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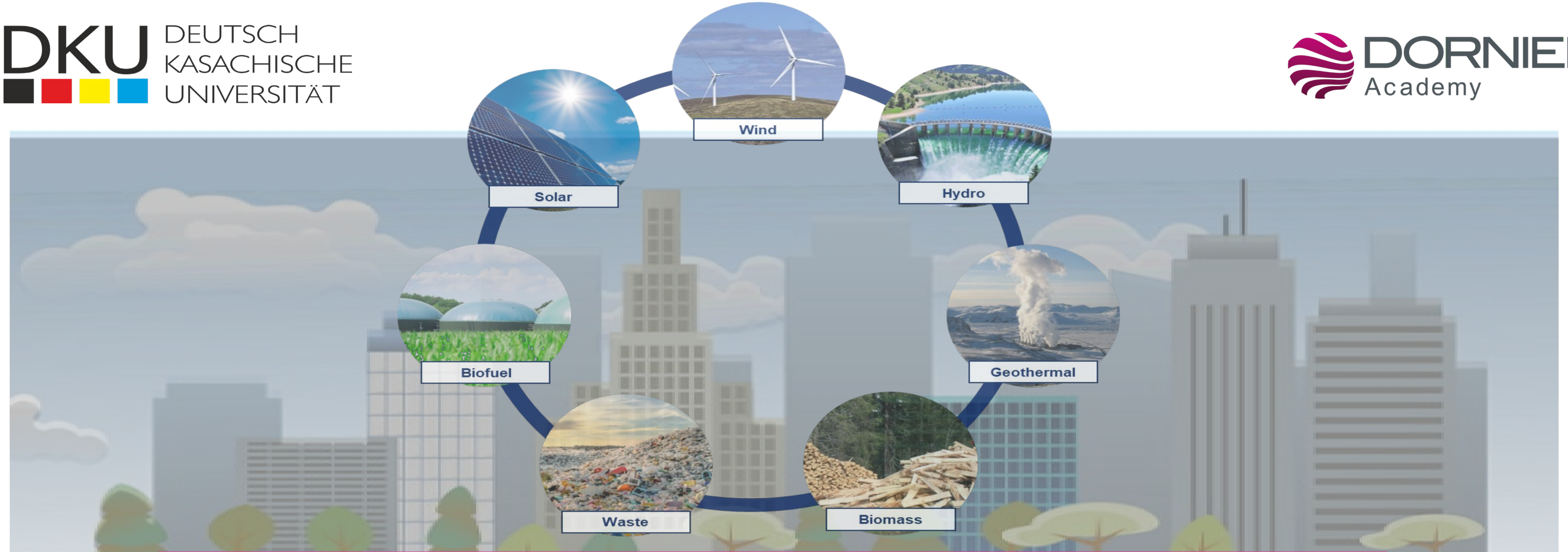

2.1 Heat System Planning - Methodology

Lennart Larsson

Modern heating sector - international trends and challenges for the Republic of Kazakhstan. Webinar Course in connection with the preparation of the "Law on Heating"

ADB

Supporting Renewable Technology Inclusive Heat Supply Legislation – Technical and Legal Consultancy ADB. TA 6564 KAZ

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Content of this session

- **Basic principles**
- **Basic model**
  - **Necessary input - Demand / Supply Cost Characteristics**
  - **Output - Least cost / Utilization of different sources**
- **Introduction to Detailed modelling**
  - **Demand – Uncertainties, typical values, extreme values**
  - **Supply – Uncertainties, Disturbances, Spare capacity**
  - **Scenarios**
- **Example of tools for**
  - **Detailed simulations of operation**
  - **Financial simulations**
- **Discussion**
- **Results from discussion**

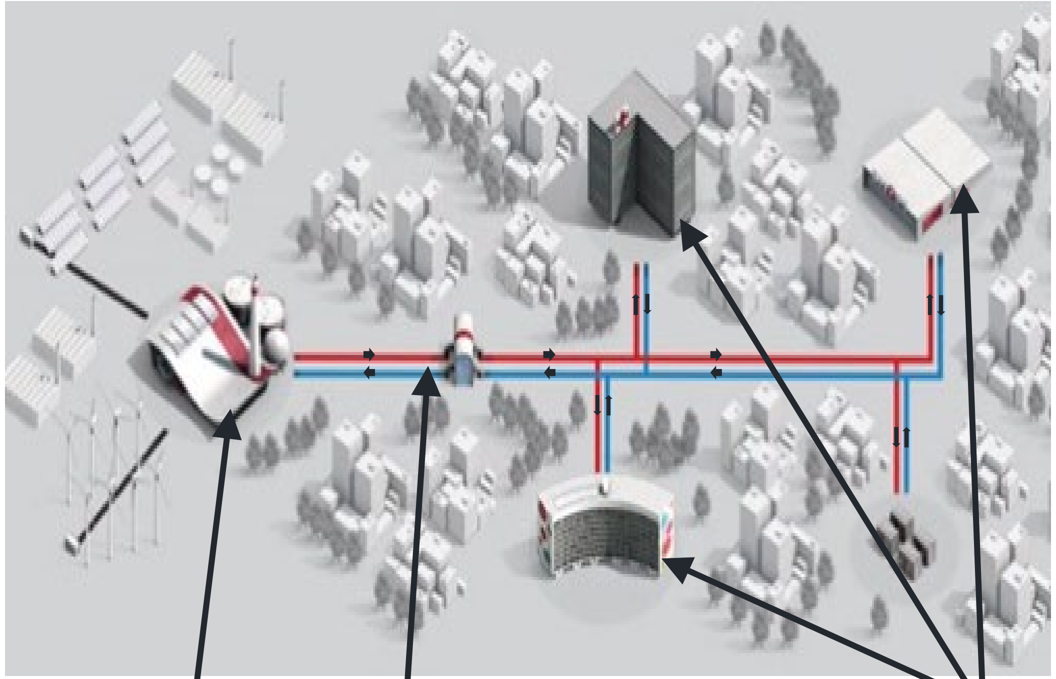
Methodology of Heat System Planning

District Heating

- Is usually the most efficient way to supply Heat in densly populated areas
- Is usually the easiest way to improve the local environment
- Is a system that can use Heat from CHP units, which means efficient production of Electricity and Heat and by that reduction of CO2 emissions

