Incineration: what's the effect on gas consumption?

Report

October 2022 – Equanimator Ltd for Zero Waste Europe

Executive Summary

Context

The war in Ukraine has led to major shifts in the EU's energy markets. A combination of Russia's weaponising of its energy supplies by reducing supply, particularly of gas, allied with a determination on the part of the majority of EU member states to stem the flow of energy-related revenue to Russia, has led to a significant increase in the price of gas in wholesale markets. Prices in EU electricity markets are generally set through marginal pricing on the basis of day-ahead supply offers and demand bids, with market equilibrium rules deriving prices for each hour of the delivery day.

30 years after the United Nations Framework Convention on Climate Change entered into force, the EU27, as a bloc, remains stubbornly reliant on fossil fuels for its energy supply. Gas has frequently been perceived as part of a transition pathway through which member states could pass on the way to a lower carbon future. The experience, back in the 1990s, of the UK's progressive shift from coal to gas, and the significant (in percentage terms) reduction in greenhouse gas emissions to which this led, has raised the prospect of a seductively simple route to the phasing out of coal, with one form of centralised fossil-based generation being replaced by a somewhat lower carbon alternative. Similarly, at the household level, shifting away from solid fossil fuels to gas-fired boilers has offered a route to a reduction in greenhouse gas emissions linked to the heating of households in those countries where solid fuels have dominated.

There is panic in the air. Addressing climate change – still seen as a relatively long-term objective, despite the growing weight of evidence that suggests the need for radical emissions reduction is urgent – is at risk of being placed, temporarily, on the fossil-fuelled back burner. Several member states are seeking to address the current turmoil in the gas, and hence, electricity market by a range of measures, ranging from demand reduction, to back-pedalling (hopefully, only temporarily) on commitments previously made to scale-back or phase out fuels that are now being regarded as an evil made necessary by the far greater evil of Russia's invasion of Ukraine.

Waste management and the energy crisis

In this context, it might be tempting for any supplier of energy that is unrelated to the use of fossil-derived oil and gas to highlight the potential merit of their offering. The waste management industry has advanced its case as a potential contributor to a solution to the gas and climate crises. And it is undoubtedly true that this may be the case. Where increased recycling can supplant EU-based production from primary materials, it can reduce demand for fossil-derived energy and / or fossil-derived feedstocks, and reduce overall demand for energy. Furthermore, recycling processes themselves may be more amenable to deployment of renewable energy sources than primary ones (mechanical recycling of plastics being a good example here). Separate collection of unavoidable food waste might enable more biogas to be generated at anaerobic digesters, with the cleaned gas allowing use for heating. These changes are, by and large, consistent with the direction of travel for the EU for the medium-term, and show some alignment with a strategy for addressing climate change. Beyond the management of waste that is being generated, prevention of waste through reduced consumption, and consumption shifting towards longer lasting products, and wider adoption of reuse / refill can reduce the use of energy which is embodied in the products that we consume.

Somewhat more controversially, the waste management industry has claimed that incineration and co-incineration could be deployed more widely than is currently the case, with claimed benefits for climate change, and fossil fuel consumption. For example, a recent FEAD Press Release noted:[1]

> *Whereas Member States reached yesterday a political agreement on a voluntary reduction of natural gas demand by 15% this winter, and the European Commission has recently presented the REPowerEU Plan in response to the hardships and global energy market disruption caused by Russia's invasion of Ukraine, the waste management sector is not (yet) at its full capacity of producing and saving energy.*
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> *Today more than ever it is essential to end the EU's dependence on Russian fossil fuels and to tackle the climate crisis, which can be done "through energy savings, diversification of energy supplies, and accelerated roll-out of renewable energy to*

[1] FEAD (2022) The waste management sector is not at its full capacity of producing energy, *Press Release*, 27 July 2022, fead.be/position/the-waste-management-sector-is-not-at-its-full-capacity-of-producing-energy

replace fossil fuels in homes, industry and power generation".[1] Here, the waste management sector has a fundamental role to play as:

- *Recycling and recovery operations save material resources, energy and CO2 emissions by avoiding the extraction, processing and use of virgin raw materials and fossil fuels; and*
- *The electricity and heat produced from waste through incineration and anaerobic digestion is generated from a local, reliable and secure source, which allows to diversify our energy supply, in particular with regards to District Heating and Cooling networks, and accelerates the roll out of renewable energy.*

At the philosophical level, the argument that waste – of whatever origin, and however used – could be considered as 'renewable' is not, and never has been, especially credible. Waste prevention sits, rightly, at the apex of the waste management hierarchy. No industry sets out with an objective of generating waste. Wasted materials represent wasted embodied energy and emissions. As long as we have waste, it should, of course, be managed, but in the context of frameworks designed to reduce its generation. Claiming that waste should be viewed as a resource which is "renewable" is problematic. The energy derived from it may, depending on how it is derived, and how one accounts for different pools of carbon, be low in its (fossil) carbon intensity. That, though, is a distinct question to the decision regarding its "renewable" nature.[2]

Accepting terminology as it is currently applied, only the energy derived from non-fossil resources is currently considered renewable.[3] Where incineration of leftover (after source separation) mixed waste is concerned, most member states assume that around half of this is "renewable", and the rest is "non-renewable". The "non-renewable" energy is largely derived from plastics. A recent report indicates how reliant the EU plastics industry is on use of gas and oil.[4] It follows that unless the waste is of a somewhat strange origin, or unless there is a targeted attempt to remove all plastics, then incineration will not lead to generation of purely renewable energy, even under existing definitions. Any "low-carbon" energy which is generated is delivered simultaneously alongside energy with a high fossil carbon content.[5] It follows that incinerating leftover mixed waste will not be part of a long-term solution to the issues of climate change and dependence on gas without a concerted attempt to address the "non-renewable" component that gives rise to fossil-derived carbon emissions (or until facilities are equipped with carbon capture, utilisation and/or storage).

How much gas does incineration displace?

Electricity and heat are already being produced by incineration. Existing facilities make no additional contribution to reducing gas consumption unless they generate more energy. The level of gas consumption already takes existing generation into account. We sought to understand – using 2020 data – the impact of incineration on gas consumption under different assumptions.

Unrealistic maximum

The claimed potential for energy from incineration and co-incineration to displace energy derived from fossil fuels imported from Russia mainly concerns gas. Incineration is used to generate electricity and/or heat, and it is gas, as opposed to oil, that plays the more

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[2] Of course, this raises questions as to whether the term 'renewable' is at all useful: should the focus not be on the carbon intensity of the sources of energy we use? The term 'renewable' might still be useful: we should seek to derive energy, and materials, from sources which are both low in carbon intensity, and are not diminishing the stock of capital from which resources are drawn. Non-renewable sources, by definition, draw down resources which are not replaced. Even the non-fossil component of waste includes materials which can be derived from practices which could not be considered 'renewable', whether this be in the manner in which timber, for example, is harvested, or the type of ecosystem from which it is harvested.

[3] There are ongoing discussions, in the context of the Renewable Energy Directive, as to whether additional criteria should be applied at facilities such as incineration facilities where, for example, the generation of energy that is considered renewable is always accompanied by generation of non-renewable energy of fossil carbon origin (with associated implications for fossil-derived carbon dioxide emissions).

[4] See Break Free From Plastic and CIEL (2022) *Winter is Coming: Plastic has to Go*, September 2022, www.ciel.org/wp-content/uploads/2022/09/September-2022-CIEL-BFFP-Winter-is-coming-report.pdf

[5] See, for example, D. Hogg (2022) *The case for sorting recyclables prior to landfill and incineration*, Report for Reloop, June 2022; D. Hogg (2021) *Rethinking the EU Landfill Target*, Equanimator Report for Zero Waste Europe, October 2021.

important role in the supply of electricity and heat.[6] The EU is heavily dependent on imports for its gas. EU production of gas is more or less the same as the EU's exports, so that imports equate, more or less, to the quantity of gas available for final consumption in the EU.

Using data from Eurostat, we estimated the amount of gas that might be displaced by incineration under the unrealistic assumption that all electricity and all derived heat produced in 2020 was displacing energy from gas. This considers all incinerated waste, whether renewable or non-renewable in origin, and whether municipal or not. The total amount of gas displaced by electricity production would equate to around 1.9% of total current demand for gas. Derived heat produced from waste equates to a further 1.8%.

Average EU27 mix assumption

The assumption, though, that energy derived from incineration always displaces gas is clearly not always true. Recent work for FEAD, CEWEP, the Dutch Waste Management Association and the RDF Industry Group, conducted by Prognos and CE Delft, assessed the impact of changes in waste management on climate change. In the central assumption, the avoided source of electricity and heat was the average mix of fuels used to generate electricity or heat.[7] If this assumption was applied to 2020 levels of generation of electricity and heat from waste, then electricity would displace around 0.4% of gas imports, and heat would displace around 0.7% of gas imports.

Average mix, member state-specific

The same analysis was conducted using member state-specific figures for the average mix of sources of electricity and heat. The overall contribution was very similar to the average EU27 mix, although more of the gas displacement was associated with electricity, and less with heat, under this assumption. The contribution to avoided gas use comes predominantly through the power and derived heat generation in a small number of countries. Incineration capacity in the EU is unevenly distributed across member states, but this analysis indicates that the gas displacement is not directly linked to the quantity of energy generated, or waste incinerated. A small number of member states feature disproportionately relative to waste incinerated.

Marginal mix, member state-specific

These results indicate a smaller displacement of gas from electricity generation of 0.29% and from heat generation, of 0.42%. Under this approach, a similar group of member states (as are indicated by the member state average mix analysis) are responsible for the majority of the gas displaced.

Summary results

The results under the four Scenarios, and comments regarding their application, are shown in Table 1. It might be reasonable to assume a displacement of the order of 1.1% of current gas consumption linked to existing incineration. The scope for additional incineration is, however, limited, and we suggest that a more thoughtful application of the marginal mix approach should be used to understand the impact of any new incinerators being used to supply energy and heat in future (and similarly, in relation to decisions to phase out existing incineration capacity).

[6] Note, though, that both oil and gas are used in plastics production in the EU27. As an energy carrier in the EU, oil is more closely linked to use in transport, though this is far from exclusively the case. Around 1.8% of gross electricity production, and an amount of heat production equivalent to 3% of gross derived heat production is derived from oil and petroleum products. By comparison, gas accounts for around 20% of gross electricity supply, and is responsible for heating equivalent to almost 5 times the gross generation of derived heat (most of the heat generated from gas is not via central facilities).

[7] Prognos and CE Delft (2022) *CO_2 Reduction Potential in European Waste Management*, Study for FEAD, CEWEP, Dutch Waste Management Association and RDF Industry Group, January 2022.

Table 1: Avoided gas consumption from incineration under different assumptions, and applicability of approaches

	Electricity	Gas	Comments re: applicability
Unrealistic maximum assumption – always gas	1.9%	1.8%	Never applicable – sets an upper bound to contextualise analysis
Simple assumption – EU average mix	0.39%	0.73%	Only for 'quick and dirty' analysis of scale of impact of existing facilities - assumes averages irrespective of country-specific conditions
Simple assumption – MS-specific average mix	0.45%	0.65%	Allows some member state-specific insight into effect of existing facilities. Can only give a snapshot of reality (no appreciation of dynamics) so cannot be applied over a facility's lifetime Drawbacks are its lack of distinction between 'firm' sources of energy heat, and sources whose role is magnified in times of peak demand.
Marginal capacity assumption	0.29%	0.42%	Allows some member state-specific insight – more appropriate for new facilities Drawbacks are lack of distinction between 'firm' sources of energy/heat, and sources whose role is magnified in times of peak demand. Also, it is backward looking and sensitive to the chosen time-period. Takes insufficient account of recently announced/implemented firm policies

Appropriate counterfactuals

If incineration/co-incineration is to contribute additional energy above and beyond what it currently generates, this could happen in a number of ways:

1. **Capacity Utilisation**
   Where dedicated facilities are not currently operating at capacity, there could be additional waste combusted. In the system context, understanding what might otherwise have happened to that waste may be important – even where the same waste would have been landfilled, landfilling may have led to energy being generated through gas collection. If the waste might otherwise have been recycled, then the issue of the implications of 'not recycling', and where that recycling might have taken place, might be considered relevant.

The consequences of the change for the energy system would also need to be considered, and this depends on a range of issues related to the nature of the facility, the nature of the energy generated, the nature of the users, the sources currently used to supply energy in the forms generated, and the policies being pursued in the member state (and region) concerned, both in respect of waste and energy.

Regarding this option, the extent of existing spare capacity is unclear. The R1 (recovery) criterion has facilitated greater movement of waste for incineration (and co-incineration) across the EU. In principle, that should enable greater capacity utilisation across the EU. If rising energy prices are reflected in the price at which energy is sold by the operator of the incinerator, then the net (marginal) costs of incineration may be expected to fall. This alone might be expected to lead to uptake of additional capacity. Note, in this regard, that the rationale for member states altering tax plans vis a vis incineration may be at risk of overlooking this point. The cost of the inputs to existing incineration in plants, in terms of auxiliary materials, may be increasing in line with rising prices across the economy, but revenues from the sale of energy may well be on the increase also, so that net costs might not necessarily be rising;

2. **Co-incineration**

In the case of co-incineration, there could be additional waste used as a source of energy in such facilities. The use of waste in co-incineration facilities may be constrained by the extent to which the facility (e.g., a cement kiln) is equipped to handle waste materials, the extent to which the waste is prepared in a form suitable for use (facilities may be equipped differently to handle waste with higher chlorine content, for example), as well as (in some cases) the applicable permits, which might limit the extent of use of different sources of energy. Cement kilns and power generation facilities may already be expected to have incentives, notably through the emissions trading scheme (ETS), but also, price volatility of fossil fuels, to substitute the use of fossil fuels with alternative sources of energy, especially (though not only) those which have a high non-fossil content. Different wastes may be more or less attractive at these times.

A recent paper from Cembureau highlights, also, that the cement industry is a marginal user of gas as a source of fuel.[8] The paper indicates that so-called alternative fuels, those based on waste materials and biomass, now account for around half the fuel input for cement production. Of the remaining 50% of fuel use based on fossil fuels, the main ones are petcoke, along with coal and lignite. Natural gas, along with diesel oil and shale, account for 2% of the fossil fuel use, or 1% of total energy use.

The extent to which further substitution by alternative fuels is possible will, most likely, depend upon a range of factors, but it is expected that many producers will already be operating close to maximum rates of fuel substitution, subject to the constraints of their facilities. Some facilities could, in principle, bring forward investments to enable greater use of waste as an alternative fuel.

The major issue affecting cement producers today – according to Cembureau - might be the cost not of the fuel mix, but of electricity needed to operate facilities.[9]

Lastly, as the cement industry seeks to meet its own targets for further substitution by alternative fuels, it will seek to shift the use of these from the 2019 level of 50%, of which 18% was biomass, to 60% by 2030, of which 30% should be biomass, and 90% alternative fuels by 2050, with 50% biomass. There is, therefore, limited scope for using more non-biomass alternative fuels in the mix by 2030 if these targets are to be achieved, let alone if the 2050 targets are to be met. These targets are linked to the sector's net zero strategy. Indeed, a consequential analysis might suggest that if these targets are being taken seriously, then increased use of waste might be displacing more biomass-rich alternative fuels.

Note also that although there is very limited use of gas at present, that in itself would not be a sufficient reason to argue that gas was not being displaced when additional waste is coincinerated. Suppose, for example, that a key shift in the sector was a move away from petcoke and coal/lignite and towards gas, but that this had barely begun. In those circumstances, it might

[8] Cembureau (2022) *The War in Ukraine, Repower EU and the EU Cement Industry – Taking Decisive Policy Actions in a Changing Geopolitical Context*, April 2022.
[9] See Cembureau (2022) *Energy Prices – CEMBUREAU statement*, 5th September 2022, cembureau.eu/media/peapvljn/220905-cembureau-statement-energy-prices-september-2022.pdf

be possible to argue that gas was the displaced source of fuel. This highlights one reason why 'average mix', or attributional approaches are likely to offer the wrong results.

Similar comments could be made in relation to the power sector. The case for further use of leftover mixed wastes in electricity production seems, for anything other than a short-term means of ameliorating a tight market, likely to be limited by the design of facilities, and the extent to which they are geared up to receive such wastes. Those which are able to use prepared forms of waste, such as solid recovered fuel, might be better equipped to utilise waste in a prepared form, but their ability to increase co-incineration may be limited by the extent to which wastes have been prepared in such a way as to allow them to process the wastes without detrimentally impacting on their wider operation.

3. **New Incineration Capacity**
The final option is to develop new capacity for incineration. Unless plans are already being made in this regard, then it seems unlikely that a facility could be constructed and commissioned in the short-term. In a recent FEAD/ČAObH event, the suggested time that might elapse between planning for, and completing a new facility was placed at seven years.[10] There will, clearly, be instances where such a time period can be reduced (for example, where municipalities own/finance their own infrastructure, or where plans are already far advanced), but the construction period alone is likely to extend to a period which may or not endure beyond the period of the ongoing conflict/market turmoil. If the business case for the facility's construction rests on energy prices which prevail in a period of market turmoil, then how might that case look at the time when the facility becomes operational, and over its expected lifetime?

The reality is that decisions as to whether or not to build a waste management facility are likely to continue to be driven more by considerations of how best to manage waste in the round and with the future in mind, than by the contribution which waste could make to energy markets in the short-term. Understanding the latter in the context of the former may be important in future decarbonisation pathways (for instance, in requiring sorting of leftover mixed waste, and carbon capture and storage at dedicated incinerators, and at co-incineration facilities).

If, taking those factors into account, the decision is made to construct a new incineration facility, then there is a question to be asked as to what energy source, or sources, may be being displaced by the facility, recognising that unless otherwise explicitly planned for, it is likely to be in place for a period of the order of 20 years.

This report spends some time on the question just raised: what source of energy might be considered to be avoided by a new incinerator? We noted above that lifecycle assessment methodology has attempted to distinguish two approaches, the attributional approach, and the consequential approach, with the latter being the method of choice where the analysis is oriented towards informing decision making (it is not entirely obvious why one would resort to an attributional approach other than to significantly simplify the analysis where the information or data necessary to conduct consequential analyses are unavailable).

These approaches have often been likened, or deemed equivalent to (often incorrectly) approaches to analysing avoided energy mixes either by reference to 'average mix' of generation of delivered power or heat (attributional), or 'marginal sources' of the mix of power or heat (consequential). The term 'marginal', though, can be used in all sorts of ways: for example, work undertaken for FEAD by Prognos and CE Delft took 'marginal' to mean 'the most carbon intense' sources.[11] Others have considered this in terms of marginal sources of capacity.[12] Other uses of the term 'marginal' have also been applied, notably in respect of costs. A much-discussed characteristic of EU electricity markets right now is the system of marginal cost pricing – matching of day-ahead supply with the level of demand allows the electricity price to be set by the cost of supply of the marginal (in the economic sense) source. As gas prices have risen, and because the marginal cost of electricity production from gas is influenced by the price of the fuel itself, so the role of gas in setting prices has become prominent, even more so than it already was in some member states.

We consider appropriate questions regarding the counterfactual scenario in relation to new incineration investments. We find it unlikely that, over the course of a facility's lifetime, given the decarbonisation imperative (which, notwithstanding short-term decisions in respect of existing market conditions, will remain), the displacement effect of incineration will be relative to fossil-carbon intense sources of energy. Instead, the displaced sources are likely to be the 'firm', or 'invariant' sources of electricity or heat that will come to

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[10] caobh-eventy.cz/konference_fead.html

[11] Prognos and CE Delft (2022) *CO_2 Reduction Potential in European Waste Management*, Study for FEAD, CEWEP, Dutch Waste Management Association and RDF Industry Group, January 2022.

[12] See, for example, I. Muñoz and B. P. Weidema (2021) *Example – Marginal Electricity in Denmark. Version: 2021-06-08*. www.consequential-lca.org

dominate specific member states' energy supply in a net zero future. In some countries, it is already becoming clear what these firm loads are likely to be, in others, it is less so. In such a future, some member states may well still have some resort to gas as a dispatchable source of electricity, not least as a form of supply that matches fluctuations in generation by variable renewables such as wind and solar.

The fundamental role of incineration is likely to remain the treatment of waste. Indeed, to the extent that it remains as a form of waste treatment, then to the extent that fossil-derived materials remain within the combusted waste, so the fossil-derived CO_2 emissions will likely become increasingly problematic. Managers of power grids will, for the time being, view the energy generated by existing waste incinerators as a useful adjunct to its principal function. In specific locations, where waste is providing a key source of heat into district heating networks, its role as a supplier of energy may be more important, but new waste incineration facilities will likely be planned mainly on the basis of strategies and plans for managing waste, not on the basis of policies on energy, unless policy was to shift in such a way as to incentivise – for the medium- to long-term – the generation of energy from waste incineration facilities. Such incentives – in the form of price support for renewable energy generation, or in the form of exemptions from taxes that might otherwise apply – affect the costs of incinerating waste, and have played a role in reducing the costs of incineration in the past. Yet the fact that incinerating waste is never entirely renewable, and that the activity also releases fossil-derived CO_2 into the atmosphere (as well as a roughly equal fraction of CO_2 of non-fossil origin), is leading to questions as to how to constrain these emissions through either taxation, or including incineration within the ETS (where it is not already included). In any event, the effect of new incineration on the wider energy system will be affected by the strength of commitments to shift generation of electricity and heat away from reliance on fossil fuels (and to ensure that, where fossil fuels continue to be used, that the majority of the CO_2 emitted is captured).[13]

There have been major developments in renewable energy supply over recent years. In the case of wind and solar, however, these offer supplies of electricity (and heat, in the case of solar thermal) which vary across any 24 hour period, and with the seasons. As a result, matching supply and demand in the case of these variable renewable energy sources has to be considered if renewables are to be integrated into the energy mix. Some fuels are designed to be more easily turned on and off (or to increase, or scale back, supply) to match demand, and these are considered dispatchable sources of supply, such as the fossil-derived gas or coal, or low-carbon sources, such as biomass and hydro. Hence, the increased penetration by renewables may be accompanied, in some member states, by some 'matching' use of locally available dispatchable sources, at least until matching is achieved better by smarter use of energy, deployment of storage, or (likely) both (and even then, such dispatchable sources are likely to have a role to play). Integrating EU electricity markets may help in the process of reducing the carbon intensity of these more rapidly than would otherwise be the case (not least in enabling more rational deployment of variable renewables across demand that spans a wider geographic territory).

Conclusions and recommendations

Understanding the effects of waste incineration on sources of energy consumption is not entirely straightforward, and claims are made in various directions: whilst it might be politically eye-catching to argue that gas is displaced today, on another day, the advocates of incineration will claim displacement of coal, a claim which, thankfully, over the last decade, has become more difficult (if not impossible) to sustain in most member states.

Marginal changes in the quantity of waste used to generate energy from an existing facility ought to be considered quite differently to decisions to invest in new capacity. In the former case, without clear sight of the counterfactual at the time a given facility was planned, then the best approach to the counterfactual for a power generating installation might be (as long as the increase is sustained over time) to consider the impact of incinerating waste on the firm supply of electricity; what other firm sources of supply are used, and what source might preferentially be reduced as a consequence of the additional generation from the incinerator? In the case of heat, and existing heat networks, then the counterfactual can be similarly construed.

For co-incineration, the considerations seem different for power and for cement kilns. The relevant consideration for a coal fired power plant is not necessarily the displacement, at the facility, of calorific value from coal by calorific value derived from waste. The facility, and the electricity network, may be under wider constraints that incentivise use of sources other than coal. An increase in waste use at a given facility might, proximately, be seen to replace the use of coal, but in the system context, it might displace other sources. Where cement kilns are concerned, depending on incentives and constraints, displacement of other alternative fuels may be a plausible counterfactual (or no less plausible that the displacement of conventional fossil fuels).

[13] In a net zero consistent pathway, as the supply from renewables whose supply is variable increases, fossil fuels may have a role to play as a matching dispatchable source of energy. To the extent that they continue to do this, they may need to be equipped with CCUS in future.

If one assumes, in the absence of better information on specifics of each facility, and recognising that this is unlikely to reflect the average mix of 'firm sources' of energy and heat, that what is displaced by existing facilities is 'the average mix' of power or derived heat, then we estimate that the contribution of incineration is to reduce EU27 gas consumption by 1.1% (or around 2.5% of the level of import of gas from Russia in 2020). This should not be considered as an additional contribution to what now happens: it is an estimate of the effect of existing incineration on EU27 gas consumption.

The case for building new facilities has to be set against the backdrop of an urgent need – with the urgency heightened by the current crisis related to Russia's invasion – to decarbonise energy and waste. As we have highlighted previously, this would argue in favour of deployment of the sorting of mixed leftover waste before waste is incinerated, and also, in front of facilities which stabilise waste prior to landfilling.[14] Given the effect of the former on the capacity of incinerators to treat waste, the need for additional capacity is minimised, whilst it also becomes diminishingly desirable as the displaced energy source for new capacity declines in carbon intensity in the face of renewed commitments to tackle greenhouse gas emissions from energy generation. It should also be considered that the time to develop new incineration facilities is unlikely to be short where these have not already been planned. In the short-term, therefore, it seems highly unlikely that an additional contribution from incineration will be forthcoming, whilst in the longer-term, the case for additional capacity remains weak.

Perhaps the most important recommendation that flows from this is that, although some unpalatable decisions may need to be taken in the short-term (in that they imply a temporary relaxation of commitments to climate change goals), it makes no sense to allow short-term perturbations, however large, to derail plans to decarbonise energy. On the contrary, this shock might even provide a reality check on the pace at which change has to be made in many Member States. Notwithstanding progress made in increasing renewable and low-carbon energy generation, EU energy supplies are still heavily dependent on carbon-intense supplies based on fossil fuels. Campaigns to cease use of, or investment in, coal go nowhere near far enough, and may even have tempted some policy-makers to imagine that increasing supplies from gas, as an interim step as coal is phased out, will suffice to meet climate change objectives. That is not the case.

As long as it might be possible to sustain the argument that additional generation of heat or power from whatever source always displaces a carbon intense source of energy, then it is likely that we are continuing to fail to configure policy and markets to deliver the necessary outcomes. In reality, these sources need to be marginalised to such an extent that their phase out is secured, and so that the sources displaced are not those whose demise is secured by regulation and incentives, but the other sources that would otherwise have been included as part of the mix in achieving the desired objectives.

