Sustainable alternatives for coal in the heating sector

The hastening phase-out of coal in the European power sector requires new solutions for local district heating grids. This paper locates and quantifies the issue in Europe, describes challenges on the way towards decarbonisation and outlines what can be done to transition to sustainable solutions.

A phase-out of coal power generation by 2030 at the latest has been decided or is within reach in many European countries. At the same time, there is growing tailwind for renewable power sources like wind and photovoltaic energy. Continued cost reductions and more progressive transition policies have led to a share of 38 percent of renewable energy sources (RES) in the EU power mix in 2020. This is a considerable increase of 16 percentage points relative to 2010. In the same period, the share of coal power fell from 24 to 13 percent [1].

Hanasaari combined heat and power plant: as coal retires, sustainable solutions must take over.

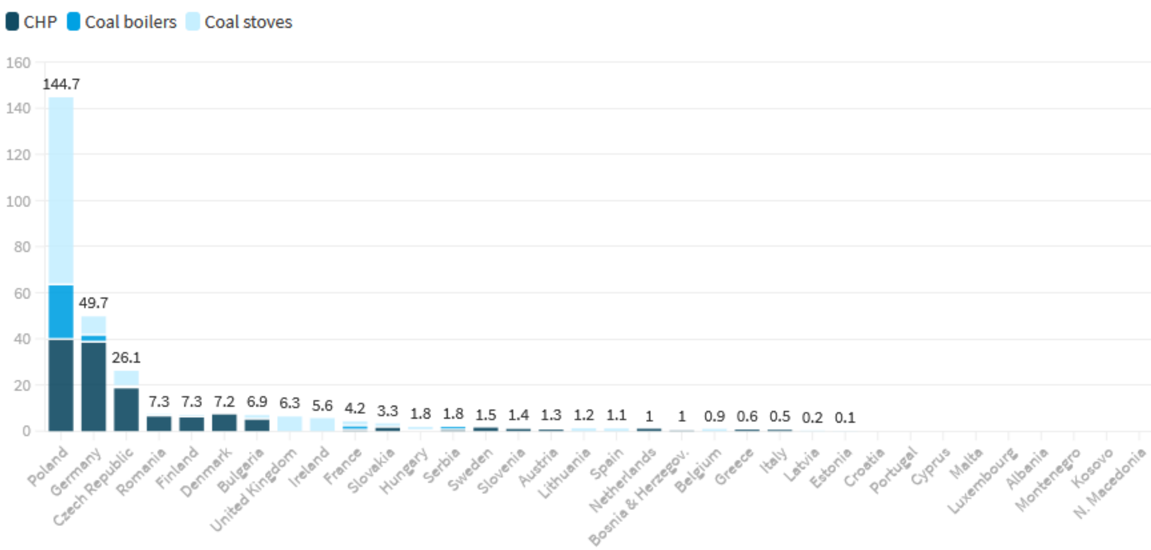
However, the end of coal and its replacement with renewable energy is not only needed in the power sector, but also in the heating sector. Since the end for this energy carrier is approaching, it is important to find and implement sustainable substitutes now.

Coal-based heat is used in two main areas. Nearly half of the supply is burned in household coal stoves, which are almost exclusively located in Poland. Not only do they cause significant CO2 emissions [2], but the largely unfiltered exhaust gasses also lead to serious air pollution, which causes severe health problems and premature deaths [3].

The second half of coal-derived heat is generated in combined heat and power plants (CHP) and, to a smaller extent, in heat-only boilers [4]. These facilities supply most of that heat to urban district heating grids and are primarily located in Poland, Germany, and the Czech Republic. More installations can be found in Northern Europe (Denmark, Finland), Eastern Europe (Slovakia) and South East Europe (Bosnia and Herzegovina, Bulgaria, Greece, Romania). In the Western Balkan countries (in particular in Montenegro and Serbia), there are several projects that aim to connect existing conventional coal power plants to district heating systems.

