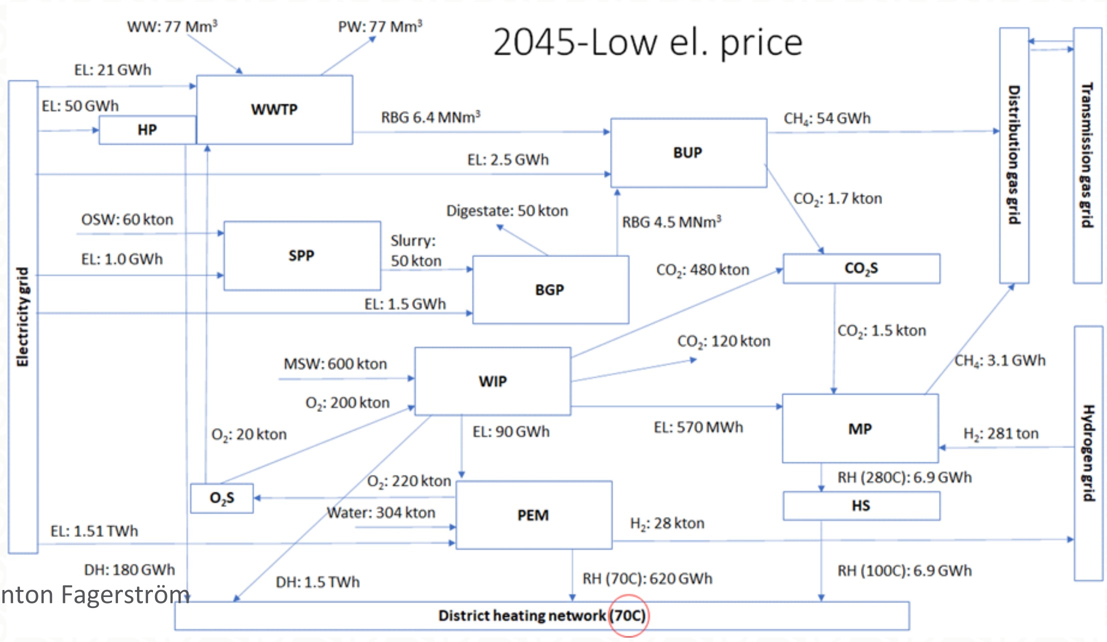
No. C 608
June 2021

Dispatchable electricity production in the North Harbour area in Malmö via renewable gases



Anton Fagerström

In cooperation with Region of Skåne, City of Malmö, E.on, Uniper, Nordion Energi, VA-Syd, Sysav, RWE Renewables

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Funded by: Region of Skåne and IVL Swedish Environmental Research Institute
Report number C 608
ISBN 978-91-7883-297-2
Edition Only available as PDF for individual printing

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Preface

This document reports the results from the project Dispatchable electricity production in the North Harbour area in Malmö via renewable gases, which has been a joint project between IVL Swedish Research Institute and Region of Skåne.

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Summary

The main purpose of this project has been to identify and discuss a concept for the North Harbour area in Malmö regarding increased dispatchable electricity production and Power-to-gas/Liquids (PtX) being made possible through sector coupling of existing and added infrastructure. The work towards this main purpose has entailed the establishment of a cluster of relevant stakeholders, both those that have activity within the area but also others that are deemed important for the main purpose in one way or another.

The report describes challenges in the electricity supply of Malmö and the North Harbour area of Malmö in general. A background is given around the concept of sector coupling, types of sector couplings, the concept of Power-to-X, and other relevant projects and endeavours related to the project at hand. The current situation is described starting with the history of Malmö and its harbour and continuing by describing the current infrastructure, and mass and energy flows. From there, possible sector couplings and the future access to power and electricity is elaborated on. The question -Why sector coupling the electricity power grid will be needed, is viewed in the Malmö-context and how an increase in electricity demand can result in periods of low and high electricity prices is described.

A possible transformation of the area in question is depicted for 2030 and 2045 with the additional sector couplings in place and active, both for a high and a low electricity price for the respective timeframe. Finally, the report is concluded with a lookout on further optimization of the system in question and how the results from the project could be continued in a wider scale. There has been a pronounced goal within this project to lead to relevant future cooperation between the stakeholders and future projects that can take the concept started within this project closer to realization. One such option is the participation in an application for an EU-project partly based on the results from the project at hand.

Sammanfattning

Huvudsyftet med detta projekt har varit att identifiera och diskutera ett koncept för Norra hamnen-området i Malmö om hur ökad planerbar elproduktion och el-till-gas (Power-to-gas) möjliggörs genom djup sektorkoppling av befintlig och tillförd infrastruktur. Arbetet mot detta huvudsyfte har inneburit att ett kluster av relevanta intressenter har skapats, både de som har verksamhet inom området och andra som på ett eller annat sätt anses vara viktiga för huvudsyftet.

Rapporten beskriver utmaningar i elförsörjningen i Malmö och Norra hamnen-området i Malmö i allmänhet. Bakgrund ges kring begreppet sektorkoppling, typer av sektorkopplingar, konceptet Power-to-X och andra relevanta projekt och ansträngningar relaterade till det aktuella projektet. Den nuvarande situationen beskrivs med avstamp i Malmös och hamnens historia och fortsätter med en beskrivning av den nuvarande infrastrukturen samt mass- och energiflöden. Därifrån utarbetas möjliga sektorkopplingar och framtida tillgång till kraft och el. Frågan - varför sektorkoppling av elnätet kommer att behövas, ses i Malmö-sammanhanget och hur en ökning av el-efterfrågan kan resultera i perioder med låga och höga elpriser beskrivs.

En möjlig omvandling av området i fråga avbildas för 2030 och 2045 med ytterligare sektorkopplingar på plats och aktiva, både för ett högt och lågt elpris för respektive tidsram. Slutligen avslutas rapporten med en utblick efter ytterligare optimering av systemet i fråga och hur resultaten från projektet kan fortsätta i en större skala. Det har funnits ett uttalat mål inom detta projekt att leda till relevant framtida samarbete mellan intressenterna och framtida projekt som kan ta konceptet som startas inom detta projekt närmare realisering. Ett sådant alternativ är deltagandet i en ansökan om ett EU-projekt delvis baserat på resultaten från det aktuella projektet.

1 Introduction

This project investigates the opportunities for increased dispatchable electricity production in the North harbour area in the city of Malmö through renewable gases. This is done, in part, through the establishment of a network of relevant stakeholders with the aim of contributing to the development of the concept in the area. The concept has a strong foundation in coupling of different sectors and the project contains the mapping of current and future potential flows of mass and energy between the stakeholders within the area. This mapping enables the development of a simplified mass- and energy balance for the coupled systems and also highlights points for potential additional infrastructure to enhance the integration of the whole system being studied in this project.

The project has been led in a cooperation between the Region of Skåne (RS) and IVL the Swedish Environmental Research Institute (IVL).

1.1 Purpose and goal

The main purpose of this project is to identify and discuss a concept for the site (the North harbor area in Malmö) regarding increased dispatchable electricity production and Power-to-gas made possible through deep sector coupling. The work towards this main purpose entails the establishment of a cluster of relevant stakeholders, both those that have activity within the area but also others that are deemed important for the main purpose in one way or another. Moreover, there is also a goal of this project leading to relevant future cooperation between the stakeholders and future projects that can take the concept started within this project closer to realization. One such option is the participation in an application for an EU-project partly based on the results from the project at hand.

Regular meetings have been held with the cluster to: i) map relevant flows of mass and energy in the area, both current and forecasted for 2030 and 2045, ii) identify possible couplings, interconnections and synergies within the system in question and iii) develop a basic mass and energy balance for the concept at the site. Work has been carried out by IVL and RS in between the stakeholder meetings and regular discussions have been had with the individual stakeholders to find out their main interest in the concept.

1.2 Challenges in the electricity supply of Malmö

The electricity supply to the southern parts of Sweden (electricity area SE3 and SE4) have been strained for some time. The most acute situation for the city of Malmö have recently been resolved through an agreement between the central stakeholders on a national level, but the challenge and need for additional capacity in the grid remains. As the base-load electricity production capability in these areas (mainly in the form of nuclear power) is being phased out, the general picture will become even more emphasized; that electricity will mostly be produced in the northern parts of the country (in the form of hydro and wind), while part of the consumption will be in the southern parts of the country. This entails that available electric power will not be enough for the main consumption areas and that voltage and frequency consistency can no longer be taken for granted. Malmö is located almost on the southernmost tip of Sweden and is a city of rapid expansion and is hence very susceptible to potential negative consequences of a failing electricity supply.

It is the responsibility of the Swedish TSO (Transmission System Operator) for the power grid, Svenska Kraftnät (SVK), to make sure that the electrical power supply system always can cope with disturbances and to rapidly reinstate normal operation of the system. The disturbance reserve ensures that SVK lives up to this responsibility and today consists of an installed capacity of 1350 MW in the electricity areas SE3 and SE4. The disturbance reserve is today mostly composed of gas turbines. The situation past 2030 will likely entail a national electrical power supply system with a higher ratio of intermittent power.

1.3 The North Harbour area of Malmö

The North harbor area in Malmö has some rather unique prerequisites making it suitable for a concept like the one developed within this project. First, it is a rather small geographical area located at the north-north-eastern edge of the city. Secondly, it contains no residential areas and only a rather small amount of office and administrative buildings, the area is strongly focused on mostly light to medium industry. Thirdly, the area is a cluster of waste handling and energy production. Fourthly, connections exist to the electricity grid, the national transmission grid for gas and the district heating network for the city.

Thus, the area presents a compelling opportunity to create a strong cluster of stakeholders working together towards the aim and purpose of this project. The stakeholders that have been included in the discussions and work in this project (apart from IVL and RS, mentioned above) consists of:

- **Sysav**, that runs the central waste handling and incineration facility for the city in this area and has boilers that need to be renewed in the upcoming years (around 2030).
- **Uniper**, that owns the land where the decommissioned gas combi power plant Öresundsverket is located with a direct connection to the Swedish transmission grid for gas. They also own and operate an existing facility within the disturbance reserve, consisting of two gas turbines, located in the area.
- **VA SYD**, that operate Sjölunda wastewater treatment plant in the area which faces a major renovation and vast expansion in capacity over the next decade.
- **E.on**, that operate a biogas upgrading facility from sewage sludge from the Sjölunda wastewater treatment plant in the area and also owns the district heating network for the city. (The part of E.on that operates the upgrading facility has recently been acquisitioned by St1.)
- **Nordion Energi**, that is the Swedish TSO for gas, so also the owner and operator of the DSO (Distribution System Operator) grid for gas in the city.
- **RWE Renewables**, that owns facilities for renewable electricity production in the southern parts of Sweden.
- **The city of Malmö**, that with its new Environmental program has set the climate mission for 2030, aligning with the Paris agreement limiting global warming to 1,5-2°C. With the mission set Malmö has created an ambitious new energy strategy in order to accelerate the transition of the local energy system. The City of Malmö is heavily engaged in several networks and discussions around this specific subject as

well as adjacent areas, such as the role of Sysav in the future energy system (which they own together with other municipalities).

2 Background

The strain on the electrical power supply to the city of Malmö has become more apparent in recent years and discussions are currently being held on all levels of society (local, regional, and national) how to address this pressing issue. The energy office at the Region of Skåne (RS) is involved in these discussions and has identified the North harbor area in Malmö as a hotspot for potential additional dispatchable electricity production. IVL has conducted several projects in the field of Power-to-Gas/Liquids, electrofuels, synthetic fuels, hydrogen, and carbon capture in recent years e.g. [1]. The energy office at RS and the energy group at IVL have a continuously ongoing dialogue on potential projects, and in those discussions the foundation for the project at hand were laid.

2.1 The concept of sector coupling

The Swedish energy system is set in rapid change; electricity is produced in new ways, the society is becoming more electrified, and industrial sectors are re-setting for renewable production techniques, which put-together poses new challenges for the energy system. Increased coupling of sectors can provide new opportunities to address the challenges and hence contribute to a more carbon-neutral and resource efficient energy system.