Time is not on our side. We do not have the luxury of multiple investment cycles in which to act. In terms of the lifetimes of fossil-fuel powered assets, radical changes need to be made over a time period which is less than one investment cycle. The time for discussing 'transition technologies' has passed; adopting such pathways will likely increase costs if climate change targets are to be met by effectively 'designing in' investment in assets which are destined to become stranded (because they must). No doubt, in a suitable rapid planned transition, some assets will indeed be under-utilised, and policy-makers may need to plan for this (and minimise it through rational planning, and at EU level, further improving market integration), recognising that it is a price that may well be worth paying in playing a leadership role on climate change, and reducing dependence on sources of energy who cannot be relied to act in good faith. Rather than considering an expansion of facilities which, without CCUS, are significant emitters of CO_2, and which will neither become operational in the short-term, nor be straightforward to 'switch off', the objective should be to focus on reducing consumption (and waste), and maximising recycling of materials at end of life, including through use of mixed waste sorting prior to incineration. This last measure would actually have the effect of increasing the capacity of existing facilities to treat waste, should that be needed.

Finally, and in relation to the transition, the EU would be well advised to consider the geopolitical risks associated with the supply of products and raw materials whose use is central to those technologies that will be needed to support a transition to a net zero EU. It would be unfortunate, to put it mildly, if the EU (and other countries) become overly-reliant for the supply of key materials on a narrow supplier base of varying reliability. A balance of indigenous supply, and support for diverse sources of supply from outside the EU, will be necessary, as well as the development of a recycling industry that builds on EU expertise to ensure that the extraction of critical raw materials is maximised at end of life.

[14] D. Hogg (2022) *The case for sorting recyclables prior to landfill and incineration*, Report for Reloop, June 2022.

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What role does incineration play in reducing demand for gas?

The incineration of waste has long been recognised as a source of energy supply. At facilities which have been constructed specifically for the incineration of waste – we will refer to these as 'dedicated incinerators' - the process can be a source of either electricity, or of heat (or cooling), or both. There are facilities which have not been built specifically for the purpose of combusting waste but which, nevertheless, may burn waste as a source of energy. This may happen, for example, at power generation facilities, or at cement kilns. We will refer to these collectively as co-incineration facilities, recognising that waste is rarely the only thing they burn (whether today, or in the past).

The discussion as to what source of power, or heat (for dedicated incinerators), or calorific value (in the case of co-incineration facilities) is being displaced by the combustion of waste is one that has frequently taken place in the context of discussions regarding the climate change impacts of incineration or co-incineration. More recently, as gas prices have sky-rocketed across Europe (and elsewhere), there have been a range of claims made by various trade bodies regarding the role which might be played by incineration and co-incineration in reducing demand for gas. For example, a recent FEAD Press Release noted:[15]

> *Whereas member states reached yesterday a political agreement on a voluntary reduction of natural gas demand by 15% this winter, and the European Commission has recently presented the REPowerEU Plan in response to the hardships and global energy market disruption caused by Russia's invasion of Ukraine, the waste management sector is not (yet) at its full capacity of producing and saving energy.*
>
> *Today more than ever it is essential to end the EU's dependence on Russian fossil fuels and to tackle the climate crisis, which can be done "through energy savings, diversification of energy supplies, and accelerated roll-out of renewable energy to replace fossil fuels in homes, industry and power generation".[1] Here, the waste management sector has a fundamental role to play as:*
>
> - *Recycling and recovery operations save material resources, energy and CO2 emissions by avoiding the extraction, processing and use of virgin raw materials and fossil fuels; and*
> - *The electricity and heat produced from waste through incineration and anaerobic digestion is generated from a local, reliable and secure source, which allows to diversify our energy supply, in particular with regards to District Heating and Cooling networks, and accelerates the roll out of renewable energy.*

Whilst the role of recycling in reducing demand for energy is recognised by FEAD, the role that might be played in reducing demand for gas is deserving of closer inspection.

This report seeks to cast light on whether, and to what extent, incineration can be said to reduce dependency on gas, and the extent to which it could claim to do so in the future. In doing so, it bases its perspective largely on considering the issue of the counterfactual, of which there may be more than one – starting point questions are, what would have happened if the facility had not been constructed, or what would happen if the facility was not there, or what would happen if a facility being planned is not constructed? This might require some speculation in the case of existing facilities which may have been constructed under different policy regimes to those which exist today. The point, though, is to consider what sources of energy might need to be used if incinerators were not functional today, or what sources of energy might be avoided if they are constructed in future. Questions regarding 'what else may happen in the system' are also of relevance.

The future orientation is, arguably, the easier one to deal with: to the extent that there are claims that incineration reduces demand for gas, this may be somewhat less interesting in the case of facilities which are already operational. Indeed, it might be considered that it is rather difficult to understand the counterfactual for existing facilities without understanding the situation which prevailed at the time the facility was planned, and became operational. Unless existing facilities have significant spare capacity available, then they likely generate whatever energy they generate, and demand for gas is whatever it happens to be in the policy and market context in which they operate. The argument that there should be an increase in incineration on the basis of its suggested impact on demand for gas is worthy of closer inspection.

[15] FEAD (2022) The waste management sector is not at its full capacity of producing energy, *Press Release*, 27 July 2022, fead.be/position/the-waste-management-sector-is-not-at-its-full-capacity-of-producing-energy

Characterising types of incineration/co-incineration

Where incinerators are constructed for the purpose of treating mixed residual waste, it is generally the case that they are commissioned with a view to the facility operating with a high level of 'availability'. The term 'availability' effectively describes the proportion of a given time period (for example, an average year) for which a facility is (expected to be) operational and receiving waste. Incinerators would, ideally, operate without the necessary periods of interruption for maintenance, but in reality, facilities need to have some 'downtime'. This, though, is not a large proportion of the time, and outside these periods, facilities operate more or less continuously.

It follows that the energy associated with burning waste is being generated more or less continuously, so that a facility designed to export energy only in the form of electricity might be considered to supply electricity more or less continuously to the electricity grid. It is likely to contribute to 'base load' electricity, or 'firm power'.[16]

Where a dedicated incinerator has been designed to supply heat, the situation – in terms of the continuous nature of energy generation – is similar, although the form in which the energy is supplied, and the nature to whom it is supplied, may have implications for how the energy displacement issue is understood.

A large number of facilities generate both heat and power. In such cases, the demand for heat is likely to be a stronger driver for variation in demand than the demand for electricity, usually because the heat is provided to a defined network of users (whereas the electricity will be supplied to a grid which will be able to make use of whatever an incinerator generates). As a result, depending on the nature of the facility, the amount of power generated relative to heat may change over the course of the year, but the extent to which such change can occur will be limited by the design of the facility. The relative demands on heat and power might be a relevant consideration in the case of cogeneration facilities. For example, if at times of peak demand for electricity, the demand for heat is high, power generation may decline. What source is or is not displaced by the incinerator might have to consider these changes.

Where co-incineration facilities are concerned, the facilities are often such that they are not designed to receive mixed residual waste if it has not first been subject to prior treatment to prepare it for combustion at the type of facility concerned. The term refuse-derived fuel (RDF) is a generic terms used to describe waste that has been processed in some way with a view to its being used as a fuel. Some RDFs may be processed in such a way as to satisfy ISO standards that have been established for 'solid recovered fuels' (SRF) of different classes.[17] These standards themselves are fairly broad in nature, but they enable SRFs to be classified according to key properties such as net calorific value, chlorine content and mercury content, as well as indicating further details in specifications.

RDFs/SRFs can be more amenable to storage than raw mixed residual municipal waste. It follows that in theory, and sometimes, in practice, RDFs/SRFs may be combusted on a non-continuous basis. For example, at a given power plant, it might be that a greater quantity of SRF is combusted in one part of the year than in another. Notwithstanding the fact that RDF/SRF is bulky to store, this might allow for some flexibility in either the mix of fuels used from one period to another, or in the quantity of fuel used from one period to another, potentially responding to changes in market conditions, or demand, respectively.

Grids and networks

The way in which electricity grids, or district heating networks, are operated, and the access they have to different sources of power or heat supply, will have implications for the question of what source of power or heat might be being displaced by an incinerator. As indicated above, most incinerators are not being asked to switch on or off, or to vary the amount of waste they incinerate to coincide with times of peak demand. In the context of electricity grids, their contribution is generally a very small share of production, so that fluctuating amounts of a small share would have limited impact, and would also imply storing waste, which presents its own hazards if the waste has not been prepared such that it can be readily stored (as with some RDFs/SRFs).

Demand for heat, and for electricity, changes over the course of a given day, and over the seasons. The contribution of different fuels to production of power and heat changes more or less continuously as network operators seek to match supply to fluctuating demand.

[16] This refers to sources of predictable electricity generation, such as nuclear generation, which is (usually) designed to run continuously. By contrast, we also refer to dispatchable sources of electricity, which may include coal and gas, and which can be planned to operate at various future times, but may also be relied upon to run continuously if required.
[17] See ISO (2021) *ISO 21640:2021: Solid recovered fuels — Specifications and classes* www.iso.org/standard/71309.html

Although some member states have access to supplies of considerable amounts from hydro, or geothermal, and although many with extensive heat networks are seeking to use biomass and electricity (directly, or indirectly in the form of heat pumps), most member states are installing increasing capacity of solar PV and wind as sources of low carbon renewable generation. The supply from these is variable, and so network operators' challenge of matching supply and demand is augmented by the fact that they exert no control over the power that might be produced from these. As a result, either storage solutions, or resort to use of supplies whose production profile can 'match' the variable supply, might be necessary.

Against this backdrop, it perhaps becomes obvious why the effects of any source – incineration, or otherwise – on the use of other fuels needs to be considered in the context of the nature and variability of supply, as well as the way that supply helps to meet demand in the context of a given supply network. In respect of power, greater integration of EU networks is envisaged, and may help ease some of the issues associated with variability of production from renewables, but the issue also needs to be considered in the context of how network operators are managing this issue today, and in the case of new capacity (or phasing out existing capacity), how they are planning to manage this issue in future.

Approaches taken to understanding sources of energy displaced

As mentioned previously, there has been much interest in the nature of energy sources that might be assumed to be displaced by energy generation from incineration in the context of discussions on climate change. In life-cycle assessment (LCA), a distinction is generally made between two methodological approaches to LCA, 'attributional' and 'consequential', the distinction having been made to seek to resolve debates regarding what type of input data to use in LCAs, and how to deal with problems of allocation of burdens when a process produces more than one product. It is not entirely clear that these terms have managed to do what they set out to, though it does seem clear that – where the intent is to understand the impact of decisions in a 'real world' context - the consequential approach is to be recommended. Indeed, there appears to be a growing trend towards consequential approaches, perhaps understandably given the desire to understand impacts of decisions being taken.

Work undertaken for FEAD, CEWEP, the Dutch Waste Management Association and the RDF Industry Group by Prognos and CE Delft considered the effect of incineration and co-incineration, amongst other things, and changes in their deployment. It sought to understand their impact on greenhouse gas emissions, and in doing so, like all studies of this nature, it had to make assumptions regarding sources of electricity, heat, and energy that might be avoided as a result of the incineration and co-incineration of waste. It conducted the analysis under both 'average' (akin to an attributional approach) and 'marginal' (which then study suggested was akin to a consequential approach) assumptions.

The first 'average' scenario, deemed to be the central one, was based on:

- For electricity, the average mix of sources of electricity generation across the EU;
- For heat, the average mix of sources of heating in the EU;
- For co-incineration, it was assumed that in the short term, half of waste coincinerated would be treated in coal fired power stations, and half in cement kilns, with the share of cement kilns rising over time to 90% in 2035. In power stations, waste was deemed to displace coal, and in cement plants, coal and lignite, and a small amount of fuel oil, were assumed to be avoided.

The sensitivity scenario, based on assuming displacement of marginal sources, assumed:

- For electricity, marginal sources were the mix of fossil fuel supplies in 2019, though with natural gas deemed to be the sole source displaced by 2035;
- For heat, the avoided source of energy was the normalised (to 100%) share of fossil-fuel heat sources. This was deemed to remain constant to 2035.
- For co-incineration, it seems there was no change in the assumption.

The study noted:

> *The avoided emissions from incineration in a WtE plant are based on the average electricity and heat mix. As a sensitivity assessment, CO_2 factors were also calculated with a marginal approach. This means that the most carbon intensive power generation technologies – fossil fuel sources – are avoided instead of the average mix.*

Elsewhere, it stated:

> *A marginal approach means that the energy generated at WtE plants avoids the most carbon intensive conventional power generation technologies – fossil fuel sources – instead of the average electricity and heat mix that also contains renewable energy.*

The paragraph is interesting in that it assumes that a marginalist approach would always indicate fossil fuels as the marginal source.[18] Yet consequential logic is far richer than this suggests. What the marginal source may be at a given point in time (and this might not be the best way to consider the matter) and in a given country is not simply a matter of understanding the carbon intensity of fuels, but might also be informed by the relevant policy environment, and the associated economics; the economics are to some – perhaps an increasing - extent determined by what sources of electricity are included, at the margin, in different grids. These marginal sources, however, might not necessarily reflect what sources, such as dedicated incinerators, might be displacing on an ongoing basis, given that most will burn waste throughout the year (because that is their principle purpose). Furthermore, it seems reasonable to argue that the nature and consequences of a decision to construct a new facility are rather different to the considerations that might affect marginal changes in utilisation of an extant facility. The two are qualitatively (and quantitatively) different decisions.

The study suggests that as regards incineration, it considers both assumptions – average and marginal – to be founded on consequential logic:

> *The reasoning behind the approach – substituting coal, based on energy content – is consequential reasoning:*
>
> - *if waste is not co-incinerated in a coal-fired power plant, more coal would have been used in the power plant. So coal is avoided (on an energy basis (LHV)*
> - *if waste is not co-incinerated in a cement kiln, more coal/lignite would have been used in the cement kiln. So coal is avoided (on an energy basis (LHV)*
>
> *This approach differs from incineration in a WtE plant, because in a WtE plant the consequential reasoning is as follows:*
>
> - *If waste is not incinerated in a WtE plant, more electricity and heat are generated from conventional sources for heat and electricity.*

This implies a very limited consideration of possible counterfactuals. For example, suppose a co-incineration facility operates under incentives that drive use of alternative fuels, and especially, low carbon fuels of that nature. A plausible counterfactual to the situation where an additional quantity of waste is used is one where the facility, operating under constraints on its ability to substitute fossil fuels, might substitute other alternative fuels. Much may depend on the nature of the drivers in place, but it is worth considering what might drive the mix of fuel use at a given point in time, and why current fuel usage is as it is.

Similarly, in the context of district heating, the counterfactual depends on a host of factors, not least what sources are locally available for feeding into the network. The situation is also very different depending on whether more waste is being used as a source of heat at an existing network, or whether a heat network is to be constructed anew. In one that already exists, the other sources of heat available to supply the network need to be considered before one can make any reliable assumption about the energy source being displaced being 'average mix', or fossil fuels. In a network being considered as a heat source for, for example, a new housing development, the alternative source of heat might be suitably well-configured heat pumps, as well as additional measures to reduce heat demand in the first place.

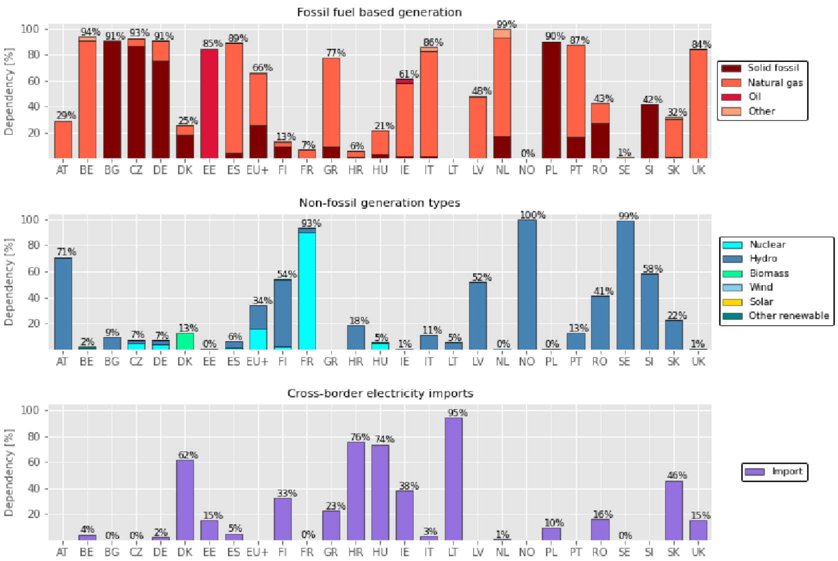
The question of the counterfactual is much richer than is often assumed. It is also worth considering how different the relevant counterfactual questions may be for the case of an existing facility incinerating more, or less, waste, or a facility whose construction is being considered, or a facility which is being considered for mothballing. Decisions regarding new facilities brings into focus the longer-term. And yet, at some point in time, all facilities would (or should) have been subject to such longer-term considerations, but from where we stand today, we are not so well-placed to appreciate what these were. How does the decision to build a new facility affect ambition in relation to greenhouse gas emissions and climate change? What, where electricity is concerned, are the other 'firm sources' of power being considered as the ones most likely to be needed in future (and equally, what sources are being phased out)? In that context, if a decision to phase out fossil fuels is already made, then isn't an appropriate counterfactual one where other non-fossil sources of supply would have to play a more prominent role? Those conducting consequential life cycle assessments understand that

[18] Note that the source used by the study indicates a source of fossil energy denoted 'other fossil': that likely includes the fossil component of waste, which would account for around 20% of the 'other fossil' category according to more detailed EU statistics on gross electricity production for the year 2021.

such approaches ought to consider the dynamics in play, and not only historic changes, but also ones that are being firmly planned.[19] It is also recognised that a complete understanding of the future might be elusive: few, even two years ago, would have imagined that a war in mainland Europe would trigger major movements in energy markets. Policy is also evolving – what may be happening in the market today could reflect policies developed very recently, or more than a decade ago, or both. In that situation, seeking to understand 'marginal sources' on the basis of past trends (as Munoz and Weidema attempt to do) is problematic: what if the last two years reflect a completely different policy and dynamic to the previous ten? Over what time period should we consider change? How (and when) should one factor into the analysis 'the likely future'? What weight should be attached to stated objectives of government?

It is worth considering an economic perspective of what might be the marginal sources for electricity in different member states. Figure 1 below shows the estimate made in a recent econometric study regarding the marginal (in the economic sense) source of electricity supply by country, as indicated by pricing in day-ahead electricity markets.[20] Note that this does not necessarily indicate the correct choice of source being displaced by energy derived from waste since it does not clarify the role played by the marginal source in meeting fluctuating demand. Note also that things may have changed somewhat since 2019. Nonetheless, these figures indicate the proportion of the year for which a given source plays the role of 'marginal source' in different countries. There are many member states where fossil fuels were, in 2019, playing a strong role in electricity markets, with gas being the marginal source for more than 50% of the time in Belgium, Spain, Greece, Ireland, Italy and Portugal. Solid fossil fuels were setting marginal prices for the majority of the year in Germany, Poland, Bulgaria and Czech Republic. Non-fossil sources played a key role in Austria, Finland, France, Latvia, Norway, Sweden and Slovenia. One might expect the role of gas to have become more prominent, at the margin, since the rise in global gas prices.

Figure 1: Marginal shares of fossil fuel, non-fossil, and cross-border electricity imports in different European countries in 2019. EU+ represents EU-27 plus UK and Norway.



Note: The marginal shares represent the dependency of electricity prices on each generation type as % of the time in one year. The results for EU+ are based on the weighted average of the marginal shares of the European countries, i.e., the marginal share of each European country multiplied by electricity generation in that country.
Source: Zakeri, Behnam and Staffell, Iain and Dodds, Paul and Grubb, Michael and Ekins, Paul and Jääskeläinen, Jaakko and Cross,

[19] See, for example, Tomas Ekvall (2019) Attributional and Consequential Life Cycle Assessment, in María José Bastante-Ceca, Jose Luis Fuentes-Bargues, Levente Hufnagel, Florin-Constantin Mihai and Corneliu Iatu (eds.) (2019) *Sustainability Assessment at the 21st Century*, www.intechopen.com/chapters/69212; I. Muñoz and B. P. Weidema (2021) *Example – Marginal Electricity in Denmark. Version: 2021-06-08.* www.consequential-lca.org

[20] Zakeri, Behnam and Staffell, Iain and Dodds, Paul and Grubb, Michael and Ekins, Paul and Jääskeläinen, Jaakko and Cross, Samuel and Helin, Kristo and Castagneto-Gissey, Giorgio (2022) *Energy Transitions in Europe – Role of Natural Gas in Electricity Prices*, Working Paper 1 in the UCL Institute for Sustainable Resources series, Navigating the Energy-Climate Crises, July 23, 2022.

Samuel and Helin, Kristo and Castagneto-Gissey, Giorgio (2022) Energy Transitions in Europe – Role of Natural Gas in Electricity Prices, Working Paper 1 in the UCL Institute for Sustainable Resources series, Navigating the Energy-Climate Crises, July 23, 2022.

Appropriate counterfactuals

The somewhat formalised approach to defining a consequential approach to LCAs – albeit, this does not rigidly define the details of the approach – might simply be considered as a way of understanding counterfactuals. Constructing plausible counterfactuals is necessary to shed light on what may happen if a specific decision is made/what might have happened had a specific decision been made differently. In this respect, as with consequential LCAs, the nature of the counterfactual has to reflect the nature of the decision under investigation. To formulate the right counterfactuals, we need to formulate our question carefully.

Discussions regarding the potential impact of incineration on the use of gas risk confusing two completely different types of decision. The first is the contribution currently made by existing facilities to energy supply, and the implications of this for gas use. The second relates to additional contributions from incineration, and in this respect, at least two different situations can be identified. The first is where existing facilities make use of additional capacity, to the extent that this is available; the second is where new facilities are considered for construction.

Understanding the most plausible counterfactuals in the case of dedicated facilities requires some attention to be paid to a number of issues. For a start, for a dedicated incinerator (or any other long-life asset), the policy and economic environment, not to mention the geopolitical one, that can be expected to influence decision making may be very different towards the end of the expected life-time of the facility to the situation prevailing when the decision was made to construct it in the first place. It could reasonably be argued that the way the facility is used influences also the impact that it has, but if it is the case that its use is more or less assured (perhaps, even, contractually, though contracts can, of course, be renegotiated) for its lifetime, then arguably, what happens thereafter, in terms of its energy generation, is more or less 'set' at the point at which it is constructed. That might not mean that its impact is 'constant' over its lifetime, more that its anticipated impact over time might be best understood as the most plausible counterfactual prevailing when the facility was constructed. The energy from incineration is, from this perspective, seen as a useful output that comes alongside the principal function of incineration as a means of treating waste. The construction of counterfactuals probably is most meaningful at the time when a facility is being planned.

The complexity, however, does not go away. There will be different viewpoints at the time a facility is being planned as to what sources of energy are expected to be displaced over time. What matters is that the counterfactual is plausible based on the available evidence, and taking into account a reasonable view as to what the future may hold. It was, for example, never going to be the case – as it was frequently argued in the UK planning context twenty years ago - that the electricity generated by an incinerator could always be assumed to be displacing coal-fired generation. It might not have been possible to predict accurately what could be assumed to be the carbon intensity of marginal consumption of electricity, Tables for which are now produced by UK Government for the purpose of policy analysis. It also might not have been possible to predict the exact date at which the UK Government would phase out coal-fired generation. It was, though, even back in the early 2000s, possible to reason that with targets already in place for renewable energy generation, then as long as electricity generated from waste was considered partially renewable, circumstances might arise whereby the deployment of more incineration might, at the margin, reduce the supply of renewable electricity from sources such as wind, or solar. That argument, whether or not it was found convincing (and this tended to reflect who it was that one sought to convince), at least indicated a direction of travel. A new incinerator, to the extent that it added to new base load generation capacity, would be unlikely to displace only the most polluting forms of supply (and indeed, had policy been configured as it should have been, there would, by now, be little or no coal to be displaced, either in the UK or in the EU27).

As an example of how plausible counterfactuals should inform decisions about displaced energy sources, consider a country that seeks, for example, to avoid the use of gas in its energy mix. Suppose it intends to make additional use of waste as a means to do so. How should one then consider the displacement question? If demand was to be met, then if it is prevented from being met by use of gas, then it has to be met from other sources. The choice is no longer between 'waste' or 'gas', but between 'waste' and other sources which might be used to meet the same pattern of demand. Gas is not being displaced by waste: rather, a decision has been made to use sources other than gas, so that the displacement is of 'other alternatives' (to gas) deployed to meet this policy objective.

As to the war in Ukraine, it seems unlikely – or perhaps, one should hope (for it would only seem likely in the event the war takes an obviously protracted course) - that new facilities will be built as a specific response to these price movements, given a) the time-lag between planning a facility and its being commissioned, b) the fact that the facilities themselves will need to justify the case for their existence over the medium- to long-term (i.e. over a period of the order 15 to 20 years), and c) the likely forward counterfactuals for waste and for carbon over the expected lifetime of the facility. Gas should be expected to come under increasing pressure from renewables, as it already is, and whilst some policy-makers may choose to make some questionable choices (some UK politicians' reawakened enthusiasm for fracking – it barely had time to fall asleep - being an excellent case in point), most recognise that it is possible to address over-dependence on (imported) gas and the climate crisis at the same time.

No facilities have been built on the basis that it was understood that Russia would invade Ukraine, and few would have envisaged a situation where gas prices would sky-rocket as a result of both the war, and the tightening gas market that preceded it. Although LCA distinguishes between attributional and consequential approaches, there is a sense in which a consequential perspective might also be informed by the extent to which specific consequences or outcomes are attributable to a specific decision. Very little of what is currently noteworthy in energy markets could be said to be 'the consequence of' the collective decisions to build (or not) incinerators in the EU. Rather, the decision to build each incinerator had some more or less well understood consequences at the time each was constructed. The fact that the world no longer looks as it might have looked at the time of construction is a consequence of other factors –the decisions of Russia's leadership, the functioning of electricity markets – not the decision to construct an incinerator. In policy appraisal, in seeking to assess the impact of a specific policy where multiple policies are in place, this question – of how to attribute specific outcomes to a specific policy – always looms large. In the same way, perhaps, we might do well to consider the limits to which we should ascribe outcomes to decisions which are not obviously linked. If some additional coal-fired generation is considered necessary in the EU27 in the short-term as a result of Russia's invasion, does that mean incinerators might be deemed to be displacing coal? Perhaps it might be better to consider that whatever incinerators were displacing before the war, and whatever they will be displacing after, that in the intervening period, the consequences which flow stem from the war, not the decision as to whether to incinerate a changed amount of waste.

