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MULTI-SCENARIO SIMULATION AND ENERGY - EXERGY ANALYSIS OF A DISTRICT HEATING NETWORK FOR A CASE STUDY IN VIENNA

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4DH
4th Generation District Heating
Technologies and Systems

CONTENTS

1. CI-NERGY PROJECT

CINERGY

MARIE CURIE ACTIONS

SEVENTH FRAMEWORK PROGRAMME

- CI-NERGY is a Marie Curie European project concerning Urban Energy Planning.
- Two case studies: cities of Geneva and Vienna.
- 14 researchers involved, my topic: District heating and cooling systems.
- Supported by the 7th Framework Programme for Research and Technological Development.

2. PURPOSE OF THE PROJECT

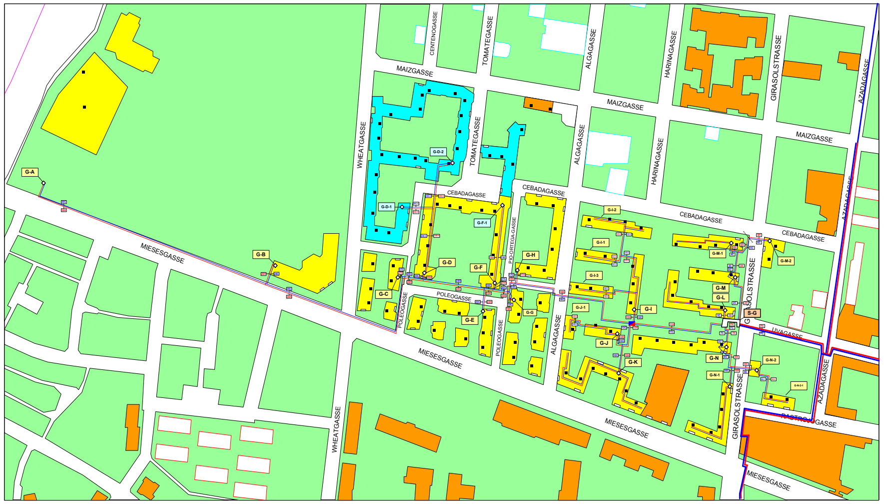
- Defining a methodology which is able to build simulations and make energy-exergy studies of DH Networks extrapolable for all kind of cities.
- 9 hypothesis are studied, defined as “scenarios” each one is a simulation of the network combining different improvements and technologies:
  - Replacing radiators for heated/cooled floors.
  - Connecting heat pumps supporting the DHN
  - Adapting to Low Temperature district heating network.
- Informing urban planners about all possible advantages and disadvantages for each considered hypothesis during the transition to 4th GDHN

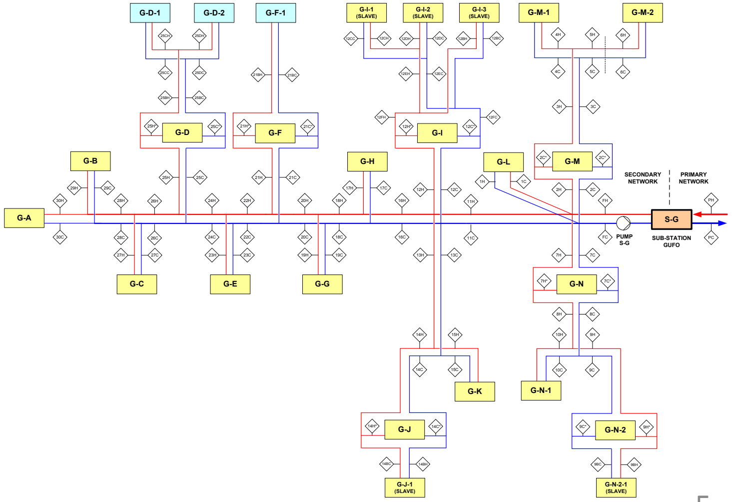
3. CASE STUDIED

- Simulation of a local district heating network located in Vienna.
- 21 residential buildings

  - 20 with hot water and heating services.

