 2009/28/EC. Promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. L 140/16 EN(5.6.2009)., Brussels: Official Journal of the European Union.

[92] European Commission (2012). 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, Brussels, 17.10.2012, COM(2012) 595 final, 2012/0288 (COD).

The Commission proposed a cap for food-based biofuels at 5% of total fuels (energy content), and this would thus have a direct impact on the market by limiting the development for first generation biofuels and possibly promoting second and third generation biofuels. There were also other strong incentives in the same direction. Transport biofuels produced from, for instance, straw, bark, branches, tall oil pitch, and animal manure are to be counted as four times their energy content in the proposal. The intent being to make it more attractive for member states to utilise residues, wastes and by-products in their pursuits to fulfil the RES target for renewables in the transport sector. While the proposal was not passed in its entirety, the directive that eventually was passed[93] contains stricter regulations for the sustainability criteria for biofuels as well as a more specific list for the eligible feedstock of the biofuels that shall be double counted for the RES targets. The stricter sustainability criteria require that the estimated greenhouse house savings should be at least 60% for fuels produced in installations that started operation after 5 October 2015 and that the estimated greenhouse house savings should be at least 50% from 1 January 2018 for other installations. Here it is worth noting that the directive allowing double counting has no direct impact on the fuel producers using the feedstock. It is the member states that may benefit from the double counting and it is also up to the member states to create their policy instrument in accordance with the framework as set by the directives. The tax alleviations used in Sweden are not more generous towards biofuels produced from feedstock in the list from the amended RES. Moreover, since Sweden have no problems at all to fulfil the target of 10% biofuels in land-based transport in 2020, it is hard to see that this will change if the EU does not subsequently set stricter targets.

In some cases, the EU legislation will also have a direct impact on renewable transportation fuels for technical reasons. The so called Fuel Quality Directive 98/70/EC[94] with its amendments in Directive 2009/30/EC[95] specifies limitation in the amounts of ethanol (10.0% v/v) and methanol (3.0% v/v) to be used in petrol and the amount of FAME (7.0% v/v) to be used in diesel fuels. Although technical, these limits also lead to restrictions on the possibilities to use low-blend biofuels to reach the RES target for the land-based transportation sector.

Minimum levels of taxes on energy products including transportation fuels are set in the Energy Tax Directive 2003/96/EC.[96] In Article 2 of the directive it is stated that for motor fuels where minimum tax levels are not specified in the directive, the tax rate should be the same as for the equivalent conventional motor fuel in the tables in the directive. This means that the general rule should be that biofuels are taxed at the same levels as the conventional fuels. Moreover, since the minimum tax levels in the directive are expressed per volume of the fuels, the tax rate for a fuel such as ethanol with a low energy density will thus be higher than for gasoline in energy units. It is not hard to see that this taxation level in the absence of another support system would eliminate the

[93] DIRECTIVE (EU) 2015/1513 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 9 September 2015 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.

[94] DIRECTIVE 98/70/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 13 October 1998 relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC.

[95] DIRECTIVE 2009/30/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC.

[96] COUNCIL DIRECTIVE 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity.

biofuels from the market. This general rule that alternative fuels should be taxed equally to conventional fuels has also been valid before the Energy Tax Directive. However, in article 16.1, the directive left a gap open for a reduced tax exemption or a reduced rate of tax for biofuels, and Sweden has had exemptions for biofuels since the introduction of renewable transportation fuels in the 1990s.[97] In order to maintain a favourable situation for biofuels in its domestic market, Sweden has thus sent in applications for the exemptions of taxes a number of times and these have also been approved – albeit, only for limited time periods. In essence, this has resulted in a situation where certainty for investment in the sector has been limited to around three years in the country – a marked contrast to the 12 years discussed above for the price-premium model – which in turn was based upon typical investment horizons for large scale plant investments.[98]

The last exemption for Swedish biofuels was approved in mid December 2015, only days before the previous approvals for exemptions of taxes would no longer be valid (1 January 2016). The present approval for tax exemptions for liquid biofuels was granted for three years[99] – that is until 31 December 2018, and for biogas for five years.[100] One of the requirements in order to prolong the tax exemptions was that Sweden would continue the measures to secure that overcompensation of the biofuels do not occur. Overcompensation is when the support is judged to be greater than the extra costs for the production of biofuels and thereby is considered to distort EU market conditions.

The importance of enabling infrastructure is also recognised in EU policy. The Alternative Fuel Infrastructure Directive[101] (Directive 2014/94/EC) specifies a required renewable fuels distribution infrastructure and refuelling/recharging points for each member state to fulfil by 2025. These are to support the development of a core corridor called TEN-T. The energy carriers for which the distributions infrastructure is specified are compressed natural gas (CNG) for road transport, liquefied natural gas (LNG) for road and maritime transport, and electricity. Hydrogen is also mentioned but no specific demands or targets are set for this energy carrier.

The TEN-T corridor in Sweden only covers some main roads on the west coast and up to Stockholm and Örebro and this corridor is already covered with the required refuelling stations every 150 km.[102] The required distance between filling stations for LNG is 400 km and this means that this demand is also met or essentially met today.[103] The demands for charging stations for electricity are not met yet, but this is not expected to constitute a significant challenge given the tremendous development of sales of electrical vehicles in Sweden.[104] In summary, as much of the infra-

[97] National revision in Sweden [Riksrevisionen], 2011. Biofuels for at better climate – How is the tax exemption used? [Biodrivmedel för ett bättre klimat – Hur används skattebefrielsen?], RiR 2011:10.

[98] Government of Sweden, 2013. A vehicle fleet independent of fossil fuels [Fossilfrihet på väg]. SOU 2013:84, Stockholm: Statens Offentliga Utredningar. Basis report 24 [Underlagsrapport 24].

[99] European Commission, 2015. SA.43301 (2015/N) – Sweden – Tax exemptions and tax reductions for liquid biofuels. Brussels, 14 December 2015.

[100] European Commission, 2015. SA.43302 (2015/N) – Sweden – Tax exemptions for biogas used as motor fuel. Brussels, 14 December 2015.

[101] DIRECTIVE 2014/94/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 October 2014 on the deployment of alternative fuels infrastructure.

[102] Lönnqvist, T., Grönkvist, S., Sandberg, T. (2015) How can forest-derived methane complement biogas from anaerobic digestion in the Swedish transport sector? Report No 2015:11, f3 The Swedish Knowledge Centre for Renewable Transportation Fuels, Sweden.

[103] Energigas Sverige, 2014. Map over refueling stations for liquid vehicle gas in Sweden. http://www.energigas.se/Energigaser/Fordonsgas/Tankstallen (accessed 19 April 2016)

[104] Power Circle. Press release: Close to 17 000 electrical vehicles in Sweden. 2016-03-08. http://powercircle.org/nyhet/nara-17-000-laddbara-bilar-sverige/ (accessed 19 April 2016)

structure to satisfy TEN-T requirements exist, this analysis judges that the Alternative Fuel Infrastructure Directive will not have a significant impact on the development of renewable transportation fuels in Sweden.

An EU administrated investment support system that may have had an affect on biofuel production is the NER300[105] (New Entrants' Reserve). The NER300 is financed by 300 million European Union Emission Allowances (EUA). These can be allocated to provide support for installations of innovative renewable energy technology and carbon capture and storage (CCS). In Sweden, two projects linked to biofuel production were awarded funding in the first call of NER300: the pyrolysis production project Pyrogrot at the pulp mill Skärblacka bruk (€31 million in support) and the biomass gasification GoBiGas phase 2 (€59 million in support).[106] Despite this substantial support, these projects have not been realized.

#### *2.3.3.2 Swedish policy instruments*

Policy instruments used in the different member states usually interact with the development of biofuels in a more direct way than the EU support systems presented above. The instruments used in Sweden have included a suite of cross-sectorial policy instruments, such as tax exemptions. These are intended to contribute to similar marginal effects to all actors in a field. Swedish policy instruments have also included investment support schemes that are targeted towards certain actors and that commonly are provided without a linkage to the actual production over time. There are advantages and disadvantages with both these types of policy instruments.[107]

Three taxes in Sweden are directly put on transportation fuels: energy tax, carbon dioxide tax, and value added tax (VAT). The two first of these have been reduced or exempted for ethanol since the beginning of the 1990s. At that juncture, ethanol was the only biofuel used at any significant extent in the Swedish transportation sector. Ethanol was exempted from the carbon dioxide tax at the introduction of the tax in 1991 – the first carbon dioxide tax in the world – and was also exempted from the energy tax in 1992.[108] Even if there was an introduction of biofuels in Sweden in the 1990s, the total use amounted to 0,3% of the energy use in the transport sector in 2000, indicating that the real growth took place after the turn of the century.[109]

While tax exemptions have been used as the foundation for the promotion of renewable transportation fuels in Sweden, other complementary policy instruments have been directed towards all links in the chain from production to use. As noted, tax exemptions for biofuels are not in accordance with the general tax regulations in the EU (this, and the process for approval has been mentioned above). Overcompensation, i.e. that the tax exemption would cover more than the extra costs for the production and distribution of biofuels, is considered illegal state aid in the European Union. In

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[105] NER300, 2016. Finance for installations of innovative renewable energy technology and CCS in the EU. http://www.ner300.com/ (accessed 20 April 2016)

[106] European Commission, 2012. Questions and Answers on the outcome of the first call for proposals under the NER300 programme, Brussels, 18 December 2012. http://europa.eu/rapid/press-release_MEMO-12-999_en.htm

[107] See: Grönkvist, S., Peck, P., Silveira, S., Åkerman, J., Larsson, M., and Khedkar, P. (2013) Policy Instruments Directed at Renewable Transportation Fuels – An International Comparison. Report No 2013:15, f3 The Swedish Knowledge Centre for Renewable Transportation Fuels, Sweden.

[108] National revision in Sweden [Riksrevisionen], 2011. Biofuels for at better climate – How is the tax exemption used? [Biodrivmedel för ett bättre klimat – Hur används skattebefrielsen?], RiR 2011:10.

[109] National revision in Sweden [Riksrevisionen], 2011. Biofuels for at better climate – How is the tax exemption used? [Biodrivmedel för ett bättre klimat – Hur används skattebefrielsen?], RiR 2011:10.

a case when overcompensation has occurred, the producers/fuel suppliers have to refund the estimated overcompensation and thereby carry the financial risk for this. To avoid this risk and as a measure to facilitate the approval process for the tax exemptions from the EU, the Swedish Energy Agency monitors the levels of tax exemptions and a monitoring report is released each year.[110] The levels of the tax exemptions are adjusted accordingly and only granted for biofuels that are considered sustainable in accordance with the EU criteria. Such biofuels are all granted full tax exemptions for the carbon dioxide tax. As of April 2016, exemptions for the energy tax are:[111]

- 74% and 73% for low and high blend ethanol respectively
- 8% and 50% for the biomass-derived share of low and high blend FAME respectively
- 100% for the biomass-derived share of ETBE (ethyl tetra-butyl ether, an oxygenate additive for petrol)
- 100% for the biomass-derived share of HVO
- 100% for biogas

Ethanol and FAME in low blends were previously only granted tax exemptions for a certain percentage by volume but now there are currently no such volume restrictions. However, the percentage of ethanol in petrol and FAME in diesel are limited to 10.0% v/v and 7.0% v/v by the Swedish law for transportation fuels.[112] This in turn has applied the volume restrictions from the Fuel Quality Directive 98/70/EC (see Section 2.3.3.1 above). These limits are mainly posed for technically related issues (such as engine manufacturer guarantees). Another restriction of importance for the Swedish ethanol production is that for low-blend ethanol, the only ethanol allowed for use by the Swedish tax law for energy is non-denatured.[113] This, in turn, means that for low blend ethanol, the imported ethanol has a duty tariff that is €192 per $m^3$ while the import tariff on the denatured ethanol that may be used for high blend ethanol fuels is subject to an import tariff of €102 per $m^3$.[114] The consequence being that almost all of the ethanol used in low blends is produced in Sweden or elsewhere in the EU.

As noted previously, the exemptions have been, and are, the foundation for policy instruments that support renewable transportation fuels in Sweden. However, investment support schemes such as the climate investment programme (klimatinvesteringsprogram) KLIMP[115] have been used to support investments for production of biofuels, as has its predecessor, the local investment programme

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[110] Swedish Energy Agency, 2016. Monitoring report for tax exemptions for liquid biofuels during 2015 [Övervakningsrapport avseende skattebefrielse för flytande biodrivmedel under året 2015], Dnr 15-116 67.

[111] Swedish Tax Agency, 2016. Tax exemptions for biofuels [Skattebefrielse för biodrivmedel]. https://www.skatteverket.se/foretagorganisationer/skatter/punktskatter/energiskatter/energiskatterpabranslen/skattebefrielseforbiodrivmedel.4.2b543913a42158acf800021393.html (accessed 20 April 2016)

[112] Swedish Code of Statutes, 2016. Law for transportation fuels 2011:319 [Drivmedelslag 2011:319]. http://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/Drivmedelslag-2011319_sfs-2011-319/ (accessed 21 April 2016)

[113] Swedish Code of Statutes, 2016. Tax law for energy 1994:1776 [Lag om skatt på energi 1994:1776]. https://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/sfs_sfs-1994-1776/ (accessed 21 April 2016)

[114] USDA, 2015. EU Biofuels Annual 2015. GAIN Number NL5028. http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_The%20Hague_EU-28_7-15-2015.pdf

[115] Swedish Environmental Protection Agency [Naturvårdsverket], 2013. Climate investment programme Klimp 2003-2012, Final Report, Accounts to the government January 2013, Report 6517. [Klimatinvesteringsprogrammen, Klimp 2003-2012, Slutrapport, Redovisning till regeringen januari 2013, Report 6517]. ISBN 978-91-620-6517-1, ISSN 0282-7298.

(lokala investeringsprogram) LIP.[116] The total support provided in LIP was SEK 6.2 billion during 1998 to 2002, while the total support in KLIMP was SEK 1.2 billion. Energy-related investments and, more specifically, support to production, distribution, and use of renewable transportation fuels have been major parts in both these investment support programmes.[117] An on-going investment support scheme that resembles LIP and KLIMP is the KLOKT support, Climate step – local climate investments (Klimatklivet – lokala klimatinvesteringar).[118] This support is to be provided to local investments that bring about climate benefits and several biogas production units have received funding during 2015, the first year of the support. The total support during 2015 was SEK 125 million and an additional SEK 600 million will be provided annually in 2016, 2017, and 2018.

A more controversial policy instrument that has been directed at the distribution of renewable transportation fuels is the so-called "pump law" from 2005.[119] This law stated that all tank stations should provide at least one type of renewable transportation fuel. Tank stations with an annual supply below 1500 $m^3$ (present adjustment) petrol and diesel were exempted. The main reason this law has been heavily criticized was that it is an obvious example of when the Swedish government in the endeavour to be neutral in the choice of technology, is just the opposite of that. The investment costs for an ethanol pump were so much lower than the investment costs for e.g. a vehicle gas supply pump and the result was that almost all stations invested in ethanol pumps.[120] The overwhelming tendency to only invest in ethanol pumps was noted by the government and as a response to this, a support was provided for investments in any renewable fuel supply pump except for ethanol. This resulted in investments in 57 new stations for vehicle gas between 2007 and 2010 and by the end of 2012 there were 1 832 ethanol pumps and 135 vehicle gas pumps in Sweden. [121]

In 2012, the Swedish government proposed a change of the Swedish support system towards quota obligations for biofuels. This became the law (2013:984) regarding quota obligations for biofuels [Lag (2013:984) om kvotplikt för biodrivmedel]. The purpose was to gain control over the share of biofuels in Sweden while avoiding some of the tax losses for low blend biofuels induced by the current tax exemptions; the exemptions for the carbon dioxide tax were still kept for low blend biofuels. The quota obligations should only be for the low blend biofuels thereby keeping the support to the pure or high blend biofuels intact. However, the Swedish government had to withdraw the law before it entered into force, since the European Commission judged that the combination of

[116] Swedish Environmental Protection Agency [Naturvårdsverket], 2008. Local investment programme is finished, Experiences and results from ten years of environmental work [Lokala invetseringsprogram i mål, Erfarenheter och resultat av tio års miljöarbete]. ISBN: 978-91-620-8338-0.

[117] Hansson, J and Grahn, M., 2013. Possibilities for renewable transportation fuels in Sweden – Update and extension of the study Possibilities for renewable transportation fuels in Sweden 2030 by Grahn and Hansson, 2010 [Utsikt för förnybara drivmedel i Sverige – Uppdatering och utvidgning av studien Möjligheter för förnybara drivmedel i Sverige till år 2030 av Grahn och Hansson, 2010]. IVL Report B2083.

[118] Swedish Environmental Protection Agency [Naturvårdsverket], 2016. Climate step – local climate investments [Klimatklivet – lokala klimatinvesteringar]. http://www.naturvardsverket.se/Stod-i-miljoarbetet/Bidrag/Lokala-klimatinvesteringar/ (accessed 21 April 2016)

[119] Swedish Code of Statutes, 2016. Law (2005:1248) about the duty to provide renewable transport fuels [Lag (2005:1248) om skyldighet att tillhandahålla förnybara drivmedel]. https://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/Lag-20051248-om-skyldighet-_sfs-2005-1248/https://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/sfs_sfs-1994-1776/ (accessed 21 April 2016)

[120] Parliament of Sweden, 2009. Pump law – follow-up of the law about the duty to provide renewable transport fuels, Summary of follow-up report 2009/10:RFR7 [Pumplagen – Uppföljning av lagen om skyldighet att tillhandahålla förnybara drivmedel, Sammanfattning av uppföljningsrapport 2009/10:RFR7].

[121] Parliament of Sweden, 2009. Pump law – follow-up of the law about the duty to provide renewable transport fuels, Summary of follow-up report 2009/10:RFR7 [Pumplagen – Uppföljning av lagen om skyldighet att tillhandahålla förnybara drivmedel, Sammanfattning av uppföljningsrapport 2009/10:RFR7].

carbon dioxide tax exemptions and the quota obligations for low blend biofuels constituted illegal state aid. The withdrawal was put in place with the law (2014:1368) addressing the amendment of the law (2013:984) for quota obligations for biofuels.[122]

Several policy instruments that affect the demand side for biofuels have also been launched – not only on the national level but also on a regional or local level. Different premiums and vehicle tax exemptions have been given for environmental cars [miljöbilar] since 2007.[123] From April 2007 till June 2009 a premium of SEK 10 000 was granted when a so-called 'environmental vehicle' was purchased, this was followed by a five-year vehicle tax exemption for environmental cars introduced in 2010. [124] However, negatively for biofuels, the definition of an 'environmental vehicle' was changed in 2013 together with the introduction of a 'super environmental vehicle' premium. This was based on maximum tailpipe emissions of carbon dioxide that in principle excluded all cars except electrical vehicles, plug-in hybrids, and subsequently fuel cell vehicles. The grant for super environmental premium vehicles still exists, but is now split in two categories: electrical and fuel cell vehicles in one category and plug-in hybrids in another.[125]

Public procurement has also been used as a policy instrument to promote the sales of environmental cars both nationally and locally. As of 2009, administrative authorities should only purchase and/or lease environmental cars. This often applies as a demand for service providers to these authorities as well.[126] In addition, authorities at local and county level have also used exemptions from parking fees and exemptions from congestion taxes to promote the sales of environmental cars. [127] At times however, they have applied different definitions of environmental cars than the one used nationally.

These demand-side policy instruments are affecting the production of forest-derived transportation fuels very differently. For a fuel such as bio-SNG (also referred to as biogas, biomethane, or BNG), the number of vehicles is crucial, as the market is so limited (see Case Studies in Section 4.5 and 4.6). Actors such as E.ON have here been actively involved in building up a market before the investments in production facilities have been made – for them, alterations to the definition of 'environmental vehicle' in ways that disadvantage gas vehicles have had significant negative influences on the development of the market. For others that produce fuels that are totally compatible with the existing vehicle fleet, such as the HVOs produced by Preem, the demand-side measures are in most cases of minor importance.

[122] Law 2014:1368 regarding changes in the law 2013:984 regarding the quota obligation for biofuels [Lag (2014:1368) om ändring i lagen (2013:984) om kvotplikt för biodrivmedel]

[123] Lönnqvist, T., Grönkvist, S., Sandberg, T. (2015) How can forest-derived methane complement biogas from anaerobic digestion in the Swedish transport sector? Report No 2015:11, f3 The Swedish Knowledge Centre for Renewable Transportation Fuels, Sweden.

[124] Lönnqvist, T., Grönkvist, S., Sandberg, T. (2015) How can forest-derived methane complement biogas from anaerobic digestion in the Swedish transport sector? Report No 2015:11, f3 The Swedish Knowledge Centre for Renewable Transportation Fuels, Sweden.

[125] Swedish Transport Agency [Transportsyrelsen], 2016. Super environmental car premium [Supermiljöbilspremie]. https://www.transportstyrelsen.se/sv/kontakta-oss/Vanliga-fragor-till-Transportstyrelsen/Supermiljobilspremie/ (accessed 22 April 2016)

[126] Hansson, J and Grahn, M., 2013. Possibilities for renewable transportation fuels in Sweden – Update and extension of the study Possibilities for renewable transportation fuels in Sweden 2030 by Grahn and Hansson, 2010 [Utsikt för förnybara drivmedel i Sverige – Uppdatering och utvidgning av studien Möjligheter för förnybara drivmedel i Sverige till år 2030 av Grahn och Hansson, 2010]. IVL Report B2083.

[127] *Ibid*

## 2.4 DYNAMICS IN FOSSIL FUEL MARKETS

As forest-derived advanced biofuels are to be used as substitutes for fossil oil derived products, it is natural that the price of oil is an important determinant for the viability of proposed projects. During 2014 and 2015, global oil prices fell drastically – from mid-2014 levels of around US$100/bbl to a low of around US$30/bbl in January 2016.[128] This brief discussion seeks to set this fall, and quite marked volatility in oil prices over the past decade, into context for this report.

Although both liquid and gaseous fuels are covered within the suite of projects addressed here, the prime issue for project viability is related oil markets rather than natural gas. In principal, gaseous renewable transportation fuels (e.g. bio-SNG or biogas) compete with existing liquid transportation fuels; due to the market structures and taxation base for industrial or heating markets, renewable gas is not currently attractive in those markets. As such, the oil price level can be considered as a price base rather than natural gas.[129]

### *2.4.1 Oil and gas price trends*

Current low oil prices present an environment that is not nearly as attractive for investment in a the projects addressed by this study as was experienced the period 2007/8 to 2014 when oil and gas prices generally were generally higher (we do note however, the drastic fall in 2008, which is discussed below). Further, forecasts into the future indicate that is not anticipated that the high prices of that period will be approached over the coming decade.[1] This stated – and considering that major forecasters did not anticipate the price fall in 2014-15[130] – it is still important to place the oil price in a longer-term perspective both backwards and forwards in time.

Figure 1 shows historical and projected annual average prices supplied by the World Bank (Pink Sheets) for both oil (world average) and natural gas (Europe) from 1980 forward. Several general points can be taken from this graph. First, is that both oil and gas prices were relatively stable, and low for the period from the late 1980s until the early 2000s. The oil price (nominal US$)[131] was around 20 US$/bbl during this period. Prices then rose steadily (driven significantly by the expansion of the economies of China and India) until the time of the Global Financial Crisis (GFC) when they fell markedly to result in a yearly average of around 60 US$/bbl for 2008 (although the bottom of the market was at around 40 US$/bbl), a level still notably higher than 'historical averages'. Prices then rose to a historical peak (average yearly price) in mid-2011/12.[132] A break has been inserted in the graph to highlight where recorded oil and gas prices switch to projections.

Shifting focus to our study, the oil price in mid-2007, the starting point for most case studies addressed here, was around US$70/bbl. It seems reasonable to assume that pre-planning for such initiatives began earlier than this, but it also seems reasonable to suppose that all project initiation

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[128] See also http://www.indexmundi.com/commodities/?commodity=crude-oil&months=60

[129] Interview with Björn Fredriksson Möller, (P. Peck, Y. Voytenko) 29 September 2015.

[130] Indeed, in the IEA:s World Energy Oultlook från 2008 it was even quoted "The era of cheap oil is over". See p3. at http://www.worldenergyoutlook.org/media/weowebsite/2008-1994/weo2008.pdf

[131] Nominal value is not adjusted for inflation, and so increases in nominal value reflect the effect of inflation. Real value on the other hand, presents a value that is relative to other commodities or goods. It is adjusted for inflation, which enables comparison of quantities as if prices had not changed. Changes in real terms therefore exclude the effect of inflation. ref: R. O'Donnell (1987). "real and nominal quantities. *The New Palgrave: A Dictionary of Economics*, v. 4, pp. 97–98.

[132] The all time peak monthly price however occurred in 2008 just before the GFC caused the market to crash. Monthly trends can be seen at http://www.indexmundi.com/commodities/?commodity=crude-oil&months=120.

processes took place when oil prices were high – greater than US$60/bbl or so. At the time of writing (April 2016), the oil has recovered slightly from lows to around US$40/bbl, roughly equivalent to the average 2004 price but still very much below the average yearly levels of 2007-08.[133]

While this analysis will consider any sort of oil price to be highly uncertain.[134] Forecasts into the future from the IMF and the World Bank[135] currently indicate projected oil prices in the US$60 to US$70/bbl range in the period 2018 to 2020. As this price lies somewhat (5-15 US$/bbl) below average world production prices for many (large volume) non-conventional oils sources (circa US$70-80/bbl)[136] – thus a conceptual threshold level for markedly increased production of non-conventionals – this will be assumed to be a reasonable figure for the terms of this discussion.

An observation however, that seems particularly relevant to this discussion, is that current oil and gas price levels (expressed in nominal terms) appear to have returned to levels more representative of long-term averages before the rapid expansion of the Chinese economy – an expansion that is now widely viewed to be slowing.

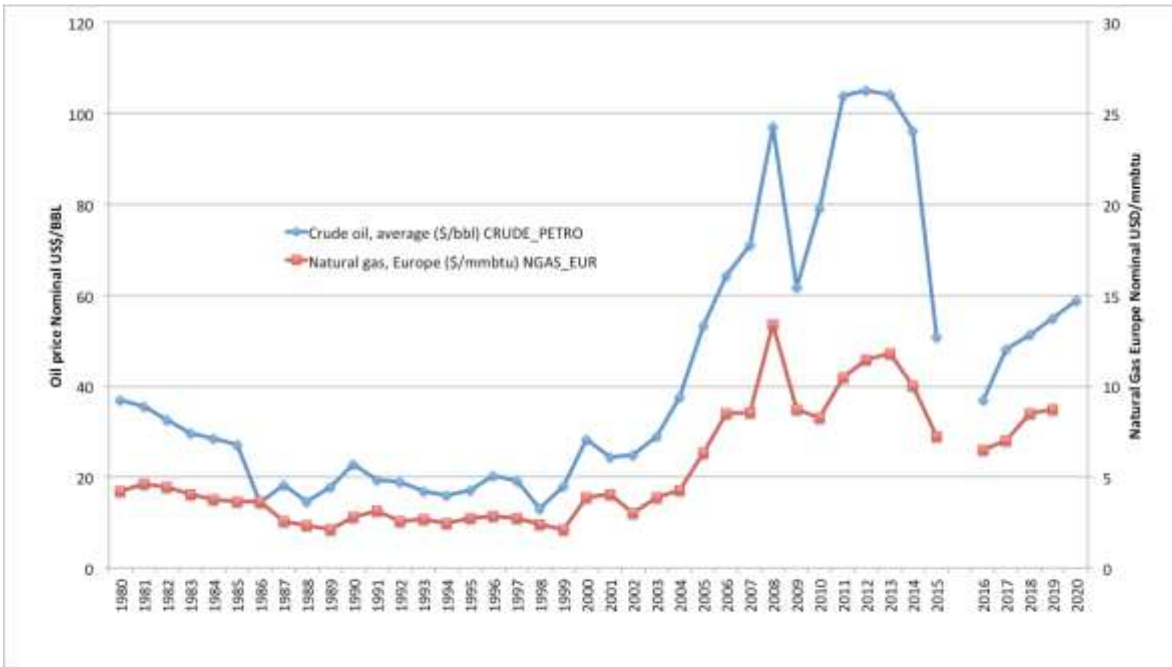


**Figure 1. Oil and Gas price developments and projections 1980-2020137 (Data sources: World Bank Pink Sheets; World Bank Commodity Price Forecast Data, and EIU Economic Commodity Forecast).**

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[133] While the World Bank expect slightly higher prices for energy commodities over the course of the year as markets rebalance after a period of oversupply, they also indicate that it is feasible that energy prices could fall again if OPEC increases production significantly, and if other non-OPEC production does not fall as fast as expected. See: http://www.worldbank.org/en/news/press-release/2016/04/26/world-bank-raises-2016-oil-price-forecast-revises-down-agriculture-price-projections

[134] As just one example of how far from reality estimates can be, oil price forecasts for 2015 utilised by the EU when considering the extension of Swedish tax exemptions used estimate of between 50 and 75 USD/bbl for 2015 and 2016 65 and 80 USD/bbl for 2016 See: (Kommissionens beslut, 14.12.2015, Skattebefrielser och skattenedsättningar för flytande biodrivmedel. European Commission C (2015) 9344 final

[135] http://knoema.com/yxptpab/crude-oil-price-forecast-long-term-2016-to-2025-data-and-charts

[136] National Geographic, March 2016, *In the Arctic's Cold Rush, There Are No Easy Profits*.See: http://www.nationalgeographic.com/magazine/2016/03/new-arctic-thawing-rapidly-circle-work-oil/

[137] World Bank Commodity Price Data (The Pink Sheet) annual prices, Updated on April 04, 2016 - http://databank.worldbank.org/data/databases/commodity-price-data with forecasts for oil fro m World Bank Commodity Price Forecast Data, January 2016 and forecasts for gas from EIU Economic Commodity Forecast, Dec. 2015.

