



PLANNING DISTRICT ENERGY

IEA ANNEX 73

RAMBOLL ENERGY

ANDERS DYRELUND

CONTENT

- General approach for planning of DH&C systems
- Methodology for district heating planning
- Developed by Ramboll
- Used in many small and huge projects for District energy in Denmark
- Tested in Scotland

GENERAL METHODOLOGY FOR PLANNING DISTRICT ENERGY SYSTEMS

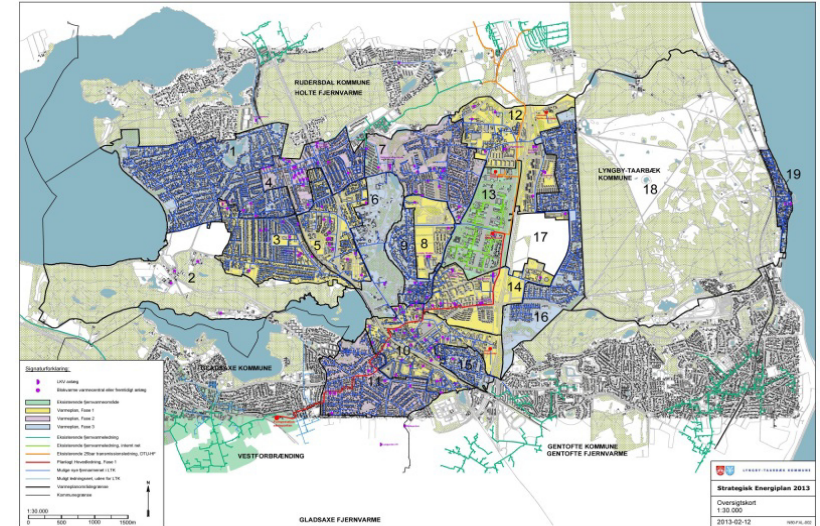
STAKEHOLDER ANALYSIS



- Identify and contact major stakeholder for acceptance
 - Municipality, City, Mayor
 - Local district heating network companies
 - Identify and contact other stakeholders important for the analysis
 - Regional gas, power and waste company
 - Waste management company
 - Industries and other potential suppliers and large consumers
 - Campus, Housing companies etc.
- Define stakeholders who will share the benefits - **all stakeholders represent the local community**
- Work for **transparency** and exchange of true information within the local community

DATA COLLECTION ON SITE

- Geographic digital map
- Heat map data for all buildings
- District heating companies/producers
 - Network, Heat production, develop. plans
- Large heating and cooling consumers
 - Supply area, (x,y), demand (MWh, kW) production plant supply and temperatures, eventual local grid, campus
- Small individual consumers
 - Address, (x,y), m2, type, age, demand kWh/m2, supply and return temp
- Prognosis for urban development
 - m2, building type, heat and cold demand



Område	Anvendelse	VEJ	HusNr	Opvarmet Areal	ForbrugSpec_KWh_m2
01 Virum	Parcel- og stu	Agerbakken	3	120	227
01 Virum	Parcel- og stu	Agerbakken	4	166	111
01 Virum	Parcel- og stu	Agerbakken	5	233	82
01 Virum	Parcel- og stu	Agerbakken	6	168	135
01 Virum	Parcel- og stu	Agerbakken	7	164	227
01 Virum	Parcel- og stu	Agerbakken	9	159,5	80
01 Virum	Parcel- og stu	Arnevej	3	98,5	227
01 Virum	Parcel- og stu	Arnevej	4	105	167
01 Virum	Parcel- og stu	Arnevej	5	92,5	227
01 Virum	Parcel- og stu	Arnevej	6	185,5	80
01 Virum	Parcel- og stu	Askimvej	3	165	80

GENERAL DATA FOR THE REGION

- Unit cost of energy delivered to the local community, tariff structure, time fluctuations, and prognosis
- Unit costs of pipes, city, open area, open land
- Unit costs of individual boilers, heat pumps and substations
- Operation and maintenance costs of network and substations
- Etc.

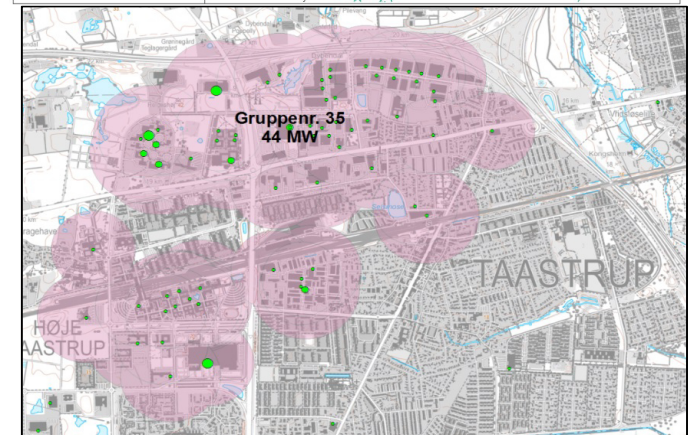
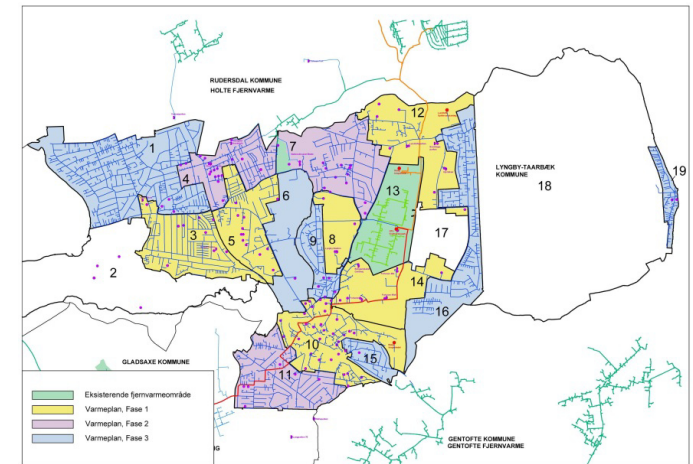
Brugerinst.		Fjernvarme		Naturgas		Individuel VP	
MWh/år	kW	kr/kW	kr	kr/kW	kr	kr/kW	kr
10	5	4.600	23.000	6.900	34.500	20.100	100.500
20	10	2.300	23.000	3.450	34.500	12.050	120.500
100	50	1.214	60.686	1.821	91.029	8.248	412.402
200	100	864	86.414	1.296	129.621	7.024	702.450
1.000	500	393	196.332	589	294.497	5.374	2.687.161
2.000	1.000	280	279.567	419	419.350	4.978	4.978.484
10.000	5.000	127	635.170	191	952.756	4.445	22.223.096

Dimension DN	Enhedspris kr/m
DN20	2.300
DN25	2.300
DN32	2.300
DN40	2.300
DN50	2.300
DN65	2.500
DN80	2.300
DN100	3.400
DN125	4.000
DN150	4.800
DN200	5.400
DN250	6.000
DN300	7.100
DN350	17.124
DN400	18.620

Individuel solvarme på tag, med en solvarmedækning på: 15%					
Årsbehov	Solvarme	Paneler	Pris pr m2	Investering	Kap. Omk.
MWh/år	MWh	m2	kr/m2	kr	kr/MWh
10	2	4	7.400	27.750	1.369
20	3	8	6.900	51.750	1.277
100	15	38	5.500	206.250	1.018
200	30	75	5.000	375.000	925
1.000	150	375	3.700	1.387.500	685

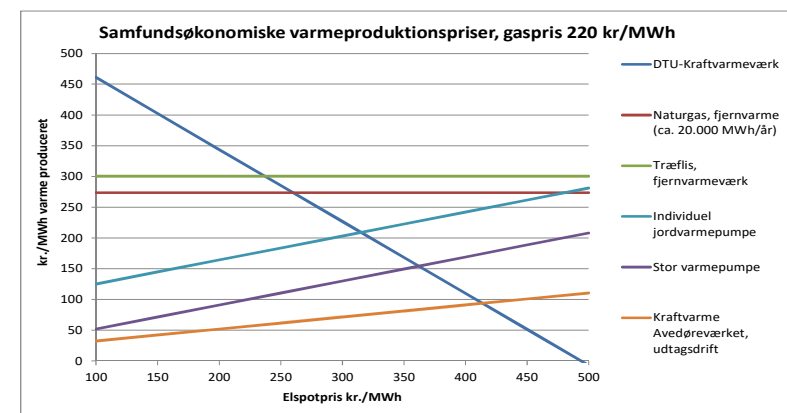
ENERGY DISTRICTS AND CONSUMER DATA SCREENING ZONING OF DH DC DISTRICTS

- Define energy districts based on:
 - Large consumers
 - Uniform urban structure
- A first ranking of districts based on experience and geographic location
- A screening of the potential district heat supply zones,
- A screening of the potential district cooling zones, DC-mapper model



MAPPING OF HEAT AND COLD SOURCES

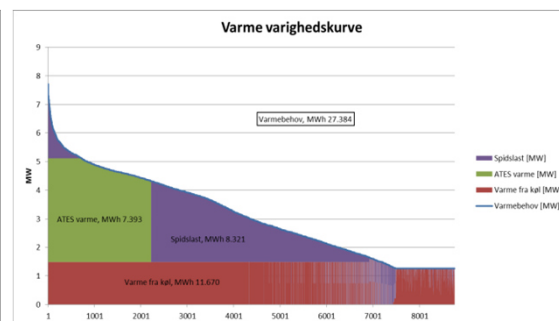
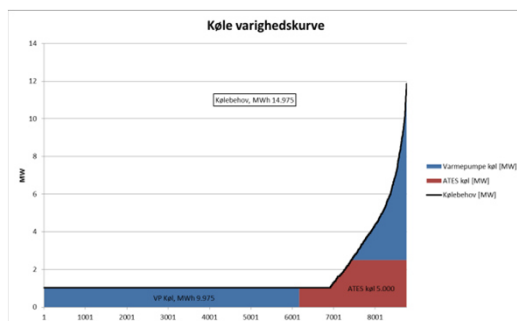
- Existing sources for district heating and cooling, Waste to energy, CHP, Industrial surplus heat, boilers, heat pumps, free cooling..
 - Capacity
 - Fuel, energy efficiency data, COP, power-to-heat-ratio etc.
 - Technical availability
 - Commercial availability, depending on power market etc.
 - Costs or tariffs for purchased heat and cold
- Compare sources
- Other planned competing sources ?



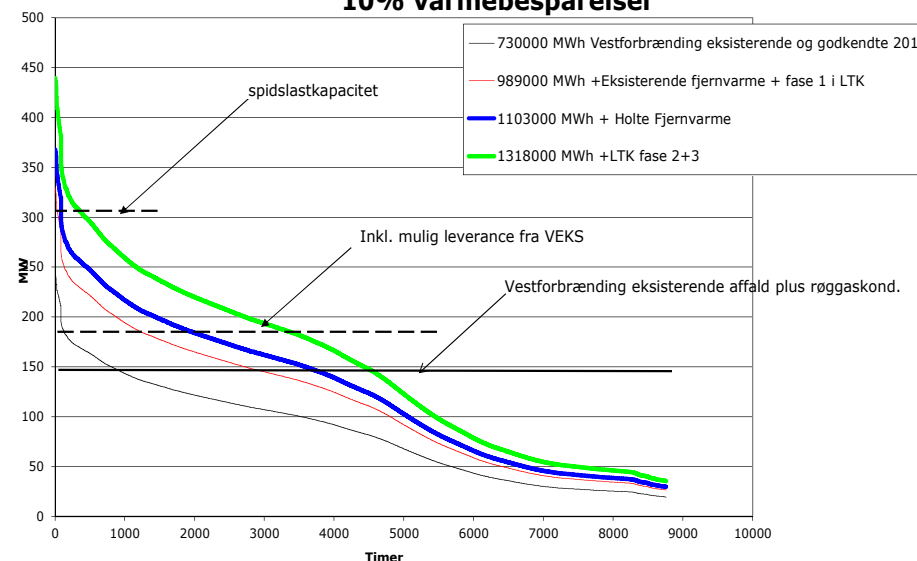
FIRST STEP SYSTEM ANALYSIS

HEAT DURATION CURVE AND CONCEPTS

- Annual heat and cold duration curves
 - Priority of zones
 - Priority of production
- Dynamic heat and cold load fluctuations
- Estimate return and supply temperature duration curve
- Concepts for thermal storages