Basic principle for District Heating production planning:

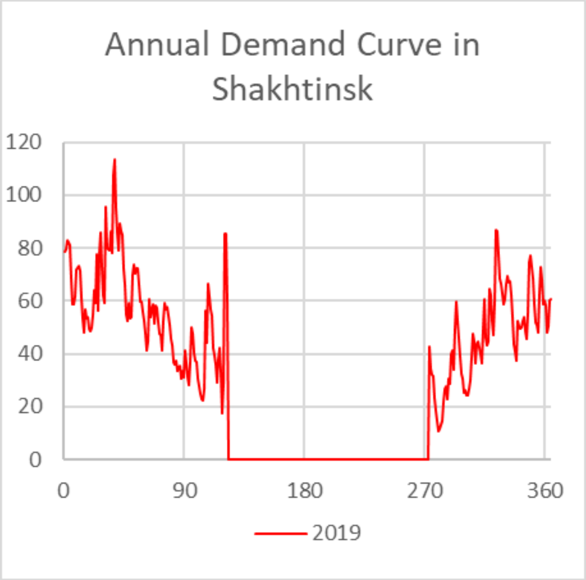
- Find least total cost to supply the customers with secure and environmentally acceptable heat

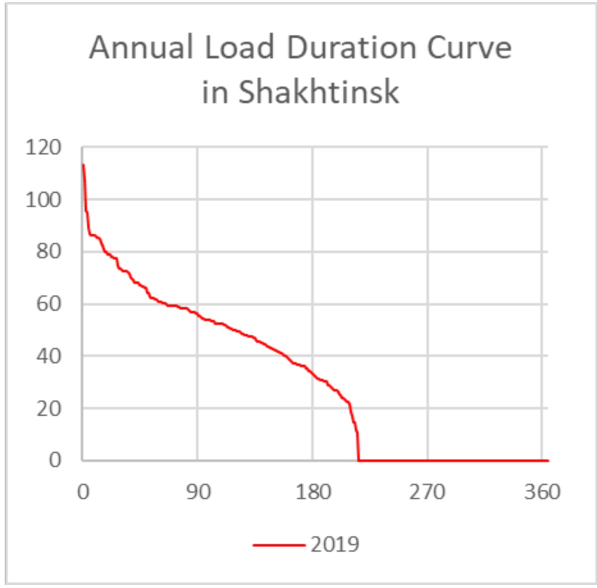


Production	Distribution	Consumer
Produce heat and deliver it as hot water to the distribution system	Distribute heat from production to the consumer	Use heat for space heating and hot tap water

Demand – Load curve and Load Duration curve - Example

1. Annual Demand is not enough for planning of supply, because demand varies during the year
2. A curve that describes the duration of different demand levels between maximum and minimum will be necessary to find suitable supply units
   - The diagrams show two different curves that represent the annual demand
     - Annual demand curve for January 1 – December 31
     - Load duration curve, highests, second highest …..lowest

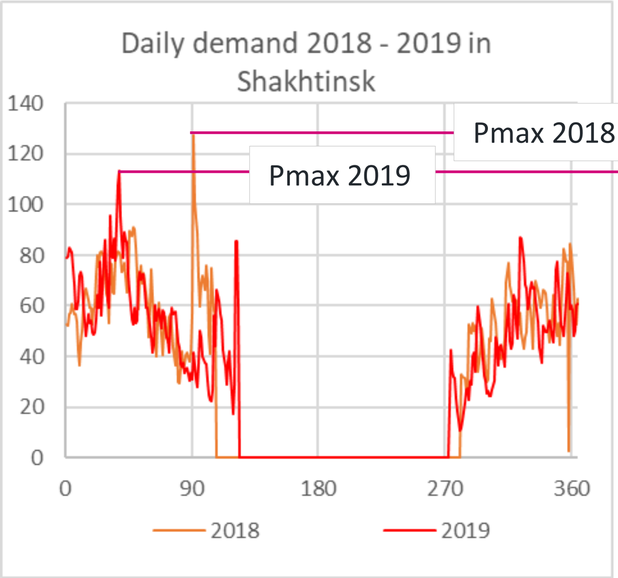


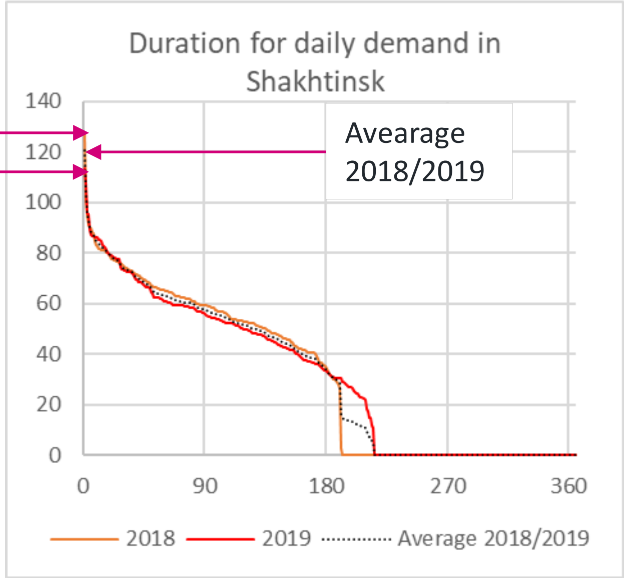


Note: In this example, Heat is supplied only during the heating season

Typical Load Duration Curve - Example

- Demand curve varies between different years due to variations in weather
- Pmax(2019) = 113 MW
- Pmax(2018) = 127 MW
- Average of LDC from 2 years -> A typical LDC
- Pmax,average = 120 MW
- Standard deviation for maximum demand should also be calculated, but that need values from more than 2 years





Note:

- In this example, 2 years is used to make it simple, in real life 3-5 years ought to be used
- For system with changes in heat market annual demand curves have to be normalised by the annual average demand before calculating the average between different years

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Supply – Cost characteristics – Least annual cost