### *2.4.2 Real European fuel price trends*

This theme of a possible return to longer-term average price conditions is supported by an examination of European Environmental Agency data and trends for European fuel prices. Also important in this discussion of transportation fuels is that the crude oil price has less impact on the retail transportation fuel process than might be expected, especially in Europe where the tax level on petrol and diesel fuels commonly make up a large share of the retail price. The general patterns in the oil market are still seen in Figure 2 below that presents nominal and real fuel prices for European diesel and petrol for the period 1980 to mid 2013.

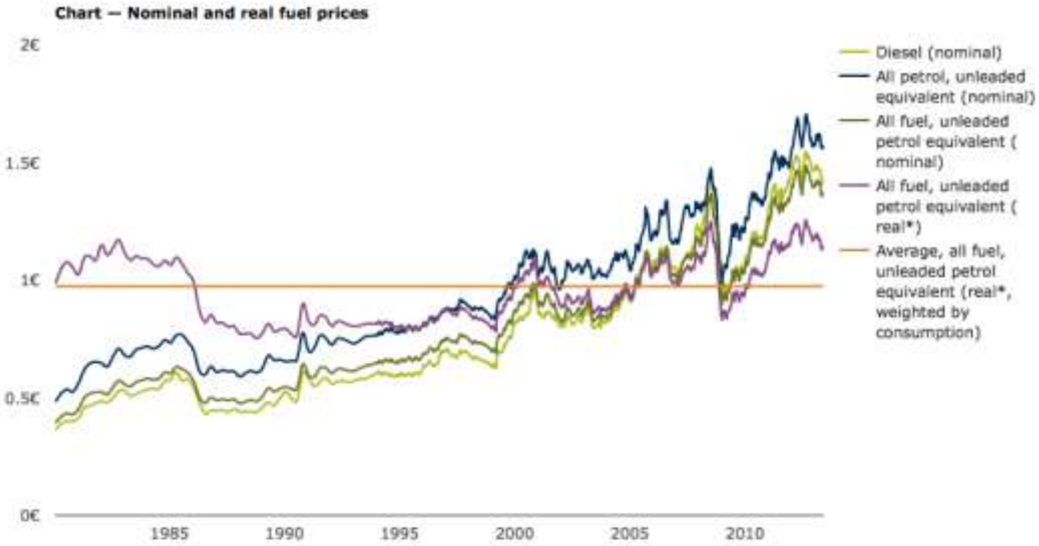


**Figure 2. European fuel price trends €/litre 1980-2014.**[138] [139]

In the period since 1980 the real price[140] of transport fuel in Europe has fluctuated between €0.75 and €1.25/litre (average for all fuels). The long-term average real price has been €0.96/litre. Mirroring the oil price trends shown earlier, real fuel prices peaked in July 2008, prior to the GFC, at around €1.25/litre, but then fell by around 30% later that year. This was largely due to a significant drop in the price of crude oil. Another peak occurred in April 2012 when fuel prices reached €1.24/litre. Since then fuel prices have fallen again. This graph tracks trends until May 2013 when fuel prices where at €1.14/litre, falls in the oil price since then would suggest that prices again lie at around the long-term average levels of close to €1/litre (equivalent consumption in unleaded petrol, corrected for inflation to 2005 prices).

[138]See: http://www.eea.europa.eu/data-and-maps/indicators/fuel-prices-and-taxes/assessment-§3

[139] Definitions: a) 'All petrol' is a consumption-weighted average price of both leaded and unleaded fuel, corrected using energy-content to the equivalent amount of unleaded petrol. b) 'All fuel, unleaded petrol equivalent' is a consumption-weighted average price of unleaded, leaded petrol and diesel, corrected using energy content to the equivalent amount of unleaded petrol. c) 'Nominal' is the price with no adjustment for inflation. d) 'Real' is the price corrected for inflation, using 2005 as the baseline year. e) 'Average, all fuel, unleaded petrol equivalent (real, weighted by consumption)' is the consumption-weighted average of the 'All fuel, unleaded petrol equivalent (real)' line across the full time series.

[140] All road transport fuels, expressed as the equivalent consumption in unleaded petrol, corrected for inflation to 2005 prices.

Note: care needs to be taken when examining this figure as the figures are expressed in 2005 euros. Current (25 April, 2016) EU fuel prices for gasoline in current 2016 Euros range from €0.96/litre in Poland to €1.56/litre in the Netherlands. Prices in Sweden are circa €1.45/litre).[141] The 2005 figure must be inflated by 10 years of inflation to be equivalent – these figures correlate with an average inflation rate of just over 2% for the period.

In summary, this brief examination of oil, gas and retail fuel prices indicates that the period addressed by the case studies represents a time period when fossil fuel prices were more expensive than their long term average levels. If seen from that perspective alone, then the period of circa 2005 to 2014 may be actually turn out to be an anomaly. At the time of writing, there are indications that oil prices may have returned to levels more in line with longer-term averages.

While there were expectations that an 'age of high oil prices' had been entered[142] and such beliefs contributed to initial confidence by project proponents regarding the financial viability of their projects. Existing projections for the coming years do not indicate that the high levels of that period will be approached. While past experiences with the best forecasts available being wrong indicate that there is no guarantee that this will be the case, it can be supposed that future projects pursuing the production of advanced biofuels will be more cautious than regarding oil prices than those of the past.

[141] http://www.globalpetrolprices.com/gasoline_prices/Europe/

[142] See p3. at http://www.worldenergyoutlook.org/media/weowebsite/2008-1994/weo2008.pdf

# 3 METHOD

This project commenced guided by a number of working assumptions (detailed within description of the knowledge gap in Section 1.1.1), as it pursued work to support the development of strategies that define:

- which pathways forward for the Swedish advanced biofuels sector are the most relevant;
- 'how to support specific technology platforms';
- 'how to structure collaboration or cooperation'.

As noted, the study is based upon case studies. The case studies and the key informants involved are summarised in the table below.

**Table 2. Case studies**

| Case Study | Name, role | Organization | Input to study |
|---|---|---|---|
| GoBiGas | Lars Holmquist, Business Strategic Planner;<br>Ingemar Gunnarsson, Development Engineer;<br>Eric Zinn, Biogas Products Coordinator | Göteborg Energi | Case study interview(s): GoBiGas;<br>Written input to webinar |
| Biorefinery Norrtorp | Göran Eriksson, Former President | Sekab | Case study interview(s): Biorefinery Norrtorp |
| VärmlandsMetanol | Björn Gillberg, President | VärmlandsMetanol | Case study interview(s): |
| Chemrec | Jonas Rudberg, former CEO;<br>Max Jönsson CEO | Chemrec | Case study interview(s): |
| E.ON | Björn Fredriksson Möller, Project Manager | E.ON | Case study interview(s): Bio2G |
| LTU Green fuels | Ingvar Landälv,<br>Project Manager (former VP Technology at Chemrec) | Luleå University of Technology | Case study interview(s): LTU Green fuels |
| Preem | Sören Eriksson, Product Developer; Åsa Håkansson, Business Developer | In person, 2015-12-10 | Case study interview(s): |
| RenFuel | Sven Löchen, CEO | RenFuel AB | Case study interview(s): |
| Södra/SunPine | Gustav Tibblin (Chairman of the Board of SunPine) | Södra | Case study interview(s): SunPine |

## 3.1 THEORETICAL UNDERPINNING

As noted in the opening words of this report, it is held that structured research in technological transitions has potential to provide policy-makers and industry actors with knowledge that may help them move biofuel technology systems forward. When we proposed this project we chose to apply an actor-focused perspective that examines how the actual 'players' within the system behave and interact so as to influence institutions, interactions with incumbent technologies and infrastructure, and interactions with those in control of such. This choice is directly related to the fact that the study collects information directly from organisations involved in both (a) activities directed towards the creation and testing or new innovative technologies for fuel production and utilisation, and (b) are participating in coordinated network(s) that have the specific aim to foster collective action towards uptake of such innovations (e.g. the aforementioned f3 Centre).

To achieve this we formulated a research plan that utilises insights from theoretical work focused on entrepreneurial strategies for industry creation (here we call these *Innovation Proponent Strategies*). We examine lines of action suggested to be important for innovation proponents to pursue as they seek to foster the emergence of new industries/socio-technical systems. This has a strong focus on the examination of strategies to pursue collective action, and processes of institutionalisation and/or legitimation.[143] This approach takes a view that such strategies can help overcome the difficulties of emergent technology systems via achievement of cognitive and socio-political legitimacy in supply chains, markets and political spheres.

After commencing the fieldwork, it became apparent that a more encompassing theoretical framework within which to place the work was required. In particular, we sought a framework that analyses not only the actors but also the technology system itself and its place within the broader socio-technical environment.  To achieve this, we enriched the analytical framework with theoretical insights drawn from the multi-level perspective (MLP) after Geels and others.[144]

MLP has developed as the key meso-theory to explain transition processes in systems of consumption and production.[145] The principal idea of the MLP is that the establishment of new socio-technical systems comes about via transitions through, and interactions between, three different levels: niche, regime and landscape.[146] Of special interest for this work was the pursuit, or emergence, of specific activities that can serve to create 'protected spaces' within the market – that which the MLP refers to as 'niches' These are phenomena that are examined in a rich suite of technology innovation and business studies of the emergence of new industrial sectors.[147] Again, the focus here is on innovative technology systems as they transition from early stages of growth to become established in markets.

While there is closely related literature on Strategic Niche Management (SNM) that addresses the development of technological niches by system actors as tools to stimulate transitions towards new regimes,[148] such was not explicitly applied in this work. This for the simple reason that interview and analysis work had already commenced following themes of legitimation listed above, and resources were not available for further extension of the project to enfold this literature. This stated, as SNM is an important part of the MLP analysis perspective, SNM structures and views have in-

[143] Largely inspired by work by Aldrich, H. E., & Fiol, M. C. (1994). Fools Rush in? The Institutional Context of Industry Creation, 645–670; Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis., 407–439; Bergek, A., Jacobsson, S., & Sandén, B. A. (2008). "Legitimation" and "development of positive externalities": two key processes in the formation phase of technological innovation systems, 575–593, and even Bower, J. L., & Christensen, C. M. (1995). Disruptive technologies: Catching the wave, 43–54.
[144] See: Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions*, 1(1), 24–40. http://doi.org/DOI:10.1016/j.eist.2011.02.002; Geels, Frank W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. Research Policy, 31(8-9), 1257–1274. http://doi.org/DOI:10.1016/S0048-7333(02)00062-8; Geels, Frank W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, 33(6-7), 897–920. http://doi.org/DOI:10.1016/j.respol.2004.01.015, and Schot, J. W., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management*, 20(5), 537–554.
[145] Markard, J., Raven, R. and Truffer, B., 2012. *Sustainability transitions*: An emerging field of research and its prospects. *Research Policy*, *41*(6), pp.955-967.
[146] See Geels and Schot & Geels as cited above.
[147] See for example items addressed by footnote referencing Aldrich & Fiol, Bergek *et al*, etc. above.
[148] See work such as the following for an overview of this literature: Hoogma, R., Kemp, R., Schot, J. W., & Truffer, B. T. (2002). Experimenting for sustainable transport: the approach of strategic niche management. Spon Press, and Kemp, R., Schot, J. W., & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. Technology Analysis and Strategic Management, 10(2), 175–196.

deed been applied. A case in point involves the multiple parameters within the socio-technical regime that appear in the analysis structure (see Table 6) – these being items clearly identified by SNM work. Moreover, later SNM analysis[149] now also highlights the importance of consideration of active work towards legitimation in order to shape protective niches.

Applying these conceptual lenses, this study seeks evidence of particular patterns and mechanisms in technology transition processes underway, or being attempted, in the Swedish forest-based biofuels sector. As noted earlier, the project is to contribute to the transition outlined in analyses such as the Swedish Government's Commission on fossil-free road transport – particularly the goal to become independent of fossil fuels in transportation. We hold that these processes represent a part of a major, long-term technological change in the way a societal function is fulfilled in Sweden. On the one hand, the function being the 'fuelling of Swedish motorized transportation' (i.e. a switch from fossil to renewable); on the other hand, there is also a second deeper function – that of producing the fuel itself. This entails a transition from exogenous fossil fuel supply/processing to an endogenous fuel production system.

Central to this work is that technology transitions require much more than changes in technology; they also inextricably interlink with factors such as changes in user behaviour, regulations and standards, the existence or operation of industrial networks, incumbent or required infrastructure, and symbolic meaning or culture. Relevant to this latter item, an overarching social objective in Sweden is the achievement of the Swedish environmental quality objective (miljömål) of reduced climate impact. The climate discourse increasingly permeates discourse in Sweden, and we perceive that cultural norms are passing through a marked transition in this area.

The theoretical considerations listed above are explained and placed in the context of this work in a separate publication (*Investigating institutional constraints on the production of forest-derived transport biofuels in Sweden: A study design)* that is also an output of this project. This was delivered as a conference paper to the European Biomass Conference and Exhibition (EUBCE) in June 2015, and is published in the proceedings of that conference.[150]

This paper is available via the following web link: Research Gate: INVESTIGATING SOCIO-TECHNICAL & INSTITUTIONAL_CONSTRAINTS

The prime outputs in the paper included an explanation of how the research team linked the theoretical insights to the cases being investigated. This was then followed by a series of tabulations communicating 'what sorts of phenomena' were being searched for in the (then upcoming) series of interviews to be conducted in this project.

Key tables used to support the analysis are included in Section 3.5.4 (see **Table 4** to **Table 8**) with brief explanations of relevant content. Figure 3 below provides a representation of the key terms utilised within the analysis tables.

[149] See for example: Smith, A., & Raven, R. (2012). What is protective space? Reconsidering niches in transitions to sustainability. *Research policy*, *41*(6), 1025-1036 as an example of work that is directly applicable in the context of this study – and has been used to support the analysis.

[150] Peck, P.C., Grönkvist, S., Hansson, J., Voytenko, Y., Lönnqvist, T., 2015. *Investigating institutional constraints on the production of forest-derived transport biofuels in Sweden: A study design.* In proceedings of the European Biomass Conference and Exhibition (EUBCE) 2015, Vienna, Austria.

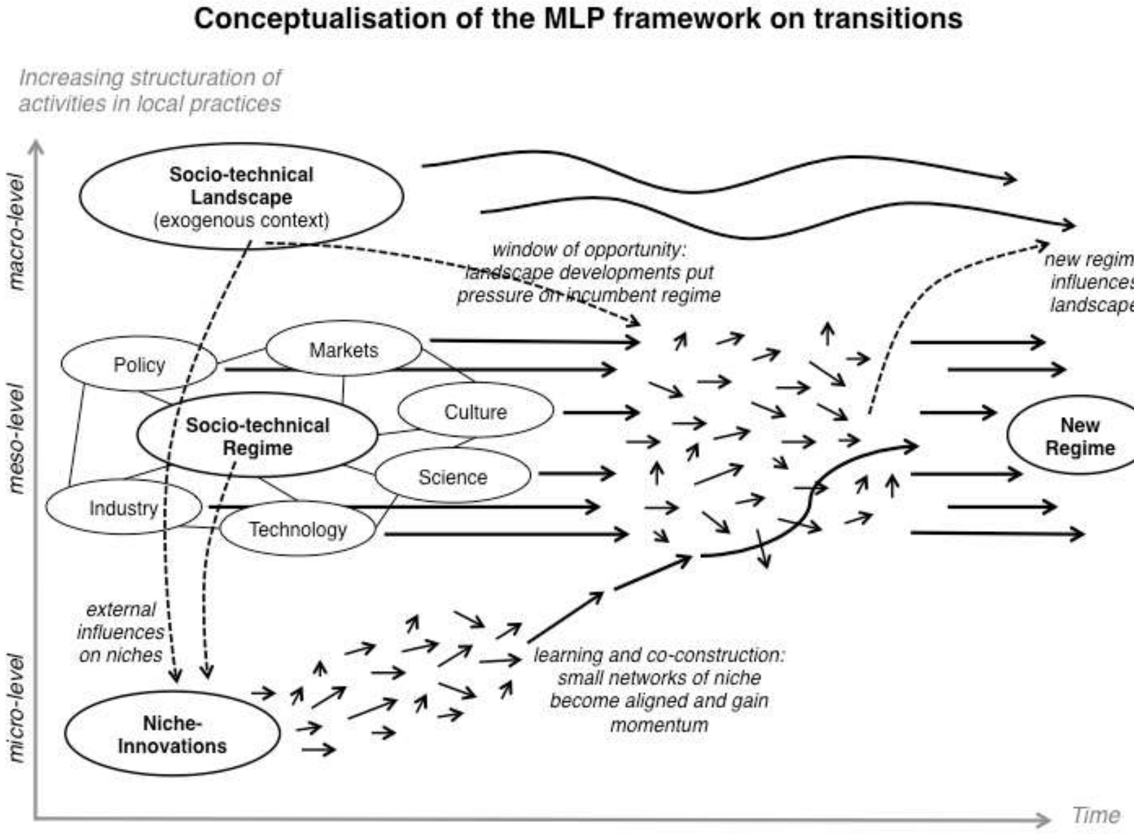


**Figure 3. Illustration of the multi-level perspective (MLP) on socio-technical transitions. Source: redrawn and simplified by Sandro Benz (IIIEE) from Geels.151, 152**

Figure 1 illustrates technological transitions in which innovations emerging from protected niches substitute established socio-technical systems at the regime level when factors at the landscape level are favourable. When there is an alignment between innovations that have matured in niches (e.g. protected markets and universities) and favourable landscape conditions (e.g. oil price) there is a window of opportunity and the emerging technology may substitute the established technology.

Another transition pattern described by Geels is systemic innovation through stepwise reconfiguration. Innovations may replace components of the system and thus reconfigure it stepwise.

*"Novelties are initially adopted as 'modular innovation' into existing systems and subsequently reconfigures the basic architecture through new combinations of new and old elements"*[153]

Typical for this transition pattern is that incumbent actors may survive through adapting to the new system configuration that includes new combinations of new and old system components. Modular innovations gradually reconfigure the socio-technical system. One component replaces another, but

[151] Geels, F.W. & Schot, J., 2007. Typology of sociotechnical transition pathways. Research Policy, 36(3), pp.399–417.
[152] Geels, Frank W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8-9), 1257–1274. http://doi.org/DOI:10.1016/S0048-7333(02)00062-8
[153] Berkers, E. & Geels, F.W., 2011. System Innovation through Stepwise Reconfiguration: The Case of Technological Transitions in Dutch Greenhouse Horticulture (1930–1980). Technology Analysis & Strategic Management, 23(3), pp.227–247. Available at: http://www.tandfonline.com/doi/abs/10.1080/09537325.2011.550392.

it does not affect the other components of the system.[154] However a modular innovation may trigger additional changes in the system once adopted in the regime.[155] This pattern thus differs from a transition where an emerging technology directly substitutes an established technology. Both transition patterns, substitution and stepwise reconfiguration, are used in this study to understand technological transitions that involve forest-derived transport fuels.

## 3.2 RESEARCH HYPOTHESES

The hypotheses that guided the design of this project are paraphrased as postulations below:

> **Postulation 1.** The emergence of new socio-technical system delivering forest transportation biofuels requires that proponents can better account for the alignment, overlap, synergies and areas of competition between their technology platforms and incumbent industries; including their strategies, existing infrastructure and markets.

A second subsidiary assumption, focusing on "softer" issues supported this:

> **Postulation 2.** It is important that proponents can better account for the preferences and beliefs of key 'supply chain' and 'user chain' actors regarding the future and function of socio-technical system delivering forest transportation biofuels – and their role as drivers and constraints for progress for the sector (including e.g., viability, success and/or failure related to projects, supposed understanding and misunderstanding, and attention spans.

In order to provide structure related to the interaction of the various technology platforms addressed by the study, a third postulation was formulated:

> **Postulation 3.** Advanced biofuel technology systems (production, distribution and utilisation) will be affected by interactions between, three different levels: niche, regime and landscape and generally need to evolve to fit within established socio-technical systems (the socio-technical regime) in order to transition from isolated niche applications into the mainstream regime.

As described in the Method section, the work has been theoretically framed with the points of departure that organisational, intra industry and inter-industry phenomena could usefully be viewed via sociological, business and institutional lenses and that phenomena affecting the progress of technology systems could be usefully framed in multi-level perspective (MLP) where interactions between, three different levels: niche, regime and landscape are considered.

## 3.3 THEMATIC DIVISION OF WORK

This research focuses on a range of barriers and drivers to the development of, production of, and utilisation of sustainable transport fuels from the forestry sector. This demands focus on the Swedish pulp/paper sector, but to adequately cover the forest-derived transport biofuels field, work include actors beyond that sphere – not least the petrochemical sectors, and manufacturers of vehicular drive-chains (principally the heavy goods sector), and to some extent, incumbent 1st

[154] *Ibid.*
[155] Geels, F.W. & Schot, J., 2007. Typology of sociotechnical transition pathways. Research Policy, 36(3), pp.399–417.

generation biofuels producers. While the study utilises a significant volume of enfolding literature, and draws upon previous research (for example work by the authors), the analysis in this study particularly relies upon the collection of significant volumes of primary qualitative data delivered by interviews as its key information source.

Three key thematic areas: forest sector strategies, engine platforms and fuel infrastructure issues, and petrochemical sector strategies have been used to structure the activities in the project. Since, in practice nearly all initiatives studied, and all project proponents involved were active in at least two of the three areas, three distinct and separate sub-projects were not pursued. In practice, the pursuit of information and the conduct of analysis addressed these three areas within the suite of case studies following the general themes detailed below.

**Organizational or intra-industry (internal) drivers & constraints:** At this level our research generally sought evidence of issues within organizations, or between sectorial organizations in the forest sector (thus generally organizational or intra-industry).

> Casework investigated forest sector perceptions and preferences regarding how involvement in advanced transportation biofuels production should be pursued, and how this should be linked to the existing petrochemicals sector. In particular, evidence of consensus (or a lack thereof) was targeted. Key items of interest were: the fuel types considered most desirable, or strategically advantageous; evidence of concern regarding biomass feedstock competition; and views related to existing infrastructure, and sunk costs.

**Inter-industry and socio-technical regime drivers and constraints[156]:** At this level our research generally sought evidence of inter-industry interactions. Notably, this is linked to factors such as: transportation fuel policy in general; changes in the Swedish passenger vehicle fleet morphology; incumbent fuel logistics infrastructure; and the strategies of some engine platform/vehicle makers.

> Casework investigated alignment between the technology initiatives and the established socio-technical system in the country. This includes items such as: infrastructure, institutions, policy frameworks, established practices, behavioural patterns, markets, and industry structures. Three key themes pursued were: a) the role of fuel system production and distribution infrastructure; (b) the need for special engines, dedicated fleets, or both; and (c) the function of the incumbent fossil fuel industry within the advanced forest-derived fuel sector.

**External and/or landscape-level drivers and constraints:** At this level our research generally sought evidence of interactions with phenomena from outside the forest and biofuel production sector, and outside the industries that directly interact with forest-derived fuel production systems. Notably, this is linked to factors such as: stakeholder views regarding biofuels in general, and forest-derived fuels in particular; the global climate discourse; macro-economic and macro-political trends; significant environmental changes; demographic trends, and so forth.

> Casework and workshop/interview discussions with key informants investigated issues such as: general 'windows of opportunity' for the implementation of larger initiatives for

[156] In the project proposal this was described as 'hybrid' (internal/external).

forest-derived transportation frameworks; the influence of (particularly) oil markets dynamics; the increasingly high profile of electromobility in discussions; and experiences, perceptions of risk, and expectations, regarding EU and Swedish policy frameworks that enfold transportation biofuels.

Casework also included workshop input and related interview discussions with key informants.

## 3.4 CASE STUDIES

The work relied principally upon qualitative approaches. A total of 12 case studies were produced focusing upon the projects and actors involved.

provides an overview of the cases, and the informants involved. The projects addressed by case studies are in different phases; some have been realized, some have been cancelled/halted and some are still in the planning stage, or on hold. The key source of information for all cases was the interview (or interviews) held with proponents of the different case studies. This base was then reinforced and developed with material derived from desk-top study (e.g. literature review), web based surveys, a project webinar, supplementary interviews with key actors and material obtained from the proponents.

**Table 3. Overview of Case Studies.**

| Cases | Technology, Feedstock & Output | Proponents or informant organisation | Key informants |
|---|---|---|---|
| GoBiGas, Göteborg 20/100MW | Indirect gasification, solid biomass (pellets at first), Output: methane, heat | Göteborg Energi (municipally owned energy company) | Project manager |
| Bio2G 200MW | Gasification, wood chips, forest residues, Output: methane | E.ON Sverige AB (E.ON Sweden) | Project leader - gasification |
| Chemrec and Domsjö Fabriker, Örnsköldsvik 100 MW | Entrained flow biomass gasification, black liquor, Output: DME or methanol | Chemrec | (former) Managing Director |
| LTU Green Fuels, Piteå (3MW) | Entrained flow biomass gasification, black liquor & pyrolysis oil, Output: DME and methanol | Luleå University of Technology | |
| Värmlands Metanol, Hagfors, 110MW | CFB gasifier, wood chips, OP: methanol, heat | Värmlandsmetanol AB, Hagfors (Värmland) | |
| Bioraff (biorefinery) Norrtorp 250MW | Gasification, forest residues & waste, OP: methanol and/or methane | SAKAB et al., Kumla | |
| Preem | Diverse:<br>HVO from bio-diesel<br>Biooils to diesel<br>Solid biomass to diesel (future?) | Preem | |
| Rottneros biorefinery[157] 200MW | Gasification, lignocellulosic biomass, OP: methanol | Rottneros AB, Rottneros (Värmland) | Cancelled. Company withdrew from interview process. |
| SunPine, Piteå 100 000 $m^3$ per year | Raw tall diesel is separated from raw tall oil | Södra (other owners: Preem, Sveaskog, Kiram, and Lawter) | |
| Renfuel | Catalytic conversion of lignin into lignin oil | Renfuel | |
| Scania Trucks | Engine platforms – case focus ethanol | Scania AB | |
| Volvo Trucks | Engine platforms multiple – case focus DME | Volvo Trucks | |

## 3.5 RESEARCH PROCEDURES

This section briefly outlines the general research approach and provides examples of tabular analysis tables used for grouping and processing of information gathered during the study.

### *3.5.1 Informants and data collection*

A purposive sampling approach[158] was utilised; thus the study targeted senior actors directly involved in the transportation biofuel initiatives under study. This process commenced with a mapping of relevant initiatives throughout Sweden – both on-going efforts, and past initiatives. This overview was presented in Section 1 as **Table 1**. In essence, the project sought to capture all relevant projects in the country.

[157] In spite of this case study being considered important, the process to arrange interviews as the key information pathway failed after a last minute cancellation by the company. As minimal information is available in the public domain for the iniative, this case study was canelled.
[158] See: Palys, T. (2008). *The Sage Encyclopedia of Qualitative Research Methods*. (L. M. Given, Ed.) (Vol. 2). Thousand Oaks, CA: Sage.

