HyWays

European Hydrogen Energy Roadmap

MEMBER STATE PROFILING REPORT - POLAND	
Relevant Work Package	WP3
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Intended audience	HyWays partners and Member State stakeholders in Poland
Purpose of document	Within HyWays Context The results will be used as an input for HyWays hydrogen pathway / chain selection by LBST as well as input to the energy models (e.g. potentials for biomass, wind, CCS etc.). The results will also be used for end vision building by the transition analysis team run by ECN. Task Specific Reports that aim to outline the main issues that are discussed by national stakeholders regarding the present potential, the identified potentials, and the future vision for hydrogen energy at the national level in a structured way that aids ongoing discussion and provides information which could be used for purposes of comparison and selection.

Member State Profiling Report – Poland

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Aims and objectives

This profiling report has been prepared to provide qualitative socio-economic input to the HyWays hydrogen pathway selection process, and ultimately, to the energy modeling work. The report will be used in the end vision building process conducted by the transition analysis team led by ECN, as shown in Figure 1.

Specifically, the report will outline the main issues regarding the present potential and future vision for hydrogen in Poland, thus providing a foundation for subsequent work.

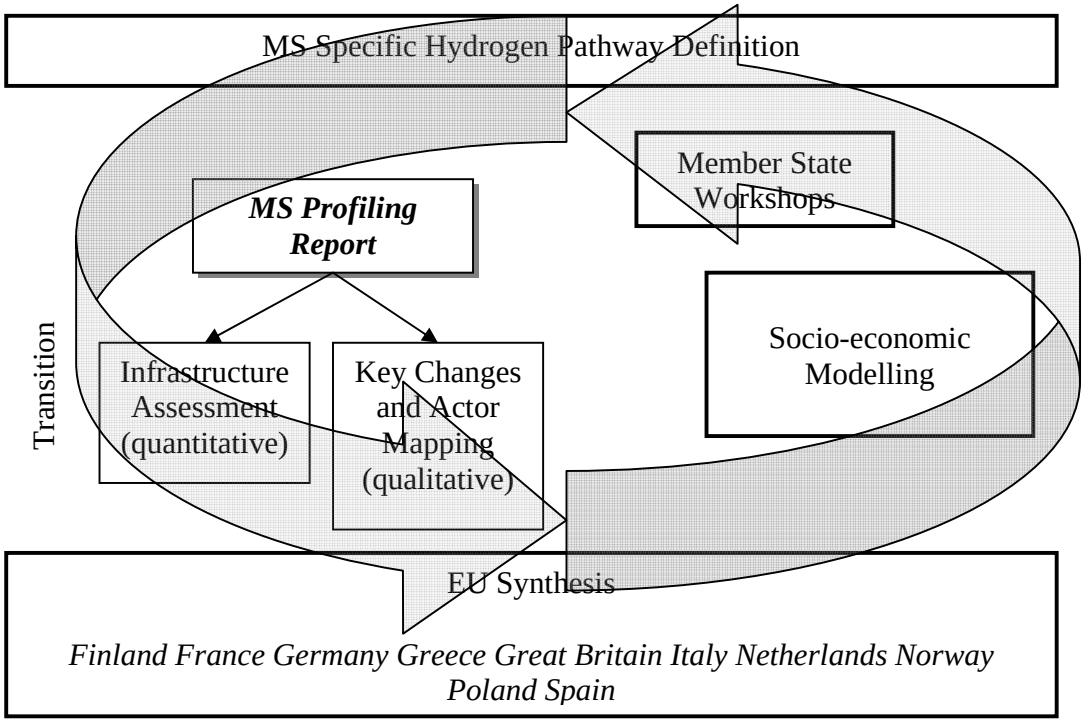

Figure 1 Member State Profiling in the HyWays process

Current Status of Energy System

In 2003 Poland's total primary energy supply (TPES) was 93.67 Mtoe, to which domestic energy production contributed 80.63 Mtoe, while net energy imports amounted to 13.71 Mtoe.[i] Energy consumption appears to have experienced limited growth over the last few decades in Poland, rising from around 55 Mtoe in 1970 to around 60 Mtoe in 2003. However, this masks relatively

steep changes with consumption having peaked at around 83 Mtoe in 1987, subsequently bottomed out in 1992 and on the rise since then.[ii]

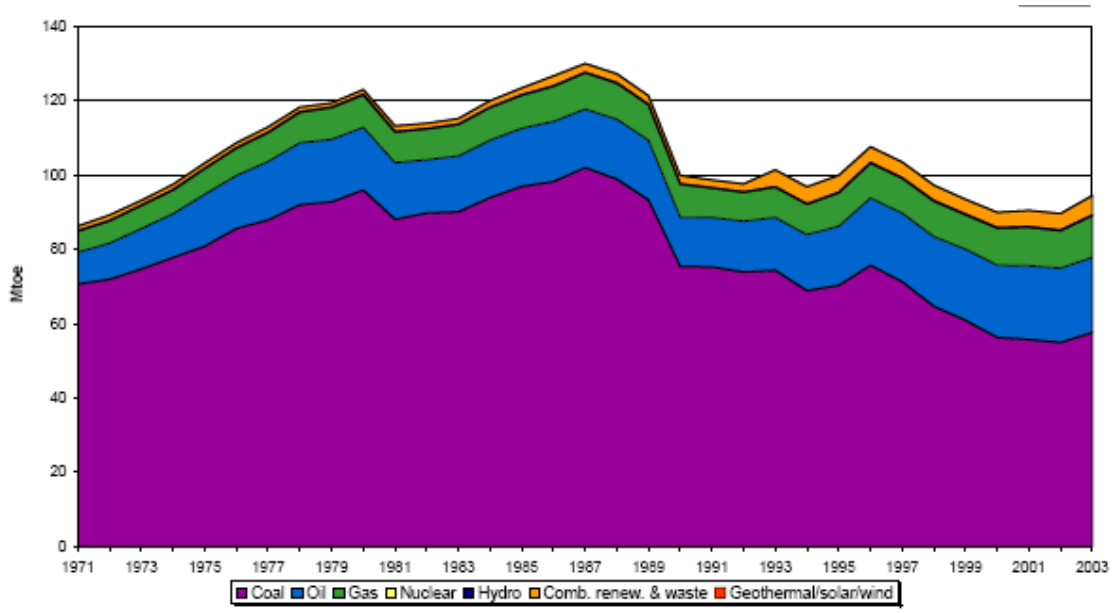

Figure 2. Evolution of TPES in Poland, 1970- 2003

Coal

The Polish energy mix is dominated by coal, in 2003 coal made up over 60% of TPES see Figure 3 below. Poland has a large indigenous hard coal resource mostly located in the Upper Silesian Basin, and despite a decline in coal production as a result of deep reform in the industry, Poland remains the only world class exporter of coal in Europe. Germany, Denmark and the UK are currently Poland's largest export markets for coal. The net output of coal amounted to 95,623 thousand tons in 2004 from 48 operating underground mines. The identified economic resources of coal reserves as of December 31, 2004 amounted to 42,580 million tons.[iii] The reserves of the exploited deposits constitute about 37,6% of the economic reserves and amount to 16,040 million tons. Identified coal resources, economic resources, as well as their identification, qualitative characteristic of the coal deposits and state of their management are shown in Table 1 below. More than 20% of coal is designed for exports. The directions of Polish exports of coal are shown in table 2 below.

