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Guideline

Energy balance tool

For creating local energy strategies

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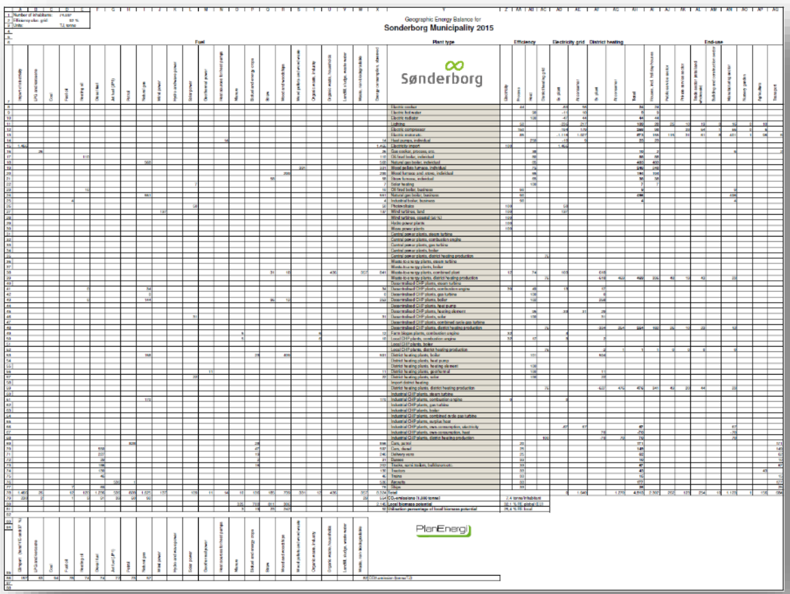

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Abstract

The purpose of this document is to explain how to use the energy balance method in the local energy planning process.

The document describes how to make and use an energy balance:

- Collecting data
- Setting up and energy balance
- Using the energy balance in the energy planning process

The document can be used in the SmartEnCity project to set up an Energy Balance for Tartu, Vitoria-Gasteiz and Sonderborg by guiding data collection and calculations. This can serve as a common platform to measure, present and compare energy performance across the three Lighthouse cities.

Available but not included in this document is also a guideline for how to use the energy balance to make a baseline emission inventory in the Global Covenant of Mayors for Climate & Energy template.

Energy Balance Tool

1 Introduction

The energy balance tool is widely used for baseline studies and making energy strategies among municipalities in Denmark.

For instance The Central Denmark Region and its 19 municipalities has been using the energy balance model since 2007. The model is used I relation to:

- Mapping progress every second year (2007, 2009, 2011, 2013 and 2015)
- Making a baseline emission inventory in the Global Covenant of Mayors for Climate & Energy template
- Making local future plan scenarios and action plans

In SmartEnCity the tool will be used to set up an energy balance for the calendar year 2015 for the geographical area of Sonderborg Municipality. Sonderborg Energy Balance 2015 is intended to generate results for indicators and text sections in D5.1 on energy consumption and energy supply, and is planned to be updated at the end of SmartEnCity to show progress on the indicators.

Sonderborg Energy Balance 2015 could also be used as reference point for the baseline before interventions in D5.2, depending on protocols for the overall measuring of energy supply, integration of infrastructures, etc. defined in WP7.

Energy Balances set up for in the three Lighthouse cities in SmartEnCity could serve as a common platform to measure, present and compare energy performance across the Lighthouse cities.

2 Method and concept

The aim of the energy balance spreadsheet is to introduce a methodology for organizing information about the local energy supply suitable for energy system analysis. The energy balance methodology is intended to be simple, easy to implement and the basic calculation of the energy balance for a country or region can be done on a 1-page spreadsheet.

The principles of the geographic energy balance are illustrated in Figure 2.1. The figure is read from left to right.

2.1 The overall concept

On the left side of the energy balance the fuel enters into an energy conversion unit that converts the fuel to process energy, heat or electricity. If the produced electricity or heat are supplied to a public supply system, the distributed electricity and heat is distributed to the end user with a specified efficiency for the electricity or district heating grid. Far right in the energy balance the end-users energy consumption is defined, excluding the losses that may be associated with delivering a given energy service. In this way it is possible to read off the gross energy consumption, gross final energy consumption and end-use in the energy balance.

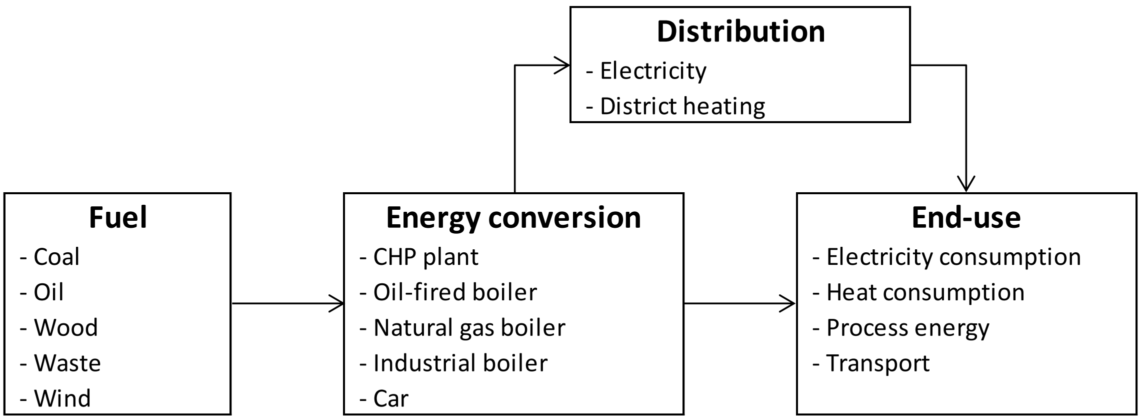

Figure 2.1 Principle sketch for the energy balance.

Example of energy conversion in the energy balance

Figure 2.2 illustrates how natural gas is converted into an end-use of electricity and district heating through a CHP plant. It is seen that with these system boundaries there is a total energy efficiency of 77 % in the energy system below.

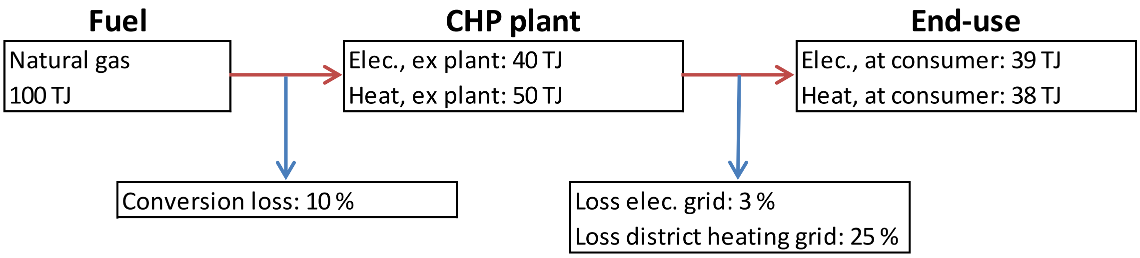

Figure 2.2 Example of conversion to illustrate the principles of the energy balance.

3 Using the energy balance

There are many ways of using the Energy Balance in the energy planning process.

3.1 Baseline and monitoring

The most basic way to use the energy balance is to make baseline studies and monitoring progress in local conversion from fossil to renewable energy.

Since the energy balance is a spreadsheet, it is possible to customize graphical presentations for individual needs. The figures below serve as examples of graphs that were based on the energy balance model.

Figure 3.1 shows the renewable energy share in Sonderborg 2015 mapped using the energy balance tool.

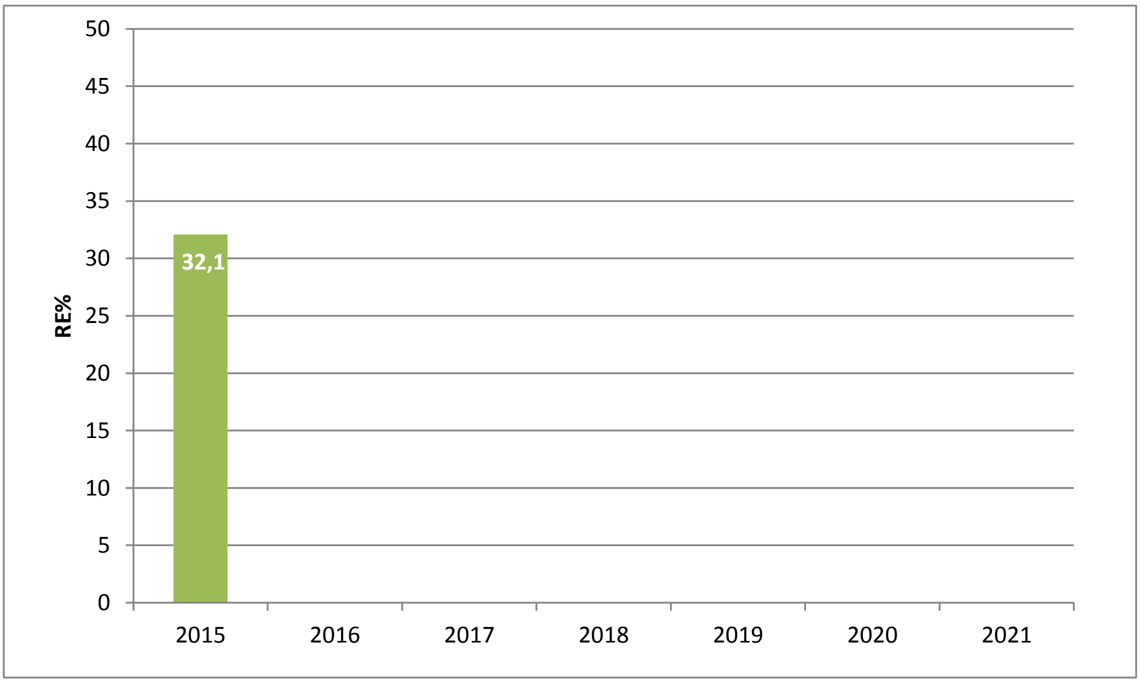

Figure 3.1 Renewable energy share in Sonderborg 2015 prepared to present progress towards 2021.