The full set of cases that were pursued in more depth is show above in

. For each case, the targeted informants were middle-to-top level management actors that were involved directly in the initiative being studied – generally, this involved project managers or senior directors of the organisations involved. A full listing of all case informants is included in Appendix Section 8.2.

More general information enfolding the cases, or supporting the project, or both, was collected in a number of ways. Among others, approaches included the following:

- **Desktop research** – significant volumes of desktop research were performed to underpin both the background sections of this work, and the case studies. A wide range of materials are utilised including: peer reviewed scientific articles, governmental reports, regulatory documents and EU directives, reports and statistics from governmental and intergovernmental agencies, company reports and studies, company presentations, industry websites, branch-organisation materials, and more.

- **Participation in, and attendance of related conferences** – during the period of the project, team members attended numerous presentation at conferences directly relevant to the project, collecting data, presentations and conducting informal information gathering discussions with authorities. Conferences included inter alia: the European Biomass Conference and Exhibition (EUBCE, 2015), Advanced Biofuels Conference – For Aviation, Maritime and Land Transport (2015); Bioenergy Australia (2015); and numerous *f3* workshops, conferences and meetings.

- **Involvement with and/or collaboration with related projects** – a number of on-going projects for the project team overlapped with this study. Impressions, material and analysis from at least the following parallel *f3* projects has been used to enrich this study:

    - *'The value chain for biomethane from the forest industry'* – with focus on results directly in consideration of biomethane fuel platforms and liquefied biogas production from pulp and paper facilities (involves the KTH department participating in this proposal).

    - *'Enabling the transition to a bio-economy: innovation system dynamics and policy'* – the broad spatial analysis of EU biorefineries provided by the project complements the deeper and narrower focus on fossil free fuels for the Swedish context pursued in this project (involves the University of Lund department participating in this project).

    - *'Environmental and Socio-Economic Benefits from Swedish Biofuel Production'* – pursues knowledge on the overall benefits resulting from biofuel production which may enable the creation of more advanced policy instruments to support future biofuel production (involves the University of Lund department participating in this project).

    - *'Integrated assessment of transportation fuels with a sustainability LCA – social and environmental consequences in a life cycle perspective'* pursues knowledge on the comparative benefits resulting from biofuel production contra fossil production chains (involves the IVL researcher participating in this project).

- **A project webinar/focus group discussion** – in the closing phase of the project, an expert group was convened via a commercial web-platform to discuss key issues identified during the analysis with the project team. Informants to the group discussion included both case study informants and other external parties involved with advanced biofuel issues. The webinar inputs were reinforced by a series of short telephone interviews with a number of invitees that were unable to attend the online discussion. This interaction is discussed in Section 3.5.3 below.

### 3.5.2 Interview structure and conduct, and framework for analysis

The full team participated in the field research process – through field research design, interview protocol development, conduct of literature reviews, conduct of interviews, interpretation and analysis of interviews, and final analysis and report generation.

A common platform was required to support qualitative (e.g. experiences, opinions, preferences) and quantitative data (e.g. plant capacities, costs, market size, etc.) collection and analysis of issues such as: the degree of alignment of the technology with incumbent industries; the overlap and synergies between varying technology platforms; the role of preferences (or beliefs) among key 'supply chain' and 'user chain' actors; and the manner in which technology systems themselves may evolve to fit with established socio-technical systems as they transition from isolated niche applications into the mainstream (as introduced in Sections 1.1.1 and 3.1).

To support the interview process a combined field interview template and web-based survey document was developed iteratively (both items included in the Appendices as Sections 8.3 and 8.4). These were utilised in semi-structured in-depth interviews with case informants (ranging in time period from 45 minutes to 2.5 hours). The interviews were followed up with an online version of the questionnaire filled in by the case informants or the researcher based on the input from the informants.

A detailed manuscript was also developed to reinforce the on-going case study interviews and support the analysis process. This mapped the underlying theoretical concepts, provided a series of examples demonstrating operationalization of the lines of questioning pursued in interviews, and also defined a tabular structure for analysis of case material. This was published in the proceedings of the European Biomass Conference and Exhibition (EUBCE) in June 2015.[159]

### 3.5.3 Interactive focus group discussion

On 25 April 2016, a webinar brought together a Focus Group to discuss focus questions arising from the analysis process within the project. A focus group discussion is a form of qualitative research in which a group are asked about their perceptions, opinions, beliefs, and attitudes regarding an issue or item of focus. Questions are asked in an interactive group setting and discussion ensues.

The process involved presenting authorities with a small number of questions that paraphrased key 'finding themes' (in a slightly provocative fashion) as a basis for a moderated discussion. The aim was to capture expert views regarding the prospects of large-scale projects to deliver forest-derived

[159] Peck, P.C., Grönkvist, S., Hansson, J., Voytenko, Y., Lönnqvist, T., 2015. *Investigating institutional constraints on the production of forest-derived transport biofuels in Sweden: A study design.* In proceedings of the European Biomass Conference and Exhibition (EUBCE) 2015, Vienna, Austria.

transport biofuels of ‘advanced generations’ so that these could be used as a ‘reality check’ against project findings.

### *3.5.4 Processing of information/data*

Multiple steps were undertaken when processing of information gathered in the study.

First, the responsible researcher for each interview developed a summary protocol. This was then sent to the interviewee for review, comment and approval – and then revised accordingly. Second, as noted in the previous sub-section, information from the protocol was processed in the online questionnaire tool was used to provide a “summary view” of a suite of case study results across the full span of the case studies. Third relevant information from each case was input to the analysis framework tables derived from the theory/analysis paper described in Sections 3.1 and 3.5.1 (see **Table 4** to **Table 8**) shown on the following pages. The researcher responsible for the case generation conducted this third step, but this was then crosschecked with at least one other team member as a measure to ensure consistency in application of the analysis framework tables.

Fourth, a summary table was generated utilising the main analysis categories (see the example shown as **Table 9**.) Again the responsible researcher completed this summary. A ‘cross-checking’ process was conducted for each case analysis via an online team discussion. In this, the qualitative ‘scoring’ of each case against each analysis category was discussed among the research team.

**Table 4. Niche phenomena – example of table used in case analysis**

| **Level of Analysis** | **Underlying phenomena** | **Parameters of particular interest in this study** | **Examples of anticipated information from case studies** |
|---|---|---|---|
| **Niche** (location/ situations/properties)<br>*Brief description of the core technology niche that the case examines.* | A location for a learning process (a niche)<br>A distinct/special/novel socio-technical offering (a niche offering) | Distinct place or situation where an innovation is hosted, tested or applied<br>The form and novelty of the innovation | Description of the nature and elements of the innovation and how it differs from established systems.<br>Description of the 'business ecosystems' forming around the system and influencing the business model, including collaborators and others that benefit.<br>Boundaries of the system and relevant actors. |
| **Describe the niches relevant to case study.** | **Describe location**<br>**Describe offering** | **Describe how it is hosted, tested or applied.**<br>**Describe novelty** | **Specific examples or anecdotes from case.** |
| **Core niche technology in case study** | e.g. relevant gasification plant | Explanations and examples are drawn from each case study (see individual cases in the second volume of this report *Part B: Case Studies*). | |
| **Important application niches** | e.g. public or private fleets using fuel | Explanations and examples are drawn from each case study | |
| **Supporting niche/regime technologies or infrastructure** | e.g. related 1$^{st}$ generation production activities, pipelines, or distribution infrastructure | Explanations and examples are drawn from each case study | |

* Note: Each case study included in the second part of this report (Part B: Case Studies) has a version of this table summarising case phenomena.

**Table 5. Niche-regime transition phenomena – example of table used in case analysis**

| **Level of Analysis** | **Underlying phenomena** | **Parameters of particular interest in this study** | **Examples of anticipated information from case studies** |
|---|---|---|---|
| **Niche – to – regime** (locations and processes)<br>*Brief description of locations and processes aiding migration from niche to regime for key niche items associated with core niche technology.* | Co-evolution of new technologies, markets, and user preferences<br>Formation of market spaces that are protected or insulated from 'normal' market selection in the regime | Synergies with new markets and user preferences and parallel evolution of differing parts of the technology system<br>Examples of learning by doing, learning by using and learning by interacting<br>Evidence of protected spaces – 'incubation rooms' for new technology system that rely on a special technical application, geographical situation, social context, subsidy regime, etc.<br>Spaces where social networks to support the innovations arise: e.g. supply chains, user–producer relationships | Research and R&D history and development<br>Funding provided for the innovation, why given, and where in the process.<br>Description of critical phases perceived for the innovation emergence and anticipated scale(s).<br>Role of incumbents vs. new entrants (synergistic, antagonistic, parasitic)<br>Policies that have helped the innovation forward.<br>Policies that can help them to scale up.<br>Trends to a dominant design among (similar) innovations |
| **Niche to regime phenomena** | **Insulated market spaces** | | **Co-evolution of technologies, markets and preferences** |
| **Core niche technology in case study** | Explanations and examples are drawn from each case study (see individual cases in the second volume of this report *Part B: Case Studies*). | | Explanations and examples are drawn from each case study |
| **Important application niches** | Explanations and examples are drawn from each case study | | Explanations and examples are drawn from each case study |
| **Supporting niche/regime technologies or infrastructure** | Explanations and examples are drawn from each case study | | Explanations and examples are drawn from each case study |

* Note: Each case study included in the second part of this report (Part B: Case Studies) has a version of this table summarising case phenomena.

**Table 6. Regime phenomena – example of table used in case analysis**

<table>
<tr><th>Level of Analysis</th><th>Underlying phenomena</th><th>Parameters of particular interest in this study</th><th>Examples of anticipated information from case studies</th></tr>
<tr><td>Regime<br>(conditions – precursors for drivers & constraints)<br>Here regime conditions focus on the semi-coherent set of rules carried by different social groups.</td><td>Constraints (and drivers) arising because regulations, infrastructure, user practices, maintenance networks are aligned to the existing technology.</td><td>Constraints:<br>Mismatch with one or more of the (seven) dimensions in the incumbent sociotechnical regime:<ul><li>technology,</li><li>user practices and application domains (markets),</li><li>symbolic meaning of technology,</li><li>infrastructure,</li><li>industry structure,</li><li>policy, and</li><li>techno-scientific knowledge</li></ul>Drivers: Supportive situation(s) and synergies with incumbent regime dimensions.</td><td>Limitations/opportunities posed by the current established systems<br>Social, regulatory and market barriers and opportunities<br>Specific Policies and regulations, clashes between policies, clarity and stability of policy interventions.<br>Collaboration with established sectors/regimes<br>Impacts and benefits associated with material flows and benefit accrual (e.g. fossil- to bio)</td></tr>
<tr><td>Core niche technology in case study</td><td colspan="3">Explanations and examples addressing the following categories are drawn from each case study (see individual cases in the second volume of this report Part B: Case Studies).<ul><li>Technologies, operations and maintenance networks</li><li>User practices and application domains (markets)</li><li>Symbolic meaning of technology*</li><li>Infrastructure</li><li>Industry structure**</li><li>Policy</li><li>Techno-scientific knowledge</li></ul></td></tr>
<tr><td>Important application niches</td><td colspan="3">As above</td></tr>
<tr><td>Supporting niche/regime technologies or infrastructure</td><td colspan="3">As above</td></tr>
</table>

Note: Each case study included in the second part of this report (Part B: Case Studies) has a version of this table summarising case phenomena.

* For this study, this term is intended to capture the relative richness of **symbolism** attached to the **advanced biofuel production technology** initiative. This has been categorised by qualitative judgement of how it seems to be perceived (implying and meaning to stakeholders) regarding 'positive' aspects such as the following: climate responsible; low pollution and healthy; fossil free; modern, reformative, futuristic; robust and functional.
** For this study, this is intended to capture the general strength of the project and its proponents against the following: industry competitors delivering the same or similar product; the customers for the fuel products; suppliers and support organisations to the project proponent; other new market entrants who might enter the industry to compete with the new fuel product; companies that provide a substitute to the product.

**Table 7. Landscape phenomena – example of table used in case analysis**

| **Level of Analysis** | **Underlying phenomena** | **Parameters of particular interest in this study** | **Examples of anticipated information from case studies** |
|---|---|---|---|
| **Landscape (conditions)**<br>*Here landscape conditions focus on heterogeneous factors including oil prices, economic growth, wars, emigration, broad political coalitions, cultural and normative values, and environmental problems.* | On-going processes, or disruptions, at the landscape level – and between regime and landscape – change conditions that are central to the progress or success of the new technology. | **Constraints**: Reversals in progress as a result of new conditions disadvantageous to the technology<br>**Drivers**: Windows of opportunity for breakout (from niche level) related to special conditions advantageous to the new technology | Effects of structural shifts in forestry industry<br>Impact of oil prices on development<br>Influence of the political economy of biofuels (all generations)<br>Escalating environmental concerns and drivers. |
| | **Constraints** | | **Drivers** |
| **Core niche technology in case study** | Explanations and examples are drawn from each case study (see individual cases in the second volume of this report *Part B: Case Studies*). | | Explanations and examples are drawn from each case study |
| **Important application niches** | Explanations and examples are drawn from each case study | | Explanations and examples are drawn from each case study |
| **Supporting niche/regime technologies or infrastructure** | Explanations and examples are drawn from each case study | | Explanations and examples are drawn from each case study |

* Note: Each case study included in the second part of this report (Part B: Case Studies) has a version of this table summarising case phenomena.

**Table 8. Proponent Strategies to Promote Innovation Development – example of case analysis table**

| Level of Analysis | Cognitive Legitimacy | Sociopolitical Legitimacy | Examples of anticipated information from case studies |
|---|---|---|---|
| **Organizational** | Develop knowledge base via symbolic language and behaviours (key theme of **knowledge**) | Develop trust in new activity by maintaining internally consistent stories<br>(key theme of **trust**) | Consistent details of how their system contributes to environment and society<br>How this innovation builds upon track record, trust etc.<br>Symbolic framing of the technology system |
| **Cognitive legit.** Explanations and examples are drawn from each case study (see individual cases in the second volume of this report *Part B: Case Studies*). | | **Sociopolitical legit.** Explanations and examples are drawn from each case study | |
| **Intraindustry** | Develop knowledge base by encouraging convergence around a dominant design | Develop perceptions of reliability by mobilizing to take collective action | Activities across the industry to build common industry knowledge base<br>Convergence around a dominant design/technology platform, performance standards<br>Development of industry organisation, collective lobby group, etc.<br>Stable and reliable sequences of interaction with other actors in industry |
| **Cognitive legit.** Explanations and examples are drawn from each case study | | **Sociopolitical legit.** Explanations and examples are drawn from each case study | |
| **Interindustry** | Develop knowledge base by promoting activity through third-party actors | Develop reputation of new activity as a reality by negotiating and compromising with other industries | Evidence of cooperation, negotiation or compromise with other industries where there is competition for resources, markets etc.<br>Promotion of their new activity through third-party actors (e.g. third party testing, pilots, etc.) |
| **Cognitive legit.** Explanations and examples are drawn from each case study | | **Sociopolitical legit.** Explanations and examples are drawn from each case study | |
| **Institutional** | Develop knowledge base by creating linkages with established educational curricula | Develop legitimacy by organizing collective marketing and lobbying efforts | Evidence of broader public/political knowledge and awareness of the innovation and its importance<br>How and why other actors have joined to build up much of the trust and reliability of the new activities<br>Established activities of industry councils, alliances, and other affiliations that perform collective marketing and lobbying efforts.<br>Linkages with established educational curricula at universities etc. |
| **Cognitive legit.** Explanations and examples are drawn from each case study | | **Sociopolitical legit.** Explanations and examples are drawn from each case study | |

* Note: Each case study included in the second part of this report (Part B: Case Studies) has a version of this table summarising case phenomena.

**Table 9. Case summary and comparison table for cross case analysis**

*Table entries provide an example of the qualitative scoring approach applied.

| | Case parameter | Case A | Case B |
|---|---|---|---|
| **NICHE innovations** | **Number and 'establishment status' of niches** | | |
| | Core technology | + + | + + |
| | Enabling technologies | + + + | + + |
| | Distribution/utilisation technologies | + + + | + + + |
| **TRANSITION** | **Presence and status of key phenomena** | | |
| | Insulated market spaces | + + | + + |
| | Co-evolution of technologies, markets and preferences | + + | + |
| **REGIME** | **Regime Match/mismatch** | | |
| | Techns, op.s, & maint., network | + | + |
| | User practices and applications | + | + |
| | Symbolic meaning of technology* | - / + | - / + |
| | Infrastructure | + + | + |
| | Industry structure** | + + | + |
| | Techno-scientific knowledge | + | + + |
| | Policy/policy support | - / + | + / - |
| **LANDSCAPE** | **Landscape developments** | | |
| | Fossil fuel markets | + / - | - - |
| | Bioeconomy | + | + |
| | Climate discourse | + | + |
| | Enviro/resource eff. discourse*** | + + | + |
| **PROPONENT STRATEGIES** | **Contribution to Cognitive and Sociopolitical legitimacy** | | |
| | Organisational | + | - |
| | Intra-industry | + + + | + + |
| | Inter-industry | + + | + |
| | Institutional | + | + + |

*** Note: A fully populated version of this table is available as Table 12. Cross case analysis for transitions and proponent strategies: Forest based biofuels projects in Sweden.**

# 4 FINDINGS

In this section, the case studies are provided in summary form so as to communicate the major results of the study. These provide only a short summary of the facts, figures, opinions, and so forth collected during the research work. Detail versions of each case (cases studies ranging from 5 to 20 pages in length are documented in Part B (Case studies) of this report, with the exception of the motor platforms case which is documented separately in a Swedish language report.

The cases presented here include nine fuel production case summaries and one motor platform case. To aid the reader, Table 10 below provides an overview of the fuel production case study projects.

**Table 10. Overview of Case Studies.**

| **Cases** | **Technology, Feedstock & Output** | **Plant capacity** (MW capacity and approximate yearly production) |
|---|---|---|
| Chemrec and Domsjö Fabriker, Örnsköldsvik Chemrec | Entrained flow biomass gasification, black liquor, Output: DME or methanol | 100 MW<br>≈ 1000 GWh/yr |
| LTU Green Fuels, Piteå<br>Luleå University of Technology | Entrained flow biomass gasification, black liquor & pyrolysis oil, Output: DME and methanol | 3MW |
| Bioraff (biorefinery) Norrtorp<br>SAKAB et al., Kumla | Gasification, forest residues & waste, OP: methanol and/or methane | 250MW<br>≈ 1800 GWh/yr |
| Värmlands Metanol, Hagfors<br>Värmlandsmetanol AB | CFB gasifier, wood chips, OP: methanol, heat | 110MW<br>≈ 600 GWh/yr |
| GoBiGas, Göteborg<br>Göteborg Energi (municipally owned energy company) | Indirect gasification, solid biomass (pellets at first), Output: methane, heat | 20MW (≈1000 GWh/yr)<br>100MW (≈800-1000 GWh/yr) |
| Bio2G<br>E.ON Sverige AB (E.ON Sweden) | Gasification, wood chips, forest residues, Output: methane | 325$MW_{th}$ feedstock<br>200MW biogas<br>≈ 1600 GWh/yr |
| Renfuel | Catalytic conversion of lignin into lignin oil | >3000tonnes/yr<br>>20 GWh/yr |
| Preem | Diverse:<br>HVO from bio-diesel<br>Biooils to diesel<br>Solid biomass to diesel (future?) | 160 000 $m^3$/year<br>≈ 1600 GWh/yr |
| SunPine, Piteå<br>Södra (other owners: Preem, Sveaskog, Kiram, and Lawter) | Raw tall diesel separated from raw tall oil | 100 000 $m^3$/year<br>≈1000 GWh/yr |

Note: Figures in table assume the following calorific contents: HVO and raw Tall oil diesel 34.4GJ/$m^3$, lignin oil 25MJ/kg.

## 4.1 CASE STUDY 1 – CHEMREC AND DOMSJÖ FABRIKER, ÖRNSKÖLDSVIK

This case study information is based on an interview with Jonas Rudberg, of Porcupine AB; he was CEO at Chemrec 2000-2008 (performed in September, 2015). That material was supplemented with information from an interview with Max Jönsson, CEO at Chemrec (performed in January, 2016).

This project studied involved biofuels (dimethyl Ether DME or methanol) production via gasification from black liquor at a full-scale (approximately 100 MW product, 220 MW feedstock) facility in Örnsköldsvik in connection to Domsjö Fabriker. The project was based on the technology from Chemrec AB. Gasifier scale up is about 35 times the capacity of the LTU Green Fuels pilot plant in

Piteå (the original pilot project). The Domsjö plant was to have three gasifier trains each having a capacity of 50% of the thick liquor capacity meaning that the gasification plant would have 50% spare capacity. The planned production capacity corresponded to approximately 0.88 $TWh_{fuel}$/year. The planned location of the facility in connection to Domsjö Fabriker in Örnsköldsvik was dependent upon the associated network of engaged contacts. But the key driver was the need for new recovery capacity because the existing recovery boilers are old, from around 1960. Chemrec was the initiator of the full-scale facility in Örnsköldsvik, but there is a long history (some 30 years) behind the collaboration including several engaged persons with different experiences from the oil, forest and petrochemical industries.

The project was abandoned in 2012. According to the interviewees, the sole reason for project closure was the lack of stable policy framework for transport biofuels. $CO_2$ and energy tax exemption rules only known one year in advance at the time of the decision. They claim that as a result of the Swedish government and parliament failing to provide any clear and stable long-term rules, financial institutions were unwilling to lend money to biofuel projects. Further, they indicated that all risks except the political were addressed. Technical guaranties were available and financial support from the Swedish Energy Agency approved by EU DG Competition. According to Chemrec, general policies are not enough to realize new large-scale production of biofuels. Specific support is needed for the first production plants for example the proposed “price premium model” for domestic production of 2$^{nd}$ generation biofuels (see the FFF inquiry). A quota system is not considered to provide enough clarity since a situation could appear when there is an over capacity in the production.

## 4.2 CASE STUDY 2 – LTU GREEN FUELS

This case study information is based on an interview with Ingvar Landälv, Project Manager at Luleå University of Technology, formerly EVP Technology at Chemrec (performed in January, 2016).

LTU Green fuels is the name of the pilot plant (circa 3 MW) for the development of biofuels based on gasified black liquor and other biomass based products in Piteå. The pilot plant has operated since 2005 with syngas production and since 2011 with methanol/DME production and is based on technology developed by Chemrec. Chemrec, with a long history of activity leading up to the pilot, was the main initiator behind the pilot plant. The pilot focused on the development of the gasification technology. The selection of DME was directly related to the involvement of Volvo (trucks division) as a tester of the fuel in new engines, and the high conversion efficiency from biomass to methanol/DME. Most of the approximately 1000 tonnes of BioDME produced has been used to fuel 10 Volvo trucks, totally driving about 1.5 million kilometres. The responsible EU case officer considered the BioDME project “a success story”. Since 2013, activities at the pilot plant have been led by Luleå Technical University. The Swedish Energy Agency (SEA), Volvo and two cleantech investment funds, one American and one British, have supported the plant. In April 2016, it was announced that the pilot plant would close down due to lack of funding.

The three main reasons behind the pilot plant were: 1) to provide data for further upscaling, 2) to test equipment and construction materials, and 3) to test and validate different kinds of pulp mill liquors as a feedstock for biofuel production. The driving force has been a desire to reach commercial scale for the technology. The main reasons behind the localization in Piteå were the size of the chemical pulp mill in Piteå, a considerable research tradition and experience in in field of wood-related sciences in the area, and the availability of an existing industrial area and infrastructure.

The next step for this technology is demonstration in a larger plant that was planned in relation to Domsjö Fabriker in Örnsköldsvik. This project has however been cancelled (see the case study on Chemrec and Domsjö Fabriker), primarily (according to case informants) as a result of inadequate policy support frames.

A complication for (eventual) future projects is that black liquor gasification implies a drastic change for the pulp mills as it competes current technology, infrastructure, and also has implications for feedstock supplies (increased plant feedstock is required). Interviewees indicate that future oriented mill owners and new strong suppliers are needed for the technology to be taken forward to commercial production. Further they argue that the pulp mills are dependent on their key technology providers. If these actors are not supportive of new technologies within a plant, or its immediate industrial system, then it is difficult for the mills to invest in them. Informants also express concerns that if a full-scale demonstration project is further delayed the technical and organizational competencies required to deliver such a project will disappear and key patents will expire.

## 4.3 CASE STUDY 3 – BIOREFINERY NORRTORP

This case description is based on an interview with Göran Eriksson (GE), former president of Sakab. Tomas Lönnqvist, KTH, performed the interview via telephone 2015-09-22. A thorough pre-study providing technical data was also utilized.

Biorefinery Norrtorp was planned to deliver large-scale production of methanol and/or methane (Bio-SNG) transport fuels from forest biomass. Several actors joined a collaboration to prepare a pre-study; the most active were the municipality of Kumla, Sekab, E.ON, and Värmlandsmetanol. The project received funding for the pre-study work from the Swedish Energy Agency (SEA/ Energimyndigheten). A working hypothesis at the outset was that combined methanol and methane production might be more efficient than dedicated lines and that there may be synergy effects if a combined production model was applied. Three cases were considered: methanol production, methane production, and combined production. No major synergy effects were found, although dedicated methanol production was found to be less efficient than the other two cases. In addition, the chosen site – a property owned by Sekab in the Kumla municipality – lacked and still lacks access to a natural gas pipeline and a link to the nearest local district-heating grid. As a result, the project considered using the heat internally to dry incoming biomass feedstock. It also considered liquefying the produced methane to facilitate distribution. In spite of this extra production step, the production cost at gate was found similar for liquefied methane and methanol. The project was modelled upon a production of 1.8 $TWh_{pa}$ of transport fuel. As there are not enough forest residues in the nearby area for this production capacity, the project group also evaluated the option to purchase round wood.

The project did not proceed – but has not been terminated and a steering group still conducts a phone meeting every second month. The interviewee, Göran Eriksson, the former president of Sekab one of central project proponents, is however quite sceptical about the potential to realize this project and also sceptical regarding the likelihood of production of transport fuels from forest biomass in Sweden in general. According to him the lack of policy support and the oil price are the two determining factors. Interestingly, the project has indicated that it is not interested in NER 300 support from EU. It is claimed this is because this support requires knowledge sharing which may be a problem with the technology providers. The project had great expectations that policy support as described in the FFF investigation would materialize. Eriksson went further to state that policy in Sweden has very short life length span; too short to make an investment decision. He added that he considered that politicians are generally interested in supporting "the next big thing", which he now describes as electrical vehicles.

## 4.4 CASE STUDY 4 – VÄRMLANDSMETANOL

This case description is based on an interview with Björn Gillberg (BG), president of Värmlandsmetanol. Tomas Lönnqvist, KTH, performed the interview via telephone 2015-10-08.

The proposed Värmlandsmetanol is intended to produce methanol for transport fuel-related purposes via gasification of woody biomass. The plans are quite advanced but have not yet materialized. The company's president, Björn Gillberg (BG), states that production could be ready within three years, of an investment decision being taken. According to him the necessary conditions include a reliable long-term tax exemption for biofuels and a higher oil price than the present. BG states that a tax exemption must be guaranteed for at least 15 years, however it is perceived that Swedish policy instruments have low predictability. He indicates that an oil price of $US60/bbl or higher is required to ensure profitability.

An agreement has been made with the technology provider ThyssenKrupp industrial solutions (TKIS) to minimize the technical risk. The agreement guarantees a plant delivery price and performance. BG states that the technology is mature and that they are not interested in research cooperation with academia. Further he indicates that TKIS is rather protective with their technology, which hinders this type of cooperation. The company's position also hinders obtaining investment support from EU that sometimes requires knowledge sharing.

The plans encompass a large-scale plant, 600 $GWh_{pa}$, located in Värmland in mid-western Sweden. The location is chosen because of proximity to feedstock and road infrastructure. The location would also permit using about 10 GWhpa surplus heat in district heating. It is planned that the remainder of the surplus heat would be used internally to dry incoming biomass. Björn Gillberg is also involved in the project Biorefinery Norrtorp. He claims that methanol is now receiving increasing attention as a promising transport fuel. He indicates that the fact that methanol of fossil origin is used for sea transport and that this market is opening up for biofuel is a promising development that legitimizes the fuel.

