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PROSPECTS FOR A HYDROGEN ECONOMY IN LATVIA

ŪDEŅRAŽA SAIMNIECĪBAS IZREDZES LATVIJĀ

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Introduction

Hydrogen is increasingly seen as the versatile fuel of future, with the potential to replace fossil fuels. If produced sustainably, hydrogen can be the basis of a low carbon economy, enabling a reduction in emissions of greenhouse gases and other air pollutants, with the associated benefit of improving the security of the energy supply and allowing an infrastructure based on distributed generation. Nowadays, hydrogen energy has become a popular topic in the World's most developed countries like the US, Canada, Japan, and Germany [1,2,3]. These countries have heavily invested in the development of hydrogen related technologies. They also created their visions of the hydrogen economy and developed theirs national roadmaps to reach the hydrogen economy. The issue of hydrogen energy has become part of the vision for the future at the EU [4] level and has resulted in the establishment of research and development programs, as well as the hydrogen and fuel cells technologies platform as part of the EU strategy concerning hydrogen.
Latvia is currently investing large amounts of money in the expansion and modernisation of its energy and transport infrastructure. These developments could be considered as favorable opportunities for Latvia to consider hydrogen use in its future energy systems.
A key question that often remains open is how to accelerate the transition to hydrogen as quickly as possible and without a parallel increase in emissions. There is an urgent need to know, as early as possible, which technologies will work and at what cost.

Latvian energy sector analysis

Energy Supply
The primary resource supply in Latvia is provided by local and renewable resources (fuelwood, straw, hydroresources, biogas, etc.) and imported energy resources (oil products, natural gas, coal, etc.). The Latvian ministry of the environment projects Latvia's total energy consumption to increase by an average of 2.4% a year out to 2020 [5]. Fossil fuels will continue to supply the majority of Latvia's domestic energy needs, with oil's share slightly increasing from 30.11% in 2004 to 33.74% in 2020. The share of natural gas share in primary energy consumption will increase from 29.62% (Fig.1) in 2004 to 31.62% in 2020. Coal consumption will increase by 8% by 2020.

The share of renewable sources (36% in 2004) in the total supply is significantly above the EU-27 average [5], and forecasts show that this share will grow slightly at the expense of other solid fuels. Latvia's increasing reliance on imported oil products and natural gas could result in grater exposure to potentially volatile oil and gas prices and possible disruptions of supply.

Energy Consumption
Fossil fuels remain the dominant source of final energy consumption in 2004. Their share represents about 62% of final energy consumption in 2004. The share of natural gas in final energy consumption has grown by 1.7%. The share of biomass is about 28%; peat disappeared as fuel but biogas comes in sight. Electricity consumption increases in line with the growth in the national average energy consumption; retaining a share of final energy consumption of 9%. Fig.2 shows the final energy consumption in Latvia in 2004.

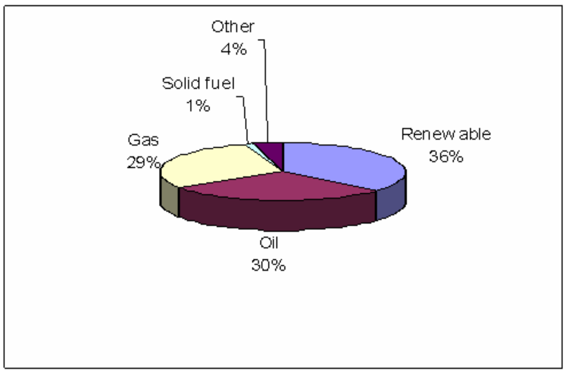

Fig.1**:** Latvia primary energy supply in 2004

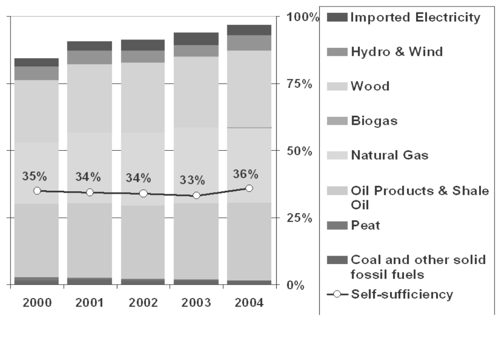

Fig. 2: Latvia's final energy consumption in 2004[5].

