Description of Biofuels and Shale Gas Development

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Abstract

World effort to reduce climate changes drives demand for more environmentally friendly alternative fuels, since transport emits quarter of total greenhouse gas emissions. For many years biofuels were main mean for achieving more green transport. Nevertheless, there are rising concerns that some of biofuels have negative environmental and social impacts sometimes worse than fossil fuels. This work links European Union's biofuels development with expansion of natural gas caused by exploitation from shale formations. We conclude that the expansion will not be driven by exploitation of shale gas at European Union territory.

Keywords: biofuels, shale gas

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1 Introduction

World effort to reduce climate changes drives demand for more environmentally friendly alternative fuels, since transport is one of the largest contributor to greenhouse gas emissions. States create distribution networks and encourage their production through

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favourable regulation. The most successful are biofuels. Many states successfully created economic environment that makes biofuels competitive with traditional fossil fuels. Nevertheless, rush for a new types of fuels, mainly biofuels, does not have desired results. There are rising concerns that some of biofuels have negative environmental and social impacts sometimes worse than fossil fuels. Biofuels are known as one of the causes of rising food prices and they are being associated with negative impact on engines. Furthermore, the boom of fracking has driven prices of oil products down which makes biofuels more costly alternative. Along with other things that is being mentioned as one of the obstacles for future development of biofuels (McCarl, 2015). On the other hand, fracking brings another alternative fuel on the market. Development of fracking enabled exploitation of gas and oil from shale and pushed prices of natural gas down. Natural gas is sometimes called "transition fuel" to low carbon energy systems and it can be used in transportation for meeting environmental targets since it burns with very low emissions.

2 Biofuels

Biofuel is a fuel derived from organic matter. It can be obtained directly from plants or indirectly from agriculture, domestic, or industrial waste. Term biofuel covers wide range of fuels from solids to gases. Nevertheless, main interest of this work belongs to the liquid ones, ethanol and biodiesel, as they are substantive part of transportation sector. This section focuses on the first generation biofuels, because they account for substantial part of world production and are those that are produced from food crops. We provide introduction to biodiesel and ethanol, state their pros and cons and policy development in the European Union (EU) based on BABU et al. (2013), EU Biofuels Annual 2014 (USAD Foreign Agricultural Service), the Worldwatch institute (2011), Renewable Energy Directive (RED) (2009), Rosegrant (2008), and data from Eurostat. We finish this section with description of Fisher-Tropsch process based on Ojeda and Rojas (2010) and Swain et al. (2011).

2.1 Biodiesel

Biodiesel or fatty acid methyl ester (FAME) is a representative of first generation biofuels. The first generation biofuels are those that come from food crops, more precisely from sugarcane, starch and vegetable oils.

Both major producer and consumer of biodiesel is Europe with Germany as a leader. Biodiesel holds approximately 80 percent of the transport biofuels market in the EU. According to the Worldwatch Institute (2011), the EU holds approximately 53 percent of the market share in the production of biodiesel. The most common feedstock for biodiesel in the EU is rapeseed. It accounts for approximately 58 percent of a total European production followed by palm oil that contributes with 16 percent of the production in 2013. Although the EU is the largest biodiesel producer, EU's production capacity is underused. In 2015, the EU is projected to produce 11 billion litres with production capacity of 26 billion litres, i.e. 42 percent of the capacity (USAD-FAS, 2014). Abdelradi and Serra (2015) assign the idle capacity to intensive public promotion of biofuels, subsidized biodiesel imports from Argentina, Indonesia and the US. However, the global increase in agricultural commodity prices raised feedstock costs and thereby affected production as well.

Conventional biodiesel is produced by process called transesterification. The most common form of biodiesel arises when vegetable oils are transesterified with alcohols. The great advantage of biodiesel over ethanol is that the transesterified oil (biodiesel) has similar characteristics as mineral diesel and it can replace it without any modification of the engine. Thus, is can be blended with fossil fuels at any proportion (BABU et al., 2013).