In order to help inform the discussion, we consider how additional capacity might be provided.

New dedicated facilities, electricity

Consider the case of a new dedicated facility being constructed for the purposes of generating electricity. Assume for the moment that the facility is linked to a contract with one or more municipalities, and that it will operate at close to full capacity. We abstract, for the time being, from the potential wider links to (for example) waste prevention and recycling opportunities.

In these circumstances, the facility may be expected to operate on a more or less continuous basis. As such, it is unlikely to be operated, itself, as a facility that meets those marginal changes in demand that result from fluctuations in the demand for electricity over the course of a day, or over the course of a year. In practice, it contributes to firm power/base load for electricity, and supplies electricity based on what waste it receives. It would be tempting, then, to argue that the facility 'knocks out' the most expensive marginal cost contributor to baseload generation. That abstracts, however, from (at least) two other issues:

- Whether demand for electricity is increasing, or in decline; and
- What policies are influencing the contribution of various sources of energy to baseload supply (and this may also be influenced by past policies).

In the case of the first of these, at the EU-27 level, Eurostat data indicates a relatively flat consumption of electricity over the last decade.[21] However, notwithstanding ongoing improvements in the efficiency of appliances (lighting, fridges, freezers, washing machines, for example), a combination of rebound effects (people purchasing larger TVs, driving electric cars more than petrol driven ones), increases in use of electricity for electronic appliances, as well as a switch to greater use of electricity for provision of heating and transport, may be expected to lead to increases in electricity demand over time.

On the second of these, the nature of policy drivers and instruments affects what new sources 'come on stream', and which sources are being phased out. Here, one could consider two extremes: suppose that there is no policy expressing any preference for one or other type of technology in terms of electricity provision. Depending on how grids are operated (and integration appears to be increasing across the EU), the displacement of baseload by a new incinerator might be expected to be driven mainly by cost. At the other extreme, supposing that there is a clear policy to (for example) phase out coal, and a drive towards a greater share of renewables, then one might run an argument in one of two ways. In the first instance, the argument might be that an incinerator always displaces coal, at least to the extent that coal provides baseload electricity during the period over which the assumption is made. This approach, though, looks more and more tenuous the longer is the period over which the policy has achieved, or exceeded, its intended objective. A second approach argues that the phase out of coal is dictated by – it is a requirement of – the policy. In that

[21] *Eurostat Energy Statistics, Final energy consumption by product, electricity.*

sense, the incinerator might be considered to displace not the coal fired power itself, but the next most likely (not coal) source of additional baseload supply. Effectively, the policy dictates the displacement: what is in question in the counterfactual is not the ban per se – this is taken as read – but only what technology plugs the gap, and if the choice is restricted to 'incineration' and 'other sources', then it might be more correct to assume that incineration displaces the most likely other source (or a mix thereof). In some countries and contexts, that might well include renewables, though this could change over the course of the seasons, and if intermittent renewables are being deployed, then in the absence of suitable storage facilities/smart grids, it could be argued that they contribute alongside other balancing dispatchable sources, and for some countries, that other source might indeed be gas.[22]

The second approach has far more to recommend it in situations where the policy intentions are clear, and the associated measures are likely to be effective. It accounts for the fact that building new capacity (of any type) cannot really be said to 'displace' sources whose demise has been signalled by policy, and capacity for which is being, or is expected to be, progressively mothballed.

It follows that it is a simplification to assume that new incinerators displace 'the average mix' (at a given point in time) of electricity. This assumption might be more defensible when made in association with existing facilities, partly for reasons of simplicity, and partly because the proposal above requires country-specific knowledge, and might rely upon (when analysing at the EU level) a complexity of analysis that might not always be warranted or possible. It represents a 'fall-back' in situations where Member States have not already articulated how they perceive their own policies to be affecting the sources of energy being displaced by marginal (in the macro-sense) changes in supply of electricity or heat.

Any contribution new facilities might make to reducing gas consumption in the short term is likely to be limited by the time-horizon for new capacity development. Unless plans are already being made in this regard, then it seems unlikely that a facility could be constructed and commissioned in the short-term. In a recent FEAD/ČAObH event, the suggested time that might elapse between planning for, and completing a new facility was placed at seven years.[23] There will, clearly, be instances where such a time period can be reduced (for example, where municipalities own/finance their own infrastructure, or where plans are already far advanced), but the construction period alone is likely to extend to a period which may or not endure beyond the period of the ongoing conflict/market turmoil. If the business case for the facility's construction rests on energy prices which prevail in a period of market turmoil, then how might that case look at the time when the facility becomes operational, and over its expected lifetime?

The reality is that decisions as to whether or not to build a waste management facility should continue to be driven more by considerations of how best to manage waste in the round and with the future in mind, than by the contribution which waste could make to energy markets in the short-term. Understanding the latter in the context of the former may be important in future decarbonisation pathways (for instance, in requiring sorting of leftover mixed waste, and carbon capture and storage at dedicated incinerators, and at co-incineration facilities).

If, taking those factors into account, the decision is made to construct a new incineration facility, then there is a question to be asked as to what energy source, or sources, may be being displaced by the facility, recognising that unless otherwise explicitly planned for, it is likely to be in place for a period of the order of 20 years.

New dedicated facilities, district heating

Consider now the case of a new dedicated facility delivering district heating.[24] Here, similar considerations may apply, albeit in a somewhat different context.

First, it matters whether the heat network is already in existence, or whether the network needs to be constructed.

Suppose, for example, that a heat network is to be used to provide heating to homes which are soon to be (or in the process of being) constructed. In this case, it is reasonable to ask what, in the new homes, would be the alternative source of heating. Here, policies

[22] In their analysis of the sources of electricity that set marginal prices, Zakeri et al note, regarding coal; "*We have found that coal has continued to dominate marginal costs in a small number of European countries, especially Germany and Poland, which is confirmed by other studies [100], but its role has transitioned from baseload generation to providing peak capacity at times of high demand. However, lignite has persisted as baseload in Germany, at least until 2020*" (Zakeri, Behnam and Staffell, Iain and Dodds, Paul and Grubb, Michael and Ekins, Paul and Jääskeläinen, Jaakko and Cross, Samuel and Helin, Kristo and Castagneto-Gissey, Giorgio (2022) *Energy Transitions in Europe – Role of Natural Gas in Electricity Prices*, Working Paper 1 in the UCL Institute for Sustainable Resources series, Navigating the Energy-Climate Crises, July 23, 2022). This is illustrative of the changing roles played by different sources of energy for electricity provision.
[23] caobh-eventy.cz/konference_fead.html
[24] Although we have not considered the specific case of business users of heat, the evidence suggests that most networks supply the majority of heat to domestic users. This in part reflects concerns regarding the longevity of demand from business 'off-takers'. The balance of costs and revenues might not be so favourable if costs are incurred in connecting businesses to a network, but they subsequently cease trading.

regarding the regulation of new buildings, or use of land, or construction, which govern how new homes have to be built, have a role to play, as do wider policies regarding (for example) phase out of fossil fuel sources of heating. If new homes are required, consistent with decarbonisation objectives, to be designed with a zero (or close to zero) operational carbon concept in mind, the counterfactual supply of heat may be low carbon forms of heating, such as (air-source, ground-source, or water-source) heat pumps rather than fossil fuels, introduced in buildings designed to have a low thermal energy demand (for example, achieving Passivhaus design standard). Introducing new district heating schemes powered by incineration might do nothing to improve emissions, or reduce gas consumption, other than – possibly indirectly – through the role played by gas in electricity provision (new buildings may also be required to include provision for solar PV and If this is not the case, then the costs of alternative heat sources may be more relevant). It may also have the effect of increasing overall thermal energy demand if the connection to a heat network can be used as an argument for reducing the energy efficiency properties of the buildings.

If the network already exists, then the nature of the most likely alternative energy sources to power district heating schemes becomes relevant. What source of heat provision is 'displaced' by bringing additional incineration into the mix depends on what sources are available to feed in heat to the network. Once again, it seems relevant to mention the potential for reducing heat demand in such circumstances. Some studies have indicated that district heating systems may be locking in demand for heat, and underplaying the potential for reducing heat demand from the district heating network.[25]

Linked to the previous point, as with facilities designed to deliver power, the policies in place to drive further decarbonisation of district heating are also relevant. Where these policies are clearly driving decarbonisation, then it would be more difficult to justify the argument that the incinerator itself played the role of displacing a fossil-fuel alternative. If policy demands that there is decarbonisation, then the counterfactual in the absence of an incinerator might be a non-fossil fuel alternative source of heating energy.

Note that where district heating systems are concerned, there are sources which may be under-utilised at any given point in time. For example, industry may have excess heat to deliver to a network which may or may not be utilised, depending upon the nature of demand. That may affect the nature of what source is avoided by an incinerator delivering heat into an existing network. Although there may be electricity delivered to the grid by cogeneration facilities which are mainly oriented towards heat provision, it is unlikely that this would be a source that is 'displaced' by incineration unless policy reasons dictate this. That is because the facilities will typically provide electricity at a low marginal cost, and would rarely not be 'put to use' where they are available.

Use of additional capacity at existing facilities

If incineration/co-incineration is to contribute additional energy above and beyond what it currently generates, then one approach is through additional capacity utilisation and associated power/heat generation. In the system context, understanding what might otherwise have happened to that waste may be important, noting that even where the same waste would have been landfilled, landfilling may have led to energy being generated through gas collection. If the waste might otherwise have been recycled, then the issue of the implications of 'not recycling', and where that recycling might have taken place, might be considered relevant.

The consequences of the change for the energy system would depend on a range of issues related to the nature of the facility, the nature of the energy generated, the nature of the users, the sources currently used to supply energy in the forms generated, and the policies being pursued in the member state (and region) concerned, both in respect of waste and energy. If a change in capacity utilisation occurs so that energy generation increases, then it does seem likely that in some countries, the change would likely displace gas, not always for all of the time. It also seems quite possible that in other countries, there would be no such displacement. Some of these countries are those already importing considerable amounts of waste – if the argument is to be made that energy from incineration can help displace gas, additional capacity utilisation would need to occur in those countries where that is the most likely outcome.

It is worth noting that the extent of existing spare capacity is unclear. The R1 (recovery) criterion has facilitated greater movement of waste for incineration (and co-incineration) across the EU. In principle, that should enable greater capacity utilisation across the EU. If rising energy prices are reflected in the price at which energy is sold by the operator of the incinerator, then the net (marginal) costs of incineration may be expected to fall. This alone might be expected to lead to uptake of additional capacity. Note, in this regard, that the rationale for Member States altering tax plans vis a vis incineration may be at risk of overlooking this point. The cost of the inputs to

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[25] See, for example, Stockholm Environment Institute (2017) *Swedish heat energy system – new tensions and lock-ins after a successful transition: Policy Brief*, mediamanager.sei.org/documents/Publications/SEI-2017-PB-Dzebo-Nykvist-SweHeatEnergySystem-eng.pdf

existing incineration in plants, in terms of auxiliary materials, may be increasing in line with rising prices across the economy, but revenues from the sale of energy may well be on the increase also, so that net costs might not necessarily be rising.

Co-incineration of additional wastes

In the case of co-incineration, there could be additional waste used as a source of energy in such facilities. The use of waste in co-incineration facilities is often constrained by the extent to which the facility (e.g., a cement kiln) is equipped to handle waste materials, the extent to which the waste is prepared in a form suitable for use (facilities may be equipped differently to handle waste with higher chlorine content, for example), as well as (in some cases) the applicable permits, which might limit the extent of use of waste (and other so-called alternative fuels). Cement kilns and power generation facilities may already be expected to have incentives, notably through the emissions trading scheme (ETS), but also, price volatility of fossil fuels, to substitute the use of fossil fuels with alternative sources of energy, especially (though not only) those which have a high non-fossil content. Different wastes may be more or less attractive at these times.

A recent paper from Cembureau highlights that the cement industry is, currently, a marginal user of gas as a source of fuel.[26] The paper indicates that so-called alternative fuels, those based on waste materials and biomass, now account for around half the fuel input for cement production. Of the remaining 50% of fuel use based on fossil fuels, the main sources are petcoke, along with coal and lignite (see Figure 2). Natural gas, along with diesel oil and shale, account for 2% of the fossil fuel use, or 1% of total energy use.

The extent to which further substitution by alternative fuels is possible will, most likely, depend upon a range of factors, but it is expected that many producers will already be operating close to maximum rates of fuel substitution, subject to the constraints of their facilities. Some facilities could, in principle, bring forward investments to enable greater use of waste as an alternative fuel.
The major issue affecting cement producers today – according to Cembureau - might be the cost not of the fuel mix, but of electricity needed to operate facilities.[27]

Lastly, as the cement industry seeks to meet its own targets for further substitution by alternative fuels, it will seek to shift the use of these from the 2019 level of 50%, of which 18% was biomass, to 60% by 2030, of which 30% should be biomass, and 90% alternative fuels by 2050, with 50% biomass. There is, therefore, limited scope for using more non-biomass alternative fuels in the mix by 2030 if these targets are to be achieved, let alone if the 2050 targets are to be met. These targets are linked to the sector's net zero strategy. Indeed, a consequential analysis might suggest that if these targets are being taken seriously, then increased use of waste might be displacing more biomass-rich alternative fuels.

Note also that although there is very limited use of gas at present, that in itself would not be a sufficient reason to argue that gas was not being displaced when additional waste is coincinerated. Suppose, for example, that a key shift in the sector was a move away from petcoke and coal/lignite and towards gas, but that this had barely begun. In those circumstances, it might be possible to argue that gas was the displaced source of fuel. This indicates another reason why the 'average mix' assumption can offer misleading results.

Similar comments could be made in relation to the power sector. The case for further use of leftover mixed wastes in electricity production seems, for anything other than a short-term means of ameliorating a tight market, likely to be limited by the design of facilities, and the extent to which they are geared up to receive such wastes. Those which are able to use prepared forms of waste, such as solid recovered fuel, might be better equipped to utilise waste in a prepared form, but their ability to increase coincineration may be limited by the extent to which wastes have been prepared in such a way as to allow them to process the wastes without detrimentally impacting on their wider operation.

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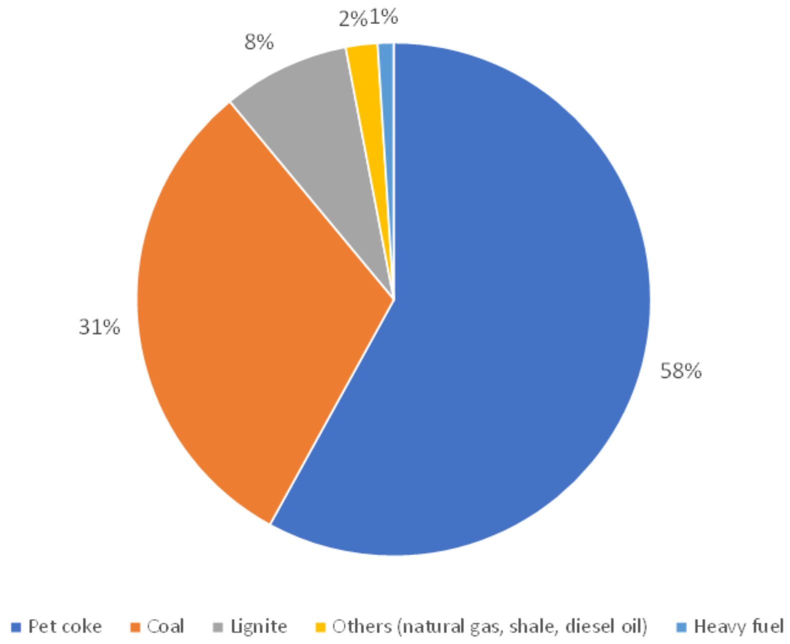
[26] Cembureau (2022) *The War in Ukraine, Repower EU and the EU Cement Industry – Taking Decisive Policy Actions in a Changing Geopolitical Context*, April 2022.
[27] See Cembureau (2022) *Energy Prices – CEMBUREAU statement*, 5th September 2022, cembureau.eu/media/peapvljn/220905-cembureau-statement-energy-prices-september-2022.pdf

Figure 2: Breakdown of conventional fossil fuel use, EU cement industry, 2019

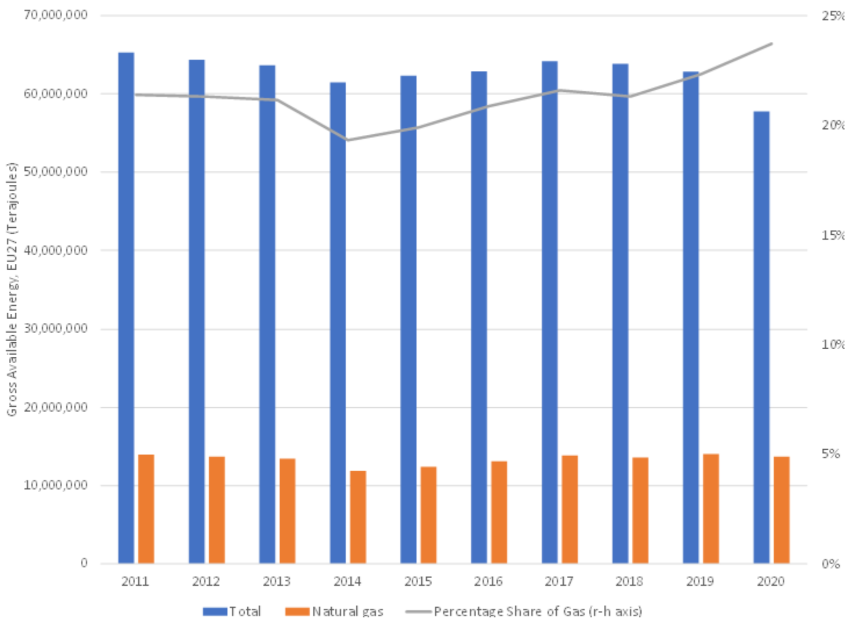


Source: Global Cement & Concrete Association, in Cembureau (2022) The War in Ukraine, Repower EU and the EU Cement Industry – Taking Decisive Policy Actions in a Changing Geopolitical Context, April 2022

Gas use in the EU

According to Eurostat data, natural gas contributes around 20% to gross available energy in the EU27.

Figure 3: Natural gas contribution to gross available energy, EU27



Source: Eurostat energy database

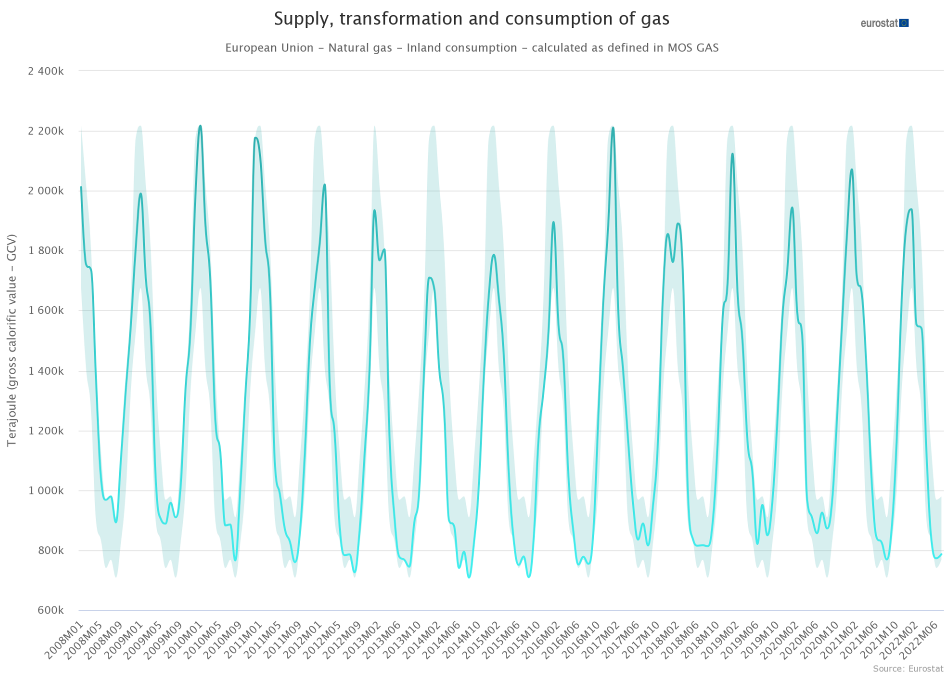
Overall gas consumption has not changed significantly in the EU27 over the last fifteen years (see Figure 4).

Gas use in the EU27 is broadly split three ways (see Table 2) between:

- Use as a source of energy (for generation as electricity or as derived heat (in heating plants and combined heat and power plants)). The majority of this (around 80%) is used for the generation of electricity;
- Final consumption in industry (both for energy and for non-energy uses); and
- Final consumption in other sectors, of which households account for the lion's share.

A small amount is used in transport. These aggregate figures mask considerable variation in levels of, and patterns of use at the member state level.

Figure 4: Inland consumption of natural gas, EU27, Jan 2008- Jun 2022



Source: Eurostat visualisations (ec.europa.eu/eurostat/cache/infographs/energy_portal/enviz.html)

Table 2: Gas use in the Eu-27, gross calorific value in terajoules

	2019		2020	
Observed Consumption	15,576,437		15,170,927	
Transformation input - energy use	4,960,304	32%	4,861,608	32%
Energy sector - energy use	584,900		569,308	
Gross electricity production	*2,049,885*		*2,016,187*	
Gross heat production	*807,396*		*791,126*	
Final Consumption				
Energy use/non-energy use, industry sector	4,229,782	27%	4,105,152	27%
Energy use, transport sector	173,918		147,094	
Energy use, other sectors	5,562,930	36%	5,433,963	36%
Of which, households	*3,702,375*	*24%*	*3,653,885*	*24%*

Source: Eurostat Supply, transformation and consumption of gas [nrg_cb_gas]

The EU is enormously reliant on imports of natural gas. The extent of this is shown in Table 3.[28] Because exports more or less match primary production, imports account for roughly the same amount as the total gas available for consumption (though changes in stocks also play a role, which is an important one at present). In both years, Russia was the source of 43% of all natural gas imported into the EU27.

Table 3: Production and trade in natural gas, EU27 (TJ)

	2019	2020
Primary production	2,188,162	1,725,189
Imports	15,084,182	13,785,912
From Russia	*6,461,869*	*5,929,770*
Exports	2,504,985	2,336,343
Stock change	-733,247	521,419
Gross Available Energy	14,034,112	13,696,177

Source: Eurostat energy balances

The aggregate picture, regarding how gas is used in the EU27, masks some wide variation in how significant its role is in different uses. Different countries make greater or lesser use of gas in their electricity supply. As regards heat, different countries make greater or lesser use of district heating (and other centralised forms of heat generation) as a means of delivering heat to households (and commerce/industry) – those with proportionately fewer households connected to district heating tend to rely, for heating of households, on decentralised heating, based on, for example, gas boilers. District heating systems, on the other hand, may make use of a range of different fuels, of which gas may be one. These different approaches register differently in energy balances, the heat generated in heat networks being reported as 'derived heat', the household boilers being reported as 'final consumption by households'.

How does incineration of waste affect demand for gas?

This has some implications for how one can consider the role of waste in meeting demand for electricity and demand for heating (a relatively small share, at EU27 level, is now met by electricity). The former is relatively straightforward, and can be taken directly from Eurostat data.

The data in Table 4 indicates how much electricity is generated, gross, from waste (both municipal and industrial, including both renewable and non-renewable elements). Waste accounts for 1.4% of EU27 electricity generation. This compares with the 20% of electricity coming from natural gas. The share of total gas used to generate this 20% of electricity is around 13.2% of total consumption.

Maximum displacement (unrealistic) scenario

Supposing one made the extreme assumption – which is difficult to sustain (and also a very different assumption to the central one used by Prognos and CE Delft) – that all energy generated by waste displaced the use of gas, then we can estimate the contribution that all waste incineration makes to gas consumption.

[28] Both Tables originate in Eurostat data, and we would have expected 'observed consumption' in the first Table to be rather closer to 'gross available energy' in the second.

We calculated the proportion of gas consumption that might be displaced under this extreme assumption gas (see Table 4). We took the gross electricity production from waste in the EU27 (a) and used the average conversion efficiency for gas fired electricity generation in the EU27 (b)[29] to convert electricity produced from waste to an equivalent energy value for the gas used to generate the same (gross) electricity from gas (c,d). Expressed as a percentage of EU27 gas consumption (e), this figure is 1.9%.

Table 4: Share of gross electricity production from waste, by member state, 2011-2020

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
EU 27	1.2%	1.2%	1.2%	1.3%	1.3%	1.3%	1.3%	1.4%	1.4%	1.4%
Belgium	2.3%	2.4%	2.3%	2.8%	3.0%	2.5%	2.6%	2.9%	2.2%	2.4%
Bulgaria	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.1%	0.0%
Czechia	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%
Denmark	4.9%	5.3%	4.6%	5.0%	5.8%	5.1%	5.2%	5.2%	5.9%	6.0%
Germany	1.8%	1.8%	1.9%	2.2%	2.0%	2.0%	2.0%	2.1%	2.1%	2.2%
Estonia	0.0%	0.0%	0.5%	0.6%	1.3%	1.1%	1.1%	1.2%	1.7%	2.5%
Ireland	0.0%	0.4%	0.5%	0.5%	0.5%	0.5%	1.0%	2.0%	2.0%	1.9%
Greece	0.2%	0.1%	0.1%	0.2%	0.2%	0.4%	0.0%	0.5%	0.6%	0.1%
Spain	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.6%	0.6%	0.6%	0.7%
France	0.7%	0.8%	0.7%	0.8%	0.7%	0.8%	0.8%	0.8%	0.8%	0.8%
Croatia	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Italy	1.5%	1.5%	1.6%	1.7%	1.7%	1.7%	1.6%	1.7%	1.6%	1.7%
Cyprus	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Latvia	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Lithuania	0.0%	0.0%	1.0%	1.7%	2.2%	3.8%	4.0%	4.0%	3.6%	3.9%
Luxembourg	2.7%	2.5%	3.3%	3.0%	3.8%	5.1%	5.6%	5.6%	6.5%	5.1%
Hungary	0.7%	0.7%	0.8%	0.9%	1.2%	1.4%	1.1%	1.2%	1.1%	1.2%
Malta	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Netherlands	3.3%	3.9%	3.7%	3.4%	3.3%	3.3%	3.1%	3.7%	3.3%	3.3%
Austria	1.2%	1.3%	1.3%	1.4%	1.5%	1.5%	1.4%	1.5%	1.5%	1.5%
Poland	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.3%	0.4%	0.4%
Portugal	1.2%	1.1%	1.1%	0.9%	1.1%	1.0%	1.1%	1.0%	1.2%	1.1%
Romania	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Slovenia	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%
Slovakia	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%	0.2%	0.3%
Finland	0.7%	0.8%	1.0%	1.2%	1.3%	1.4%	1.5%	1.7%	1.6%	1.4%
Sweden	2.1%	1.7%	1.9%	1.8%	1.8%	2.1%	2.1%	2.0%	2.0%	1.9%

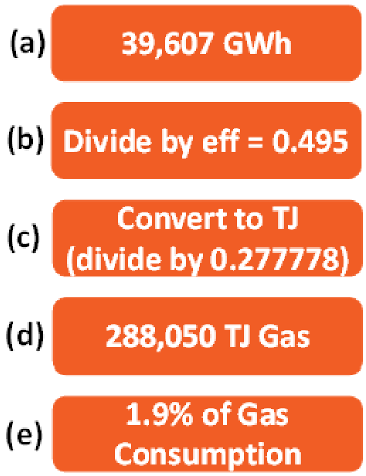
Source: Equanimator calculations based on Eurostat data.

