A qualitative analysis of policy instruments meant to promote biofuels for transport

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1 Introduction

According to the Swedish Energy Agency and the Swedish EPA's joint evaluation there is no coordination of policy instruments nor concerted strategy in the area of biofuels[1] and clean vehicles.[2] Furthermore, the existing policy instruments have, in the main, not been evaluated or assessed as to their impact. Formulating policy for the transportation sector is a complex task where the users as well as other actors such as the transportation fuel industry, the auto industry, and fuel distributors need to be taken into account. The system has intrinsic inertia; in order for measures on the production side to have effect, complementary and concurrent measures on the demand side and/or directed toward the distribution side may be required in order to avoid catch-22 type situations.

This report is meant to contribute to the knowledge of policy instruments for the transportation sector[3]. The more precise goal is to, from a number of perspectives, qualitatively analyse various policy instruments meant to promote biofuels. The analysis is based on a general characterization of the relevant instruments which are evaluated with respect to their significance for a selection of political objectives. This yields a systematic, theoretical summary and a qualitative comparison of the policy instruments.

A schematic matrix is used to collect and represent the results. For each instrument and political objective, a relative measure is entered into the matrix, as applicable, indicating which significance the instrument has for the given political objective in comparison with the other policy instruments. The measures 0, +, and ++ are used to indicate that the instrument lacks effect (0) or has an effect (+ and ++). The text will explain the individual choices of relative measures for each combination of policy instrument and political objective.

The matrix provides a compact summarizing characterization of the various policy instruments' relative significance for their respective objectives. However, the measures cannot be compared and summed up across political objectives (without weighing the objectives themselves, which is mainly a political task). The results of the analysis indicate, to the extent possible, the ranking of instruments for each objective (but will not quantify the individual instruments' relative effect on the various objectives or provide an overall ranking of the policy instruments.

[1] Throughout this report, the term "biofuels" refers to biofuels for transport, i.e. excludes solid biofuels such as pellets.
[2] Ekonomiska styrmedel i miljöpolitiken, Rapport från Naturvårdsverket och Energimyndigheten, 2006 (Economic policy instruments in environmental policy, Report by the Swedish Environmental Protection Agency and the Swedish Energy Agency—not available in English). The report examines current policy instruments in this area and summarizes the available evaluations.
[3] The report is produced to support Swedish Energy Agency's project "Policies for promoting the use and production of biofuels".

The analysis described above can be found in section 3 which also describes a few complementary aspects. Section 2 provides the economics theory context for the policy instrument discussion, with a focus on carbon dioxide emission reductions. Section 4 closes with recommendations for developing policy instruments for biofuels.

2 Policy instruments for biofuels from the perspective of economics

From the perspective of economics, policy instruments for biofuels can be considered a response to the following market failures:

- A failure to internalise the cost of environmental externalities associated with the use of fossil fuels (that is, insufficient consideration has been given to the impact of emissions and those who emit do not in general compensate for the damage caused).
- A failure to provide sufficient incentive for research that aims to find solutions to the climate issue, which in part is caused by carbon dioxide emissions from the use of fossil fuels. The reason not enough research is being done (i.e., that not enough funds are invested in research on solutions) is that R&D are expensive. The corporation or nation making the investment can also not be sure to obtain the entire benefit/profit of the research since there may be spill-over effects that can be used by other corporations or nations. The options for protecting new technology through patents etc may also be limited if the results to some extent are considered a general discovery that should benefit all. Basically, this applies to all important research whether we are talking about HIV or climate change. Research advances that provide solutions may not provide patentable solutions. This reduces the incentive to conduct this kind of research, and this is why there is not enough privately-funded research. For this reason, government funds are required for these research areas.
- Technologies may need initial support since the market may not itself overcome initial thresholds/market difficulties due to the high costs and long lags associated with these. For this reason it is also important to provide support for market creation and to contribute to establishing commercially viable technology. This can be done with pilot projects and demonstrations, which can be important because it may take a long time for new technologies to be developed to the point of breaking into the market.

In addition, there is a potential market failure when it comes to the oil supply and transaction costs associated with energy security having to do with the fact that oil is a finite and geographically unevenly distributed resource. However, the significance of this market failure and the costs associated with failures in energy security are discussed in economic terms (appendix 1 will include an account of this).

The effect of CO_2 emissions from the use of fossil fuels is a global environmental problem which is independent of which sector the emissions come from. In addition, the CO_2 emissions are in principle directly proportional to the use of fossil fuels. According to economics theory, the most appropriate policy instrument—the "first best" option—for reducing the total amount of CO_2 emissions at the lowest cost is to increase the cost of emitting fossil CO_2. This can be achieved with a CO_2 tax[4] on fossil fuels at the global level in all sectors or a corresponding emission trading scheme with a cap, where those who cause the external costs are responsible for paying society to correct for these. This tax should be a so-called Pigouvian tax which on the margin is equal to the value of the external costs.[5] A tax on transportation fuels has shown itself to have a major effect on the use of fuel in real life and constitutes a powerful means for limiting global warming, but the tax should apply to all use of fossil fuels, not just in the transportation sector.[6]

However, in practice a global CO_2 tax on all fossil fuel use does not seem politically feasible within the foreseeable future. Cost efficiency does not always match political feasibility. One problem has to do with the use and control of the tax revenues. This problem could be solved through international coordination of the tax level in combination with national tax collection. But even this system would probably mean that a CO_2 tax would meet with substantial opposition, and powerful lobby groups (representing fossil fuel interests) would attempt to block its effect. In general it seems politically difficult to introduce environmental taxes in a given sector or at the national or regional level (even if from the financial perspective this would be an efficient way to reach optimal levels of emissions).[7]

In order to correct for the market failure pertaining to insufficient incentives for R&D on new technologies, a combination of a tax on CO_2 emissions and subsidies for R&D – and even actual use of biomass for energy purposes — should be considered.[8]

Because the "first best" policy instruments are not feasible in their entirety[9], alternative instruments are called for to support energy use that does not lead to CO_2 emissions, for

[4] A tax on carbon dioxide is equivalent to a carbon tax, from a policy instrument perspective. Systems with emission trading also play an analogous role.
[5] An optimal environmental tax is called a Pigouvian tax. In the absence of other effects, this is equal to the marginal cost of the external effect (see Pigou, A.C., 1920. The Economics of Welfare. 4th ed. London: MacMillan). That an optimal environmental tax is set below this level can be explained by other taxes reducing the economic activity and therefore contributing to internalising part of the environmental externality.
[6] Sterner, Thomas (2003), "Policy Instruments for Environmental and Natural Resource Management", RFF Press, Resources for the Future, The World Bank, SIDA
[7] Kåberger, T., Sterner, T., Zamanian, M., and Jürgensen, A., 2004. Economic efficiency of compulsory green electricity quotas in Sweden, Energy & Environment, 15(4), pp. 675-697.
[8] Fischer, C., and Newell, R., 2004. Environmental and technology policies for climate change and renewable energy. Resources for the future. Discussion paper 04-05, April. Available at: http://www.rff.org/rff/documents/RFF-DP-04-05.pdf
[9] However, introducing subsidies for R&D and for use of renewable energy sources may be politically feasible.

instance sector specific instruments. In practice what needs to be considered is what is politically feasible, and in Sweden this means more stringent requirements in the transportation sector. Placing stringent demands on the power generation sector and on industries has proved difficult, since this affects the competitiveness of the EU and Sweden, and for reasons of competitiveness a high tax in the transportation sector and a low tax elsewhere may be better than a low tax in all sectors. Additionally, the willingness to pay is typically greater in the transportation sector which would indicate the possibility of introducing more measures there. There is also a tendency in society to prefer policy instruments other than the more general price signals, for instance tax exemption for biofuels. Such efforts aim toward partial objectives and may be cost inefficient but may in some cases be justified due to the difficulties involved in introducing high carbon dioxide taxes. However, constant improvement and updating of these instruments is required in order to ensure that promising new technologies are not disadvantaged.

Since several underlying market failures need to be corrected for, a combination of policy instruments will probably be required (for example, subsidies for R&D on alternatives in general appear necessary even with a CO_2 tax). In Sweden several different policy instruments that affect biofuel production and use in Sweden have been adopted and more are being discussed (see section 3.1).

