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SOCIO-ECONOMIC METRICS FOR TRANSPORT BIOFUELS: A REVIEW

A support analysis for the project *Environmental and socio-economic benefits from Swedish biofuel production* within the f3 and Swedish Energy Agency collaborative research program “Renewable transportation fuels and systems”.

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THE SWEDISH KNOWLEDGE CENTRE
FOR RENEWABLE TRANSPORTATION FUELS

PREFACE

This report is a synthesis analysis to a project that has been carried out within the collaborative research program *Renewable transportation fuels and systems* (Förnybara drivmedel och system), Project no. 40771-1, Environmental and Socio-Economic Benefits from Swedish Biofuel Production. The project has been financed by the Swedish Energy Agency and f3 – Swedish Knowledge Centre for Renewable Transportation Fuels.

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. Chalmers Industriteknik (CIT) functions as the host of the f3 organization (see www.f3centre.se).

Partners engaged in project 40771-1 include IVL Swedish Environmental Research Institute, Bio4Energy/Luleå University of Technology and Lund University (International Institute for Industrial Environmental Economics, IIIEE). This synthesis analysis is produced by the IIIEE.

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EXECUTIVE SUMMARY

This analysis examines socio-economic and environmental co-benefits related to biofuels production for the transport sector. It has a point of departure that regional transportation biofuel production will require an expanded set of economic activities in that region in order to deliver functional fuels. This supports an expectation that domestic biofuel production demands both expansion of existing socio-technical systems, and the creation of new systems, and that stimulation of employment and economic activities along biomass and transport fuel value chains flow on from such.

A further rationale underlying this work is that Sweden hosts large quantities of biomass, and the country has highly developed bioenergy systems – including systems to produce transportation biofuels. These factors indicative of significant potential to expand Swedish biofuel production based on domestic feedstocks. Current Swedish biofuels is however largely dependent upon imported fuels and feedstocks. Logically, a significant proportion of socio-economic co-benefits, presumed to be associated with biofuel production, cannot accrue in Sweden when this is the case. Improved knowledge of the benefits that Sweden could experience if higher proportions of the national consumption were met by domestic production should be of interest in this instance.

This socio-economic analysis delivers a screening review of job (employment opportunity) creation assessments, and a review of methods used to enumerate other socio-economic and environmental benefits. It is intended that this deliver insights to the relative performance of biofuel systems as compared to the status quo (e.g. systems where fossil fuels are used in transportation, or where biofuels or feedstocks, or both are imported). The review has a principal focus on job creation metrics. Within this report, the term ‘metric’ is intended to convey the meaning of a standard of measurement by which the efficiency, performance, progress, or quality of a process, or product can be assessed.

The method assessment included examination of a range of different pathways by which analysts calculate or measure parameters such as job creation, wealth creation, ancillary environmental benefits, and socio-economic benefits. This required compilation and synthesis of several types of studies. These include: assessments of national level benefits; benefits delivered by a specific sector, project, or projects; biofuels-related metrics for employment and economic stimulation; measures of contribution to energy security; and valuation of environmental benefits related to both production and consumption of biofuels.

PURPOSE AND OBJECTIVES

The overarching aim of this analysis is to deliver increased knowledge of benefits that can be derived from biofuel production systems. The ambition is that this can support the development of more better policy instruments to support future biofuel production. At a lower level, this analysis seeks to provides a suite of values, or ‘value-spans’, for key socio-economic and environmental metrics associated with biofuels production and utilization. It is envisaged that such indicative performance measures can support biofuel-related industry actors, policy-makers, and political decision-makers in their communications regarding the future of transport biofuels.

This analysis has specific objectives to:

(i) Screen and review metrics published in publicly available literature that detail socio-economic benefits accruing from transportation biofuel production activities – with key emphasis on job creation;

(ii) Screen and review approaches (i.e. methods/methodologies) for assessment of socio-economic benefits in general that are connected to transportation biofuel production systems.

GENERAL APPROACH

This report is built upon the results of a desk-based study of socio-economic metrics related to ancillary benefits of biofuels production. Extensive searches of biofuel-related literature were conducted targeting the following topics:

- socio-economic benefits/co-benefits (in Sweden and internationally);
- environmental benefits/co-benefits (in Sweden);
- job creation/employment creation;
- energy security;
- rural development;
- social welfare.

In addition, a limited amount of field data was gathered (via telephone interview/email exchanges) from two Swedish biofuel producers – Perstorp Bioproducts, and Lantmännen Agroetanol.

Information obtained was grouped according to four key areas: a) employment related metrics; b) revenue, gross domestic product (GDP/GNP), or gross regional product (GRP) related figures; c) monetized ancillary environmental benefits (e.g. values attached to pollution reduction); d) other monetized benefits (e.g. energy security).

The analysis was structured so as to encompass the following general topics:

- background to biofuels-related metrics on and employment/economic stimulation, welfare creation, energy security and valuation of environmental benefits;
- an overview of international perspectives and metrics related to employment, economic stimulation and welfare gains related to biofuels;
- a compilation and comparison of metrics and quantifications related to employment, economic stimulation and environmental gains related to biofuels.

An overview of results and conclusions drawn from the study are included below.

ACCRUAL OF SOCIO-ECONOMIC BENEFITS

A central and important finding of this study is that essentially all referenced works, and input from industry, indicate that biofuels initiatives generate substantial direct and indirect[1] employment opportunities. Biofuel production efforts also stimulate economic activities along both fuel and feedstock value-chains.

Benefits are observed when impacts are measured at a sub-regional level, and when measured across national economies. This stated, there is evidence that (positive) direct and indirect socio-economic impacts induced by biofuels production are reduced – perhaps substantially – when a significant proportion of raw materials used for biofuel production are imported. Based on the evidence gathered in this report, it is concluded that transportation biofuels initiatives of the types currently pursued in Sweden appear likely to deliver significant socio-economic benefits, and that the benefits will be greater if feedstocks are domestically sourced.

BENEFITS ACCRUING AT THE NATIONAL LEVEL

Such assessments build upon equilibrium or partial equilibrium models for the agricultural and energy sectors. They generally compare different (candidate) policy tools (intended to support biofuel production) against each other *ex-ante*. Using input-output modelling, they gauge the effects of a new (expanding) biofuels sector upon other parts of the economy. Thus, they count both ‘positive’ and ‘negative’ effects across the economy. These include overall welfare effects, labour market effects, economic revenues, or combinations of these. The studies examined in this analysis each showed that the new biofuels industries created new employment opportunities, and created financial benefits at national levels. Studies addressing systems with dominant proportions of domestic feedstock indicate that benefits exceed the costs of support to the sector.

BENEFITS DELIVERED BY A SPECIFIC SECTOR, A PROJECT, OR A GROUP OF PROJECTS

These assessments are grouped in two main categories. The first involves ‘bottom-up’ exercises conducted in collaboration with biofuel industries in specific sub-regions. The second, centres upon regional forecasting and modelling efforts that use software linked to regional demographic and economic databases. Most bottom-up assessments focus upon direct and indirect employment opportunities, and direct economic effects. Most modelling exercises also include indirect or induced employment effects (or both). While such analyses can also provide details of economic metrics (e.g. regional level ‘domestic product’), some limit this to business turnover or wages.

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[1] In general, we present **direct** employment as the employment opportunities by the business or organizations active in the production system being studied. **Indirect** employment opportunities arise as the results of business-to-business transactions indirectly caused by the direct effects. **Induced** effects are the results of increased personal income caused by the direct and indirect effects (e.g household-to-business activity).

EMPLOYMENT AND REGIONAL DOMESTIC PRODUCT (RDP[2]) METRICS

Indicative ranges for results drawn from both bottom up and modelling exercises are summarized below. All values have been normalized to **full time equivalent (FTE)** employment opportunities created per energy equivalent (TWh or GWh) of produced fuel.[3]

International and Swedish **ethanol** initiatives reviewed here documented employment stimulation in the order of:

- 40 to 80 direct (FTE)/TWh;
- 250 to 1100 total FTE/TWh;
- Stimulation of Regional Domestic Product (RDP) of 0.75MSEK/GWh to 1.5MSEK/GWh.

International (US) **biodiesel** initiatives have documented:

- 200 to 400 direct FTE/TWh;
- 1000 to 1200 total FTE/TWh;
- Stimulation of Regional Domestic Product (RDP) of circa 2.3MSEK/GWh.

Swedish **biogas** efforts have documented:

- 200 to 850 direct FTE/TWh;
- 300 to 1400 total FTE/TWh;
- Stimulation of Regional Domestic Product (RDP) in the range of 0.5MSEK/GWh to 2MSEK/GWh.

VALUATION OF ENVIRONMENTAL BENEFITS AND ENERGY SECURITY

Valuations of co-benefits in this category were principally found in Swedish analyses. They show that a relatively broad suite of ancillary benefits is now entering mainstream use. The most prominent metric at the national level in Sweden in this category is for carbon dioxide, however a range of other measures of environmental benefit have also been defined for both sub-regional or local perspectives.

They encompass benefits accruing from both the production and the utilization of biofuels. Examples related to reduced environmental damage include categories such as: methane, nitrous oxides, and particulate emissions, and the leakage of nitrates to groundwater. Examples of gains include the value of feed (e.g. from oil-seed press-cake and spent formation grains), and bio-fertilizers (e.g. derived from biogas digestates). The assessment of ancillary benefits for such categories have been

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[2] Regional Domestic Product (RDP) is used to denote Gross Regional Domestic Product (also GRDP). This is a subnational gross domestic product for measuring the size of a region's economy. It is the aggregate of gross value added (GVA) of all resident producer units in the region.

[3] The figures delivered for liquid transportation biofuels are based upon (observed) industrial systems at large scale – and modelling of large-scale hypothetical initiatives. Thus, they describe industries where scale economies already apply, and relative employment intensities can be expected to be lower than for small scale initiatives. Biogas figures are based on (observed) small, and medium scale projects, and hypothetical larger scale projects (i.e. assessed by modelling). Reflecting scale economies, lower end figures for employment intensity generally represent larger scale projects.

applied in a number of biofuels studies commissioned by regional decision-makers. The approaches followed when creating estimates of benefits in these categories generally build upon results from LCA studies.

Regarding the valuation of *Energy Security*, it is observed in both Swedish and international studies that the notion of a contribution to energy security is first related to the value of imported fossil oil displaced. In Sweden however, another value explicitly addressing ‘security’ is also applied. This utilises a figure proposed by the Swedish Energy Agency that is based on a valuation of the reduced need for (strategic) oil storage; in this case 15kr/MWh_{fuel}. While not widespread in use, it seems that this should be suitable for application to all renewable transportation biofuels that are produced within national borders.

KNOWLEDGE GAP(S) AND CAPACITY NEEDS FOR ASSESSMENT OF SOCIO-ECONOMIC BENEFITS

In addition to the insights provided into metrics by this work, a potentially important knowledge gap is discerned within Sweden’s biofuel related research. There is an apparent absence of detail evaluations (of social, environmental and economic benefits) related to liquid biofuels production – particularly if such is based upon domestic feedstocks.

Modelling work (e.g. with Sweden’s rAps model[4]) has addressed both existing digestion-based systems, and proposed thermochemical pathways for gaseous fuel production, in quite considerable detail, but evidence was not found that liquid transportation fuel initiatives have been assessed in similar ways. Such work may be important for achievement of Swedish goals in in the emerging bioeconomy as well as in the renewable fuels sphere. It is logical that such assessment work could support decision-making processes for the significant investments required to advance renewable fuels and to create biorefineries in the country.

Related to the apparent lack of assessment work, this study also provides evidence that there may be an important lack of capacity to perform both modelling and research in this area. Application of the aforementioned rAps model is an example. Despite the model being available to academia and to governmental agencies, it remains unclear if the competencies to apply such tools exist within the biofuels sphere, or if they are being used within governing bodies in the biofuels or bioeconomy contexts. Further, it remains unclear if the methods and tools for producing socio-economic evaluations are sufficiently developed to utilise in the bioeconomy field. As such, a finding of this work is that there may be a need for development of new and deeper research and modelling capacity, within technically skilled academic/research institutions, to serve the needs of the renewable fuels sector, and the future bioeconomy. A starting point for such work could be a focused assessment study focused on assessment of needs in such areas. Such work could include an effort to map capacity within Swedish research institutions, and to assess the suitability of the existing tools to provide assessment of future biofuel, or bioeconomy, initiatives.

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[4] Sweden’s Regional Analysis and Prognosis System (rAps-model or ‘Regionalt analys- och prognossystem in Swedish’) is a regional level planning tool available for quantification of regional growth and employment impacts.

SAMMANFATTNING

Denna rapport undersöker samhällsekonomiska effekter av biodrivmedelsproduktionssystemen. Den förutsätter att om biodrivmedel produceras inom en region så kommer det att leda till utökade regionala ekonomiska aktiviteter. En inhemsk biodrivmedelsproduktion kräver både expansion av befintliga socio-tekniska system och skapande av nya system. En konsekvens av detta blir stimulering av sysselsättning och ekonomisk verksamhet längs biomassans och transportbränslens värdekedjor.

Ett ytterligare motiv till föreliggande rapport är att Sverige har såväl stora mängder biomassa som ett välutvecklat bioenergisystem – inklusive system för biodrivmedelsproduktion. Trots detta bygger Sveriges drivmedelsmix till stor del på importerade drivmedel eller råvaror. Detta innebär rimligtvis att en betydande del av de positiva samhällsekonomiska effekter som antas vara förenade med biodrivmedelsproduktionen kommer att gå förlorade. Förbättrad kunskap om de samhällsvärden som Sverige skulle kunna få om mer av den nationella drivmedelskonsumtionen uppfylldes av inhemsk produktion bör följaktligen vara av intresse.

Föreliggande analys innehåller en granskning av möjliga sysselsättningseffekter och metoder för att beräkna andra positiva samhällsekonomiska värden och miljöeffekter. Dessa beräkningar ger insikter om biodrivmedelsystemets relativa prestanda jämfört med *status quo* (t.ex. system där fossila drivmedel används).

Metodjämförelsen omfattar en granskning av olika sätt att uppskatta skapande av nya arbetstillfällen, positiva miljö- och samhällsekonomiska värden och välstånd. Beräkningarna baseras på en syntes av studier som genomfört beräkningar på projekt-, sektor- och nationella nivåer. De biobränslerelaterade kategorierna inkluderar sysselsättning, ekonomisk stimulans, energisäkerhet och värdering av miljöförbättringar.

SYFTE OCH MÅL

Analysens övergripande mål är att ge ökad kunskap om fördelar som kan härledas till biodrivmedelproduktion. Ambitionen är att denna kunskap skall vara ett övergripande stöd för utvecklingen av policyverktyg relevant för framtida biodrivmedelsproduktion. Ett annat syfte är att analysen skall tillhandahålla vägledande samhällsekonomiska värderingar och nyckeltal för viktiga socioekonomiska och miljömässiga mätvärden som är relevanta för att stödja utvecklingen av biodrivmedel. Analysen har vidare två specifika mål:

- att granska studier som beskriver socioekonomiska fördelarna förknippad med biodrivmedelsproduktion - med huvudfokus på arbetstillfällen;
- att granska metoder för bedömning av socioekonomiska fördelar i allmänhet som kan uppstå som ett resultat av biodrivmedelsproduktion.

METOD

Rapporten bygger på en skrivbordsbaserad studie av socioekonomiska mätvärden. Litteratursökningar genomfördes inom följande ämnesområden kopplade till biodrivmedel:

- samhällsekonomiska förbättringar/stimulans (i Sverige och internationellt)
- positiva miljöeffekter (i Sverige)

- nya arbetstillfällen
- energisäkerhet
- landsbygdsutveckling
- välfärd

Insamlade data grupperas i fyra nyckelområden: a) Arbetsrelaterade nyckeltal; b) Inkomster, bruttonationalprodukt (BNP) eller regional-bruttonationalprodukt (GRP) c) Monetär värdering av miljöeffekter; d) Övriga fördelar (t.ex. energisäkerhet).

Analysen är strukturerad så att den omfattar följande generella komponenter:

- Bakgrund till biodrivmedelsrelaterade nyckeltal och sysselsättning/ekonomiska stimulanseffekter, välfärdsskapande, energisäkerhet och värdering av miljöeffekter.
- En översikt av internationella nyckeltal relaterade till sysselsättning, ekonomisk stimulans och välfärdeffekter relaterade till biodrivmedelsproduktion.
- En sammanställning av nyckeltal och kvantifieringar relaterade till sysselsättning, ekonomisk stimulans och miljöeffekter relaterade till biobränslen.

En översikt av resultaten och slutsatserna från studien redovisas nedan.

SAMHÄLLSEKONOMISKA EFFEKTER

Ett viktigt resultat är att i stort sett alla studier som granskades visar att biodrivmedelsproduktion skapar betydande positiva sysselsättningseffekter. De stimulerar också ekonomiska aktiviteter längs både drivmedels- och råvarukedjor.

Positiva samhällsekonomiska effekter uppstår både när effekterna mäts på en subregional nivå, och när de mäts över nationella ekonomier. Dock finns det indikationer att dessa effekter kan minskas om en betydande andel av råvarorna för produktion av biodrivmedel importeras. Baserat på de belägg som samlats in kan man hävda att biodrivmedelsproduktionssystemen i Sverige sannolikt kommer att ge samhällsekonomiska vinster, och att denna sannolikhet ökar om råvarorna är av svenskt ursprung.

POSITIVA EFFEKTER PÅ NATIONELL NIVÅ

Analyserna av effekter på nationell nivå bygger på allmänna eller partiella jämviktsmodeller för jordbruks- och energisektorerna. De jämför i allmänhet olika (tänkbara) policyverktyg mot varandra *ex ante*. Med hjälp av input/output-modellering mäter de effekterna av ny (expanderande) biodrivmedelsproduktion på andra delar av ekonomin. Således räknar de både ’positiva’ och ’negativa’ effekter. Dessa modeller ger en övergripande bild av välfärds- och arbetsmarknadseffekter, ekonomiska intäkter eller kombinationer av dessa. De studier som analyserades i denna rapport visade att biodrivmedelsindustrier skapar nya sysselsättningar och positiva ekonomiska effekter på nationell nivå, och att dessa positiva värden översteg kostnaderna för stöd till sektorn.

POSITIVA EFFEKTER FÖR EN VISS SEKTOR, ETT PROJEKT, ELLER EN PROJEKT-GRUPPERING

Analyserna är grupperade i två huvudkategorier. Den första omfattar ’bottom-up’-studier som genomförs i samverkan med biodrivmedelsindustrin i specifika regioner. Den andra baserar sig på regionala analysprognoser och modellering, med modelleringsverktyg kopplade till regionala demografiska och ekonomiska databaser. De flesta undersökningarna baseras på direkta och indirekta sysselsättningsstimulanser samt direkta ekonomiska effekter. Flertalet modelleringar inkluderar också indirekta eller inducerade sysselsättningseffekter (eller både och). Även om sådana analyser också har möjlighet att ge insikter om bredare ekonomiska spridningseffekter (t.ex. regionala BNP), begränsas flertalet analyser till att enbart omfatta företagsomsättning eller löner.

EFFEKTER PÅ SYSSELSÄTTNING OCH REGIONALA NETTOPRODUKTIONER

Indikativa resultat från studierna som analyserats sammanfattas här. Alla värden har normaliserats till heltidsekvivalenter uttryckta i s.k. helårssysselsättningar (HÅS) per TWh eller GWh producerat drivmedel.

Internationella och svenska etanolsatsningar som är dokumenterade i rapporten har genererat sysselsättningseffekter i följande storleksordningar:

- 40 till 80 direkta HÅS/TWh;
- 250 till 1100 totala HÅS/TWh;
- Stimulering av den regionala nettoprodukten ligger i intervallet 0,75 MSEK till 1,5 MSEK/GWh.

Internationella (USA) biodieselsatsningar har dokumenterat följande storleksordningar:

- 200 till 400 direkt HÅS/TWh;
- 1000 till 1200 totalt HÅS/TWh;
- Stimulering av den regionala nettoprodukten på ca 2.3 MSEK/GWh.

Svenska biogassatsningar har dokumenterat följande:

- 200 till 850 direkt HÅS/TWh;
- 300 till 1400 totalt HÅS/TWh;
- Stimulering av den regionala nettoprodukten i intervallet 0.5 MSEK till 2 MSEK/GWh.

POSITIVA MILJÖEFFEKTER OCH ENERGISÄKERHET

Värderingarna i denna kategori baseras huvudsakligen på svenska analyser. Dessa analyser bygger på en relativt bred uppsättning av explicita monetära värderingar av miljöeffekter, som används regelbundet i trafik- och energipolitiska analyser. Den mest betydande tillämpningen på nationell nivå i Sverige gäller för koldioxid. Men även andra miljöeffekter värderas i explicita monetära värden, framför allt på lokal nivå.

Analysen omfattar effekterna från både produktion-och förbrukning av biodrivmedel. Exempel på positiva miljöeffekter inkluderar minskning av metan, kväveoxider och partikelutsläpp samt läckage av nitrater till grundvatten. Exempel på andra positiva utfall är ökad produktion av djurfoder (t.ex. från oljeväxtpresskaka och förbrukade mäskningskorn) och biogödsel (t.ex. biogasrötrest). Dessa uppskattningar bygger generellt på LCA-studier.

När det gäller värderingen av energisäkerhet finner man såväl i svenska som i internationella studier att begreppet ’bidrag till energisäkerhet’ är relaterat till värdet av den mängd importerad fossilolja som ersätts. I Sverige tycks emellertid ett värde som uttryckligen är knutet till ’säkerhet’ vara likställt med en värdering av det reducerade behovet av (strategisk) oljelagring. I detta fall uppskattas värdet till 15 kr/MWh drivmedel. Även om denna värdering inte tillämpas generellt, borde den gälla för alla biodrivmedel som produceras inom landets gränser.

KUNSKAPSGLAPP OCH KAPACITETSBEHOV: SAMHÄLLSEKONOMISKA VÄRDERINGAR

Utöver de insikter som förmedlas genom mätvärdena som rapporten redovisar, kan en potentiellt viktig kunskapsbrist inom Sveriges biodrivmedelsforskning noteras. Det råder en uppenbar brist på utvärderingar av de positiva sociala, miljömässiga och ekonomiska effekterna av biodrivsmedelsproduktion – särskilt om sådan är baserad på inhemska råvaror.

Modelleringsarbete (t.ex. med rAps-modellen) har omfattat både befintliga rötningssystem och föreslagna termokemiska anläggningar för gasformig drivmedelsproduktion. Däremot har likvärdiga värderingar för flytande drivmedelsinitiativer inte utförts. Sådant arbete kan dock vara viktigt för att uppnå svenska mål inom den framväxande bioekonomin såväl som inom biodrivmedelsindustrier. Det är högst troligt att sådana utvärderingar kan stödja beslutsprocesser för de betydande investeringar som krävs för att ta fram förnybara drivmedel och skapa bioraffinaderier.

Samtidigt som rapporten visar på bristen av utvärderingsarbete på detta område, så konstateras också att det torde föreligga en betydande brist på forskningskapacitet inom området. Den ovannämnda rAps-modellen är ett exempel på detta. Trots att modellen är tillgänglig för såväl akademi som statliga myndigheter är det oklart dels vilken kompetens som finns bland biodrivmedelsforskare att tillämpa den eller liknande verktyg, dels om vektygen verkligen används som stöd för beslutsfattare i biodrivmedels- och bioekonomiska sammanhang. Det skulle behöva utvecklas ny och djupare forsknings- och modelleringskapacitet inom akademi och forskningsinstitutioner för att dessa skall kunna tillgodose kunskapsbehoven inom förnybara drivmedelsindustrier och den framtida bioekonomin. Vidare är det oklart om metoderna och verktygen för samhällsekonomiska utvärderingar är tillräckligt utvecklade för tillämpning inom den växande bioekonomin.

LIST OF ABBREVIATIONS

ASEK	Analysmetod och samhällsekonomiska kalkylvärden för transportsektorn [Analysis methods and socio-economic calculation values for the transport sector]
BAU	Business as Usual
BEA	Bureau of Economic Analysis (United States)
EIA	Energy Information Administration
FTE	Full Time Equivalent (employment year), used to denote employment opportunities – 1 FTE is equivalent to one working person for one year.
GDP	Gross Domestic Product
GNP	Gross National Product
GRDP	Gross Regional Domestic Product, a subnational gross domestic product for measuring the size of that region's economy. It is the aggregate of GVAs.
GVA	Gross Value Added of all resident producer units in a region.
GWh	Gigawatt hours
HVO	Hydrotreated Vegetable Oil
HÅS	Helårssysselsättning (see FTE)
ILUC	Indirect Land Use Change
I/O	Input/Output
I/O-LCA	Input/Output-Life Cycle Analysis
LCA	Life Cycle Analysis
MS	Member State (of the European Union)
MWh	Megawatt hours
PPP	Purchasing Power Parity
rAps	Regionalt analys- och prognossystem [Regional Analysis and Prognosis System]
RDP	Regional Domestic Product; also used to denote Gross Regional Domestic Product
RME	Rape methylester
SI	International System of Units (Système International d'Unités)
DDGS	Dried Distillers Grains with Solubles
WIOD	World Input–Output Database

SIKA	Statens institut för kommunikationsanalys [Swedish national institute for analysis of the transport sector]
TWh	Terawatt hours

CONTENTS

1 INTRODUCTION

This report examines biofuels production for utilisation in the transport sector. It has a point of departure with the premise that when transportation biofuels are produced within a region, they require that a set of economic activities be conducted to deliver functional fuels to the market. In turn, this supports an expectation that domestic production of biofuels demands expansion of existing socio-technical systems – and the creation of new systems. Stimulation of employment and economic activities along biomass and transport fuel value chains flow on from such.

The research work reported in this report was motivated by observations that proponents of biofuels present views that transportation biofuel systems (and their value chains) have the potential to provide considerable socio-economic benefits, but that the evidence of benefits stimulated by biofuel process industries remains insufficient, or unclear. This situation compounds challenges to the transportation biofuels sector as opponents to the sector have highlighted many problems – both potential and actual. Simply put, there has been considerable communication of potential negative socio-economic effects put forward by critics of biofuels (cf. Keyzer, Merbis & Voortman, 2008) but this is not matched by communication of positives. A first outcome of this has been increased pressure on biofuel producers to work toward reduction of negative environmental and socio-economic impacts identified by the sector's critics (Keyzer *et al*., 2008; Sheehan, 2009). Another outcome has been policy interventions constraining the expansion of biofuel systems, and negatively affecting the viability of those that already exist.

A further rationale underlying this work is that Sweden hosts large quantities of biomass, and the country has highly developed bioenergy systems – including systems to produce transportation biofuels. While this is so, the current biofuels mix in Sweden is built to a large extent upon imported fuels. Logically, the majority of socio-economic co-benefits presumed to be associated with biofuel production do not accrue in Sweden when this is the case. Improved knowledge of the positives that could accrue in Sweden if higher proportions of the national consumption were met by domestic production should be of interest in this instance.