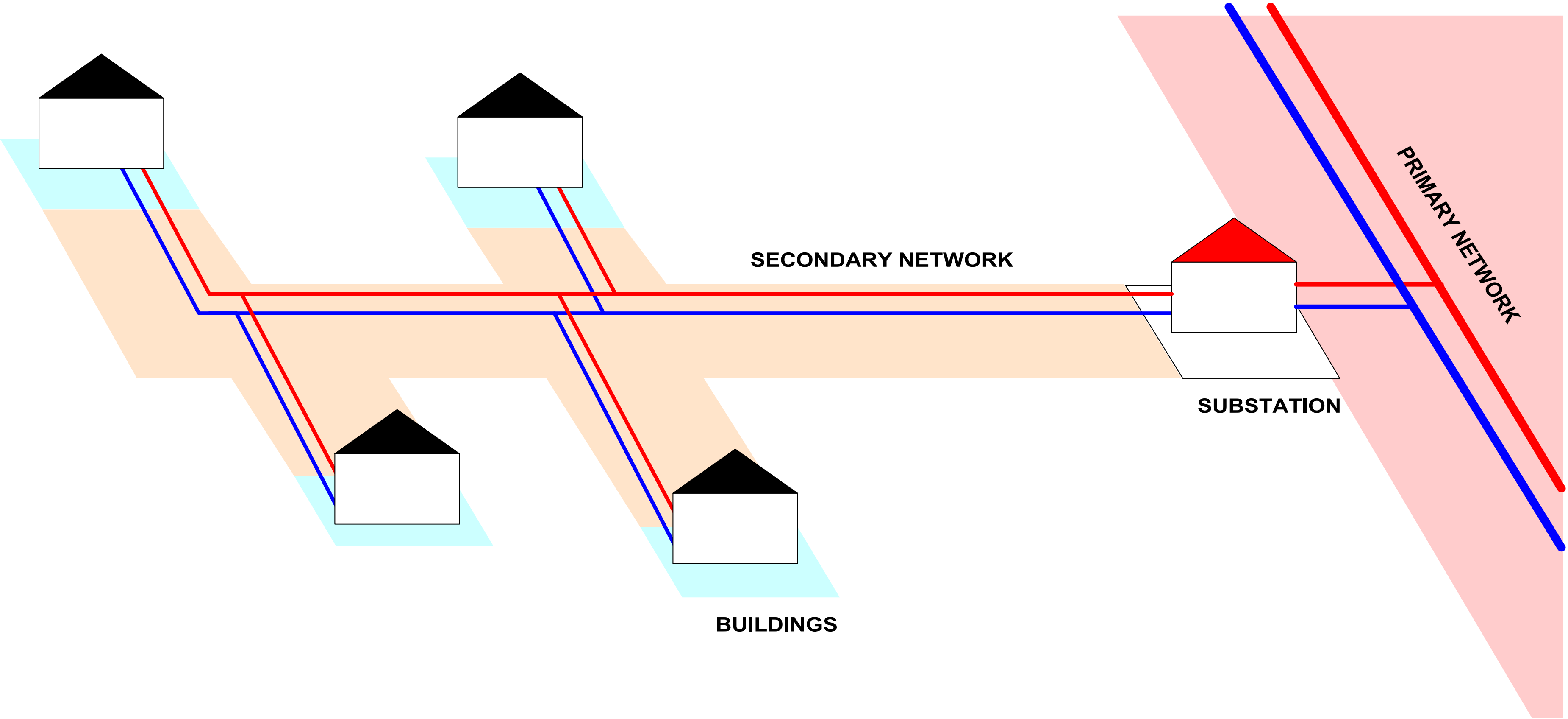
  - 1 with heating service only

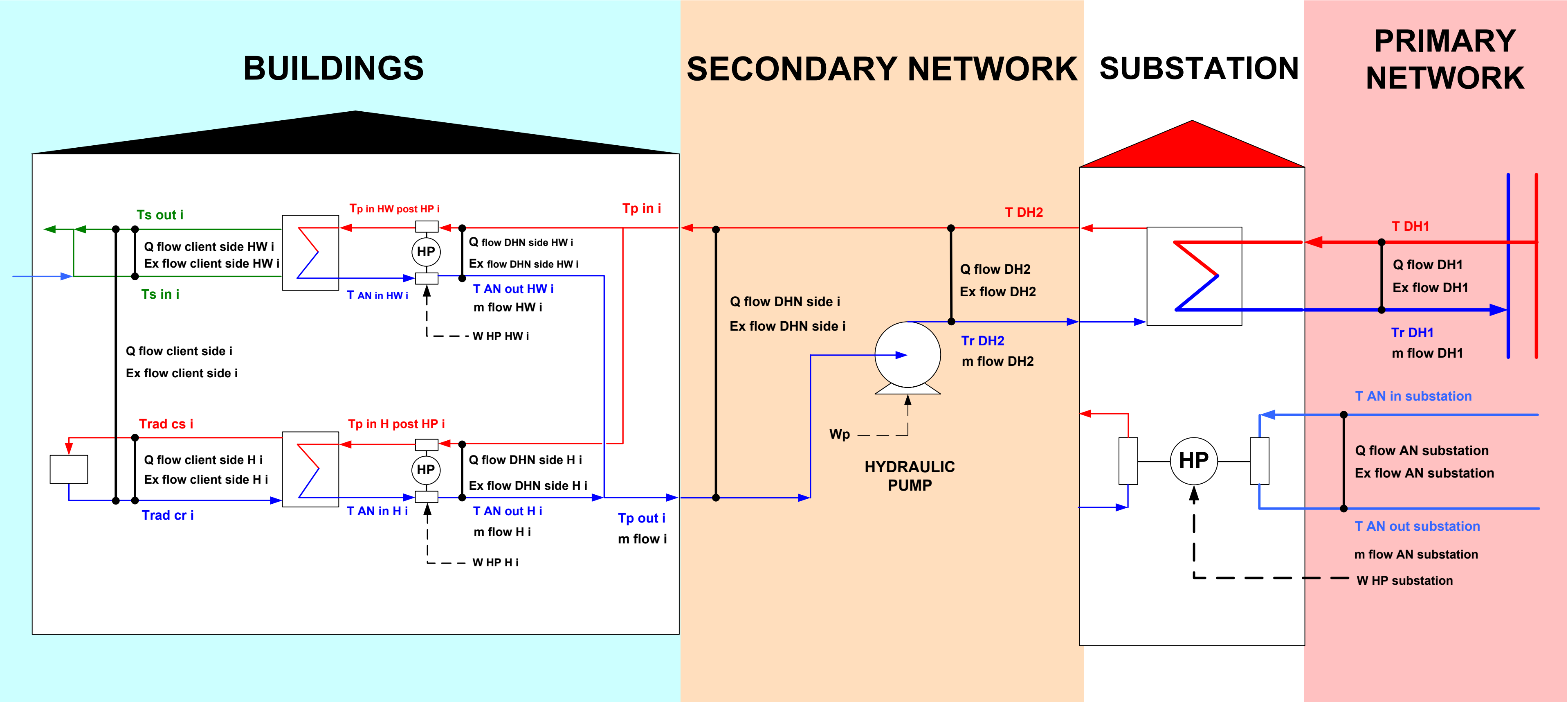




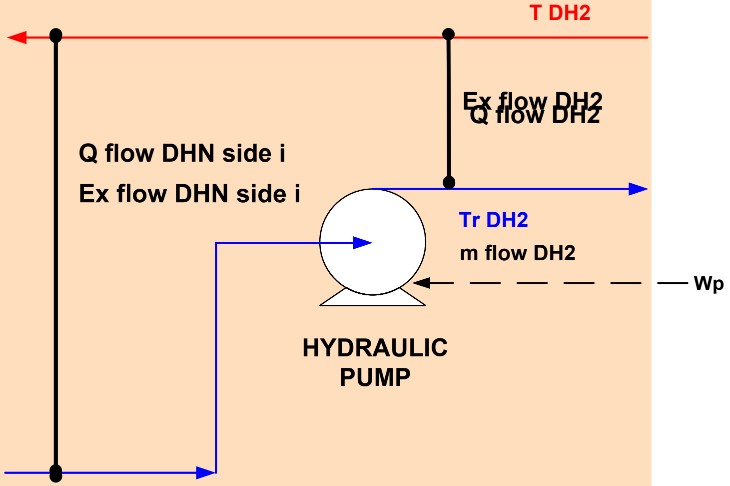
4. METHODOLOGY

DEFINING THE THERMODYNAMIC SYSTEMS




BUILDINGS
SECONDARY NETWORK
SUBSTATION
PRIMARY NETWORK
Ts out i
Tp in HW post HP i
Tp in i
Q flow client side HW i
Ex flow client side HW i
HP
Q flow DHN side HW i
Ex flow DHN side HW i
Ts in i
T AN in HW i
T AN out HW i
m flow HW i
W HP HW i
Q flow client side i
Ex flow client side i
Trad cs i
Tp in H post HP i
Q flow client side H i
Ex flow client side H i
HP
Q flow DHN side H i
Ex flow DHN side H i
Trad cr i
T AN in H i
T AN out H i
m flow H i
W HP H i
Tp out i
m flow i
Q flow DHN side i
Ex flow DHN side i
T DH2
