CODE2

Cogeneration Observatory and Dissemination Europe

D5.1 Final Cogeneration roadmap

Member State: ***POLAND***

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Version: 1.0

Leading CODE2 Partner: ***Jozef Stefan Institute***

Co-funded by the Intelligent Energy Europe Programme of the European Union

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Introduction and Summary

The CODE2 project[1]

This roadmap has been developed in the frame of the CODE2 project, which is co-funded by the European Commission (Intelligent Energy Europe – IEE) and will launch and structure an important market consultation for developing 27 National Cogeneration Roadmaps and one European Cogeneration Roadmap. These roadmaps are built on the experience of the previous CODE project (www.code-project.eu) and in close interaction with the policy-makers, industry and civil society through research and workshops.

The project aims to provide a better understanding of key markets, policy interactions around cogeneration and acceleration of cogeneration penetration into industry. By adding a bio-energy CHP and micro-CHP analysis to the Member State projections for cogeneration to 2020, the project consortium is proposing a concrete route to realise the Europe's cogeneration potential.

Draft roadmap methodology

This CHP roadmap for Poland is written by Jozef Stefan institute and has been based on a range of studies (see list of Sources) and has been developed through a process of discussion and exchanges with experts.

The first draft of the roadmap was discussed and reviewed on an interactive workshop with stakeholders on 4th December 2013 in Warsaw. The input from the workshop and any additional input from experts have been used to produce the current version.

Acknowledgement

Jozef Stefan Institute and the CODE2 team would like to thank all experts involved for their contributions to develop this roadmap, which has been valuable regardless of whether critical or affirmative. It has to be stressed that the statements and proposals in this paper do not necessarily reflect those of the consulted experts.

[1] For more details and other outcomes of the CODE2 project see: http://www.code2-project.eu/.

Summary

Poland is one of the member states with the largest volume of cogeneration in the EU. The long cogeneration tradition reflects in a rather broad awareness of cogeneration's advantages and slightly growing CHP electricity generation as a result of the incentive certificate based support framework. Cogeneration fits well into the key national energy policy goals to improve energy efficiency, increase utilisation of renewable energy sources and decrease emissions of CO_2 and air pollutants especially by the necessary retrofit and replacement of existing old CHP plants in district heating systems by modern CHP units and a gradual switch from coal to natural gas and wood biomass. CHP electricity generation could be doubled till 2030 compared to the 2006 level and provide more than 1/5 and more than 2/5 of the expected final electricity and heat demand and could significantly contribute to the more sustainable use of domestic fossil and renewable energy resources.

The CHP roadmap path would deliver 21 TWh of additional electricity generation and 47 TWh/a of primary energy saving (PES) and up to 30 million tonnes yearly of CO_2 emission reduction under the EED methodology until 2030. Considering the likely implementation path of such a roadmap more than 20% (36 TWh) of the national indicative primary energy saving target 2020 are achievable in practice until 2030 resulting in a huge benefits for the national economy. Establishing a stable long term support framework for cogeneration and for the energy retrofit of district heating systems, along with the removal of other key barriers are prerequisite conditions for achieving these results. Conscientious implementation of the European Energy Efficiency Directive (EED) could significantly contribute to a significant future CHP role in the Poland sustainable energy supply and for the implementation of this roadmap.

Poland is the EU CHP giant:

- **1st place:** by **installed capacity 32,8 GWe (8,8GWe)** (2010)
- **3rd place:** by CHP **heat generation 252 PJ** (2010) (D, FIN)
- **5th place:** by CHP **electricity generation 27 TWh** (2010) (D, NL, I, FIN)
- **7th place:** by **share of CHP electricity generation 17,6%** (2010) (DK, LV,FIN,LT, NL, H)

1. Where are we now? Background and situation of cogeneration in Poland

1.1. Current status: Summary of currently installed cogeneration

The installed capacity and total electricity and heat production from high-efficiency cogeneration in Poland in the period 2006-2012 are shown in the table below (Table 1). The installed capacity of high-efficiency cogeneration in that period was about 8,7 GW, but the electricity production from the high-efficiency cogeneration varied around 27 TWh in this period (Table 1). The total heat production of high-efficiency cogeneration has slight negative trend toward 72 TWh annual generation whereas the cogeneration share in gross electricity production is growing and moving around 17%.

Table 1 – Eurostat data on cogeneration in Poland 2006 - 2012

CHP	Installed electrical capacity [GW]	Total heat supplied [TWh]	Total electricity generated TWh]	Total % of gross electricity production**
2006	8,47	76,5	26,0	**16,05%**
2007	9,02	72,5	27,6	**17,30%**
2008	8,78	72,1	26,4	**16,91%**
2009	8,63	71,8	26,1	**17,19%**
2010	8,69	77,0	27,7	**17,57%**
2011	8,84	73,2	27,1	**16,58%**
2012	8,33	72,4	27,0	**16,68%**

Source: Eurostat 2014

The electricity production from cogeneration (steam turbine) in Poland is mainly produced in cogeneration using coal (about 88%). The share of electricity produced from gas-fired cogeneration (Combined Cycle Gas Turbine - CCGT) and in cogeneration with electrical power below 1MW (Internal combustion engine) present less than 12% of all electricity produced in cogeneration. Electricity produced from biogas did not exceed 1% in 2010 (about 101 GWh).

The electricity production in high-efficiency cogeneration is shown graphically in Figure 1 and structure of the installed cogeneration capacity is shown in Figure 2.

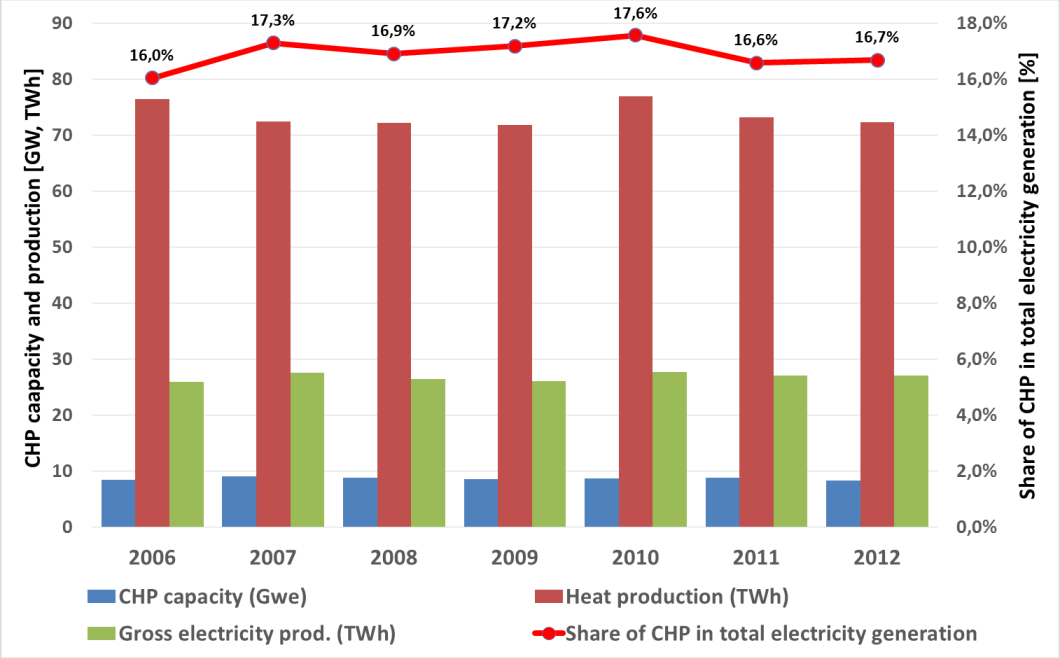

Figure 1 - Electricity and heat production in high-efficiency CHP and share in total electricity production in the period 2006 - 2012

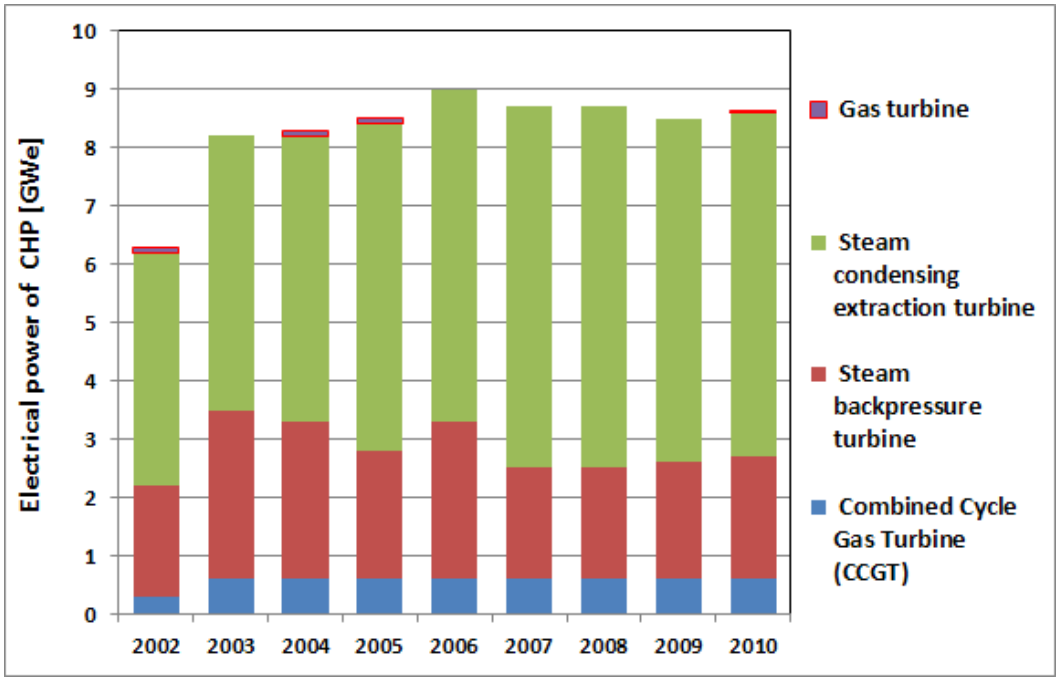

Figure 2 - Electrical power of CHP by technology in Poland

Source: Report evaluating the progress towards increasing the share of high-efficiency cogeneration in the total annual production of electricity in Poland

1.2. Energy and Climate Strategy of Poland

Improving energy efficiency, increasing utilisation of renewable energy sources and decreasing the emissions of CO_2, SO_2, NO_X and dust are the key priorities. Cogeneration can contribute 295 PJ of the primary energy savings and 32 Mt CO_2 savings to the stated energy efficiency and CO_2 reduction targets of Poland according to the government own assessment under Directive 2004/08/EC.[4]

The key goals of energy and climate policies are to improve energy efficiency, increase utilisation of renewable energy sources and decrease the emissions of CO_2, SO_2, NO_X and dust in the next years. One of the targets of energy policy is to achieve zero-energy economic growth (economic growth without growth in primary energy supply).

The target of the climate strategy of Poland is to significantly decrease CO_2 emissions from about 300 Mt in 2010 (332 Mt in 2006) to about 280 Mt in 2020 and after that CO_2 emissions would be gradually increasing to about 300 Mt in 2030.

