Local Energy Balance Assessment, Aalborg East

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Introduction

The aim of FLEXPOSTS (FLEXible energy POSitivity districTS) is to develop effective and replicable strategies to enhance the process of establishing Positive Energy Districts (PEDs). WP5 investigates how a PED can be established in the demo site Aalborg East in Denmark. The aim of this report is to carry out an assessment of the current energy balance in Aalborg East (D5.1), showing energy flows in different energy sectors. Modelling of current energy system was done in Energy Plan, investigating the possibility of using the concept of Positive Energy Districts in the development of future energy system of Aalborg East.

This report analysing the local energy balance in Aalborg East (D5,1) is the first report in WP5 on implementing a PED in Aalborg East. An overview of the reports that will be published about turning Aalborg East into a PED is presented below.

Textbox 1: Reports in WP5 – Demo Site Aalborg East

D5.1: Local energy balance assessment

D5.2: Barriers and potentials for implementing PEDs in Denmark

D5.3: Mapping of existing partnerships and networks

D5.4: Future energy scenarios in Aalborg East

D5.5: Business models and implementation strategy in Aalborg East

Aalborg East

Aalborg East is a developing suburb of the city of Aalborg, which was constructed in a rural area during the late 1960s and 1970s. This part of the city encompasses a diverse environment, featuring single-family houses, terraced housing, housing estates with blocks of flats, and a mix of owner-occupied and rented housing, with a population of approximately 20,000. Within the area code of Aalborg East (9220), prominent facilities such as a large cement factory (Aalborg Portland), a waste incineration plant, a university hospital, and the main University campus are located.

Figure 1. Geographical boundaries of Aalborg East

To highlight the scale of Aalborg East, Table 1 shows the population of the area, compared to the city, municipality and Denmark.

Table 1. Aalborg East statistical data

Area	Population	Reference
Aalborg East	Approximately 20 000	
Aalborg City	120 914	https://www.statistikbanken.dk/BY1
Aalborg Municipality	225 571	https://www.statistikbanken.dk/BY1
DK1 Electricity market	3 195 424	
Denmark	5 965 990	https://www.dst.dk/da/Statistik/emner/borgere/befolkning/befolkningstal

System boundaries

In terms of energy transition, urban areas are of exceptional importance. Local actions and local strategies are essential for climate change mitigation. In this regard, PEDs represent the important role in creation of future energy scenarious. Urban districts should be considered as part of larger entities, such as cities or country, rather than energy islands. Hence, it is crucial establish a clear definition, not only in geographical terms, but also in terms of energy balance. This is important because only in this way PEDs can have a role in achieving national and international goals and in establishing a just energy transition.

In this context, to meet the national climate goals of Denmark, it is crucial to define boundaries of the referent scenario for Aalborg East. The current scenarios are based on the fair distribution of energy demand and production within the country:

1. electricity demand is defined based on the Aalborg East population share of total electricity demand in Denmark;
2. Industry and transport demand are also defined based on a just principle, taking into account the population share of total fuel demand of these sectors, including international shipping and aviation;
3. heating demand is defined based on actual energy consumption in the households and industry in Aalborg East, both for individual and district heating.

A more detailed overview of the energy demands and production in Aalborg East is presented in the following chapters.

Energy demands

To identify the current energy demands of Aalborg East, Table 2 highlight energy and fuel needs excluding heat losses in different energy sectors and reference for each.

