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REWARDHeat

District heating systems modeling: A gamification approach

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Serious game

The objectives:

- to simulate and show the interaction between different stakeholders in the heating sector of a fictional town;
- to simulate and show how existing fossil fuel-based heating systems can be developed and transformed to the green, sustainable ones (from 2GDH and 3GDH to 4GDH and 5GDHC concepts);
- to increase knowledge and raise awareness of students, engineers, involved citizens, building owners, investors, local authorities, decision-makers and all who are interested in sustainable development of both technical, economic, ecological and sociopolitical aspects related to the heating sector and potential advantages of low-temperature district heating.

Initial conditions

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Population [mln people]	Fossil fuel share [%]	Number of CHP plants [-]	Generation of district heating [-]	Share of demand covered by		
				CHP plants [%]	Individual gas boilers [%]	Players in the 1st round [%]
0.1-0.2	100	2	2 and 3	15	50	35

Roles and goals of players:

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1. The government
(1 player)

Goals:
- CO_2 reduction
- Approval rating

2. Producers
(up to 4 players, a half is newcomers)

Goals:
- Profit growth
- Share of the market

3. Consumers
(up to 9 players)

Goals:
- Low heat costs

Model of heat supply sector

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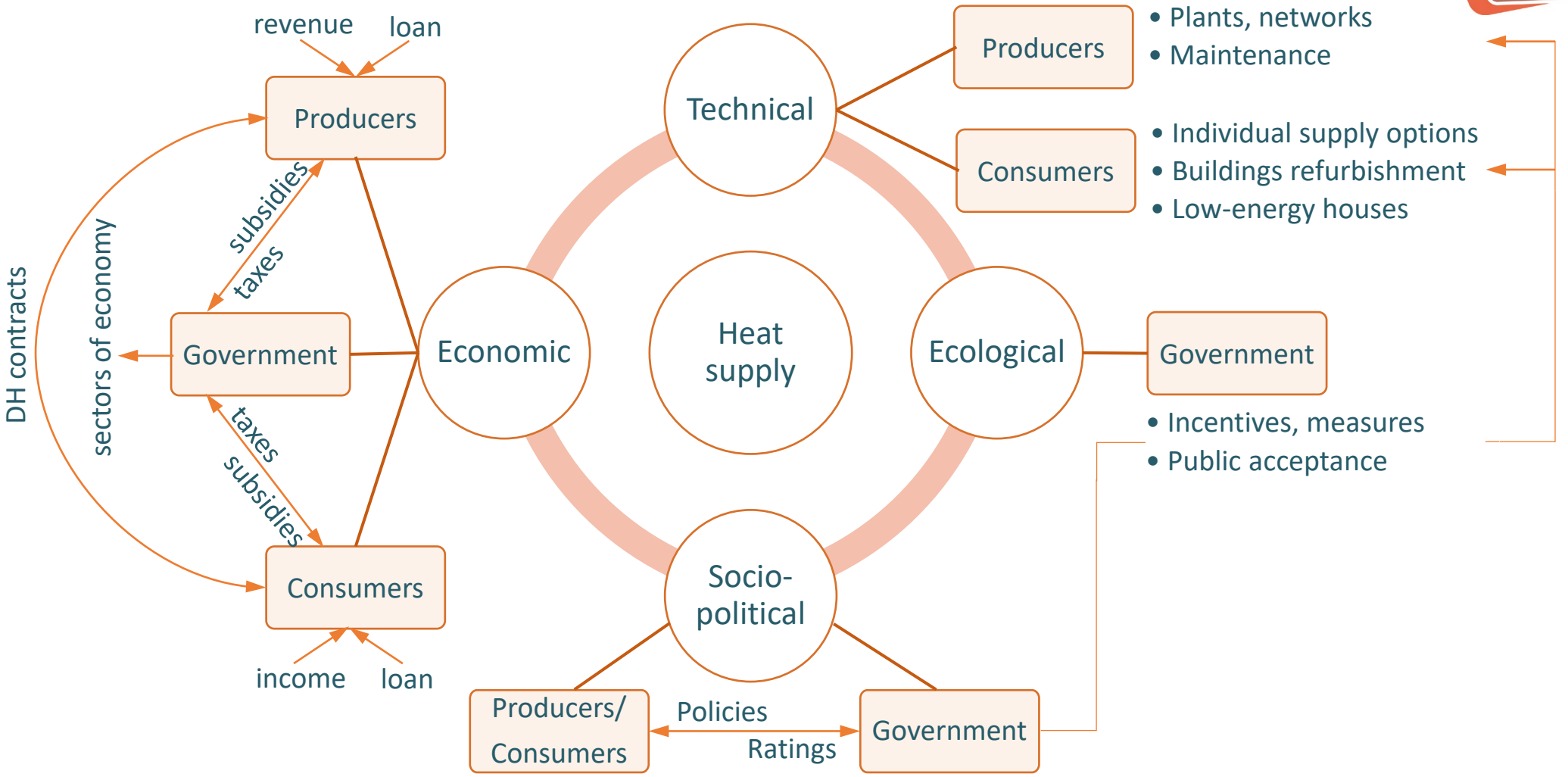