Finally, it should be emphasised that apart from biofuel use there are other ways to reduce CO_2 emissions from the transportation sector (for instance other fuels, altered driving patterns, other modes of transportation, and increased efficiency), although these are not analysed here.

3 Qualitative analysis of policy instruments

3.1 Policy instruments and political goals subject to analysis

The EU's member nations currently employ two general mechanisms for introducing biofuels[10]:

- Tax Exemptions (e.g. Sweden, Germany, Finland, and Austria);
- Mandatory biofuel blendning[11] in conventional fuels (Austria has implemented, and Germany has decided to implement, mandatory use of low-blend biofuels).

Table 1 shows a list of the policy instruments that currently impact the production and use of biofuels in Sweden.

[10] For more information about existing and proposed policy instruments for biofuels in selected European countries, refer to the European Biomass Association's "Boosting Bioenergy in Europe" project.
[11] This study uses the term "biofuel blending" to signify that a certain percentage of the fuels are produced from renewable energy sources.

Table 1 List of policy instruments that in different ways impact the use and production of biofuels.

Policy instrument	Purpose	Primary impact on biofuels
Tax on carbon dioxide	Reduce carbon dioxide emissions	Use
Tax on energy	Generate income	Use
Exemptions from carbon dioxide / energy taxes	Provide alternative transportation fuels with a competitive advantage	Use
Public information campaigns	Increase public awareness	Use of and demand for clean vehicles
Reduced benefit value	Reduce the cost of owning a clean vehicle	Demand for clean vehicles
Government purchase of and targets for clean vehicles[a]	Increase the share of clean vehicles	Demand for clean vehicles
Congestion charge (exemption from)	Decrease traffic in the city centre	Demand for clean vehicles
Requirement for petrol stations to provide renewable transportation fuels	Improve spread and distribution of renewable transportation fuels	Distribution and use
Funding for R&D	Support technology development	Production of biofuels and development of clean vehicles, e.g., the DME engine
LIP/Klimp[b]	Reduce greenhouse gas pollution, improve energy efficiency, induce development towards sustainability, create jobs	Demand for clean vehicles, production and use of biofuels.
Targets for use of biofuels	Support the introduction of biofuels	Use
Agricultural subsidies	Support certain crops or regions	Production
Targets for renewable electricity	Increase use of renewable electricity	Production (competition for biomass)
Electricity certificates	Increase use of renewable electricity	Production (competition for biomass)
Emissions trading	Limit carbon dioxide emissions	Production (competition for biomass)

[a] According to the Swedish Road Administration's definition, a clean vehicle is fuel efficient, has low carbon dioxide emissions, and low emissions of substances that are harmful to human health and the environment. All clean vehicles must minimally pass at the emission requirement in environmental class 2005 (Mk 2005). Additionally, particle emissions for diesel cars must be under 5 mg/km. The CO2 emissions for autos running on petrol or diesel (including hybrid cars) must be below 120 g/km (125 g for autos of the minivan type). Cars running on renewable fuel are permitted to have a fuel consumption of 9.2 L petrol/100 km.. However, the definition of clean vehicles varies from place to place in Sweden.
[b] In 2002, LIP (Local Investment Programmes) was replaced with KLIMP (Climate Investment Programmes), but LIP-financed projects are still active.

The following policy instruments are analysed in this part of the project:

- Tax relief for biofuels (through CO_2 and energy tax exemptions for biofuels)[12];
- Policy instruments that stimulate the use of so-called clean vehicles (for instance, reduced compensation/benefit value; targets for government purchasing of clean vehicles; free parking; or congestion tax exemption);
- Legislation requiring petrol stations to provide renewable fuels;
- Directed technology support (including research support, development support, demonstration support, and investment support, etc.[13])
- A certificate scheme for biofuels (this analysis assumes a Swedish biofuel certificate scheme, where only Swedish facilities are awarded certificates when producing biofuels and where those who sell fuels must provide a certain amount of biofuels, which may vary with time, but always must possess the corresponding number of certificates);
- A so-called feed-in tariff for biofuels, whereby Swedish facilities that produce biofuels are guaranteed compensation for their production (which directly burdens the consumers or the national budget);
- Mandatory use of blended biofuels up to a particular level, alternatively a quota obligation for biofuels.
- A national emissions bubble for CO_2 emissions from the transportation sector; and
- CO_2 tax on the use of fossil fuels.

We will analyse the extent to which each of these policy instruments contributes to:

- Decreasing the energy consumption in the transportation sector.
- Decreasing CO_2 emissions in the transportation sector.
- Reaching the government's long-term goal of reducing greenhouse gas emissions 25% by 2020.
- Reducing the use of oil.
- Reaching set goals for national biofuels.
- Technology neutrality in the sense that it does not explicitly favor certain biofuels (also means that it must not result in the market selecting one biofuel over another).
- Promoting biofuels with significant climate benefit[14].
- The increased use of domestic resources (i.e. contributes to the preconditions necessary for forestry and agriculture to conduct business in the area)[15].
- The effective use of biomass resources.

[12] Note that the loss of tax revenue due to the promotion of biofuels through tax relief constitutes a subsidy.
[13] Because a comparison between different types of technology support is beyond the scope of this part of the project, this policy instrument category will represent directed technology support in general.
[14] For example, sugar cane ethanol in tropical nations has better yield per area and energy efficiency than grain ethanol and RME in Sweden/EU.
[15] Because of the nature of the market and competitive aspects, the EU level is interesting in this context, but a Swedish perspective has been retained because this level is often used in discussions.

- Economizing with the national budget (only direct effects are included).
- Creating long-term, stable rules for producers and users.
- Promoting Swedish development of new technology (for instance, cellulose-based fuels).

3.2 The impact of various policy instruments on the related political objectives

This section discusses the impact of the policy instruments on each of the related political objectives from a theoretical perspective. The matrices in Table 2 and Table 3 are used to illustrate the results, and the accompanying text explains the results in more detail. The relative significance of each policy instrument to the attainment of the relevant political goal, is indicated by the scores 0, +, ++ and -. The indicators are used to describe whether the policy instrument lacks impact (0), is effective (+ and ++), or has a negative impact (-). Note that ++ should not be interpreted as meaning "twice as effective as +", but merely as "more effective than +." Also note that in many instances, the indicators only apply under certain circumstances, marked by and described in a footnote. It should also be noted that the various policy instruments analysed do not impact the biofuels use in the same way. Policy instruments that promote the use of clean vehicles primarily impact the demand for clean vehicles, but also impact the demand for biofuels, assuming the vehicles run on biofuels. Legislation requiring that renewable fuels be provided primarily impacts the distribution of biofuels, but could also affect use. Directed technology support primarily impacts the production of biofuels. Tax relief, certificate schemes, feed-in tariff subsidies, mandatory use of blended fuels or a quota obligation, a national emissions bubble, and the CO_2 tax impact the production and use of biofuels.

Table 2. Description of the relative impact of each policy instrument analysed on the related political objectives. The indicators are described above.

Policy instrument	**Political objectives**					
	Reduce energy use in the transport sector	Reduce CO2 emissions from transports	Attain the government's climate goals [g]	Reduce oil use [h]	Attain national biofuel goals	Technology neutral (in practice) [i]
Tax relief	0 or – [a]	+	+	+	+	-
Incentives for clean vehicle use	0 or – [a]	+ [d]	+ [d]	+ [d]	+ [d]	-
Legislation requiring that renewable fuels be provided	0	0 [e] or + [f]	0 or + [f]	0 or + [f]	0 or + [f]	-
Technology support	0	0 [e]	0	0	0	-
Certificate scheme	0 or + [b]	+	+	+	++	-
Feed-in tariff subsidy	0 or + [b]	+	+	+	+	-
Mandatory use of blended fuels, or quota obligation	0	+	+	+	++	-
National emissions bubble for transportation sector	0 or + [c]	++	++	+	+	-
CO2 tax	0 or + [b]	+	++	++	+	-

[a] The "-" signifies that the policy instrument could increase energy use. The reason is that with these policy instruments, consumers save money, which may be spent on more driving.
[b] Applies when the cost of the feed-in tariff subsidy and the certificates burden the consumers, resulting in reduced consumer spending on fuels (a CO_2 tax could create the same effect since it results in increased costs for consumers).
[c] Applies when the entire reduction in fossil fuels required by a strict bubble is not replaced with biofuels but is satisfied due to improved efficiencies in the transportation sector.
[d] Applies assuming they run on fuels that emit less CO_2
[e] No direct impact
[f] Applies assuming the improved distribution opportunities result in an increase in biofuel use.
[g] Each policy instrument marked "+" in this category has the potential to contribute to a reduction in CO_2 emissions and could thereby contribute to attaining the goal.
[h] Note that it is difficult to theoretically rank the effect of various policy instruments for this objective.
[i] Here, "-" signifies that the policy instrument is not technology neutral in practice.