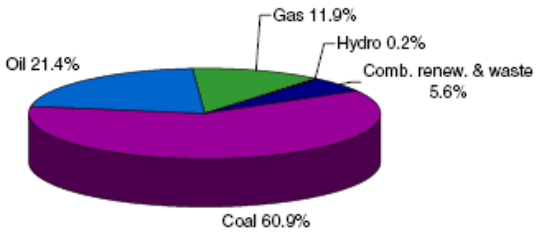

Figure 3. Share of Total Primary Energy Supply in Poland in 2003 (94 Mtoe)[viii]

Specification	Number of deposits	Reserves/resources					
		I E R				Potentially economic: marginal economic submarginal	Economic reserves
		Total	Exploration		Prospecting		
			A+B	C1	C2		
Total resources	**133**	**42,580**	**4,455**	**11,596**	**26,529**	**17,214 10,156**	**6,928**
including reserves of exploited deposits							
Total	48	16,040	4,132	7,002	4,906	5,741 5,060	6,928
including resources of not exploited deposits							
Total	44	26,474	321	4,591	21,562	11,210 1,338	-
1. Exploration	31	13,550	321	4,351	8,878	4,294 1,231	-
2. Prospecting	13	12,923	-	239	12,684	6,916 107	-
including abandoned deposits							
Total	41	66	2	3	61	263 3,758	-

Table 1 Hard Coal (millions tons)

	Country	Thousand tons	Thousand PLN		Country	Thousand tons	Thousand PLN
Hard coal							
	Total	**19,697.55**	**5,079,570**				
1	Germany	7,264.32	1,802,025	15	Norway	183.01	54,101
2	Austria	2,145.11	529,642	16	Netherlands	190.56	51,306
3	Slovakia	1,291.91	523,396	17	Italy	96.10	23,723
4	Finland	1,619.15	401,627	18	India	45.67	19,077
5	Czech Rep.	1,245.07	320,894	19	USA, the	67.68	17,754
6	United Kingdom	1,399.16	304,304	20	Egypt	37.13	14,466
7	France	818.63	245,411	21	Croatia	42.10	9,852

	Country	Thousand tons	Thousand PLN		Country	Thousand tons	Thousand PLN
8	Denmark	1,090.73	223,228	22	Slovenia	25.65	7,595
9	Belgium	499.74	124,181	23	Turkey	19.01	5,252
10	Morocco	500.59	114,251	24	Island	8.74	2,244
11	Ireland	265.86	82,075	25	Azerbaijan	7.24	1,541
12	Hungary	339.64	78,240	26	Serbia & Montenegro	3.35	1,101
13	Spain	162.18	63,916	27	Latvia	4.22	1,067
14	Sweden	323.52	56,806	28	St. Thomas Islands	1.35	325

Table 2 Directions of Polish export of hard coal

Oil

Poland constitutes an important bridge in the Eurasian energy markets. Low levels of domestic oil reserves account for less than 5% of TFC. The Przyjazn pipeline brings Russian oil via Poland for Germany, Figure 4. Oil imports for domestic consumption via pipeline from Russia fell rapidly during the 1990's due to political and environmental pressures. This was replaced with oil arriving by ship from the North Sea (British and Norwegian) and OPEC countries. However, Russia still holds the dominant position with about 94.5%. Crude oil can be supplied to Poland from two directions; via the 'Przyjazn' pipeline from Russia through Belarus, and by sea unloading at the North Port in Gdansk. The intrinsically economic oil resources of Poland amounted to about 19,519 thousands tons in 2004, with the total economic reserves amounting to 16,218 thousand tons.[iv]

Natural Gas

In 2003 IEA statistics show that domestic production of natural gas in Poland accounted for approximately one third of TFC.[v] The table 3 below presents the recoverable reserves of natural gas in Poland; (the degree of geological exploration is accounted for). Current energy policy intends to increase the utilization of natural gas. The signing of a new supply contract with Russia, by the year 2010 Poland is expected to use over 20 x 10^9 m³ of natural gas from Siberia per year. Poland is also considering diversifying supplies of natural gas through entering into an agreement with Denmark and Norway.

Specification	Number of	Extractable Reserves / resources		
		I E R	Potentially	Economic

	fields	Total	Exploration	Prospecting	economic	reserves
Total resources	*** 256**	**154,355**	**107,330**	**47,025**	**2,223**	**80,723**
	**** 68**	**25,651**	**11,946**	**13,705**	**657**	**9,968**
	***** 185**	**122,140**	**90,625**	**31,515**	**1,567**	**66,006**
	****** 6**	**4,758**	**4,758**	**-**	**-**	**4,749**

*total, ** in oil and oil condensate fields, *** in gas fields, **** underground gas stores (PMG)

Table 3, Natural Gas in Poland (million m^3)

In 2004, 43.2 % of the national natural gas demand was satisfied by the gas output. Imports amounting to 6,226 million m^3 (mainly from Russia 59.6 %) balanced the deficit. Prognostic gas resources, estimated at about 650 billion m^3, reveal the possibility of finding new fields.