High efficiency cogeneration plants with assessed 20% primary energy savings provided 5,3 Mt of coal (133 PJ) savings in the year 2010 and reduction of CO_2 emissions of 14,5 Mt CO_2.[2]

The important objectives and goals and measures in the Poland energy policy considering cogeneration are:

- Pursuing a „zero-energy" economic growth, economic growth without an increase of demand for primary energy.
- Increasing the efficiency of electricity generation, through construction of high efficiency units, reducing network losses and development of distributed generation.
- Doubling electric energy production in high efficiency cogeneration technologies until 2020, compared to production in 2006.
- Stimulating developments of cogeneration, including cogeneration from sources below 1 MW, through support mechanisms, and adequate regional policies.
- Aiming at replacing the heat only plants supplying district heating systems with cogeneration by 2030.
- Preferential treatment of cogeneration as the technology recommended for building new generation capacity.
- Implementation measures to achieve the target in the national action plan for energy efficiency.
- Maximising the utilization of local renewable energy potential in cogeneration of heat, cold and electricity.
- Developing the district heating systems.

[2] Second Report evaluating the progress towards increasing the share of high-efficient cogeneration in the total annual production of electricity in Poland, Warsaw, February 2012.

- Cogeneration is listed between technologies of the greatest potential for growth[3].

The share of renewable energy sources in the final energy consumption in 2030 is expected at 15% and the annual CO_2 emission in the utility of power generation is expected at level 0.7 tons CO_2/MWh.

1.3. Policy development

Additional support of existing and new cogeneration units through the certificate support scheme is key instrument, essential for both the cogeneration operational cost recovery and the necessary return of investment projections of new cogeneration plants in current unfavourable energy market conditions.

The current support scheme for electricity production in cogeneration has been in force since 2007. The support scheme for electricity generation in cogeneration is based on a quota system and on the so-called "certificate of origin from cogeneration" (Energy law, Article 9l). Also the system support for renewables is based on the so-called "certificate of origin" and "certificate of origin from biogas".

The support mechanism for electricity from high efficiency cogeneration depends on the capacity of the source and types of the fuels used.

The support for high efficiency cogeneration is dependent on the types of obtained certificates marked by colour of certificates:

- **Yellow certificates** for cogeneration units fired by gaseous fuels or with total capacity below 1 MW independently of type of used fuels, the price of the yellow certificates must amount from 15% to 110% of the average electricity price,
- **Red certificates** for other cogeneration units with total capacity over 1 MW and fired with coal. Price of the red certificate unit substitute fee must be in the range of 15-40% of the average electricity price.
- **Purple certificates** for cogeneration units fired with methane obtained from mines or biomass methane. Price of the purple certificate unit substitute fee must be in the range 30-120% of the average electricity price,
- **„Several colours certificates"**: The high efficiency cogeneration units, which used various types of fuels (co-firing), according to the Polish Energy Law is eligible for support by various "colour certificates". The support for each certificate is based on the share (proportion) of amount of chemical energy of fuels used calculated on the basis of the actual energy value of particular fuels used in the process.

The unit substitute fees for 2013 were determined as follows:

- 149.30 PLN/MWh (**35.7 EUR/MWh**) for yellow certificate,

[3] Results of the industry technological foresight project – InSight 2030, "Programme to support investments of the utmost importance to the Polish economy for 2011-2020" (National Reform Programme Europe 2020)

- 29.84 PLN /MWh (**7.1 EUR/MWh**) for red certificate,
- 60.00 PLN /MWh (**14.4 EUR/MWh**) for purple certificate.

The system support based on Red and Yellow Certificates of origin, valid till the end of 2012 was extended till the end of March 2015, when the Purple certificates become valid to end of 2018.

Although already in 2013 the notification procedure for the extended support scheme has been started at the EU DG Competition, the final decision has not yet been issued which pose huge uncertainty on the cogeneration market about the support in the future.

1.4. Awareness

General public awareness about cogeneration is in Poland is rather good. The attitude toward cogeneration is positive on the several levels of discussions (parliament, government, press, etc.) and the awareness on the advantages and benefits is growing.

Cogeneration investments rely on a commercial proposition and a functioning market for the application of cogeneration. The policy intervention of the European Union to support cogeneration and assist the removal of market barriers is an important element of creating a good commercial proposition however in itself it will not be sufficient to grow sales of cogeneration if the customers are unaware or misinformed and lacking support within influencing groups or and if the supply chain of skills and suppliers does not exist.

A final buying decision by a customer is the result of a set of complex interactions, involving the supplier, the supply chain and the customer. External conditions influence the process as do the market structure and the policy structure. A mature market for a product is characterized by a high degree of awareness among all the relevant players in the market and ongoing buying and selling activity.

The following 4 groups of socio-economic actors can play an important role in the cogeneration market, either by direct involvement or by creating the appropriate economic and market structure:

- **Customers:** utilities (DH), industry, households, SMEs (services);
- **Market and supply chain:** manufacturers, installation companies, grid operators, consultants, architects, banks/leasing, ESCOs;
- **Policy structure:** energy and climate legislators on all levels of various institutions on state, regional and local level, energy agencies, planners;
- **Influencers:** sector organisations, general public, media, academic area, NGOs, research.

The list is not exhaustive but contains all the most relevant players.

An assessment of awareness of cogeneration among key market actors in Poland has been developed. Using qualitative interview techniques with experts and market participants four groups of the socio-economic actors for cogeneration were assessed as shown in **Figure 3**, more detailed information is presented in **Annex 1**).

General public awareness about cogeneration is in Poland is rather good having in mind the prevailing large scale cogeneration units currently active in district heating. District heating is the most common form of heat supply to household and services in Poland[4]. The attitude toward cogeneration is positive on several levels of discussions (parliament, government, press, etc.) and the awareness on the advantages and benefits is growing. Awareness on the benefits of small scale (less than 1 MWe) and micro-CHP is still very low due to the premature market, unfavourable economic conditions and good natural gas penetration only in south and west part of Poland. Several successful renewable cogeneration projects on biogas and biomass are raising awareness of RES cogeneration[5].

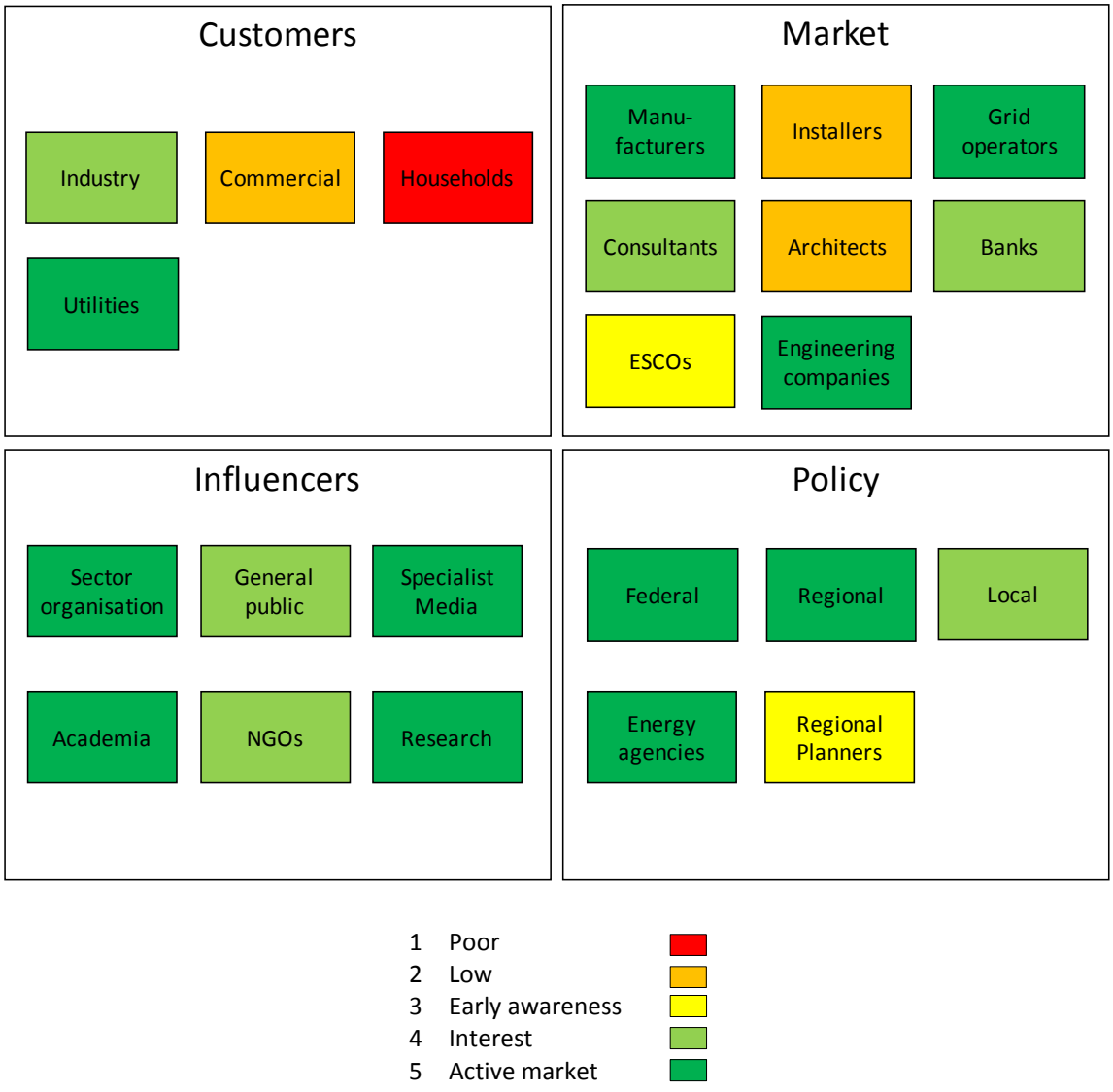

Figure 3 - Assessment of four groups of the socio-economic actors awareness of cogeneration in Poland

[4] District heating have more than 50% market share in heat for heating (40% in households), RENEAP.

[5] From the published data of Energy regulatory office , there are more than 200 biogas plants and 29 biomass plants already installed in Poland (presented on the interactive map http://www.ure.gov.pl/uremapoze/mapa.html).

Compared to the cogeneration leading member states (Germany and Belgium) we have identified next key differences in the awareness:

- **Firm governmental and political support and awareness** resulting in clear, stable and predictable long term legislative framework is still not yet present. Although cogeneration is properly positioned in several strategic documents current expiration of certificate support scheme and gap of support is causing huge problems for existing cogeneration plants and uncertain environment for the investors and banks.
- **Lack of awareness on small scale cogeneration on all levels:** although large scale cogeneration in district heating and industry is key priority and orientation for Poland, large complementary potential of small scale cogeneration could be exploited in next years by raise of awareness of all actors necessary for establishing proper conditions for implementation. Besides developing market and supply of natural gas (shale gas, LNG terminal), renewable cogeneration could have important role on small scale level.

1.5. The economics of CHP

The current framework is providing a proper basis for the further development of cogeneration in Poland in all sectors where the largest economic cogeneration potential is assed: RES CHP units (biogas and solid biomass), large CHP units on coal and industrial CHP units on natural gas and other fuels.