Table 3. Description of the relative impact of each policy instrument analysed on the related political objectives (cont'd).

Policy instrument	**Political objectives**					
	Biofuels with significant climate benefit	Use of domestic resource	Effective use of biomass [n]	Economize with the national budget [o]	Stable rules	Swedish technology develop-ment
Tax relief	0 or x [j]	0	0	-	0	0
Incentives for clean vehicle use	0	0	0	-	0	0
Legislation requiring that renewable fuels be provided	0	0	0	+ [p]	+	0
Technology support	++ [k]	0 or + [l]	++ [k]	-	++	++ [s]
Certificate scheme	+ [l]	0 or + [l]	+ [l]	+	+ [r]	+ [t]
Feed-in tariff subsidy	+ [l]	0 or + [l]	+ [l]	- alt + [q]	+ [r]	+ [t]
Mandatory use of blended fuels, or quota obligation	0	0	0	+	+ [r]	0
National emissions bubble	0 [m]	0	0	+	+ [r]	0
CO_2 tax	0 [m]	0	++	++	+	0

[j] Assuming they are designed so as to promote the use of biofuels with significant climate benefit, rather than those without.
[k] Assuming they support technologies that produce fuels with significant climate benefit, or that result in the effective use of biomass.
[l] Assuming the policy instrument is designed so as to promote the use of fuels with significant climate benefit or that result in the effective use of biomass rather than other fuels, or that the biofuels that are consequently introduced are produced using Swedish raw product.
[m] Assuming that all biofuels are carbon dioxide neutral.
[n] Note that only the related policy instruments are compared against each other. Thus, "++" is given to the policy instrument with the potential to promote biofuels that represent a more efficient use of biomass compared with other biofuels, and is not given to a policy instrument that promotes the most efficient use of biomass in general, since these are not included in the analysis.
[o] Here, "-" indicates a policy instrument that constitutes a relatively severe burden on the national budget. Note that only direct effects are considered in the analysis.
[p] Disregarding the subsidies available as of February 1 for the installation of biogas pumps.
[q] Applies assuming the subsidy does not burden the national budget, but rather is financed by, e.g., consumers.
[r] Applies assuming these policy instruments are guaranteed to be in effect long into the future.
[s] Assuming that the support is directed at the development of Swedish technology.
[t] Assuming that they are designed to promote those fuels that result from Swedish technology development.

3.2.1 Decreasing the energy consumption in the transportation sector.

Tax relief and incentives for clean vehicle use provide consumers with more money, which they can spend on fuel for transportation, which thereby could counteract a decrease in energy use. A certificate scheme, a feed-in tariff subsidy, and a CO_2 tax, on the other hand, will increase the cost to consumers, so long as they are designed so that the consumers pay the costs associated with the schemes, resulting in a reduction in the demand for energy. None of the other policy instruments included in the analysis are likely to result in a noticeable decrease in energy use in the transportation sector[16]. A national emissions bubble for fossil fuels could have that effect. The precondition would be that the reduced use of fossil fuels (required by a strict bubble) would not be completely compensated for by a corresponding increase in biofuels use, but rather that the bubble actually makes the transportation sector more efficient.

3.2.2 Decreasing CO_2 emissions in the transportation sector

A national emissions bubble for fossil fuels has a significant potential for reducing CO_2 emissions in the transportation sector, because an emissions bubble could regulate the CO_2 emissions from the transportation sector, for instance, in accordance with the goals specified by the government.[17] The size of the bubble determines the amount of CO_2 emissions by the transportation sector. Any demand for transportation energy in excess of this level must be met with biofuels or other CO_2 neutral fuels.

A CO_2 tax on the use of fossil fuels will make biomass more competitive relative to fossil fuels and thereby more attractive to the transportation sector. Moreover, a CO_2 tax makes biomass more attractive in other energy sectors as well, which could result in increased competition for the available resource. If ambitious climate targets are sought and the finitude of biomass is taken into account, a CO_2 tax alone might not lead to much use of biofuels in the transportation sector, since as far as CO_2 reductions are concerned, biomass is used more efficiently in the heat sector.

Tax relief for biofuels may reduce CO_2 emissions in the transportation sector, if it causes an increase in the use of biofuels; however, the impact depends on the appeal of biofuels. A certificate scheme, mandatory use of blended fuels, a quota obligation, or feed-in tariff subsidies for biofuels could also lead to a reduction in CO_2 emissions in the transportation sector (assuming that they result in the use of biofuels increasing more than the use of fossil based fuels, which is a likely result). But the effect of these

[16] An increase in the use of biofuels with a lower energy content per litre of petrol (e.g. ethanol) and diesel would – if everything else is equal – lead to an increase in energy use, since the larger total fuel volume must be distributed to the petrol stations.

[17] To reduce emissions by the transportation sector, an objective has been established that specifies that by 2010, CO_2 emissions from transports in Sweden should be stabilized at the 1990 level (Proposition 1997/98:56 Transportpolitik för en hållbar utveckling (Transportation Policy for Sustainable Development)).

policy instruments on the total CO_2 emissions is uncertain, because these instruments have no direct impact on the total amount of fuels used in the transportation sector. The policy instruments that stimulate the use of clean vehicles could contribute to a reduction in CO_2 emissions in the transportation sector, assuming that the purchased clean vehicles run on fuels that release less CO_2 than the fossil-fueled vehicles they are intended to replace.

Neither legislation requiring petrol stations to provide renewable fuels, nor directed technology support will directly impact the emissions of CO_2 in the transportation sector, but both impact the conditions necessary for this to occur. Assuming that legislation requiring petrol stations to provide renewable fuels results in increased use of biofuels, it would, however, contribute to a reduction of CO_2 emissions in the transportation sector if these biofuels were to replace fossil fuels.

3.2.3 Reaching the government's long-term goal of reducing greenhouse gas emissions 25% by 2020

Among the included policy instruments, only a national emissions bubble for fossil fuels can be used to ensure that a particular goal with respect to CO_2 emissions from the transportation sector is reached (even if other policy instruments can have the same effect). A bubble has great potential for contributing to attaining the general goal of reduction. A CO_2 tax, likewise, would likely contribute to attaining a particular climate goal, but whether the goal is attained will depend on the tax level and the degree of the actual reduction in fossil fuels. However, tax relief, a certificate scheme, mandatory use of blended fuels, quota obligation, and feed-in tariff subsidies for biofuels are all capable of contributing to a reduction of CO_2 emissions in the transportation sector, assuming that they cause a reduction in the use of fossil fuels. Even policy instruments that stimulate the use of clean vehicles could contribute to attaining CO_2 goals, assuming that the clean vehicles that are purchased run on fuels that emit less CO_2 than their fossil-based equivalents. A law requiring petrol stations to provide renewable fuels could also contribute to the attaining a CO_2 goal, assuming the improved distribution capacity results in an increase in the use of biofuels.

3.2.4 Reducing the use of oil.

A CO_2 tax will increase the price of oil, and thus has great potential for reducing the use of oil (in the case of a general CO_2 tax this would apply to total oil use, not just the use of oil in the transportation sector). The policy instruments that cause an increase in the use of those biofuels that replace petrol and diesel in the transportation sector would simultaneously reduce the Swedish use of oil. This effect is achieved by a national emissions bubble for fossil fuels, tax relief, a certificate scheme, mandatory use of blended fuels, a quota obligation, and feed-in tariff subsidies for biofuels. Even policy

instruments that stimulate the use of clean vehicles could contribute to this effect, assuming that such vehicles run on other fuels than petrol and diesel.

Legislation requiring petrol stations to provide renewable fuels or directed technology support would not by themselves increase the use of biofuels. Thus, these policy instruments in isolation do not affect the consumption of oil. But, of course, they do impact the conditions necessary for increased biofuels use, which in turn leads to a reduction of oil use. But assuming that the law requiring petrol stations to provide renewable fuels results in increased use of biofuels in place of oil, this policy instrument would, of course, reduce the consumption of oil.