Table 2. Energy demands in different energy sectors (Aalborg East, 2022)

Sector	Demand [GWh]	Reference	Note
		Electricity	
Traditional electricity demand	148.34	Energinet.dk	Electricity demand in DK split by population share
Electric vehicles	N/A		Unavailable
Electricity for heating	2.41	Heat Atlas for Denmark	Based on heat demands and efficiency of HP/EB
		Heating	
District heating - households	33.07	Data from Aalborg Forsyning	Based on hourly time series
District heating - business	125.19	Data from Aalborg Forsyning	Based on hourly time series
Individual heating heat pumps	0.43	Heat Atlas for Denmark	
Individual heating - electric boiler	2.27	Heat Atlas for Denmark	
Individual heating - oil boilers	2.9	Heat Atlas for Denmark	
Individual heating - gas boilers	3.4	Heat Atlas for Denmark	
Individual heating - biomass	9.1	Heat Atlas for Denmark	
		Fuel for industry	
Oil demand	34.72		Average Danish consumption based on national statistics
Gas demand	23.64		Average Danish consumption based on national statistics
Coal demand	5.23		Average Danish consumption based on national statistics
Waste demand	1.39		Average Danish consumption based on national statistics
Biomass	15.01		Average Danish consumption based on national statistics
		Fuel for transport	
Road transport - Gasoline	49.46		Average Danish consumption based on national statistics

Road transport - Diesel	85.98		Average Danish consumption based on national statistics
Road transport - natural gas	0.27		Average Danish consumption based on national statistics
Road transport - biogas	0.08		Average Danish consumption based on national statistics
Road transport - Bioethanol	3.25		Average Danish consumption based on national statistics
Road transport - biodiesel	6.94		Average Danish consumption based on national statistics
Roadtransport - electricity	0.80		Average Danish consumption based on national statistics
Rail transport - diesel	2.36		Average Danish consumption based on national statistics
Rail transport - electricity	1.55		Average Danish consumption based on national statistics
Sea transport - LNG	0.08		Average Danish consumption based on national statistics
Sea transport - Fuel oil	0.80		Average Danish consumption based on national statistics
Sea transport - Diesel	4.67		Average Danish consumption based on national statistics
Domestic aviation - jetfuel	0.73		Average Danish consumption based on national statistics
International aviation - jetfuel	16.97		Average Danish consumption based on national statistics

Heating

Households and industry buildings in Aalborg East are usually connected to the district heating system. Less than 50% of households have individual heating systems, where the primary heating fuel is biomass (10 GWh/year) and natural gas (3.78 GWh/year). More details about fuel consumption in the heating sector, as well as overall efficiency are shown in Appendix 1. Characteristics of both individual households and district heating systems are shown in Table 3.

Table 3. Efficiency of the heating system in Aalborg East

	Value
Efficiency individual heat pumps	300%

Efficiency individual electric boilers	100%
Efficiency individual fuel boilers	90%
Efficiency district heating grid	79% (grid loss of 21%)

Energy Production

Energy production within Aalborg East is dominated by Nordværk, a waste incineration plant, and excess heat production from Aalborg Portland. However, Nordværk uses waste from the entire municipality of Aalborg, and delivers district heating to the entire Aalborg grid as well as electricity for the grid. Hence, only the population share of production and waste utilization in the energy production from Nordværk was accounted to be attributed to Aalborg East.

Apart from the electricity generated in waste incineration plant, there is no production of electricity within the geographical boundaries, either from power plants or from renewable energy sources. For Aalborg Portland, only the population share of excess heat was used, as it was delivered to the entire Aalborg DH grid.

Any surplus energy production will be exported as well as any missing production will result in an import of either heat or electricity.

Nordværk

As can be seen in Table 4, in the plant of Nordværk from the waste incineration, 22.53 GWh of electricity (15% of total electricity demand) and 77.77 GWh of heat energy (37% of total district heating demand) are produced in the early basis.

Table 4. Electricity and heat production in incineration plant Nordværk, Aalborg East share

	Value
Waste consumption (GWh)	96.3
Electricity production (GWh)	22.53
Heat production (GWh)	73.77

Electric efficiency	23.4%
Thermal efficiency	76.6%

Extra info on Aalborg Portland

Aalborg Portland belongs to the energy-intensive cement production industry. Based on the annual environmental report (Aalborg Portland Miljøredegørelse 2019), the total fuel used in Portland is shown in Table 5. Also, 320,849 MWh of electricity is used in Portland annually.