Three Major Cost Components

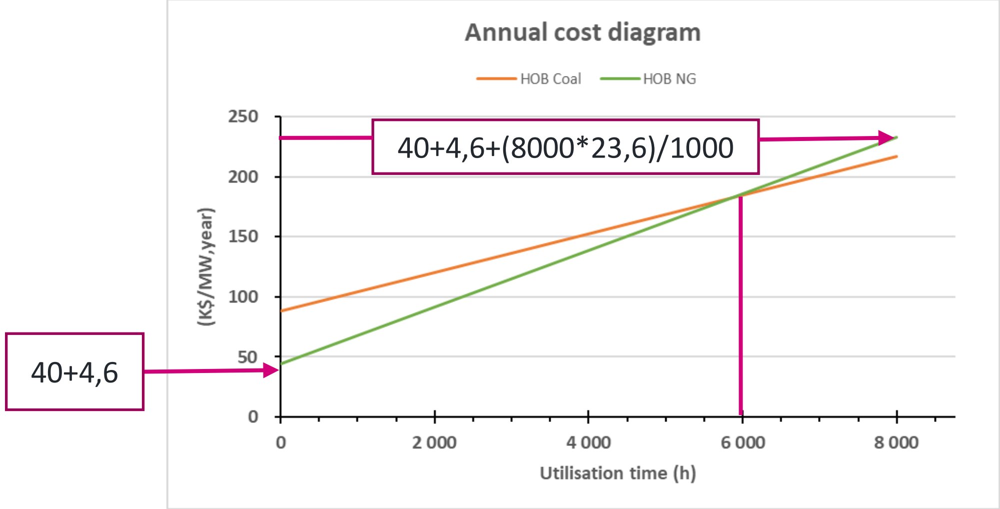
- Investment => Annual cost of capital
- Fixed annual cost (Maintenance, saleries etc)
- Variable cost (Fuel, chemicals, etc)

Example – Total annual cost Coal and Natural gas fired HOBs

Fuel price		
Coal	10	$/MWh
Natural gas	20	$/MWh
Waste	-5	$/MWh
Pellets	30	$/MWh
Other prices		
Electricity value	40	$/MWh,el
CO_2 emission price	10	$/ton,$CO_2$
Note: 2020-2-11 Europé	25	$/ton,$CO_2$

Cost component / Unit type and fuel	Investment (K$/MW,heat)	Annual cost of capital (K$/MW,heat)	Fixed annual O&M (K$/MW,year)	Variable O&M ($/MWh,fuel)	Fuel Price ($/MWh,fuel)	CO_2-fees ($/MWh,fuel)	Total variable cost ($/MWh,heat)
HOB Coal	924	72	16,0	0,8	10,0	3,3	16,0
HOB NG	507	40	4,6	0,3	20,0	2,0	23,6

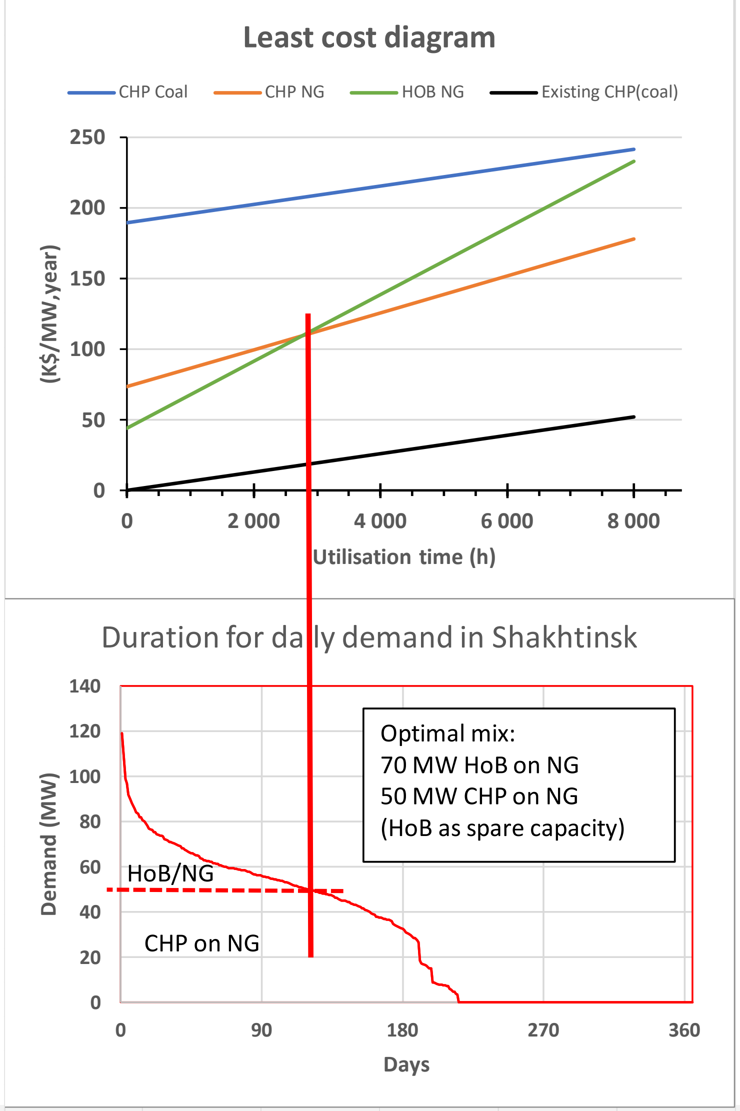
Calculated annual cost (K$/MW,år)				
Unit type	**Discount rate (%)**	**Life time (years)**	**Utilisation time (h) 0**	**8000**
HOB Coal	6%	25	88	217
HOB NG	6%	25	44	233



Operation over 6000 hours/year HOB on coal gives lowest cost and below that NG give lowest total cost

Least cost planning - Example

- Demand curve from Shakhtinsk
- 3 alternatives for a new system
  - Coal fired CHP
  - NG fired CHP
  - NG fired HOB
- Least cost for a new system
  - 50 MW CHP on Natural Gas
  - 70 MW HOB on Natural gas
- But as long as the existing units can operate without major investments it will be cheaper than any new alternative



Shortcomings of Basic Least Cost Supply Model

Output valid for

- Same annual demand
- Same maximum demand
- No spare capacity

Load duration curve doesn’t reflect the demand’s variation over and by that regulation, start and stop of the plants

