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This document includes country-specific political roadmaps, which are based on country-specific policy assessments and identified barriers and involves recommendations directed at political actors and energy planners.

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1. SLOVAKIA

1.1 NATIONAL (SPECIFIC) GOALS

The key document specifing the national goals in energy and climate sector is the: **Integrated energy and climate plan for 2021-2030.** The general approach of this document is in line with EU to move from fossil fuels to renewable sources.

The main quantified objectives of the NECP within the Slovak Republic until 2030 are to reduce greenhouse gas emissions for sectors outside of emissions trading (non-ETS) by 20% (the share was increased from the originally declared level of 12%). The use of RES in the final energy consumption is set in 2030 to be 19.2% with the fulfillment of the required goal of 14% of RES in transport. The energy efficiency goal is to reach 30,3% by 2030 and the interconnection of electrical systems 52%. The full Carbon neutrality is set to be achieved by 2050.

Considering the hydrogen activities in Slovakia, it is worth to mention the fresh National hydrogen action plan has been introduced and is still under evaluation in the interdepartmental commenting. While the main goal is to support the building of hydrogen production capacities directly connected to RES or other low-emission energy sources to cover the growing demand for clean hydrogen, the sectional goals are also to be mentioned:

- Total annual domestic production of green and blue hydrogen 45 000t
  - Production of hydrogen by electrolysis 25,000 t,
  - 300 MW of installed electrolyzers,
  - At least 600 MW of RES and use of nuclear resources for hydrogen production
  - Production of hydrogen from waste and biomass 20,000 t
- Total annual domestic consumption of green and blue hydrogen 45,000 t
  - industry 30,000 t, energy 5,000 t,
  - transport sector 10,000 t
    - 4,000 passenger cars
    - 260 buses
    - 600 light commercial vehicles
    - 600 heavy commercial vehicles, municipal vehicles and work machines
    - 12 regional train sets

This is to be financed with planned expenditures for the implementation of hydrogen projects until the year 2030 from the state and direct European financial support totaling 0.954 billion. Euro and also estimated private resources in the amount of 1.5 billion. Euro.

To create a functional hydrogen market competetive to the rest of the EU, another goal must be met. The goal is to join the Slovak Republic in the European market with guarantees of hydrogen origin by establishing a register of renewable gases. As of November 2021, a draft law was introduced amending Act No. 309 2009 Coll. on the support of renewable energy sources that regulates the establishment of the Register of Renewable Gases for the purpose of recording the production of renewable gases and issuing guarantees of the origin of renewable gas. The founder and operator of the register is to be SPP distribúcia (the gas distribution system operator), and with the Amendment to the Act it is to be effective from 1 November 2022.

In 2009, only 6,8% of communal waste was energetically recovered. Since 2021, the key measure was adopted ordering the municipalities to separate the biodegradable municipal waste. Many municipalities still struggle with this task, however, it is clear that over 40% of the municipal waste is biodegradable and can be used for energetic purposes. More legislative updates are to be presented in 2023 and 2027 that will lead to prohibition of land-filling of other than inert waste. That means all other waste must be either separated and reused, or energetically used.

1.2 OVERVIEW OF POWER-TO-GAS RELATED ACTIVITIES

LEGAL

The Ministry of Economy is responsible for development of an implementation strategy for renewable energy and decarbonization of the Slovak industry and transport. In june 2021 a non-legislation document “National Hydrogen Strategy” (NHS) was finalised and published. It defines the strategic role of the state in the use of hydrogen technologies in the Slovak Republic in the context of current developments in European Union countries. The aim of NHS is to increase the competitiveness of the Slovak economy and at the same time significantly contribute to a carbon-neutral society. Indicative goals set for hydrogen in 2030 are production of 45000t of hydrogen, from which 20000t from waste and biomass. Also to build 25 hydrogen “gas” stations for transport needs and infrastructure for storing and transport of hydrogen according to market demands.

Eu has accepted Hydrogen strategy for climate-neutral Europe on 8.6.2020 and conference Hydrogen future of Slovakia was held 2 weeks later, where strategic development agreements were formed among representatives from industry, science and research fields, academic institutions and social practices. The Slovak republic

already recognizes hydrogen as an energy carrier and is undertaking research in the field of electricity productions, automotive and other industries.

Slovakia hasn't introduced its own legislation or regulations regarding hydrogen blending and its injection into the gas grid yet. More research and quality standards from across Europe need to be studied, tested and accepted. Distributed gas must meet the current conditions set primarily for natural gas. Current rules are allowing a minimum insignificant amount of hydrogen to be supplied to the gas network (0,2% mol).

However, in September 2022 the fresh National hydrogen action plan has been introduced and is still under evaluation in the interdepartmental commenting. This Action plan is likely to be adopted soon and it will set conditions for the implementation of hydrogen technologies in accordance with the National Hydrogen Strategy of the Slovak Republic. In this document, the statement of the authorities clearly agrees with the EU approach expressed in The European Green Deal: the European Commission's plan for the green transformation of the EU economy for a sustainable future recognizes the ability of hydrogen technologies to help meet the EU's climate neutrality goals.

One of the goals of the National hydrogen action plan os SR is to support the building of hydrogen production capacities directly connected to RES or other low-emission energy sources to cover the growing demand for clean hydrogen which will crate new opportunities for the P2G concept in Slovakia. More sectional goals are stated in the previous chapter.