Poland, Germany and Czech Republic are the top 3 coal countries in the heating sector in Europe

Heat supply from coal in Europe (2015), in TWh

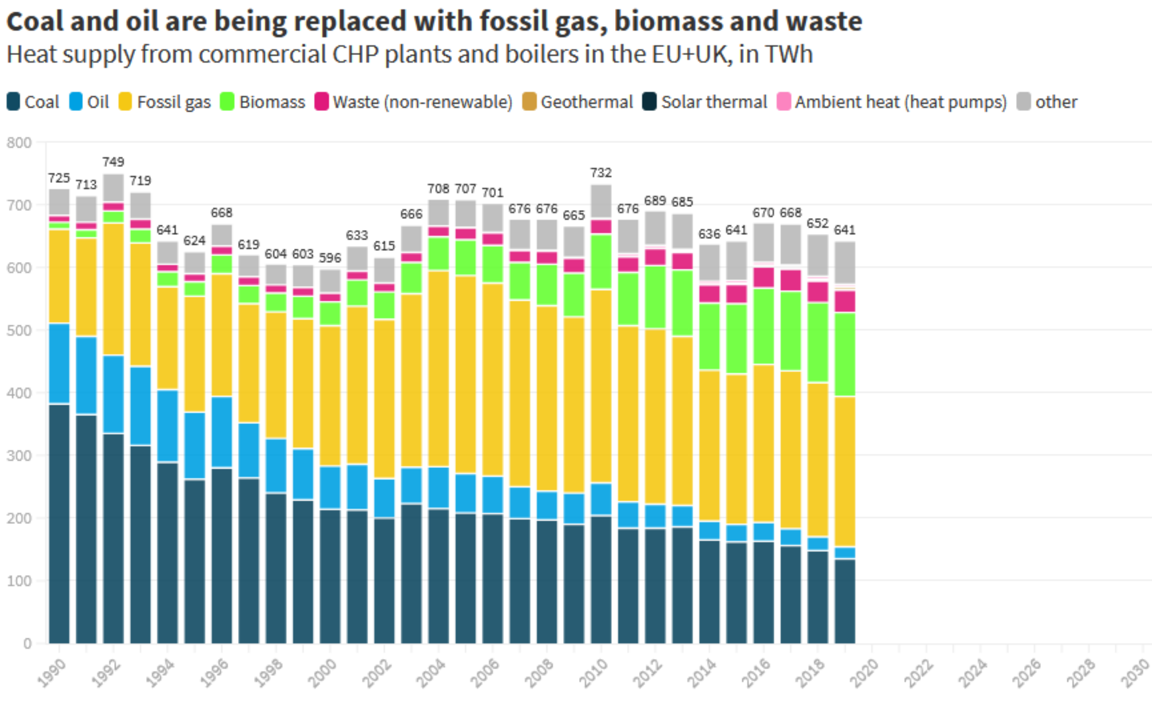


Source: Heat Roadmap Europe, Eurostat • The values for coal stoves are final energy. Values for CHP and coal boilers are secondary energy, i.e. final energy plus transport losses (in the district heating grid). Data for coal stoves in the Western Balkans not available.

This briefing focuses on the second half of coal in the heating sector, i.e. coal-fired heat supplied from utility-scale installations.

HARMFUL ALTERNATIVES ON THE TABLE

Coal used to be the dominant source of energy in European district heating grids. In 1990, its share was 52 percent. The rest was predominantly supplied by oil and gas.



Source: Eurostat

After 1990, heat generation from coal, formerly the most important source of district heating energy, was partially replaced by fossil gas, which peaked around the year 2005. Since then, heat from gas has been partially replaced by biomass, while coal kept a significant market share, which has been shrinking only slowly.