The tool automatically generates graphical presentations to display progress of the energy sector from an overall perspective, as well as in more detail for e.g. heating, electricity, mobility, etc.

As an example, Figure 3.2 shows the type of renewable energy sources used in the energy sector in the Central Denmark Region from 2006-2013. The column on the right of the figure shows the local potential of producing biomass. This is a relevant figure, since it shows that the region's total use of biomass exceeds the total potential of producing biomass.

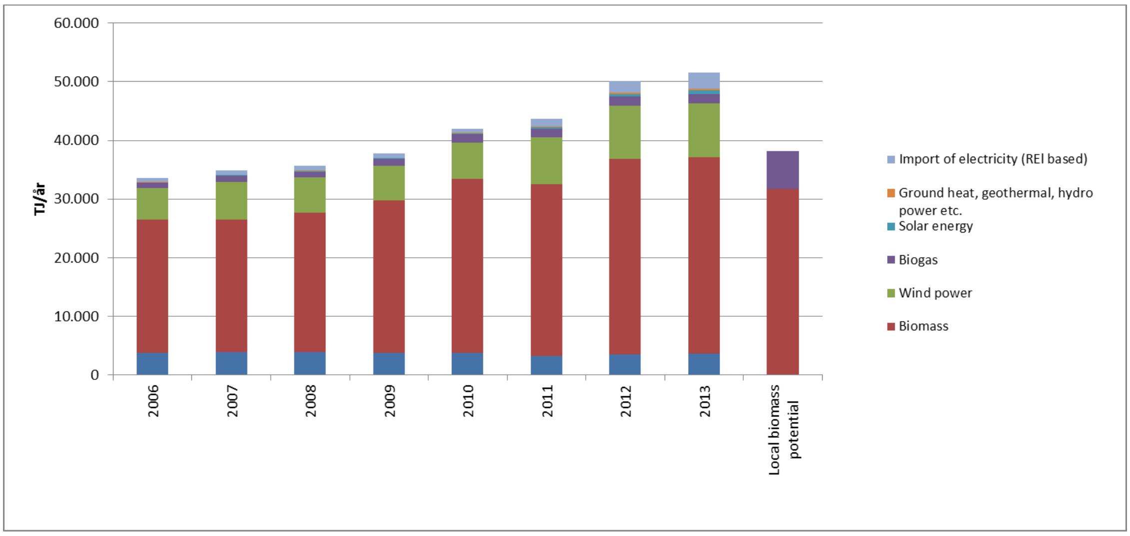

Figure 3.2 Gross energy consumption from renewable energy fuels in the Central Denmark Region from 2006-2013, moreover, local biomass potential. [1]

Figure 3.3 shows the gross final energy consumption in the Sonderborg in 2015 allocated to categories. The figure shows that the dominant users of energy are households, manufacturing and transport.

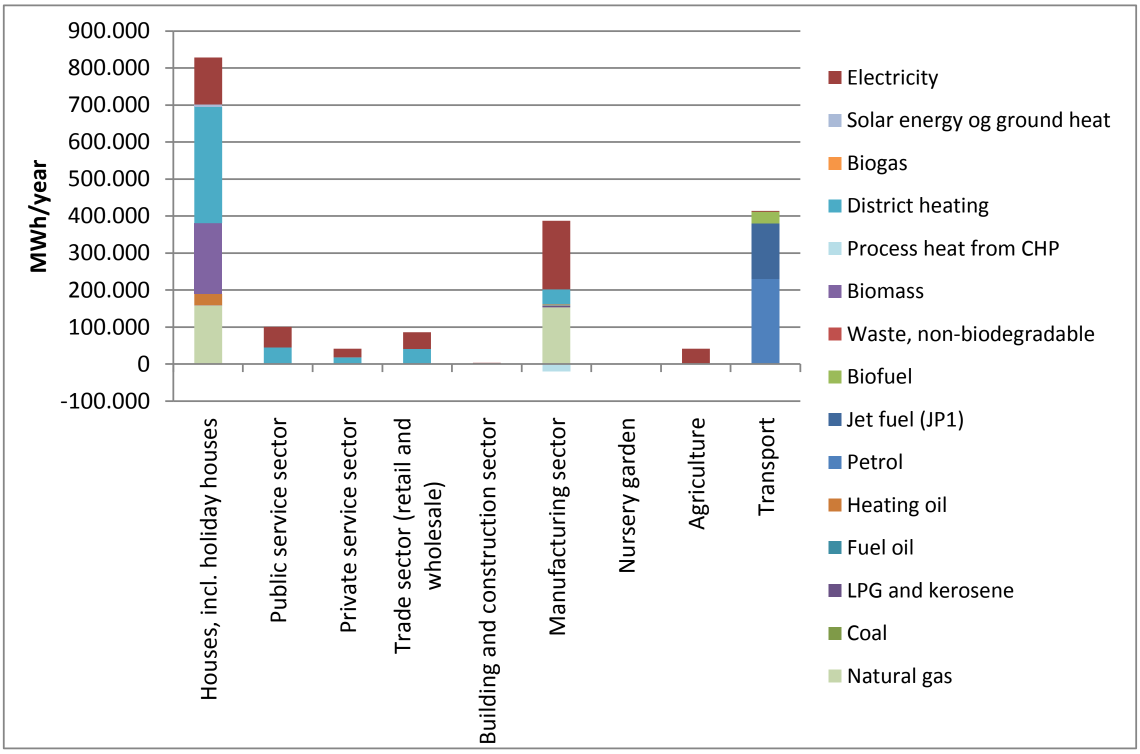

Figure 3.3 Gross final energy consumption in Sonderborg 2015 allocated to categories.

[1] The energy balance tool use TJ as default unit, but is easily convertible to preferred units.

Figure 3.4 shows the end-use of heat allocated to plant type in Sonderborg 2015 allocated to categories. The figure shows that the majority of the generated heating comes from district heating.

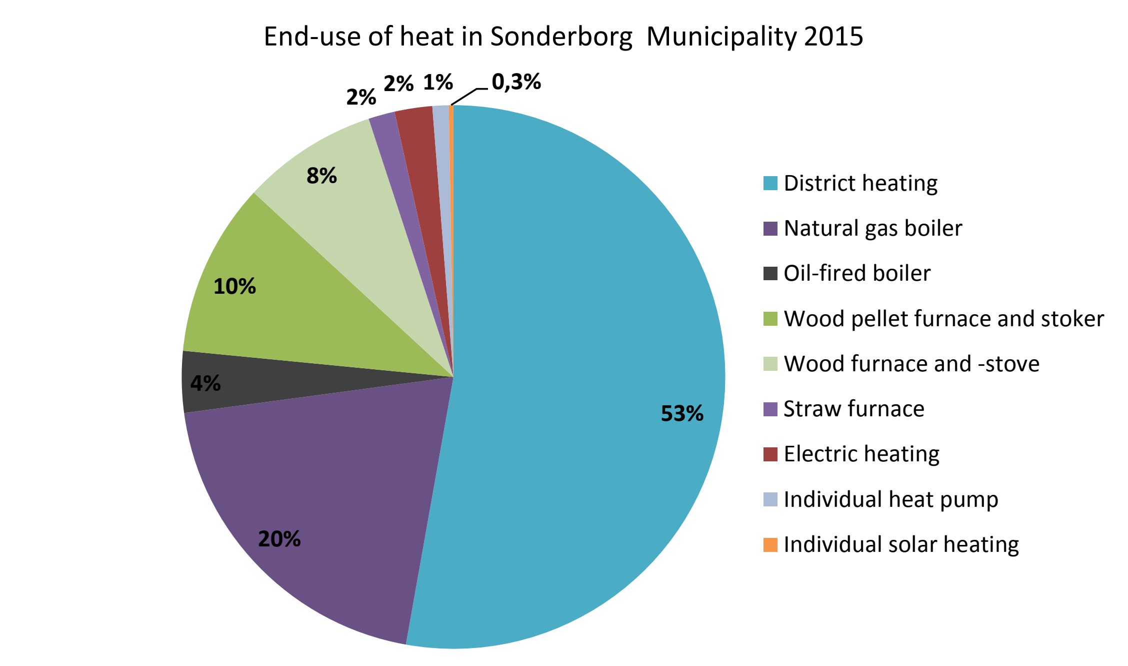

Figure 3.4 End-use of heat allocated to plant type in Sonderborg 2015.