Introduction of hydrogen as alternative fuel into Latvian energy sector

Hydrogen can be used in various applications in the industrial and utility sector. In industry hydrogen is used in metallurgy, chemical synthesis processes, as well as in mineral oil industries. In other sectors hydrogen can be used most fruitfully in transport and in cogeneration applications by providing heat and electricity for industrial and commercial establishments [6]. As the growth of the hydrogen supply infrastructure faces different constraints in the heat and power sector, this study is limited to the use of hydrogen in the transport sector in Latvia.

Hydrogen demand in transportation

The transport sector in Latvia comprises road vehicles, trains, ships, and aircrafts. Transportation remains a vital component of Latvia's economy and affects the lives of many individuals. The current transport system, however, also creates challenges and problems. Indeed, the transport sector in Latvia has a poor environmental record: it impoverishes local air quality, causes acidification and is one of the major emitters of carbon dioxide. Even with significant progress in energy technologies, primary energy use and greenhouse gas emissions will likely grow over the next decades, because of the increasing demand for transport in Latvia.

Energy for transportation truly represents one of the major sources of short and medium-term vulnerability for Latvia's society and economy today. While changing behavior has the potential to reduce transportation fuel and greenhouse gas emissions, large and sustainable reductions have never been achieved in this manner in Latvia. Therefore the substitution of petroleum–based transportation fuel by non-petroleum fuels is seen as a key means of reducing the vulnerability of the Latvian transportation sector to disruptions in the petroleum supply.

A variety of efficient end-use technologies and alternative fuels (ethanol, methanol, hydrogen, liquefied petroleum gas, dimethyl ether, and natural gas) have been proposed to help address future energy-related environmental and/or supply security challenges in fuel use. Among these alternative fuels, hydrogen has recently received increased attention, perhaps because of the greatest long-term potential it offers to radically reduce the impacts of fossil fuel use.

Hydrogen scenarios for Latvia

Any transition to a hydrogen economy will inevitably be a long-term process spanning several decades. One approach to planning under conditions of uncertainty is the scenario analysis. Scenario planning is a systematic approach to thinking about the mid-and long-term future. It is a tool for finding robust policy options because it allows outlining the future development of energy systems in relation to a variety of framework conditions and policy settings [7].

In order to cover a certain range of possibilities, three scenarios are developed in this paper to reflect the uncertainties regarding the technological breakthrough of hydrogen vehicles into Latvia's fleet between 2010 and 2050.

Scenario A: Low market penetration of H_2 cars

Scenario A is more conservative and pessimistic. Hydrogen penetration occurs over a longer period and results in an extremely low share of 12% for hydrogen cars in the road transport.

Scenario B: Medium penetration of H_2 cars.

Scenario B is a less conservative scenario and is characterised by continuous government support for the introduction of hydrogen vehicles into the fleet. The mass market introduction of hydrogen happens around 2020, leading to a very low share of hydrogen vehicles on the order of 15 % of all passenger cars by 2050.

Scenario C: High penetration of H_2 cars

The innovative and optimistic scenario C is characterised by an early introduction of hydrogen vehicles leading to a significant share of 24% hydrogen cars in the fleet by 2050. The assumptions on the introduction of hydrogen vehicles in Latvia are shown in Table 1.

Table 1:
Hydrogen vehicles in Latvia (passenger cars only)

	2010*	**2020**	**2030**	**2040**	**2050**
Total car stock in Latvia (thds of cars)	*875.7*	*1194.7*	*1513.7*	*1832.7*	*2151.7*
Stock share H_2-cars					
Low	-	*0.2%*	*2%*	*6%*	*12%*
Medium	-	*0.4%*	*4%*	*9%*	*15%*
High	-	*1%*	*6%*	*15%*	*24%*

*Demonstration vehicles and fleet

Hydrogen supply

There are several pathways for producing hydrogen. However, all of these pathways have two points in common. First, they all require some form of feedstock (gas, coal or water) from which to extract hydrogen. Second there must be some form of energy input to break down the feedstock and release the hydrogen.

Fossil fuel pathways

Fossil fuels such as coal, crude oil, and natural gas can serve as feedstock in hydrogen production systems. Steam reforming of natural gas is currently the least expensive method and is responsible for more than 90% of hydrogen production worldwide. Natural gas is first cleared from sulphur compounds. It is then sent over a nickel-alumina catalyst inside a heated externally tube, where carbon monoxide and hydrogen are generated. This first step is followed by a catalytic water-gas shift reaction which converts the carbon monoxide and water to hydrogen and carbon dioxide. The hydrogen gas is then purified. Hydrogen produced from natural gas or other fossil fuels is unsustainable because supplies are limited and not pollution free.

