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Efficient District Heating and Cooling

Background report on accounting and reporting guidelines in the context of the Energy Efficiency and the Renewable Energy Directives

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Abstract

This is a background report designed to provide guidance on defining and accounting for efficient district heating and cooling networks under Article 14 of the Energy Efficiency Directive and Articles 23 and 24 of the Renewable Energy Directive. It also analyses the options for a future definition of efficient district heating and cooling that would support the net zero decarbonisation target of 2050.

1 Introduction

The objectives of this report are to explain the current definition on Efficient District Heating and Cooling, and to analyse the options for future definitions that can meet the decarbonisation targets from 2030 to 2050. Although, the current definition of Efficient District Heating and Cooling has supported the conversion to, or construction of, cleaner and more efficient district heating and cooling networks, it needs to be strengthened to meet future objectives.

We begin this report by presenting the definition of district heating and cooling and on efficient district heating and cooling as established in Article 2(41) of the Energy Efficiency Directive (EED) and referred to in Article 2(20) of the Renewable Energy Directive (RED II). As some Member States and stakeholders have expressed uncertainty about certain elements of the current definition, we recap existing guidance prepared by EUROSTAT and complement it with our own analysis. These areas include for instance, whether it is primary or gross net energy that should be counted in the definition, treatment of thermal losses, and cogeneration.

Taking into account the expected evolution of the energy sector until 2050, we propose an alternative definition of efficient district heating and cooling, in which we move from an energy efficiency criteria towards one with more focus on sustainability. It is analysed how the thresholds of waste heat and renewable energy sources gradually could increase over time to support the decarbonisation of the heating and cooling sector. The role of cogeneration is also analysed.

Finally, the EDHE tool is presented. It is an ad-hoc tool developed for the purpose of assessing efficient district heating and cooling networks under the existing legislation. The tool is available for use by Member States (MS), regions, municipalities, and district heating and cooling practitioners and operators.

Annex I includes examples of district heating and cooling and Annex II gives a short European overview of heat supply via district heating, along with future projections. Annex III provides information on carbon intensity factors for fuels that can provide heat via thermal networks. Lastly, Annex IV provides information on existing allocation methods for Combined Heat and Power (CHP) technologies.

The main elements of this study were presented at Concerted Action meetings related to the Energy Efficiency Directive on 14 October 2020, the Renewable Energy Directive on 27 October 2020, and at a dedicated stakeholder consultation on 26 May 2021. The comments received were incorporated as deemed appropriate.

2 Definition of the district and efficient district heating and cooling concepts

This chapter presents the current definitions for district heating and cooling systems and efficient district heating and cooling systems. Then the targets set for Efficient District Heating and Cooling (EDHC) under the recast RED II and the EED [1],[2] are reviewed.

2.1 Definitions

District heating and cooling

A coherent definition of district heating and cooling systems helps Member States (MS) account the share of heating and cooling supply from DHC in a consistent way. This definition has to clearly set the limits between district and individual energy supply solutions.

Based on the existing definition set out in Article 2(19) of the RED II (2018/2001) [1], 'district heating' or 'district cooling' means the distribution of thermal energy in the form of steam, hot water or chilled liquids, from a central or decentralised source of production through a network to multiple buildings or sites, for the use of space or process heating or cooling".

According to the reporting instructions for completing the district heating and cooling template, under Article 24(6) of the EED, and provided by EUROSTAT [3] , the thermal energy has to be:

— produced in another site(s) than the one where it is consumed;

— sold to at least two different customers who:

  - own/occupy multiple buildings or multiple sites.

Based on the above, it is important to clarify the concepts of buildings and sites:

— according to the Energy Performance of Buildings Directive (EPBD) Art 2(1), building means a roofed construction having walls, for which energy is used to condition the indoor climate;

— site refers to a defined space that includes buildings or any other facility involving an economic activity such as industrial processes or services[1].

The simplest distribution of thermal energy consists of a supply site providing thermal energy to two buildings located on another site, while the most complex includes multiple supply and demand sites. In Annex I, we present illustrative examples of different configurations of what is — and what is not — considered district heating and cooling thermal networks.

Efficient district heating and cooling

'Efficient district heating and cooling', as defined first in Article 2(41) of the EED, means a district heating or cooling system using at least 50% renewable energy, 50% waste heat, 75% cogenerated heat or 50% of a combination of such energy and heat.

These two definitions, on the district heating and cooling and the efficient district heating and cooling, are the basis for the accounting and reporting of the efficient district heating and cooling systems in the context of the EED (Article 14) and the RED II (Article 24(4)).

2.2 Targets for efficient DHC under the EED and RED II

Under Article 14 of the EED, MSs are required to carry out a comprehensive assessment of the efficiency potential in the heating and cooling sector, including efficient district heating and cooling every 5 years. Moreover, Article 15(7) of RED requires an assessment of the use of waste heat and

[1] Site is not defined in European legislation

cold, and of renewables in the heating and cooling sector. The identified economic technology solutions should then be realised by implementing strategies that include policies and measures to be adopted up to 2020 and 2030. The first national assessments were due by 31 December 2015. Following requirements laid down in Annex VIII and IX of EED defining the content and methodology, the focus of this first round of assessments in 2015 was on identifying potential for efficient cogeneration, waste heat, and efficient district heating and cooling. The second round of assessments were due in 2020. Compared to the assessments from 2015, the scope was broadened to include renewable heat and cold.

The assessments should be based on a cost-benefit analysis, which takes into consideration new or substantially refurbished energy generation and industrial installations.

Also, the RED, Article 24(4) encourages MSs to promote measures to increase the share of waste heat and renewable energy sources in district heating and cooling systems. By doing so, they contribute to increase the overall share of renewable energy for the entire heating and cooling sector — as required by Article 23(1) of that directive.

Specifically, under Article 24, Member States have to endeavour to facilitate the increase of the share of energy from renewable sources and from waste heat and cold in district heating and cooling (DHC) by at least one percentage point as an annual average calculated for the period 2021 to 2025 and for the period 2026 to 2030, starting in 2020, see Figure 1 as an exemplary case. This share should be expressed in terms of final energy consumption (FEC) in DHC. This provision, not only reinforces the role of efficient DHC, but also envisages its evolution to, ultimately, contribute to the decarbonisation of the heating and cooling sector.

Figure 1 Example evolution of the share of energy from RES and waste in DHC based on Article 24(4) RESII.

Source JRC, (2021)

It is worth highlighting that waste heat and cold streams, for the purposes of targets set in Article 23 and 24, cannot be counted towards the overall EU renewable target set under Article 3(1) of the recast RED. Furthermore, the use of waste heat and cold is optional, as MSs are allowed to choose only renewables to fulfil the target. However, in case a MS decide to use waste heat and cold, they must be able to count them in their average annual increase. Therefore, when discussing targets under Article 23 and 24, we refer to both renewable and waste heat and cold. In the case of Article 3(1), however, we should strictly consider renewable energy sources.

3 The Efficient District Heating and Cooling definition under the EED and REDII

In this section, we present the current definition of EDHC (Efficient District Heating and Cooling). We discuss its elements and how to interpret them.

3.1 The current EDHC definition

The current definition of EDHC aims to promote deployment renewables, waste heat, and cogeneration. To this end, the current definition includes the following elements:

— renewables;

— cogeneration;

— waste heat;

— combinations of the above.

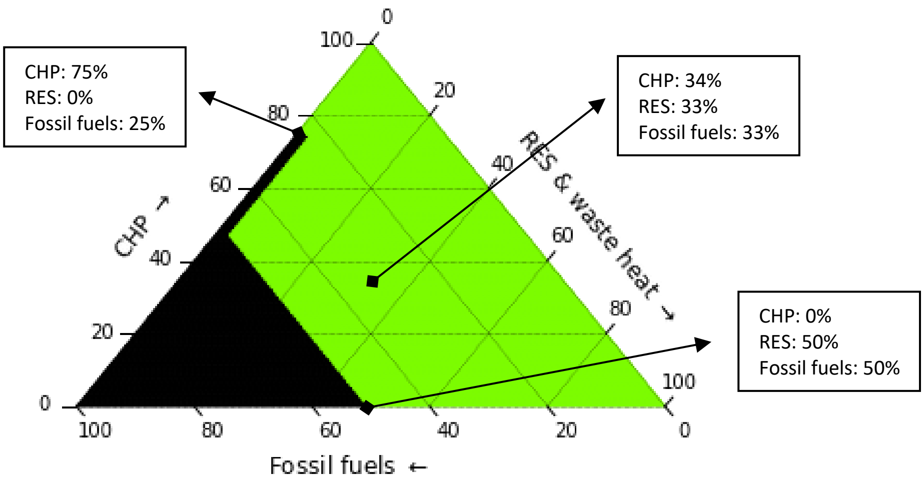
It sets minimum thresholds for the respective energy and heat inputs required for a thermal network to qualify as efficient. Thus, a thermal network fed with ≥50% renewable energy it is considered as efficient DHC. The same threshold applies for waste heat while for the case of cogenerated heat the threshold is 75%.

Current definition of Efficient District Heating and Cooling

'Efficient district heating and cooling', as defined first in Article 2(41) of the EED, means a district heating or cooling system using at least 50% renewable energy, 50% waste heat, 75% of cogenerated heat or 50% of a combination of such energy and heat'. [2]

In Figure 2, we present the area that qualifies as EDHC as a combination of fossil-fuelled CHP, RES & waste heat, and fossil fuels in the form of a ternary plot.

Figure 2 Interpretation of the definition in the form of a ternary plot. Green area shows the combinations that fall under the definition of efficient district heating and cooling.



Source: JRC, (2021)

In the follow sub-sections, you can find explanations about areas where either stakeholders or Member States have expressed that they need more clarity.

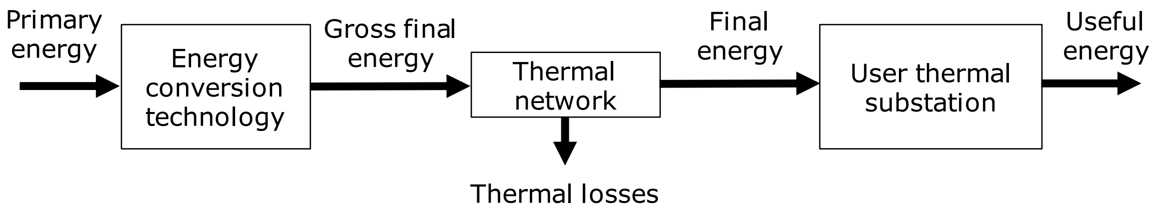
[2] Article 2(20) of REDII refers to Article 2(41) of EED for the definition of efficient district heating and cooling.

Energy and heat

The definition of EDHC requires accounting of energy flows instead of installed capacities. The EDHC definition refers to renewable *energy*, waste *heat*, and cogenerated *heat*. EUROSTAT clarified in the [3] that the definition shall be evaluated on the basis of the net heat output of each heat generation unit. The net heat output of each generation unit has to be set in relation to the total net heat provided to the district heating network. Hence, the 'efficiency' criteria refer to the average of all connected generation units, not to each generation unit itself. It should also not consider the primary energy consumption of the heat sources.

REDII Article 7(1) stipulates that to calculate the shares of renewable sources the gross final energy consumption shall be used. At the level of a thermal network that would similarly be the heat going into the thermal network, see Figure 3.

Figure 3 Nomenclature of energy flows in district heating and cooling networks.



Source: JRC, (2021)

From here on, we call the net heat provided to the network the gross final energy consumption.

Combination of thresholds

The fourth element of the definition concerns the combination of heat or energy from renewables, waste heat, and cogeneration. This should be understood as displayed in the ternary plot of Figure 2. Here the corresponding values for a portfolio or mixture of 3 elements indicate the allowed combinations with green colour. Each point in the plot corresponds to a unique combination of fossil-fuelled CHP, RES and waste heat, and fossil fuels.

Thermal losses

The concept of thermal losses is not considered in the current definition of EDHC. This is due to that the EDHC is evaluated at the heat/energy entry points to the thermal network, which is before distribution losses will occur.

Cogenerated heat

The current definition contains a threshold for all cogenerated heat. There are no restrictions concerning fuels, nor a threshold for the efficiency of cogeneration compared to individual production of heat and electricity.

Cogeneration using renewable fuels can either contribute to the threshold of 75% of cogenerated heat or to the 50% renewable energy threshold in order to comply with the efficient district heating definition. However, since double counting is not allowed, logically, one would choose to count it towards the renewable threshold as it is easier to reach.

Since the net heat output is counted, the various methods (mentioned in Annex IV) to allocate fuel consumption to heat or electricity production for cogeneration do not apply here[3].

[3] This would only be relevant if the EDHC definition used the primary energy consumption of the heat sources, which is not the case. The net heat output from each heat sources should be used.

3.2 Examples of Efficient District Heating and Cooling

Based on the current definition and following the clarifications above, in the following figures we present illustrative examples for each mode of efficient district heating and cooling. This is DH networks using at least:

— 75% cogenerated heat;

— 50% waste heat;

— 50% renewable energy;

— 50% of a combination of such energy and heat.

To show these alternatives of the current definition, we consider a district heating network that includes:

— four different energy conversion technologies (orange boxes):

  - condensing boiler that can run on either biogas or natural gas (dual boiler);
  - large-scale heat pumps (HP);
  - combined heat and power running on natural gas (CHP);
  - heat pumps (HP II).

— a waste heat stream (teal blue box);

— a gross final heat consumption (gross FEC) of 50 units of heat (red box).

In addition, we have assumed conversion factors as follows:

— boiler: 90%;

— heat pumps: 250%, i.e. seasonal performance factor of 2.5;

— CHP: 40% (for the heat production).

Based on these elements and assumptions, the different cases are presented.

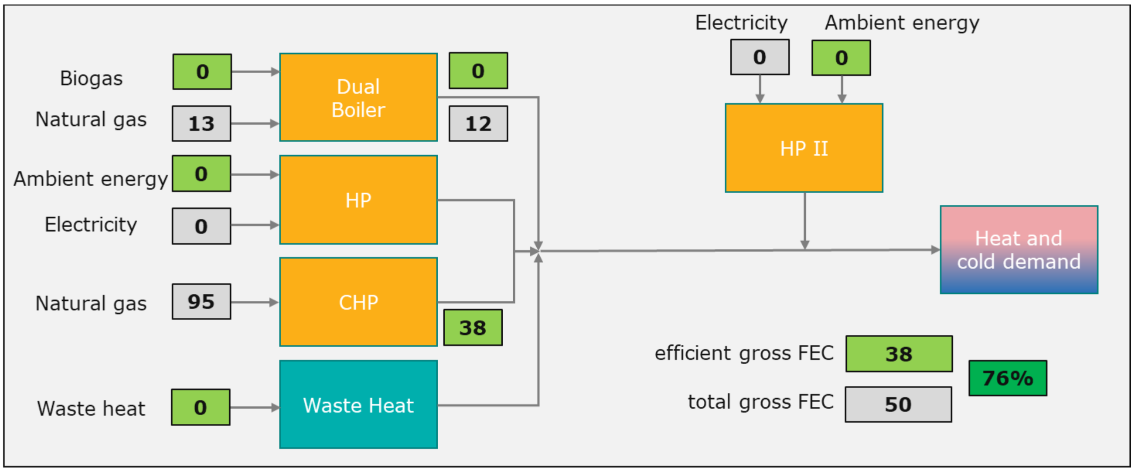
In the following DH illustrations, which represent examples of EDHC under the different modalities, the green squares indicates the amount of heat that can be accounted towards the EDHC thresholds while the grey ones cannot. In the case of technologies that can be fed either by RES or fossil fuels (i.e. dual boilers), the heat output is separated in a green and grey square depending on the input fuel.

With this in mind, the efficient gross FEC is the sum of all the green quantities and the total gross FEC is the sum of both green and grey quantities. The ration of these two quantities determines the compliance with the EDHC requirements.

75% cogenerated heat option (75%COGEN)

Up to 38 units of heat are supplied by the CHP, while the remaining 12 come from the dual boiler running on natural gas (Figure 4)

Figure 4 Example of efficient district heating which is above the 75% cogenerated heat threshold.