3.2 Reference forecast

The purpose of making a reference forecast is to show how the energy supply will be in the future if no new changes are made. In Denmark such forecast is made on the national level by the Danish Energy Agency. Some of the key numbers from the national forecast can be used to make a business as usual forecast. Moreover already decided on changes in the local energy supply can be added.

Key factors that need to be considered when making a reference forecast can be divided into global- and local conditions.

3.2.1 Global conditions and trends

1) Demand for energy services (end-user behaviour)

These changes are primarily driven by overall societal, economic and structural development and determine the demand for:

- Lighting
- Heating/cooling
- Production
- Transport (mobility)

2) **Final energy consumption (demand, technology and efficiency)**

These changes are primarily driven by norms, standards, taxes, legislation and technological development.

Some examples could be:

- More efficient lighting, refrigerators, buildings and power stations.
- Shift from inefficient to more efficient energy technologies. For instance from oil boilers to heat pumps or from petrol cars to electric cars.

3) **Gross energy use (demand, technology, efficiency and policies)**

The gross energy use is affected by the demand for energy and the efficiencies of the dominant energy technologies. But in the long term it is also affected by renewable energy goals and CO_2 emissions trading systems. Local, regional, national and international renewable energy goals can be included in a reference scenario.

3.2.2 Local conditions

Already decided on or expected changes in local conditions should be included in the reference forecast. Relevant changes in local conditions could be:

- The expected population growth
- Plans for new industry and service
- Expected development in the use of heat in existing and new buildings
- Improvements in existing technologies
- Already decided on changes in the local energy supply.

3.2.3 Setting apart reference- and future plan scenarios

In practice it can often be hard to determine a concrete line between a reference and a future plan scenario. One should take care not to take to many decisions and frame conditions for granted in the reference scenario, since it can remove focus from necessary short-term actions necessary to reach political goals. Depending on the task it can, therefore, be feasible to make a simple reference scenario based on primarily changes in the end-users demand for energy.

3.3 Future plan scenario

Predictions of the future cannot be based only on studies of the existing societies as it is done in the reference scenario. The whole point in human choice is that options are available, that are different from past trends. The future plan spreadsheet presents a policy option that may come true only if a prescribed number of actions are carried out. The more the scenario differs radically from the reference scenario, the larger the support from the democratically participating population must be.

Depending on the scope there are two overall approaches to making future plan scenarios:

1) **The analytical approach**

In this approach future plan scenarios are made with no or very little involvement of local actors. Instead, we try to optimise the energy system from a set of given conditions.
For instance we want to optimise the energy system towards:

- The most economically feasible energy system
- The most energy efficient energy system
- An energy system that uses local energy resources
- An energy system with renewable energy

2) **The explorative and actor driven approach**

This is a more practical approach focusing on local potentials and opportunities. These approach meetings are held with relevant stakeholders from the local energy sector and possible actions are identified. The Energy balance can then be used to calculate the effects from relevant actions. Moreover the energy balance can be used to set up a future plan scenario that local actors commit to promote.

In the future energy balance the following changes can be introduced:

- End use savings
- More efficient energy conservation technologies
- Changes in fuel from fossil fuels to renewable fuels (solar, wind, hydro, biomass)

4 Making an energy balance

This chapter describes in general terms how to collect data and how to set up an energy balance for a local city or municipality.

4.1 Collecting data

When calculating the present energy consumption and making energy balance for a region or local area, one should use official statistics as much as possible to reduce the work and make it possible to replicate the balance year after year. In some cases, the values can be taken directly from the official statistics. In other cases, values such as average electricity consumption per person (kWh/person) can be found from national key figures. If not available, estimated values could be taken and then multiplied by the number of inhabitants in the region.

Other possibilities are green accounts form companies or making questionnaires in order to obtain specific data. This is most useful when getting information from large consumers or producers. It can also be useful to ask a few representative end-use consumers and obtain average key figures in that way.

Table 4.1 shows an overview from where some of the most important data for a local energy balance could be obtained.

Needed data	Typical data supplier
The efficiency of the electricity grid	Local transmission system operator (TSO)
CO_2-emmission of imported electricity	Local transmission system operator (TSO)
CO_2-emmission of fossil fuels	Local Energy Agency or IEA
Electricity consumption	Local electricity companies
Electricity production from wind power	Electricity companies, TSO or local Energy Agency
District heating consumption and grid loss	Local district heating plants
Fuel consumption for public electricity and heat supply	Energy Agency or local energy companies
Natural gas consumption	Local natural gas distribution companies (TSO)
Electricity production from photovoltaic	Local transmission system operator (TSO) or electricity companies
Individual heating (excl. natural gas)	Local chimney sweep masters, number of heating units
Road transport	Estimated from national statistics or local traffic models
Fuel consumption of the industry (excl. natural gas)	National Statistics or collected data from each industry using for instance green accounts
Transport non road, aviation fuel (aircrafts), fuel oil (ships), diesel (train)	Estimated from national statistics or local data
Individual solar heating	Estimated from national statistics or local data

Table 4.1 Data collection.

The available valid data for the energy balance will vary depending on country and region. In most cases valid data can be collected in relation to:

- Heat- and electricity production from local power- and combined heat and power plants
- Electricity production from wind power
- Electricity consumption
- Natural gas consumption
- Industrial use off energy

It is typically harder to get valid data regarding transport and individual heating. When valid measured data are not available, an estimate based on the available data has to be made.

4.2 Making a baseline spreadsheet

This section will show how to put collected data into the spreadsheet and make an energy balance step by step.

1) **Basic information (D1:D3 and Y3)**
   The top of the spreadsheet shows information like geographical area, year, energy unit, number of inhabitants, overall efficiency of the electricity grid.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Number of inhabitants:			74.937									
2	Efficiency elec. grid:			92 %									
3	Units:			TJ, tonne									
4													
5													
6													Fuel
7	Import of electricity	LPG and kerosene	Coal	Fuel oil	Heating oil	Diesel fuel	Jet fuel (JP1)	Petrol	Natural gas	Wind power	Hydro and wave power	Solar power	Geothermal power

2) **CO_2-emissions from imported electricity and fossil fuels (A86:W86)**

73						183										16								199	Trucks, semi
74						130																		130	Tractors
75						46																		46	Trains
76							536	1																536	Aircrafts
77				7		69																		76	Ships
78	1.466	26		12	120	1.244	536	828	1.625	137		109	11	14	10	136	185	739	331	12	436		357	8.332	**Total**
79	230	2		1	9	92	39	60	92														29	554	**CO_2-emissions**
80															325	703	811	306						2.145	**Local biomass**
81															3	19	23	242						50	**Utilisation per**
82																									
85	Elimport (heraf VE-andel: 37 %)	LPG and kerosene	Coal	Fuel oil	Heating oil	Diesel fuel	Jet fuel (JP1)	Petrol	Natural gas	Wind power	Hydro and wave power	Solar power	Geothermal power	Heat sources for heat pumps	Manure	Biofuel and energy crops	Straw	Wood and woodchips	Wood pellets and wood waste	Organic waste, industry	Organic waste, households	Landfill, sludge, waste water	Waste, non-biodegradable		
86	157	63	94	78	74	74	72	73	57														82	CO2-emission (tonne/TJ)	

3) Biomass potential (O80:R80)

The local biomass potential consists of manure, energy crops, straw and wood. The percentage of local resources used today is calculated in row 81. This figure shows whether or not the existing use of biofuels can be covered by local resources.

	N	O	P	Q	R	S	T	U	V	W	X	
76											536	Aircrafts
77											76	Ships
78	14	10	136	185	739	331	12	436		357	8.332	**Total**
79										29	554	**CO_2-emissions (1.000 ton**
80		325	703	811	306						2.145	**Local biomass potential**
81		3	19	23	242						50	**Utilisation percentage of**
82												
83												
84												
85	Heat sources for heat pumps	Manure	Biofuel and energy crops	Straw	Wood and woodchips	Wood pellets and wood waste	Organic waste, industry	Organic waste, households	Landfill, sludge, waste water	Waste, non-biodegradable		

4) Fuel (A8:W77)

Fuel used in different energy conversion units (Y) is shown on the left side of the energy balance.

Fuel														Plant type
Hydro and wave power	Solar power	Geothermal power	Heat sources for heat pumps	Manure	Biofuel and energy crops	Straw	Wood and woodchips	Wood pellets and wood waste	Organic waste, industry	Organic waste, households	Landfill, sludge, waste water	Waste, non-biodegradable	Energy consumption, observed	Sønderborg
														Central power plants, steam turbine
														Central power plants, combustion engine
														Central power plants, gas turbine
														Central power plants, boiler
														Central power plants, district heating production
														Waste-to-energy plants, steam turbine
														Waste-to-energy plants, boiler
						31	18			436		357	841	Waste-to-energy plants, combined plant
														Waste-to-energy plants, district heating production
														Decentralised CHP plants, steam turbine
													34	Decentralised CHP plants, combustion engine
													0	Decentralised CHP plants, gas turbine
						96	12						253	Decentralised CHP plants, boiler
														Decentralised CHP plants, heat pump
														Decentralised CHP plants, heating element
	31												31	Decentralised CHP plants, solar
														Decentralised CHP plants, combined cycle gas turbine
														Decentralised CHP plants, district heating production
				5					6				12	Farm biogas plants, combustion engine
				5					6				10	Local CHP plants, combustion engine
														Local CHP plants, boiler
														Local CHP plants, district heating production
					23		409						591	District heating plants, boiler

5) **Efficiency (Z7:AC77)**

The efficiency cells give data regarding the different energy conversion units and the district heating grid. The spreadsheet will calculate the electricity and heat available for the end-user in column AD31:AG68.