Note these figures apply to electricity production, and do not account for trade in electricity. Imports from outside the EU27 are important in, for example, Denmark, whose domestic electricity production is affected by imports of electricity from Norway (and Sweden, though the Swedish generation is 'covered' in the data on which the Table is based). Note, though, that in that specific case (imports from Norway), the import is not of electricity derived from natural gas (or other fossil fuels), but usually, by hydro.

[29] This is estimated from the EU27 data. Modern combined cycle gas turbines may generate at much higher efficiencies, but this reflects the calculated EU27 average.

This might overstate the displacement. Some member states report differentials between gross and net electricity generation of the order 20%. It may well be that the figures are rather lower for gas fired generation

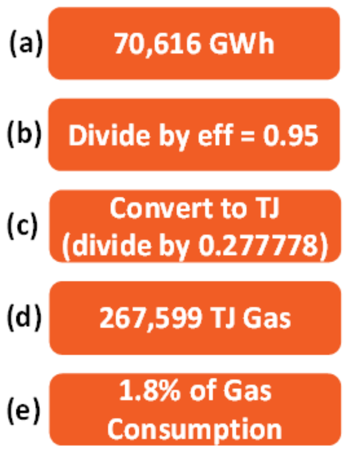
Figure 5: Calculation of gas displaced by electricity generation, unrealistic maximum displacement scenario



Source: Equanimator calculations based on Eurostat data

In respect of heating, we followed a similar approach (see Figure 6).[30] We took the gross derived heat production from waste (a) and assumed a conversion efficiency (b) to estimate the net calorific value of the gas that would be required to produce the same (gross) derived heat in TJ (c,d). Expressed as a percentage of EU27 gas consumption (e), the figure is 1.8%.

Figure 6: Calculation of gas displaced by derived heat production, unrealistic maximum displacement scenario



Source: *Equanimator calculations (based on Eurostat data)*

[30] We have chosen not to show the share of waste in gross generation of derived heat. They do not represent a basis for like-for-like comparison across member states in respect of all consumption of heat, since they are influenced strongly by the extent to which member states have (amongst other things) invested in district heating networks (some countries – Ireland, Spain and Malta, for example - reported no derived heat in 2020).

Even if all energy generated from waste was assumed to displace gas, therefore, the total amount of waste incinerated today is equivalent to 3.7% of EU27 gas consumption.

Average mix assumption

But of course, not all energy derived from waste does displace gas. We noted above the central assumption in work by Prognos and CE Delft – that waste would displace the average mix of fuels used to generate each.[31] If we consider the role played by gas in electricity and heat generation today, at the EU27 level, then we find that, once we normalise the figure to exclude the contribution from waste itself, the proportion of gross electricity production from gas was, in 2020, 20.4%. Incineration was responsible for 39.6TWh of gross electricity generation. If 20.4% of this is assumed to displace gas, then the displacement effect amounts to 0.4% of total observed consumption of gas in 2020.

The same calculation for gross derived heat production indicates that gas accounts for a normalised (to exclude waste's contribution) 40.2% of gross derived heat generation. This implies a displacement of 0.7% of total observed consumption of gas in 2020.

Under an 'average mix' assumption, therefore, energy generated from waste would displace an amount of gas equivalent to 1.1% of EU27 gas consumption, based on 2020 figures.

Summary

The quantity of electricity generated has increased 13% over the period 2011-2020, whilst waste's contribution to derived heat production has increased by 45% over the same period.

Even if all energy that is generated from waste today was displacing gas, the total quantity of energy from waste incinerated would be displacing around 3.7% of all gas consumed in the EU.

If one assumes displacement is with respect to 'average mix', then the figure would fall to 1.1% of all gas demand.

Neither of these approaches is, however, adequate for understanding what is happening as a result of the use of waste in the EU27. The obvious flaw in assuming all energy from waste always displaces gas is that in some member states, waste is contributing to energy generation at times, and in ways, where gas is simply not being used. In theory, it is possible to argue that even in those circumstances, some gas might otherwise have been used for the purpose, because waste's contribution makes it possible to avoid use of gas. That argument may or may not have validity in some circumstances, but it would be difficult to argue that for all times and uses.

The other reasons why the universal application of the assumption does not hold are also relevant, by and large, to the average mix assumption. The contributions of different sources of heat and (especially) electricity fluctuate within a given day, and also, over the course of the year. A brief view of the contributions made by waste to electricity generation in the different member states suggests, however, that in most countries – Germany may be an exception – the contribution made by waste to electricity production is relatively even across a given day. That would suggest that waste never really displaces a 'mix' derived from aggregated averages of production across the year. Rather, waste contributes to firm power, and its displacement ought to be considered relative to the other sources that contribute (or would, if no power came from incinerators) to firm power. That might, in some instances, increase the extent to which gas was considered to be displaced (that could be the case, for example, in the Netherlands). In others, it would likely reduce its contribution (that might be the case in France, or in Poland).

Although the concept of firm power can help in terms of distinguishing the possible roles played by some sources to energy generation, in practice, variable sources might, in future, contribute to 'firm power' to the extent that their inherent variability can be

[31] Prognos and CE Delft (2022) *CO_2 Reduction Potential in European Waste Management*, Study for FEAD, CEWEP, Dutch Waste Management Association and RDF Industry Group, January 2022.

made more predictable, in respect of their contribution to meeting demand, either by use of storage, or by use of matching dispatchable sources (i.e. sources of energy whose contribution is more easily increased or diminished). In this respect, variable renewables' contribution can be 'matched' by gas, so that it may also be considered that (where this already happens) contributions from waste could displace 'variable renewables plus gas'. Other variable sources are, however, available (e.g. biomass).

Similar considerations apply in respect of the variation across the seasons. Demand for electricity may change over the year, so that the contributions of sources to firm power may change also.

Finally, the aggregated EU27 approach masks enormous differences across countries. Progress is being made to integrate the EU electricity market, but there remain huge variations in production capacity, and so it would be difficult to dispute the view that waste incineration has different effects in different places (not least in relation to the relative contributions to production of electricity and derived heat). Waste destined for incineration moves across borders in the EU27. It moves in response to available capacity, and in response to different gate fees for treating waste. Intriguingly, it might not always be moving to places where its effect – on the displacement of energy sources and its effect on EU27 carbon dioxide emissions – is likely to be greatest.

We consider Member-state specific approaches in a separate Section below.

Country-specific details

Table 5 and Table 6 indicate the quantity of municipal waste, and all waste, respectively, treated using R1 and D10 facilities in the EU27. The same top 11 countries account for more than 90% of the total in both cases. We review energy generation in each country below.

Table 5: Quantity of municipal waste incinerated (R1 and D10) and shares of EU27 totals (2020) by member state

Country	Quantity ('000 tonnes)	Share of EU total incinerated
Germany	16,935	27%
France	13,758	22%
Italy	5,889	10%
Netherlands	3,894	6%
Poland	2,823	5%
Sweden	2,680	4%
Spain	2,487	4%
Denmark	2,226	4%
Belgium	2,061	3%
Austria	2,004	3%
Finland	1,908	3%

Source: Eurostat waste database
Note: these data and calculations based on EU totals using a figure for Bulgaria from 2018, and figures for Greece, Italy and Austria from 2019.

Table 6: Quantity of waste of all types incinerated (R1 and D10) and shares of EU27 totals (2018) by member state

Country	Tonnes Incinerated, R1 and D10	Proportion of Total in EU 27	Cumulative Proportion
Germany	48,468,971	34%	34%
France	22,155,785	15%	49%
Italy	12,099,189	8%	57%
Netherlands	11,462,144	8%	65%

Country	Tonnes Incinerated, R1 and D10	Proportion of Total in EU 27	Cumulative Proportion
Sweden	9,066,586	6%	72%
Belgium	7,248,008	5%	77%
Finland	6,348,886	4%	81%
Poland	6,273,797	4%	86%
Spain	3,720,677	3%	88%
Austria	3,500,000	2%	91%
Denmark	3,457,930	2%	93%

Source: Eurostat waste database

Note: The Austrian figure was estimated at 3.5 million tonnes for the purpose of this analysis

Germany

A report by ITAD indicates the following outputs from energy-from-waste facilities in Germany

Table 7: Quantity of energy generated from waste-to-energy facilities in Germany

Energy	Amount (MWh)	T CO_2 / MWh	Source	Emission
Electricity	10,350,000	0.811	UBA (2022),ITAD	8,393,850
Process steam (exp.)	13,390,000	0.365		4,886,681
District heating (exp.)	11,180,000	0.230		2,571,400
	34,920,000			

Source: ITAD (2022) ITAD Jahresbericht 2021, www.itad.de/ueber-uns/mehr/jahresbericht/itad-jahresbericht-2021

Closer inspection suggests that it may be the gross amount of energy produced being reported above. In practice, facilities will, for example, make use of electricity in their operation, whilst different reporting may allow for transmission and distribution losses in estimating net generation available for consumption.

Official German statistics indicate gross electricity generation in Germany by energy source (2021) at 11.2 TWh, and net electricity generation to be 9 TWh. In Germany, the total amount of electricity available for consumption was reported by the same source to be 556.5TWh.

In the German electricity system, the main changes over recent years have been:

- A significant upturn in generation from renewable sources, especially from wind, biomass and PV, since the early 2000s;
- A decline in use of coal and nuclear, the former, especially pronounced since the late 2000s, the latter, since 2010; and
- An increase in use of natural gas, increasing in the period to 2008, then fluctuating over the last decade, though increasing since 2014 (so that use in 2020 was marginally above levels reached in 2008).

Of the 557TWh of net electricity production in 2021, 226TWh was considered renewable. Of the 226 TWh of net production of electricity from renewables in 2020, 4.5TWh came from waste. This quantity has not changed greatly since 2010. Another 4.5TWh was produced from waste, but is not considered renewable.

It would be difficult to attribute a strong effect on the electricity generation system to incineration given its small (and relatively constant) contribution to net production. Its role - as both renewable and non-renewable source – makes it a less obvious choice as a means to substitute fossil fuel sources, or, in the case of Germany, nuclear. In reality, it is generally waste management decisions that affect the decision to build, or not, energy from waste facilities. Energy and climate policies can (and do, and will) influence these, but it seems reasonable to argue that electricity markets are happy to receive the electricity generated, but that they are not driving decisions regarding whether or not to invest in new capacity, and nor should they be.

Many incinerators in Germany have been in place for some time, so that electricity generation is not on the increase (the years since 2017 have actually witnessed a decline). At the time some were first constructed, it might well have been reasonable to argue that there was significant displacement of fossil-derived energy generation (and nuclear), though this abstracts from the role of policy whose role has not been examined here. It does not follow that because gas consumption has been increasing, that there has been no effect on displacement of gas: counterfactuals are more complex than that – they ask what would have happened in the absence of a given change, and it remains possible, for example, that even where gas consumption was increasing, it might otherwise have increased more without any contribution from incineration. Figure 7 above shows that whilst in Germany, the economically marginal source has mainly been coal, that gas is also the marginal source for just over 10% of the year, roughly the same proportion of the year for which solar PV is the marginal source. This is likely to have increased since 2019.

The answer to the question as to what was being/now is displaced should consider what have been, and what are, the firm power sources in Germany, what does policy say about the changing use of these over time, and how does the market determine which firm sources are likely to be in place in future. Should new facilities be considered, it would be best to place these questions in a longer-term context – what is expected to occur over the lifetime of the facility in these respects? These will not be – they never are – easy questions to answer, but they are the right ones to ask in arriving at a meaningful answer to the question regarding the likely impact of new capacity in the electricity market (and indeed, similar questions would apply for other sources of generation, depending on whether their contribution to generation is of a firm, or variable, or dispatchable nature).

Heat

On heat generation, the picture is somewhat complicated. The ITAD figure indicates 11,180 MWh of heat into district heating schemes. A recent by Triebs et al seeks to characterise the existing district heating facilities and shed light on the potential for decarbonising these in future. They note:[32]

> *The federal government is confident that the decision to phase out lignite and hard coal by 2038 and the compensation structure for hard-coal fired plants will lead to a substantial decrease in heat supplied by fossil fuels by 2030. According to the "National Energy and Climate Plan", the arising gap in heat generation capacity should be filled by stimulating investments in renewable technologies through financing options.*

They add:

> *Although the efforts for decarbonisation will be legally obliging in the near future, the German DH* [district heating] *sector lacks of practical transformations towards RE* [renewable energy] *and is still dominated by the combustion of fossil fuels. In 2018, biomass accounted for 6 % and heat recovery from waste incineration for 12% of the fuel used in combined heat and power (CHP) plants, whereas 82% was fossil fuel (45% supplied by natural gas, 27% by hard coal, and 10% by lignite) according to AGFW [7]. A similar situation was reported for non-CHP plants (i.e., heat-only plants, see Section 2.3) and external heat supply: only 13% of the fuel used in 2018 consisted of biomass and waste heat, and 3% of non-defined primary energy carriers [7]. The rest consisted of a major share of natural gas-fired (78%), and minor shares (3% each) of hard coal-fired and oil-fired heat-only plants [7]. Fig. 1 shows the development of the fuel share for CHP and non-CHP plants in the district heating sector over the past years*

The sources of energy used for district heating systems are shown in Figure 8 below. The key observations here are that especially since the early 2000s, the renewable sources and other energy carriers have increased at the expense of coal and gas. The contribution of waste comes within the renewables and other energy carriers categories. If one takes the ITAD figures, then waste would contribute around 20 PJ to the renewable sources, and a similar amount to the other energy sources.

Triebs et al note, regarding facilities using waste:[33]

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[32] M. S. Triebs, E. Papadis, H. Cramer, G. Tsatsaronis (2021) Landscape of district heating systems in Germany – Status quo, *Energy Conversion and Management*, 2021.

[33] M. S. Triebs, E. Papadis, H. Cramer, G. Tsatsaronis (2021) Landscape of district heating systems in Germany – Status quo, *Energy Conversion and Management*, 2021.

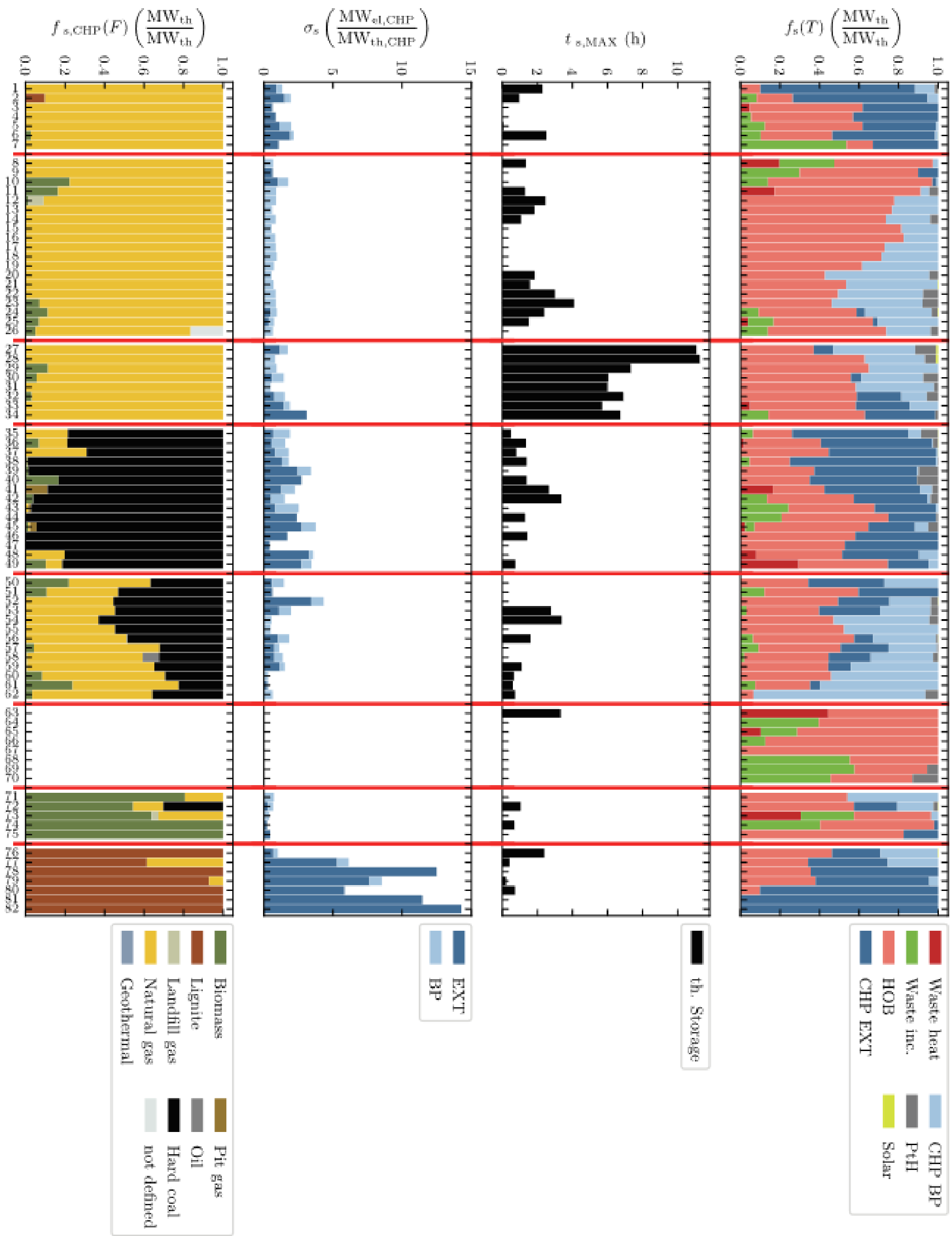
> *Waste incineration plants are treated as a separate technology type. The feed-in time series of waste-to-energy plants show that these plants are mainly operated independently of factors such as electricity price and heat demand. The primary task of these plants seems to be the disposal of waste.*

This is consistent with the discussion above regarding the nature of incineration facilities, and the fact that they tend to be operated on a continuous basis. The paper seeks to characterise facilities into eight classes of district heating systems. The one where waste plays the most prominent role is described as follows:

> *In some smaller DHSs, waste incineration plants take over the provision of thermal energy to the district heating system. The medium installed thermal capacity per system is significantly smaller in systems of this category than for the others (see Table 2). If the waste incineration plants are unavailable or not capable of supplying the demanded heat, heat only boilers are the preferred backup option. An alternative to waste incineration plants is industrial waste heat if there is enough provided by third parties. The significant share of continuously operating waste incineration plants leads to a steady heat supply, making the use of storages unappealing in these systems.*

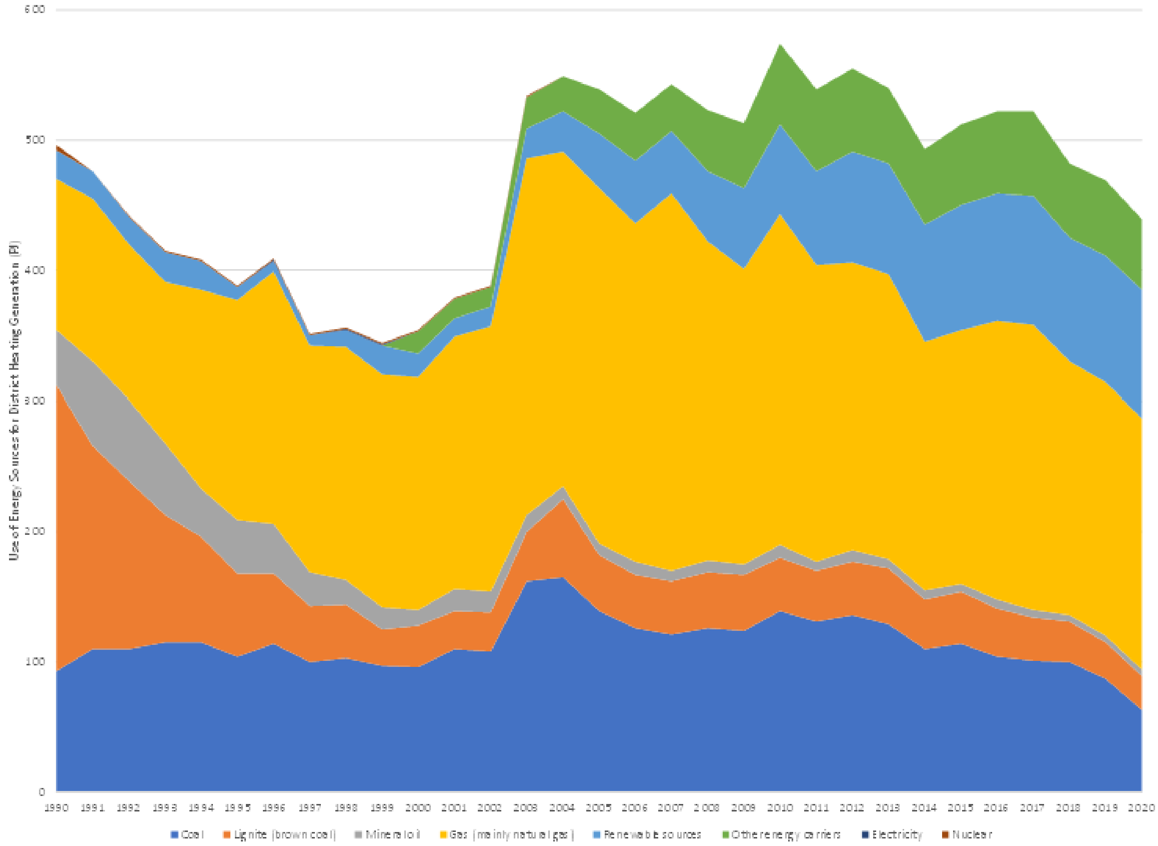
The backup – heat only boilers – are described as facilities which generate heat from combustion mainly of fossil fuels, '*typically natural gas and oil*'. It might be supposed, therefore, that incineration of waste has, in the past, had an impact on the consumption of fossil fuels, including gas. Waste is also used as a source of heat energy in other types of facility described in the Triebs et al paper, including those where natural gas plays a prominent role.

Figure 7: Key figures of district heating systems with effective thermal output capacity greater than 50 MWth (note: facilities 63-70 represent those linked to incineration referenced in the body of this report)



Source: M. S. Triebs, E. Papadis, H. Cramer, G. Tsatsaronis (2021) Landscape of district heating systems in Germany – Status quo, Energy Conversion and Management, 2021.

Figure 8: Use of energy sources for district heating generation in Germany, 1990-2020 (PJ)



Source: Eurostat energy balances

France

The French Agency, ADEME, conducts a study on management of waste periodically, and the 2022 version of that indicates that in 2020, French incineration facilities treated 14.57 million tonnes of waste.[34] It also shows the energy generated by different facilities, and this is shown in Table 8.

Table 8: Energy generated at household waste incineration facilities in France, 2020

Type of Energy Generated	Number of Household Waste Incineration Plants	Quantity of waste received (kt)6	Amount of energy consumed by plants (MWh)	Quantity of energy sold (MWh)
Electrical	17	1,634	145,962	637,510
Thermal	15	724	133,884	889,155
Cogeneration	84	12,123		
		Of which, electrical	*964,271*	*2,571,933*
		Of which, thermal	*1,969,476*	*7,972,010*

[34] ADEME (2022) *Le traitement des Déchets Ménagers et Assimilés en 2020: Exploitation des données de l'enquête sur les installations de traitement des déchets ménagers et assimilés en France en 2020.* Mai 2022, librairie.ademe.fr/cadic/7176/resultats_enquete_itom_2020-v2.pdf

Type of Energy Generated	Number of Household Waste Incineration Plants	Quantity of waste received (kt)6	Amount of energy consumed by plants (MWh)	Quantity of energy sold (MWh)
		Without valorisation of energy	2	53

	Electrical	Thermal
Total energy produced (GWh)	4,320	10,965

Source: ADEME (2022) Le traitement des Déchets Ménagers et Assimilés en 2020: Exploitation des données de l'enquête sur les installations de traitement des déchets ménagers et assimilés en France en 2020. Mai 2022, librairie.ademe.fr/cadic/7176/resultats_enquete_itom_2020-v2.pdf

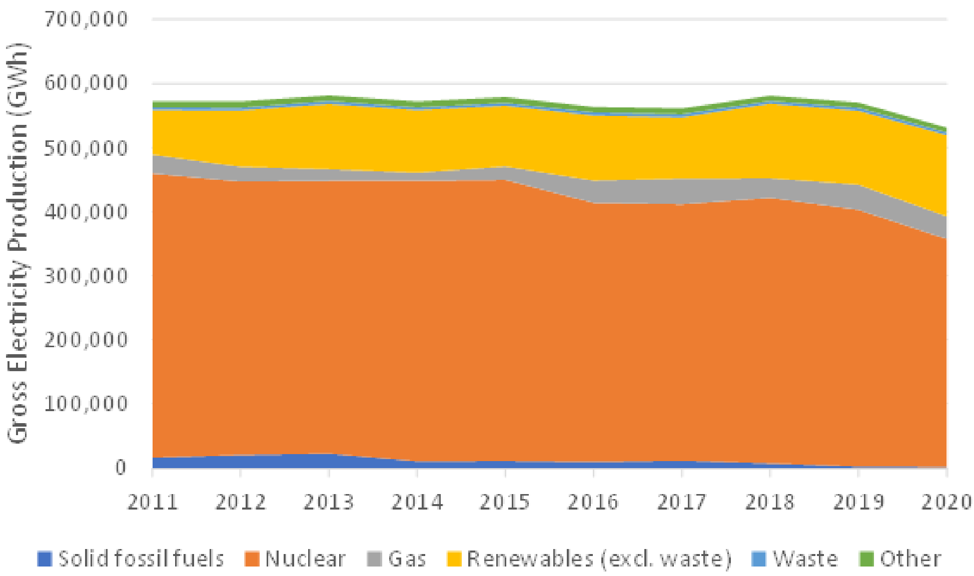
An important feature of the incinerators is that the majority of the generation is at cogeneration (or combined heat and power) facilities. The role of these is interesting in that whether their demand is led principally by heating or power generation, the complementary power or heat becomes available at the same time.[35] This is another way in which the 'displacement' discussion is rendered more complex.