Q flow DH2
Ex flow DH2
Tr DH2
m flow DH2
Wp
HYDRAULIC PUMP
T DH1
Q flow DH1
Ex flow DH1
Tr DH1
m flow DH1
T AN in substation
HP
Q flow AN substation
Ex flow AN substation
T AN out substation
m flow AN substation
W HP substation

ENERGY AND EXERGY BALANCES: NETWORK



$$\dot{Q} = \dot{m}\, C_p \left(T_{feed} - T_{return}\right)$$

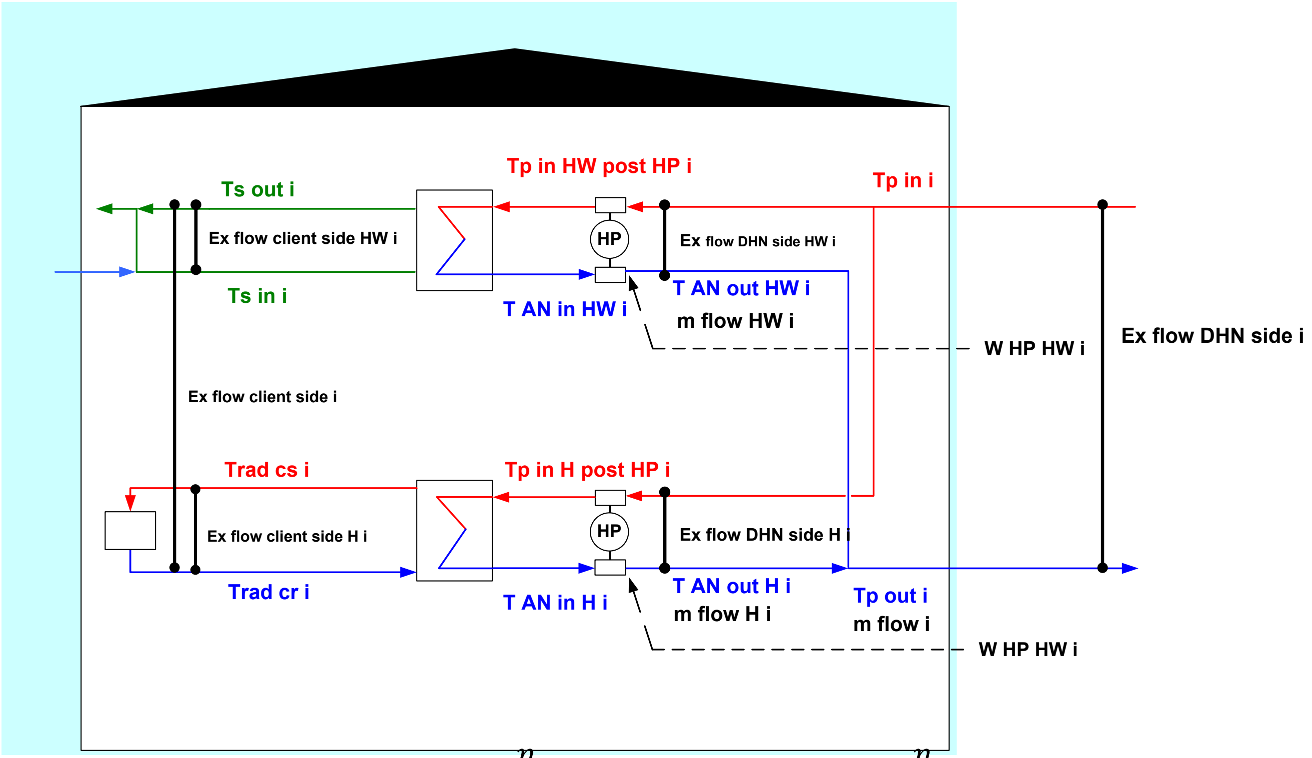
$$\dot{Q}_{losses\ NETWORK} = \dot{Q}_{DH2} + \dot{W}_p - \sum_i^n \dot{Q}_{DHN\ side\ i}$$

$$\eta_{EN\ NETWORK} = \frac{\sum_i^n \dot{Q}_{DH\ side\ i}}{\dot{Q}_{DH2} + \dot{W}_p}$$

$$\dot{E}x_{losses\ NETWORK} = \dot{E}x_{DH2} + \dot{W}_p - \sum_i^n \dot{E}x_{DHN\ side\ i}$$

$$\eta_{EX\ NETWORK} = \frac{\sum_i^n \dot{E}x_{DHN\ side\ i}}{\dot{E}x_{DH2} + W_p}$$