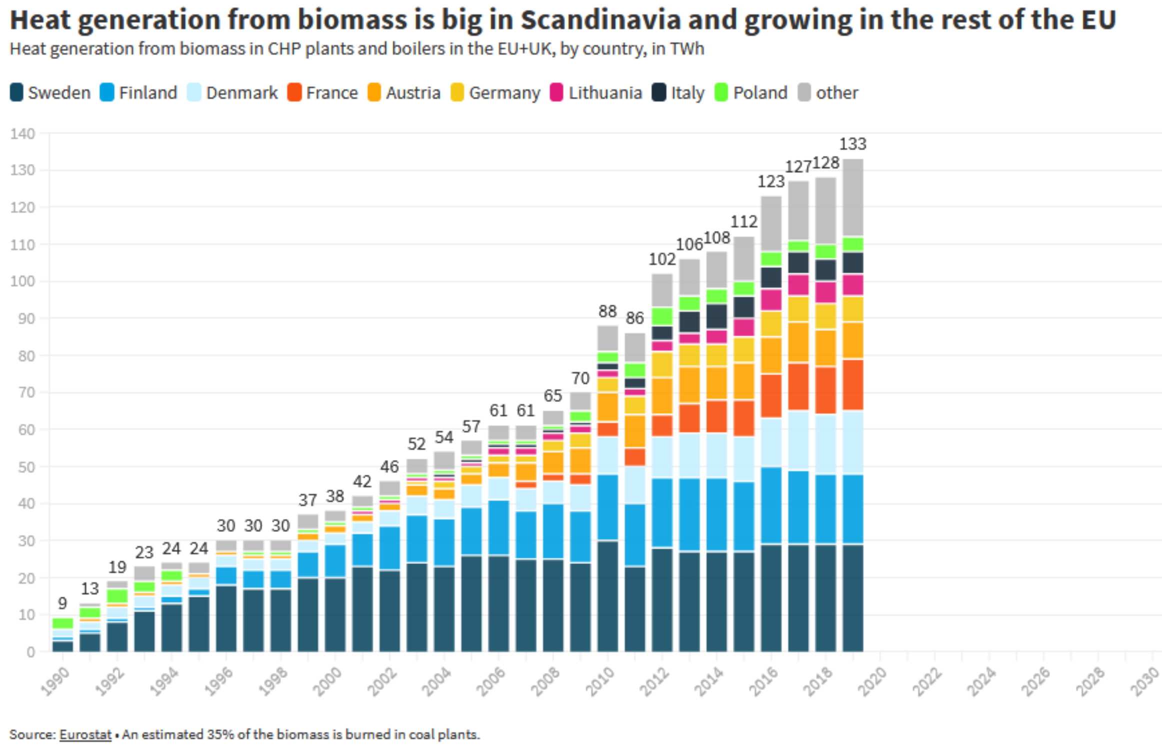
Since 2000, the market share of biomass in district heating has increased from 10 to 26 percent. The fuel is either burned in dedicated facilities or by co-incineration in coal-fired CHP plants. An estimated 35 percent of all biomass used for energy production is burned in coal plants, the rest in biomass plants [5].

To some degree, the burning of waste is being promoted, too. However, waste supplies only a relatively small part of the energy in district heating grids.

Proponents argue that these fuels can be used in the moment they are needed and provide heat at high temperature levels, which facilitates their integration into traditional district heating grids; that fossil gas causes less air pollution than coal and is relatively cheap; and that biomass is considered a renewable energy source with a competitive market price. However, the reality is more complex as these fuels all come with specific problems.

NO FUTURE FOR FOSSIL GAS

Natural gas is a fossil fuel for which methane leakage has to be taken into account as well. This additional source of climate warming substantially adds to its climate impact, nullifying the argument that gas is significantly less climate warming than coal [6]. This means fossil gas can have