	Import				Export		
	Country	Million m^3	Thousand PLN		Country	Million m^3	Thousand PLN
	Total	**6,226**	**4,904,000**		**Total**	**30**	**12,368**
1	Russia	3,712	2,883,076	1	Germany	30	12,164
2	Kazakhstan	997	847,473	2	Sweden	0	203
3	Turkmenistan	605	381,735				
4	Norway	350	330,772				
5	Germany	316	296,938				
6	Uzbekistan	149	89,521				
7	Hungary	85	58,647				
8	Lithuania	12	15,640				

Table 4 Flows of Polish Natural Gas imports and exports[vi]

Natural gas imports come via the Yamal – Europe pipeline from Russia (about 53% of domestic consumption) under the Jamburg agreement (signed in 1996 for 25 years[vii]), Figure 4. Other imports come from Ukraine (8%), Norway (4%), and from Germany (3%).Poland is likely to receive increased levels of capacity for natural gas transit as Russia attempts to increase its levels of supply to Europe and avoid Ukraine[viii]. Plans to import natural gas via a Baltic pipeline (from Denmark and Norway) were deferred in 2001 due to an increase in domestic production and lower than predicted levels of domestic demand. In February 2003 progress started on the

"Amber" project to connect the Polish and the Lithuanian gas system with the EU network in order to ensure gas supplies security to Poland and Lithuania, as well as Latvia, Estonia and Finland.[ix]

Coal Bed Methane

The status of Coal Bed Methane (CBM) resources is shown in Table 3. Proven initial resources occur in 44 deposits of the Upper Silesian Coal Basin. Within the area of exploited coal deposits, the reserves extractable by the so called de-methanization of mines are regarded as proven initial ones. In the other Polish coal basins, i.e. the Lower Silesian Coal Basin and Lublin Coal Basin ones, no fields of CBM reserves have been documented.

The methane output from the fields of proven initial resources amounted to 266 million m^3 in 2004. The quantity of methane, called "emission from ventilation system," emitted in 2004 to the atmosphere from the above-mentioned coal deposits equalled 149 million m^3 and decreased by 45 million m^3 as compared to 1999. [x]

Specification	Number of deposits	Reserves/resources				Economic reserves
		I E R			Potentially economic	
		Total	Exploration	Prospecting		
Total resources	**44**	**84,944.05**	**5,887.69**	**79,056.36**	**24,627.29**	**3,085.87**
including: Resources in the hard coal exploitation regions	28	24,978.88	5,031.40	19,947.48	3,832.06	1,916.32
Resources outside the hard coal exploitation regions	19	59,965.17	856.29	59,108.88	20,795.23	1,169.55

Table 5 Coal bed methane (million m^3)

The Upper Silesian Coal basin reveals the highest potential of CBM with prospective resources estimated at about 350 billion m^3 in 1991. In the Lower Silesian Coal Basin, the estimated resources amounted to only about 5 billion m^3. In the Lublin Coal Basin, the possibility of CBM occurrence is not excluded, but quantitative estimates do not exist due to insufficient data.[vi]

Renewables

In 2001 the share of renewable electricity in Poland was 2.61%, with large hydro making up 53.55% of this total. The next were small hydro – 24%, biomass – 17%, biogas – 5%, and wind –

0.5%. The total installed capacity in 2001 was 939 MWe. Biogas 54 MW, biomass 330 MW, large hydro 345 MW, small hydro 182 MW, wind 28 MW (in 2003 it is 58 MW). [xi]

1999, utilization of RES (electricity, thermal energy and liquid biofuels for transport) provided around 370 PJ. The vast majority of this energy was produced as heat at over 100,000 small and medium scale boilers utilizing wood pieces, saw dust and wooden shavings with a total estimated capacity of over 5000 MW. A significant portion of RES was also produced at combined heat and power plants utilising organic waste from pulp and paper (90 GWh of electricity and 12500 TJ of heat), automatic wood-fired heating plants mainly from the furniture industry (4200 TJ) and also at straw-fired heating plants (620 TJ).

In the case of electricity from renewable energy sources (RES-e) most of the energy came from small hydro plants (480 GWh) and biogas plants (103 GWh). Despite significant potential the total installed capacity in wind energy was only 4 MW.

Finally, bioethanol produced from agricultural products and used as admixture to E-95 petrol in 1999 represented equivalent of 3800 TJ. Production of biodiesel (RME) at that time was stopped as uncompetitive due to high production costs.[xii]

The location and growth of wind farms in Poland can be seen in Figures 4 & 5 respectively. Estimates from national, EC Baltic Renewable Energy Centre, and the World Bank for the technical potential for renewable energy sources in Poland vary from 337 – 2,514 PJ/yr and from 30% - 60% of Poland's primary energy demand.[xii] The technical potential of renewable energy sources is presented in Table 6. The national "Strategy for the Development of the Renewable Energy Sector" adopted after September 2000, contains strategic targets to increase the share of RES in Poland's primary energy balance from 2.5% in 1999 to 7.5% in 2010 and 14% in 2020.

Source of energy	EC BREC's expert appraisal 'Economic and Legal Aspects of Utilisation. . .' (EC BREC, 2000) [PJ]	Report prepared for the World Bank (Hauff,1996) [PJ]
Biomass	895	810
Water	43	30
Geothermal resources	200	ca. 200
Wind	36	4 – 5
Solar radiation	1340	370
Total primary energy consumption in 1998	2514	ca. 1414

Table 6 Annual technical potential of renewable energy in Poland [xii]

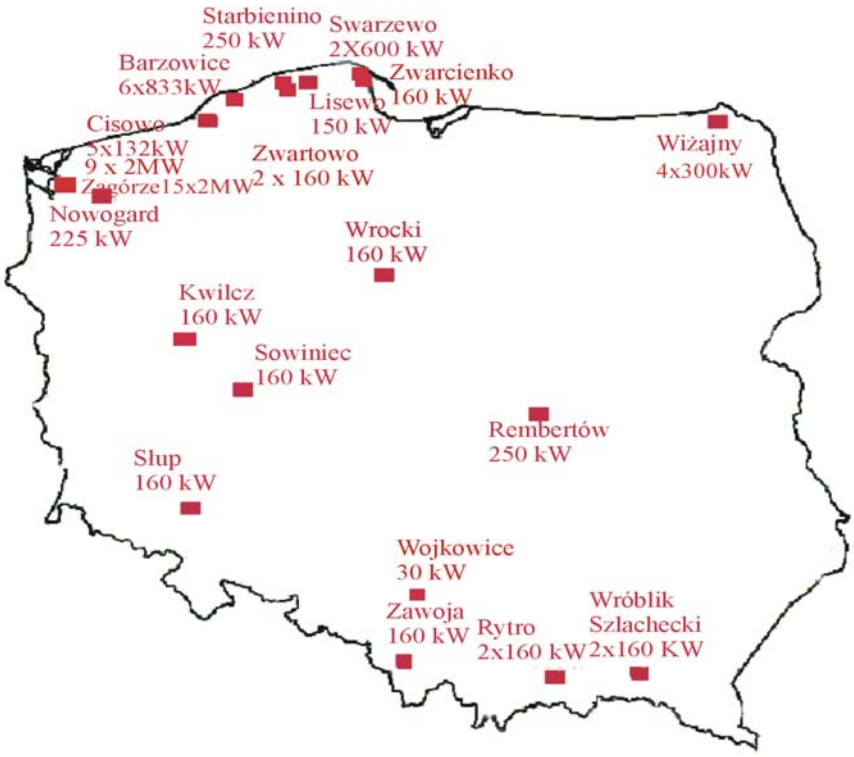

Figure 4 Wind Farms in Poland as of January, 2003[xiii]