It is not possible to provide a theoretical answer to the question of which policy instrument would have the largest impact on the use of biofuels (and thereby have the largest effect on the reduction of the consumption of oil). Consequently, the matrix does not distinguish between these policy instruments. Using a national emissions bubble, the amount of fossil fuels used in the transportation sector can be regulated; thereby, the extent of the use of such fuels in the transportation sector can be controlled. The certificate scheme and the mandatory use of blended fuels or the quota obligation could be designed so that these two in principle provide the same result. With a specific number of certificates, a certain level of mandatory use of blended fuels, or a particular quota obligation, the potential is good for controlling how much biofuel will be used nationally, and thereby also the amount of fossil fuels to be replaced. The effect on oil consumption caused by future tax relief, feed-in tariff subsidies, or policy instruments that stimulate the use of clean vehicles, is more difficult to estimate.

3.2.5 Reaching set goals for national biofuels, i.e. increasing the amount of biofuels in the Swedish transportation sector

A certificate scheme for biofuels can be designed to reach specified biofuel goals. This applies to the policy instruments with respect to mandatory use of blended fuels, and to the quota obligation. Tax relief is not connected to the extent to which biofuel goals are met, but of course impact the use of biofuels. The same applies to the feed-in tariff subsidies for biofuels and the CO_2 tax.

A national emissions bubble for CO_2 emissions from the transportation sector has a good potential for resulting in an increased use of biofuels, since the possible transportation energy demand (improved efficiency is another alternative) in excess of the maximum level of permitted CO_2 emissions must be met with biofuels that are CO_2 neutral. Policy instruments that stimulate the use of clean vehicles could contribute to attaining the biofuels goal, so long as the vehicles run on biofuels. A law requiring petrol stations to provide renewable fuels improves the chance of attaining specified biofuels goals, but a positive impact on the goals is only attained if the increased

distribution capacity results in an increased use of biofuels. In the short run, technology support does not affect biofuels use; but in the long-term, it could.

3.2.6 Technology neutrality in the sense that it does not favor certain fuels over others

The point of a technology neutral policy instrument in this context is that it would not favor a particular technology or fuel over another. In this analysis, we have assumed that this applies to both the policy instrument and its effects.[18] A certificate scheme, a feed-in tariff subsidy, mandatory use of blended fuels, a quota obligation, tax relief, a national emissions bubble, and a CO_2 tax (if they encompass all biofuels) in theory appear to be technology neutral with respect to the selection of biofuels, but in practice there is a risk (at least initially) that they will favor those biofuels that are available on the market, and among those, the ones that currently are the most cost effective, and not the biofuels that are considered more promising in the long run (cellulose-based fuels). This is because the market for biofuels is at a germinal stage, where certain fuels can be produced, distributed and used on a large scale, while others are at a less advanced stage of development.

A certificate scheme promotes competition between various types of biofuels, but only among biofuels that currently are competitive. The policy instrument could, however, be designed so that each biofuel is promoted to a varying extent. The same applies to the feed-in tariff subsidy and probably also to the quota obligation. But then they are no longer technology neutral in the traditional meaning, because in theory they do not promote all fuels equally.

The purpose of directed technology support is precisely that, to support technologies and biofuels that are not yet commercial, but that are likely to make a meaningful contribution in the fuels market and that are promising in the long run. The policy instrument that stimulates the use of clean vehicles in practice only promotes those vehicles and technologies that are available on the market today, and primarily those that currently are the most competitive. Legislation requiring petrol stations to provide renewable fuels could, in theory, also be viewed as technology neutral, but in actuality, it would further increase the advantage enjoyed by those technologies that are the most competitive with respect to distribution. For instance, investing in ethanol pumps has proven to be considerably cheaper than investing in gas pumps that can distribute biogas, and attempts to correct this have been made subsequently.

[18] Of course, other definitions of technology neutrality are conceivable: for example, a policy instrument could be technology neutral if it lets the market decide the winning technology, because this would not entail the explicit support of one technology over another.

3.2.7 *Promoting biofuels with significant climate benefit*

Directed technology support can be applied so that it promotes fuels with significant climate benefit. Tax relief can probably also be designed so that it favors certain biofuels over others. Technically, the certificate scheme and the feed-in tariff subsidy could be designed to favor fuels with significant climate benefit over other fuels (for example, by addendums to the certificates).[19] The actual impact of these policy instruments, however, depends on how well one anticipates the different levels of support required to make those fuels that have significant climate benefit more competitive than other fuels.

The policy instruments that stimulate the use of clean vehicles usually are incapable of influencing the origin or performance of the biofuel, but in theory, they could be designed in such a way as to provide additional support to vehicles that run only on biofuels with significant climate benefit. In practice, however, it can be difficult to monitor whether the vehicles actually run on such fuels (which is why such a contribution is not specified in Table 3). Tax relief, mandatory use of blended fuels, and legislation requiring petrol stations to provide renewable fuels are not capable of influencing the selection of biofuels in a meaningful way. If all biofuels are presumed to be carbon dioxide neutral, the national emissions bubble for the transportation sector and the CO_2 tax, likewise, are incapable of promoting biofuels with significant climate benefit over others. Thus, this is a difficult goal to reach using the policy instruments included in the analysis.

3.2.8 *Contributing to the increased use of domestic resources*

Tax relief does not result in direct pressure on market actors to invest in Sweden. The same applies to a national emissions bubble for the transportation sector, a general requirement regarding the use of blended fuels, policy instruments that stimulate the use of clean vehicles, legislation requiring petrol stations to provide renewable fuels, and a CO_2 tax (the latter would, however, make biomass more competitive, which increases the demand, possibly resulting in stronger demand for Swedish biomass).

Both the certificate scheme (encompassing only nationally produced fuels) and the feed-in tariff subsidy (at a level that produces an increase in production) would result in a national buildup of the capacity for biofuel production. But this does not guarantee that the utilized raw product will be Swedish; it could be imported. These policy instruments, however, could probably be designed so as to distinguish between biofuels produced using different raw products. Support could be directed at technologies based on cellulose, for example, but whether these technologies use domestically produced cellulose when they reach the market remains to be seen.

[19] Similarly, if a scheme for certifying biofuels were implemented, these two policy instruments could technically be designed to favor certified biofuels over other biofuels.

The conclusion is that it is difficult to determine in advance which policy instruments will contribute to the increased use of a domestic resource, whether traditional crops or cellulose. It would also be difficult from a competition perspective to be allowed to favor certain resources over others.

3.2.9 Contributing to the effective use of biomass resources

In general, biomass is considered more efficient for heat generation, for instance, than for the production of fuel. Out of the policy instruments analysed, a CO_2 tax is the one with the greatest potential to contribute to the efficient use of the biomass resource. Different biofuels, however, have different potential for contributing to an efficient use of the biomass resource. Using directed technology support, it is possible to choose which biofuel technologies to support, for example, those technologies that result in an efficient use of the biomass resource. Technically, the certificate scheme and the feed-in tariff subsidy could be designed to favor certain fuels (for example, fuels that contribute to the efficient use of the biomass resource) over others. The real impact, however, depends on the design of each policy instrument and its impact on various biofuels in practice.

Using a national emissions bubble for fossil fuels, tax relief for biofuels (unless these only apply to certain biofuels), and a general requirement regarding the use of blended fuels, however, there is no opportunity to monitor which biofuels are introduced, since this is determined by the market. Policy instruments that stimulate the use of clean vehicles also have a relatively poor potential for creating requirements with respect to the efficient use of biomass. The legislation that has passed in Sweden requiring petrol stations to provide renewable fuels also is incapable of influencing the selection of renewable fuel.

3.2.10 Economizing with the national budget

The policy instruments that burden the national budget consist of tax relief for biofuels, an feed-in tariff subsidy (if the subsidy is taken out of the national budget), directed technology support, and to some extent instruments that provide incentives for the use of clean vehicles (e.g. reduced compensation/benefit value and free parking). So far, the tax relief for biofuels has burdened the national budget significantly more than the resources allocated for research and development (which includes technology support). The cost of an feed-in tariff subsidy depends on how the policy instrument is designed and on its impact on biofuel production. Of course, the cost of policy instruments that provide incentives for the use of clean vehicles depends on the growth of the market for clean vehicles. Consequently, it is difficult to compare the burden on the national budget created by the two latter policies with that created by the two former policies.