Currently there is also lack of a “Least Cost Energy Efficiency model”

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Introduction to Detailed modelling

- **Demand**
  - **Development of annual demand**
  - **Typical demand curve**
- **Supply – Uncertainties, Disturbances, Spare capacity**
- **Supply / Demand - Dimensioning**
- **Scenarios**
- **Simulations - example**
  - **Utilisation**
  - **Financial outcome**

Methodology of Heat System Planning

Development of Annual Demand

- Expansion
  - New connections
  - Increased comfort
- Customers leaving the District Heating system
  - Dissatisfaction with quality of supply
  - Cheaper alternative
- Efficiency measures
  - Improvement of windows
  - Improved insulation
  - Improved control system
- Action drivers
  - Individual metering
  - Tariff level and structure
  - Regulations and subsidies

Input from city planners
Experience from other systems

Keep a reasonable level for quality of supply
Not likely

Sealing, add another window pane
To be combined with outside repair of the whole building
Central for the house, individual radiator thermostats

Necessary if the apartment owner should be interested
Price - high enough, Variable part – big enough
Experiences from other countries

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Demand curve

Load duration curve

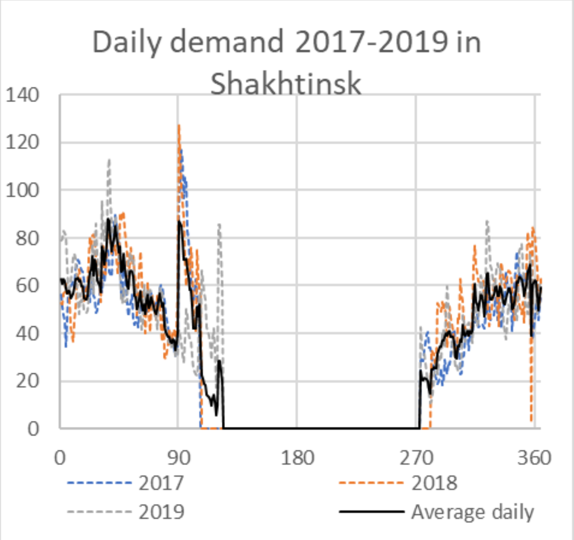
- Correct reflection of different load levels and maximum demand (Example - 120 MW)
- Does not reflect when different levels occur - Not enough for detailed simulations of operation

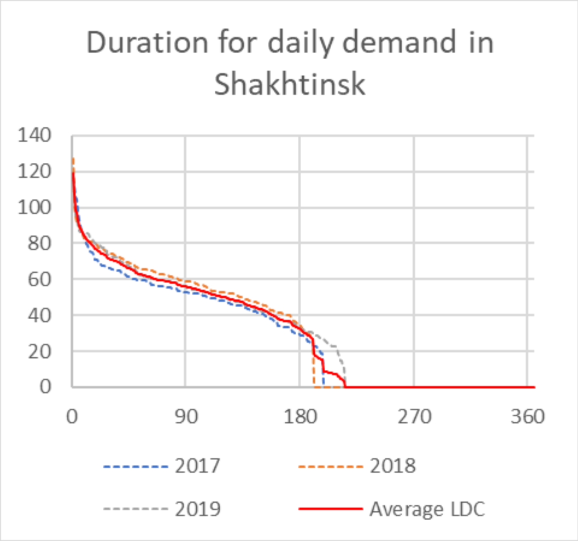
Average of annual demand curves

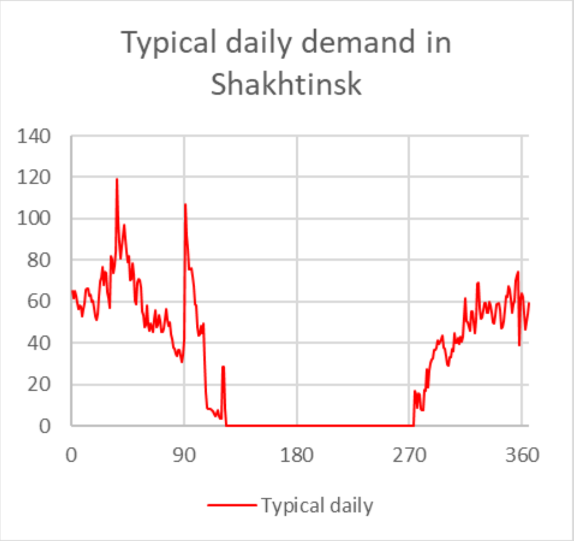
- Flattened out – Wrong reflection of:
  - Duration of load levels
  - Maximum demand (Example - 88 MW)

Typical load curve

- Reflects the variations between different load levels and when they occur in a statistical correct way
- A typical curve should be used for simulations, otherwise:
  - Peak capacity will not be utilized
  - Base capacity will be utilized more than in reality







Dimensioning of Supply system

Spare capacity principles – small systems

- It should be possible to supply heat:
  - When normal maximum demand occurs even if the biggest unit fails
  - When dimensioning demand occurs if all units can operate
- Dimensioning demand = Upper limit of a 95% confidence interval (roughly normal max plus 2*Standard deviation for the maximum demand in the typical demand curve)

Security of supply check	
"Shakhtinskteploenergo"LLP	(MW)
Total installed capacity	165
Biggest unit	55
Capacity after loss of biggest unit	110
Maximum demand	92
Capacity after loss of biggest unit - Maximum demand	17
Dimensioning demand (95% interval)	103
Installed capacity - Dim demand	61

