Intended for
Technical Advisory Group Subcommittee

Document type
Briefing and assumption note

Date
May, 2015

FORD SITE ENERGY STUDY
FINANCIAL ANALYSIS BRIEF

RAMBOLL

FORD SITE ENERGY STUDY
FINANCIAL ANALYSIS BRIEF

Revision	**01**
Date	**01/05/2015**
Made by	**DAVB**
Checked by	**JAKB**
Approved by	**PMO**
Description	**Briefing on assumptions and setup to be used for the financial analysis of energy concepts for the Ford Site Energy Study**

Ref 1100012867-39

Ramboll
Hannemanns Allé 53
DK-2300 Copenhagen S
Denmark
T +45 5161 1000
F +45 5161 1001
www.ramboll.com

CONTENT

TABLE OF FIGURES

1. INTRODUCTION

Building on the Energy Study work for the Ford Site Redevelopment to date, Ramboll will in Activity 1.7 carry out an analysis of the financial viability of the derived energy supply concepts.

Ramboll have started work on the following analysis:

- Based on **development scenario 5,** estimations of the likely build out phasing of the site, and the likely energy demand and its duration throughout the year.
- Analysis of three (3) concepts for financial viability (as agreed at the TAG meeting on 2015-29-01):
    0. Business as usual scenario (Grid electricity, natural gas individual heating, and air Conditioning cooling)
    1. District energy scenario (Hydro plant, Solar Thermal, River Heat pump for heating and cooling, gas back-up, thermal storage (seasonal/daily))
    2. Individual generation scenario (Solar PV, Solar thermal, heat pump heating and cooling (ground source heat pump potentially), hot water storage)

The analysis methodology and process is briefly outlined below.

To add most value to the study it is important that the financial analysis has inputs from the Technical Advisory Group (TAG) subcommittee in particular on pricing installations and pipes, and on the expected build out of the site.

This document serves as the initial outline of the analysis as information for the TAG subcommittee prior to a conference call on May 5, 2015. The ambition is to clarify the setup of the analysis, align expectations and engage the TAG to provide the input needed.

The document is structured in 5 sections elaborating on the 2) Site build out, 3) Energy Demand, 4) Energy Supply Concepts, 5) General Financial Assumptions and 6) Prices and tariffs.

The results of the analysis will be presented to the full TAG late May.

2. SITE BUILD OUT AND CONNECTIONS

As noted in Section 1 the financial analysis is based on the Scenario 5 from the Phase 1 Summary Report[1].
Ramboll suggest assuming the following build out of the site.

Table 1 Start development year

Area	Year
Green	0
Yellow	3
Blue	6
Red	10

Each area is assumed to be built within 5 years from start development year, and buildings fully occupied within 5 years of completion.

Figure 1 Site Development

[1] http://www.stpaul.gov/DocumentCenter/Home/View/3162

3. ENERGY DEMAND

The client and their advisors have chosen to proceed with Activity 1.7 using scenario 5 with an increase residential density as the baseline for building stock area and type distribution.

An overview of the building type areas included in scenario 5 is listed in table 2 below:

Table 2 - Scenario 5 Building Type Areas

Unit	Total Heated/Cooled Floor Area (ft^2)
Apartment/Condo (Low Density - 28 units/acre)	534.000
Apartment/Condo (Medium Density - 45 units/acre)	1.296.000
Apartment/Condo (High Density - 80 units/acre)	570.000
Civic	50.000
Retail/Mixed use	375.000
Official/Institutional	194.000

The estimated Site Energy Utilization Intensity (EUI) for different building types have been provided according to climate zone 6A (St. Paul) and the SB 2030 code. These are outlined below in table 3. For this assessment we have used the SB 2020 energy demands (highlighted in blue) as a basis:

Table 3 - Site Energy Utilization Intensity (EUI)