Table 5. Aalborg Portland Fuel consumption

Fuel	Consumption [t]	Consumption [GWh]*
Koks	77,072	627.3
Coal	236,984	1,591
Oil	4,644	1.02
Alternative	199,168	586.44
Total	**517,868**	**2,805.76**
*Conversion according to the heating value presented in Denish statistical data Energy Statistics 2021 (ens.dk). The HV for alternative fuel is the one for waste.		

Since one of the factory's goals is to reduce the carbon footprint, excess heat from Portland is supplied to citizens in Aalborg Municipality and internally at the factory (3.8 GWh). In 2019, the excess heat corresponded to the annual heat consumption of 25,000 households (420 GWh).

It is important to note that Portland's share of the industry's total energy requirements in Denmark (23,423.61 GWh) is 12%, and the population of Aalborg East represents 0.34%. In this regard, to establish justice the excess heat from Aalborg Portland in Aaborg East share is 49.62 GWh, and the energy demand for the Portland is included in the rest of the industry (see chapter "Energy Demand"). The population share of excess heat from the Aalborg Portland is 25% of the total district heating demand.

Building an EnergyPLAN model

The annual energy balance (Appendix 1) is converted to an input file for the energy system analysis tool EnergyPLAN.

EnergyPLAN will be used as a tool to further investigate the possibility of Aalborg East as a Positive Energy Districts. Thus, the objective in this section is to create a reference scenario, detailing the 2022 Aalborg East reference system.

Converting demands

To model in EnergyPLAN, technical parameters, such as total production demand, the capacity of installed energy supply units, and hourly distribution files are needed. Demand is divided into different energy sectors: electricity, heating (and cooling), industry, and transportation, as shown in Figure 2.

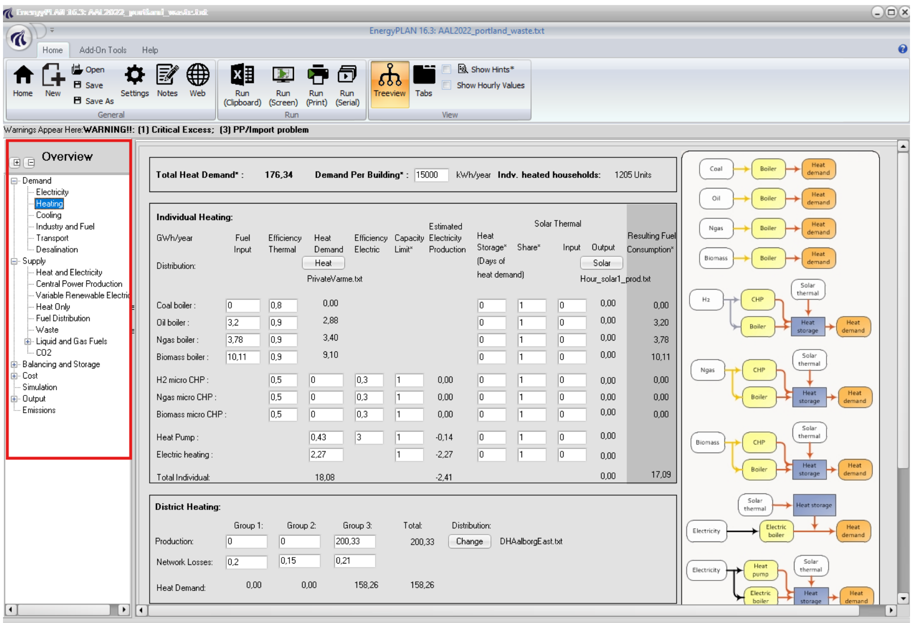

Figure 2. EnergyPLAN interface

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Total heating demand consists of individual households and district heating groups. In Aalborg East, district heating demand includes heating demand for households connected to the grid and office buildings and businesses. To define the total energy demand for district heating systems, network losses should be considered. According to the national statistics, heat pumps and electric and fuel boilers are used in individual households. All the information about the efficiency of the systems and fuel demand is defined in Table 3.