Figures reported to Eurostat indicate that waste combustion contributed (see Figure 9 and Figure 10):

- 4,454 GWh to gross electricity production in 2020 out of a total of 531,201 GWh (less than 1% of total); and
- 8,668 GWh to gross heat production in 2020 out of a total of 44,716 GWh (19% of total).

The electricity market in France is dominated by nuclear, though its contribution has declined somewhat in recent years as gross electricity generation has declined. Generation from gas has increased somewhat with generation from fossil fuels having declined significantly over the same period.

Figure 9: Shares of fuels in gross electricity production in Germany, GWh



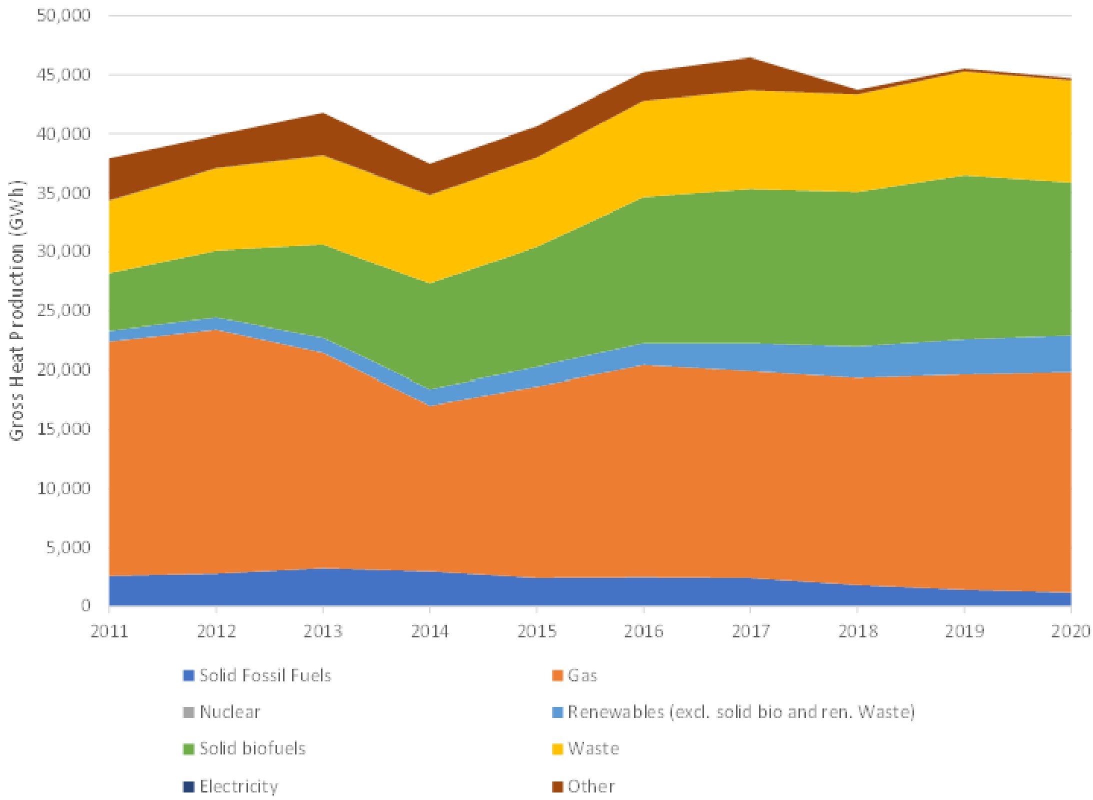
Source: Eurostat energy balances

[35] Different forms of cogeneration are more and less able to tweak the ratio of electricity to heat generated, some being more fixed in this respect, others, less so.

The contribution from waste has been more or less constant over the last decade. The effect of incineration is limited in this context, and it would be difficult to be completely clear about what sources incineration has been displacing over the last decade or so. Obviously, were that assumption based on 'average mix', the displaced source would be dominated by nuclear. Figure 9 above indicates that nuclear has also been the marginal source economically for the majority of the time, with gas the marginal source for around 7% of the year.

Where heat is concerned, gross production has increased over the past decade, and this has been largely down to an increase in the use of solid biofuels, though the contribution from waste has increased also. Gas use in heating has fallen, as has the use of coal. It seems likely that the use of fuels such as gas and solid biomass would complement the constant supply of heat from waste incineration.

Figure 10: Shares of fuels in gross derived heat generation in France, GWh

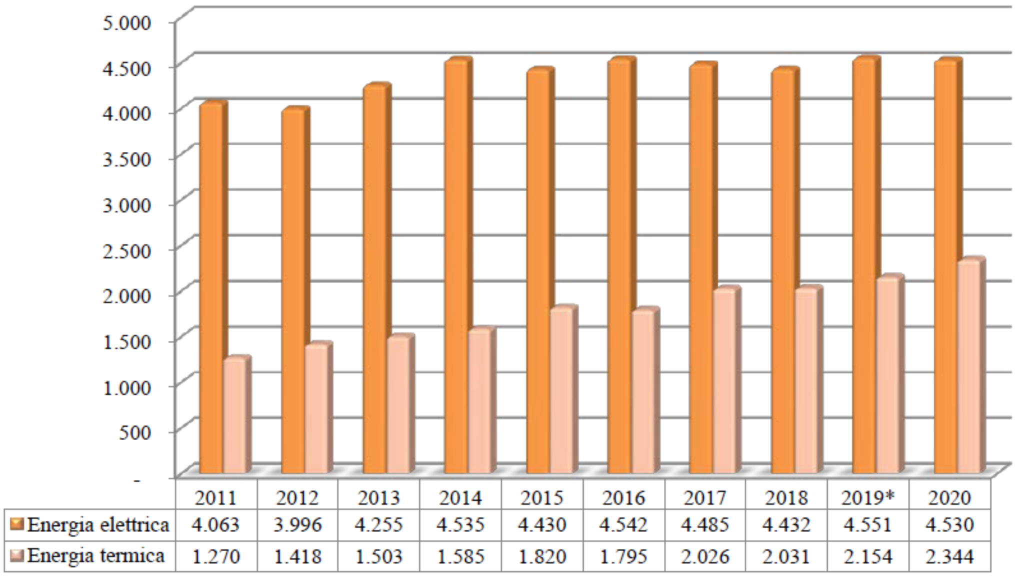


Source: *Eurostat energy balances*

Italy

Regarding municipal waste, ISPRA reports that in 2020, 4,530 GWh of electricity and 2,344 GWh of heat were generated.

Figure 11. Energy recovered from waste at incineration facilities, 2010-2020



Source: ISPRA (2021) Rapporto Rifiuti Urbani, Edizione 2021, Rapporti 355/2021, December 2021.

Table 9: Waste incineration facilities: treatment of waste and energy recovered, 2020

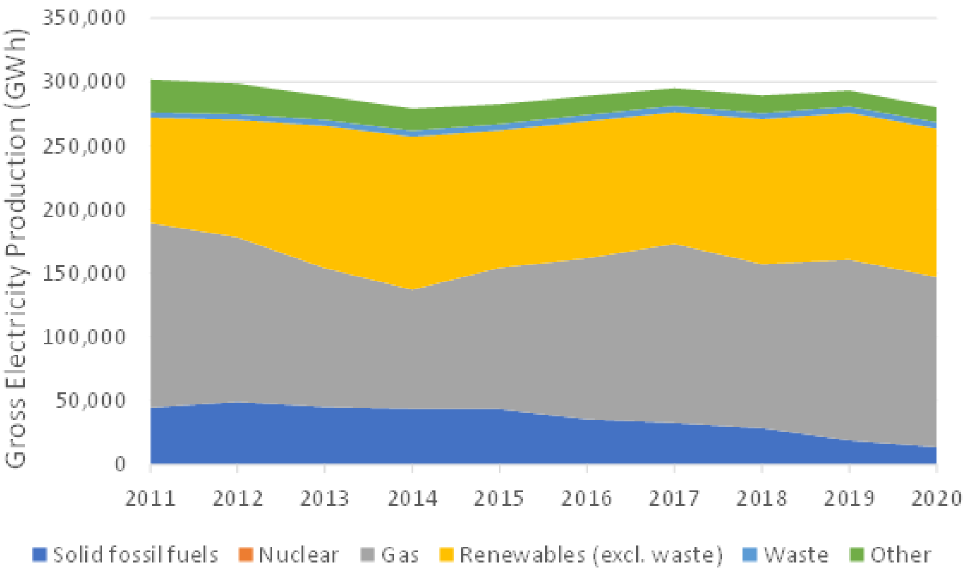
	No of facilities	Total waste treated (t)	Energy Generation		Energy per kg	
			Electricity (MWh_e)	Heat (MWh_t)	kWh_e/kg	kWh_t/kg
Combined heat and power	13	3,001,018	2,061,939	2,344,475	0.78	0.69
Electricity Only	24	3,241,493	2,467,641		0.76	-
Total	**37**	**6,242,511**	**4,529,581**	**2,344,475**	**0.73**	**0.38**

Source: ISPRA (2021) Rapporto Rifiuti Urbani, Edizione 2021, Rapporti 355/2021, December 2021.

In addition to the above, the ISPRA report notes that over 326 thousand tons of waste were sent to co-incineration (at cement facilities, and for electricity production/wood processing), or 3.9% of the total product. This waste consists mainly of solid recovered fuels (265 thousand tons) and the dry fraction (21 thousand tons) of municipal waste.

On electricity, over the last decade, the main changes in the Italian generation mix have been the decline in domestic generation, with the share of renewables increasing, and the share of solid fossil fuels falling significantly. Gas use has fluctuated over the decade. It may be that as well as providing firm load, it plays the role of balancing the input from variable renewables, such as solar. The contribution from waste has barely changed over the decade. It might be argued, therefore, that were there less generation from waste, there might be increased demand for gas. On the other hand, new build incineration facilities might not be displacing gas to the extent that future projections seek to reduce reliance on gas, especially for firm power. Note that there was no contribution from nuclear in Italy as of 2020.

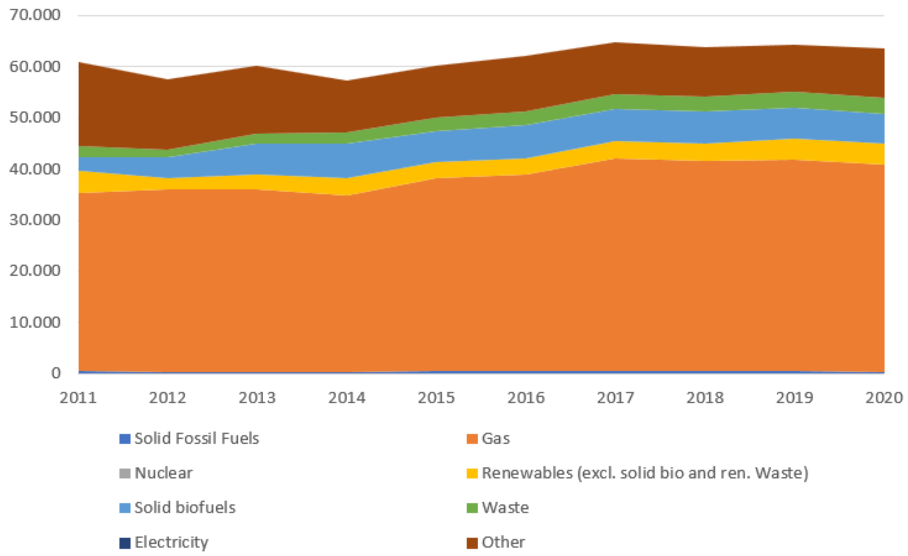
Figure 12: Shares of fuels in gross electricity production in Italy, GWh



Source: Eurostat energy balances

On derived heat, only 5% was derived from waste. The relative shares of electricity and heat are, however, very much in favour of electricity. The vast majority of derived heat (64%) was derived from gas, whose use in the supply has increased. It would be reasonable to argue, in the absence of information relevant at the time of construction, that facilities already built currently displace gas and biofuels.

Figure 13: Shares of fuels in gross derived heat generation in Italy, GWh



Source: Eurostat energy balances

Netherlands

All waste incineration plants in the Netherlands generate energy in the form of electricity and/or heat when processing the waste (see Table 10). In 2019, the Rijkswaterstaat noted that 4,009 GWh of gross electricity generation was produced by incineration facilities. About 80 percent of the electricity produced was exported to the grid or other installations outside the WIP. The rest is intended for own use, mainly for flue gas cleaning. In addition, 15.7 Peta Joules (PJ) of heat was reported to be supplied externally by the facilities. The heat is used for industrial processes, district heating or heating greenhouses. This is roughly equivalent to the 3,750 GWh reported by Eurostat in 2020 (which equates to 13.5 PJ).

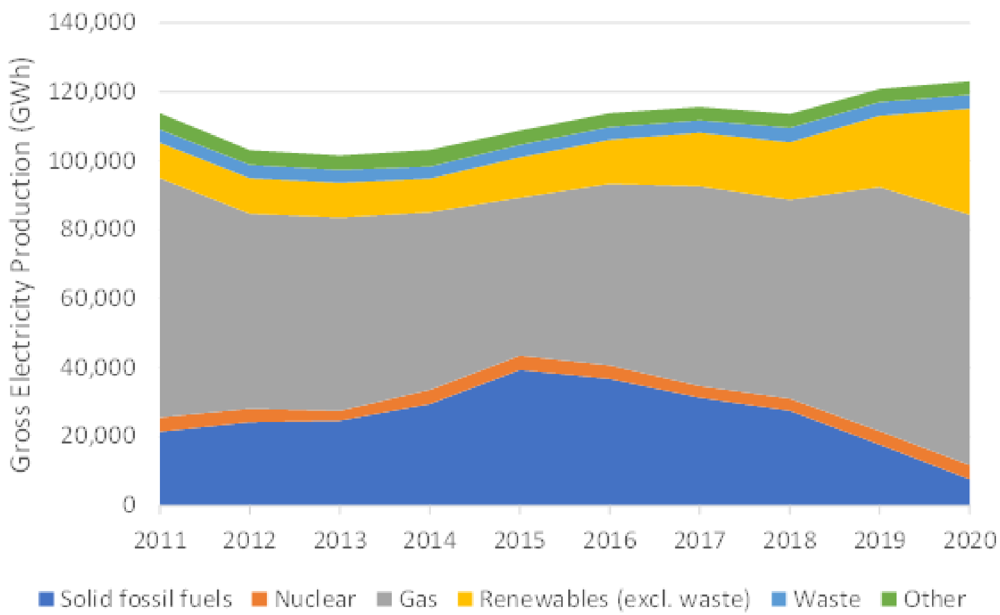
Table 10: Gross energy produced by waste incineration, 2015-2019.

	2015	2016	2017	2018	2019
Gross electricity production (GWh)	3,651	3,761	3,688	4,204	4,009
Delivered heat (PJ)	21.3	22.5	23.5	14.9	15.7
Total (PJ)	**34.4**	**36.0**	**36.8**	**30.0**	**30.2**

Source: Rijkswaterstaat (2021) Afvalverwerking in Nederland: gegevens 2019, report of the Werkgroep Afvalregistratie. – Utrecht: Rijkswaterstaat, August 2021

Figure 14 shows how different fuels contribute to gross electricity generation. Waste has provided a more or less constant contribution to firm power. Solid fossil fuel use initially increased, but has declined significantly after 2018, whilst gas use, having previously provided a more or less constant contribution, increased its share since 2018. Renewables have shown a similar evolution to gas, increasing slowly to 2016, but increasing more sharply thereafter. On this basis, displacement at existing facilities might be considered to affect developments mainly in gas and other renewables.

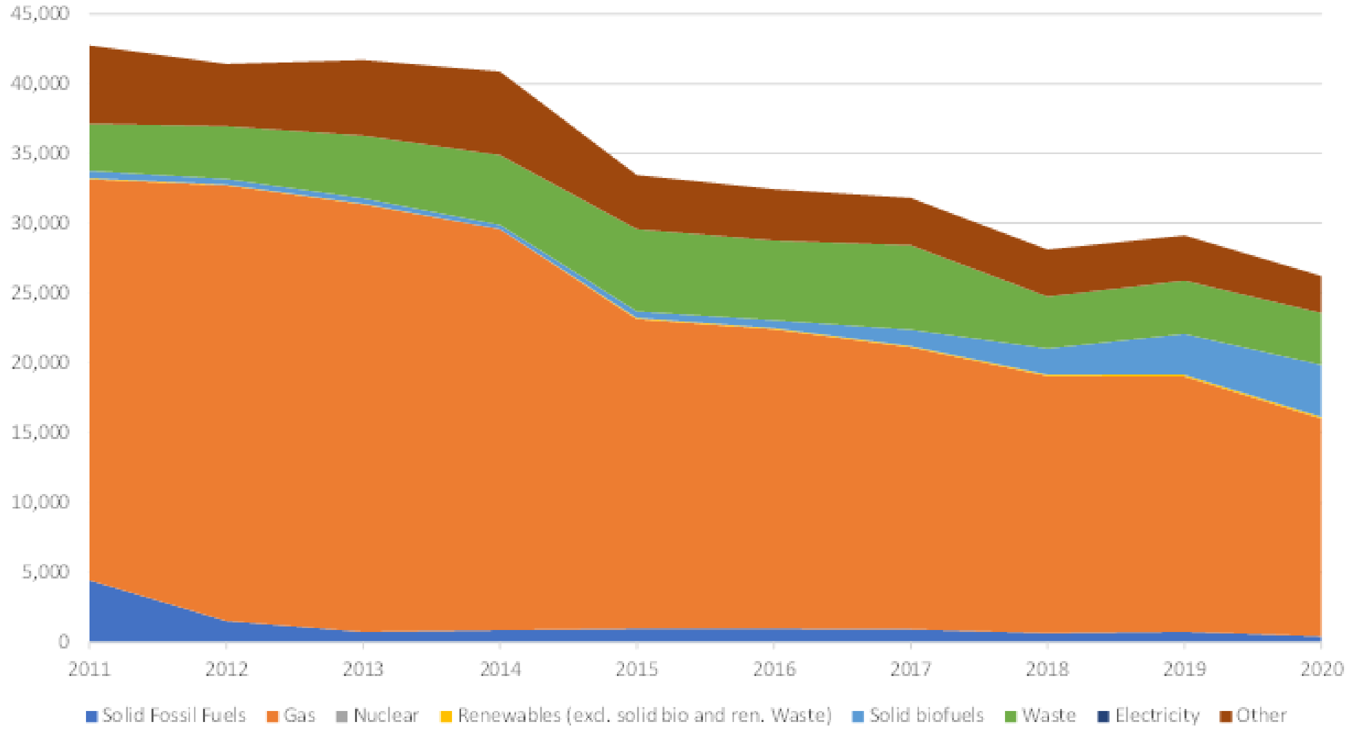
Figure 14: Shares of fuels in gross electricity production in Netherlands



Source: Eurostat energy balances

Regarding heat, the contribution from waste increased to 2017, but then fell after 2017. The total derived heat has fallen significantly since 2014. Solid fossil fuels have more or less disappeared from the supply mix, whilst gas use has also fallen significantly since 2014. This mode of heating appears to be being scaled back in Netherlands in favour of other modes of heating. There has been an increase in electricity generation since 2014, so the main changes regarding waste may be to switch more of generation away from heat and towards electricity.

Figure 15: Shares of fuels in gross derived heat generation in Netherlands



Source: Eurostat energy balances

In the National Climate Agreement (2019) (or '*Klimaatakkoord*'), the Netherlands has set the goal to phase out natural gas as the main source of heat supply for over 7 million households by 2050. In this context, it might be difficult to argue that any new incineration capacity in the Netherlands would displace gas. Other sources, including non-fossil district heating, either centralised or decentralised, are expected to play a major role.

Sweden

The case of Sweden is of some interest in that of the member states incinerating most waste, it is the one most clearly focussed on heat provision. A summary of quantities of waste managed via incineration, and associated energy generation, is shown in Table 11.

Table 11: Waste processed and energy generation, Sweden

	Incineration (tonnes)				
	2016	**2017**	**2018**	**2019**	**2020**
Municipal waste	2,262,610	2,400,440	2,362,160	2,426,610	2,240,990
Business waste	4,231,500	4,334,230	4,138,760	4,281,900	4,646,980
Total	**6,494,110**	**6,734,670**	**6,500,920**	**6,708,510**	**6,887,970**
Production (MWh)					
Heating	17,519,352	17,904,587	17,049,448	17,824,810	18,607,670
Electricity	2,199,820	2,242,370	2,183,250	2,296,890	2,593,970
Total	**19,719,172**	**20,146,957**	**19,232,698**	**20,121,700**	**21,201,640**

Source: Avfall Sverige (2021) Swedish Waste Management 2020,
www.avfallsverige.se/fileadmin/user_upload/Publikationer/Svensk_Avfallshantering_2020_EN_01.pdf

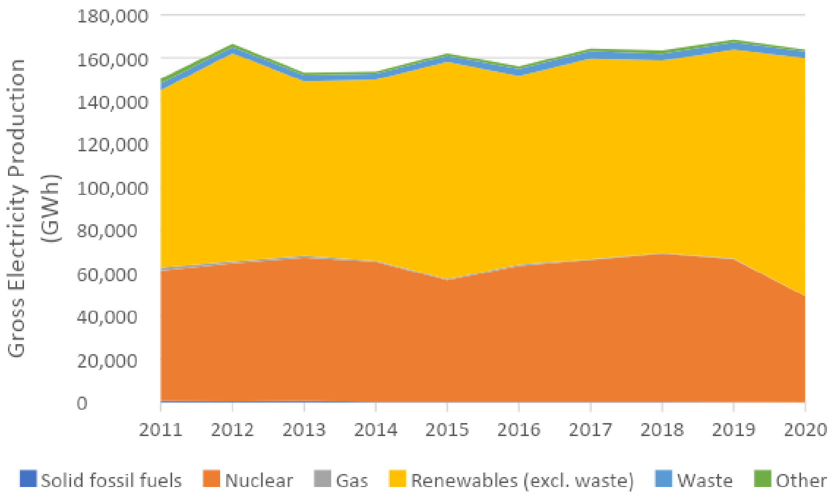
Avfall Sverige notes:[36]

> *Waste is a fuel used in Swedish district heating systems. Energy recovery from waste meets the heating needs of more than 1,445,000 apartments and the electricity needs of more than 780,000 apartments. In 2020, 21.2 TWh of energy was recovered, of which 18.6 TWh was used for heating and 2.6 TWh for electricity. In addition, four plants reported that they delivered 0.12 TWh of district cooling. [...]*
>
> *The capacity for energy recovery in Sweden is greater than the domestic availability of combustible waste. In 2020, Swedish energy recovery plants therefore also treated 1.9 million tonnes of waste from other European countries, 550,000 tonnes of which was municipal waste.*

Waste accounts for around 1.9% of electricity generation in Sweden. The electricity mix in Sweden is dominated by renewables and nuclear. Note that (see below) electricity is also utilised as an indirect source of heating for heat pumps, as well as more directly via resistive heating. By 2019, gross electricity generation had increased by 12% relative to 2011 levels, falling back somewhat in 2020. It would be difficult to argue that gas, or fossil fuels more generally, would be strongly represented in displaced sources, not least given that within the renewables share, hydropower plays a prominent role (so that the requirement for fossil-derived dispatchable sources to match variable renewables might be reduced).