Renewable energy source pathways

The most common method of hydrogen production after steam reforming of natural gas is electrolysis. In this process, an electrical current passes through a conducting aqueous electrolyte, splitting water into hydrogen and oxygen. The efficiencies of electrolysis generally exceed 80%, and the process produces no air pollution. Electricity produced from any source can be used to provide the energy to produce hydrogen through electrolysis. Therefore any renewable resource that can be used to generate electricity is capable of producing hydrogen through electrolysis.

Demand and supply integration

This paragraph describes the approach used to integrate hydrogen demand and supply in an analytical framework using the “well to wheel life cycle and scenario techniques” to analyze hydrogen transition over the 2010 to 2050 time period. The aim of the approach is to determine the energy and greenhouse gas emissions associated with hydrogen demand in Latvia.

Determining Hydrogen usage

The total amount of hydrogen demanded by cars for the period 2020 to 2050 in the high penetration scenario was calculated using the number of cars, the vehicle kilometres traveled per year, the forecasted fuel efficiencies and the penetration rate of hydrogen cars. Hydrogen demand by 2050 reaches 49687 tonnes (see Table 2); all this demand is produced by light duty fuel cell vehicles.

Determining the additional electricity demand, kilometres displaced, and emissions avoided assuming hydrogen adoption in Latvia

The total additional electricity required to meet hydrogen demand through electrolysis was determined for 2020 and 2050 under scenario C using values of specific electricity requirements for hydrogen production[1]; the indirect greenhouse gas emissions associated with electricity use were calculated using the specific emission factor[2] of Latvian electricity.

Under the scenario C, 1% of total passenger cars in Latvia were assumed to operate solely on hydrogen by 2020, and 24% by 2050. Therefore 1% of the passenger car kilometres travelled estimated in the base case are displaced with the need being met by hydrogen powered cars by 2020 and 24% displaced by 2050.

Table 3 reports the main results of additional electricity required; kilometres displaced; emissions avoided; and net greenhouse gas emissions related to the adoption of hydrogen as alternative fuel for road transport in Latvia.

Table 3:

Electricity required meeting the demand and Net greenhouse gas emissions

Hydrogen demand for Scenario C-*High penetration of H_2 cars into road transport in Latvia-*

Electricity required to meet hydrogen demand (MWh)				
	Hydro	Nat. G	Wind	Mix
	66%	33%	1%	100%
2020	64281	32141	974	97396
2030	*425667*	*212833*	*6450*	*644950*
2040	*969345*	*484672*	*14687*	*1468704*
2050	*1508497*	*754249*	*22856*	*2285602*
GHG by fuel based on Latvia emission factor(ton CO_2 eq)				
2020	2250	15929	17	18200
2030	14898	105421	110	120429
2040	33927	240203	250	274380
2050	52797	373806	389	426992
LDV kilometre displaced by hydrogen (10^6 km)				
2020	187.3			

2030	1433.22			
2040	4371.14			
2050	8281.16			
Avoided GHG associated with Gasoline (ton CO_2 eq)				
2020	*-16071*	*-8035*	*-243*	*- 24349*
2030	*-113511*	*-56755*	*-1720*	*- 171986*
2040	*-317345*	*-158672*	*-4808*	*- 480825*
2050	*-546557*	*-273278*	*-8281*	*- 828116*
Net greenhouse gas emissions (tonnes CO_2 eq)				
2020	-13821	7894	-226	- 6153
2030	-98613	48666	-1610	-51557
2040	-283418	81531	-4558	- 206445
2050	-493760	100528	-7892	-401124

Hydrogen transition pathway analysis

Renewable Electrolysis vs Biomass Gasification/fermentation

Hydrogen produced mainly from renewable energy sources is and remains the overall goal. However, as we can see in Fig. 4, there is a substantial gap in supply and demand of renewable energy for the production of hydrogen. Even with improvements in energy efficiency, the gap is

[1] The specific electricity required for hydrogen production were assumed to be 55, 52, 50, 48, and 46 kWh/kg H_2 for 2010, 2020, 2030, 2040, and 2050, respectively.