A recent study on sector coupling published by The Swedish energy research agency[2] defined sector coupling as: The technology that connects at least two energy systems and transforms one energy carrier to another. The benefits of sector coupling can for example include balancing of the electricity system, reduced emissions or recovery of energy flows that would otherwise be lost.

The feasibility study mentioned above examined six different types of sector couplings to assess their potential of being realized in the timeframes 2025, 2030 and 2040. The study also includes a section on further processing of hydrogen to various forms of electrofuels or synthetic chemicals. The aim of that study was that the results should be used in future, more detailed studies, which the project at hand is an example of.

2.1.1 Types of sector couplings

This section is adapted from the recent report on sector coupling by The Swedish energy research agency[2].

Gas turbines in the electrical system. This sector coupling includes the potential of gas turbines to contribute with power during strained hours in the electricity system and to solve bottleneck problems. Gas turbines are a conventional technology that already exists in the electrical system today for this purpose. For this sector coupling to become economically feasible, higher electricity

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[1] Large scale bio electro jet fuel production integration at CHP-plant in Östersund, Sweden, IVL B 2407, Fagerström et. al

[2] Linda Dyab, Pia-Maria Bondesson, Håkan Sköldberg, Johan Holm, Magnus Brolin, Sofia Nyström, Rebecca Samuelsson Sektorkoppling för ett mer effektivt energisystem - Förstudie gas tillsammans med el och fjärrvärme, Rapport 2021:764, Energiforsk media, ISBN 978-91-7673-764-4

prices are deemed necessary, or a change in electricity market design, for example the implementation of s strong capacity market. Nevertheless, the technical function and potential of the sector coupling are assessed to be good as flexible electricity production will be needed to a greater extent when more variable electricity production is introduced into the market.

Gas fired co-generation. This sector coupling can contribute with great benefit, both as a general producer of heat and electricity, and at the same time as it contributes to electricity power security in some of Sweden's larger cities. However, investment in new facilities is unprofitable under current conditions, but operation of existing ones may continue, especially as problems linked to electricity network restrictions are predicted to be greater. Imbalances in the electricity system can lead to a model for power revenues, which benefits the gas-fired co-generation. How much existing plants will be used in the future depends on the supply and price of gases and the price picture that will apply in the markets for electricity and district heating in the future.

Gas boilers in the district heating system. This sector coupling consists of simpler hot water boilers in district heating systems that are fired with gas. These plants have low investment costs but high variable costs, which makes them attractive for peak production. An investment in gas boilers must be weighed against other alternatives which include other types of production or flexibility in the form of storage. Each district heating system's unique composition of production facilities will determine whether a gas boiler is the most profitable investment.

Electricity production through hydrogen. This sector coupling is hydrogen-powered gas turbines and fuel cells that can contribute to peak load production for the electricity system. The analysis shows that both technologies have good technical potential and approximately equal investment and operating costs. However, better financial coverage is required for this sector coupling to be economically feasible in the short term, as these are far too expensive in comparison with existing technology (conventional gas turbines). With the EU's hydrogen investment plan, the price of hydrogen is expected to fall at the same time as stricter climate requirements will be introduced. Towards 2040, this, together with a more favorable market design, can enable realization for this type of solutions.

Balance regulation by electrolyzers. This sector coupling consists of electrolyzers contributing with balance regulation by increasing or decreasing the electricity consumption, to provide support services in the balancing power market. The starting point is that the electrolyzers are part of an industrial process and dimensioned, with or without a hydrogen storage, to be able to operate in the balancing power market while the amount of hydrogen required for the industrial process is not compromised. Under these prerequisites, the analysis shows that there is technical and economic potential to operate electrolyzers in this way, both now and in the future.

Residual heat from hydrogen production by electrolysis. This sector coupling entails that residual heat from electrolyzers possibly can be used in district heating (DH) systems. In the short term, the conditions are generally mediocre due to a small temperature difference between the DH flow temperature and the residual heat temperature, but local differences are likely. In the longer term, the conditions improve, which can be explained by one or more reasons such as that the electrolyzer capacity increases, that high-temperature electrolyzers take place on the market, or that conventional district heating is converted to / replaced by low-temperature district heating.

Other. It is possible to further refine hydrogen through methanation, which means that existing infrastructure and technology can be used to a greater extent without modification.

The table below summarizes the various sector connections' estimated realization potential for 2025, 2030 and 2040.

Table 1. Realization potential for several sector couplings for the years 2025, 2030, 2040. 3 equals high potential, 2 equals medium potential, and 1 equals low potential. Re-structured from [3].

Sector coupling	Assessment		
	2025	2030	2040
Gas turbines in the electrical system	2	2	3
Gas fired cogeneration	2	2	2
Gas boilers in the district heating system	2	2	2
Electricity production through hydrogen (gas turbine)	1	2	2
Electricity production through hydrogen (fuel cell)	1	2	2
Balance regulation by electrolyzers	3	3	3
Residual heat from hydrogen production by electrolysis	2	3	3

2.2 The concept of Power-to-X

PtX (Power-to-gas/-liquids) could be used for seasonal storage of energy. However, the conversion sequence electricity-hydrogen-electricity gives low overall efficiency, 30-40% if fuel cells are used for electricity production and even lower with gas turbines. The remaining energy is in the form of heat. Hydrogen can be produced for industrial applications, or be converted to methane and stored in the gas grid or used as biofuels or energy carrier in industry. An electrolyzer has good properties for constituting an adjustable load in the electricity grid because it reacts immediately to input electricity, regardless of electrical power. The technology for using the gas network as an energy storage has been tested in several places in Europe, both in the form of hydrogen and as methane after a consecutive methanation process. Only a few percent of hydrogen can be discharged into the gas network in Sweden and methanation of the hydrogen gas is therefore a prerequisite for increasing the potential for energy storage in the national TSO existing gas grid for methane. To form methane or other biofuels from hydrogen gas, carbon dioxide is also required, preferably of biological origin. To achieve efficiency for the concept, the residual heat from the processes needs to be used in some meaningful way. Compared to other energy storage technologies, synthetic natural gas (SNG) in the form of methane from P-t-G is superior in terms of energy management, energy carrier transport and capacity, as is depicted in the Ragone plot in figure 1. The Ragone plot describes the specific energy versus specific power; in other words, how

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[3] Linda Dyab, Pia-Maria Bondesson, Håkan Sköldberg, Johan Holm, Magnus Brolin, Sofia Nyström, Rebecca Samuelsson Sektorkoppling för ett mer effektivt energisystem - Förstudie gas tillsammans med el och fjärrvärme, Rapport 2021:764, Energiforsk media, ISBN 978-91-7673-764-4

much energy that can be stored and how fast dissipation of that energy can occur. To some extent, the energy storage technologies have complementary functions. An imaginary line can be created between the bottom left corner at flywheels (power quality section) to batteries (bridging power) to the top right corner with power to gas (energy management)[4]

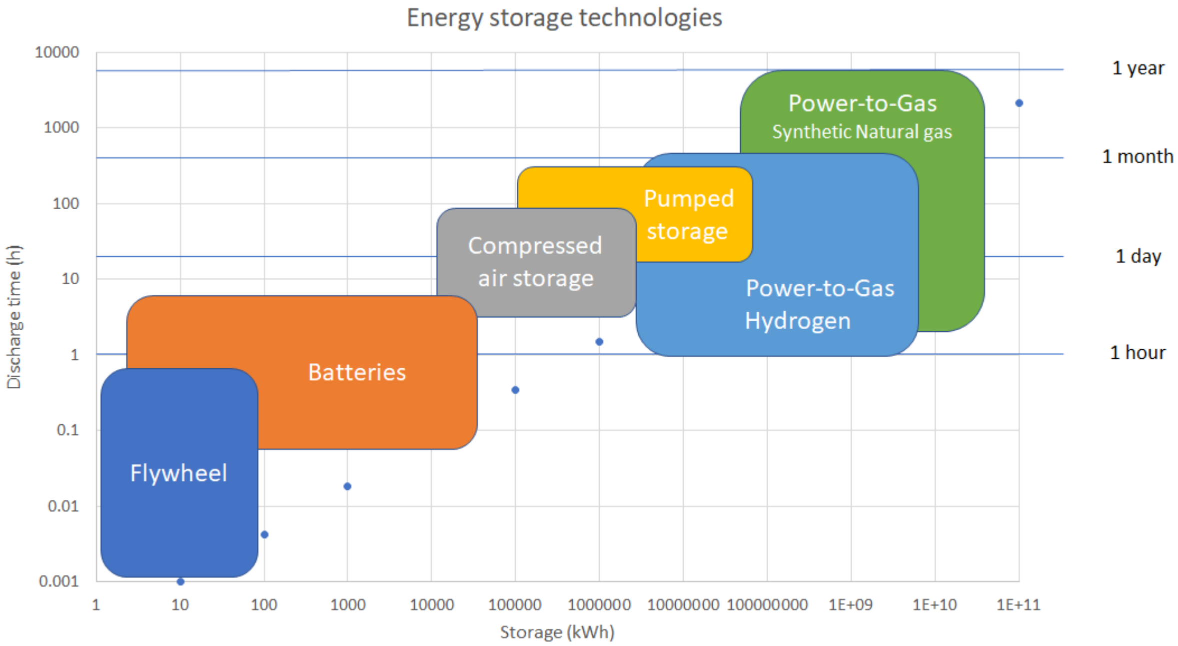

Figure 1. Ragone plot of energy storage technologies. Remade with inspiration from [4].

2.3 Other relevant projects and endeavours

There are several other projects and endeavors that correlate or overlap with the project at hand in one way or another. For example, the city of Malmö is currently developing an Energy strategy that will pave the way for the future energy landscape in the city and its close surroundings. The project at hand corresponds to several of the specific goals currently being discussed within this strategy and the directional movements that are likely to take place after the energy strategy is implemented in the near future. Another endeavor that is currently being made is the so-called Climate transition Malmö, which is the forum and arena for the efforts of the city to drastically decrease its territorial climate emissions to lineate clearly with the Paris agreement. The project at hand is very well aligned with the work in this arena. Moreover, E.on is currently performing trials on deep geothermic within the city limits which potentially could supply between approximately 10-50% of the district heating needs of the city. And, as mentioned above, the Swedish energy research agency recently published a report on sector couplings related to gases, which is an important source of information for the project at hand. Finally, there are several other projects ongoing which have some type of bearing on the project at hand; locally, regionally, nationally, and internationally, at the EU-level. Specifically, there are several on-going and finished symbiosis-projects in the North Harbor area, indicating an interest from the stakeholders at the site for the subject. Two examples are: "Delad energi är dubbel energi" (Shared energi is double the energy), and "Hållbar hamn" (Sustainable seaport).

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[4] Joakim Holmberg Bårman, Power to Gas- Background & techno-economic scenario analysis at Söderåsen Biogas plant. Master of Science Thesis EGI 2010:xxx, Royal Institute of Technology, Sweden.

3 Current situation

3.1 History of Malmö and the Harbour

Malmö is a city by the sea, and the sea has been a central part of the history of the city.

The growth of medieval Malmö, a name that literally means "sand hill", during the thirteenth century occurred for two main reasons. Firstly, due to its location just opposite the new city of Copenhagen on the other side of the straits of Öresund, Malmö became a convenient landing place for the maritime traffic between Copenhagen and the old archbishopric in Lund. Secondly it was a part of the herring market along the Öresund which was controlled by the Hanseatic League. During early autumn, the flat sand beaches were full of fishermen bringing their catches ashore and salting the herring in barrels. Malmö's location can be said to depend more on the conditions in and around the Öresund than on the surrounding countryside. This fact was the distinguishing feature of Malmö until the industrialization in the nineteenth century. [5]

By 1914, Malmö was one of the fastest growing cities in northern Europe with almost 100 000 citizens. It was also regarded as one of the leading industrial cities of Sweden with over 10 000 employees in more than 300 factories. The strong industry also meant that Malmö was one of the richest cities in Sweden. But during 1960s, the tide turned. First, the textile industry collapsed, and in the 1980s also the ship building industry. From the early 2000s sustainable urban development framed the new agenda and Malmö was lifted as a hub for knowledge. An important part of this was a new commercial/residential waterfront development. [5]

The city of Malmö has been named Sweden's best environmental municipality in 2021[6].