[36] Avfall Sverige (2021) *Swedish Waste Management 2020*, www.avfallsverige.se/fileadmin/user_upload/Publikationer/Svensk_Avfallshantering_2020_EN_01.pdf

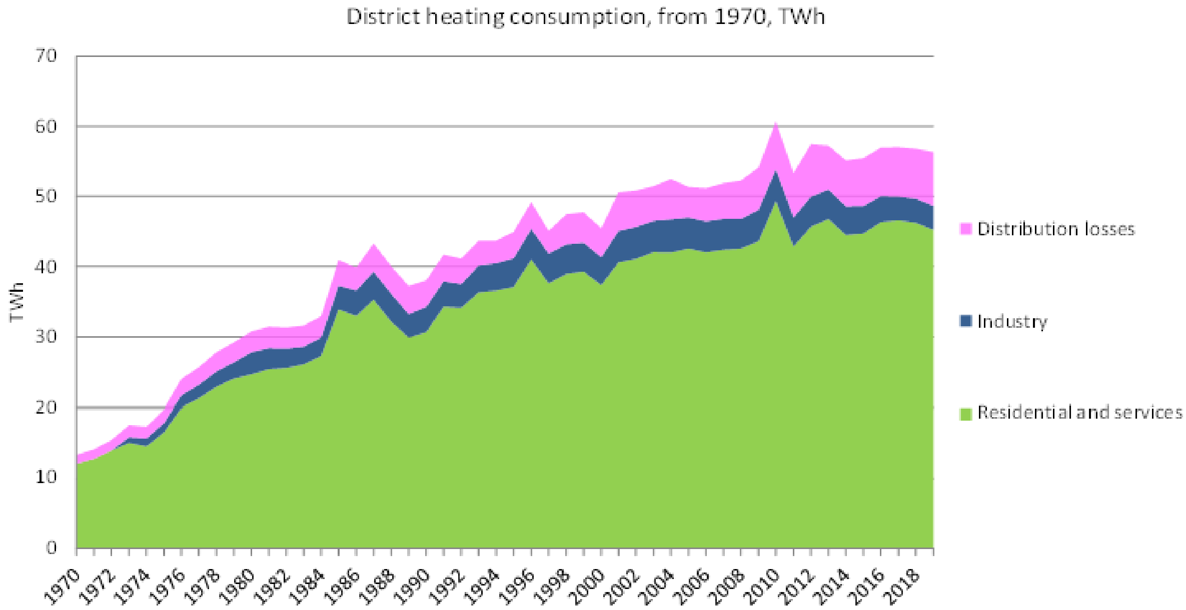
Figure 16: Shares of fuels in gross electricity production in Sweden



Source: Eurostat energy balances

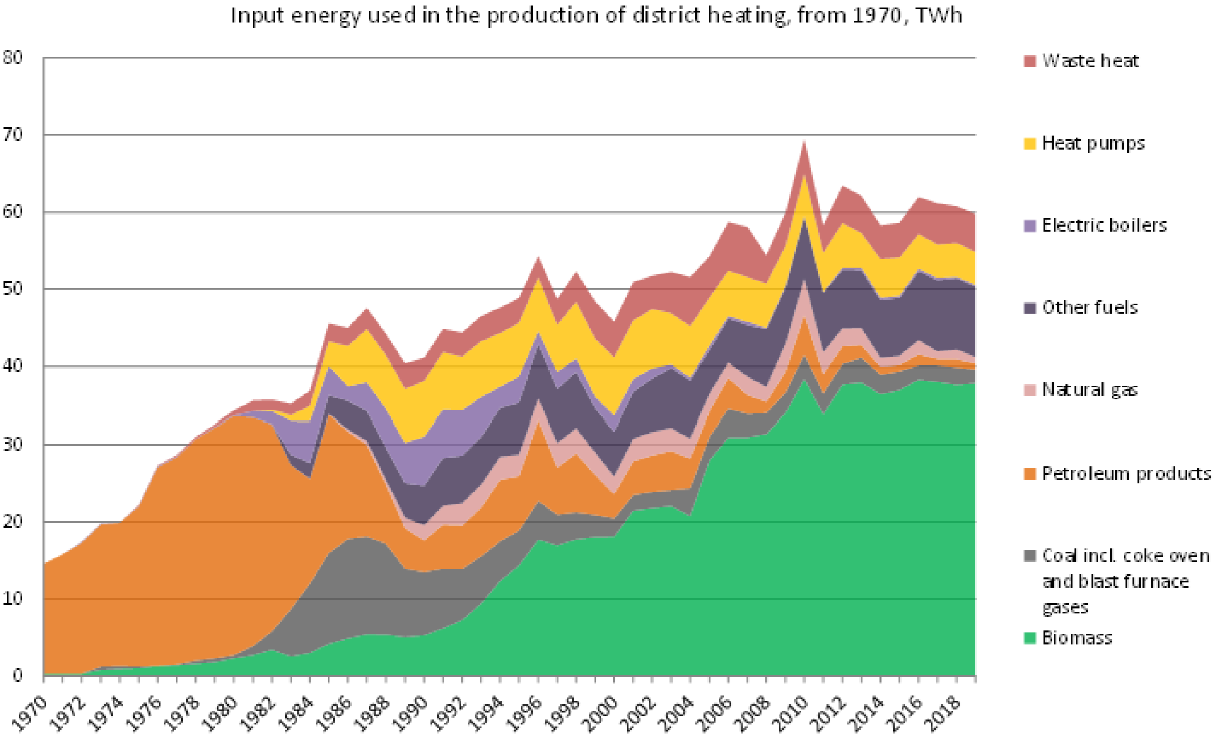
The district heating systems in Sweden are mainly supplying households, though around 10% of the heat provided to final consumers is used by industry (see Figure 17). The sources of heat in the Swedish district heating network are shown in Figure 18 and again – to highlight the specific role of incineration more clearly (the previous figure likely splits this across biomass and other fuels) – in Figure 19.

Figure 17: Overall district heat generation, losses, and consumption by end-use sector, Sweden



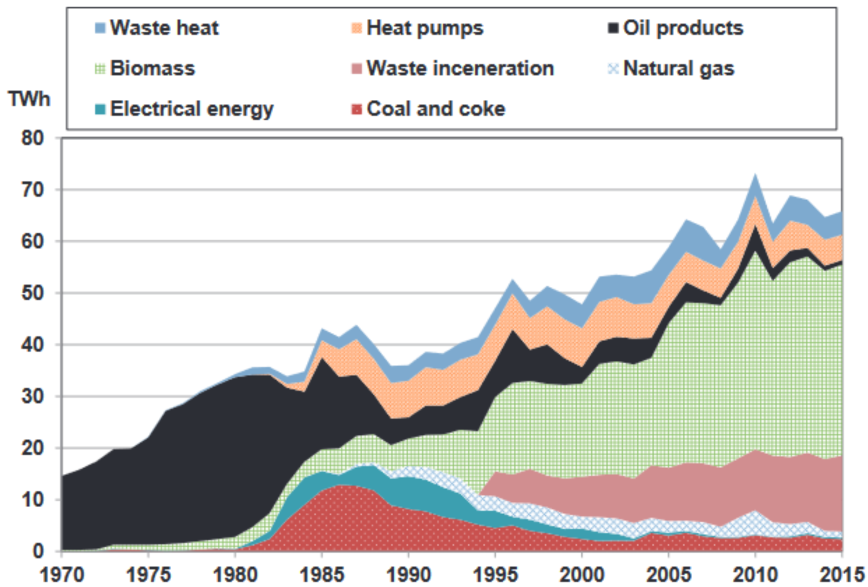
Source: Swedish Energy Agency and Statistics Sweden.

Figure 18: Input energy sources to Swedish district heating, Sweden



Source: Swedish Energy Agency and Statistics Sweden.

Figure 19: Fuels in the district heating system in Sweden (with incineration shown separately)



Source: Stockholm Environment Institute (2017) Swedish heat energy system – new tensions and lock-ins after a successful transition: Policy Brief, mediamanager.sei.org/documents/Publications/SEI-2017-PB-Dzebo-Nykvist-SweHeatEnergySystem-eng.pdf

What these figures show is a very small contribution to district heating being made by solid fossil fuels and by gas. Incineration's share has been increasing, but the main source of supply of heat is biomass. Waste heat and heat pumps are also important contributors.

It would be rather difficult to sustain the case, based on a snapshot today, that incinerators were displacing a fossil fuel-rich mix of supply. On the other hand, and pertinent to the points made above regarding the validity of approaches to understanding counterfactuals, at the time facilities were being developed in the mid-1990s, it might well have appeared that they could displace use of natural gas and coal (see the above Figure). Consistent with our line of argument above, whether that assumption was reasonable ought to have been influenced, at the time, by the nature of prevailing policy. Note also, however, that such facilities may or may not have been renewed or retrofitted in the meantime, given their vintage. As a facility's lifetime draws to a close, it would be natural to review their likely role in the heating mix, set against the most plausible counterfactuals.

Also relevant to the above discussion is consideration of counterfactuals in the case of a hypothetical expansion in new capacity. First of all, it would appear that across all housing in Sweden, the source of heat is low- fossil carbon. Electricity – which is derived from renewables and nuclear - is the main source of heating in single-dwelling houses (see Table 12). Earlier systems have been replaced by heat pumps (Sweden and Switzerland are the two countries with the largest number of installed heat pumps per capita). The Swedish government played a key role in the development and commercialisation of heat pumps by supporting technology and knowledge development, and providing subsidies for conversion from oil-fired boilers and resistive heating.

Consequently, as well as some concerns emerging regarding the effects of over-capacity in incineration on waste management (especially recycling), there have been concerns expressed regarding the effect of existing heating systems on the level of demand for heat. Hence, the Stockholm Environment Institute noted:[37]

> *At the same time, continued investment in new waste-burning combined heat and power plants has led to a debate about over-capacity, lock-in of waste incineration, and dependency on waste imports. The Swedish heat regime is thus experiencing increasing tensions, disagreements and competing interests among regime actors. A lock-in of waste incineration as a major fuel source would conflict with the EU Waste Framework Directive (2008/98/EC), which defines disposal through incineration as the second least effective treatment of waste, after landfills. In addition, waste incineration may be disrupting the potential of industrial waste heat in district heating systems.*

[37] Stockholm Environment Institute (2017) *Swedish heat energy system – new tensions and lock-ins after a successful transition: Policy Brief*, mediamanager.sei.org/documents/Publications/SEI-2017-PB-Dzebo-Nykvist-SweHeatEnergySystem-eng.pdf

Table 12: Energy statistics for dwellings and non-residential premises

	One- and two-dwelling buildings						Multi-dwelling buildings						Non-residential premises					
	Oil	District heating	Electric heating	Natural gas	Biomass	Total	Oil	District heating	Electric heating	Natural gas	Biomass	Total	Oil	District heating	Electric heating	Natural gas	Biomass	Total
1983	17.0	1.7	15.1	0.2	8.8	**42.8**	15.8	15.6	1.2	0.2		**32.8**	14.1	8.3	3.0	0.0		**25.4**
1984	14.8	1.8	17.3	0.2	9.6	**43.7**	13.2	16.4	1.5	0.2		**31.3**	12.5	9.2	3.2	0.0		**24.9**
1985	13.5	2.1	20.0	0.2	10.9	**46.7**	13.0	19.5	1.9	0.2		**34.6**	12.4	10.7	3.6	0.1		**26.8**
1986	13.6	2.1	19.7	0.2	10.1	**45.7**	11.2	19.7	2.2	0.3		**33.4**	9.4	11.4	4.4	0.2		**25.4**
1987	15.9	2.1	21.3	0.2	9.4	**48.9**	11.0	21.7	2.3	0.3		**35.3**	11.2	11.6	4.8	0.4		**28.0**
1988	15.2	2.1	19.8	0.2	8.9	**46.1**	8.0	18.9	2.2	0.4		**29.5**	9.1	11.0	4.2	0.4		**24.7**
1989	14.8	2.0	17.6	0.2	9.0	**43.6**	6.8	17.8	1.9	0.4		**26.9**	8.7	9.8	4.1	0.5		**23.1**
1990	15.0	2.1	17.9	0.2	10.0	**45.2**	6.7	17.0	1.9	0.4		**26.0**	9.2	11.4	6.0	0.6		**27.2**
1991	14.4	2.2	18.9	0.2	10.2	**45.9**	7.0	19.1	2.0	0.6		**28.7**	7.2	13.1	5.5	0.7		**26.5**
1992	14.1	2.3	18.4	0.3	10.3	**45.3**	6.4	18.9	1.7	0.6		**27.6**	6.7	12.7	6.2	0.7		**26.3**
1993	13.7	2.4	18.2	0.3	10.9	**45.5**	6.6	21.0	2.0	0.6		**30.2**	6.7	13.3	6.3	0.9		**27.2**
1994	14.0	2.6	18.4	0.3	10.4	**45.7**	6.8	20.5	1.7	0.7		**29.7**	6.4	13.3	6.0	0.8		**26.5**
1995	13.9	2.4	17.9	0.3	11.1	**45.6**	6.2	20.6	2.4	0.8		**30.0**	5.2	14.9	5.0	0.9		**26.0**
1996	14.2	2.7	19.4	0.3	11.2	**47.8**	5.7	21.9	2.2	0.8		**30.6**	5.9	15.6	5.7	0.9		**28.1**
1997	12.5	2.5	19.5	0.3	10.3	**45.1**	4.9	21.8	2.2	0.7		**29.6**	5.0	14.5	4.4	1.0		**24.9**
1998	13.6	2.7	18.0	0.3	9.8	**44.4**	4.7	22.7	1.8	1.0		**30.2**	4.8	14.8	4.1	1.0		**24.7**
1999	12.5	2.7	16.1	0.3	9.6	**41.2**	3.8	21.9	1.7	1.1		**28.5**	4.8	14.9	3.7	1.0		**24.4**
2000	11.4	2.6	14.9	0.3	9.7	**38.8**	3.4	21.5	1.8	0.9	0.1	**27.6**	4.6	14.9	3.9	0.9	0.0	**24.3**
2001	9.9	2.8	16.2	0.3	9.4	**38.5**	3.0	22.5	1.8	1.0	0.2	**28.6**	3.9	15.0	3.9	1.0	0.6	**24.4**
2002	9.0	3.0	16.5	0.3	9.9	**38.7**	2.5	23.2	1.5	0.4	0.2	**27.8**	3.3	14.8	3.8	0.5	0.3	**22.8**
2003	8.1	3.6	15.8	0.2	10.7	**38.4**	2.4	23.2	2.1	0.4	0.3	**28.4**	3.2	15.3	3.9	0.5	0.4	**23.3**
2004	7.8	3.7	16.3	0.2	10.0	**38.0**	1.9	22.8	2.1	0.4	0.2	**27.4**	1.8	15.5	4.2	0.4	0.6	**22.5**

	One- and two-dwelling buildings						Multi-dwelling buildings						Non-residential premises					
	Oil	District heating	Electric heating	Natural gas	Biomass	Total	Oil	District heating	Electric heating	Natural gas	Biomass	Total	Oil	District heating	Electric heating	Natural gas	Biomass	Total
2005	5.4	3.7	15.3	0.4	11.2	**36.0**	1.3	23.1	1.7	0.4	0.3	**26.8**	1.9	15.5	3.6	0.6	0.4	**22.0**
2006	3.4	4.7	15.3	0.3	10.4	**34.1**	1.1	22.4	1.5	0.3	0.2	**25.5**	1.6	14.7	3.9	0.4	0.5	**21.1**
2007	2.6	4.2	13.7	0.2	11.1	**31.8**	0.7	22.8	1.2	0.3	0.2	**25.2**	1.4	15.4	3.3	0.4	0.6	**21.1**
2008	2.0	5.4	12.9	0.2	11.4	**31.9**	0.5	22.3	0.8	0.2	0.2	**24.0**	0.8	14.8	2.9	0.3	0.5	**19.3**
2009	1.5	5.2	14.6	0.2	13.0	**34.5**	0.4	21.9	1.1	0.2	0.2	**23.8**	0.8	16.2	2.2	0.4	0.6	**20.2**
2010	1.3	5.8	16.1	0.2	12.4	**35.8**	0.4	24.9	1.0	0.2	0.2	**26.7**	0.9	18.5	2.2	0.3	0.5	**22.4**
2011	0.9	6.0	14.4	0.1	12.0	**33.4**	0.3	21.1	1.1	0.2	0.2	**22.9**	0.7	15.5	2.7	0.3	0.6	**19.8**
2012	0.9	5.7	14.6	0.2	11.5	**32.9**	0.3	23.3	1.3	0.3	0.2	**25.3**	0.7	16.6	2.8	0.3	0.7	**21.2**
2013	0.9	5.8	14.7	0.1	11.1	**32.6**	0.2	23.0	1.3	0.3	0.2	**24.9**	0.5	17.9	3.3	0.2	0.7	**22.6**
2014	0.7	5.8	14.0	0.2	10.3	**31.1**	0.1	22.0	1.4	0.2	0.3	**24.1**	0.4	16.5	2.9	0.3	0.5	**20.7**
2015	0.8	5.9	14.1	0.2	10.4	**31.3**	0.0	22.1	1.4	0.2	0.3	**24.1**	0.4	16.6	3.0	0.3	0.5	**20.8**
2016	0.4	5.5	15.3	0.3	10.4	**31.9**	0.2	24.0	2.0	0.2	0.2	**26.6**	0.4	16.8	3.5	0.4	0.8	**21.8**
2017	0.4	5.5	15.2	0.3	10.4	**31.9**	0.2	24.0	2.0	0.2	0.2	**26.6**	0.4	16.7	3.5	0.4	0.8	**21.8**
2018	0.4	5.5	15.4	0.3	8.8	**30.4**	0.2	24.2	2.1	0.2	0.2	**26.8**	0.4	16.6	3.5	0.4	0.8	**21.7**
2019	0.4	5.5	15.3	0.3	8.8	**30.2**	0.1	23.6	2.1	0.2	0.1	**26.1**	0.3	15.9	3.6	0.3	0.4	**20.4**

Source: Swedish Energy Agency and Statistics Sweden.

They went on to say:

> *Reducing demand through more energy efficient but expensive building techniques, such as materials and heat control systems, will likely continue to meet resistance from the main actors in the system. As electricity is already nearly fully decarbonised, and institutional barriers are strong, it is not clear that future policy development will include the range of instruments and interventions needed to achieve deep reductions in demand and thus meet the EU and national policy targets.*

Nevertheless, in its report to the European Commission, the Ministry of Infrastructure has written:[38]

> *District heating is already available in 285 of Sweden's 290 municipalities and is, for the most part, fossil-free. Where district heating is not profitable, heating is primarily achieved using heat pumps which use almost completely fossil-free electricity. Conversion to efficient and renewable/fossil-free heating has already been broadly implemented in Sweden.*
>
> *The remaining fossil fuel boilers in the district heating systems are already being phased out and the individual oil boilers are being converted and disappearing completely as they are no longer cost-effective. The challenge remains to replace natural gas heating in housing and premises which amounts to approximately 0.8 TW as well as to replace or reduce the fossil content of waste in waste cogeneration.*

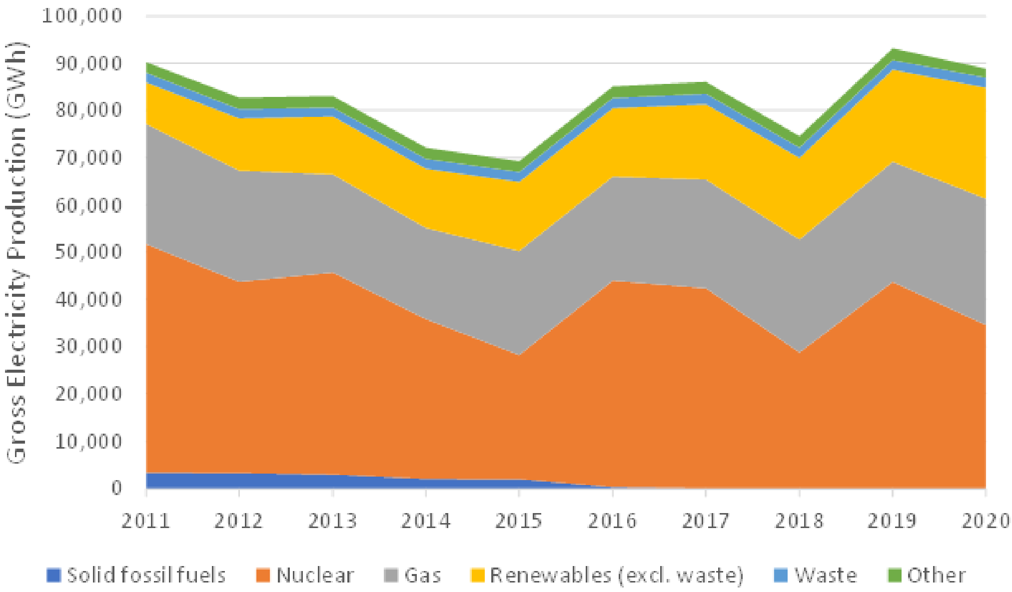
This would appear to confirm not only that the scope for additional incineration in the heating system is limited, but also, that there are plans being considered to reduce the carbon intensity of the waste stream itself. Elsewhere, we have argued that one way of doing this, consistent with meeting recycling targets, is to remove plastics from the leftover mixed waste stream through mixed waste sorting. This, though, has the effect of increasing the capacity of existing incinerators to treat waste, so that without some facilities being mothballed, there will potentially be pressure for further imports.

Belgium

In Belgium, the share of waste in gross electricity production has remained relatively constant, albeit it has increased slightly in absolute terms (see Figure 20). The contribution from gas, although it has fluctuated, has remained relatively stable over the 2011-2020 period, and contributed 30% of gross generation in 2020. Nuclear power accounts for the largest share of generation, with solid fossil fuels having been all but phased out. Generation from renewables has increased by around 267% over the period, so that renewables now make roughly the same contribution as gas.

[38] Ministry of Infrastructure (2021) *Sweden's report under Article 14(1) of Directive 2012/27/EU on energy efficiency – Promotion of efficiency in heating and cooling*, 25 February 2021, energy.ec.europa.eu/system/files/2021-10/se_ca_2020_en.pdf

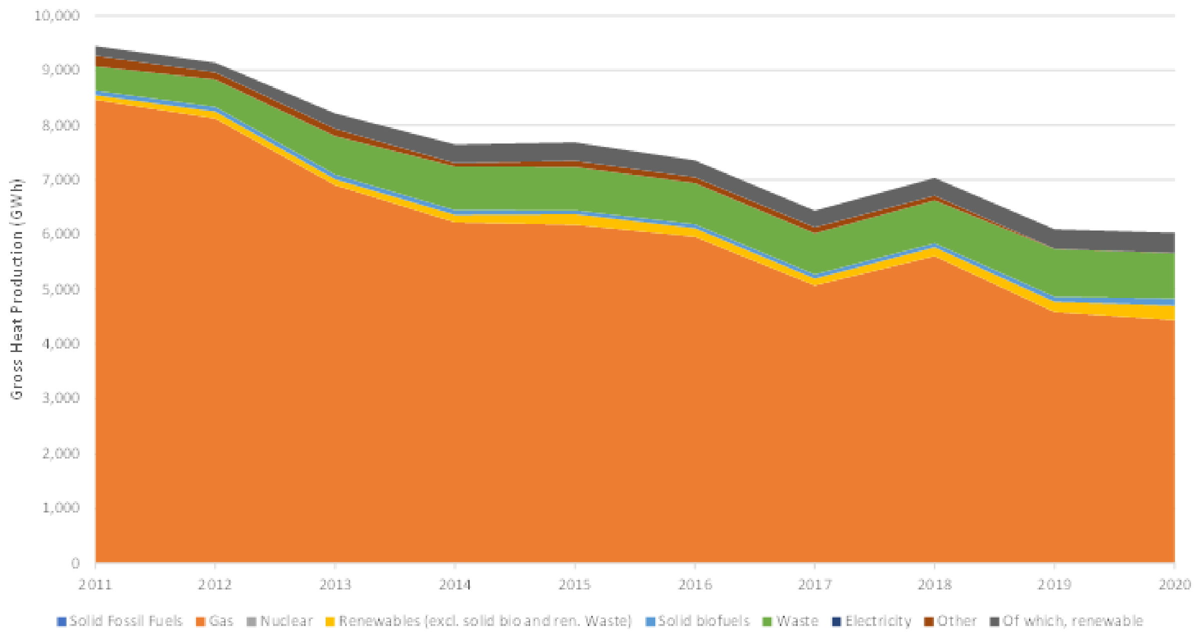
Figure 20: Shares of fuels in gross electricity production in Belgium



Source: *Eurostat energy balances*

Derived heat is less important than electricity in the generation of energy from waste. Derived heat generation is not a major factor in Belgian energy supply, and the majority comes from gas, with 15% coming from waste. The quantity of derived heat generated (from all sources) has dropped significantly over the 2011-2020 period, a period in which the absolute contribution from waste has almost doubled. This may have helped quicken the decline in use of gas as the derived heat generation has fallen (see Figure 21).

Figure 21: Shares of fuels in gross derived heat generation in Belgium



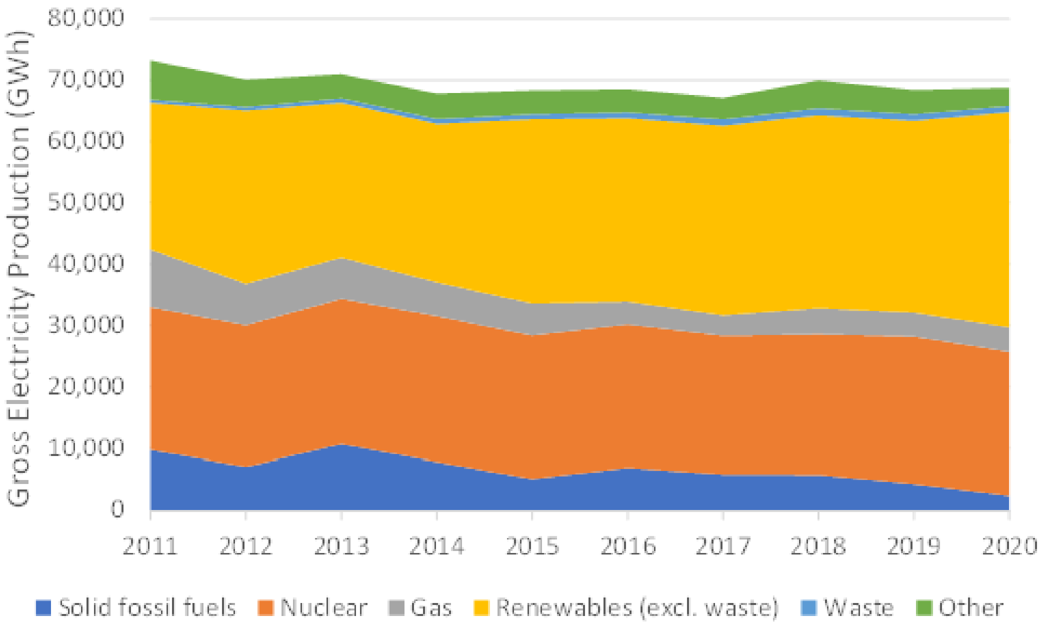
Finland

Statistics Finland states that 1.63 million tonnes of MSW were sent for incineration with energy recovery in 2020. Nine waste-to-energy plants were in operation and one was (as of 2021) under construction (commissioning in 2021). In addition, approximately 20 conventional power plants have a license to co-fire waste derived fuels (SRF/RDF), though it was reported that fewer than 10 plants were doing so at the time of reporting.

Statistics Finland reports on the use and transformation of waste as a source of energy. It indicates a figure of 188,178 TJ for all use of waste, with most of these reported as used in industry. If one considers only the non-renewable wastes, the figure falls to 14,764 TJ, suggesting that much of the us and transformation of waste is of waste biomass, for example, from the forest industries which are important in the Finnish economy. If one assumes that roughly half of municipal type waste is non-renewable, then taking into account likely conversion efficiencies to electricity, the figures reported by Statistics Finland, and reported to Eurostat appear more consistent than they otherwise do. The role played by industrial waste biomass in statistics is, though, worth bearing in mind. Statistics Finland reports that use of waste for 'electricity, gas, steam and air conditioning supply', consists 23,583 TJ in total, of which 10,252 TJ is considered renewable.[39]

Most of the electricity generated in Finland derives from renewables and nuclear. Generation has fallen since 2011, and though the absolute contribution from waste has more or less doubled over the same period, waste was responsible for only 1.4% of electricity supply in 2020. Solid fossil fuels have been trending down since 2013, whilst generation from gas has been falling throughout the 2011-2020 period. It would be difficult to argue a case that gas would be displaced by additional generation from waste.