2.2 Ethanol

While biodiesel is mainly produced and consumed in Europe ethanol has primacy in the world. The largest producer is the United States (US) followed by Brazil which is the largest exporter (BABU et al., 2013). The EU is the third largest producer of biofuels altogether, but it holds only 28 percent share in the production of bioethanol.

The most common feedstocks for production of bioethanol are sugar, corn, soybean and wheat. As bioethanol is the most common biofuel in transport it is ready to replace gasoline (BABU et al., 2013). There are various blends with gasoline. Usual blends are E10 and E15 where number stands for percentage content of ethanol in a fuel, however, Brazil has mandatory use of 27.5 percent bioethanol (Dezem, 2014). Policy like that has capacity to reduce greenhouse gases (GHG) emissions, because ethanol increases octane in gasoline and improves its emissions. On the other hand, it also has some drawbacks. Using bioethanol in higher blends can damage the engine by corrosion due to its water content. Nevertheless, there are flexible fuels vehicles (FFVs) which are designed to burn gasoline even in E85 blends or higher. This type of vehicle is common in Brazil and the US, however not in the EU. In Brazil, FFVs accounts for approximately 55 percent share of total fleet and industry expects that the share will reach 80 percent in 2020 (USAD-FAS, 2014). However, main interest of this work is the EU, thus we provide more detailed overview of EU regulation in subsequent subsection.

2.3 EU policy development

The first regulation which launched broader development of biofuels was Directive 2003/30/EC sometimes called "Biofuels Directive 2003." It bound Member States (MS) to develop national policy frameworks for biofuels development. It also set indicative targets of 2 and 5.75 percent use of biofuels and other renewable fuels in transport in 2005 and 2010, respectively. Nowadays EU biofuels market mainly depends on ambitious targets set within the EU Energy and Climate Change Package (ECCP) (2009) through Renewable Energy Directive 2009/28/EC (RED). These targets are known as "20-20-20" targets and define three main objective to achieve in 2020. They are:

- A 20 percent reduction in EU greenhouse gas emissions from 1990 levels;

- A 20 percent improvement in the EU's energy efficiency;
- Raising the share of EU energy consumption produced from renewable resources to 20 percent.

Part of the third target is to reach minimum of 10 percent share of renewable energy in transportation sector in all MS. The use of biofuels in transport sector accounted for 5.4 percent in 2013[1]. Therefore, it seems that substantial part of the 10% share will be arranged by biofuels, broadly speaking there has to be nearly twofold increase till 2020. Information under National Renewable Energy Action Plans[2] (NREAPs) predicts that the overall share of renewable energy in 2020 will be 20.7 percent, i.e. even above the target (USAD-FAS, 2014). Share of renewable energy in the total energy consumption was 15 percent in 2013[3] which kind of confirms that prediction.

The ECCP is followed by the 2030 climate and energy policy framework. It continues in the objectives set out in the RED. Proposed legislative requires at least 40 percent reduction in GHG emissions in 2030 compared to level in 1990. The objective is likely to be achieved by reducing GHG emissions 43 percent below the 2005 level in sectors covered by the EU emission trading system. Furthermore, the framework sets targets that requires increasing both energy efficiency and share of renewable energy in EU's consumption to at least 27 percent in 2030. The proposed framework should ensure EU's economy and energy to be competitive, secure and sustainable.

The largest impact on biofuels development in EU has the Fuel Quality Directive (FQD) (2009). It requires 6 percent reduction in GHG intensity of the fuels used in vehicles by 2020. Nevertheless, this restriction is imposed on whole life-cycle of the fuel and not only on the final consumption. It means that emissions from extraction, processing and distribution are included into calculations. Although, the reduction is likely to be

[1]Eurostat: Share of renewable energy in fuel consumption of transport,"tsdcc340", downloaded: March 23, 2015