This analysis has significant overlap with a related research effort also involving the author (Martin *et al* (2017a) and Martin *et al* (2017b)). These efforts quantify and disaggregate the benefits provided by: a) expanded biomass production and b) from the biofuel process industries. As for the study reported in this document, it also worked from the point of departure that studies often indicate that agricultural and biomass production systems have the potential to provide considerable socio-economic benefits, but that the level of detail and clarity regarding benefits provided by expanded biomass production and biofuel process industries are insufficient. The overarching aim for the LCA methodology project (Martin *et al* 2017a) was to deliver increased knowledge of benefits that can be derived from biofuel production systems. As for the analysis detailed in this document, the knowledge was to support the development of more advanced policy instruments to support future biofuel production. That research effort however, had prime focus in the field of Life Cycle Analysis. This analysis, on the other hand, provides a synthesis report of a) methodologies for assessment, and b) (economic) values, and 'value-spans', for key socio-economic and environmental metrics associated with biofuels production and utilization.

1.1 AIMS AND OBJECTIVES

The overarching aim of this analysis is to deliver increased knowledge of benefits that can be derived from biofuel production systems. The ambition is that these insights can support the development of more advanced policy instruments to support future biofuel production. At a lower level, this analysis seeks to provides a suite of (economic) values, and 'value-spans' for key socio-economic and environmental metrics associated with biofuels production and utilization. It is envisaged that such indicative performance measures will aid biofuel-related industry actors, policy-makers, and political decision-makers in their communications regarding the future of transport biofuels.

This analysis has specific objectives to:

(iii) Screen and review metrics published in publicly available literature detailing socio-economic benefits attributed to transportation biofuel production systems – with key emphasis on job creation;

(iv) Screen and review approaches (i.e. methods/methodologies) for assessment of socio-economic benefits in general that can accrue from transportation biofuel production systems.

1.2 SCOPE OF WORK

This socio-economic synthesis analysis involved a screening review of job creation assessments, and a review of methods for enumerating other socio-economic and environmental benefits (e.g. performance). The screening review focused on job creation metrics. Within this report, the term 'metric' is applied as a standard of measurement by which the efficiency, performance, progress, or quality of a process, or product can be assessed.

A number of tasks are addressed in the work process required to identify, enumerate and contextualize employment/job creation opportunities – and other ancillary benefits – associated with current and future biofuel production processing. A common metric of focus applied across nearly all examples in this report is that of job creation. In essence, this reflects the logic presented by Sastresa *et al* (2010) who developed their analysis: *"considering the jobs created as the most direct measure of the socio-economic potential of renewable energy sources"*.

Pursuant to this, and reflecting the first objective, a considerable portion of the work is devoted to the identification and discussion of employment/job creation opportunities associated with current and future biofuel production processing in Sweden and abroad. Nearly all of the studies reviewed in this analysis report the results of either activities in the field, modelling studies, or combination of the two. As far as is feasible, each study review also includes a summary description of the method applied within the work, and examination of its limitations (and so forth). As such, work to fulfil the second objective related to method assessment is delivered in parallel. This work encompassed methods for counting: job creation; wealth creation; and ancillary environmental or socio-economic benefits. This in turn required compilation and synthesis of studies of: national level benefits; benefits delivered by a specific sector, project, or projects; biofuels-related metrics for employment/economic stimulation; and energy security and environmental benefit valuation.

The second objective clearly encompasses a broader suite of issues than just labour-market effects. These include *inter alia*: economic revenues at regional and national levels, stimulation of agriculture and regional development, positive environmental effects, energy security gains, and broader contributions to welfare. These are not common to all studies reviewed to the degree that job creation is, and thus the structure and content of each study-review differs.

1.2.1 Normalization and presentation of results

The task to set numbers against socio-economic and environmental performance metrics has in turn required an important secondary task in this analysis; a process of normalization between information sources. As studies of the socio-economic performance of biofuel systems typically address differing fuels, report in differing volumetric or energy units, and monetize in different currencies, a (not insignificant) process of data conversion and normalization is required. Where feasible, SI (International System of Units) metric units have been applied to allow comparison.

Where feasible, effort has been made to provide a normalized value as a 'metric per MWh/GWh or TWh'. A simple aim being to provide the reader with relative scale measures that are possible to grasp. This is essentially impossible when results are presented across different fuels types with different base units for volume, energy content and so forth. A considerable amount of biogas analysis is also included in this study. This is largely related to the relative abundance of published material addressing this topic in comparison to other fuels.

As noted, labour market stimulation is a central theme within this work. In general, the measure full-time equivalent (abbreviated as FTE) is used in this report to describe 'jobs created'. FTE is an essentially universal unit applied to measure the equivalent workforce positions of employed persons (or students) in a way that makes them comparable although they may work (or study) a different number of hours per week.[5] The workforce of an enterprise, activity, or country can then be added up and expressed as the number of FTEs. FTE is a commonly used and well understood function and is used both in Sweden in general (heltidsekvivalent), and also in the context of bioenergy (see for example SOU 2007:36). The term HÅS (helårssysselsättning) is also applied in some Swedish sources. No attempt has been made however to rationalize Swedish and international figures against each other (e.g. by comparing and correcting for national regulated work and holiday structures).

While job creation is central within the cases examined, other metrics of importance are also presented. This discussion concludes with a presentation of 'indicative metrics' (i.e. apparently 'typical' figures emerging from studies) and a discussion of the assessment methods applied in order to quantify socio-economic benefits.

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[5] The unit is obtained by comparing the average number of hours worked by an employee (or student) to the average number of hours of a full-time worker (or student). A full-time person is therefore counted as one FTE, while a part-time worker (or student) scores in proportion to the hours he or she works (or studies). See http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Full-time_equivalent_(FTE)

1.2.2 Intended audiences

The scope and presentation of differing materials examined in this report should deliver differing audiences with insights. Specific areas addressed, and likely interested audiences, are presented below:

- regional biofuel initiative studies and project-based studies can be:
  - useful for local and regional administrations when they seek to formulate reasonable expectations of socio-economic gains within their jurisdictions;
  - of value to industry actors when they communicate the potential benefits of their activities to general stakeholders (e.g. strengthening social licence to operate) or to policy-makers and politicians (e.g. seeking political support);
  - of value to academic interests as the figures drawn from them can provide: ‘rules of thumb’ when seeking to estimate possible benefit-values when scoping biofuel projects; as a basis for calibrating economic or environmental models; and for the scoping of research work in the field.
- national input output (I/O) studies are useful as they:
  - provide for comparison of international policy contexts (policy sphere and economic modellers).

1.3 METHOD/APPROACH

This report is built upon the results of a desk-based study of socio-economic metrics related to ancillary benefits of biofuels production. The basis of the work has been material obtained from a review of peer-reviewed and ‘grey’ literature. Grey literature in this instance including a) material generated by consultants to industry, and b) generated by consultants to local or regional governments. Swedish and English language sources are utilized.

Extensive literature searches were conducted utilizing on the following topics as linked to biofuels:

- socio-economic benefits/co-benefits (in Sweden and internationally)
- environmental benefits/co-benefits (in Sweden)
- job creation/employment creation
- energy security
- rural development
- social welfare

From the material gained via initial literature searches, the material base was first reduced by examination of abstracts and conclusions for information or data relevant to the general scope of the study. Using this material, a preliminary selection of proposed metrics, and metrics related to the above area, was created. The data was grouped according to four key areas: a) employment related metrics; b) revenue, gross domestic product (GDP/GNP), or gross regional product (GRP) related figures; c) monetized ancillary environmental benefits (e.g. values attached to pollution reduction); d) other monetized benefits (e.g. energy security).

The information base was then incrementally increased as each source was examined in detail – principally drawing upon cited sources of relevance within reference lists of various studies. In addition, a limited amount of field data was gathered (via telephone interview/email exchanges) from two Swedish biofuel producers – Perstorp Bioproducts, and Lantmännen Agroetanol.

The analysis was structured so as to address the following general topics:

- Background to biofuels-related metrics on and employment/economic stimulation, welfare creation, energy security and valuation of environmental benefits;
- An overview of international perspectives and metrics related to employment, economic stimulation and welfare gains related to biofuels.
- A compilation and comparison of Swedish metrics and quantifications related to employment, economic stimulation and environmental gains related to biofuels.

1.4 LIMITATIONS AND SCOPING CHOICES

There are a number of significant limitations on the content of this work, presented here in general terms. Specific limitations associated to parts of this analysis are presented in more detail in the relevant portions of the report.

First and foremost is the fact that this study is primarily a desk-top study based on secondary sources. Resources available for the study were insufficient to collect primary data in volumes that could yield metrics from Swedish biofuel producers.

As broad but very important limitations regarding the content of this report, issues such as the following must be kept in mind by all readers.

- Most of the studies, and much of the data that has been compared in this analysis is NOT truly comparable; the studies have been performed with different aims, at different scales, in different regional contexts and with differing levels of primary field data input – among other things. Yet it has been chosen to compare them in the belief that they are sufficiently similar to provide indications for the reader of the general span of socio-economic and environmental benefits related to biofuels.

- A number of the assumptions taken by the authors of studies cited in this is were not found, or were found to be unclear – thus, some interpretations of previous studies may be flawed;

- Many of the normalization processes used within this analysis have in turn required assumptions.

- There remains a lack of clarity regarding employment intensity (and thus also associated flow-on effects to regional or local economies) when comparing large or small-scale operations. From the studies examined, it is difficult to obtain a definitive picture of the effects of scale economies upon items such as employment intensity – beyond saying that employment intensity is clearly expected be less for larger operations than smaller operations. The reader should note that the figures delivered for liquid transportation biofuels are based upon industrial studies at large scale – and modelling of large-scale hypothetical initiatives. Thus, they describe industries where scale economies (presumably) already apply, and relative employment intensities can be expected to be lower than for small scale initiatives.

> No studies were reviewed that provided details of employment intensity for smaller operations for liquid fuels. Biogas figures on the other hand, are based on observed small, and medium scale projects, and hypothetical larger scale projects. Lower end figures for employment intensity generally represent larger scale projects. Here, clear expectations of reductions in employment are communicated.

Thus, great care should be taken when citing or using the figures generated in this analysis.

Further to the above, the reader should also note that a scoping choice for the study has been to allocate significant effort (and space in the report) to biogas as a transport fuel in Sweden. This, despite the fact that ethanol and biodiesel make up the majority of the biofuel mix in the Swedish transportation fleet(s). The reason is that there is a rich base of studies enumerating both socio-economic benefits of biogas production – and the potential for benefits in other areas. The analysis in this instance, is additionally motivated by the assumption that this is the result of biogas efforts having spread around the country under the influence of a number of socio-economic and environmental drivers that are somewhat different to those for ethanol, biodiesel, or future forest derived fuels (cf. Peck *et al* 2016). This is perceived by the authors as a prime example of the types of assessments that are notably absent from studies for other transport biofuels – and notable those derived from cereals and oilseeds. Drivers for uptake of biogas production – and for interest in ancillary benefits associated with its production – include, among others: requirements under other regulatory mechanisms to store manure and to divert organics from landfills; restrictions on manure spreading due to nutrient leakage; the potential to reduce climate gas emissions from wastes; a history of efforts to build multifunctional biogas systems; and not least, studies examining (and promoting) the utilization of biogas in vehicles.

Despite the significant scientific limitations on this work noted above, the reader is reminded that the tasks within the study were general in nature and centred upon screening and reviewing a broad suite of studies. The purpose of the study centred on providing new insights into the relevance of, and scale of socio-economic metrics related to transportation biofuels.

1.5 DISPOSITION

Following this introduction, chapter 2 provides a brief review of expectations that key social actors often have regarding socio-economic or environmental benefits related to biofuels. This introduces the premise that biofuels can be a stimulant for: agriculture and rural development; improvement of energy security; job creation, and welfare improvement. This review also introduces the theme of trade-offs – a recognition that stimulation of activity in one part of the economy can also impact other sectors negatively. In recognition that policy interventions address both regional and national concerns, these opening sections address both the regional and national levels.

Chapter 3 provides a review of international perspectives, and metrics, related to biofuels production. It provides examples of analysis and modelling efforts that seek to delineate employment and welfare effects, at both national and regional levels. Two detail industry studies from the US are presented.

Chapter 4 provides details of a suite of Swedish studies that assess socio-economic benefits associated with biofuels production and use. Examples are drawn from biogas, biodiesel and ethanol production systems. Chapter 5 then provides a summary and cross comparison of employment and financial metrics.

The final chapter (6) concludes the report and provides commentary against key knowledge gaps identified for the work. Topics addressed include: approaches for assessment of socio-economic benefits at a national level, assessments at regional and sectoral levels, and general approaches being taken to evaluate environmental cobenefits.

2 BACKGROUND

Reflecting the role of this text to perform a "*screening and review of job creation and assessment methods for other benefits"*, a starting point in this discussion regards 'the place within the broader discourse' of 'job creation' as a meaningful metric when addressing the socio-economic benefits of transportation biofuel production in Sweden (or any producing country for that matter).

Regarding 'job creation' (and applying differing methods to count such), a number of studies with both Swedish and broader European perspectives (See details in Table 1 overleaf) have examined employment effects of biofuels production systems in some way.

Most of these studies express tangible expectations that there will be meaningful and tangible positive contributions to socio-economic conditions from such projects. A number provide numerical evidence of such, or models that predict such.

A number of other studies have addressed 'other benefits' of a socio-economic or environmental nature, or both. Among these are studies related to the deeper implications of employment creation and studies addressing the physical effects of products and by-products. This latter category in particular links strongly to the outputs of the LCA-based environmental assessments in this project. Areas of linkage or overlap include items such as: implications of biofuels in use (e.g. CO_2, methane, NO_X or particulate emission reductions) or the implications of by-product valorisation and use (e.g. protein rich substrates as feed, and digestates as fertilizer).

A summary of the general scope of the studies referenced in this work is provided in Table 1 overleaf.

Table 1. Overview of information sources and their focus.

General scope	Geographical focus	Fuel types	Sources informing this work
Social welfare	National	Liquid transport biofuels	(Moschini *et al.*, 2010) (Moschini *et al.*, 2012) (Sastresa *et al.*, 2010)
Employment	Supranational	Liquid transport biofuels	(Neuwahl *et al.*, 2008)
	National	Liquid transport biofuels	(Duer & Christensen, 2010) (Malik *et al.*, 2014) (Sastresa *et al.*, 2010) (Wydra, 2009) (LMC International, 2013)
	Regional/sub-regional	Liquid transport biofuels	(Urbanchuk & Norvell, 2015) (Martínez *et al.*, 2013)
		Biogas	(KanEnergi AB, 2012) (Länsstyrelsen Dalarnas Län, 2012) (Waluszewski *et al.*, 2011) (WSP Analys & Strategi & Region Skåne, 2012)
Ancillary benefits (health and/or environmental)	National	Biogas	(Brännlund *et al.*, 2010) (Dale *et al.*, 2013) (Profu AB, 2012)
	Regional/sub-regional	Biogas	(Korzhenevyck *et al.*, 2014) (Börjesson *et al.*, 2010) (Grontmij, 2014)
Ancillary benefits (economic)	National	Liquid and gaseous transportation biofuels	(Malik *et al.*, 2014) (LMC International, 2013)
	Regional/sub-regional	Liquid and gaseous transportation biofuels	(Korzhenevyck *et al.*, 2014) (KanEnergi AB, 2012) (Länsstyrelsen Dalarnas Län, 2012) (Urbanchuk & Norvell, 2015) (Waluszewski *et al.*, 2011) (WSP Analys & Strategi & Region Skåne, 2012)

2.1 RENEWABLES, CLIMATE, ENVIRONMENT, ENERGY SECURITY AND RURAL STIMULATION

One simple manner in which to ‘ring in’ benefits of interest pertinent to this discussion is to outline the suite of ‘co-benefits’ that policy support mechanisms for biofuels are generally directed towards. A suite of selected citations from a number of studies utilized in this project, along with brief contextualizing comments, are provided here to support this.

In an EU study examining employment aspects, Neuwal *et al* (2008) state:

> *“the promotion of biofuel use has been advocated as a means to promote the sustainable use of natural resources and to reduce greenhouse gas emissions originating from transport activities on the one hand, and to reduce dependence on imported oil and thereby increase security of the European energy supply on the other hand.”*

Thus, a number of key thematic areas addressed by policy can be identified:

- reduction of non-renewable resource consumption;

- reduction of climate gas emissions;
- enhancement of energy security.

These three items are reiterated, and an important (and central) fourth policy issue of agricultural sector stimulation is highlighted by other authors such as Duer and Christensen (2010).

> *"there are several policy drivers for biofuels on a larger scale in the EU transport sector, including increased security of energy supply, reduced emission of greenhouse gases (GHG), and new markets for the agricultural sector"*

In this work, it shall be assumed that this also reasonably approximates to a category of 'rural or regional jobs'.

It is clear however, that the EU is neither the centre of global biofuels activity, nor the only region motivated by issues such as greenhouse gas emissions, energy security, or agricultural stimulation.[6] In the US, Moschini *et al* (2010; 2012) echo such drivers. They also add a fifth category for policy to address. This being environmental damage related to fossil fuel consumption:

> *"the rationale typically invoked to justify government intervention in this setting: to alleviate the environmental impact of energy consumption and to decrease U.S. energy dependence on foreign sources."* (Moschini *et al*., 2010)

> *"three reasons are routinely cited to rationalize biofuel production and biofuel support policies: energy security, environmental impacts, and support for agriculture and rural development"* (Moschini *et al*., 2012)

Among the many studies listed above, the themes of rural development and job creation are a major focus for many. However, depending on the study, weight may be placed in any one, or all of the following areas:

a) production of biofuel feedstocks (e.g. cereal grains, oilseeds, harvest wastes, forest biomass, etc.);
b) primary processing of fuel feedstocks (e.g. oilseed pressing for oil+seedcake);
c) production of biofuels (e.g. the conversion of oils to vehicle fuels);
d) transportation and logistics;
e) equipment manufacturing and maintenance (e.g. for fuel production);
f) scientific support and research;
g) sale of supplies and consumables required to produce or run any of the preceding items.

These are commonly categorized according to the nature of their relationship/link to biofuels production using the terms 'direct' (typically items b, c), 'indirect' (typically items a, d, e), and 'induced' (often items such as f and g). These three terms are important within this work and are generally represented as follows:

- direct effects are the known or predicted changes in the economy;

[6] The importance of such items in other regions – not least the US and Brazil is detailed within many studies with an overview of such being provided in Grönkvist e*t al*. (2013). Moreover, that study clearly demonstrates (chapter 5) how the scale of the US and Brazilian biofuel sectors dwarfs that of the EU.

- indirect effects are the business-to-business transactions required to produce direct effects (i.e., increased output from businesses providing intermediate inputs);
- induced effects are derived from spending on goods and services by people working to satisfy direct and indirect effects (i.e., increased household spending resulting from higher personal income).

These categorizations are important when discussing 'direct employment effects' (e.g. directly observed employment in the activity in focus), indirect employment (e.g. employment in businesses supplying/trading with the activity in focus), 'induced economic effects' and the like. Further details are supplied in Box 1 below.

Box 1. Direct, Indirect and Induced Effects (after Weisbrod and Weisbrod (1997))

Direct effects are the results of the money initially spent in the study region by the business or organization being studied. This includes money spent to pay for salaries, supplies, raw materials, and operating expenses.

Indirect effects are the results of business-to-business transactions indirectly caused by the direct effects. Businesses initially benefiting from the direct effects will subsequently increase spending at other local businesses. The indirect effect is a measure of this increase in business-to-business activity (not including the initial round of spending, which is included in the direct effects).

Induced effects are the results of increased personal income caused by the direct and indirect effects. Businesses experiencing increased revenue from the direct and indirect effects will subsequently increase payroll expenditures (by hiring more employees, increasing payroll hours, raising salaries, etc.). Households will, in turn, increase spending at local businesses. The induced effect is a measure of this increase in household-to-business activity.

For simplicity, this discussion generally directs most attention to the actual production of the biofuels (thus direct employment effects in the transportation biofuels sector). However, where the studies examined clearly delineate different employment categories in a sufficiently transparent manner, details of such are provided. This inclusion is important as the flow on effects to the agricultural sector are well established as a motivating factor where projects involve fuels such as Rape methylester (RME), grain ethanol, maize ethanol, or soy-derived biodiesel.

Again, as stated by Moschini *et al*. (2012):

> *"One of the obvious economic impacts of biofuels is to increase the demand for agricultural output, beyond the traditional uses for food and feed. The resulting price effects positively impact incomes and returns in agriculture, and thus biofuels can play a positive role in the longstanding perceived need (especially in developed economies) to support agriculture. In*

> *particular, there is interest in the potential of biofuels to help with rural economic development, by spurring investment and employment in rural areas with sluggish economic activity.''*[7]

Nonetheless, for the Swedish context, it has been chosen to largely scope out the indirect and induced effects in the agricultural sector in this work. At this time, a large proportion of the feedstock for biofuels production is imported (cf. Härnesk, Brogaard, & Peck, 2015 for indicative figures) – and these proportions fluctuate significantly from period to period. This situation largely precludes the generation of meaningful estimates with the resources available to this study. Further, and of central importance, is that under the conditions of the EU ILUC Directive[8] it appears very difficult for the European agricultural system to expand production systems for transportation biofuels derived from agricultural crops such cereals or oilseeds.

In addition to interest in jobs in rural areas, regional development and so forth, analysts of biofuels-related activities also explicitly recognize that when examining employment as an indicator of benefit, 'a job is not just a job'. Rather, recognition of different quality employment opportunities, and other more nuanced spin offs is important. (Such is implicit in the mention of items such as equipment manufacture and maintenance, scientific support and research mentioned above). Such is explicitly reflected in work by Sastresa *et al* (2010). These analysts pursued deeper insights into the effects of renewable energy sources on the jobs created, the quality of the jobs and other factors related to the socio-economic development of a jurisdiction: technological development, per capita income, regional development, and human capital. Their study worked on methodologies that could increase the degree of certainty related to job ratios (types and divisions between direct, indirect etc.) often used within, and yielded by analyses of socio-economic impacts related to biofuels.

The importance of jobs across sectors, and at varying levels of complexity (thus aligned with job 'quality' and levels of 'human capital' development) is also implicit with work performed within modelling work referenced in this study (see Table 1). Studies by Neuwal *et al* (2008) [EU level], Wydra (2009) [Germany] and Malik (2014) [Australia] for example, model employment and economic effects of large scale biofuel production efforts across a large number of sectors. While not explicitly delineated, issues related to relative job status and complexity can be inferred from such works (an issue taken up in later sections of this document).

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[7] Moschini, *at al* (2012) also note direct links to concerns for issues such as food versus fuel etc. We stress that this lies outside the scope of this particular discussion (and indeed, can be said to be outside the geographical boundary, as this analysis is predominantly focused on distinct producing regions or countries. Employment figures presented here thus ignore additional employment opportunities accruing elsewhere for such demand related reasons.

[8] EU ILUC Directive (Directive to reduce indirect land use change for biofuels and bioliquids - (EU)2015/1513) amends the earlier Renewable Energy Directive and Fuel Quality Directive to take account of the effect of indirect land use change (ILUC). It has the central aim to reduce the risk of indirect land use change and to prepare the transition towards advanced biofuels. In addition to greenhouse gas reduction threshold requirements (including ILUC penalties) that are designed to be challenging for such biofuels, a key component of the Directive affecting expansion in Sweden is the limiting of the share of biofuels from crops grown on agricultural land that can be counted towards the 2020 renewable energy targets to 7 %. See https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/land-use-change for details of the 2015 amendments.

In summary, a number of general expectations can be drawn from the sources reviewed and analysed within this analysis:

- 'significant' employment opportunities are expected from biofuels activities;
- 'rural employment' associated with the stimulation of demand for agricultural activities that produce fuel feedstocks should increase;
- job creation and economic activity related to fuels production and other (higher) knowledge-based inputs will also accrue;
- a range of other ancillary benefits will contribute to socio-economic conditions in the regions or countries hosting biofuels production and utilization:
    - such include *inter alia*: improved energy security, reduction of non-renewable resource consumption, and reduced environmental damage (including, but not restricted to climate-related).

2.2 JOBS ACROSS THE ECONOMY AND OVERALL WELFARE

The views outlined above have established expectations of benefits from renewable fuels production activities, particularly when the situation is viewed at a large scale (e.g. pan European, US, etc.). However, it is necessary to recognize that other studies have smaller scope and examine a project, or a distinct set of projects to produce biofuels. These are generally hosted at a local or sub-regional level. It is also observable that a substantial proportion of projects are sponsored to various degrees by local or regional governments.[9] Presumably, this is related to the (politically valuable) job creation and economic activity related to fuel and fuel-feedstock production that will accrue at local or subregional levels – and as mentioned often from rural settings.

National economies however, have many more components, and also host a range of potentially competing interests (be they industrial or otherwise). This issue being central to the aforementioned I/O studies (i.e. Neuwal *et al* (2008) and Malik (2014)). This is important to this discussion, as a balanced national (or larger regional) perspective of the relative worth of biofuels initiatives requires consideration of potential/likely gains and losses (typically employment related and economic)[10] across the broader economy. In simple terms, that which may be beneficial for a small sub-region, might be detrimental overall to the regional or national economy.

Analysts also interest themselves in such trade-offs and this discussion draws upon a number of other studies that take account for such trade-offs and then model the contribution of biofuels-related activities at a higher level (or broader scale). Here they have been grouped according to two

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[9] This study observes this for biogas in particular. This is highlighted as it is important to consider if there is a likely tendency for local or subregional actors to just focus on the 'positives' and discount the 'negatives' (e.g. 'not their jurisdiction', 'not their constituency'). This scoping issue also relevant to analysts that deliver studies to proponents of biofuels.

[10] Note however, that the relative gains associated with other 'benefits' such as greenhouse gas emission reductions (of course CO_2, but also other emissions such as CH_4) and enhanced national energy security accrue at higher levels.

general categories: firstly, employment related, and secondly welfare related (see Box 2). Brief details are provided here so as to provide context for both general discussions of ‘trade-offs’ and in order to support results presented later in this report.

Box 2. Key concepts commonly applied in biofuel benefit modelling studies

Welfare - the availability of resources and presence of conditions required for reasonably comfortable, healthy, and secure living .Generally speaking, the term ‘welfare’ in economics, is a term applied by those concerned with measuring human ‘welfare and social conditions’. Key performance metrics are based on factors such as the distribution of wealth across society, the relief or reduction of unemployment, and so forth. This is markedly different to measures applied to so called ‘economic growth’ such as **Gross Domestic Product (GDP)**. GDP for example is (essentially) the monetary value of all the goods and services produced within a nation’s borders and within a particular period of time, typically a year.

Consumer surplus – a measure of the welfare that people gain from consuming goods and services. It is surplus is defined as the difference between the total amount that consumers are willing and able to pay for a good or service (as indicated by a demand curve) and the total amount that they actually do pay (i.e. the market price).

Producer surplus – a measure of producer welfare. It is measured as the difference between what producers are willing and able to supply a good for and the price they actually receive.

2.2.1 Employment focused studies

Three employment-effect focused studies inform this work. The German and Australian examples here also provide estimates of potential economic benefits.

- A German study (Wydra, 2009) presents results from a modelling of potential development and diffusion of biotechnology. It focuses on the potential for tangible economic effects on production and employment. The analysis examines different diffusion paths for four biotechnology sub-sectors (Biopolymers, Bioethanol, Fine and specialty chemicals, Biopharmaceuticals). Combining and integrating bottom-up technology information from literature, expert judgements and explicit scenario assumptions for various impact factors in an input-output framework, the study delivers insights into direct and indirect production and employment effects across eight macro sectors. These being: agriculture; chemical industry; pharmaceuticals; capital goods; energy/water; ‘other industries’; construction and services.