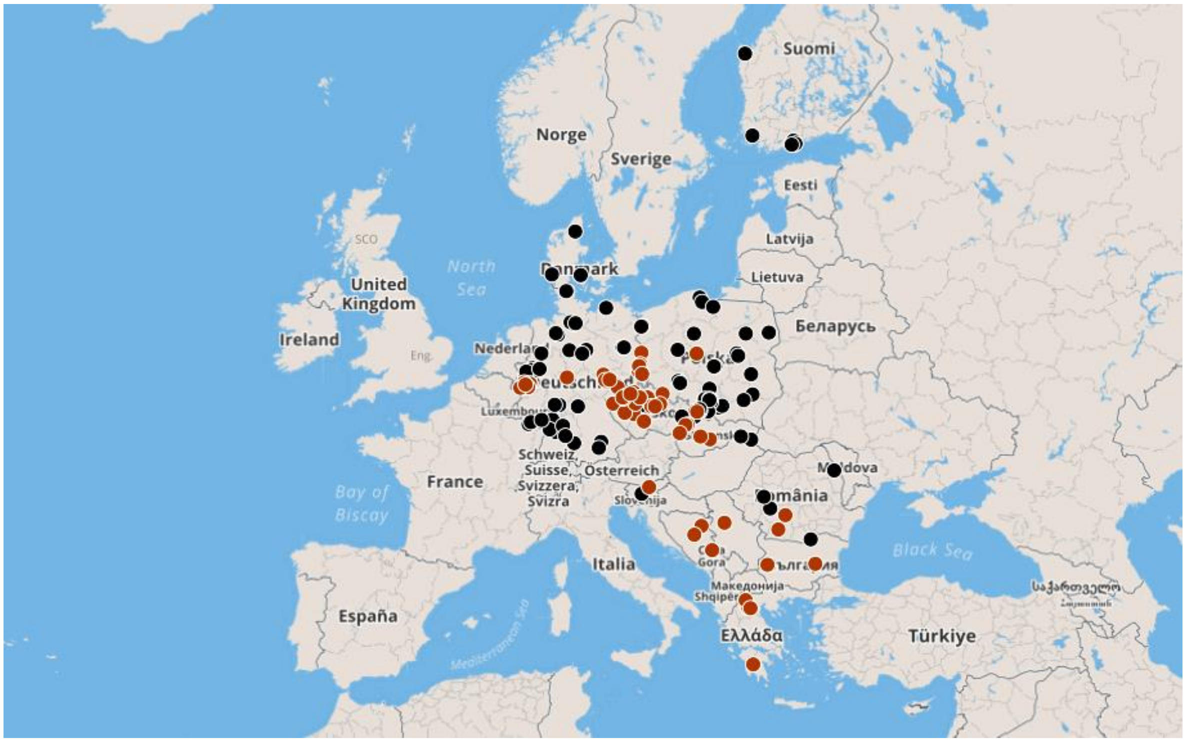


no future in sustainable district heating grids. Yet, gas-fired CHPs are many utilities' preferred option to replace coal CHPs across Europe.

In order to justify investments in gas assets, proponents refer to a lack of short-term alternatives. It is, however, a lack of planning and investing in sustainable alternatives that creates this perceived gap in the first place. Intentions to eventually replace district heat from fossil gas with hydrogen produced from renewable power, also known as "green" hydrogen, may be genuine, but the reality of this happening at scale is doubtful.

Green hydrogen is a costly energy carrier and will be scarce in the future, too. As there are other technologies to satisfy heat demand in buildings, hydrogen is better placed in other sectors like industry or certain modes of transport and should only be used as a gap filler for district heating grids and only if the full potential of local sustainable solutions is not high enough to meet demand. If, however, a future setup that primarily relies on hydrogen is pursued, today's transition steps will lead to many new fossil gas assets that will continue to harm the climate for a long time.

Prominent proponents of gas are the gas industry, coal-heavy utilities that are looking for easy transition pathways, but also national governments. Examples include Germany's dedication to commission the Nordstream 2 gas pipeline, Poland's state-owned utility PGE that continues to lobby for favourable fossil gas regulation [7], and a group of Eastern European countries that promotes coal-to-gas conversions [8].



Coal-fired CHP plants in Europe: This map shows locations with coal-fired CHP capacity in Europe. Please note that in some locations there can be more coal capacity that does not provide heat. In some of the listed locations, generation of heat plays only a minor role. Black: hard coal. Brown: lignite. Status: March 2021.

Source, license and more information: https://www.beyond-coal.eu/database/

LIMITING THE USE OF BIOMASS

An important reason for the constant growth of biomass in district heating grids in the last decades is its ability to provide heat at high temperatures. In many cases, it is also the most economic among the renewable energy sources for heating purposes.

From a climate perspective, however, some types of biomass have questionable aspects. Close attention must be paid to the origin of the fuel. There are considerable quantities that can be used without interfering with sustainability criteria, climate concerns, or competing with food production. Such biomass can consist of post-consumer wood, sawmill dust, or forest residues that would otherwise decompose and emit CO2 anyway. Yet, more than a third of woody biomass used for energetic use originates from primary wood [9].