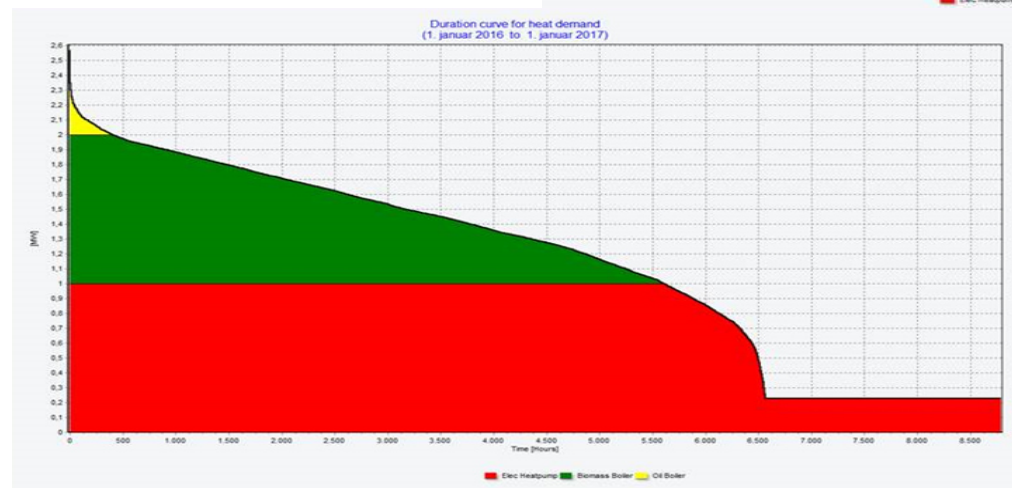
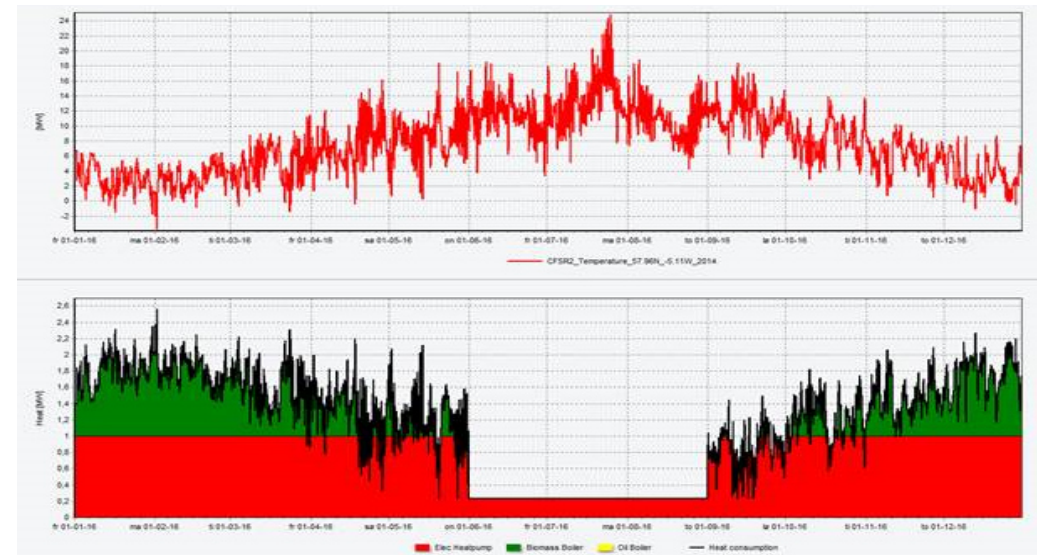


Skematisk Varighedskurve for Vestforbrænding inkl. 10% varmebesparelser



SECOND STEP, DETAILED LOAD OPTIMIZATION WITH ENERGYPRO

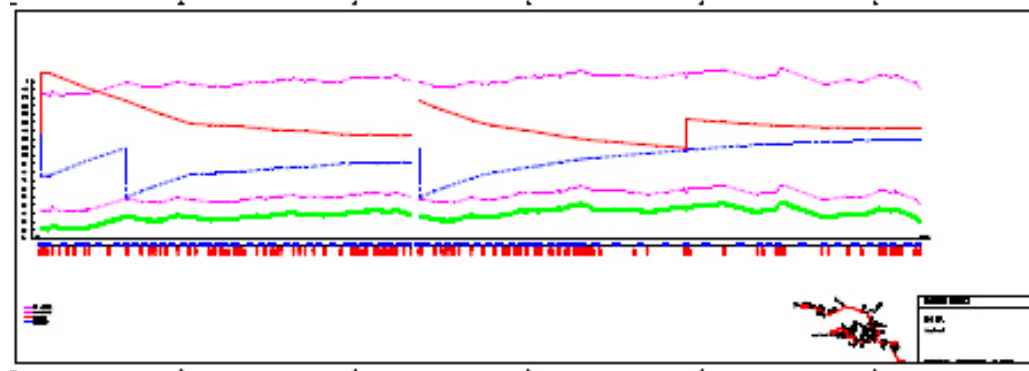
- Load dispatch to the economic model
- Optimize production
- Optimize size of thermal storage



NETWORK ANALYSIS

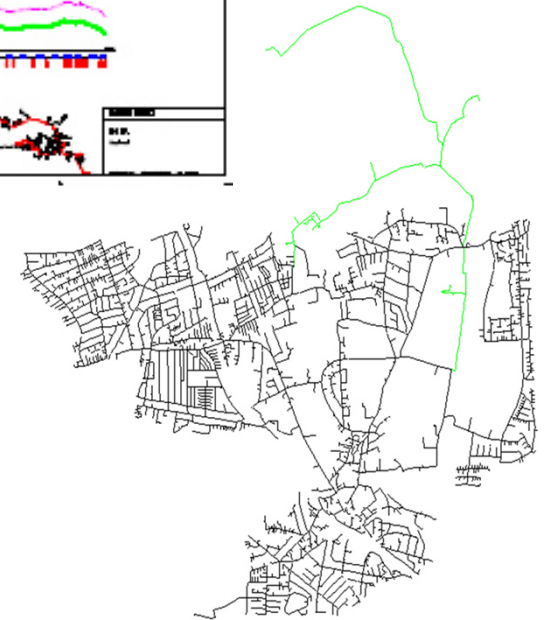
- Identify load cases on the heat duration curves

- Maximal peak load
- Maximal use of base load
- Summer load



- Trench in hydraulic model

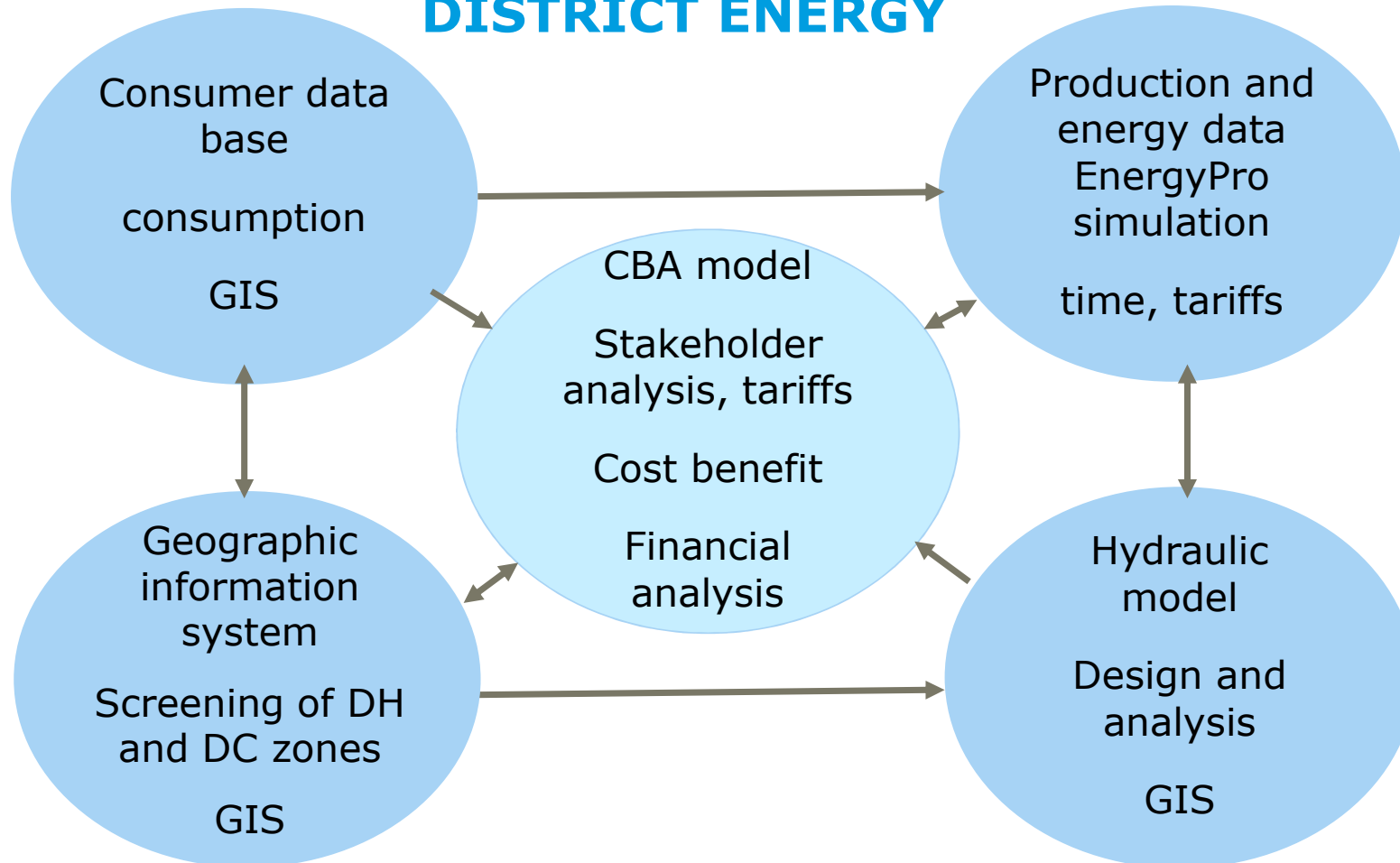
- Transfer demand and production capacity (x,y) to the grids
- Design parameters, pressure levels and zones, temperature
- Design of network for the base case, including booster pumps
- Calculate heat losses, temperature drops in summer
- Optimization, booster pumps and considerate future expansion
- Loop, back to EnergyPro with network capacity constrains, if any



RELEVANT SCENARIOS TO ANALYSE IN TWO DIMENSIONS: NETWORK AND ENERGY SOURCE

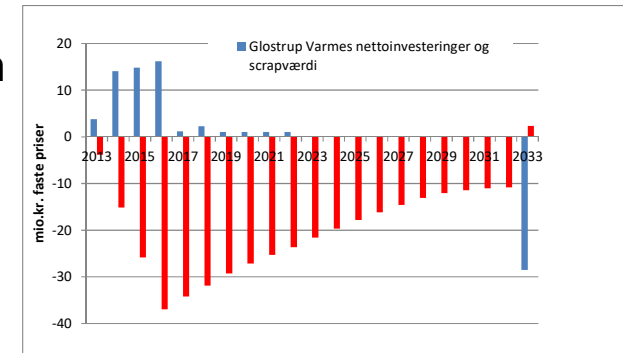
- Baseline:
 - existing production, gas or oil
 - new production, heat pumps
- Network
 - in best districts
 - extended to additional districts
- Production and storage
 - CHP with storage
 - Biomass boiler
 - Large heat pump for combined heat and cold, heat only or cold only
 - Data centre, waste water, ground water or ambient air heat pump

MODEL AND METHODOLOGY FOR PLANNING DISTRICT ENERGY



COST BENEFIT ANALYSIS, CBA (FIXED COST) FOR THE LOCAL COMMUNITY STAKEHOLDERS

- Identify all incremental net costs in the local community for each scenario for providing the services
- Careful comparison of the costs of scenarios to assure that they deliver the same services
- Include a realistic forecast for energy costs etc.
- NPV analysis, define life time and discount rate (4%?)
- Total PV of all costs for each scenario in 20 years
- Include residual value for assets which have longer life time
- Calculate NPV and IRR of investment scenarios compared to baseline for the local community
- Sensitivity for major assumptions

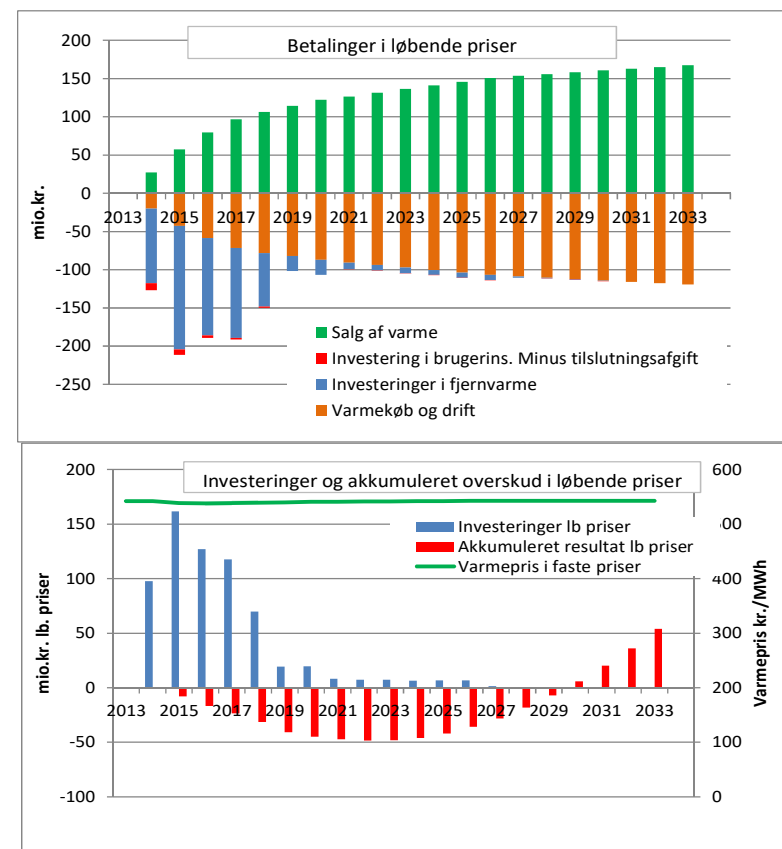


TARIFF ANALYSIS AND SHARE OF BENEFITS OR HOW TO “SHARE THE CAKE”

- Identify and propose tariffs for exchange of energy between stakeholders in the local community
- Calculate NPV and IRR of investment scenarios compared to baseline for each stakeholder
- The NPV benefit for the local community is equal to the total of the NPV benefit for each stakeholder
- Sensitivity analysis for changing tariffs (to ensure that all major stakeholders get a benefit and incentives to continue)

FINANCIAL ANALYSIS FOR INVESTOR

- Transfer of CBA data for the major stakeholder to prices of the year
- Depreciate investments
- Long-term financing of long-term debt
- Profit/loss account
- Cash flow analysis
- Short-term financing of eventual accumulated deficit
- Evaluate financial key-figures etc.