- An Australian biofuels production study (Malik *et al*., 2014) investigates economic and employment consequences of the development of a new sugarcane-based biofuel industry. A hybrid IO-LCA (input–output life cycle assessment) approach is used to model the new industry based on experiences of the Brazilian biofuels economy. They utilize an approach, which involves inserting data on new processes and/or sectors into an existing national I/O table. Results are presented as changes in economic output and employment in the Australian economy.

- An EU-25 policy perspective is provided by Neuwahl *et al* (2008). This work compares the consequences of two different policy formats for the support of biofuels. Employment and economic effects were assessed in an input–output framework that considered bottom-up technology information (specifying biofuels activities) linked to partial equilibrium models for the agricultural and energy sectors. A range of flow on effects from transportation biofuels policy stimulation were considered – *inter alia*: additional demand for capital goods and agricultural feedstocks required to produce biofuels, higher fuel prices or reduced household budgets as a result of price subsidization, price effects flowing from (hypothetical) world oil price reductions related to fossil oil substitution and price impacts on agro-food commodities.

In addition to the above, a Brazilian analysis conducted by Scaramucci and Cunha (2007) was also examined and for completeness is recognised here. This work modelled the effects on the economy of Brazil if replacement of 5% of the world gasoline demand with ethanol from sugar cane produced in Brazil by the year 2025 were achieved. It concluded that this would increase Brazilian GDP by more than 11% and generate more than 5 million jobs.

While elements of the work such as the method are of interest, (e.g. they utilize an input–output model enriched with bottom-up technology specification), the direct and relatively transparent links between production figures and employment included in the preceding three studies described were not present. Beyond this brief summary and noting of the principal conclusion that supports generally 'positive' findings of other studies (i.e. that biofuel production has positive effects on GDP and employment) it was chosen not to further examine or dissect this work.

2.2.2 *Studies focused upon overall welfare across an economy*

Analyses for two countries that include overall welfare effects as a consideration support this discussion. The first (addressing the US) is the product of a considerable body of work rather than one modelling exercise.

- In the US, a series of analyses that examine biofuel policy formulation have been generated to provide insights into the relative worth of ethanol sector support to the US economy. In general welfare gains/losses are utilized with sectoral surpluses/losses to express results [(Lapan & Moschini, 2009) [11] (Moschini *et al*., 2010) [12] (Moschini *et al*., 2012)[13]] Specifically, they use open economy, multimarket equilibrium models that link world and US energy and agricultural markets to examine positive and normative implications of alternative policy instruments, including the subsidies and mandates specified by the 2007 Energy Independence and Security Act. The latter item provided important stimulus to US Biofuels. Consumer surpluses, producer surpluses, and consumer/producer losses across the economy are categorized within the following areas: fuel demand (consumers); corn supply (producers); petroleum by-product demand (consumers); corn demand (consumers); and oil supply (producers). These factors are then juxtaposed to tax revenues, pollution and overall social welfare.
- In a Spanish study (Santamaria & Azqueta, 2015) an effort is made to analyse the potential contribution of biofuels to reduce energy dependency; improve environmental quality and to stimulate economic activity and employment under the influence of national biofuel stimulation policies. Impact categories are measured in economic terms with a simple cost-benefit analysis. Three main impact categories are addressed: [i] environmental impact, including greenhouse gases and other regional and local pollutants; [ii] economic impact or potential stimulus for the national economy related to the new sector; and [iii] potential economic consequences of using biofuels to reduce Spanish energy dependency.

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[11] Lapan and Moschine (2009) present results are obtained from an open economy, multimarket equilibrium model that links world and domestic energy and agricultural markets, and explicitly accounts for the externalities of carbon emissions. These analyses assess the main welfare implications of US policies to support biofuels, with an emphasis on maize-based ethanol.

[12] Moschine, Cui, Lapan and Cooper (2010) examine both the positive and normative implications of alternative policy instruments, including the subsidies and mandates specified by the 2007 Energy Independence and Security Act. From a perspective assessing the function of policy alternatives, they find that biofuels mandates are equivalent to a combination of fuel taxes and biofuels subsidies that are revenue neutral. From a welfare perspective, their analysis shows that biofuels mandates dominate biofuels subsidies, and that combining fuel taxes (rather than subsidies) with mandates would enhance welfare conditions.

[13] Moschini e*t al* (2012) review several existing studies that have estimated the economic impacts of biofuels, presents modelling results, and outlines an appraisal of biofuel policies and the environmental impacts of biofuels.

3 INTERNATIONAL PERSPECTIVES AND METRICS

The results drawn from the desktop study in this project are presented in two chapters. This, the first, summarizes the general findings of the international studies examined. Where feasible, the data presented in those works are also utilized to generate indicative employment and/or financial metrics for the benefits derived from biofuels initiatives.

This chapter first follows up on the employment and welfare related studies introduced in Section 2.2; it then presents results from industrial studies of the socio-economic value of the US ethanol and biodiesel industries.

Chapter 4 of this report addresses studies and metrics derived from Swedish research efforts.

3.1 BIOFUELS EMPLOYMENT MODELLING

As noted in earlier in the report, national economies have many components, and also host a range of potentially competing interests. Although there are broadly held expectations that biofuels will contribute social and economic benefits to a country, and that new jobs will be an important evidence of this, it is also clearly recognized that this may not be the case. Jobs elsewhere in the economy can disappear, and it cannot be automatically presumed that 'overall' there will be more employment opportunities. This discussion examines this issue.

3.1.1 EU 25 scenario modelling (policy options and employment effects)

Neuwahl *et al* (2008) modelled potential employment consequences of policies aimed to support biofuels across the EU-25. One key motivation for the study was concern that policies to support biofuels in the EU had potential to negatively affect employment markets (recognizing the relative costs associated with policy interventions, the potential for such interventions to affect markets).

Two different policy-based financing schemes were assessed:

- Policy Business As Usual (BAU) that assumed tax exemption equivalent to the cost disadvantage of biofuels (subsidized biofuels); and
- Mandatory blending obligation, in which case the fuel prices at the filling station would increase as the extra cost is transferred to the consumer rather than billed to the taxpayer.

Employment effects were assessed in an input–output framework that considered bottom-up technologies related to biofuels activities. This was linked to partial equilibrium models for the agricultural and energy sectors. Flow on factors affected by policy stimulation of transportation biofuels in Europe included *inter alia*: additional demand for capital goods and agricultural feedstocks required to produce biofuels, higher fuel prices or reduced household budgets as a result of price subsidization, price effects flowing from (hypothetical) world oil price reductions related to fossil oil substitution and price impacts on agro-food commodities.

Details of the scenarios examined are included in Table 2.

Table 2. Scenarios applied in study.

Scenario	General description
Business as Usual (BAU)	6.9% total biofuels share, mostly first generation
PRIMES Hi Resolution 1st generation (PRIMES G1)	15.2% total biofuels share, with EU production mostly with first generation technology
PRIMES Hi Resolution 2nd generation (PRIMES G2)	15.2% total biofuels share, with EU production mostly with second generation technology
Green X least cost (GX-LC)	12.3% total biofuels share, with a larger share of imported biofuels.
Sensitivity[14]	In addition to the base simulation setting, four sensitivity runs were run on all scenarios, corresponding to the following assumptions: **Sensitivity run S1**: total results without exports of biofuels technologies; **Sensitivity run S2**: total results without crude oil price effects; **Sensitivity run S3**: total results without considering any price changes (except, in the case of the mandatory blending obligation policy option, the price of petrol and diesel); **Sensitivity run S4**: total results with vegetable oil price increase locked to the lower level experienced by oil seeds.

While this analysis clearly notes trade-offs (e.g. employment and welfare losses in other parts of the economy) their base case scenario[15] yielded some 100 000 additional jobs[16] across the EU-25, regardless of whether subsidies or fuel mandates are applied.[17] Further, the simulations suggest that biofuels targets of around 10–15 % could be achieved without adverse effects on net employment across the economies assessed. As such, the findings of the study were held to support the EC in proposing the Renewable Energy Roadmaps (cf. "2020 climate & energy package," 2017) mandatory target of 10 % biofuels substitution in 2020. It was also noted however, that the overall employment effects should be seen as modest when viewed against a base of 250 million jobs in the EU-25 (as of the year 2001).

[14] Depending on the scenario, on the financing scheme and on the conditions introduced by the sensitivity runs, the net effects switch sign form slightly positive from slightly negative. The predominance is however for positive net figures not only for moderate biofuels penetration scenarios (BAU, 6.9 % replacement share) but also for the scenarios assuming a high substitution rate (up to 15.2 %).
[15] BAU policy, 6.9 % biofuel content, displacement of 25 Mtoe imported crude oil from transportation markets, 80 % first generation biofuels.
[16] Figure 1 overleaf shows the average figures across the base sensitivity case for all four scenarios. These are lower; ranging from approximately 25 000–80 000 employment opportunities.
[17] A cross-check of the base figures for oil displacement in this scenario was performed within this work using Eurostat data. A calculation subtracting the consumption of Croatia, Romania and Bulgaria from the EU-28 data yields circa 356 Mtoe of fuel for the EU 25 at that time. For the base sensitivity case (% biofuels) used by Neuwahl this corresponds to 24.5 Mtoe biofuels (25 Mtoe in the scenario work).

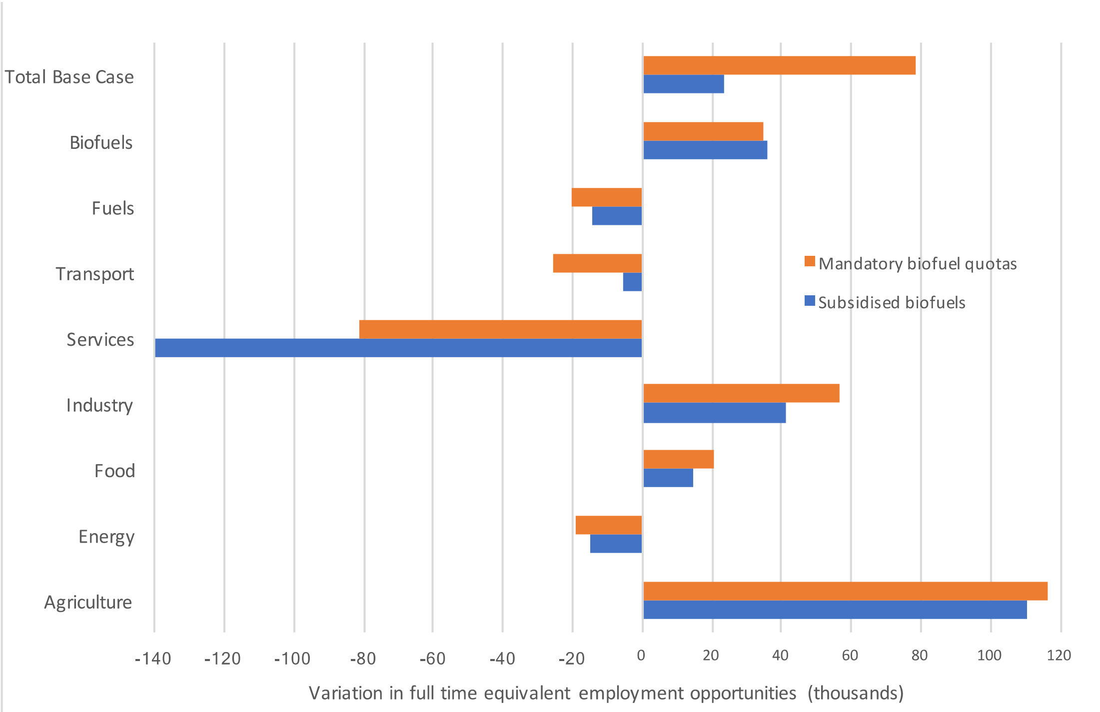

Figure 1. Employment impacts on eight aggregate sectors in the two alternative policy cases* (fuel subsidies and fuel mandates)[18] After Neuwahl *et al* (2008). Note that the 2009 EU Energy and Climate Change Package (CCP) (cf. "2020 climate & energy package," 2017) included a 10 percent minimum target for renewable energy consumed by the transport sector to be achieved by all EU member states (MS) in their countries in 2020. Many MS adopted minimum biofuel use mandates in order to achieve such goals (GAIN, 2016).

Table 3 shows, for the default policy case (subsidized biofuels), sectoral results aggregated to the eight macro sectors for the base simulation case. Table 4 reports the same figures for the alternative policy case in which non-subsidized mandatory biofuels blending obligations cause fuel prices to increase. While differences can be seen as marginal, results indicate that mandatory fuel quotas deliver more employment than subsidies. Most marked results are that there are many more jobs in agriculture, industry and the biofuels sector, and notably less jobs in the service sector.[19]

Table 3. Aggregate employment impacts (FTEs) for the four scenarios (subsidized biofuels). Note: See Table 2 for Scenario identifiers and abbreviations.

Scenario	**BAU**	**PRIMES G1**	**PRIMES G2**	**GRX-LC**
Agriculture	118 051	176 360	76 678	64 850
Energy	-2833	-15 672	-23 031	-19 441
Food	29 633	28 942	-1062	-3557
Industry	24 797	37 813	55 232	47 679
Services	-73 040	-171 899	-176 077	-138 786
Transport	-2078	-1103	-14 939	-4476
Fuels	-8967	-18 165	-18 666	-14 554
Biofuels	14 629	34 002	61 892	29 946
Total Base	**100 222**	**70 280**	**-39 974**	**-38 340**

[18] All results are for the base sensitivity case and averaged across the four scenarios.

[19] Rather than impacting a specific 'service', the authors indicate that this figure is large as the employment base in the 'service sectors' is very large, and many smaller sub sectors are affected in some way.

Table 4. Aggregate employment impacts (FTEs) for the four scenarios (non-subsidized mandatory biofuels blending obligation). Note: See Table 2 for Scenario identifiers and abbreviations.

Scenario	BAU	PRIMES G1	PRIMES G2	GRX-LC
Agriculture	121 217	186 853	83 170	72 189
Energy	-6487	-20 447	-27 868	-23 015
Food	31 668	37 774	-5853	-2748
Industry	26 299	62 240	72 161	65 564
Services	-85 114	-68 639	-104 370	-66 494
Transport	-15 952	-21 741	-42 104	-21 436
Fuels	-13 032	-25 756	-26 264	-20 571
Biofuels	14 201	32 154	59 186	28 977
Total Base	**72 799**	**182 438**	**-19 764**	**-37 961**

Overall, it is interpreted that this analysis indicates that at a 'continental scale' the impact of biofuels implementation from an employment point of view the effects seem to be positive, or at worst, quasi-neutral.

Calculations performed in this study indicate employment stimulation in the range of circa 0.35 FTE/GWh biofuel – as noted, employment intensity is discussed in more detail later in this report.

Table 5. Summary impact upon employment: including impact on other sectors.

	GWh	Net employment effects	Net (across economy) employment/GWh
EU 25	285 000	100 000	0,35

3.1.2 Germany scenario modelling (employment effects)

At a nation-state level, Wydra (2009) modelled potential developments in the Germany biotechnology field (including ethanol biofuel production as one of the items). The work was motivated by perceptions of a high potential for far-reaching (positive) social, environmental and economic impacts. This work focused on the development and diffusion of biotechnology and its potential for tangible economic effects on production and employment. The analysis examines the economic impacts of different diffusion paths of biotechnology (Biopolymers, Bioethanol, Fine and specialty chemicals, and Biopharmaceuticals) in a range of major application fields. The modelling effort combines and integrates bottom-up technology information from literature, expert judgements and explicit scenario assumptions for various impact factors in an input-output framework. Results yields insights into (potential) direct and indirect production and employment effects across eight macro sectors (agriculture; chemical industry; pharmaceuticals; capital goods; energy/water; 'other industries'; construction and services).

The Wydra study found that the impact on net production and employment differs greatly between the different application sectors and that the indirect economic effects (see Weisbrod & Weisbrod, (1997) for definitions) are rather high. Indeed, in some instances they can even exceed direct economic effects. Overall, it was projected that the impact on employment across the German economy would be generally positive for all biotech excepting fine and specialty chemicals. The substitution effects of bioethanol and biopolymers across the German economy were found to be highly favourable. Bioethanol was seen to significantly contribute to new jobs (almost 3000 for a reference scenario of 6 % fuel share, and 9300 for a high diffusion scenario of 14 %).

Calculations performed in this study indicate that the scenarios examined translate to a range of 0.4 to 0.7 net jobs per GWh of fuel produced.

Table 6. Summary impact upon employment and domestic product: including impact on other sectors.

	GWh	Net employment effects	Net (across economy) employment/GWh	Net production impacts (millions EUR)	RDP_EUR/GWh RDP_SEK/GWh*
Germany (FZID) Reference	6619	2 982	0,45	462	EUR 69 803 SEK 751 800
Germany (FZID) High Diffusion	12781	9 313	0,73	1 069	EUR 83 641 SEK 900 800

***All exchange rates taken mid-year 2009 (Oanda.com)**

3.1.3 Australia scenario modelling (employment effects and revenues)

Again at a national level, Malik *et al* (2014) created a simulation of the impact of a new biorefining industry in Australia. They investigated the economic and employment consequences of introducing a new sugarcane-based biofuel industry into the country. Australia has a well-developed and large sugarcane/sugar industry and as a consequence, expansion possibilities were modelled on the production format of the existing large-scale gasoalcohol and alcohol sectors in the Brazilian economy. The analysts utilized a hybrid IO-LCA (input–output life cycle assessment) approach, which involved the insertion of data on new processes and/or sectors into an existing IO table for the Australian economy.

After modelling changes in economic output and employment in the Australian economy, they concluded that a future biofuel industry will be employment-positive for Australia (circa +1400 jobs) and would result in a net positive result for the Australian economy of some 2.5 billion AUD. The dynamics in employment markets indicated by modelling are shown in Figure 2. Positive values indicate gains in employment, whereas negative numbers signify job losses.

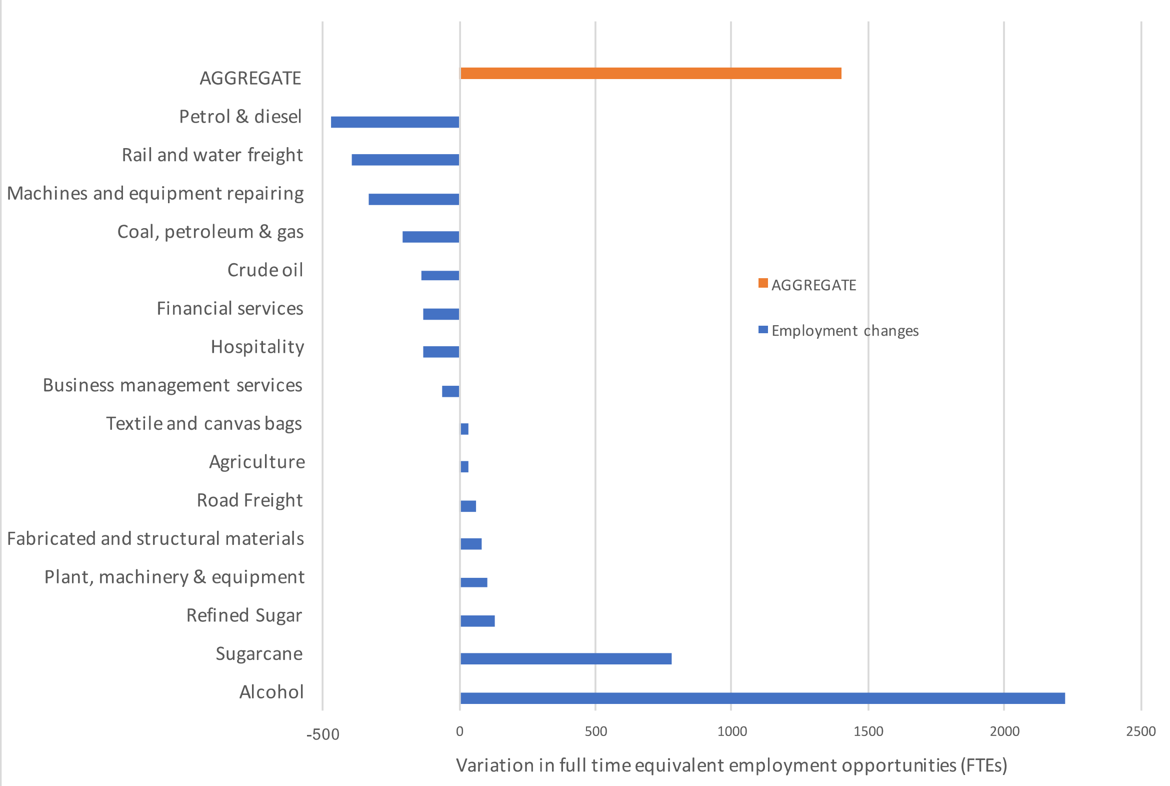

Figure 2. Bottom-and top-ranking sectors in terms of changes in their employment as a result of replacing petrol with alcohol. Derived from Malik *et al*. (2014) p. 90.

Again, as mentioned earlier, the relative quality and types of employment stimulation is also considered. Indeed, these analysts explicitly identify likely employment roles included in their work – these in turn being informed by Felix, Cardona and Quintero, (2007). To cite:

> *The alcohol sector requires personnel to set-up and operate the refinery. As the area of plantation increases, additional farmers, harvester operators and tractor drivers are needed in the sugarcane and agriculture sectors. The refined sugar sector needs skilled manpower such as operations managers, production engineers, quality control managers, laboratory staff and logistics workforce. Jobs for steel fabricators, design engineers and steel erectors are created in the fabricated and structural materials sector. Plant, machinery and equipment industries need mechanical and electrical engineers to manage the infrastructure of the alcohol refinery. More drivers and logistics staff are needed in the road freight sector to transport feedstock to an alcohol refinery*.

Calculations performed in this study indicate that this scenario translates to circa 0.12 net jobs per GWh of fuel produced (See Table 7 overleaf). While indicating a lower potential employment impact across the economy than the EU-wide and German base-case modelling efforts (0.35 and 0.44 net jobs per GWh of fuel produced respectively), the indicated economic yield to the national economy (143 000 AUD, corresponding to 99 000 EUR) is similar to the German figure.

As a crosscheck of scale relevance, the volumes of ethanol modelled in this study were also compared to the national consumption of transportation fuels in Australia to ensure that they matched reasonable expectations of market demand for ethanol fuels. In scenario developments for transportation fuels produced by Graham, Reedman and Poldy (2008) the consumption of gasoline in

Australia[20] lies at circa 167 TWh (600 PJ petrol, 400 PJ diesel). As such, the 12 TWh production modelled in this study represents a replacement of some 7 % of domestic gasoline. While current ethanol utilization in Australian gasoline mixes is low (<25 PJ), E10 petrol is widely available in several Australian states. Thus, the scale and modelled penetration of fuels in this study does not appear unrealistic.

Another item of relevance to this analysis is the Australian study explicitly highlights the low employment intensity of the Australian oil industry (0.42 FTE/million AUD for oil products). In comparison to the values for oil, the study yields values that demonstrate the marked differences of job intensity of biofuels versus fossil fuels.

If the value of ethanol on international markets is calculated (at USD 0.5 per litre), this translates to approximately 19.5 FTE/million AUD ethanol produced.[21] If one assesses net figures across the economy (including losses in other sectors such as oil and its supply chains), this yields circa 1.3 FTE_{direct}/million AUD for alcohol production, plus an additional 0.45 FTE_{direct}/million AUD for additional sugarcane production activities required to supply that industry.

Table 7. Summary impact upon employment and domestic product: including impact on other sectors.

	GWh	Net employment effects	Net (across economy) FTE/GWh	Net (Ethanol + Sugarcane) FTE/GWh	Net production impacts (million AUD)	RDP/GWh (AUD, EUR, SEK)*
Australia Ethanol Biorefinery	12 000	1402	0.116	0.25	AUD 1 710 AUD	142 800 AUD 99 100 EUR 889 600 SEK

***All exchange rates taken mid-year 2014 (Oanda.com)**

3.2 BIOFUELS WELFARE MODELLING

The most significant items found in this category are absolutely the US based studies by Researchers from Iowa State University and the Economic Research Service, of the US Department of Agriculture. Three studies from this group are addressed here (Lapan & Moschini, 2009; Moschini *et al.*, 2012, 2010) from figure. These analysts have studied both positive and normative implications of alternative policy instruments, including the subsidies and mandates specified by the 2007 Energy Independence and Security Act – and in a number of ways related them to overall welfare generation in the US. While welfare issues are implicit in (and can be inferred from) the three studies addressed in the preceding section, they are not explicitly addressed. Only one other study found in the literature review for this work explicitly includes welfare assessments in its findings. However, this Spanish study (Santamaria & Azqueta, 2015) has key focus on policies demanding biofuel consumption (with some biofuels production) as distinct from policies stimulating domestic biofuels production.

[20] Estimates are generated using information from Figure 2.

[21] This figure is calculated (normalized for comparison) using a figure of 1.2 TWh ethanol production (circa $2.1x10^8$ liters). If this is valued at 0.5 USD/liter, then in turn it indicates a production value of some 103.7 million USD for the year 2014. At an indicative average 2014 exchange rate of 1.099, this yields 114 million AUD. 2223 FTEs in ethanol yields 19.5 FTEs/million AUD.

3.2.1 US studies

A series of analyses have examined biofuel policy formulation for the US. Foremost among these are works by Moschini and co-authors. This work was largely stimulated by the unprecedented changes to the agricultural production systems for maize in the US arising from varying, and escalating, policy support for bioethanol in the period post 2003 (a detail timeline of US biofuels support is provided in Grönkvist *et al*., (2013). As the most drastic increases resulted from policy instruments related to the subsidies and mandates specified by the 2007 Energy Independence and Security Act, their principal focus has been upon these interventions. In a number of ways, they have related them to overall welfare generation in the US.

As policy analysts, much of the Moschini analytical effort has been directed towards assessment of which types of policy intervention would have been better than the status quo (e.g. yielding findings such as ‘mandates better than subsidies’, and ‘a carbon tax better than subsidies or mandates’). Contributions to overall national welfare are in essence only a metric with which to measure different options against each other. In this light, their works indicates, that from a welfare perspective, biofuels mandates dominate biofuels subsidies, and that combining fuel taxes (rather than subsidies) with mandates would increase overall welfare. Important for this study however, is that their assessments indicate that the current status quo policy support regimes deliver overall social welfare to US society (despite being sub-optimal support regimes according to their analysis).

The modelling work from such studies help to cast light on the manner in which biofuels production (in these modelling efforts, under the stimulation of policy intervention) results in pluses and minuses across the economy (expressed as welfare). Figure 3 below shows how the incumbent 2010 ethanol subsidy regime in the US results in a net welfare benefit of (+12.3 billion USD), across the US economy. However, it also indicates where losses can accrue. If this is related to the 2010 production of ethanol in the US (circa 304 TWh) (Grönkvist *et al*., 2013), this indicates a net gain to the US economy of some 40 000 USD/GWh.