		ASHRAE 90.1-2004 [1]			2012 IECC / ASHRAE 90.1-2010 [1] [2]		2015 IECC / ASHRAE 90.1-2013 [2]		SB 2030					
	Prototype Floor Area (sf)	National Average Site EUI	**Climate Zone 6 Average Site EUI**	Factor between National and Climate Zone 6A	National Average Site EUI	**Climate Zone 6 Average Site EUI**	National Average Site EUI	**Climate Zone 6 Average Site EUI**	2003 Baseline	2010 60% below	2015 70% below	2020 80% below	2025 90% below	2030 100% below
Small office	5.502	42,4	**53,7**	1,267	33,0	**41,8**	29,4	**37,2**	157,5	63,0	47,3	31,5	15,8	-
Medium office	53.628	49,5	**62,2**	1,256	36,8	**46,2**	34,1	**42,8**	155,0	62,0	46,5	31,0	15,5	-
Large office	498.588	84,5	**99,7**	1,179	71,9	**84,8**	70,8	**83,5**	150,0	60,0	45,0	30,0	15,0	-
Stand-alone retail	24.692	79,5	**107,2**	1,348	53,4	**71,9**	45,9	**61,9**	147,5	59,0	44,3	29,5	14,8	-
Strip mall retail	22.500	83,7	**118,3**	1,414	60,4	**85,4**	55,1	**77,9**	150,0	60,0	45,0	30,0	15,0	-
Supermarket [3]	n/a	179,0	**208,0**	1,162	*124,8*	**145,0**	*110,8*	**128,7**	297,5	119,0	89,3	59,5	29,8	-
Primary school	73.959	80,1	**100,1**	1,250	60,1	**75,1**	54,2	**67,8**	175,0	70,0	52,5	35,0	17,5	-
Secondary school	210.887	72,9	**98,4**	1,348	48,0	**64,7**	41,7	**56,2**	150,0	60,0	45,0	30,0	15,0	-
Hospital	241.501	170,5	**179,9**	1,055	131,3	**138,5**	123,7	**130,5**	197,5	79,0	59,3	39,5	19,8	-
Outpatient health care	40.946	157,4	**161,5**	1,026	120,2	**123,3**	115,8	**118,8**	130,0	52,0	39,0	26,0	13,0	-
Full-service restaurant	5.502	471,2	**570,2**	1,210	389,1	**470,9**	372,5	**450,8**	225,0	90,0	67,5	45,0	22,5	-
Quick-service restaurant	2.501	653,6	**781,9**	1,196	604,4	**723,0**	576,4	**689,6**	245,0	98,0	73,5	49,0	24,5	-
Small hotel	43.202	73,3	**87,4**	1,192	63,6	**75,8**	60,0	**71,5**	125,0	50,0	37,5	25,0	12,5	-
Large hotel	122.120	123,5	**151,8**	1,230	96,9	**119,1**	89,0	**109,4**	157,5	63,0	47,3	31,5	15,8	-
Warehouse	52.045	25,5	**35,3**	1,381	18,2	**25,2**	17,1	**23,6**	105,0	42,0	31,5	21,0	10,5	-
Mid-rise apartment	33.741	52,1	**68,0**	1,304	46,3	**60,4**	43,9	**57,3**	205,0	82,0	61,5	41,0	20,5	-
High-rise apartment [4]	84.360	55,3	**72,1**	1,304	50,4	**65,8**	46,9	**61,2**	220,0	88,0	66,0	44,0	22,0	-

Using these figures a total energy demand for each building type can be calculated. This is detailed as per the table 4 below:

Table 4 - Scenario 5 Total Energy Demands

Unit	Total Heated/Cooled Floor Area (ft^2)	Total Demand (MBtu/yr)
Apartment/Condo (Low Density - 28 units/acre)	534.000	21.894.000
Apartment/Condo (Medium Density - 45 units/acre)	1.296.000	53.136.000
Apartment/Condo (High Density - 80 units/acre)	570.000	25.080.000
Civic	50.000	1.500.000
Retail/Mixed use	375.000	11.156.250
Official/Institutional	194.000	5.981.667

Based on our experience and input from University of Minnesota we have assumed an energy distribution for the various building types at this stage. This is shown divided into heating, cooling and other as per table 5 below:

Table 5 - Scenario 5 % Energy Distribution

Unit	Total Heated/Cooled Floor Area (ft^2)	Total Demand (MBtu/yr)	Energy Distribution Heat/Cooling/Other
Apartment/Condo (Low Density - 28 units/acre)	534.000	21.894.000	40%/20%/40%
Apartment/Condo (Medium Density - 45 units/acre)	1.296.000	53.136.000	40%/20%/40%
Apartment/Condo (High Density - 80 units/acre)	570.000	25.080.000	40%/20%/40%
Civic	50.000	1.500.000	40%/30%/30%
Retail/Mixed use	375.000	11.156.250	40%/30%/30%
Official/Institutional	194.000	5.981.667	40%/30%/30%