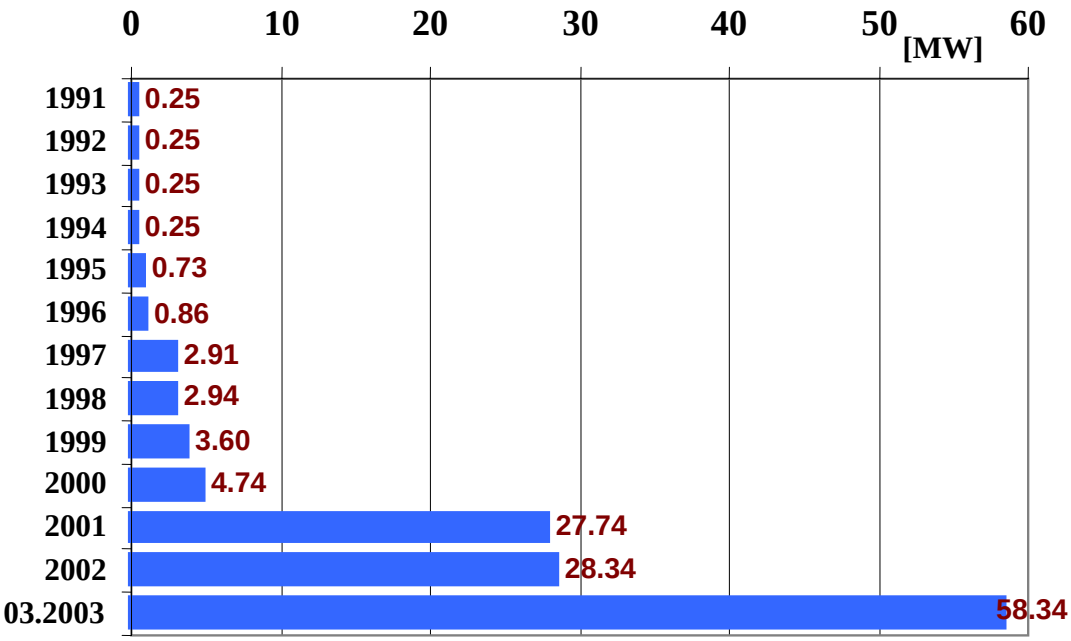

Figure 5 Growth of Wind Energy Share in Poland, 1999 - 2003[xiii]

Electricity Generation

Electricity generation in Poland is primarily from coal and lignite powered thermal generation plants. In 2001 the share of coal in electricity generation was 96.26%. Poland is a net exporter of electricity exporting to neighboring Visegrad countries. EU accession has pushed the liberalization of electricity markets and by 2006 this process was completed.[ix] A major strategic investment completed recently was the Baltic underwater grid connection with the Swedish electricity system. Figure 6 describes the energy infrastructure of Poland.

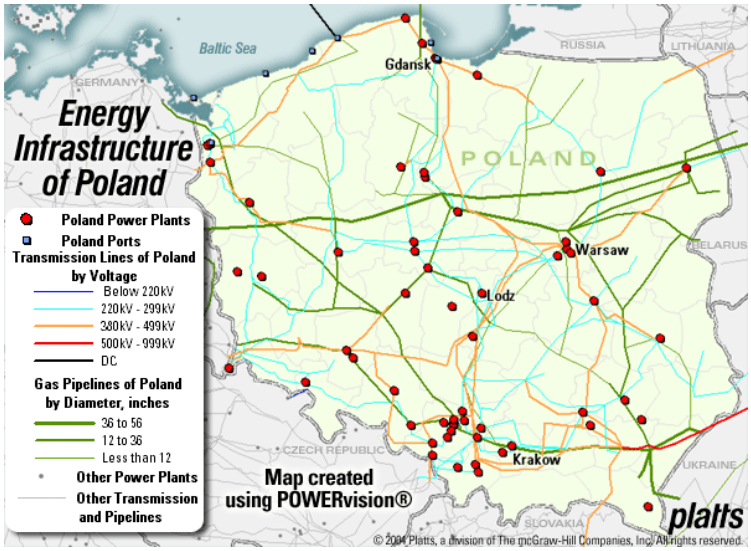

Figure 6 Energy Infrastructure of Poland

Projected energy system evolution

Short – term projections (up to 2010) of future Poland energy system evolution were produced in 1995 via the document "Assumptions of the Polish Policy Regarding the Energy Sector to the year 2010". [xiv] However, this document was produced at a time of political and economic transformation that made predictions very uncertain.

Longer - term projections (up to 2020) were made in 2000 when the Council of Ministers adopted the document “Assumptions for Poland’s Energy Policy Until 2020”[xv]. Three scenarios were drawn up: survival, reference, and progress-plus together with an updated set of assumptions until the year 2020.

The latest projections of energy system development in Poland come from the 2005 document "Energy Policy of Poland Until 2025".[xvi] Four scenarios are used to forecast future energy system development in Poland, Table 4. In this paper Poland's extensive coal resources resources are predicted to remain dominant for the generation of electricity and heat from hard coal and lignite. Old coal generation capacity will be replaced by clean coal combustion technologies. Investment in increased shares of gas heat and power plants is also forecast as domestic natural gas resources are exploited further alongside imports. While the volumes of coal and heat will remain at current levels, under the projected structure the share of electricity, liquid fuels and gas will grow substantially. Total demand for final energy under the Treaty, Basic Coal, and Basic Gas variants are predicted to increase by 55% until 2025. Poland's key role as a transit country in the Eurasian energy market and the creation of internal energy markets also mean that transport capacities and transmission infrastructure will be upgraded and expanded.

SCENARIO	**DESCRIPTION**
Treaty Variant	This takes into account the provisions of the Accession Treaty concerning the energy sector, i.e. achieving 7.5% index for electricity consumption from renewable sources by 2010, achieving 5.75% index for bio-fuels share in total gasoline and fuel oil sales by 2010, and restricting the total emissions from large combustion facilities to the values established in the Treaty;
Basic Coal Variant	This differs from the Treaty variant by the fact that the requirement concerning the restriction of emissions from large combustion facilities is replaced by the implementation of the National Emission Reduction Plan (KPRE), which allows the postponement until 2020 of the deadline for compliance with emission requirements established in the Accession Treaty for 2012. In this variant the hard coal supply restrictions are not assumed, and no presumption is made for the domestic and imported coal shares;
Basic Gas Variant	This differs from the Basic Coal variant only by the fact that the hard coal supplies for electricity generation will be kept on present level, and the necessary additional quantities of electricity in this variant will be generated basing primarily on natural gas as the fuel;
Effectiveness Variant	This fulfils the same ecological criteria as the Basic variants, but assumes achievement of additional power industry effectiveness in the areas of electricity generation, transmission and distribution, and also its consumption, as a result of pro-active state policies.