Looking at a map, the harbor area of Malmö makes up around 20-25% of the city area. And during the decades the area has continuously expanded as more (non-waste) landfill has been added. The harbor is divided into different parts. The Western harbor, where the dockyards used to be located has transformed to a residential and commercial district and there are similar plans for the middle section of the harbor as well. The largest areas, the northern and north eastern parts are not likely to be in cooperated into the city-center anytime soon. The area in focus for the project at hand is the north-north eastern part of the harbor, the part furthest from the city-center. This is a place of industrial production, waste handling and energy production. The city of Malmö has concrete plans of keeping the area in question as an industrial zone for the foreseeable future. A map of the area is shown in figure 2.

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[5] Urban Historia, Accessed on 21-05-13, https://blogg.mah.se/urbanhistoria/history-of-malmo/

[6] Sveriges Radio p4 malmöhus, accessed on 21-05-14, https://app.retriever-info.com/go-article/00112620210511332403803/2137465/monitor/search?type=jwt

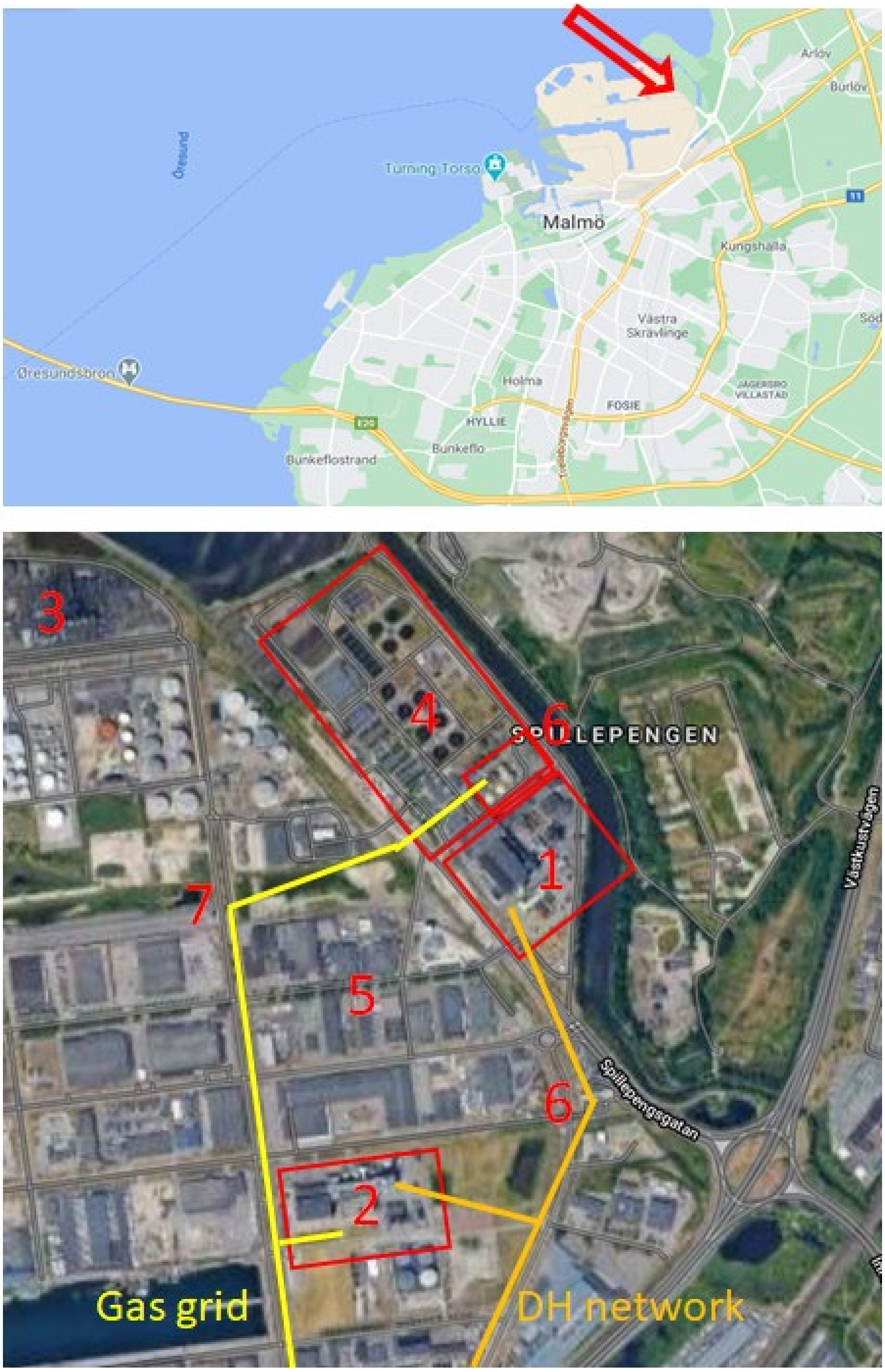

Figure 2. A map of the area in focus for this project. 1: Sysav, 2: Uniper, 3: RWE Renewables (outside map), 4: VA-Syd, 5: City of Malmö (as well as outside map), 6: E.On, 7: Nordion Energi. Re-worked from: google.se/maps

3.2 Current infrastructure

The North harbor houses several activities that potentially could benefit from sector coupling. Those that are included in the project are listed in this section, but there are more industries, installations and activities close to the area in question that could potentially also enjoy similar benefits from this concept. However, this project is limited in scope and sector couplings between the following is its primary focus.

3.2.1 Waste incineration plant

Sysav, Sydskåne's waste company, which was formed in 1974, has just over 300 employees and a turnover of approximately SEK 1 billion. In 2016, the publicly owned limited company was owned by 14 municipalities in southern Skåne: Burlöv, Kävlinge, Lomma, Lund, Malmö, Simrishamn, Sjöbo, Skurup, Staffanstorp, Svedala, Tomelilla, Trelleborg, Vellinge and Ystad.

Sysav's waste cogeneration plant is located at Sjölunda in Malmö. The company's waste cogeneration plant is one of the world's most advanced plants for incineration of waste with energy production. Of the sorted waste that was recycled in 2015, 98 percent as materials and energy. The remaining two percent was deposited for safe storage. Every year, Sysav delivers 60 percent of the district heating to Malmö and Burlöv. About 43 percent was recycled as other materials, such as woody material, metals, textiles and plastics, a part of which is re-used in its current form.

Sysav takes care of and recycles waste from households in southern Skåne. The subsidiary Sysav Industri AB handles industrial and operational waste, as well as household waste from other than the owner municipalities. Sysav has 16 recycling centers. Sysav also works to prevent the amount of waste in various ways. [7]

3.2.2 Slurry production plant

Sysav also operates an integrated slurry production plant at Sjölunda. From the incoming food waste, almost 50 ktons of slurry were produced, which is currently converted into biogas externally, corresponding to approximately 4.5 million liters of petrol.

3.2.3 Combi gas power plant

Uniper owns Öresund Power Plant/Öresundsverket and the land around it. Öresundsverket in Malmö is a combined cycle power plant that has produced heat and electricity from natural gas. The plant was originally built 1953 and has since been expanded in 1957 and 1964 but was mothballed in 1993.

At the beginning of the 2000s, the plant was rebuilt as a response to the increasing need for electricity in southern Sweden that the closure of Barsebäck's nuclear power plant entailed. The rebuilt plant was inaugurated in December 2009. The natural gas-fired CHP plant had a production capacity of 440 MW of electricity and 250 MW of heat. This means that the power plant could supply up to 3 TWh of electricity to the Nordic electricity system, which can be compared with the current electricity use in Malmö, which amounts to approximately 2 TWh per year. In addition to electricity, Öresundsverket could also supply approximately 1 TWh of heat per year to Malmö's district heating network. Normally, however, the power plant was not intended to be in operation all year but instead being started when the need for district heating or electricity increased, mainly during the winter. In a crisis with a shortage of natural gas, the Öresundsverket could also be fired

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with diesel oil. In 2017, the owners announced that the power plant will not be in commercial operation for the time being due to market situation with low electricity prices. In 2019, a decision was made to liquidate the plant. [8] The area on which the powerplant is located has been classified as a national interest for energy production.

3.2.4 Disturbance reserve power plant

Uniper also operates a disturbance power plant in the area consisting of two gas turbines powered by gas oil.

3.2.5 Wastewater treatment plant

VA SYD operates Sjölunda wastewater treatment plant which is in the northern part of Malmö harbor and receives wastewater corresponding to 7 full baths per second (approx. 1350 l / s). The wastewater currently comes from most of the city of Malmö as well as Burlöv, and parts of Lomma, Staffanstorp and Svedala municipalities. The plant, which was put into operation in 1963, has about 300,000 people connected to it and is thus currently one of Sweden's largest wastewater treatment plants. [9]

VA SYD is currently performing a major overhaul of the plant. The project, which in short is called Sustainable wastewater treatment, is a solution for a future regional wastewater treatment plant for up to seven municipalities: the member municipalities Burlöv, Lomma, Lund and Malmö, but also and Kävlinge, Staffanstorp, Svedala which are offered to connect to the wastewater treatment plant and become members of VA SYD. These municipalities have common challenges in that societal development, climate change and environmental legislation require the expansion and modernization of sewage treatment plants. The picture is the same throughout Sweden. Several major expansions are already underway, including in Stockholm, Kalmar and Kristianstad.

The project, Sustainable wastewater treatment in a growing Skåne, includes four related projects that are connected:

- a new wastewater treatment plant, Nya Sjölunda
- a tunnel from central Malmö to transport wastewater to Sjölunda
- a tunnel from Lund to transport wastewater to Sjölunda
- environmental permit for the entire system in the three projects above

At the beginning of 2022, the member municipalities of VA SYD will make an implementation decision. [10]

Linked to the WWTP, E.On currently have several heat pumps installed that draws heat from the wastewater and raising the temperature in a connection to the district heating network from 55 to

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[8] Uniper, Press release 2018-06-08, https://www.mynewsdesk.com/se/uniper/pressreleases/uniper-ansoeker-om-tillstaand-foer-permanent-staengning-av-oeresundsverket-i-malmoe-2534593

[9] Välkommen till Sjölunda reningsverk, Accessed on 20-05-13, https://www.vasyd.se/-/media/Documents/Informationsmaterial/Vatten-och-avlopp/Avloppsreningsverk-och-pumpstationer/SjolundaReningsverk2014-webb.pdf

[10] VA-Syd, Accessed on 21-05-13, https://hallbaravloppsrening.vasyd.se/Artiklar/om-Hallbar-avloppsrening

65˚C. The installation produces between 160 and 200 GWh heat per year, corresponding to around 8-10% of the district heating need in the city of Malmö. The plant has a COP of 3.5.

3.2.6 Biogas upgrading plant

E.on is operating the biogas upgrading plant in the area. The plant currently only takes gas from Sjölunda WWTP close by but could be expanded to treat greater amounts of raw biogas. The upgrading plant employs a pressure swing adsorption technique to produce high-grade biomethane, today primarily used as transport fuel.

3.3 Current mass and energy flows

I order to assess the potential for sector coupling for the system in the area the current mass and energy flows of the present included facilities were mapped. This was done in dialogue with representatives from the respective stakeholders in this project. Table 2 shows the current flows of mass and energy in the system. Besides the facilities presented in Table 2, the system also contains the electricity grid, the gas grid, and the district heating network.

Table 2. Current mass and energy flows in the system, mapped within the project.

