Promoting Renewable Energies in Transport Sector (Targets, Strategies, Costs, by Technology- 2005-2015)

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Abstract

This paper investigates ways promoting renewable energies in transport sector, regarding targets, strategies and costs by technologies.

The world's demand of fuels for transportation has multiplied over the last decades due to the concurrent fast expansion of population, urbanization, and global mobility. The majority of the energy used in transportation is utilized on the movement of passengers and goods on roads locally, nationally, and across regions. Transportation weighs heavily on climate, energy security, and environmental considerations, as majority of transport energy comes from oilbased fuels. Transportation is the cause of other critical challenges due to its supporting role in local and global economies, as well as the implications of increasing transportation on human health and social interactions.

As part of the efforts to reduce greenhouse gas emissions of the transport sector, to reduce the sector's oil dependence and diversify energy sources, the EU aims to gradually increase the share of renewable energy in the transport sector's energy mix.

Although the current climate for renewables in transport is challenging, studies specially regarding use of biofuels show that the outlook for the future in terms of costs is increasingly positive.

Introduction

The transportation sector is an engine of economic strength, contributing directly to gross domestic product and also supporting every sector of the economy indirectly[1]. Automakers, drivers, fleet operators, legislators, and regulators of the future will face challenges in enabling growth while reducing impacts on climate change and lowering dependence on petroleum.

The world's demand of fuels for transportation has multiplied over the last decades due to the concurrent fast expansion of population, urbanization, and global mobility. The majority of the energy used in transportation – 70% – is utilized on the movement of passengers and goods on roads locally, nationally, and across regions[2]. Transportation weighs heavily on climate, energy security, and environmental considerations, as 95% of transport energy comes from oil-based fuels[2].

The transport sector now accounts for about 23% (7.3 Gt) of annual global energy-related CO2 emissions (32 Gt)[3]. This is a significant rise (about 120%) from 3.3 Gt/year during the 1970s[3], and to achieve a two-degree scenario (2DS) *[The two-degree scenario (2DS) involves putting in place an emissions trajectory which would result in at least a 50% chance of limiting average global temperature increase to 2°C]*., CO2 emissions from transport would need to decline to 5.7 Gt annually. By 2015, global road transport CO2 emissions should have already peaked in order to achieve a 2DS, but this is not likely to happen under current trends.

Oil is expected to remain the dominant transport fuel in the coming years, and thus must be offset by a rapid decarbonisation of fuels and scaling up of renewable energy in the transport sector.

At present the transport sector is the least diversified energy end use sector. In 2013, only about 3.5% of renewable energy was consumed in transport sector globally. [3]

Transportation is the cause of other critical challenges due to its supporting role in local and global economies, as well as the implications of increasing transportation on human health and social interactions. The immense and multi-faceted challenges of a global transportation system deeply rooted in fossil fuels are compounded by the quickly evolving aspirations of a worldwide population that is increasingly on the move and has learned to regard mobility, in particular by motorized modes, as an important component of the modern lifestyle they have or are seeking to attain.

1. The Role of Renewable Energies

Globally about 93% of the transport sector is driven by oil, with biofuels still meeting only 2% of road transport fuel demand (mostly in Brazil, the United States and the European Union) and natural gas contributing to only about 1% of total transport fuel use[3].

From 2000 to 2012, biofuel consumption within the transport sector has seen a six-fold increase globally. During the same period, natural gas use in transport modes (excluding pipelines) has experienced a tenfold increase[4]. In both cases, however, these increases are measured from a very low baseline, and thus these fuels still make up an insignificant share of total global fuel consumption.

2. Required Policies

First of all if we want to answer this question that how fast do we need to decarbonize transport, we have to say decarbonizing the economy will require rapid transformation within the transport sector. It has been well established that decarbonizing the transport sector is likely to be more challenging than for other sectors, given the continuing growth in global demand, and the rapid increase in demand for faster transport modes in emerging economies[5]. Lack of progress to date in slowing growth of global transport emissions to meet IEAs requirement to peak transport emissions by 2020 to achieve a 2DS will require deeper emission reductions in the middle and longer term with high intensive transition to a more diversified transport energy sector.

Before explaining required policies to achieve a successful transformation of transportation systems, we want to draw your attention to the following points:

- The transformation of transportation systems locally and globally must start now. Time is of the essence. Achieving multiple goals is possible, as transportation impacts all other areas in society. The strengthening of institutional capacity will be necessary to deal with solutions that require merging concepts to improve energy and transport systems interaction, technology, urban and regional spatial planning, infrastructure development, and economic and social innovation.

- Transportation goals for reducing fossil fuel consumption need to be pursued while simultaneously increasing and maintaining the provision of satisfactory economical and social levels of transportation services. Technological improvement is vital, but it is equally important to secure a timely and uninterrupted policy and decision making framework for action.

- The many chances available today for improving conventional technologies require sustained attention. Enhancing the energy efficiency of all modes of transportation can help reduce transport fossil fuel use. Increasing efficiency can be effectively and immediately pursued through widespread adoption of current best available technologies and practices. Fuel economy standards have been effective in reducing fuel consumption, and therefore should be tightened and adopted worldwide. The overall effectiveness and political feasibility of standards can be significantly enhanced if combined with fiscal incentives and consumer information.

- Reducing the use of fossil fuel energy in transport can potentially be achieved through the adoption of alternative energy sources such as advanced biofuels, fuel cells, and electric vehicles.

