D4.1 - Energy price assessment

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PROJECT SUMMARY

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Project Coordinator	Roberto Garay. TECNALIA roberto.garay@tecnalia.com
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Acronyms

CHP	Combined Heat and Power
COP	Coefficient of Performance
DH	District Heating
EC	European Commission
GOG	spot market pricing in competitive gas markets
GRP	Government Regulated Prices
H2020	Horizon 2020 EU Research and Innovation programme
HOB	Heat Only Boiler
LNG	Liquified Natural Gas
LT	Low Temperature
LTC	Long Term Contract
M	Month
OPE	Oil-Price Escalation
RES	Renewable Energy Sources
ULT	Ultra-Low Temperature
WTE	Waste-to-energy

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1. Executive Summary

The energy price assessment performed in this document provides a comprehensive review of the main heat production systems and primary energy sources associated with District Heating systems in Europe.

Performance levels and the required investments for different heat production systems are identified. The evolution of fuel costs over the last decades is reviewed, and present and future costs of main fuels for District Heating Systems are provided. All this is based on an extensive review of scientific and sectorial publications, comprising high level sources such as the European Union and the International Energy Agency.

The particularities of fuel supply to Europe, with the dominancy of few suppliers, and periodical crisis implies that security of supply is a critical issue when defining the primary energy mix of district heating systems. In this context, long term supply contracts and the evolution to spot markets in Western Europe is explained. Price fixation mechanisms and the particular context of DH operators are also explained.

Also, a section is devoted to developing business cases for the integration of Renewable Energy Sources (RES) in district heating systems. Economic metrics that will be used along the project are defined, particular considerations for district heating systems are provided and scenarios for profitable investments are defined.

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2. Introduction

RELaTED is a 4-year research & development project which will provide an innovative ultra-low temperature concept for thermal district energy networks with lower cost, fewer heat losses, better energy performance and more extensive use of de-carbonized energy sources than actual district heating concept.

District heating (DH) systems are one of the most energy efficient heating systems in urban environments. DHs are key systems in the de-carbonization of heating energy in European Cities.

Renewable and waste heat sources are foreseen at the same time as de-carbonized heat sources and the way to guarantee competitive energy costs with limited influence of fossil fuel supply price volatility. To achieve this, conversion of DHs is needed.

RELaTED will provide an innovative concept of decentralized Ultra-Low Temperature (ULT) DH networks, which allow for the incorporation of low-grade heat sources with minimal constraints. Also, ULT DH reduce operational costs due to fewer heat losses, better energy performance of heat generation plants and extensive use of de-carbonized energy sources at low marginal costs.

In this context, it is of vital importance to ensure the economic viability of DH systems in their transition to ULT. DH operators need to deliver competitive costs of heating energy when compared to isolated technologies in order to maintain their economies of scale.

RELaTED pays great attention to this issue. A complete Work Package is dedicated to “Economic Feasibility & Business Analysis” (WP4). The present document, Deliverable “D4.1 – Energy Price Assessment”, framed in Task 4.1 with the same name, provides an insight to energy costs in the context of DH.

A Comprehensive review of heat production technologies and associated fuels is performed. Present, medium and long-term energy costs are evaluated, and business cases for DH are identified. Local constraints, such as availability of biomass, geothermal energy, and supply sources for fossil fuels such as gas and oil are considered. The particular cases of security of supply are considered for the case of unique suppliers (e.g. Russian natural gas) in order to avoid excessive price volatility.

The information gathered in this task are later used within the project to select the most suitable heat production mix for each of the districts and surrounding regions within RELaTED

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3. Heating technologies in DH

District heating networks can be fed by various heat generation sources, including combustion plants (based on fossil fuel or biomass), CHP (combined heat & power) plants or renewable-based plants. The characteristics of each of these heat technologies are outlined in this section.

The combination of multiple heat sources is beneficial, especially for large district heating schemes, as it allows shifting from source to source depending on specific conditions and market prices. In Figure 1 is shown the heat production mix for European countries.

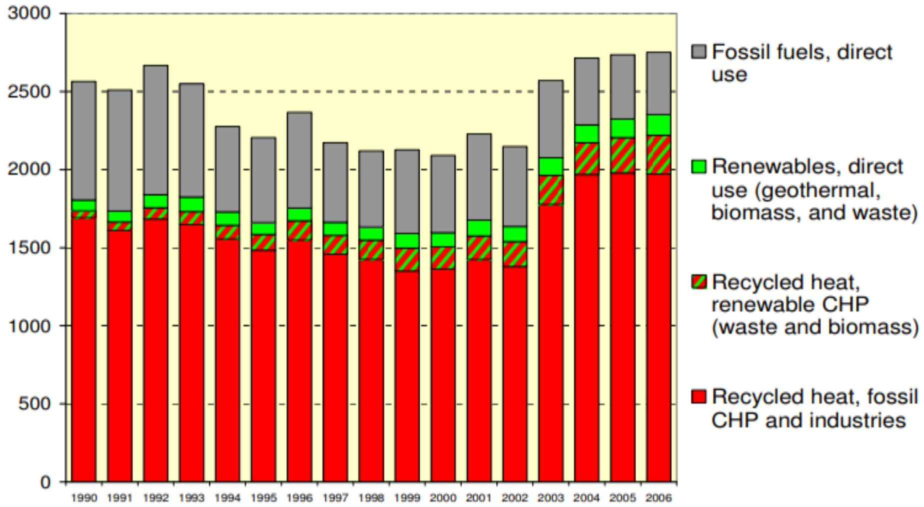

Figure 1 Heat sources for district heating in EU27 (PJ/year). Source: Dr Sven Werner, Halmstad University, quoted in [1]

The trend for last decade was to increase CHP and the objective for the following years is to inject renewable and waste heat sources.

As a summary, typical features (application, cost, production and performance levels) for each heat generation technology are listed in Table 1. More specific information on these technologies is provided in the relevant subsections.

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Table 1. Heating technologies for district heating

	Boiler stations	Combined Heat & Power (CHP)	Solar thermal plants (CSHP)	Heat pump systems
Typical application	Back-up or peak load coverage	Base load	Combined with additional heat generation systems	Base load or complement to renewable systems
Type of fuel(s)	Gas, oil, biomass, waste	Gas, oil, biomass, waste	Solar radiation	Low-temp. heat (geothermal, sewage or other)
Rated power (MW heat)	0.5 to 20 MW (gas), 0.3 to 5 MW (biomass), 15–50 MW (waste) [2]	2 to 50 MW (gas) [1], 10 to 50 MW (biomass, waste heat) [1][2]	3 to 50 MW [2]	10-15 MW per well (geothermal), 1-10 MW per unit (another HP) [2]
Service temperature	80-–140 °C [3]	80-–140 °C [3]	40-90 ºC	80–85 °C [2]
Performance levels	97–108% net efficiency [2]	Electric efficiency 29%, heat efficiency 64–77% [2]	25-60% from solar radiation	COP 1,7–3,8 [4]
Seasonality	Gas ~100%, Biomass 96–98% [2]	~90% [2]	High seasonal variation, storage necessary	Slight seasonal variation, depending on source
Investment cost	100 k€/MW (gas), 250–500 k€/MW (pellets), 0.5–1 M€/MW (wood chips/straw), >1 M€/MW (waste) [2]	2.6 M€/MW (biomass), 7–10 M€/W (waste) [2]	400 €/MWh/year [2]	2 M€/MW (absorption HP, geothermal) [2], 500–800 k€/MW (electric HP) [4]
Service span	30–40 years (gas), 20 years (biomass, waste) [2]	20–30 years (biomass) [5], 20 years (waste) [6]	30 years [7]	20–25 years [4]

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3.1. Boiler stations

Boiler stations are specifically dedicated to the generation of thermal energy, which is produced through combustion of fossil fuels (such as natural gas, heating oil, coal), renewable-sourced fuels (biomass), or incineration of solid waste. The transmission medium is typically water or steam.

As co-generation plants (described in the next section) are becoming more common (due to the advantage of providing electric power as well, unlike boiler stations), fossil-fuelled heating plants are currently built only as a back-up for peak load coverage or for small utility networks. Their installed power is usually limited (up to 5 MW), while combined heat and power is favoured for larger units.

In the case of fossil-fuelled boiler systems, the main advantage is provided by their centralised layout, which allows a more efficient removal of pollutants, compared with individual decentralised systems. While they also provide a higher efficiency than individual systems, this advantage is offset by distribution heat losses in the network. In special cases, condensing boilers can be used in such heating plants for improving their efficiency. The combination of boiler stations fired by different fossil fuels within a district heating scheme can also avoid the dependence on one energy source.

Conversion efficiencies of modern boiler stations are usually above 97% (based on lower heating value), and can exceed 100% if flue gas condensation is used [2]. Older coal-fired power plants used to have a much lower efficiency in the range of 30-40%.

Biomass-fired heating plants are being promoted within the EU since they provide a more sustainable energy source. Thermal energy is usually generated by the combustion of pellets, wood chips or residual wood products. Wood pellets are not economically advantageous for plants above 1–2 MW, as alternative fuels become less expensive for plants above this range. Large volumes for fuel storage can be helpful in securing provision and minimising deliveries.

Waste-to-energy district heating plants are based on the incineration of waste in a furnace. In this way, part of the energy content of the waste is recovered.

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3.2. Combined Heat & Power

Unlike in boiler stations, which are specifically dedicated to the production of thermal energy, in combined heat & power (CHP) systems thermal energy is produced as a by-product of electricity generation. The cogeneration of heat and electricity is more efficient than the boiler systems mentioned above, as the waste heat from electricity production can be recovered. This is achieved through a power station or heat engine that simultaneously generates electricity and heat. The provision of cooling is also possible through this technology, by using absorption chillers to produce cold from by-product heat (100–180 °C).

The efficiency of the total energy conversion (both electricity and heat) ranges from 60% to 80%, which greatly exceeds the efficiency of fossil-fuelled power plants [8]. In practice, the efficiency or viability of combined heat & power depends on the demand for both heat and electricity, which are rarely coupled in reality. If electricity production is the main goal, as is often the case, storage is necessary and efficiency decreases from theoretical values. Heat-driven operation, where heat production is the main goal, achieves a greater efficiency. If the cogeneration system is able to produce cooling, efficiency is further increased.

CHP plants for district heating are typically sized for providing approximately half the peak load [1], with peaks provided by boiler systems.

Typical fuels for cogeneration are not different to conventional power plants: natural gas, oil, renewable sources (biomass, solar thermal, geothermal) or solid waste. There is also the possibility of integrating solar PV generation. This distribution of fuels for EU-27 is shown Figure 2.

Gas-fired CHP is a well-established technology scalable to different sizes. Direct biomass CHP is currently technically and economically viable for large-scale plants only (above 10–20 MW). Gasification and ORC (Organic Rankine Cycle) technologies can be used to run smaller plants from biomass. Energy from waste is currently used for large-scale schemes, but it is expected that new technology developments will allow its adoption at smaller scale.

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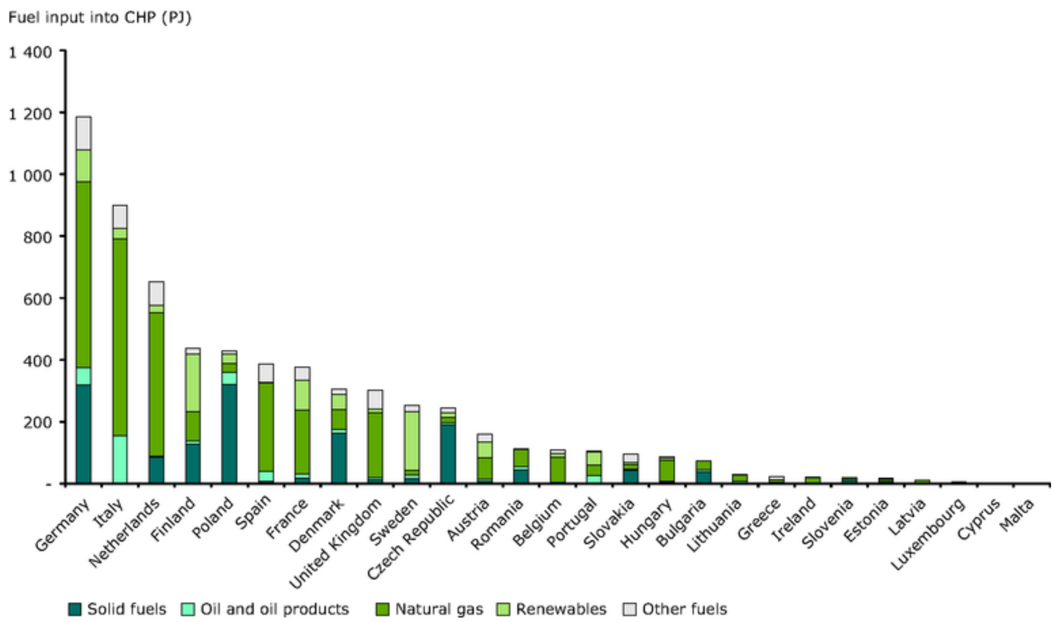

Figure 2. Fuel input to Combined Heat and Power plants in EU-27 and EEA countries in 2009. [13]

The European Union promotes cogeneration through its 2012/27/EU directive [9], with the double aim of increasing energy efficiency and securing energy supply.

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3.3. Solar Thermal Plants

Solar thermal plants are divided into Central solar heating plants (CSHP) and Building Integrated Solar Thermal Systems (BISTS). CSHP systems are large and centralized systems, usually situated far away from consumption point. On the other hand, BISTS are distributed systems installed near to the consumption point.

Firstly, CSHP provide hot water, heated by arrays of solar thermal collectors. In the case of centralised installations, the collectors are usually installed on the ground (as opposed to individual installations, which are usually installed over rooftops). This is especially true for Nordic countries, where industrial and agricultural land can be found at relatively low price.

Solar plants deliver the highest output in the summer season, when district heating load is low.

Due to the intermittent nature of solar energy supply, large-scale thermal storage (diurnal or seasonal) plays an important role for achieving a high solar fraction in these installations.

Solar thermal plants can also provide district cooling. Energy storage is much less relevant for this application, as usually cooling demand and solar energy supply are highly correlated.

The usual sizes of collector arrays range between 5000 and 50000 m^2, providing a thermal power from 3 to 50 MW. The largest solar system of the world, installed in 2017 in Silkeborg (Denmark), is an exception in that it doubles the capacity of the high end of the typical range [14].

If suitably protected, solar collectors can work below freezing temperatures and should be protected from overheating on hot sunny days.

The market for large-scale solar water heating is experiencing a fast growth in Northern Europe [1]. In global, the technology has declined by 4,7% in 2017, but

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positive market developments were recorded in many countries, such as China or India.

When used for district heating systems, to guarantee energy supply, solar heat plants are with any other heat generation sources for district heating. Solar heat has high investment costs and low operational costs, and so its environmental and economic feasibility needs to be assessed. Generally, solar heating plants are most efficient when combined with gas-fired boiler stations and CHP systems, as these are quick to start and stop and therefore allow a better exploitation of the energy provided by solar plants.

The current production price for solar heating plants is >0.03 €/kWh in Northern Europe and >0.02 €/kWh in Southern Europe [10]. However, the cost is very dependent on the scale of the system, as shown in Table 2.

Table 2. Solar heat cost vs. system size for Denmark.[1]

Size of Solar Collector Array		Annual Heat Production	Cost of Heat
m^2	MW	kWh	p/kWh, FOB
500	0.25	250,000	7.3
1.000	0.5	500,000	6.2
5,000	2.5	2,500,000	3.8
10,000	5	5,000,000	2.8
20,000	10	10,000,000	1.6

Secondly, the BISTS have similar characteristics as the CSHP. The mayor difference resides in the size of each system and in consequence, in the output heat production. These systems are not designed to reach a specific heat production. These systems are constructed under the restrictions of size of each localization. Basically, it can be installed into the rooftop of buildings, where the solar radiation is the highest and if a higher solar fraction is required, it can also be installed into the façade. For the last application, unglazed solar collectors are the most appropriate due to its architectural characteristics. The prices for BISTS can be also interpolated from the prices from Table 2.

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3.4. Heat Pump Systems

Heat pumps allow for heat recovery from the ground (geothermal heat pump systems) and alternatively from other low-grade heat sources such as sea water or treated sewage water. It is shown in Figure 3 the potentiality density of this heat source in Europe.