Incoming flow	Facility	Outgoing flow
Municipal solid waste (599 kton)	Waste incineration plant	District heating (1 486 GWh)
		CO_2 (608 kton (40% fossil))
		Electricity (199 GWh)
Organic solid waste (64 kton)	Slurry production plant	Slurry (50 kton, external)
Electricity (appr. 1000 MWh)		
CH_4 (0 MWh)	Combi gas power plant	District heating (O MWh)
		Electricity (O MWh)
		CO_2 (O ton)
Gas oil (208 ton)	Disturbance reserve power plant	Electricity (613 MWh)
		CO_2 (750 ton)
Raw biogas (3.6 MNm³)	Biogas upgrading plant	CH_4 (17 GWh)
Electricity (800 MWh)		CO_2 (522 ton)
Wastewater (39 Mm³ ton)	Wastewater treatment plant	Purified water (39 Mm³)
Electricity (17 GWh)		Raw biogas (5.5 MNm³, 63% CH_4)
Electricity (50 GWh)	Heat Pumps	District heating (180 GWh)

3.4 Possible sector couplings

Based on the assessment of current mass and energy flows, a block diagram of the system could be produced and the presence of already existing couplings between the facilities clarified. Moreover, this also enabled the assessment of where in the system additional sector couplings could potentially be established. In figure 3, the facilities, the mass- and energy flows and the already present couplings of the current system is shown.

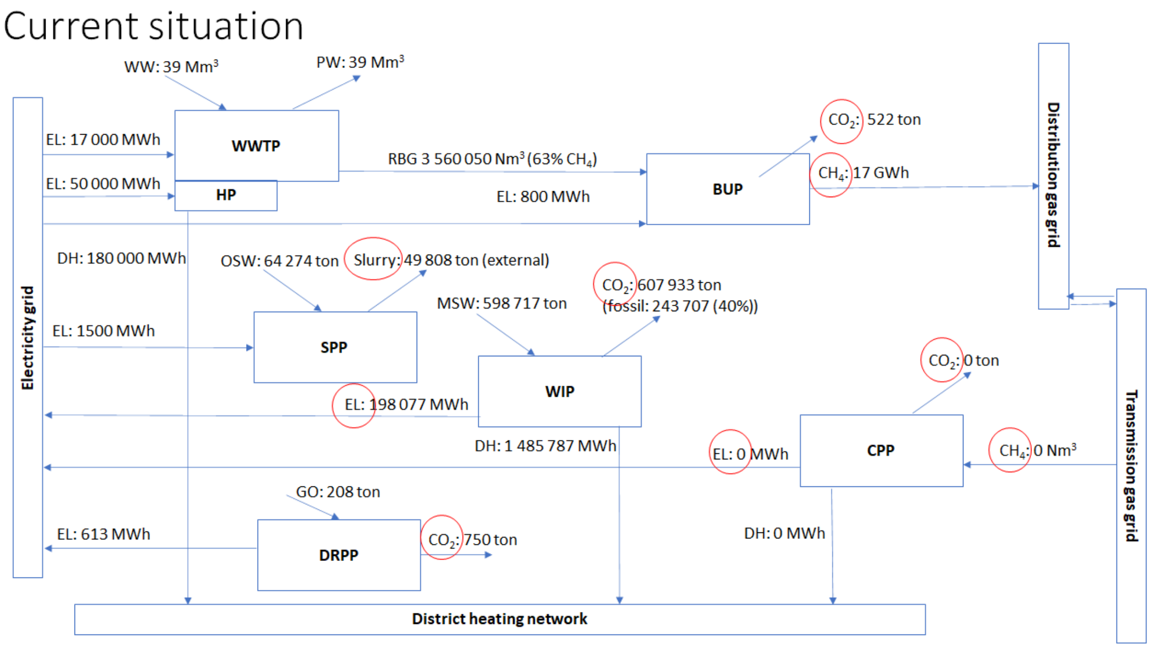

Figure 3. Block diagram of the current situation in the area of interest for this study. Red circles highlight spots where potential additional sector couplings could be established and integrated in the system. WIP = Waste incineration plant, MSW = Municipal solid waste, DH = District heat, EL = Electricity, SPP = Slurry production plant, OSW = Organic solid waste, CPP = Combi gas power plant, DRPP = Disturbance reserve power plant, GO = Gas oil (diesel), WWTP = Wastewater treatment plant, WW = Wastewater, PW = Purified water, RBG = Raw biogas, BUP = Biogas upgrading plant, HP = Heat pumps. See Appendix A for a larger version.

4 Future access to power and electricity

4.1 Why sector coupling the electricity power grid will be needed

The first section of this chapter is largely based on the recently published report by the Swedish energy research agency on sector coupling. [11]

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[11] Linda Dyab, Pia-Maria Bondesson, Håkan Sköldberg, Johan Holm, Magnus Brolin, Sofia Nyström, Rebecca Samuelsson Sektorkoppling för ett mer effektivt energisystem - Förstudie gas tillsammans med el och fjärrvärme, Rapport 2021:764, Energiforsk media, ISBN 978-91-7673-764-4

One reason why sector coupling between gas, electricity and district heating systems are attracting particularly great interest right now is the major electricity system challenges created by efforts away from fossil fuels and towards climate neutrality. Increased electricity use and more variable electricity production, together with declining capacity in planned electricity production and capacity restrictions in the electricity networks, are changing the conditions for the electricity power balance. To provide a picture of the electrical system conditions that constitute important external conditions for the sector connections proposed in this project, various aspects of the electrical system challenges are presented here. These are mainly based on analyzes, results and conclusions from the project NEPP's synthesis report, which deals with the "electricity power issue" in a broad sense. [12],[13],[14]

- Increased electricity use and more variable electricity production, together with less dispatchable electricity production, create power challenges - the need for top power and the balancing of the electricity system as well as local network capacity shortages.
- The paradoxical situation that there are smaller and smaller margins in terms of power in the electricity system at the same time as the export of electricity increases and reaches historically high levels.
- For a long time, the electrical system needed balancing solely on the basis of varying use, which was relatively easy to predict. Today, balancing is also added as a result of variable, difficult-to-forecast electricity production from wind and solar, which in 20 years' time will lead to twice as large a change in the net need per hour and per week compared with today.
- Today, no single stakeholder today has the long-term responsibility for ensuring that sufficient production capacity exists to meet electricity needs in the future. This raises questions about who will build planned electricity production and whether there will be any power to import when the system is strained the most.
- In the short term, local network capacity shortage is the most acute power challenge. If left untreated, it can hinder the growth of cities and regions. However, the concept of 'local network capacity shortage' can be misleading as the solution consists not only of network expansion, but also of measures at the production and user level.
- It is becoming increasingly cumbersome and time-consuming to build electricity networks, for example because of protracted permit processes. If this is not changed, the overall energy transition may be threatened.
- The power and flexibility needs are solved not only with production and networks, but also energy efficiency, demand flexibility and storage are growing in importance and the balance between all these types of measures is becoming increasingly important.
- The power challenges are not insurmountable. The electricity sector can meet a sharp increase in electricity demand in a long-term sustainable way. The measures and costs differ depending on the choices made in the electrical system development. The system cost of electricity increases, but not drastically.

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[12] NEPP: North European Energy Perspective Projects, https://www.nepp.se/om.htm

[13] NEPP: Eleffektfrågan - utmaningar och lösningar, 2020, https://www.nepp.se/pdf/Eleffektfragan.pdf

[14] NEPP: Färdplan fossilfri el – analysunderlag, 2019, https://www.nepp.se/pdf/energiforetagens_fardplan_fossilfri_el_analysunderlag.pdf

4.2 Increase in electricity demand

For a long time, 25-30 years, Swedish electricity use has been stagnant at about 140 TWh per year, including losses. A few years ago, around 2015, the general expectations were that electricity consumption would only increase moderately in the long term, to about 150 TWh in 2045. In recent years, however, expectations have been significantly raised, for example because of expectations of electrification of the transport sector, data server halls and the levels of use that various industries' roadmaps for fossil-independence have indicated. This has meant that there are now also scenarios that point to a sharp increase in electricity use, by 50 TWh or more in 25 years' time, to perhaps 190 TWh in 2045. Increased electricity use would at the same time increase the need for maximum power production. In a document to Energiföretagen Sveriges Färdplan El (The Swedish Energy companies roadmap for electricity) - which is based on a scenario with a sharp increase in electricity use - the maximum power requirement during a normal year is estimated to increase from the current 26 GW to 32 GW in 2045.[15],[16]

This figure presupposes a certain degree of flexibility in the additional electricity use. However, there is great uncertainty about the future use of electricity. Different scenarios for the year 2045 show a difference in electricity use of as much as 100 TWh, hence in the range 145 - 245 TWh. On the production side, there is already today, and in the long run in the scenarios with sharply increased electricity use, a very strong expansion of variable electricity production, mainly wind power but also solar. This leads to changed conditions to be able to meet the increasing need for power. The future power challenges do not consist “only” of ensuring power adequacy in the most strained operating situation, during a ten-year or twenty-year winter, for example, but a power and flexibility challenge in a broader sense. Thus, instead based on the overall power system challenges that are already experienced today or are foreseen in the long term. These are mainly two different types of challenges:

- Peak power requirements and balancing in the event of increasing electricity use together with more variable electricity production and phasing out of dispatchable power.
- Local network capacity shortage.

There are several operational cases that create challenges in such an electricity production mix as described in the first point, for example: i) very variable production and low use of electricity, and ii) little variable production and high use of electricity. In addition, iii) general challenges arise in all operational situations to maintain the balance and operational reliability of the system. In all three of these operating cases, there may be a lack of power and / or flexibility in the electrical system. The other main type of challenge is that capacity constraints in the electricity networks occasionally make it difficult to supply certain cities and regions with electricity. Malmö is a typical example of this. [15]

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[15] Linda Dyab, Pia-Maria Bondesson, Håkan Sköldberg, Johan Holm, Magnus Brolin, Sofia Nyström, Rebecca Samuelsson Sektorkoppling för ett mer effektivt energisystem - Förstudie gas tillsammans med el och fjärrvärme, Rapport 2021:764, Energiforsk media, ISBN 978-91-7673-764-4

[16] NEPP: Färdplan fossilfri el – analysunderlag, 2019, https://www.nepp.se/pdf/energiforetagens_fardplan_fossilfri_el_analysunderlag.pdf

4.3 Low electricity price

When the wind is blowing, the water reservoirs are well filled, the temperatures are well above freezing and the electric power system are fully operational – all should be fine, also in a future scenario with a higher share of intermittent power production. In fact, in such a case, there will be a surplus of both electric energy and power and hence, the electricity price will be low, or even negative. Negative prices are usually reflecting insufficient interconnections and/or some generating capacity lacking the technical flexibility or economic incentive to reduce production. A case like this is more likely to dominate the further north you go in Sweden, but it will also be valid in the very south of the country. In discussions with the stakeholders engaged in the project at hand, a reasonable assessment of when a scenario like this will be valid is deemed to be around 80% of the time.

A sector coupled system could in such a scenario primarily be used to transform readily available electricity to something transferrable in time and space. In other words, something can be produced that can be stored and transported for usage at a time where electrical power is not readily available to the same extent, and the price of electricity is higher, and at a place where it is sought after.

The choice of an electrolyzer to produce hydrogen from electrical energy and water is a rather obvious choice. For this project, a PEM-type electrolyzer is suggested due to its very short ramp-up-and-down time, its ability to produce high purity hydrogen and it relatively high technical maturity. Several other projects in the pipeline towards implementation are also looking closer at PEM-type electrolysis as their primary choice for hydrogen production technology[17]. The electrolyzer could also be scaled in such a way as to provide valuable balancing services to the electricity power system.

However currently, pure hydrogen is not easily storable nor transportable and hence, the coupling of a P-t-X unit such as a methanation facility can be employed. Such a unit will also need access to large amounts of CO_2, preferably at a highly concentrated point source for ease of capture, and for the final product, methane, to have as good emission characteristics as possible the origin should be biogenic. Therefore, a biogas production facility coupled with an expanded biogas upgrading facility is suggested. Those would provide both sources of biomethane and CO_2 with very good climate characteristics in highly concentrated streams. The produced methane, both from the upgrading facility and the methanation ditto can then be inserted to the transmission grid for gas and used in another occasion and location. This would also provide the additional benefit of increasing the degree of renewability in the Swedish gas grid as a whole. If a new production facility for biogas is constructed, it would affect the current user of the slurry. There is also the option of transporting the slurry to an existing biogas production facility with a connection to the transmission grid for gas. In this case, the gas from the slurry could still be used at the site, since both places have grid connections. However, additional transport of slurry is needed and potential for sector coupling is being lost, lowering the overall efficiency of the coupled system in the North Harbor area.