INCENTIVES TO CONSUMERS

- Assess the competitiveness of DH compared to existing gas boilers, oil boilers electric heating, heat pumps etc.
- Assess incentives to encourage consumers to connect from year one, e.g.
 - Package solution including substation all included in the tariff
 - Package of District heating and district cooling
 - Incentives to reduce need for large supply temperature
 - Incentives to reduce return temperature

STRATEGY FOR NEW NETWORK ECONOMIC ASSESSMENT

- Cost-benefit analysis (NPV, 20 year life time) for the local community, city gate prices, eventual including externalities
 - District heating company
 - New consumers
 - Private producer, e.g. CHP plant
 - Private producer, e.g. surplus heat
- Cost-benefit analysis for all parties in local community based on a model for tariffs to share benefit in a reasonable way
- Sensitivity analysis
- Financial analysis for investment projects
- Consumer analysis, total costs before and after connection first year

MODEL FOR SCOTLAND BASED ON THE METHODOLOGY FOR DISTRICT HEATING PLANNING

THE STRUCTURE IN THE MODEL

Summary / Project / Baseline / Network / Consumers / Comparison

- Summary: data and results
- Project: the district heating scenario
- Baseline: the baseline scenario
- Network: calculate cost and heat losses of network
 - Data from network analysis, length and dimensions
- Consumers: consumer data and costs of heat supply for each
 - Data from Heat Map, identification, (x,y), MWh, kW
 - Data from urban planning for new buildings
- Comparison of DH and individual, data from “consumers”
- Additional sheets: transfer of data from Heat Map sheet, network design sheet, sheet for design of figures etc.

HEAT MAP SHEET

- Selected columns to be transferred to the model's consumer sheet

UPRN	Category	X_COORD	Y_COORD	UNIQUE_CO	CLASS	IS_UNIQ	Unique Conn	SOURCE	STREET_DESCRIPTOR	POSTCODE	ADMINISTRATIVE	POST_TOWNSHIP	Heat Demand (kWh)
9059075860	Unknown	339879	730457	DC001-1	CC02	1	339879:730	Assessor	WEST BELL STREET	DD1 1AD	DUNDEE CIT	DUNDEE	57.916
9059075856	Office	339841	730438	DC001-2	CC02	1	339841:730	Assessor	WEST BELL STREET	DD1 9AD	DUNDEE CIT	0	652.835
9059075859	Office	339975	730459	DC001-3	CC08	1	339975:730	Assessor	WEST BELL STREET	DD1 1EX	DUNDEE CIT	0	136.552
9059024503	Unknown	340138	730515	DC001-4	CE04SS	1	340138:730	Assessor	EUCLID CRESCENT	DD1 1HU	DUNDEE CIT	DUNDEE	4.126.983
9059033362	Education	340115	730558	DC001-6	CE05	1	340115:730	Assessor	BELL STREET	DD1 1HG	DUNDEE CIT	DUNDEE	7.219.555
9059041174	Industrial	339990	730466	DC001-7	CI03	1	339990:730	Assessor	WEST BELL STREET	DD1 1EX	DUNDEE CIT	0	47.167
9059077215	Industrial	340148	730575	DC001-8	CI03	1	340148:730	Assessor	BELL STREET	DD1 1HF	DUNDEE CIT	0	29.258
9059075908	Industrial	340213	730609	DC001-10	CI04	1	340213:730	Assessor	VICTORIA ROAD	DD1 1JG	DUNDEE CIT	0	25.559
9059077217	Industrial	340210	730605	DC001-11	CI04	1	340210:730	Assessor	BELL STREET	DD1 1HN	DUNDEE CIT	0	76.474
9059066064	Industrial	340154	730579	DC001-13	CI04	1	340154:730	Assessor	BELL STREET	DD1 1HF	DUNDEE CIT	DUNDEE	12.610
9059075853	Office	339963	730495	DC001-14	CL03	1	339963:730	Assessor	WEST BELL STREET	DD1 9AD	DUNDEE CIT	0	529.858
9059075848	Recreation	340006	730467	DC001-15	CL06	1	340006:730	Assessor	WEST BELL STREET	DD1 1EX	DUNDEE CIT	0	259.110
9059082570	Office	339810	730573	DC001-17	CM04	1	339810:730	Assessor	DUDHOPE CRESCENT	DD1 5RR	DUNDEE CIT	0	38.934
9059014893	Office	339969	730457	DC001-23	CO01	1	339969:730	Assessor	WEST BELL STREET	DD1 1EX	DUNDEE CIT	DUNDEE	6.832
9059019073	Office	340150	730571	DC001-24	CO01	1	340150:730	Assessor	BELL STREET	DD1 1HF	DUNDEE CIT	DUNDEE	11.799
9059042356	Office	340193	730593	DC001-26	CO01	1	340193:730	Assessor	BELL STREET	DD1 1HN	DUNDEE CIT	0	55.469
9059028536	Office	340235	730625	DC001-28	CO01	1	340235:730	Assessor	VICTORIA ROAD	DD1 1EL	DUNDEE CIT	DUNDEE	5.914
9059058349	Office	340213	730608	DC001-30	CO01	1	340213:730	Assessor	VICTORIA ROAD	DD1 1JG	DUNDEE CIT	0	38.543
9059082569	Office	339785	730569	DC001-35	CO01	1	339785:730	Assessor	DUDHOPE CRESCENT	DD1 5RR	DUNDEE CIT	0	435.597
9059075907	Office	340241	730614	DC001-37	CO01	1	340241:730	Assessor	VICTORIA ROAD	DD1 1EL	DUNDEE CIT	0	68.109
9059076628	Office	340134	730639	DC001-38	CO01	1	340134:730	Assessor	SOAPWORK LANE	DD1 1HX	DUNDEE CIT	0	49.733
9059077214	Office	340143	730568	DC001-39	CO01	1	340143:730	Assessor	BELL STREET	DD1 1HF	DUNDEE CIT	0	7.342
9059075858	Office	339954	730449	DC001-40	CO01	1	339954:730	Assessor	WEST BELL STREET	DD1 1EX	DUNDEE CIT	0	90.239
9059035491	Office	340156	730574	DC001-45	CR02	1	340156:730	Assessor	BELL STREET	DD1 1HF	DUNDEE CIT	DUNDEE	6.410

CONSUMER SHEET SUMMARIZE DATA IN EACH OF 15 DISTRICTS

No	District	Type of building	Description	Post code	Street no	Floor area consumer	Heat demand Heat map	Specific demand	Data source	Consumer in all distr.	Consumers in project	Base line supply
						m2	MWh	kWh/m2				
Summary for all districts												1=indiv VP
												2=indiv oil
												3=indiv gas
	1	Ullapool 1						183		59	0	-
	2	Ullapool 2						152		79	0	-
	3	Ullapool 3						155		79	0	-
	4	Ullapool 4						131		76	0	-
	5	Ullapool 5						137		103	0	-
	6	Ullapool 6						161		75	0	-
	7	Ullapool 7						113		103	0	-
	8	Ullapool 8						178		58	0	-
	9	Dundee Master						0		66	0	-
	10	Dundee Soapworks Lane						0		31	0	-
	11	Dundee Waterfront East						0		11	0	-
	12	Dundee Waterfront West						0		14	0	-
	13	Dundee Dallfield						0		1	0	-
	14	Dundee Coldside						0		1	0	-
	15	DUNDEE CITY						148		396	396	2,98
	Total									1.152	396	
7	DUNDEE CITY	Industrial	BELL STREET	DD1 1HF		195	29	150	default	1	1	3
8	DUNDEE CITY	Industrial	VICTORIA ROAD	DD1 1JG		170	26	150	default	1	1	3
9	DUNDEE CITY	Industrial	BELL STREET	DD1 1HN		510	76	150	default	1	1	3
10	DUNDEE CITY	Industrial	BELL STREET	DD1 1HF		84	13	150	default	1	1	3
11	DUNDEE CITY	Office	WEST BELL STREET	DD1 9AD		3.532	530	150	default	1	1	3
12	DUNDEE CITY	Recreational	WEST BELL STREET	DD1 1EX		1.727	259	150	default	1	1	3
13	DUNDEE CITY	Office	DUDHOPE CRESCENT ROAD	DD1 5RR		260	39	150	default	1	1	3
14	DUNDEE CITY	Office	WEST BELL STREET	DD1 1EX		46	7	150	default	1	1	3
15	DUNDEE CITY	Office	BELL STREET	DD1 1HF		79	12	150	default	1	1	3
16	DUNDEE CITY	Office	BELL STREET	DD1 1HN		370	55	150	default	1	1	3
17	DUNDEE CITY	Office	VICTORIA ROAD	DD1 1EL		39	6	150	default	1	1	3
18	DUNDEE CITY	Office	VICTORIA ROAD	DD1 1JG		257	39	150	default	1	1	3

NETWORK DATA FROM SYSTEM RORNET OR MANUAL DESIGN

DN	D _y	t	D _i	Velocity	Flow	Flow	Power	Loss	Data from hydraulic analysis						Dimension	Length
mm	mm	mm	mm	m/s	l/s	m ³ /h	MW	W/m ² °C	S001	K001	K002	97	200			
Dn	Dy	t	Di	Hastighed	Flow1	Flow2	Effekt	Tab1	S002	K002	K003	66,8	50	20	232	
DN15	21,3	2,0	17,3	0,29	0,068	0,245	0,009	0,070	S003	K003	K004	182,1	50	25	469	
DN20	26,9	2,0	22,9	0,36	0,148	0,534	0,0186	0,070	S004	K004	K005	112,5	50	32	1357	
DN25	33,7	2,3	29,1	0,42	0,279	1,006	0,0350	0,070	S005	K005	K082	136,3	40	40	527	
DN32	42,4	2,6	37,2	0,50	0,544	1,96	0,0681	0,070	S006	K082	K006	136,6	25	50	1551	
DN40	48,3	2,6	43,1	0,55	0,803	2,89	0,101	0,100	S007	K002	K007	111	50	65	585	
DN50	60,3	2,9	54,5	0,64	1,493	5,38	0,187	0,100	S008	K007	K008	73,3	32	80	471	
DN65	76,1	2,9	70,3	0,76	2,95	10,62	0,370	0,110	S009	K008	K009	59,4	25	100	71	
DN80	88,9	3,2	82,5	0,84	4,49	16,2	0,563	0,120	S010	K007	K010	107,3	40	125	161	
DN100	114,3	3,6	107,1	1,00	9,01	32,4	1,129	0,120	S011	K010	K011	103,3	32	150	375	
DN125	139,7	3,6	132,5	1,14	15,7	56,6	1,97	0,226	S012	K011	K012	20,9	20	200	97	
DN150	168,3	4,0	160,3	1,29	26,0	93,7	3,26	0,255	S013	K002	K013	108	150	250	0	
DN200	219,1	4,5	210,1	1,52	52,7	189,7	6,60	0,270	S014	K013	K014	140,9	50			
DN250	273,0	5,0	263,0	1,75	95	342	11,91	0,280	S015	K013	K015	37,1	150	Total	5895	
DN300	323,9	5,6	312,7	1,95	150	539	18,76	0,318	S016	K015	K016	77	150			
Design parameters																
Cooling		30	°C	Tf average	90	°C										
Pressure loss	10	0/00		T _r average	60	°C										
Max hours	2.000	h/år		Tj average	8	°C										

NETWORK SHEET CALCULATE NETWORK INVESTMENTS AND HEAT LOSSES

1 Network

2	Dimension	m	DN15	DN20	DN25	DN32	DN40	DN50	DN65	DN80	DN100	
3												
4	Length of distribution network first stage, branch lines included in Network for all potential districts											
5	0 Ullapool 1	m	0	232	469	1,357	527	1,551	585	471	71	
6	0 Ullapool 2	m	0	0	0	0	0	0	0	0	0	
7	0 Ullapool 3	m	0	0	0	0	0	0	0	0	0	
8	0 Ullapool 4	m	0	0	0	0	0	0	0	0	0	
9	0 Ullapool 5	m	0	0	0	0	0	0	0	0	0	
10	0 Ullapool 6	m	0	0	0	0	0	0	0	0	0	
11	0 Ullapool 7	m	0	0	0	0	0	0	0	0	0	
12	0 Ullapool 8	m	0	0	0	0	0	0	0	0	0	
13	0 Dundee Master	m	0	97	42	65	63	54	100	92	230	
14	0 Dundee Soapworks Lane	m	0	97	42	65	63	54	100	92	230	
15	0 Dundee Waterfront East	m	0	97	42	65	63	54	100	92	230	
16	0 Dundee Waterfront West	m	0	97	42	65	63	54	100	92	230	
17	0 Dundee Dallfield	m	0	97	42	65	63	54	100	92	230	
18	0 Dundee Coldside	m	0	97	42	65	63	54	100	92	230	
19	1 DUNDEE CITY	m	0	581	253	387	377	326	602	551	1,381	
20	All potential distribution lines	m	0	1,394	975	2,132	1,282	2,203	1,788	1,572	2,833	
21	Distribution lines included	m	0	581	253	387	377	326	602	551	1,381	
22	Total incl. Additional	m	0	581	253	387	377	326	602	551	1,381	
23												