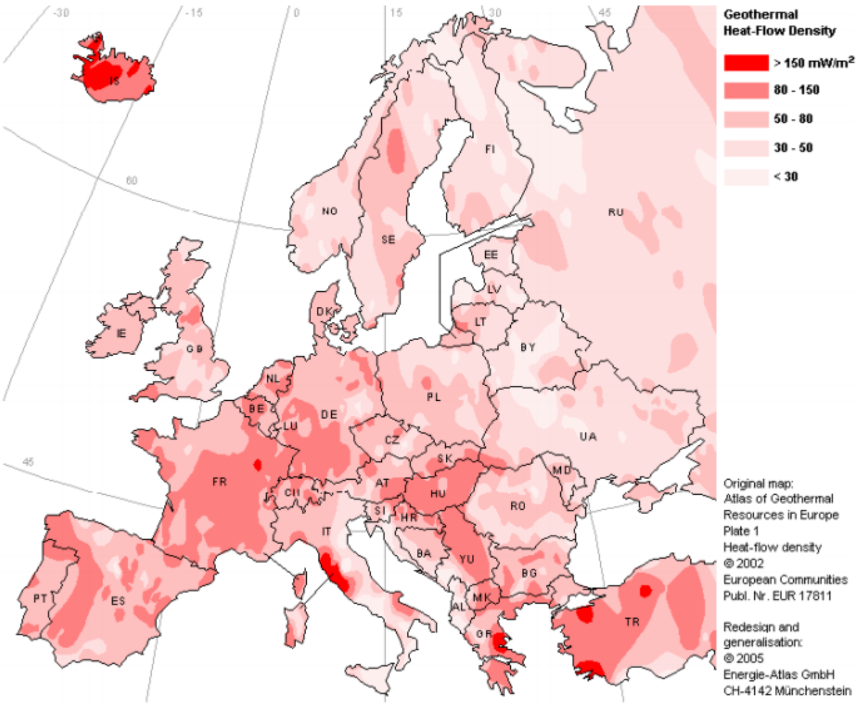

Figure 3. Geothermal heat flow density in Europe, EC 2012. [11]

Heat pumps use electricity (electric HP) or thermal energy (absorption HP) as their main primary energy source, and are able to upgrade low-temperature heat sources to higher temperature levels. Since electric heat pumps can convert electricity into heat with very high efficiency, they can be very advantageous for district heating systems that have renewable electrical generation systems with intermittent supply. Heat pumps in district heating systems typically have coefficients of performance (COP) ranging between 1.7 and 3.8, but modern heat pumps can reach even better values [8].

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Absorption heat pumps, powered by thermal energy, usually deliver heat at temperatures of 85–87 °C.

The capacity of large heat pumps is usually in the range of 25 kW to 5 MW. For covering a bigger capacity, a number of heat pumps are usually laid out in parallel.

The main advantage of heat pumps is that they can make use of energy from low temperature sources. Therefore, they provide great flexibility for the use of renewable, waste and surplus energy.

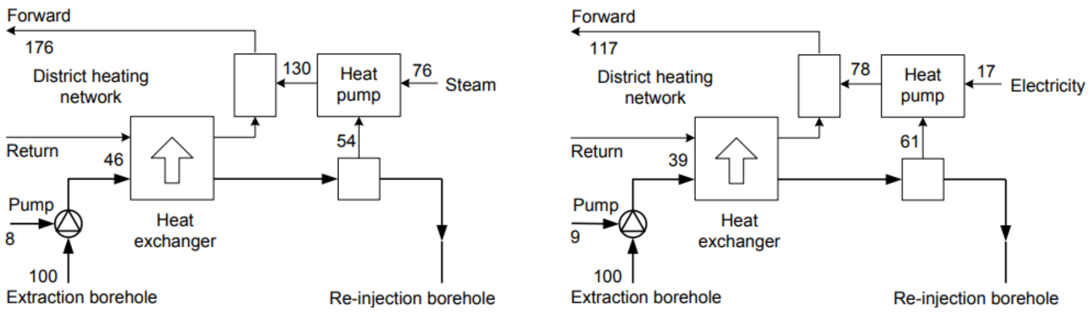

Figure 4. Examples of absorption heat pump (left) and electric heat pump (right) with geothermal heat source (100 units extracted). [2]

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3.5. Other heat sources

Waste heat from industrial processes, solid waste incinerators or other applications can be recovered using heat exchangers or heat recovery boilers. Most of the energy currently used for district heating in the European Union comes from waste heat from power stations, as shown by Figure 1. Preferably, the heat source should be close to the distribution plant and its temperature should be above 100 °C [12]. In particular, waste heat from nuclear power stations has a high potential as an energy source for district heating, which could be exploited by countries such as France and the UK [1].

Geothermal district heating, using low-temperature ground-sourced heat, has been used since a long time ago but is only available at specific locations, requiring abundant geothermal heat within a short distance of the heat demand area [2].

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4. Fuel costs

This chapter describes wholesale cost of fuels – natural gas, coal, oil, biomass also electricity, energy cost schemes from incineration and industrial waste heat.

For every type of fuel or produced energy the existing price level, expected trends and volatility in history are shown. For crude oil, natural gas European and/or global price is described. For coal the prices in Europe and for biomass regional price is shown. Electricity price is available in regional areas or country level, there is no existing European or global electricity price.

All data used in this chapter are collected from publicly available sources.

4.1. Expected trends of energy pricing

Energy price trajectories and the evolution of costs for various energy technologies are generated within the World Energy Model (*WEM)* for each of the scenarios. The *WEM* is a large-scale simulation tool [15], developed at the IEA over a period of more than 20 years. It is designed to replicate how energy markets function and covers the whole energy system, allowing for a range of analytical perspectives from global aggregates to elements of detail, such as the prospects for a particular technology or the outlook for end-user prices in a specific country or region.

The above mentioned main scenarios in this document are the New Policies Scenario, the Current Policies Scenario and the Sustainable Development Scenario, described and used in Document "World Energy Outlook 2017" [16] issued by IEA.

Energy prices are a major element of uncertainty. In each of the scenarios, the international prices for oil, natural gas and coal need to be at a level that brings the long-term projections for demand and supply into balance, avoiding either surfeits or shortfalls in investment: multiple model iterations are typically required to meet this condition. These are not price forecasts. It is all resumed in Table 3 & in Table 4.

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Table 3. Fossil- fuel import prices by scenario [16]1

Real terms ($2016)	2000	2010	2016	New Policies 2025	New Policies 2030	New Policies 2035	New Policies 2040	Current Policies 2025	Current Policies 2040	Sustainable Development 2025	Sustainable Development 2040
IEA crude oil ($/barrel)	38	86	41	83	94	103	111	97	136	72	64
Natural gas ($/MBtu)											
United States	5.9	4.8	2.5	3.7	4.4	5.0	5.6	4.3	6.5	3.4	3.9
European Union	3.8	8.2	4.9	7.9	8.6	9.1	9.6	8.2	10.5	7.0	7.9
China	3.5	7.4	5.8	9.4	9.7	10.0	10.2	10.4	11.1	8.2	8.5
Japan	6.4	12.1	7.0	10.3	10.5	10.6	10.6	10.8	11.5	8.6	9.0
Steam coal ($/tonne)											
United States	37	63	49	61	61	62	62	62	67	56	55
European Union	46	101	63	77	80	81	82	81	95	67	64
Japan	44	118	72	82	85	86	87	86	101	71	68
Coastal China	34	127	80	87	89	90	91	90	101	78	77

The IEA crude oil price is a weighted average import price among IEA member countries. Natural gas prices are weighted averages expressed on a gross calorific-value basis. EU gas prices reflect a balance of pipeline and Liquefied Natural Gas (LNG) imports; the LNG prices used are those at the customs border, prior to regasification. Steam coal prices are weighted averages adjusted to 6 000 kilocalories per kilogramme. The EU steam coal price is solely for imports

[1] MBtu = million British thermal units

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Table 4 Fossil- fuel import prices by scenario, adapted from [16] in €/MWh

Real terms				New Polices				Current policies		Sustainable Development	
	2000	2010	2016	2025	2030	2035	2040	2025	2040	2025	2040
IEA crude oil											
$/barrel	38	86	41	83	94	103	111	97	136	72	64
EUR/MWh	19	42	20	41	46	50	54	48	67	35	31
Natural gas											
$/MBtu	3,8	8,2	4,9	7,9	8,6	9,1	9,6	8,2	10,5	7	7,9
EUR/MWh	11	23	14	22	24	26	27	23	30	20	22
Steam coal											
$/t	46	101	63	77	80	81	82	81	95	67	64
EUR/MWh	5	12	8	9	10	10	10	10	11	8	8

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4.2. Natural Gas

Wholesale customers’ gas procurement is based on supply and connection agreements and annual orders that supplement these, in which the customer determines the annual maximum capacity for gas transmission as well as the amount and capacity of gas required per month.

The traditional long-term supply agreement is somehow into evolution, with some local spot markets and pools being created. For example, GASPOOL, the German biggest market area for natural gas. Five major gas network operators (Gasunie, Ontras, Wingas, Dong, Statoil) have now merged all of their market areas (in Hanover, Leipzig, Kassel, Emden, and Kiel) and set up a new company, GASPOOL, which will be responsible for balancing pool management. GASPOOL creates a new market area for transporting and trading H-Gas (high-calorific) in Germany that includes more than 300 virtual networks.

In February 2018 the price of natural gas in Gaspool was EUR 0,01998 per kWh. Prices for all the other months are presented in Table 5.

Table 5. Price for natural gas in last 12 months in Gaspool

Month	Monthly average price GASPOOL [Eurocent/kWh]
February.18	1,998100
January.18	1,868800
December.17	2,048300
November.17	1,940400
October.17	1,729700
September.17	1,705900
August.17	1,586900
July.17	1,508800
June.17	1,514000
May.17	1,583600
April.17	1,620900
March.17	1,615000

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The cost of Natural Gas varies depending on each type of market. In EU, there is a large dependency upon a relatively small number of suppliers (Russia, Norway…). In order to diversify energy sources, LNG terminals have been constructed in the last decades. Still, the dominancy of these main suppliers remains. Due to the nature of transport system, LNG sources can select which is the best destination market. Due to high LNG prices in Japan, LNG is limited to the spare production/transport capacity not required in Eastern Asia.

Price fixation mechanisms

With regard to wholesale trading of natural gas, market structures and pricing mechanisms are quite diverse around the globe but also within the EU.

There are three main different pricing mechanisms that coexist on the global scale, sometimes even within the same region, namely

- government regulated prices (GRP),
- oil-price escalation (OPE) and
- spot market pricing in competitive gas markets (GOG).

Natural gas is traded partly via bilateral agreements and partly at hubs with shares differing dependent on the region.

While OPE is mainly based on long-term contracts (LTC), spot markets with various kinds of time frames (in particular day-ahead, month-ahead, one-year-ahead) exist at trading hubs. The hubs may be physical hubs representing the exchange of gas at network interconnectors or virtual trading points.

The following table presents natural gas prices in global wholesale markets.

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Table 6 Natural Gas prices in different markets (2016) [29]

		2016
Japan cif (LNG)	EUR/MWh	19,729
Germany (AGIP)	EUR/MWh	14,025
UK (Heren NBP Index)	EUR/MWh	13,34
US Henry Hub	EUR/MWh	7,0018
Canada (Alberta)	EUR/MWh	4,4097

Price variability in the last decades

Macro-economic variables such as economic cycles, security/war issues in supply/transport regions, etc., have a large impact in the cost of supply of natural gas. In the Figure 5, cost variations since 1999 show that cost sensitivity to macro-economic variables is in the range of 2:1 for European markets (German import price and UK NBP).

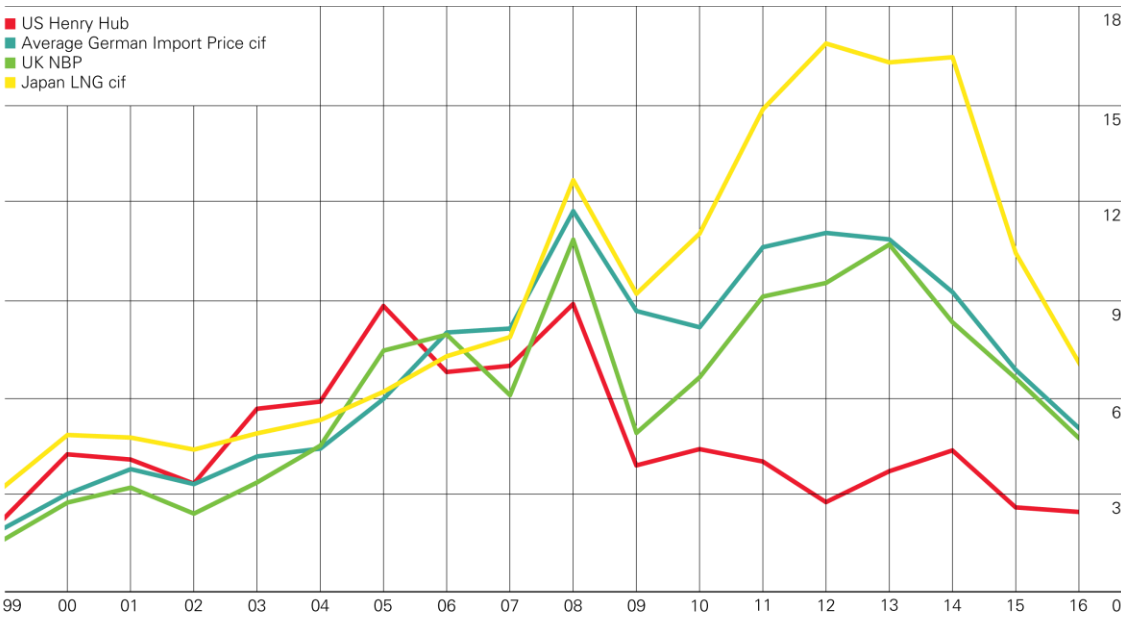

Figure 5. World Natural Gas prices USD/ mmBTU2, BP 2017. [29]

[2] mmBTU = 293 kWh

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In the following figure (Figure 6), the evolution of wholesale price of natural gas is shown for several supply sources in Europe.

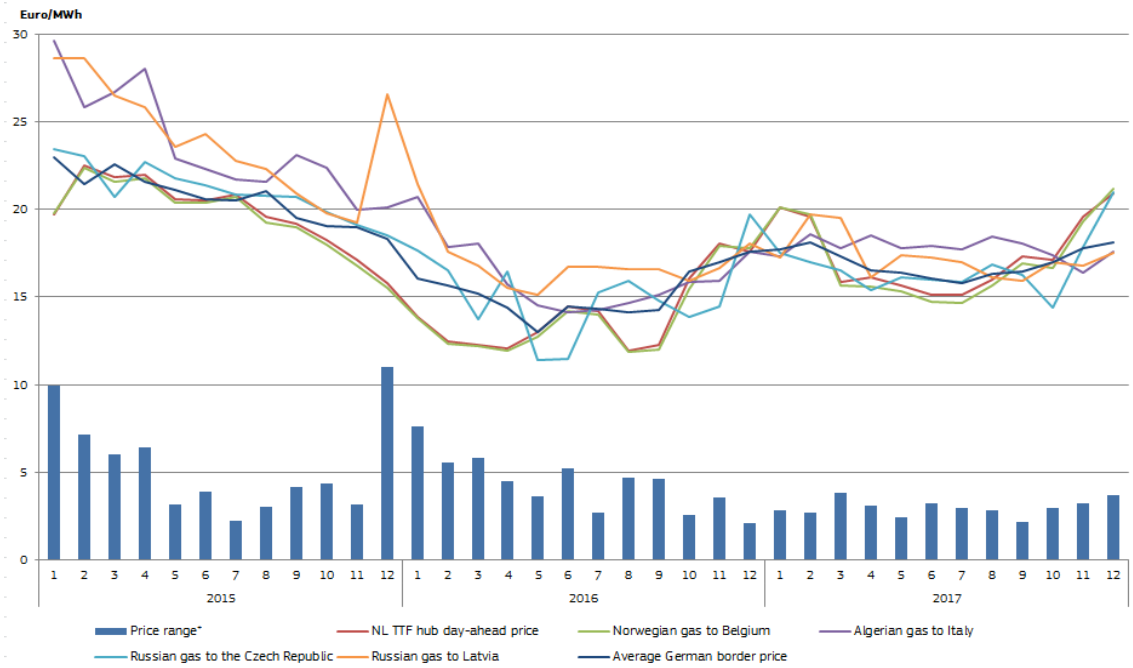

Figure 6. Price difference of gas by region in Europe, BP 2017. [29]

In general, wholesale gas prices at spot markets can be affected by the following drivers [30]:

- Fundamentally, markets are expected to be driven by the relation between supply and demand, both on the regional and on the global level.
- Moreover, the spot price is influenced by the oil-indexed prices of long-term contracts and should thus show a positive correlation with the global crude oil price lagged in time.
- Local gas storage capacities allow reduced price peaks and should therefore, help to avoid peak prices.