Note: For bigger systems, the "Loss of load probability method" ought to be used

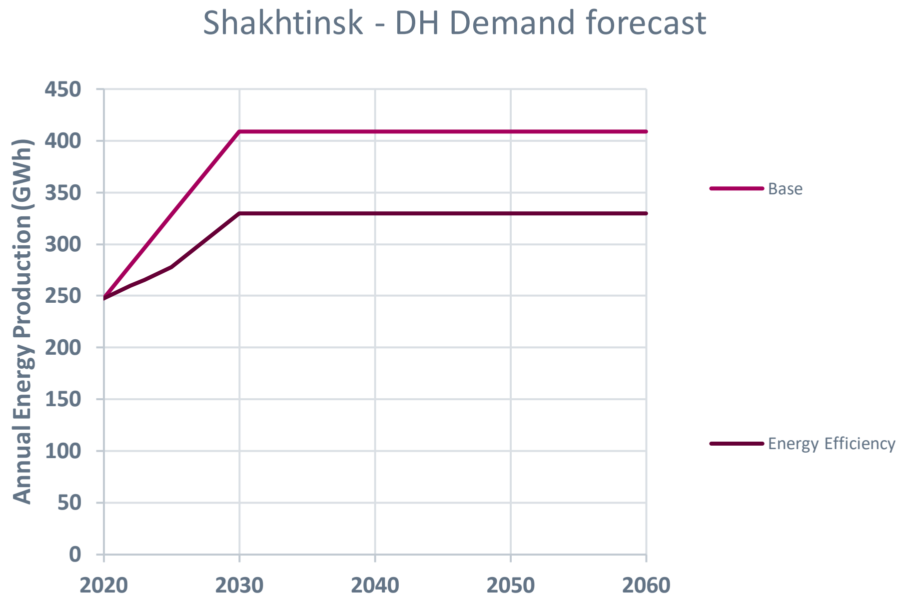
General

- **Scenario methodology**
    - Create a base scenario for at least 20 years ahead
    - Create alternative scenarios for the same period
    - Simulate operation of the system 20-40 years ahead
    - Compare the results for the alternative scenarios with the base scenario
        - Financial outcome
        - Environmental outcome

Methodology of Heat System Planning

Scenarios - Example

	Base Scenario	Energy Efficiency and Renewable Energy Scenario
Customers/ Demand	Specific consumption per customer constant Number of Customers are increased by 80% of the potential within 5 years and that trend goes on for 5 more years	As in Base Scenario, but with EE measures on customer side (from 250 kWh/m2,y to 150 kWh/m2,y within 10 years)
Distribution System	Exchange of old pipelines at ongoing rate in order to reduce losses to 10% within 10 years	As in Base Scenario, but with increased speed of pipe-line renewals (reduce losses from current value to 10% of current production within 5 years)
Production System	Old units will be retired at an age of 60 years. New least cost units added, when necessary, for keeping security of supply	As Base Scenario, but all new base load production facilities based on renewables



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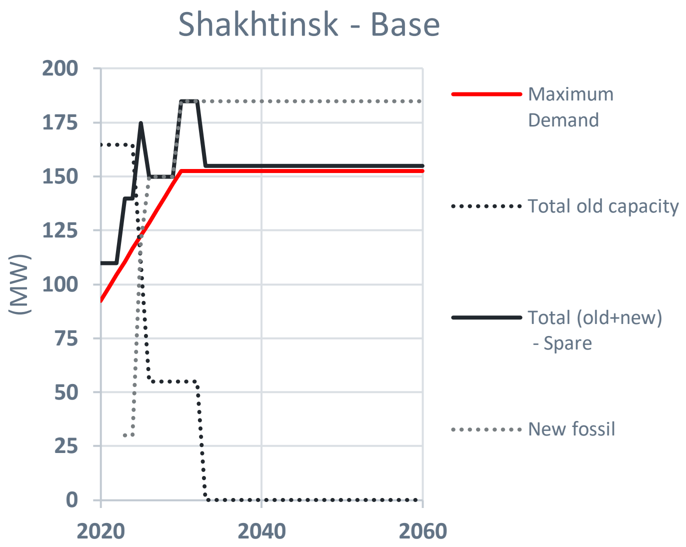
Scenarios - Example

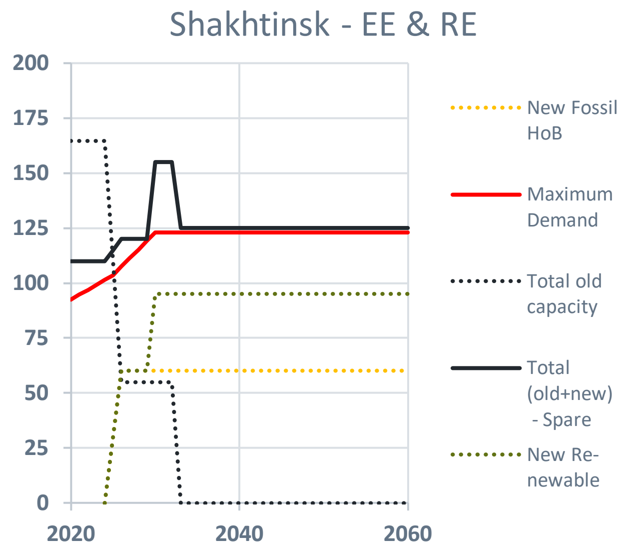


Capacity:

- New in 2023
- Fossil CHP/HoB (180 MW)

Demand:

- \+ New customers
- \- Reduction of losses



Capacity:

- New 2025
- New base capacity-Renewable (90 MW)
- Peak capacity – fossil (60 MW)

Demand:

- \+ New customers
- \- Customer Efficiency measures
- \- Reduction of losses

Methodology of Heat System Planning

Tools

Model for Simulation of Utilisation

1. Utilisation principles

    Merit order

    Stepwise simulation: External heat deliveries, Storage utilisation, Basic production simulation, Treatment of unavailabilities

1. Demand forecast

    Annual Energy

    Annual maximum demand

    Typical Annual Demand curve

1. Production system

    Installed capacities (heat and electricity)