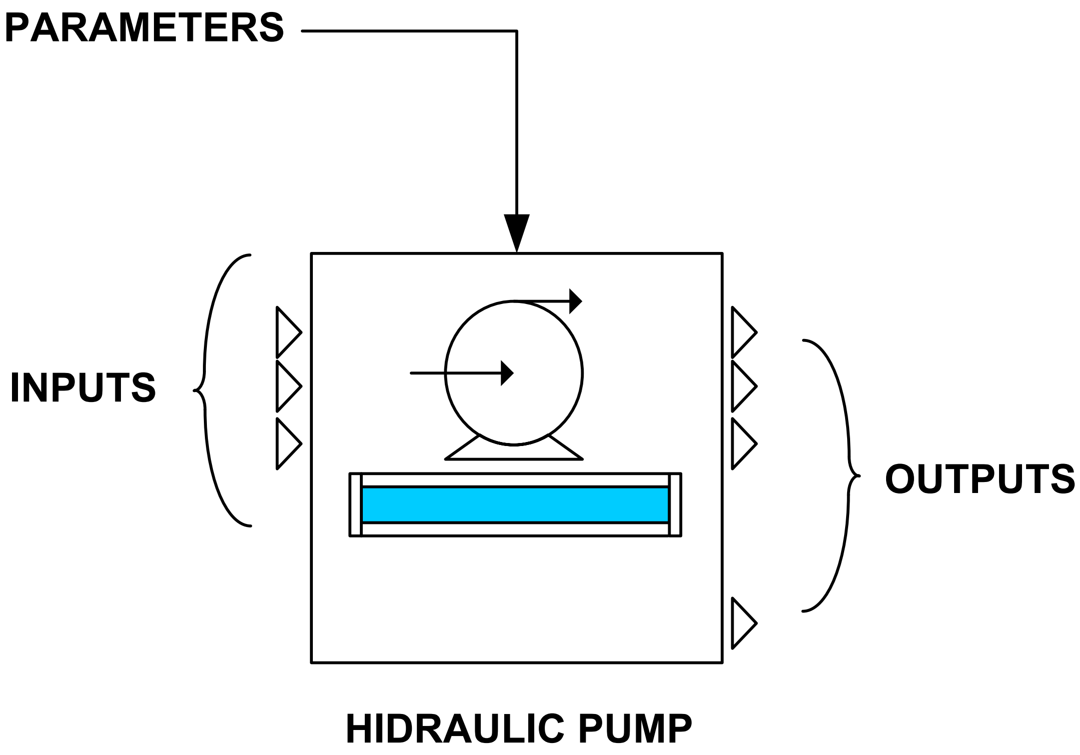
ENERGY AND EXERGY BALANCES: BUILDINGS



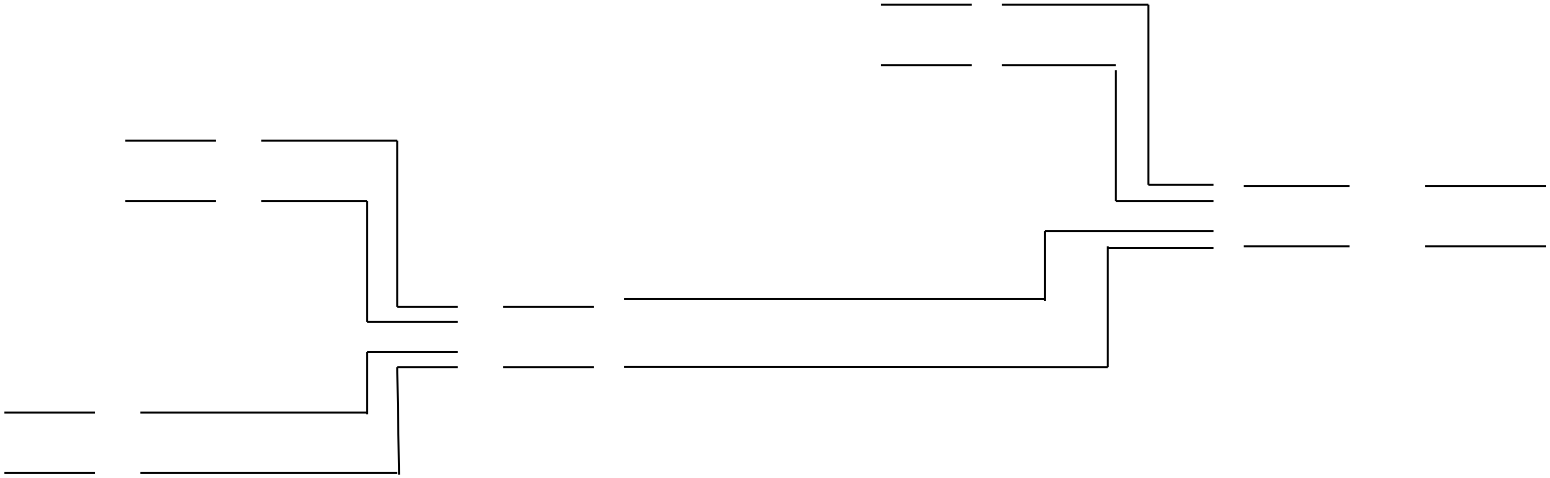
$$\dot{E}x_{losses\ BUILDINGS} = \sum_i^n \dot{E}x_{DHN\ side\ i} - \sum_i^n \dot{E}x_{client\ side\ HW\ i} - \sum_i^n \dot{E}x_{client\ side\ H\ i} + \sum_i^n \dot{W}_{HP\ HW\ i} + \sum_i^n \dot{W}_{HP\ H\ i} + \sum_i^n \dot{B}_{HW\ i} + \sum_i^n \dot{B}_{H\ i}$$

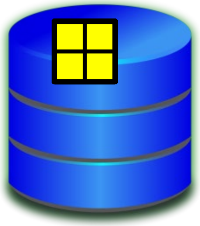
$$\eta_{EX\ BUILDINGS} = \frac{\sum_i^n \dot{E}x_{client\ side\ HW\ i} + \sum_i^n \dot{E}x_{client\ side\ H\ i}}{\sum_i^n \dot{E}x_{DHN\ side\ i} + \sum_i^n \dot{W}_{HP\ HW\ i} + \sum_i^n \dot{W}_{HP\ H\ i} + \sum_i^n \dot{B}_{HW\ i} + \sum_i^n \dot{B}_{H\ i}}$$