Those policy instruments that burden the national budget to a lesser extent include a certificate scheme for biofuels; a requirement of mandatory reformulation of transportation fuels with biofuels; a national emissions bubble for fossil transportation fuels; and legislation requiring petrol stations to provide renewable fuels (disregarding the subsidies -- available as of February -- for the installation of biogas pumps.) By comparison, a CO_2 tax or a fossil fuel tax increase would increase the state revenue.

Policy instruments that provide incentives for the use of clean vehicles – legislation requiring petrol stations to provide renewable fuels, a requirement of mandatory reformulation of transportation fuels with biofuels, and a mandatory quota – are relatively easy for the government to implement. The implementation of tax relief, a certificate scheme, a national emissions bubble for fossil transportation fuels, directed technology support, and an feed-in tariff subsidy, on the other hand, would be more demanding (in terms of design, being accepted, etc.). For example, the feed-in tariff subsidy, tax relief, and, in certain cases, directed technology support, are considered government subsidies and implementation requires approval by the EU (see Section 3.4 for more information about input subsidies), which usually takes several years. Moreover, the certificate scheme, the national emissions bubble for fossil transportation fuels, and the feed-in tariff subsidy all require relatively significant oversight, which would probably be conducted by a suitable government agency requiring financial resources.

3.2.11 Creating long-term, stable rules for producers and users

Each of the policy instruments analysed indicates that the government considers the introduction of biofuels to be important. Directed technology support indicates that the government considers biofuels to be important in the long-term as well (though the government could, of course, change its opinion[20]). Because the tax relief becomes more costly for the State as the use of biofuels increases (i.e. when the tax revenue decreases from the petrol and diesel that is replaced by biofuels), this policy instrument will probably not survive if the amount of biofuels continues to increase considerably. The same goes for those policies that provide incentives for the use of so-called clean vehicles, in so far as they burden the national budget.

Whether long-term, stable rules for producers and users result from legislation requiring petrol stations to provide renewable fuels, a certificate scheme, an feed-in tariff subsidy, a requirement of mandatory reformulation of transportation fuels with biofuels, a national emissions bubble, and a tax on CO_2 depends on how the particular policy instrument is designed and whether it is guaranteed to last long into the future. But each

[20] The government's role could be seen as investing in technologies that will not survive without support, and evaluating the technologies as they are developed. Some technologies are provided continued support, while others that are considered less promising, are not.

has the potential to create relatively stable rules. A feed-in tariff subsidy can guarantee the producers a fixed price over a long period of time, while the prices generated by a certificate scheme are less certain. The stability of the rules created by a particular policy instrument will, of course, also depend on whether the policy instrument could be removed or changed easily. The importance of long-term rules should be weighed against the flexibility and importance of being able to change the policy instrument over the course of time.

3.2.12 Promoting the development of new technology in Sweden

Directed technology support can be designed in a way that promotes the Swedish development of new technology, for instance utilizing cellulose or engines/vehicles that run on biofuels. Technically, a certificate scheme and the feed-in tariff subsidy could be designed to promote those fuels that result from Swedish technology development over other biofuels (for example, by addendums to the certificates).

Biofuels tax relief, policies that provide incentives for the use of clean vehicles, mandatory reformulation of transportation fuels with biofuels, the national emissions bubble, and the CO_2 tax are less capable of contributing to the promotion of Swedish development of new technology for cellulose-based fuels, for instance. Legislation requiring petrol stations to provide renewable fuels does not, by itself, affect the development of new Swedish technology, but could in certain cases facilitate the distribution of the new fuels, which may result from Swedish technology development, if the legislation leads to investment in infrastructure that can be utilized by the new fuels as well.

3.3 Combination of policies

In some cases a combination of different policies is necessary to correct market failures. Several of the policies maintain their function even when used together with other policies. For example, a tax can be combined with a subsidy. These two policies can also be combined with a feed-in tariff, a certificate scheme and/or a required share of renewable energy or renewable fuels. A system of CO_2 emissions permits for the transportation sector can be combined with a tax, but in that case the effect of the CO_2 emissions will in principle depend exclusively on the system of emissions permits. Supplementing a CO_2 tax with a subsidy of bioenergy in general or biofuels in particular will result in increased use of bioenergy or biofuels, assuming that other means of reducing CO_2 emissions than the use of bioenergy/biofuels are utilized in the case of tax-only.

If a subsidy of biofuels is introduced where there already is a quota system that, for instance, defines the maximum amount of permissible CO_2 emissions from the

transportation sector, the emission of CO_2 will, in principle, not be further reduced due to the subsidy, because the CO_2 emissions are already regulated by the quota system. However, the use of biofuels could increase. On the other hand, if the quota is represented by a mandatory amount of renewable fuels, the subsidy will in practice not produce any further contribution of renewable fuels, as long as the subsidy is not so large as to render the quota system superfluous.

In practice, decisions regarding policies are usually made gradually, for instance if a CO_2 tax is introduced and turns out to be too low, it could later be raised or supplemented with a subsidy of bioenergy in general or of biofuels. If a quota system that sets the maximum permissible amount of CO_2 emissions from the transportation sector is implemented and turns out to be too generous, it cannot be supplemented in the same way (i.e. through a subsidy) and is thus more difficult to adjust later. If the quota for the mandatory renewable fuels amount turns out to be too low, the quota should be modified, which – if done very shortly after the implementation – could impact the actors' faith in the system.

Finally, it should be noted that the usefulness of combining policies may change as the policies change. It sometimes appears as though politicians generally take a cautious approach to taxation. They hesitate to raise taxes drastically, but will increase them gradually. For instance, if the law makers realize that the CO_2 tax is too low, the policy instrument could be supplemented with a subsidy of bioenergy, for example. This process works somewhat well, because a subsidy of biofuels complements and improves the effect of the CO_2 tax with respect to the use of biofuels. When politicians implement a trade system with general emissions permits, or specifically in the transportation sector, a gradual approach will work less well. If such a system is not sufficiently ambitious (which in this context means that the number of emissions permits issued is too large), this error cannot be corrected in a simple way by subsidizing biofuels, since such a policy instrument would not impact CO_2 emissions. It is important to consider these aspects when selecting and implementing policy instruments.

3.4 Certificate scheme vs. feed-in tariff subsidy

When comparing a certificate scheme to an feed-in tariff subsidy, an argument can be made that it is more difficult to attain goals with the feed-in tariff. The reason for this is that this policy instrument primarily affects the price and generally stimulates the production, and cannot be used directly to regulate the amount of biofuels. In a certificate scheme, on the other hand, it is possible to specify the desired amount biofuels. That said, a feed-in tariff system is considered a better form of support for new technologies and industries. The reason is that certificates are associated with uncertainty (because the future value of the certificates is uncertain and thus associated with higher risk taking, as banks are skeptical about supporting this alternative) and that

a certificate scheme has proved to work best with technologies that are relatively close to being commercialized. Both the national certificate trading system and the feed-in tariff system would, however, result in a national buildup of the capacity for biofuel production.

In other words, the certificate scheme and the feed-in tariff system each has its advantages. Both policies can be developed and their actual features will depend heavily on the details of their respective design. For example, it would be possible to imagine a Swedish certificate scheme for biofuels based on a Swedish goal for biofuels, where foreign fuel certificates are approved in order to fulfill the goal completely or partially (partially, to ensure the buildup of the Swedish capacity for biofuel production; completely, in order to instead ensure the lowest possible cost for attaining the Swedish goal). Whether each policy instrument will promote new and innovative methods (in Sweden or abroad) depends on how the criteria are defined. It may seem easier to fine-tune the feed-in tariff system criteria, but in principle, it should be possible to use the same criteria (e.g. that encompass only innovative and not-yet commercial technologies) for a certificate scheme.

One difference that is perhaps worth noting concerns the way these policies are viewed by the EU with respect to ”government support.” One of the advantages of the certificate scheme is that it does not entail any direct transfers of resources from the government to a particular industry (the cost lies directly with those who buy fuels and does not burden the national budget in a substantial way) and that it thus does not constitute government support. Feed-in tariff subsidies, however, are considered government support, and even if this is acceptable when it comes to important environmental issues, in principle the relationship will always be temporary.