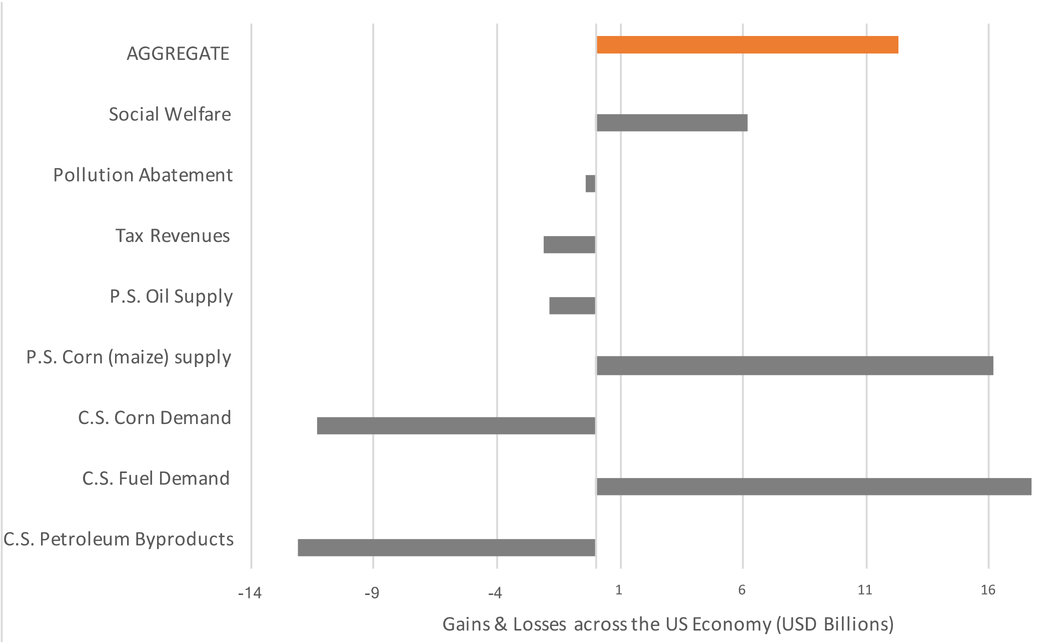

Figure 3. Welfare effects of US ethanol support policies measured against no policy support. Source: after Moschini *et al* (2012). Note: C.S. denotes 'Consumer Surplus'; P.S. denotes 'Producer Surplus'.

Gains and losses were presented as [a fuel demand consumer surplus[22] (+17.1 billion USD), a corn supply producer surplus[23] (16.1 billion USD) and a social welfare gain (6.2 billion USD)] that were indicated to outweigh a [petroleum by-product demand consumer loss (-12.1 billion USD), a corn demand consumer loss (-11.3 billion USD) an oil supply producer loss (-1.9 billion USD) a tax revenue loss (-2.1 billion USD) and a pollution abatement loss (-0.4 billion USD)]

3.2.2 Spanish assessment of environment, economic activity and national welfare

In recognition that support for renewable energy is usually justified in terms of its contribution to reducing energy dependency; greenhouse gas emissions reduction; an improvement in environmental quality and a stimulation of economic activity and employment, a Spanish study (Santamaria & Azqueta, 2015) delivered a cost-benefit analysis to assess the effects of biofuel promotion policies in Spain. This study apparently departed with negative expectations indicating that the authors recognized as *potentially negative impacts revealed from their* [biofuels] *production on a large scale.*

With the analysis scoped at the national level, the study seeks to cover three main impact categories: [i] the environmental impact, including not only the greenhouse gases but also other kind of regional and local pollutants; [ii] the economic impact or potential stimulus for the national economic activity derived from a new productive sector; and [iii] the potential consequences on the economy derived from using biofuels to reduce the Spanish energy dependency.

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[22] Consumer surplus is a measure of the welfare that people gain from consuming goods and services. It is surplus is defined as the difference between the total amount that consumers are willing and able to pay for a good or service (indicated by the demand curve) and the total amount that they actually do pay (i.e. the market price).

[23] Producer surplus is a measure of **producer welfare**. It is measured as the difference between what producers are willing and able to supply a good for and the price they actually receive.

The work utilized the Input–Output Table for Spain of 2009 as provided by the World Input–Output Database, WIOD) (Banse, Van Meijl, Tabeau, & Woljter, 2008) and substitution effects were evaluated by assessing the reduction in final consumption derived from the incremental cost of biofuels.

Viewed from an environmental point, the study indicates that biofuel utilization has a positive impact on environmental quality, mainly due to the reduction of greenhouse gases, SO_2 and particulate matter emissions. In contrast, analysing the whole effect on the economy, the use of biofuels is displacing income from other economic sectors, resulting in a net negative impact. In terms of energy dependency, the study finds that biofuels do not significantly contribute to reduce the risk of supply disruptions nor the impact on the economy derived from increases in fuel prices.

According to the authors, the results obtained for Spain are of the same order of magnitude of those obtained at the EU level by Neuwahl *et al* (2008) (see Section 3.1.1). Among the studies addressed in this discussion, the Neuwahl study appears that which is most comparable – as both these works assess the impacts of complying demands to increase the proportion of renewable transportation fuels – as distinct from building a renewables fuel production capacity to do so. While both studies do include domestic production, significant proportions of feedstock, and finished fuel, may be imported from abroad. However, while the Neuwahl study for the EU indicates neutral or generally positive impacts upon economies, the Spanish case indicated that the whole Spanish economy would experience a decline in national income. Note that this is quite a different context than presented by the German study (Section 3.1.2), and the Australian study (Section 3.1.3) where impacts of domestic production are assessed. The German study includes some feedstock import, while the Australian study examines a wholly domestic value chain.

The Spanish authors indicate that their negative results are mainly due to the shift in demand towards sectors from those with high added value to those with low added value. Results (cf. figure 8 in Santamaria & Azqueta, 2015, p. 1421) indicate an overall loss of circa 40 EUR per tonne of oil equivalent biofuel consumption – or an average of around 400 million EUR per year over the period 2008–2020. It is apparent in the work that (positive) direct and indirect socio-economic impacts induced by biofuels production are limited because both most raw materials used for domestic biofuel production, and a significant portion of biofuels are imported.

Apparently as a result of biofuel import dependency for the Spanish context, the use of biofuels displaces income from other sectors, and results in a net negative impact on the economy. Further, the strategy modelled for Spain does not contribute to improved energy security. The scale of import results in a situation where that biofuels do not significantly to reduce risk of supply disruptions or the impact on the economy derived from increases in fossil fuel prices. Rather, this strategy could even increase this impact. Overall, the study indicates that introduction of mandatory targets of biofuel consumption along the time frame of 2008–2020, based on the feedstock and biofuel import balances included in the modelling, could result in a welfare loss for the Spanish society.

The study does not however cast light on whether distinct domestic activities to produce biofuels (with or without domestic feedstock supply) would result in the welfare gains indicated by other studies.

3.3 BIOFUEL STUDIES FROM THE UNITED STATES (INDUSTRY DATA)

In the time since circa 2001, the production of biofuels in the US has grown rapidly. As Figure 4 indicates, a steady trend in ethanol consumption in the US rapidly escalated from 2001, while biodiesel consumption rapidly increased from circa 2005. The US production of biofuels essentially matched these consumption trends with strong support from US policy stimuli (Grönkvist *et al*., 2013).

It was not until recent years however; that sector wide analyses that provide an overview of socio-economic impacts of such expansion focused on the production side became available. Two such studies are presented here. Industry interests produced both and neither is (openly) peer reviewed, however presentation of these results is useful as it provides for comparison against Swedish addressed in Section 4.2. The US studies are primarily focused upon direct, indirect and induced benefits delivered to host sub-regions (via employment stimulation, business revenues, business stimulation, etc.); and upon taxation revenues delivered at local, state and federal levels. No explicit recognition of macroeconomic trade-offs (as discussed in Section 2.2) is made in these studies. Considerable effort has been expended in this work to convert the US data to comparable (metric) units, and to run crosschecks against key metrics presented in the reports in order to establish validity.[24]

[24] Without insights to the detail of modelling inputs, difficulty was experienced in a number of instances in establishing where boundaries of direct business revenues, direct employment opportunities (FTEs), etc. were made (e.g. from indirect and induced items, and from different portions of the value chain outside the biofuel production facility). Seeking to avoid misleading information in this discussion, cross checks were performed to ensure that interpretation of the source material was correct. As one example, gross production figures for ethanol and DDGS were multiplied by indicative international market prices in order to establish the likely business revenues of operations. These numbers could then be compared to the quoted numbers for the business revenues included in reports in reports to establish whether farming revenues, or supplier revenues appeared to be included.

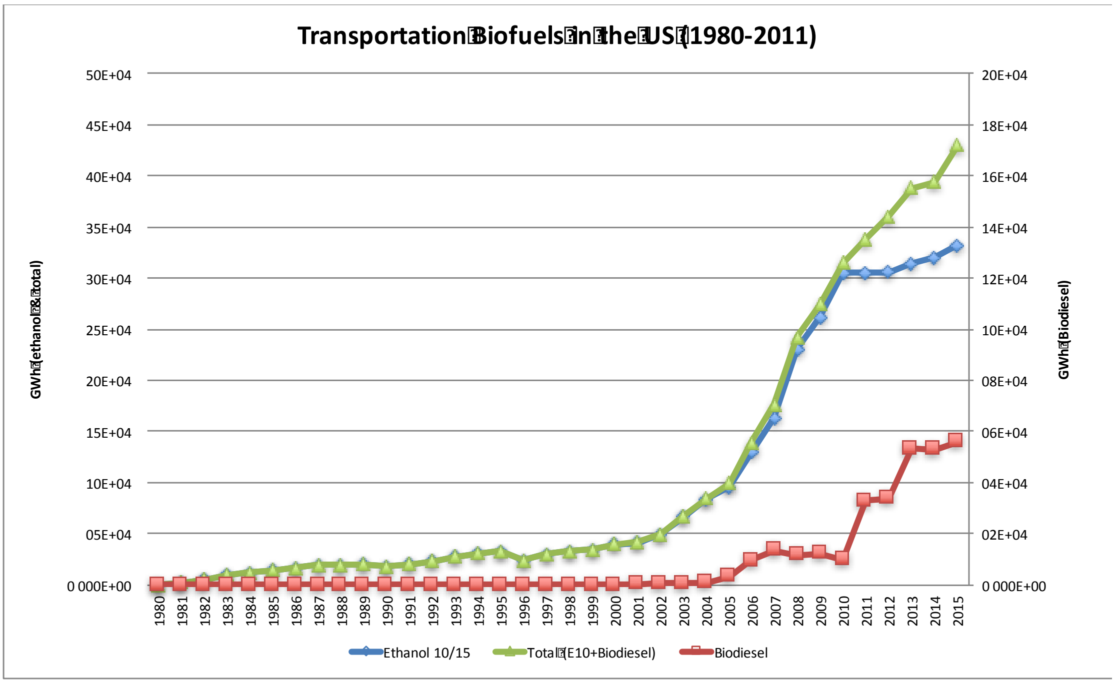

Figure 4. Development of US transport biofuel consumption. Data sources: DOE/EIA Monthly Energy Reviews Dec. 2012, Dec 2016 (cf. https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf). Note: Biodiesel alone is represented on the right-hand axis. Ethanol and total biofuel consumption are related to the left-hand axis.

3.3.1 Maize ethanol production (POET)

Headquartered in South Dakota, POET is a privately held U.S. company and is a vertically integrated ethanol producer. The company designs, constructs and operates 27 ethanol refineries in seven states throughout the U.S.: South Dakota, Minnesota, Iowa, Missouri, Indiana, Ohio, and Michigan. Presumably seeking recognition that POET provides jobs and income not only for people who work at the plants, but also for businesses that sell ethanol plants supplies, and U.S. farmers that produce the maize feedstock, the company commissioned a study to delineate such benefits. A detailed report on the economic contribution of POET biofuels production on national and state economies was published in August 2015 (Urbanchuk & Norvell, 2015).

The impact of POET operations on the national and state economies was estimated by creating and applying economic impact models with a commercially available economic modelling tool Impact Analysis for Planning (IMPLAN Pro) software and datasets (http://www.implan.com/software/). IMPLAN is a commonly used economic input-output (I-O) model in the US. It combines a set of databases addressing economic factors, multipliers, and demographic statistics with a modeling software. The model allows the user to develop local-level input-output models to estimate the economic impact of new economic activities. Work requires identification of direct impacts by sector, then develops a set of indirect and induced impacts by sector through the use of industry-specific multipliers, local purchase coefficients, income-to-output ratios, and other factors and relationships.

The ABF study presented a range of economic indicators that describe the contribution of POET including:

- Business revenues;

- Gross Domestic Product (GDP) – encompassing corporate income, household earnings and other types of income or profits;
- Households earnings representing wages, salaries and income for self-employed individuals;
- Employment (number of full time job equivalents FTEs); and,
- State, local and federal tax revenues.

Within the study a model of the U.S. and each state economy focusing on the sectors that support the ethanol industry was created. For this analysis, ABF constructed a model to estimate economic impacts of the ethanol industry, incorporating Bureau of Economic Analysis (BEA) Benchmark input-output (I-O) tables released in 2014, and data from the latest BEA Regional Economic Accounts, the 2012 Economic Census, and the 2012 Census of Agriculture, also released in 2014.

The analysis indicates that at the national level in 2014, POET spent approximately USD3.1 billion on raw materials (mostly maize), and other goods and services to produce some 6.4 Mm^3 or 35.3 TWh of ethanol (1.7 billion gallons) and a range of primary co-products – these principally being animal feed DDGS (distiller's dried grains with solubles) and corn refiner oil (maize oil).

Key metrics outlined in the report include (for 2014):

- stimulation of some 13.5 billion USD in sales for U.S. businesses (this includes values along the full value chain, POET sales being estimated at some 4.3 billion USD in this study[25]);
- circa 5.4 billion USD contribution to national GDP;
- approximately 3.1 billion USD contribution to U.S. household income;
- a total of some 39 000 FTE employment opportunities;
- contribution in excess of 450 million USD to state and local government tax rolls, and 1.5 billion USD in federal taxes annually.

Normalized results from the POET study are summarized and presented in Tables 8 to 11.

Table 8. US ethanol production: examples of total employment effects (POET).

	GWh	Total Employment (direct, indirect & induced, full value chain)	Total bioETHANOL employment/GWh
POET USA (27 plants)	35265	39 378	1,1
POET Iowa (largest)	9222	6 178	0,7
POET Indiana (most jobs/unit)	6620	5 327	0,8
POET Michigan (smallest)	1103	1 086	1,0

[25] In addition to cross checking modelling results published in the report, an examination of international markets for 2014 was conducted in order to increase confidence in figures included in the POET report. For example, ethanol prices for 2014 were some 2.45 USD/gallon (FOB Omaha). Production for POET of 1.694 billion gallons indicates some 4.15 billion USD in revenue from ethanol. The other major volume product from ethanol refining is DDGS. Prices typically have lain at around 200 USD/metric tonne, but in 2014 were as low as half of this. For POETs production levels, a factory gate price would yield some 1 billion USD in revenue. As such, the figures provided in the report can be correlated with market prices at the time. See: http://www.fapri.iastate.edu/outlook/2012/tables/5-biofuels.pdf as one example.

Table 9. US ethanol production: employment intensities (POET).

	Direct Employment	Direct FTE jobs/GWh	Indirect Employment	Induced Employment
POET USA (27 plants)	1594	0,0452	21781	16002
POET Iowa (largest)	357	0,0387	3902	1920
POET Indiana (most jobs/unit)	167	0,0252	3832	1328
POET Michigan (smallest)	42	0,0381	790	254

Table 10. US ethanol production: revenues and domestic product (POET)

	Business Revenues (ethanol) (USD million)	Business revenues (ethanol D+ID+In) (USD million)	Regional Domestic Product (USD million)	Rev_USD/GWh (direct)	Rev_USD/GWh (direct + indirect + induced)	RDP_USD/GWh (direct + indirect + induced)
POET USA (27 plants)	4 342+	6 085	5391	123 100	172 600	152 900
POET Iowa (largest)	1 158*	1 624	843x	125 600	176 000	91 500
POET Indiana (most jobs/unit)	828*	1 161	555x	125 100	175 400	83 900
POET Michigan (smallest)	146*	205	95x	132 500	185 700	86 300

+ *Counting only business revenues from ethanol production sites (i.e. primarily ethanol, DDGS, and corn oil)*

* *Contribution estimated by relative share of business revenue (Exhibit 1) Iowa 26.7%, Indiana 19.1%, Michigan 3.4% of business revenues*

x *State level domestic product*

Table 11. Key economic figures from POET report – Economic impacts of operations [source: ABF Economics in (Urbanchuk & Norvell, 2015)].

State	Business Revenues (USD million)	Gross Domestic Product (state level) (USD million)	Employment (FTE jobs)	Household earnings (USD million)	State and local taxes (USD million)
South Dakota	2052.0	636.3	4553	384.4	38.4
Iowa	2694.2	843.4	6178	433.7	58.1
Minnesota	1064.4	376.9	3039	234.8	26.2
Indiana	1926.7	555.3	5327	324.4	31.1
Missouri	649.5	174.6	2356	98.7	10.1
Ohio	1370.5	412.1	4520	228.2	25.7
Michigan	339.9	95.2	1086	57.5	6.7

Table 12. Key economic figures from POET report – economic contribution to the US Economy in 2014 Source: After (Urbanchuk & Norvell, 2015)[26].

	Gross Output (USD million)	Gross Domestic Product (USD million)	Employment (FTE jobs)	Household Earnings (USD million)
Ethanol Production				
Direct	4341.5	1307.1	1594	824.9
Indirect	1264.7	571.5	2567	250.2
Induced	479.1	713.1	7386	407.9
Total (ethanol)	**6085.3**	**2591.6**	**11 548**	**1483.0**
Agriculture				
Direct	5845.0	843.4	6178	58.1
Induced	1503.9	555.3	5327	31.1
Total (agricult.)	**649.5**	**174.6**	**2356**	**10.1**
Biofuels R&D				
Direct	14.2	12.8	122	8.8
Induced	9.4	5.5	59	3.1
Total (R&D)	**23.7**	**18.3**	**181**	**11.9**
Total Impact				
Direct	4341.5	1307.1	1594	824.9
Indirect	7124.0	2534.7	21 781	1358.4
Induced	1992.4	1549.1	16 002	883.3
Grand Total	**13 457.8**	**5390.8**	**39 378**	**3066.5**
State and Local Tax Revenues	**464.6**			
Federal Tax Revenues	**1474.7**			

[26] Details within this study are difficult to reconcile in a number of areas, and thus should be used with care. As examples of initial 'estimate' cross checks for the above tabulation: the farm gate value of Maize is approximately 2.5 billion USD based on commodity prices for 2013, while the sale value of ethanol is approximately 0.5 USD/L on 6.41 billion litres (circa 2 USD/gallon), while DDGS yields approximately 0.25 USD/$L_{ethanol}$ (this being revenue yield component, not price per litre of DDGS, thus indicating circa 4.8 billion USD total revenue) Such figures then need to be reconciled against tabulated values of the direct output of ethanol production = 4.34 billion USD. Direct employment in POET plants is 1594 FTEs for that period.

Table 13. US ethanol production: tax revenues & energy security (POET).

	Household Earnings USD & USD/GWh	State/Local Tax USD & USD/GWh	Energy Security (USD /GWh)
POET USA (27 plants)	3 066 500 000 86 900/GWh	464 600 000 13 000/GWh	155 963
POET Iowa (largest)	433 700 000 47 000/GWh	58 100 000 6 300/GWh	
POET Indiana (most jobs/unit)	324 400 000 49 000/GWh	31 100 000 4 700/GWh	
POET Michigan (smallest)	57 500 000 52 200/GWh	6 700 000 6 000/GWh	

3.3.2 Biodiesel (National Biodiesel Board)

In 2012, the US National Biodiesel Board (NBB),[27] contracted international consultants LMC International to produce an assessment (LMC International, 2013) of their industry's contribution to the US economy. LMC offers consultancy services to organizations working with agricultural commodities, biofuels, foods and industrial materials, and their end-use markets.

The work further develops existing 'rules of thumb' in the industry (LMC International, 2013). A first is that a 'typical'[28] biodiesel facility in the U.S. [i.e. with an average annual fuel production capacity of 1450 – 2176 GWh/yr (40-60 million US gallons/yr)] would directly employ between 40 and 50 people; thus circa 0.025 FTE_{direct}/GWh; or alternatively 25 FTE_{direct}/TWh biodiesel fuel delivered.

A second 'rule of thumb' stated in the work, is that biodiesel production facilities, plus those industries that support their operation, contribute circa 25 % of the biodiesel value-chain's total worth. The LMC report indicates that for 2012, this was around 3 billion USD across the U.S. economy.

In the LMC study, the impact of the biodiesel industry on the U.S. economy, employment, and wages is examined with results addressing three metrics:

- economy – quantifying the value added to the U.S. economy across the biodiesel value chain;
- employment – estimating the number of FTE (full-time equivalent) jobs contributed by biodiesel production, processing, and distribution;
- Wages impact – evaluating the total wages for individuals employed along the biodiesel value chain.

In addition to quantifying the impacts of the burgeoning biodiesel industry on the U.S. economy, the work also communicates estimates of environmental benefit provided by greenhouse gas emission reduction.

While the work generally yields metrics that are comparable to the ethanol assessment presented in the previous section, the study has a number of methodological differences. Rather than an active

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[27] The national trade association representing the biodiesel industry in the U.S. See: http://biodiesel.org
[28] LMC note however that there is considerable variation across the capacity and staffing rates of the country's more than 100 operational facilities.

modelling assessment, it will be described here as a quasi-modelling assessment. The work apparently uses bottom up data compilation for direct impacts[29] (e.g. applying estimates for business revenues, employment, wages, etc. collected from the U.S. biodiesel sector) to yield estimates of indirect and induced impacts[30] using generic industry multipliers and manual calculation (e.g. with indices from the U.S. Department of Commerce)[31]. This work in applied to 11 distinct activities along the biofuel value chain (see Exhibit 4).

Exhibit 3 presents the most important multipliers used in the LMC study, along with the industry classification NAICS code (North American Industry Classification System). These multipliers were applied to the manually calculated direct effects to capture indirect and induced effects. This study has also back-calculated to yield direct employment figures for a) the full value chain, and b) for only refining, in order to increase the comparability of this work to other studies cited in the report.[32]

Table 14. Input-output multipliers for biodiesel production activities NBB analysis 2012 (From Table 5, p. 11 LMC International, 2013).

	Direct + Indirect			Direct + Indirect + Induced		
NAICS* activity	Economic	Employment	Wage	Economic	Employment	Wage
Crushing	2.02	3.48	2.73	2.38	4.84	3.61
Refining	1.93	2.80	2.60	2.28	4.03	3.44
Rail Transport	1.49	2.45	1.83	1.87	3.78	2.41
Oilseed Farming	1.63	2.27	2.18	1.93	2.90	2.88
Trucking	1.52	1.69	1.61	2.05	2.33	2.12
Animal Processing	1.94	2.56	2.58	2.28	3.44	3.40

** North American Industry Classification System (managed by the US Census Bureau).*

[29] Direct effects were calculated based on models driven by publicly and privately available data, industry knowledge, and interviews with industry stakeholders.
[30] Following standard practice, indirect effects are the economic, employment, and wage impacts created by those industries that supply the biodiesel value chain, or by individuals who work at the periphery of the sector; while induced effects are those economic, employment, and wage impacts that stem from household spending of the income earned from the biodiesel sector.
[31] Input-output tables and economic multipliers multipliers are sourced from the U.S. Department of Commerce's Bureau of Economic Analysis and encompass 406 detailed industries.
[32] As for ethanol, an examination of international markets for 2014 (as compared to the LMC report content) was conducted in order to increase confidence in the report results. For 2012, a biodiesel (at plant) price of 4.84 USD/Gallon appears to be representative (see: http://www.fapri.iastate.edu/outlook/2012/tables/5-biofuels.pdf). A production of 1.05 billion gallons would thus be anticipated to yield circa 5 billion USD in revenues. Utilizing the direct multipliers listed in Exhibit 3, one would expect an economic multiplier of slightly less than 2. As such, the figure of 9.8 billion USD for economic impact of supply chain activities that appears in Table 16 appears appropriate.

Table 15. US Biodiesel: Total employment intensities.

	Gallons	GWh	Total Employment (FTEs)	Total bioDIESEL employment/GWh
2012 -- US BIODIESEL: LMC study for NBB	1.05 billion	38 087	46 900	**1,231**
	Assumed only biodiesel processing is DIRECT employment			
2013-Projection --US BIODIESEL: LMC study for NBB	1.70 billion	61 664	62 200	**1,009**

Table 16. US biodiesel: direct employment intensities.

	Total economic impact of supply chain activities	Revenue USD/GWh (full supply chain)	Direct FTEs in full value chain[33]	Direct FTEs in biodiesel refining	Estimated Direct FTE refining/GWh	Estimated Direct FTE full chain/GWh
2012 -- US BIODIESEL: LMC study for NBB	USD 9 740 million	USD 255 733	46 900/ 3.39 multiplier[+]	13 300/ 4.03 multiplier*	**0,087**	**0.363**
2013-Projection -- US BIODIESEL: LMC study for NBB	USD 16 780 million	USD 272 120	62 200 / 3.39 multiplier	14 800/ 4.03 multiplier	**0,060**	**0.298**

* The direct employment has been estimated by dividing by the refining stage multiplier taken from Exhibit 3.
[+] A weighted average of multipliers was calculated to enable estimation of direct FTEs in the full value chain. Values for crushing, refining, rail transport, farming, trucking and animal processing were multiplied by their relative share of total employment taken from Exhibit 5, then summed to form an aggregate multiplier.

[33] In order to increase comparability with Swedish studies of employment intensity, it has been chosen to include only specific portions of the biodiesel value chain detailed in the US report by LMC (2013). The assumptions and alterations to metrics made are detailed in table annotations.

Table 17. Actual and Projected Economic Impact of US biodiesel: NBB analysis 2012 (USD billions) (from Table 2, p. 6, LMC International, 2013).

	Actual		Projections
	2011	**2012**	**2013 & 2014***
Seed production	5.26	5.35	10.22
Animal processing	-	-	-
Seed delivery	0.07	0.07	0.13
Elevation	0.30	0.26	0.50
Oilseed crush (oil share)	1.44	0.82	1.13
Biodiesel processing	2.69	3.03	4.38
Rail deliveries: biodiesel & glycerine for domestic market	0.10	0.1.	0.22
Rail deliveries: biodiesel for export market	0.04	0.04	0.08
Barge deliveries	0.00	0.00	0.01
Port activities	0.00	0.00	0.01
Trucking to point of sale	0.06	0.06	0.11
Total	**9.96**	**9.74**	**16.78**
Gallons produced (Billions)	1.07	1.05	1.70*
GWh biodiesel fuel produced	38.8	38.1	61.7*

** While biodiesel production did grow significantly during 2013, these projected figures did not eventuate. Actual 2012 to 2014 figures available at the US Energy Information Administration (2014) indicate 1.359 billion gallons or ca. 49 TWh in 2013; 1.269 billion gallons or ca. 46 TWh in 2014). The figures drawn from the LMC International report have been left in this table as examples only.*

Table 18. Employment impact of US biodiesel on the US Economy: NBB analysis 2012 (from Table 3, p. 7 LMC International, 2013).