Heat losses distribution	Heat losses branch lines	Heat losses total
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
1,076	637	1,713
1,076	637	1,713

Dimension DN	Unit price £/m	Distribution m	Branch m	Distribution k£	Branch k£	Investment k£
DN20	315	581	0	183	0	183
DN32	338	253	2,925	86	988	1,074
DN32	354	387	0	137	0	137
DN40	367	377	2,800	138	1,027	1,165
DN50	392	326	575	128	226	353
DN65	428	602	0	258	0	258
DN80	478	551	0	263	0	263
DN100	552	1,381	0	762	0	762
DN125	649	494	0	320	0	320
DN150	750	426	0	319	0	319
DN200	937	424	0	397	0	397
DN250	1,222	197	0	241	0	241
DN300	1,471	172	0	252	0	252
Total		6,171	6,300	3,485	2,241	5,726
Correction for trench						0
Total						5,726



BASELINE

Market share of individual production					2015	2016	2017	2018	2019	2020
Heat pump	954	10.770	MWh/a		0	285	472	564	655	744
Oil boilers	0	0	MWh/a		0	0	0	0	0	0
Gas boilers	106.483	1.202.103	MWh/a		0	31.785	52.710	62.936	73.058	83.078
Total individual production	107.437	1.212.873	MWh/a		0	32.070	53.182	63.500	73.713	83.822
<i>Control figure (zero)</i>			<i>MWh/a</i>		<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>
Individual investments	5.666	5.099	4.704	k£	0	1.700	1.133	567	567	567
<i>Contribution to residual value all individual</i>		<i>-708</i>		<i>k£</i>	<i>0</i>	<i>-85</i>	<i>-113</i>	<i>-85</i>	<i>-113</i>	<i>-142</i>
Residual value of individual investments			-392	k£	0	0	0	0	0	0
Individual investments including residual value			4.312	k£	0	1.700	1.133	567	567	567
Cost of energy for individual supply		£/MWh								
Heat Pumps	606	40,94	441	k£	0	12	19	23	27	30
Oil boilers	0	100,00	0	k£	0	0	0	0	0	0
Gas boilers in average	65.003	39,38	47.337	k£	0	1.252	2.076	2.478	2.877	3.271
Energy costs for individual supply	39,39		47.778	k£	0	1.263	2.095	2.501	2.904	3.302

200										
201	Total costs of individual supply in average	£/MWh				2015	2016	2017	2018	2019
202	Investments	4	4.312	k£		0	1.700	1.133	567	567
203	Energy	39	47.778	k£		0	1.263	2.095	2.501	2.904
204	O&M costs	5	5.514	k£		0	139	232	278	325
205	Total individual	47	57.604	k£		0	3.102	3.460	3.346	3.795
206										
207	CO2 emission									
208	Heat production									
209	Heat pump			MWh		0	285	472	564	655
210	Oil boilers			MWh		0	0	0	0	0
211	Gas boilers			MWh		0	31.785	52.710	62.936	73.058
212	Total heat production			MWh		0	32.070	53.182	63.500	73.713
213										
214	Fuel consumption									

PROJECT

Consumers						2015	2016	2017	2018	2019	2020
444	Purchase of heat from	District heating	in scenario		MWh/a	0	32.070	53.182	63.500	73.713	83.822
445	Own heat production from	Heat pump	in baseline		MWh/a	0	285	472	564	655	744
446	Own heat production from	Oil boilers	in baseline		MWh/a	0	0	0	0	0	0
447	Own heat production from	Gas boilers	in baseline		MWh/a	0	31.785	52.710	62.936	73.058	83.078
448											
449	Connection fee	District heating		-1.639	k£	0	-592	-395	-197	-197	-197
450	Purchase of district heating	District heating		-46.669	k£	0	-1.234	-2.046	-2.443	-2.836	-3.225
451	Investment and O&M of substations	District heating		-3.819	k£	0	-1.063	-747	-418	-431	-443
452	Investments	Base line		4.312	k£	0	1.700	1.133	567	567	567
453	Energy	Base line		47.778	k£	0	1.263	2.095	2.501	2.904	3.302
454	O&M costs	Base line		5.514	k£	0	139	232	278	325	371
455	Total benefit for consumers			5.477	k£	0	213	272	288	331	373
456											
Total benefit for all stakeholders						2015	2016	2017	2018	2019	2020
458	Supplier, large CHP			0	k£	0	0	0	0	0	0
459	Supplier, Surplus heat			679	k£	0	-80	34	41	47	54
460	District heating company			2.137	k£	-1.635	-13.223	-362	-540	1.027	1.198
461	Consumers			5.477	k£	0	213	272	288	331	373
462	Total local community			8.293	k£	-1.635	-13.090	-56	-211	1.405	1.625
463	IRR			7%	%						

24	Forecast for development of the new DH network				Default values can be replaced. Only increasing values					
25	1	Ullapool 1		%	0%	30%	60%	100%	100%	100%
26	2	Ullapool 2		%	0%	30%	60%	100%	100%	100%
27	3	Ullapool 3		%	0%	30%	60%	100%	100%	100%
28	4	Ullapool 4		%	0%	30%	60%	100%	100%	100%
29	5	Ullapool 5		%	0%	30%	60%	100%	100%	100%
30	6	Ullapool 6		%	0%	30%	60%	100%	100%	100%
31	7	Ullapool 7		%	0%	30%	60%	100%	100%	100%
32	8	Ullapool 8		%	0%	30%	60%	100%	100%	100%
33	9	Dundee Master		%	0%	30%	60%	100%	100%	100%
34	10	Dundee Soapworks Lane		%	0%	30%	60%	100%	100%	100%
35	11	Dundee Waterfront East		%	0%	30%	60%	100%	100%	100%
36	12	Dundee Waterfront West		%	0%	30%	60%	100%	100%	100%
37	13	Dundee Dalfield		%	0%	30%	60%	100%	100%	100%
38	14	Dundee Coldside		%	0%	30%	60%	100%	100%	100%
39	15	DUNDEE CITY		%	0%	30%	60%	100%	100%	100%
40										

SUMMARY, SELECT DISTRICTS

Project Dundee Heat map					District heating project compared to baseline				
Cost benefit model	Capacity	Energy	Currency	start year	Project	Baseline			
	MW	MWh	£	2015	DH	Heat pumps	Oil boilers	Gas boilers	
Maximal heat demand in the project area					MWh/a	0	954	0	106.483
Heat connected end year	Growth p.a.	-0,5%	1 GHP, 2 oil, 3 gas	0 excluded 1 included					
Districts from Heat Map of Scotland					Dundee Heat map				
1	Ullapool 1		3	0	MWh/a	0	0	0	
2	Ullapool 2		3	0	MWh/a	0	0	0	
3	Ullapool 3		3	0	MWh/a	0	0	0	
4	Ullapool 4		3	0	MWh/a	0	0	0	
5	Ullapool 5		3	0	MWh/a	0	0	0	
6	Ullapool 6		3	0	MWh/a	0	0	0	
7	Ullapool 7		3	0	MWh/a	0	0	0	
8	Ullapool 8		3	0	MWh/a	0	0	0	
9	Dundee Master		3	0	MWh/a	0	0	0	
10	Dundee Soapworks Lane		3	0	MWh/a	0	0	0	
11	Dundee Waterfront East		3	0	MWh/a	0	0	0	
12	Dundee Waterfront West		3	0	MWh/a	0	0	0	
13	Dundee Dallfield		3	0	MWh/a	0	0	0	
14	Dundee Coldside		3	0	MWh/a	0	0	0	
15	DUNDEE CITY		3	1	MWh/a	87.469	777	0	
23	Heat demand to DH end-year				MWh/a	87.469	777	0	86.693
24	Heat losses end-year				MWh/a	1.649	2%		
25	District heating production end-year				MWh/a	89.118	100%		

SUMMARY, PRODUCTION

27	Heat production	Name of plant	Ownership	MW	%		Max load h	Max. Hours
28	Capacity and	Supplier, large CHP	External	0,0	0%	MWh/a	0	8.760
29	heat production	Supplier, Surplus heat	External	1,0	8%	MWh/a	7.129	8.760
30	divided on	Gas CHP	Internal	20,0	80%	MWh/a	71.295	3.565
31	plants end-year	Biomass boiler	Internal	0,0	0%	MWh/a	0	8.760
32		Large heat pump	Internal	1,0	7%	MWh/a	6.238	8.760
33		Peak boiler	Internal			MWh/a	4.456	275
34	Load to netw.	Max load hours 2021	3.000			MW	31,8	Security min 120%
35								
36	District heating tariff			Variable	Fixed		Fixed	
37	Annual heat meter fee	Fixed			100	£/no		
38	Interval for fixed tariff	Var/fixed		24	18	£/MWh		
39	Fixed fee 0-250 MWh	Reduction			1	£/MWh	18	
40	Fixed fee 250-2500 MWh				0,8	£/MWh	14	
41	Fixed fee 2500-25000 MWh				0,7	£/MWh	13	
42	Fixed fee 25000-250000 MWh				0,4	£/MWh	7	
43								
44	Investments in project							
45	Total investment in network					NPV k€	5.137	
46	Residual value network					NPV k€	-1.702	
47	No contribution to residual value	from production plants				NPV k€	0	
48	Investment cost in production					NPV k€	13.852	
49	Investments in DH substations					NPV k€	2.835	
50	Residual value of DH substations			Max. 10%		NPV k€	-529	
51	Total investments in the city in the project period, incl. Residual					NPV k€	19.593	
52	Total investments in the city in the project period, without residual value					NPV k€	21.294	
53	<i>Priority figure: NPV of total investments including residual per heat sale</i>					£/MWh	224	
54								

SUMMARY, RESULTS

55 Summary of results			Project
56	Total benefit for all stakeholders		
57	Supplier, large CHP	NPV k£	0
58	Supplier, Surplus heat	NPV k£	679
59	District heating company	NPV k£	2.137
60	Consumers	NPV k£	5.477
61	Total local community	NPV k£	8.293
62	IRR for the district heating company compared to the baseline	%	4%
63	IRR for the local community compared to baseline	%	7%
64	Compared to a new individual supply, consumers save in average first year	%	10%
65	Accumulated profit for DH company end-year	k£2035	13.049
66	Economic pay-back time	years	14
67	Financial pay-back time of cash credit	years	12
68	Financial pay-back time of all debt	years	16
69	Total CO2 emission district heating	20 years Tonn	134.301
70	Total CO2 emission baseline	20 years Tonn	425.521
71	Saved CO2 emission district heating compared to baseline	20 years Tonn	291.220
72			
73	Financial parameters		
74	Discount rate	%	3%
75	Inflation	%	2%
76	Nominal interest rate	%	5%
77	Depreciation of district heating investments	Years	20
78	Amortisation of consumer investments in district heating installations	%	7,4%
79	Amortisation of consumer investments in individual solutions	%	9,0%