Owe Andersson of EKAN Gruppen has evaluated the use of a national certificate scheme for biofuels on behalf of the Swedish Energy Agency and the Swedish Road Administration. The evaluation assumes that the end user will have a quota obligation, but if the end user does not express an interest in managing the quota obligation herself, the obligation will fall on the fuel supplier while the companies producing the biofuels are the ones obtaining the certificates. This means that in actuality, there is a small number of actors on both the demand and supply side of the certificates market, and the starting volumes are small. For this reason, the evaluation concludes that it will be difficult to design an effective, competition-promoting and well-functioning Swedish certificates market for biofuels.

3.5 Policies directed at vehicles vs. fuels

The reduction in the compensation/benefit value of automobiles that can run on alternative fuels has stimulated the sale of clean vehicles.[21] The exemption of clean vehicles from the congestion tax that was tested in Stockholm seems to have hade an impact on the sale of clean vehicles in that region. On the other hand, it is difficult to ensure that these vehicles are actually run on alternative fuels. Moreover, on several occasions it has proven to be less costly to run these vehicles on liquid fossil fuels than on ethanol, for example. In other words, these subsidies have not reached the level of incentive for renewable fuels use that was hoped for. Subsidies for clean vehicles can be criticised from a societal perspective because it means rewarding those who buy vehicles rather than those who do not (usually without any way to ensure that the clean vehicles are actually run on biofuels), while it also means that governments are involved in selecting which technologies to use to solve the climate question. From this perspective, a higher fee for non-clean vehicles could be a more appealing alternative. Generally, policies that directly promote the use of biofuels or other renewable fuels have a greater chance of accomplishing a fuel shift. If subsidies of clean vehicles were based on the actual CO_2 emissions, this would increase the incentive to use renewable fuels.

3.6 Including the transportation sector in the European emission trading scheme

Currently, discussions are underway to include the transportation sector in the European emission trading scheme (which would, however, not occur until after 2012). Basic principles of economics suggest that in order to achieve economic efficiency, the price of CO_2 should be the identical in all sectors. This is achieved if all sectors are included in the trading system for CO_2 emissions permits. A ceiling for total emissions that spans all sectors would also reflect the politicians' true ambitions.

The main argument against including all sectors is that the willingness to pay for emissions is significantly higher in the transportation sector than in the industrial sector. This is due to the fact that many industries are exposed to competition on the international market, which means that high emissions permit costs affect this segment more severely. If the transportation sector is included, the demand for emissions permits in that sector will probably drive up the permit price, thereby exerting more pressure for reductions within the industrial sector, which may lead to industries questioning the system and lobbying even harder against strict emissions goals. This could undermine the system entirely. There is also a risk that the transportation sector will argue for a phasing-out of taxes on CO_2 and petrol when joining the trading scheme. The effect of this could be that the price of petrol will drop, not rise, which would increase the

[21] Ekonomiska styrmedel i miljöpolitiken, Rapport från Naturvårdsverket och Energimyndigheten (Economic Policy Instruments in Environmental Policy – A Report by the Swedish Environmental Protection Agency and the Swedish Energy Agency), 2006.

transportation sector's demand for energy.[22] Finally, including the transportation sector would also mean the loss of any chance of implementing stricter policies and goals within the transportation sector. A study by IVL analyses the various options for implementing the trade of emission permits for CO_2 and other greenhouse gases in the transportation sector; the study likewise concludes that a complete integration of the transportation sector into the European emission trading scheme poses great risks[23].

4 Recommendations

The premise of the analysis presented in this text is that biofuels should be promoted through the use of policy instruments. The development and eventual implementation of policy instruments for biofuels will primarily complement the existing policy instruments in this area. Moreover, traditionally, the implementation of new policy instruments typically complements rather than replaces old policy instruments. From a macroeconomic perspective, however, a small number of general policy instruments – for example a CO_2 tax in combination with support for research and development of alternatives for solving the climate problem – is preferable to stacking one policy instrument on top of the next.

Below, recommendations are given. These are based on the above analysis and on discussions held during a meeting (Stockholm, January 11, 2007) with the reference group established to support to the development of biofuel policies at the Swedish Energy Agency.

- In developing and designing a policy instrument intended to promote biofuels it is important to specify the goals that are to be achieved in addition to increasing the amount of biofuels, and the reasons behind them.

- Regardless of which policy instrument is selected, a commitment to reducing the energy use in the transportation sector is very important, primarily by promoting energy efficient vehicles and fuels. It is important to remember that a reduction in the use of petrol and diesel in absolute numbers is an attractive way to increase the share of renewable fuels and helps to achieve any given biofuels-related goal. Reducing the demand for energy also makes it easier to both reach the CO_2 goals and reduce oil consumption.

- Assuming that a reduction in oil consumption is important, the following policy instruments are appropriate: Tax relief; certificate scheme; input subsidies; mandatory low blending and a quota obligation; a national emissions bubble.

[22] Fuel taxes: An important instrument for climate policy, Thomas Sterner 2006
[23] Holmgren, K; Belhaj, M; Gode J; Särnholm, E; Zetterberg, L; Åhman, M. 2006. Greenhouse gas emissions trading for the transport sector. Rapport (Report) B1703, IVL Swedish Environmental Research Institute.

Technology support and legislation regarding fuel availability are instruments that lack direct impact.

- Assuming that it is important to reduce CO_2 emissions, the following policy instruments are appropriate: National emissions bubble, but also tax relief; certificate scheme; input subsidies; mandatory low blending and a quota obligation. Technology support and legislation regarding fuel availability are instruments that lack direct impact.

- Assuming that it is important not to burden the national budget directly, the following policy instruments are appropriate: Certificate scheme, mandatory low blending and a quota obligation, a national emissions bubble, input subsidies (depending on their design) and legislation regarding the availability of renewable fuels (assuming that petrol pump subsidies are excluded). Tax relief, incentives for clean vehicles, and technology support, however, are instruments that burden the national budget

- Assuming that Swedish development of technology in the biofuels area is important, technology support would be an appropriate policy instrument, though a certificate scheme and input subsidies may also work if specifically designed to promote this goal. The policy instruments that lack a direct impact are: Tax relief; incentives for clean vehicles; legislation regarding the availability of renewable fuels; mandatory low blending and a quota obligation; and a national emissions bubble.

- There are several reasons why it is difficult to select policy instruments in the area in question. First, there are several different goals to strive for, and it is somewhat unclear which goal should be prioritized (selecting a policy instrument is generally easier when only one thing needs to be corrected). Second, the different phases of the biofuels development require different policy instruments (technology support is required early, and input subsidies as well, while certificate schemes tend to favor fuels already in the market or near commercialization) and different combinations of policy instruments have different effects.

- The societal use of introducing policy instruments that promote Swedish technology in the biofuels area should be further examined. This would make it easier to justify the choice of policy instrument. The cost effectiveness of using various policy instruments to attain a particular goal should also be analysed.

- Policy instruments designed to promote biofuels should be viewed as transitional policies that can be terminated once a well-functioning biofuels market is in place, or when other alternatives become available (e.g. hydrogen and/or electric cars on a large scale). Consequently, the timing of the policy instruments needs to be discussed, for instance at which biofuels level a certain policy instrument ought to

be modified. For example, it is evident that the existing tax relief for biofuels will be very expensive for the government in the long run if it is utilized extensively, because it results in a decrease in tax revenue. But keeping a long-term perspective is important with respect to policy instruments, their acceptance, and their impact.

- Studies and proposals regarding policy instruments designed to reduce carbon dioxide emissions in the transportation sector by promoting biofuels should consider the cost effectiveness and feasibility of each instrument.

- Designing a policy instrument is a complicated task and combining different policy instruments may have complex effects in practice. Implementing a combination of policy instruments requires a careful analysis of the interaction of the particular instruments.

- The *timing* of the implementation of a policy instrument and the instrument's *design* are central to their actual effect, which should be taken into account when developing the policy instrument. For instance, the timing is significant with regard to which biofuels will be promoted. Implementing a policy instrument that primarily promotes use and related production will not promote biofuels that are not yet on the market and that need further technology development. In designing the policy instruments, it may be possible in some cases to select which existing technologies/fuels to promote (if desirable).

- The need for separate support for research and development (in the form of directed technology support in general) tends to exist independently of what other policy instrument is selected to boost the introduction of biofuels.