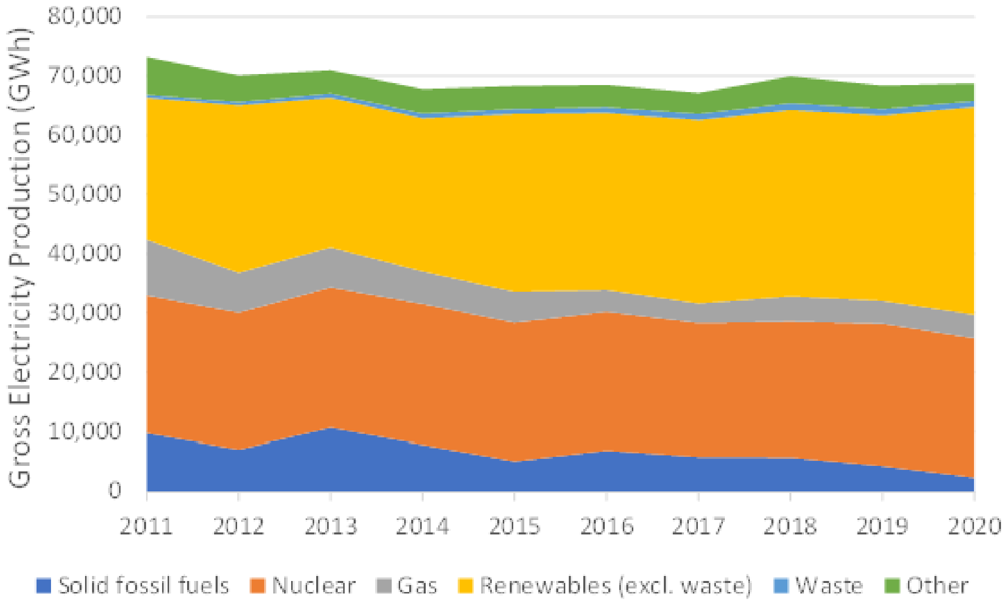
Figure 22: Shares of fuels in gross electricity production in Finland



According to Eurostat data for gross derived heat production, waste (likely excluding the waste biomass largely used by industry – see below) accounts for around 9% of the total. Biofuels play an important role.

[39] Taken from *Statistics Finland Database - 11wx -- Energy Accounts, 2011-2020*, pxweb2.stat.fi/PxWeb/pxweb/en/StatFin/StatFin__entp/statfin_entp_pxt_11wx.px

Figure 23: Shares of fuels in gross derived heat generation in Finland



Source: *Eurostat energy balances*

Statistics Finland gives specific splits for use of fuels for each of district heating and industrial heating. In district heating systems, fossil fuels still play an important role, but they are diminishing in importance, with wood based biomass increasing significantly. In the Table below, other fossil fuels and other renewables are likely to be mostly the non-renewable and renewable portions of waste. It could be argued, therefore, that waste, alongside other renewables (notably those derived from forest industries) may have been supporting a reduction in use of fossil fuels in district heating. The industrial heating fuel mix is rather different with use of materials from forest industries providing the majority of the fuel.

Table 13: Fuels used in production of district heating and industrial heat, 2011 and 2020, GWh

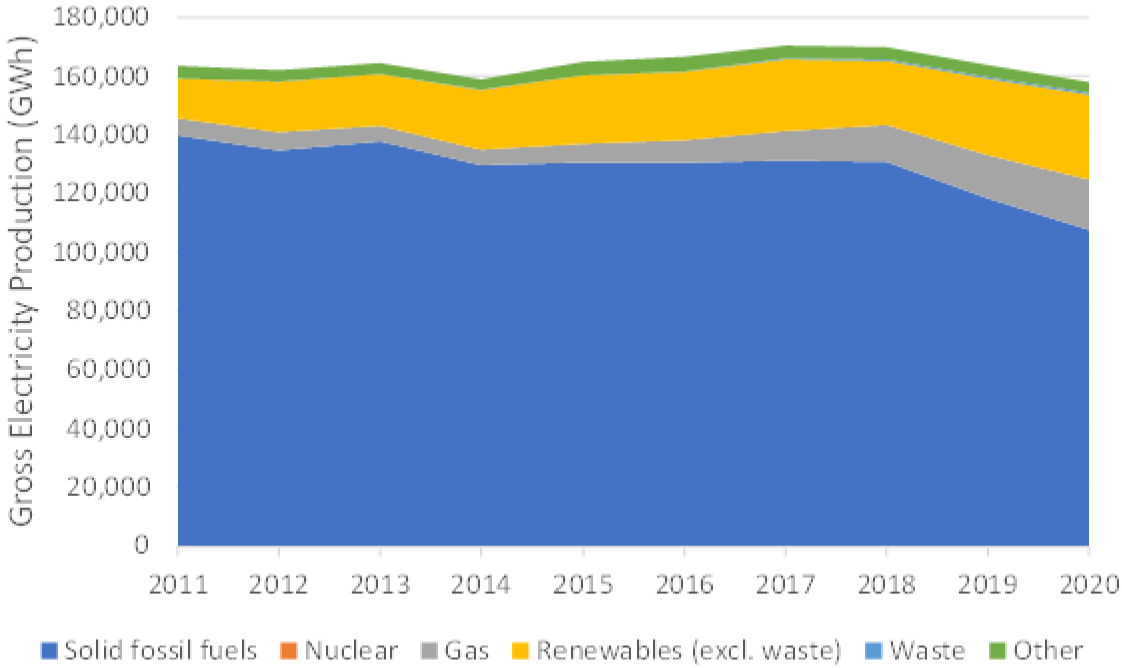
	District heating		Industrial Heat	
	2011	**2020**	**2011**	**2020**
Oil (Fossil fuels)	1,852	517	2,467	2,011
Hard coal (Fossil fuels)	7,582	4,214	888	446
Natural gas (Fossil fuels)	9,293	4,335	5,996	3,565
Other fossil fuels	585	1,448	681	705
FOSSIL FUELS TOTAL	**19,312**	**10,514**	**10,032**	**6,727**
Peat	6,712	4,626	4,582	2,515
FOSSIL FUELS AND PEAT TOTAL	26,024	15,140	14,614	9,242
Black liquor (Renewable fuels)	175	195	23,893	27,366
Other wood fuels (Renewable fuels)	7,917	13,369	10,782	11,138
Other renewables	461	1,735	652	939
RENEWABLE FUELS TOTAL	**8,552**	**15,299**	**35,327**	**39,443**
Other energy sources	892	4,709	3,237	2,414
TOTAL PRODUCTION OF DISTRICT/INDUSTRIAL HEAT	**35,469**	**35,148**	**53,178**	**51,099**

Source: Statistics Finland

Poland

Waste in Poland accounts for only 0.4% of total electricity generation in 2020, but in absolute terms, the contribution this has multiplied by a factor of more than 20 over the last decade (Figure 24). Poland's electricity supply is notoriously dependent on solid fossil fuels, but there are signs of change, with the amount generated from renewables increasing, and use of gas also on the increase.

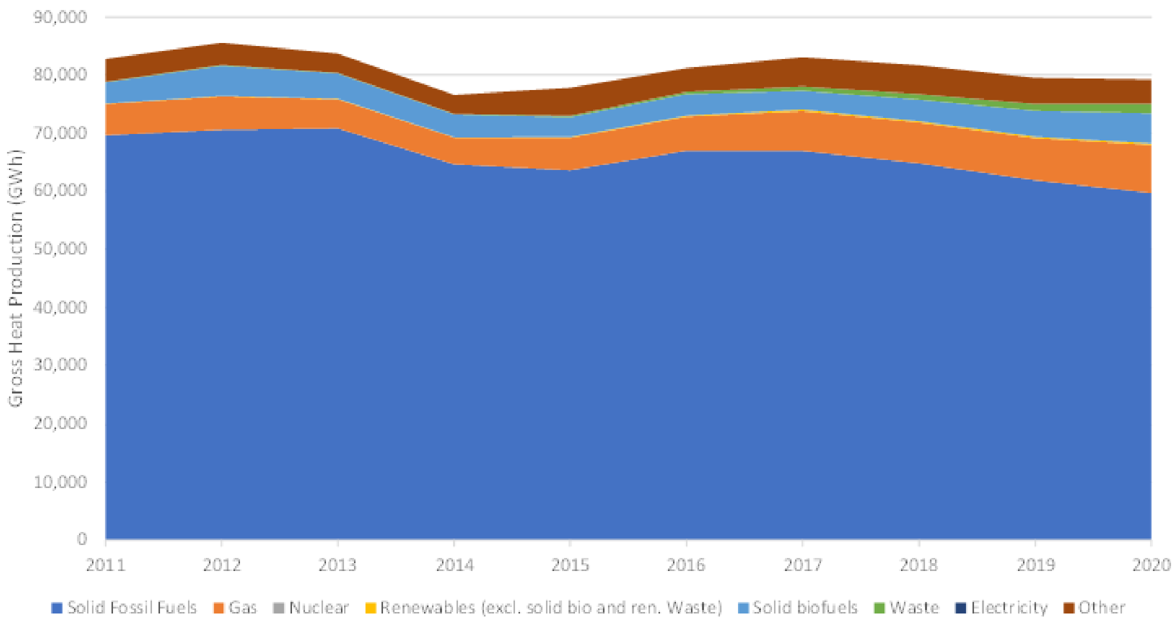
Figure 24: Shares of fuels in gross electricity production in Poland



Source: *Eurostat energy balances*

Waste accounted for only 2% of total derived heat generation in Poland in 2020, but in absolute terms, the contribution has multiplied by a factor of 16 over the last decade (Figure 25). Like its electricity supply, Poland's gross derived heat supply is heavily dependent on solid fossil fuels, but as with electricity, gas is playing a more prominent role, while solid biofuels are also playing a growing role.

Figure 25: Shares of fuels in gross derived heat generation in Poland



Spain

Spain reports no derived heat and so, one assumes, energy from waste incineration is generated mainly in the form of electricity. The total power generated by incinerators dealing with municipal waste in 2019 was reported by MITECO as 1,627 GWh.[40] This is broadly similar to the figure reported by Spain to Eurostat for gross electricity production from waste (in 2019 and 2020). RED Eléctrica (the operator of the national electricity grid in Spain), on the other hand, reports (for 2021) that renewable wastes generated 878 GWh whilst non-renewable wastes were also responsible for a further 2,238 GWh (see Table 14). If one assumed a roughly 50:50 split, this would suggest that RED was reporting a contribution of 1,460 GWh from non-renewable non-municipal wastes. The basis for these different figures is unclear, but it may simply relate to scope of wastes being reported upon by MITECO and by RED Eléctrica.

Table 14: National balance for electrical energy

	Peninsular System		Non-peninsular Systems		National Total	
	GWh	%21/20	GWh	%21/20	GWh	%21/20
Hydro	29.592	-3,4	3	-12,6	29.595	-3,4
Hydro-wind	-	-	23	18,2	23	18,2
Wind	59.184	10,0	1.312	18,9	60.496	10,2
Solar PV	20.504	37,4	451	19,4	20.954	36,9
Solar thermal	4.706	3,7	-	-	4.706	3,7

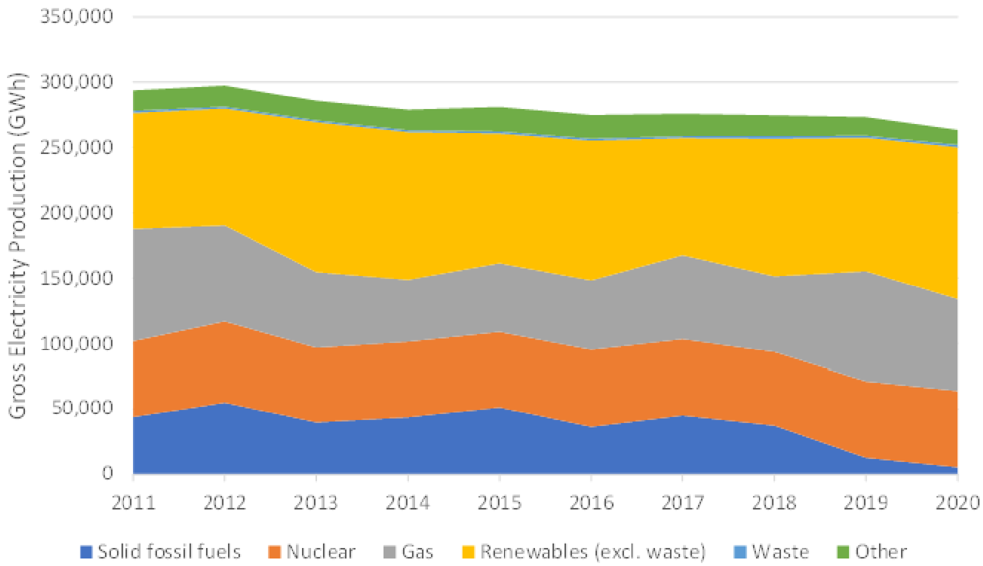
[40] MITECO (2020) *Memoria Anual de Generación y Gestión de Residuos: Residuos de Competencia Municipal. 2019,* www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/publicaciones/memoriaanual2019generacionygestionresiduosrescompetenciamunicipal_tcm30-534462.pdf

	Peninsular System		Non-peninsular Systems		National Total	
	GWh	%21/20	GWh	%21/20	GWh	%21/20
Other renewables	4.709	5,3	10	-1,9	4.719	5,3
Renewable wastes	*751*	*23,9*	*127*	*6,3*	*878*	*21,0*
Renewable Generation	**119.445**	**9,6**	**1.926**	**17,9**	**121.371**	**9,7**
Turbine pumping system (3)	2.649	-3,7	-	-	2.649	-3,7
Nuclear	54.041	-3,1	-	-	54.041	-3,1
Coal	4.941	3,0	45	-79,9	4.986	-0,7
Fuel/gas	0	-	4.049	-3,4	4.049	-3,4
Combined Cycle	37.581	-2,0	6.912	22,0	44.493	1,1
Cogeneration	26.036	-3,6	41	22,2	26.078	-3,5
Non-renewable wastes	*2.110*	*11,3*	*127*	*6,3*	*2.238*	*11,0*
Non-renewable generation	**127.359**	**-2,5**	**11.175**	**9,2**	**138.534**	**-1,6**
Distribution losses	-4.318	-6,7	-	-	-4.318	-6,7
Peninsula-Balearic Islands link (6)	-890	-37,6	890	-37,6	0	-
Balance of International Exchanges	895	-72,7	-	-	895	-72,7
Demand	**242.492**	**2,4**	**13.991**	**5,2**	**256.482**	**2,6**

Source: RED ELÉCTRICA (2022) El Sistema eléctrico español, Sistema eléctrico 2021, 8th April 2022, www.sistemaelectrico-ree.es/sites/default/files/2022-08/InformeSistemaElectrico_2021.pdf

If one takes the figures reported to Eurostat, waste accounts for 0.7% of electricity generated. This figure increases to 1.2% if one uses the RED Eléctrica figures. The Spanish electricity system has more or less phased out solid fossil fuels over the past decade, the decline being particularly marked since 2017 (see Figure 26). Gas use has fluctuated significantly in recent years, potentially indicating a role for gas as a matching dispatchable source for the increasing amount of renewable generation, much of which is derived from variable sources, solar PV and wind. The contribution from waste has not changed greatly since 2018, having increased by around 12% from 2011 to 2018. It would be difficult to assign any major role to waste in displacing specific sources, though depending on interpretation of policy, that might include renewables.

Figure 26: Shares of fuels in gross electricity production in Spain

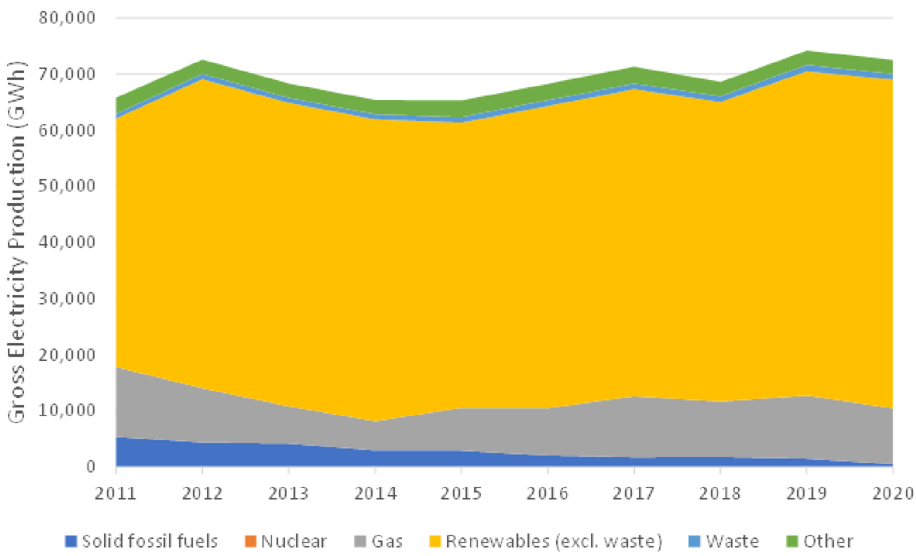


Source: *Eurostat energy balances*

Austria

In Austria, waste was responsible for 1.5% of gross electricity production in 2020. More than 80% of gross production was derived from renewables, with gas responsible for a fluctuating share over the past decade (Figure 27). Solid fossil fuels have been phased out steadily during the past decade so that their share is now minimal.

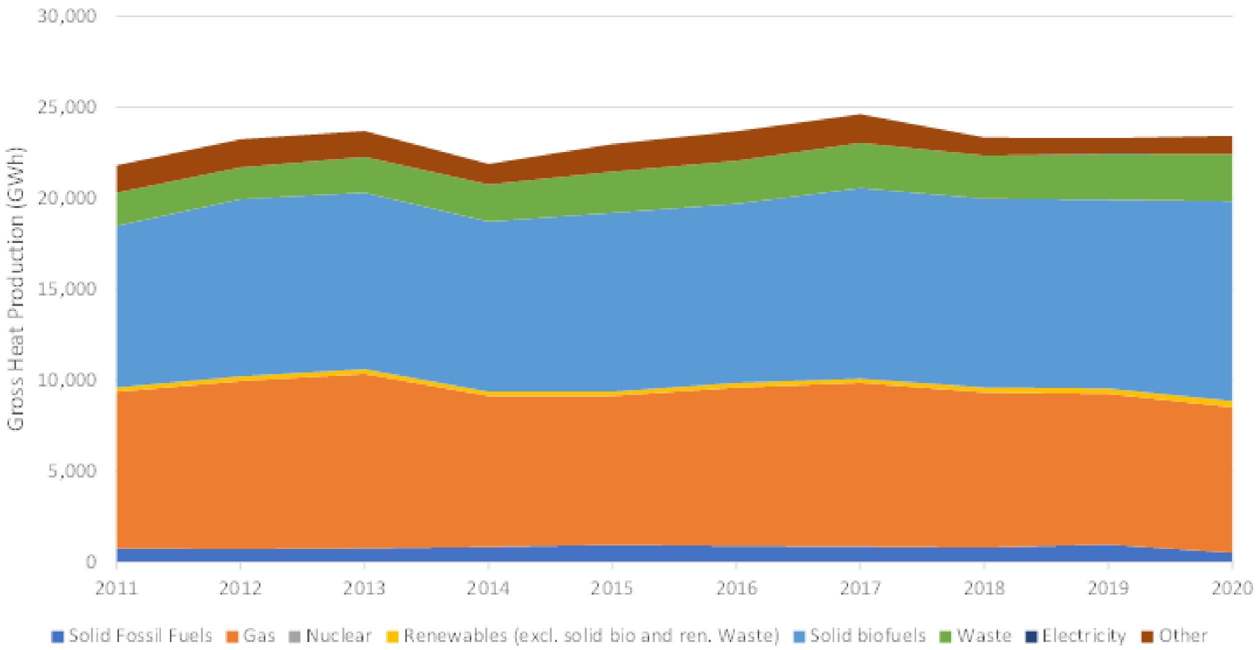
Figure 27: Shares of fuels in gross electricity production in Austria



Source: *Eurostat energy balances*

Waste was responsible for 11% of gross derived heat generation in 2020. The absolute contribution has increased by around 40% between 2011-2020, this increase representing around 3% of the total gross derived heat production (Figure 28). More than 80% of gross production was derived from a combination of gas and solid biofuels, with the former declining slightly over the period, and the latter increasing by a somewhat greater amount. Solid fossil fuels play a marginal role, though this has been more constant over time than in the case of electricity.

Figure 28: Shares of fuels in gross derived heat generation in Austria

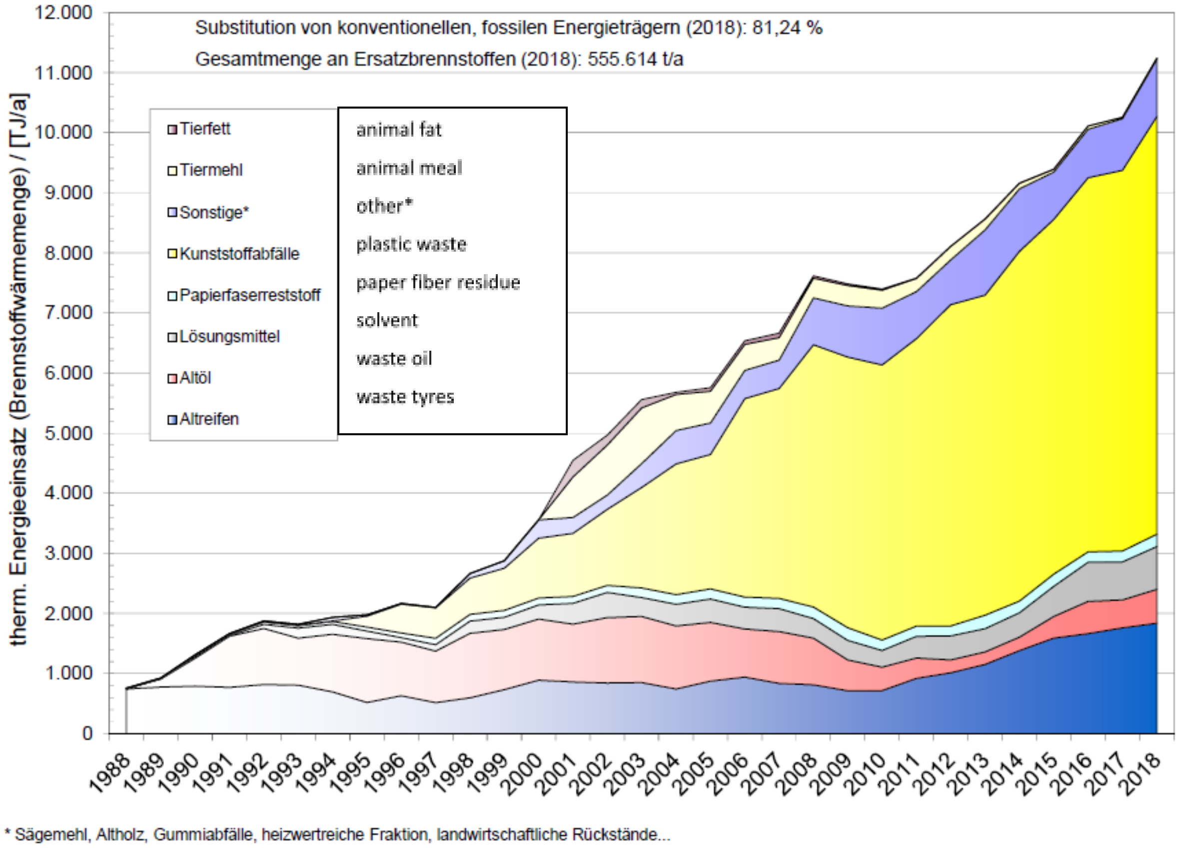


Source: *Eurostat energy balances*

There is some interesting insight from a paper by Mauschitz regarding the alternative fuels used to displace conventional fossil fuels at cement kilns in Austria.[41] The paper shows the development of the use of alternative fuels used over the period 1988 to 2018, with a breakdown by the nature of the fuels displacing the conventional fuels (see Figure 29). A fairly telling observation is that the main alternative fuel source is waste plastics, with the second highest contribution coming from waste tyres. Together, these fossil-derived fuels account for around 80% of alternative fuels. The next largest category is 'other', which includes high calorific fractions, likely from MBT facilities, with appreciable fossil carbon content. The switch away from conventional fossil fuels appears to be being made through reliance on high calorific, mainly high fossil carbon, wastes.

[41] Gerd Mauschitz (2019) *Emissionen aus Anlagen der österreichischen Zementindustrie Berichtsjahr 2018*, May 2019.

Figure 29: Fuel heat quantities from the combustion of substitute fuels in Austrian cement facilities (excluding grinding / milling facilities) in the observation period 1988 to 2018



** Other = Sawdust, waste wood, rubber waste, high calorific fraction, agricultural residues*

Source: Gerd Mauschitz (2019) Emissionen aus Anlagen der österreichischen Zementindustrie Berichtsjahr 2018, May 2019

Denmark

The Danish Energy Agency indicates that in 2020, non-renewable waste contributed 16 PJ and renewable waste 20 PJ to total energy production. 6,184 TJ of electricity (gross) was produced using waste, of which 3,401 TJ was renewable. 30,156 TJ of derived heat was produced (gross) using waste, of which 16,476 TJ was considered renewable.[42]

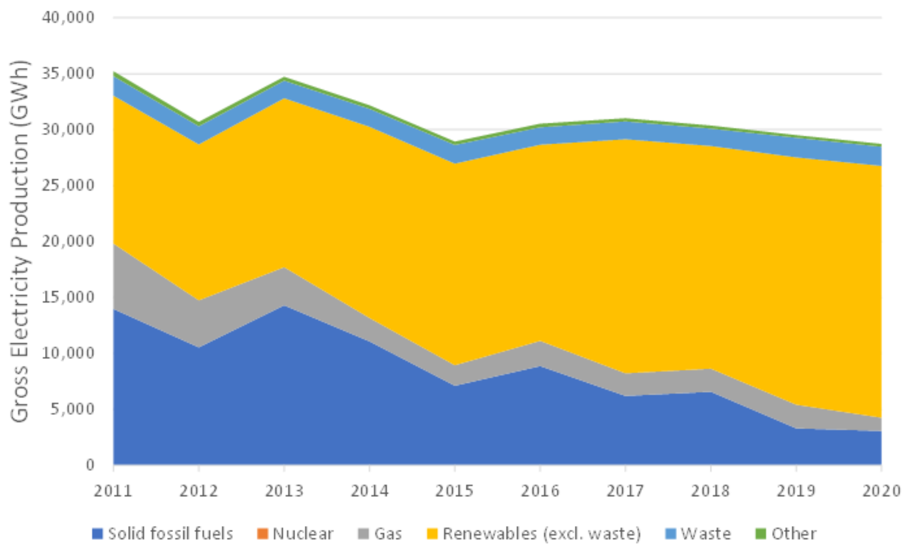
The share of waste in Danish electricity generation is the highest of any country in 2020 (only Luxembourg, Lithuania and Netherlands have shares above 3%). Its share is increasing partly because although its contribution has remained more or less constant over the last decade, domestic electricity generation (and energy production more generally[43]) has been falling (see Figure 30). Gas and solid fossil fuels have declined steadily over the last decade, and non-waste renewables had increased their share to 78% of gross electricity production by 2020. Part of the reason for declining

[42] Danish Energy Agency (2022) *Energy Statistics 2020: Data, Tables, Statistics and Maps*, March 2022, ens.dk/sites/ens.dk/files/Statistik/energy_in_denmark_2020.pdf

[43] Energy production in Denmark fell from 1,165 PJ in 2000 to 979 PJ in 2010, to 398 TJ in 2020 (Danish Energy Agency (2022) *Energy Statistics 2020: Data, Tables, Statistics and Maps*, March 2022, ens.dk/sites/ens.dk/files/Statistik/energy_in_denmark_2020.pdf

electricity (and energy) production is explained by the situation of Denmark in relation to the Nordic Electricity Exchange, Nord Pool, the effect of which is felt through price trends that have, in turn, been significantly influenced by precipitation in Norway and Sweden, which affects generation of electricity through hydro sources.