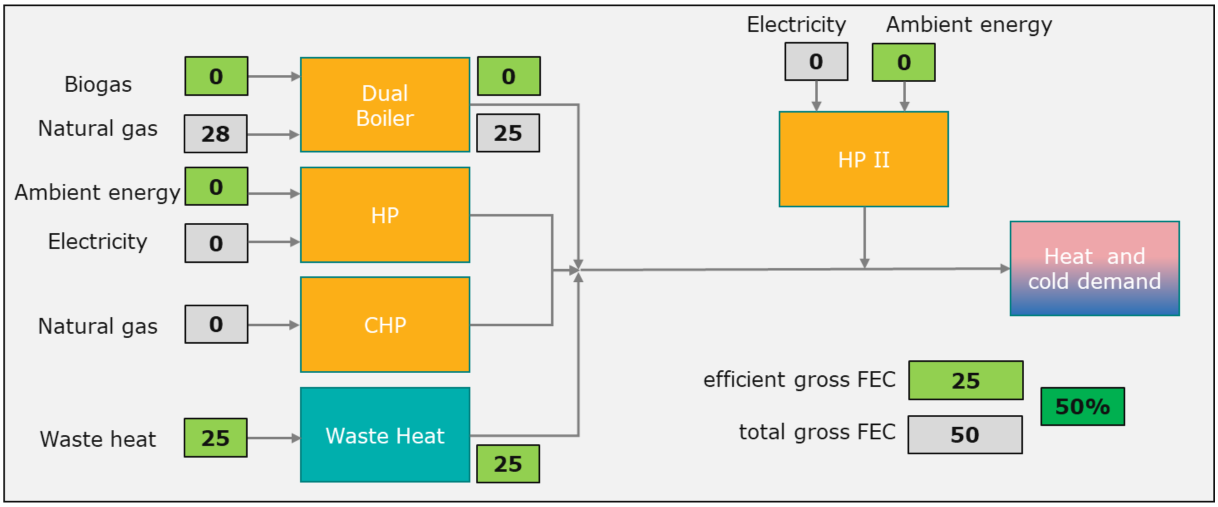


Source: JRC, (2021)

50% waste heat option (50%WASTE)

In this case, 25 units of heat are supplied from waste heat, while the remaining 25 are produced from natural gas in the dual boiler (Figure 5).

Figure 5 Example of today's efficient district heating under the 50% waste heat option.

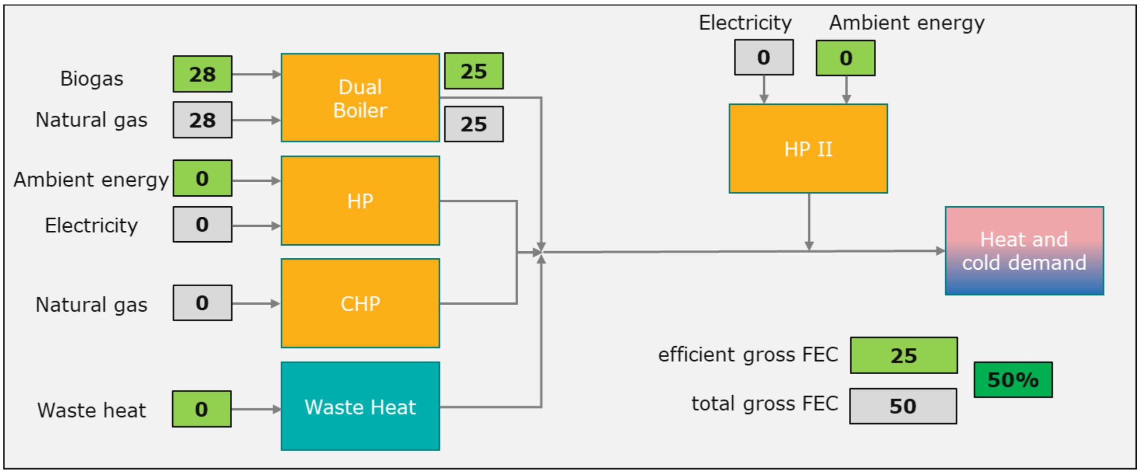


Source: JRC, (2021)

50% renewable option (50%RES)

For this case, the dual (co-firing) boiler provides all the energy required, running 50% on biogas and 50% on natural gas (Figure 6).

Figure 6 Example of today's efficient district heating under the 50% renewable option.

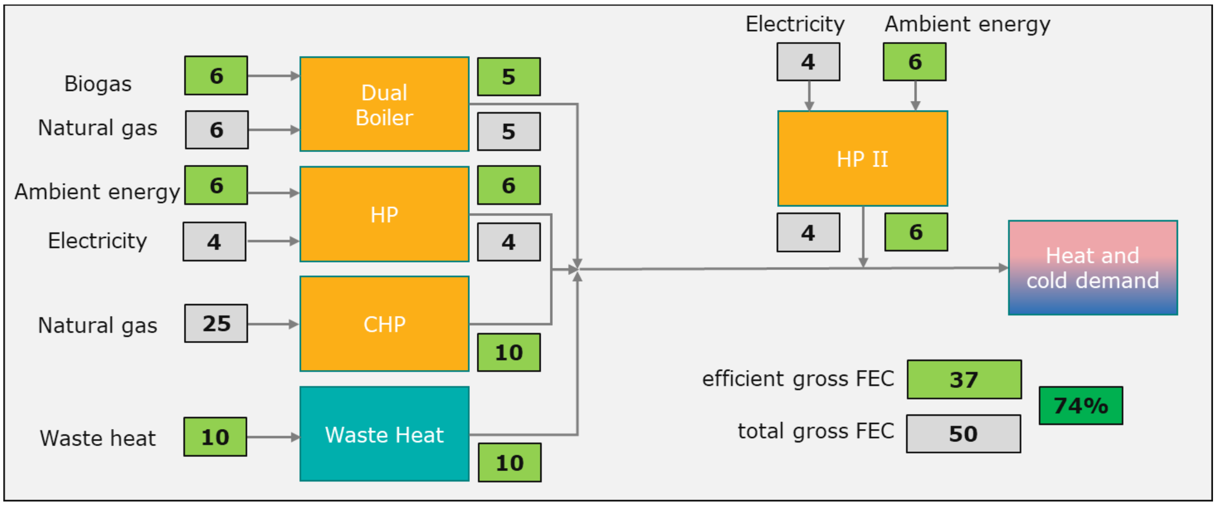


Source: JRC, (2021)

50% of a combination of such energy and heat (50%COMBI)

This is the most complex case as it combines multiple sources. Here, we have considered that all supply options provide 20% of the energy needs (10 units of heat) (Figure 7).

Figure 7 Example of today's efficient district heating under the 50 % of a combination of such energy and heat.



Source: JRC, (2021)

3.3 Discussion on the current EDHC definition

Above, we explain how the current definition should be understood. In this section we discuss areas of the current EDHC definition that could be further improved and strengthened to meet more ambitious energy policy goals. We focus on the four elements explained in Section 3.1.

The overall objective is that the definition of EDHC should contribute to increase:

— the energy efficiency of the DHC and the energy system as a whole;

— the use of renewable energy sources in DHC.

According to Article 7(1) of REDII and the EUROSTAT methodology that applies to statistical reporting it is the net heat output from the supply sources that should be counted for the purposes of the EDHC definition. Here we explore the possible alternatives or additions to that definition.

If the EDHC definition would be calculated from the primary energy used by the heat supply technologies, see Figure 3, a further breakdown of the fuel mix (natural gas, biofuels or others) would be needed to establish the production of secondary fuels (i.e. electricity, hydrogen or biofuels). Although possible, this allocation requires additional efforts to characterise a larger amount of transformations in the national energy sectors. In the case of CHP, accounting in PE terms can lead to different approaches and multiple interpretations, see Annex IV. The allocation of the input fuel into the two outputs (heat and power) can follow various approaches (i.e. proportional or exergetic allocation) that lead to a different heat accounting. As a result, for those secondary fuel-to-heat technologies the approach of either gross final or final energy terms is more suitable. For heat pumps, the electricity cannot be included in the calculation due that it would result in double counting.

From the discussion, it is clear that to make energy flows comparable and avoid the potential conflicts presented before, the definition is better built on gross final energy terms as defined in Article 7(1) of the RED II. To make the current definition more explicit, an easy solution would be to remove 'energy' and keep only the term 'heat' or 'thermal energy' delivered to the network.

Thermal losses

As we presented before, thermal losses are not considered in the current definition of EDHC. This assumption is reasonable if the accounting is done in gross final energy. A consequence from this is that the current definition does not promote energy efficiency measures that reduce thermal losses from the distribution grid. The efficiency aspects comes from employing a CHP or using waste heat in the in the heat supply mix.

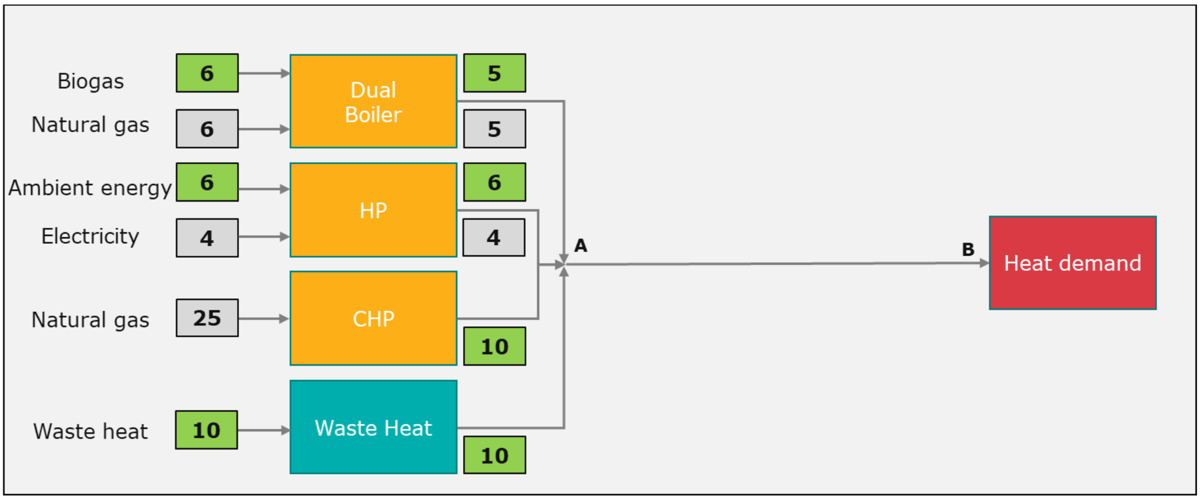
To provide a rough estimation on the impact of thermal losses, we performed an analysis using the information contained in national energy balances [4]. For the latest available year — 2018—, data show that losses in the EU, under the 'derived heat' category, is about 8%. It should be realised that statistics related to thermal losses contain significant uncertainties, and the losses from individual networks vary considerably. As a comparison, an international review from 2017 said that thermal losses varied from 5-35% [5]. As supply temperatures (4^{th} and 5^{th} generation) are gradually lowered and because of better insulated distribution grids, one can expect lower thermal losses.

Losses will play a role in future DHC. Given that the energy efficiency first principle is one of the guiding principles of EU energy policy, one could argue that thermal losses should be better monitored and their reduction promoted in future energy policy. The question is if one should introduce it in the EDHC definition or as a separate measure.

Two examples: The lower temperature requirement, allows to recycle heat from low-temperature waste heat and to use low temperature renewable energy sources, such as solar and geothermal heat. In some applications, when the temperature is not high enough, booster heat pumps are used to upgrade the heat quality (to reach higher temperatures) [7]. The place where the heat supply sources are located in the thermal network will also impact the total heat losses from the thermal network. The closer heat supply sources are to the demand, the lower the losses are. However, under the current EDCH calculation method, it depends only on the type of the technology whether and how the thresholds for meeting the efficient DHC definition are reached, and losses do not play a role.

As an illustration, we consider the application of losses at different heat supply points and the losses themselves can change the performance of a network under the EDHC definition. Figure 8 presents a simplification of an EDHC with a single supply point.

Figure 8 Example of an EDHC with a single supply point.



Source: JRC, (2021)

Based on the current definition the total generated heat (measured in units of heat) entering the network from RES, waste and cogenerated heat is 31;

— 5 from the biomass boiler;

— 6 from the heat pump;

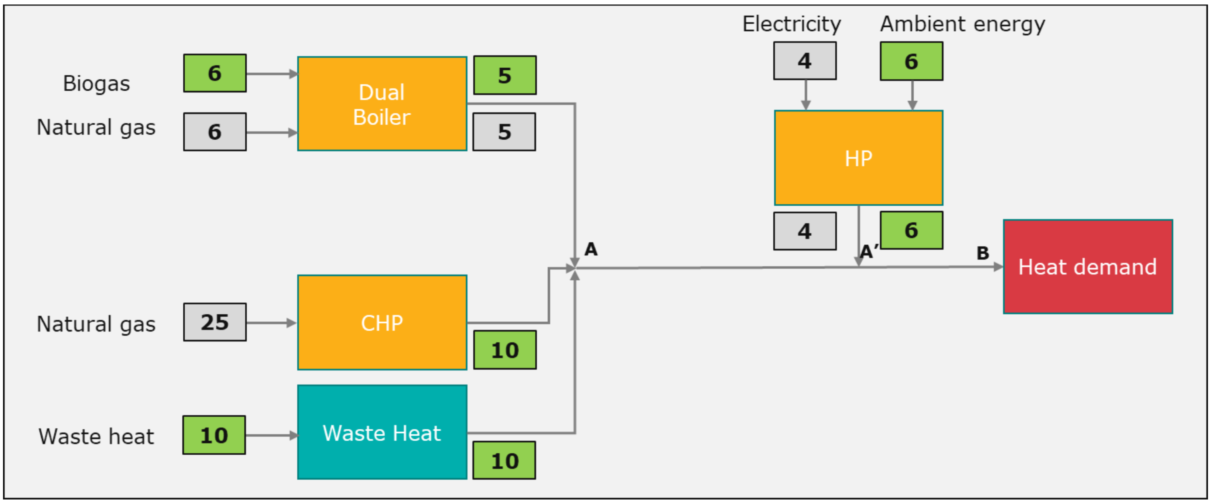
— 10 from the CHP and;

— 10 from a waste heat source.

while the total generated heat coming into the network is 40 (10 from the dual boiler, 10 from the heat pump, 10 from the CHP and 10 from waste heat). For this specific case, the ratio between efficient FEC and total FEC is 78% (31/40). When considering thermal distribution losses the result would have been the same since all losses affect all heat sources equally in this example.

However, if there are thermal generators that provide thermal energy at different points of the network, losses play a role in the calculation of the shares to qualify as EDHC. Following the previous example, but the heat pump is moved to a point closer (A') to the heat demand. For this new point A' we consider an energy loss of 10% (based on proximity to the end user), while for the point A is still 30% losses (Figure 9).

Figure 9 Example of an EDHC with multiple supply points.



Source: JRC, (2021)

Now the calculation of the fraction of energy supplied from RES, waste or cogeneration is as follows:

$$\text{Share}=\frac{(1\text{-}0.3)\cdot(5+10+10)+(1\text{-}0.1)\cdot 6}{(1\text{-}0.3)\cdot(10+10+10)+(1\text{-}0.1)\cdot(10)}=76.3\%$$

Both examples qualify as EDHC, but in the second example the share is reduced. Hence reduced thermal losses does not always increase the calculated fraction of RES, waste heat or cogeneration. It can be concluded that the EDHC definition as it is currently designed is not suitable to address the thermal losses in district heating and cooling networks.

Combined heat and power and combination of thresholds

The contribution of the cogenerated heat has implications for two thresholds: 75% cogenerated heat and the combination of thresholds of 50%. There are no conditions included in the definition concerning what kind of cogenerated heat could be counted in the 75% pure cogeneration or the 50% combination threshold as regards the type of fuel used or the level of primary energy savings achieved compared to separate production of electricity and heat. As a result, there is a possibility, although slight, that the heat produced neither contributes to greater efficiency nor increases the use of renewable energy sources.

In our view, since the EED already requires the application of high-efficiency cogeneration, as presented in Annex II of the EED, this should be required in the EDHC definition too. Annex II of EED stipulates that cogeneration should provide primary energy savings of at least 10% compared to the reference efficiency values of separate heat and electricity production. The >10% primary energy saving is the characteristics of high-efficiency cogeneration, and it to fulfil this high-efficiency criterion in the EDHC definition too.

In addition, the adequacy of including cogenerated heat from fossil fuels as part of the EDHC definition after 2030 is also questionable. As the energy system evolves towards its decarbonisation goals set for 2050, the condition to reach a certain primary energy saving (PES) from cogeneration will not be sufficient, since cogeneration fuelled by fossil fuels would still emit too much greenhouse gases. We elaborate more on this matter in Section 4.

Proposed near-term addition to the definition of Efficient District Heating and Cooling for the time period until 2030

In summary, we have tried to find a balance between short term improvements without changing the current definition too much. The current definition of EDHC clearly states the need of accounting energy flows over a given period (typically a year) and not available capacities. However, it does not clearly state whether the accounting is on GFE (gross final energy) or PE (primary energy) terms, so we propose to make the addition about thermal energy going into the network. Also, in order to guarantee that the cogenerated heat is produced efficiently, we propose to add that the cogenerated heat should qualify as high-efficiency following the definition of Annex II in EED.

Proposed revision of the current definition of Efficient District Heating and Cooling
'Efficient district heating and cooling', as defined first in Article 2(41) of the EED, means a district heating or cooling system using at least 50% renewable energy, 50% waste heat, 75% of **high-efficiency** cogenerated heat or 50% of a combination of such **thermal energy going into the network**'.

In the following chapter, we propose a new approach for the definition of EDHC based on climate neutrality targets — CO_2 evaluation. We provide methods and data to enhance such accounting.

4 A new definition of efficient district heating and cooling in a future context

As we introduced before, the current definition of efficient district heating and cooling aims to promote a cleaner and more efficient district heating and cooling sector in Europe. However, these two dimensions — clean and efficient — do not necessarily come together unless additional provisions are added to the current definition. In fact, the current definition of efficient district heating and cooling refers to energy sources, except indirectly for the case of CHP, rather than energy efficiency in the proper sense (ratio output to input).