The current energy market trends are unfavourable for developing of cogeneration in Poland in the near term:

- Recent decrease of electricity wholesale market prices[6] is especially influencing large district heating cogeneration plants on the competitive electricity market[7].
- Increase of natural gas prices is decreasing economics of natural gas cogeneration plants and their competitiveness toward coal generation
- Ratio between electricity and natural gas price was around 2, which is less than the necessary level around 2.5 for economic operation of natural gas cogeneration plants.

Recent natural gas and electricity prices by Eurostat consumers groups and the ratio between electricity and natural gas prices (cogeneration Energy price ratio) are shown in the following Figure 4. **Additional support of existing and new cogeneration units through the certificate support scheme is key instrument, essential for both the cogeneration operational cost recovery and the necessary return of investment projections of new cogeneration plants in current unfavourable energy market conditions.**

[6] Average electricity selling price in the year 2012 was around 48 €/MWh.

[7] On the other hand final end use electricity prices are growing (additional fees on RES, CHP, etc.).

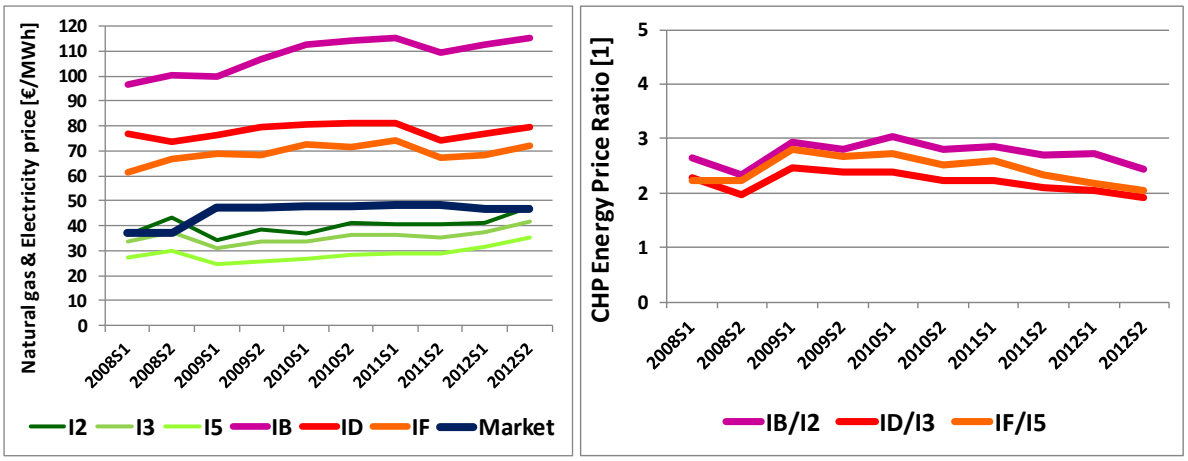

Figure 4 - Recent natural gas and electricity prices and the CHP Energy Price Ratio for Poland [8]

The regulated certificate support scheme will operate most effectively if it is set to ”balance” the market conditions with respect to each fuel type specifically to enable the economic operation of cogeneration plants, which are exposed to both electricity and fuel price variation which are larger for gas compared to the more predictable conditions for cogeneration plants using domestic coal[9].

The economic assessment of four typical cogeneration projects for Poland[10] in market conditions in the year 2012 shows that the expected profitability of investments varies significantly between assessed cogeneration units (**Figure 5**). Economic indicators (IRR and simple payback time) show that:

- Profitability of the 50 kWe micro-CHP unit is low (IRR 4%) and bellow the usual requested level for the investors.
- Small scale 1 MWe cogeneration unit is showing favourable conditions due to rather high end use electricity price which together with the certificate support offer good incentive for the investment.
- Poor (negative IRR) profitability is evident for 10 MWe CC natural gas district heating cogeneration plant mainly due to low electricity market price.
- Bio gas cogeneration unit is showing still acceptable return (IRR 6%).

[8] Eurostat prices in NCV without taxes.

[9] Recently set of wood biomass co-firing

[10] Micro CHP unit with 50kWe gas engine, 1 MWe gas engine in industry and services, 10 MWe combined cycle unit in district heating and 50 kWe biogas unit.

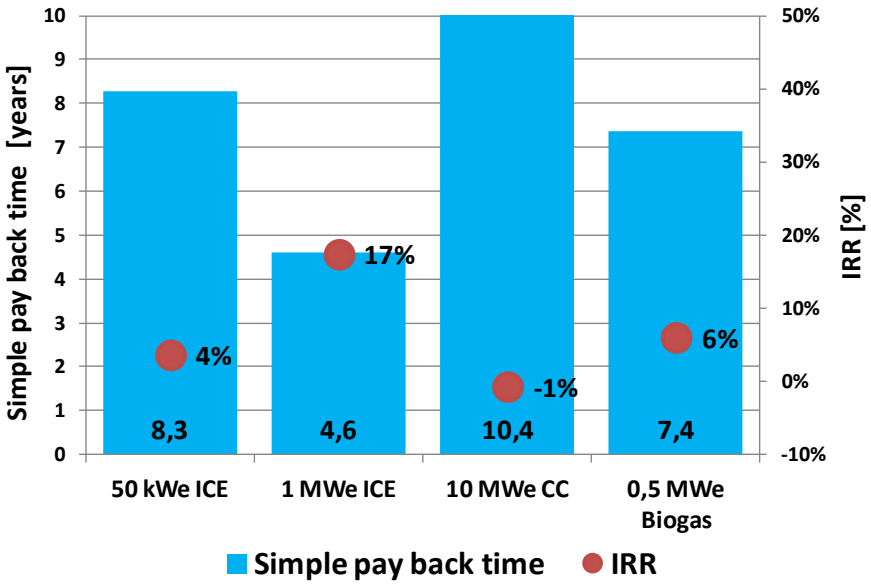

Figure 5 - Economic indicators of typical CHP projects in Poland in the year 2012

The assessment shows that different market variables have a significant influence on the economic indicators of different cogeneration projects and these should be properly taken into account in the regulation of the cogeneration support to enable favourable economic conditions for new investments. More details of four typical cogeneration projects economic assessment is presented in Annex 2.

1.6. Barriers to CHP

1.6.1 Barriers noted in the 2008 report to the Commission

The report of Poland to the Commission in 2008 identified economic (financial), legal, administrative and social barriers for the insufficient development of cogeneration in Poland. The report did not identify any technical barriers, as having an important influence on the development of cogeneration in Poland.

Economic barriers

Under the economic barriers on the development of cogeneration, the price of electricity and heat on the national competitive markets, uncertain CO_2 cost, high-cost of constructing heating network and environmental refurbishment, high cost of small scale cogeneration units and lower investment cost of other heat supply alternatives (boilers, heat pumps, etc..) were identified. Also there was the risk of the introduced support system based exclusively on high-efficiency cogeneration certificates of origin failing to create sufficient investment incentives.

Legal barriers

Uncertain expected changes of legal environmental requirements for large combustion plants (SO_2, NOx and dust). An obligation to obtain a licence to operate according to the amendment of the Energy Act was considered a barrier especially for micro-CHP units. The Energy Act

imposes on the Gmina (province) the obligation to develop "Assumptions regarding the Heat, Power and Gas Fuel Supply Plan". As the act has not foreseen any sanctions if this obligation is not performed implementation of this important planning task is rather poor.

Administrative and social barriers

The social barriers to the development of cogeneration which are connected with the common perception that centralised heating is worse i.e. less user friendly as opposed to individual boiler installations (from era before 1990).

1.6.2 General barriers noted independent of the application area

Although several improvements have happened in recent years, lack of real action *"Lots of plans, little concrete action"*[11] is recent general assessment of the situation in the energy sector in Poland and cogeneration as-well with only limited growth in recent years. Poland is still facing several barriers preventing faster development of cogeneration investments as presented in the analysis below and on **Figure 6**.

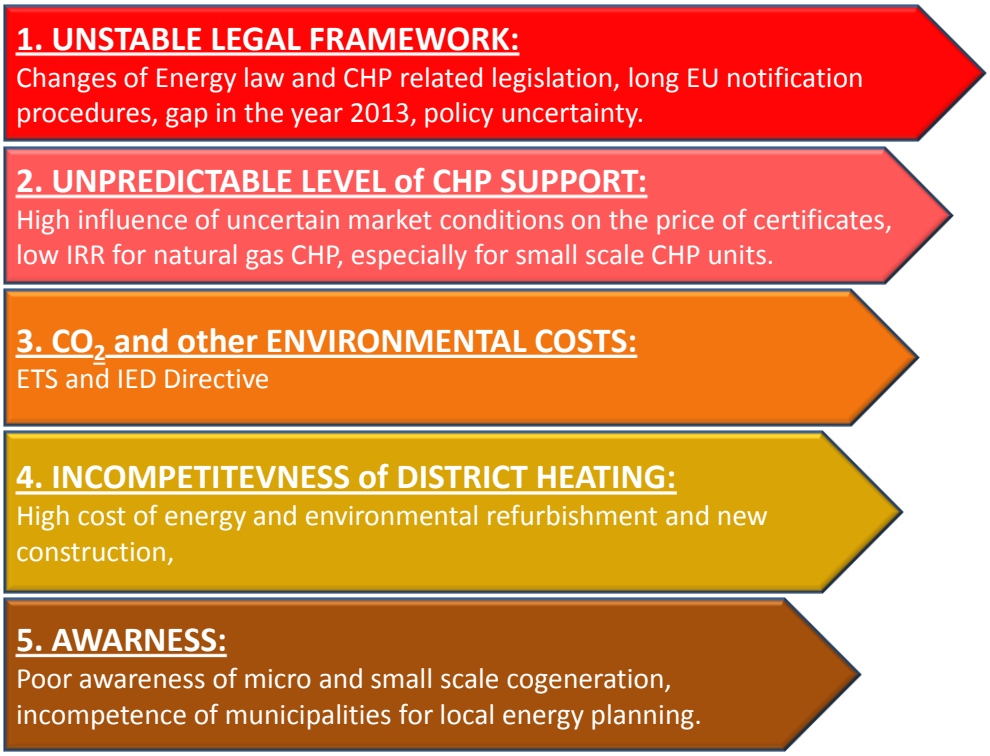

Figure 6 - Main actual barriers preventing faster CHP development in Poland

[11] Polska energetyka 2013,eGospodarka.pl

Unstable legal framework for cogeneration stopped or postponed several planned investments

An unstable legal framework for cogeneration resulting from a very long ongoing process of legislation change and renewal –("energy three-pack: Energy law renewal, draft new Renewable law[12], Gas law and all the related executive legislation for cogeneration)has resulted in a current gap of the support[13] and huge uncertainty of the future conditions for cogeneration. This is the key barrier to further cogeneration development today for the cogeneration investors and financing institutions[14]. Several planned projects were postponed or stopped due to the uncertain conditions for investments.

Unpredictable level of CHP support is increasing risks for investors

Predictable and stable economic conditions are a precondition for new investments in cogeneration. The current certificates support scheme is facing several challenges which should be properly resolved:

- Legislative gap which stopped almost all cogeneration support from 1.1.2013 is key barrier today for the new investments.
- Announced but uncertain changes in the support for RES CHP by New renewable law which is in the approval procedure.
- Setting proper level of support to enable incentive economic conditions for new investments - especially for natural gas fuelled cogeneration and small scale cogeneration (proper regulation that would minimize risk linked to the energy market conditions, as large market energy price fluctuations, unstable foreign exchange rates, high cost of investment loans, cost of connection to the power grid, etc.).