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[17] Large scale bio electro jet fuel production integration at CHP-plant in Östersund, Sweden, IVL B 2407, Fagerström et. al.

4.4 High electricity price

When the electrical power system is strained in one way or another, either from lull, previous drought, cold weather or malfunction, there will be a shortage of available power in the city of Malmö and the electricity prices can become very high. Effects like this will be more common, and more severe the further south you go in Sweden. Despite the general difficulties of predicting the future, the stakeholder group of this project assess that a situation like this may be prevalent around 20% of the time in a near future.

A sector coupled system could in such a scenario primarily be used to provide electrical power to meet demand, right there and at that moment.

As described above in this report, there are several different sector couplings that could be used for this purpose. In the present case, a gas turbine solution is suggested to take the role of dispatchable electricity production. This is due to the ability of such a facility to provide large amounts of power at a very short notice. Given the availability of renewable gas in the vicinity, the primary fuel of the turbines is suggested to be methane taken directly from the TSO grid. Potentially, in a more visionary approach, an electricity production solution based around some version of oxy-fuel combustion, like the Allam-Fetved cycle, could be employed. However, this type of technology is deemed to be mature enough for this no sooner than past 2030.

5 2030

The stakeholder group engaged in the project at hand suggested that two timeframes were used for the predictions employed in this report. First, a more realistic approach for what a sector coupled system could look like in the North harbour of Malmö in the year of 2030. This system is completely based on available and mature technologies for the individual facilities and could in principle be realized starting today, given the economic prerequisites would be met.

For 2030 no significant changes in the electrical power systems that affect the power supply to Malmö is expected to have been realized. The deep geothermal experiment (EGS) in Malmö are not to have affected the possibilities to offsetting residual heat in the district heating network in any significant way. According to Nordion Energi and co-partners in the recent published report about a pan-European hydrogen grid, such a system could possibly have been constructed linked to Malmö sometime between 2030 and 2045[18]. This is expected to be implemented to a large enough extent to be used as an asset for storage and transport for the hydrogen produced by the electrolyser in the system in focus for this project. The wastewater treatment plant is expected to have come close to finished in their plans for expansion and will have incorporated oxygen usage in their treatment process. The waste incineration plant is expected to handle similar amounts of waste as today and produce similar amounts of heat and electricity. Carbon capture is expected to be partly implemented at this plant capturing around 60% of the released CO_2 at an electricity consumption of 80 GWh. The district heating temperature is expected to be largely unchanged compared to the current status.

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[18] Extending the European Hydrogen Backbone – A European hydrogen infrastructure vision covering 21 countries, 2021, Creos, DESFA, Elering, Enagás, Energinet, Eustream, FGSZ, Fluxys Belgium, Casgrid Finland, Gasunie, GAZ-SYSTEM, GCA, GNI, GRTgaz, National Grid, NET4GAS, Nordion Energy, OGE, ONTRAS, Plinovodi, Snam, TAG, Teréga

5.1 Additional units

For 2030 the following sector coupling units are suggested to be implemented:

- Biogas production plant (BPP) at the site based on the available slurry.
- Extended and renewed (possibly with the addition of new technology) biogas upgrading plant (BUP) based on the raw biogas from the BUP and the wastewater treatment plant producing biomethane and pure CO_2.
- Methanation plant (MP) producing methane as synthetic natural gas. Connected off-grid to the waste incineration plant for electricity. Scaled after the available pure CO_2 stream from the BUP.
- PEM Electrolyzer producing hydrogen at a low electricity price. Connected off-grid to the waste incineration plant for electricity. Scaled after the needed hydrogen in the methanation plant.
- Gas turbines (GT) producing electricity and providing power at high electricity prices. Scaled after deemed needed power in a modular solution (2 x 50MW) according to an expected usage profile discussed within the stakeholder group.
- Oxygen storage.
- CO_2 storage.
- H_2 storage depending on if H_2 grid is available or not.
- Heat storage as buffer.

5.2 Mass and energy flows

Table 3 shows the calculated incoming and outgoing mass-and energy flows for a sector coupled system as it is suggested for 2030.

Table 3. Mass and energy flows in the system for 2030, mapped within the project.

Incoming flow	Facility	Outgoing flow
Municipal solid waste (600 kton)	Waste incineration plant	District heating (1.5 TWh)
		CO_2 (600 kton)
		Electricity (200 GWh)
Organic solid waste (60 kton)	Slurry production plant	Slurry (50 kton)
Electricity (1.0 GWh)		
Water (3.1 kton)	PEM Electrolyzer	H_2 (282 ton)
Electricity (16 GWh)		O_2 (2.2 kton)
		Residual heat (70˚C) (6.3 GWh)
H_2 (280 ton)	Methanation plant	CH_4 (3.1 GWh)
CO_2 (1.5 kton)		Water (1 .3 kton)
Electricity (570 MWh)		Residual heat (280˚C) (6.9 GWh)
CH_4 (200 GWh)	Gas turbines	Electricity (105 GWh)
		CO_2 (105 kton)
		RH (600˚C) (105 GWh)

Wastewater (58 Mm^3) Electricity (19 GWh) O_2: 2.2 kton	Wastewater treatment plant	Purified water (58 Mm^3) Raw biogas (5.9 MNm^3, 63% CH_4)
Slurry (49 808 ton) Electricity (1 472 MWh)	Biogas plant	Raw biogas (4.5 MNm^3, 65% CH_4) Digestate (50 kton)
Raw biogas (10.5 MNm^3) Electricity (2 353 MWh)	Biogas upgrading plant	CH_4 (50 GWh) CO_2 (1.5 kton)
Electricity (50 GWh)	Heat Pumps	District heating (180 GWh)

5.3 Low electricity price system

The primary function of the sector coupled system in a low electricity price scenario is to convert the electrical power to something movable in time and space. Based on the calculations of possible mass- and energy flows 2030, a block diagram of the system could be produced including additional couplings between the facilities, compared to today. In figure 4, the facilities, the mass- and energy flows of the activity a potential 2030-system would have in a low electricity price scenario is shown.

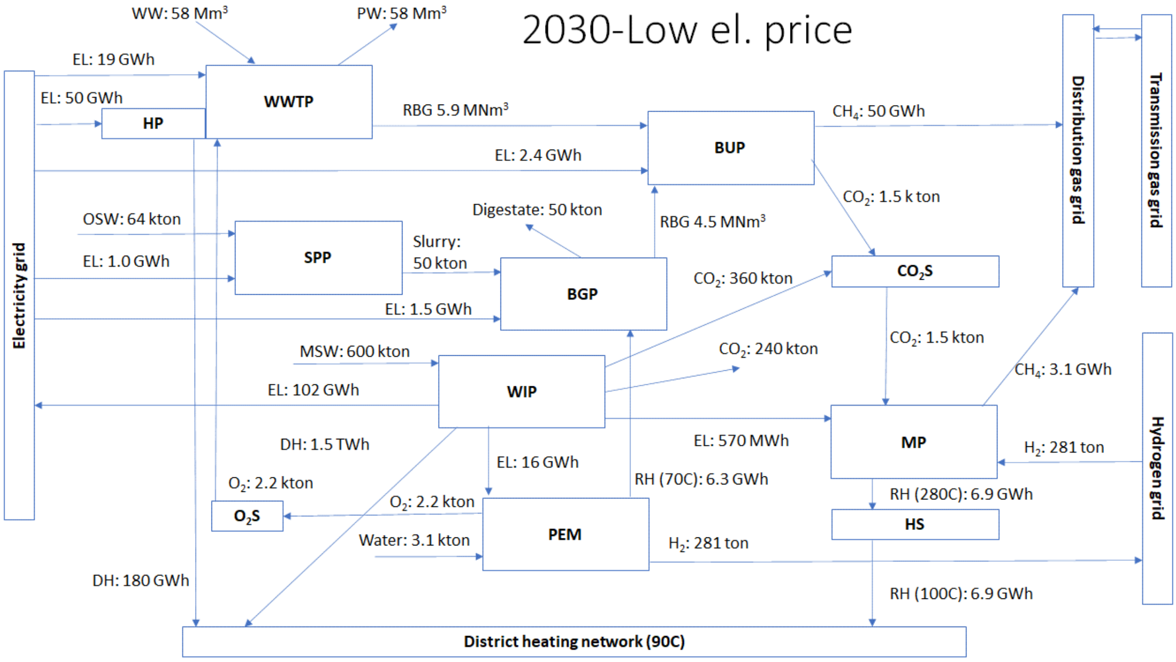

Figure 4. Block diagram of the 2030-system in the area of interest for this study, for a low electricity price scenario. WIP = Waste incineration plant, MSW = Municipal solid waste, DH = District heat, EL = Electricity, SPP = Slurry production plant, OSW = Organic solid waste, PEM = PEM electrolyzer, RH = Residual heat, MP = Methanation plant, WWTP = Wastewater treatment plant, WW = Wastewater, PW = Purified water, RBG = Raw biogas, BUP = Biogas upgrading plant, BGP = Biogas plant, CO_2S = CO_2 storage (local), O_2S = O_2 storage (local), HS=heat storage (local), HP = Heat pumps. See Appendix A for a larger version.

5.4 High electricity price system

The primary function of the sector coupled system in a high electricity price scenario is to provide electrical power to meet demand. Based on the calculations of possible mass- and energy flows 2030, a block diagram of the system could be produced including additional couplings between the facilities, compared to today. In figure 5, the facilities, the mass- and energy flows of the activity a potential 2030-system would have in a high electricity price scenario is shown.

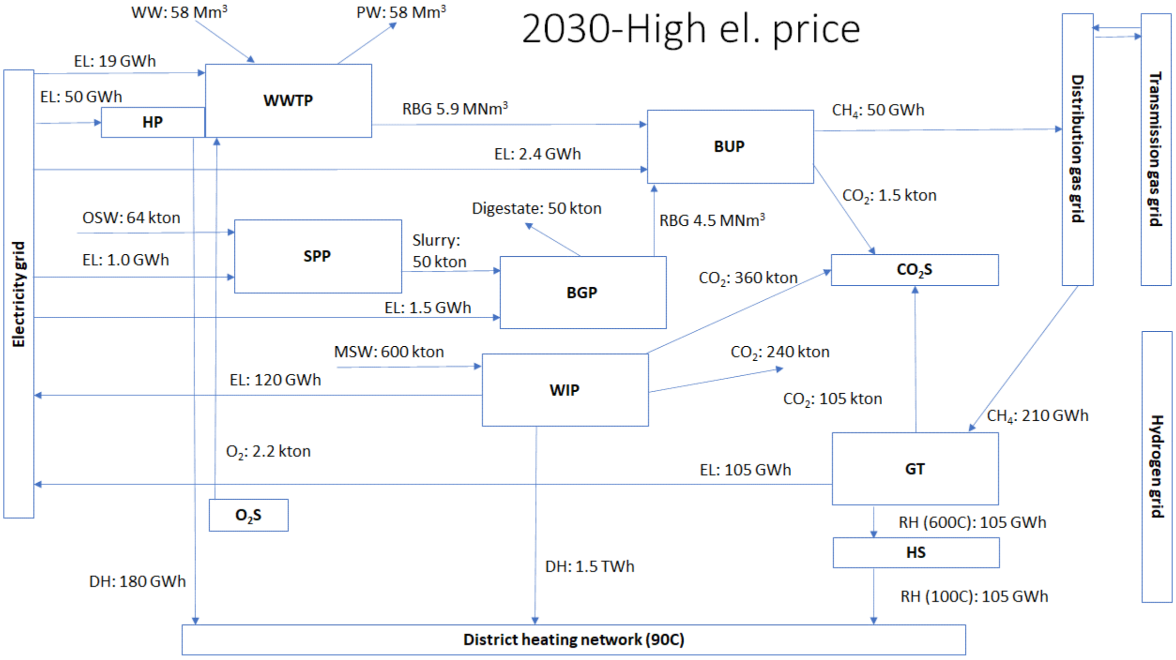

Figure 5. Block diagram of the 2030-system in the area of interest for this study, for a high electricity price scenario. WIP = Waste incineration plant, MSW = Municipal solid waste, DH = District heat, EL = Electricity, SPP = Slurry production plant, OSW = Organic solid waste, GT = Gas turbine, RH = Residual heat, WWTP = Wastewater treatment plant, WW = Wastewater, PW = Purified water, RBG = Raw biogas, BUP = Biogas upgrading plant, BGP = Biogas plant, CO_2S = CO_2 storage (local), O_2S = O_2 storage (local), HS=heat storage (local), HP = Heat pumps. See Appendix A for a larger version.