	Actual		Projections
	2011	2012	2013 & 2014*
Seed production	12 800	15 800	24 500
Animal processing	11 700	10 600	13 500
Seed delivery	400	500	800
Elevation	1100	1300	2000
Oilseed crush (oil share)	4700	3800	3800
Biodiesel processing	15 500	13 300	14 800
Rail deliveries: biodiesel & glycerine for domestic market	500	700	1000
Rail deliveries: biodiesel for export market	100	100	200
Barge deliveries	100	100	100
Port activities	100	100	100
Trucking to point of sale	400	600	1400
Total	**47 400**	**46 900**	**62 200**
Gallons produced (Billions)	1.07	1.05	1.70*
GWh biodiesel fuel produced (TWh)	38.8	38.1	61.7*

** See comments for Table 17.*

4 DEVELOPING METRICS FOR SWEDISH BIOFUELS

This chapter presents details from a suite of Swedish studies that evaluate benefits associated with biofuels production and use. A number of areas are addressed. First, a very brief overview of the development of Swedish transportation biofuel consumption is provided. This addresses the three significant biofuels used in the Swedish market – biodiesel (both FAME and HVO), ethanol and biogas. Section 4.2 then provides background to Swedish metrics and quantifications relevant to this report, starting with a short overview of early assessments and 'rules of thumb' figures related to biofuels. This is followed by information that places the valuation of carbon emissions in Sweden in an international perspective; an overview of values placed on pollution reduction delivered by biofuels production and utilisation; and a detail example of co-benefit valuation related to biogas.

As regional biogas projects have been the focus of detail assessments of socio-economic benefit in Sweden, section 4.3 is used to provide summaries of four such evaluations. Details of studies from Skåne, Östra Götaland, Västra Götaland and Norrbotten/Västerbotten have been translated and summarised. The final subsection presents some (limited) details of metrics associated with two leading Swedish biodiesel and ethanol production facilities.

4.1 DEVELOPMENT OF BIOFUEL CONSUMPTION IN SWEDEN

Transportation biofuel consumption has increased rapidly in Sweden in the period since 2005, when biodiesel volumes began a rapid expansion. Figure 5 displays consumption trends for biodiesel, ethanol and vehicle biogas. While this discussion does not seek to go into depth regarding the underlying policy, social, and technical dynamics underlying these trends, a brief discussion of feedstock supply sources is included. Domestic feedstock supply is perceived as a salient issue for this analysis as supply chain activities are anticipated to have direct implications for job creation and economic benefit accrual (the focus of this work).

Figure 6 presents biogas at greater resolution and includes the trend for domestic production. This in recognition of the fact that the majority of biogas used in the Swedish transportation sector is derived from feedstocks of domestic origin, a situation markedly different from liquid biofuels where significant portions of both feedstock and fuels are imported.

As can be seen in Figure 5, ethanol expansion began in earnest at the turn of the century and grew until circa 2008. Since that time the ethanol fuel consumption has stagnated and then declined steadily (from 2010). Underlying reasons for this decline are held to involve a complex and interlinked mix of environmental and economic factors – all in turn influenced by policy, the media, and competing vehicle options (see for example: Sprei (2013) and Andersson, Ek, Kastensson & Wårell (2016)). Further discussion of this topic however, lies beyond the scope of this work.

Biodiesel consumption in contrast grew steadily from 2005 until 2010, and since then has grown rapidly – by 2016 biodiesel accounted for nearly one quarter of the diesel fuel utilised in the country (Swedish Energy Agency, 2017). Biodiesel includes Hydrogenated Vegetable Oils (HVO) and Fatty Acid Methyl Esters (FAME). In 2016, the Swedish Energy Agency (2017) reported that slightly more than 1.22 million m^3 HVO and 0.32 million m^3 FAME were used in Sweden.

HVO feedstocks include tall oil from the pulp sector, recycled vegetable oils and animal fats. Increasing volumes of HVO feedstock are sourced from certified palm oil plantations (Swedish Energy Agency, 2017). Swedish FAME is mainly derived from rapeseed.

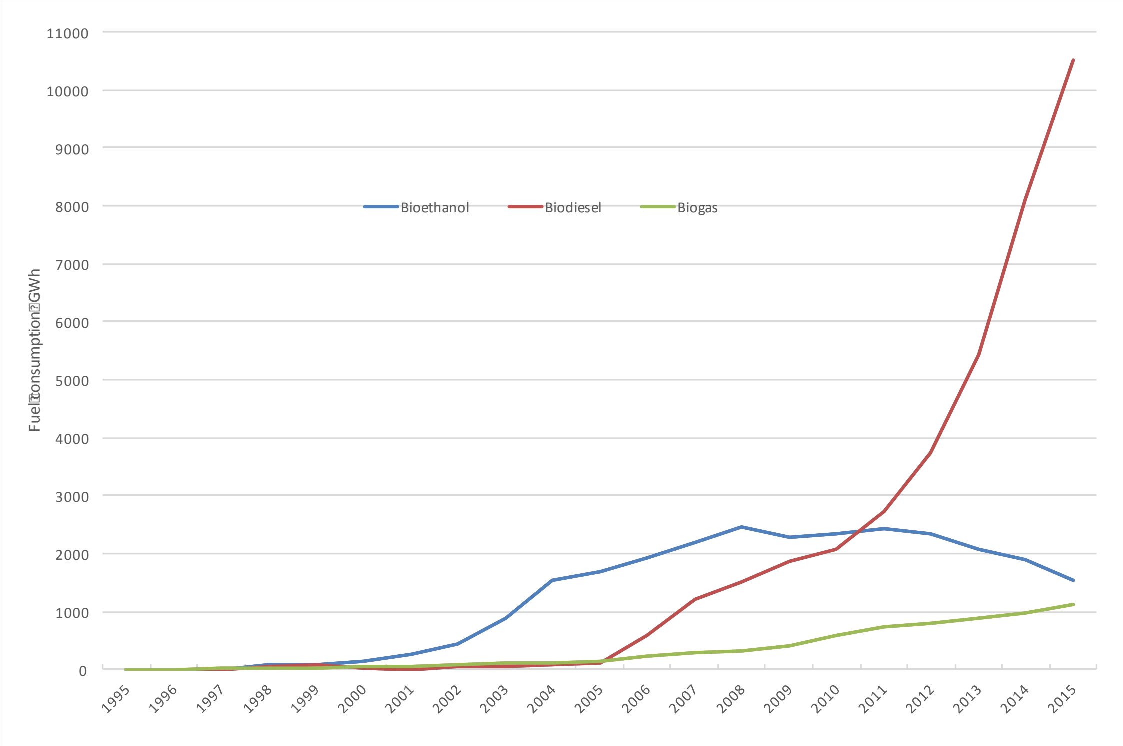

Figure 5. Biofuel consumption in the Swedish transport sector: 1995-2015. Data from Swedish Energy Agency (2017).

Returning to the topic of domestic feedstock supply, The Swedish Energy Agency (2017) reports that feedstocks for biodiesel and ethanol biofuels[34] were predominantly imported. Of the circa 1.22 million m^3 HVO consumed in 2016, 3.8% was from domestic feedstocks (predominantly tall oil). Of some 324 thousand m^3 FAME barely 2% was derived from domestic feedstock. In contrast to the biodiesel, domestic ethanol feedstocks accounted for 16.3% of the 216 thousand m^3 used in the country.

As shown by Figure 6, biogas consumed in Swedish transportation has steadily increased since at least 2005, and biogas production continues to grow. The rates of growth however, are much lower than that observed in liquid biofuel markets – biodiesel in particular. Further breakdown of biogas production, and its development over time, is presented in Section 4.3.

While Figure 6 indicates steady growth across the nation, when viewed at a regional level stagnation is observed in some instances. Examples of stagnation are presented in more detail in subsections 4.3.1 and 4.3.2.

[34] That meet so called 'sustainability' requirements making them eligible for fiscal support, reported as 'sustainable volumes'by Energimyndigheten (2017).

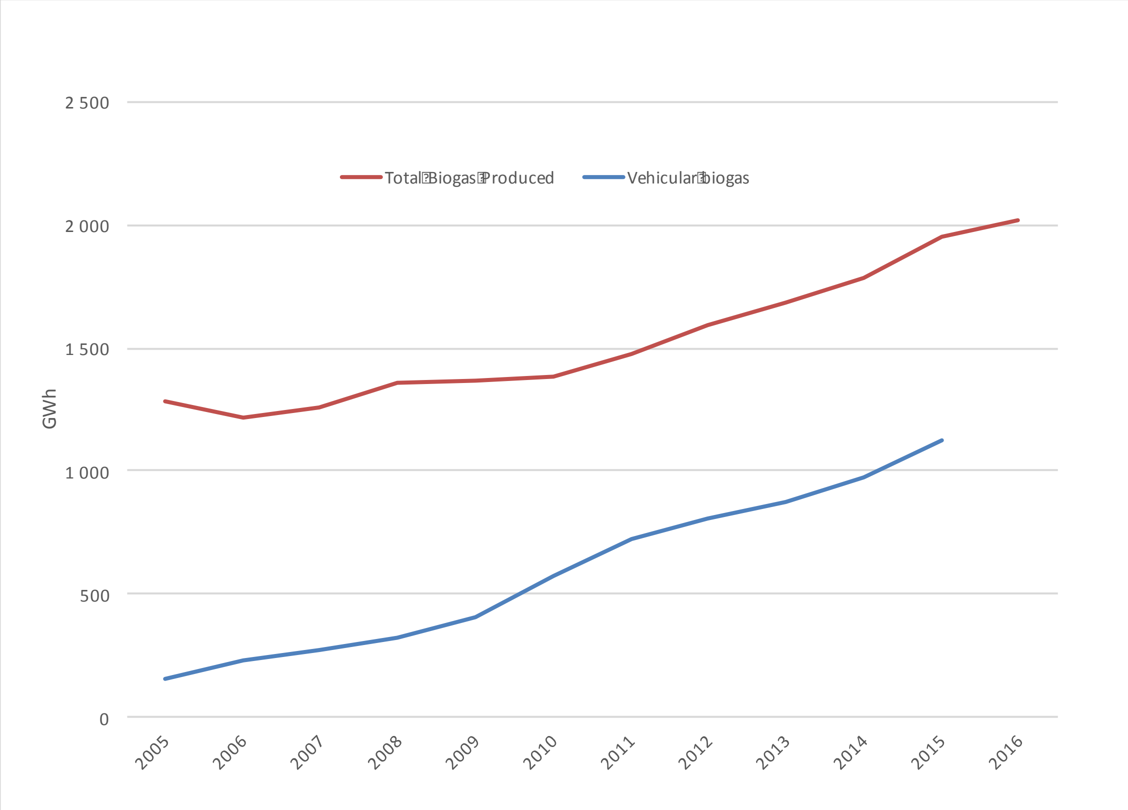

Figure 6. Biogas production and vehicle biogas consumption in Sweden. Data from Swedish Energy Agency (2017).

4.2 SWEDISH METRICS AND QUANTIFICATIONS

There has long been recognition in Sweden of socio-economic contributions that bioenergy can deliver. A state public report (SOU 2007:46) reports that the Swedish utility Vattenfall conducted studies of this as early as the 1970s. SOU 2007:46 also relates how, in the period 1989 to 1997, Vattenfall, LRF, and SLF and Skogsägarna jointly conducted a development initiative for the power production sector with the name “Projekt Bioenergi”. The prime focus of such assessment work was employment stimulation in the heat and power sector. The *Projekt Bioenergi* study for example, reported significant employment stimulation related to both the production of fuels and then their conversion to heat and power; it also assessed the secondary stimulation likely to be supplied by capital investments, and supporting businesses in the value chain. Importantly, this study also showed that the all employment effects were additional, as the loss of employment in the (displaced) fossil sector was negligible. Further, the work estimated that the most significant employment effects in the production chain for heat to power, accrue when one uses harvest wastes – this delivering around 290 FTEs/TWh. Other biofuel sources lay in the range 80-280 FTE/TWh. For the fuel conversion chain (pellet production and so forth), the estimates spanned the range of 200-300 FTEs/TWh. Thus, for an entire bioenergy supply chain from fuel source to energy plant gate, the employment effects were expected to be in the order of 0.5 FTE for each GWh of heat/power delivered from a site.

Important to this discussion is that two key presumptions are interpreted to have constituted the ‘body’ of motivation for such work in Sweden (SOU 2007:46). The first is that endogenous bioenergy will contribute to national energy security of supply. The second is that there will be positive employment effects, particularly in rural areas. In other words, for a considerable period of time in Sweden, there has been an explicit expectation that bioenergy transitions (from fossil fuels) will support local employment. At the same time, it has embodied an expectation that bioenergy will deliver (many) more jobs per unit of energy than fossil fuels provide. Moreover, as a rational programme for bioenergy extraction requires short transport distances (in the sectors assessed, and at that time), underlying assumptions are observed that reflect a view that fuel beneficiation activities should be located where the feedstocks are – thus that these activities would also take place in the countryside and contribute to rural economies.

A working assumption within this project has been that this can also contribute to a more diversified and decentralized economy than that supported by fossil energy carriers; these having predominantly large-scale centralized models of distribution.

There was also significant interest among Swedish actors in the production of dedicated energy crops from agriculture, for biogas, and for liquid transportation biofuels. Here it was stated that the assessment task was significantly more complicated than for forestry. In addition to the fact that there was insufficient documentation, the state public report (SOU 2007:46) indicated that complications accrue as many of these products replace some other activity (such as grain production in the case of coppice crops for instance). For this reason, the SOU analysis only included the 'additional' employment effects for energy crops that accrue over and above the traditional cropping activities (known as 'bassysselsättning'). For straw, this was estimated at 180 FTE/TWh, for Salix 145 FTE/TWh and for Miscanthus 180 FTE/TWh.

Over ensuing years, other figures addressing potential or realized employment effects were quantified in fuel beneficiation chains – with one key source being Reidius (2005). The assessment of additional flow on jobs to be added to the base figures for employment stimulation for various energy carriers (adding for direct, indirect and transport) were estimated as follows:

- Briquette manufacture – 140 FTEs/TWh (0.14FTE/GWh)
- Pellets – 220 FTEs/TWh
- Powder fuels – 200 FTEs/TWh
- Biogas – 200 FTEs/TWh[35]
- Ethanol manufacture from grains – 165 FTEs/TWh (at 50 000m^3/yr or 295GWh/yr scale)

In summary, it can be stated that over the past decades a number of studies have assessed bioenergy systems. However, they have apparently been focused on bioenergy in general, and the transport sector was not a specific focus area. Across the board they have provided evidence that significant bioenergy socio-economic benefits accrued or were expected to accrue. However, such work also recognized that the production costs of agriculture in particular were too high for many fuels to be competitive on energy markets. In turn, there was recognition that more extensive production with lower levels of labour intensity were required.

Important for the context of the discussion in this report is that developments that have ensued since 2007 may have changed this situation markedly regarding the production costs profiles.

[35] These figures are based on three farm-scale biogas plants in Southern Sweden, and one in mid-Sweden. As such, these can be seen as an 'early and preliminary estimate'. Later quantifications based on much larger and more developed systems are included later in this report.

Swedish agriculture has progressively developed to fewer farms of substantially larger size over recent decades (SCB, 2013). Rationalization has increased the size of farms over the entire EU and in Sweden. As a consequence, labour requirements today would reasonably be expected to be somewhat lower than those assessed or projected in studies issued a decade ago. Moreover, more extensive production patterns and technical developments in a number of areas related to bioenergy have also decreased production costs.

While these earlier studies clearly recognized the importance of employment opportunities and rural employment/development, other potential environmental and social issues are generally absent. In particular, there is now recognition of the value reduction of external costs associated with both the production and utilization phases of fuels. The next two sub-sections provide a brief overview of some metrics where positive costs are now counted.

4.2.1 Valuation of carbon emissions – Sweden in an international perspective

A first point to note in this area is that Swedish valuations for carbon are very high when viewed from an international perspective. The general Swedish CO_2 tax is set at a level of 1,14 SEK/kg (1,05 SEK/kg until April 2016) – with the explicit intention to achieve political goals (as distinct from tradition cost benefit analyses targeting socio-economic costs). International comparison shows however that the Swedish figure is an extreme value compared to a range of estimates of the damage costs related to CO_2 emissions used by other countries. According to Brännlund (2010) a representative average value of a large number of these lies at around 0.2 SEK/kg (thus, 200 SEK/t; circa 21 EUR/t).

In the Swedish transportation fuels context, an even higher value has been applied where biofuels are seen to replace gasoline and diesel in the transport sector. For many years Sweden has applied a valuation based on intervention costs associated with the achievement of political goals. It is important to note however, that such fiscal instruments are significantly more effective in other sectors where price elasticity is greater. Also, it should be kept in mind that these levels of taxation are not applied in sectors/industries that are vulnerable to international competition. In 1999 the Swedish National Institute for Analysis of the Transport Sector (SIKA)[36] applied a value of 1.5 SEK/kg CO_2 (SIKA, 2009) – this being equivalent to circa 158 EUR/t. This value was based upon calculations of the marginal intervention costs required to meet relevant milestone goals for CO_2 emissions from the transport sector.

This basis for valuation has recently been modified somewhat. The ASEK methodology applied by SIKA now recommends that CO_2 or CO_2 equivalents should be valued according to a political shadow price, which is derived in turn from the CO_2 tax. As of 2016, this yields a calculation value for CO_2 of 1.14 SEK/kg (circa 120 EUR/t) released measured in 2014 SEK currency values. However, for sensitivity analyses, the ASEK methodology now recommends that a CO_2 value of 3.50 SEK/kg is applied (cf. Swedish Transport Administration, (2016) for more details)– this being equivalent to circa 368 EUR/t.

[36] Note: essentially all references to this governmental department are found in the original Swedish (*Statens institut för kommunikationsanalys, SIKA*).

To place the Swedish transportation emission values in context to international work, summary of results from a study by Becker *et al* (2012) can be used. This work combined and compared results by Kuik *et al* (2009), a meta-analysis of avoidance cost estimations extracted from the results of 26 different models, with other studies, notably those performed by Maibach *et al* at CE Delft (Maibach *et al*., 2007).[37] Figures refer to costs to reduce transport emissions. Table 19 below summarizes the major sources, the results of several studies, and a general overview on CO_2 cost factors. A range of 70–86 EUR/t CO_2 is observed across these works.

Table 19. Overview of projected CO_2 cost figures for future targets (After Becker *et al*., 2012).

Author	Time frame	Modelling goal condition or aim of analysis	Geographical scope	Central value	Range
Federal Environmental Agency of Germany (2008)	2050	Methodological guidelines for Germany	na	70 EUR/ t CO_2	20-280 EUR/ t CO_2
Maibach *et al* (2007) (CE Delft)	2050	Summarize scientific and practitioner approaches for estimating and internalization of external transportation costs	For EU application	85 EUR/ t CO_2	20-180 EUR/ t CO_2
Kuik *et al* (2009)	2025	450ppm	Global	129 EUR_{2005}/ t CO_2	69-241 EUR_{2005}/ t CO_2
Kuik *et al* (2009)	2050	450ppm	Global	225 EUR_{2005}/ t CO_2	128-396 EUR_{2005}/ t CO_2
Morriss *et al* (2012)	2050	50% reduction	EU	44 EUR_{2005}/ t CO_2	
Akashi and Hanaoka (2012)	2050	50% reduction	Global	486 EUR_{2005}/ t CO_2	
Korzhenevyck *et al* (2014) (CE Delft)[38]	2050	As for Maibach *et al* (2007)	EU	90 EUR/ t CO_2	48-168 EUR/ t CO_2

4.2.2 Positive externalities associated with pollution reductions delivered by biofuels

Swedish work has also produced a number of valuations for benefits delivered by a broader suite of pollution reductions that (can) result when biofuels are utilized, or when biofuels are produced. As mentioned in the opening of this report, a considerable volume of this work has been focused on biogas production in Sweden. In many cases, the uses of by-product streams, or the very processes of gathering waste for biogas production, result in tangible reductions in pollution.

An important portion of the reduction of climate gas emissions is generated by reduced emissions of methane and nitrous oxide gases (with considerable focus on N_2O) – for example where stable wastes/manure are used to produce biogas. Methane losses from stored manure varies across the different parts of Sweden and in recognition of this two separate values are often used (Brännlund

[37] Cost factors in the Becker study differ from the Delft work due to a different approach being used to discount the values yielded by other modelling efforts.

[38] This work for the European Commission by Korzhenevyck *et al* (2014) provide updates for work by Maibach *et al* (2007). Discount rates have not been changed from the original here.

et al., 2010). In this study, the figures are for mid-Sweden methane are estimated at 71.64 SEK/MWh biogas while the figure is 32.40 SEK/MWh biogas for nitrous oxide.[39]

Digestate that is recovered by biogas production also can be used to displace fossil based mineral fertilizers and thus can give additional positive effects. A study by Börjesson *et al* (2010) calculated that utilization of digestate to displace mineral fertilizer can reduce greenhouse gas emissions by some 13 kg $CO_{2equiv.}$ per ton of digestate.

A summary of such figures is included in Table 20 overleaf. While, a summary of values ascribed to particulate emissions is supplied Table 21.

Table 20. Ancillary environmental socio-economic metrics applicable in Sweden. Sources: Derived from Waluszewski *et al* (2011), Brännlund *et al* (2010), SIKA (2009), Börjesson *et al* (2010); WSP (2012), and Profu (2012).

Emissions reductions	Swedish Kronor (SEK) per (varying) unit	EUR$_{(9.5\ SEK/EUR)}$	USD$_{(9.0\ SEK/USD)}$
CO_2 reduction C_{tax} on transport C_{tax} other sectors International value for comparison	1.5 SEK/kg 1.05 SEK/kg [40] (previously 1.02kr/kg) 0.2 SEK/kg	0.16	0.17
NOx reduction (source animal manure)	32.0 SEK/MWh$_{biogas}$	3.37	3.54
Nitrogen leakage to groundwater	5.4 SEK/MWh$_{biogas}$	0.57	0.60
Methane reduction (see CO_{2equiv})	71.6 SEK/MWh$_{biogas}$	7.54	7.92
Replaced mineral fertilizers 13.3 $KgCO_{2equiv}$/tonne $_{digestate}$	13.65 SEK/$t_{digestate}$[41] or circa 35,7 SEK/MWhbiogas	1.40/$t_{digestate}$	1.47/$t_{digestate}$
Estimated digestate production	circa 2.6$t_{digestate}$/MWh[42]		
Energy security[43]	15 SEK/MWh	1.58	1.66
Particulate Emissions	400 SEK/kg$_{rural}$ 2000 SEK/kg$_{towns}$ 4000 SEK/kg$_{cities}$	42.11 211 421	44.34 222 443
Particulate emissions City example (biogas from household/industry waste)[44]	Car_9.4 kg/GWh$_{biogas}$ 37.4 SEK/MWh Truck_20.88 kg/GWh$_{biogas}$ 83.5 SEK/MWh	3.94 8.79	4.13 9.23

[39] These values are derived using a CO_2 valuation of 1.00 SEK/kg CO_{2equiv} and can be found in Brännlund *et al* (2010).

[40] Note that the revision of this figure to 1.14 SEK/Kg (as of 2016) is presented in Section 4.1.1. It has been chosen not to change the value in this table – so as to retain comparability to the sources that the table is derived from.

[41] A circa figure using assumptions from Waluszewski *et al* (2011), assuming 50 % manure and 50 % waste as substrate. Biogas production in Sweden has varying substrate makeup. As a point in case, WSP (2012) report 53 % manure, 20 % waste and 26 % sewage sludge for Skåne (the southernmost province of Sweden) in 2009.

[42] Extrapolated from Table 6 in Waluszewski *et al* (2011) and assuming 50 % manure and 50 % waste as substrate.

[43] This value was included in a proposal to the Swedish national biogas strategy by the Swedish Energy Agency. The figure, presented in Brännlund *et al* (2010) is based on a valuation of biogas' contribution to a reduced need for (strategic) oil storage. In this case 0.015 SEK/KWh$_{biogas}$.

[44] The value ascribed to particulate emission reductions resulting from the use of biogas in vehicles (replacing fossil fuels) shown in this table are calculated using the figures provided in Table 21.

Table 21. Valuations of particulate emissions reduction in Sweden. Sources: ASEK (2009) and Profu (2012).

Emissions valuation	Swedish Kronor (SEK) damage cost per unit of particulate emission	EUR (9.5 SEK/EUR)	USD (9.05 SEK/USD)
Particulate Emissions	400 SEK/kg_{rural} 2000 SEK/kg_{towns} 4000 SEK/kg_{cities}	42.11 211 421	44.34 222 443

According to Profu (2012), there are now a number of 'potential' ancillary benefit categories relevant for study or quantification related to the production of biogas. It can be observed in analyses (i.e. those used to generate Table 20 above) that these are presented in three general categories. The word 'potential' is important as some of these are dependent upon the actual application of biogas. This can vary, as can the utilization of by-products of biogas production (e.g. digestate). The combustion of biogas in vehicles not a given but is that which is addressed here. For the terms of this report, the benefits are summarized in three categories. Notably, the third category of benefits falls in areas not directly connected to pollution reduction.

Category 1. Clearly recognized emission reductions resulting from biogas substrate management procedures, or the biogas production process, or both.

- Methane
- N_2O (nitrous oxide)
- Particles
- Nitrogen (particularly nitrogen leakage to ground and surface waters)

Category 2. Other (potential) emission reductions that can arise from fossil fuel displacement in combustion processes, or cleaner operation of combustion processes, or both.

- Fossil carbon dioxide
- Nitrous oxides (NOx)
- Carbon monoxide (CO)
- Hydrocarbons (HC)

Category 3. Other (potential) ancillary benefits arising from fossil-derived process input displacement in system activities (e.g. fuel/fertilizer in agriculture) or achievement of other socio-economic benefits (see examples).

- reduced costs for fuels that are replaced by biofuel (biogas)
- value of improved crop rotation practices facilitated by biogas feedstock crops
- employment opportunities – at least in part in rural areas
- non-renewable resource conservation (e.g. phosphorous)
- achievement of political goals
- technology development and potential for technology export revenues
- reduced import dependence (particularly fossil fuels)
- reduced waste management costs.

An item to note about the third category – a number of these items deliver tangible benefits that are closer to the actors within the system (e.g. regional benefits of N_2O reduction, the on-farm benefits of employment, reduced fertilizer purchase needs, and so forth).

4.2.3 Counting and valuing co-benefits – a biogas example

In a study conducted in 2012, figures presenting the value to society delivered via biogas generation and utilization were calculated (Profu AB, 2012).[45] Portions of that study are translated and summarized here. Drawing significantly from work by Brännlund *et al* (2010), the Profu study estimated a range of socio-economic benefits related to reductions of pollution (i.e. methane and nitrous oxide in waste management systems; particulate matter from diesel traffic; nitrogen release to surface and groundwaters in waste (manure) management or utilization) and the value of displaced fossil diesel. Key results of this work are summarized very briefly in the text below and in Table 22.

Value of methane and nitrous reductions: a median value for the value of methane and nitrous oxide for mid-Sweden and Denmark was taken as 173 SEK/MWh of biogas production (Profu AB, 2012, p. 7 drawn from Table 3.1 in Brännlund (2010)).

Value of particulate matter reductions: the value of particle reduction (calculated as biogas generated in a small town, replacing diesel used for heavy goods traffic in larger towns/cities)[46] was valued at 91 SEK/MWh. (Profu AB, 2012, p. 7 drawn from Table 4.2 in Brännlund (2010)).

Value of nitrogen reductions: the value of nitrogen reduction calculated at 7 SEK/MWh (Profu AB, 2012, p. 7 drawn from upper value in Table 5.1 in Brännlund *et al* (2010))

Value of fossil energy carrier CO_2 displaced: fossil CO_2 reduction is calculated as diesel replacement at a rate of 0,073kg/MJ diesel. Thus a value of 263 SEK/MWh of biogas. (Profu AB, 2012, p. 7).