This can be illustrated with an example. Let's assume that we have a district heating network supplied from a boiler (n_{cb} = 90%) running on natural gas. As a result of the input fuel, this network does not qualify as efficient. However, if the same network is supplied by a non-condensing boiler (n_{cb} = 85%) running on biomass, then, it qualifies as efficient district heating and cooling — 100% RES — despite the fact its conversion efficiency is lower than in the first case.

The different performances in terms of efficiencies and emissions make it clear that further provisions are needed to ensure that both dimensions are addressed, or if not both, which of the two should be prioritised and under which conditions. This becomes even more relevant in the context of a future decarbonised heating and cooling sector by 2050.

Coming back to the discussion in section 3.3, but focusing now on the future rather in the current definition of efficient district heating and cooling, four major elements require further elaboration. Those are:

- the conditions framing the use of cogenerated heat;
- the thermal losses coming intrinsically with the network;
- the need to introduce more RES in DHC systems in order to achieve full decarbonisation;
- the boundaries for the accounting.

While thermal losses impact the efficiency dimension, the case of heat from cogeneration — when running on fossil fuels — affects both dimensions in different ways: combined heat and power is increasing the efficiency, while still emitting CO_2 and thus decreasing the environmental performance, and even more so when compared to alternative renewable-based technologies, expected to have a larger use in the future heating and cooling sector.

Ultimately, all these elements pose the question of whether an evaluation in energy flows is sufficient or whether there is a need to add another indicator to assess the adequacy of DHC in future decarbonised systems in GHG emissions terms. Our new definition proposal builds on this second approach, i.e. to apply both an energy efficiency and a GHG emission indicator.

In the following, we first focus on the role of cogenerated heat. We use this case to explain why a GHG analysis (CO_2 evaluation) is needed in comparison with the one focusing on, solely, efficiency criteria. Next, and under the same approach, we discuss how different reporting conditions — in terms of either useful, final or primary energy terms — including the role of thermal losses, would modify the CO_2 performance of the DHC system. Last, we describe how the CO_2 thresholds could be applied based on the evolution of the energy system towards 2050 goals.

4.1 The use of cogenerated heat

Currently, the concept of efficient district heating and cooling is defined based on the shares of thermal energy produced from renewables, waste heat and combined heat and power (CHP). By definition, as we presented before, this can lead to a situation where associated efficiencies or emissions are not in line with future goals.

With full decarbonisation as a target by 2050, we will need more stringent criteria for future district heating and cooling. This, particularly, applies to cogeneration. CHP is using the primary energy of the fuel in an efficient way by delivering both heat and power. However, if a non-renewable fuel is used as input, situation that currently counts towards the fulfilment of EDHC requirements, it may lead to higher emissions compared to other renewable based technologies.

Therefore, the presence of CHP in the current definition of EDHC is based on its high efficiency compared to the separate production of heat and power. However, the definition is not seeking for high efficiencies, in its classical form, but rather on a cleaner heat production mix. These two aspects are not compatible in fossil-fuelled CHP. As a result, additional requirements or different approaches are required for the inclusion of fossil-fuelled CHP in the EDCH definition. Let's start looking into these two dimensions: efficiency and sustainability.

Fossil-fuelled CHP under the efficiency criteria

Today, cogeneration units, following Directive 2012/27/EU integrating and replacing DIRECTIVE 2004/8/EC [8], are considered high efficiency when they provide positive primary energy savings (Eq. 1) of at least 10% compared to producing the same amount of electricity and heat separately from the same fuels, without examining any other criteria. For this to happen, a given CHP has to perform, combining both heat and power generation, better than the corresponding reference efficiencies — these are average efficiencies for the separate production of both energy carriers (heat and electricity) in an energy system.

$$PES = 1 - \frac{1}{\frac{CHPH_n}{RefH_n}+\frac{CHPE_n}{RefE_n}} > 0.1 \tag{1}$$

where:

PES is primary energy savings

$CHPH_n$ is the heat efficiency of the cogeneration production defined as useful heat output divided by the fuel input used to produce the sum of useful heat output and electricity from cogeneration.

$CHPE_n$ is the electric efficiency of the cogeneration production defined as useful electricity output divided by the fuel input used to produce the sum of useful heat output and electricity from cogeneration.

$RefH_n$ is the efficiency reference value for the separate production of heat

$RefE_n$ is the efficiency reference value for the separate production of electricity

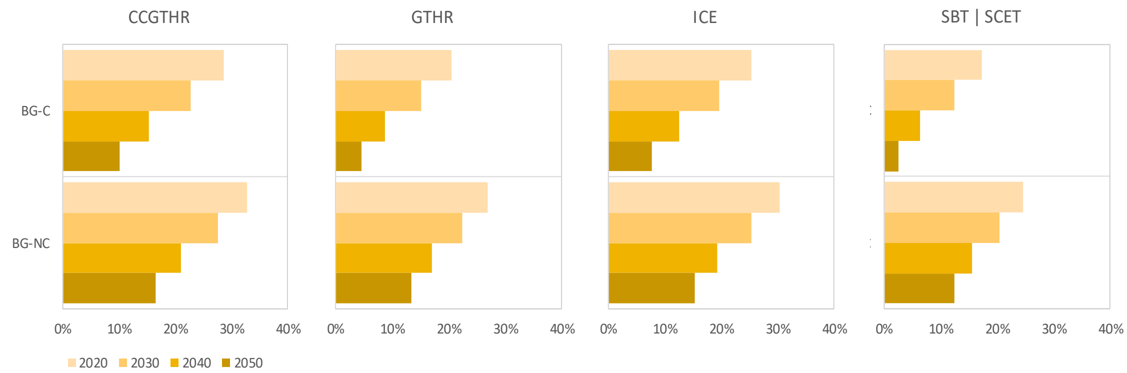
This definition is relevant today, but in the future energy system it gradually loses significance since other technologies become more efficient, e.g. wind electricity and heat pumps. In other words, if as expected the power and heat systems improve their efficiencies in the future, the CHP will have more and more difficulty to provide positive PES for the energy system as a whole.

To illustrate this, in Figure 10 we present the performance of different CHP technologies[4] — assuming a global efficiency[5] of 90% — in comparison with two gas-fuelled heating technologies (BG-C: gas boiler condensing and BG-NC: gas boiler non-condensing) for the period 2020-2050 over which the reference efficiencies for both the heat and electricity sectors are updated (Figure 11).

[4]

[5] Global efficiency in CHP is defined as the ratio of the sum of the heat and power production to the total input fuel

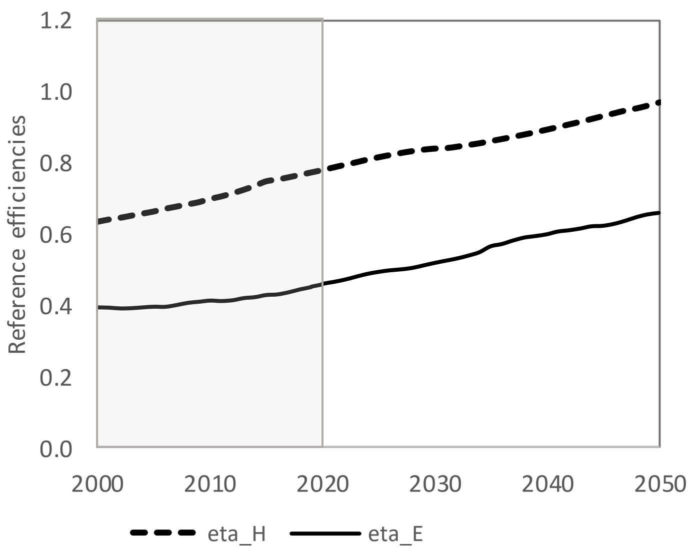
Figure 10 Primary energy saving for several CHP technologies[4] in comparison with heat supply options: BG-C: gas boiler condensing, BG-NC: gas boiler non-condensing. Note: global efficiency: 90%, power-to-heat ratios as defined in the Directive 2012/27/EU.



Source: JRC, (2021)

We observe that, today, CHP provides positive savings and will keep doing so until 2050. Here, we claim that for CHP to be considered clean — rather than efficient in its classical approach — an evaluation in terms of CO_2 emissions is needed. What is more, heat pumps are the expected future main competitor for the provision of heat. The high efficiency of these reduce the efficiency advantages of CHP.

Figure 11 Ratio of energy service to energy consumption for the EU heating (eta_H) and electricity (eta_E) sector. Note: eta_H is calculated as the weighted average of the residential and services sectors (Source: POTEnCIA [9])[6].

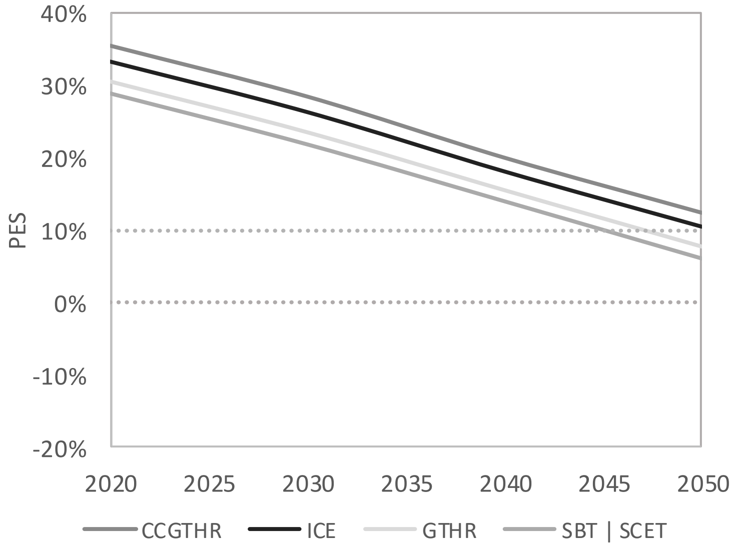


Source*: JRC, (2021)*

In Figure 12, we continue with the same approach, but here we compare the CHP to an average heating technology that reflects the evolution of efficiencies (dotted line in Figure 11) for the heating sector as a whole — defined as the ratio of the energy service to the energy consumption (RefHn in Eq. (1)). As observed, by 2045 none of them provide PES of 10% — all this assuming a high value for the global CHP efficiency.

[6] Both for electricity (as already considered in the previous figure) and heat, we observe a positive trend for the coming years. This is mainly caused by the penetration of renewable electricity (100% efficiency) and heat pumps (>250% efficiency) in the power and heating sector respectively. This positive trend means that the performance of the CHP has to increase accordingly in order to continue providing positive PES values. However, as we said before, this efficiency increase is technically limited (~90%).

Figure 12 Primary energy saving trend for several CHP technologies. Note: global efficiency: 90%, power-to-heat ratios as defined in the DIRECTIVE 2004/8/EC [8].



Source*: JRC, (2021)*

It is worth noting that our analysis of the primary energy savings provided by CHP is based on average reference efficiencies for both the power and the heat sector.

Regarding the power sector and based on its merit order effect, it is not possible to determine which generation unit will be replaced by CHP in the future years. This will depend in many factors, including the deployment of renewable capacity, power demand trends, etc.

In the case of heating the technology evolution of the coming years is also uncertain. An electrification trend is expected, which would increase the overall efficiency of the sector if largely based on heat pumps. Again, as for the case of the power sector, we cannot determine which heating technology would be displaced by CHP units.

Having said so, the main goal of our discussion about fossil-fuelled CHP is to highlight the fact that a single efficiency criteria is not sufficient under specific conditions to justify its inclusion under the EDHC. This does not undermine the benefits of fossil-fuelled CHPs, let alone RES-fuelled CHPs.

Fossil-fuelled CHP under the sustainable criteria

The CHP efficiency criteria alone does not imply similar performance in terms of CO_2 emissions when CHP is fuelled by fossil fuels[7]. The PES efficiency metric depends on the reference energy system under which CHP is assessed. This is usually a reference technology or an average technology based on the energy system characteristics as explained before. Let's assume that for a specific reference technology a fossil-fuelled CHP provides positive PES. After a while, the choice of the reference system may either increase its efficiency (as explained in the previous Section) or undergo a fuel shift to cleaner fuels (i.e. gas boiler to biomass boilers). This fuel shift alone would not affect their efficiency but substantially reduce their associated CO_2 emissions. Under this assumption, the fossil-fuelled CHP would still qualify as an efficient option — as efficiencies do not change. However, after the shift, the CHP associated CO_2 emissions may be higher than those of the reference system. Scenarios like this challenge the contribution of fossil-fuelled CHP to the decarbonisation of the energy supply.

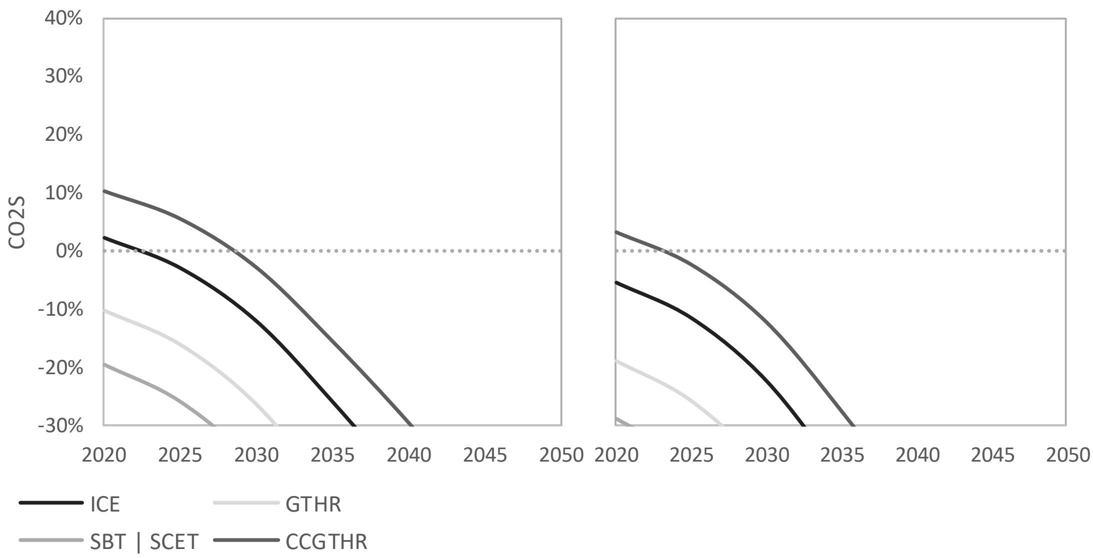
To illustrate the above, we define, analogously to the PES, the CO_2 emissions savings (CO_2S) (Eq. 2). In Figure 13, we present the performance in terms of CO_2S of the CHP technologies introduced in the

[7] RES-fuelled CHP is not included in the discussion around sustainable criteria. RES-fuelled CHP lies with the rest of RES options and in some applications providing better performances than those.

previous section when compared to condensing and non-condensing gas boilers and the expected evolution of the electricity emission factors until 2050. To calculate the CO_2S we have assumed an exergetic allocation of emissions (described in Annex 6B of the REDII). In ANNEX IV we present the two mainstream ways of allocating emissions (proportional or exergetic) from a single fuel to multiple energy products as in the case of cogeneration. In the rest of the report, when discussing about cogenerated heat, we will be using the exergetic allocation method (also described in REDII, Annex 6B) as it addresses more fairly the issue of power-heat equivalence.

$$CO2S = 1 - \left(\frac{CHP_{ef,h}+CHP_{ef,el}}{Ref_{ef,h}+Ref_{ef,el}}\right) \tag{2}$$

Figure 13 Primary energy saving trend for several CHP technologies. Note: global efficiency: 90%, power-to-heat ratios as defined in the DIRECTIVE 2004/8/EC [8].



Source*: JRC, (2021)*

As it can be observed, after 2030, the CO_2S is negative when compared with non-condensing gas boilers for every CHP technology considered. This happens even earlier — by 2025 — when condensing gas boilers are used for the comparison. When we look at the case of ICE, this option provides positive energy savings even in 2050 (Figure 10). However, it can barely provide positive CO_2S when compared to non-condensing gas boilers, and it is going negative after 2025.

This is the situation when we compare CHP technologies to the average existing technologies today — condensing and non-condensing gas boilers. But, the future deployment of more efficient heating technologies, i.e. heat pumps, can exacerbate this even more. This is that CO_2S will be even lower (more negative).

Under these conditions we are led to the need of sustainability criteria and accounting for the carbon intensity of the cogenerated heat when it is produced based on fossil fuels.

The CO_2 evaluation criteria in the context of Efficient District Heating and Cooling

The discussion around the CHP allowed us to introduce the need of moving to a CO_2 accounting when it comes to evaluating the adequacy of an energy generation option within a whole energy system. This also applies in the context of a district heating and cooling system. Indeed, as we stated at the beginning of the section, additional aspects require further considerations under this new CO_2 approach: boundaries for the accounting, thermal losses and the required minimum thresholds to qualify as EDHC.

