Smart integration of power to heat technology in thermal networks

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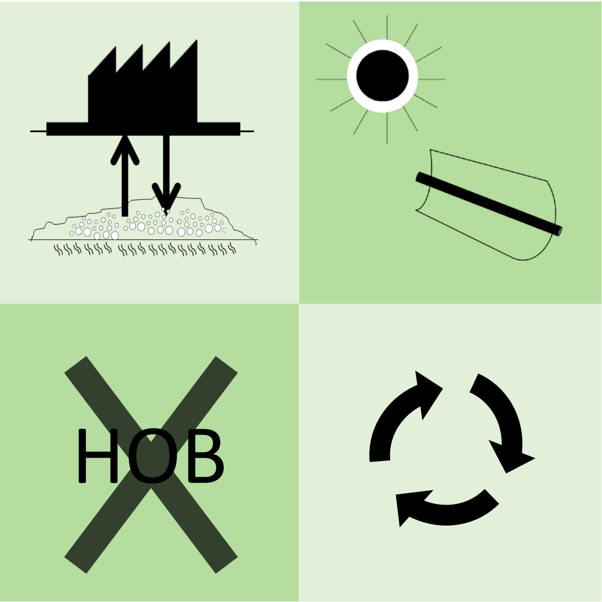
RESEARCH ON DISTRICT HEATING

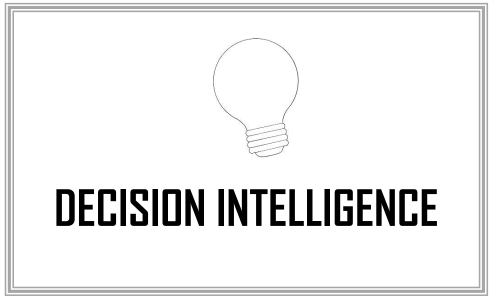
POLITECNICO DI TORINO

NEXT GENERATION ENERGY SYSTEM WILL BE BUILT:

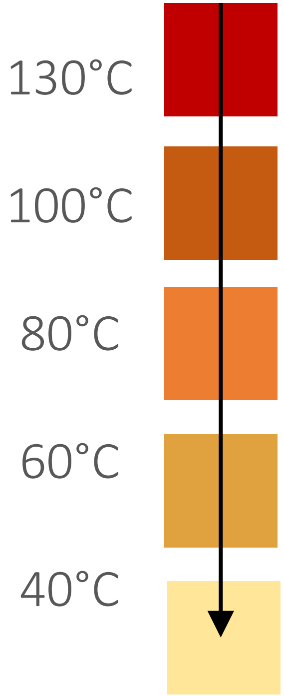
FED BY RENEWABLE SOURCES AND WASTE HEAT

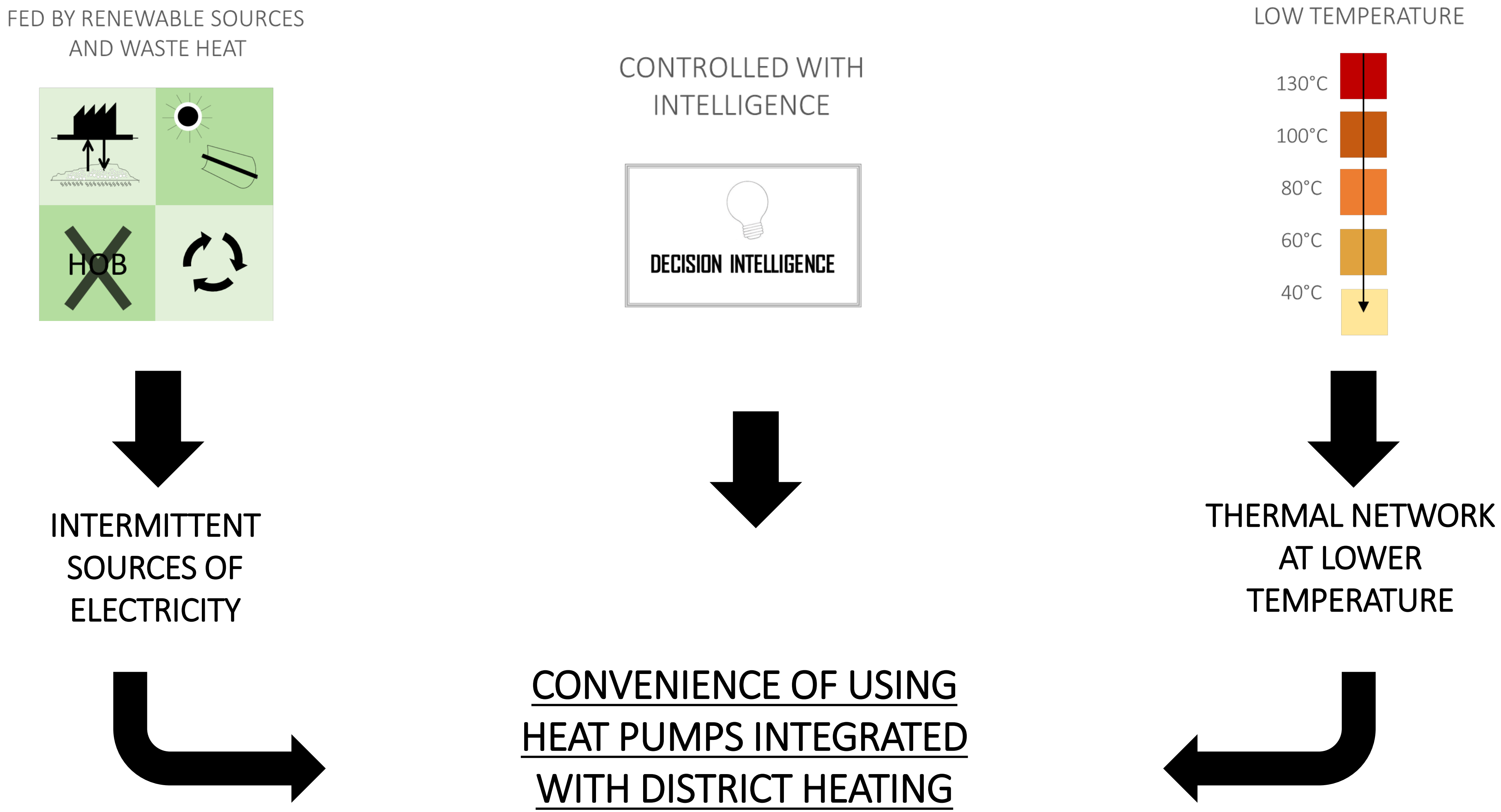


CONTROLLED WITH INTELLIGENCE



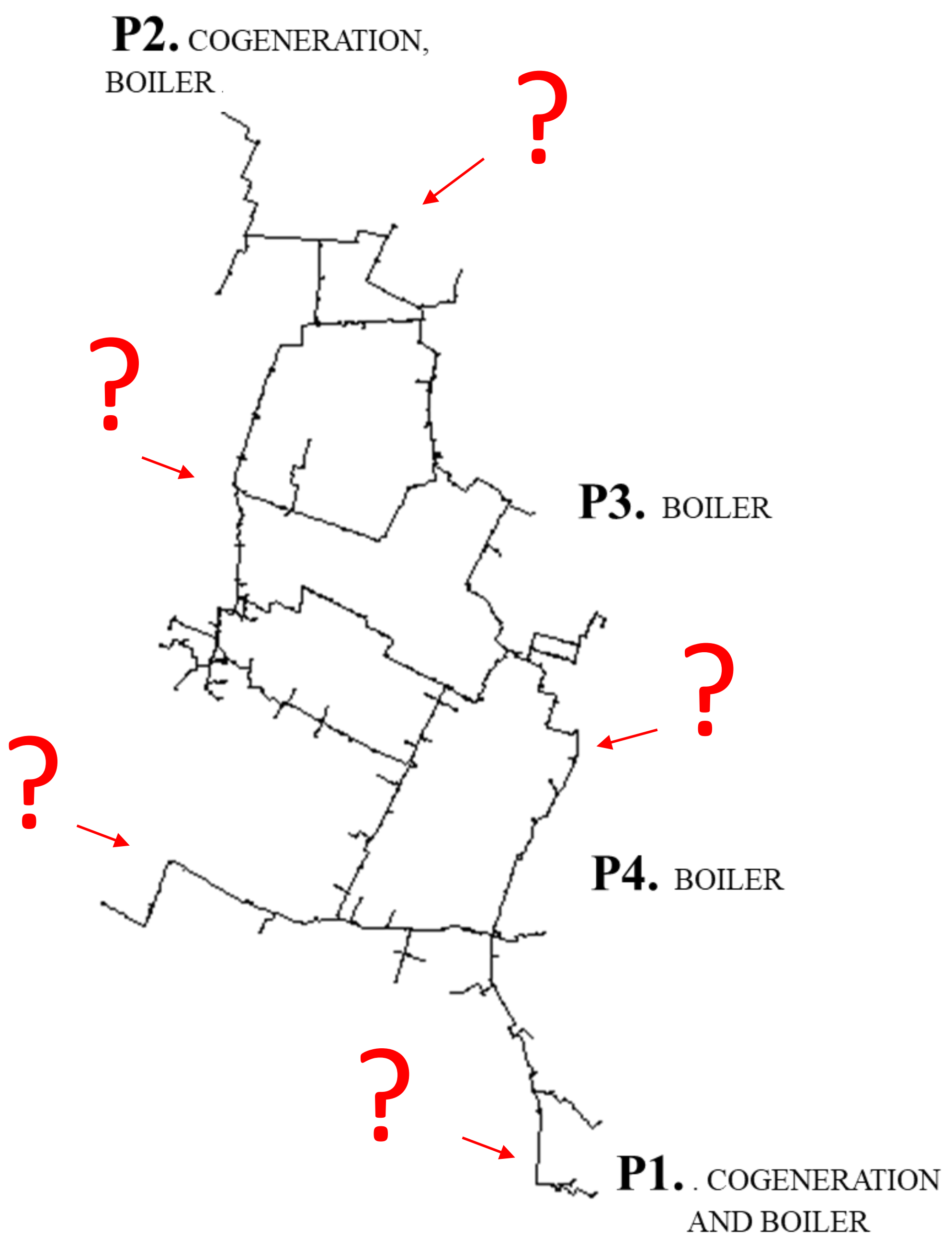
LOW TEMPERATURE




FED BY RENEWABLE SOURCES
AND WASTE HEAT
HOB
CONTROLLED WITH
INTELLIGENCE
DECISION INTELLIGENCE
LOW TEMPERATURE
130°C
100°C
80°C
60°C
40°C
INTERMITTENT