Based on this, the annual heating and cooling demands for scenario 5 is therefore as summarised in table 6:-

Table 6 - Scenario 5 Annual Heating and Cooling Demands

Annual Total Heat demand	Annual Total Cooling demand
47.503.115,77 Mbtu/yr	25.616.336,83 Mbtu/yr
13.921,789 MWh/yr	7.507,407 MWh/yr

In order to calculate the peak building heating and cooling load we have estimated the number of full load hours that the new energy plant will need to run for. These assumptions are detailed in table 7 below:-

Table 7 - Scenario 5 Full Load Hours for Heating and Cooling Plant

Unit	Total Demand (MBtu/yr)	% Energy Distribution Heat/Cooling/Other	Full load hours per year Heat/Cooling
Apartment/Condo (Low Density - 28 units/acre)	21.894.000	40%/20%/40%	1800/1200
Apartment/Condo (Medium Density - 45 units/acre)	53.136.000	40%/20%/40%	1800/1200
Apartment/Condo (High Density - 80 units/acre)	25.080.000	40%/20%/40%	1800/1200
Civic	1.500.000	40%/30%/30%	1800/1500
Retail/Mixed use	11.156.250	40%/30%/30%	1800/1500
Official/Institutional	5.981.667	40%/30%/30%	1800/1500

The estimated peak heating and cooling load for scenario 5 are therefore summarised as follows in table 8:

Table 8 - Scenario 5 Peak Heating and Cooling loads

Peak Heat load	Peak Cooling load
26.390,62 Mbtu/hr	20.414,56 Mbtu/hr
7,73 MW	5,98 MW

Further Assumptions

In order to obtain realistic building footprint for each of the 38 building units, the scenario 5 map from the *Phase 1 summary report* has been integrated into a GIS platform.

Same type Buildings are assumed to have an equal number of floors so that there is proportionality between footprint area and the actual unit square footage.

Average site EUI's apply according to SB 2030 (year 2020).

To account for the uncertainty regarding category (small, medium or large) median values are used.

Based on typical HVAC load profiles and ASHRAE weather data, 70% of the cooling capacity would meet the total daily cooling requirements 85% of the time.

4. ENERGY CONCEPT

The 3 concept designs are based on previous knowledge attained in the two review memos of December 2014 prepared by Rambøll in collaboration with Krifcon.

1. "*Energy Technologies and System Report*" and
2. "*Best Practices in Building Design*" respectively,

4.1 Concept 1: Business As Usual - Individual Energy Production per Building

This is a "Business As Usual" (BAU) case where individual heating and cooling is assumed in each building unit.

Assumptions
Each unit has its own individual heating and cooling production (excluding electricity).

The chosen technology may differ depending on which building type it supplies.

Some suggestions are as follows:-

- **Small residential unit**: Natural gas boiler (with HWT) for heating/AC unit for cooling
- **Medium/Large residential unit**: Natural gas boiler central for heating /cooling central and local distribution
- **Official/Institutional**: Natural gas boiler central for heating/cooling central and local distribution

It is assumed that a Natural Gas (NGas) network is established throughout the area.

Table 9 - Concept 1 Specifications

Individual Scenario	Heating	Cooling	Electricity
Plant type	Ngas boiler Individual or Common	AC unit Individual or Common	Grid
Plant size, MW	Depending on Building type and size	Depending on Building type and size	
Plant efficiency, %	100%	200-400%	
Operating hours	1800	1200	
Maintenance	300 $/unit/yr	300 $/unit/yr	

For the installations for Concept 1, Ramboll would appreciate if the TAG subcommittee could provide input on the cost estimates to use for:

1) Natural gas installations (boiler, hot water tank, burner, gas ramp) of various sizes,
2) Natural gas network (unit prices installed on various dimensions of gas pipes, including service pipes), and
3) AC units of various sizes)

Alternatively Ramboll will use figures based on their experience from other similar projects.

4.2 Concept 2: Business As Usual with focus on high share of integrated Renewable Energy Supply (RES) on an individual building level

This is a further development of the BAU case described in concept 1 with individual heating and cooling production as close to 100% sustainable as possible.

Assumptions
Individual heating and cooling by Heat Pumps and Chillers respectively e.g. with electric rod.

Solar PV panels integrated into building mass with area according to electricity consumed by Heat Pumps and Chillers. The specification for the Solar PV is taken from the EPA Rooftop PV report.