Table 7 Four Variants for Energy System Development in Poland to 2025

The development of the renewables sector offers an opportunity to contribute towards the country's important sustainable development goals.[xvii] In general, it appears that biomass

(agricultural, industrial, and forest wastes and biogas) and wind energy offer the largest potential in Poland. EU accession obligations will be an important driver for the penetration of these technologies.[xviii] According to the Safire model[xix] the estimated level of projections for the production of RES electricity in 2010 are with: biomass (wood 46%, straw 9%), and wind 29%, large hydro 8%, small hydro 4% and biogas 4%.

Overview of Policies and Measures

The Ministry of Economy and Labour paper "Energy Policy of Poland Until 2025"[xx] defines a strategic vision for energy policy in terms of the three key objectives:

- to ensure energy security,
- to increase economic competitiveness,
- to protect the environment from the negative effects of energy-related activities.

The rapid advancement and restructuring of the Polish energy sector has resulted in the above paper being the fifth government program document outlining the State's energy policy, since the transformation of the Polish economy in 1989. The fundamental long-term goal of energy policy is to ensure energy security, while the reduction of costs of operation combined with the improvement of energy security were selected as the strategic short and medium-term objectives. Accession into the EU and its concurrent obligations alongside the emerging internal market in electricity and gas were the main two drivers of the current "energy policy doctrine". Integration with the long-term vision of the Poland economy outlined in the National Development Plan for the years 2007 – 2013 is also viewed as essential.

The government objective for renewables is to reach 7.5% share of electricity by 2010. This is being encouraged through the renewables development strategy that includes support mechanisms for the development of energy from RES, in order to guarantee stable conditions for investment.

Details of the government supported research and development into innovation and technology transfer in Poland are found in the Roadmap for Implementation of Environmental Technology Action Plan in Poland.[xviii] This sets out a plan to increase the uptake of innovative energy technologies and transport infrastructure. In this document hydrogen energy systems are not identified specifically as a priority.

The main policies and measures relevant to the development of hydrogen systems in Poland are summarized in Table 5.

Policy name	Date	Description
Energy Law Act	1997	Sets out the principles for shaping State energy policy, the principles and conditions for supplying and using fuels and energy, including heat, and for operation of energy sector enterprises, and defines the agencies empowered to administer questions of fuels and energy management.
First Ordinance, Ministry of Economy	2000	Introduced obligatory purchases of electricity and heat form non-conventional sources and from cogeneration. The share of electricity purchased by energy enterprises should be 7,5% in 2010.
Second Ordinance	2001	Introduced energy efficiency requirements and regulates equipment produced in Poland or imported, and energy labeling for household appliances in line with EU directives.
Development Strategy of Renewable Energy Sector	2001	The strategic objective is the increase of the share of energy from renewable sources in Poland's primary energy balance to 7.5% in 2010 and to 14% in 2020.
Quota Obligation Ordinance	2003	Gradual stimulation of demand for RES electricity and facilitates the competitiveness among RES energy suppliers
Purchase Obligations and Quota system	2004	The regulation determines requirements for energy enterprises, as appropriate to their economic activity, concerning the purchase of electric energy and heat generated in renewable energy sources connected to grids in order to achieve a target of renewable energy systems electricity production of 7.5 % of total

Policy name	Date	Description
		electricity production in 2010.
Energy Law Act Poland	2005	Updates the Energy Act, introducing several changes reflecting on the energy market in Poland, in particular on laying the grounds for more extensive liberalisation of the energy market in Poland. It defines renewable energy sources as: Hydropower, wind power, biomass, biogas, photovoltaic, and geothermal.
National Strategic Reference Framework	2005	Within the framework of new operational programmes addresses the following priorities: • Technological research & development • Innovations • Entrepreneurship • Environment • Prevention of technological risk • Prevention of risk to nature
Roadmap for Implementation of Environmental Technology Action Plan in Poland	2006	Presents current activities, strategies and future plans for environmental technologies and establishes a framework for coordination of these activities in Poland.

Table 8 Overview of Energy System Policies and Measures in Poland

Hydrogen Pathway Components

Feedstock Production

- Biomass

Biomass technologies are expected to offer the leading opportunities for the development of RES in Poland. It is assumed that biomass obtained for energy generation will come largely from energy crops. A wide range of biomass sources are planned, including biomass contained in various types of industrial and communal waste. Such non-plant and animal production sources will provide an opportunity for local enterprise development and an

opportunity for the agricultural sector that is in decline since the start of the economic transition. Expected barriers to using biomass for energy purposes are the potential shortage of timber for wood-using industries, and the need for an integrated strategy to be developed engaging energy policy and agricultural policy, as well as the cost of the process and technology.[xxi]

- Renewable energy electricity

The government of Poland has a target of 7.5% of electricity generation from renewable sources by 2010, and aspires to achieving 14% by 2020. The introduction of support mechanisms for RES development through the renewables development strategy and the Quota Obligation Ordinance has resulted in the investment conditions for some initial development. However, considerable barriers remain to be overcome if the targets for RES are to be met. In future the support mechanisms need strengthening in order to ensure that existing problems with compliance, financing, stable revenues, grid access and complicated administrative procedures are resolved. The overall view is that renewables are expected to remain marginal in the Poland energy mix, with wind being touted as the most likely renewable energy source for the production of hydrogen.

- Natural gas with CCS

Poland has significant operational domestic natural gas resources and continued exploration and research is likely to secure long-terms future supplies. Moreover, low quality natural gas, the so-called nitrified natural gas containing from 30 to 80% of methane can constitute another potential source of hydrogen. According to Polish Statistical Yearbook 2004, the production of nitrified natural gas amounted to 3259 million of cubic meters of, which 1792 million of cubic meters was transformed into other energy commodities.[xxii] There is some planned investment in a more efficient natural gas generation plant. A large amount of natural gas is also piped through the country from Russia to Europe. Poland has a well developed natural gas infrastructure. As a result, natural gas as a feedstock for hydrogen seems possible, especially given the additional carbon savings.