## 4.5 CASE STUDY 5 – GOBIGAS

GoBiGas is a gasification plant that produces upgraded methane – also Bio-SNG – from forest residues. A demonstration plant of 20 MW (methane) has been commissioned and it successfully delivers methane to the natural gas grid and heat to the Gothenburg district-heating grid – the planned market for Bio-SNG is for use in the transport sector. The plant is the first of its kind and was intended to pave the way for a full-scale commercial plant of 100 MW. The intention is to introduce twigs and tops (GROT) in the near future. This is also expected to require a new period of commissioning.

Despite the successful commissioning of the plant,[160] the commercial plant has been postponed. The investment decision for the demonstration plant was taken under different commercial conditions than the present, mainly that the oil price was higher – the oil price being an important determinant due to the focus on gas production as a transport fuel. Policy support is also seen as important, and the owner of the plant, Göteborg Energi, would like to see the price-premium-model (as outlined in the FFF-investigation) implemented. They consider that the price-premium-model would support second-generation biofuel producers. The value of the premium depends on when the plant is commissioned, the production cost of diesel, and the $CO_2$ tax on diesel. It was proposed that it be formulated so as to liberate the producers from both the oil price risk and the risk of changes in policy instruments such as the $CO_2$ tax. The premium would be financed by all fuel distributors and according to Göteborg Energi would thus not be considered as state aid by the EU.

Gas is part of the company's core business and it is also involved in conventional biogas production, upgrading and distribution. GoBiGas is located quite centrally in Gothenburg with access to railway, harbour, natural gas pipeline, and district heating grid. The plant was first commissioned on wood pellets; one of the reasons for this is that the company had a receiving terminal on site. Technical difficulties were encountered during the commissioning causing the fluid bed central to the gasification process to clog. After a period of research and additional testing, these difficulties were resolved in cooperation with the local university Chalmers. Göteborg Energi cooperates with Chalmers and also with industries. The organization claims that GoBiGas may thus be seen as an example of a triple-helix collaboration.

Göteborg Energi is a municipal company and the GoBiGas project has received much media since it is a large public investment. Göteborg Municipality has decided to postpone Phase 2, investigate how biogas production costs could be reduced, and to investigate the consequences of cancelling all biogas activities (including anaerobic digestion). This political decision was also discussed in media. Göteborg Energi issued a statement to nuance the debate. It underlines firstly that phase 2 would in either case not be built during current conditions (low oil price) and secondly that it has not been decided to close any facility only to investigate the possible consequences. Thus, according to Göteborg Energi, the political decision has no direct effect on their biogas activities. The company continues its efforts to improve profitability and efficiency of the operations.

## 4.6 CASE STUDY 6 – BIO2G

This case study information utilizes insights obtained from a detail interview with Björn Fredriksson Möller, Project Manager Gasification Development (performed in 25 September, 2015). This is supported by a volume of material sourced by desktop research – including material created and disseminated publicly by E.ON.

The E.ON Bio2G project commenced in 2007. It has the aim to deliver a biomass gasification plant producing biogas synthetic natural gas (in this report: bio-SNG). Led by a division of the German utility E.ON in Malmö Sweden, the proposal encompasses a biomass gasification plant to be located at a port location along the Swedish natural gas pipeline corridor in the Swedish southwest. With a planned bio-SNG production capacity of 200 MW (1.6TWh/yr), the proposed plant will

[160] Note however, that the plant was commissioned on wood pellets. It now must go through a new commissioning phase on wood chip fuels – and conceivably even a third commissioning phase on forest slash (branches and tops).

require circa 1 million tonnes biomass per annum (fuel input ~325 MWth) and is projected to cost some €500 million (circa SEK4.3billion). Bio2G made a successful NER300 application during 2012; this secured EU production support over 5 years that would total approximately €200million (SEK1.9 billion).

While not finalized, the location of the plant has generally been discussed in terms of a port city location (e.g. Malmö or Landskrona in the southwest of Sweden) or a pulp mill location (e.g. Varö, south of Gothenburg, again on the Swedish west coast). An estimated 50-100 staff would be required for the plant. The key parameters of the proposed Bio2G plant are shown in the table below.

**Table 11. Bio2G Preliminary key parameters.**[161]

| Fuel Input | Feedstock mass | Biogas production | Biogas annual | Biogas efficiency | Total efficiency | Heat |
|---|---|---|---|---|---|---|
| 325 MWth | Circa 1Mtpa biomass (forest chips, slash). | 200 MW ~ 21 000 $m^3$/h | Circa 1600 GWh | 62-63% (excl. ASU) | 70-80% | 50*MW |
| **Other products** | | 10MW internal power<br>potential for $N_{2liquid}$<br>potential biorefinery setup for CO & $H_2$ | | | | |

* depending on feedstock moisture content.

E.ON is a dominant actor in the Swedish biogas for vehicle transportation market. As of 2015 the company accounted for about 500 GWh of the circa 1700GWh fuel sold on the market. The Bio2G initiative can thus be seen as an important portion of E.ON’s strategy to both grow its market, and maintain a dominant presence.

E.ON has been active in a suite of differing networks promoting biomass gasification since its entry to the Swedish market. It is observed that in essentially all communications related to the Bio2G project, E.ON highlights the importance of strong local support for E.ON Bio2G localisation in its targeted locations. Further, it stresses the importance of partnering opportunities with local utilities, fuel suppliers, equipment suppliers for reference plant technologies, and the forestry industry.

Under the influence of policy support for the growth of biogas vehicle fleets[162] and municipal investments in gas fleets, the market grew steadily and at a slowly escalating rate in the period from the turn of the century to 2012/13. However, since then a slowing of the gas vehicle market growth has been observed – largely related to uncertainty regarding on-going policy support for gas vehicles.[163] The gas fleet is around 50 000 vehicles and as of 2016, growth is around 500 vehicles per month.

E.ON notes that in the past, there was a shortage of gas production. Now it is the market that is the bottleneck. The current market it is quite insufficient to absorb the production of a facility such as Bio2G. They indicate both a need for a new segment, or new segments of gas buyers on the transportation market, and more considered growth of existing segments. This in turn requires market stimulation via policy intervention.

[161] *Bio2G – A full-scale reference plant in Sweden for production of bio-SNG (biomethane) based on thermal gasification of biomass*, Björn Fredriksson Möller, Anders Molin, Krister Ståhl E.ON Gasification Development. The International Conference of Thermochemical Conversion Science, 2013.
[162] *Ibid.*
[163] Interview: Tomas Lönnqvist (KTH) with Björn F. Möller (E.ON) 18 Nov. 2015; Interview with Björn Fredriksson Möller, (P. Peck, Y. Voytenko) 29 September 2015.

A common theme regarding this project is a lack of certainty (low 'foreseeability') regarding policy instruments affecting biofuels in Sweden. While a suite of policy instruments has supported biogas, their time horizons have been short, and they have been surrounded by uncertainty. It is held by project proponents, that to underpin investment decisions, a time horizon of significantly longer than 3 years (roughly the current best situation) is required, and support needs to be better targeted to achieve climate and fossil-free transportation goals. Policy instability affects the growth of the vehicle gas market – which in turn delivers uncertainty for any investment in biogas or bio-SNG production. Related to such uncertainty, the project was placed in a "wait mode" in 2013.

## 4.7 CASE STUDY 7 – RENFUEL

This case study information is based on an interview with Sven Löchen, CEO at RenFuel AB (performed in March, 2016).

The Renfuel project involves the building of a pilot plant that converts lignin into a liquid renewable carbon and hydrogen based lignin oil (catalytic lignin oil, called Lignol). The lignin is extracted from a kraft pulp mill where it is considered a by-product, being part of the black liquor. The catalytic process (under patent protection) decomposes the lignin (which is blended with oil) at atmospheric pressure, below the boiling point. One tonne of lignin yields around one cubic meter of lignin oil. The lignin oil can then be refined to renewable petrol and diesel having the same characteristics as the fossil counterpart and can be used as drop-in fuel at different levels. Renfuel focus on the described specific link in the transport fuel production chain – namely lignol production only. They indicate that in order to increase the chances of succeeding (using a non-controversial raw material, requiring relatively low capital expenditure (CAPEX), and leaving the final delivery step to more experienced actors with established refining infrastructure.

The planned size of the pilot plant corresponds to a 'few thousand' tonnes of lignin oil per year. In recognition of the substantial increase in process scale from earlier research work, Renfuel refers to their chosen scale as 'industrial scale'. This is scale has been selected as it is considered large enough to reduce the technical risk of the future transition to commercial scale. The pilot plant will be co-located with the Nordic Papers pulp mill in Bäckhammar, Värmland. The total budget of the entire pilot initiative amounts to 140 million SEK and the Swedish Energy Agency is the main economic contributor (slightly over 100 million SEK in total); existing owners provide the rest. Renfuel have access to extensive knowledge about the forest industry and refinery technology but for business reasons, refineries are not included in the company. Renfuel is the result of a case within a mentor program by the Royal Swedish Academy of Engineering Sciences (IngenjörsVetenskaps-Akademien). As its feedstock is lignin, and related to the fact that it will produce a drop-in fuel, Renfuel has not been significantly impacted by the competition from other forest based transport fuels under development. The development of national policies for renewable fuels however, remains important for Renfuel. The project proponents are in favour of a national quota system for biofuels for transport. However, if the future domestic prerequisites are not sufficient, they claim that the product can be sold to other nations with better policy set-ups.

## 4.8 CASE STUDY 8 – SUNPINE

This case study is based on an interview with Gustav Tibblin, Södra and chairman of the board of SunPine (performed in October, 2015).

At the SunPine facility in Piteå, raw tall diesel is produced from raw tall oil, a by-product from the pulp and paper industry. Preem at the refinery in Göteborg then processes the raw tall diesel further to HVO diesel fuel. The SunPine facility in Piteå (since 2010) is the first facility of this kind in the world. The current production capacity for raw tall diesel is 100 000 $m^3$ per year. Lars Stigsson of the Swedish technology development and commercialization[164] company, Kiram, is the innovator behind the process. In 2006, Stigsson searched for interested parties to commercialise a process that he had developed. SunPine was formed and is owned by Preem (25%) Sveaskog (25%), Södra skogsägarna (25%), KIRAM (15%) and Lawter 10% (Lawter joined in 2014).

There are three main reasons behind the localization in Piteå. Firstly, there is an abundance of tall oil in that region and a range of industrial activities. Secondly, Solanders Science Center, which is a demonstration plant for gasification as well as other development of forest based process technologies, is located in Piteå and Lars Stigsson had experience from this location. Thirdly, Piteå is a held to be a truly industry friendly municipality. Södra joined the project for a number of reasons: Södra is a significant producer of tall oil and they considered that the market for tall oil was not working well and an alternative market was attractive; the company promotes innovation and processes replacing fossil fuels with biomass, and finally for the reason that the project was considered to be profitable.

Supply chains and market related issues are facilitated by the involvement of tall oil and diesel producers in SunPine. Project financial risk was managed via the participation of economically strong owners that invested equity, while technical risks were reduced by patents. Regarding polices, the informant indicates that the project consortium was naive in believing that stable and long term policies would be implemented in Sweden; this has not been the case. As a closing comment, Tibblin indicates that had they had known what they know today about the management of biofuel policies in Sweden, it is quite uncertain that the partner companies would have invested in SunPine.

## 4.9 CASE STUDY 9 – PREEM

This case study information is based on interviews and a series of telephone discussions with Sören Eriksson (Product Developer) and Åsa Håkansson (Business Developer). (Key interview performed 10 Dec. 2015 with Åsa Håkansson).

Preem is a major actor in the Swedish transportation fuels market and this has several implications for their activities in the biofuels area – where they are the central actor in HVO production. The company has been expanding production capacity almost constantly since they started HVO production in 2010. Present production capacity of HVOs at the Gothenburg refinery is more than 160 000 $m^3$ per year and there are several modifications being pursued that will increase the production capacity. However, the market has grown even faster – 510 000 tonnes (655 000 $m^3$)[165] of HVO was sold in Sweden in 2015 – and Preem are keen on keeping up with this development. While Preem is developing their own technical systems for the production of renewable transporta-

[164] The company describes its key activities as the development and commercialisation of projects wtihin cellulose and biotechnology areas, and energy/management consultancy.

[165] SPBI, 2016. Press release: Renewable transportation fuels in Sweden increased to 14.7% in 2015 [Förnybara drivmedel i Sverige 2015 ökade till 14,7 %], 16 March 2016. http://spbi.se/blog/2016/03/16/fornybara-drivmedel-i-sverige-2015-okade-till-147/ (accessed 28 April 2016)

tion fuels, Neste, the Finnish world leader in HVO production, also heavily influences them. Almost all of the considered future options for development of the production of renewable transportation fuels are trajectories based on the concept "liquid in – liquid out". This approach shows clear recognition of Preem's considerable infrastructure that is available for the handling of liquid feedstocks and products.

Transportation fuels are the core business for Preem and they are confident that they know the market and what kind of investments that will be profitable. It is also clear that they intend to use their refineries. Their present production activities, and almost all of the considered future options are based on co-processing in refineries. This is one noticeable difference in their approach than that of Neste, which also involves dedicated production lines. According to Preem, their co-processing strategy facilitates investments of around one tenth of that required for dedicated production lines. Preem also believes strongly in using existing distribution infrastructure for liquid transportation fuels. They state that a rapid change demands that we use the current vehicle fleet and thus can use the current infrastructure for the fuels.

Preem reveal a relatively strong belief in the Swedish policy sphere and in the stability of the policy instruments used in Sweden. They do not believe that the current tax alleviations will last. In fact, they do not even consider this policy instrument as the best option even if they have made all their investments with this as the strongest driver. The interviewees are advocates of a quota system that resembles the green electricity certificates. From their viewpoint, they believe that a quota system that will serve after the tax alleviations have been removed will be at least as effective as the current tax alleviations.

## 4.10 CASE STUDY 10 – MOTOR PLATFORMS

This case study information is based on a suite of interviews with Volvo Trucks (Volvo Lastvagnar) and Scania AB, and an extensive desktop study, performed in 2015. Key informants to the study were Lars Mårtensson, Volvo Trucks (interviewed 2015-03-03), Eva Iverfeldt (Scania AB) and Jonas Strömberg (Scania AB) (both interviewed separately 2015-03-09).

The full case is documented as a Lund University MSc thesis produced by Erika Peltonen Ramkvist: *Dimetyleter och etanol som biodrivmedel för tunga fordon i Sverige – En intervju- och litteraturstudie över Volvo och Scanias motorplattformar.* The MSc thesis was produced under the direct supervision of Philip Peck, IIIEE at Lund University as a part of this project. As a subsidiary work, a detail case version has not been produced for this report, but rather an extended summary is provided here. Reflecting this, the structure of this case summary is slightly altered from that followed for the cases addressing fuel production initiatives. The full thesis (Swedish language) is available at the following web link: https://lup.lub.lu.se/student-papers/search/publication/5469170.

### *4.10.1 Introduction*

This case examines drivers and barriers for the broader provision of motor systems developed for two biofuels in Sweden: Di-methyl ether (DME) and ethanol. A literature review and desktop study provided a foundation for the project, and was used to build an interview document. Interviews with actors at Volvo Group and Scania were then conducted to provide first-hand information and insights for the study. The analysis also reflects upon Volvos and Scania's engine technology and emergent strategies for provision of engine tailored for biofuels.

The case study is important to this research project in that it highlights a number of drivers and challenges facing the widespread implementation of biofuels in heavy goods transport in Sweden from a different perspective to that applied for all other cases – that of the users rather than producers. While informants stress that the shift from non-renewable fuels to renewable fuels is vital for the transport sector's carbon footprint reductions – and thus that they believe they will be providing engines to support such developments at much larger scale than at present – they provide many examples of how their development activities are constrained. Political and policy uncertainty is a major theme in this regard.

Informants also stress that they serve global markets, and thus remained focused on mainstream diesel engine platforms. The study underlines the prime importance of development strategies that deliver engine platforms for biofuels with low pollutant emissions and high motive performance, while still remaining very closely related to mainstream diesel-fuelled engines in form and function.

### Focus fuels

While both truck manufacturers produce engines that can run on a range of other fuels, ethanol and DME are taken up specific reasons within this analysis. Firstly these have appeared most frequently in the Swedish media as what could be termed 'flagship renewable fuels'. Secondly, ethanol has been a long-term commercial reality for Scania – they have, for example, provided engines for ethanol driven buses in Stockholm since the 1980s. Thirdly, DME figures centrally in this study due to the Piteå black liquor gasification projects (Chemrec and LTU Green Fuels Cases), and fourthly, related to this, Volvo has been as a high profile partner in the DME production field-testing efforts.

These chosen platforms however are not equivalent. Ethanol is available and in commercial use in Sweden (and elsewhere) today. While the scale of ethanol production and use in Sweden is tiny compared to Brazil and the US, it is well established. DME in comparison is a new fuel – and requires an entirely new technology system for use in transportation. Further, when considered in terms of the renewable DME production systems addressed in this report, it is novel as it is derived from a waste/by-product stream, and avoids a number of legitimacy issues (e.g. food-versus-fuel, and land use considerations) that affect ethanol markets.

Related to the above, it is also important to note that both engine makers addressed by this case study have demonstrated the ability to produce, demonstrate (and supply to markets) engines that can run on a number of fuels. Volvo for example has manufactured gas motors since the 1990s[166]

[166] See more at: http://www.volvogroup.com/group/sweden/sv-se/sustainability/envdev/alt_drivelines/gas_engines/Pages/gas_engines.aspx#sthash.wd6W4R9U.dpuf

and has also presented models that can utilise a mix of biogas and biodiesel, DME, ethanol/ methanol, synthetic diesel and a mixture of hydrogen and biogas.[167] Scania has also launched engines designed to run on biogas as well as natural gas.[168]

### *4.10.2 Drivers for change and strategies for biofuel engine platforms*

Seen from a historical perspective, Sweden's heavy vehicle engine manufacturers indicate that initiatives pursuing alternative fuels have invariably been related to a form of crisis. Important efforts and developments based on ethanol during the last century were either related to conflicts (e.g. fuel shortages during the second world war) or to economic crises related to oil dependency (e.g. Brazil in the 1970s). With regards to the present drivers for renewable fuels (with climate issues perceived by informants to have grown to be the principal issue) the situation is somewhat different. Importantly, rather than a crisis the interviewees describe a situation of biofuels being part of a new emerging norm – or a realistic option that must be taken up if national climate goals are to be met. This however, is not as clear or unifying as a 'crisis'. As a new 'norm' requires changes in social expectations and behaviour, this is not happening quickly.

While shifts in Sweden commenced with a strong oil (in)dependency rationale, thus supporting existing and emerging biofuel systems (thus for example ethanol and DME type fuels), this has been affected by a shift to climate in the discourse. Public perceptions that ethanol performs less well from a climate perspective has affected the development of biofuels platforms perceived to belong to the so-called 'first generation'. Doubt from broader stakeholder groupings regarding biofuels has reduced the intensity of drivers for change.

This may have more significant potential to undermine development strategies for Scania than Volvo. Interviewees explain that Scania has focused its efforts more on the use of fuels and engine platforms that exist, and are commercially available (or can be commercially functional in the shorter term). They have then worked with the 'engine, truck, transport and user system' to find pathways to effectively reduce carbon dioxide emissions from goods transport as a whole. They have given less focus on which generational category a biofuel is held to belong to. Scania's informants relate that they do not wish to divide out their biofuels work as a separate area, but rather, something that they work with just as they do with traditional fuels and motors.

The Volvo informant on the other hand, indicates that the company has profiled itself as more aligned with a new generation advanced fuel. The company has a clear message that it has been working with a future system with the highest yield of fuel per hectare, and the lowest overall carbon footprint – a 'fuel of the future'. Despite the market availability as of today for E85 and ED95 fuels for the ethanol platform, Volvo holds that DME has better potential in the future as a high mix fuel platform. As noted, their highest profile activity has been their extensive work with the DME initiative in Piteå – which is not based on a commercial production of fuel.

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[167] http://miljonytta.se/branscher/fordonsindustrin/bussar-och-lastbilar-miljoanpassas-med-ny-teknik-och-ratt-korsatt/
[168] 22 September 2010 http://www.scania.com/group/en/new-gas-engines-for-trucks-and-buses-diesel-like-performance-and-modular-design/

### *4.10.3 The policy sphere and support*

The need for long term stability and foreseeability featured as the most central theme for motor producers. They are of the opinion that political directions and policy are weak and are quite insufficient to deliver the development of advanced biofuels. While the goals may be ambitious, there is a lack of clear interventions to support goal achievement. As a result, they see that it will be difficult to implement widespread application of the fuels that their motor platforms primarily run upon (ethanol and DME)

Interviews indicate that they relate to this issue from several viewpoints. First is that a lack of clear direction in the biofuels sector (e.g. both fuel production and distribution) naturally creates uncertainty regarding which fuels will (or could most likely be) relevant for future heavy goods fleets. They relate that the development of an engine that is truly developed for a specific new fuel can take up to a decade. Thus, the engine sector can only devote limited resources for adaptive work on their existing engine systems.

Second, as they view the developments in the fuel production sector, both in Sweden and in the EU, they observe an escalating tendency for investors to back away from biofuel investments. This in turn amplifies the barriers to commitment from their side mentioned above. Third is that they serve global truck markets while Sweden is only a small market. Thus, while Sweden is a useful test or ‘reference’ market, and can be served with special engines, their major focus must remain on the global market for their products. Fourth it was related (Volvo) that the very range of potential biofuels (the richness of possible fuel platforms and the potential for high, low, medium fuel mixes) is an issue that may be on that is also contributing to difficulties. Had there been fewer possibilities then it may have been easier for policy and markets to give direction.

### *4.10.4 Closing comments*

The case addressing biofuel engine platforms indicates that the current market and political structures do not allow substantial divergence from mainstream engines – a situation that in some instances constrains technical development.

The study also shows that both Volvo and Scania have developed their engine platforms and biofuel strategies in quite different ways. Both manufacturers are able to supply engines to serve existing and foreseeable markets, but the provision of truly adapted engines seems likely to follow fuel markets and not be a significant driver for it. While interviewees all indicate that climate change and air pollution are now principle driving forces for the on-going development of biofuels, and the engines that can use them, Volvo and Scania seem to pursue different paths as they adapt to such drivers.

The study concludes that major barriers for optimal engine development are found in the general lack of long-term thinking and stability in the policy sphere that affects biofuels development. The substantial volatility in the policy environment is perceived to slow and inhibit the development engines as well as that of biofuels.

# 5 ANALYSIS AND DISCUSSION

The structure of this section relates directly back to Sections 1.1.1 and 1.1.2 where the key research tasks and areas of enquiry were outlined.

## 5.1 CROSS CASE ANALYSIS

Table 12 overleaf presents the cross case analysis for transitions and proponent strategies related to the included forest based biofuel projects in Sweden. This summary table has been generated utilising the detail case studies, and their analyses as provided in Part B of this report (*Systemic constraints and drivers for production of forest-derived transport biofuels in Sweden – Part B: Case studies*. Report No 2016:09B, f3).

The table represents a qualitative assessment of each case as compared to the analysis categories presented in the method section of this report. Each parameter listed in column two of the table overleaf represents one category. While a summative scoring system has not been applied (and nor do we consider that it should be), each category has been marked with an indicative strength or weakness. Here, ( + + +) has been indicated as representing descriptors such as 'very strong', or 'complete', or 'strongly positively affected by'. A comparable indicator at the opposite end of this scale, (- - -), thus represents descriptors such as 'very weak', 'missing essentially all components', or 'strongly negatively affected by'.

Before discussing the patterns and details revealed by the case study and analysis work (as summarised in Table 10), it is important to consider the actual status of projects under examination. For the terms of this discussion, these are categorised as followed:

- Commercial plants in operation – Preem, SunPine
- Pilot and demonstration plants – LTU Green Fuels[169] and GoBiGas Phase I
- On hold, awaiting improved investment conditions – Bio2G, GoBiGas Phase II and VärmlandsMetanol
- Closed or open-endedly on hold – Chemrec/Domsjö and Biorefinery Norrtorp*.[170]
- Under development – Renfuel

The suggested categorisation immediately provides a context for discussion. For operational projects, the case analysis is to be used to a) provide insights into parameters crucial for the success of the initiative, and b) provide insights into areas of weakness where work may be required to ensure future success. For projects on hold, the analysis should provide insights into key areas that may provide improved conditions for progress. For projects deemed to be closed, or open-endedly on hold, the case analysis can help to underpin a diagnosis of the key areas of weakness for the case.

[169] Note that the status of LTU Green Fuels has changed during the analysis made in this project; a successful pilot plant has delivered, but a lack of funding does not allow for further experimentation.
[170] * Officially, project proponents have not cancelled this projects. Nor have they deemed it to be indefinitely on hold.

**Table 12. Cross case analysis for transitions and proponent strategies: Forest based biofuels projects in Sweden.**

| | Case parameter | Bio2G | GoBiGas | Värmlands-metanol | Biorefinery Norrtorp | Renfuel | SunPine | LTU Green Fuels | Chemrec - Domsjö | Preem |
|---|---|---|---|---|---|---|---|---|---|---|
| **NICHE innovations** | **Number and 'establishment status' of niches** | + + | + + | + | + | + | + + + | + | + / - | + + + |
| | Core technology | + + | + + | + + + | + + + | + / - | + + + | + + + | + + + | + + + |
| | Enabling technologies | + + + | + + | - | - | + | + + + | - | - | + + + |
| | Distribution/utilisation technologies | + + + | + + + | + | + | + + + | + + + | + | - | + + + |
| **TRANSITION** | **Presence and status of key phenomena** | + + | + | + / - | + / - | + / - | + + | + / - | + / - | + + + |
| | Insulated market spaces | + + | + + | + | + | - | ++ | + | + | + + + |
| | Co-evolution of technologies, markets and preferences | + + | + | +/ - | +/ - | + | + + + | + / - | - | + + + |
| **REGIME** | **Regime Match/mismatch** | + | + / - | + / - | + / - | + / - | + + | + / - | - | + + + |
| | Techns, op.s, & maint., network | + | + | - | - | + / - | + + | + | - | + + + |
| | User practices and applications | + | + | + / - | + / - | ++ | + + | - | - | + + + |
| | Symbolic meaning of technology* | - / + | - / + | + / - | + / - | ++ | + + | + + + | + / - | + + |
| | Infrastructure | + + | + | + / - | + / - | + | + + + | + | - | + + + |
| | Industry structure** | + + | + | + | + | + | + + | + | - | + + + |
| | Techno-scientific knowledge | + | + + | + | + | + / - | + + + | ++ | ++ | + + + |
| | Policy/policy support | - / + | + / - | - | - | ++ | + | + / - | - - - | + |
| **LANDSCAPE** | **Landscape developments** | + | + | + / - | + / - | + | + | + / - | + | + |
| | Fossil fuel markets | + / - | - - | - - | - - | + / - | - | - - | - - | + / - |
| | Bioeconomy | + | + | + / - | + / - | ++ | ++ | + | + | ++ |
| | Climate discourse | + | + | + | + | + | + | + | + | + |
| | Enviro/resource eff. discourse*** | + + | + | + / - | + / - | ++ | + | ++ | ++ | + |
| **PROPONENT STRATEGIES** | **Contribution to Cognitive & Sociopolitical legitimacy** | + + | + | - | + / - | + | + + | + | + / - | + + |
| | Organisational | + | - | + / - | + / - | ++ | + + | + | + | + + + |
| | Intra-industry | + + + | + + | - | + | + / - | + / - | + / - | + / - | + / - |
| | Inter-industry | + + | + | + / - | + | ++ | + + + | + | - | + + + |
| | Institutional | + | + + | - | - | + / - | + / - | + | + | ++ |

**Detail analyses provided in Part B.**

* This term is intended to capture the relative richness of **symbolism** attached to the **advanced biofuel production technology** initiative. This has been categorised by qualitative judgement of how it seems to be perceived (i.e. implying and meaning to stakeholders) regarding 'positive' aspects such as the following: climate responsible; low pollution and healthy; fossil free; modern, reformative, futuristic; robust and functional.

** This is intended to capture the general strength of the project and its proponents against the following: industry competitors delivering the same or similar product; the customers for the fuel products; suppliers and support organisations to the project proponent; other new market entrants who might enter the industry to compete with the new fuel product; companies that provide a substitute to the product the industry competitors are selling

*** This category is intended to capture the relative importance of drivers related to environmental quality, resource efficiency, and the so-called circular economy.