    Variable operation cost

    Annual revision plan

    Availability

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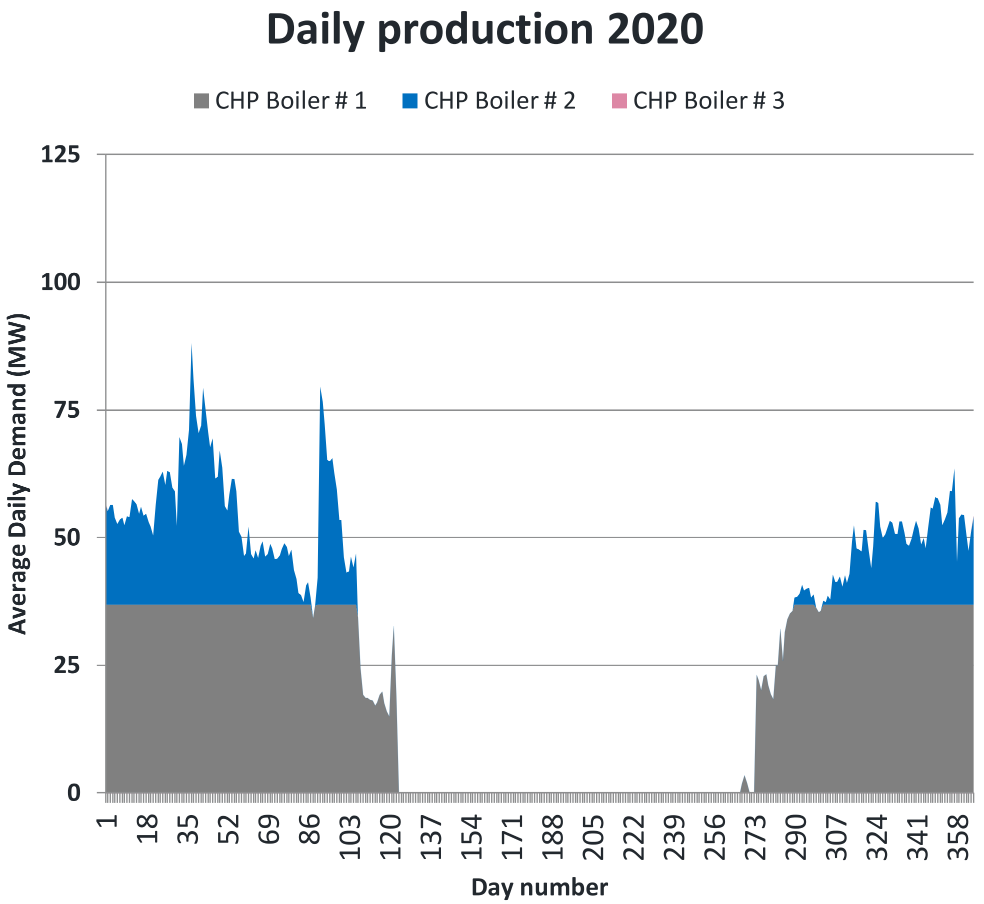
Analysis – Utilisation

Utilisation 2020

- Boiler 1 - utilisation time 3000 hours
- Boiler 3 – utilization time 2000 hours
- Boiler 4 – used only as spare capacity
- Waste of resources to have a CHP as spare capacity
- Important to remember when units should be replaced



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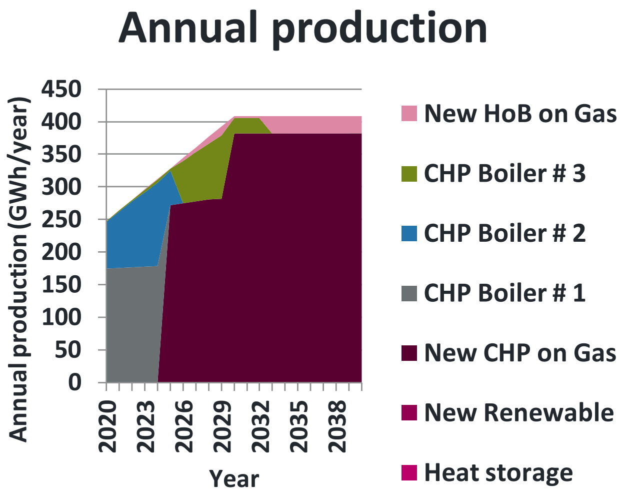
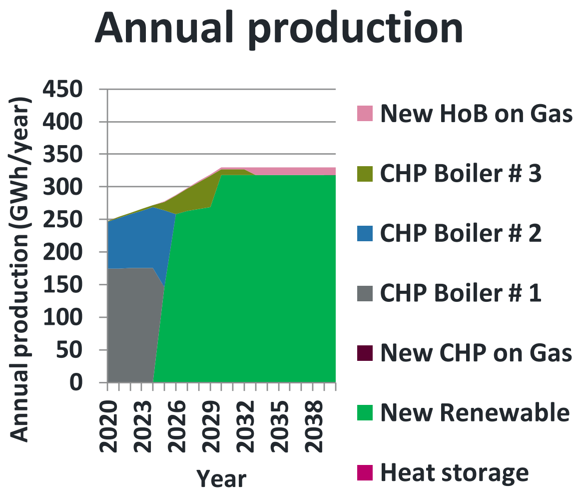
Base



Energy Efficiency & Renewable (EE&RE)

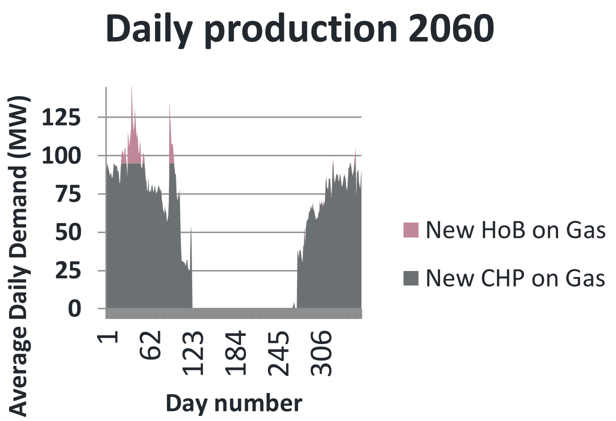


This example shows the annual heat production in different units from 2020 to 2060 for Base and for EE & RE scenarios

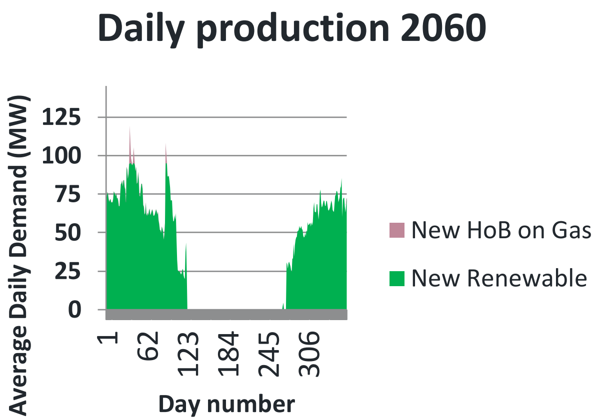
- In 2020 this is a system with 3 coal fired CHPs whereof 1 is utilized to a reasonable degree
- In both scenarios replacement of old production units starts as soon as possible, due to the age of the production units
- In EE & RE scenario the demand is reduced by EE measures.
- A good combination, that will end in the same as the EE & RE Scenario ought to be:
  - To introduce Energy Efficiency measures on customer side as soon as possible
  - Build 2x30 MW HoB based on gas and close the oldest CHP unit as soon as possible
  - Then replace the other 2 old CHP units, when necessary, by 3x30MW renewable units