- Electricity produced from renewable sources can provide a significant stronghold for the global transformation of the transportation system. Plug-in hybrid electric vehicles (PHEVs) allow for zero-tailpipe emissions for small vehicle driving ranges, e.g., in urban conditions. Hybrid electric vehicles (HEVs) can improve fuel economy by 7–50% compared to comparable conventional vehicles, depending on the precise technology used and driving conditions[2].All-electric or battery-powered electric vehicles (BEVs) can achieve a very high efficiency (up to four times the efficiency of an internal combustion engine vehicle) but have a low driving range and short battery life. The rate of new vehicle technology adoption and the associated rate of petroleum-use and GHG reductions depends on how rapidly vehicles with these technologies enter the fleet through new vehicle purchases. How quickly this happens depends on consumer preferences. New technologies often increase the prices of vehicles. In addition, there are barriers to adoption that are not related to increased purchase prices.

  non-cost factors that influence consumer decisions, including range anxiety, refueling availability, technology reliability, and lack of consumer familiarity. Non-cost barriers are ranked according to the assessed magnitude of severity and potential effectiveness of available policies.

- Reducing transport energy use can also be achieved by favoring those modes that are less energy-intensive, both for passenger and freight transport. Strong local and regional urban planning policies, practices, and implementation should aim to enhance the diversification and quality of public modes of transport. In cities worldwide, a combination of push and pull measures and traffic demand management can induce a modal shift from cars to the more prevalent use of public transit and cycling, which has multiple benefits.

Achieving needed increases in renewable energy in the transport sector and reduction in the emission gap will require implementing a set of concerted strategies.

First, policies that are currently in place should be fully implemented. For example, in Germany, a commitment to achieve an EV share of 20 percent of new registrations by 2020 appears overly optimistic, based an EV share of less than one percent in 2014[3].

Second, additional policies must be put into place to increase the diversification of the transport energy mix. IEA believes that to reach a 2DS scenario, sales of electric vehicles (EVs), which currently constitute less than 1% of car sales worldwide *[In recent years electric cars have received a great deal of attention, but globally electric bikes and scooters dominate electric cars sales by a wide margin, with around 350 e-bikes or scooters are sold for every 1 electric car purchase. About 112,000 electric cars were sold worldwide in 2013. By comparison something in the region of 40 million e-bikes or scooters were sold worldwide in 2013. In China, there are more electric bikes and scooters than the total number of cars on the road. The global pattern for sales of e-bikes and scooters in 2013 has China in first place, at about 32 million, followed by Europe at 1.8 million, and Japan at 440,000. The U.S. had sales of an estimated 185,000 e-bikes.]*, will need to exceed 40% of total passenger car sales by 2040, and biofuels will need to support more than 10% of road transport fuel demand, 11% of shipping energy demand and 33% of aviation sector fuel demand by 2040. [3] Natural gas is also important as a road transport fuel in some markets, but it cannot deliver the long-term decarbonization required, as it is still a carbon based fuel[6]. However, natural gas may be important for cutting CO2 emissions from heavy--duty vehicles (HDVs) where potential application of electrification appears to be more limited[7].

Third, the market attractiveness of policies in favor of decarbonizing fuel depends upon the removal of fossil fuel subsidies[6], as current fossil-fuel alternatives are likely to remain uncompetitive in market segments with subsidized fuels[8]. Current subsidy arrangements for oil in transport not only obscure the direct costs of producing and distributing fuels, they also neglected the costs incurred by negative externalities, and thus give unfair advantage to oil over cleaner fuels[9]. Further, refueling infrastructure costs and implementation timeframes can also pose significant barriers to the transition to a more diversified fuel economy.

Finally, current low oil prices – even without subsidies – pose a major obstacle to overcoming the current cost of biofuels, and thus the transport sector could also benefit from a low carbon transition in other sectors to help make biofuels more cost competitive.

The transport sector can benefit greatly from decarbonizing efforts in the electricity sector. IEA estimates that renewable energy could become the leading source of electricity by 2030 and the carbon intensity of the power sector is projected to improve by 30% during the same period[6]. This will be helped by more than 100 countries have established renewable energy targets over the last decade[10]. This expected improvement in carbon intensity of the power sector may justify the near term rollout of electric vehicles, even if current LCAs [*Life Cycle Assessments*] yield negative results for electric vehicles.

3. Future Transport Fuels

Transport fuel supply today, in particular to the road sector, is dominated by oil [11], which has proven reserves that are expected to last around 40 years [12]. The combustion of mineral oil derived fuels gives rise to CO2 emissions and, despite the fact the fuel efficiency of new vehicles has been improving, so that these emit significantly less CO2 , total CO2 emissions from transport have increased by 24% from 1990 to 2008, representing 19.5% of total European Union (EU) greenhouse gas emissions.

The EU objective is an overall reduction of CO2 emissions of 80-95% by the year 2050, with respect to the 1990 level [13]. Decarbonisation of transport and the substitution of oil as transport fuel therefore have both the same time horizon of 2050. Improvement of transport efficiency and management of transport volumes are necessary to support the reduction of CO2 emissions while fossil fuels still dominate, and to enable finite renewable resources to meet the full energy demand from transport in the long term.

Alternative fuel options for substituting oil as energy source for propulsion in transport are:

- Electricity/hydrogen, and biofuels (liquids) as the main options
- Synthetic fuels as a technology bridge from fossil to biomass based fuels
- Methane (natural gas and bio methane) as complementary fuels
- LPG as supplement

Electricity and hydrogen are universal energy carriers and can be produced from all primary energy sources. Both pathways can in principle be made CO2 free. Propulsion uses electric motors. The energy can be supplied via three main pathways:

- Battery-electric, with electricity from the grid stored on board vehicles in batteries.
- Fuel cells powered by hydrogen, used for on-board electricity production.
- Overhead Line / Third Rail for tram, metro, trains, and trolley-buses, with electricity taken directly from the grid without the need of intermediate storage.