CO_2 and other environmental costs – challenging burden especially for coal fired CHP plants

The prevailing share of coal and ageing of cogeneration units are key reasons for the increase in operation costs linked to the environmental costs under ETS and IED Directives. Lack of adequate support instruments which would ease fulfilment of legislation requirements and preserve competitiveness of the high efficiency cogeneration plants especially on the heat market, where district heating supply should be competitive with the other heat supply

[12] Reduction of support for the wood biomass co-firing (Poland's most popular renewable-energy source) is expected which will affect several larger CHP plants on coal. In parallel with procedure in Parliament, a notification process before the European Commission (EC) is going on. Since this process could last up to 8 months, it is believed that Poland's new renewable energy law will not enter into force until mid-2014, however (PV magazine).

[13] Current certificates scheme expired end of March 2013, but as from 1 January 2013 already support is not granted to CHP units.

[14] Due to prolonged discussions on individual Acts included in the abovementioned "three-pack", in January 2013 The Council of Ministers decided to start the work on amending the current Act – Energy Law in order to avoid a time gap in the current system of support for heat and electricity generation in high-efficiency cogeneration.

options, outside ETS and not burdened by CO_2 costs or strict emissions requirements is an important observed barrier for cogeneration today.

Lack of competitiveness of District heating systems is large threat for existing cogeneration and its further development in Poland

Today more than 80% of cogeneration units are linked to the district heat supply in Poland. This is the reason than the future development and operation of district heating systems is crucial for further development of cogeneration in Poland. The current high cost of retrofitting and construction of district heating networks is a huge barrier toward competitive and efficient operation and extension of existing DH networks. This is in addition to the burden of costs relating to ETS and emissions which are borne by large central plan and not by the competing individual household options. Administrative procedures and costs involved in the connection of the building to the central district heating system are the reason that building owners are reluctant to connect to the district heating network.

Poor awareness on small scale and micro cogeneration is important barrier toward exploitation of not negligible small scale potential

Low general awareness on all levels on opportunities of small scale and micro cogeneration and is important obstacle that should be seriously considered for more integrated and quality development of cogeneration. Proper energy planning on province and municipality level with awareness of benefits of cogeneration is one of the important aspects to trigger faster exploitation of this potential, where several opportunities are on RES cogeneration, especially on bio gas.

2. What is possible? Cogeneration and market opportunities

2.1 Market opportunities

The installed capacity of high-efficiency cogeneration in Poland could be increased by more than 50% i.e. 4.000 MWe (total more than 12 000 MWe installed) by2030. The heat generation from cogeneration plants would be increased for almost 200 PJ, electricity production would more than double compared to the production in year 2006 and supply 48 TWh or 22% of gross electricity demand.

2.1.1 Potential assessment in 1st Progress report 2008

Potential for high efficiency cogeneration in Poland in the year 2020 reported in 2008 was assessed against an estimated technical potential of an additional **403 PJ** of heat generation to have an economic potential of **253 PJ** and app. **39 TWh** of additional electricity generation.

2.1.2 New potential assessment in 2nd Progress report 2012

The latest assessment of the high-efficiency cogeneration potential was prepared in the framework of strategic document "Energy Policy of Poland until 2030"[15] and several other studies[16], reported in the latest progress report on high-efficiency cogeneration in Poland[17], estimated on the basis of the heat demand forecast.

The technical potential for heat supply from high-efficiency cogeneration[17] was set as the difference between the forecast of total useful heat production and heat production from current cogeneration plants (252 PJ) and is estimated at about **444 PJ** in the year 2020. Considering several additional technical and market aspects[18], economic potential of high-efficiency cogeneration heat supply in the year 2020 is assessed to **206 PJ.** Within the new projection of economic potential till the year 2030[15] the total forecasted capacity of high-efficiency cogeneration in Poland is estimated at 12.051 MW_e in the year 2030, which presented increase for more than **4.000 MWe** in comparison to installed cogeneration capacities in 2010 (**Figure 7**). The electricity production from cogeneration in 2030 is expected to increase for 21 TWh to 48 TWh or to 22% share in gross electricity demand.

2.1.3 The highest potential estimated for RES CHP

The highest increase is expected in the cogeneration using bio energy (solid biomass and biogas) as fuels. The expected additional potential of bio energy cogeneration is estimated at **2.500 MW_e** of which about 1.200 MW_e of cogeneration on solid biomass and 1.300 MW_e of cogeneration on biogas mainly in agriculture. Development of cogeneration is supported by special action plan[19].

2.1.4 Further development of district heating cogeneration

The expected potential of primary producers cogeneration using fossil fuels (coal and gas) is estimated of additional **1.240 MW_e** in the year 2030 of which 860 MW_e of cogeneration on coal and 380 MW_e (increase for 17%) of cogeneration on natural gas (more than doubling the capacity in 2010).

2.1.5 Moderate potential for CHP in industry

The additional potential of industrial cogeneration is estimated at **366 MW_e** for the period from 2010 to 2030 of which a half cogeneration on coal (144 MW_e) and gas (42 MW_e).and half on other fuels (180 MW_e).

Small scale and micro-CHP potential is not assessed.

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[15] Policy of Poland until 2030, Ministry of Economy, Energy Warsaw 2009.

[16] Programme for the Development of cogeneration in Poland, Warsaw University of Technology, November 2010.

[17] Second Report evaluating the progress towards increasing the share of high-efficient cogeneration in the total annual production of electricity in Poland, Warsaw, February 2012.

[18] The economic potential is estimated on the basis of the use of 80% of heat for industry, 20% of space heating of building and all heat for large building, domestic heat water and heat generated to provide cooling in summer.

[19] Directions of development for agricultural biogas plants in Poland between 2010 -2020, Ministry of Agriculture and Rural Development, Warsaw, 2010.

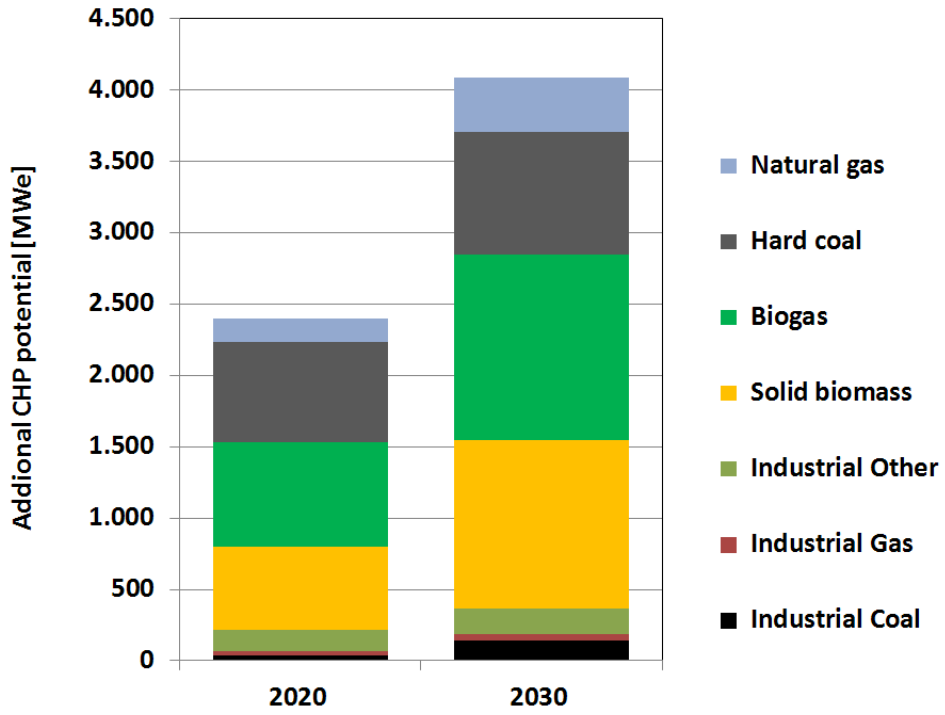

Figure 7 - Additional economic CHP potential till the year 2030

Coal is expected to remain the major fuel for cogeneration in Poland in the period till 2030. The expected increase of cogeneration in the future will be based on extended capacities of existing cogeneration plants, introduction of cogeneration in electrical plants and industry and large increase of cogeneration plants using bio energy fuels (solid biomass and biogas). Growth of natural gas cogeneration will be rather moderate with only 10% share of total new expected cogeneration capacities, where dominating share with more than 60% will have solid biomass and biogas capacities and with almost 30% share new cogeneration plants on coal and other fuels.

2.1.6 CODE2 - Bio energy potential assessment

An analysis of Bio CHP potential for the Poland was carried out within CODE2 project, based on published bio –energy forecasts and member states own reporting with a "score cards analysis". The analysis suggests that the potential for bio CHP growth till 2030 is very huge as heat generation could be increased for more than factor 4 to **1,8 Mtoe** (see annex 4). This growth is in line with the presented national RES CHP potential in this period[19], where close to 1.200 MWe and 1.300 MWe of the RES CHP capacity on wood biomass and biogas are foreseen, which could generate more than **2,5 Mtoe** of heat from RES.

2.1.7 CODE2 Micro CHP potential assessment

The CODE2 micro CHP potential analysis estimated that the market potential in the year 2020 for micro CHP units in Poland is around 1.000 units per year (30 MWe - 300 units of ±1 kWe in households and 750 units of ±40 kWe in services). Expectations till 2030 are significantly higher and reach more than 30.000 CHP units yearly (200 MW), majority of them in households. Although the current market conditions are still not enabling the economic feasibility of the smallest CHP

investments, assessed potential shows on the huge business opportunity for manufacturing of small CHP units in Poland as with existing broad knowledge on machinery and electrical appliances manufacturing that could create huge number of new jobs. For more information about the analysis see Annex 3.

2.2 Considering the framework of the EED

We assume that EED implementation is very exacting task which should be well coordinated and carried out as part of the whole energy policy process with integration of large number of relevant stakeholders. Successful implementation of EED should have several positive effects on cogeneration development in Poland.

Efficient heating and cooling as new objective of the Energy Efficiency Directive (EED)[20] could bring important benefits to the future planning and utilization of traditionally well-developed heat market in Poland with benefits for further development of cogeneration as well. EED requirements fit well with the Poland latest strategic orientation toward 20% improvement of the energy efficiency to 2020[21].

- **New assessment of heating and cooling potential** (Article 14) could bring new information of the real technical potential and advantages of cogeneration and DHC options. CBA for market potential could contribute to better awareness of the cogeneration opportunities in all sectors and potential contribution to the national strategic climate energy goals with approval of necessary additional adequate measures for the cogeneration support.
- **Clear priorities in heat supply** – new comprehensive approach as basis for the shaping of local legislative rules and practice on municipality level to enforce local energy planning and new sustainable investments in the heat supply.
- **Assessment of energy efficiency potential in gas and electricity infrastructure** (Article 15(2)): as cogeneration has positive influence on better infrastructure utilisation, decrease of losses and load balancing, assessment should better position the role and contribution of cogeneration units to the energy efficiency in gas and electricity grids.
- **Article 15: Access to electricity networks and priority of dispatch -** implementation could introduce several important improvements and new issues for cogeneration units:
    - Enable conditions for introduction of system services from cogeneration (demand response, balancing, etc.).
    - Simplification of administrative procedures for micro-CHP - **simple notification "install and inform"**, net metering, etc.