COMPANIES AND PROJECTS THAT COULD BE RELATED TO P2G IN SLOVAKIA

SPP-DISTRIBUCIA a.s. is the main Slovak gas grid operator and distributor. The company is a leader in the field of hydrogen blending and therefore have joined **H2PILOT** project to further study and upgrade its knowledge in this field. The project proposition is to reach 20% of hydrogen in gas mixture blending.

NAFTA a.s. is an international Slovak based company in Bratislava, that is experienced in underground storage of natural gas and hydrogen in already extracted natural gas reservoirs and leader in research and mining of hydrocarbons. It has been running its projects since 2014. It works as developer and technical advisor for storages in Czech Republic, Germany, Great Britain, Austria and Ukraine. It takes part in projects dedicated to innovation, in the field of storing energy from renewable sources. Their work is done both in laboratory conditions as well as on extracted natural gas deposits. The company is part of konsortium in **Underground Sun** Storage project, where they joined in 2014. It is an unique project in Europe that both takes place in laboratory conditions as well as at an exhausted natural gas deposit. This project is showing that storing hydrogen mixed with natural gas in porous geological structures is technically feasible.

Joining a call from Important Projects of Common European Interest (IPCEI) Nafta a.s. has succeeded in the national selection process for research, development and innovative projects. Result is joining **H2-Infrastructure Storage and Distribution project**. Another call from the Fuel Cells and Hydrogen Joint Undertaking (FCHJU) resulted in partnership with broad consortium in another two European project, **HyUsPRe** and **HYSTORIES**[1].

Nafta has also defined 6 other projects that were included into the 10 year development plan of gas infrastructure in the EU (TYNDP). To mention one, UGS Veľké Kapušany, where they aim to use underground storage from natural gas, also to store renewable gases.

Proposal for green hydrogen production is the key element of **Project H2Muctynic by Duslo AS**, which is one of the biggest SK factories in the field of chemical production. The aim is to produce green hydrogen, using renewable energy sources (wind 36MW and solar 14MW) to power electrolysers (20 MW, which is one of the biggest in the region) and produce 2300 t/year of green H2. This would bring CO2 emissions down by 20,000 t/year.

Already existing practical examples of the partial use of P2G technology in Slovakia can be represented by already running project, where **Biogas station Jelšava III** is the first biogas station that started to obtain biomethane and inject it into gas network (from total 108 biogas stations, which produce only energy and warmth)[2]. Process of getting biomethane is due to new technical accessories from Dutch BrightBiomethane which can extract it from biogas. Biomethane is also partly obtained from waste material. The aim is to get certified to process also other biodegradable municipal waste. This concept is probably going to be followed by other biogas stations, as there is open call for modernization and transfer from biogas to biomethane production. It is expected that this evolving trend will be part of the whole restructuralization proces, where also big waste companies, like Brantner, have plans for building 3 large biomethane stations.

Brantner a.s. is a consortium of 15 waste companies dealing with services for almost a million people. They have their program Altgas, where some part of waste (after certain modification) is used as a fuel in high heat stoves while producing cement. Their Centers for energy and biological recovery of waste (CEBZ) are proposed. The plan is to build 3 large regional centres where biogas and biomethane is obtained.

[1] https://www.nafta.sk/en/gas-storage/innovative-and-development-projects

[2] https://mynovohrad.sme.sk/c/22853944/bioplynova-stanica-jelsava-zacala-ako-prva-vtlacat-do-distribucie-biometan.html

Fig. 1: The planned project of Brantner facility

1.3 SECTOR-COUPLING POTENTIAL IN SLOVAKIA

The connection of the energy and gas industry sector has a very large potential in Slovakia, as the infrastructure of both energetic and gas grid networks is very well developed.

Slovakia has plenty of renewable sources of energy, with the highest representation of hydro and solar sources, less wind energy. It is estimated that in 2030 about 30% energy should be from renewable energy sources. Historically the energetic legislation doesn't include renewable gasses so much, but this topic has been already opened and discussed among academics, researchers and producers, as the gas grid infrastructure is very well developed.

1.3.1 BIOMASS POTENTIAL

HERBACEOUS BIOMASS

Biomass processing is considered to be the most effective way of obtaining energy from renewable resources. It is important to take into account the principle of conservation of health of the human population as well as the health of soil composition. It is important to prioritize leaving a certain amount of biomass on the ground for soil regeneration over use of artificial fertilizers. The use of biomass potential is 42,7% from all RES in Slovakia, and the trend observed in Slovakia is that the potential of biomass as a source of energy is slowly being discovered. Most developed industry that processes biomass is wood=processing and the forest industry. The Ministry of Economy suppose that energy obtained from processing biomass could reach up to 30% of all energy use in 2050.

The biggest source of biomass is of forest origin, as about 41% of the area of Slovakia is covered by it. About 43,2% belongs to the state (lowest price for woody biomass). Forest wood biomass should not be considered a renewable energy source since 2018, as companies getting subsidies for producing chip from any kind of wood have been cutting down even the very good quality one and burning it in heat plants. Similar laws should be currently discussed throughout the EU.