Industry fuel consumption is defined on a yearly basis according to the total fuel (coal, oil, gas, biomass, and hydrogen) used in the industrial processes. It should be noted that the biomass input includes not only biomass but also waste used in the industrial processes (16.4 GWh in total for Aalborg East).

The fuel consumption in the transport sector in the referent scenario for Aalborg East is divided by Jet fuel, Diesel, Petrol/Methanol, N gas, and electricity for electric vehicles. Also, the demand for biofuels, such as bioethanol and biodiesel, is included. Transport energy demand includes road, rail, sea transport, and aviation fuel, both for domestic and international aviation to achieve energy justice, as explained in Table 2.

Distribution files

Distribution files define the amount of energy produced or required per hour. The files have 8784 data points, one for each hour during the year. In the case of Aalborg East distribution for heating is obtained from Aalborg Forsyning ([Aalborg Forsyning: Privat]()), based on the actual heating consumption during 2022, both for households and businesses (Figure 2).

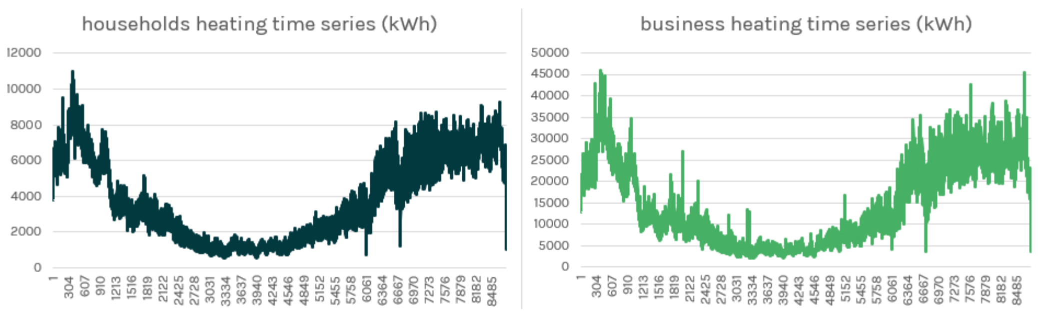

Figure 2. (District) heating demand in 2022

According to the actual electricity demand, distribution files are obtained from Energinet (Energinet).

It is assumed that distribution files for excess heat from Portland and waste incineration are constant.

Results: Aalborg East 2022

During the reference year, total fuel consumption in Aalborg East was 449.55 GWh, with the emission of 77 kt of CO_2. Since the energy demand for industry and transport was included, the share of RES is only 28 %, mainly biomass including waste (Figure 3).

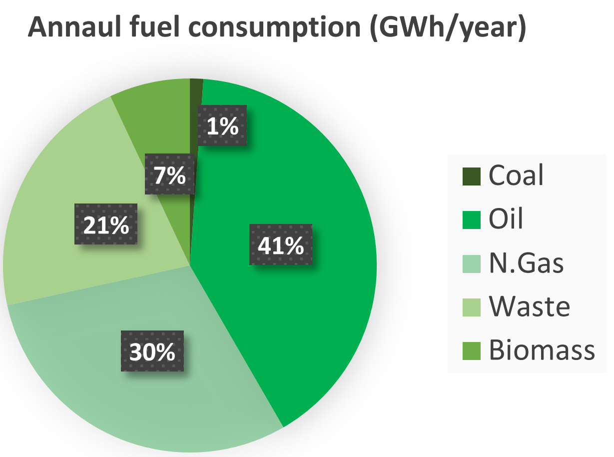

Figure 3. Annal fuel consumption

As previously explained, district heating is based on waste incineration, excess heat from Aalborg Portland and natural gas boiler for peak demand. The amount of energy (GWh/year) produced by different sources in district heating is shown in Figure 4.