- Policy instruments for biofuels should be flexible and dynamic in order to avoid a lock-in effect and so that developments in technology and other changes can be taken into account.

- AN EU perspective is important in the ongoing analysis. For example, it may be good if the policy instruments can be modified in step with the development in the field within the EU.

- Policy instruments that promote biofuels should be compared with other available alternatives for achieving the same goal. For instance, if the goal is to reduce oil consumption, biofuels should be compared with other strategies, such as using more efficient vehicles, etc.

- From a climate perspective, an increase of the CO_2 tax is recommended, alternatively the transportation sector should be included in the trading scheme.

The latter is only recommended, however, if it proves feasible without undermining the trading scheme.

- Long-term, the transportation sector may be included in the European emission trading scheme. Therefore, the compatibility of other selected policy instruments with this system should be evaluated, along with how they affect the development of the price of future emissions permits, for instance.

- Further studies of the consequences of biofuels policy instruments (both existing and future) are desired. How can the existing policy instruments be improved?

- The certification of biofuels is an aspect that should be included in the continued analysis. What can be done by the Swedish Energy Agency and Sweden, and how would that impact the policy instruments/choice of instruments? It may be useful to start by considering what is happening in the Netherlands on this issue.

- Using renewable atoms and molecules from the gasification of biomass, for example into oil refineries is an appealing way, from a systems perspective, to make petrol and diesel more environmentally friendly. Developing policy instruments that promote this should also be discussed in the continued analysis.

- The continued analysis should include aspects such as, "How to distribute the cost of the new policy instrument?", for example how the consumers are burdened.

- One suggestion for how to advance the project is to select a small number of policy instruments from the list (for example, quota obligation, mandatory reformulation of transportation fuels, input subsidies and an emissions bubble for CO_2 emissions in the transportation sector (where the EU level is deemed more interesting than having one for Sweden only)) and design these for optimal impact and goal attainment, and then compare them again to get a better picture of how they may/could function in practice (this analysis should also include negative effects). This should then be compared to the impact of further increasing the CO_2 tax.

- Many of the reference group participants advocated a quota obligation, and this would be well suited for inclusion in the continued analysis. This analysis should also include a discussion of how to combine a quota obligation with other policy instruments, for example tax relief, to ensure that is promotes fuels that are of great use from a climate perspective, etc.

- The project should also study the selection, design, and impact of policy instruments in other countries (e.g. Germany).

Acknowledgements

We are grateful to our colleagues Maria Grahn, Fredrik Hedenus, Karl Jonasson, and Thomas Sterner for their constructive comments.

Appendix 1: Energy security

While the cost of environmental externalities (for example, those associated with the use of fossil fuels) has been addressed in detail in the field of economic theory, the externalities associated with energy security and possible disruptions in the supply of energy are more complicated. The economics literature has addressed questions about market failures related to energy security.[24] When disruptions in the energy supply occur as a result of more or less unexpected events, for example war and natural disasters, the actors in the energy market expect state intervention. It is also the state's obligation to take preventive measures to reduce the impact of such events. The best way to do this, however, is very difficult to determine.

There are primarily two costs associated with a sudden energy shortage: (1) transfer of consumer surplus; and (2) macroeconomic, so-called adjustment costs. When the energy supply is disrupted, the price of energy increases, which in economic terms entails a welfare transfer from the importers to the exporters of energy. This welfare transfer should not be viewed as an actual externality, because it is the result of market mechanisms. Externalities of this kind usually do not burden the economy as a whole, and consequently state intervention through policy instruments is not required. The externalities do, however, result in a cost for the region or country importing the energy.[25] Macroeconomic adjustment costs occur because producers and consumers of energy cannot adjust to the new, higher energy prices immediately.[26] If the actors in the energy market and the state do not anticipate the entire future energy supply risk, there will be externalities associated with the macroeconomic adjustment costs.[27]

It could be argued that the policy instruments that promote domestically produced biomass for energy purposes reduce the vulnerability to sudden shortages in the energy supply (and prevent the transfer of the consumer surplus). But when the supply of oil, for instance, is disrupted it is likely that the global demand for biofuels will increase, which could lead to a price increase. The extent to which the development of the biofuels sector actually reduces the effect of macroeconomic adjustment costs depends on the short-term price relationship between the bioenergy consumed and the disrupted supply of energy. There is a risk that biofuels will not contribute to lower macroeconomic adjustment costs, because the price of such biofuels may follow the price of oil. Moreover, the biofuels produced in Sweden may not go to the domestic

[24] See, e.g., Bohi, D.R., and Toman, M.A., 1993. Energy security: Externalities and Policies, Energy Policy, 21(11), pp. 1093-1109 and Nesbitt, D.M., Choi, T.Y., 1998, Is an oil tariff justified? An American debate: The numbers say no. The Energy Journal 9(3), pp. 21-50.
[25] Parry, I.W.H., and Damstadter, J., 2003. The costs of US Oil Dependency. Resources for the future, Report 03-59 and Leiby, P.N., Jones, D.W., Curlee, T.R., Lee, R., 1997. Oil imports: An assessment of benefits and costs. Oak Ridge National Laboratory, November 1997.
[26] Leiby, P.N., Jones, D.W., Curlee, T.R., Lee, R., 1997. Oil imports: An assessment of benefits and costs. Oak Ridge National Laboratory, November 1997.
[27] Bohi, D.R., and Toman, M.A., 1993. Energy security: Externalities and Policies, Energy Policy, 21(11), pp. 1093-1109.

market since the market is global. The conclusion is that the significance of biofuels for energy security is complex and needs further examination.

Appendix 2: Arguments for and against introducing biofuels in Sweden: a quick guide

There are two reasons why biofuels may enter the market. *First*, biofuels may be competitive with the alternatives (this may hold in a particular market currently, for instance for ethanol in Brazil, but on the larger scale, this will take time unless subsidies and other support are taken into account). *Second*, there may be political goals that motivate introducing biofuels.

This quick guide summarizes arguments for and against introducing biofuels in Sweden. The purpose is to methodically highlight the issues involved in introducing biofuels. The aim is not to cover all aspects of the issue; instead it accounts for a few perspectives with an emphasis on climate benefit. The arguments are not listed in order of significance. Note that some of the arguments are only valid given certain conditions, which makes it harder to weigh them against each other.

In addition to the arguments listed below, it may be argued that government support for biofuels is required because the actual biofuel introduction in itself may need help getting started. This is due to the fact that introducing biofuels requires synchronized investments in production, distribution, and sometimes even in vehicle fleets. The market tends not to overcome such hurdles by itself and may need government help. Importantly, the argument for these measures only holds if it has already been shown that introducing biofuels is preferable.

A2.1 Arguments in favor of introducing biofuels in Sweden

A2.1.1 Reduce oil dependence / increase energy security

Introducing biofuels at a level that surpasses the increase in energy required in the transportation sector results in Sweden reducing its import of oil from oil producing countries. If Sweden imports all its biofuels from a handful of regions there is a risk of renewed dependence, but the risk has at least been distributed somewhat since currently potential biofuel exporters can be considered more stable than the Middle East (the risk is more related to annual difficulties with the harvest). However, domestic biofuel production strengthens the domestic security of supply given that the raw materials are domestic. Focusing on biofuels now can prepare us for the time when oil prices rise due to reduced supply. There is also reason to believe that the total cost for Sweden will be

lower the earlier and more controlled the shift is and that it may take a long time to move from concept to a full-scale up and running production.

Allows Sweden to reduce carbon dioxide emissions in the transportation sector and increase domestic bioenergy use at the same time

Introducing biofuels in Sweden means that Sweden's use of bioenergy can increase (by making biomass usable in one more sector) and that the corresponding amount of fossil fuel use and associated carbon dioxide emissions in the transportation sector can be avoided. Sweden has already increased the use of biomass in the heat sector[28] (but has not claimed that additional reductions are not possible). Today's options for reducing emissions in the transportation sector, apart from reducing demand by increasing efficiency or through hybrid vehicles, are biofuels, natural gas, carbon neutrally produced hydrogen or electricity. What currently makes biofuels attractive is that most of the other options are not yet sufficiently technologically or financially mature for large-scale deployment. If the barriers to carbon neutral hydrogen and power for transportation prove hard to overcome, the argument for biofuels may grow stronger in the long run because all sectors will need to reduce their carbon dioxide emissions if we want to reach tough climate targets in the future.