Pollution related added value to society: thus the total value to society for biogas generated in a small Swedish town, replacing diesel used for heavy goods traffic in larger Swedish towns/cities was calculated to be 534 SEK/MWh (Profu AB, 2012, p. 8) [(173 + 91 +7 + 263) SEK/MWh].

Value of the displaced fossil energy carrier: biogas (and indeed all domestically produced biofuels) also have a value in the form of costs for the fuels that they replace in the transport sector. When such biofuels were assumed to substitute imported fossil diesel (exclusive of taxes) a diesel cost (year 2011) of 670 SEK/MWh was applied (Profu AB, 2012, p. 8).

Total socio-economic benefits: the figures provided here thus indicates a total socio-economic benefit of circa 1200 SEK/MWh biogas (circa EUR126/MWh).

Total production costs of biogas: This estimate for the socio-economic value for biogas must be compared in turn to estimates of production costs. Profu (2012) holds that a span of 800–2400 SEK/MWh has been observed in Sweden. The wide span in these figures is observed because

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[45] These calculations have not taken into account any cost increases for the actual vehicles that use biogas. Moreover, the study assumes that there is no difference between the relative efficiencies of conversion of fuel into motive power for the differing fuel/engine/drivechain systems.

[46] While this choice of assumptions has the effect of markedly increasing the value of particulate emission reductions (see Table 20), it is not at all unrealistic in the Swedish context. A number of larger Swedish cities require that that truck fleets (e.g. waste collection trucks) in densely populated urban areas are run on natural- or biogas. This contributes to both quieter and cleaner air in cities.

this covers biogas from all substrates – and much of the variation arises because of differences in upgrading, distribution and sales systems. In their study Profu (2012) argue that biogas from sources such as manure will fall at the lower end of this range – an assumption based on an earlier Profu study (2011) that established costs of 900 SEK/MWh (circa 95 EUR/MWh) for transport biogas from waste fractions (including among other things manure).

Based on their study, Profu conclude that the representative net value to Swedish society, delivered by biogas exceeds its costs by some 300 SEK/MWh (circa 32 EUR/MWh) (Profu AB, 2012).

Profu, (Profu AB, 2012, pp. 8–9) also indicates, that if one instead applies lower values of CO_2 reduction (as discussed in Section 4.2.1, these are typically around 0.2 SEK/kg but also observed to be increasing markedly with time), then the socio-economic benefits of biogas are of course reduced. At the 0.2 SEK/kg value the benefit thus falls at some 860 SEK/MWh (circa 91 EUR/MWh). While markedly reduced against the figure using a CO_2 value of 1 SEK/kg or more, this value nevertheless lies very close to the indicated 'likely' overall production cost of 900 SEK/MWh.

This lower figure does NOT include most of the additional values described as Category 3 in Section 4.2.2. Where these accrue – and this analysis indicates strongly that they do in Sweden – then it is quite likely that they reach or exceed the costs, even in such calculation scenarios. A case in point in this regard, is the contribution to energy security. A range of international valuations exist in this regard and a nominal figure per use of energy 15 SEK/MWh for Sweden also exists based on the value of reduced oil storage requirements. The market value of reduced fossil fuel or oil is the approach applied in this Profu example, and as also used in the US (cf. POET study presented in Section 3.3.1 and the US Biodiesel study presented in Section 3.3.2.)).

Table 22. Overall Biogas Co-benefit Estimations in Profu study.

Category	Value addition items	Swedish Kronor (SEK)/MWh	EUR (9.5 SEK/EUR)
1	Methane and N_2O reduction (e.g. manure mgt.)	173 SEK/MWh_{biogas}	18.21
	Nitrogen leakage to surface/groundwaters	7 SEK/MWh_{biogas}	0.74
	Particulates	91 SEK/MWh_{biogas}	9.58
2	Nitrous Oxides from combustion	Not priced	------
	CO_2	263 SEK/MWh_{biogas}	27.68
	CO	Not priced	------
	HCs	Not priced	------
3	Reduced costs of fuel	670 SEK/MWh_{biogas}	70.53
	Employment opportunities	Not priced	------
	Reduced import dependence (esp. fossil fuels)*	Not priced	------
	Achievement of political goals	Not priced	------
	Non-renewable resource conservation (e.g. P)	Not priced	------
	Reduced waste management costs	Not priced	------
	Technology development and export potential	Not priced	------
	Value of improved crop rotation practice	Not priced	------
	Total	1204 SEK/MWh_{biogas}	127

** Note that a value of 15 SEK/MWh has been indicated as relevant for Sweden by the Swedish Energy Agency (Brännlund et al., 2010) but utilization of this value in studies does not appear to be widespread. Such issues can have important trade balance implications for national economies, particularly those that are net oil importers. Biofuels on the other hand can often be domestically produced with benefits accruing within the economy.*

As can be seen from the analysis presented above, there is emerging praxis with regards to the counting of ancillary benefits related to biogas that have tangible economic value for society. Relevant to this discussion however, is the notable economic parameters that are not counted in this otherwise detailed analysis; these include employment opportunities and other flow on economic effects of the production systems. This can be compared to values drawn from earlier content in this report (i.e. particularly sections 3.1 and 3.3 that addressed liquid biofuels), which placed likely socio-economic benefits related to employment and business stimulation in the order of circa 100 EUR/MWh of biofuels produced.

4.3 OVERVIEW OF BIOGAS ANALYSES CONDUCTED IN SWEDEN

As noted, in Section 4.1, there has been a significant development of biogas production and consumption in Sweden in recent years.

Figure 7 below details growth in Swedish biogas production in the period 2005 to 2016. When broken down by main production source, it is clear that the most significant growth in biogas production during this period is the result of production in newly built or expanded anaerobic digestion facilities. This is strongly linked to the reduction of the landfilling of organic materials pursuant to the EU landfill directive (Council Directive 1999/31/EC of 26 April 1999).

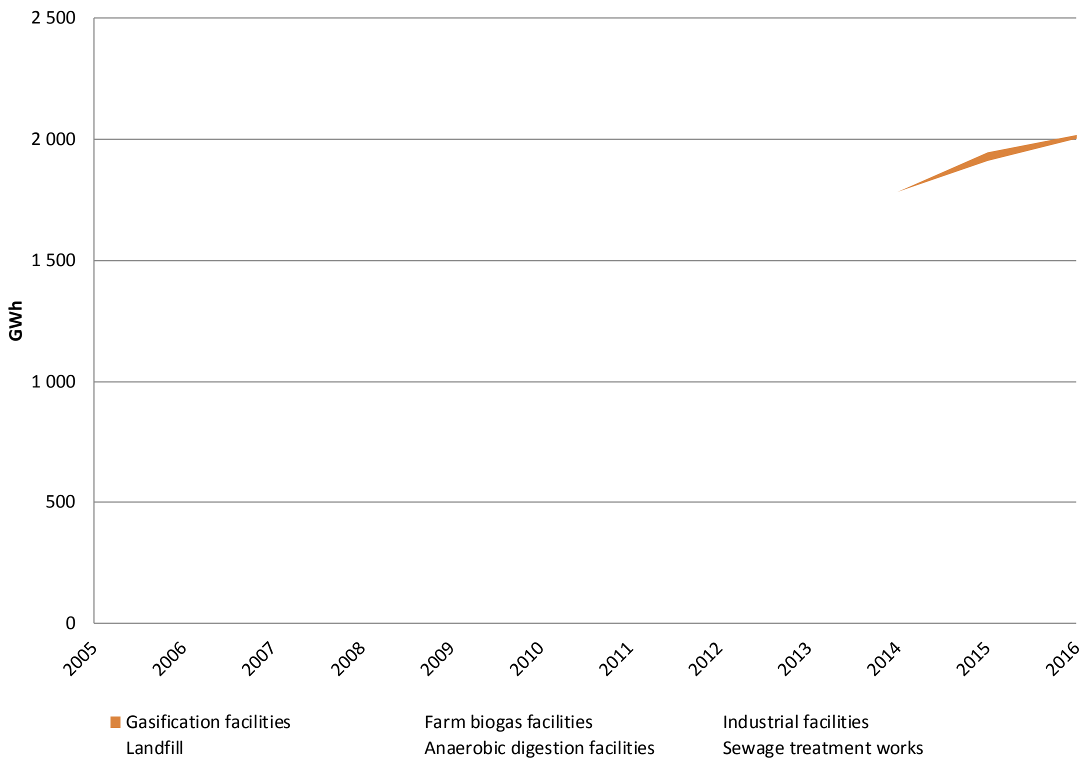

Figure 7. Biogas production in Sweden by source 2005-2016. Data from Swedish Energy Agency (2017).

This section presents brief overviews of the rationale and key results for four Swedish biogas evaluations. Each is related to regional ambitions to expand biogas production – with a focus on utilization as a transportation fuel. All were motivated by a need for regional authorities, and regional business actors to be able to provide clear evidence of a) positive effects on regional economies, b) stimulation of employment, and c) positive effects on the environment and/or human health. While five Swedish biogas analyses were found within this project, deeper examination of an agricultural biogas project in Värmland [Lantbruksbaserad biogas i Värmland] (Grontmij, 2014)] has been excluded as the regional metrics for labour and economic effects are not comparable to the other studies. It is still mentioned here however, as recognition that it shares a common goal with the other studies. Namely that the county authority was seeking to create conditions conducive for the economic, social and environmentally sustainable regional growth.

Three of these evaluations have been produced by the same consulting company (WSP Sverige AB) – although by different consultants from differing offices within the organization. All of these apply the *Regional Analysis and Prognosis System* (*Regionalt analys- och prognossystem),* rAps – see Box 3 for details.

Box 3. Regional Analysis and Prognosis System, rAps (source: Jernström & Pichler, (2013))**.**

> The rAps model was developed as a tool for regional planning and is used in Sweden to quantify regional growth and employment impacts.
>
> Administered by The Swedish Agency for Economic and Regional Growth (Tillväxtverket), and The Swedish Agency for Growth Policy Analysis (Tillväxtanalys), it is intended that the system be used for prognosis calculations, and scenario analyses. rAps is available for use by actors such as regional federations, county administrative boards, municipal councils, state authorities, private consultants, Swedish Universities, and schools of higher education.
>
> The modelling tool builds upon a database of regional statistics that cover a number of areas important to regional development. One portion is addressed by an internet hosted database – the Regional Information System (RIS). The second consists of a modelling system, which in turn builds upon a prognosis database. RIS provides the user with access to regional statistics that define the dimensions of population, employment markets, businesses and regional economic metrics.

In addition, all three studies highlight a number of other ancillary environmental benefits that accrue. To do this, they step beyond the modelling effort and apply metrics developed previous research work in Sweden. The fourth study (KanEnergi AB, 2012) was prepared by the consultancy KanEnergi Sweden AB for a consortium of actors in Västra Götaland (the County of Western Gothia). While highly relevant to this study because of the manner in which it provides detail of the economic and environmental effects of the regional biogas system and its planned extension, it is only partly comparable to the former three.

4.3.1 Biogas in Skåne 2011-2020

The consultancy company WSP Analysis and Strategy in collaboration with the regional county authority Region Skåne in 2012 generated this report covering the southernmost province of Sweden, Skåne. This summary is largely drawn from the foreword of their joint report (WSP Analys & Strategi & Region Skåne, 2012). The work is considered particularly useful for this overview report as it draws together a number of the parameters discussed so far in this analysis: a) estimates of labour market impacts related to biogas projects; b) regional-level modelling of regional GDP effects, and c) ancillary environmental benefits.

The background to the analysis is that Region Skåne together with a suite of actors across the whole biogas value chain, expressed desires to increase biogas production and utilization, principally as a road transportation fuel. The group; including municipalities and utility companies, agricultural companies, research, transport, and transport fuel companies developed a roadmap describing an increase in biogas production from levels of 350 GWh/yr. to 3 TWh by the year 2020.

An anticipated result of the Skåne roadmap for biogas was/is increased employment, new companies, positive environmental effects, investments and generally positive effects upon gross regional domestic product. The WSP study was conducted in order to improve the knowledge foundation regarding the effects biogas production can create. In turn, it examined how the expansion scenarios would contribute to green growth. 1.5 TWh of the 3 TWh was related to the development of a large biomass gasifier project to be located in the county. This project is presently (indefinitely) on hold, and is not given focus in this analysis (See Bio2G case and discussions in Peck *et al*., 2016).

Focus is instead directed towards the assessment of the status quo, and of a scenario addressing biogas from digestion facilities – where growth from circa 350 GWh (2011) to 1500 GWh was envisaged to take place by 2020. This scenario assumes that new production of gas will be derived from digestion in 60 new facilities and that the total production will total 1.5 TWh. While this rate of expansion has absolutely not been achieved, the assessment of such expansion is considered relevant for this analysis.[47]

In order to highlight the order of magnitude of these effects that can be created by biogas production in Skåne, the county authority tasked WSP with the estimation of effects. The Swedish rAps model (see Box 3, Section 4.3) was used to quantify regional growth and employment impacts. This approach applies statistics and models focused on the regional level. In addition, the study highlights a number of other benefits that utilization of biogas generates – including ancillary environmental benefits accruing (using a very similar approach, sources and categories as that presented in Section 4.2.3). One of the study's principal questions addresses the contribution that biogas delivers to green growth in Skåne. The rAps analysis shows that employment in the biogas area results in significant 'flow-on-effects' to other portions of the economy. Key results for the 2011 status quo and an expansion to 1500 GWh are shown in Table 23.

Table 23. Summary impact upon employment and RDP related to biogas production: including impact on other sectors.

	GWh biogas	Direct employment effects in production	Total employment effects in economy⁺ (FTE)	FTEs/GWh (direct)	FTEs/GWh (direct + indirect)	GRP (total) MSEK	GRP/GWh MSEK/GWh
2011 status quo	350	293*	492	0.84	1.41	731 (of which 422 direct.)	2.09
2020 modelling	1500	1000	1554	0.67	1.04	3 856 (of which 2875 direct[Y])	2.57

** This figure includes 148 employment opportunities related to the building of biogas facilities in Skåne.*

⁺ This figure includes the employment opportunities (indirect and induced) that flow on from biogas production. However, the number excludes additional jobs related to the construction of new infrastructure and facilities. In the scenario work, a budget of 1.125 billion SEK was invested in from 2012-2020 at a rate of 138.9 MSEK per year. Employment resulting from such infrastructure investment was estimated to result in 310 direct, and 75 indirect FTEs each year, every year during the period.

[x] As the study models "additional jobs", the normalization has been performed against "additional biogas production" and "additional GRP".

[Y] Breakdowns of direct and indirect economic effects are summarized in WSP (2012, p. 18)

The modelling efforts help demonstrate how flow on effects accrue to the economy from biogas initiatives. For the status quo, it is estimated that new direct employment of 293 FTE in Skåne arises, and that these in turn contribute indirectly to some 199 indirect employment opportunities. The direct impact to net regional product is estimated at 422 MSEK, while an additional 309 MSEK accrues in the form of flow-on-effects throughout the economy. As shown in the table, such patterns are also observed for the larger scale scenario.

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[47] Examination of the County authority information page addressing their biogas roadmap indicates that by 2015, circa 400 GWh of biogas production had been achieved (Länsstyrelsen Skåne, 2017). The most recent figure found (October 2016) on Biogas Syd's Facebook page reported 417GWh for Skåne. More recent figures have not been found in this study, but this indicates that the total production could be expected to be significantly less than 500 GWh.

A second useful output from this study is the estimation provided of where jobs have accrued, and are expected to accrue, as the biogas sector expands. Table 24 exemplifies the distribution of employment opportunities across sectors for Skåne's existing production of 350 GWh of biogas, and then normalizes these to FTEs per TWh of biogas produced (for gas production systems only).

Table 24. Full time equivalent employment (FTEs) in the biogas sphere in Skåne (by sector) – (2011, 350 GWh annual production).*

Operation	Total employment (direct) within Scanian biogas production (2011)	Direct FTE/TWh_{equiv} biogas production and utilization
Construction of facilities	148**	Not applicable – as capacity expansion related
Farmbased – codigestion facilities and energy companies	55(.1)	157.4
Wastewater treatment plants	6	17.1
Industry/company support functions	38	108.6
Waste management and landfill	8	22.9
Public transport	5	14.3
Public sector	10	2.9
Research	23	65.7
Total – biogas sphere	293***	Not applicable
Total – biogas production and operations	**145**	**414** FTE/TWh_{equiv}

**Summarized from Tables 5 and 6, pages 14, 17 in WSP Analysis & Strategy and Region Skåne (2012)*

***Note that expansion of the sector demands new construction jobs, but this is not directly related to biogas production figures.*

****199 indirect jobs were indicated by modelling (adding to the figure for direct FTEs shown above).*

The study also shows that biogas provides details of positive environmental effects related to utilization, and monetizes several of these. The largest benefit is reduction of greenhouse gas releases in the transport sector. Within the scope of this study, this is valued in the range of 100 MSEK/year for biogas production at 2011 levels, and at some 600 MSEK/year for the 2020 scenario. Other positive effects related to gas utilization that are valued, are however significantly smaller. Again, these include reduced particulate emissions, nitrogen leakage to water, and energy dependence. Calculations and the base metrics utilized to support the calculations are very similar to those presented in Section 4.2.3 and are not repeated here.

Beyond the scope of valued effects, it should be noted that there are also a number of benefits that while difficult to value monetarily, are clearly perceived as being beneficial to society. Examples of these include contributions to 'a living rural environment', reduction of noise, reduced smell from manure management, and resource preservation. Further, there are additional positive effects on economic growth that are noted but not monetized. One such item taken up in the report is the potential for technology exports that can arise when a region achieves a position at the leading edge within a growing economic area.

4.3.2 Biogas Öst 2010 – 2020

Biogas Öst (East) is a regional project operated by the Energy Office in Mälardalen AB (Energikontoret i Mälardalen AB). Via collaboration with other regional actors, the role of the organization was to influence and strengthen the potential for biogas production in the region and contribute to the achievement of environmental goals. Participants in Biogas Öst include the energy office, municipalities in the region, the county authority, universities, private actors, and the alliance of regions. Regions where Biogas Öst is active include Uppsala, Stockholm, Örebro, and the counties of Västmanland, Östergötland and Södermanland. Again, this analysis involved the consultancy company WSP and drew upon their capacity to perform rAps modelling of regional socio-economic effects. This summary is principally drawn from the foreword of their joint report authored by Waluszewski *et al*. (2011).

This study had the aim to delineate and quantify the social benefits that biogas has generated in the Biogas Öst region to date, and then to provide a forecast of potential for socio-economic benefits forward to the year 2020.

The ambition within the study was to investigate biogas in the Biogas Öst area and deliver understanding of its effects upon regional level growth and employment. The rAps-model was applied in order to deliver quantifications and projections of the general social economic benefits out to 2020. In this instance, the prime focus of the work was upon employment generation, investment, security of energy supply and ‘good will’, as other aspects such as environmental benefits were held to be better known by actors in the region. The socio-economic benefits of biogas were assessed in contrast to gasoline and diesel – the transportation fuels that it replaces.

The point of departure for the study was Biogas Öst’s long-term goal to achieve a regional biogas production of 3 TWh/year – a volume equivalent to circa 10 % of the transport sector consumption in the area. Building from analysis that established likely levels of biogas related employment for 2010 of 338 direct FTEs, and some 224 indirect equivalent jobs, the work indicated that the total number of employees within the biogas sector would approach some 3500 FTEs should the 3 TWh prognosis for biogas production for year 2020 be achieved. While the majority of the employment opportunities accrue in biogas production activity areas, there is also significant generation of employment in business services, agriculture, administration and in logistics. As for the analysis detailed in Section 4.3.1 estimates were created of the number of FTEs supported in differing parts of the system for the status quo case (2010) (e.g. digestion facilities, authorities, research bodies, etc.) – in this study, this level of detail was also provided for the 2020 scenario.

While the projections noted above, were generated for some 3 TWh gas per year, information from the Biogas Öst region (as of end 2016), indicates that 2015 consumption lay at around 0.5 TWh with a linear upward trend of around 0.07 TWh per year. Assuming that biogas consumed in the region is also produced in the region, this in turn indicates that a 2020 production volume for the area is likely to be around 0.7 to 0.75 TWh per year. It must also be noted however, that while biogas production continues to modestly increase, the consumption in this regional market has apparently stagnated since 2012. Market development for Biogas Öst is shown in Figure 8, while a geographical overview of biogas activities is supplied in Figure 9.

The modelling results indicate that biogas production has a high value-adding factor that in turn has a large effect on the regional domestic product. The modelling indicated an increase in yearly gross regional domestic product of some SEK 4.3 billion for a production level of 3 TWh.

The study also indicates a suite of other positive benefits of biogas production. As the approach is very similar to that documented in Section 4.2.3, again those details are not repeated here.

The total value of ancillary benefits for the year 2010, totalled circa 168 MSEK. For the 3 TWh scenario, the combined environmental benefits were valued at more than 1.7 billion SEK, of which almost 1.6 billion SEK are related to climate gases. Other reductions valued were transportation noise associated with quieter gas vehicles (some 46 MSEK), and reduction in particulates were valued at some 60 MSEK.

Table 25. Summary Biogas Öst.

	GWh biogas	Direct employment effects in production	Total employment effects in economy (FTE)	FTEs/GWh (direct)	FTEs/GWh (direct + indirect)	GRP (Direct) MSEK	GRP (total) MSEK	GRP/GWh MSEK/GWh
2012 status quo	518	338	562	0.65	1.085	437	579	1.12
2020 modelling	3000	1960	3173	0.65	1.058	3286	4310	1.44
2010-2020 facility construction FTE/year*		225	296			131	184	

** 296 extra FTEs were projected to be involved (year by year, each year) during the ongoing construction period up to 2020 (adding to the figure for biogas related FTEs shown above). Only the figure for 2020 is shown in the table.*
ˣ As the study models "additional jobs", the normalization has been performed against "additional biogas production" and "additional GRP".

Returning to the fact that growth in the biogas market has (apparently) not increased at rates adequate to come even close the 2020 scenario target, then if the modelling numbers are consistent at this smaller scale (around 0.7–0.75 TWh/year), then around 800 to 900 FTE jobs may have accrued. This figure would thus more than 200 more than in 2010 when the study data was collected. Corresponding economic figures for the reduced volumes of biogas production that appear likely to be achieved by 2020 would thus be: RGDP of 1.1 billion SEK/year, reduced environmental costs of 0.41 billion SEK/year, and noise reductions of 11.5 MSEK/year.

While these results are not of the scale of the 3 TWh projections (or aspirations), these figures can still be deemed to represent a significant benefit to the region.

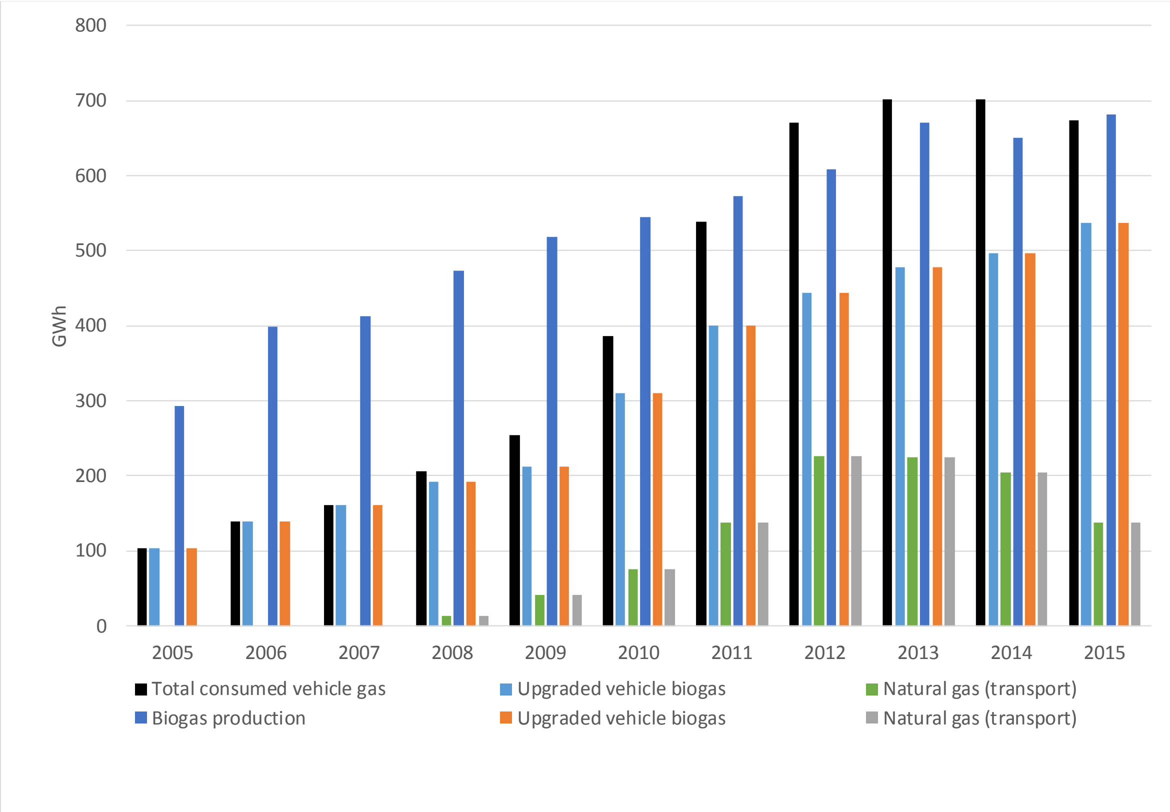

Figure 8. Biogas Öst: Biogas production and vehicle gas consumption 2005-2015. Sources: Swedish Energy Agency (2017) [Energiläget i siffror] and Biogas Öst (2017).

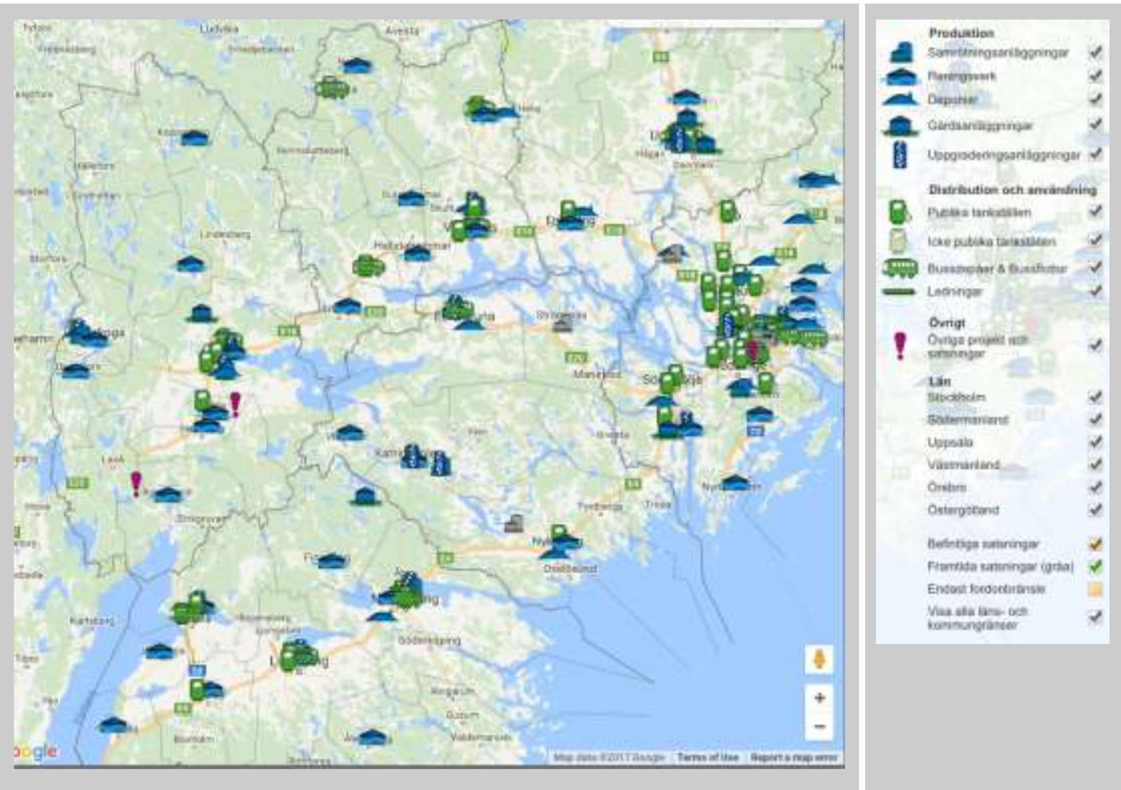

Figure 9. Overview of biogas activities in Biogas Öst area (2016). Source: Biogas Öst (2017).