[20] Commission Directive 2012/27/EU on energy efficiency.

[21] "Energy Policy of Poland until 2030" - the supporting measures in the energy policy of Poland at the regional and local level include aims regarding fuel and energy savings in the public sectors, maximising the use of renewable energy sources for generation of electricity, heat and cold, increasing the high-efficient CHP in district heating and cooling systems.

- **Article 7: Energy efficiency obligation schemes –** energy supplier's programmes to fulfil 1.5% energy saving target per annum will most probably include also cogeneration and will accelerate new investments[22].
- **Article 8, 9, 18: Promotion and obligation of energy audits, energy management, energy services and individual metering** will improve the conditions for better planning and implementation of cogeneration projects in all sectors (better data availability, raise of awareness, better support, etc.)

3. How do we arrive there? : The Roadmap

3.1 Preliminary remarks

Having in mind current economic conditions (before the end of support in 2013) for cogeneration units in Poland presented by the following cogeneration economics matrix (Table 2) is prerequisite for developing a workable future scenario for cogeneration in Poland.. Hopefully we can observe that for the majority of cogeneration categories we can talk on **"normal"** and **"modest"** economic conditions provided by the existing support scheme which is triggering interest in new investments[23]. In spite of prevailing rather favourable economic conditions we can document some exceptions only in micro size class:

- **Micro fossil cogeneration:** economics for the smallest house micro-CHP units (nano 1 – 5 kW_e) is still "**poor**" – negative return due to still high investment costs of the technology,
- **Micro RES CHP:** economics is in general "**poor**" and is not enabling proper return on investments (too high costs of market premature technology).

Table 2 - CHP economics matrix

Poland	Micro		Small & Medium		Large		
	up to 50kW		*up to 10 MW*		*more than 10 MW*		
	NG	RES	NG	RES	NG	Coal	RES
Industry							
District heating							
Services							
Households							

[22] Support of cogeneration could be used also as alternative measure to the energy suppliers obligation schemes to fulfil 1,5% energy saving target per annum.

[23] Due to current gap in the granting of support, several planned investments are stopped waiting for the new support conditions.

Legend:

"normal"	CHP Investment has **good economic benefits**, return on investment acceptable for the investors, **interest for new investment exists**; there are no significant economic barriers for the implementation.
"modest"	CHP Investment has **modest/limited economic benefits** and return on investment(Y?), **limited interest for new investments**.
"poor"	CHP Investment has **poor or negative return on investment (Z?) or is not possible due to other limitations**, **no interest/possibilities for new investments**.
	Not applicable for the sector
NG	**Natural Gas** or appropriate fossil fuel
RES	**Renewable energy sources** (wood biomass, biogas, etc.)

Based on the **Table 2** the current framework is providing a proper basis for further development of cogeneration in Poland in all sectors where the largest economic cogeneration potential is assed: RES CHP units (biogas and solid biomass), large CHP units on coal and industrial CHP units on natural gas and other fuels. How to preserve a similar stable condition also in the future is a present challenge beside additional efforts needed to establish incentive framework also on new emerging small scale technologies (fuel cells, Stirling engine, etc. especially on micro level and for utilisation of RES). How to fulfil this and overcome other barriers and create incentive framework to realize as far as possible the assessed economical cogeneration potential is key goal of the following Roadmap strategy.

3.2 Overcoming existing barriers and creating a framework for action

The main requirement to achieve the measurable goals of the cogeneration strategy we should establish a proper supporting framework & different specific measures to address identified barriers.

Following the publication of the **Energy Policy of Poland until 2030** and recent Poland energy policy orientation, energy efficiency and RES are key priorities to achieve EU goals for the year 2020 and 2030 where cogeneration is one of the key technologies for the implementation.

The following **Strategy for development of cogeneration till the year 2030** with next three key quantitative goals for cogeneration would result in a clear growth scenario for cogeneration in Poland.

1. **Electricity generation in high efficiency cogeneration should double till the year 2030 compared to 2006 to 48 TWh;**
2. **High efficiency cogeneration on RES should reach at least 20% of total cogeneration capacity installed in the year 2030.**
3. **Enforcing sustainable local energy planning to enable sustainable solutions for heat supply with special emphasis on further development of district heating and cooling (DHC) with cogeneration, use of RES and waste heat utilisation.**

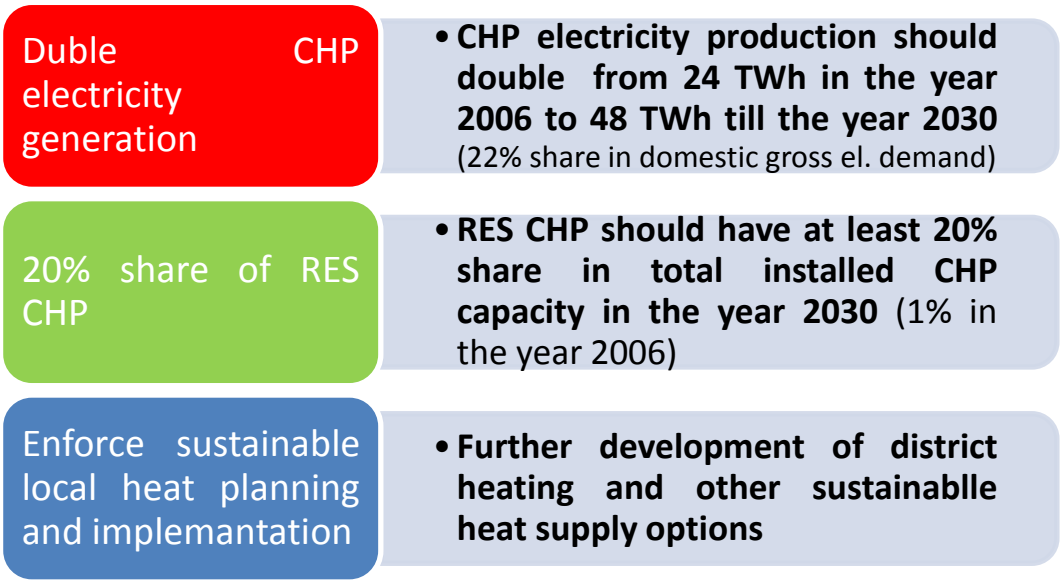

Figure 8 - Key goals of the Strategy for development of cogeneration till the year 2030

The main requirement to achieve these measurable goals of the cogeneration strategy we should establish a **proper supporting framework with the following different specific measures to address the barriers identified and fill policy and market gaps.**

Establishing long term stable legal framework for cogeneration

To set the framework for action a vision and set goals for cogeneration in existing strategic, policy and action documents on the national level, should be better reflected in the related executive legislation and support instruments to enable a meaningful contribution of cogeneration to the EU and national goals.

The Ministry of Economy should **accelerate legislative procedures** for approval of all cogeneration related legislation (Energy law renewal, issuing new Renewable law and all related executive legislation for support and operation of cogeneration) and especially the notification procedure within the DG Competition **to establish a long term stable legal framework for cogeneration.** Establishing better actors' coordination and cooperation in preparation of legal framework for cogeneration would contribute to the final quality and success of the framework.

Modify the CHP & RES certificates support scheme as necessary to achieve a stable and effective system.

Overcoming the current gap in cogeneration support with fast approval of all necessary legislative acts is an urgent task of the Ministry of Economy. The final goal is **to establish midterm, a stable and predictive support environment** (at least till the year 2020, orientated toward 2030) for implementation of a cogeneration growth strategy following set goals. Special focus on instruments for assuring sufficient economic incentive for investors should be on:

- setting different levels of the support for the existing and new installed CHP plants,

- transparent and active regulation of the support scheme witch should if possible include some elements for mitigation of excessive energy market volatility especially the current extremely low electricity prices, fluctuation of fuel prices, inclusion of all environmental costs (ETS, IED), etc.,
- setting a predictable behaviour of the support scheme of a time period of the support to enable investors to calculate a reliable return on investment[24],
- keep the support for wood biomass co firing for cogeneration plants.

Providing measures to assure competiveness of district heating networks to encourage development of additional cogeneration in DH in Poland

Considering existing huge cogeneration heat supply in district heating network and large assessed economic potential, Ministry of Economy should devote special concern to further development and competitiveness of district heating systems. New instruments are proposed to support energy efficiency and environmental retrofit in DH and assure the competitiveness of DH compared to the other individual heating alternatives:

- Subsidies (EU funds) and soft loans for energy and environmental retrofit and extension of district heating system with cogeneration and use of RES,
- Active programs and financial support of new connections to the district heating network,
- Simplification of administrative procedures (simple standardised procedures), obligatory connections for new buildings in the DH area (effective legislation provision),
- Improvement of heat price regulation – better reflection of market conditions and cogeneration specifics (implementation of the benchmarking method for the determination of heat prices).

Enforcing the local energy planning is ground for sustainable heat supply

Improving the current legal framework for provinces on their obligation to develop the "objectives for the heat, electrical energy and gaseous fuel supply plan" within the process of implementation of EED, is important task of the Ministry of Economy. This will enable quality energy planning and the selection of sustainable heat supply alternatives. The Ministry of Economy should consider the following actions:

- Setting clear deadlines for the preparation of "objectives" and legal sanctions for provinces if they do not comply with the Energy law.
- Setting clear sustainable heating mode priorities with proper legislative provisions for implementation at the municipal level and with special focus on district heating and cooling and the use of RES.
- Providing financial and expert support, training for municipal staff and development of a standardized planning tool for local heating and cooling..

[24] Maximum 10 years supporting period prescribed by State Aid guidelines is usually to short for return of investment for larger CHP units.

Support for development of new financing & business models is key for the project implementation facing lack of private capital in the economic crisis

The Ministry of Finance in cooperation with the Ministry of economy should establish necessary conditions which will enable the further development of new financing models for the implementation of energy efficiency projects by ESCOs and other private investors:

- Improving legislation on energy contracting, public private partnership and ESCO project implementation (clear legal basis for constitute of ESCo contracts, exclusion of ESCo contracts from municipal depth, ownership issues, etc.)
- Preparing clear legislation interpretation and guidelines for public sector on ESCO project implementation
- Inclusion of the ESCO concept in the subsidies program for more efficient allocation of public founds[25]
- Training and promotion activities for the potential customers, banks, and implementation of pilot projects[26].

Raise of awareness and promotion of cogeneration is necessary for development of small scale and micro cogeneration

Several responsible ministries should coordinate and steer wide promotion campaign on advantages of cogeneration technology for Poland on all levels including:

- Assessment of the economic benefits of faster development of the small and micro scale cogeneration in the area not covered by the district heating network:
  - establishing the domestic CHP manufacturing - creating new jobs),
  - support of the electrical grid (improving the quality of electricity supply).
- Promotion activities, good practice exchange
- Incorporation of cogeneration in education and research programs

Precise overview of needed actions, deadlines and responsibilities for the implementation of **the Strategy for development of cogeneration till the year 2030** is shown in Annex 6 (**Table 5**)**.** To build up on the existing successful measures several actions are taken from Energy policy of Poland until 2030, updated with recent new proposals of actions[27].