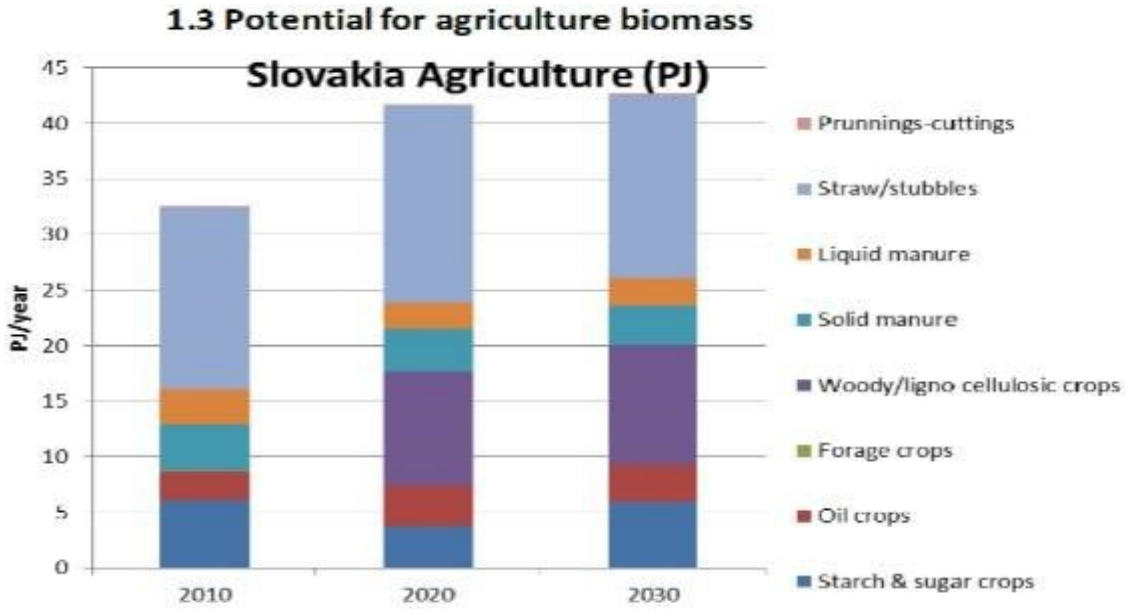


Fig. 2: The composition of agricultural biomass potential for energy use. Source: Biomass policies SIEA

Another type of herbaceous biomass is the leftover biomass from agriculture. For the purpose of this project, we will briefly mention post-harvest residues, that can be used either directly in the cogeneration plant or indirectly by using them in the animal agriculture and later digest them in the biogas plant. In 2007, 40% of the production of post-harvest residues of the most energetically suitable agricultural crops (cereals, rape) represented approximately 1,955,908t.

In the territory of the Slovak Republic, permanent grasslands also represent an important source of biomass, especially in foothills and mountain areas after the suppression of livestock production. However, there is a problem of processing such amounts of biomass. One of the possible solutions is the energy use of grass phytomass, as solid fuels in the form of briquettes, pellets or input raw material for biogas stations.

Other subtypes of herbaceous biomass such as fruits, seeds, leftovers from kilns are not much discussed yet in Slovakia and their potential is used minimally or only by the producers themselves.

At the time of writing this Road Map, we have no knowledge of an existing market nor producer of biochar in Slovkia.

ANIMAL AND HUMAN WASTE BIOMASS

The main strategy is "Waste Management Program of the Slovak Republic 2016-2020". The previous goal from 2013, to reduce the disposal of biodegradable waste to 50% of the level of 1995, was not achieved. Also, the goal of recycling 35% of municipal waste by 2015 was not achieved as well.

Currently there is a published plan for 2021-2025, including several measures introduced earlier, also that the amount of biodegradable waste in mixed municipal waste is to be reduced by 60% by 2025 compared with the situation of 2016. Biodegradable waste is around 40% from the whole municipal waste now.

Every municipality has the obligation to introduce and ensure the implementation of sorted collection of biodegradable municipal waste. This law (Act 79/2015 Coll. section 81, paragraph 21) is valid from 1.1.2021.

According to the document prepared by the Ministry of the Environment of the Slovak Republic in February 2022 entitled "Situational report on the disposal of municipal wastewater and sewage sludge in the Slovak Republic for the years 2019 and 2020" in 2020 the total production of sludge in the Slovak Republic represented 55,519 tons of dry matter. 48,490t of sludge dry matter (87.34%) were evaluated. Of this, 36,562 tons of sludge dry matter (65.86%) were used in soil processes: - 26,403t of sludge dry matter (47.56%) were used for compost production - they were used in other ways in soil processes (reclamation of landfills, areas, production of growing substrates, etc.) 10,159t of sludge dry matter (18.30%), - sludge was not applied directly to agricultural and forest land this year. In addition, 11,928t of sludge dry matter (21.48%) were biologically processed and energetically recovered. 2,302 tons of dry sludge (4.15%) were deposited in landfills, and 4,727 tons of dry sludge (8.51%) were temporarily stored in the premises of the WWTP.

By law, the regulation to separate biodegradable waste in Slovakia started only in 2021. Biodegradable waste and sewage sludge is a highly undervalued source of energy that has not yet been discovered to its full extent in Slovakia. Some of the sludge and manure is being used by biogas plants, but since the regulation to separate the biodegradable waste started only last year, the potential for Power-to-gas projects is very big.

1.3.2 DESCRIPTION OF SLOVAK INFRASTRUCTURE LANDSCAPE

Related laws:

Act No. 250/2012 Coll. - on regulation in network industries (deals with electric market, natural gas market and water)

Act No. 251/2012 Coll. - energy law

Act No. 309/2009 Coll. - on the promotion of renewable energy sources and high-efficiency of electricity cogeneration

GAS NETWORK

The structure of the gas grid in Slovakia is very well developed. 94% of all Slovak citizens have access to gas[3]. This is the second highest number in Europe, after the Netherlands. There is about 33000km of gas tubing, and inter-connection points with all neighbouring countries (Czech Republic, Austria, Poland (opened recently on 26.8.22), Hungary and Ukraine).