SOURCES OF
ELECTRICITY
THERMAL NETWORK
AT LOWER
TEMPERATURE
CONVENIENCE OF USING
HEAT PUMPS INTEGRATED
WITH DISTRICT HEATING

SEVERAL WAYS TO INTEGRATE HEAT PUMPS INTO DISTRICT HEATING (SUPPLY, RETURN, DIFFERENT LOCATIONS)

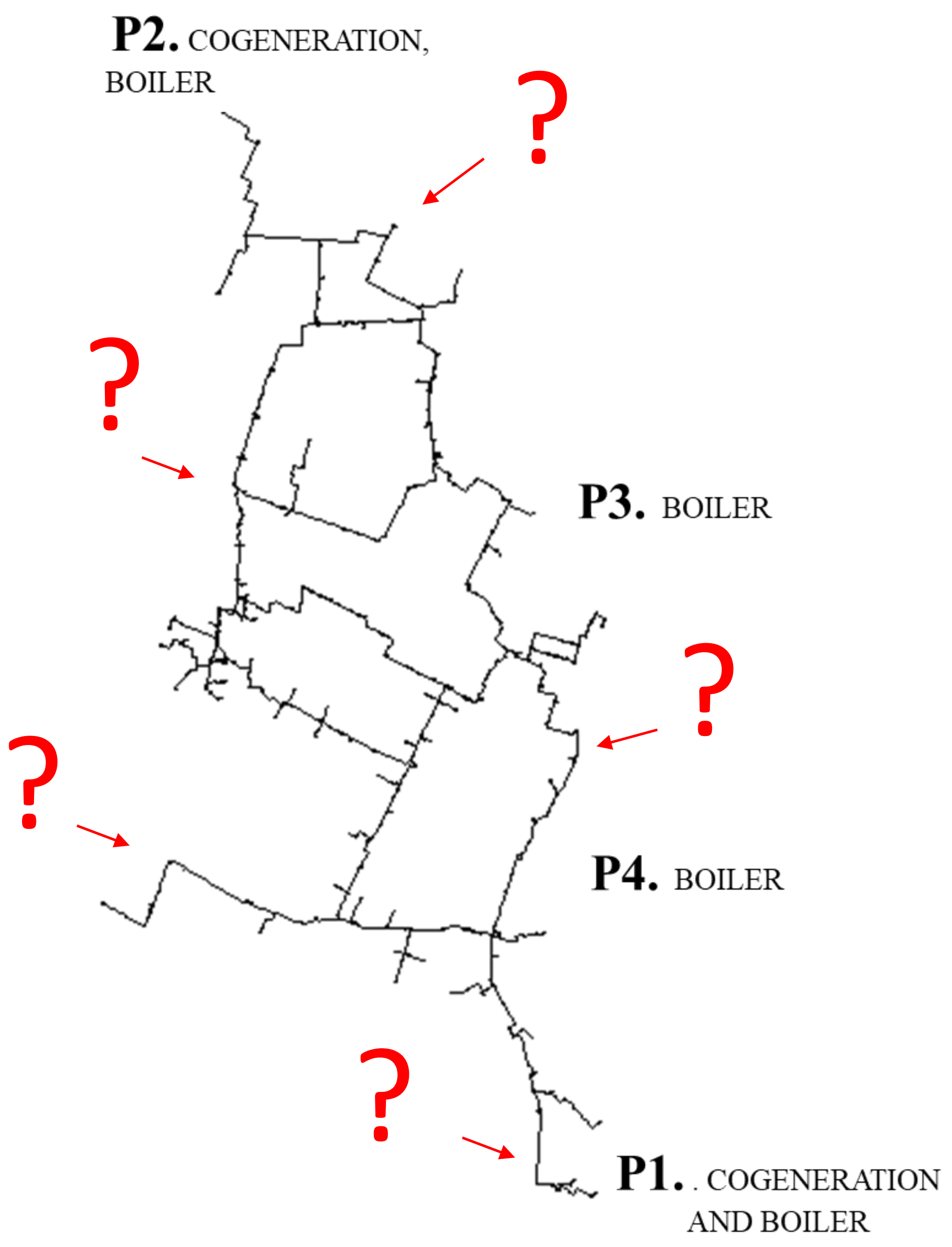
WHERE TO LOCATE
THE HEAT PUMP
IN A DISTRICT HEATING SYSTEM
(IN THE MOST FAVOURABLE
WAY) ?