6 2045

The second timeframe is a more visionary approach for what a sector coupled system could look like in the North harbour of Malmö in the year of 2030. This system is partly based on technologies for the individual facilities not yet currently mature and the scenarios for 2045 is thus more uncertain.

For 2045 some changes in the electrical power systems that affect the power supply to Malmö are expected to have been realized. What those could entail is not considered within the scope of this study but the amount of available electricity in a low-price scenario is expected to have increased drastically enabling expanded electrolyser capacity. The deep geothermal experiment (EGS) in Malmö are not to have affected the possibilities to offsetting residual heat in the district heating network in any significant way. The pan-European hydrogen grid is expected to have been realized, at least in the geographical areas of concern here. The wastewater treatment plant is expected to have been fully expanded and incorporates oxygen for aeration as well as for ozone-treatment. The waste incineration plant is expected to handle similar amounts of waste as today and produce similar amounts of heat and electricity. Carbon capture is expected to be extended with more efficient technology at this time, capturing around 80% of the released CO_2 at an electricity consumption of 60 GWh. Additionaly, an oxy-fuel solution is suggested to have taken a role within this facility. The district heating network is suggested to have been transformed to a low-temperature network.

6.1 Additional units

In this more visionary timeframe, the waste incineration plant is suggested to have been partly converted into oxy-fuel operation. A vast expansion of electrolyser capacity is suggested, in-line with a movement towards hydrogen as an energy carrier in general in society. The methanation is just slightly expanded compared to 2030. The gas turbines have been converted to hydrogen operation. The biogas related facilities are slightly expanded compared to 2030 to cope with increased amounts from a fully expanded wastewater treatment plant.

6.2 Mass and energy flows

Table 4 shows the calculated incoming and outgoing mass-and energy flows for a sector coupled system as it is suggested for 2045.

Table 4. Mass and energy flows in the system for 2045, mapped within the project.

Incoming flow	Facility	Outgoing flow
Municipal solid waste (600 kton)	Waste incineration plant	District heating (1.5 TWh)
O_2: 200 kton		CO_2 (600 kton)
		Electricity (150 GWh)
Organic solid waste (60 kton)	Slurry production plant	Slurry (50 kton)
Electricity (1.0 GMWh)		
Water (304 k ton)	PEM Electrolyzer	H_2 (28 kton)
Electricity (1.6 TWh)		O_2 (220 kton)
		Residual heat (70˚C) (620 GWh)
H_2 (282 ton)	Methanation plant	CH_4 (3.1 GWh)
CO_2 (1.5 kton)		Water (1.3 kton)
Electricity (570 MWh)		Residual heat (280˚C) (6.9 GWh)
H_2 (210 GWh)	Gas turbines	Electricity (105 GWh)

		CO_2 (105 kton)
		RH (600°C) (105 GWh)
Wastewater (77 Mm^3)	Wastewater treatment plant	Purified water (77 Mm^3)
Electricity (21 GWh)		Raw biogas (6.4 MNm^3, 63% CH_4)
O_2: 20 kton		
Slurry (50 kton)	Biogas plant	Raw biogas (4.5 MNm^3, 65% CH_4)
Electricity (1.5 GWh)		Digestate (50 k ton)
Raw biogas (10.5 MNm^3)	Biogas upgrading plant	CH_4 (50 GWh)
Electricity (2.4 GWh)		CO_2 (1.5 kton)
Electricity (50 GWh)	Heat Pumps	District heating (180 GWh)

6.3 Low electricity price system

The primary function of the sector coupled system in a low electricity price scenario is to convert the electrical power to something movable in time and space. Compared to 2030 above, a movement towards hydrogen is suggested for 2045. In figure 6, the facilities and the mass- and energy flows of the activity a potential 2045-system would have in a low electricity price scenario is shown.

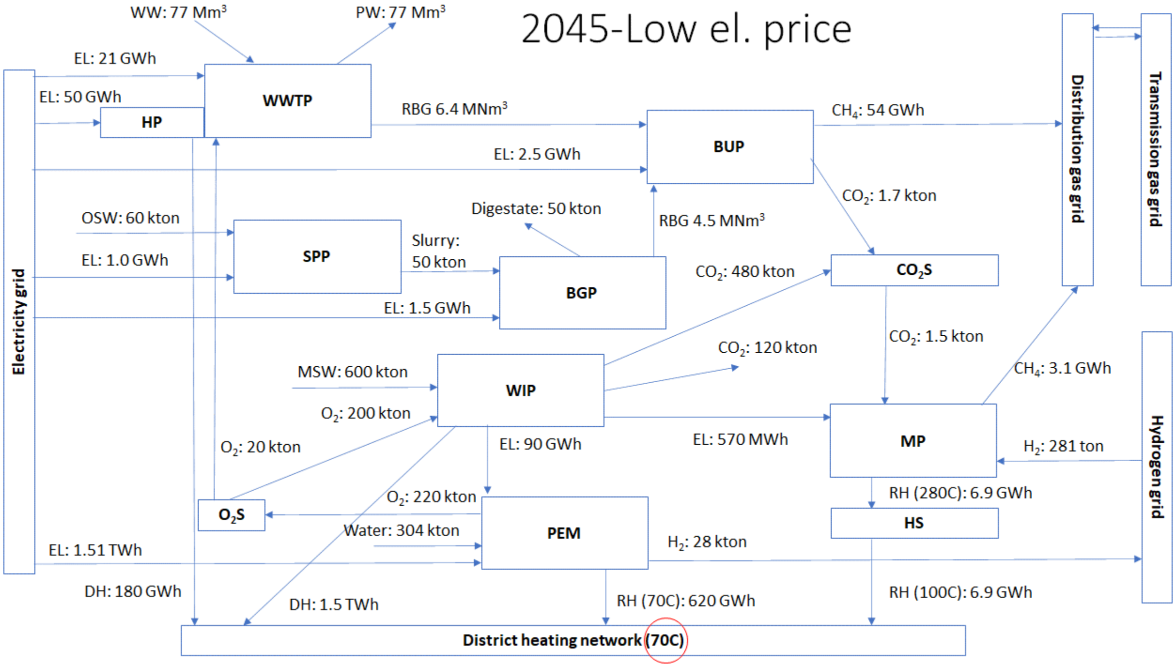

Figure 6. Block diagram of the 2045-system in the area of interest for this study, for a low electricity price scenario. WIP = Waste incineration plant, MSW = Municipal solid waste, DH = District heat, EL = Electricity, SPP = Slurry production plant, OSW = Organic solid waste, PEM = PEM electrolyzer, RH = Residual heat, MP = Methanation plant, WWTP = Wastewater treatment plant, WW = Wastewater, PW = Purified water, RBG = Raw biogas, BUP = Biogas upgrading plant, BGP = Biogas plant, CO2S = CO_2 storage (local), O2S = O_2 storage (local), HS=heat storage (local), HP = Heat pumps. Note the temperature for the district heating system enabling utilization of large amounts of residual heat streams into this system. See Appendix A for a larger version.

6.4 High electricity price system

The primary function of the sector coupled system in a high electricity price scenario is to provide electrical power to meet demand. Also, here a shift towards a more hydrogen-based system is suggested. In figure 7, the facilities and the mass- and energy flows of the activity a potential 2045-system would have in a high electricity price scenario is shown.

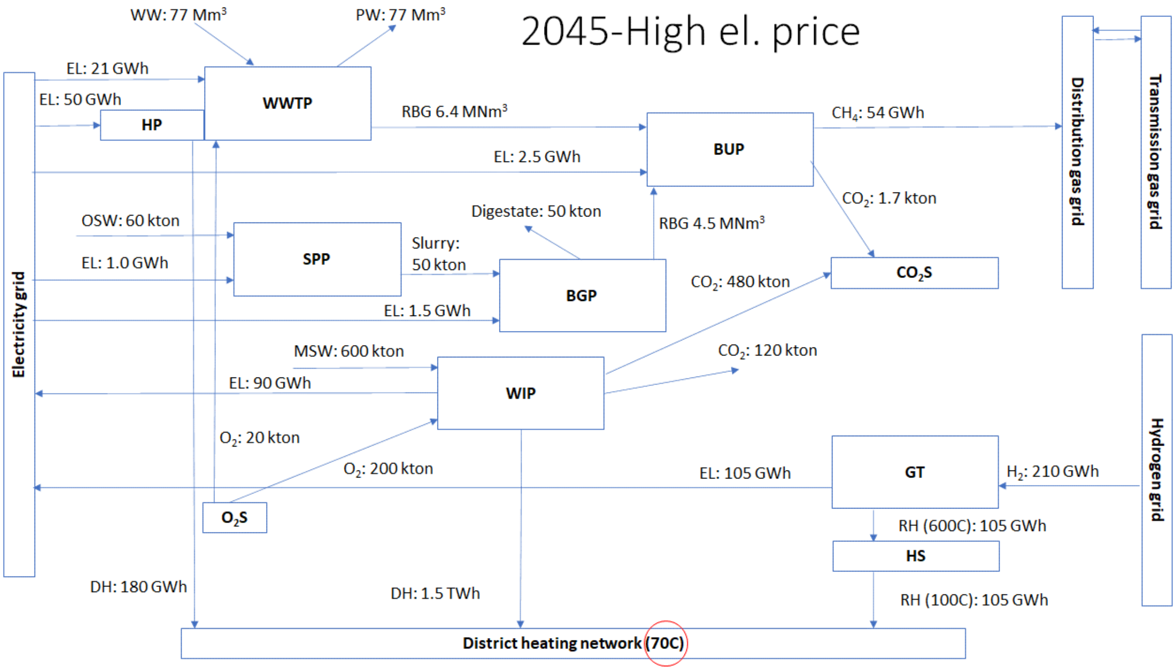

Figure 7. Block diagram of the 2045-system in the area of interest for this study, for a high electricity price scenario. WIP = Waste incineration plant, MSW = Municipal solid waste, DH = District heat, EL = Electricity, SPP = Slurry production plant, OSW = Organic solid waste, GT = Gas turbine, RH = Residual heat, WWTP = Wastewater treatment plant, WW = Wastewater, PW = Purified water, RBG = Raw biogas, BUP = Biogas upgrading plant, BGP = Biogas plant, CO_2S = CO_2 storage (local), O_2S = O_2 storage (local), HS=heat storage (local), HP = Heat pumps. Note the temperature for the district heating system enabling utilization of large amounts of residual heat streams into this system. See Appendix A for a larger version.

7 Optimization

This project has investigated the opportunities for increased dispatchable electricity production in the North Harbour area in the city of Malmö though renewable gasses. This has in part been done through the establishment of a network of relevant stakeholders with the aim of contributing to the development of the concept in the area.

Mass and energy flows have been mapped for today and for four future scenarios: low electricity price 2030, high electricity price 2030 and ditto for 2045. Several sector couplings are suggested to be implemented at the site to fulfil the purpose of the project. However, the study was limited in scope, time and budget, so advanced modelling, simulation and optimization of the system was out of the scope. So was the issue of CAPEX and OPEX for various parts of the system. This project instead relied on dialogue with the involved stakeholders to assess and perform basic calculations based on data in literature. Hence, there is definitely room for improvement in the selection of sector couplings and specificity in numbers in the results produced within the project.