Biofuels could technically substitute oil in all transport modes, with existing power train technologies and existing re-fuelling infrastructures.

Synthetic fuels, substituting diesel and jet fuel, can be produced from different feedstock, converting biomass to liquid (BTL), coal to liquid (CTL) or gas to liquid (GTL). Hydro treated vegetable oils (HVO), of a similar paraffinic nature, can be produced by hydro treating plant oils and animal fats. Synthetic fuels can be distributed, stored and used with existing infrastructure and existing internal combustion engines.

Methane can be sourced from fossil natural gas or from biomass and wastes as biomethane. Biomethane should preferentially be fed into the general gas grid.

LPG (Liquefied Petroleum Gas) is a by-product of the hydrocarbon fuel chain, currently resulting from oil and natural gas, in future possibly also from biomass. LPG is currently the most widely used alternative fuel in Europe, accounting for 3% of the fuel for cars and powering 5 million cars. The core infrastructure is established, with over 27,000 public filling stations[14].

4. Current Status Que in the Europe

As part of the efforts to reduce greenhouse gas emissions of the transport sector, to reduce the sector's oil dependence and diversify energy sources, the EU aims to gradually increase the share of renewable energy in the transport sector's energy mix. The most relevant current EU policy in this respect is the Renewable Energy Directive (2009/28/EC), which sets a target of 10% renewable energy in transport for 2020, for each Member State. This Directive also defines the sustainability criteria that the biofuels need to meet in order to count towards the target, and describes the methodology with which this renewable energy share should be calculated (for example, renewable electricity used in road transport shall be multiplied by 2.5 and biofuels that are produced from waste and residues count double). The Member States have all submitted National Action Plans in which they describe, among other things, how they intent to meet this target.

Also relevant is the GHG emission target set in the Fuel Quality Directive (2009/30/EC): fuel suppliers have to reduce GHG emissions by 6-10% between 2010 and 2020. This directive is also expected to drive the renewable energy use in transport, although it is not yet clear to what extent this will impact the renewable fuel mix, or if it will lead to renewable energy use that will be additional to the RED target.

Looking at the current situation in the EU, the renewable energy share is increasing steadily because of increasing biofuel use: from 4.5% in 2010 to 4.9% in 2010[15], see

Figure 1. The large majority of these biofuels is currently used in road transport, with some use in rail and inland shipping.

These renewable energy shares are expected to further increase towards the 2020 target and beyond. In the Commission's White Paper 'Roadmap to a Single European Transport Area'[16], ambitious goals regarding alternative transport fuels are set for the longer term, such as:

- halve the use of 'conventionally-fuelled' cars in urban transport by 2030, phase them out by 2050;
- low-carbon sustainable fuels in aviation to reach 40% by 2050.

It is expected that in the short to medium term, biofuels will continue to be the main renewable energy source in the road, air and maritime sector. However, alternatives such as electric and hydrogen powered vehicles are being developed and brought on the market, and especially battery electric cars have received much attention recently by car manufacturers, governments and car buyers. It is, nevertheless, expected that it will take at least another 5-15 years before these alternative drive systems have matured and start to gain significant shares in the EU's vehicle fleet.

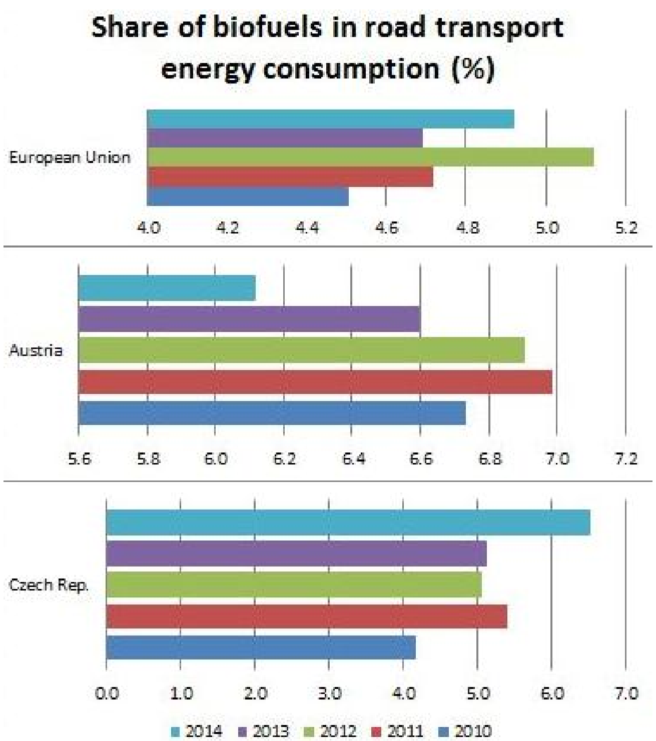


Figure 1- Share of Biofuels in Transport Energy Use between 2010 and 2014 (World Energy Council)

5. Drivers for the Increase in Production of Renewable Energies in Transport Sector

There is a wide range of drivers that need to be considered: in particular, the EU policy framework, specific measures implemented at the Member State level, and sub-national initiatives. There is also a range of relevant commercial developments taking place, including the development of new business models and new technologies. The combined effect of these drivers will determine the rate and nature of the uptake of new technologies and the extent to which renewable energy is used in transport.

Increasing the share of electricity, hydrogen and methane from renewable sources in the transport sector requires a two-sided transformation. First, there is a need to shift away from conventional vehicles and fuels (links to measures to stimulate the demand for renewable energy sources in transport), and second, there is a need to shift to renewable energy sources (links to measures to stimulate the supply of renewable energy sources in transport). These steps can be taken in parallel or in sequence, but both require significant effort and changes.