HOW THE SIMULATION WORKS:
THE SIMPLE BLOCK

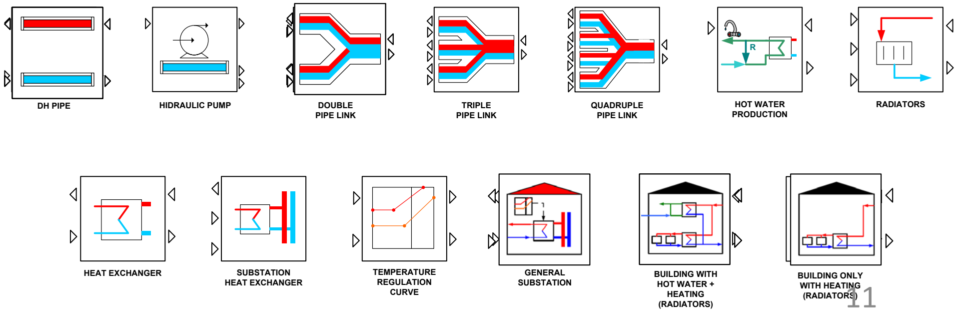


HOW THE SIMULATION WORKS:
CREATING THE SIMULATION



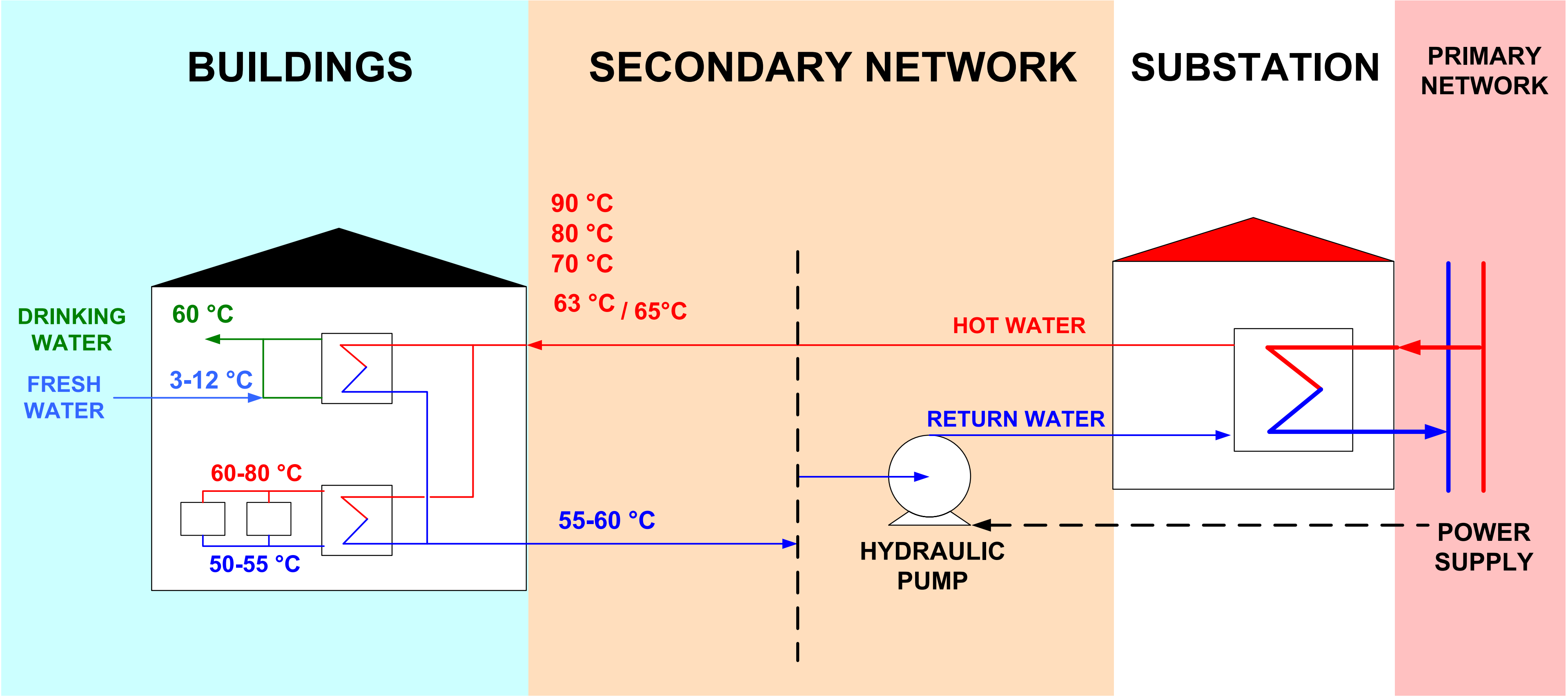


PARAMETERS DATABASE

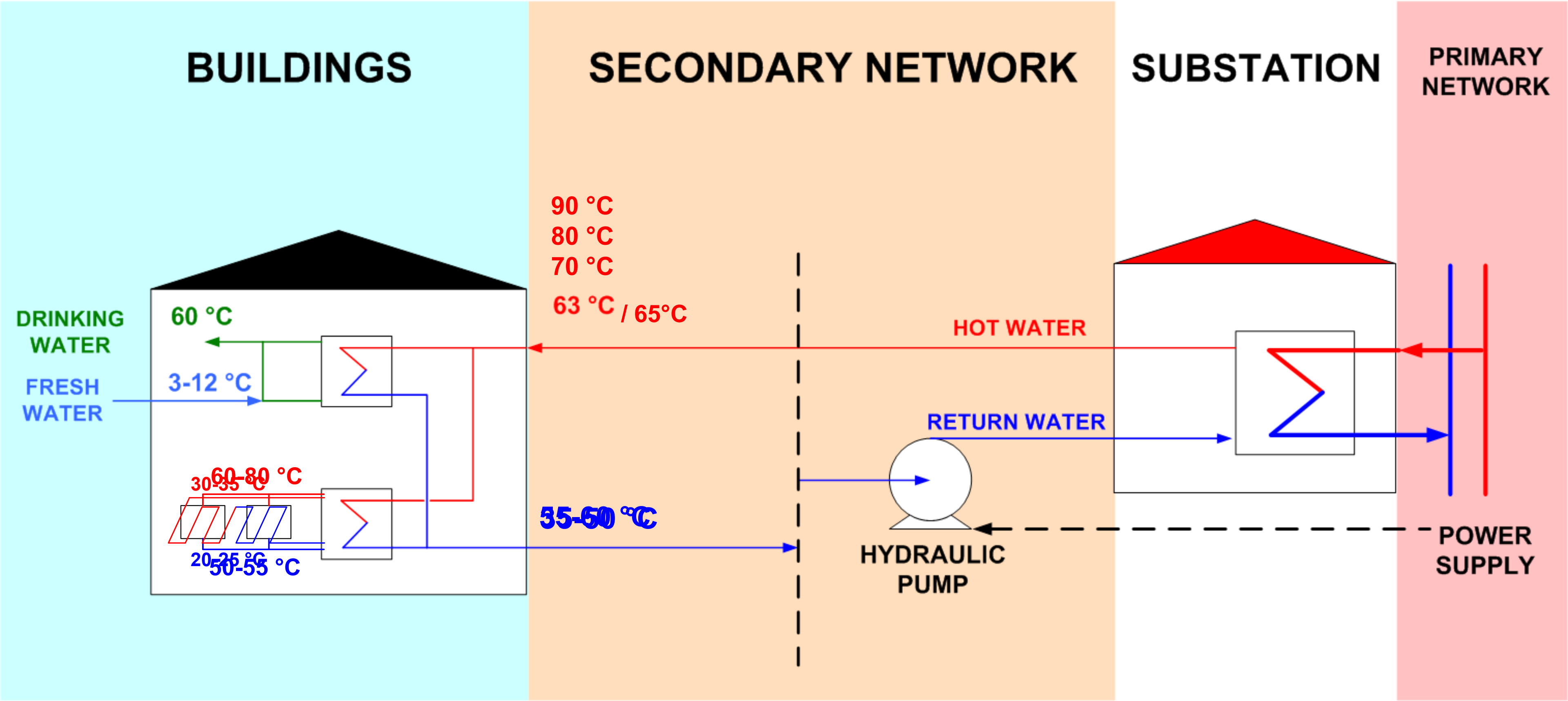


5. SCENARIOS AND RESULTS

1^{ST} SCENARIO: CURRENT SITUATION



2ND SCENARIO: BASIC REFURBISHMENT



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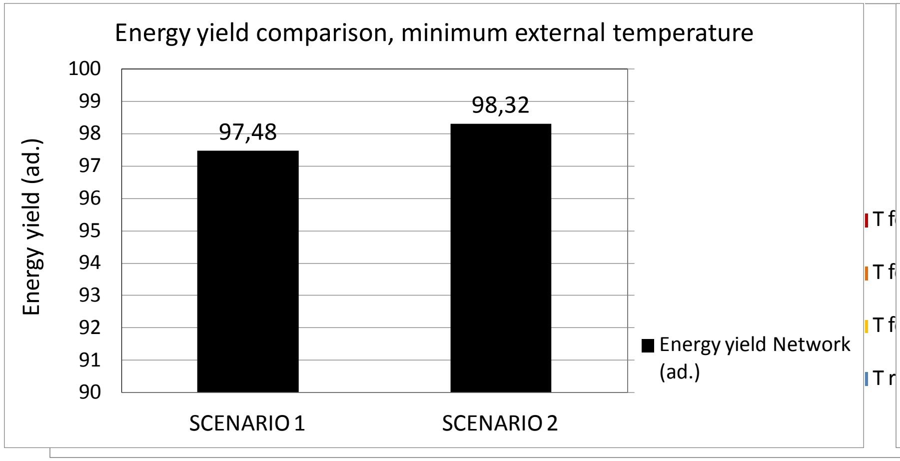
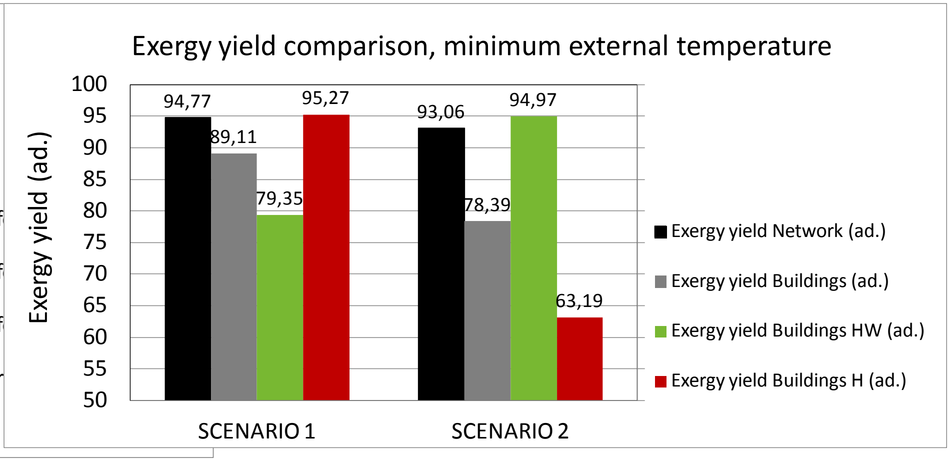
RESULTS:
COMPARISON BETWEEN 1ST AND 2ND SCENARIO