Boundaries for the accounting

As discussed in Section 3, the current definition of EDHC implies an accounting in terms of gross final energy. However, if we move to a CO_2 evaluation this approach is not sufficient to determine the carbon intensity of DHC. The energy flows[8] involved in a DHC are:

— primary energy (PE);

— available primary energy for heat (APEH);

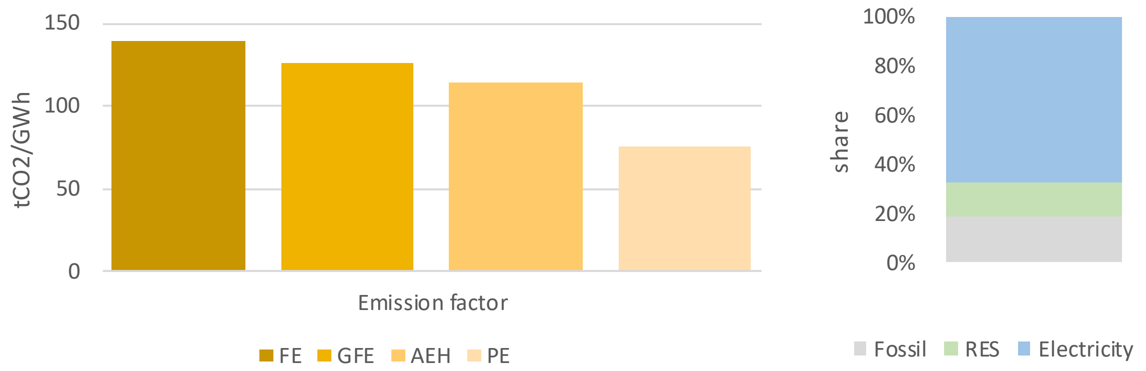
— gross final energy (GFE);

— final energy (FE) and;

— useful energy (UE).

The different options for the boundaries of the DHC will lead to different amounts of energy accounted and, thus, its carbon intensity — defined per unit of energy. From the previous list we exclude the useful energy as we treat heat as a commodity and not as a service. In the figure below, we present the different carbon intensity for the same DHC system depending on where we set the boundaries of our accounting (FE, GFE, APEH and PE). As it can be observed the broader the boundaries the bigger the energy amounts and as a result the smaller the carbon intensity. This is the result of larger amounts of energy due to transformation and associated inefficiencies that increases the denominator of the ratio emissions to energy.

Figure 14 Carbon intensity for different accounting boundaries (left) for a DHC with a given gross final heat (GFE) breakdown per input fuel (available primary energy for heat - APEH) (right).



Source: JRC, (2021)

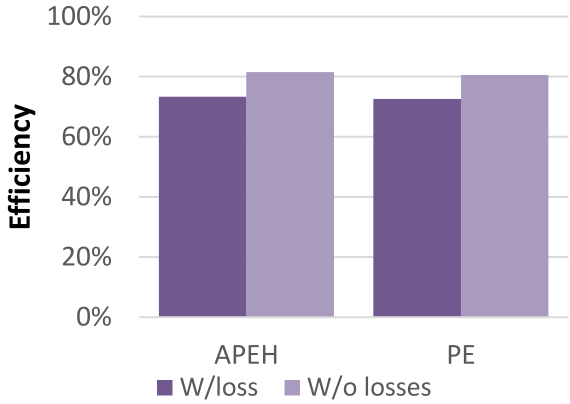
In order to cover a comprehensive CO_2 evaluation, we propose that the assessment has to cover from primary energy to final energy. In this way, transformations in the energy sector, i.e. greener generation, cleaner secondary fuels, etc., can be captured and reflected in the environmental performance of the DHC.

The role of thermal losses

The discussion about the boundaries ties directly with the role of thermal losses. As a key element for the evaluation of the efficiency of DHC, thermal losses have an impact on the efficiency of the DHC. In the example presented in Figure 14, we assumed that 10% of the gross final energy was lost through the network. Thermal losses reduce the efficiency of the system measured both in terms of gross final or primary energy (Figure 15). Still, in both examples presented, the conditions to qualify as efficient DHC are satisfied, as such eta, i.e. the proper.

[8] PE: Energy content of the input fuels before any transformation; APEH: Available energy content of fuels after all transformations into secondary fuels and right before their conversion into thermal energy; GFE: Thermal energy introduced in the network; FE: Available energy at the end user delivery point; UE: Thermal energy required by end users after all energy transformations.

Figure 15 Efficiency in terms of GFE and PE for the DHC systems presented in previous figure under two scenarios: 10% and no thermal losses.



Source: JRC, (2021)

With the need of incorporating thermal losses becoming clear, reality, however, is more complex when it comes to quantifying them. Normally, DHC networks provide energy to different users at different locations while the generators supply energy in different points across the network. As a result it is not easy to estimate losses in a thermal network unless the network operator provides real data.

For the current status of data collection on losses carried out by EUROSTAT, check Annex II.

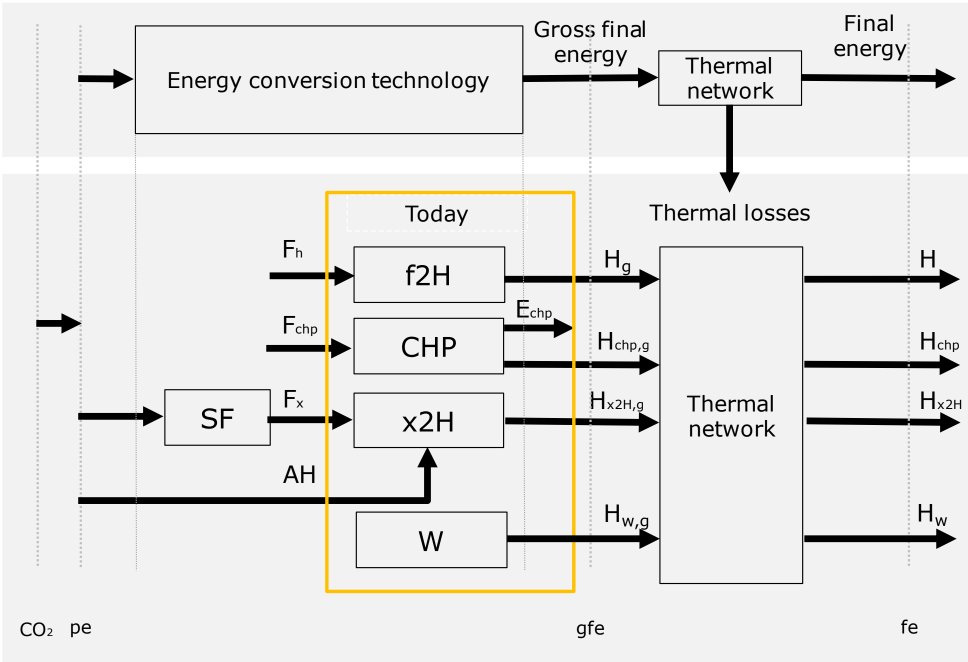
Moving from efficient to clean district heating

As we have discussed before, to determine the adequacy of a district heating and cooling system in a future decarbonised energy system, it is required to consider not only the technologies but also the fuels used. Fossil-fuelled cogenerated heat and thermal losses are not addressed under the current definition of efficient district heating and cooling and can be elements of those systems without any consideration or limits. This can make them difficult to address and ensure that the definition is future proof, i.e. only promotes DHC adapted to the future needs of a carbon neutral, decarbonised energy system.

Therefore, in line with the discussion above, what we propose is to establish adequate combinations of shares from renewable and waste heat, fossil-fuelled CHP, and fossil fuels in a thermal networks based on their carbon intensity and covering flows from final to primary energy,

In Figure 16, we present a detailed layout of this approach. In the upper part we present the basic energy flows involved. In the lower part we provide detailed elements that we find in such a system. Reading from the right, we first identify the different heat streams provided at the end user delivery point from different technology generations in the final energy layer (H: heat from fuel-to-heat technologies, Hchp: heat from CHP, Hx2H: heat from X-to-heat technologies, Hw: heat from waste heat sources). Then, moving to the gross final energy layer we can find the corresponding fuels before they enter the thermal network (H_g, $H_{chp,g}$, $H_{x2H,g}$, $H_{w,g}$). Moving on to the left, we find the conversion technologies (f2H: firing techs, CHP: combined heat and power, x2H: heat technologies fed by secondary fuels such as electricity or hydrogen, W: waste heat sources). At this point, to reach the primary energy layer we need the conversion of secondary fuels into primary fuels (SF block) (i.e. power generation mix per electricity unit). Last, once everything is converted into primary energy, we can allocate the CO_2 emissions of the system.

Figure 16 Scope of current approach (today) and proposed to determine the adequacy of a district heating and cooling system[9] (Acronyms: SF: secondary fuels, f2H: firing techs, W: waste heat sources, x2H: heat technologies fed by secondary fuels, CHP: combined heat and power).



Source: JRC, (2021)

In the energy policy context, qualifying as efficient district heating and cooling — today's approach — or as clean district heating and cooling — new approach proposed —, implies not only contributing to the national energy targets but also benefiting from supporting mechanisms in place (i.e. favourable financing packages). As a result, in the design phase of a district heating and/or cooling project, these policy-related aspects should be thoroughly assessed.

However, one should keep in mind that thermal networks are investments with a lifetime of at least 50 years. Along this period, it is highly probable that, following the energy policy trends, they have to comply with more stringent standards. Hence, at some point during its lifetime the network might not comply with such standards. For example, it may happen that the threshold for the share of RES increases from today's 50% up to 80% while the district heating and cooling was designed for a 50% share.

As a result of the above and given the long investment cycles associated to thermal networks, we suggest to evaluate the compliance with the energy policy in place every 5 years. In the cases where this evaluation shows that the system does not comply with the new requirements, we propose to submit a 10 years plan to converge to those requirements. By doing so, the system will retain its status as clean district heating and cooling for the 10 years period.

The above applies for existing district heating and cooling system. The new ones should always comply with the energy policy in place at the design phase.

4.2 Proposal for a new definition

Combination of thresholds

In this section we aim to make the definition suitable for the decarbonisation targets of 2030 and 2050. We aim for a new definition based on quantifiable sustainability criteria that can be easily updated in the future. To do so, we translate the current shares of input fuels (and technologies) into

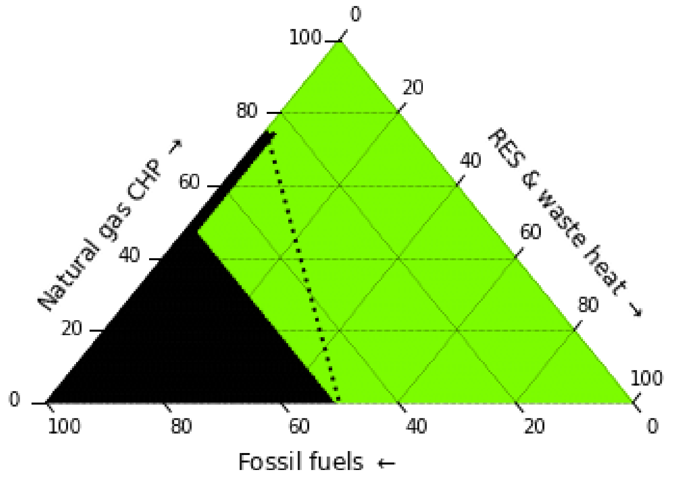
[9] Heat flows are replaced by corresponding cold flows in the case of district cooling.

associated CO_2 emissions, discuss what should be the maximum CO_2 emission thresholds for different scenarios and, then, translate those thresholds back into new shares of input fuels, leading to an updated definition. The CO_2 emissions approach has already been adopted in the Netherlands to evaluate the sustainability of thermal networks.

By doing so, we anticipate that the current definition based on shares of technologies is in a good direction to promote clean and efficient energy sources. However, some additional improvements are required.

To begin with, we recall the ternary plot (presented in Section 3.1) indicating the area (green) that complies with the current definition of efficient district heating and cooling. One problem that we already noted in the previous sections is that it includes some cases where there is inconsistency between the third and fourth clause of the definition that causes lower CHP shares to qualify for the definition as long as it is accompanied by a small fraction of Renewables. For example, 1% Renewables and 50% fossil-fuelled CHP qualifies as efficient DH under the last clause of the definition (50% combination of above) but not under the third clause (more than 75% cogeneration). This corresponds to the green area to the left of the dotted line (see Figure 17). To our view the dotted line corresponds better to the implied boundary in the current EDHC definition.

Figure 17 Current definition (green area) and implied boundary (dotted line).



Source*: JRC, (2021)*

For that reason and to have a stronger link with current and future policy trends, we will try to identify the proper boundary between efficient and non-efficient DH systems by defining a more robust boundary for the mid-term and for the long-term context.

First, we map the emission factors of all possible combinations for the technology families considered. We did that based on the following assumptions:

- waste heat and renewables are treated as the same category with an emission intensity of zero. This category also includes renewable fired cogeneration, ambient heat and biofuels[10].
- waste heat is considered as a carbon free heat stream under the assumption that it complies with the definition of waste heat provided in Article 2(9) of the REDII. Therefore, only the unavoidable heat or cold generated as a by-product which would be dissipated unused. In other words, no additional primary fuel has been consumed to provide the waste heat.
- biomass or other biofuels are considered as carbon free fuels if they comply with the sustainability and greenhouse gas emission savings criteria according to Article 29 of the REDII.

[10] if they comply with the sustainability and greenhouse gas emissions savings criteria according to Article 29 of the REDII

Even when complying with these criteria, biofuels show different emission factors depending on the type of fuel and the specific supply chain (i.e. distance between production and consumption sites). Still, we assume that the biofuels under consideration show limited emission factors (<20 gCO_2/kWh).

— cogenerated heat is extracted at lower temperature than the heat used for electricity production. It is evaluated based on the exergetic allocation method (see Annex IV as proposed in REDII Annex VI(6)). This implies that most of the emissions will be allocated to electricity due to its higher exergy/value/quality.

— gas fired solutions are considered for both cogeneration and fossil fuelled solution as one of the cleanest mainstream non-renewable fuels. Coal based solutions are excluded in the new definition.

— the renewable electricity input to power-to-heat technologies has not been considered. Thus, for heat pumps only the ambient heat is accounted as renewable.

— the emission factors are defined per unit of gross-final energy.

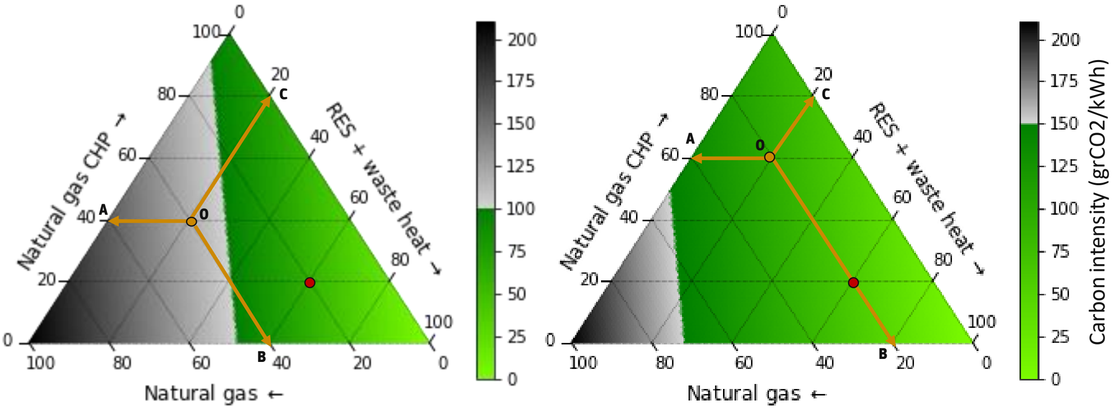
Next, we discuss the implications on the shares of technologies by setting different carbon intensity thresholds. The selection of one specific carbon intensity threshold determines all the possible combinations that lead to lower emissions (green area). The more stringent the threshold the smaller the area. Following this approach, a district heating and cooling system falling in the green area will qualify as a 'clean' one.

In Figure 18, we present the CO_2 intensity of all possible technology combinations and the implied boundary for two different carbon intensity thresholds: 100 (left) and 150 (right) $grCO_2$/kWh. These thresholds are chosen based on the current definition of EDHC that stands in between those (Figure 17). To construct the ternary plots we have assumed the following emission factors: for fossil fuels a factor of 220 $grCO_2$/kWh and for CHP a factor of 90 $grCO_2$/kWh following an exergetic allocation with a heat supply temperature of 60°C. As explained above, the emission factor of renewables and waste heat is assumed to be 0 $grCO_2$/kWh.

To better understand what the ternary plots represent, here we provide a detailed guide to read them via illustrative examples. Focusing on the right of Figure 18 — which represents the 150 $grCO_2$/kWh threshold —, each point depicts a combination of energy sources in a DHC network. These are natural gas, gas-fuelled CHP, and renewables and/or waste heat forming the triangle legs. The three vertexes represent the following: the top is 100% CHP, the bottom right 100% RES and the bottom left 100% natural gas. How to read the shares of these sources for any given point? Let's look at the orange highlighted point on the right side of Figure 18. Moving horizontally (line OA), we obtain the share of gas-fuelled CHP: 60%. Then, moving along the line OB, we get the share of fossil: 20%. The latter is typically a gas-fuelled boiler. To complete the ternary, we follow line OC, to reach 20% share of RES + waste heat. This combination lies within the green area which means that it qualifies for the 150 $grCO_2$/kWh threshold.