The diagram below illustrates the different levels of drivers that act to influence the uptake of renewable sources of electricity, hydrogen and methane. Each level of policy, program or incentive can coexist with the policies, programs and incentives introduced at higher or lower levels of government.

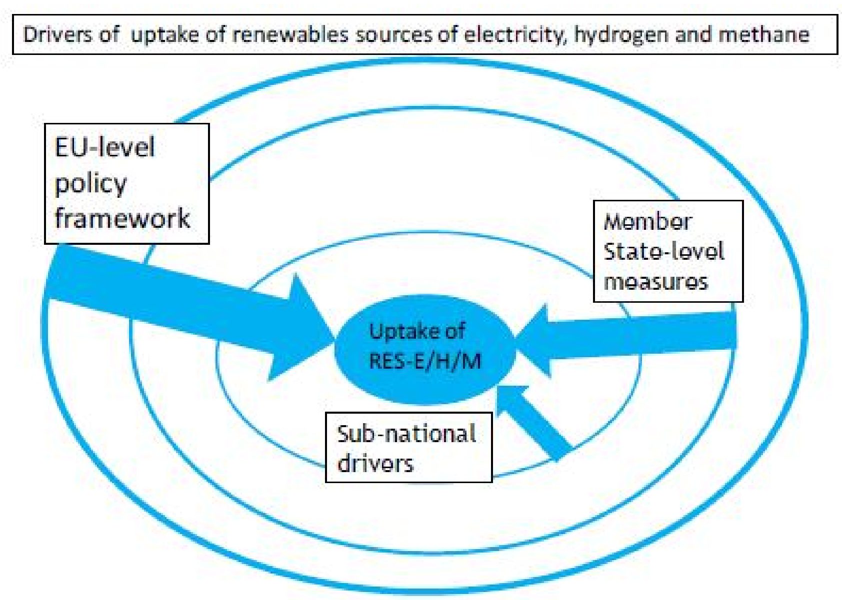


Figure 2- Different levels of Drivers Coexist at the EU, Member State and Sub-National Level

5.1 EU Level Drivers for the Promotion of Renewable Energy in Transport

At the EU Level, there is the EU's broad policy framework relating to climate change and energy, and the policy directives aimed at driving the use of renewable energy in general and more specifically for use in transport. Aside from policies aimed at directly stimulating the uptake of renewable energy, there is also a range of policy instruments aimed at improving the fuel efficiency of vehicles. These measures could act as indirect drivers to increase the uptake of renewable energy since fuel taxes and mandatory fuel efficiency targets will over time affect the purchasing behavior of consumers when deciding on buying either a more efficient conventional vehicle versus an alternative drive-train vehicle (i.e. one powered by electricity, bio methane or renewable hydrogen).

The 'Europe 2020 Strategy' for smart, sustainable and inclusive growth commits the EU to reducing greenhouse gas emissions by 20%13, increasing the share of renewable energy in the EU's energy mix by 20% (with differentiated Member State targets in the RED) and improving energy efficiency by 20%, by the year 2020.

The EU also has the objective of reducing its greenhouse gas emissions by 80-95% by 2050 compared to 1990 levels.

Furthermore, the **RED** is currently the most significant policy driver at the EU level. It contains an overall 20% renewable energy target in final energy consumption and a 10% target of renewable energy in transport for the EU for 2020. The RED also defines a legally binding national renewable energy target in final energy consumption for each Member State and requires Member States to meet the 10% transport target by 2020. All forms of energy from renewable sources can count towards meeting the transport target, and all transport sectors may contribute (numerator). The 10% target is accounted against the final energy use in road vehicles and rail (denominator).

Regulation **(EC) No 443/2009** sets fuel efficiency performance standards (CO2 emission limits) for manufacturers of new passenger cars. CO2 standards have been extended to the regulation of vans and light commercial vehicles under Regulation **(EC) No 510/ 2011** of 11 May 2011. Due to the similarity in the approach and time restrictions, focus is on the regulation for passenger vehicles.

In 2009, **Directive 2009/30/EC** revised the Fuel Quality Directive (FQD), which aims to achieve a number of improvements in the environmental impact of diesel and petrol transport fuels. Under Article 7a of the Directive, Member States are required to oblige fuel suppliers to gradually reduce the life cycle greenhouse gas intensity of energy supplied for road transport and allows for a wide range of measures to be applied to meet the target.

Directive 2009/33/EC, the Directive on the Promotion of Clean and Energy Efficient Road Transport Vehicles (Clean Vehicles Directive), aims to support the broad market introduction of environmentally-friendly vehicles and extends to all purchases of road transport vehicles, as covered by the public procurement Directives and the public service Regulation.

5.2 Member State Level Drivers for the Promotion of Renewable Energy in Transport

As described above, the RED is the key policy document at the EU level driving the uptake of renewable energy. The RED must be implemented by Member States, which were required to submit a National Renewable Energy Action Plan (NREAP) by 2010. In its NREAP each Member State reports to the European Commission how it intends to fulfill its target as set out by the RED. All 27 Member States have now submitted their NREAPs.

In order to reach the prescribed targets, Member States are applying a wide range of different policy approaches. Table 1 & 2 [17] below describes the types of instruments being utilised and provides a selected list of examples of these measures as implemented across Austria and Czech Republic.

Table 1- Brief Overview of Policy Measures being Employed by Austria

Type of Policy	Brief Description
Feed-in tariffs	Guarantees renewable energy producers a fixed price or a bonus on top of the regular market price. Can be combined with preferential grid access.
Grants	Non-repayable financial aid provided by Austrian Government (up to 10% of costs for medium sized hydro plants) to support project investment.
Information	Promotion, education, outreach, capacity building and other communication activities aimed at supporting renewable energy. In this case Austria is one example of successful information campaigns.