Alternatively we propose the Solar PV panels could be located centrally at the concrete sealed area next to the river. A total of about 40% of the site area (approx. 4 acres) in solar Photovoltaics could be installed.

Table 10 - Concept 2 Specifications

Individual Scenario	Heating	Cooling	Electricity
Plant type	Heat Pump Individual or Common	Chiller Individual or Common	Solar PV + Grid
Plant size, MW	Depending on Building type and size	Depending on Building type and size	Depending on roof space
Plant efficiency, %	200-400%	400%	-
Operating hours	1800	1200	1300[2]
CAPEX/plant,	800$/kW	?	2,000$/kW[3]
Maintenance	450$/unit/yr.	300 $/unit/yr	-

Ramboll would appreciate input for costing of the units, in particular the chiller.

4.3 Concept 3 District Energy – Centralized Energy Production

The third concept is based on energy supply to the site via a District Heating & Cooling (DHC) network.

In this case both heating and cooling will be produced in a central energy center and then distributed via a buried pipe network with individual connections to each building unit.

In this DHC concept we propose to utilise the adjacent Mississippi River as an energy source with large scale heat pumps acting as the primary heat mover to the site.
Ramboll will, during the analysis, investigate the potential for introducing a solar thermal plant, at the 4 acres available space next to the energy plant.

The following simple schematic diagrams aim to show how this could be realised by either providing dedicated or integrated heating and cooling via the heat pumps.

[2] Assuming a little less than the maximum production (1400) mentioned in the EPA report.
[3] Assuming the average cost projections for 2019, p. 23 of the EPA report.

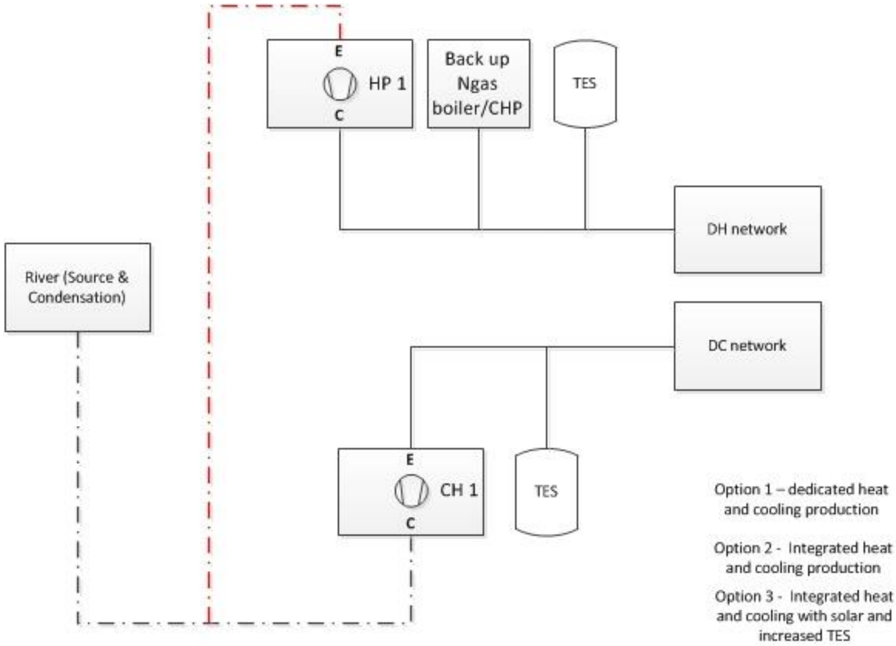

Figure 2 - Concept 3 with integrated heating and cooling production + thermal storage

The energy production will be on a modulated approach with smaller units added on, to delay CAPEX and ensure reliability when units are out.

Based on the energy demands described in section 2 we have simulated the dedicated DHC concept using EnergyPro software. For now only the fully built out demand have been simulated.

By simulating the energy demand of the site in line with available weather data for the city of St Paul it has enabled us to provide an initial indication of the possible major plant sizes. i.e. heat pump, chillers, thermal energy storages (TES) etc.