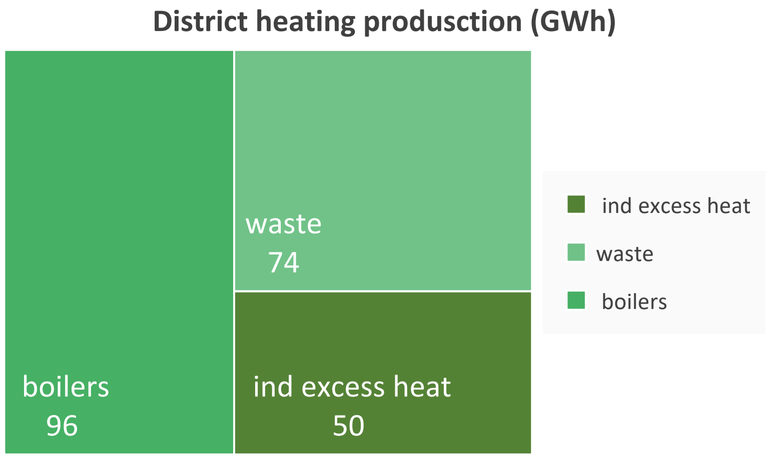

Figure 3. Yearly district heating production

Figure 5 shows the Sankey diagram of the Aalborg East reference energy system, created based on the principles outlined in this report. The Sankey diagram is an illustrated representation of energy flows and conversions, commonly used to illustrate the energy balance. This Sankey diagram of Aalborg East referent scenario presents the starting point for modeling of future energy systems of Aalborg East as Positive Energy District, and it is based on the input data and simulation in EnergyPLAN.

As can be seen, the transport and industry sectors are based on the consumption of fossil fuels, primarily oil and natural gas. When it comes to electricity, since there is no local production, apart from waste incineration plant (22,53 GWh), to fulfill the electricity demand of Aalborg East, 130.66 GWh of electricity was imported in the system.

The waste incineration plant also produces a significant share of district heating demand, as well as excess heat from industry. However, these energy producers are not sufficient for the total district heating demand of this part of the city, therefore the natural gas boiler is used to a significant extent.

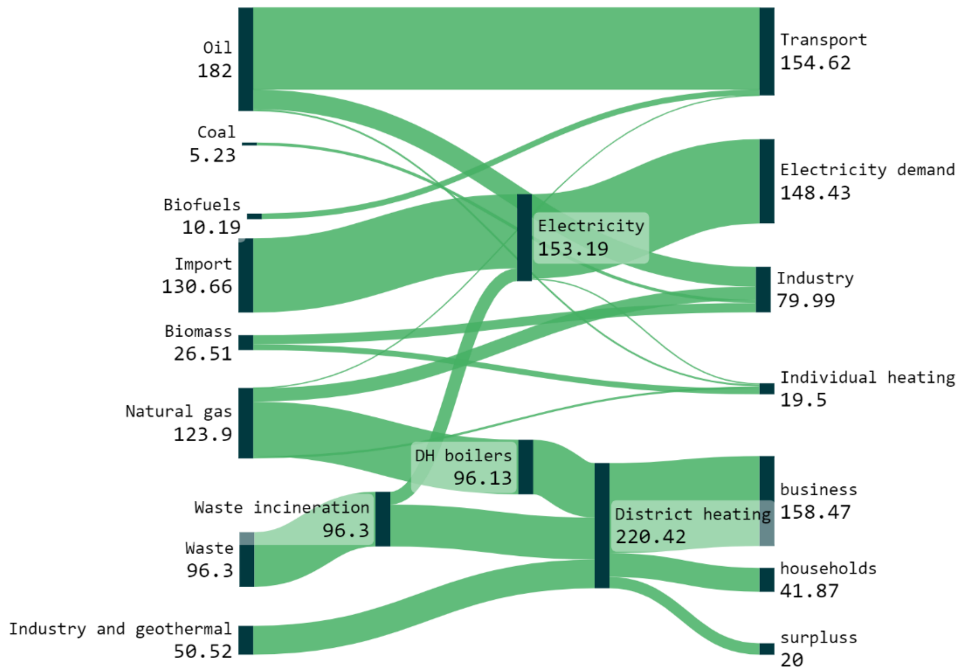

Figure 5. Energy flow diagram for Aalborg East 2022 (GWh/year)

Validating the EnergyPLAN model

To ensure that reference model is correct, energy outputs must be compared with the national/local energy statistics. As can be seen in Figure 6, the simulation results have no significant deviations from the statistical energy balance for Aalborg East. Therefore, the reference model represents a good starting point for analyzing and comparing future energy systems and PED potential.