The Slovak gas market is regulated by the Office for the Regulation of Network Industries (URSO, Úrad pre reguláciu sieťových odvetví). They are setting gas quality standards and compliances. The Slovak Innovation and Energy Agency (SIEA) is a state funded organisation providing free energy consultancy, prepares energy audits and concepts, and studies the efficiency of operation of heating systems. It also provides mediation and allocation in the field of drawing financial aid from European funds. It cooperates with Slovak Ministry of Economy, which is a government entrusted organisation which elaborates and coordinates the National Hydrogen Strategy Action plan.

Within the Slovak gas legislative framework, there is no mention of Power to gas concept. The closest is a hydrogen utilization technology or a technology, that uses electricity to produce gaseous fuel.

The restrictions for the ownership, development, management or operation of the P2G plant are not in place at the moment. The § 6 of the 251/2012 law however specifies that permission is not required in the case of production and supply of gas from biomass and also production and supply of gas from biogas. Operators of the transmission or distribution systems own their networks, and providing conditions of the ownership, it is also assumed that they can own, manage or develop P2G technology, if we speak about mixing hydrogen into the gas distribution / transmission network.

The hydrogen mixture compounds haven't been determined yet, there are only technical rules for biomethane. However, the objective of Slovak Hydrogen action plan is to adjust the industrial natural gas connections and part of the gas infrastructure for the supply of a mixture of natural gas with a hydrogen content of up to 5% by volume by end of 2025.

[3] https://www.urso.gov.sk/data/att/dad/2030.b1313b.pdf page 35

Fig. 3: Gas consumption by customer category in 2021: Households 29.14%

It is important to mention that the transport network in the Slovak Republic primarily fulfils the requirements of gas transit to the EU, only 9% of gas volume has been consumed within the country (about 5 billion m3 in 2019). The representation of natural gas in the energy mix has long been more than 24% and in the production of electricity 9.2%.

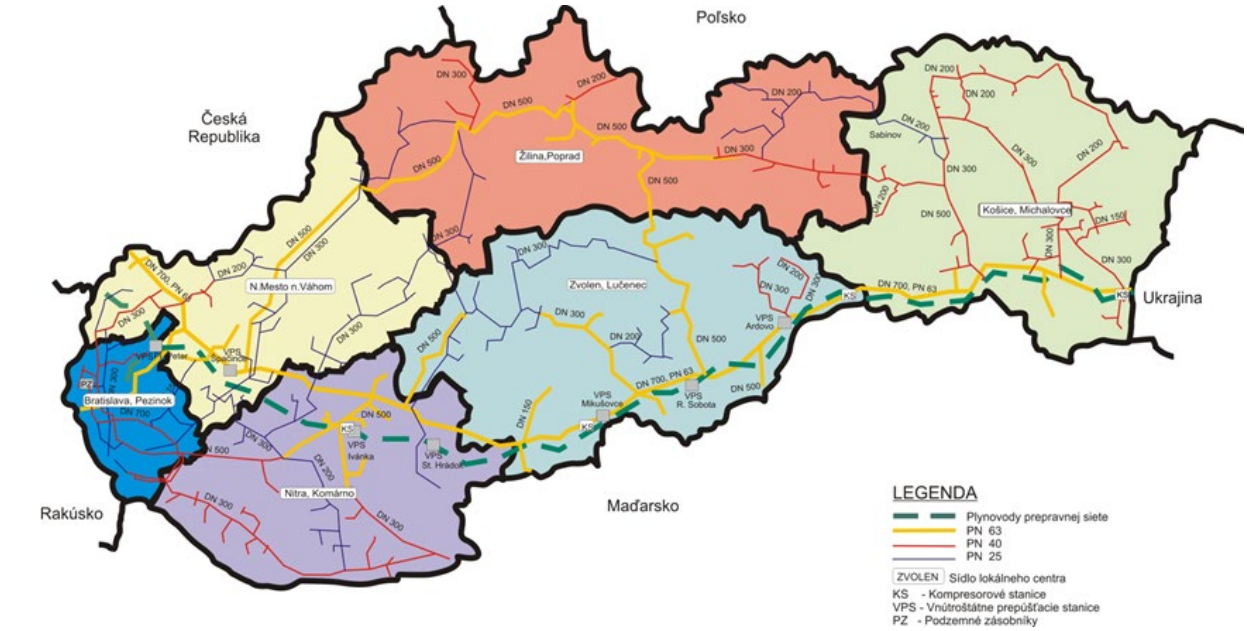


Fig. 4: Gas grid network in Slovakia

There are almost 2270 km of gas transit lines, 4 compressor stations (2 on borders) to maintain the pressure of gas with a total output of 600MW. Total transport capacity of the network is 90 billion m3/year.

To upgrade the gas distribution network for use with hydrogen it is necessary to take into consideration the fact that certain financial assets need to be invested into modernization to fulfil technical and safety requirements.

So far, only one biomethane station in Slovakia (near Jelsava) was connected to the natural gas distribution network in 2021, that converts biogas in biomethane and inject into the gas network directly. There are about 100 other biogas plants in Slovakia, of which at least half could be upgraded to produce and inject biomethane to the grid, if technically improved.