Following exactly the same procedure, we now read the orange highlighted point on the left of Figure 18 where the 100 $kgCO_2$/kWh is depicted. This point represents 20% RES+waste heat, 40% gas-fuelled CHP and 40% natural gas in a boiler. Under the 100 $kgCO_2$/kWh threshold, this point does not comply with the EDHC definition. However, if we check the highlighted red point in both left and right of Figure 18 — 60% RES+waste heat, 20% gas-fuelled CHP and 20% natural gas in a boiler — we observe that it qualifies as EDHC under both CO_2 criteria.

Figure 18 Evaluation of the clean (green) areas for different combination of energy sources shares in district heating and cooling systems. Two CO_2 thresholds are considered: 100 $gCO_2eq./kWh$ (left) and 150 $gCO_2eq./kWh$ (right).



Source: JRC, (2021)

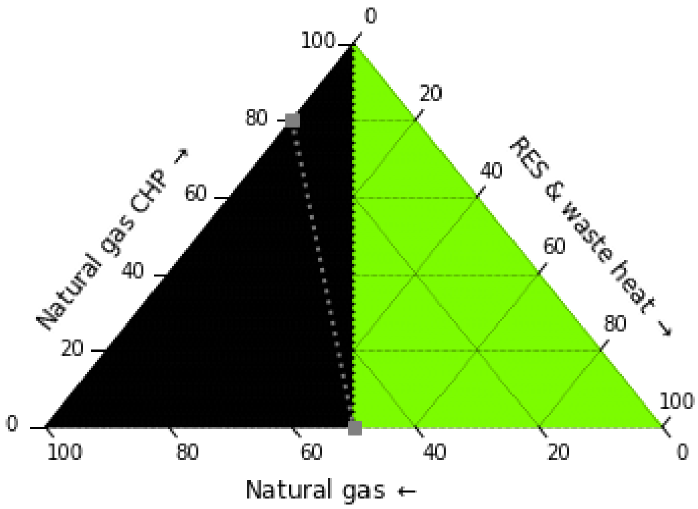
We mentioned before that the current definition is in a good direction to promote clean and efficient energy sources. If we compare the green area in Figure 18 (left) with the area to the left of the dotted line in Figure 18, they turn out to be relatively similar. This means that the current definition, if we exclude the green area to the left of the dotted line in Figure 18, is promoting solutions that perform in the order of 100 $grCO_2/kWh$ or below.

Having all the above in mind, and looking into two future milestones for the energy policy trend, 2030 and 2050 we propose to improve the clarity of the definition and also give both a mid-term and a long term perspective for efficient/clean district heating and cooling.

The EU aims to be climate-neutral by 2050 – an economy with net-zero greenhouse gas emissions. However, this does not mean that all technologies used will be at zero emissions, some will be more and some less. Clean DHC should be supporting these goals. That is why we are coming up with a new definition for EDHC. By 2030, we design a 'Efficient/clean' district heating and cooling definition having in mind a threshold of the order of 100$grCO_2/kWh$. A definition that respects that criteria can be formulated as follows: "A district heating or cooling system that uses always equal or more renewable energy technologies than fossil fuelled individual generation energy technologies".

To make it more clear and specific, this condition is graphically represented in Figure 19. As it can be observed, our proposal (green area) is slightly more restrictive than the 100 $gCO_2eq./kWh$ isoline (dotted line). The reason for that is setting the vertical line as boundary we simplify the wording of the new definition which also makes it easier to understand. Otherwise, analytical equations would be required. Given the assumptions above this line corresponds to combinations that have an emission intensity ranging between 95 – 105 gCO_2eq/kWh. This is acceptable for the sake of a clearer definition. Thus, starting from a threshold of 100 gCO_2eq/kWh, a periodic revision every five years signifying a decrease of 16.67 gCO_2eq/kWh for every 5 year period would allow reaching a net-zero threshold (0 gCO_2eq/kWh) in 2050. Strictly speaking, the proposed threshold decrease will eventually exclude biomass from the definition of EDHC at some point. This does not exclude biomass from being used in regular DHC, though. Even more, the use of sustainable biomass in EDHC by 2050 will be subject to the feasibility of reaching EDHC targets by other energy sources.

Figure 19 Proposed definition of efficient/clean district heating and cooling by 2030. CO_2 threshold of $100gCO_2eq./kWh$.



Source: JRC, (2021)

Examples under which qualify under this definition are the following:

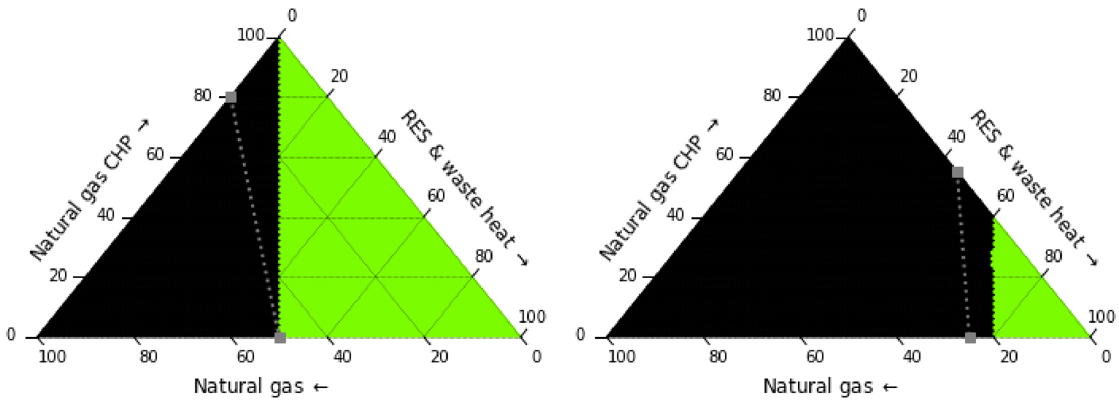
— example 1: 0% RES+WH, 0% Fossil fuelled (non-CHP), 100 % CHP;

— example 2: 50% RES+WH, 50% Fossil fuelled (non-CHP), 0 % CHP;

— example 3: 30% RES+WH, 20% Fossil fuelled (non-CHP), 50 % CHP.

Biomass fuelled CHP would count as renewable, so for example a 50% biomass CHP and 50 natural gas would also qualify. By 2050, when associated emission should tend to zero (2050 Zero carbon targets) we can introduce also a new concept called '*Clean* district heating and cooling', which means a district heating or cooling system using exclusively a combination of renewable fuelled (either individual or combined generation) heat, including ambient heat, and waste heat sources. For the period 2030 to 2050, the fossil fuel contribution will decline by 16.67% every 5 years following the direction of the taxonomy for sustainable financing [8]. In line with this, by 2040 district heating and cooling will qualify as efficient if the share of thermal energy from renewables is 60 percentage points higher than the one from fossil fuels. This condition will keep the emission factor below 50 gCO_2eq/kWh.

Figure 20 Evolution of the proposed definition (left) by 2030 (right) and by 2040 (right) to reach the zero-emission district heating by 2050.



Source: JRC, (2021)

Proposal for new definitions[11]

By 2030, 'Efficient district heating and cooling', means a district heating or cooling system using always **equal or more** renewable energy technologies than fossil fuelled individual generation energy technologies.

By 2040, 'Clean district heating and cooling', means a district heating or cooling system using **always 60 percentage points** more renewable than fossil fuels fuelled individual generation energy technologies.

By 2050, 'Clean district heating and cooling', means a district heating or cooling system using **exclusively** a combination of renewable fuelled (either individual or combined generation) heat, including ambient heat, and waste heat sources.

* being the different energy flows accounted in gross final energy terms

This new proposed definition is particularly challenging for large DHC networks. In those cases aspects such as a security of supply prevails over the compliance with the EDHC concept. Still, the new definition presented here seeks for a progressive transformation of the DHC sector towards 2050 and aims for the incorporation of cleaner energy sources. For the case of large thermal networks, this means a gradual incorporation of clean energy sources even if the thresholds cannot be achieved. On the contrary, the definition fits perfectly thermal networks at the design phase.

[11] This proposed definition does not prejudice any legal review of the efficient district heating and cooling definition under the Energy Efficiency Directive. Instead it is aimed to inform possible directions for revision.

5 Accounting efficient District Heating and Cooling in the context of the EED and REDII

In this section, we present how the accounting of district heating and cooling networks is carried out today, which data is currently collected and what is the additional information required to quantify if thermal networks comply with the concept of efficient district heating and cooling.

At the end of the section, we present a simplified tool to calculate if a given thermal network qualifies as efficient and additional indicators that help understand the performance of the system. This tool is designed to assess both EDHC systems under the current approach as well as following the CO_2 criteria.

5.1 Current data collection and accounting

According to provisions laid down in Article 24(6) of the EED, Member States shall submit to the Commission before 30 April each year statistics on national electricity and heat production from high and low efficiency cogeneration. They are also required to submit annual statistics on cogeneration heat and electricity capacities and fuels for cogeneration, and **on district heating and cooling production and capacities**, in relation to total heat and electricity production. Member States shall submit statistics on primary energy savings achieved by the application of cogeneration.

To this end, Eurostat has provided reporting guidelines and templates (questionnaires). In those, most elements are voluntary. Nevertheless, only the total installed net heat and cooling capacity — to comply with Article 24(6) of the EED — and the total net heat and cooling output are compulsory (green cells in Table 1). This impedes the reporting of the renewable energy shares in DHC. Still, the proposed voluntary breakdown, although not compulsory yet, can provide part of the information needed to account the efficient DHC and the shares of fuels used.

It is worth mentioning that the current data collection follows a bottom-up approach, from a single district heating and cooling system to the whole national sector. MSs collect the information per site, when available, and aggregates it to build a national overview.

In Table 1 and Table 2, we present the data questionnaires related to district heating and district cooling respectively as used today by EUROSTAT. The grey cells of both tables represent the voluntary data, whereas only the green cells show the compulsory data asked from Member States today.

Table 1. District heating reporting template under Article 24(6) Directive 2012/27//EU [3]

Technology of generation unit delivering heat to the network	Installed net heat capacity MW	Net heat output delivered to the network TJ		
	Net	Total	Hot water	Steam
	A	B	C	D
CHP units using non-renewable fuels				
CHP units using renewable fuels				
CHP units using geothermal energy or solar energy				
CHP units using recovered heat from chemical processes and other processes (e.g. surplus heat from industrial or other processes)				
Heat only units using non-renewable fuels*				
Heat only units using renewable fuels*				
Heat only units using electricity (electric boilers)				
Heat only units using geothermal energy, ambient heat or solar energy				
Heat recovery units recovering heat from chemical processes and other processes (e.g. surplus heat from industrial or other processes)				
Total	0	0	0	0

Table 2 District cooling reporting template under Article 24(6) Directive 2012/27//EU [3]

Technology of generation unit delivering cold to the network	Installed net cooling capacity MW	Net Heat removal from the DC network TJ
	A	B
Absorption units for cooling using non-renewable energy input		
Absorption units for cooling using renewable energy input		
Vapour compression chiller units (electric or gas chillers)		
Free cooling (lakes, rivers, seasonal storage below surface, etc.)		
other technologies*		
Total (1 - 5)	0	0

*grey is optional

The current accounting already provides a set of the most common technologies and corresponding fuels — following the EED and Commission Decision 2008/952/EC, that can be found in district heating and cooling systems (Table 3).

Table 3 Input categories and clarifications [3]

Technology category	**Technology of generation unit delivering heat to the network**	**Fuel used**	**Comment**
CHP	CHP units using non-renewable fuels	Non-renewable fuel[12]	—
	CHP units using renewable fuels	Renewable fuels[13]	—
	CHP units using geothermal energy or solar energy	Geothermal and solar thermal	—
	CHP units using recovered heat from chemical processes and other processes (e.g. surplus heat from industrial or other processes)	Waste heat	If recovered heat from chemical processes and other processes is not the main fuel input, the data of this CHP unit should be reported following the current method of the Annual Electricity and Heat Questionnaire in rows 1, 2 or 3
Single-purpose technologies	Heat only units using non-renewable fuels*	Non-renewable fuel[12]	Reduction of heat has to be included here
	Heat only units using renewable fuels*	Renewable fuels[13]	Reduction of heat has to be included here
	Heat only units using electricity (electric boilers)		
Renewables	Heat only units using geothermal energy, ambient heat or solar energy	Geothermal, Solar or ambient heat (Heat pumps)	Do not account the additional heat capacity from Booster Heat Pumps. *Report only the capacity of the heat exchanger
Waste heat	Heat recovery units recovering heat from chemical processes and other processes (e.g. surplus heat from industrial or other processes)		Excluding CHP. Account the capacity of the heat exchanger excluding booster heat pumps

The approach built by EUROSTAT sets the basis for our proposal on how to enhance the current accounting approach and, thus, have a clearer identification of efficient district networks. Using both the technology and input fuel list proposed by EUROSTAT, in the following section, we come up with an accounting proposal.

It is worth mentioning that the DH/DC questionnaire is not yet used by EUROSTAT to monitor the progress of EDHC. So far, the available information on district heating at national level is included in the national energy balances. However, the energy flow defined as 'derived heat' or 'heat' does not correspond in all cases to district heating according the definition set in Article 2(19) of the RED II. For example, the 'derived heat' flow includes one-to-one heat exchange as well, which in not

[12] Non-renewable fuels includes: Hard coal and patent fuels, Sub-bituminous coal, Lignite/brown coal and BKB, Peat, Coke-oven gas, Blast furnace and oxygen steel furnace gas, Other solid coal products, Residual fuel oil, Refinery gas, Other liquid fossil fuels, Natural gas and gas works gas, Nuclear heat, Industrial waste: Wastes of industrial non-renewable origin (solids or liquids), Municipal solid waste (non-renewable): Wastes produced by households, industry, hospitals and the tertiary sector which are non-biodegradable materials incinerated at specific installations.

[13] Solid biomass, municipal solid waste, biogas, liquid biofuels, other renewable sources

considered district heating in the legislation. This means information provided in the energy balances could be considered as an upper gross estimation of the centralised heat supply. However, details needed to characterise a network as efficient or not cannot be found in the energy balances. This also affects any analysis on thermal losses at national level. Still, in Annex II we provide the national thermal losses time series based on the derived heat energy flow for all Member States.

5.2 Enhancing the current accounting of Efficient District Heating and Cooling under the CO_2 evaluation criteria. EDHE tool

To facilitate the identification, accounting and evaluation of current and future network developments within the definition of efficient district heating and cooling we propose to base it on Eurostat's approach. This has the advantage that Member States are already familiar with it. We aim to enhance it and to provide a better view and understanding on the efficiency and cleanliness of district heating and cooling networks (following the discussion in Section 4).

Accompanying our proposal, a simple calculation tool was developed — EDHE (Efficient District Heating Evaluation), which can be used by MSs to get an estimate of the impact on the RES shares from different heat supply combinations, e.g. by installing heat pumps.

Our purpose is to identify if each district heating and cooling network falls under the definition of efficient district heating and cooling according to the EED and REDII[14], as described in previous sections. This approach is meant to be applied bottom-up; starting from a single thermal network or a local site (including several networks) up to a national assessment overview.

In addition, the tools is designed to evaluate the CO_2 performance of the DHC system and, thus, setting the basis for the future enhanced accounting.

5.2.1 Input data requirements

In order to characterise both efficient and clean district heating and cooling systems we require additional data compared to the approach under the current definition.

Below a list of input data required is presented — we split the list between those inputs needed for the efficient district heating and cooling characterisation, and the additional performance indicators, including the sustainable one:

Input data for EDHC — to monitor the compliance with article EED 2(41):

- energy conversion technologies:
  - Input fuel per technology;
  - Total output heat per technology [TJ];
- Seasonal Performance Factor (SPF), to compute ambient energy in the case of heat pumps.

Input data for additional indicators:

- emission factors per fuel (ef) [t CO_2/TJ];
- national power emission factor [t CO_2/TJ];
- national power efficiency (nref,e) [%];
- thermal efficiencies for all the energy conversion technologies;
- electric efficiencies for CHP technologies;
- temperature of the heat supplied from CHP (°C);
- use: single- or multi-purpose technology;
- share of total thermal losses during transmission and distribution [%];

[14] REDII uses the same definition as EED, by referencing Article 2(41) of EED in its Article 2(20).

— year of the analysis (national power parameters and default thermal efficiencies for the energy conversion technologies are updated).

Input data values for the calculation of additional indicators

— thermal losses as a share of the gross-final energy going into the network. Source: EUROSTAT balances;

— national power efficiencies. Source: EUROSTAT;

— national heat efficiencies. Source: POTENcIA;

— list of typical energy conversion technologies Source: PRIMES.

To account for these indicators, data from the operation of the networks has to be collected. Relevant stakeholders — Member States, network operators, etc. — have to provide this information to their national authority that is responsible for the accounting and reporting on thermal networks. In case the information cannot be provided, relevant literature offers default values that will allow to perform the analysis. For some of the items above, we have included sources where default values can be extracted from.

5.2.2 The EDHE tool

The EDHE tool is a simplified MS Excel-based tool that provides multiple indicators for a given district heating and cooling system.

EDHC Indicator

To begin with, for the characterisation of a network as efficient or not, we need to account the ratio of gross final energy going into the network from waste heat, CHP and renewable sources to the total gross final energy.