	Y	Z	AA	AB	AC	AD	AE	AF	AG
5									
6	**Plant type**	**Efficiency**				**Electricity grid**		**District heating**	
7	Sønderborg	Electricity	Process	Heat	District heating grid	Ex plant	At consumer	Ex plant	At consumer
8	Electric cooker		44			-60	56		
9	Electric hot water			90		-11	10		
10	Electric radiator			100		-47	44		
11	Lighting		50			-236	217		
12	Electric compressor		150			-194	179		
13	Electric motor etc.		85			-1.116	1.027		
14	Heat pumps, individual			250		-10	9		
15	Electricity import	100				1.466			
16	Gas cooker, process, etc.			38					
17	Oil-fired boiler, individual			80					
18	Natural gas boiler, individual			85					
19	Wood pellets furnace, individual			75					
20	Wood furnace and -stove, individual			65					
21	Straw furnace, individual			65					
22	Solar heating			100					
23	Oil-fired boiler, business		90						
24	Natural gas boiler, business		90						
25	Industrial boiler, business		90						
26	Photovoltaics	100				50			
27	Wind turbines, land	100				137			
28	Wind turbines, coastal (50 %)	100							

6) **End-use of electricity (AI8:AQ13)**

The end-use of electricity is distributed into different categories specifying the sector where the energy is used and the conversion/purpose of the energy use. The categories are:

- Households
- Public service
- Private service
- Trade

- Building and construction
- Manufacturing
- Nursery garden
- Agriculture
- Transport

	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ
5																			
6	**Plant type**	**Efficiency**				**Electricity grid**		**District heating**			**End-use**								
7	Sønderborg	Electricity	Process	Heat	District heating grid	Ex plant	At consumer	Ex plant	At consumer	**Total**	Houses, incl. holiday houses	Public service sector	Private service sector	Trade sector (retail and wholesale)	Building and construction sector	Manufacturing sector	Nursery garden	Agriculture	Transport
8	Electric cooker		44			-60	56			**24**	24								
9	Electric hot water			90		-11	10			**9**	9								
10	Electric radiator			100		-47	44			**44**	44								
11	Lighting		50			-236	217			**109**	28	25	10	19	0	16	0	10	
12	Electric compressor		150			-194	179			**268**	98		33	64	1	66	0	6	
13	Electric motor etc.		85			-1.116	1.027			**873**	155	115	31	61	8	401	1	96	6

7) Calculated key indicators

When all data has been inserted into the spreadsheet a number of key figures can be extracted from the spreadsheet. Some of the most relevant ones are:

- Total CO_2-emmision of the community (X 79)
- CO_2-emmision pr. inhabitant (Z 79)
- Percentage of fuel consumption covered by renewable energy (Z 80)
- Percentage of fuel consumption covered by locally produced renewable energy (Z 81)
- Local biomass potential (X 80)
- Use of local renewable energy resources (X 81)
- Total fuel consumption (X78)
- Total end-use of energy (AH 78)
- Total heat delivered to consumers in the district heating grid (AG 78)
- Total electricity consumption (AE 78)
- The distribution of fuels used in the energy supply (A78:W78)
- The energy consumption distributed on different energy Plant types (X8-X77)

4.3 *Mapping local renewable energy resources*

4.3.1 Solar Energy

A solar thermal collector generating heat for domestic hot water produces approximately 400-500 kWh/m_2 solar collectors under Baltic conditions.

Photovoltaic technologies generating electricity produce approximately 100-140 kWh/m_2 under Baltic conditions.

4.3.2 Wind Energy

The energy of the wind depends on the surrounding terrain, with optimal locations being offshore or close to the sea or a lake. For example, in the Baltic area typical figures for the power generated by similar turbines located inland (carefully chosen location), near to the shore and offshore would annually generate 2.500 kWh/kW, 3.500 kWh/kW and 4.500 kWh/kW of electricity, respectively.

4.3.3 Hydropower

The potential of the hydropower resource is determined by the flow rate of water along the river; its volume and its speed. Large hydro plants, i.e. in MW sizes can have large impact on the surroundings due to damming, while small-scale hydro plants (micro hydro) can be utilised without having an impact on the surroundings.

4.3.4 Biomass

The wood resources can be a mix of surplus wood from the forests, waste wood from the woodworking industry and energy crops. The resources can be limited due environmental considerations.

The straw resources are the remaining straw, when the straw for fodder and other farming purposes has been used. The resources will change from year to year with up to 30 % depending on the weather conditions.

Biogas from manure or organic waste can be utilised for electricity and/or heat production.
In the case of manure, the quantities available, and thus the power production potential, are depending very much on the agricultural practices. If the animals are in stable all year round then all of the manure can be collected and the amount will be considerably more than if the animals are kept outdoors for some or all of the year. Likewise, the way of feeding the animals influences the amount of manure and the energy content in the manure.
The typical energy content of the manure from various animals which have been intensely fed and kept in stable all year is:

- Milk cow 17.5 GJ/Year
- Cattle cow 9 GJ/Year
- Pig 1.8 GJ/Year

- 100 chickens 5 GJ/Year

To utilise the biogas from organic waste, first, it must be separated in the households or industries. Then the material should to be sorted again before digestion to ensure that it does not contain plastics and other non-organic materials.

5 Energy balance calculation exercises

5.1 Key figures energy balance

In the exercises one should make some calculations in order to learn how to use the energy balances to calculate the effects of different actions.

5.1.1 Exercise: Find and write down the following key figures

- Actual energy consumption (TJ), cell X78:
- CO_2-emmisions (1.000 tons), cell X79:
- Renewable energy share RE %, cell Z80:

5.2 Electricity savings

The energy balance shows the total use of electricity in cell AE78.
The use of electricity is shown in column AI8:AQ14.

In the energy balance the use of electricity is shown in different categories:

- Private houses and summerhouses
- Public service
- Private service
- Trade (retail and wholesale)
- Building and construction
- Industry
- Horticulture (greenhouses, nursery garden)
- Agriculture
- Transport (electric cars)

5.2.1 Exercise: Reduce the use of electricity in private buildings by 10 %

Reduce the electricity used in cell AI8:AI14 by 10 %.

5.2.2 Effect of action

- Actual energy consumption (TJ), cell X78:
- CO_2-emmisions (1.000 tons), cell X79:
- Renewable energy share RE %, cell Z80:

5.3 Savings in individual heated private buildings

The energy balance shows the use of fuel for individual heating in private buildings which is shown in E17, I18, S19, R20 and Q21.

The energy balance shows the following technical installations for heating private houses:

- Oil boiler

- Natural gas boiler
- Wood pellets boiler
- Wood furnace/stove
- Straw furnace
- Solar heating
- Heat pumps

5.3.1 Exercise: Reduce heating in private buildings with oil boiler by 10 %

Reduce the use of oil in cell E17 by 10 %.

5.3.2 Effect of action

- Actual energy consumption (TJ), cell X78:
- CO_2-emmisions (1.000 tons), cell X79:
- Renewable energy share RE %, cell Z80:

5.4 Heat savings in buildings with district heating

The energy balance shows the use of fuel for producing district heating in cell A31:W63.

The following plants in the energy balance can produce heat for district heating systems:

- Central power plants
- Decentralised combined heat and power plants
- Local combined heat and power plants
- District heating plants
- Industrial plants

5.4.1 Exercise: Reduce the production of district heating at decentralised CHP by 10 %

Reduce the use of fuel in cell B40:W48 by 10 %. Observe that the production of district heating is reduced in cell AF48.

5.4.2 Effect of action

- Actual energy consumption (TJ), cell X78:
- CO_2-emmisions (1.000 tons), cell X79:
- Renewable energy share RE %, cell Z80:

5.5 Changing fuel at power plants and district heating plants

The following plants in the energy balance can produce heat for district heating systems:

- Central power plants
- Decentralised combined heat and power plants
- Local combined heat and power plants
- District heating plants

Industrial plants

5.5.1 Exercise: Change fuel from natural gas to biogas at a decentralised CHP

The use of natural gas (I41) is reduced by 100 TJ. Natural gas is replaced by biogas based on manure and energy crops (O41 and P41).

5.5.2 Effect of action

- Actual energy consumption (TJ), cell X78:
- CO_2-emmisions (1.000 tons), cell X79:
- Renewable energy share RE %, cell Z80:

5.6 Converting individual heating to district heating

The energy balance shows the following units for individual heating:

- Oil boiler
- Natural gas boiler
- Wood pellets boiler
- Wood furnace/stove
- Straw furnace
- Solar heating
- Heat pumps

1.1.1 Exercise: Convert 30 % of heating with individual natural gas to district heating based on natural gas

The efficiency of an individual gas boiler is approximately 85 % (I18). Replace 30 % of the heat production with heat from decentralised CHP based on natural gas. The efficiency of heat production on decentralised CHP engine is 60 %.