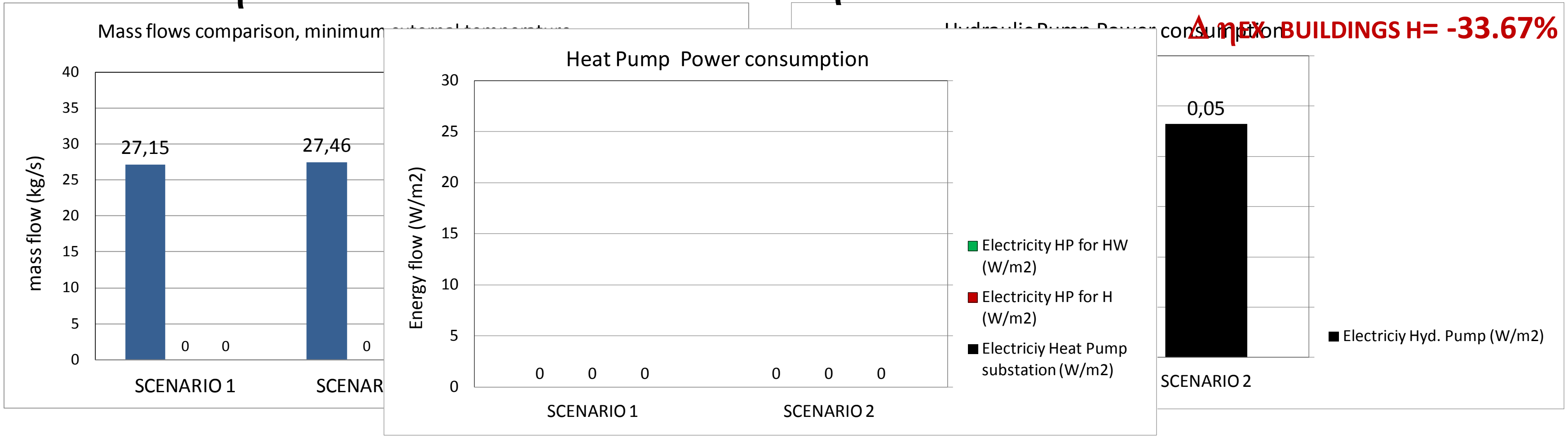


Δ ηEN = +0.86%

Δ ηEX NETWORK= -1.8%

Δ ηEX BUILDINGS HW= +19.68%

Δ ηEX BUILDINGS H= -33.67%

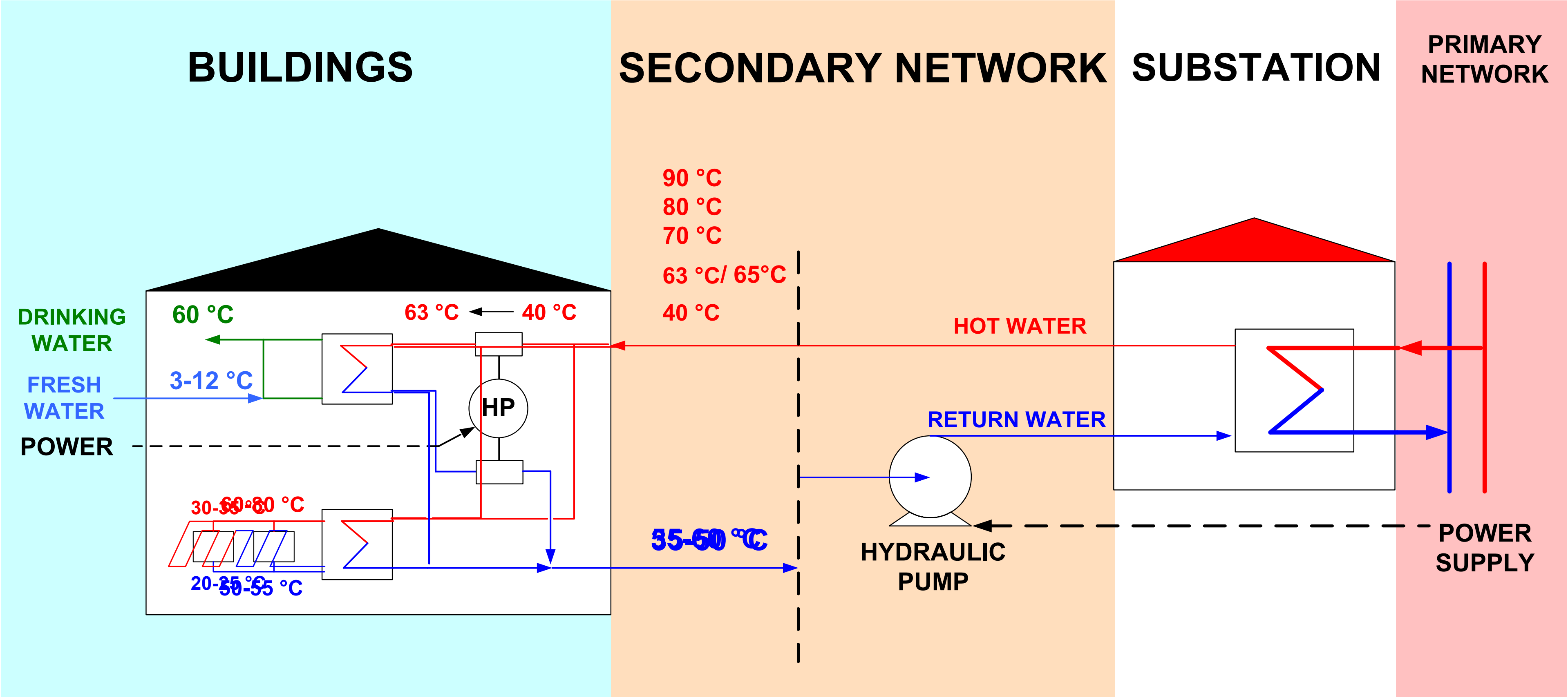


Δ mass flow = +1.15%

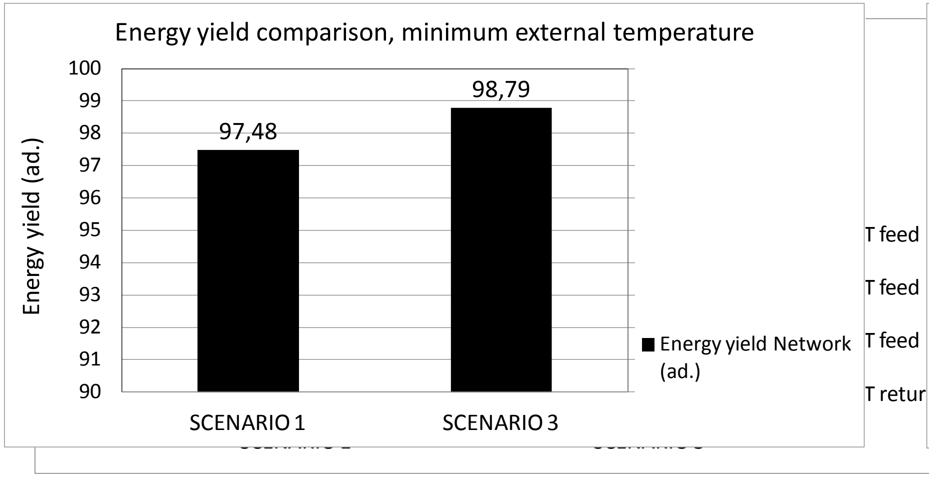
Δ Hyd. Pump Power consumption = +4.28%

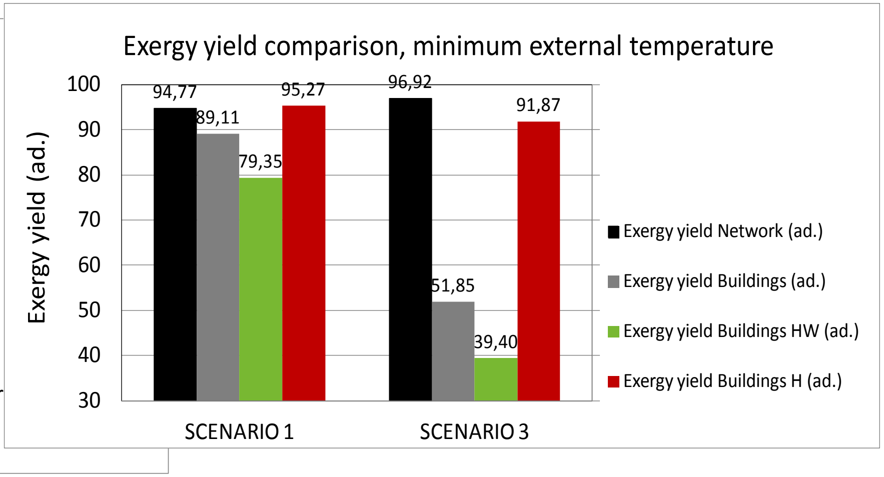
No heat pumps installed

3RD SCENARIO: BASIC REFURBISHMENT FOR LOW TEMPERATURE DHN



RESULTS:
COMPARISON BETWEEN 1ST AND 3RD SCENARIO



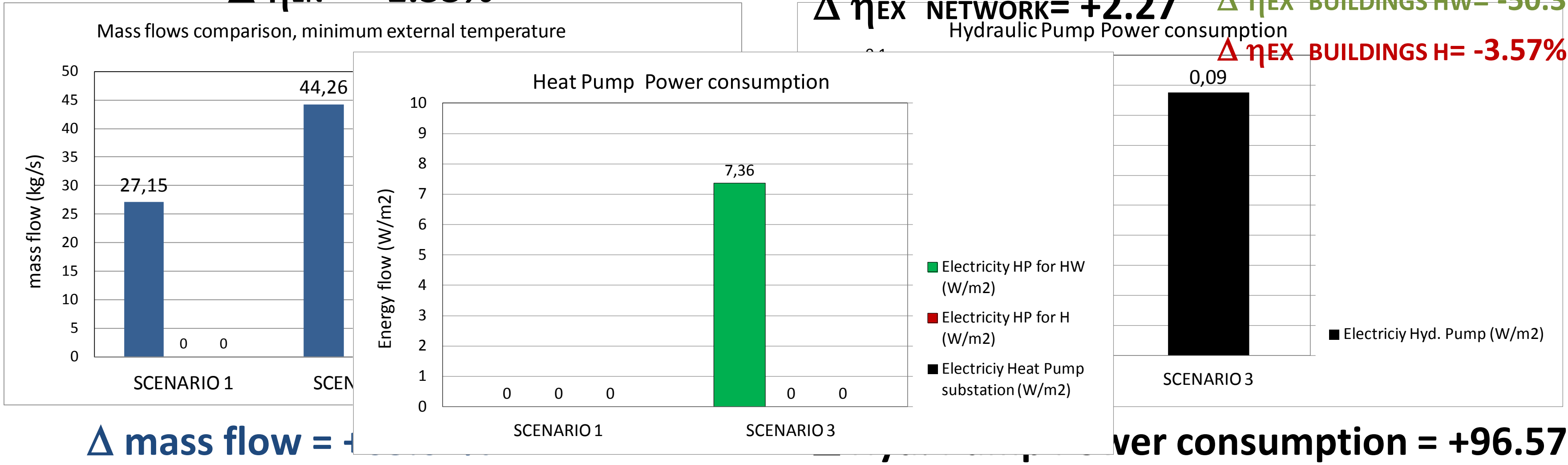


$\Delta \eta_{EN}$ = +1.33%

$\Delta \eta_{EX}$ NETWORK= +2.27

$\Delta \eta_{EX}$ BUILDINGS HW= -50.35%

$\Delta \eta_{EX}$ BUILDINGS H= -3.57%

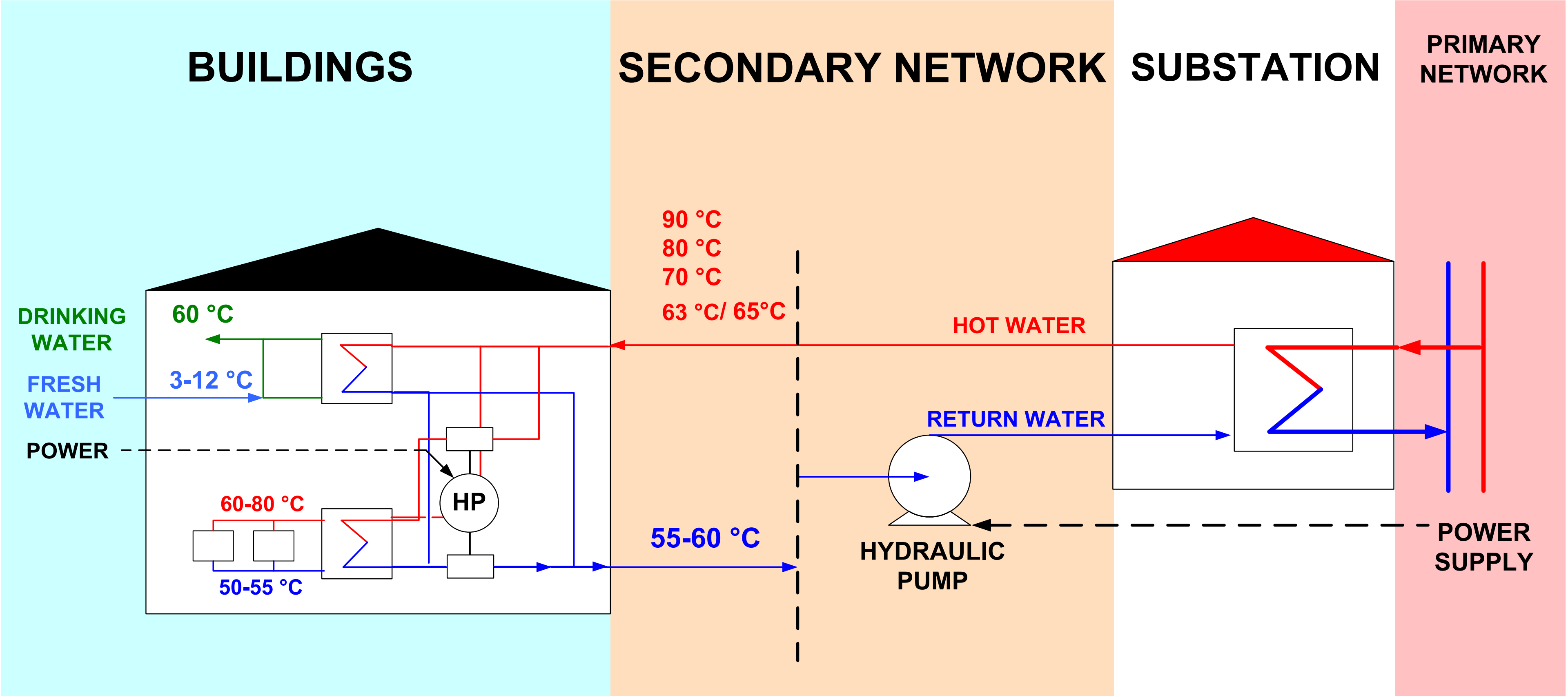


Δ mass flow = +

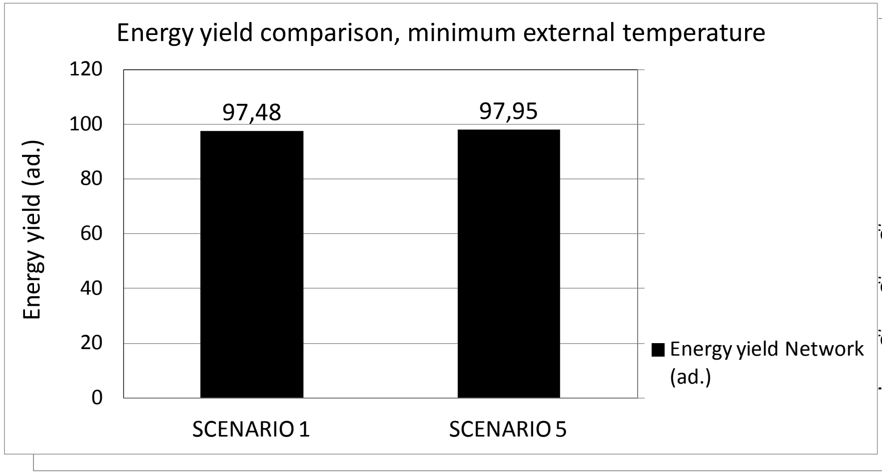
ver consumption = +96.57%

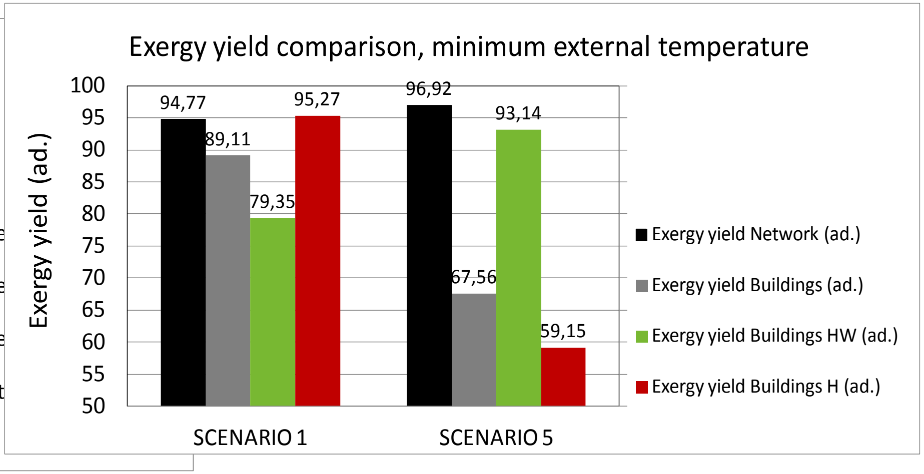
Heat Pump Power consumption HW= 7.36 W/m2