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- Due to the trade of commodities in fixed currencies, exchange rates can also be of importance.
- There are drivers linked to the market structure, such as the shares of GOG in the consumption, as well as the share of domestically produced natural gas in total consumption. Here the hypothesis is that a higher share of GOG results in lower prices, due to the higher level of completion and a high share of domestic production in lower ones.
- The demand for gas shows strong seasonal variations with low demand in summer and peak-demand times in winter. An important factor is therefore, the monthly level of consumption

However, the supply-side is well adapted to the seasonal pattern of demand, in particular by filling up gas storages in summer, and emptying them in winter.

There may still be deviations from the usual seasonal pattern, e.g. during warm winters or severe cold spells, consumption peaks may result in price peaks. This kind of impacts may be reflected by heating degree days per month on the one hand and a monthly consumption index that measures deviations from the usual seasonal pattern on the other hand. Deviations from the seasonal pattern can have different kinds of impacts, in particular, because LTCs commonly include take-or-pay clauses that may result in penalties in case of a demand below the lower limit of expectations.

In Table 7 gas price for industrial consumers in EU [31] are shown as example of price difference and volatility.

Table 7. Gas price for industrial consumers in EU [31]

€/GJ (GCV)	2009	2010	2013	2014	2015	2016
EU-28	8.32	9.15	11.13	10.27	9.59	8.37
BE	8.50	8.20	9.54	8.13	7.94	7.15
BG	5.96	8.41	9.77	9.48	7.49	5.34
CZ	7.56	10.07	9.21	8.45	8.17	7.16
DK	6.85	10.72	12.23	10.27	9.54	8.37
DE	9.61	11.09	13.30	11.15	10.47	9.21
EE	6.39	7.85	9.80	10.24	7.54	6.50
IE	7.31	8.80	13.16	11.57	10.28	9.43
EL			14.11	12.96	10.00	7.85
ES	7.53	8.08	10.47	10.39	8.81	7.22
FR	8.80	9.69	10.79	10.52	10.19	10.51
HR	7.43	10.95	11.80	11.15	9.74	7.63
IT	7.83	8.34	10.44	9.58	8.87	7.58
CY						
LV	7.69	8.84	10.31	9.89	8.17	6.89
LT	7.55	9.40	11.34	10.40	6.05	6.81
LU	10.03	11.72	12.49	10.94	10.33	9.17
HU	10.06	9.93	13.28	10.81	9.38	7.63
MT						
NL	9.72	8.62	9.67	9.34	8.91	7.91
AT	9.07	9.78	11.90	11.13	10.50	9.48
PL	8.36	9.02	10.12	10.12	9.39	7.26
PT	7.22	9.28	11.66	12.33	10.52	7.67
RO	5.93	6.11	8.01	8.54	8.05	7.27
SI	9.61	11.81	13.33	12.16	10.57	9.07
SK	8.91	10.22	10.74	10.45	9.63	8.67
FI	8.00	9.13	13.01	12.98	11.73	12.21
SE	12.47	13.43	15.16	12.26	11.61	10.67
UK	6.06	6.33	9.95	9.65	9.75	6.91

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Expected trends

There is no single future global price for gas, as there is for oil, gas price is more region based. Instead a range of regionally determined prices can be found, each of them with their own specificities. These prices tend to gradually be more interlinked, in line with the increasingly interconnected global market for Natural Gas. This interconnection is driven by the increasing share of liquefied natural gas (LNG) in global trade, and by the increasing flexibility of this trade to seek the most advantageous commercial destination.

IEA projections are based on the assumption that gas markets will steadily increase their integration into a global gas market, in which internationally traded gas moves in response to price signals, determined by the balance of gas supply and demand in each region. With this global gas-to-gas competition, regional price differences should reflect only the costs of transporting gas between them. These projections are shown in Figure 7.

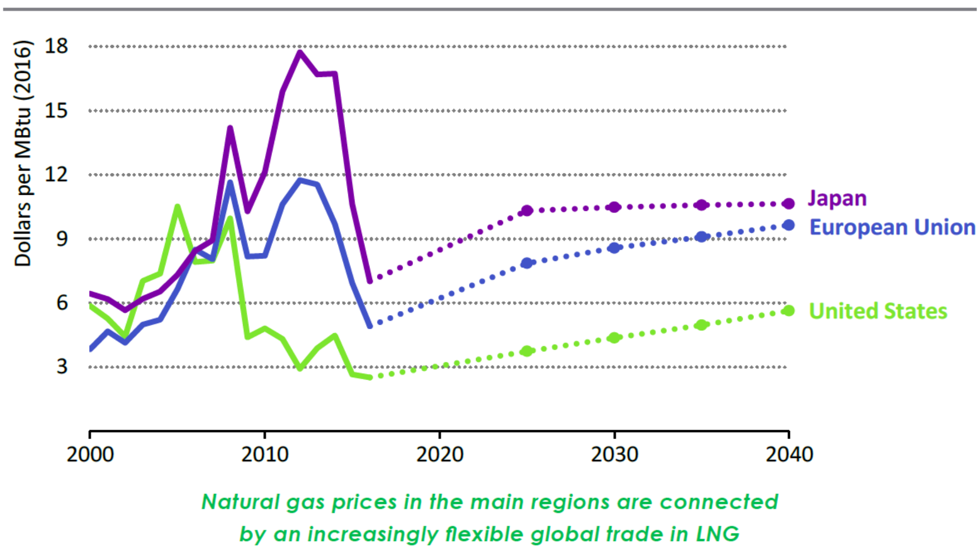

Figure 7. Natural gas prices by key region in the New Policies Scenario, IEA 2017 [16]

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Summary table

Based on the study on historical costs, and price projections presented in this section, the following table summarizes the evolution of Natural Gas prices.

Table 8. Summary table on present, past and future cost of Natural Gas

	Year	Cost	Cost Unit	Cost [€/MWh]
Present	2017	4,9 [16]	USD/MBTU	14
Maximum in 20 years	2008	10,79 [29]	USD/MBTU	30
Minimum in 20 years	1998	1,9 [29]	USD/MBTU	5
Foreseen cost	2025	7,9 [29]	USD/MBTU	22
	2030	8,6 [29]	USD/MBTU	24

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4.3. Coal

“Coal -including both hard coal and lignite is currently mined in 12 EU countries, in a total of 41 regions. This makes it the most abundant fossil fuel in the EU and an important source of economic activity in these regions.

The coal sector provides jobs to about 240,000 people: about 180,000 in the mining of coal and lignite and about 60,000 in coal- and lignite-fired power plants.

Coal accounts for about a quarter of all electricity production in the EU and is also an important fuel for industrial processes such as steel production, although the production and consumption of coal in the EU has been steadily declining over the past few decades.” [38]

InTable 9, the EU dependence from coal and TOP 10 countries with biggest share of imported coal are shown. The share of imported coal is specifically relevant for Italy and Netherland, with imports exceeding 30% of produced primary energy.

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Table 9 Coal imports of top 10 countries in EU[31]

Mtoe and %	1995			2015		
Top 10 Ranking	MS	Imports	EU-28 Share	MS	Imports	EU-28 Share
Solid Fuels						
1	IT	13.1	11.3%	DE	37.5	24.7%
2	DE	12.3	10.5%	NL	34.3	22.6%
3	NL	11.6	10.0%	UK	15.9	10.5%
4	UK	11.3	9.7%	IT	12.6	8.3%
5	BE	10.3	8.9%	ES	11.0	7.2%
6	FR	9.6	8.3%	FR	8.7	5.7%
7	ES	8.7	7.4%	PL	5.1	3.3%
8	DK	7.7	6.6%	PT	3.2	2.1%
9	SK	4.2	3.6%	BE	3.2	2.1%
10	PT	3.9	3.3%	SK	2.8	1.9%
Top 5 Total		58.6	50.4%		111.2	73.4%
Total EU-28		116.3	100.0%		151.5	100.0%
Of which: Hard Coal						
1	IT	12.6	11.9%	DE	35.3	24.6%
2	NL	11.1	10.4%	NL	34.0	23.7%
3	UK	10.9	10.3%	UK	15.2	10.6%
4	DE	9.5	9.0%	IT	12.1	8.4%
5	BE	9.4	8.9%	ES	10.7	7.5%
6	FR	8.9	8.4%	FR	8.3	5.8%
7	ES	8.1	7.6%	PL	4.9	3.4%
8	DK	7.6	7.2%	PT	3.2	2.2%
9	PT	3.8	3.6%	BE	2.7	1.9%
10	FI	3.7	3.5%	SK	2.5	1.8%
Top 5 Total		53.4	50.5%		107.4	74.8%
Total EU-28		105.9	100.0%		143.5	100.0%

As in the case of natural gas, there is not a single global coal price but various regional coal prices that are usually closely correlated. The difference between the regional coal prices reflect the transport cost between locations, infrastructure bottlenecks and differences in coal quality. Although coal pricing follows market-based principles in most major coal producing countries, there are a few notable exceptions in India and in South-Africa where state-owned companies have regulations on price calculations.

In February 2018 the price of coal was EUR 7,64 per MWh (64 USD/t)

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Table 10. Coal imports of top 10 countries in EU[31]

		2016
NW Europe marker	EUR/MWh	7,1497
US Central spot index	EUR/MWh	6,3965
Japan coking coal (cif)	EUR/MWh	10,676
Japan steam coal (cif)	EUR/MWh	8,7139
Asian marker	EUR/MWh	8,3483
China Qinhuangdao spot price	EUR/MWh	8,5207
Japan steam spot cif price	EUR/MWh	8,5576

Price variability in the last decades

The dramatic increases in oil and gas prices in 2003-2008 years have made coal-fired generation significantly more attractive where there is a choice of capacity. This led to high coal demand in 2006. But as gas prices reduced during 2007, coal demand fell back; during 2008 it was further constrained by environmental factors. On 2009-2010 in time of financial crises and higher demand in China the price jumped up, see on Table 10.

After this period, coal prices declined for four consecutive years before bottoming out in early 2016, at less than half the levels they reached in 2011. The price slump was caused by massive overcapacity from the building of new capacity when prices were high.

Despite cost cutting, the drop-in prices have put many coal companies around the world in a tight corner, forcing them to close mines or even go into bankruptcy.

Overall, coal prices are now ~50% higher than average values in the 1980-2000 period, after the aforementioned volatile period in the 2004-2014 decade.

By IEA the main markets updates for coal market was:

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- Coal market price has dropped from 2014-2016 marks the largest 2-year drop in global coal demand. The drop occurred in spite of economic growth.

- The 2016 was the 3rd consecutive year of decline in China and the 2nd in US.

- Coal to gas switch in power generation in US and Europe, and in industrial/residential sector in China together with renewables were the drivers.

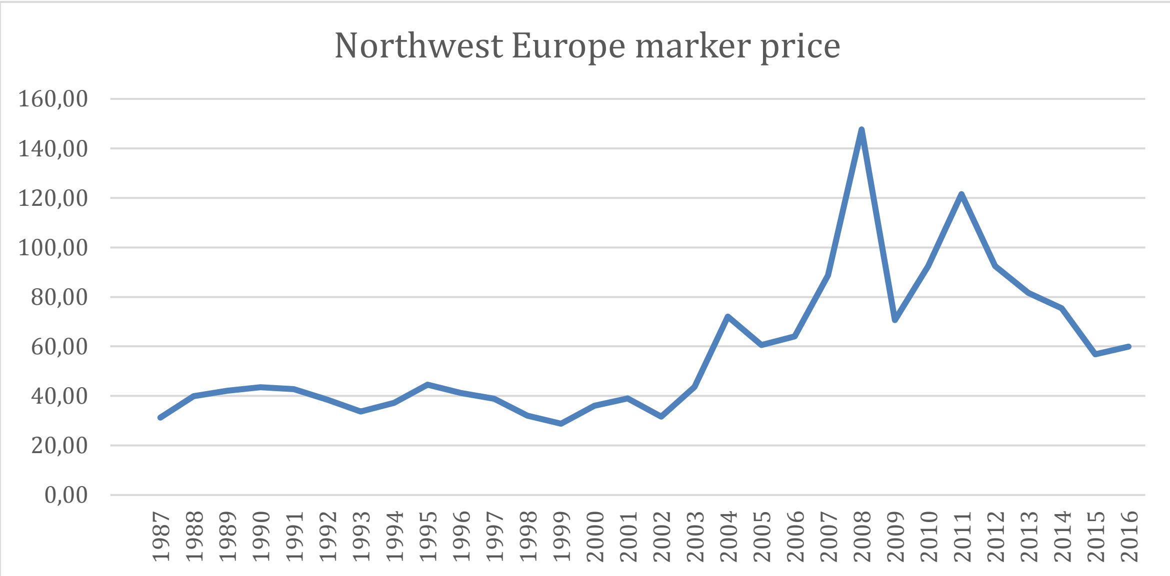

Figure 8. Coal price USD/tonne, in history 1988-2016, average monthly (1990-2000) and weekly (2001-2016). Source: IHS Northwest Europe prices.

Expected trends

In the long term, worsening geological conditions, declining coal quality in mature mining regions, and longer transport distances in new mining regions combine to put modest upward pressure on coal prices.

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Mining costs are also increasing as cyclically low prices for consumables like fuel, explosives and tyres are trending upwards.

Some European countries announced plans to phase out coal-fired power completely, including France by 2023, the United Kingdom by 2025 and Finland by 2030. price forecast for 2025 in Europe is between 60-65 EUR/tonne (see Figure 9).

As shown in Figure 9, the price keeps increasing in main markets and expected cost by 2040 of European Union coal reach $82/tonne, ca 69-70 EUR/tonne.

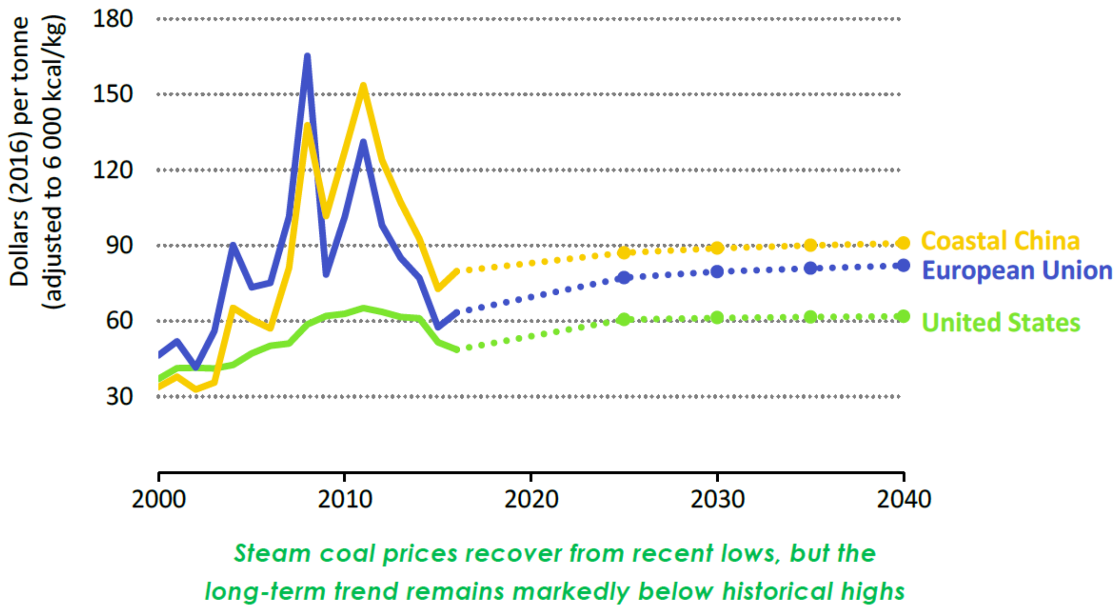

Figure 9. Steam coal prices by key region in the New Policies Scenario, IEA 2017 [16]

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Summary table

Based on the study on historical costs, and price projections presented in this section, the Table 11 summarizes the evolution of Coal prices.