Table 2- Brief Overview of Policy Measures being Employed by Czech Republic

Type of Policy	Brief Description
Feed-in tariffs	Guarantees renewable energy producers a fixed price or a bonus on top of the regular market price. Can be combined with preferential grid access.

In 2020 the use of electricity from renewable sources in road transport is still very limited in comparison to the use of electricity from renewable sources in non-road transport and in comparison to total energy consumed in the sector. Only 0.2% of total energy consumed can be accounted to electric vehicles (and other forms of electric road transport).

The (intended) growth of electricity from renewable sources in the transport sector 2005-2020 for Austria and Czech Republic is shown in Table 3.

Table 3- Overview of Electricity from Renewable Sources in the Transport Sector for AU and CZ in 2020 (NREAPs)

Member State	Total		Road		Non-Road	
	ktoe	%	ktoe	%	ktoe	%
Austria	272	3.2%	68	0.8%	204	2.4%
Czech Republic	19	0.3%	1	0.0%	19	0.3%

Note: Percentages are share of renewable electricity in the final gross energy consumption in the transport sector.

Regarding different kinds of transportation fuels, the Member States were not asked to specify in the NREAPs whether the biomethane would then be used in transport via a dedicated distribution system, or via the general natural gas infrastructure. In the first case, the biomethane can be counted towards the 10% target with the standard biofuels methodology described in the RED. Only the biomethane distributed through the general natural gas infrastructure is part of the scope of this study.

Table 4 below provides an overview of the results for the ‘other biofuels’ category (such as biogas, vegetable oils, etc.).

Table 4- Overview on AU and CZ Use of 'Other Biofuels', Among them bio methane, to Fulfill the 2020 Target of Renewable Energies in Transport (Data Source: National Renewable Energy Action Plan- NREAP)

	Total amount of 'other biofuels' ktoe	Share of 'other biofuels' in the final gross energy consumption in the transport sector %
Austria	94	1.1%
Czech Republic	49	0.7%

5.3 Drivers for the production of Bio Methane for injection into the grid

The broad motivations for the uptake of bio methane in transport fuel are:

- Diversification of the transport fuel supply base, including reduced dependency on imports.
- Reduction of GHG emissions from the transport sector.
- Reduction of particulate matter (PM) emissions from diesel-powered drive-trains. And
- The option to introduce a renewable fuel which:
    a. Utilizes existing internal combustion engine technology.
    b. Utilizes a form of bioenergy that can meet the sustainability criteria, if often produced locally and has very high technical potential.

In terms of policy drivers, the following can be identified:

'Push' drivers: Funding for Research and Development, subsidized capital costs for plant construction, etc.

'Pull' drivers: Financial incentives, such as feed-in tariffs or tax deductions/ refunds allow for financial 'low or no regret' decisions by customers. Mandatory targets such as company renewable portfolio standards can serve as strong drivers for the production of biogas, subsequent upgrading to bio methane (i.e. natural gas quality) and eventual feeding into the natural gas grid.

'Eco-tariffs' could be another driver for bio methane in the natural gas grid.. In some Member States, electricity consumers can select 'eco electricity tariffs' as part of the deregulation of the electricity market. Despite deregulation efforts in the natural gas sector, developments of 'eco-tariffs' for natural gas/bio methane are, however, only slowly developing.

'Information obligations' such as the CO2 labeling of cars, allow for an informed decision of environmentally conscious buyers.

The availability of CNG and/or LNG filling stations is a prerequisite. If available to sufficient extent, they act as a pull driver for the admixture of bio methane for use in transport.

5.4 Drivers for the production of hydrogen from renewable sources

If hydrogen (and especially hydrogen from renewable energy feedstocks) takes off as a fuel in road transport, significant shares in the existing stock of vehicles will be achieved only after 2020.

There are push and pull drivers for hydrogen. Being of generic nature, push and pull drivers for renewable hydrogen are similar to those mentioned above for the case of bio methane.

A prerequisite for the production of hydrogen from renewable resources is the availability of renewable primary resources. Because of their potential and cost structure, in this decade hydrogen from renewable energy sources will be produced predominantly from wind energy in Europe. The faster the ramp-up of wind power and the slower the enforcement of the electricity grid and the lower the flexibility to shift electricity demand to times when there is an abundance of wind available, the more 'excess wind energy' will become available that is not consumed. The central production of hydrogen at major feed-in points of renewable power into the grid could make use of this 'excess wind energy' and provide for an alternative energy storage and transmission vector.

5.5 Financial incentives for alternative vehicle purchases at AT and CZ

Austria and Czech Republic are using various types of fiscal incentives to encourage the purchase of EVs. A key barrier facing more widespread uptake of battery-powered EVs and fuel-cell powered vehicles (FCEVs) at present are the high costs of battery and fuel cell technology. The lack of full-scale vehicles is also a current barrier, however, a number of manufacturers are planning to introduce more attractive vehicles in the near future.

The European Automobile Manufacturer's Association (ACEA) has compiled a list of tax initiatives adopted by Member States to encourage the uptake of alternative vehicles

(ACEA, 2016). The information about Austria and Czech Republic provided by ACEA are gathered in table 5.

Table 5- AT and CZ Tax and Financial Incentives for Alternative Vehicle Uptake

Member State	Tax/Financial Incentives
Austria	Electric vehicles are exempt from the fuel consumption tax and from the monthly vehicle tax.
Czech Republic	Electric, hybrid and other alternative fuel vehicles are exempt from the road tax (this tax applies to cars used for business purposes only).

Primary source: ACEA, 2016

5.6 Country Case Studies

A second step in our analysis of the drivers of renewable energy uptake includes the consideration of a number of country case studies. These case studies can help to understand the real world conditions that apply in specific countries.