[25] Subsidies programs eliminate the possibility of ESCO co-financing. High subsidy rates discourage local government units from using other forms of financing (ESCO market in Poland - current state and development perspectives, IEE, March 2012).

[26] Public private partnership has been unpopular among local government units, institutional capacity needs to be increased and trained (contracting, risk identification and allocation, etc.) to enable further development of this efficient implementation model.

[27] Incorporated tasks from Energy policy of Poland until 2030 are referred with measure title in italic text.

3.3 Roadmap impact assessment

Following developing trend in recent years approximately 30% of assed cogeneration economical potential could be economically exploited by further use of the already established support mechanisms till the year 2030 as **"business as usual"** but the potentials will be far away from being completely fulfilled using this approach

With the proposed **Road map Cogeneration strategy** implementation we can significantly improve the environment for cogeneration development and facilitate faster and more balanced growth of cogeneration utilisation in several applicable areas: district heating, industry, services and agriculture[28]. We have used the following standard energy and environmental indicators for the Roadmap impact assessment:

- **Electricity generation from cogeneration:** cogeneration could be almost doubled till the year **2030 to 48 TWh** from existing 24,4 TWh in the year 2006 (27 TWh in 2012). The largest generation growth could be implemented in new CHP plants using biogas and solid biomass.
- **Share of cogeneration electricity in gross electricity demand:** in the year 2030 cogeneration could contribute at least **22% of the final electricity demand** compared to the current 16% (an expected growth of the gross electricity demand in the period 2010 – 2030 is more than 50%)
- **Heat generation from cogeneration:** 252 PJ of current cogeneration heat generation could be increased to the more than **440 PJ in the year 2030**.
- **Share of cogeneration heat in the final heat demand:** more than 40% of the expected heat demand in the year 2030 could be supplied by cogeneration compared to current 25% share.
- **Primary energy savings (PES): 47 TWh**[29] **or 4,1%** of the current primary energy supply could be reached by the cogeneration. Additional cogeneration units could contribute around **20% i.e. 3 Mtoe** of the Poland indicative primary energy saving target 13,6 Mtoe in 2020.
- **CO_2 savings:** potential cogeneration CO_2 savings in the year 2030 could reach up to **30 million tCO_2**.[30]

Graphical presentation of used electricity indicators for Business as usual and Roadmap scenario is shown in **Figure 9**. Removal of barriers and activities foreseen in Roadmap scenario would especially speed up the modernisation of large cogeneration and replacement of heat only boilers in existing smaller district heating systems and enable faster utilisation of RES in cogeneration. Roadmap scenario would have several benefits also for faster renovation and development of cogeneration in industry, resulting in increased competitiveness and new jobs.

[28] We are still facing lack of proper assessment of small scale and micro CHP potential in households, which is not included in this assessment.

[29] Calculated by substitution method – new developed method for assessment of actual achieved savings, which is higher than 39 TWh assessed by the EED methodology.

[30] General estimate assuming achieved PES and CO_2 emission factor for coal (coal has the largest share in CHP fuel consumption, beside use of RES).

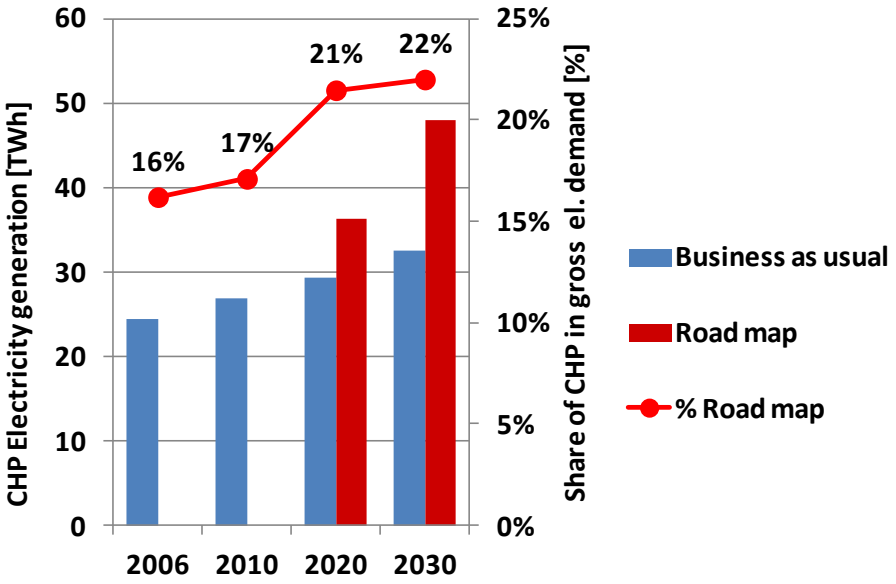

Figure 9 - CHP Electricity indicators for Roadmap and both scenarios

Within CODE2 project two approaches for assessment of primary energy savings (PES) and CO_2 emissions savings are used to demonstrate advantages and contribution of CHP technology to the reduction of energy use and CO_2 emissions:

1. **Methodology prescribed by EED** (according to Annexes I and II) [31]
2. **Substitution method –** new developed method for assessment of actual achieved savings[32]

New CHP generation proposed by Road map would contribute **39 TWh PES** calculated by the EED methodology or **up to 47 TWh of PES (169 PJ)** calculated by substitution method as shown in Table 3. Especially reconstructed CHP plants which are replacing existing old steam turbine on coal and natural gas plants contribute the majority of the potential PES which is important from the perspective of national goals till the year 2020 and 2030. Real potential savings by substitution method are for almost 20% larger than assessed savings by EED methodology where comparison to the best available alternative technology for separate electricity and heat generation do not reflect the actual savings in the country.

[31] **EED method** is used at a member state level today for national reporting to the European Commission and at project level for determining if a specific CHP plant is highly efficient. In the methodology, the efficiency of each cogeneration unit is derived by comparing its actual operating performance data with the best available technology for separate production of heat and electricity on the same fuel in the market in the year of construction of the cogeneration unit using harmonized reference values which are determined by fuel type and year of construction. More about PES assessment methodology you can find in Annex 7.

[32] **Substitution method** has been developed within the project and estimates the amounts of electricity, heat and fuel which are actually replaced by additional new CHP based on a projection of the supply base changes in the member state supply over the period are calculated. The situation in 2030 is compared to the current status in the country.

Assessed PES potential of CHP (39 to 47 TWh till 2020) is around 20% of the 158 TWh (13,6 Mtoe) set indicative national target of primary energy savings in the year 2020 in NEAP 2014 [23] which mean that implementation of CHP roadmap can contribute significant part or even increase the foreseen national goals for the year 2020 and additionally contributes to the new goals for the year 2030.

By using same approach potential real achievable CO_2 savings by substitution method are 30 Miot of CO_2, much higher than 3 Miot CO_2 savings by EED methodology[33] as shown in Table 3. By increasing the share of renewable energy and faster transition to natural gas a potential CO_2 savings would be even higher.

Table 3: Saving of the primary energy and CO_2 by the Poland CHP roadmap till 2030

	Substitution method		EED method	
	Business as usual	**Road map**	**Business as usual**	**Road map**
PE saving	13 TWh/a	**47 TWh/a**	11 TWh/a	**39 TWh/a**
CO_2 saving	9 Mio t/a	**30 Mio t/a**	1 Mio t/a	**3 Mio t/a**
- per kWh_{el}*[34]	1,52 kg/kWh_{el}	**1,43 kg/kWh_{el}**		

The advantages of the proposed CHP Roadmap strategy are evident, as the cogeneration could contribute more than 1/5 of the future electricity and more than 2/5 of the heat demand in Poland, doubling the today's electricity generation and significantly contributing 4 Mtoe of the primary energy savings and at least 30 Mt of the CO_2 reduction till 2030. Further development of cogeneration would have several broader economic benefits by reinforcing of the domestic cogeneration manufacturing and support services and creation of new jobs.

[33] CHP plants using renewable energy are not achieving CO_2 savings by EED methodology (compared to separate renewable generation), but in reality they are replacing current and new fossil generation.

[34] This value represents the CO_2 reduction of the power generation. It includes the avoided CO2 emissions from fuel savings for separate heat generation in boilers; it must not be confused with the considerably lower CO2 emissions of the substituted condensation electricity or with even lower emissions of compared power production according to the BAT approach in accordance with the EU CHP directive reference values.

4. Conclusions

The Presented Cogeneration Roadmap for Poland, develops a scenario for growth of cogeneration in Poland and provides several advantages and benefits of exploitation of the estimated more than 4.000 MWe economic potential of high efficiency cogeneration in Poland. By removing the listed barriers and facilitating faster and more balanced growth of high efficient cogeneration utilisation in all applicable sectors till the year 2030, cogeneration in Poland could:

- **Supply 48 TWh or more than 22% of gross final electricity demand till 2030.**
- **Provide more than 50 TWh of the additional heat supply.**
- **20% of the total installed cogeneration capacity would use RES.**
- **Reduce the CO_2 emissions for up to 30 miot CO_2.**
- **Contribute around 20% to indicative target on primary energy savings and 20% to set targets on Energy Efficiency and RES electricity generation till the year 2020.**

Roadmap implementation would have several other positive effects on development of new energy services, local cogeneration technology providers, on new jobs creation, reduced pollution and would have significant benefits for the whole economy in the sensitive period of sustainable economic crisis recovery.

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Annex 1: Stakeholder group awareness assessment

Users	
Industry	Rather high level of awareness about the cogeneration in industry due to long tradition of cogeneration in process intensive industry. Large potential on several locations is not resulting in new investments due to uncertain future support and too short support period.
Utilities	The cogeneration is especially well developed in large district heating systems, where cogeneration has old tradition and huge potential for new investments.
SMEs	Cogeneration awareness in SMEs, service sector, including public sector, is still on a relatively low level, due not proper economic incentives for new investments.
Households	Low level of awareness on micro cogeneration in households due to high share of district heat supply and not yet available economical solution of micro-CHP on the market.
Market and supply chain	
Manufacturers/ Technology providers	Several national and international cogeneration manufacturers and technology providers are key actors on the large and medium scale market (>1MWe). Small and micro-CHP market is still in premature phase.
Installation companies	The awareness about cogeneration on small scale level is still on a quite low level.
Grid operators	Grid operators are traditionally acquainted with cogeneration. The preferential terms for the connection o renewable energy sources (capacity <5MW_e) and cogeneration (<1MW_e) at 50% reduced connection costs (50% of the connection cost is paid by grid operator) is important incentive for these units.
Consultants	Excellent knowledge and awareness on large and medium scale cogeneration, detailed know-how on small scale is often missing.
Architects	The awareness about cogeneration is on a quite low level.
Banks, leasing	The financial sector is financing larger cogeneration investments. Although current uncertainty with future support of cogeneration has stopped majority of the financial activities.
ESCOs	Although the Polish ESCO market has a significant potential, it still remains at the initial stage of its development. The number of its players – both ESCOs and clients – is rather small. Limited number of cogeneration projects has already been implemented in industry, some of ESCOs are focused also on micro-CHP projects.
Policy	
Policy makers on different levels	Improving energy efficiency is the first priority of Energy Policy of Poland until 2030, where cogeneration has important role. The main actors for cogeneration promotion on a state level are Ministry of Economy infrastructure and Energy Regulatory Office, responsible for the energy policy and certificates support scheme implementation (ongoing process of legislation renewal which is resulting in current gap and huge uncertainty about the future support is the key barrier for further cogeneration development). Shifting responsibility for security of heat supply to the municipal level has increased the role of local policy makers, traditionally aware of cogeneration in district heating system, although the awareness on smaller decentralised cogeneration options is still on the low level.
Energy agencies	Energy agencies offer services and support to the municipalities in preparation of local energy strategies ("Objectives for heat, electricity and gaseous fuel supply plan") where cogeneration is one of the important efficient supply option.