[2]NREAPs are national policies developed by each MS to meet RED targets

[3]Eurostat: Share of renewable energy in gross final energy consumption,"t2020_31", downloaded: March 23, 2015

achieved mainly through intensive use of biofuels the FQD sets some restrictive criteria to ensure their sustainability and to minimise possible externalities resulting from their production. Directive states that GHG emission must be 35 percent lower than from the fossil fuel they replace. This requirement is gradually increased till 60 percent threshold in 2018 for new installations. Further, the feedstocks for biofuels cannot be grown on land with high biodiversity or high carbon stock. Since food-based biofuels contribute to land conversion, the European Commission (EC) proposed to limit amount that can be counted into 10 percent renewable energy share in transport sector target. Only recently at the end of April 2015, the European Parlament (EP) passed amendment to the RED and the FQD which caps this amount to 7 percent and deals with indirect land-use change (ILUC). The measure should arrange larger contribution to the 10 percent target from the second and third generation biofuels which do not require additional land. Amendment further encourages to shift production from conventional to advanced biofuels by setting indicative target of 0.5 percent. Document also introduces incentive for renewable electricity use in transport. Namely, multiplication by factor 5 for electricity from renewable sources in electric road vehicles and 2.5 for rail road. However, exact threshold for the first generation biofuels was subject of vigorous debates for past three years. A bargaining about exact form of the regulation caused biofuels policy to be uncertain and left the market hesitant. The European Biofuels Technology Platform (EBTP) prepared report which seeks for crucial obstacles at European biofuels market. According to responses from national agencies[4], they obtained, while technological barriers are being significantly mitigated, industry suffers mainly from aforementioned uncertainty about regulatory framework and EU strategy for advanced biofuels at the same time. Biofuels industry also lacks consistent approach at national level. For instance, the Parliament of the Czech Republic currently discuss extension of amendment to the Act for promotion of biofuels for the next five years (The Ministry of Agriculture of the Czech Republic,

[4]Questionnaires was sent to Governments, Line Ministries, Agencies and Associations in EU28 and Energy Community Contracting Parties (EnC) in mid-2014.Feedback was received from France, Netherlands, Norway, Spain, Sweden, Latvia, Germany, Greece, Hungary, Kosovo, Macedonia, Moldova, Poland and United Kingdom.

2015). It is in compliance with the RED (2009), however the amendment mainly promotes first generation biofuels which may not be in accordance with forthcoming amendment to RED and FQD which contrarily restrict conventional biofuels and promote advanced ones. Hence, it will probably enforce additional amendment to Czech act. Nevertheless, the new limit for conventional biofuels is stated in terms of energy content and even though total last year's consumption of the first generation biofuels accounted for 6.5 percent in the Czech Republic, their energy content represented only 5.5 percent of the total consumption (Tramba, 2015). Therefore, there is possibility to increase sales by one-quarter for producers. Although the EU's amendment was finally passed, incoherent actions definitely do not suit market and can potentially deter future investments. Further, the RED introduced so called double counting for second generation biofuels. It should have assured more intense use of them. However, both double counting and reduced blending mandates in some countries resulted in declining biodiesel consumption by 5 and 9 percent in 2012 and 2013, respectively (USAD-FAS, 2014). The double counting measure is being criticised for vague definition of what can and cannot be counted twice toward RED 10 percent target and the fact that each MS can determine what can be counted twice.

2.4 Impact on food prices

While biofuels promise relatively favourable GHG emission reduction both in life-cycle and combustion, some questions arise about impact of biofuels on prices of food crops and consequently on eatables. Price linkages between agricultural commodities and corresponding biofuels have been investigated by numerous studies. For instance, Krištoufek et al. (2014) quantified price transmission between biofuel and its respective feedstock. According to the study, ethanol price is elastic to the corn while biodiesel is related to German diesel. Further, the price transmission was changing over time with peak in 2008. The findings are in accordance with another studies that indicate increasing positive correlation among agriculture commodities and energy prices before the so called food crisis in 2008 (Abdelradi and Serra, 2015; Busse et al., 2012). However, Busse found link among biodiesel, rapeseed and soy oil prices as well. Besides, their dependence was changing over time with respect to policy development. On the other hand, Abdelradi and Serra (2015) examined EU biofuel market and assert that biodiesel price does not affect rapeseed price, however it can cause instability in the market by increasing rapeseed price volatility. Conversely, rapeseed price strongly affects biodiesel price. The study further claims that stocks of rapeseed and euro-dollar exchange rate have positive influence on volatility in biodiesel price. They conclude that EU biofuel industry cannot increase long run food prices.