EUSTREAM is the operator of the natural gas transmission network in the Slovak Republic, whose basic mission is safe, reliable and ecological transportation for European markets. The company has been associated with joint responsibility for the energy supply of a significant part of the European market since 1972.

Fig. 5: Volume of gas transport in billion m3: The full transport capacity of the gas grid network is 90 billion m3 in total.

ELECTRICITY NETWORK

The operator of the transmission system in Slovakia is called the Slovak Electricity Transmission System (SEPS). Electricity grid is standardised by the usual 400kV, 220 kV and 110 kV in operation. Electricity distribution is currently ensured by three regional distribution systems (east, centre and west of Slovakia) and approx. 150 local distribution systems.

Average price of electricity in 2021 was 0.094 € / kWh. Maximum 0.330 € / kWh and minimum 0.053 € / kWh.

Slovakia operates two nuclear plants that produce over half of the energy (52,88%) needs of the country. This means the energy demand is covered in a stable manner and there are no seasonal or other climaxes or fluctuations. Thanks to nuclear energy, the Slovak electric power industry has one of the least carbon-demanding mixes in the entire European Union, one of the lowest carbon footprints in electricity production. This affects the general approach towards renewable sources. However, the environmental impact of the nuclear waste and other components of the nuclear plants are still being discussed and Slovakia follows the general approach towards renewable energy in in

with the whole Europe. At the moment, the composition of slovak electricity energy mix looks as follows:

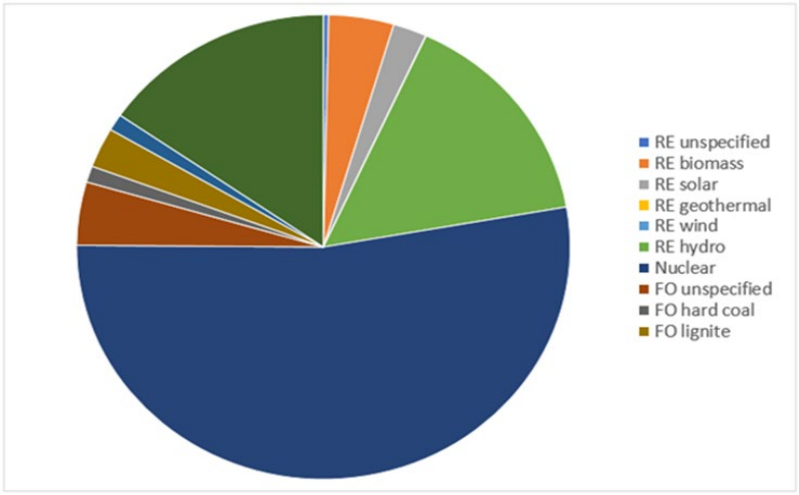


Fig. 6: The composition of Slovak electricity energy mix in 2021

There is still potential to improve utilisation from Renewable energy sources. Below is the overview of electricity production from renewable energy sources in 2020 in Slovakia:

Biomass .....317 731 MWh

Anaerobic biogas.....510 777 MWh

anaerobic biogas-other.....13 862 MWh

other RES and secondary fuel.....62 607 MWh

gas Wastewater Treatment Plant.....10 005 MWh

landfill gas.....10 794 MWh

sun energy.....684 267 MWh

hydropower.....2 124 132 MWh

INTERMODAL TRANSPORT HUBS

The concept of intermodal transport has set up a priority to shift as much transport from road to other, more ecological way of transportation.

Slovakia has 4 intermodal terminals road-train (Bratislava, Zilina, Leopoldov-Sulekovo and Kosice), and 2 ports (Bratislava and Komarno), which are 3-modal terminals (road-train-water), as part of the Danube river infrastructure.