Table 11. Summary table on present, past and future cost of Coal

	Year	Cost	Cost Unit	Cost [€/MWh]
Present	2018 (Feb)	7,64	EUR/MWh	7,64
Maximum in 20 years	2008	147,67	USD/t	17,6
Minimum in 20 years	1999	28,79	USD/t	3,44
Foreseen cost	2025	77	USD/t	9
	2030	80	USD/t	10

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4.4. Oil

Oil still remains the world’s leading fuel, accounting for a third of global energy consumption. In Europe oil is the second fuel by consumption after natural gas.

EU28 production of energy form petroleum and products is equal with 89,3 Mtoe having 11.4 % of share of total energy production. The distribution for energy production sources is presented in Figure 10.

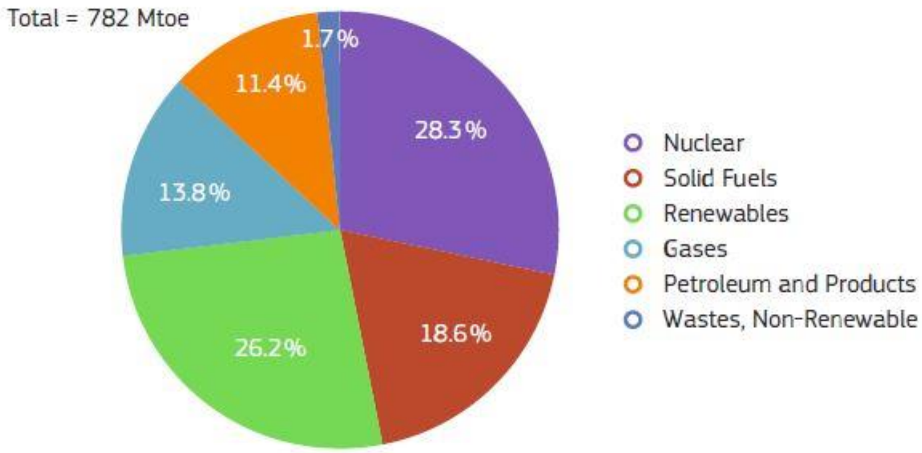

Figure 10. Energy production by fuel in EU28 countries (2015), in Mtoe, EU 2017 [21]

Retail prices for heating oil show a broader variety of values within the Member States. Until 2012, there were two price groups of countries. In Italy, Sweden, Denmark and Hungary prices were about 200 €/kl higher than in the other European Member States. Portugal and Greece have crossed this gap between the two groups Figure 11 illustrates this development.

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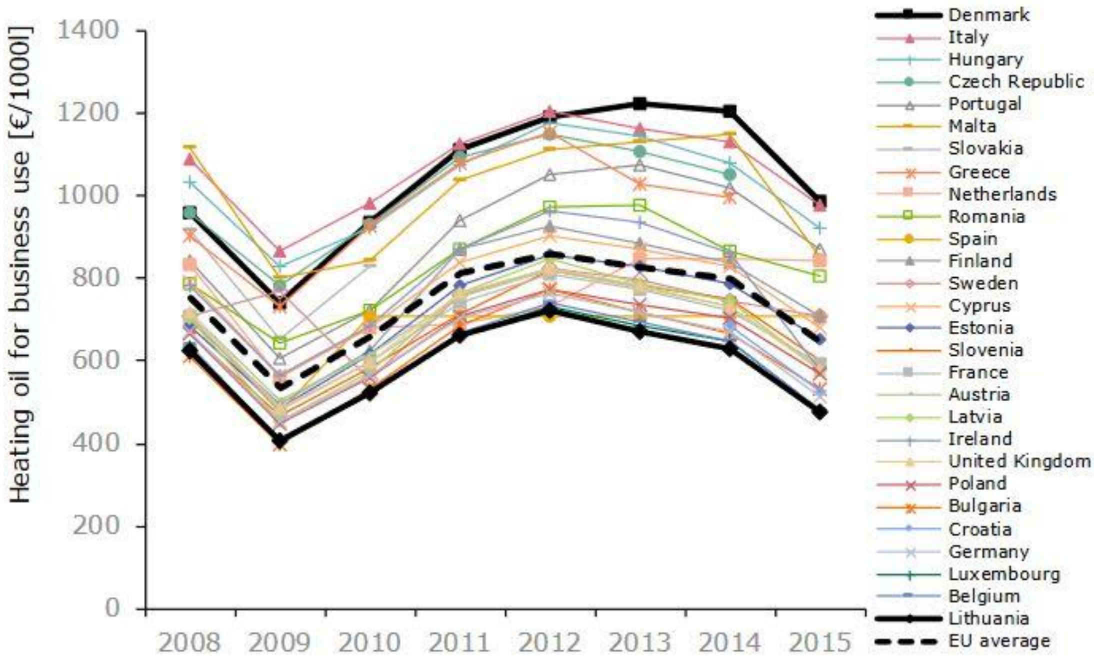

Figure 11. Trends of retail prices of heating oil in business use 2008-2016.

In 2008, heating oil prices for non-business use ranged from 709 €/kl in Luxembourg to 1307 €/kl in Italy. This range has opened a little, with 2015 figures showing a spread from 548 €/kl in Luxembourg to 1240€/kl in Denmark.

The relative position of national prices within that range has changed little. Supply of heating oil was most expensive in Denmark, Sweden, Hungary and Italy throughout the entire period. Lowest retail prices could be found in Luxembourg, Belgium and the UK, as well as in Germany and Lithuania in 2015.

The average price for heating oil decreased by 19%, from 857 €/kl to 694 €/kl in the 2008-2015 period.

As the average price is calculated from weighted consumption, the fact that it is at the lower end of the price spread shows that heating oil is lower priced in countries with highest consumption of heating oil.

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The price of heating oil plays important role in regions with District Heating based on oil, which is the main driver for price for heating. The price of heating oil follows the price of crude oil in world market, and this is show and described in next section.

Price variability in the last decades

As explained in [32], "most major oil price fluctuations dating back to 1973 are largely explained by shifts in the demand for crude oil". As the global economy expands, so does demand for crude oil.

When considering demand, the reader should consider also "demand for stocks (or inventories) of crude oil" which are required to avoid future shortages in the oil market.

Historically, inventory demand has been high in times of geopolitical tension in the Middle East, low spare capacity in oil production, and strong expected global economic growth.

Political events can have a strong influence on the oil price. Historical examples include OPEC's 1973 embargo in reaction to the Yom Kippur War and the 1979 Iranian Revolution. An overview of the correlation between on world events and oil price is shown in the Figure 12.

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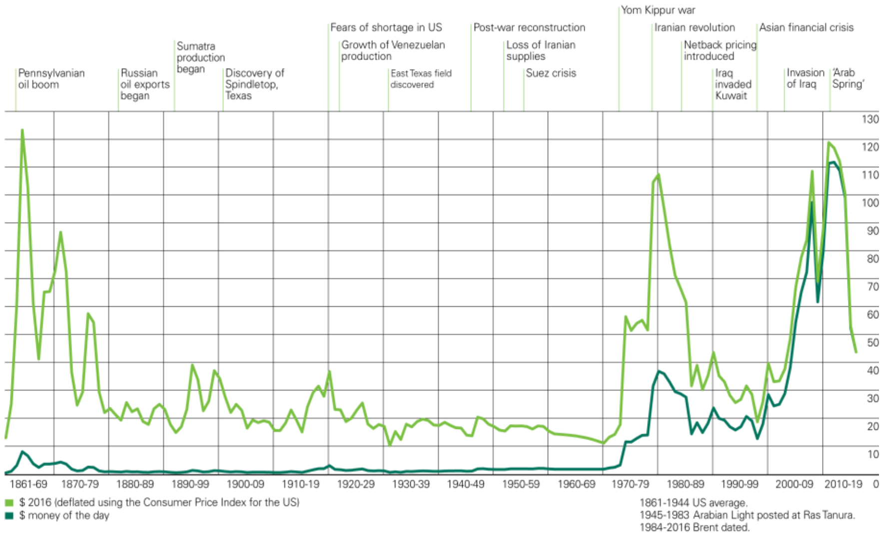

Figure 12 Crude oil prices 1861-2016 (US dollars per barrel) and world events. BP 2017 [17]

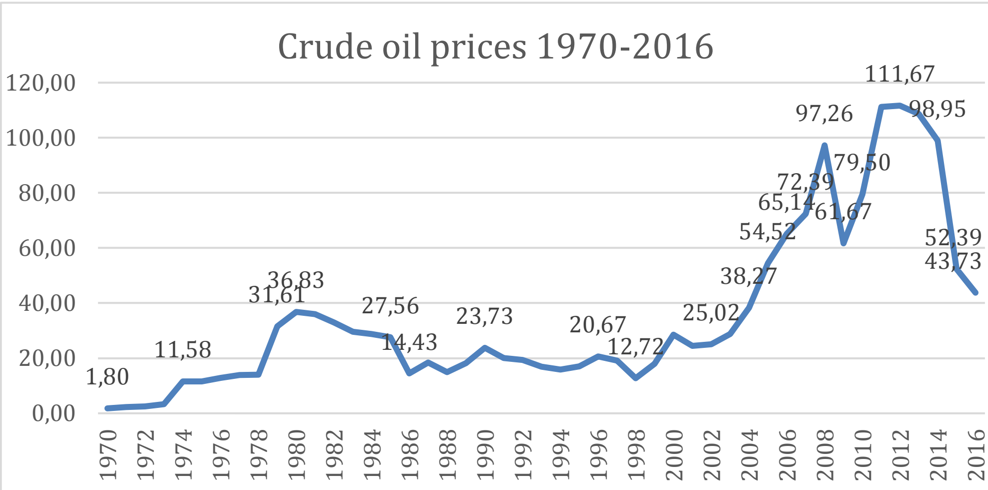

Figure 13. Crude oil price from 1970-2016, BP 2017 [29]

As it shown in Figure 13, the highest price of crude oil in the period 2000- 2016 was in 2011 and was 111,67 US dollars per barrel and lowest price in that period was 24,41 US dollars per barrel in 2001, difference ca 500%

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Expected trends

By the IEA World Energy Outlook [16] the oil price trend continues to edge gradually higher post- 2020 under all scenarios. There remains increasing of the oil price over the period to 2040 in the in all policies except of sustainable scenario.

This is due to the large requirement for new resource development, most of which is needed to compensate for declines at existing fields. The need to move to higher cost oil in more challenging and complex reservoirs means that the marginal market cost required to balance the project costs becomes steadily more expensive.

Market dynamics and price trends are however quite different in the Sustainable Development Scenario. The main changes, relative to our central scenario, are a much more rapid growth of electric cars, a doubling of the assumed size of the US tight oil resource base, more rapid technology learning in the upstream and a favourable assumption about the ability of the main oil-dependent producing regions to weather the impact of lower hydrocarbon revenues. In Figure 14 is simplified the possibilities for oil prices depending on the scenario expected.

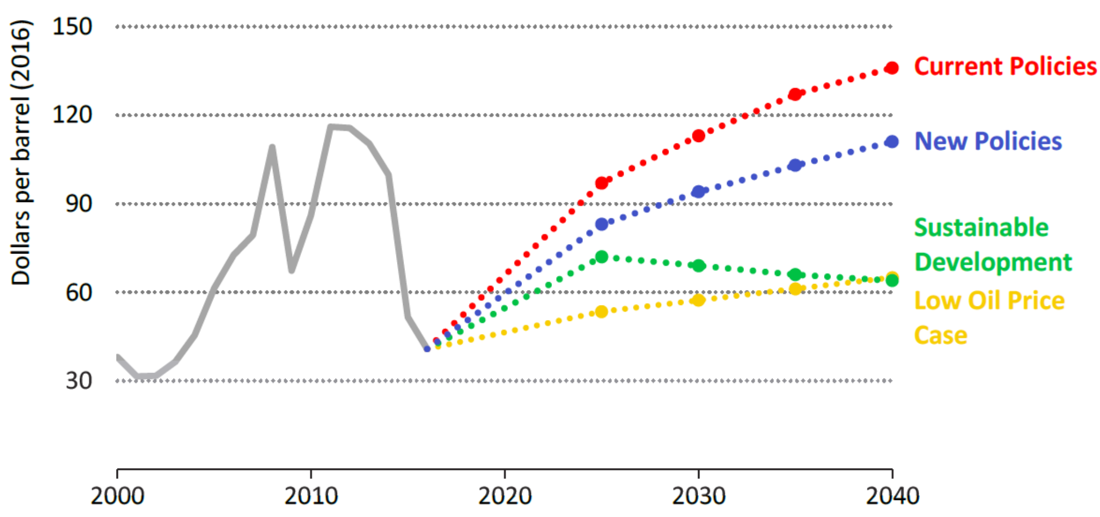

Figure 14. Average IEA crude oil price by scenario and case, IEA 2017 [16]

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Summary table

Based on the study on historical costs, and price projections presented in this section, the Table 12 summarizes the evolution of Oil prices.

Table 12. Summary table on present, past and future cost of Oil

	Year	Cost	Cost Unit	Cost [€/MWh]
Present	2018 (May)	76	USD/barrel	37
Maximum in 20 years	2012	112	USD/barrel	55
Minimum in 20 years	1998	13	USD/barrel	6
Foreseen cost	2025	83	USD/barrel	41
	2030	94	USD/barrel	46

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4.5. Biomass

"Biomass is the only renewable, affordable energy source available on-demand. European countries need to make sure it is sourced sustainably, writes Philip Lowe" [3].

From all the renewable primary energy sources, sustainable biomass is the unique capable of fulfilling both, baseload and flexible generation. It can run constantly in medium to large generation plants but also can be rapidly changed to fill a changeable supply gap. So, it provides the possibility to fill the gap created by the outgoing fossil fuels and at the same time act as an intermittent renewable technology.

Because biomass availability is limited the role it plays must also be limited. Thus, biomass is envisaged as a key fuel supply on the local level. There are some exceptions like pellets (wood granules) trade on global or regional (EU) markets.

Biomass has different economic benefits compare with other fuels. Due the biomass availability on local level they have impact to socio-economic development of regions and to local economy (like job creation and income).

The price volatile is lower than other fuels, by same reason mentioned above.

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[3] *Philip Lowe is former Director General for Competition (2002-2010) and Energy (2010-2014) at the European Commission*

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Wholesale cost of Biomass

Biomass as mostly locally sourced fuel enhances the security of the supply in terms of both its availability and its cost. Local sourcing secures clients against ‘fuel shocks’ caused by increasing global demand for fuel and political instability overseas. A localised nature of the supply chain minimises the financial and environmental costs of transporting fuel.

Data about price of biomass fuels are taken individually by country.

Biomass products for heat production are further divided in different fuels. In wholesale market the firewood (low-quality roundwood), pellets (wood granules) and woodchips are sold for energy generation.

Price level of different types of biomass in project RELaTED countries show in **¡Error! No se encuentra el origen de la referencia.**. Data collected by partners.

Table 13. Different biomass prices by RELaTED countries[4], EUR/MWh

Country	Type of biomass	Price (EUR/MWh)
Estonia [33]	Firewood	13,00
	Woodchips	13,12
	Pellets	36,9
	Peat	9
GERMANY [18]	Woodchips	25,6 or 66,8 €/t
SERBIA	Woodchips	19

[4] Data collected by RELaTED partners from national and regional sources

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	Pellets	27,9
SWEDEN [20]	Refined biomass:	28
	Forestry woodchips	17
SPAIN [19]	Woodchip	25
	Pellets	35
	Olive bones:	19

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Price range of different types of biomass in Sweden shown in Figure 15 and in Spain on Figure 16.