### *5.1.1 Patterns from the cross case analysis – Key aspects along the way towards commercialisation*

The cross case analysis immediately indicates a number of patterns. These are briefly presented in the following text.

Addressing operational commercial projects, Preem (HVO) and SunPine:

- Relative strength of initiatives as against analysis criteria shows gradation in overall strengths and weaknesses. Preem is the strongest iniative; to a large extent due to the fact that the initivtive is fully in line with their established core business and that they also have the possibility to use different types of feedstock in their co-processing of HVO. Careful preparations, mutual dependence, and the involvment of experienced and financially strong actors seem crucial for both the Preem and SunPine cases.

- Case evidence suggests that the Preem initiatives, having adapted significant portions of existing technological infrastructure and using existing distribution systems, and requiring no modifications for vehicles, provided a smooth path towards mainstream production. Even in comparison with industry peers, such as Neste of Finland, the Preem strategy has via co-processing, pursued the utilisation of existing infrastructure and refinery resources to an even greater extent. Preem claims that it has minimised CAPEX drastically in comparison to Neste's HVO plants.

- In contrast, SunPine is a new plant built from the ground up, as a new distillation/refining initiative utilizing the undeveloped structure of the crude tall oil market. It could utilise storage tanks at Piteå harbour, and existing logistics infrastructure. While built largely upon known technologies, the SunPine plant experienced technological difficulties (requiring a substantial rebuild) at the commissioning phase. It has thus experienced 'technical risk taking the form of actual harm'. The involved parties shared a relatively strong belief in the foreseeable development of the policy support that has only been partly satisfied; the tax exemptions have remained. SunPine are critically reliant upon current levels of policy support for survival. In the words of the Chairman of the Board of SunPine the company remains 'one political decision from bankruptcy'.

- While different to each other in form, the proponent strategies of SunPine and Preem both appear stronger than other projects. They have strong organisational and inter-industry collaboration and cooperation, all along the chain from feedstock to distribution of the product. A valuable example for the analysis is SunPine, where both producers of the required raw material and the user of the product were involved in the project.

- SunPine and the Preem HVO initiatives differ from each other in a limited number but, never-the-less, important areas. It has been judged from the case investigation that Preem's HVO projects are stronger in areas related to the technologies, operations and maintenance networks, and user practices and applications. However, the projects are linked and the Preem HVO project is strong partly due to the link to the SunPine project.

Addressing pilot and demonstration projects, LTU Green Fuels and GoBiGas Phase I:

- LTU Green Fuels represents a long-lived and technically successful pilot plant that will soon be shut down (announcement in April 2016[171]). The series of initiatives undertaken at the facility have successfully demonstrated the technologies installed. Moreover, the trials have produced a functional fuel on an on-going basis – as demonstrated by over 1.5 million km of transport. As the plant served to prove the technology of Chemrec, and initiative that has not been taken forward, the case study clearly reminds analysts that even in the case of successful technical verification in a pilot plant, there are no guarantees that the technology will be commercially successful.

- GoBiGas Phase I also presents a (largely) technically successful pilot plant. Despite cost overruns in construction, and significant commissioning challenges, the initial stage of trials has demonstrated that bio-SNG can be produced in long production runs from wood pellets. Moreover the initiative claims that significant learning has taken place that will ensure CAPEX savings in any eventual scale-up versions of the plant. On-going trials must now demonstrate capabilities to run on forest chips, and eventually on forest harvest wastes. While still operational, GoBiGas is threatened to some extent from the regional political sphere – and Phase II of the project is on hold.

- The most apparent areas of difference among these can be seen in the degree of match with the regime components. Here it can be seen that GoBiGas is comparable to projects on hold – a logical outcome considering that the scale-up progression for actual implementation is the GoBiGas Phase II project (as this is on hold, both initiatives will be discussed). LTU Green Fuels has no comparable alignment with the current biofuel – or any commercial – regime.

Addressing projects deemed to be on hold awaiting improved investment conditions, Bio2G, GoBiGas Phase II, and Värmlandsmetanol:

- Actors that already are involved in the biogas business and thus have significant knowledge of production, distribution, and marketing of vehicle gas run the bio-SNG projects. In contrast, the chain for methanol (Värmlandsmetanol) as a vehicle fuel does not exist and the actors therefore have to build up all the necessary know-how to develop the production, distribution, and marketing, for which they are dependent upon external service providers. Despite this, there are also factors that strengthens the methanol chain compared to the biogas: a (liquid) drop-in fuel for petrol is easier to handle and to find a market for than a fuel that demands an expanded market for dedicated vehicles and distribution infrastructure. Further renewable methanol could be sold for other purposes, e.g. for the production of FAME or as a fuel for maritime transport, both being existing markets. A strength may lie in their focus upon a smaller number of large niche customers.

- The relative strength of the bio-SNG initiatives as against the analysis criteria is judged as rather similar. However, Bio2G is judged to be slightly stronger between these two prospective bio-SNG producers in a number of strategic areas. Key among these being the

[171] http://www.pt.se/nyheter/pitea/ltu-green-fuels-lagger-ner-9987917.aspx

deeper and broader involvement of E.ON in enabling technologies such as fuelling stations and distribution networks, the financial and market power of E.ON as a gas distributor and renewable market actor, its role in the industry structure, and finally, the relatively high level of presence, and activity in dissemination and outreach of E.ON at an intra and inter-industry level.

Addressing the one project under development, Renfuel:

- At this stage (with funding just secured, and the pilot plant being built) no technical data regarding performance is available. However, it is judged that this technology has a well-supported technical niche. Interestingly, the project proponents have distanced the initiative from large potential customers at this stage. If technically successful at scale, this technology likely has a ready market for it bio oil products. With knowledge of the progress of SunPine, it appears that a significant addition to domestic fuel feedstock can be made if this technology works (although lignin supply is limited, it can be considered abundant in comparison to tall oil). Renfuel clearly has strength in that it is limiting its exposure to technical risk by focusing on one process step. As such, it appears that the risks and how to avoid them have been identified based on the experiences from earlier Swedish biofuel production projects. We consider that the analysis scoring can be considered comparatively conservative – when the project has successfully demonstrated bio oil production, this would change.

Addressing projects deemed to be closed or open-endedly on hold, Chemrec/Domsjö, and Biorefinery Norrtorp:

- This analysis indicates that Chemrec's most apparent weaknesses lies in the general lack of enabling technology systems. Further, it represents an expensive, largely 'build from scratch', effort. Moreover, while some offset markets exist (e.g. DME firing in asphalt plants) the technology is also reliant upon a rapid provision of infrastructure and engines suited for its utilisation should it become a functional fuel system with meaningful market share. A proviso is that as it has been strongly backed by the motor platform developer Volvo, this obstacle is might be less than expected. The number of filling stations to supply the long-haul transports it is intended for are less than for other fuels not so directly intended for a niche in the transportation fuel market and extensive field testing for this market has already been carried out in the Chemrec/LTU Green Fuels project in Piteå. On the negative side is that the initiative is clearly reliant upon a strong policy support over a long period. Notably, insufficient/short-term policy support given as the absolutely dominating reason for project cancellation – our analysis indicates a number of other concern areas that logically must have played a significant role in such decision calculi.

- Biorefinery Norrtorp shares a number of the challenges stated above for Chemrec. As commented for the other methanol case (Värmlandsmetanol) transport, methanol strategies also have a number of strengths.

- Comparing Chemrec/Domsjö to its pilot in Piteå, a number of issues of potential relevance for the future may be discerned. The pilot at a very much smaller scale perhaps gave more than just proof of technical concept. It has been a successful symbol of this technological system. Chemrec's initiative however, in contrast may be seen as too much, too soon. Its scale is potentially disrupting the chemical pulping industry, especially as the gasifiers (three in parallel) are expected to fully replace the recovery boiler at the heart of the pulping process, an industry with an availability of up to 360 days annually. This means that the industry has to face a new technology that may not be as reliable as the conventional recovery boilers, thereby risking the stability of the core product, and at a higher capital cost. Chemrec were, as the previous owners of the pilot in Piteå, well aware about the extended tests performed, but this analysis indicates that they were unlikely able to provide the same type of guarantees about the process as the established equipment suppliers that the pulping industries were familiar with. The possible gain would have been the significantly higher value of the by-product, DME or methanol in comparison with the electricity, but at a market where the value could have been diminished by a single political decision not even fully in the hands of the Swedish government (see Section 2.3).

### *5.1.2 Concluding remarks: cross-case analysis*

If SunPine and Preem are considered to belong to the same production line, only one out of six planned full scale production plants for forest-derived transportation fuels studied here have been realized. There are a number of reasons for this, one being the low oil prices during 2015 and 2016; another being high capital costs, that in combination with perceptions of high technical risks for the conversion of solid forest biomass to biofuels poses a major barrier. It must be kept in mind that these technology pathways have not been commercialised anywhere as yet. Also Worth noting is that the SunPine/Preem line uses a liquid feedstock, thereby using other processes for the first conversion step, which limits the technical difficulties as well as the capital costs. Moreover, the product HVO does not require any adaptation on the consumption side, which eliminates most market side risks apart from the price. Due to these circumstances, the risk was moderate and the specific capital costs low in comparison with the other full-scale cases, but this is not the full answer to why SunPine/Preem has been realised. Careful preparations and the involvement of experienced and financially strong actors seem crucial and if the SunPine case is considered separately, both producers of the required raw material and the user of the product were involved in the project.

Given that investors cannot be certain about the future price for crude oil and that the cases studied are truly new concepts that have to compete in a regime where conventional transportation fuels dominate all links in the chain from feedstock to vehicle fleets, the case studies unambiguously confirm that the successful implementation of production concepts for forest-derived biofuels is heavily dependent on a supportive, stable and foreseeable policy framework. Other studies have also confirmed that there is a lack of policies for the up scaling of innovative technologies[172,173] Thus, the role of the policy maker should not be underestimated; the political risk is the most complex risk to handle in a biofuel project. An example from the case studies is that if the actors involved in SunPine would not have believed that favourable policy instruments were to be kept, it is uncertain if the companies would have invested in the plant. Another example is that the uncertainty in the future of the (by then) current policy instruments is likely to be the main reason why the investments were not carried through in the Chemrec/Domsjö Fabriker case.

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[172] (Hellsmark, H., Mossberg, J., Söderholm, P., & Frishammar, J. (Forthcoming). Innovation System *Strengths and Weaknesses in Progressing Sustainable Technology: The Case of Swedish Biorefinery Development. Under review in Journal of Cleaner Production.*)
[173] *Swedish Energy Agency, 2014. Teknologiska innovationssystem inom energiområdet. ER 2014:23.*

The successful outcome of the SunPine/Preem line may also provide a valuable lesson, e.g. that the strategy by Renfuel to focus on a specific link of the production chain and on a fuel that can be blended with fossil based transport fuels in order to increase the chances to be successful seems promising. Nevertheless, the LTU Green Fuels case also reveal that even in the case of relatively successful technical verification in pilot plant, there are no guarantees that a demonstration plant will be realised. In the case of Renfuel, risks and how to avoid them have been identified based on the experiences from earlier Swedish biofuel production projects.

Notably however, is that the possibilities to integrate the production of forest-derived biofuels with incumbent forest industry processes are not so obvious for all parts. SunPine (via its key forest sector partners Södra and Sveaskog) contrasts somewhat with the mainstream views and goals of the forest industries, where the focus at least previously has been towards products using the mechanical characteristics of the wood. Major lobby groups representing the pulp and paper processing industries have been ambivalent or negative towards biofuels, this undermining the efforts of biofuel proponents to secure support from various social and political constellations.

## 5.2 EXTERNAL AND/OR LANDSCAPE-LEVEL DRIVERS AND CONSTRAINTS

At this level this research project generally sought evidence of interactions with phenomena from outside the forest and biofuel production sector, and with stakeholder groups outside the actor constellations that directly interact with forest-derived fuel production systems. As operationalized in casework, applying the transitions framework, this was linked to so-called landscape factors such as: stakeholder views regarding biofuels in general and forest-derived fuels in particular; the global climate discourse; macro-economic and macro-political trends; development of other alternative transport fuels, significant environmental changes, and so forth. Analysis at this level is documented in detail in Section 3 of Part B for this report (Part B: Case Studies).

In particular, casework and workshop/interview discussions investigated issues such as: how altered landscape conditions may open or close general ‘windows of opportunity’ for the implementation of larger initiatives for forest-derived transportation frameworks; the influence of (particularly) oil markets dynamics; the increasingly high profile of electromobility in discussions; and experiences, and social views (largely outside the Nordic zone) on how Europe’s forests should be used.

Of these items, the global climate discourse and oil price trends appeared as most relevant in this study. Regarding key landscape factors with potential to affect the emergence of advanced biofuels production, this analysis argues that a ‘window of opportunity’ started to open in the early to mid 2000s related to climate concerns and energy security. A steady increase in oil prices to high levels – as discussed in Section 2.4– that was then even being portrayed as a new norm, truly opened this ‘window’ in circa 2006.

### *5.2.1 Oil market conditions*

Of the nine cases studied, seven examine full-scale commercial size production units of biofuels in Sweden. Two are in operation as part of the same feedstock to production line (SunPine and Preem). In the case of GoBiGas the demonstration plant is in operation but the full-scale plant has been postponed. Of the four remaining, one (Värmlandsmetanol) is still actively pursuing investors, while the other three projects have been placed on hold, or cancelled. Given the likelihood (or inevitability) of an important level of influence on the financial viability of projects from the prices on the current fossil-based transportation fuel market, it is worthwhile to examine the timing of project hold decisions as against fossil fuel price trends. In this instance to examine if it can be seen as a key precursor to a project 'hold' or cancellation decision. Here the focus is foremost on the price of crude oil – as that also influences other fuel prices such as the price of natural gas (see Section 2.4).

In the Biorefinery Norrtorp case it is explicitly taken up that the decline in prices for natural gas that followed the declining oil price in 2014, had an important influence in the decision not to continue with the project. The decision to place GoBiGas Phase 2 on hold in December 2015[174] was also preceded by a discussion of oil and gas prices. The remaining two decisions, for Chemrec/Domsjö Fabriker and Bio2G in Malmö, were made prior to the dramatic fall in oil prices in 2014. They were thus presumably were dominantly influenced by factors other than the low oil price. The lack of a stable and foreseeable policy framework was mentioned as a reason not to proceed in all cases, but it is only in these two last mentioned cases that the oil price can be ruled out as the main driver for not to proceed with the investments. The Bio2G case for instance, identifies the fundamental importance of a rapidly growing market for biogas, which in turn requires sales of gas vehicles. Such is reliant upon both policy stimuli affecting the fleet morphology (e.g. company car fringe-benefits taxation) and biofuel pump prices for project viability. Media focus, and the high profile of electromobility in the social and political discourse were also identified in the Bio2G case as factors directly (and negatively) affecting policy frames around gas vehicles. For the Chemrec/Domsjö Fabriker case, the lack of stability and foreseeability in policy affecting fuel (user) market price was put forward as being fundamental for project viability.

### *5.2.2 Social discourses*

While not as immediately visible in cases as policy stability or oil prices, the impact of social views as a barrier to progress in the field were also taken up on numerous occasions in case studies and in other interactions with informants (e.g. webinar and written correspondence). Key among these was the influence on the policy sphere at the EU level of views that forest utilisation for energy purposes – including forest derived transportation fuels – was generally undesirable from a carbon perspective, or a biodiversity perspective, or both. Study informants expressed concerns that policy conditions arising (or potentially arising) from the EU level, that in turn can affect Swedish initiatives, were based on visions of (continental) European 'park-like forests' rather than the 'working forests' of the Nordic zone. In turn, there were concerns that the policy making process in Brussels had been 'captured' by special or 'single' interest groups with views on forestry that are potentially damaging for the Scandinavian forest industries.

Views were also expressed that such views, and other critical discussions based on concepts such as cascading use and indirect land use change (ILUC), ignored the Swedish context where a prime focus is placed on the utilisation of residues and lower quality timber for applications such as trans-

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[174] Göteborg Energi, 2016. Decision about GoBiGas in The city Council of Gotherburg [Beslut om GoBiGas i Göteborgs kommunfullmäktige]. http://GoBiGas.goteborgenergi.se/Svensk_version/Nyheter/Beslut_om_GoBiGas_i_Goteborgs_kommunfullmaktige

portation fuel production. It is also observed that this issue has also been influenced by spill over from the polarised transportation ethanol and FAME biofuels discourse associated with ILUC.

This analysis notes that significant parallels can be drawn here with another study that examined how European stakeholders were found to view forest-energy initiatives (solid biomass in power generation) negatively.[175] That study takes up how stakeholder views regarding issues related to issues such as ‘conservation of primary forest’, ‘biodiversity protection’, ‘ecosystem protection’, ‘greenhouse gas balance’ and ‘temporal carbon balances’ (or ‘carbon debt’) pose constraints on the European heat and power utilities. Further, that work found that with the mitigation of climate change as a central EU policy goal, interest in the carbon and the biodiversity performance of biomass production and utilisation chains appeared unlikely to dissipate. As such this work also suggests that critique from stakeholders, whether well founded in science or not, will remain an important issue in such areas.

As a last point in this examination of social and political discourse affecting the progress of forest-derived transportation biofuels initiatives, the role of the bioeconomy and its place in discussions is deemed worthy. Despite a clear framing of biofuels production within the biorefiney concept, and widespread recognition of the forest industries foundational role in the (present and future) ‘European bioeconomy’ (as outlined in the introduction) discussion of the bioeconomy from the side of informants was essentially absent in research interactions undertaken in this project. Considering the high status of the bioeconomy in EU policy enfolding both innovation and economic growth, and the clear links drawn to projects such as those addressed by this study,[176] this is found to be somewhat counter-intuitive. While the absence of this theme from the side of informants does not indicate non-recognition of the communication value of this item, we can take this as *prima facie* evidence, that it is not a common ‘high profile’ theme taken up when seeking support for such initiatives.

## 5.3 INTER-INDUSTRY AND SOCIO-TECHNICAL REGIME DRIVERS AND CONSTRAINTS

At this level this research project generally sought evidence interactions between different industries affected, or affecting the forest-derived fuels sector, and phenomena related to the so-called socio-technical regime within which the initiatives are embedded. As operationalized in casework using the transitions framework, investigation focused on the alignment between the technology initiatives and the established socio-technical system components such as meso-level infrastructure, institutions, policy frameworks,[177] established practices, behavioural patterns, markets, and industry structures. Analysis at this level is documented in detail in Section 3 of Part B for this report (Part B: Case Studies).

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[175] See discussion in Sluka, C., & Peck, P. C. (2015). Stakeholder dynamics in the forest energy sector: key issues to manage and ways forward. Biofuels, Bioproducts and Biorefining, 9(1). Volume 9, Issue 1, pages 51–71, January/February 2015. DOI: 10.1002/bbb.1501
[176] See material referenced at the European Commission Research and Innovation web page on the bioeconomy http://ec.europa.eu/research/bioeconomy/index.cfm?pg=policy for an introduction.
[177] As such, policy was viewed as a internal/external factor rather than an external factor.

In particular, casework and workshop/interview discussions with key informants revealed that the stability of Swedish policy frameworks, certain aspects of fuel system infrastructure, and fleets as a market determinant were particularly important. These items are discussed in more detail below.

### *5.3.1 Biofuels policy*

A central theme in all cases was the negative effect of unfulfilled expectations, and increased perceptions of risk, that have grown with increased exposure to the EU and Swedish policy frameworks that enfold transportation biofuels. Perceptions of political and policy risk appear to have intensified over the time frame addressed by the cases (circa one decade).

A recurring issue for project initiatives was that the temporal stability and predictability of the policy instruments used to promote biofuel in Sweden have been insufficient to attract investors, or support project profitability, or both. Incentives for biofuels, based on a system of taxation alleviations, have never been guaranteed for periods deemed long enough to support the large financial decisions required for these projects. This, because Sweden, by choosing tax alleviation as the support pathway, has had to apply for exemption from the general principles set by the EU Energy Tax Directive on a regular basis (see Section 2.3.3) Further, there have also been a number of changes to certain parameters of regulations imposed which increases perceptions of policy instability. Examples include the maximum allowed share of blend-in biofuels, and the levels of tax alleviation for some biofuels (e.g. to avoid so-called overcompensation).

While a new term of tax alleviation was granted at the end of 2015, there are further anticipations of change. One significant difference that is now clearly recognised by project proponents is that the share of biofuels has now grown to such levels that the tax losses faced by the state are comparatively large. As such, there are views that a quota obligation system (market share mandate) is imminent. One such system was about to be introduced in Sweden in 2013 but was rejected by the EU, (see Section 2.3.3). However, the shift from tax exemptions to quota obligations has not been an unknown shift for actors involved in the projects and therefore not to be considered a new risk – however, there does remain uncertainty regarding the form it will take, and the manner in which it will impact high versus low blends.

Viewed as a whole, it can thus be stated that the general picture considering policy instruments is similar now (2016), to how it was when the plans for the studied projects materialized or were cancelled, i.e. the tax alleviations have never been guaranteed for more than a few years in advance. As such, it is worthy of discussion as to why some ideas appear in a policy environment that resembles the one where the decisions are made to put the projects on hold or cancel them. The price on oil affected some of the decisions, but not all. A first supposition can be that in some cases project proponents have been overly optimistic considering the future biofuel market conditions. In this regard, the breakdown of the international climate negotiations in Copenhagen in late 2009 was a major setback for beliefs that a more stringent general climate policy framework would come to be, especially regarding binding agreements including all major economies. This may have had an influence driving expectations of a more stringent and reliable policy framework that also would affect the Swedish transport sector.

Facing the current picture of a relatively prolonged period with low oil prices and with continued – perhaps even increased – uncertainty regarding Swedish policy instruments in mind, it is also relevant to consider whether the window of opportunity for large scale investments in plants for forest-derived biofuels has now closed (a topic that was specifically taken up in an expert webinar during the closing phase of this research). Important for this discussion is to view the development of the biofuel market in Sweden and the possible implications this may have on the policy-makers formulating the future policy framework. A first issue is the major increase in the share of HVO on the Swedish fuel market. Despite domestic production from Preem, most of this is still imported, or a large portion of the feedstock is imported for the domestic production. A second issue is that significant shares of other biofuels sold on the Swedish market are also imported. A third issues is the RES targets are bypassed by a significant margin – thus, Sweden exceeds EU requirements in this regard. Seen together, there can be a number of implications. Whilst many can view over-delivery of (in this case EU) policy goals positively if the costs are balanced by other tangible and visible benefits to the environment or society, this may be difficult to rationalise for Sweden. The trade balance is barely improved compared to the production of conventional transportation fuels; rural development in Sweden is apparently not stimulated as the feedstocks are produced elsewhere; and energy independence is not strengthened. Added to this picture are also that the prospects for a domestic feedstock for biofuels are better in Sweden than in almost all other European countries (presumably raising expectations that domestic feedstocks should be used) and that Swedish biofuel producers only can be certain about the current tax alleviations until 31 December 2018 (until 31 December 2020 for biogas), (see Section 2.3.3). As such, there are a number of other factors that add to the issue of tax losses to the state that would logically influence a decision about the future policy framework. Further, it might even be the case that primarily driven by the tax losses, there might be sufficient political will to have a new system in place before the end of 2018.

Here it should be noted that quota obligations (mandates) are not anticipated by themselves to automatically promote production with a domestic feedstock; rather, it is viewed that a quota system (several informants to this study have given the examples of a system resembling the green certificate system for electricity in Sweden) would have the potential to promote both domestic fuel production and feedstock production. The same is also true for the price premium model presented in the FFF inquiry (see Section 2.3.3). As such, it is suggested that both these policy instruments show promise as enablers of the long-term policy framework required for most of the investments that have been studied in this project. While it remains unknown whether the creators of the new Swedish policy framework will consider the potential to use a domestic feedstock, it is not illogical that this will be the case. Another anticipated[178] development is that the oil price will stabilize at a higher level than that experienced at present (first quarter 2016), (See Section 2.4); this in turn implying that biofuels are more competitive on the fuel market.

As such, it is deemed feasible be optimistic and to assume that Sweden can be placed within an environment of (somewhat) higher oil prices and stable long-term policy instruments within a few

[178] As presented in Section 2.4 of the report, forecasts from bodies such as the World Bank, the EIU Economic Commodity Forecasting group, and others present projections for global average oil price in the range above US$40/bbl and below US$70/bbl in the coming years. Such forecasts have however, in the past, shown to be unable to capture the dynamics of oil prices. This analysis takes the position that there is no reason to expect that they shall be more reliable in the future than they have been in the past.

years. Should this situation arise, it could provide the foundation for domestic forest-derived biofuel production that has been absent in recent years. The window of opportunity spoken of above might therefore be temporarily shut, but it may open again.

### *5.3.2 Fuel system infrastructure*

While it can be considered a given that biofuels that can be utilised directly within existing infrastructure (drop in fuels, and low-blends) face fewer infrastructure-related constraints, this study has highlighted the need for a broader view of infrastructure in discussions than just one focused in distribution systems.

A first point that can be taken forth from the successful Preem initiatives to date, is that higher degrees of integration of biofuel production with existing petro-chemical production facilities required significantly lower overall capital expenditure; this in comparison to both other biofuel-type initiatives (e.g. DME or bio-SNG) and in comparison to industry peers such as Neste of Finland. The consequent reduction of overall financial exposure has contributed to reduced overall project risk and appears to have had significant importance to the progress of their initiatives. When combined with the fact that Preem has pursued a drop-in fuel strategy with the HVO fuels, thus avoiding significant constraints from the distribution and refuelling system side, their position appears robust in comparison to other initiatives. As imported HVO fuels on the market far exceed domestic production at present, new domestic production of fuels has an immediate receiving market, and faces no significant distribution issues. With the Swedish diesel passenger vehicle fleet still expanding rapidly.

This absence of market constraint is not the situation in the biogas/bio-SNG sphere. While a distribution network exists along the Swedish west coast, and while distribution of biogas can be achieved cost effectively by road for significant distances (up to 400km), initiatives to build production facilities at medium or large scale are markedly constrained by the market. The target market is vehicle-gas – gas utilisation in industry or heat and power generation is technically feasible but absolutely unattractive from a financial viewpoint. The vehicle fleet to absorb significant additions to the biogas supply is required to grow in advance of the creation of production facilities (or be steadily growing to match such demand within a financially reasonable timeframe). Thus while the existing gas infrastructure provides both distribution capacity for significant volumes of gas, and a buffering capacity for biogas supply/demand fluctuations, without a healthily growing gas vehicle fleet, investments in bio-SNG facilities are not viable.

While the focus of much of this study has implicitly been upon biofuels that will be used directly in the tank of a road vehicle, examination of the methanol initiatives in this study, indicate that this energy carrier’s principal markets may lie somewhat outside this area. As a first example, there is significant existing demand for biogenic methanol as a feedstock for the production of FAME biodiesel (displacing fossil methanol) thus contributing to an improved carbon footprint of FAME fuel. As a second, there is considerable attention being given to the future role of methanol as a maritime fuel. Both of these markets have the comparative advantages of large potential consumption sites/markets (e.g. a harbour refuelling facility, or a FAME biodiesel production facility). There is of course also the potential to utilise methanol directly in petrol as a low blend (up to 3%).

The situation for DME production initiatives and utilisation shows parallels to all of the bio-fuel systems discussed above – not least methanol as DME facilities can also be built to synthesise methanol (and vice-versa). As a new fuel platform for Sweden, DME has the drawback that new engine fleets are required. Here however, the deep involvement of Volvo served to increase confidence that a transportation market (both domestic and international[179]) could be grown. Also related to this, production sites associated with pulp mills facilitate both feedstock logistics, and provide for a potential fleet market (biomass transportation fleets). Regarding distribution infrastructure, DME represents also somewhat of a hybrid situation. While DME is gaseous at normal temperature and pressure, a mild pressure of approximately 6 bar is sufficient to keep it in liquid form. In this respect, DME resembles liquefied petroleum gas (LPG), which consists of propane and butane, and in principal existing LPG infrastructure can be utilised.[180] Further DME has also other potential markets (that can be large volume sites) with modest 'willingness-to-pay' for low carbon fuels. One demonstrated market in this instance is that for municipal asphalting. During 2015 for instance, biogenic DME was being utilised by Svevia at its Arlanda asphalt mixing plant[181] – Svevia held at that time that 'green' asphalt was increasingly demanded in some markets as a pathway towards reduced climate emissions.