Planners	Cogeneration is well known on national and municipal level, but usually the project initiators are technology providers not planers.
Influencers	
Sector organisations	There are several strong organisation, like Polish Cogeneration Association (PTEZ) and Polish District Heating Chamber of Commerce that are supporting cogeneration in Poland.
General public	General public awareness about cogeneration in Poland is good, especially very positive attitude to cogeneration in district heating systems. High - close to 50% share of district heating in total heat supply in Poland and limited economics are key reasons for low awareness on local small scale cogeneration.
Media	Media has positive attitude in reporting on cogeneration.
Academic area/ Research	Long cogeneration tradition in district heating and industry is resulting also in strong research and academic support and awareness.
NGOs	In general NGOs support cogeneration although they are sensitive to the environmental aspects of coal cogeneration (air and environment pollution).

Table 4 - Ratings of CHP awareness of different influential groupings

Legend:

- Active CHP market
- Interest in CHP
- Early CHP awareness
- Low CHP awareness
- Poor CHP awareness

Annex 2: Economic assessment of typical CHP projects

Sector		Heating in services and multifamily houses	Industry and service process heat and heating supply	District heating	Bio gas CHP (agriculture, waste, industrial wastewater or sewage treatment)
		50 kWe ICE	1 MWe ICE	10 MWe CC	0,5 MWe Biogas
Technology		**ICE**	**ICE**	**CC**	**ICE**
Power	**MW_{El}**	**0,05**	**1**	**10**	**0,5**
Efficiency-el.	Eff_{EL}	34%	40%	46%	38%
Efficiency-th.	Eff_{H}	56%	45%	42%	37%
Efficiency-sum.	Eff_{SUM}	90%	85%	88%	75%
Operation	**h/a**	**4.000**	**6.500**	**3.500**	**7.500**
Fuel	MWh	588	16.250	76.087	9.868
Electricty	MWh	200	6.500	35.000	3.750
Heat	MWh	329	7.313	31.957	3.651
Investment	**EUR**	**115.000**	**1.100.000**	**9.500.000**	**1.850.000**
	€/kWel	2.300	1.100	950	3.700
O&M costs	% of Inv.	5%	7,0%	3%	4%
	€/MWh	28,8	11,8	8,1	19,7
Price of fuel	€/MWh	47	42	42	20
Value of electricity	€/MWh	115	65	47	47
Other market revenues	€/MWh				
Value of heat	€/MWh	53	46	46	10
Support					
Electricty	$€/MWh_{El}$	35,7	35,7	35,7	82,95
Other support or benefits	€/a				
Investment subsidy	€				
Costs & revenues					
Fuel	€/a	-27.794	-676.403	-3.167.104	-197.368
Electricty	€/a	23.020	422.500	1.637.129	175.407
Heat	€/a	17.294	338.202	1.477.982	36.513
Support	€/a	7.144	232.165	1.250.120	311.071
Other market revenues	€/a	0	0	0	0
O&M costs	€/a	-5.750	-77.000	-285.000	-74.000
TOTAL	**€/a**	**13.914**	**239.464**	**913.126**	**251.622**
SPB	**years**	**8,3**	**4,6**	**10,4**	**7,4**
IRR	**%**	**4%**	**17%**	**-1%**	**6%**

Annex 3: CODE 2 micro CHP potential analysis for Poland

micro-CHP potential summary Poland

Country statistics

Population: 38 500 000 (2010)
Number of households: 14 800 000 (2010)
GDP per capita: € 16 200 (2010)
Primary energy use: 66 000 ktoe/year (2010)
GHG-emissions: 401 Mton $CO_{2,eq}$/year (2010)

Household systems (±1 kWe)
Boiler replacement technology

Present market (2013)
Boiler stock: 1 230 000 units
Boiler sales: 217 000 units/year

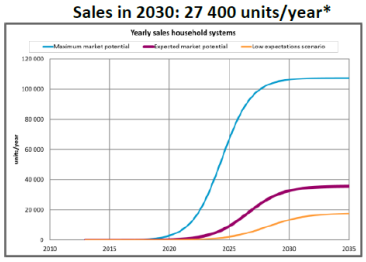
Potential estimation

Indicator	Score
Market alternatives	0
Global CBA	2
Legislation/support	1
Awareness	0
Purchasing power	1
Total	**4 out of 12**

Expected final market share: 17% of boiler sales in Household sector

Yearly sales

Sales in 2020: 300 units/year*
Sales in 2030: 27 400 units/year*



Stock

Stock in 2020: 740 units*
Stock in 2030: 102 000 units*
Stock in 2040: 345 000 units*

Potential savings in 2030

Primary energy savings:
2 PJ/year*
50 ktoe/year*
GHG-emissions reduction:
0.3 Mton $CO_{2,eq}$/year*

SME & Collective systems (±40 kWe)
Boiler add-on technology

Present market (2013)
Boiler stock: 170 000 units
Boiler sales: 30 400 units/year

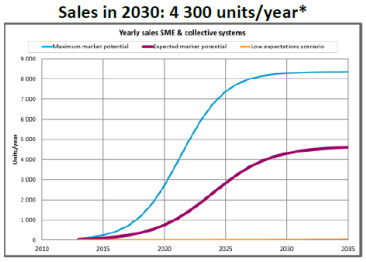
Potential estimation

Indicator	Score
Market alternatives	0
Global CBA	4
Legislation/support	1
Awareness	0
Total	**5 out of 9**

Expected final market share: 15% of boiler sales in SME & Coll. sector

Yearly sales

Sales in 2020: 750 units/year*
Sales in 2030: 4 300 units/year*



Stock

Stock in 2020: 4 500 units*
Stock in 2030: 29 000 units*
Stock in 2040: 46 000 units*

Potential savings in 2030

Primary energy savings:
21 PJ/year*
512 ktoe/year*
GHG-emissions reduction:
3.4 Mton $CO_{2,eq}$/year*

*Corresponding to the expected potential scenario.

micro-CHP score card Argumentation

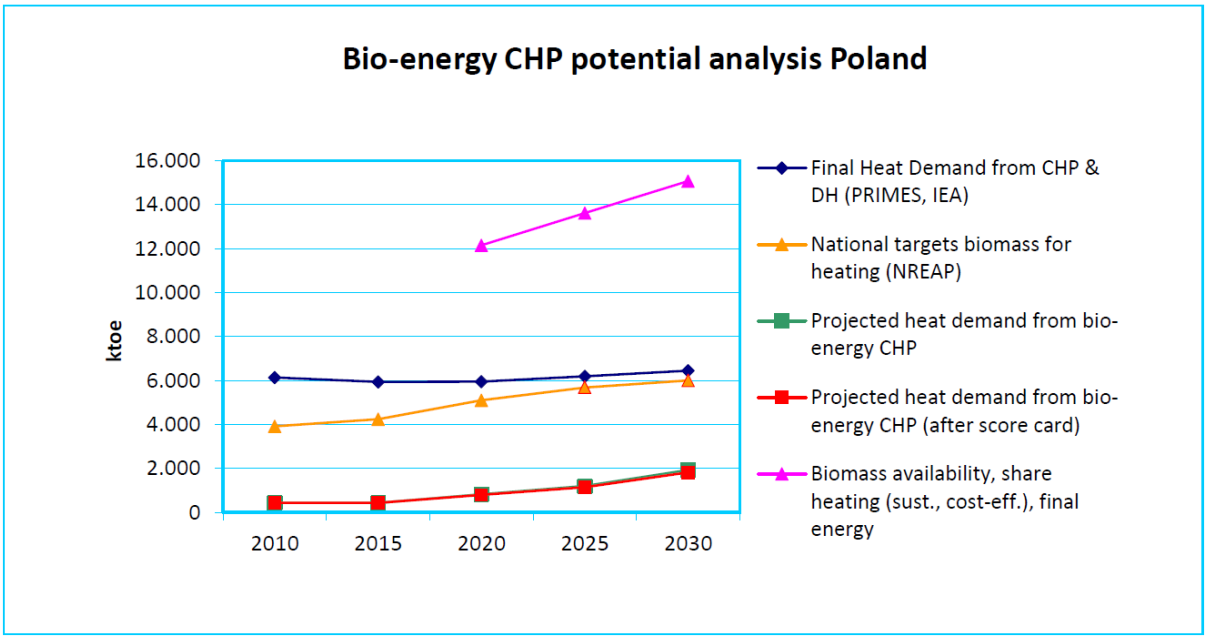
The score card is used to assess the relative position of an EU country based on current regulations, markets and economics. The score itself functions as input to the implementation model to 2030.

±1 kWe systems (Households) Boiler replacement technology	±40 kWe systems (SME & Collective systems) Boiler add-on technology
Scorecard	**Scorecard**
Indicator / Score Market alternatives: 0 Global CBA: 2 Legislation/support: 1 Awareness: 0 Purchasing power: 1 **Total: 4 out of 12**	Indicator / Score Market alternatives: 0 Global CBA: 4 Legislation/support: 1 Awareness: 0 **Total: 5 out of 9**
Market alternatives	**Market alternatives**
*There is **strong competition of other heating technologies in households**: extensive district heating systems in towns, heat pumps (low electricity prices), wood biomass (cheap heating source).*	*There is **very strong competition of other heating technologies in services:** extensive district heating systems in towns, natural gas is more penetrated only in south and west part of Poland, heat pumps (low electricity prices).*
Global CBA	**Global CBA**
*SPOT: **7 years***	*SPOT: **4 years***
Legislation/support	**Legislation/support**
***Existing limited support on micro CHP in households (certificates) are not providing sufficient incentive** for the economic CHP project implementation in households.*	***Current low support through certificates is not sufficient for the micro CHP investments in services** (only first few investments happened in recent years).*
Awareness	**Awareness**
*Due to the too high investment costs and not sufficient support for the economic implementation, **current awareness of micro CHP technologies for households is still very low** or poor on all levels.* ***Manufacturers are not yet active in the market.***	*Due to lack of good CHP practice examples, **awareness of CHP is still on the very low level**.*
Purchasing power	
*GDP: **€ 16 200 per year***	

Annex 4: CODE 2 Bio-energy CHP Potential Analysis for Poland

Bio-energy CHP potential analysis Poland

Figures (projections)	2010	2020	2030
Final heat demand from CHP and DH (PRIMES, IEA), ktoe	6.133	5.948	6.447
(Projected) heat demand from bio-energy CHP and DH (after score card), ktoe	429	785	1.816
Bio-energy penetration rate in CHP markets (2009: EEA, Eurostat)	7,0% (2009)	13,2%	28,2%
Biomass availability, share heating (sust., cost-eff.), final energy (Biom. Futures), ktoe		12.143	15.072