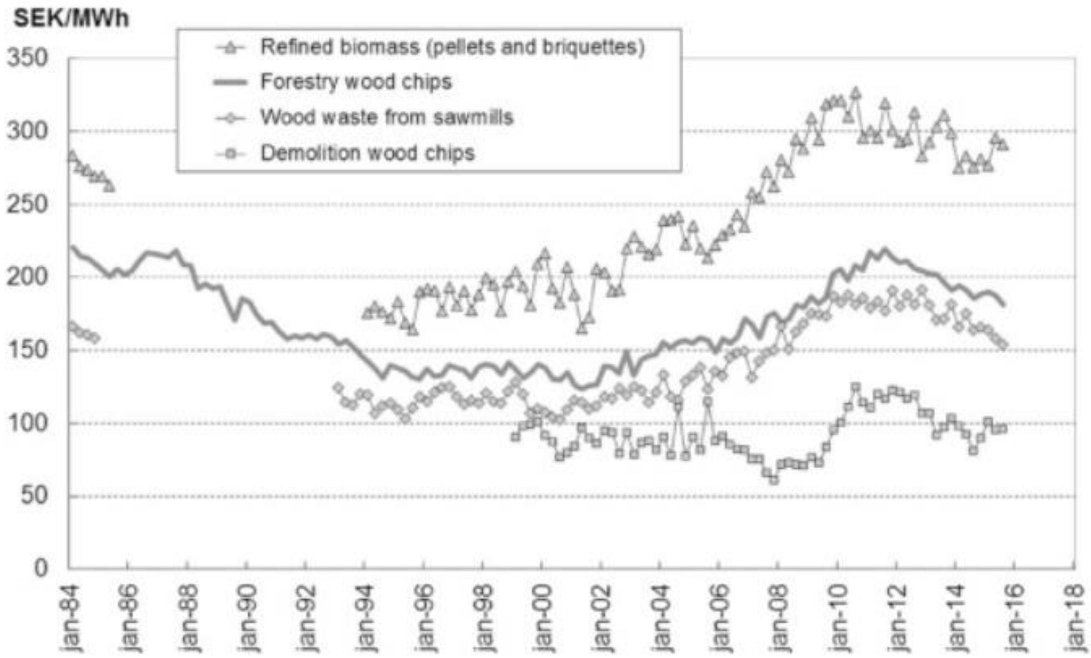

Figure 15. Biomass price range in Sweden, SEK/MWh

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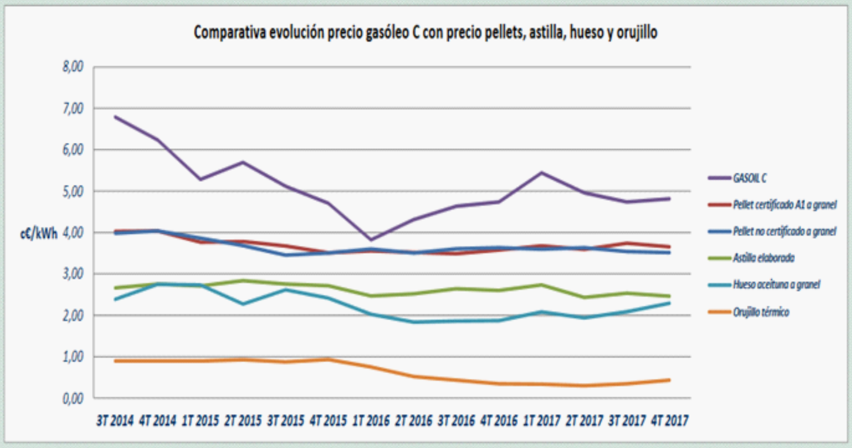

Oil
A1 certified Pellet
Non certified pellet
Woodchip
Olive bones
Orujillo (subproduct of olives)

Se presentan los datos de comparación de la evolución de precios (c€/kWh) también en formato tabla:

Precios en c€/kWh	2T 2015	3T 2015	4T 2015	1T 2016	2T 2016	3T 2016	4T 2016	1T 2017	2T 2017	3T 2017	4T 2017
GASOIL C	5,69	5,11	4,71	3,82	4,31	4,63	4,74	5,44	4,96	4,74	4,81
Pellet certificado A1 a granel	3,78	3,68	3,51	3,55	3,52	3,49	3,58	3,68	3,59	3,74	3,66
Pellet no certificado a granel	3,69	3,45	3,51	3,60	3,51	3,61	3,63	3,60	3,63	3,54	3,52
Astilla elaborada	2,84	2,76	2,71	2,47	2,52	2,64	2,60	2,74	2,43	2,53	2,46
Hueso aceituna a granel	2,27	2,62	2,42	2,03	1,84	1,86	1,87	2,08	1,94	2,09	2,29
Orujillo térmico	0,93	0,88	0,93	0,75	0,52	0,44	0,34	0,34	0,30	0,35	0,43

Oil
A1 certified Pellet
Non certified pellet
Woodchip
Olive bones
Orujillo (subproduct of olives)

Figure 16. Price evolution of biomass in Spain. 2015-2017, IDAE 2018 [19]

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Summary table

Based on the study on historical costs, and price projections presented in this section, the Table 14 summarizes the evolution of Biomass prices.

Table 14. Summary table on present, past and future cost of Biomass (woodchips)

	Year	Cost	Cost Unit	Cost [€/MWh]
Present	2017	13	EUR/MWh	13
Maximum in 20 years	2014	15	EUR/MWh	15
Minimum in 20 years	2016	11	EUR/MWh	11
Foreseen cost	2025			13 (price stability)
	2030			14-15 (price stability)

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The Table 15 summarizes the evolution of pellets prices for the particular of Estonian case.

Table 15. Summary table on present, past and future cost of Biomass (pellets) by Estonian case

	Year	Cost	Cost Unit	Cost [€/MWh]
Present	2017	32	EUR/MWh	32
Maximum in 20 years	2014	36	EUR/MWh	36
Minimum in 20 years	2016	20	EUR/MWh	
Foreseen cost	2025	32	EUR/MWh	31
	2030	32	EUR/MWh	31

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4.6. Electricity

The price of power energy in the EU depends on a range of different supply and demand conditions, including the geopolitical situation, the national energy mix, import diversification, network costs, environmental protection costs, severe weather conditions, or levels of excise and taxation.

Note that prices presented in this chapter are not end-user prices and exclude taxes, levies and VAT.

The price of electricity is fixed or developed in different ways by countries. In some of countries the electricity price is fixed or agreed by national regulations but in the other countries the price will be fixed on market bases.

On the open market, producers sell electricity to the wholesale market, where wholesale buyers, who are usually electricity sellers, buy it.

Electricity price is high volatility due to daily fluctuations in correlation of the demand/response in market and available of solar and wind energy. As an example, in Figure 17, daily fluctuations of the cost of electricity is shown for a particular day in the Estonian price region of Nordpool.

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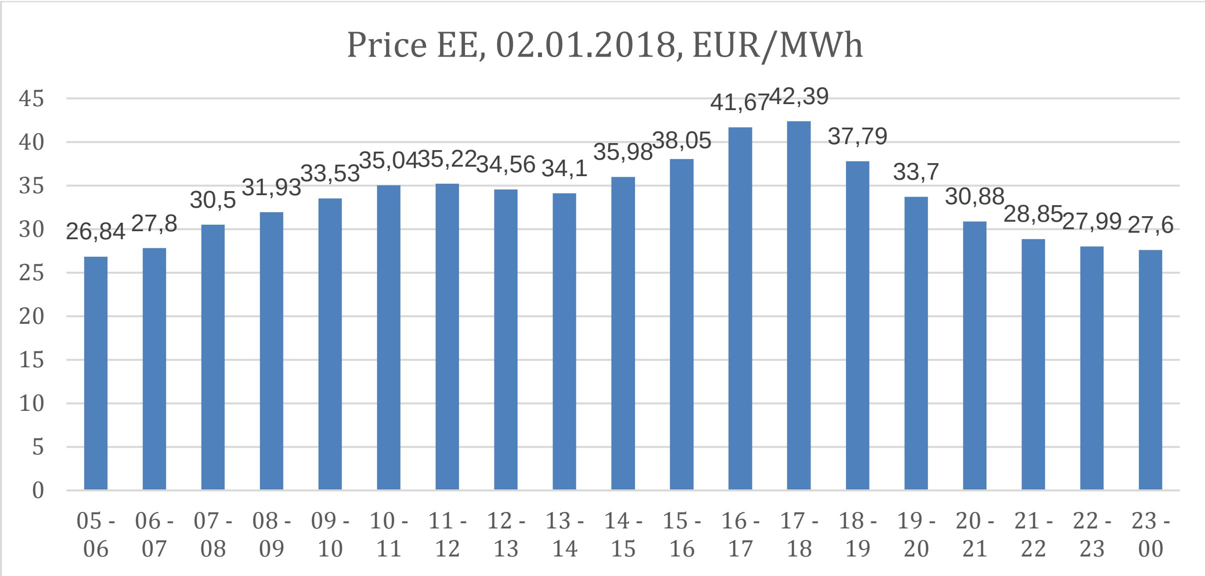

Figure 17. Estonian price region in Nordpool. price fluctuations in 02. January 2018 on hourly basis, EUR/MWh

Present costs

Electricity cost for industrial use by Estonia is shown in Figure 18.

The cost to supply electricity actually varies minute by minute. During the course of a single day, the wholesale price of electricity on the electric power grid reflects the real-time cost for supplying electricity

Demand for electricity contributes to the cost of supplying electricity. Electricity demand is usually highest in the afternoon and early evening (peak hours), and costs to provide electricity are usually higher at these times.

Most consumers pay prices based on the seasonal average cost of providing electricity, so they do not experience these daily price fluctuations. Some utilities offer their customers time-of-day pricing to encourage electricity conservation and to reduce peak demand for electricity.

There are different prices for different consumer groups. Most consumers pay prices based on the seasonal average cost of providing electricity, so they do not experience these daily price fluctuations. Some utilities offer their customers time-of-day pricing to encourage electricity conservation and to reduce peak demand for electricity. The particular pricing scheme may vary, from 2/several fixed price levels (e.g. day and night price levels) to fully market based price, with variable price every 15 min[5], depending on demand -response balance.

Large industries have usually negotiated market price.

Estonia is part of the integrated electricity wholesale market of the Nordic countries, Nord Pool since 2013. Nord Pool runs the leading power market in Europe where provides trade of seven counties: Baltics, Nordic, Germany and UK.

[5] NORDPOOL, other subdivisions possible in other European markets

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In Estonian market the weighted average monthly price for electricity in Nordpool in February 2018 was:

- 24-hour rate: EUR 0,0529 per kWh
- Day-time rate: EUR 0,0626 per kWh
- Night time rate: EUR 0,0427 per kWh

The Estonian market price volatility of last 12 months is shown in table:

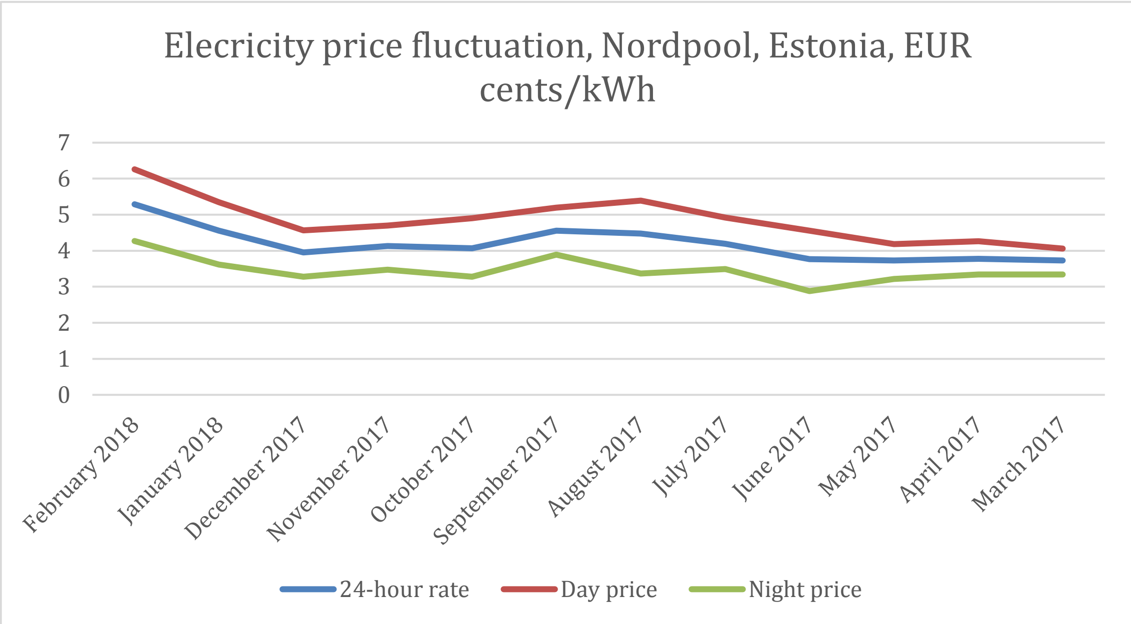

Figure 18 Eesti Energia weighted average price last 12 months.

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Price fluctuations in the last decades

Energy prices have experienced several shifts during the last decade. With oil prices leading the events as the world's primary fuel, prices have increased to record highs only to fall dramatically during the financial crisis and now due to excess supply. Large movements in energy prices affect the price of electricity and price volatility is a major concern for both producers and consumers

In Table 16 electricity price differences by years are show.

Table 16 Electricity price fluctuations 2009-2016 for industrial consumers in EU28 and RELaTED countries, EUR/MWh [21]

	2009	2010	2013	2014	2015	2016
EU28	102,40	105,10	118,20	120,60	118,70	114,00
Belgium	107,90	105,40	109,90	108,60	108,10	115,80
Denmark	92,00	96,10	99,80	97,20	90,60	93,60
Estonia	64,50	72,70	97,00	93,10	95,80	89,60
Poland	93,30	98,70	87,80	83,30	86,10	81,50
Spain	112,00	109,30	12,02	116,70	113,30	102,90
Sweden	68,90	84,10	74,70	66,60	59,00	65,60

Data show in table above describe electricity price for industrial consumers with consumption between 2000 MWh – 20000 MWh

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Expected market trend

As it is shown in Figure 19, current trends and policies are progressing in the direction of an increasing share of electricity from renewable energy sources in the EU electricity system, in particular from variable sources such as wind and photovoltaics. In parallel to this, there is increasing use of electric appliances in households, varying significantly throughout the day. Together this results in potentially large and sometimes fast variation of both electricity production and consumption.

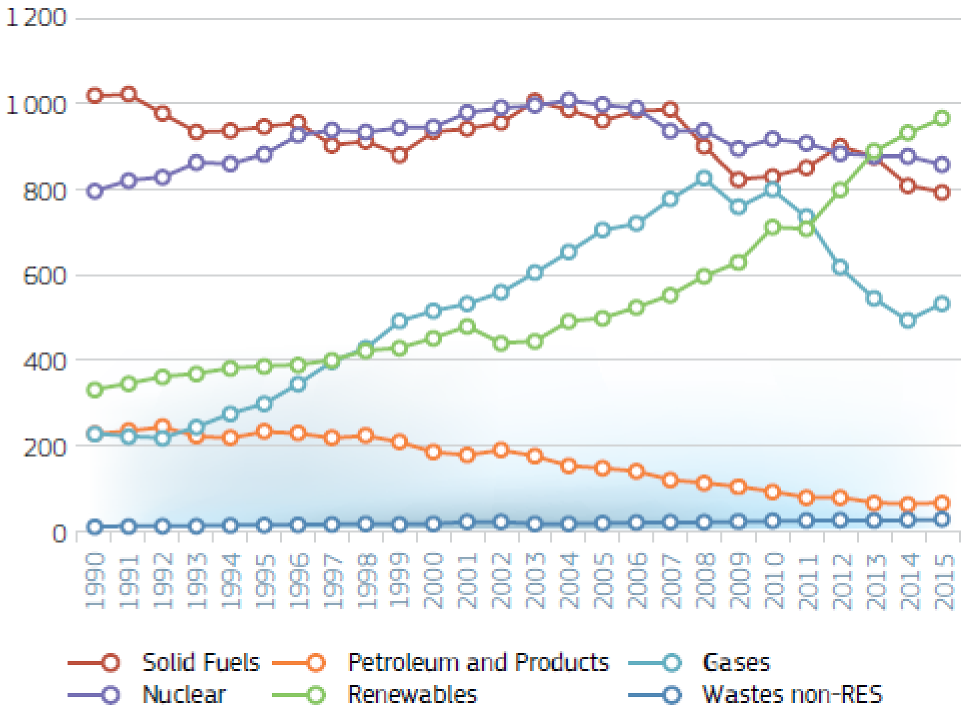

Figure 19. Electricity production mix by primary energy source. EU 2017 [21]

Traditional power grids — which mostly rely on fossil fuels to generate electricity are designed so that output matches demand. But renewable energy technology hasn't yet been developed to produce according to demand, since generation is a function of weather.