5.6.1 Case study 1: Bio Methane Used in Transport in Sweden

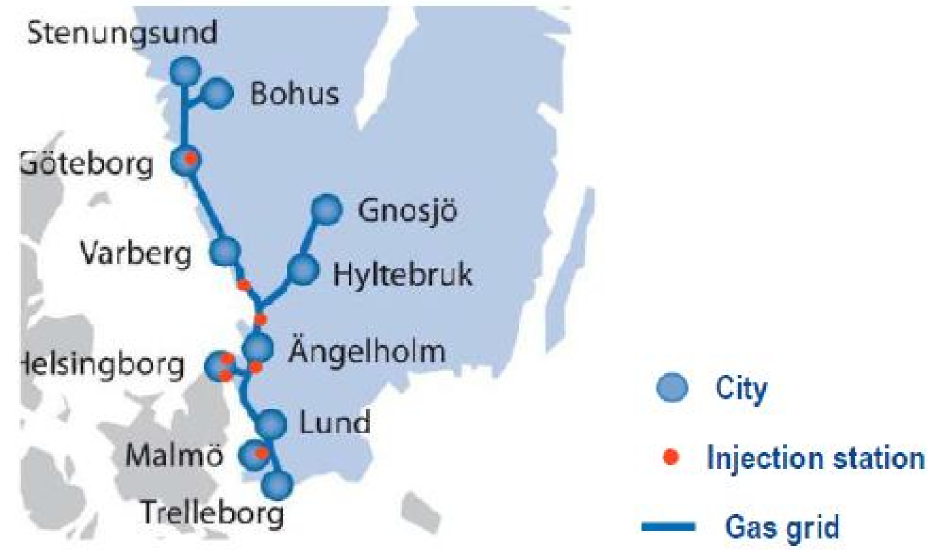
The Swedish government supports municipally owned biogas plants[18] and in the past co-financed investments for biogas production, upgrading and CNG filling stations.

Furthermore, there are various incentives for CNG vehicles and the use of bio methane in transport according to Mathiasson, 2010 and NGVA[18]:

- a 40% reduction of income tax for use of CNG company cars;
- free municipal parking for CNG vehicles in many cities;
- priority lanes at airports, railway stations and ferry terminals for CNG taxi cabs;
- financial (investment) support for some types of bio methane production units;
- a zero fuel tax on bio methane.

Incentives have resulted in some 26,000 CNG light duty vehicles, 1,300 CNG buses and 600 CNG heavy-duty trucks being on the road in Sweden in 2010, the third largest CNG vehicle fleet in Europe.

The Swedish methane grid is small with some 300 km in length along the western coastline only. In 2008 there were almost 40 biomethane upgrading plants (Dahlgren, 2008) and 7 stations for injection into the gas grid in Sweden as depicted in the following map.



Source: Dahlgren, 2008.

Figure 3- Gas Grid and Locations of Bio Methane Injection Stations in Sweden

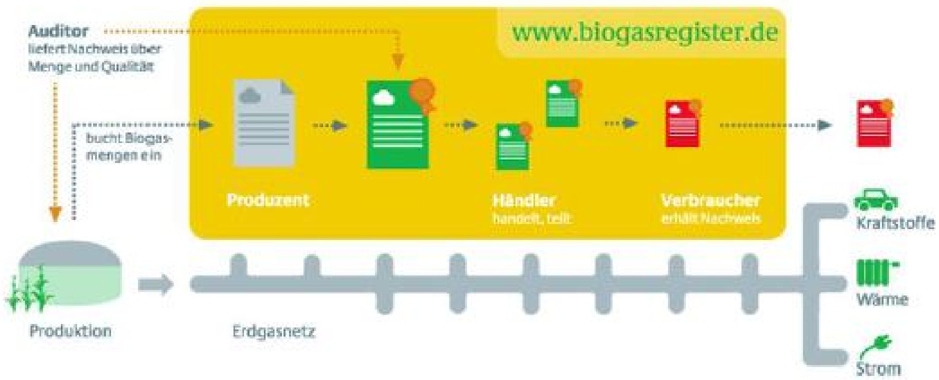
5.6.2 Case study 2: Bio Methane Used in Transport in Germany

Since the year 2000 electricity production from biogas is incentivised by the German Erneuerbare Energien Gesetz (EEG). With the EEG update in 2009, power production from upgraded biogas fed into the natural gas is incentivized with a so called 'Technologiebonus'.

In 2009, the German Energy Agency (dena) has started a Biogas Registry (http://www.biogasregister.de) which is designed to function as depicted in the following figure. The registration criteria include sustainability provisions according to the German BioKraftNachV, which is the national implementation of the EC-RED, and an IT interface to the NABISY mass balance system.

Furthermore, biofuel producers with an installed production capacity of more than 1,000 t/a are obliged by the Energy Taxation Law (EnergieStG) to submit their actual production quantities once a year to the Biofuel Quota Body of the Federal Customs Office Frankfurt/Oder (Zoll, 2011).

Point 2 of § 27c (1) of the draft 2012 amendment of the German Renewable Energy Law (Bundesrat, 2011) foresees a mass balance system for the use of biomethane from the grid for power production, e.g. through the dena Biogas Registry (see above). This mechanism could also be used for accounting of biomethane from the grid for use as a transport fuel.



Source: http://www.biogasregister.de.

Figure 4- Functioning of the German 'Biogas Registry' Mass Balance System

5.6.3 Case study 3: Hydrogen Used in Transport in Germany

The German National Innovation Program (NIP) is a public-private initiative to bring forward hydrogen and fuel cells in transport.