8 Conclusions

This project has been led in a cooperation between the Region of Skåne (RS) and IVL the Swedish Environmental Research Institute (IVL). The main purpose of this project has been to identify and discuss a concept for the site (the North Harbor area in Malmö) regarding increased dispatchable electricity production and power-to-gas being made possible through deep sector coupling. The work towards this main purpose has entailed the establishment of a cluster of relevant stakeholders, both those that have activity within the area but also others that are deemed important for the main purpose in one way or another.

Within the project relevant flows of mass and energy in the area have been mapped, both current and forecasted for 2030 and 2045. Possible suitable couplings, interconnections, and synergies within the system in question have been highlighted and discussed. A basic mass-and energy balance for the concept at the site have been developed. Work has been carried out by IVL and RS in between the stakeholder meetings and regular discussions have been had with the individual stakeholders to find out their main interest in the concept.

As can be seen in the four block-diagrams for scenarios in this report, there exists high potential for sector couplings at the site. This is apparent from the several residual streams that have been integrated and used within the system to increase the overall system efficiency. Additionally, the system can both produce storable and transferable energy-carriers at times when electricity is available, as well as provide a considerable amount of dispatchable power, when needed. The overall emissions from the site has not increased because of this integration, rather the opposite. A more sustainable and flexible system for dispatchable energy production through renewable gasses can thus be implemented at The North Harbor area in Malmö.

9 Continuation

There has been a pronounced goal within this project to lead to relevant future cooperation between the stakeholders and future projects that can take the concept started within this project closer to realization. One such option is the participation in an application for an EU-project partly based on the results from the project at hand.

Appendix A

This appendix contains larger versions of the block diagrams of the 2030- and 2045-system. On separate pages.

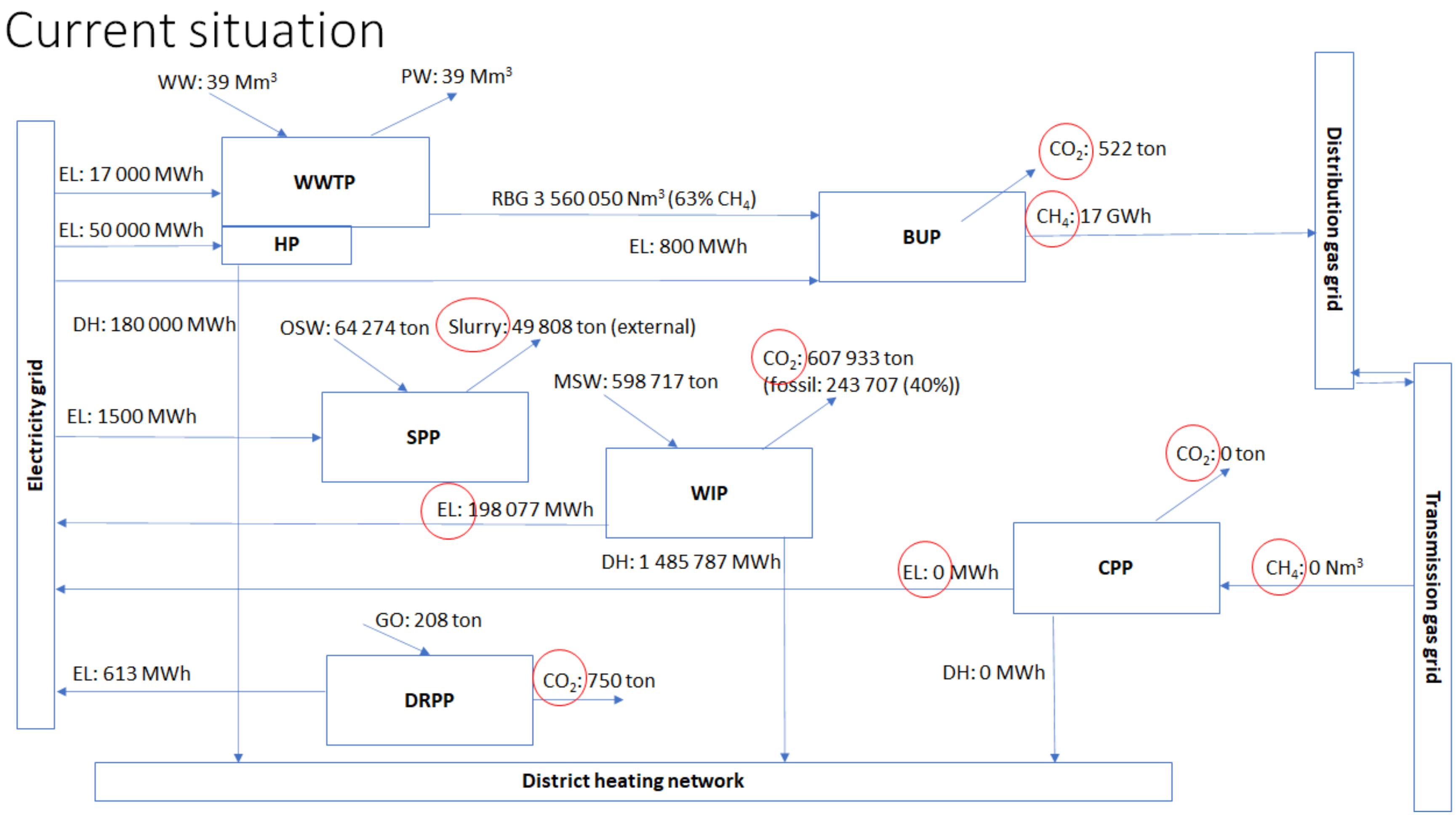

Figure 3. Block diagram of the current situation in the area of interest for this study. Red circles highlight spots where potential additional sector couplings could be established and integrated in the system. WIP = Waste incineration plant, MSW = Municipal solid waste, DH = District heat, EL = Electricity, SPP = Slurry production plant, OSW = Organic solid waste, CPP = Combi gas power plant, DRPP = Disturbance reserve power plant, GO = Gas oil (diesel), WWTP = Wastewater treatment plant, WW = Wastewater, PW = Purified water, RBG = Raw biogas, BUP = Biogas upgrading plant, HP = Heat pumps.

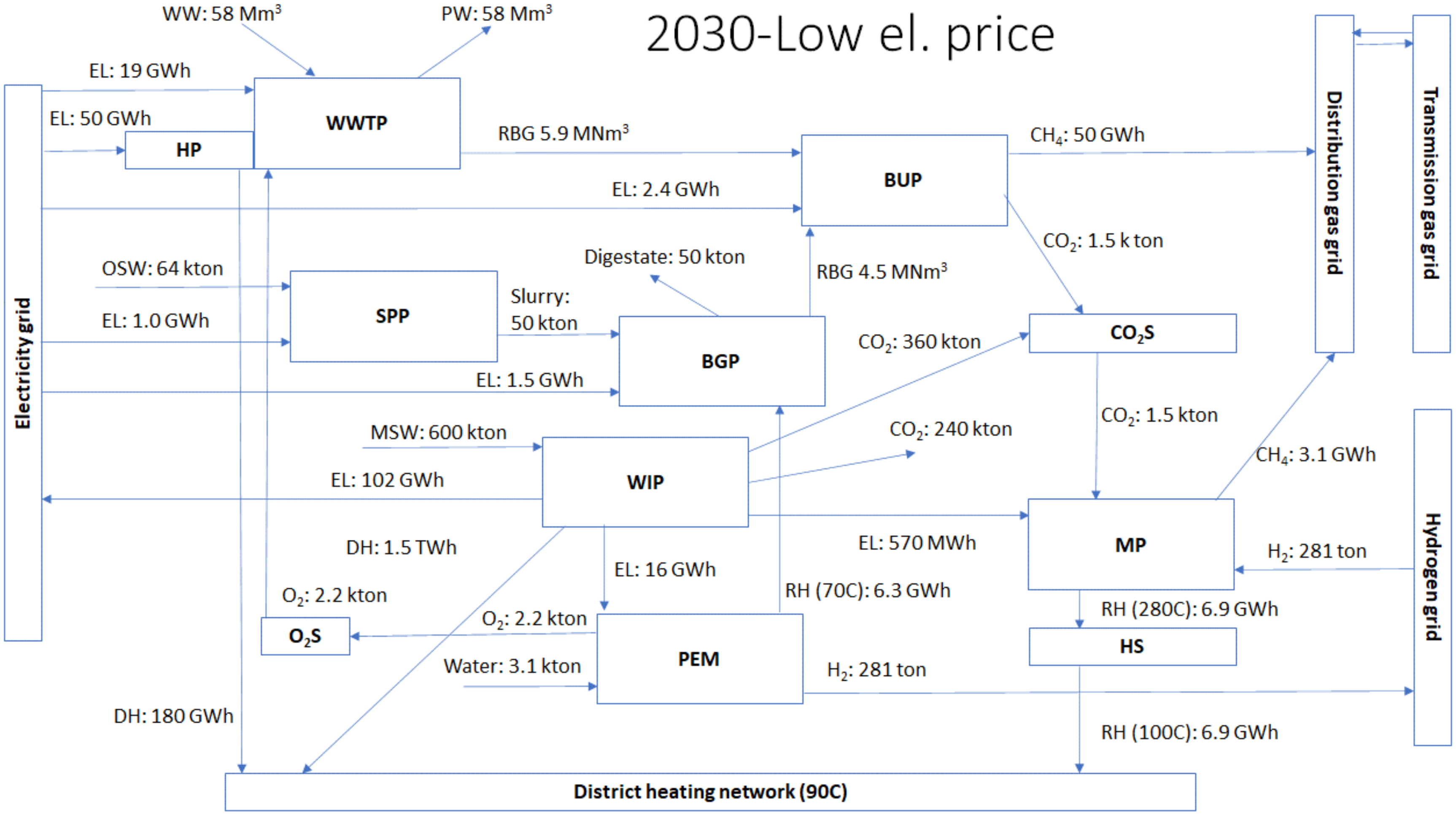

Figure 4. Block diagram of the 2030-system in the area of interest for this study, for a low electricity price scenario. WIP = Waste incineration plant, MSW = Municipal solid waste, DH = District heat, EL = Electricity, SPP = Slurry production plant, OSW = Organic solid waste, PEM = PEM electrolyzer, RH = Residual heat, MP = Methanation plant, WWTP = Wastewater treatment plant, WW = Wastewater, PW = Purified water, RBG = Raw biogas, BUP = Biogas upgrading plant, BGP = Biogas plant, CO2S = CO_2 storage (local), O2S = O_2 storage (local), HS=heat storage (local), HP = Heat pumps.