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Today, observations show that high renewable generation during low demand periods lead to negative electricity price spikes in Central Western European electricity markets such as Germany, France, and Belgium. These negative prices represent the challenge of power systems to cope with high renewable electricity injections. This phenomenon is caused by the limited storability of electricity, the low elasticity of electricity demand**,** and the technical constraints of operating power system.

Volatile, and negative electricity prices correctly represent the need for downward flexibility, which needs to be resolved by trade, demand response, storage, conventional flexibility, and active participation of renewable energy.

The negative or "free" energy can be used for benefit of energy consumers but can be done if there are possibilities to store energy. It is meaning that electricity needs to be converted to heat and stored as heat for District heating systems or used so called pump stations. The advantage of negative prices by being paid to pump large volumes of water into a reservoir or mountain lake. When prices are higher, by releasing the water and using turbines to generate electricity.

Electricity price forecast

The gross electricity generation covering the demand will increase by 18 % till 2050 as a result of higher demand due to the electrification of the heat and transport sectors.

While electricity production from coal-fired power plants will significantly decline the production of electricity by means of natural gas will double.

In 2050, fluctuating renewable energies will generate 36 % of electricity while over 44 % will be produced by controllable conventional power plants. The remaining electricity production will be generated by controllable renewable energy technologies such as biomass power plants [34].

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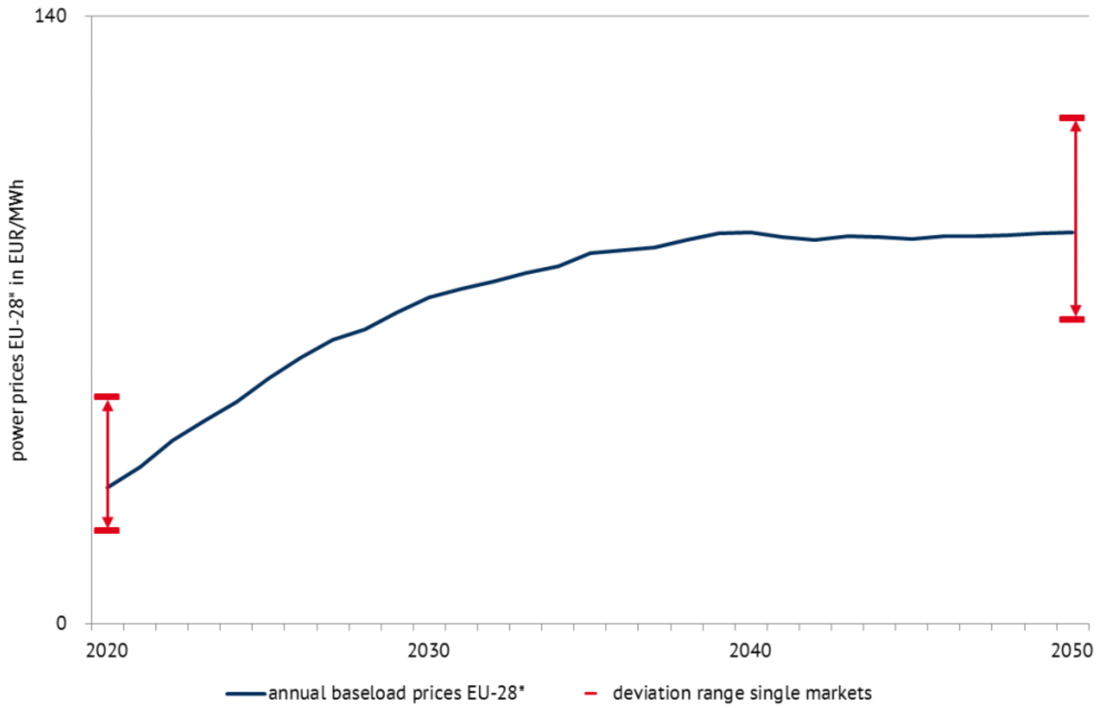

Figure 20. Power prices (real: EUR 2015) and deviation range in national EU-28[6] markets, Perez-Linkenheil, C 2017 [34]

In Figure 20 shown above is shown the expected price for electricity with a possible price deviation caused by external conditions from 2020 to 2050. Until 2020, the prices will be characterized by low prices for primary energy carriers on the future markets. From this point forward until 2040 complies with the time where the prices for primary energy and CO_2 certificates will increase the most. From 2040 onwards, electricity prices are expected to maintain approximately constant (or slightly declining) despite rising prices for primary energy carriers and CO2. The reason for that is the high feed-in of wind and solar power plants increasing the periods of low and even negative electricity prices.

[6] EU-28 including Norway and Switzerland

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The development of periods where electricity may be priced at negative cost or almost cost-free, makes room for electric driven heat generation systems such as district-heating connected heat pumps. These type of events have already occurred [22][23][24] in the last years, and are more likely to happen again in the near future.

For composing and calculating of forecast of electricity price for future, several price scenarios were modelled for different markets.

One of them is done by EC Delft, report “Energy and electricity price scenarios 2020-2023-2030” [25]. It´s composed for Dutch market but can be bases of price forecast and modelling for other markets. It shows the dynamics by scenarios. Scenarios and input data are described in report.

Report conclusion says that simulations of power market have resulted in a set of time series of simulated power prices for day ahead spot market. The time series shows that:

- The average (baseload) electricity price level depends strongly on prices for coal, gas and CO2.
- Increases in renewable electricity depresses prices, but this effect is most pronounced during the 900-1,800 hours that the price is already relatively low (the tail of the price duration curve). *
- Over time, the volatility of the electricity price is expected to increase significantly. This is most extreme in the high-RES scenario for 2030.

Power price boxplots of simulation results: median, first and third quartiles and extreme values are shown in the figure below.

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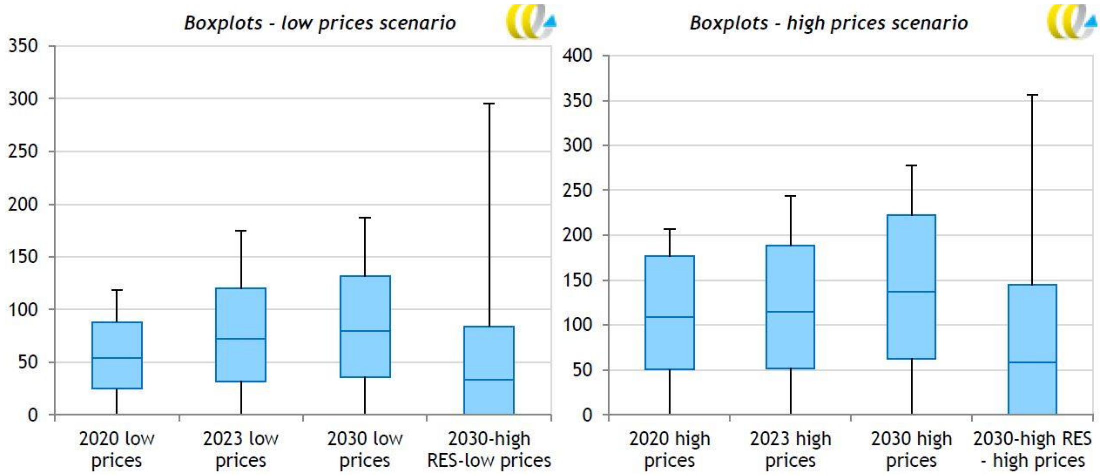

Figure 21. Boxplots of simulation of price (EUR/MWh) by scenarios. EC 2017 [25]

In Figure 21 it is observed that prices are expected to increase modestly from 2020 to 2030 scenario years. This is arguably driven by rising fuel and CO2 prices. The 2030 high-RES scenario is the exception; in this scenario the majority of prices tend to be lower but there are also some higher prices or price extremes.

Furthermore, the boxes become wider over time, indicating that volatility in prices is increasing (50% of the simulated prices fall in the box). This is also seen in the widening whiskers, especially in the high-RES scenario [25].

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Summary table

Based on the study on historical costs, and price projections presented in this section, the Table 17 summarizes the evolution of Electricity prices.

Table 17. Summary table on present, past and future cost of Electricity

	Year	Cost	Cost Unit	Cost [€/MWh]
Present	2016	114	EUR/MWh	114
Maximum in 20 years	2014	120	EUR/MWh	120
Minimum in 20 years	2009	102	EUR/MWh	102
Foreseen cost	2025	38,8[7] to 60,3[8]	EUR/MWh	38,8- to 53
	2030	41,81 to 69,8	EUR/MWh	41,8 to 69,8

[7] lower price scenario

[8] higher price scenario

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4.7. Waste heat streams

Current excess and renewable heat streams are found mainly in thermal power generation, waste-to-energy incineration facilities, energy intensive industrial processes, geothermal fields, biomass availabilities, and annual solar irradiancies [40].

In the Ecoheatcool study [41] the future possible heat resources from combined heat & power, waste-to-energy, heat recycling of industrial excess heat, geothermal heat, and biomass was quantified on an aggregated level for 32 European countries. Those findings [40] can be summarized as:

- Approximately 17% of all residual heat from thermal power generation was recycled into district heating systems or used directly for industrial demands
- Only 1% of the European biomass potential was used in district heating systems for urban heat demands
- Approximately 7% of the calorific value of non-recycled waste was utilised as heat in district heating systems
- Only 3% of the direct available industrial excess heat was recycled into district heating systems
- Less than 0.001% of the geothermal resources suitable for direct use was utilized in district heating systems

Price fixation mechanism

Supply-side price fixation

Price setting in DH networks is commonly related to capital and operational costs of heat production plants. For regular heat production plants, over the course of a year, incomes should exceed operational costs (personnel, repairs, fuels, etc.) and capital costs (deprecation of investment, interests, etc.) and deliver a certain profit.

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For regular plants, operational costs (fuels) are the largest part of the overall cost structure.

In this context, all heat production plants are profitable, provided that they operate a sufficiently large number of hours per year. Those plants operating a reduced number of hours may require special considerations (e.g. payments for backup capacity).

Under a supply market, overall heat cost reduction is achieved in a heat production plant with lower costs is introduced, and consumption of heat from a more expensive source is avoided. At some point redundant & expensive heat production capacity would be de-commissioned.

Demand-side price fixation

In demand-side price fixation, the consumer sets the allowable cost of heat. In this case, heat producers with production costs below the allowable cost would be willing to inject heat to the network.

Under this scheme all producers would be paid for the heat at the same price.

Particular case for production plants using waste heat sources

Not considering investment costs, waste heat sources are commonly free or low-cost. This is particularly true for industrial waste heat.

Under this condition, in a supply-side price fixation mechanism, heat production units using waste heat streams are the cheapest producers. In this context, waste heat producers would be used as the base production for the DH system, but the specific profit for each heat unit would be substantially lower than for alternative plants (e.g. natural-gas burning boiler plants). This is an unfair environment, where the development of waste heat sources would be difficult.

In a demand-side price fixation mechanism, again, waste heat producers would be used as base production for the DH system. After all, the marginal cost of heat produced by means of waste heat plants will always be cheaper than in any other heat production plant, thus always below the allowable price set by the consumer.

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In this case, the specific profit per heat unit would be substantially larger than for alternative plants, due to the substantially lower operational cost (almost no fuel cost).

In a perfect market, with many heat producers & consumers, elasticity of consumption to the marginal cost of heat, a balanced situation would be achieved. But DH networks are not perfect markets. In DH networks there are only a relatively small number of stakeholders in the market. As final consumers are connected to the network based on a contract with fixed energy costs, all consumers can be considered as a unique large consumer. Equally, there is only a handful of heat producers in each DH network. Furthermore, in many networks, all production plants are owned by the DH operator itself.

Considering waste heat producers as new entrants in this context, an agreement must be reached between the producer and the consumer in the following broad terms:

- Waste heat production is valued at an intermediate cost between its low marginal cost and the cost of heat produced by means of fossil fuels
- In the case where waste heat streams are used in the base of the heat production, its cost should be lower as they cannot compensate for fluctuations in the heat load.
- Considering investments & maintenance costs, waste heat production plants should be provided with fair ROI, internal return rate, etc.
- Considering that waste heat streams are not bound to fluctuations in the wholesale cost of oil products, price fixation mechanisms should not be indexed to these.
- In the case where the implementation of waste heat recovery (e.g. in industrial facilities) increases heating costs in the process, cost allocation processes shall be implemented to incorporate these costs into the cost of heat.

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4.7.1. Waste incineration

Waste incineration with energy recovery belongs to the fourth recovery step of the waste management hierarchy after prevention, re-use, and recycling in the Waste Framework Directive [43]. The primary purpose with waste incineration is to avoid the environmental problems associated with landfills, the fifth and final step in the waste management hierarchy.

Waste-to-energy (WTE) generation is being increasingly looked at as a potential energy diversification strategy. Waste-to-energy plants can supply power almost 365-days-a-year, 24-hours a day. Waste-to-energy plants generally operate in or near an urban area, easing transmission to the customer. Waste-to-energy power usually is sold as “base load” electricity.

Waste-to-energy plants may have a significant cost advantage over traditional power options, as the waste-to-energy operator may receive revenue for receiving waste as an alternative to the cost of disposing of waste in a landfill.

Waste-to-energy plants are designed to reduce the pollutant emissions to the atmosphere.

The price and worth of a special kind of waste depends on whether the waste can be used (e.g. as secondary fuel in power stations or in industrial processes) or has to be disposed in an incineration plant or in a landfill.

In Figure 22 is shown the distribution of municipal solid waste treatment in EU 27 during 2010 according to waste hierarchy. There is potential for future also.

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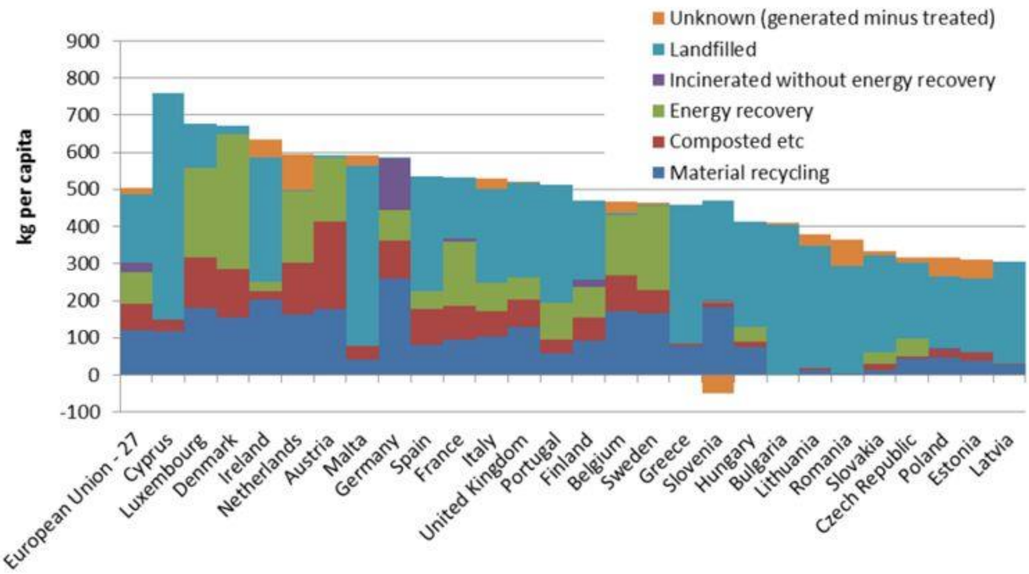

Figure 22 Distribution of municipal solid waste treatment in EU27during 2010

414 WTE plants currently operating within EU27. These plants receive about 65 million tons of waste per year, representing a calorific heat value of between 180 and 200 TWh. Currently, less than half of this calorific heat value is recovered as electricity and heat.

Hence, more heat can be generated from WTE plants, both from better utilization of existing plants and establishment of new WTE plants.

As an example, DH in Barcelona mainly based on waste incineration declares a production cost of 4.2 c€/kWh [26].

In Estonia one waste incineration plant generates electricity and waste heat. Heat will be used by DH grid in Tallinn and Maardu.

In Estonia the limit (cut-off) price or price limit for heat production approved by the Competition Authority is 30.60 EUR/MWh (without VAT). The price for electricity generated from waste is based on Nordpool prices, means market price.