COMPARISON

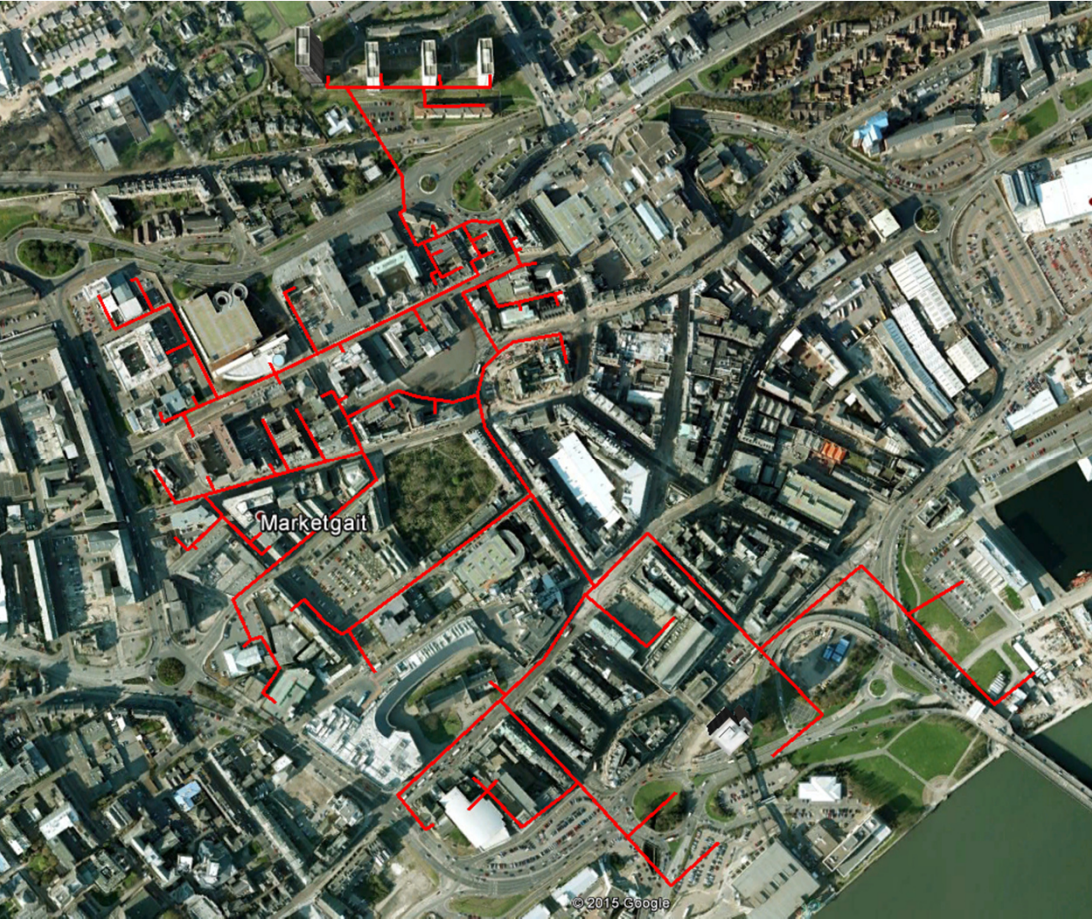
District heating prices compared to individual	Unit	District heating, existing buildings					District heating to new buildings				
		Large	Medium	Medium	Small	Small	Large	Medium	Medium	Small	
Heated floor area	m2	20.000	5.000	1.500	130	100	10.000	5.000	900	150	
Specific demand	kWh/m2	110	100	100	139	139	60	60	60	60	
Heat demand	MWh	2.200	500	150	18,1	14	600	300	54	9	
Max load hours at consumer	h	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	
Capacity demand at consumer	kW	1.100	250	75	9,0	7,0	300,0	150,0	27,0	4,5	
Cost of connecting to DH											
Branch line connection fee	50% of cost	£	0	0	3.668	2.534	2.534	0	4.904	3.668	2.534
Fixed connection fee	25% of subst.	£	10.482	4.924	2.665	906	792	5.404	3.795	1.583	635
Payment to district heating company		£	10.482	4.924	6.333	3.440	3.327	5.404	8.699	5.251	3.169
Consumer installation		£	41.927	19.697	10.661	3.623	3.170	21.616	15.180	6.332	2.540
Total investment for connection		£	52.409	24.621	16.994	7.063	6.496	27.020	23.879	11.583	5.709
Annual payment for DH											
Amortisation 4 % in 20 years	7,4%	£	3.878	1.822	1.258	523	481	1.999	1.767	857	422
Fixed payment to district heating											
Fixed fee per meter	100 £/inst.	£	100	100	100	100	100	100	100	100	100
Fixed fee 0-250 MWh	18 £/MWh	£	4.500	4.500	2.700	325	250	4.500	4.500	972	162
Fixed fee 250-2500 MWh	14 £/MWh	£	28.080	3.600	0	0	0	5.040	720	0	0
Fixed fee 2500-25000 MWh	13 £/MWh	£	0	0	0	0	0	0	0	0	0
Fixed fee 25000-250000 MWh	7 £/MWh	£	0	0	0	0	0	0	0	0	0
Annual fixed fee		£	32.680	8.200	2.800	425	350	9.640	5.320	1.072	262
Variable fee	24,00 £/MWh	£	52.800	12.000	3.600	434	334	14.400	7.200	1.296	216
-Discount for low return temperature		£	0	0	0	0	0	0	0	0	0
Annual district heating payment		£	85.480	20.200	6.400	859	684	24.040	12.520	2.368	478
Average district heating fee		£/MWh	39	40	43	48	49	40	42	44	53
Operation of consumer installations											
Fixed cost	50 £/inst.	£	50	50	50	50	50	50	50	50	50
Variable cost	1 £/MWh	£	2.200	500	150	18	14	600	300	54	9
Annual O&M cost of consumer installation		£	2.250	550	200	68	64	650	350	104	59
Annual heating cost		£	91.608	22.572	7.858	1.450	1.228	26.689	14.637	3.329	959
<i>Average cost including capital costs of connection</i>		£/MWh	42	45	52	80	88	44	49	62	107
<i>Average cost minus capital cost (sunk cost)</i>		£/MWh	40	42	44	51	54	41	43	46	93

COMPARISON

Individual supply	Unit	Natural gas boilers					Heat pumps to new buildings				
		Large	Medium	Medium	Small	Small	Large	Medium	Medium	Small	
Cost first year after installation of individual plant		New	New	New	New	New	New	New	New	New	
		cond. Boiler	cond. Boiler	cond. Boiler	cond. Boiler	cond. Boiler	Heat pump	Heat pump	Heat pump	Heat pump	
Tilslutningsafgift	kr.	0	0	0	0	0	0	0	0	0	
Heat pump	£						195.655	113.131	32.962	10.689	
Condensing gas boiler	£	71.276	33.485	18.123	4.800	4.800					
Total investment	£	71.276	33.485	18.123	4.800	4.800	195.655	113.131	32.962	10.689	
Annual heat production	MWh	2.200	500	150	18	14	600	300	54	9	
Efficiency gas boiler	%	80%	80%	80%	80%	80%					
Annual gas consumption	MWh	2.750	625	188	23	17					
COP							3,0	3,0	3,0	3,0	
Annual consumption of electricity	MWh						200	100	18	3	
Annual cost of heating first year											
Amortisation											
Amortisering 4% 15 år	9,0%	£	6.415	3.014	1.631	432	432	17.609	10.182	2.967	962
Energy cost for individual heating											
Fixed payment for gas	0,00 £/inst.	£	0	0	0	0	0	0	0	0	
	278 45,00 £/MWh	£	12.510	12.510	8.438	1.016	782	0	0	0	
	2.778 29,25 £/MWh	£	72.306	10.150	0	0	0	0	0	0	
	27.778 27,00 £/MWh	£	0	0	0	0	0	0	0	0	
	277.778 22,50 £/MWh	£	0	0	0	0	0	0	0	0	
Total natural gas cost		£	84.816	22.660	8.438	1.016	782	0	0	0	
Average gas cost		kr./MWh	30,84	36,26	45,00	45,00	45,00				
Electricity cost, marginal	140 £/MWh	£					28.000	14.000	2.520	420	
O&M of consumer installations											
Fixed O&M cost of individual installations		£	80	80	80	80	80	200	200	200	
Variable O&M of gas boiler	4 £/MWh	£	8.800	2.000	600	72	56				
Variable O&M of heat pump	6 £/MWh	£					3.600	1.800	324	54	
O&M of consumer installations		£	8.880	2.080	680	152	136	3.800	2.000	524	
Annual cost of heating		£	100.111	27.753	10.749	1.601	1.349	49.409	26.182	6.011	
Average cost of heating		kr./MWh	46	56	72	89	97	82	87	111	
Savings first year with DH compared to new plant	kr		8.503	5.181	2.891	151	121	22.720	11.545	2.681	677
Savings first year with DH compared to new plant	%		8%	19%	27%	9%	9%	46%	44%	45%	41%
Savings first year with DH compared existing plant	kr		2.088	2.168	1.260	-281	-311	5.111	1.363	-285	-285
Savings first year with DH compared existing plant	%		2%	8%	12%	-18%	-23%	10%	5%	-5%	-17%

CASE 1: DUNDEE

DUNDEE, MAP



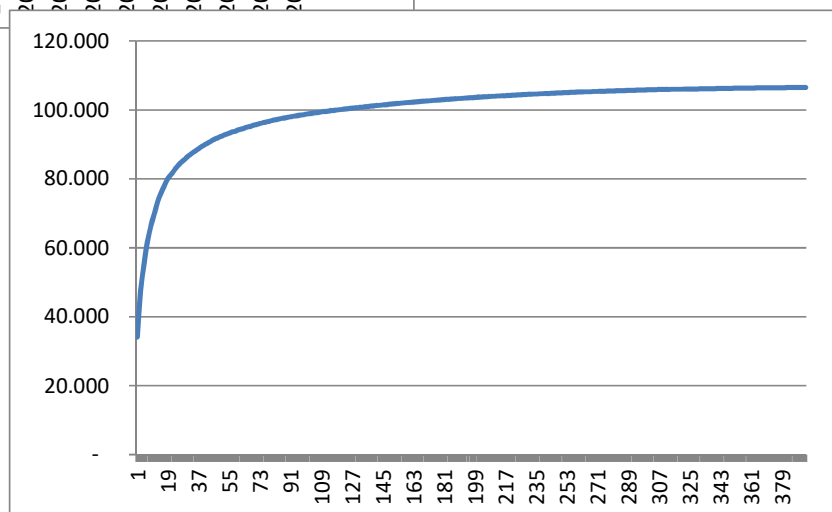
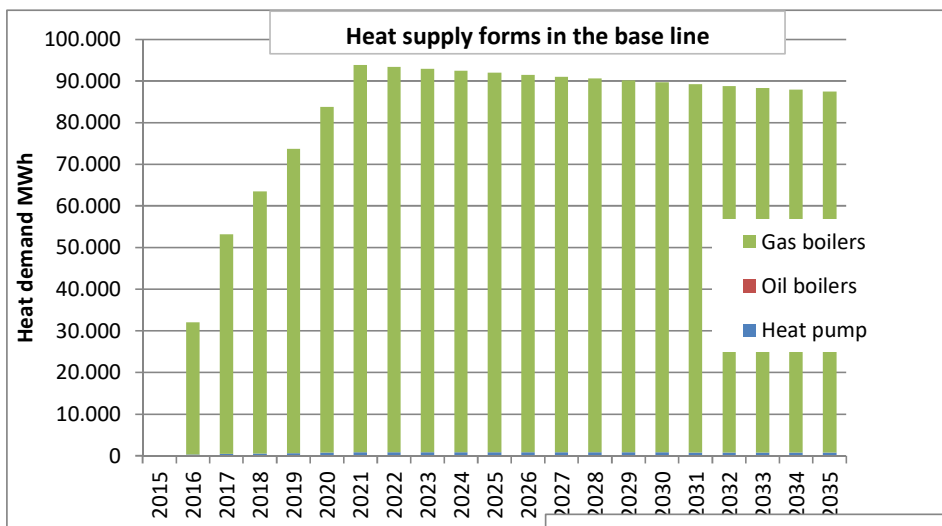
DUNDEE HEAT MARKET AND NETWORK



Heatmap Scotland 2014 - Dundee



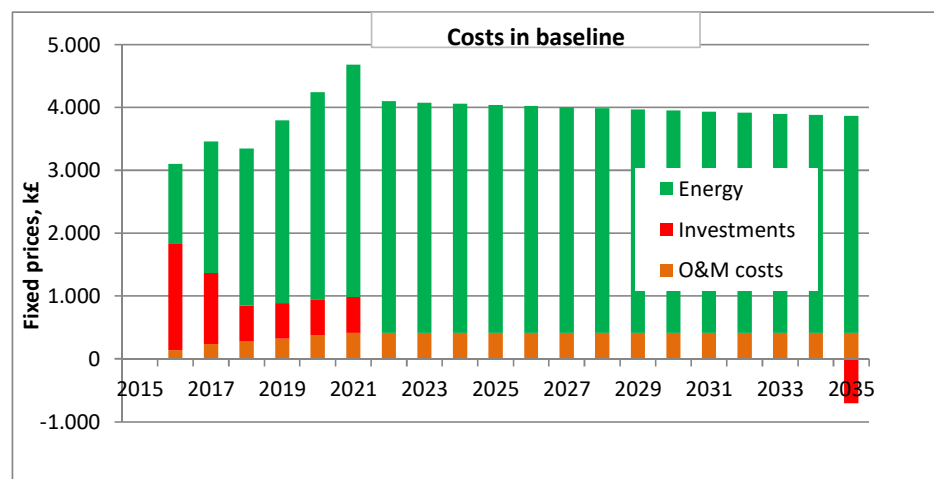
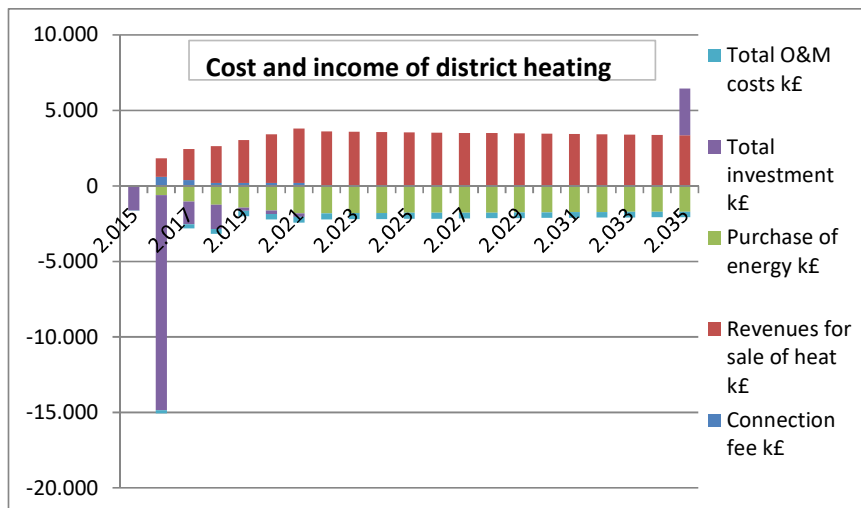
DUNDEE, HEAT MAP AND NEW BUILDINGS