There are various national policies to fight with food price spikes like encouraging imports by reducing tariffs. In the short-term price increases are mitigated mainly by increasing available supplies. However, these measures are constraint by both physically in terms of production and politically when, for instance, given amount of potential food corps is used for production biofuels to satisfy mandatory blends (FAO, 2014).

The largest attention gets food crisis in 2008, when food prices soared by 40 percent (Rosegrant, 2008). Practically all agricultural commodities were affected. Rosegrant claims that one of triggers of the crisis was biofuels development. High demand for biofuel feedstocks was offset by larger part of crops that used to serve for food production. According to the the International Food Policy Research Institute's IMPACT model, increase in demand for biofuels is estimated to have accounted for 30 percent of the price increase in case of grain. Even larger impact is estimated to maize price. According to the model, the increase in biofuel demand has accounted for 39, 21 and 22 percent in price increase of maize, rice and wheat, respectively. While such kind of price increase may not be serious issue in rich countries, people in developing countries could feel it substantially, since they spent considerable portion of their income on foodstuff. Therefore, second and third generation biofuels are being promoted these days.

2.5 Fisher-Tropsch Synthesis

With connection of the future development of the second generation biofuels term Fisher-Tropsch synthesis (FTS) is being inflected frequently. The FTS is a process that converts mixture of carbon monoxide and hydrogen (CO/H2 also referred as syngas) into liquid hydrocarbons (Ojeda and Rojas 2010). Great advantage of the FTS is that syngas can be obtained practically from every source that contains carbon. In early days of the FTS, the major feedstock for syngas was coal (coal-to-liquids, CTL). Thereafter, companies started to use natural gas (gas-to-liquids, GTL) and recently, the FTS was proved to work with biomass (biomass-to-liquids, BTL). In the context of biofuels, the BLT process seem to be a right way of development in production of second generation biofuels. The BTL promises substantial GHG benefits, relative to the refinery produced gasoline. Swain et al. (2011) estimate that life-cycle GHG emissions savings from BTL range between 60 to 90 percent in comparison to refinery. However, achievement of such benefits strongly depends on a feedstock used. Aforementioned values refers to forest wood which has lower negative impacts on biodiversity than agricultural land. For instance, feedstock like straw and short-rotation wood are estimated to have even worse impacts than petrol, mainly due to the estimated land use impacts. Further, they claim that GHG emissions from the GTL are comparable to those from refinery, i.e. ± 5 percent. There is not big difference in GHG emissions from production between GLT and BLT. The difference follows rather from the estimates of life-cycle GHG emissions connected to feedstocks. So BLT-fuel is CO_2 neutral in comparison to fossil fuel since it only releases CO_2 which was captured from the atmosphere earlier. Further it has practically no sulphur and aromatic components which are serious air and water pollutants. However, sulphur serves as a lubricant in an engine. Its absence can be solved by blending synthetic fuel with biodiesel which has low sulphur content but still good lubricity property (Swain et al., 2011). Thus BLT-fuel is cleaner in terms of combustion than the fossil fuel, however with a few exceptions its production has higher negative environmental impacts.

Synthetic fuel produced by using the FTS can be used in pure form or in blend with conventional gasoline. Therefore, it directly compete with traditional oil fuels and its economic feasibility depends mainly on the price of crude oil. Furthermore, BLT production costs greatly depend on production scale as well. Large scale BLT plants benefit from economy of scale and the optimum scale of the BLT plant lies between 16,000 and 32,000 barrels per day, according to the Swain et al. They further claim that BLT fuel is competitive with oil prices around $60[5]. Nevertheless, large initial investment for BLT plant and highly volatile oil market make it less economically attractive. If suitable feedstock is used, the FT conversion can be environmental effective and can bring desired GHG savings. Therefore, it can be convenient means to support EU's climate change strategy and eligible for EU endowment to make it more economically feasible.