- Coke oven gas

The cokeries located in Poland, predominantly in the South of the country, offer the possibility of raw coke oven gas as a source of hydrogen supply. In 2004 alone, Polish cokeries gave 4385 million of m^3 of coke oven gas. Having satisfied the needs of the cokeries and the associated steel mills, there was a coke oven gas surplus of 1363 million of m^3, of which

1275 million of m^3 was sold; the remaining 88 million of m^3 was burnt. It is estimated that commercial utilization of the coke oven gas generated at the two biggest Polish cokeries, ZK Zdzieszowice and Przyjaźń could yield approximately 1660 million of m^3 of hydrogen per anuum.[xxiii]

- Coal with CCS

Poland has significant coal reserves and is the only world class exporter of coal in Europe. The coal mining industry in Poland has become more competitive through radical reforms with output remaining relatively stable. Many of the thermal coal plants are reaching the end of their lifecycle and will have to be modernized, giving an opportunity for clean coal technologies and CCS. Whether CCS plays a major role in the production of energy from coal is uncertain owing to the costs involved. The recent working group on CCS in Brussels suggests that CCS is a possibility technically and physically there are a sufficient number of suitable aquifers. Further research is also underway hosted at the Institute of Power Engineering in Warsaw. However, it is uncertain who will be required to pay for the process, and the cost of plant, transportation and sequestration make zero emission coal based power plant a challenge. It is thought more likely that new technologies for carbon capture will be investigated, such as oxifuel. A greater emphasis on increased combustion efficiency from coal is also likely as new, improved technologies for coal are thought to be cheaper and easier to apply than CCS. The use of coal to produce hydrogen appears promising, although whether CCS or new combustion technologies and capture technologies will be used remains uncertain. [xxii]

- Nuclear Electricity

Significant increases in electricity demand up to 2025 coupled with emissions obligations and the need to diversify energy sources mean that the introduction of nuclear is predicted after 2020 in all four of the latest government energy scenarios.[xvi] Assuming the planned public acceptance campaigns are successful, nuclear power has the potential to produce a competitive source of hydrogen but needs to be reduced in cost and the issues of technological capacity, security, waste and finance need to be resolved.

Feedstock Transport

- Pipeline

Poland has a well developed domestic natural gas pipeline network covering most of the country; this is especially good in industrial areas. There are some weaknesses in rural areas pipelines that may need extending and upgrading.

- Electricity grid

The Polish electricity supply industry has undergone radical changes liberalizing the electricity grid over the last five years. However, the Team for System Solutions of the energy market (RSREE Team) still feels that decisive steps are needed to improve the quality of the market.[xxiii] There is sufficient capacity across the whole country as the medium and high voltage network is very good. The transmission and distribution networks may need to be upgraded in rural areas. Cross border transmission lines are likely to be constructed in the near future in order to increase the potential for exporting electricity into the European electricity market.

- Truck

The road system in Poland is extensive and well developed and should not present any problems for the movement of feed stocks.[xxiv]

H2 Production

In Poland, a range of processes are currently used by major chemical plants in large scale hydrogen production, including cryogenic, PSA adsorption, SMR and electrolysis.

- Natural gas reforming (SMR)

Poland has considerable industrial experience of SMR in conjunction with oil refining. Evidence of advanced SMR techniques in Poland exists such as the production of hydrogen for the desulphurization of petroleum products by the multi-national company Air Liquide.[xxv]

- Electrolysers

There is significant current and historical experience in Poland of electrolysis. Currently small scale installations are sold in Poland by technical gas companies, for example Messer Polska builds such installations on site, on the customer premises and they are tailored to the customer needs, the capacity of such systems can be from 0.5 to 1.000 N cubic meters per hour. They produce gas with 99.9% purity.

- Novel hydrogen production technologies

There are a number of novel hydrogen production technologies that are being researched and developed worldwide. These technologies use low cost neutral feed stocks such as photo electrolysis, photobiology or bio mimetic techniques, although these have not yet been commercialized.[xxvi]

- Coal gasification to hydrogen

Extracting clean energy from coal is a major point of interest in Poland. The recent establishment of an International R & D Centre of Separation Technologies for hydrogen economy needs in Poland demonstrates this point. The centre is investigating coke oven gas as separation model fluid.[xxvii] Research is also on-going into advanced separation techniques, such as: chemical and thermal looping cycles, Rapid Temperature Swing Absorption, and Oxygen Enriched Combustion and new oxygen production techniques. The recent merger of two key players on technical gases market, namely BOC and Linde is likely to lead to an increase in the demand for hydrogen. To date, gas companies have been importing pure hydrogen and it is thought that the new situation on the gas market may contribute to a dedicated hydrogen production plant in the next 5 to 10 years.

Hard coal deposits that can be extracted by means of classic methods are in fact quite limited. In Poland, the use of current technologies may continue for approximately 20 years. In the long-term, if the Polish mining industry is to survive, underground gasification of the deep coal beds will have to be considered. [XXIV] As Europe does not possess any significant achievements in this area, the need for an alliance with major oil or energy companies such as Shell or Texaco that have long and specialized experience in the field of various gasification technologies seems to be a likely option.

- Carbon Capture and Storage (CCS)

The development of the Czech – Slovak – Polish HyCom in Cieszyn / Tesin is a target of the European Green Electricity from Coal Technology Development Area. There is strong political will to develop CCS capacity in Poland [xxvii]. Research is on-going at the Institute of Power Engineering in Warsaw. The most active research in Poland in the CCS area is executed through the country participation in three FP6 RTD STREP projects as shown in table 6. It is expected that the first two projects will lead to demonstration projects within the frame of Hypogen JTI initiative of the 7th RTD Framework Programme.

1.	**ISCC**	In Situ Carbon Capture project, aimed at anaerobic gasification of coal to fuel cell quality hydrogen and sequestration ready carbon dioxide streams. Specific Targeted Research Project in priority thematic area 6.1.3.2.4 Capture and sequestration of CO2, associated with cleaner fossil fuel plants.
2.	**RECOPOL**	Project – demonstration level activity focused on technical scale tests of carbon dioxide storage in uneconomic deep bituminous coal seams

		(CMI/GIG is a Polish partner to the project). The projects is assumed to be continued in an expanded version taking into account the potential coal bed methane recovery from approached coal deposits
3.	**C3-Capture**	Calcium Cycle for Efficient and Low Cost CO2 Capture by means of Fluidized Bed Systems

Table 9 Active CCS Research Projects in Poland

The most promising option of carbon dioxide storage on the territory of Poland seems to be the so called distributed geological sequestration in locations occurring in geographical proximity of the emission sources. This method consists in injecting CO_2 into appropriate underground geological formations, for example exploited oil and gas reservoirs, unmineable coal beds and deep saline aquifers. The major benefit resulting from distributed sequestration is that it allows to reduce the costs related to CO_2 transport. The following potential sequestration techniques could be considered for Poland.