## 5.4 ORGANIZATIONAL OR INTRA-INDUSTRY (INTERNAL) DRIVERS & CONSTRAINTS

**Organizational or intra-industry (internal) drivers & constraints:** At this level our research generally sought evidence of issues within organizations, or between sectorial organizations in the forest sector (thus generally organizational or intra-industry). In particular, evidence of consensus (or a lack thereof) was targeted. Key items of interest were: the fuel types considered most desirable, or strategically advantageous; evidence of concern regarding biomass feedstock competition; and views related to existing infrastructure, and sunk costs.

Firstly one issue that was raised by informants on a number of occasions throughout the project was that there is indeed a form of schism within the forestry industry itself as outlined in the introduction of this report. However, as data collection was focused on fuel initiatives, essentially all research interactions were with supporters of the concept. The portion of the industry opposed or ambivalent to such initiatives is not represented; this stated, project proponents did express views that this poses a constraint. At least one outcome of the lack of a united front from the sector apparently appears at the EU level – here, there is an insufficient presence of forest sector lobbying and policy-framing input that serves to support projects such as those addressed by this research.

Regarding the actual fuel projects themselves, it is apparent that Swedish forest related actors involved in forest-derived transport fuel initiatives do not display a united front regarding potential pathways forward. The portfolio of projects located in the forest sector itself is evidence of this – black liquor gasification for DME production; wood gasification for methanol production; tall oil

[179] The IEA-AMF reports that a vehicle market of 13 million tonnes/annum exists in China. See http://www.iea-amf.org/content/fuel_information/dme

[180] Therefore refuelling and storage requirements of these fuels are close to each other. In principle, transport and distribution of DME could use the existing LPG infrastructure with some modifications to the pumps, seals and gaskets. New infrastructure for DME would be needed in the regions where the LPG infrastructure does not exist. See: Semelsberger, T.A., Borup, R.L. and Greene H.L. (2006) Dimethyl ether (DME) as an alternative fuel. Journal of Power Sources 156 (2006) 497–511.

[181] Personal observation and discussions, Philip Peck, September 2015; site visit to Svevia plant. See also https://www.svevia.se/stat--kommun/startsida---stat--kommun/dina-behov/asfalt--belaggning/svevias-asfaltverk.html

refining for HVO production and now lignin processing to bio oils. While each initiative has been seeking its own niche, there is clear evidence that the different projects do compete for legitimacy, attention, funding and financing within the Swedish system. While obviously difficult to avoid completely, such competition is seen within this analysis as a factor that has constrained progress.

If one shifts focus from intra industry relationships in the interactions among actors from the forest sector related to fuels, to a sector that could be described as a 'forest-derived transportation biofuels sector', a slightly different picture may arise. While actor-constellations here can still be seen to compete for resources as outlined above, a number of synergies and collaborative actions are also seen. Here, Preem represents the petrochemical sector, and gas utilities and vehicular gas suppliers are represented by E.ON and/or Göteborgs Energy. These sectors control or influence important resources – not least processing, production and distribution infrastructure. While discussed in the preceding section as inter-industry relations, if one considers a 'forest-derived transportation biofuels sector' one can perhaps also see critical future pathways. A first observation is that the Preem project relies on an upgraded 'by-product' stream from a forest sector partner in a deep interdependency. It is conceivable that bio oils projects such as Renfuel may also deliver deep interdependencies. A second observation is that future bio-SNG projects would conceivably deliver an on going 'licence to operate' for existing (and/or expanded) natural gas storage and distribution networks into the future. It is notable in this context that policy goals for Sweden essentially require the removal of fossil fuels within a generation.

## 5.5 REFLECTIONS UPON ANALYTICAL PROCESS AND THE CASES

This brief discussion seeks to further discuss the case studies within the chosen analytical frame prior to drawing conclusions for this study.

### *5.5.1 The process of transitioning*

This study analyses different pathways for forest-derived transport fuels in Sweden. The initiatives to deliver biofuels from forest feedstocks that can replace fossil fuels to renewable transport fuels have been examined as a technological transition process. However, the different pathways studied (e.g. HVO, bio-SNG, methanol and DME) have been posed as also competing with each other to some extent – in this sense, different technology systems compete for investments, policy maker attention, research funds, and other resources. As has been detailed throughout the analysis, a fuel system is multi-faceted; it generally contains a suite of production and distribution infrastructure, a vehicle fleet and other customer markets beyond transportation. In this sense it is also reasonable to talk about path dependency; once large investments are thoroughly established for the production, distribution, and use of one vehicle fuel type, it is in place it less likely that investments in an alternative fuel will be realized.

Although the pathways examined in this work share certain characteristics – they are based on forest biomass as feedstock and a central aim is usually provision of road transport fuels (methanol may differ in this regard), this study has established that each will follow its own transition pattern.

Regarding the form of transitions, the analysis indicates that the most successful of the studied cases – the blend-in of HVO in conventional diesel by Preem and SunPine – can best be described as a reconfiguration process. In this transition, which is *de facto* taking place, the incumbent actor

Preem is replacing (fossil) crude oil with biogenic feedstocks as input to its refinery. Their highest profile feedstock at present is raw tall oil diesel supplied by SunPine. The new product, Evolution Diesel, is distributed through existing infrastructure to existing users (diesel vehicles). In this manner Preem appears to be following a so-called survival pathway as it transitions from fossil to renewable transport fuels. Transition analysts hold that this transition pattern is different from a substitution process in which a technology emerges from the niche level and replaces another technology at the socio-technical regime level. Transition through reconfiguration is a stepwise process in which one modular innovation replaces another, without substantially changing the rest of the system.

However it is also noted that the adoption of the modular innovation may enable and trigger subsequent changes. Indeed, Preem is now making additional investments to incorporate HVO production based on other feedstock than tall oil. A simple reason for this exists as the supply potential for tall oil is limited (as is the production capacity of SunPine providing the tall oil diesel produced from tall oil). The HVO case/pathway can thus be seen as an example of 'systemic innovation through stepwise reconfiguration' in which an incumbent actor adopts modular innovations that enables additional innovations.

This study finds aspects of both stepwise reconfiguration and substitution underway for the bio-SNG systems. Substitution differs from the HVO reconfiguration described above, a transition in which an emerging technology substitutes an established technology within the socio-technical regime. According to Geels & Schot[182] timing is crucial, and the transition may follow different patterns depending on if the technology has matured sufficiently in the niche or not when the change at the landscape level occurs. This study indicates that methanol and bio-SNG may be seen as transitions that would not fit seamlessly into the substitution or reconfiguration patterns.

For gas, on the supply side, established actors within the natural gas supply-utilisation system and the vehicular biogas system (e.g. E.ON and Göteborg Energi, but principally E.ON) have incrementally fed biogas into the system. Bio-SNG and upgraded biogas from anaerobic digestion is interchangeable with natural gas. A mixture of mainly biogas and natural gas is commercialized as vehicle gas and this product replaces conventional fuels in Swedish road transport (although currently only 1.6 TWh of totally 85 TWh in Swedish domestic transport sector). As noted, this does not substitute natural gas *per se*; rather it displaces petroleum fuels from the transport sector.

On the other hand, a reconfiguration is taking place within the natural gas supply system infrastructure utilisation where a renewable gas module(s) have been incorporated into the natural gas systems without substantially changing the system. Vehicle gas may be seen as a fuel – or rather as a sociotechnical system – that replaces conventional fossil fuels. Biogenic gas <u>plus a vehicle able to utilise biogas</u> is used to substitute an established technologies (the petrol and diesel vehicles and their fuels). As Geels and Schot note: "transition pathways need not always to occur in their purest form".[183]

The introduction of large-scale bio-SNG systems however, requires a much more substantial rate of change than has been taking place over recent years. The implementation of the Bio2G project for

[182] Geels, F.W. & Schot, J., 2007. Typology of sociotechnical transition pathways. Research Policy, 36(3), pp.399–417.
[183] *Ibid.*

example would in essence double the supply of biogas to the market. Also of note in this context is that the relationship between natural gas industry and renewable gas (bio-SNG and upgraded biogas from anaerobic digestion) is symbiotic; biogas legitimizes natural gas and it is sometimes argued that "natural gas is a bridge into the biogas society".[184] Natural gas may also benefit biogas development: distribution infrastructure may be used; natural gas regulates the price of vehicle gas; and natural gas may also act as a back-up if biogas supply fails to meet vehicle gas demand. The embracing of renewable gas within the (previously fossil) natural gas network also serves to improve the image of the Swedish gas-for-energy market.

Methanol may substitute gasoline or diesel if applied as a pure transport fuel (M100). However methanol may also be applied as (low) blend-in fuel in conventional gasoline. If blended-in the transition may assimilate the stepwise reconfiguration described for Preem. As noted earlier, there is also demand for biogenic methanol as a feedstock for the production of FAME biodiesel and there is considerable attention being given to the future role of methanol as a clean maritime fuel where it would replace diesel and heavier fuel oils.

Lastly, DME is another example of a possible transition/pathway in which the emerging technology (seeks to) substitute the established one; DME also demands significant changes and additions to dedicated distribution infrastructure and vehicles, however its potential compatibility with the (somewhat limited) LPG infrastructure, also indicates opportunities for stepped reconfiguration strategies.

We can conclude that the currently most successful case/pathway in Sweden – HVO – may best be described as a stepwise reconfiguration, while the pathways that have not (yet) materialized may best be described as more substitution oriented transitions. This study indicates significantly larger challenges for the latter pathways.

[184] Energigas Sverige 2010, Naturgas en bro in i biogassamhället (natural gas a bridge into the biogas society). Report available at www.energigas.se

# 6 CONCLUSIONS

This analysis has been generated with the intent to deliver knowledge useful to the shaping of policy and research activities that enfold forest derived biofuels production in Sweden. To contribute to this overall aim, this project gathered information directly from actors involved in a range of forest derived forest-biofuel project initiatives. Utilising a broad range of supporting material, these views and experiences have been documented in detailed case studies and then subjected to both in-case analysis and cross case analysis through a lens based upon technology transitions literature.

Three objectives were outlined to operationalize the work. The work documented throughout this report – including the findings, analysis and discussion has delivered against each of these. The objectives of the analysis as outlined in Section 1 of this report are summarised and paraphrased here.

> **Objective 1.** Provide understanding of the positions and views among existing and potential transportation biofuel producers in areas such as competition for important market space or political support; key strategies of the forest-derived transport fuel initiatives and the petrochemical sector, and the relative importance of leading fuel-engine pathways.
>
> **Objective 2.** To describe and delineate notable differences between strategies and perceptions of need in the field and the scientific work undertaken and knowledge yielded by the research community – with the intent to identify areas where the research community can better serve forest-derived transport fuels activities.
>
> **Objective 3.** To provide recommendations to policy makers, government, industry and other actors regarding areas for improving conditions for the production of forest-derived transport fuels, with focus both upon policy-related barriers and upon other intra-industry, inter-industry or institutional barriers that may be hindering progress.

This concluding section delivers final comments regarding the content of the first objective, and then conclusions that deliver against the second and third objectives. Conclusions are supplied under headings and sub-headings below. Each sub-section heading has been phrased so as to further refine the parts of larger issues that we conclude are most important with regards this analysis.

## 6.1 COMPETITION FOR RESOURCES, STRATEGIES, AND FLEET IMPLICATIONS

In this section, conclusions are provided within three themes drawn from the research objective. Namely competition for important resources; the nature of strategies pursued in forest-derived transport fuel initiatives; and the relevance of fleet-fuel-engine systems. It is important to note that as the focus is on the relationship of fuel initiatives to each other, the focus of the term 'resources' is generally NOT directed towards raw material feedstocks competition.

### *6.1.1 Synergies and/or competition for important markets and resources*

A central conclusion of this work is that the initiatives, or portions of initiatives, that have been successful thus far have built substantially upon synergies and complementarities. The Preem-SunPine system provides numerous examples in this regard. These include *inter alia*: synergistic incorporation of Preem's HVO system within its refinery structures; in the SunPine/Preem value chain, two separate projects have been combined to complement each other (e.g. HVO/tall oil diesel refining); SunPine redefines market conditions for the tall oil by-product streams thus complementing core business areas among the ownership consortium; and HVO fuels seamlessly mesh with the existing diesel fuel infrastructure that Preem utilises within its mainstream business. While synergetic or complementary aspects were found in all cases, this particular case stands out due to the breadth and depth of 'fit' with other portions of the technical and institutional systems. Other examples of synergies include: methanol projects feeding to FAME diesel production; bio-SNG supporting mainstream natural gas business models; DME initiatives supporting new models for forestry timber fleet operation, or pulp plant operation, and more. As such it is held that the presence of a significant number of complementarities that can serve to reduce technical or financial risk have been central to success. Thus an important lesson for future efforts should be that the pursuit of cross industry and multi-faceted synergies will improve the strength of an initiative – and may be crucial to success.

A subsidiary conclusion regarding synergies/complementarities is that we find that Sweden has a suite of different forest-derived fuel platforms: (e.g. methanol, tall oil HVO, DME, and Bio-SNG) rather than a common 'forest-derived fuel' field or 'sector' (if such could be envisaged). Evidence suggests that this 'constellation' of actors do not effectively work in a synergistic fashion to further their common interests – as a more cohesive grouping might. Following directly from the theme of 'many platforms', this study has found significant evidence that initiatives compete in different ways for important resources. Here, the resources primarily under discussion are important institutional factors rather than the feedstocks for fuel production. As such, multiple platforms vying for media attention, social and political attention and support, research funding, policy sphere support, market space and so forth are the phenomena in focus.

The cases taken up in this study have delivered insights into how individual platforms or initiatives, have to some degree worked to obtain such for their own means. Yet, as studies have shown, common issues such as continuing policy instability and short-termism are those that have apparently posed the most significant barriers to initiatives moving forward.[185] While competition between platforms is natural – and very likely healthy – an apparent lack of effective work for the collective means is presumably unhealthy. Despite the existence of branch organisations such as the Swedish Bioenergy Association (Svebio) that in turn have connections to the proponent organisations, a common platform seeking to address the common issues found in this study was not observed.

Competition for physical resources was also raised as an important issue within this study but primarily as an intra-sectorial issue for the forest industries. Indeed, the expectation that this would be the case was explicitly flagged in the introduction to this work. Examples found throughout the study indicate that key forest sector actors such as Södra and Sveaskog, which have engaged deeply in transport fuel activities, contrast with the mainstream views and goals of the forest industries. There is evidence that major lobby groups representing the pulp and paper processing industries are at best ambivalent towards biofuels. Examples of reasons why included: increased competition for feedstocks, potential effects on (pulp) plant operations, and that biofuel-related activities had poten-

[185] This is not to say that project proponents are not active. To the contrary, project proponents <u>are</u> in general active in the public debate, in forming national and international collaborations with industry, and in informing policy makers. However, as noted, such activities vary across initiatives, and there is strong evidence that much work is not collective.

tial to affect the manner that the industry's transport/logistics systems operate. In short, engagement with forest-derived transport biofuels is perceived to have potential to increase industry costs. As such, it is concluded that the forest sector is indeed still partially divided regarding the engagement with forest-derived transport fuels activities, and that this apparent 'divide' in the industry likely undermines the efforts of biofuel proponents to secure support from various social and political constellations.

### *6.1.2 Key strategies pursued in forest-derived fuel initiatives*

This study concludes that the key strategies being pursued in the initiatives can be described using variations of two concepts. The first being substitution and the second being stepwise reconfiguration. For substitution, an emerging technology may (seek to) substitute the established technology with largely new system. Reconfiguration strategies on the other hand apply changes at module, or even component levels, and thus innovations gradually reconfigure the system.

The principle differences in strategies is that some require fundamental changes to large portions of the existing system – and also require changes in systems upstream, or downstream, or both. Other initiatives however, require much more modest changes, and may barely affect other items upstream and downstream. Simply put, the degree of alignment with the current regime for production, distribution and use of fuels in the transport sector varies considerably among the different cases.

The commercial size gasifiers GoBiGas Phase 2, Bio2G, and also Biorefinery Norrtorp (if directed towards biomethane), were planned to be of a size that would demand a very large increase in size of the relatively small market for vehicle gas – if the projects came to fruition. With no small portion of the market to fit within, this required a substitution strategy where significant portions of the diesel and petrol market needed to be substituted. This in turn required very considerable efforts – from the project proponent side – to grow the market for the fuel via fleet change *ex ante*. The strategy is clearly delineated in the summary statement from the E.ON case, '*we need to create the market for the gas before we build the production plant where the gas is produced'.* On the technology side, these projects are also strongly substitutional – new gasification plants are in essence substitutes for traditional petroleum fuel infrastructure.

For Domsjö Fabriker, where the intended fuel was either DME or methanol, the market situation was considerably different. For DME, a dominantly substitution strategy was also being pursued on the market side, but under quite different conditions than for the gas vehicle market. Elements of a reconfiguration strategy are also possible to a limited extent in this initiative – as LPG infrastructure, which exists in part of the country can likely be adapted. As DME is a fuel intended for heavy vehicles, or more specifically long-haul transports, a much more targeted and limited market exists. Further, some industrial markets for DME also exist. Moreover, Volvo, as an important and highly visible market actor, had been promoting this alternative fuel and has also been involved in extensive field tests of the fuel together with Chemrec/LTU Green fuels. Thus, building a fleet of the size to support production quantities, while a considerable task, can be seen as an industrial initiative rather than a business and social change process as for passenger vehicle fleets. Finally, as the number of filling stations needed to supply the fuel to this market is relatively limited, and the product readily transportable, fewer challenges existed than for bio-SNG.

Shifting focus to methanol strategies – variations of reconfiguration strategies potentially leading to larger substitution strategies are found on the market side. Thus for Domsjö Fabriker and Biorefinery Norrtorp (if methanol had been the preferred choice) as for Värmlandsmetanol, the most likely initial market option would have been as a drop-in fuel for petrol. Methanol is already approved as a drop-in fuel up to 3.0% v/v by the Fuel Quality Directive 98/70/EC[186] with its amendments in Directive 2009/30/EC[187], and the introduction into the market is not likely to pose a major obstacle. Another options open to such actors would be to supply the methanol on the market for FAME production. Both of these applications represent modular reconfiguration of a part of the other systems – requiring minor if any change to other technological system components. Notably, renewable methanol is an attractive option to increase the renewable content of FAME via replacement of methanol with fossil origin.

A substitution market strategy is also available for methanol producers – as methanol is a key emerging market as a fuel for more cleaner and climate friendly maritime transport, and this market is also served by fossil methanol. Both traditional maritime (oil) fuels and fossil methanol would be replaced. In summary, while the markets for the innovative biofuels methanol and DME are untested, the relative degree of alignment with viable markets allows for both reconfiguration and substitution strategies to be pursued. Further the larger ‘fuel consumption per unit’ and industrial nature of potential fleets likely serves to reduce market risk. The possibility to shift between methanol and DME production via a minor conversion step also serves to reduce market risk.

Shifting to the technology side however, methanol and DME pathways are strongly substitutional. They are not aligned with any conventional fuel chains in the transportation sector. Further, both types of gasifiers – low and high temperature for methane and methanol production respectively – are untested at commercial size, and are extremely capital intensive. For the pulp mill gasifiers that would replace the recovery boiler, the concept is also considered as a major technical risk for the operation of the core product line.[188]

Shifting to the case that involved the petrochemical sector; namely HVO production from crude tall oil or other types of feedstock, the study has clearly shown that strategies to incrementally develop the production, distribution and use of the fuel through co-processing with conventional diesel has been successful. The HVO case/pathway can thus be seen as an example of ‘systemic innovation through stepwise reconfiguration’ in which the project proponent has adopted modular innovations – with each new step enabling additional innovations.

This analysis sees Preem’s strategy as a combined technical and market example of stepwise and modular reconfiguration. The whole chain is part of the same market and it utilizes a distribution infrastructure that already is aligned with the core business of Preem. All parts of the conventional fuel chain are used and it is only specific modules of the fuel production system that have been

[186] DIRECTIVE 98/70/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 October 1998 relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC.

[187] DIRECTIVE 2009/30/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC.

[188] Grönkvist, S.: 2010. Specific possibilities for carbon capture in Sweden (In Swedish: Specifika förutsättningar för koldioxidavskiljning i Sverige), ÅF Foundation for Research and Development, (Ångpanneföreningens forskningsstiftelse), Report No. 09-396.
http://www.aforsk.se/sites/default/files/09-396%20Slutrapport.pdf

modified. Preem has marketed the fuel for all diesel consumers via the creation of the Evolution brand and this has also been tested for the petrol market. While the investments have been very considerable, Preem claims that the specific investments in the co-production line, building on existing plant and equipment, represent only (circa) one tenth of a comparable dedicated HVO line. This comparison is also approximately valid for the production concepts that involve gasifiers. The feedstock is not solid biomass and the strategy for the development has thus far focused on 'liquid in liquid out' use of their Gothenburg refinery. The same holds for their pending projects. While reliance on 'liquid' reconfiguration strategies may be a limitation that could pose obstacles to a future expansion, at least for the feedstock; considering all other factors in the chain from production to use, it seems like the alignment with the current regime has been an important component for the fruitful outcome – perhaps the most important. This study concludes that this is a major aspect in the explanation why this initiative is the only of commercial size project studied that has been realized commercially (albeit, two linked projects, Preem and SunPine). Another major aspect is the lower specific investment costs (that are also related to modular reconfiguration approaches).

### *6.1.3 The role of fuel-engine systems*

The preceding section has clearly outlined the role of fuel-engine-systems for initiatives such as those addressed in this work. Simply put, different substitution or reconfiguration strategies mentioned above create different engine platform and fleet requirements. Reconfiguration strategies, particularly those with drop-in fuels have many advantages, but the case for substation of specific fleets can also be made in specific situations. The situation is more challenging for the latter however.

This stated, it is important to note that Swedish heavy vehicle manufactures in particular have demonstrated the ability to produce, demonstrate (and supply to markets) engines that can run on a number of fuels. Volvo for example has manufactured gas motors since the 1990s and has also presented models that can utilise a mix of biogas och biodiesel, DME, ethanol/methanol, synthetic diesel and a mixture of hydrogen and biogas. Scania has decades long commercial experience of ethanol engines and has also launched engines designed to run on biogas as well as natural gas. Both have demonstrated the ability to supply motive power to fleets of many hundreds of vehicles. Other manufacturers have not been studied in this project, but it is reasonable to assume that the same applies.

As such, we suggest that if fuels eventuate then the engines will be there. The challenge is in growing the fleet. As discussed above, the Bio2G case is a prime example of this. Work to stimulate fleet growth prior to the construction of fuel supply infrastructure can be a daunting prospect.

## 6.2 RESEARCH GAPS: FOREST-DERIVED TRANSPORT FUELS ACTIVITIES

Regarding the second research objective, this research project has drawn upon a large body of high quality scientific work performed by the Swedish research community that has supported the development of the fuel production initiatives from the very outset. Among other things, scientific work has been performed to: develop the technologies used for fuel production; assess feedstock potentials; model key locations for fuel production sites; develop process models for synergistic combination with existing forest plants; develop fleet development scenarios based on different fuel mixes, and so forth. Further, in all cases, project proponents were found to be experienced actors with considerable scientific knowledge and well developed scientific and industry networks – and each pilot and demonstration plant studied in this project has strong links to national universities.

However, at the very outset of this report (and project) a number of inferences were made regarding knowledge gaps of importance. In paraphrased terms these were that:

- insufficient knowledge exists regarding the degree of alignment of (proposed) fuel production technology systems with incumbent industries;
- better understanding is required of the overlap of synergies (or competitive issues) between varying technology platforms;
- clearer insights were required into the preferences (or beliefs) of key 'supply chain' and 'user chain' actors regarding the future of a sector, and that
- insufficient delineation of 'trade-off areas' that the advanced transport fuels community must recognize and resolve in coming years.

We argue that substantial evidence is demonstrated in this study that confirms the relevance of these phenomena and indicates that there are unanswered questions found in each of these areas. These are areas that have not been well covered by the research to date. Moreover, the analysis and discussion section of this report provides detail regarding problematic issues that fall under each of these topic areas. One notable area not covered within this analysis is the views of the broader industrial portion of the forest industries – as distinct from the actors in the forest industries that are engaged in transport fuel initiatives – inclusion of this actor grouping will be vital within some of the work listed above. As is developed in the following two subsections, pursuit of deeper understanding of the nature of risk perceptions, and openings for alliance building via research in the areas above is an important area for such work. An immediate knowledge gap that we consider should be given priority is the pursuit of a clearer picture of the deeper nature of 'ambivalence' or 'opposition' to transportation fuels initiatives from within the forest sector. Similarly, the development of such attitudes as global market conditions for both the biofuels and the pulp and paper sectors unfold can provide important insights for all relevant stakeholders.

As such, we conclude that the points above provide an outline for an important research agenda in the short – to medium term.

## 6.3 PATHWAYS FOR ACTION

Here, it has been chosen to focus on two key audiences identified within the *f3* community; namely, the policy sphere and the forest sector actors hosting initiatives relevant to this study. We consider that action required from the research community is addressed by the sub-section delivering insights regarding knowledge gaps and research needs above.

Here it is important to stress that this study has been conducted at a conceptual level and at an applied level.[189] Conceptual issues relate to research that addresses “What should we think?” Applied issues relate to “What must we understand before we know what we should do?” This project has not applied so called ‘practical’ questions of “What should we do?” In light of this framing, we have also sought to pose our closing comments regarding pathways for action (we see these more as quasi-recommendations) in general terms that direct attention to where and why target audiences can direct efforts if they wish to improve conditions for the production of forest-derived transport fuels in Sweden.

Pursuant to the content and context of this study, the focus is upon (a) policy-related barriers and (b) intra-industry, inter-industry or institutional barriers that may be hindering progress. This study has focused a significant proportion of its content upon delineation of knowledge gaps, thus these recommendations principally focus on such.

### *6.3.1 Policy sphere*

Before any future policy instruments preferred by initiative proponents are mentioned, or any policy-related advice is proffered, we deem it necessary to recap a number of items regarding the present ‘policy environment’ compared to the context when several of the large projects were planned.

A first issue is that before the unsuccessful international climate negotiations in Copenhagen in late 2009, many believed that a truly international binding climate agreement was a possibility. We consider these beliefs flavoured the discourse about the mitigation of climate change at that time. There was also a functioning carbon market through the EU ETS that even affected the price for greenhouse gas emissions outside Europe to a degree through the connection to the clean development mechanism (CDM). As such, we also hold that there was broader belief that the climate policies would become stronger. With Sweden as a front-runner in this field, it is feasible that this in turn bolstered expectations that the Swedish policy framework working in the direction to promote climate friendly technologies would become firmer with time.

In this light, it is relevant to consider general expectations regarding a strengthening of policy instruments affecting investment conditions for plants for forest-derived transportation fuels. In hindsight it can be observed that with the notable exception of the launch of the EU sustainability criteria, the general policy framework has not actually changed greatly during the last decade. The levels of the tax alleviations have changed somewhat over time, as have parameters such as the share of a blend-in biofuel that have been eligible for tax alleviations or exemptions, but not more. Sweden has never been able to provide guarantees that the tax alleviations and exemptions will last for more than a few years at a time, as this decision has outside the control of the Swedish government for the whole period. Sweden has had to apply to the EU every few years to be able to continue with the tax alleviations and exemptions. The risk that the taxes will change within a few years has thus represented a sort of *status quo* condition as long as the tax alleviations and exemptions have existed. Investment support schemes have also shifted, but this more on an individual basis. In con-

[189] Turabian, K. (2013). *A Manual for Writers of Research Papers, Theses, and Dissertations:* (8th ed.). Chicago and London: The University of Chicago Press.

trast to all of these factors, one important factor has changed considerably: the oil price. This has been an issue that affects all investments in fuels for the transportation sector.

A third key issue for consideration is that policy instruments should also clearly reflect the aim or aims of the underlying policy outcomes that they seek to achieve. If only the measurable Swedish climate goals and specific goals for renewables in the Swedish transport sector are considered, the current policy instruments seem to perform well, as the share of biofuels is increasing rapidly. Important for this study however, is that these two goal areas are not necessarily directly aligned with issues also central to forest-derived fuel initiatives. If other policy outcomes are of priority, such as the strengthening of the Swedish biofuel industry, stimulation of rural development, improved trade balances, innovation and domestic technology development, and the possibilities for greentech exports, then current policy instruments do not appear as successful.