3 Natural gas

In this section we provide introduction for shale gas, state its advantages and potential drawbacks and controversies and its policy development in the EU. Further, we describe application of natural gas as an alternative fuel. Section is based on Nash (2010), Asche et al. (2012) The Energy study 2013 (Federal Institute for Geosciences and Natural Resources), Erbach (2014), Short-Term Energy and Summer Fuels Outlook (EIA, 2015), Wang et al. (2011), the Directive 2014/94/EU and data from U.S. Energy Information Administration (EIA).

Phrase "shale gas" has been mentioned in plenty of headlines with links to energy independence in recent years. It should be noted that shale gas is a designation for natural gas trapped in hydrocarbon rich shale formations. Although, it may seem like gas from shales is a new discovery at first sight, that kind of gas reserves were known for quiet long time. Nevertheless, extraction of natural gas from shale formations was economically unattractive. Only recent advances in development of directional well drilling and hydraulic fracturing with high natural gas prices prior to 2008 have made produc-

[5]They calculate with production costs of 15ct/L

tion of shale gas lucrative (Nash, 2010). However, gas price plummeted in 2009. The price drop is assigned not only to excessive supply shift, but also to overall economic decline after 2008 financial crisis when oil and other types of energy prices have fallen as well (Asche et al., 2012). Despite the low prices of both oil and natural gas in recent months, production in the US is expected to grow by 5 and 1.9 percent in 2015 and 2016, respectively (EIA, 2015a). Consumption will increase as well. The EIA predicts that US power and industrial sector demand will increase by 11.5 and 4.9 percent in 2015, respectively. The growth in consumption of industrial customers is driven by low natural gas prices as they take advantage of energy costs. Pioneer in shale gas production is the US where share of shale gas on total natural gas output soared from 1 in 2000 to 40 percent in 2012 (EIA, 2015b). The share is projected to grow and the US is predicted to become natural gas exporter before 2020. Asche claims that very important role in the US shale gas production development had substantial decline in extraction of conventional gas onshore. The decline was accompanied by excess of inexpensive drilling capacity which made extraction from shales even more attractive. Nevertheless, the US is not only country which has a shale gas reserves. The EIA estimates that there are 7,299 trillion cubic feet (tcf) of technically recoverable shale gas resources worldwide. China's reserves is estimated to be largest in the world of 1,115 tcf of technically recoverable shale gas. Estimates for countries with biggest reserves are depicted in table 2.1. Even though, the table does not contain any European country, according to the Germany's Federal Institute for Geosciences and Natural Resources study carried out in 2013, whole Europe is estimated to have 14 trillion m^3 (approximately 500 tcf) of technically recoverable shale gas reserves. Largest estimates are assigned to Poland and France with 148 tcf and 137 tcf, respectively.

Table 1: Top 10 countries with technically recoverable shale gas resources

Rank	Country	Shale gas (tcf)
1	China	1,115
2	Argentina	802
3	Algeria	707
4	U.S.	665
5	Canada	573
6	Mexico	545
7	Australia	437
8	South Africa	390
9	Russia	285
10	Brazil	245
	World Total	7,299

Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States. U.S. Energy Information Administration. 2013.

3.1 Development in the EU

As we mentioned above, Europe has relatively large shale gas reserves even comparable to the US[6]. Some European countries are enthusiastic about shale gas development. They argue for shale gas as solution to lower energy dependence on Russia. These concerns had become stronger after the Ukraine crisis. It worth mention that the EU imports 53 percent of its energy needs[7]. In 2013, 10.7 tcf of natural gas was imported. It was 66 percent of total EU consumption. Major supplier was Russia which accounts for 39 percent of imported gas (Erbach, 2014). Further, combustion of natural gas produces less CO_2 emissions than burning of coal. This is a powerful argument for meeting GHG emission targets set by EU, however there are some concerns about life-cycle GHG footprint of shale gas that have to be addressed (Wang et al., 2011). Nevertheless, there are many obstacles that have to be overcome before commercial production can start. Opponents of shale gas warn about many environmental risks accompanied with horizontal drilling

[6]The Energy Information Administration estimates that the US has 665 tcf of technically recoverable shale gas reserves.