A2.1.2 Biofuels can function as an interim solution and provide a transition to future alternatives in the transportation sector

As long as biomass is not scarce and the Swedish power generating sector is almost entirely carbon neutral and the heat sector is well on its way toward carbon neutrality (and limits may exist preventing further improvements there), there is a possibility that it would be better to use the biomass for transportation biofuels, too, because this will build up a working market for this resource within Sweden. However, the counter-argument points out that the market is global and that this market gets underway equally well if the biomass is exported and for instance burned alongside coal in plants in Europe. But one could consider biofuels a force of change in the transportation sector, especially on the demand side (increasing the consumers' acceptance of alternative fuels). Later, when biomass is subject to competition, the transition can be made to another alternative in the transportation sector and the biomass used for something else. This presupposes that nuclear power is not decommissioned too rapidly. Decommissioning nuclear power increases the demand for biomass in the power generating sector and provides the same effect of establishing a market for bioenergy.

[28] In 2002, biomass represented more than one third of the energy used for heat in Sweden and roughly 3% of the energy for power generation (IEA Energy Balances, 2004). At the same time, a very small amount of biomass was used in the transportation sector. In 2004, renewable transportation fuels, almost exclusively biomass-based, accounted for 2% of the energy use in the transportation sector, STEM (2005) Energiläget 2005 ET2005:23 Energimyndigheten (Energy in Sweden Facts and Figures 2005, Swedish Energy Agency).

The reasoning above holds at the international level, too, for instance under the presumption that certain countries (presumably mainly developing countries) do not have policies to limit carbon dioxide emissions, which could mean that biomass does not becomes scarce even in the midrange (2020-2040). Naturally, whether biomass will be scarce is uncertain. But given that it is not scarce, it could be interesting to consider biomass a driving force for increasing the demand for bioenergy, globally, and developing technology, institutions, and markets worldwide. As more countries assume emission reductions and have the same price for CO_2—through the flexible mechanisms of the Kyoto protocol—it would be possible to convert back to oil in the transportation sector and use the biomass in other sectors. Given these conditions, even low blending would be an appealing option since it makes converting back to oil simple. This only holds if the risk of institutional and technological locking-in is negligible. If large barriers to conversions and transfer of biomass between sectors are built up, the reasoning does not hold.

In addition, certain biofuels may involve certain developmental stages (for instance, gasification technology) that may link to and simplify a transition to the hydrogen society. However, the significance of biofuels as a bridge technology is hard to estimate.

A2.1.3 Politically feasible climate targets

The transportation sector (excluding air and water) and the households do not compete internationally; the energy-intensive industries do. This means that it is politically possible to introduce more stringent climate targets for households and transports than it is for the energy-intensive industry, including the power sector[29]. Unless the transportation sector is included in the EU emission trading scheme, it is thus possible to argue for more ambitious emission reductions than in the case where the same CO_2 price holds for all sectors. This means that rather than minimizing the cost of emission reductions, the societal cost is minimized since indirect impact on the energy intensive industries can be limited which may yield increased support for the political decisions concerning climate change. Furthermore, there may be other factors in other sectors that limit these sectors' demand for biomass due to technical or financial reasons such as process temperature requirements and logistical problems.

A2.1.4 The significance of Sweden as role model

For Sweden to further reduce CO_2 emissions, these reductions pretty much have to come from either the transportation sector or the energy intensive industries (the power sector is almost completely carbon neutral and the heat sector is well on its way,

[29] Power generation is not subject to international competition, but ambitious reduction targets raise the price of power, deteriorating conditions for the energy-intensive industries.

although further reductions may be possible[30]). Sweden's ambition so far has been to adopt more stringent policies than the rest of the EU. For example, Sweden's climate target is based on global carbon emissions converging by 2050 to per capita emissions that correspond to one-third of Sweden's current per capita emissions.[31] In order to continue to push this target in international contexts, credibility is important—reductions in the transportation sector can help. Tougher climate policies in the rest of the EU could increase the demand for biomass and therefore increase the price which could be a disadvantage for biofuel productions and introduction in Sweden. There is also great hope that Sweden by acting early and focusing on technological development in biofuels can achieve a strong international position which could create jobs and generate export income.

A2.1.5 May mean a spread of knowledge and technology that brings global climate benefits and potentially creates a new domestic industry

Someone has to dare to be first when it comes to establishing and spreading climate neutral technology. The point of this argument is that the greatest climate benefits from a Swedish focus on biofuels may not be had in Sweden, but indirectly in other parts of the world, in time. However, the same effect may be achieved with other bioenergy use, but many nations have the reduced dependence on oil (which mainly goes to the growing transportation sector) at the top of the political agenda. There is therefore a possibility that biofuels can spread to nations through channels other than climate policy. Note though that a reduced dependence on oil means a lower demand for oil which should result in a lower price which would mean less political incentive to reduce the oil imports. The effects are of course quite dependent on the political development globally and the climate benefit from the spread is of course quite uncertain. The spread in this case does not refer solely to the actual technology but also to how working institutions and infrastructure systems for biofuels are created.

An early focus in an area where Sweden has good potential for success could lead to a strong international position and the possibility to export biofuels as well as know-how and technological expertise. Early introduction in Sweden could thus give Swedish industry a competitive advantage. But this assumes that the international market for biofuels also increases substantially, at the same time. This argument only applies from the Swedish perspective. From a global perspective, the industry should grow where it is most cost efficient for it to do so.

[30] Continuing to decommission nuclear power makes it harder to reduce CO_2 emissions; this could make introducing biofuels more difficult because it would increase the competition for biomass.

[31] The one-third figure corresponds to emissions somewhat lower than those indicated in the climate proposition of 2001, but correspond to a level that allows for a reasonable chance to reach the EU's two degree target.

A2.1.6 May potentially mean a reduction of emissions other than carbon dioxide in the future

Emissions and environmental impacts other than those associated with carbon dioxide are also important. However, the difference between conventional transportation fuels and biofuels in terms of emissions of dangerous substances depends on which biofuels are used to replace which conventional fuels (petrol-driven cars are different from large diesel-driven vehicles). Of course, preventing, for instance, large oil spills is also important.

A2.2 Arguments against introducing biofuels in Sweden

A2.2.1 Cost efficient use of biomass should be promoted

Given that biomass is a finite resource, given that there are no factors that limit an increased use of biomass for heat or power, given that CO_2 neutral alternatives other than biofuels become available in the transportation sector in the future, and given that we want to reach an ambitious climate target where all nations reduce emissions, the biomass is used most efficiently in the heat sector. In other words, given that there is open competition for biomass between different energy uses and the target is to reduce the total carbon dioxide emissions, from a societal perspective it is advisable to use the biomass where it has the greatest climate benefit.

A2.2.2 Reduces the incentive for other climate measures in the transportation sector

Focusing on biofuels may reduce the incentive to take other climate change abating measures in the transportation sector, for example, energy efficiency measures and changes in transportation patterns (which lead to a reduced transportation energy demand). This can happen if the political will to take measures in the transportation sector focuses solely on biofuels (or at least is satisfied with a focus on biofuels if this means that the transportation sector's carbon dioxide emissions / climate targets are reached). Reduced incentives can also follow if the governmental and industrial research budgets cannot cover additional areas of research. For example, pilot and demonstration constructions tend to be expensive in research contexts.

A2.2.3 Problems associated with biofuels as interim solution

If a Swedish introduction of biofuels is supposed to constitute an interim solution on the road to hydrogen, certain aspects, such as locking-in and creation of networks, should be considered. Introducing biofuels means that distribution, a market, and a network of actors such as lobby groups as well as perhaps vehicles and the like are created. This

carries with it the risk that it may be harder in the future to switch to another fuel in the transportation sector if this should prove more interesting in the future from a societal perspective. The risk of locking-in is uncertain, however.

A2.2.4 Production of biomass may have negative consequences for the environment

One argument that has been made points out that biofuels require large areas and therefore constitute a threat to biological diversity and natural environments. This problem has been discussed in the context of Brazilian ethanol and expansion in rainforests or other valuable areas. This concern is justified and the question of the entire effect on the environment deserves more attention than it has received to date. At the same time, we need to remember that this argument does not only apply to biofuels but to all use of bioenergy.