Methodology of Heat System Planning

Base



Energy Efficiency and Renewable



Daily heat production 2060

- Base scenario all existing units are replaced by:
  - 95 MW CHP (3 units on Fossil fuel)
  - 90 MW HoB (3 units on Fossil fuel)
- EE & RE scenario demand is heavily reduced by EE measures => new capacity:
  - 95 MW CHP (3 units on Renewables)
  - 60 MW HoB (2 units on fossil fuel)

Result

- Efficiency measures reduces:
  - The need for new heat capacity from 185 MW to 155 MW (-15%)
  - The annual production from 409 GWh to 329 GWh and by that CO_2 emissions with 20%
- RE measures reduce the fossil based generation by 318 GWh and by that the remaining CO_2 emissions by 96%

Methodology of Heat System Planning

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Methodology

1. Input from annual report
   - Income
   - Variable cost (volume dependent)
   - Fixed cost
2. Assumptions
   - Constant real prices on sales and purchases during the whole period
3. Simulations
   1. Necessary price to get 0-result for year 2019
   2. Necessary price to get 0-result for a 40-year period using 6% discount rate, taking into consideration necessary investments in accordance with the scenario used for the simulation (Base and Energy Efficiency&Renewable)
   3. Sensitivity analysis for variations in CO_2 trading price

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Current situation – No CO_2 cost

		2019		Current average	2019 balanced	Price for 0-result
		Mtenge	(GWh)	tenge/kWh,heat	Mtenge	tenge/kWh,heat
Income	Sales	613	193,7	3,16	1663	8,59
	Total income	613				
Cost	Fuel	849,3	353,9		849,3	
	Other	813,7			813,7	
	Total	1663				
Annual Result		-1050			0	
Average fuel cost per sold heat unit			4,38	tenge/kWh,heat		

Current heat price has to be increased by:

- 39% to cover the fuel cost and by
- 172% to cover annual operational cost

Financial projections Example

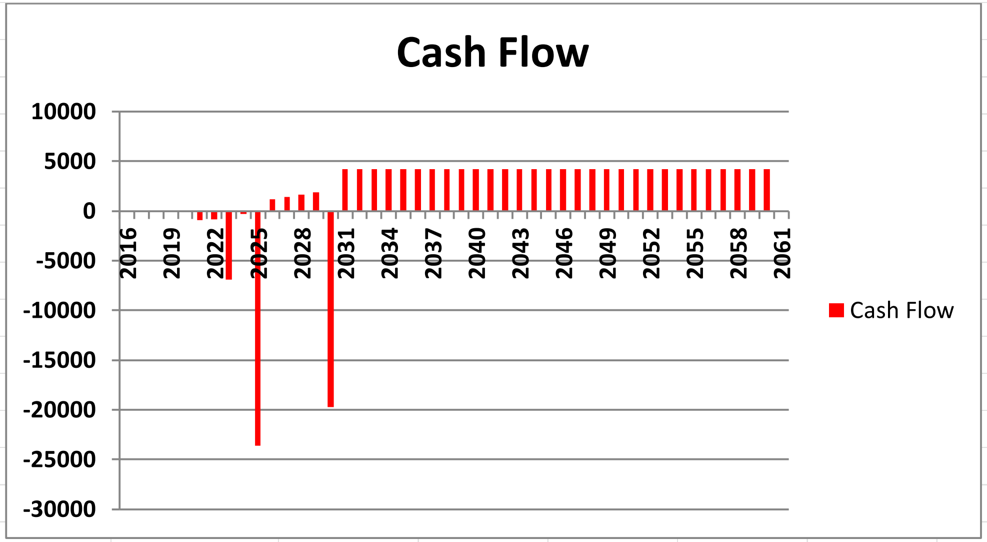
Base 2020-2060, Long term price balance

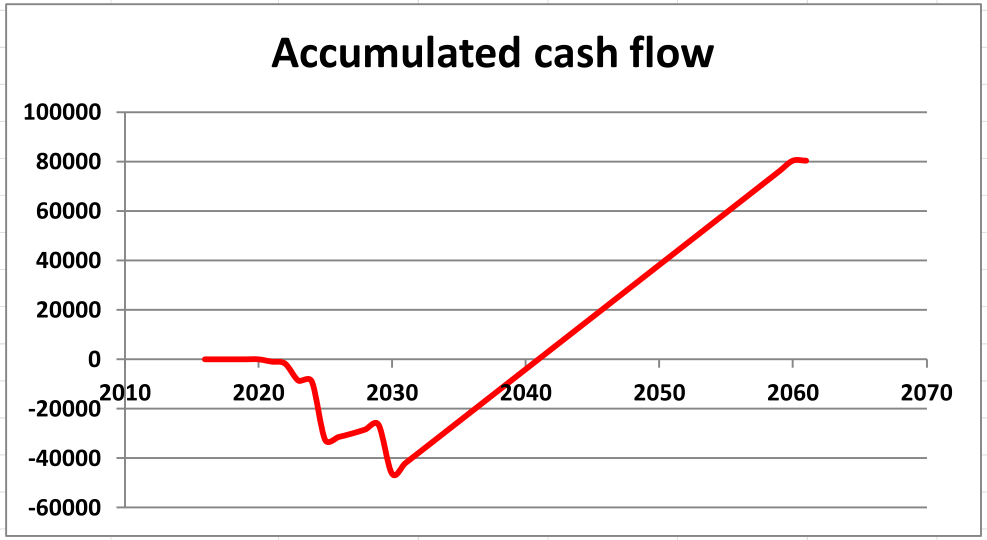
	2020		2030		
Sales	193,7	GWh	346,0	GWh	
Distribution losses	54,0	GWh	44,0	GWh	
	22%	of prod 2020	10%	of prod 2020 adjusted with sales increase	
Production	247,7	GWh	390,0	GWh	
Boiler efficiency	70%		90%		
Fuel consumption	353,9	GWh	433,3	GWh	
Investments in network					
Immediate actions	15	M$	5 years		
Continous reinv.	1	M$/year	from year 6		
New connections	30	M			
		M			
		MW	45	M$	30 / 60