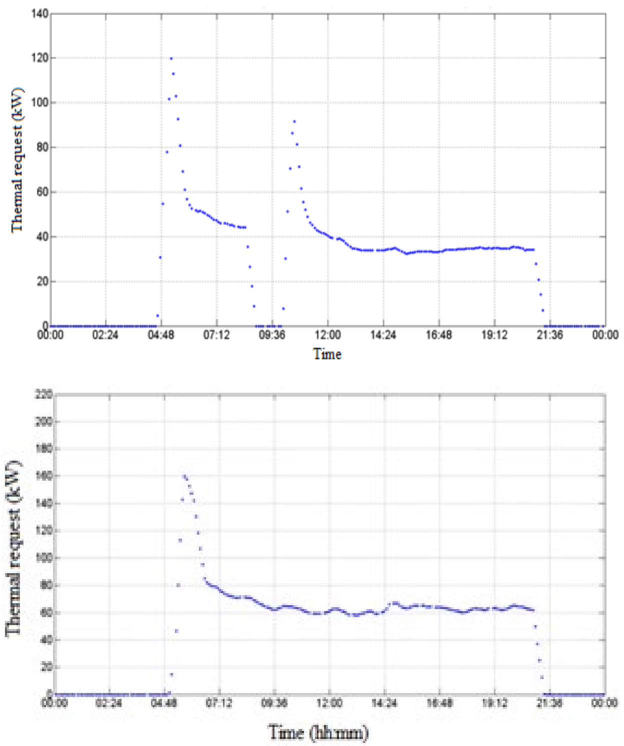
BEST LOCATION DEPENDS ON:

1. THE THERMAL LOSSES ALONG THE NETWORK
2. THE PROCESSEDMASS FLOW RATE
3. THE TYPE OF THERMAL PLANT THE RETURN MASS FLOW IS PROCESSED TO

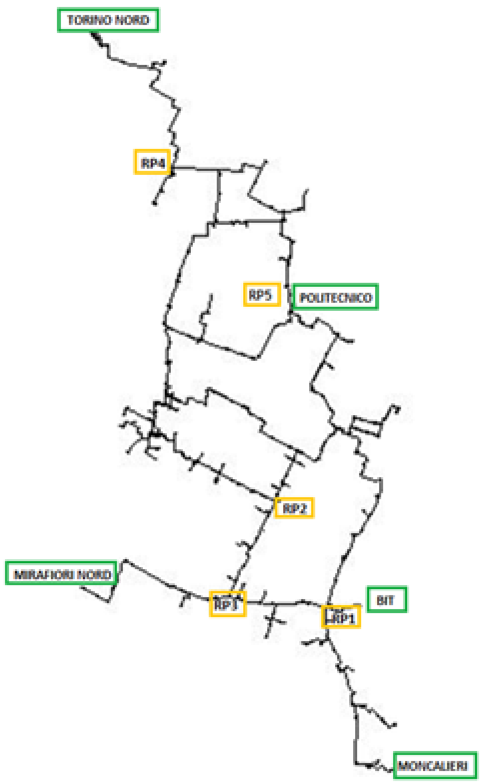
DEPENDS ON THE THERMAL DYNAMIC OF THE NETWORK