Gameplay

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The game consists of 5 rounds each representing a 5-year period (25 years in total). Before the start, the orientation round is played.

The sequence of actions within a round:

1. Initial conditions and random events (gas and oil prices fluctuations, political and economic instabilities, natural disasters, global pandemics and so on) set up boundary conditions for a round.
2. Producers and consumers identify the subdistricts where heat is needed and the plants, networks, building stock with expiring technical lifetime; the government plans how to spend budget money and identifies its sociopolitical priorities;
3. Producers and consumers use calculation tools (simplified algorithms on annual basis) to estimate levelized cost of heat (LCOH) and CO_2 emissions for different heat supply options (decentralized, centralized, fossil fuels, renewables); the government considers subsidizing producers and consumers.
4. Interaction between the government, producers and consumers via a built-in chat or in person.
5. Decision-making phase.
6. Assessing economic and ecological results of a round and rating the government.

Decision-making phase

The decisions of players:

1. **The government**
- Which sectors of economy to allocate budget money for the next round to;
- Which green projects of producers and consumers to support financially;

2. **Producers**
- Which plant to build and where;
- Old plants' replacement;
- Which consumers to connect to the network;

3. **Consumers**
- Individual plants or district heating;
- Old individual plants' replacement;
- Which producer (DH) to sign contract with;
- Building stock renovation;

Available heat supply options

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Individual heating			District heating				
gas boiler	biomass boiler	groundwater source heat pump	gas CHP plant	biomass CHP plant	deep geothermal energy plant	large-scale heat pump	solar thermal power plant

*Calculation tool for **consumers***

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Input data

Heat and cold demand;

Type of plant

Average annual COP

Specific CO_2 emissions

CO_2 tax

Prices of fuel and electricity

CAPEX of plant

Inflation rate and discount rate

Calculation tool

Output data

Levelized cost of heat

CO_2 emissions

*Calculation tool for **producers***

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Input data

Additionally

Subdistrict(s)

Land and building space area

Linear heat density

Trench length;

CAPEX (pipes, substations, TES)