[7]Eurostat: Energy dependence,"tsdcc310", downloaded: March 28, 2015

and hydraulic fracturing. Hydraulic fracturing is a drilling method used to recover shale gas. It is a process when water, sand and chemicals are injected into rock formation under high pressure in order to break up the rock and extract gas or oil. There are great concerns whether the mixture of water and chemicals can contaminate adjacent drinking water sources (Asche et al., 2012). In addition, there are some clues that unconventional production of shale gas is connected with earthquake occurrence. Europe is more densely populated then the US, thus it will be much difficult to find place where drilling wells could be set up to be both far from inhabited area and in proximity of pipeline network. Due to many environmental hazards, numerous countries proceed with caution in shale gas development. For instance, French government banned hydraulic fracturing for shale gas in 2011 due to concerns about its environmental impacts. Government cancelled exploration licences as well. President Francois Hollande (2013) added: *"As long as I am president, there will be no exploration for shale gas in France."* On the contrary, majority of Poles support shale gas exploitation as well as Polish government. They promised tax exemption for shale gas extraction until the end of 2020 to encourage exploration. Nevertheless, the first attempts of drilling did not reach expectations. Furthermore, the EC started investigation of Geological and Mining law that Polish government adjusted to be more favourable with respect to shale gas exploration. The EC claims that the law violates environmental impact assessment directive. While there are some more countries that support shale gas exploration like the United Kingdom (UK) and Romania, general stance on the EU states can be described with words "caution" and "negative attitude" towards future development or waiting for appropriate environmental and social impact studies.

3.2 Natural gas as an alternative fuel

Both biofeuls and natural gas are directly or indirectly in form of additives used in transportation sector. During intensive government policies of reducing GHG emissions both energy sources promise significant GHG savings. This section introduces application of natural gas as an alternative fuel in transportation sector and its possibility of reduction both costs and GHG emissions. The section is based on Stephenson et al. (2012), Beach (2013), National Petroleum Council (2007) and Chemlink assessment of GTL (2007).

Climate changes place us in a difficult situation when meeting of energy needs is accompanied with reducing GHG emissions. While transportation sector contributes nearly quarter to EU's total GHG emissions, application of more GHG friendly fuels is crucial in meeting environmental targets. Both aforementioned resources have proponents which promoting their environmental friendliness.

Undoubtedly, natural gas is the "cleanest" fossil fuel in term of combustion. It burns cleaner and more efficiently than coal and oil. Furthermore, it is a prominent way how to support discontinuous supply of energy from renewable resources with easily dispatchable and scalable generators in power generating industry. The Intergovernmental Panel on Climate Change called it a "bridging fuel" and experts see natural gas as a transition fuel to the low carbon energy system (Stephenson et al., 2012).

There are variety of technologies that enables natural gas to be used in transportation. Most commonly, natural gas is used as liquefied natural gas (LNG) and compressed natural gas (CNG). The LNG is produced by cooling down natural gas to approximately -150 °C depending on the composition of the gas. The conversion process removes compounds such as water vapour, CO_2 and sulphur which results in purer methane that emits lower emissions during combustion. Both CNG and LNG have lesser energy density. Therefore, natural gas powered vehicles require larger fuel tanks than diesel or gasoline powered vehicles. In case of CNG, there are additional requirements on fuel tank. It has to be capable of sustaining high pressures of fuel. Although LNG does not require such high pressure tank, its tank has to be capable of insulation of fuel to keep it cold. Such properties causes fuel tanks to be large and heavy and they often fill significant space in vehicle. Thus, it is unlikely to place drive using CNG or LNG to passenger car, since it would take up precious passenger or a trunk space. That's why they are mainly used in heavy and medium duty trucks. Due to lower energy density nature of these fuels, such vehicles have limited tank range, however they can be suitable for municipal buses and fleet passenger vehicles in case of CNG. LNG with higher energy density than CNG is suitable for long-haul tractor trailers (Beach, 2013). Naturally, development of CNG and LNG vehicles has to be accompanied with development of appropriate filling stations.