[2] The specific indirect greenhouse gas emission factors associated with electricity production and use in Latvia are: 0.4956, 0.035, 0.017, and 0.187 tonnes CO_2 eq/MWh for natural gas, hydro, wind, and electricity mix, respectively.

still huge. The size of this gap is about the same as the amount of renewable electricity generated in Latvia today; and constitutes a barrier for hydrogen production via electrolysis.
Although there is a net gain in greenhouse gas emissions if Latvia chooses to use renewable electricity for hydrogen production rather than to use it directly in conventional electricity generation[3], the state-of-art renewable hydrogen production through electrolysis is one of today's most energy intensive and costly sources of hydrogen. This situation also serves as a barrier to the development of hydrogen technology and will delay the transition to a hydrogen economy. Given the fact that about half of electricity consumed in Latvia is imported, any kWh of renewable electricity should preferably be used to decrease the share of imported electricity, which is, therefore, another barrier for the transition to hydrogen.

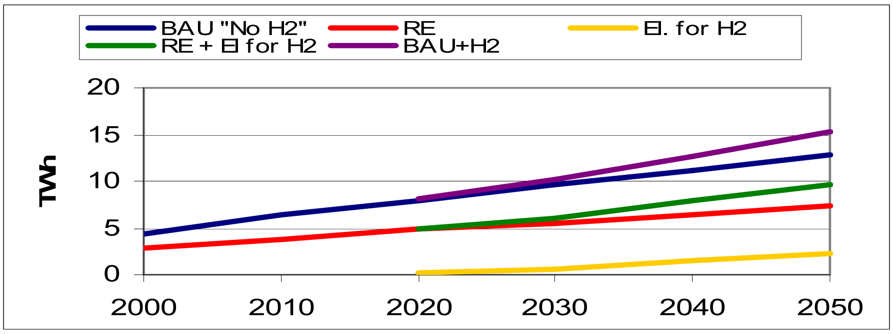

Fig. 4**:** Total additional electricity demand assuming hydrogen adoption.

There are other ways of producing renewable hydrogen apart from electricity based pathways, such as directly from biomass gasification or fermentation. The conversion of biomass and biowaste to hydrogen is the only source of hydrogen that comes close to competing with fossils. The technical potential of these resources could cover between 65% and 70% of hydrogen demand in Latvia, still leaving some gap.

Fossil with sequestration vs Renewable
As the renewable hydrogen pathway has been discussed in paragraph 6.1, the focus here is on the fossil de-carbonised hydrogen production pathways. Fig. 5 shows that fossil hydrogen pathways based on electrolysis using electricity from the grid have the highest well to tank CO_2 emissions. Figures range between 16435 gCO_2/kg H_2 for coal gasification and 9230 gCO_2/kg for natural gas reforming.

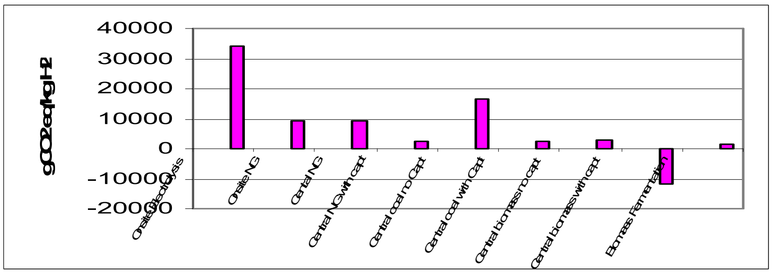

Fig. 5: CO_2 emission for different hydrogen technologies

Emissions are slightly reduced if carbon capture and sequestration are applied (around 2539 gCO_2/kg for natural gas), or if hydrogen is produced via biomass gasification (2930 gCO_2/kg) or

[3] Indeed, 1 kWh of renewable electricity displaces about 190 gCO_2 eq from public grid generation in Latvia if this renewable electricity is used for electrolysis and, in the end, for hydrogen vehicles. Thus, a reduction of specific emissions by 198 gCO_2 eq/kWh can be achieved.

via biomass fermentation (1375 gCO_2/kg). Fossil hydrogen production via de-carbonised natural gas reforming is the most attractive fossil production option with respect to cost and CO_2 emissions. However, a careful analysis is required to determine whether the investment in hydrogen infrastructure based on natural gas will lay the foundation for the production and widespread use of hydrogen fuel from renewables in the long-term, or whether such a system will be a waste of energy and money.