Margin rate

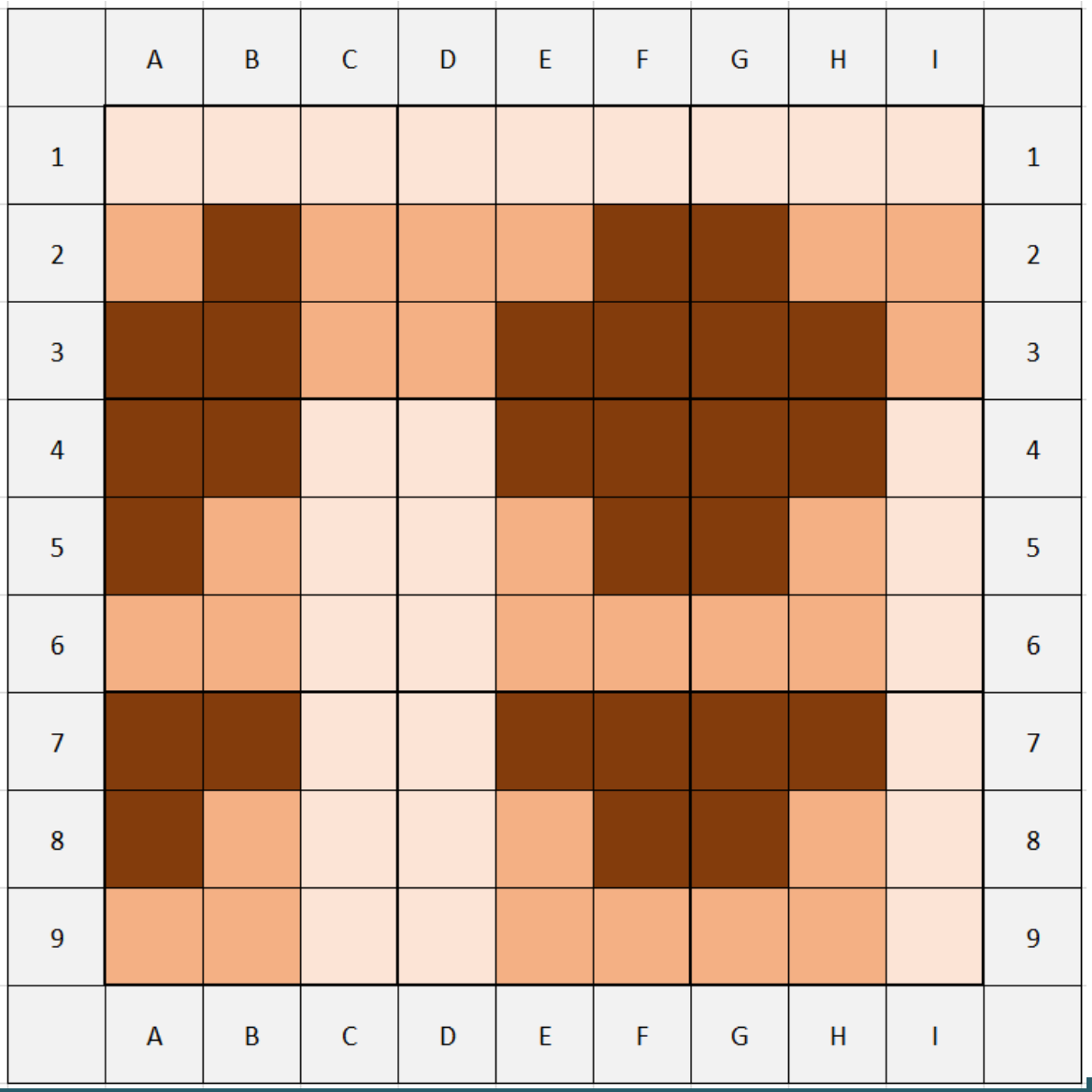
Calculation tool

Output data

Heat tariff

CO_2 emissions

Draft/idea of game map



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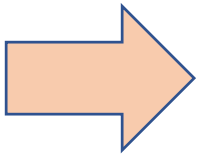
- 9 districts – 9 consumers;
- 9 districts are further divided into 9 subdistricts;
- Plants and the network appear on the map when built by producers;
- Different shades of the color represent population (heat) density;
- The map should be interactive; events and menus should appear on click.

Storyline development

G	H	I	
IND R5	IND R0	IND R5	1
DHC R10	IND R0	IND R5	2
DHC R10 CHP10	IND R10	IND R0	3
IND R10	IND R10	IND R0	4
IND R0	IND R5	IND R5	5
DHC R5 CHP5	IND R10	IND R0	6



G	H	I	
IND R5	IND R10	IND R15	1
DHC R15	DHC R5	DHC R5	2
DHC R15 ST15	DHC R5 HP5	DHC R5	3
DHC R15	DHC R15	DHC R10	4
DHC R10	DHC R10	DHC R10 BM 15	5
DHC R10 DG10	IND R10	IND R10	6

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IND – individual supply option
DHC – district heating and cooling
CHP – combined heat and power plant
ST – solar thermal
HP – heat pump
BM – biomass boiler
DG – deep geothermal

Players' decisions as well as their responses to random events shape the course of the game