5TH SCENARIO: INDIVIDUAL HEAT PUMPS FOR HEATING WITHOUT REFURBISHMENT



RESULTS:
COMPARISON BETWEEN 1ST AND 5TH SCENARIO



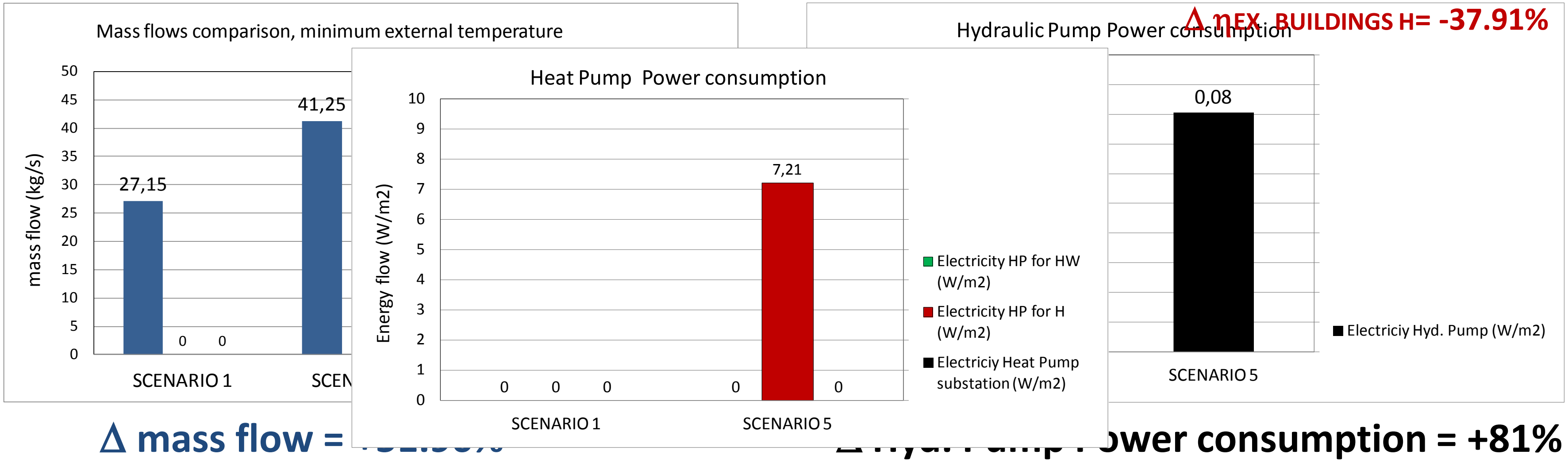


Δ ηEN = +0.48%

Δ ηEX NETWORK= +2.27

Δ ηEX BUILDINGS HW= +17.38%

Δ ηEX BUILDINGS H= -37.91%

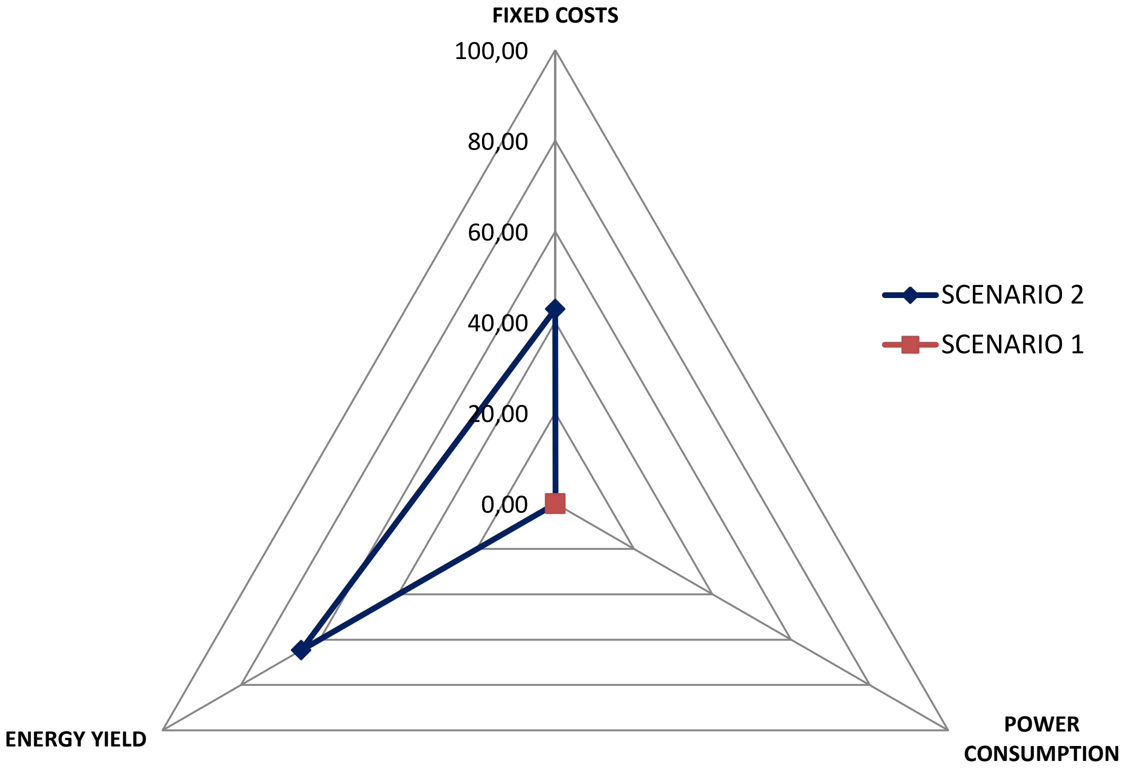


Δ mass flow =

ower consumption = +81%

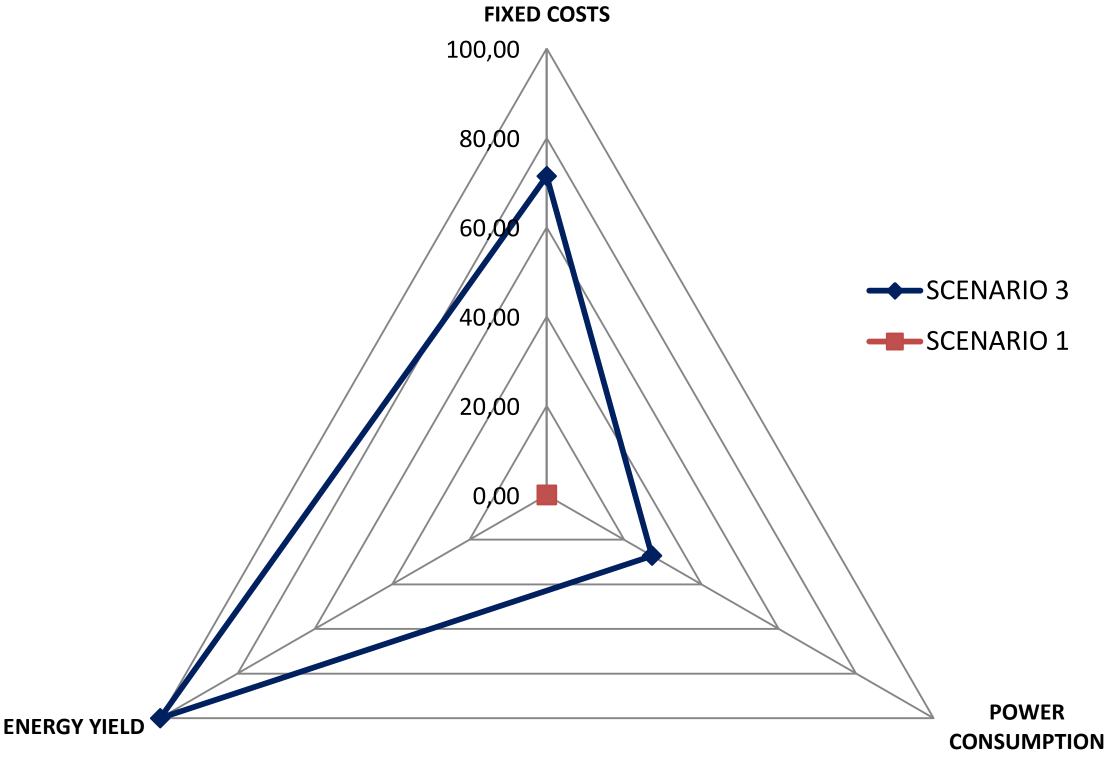
Heat Pump Power consumption H= 7.21 W/m2

CONCLUSIONS:
COMPARISON BETWEEN 1ST AND 2ND SCENARIO



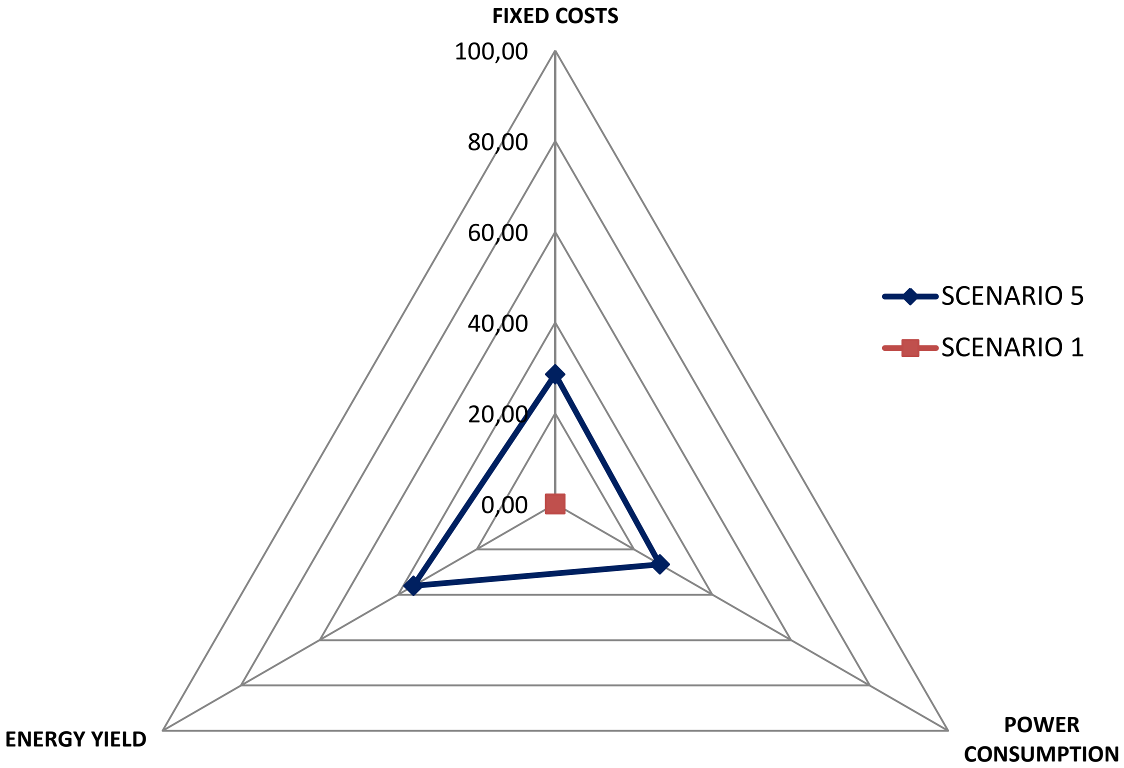
A spider diagram shows the characteristics, advantages and disadvantages for each hypothesis in a graphical way. In this case, SCENARIO 2 has almost the best energy efficiency with intermediate fixed costs. No extra power consumption required.

CONCLUSIONS:
COMPARISON BETWEEN 1ST AND 3RD SCENARIO



- SCENARIO 3 is the natural evolution of SCENARIO 2, and the most appropriate from the η_{ENERGY} perspective. Involves high fixed costs from the installation of heat pumps, leading to extra power consumption.
- This scenario contemplates the adaptation of the current Viennese DHN to a LTDHN.

CONCLUSIONS:
COMPARISON BETWEEN 1ST AND 5TH SCENARIO



Adaptation of the current Viennese DHN to a partial LTDHN at 65°C, without modifying the radiators system inside the buildings. The counterpart is the installation of heat pumps in the buildings supporting the heating branch.

This is the best option if we want to avoid installation works in individual homes.

THANK YOU
FOR YOUR ATTENTION!

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