At the same time, there is a growing threat to use wood pellets made of high-quality stem wood. The biomass policies in the United Kingdom illustrate these concerns: from 2010 to 2018, imports of wood pellets increased from 0.6 to 7.8 million tonnes. Most of these wood pellets are used for electricity generation in the former coal power plant Drax [10]. As a result, more than a quarter of

Biomass used for heat generation must come from sustainable sources
Photo by Kyle Spradley

the UK's bioenergy feedstocks is imported [11]. Concepts that are similar to the Drax case exist in other European countries, e.g. in France [12], the Netherlands [13], or Germany [14].

EU legislation considers all these types of biomass to be carbon-neutral, assuming the carbon emissions are compensated by growing new trees on the land where it was harvested from. A confirmation whether this actually is the case is not required.

This specific biomass concept comes with a "carbon debt": the release of carbon when burning the wood is only compensated after decades that a new tree needs to grow and absorb the equivalent amount of CO2 [15]. In the meantime, burning trees leads to a net increase in atmospheric CO2 concentration. However, carbon emissions need to be reduced now and not in the far future.

This means that the use of biomass, which has a limited potential in the first place, can only partially be used for energy production while securing a positive impact for the climate. Its energetic use also still causes local air pollution, in particular if used in household heating, with the associated health and economic costs.

ALTERNATIVES: HEAT DEMAND REDUCTION IS KEY

The most important measure to tackling the heating challenge is the reduction of demand via energy efficiency measures, particularly in existing buildings. Reducing heat energy demand is key to reducing peak demand and bringing down the cost of decarbonisation. But most importantly, a lower heat demand is necessary because sustainable heat supply is usually limited and can meet demand best if it's low. The Heat Roadmap project recommends overall demand reductions of approximately 30-45 percent of current levels. [16] The "Paris Agreement Compatible Scenarios for Energy Infrastructure" (PACS) even assume demand reductions of nearly 70 percent [17].

Energy efficiency also facilitates the reduction of operating temperatures in the distribution grid, which in turn is necessary for the integration of a range of renewable energy sources. Furthermore, energy efficiency enables more house connections to the existing district heating grids without changing their capacity.

SUSTAINABLE TECHNOLOGIES EXIST

Fossil gas will not deliver a setup compliant with net zero emissions. Waste is a fuel that needs to be reduced via recycling. Increasing the incentive for burning waste is not the way forward. And sustainable biomass has limited potential. What can therefore be deployed to decarbonise district heating grids?

Box 1 describes the most relevant among the sustainable substitutes for the aforementioned fuels and explains their most important specifics. It is important to investigate the potential of each of these solutions in every location with an urban district heating grid.

CURRENT REGULATORY FRAMEWORKS SLOWING DOWN THE TRANSITION

Developing all these different sources is more complex than the current setup, which usually relies on few but large heat generators. But it is a necessary step towards net zero heating.

TECHNOLOGIES

DEEP GEOTHERMAL ENERGY is a dispatchable, clean, renewable and carbon-free energy source with low space requirements and a significant potential in urban areas. In recent years, technological learning has led to cost reductions. Yet, the technology still suffers from low prices and subsidies for fossil fuels. Geological uncertainties come on top of this. They are due to the low level of resource exploration in many regions of Europe, which leads to a low number of concrete projects.

However, the technology characteristics make geothermal energy generally very attractive for decarbonised district heating grids. If a general potential is known or suspected to exist, municipalities should further investigate if it can be exploited. National governments are advised to create favourable conditions for this mature technology, in particular by reducing the geological uncertainties.

Further reading:
Information portal Think Geoenergy
Geothermal energy: Opportunities in Eastern Europe
Geothermal energy applied in Hamburg, Germany

SOLAR THERMAL ENERGY is a cost-competitive, clean, renewable, and carbon-free energy source that is well-suited to supply heat to district heating grids. The technology plays out its full-scale strength when built as a large collector field. Such applications exist, primarily in Denmark, but also in Austria, Germany, and Poland. With better market conditions and enough space available, the technology is ready to grow significantly. Without seasonal storage, up to 20 percent of a municipality's space heating demand can be provided by solar thermal energy. When seasonal storage is included, as much as 50 percent and more is possible [18]. The high space requirements and the need to produce heat in proximity to consumers reduce the potential, in particular in densely populated areas, but there are ways to deal with these challenges (e.g. multi-uses of the area).