1.1.2 Effect of action

- Actual energy consumption (TJ), cell X78:
- CO_2-emmisions (1.000 tons), cell X79:
- Renewable energy share RE %, cell Z80:

5.7 Changing fuels for individual heating

The energy balance shows the following units for individual heating:

- Oil boiler
- Natural gas boiler
- Wood pellets boiler
- Wood furnace/stove
- Straw furnace
- Solar heating
- Heat pumps

1.1.3 Exercise: Reduce the use of individual oil by 20 % by using individual solar heating

According to the energy balance an individual oil boiler has an efficiency of 75 %, while solar heating has an efficiency of 100 %.

Reduce the use of fuel for individual oil boilers by 20 % (E17). Insert solar heating (L22), corresponding to the reduced heat production from oil boilers.

Remember to compensate for different energy efficiency in oil boilers and solar heating.

1.1.4 Effect of action

- Actual energy consumption (TJ), cell X78:
- CO_2-emmisions (1.000 tons), cell X79:
- Renewable energy share RE %, cell Z80:

5.8 Electricity production from wind power and photovoltaics

These plants in the energy balance can produce electricity from the wind and the sun:

- Large wind turbines, sea
- Large wind turbines, land
- Small wind turbines, land
- Photovoltaics
- Hydro power plants

1.1.5 Exercise: Increase the electricity production from wind power (land) by 100 %

Change cell J27.

1.1.6 Effect of action

- Actual energy consumption (TJ), cell X78:
- CO_2-emmisions (1.000 tons), cell X79:

- Renewable energy share RE %, cell Z80:

6 Example - Energy balance of Sønderborg

The Energy Balance is constructed as an Excel file containing different spreadsheets for the different inventoried years (2015-2021).

The Energy Balance consists of energy consumption (in Terajoule (TJ)) for over 70 different plant types (rows) which are distributed among 24 fuel types (Annex 1, columns B to W). The energy consumption (gross energy consumption) is converted to end of use consumption (Annex 1, columns AI to AQ), using efficiencies factors (Annex 1, columns Z to AC) as described in Table 6.1 below (see also ***Figure 2.1*** and ***Figure 2.2***). The Energy Balance also includes the electricity grid (Annex 1, column AD to AE) and district heating grid (Annex 1, columns AF to AG).

The Energy Balance spreadsheet comes with an additional spreadsheet called **Energy Balance Overview** (Annex 1) where the source of the data (entered or calculated) is indicated using the reference codes shown in Table 6.1.

Code	Source to cell value
1-16	Refers to appendix 1-16. Entered values are marked with green in the appendixes.
E	Energy Statistics 2014 from Danish Energy Agency. (DEA 2016a, p. 59)
M	Environmental report 2014 & Environmental declaration for electricity 2015 from the Danish TSO Energinet.dk (Energinet.dk 2016)
F	Cell formulas which are calculated from values in other cells in the energy balance.
V	Estimated efficiencies cf. section 6.1

Table 6.1 Reference codes in the Energy Balance Overview for the energy balance (see Annex 1).

The Energy Balance Overview gives a quick overview of the entered values and formulas in the Energy Balance with reference codes in the cells instead of values and formulas. The entered **reference codes in the Energy Balance Overview are shown in table 6.1.** The entered data can be found in 16 appendixes, which are attached to the Energy Balance (see Annex 2 for the detailed description of the appendixes). The appendixes contain the background data used to build the Energy Balance, which are highlighted with green in the appendixes.

The following sections Efficiencies for conversion units (”V”)6.1 to 6.7 refer to the different elements of the Energy Balance, which can be seen in the Energy Balance Overview. They give detailed description of how these elements are used in the Energy Balance.

6.1 *Efficiencies for conversion units ("V")*

The efficiencies are a measure for how efficient a conversion unit utilises the used fuel. The efficiencies in the energy balance are divided into electricity, process and heat.

For a range of the energy conversion units the actual efficiency cannot be determined based on measured data. In these cases an estimated efficiency is used in order to calculate the end-use in the right side of the energy balance.

Table 6.2 shows the estimated efficiencies in the energy balance. These efficiencies are marked with "V" in the Energy Balance Overview (Annex 1, columns Z to AC).

Energy conversion unit	**Efficiency**	**Reference**
Gas cooker	0,38	PlanEnergi's estimate
Electric cooker	0,44	PlanEnergi's estimate
Electric hot water	0,90	A 60 litres electric hot water unit are estimated to have a heat loss of 100 W. The loss are typically left out in the summer 120h x 100 W = 288 kWh. The hot water consumption is about 800 kWh/person/year. Then the loss makes up for about 10 %.
Electric radiator	1,0	There are not included conversion losses for electric heating.
Lighting	0,5	Efficiency varies from 14 % for light bulbs to 85 % or more for fluorescent tubes and LED-bulbs. 50 % is used as an average.
Electric compressor	1,5	Efficiency for cooling.
Electric motor	0,85	Electric motor typically has an efficiency of 80-95 %.
Solar heating	1,0	The output of the solar heating is measured as utilised energy. Conversion loss is therefore not included.
Heat pumps, individual	2,5	Average efficiency for a heat pump for heating cf. *Standardværdikatalog*, (DEA 2008)
Oil-fired boiler, individual	0,80	*Strategisk energiplanlægning i kommunerne* (DEA 2012)
Natural gas boiler, individual	0,85	*Strategisk energiplanlægning i kommunerne* (DEA 2012)
Wood pellets furnace, individual	0,75	*Strategisk energiplanlægning i kommunerne* (DEA 2012)
Wood furnace and -stove, individual	0,65	*Strategisk energiplanlægning i kommunerne* (DEA 2012)
Straw furnace, individual	0,65	*Strategisk energiplanlægning i kommunerne* (DEA 2012)

Natural gas boiler, business	0,90	PlanEnergi's estimate
Oil-fired boiler, business	0,90	PlanEnergi's estimate
Photovoltaics	1,0	The output of photovoltaics is measured at grid. Conversion loss is therefore not included.
Wind turbines	1,0	The output of wind turbines is measured at grid. Conversion loss is therefore not included.
Hydro power plants	1,0	The output of hydro power plants is measured at grid. Conversion loss is therefore not included.
Wave power plants	1,0	The output of wave power plants is measured at grid. Conversion loss is therefore not included.
Cars, petrol	0,20	*Alternative drivmidler i transportsektoren 2.1* (DEA 2014)
Cars, diesel	0,25	*Alternative drivmidler i transportsektoren 2.1* (DEA 2014)
Delivery vans	0,25	*Alternative drivmidler i transportsektoren 2.1* (DEA 2014)
Busses	0,33	*Alternative drivmidler i transportsektoren 2.1* (DEA 2014)
Trucks, semi-trailers, bulldozers etc.	0,33	*Alternative drivmidler i transportsektoren 2.1* (DEA 2014)
Tractors	0,33	Danish Technological Institute, Engine technology

Table 6.2 Estimated average efficiencies for energy conversion units in the energy balance.

6.2 Import of electricity

In the Energy Balance the imported electricity (Annex 1, column A) is assumed to be residual electricity produced by power stations in condensing mode and by offshore wind turbines. Residual electricity is described in the upcoming update of the "*Guide to the mapping methods and data capture for the municipal strategic energy planning – Method Description*" where DEA have made a new guidance for managing electricity imports in energy balances (DEA 2015b).

For further information regarding CO_2 emissions from import of electricity in the Energy Balance, see also section 6.6.

6.3 Grid loss in the electricity grid ("M")

The total grid loss in the electricity grid consists of distribution losses and transmission losses. As described in the "Background Data for Environmental Report 2016" report ('Baggrundsdata til Miljørapport 2016') from the Danish TSO Energinet.dk (Energinet.dk, 2016), the distribution loss is set to 5 %.

The transmission loss for Western Denmark can be calculated from the environmental impact statement from Energinet.dk as: Grid losses in the transmission grid / sale at the transmission grid which is equal to 2.96 % for 2015.

The total grid loss in the electricity grid (Annex 1, cell D2) as summed up from above is equal to 7.96 %, corresponding to an efficiency of the electricity grid of 92.04 %.

6.4 Import of district heating

In most municipalities in Denmark the district heating production takes place in the same municipality as the heat is consumed.

However, in some municipalities the district heating grid is connected across municipal boundaries.

When the district heating is delivered across municipal boundaries an average heating composition is calculated which is allocated to municipalities in the district heating grid proportionally in accordance with the recommendations from DEA (DEA, 2012). The fuel mix of the imported district heating is then added to the Energy Balance (Annex 1, row 58).

6.5 Local electricity production from central power plants

In some of the larger cities in Denmark there are so-called extraction plants that can operate both as a cogeneration plant with production of both heat and electricity and as a power plant that purely produces electricity and cools the heat away (condensing mode). Fuel consumption related to electricity production in condensing mode without simultaneous production of heat is not included in the Energy Balance. Furthermore, the calculation of the fuel mix for district heating for the municipalities with extraction plants does not include the fuel consumption related to electricity production in condensing mode. This allocation of fuel consumption is following the recommendations from (DEA, 2012).

Fuel consumption for local electricity and heat production from CHP plants are included in the Energy Balance.

6.6 Calculation of CO_2-emissions (”E”)

6.6.1 CO_2-emissions from fossil fuels

At the bottom of the energy balance the CO_2-emissions are shown for a number of fossil fuels (Annex 1, row 86), stated as tonnes per TJ. The data is from the ‘Energy Statistic 2014’ from DEA (DEA 2015, p. 59).