An indication of the annual contribution each major plant item makes to the energy demand can be seen below:

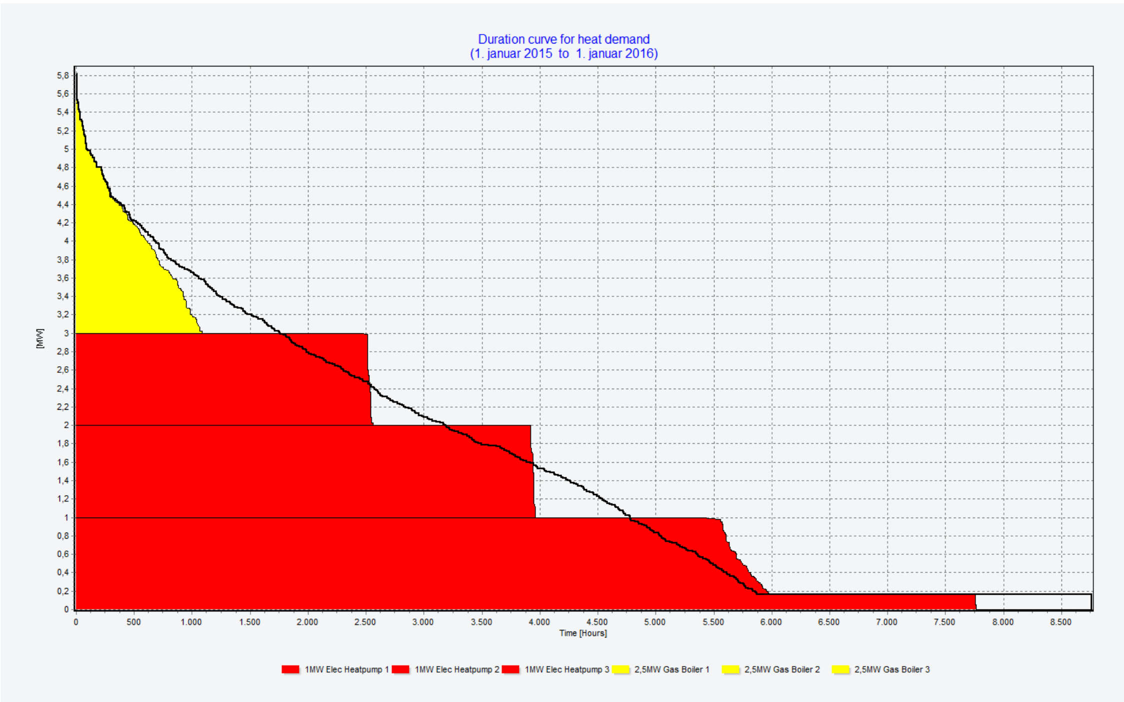

Figure 3 Heat Duration Curve with Productions from Heat Pumps and Ngas boilers Plant

The heat duration curves will change as they have so far not been optimized with MISO electricity prices.