DUNDEE, PRODUCTION AND DH TARIFF

23	Heat demand to DH end-year				MWh/a	87.469	777	0	86.693
24	Heat losses end-year				MWh/a	1.649	2%		
25	District heating production end-year				MWh/a	89.118	100%		
26									
27	Heat production	Name of plant	Ownership	MW	%		Max load h	Max. Hours	
28	Capacity and	Supplier, large CHP	External	0,0	0%	MWh/a	0	0	8.760
29	heat production	Supplier, Surplus heat	External	1,0	8%	MWh/a	7.129	7.129	8.760
30	divided on	Gas CHP	Internal	20,0	80%	MWh/a	71.295	3.565	8.760
31	plants end-year	Biomass boiler	Internal	0,0	0%	MWh/a	0	0	8.760
32		Large heat pump	Internal	1,0	7%	MWh/a	6.238	6.238	8.760
33		Peak boiler	Internal			MWh/a	4.456	275	8.760
34	Load to netw.	Max load hours 2021	3.000			MW	31,8	Security min	120%
35									
36	District heating tariff			Variable	Fixed		Fixed		
37	Annual heat meter fee	Fixed		100	£/no				
38	Interval for fixed tariff	Var/fixed	24	18	£/MWh				
39	Fixed fee 0-250 MWh	Reduction		1	£/MWh		18		
40	Fixed fee 250-2500 MWh			0,8	£/MWh		14		
41	Fixed fee 2500-25000 MWh			0,7	£/MWh		13		
42	Fixed fee 25000-250000 MWh			0,4	£/MWh		7		

DUNDEE, COST



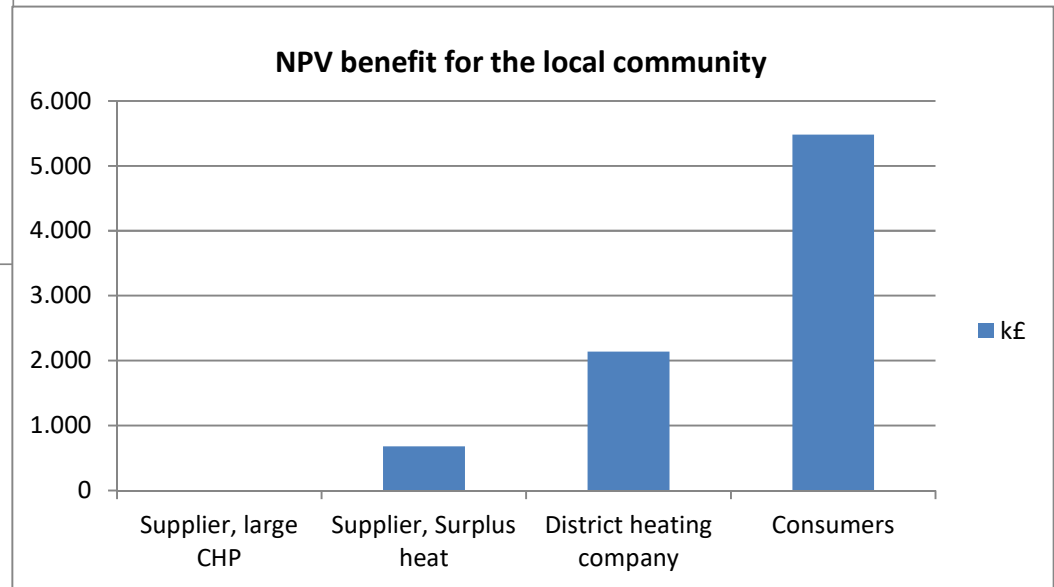
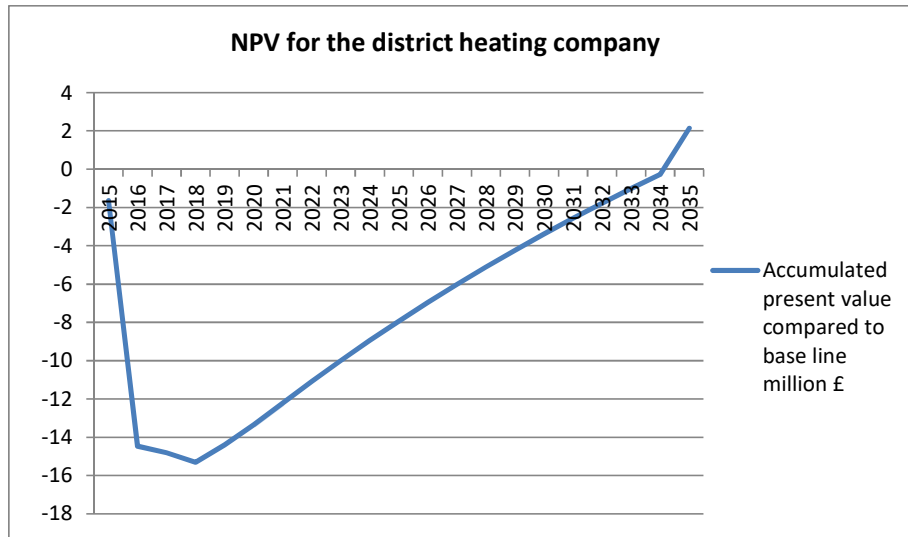
44 Investments in project

45	Total investment in network	NPV k£	5.137
46	Residual value network	NPV k£	-1.702
47	No contribution to residual value from production plants	NPV k£	0
48	Investment cost in production	NPV k£	13.852
49	Investments in DH substations	NPV k£	2.835
50	Residual value of DH substations Max. 10%	NPV k£	-529
51	Total investments in the city in the project period, incl. Residual	NPV k£	19.593
52	Total investments in the city in the project period, without residual value	NPV k£	21.294
53	<i>Priority figure: NPV of total investments including residual per heat sale</i>	<i>£/MWh</i>	<i>224</i>

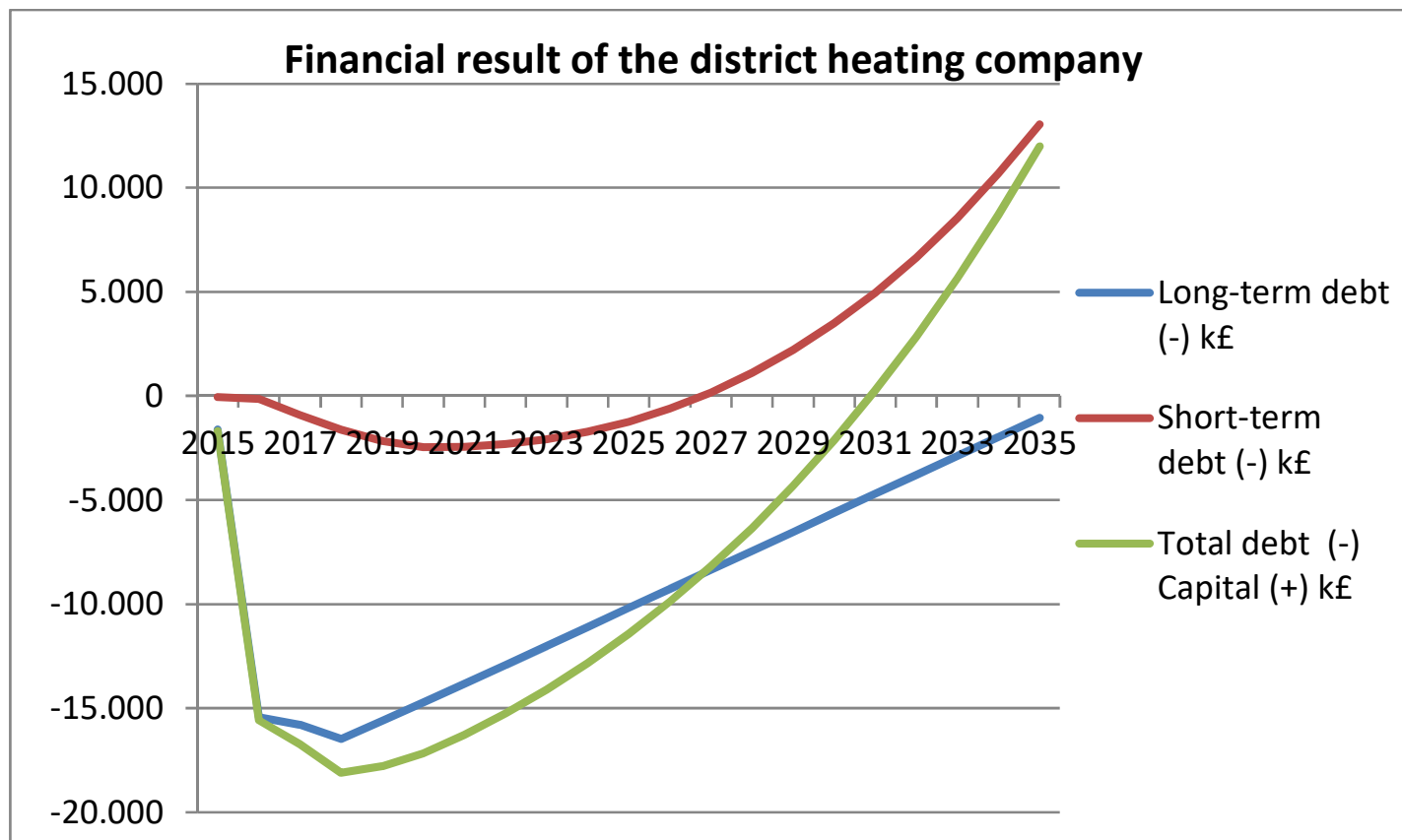
DUNDEE, RESULT

55	Summary of results		Project
56	Total benefit for all stakeholders		
57	Supplier, large CHP	NPV k£	0
58	Supplier, Surplus heat	NPV k£	679
59	District heating company	NPV k£	2.137
60	Consumers	NPV k£	5.477
61	Total local community	NPV k£	8.293
62	IRR for the district heating company compared to the baseline		4%
63	IRR for the local community compared to baseline		7%
64	Compared to a new individual supply, consumers save in average first year		10%
65	Accumulated profit for DH company end-year	k£2035	13.049
66	Economic pay-back time	years	14
67	Financial pay-back time of cash credit	years	12
68	Financial pay-back time of all debt	years	16
69	Total CO2 emission district heating	20 years Tonn	134.301
70	Total CO2 emission baseline	20 years Tonn	425.521
71	Saved CO2 emission district heating compared to baseline	20 years Tonn	291.220