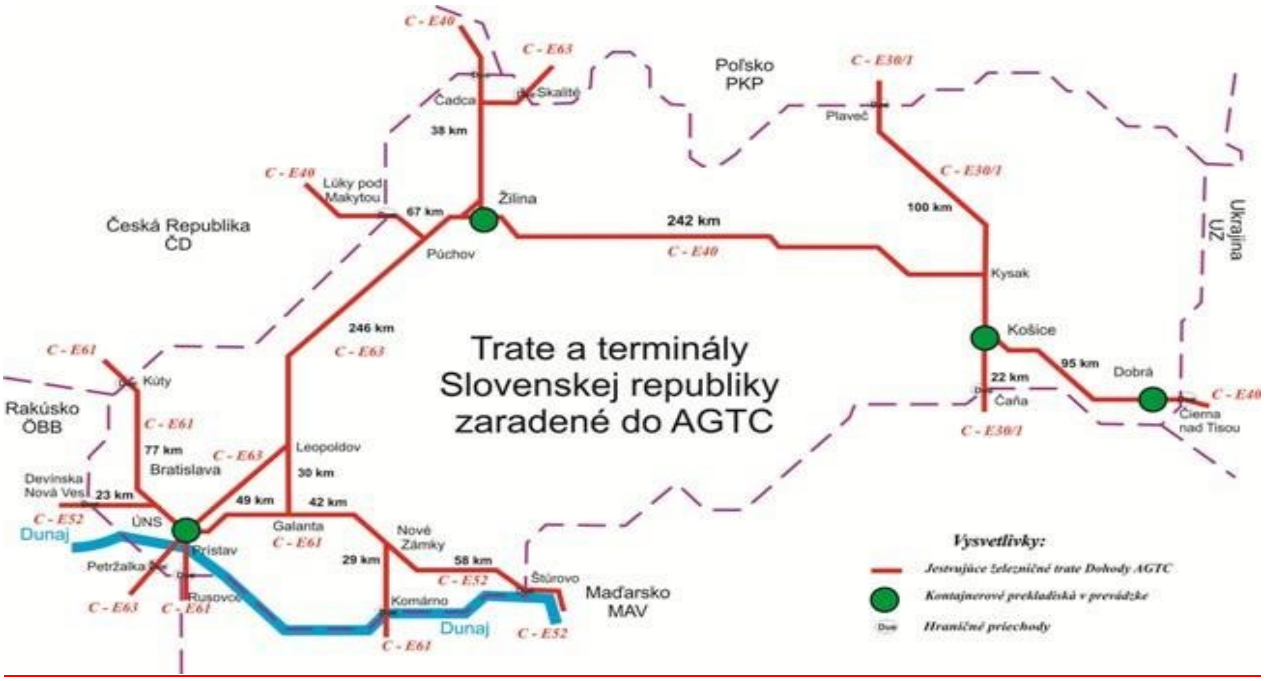


Fig. 7: Roads and terminal from Slovak Republic included in AGTC

Regarding transnational electrical and gas transmision points, Slovakia has good connection to all neighboouring countries.

1.3.3 USE CASE ANALYSIS

In this chapter, 3 case study examples are evaluated using the Optimisation Tool and data provided in Infrastructure table od the DanuP-2-Gas project in Slovakia. The examples are calculating with the price of gas at the current level (2022) and 10times higher. The amount of subsidy evaluated is also preset, at 0 and 50% of support. In Slovakia, following locations were chosen based on the geographical location, available sources of biomass and the availability of input data:

1. Bučina Zvolen (biomass plant processing waste-wood) **(REP)**
2. Chemosvit (large industrial factory, mainly on the field of chemistry production) **(IP)**
3. The greenfield location (Jesenské). **(GF)**

Together, there are 12 different results, which provide information about sustainability and efficiency of a given solution.

	Conservative prices of methane			10 × Higher prices of methane		
	REP	**IP**	**GF**	**REP**	**IP**	**GF**
No subsidy	No investment, Fig. 1	No investment, Fig. 5	No investment, Fig. 9	Possible investments, Fig. 3	Possible investments, Fig. 7	Possible investments, Fig. 11
Subsidy of 50 %	No investment, Fig. 2	No investment, Fig. 6	No investment, Fig. 10	Possible investments, Fig. 4	Possible investments, Fig. 8	Possible investments, Fig. 12

Fig. 8: The results table form Pre-feasibility study in Slovak republic

As seen from the calculations shown above, the Slovak territorial perspectives for introducing the P2G hub with the current prices of methane does not seem economically profitable. Zero investment possibilities were shown for the situations of investing to P2G next to Renewable energy source, Industrial plant and also building it on the greenfield location. The same result was shown when adding a 50% subsidy.

Economically viable calculations started to appear when higher prices of methane were simulated. In all three cases, both for situations with and without subsidy, investments into different P2G components were suggested. The major change for the calculations with subsidy was shorter payoff period.

However, the results may change if the actual existing market possibilities for hydrogen, oxygen, methane and biochar were added. The market with hydrogen is slowly being introduced to Slovakia and we believe that in few years this commodity will be highly demanded. For this reason, we would suggest to potential investors to at least include hydrogen market possibilities into the calculation, maybe also biochar. When simulating calculations with biochar, possible investment appeared also for the current prices of methane.

1.3.4 EXISTING FUNDING POSSIBILITIES

To reach the global goal of efficient use of natural resources and ensuring environmental protection, while adapting to climate change and a low-carbon economy is a complex task that would not be possible without funding from the EU. Operational program Quality of Environment (OP KZP) is a program document of Slovakia for drawing financial aid from EU structural funds and the Slovak Cohesion Fund. There are various calls for subsidising and funding P2G technologies in Slovakia. Listed below is the

overview of funding possibilities to P2G related activities found in the course of the project. Some of the subsidies are not active at the moment, but they are worth to mention as the call may reopen again or some similar call may be linked to these precious funding possibilities.

Recovery and Resilience Plan of the Slovak republic (Plan obnovy a odolnosti SR) [4]

A call for modernization/transformation of existing energetical facilities producing electricity from RES was opened on 3.8.2022. The aim is to transform existing biogas stations into biomethane stations. This call should increase efficiency of production of electricity from renewable sources and increase the energetic sustainability and safety of Slovakia from inside sources. 20 mil Euros have been allocated for this call. For repowering of biogas stations max 1 million Euros per project and the level of contribution for biomethane transformation is set at 1,5 million Euros per project. The amount of contribution is given between 45% till 60% from total eligible costs. The condition for obtaining support is the amount of electricity produced in previou year. Call closes on 31.10.2022.

Slovak Innovation and energetic Agency – SIEA [5]

OPKZP-PO4-SC411-2020-63 Power plants for the production of electricity and heat by highly efficient combined production up to 20 MW - support for cogeneration technologies based on usable heat demand, while not supporting the construction of coal-based installations.

OPKZP-PO4-SC411-2019-61 Increasing the share of RES in the gross final energy consumption of the Slovak Republic is aimed for reconstruction and modernization of existing energy facilities.