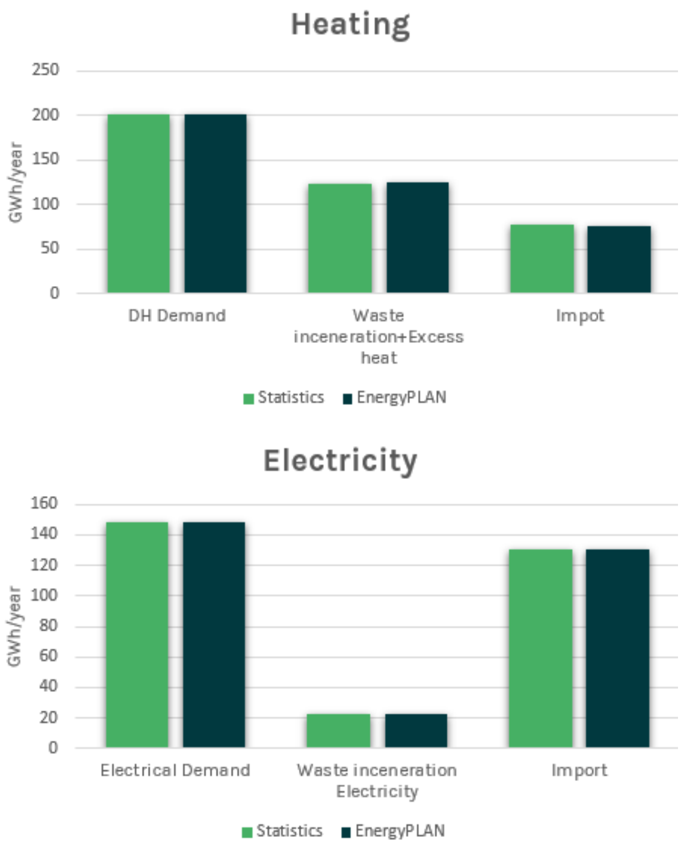

Figure 6. Comparison of electricity and heating generation in 2022 and the EnergyPLAN simulation

Conclusion

It is important to establish clear boundaries for energy districts, as they are pivotal in addressing today's energy challenges and driving energy transitions. Using Aalborg East as a case study, it demonstrated how energy demands across all sectors can be defined to adhere to principles of fairness and contribute to achieving national climate goals. This is particularly critical for future energy systems based on positive energy balances. The case of Aalborg East underscores the importance of equitable distribution of both energy demands and production. According to Figure 7, when considering only the geographical boundaries of the district and the energy generated within them, Aalborg East can already be considered a positive energy district, as the amount of waste heat produced is sufficient to meet all heat requirements. Furthermore, given that the total waste produced in Aalborg City is incinerated in this part of the city, it can be inferred that Aalborg is already fulfilling also its electricity needs.