Another way how to implement natural gas into transportation sector is through GTL process (see FTS section). Natural gas can be converted into gasoline or diesel hydrocarbons that are similar in terms of energy density and can be used in common vehicle. Fuel produced through GTL process may has properties that allow for better engine performance and potential GHG emissions reduction (Beach, 2013). It has to be mentioned that natural gas and biomass, as a feedstocks for the FTS, compete as direct substitutes. For instance, US startup company Primus Green Energy, primarily specialized on production of gasoline and jet fuel from biomass, used natural gas as a feedstock in low natural gas price period. The company projected that they could be competitive till price of $65 per barrel of crude oil (LaMonica, 2012). Although world price of crude oil currently oscillates around $50 per barrel, there were only few periods of time when the price was below $65 in past decade. Nevertheless, this estimate is conditional on cheap natural gas. According to the National Petroleum Council (2007), GTL process requires approximately 10 thousand cubic feet (mcf) of natural gas to produce 1 barrel oil-equivalent product output. Having todays price of $4.8 per mcf[8] for natural gas, it would result in output of $48 per barrel of oil-equivalent, so hardly competitive currently. Nevertheless, if GTL plant was made at place where natural gas is extracted, the EIA estimates that the cost of GTL fuel would be around $25 per barrel. To achieve such price, natural gas that would be flared at oil well otherwise, has to be used as a feedstock.

While there is a potential for reducing fuel costs in CNG and LNG systems, total costs of shift from diesel or gasoline powered vehicles to natural gas vehicles would be exten-

[8]The Energy Information Administration: Industrial price, Jan 15, 2015

sive. An average price of CNG or LNG vehicle is higher than conventional vehicle and if we add costs of maintenance facilities, we conclude that it is not that much economically attractive (Beach, 2013). Even though it is costly alternative, it is a cleaner alternative and suitable for city buses and for medium and heavy duty trucks. Therefore, again with appropriate state support it can be applicable means for meeting environmental targets and, as we state in following subsection, the EU reckons with it in near future.

3.3 EU legislation and its impact

While the EC is sceptical in exploration of shale gas, it counts with natural gas based alternative fuels such as CNG and LNG in future. Directive 2014/94/EU on the deployment of alternative fuels infrastructure, adopted in the fall 2014, introduced EU's efforts to lower GHG emission from transport and to reduce dependence on oil. There are some principal barriers that prevent clean fuels such as LNG, CNG, but also electricity and hydrogen from more intensive use. Firstly, the high cost of vehicles naturally deters people from buying them. Further, there are only few refuelling and recharging stations, because there are few alternative vehicles. Hence there is a little incentive for customer to buy it which causes producers to sell at high prices. It is a vicious circle and the EC tries to correct this market failure by regulation. Directive binds MS to develop national policy frameworks for support of alternative fuels, primarily their distributional infrastructure. Document requires installation of LNG filling station along the Trans-European Transport Network (TEN-T) with distances 400 km, the minimum tank range of LNG heavy-duty motor vehicles. Similar requirements are placed on CNG stations. Targets are set to achieve by 2020 and the aim of the directive is to create Europe-wide alternative fuel station network with common standards for their design and use.

A natural gas vehicles (NGVs), vehicles with CNG or LNG drive, are not much widespread in the EU yet. Their share among all vehicles accounted for 0.41 percent in 2014[9]. However, development of NGVs differed significantly across Europe in the past