OPKZP-PO4-SC411-2022-74 The call focused on the construction of facilities for the production of hydrogen by electrolysis using RES - OPKZP-PO4-SC411-2022-74

OPKZP-PO1-SC111-2019-56 call aimed at the recovery of biodegradable municipal waste

[4] https://www.planobnovy.sk/aktuality/plan-obnovy-podpori-modernizaciu-bioplynovych-stanic/

[5] https://www.op-kzp.sk/

OPKZP-PO4-SC441-2019-53 Increasing the number of local plans and measures related to the low carbon strategy for all types of territories development and implementation of low-carbon strategies for all types of areas, especially for urban areas, including updating and implementation of municipal development concepts in the field of thermal energy. Possible usage of the funding instrument in the P2G context is that within there is a possibility to develop a strategy to implement P2G technology and infrastructure into a development strategy of the regions.

OPKZP-PO1-SC111-2019-56 Call aimed at the recovery of biodegradable municipal waste

SlovSEFF [6]

funding instrument for sustainable energy projects developed by the European Bank for Reconstruction and Development (EBRD). It is EBRD's first credit program financed by a market mechanism. Profits from the sale of emission credits from the Slovak Republic to Spain are used to achieve a reduction in additional greenhouse gas emissions through investments within SlovSEFF.

1.4EXISTING BARRIERS

In the following chapter existing barriers and needed actions for the deployment of P2G projects in Slovakia are listed. These are based on the evaluation of the P2G related activities in Slovakia and the current legislative framework within the energy sector.

LEGAL BARRIERS

1. P2G are not clearly defined, as it is questionable if they are classified as consumer, producer or energy storage? This needs further legal assessment, due to linking provisions of energy law that is determined by category classification. It is necessary to assess who is also allowed to own, develop, manage and operate P2G plants.
2. Proper legal classification and definitions of products is lacking.
3. The main legal provision governing hydrogen is § 2 (4) Act No. 309/2009 Coll. on the Promotion of Renewable Energy Sources and Highly Efficient Cogeneration and on Amendments to Certain Acts, which recognises hydrogen as a source of renewable energy: "for the purposes of this Act, a fuel produced from renewable energy sources (hereinafter referred to as "biofuel") means (i) biohydrogen, which is hydrogen produced from biomass".

[6] http://www.slovseff.eu/index.php/en/

4. Biomethane is defined as treated biogas, which has technical parameters comparable to the ones natural gas have, and therefore the legislation applicable to natural gas is also generally applicable to biomethane. However, this cannot be said for hydrogen, nor for renewable (green) hydrogen, and renewable natural gas, which is not yet really mentioned in the legislation, and if, then only as a fuel.
5. Thus regulatory classification for the operations by Electricity and Gas Transmission System Operators, Electricity and Gas Distribution System Operators, Gas storage operators and producers needs to be developed. Also products (renewable hydrogen and renewable natural gas) need to be classified using gas quality standards and these points need to be answered for proper recognition by law. Question is also if general law coverage (definition) or a specification of every individual plant by its explicit corresponding provision should be assumed.
6. Legal and regulatory framework including funding possibilities is under development. Since P2G technologies are reaching various fields of these frameworks, the whole process of identifying, describing, communicating and solving various situations might take longer than if the processes have some past development and accepted & tested solutions.
7. The link between the law on the promotion of renewable resources and waste legislation is completely missing. Some biomethane production processes could recover waste. It is therefore necessary to amend the legislation so that financial resources for waste disposal and recovery can be better used in the production of biomethane.

SOCIO-TECHNICAL BARRIERS

1. When building new biogas/biomethane production facilities, there is usually fundamental disagreement from the side of the population, as it is lacking correct insights and false concept imagination.
2. Awareness about climate change is generally very low in the general public. Only a small group of experts have extended knowledge. The transformation is slow and requires time and combined effort of several departments.
3. Long permission and status evaluation procedures are also an obstacle, as the public authorities don't possess enough expert knowledge.
4. Very huge barrier is that Slovakia itself doesn't possess so much free and disponible capital to immediately power up the whole transformation of industry based on fossil fuels towards its green alternatives.

TECHNO-ECONOMIC BARRIERS

1. It is important to determine gas quality standards and restrictions (also for feed-in into the grid), if it is possible directly or if some other requirements must be met. This also calls for an upgrade for the measuring technology to detect hydrogen higher than 6% . The gas grid network technical improvements need to be set as well. For example, higher permeability of individual materials (both steel and plastic), fittings, seals, etc., due to the much smaller size of the H2 molecule compared to the CH4 molecules.
2. The biomethane producer bears the costs of building a connection to the distribution network in the amount of 25% of the actual costs; however, not more than € 250,000 and no longer than 4km. Over 4 km the costs are taken by the producer. The connection becomes property of the distribution network operator.
3. Taxes rates for electricity have been stated in 2010 at level 1.32 Euros/MWh. The electricity from renewable sources is exempt from excise duty. This could be applicable for the P2G production.
4. P2G technology is not market competitive with current technologies in the short run, but in the long run they carry excessive advantages, both for the public as well as the industrial sector.
5. Certifications for environmentally friendly ways of production (guarantees of origin) for renewable hydrogen should be in place in national legislation in 2022.
6. Biomethane Register is being created (based on the model of Austrian Biomethane Model) and should be introduced November 2022.
7. EU legal provisions should match national legal provisions, for example term “energy storage unit” introduced by EU in 2019 (Electricity Directive 2019)

1.5 ACTION ITEMS AND RECOMMENDATIONS

ACTION ITEMS NEEDED TO OVERCOME LEGAL BARRIERS.