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The cut-off price is the price at which the company cannot apply a higher price for the sale of heat. On the basis of the Estonian District Heating Act [39], a heat supplier who is required to coordinate the heat ceiling may sell heat at a price not exceeding the agreed price limit. [39]

Summary table

There is hard to show price projections for waste incineration. Considering that WTE plants are mainly constructed to better deal with an already available fuel -waste-, it is expected to have a stable price scheme.

Table 18. Summary table on present, past and future cost of waste to heat

	Year	Cost	Cost Unit	Cost [€/MWh]
Present	2018		EUR/MWh	30,49
Maximum in 20 years	2018		EUR/MWh	30,60
Minimum in 20 years	2016		EUR/MWh	30,26
Foreseen cost	2025		EUR/MWh	30,60*
	2030		EUR/MWh	30,60*

*by company, the price is stays in same level if price for waste is not increasing

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4.7.2. Industrial waste heat

Industrial heat recovery can be used in district heating systems. It is a possibility to make use of heat that is otherwise lost. Increased usage of industrial heat recovery reduces the need for fuel combustion lowering greenhouse gas (GHG) emissions, such as CO_2.

K.Lygnerud & S.Werner [42] concluded that "A large majority of the identified co-operations have an operation life of 5 years or more. Such a time frame should be enough for most industrial heat recovery investments to pay themselves back and to generate a return. It seems as if the investment risk of industrial heat recovery co-operations is rather limited. Industrial heat recovery investments are undertaken in a variety of industrial branches. This diversity indicates that the idea to put the excess heat generated to use is spread and appeals to different kinds of industries. It appears as if risks related to industrial heat recovery co-operations is not correlated to particular branches."

With a longer tradition for DH integration of waste heat than in other locations there are several examples in Denmark where excess heat/local produced heat is supplied to the district heating network. This even though, the regulation and taxation can be quite complicated. Some of the applications where purchase of heat exists are:

- Supermarkets (excess heat from cooling): More than 20 supermarkets are connected today. The business case is not extraordinary. In some cases, supermarkets are delivering the heat for free to the district heating. In these cases, it is done so in order to build on their green image.
- Industrial sites: Even with a relatively small heavy industry, there are some cases in Denmark.
- Data centres: 5-6 very large data centres are under construction in Denmark, built by large trans-national companies (Apple, Google, Facebook). Most of these will be located close to district heating areas and have massive excess heat. The electricity consumption of Denmark is expected to rise by more than 10 % due to these data centres alone. Data

centres close to Viborg and Odense will be first to be constructed. It is unclear if a heat purchase agreement has already been set.

Risks associated to industrial symbiosis processes

According to academics of Halmstad University [42], there are several risks for residual heat investments like:

- Geography, where distance can hinder investments;
- Different mindsets in industries compared to municipally owned district heating companies;
- A desire of industries to have own and independent heating solutions;
- Volatile residual heat deliveries into district heating systems;
- The risk that industries go out of business;
- The notion that residual heat losses must be covered for by back-up facilities;
- An inability between parties to reach agreements that are mutually beneficial.

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Production cost of heat from industrial waste heat

In general, purchase agreements are made individually with each producer and will reflect the size of investment, risk of investment, existing district heating tariffs, and security of supply.

For a district heating company, long payback times will typically not be a problem. It is not unusually to see payback times exceeding 10 years for projects utilizing excess heat.

Interesting and promising result were presented in the report [28].

The main aim of this work was to assess the suitability of excess heat (EH) from specific industries for district heating (DH). This is done by determining to which degree industrial EH can be cost effectively utilized for district heating.

The performed analysis is subject to several degrees of uncertainty. Four major factors of uncertainty in the determination of the heating costs were investigated, namely the future development of electricity prices, the influence of the discount rate, the investment horizon and the assumption that the EH itself is available at no cost.

The emitter of EH has (i) costs for the utilization of EH even if, in theory, no investments would have to be performed. It would require internal process adjustments and working hours to initiate the project, to oversee the delivery of EH and general administration. There are also (ii) risks involved, (iii) lack of knowledge and business models, need for use of nonstandard equipment, and (iv) ultimately the delivery of EH can decrease future options for fuel consumption reductions. This is in particular important as EH originates from e.g. the combustion of a fuel of which a part of the costs can be allocated to the EH. The industry has in theory thus a strong interest in reducing the EH amount or profit from its utilization. It is however difficult to determine a global price of EH as it will depend on many local factors, of which many can be hardly quantified (e.g. risks and technology lock-in).

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In the other studies done about using of EH in DH have estimated the price of EH at 15 € /MWh.

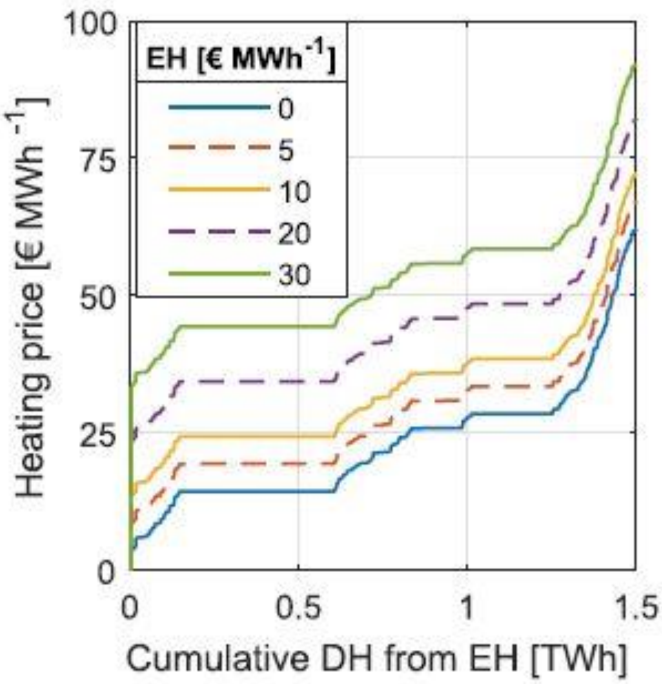

Figure 23. Price of DH €/MWh by different EH costs. Bühler, F 2018 [28]

Sensitivity analysis was performed with 5, 10, 20 and 30 € /MWh, to see how such a cost would impact the potential. EH prices of up to 10 € /MWh would only marginally decrease the DH available at heating prices below 50 €/ MWh. An EH price of 30€/MWh reduced the potential by more than 50%.

However, a majority of the EH is still cheaper than solar district heating.

The study shows that a majority of the excess heat can be utilised at socio-economic heating costs lower than the average Danish district heating price and the cost of solar district heating.

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Price fixation mechanisms & concurrence

Each case needs to be considered in a particular way since the local constraints are different for each location of the system.

In the case of Stockholm's´ (Sweden) Exergis (a FORTUM company) district heating, they are experimenting with the "Open DH" concept, where access to produce and supply heat to the district heating network is simplified. With ODH concept, suppliers and DH owners agree on what levels of capacity of heat are able to be supplied to the district heating. In this particular case, the price fixation is based on two components: a fixed monthly payment for capacity delivered and a variable energy payment for delivery heat. There is another type of payment more appropriate for suppliers with variable levels of excess heat. Energy payment is only dependent of heat supply. Payments are based on outdoor temperatures and they increase when temperature decreases. In this district heating is able to connect excess heat both to flow line and return line, taking into account that flow line temperature are from 68 ºC to 103 ºC and for connecting to the return line it is necessary to delivery heat 3 ºC above incoming return temperatures in every moment.

As for the particular case in the greater Aarhus (Denmark) area, where there is a large transition scheme supplying heat to a number of district heating distribution companies, a variable tariff system (hourly values) has existed for some years now. This implies that e.g. peak load capacity cost much more than base load capacity when the distribution companies buy heat. The idea in Aarhus is that local producers/distributed energy sources can be supplied to the grid and that the distribution company can buy it according to the variable tariff system hour by hour. Also, the connection permits/agreements are simplified. In this case, the producer will typically cover all investments.

Also, the "quality" (temperature) of heat supplied to the district heating can be reflected in the purchase price (it is in Stockholm). However, in Aarhus this is not an issue yet due to the relatively small part of local produced heat supplied to the distribution network at the moment. Though, in Aarhus it is not allowed to feed the heat into the return pipe.

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By Estonian experience and example following findings are by Fortum:

In case of Fortum, the purchase of waste heat on the network is complicated. According to the law, the competition should be made, for a large producer this is the case. According to today's law, the heating network should make a competition for the purchase of heat for the network for 12 years. The terms of the competition will also raise the price.

Small "micro" manufacturers the heat is more complicated. Here is the topic divided into two. Heat pumps from our own cold storms provide heat to the network on the same basis as the boilers of utility, because they are part of the heat production system (hot-cogeneration), the price of sales of utility to the network is coordinated by the competition authority. At present, the second heat pump of Aardla cooling station only works during the heating season, and we work with cooling towers in the summer.

From the outside of the group, Fortum buys heat from the Kroonpress (printing company) today, the heat of which comes from the drying process. In the summer, nothing can be done with this heat, as the residual heat of the power plant goes into the air. In essence, this heat from the outside of the net comes from the atmosphere in the summer with coolers. During the heating period, when purchasing the network, it must be taken into account the regulations of KKüS [39] and the Competition Authority, and the price of heat purchased must be such that it does not affect the regulated sales price. Essentially, such residual heat replaces our fuel. The heat given on the net replaces the fuel supplied by the furnace. On average, 92 to 94% of our fuel is anyway renewable like wood chips and peat.

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Summary table

There is no common solution or pricing model on industrial waste heat harvesting to district heating systems, and considering that industrial heat is very different by quantity and temperature therefore price projections presented in this section are taken from review of Danish example from document “Spatiotemporal and economic analysis of industrial excess heat as a resource for district heating” [28].

Table 19. Summary table on present, past and future cost of industrial waste

	Year	Cost	Cost Unit	Cost [€/MWh]
Present	2016		€/MWh	53
Maximum in 20 years	-	-		N/A
Minimum in 20 years	-	-		N/A
Foreseen cost	2020		€/MWh	27,7…38,4
	2035		€/MWh	32,6…45,7

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5. Security of Supply & Local constraints

5.1. Business schemes for securing strategic resources

5.1.1. Relevance of energy imports & price volatility

The heating sector shows a clear dependency upon fossil fuel supplies. This is true not only for District Heating, but also for individual heating systems. With the incorporation or RES into the heating mix, this dependency is expected to be reduced. Anyhow, securing strategic resources remains critical in the short-to-medium time frame.

Fossil fuels are mainly produced outside Europe. As shown in Table 20, EU depends on imports for 88% and 69% of its oil[9] and natural gas imports[10]. This import dependency has been increased over the last decades. On average, energy imports have increased by 11% in the last 20 years (43 to 54%).

[9] A Study on Oil Dependency in the EU, Cambridge Economics, 2016

[10] EU Energy in Figures. Statistical Pocketbook 2017. European Commission, 2017

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Table 20 EU-28 Energy Import Dependency by fuel[11]

	1995	2000	2005	2010	2014	2015
Total	43.1	46.7	52.1	52.6	53.4	54.0
Solid Fuels	21.5	30.6	39.4	39.4	45.7	42.8
of which Hard Coal	29.7	42.6	55.7	57.9	68.0	64.1
Petroleum and Products	74.1	75.7	82.1	84.5	87.5	88.8
of which Crude and NGL	73.0	74.4	81.3	84.6	87.9	88.4
Natural Gas	43.3	48.8	57.1	62.2	67.3	69.1

In relation to the country of origin, the supply of oil/gas products, the dependency is mainly towards a relatively small amount of countries. Main imports are delivered by Russia (>30% for oil and gas), Norway (32% of natural gas, 12% of oil) & Algeria (11% of natural gas).

In the case of Russia, there have been several incidents over the last decade where geopolitical reasons have driven to shortages in gas supplies[12][13]. Although several alternative routes are under study, main gas pipelines to Central Europe transit through Ukraine, where territorial and economic disputes between Russia and Ukraine are ongoing.

Over the last decades, Liquified Natural Gas(LNG) terminals have been constructed across EU in order to facilitate the incorporation of new suppliers into the energy mix. This has led to the progressive introduction of Natural Gas from Qatar, Nigeria, Trinidad & Tobago, etc.

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[11] EU Energy in Figures. Statistical Pocketbook 2017. European Commission, 2017

[12] Russia-Ukraine gas crisis intensifies as all European supplies are cut off, The Guardian, https://www.theguardian.com/business/2009/jan/07/gas-ukraine (2018/03/16)

[13] Russia's gas fight with Ukraine, BBC, http://www.bbc.com/news/world-europe-29521564 (2018/03/16)

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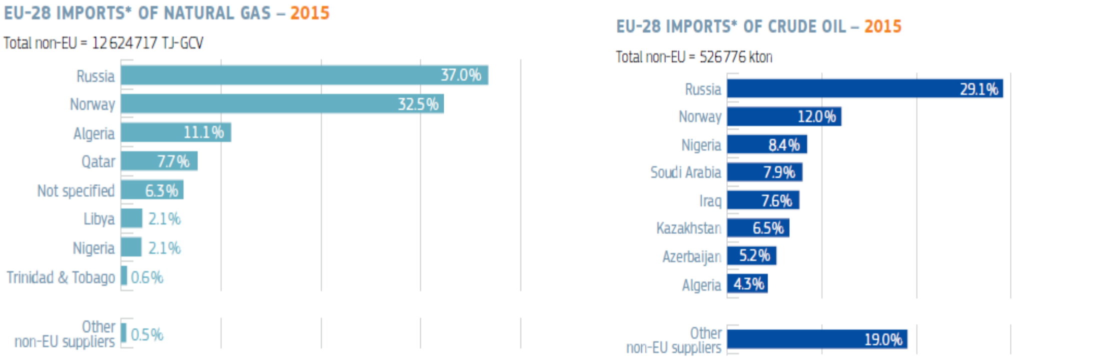

Figure 24. EU-28 Energy Import Dependency by fuel[14]

Also, as developed within section 4, prices of fossil fuels have oscillated by 50-100% over the last decade.

Considering the joint influence of fuel cost and a relatively small number of suppliers, long term supply agreements are needed to secure a stable supply of primary energy with smooth variations of energy costs.

5.1.2. Investments in infrastructure

Energy supply systems commonly imply large investments which require of secure financing. Several infrastructures have been projected and/or constructed over the last decades with budgets in the vicinity of 1.000 million €[15].

These infrastructures require that the operation of them is guaranteed over decades. For this reason, long term supply contracts bound to new infrastructure are commonly binding for 15-20 years.

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[14] EU Energy in Figures. Statistical Pocketbook 2017. European Commission, 2017

[15] MEDGAZ, the gas pipeline between Algeria and Spain required 900 million € (>1 million €/km)

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5.1.3. Development of a spot market in western EU

The natural gas market in EU has been mainly driven by oil-indexed long-term supply agreements between EU member states and gas producers. With oil being traded across the globe and monopolistic gas supplies indexed to oil. The primary energy market in EU has proven to be inelastic to domestic demand, and with little resiliency to international trends.

In the last decade, a local spot market (also named hub) has evolved in Western EU. The main balancing points of these are the Dutch Title Transfer Facility (TTF) and the British National Balancing Point (NBP).

Norwegian Gas and LNG supplies of several countries have been traded over the last decade under this environment. In principle, this has led to a certain freedom in the cost of natural gas. Still, major buyers in EU are bound to long term supply contracts, with minimal purchasing quantities. In the end, this implies that fossil fuel trading in EU is majorly linked to Oil.

5.1.4. Capacity modulation & price fixation

Long term supply contracts commonly allow for oscillations in the supplied quantity. Oscillations in the range of 10-20% of the yearly contracted amount are commonly allowed.

Price of supplies is reviewed every quarter. Net prices are commonly fixed based on average oil prices and €/$ exchange rate of the preceding quarter.

5.1.5. Context of DH operators

With the progressive transition to NZEBs, electrified societies, and increase in local heat production in ST plants, it should be expected that the requirement of fossil fuels in DHs will be progressively reduced. Still, they are critical in order to ensure an economic supply of heat, and will remain so for several decades.