[9]NGVA Europe: European NGV statistics, European NGV shares in total vehicle market

decade. There are countries with much larger fleets. For instance, Italy had 885,300 NGVs which represented 2.16 percent of the total vehicle population. For reasons we stated in previous section, NGVs are more often used in medium and heavy duty vehicles. They account for 6.91 and 5.4 percent among municipal buses in the Netherlands and Sweden, respectively. Gas-powered vehicles are attractive not only for its environmentally friendliness, but also for prices of CNG and LNG fuels. According to the Natural & bio Gas Vehicle Association (NGVA), average CNG price of litre of gasoline and diesel equivalent was 0.72 and 0.81, i.e. 54 and 64 percent of actual gasoline and diesel average price in the EU in 2014[10]. It can be source of considerable savings for company with large fleet. While NGVs still represent only mirror portion of total vehicles on road, their numbers have been growing rapidly in recent years. Let's take more detailed look at the CR. According to the Czech Gas Association (CGA), there were 8,500 NGVs on Czech road in 2014, however 2000 vehicles were added to the fleet in the same year which is approximately 30 percent growth. Further, NGVs hold 0.83 percent share on all new registered cars which is almost twofold increase in compared to 0.46 percent from 2013. The ČPS expects that there will be total of 9, 581 NGVs on road in the second quarter of 2015 which means comparable growth to the previous year. Vast majority of NGVs in the CR is represented by cars and light duty vehicles, however subsidy of 40 million from the Czech Ministry of the Environment will help to replace 300 buses by CNG ones. It will increase public transport fleet of 500 CNG buses that are already on roads. Consumption of natural gas as fuel has been increasing along with the NGV fleet and infrastructure by 50 and 36 percent in 2014 compared to 2012 and 2013[11], respectively. The NGVA stated that the CR is on a good way to fulfil objectives set in the Directive on alternative fuels infrastructure. The CR is not the only one who experience boom of gas-powered vehicles and it seems that the EU's regulation works well. To sum up, while NGVs still represent only little share of total amount of vehicles, there has been substantial increase both in number of vehicles and consumption and the growth is likely to continue.

[10] NGVA Europe: European NGV statistics, Comparison of fuel prices in Europe
[11] Czech Gas Association: Statistic of NGV in the Czech Republic, 2004-2014

4 Conclusions

Biofuel industry has come long way in the past decade. Through favourable regulation MS successfully managed to place biofuels on the market and their consumption reached to units of percent. After years of development the vast majority of biofuels on the market comprises of the first generation biofuels. They were proved to have impact on food prices, besides there are concerns that they cause more environmental damage than fossil fuel they replace. The first generation biofuels contribute to land conversion to agricultural fields. The impacts of production of biofuels are referred to as indirect land-use changes and they are treated in the last legislation affecting biofuels. In effect of environmental and social impacts they have, the European Commission decided to cap their amount that can be counted towards Renewable Energy Directive target to 7 percent. It is sign that the EU is turning its support elsewhere. An alternative is an advanced biofuels which use organic waste as feedstock, however their share on the market is mirror.

On the other hand, the Directive on alternative fuels infrastructure adopted in the fall 2014 promotes besides biofuels other alternative fuels. The aim of the directive is to create Europe-wide alternative fuel station network with common standards for design and use. One of involved alternative fuels is natural gas as the cleanest fossil fuel. The Directive promotes the CNG and the LNG drive as their are suitable for medium and heavy duty trucks and buses and can lower greenhouse gas emissions. Although, NGVs still represent only mirror portion of total vehicles on road, their numbers have been growing rapidly in recent years. Natural gas is sometimes called bridging fuel to low carbon energy system. However, whole life-cycle of a fuel has to be taken into consideration. We reviewed relevant studies connected to impacts of shale gas exploitation. There are serious concerns about environmental impacts of hydraulic fracturing and shale gas exploitation in a large scale is not likely to happen in most of the Member States. Still natural gas from conventional extraction can serve as alternative fuel as well and there is a plenty of it.

Thus does the shale gas revolution mean the end of biofuels? The revolution in onshore exploitation of gas and oil from unconventional resources brought prices of oil products down. This is often mentioned as a one of the obstacles for biofuels. However, there are plenty of others and if the EU as well as other states want to support environmentally friendly fuels, the shale gas does not seem to be the right way for now. Biofuels still have support in EU's legislation and it is no likely to completely diminish in near future, however the EU starts to count with other alternative fuels besides biofuels, thus their importance will be smaller.

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