1. To define and anchor technological P2G solutions (products, by-products, derivatives, funding, investments, etc.) into a regulatory (energetic) framework. This needs to be done also on a trans-national level.
2. Establishing terms of P2G on all levels of terminology (scientific, academic, regulatory framework) to be clear what is what, and how it all works together. This needs to be done on both national and European level (english).
3. To set up interdepartmental “P2G agency” that would concentrate all relevant types of data and would work as an advisory subject. It would also communicate with all stakeholders and participants, on both commercial and legislation-wise levels. We suggest it to be part of SEIA (Slovak Energetic Innovation Agency.

ACTION ITEMS NEEDED TO OVERCOME SOCIO-TECHNICAL BARRIERS.

1. To develop strategy for promotion of P2G related campaigns for the general public. State clear and understandable examples about why this technology has its future, what risks are met and why and how it is beneficial for the general public. P2G concept is quite new and lacks a sufficient amount of practical demonstrations.
2. To anchor basics of energetic and climatic literacy into basic education, develop changes that will prepare society to be aware of its impacts.
3. To create more effective ways to receive grants, fundings and subsidies from the common European framework.
4. At current state, and according to the prefeasibility study as well, we can conclude that P2G business cases are not competitive yet. On the other hand, they bring many other positive effects that from a long-term point of view they are a success. Lack of competitiveness should be balanced by additional extra funding possibilities.

ACTION ITEMS NEEDED TO OVERCOME TECHNO- ECONOMIC BARRIERS.

1. To anticipate innovations as soon as possible.
2. To set up decent conditions for small scale producers, so the market is decentralized and focusing on disponible local potential.

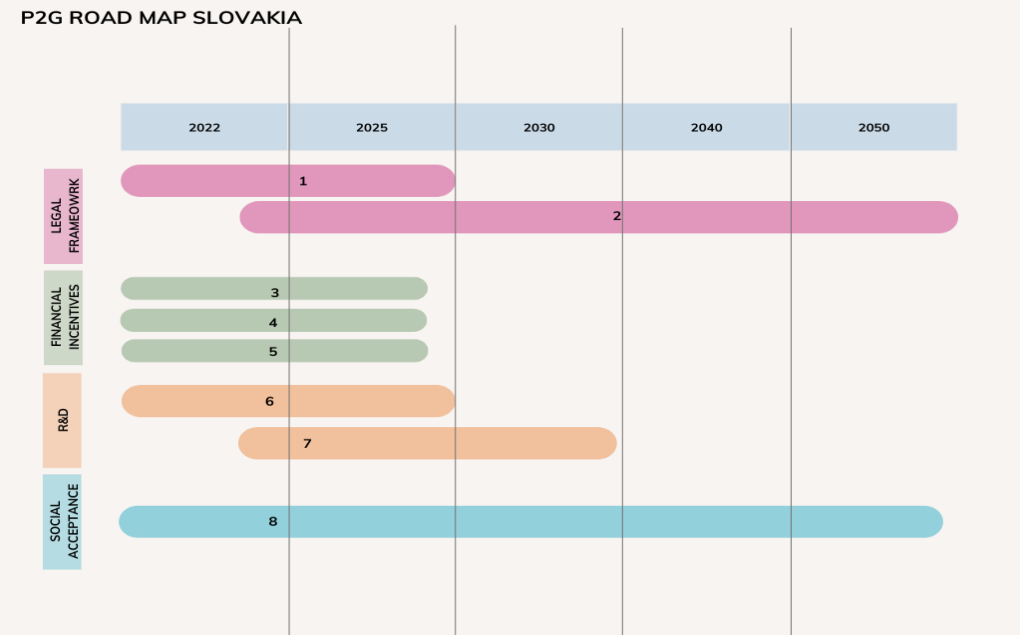
1.6 LIST OF ABBREVIATIONS

EU	European Union
NHS	National Hydrogen Strategy
MW	Megawatt
NECP	National Energy and Climate Plan
NHS	National Hydrogen Strategy
RES	Renewable Energy Sources
SIEA	Slovak Innovation and Energy Agency
URSO	Office for the Regulation of Network Industries
WP	Work Package
WWTP	Waste water treatment plants

1.7 REFERENCES

1. Integrated National Energy and Climate Plan for 2021 to 2030 https://energy.ec.europa.eu/system/files/2020-03/sk_final_necp_main_en_0.pdf
2. Waste Management Program of the Slovak Republic 2016-2020 https://www.minzp.sk/files/sekcia-enviromentalneho-hodnotenia-riadenia/odpady-a-obaly/registre-a-zoznamy/poh-sr-2016-2020_vestnik_en-2.pdf

1.8 GRAPHIC DISPLAY OF THE ROAD MAP



1. establishing P2G solutions in terminology, scientific, academic, regulatory framework

2. "P2G interdepartmental agency concept" with access to all relevant data, works as advisory organ

3. R@D funding

4.To set up decent conditions for small scale producers, so the market is decentralized and focusing on disponible local potential.

5.To create more effective ways to receive grants, fundings and subsidies from the common European framework.

6. establishing P2G solutions in terminology, scientific, academic, regulatory framework

7. certifications according to adopted laws and regulations

8. rising energetic and climatic literacy, information campaigns for authorities and general public