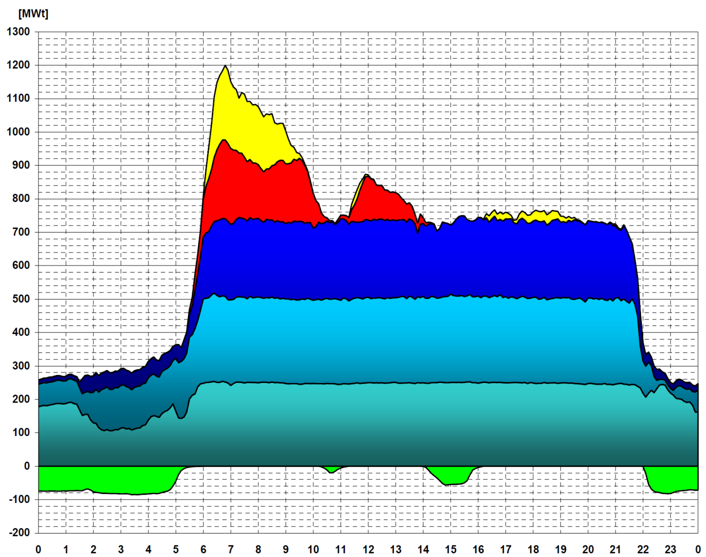
DEMAND OF BUILDINGS

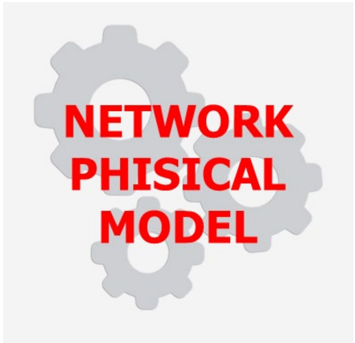


NETWORK



THERMAL LOAD AT THE PLANTS





NETWORK PHISICAL MODEL

MASS CONSERVATION EQUATION

N nodes of the network

N equations in the matrix form

$$\mathbf{A} \cdot \mathbf{G} + \mathbf{G}_{\mathbf{ext}} = \mathbf{0}$$

MOMENTUM EQUATION

M branches of the network

M equations in the matrix form

$$\mathbf{G} = \mathbf{Y} \cdot \mathbf{A}^{\mathrm{T}} \cdot \mathbf{P} + \mathbf{Y} \cdot \Delta\mathbf{p}_{\mathrm{pumps}}$$