— total heat delivered into the network per generation unit [TJ].

Additional indicators

On top of this, we propose additional indicators to provide more information on the performance of the network. These are:

— emission factor per unit of heat delivered [gCO_2/TJ];

— heat efficiency [%];

— electric efficiency — if cogeneration exists in the network [%];

— non-RES heat efficiency [%];

— non-RES electric efficiency [%].

Additional considerations

— waste heat is treated as a direct heat flow going into the network (efficiency 100%)

Calculation options

— proportional/exergetic allocation of CO_2 emission for the cogenerated heat

Equations

Next, we present the equations used to calculate the above indicators:

Efficient district heating and cooling indicators

Share of RES: $sRES = \frac{\sum_i^{RES} Q_i}{\sum_j^N Q_j}$ (3)

Share of waste: $sW = \frac{\sum_i^W Q_i}{\sum_j^N Q_j}$ (4)

share of cogenerated heat $(sCHP_H) = \frac{\sum_i^{CHP} Q_i}{\sum_j^N Q_j}$ (5)

combined share $= \frac{\sum_i^{RES} Q_i + \sum_i^{W} Q_i + \sum_i^{CHP} Q_i}{\sum_j^N Q_j}$ (6)

Ambient energy: $ae = Q_{HP} \cdot (1 - \frac{1}{SPF})$ (7)

Equations for additional indicators

Emission factor per unit of heat delivered: $ef = \frac{\sum_i^N \frac{Q_i}{\eta_{i,th}} \cdot ef_i}{\sum_i^N Q_i}$ (8)

Heat efficiency: $\eta_H = (1 - \mathrm{losses}_{th}) \cdot \sum_i^N \frac{Q_i}{\eta_{i,th}}$ (9)

Electric efficiency: $\eta_E = \sum_i^N \frac{E_i}{\eta_{i,el}}$ (10)

non-RES final heat efficiency: $\eta_{H,\mathrm{non}RES} = (1 - \mathrm{losses}_{th}) \cdot \sum_i^{nonRES} \frac{Q_i}{\eta_{i,th}}$ (11)

non-RES final electric efficiency: $\eta_{E,\mathrm{non}RES} = \sum_i^{nonRES} \frac{E_i}{\eta_{i,el}}$ (12)

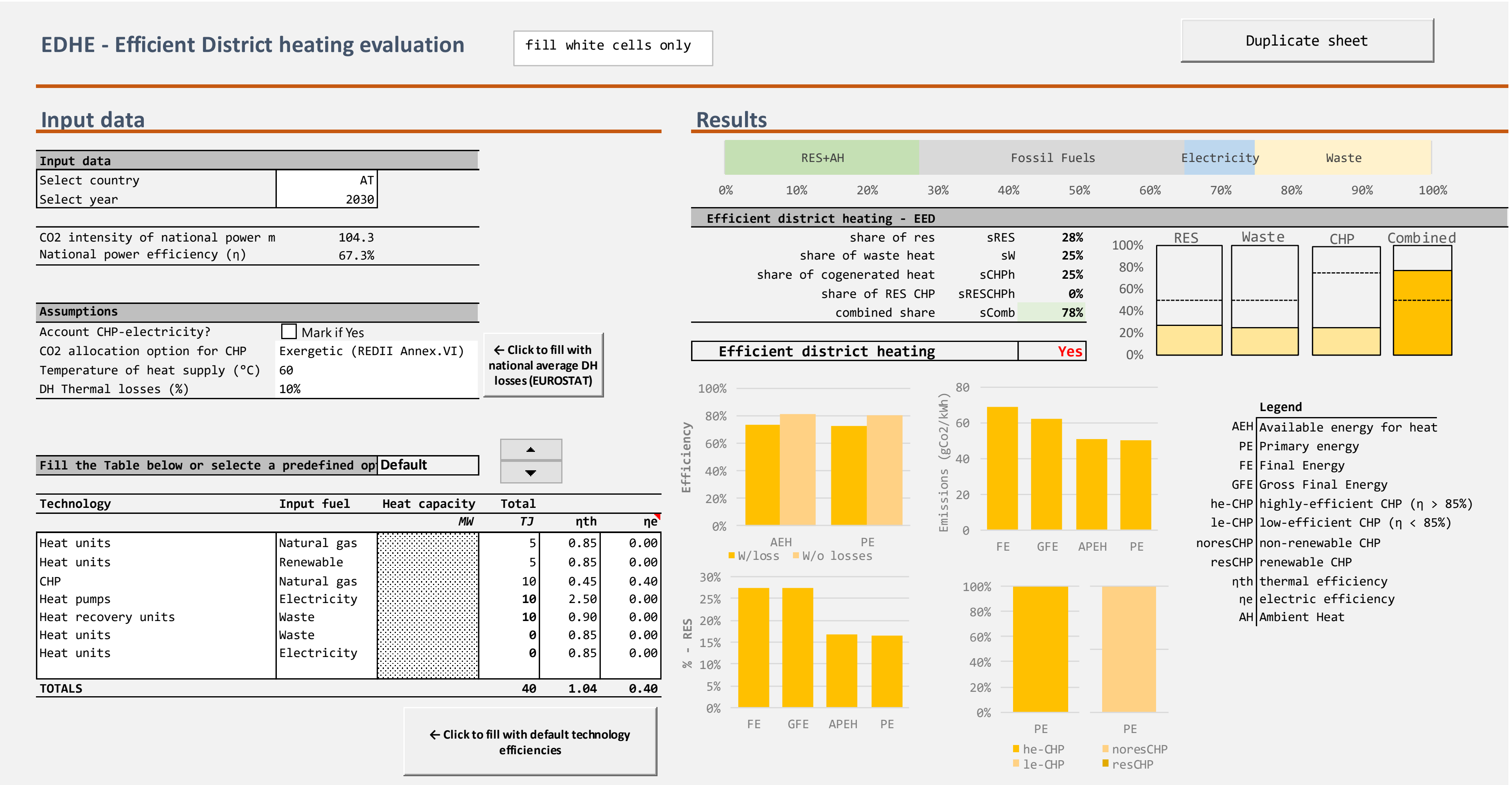
To help users calculate the above indicators we provide an Excel based calculation tool — EDHE tool. EDHE includes background information to ease the accounting process. Specifically, it provides a list of energy conversion technologies and corresponding input fuels (Table 4) and their carbon intensities following the agreed IPCC guidelines used by EUROSTAT (Annex III). However, when a MS or a network operator have more precise information on carbon intensities they should use those by replacing the default data in the tool.

Table 4 Input list for energy conversion technologies and fuels

Technology of generation unit delivering heat to the network	Code	Input fuel
CHP	CHP	non-renewable fuels (excluding gas)
		gas
		renewable fuels
		geothermal
		solar
		waste heat
Heat units	Hunits	non-renewable
		renewable
		geothermal
		solar
		waste heat
Heat pumps	HP	electricity
Heat recovery units	Hrec	Waste heat

Once the information on all local DHC networks has been collected in a national registry, aggregated information can be sent to EUROSTAT.

Figure 21 The EDHE tool layout.



Source: *JRC, (2021)*

5.3 Examples

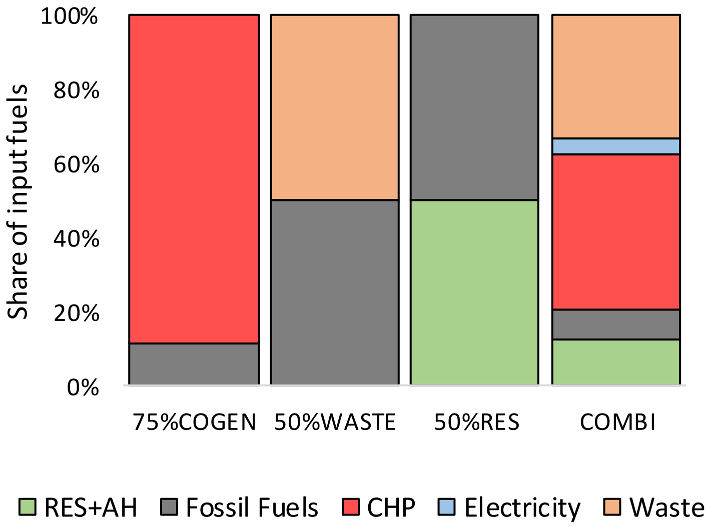
We use EDHE to reproduce the examples we presented in section 3.

For all cases we assume then following:

- thermal losses: 10%;
- temperature of heat supply: 60 °C;
- CHP CO_2 allocation method: exergetic;
- national power efficiency: 67%.

We have examined 4 cases that correspond to those introduced in Section 3.2. The fuel mixes for those cases are the following:

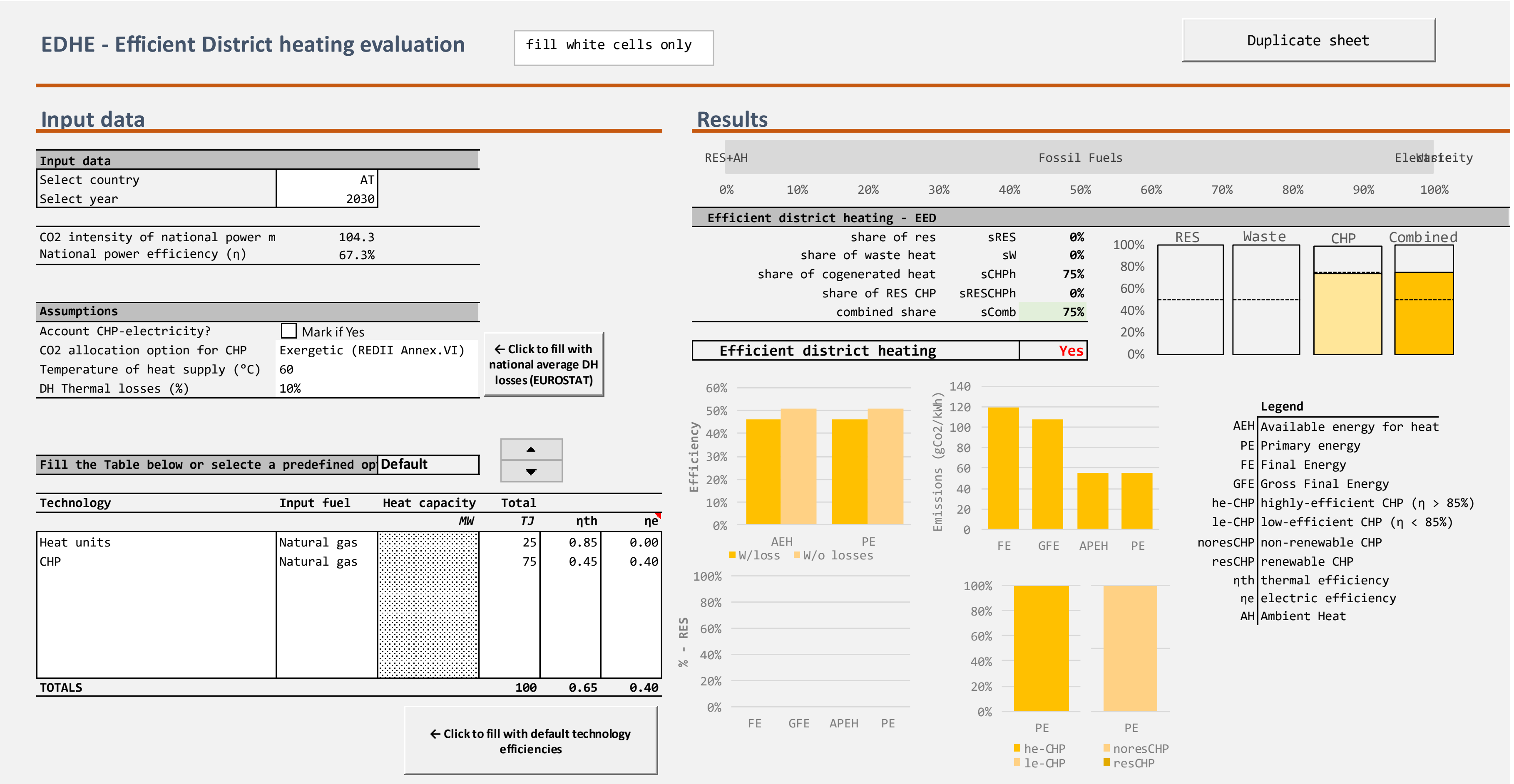
Figure 22 Input fuel shares for the different modalities of efficient district heating and cooling under the current definition.



Source: *JRC, (2021)*

Case 1. 75% cogenerated heat option

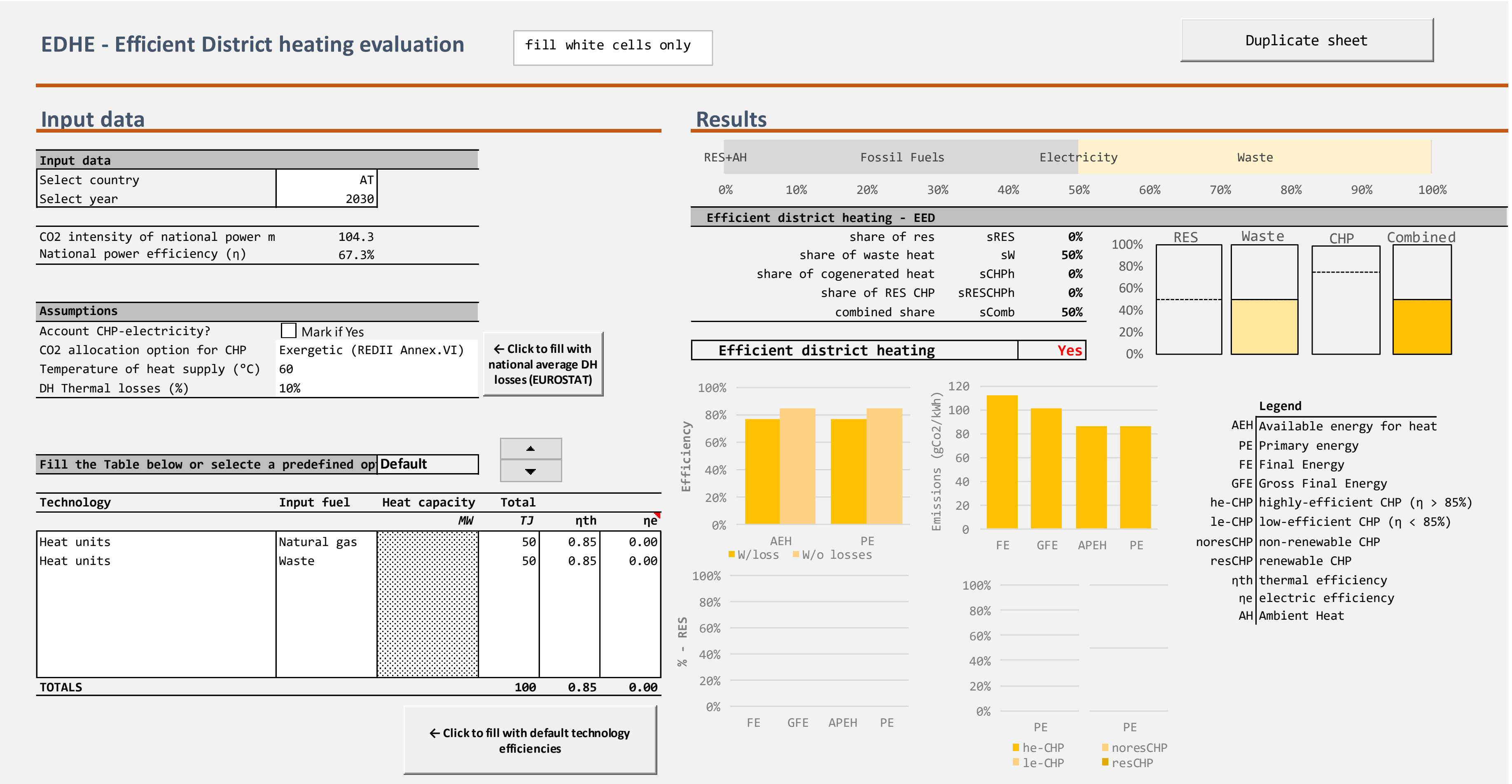
Figure 23 Screenshot of the EDHE tool interface. Results for the 75% cogeneration option.