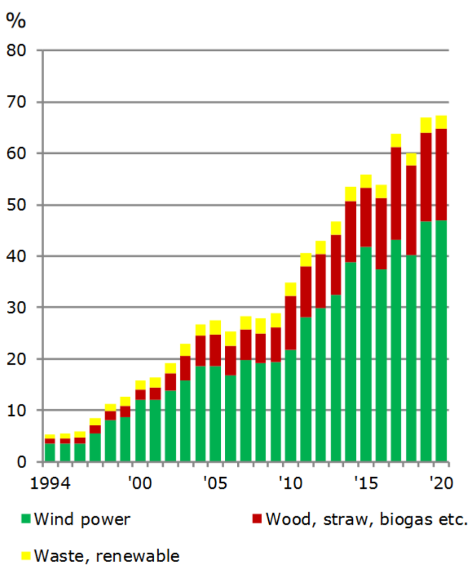
Figure 30: Shares of fuels in gross electricity production in Denmark



Source: Eurostat energy balances

Denmark's renewable electricity generation includes, as well as waste of renewable origin, both variable (wind) and dispatchable sources (see Figure 31).

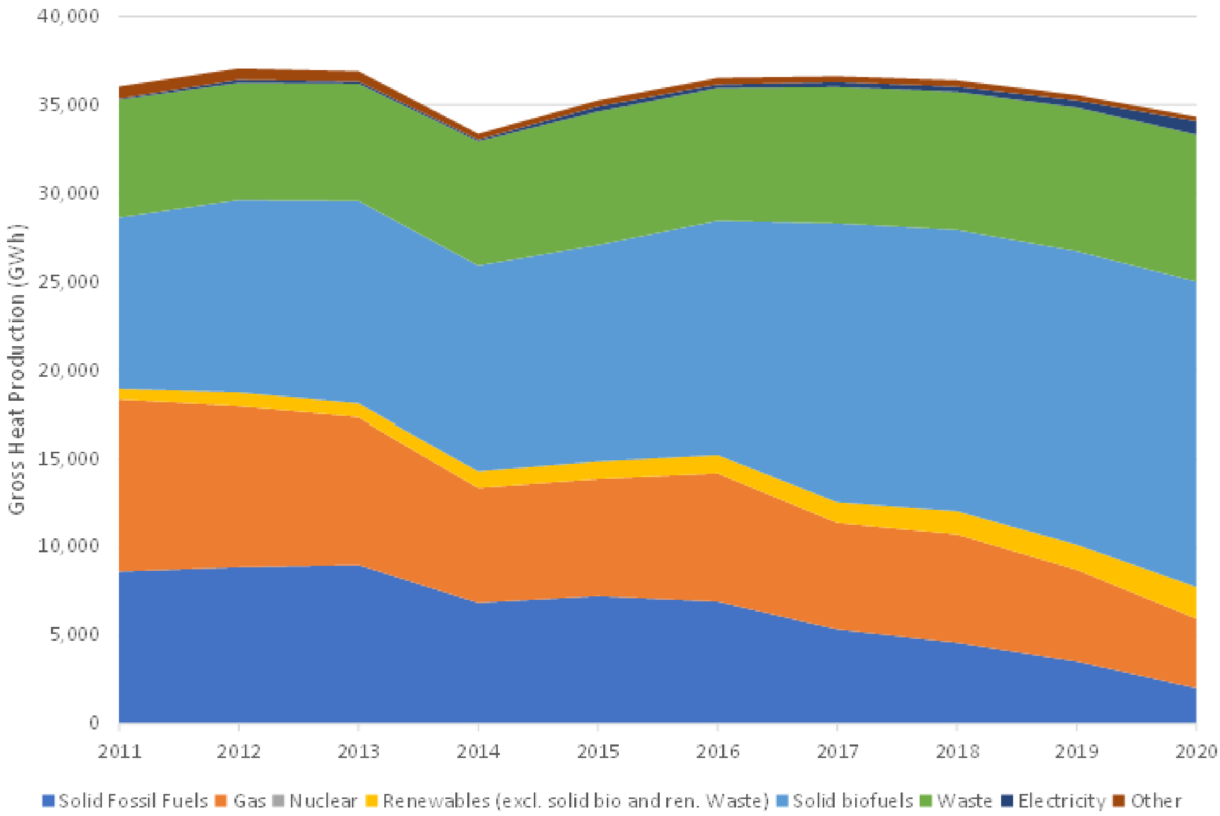
Figure 31: Sources of renewable electricity in Denmark



Source: Danish Energy Agency (2022) Energy Statistics 2020: Data, Tables, Statistics and Maps, March 2022, [*ens.dk/sites/ens.dk/files/Statistik/energy_in_denmark_2020.pdf*](ens.dk/sites/ens.dk/files/Statistik/energy_in_denmark_2020.pdf)

As regards heat, waste accounted for 24% of gross derived heat production accounts in 2020, with its absolute contribution increasing by 24% between 2011 and 2020 (see Figure 32). Over the same period, solid fossil fuels and gas have declined in use by 77% and 59%, respectively, with their combined share now standing at 17%. Solid biofuels have made significant strides over the period, their use increasing by 78% so that they now account for half of gross derived heat generation.

Figure 32: Shares of fuels in gross derived heat generation in Denmark



Source: Eurostat energy balances

Denmark is known to have been, like Sweden, an early adopter of the use of incineration as a source of energy. It is tempting to consider, therefore, that waste has displaced fossil fuels in district heating schemes. In the years 1994, 2000 and 2010, the contribution from gas and coal remained constant, though the share of gas increased relative to coal. Non-waste renewables increased their contribution faster than gas. In this context, the increase in the contribution from waste (13 PJ) was significant, but smaller than the increase from gas (20 PJ) and non-waste renewables (28 PJ).

Table 15: Fuels Used in district heating systems in Denmark in selected years 1994-2020

[PJ]	1994	2000	2010	2020
Total gross production	113	120	150	128
Oil	6	4	5	1
Natural gas	25	42	45	12
Coal	56	39	36	7
Surplus heat	3	4	3	5

[PJ]	1994	2000	2010	2020
Electricity	0	0	0	3
Waste, non-renewable	6	9	11	13
Renewable energy	17	22	51	87
- Straw	4	6	12	12
- Wood	4	5	24	50
- Waste, renewable	7	11	13	16
- Other	1	1	3	8

Source: Danish Energy Agency (2022) Energy Statistics 2020: Data, Tables, Statistics and Maps, March 2022, ens.dk/sites/ens.dk/files/Statistik/energy_in_denmark_2020.pdf

Member state-specific calculations

Previously, we estimated the impact of energy generation from waste on gas consumption under two assumptions. The second of these, using the average mix approach, was based on EU27 averages. In this Section, we make member state specific calculations, the first based on average mix, the second, based on estimating the marginal sources of electricity and derived heat based on historical data. Each of these has its limitations, but the analysis sheds further light on considerations which need to be taken into account in positing a sensible counterfactual, which can help inform what sources are displaced by electricity and heat generated from incineration in the different contexts.

Average mix, member state-specific

In this approach, we have followed the same approach as set out in section X above, but applied at the level of each member state, before aggregating to an EU27 impact on gas consumption. The results for electricity and heat are shown in Table 16 and Table 17, respectively. They indicate similar shares (perhaps unsurprisingly, given that they run off averages) to those obtained at the aggregated level. However, they do provide some interesting insights when one compares, for example, the relative contributions made by different member states to, on the one hand, generation of energy from waste, and on the other, the amount of gas displaced (based on the assumption made).

In principle, if the objective was to displace gas, then it might best be done in member states where the ratio of their share of gas displacement to their share of generation was greatest, though this assumes spare capacity exists. We have highlighted those countries for which this ratio is greater than 1 in Tables 18 and 19. Belgium, Italy, Spain and the Netherlands are countries where the ratio is high, though spare capacity may not be significant: Belgium has had a moratorium on new incinerators in the past, whilst Netherlands has imported waste from elsewhere to make use of spare capacity. Other countries which have become significant importers of waste, such as Sweden, seem to be locations where the effect on gas consumption seems marginal (at least, as indicated using this method), though the bulk of energy from incineration in Sweden is delivered as heat.

The analysis in relation to heat is a little less satisfactory in that it effectively constrains the analysis to existing derived heat provision. Belgium, Italy and the Netherlands again feature, but other countries that feature, and have considerable incineration capacity, are Germany, France and Austria. These countries have a number of cogeneration facilities, and it may be the case that their deployment in heating is more effective in displacing gas than their deployment in electricity generation.

An overarching conclusion, however, is that whatever result is derived for displacement of gas through using a 'marginal mix' assumption at the EU27 level, that masks the fact that the majority of any displacement of gas that is deemed to occur using this assumption most likely takes place in a small number of member states. Because this assumption, however, is not appropriate for assessing the effect of new capacity, it carries weight only in respect of efficient utilisation of existing capacity.

Table 16: Avoided gas consumption based on average electricity mix in each member state

	Normalised Share of Gas in Electricity Mix	Gross Electricity from Waste (GWh)	Avoided Gas Consumption (TJ)
Belgium	30.9%	2,144	4,813
Bulgaria	5.6%	5	2
Czechia	8.4%	213	131
Denmark	4.4%	1,718	548
Germany	17.0%	12,405	15,374
Estonia	0.5%	149	5
Ireland	51.3%	625	2,331
Greece	39.9%	40	117
Spain	26.7%	1,751	3,397
France	6.7%	4,454	2,172
Croatia	25.7%	0	0
Italy	48.6%	4,732	16,712
Cyprus	0.0%	0	0
Latvia	36.2%	0	0
Lithuania	33.3%	206	499
Luxembourg	8.7%	115	73
Hungary	26.4%	408	785
Malta	85.9%	0	0
Netherlands	61.1%	4,061	18,038
Austria	13.9%	1,068	1,081
Poland	11.0%	678	542
Portugal	33.5%	582	1,420
Romania	16.9%	0	0
Slovenia	3.4%	11	3
Slovakia	12.4%	87	79
Finland	5.9%	963	412
Sweden	0.1%	3,190	14
Totals		39,607	68,545
Avoided gas as % EU consumption			0.45%

Source: Equanimator calculations based on data from Eurostat energy balances

Table 17: Avoided gas consumption based on average derived heat production mix in each member state

	Normalised Share of Gas in Derived Heat Mix	Gross Derived Heat from Waste (GWh)	Avoided Gas Consumption (TJ)
Belgium	92%	830	2,885
Bulgaria	60%	70	159
Czechia	32%	916	1,098
Denmark	15%	8,321	4,777

	Normalised Share of Gas in Derived Heat Mix	Gross Derived Heat from Waste (GWh)	Avoided Gas Consumption (TJ)
Germany	60%	20,563	46,385
Estonia	15%	325	186
Ireland			
Greece	10%	-	-
Spain			
France	52%	8,668	16,944
Croatia	71%	-	-
Italy	67%	3,118	7,944
Cyprus	0%	-	-
Latvia	45%	-	-
Lithuania	21%	589	464
Luxembourg	25%	22	21
Hungary	76%	485	1,402
Malta			
Netherlands	69%	3,750	9,841
Austria	38%	2,575	3,726
Poland	11%	1,656	671
Portugal	98%	-	-
Romania	74%	0	1
Slovenia	30%	40	46
Slovakia	51%	56	108
Finland	16%	3,675	2,195
Sweden	1%	14,957	515
Totals		70,616	99,368
Avoided gas as % EU consumption			0.65%

Source: Equanimator calculations based on data from Eurostat energy balances

Table 18: Share of avoided gas from waste-derived electricity expressed relative to share of gross electricity production from waste

	Contribution to gross electricity production from waste	Contribution to avoided gas	Ratio
Belgium	5%	7%	**1.30**
Bulgaria	0%	0%	0.24
Czechia	1%	0%	0.35
Denmark	4%	1%	0.18
Germany	31%	22%	0.72
Estonia	0%	0%	0.02
Ireland	2%	3%	**2.15**
Greece	0%	0%	**1.68**
Spain	4%	5%	**1.12**
France	11%	3%	0.28
Croatia	0%	0%	
Italy	12%	24%	**2.04**
Cyprus	0%	0%	

	Contribution to gross electricity production from waste	Contribution to avoided gas	Ratio
Latvia	0%	0%	
Lithuania	1%	1%	**1.40**
Luxembourg	0%	0%	0.36
Hungary	1%	1%	**1.11**
Malta	0%	0%	
Netherlands	10%	26%	**2.57**
Austria	3%	2%	0.59
Poland	2%	1%	0.46
Portugal	1%	2%	**1.41**
Romania	0%	0%	0.71
Slovenia	0%	0%	0.14
Slovakia	0%	0%	0.52
Finland	2%	1%	0.25
Sweden	8%	0%	0.00

Source: *Equanimator calculations based on data from Eurostat energy balances*

Table 19: Share of avoided gas from waste-derived heat expressed relative to share of derived heat produced from waste

	Contribution to derived heat generation	Contribution to avoided gas	Ratio
Belgium	1%	3%	**2.47**
Bulgaria	0%	0%	**1.62**
Czechia	1%	1%	0.85
Denmark	12%	5%	0.41
Germany	29%	47%	**1.60**
Estonia	0%	0%	0.41
Ireland	0%	0%	
Greece	0%	0%	
Spain	0%	0%	
France	12%	17%	**1.39**
Croatia	0%	0%	
Italy	4%	8%	**1.81**
Cyprus	0%	0%	
Latvia	0%	0%	
Lithuania	1%	0%	0.56
Luxembourg	0%	0%	0.69
Hungary	1%	1%	**2.05**
Malta	0%	0%	
Netherlands	5%	10%	**1.87**
Austria	4%	4%	**1.03**
Poland	2%	1%	0.29
Portugal	0%	0%	
Romania	0%	0%	**2.00**

	Contribution to derived heat generation	Contribution to avoided gas	Ratio
Slovenia	0%	0%	0.82
Slovakia	0%	0%	**1.37**
Finland	5%	2%	0.42
Sweden	21%	1%	0.02

Source: *Equanimator calculations based on data from Eurostat energy balances*

Marginal sources of capacity

Suppose, instead, that we sought to understand the effect of incineration facilities in terms of their impact on capacity. This is probably a less relevant question for providing an answer to the question 'what is the effect of existing capacity?', and more relevant to considerations of the impact of additional capacity. It might also be relevant if one was seeking to understand the potential implications of removing all incineration capacity, which some might argue is an appropriate way to phrase the counterfactual when seeking to understand what is the effect of existing facilities on gas consumption. That question, however, is not being asked at the aggregate level (it might be being asked in the case of specific installations, notably those coming towards the end of their life time).

In their paper on consequential LCA, Muñoz and Weidema suggest a way of estimating marginal source of capacity.[44] Following their approach, we have estimated this for each of the eleven countries which collectively account for more than 90% of all incineration in the EU. We did this by assessing what appears to be happening to capacity over the past ten years. The results are shown in Table 20 and Table 21.

These results indicate a smaller displacement of gas from electricity generation of 0.29% and from heat generation, of 0.42%. Under this approach, a similar group of member states (as are indicated by the 'EU average mix' analysis) are responsible for the majority of the gas displaced, though Germany's role is more prominent under this assumption where power is concerned (it is similarly dominant in respect of displacement by heat), and Finland appears more prominent in the displacement of gas by heat.

Summary

These analyses highlight that the member state specific analysis suggests that the effect on gas displacement may be heavily skewed towards a small number of member states. This does not simply reflect the relative share of the production of respective energy types (power and heat) because of the quantity incinerated. It also reflects the nature of the energy production in the member states concerned.

Nonetheless, the influence of Germany is particularly strong, and this is the case for heat under both assumptions, and for power under the marginal mix approach. Both power and heat in Italy, and electricity in the Netherlands and Belgium, are contributing higher shares to displacement than their generation, whilst in France, the net contribution is high, though lower than the share of energy generated.

The aggregated shares of total gas displacement are shown in Table 22 alongside the shares of all waste sent to R1 and D10 facilities. We have highlighted those contributions to gas displacement, as calculated under the different assumptions (we have combined the displacement from power and heat) from specific member states which are above their respective share of waste incinerated. Although crude, this gives some indication of different countries' impact on gas displacement. The most effective locations for displacement seem to be Germany, Italy, Netherlands, Belgium, Poland, and Finland. Although Denmark is highlighted, its contribution is made under the average mix assumption: under the marginal source assumption, there is no gas displaced, but as we note below, this assumption is likely more suitable for new facilities, not existing ones.

[44] I. Muñoz and B. P. Weidema (2021) *Example – Marginal Electricity in Denmark. Version: 2021-06-08.* www.consequential-lca.org

Table 20: Estimation of gas consumption avoided through gross electricity production from waste, 2020, marginal mix method

	Germany	France	Italy	Netherlands	Sweden	Belgium	Finland	Poland	Spain	Austria	Denmark
Solid fossil fuels	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Nuclear	0%	1%	0%	1%	2%	0%	18%	0%	16%	0%	0%
Gas	12%	12%	28%	35%	0%	23%	0%	44%	8%	2%	0%
Renewables (excl. waste)	87%	86%	72%	63%	98%	76%	82%	55%	76%	97%	100%
Waste											
Other	1%	0%	0%	0%	0%	1%	0%	1%	0%	1%	0%
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Electricity from waste	12,405	4,454	4,732	4,061	3,190	2,144	963	678	1,751	1,718	1,718
MS Share of Electricity (of analysed)	*33%*	*12%*	*13%*	*11%*	*8%*	*6%*	*3%*	*2%*	*5%*	*5%*	*5%*
Electricity from waste avoiding gas (GWh)	1,549	554	1,333	1,425	0	490	0	299	138	39	0
Electricity from waste avoiding gas (TJ)	5,575	1,995	4,800	5,131	0	1,765	0	1,075	495	140	0
MS share of avoided gas (of analysed)	*27%*	*10%*	*23%*	*24%*	*0%*	*8%*	*0%*	*5%*	*2%*	*1%*	*0%*
Gas use to produce equivalent elec. (TJ)	42,376										
Scaled to All EU27	44,385										
Total gas consumption EU (TJ)	15,170,927										
Displaced gas as share of EU27 use	**0.29%**										

Source: Equanimator, derived using data from Eurostat energy balances

Table 21: Estimation of gas consumption avoided through gross derived heat production from waste, 2020, marginal mix method

	Germany	France	Italy	Netherlands	Sweden	Belgium	Finland	Poland	Spain	Austria	Denmark
Solid Fossil Fuels	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Gas	42%	18%	73%	0%	0%	0%	55%	55%	0%	27%	0%
Nuclear	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Renewables (excl. solid bio and ren. waste)	45%	20%	4%	1%	7%	85%	6%	6%	0%	3%	14%
Solid biofuels	12%	62%	22%	99%	86%	15%	25%	25%	0%	70%	73%
Waste											
Electricity	0%	0%	0%	0%	7%	0%	0%	0%	0%	0%	13%
Other	1%	0%	0%	0%	0%	0%	14%	14%	0%	0%	0%
Derived heat from waste	20,563	8,668	3,118	3,750	14,957	830	3,675	1,656	0	2,575	8,321
MS share of derived heat (of analysed)	*30%*	*13%*	*5%*	*6%*	*22%*	*1%*	*5%*	*2%*	*0%*	*4%*	*12%*
Derived heat avoiding gas (GWh)	8,603	1,517	2,288	0	0	0	2,015	908	0	703	0
Derived heat avoiding gas (TJ)	30,969	5,462	8,236	0	0	0	7,254	3,269	0	2,530	0
MS share of avoided gas (of analysed)	*54%*	*9%*	*14%*	*0%*	*0%*	*0%*	*13%*	*6%*	*0%*	*4%*	*0%*
Gas use to produce equivalent heat. (TJ)	60,759										
Scaled to all EU27	62,993										
Total gas consumption EU (TJ)	15,170,927										
Displaced gas as share of EU27 use	**0.42%**										

Source: Equanimator, derived using data from Eurostat energy balances

Table 22: Member state share of gas displacement (electricity and heat) against share of total waste managed at R1 and D10 facilities

Member State	Share of Gas Displacement by Average Mix Method	Share of Gas Displacement by Marginal Mix Method	Share of Total waste sent for R1 and D10 Treatment
Belgium	5%	2%	5%
Bulgaria	0%		
Czechia	1%		
Denmark	3%	0%	2%
Germany	37%	46%	34%
Estonia	0%		
Ireland	1%		
Greece	0%		
Spain	2%	1%	3%
France	11%	9%	15%
Croatia	0%		
Italy	15%	17%	8%
Cyprus	0%		
Latvia	0%		
Lithuania	1%		
Luxembourg	0%		
Hungary	1%		
Malta	0%		
Netherlands	17%	7%	8%
Austria	3%	3%	4%
Poland	1%	6%	4%
Portugal	1%		
Romania	0%		
Slovenia	0%		
Slovakia	0%		
Finland	2%	9%	4%
Sweden	0%	0%	6%

Source: Equanimator, derived using data from Eurostat energy balances

Concluding remarks

In this study, we have considered four different approaches to understanding the role played by existing incineration in displacing gas use at the EU level. The results of these four methods are shown in Table 1 below:

The first scenario is not a realistic assumption to make but sets an upper bound for what could be considered, based on energy generated from waste. There are many reasons why this assumption would be unreasonable to make. It also helps provide a benchmark against which to understand the results under more realistic assumptions;

The EU average mix assumption might be suitable for use in high level analysis when no more detailed evidence is being sought. It obviously abstracts from member dtate specifics. It also suffers from the shortcomings of the approach based on the member state average mix assumption;

The member state average mix assumption is probably a reasonable proxy for understanding the impact of existing incineration facilities. However, it still suffers from the fact that it fails to take account of the role played in the way sources of supply are managed in grids and networks by electricity and heat produced from incineration. If, as seems to be the case in most countries, most incineration is a source of relatively continuous supply, then that ought to be accounted for in the analysis. Note also that 'average mix' in any given member state will change over time. For a given facility already in place, it might be more relevant to consider its role relative to the context when it was planned if the intention is to comprehend the role it has played over time. The consequences, at the margin, for use of different energy sources of building an incinerator are undoubtedly path dependent, but the impact it might reasonably have been expected to have at the time of its planning/construction would not necessarily have been foreseeable;

The marginal capacity assumption, as estimated here, relies on past data for its calculation. It ought to be the approach best suited to understanding the consequence of building new facilities (or, albeit with some modifications, for phasing out existing ones), but that would require a consideration of the future. As used here, it is backward looking. It provides a 'bridge' between the average mix assumption for existing facilities, and the marginal mix counterfactual as it might be construed when considering new capacity. Notably, it gives a lower value for displacement of gas than the MS average mix assumption. As estimated here, it is overly reliant on a quantitative assessment of the past, and the results will reflect the time period chosen. Looking forward, if (for example) the same approach was deployed in the period following a cessation of the war in Ukraine, some unusual results might be obtained if only short-term trends were used as the basis for understanding marginal capacity. A plausible post-war counterfactual should not be grounded on an approach which implicitly assumes that the war continues indefinitely, and if that assumption is being applied, then equally, it would make sense to move extremely quickly away from all fossil fuels (including for transport)..

Avoided gas consumption from incineration under different assumptions, and applicability of approaches

	Electricity	Gas	Comments re: applicability
Unrealistic Maximum Assumption – always gas	1.9%	1.8%	Never applicable – sets an upper bound to contextualise analysis
Simple Assumption – EU average mix	0.39%	0.73%	Only for 'quick and dirty' analysis of scale of impact of existing facilities - assumes averages irrespective of country-specific conditions
Simple Assumption – MS-specific average mix	0.45%	0.65%	Allows some member state-specific insight into effect of existing facilities. Can only give a snapshot of reality (no appreciation of dynamics) so cannot be applied over a facility's lifetime Drawbacks are its lack of distinction between 'firm' sources of energy heat, and sources whose role is magnified in times of peak demand.

	Electricity	Gas	Comments re: applicability
Marginal Capacity Assumption	0.29%	0.42%	Allows some member state-specific insight – more appropriate for new facilities Drawbacks are lack of distinction between 'firm' sources of energy/heat, and sources whose role is magnified in times of peak demand. Also, it is backward looking and sensitive to the chosen time-period. Takes insufficient account of recently announced/implemented firm policies

Source: Equanimator

Consideration of 'marginal capacity' for new facilities should consider the forecast change in capacity independent of any change in incineration capacity. This would be based on existing policy, but ought to discount objectives that are not supported by firm policy action. Evidently this implies a judgement regarding what is likely in future. To the extent that facilities are proposed by public sector bodies, the argument for taking government forecasts – where these have been made – as the baseline is relatively compelling. The type of quantitative approach conducted above for estimating the marginal source might then be adapted to reflect the recent past and the expected future development of power and heat generation.

Similarly, in the context where the decommissioning of a facility is being considered, once again, its effect could be considered against a similar counterfactual, but this time, taking into account the effect of removing power and heat generated by the incinerator on forecast changes in the generation mix.

As far as possible, this understanding should also reflect the evolution in the management of different sources, and how the power and heat generated by the incinerator feeds into the grid/network, and hence, what fuel sources can be said to be displaced.

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Zero Waste Europe, 2022

Zero Waste Europe is the European network of communities, local leaders, experts, and change agents working towards the elimination of waste in our society. We advocate for sustainable systems and the redesign of our relationship with resources, to accelerate a just transition towards zero waste for the benefit of people and the planet.

Zero Waste Europe gratefully acknowledges financial assistance from the European Union. The sole responsibility for the content of this material lies with Zero Waste Europe. It does not necessarily reflect the opinion of the funder mentioned above. The funder cannot be held responsible for any use that may be made of the information contained therein.