Municipal solid waste (MSW) is considered by many to be CO_2-neutral. However, MSW contains large amounts of plastic waste that is produced from fossil oil. DEA has prepared a separate inventory of CO_2-emissions from the incineration of non-biodegradable waste in 'Energy Statistic 2014'. The reason for the separate inventory is i.e. found in "Note on CO_2-emissions from waste incineration", NERI, 2008 ('Notat vedrørende CO_2-emissioner fra affaldsforbrænding', DMU 2008). Thus, the energy balance is divided into a non-biodegradable and a biodegradable fraction with 45% and 55%, respectively ('Energy Statistic 2014').

Computationally this corresponds to using an emission factor of 37.0 tonnes/TJ CO_2 from waste (MSW). The emission factor for the non-biodegradable fraction is therefore set to 82.2 tonnes/TJ and 0 tonnes/TJ for the biodegradable fraction.

6.6.2 CO_2-emissions from electricity in Denmark

The definition of the CO_2-emission from imported electricity is found in the "Declaration" of residual electricity in the new guidance for managing electricity imports in Energy Balances from DEA (see section 6.2). The following CO_2 emission coefficients and Renewable Energy (RE) fractions are used in the Energy Balance (DEA, 2015b).

- 2014 : 157.0 tonnes/TJ (Annex 1, cell A86) including 37 % renewable energy (Annex 1, cell A84)
- 2013 : 167.0 tonnes/TJ and 33 % of RE
- 2011: 176.0 tonnes/TJ and 29 % of RE
- 2009 : 210.4 tonnes/TJ and 14 % of RE
- 2007: 221.4 tonnes/TJ and 11 % of RE

The calculation of the emission factors for electricity does not include transmission and distribution losses, since the observed energy consumption of imported electricity in the Energy Balance has included transmission and distribution losses.

6.7 Share of renewable energy (RE %)

In the Energy Balance the share of renewable energy (RE %) is calculated from a global perspective (Annex 1, cell Z80) and a local perspective (Annex 1, cell Z81). The RE % in the global perspective is calculated by taking the gross final energy consumption which is derived by taking the final energy consumption excl. consumption for non-energy purposes, and adding the grid losses from electricity, district heat and own-consumption from the production of electricity and district heat. This follows the method for making up share of renewable energy in the EU. The RE % seen in a local perspective is calculated by taking the consumption of renewable energy in the final energy consumption and divide it by the total final energy consumption.

6.8 *Data quality*

The energy balance is based on a diverse range of data of different quality and from different sources. Some data are measured, some are estimated based on local data, and a few are based on allocation of national consumptions/productions by population.

Table 6.3 shows the energy balance's main data priorities by data quality. The "energy consumption of industry" statistics are placed in medium despite the fact that they are based on reporting of measured consumptions.

Data Quality	Area	Data supplier
High Measured consumption / production	Electricity production from wind power	Danish Energy Agency
	District heating consumption and grid loss	Local district heating plants
	Fuel consumption for public electricity and heat supply	Danish Energy Agency
	Electricity consumption	Local electricity distribution companies
	Natural gas consumption	Local natural gas distribution companies
Medium Estimated / local data	Electricity production from photovoltaic	Energinet.dk (TSO)
	Individual heating (excl. natural gas)	Local chimney sweep masters, number of heating units
	Road transport	Statistics Denmark, number of registered vehicles
	Fuel consumption of the industry (excl. natural gas)	Statistics Denmark, information from industries with more than 20 employees
Low Estimated / allocated on population etc.	Transport non road, aviation fuel (aircrafts), fuel oil (ships), diesel (train)	Danish Energy Agency's Energy Statistic and Statistics Denmark
	Individual solar heating	Danish Energy Agency's Energy Statistic and Statistics Denmark

Table 6.3 Overview of data quality for the primary data sources for the creation of energy balances for each municipality.

7 Annex 1: Energy Balance Overview

Number of inhabitants:
Efficiency elec. grid: M %
Units: TJ, tonne

Geographic Energy Balance for
ENERGY BALANCE OVERVIEW

Fuel

Row	A Import of electricity	B LPG and kerosene	C Coal	D Fuel oil	E Heating oil	F Diesel fuel	G Jet fuel (JP1)	H Petrol	I Natural gas	J Wind power	K Hydro and wave power	L Solar power	M Geothermal power	N Heat sources for heat pumps	O Manure	P Biofuel and energy crops	Q Straw	R Wood and woodchips	S Wood pellets and wood waste	T Organic waste, industry	U Organic waste, households	V Landfill, sludge, waste water	W Waste, non-biodegradable	X Energy consumption, observed	Y Plant type
8																									Electric cooker
9																									Electric hot water
10																									Electric radiator
11																									Lighting
12																									Electric compressor
13																									Electric motor etc.
14														F										F	Heat pumps, individual
15	F																							F	Electricity import
16		2																						F	Gas cooker, process, etc.
17					14																			F	Oil-fired boiler, individual
18									13															F	Natural gas boiler, individual
19																			14					F	Wood pellets furnace, individual
20																		14						F	Wood furnace and -stove, individual
21																	14							F	Straw furnace, individual
22												16												F	Solar heating
23					15																			F	Oil-fired boiler, business
24									13															F	Natural gas boiler, business
25		15	15	15															15				15	F	Industrial boiler, business
26												7												F	Photovoltaics
27										6														F	Wind turbines, land
28										6														F	Wind turbines, coastal (50 %)
29											1													F	Hydro power plants
30																								F	Wave power plants
31			1	1	1	1	1	1	1						1	1	1	1	1	1		1	1	F	Central power plants, steam turbine
32			1	1	1	1	1	1	1						1	1	1	1	1	1		1	1	F	Central power plants, combustion engine
33									1															F	Central power plants, gas turbine
34			1	1	1	1	1	1	1						1	1	1	1	1	1		1	1	F	Central power plants, boiler
35																									Central power plants, district heating production
36			1	1	1	1	1	1	1						1	1	1	1	1	1	1	1	1	F	Waste-to-energy plants, steam turbine
37			1	1	1	1	1	1	1						1	1	1	1	1	1	1	1	1	F	Waste-to-energy plants, boiler
38			1	1	1	1	1	1	1						1	1	1	1	1	1	1	1	1	F	Waste-to-energy plants, combined plant
39																									Waste-to-energy plants, district heating production
40			1	1	1	1	1	1	1						1	1	1	1	1	1		1	1	F	Decentralised CHP plants, steam turbine
41			1	1	1	1	1	1	1						1	1	1	1	1	1		1	1	F	Decentralised CHP plants, combustion engine
42									1															F	Decentralised CHP plants, gas turbine
43			1	1	1	1	1	1	1						1	1	1	1	1	1		1	1	F	Decentralised CHP plants, boiler
44														F		1	1	1	1					F	Decentralised CHP plants, heat pump
45																									Decentralised CHP plants, heating element
46												1												F	Decentralised CHP plants, solar
47			1	1	1	1	1	1	1						1	1	1	1	1	1		1	1	F	Decentralised CHP plants, combined cycle gas turbine
48																									Decentralised CHP plants, district heating production
49															1					1		1	1	F	Farm biogas plants, combustion engine
50			1	1	1	1	1	1	1						1	1	1	1	1	1		1	1	F	Local CHP plants, combustion engine
51			1	1	1	1	1	1	1						1	1	1	1	1	1		1	1	F	Local CHP plants, boiler
52																									Local CHP plants, district heating production
53			1	1	1	1	1	1	1						1	1	1	1	1	1		1	1	F	District heating plants, boiler
54														F		1	1	1	1					F	District heating plants, heat pump
55																									District heating plants, heating element
56													F	1	1	1	1	1	1					F	District heating plants, geothermal
57												1												F	District heating plants, solar
58			11	11	11	11	11	11	11			11	11	11	11	11	11	11	11	11	11	11	11	F	Import district heating
59																								F	District heating plants, district heating production
60			1	1	1	1	1	1	1						1	1	1	1	1	1		1	1	F	Industrial CHP plants, steam turbine
61			1	1	1	1	1	1	1						1	1	1	1	1	1		1	1	F	Industrial CHP plants, combustion engine
62			1	1	1	1	1	1	1						1	1	1	1	1	1		1	1	F	Industrial CHP plants, gas turbine
63			1	1	1	1	1	1	1						1	1	1	1	1	1		1	1	F	Industrial CHP plants, boiler
64			1	1	1	1	1	1	1						1	1	1	1	1	1		1	1	F	Industrial CHP plants, combined cycle gas turbine
65																									Industrial CHP plants, surplus heat
66																									Industrial CHP plants, own-consumption, electricity
67																									Industrial CHP plants, own-consumption, heat
68																									Industrial CHP plants, district heating production
69								5								5								F	Cars, petrol
70						5										5								F	Cars, diesel
71						5										5								F	Delivery vans
72						5										5								F	Busses
73						5										5								F	Trucks, semi-trailers, buldozers etc.
74						12																		F	Tractors
75						3																		F	Trains
76							4	3																F	Aircrafts
77				3		3																		F	Ships
78	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	Total
79	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	CO_2-emissions (1.000 tonne)
80															9	9	9	9						F	Local biomass potential
81															F	F	F	F						F	Utilisation percentage of local biomass potential
84	E																								
85	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
86	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	CO_2-emission (tonne/TJ)	