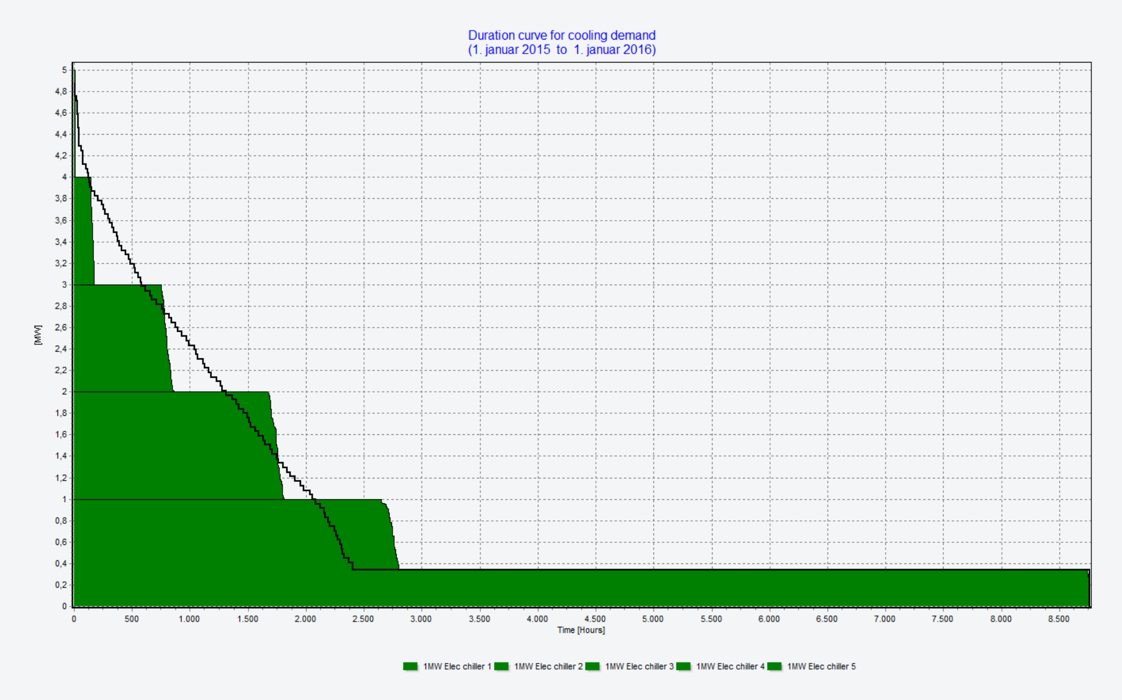

Figure 4 - Cooling Duration Curve with Productions from Chiller Plant

<u>Assumptions</u>
Natural gas boilers to be provided with standby capacity in N+1 configuration

Chillers to be provided with standby capacity in N+1 configuration

Table 11 - Concept 3 Specifications

District Energy Scenario	District Heating			District Cooling	
Plant type	Heat pump	Natural gas boiler	Thermal Store	Chiller	Cold Store
Plant size, MW	3 x 1MW	4 x 2MW	1000m^3	5 x 1MW	1000m3
Plant efficiency	500-1000%[4]	100%	-	500%	-
CAPEX/plant, M$/MW	0,7	0,1	200$/m^3		200$/m^3
OPEX, $/MW	6000	4000	-		-

Ramboll would appreciate input for costing of the units, in particular the chiller.

DHC Network

Network dimensions will be chosen following more detailed hydraulic modelling of the proposed DHC concept. This will be carried out at the next stage using our in-house hydraulic modelling software.

At this stage we envisage a low temperature DH network will be employed with the following operating parameters:-

- Winter Operating temperatures 85°C for the supply and 35°C for the return
- Summer Operating temperatures 70°C for the supply and 35°C for the return
- Operating pressure 6 to 10bar

It should be noted that these temperatures requires a different design to the secondary systems than is normal practise in the US.

[4] Depending cooperation with chiller and river water temperature.

Installed district energy pipe prices are assumed to be approximately:

Table 12 - Prices pipes installed

Pipes	DN (mm)	25	32	40	50	65	80	100	125	150	200
Heating/ Cooling	$/m	700	750	780	825	900	1050	1300	1450	1750	2400

It's assumed that heating and cooling pipes are installed simultaneously thereby lowering the installation costs.

Pre-insulated pipes have been assumed for both the heating and cooling network.

The TAG subcommittee's view on these prices would be appreciate

5. FINANCIAL ASSUMPTIONS

For the analysis Ramboll will use the following financial inputs unless otherwise requested by the TAG subcommittee.

Parameter	Ramboll suggestion
Start year	2019
Inflation	2%
Discount rate (WACC)	5%
Interest on debt	5%

Ramboll will assume that all CAPEX is financed through debt. Taxes are currently not taken into consideration.

6. OPERATIONAL COSTS AND TARIFFS

For the price assumptions in the analysis a number of different components are needed.

6.1 Energy prices

The following energy prices are initially assumed.

Natural gas prices, for energy plants in DH scenario and for end users in BAU scenario. We assume 4 different price levels dependent on customer type (DH company, industrial, commercial/retail, residential). The price is for the base year (2016), and the price is adjusted annually by the chosen rate of inflation.
Flat rate prices are assumed for all utilities except electricity for the district energy company.

Table 13 Energy Prices ($/MWh)

	Residential	Commercial/Retail	Industrial	District energy utility
Natural gas	35	25	20	19
Electricity	148	139	117	-

The prices are only indicative and Ramboll will appreciate input from the TAG subcommittee.

The electricity prices for the district energy utility will, unless otherwise advised, be based on historical hourly day-head prices from the MISO market with a markup of 20% for distribution charges.

6.2 Capital, operation and maintenance cost

Capex and O&M cost are noted under the individual technologies in section 3. The Capex estimations for the analysis will be based on the estimates from the Danish Energy Authorities, unless otherwise is suggested.

6.3 Tariffs and fees

Various tariff and fee structures will be simulated within the analysis to highlight impact on business case.