4.3.3 Biogas in Norrbotten and Västerbotten

This summary is principally drawn from the foreword of an overarching report authored by a branch of the consultancy company WSP (WSP Sverige AB, 2013). The investigation was commissioned by Biofuel Region AB, a non-profit organization founded in 2003 as a private/public initiative.[48] Biofuel Region AB was tasked with leading the regional development, and deployment, of alternative fuels for vehicles in the four northern-most counties of Sweden. The study had the aim to calculate and analyse affects upon growth and employment as a result of increased production and utilization of biogas in the counties of Norrbotten and Västerbotten. In parallel, it was also intended to provide an indication of the potential for biogas production importance using the rAps model. As such, parts of this work again mirror the work process described in the previous two biogas cases. However, a number of important contextual differences exist. Firstly, the upgrading of biogas for utilization in motor vehicles in this region was much less common than elsewhere in Sweden at the time of analysis (2013). Secondly, the flaring of biogas is much more common, and thirdly the utilization of biogas in industry is more common.

Moreover, a mathematical difference is also interpreted. Whereas the aforementioned studies reported ‘employment’ (thus interpreted as the total number of direct or indirect employment positions against a baseline of ‘no biogas’), this report is interpreted to deliver ‘new employment’ (thus additional employment opportunities over and above the existing biogas production). The point of departure was the estimated regional biogas production of around 75 GWh/year (as of 2012/13) as compared to an estimated potential of 570 GWh. Three sectors in particular dominate the potential: the food industry, animal husbandry (manure), and the forest-derived paper/pulp industry.

Table 25 provides an overview of the report results. The categories listed in the table are limited to the items addressed by the earlier Swedish case studies.

The key scenario (labelled Scenario I in Table 25) examined the effects of an increase in biogas production to the ‘full potential’ of 570GWh. This yields an increase in the total employment by 329 FTEs (127 direct and 202 indirect), and an increase in regional domestic product of 556 MSEK/year over the baseline (463 direct and 93 indirect).

In addition, five sensitivity runs were conducted. One of these; that which examines a more modest development of biogas production is also included in Table 25 (labelled Scenario II). This examines a situation where biogas production is assumed to double compared to current levels. This analysis yields an increase in the total employment by 87 FTEs, and an increase in regional national product of 146 MSEK over the baseline.

One finding from the study, highlighted here as being important in the context of rural development, and especially relevant for the more remote north of Sweden – is that most of those gaining employment will be from within the region, and that the workforce would largely be drawn from under-employed portions of the workforce. As such, biogas is presented as having the added appeal of providing employment opportunities to those in a social demographic that has a relatively higher difficulty in obtaining work otherwise.

[48] http://biofuelregion.se/en/vad-vi-ar/

Table 25. Summary Biogas Norrbotten and Västerbotten.

	GWh biogas	Direct employment effects in production*	Total employment effects in economy (FTE)	FTEs/GWh (direct)	FTEs/GWh (direct + indirect)	GRP⁺ (Direct) MSEK	GRP (total) MSEK	GRP/GWh MSEK/GWh
Scenario I* – Increase to full potential	570 (495 new biogas)	127	329	0.26	0.66	463	556	1.12
Scenario II – doubling of existing production	150 (75ˣ new biogas)	na	87	na	1.16	na	146	1.95

* In the study report, these figures are split between Västerbotten and Norrbotten.

⁺ The study also provides estimates of increased incomes (payrolls) and municipal taxation gains.

ˣ As the study models "additional jobs", the normalization has been performed against "additional biogas production" and "additional GRP".

Lastly, the study indicates explicitly that the utilization of biogas influences more than the employment market; it also provides a suite of positive environmental effects. In this study, the most important effects of biogas utilization displacing transportation fuels have been calculated and then monetized. The pollutant categories addressed in this study include particulates (PM2.5), hydrocarbons, NOx, SOx and CO_2. The study concludes that the yearly value of reduced emissions from transport in the year 2020 would be in the order of 17.5 million SEK, and or the order of 26.3 million SEK per annum in the 2030.

4.3.4 Västra Götaland

This section is summarized from a resulting consultancy report (KanEnergi AB, 2012) prepared for Västra Götaland, the county environmental secretariat and Biogas Väst.

Based upon expectations of environmental and socio-economic benefit, regional government actors in Västra Götaland desired an increase in the production and utilization of biogas in the transportation sector. Following from this, the environmental authority (Miljönämnden) adopted the regional development programme "Biogas Väst" in December of 2010. The specific goals of the programme were that the production of biogas in Västra Götaland should be 2.4 TWh per year by 2020. Half of this to be produced via digestion, and half via gasification. Utilization of biogas as transportation fuel was prioritized as the need to find renewable alternatives was deemed greatest in the transport sector.

An explicit outcome expected from the biogas programme was that an increased production and utilization of biogas will lead to employment increases and the development of new businesses. Pursuant to this expectation, a study was commissioned to investigate how many jobs that (business) activities and development enfolding the biogas field provide at present (then 2010) and how this situation may develop if the 2020 goals should be achieved.

A brief examination of the region's biogas related activities at that time reveal a suite of significant endeavours related to both biogas production and utilization. Items highlighted in the report include:

- Biogas production (2010) of circa 168 GWh (KanEnergi AB, 2012, p. 35, 41 and 43);

- the presence of the Gobigas project (involving among other things, significant resources from Göteborg Energi) with construction of Stage I for Gobigas scheduled circa 1 year after the time of the study;
- a strong related field of biogas and gasification research in the Västra Götaland region and its Universities;
- the presence of world leading vehicle and engine manufacturers that use natural gas and biogas in the region (e.g. Volvo Trucks, Volvo Buses, Alternative Fuel Vehicles [AFV] Sweden);
- the location of (then) subsidiary of Linde Group (Cryo AB) specializing in the production of gas storage and transfer systems.

There is also clear evidence that these activities have progressed significantly since that time. More recent items include:

- 351 GWh biogas produced (2015);
- 255 GWh vehicle gas sold in 2016 of which 79% biogas (i.e. 201 GWh);
- 44 public filling stations for gas plus 6 for busses (2015);
- One (1) filling station for liquid vehicular gas (2015);
- 47 digestion facilities (2015);
- One (1) biomass gasification facility (CoBigas I) that at full production can deliver 160 GWh.

Despite the richness of activity in Västra Götaland, a good deal of the analysis is not comparable to the other studies. There are a number of factors affecting comparability; prime among these are that bottom up research to map the number of persons 'involved in the biogas field' yielded very high figures. This held for both for the number of employees, and for the financial turnover. The presence of large international equipment manufacturers – that also export very significant volumes of their products – made the situation assessed quite different to other cases addressed in this report. The resulting 'biogas related employment' and 'biogas related economic impacts' are very much larger than in other regions.

Even after efforts by the analysts (KanEnergi, 2012, p. 36) to reduce their boundaries in an attempt to make their work more comparable to other studies, their work still yielded results (i.e. FTEs or RDP/unit of gas production) differing very significantly from other studies. In simple terms, it can be judged that the scoping of 'biogas related' activities for the Västra Götaland case were not narrow enough to support comparability.

In raw form, the results indicated employment impact for the year 2010 to be 600-650 FTEs thus indicating total employment intensities of some 3.6–3.9/GWh (more than 300% of the intensities reported in other studies). Similarly, the biogas related turnover of businesses yielded by the data collection method applied[49] yielded circa 1692 MSEK – indicating some 10 MSEK per GWh (circa 10 times that yielded by other studies).

[49] First a so-called 'status quo' analysis was conducted. It included a mapping of actors (companies and other organizations). The status quo was then utilized as a foundation for the development of a forecasting model based upon a regression analysis.

As a result, only a limited amount of material from the study is shown here. The first is a break-down of the substantial suite of employment activities that were mapped in the region (see Table 26 and Figure 10). Second is a summary table (Table 23) of metrics that have been manipulated to make them more comparable to the other studies shown here.

Table 26. Summary Västra Götaland's biogas related employment 2010.

Biogas value chain activity	Total FTEs
Substrate & waste	195
Distribution	180
Transport and vehicles	182.5
Consultants	52.5
Production	35
R&D	30
Refuelling stations	17.5
Suppliers-(technology)	17.5
Strategists	5.5
Regulation/Oversight	3
Total	**618.5**

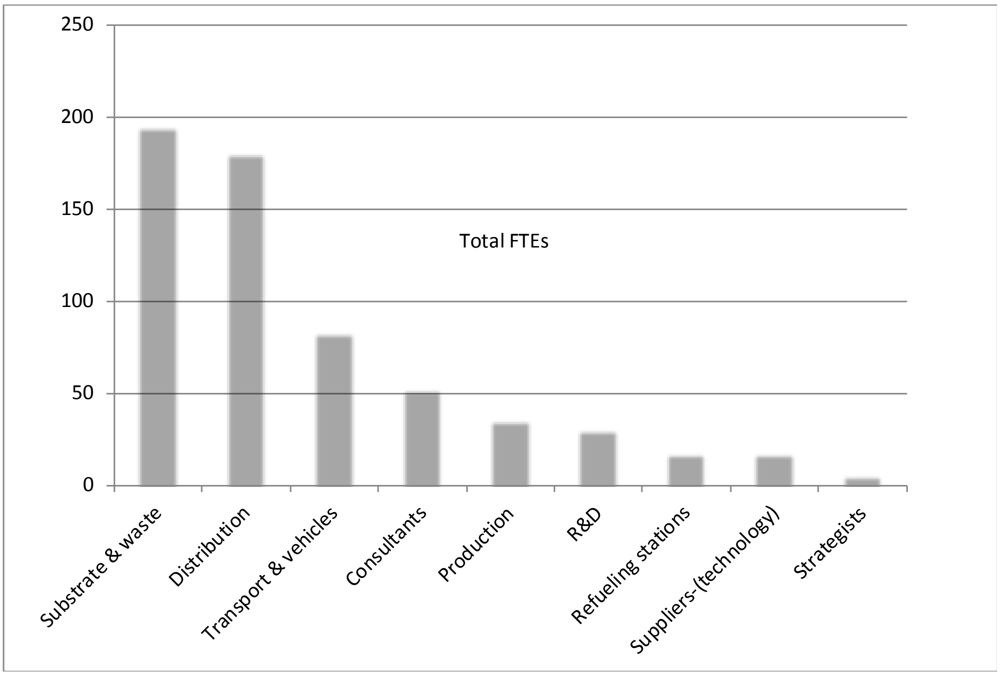

Figure 10. Distribution of work opportunities in Västra Götaland's biogas value chains.

Table 27. Summary Västra Götaland.

	GWh biogas	Direct employment effects in production	Total employment effects in economy (FTE)	FTEs/GWh (direct + indirect)
Status Quo 2010 (based on study data collection with downward correction)*	168	250-270	400-450*	circa 2.4 – 2.7*
2010 (benchmark estimate 2010)	168	circa 109ˣ	circa 200*	circa 1.2*

* Vehicle manufacturing and technology experimentation hub inflate these figures very significantly in comparison to other studies. The scope of this study (biogas related activities) brings in both a complex R&TD environment and international (export oriented) original equipment manufacturers. As a result, the study authors deliver both a discussion of this, and calculate downward corrections - see discussion in KanEnergi (2012, p. 36)

ˣ KanEnergi (2012, p. 36) relate their benchmark estimate to the Biogas Öst study detailed in Section 4.3.2 of this report, and to the German study discussed in Section 3.1.2. The lower value (that of Biogas Öst) has been applied here.

4.4 BIODIESEL AND ETHANOL

Within this study, very little material was found that can be directly presented for the prime liquid transportation fuels that dominate in Sweden (e.g. RME biodiesel, HVO diesel, and ethanol). These value chains have not been subject to as detailed analysis as has biogas. Indeed, the reader should note that this report contributes to the broader LCA methodology project titled (Martin *et al*, 2017a,b). The LCA analysis seeks to quantify and disaggregate the benefits provided by biomass production, and the biofuel process industries, to increase the benefits level of detail and clarity regarding benefits provided.

In lieu of deeper evaluation in this report, two very brief summaries of contributions to employment from two Swedish liquid biofuel producers are provided here. These are derived from a short series of interviews conducted during 2016 within the scope of this project (cf. Jonsson Larsson, 2016). As only truncated portions of the fuel value chains are included in these estimates, they can only be viewed as partial indications of the employment effects of biodiesel and ethanol production in Sweden. Comparison against all of the ethanol and biodiesel modelling efforts delineated earlier in this report shows clearly that these figures are much smaller – thus reflecting the fact that only a portion of employment effects is represented.

4.4.1 Lantmännen

According to Lantmännen, 1264 GWh of bioethanol was being produced on a yearly basis during 2016. Lantmännen stated that 96 people are considered to be directly employed and indirect FTE employment is estimated as 75 persons. The latter consists of maintenance, consultants and so forth, but does not include the grain production chain. Estimates of direct and indirect employment in the agricultural sector are not provided (Jonsson Larsson, 2016). This yields the indicative employment intensity figures shown in Table 28.

Table 28. Lantmännen Agroetanol: total employment intensities.

	GWh	**Total** Employment	**Total ethanol employment/GWh**
2016 – Agroetanol (direct employment)	1264	96	**0.076**
2016 – Agroetanol (direct & indirect employment)	1264	171	**0.134**

4.4.2 Perstorp

According to Perstorp, approximately 2000 GWh of biodiesel was being produced on a yearly basis during 2016. Perstorp stated that 25 people were directly employed, and indirect FTE employment was estimated at up to 30. The latter consists of transport, distribution, retailers, marketing agencies, external analysis and certification institute, and sustainability auditors. Neither direct and indirect employment in the agricultural sector, nor the seed crushing, are included in the estimates (Jonsson Larsson, 2016). This yields the following indicative employment intensity figures shown in Table 28.

Table 29. Perstorp Group: total employment intensities.

	GWh	**Total** Employment	**Total bioDIESEL employment/GWh**
2016 – Perstorp (direct employment)	2000	25	**0.0125**
2016 – Perstorp (direct & indirect employment)	2000	55	**0.0275**

5 OVERVIEW OF EMPLOYMENT AND FINANCIAL METRICS

This section serves as an 'overview summary' of results from the earlier parts of this report. It compiles the results of the varying analyses (i.e. the metrics yielded) in a visually comparable form. Supporting text in this section is limited to brief explanatory information intended to provide the reader with a sense of 'how comparable' the information shown is likely to be – and how (un)certain relative measures are considered to be. This material serves as a foundation for the concluding section of the report.

At this point it is underlined that the majority of the metrics here are not directly comparable – examination for the methods in which they have been derived that are presented in the earlier chapters make that abundantly clear. Nevertheless, they have been grouped together in graphical figures. This has been done in the belief that the measures shown are sufficiently similar to provide a general picture for the reader of the likely span of metrics. Moreover, as the aim of this work has been to provide *a screening and review of job creation and assessment methods for other benefits*, it is considered that these general presentations of likely 'scales' of benefit, and the fact that they seem to lie reasonably close to each other, will be useful to stakeholders – at least in the area of job creation and economic benefits.

5.1 METRICS FOR ETHANOL

Findings for the ethanol studies are summarized in this sub-section. The US figures are drawn from the POET study (Urbanchuk & Norvell, 2015) presented in Section 3.3.1; the German figures are taken from the study by Wydra (2009) provided in Section 3.1.2; and the results for Australia are drawn from work by Malik *et al* (2014) presented in Section 3.1.3. Brief comments on assumptions and comparability are provided where feasible. Preliminary (and only indicative) Swedish figures were presented in Section 4.4.1.

5.1.1 Employment intensity ethanol

Figure 11 below summarizes a suite of employment intensity estimates. The results are presented for <u>total</u> full-time equivalent yearly employment positions (FTEs) per GWh of fuel produced and <u>direct</u> FTEs per GWh.

All three US figures are directly comparable to each other – their differences are interpreted to be related to scale and position of the relevant production facility (or facilities) within the POET Corporation. Regarding scale, the smaller production unit example (Michigan) demonstrates higher employment intensities than the larger (Iowa). Regarding the whole corporation (all 27 plants), it is interpreted that corporate functions, R&D services, engineering etc. add to the overall employment intensity.

The other studies have markedly different boundaries and assumptions for modelling. The Australian and German figures should be somewhat more conservative than the US figures as they include jobs lost in other sectors as well as jobs gained in the ethanol sector. The Australian figures may be more conservative than the German figures as they considered more sectors in their modelling. Note that the Swedish figure is an estimate based on figures provided by the producing company in a single data gathering exercise (Jonsson Larsson, 2016), and is included as an indicative comparison.

Despite these differences, the examination of modelling and available data sets within this study indicates that, with the exception of the Swedish figure, the broad (blue) bars (total FTEs) can be considered 'somewhat' comparable. However, it does not seem reasonable to compare direct FTEs due to the markedly different boundary settings in studies.

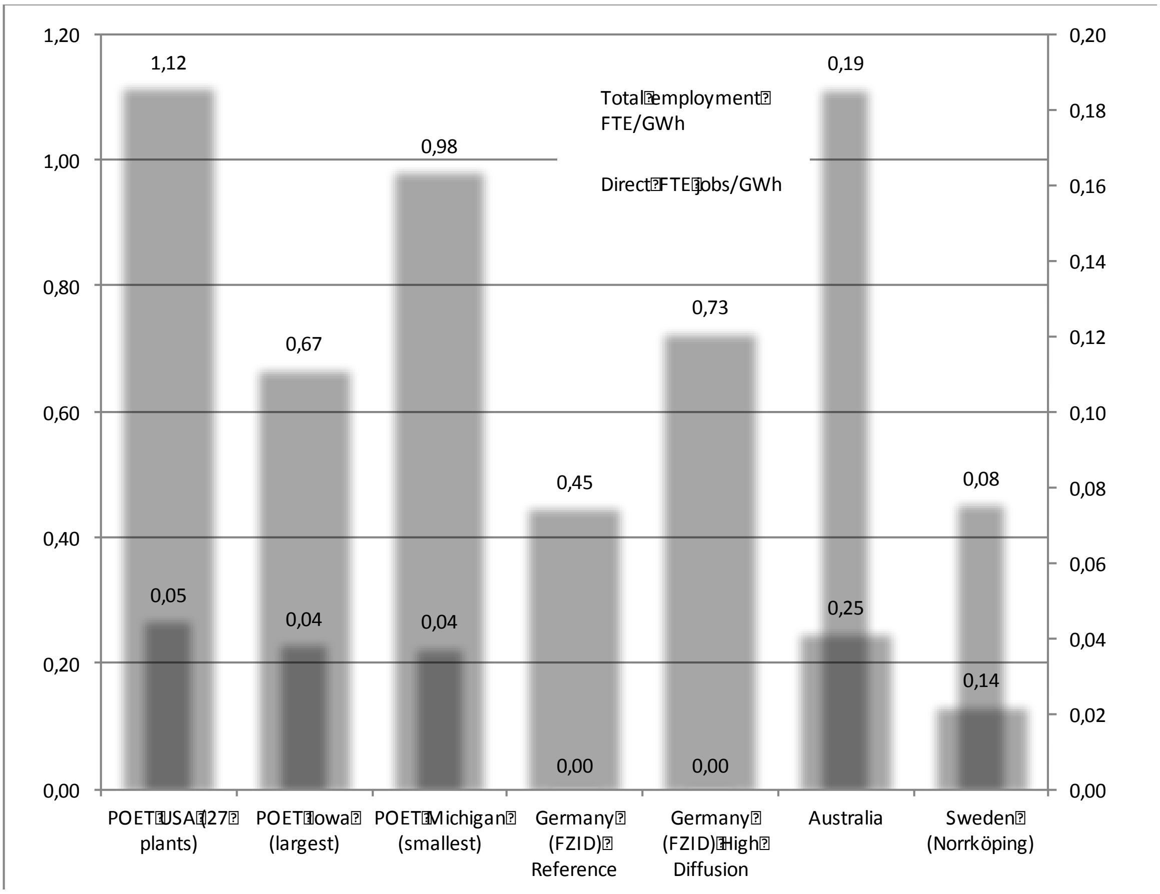

Figure 11. Indicative employment intensities for ethanol.

Based on the figures above the following indicative spans are suggested (provided per TWh so as to deliver round numbers):

- 40 to 80 FTE/TWh direct employment opportunities (Swedish value 80; Australian value excluded as an outlier);
- 250 to 1100 FTE/TWh total employment opportunities (Swedish value excluded as an outlier).

5.1.2 Economic contributions: ethanol

Figure 12 below summarizes estimates for the Regional Domestic Product (RDP) contributions related to ethanol production. Figures are converted to USD PPP (Purchasing Power Parity). Again, all three US figures are directly comparable to each other and are drawn from the POET (Urbanchuk & Norvell, 2015). While, the Australian (Malik *et al*., 2014) and German studies (Wydra, 2009) have different boundaries and assumptions for input/output modelling, it seems reasonable that they are somewhat comparable to each other. Again, it is considered that they are likely to be somewhat more conservative than the US figures as they include revenues lost in other sectors as well as those gained in the ethanol sector. The Swedish figure is a crude estimate based on the 2015 turnover of the producing company (without application of multipliers for flow-on economic effects, and without consideration of losses in other sectors). As such, it is considered that the broad (blue) bars (Total FTEs) are likely to be 'somewhat' comparable, but that direct FTEs should not be compared due to the markedly different boundary settings in studies.

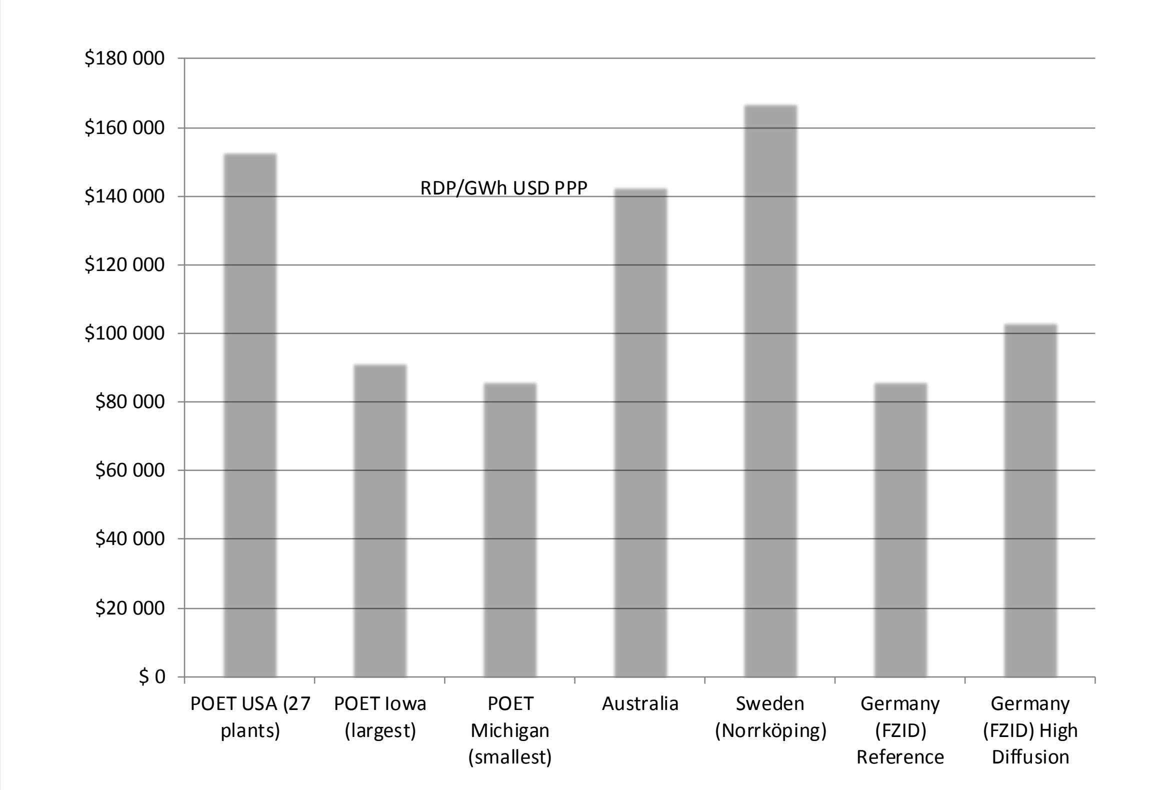

Figure 12. Indicative regional economic stimulus from ethanol value chains.

Based on the figures above the following indicative spans are suggested (provided per TWh so as to deliver round numbers):

- 0.75–1.5 MSEK/GWh (85 000–165 000 USD/GWh) (Swedish value 1.5 MSEK/GWh).

5.2 METRICS FOR BIODIESEL

Only findings for biodiesel effects in the US are summarized in this sub-section. The figures are drawn from the US biodiesel study by LMC International (2013) that is detailed in Section 3.3.2. It is important to note that the figures for 2013 in this graphical representation were estimates generated in 2012/13 before annual production figures for the US became available. These are included as they may provide insights into the expected scale economy and maturation developments that can likely be expected as the industry becomes larger and benefits from further scale economies – i.e. by reduced employment intensities among other things. It should be noted that the actual biodiesel production figures were significantly less than the 60 % increase assumed in the LMC study – thus these figures cannot be used in the same manner as the *ex post* figures of 2012.

It has been chosen not to present Swedish figures for biodiesel (see Section 4.4.2) in this summary due to insufficient data and significant uncertainty regarding the data received.