Framework Assessment (Score card)	Score	Short analysis
Legislative environment	+ 2 (of 3)	Green certificate support scheme; CO2 reduction goals; High cost of investment loans; The cost of CHP connection to the power grid
Suitability of heat market for switch to bio-energy CHP	++ 3 (of 3)	Expected growth of heat demand in industry in the future
Share of Citizens served by DH	++ 3 (of 3)	The share of citizens served by DH is over 50%; Energy plan: one biogas

		plant in each municipality should be created by 2020
National supply chain for biomass for energy	++ 3 (of 3)	The biomass market potential is sufficient
Awareness for DH and CHP	++ 3 (of 3)	The share of citizens served by DH is over 50%; Extension of CHP biomass co-firing Good practice of CHP biomass co-firing

Comments on country analysis

General comments

- The national framework assessment through the scorecard results in a very good score (14 of 15 possible points).
- Thus, it is projected that the growth potential for bio-CHP until 2030 will be exploited to 93%.
- The possible bio-CHP penetration rate in 2030 (2030 dot of green curve) under ideal framework conditions is seen at 29,7%
  (the country's RE target according to RED (28/2009) is at 15% in 2020)
- The share of bio-fuels in CHP (bio-energy penetration rate in CHP markets) is expected to increase from 7% (2009) to 28,2% (2030)
- The national biomass availability (cost-efficient, sustainable; pink curve) is sufficient to enable the projected growth; however, these biomass resources include types of biomass which are currently not usually used in CHP, but are expected to be utilisable by 2030

Specific issues

- The projected development of CHP heat demand (PRIMES, blue curve) foresees stable figures with a slow growth after 2020
- National targets for biomass for heating (yellow curve) also see a growth until 2020, which is expected to continue in a lesser intensity
- The growth projections of the bio-energy CHP heat demand (green and red curves) apply the average growth rates of both the blue and the yellow curve (weighting 50:50)

To be re-confirmed, checked

- Is maybe the growth in the bio-CHP market (red and green curves) too low between 2015 and 2020? Should the growth rate be adapted (e.g. weighting 20:80), so that it more follows the shape of the yellow curve?

Annex 6: Indicative timeline for the Roadmap implementation

Table 5 - Actions, terms and responsibilities for implementation of the CHP strategy

Actions	Deadline	Responsible bodies
1. Establishing long term stable legal framework for cogeneration		
Accelerate legislative procedures for approval of all cogeneration related legislation (Energy law renewal, notification procedure, issuing new Renewable law and all related executive legislation for support and operation of cogeneration). Establishing better actors' coordination and cooperation in preparation of legal framework for cogeneration till the year 2020 and 2030. Yearly preparation of a report evaluating progress achieved in increasing the share of electricity generated in high efficiency co-generation in total domestic electricity generation. *(task 4 of Measure 1.3: Stimulating development of cogeneration through support mechanisms, taking into account cogeneration from sources up to 1 MW and appropriate commune policy)*	End of 2014 Yearly evaluation	Minister competent for the economy President of the Energy Regulatory Office
2. Stable and effective performing of the CHP & RES certificates support scheme		
Maintaining the electricity support system for high efficiency cogeneration at the level ensuring profitability of existing units and investments in new generation capacity as well as predictability of this system over the next 10 years (till 2020 and 2030). Yearly evaluation of the efficiency of the cogeneration energy support scheme. *(task 2 and 4 of Measure 1.3: Stimulating development of cogeneration through support mechanisms, considering cogeneration from sources up to 1 MW and appropriate commune policy)*	End of 2014 yearly evaluation	Minister competent for the economy President of the Energy Regulatory Office
3. Raise of competiveness of district heating networks		
Supporting investments through soft loans and subsidies in high-efficiency cogeneration, reduction of electricity and heat grid losses and environmental retrofit of units ensuring cleaner and energy efficient production under the Operational Program Infrastructure and Environment and regional operational programmes (2014 – 2020). *(tasks of Measure 1.7: Supporting investments in energy saving through preferential loans and grants from domestic and European funds)*	End of 2014	Minister competent for economy Minister competent for the environment Province authorities Minister competent for regional development

Actions	Deadline	Responsible bodies
Preparation and gradual implementation of new principles of regulating district heat prices which would ensure elimination of the present cross-financing of combined heat and power generation with revenues from electricity generation and certificates through the implementation of the benchmarking method for the determination of heat prices. *(task1 of Measure 1.3: Stimulating development of cogeneration through support mechanisms, taking into account cogeneration from sources up to 1 MW and appropriate commune policy)*	End of 2014	Minister competent for the economy President of the Energy Regulatory Office
Introduction of the obligation connection to the heat network for new projects implemented in areas where such networks exist into spatial development plans. *(task 6 of Measure 1.3: Stimulating development of cogeneration through support mechanisms, taking into account cogeneration from sources up to 1 MW and appropriate commune policy)*	End of 2015	Province authorities, Municipalities
Preparation of a draft regulation on supporting district heat and cold energy production from renewable energy sources. *(task 3 of Measure 4.4: Introducing additional support instruments encouraging more extensive production of heat and cold from renewable energy sources)*	End of 2015	Minister competent for the economy
4. Enforce local energy planning		
Improve current regulation for municipalities on obligation to develop the "Objectives for the heat, electrical energy and gaseous fuel supply plan". *(task 3 and 3 of Measure 1.3)* Financial and expert support to municipalities (training, standardized planning tool, etc.). Priority to replacements of heat only boilers with cogeneration in local district heating networks. *(task 2 and 3 of Measure 2.42: Preferential treatment of combined generation as the technology recommended for building new generation capacity)*	End of 2015	Minister competent for economy Minister competent for construction Local government bodies Municipalities
5. Support for development of new financing & business models		
Preparing missing legislation on the energy contracting and public private partnership. Preparing a clear legislation interpretation and guidelines for ESCO project implementation. Inclusion of ESCO concept in subsidies programs.	End of 2015	Minister competent for economy Minister competent for Finance

Actions	Deadline	Responsible bodies
Training and promotion activities for the potential customers, banks, municipalities, etc. Implementation of pilot projects.		
6. Raise of awareness and promotion of cogeneration		
Assessment of the economic benefits of faster development of the small and micro scale cogeneration in the area not covered by the district heating network: • establishing the domestic CHP manufacturing - creating new jobs), • support to the electrical grid (improving the quality of electricity supply). Wide cogeneration information and promotion campaign on all levels (promotion, good practice exchange, education and research programs, etc.) *(Measure 1.3: Informational and educational campaigns promoting efficient energy use)*	2015	Minister competent for the economy Minister competent for education Minister competent for science and higher education President of the Energy Regulatory Office

Annex 7: Methodologies used to calculate the saving of primary energy and CO_2 emissions under the roadmap

Substitution method

This method has been developed in the CODE2 project. In doing this, two other approaches have been considered: 1) the "replacement mix method[35]" from the Munich FfE institute, which however cannot be used directly for a long term comparison as needed in CODE2; 2) a method used to calculate the CO2 saving resulting from a voluntary commitment of the German industry for CO2 reduction[36], however this method has been considered as too simple. Therefor the following more differentiated approach has been developed:

Based on an estimate of the increase in cogeneration electricity the thereby caused decrease of CO2 emissions and primary energy consumption is estimated. In this approach, an attempt is made to determine the actual quantities saved compared to the base year (e.g. 2010). Hence it refers to the actual saving of fuels for the production of the amounts substituted by modern CHP plants

a) of electricity and heat in the replaced or retrofitted old CHP plants

b) of electricity in power plants

c) of heat in boilers.

The savings result from a combination of three effects:

- CHP effect

- Technology effect (improved CHP technologies)

- Fuel switching (e.g. lower carbon content of natural gas compared to coal, CO2 neutrality of bioenergy)

The results show the savings actually induced by the expansion of CHP compared to the situation in the base year.

This approach differs fundamentally from the methods for checking the high-efficiency according to the CHP Directive or in accordance with ANNEX II of the EED (Directive 2012/27/EU on energy efficiency), in which a comparison between CHP and the best available Technology (BAT) of separate production of electricity and heat produced is carried out strictly on a same-fuel basis.

This procedure is considered to be inappropriate to deliver an estimate of the actual fuel saving quantities by CHP over a longer period, which is considered relevant value, representing meaningful the contribution of CHP to the long-term objectives of the EU to reduce CO2 emissions and primary energy consumption. The BAT approach of the CHP Directive has been developed to verify the high efficiency of individual plants, but not to determine actual saved CO2 emissions and primary energy quantities by CHP expansion.

In fact, the CHP expansion is closely associated with a replacement of old by new cogeneration technologies and a change in the structure of fuel away from coal to natural gas and bio-energy. These three developments,

- replacement of separate generation by cogeneration

- replacement of old by new cogeneration technologies

- replacement of carbon-rich by low-carbon fuels,

- can be usefully seen only as an integrated process.

[35] 10. FfE Forschungsstelle für Energiewirtschaft e.V., Energiezukunft 2050; http://www.ffe.de/die-themen/erzeugung-und-markt/257

[36] The calculation has been made by the VIK Verband der Industriellen Energie- und Kraftwirtschaft e.V., 2010, Unpublished.

To account for the uncertainties in particular with regard to fuel shares and technology development, a window of possible developments with an upper value and a lower value of emission reduction and savings has been determined. The different levels of results are due to assumptions about key parameters such as current share of electricity from cogeneration, which is replaced by electricity from new or retrofitted units, fuel shares in the replaced CHP plants, power plants and boilers as well as in the new CHP plants.

The results have been calculated based on the following input values: growth of CHP power production, share of current old CHP to be replaced by new installations and retrofitting, fuel efficiency and electric efficiency of new CHP and replaced CHP for different fuels, electric efficiency of replaced power from conventional power plants for different fuels, heat efficiency of replaced heat from boilers, corresponding fuel shares.

EED method

The Primary Energy Savings methodology of the EED is used at a country level for national reporting to the Commission, and at project level for determining if CHP is highly efficient. In the methodology, each cogeneration unit is compared with the best technology for separate production of heat and electricity on the same fuel on the market in the year of construction of the cogeneration unit and the harmonized reference values are determined by fuel type and year of construction.

The underlying principle is that, knowing that regularly new investments have to be made in new energy production units, it is necessary to compare CHP with the centralized production installation which could be built using the same fuel rather than assuming a displacement of a different fuel or introduction of a new fuel. It is a logical approach when looking at the decision making process of investors or a member state government. By investing in or supporting CHP, a certain electricity generating capacity will be produced by CHP and NOT by centralized production based on the same fuel (= principle of 'avoided production').

For the timeframe of the roadmap (between 2010 and 2030), and especially in countries where there is no overcapacity, it is relevant to compare installing a certain capacity (at national level) of CHP compared to installing new capacity with another technology (power plant + gas boiler). Older installations being replaced with state-of-the-art technology.is a typical reinvestment decision. New CHP-plant (or combination of smaller installations) would not necessarily lead to less production in older production installations, but would rather pre-empt investments in e.g. new CCGT investments.