Efficiency / Electricity grid / District heating / End-use

Row	Y Plant type	Z Electricity	AA Process	AB Heat	AC District heating grid	AD Electricity grid: Ex plant	AE Electricity grid: At consumer	AF District heating: Ex plant	AG District heating: At consumer	AH Total	AI Houses, incl. holiday houses	AJ Public service sector	AK Private service sector	AL Trade sector (retail and wholesale)	AM Building and construction sector	AN Manufacturing sector	AO Nursery garden	AP Agriculture	AQ Transport
8	Electric cooker		V			F	F			F	10								
9	Electric hot water			V		F	F			F	10								
10	Electric radiator			V		F	F			F	10								
11	Lighting		V			F	F			F	10	10	10	10	10	10	10	10	
12	Electric compressor		V			F	F			F	10	10	10	10	10	10	10	10	
13	Electric motor etc.		V			F	F			F	10	10	10	10	10	10	10	10	10
14	Heat pumps, individual			V		F	10			F	F								
15	Electricity import	V				F				F									
16	Gas cooker, process, etc.			V						F	F					F			F
17	Oil-fired boiler, individual			V						F	F								
18	Natural gas boiler, individual			V						F	F								
19	Wood pellets furnace, individual			V						F	F								
20	Wood furnace and -stove, individual			V						F	F								
21	Straw furnace, individual			V						F	F								
22	Solar heating			V						F	F								
23	Oil-fired boiler, business		V							F						F			
24	Natural gas boiler, business		V							F						F			
25	Industrial boiler, business		V							F						F			
26	Photovoltaics	V				F				F									
27	Wind turbines, land	V				F				F									
28	Wind turbines, coastal (50 %)	V				F				F									
29	Hydro power plants	V				F				F									
30	Wave power plants	V				F				F									
31	Central power plants, steam turbine	1		1		F		F		F									
32	Central power plants, combustion engine	1		1		F		F		F									
33	Central power plants, gas turbine	1		1		F		F		F									
34	Central power plants, boiler			1				F		F									
35	Central power plants, district heating production				11			F	F	F	F	F	F	F	F	F	F	F	
36	Waste-to-energy plants, steam turbine	1		1		F		F		F									
37	Waste-to-energy plants, boiler			1				F		F									
38	Waste-to-energy plants, combined plant	1		1		F		F		F									
39	Waste-to-energy plants, district heating production				11			F	F	F	F	F	F	F	F	F	F	F	
40	Decentralised CHP plants, steam turbine	1		1		F		F		F									
41	Decentralised CHP plants, combustion engine	1		1		F		F		F									
42	Decentralised CHP plants, gas turbine	1		1		F		F		F									
43	Decentralised CHP plants, boiler			1				F		F									
44	Decentralised CHP plants, heat pump			1		F	1	F		F									
45	Decentralised CHP plants, heating element			1		F	1	F		F									
46	Decentralised CHP plants, solar			V				F		F									
47	Decentralised CHP plants, combined cycle gas turbine	1		1		F		F		F									
48	Decentralised CHP plants, district heating production				11			F	F	F	F	F	F	F	F	F	F	F	
49	Farm biogas plants, combustion engine	1		1		F		F		F									
50	Local CHP plants, combustion engine	1		1		F		F		F									
51	Local CHP plants, boiler			1				F		F									
52	Local CHP plants, district heating production				11			F	F	F	F	F	F	F	F	F	F	F	
53	District heating plants, boiler			1				F		F									
54	District heating plants, heat pump			1		F	1	F		F									
55	District heating plants, heating element			1		F	1	F		F									
56	District heating plants, geothermal			1				F		F									
57	District heating plants, solar			V				F		F									
58	Import district heating							F		F									
59	District heating plants, district heating production				11			F	F	F	F	F	F	F	F	F	F	F	
60	Industrial CHP plants, steam turbine	1		1		F		F		F									
61	Industrial CHP plants, combustion engine	1		1		F		F		F									
62	Industrial CHP plants, gas turbine	1		1		F		F		F									
63	Industrial CHP plants, boiler			1				F		F									
64	Industrial CHP plants, combined cycle gas turbine	1		1		F		F		F									
65	Industrial CHP plants, surplus heat			V		F				F									
66	Industrial CHP plants, own-consumption, electricity					F	1			F						F			
67	Industrial CHP plants, own-consumption, heat							1		F						F			
68	Industrial CHP plants, district heating production				11			F	F	F	F	F	F	F	F	F	F	F	
69	Cars, petrol		V							F									F
70	Cars, diesel		V							F									F
71	Delivery vans		V							F									F
72	Busses		V							F									F
73	Trucks, semi-trailers, buldozers etc.		V							F									F
74	Tractors		V							F								F	
75	Trains		V			F	10			F									F
76	Aircrafts		V							F									F
77	Ships		V							F									F
78	Total					F	F	F	F	F	F	F	F	F	F	F	F	F	F
79	CO_2-emissions (1.000 tonne)	F	tonne/inhabitants																
80	Local biomass potential	F	% RE global (EU)																
81	Utilisation percentage of local biomass potential	F	% RE local																

Used in the Baseline Emission Inventory
- Used in Table A. Final energy consumption
- Used in Table B2. Local renewable electricity production
- Used in Table B3. Local/distributed electricity production
- Used in Table B4. Local heat/cold production
- Used in Table C1. CO2 emission factors adopted
- Used as basis for Table B3 and B4

8 Annex 2: Energy Balance - Appendix description

The Energy Balance consists of a large variety of data, which can be found in 16 appendixes, which is attached to the Municipality's Energy Balance. The used data is highlighted with green in the appendixes and the data source also appears from each appendix. Not all assumptions are directly apparent in the attached appendixes, but are described in this chapter.

8.1 Appendix 1 – Energy Producer Count 2015

For the preparation of the energy balances data has been requested on all energy producers in Sonderborg from the ProjectZero. This is similar to DEAs "Energy Producer Count 2015" ('Energiproducenttælling 2015') and provides an overview of all the energy producers' energy production of heat and power, fuel type, fuel consumption, plant type, etc., (ProjectZero, 2016).

Fuel prices, electricity prices and prices of regulating power are of great importance for how much the CHP plants within the municipalities are running with their engines. Few operating hours will cause poor fuel efficiency, and raise electricity imports and give a higher CO_2-emission per kWh electricity than local produced CHP on natural gas.

ProjectZero's data in Appendix 1 may be used only for internal use as proof of the completed energy accounts. Data may not be published or used for other purposes without prior agreement. Therefore the data is not included.

8.1.1 Example of calculation of efficiency

In the shown example below there is fired 1 000 TJ of fuel into an internal combustion engine of a CHP plant. The efficiency of combustion engines is calculated as an average for the fuels used in the following way:

Thermal efficiency:
Heating Delivery (Varmelev_TJ) divided by the fired energy amount (Brutto_TJ). In this case the calculated heat efficiency as 500 TJ / 1 000 TJ x 100 % = 50 %.

Electrical efficiency:
Electrical efficiency is calculated as the electricity supplied to the grid (Ellev_TJ) divided by the fired energy amount (Brutto_TJ). In the present example, the electrical efficiency is as follows: 400 TJ /1 000 TJ × 100 % = 40 %

The fuels fired into industrial CHP plants appear from the "Energy Producer Count". Large parts of the energy production in the industrial plants will often go for own-consumption of electricity and heat.

The efficiency is calculated as total efficiency for electricity and heat. That is that efficiency for electricity and heat contains both own-consumption and energy supplied to respective district heating grid and electricity grid. Private consumption is extracted from the heat supplied to the grid.

The fuel consumption in condensing mode on the central power plants (e.g. Studstrup Power Station) is not included in the energy balance or in the BEI. Since the fuel consumption associated with condensing mode only result from electricity production traded on the Nord Pool Spot and is not associated with local heat production.

8.2 Appendix 2 – LPG and kerosene 2015

The consumption of LPG (liquefied petroleum gas) and kerosene are relatively limited in Denmark; see Energy Statistics 2014, from (DEA, 2016a). The consumption of LPG is by far the larger of the two fuels and is used within manufacturing, housing and private services.

Consumption of LPG and kerosene in the energy balance is found by allocating the national consumption by the population of the municipality as shown in Appendix 2 to the energy balance.

8.3 Appendix 3 – Diesel, petrol, and fuel oil for ships and trains 2015

Fuel oil is used for marine transport. Consumption of fuel oil in the energy balance is found by allocating the national consumption found in Energy Statistics 2014, (DEA, 2016a) by the population of the municipality (Statistics Denmark n.d.) as shown in Appendix 3 (also for municipalities without ports).

Diesel consumption for trains and ships, incl. fishing is found in Appendix 3 by allocating the national consumption of diesel from Energy Statistics 2014, (DEA, 2016a) by the population of each municipality.

Petrol consumption, incl. avgas (aviation gasoline) is found in Appendix 3 by allocating the national consumption of petrol from Energy Statistics 2014, (DEA, 2016a) by the population of each municipality.

8.4 Appendix 4 – Jet fuel (JP1) 2015

Consumption of jet fuel (JP1) is found in Appendix 4 by allocating the national consumption of petrol from Energy Statistics 2014, (DEA, 2016a) by the population of each municipality.