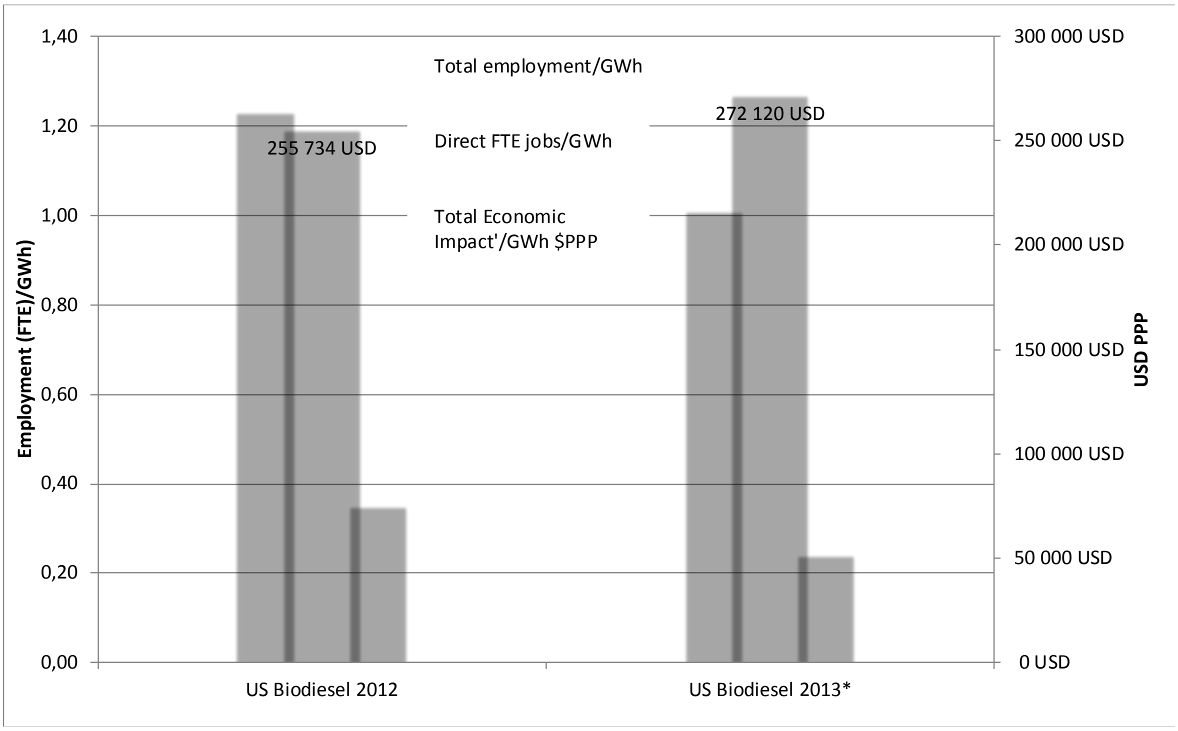

Figure 13. Indicative employment intensities and regional economic stimulus from US biodiesel production.

Based on the US figures above the following indicative spans are suggested (provided per TWh so as to deliver round numbers):

- 200 to 400 FTE/TWh direct employment opportunities (Swedish [Perstorp AB] value 12.5, US values 210-380);
- 1000 to 1200 FTE/TWh total employment opportunities (Swedish value not available);
- Regional domestic product stimulation circa 250 000 USD/GWh (2.3 MSEK/GWh) (Swedish value not available).

5.3 METRICS FOR BIOGAS

As noted earlier in this report, a number of assessments and modelling of biogas scenarios have been conducted in Sweden. The work has been directly related to a demand from regional political actors for decision-support information. In general, such demand has been related to plans related to the expansion of biogas production as part of regional climate and energy strategy development. All have had a primary focus on biogas utilization as a transportation fuel. As such studies have generally been conducted to support political strategy making, they have focused on quantification of: a) positive effects on regional economies, b) stimulation of employment, c) reduction of GHG emissions and d) other positive effects on the environment and/or human health.

Three of these evaluations have been produced by the same consulting company (WSP Sverige AB) using the rAps-model. These include: the study for Skåne in Section 4.3.1, the Biogas Öst Region in Section 4.3.2; and Norrbotten/Västerbotten in Section 4.3.3. The fourth study (KanEnergi AB, 2012) detailed in Section 4.3.4 was prepared for Västra Götaland and is only partly comparable to the former three. This final study also introduces an additional metric for employment intensities in Germany (Drawn from Table 3 in Fachverband Biogas eV, 2010). This single international metric for indicative employment intensity is included in the summary figure for employment intensities.

In addition to the figures shown here, it should be noted that Swedish biogas studies also provide enumeration of a number of other ancillary environmental benefits. These are estimated using methods and metrics developed by previous research work in Sweden. Those metrics were summarized and tabulated in Section 4.2.3, and are not repeated here.

5.3.1 Employment intensity Swedish biogas

Figure 14 below summarizes a suite of employment intensity estimates yielded by the cross comparison of Swedish biogas analyses. Again, the results are presented for Total full-time equivalent yearly employment positions (FTEs) per GWh of fuel produced and Direct FTEs/GWh.

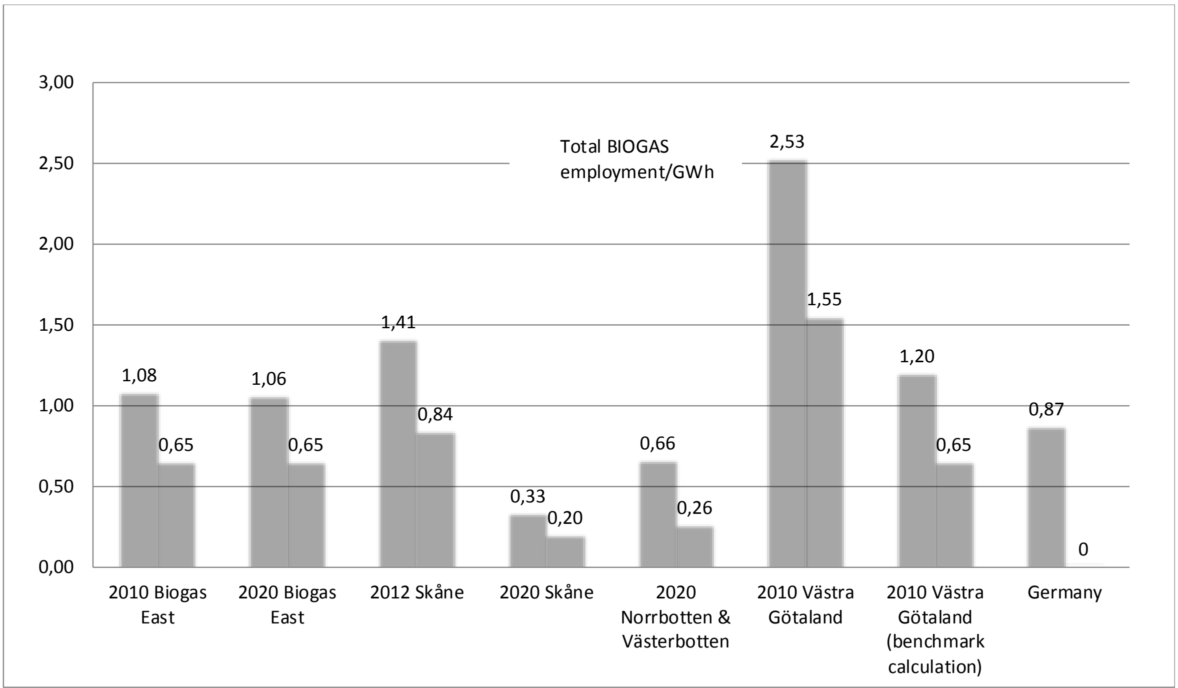

Figure 14. Indicative employment intensities of Swedish regional biogas programmes.

When examining the content of Figure 14, a number of considerations that affect comparability should be taken into account.

A first area relates to the three WSP analyses (Waluszewski *et al*., 2011; WSP Analys & Strategi & Region Skåne, 2012; WSP Sverige AB, 2013). Although produced by analysts from the same consultancy, the results presented for the Biogas Öst Region, Skåne, and Norrbotten/Västerbotten have varying levels of comparability. A number of (minor) methodological differences can also be discerned.

Within this suite of analyses, *2012 Biogas Öst* and *2012 Skåne* are considered the most comparable. This as they both are based on field data, address existing systems of biogas generation from a mixed suite of digestion facilities, and have manure and biogenic wastes as key substrates. Shifting focus to the related hypothetical forecasts (i.e. *2020 Biogas Öst* and *2020 Skåne*), these are judged here to be *somewhat* comparable as they extrapolate from the status quo analyses and share roughly the same base conditions.[50] The 2020 Norrbotten/Västerbotten scenario is also considered as *somewhat* comparable to these. However, the scale of operation, and substrate sources differ somewhat. Slightly differing approaches were applied in all of these studies when accounting for employment accruing related to capital investments.

A second set of considerations likely affect the comparability of the analysis for Västra Götaland (KanEnergi AB, 2012). This analysis was performed in a different manner to the WSP work listed above and is thus considered as *tenuously* comparable to the other studies. Most importantly, it differs in the manner that it is based upon greater inputs of 'bottom up' data, and estimations supported via interviews/surveys, and of course, it does not utilize modelling with an input-output tool.

Despite an apparently detailed approach, the indicative figures for labour effects and economic benefits are apparently significantly affected by a combination of the distinctly different economic structure in the region, and difficulties in allocation of benefits to the biogas production sphere. In short, the Västra Götaland region is markedly different to the other regions studied – and the method applied appears to have poorly supported efforts to control for this. As a key example, there is a strong regional hub of vehicle and engine manufacturers, and also of industrial gas equipment manufacturing. These industries serve not only the home region, but presumably all other Swedish regions with biogas related equipment. They also export such to the global market. This situation resulted in a notably different metrics as very much higher figures (and economic revenues) were recorded against the equipment manufacturing sectors than for other studies. In short, it appears it was difficult for the analysts to determine how much of these economic activities should be 'assigned' to regional biogas activities.

While the authors of the Västra Götaland analysis recognize this issue and go to some lengths in seeking to rationalize their figures so that they might be compared to other regions, this is only somewhat successful. The larger figure shown here (2010 Västra Götaland) indicates the number of employment opportunities for the *status quo* biogas sector after their attempt to remove (principally) 'export related' jobs. The smaller figure (benchmark calculation) is based on a 'check calculation' performed by the authors of the Västra Götaland report. Here they back-calculated based on likely biogas sales turnover in an attempt to provide a benchmark figure of 'how many jobs can conceivably be supported by the existing production levels'. As such, this figure is interpreted by this analysis as a 'reality check' rather than an outcome of the study. It is has been included in Figure 14 as it also provides a cross-check for the other graphs shown in the figure.

Thirdly, one international figure from the German biogas sector (cited in KanEnergi AB, 2012) is also included for reference. Although the structure of the biogas sector in Germany is different to that in Sweden,[51] this is incorporated so as to again provide a picture of the general scale range appearing in studies.

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[50] Note that there were two 2020 projections were produced in the Skåne report. One digestion based, and a second also including contributions from the proposed e.ON biomass gasification project Bio2G. Only the former is included here.

[51] Much larger proportions of substrate come from commercially grown crops, and much of the biogas is used for subsidized electricity production.

In the light of these provisos, it is put forward that existing Swedish **biogas** initiatives appear to offer:

- 650 to 850 FTE/TWh direct employment opportunities;
- 1100 to 1400 FTE/TWh total employment opportunities.

Further, it is put forward that potential future Swedish **biogas** initiatives at larger overall scale (including gasification projects) in Sweden are modelled to offer:

- 200 to 650 FTE/TWh direct employment opportunities;
- 300 to 1050 FTE/TWh total employment opportunities.

5.3.2 Economic contributions: Swedish biogas programmes

Figure 15 summarizes estimates for the Regional Domestic Product (RDP) contributions attributed to biogas production. Figures are again also shown as US dollars PPP (Purchasing Power Parity). The limitations presented above are also considered relevant for this sub-section. As a difference for this figure, it has been chosen not to provide the RDP figures for the Västra Götaland region. As indicated in Section 4.3.4, the RDP figures yielded by that study were an order of magnitude higher than other studies, and are thus deemed as not comparable.

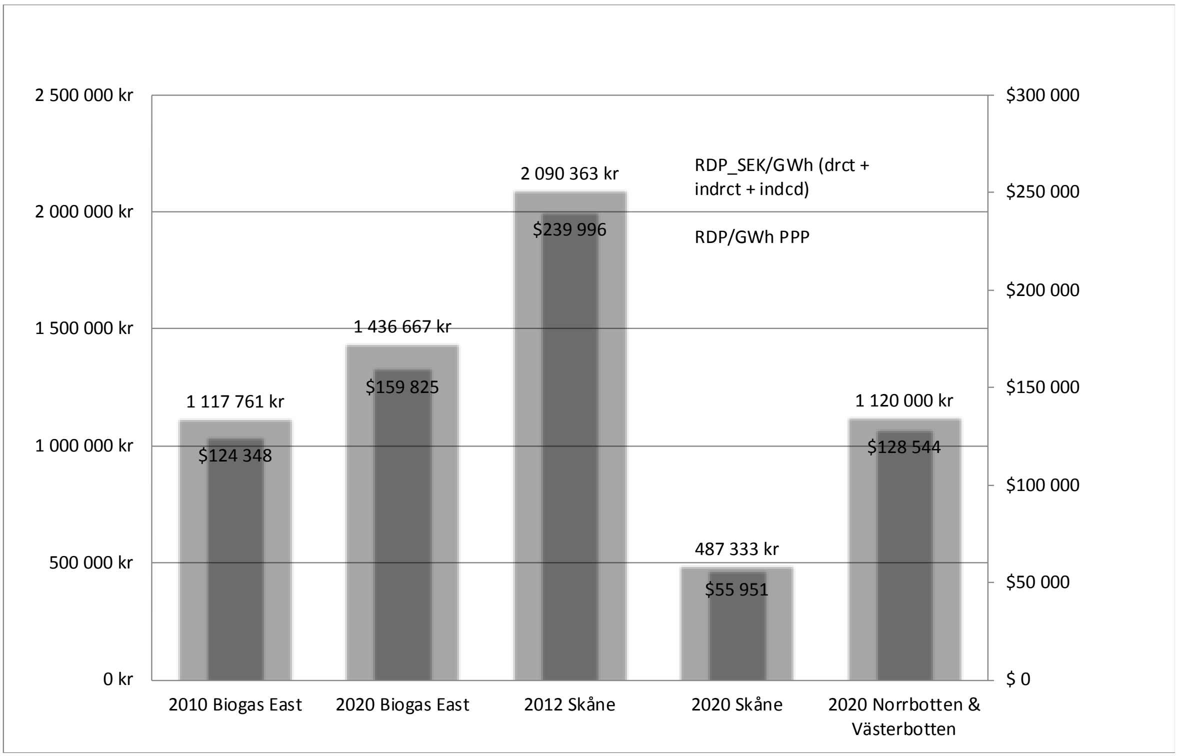

Figure 15. Indicative regional economic stimulus (RDP) of Swedish regional biogas programmes.

In the light of these provisos, it is put forward that existing Swedish **biogas** efforts appear to offer:

- Regional domestic product stimulation in the range of circa 1–2 MSEK/GWh (125 000–240 000 USD/GWh).

Potential future Swedish **biogas** efforts (including gasification projects) in Sweden appear to offer:

- Regional domestic product stimulation in the range of 0.5–1.4 MSEK/GWh (50 000–160 000 USD/GWh).

6 CONCLUSIONS

This analysis had the stated objective to examine Swedish transport biofuels production and identify the socio-economic benefits through a screening and review of job creation and assessment methods for other benefits.

The screening review applied significant focus on job creation. The assessment of methods was broader, and has delineated benefits of a number of by-product streams, and pollution reduction impacts, that result from biofuels production and utilization. These include: methods for assessing job creation; approaches applied to enumerate the economic parameters; and methods for assessing other socio-economic benefits.

6.1 ASSESSMENTS OF NATIONAL LEVEL BENEFITS

In essence, such analyses build upon equilibrium or partial equilibrium models for the agricultural and energy sectors. They are often applied to compare different (candidate) policy tools against each other *ex-ante*. Moreover, as the industries that they model are 'up and running', they apply data and assumptions that are based to varying degrees upon real life experience. As such, this work sees these efforts more as 'extrapolations of early progress reports' rather than hypothetical modelling exercises. In essence, such modelling efforts are used to test the assumptions or rationales listed in the following citations, from the EU and the US:

> *"there are several policy drivers for biofuels on a larger scale in the EU transport sector, including increased security of energy supply, reduced emission of greenhouse gases (GHG), and new markets for the agricultural sector"* (Duer and Christensen, 2010).

> *"three reasons are routinely cited to rationalize biofuel production and biofuel support policies: energy security, environmental impacts, and support for agriculture and rural development"* (Moschini *et al*., 2012).

Using input-output modelling, national level assessments gauge the effects of a new (expanding) biofuels sector upon other parts of the economy. Thus, they count both 'positives' in the bio-industries and 'negatives' elsewhere. These methods are used to assess overall welfare effects, labour market effects, economic revenues, or combinations of these.

With the exception of a Spanish study where large amounts of feedstocks were imported, the studies examined in this analysis showed that the new biofuels industries created new employment opportunities and created financial benefits at national levels. Several of the studies also showed that net benefits also accrued when the costs of fiscal support to the biofuels industries were included in calculations/modelling (e.g. as subsidies or tax reductions). These cases however, were in situations where significant or dominant proportions of biofuel feedstocks were domestic.

These results are interpreted as essential confirmation of the rationales presented in the citations that address motivations for policy support. As such, a general finding is that the new biofuels industries in the EU, and abroad, can be expected to deliver positively against expectations of: increased security of energy supply; reduced emission of greenhouse gases; reduced negative environmental effects; improved rural development; and new markets for the agricultural sector.

Regarding the reliability of metrics related to fuel production derived from these 'economy-wide' studies (e.g. jobs/unit energy carrier) – it is found that their comparability is low. Each study assessed has markedly different aims and assumptions and has in essence evaluated different things. This analysis has nonetheless extracted a small number of normalized employment metrics from these studies for **indicative** comparison against the metrics derived from the second part of the work that examined industry or project derived indicators. It is very important that the reader keep these **significant limitations** involved in mind when interpreting this work.

6.2 ASSESSMENTS OF BENEFIT DELIVERED BY A SPECIFIC SECTOR, A PROJECT, OR A GROUP OF PROJECTS

This work shows how these assessments are grouped in two main categories. The first being essentially 'bottom-up' counting exercises conducted in direct liaison with biofuel producers that are active in a specific area or sub-region. The second category generally requires the application of regional analysis forecasting and modelling software linked to regional demographic and economic databases.

Most of the bottom-up exercises examined, focus only upon direct and indirect employment opportunities, but may also include direct economic effects. Modelling exercises often also include induced employment effects, at all three levels (direct, indirect and induced). While they can also provide details of economic metrics (regional level 'domestic product'), some efforts limit this to only business turnover or wages.

6.3 APPROACHES TO GENERATED BIOFUELS-RELATED METRICS ON EMPLOYMENT/ECONOMIC STIMULATION

'Bottom-up' counting exercises conducted in direct liaison with biofuel producers very much reflect their description. First a boundary is set upon the system, second all or most participating companies or organizations are identified, these are for instance codigestion facilities, sludge digesters, energy companies, authorities on county, municipal and regional levels, research organisations, local traffic organisations, etc. Third, interviews and/or questionnaires are used to provide a basis for employment effect estimation. Next, estimates for direct and indirect employment opportunities resulting from the project(s) within the system are generated. Finally, the option to estimate induced employment effects using guideline estimates can be followed.

Modelling exercises on the other hand, combine utilize regionally maintained databases, and may also be enriched with field data specific to the area of study. The Swedish studies examined in this project were generated with rAps, a Regional analysis and Prognosis system tool, while those providing details from the US biofuels sector were produced with a model named 'IMPLAN pro data'.

Results drawn from both bottom up and modelling exercises are summarized below. All values have been normalized to benefits per TWh or GWh of produced fuel.[52]

International (US, Australia and Germany) and Swedish **ethanol** initiatives indicate the following value spans:

- 40 to 80 FTE/TWh direct employment opportunities (Swedish value 80);
- 450 to 1100 FTE/TWh total employment opportunities (Swedish value not applicable);
- Regional domestic product stimulation in the range of 0.75–1.5 MSEK/GWh (85 000–165 000 USD/GWh) (Swedish value 1.5 MSEK/GWh).

International (US) and Swedish **biodiesel** initiatives indicate the following ranges for benefit metrics:

- 10 to 380 FTE/TWh direct employment opportunities (Swedish value 12.5, US values 210-380);
- 1000 to 1200 FTE/TWh total employment opportunities (Swedish value not available);
- Regional domestic product stimulation circa 2.3 MSEK/GWh (250 000 USD/GWh) (Swedish value not available).

Swedish **biogas** efforts in Sweden appear to offer:

- 200 to 850 FTE/TWh direct employment opportunities;
- 300 to 1400 FTE/TWh total employment opportunities;
- Regional domestic product stimulation in the range of 0.5–2 MSEK/GWh (50 000–240 000 USD/GWh).

6.4 ENERGY SECURITY AND VALUATION OF ENVIRONMENTAL BENEFITS

This work shows that a relatively broad suite of ancillary benefits is now entering into mainstream use. The most prominent focus at the national level in Sweden, in this category, is on CO_2. This is also the case on the pan-European stage – a situation that is logical considering the importance of the climate change discourse internationally. A fundamental difference however, is that Swedish valuations for CO_2 are very high when viewed from an international perspective. The general Swedish CO_2 tax is set at a level of 1.14 SEK/kg (1.05 SEK/kg until April 2016) an extreme value compared to a range of estimates of the damage costs related to CO_2 emissions used elsewhere; a representative average value of these lies at around 0.2 SEK/kg (it should be noted however, that there are expectations that this latter value will increase with time).

An even higher value has been applied where biofuels are seen to replace gasoline and diesel in the Swedish transport sector. Since 1999, Sweden has applied a valuation based on intervention costs associated with the achievement of political goals (1.5 SEK/kg CO_2). This value was based upon

[52] As Swedish figures used here do not include feedstock production (large proportions of Swedish feedstock are imported), Swedish figures comparable to international metrics are not available for a number of categories.

calculations of the marginal intervention costs required to meet relevant milestone goals for CO_2 emissions from the transport sector.

The Swedish ASEK methodology now recommends that CO_2 should be valued according to a political shadow price that is derived in turn from the CO_2 tax. As of 2016, this yields a calculation value for CO_2 of 1.14 SEK/kg released (2014 SEK). For sensitivity analyses, a CO_2 value of 3.5 SEK/kg may now to be applied.

However, it can be argued that metrics that are more relevant when viewing the situation from a regional, sub-regional, or local perspective are related to other environmental benefits. While, the limited number of studies found in this work allows only an observation that the utilization of these items is not widespread, there have been a number of reviews that combine, rationalize and reinforce the relevance of the items selected.

The more focused values, and the areas they are applied within include the following:

- NOx reduction – LCA studies estimating reduced climate emissions;
- nitrogen leakage to groundwater – water quality studies and leakage modelling;
- methane reduction– LCA studies estimating reduced climate emissions;
- replaced mineral fertilizers – LCA studies estimating reduced climate emissions from fertilizers; avoided costs of purchased fertilizers;
- value of recovered nutrients – studies estimating avoided costs of purchased fertilizers;
- avoided costs of purchased fuels;
- energy security (displaced fossil fuel import) and calculations of avoided strategic storage costs;
- particulate emissions – avoided health related costs from health costs studies.

Such have been applied in a number of biofuels studies generated for regional decision-making.

Moreover, there is a suite of metrics that have been flagged in studies as relevant. In a Swedish context, the following have been used, or are under consideration for evaluation in the future:

- valuation of improved crop yields related to rotations with crops for biofuels production;
- economic benefits of technology development and eventual export earnings;
- avoided costs of alternative waste treatment.

A compilation and comparison of Swedish metrics and quantifications environmental gains related to biofuels that are in use were provided in Section 4.2 (for brevity, these are not repeated here).

6.5 APPARENT KNOWLEDGE AND CAPACITY GAPS

In addition to the insights provided into metrics by this work, a number of gaps in knowledge and capacity are discerned. Work to address these may be important for future studies related to transportation biofuels – and for broader work in the emerging bioeconomy. A number of observations are put forward in this regard.

- This study documents work that provides measures of potential social, environmental and economic benefits related to biogas production in quite considerable detail (e.g. with the rAps model). Modelling efforts have addressed both existing digestion based systems and proposed thermochemical pathways for gaseous fuel production. These methodologies are suitable for work in other contexts (i.e. they are repeatable for other fuel value chains).

- However, similar evaluations were not found in this study for liquid biofuels in Sweden (of any fuel-generation). This represents a clear knowledge gap – and it is logical that the types of knowledge detailed here for biogas can be important as decision support information for future liquid transportation fuel initiatives.

- Research and evaluation work for the emerging bioeconomy will share many of parameters found to be important in this biofuels-related study. Among others, these include: regional embeddedness; contributions to environmental quality; socio-economic benefit in rural areas as well as urban centres, and stimulation of technology development. Again, it is logical that similar assessment work will also be important to underpin decision-making for bioeconomy efforts (e.g. for biorefineries etc.). It is also logical however, that the complexity of such work could be higher than the applications viewed in this study.

- Work analysing Swedish projects using the rAps model referenced in this study were produced by a single commercial consultancy; despite the model being available to academia and to governmental agencies. Despite the work involved in this review, it remains unclear if the competencies to apply such tools exist within research groups such as the *f3* centre community of actors, or if they are being used within governing bodies. There may be a need for development of new and deeper research and modelling capacity within technically skilled academic/research institutions that are to serve the needs of the future bioeconomy.

- In the light of broader 'positives' versus 'negatives' across the economy (e.g. as shown for the analyses in Australia and Germany in Section 3.1), and the inherent complexity likely for the broader bioeconomy, it seems likely that there will be needs for both method and tool development for the Swedish rAps model if it is to serve the Swedish biofuels and general bioeconomy work in the future.

6.6 CONCLUDING COMMENTS

This analysis has examined Swedish transport biofuels production and identified and enumerated a range of socio-economic benefits associated with biofuels production. It has documented indicative spans of metrics for both job and wealth creation and how these have been derived. Emerging sets of metric, and general assessment methods for other socio-economic or environmental benefits have been identified.

The study has collated a number of general findings:

- essentially all referenced works, and input from industry, indicate that biofuels initiatives can be expected to generate new employment opportunities – both when measured at a sub-regional level and when measured across national economies;

- indicated employment generation figures produced for differing biofuels, in differing countries, at worst fall within a similar order of magnitude, and at best are very close to each other. An indicative figure of 1 FTE across a biofuel value chain per GWh of fuel production appears to be representative of the body of work reviewed. Further, many employment opportunities appear to accrue in rural areas, and the FTEs seems to be around one order of magnitude higher than the employment intensity of fossil transportation fuel value chains;

- indicative regional domestic product figures produced for differing biofuels across a range countries, at worst fall within a similar order of magnitude, and at best are very close to each other. An indicative figure of circa 1 MSEK/GWh of fuel production appears to be representative of the body of work reviewed;
- valuations of other ancillary benefits – including human health, climate, and resource efficiency – appear to be entering mainstream use. Further it seems that such are generated largely with LCA data and are thus presumably highly reliant upon robust LCA data. Importantly in the context of this work, such items also appear to add a significant benefit over and above the economic items indicated above.

Beyond socio-economic metric work the study has also indicated that:

- it appears likely that significant modelling and assessment work focused on socio-economic evaluation will be required for biofuels projects, and for the broader bioeconomy (e.g. important for decision-support), yet there is evidence that modelling and assessment work has only addressed biogas initiatives to date;
- there may be a need for extension and development of a number of the methods and tools for producing socio-economic evaluations (with the rAps model as one example).

It is stressed however, that the potential areas for future research and research capacity development presented above are speculative. A starting point for such work would logically be a brief assessment study focused on assessment of needs in such areas. Such work could include an effort to map capacity in this area within Swedish research institutions, and to assess the suitability of the existing tools to provide assessment of future bioeconomy initiatives.

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