Further reading:
Solar District Heating Initiative
Brochure about Solar District Heating solutions
Multi-use options for solar thermal energy [DE]

ELECTRIFICATION is another important element of the transition of the heating sector. This can either happen via resistance heaters, i.e. large-scale kettles, that turn electric energy, ideally surplus renewable electricity, into heat. The second and more important route is via small and large-scale heat pumps. Heat pumps use electric energy to make ambient energy from low-temperature fluids (air or water) available for heating by "pumping" (lifting via compression) the temperature of the energy carrier to a higher level. This process, also known as a "reverse fridge", is about two to four times more efficient than resistance heating, but requires a local heat source. Large-scale heat pumps usually require a water-based heat source like a river, a lake, sea water, or sewage or mining water. As an alternative, waste heat from exhaust gasses of industrial processes can also be used. If such a heat source exists, heat pumps are very valuable for the decarbonisation of heat. This technology can be cheaper than heating with gas to with relatively low levels of carbon pricing.

Further reading:
Large-scale electric heat pumps in district heating systems
Large-scale heat pumps in Swedish district heating systems
The decarbonisation of the EU heating sector through electrification: A parametric analysis

WASTE HEAT RECOVERY does not refer to the burning of waste, but to excess heat that originates from small or large-scale industrial processes. Exploiting this source is among the most efficient ways of using energy and can contribute another puzzle piece to decarbonising the heating sector. The energy itself comes at no extra cost, but it has to be integrated into the existing district heating grid, which often requires the installation of new pipes. The utility and the heat provider also need to make arrangements about the feed-in structure, which is a highly individual process. In some cases, the temperature level of the fluid needs to be increased via heat pumps to enable feed-in.

Further reading:
Quantifying the excess heat available for district heating in Europe
Preliminary assessment of waste heat potential in major European industries
Integrating renewable and waste heat and cold sources into district heating and cooling systems

The higher complexity of such a diversified supply structure is one reason why, currently, utilities still rely on incremental transformation pathways based on centralised generation from waste, fossil gas and biomass, while neglecting the aforementioned alternatives.

The current regulatory frameworks in the European countries are another essential constraint. In many cases, states subsidise district heating systems by granting a premium on power generation from CHP plants. The rationale: coupled generation of heat and power deserves public support because it is more efficient than the generation of both commodities in two separate processes.

However, such a policy setup based upon the efficiency argument, without supplementing it with steps towards a fully renewable energy system is not enough to deliver a decarbonisation of district heating. Instead, it creates subsidies for fossil fuels, and discriminates against the sources that could make a significant contribution to reducing emissions just because these sources do not generate both heat and power. Ironically, the use of heat pumps can lead to even more efficient use of primary energy than a CHP plant can deliver, but heat pumps cannot profit from CHP-based support schemes [19]. It is also noteworthy that a heat pump can run on 100 percent renewable power, while most existing and projected CHP plants run on fossil fuels.

LOCAL HEAT PLANNING, BETTER POLICY, AND DEDICATED FUNDING

The end of coal in Europe has been decided, either explicitly or implicitly. Planning and building the sustainable alternatives now is critical. Policy makers and planners on local, national and European level should acknowledge this and facilitate the implementation of sustainable solutions, taking the following into consideration:

Provide support for renewable heat, not fossil fuels: replacing subsidies for fossil CHP plants with funding for green heat technologies and reducing heat demand is an important step to build the district heating systems of the future.

Carbon pricing: The lack of carbon pricing in the heating sector is another obstacle for decarbonised district heating grids. As long as the installation of a gas-fired option is a financially attractive alternative, the full potential of decarbonised solutions will not be reaped. Legislation in Sweden and Switzerland shows where this could be going. Both countries have introduced tangible carbon prices in the heating sector [20][21]. Other countries like France and Germany are following suit with similar policy regimes.