NPV January 1	2021
Total revenue	104 804
Total operational cost	-40 882
Operational result	63 922
Total investment	-63 922
Total project	0

Net present value	**0**
Positive NPV year	**41**
Internal rate of return	**6,0%**

Price for 0-result 2020-2060
tenge/kWh,heat
21,29 (discount rate 6%)





Financial projections Example

Energy Efficiency & Renewable 2020-2060, Long term price balance

	2020	2030
Sales	193,7GWh	298,0GWh
Distribution losses	54,0GWh	38,0GWh
	22% of prod 2020	10% of prod 2020 adj with sales increase
Production	247,7GWh	336,0GWh
Boiler efficiency	70%	95%
Fuel consumption	353,9GWh	353,7GWh
Investments in network		
Immediate actions	15M$	5 years
Continous reinv.	1M$/year	from year 6
New connections	50M$	10 years

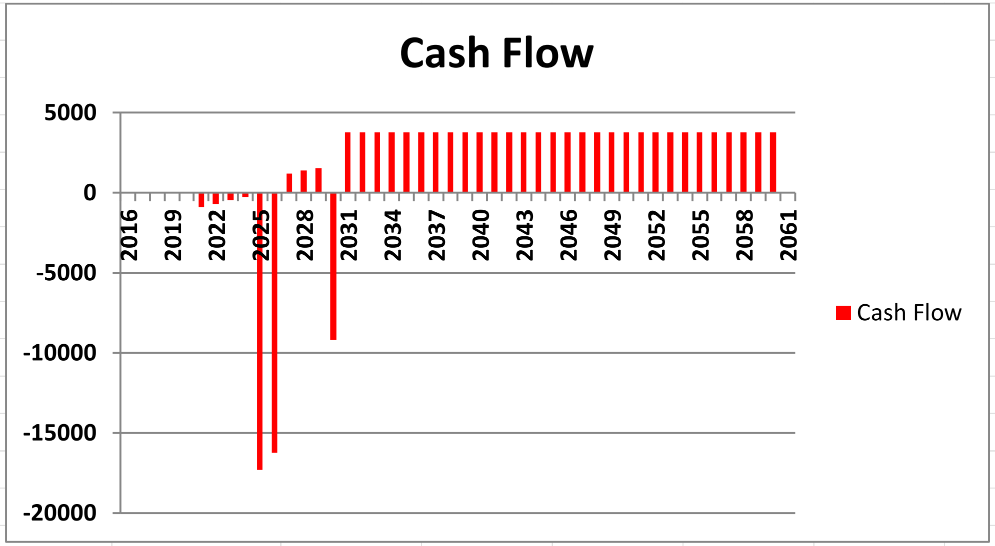
NPV January 1	2021
Total revenue	98 391
Total operational cost	-38 542
Operational result	59 850
Total investment	-59 850
Total project	0

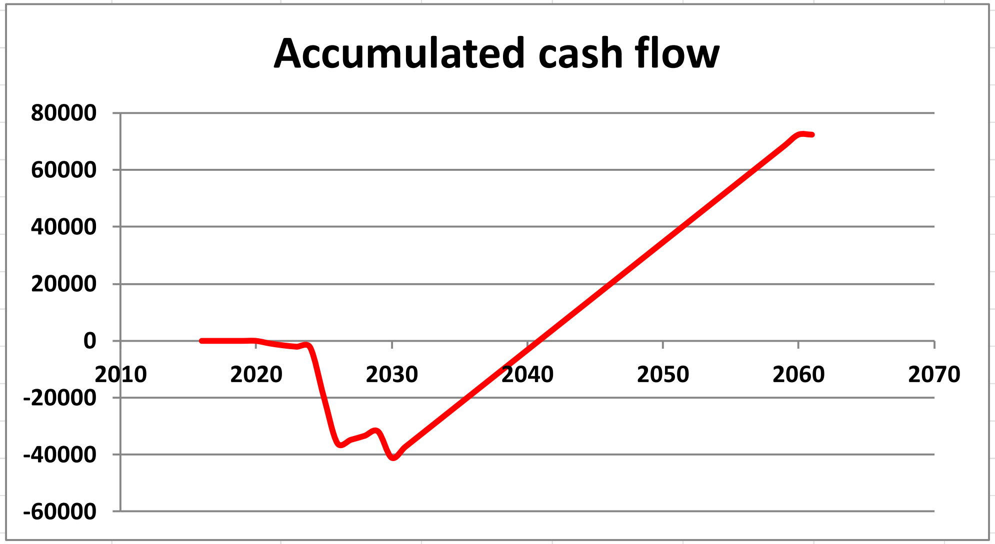
Net present value	0
Positive NPV year	39
Internal rate of return	6,0%
Pay back time (years)	20

Price for 0-result 2020-2030

tenge/kWh,heat

22,61 (discount rate 6%)





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Sensitivity analysis

Current trading price

Kazakhstan	1 $/ton
Europé	22 $/ton (lowest since 2015)
WB forecast	75 $/ton (2030)

Lowest risk - Energy Efficiency and Renewable

Highest risk – Business as usual

Methodology of Heat System Planning

Summary

- Described basic principles and input like:
  - Least cost
  - Load Duration curve
  - Cost characteristics
  - Utilization of different sources
- We have briefly looked at examples of:
  - Detailed modelling of different Scenarios for Demand and Supply
  - Tools to be used for
    - Detailed simulations of system operation
    - Financial simulations

Methodology of Heat System Planning

Discussion

- Future District Heating demand:
    - Increase due to higher living standard
    - Increase due to more connected customers
    - Decrease due to Efficiency Measures
- Use of Simulation model
    - System utilization
    - Financial simulations for prioritization of actions

Thank you for your Attention!

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