Model of DH transformation in the game

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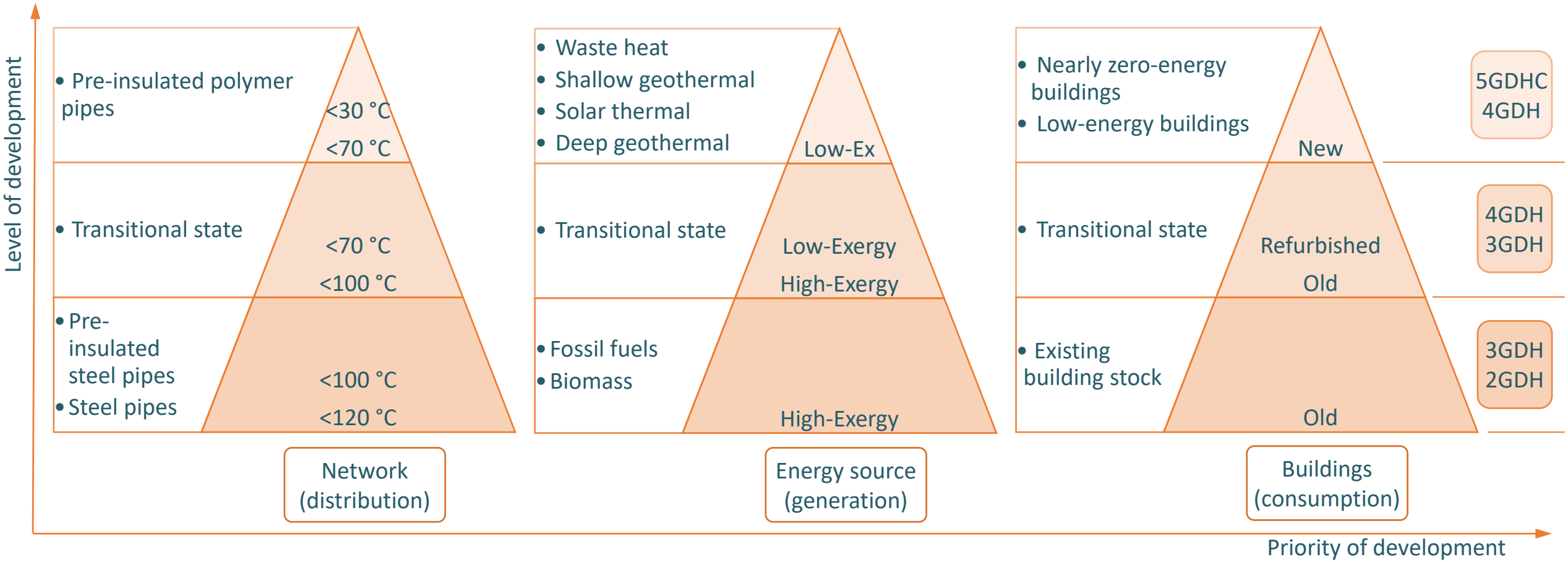

Draft of interface

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Budget = 0.00 mln €

CO_2 emissions = 0.00 t/a

Year 2025
Round 2
ends in 23:57:51

Blue

- Main page
- Calculation tool
- Game map
- Contracts
- Results/Charts

Initial conditions

Gas price, households [€/m^3]	Gas price, non-households [€/m^3]	Wood pellets price, households [€/kg]	Wood pellets price, non-households [€/kg]	Electricity price, households [€/MWh]	Electricity price, non-households [€/MWh]	CO_2 tax [€/t]	Inflation rate [%]
0.70	0.30	0.311	0.156	216.00	117.00	25.00	1.5

NW3

-- select a location for a plant --

-- where to build network --

bio_CHP_1

-- select a type of pipelines ----

3GDH_type

Calculate

Annual heat demand of subdistrict NW3

Heat load [MW]	Heat load (covered) [MW]	Annual heat demand [MWh/a]	Annual heat demand (covered) [MWh/a]	Specific domestic hot water demand [kWh/(m^2*a)]	Specific space heating demand [kWh/(m^2*a)]	Floor area [m^2]	Possibility to connect to LTDH [-]
2.12	0.00	6580.00	0.00	23	131.6	42560	Refurbishment is needed

Characteristics of heat supply source

Heat capacity [MW/unit]	Maximum heat generation [MWh/unit/a]	Lifetime [years]	Specific CO_2 emissions [t/TJ]	CAPEX [M€/unit]	OPEX_const [k€/unit/a]	OPEX_var [€/MWh]	COP_{el} [-]	Electric capacity [MW/unit]	Heat allocation factor [-]
17.00	148920.00	25	0.00	18.91	840.1	3.9	0.15	3.06	0.847

Feedback

- Questions
- Comments
- Improvements
- Remarks
- Criticism

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