Up to now a broad range of hydrogen production and distribution vectors have been used to supply the hydrogen refueling stations in Germany for technology validation reasons:

- centralized hydrogen production (mostly reformation of natural gas)
- use of by-product hydrogen from chemical processes and supply via dedicated high-pressure pipeline;
- on-site hydrogen production via small-scale reforming of natural gas or water electrolysis.

Stakeholders consider renewable energy for hydrogen production important for the mid to long-term development for reasons of benefiting from maximum environmental performance of hydrogen and public acceptance[19].

First developments are e.g. the use of certified green electricity for on-site production of green hydrogen at the TOTAL hydrogen filling station (part of CEP) that was opened mid 2010 in Berlin, Holzmarkstraße[20].

the latest infrastructure development for Germany until 2015 were established by the ‘H2 Mobility’ initiative, these are shown in Figure 24.

Source: Ronald Grasman (Daimler AG), Flottenbetrieb Mercedes-Benz F-CELL, Presentation at NIP General Assembly, Berlin, 07.11.2011.

Figure 5- H2 Infrastructure Established for Germany as Laid Out by the 'H2 Mobility' Initiative

6. Cost Analysis

Conventional biofuels, both ethanol and biodiesel, have seen their costs increase as food prices have risen, particularly since 2005. The outlook to 2020 is for little change in food prices, and hence in feedstock costs for conventional biofuels.

The key challenges for advanced biofuels, biomethane and PHEVs and EVs are to reduce their costs and improve their performance in order to achieve competitiveness with fossil fuels. The opportunities for cost reductions are good, particularly for advanced biofuels, which are only just beginning to be commercialised at scale.

Still there is a major problem with the price of the main substitute – oil. In Figure 5 we see that over past 2 years, oil price has plummeted almost by 60% and current analysis suggest that price is not going to recover in near future because there is an oversupply of oil in the market. Any attempts to freeze the output of OPEC countries has failed during 2016.

Figure 5- Brent Crude Oil Price per bbl. in US dollars. Source: Bloomberg

This price decrease endangers all the EU promotion strategies. Since strategies are more market based (as pull & push drivers) in favor of renewable energies use, they naturally compete with oil.

It is easy to see that firms choose factors of production based on their output and price. If the price of one factor decreases, based on its technical marginal rate of substitution, firm would substitute now relatively expensive factor of production by the cheaper one. The same situation we face here. It is hard to imagine that firm would not choose cheaper factor if there are no other incentives. Without any hard computations, we see that such incentives as road tax exemption can hardly compensate for plummeting price of oil.

Eventhough costs of liquid biofuels are likely to decrease in the future, the exact number could be hardly predicted. It seems reasonable to add some more economic tools to the promoters portfolio. Taking into account negative externalities of oil use which are currently not beared by the producers or utilizers, EU can impose a Pigouvian tax to internalize such externalities. That would higher the price of the oil so the renewable sources would be relatively cheaper and the substitution in favor of renewables would be more likely.

6.1 The Current costs of Liquid biofuels and Biomethane and the Outlook to 2020

The production costs of conventional liquid biofuels derived from food or animal feed crops are dominated by the feedstock cost, both for ethanol and biodiesel. As a result, the cost of conventional biofuels from food-based feedstocks is very sensitive to changes in the prices of the feedstocks used. For biofuels using food-based feedstocks, this means production costs will be volatile, as global market prices for these foodstuffs experience significant variations over time due to changes in demand and supply. If income received for these conventional biofuels do not also move with these input costs, then the profitability and economic viability of their production may be adversely affected.

Figure 6- Ethanol Futures. Price per galon in US dollars. Source: Bloomberg

The initial deployment of advanced cellulosic biofuels is hampered by many of the same problems that face any new technology. Capital costs are currently two to six times higher than for corn ethanol plants and the production processes are only now being proven at commercial scale. This means there is currently no certainty or clarity over what pathways represent the most promising development options.

One of the key advantages of advanced biofuels is that, in contrast to conventional biofuels, feedstock costs for advanced biofuels that use cellulosic feedstocks are expected to range between 30-45% of total production costs in the long term[21]. Advanced biofuels will therefore be less sensitive to variations in feedstock prices. They will also be able to secure biomass feedstocks in long term contracts that also significantly reduce the feedstock price volatility compared to conventional foodbased feedstocks. However, the high capital costs for these early commercial-scale cellulosic biofuels plants are a significant barrier to their deployment. This is also true of the uncertainties concerning the ability of different process pathways to reliably, continuously and efficiently convert cellulosic feedstocks into biofuels.

Conventional liquid biofuel production costs are projected to rise to 2020 as the result of modest increases in feedstock prices. Although food price increases are expected to slow compared to that experienced since 2005, the OECD-FAO outlook for the agricultural sector to 2020 projects increases in corn prices of around 1% between 2012 and 2020, 11% for global wheat prices and 25% in the cost of sugar cane in Brazil (OECD-FAO, 2012). At the same time, the OECD-FAO outlook projects vegetable oil prices to increase by around 10%.

This could see grain-based conventional biofuel production costs increase by between 6% and 9% compared to 2012 levels, while production costs for ethanol from sugar cane in Brazil could increase by between 20% and 22% between 2012 and 2020. The production costs of biodiesel from vegetable oils may increase by around 8% under these assumptions by 2020 [21].

Biogas production using digesters is a relatively simple and mature technology, with little opportunity for cost reductions. Current production costs for biomethane varying depend on the feedstock.

However, the upgrading process – whereby inert components such as CO2 and sometimes also N2 are removed for increased energy density and making the biomethane ready for injection into the gas network or for use in vehicles – is an area where relatively small scale applications have modest deployment numbers. Accelerated deployment and increasing the scale of individual production plants, would result in a significantly larger market and better economies of scale for manufacturers. This might also allow increased process integration and “off the shelf” solutions with lower project costs [22]. However, even assuming a 10% to 20% cost reduction for upgrading units by 2020 would only reduce biomethane production costs for vehicles by between 1% and 5% in 2020 [21].