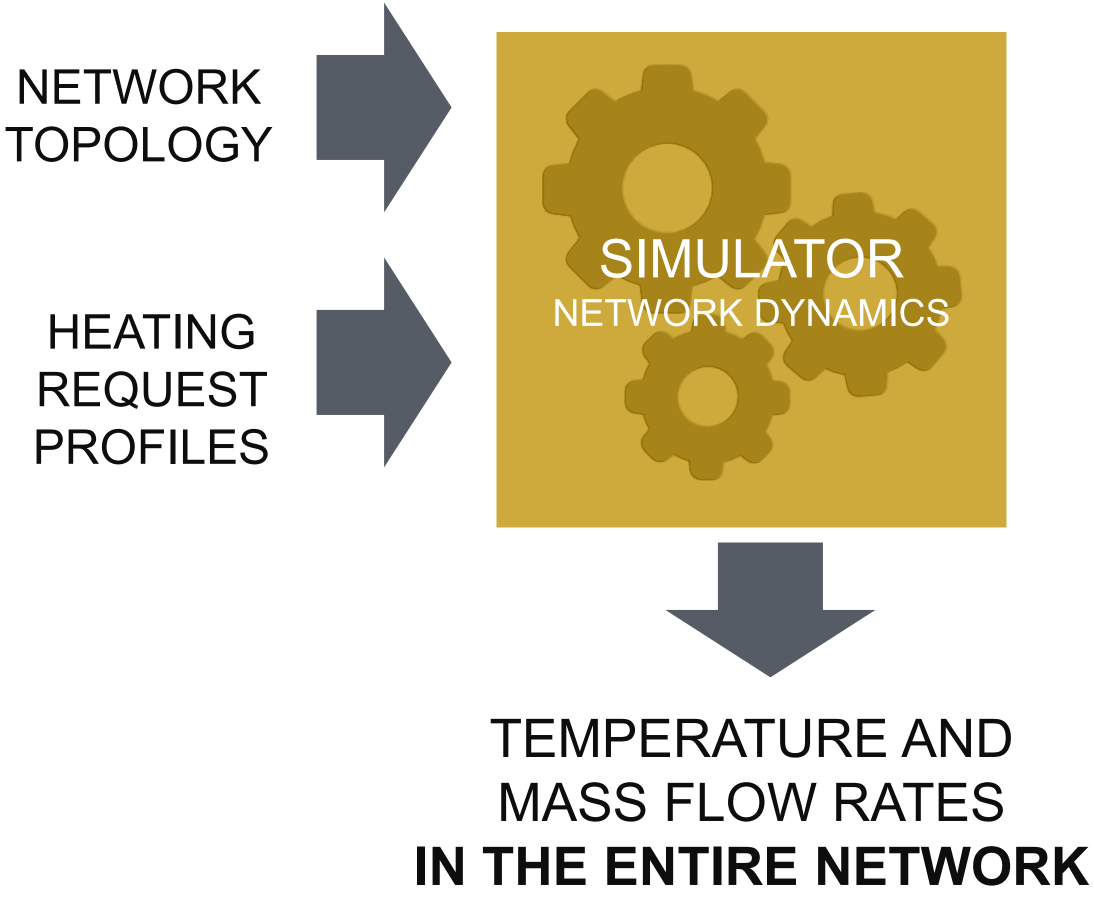
ENERGY EQUATION

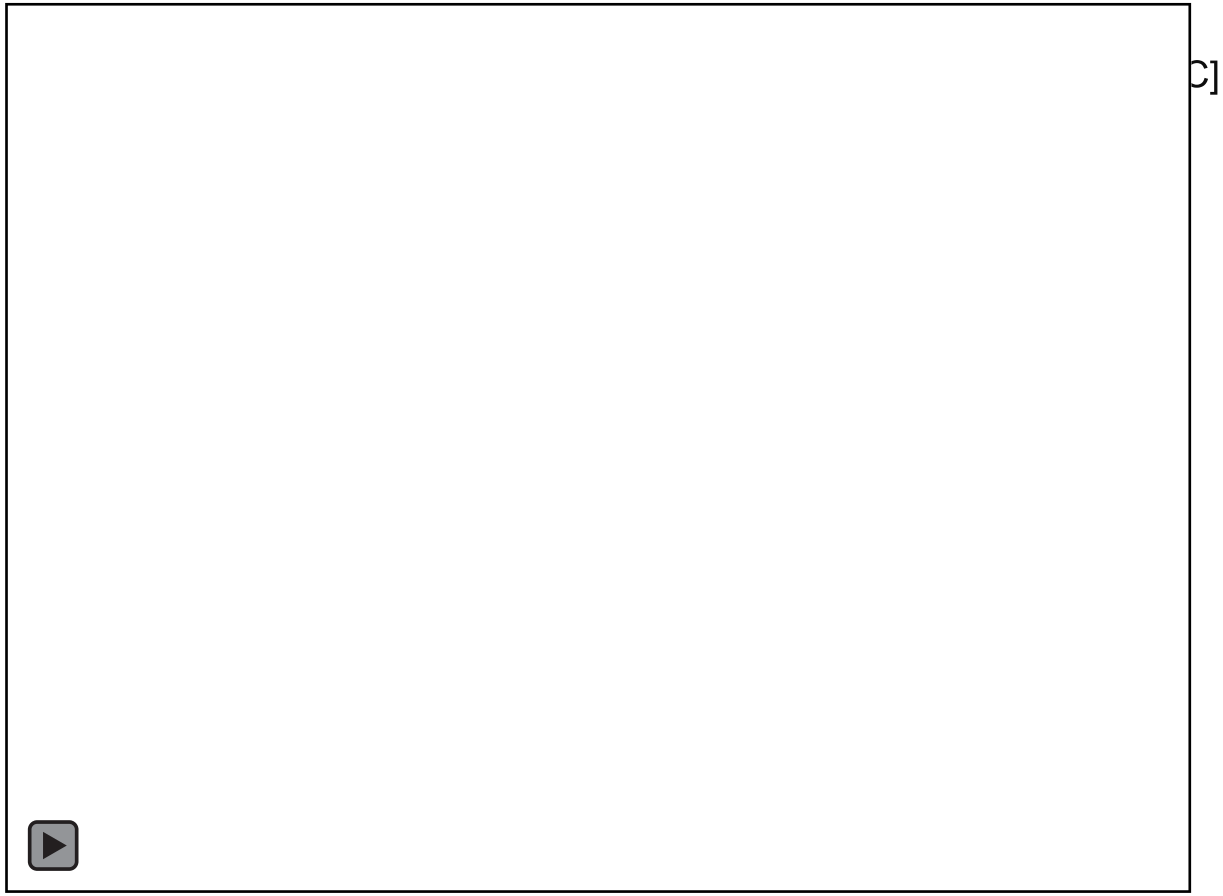
N nodes of the network

N equations in the matrix form

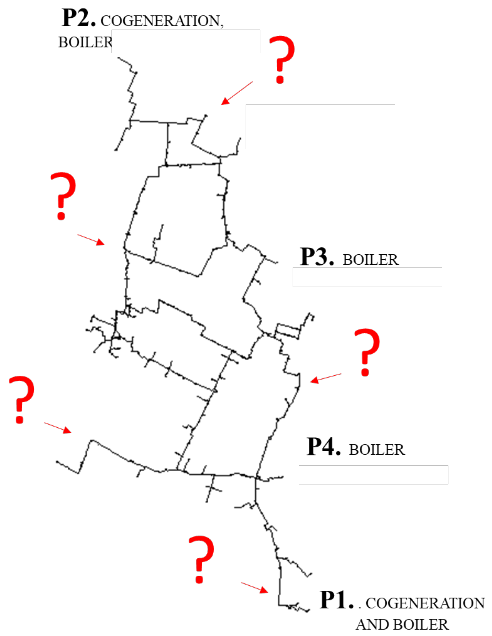
$$\mathbf{M} \cdot \dot{\mathbf{T}} + \mathbf{K} \cdot \mathbf{T} = \mathbf{g}$$