1. Injecting and storing CO_2 in salt rock deposits located in the North – East of Poland; the thickness of the formation equals up to 1,000 meters. Similar rock salt deposits also occur in central Poland.
2. Injecting and storing CO_2 in deep saline aquifers which are not considered as drinking water resources. Saline aquifers occurring in Poland are characteristic of Devon Paleozoic formations and their thickness often exceeds 1,000 meters. The map below illustrates the distribution of saline aquifers in Poland.
3. Injecting and storing CO_2 in unmineable coal beds. A large scale demonstration project of carbon dioxide sequestration combined with coal bed methane recovery was carried out in the Upper Silesia Coal Basin within the 5th Framework Program. The installation injecting CO_2 into the coal bed was built with an estimated efficiency of up to 10,000 m^3 per day for a period of at least 1.5 years.

   According to IEA the total coal bed potential of CO_2 storage of the Upper Silesian Basin in Poland could be estimated at 7.4 Mt.[xxviii]
4. Enhanced natural gas and oil recovery. There have been two installations of enhanced oil recovery operational in Poland. Other potential locations could be set up at the Baltic Sea shelf in the North of Poland and in the vicinity of Nowy Sącz in the South of Poland. The deposits of high nitrogen content Natural Gas (up to 90% or more of nitrogen content) pose another possibility of CO_2 sequestration combined with enhanced gas recovery. The possible locations are in the South of Poland in the vicinity of Gorlice, Lubaczów, Cieszyn and Sanok and in the North, in the vicinity of Cychry and Sulęcin.

5. Mineral sequestration by converting CO_2 into inert materials by means of chemical reactions, for example by reacting carbon dioxide with silicate minerals to form calcium or magnesium carbonate minerals. For example the reduction of CO_2 emission by 10% would require the use 66 Mt of serpentine. The cost of transporting the mineral material to the CO_2 emission source might be offset by an accompanying extraction of Palladium and Platinum ores that occur in the same location and have not been exploited since 1983. Limestone and serpentine deposits occur the South of Poland in a belt stretching from the east to the west border of the country[xxix]

The possibilities of geological CO_2 storage in Poland have been estimated at a few dozen billion tons. The capacity of the 6 existing underground gas reservoirs is 1.5 billion of m^3. The underground oil reservoir has a capacity of 2 million ton. The existing underground gas reservoir located in Wierzchowice (current capacity – 0.5 billion of m^3) could be extended to 3.5 billion of m^3. New reservoirs of the capacity amounting to 6.5 billion of m^3 could be created in gas and oil fields of Tuliglowy, Tarnow, Bonikowo and Daszewo. In case of salt deposits, the storage potential equals 57 billion of m^3; the storage potential of closed coal mines is 0.9 billion of m^3; the saline aquifers potential accounts for 14 billion of m^3.[xxx]

Conversion

- Compression

Poland has some industrial experience of hydrogen compression through multi-national companies operating the country such as BOC and Air Liquide.[xxv]

- Liquefaction

Historically two Polish scientists from the XIX century – Wroblewski and Olszewski – were the pioneers of cryogenic research around oxygen, nitrogen and hydrogen liquefaction.[xxxi] As with compression Poland has some industrial experience of hydrogen liquefaction through companies such as BOC and Air Liquide. [xxv]

- Novel Technologies

Other hydrogen conversion technologies such as glass micro spheres, rechargeable organic liquids and chemical hydrides do not appear to be a research priority in Poland. However, the issues surrounding storage of hydrogen in nanostructured metals have been introduced into the nanotechnology for energy and chemistry research priorities of the Ministry of Education and Science.

H2 Transport

- Hydrogen pipelines

There is no evidence of dedicated hydrogen pipelines at this point. However, Poland does have an extensive network of Natural Gas pipelines that could be converted for use with hydrogen; this appears to be the most likely method to transport hydrogen at least initially.

- Road transport of hydrogen/ Truck

There is no evidence of road transport of hydrogen by truck although it is likely that air Liquid has some experience in this area. Levels of national and international truck transport are within 10% of EU25 averages and developing the necessary capacity, regulations and measures should not present a large barrier.[xxiv]

Distribution

- Refueling infrastructure

There is no evidence of demonstration or commercial availability of hydrogen refueling infrastructure in Poland. The construction of dedicated hydrogen pipelines is thought to be unlikely unless the technology achieves greater efficiencies than electricity transmission.

- Mini grid

There is historical evidence of mini grid in Poland in the Silesia region where mini grids were used to deliver gas produced from coal to supply local energy services for the mining related population. As a result there is clear potential for mini-grid use in the transportation of hydrogen around the coal fields. The development of this potential will depend on the development of distributed generation technologies.

End use

- Fuel Cell road vehicles incl. storage

There is no evidence of fuel cell road vehicles in Poland. The creation of the Polish Technological Platform of Hydrogen and Fuel Cells suggests that there is interest in development of the domestic hydrogen and fuel cell markets. The example of low sulphur diesel where a tax reduction was used to increase its uptake in cities is an example of how policy might be used to encourage H2 uptake. FC are thought likely only beyond 2020. This can only be achieved in the face of full public acceptance and within the framework of

significant government led policies and measures, such as subsidies and codes and standards.

- The Polish Automotive Sector

According to the Polish Chamber of Automotive Industry the sector achieved its record performance in 1999 with the production volume of 715,000 and sales of 640,000 vehicles in total. Unfortunately, in the following years the trends were steadily worsening but despite the decrease, several foreign investors decided to set up their component operations in Poland; these were Toyota, Fiat-GM, VW, Valeo, Sanden, Simoldes Plasticos.

The Polish automotive market is represented by a few big players such as FAP, GM, VW, FSO, and Intral-Polska manufacturing personal cars, vans and pick-up trucks. There are also several bus manufacturers, for example Autosan, Volvo, Solaris, Scania, Man Star Truck and Buses, Solbus and Jelcz. Since 2002, the total production volume has been increasing; within the period of 2002-2004 the production rose from the level of 308,000 to 600,000 vehicles, which is a 94% increase. A considerable increase in delivery vans production, from 31,500 in 2002 to 136,000 in 2004, greatly contributed to the growth. The 431 % increase resulted from the establishment of two new production lines of VW models Caddy and T5.