8.5 *Appendix 5 – Fuel for road transport 2015*

The consumption of diesel and petrol for road transport is with the exception of route buses based on statistics of the stock of vehicles in the municipality (Statistics Denmark). The energy consumption is calculated as a share of total consumption for road transport measured in Energy Statistics 2014. The calculation is based on national data for mileage per vehicle type (Danish Road Directorate, 2016) and average fuel consumption norm per vehicle type (Danish Centre for Environment and Energy, 2015).

The allocation of route buses is based on the population of each municipality. The energy consumption to public service traffic in the Central Denmark Region for route buses have previously been allocated on the basis of in which municipality the route buses have been registered. Since route buses for public service traffic primarily is registered in some municipalities, such an allocation, however, gives a higher share of fuel consumption for these municipalities. The population-based distribution therefore better reflects the actual route bus services in the municipalities and energy to this service. The new allocation method is also used in the accounts backward and corrected.

In Denmark 3.3 % of the petrol consumption consists of bioethanol and 7.8 % of the diesel consumption consists of biodiesel in 2013. There is therefore in the energy balances allocated 3.3 % for bioethanol and 7.8 % for biodiesel of the fuel consumption for each road transport.

8.6 *Appendix 6 – Wind power 2015*

Wind power production for 2015 is based on data from the DEA's central data register for wind turbines and provides all wind turbines and their placement in all municipalities ('Master data register for wind turbines'), (DEA, 2016b).

Wind power generation from onshore wind turbines in each municipality appears directly in DEA's central data register. 50 % of wind power production from coastal turbines is allocated in accordance with DEA's guidelines to the adjacent municipality. Thus, only wind power production from wind turbines located on land in a municipality as well as any share from coastal wind turbines are included in the municipality's wind power production while all offshore wind turbines indirect are included in the residual electricity see section 6*.2 Import of electricity,* (DEA, 2015b).

8.7 *Appendix 7 – Photovoltaic systems 2015*

Electricity production from photovoltaic systems in the Central Denmark Region is calculated based on the Danish TSO Energinet.dk's database for photovoltaic "Solcelleanlæg i Danmark august 2015", (Energinet.dk, 2016b). Annual production per kWp is set to 800 kWh/kWp see 'Technology Data for Energy Plants - Generation of Electricity and District Heating, Energy

Storage and Energy Carrier Generation and Conversion', (DEA, 2012b) and 'Renewable Energy RD & D Priorities, Insights from IEA Technology Programmes', (IEA, 2006).

8.8 Appendix 8 – Biogas 2015

The total production of biogas in the biogas plants within the municipality are contained in the ProjectZero's "Energy Producer Count 2015" and also separate in the DEA's "Biogas Statistics", (DEA, 2015). Biogas production is partly based on manure and partly organic waste from industry. Biogas production is allocated between gas production from biomass and manure in the energy balances. This allocation is based on data from 2005 from biogas plants in the Central Denmark Region. According to these data gas from manure represent on average 46 % of the produced biogas, while gas from organic industrial waste on average is 54 %. This allocation is used for biogas plants in the Central Denmark Region.

8.9 Appendix 9 – Biomass potential 2015

Aarhus University has produced a dedicated and updated inventory of local biomass potentials in 2012. Biomass potential is shown under local biomass potentials in the bottom of the energy balances and consists of:

- Energy crops include: Energy crops on 15% of the present grain area
- Straw include: Rape straw and grain straw
- Wood and wood chips include: Fences, gardens and woodland
- Biogas include: Gas from manure and use of extensive grass from low-bottom areas

For further details of the method, see "Energy from biomass - Resources and technologies assessed in a regional perspective", (Aarhus University, 2008). These potentials are not used for the Covenant of Mayors.

8.10 Appendix 10 – Electricity consumption 2015

The electricity consumption within the municipality is calculated in Appendix 10, based on data provided by the local electricity distribution companies in the Central Denmark Region. Electricity consumption in the energy balance is allocated to the consumer categories on the right side of the energy balance.

The allocation of end-use on conversion units is based on data from "Technology Catalog, potentials for energy savings", (DEA, 1995). The DEA estimates that electricity consumption has remained fairly stable since 1995, with an increase in consumption for IT and a decrease for lighting (Sparenergi.dk, 2014). Data is presented in Table 8.1.

End-use	Electric cooker	Lighting	Refrigeration Equipment	Motor, etc.
Households	15,5 %	15,5 %	18 %	51 %
Agriculture		15 %	3 %	82 %

Nursery garden		15 %	3 %	82 %
Trade		25 %	28 %	47 %
Private services		25 %	28 %	47 %
Public services		27 %	0 %	73 %
Building and construction		6 %	8 %	86 %
Manufacturing		6 %	8 %	86 %

Table 8.1 Allocation of electricity end-use on conversion units.

The consumption of electricity for heating in homes with electric heating or heat pump is divided into "general electricity consumption" and "electricity consumption for heating" by calculating the difference in consumption per household for houses with electric heating or heat pump and consumption per household for houses without. The difference in consumption per household is assumed to be the electricity used for heating purposes. For holiday houses 65 % of the electricity consumption is allocated to heating. See "Description of Potential - Individual heat pumps", (Danish Technological Institute, 2010). Electricity consumption for heating is allocated with 82.5% for space heating and 17.5% for domestic hot water.

The electricity consumption data is divided into categories, where the division is somewhat uncertain, especially the sub-categories. In the energy balances only overall categories is used, and the uncertainty is therefore limited. This uncertainty does not affect the total electricity consumption within the municipality, and thus not the total energy consumption, CO_2-emissions, RE%, etc.

8.11 Appendix 11 – District heating networks 2015

There may be large local variations in grid losses in the district heating networks and there are therefore previously obtained data for transmission losses from the district heating networks in Denmark. For the energy balances the transmission losses in the district heating networks for a municipality is based on the (Danish District Heating Association, 2016) - Benchmarking statistics for 2015.

The allocation of district heating consumption in end-use categories is based on distribution data from Sonderborg District Heating Company. For municipalities that do not have obtained this data the allocation is based on the national allocation from the Energy Statistics 2014.

8.12 Appendix 12 – Diesel consumption in agriculture 2015

The consumption of diesel in agriculture tractors etc. is calculated in Appendix 12. Diesel consumption is calculated based on fuel consumption for different crop types based on "Energy Consumption and input-output relations of field operations", (Nielsen, 1989). Crop distribution for the Southern Denmark Region for 2015 can be found in Statistics Denmark, 2016.

8.13 Appendix 13 – Gas sales 2015

Natural gas consumption on the energy-producing plants is shown in Appendix 1. Gas sales figures for residential and commercial are delivered by the natural gas distribution company DONG Energy A/S. Consumption in the categories 'industry' and 'other' is calculated by deducting the consumption of natural gas in the "Energy Producer Count 2015" from the total gas sales and put it under the category 'other' and then assign the remaining consumption within the municipality to the category 'industry'.

8.14 Appendix 14 – Chimney sweeper data 2015

The chimney sweeper records are always up-to-date, and the used data extract is therefore based on the number of combustion units in early 2016. Fuel consumption is calculated based on estimated consumption per unit. E.g. unit consumption per oil-fired boilers is set to 75 GJ/year.

8.14.1 Example on estimating consumption per unit

For the estimation of the total firewood consumption per unit consumption the study "Firewood consumption in Denmark in 2011" prepared by the Danish Energy Authority and Force Technology is used (DEA & Force Technology, 2011).

With reference to this study the following average consumption per unit is determined:

- Wood stoves in houses: 30.4 GJ / year
- Wood stoves in holiday houses: 18.4 GJ / year
- Wood furnaces: 112.1 GJ / year

Unit consumption of straw boilers is calculated using data from the Danish Technological Institute. The Danish Technological Institute estimates that there are 7-8 000 straw boilers in Denmark with a total consumption of straw of approximately 330 000 tonnes/year. The heating value of straw is 14.5 GJ/tonne according to Energy Statistics 2013.

The average consumption per unit for straw boilers is calculated as:
330 000 ton/year / 7 500 x 14.5 GJ/ton = 638 GJ/year

Consumption per unit for wood pellet boiler is calculated on the basis of that the Danish Technological Institute estimates that a pellet boiler uses an average of 10-12 tons of pellets per years. The heating value of pellets is 17.5 GJ/tonne according to the Energy Statistics 2013.

Consumption per unit for pellet boiler can then be calculated as: 11 ton/year x 17.5 GJ/ton = 193 GJ/year.

8.15 Appendix 15 – Energy consumption of industry

Data has been gathered on the consumption of energy in the industry in 2014 from Statistics Denmark (Statistics Denmark, 2016). The 'energy consumption of industry' statistics is a little uncertain, as the statistics only relates to industrial workplaces with more than 20 employees.

The 'energy consumption of industry' statistics contain data on the consumption of natural gas, liquid fuels and solid fuels, and is further subdivided, for example on diesel fuel, pellets or waste. It is not apparent from the data for waste whether it is biodegradable waste (CO_2 neutral) or not.

Fuel consumption in the industry category 'Waste' is allocated on the categories 'Organic waste, industry' and 'Waste, non-biodegradable' with 45 % and 55 % respectively. See also Section *3.6.1 CO_2-emissions from fossil fuels* for more information on waste.

8.16 Appendix 16 – Energy production from solar collectors 2015

National figures for the energy production from solar collectors, c.f. Energy Statistics 2014 (DEA, 2016a), are allocated based on the number of buildings with individual supply in each municipality, c.f. Statistics Denmark (n.d.)

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