Conclusion

Large-scale sustainable energy systems will be necessary for substantial reduction of CO2. For example, the transport sector was responsible for the largest share of primary energy demand of any sector of the economy in 2013, accounting for 33% (4,326 ktoe) and also it was responsible for the largest share of energy-related CO2 emissions of any sector of the economy in 2013, accounting for 35% (12.6 MtCO2). [23].

However, large-scale implementation faces two major problems: (1) we must replace oil in the transportation sector, and (2) since today's inexpensive and abundant renewable energy resources have fluctuating output, to increase the fraction of electricity from them, we must learn to maintain a balance between demand and supply. Plug-in electric vehicles (EVs) could reduce or eliminate oil for the light vehicle fleet. Adding ''vehicle-to-grid'' (V2G) technology to EVs can provide storage, matching the time of generation to time of load.

For improving conventional technologies require sustained attention. In this regard, **Enhancing the energy efficiency**, **Increasing efficiency**, **Fuel economy standards**, **The overall effectiveness and political feasibility of standards** should be our priorities.

Regarding the possible future transport fuels, **Electricity/hydrogen**, and **biofuels** (liquids) as the main options, **Synthetic fuels** as a technology bridge from fossil to biomass based fuels, **Methane (natural gas and bio methane)** as complementary fuels, **LPG** as supplement can be considered.

Considering drivers to promote renewable energies in transport sector, in the EU level, some policies such as **The 'Europe 2020 Strategy' for smart, sustainable and inclusive growth**, **RED** has been already in effect.

Decarbonizing transport is a core theme of the EU 2020 strategy [24] and of the common transport policy. The long-term perspective for transport in Europe has been laid out in the Commission Communication on the Future of Transport of 2009 [25]. The long-term objective of the European Union on CO2 emissions is an overall reduction of 80-95% by 2050 [13].

Alternative fuels are the ultimate solution to decarbonize transport, by gradually substituting the fossil energy sources, which are responsible for the CO2 emissions of transport. Other measures, such as transport efficiency improvements and transport volume management, play an important supporting role.

In member state level, policies such as Feed in Tarifs and also Grants are in Austria and Czech Republic in effect.

Beyond 2020, there is greater potential for EVs to drive the uptake of renewable electricity production if, for example, the specific transport targets set in the RED were increased and made additional to the next round of targets for consumption of energy from renewable sources more broadly.

In line with the RED, all European Member States have now submitted NREAPs containing a wide range of measures to drive the increase in production of electricity from renewable sources in the general energy mix up to 2020.

Where the production of bio methane for injection into the grid is concerned, the extent of measures being implemented is more limited. So far not a single Member State has specified plans for implementing specific measures to drive production of bio methane for injection into the grid in its NREAP.

In the case of hydrogen, which is still in an embryonic stage of infrastructure deployment, the current outlook suggests that transport sector developments are likely to remain a very minor driver for the production of hydrogen from renewable sources over the period to 2020.

Table 6 provides a high level qualitative assessment of the strength of the different drivers for the uptake of renewable energy. The overall message is that transport sector developments are only likely to have a low or at best low-medium impact on the production of renewable electricity, biomethane and renewable hydrogen in the period to 2020.

Drivers	Assessment of current contributions from drivers for renewable energy production across different renewable energy sources (RES)			
	Renewable electricity	Renewable hydrogen	Bio Methane (grid)	Comments
Supply-side drivers				
EU renewable energy policy framework E.g. targets for production of renewable energy in RED	High	Low	Medium	Strongest where there are specific requirements on Member States
EU level policy instruments E.g. EU ETS	Medium	Low	Low	Price signal not strong enough on its own at present
Member state incentives for RE development E.g. FiTs, portfolio standards, grants, etc	High	Low	Medium	Specific policy measures for renewable hydrogen yet to be developed
Technological/commercial developments E.g. capital cost, operating	Medium	Medium	Medium	Depends on technology e.g. PV electricity to decrease, CAPEX for

cost, market prices				on-shore wind nearly mature
Demand-side drivers				
EU transport policy framework E.g. EU FQD; EU 10% transport target; EU strategy on clean/efficient vehicles	Low	Low	Low	Could make transport target additional post 2020
EU transport policy measures E.g. vehicle CO2 performance standards	Low	Low	Low	Current treatment of EVs doesn't distinguish between RE and non-RE
Member state policies and programs on transport sector E.g. tax exemptions for purchasing EVs	Low	Low	Low-Medium	Tax exemptions specifically for biomethane CNG in Sweden EV incentives do not require RE generation
City/regional initiatives E.g. City funding for EV charging, parking, separate lane, entry into inner-city	Low	Low	Low	Depends on initiative design, but at present there are few initiatives involving small numbers of vehicles only
Commercial initiatives E.g. JVs between utilities, infrastructure companies and car manufacturers	Low-Medium	Low-Medium	Low-Medium	Potential for direct contracts to support additional investment
Technological developments E.g. falling costs of EV batteries, increasing battery and fuel cell performance	Low	Low	Low	Battery performance and costs a major issue, but only will have an impact over longer term with mass uptake
Consumer tastes and preferences E.g. WTP	Low	Low	Low	Could be more of a driver in the longer

for renewable electricity in transport				term

Regarding cost analysis, the road ahead for renewables in transport is challenging, but the positive signs from early commercialization mean that the world may be witnessing the beginning of an era of competitive renewable options for road transport across a range of modes and vehicle technologies.

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