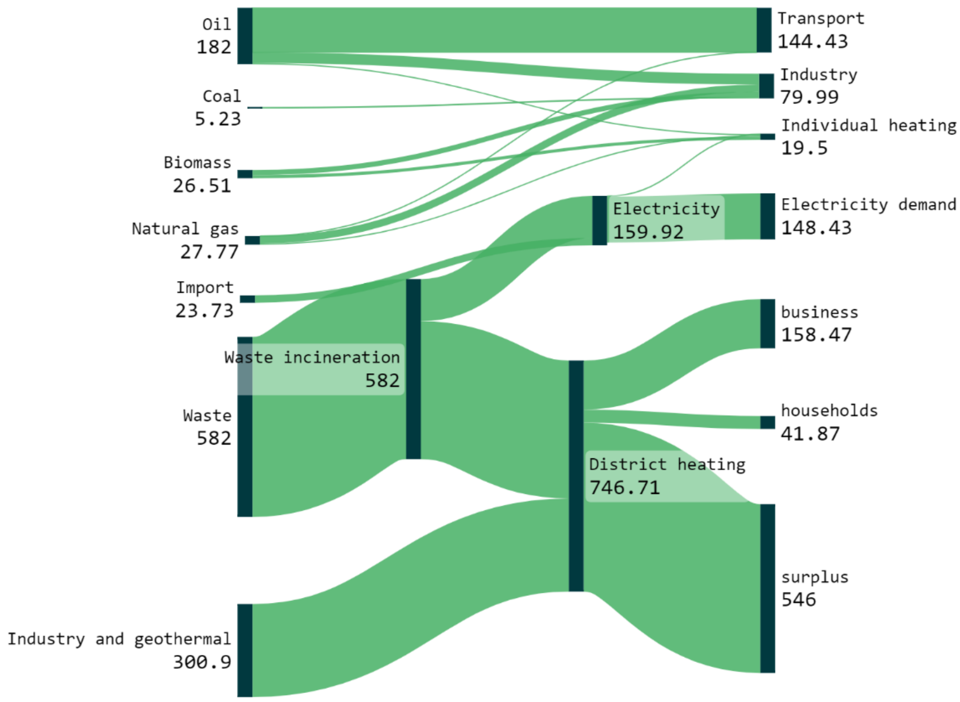

Figure 7. Energy flow of Aalborg East within real geographical boundaries of the system (GWh/year)

However, it is evident that this approach does not align with the objectives of sustainable development and decarbonization. When it comes to Positive Energy Districts, it is essential to uphold all principles of sustainable development, just transition, and integration of renewable energy sources.

Appendix 1

All the energy modelling inputs are summarized in the table below, to illustrate the annual energy balance of Aalborg East. Table includes all the energy demand (GWh/year) in all sectors and the efficiency of the energy systems.

AALBORG EAST															2022	ENERGY BALANCE						
Transport										Indsutry & Heat					GWh/kW	Efficiency			Electricity grid		DH grid	
Jetfuel	LNG	Fuel oil	Gasoline	Diesel	NG	Biogas	Bioethanol	Biodiesel	EL	Oli	Naturgas	Coal	Waste	Biomass	Catagory	EL	Heat	DH Grid efficiency	From plant	At consumer	From pant	At consumer
															District heating - households			79%			41,9	33,1
															District heating - business			79%			158,5	125,2
															Individual heating - Heat pumps		300%			0,1	200,3	0,4
															Individual heating - electric boilers		100%			2,3		2,3
										3,2	3,8			10,1	Individual heating - fuel boilers		90%					15,4
															Classical electricity demand				148,3			
															Electric vehicles							
															Electricity for heating				2,4			
															Electrolysis							
															Boilers in DH							
															CHP - heating							
															Excess heat from industry						49,6	39,2
															Heat pumps - DH							0,0
															CHP - El	40%					123,4	
															Power plant	47%						
													96,3		Waste incineration	23%	77%		22,5		73,8	58,3
															Wind turbines	100%						
															Solar PV	100%						
										10166,9	6922,8	1531,4	406,9	4395,6	Import EL	100%			128,2			
															Export EL	100%						
										34,7	23,6	5,2	1,4	15,0	Fuel - industry							
			49,5	86,0	0,3	0,1	3,3	6,9	0,8						Road transport - fuels							
				2,4					1,5						Rail transport - fuels							
	0,1	0,8		4,7											Sea transport - fuels (only domestic)							
0,7				93,0											Aviation - fuels, domestic							
17,0															Aviation - fuels, international							