Considering all the above, and pursuant to the evidence gathered in this research, we proffer a number of general conclusions regarding policy frameworks enfolding the development of domestic forest-derived biofuel production in Sweden.

- There is a clear mood of dissatisfaction among the industrial actors engaged in fuel initiatives. This mood is judged to span from ‘considerable disappointment’ to ‘a significant betrayal of trust’. Be these stances reasonable given the policy circumstances, or be they not, these views both exist and are publicly disseminated. In general, we judge that the level of trust that such actors have in the Swedish and EU political processes is now very low – lower than in the past. Moreover, we judge that the confidence that industrial actors have regarding the potential for the Swedish policy-makers to provide them support in the future is severely eroded.

- Following on from the themes of eroded confidence, trust, and faith in policy support, listed above, we take the view that these factors have already and will continue to affect investment hurdle rates. We judge that investment hurdles are now significantly higher than they were in past years, both because of escalated perceptions of political risk exposure and because of the current low oil price levels – and modest and uncertain oil price rise projections.

- The outcome of the these arguments is that if Sweden really wishes to see such fuel production initiatives in place, more stable long-term investment conditions will have to be provided via policy instruments – perhaps even more long term and more stable than have been discussed in past years. At this juncture, this points clearly in the direction of moving from tax exemptions and towards quota obligations, or instruments directed towards certain investments in production capacity, such as the price premium model. A general time horizon for the investments addressed in this work is predictability over ten to twelve years.

- This study also observes that the Swedish government has sought to remain technology neutral, but evidence is plentiful that this is very hard to achieve in reality if a richer set of socio-economic and environmental outcomes (as discussed above) are desired. We see that this strategy should conceivably be abandoned if such aims are desired. If the one of the key outcomes sought is to develop domestic biofuel processing industries that utilise domestic forest feedstock, then general policy instruments should be combined with more specific policy instruments on the market side. This could for example be policy instruments directed towards the development of the markets for vehicle gas or methanol.

- If the vision is to keep the current distributions infrastructure and vehicle fleet relatively intact while still striving towards a transport sector that is independent of fossil fuels, more directed support towards developing the industry for the production of feedstock that is possible to use within Sweden's existing refinery infrastructure is required. This and other studies have revealed that single pilot or demonstration plants cannot automatically generate commercial size production units. If forthcoming initiatives such as the Renfuel project, to utilise lignin, are to be developed to serve the refineries with large amounts of bio-oil feedstock, a clear strategy supported by directed policy instruments will be required.

### *6.3.2 Forest-derived fuel proponents*

In Section 5.4 and in Section 6.1.1 above, it was concluded that the forest sector is partially divided regarding the value of engagement with forest-derived transport fuels activities. Some parts of the industry believe it is a valuable addition to the forest industries portfolio, some believe it is a risk. If this were correct then such a 'divide' in the industry would undermine the efforts of transportation biofuel proponents – both inside the forest sector, and from outside the forest sector – to secure support from various social and political constellations. Indeed, we find that current lobby efforts representing parts of the European forest industries (at the EU level for example) likely even work against fuel initiatives.

If the forest-derived transportation fuels industry is truly a valuable addition to the forest sector portfolio, then it is apparent that this case needs to be made in a more convincing case to a broader suite of social and political stakeholders. As there is evidence of (at least some) intra-sectorial opposition, then presumably efforts to build alliances and reduce perceptions of risk also need to be invested within the sector. The more unified the forest sector appears to external stakeholders, then the higher the legitimacy of messages from fuel initiative proponents would presumably also be. Increased efforts to pursue such alliances and unity by the forest sector thus appear to be a requirement.

Pursuit of deeper understanding of the nature of risk perceptions, and openings for alliance building via research within areas outlined in Section 6.2 above, would logically provide an improved foundation for such work. An immediate knowledge gap that we consider should be given priority is the pursuit of a clearer picture of the 'ambivalence' or 'opposition' to transportation fuels initiatives from within the forest sector.

In Section 6.1.1 above, it was concluded that the suite of different forest-derived fuel platforms fails to effectively further their common interests as a more cohesive grouping might – this despite the existence and active engagement of branch organisations representing biofuel interests in the country. In that discussion the attention of media, social and political circle and policy actors were in focus – and this analysis indicates that these are indeed central areas for work. As issues such as continuing policy instability and short-termism are those that have apparently posed the most significant barriers to initiatives moving forward, then again the more unified the "forest-derived fuel sector" appears to external stakeholders, then the higher the legitimacy of messages from fuel initiative proponents would also be. Increased efforts to pursue alliances and unity among forest-derived fuel initiatives thus appear worthy of deeper consideration.

## 6.4 CONCLUDING COMMENTS

This study has uncovered a rich tapestry of phenomena and views within the forest-derived fuels field. While evidence of significant advances in knowledge and experience for advanced fuel production systems has been found, the fact of the matter is that a number of initiatives where very large resources have been invested have not moved forward. There is a clear sense of disappointment and frustration present among many actors in the field. These are principally related to 'shifting, changing and short-term' policy conditions, and difficult institutional developments as discussed earlier in this report (e.g. particularly Section 6.3.1). However, on a more positive note most informants to this study were reluctant to rule out the possibility that projects will be realised at some stage in the mid-term.

On the positive side, this work has also documented significant progress forward by some (i.e. Preem and Sunpine). Progress has been achieved where apparently stepwise and modular reconfiguration strategies have been pursued – this is where we perceive the highest likelihood of success for future developments. We judge that successful projects have achieved transition through reconfiguration in a stepwise process. Here, one modular innovation within the biofuel value chain is seen to replace another, without substantially changing the rest of the system. The success stories in the Swedish system have been able to develop within the existing difficult conditions as they have been formulated to more or less match the fossil (regime) infrastructure – to then gradually change it. We conclude also that pursuit of such strategies also show promise for more radical change should the institutional and political constraints detailed within this analysis ease.

# 7 REFERENCES / ENDNOTES

In order to support the reader, this report has been referenced with footnotes and endnotes. All footnotes have been replicated here as 'end-notes'. This in intended to provide the reader with a coherent overview of the full suite of sources utilised.


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114. USDA, 2015. EU Biofuels Annual 2015. GAIN Number NL5028. http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_The%20Hague_EU-28_7-15-2015.pdf

115. Swedish Environmental Protection Agency [Naturvårdsverket], 2013. Climate investment programme Klimp 2003-2012, Final Report, Accounts to the government January 2013, Report

6517. [Klimatinvesteringsprogrammen, Klimp 2003-2012, Slutrapport, Redovisning till regeringen januari 2013, Report 6517]. ISBN 978-91-620-6517-1, ISSN 0282-7298.

116. Swedish Environmental Protection Agency [Naturvårdsverket], 2008. Local investment programme is finished, Experiences and results from ten years of environmental work [Lokala invetseringsprogram i mål, Erfarenheter och resultat av tio års miljöarbete]. ISBN: 978-91-620-8338-0.

117. Hansson, J and Grahn, M., 2013. Possibilities for renewable transportation fuels in Sweden – Update and extension of the study Possibilities for renewable transportation fuels in Sweden 2030 by Grahn and Hansson, 2010 [Utsikt för förnybara drivmedel i Sverige – Uppdatering och utvidgning av studien Möjligheter för förnybara drivmedel i Sverige till år 2030 av Grahn och Hansson, 2010]. IVL Report B2083.

118. Swedish Environmental Protection Agency [Naturvårdsverket], 2016. Climate step – local climate investments [Klimatklivet – lokala klimatinvesteringar]. http://www.naturvardsverket.se/Stod-i-miljoarbetet/Bidrag/Lokala-klimatinvesteringar/ (accessed 21 April 2016)

119. Swedish Code of Statutes, 2016. Law (2005:1248) about the duty to provide renewable transport fuels [Lag (2005:1248) om skyldighet att tillhandahålla förnybara drivmedel]. https://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/Lag-20051248-om-skyldighet-_sfs-2005-1248/https://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/sfs_sfs-1994-1776/ (accessed 21 April 2016)

120. Parliament of Sweden, 2009. Pump law – follow-up of the law about the duty to provide renewable transport fuels, Summary of follow-up report 2009/10:RFR7 [Pumplagen – Uppföljning av lagen om skyldighet att tillhandahålla förnybara drivmedel, Sammanfattning av uppföljningsrapport 2009/10:RFR7].

121. Parliament of Sweden, 2009. Pump law – follow-up of the law about the duty to provide renewable transport fuels, Summary of follow-up report 2009/10:RFR7 [Pumplagen – Uppföljning av lagen om skyldighet att tillhandahålla förnybara drivmedel, Sammanfattning av uppföljningsrapport 2009/10:RFR7].

122. Law 2014:1368 regarding changes in the law 2013:984 regarding the quota obligation for biofuels [Lag (2014:1368) om ändring i lagen (2013:984) om kvotplikt för biodrivmedel]

123. Lönnqvist, T., Grönkvist, S., Sandberg, T. (2015) How can forest-derived methane complement biogas from anaerobic digestion in the Swedish transport sector? Report No 2015:11, *f3* The Swedish Knowledge Centre for Renewable Transportation Fuels, Sweden.

124. Lönnqvist, T., Grönkvist, S., Sandberg, T. (2015) How can forest-derived methane complement biogas from anaerobic digestion in the Swedish transport sector? Report No 2015:11, *f3* The Swedish Knowledge Centre for Renewable Transportation Fuels, Sweden.

125. Swedish Transport Agency [Transportsyrelsen], 2016. Super environmental car premium [Supermiljöbilspremie]. https://www.transportstyrelsen.se/sv/kontakta-oss/Vanliga-fragor-till-Transportstyrelsen/Supermiljobilspremie/ (accessed 22 April 2016)

126. Hansson, J and Grahn, M., 2013. Possibilities for renewable transportation fuels in Sweden – Update and extension of the study Possibilities for renewable transportation fuels in Sweden 2030 by Grahn and Hansson, 2010 [Utsikt för förnybara drivmedel i Sverige – Uppdatering och

utvidgning av studien Möjligheter för förnybara drivmedel i Sverige till år 2030 av Grahn och Hansson, 2010]. IVL Report B2083.

127. *Ibid*

128. See also http://www.indexmundi.com/commodities/?commodity=crude-oil&months=60

129. Interview with Björn Fredriksson Möller, (P. Peck, Y. Voytenko) 29 September 2015.

130. Indeed, in the IEA:s World Energy Oultlook från 2008 it was even quoted “The era of cheap oil is over”. See p3. at http://www.worldenergyoutlook.org/media/weowebsite/2008-1994/weo2008.pdf

131. Nominal value is not adjusted for inflation, and so increases in nominal value reflect the effect of inflation. Real value on the other hand, presents a value that is relative to other commodities or goods. It is adjusted for inflation, which enables comparison of quantities as if prices had not changed. Changes in real terms therefore exclude the effect of inflation. ref: R. O'Donnell (1987). "real and nominal quantities. *The New Palgrave: A Dictionary of Economics*, v. 4, pp. 97–98.

132. The all time peak monthly price however occurred in 2008 just before the GFC caused the market to crash. Monthly trends can be seen at http://www.indexmundi.com/commodities/?commodity=crude-oil&months=120.

133. While the World Bank expect slightly higher prices for energy commodities over the course of the year as markets rebalance after a period of oversupply, they also indicate that it is feasible that energy prices could fall again if OPEC increases production significantly, and if other non-OPEC production does not fall as fast as expected. See: http://www.worldbank.org/en/news/press-release/2016/04/26/world-bank-raises-2016-oil-price-forecast-revises-down-agriculture-price-projections

134. As just one example of how far from reality estimates can be, oil price forecasts for 2015 utilised by the EU when considering the extension of Swedish tax exemptions used estimate of between 50 and 75 USD/bbl for 2015 and 2016 65 and 80 USD/bbl for 2016 See: (Kommissionens beslut, 14.12.2015, Skattebefrielser och skattenedsättningar för flytande biodrivmedel. European Commission C (2015) 9344 final

135. http://knoema.com/yxptpab/crude-oil-price-forecast-long-term-2016-to-2025-data-and-charts

136. National Geographic, March 2016, *In the Arctic’s Cold Rush, There Are No Easy Profits*.See: http://www.nationalgeographic.com/magazine/2016/03/new-arctic-thawing-rapidly-circle-work-oil/

137. World Bank Commodity Price Data (The Pink Sheet) annual prices, Updated on April 04, 2016 - http://databank.worldbank.org/data/databases/commodity-price-data with forecasts for oil fro m World Bank Commodity Price Forecast Data, January 2016 and forecasts for gas from EIU Economic Commodity Forecast, Dec. 2015.

138. See: http://www.eea.europa.eu/data-and-maps/indicators/fuel-prices-and-taxes/assessment-§3

139. Definitions: a) ‘All petrol’ is a consumption-weighted average price of both leaded and unleaded fuel, corrected using energy-content to the equivalent amount of unleaded petrol. b) ‘All fuel, unleaded petrol equivalent’ is a consumption-weighted average price of unleaded, leaded petrol and diesel, corrected using energy content to the equivalent amount of unleaded petrol. c) ‘Nominal’ is the price with no adjustment for inflation. d) ‘Real’ is the price corrected for inflation, using 2005 as the baseline year. e) ‘Average, all fuel, unleaded petrol equivalent (real, weighted by consumption)’

is the consumption-weighted average of the ‘All fuel, unleaded petrol equivalent (real)’ line across the full time series.

140. All road transport fuels, expressed as the equivalent consumption in unleaded petrol, corrected for inflation to 2005 prices.

141. http://www.globalpetrolprices.com/gasoline_prices/Europe/

142. See p3. at http://www.worldenergyoutlook.org/media/weowebsite/2008-1994/weo2008.pdf

143. Largely inspired by work by Aldrich, H. E., & Fiol, M. C. (1994). Fools Rush in? The Institutional Context of Industry Creation, 645–670; Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis., 407–439; Bergek, A., Jacobsson, S., & Sandén, B. A. (2008). “Legitimation” and “development of positive externalities”: two key processes in the formation phase of technological innovation systems, 575–593, and even Bower, J. L., & Christensen, C. M. (1995). Disruptive technologies: Catching the wave, 43–54.

144. See: Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions*, 1(1), 24–40. http://doi.org/DOI:10.1016/j.eist.2011.02.002; Geels, Frank W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. Research Policy, 31(8-9), 1257–1274. http://doi.org/DOI:10.1016/S0048-7333(02)00062-8; Geels, Frank W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, 33(6-7), 897–920. http://doi.org/DOI:10.1016/j.respol.2004.01.015, and Schot, J. W., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management*, 20(5), 537–554.

145. Markard, J., Raven, R. and Truffer, B., 2012. *Sustainability transitions*: An emerging field of research and its prospects. *Research Policy*, *41*(6), pp.955-967.

146. See Geels and Schot & Geels as cited above.

147. See for example items addressed by footnote referencing Aldrich & Fiol, Bergek *et al*, etc. above.

148. See work such as the following for an overview of this literature: Hoogma, R., Kemp, R., Schot, J. W., & Truffer, B. T. (2002). Experimenting for sustainable transport: the approach of strategic niche management. Spon Press, and Kemp, R., Schot, J. W., & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. Technology Analysis and Strategic Management, 10(2), 175–196.

149. See for example: Smith, A., & Raven, R. (2012). What is protective space? Reconsidering niches in transitions to sustainability. *Research policy*, *41*(6), 1025-1036 as an example of work that is directly applicable in the context of this study – and has been used to support the analysis.

150. Peck, P.C., Grönkvist, S., Hansson, J., Voytenko, Y., Lönnqvist, T., 2015. *Investigating institutional constraints on the production of forest-derived transport biofuels in Sweden: A study design.* In proceedings of the European Biomass Conference and Exhibition (EUBCE) 2015, Vienna, Austria.

151. Geels, F.W. & Schot, J., 2007. Typology of sociotechnical transition pathways. Research Policy, 36(3), pp.399–417.

152. Geels, Frank W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8-9), 1257–1274. http://doi.org/DOI:10.1016/S0048-7333(02)00062-8

153. Berkers, E. & Geels, F.W., 2011. System Innovation through Stepwise Reconfiguration: The Case of Technological Transitions in Dutch Greenhouse Horticulture (1930–1980). Technology Analysis & Strategic Management, 23(3), pp.227–247. Available at: http://www.tandfonline.com/doi/abs/10.1080/09537325.2011.550392.

154. *Ibid.*

155. Geels, F.W. & Schot, J., 2007. Typology of sociotechnical transition pathways. Research Policy, 36(3), pp.399–417.

156. In the project proposal this was described as ‘hybrid’ (internal/external).

157. In spite of this case study being considered important, the process to arrange interviews as the key information pathway failed after a last minute cancellation by the company. As minimal information is available in the public domain for the iniative, this case study was canelled.

158. See: Palys, T. (2008). *The Sage Encyclopedia of Qualitative Research Methods*. (L. M. Given, Ed.) (Vol. 2). Thousand Oaks, CA: Sage.

159. Peck, P.C., Grönkvist, S., Hansson, J., Voytenko, Y., Lönnqvist, T., 2015. *Investigating institutional constraints on the production of forest-derived transport biofuels in Sweden: A study design.* In proceedings of the European Biomass Conference and Exhibition (EUBCE) 2015, Vienna, Austria.

160. Note however, that the plant was commissioned on wood pellets. It now must go through a new commissioning phase on wood chip fuels – and conceivably even a third commissioning phase on forest slash (branches and tops).

161. *Bio2G – A full-scale reference plant in Sweden for production of bio-SNG (biomethane) based on thermal gasification of biomass*, Björn Fredriksson Möller, Anders Molin, Krister Ståhl E.ON Gasification Development. The International Conference of Thermochemical Conversion Science, 2013.

162. *Ibid.*

163. Interview: Tomas Lönnqvist (KTH) with Björn F. Möller (E.ON) 18 Nov. 2015; Interview with Björn Fredriksson Möller, (P. Peck, Y. Voytenko) 29 September 2015.

164. The company describes its key activities as the development and commercialisation of projects wtihin cellulose and biotechnology areas, and energy/management consultancy.

165. SPBI, 2016. Press release: Renewable transportation fuels in Sweden increased to 14.7% in 2015 [Förnybara drivmedel i Sverige 2015 ökade till 14,7 %], 16 March 2016. http://spbi.se/blog/2016/03/16/fornybara-drivmedel-i-sverige-2015-okade-till-147/ (accessed 28 April 2016)

166. See more at: http://www.volvogroup.com/group/sweden/sv-se/sustainability/envdev/alt_drivelines/gas_engines/Pages/gas_engines.aspx#sthash.wd6W4R9U.dpuf

167. http://miljonytta.se/branscher/fordonsindustrin/bussar-och-lastbilar-miljoanpassas-med-ny-teknik-och-ratt-korsatt/

168. 22 September 2010 http://www.scania.com/group/en/new-gas-engines-for-trucks-and-buses-diesel-like-performance-and-modular-design/

169. Note that the status of LTU Green Fuels has changed during the analysis made in this project; a successful pilot plant has delivered, but a lack of funding does not allow for further experimentation.

170. * Officially, project proponents have not cancelled this project. Nor have they deemed it to be indefinitely on hold.

171. http://www.pt.se/nyheter/pitea/ltu-green-fuels-lagger-ner-9987917.aspx

172. Hellsmark, H., Mossberg, J., Söderholm, P., & Frishammar, J. (Forthcoming). Innovation System *Strengths and Weaknesses in Progressing Sustainable Technology: The Case of Swedish Biorefinery Development. Under review in Journal of Cleaner Production.*)

173. *Swedish Energy Agency, 2014. Teknologiska innovationssystem inom energiområdet. ER 2014:23.*

174. Göteborg Energi, 2016. Decision about GoBiGas in The city Council of Gotherburg [Beslut om GoBiGas i Göteborgs kommunfullmäktige]. http://GoBiGas.goteborgenergi.se/Svensk_version/Nyheter/Beslut_om_GoBiGas_i_Goteborgs_kommunfullmaktige

175. See discussion in Sluka, C., & Peck, P. C. (2015). Stakeholder dynamics in the forest energy sector: key issues to manage and ways forward. Biofuels, Bioproducts and Biorefining, 9(1). Volume 9, Issue 1, pages 51–71, January/February 2015. DOI: 10.1002/bbb.1501

176. See material referenced at the European Commission Research and Innovation web page on the bioeconomy http://ec.europa.eu/research/bioeconomy/index.cfm?pg=policy for an introduction.

177. As such, policy was viewed as a internal/external factor rather than an external factor.

178. As presented in Section 2.4 of the report, forecasts from bodies such as the World Bank, the EIU Economic Commodity Forecasting group, and others present projections for global average oil price in the range above US$40/bbl and below US$70/bbl in the coming years. Such forecasts have however, in the past, shown to be unable to capture the dynamics of oil prices. This analysis takes the position that there is no reason to expect that they shall be more reliable in the future than they have been in the past.

179. The IEA-AMF reports that a vehicle market of 13 million tonnes/annum exists in China. See http://www.iea-amf.org/content/fuel_information/dme

180. Therefore refuelling and storage requirements of these fuels are close to each other. In principle, transport and distribution of DME could use the existing LPG infrastructure with some modifications to the pumps, seals and gaskets. New infrastructure for DME would be needed in the regions where the LPG infrastructure does not exist. See: Semelsberger, T.A., Borup, R.L. and Greene H.L. (2006) Dimethyl ether (DME) as an alternative fuel. Journal of Power Sources 156 (2006) 497–511.

181. Personal observation and discussions, Philip Peck, September 2015; site visit to Svevia plant. See also https://www.svevia.se/stat--kommun/startsida---stat--kommun/dina-behov/asfalt--belaggning/svevias-asfaltverk.html

182. Geels, F.W. & Schot, J., 2007. Typology of sociotechnical transition pathways. Research Policy, 36(3), pp.399–417.

183. Geels, F.W. & Schot, J., 2007. Typology of sociotechnical transition pathways. Research Policy, 36(3), pp.399–417.

184. Energigas Sverige 2010, Naturgas en bro in i biogassamhället (natural gas a bridge into the biogas society). Report available at www.energigas.se

185. This is not to say that project proponents are not active. To the contrary, project proponents are in general active in the public debate, in forming national and international collaborations with industry, and in informing policy makers. However, as noted, such activities vary across initiatives, and there is strong evidence that much work is not collective.

186. DIRECTIVE 98/70/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 October 1998 relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC

187. DIRECTIVE 2009/30/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC.

188. Grönkvist, S.: 2010. Specific possibilities for carbon capture in Sweden (In Swedish: Specifika förutsättningar för koldioxidavskiljning i Sverige), ÅF Foundation for Research and Development, (Ångpanneföreningens forskningsstiftelse), Report No. 09-396. http://www.aforsk.se/sites/default/files/09-396%20Slutrapport.pdf

189. Turabian, K. (2013). *A Manual for Writers of Research Papers, Theses, and Dissertations:* (8th ed.). Chicago and London: The University of Chicago Press.

190. f3 (the Swedish Knowledge Centre for Renewable Transportation Fuels) is a networking organization, which focuses on development of environmentally, economically and socially sustainable renewable fuels. The *f3* centre is financed jointly by the centre partners, the Swedish Energy Agency and the region of Västra Götaland. *f3* also receives funding from Vinnova (Sweden's innovation agency) as a Swedish advocacy platform towards Horizon 2020.

191. Peck, P.C., Grönkvist, S., Hansson, J., Voytenko, Y., Lönnqvist, T., 2015. *Investigating institutional constraints on the production of forest-derived transport biofuels in Sweden: A study design.* In proceedings of the European Biomass Conference and Exhibition (EUBCE) 2015, Vienna, Austria.

# 8 APPENDICES

## 8.1 OUTREACH OF PROJECT

In addition to the f3-reports part A and B, the project has delivered the following publications:

Peck, P.C., Grönkvist, S., Hansson, J., Voytenko, Y., Lönnqvist, T., 2015. Investigating institutional constraints on the production of forest-derived transport biofuels in Sweden: A study design. In proceedings of the European Biomass Conference and Exhibition (EUBCE) 2015, Vienna, Austria.

Peck, P.C., Grönkvist, S., Hansson, J., Voytenko, Y., Lönnqvist, T., 2015. *Investigating institutional constraints on the production of forest-derived transport biofuels in Sweden*. Manuscript to be submitted for publication in scientific journal during 2016.

Börjesson, P., Hansson, J., Berndes, G., 2016. Future demand for forest-based biomass for energy purposes in Sweden. Submitted for publication in *Forest Ecology and management*.

The project was presented at the following conferences/seminars:

- 23rd European Biomass Conference and Exhibition (EUBCE) June, 2015, Vienna, Austria.
- Programkonferens samverkansprogrammet Förnybara drivmedel och system, February, 2016, Göteborg, Sweden.
- 24th European Biomass Conference and Exhibition (EUBCE) June, 2016, Amsterdam, the Netherlands.

## 8.2 RESEARCH INTERACTIONS/INFORMANTS

The table below provides an Overview of interviews and other research interactions.

| Organization | Name, role | Communication channel, date | Input to study |
|---|---|---|---|
| Göteborgs Energi | Lars Holmquist, Business Strategic Planner; Ingemar Gunnarsson, Development Engineer; Eric Zinn, Biogas Products Coordinator | In person, 2015-10-06; Email 2016-04-26 | Case study interview: GoBiGas; Written input to webinar |
| Sekab | Göran Eriksson, Former President | Via telephone, 2015-09-22 | Case study interview: Biorefinery Norrtorp |
| VärmlandsMetanol | Björn Gillberg, President | Via telephone, 2015-10-08 | Case study interview |
| Chemrec | Jonas Rudberg, former CEO; Max Jönsson CEO | In person, September 2015 | Case study interview |
| E.ON | Björn Fredriksson Möller, Project Manager | In person, 2015-9-25; Webinar 2016-04-25 | Case study interview: Bio2G; Webinar participation |
| Luleå University of Technology | Ingvar Landälv, Project Manager (former VP Technology at Chemrec) | Via telephone, January 2016 | Case study interview: LTU Green fuels |
| Preem | Sören Eriksson, product Developer; Åsa Håkansson, business developer | In person, 2015-12-10 | Case study interview |
| RenFuel AB | Sven Löchen, CEO | In person, March 2016 | Case study interview |
| Södra/SunPine | Gustav Tibblin (Chairman of the board of SunPine) | Via telephone, October 2015, Webinar 2016-04-25 | Case study interview: SunPine; Webinar participation |
| 2030 secretariat, Equest AB | Jacob Lagercrantz, Co-founder, Managing Director | Webinar 2016-04-25 | Webinar participation |
| LTU | Elisabeth Wetterlund, Associate Senior Lecturer | Webinar 2016-04-25 | Webinar participation |
| Chalmers | Hans Hellmark, Senior Researcher | Email 2016-04-22 | Written input to webinar |
| SEA, Chalmers | Tomas Kåberger, Former General Director, Swedish Energy Agency, Professor | Telephone, 2016-04-25 | Input to webinar (telephone mini-interview) |
| LTU | Patrik Söderholm, Professor | Email 2016-04-26 | Written input to webinar |
| Lantmännen Agroetanol | Andreas Gundberg, Technology Manager | Telephone, 2016-04-26 | Input to webinar (telephone mini-interview) |
| Volvo Trucks | Lars Mårtensson | In person, 2015-03-03 | Case study interview |
| Scania AB | Eva Iverfeldt | In person, 2015-03-09 | Case study interview |
| Scania AB | Jonas Strömberg | In persons, 2015-03-09 | Case study interview |

## 8.3 WEB-BASED (SURVEY) GUIDE & INTERVIEW GUIDE

The following document was utilised to support interviews. This document guided the process, but was also distributed to participants in advance of interviews. A similar document was available online for informants to fill out.