DUNDEE, NPV

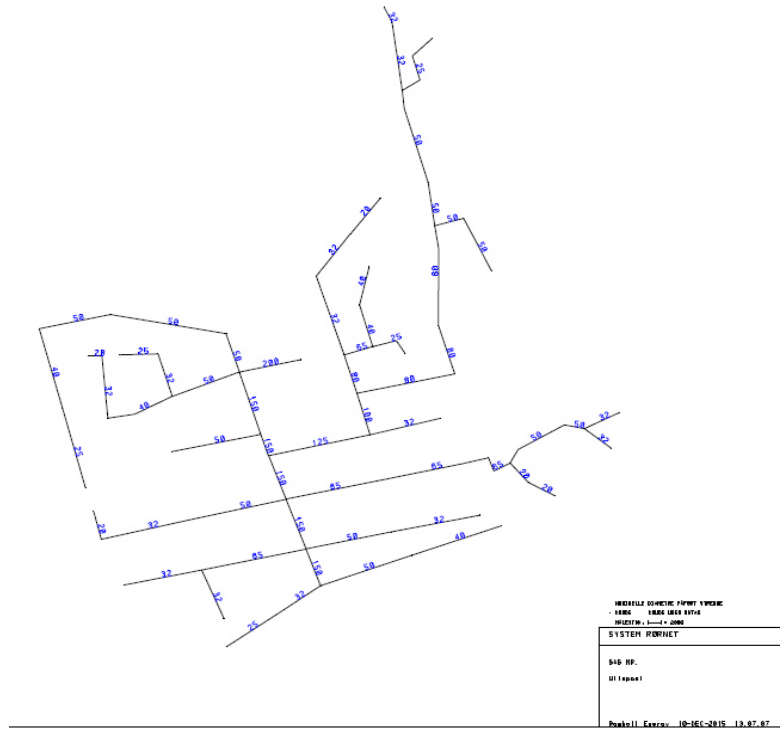


DUNDEE, FINANCIAL RESULT

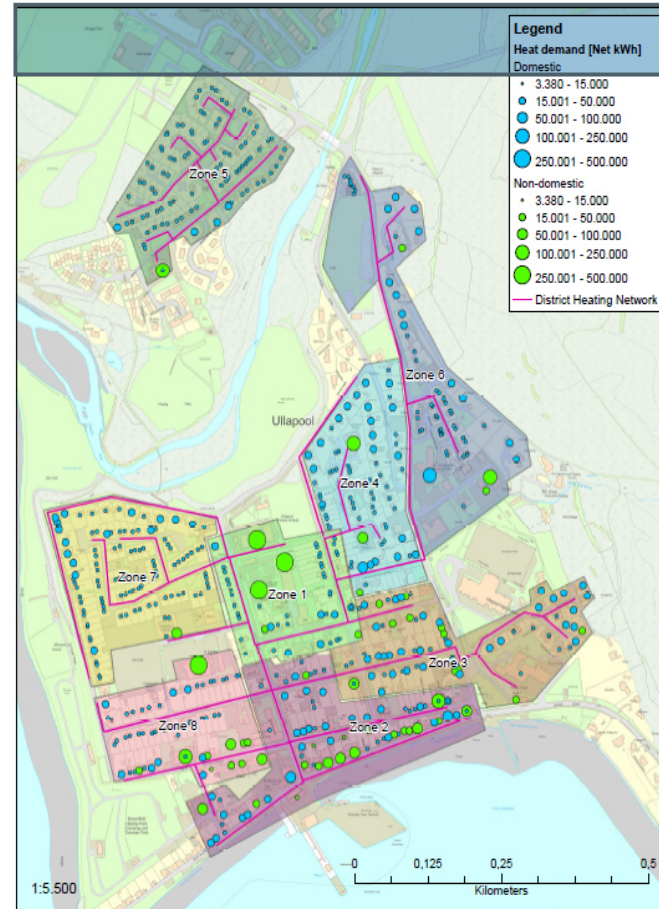


CASE 2 ULLAPOOL

ULLAPOOL, MAP



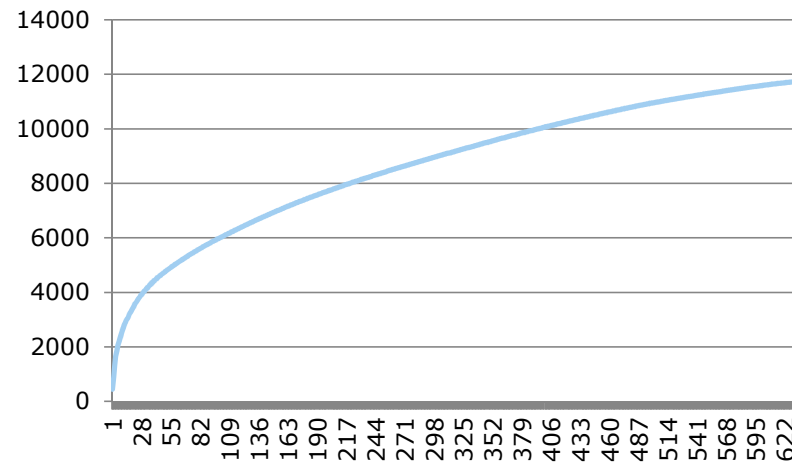
Heatmap Scotland 2014 - Ullapool



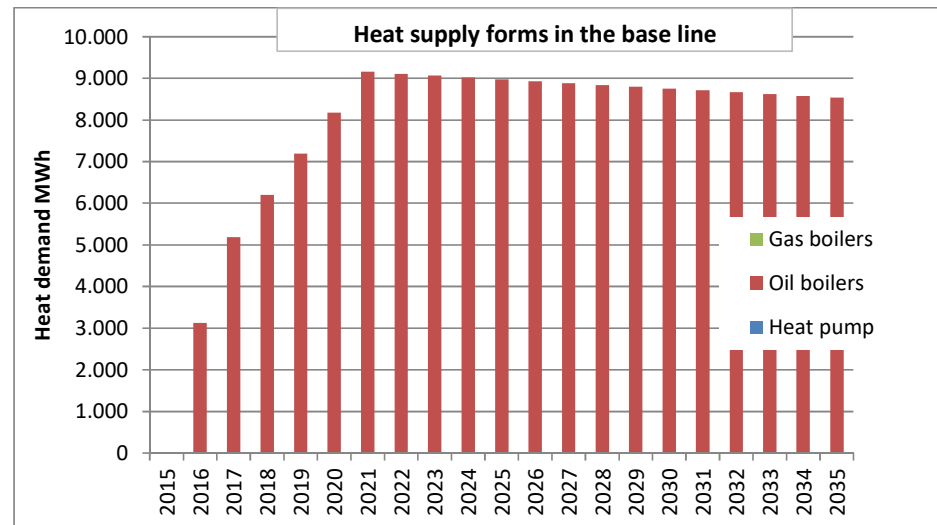
Date: 10-12-2015

ULLAPOOL, HEAT MAP AND NEW BUILDINGS

- All buildings, sorted



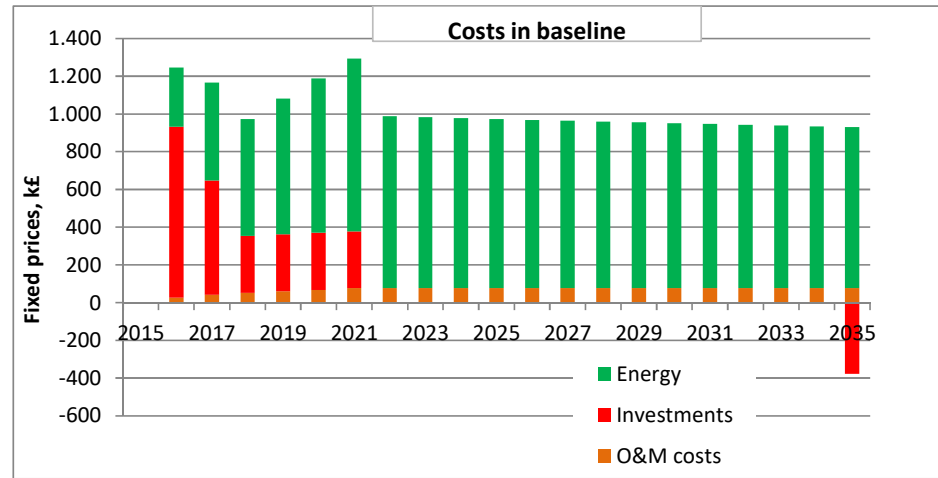
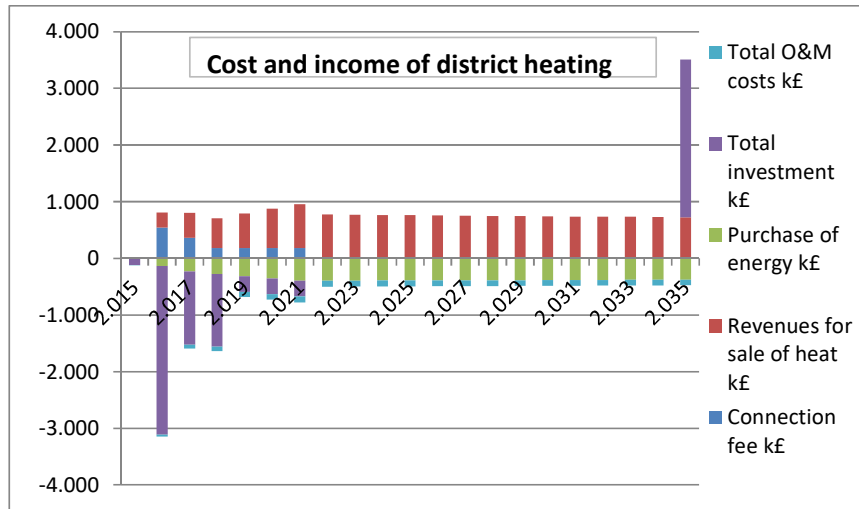
- All districts
 - Except no 5
 - 90% connected
 - Heat savings 1/2%p.a.



ULLAPOOL, PRODUCTION AND DH TARIFF

23	Heat demand to DH end-year				MWh/a	8.536	0	8.536	
24	Heat losses end-year				MWh/a	1.369	14%		
25	District heating production end-year				MWh/a	9.904	100%		
26									
27	Heat production Name of plant	Ownership	MW	%			Max load h	Max. Hours	
28	Capacity and	Supplier, large CHP	External	0,0	0%	MWh/a	0	0	8.760
29	heat production	Supplier, Surplus heat	External	0,0	0%	MWh/a	0	0	8.760
30	divided on	Gas CHP	Internal	0,0	0%	MWh/a	0	0	8.760
31	plants end-year	Biomass boiler	Internal	1,0	45%	MWh/a	4.457	4.457	8.760
32		Large heat pump	Internal	2,0	45%	MWh/a	4.457	2.228	8.760
33		Peak boiler	Internal			MWh/a	990	819	8.760
34	Load to netw.	Max load hours 2021	3.000			MW	3,5	Security min	120%
35									
36	District heating tariff			Variable	Fixed		Fixed		
37	Annual heat meter fee	Fixed		100		£/no			
38	Interval for fixed tariff	Var/fixed	60	20		£/MWh			
39	Fixed fee 0-250 MWh	Reduction		1		£/MWh	20		
40	Fixed fee 250-2500 MWh			0,8		£/MWh	16		
41	Fixed fee 2500-25000 MWh			0,6		£/MWh	12		
42	Fixed fee 25000-250000 MWh			0,4		£/MWh	8		

ULLAPOOL, COST



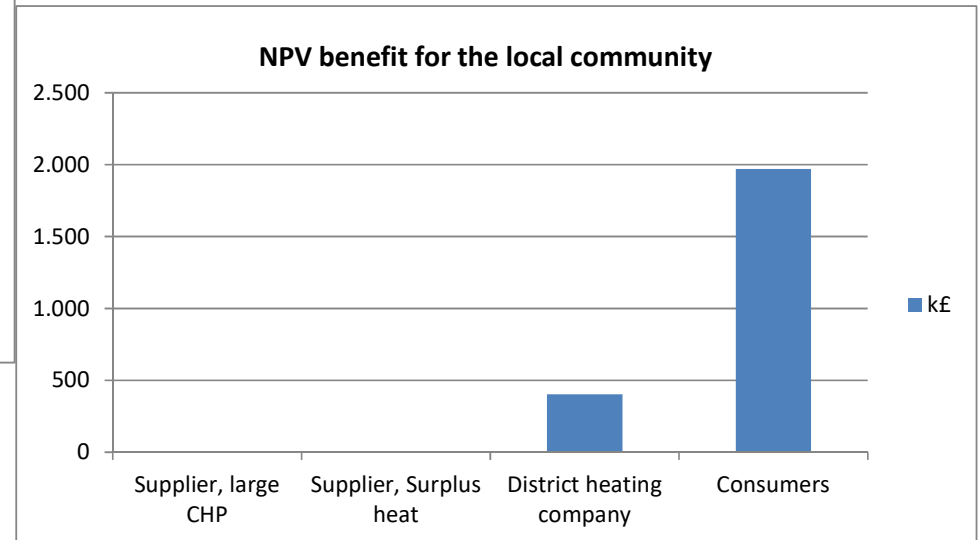
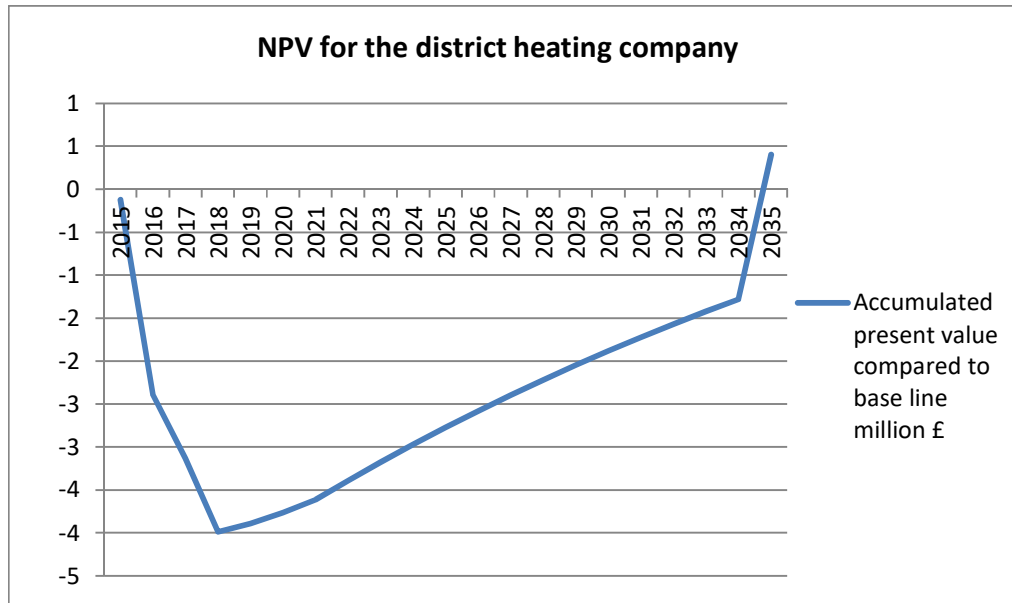
44 Investments in project

45	Total investment in network	NPV k£	4.634
46	Residual value network	NPV k£	-1.545
47	No contribution to residual value from production plants	NPV k£	0
48	Investment cost in production	NPV k£	1.480
49	Investments in DH substations	NPV k£	1.463
50	Residual value of DH substations Max. 10%	NPV k£	-273
51	Total investments in the city in the project period, incl. Residual	NPV k£	5.758
52	Total investments in the city in the project period, without residual value	NPV k£	7.303
53	Priority figure: NPV of total investments including residual per heat sale	£/MWh	6.75