Conclusion

Looking at the energy situation realistically, renewable electricity generation such as wind, photovoltaic, and tide power still have a long way to go before they can constitute any significant share of the electricity supply in Latvia. Hydrogen is a very suitable way to overcome the limitations renewable energies have according to their specific intermittent load characteristics. Regardless of these advantages, however, the market introduction of hydrogen will take time and must be well prepared.

Producing hydrogen from decarbonised natural gas will in the short term accelerate the transition towards a hydrogen economy and, at the same time, safeguard the commitment to struggle against climate change. On this background, the increase in natural gas use that can be actually observed in Latvia is very compatible with a gradual extension of renewable energies, as long as the transitional character of natural gas as limited resource is kept in mind. Obviously, such a development outline is very ambitious and requires a dedicated energy policy that is maintained for many decades. Renewable energies have to be moved into the focus of policy action and to become the second centre of gravity of energy policy.

Reaching the target of sustainable hydrogen supply is only possible when the extension of renewable energy and saving energy by use of efficient hydrogen vehicles and production processes are closely linked.

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Njakou Djomo S., Blumberga D., Ūdeņraža saimniecības izredzes Latvijā.

Ūdeņradis ir energoavots ar potenciālu radīt iespēju jaunu enerģijas tehnoloģiju un politikas izveidei. Latvija ir atkarīga no ārvalstu energoresursiem, atjaunojamais ūdeņradis varētu būt viena no tehnoloģijām, kas ļautu samazināt šo atkarību. Atjaunojamā ūdeņraža attīstības izpēte Latvijā ir nepieciešama vairāku iemeslu dēļ, ieskaitot pieejamību lielam izejmateriālu daudzumam, alternatīvas atjaunojamās degvielas ieguve, kas stiprinās Latvijas energosistēmu, siltumnīcas efektu izraisošo gāzu emisiju samazinājumu no transporta un gaisa kvalitātes uzlabošanu

Latvijas lielākajās pilsētās. Rakstā ir analizēts Latvijas enerģētikas sektors, lai identificētu ūdeņraža saimniecības priekšrocības un šķēršļus, un lai norādītu labāko sākumpunktu pārejai uz ūdeņraža saimniecību. Vēlāk balstoties uz šo scenāriju tiek novērtēts ūdeņraža pieprasījums. Tiek dotas rekomendācijas, kā uzlabot situāciju un pārvarēt barjeras, lai sāktu ražot ūdeņradi, kas veidotu ilgtermiņa ilgtspējīgu enerģijas sistēmu.

Njakou Djomo S., Blumberga D. Prospects for a hydrogen economy in Latvia.
Hydrogen is an energy carrier with the potential to open the door to a wide range of new energy technologies and policy options. Latvia is affected by a strong dependence on external energy sources, and renewable hydrogen is seen as one of the key technologies that could help in diminishing that dependence. Developing renewable hydrogen is a necessity for Latvia due to various reasons, including the abundant availability of raw material, an alternative renewable fuel to strengthen Latvia's energy security, a solution to reduce greenhouse gas emissions from transport and improve the local air quality of Latvia's major cities. This paper analyses the situation of the Latvian energy sector in order to identify opportunities for and barriers to a hydrogen economy as well as to indicate the best starting point for a transition to a hydrogen economy. Later on, a scenario-based approach is used to estimate the total hydrogen demand. Finally, recommendations are given on how to enhance opportunities and overcome barriers and move towards a hydrogen economy with a view to the long-term sustainability of the energy system.

Ньякоу Джомо С., Блумберга Д., Потенциал использования водорода в Латвии.
Водород это энергоисточник с потенциалом к развитию новых технологий и новой энергополитики. Латвия зависит от зарубежных энергоисточник, и использование возобновляемого водорода может быть одна из технологий, которая позволила бы уменьшить эту зависимость. Исследование возможности развития возобновляемого водорода в Латвии необходимо по многим причинам, включая доступ к большому количеству исходного сырья, получение альтернативного возобновляемого топлива, что усилит Латвийскую энергосистему, уменьшение выбросов тепличных газов от транспорта и улучшение качества воздуха в больших городах Латвии. В статье анализирован секторы Латвийской энергетики чтобы определить достоинства и препятствия для развития водородного хозяйства в Латвии. Далее основываясь на данный сценарий был оценен спрос на водород. Даны рекомендации как улучшить ситуацию и перейти барьер, чтобы начать производить водород для создания долгосрочной стабильной энергосистемы.