Source: *JRC, (2021)*

Case 2. 50% waste heat option

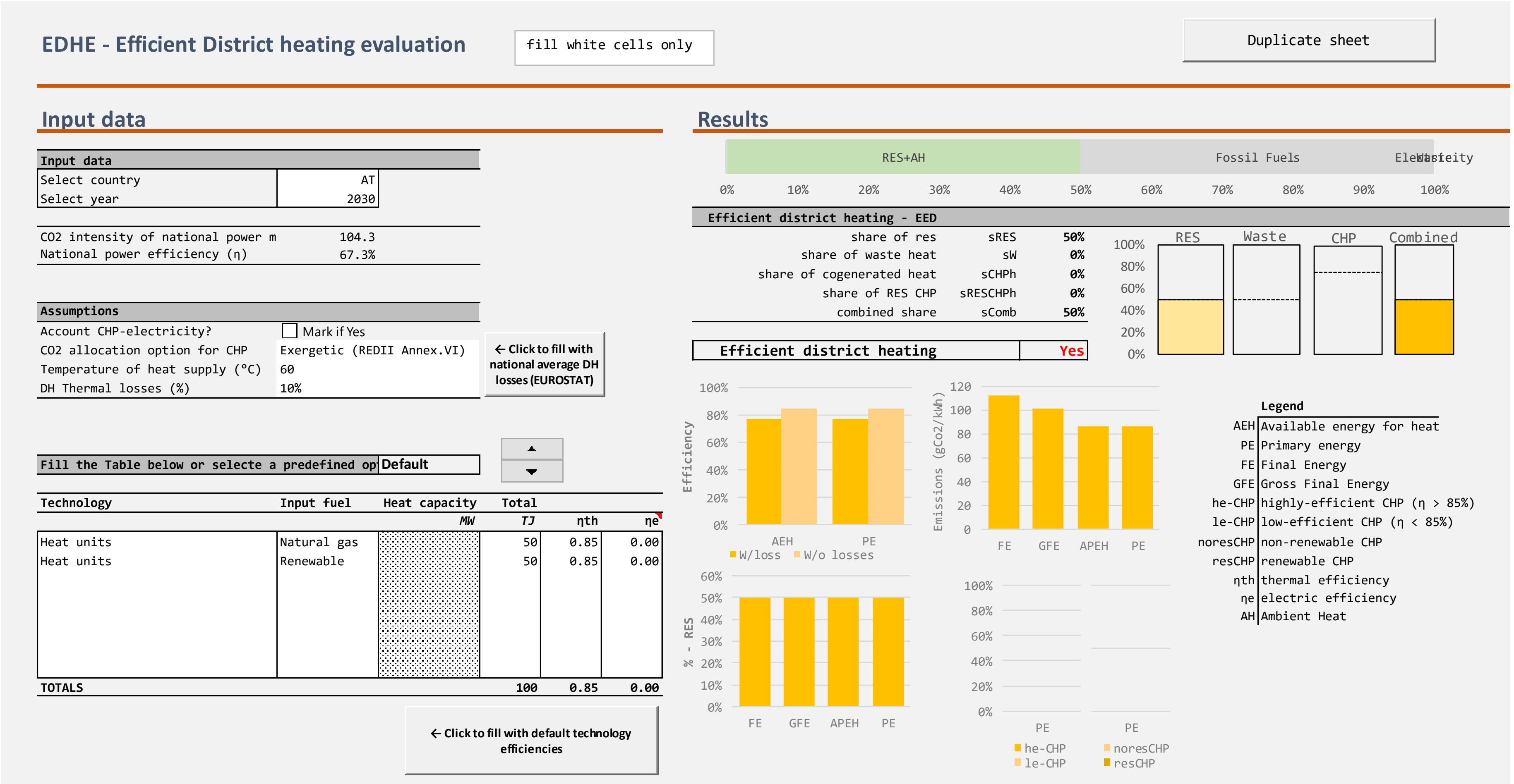
Figure 24 Screenshot of the EDHE tool interface. Results for the 50% waste option.



Source: *JRC, (2021)*

Case 3. 50% renewable option

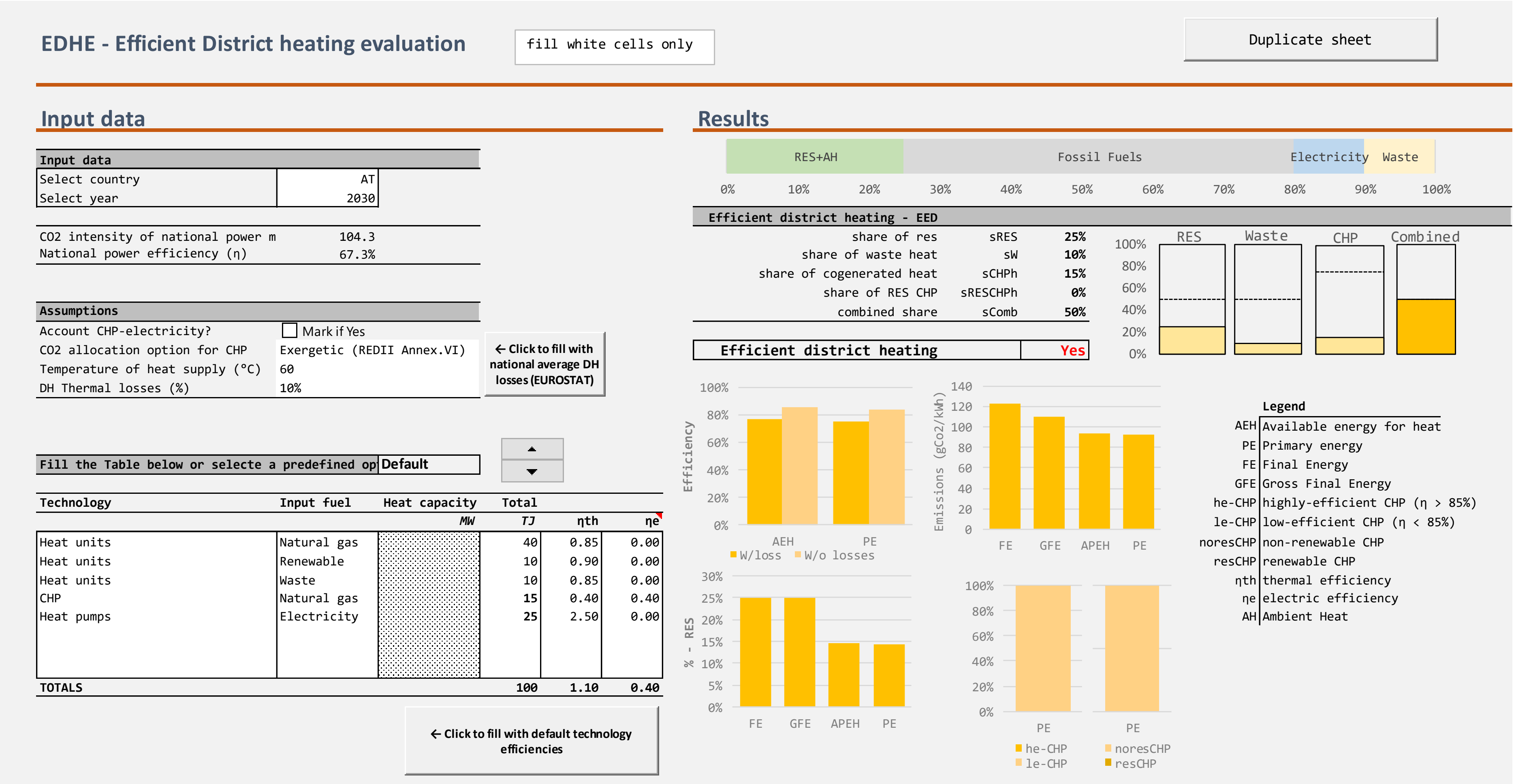
Figure 25 Screenshot of the EDHE tool interface. Results for the 50% renewable option.



Source: *JRC, (2021)*

Case 4. 50% of a combination of such energy and heat

Figure 26 Screenshot of the EDHE tool interface. Results for the 50% of a combination of such energy and heat as defined first in Article 2(41) of the EED.



Source: *JRC, (2021)*

6 Conclusions and policy recommendations

The aim of this work was, first, to explain how the current definition of efficient district heating and cooling— as defined in Article 2(41) of EED and Article 2(20) of RED II – should be interpreted. And second, to provide an accounting methodology to monitor the deployment of efficient district heating and cooling in future decarbonised energy systems.

The current definition of EDHC aims to promote the deployment of cleaner energy sources. It builds upon the opportunities that thermal networks offer concerning the utilisation of centralised energy sources.

Current definition of Efficient District Heating and Cooling 'Efficient district heating and cooling', as defined first in Article 2(41) of the EED, means a district heating or cooling system using at least 50% renewable energy, 50% waste heat, 75% of cogenerated heat or 50% of a combination of such energy and heat'

Under the current definition of EDHC, the accounting concerns energy flows over a given period (typically a year) and not available capacities. This accounting is based on the net heat delivered to the network from the heat sources. From the viewpoint of the district heating network this equates to the gross final energy.

In section 3, we propose to incorporate the following clarification to the definition of efficient district heating and cooling.

Proposed **modification of the current definition** of Efficient District Heating and Cooling 'Efficient district heating and cooling', as defined first in Article 2(41) of the EED, means a district heating or cooling system using at least 50% renewable energy, 50% waste heat, 75% of **high-efficiency** cogenerated heat or 50% of a combination of such **thermal energy going into the network**'.

Even though the current definition of efficient district heating and cooling aims to promote cleaner and more efficient district heating and cooling in Europe, it needs to be strengthened to meet the net-zero emissions target by 2050. Along these lines, we worked towards analysing the definition and its provisions. Following the CO_2 evaluation criteria, we provided three updated definitions to be applied for different time frames. By 2030, we suggest a definition that ensures carbon intensities below 100 $gCO_2eq./kWh$, while, by 2040, the share of renewables should be 60 percentage points more than fossil fuels to guarantee emission factors of the order of 50 $gCO_2eq./kWh$. Lastly, by 2050, district heating and cooling systems should have zero emissions, thus becoming clean district heating and cooling.

Proposal for new definitions **By 2030**, 'Efficient district heating and cooling', means a district heating or cooling system using always **equal or more** renewable energy technologies than fossil fuelled individual generation energy technologies. **By 2040**, 'Clean district heating and cooling', means a district heating or cooling system using **always 60 percentage points** more renewable than fossil fuelled individual generation energy technologies. **By 2050**, 'Clean district heating and cooling', means a district heating or cooling system using **exclusively** a combination of renewable fuelled (either individual or combined generation) heat, including ambient heat, and waste heat sources.

In section 5 we developed a tool that brings together the current accounting with possibilities based on the proposed definitions of EDHC developed in this work.

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[10] L. Mantzos, T. Wiesenthal, N. A. Matei, S. Tchung-Ming, and M. Rozsai, “JRC-IDEES : Integrated Database of the European Energy Sector,” 2017.

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List of abbreviations and definitions

DHC	District Heating and Cooling
EED	Energy Efficiency Directive
RED	Renewable Energy Directive
DH	District Heating
FEC	Final Energy Consumption
MS	Member State
EPBD	Energy Performance of Buildings Directive
PE	Primary Energy
GFE	Gross Final Energy
LHV	Lower Calorific Values
PtH	Power to Heat
EDHC	Efficient District Heating and Cooling
PES	Primary Energy Savings
AH	Ambient Heat
HP	Heat pumps
LHV	Lower Heating Value
RES	Renewable Energy Sources
CHP	Combined Heat and Power
HP	Heat Pumps
CCGTHR	Combined Cycle Gas Turbine with Heat Recovery
GTHR	Gas Turbine with Heat Recovery
ICE	Internal Combustion Engine
SBT | SCER	Steam Back Pressure Turbine | Steam Condensing Extraction Turbine
CO_2S	CO_2 emissions savings
UE	Useful Energy
APEH	Available Primary Energy for Heat
WH	Waste Heat
SF	Secondary Fuel
f2H	Firing Technologies
x2H	Heat Technologies fed by Secondary Fuels
AH	Ambient Heat

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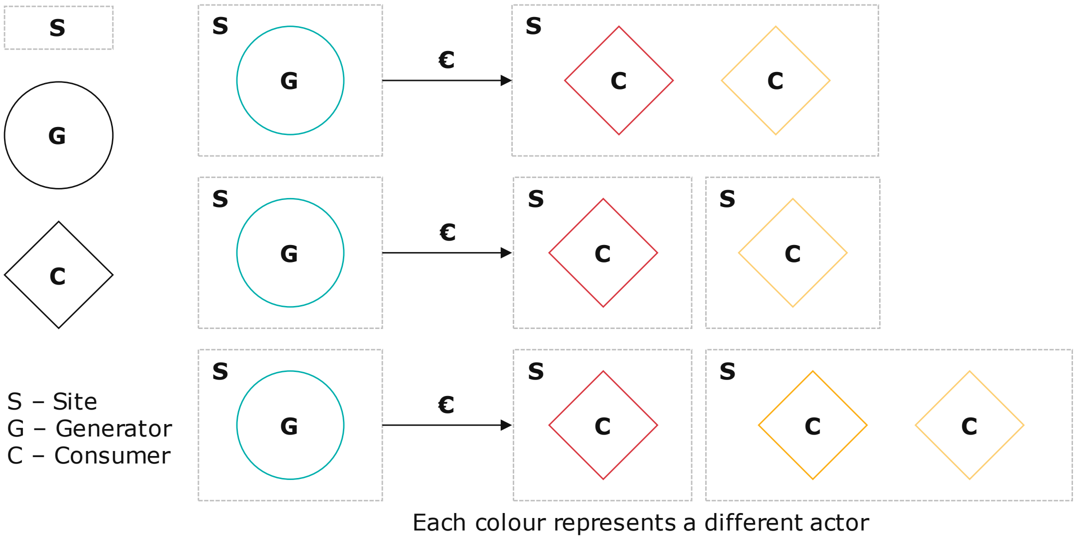
Annexes

Annex I. Examples of district heating or district cooling

In the following figures, we present some examples of what a district heating and cooling is and what is not based on the definition provided in [3]. In the figures G stands for energy generator, S for sites and C for consumers. The symbol '€' represents an economic transaction and each colour a different actor, generator or costumer.

— What is a district heating or district cooling?

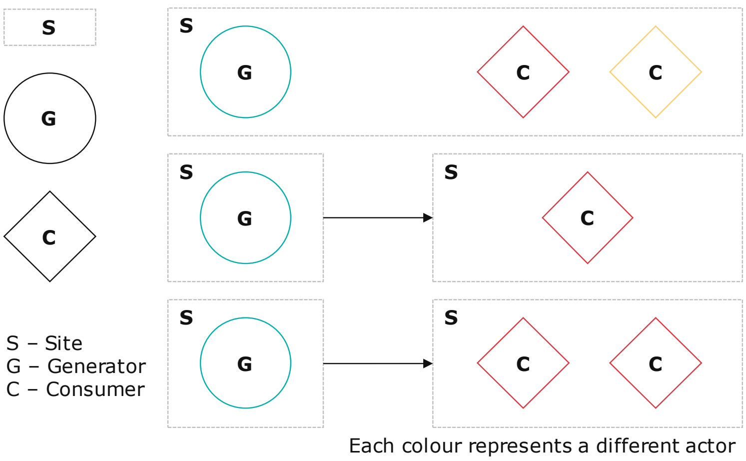
Figure 27 Simplified examples of what is a district heating as defined in [3].



Source: JRC, (2021)

— What is not a district heating or district cooling?

Figure 28 Simplified examples of what is not a district heating as defined in [3].



Source: JRC, (2021)

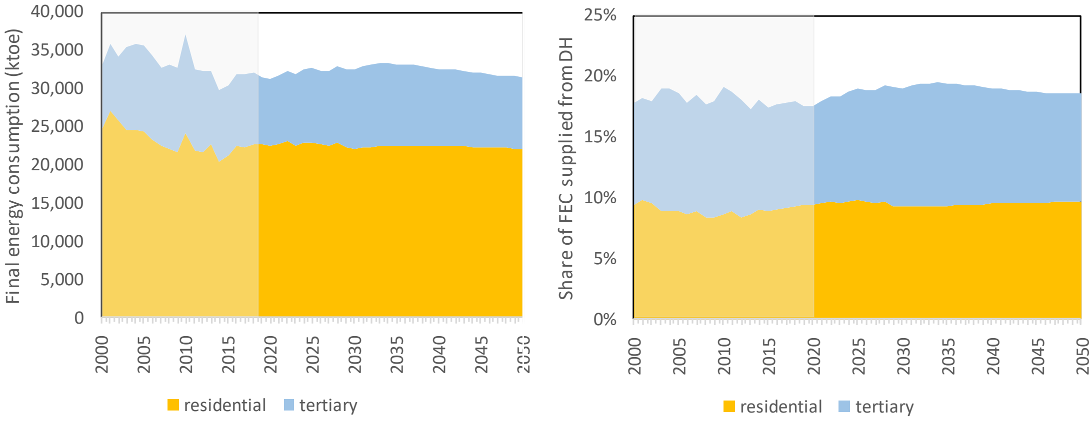
Annex II. An EU overview on the District Heating and Cooling supply

Here, we aim to give context to the provisions included in the RED II (Article 24) and, thus, provide facts that set the basis for the discussion on the definition of efficient district heating and cooling and on the suitability of RES quotas defined for the coming years.

This overview presents information on the current status and future projections. It includes data on two main aspects: the thermal demand supplied from DHC and the input fuels mixes feeding the networks. In addition, we break the information down into residential and tertiary sectors. By doing so, we try to remove uncertainties related to industrial heat transfers that may not classify as district heating and cooling. Still, we cannot guarantee that the heat included in these two sectors fully complies with the definition of district heating and cooling. This analysis is carried out based on the work done by JRC in [9], [10].