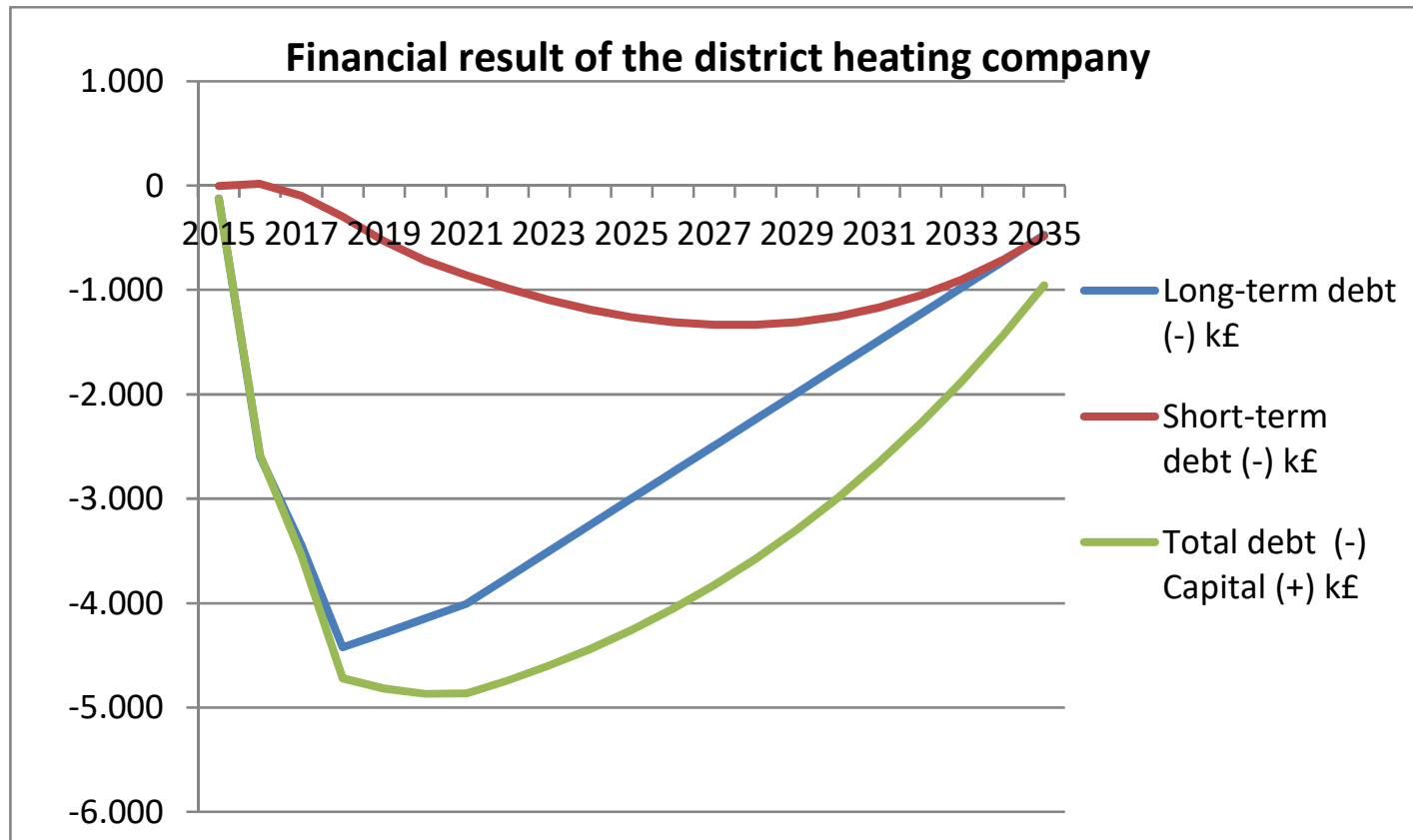
ULLAPOOL, RESULT

55	Summary of results		Project
56	Total benefit for all stakeholders		
57	Supplier, large CHP	NPV k£	0
58	Supplier, Surplus heat	NPV k£	0
59	District heating company	NPV k£	402
60	Consumers	NPV k£	1.969
61	Total local community	NPV k£	2.371
62	IRR for the district heating company compared to the baseline		4%
63	IRR for the local community compared to baseline		7%
64	Compared to a new individual supply, consumers save in average first year		15%
65	Accumulated profit for DH company end-year	k£2035	-483
66	Economic pay-back time	years	17
67	Financial pay-back time of cash credit	years	20
68	Financial pay-back time of all debt	years	21
69	Total CO2 emission district heating	20 years	Tonn 14.791
70	Total CO2 emission baseline	20 years	Tonn 54.040
71	Saved CO2 emission district heating compared to baseline	20 years	Tonn 39.249

ULLAPOOL, NPV



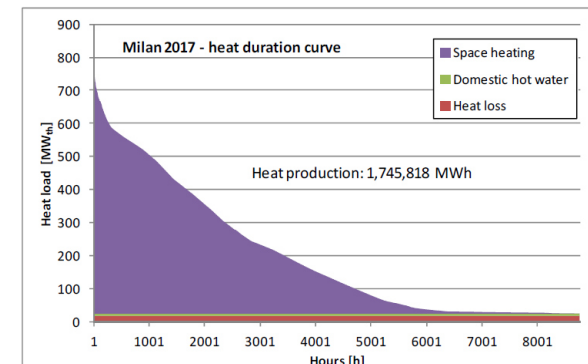
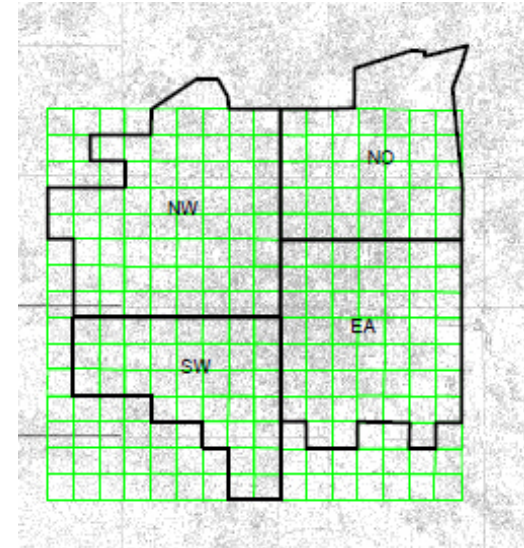
ULLAPOOL, FINANCIAL RESULT



TWO INTERNATIONAL CASES: MILAN, ITALY LYNGBY, DENMARK

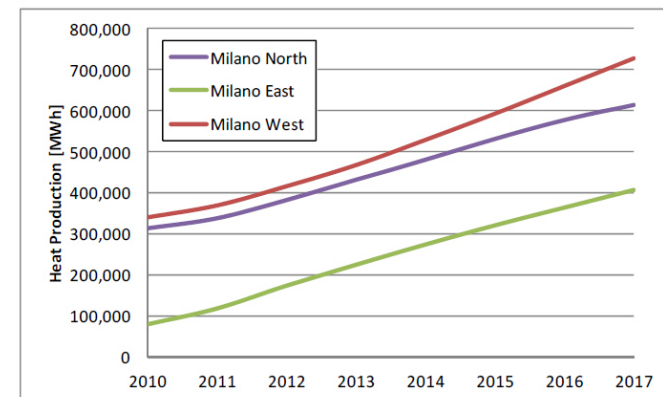
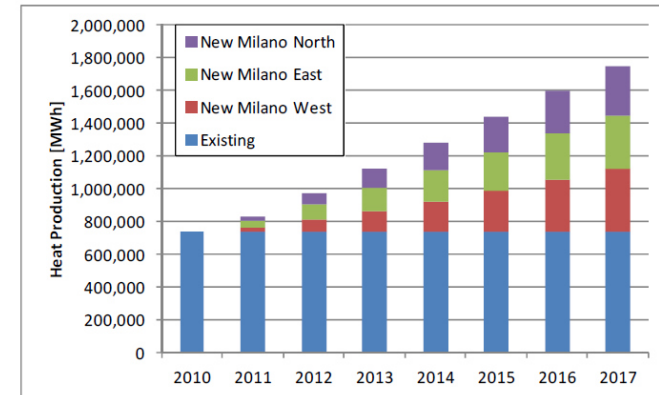
CASE 1: DH DEVELOPMENT IN MILANO (1)

- Situation:
 - Surplus waste to energy capacity 20 km from the city
 - Small DH networks in districts of the city
 - Many large gas boilers (Nox pollution)
- Methodology:
 - Heat mapping based on gas consumption for each district (divided on squares)
 - Estimate heat sale, heat duration curves, year and daily variations



CASE 1: DH DEVELOPMENT IN MILANO (2)

- Design of long distance transmission network to local existing and new distribution grids
- Design more heat storage capacity
- Estimate production
- Economic and environmental assessment of heat transmission and local distribution



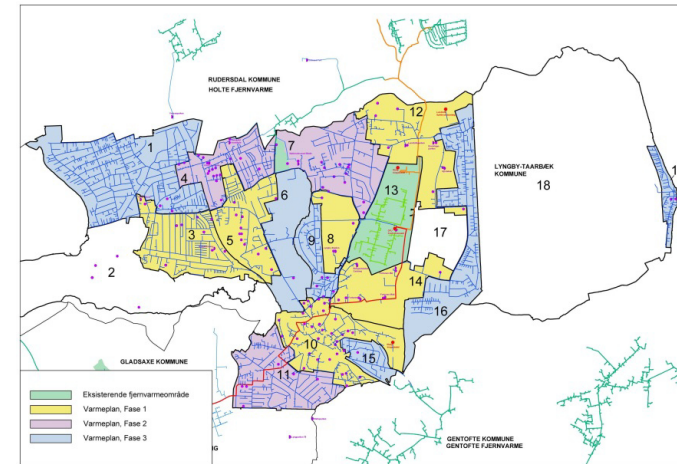
CASE 2: STRATEGIC ENERGY PLAN LYNGBY, NORTHERN SUBURB OF COPENHAGEN (1)

- Situation
 - 50 GWh local DH gas CC
 - 30 GWh 6 small gas engines
 - 200 GWh large gas boilers
 - 220 GWh small gas boilers
 - 35 MW large CHP plants
- Methodology
 - Geographic information and building data available, for 15 districts
 - Estimated heat consumption, gas consumption from gas company
 - Estimate on base load and peak load to supply 100% with DH
 - Design of network to supply all districts



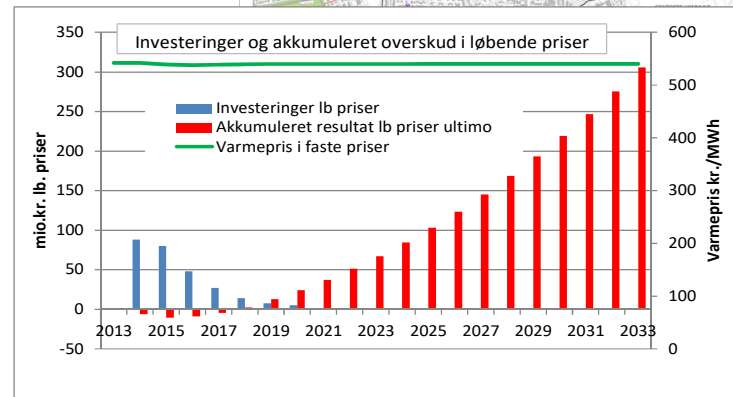
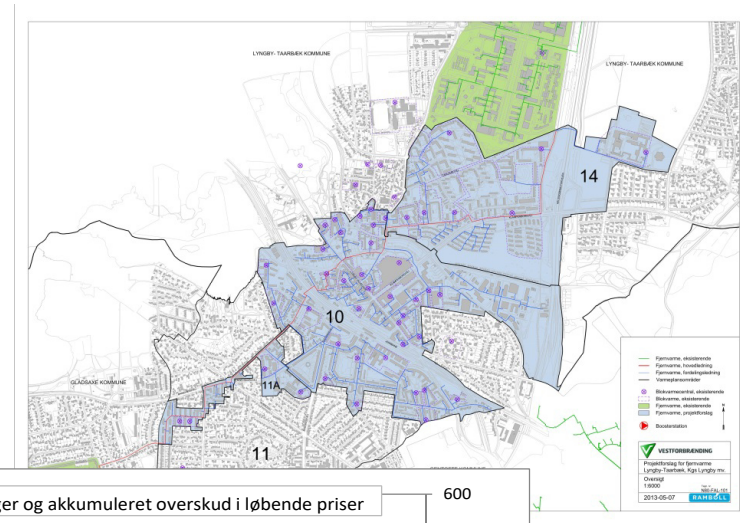
CASE 2: STRATEGIC ENERGY PLAN LYNGBY, NORTHERN SUBURB OF COPENHAGEN (2)

- Data to economic model for 15 districts
 - Heat demand for the 10,000 buildings
 - Network costs
 - Production costs
 - CBA for the society
 - CBA for DH and consumers (community)
- Selection of the cost effective part
 - 50% DH today and may be up to 100% in the longer term
 - Strategy for step by step development of capacity and network
 - Strategy for energy savings, district cooling and individual plants etc.



CASE 2: STRATEGIC ENERGY PLAN LYNGBY, NORTHERN SUBURB OF COPENHAGEN (3)

- First step, Stage A project document in accordance with the heat supply act.
 - DH to 150 GWh in the central part based on 35 MW base load
 - Network designed with capacity to be extended to 100% supply
 - Negotiation with the gas company
 - Investments: 300 mill.DKK
 - 10% IRR for the society
 - 300 mill.DKK NPV benefit for the local community
 - 300 mill.DKK acc. positiv cash flow



THANK YOU