Local heat planning: The local perspective is not less important than the policy framework on European and national level. The complex transition towards decentralised district heating systems requires dedicated and integrated planning starting now. Planners must actively anticipate supply- and demand-side opportunities, develop the grid, realise synergies, coordinate the increasing number of stakeholders that is characteristic for a diversified supply structure and drive forward the implementation of sustainable solutions.

European and national financial mechanisms that enable and incentivise sustainable alternatives: Transitioning towards renewable heat comes with significant climate and health benefits. European support mechanisms like the EU Green Recovery Fund and the EU Modernisation Fund or national measures can facilitate the choice for sustainable approaches while avoiding the risk from unsustainable loopholes.

Reconsider ownership structures: Examples from Denmark show that community-owned ownership structures that focus on sustainability targets and deprioritise profit can activate public support for climate-friendly and resilient solutions. This empowering type of public engagement is especially suited for local infrastructure like district heating grids and can serve as a valuable vehicle to kickstart a process towards sustainable, inclusive, and affordable public services.

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Notes

[1] https://ember-climate.org/project/eu-power-sector-2020/
[2] Heat Roadmap Europe assumes a final heat energy demand of 108 TWh that is covered by direct coal use in Europe's residential sector (2015 data). The resulting emissions amount to approximately 15 million tonnes of CO_2. This is comparable to the annual CO_2 emissions generated by 10 hard coal power plants with a capacity of 500 MW each and a (typical) load factor of 40 percent.
[3] The European Environmental Agency has found that an annual 450,000 deaths in the EU+UK can be attributed to the harm caused by air pollution, thereof 380,000 with a direct link to fine dust (PM2.5), for which coal is a major source, in particular when burnt without filtering the exhaust gasses (coal stoves). In line with these findings, fine dust has very high concentrations in Polish coal mining regions. In Poland overall, premature deaths related to PM2.5 are 72 percent higher than the European average, i.e. about 20,000 deaths per year more than the European average. This value is likely to be even higher in coal mining regions. Source: own calculations based on EEA (2020), page 108. Retrieved 5 March 2021.
[4] According to Eurostat, heat generation from coal-fired CHPs was about 108 TWh in 2019. Another 28 TWh of heat came from coal-fired heat-only boilers. 90 percent of the heat from coal boilers is supplied in Poland.
[5] This value is based on an analysis of data reported under the European Pollutant Release and Transfer Register Regulation (EC) No 166/2006 (E-PRTR); SOURCE (accessed 15 Dec 2020)
[6] Climate impact comparison coal vs. gas:
https://www.cmu.edu/ceic/assets/docs/publications/published-papers/2017-and-2018/farquharson-et-a l-2017.pdf
[7] https://www.reuters.com/article/us-europe-gas-finance/polands-pge-eu-advisors-increase-pressure-ov er-gas-in-green-finance-rules-idUSKBN2AM236
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[13] https://www.banktrack.org/project/dodgy_deal_rwe_biomass_conversion_project_the_netherlands.pdf
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[15] Source: http://www.pfpi.net/wp-content/uploads/2018/04/UPDATE-800-signatures_Scientist-Letter-on-EU-Fore st-Biomass.pdf, accessed 21 Feb 2021
[16] https://vbn.aau.dk/ws/portalfiles/portal/288075509/HRE_Quantifying_the_low_impact_of_the_low_car bon_heating_and_cooling_roadmaps_Executive_Summary.pdf; page 18
[17] https://www.pac-scenarios.eu/scenario-development.html (dataset)
[18] https://www.sciencedirect.com/science/article/pii/B9781782422136000096
[19] http://www.fze.uni-saarland.de/AKE_Archiv/DPG2016-AKE_Regensburg/Buch/DPG2016_AKE2.1_Lut her_KWK-WP-Waermewende.pdf
[20] https://taxfoundation.org/sweden-carbon-tax-revenue-greenhouse-gas-emissions/
[21] https://www.sciencedirect.com/science/article/pii/S0301421520305322

This Paper was issued by the Europe Beyond Coal campaign in March 2021.

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https://beyond-coal.eu/

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