Today, centralised heat supply represents around 8% of the final energy consumption (FEC) for the residential and tertiary sectors in Europe (EU27+UK). Modelling exercises foresee this share remaining stable in the coming decades [9]. If this projection holds, rather than building new efficient networks, existing DHC networks have to undergo a fuel shift — from fossil fuels to renewables — to comply with the required annual increase of 1 percentage point of renewables and waste heat of Article 24(4)(a) of the RED [1] and become more efficient, limiting their thermal losses. In other words, focus should be given to incorporate clean energy sources into existing networks.

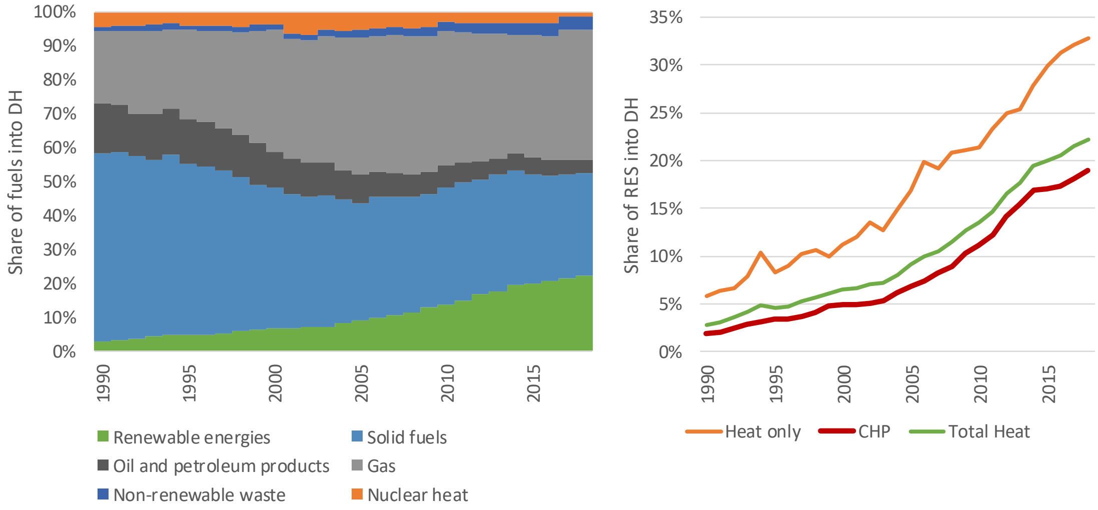
Figure 29 Final energy consumption delivered from Derived Heat in the residential and tertiary sector.



Source: JRC, (2021)

Looking into the shares of renewable sources going into DHC networks, data from EU energy balances show a constant increase for the last 30 years. The RES share reached its maximum, 22.2%, in 2018 — the latest available data (Figure 30).

Figure 30 Share of fuel going into District Heating networks (left) and of renewable sources in CHP and Heat-only technologies (right) [10].

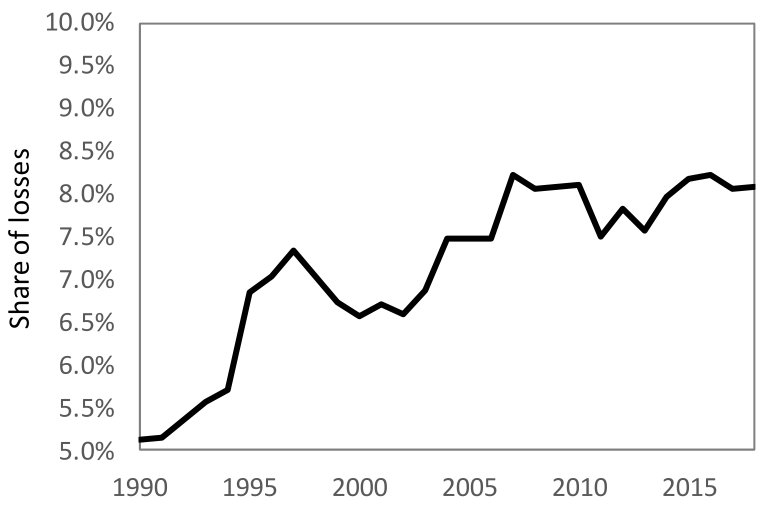


Source: *JRC, (2021)*

Beyond the input fuel mixes, the role of CHP technologies in the decarbonisation of district heating and cooling networks is of particular interest. CHP is one of the supply options included under the definition of efficient district heating and cooling, as defined in Article 2(41) of the EED. Traditionally CHP has been running on fossil fuels, such as natural gas. Indeed, when compared with heat-only technologies, the share of renewable fuels going through CHP, although growing, is lower (Figure 30 – right). Data indicates that the impact of CHP in DHC systems should be monitored to not only ensure the efficiency of these energy systems but their decarbonisation, as discussed in the document.

Last, one important element that should be considered when discussing about the concept of efficient district heating and cooling networks are their losses. The available data, based on the derived heat flow and under the statistical assumptions carried out by EUROSTAT, show an increase in the rate of losses compared with the total heat delivered up to 9% (Figure 31).

Figure 31 Share of energy losses in EU district heating and cooling networks.



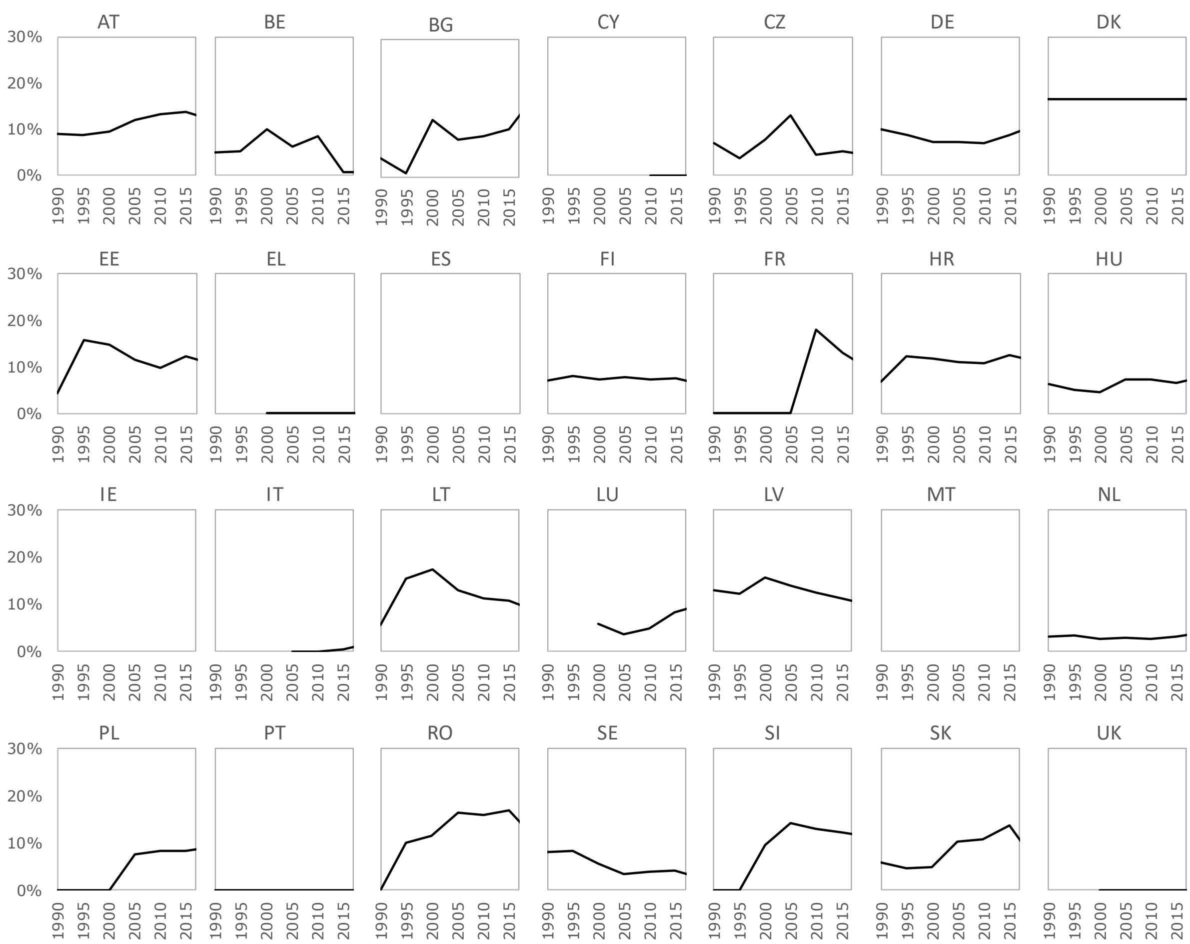
Source: *JRC, (2021)*

There is no clear explanation for the increase of thermal losses relative to the centralised heat supply. This statistical information is less reliable according to EUROSTAT and should be taken as a potential indication. They can include statistical differences, unallocated or unknown elements, and in general be used for balancing purposes of inputs and outputs rather than observed value of real distribution losses of heat.

The same applies to Figure 32

Figure 32. Here, to support the evaluation of EDHC and to fill in potential data gaps, we have brought together the time series for district heat losses at national level. The idea is to use this dataset as a back-up in case specific information per network is not available. As for the European losses, this data has to be taken as an estimation.

Figure 32 EU27 + UK overview on heat distribution and transmission losses [4].



Source: JRC, (2021)

Annex III. Carbon intensity factors

Table 5 Fuel emission factors related to net calorific values (NCV) [11]

	Emission factor (t CO2/TJ)	Net Calorific Value (TJ/Gg)	Source	Year
Renewable	0			
Waste	0			
Natural gas	56.1	48	IPCC	2006
Gas/Diesel oil	74.1	43	IPCC	2006
Natural gas Liquids	64.2	44.2	IPCC	2006
Crude oil	73.3	42.3	IPCC	2006
Electricity	50			
Orimulsion	77	27.5	IPCC	2006
Motor gasoline	69.3	44.3	IPCC	2006
Kerosene (other than jet kerosene)	71.9	43.8	IPCC	2006
Shale oil	73.3	38.1	IPCC	2006
Residual fuel oil	77.4	40.4	IPCC	2006
Liquefied petroleum gases	63.1	47.3	IPCC	2006
Ethane	61.6	46.4	IPCC	2006
Naphtha	73.3	44.5	IPCC	2006
Bitumen	80.7	40.2	IPCC	2006
Lubricants	73.3	40.2	IPCC	2006
Petroleum coke	97.5	32.5	IPCC	2006
Refinery feedstock	73.3	43	IPCC	2006
Refinery gas	57.6	49.5	IPCC	2006
Paraffin waxes	73.3	40.2	IPCC	2006
White spirit and SBP	73.3	40.2	IPCC	2006
Other petroleum products	73.3	40.2	IPCC	2006
Anthracite	98.3	26.7	IPCC	2006
Coking coal	94.6	28.2	IPCC	2006
Other bituminous coal	94.6	25.8	IPCC	2006
Sub-bituminous coal	96.1	18.9	IPCC	2006
Lignite	101	11.9	IPCC	2006
Oil shale and tar sands	107	8.9	IPCC	2006
Patent fuel	97.5	20.7	IPCC	2006
Coke oven coke and lignite coke	107	28.2	IPCC	2006
Gas coke	107	28.2	IPCC	2006
Coal tar	80.7	28	IPCC	2006
Gas works gas	44.4	38.7	IPCC	2006
Coke oven gas	44.4	38.7	IPCC	2006
Blast furnace gas	260	2.47	IPCC	2006
Oxygen steel furnace gas	182	7.06	IPCC	2006
Industrial wastes	143	n.a.	IPCC	2006
Waste oils	73.3	40.2	IPCC	2006
Peat	106	9.76	IPCC	2006

Wood/Wood waste	—	15.6	IPCC	2006
Other primary solid biomass	—	11.6	IPCC	2006
Charcoal —		29.5	IPCC	2006
Bio gasoline —		27	IPCC	2006
Biodiesels —		27	IPCC	2006
Other liquid biofuels	—	27.4	IPCC	2006
Landfill gas	—	50.4	IPCC	2006
Sludge gas	—	50.4	IPCC	2006
Other biogas	—	50.4	IPCC	2006

Annex IV. CHP emission allocation methods

There are multiple ways to allocate the emissions of fuel combusted to multiple products, like in the case of cogeneration. The two main methods are presented and compared here with the following example:

Natural gas example: We assume a natural gas High efficiency CHP with a total efficiency of 90% and a power to heat ratio of 0.75 (representative for Internal combustion engines, also example in EED Annex II).

Each kWh of Natural gas when combusted regardless of the technology emits ~200gCO_2eq. For technologies with one product the estimation of emissions per end product is simple: divide the emission factor of the fuel by the technology efficiency. For CHP technologies that produce two products, assumptions are needed to allocate this fuel to the end products. Criteria used are: the ratio between the two products, the quality of two products and the overall efficiency. There are couple of ways in the literature to do that but here we present the two most common ones, usually used in policy:

Method 1. End products have same value (proportional allocation of emissions)

The simplest way is to treat cogeneration identical to electricity generation or heat production It evenly distributes the CO_2 content of the input fuel to the two outputs (heat and power). In this way, the CO_2 associated to both outputs is calculated by the ratio of the CO_2 of the input fuel to the global efficiency (heat efficiency + electricity efficiency) of the CHP plant.

In this case both products have the same specific emissions rates, based on the overall efficiency. In our example 200 /95% = 222 gCO_2eq./kWh(useful products). Also 222 gCO_2eq./kWh(heat) and 222 gCO_2eq./kWh(power).

Method 2 (proposed in REDII Annex VI(6)) End products have different weights based on their quality[15]

This method solves the problem of power-thermal equivalence, assuming that power is more valuable than heat, and allocating the total emission based on that. This method is described in detail in RED Annex 6B. It assigns a quality indicator (exergy) for the outputs. The higher the quality the higher the associated emissions.

To calculate the quality we follow the guideline set in the RED II Annex 6 B.1(d)

— the electricity gets a quality indicator (Cel) of 1;

— the heat quality indicator varies with its temperature. The higher the temperature, the higher the quality indicator (idea behind: high temperature heat can provide more services than low temperature heat. To quantify the heat quality (Ch) we use the Carnot factor.

Ch = Th / (Th + 273.15)

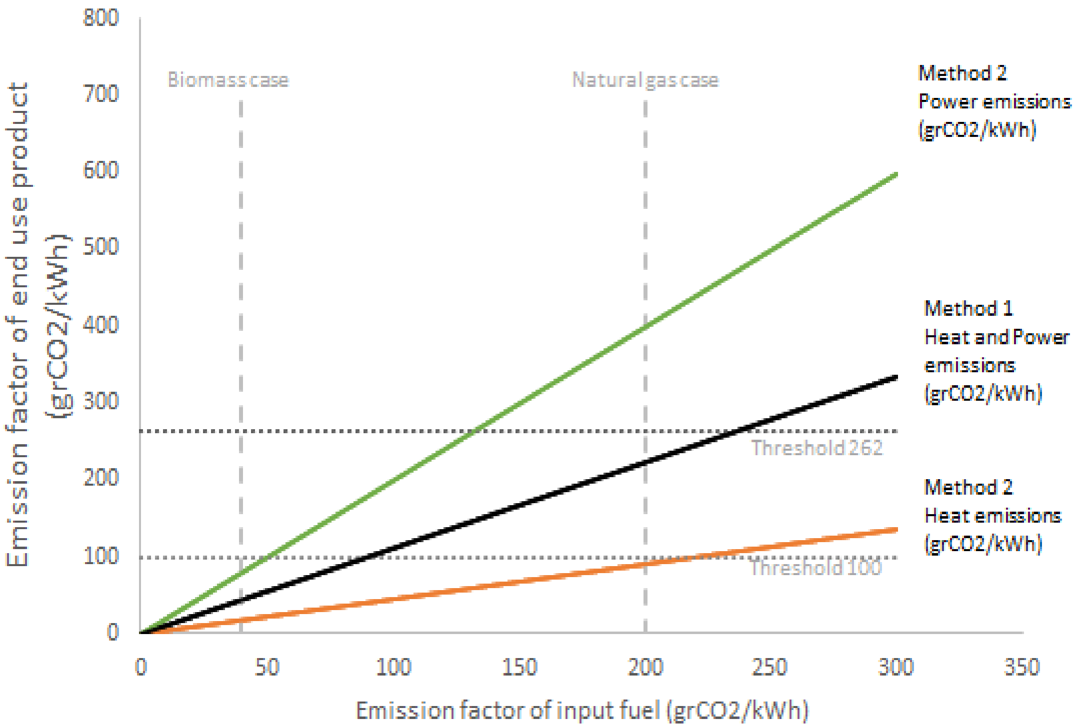
With these two values (Cel and Ch), we use the equations included in the RED II Annex 6, B. Methodology (d) (iii) and (iv) to determine the final allocation for each product.

Based on our example above that would result: 90.2 grCO_2eq./kWh (heat), 398.2 grCO_2eq./kWh (power). Taking the weighted average of both it would result to the same value as above, ie. 222 gCO_2eq./kWh (useful products).

The Figure below summarized these methods along with a biomass example and benchmarks for separate production methods.

15 The quality here is defined by the Carnot factor (exergy) which changes with the heat Temperature. Electricity is assumed 100%. This assumptions are adopted from REDII Annex VI

Figure 33 Emission factor of end use product for different allocation methods.



Source: JRC, (2021)

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