### Enkät inför intervju: svenska drivmedelsanläggningar (skogsråvara)

### Page 1: Syfte med enkäten

**Syftet med enkät och intervju: Att undersöka förutsättningarna för drivmedel från skogsråvara i Sverige och skapa underlag för utformning av styrmedel.**

**Enkäten samlar in bakgrundsinformation inför intervjun. Svar kan lämnas i skriftlig form innan intervju eller i muntlig form under intervju. Om svaren lämnas i muntlig form reserverar vi mer tid för intervjun.**

**Varför ska ni svara på enkäten? Huvudfinansiärer för forskningsprojektet är Energimyndigheten och Svenskt kunskapscentrum för förnybara drivmedel (f3) från vilka information når en bred krets av svenska beslutsfattare med anknytning till produktion och användning av förnybara drivmedel i Sverige. Genom att bidra med er organisations syn och specifika behov kan ni synliggöra dessa och i förlängningen även komma att påverka utformningen av styrmedel som berör drivmedelsproduktion baserad på skogsråvara.**

**Medverkande: Enkäten riktas till befintliga, planerade och nedlagda anläggningar som bedömts som centrala för en utveckling mot skogsbaserade drivmedel i Sverige. Enkäten utförs av KTH (Avdelningen för energiprocesser) i samarbete med Lunds universitet (Internationella miljöinstitutet) och IVL (Enheten Klimat och hållbara samhällsystem). Enkäten genomförs inom ramen för två forskningsprojekt: ”Analys av systembarriärer för produktion av skogsbaserade drivmedel” samt ”Hur kan metan från skogsbaserad biomassa komplettera metan från anaerob rötning som transportbränsle i Sverige?”. Resultaten kommer i första hand att sammanfattas i en lättillgänglig f3-rapport, men även att presenteras i andra sammanhang där beslutsfattare med anknytning till svensk biodrivmedelsproduktion nås.**

**Kontakt och information**

förnamn ______________________

efternamn ______________________

adress ______________________

företag/organisation ______________________

stad ______________________

telefon (arbete) __________

epost __________

## Page 2: Basdata om anläggningen

**Vänligen ifyll kolumn 1 (information från företag/organisation)**

| | **Information från företag/organisation** | **Ytterligare information (intervju eller uppföljning)** |
|---|---|---|
| Investeringens storlek | – | – |
| Ev. investeringsstöd (hur mycket och från vem) | – | – |
| Ev. driftsstöd (hur mycket och från vem) | – | – |
| Planerad produktionskapacitet, GWh drivmedel (LHV)/år | – | – |
| Nuvarande produktionskapacitet, GWh drivmedel (LHV)/år | – | – |
| Planerad råvaruåtgång, GWh råvara (LHV)/år | – | – |
| Nuvarande råvaruåtgång, GWh råvara (LHV)/år | – | – |

Kommentarsfält:

## Page 3: Verksamhetens inriktning och strategiska beslut

**Vänligen ifyll kolumn 1 (information från företag/organisation)**

| | **Information från företag/organisation** | **Ytterligare information (intervju eller uppföljning)** |
|---|---|---|
| Vem/vilken part var initiativtagare för anläggningen? | – | – |
| Vem/vilken part tog beslutet om investeringen? | – | – |
| Grundade sig investeringsbeslutet på några specifika omständigheter? | – | – |

| | | |
|---|---|---|
| Har några specifika omständigheter bidragit till att minska den finansiella eller tekniska risken? | _ | _ |
| Planeras en utbyggnad eller ytterligare en anläggning av samma typ? | _ | _ |
| Nuvarande råvaruåtgång, GWh råvara (LHV)/år | _ | _ |
| Kommentarsfält: | | |

## 8.4 ONLINE SURVEY DOCUMENT

**Intervju: svenska drivmedelsanläggningar (skogsråvara)**

**Page 1: Syfte med enkäten**

Syftet med intervjuer: Att undersöka förutsättningarna för drivmedel från skogsråvara i Sverige och skapa underlag för utformning av styrmedel.

Varför ska ni delta i intervjun? Huvudfinansiärer för forskningsprojektet är Energimyndigheten och Svenskt kunskapscentrum för förnybara drivmedel (f3) från vilka information når en bred krets av svenska beslutsfattare med anknytning till produktion och användning av förnybara drivmedel i Sverige. Genom att bidra med er organisations syn och specifika behov kan ni synliggöra dessa och i förlängningen även komma att påverka utformningen av styrmedel som berör drivmedelsproduktion baserad på skogsråvara.

Medverkande: Intervjuerna vänder sig till befintliga, planerade och nedlagda anläggningar som bedömts som centrala för en utveckling mot skogsbaserade drivmedel i Sverige. Intervjustudien utförs av Lunds universitet (Internationella miljöinstitutet) i samarbete med KTH (Avdelningen för energiprocesser) och IVL (Enheten Klimat och hållbara samhällsystem).

Intervjustudien genomförs inom ramen för två forskningsprojekt: *”Analys av systembarriärer för produktion av skogsbaserade drivmedel”* samt *”Hur kan metan från skogsbaserad biomassa komplettera metan från anaerob rötning som transportbränsle i Sverige?”*. Resultaten kommer i första hand att sammanfattas i en lättillgänglig f3-rapport, men även att presenteras i andra sammanhang där beslutsfattare med anknytning till svensk biodrivmedelsproduktion nås

**1.** Kontakt och information

förnamn

efternamn

adress

företag/organisation

stad

telefon (arbete)

epost

**Page 2: Basdata och verksamhetens inriktning och strategiska beslut**

**2.** Har du redan lämnat FULLSTÄNDIGA uppgifter (till KTH, IIIEE eller IVL) för detta f3-projekt om: BASDATA för anläggningen, och MOTIVERING för anläggningen? Om Ni väljer NEJ, då kan Ni lägga till ytterligare uppgifter nedan. Annars gå vidare till sidan 3.

O Yes

O No

Additional Comments

**3.** Vänligen fyll i information från företag/organisation (om inte pre-intervju enkät har ifyllts)

Investeringens storlek

Ev. investeringsstöd (hur mycket och från vem)

Ev. driftsstöd (hur mycket och från vem)

Planerad produktionskapacitet, GWh drivmedel (LHV)/år

Nuvarande produktionskapacitet, GWh drivmedel (LHV)/år

Planerad råvaruåtgång, GWh råvara (LHV)/år

Nuvarande råvaruåtgång, GWh råvara (LHV)/år

**5. Kommentarsfält: Basdata/Motivering för anläggningen:**

**Page 3: Beslutsprocess: Drivmedel**

**6**. Vilka faktorer har påverkat er beslutsprocess kring det drivmedel (t.ex. metan,metanol eller DME) ni valt att producera?

| | **5 Mycket starkt** | **4 Starkt** | **3 Neutral/i viss mån** | **2 Svagt** | **1 Mycket litet eller inget** | **vet ej** |
|---|---|---|---|---|---|---|
| Förväntad marknadsutveckling och avsättning för drivmedel | O | O | O | O | O | O |
| Marknadsrisker | O | O | O | O | O | O |
| Styrmedel (ange vilka i kommentarsfält) | O | O | O | O | O | O |
| Synergier eller potentiella synergier med andra aktörer | O | O | O | O | O | O |
| Möjlighet till – och/eller existerande samarbete med annan organisation | O | O | O | O | O | O |
| Organisationens kunskap och know-how kring den tekniska processen | O | O | O | O | O | O |
| Erfarenheter från andra drivmedelsanläggningar (liknande/annorlunda?) | O | O | O | O | O | O |
| Befintlig infrastruktur för att distribuera drivmedlet | O | O | O | O | O | O |
| Valet av drivmedel passar väl in i organisationens kärnverksamhet och tidigare satsningar | O | O | O | O | O | O |
| Miljö- och klimatprestanda | O | O | O | O | O | O |

**7. Kommentarsfält: Faktorer som har påverkat beslutsprocess:**

**8.** Om ni inte producerar metan idag: Ser ni tekniska möjligheter att konvertera (och/eller utöka) processen till produktion av metan?

Om ja, har dessa möjligheter varit av betydelse för beslutsprocessen?

**Page 4: Beslutsprocess: Råvara**

**9.** Vilka faktorer har påverkat er beslutsprocess kring den råvara (t.ex. flis, pellets eller GROT) ni valt att använda?

| | **5 Mycket starkt** | **4 Starkt** | **3 Neutral/i viss mån** | **2 Svagt** | **1 Mycket litet eller inget** | **vet ej** |
|---|---|---|---|---|---|---|
| Tillgång på råvara, konkurrens om råvara, samt infrastruktur för tillförsel | O | O | O | O | O | O |
| Pris | O | O | O | O | O | O |
| Processtekniska skäl | O | O | O | O | O | O |
| Styrmedel (ange vilka i kommentarsfältet) | O | O | O | O | O | O |
| Möjlighet till samarbete/synergi | O | O | O | O | O | O |
| Uppfattningar om råvaran hos allmänheten och även uppfattningar inom leverantörskedjan | O | O | O | O | O | O |
| Miljö- och klimatprestanda | O | O | O | O | O | O |

**10. Kommentarsfält: Råvara och beslutsprocess**

**Page 5: Beslutsprocess lokalisering**

11. Vilka faktorer har påverkat er beslutsprocess kring anläggningens lokalisering?

| | **5 Mycket starkt** | **4 Starkt** | **3 Neutral/i viss mån** | **2 Svagt** | **1 Mycket litet eller inget** | **vet ej** |
|---|---|---|---|---|---|---|
| Tillgång på råvara och infrastruktur för tillförsel | O | O | O | O | O | O |
| Lokal avsättning för drivmedel | O | O | O | O | O | O |
| Infrastruktur för producerat drivmedel | O | O | O | O | O | O |
| Lokal avsättning för biprodukter (t.ex. värme) | O | O | O | O | O | O |
| Möjlighet till ekonomiskt stöd | O | O | O | O | O | O |

| | | | | | | |
|---|---|---|---|---|---|---|
| Närhet till befintlig verksamhet | O | O | O | O | O | O |
| Existerande eller potentiella synergier med andra aktörer | O | O | O | O | O | O |

**12. Kommentarsfält: Lokalisering och beslutsprocess**

**Page 6: Styrmedel**

13. Ett stort antal direkta och indirekta styrmekanismer kan tillämpas av staten för att påverka biodrivmedelsmarknader. Ofta klassificeras dessa som:

- indirekt deltagande i marknaden (t.ex. lagar/reglering, skatter, subventioner osv.);
- direkt deltagande i marknaden (t.ex. agerande som köpare, eller som leverantör av varor/information, m.m.)

Hur har följande styrmedel/styrmekanismer påverkat Er beslutsprocess kring att genomföra investeringen?

| | **5 Mycket starkt** | **4 Starkt** | **3 Neutral/i viss mån** | **2 Svagt** | **1 Mycket litet eller inget** | **vet ej** |
|---|---|---|---|---|---|---|
| FoU stöd till producenter | O | O | O | O | O | O |
| Investeringsstöd | O | O | O | O | O | O |
| Energiskatter | O | O | O | O | O | O |
| Koldioxidskatt | O | O | O | O | O | O |
| Stöd till konsumenter (t.ex. miljöbilspremie) | O | O | O | O | O | O |
| Offentlig upphandling (t.ex. länstrafiken köper drivmedel) | O | O | O | O | O | O |
| Information från organisation inom offentlig verksamhet (t.ex. Energimyndigheten) | O | O | O | O | O | O |
| Erfarenheter från andra drivmedelsanläggningar | O | O | O | O | O | O |
| Möjlighet till långsiktiga avtal, t.ex. med köpare av drivmedel | O | O | O | O | O | O |
| Lagar och regleringar (ange i kommentarsfält [(t.ex. krav på tankstationer, %inblandning, m.m.]) | O | O | O | O | O | O |

| | | | | | | |
|---|---|---|---|---|---|---|
| Samarbete eller informationsutbyte med forsknings-, utvecklings- och demonstrations-projekt på företag och högskola. | O | O | O | O | O | O |

**14. Kommentarsfält: Styrmekanismer**

15. **Hur värderar ni ett driftsstöd gentemot ett investeringsstöd i beslutsprocessen att genomföra en investering?**

| | 5 Mycket starkt | 4 Starkt | 3 Neutral/i viss mån | 2 Svagt | 1 Mycket litet eller inget | vet ej |
|---|---|---|---|---|---|---|
| Investeringsstöd | O | O | O | O | O | O |
| Driftsstöd | O | O | O | O | O | O |

**Koimmentarsfält: Driftstöd/investeringsstöd**

**17. Vilka styrmedel bedömer du vara de viktigaste för att realisera en storskalig uppbyggnad av produktionskapacitet för drivmedel från skogsråvara? Beskriv hur ett sådant skulle kunna vara utformat.**

## Page 7: Förutsägbarhet och stabilitet

18. **Har ni redan ”räknat in” någon framtida förändring av styrmedel i underlaget för er beslutsprocess? Om Ja, kan du beskriva det?**

19. **Hur tror ni att nya och förändrade styrmedel kommer påverka förutsättningarna för drivmedelsproduktion från skogsråvara inom de närmsta fem åren?**

O Gynnsamma förändringar i stor utsträckning

O Gynnsamma förändringar i mindre utsträckning

O Oförändrat

O Ogynnsamma förändringar i mindre utsträckning

O Ogynnsamma förändringar i stor utsträckning

O Har ingen uppfattning

**Kommentarsfält:**

______________________________________________

**20.** Hur har förutsägbarheten/stabiliteten, eller avsaknad av detta, påverkat Er beslutsprocess, under de senaste fem åren, kring följande områden:

| | 5 Starkt positivt | 4 Positivt | 3 Oförändrat | 2 Negativt | 1 Starkt negativt | vet ej eller ingen uppfattning |
|---|---|---|---|---|---|---|
| Att genomföra investeringen i anläggningen | O | O | O | O | O | O |
| Investering i infrastruktur för t.ex. råvarutillförsel eller drivmedelsdistribution | O | O | O | O | O | O |
| Att ingå långsiktiga avtal | O | O | O | O | O | O |
| Val av drivmedel att producera | O | O | O | O | O | O |
| Annat beslut (ange i kommentarsfält) | O | O | O | O | O | O |

**21. Kommentarsfält: Förutsägbarhet/stabilitet**

______________________________________________

## 8.5 WEBINAR SUPPORT DOCUMENT

The following document outlined the process of the Webninar session used near the end of the project. This document guided the process, but was also distributed to participants in advance of the session.

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Dear Webinar Participant, this document contains important information for our meeting!

**Webinar Format**

From 10:45am to 12midday on 25 April, a Webinar will bring together a Focus Group to discuss the following questions. We wish to capture expert views regarding the prospects of large-scale projects to deliver forest-derived transport biofuels of ‘advanced generations’.

1. **Have Sweden's large forest-derived transport biofuels projects missed their "window of opportunity"?** For example, have developments with electro-mobility and oil prices redefined the market?

2. **Can (or will) Sweden provide the policy frameworks that many claim are required to underpin investment in forest-derived transport biofuels?**

A focus group discussion is a form of qualitative research in which a group are asked about their perceptions, opinions, beliefs, and attitudes regarding an issue or item of focus. Questions are asked in an interactive group setting and discussion ensues.

This focus group interaction will be moderated, and shall spend roughly half of the allocated time on each focus question. The aim is to capture views from key 'external-to-the-project' participants (circa 2 minutes per person per question), and then allow a round table discussion.

Note! We can now confirm that ALL participants are Swedish speakers. The discussion shall be conducted in Swedish.

Note! Please, feel free to prepare short answers to the questions raised above in advance.

Note! Pursuant to all participants giving their approval – we shall record the Webinar. The recording will be for project internal reference only.

**You will find all Videolink instructions overleaf.**

IT videolink instructions

These are the steps you need to take to attend this Webinar.

To join as a Guest, please click on this link – or PASTE the full link into your browser:

https://video.compodium.com/flex.html?roomdirect.html&key=wvyc2FNsRoDbGkh4dTs5KmBA900

To join with a video conferencing system, call: 213.134.125.8 PIN: 600172#

To join by phone, call: +46 8 400 500 05 PIN: 600172#

Support: +46 8 241201

Watch a quick user guide here: http://webbtv.compodium.se/vidyo/qs_user/en/

**Note:** a Compodium technician will be online and available to help should there be technical issues

**Desired technical requirements for video attendance**

The browsers supported by the video service are the following:

- Mac OSX: Safari, Firefox
- Windows: Internet Explorer 9 or later, Firefox, Chrome

It is desirable that you utilise a headset.

It is ADVISABLE to utilise a fixed internet connnection (most problems are related to wireless connections) – a poor sound connection that results can spoil the meeting for all.

It is ADVISABLE to install the software and test the system (e.g. with the meeting coordinator prior to the meeting) – preferably several days before.

**For best experiences we advise …**

- Sit in a quiet environment, with a light in front of you (avoid a window or strong light behind you)
- If you need to show pictures, a PPT or document this is supported by screen sharing, but please advise of this in advance.

A brief background to this discussion is provided overleaf.

Background to discussion

This communication relates to the f3 centre research project *'Examining systemic constraints and drivers for production of forest-derived transport biofuels'* (*'Analys av systembarriärer för produktion av skogsbaserade drivmedel'*).[190]

A key task of the project is to deliver a deeper understanding of the views by potential and existing transportation biofuel producers regarding a number of issues important to the growth of the Swedish biofuels sector.

Such areas include:

- synergies or competition for resources and/or political support;
- key strategies pursued by the leading actors in forest, fuel and petrochemical sectors; and
- general 'viability perceptions' for leading fuel-engine systems/pathways.

This project is soon to be concluded. We have performed an extensive body of interview-based investigation with actors involved in planning or proposal of many forest-derived transportation biofuel projects in Sweden. A rich palette of insights, data, experiences and ideas has been gathered and analysed. We have confidence that our analysis will yield valuable results to the Swedish transportation biofuels community.

However, there are also areas that we still find perplexing, and we have tentative findings that we wish to enrich with views from others. We wish therefore to explore the question themes listed at the opening of this brief in a circa 1 hour 'focus group discussion'.

[190] *f3* (the Swedish Knowledge Centre for Renewable Transportation Fuels) is a networking organization, which focuses on development of environmentally, economically and socially sustainable renewable fuels. The *f3* centre is financed jointly by the centre partners, the Swedish Energy Agency and the region of Västra Götaland. f3 also receives funding from Vinnova (Sweden's innovation agency) as a Swedish advocacy platform towards Horizon 2020.

Such discussions require the participation of informed professionals embedded within the field. We thank you for agreeing to take part in our focus group and look forward to this interaction.

## 8.6 WEBINAR SUMMARY

Webinar, 2016-04-25 (notes summarized from video recording of webinar)

**Participants**: Jacob Lagercrantz (JL) 2030 secretariat, Björn Fredriksson Möller (BF) E.ON, Gustav Tibblin (GT) Södra, Elisabeth Wetterlund (EW) LTU, Philip Peck (PP) LU, Stefan Grönkvist (SG) KTH, Tomas Lönnqvist (TL) KTH, Julia Hansson (JH), IVL.

**Format**: The discussion was focused around two key questions distributed to the participants prior to the webinar. The discussion was moderated and the two questions were (mostly) discussed separately. Each participant responded briefly to the questions, followed by a common discussion.

**Question 1: Have Sweden's large forest-derived transport biofuels projects missed their "window of opportunity"? For example, have developments with electro-mobility and oil prices redefined the market?**

**Question 2: Can (or will) Sweden provide the policy frameworks that many claim are required to underpin investment in forest-derived transport biofuels?**

A number of summarizing texts paragraphs have been created below. These are derived arising from the compiled documentation of the Webinar.

### *8.6.1 Opportunities for large forest-derived transport biofuels projects (Q1)*

The participants held that the opportunities for a number of the specific projects addressed by this study have likely been lost, or passed. This does not mean however, that new projects will not arise in the future; or that projects on hold cannot be restarted. However, there was consensus that it is now, and shall continue to be in the future, much more difficult to realize such projects.

There are a number of issues (arising from the experiences of recent years) that are seen make the situation more complex or difficult for future efforts. These include that:

- Fossil fuel price dynamics have proven to be much more volatile than project proponents had anticipated, and importantly, a growing expectation of high oil prices into the future has been shown to be wrong.
- Anticipated follow up actions to the Swedish FFF have failed to eventuate, leaving both continuing policy framework uncertainty, and unfulfilled expectations of stable and demonstrably supportive policy arrangements. These are large investments and policy frames required by investors are perceived to require stability, long-termism, trustworthiness and effectiveness for such investments to be realized.
- Projects that have been realized (e.g. GoBiGas and SunPine) have experienced significant commissioning difficulties – providing new insights to the levels of technical risk involved.
- Media and political attention is perceived to have shifted to e-mobility – and in the process of doing so, is also perceived to lack maturity, realism and a systemic view of the

transportation fuel mixes required to achieve Swedish policy goals. *"One technology (track) is discussed at a time and seen as THE solution. (Feedstock) potentials and other limitations of the technology are not discussed. Policy focus is shifting rapidly, from ethanol and gasification to presently e-mobility (EW)"*

- The latter two points have contributed to significantly eroded trust in the Swedish policy sphere, and reduced confidence that a stable and supportive framework can be delivered for projects such as those covered by the project. Proponents express emotions from indicative levels of 'disappointment' (mild views) to 'betrayal' (at extremes).

A number of themes related to political instability and uncertainty are reiterated in the following section.

### *8.6.2 Policy instruments (Q2)*

A number of the themes addressed for question 1 were nuanced with a policy focus in the second half of the webinar.

Views can be summarized according to two major themes for this second question. The first theme embraces perceptions of weakness, naivety, hesitation or vacillation, lack of clarity, short-termism – and at times even counter productiveness or inappropriateness – in the policy frameworks provided from Swedish policy makers. The second theme relates to the EU, and the negative experiences of Sweden related to restrictions upon state aid. Regarding this item, no clear picture arose of whether informants viewed that the Swedish were poorly prepared or misguided in their efforts to circumvent state aid restriction, or whether the fault was viewed to lie entirely with the EU.

Views and quotations related to the above themes include that:

- Rules that can be trusted over a long period of time are needed so that the investments can be recuperated but this has not been provided. Credibility in policy-making and policy instruments is important and this has been eroded or lost. As a result, informants perceive that it has become more difficult to obtain financing compared to when FFF was presented. **"*The hesitation in Swedish policy has undermined the credibility for investors"* (GT).**

- Informants communicated a lack of trust in policy makers – in that they perceived that policy decisions could be made at any time that negatively affected projects that had already invested large sums of capital, and needed stability into the future (based on reasonably equivalent financial conditions in place when investments were made). Related to this, informants expressed limited faith that they had true support from decision makers. *"We* [SunPine] *are only one political decision away from bankruptcy" (GT). Thus alternative strategies are needed. What if $CO_2$ and energy taxes are applied to HVO? Looking through the rear mirror, we will not take such a risk again.*

- A view was related to the meeting however that contrasted with this. SG reporting from discussions with Preem, indicated the company relates that it believes that the Swedish politicians DO display sufficient trustworthiness – a counter view was also put forward that ***"This may be a way to lead the development. Preem hopes to affect policy making by***

***saying that Sweden will provide the necessary framework and acting accordingly. Thus expectations guide the reality (JL)".***

- The EU rules (e.g. for tax exemptions, and for state aid) are perceived to set significant limits to what Swedish policy in its current forms can achieve. At the same time, there is a common view that it remains unlikely that Sweden will change course from its existing suite of policy goals that enfold fossil independent transportation and climate emissions. These are seen as important questions for Sweden that still require action in the biofuels area – ***"These are large investments and the right conditions are needed. The ethanol and RME debacles showed that the condition could change after that a decision has been made. Thus investors now demand a lower risk. A program is needed, similar to the one that replaced oil in district-heating in the 70's or an equivalence to the green electricity certificates. Without this there are not going to be any large-scale private investments."***

- However, the EU rulemaking area is perceived to have become a 'free arena' where specific interest groups can have a large effect on areas that impact biofuel pursuits. Informants perceived that the EU process has been highjacked. One area that is seen as particularly relevant in this regard are perceptions that forests should not be used for energy – Nordic forests are compared to the 'park like forests' of certain parts of Europe. Other areas where informants see that the process has become unrealistic lies with issues such as food versus fuel and ILUC. Informants perceived that much of these three debates are driven by parties with flawed scientific or practical knowledge – **"*We are close to a political collapse* (GT)".**

### *8.6.3 Swedish Forest industry strategies and communication (General)*

A brief discussion was also held surrounding the role of the Swedish forest industries in the development of biofuels. In particular it was related that the industry remains partially divided regarding the utilization of forests for energy. It was communicated that the apparent ambivalence of significant parts of the forest industry to the forest-based fuel initiatives may be related to the apparent lack of focus from the policy sector.

Importantly, forest owners and the forest companies do not always share the same views. Several key issues were raised in this regard:

- Swedish forest owners are generally positive to biofuels – forest owners are motivated for engagement in activities that increase the competition for their products (e.g. roundwood and all residues).

- Forest industries however, are wary of activities that potentially increase the cost of their feedstocks; thus the forest industry perceives biofuels as a competitor for raw material.

- Also related to costs, forest industries are one of Sweden's largest purchasers of transport services. They are concerned about any changes that can serve to increase the costs of forestry transport – widespread availability of biofuels for transport or demands that such fuels are used, or both, can be seen as a potential cost impost on this sector.

Related to the above the ***"forest industry has not positioned itself as the innovative solution it could be"*** (JL). Rather, there is perceived to be a conflict of interests within the forest sector.

This conflict is also clearly reflected within the lobby organizations, representing members with different interests.

Södra has the forest owner perspective as does Sveaskog. SCA is also gaining interest. A lobby organization that is positive to biofuels and could represent the forest owner perspective is Svebio.

While such groups do exist, forest industry consortiums and CEPI (Confederation of European Paper Industry) are much stronger and the forest industry perspective dominates over the forest owner perspective. **"*In best case scenario, the forest industry will not work against us, but they will not join us*."** Large companies such as Smurfit Kappa and Billerudkorsnäs (packaging industry) have the forest industry perspective and are remain negative to biofuels production.

The representative of Södra in the discussion also summed up that the strategic importance of an new portfolio element for the Swedish forest industries seemed to be missed – both in general (by the public) and specifically by the political sphere. ***"The forest sector generates the entire surplus in the Swedish trade balance (i.e. without this sector Sweden's imports would equal the exports). "This is our livelihood". Why do not politicians push this issue in EU? We are good at this!"***

### *8.6.4 Ways forward*

The discussion closed with expressions of frustration, but also of tentative optimism that greater policy clarity might be delivered during 2017. The following points were extracted from the closing comments:

- The political situation is locked but it is hope this might improve next year.
- Media seems to be largely unaware of the issues surrounding biofuels from forest biomass; despite the fact that the Swedish forest industries are one of, if not the most important industry sector.
- There seems to be a lack of ownership "Who is in charge?" The (forest) industry needs a strong voice.
- The industry was ready to kick-start after the FFF inquiry, yet nothing concrete arose from this. The experience has negatively affected the forest industry engagement in biofuels. **"This was a misuse of the trust that existed after the FFF investigation"**.
- There is a need for concerted proactive action from the forest sector if forest-derived biofuels are to move forward. One suggest (Södra, GT) was that the Swedish forest sector needs to draft concrete proposals for the commission. The commission has opened up for regional concerns so that Swedish forests may be treated differently than a European "park forest".
- LULUCF is an important cloud on the horizon – and there are fears that it may negatively affect the forest sector in general, and biofuels from the forest in particular – yet a great deal of uncertainty regarding effect, if any, remains.

It is important with a discussion about quality and feedstocks. Palm oil is now used which may create back-lash. Tall oil feedstock is utilized to its maximum. Lignin from black liquor is also limited. If we import HVO we will have different qualities/environmental performance, from fairly good to quite bad. It is good to market SunPine, HVO from other sources is not much discussed. Feedstock potentials must be discussed! (EW)

## 8.7 SUPPORTING THEORY PAPER (RESEARCH APPROACH)

The theoretical considerations listed above are explained and placed in the context of this work in a separate publication (*Investigating institutional constraints on the production of forest-derived transport biofuels in Sweden: A study design)* that is also an output of this project. This was delivered as a conference paper to the European Biomass Conference and Exhibition (EUBCE) in June 2015, and is published in the proceeedings of that conference.[191]

This paper is included is available via the following web link: Research Gate: INVESTIGATING SOCIO-TECHNICAL & INSTITUTIONAL_CONSTRAINTS

[191] Peck, P.C., Grönkvist, S., Hansson, J., Voytenko, Y., Lönnqvist, T., 2015. *Investigating institutional constraints on the production of forest-derived transport biofuels in Sweden: A study design.* In proceedings of the European Biomass Conference and Exhibition (EUBCE) 2015, Vienna, Austria.

THE SWEDISH KNOWLEDGE CENTRE
FOR RENEWABLE TRANSPORTATION FUELS

Swedish Energy Agency

www.f3centre.se

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