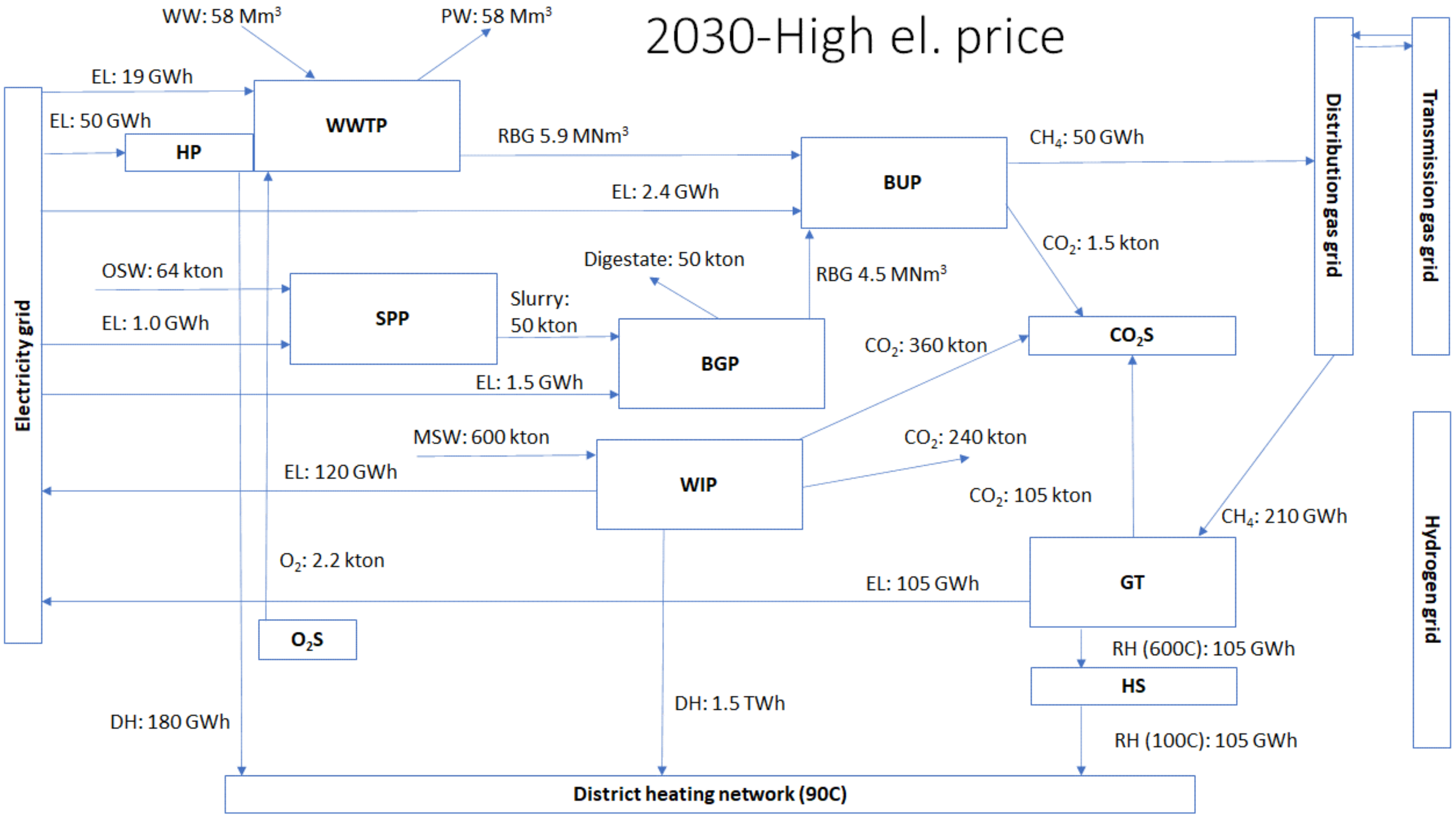

Figure 5. Block diagram of the 2030-system in the area of interest for this study, for a high electricity price scenario. WIP = Waste incineration plant, MSW = Municipal solid waste, DH = District heat, EL = Electricity, SPP = Slurry production plant, OSW = Organic solid waste, GT = Gas turbine, RH = Residual heat, WWTP = Wastewater treatment plant, WW = Wastewater, PW = Purified water, RBG = Raw biogas, BUP = Biogas upgrading plant, BGP = Biogas plant, CO_2S = CO_2 storage (local), O_2S = O_2 storage (local), HS=heat storage (local), HP = Heat pumps.

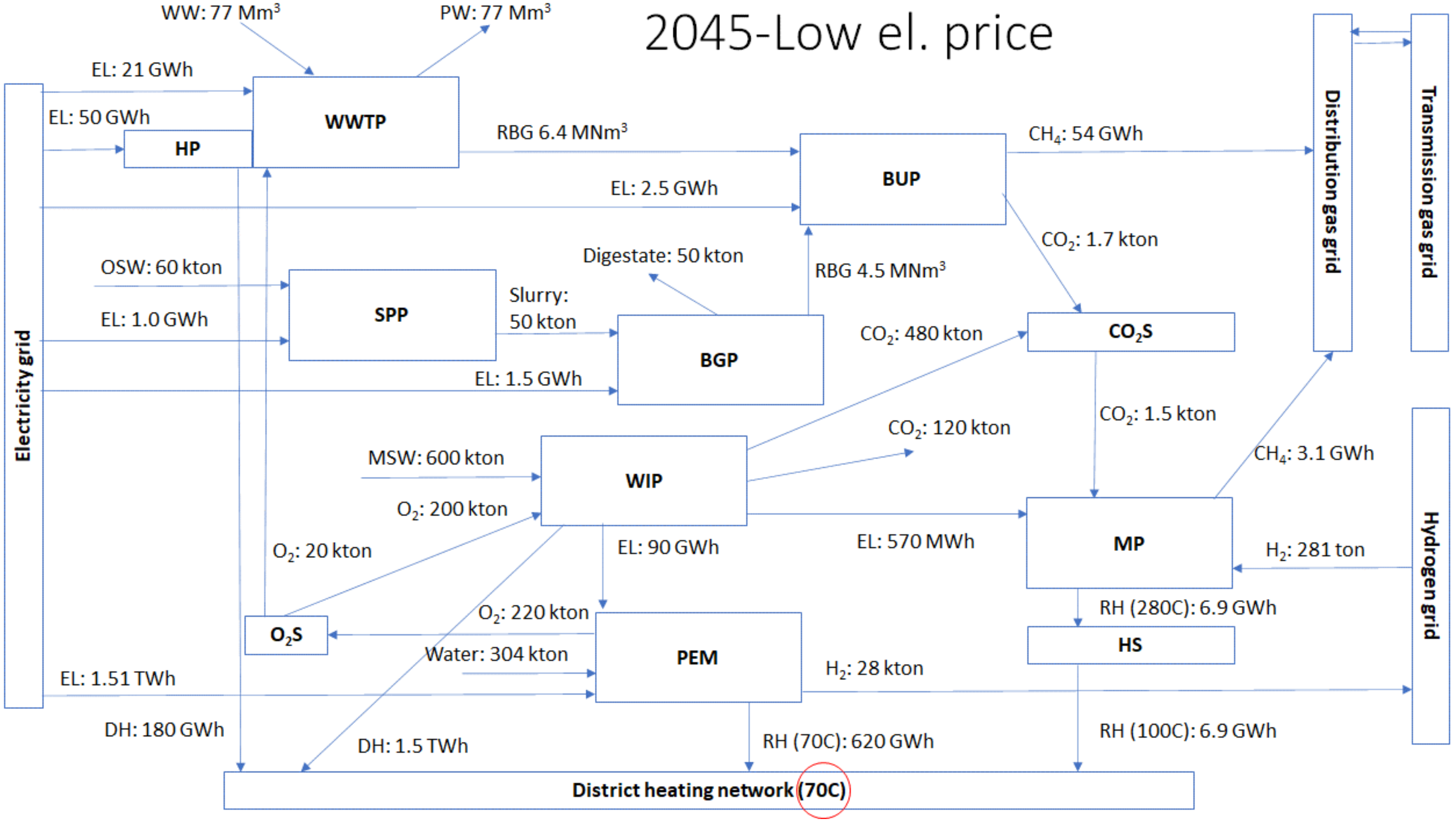

Figure 6. Block diagram of the 2045-system in the area of interest for this study, for a low electricity price scenario. WIP = Waste incineration plant, MSW = Municipal solid waste, DH = District heat, EL = Electricity, SPP = Slurry production plant, OSW = Organic solid waste, PEM = PEM electrolyzer, RH = Residual heat, MP = Methanation plant, WWTP = Wastewater treatment plant, WW = Wastewater, PW = Purified water, RBG = Raw biogas, BUP = Biogas upgrading plant, BGP = Biogas plant, CO_2S = CO_2 storage (local), O_2S = O_2 storage (local), HS=heat storage (local), HP = Heat pumps. Note the temperature for the district heating system enabling utilization of large amounts of residual heat streams into this system.

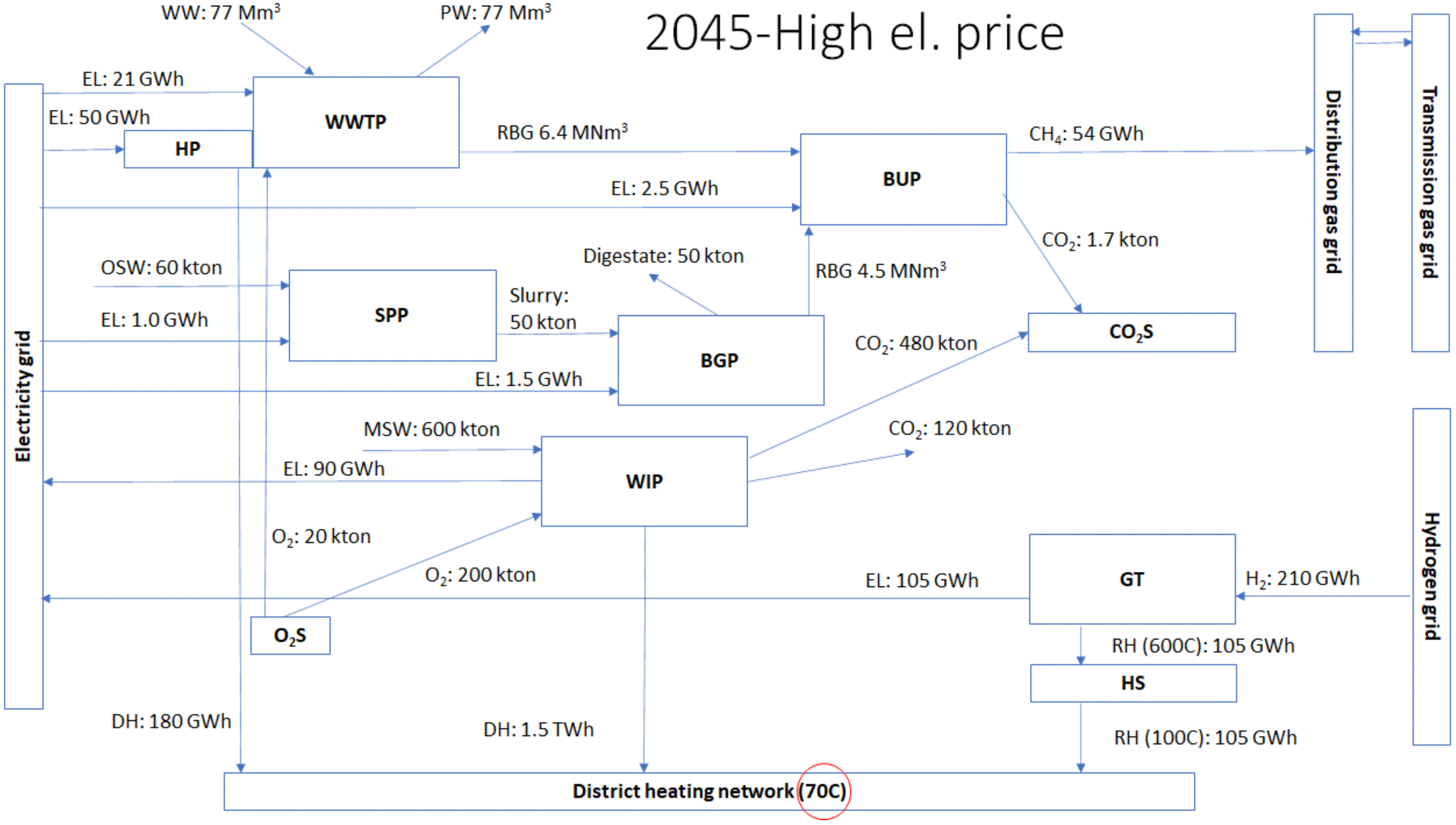

Figure 7. Block diagram of the 2045-system in the area of interest for this study, for a high electricity price scenario. WIP = Waste incineration plant, MSW = Municipal solid waste, DH = District heat, EL = Electricity, SPP = Slurry production plant, OSW = Organic solid waste, GT = Gas turbine, RH = Residual heat, WWTP = Wastewater treatment plant, WW = Wastewater, PW = Purified water, RBG = Raw biogas, BUP = Biogas upgrading plant, BGP = Biogas plant, CO_2S = CO_2 storage (local), O_2S = O_2 storage (local), HS=heat storage (local), HP = Heat pumps. Note the temperature for the district heating system enabling utilization of large amounts of residual heat streams into this system.

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