The Polish Chamber of Automotive Industry estimates that in 2005, the production of personal cars, delivery vans and pick-up trucks reached the number of 610,000 – 615,000. In case of buses, the growth equaled 34 % with the production volume of 2547 vehicles in 2004. High export rates contributed to the increased sales to foreign markets; in the period 2001-2004, the growth was 433%. In 2004, the number of exported buses was 1616, which accounted for 63 % of the sector annual production. The biggest manufacturers are Man Star Truck & Buses, Volvo and Solaris.

A new trend in the Polish transportation sector is the development of automotive R&D centers. Until recently, there was only one such a center belonging to Delphi Concern. Located in Krakow, the center was employing 600 engineers. At the beginning of 2005, two international concerns, TRW Automotive and Remy Automotive established their own R&D centers; approximately 300 engineers are to be employed.

The share of locally produced components, the so-called local content, in the final product depends whether the producer is a Greenfield type plant like GM Manufacturing Poland, or whether it took over the former state owned plants such as FSO and FAP. In case of FSO

and FAP, the local content rate accounts for 63-88%. The VW plant, located in Poznan, is characterized by the lowest rate of local content, which is below 36%.

Since 1998, the share of automotive industry in Polish export has grown from 6,4% in 1998 to 15,5 in 2004 and amounted to 11,5 billion USD in 2004 (see table 10). The biggest share included personal cars – 36,8% and delivery vans – 7,5%, components and accessories share amounted to 26,6%, and diesel engines accounted for 24,7 % of total automotive exports. The Chamber of Automotive Industry estimates that 5 existing plants can reach a production volume of 1,7 million engines annually with the major target markets in Germany (35%), Spain (16,1) and Italy (14,3).

Mode of Transport	*Passengers*			*Passenger-kilometers*			*1 passenger in kilometer*
	in thousands	*2003=100*	*%*	*million*	*2003=100*	*%*	
Total	**1 085 509.0**	**97.6**	**100.0**	**56 071.6**	**98.9**	**100.0**	**52.0**
Railway Transport	272 162.0	96.0	25.1	18 689.7	95.2	33.3	69.0
of which standard gauge	272 077.0	96.0	25.1	18 688.4	95.2	33.3	69.0
of which narrow gauge	85.0	106.4	0.0	1.3	107.1	0.0	15.0
Road Transport	807 281.0	98.1	74.3	30 118.0	100.4	53.8	37.0
Air Transport	4 044.0	101.7	0.4	7 071.4	102.9	12.6	1 749.0
Inland Waterway Transport	1 396.0	77.8	0.1	23.0	68.5	0.0	17.0
Maritime Transport	626.0	119.0	0.1	169.5	123.5	0.3	271.0

Table 10 Transport of Passengers by Mode of Transport in 2004

The condition of Polish automotive sector is also reflected in employment rates. According to the data issued by Polish Statistical Bureau, GUS at the beginning of 1999 100,000 people were employed in the industry. In the next period of 2000 – 2003 there was a substantial decrease by 23,700. However, in the first quarter of 2005 the employment rates reached the number of 99,700. Polish Chamber of Automotive Industry forecasts assumed the growth in 2005 by another 10,000 – 12,000.

The analyses carried out by the Polish Chamber of Automotive Industry reveal that Poland has become a relatively attractive location for foreign investors, predominantly due to much lower labor cost as compared to the previous 15 EU Member States, well qualified technical staff, and a strong group of 650 component suppliers, out of which 200 are in the possession of ISO/TS 16946 certificates. On the other hand, the disadvantage is that Poland has a very complicated fiscal system discouraging potential investments. Nevertheless, the condition of Polish automotive sector has improved in recent years and several important investors either have set up new operations or have been extending the existing ones, the examples to be

quoted are such concerns as Toyota, Michelin, Faurecia, Kirchhoff, Hutchinson or Man. The forecasts of the Polish Chamber of Automotive Industry assumes that the increase of production in 2006 can amount to 650,000 – 660,000 vehicles.[xxxii]

- Other hydrogen and fuel cell vehicles

There is experience of running LPG taxis in major cities in Poland, chosen for their relatively low particulate levels to improve local air quality. An alternative option for early market for H2 vehicles might be buses. It is suggested that the tourist town of Krakow might provide the ideal location for the first market, with Warsaw and Katowice also being under consideration, although policy support through subsidies would be needed initially. It is thought likely that by 2020 there will be perhaps around 20 H2 buses in Poland. The H2 for these buses could be sourced from by-product H2 which is currently created from coal via coke oven gas.

- Stationary applications (FC & IC)

There is no evidence of existing stationary applications utilizing hydrogen in Poland, and their use seems unlikely to widespread even over the longer term. The most likely stationary applications might be around the coal fields where mini-grids are established or in rural communities using micro CHP.

Conclusions

The current hydrogen infrastructure in Poland is very limited, in comparison with some other EU Member State partners. However, there is considerable research effort being made in the field of Carbon Capture and Sequestration and clean coal technologies. Poland is also an important source of coal production and has significant levels of domestic gas reserves. There is therefore an opportunity to capitalize on these strengths and apply them to the development of a national hydrogen infrastructure.

However, there are significant barriers to such a development. Although Poland has significant domestic fossil fuel feed stocks, further capacity for their conversion to hydrogen needs to be developed. At present fossil fuel-based hydrogen is most cost-competitive and is likely to remain so for the short to medium term at least. The successful deployment of a hydrogen infrastructure system will depend on the implementation of technologies for capture and storage of the carbon this process inevitably produces. Further, barriers are presented by a lack of demand for hydrogen at the end use stage, and there is a need for the development of a portfolio of demonstration projects.

The renewable sector is forecast to grow rapidly, particularly wind and biomass, providing an option for low carbon-emission hydrogen production. The government of Poland is also committed to the development of new nuclear plant, which should provide a further zero carbon source of hydrogen production. There is a need to increase capacity for technology development or transfer into the production, distribution and end use of hydrogen from nuclear, renewables and fossil fuels. The initial government led research and policy guide towards technology innovation has started this process.

The key points on interest in the development of the Polish hydrogen economy are:

- Hydrogen is seen in a balanced way, as equally important to the future transportation, as it is to the energy and chemical synthesis markets,
- Coke oven gas and hydrogen produced from coal by coal conversion with steam are assumed to be the major short and medium term sources of hydrogen,
- Underground conversion of coal deposits (thermal coking, gasification and hydro - gasification) integrated with CCS through different CS technologies is assumed to be the most important pathway for long term hydrogen production in Poland,
- Hydrogen and fuel cell research and development are treated as a very convenient backbone for a long term specialization of the country in advanced and innovative energy technology area

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The abbreviation PIM stands for The Polish Chamber of Automotive Industry.