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In this context, long term supply agreements should guarantee a smooth transition into the new, decarbonized DH environment. For that, long term supply agreements should incorporate mechanisms in the following aspects:

- De-indexation natural gas supplies from oil prices
- Periodic revisions of oil supply quantities to meet the evolution of the de-carbonised DH

Anyhow, for smaller DH networks long term supply contracts are possibly less critical, as primary energy is bought from local utilities in a national/regional spot market. These spot markets are commonly indirectly indexed to western EU spot market and/or long-term supply agreements with gas producers. In this context small and medium-size supplier are not so exposed to long term purchase volume commitments, while at the same time, they are bound to long term price agreements.

In some countries (e.g., Estonia) there is only limited exposure to foreign fossil fuels. In these cases, local fuels such as biomass are used. These fuels are traded locally, with only relative exposure to international markets. In these cases, DHs are commonly in a good position for price negotiation, due to their large volumes of purchases, so the need for long term supply agreements is not so critical.

5.2. Local constraints

While evaluating different present, medium and long-term energy supply scenarios in previous chapters of this deliverable it is also important to keep in mind and consider possible local constraints for such scenarios, as for example local availability of biomass, geothermal energy, and supply sources for fossil fuels such as gas and oil.

In particular cases of security of supply needs to be considered for the case of unique suppliers (e.g. Russian natural gas) in order to avoid excessive price volatility and other risks.

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In other cases, the scalability of a heat supply has to be considered. This is the case of land-intensive sources such as biomass (but also large-solar thermal systems).

We will look into 2 specific cases below – the Russian Gas case, most relevant for Fortum Tartu and the Biomass case most relevant for City of Belgrade.

Russian Gas

In case of Russian gas many European countries have been dependent on it as Russia has been a unique or strongly dominant supplier of natural gas in many European markets.

Over the past decades, recurring tensions in the relationship between Russia and its neighbouring countries, have led to limitations of the gas supply to Europe. Examples of these tensions have occurred in 2007 due to Russia-Belarus tensions [35] and over the 2005-2014 period due to Russia-Ukraine tensions [36]. These tensions have been caused by many factors, such as economic disputes over the cost of natural gas, and geopolitical disputes. The last one leading to the annexation of Crimea to Russia in 2014 [37].

In any case, natural gas supply to Europe is highly oligopolistic, and leads to periodic crisis due to regional tensions between Russia and its neighbours. Within these crisis, failure of supply to Central Europe is possible, as in recent years there have been periods when natural gas has not been supplied at all or the supply quantities have been strongly reduced by Russia to the markets which are directly dependent on Russia gas.

This dependency on unique supplier is due to the existing pipelines and infrastructure and therefore both the European Union and the EU countries concerned have realized that alternative infrastructures and supply chains must be created in order to minimize supply risks. Construction of alternative gas pipelines through Turkey, interconnecting the existing gas supply infrastructures between different countries and building more LNG terminal are currently under planning and implementation in many countries, in order to decrease the risks connected with Russia as a unique supplier of natural gas.

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In case of Fortum Tartu, which currently consumes Russian natural gas to offset the peak demands for energy mostly in winter periods, the risk is not very high, as their yearly consumption of Russian natural gas is about 8% of their total fuel consumption. However, Fortum Tartu has already experienced situations when the supply of Russian gas was limited and they have developed ways to use alternatives fuels in case such situations happen even if those alternatives have higher cost and stronger negative environmental footprint and are clearly not the preferred options.

Biomass

Similar to the fossil fuels, also the supply of biomass poses certain problems and risks to the scenarios discussed above. However, risks are different in nature compared to fossil fuels.

Biomass as source of energy has been increasingly popular in many European countries and has considerably contributed in making energy sector more sustainable and environmentally responsible. However certain problems have recently become evident in many countries around the world where the share of biomass production has significantly increased. Most importantly the production of biomass is directly related to the use of land and in most cases in order to increase the production volumes of biomass the land which has previously been used for agriculture or forestry needs to be converted to biomass production, which has caused problems in other areas and economic sectors and has raised a discussion on long term sustainability of biomass production and its overall environmental impact. This together with other factors is currently reflected in situation that in some countries and regions the supply of biomass is smaller than the demand resulting in price increases and making some scenarios more difficult to achieve in economic terms.

In case of City of Belgrade, the size of the city and its DH system makes it almost not possible to rely on Biomass to a large extent, as local sources make it difficult to find energy sources for a multi-million user heating system. Thus, BEOELEK is facing the de-carbonisation of heat supplies through a varied mix of

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infrastructure investments such as large solar thermal systems, heat from waste plants, geothermal heat pump systems, conversion of large power stations to CHPs, etc.

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6. Business case for RES

RES energy sources are meant to fulfil a much greater role in the heat production mix of DH networks. The economies of different heat production systems are diverse. Anyhow, in broad terms, RES energy sources are commonly characterized by relevant investment costs with relatively reduced operational costs. In summary, the marginal cost associated with RES heat production is substantially lower than for traditional heat production systems (e.g. based on the burning of natural gas, etc.).

Under a perfect market economy, RES heat produced would be sold at the marginal costs of the market (e.g. the marginal costs of the heat produced by the most expensive heat production system required to meet a particular heat load). In such an environment, RES heat production would serve to de-carbonize heat production in DH, but the DH network (and its final users) would not find almost any cost reduction until very relevant shares of RES production are installed.

Also, the economic figures of RES heat production would substantially differ for each DH network, depending on the mixture of primary energy sources in each particular DH network.

The purpose of this section is to provide an economic model, based on long term supply agreements, where the installation of RES is favoured by means of fixed & agreed energy prices in the long term which ensure a reasonable profit for newly installed of RES production, while at the same time, lower energy costs are delivered to the DH network. By doing this, the following targets are achieved:

- The installation of RES heat production is de-risked. A supply agreement is signed for the full length of the service life of the production facility. By complying with the foreseen heat delivery amounts, the heat producer has virtually no risk in performing the investment.

- Low heat prices are achieved by de-coupling price fixation mechanisms directly or indirectly linked to oil.

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- The production of as much heat as possible is encouraged. Minimum yearly supplies are required to achieve the economic performance for the investment. At the same time, with stable low-RES energy pricing, additional heat production & delivery will result in improved economic metrics.

6.1. Economic metrics

In economic terms, RES heat production systems & any other actuation over the DH network needs to be considered as an investment. Non- differing to any other investment, these infrastructures need to be assessed as an economically viable activity.

The economic viability of an investment is assessed by means of several economic indicators. Among the indicators, the following are considered the principal ones:

(discounted) Net Present Value, (d)NPV: Net Present Value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows. NPV is used in capital budgeting to analyse the profitability of a projected investment or project. Net present value is commonly discounted to take into account technical, financial (interest rate), political, etc. risk associated with the investment. In this way, the Discounted Net Present Value (dNPV) is the main metric.

$$\mathrm{dNPV} = \sum_{n=1}^{sl} \frac{Cn}{(1+d)^n} - I$$

Where:

Cn	net cash inflow during the period of analysis
I	total initial investment costs
d	discount rate
n	the number of years between the base date and the project service life
sl	is the period of analysis, the service life

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A positive net present value indicates that the projected earnings generated by a project or investment (in present euros) exceeds the anticipated costs (also in present euros). Generally, an investment with a positive NPV will be a profitable one and one with a negative NPV will result in a net loss. This concept is the basis for the Net Present Value Rule, which dictates that the only investments that should be made are those with positive NPV values.

Return Of Investment (ROI): A performance measure used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments. ROI measures the amount of return on an investment relative to the investment's cost. To calculate ROI, the benefit (or return) of an investment is divided by the cost of the investment, and the result is expressed as a percentage or a ratio.

$$\mathrm{ROI} = \frac{\mathrm{NPV}}{\mathrm{I}} \text{ x } 100$$

Where:

NPV = is the Net Present Value of service life
I = is the initial investment

PayBack period (PB): The payback period is the time it takes to cover investment costs. It can be calculated from the number of years elapsed between the initial investment, its subsequent operating costs and the time at which cumulative savings offset the investment. In general, the payback period ignores all costs and savings that occur after payback has been reached.

As in the case of NPV, discounted payback periods should be used to better reflect the economic costs associated with an investment (interest rates).

In practical situations, it has been observed that the best investment is not necessarily that reflecting the shorter payback period, as all information on events occurring after the payback is ignored. Anyhow, generally, payback is a useful technique to compare large and small investments (although adjusted internal rate of return is also used) or to assess the time period during which the investment is at risk.

6.2. Particular considerations for DH systems

DH systems are an interconnected system of particular infrastructures that jointly ensure the continuous delivery of heat to a community of users. In the DH network, the following types of systems are present:

- DH network: This is the physical system which transports heat from heat producers to consumers. The network comprises the following infrastructure: DH pipes, substations which interconnect transmission and delivery networks, Pumping stations, metering & billing.
- Heat production facilities: heat production in DHs is commonly hierarchized in the following way:
    - Main heat production facilities. These are commonly large plants, in many cases CHP systems. They require large investments and generate large amounts of heat, commonly at reduced marginal costs. Main facilities are sized to operate at full load for a large share of the year. Although they can be regulated at partial loads, they cannot cope with low loads in summer periods, and need also to be complemented with other heat production items during peak periods in winter.
    - Auxiliary heat production facilities. These are commonly medium-sized plants. With substantially lower investment costs but greater operating costs. They are commonly used to complement heat production in large facilities. They commonly operate in periods with low loads (e.g. summer, when production in large production facilities would exceed the loads in the system), and also during peak periods (e.g. winter, when all available production capacity is needed.

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- Waste heat input from industrial settings third parties. Depending on the specific location of a DH network, access to industrial waste heat streams may vary. In some DH networks, industrial streams are a large share of the heat production. It has to be clarified that the availability of industrial waste heat is linked to the schedule and intensity of the main activity of the industrial facility (e.g. weekly schedules, seasonal variations in production, maintenance downtimes, variability of demand for industrial goods over time, etc.) some studies show that the carbon intensity of DHs substantially differ based on this parameter[16]. Waste heat streams are commonly the cheapest energy available in the DH. Anyhow, due to the previously mentioned variability, care should be paid to ensure that alternative heat production facilities are available for periods where industrial streams are not available.

- Large (geothermal) Heat Pump systems. With the reduction of flow temperatures in DH, Heat Pump systems are increasingly relevant in the heat production mix. With COP levels improved over time, Heat pumps are high performance heat production systems. The marginal cost of heat with this technology is linked to the price of electricity, for this reason, heat delivery with these technologies will be heavily dependent on the economic optimum of each DH in a particular period. With the increasing electrification of society, and increasing share of renewables in the production of electricity, large price fluctuations may occur in these technologies, even over the same day.

- Thermal storage: Thermal storage facilities are being introduced in DH in order to store excess heat production at low cost in periods with reduced heat load/large RES capacity available to periods with substantially larger heat costs (e.g. peak periods in winter…) In some cases, large storage facilities are installed for inter-seasonal storage of solar thermal heat.

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- Heat consumers/prosumers

In the end, DHs are expected to be increasingly populated by RES technologies (solar thermal, waste heat streams, and heat pumps). These technologies are intermittent by nature (heat pumps are intermittent by economic reasons). In the population of DH with these systems, operators should take a close look to the following issues:

- Economies in the production of RES-based heat: Avoidance of heat cost indexing to oil/natural gas
- Balancing of the system: Backup systems should be available for the case where intermittent resources are not available. A share of this backup capacity might be expected to operate a large share of the year and should be produced with high performance technologies
- Ensuring the economic profit for all the heat producers: The introduction of RES heat in the system reduces heat delivered by traditional heat production plants in the DH. If RES is introduced in a large share, the reduction of operation hours/yearly cumulated supply for some of the traditional plants might even make them un-profitable. These plants remain critical for the system. Plants originally foreseen to operate at the base of the DH are transformed into peak/backup systems, operating a reduced amount of time over the year. The profitability of these plants need to be guaranteed, if their function of backup/peak supply is to be ensured.

In the end, modifications to DH systems are performed under long term planning. DH operators must ensure that in the long term, all stakeholders are guaranteed a fair & profitable environment.

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6.3. Operational conditions & Scenarios for profitable investment

In order to ensure the economic viability of the full DH system, the integration of new heat production systems should ensure the following:

- The internal return rate of investments in new production facilities shall consider the following criteria:
    - Reference return rate for energy related infrastructure: 10%
    - Minimum reasonable return rate for underperformance (-20%) of investments: 5%
- The benefits of LT / ULT conversion of DH network needs to be shared among all stakeholders:
    - Investments may occur in heat production plants, substations at different locations in the network, internal HVAC systems in buildings.
    - In the case of increased plant performance due to LT operation, the reduction of operational (fuel) costs to meet the same load needs to be shared among stakeholders (e.g. heat tariff modification based on the investment required).
- Economic metrics for all existing plants should be revisited, considering that margins are kept in acceptable levels:
    - Overall, facilities with full-load equivalent operational time above 3000h[17] will remain profitable.
    - Operational revenue must be kept positive, with internal return rate in similar levels as those foreseen when the investment was performed.

[17] This figure is highly speculative, and will depend on specific conditions for each production facility & DH network.

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This can be done so, by incorporating/strengthening of a fee for availability of backup heat production.

- In the case of high redundancy in heat production, the progressive closing down of production facilities needs to be planned.

- The system will be modified in such a way that cost reduction in heat production is used to compensate all stakeholders:
  - No heat producer can be prejudiced
  - Final users must find ULT DH profitable (e.g. price reduction compared to business as usual DH & alternative heat production systems)
  - DH operators must keep the system profitable. The introduction of RES cannot result in economic imbalance of the full system.

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Overall, the economic metrics shown in the following table (Table 21) shall be considered.

Table 21. Economic metrics for the assessment of investments in LTDH

	Interest rate	Expected service life	Reference Payback Period
Heat production systems	2%[18]	20 years	< 8 years
DH network		> 20 years	15 years

[18] Investments in heat production plants are considered to be safe, considering that long term heat purchase agreements, a large mass of consumers or priority in heat production or a set of these is guaranteed.

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7. Summary Table

Table 22. Summary table for all the heat sources for LTDH

Heat Sources	Cost of primary energy (EUR/MWh)		Available Technologies & Performance level	Costs (EUR/MW)	
	Present (2017)	030		Investment	O&M (per year)
Natural Gas	14	24-30	CHP: 2-50MW// 64-77%	0.5M€/MW [2]	± 3% of investment
			HOB:0.2-20MW// 97-106% (Condensation)	100k€/MW [2]	± 10k€/MWh
Oil	40	55-60	CHP: 2-50MW// 64-77%	0.5M€/MW	2-5% of investment
			HOB: 0.15-1 MW	100k€/MW [2]	
Biomass	Woodchips: 13	Woodchips: 14	HOB: 50kW-20MW// >90%	0.4 M€/MW [44]	1.8-3% of investment
	Pellets: 32	Pellets: 32			
Electricity	70-120	41.8-69.8	Electric Heat pump/ heating, COP 1.7-3.8	350-450 €/MW [45]	± 4-7% of investment
Solar Thermal	0	0	CSHP: 3-50 MW // 20-50%	400 €/m^2	± 1 EUR/ MWh
			BIST: 10-200 kW // 20-40%		
Waste-Heat	0	0	Heat Pumps: 1-10 MW	± 7-10M€/MW [46]	± 2.5% of investment

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Geothermal	0	0	Heat Pumps: 10-15 MW	± 0.7 M€/MW [46]	± 2.5% of investment

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8. Conclusions

In this deliverable, energy costs have been reviewed, considering investment costs, fuel costs and performance levels of a variety of heat production systems. Several conclusions can be taken from the document:

- Costs associated to fossil fuels are extremely variable. During the initial 2 decades of the XXI century, oscillations in the range of +200% - -80% have occurred. Price evolutions of fossil fuels are related to many macro-economic conditions, and highly impacted by geopolitical stability.
- In all scenarios, fossil fuel costs will steadily rise over the next decades.
- Local fuels such as biomass are virtually stable, but limited in capacity. Price variations are mainly related to local production/consumption balance. In large systems (i.e. Belgrade), the potential use of biomass shall be checked against local production capacity. Otherwise, supply shortages may appear.

Renewable Energy Sources are difficult to price. In most cases, energy costs for solar thermal systems are linked to particular investment costs and marginal heat supply costs in each DH. In order to achieve operational economies in DH systems, heat supply costs associated to Renewable Energy Sources should be indexed to the operational costs of these systems rather than to the marginal energy cost in the system.

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