EXAMPLE OF A DISTRIBUTION NETWORK SIMULATION





BEST LOCATION FOR THE HEAT PUMP



COEFFICIENT TO BE MAXIMIZED

$$\varphi = \frac{E_{fuel,\,without\;HP} - E_{fuel,\,with\;HP}}{W_{el,\,HP}}$$

→ FUEL SAVED (EXERGY ASSOCIATED) → DEPENDS ON THE RETURN TEMPERATURE OF WATER, THE TYPE OF PLANT, THE MASS FLOW RATE PROCESSED AND THE THERMAL LOSSES

→ ELECTRICITY ABSORBED BY THE HEAT PUMP

TEST CASE

Turin district heating network

The **largest** district heating network in Italy:

- 55% of the buildings are connected (**700.000 inhabitants**)
- **800 km** of double pipes
- **182 distribution networks**

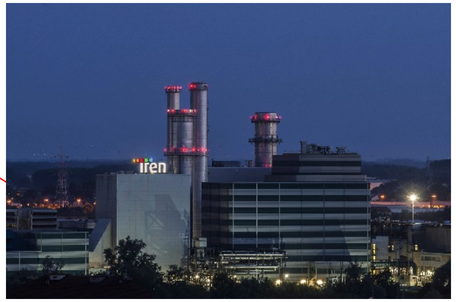
TEST CASE

P2. COGENERATION, BOILER

P3. BOILER

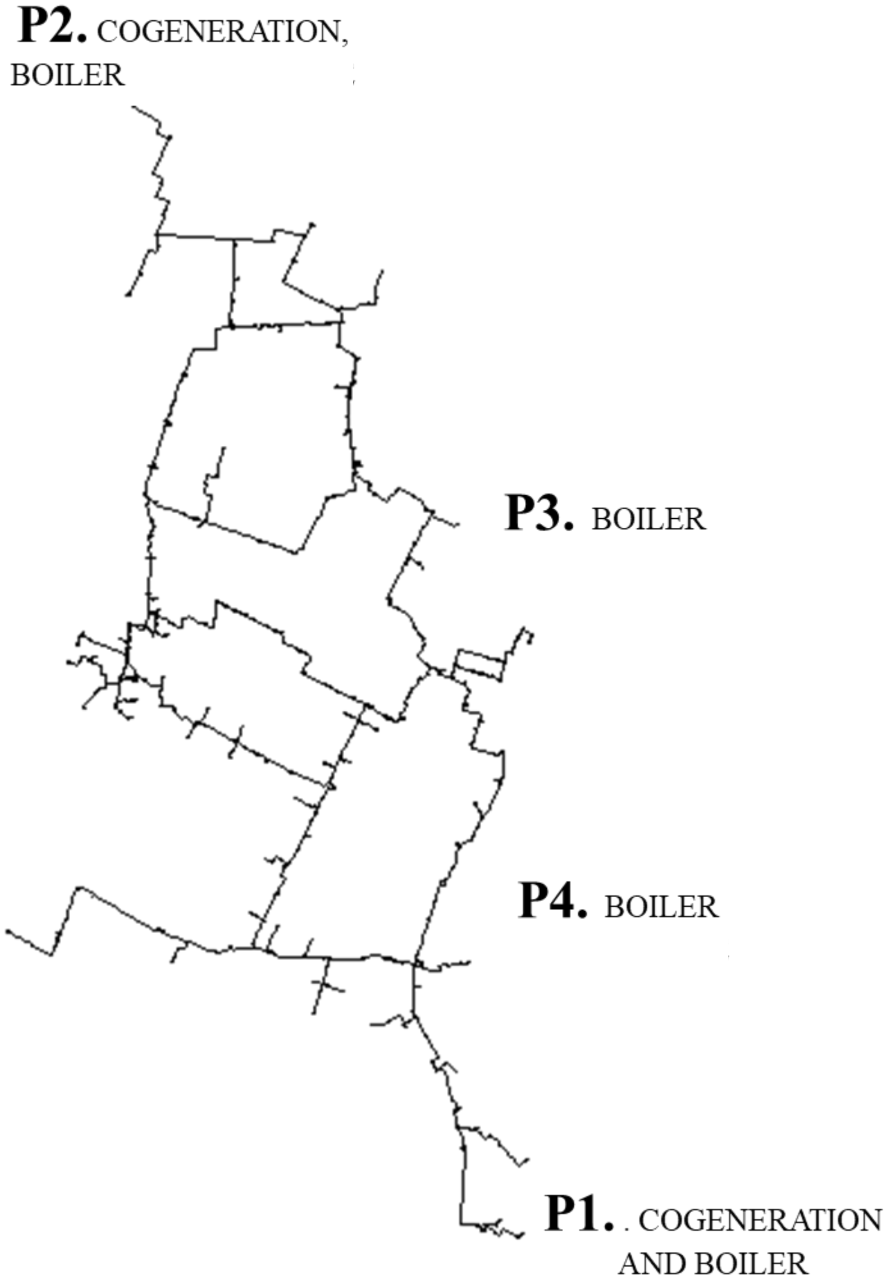
P4. BOILER

P1. . COGENERATION AND BOILER



RESULTS

- ONLY CHP
- CHP AND BOILERS
- ANNUAL RESULT



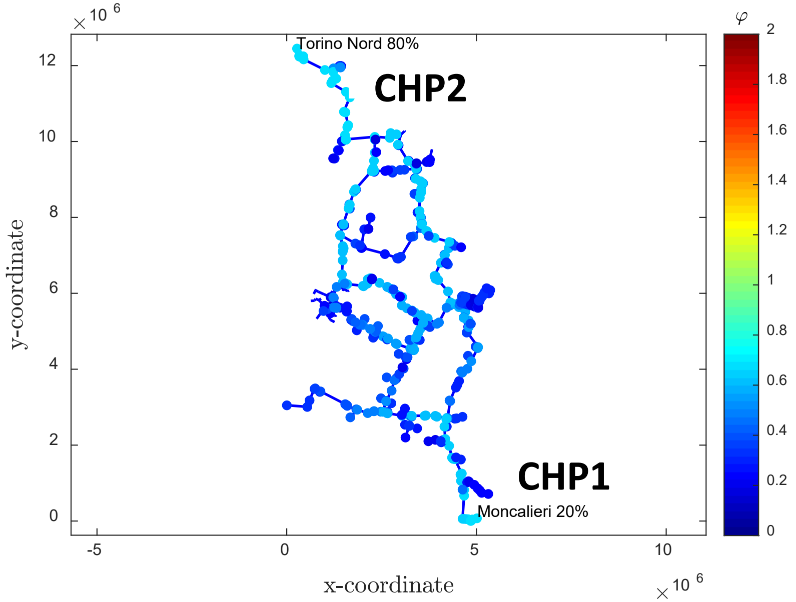
CASE 1

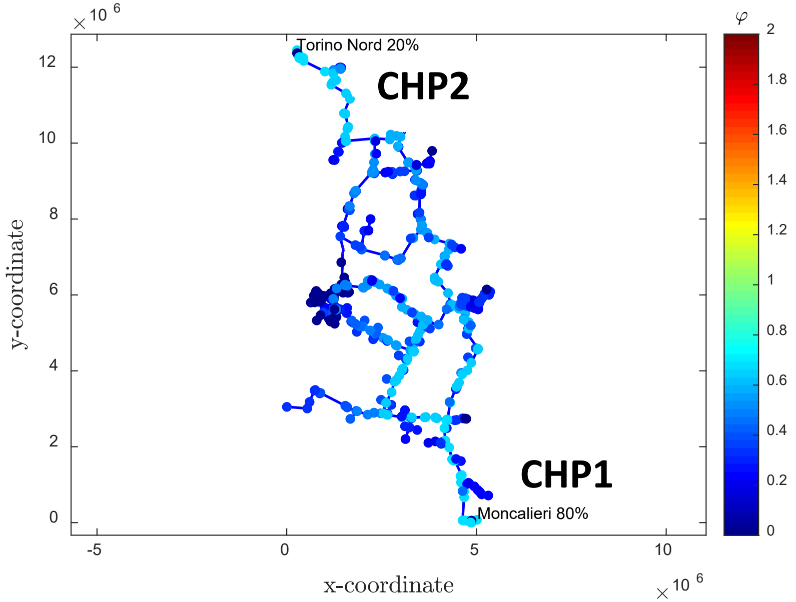
ONLY CHP

LOCATION NEAR THE THERMAL PLANTS BECAUSE OF:

- LOWER THERMAL LOSSES
- HIGHEST MASS FLOW RATES

CONVENIENT FOR INSTALLATION CLOSED TO THE PLANT WITH LARGER OPERATING HOURS



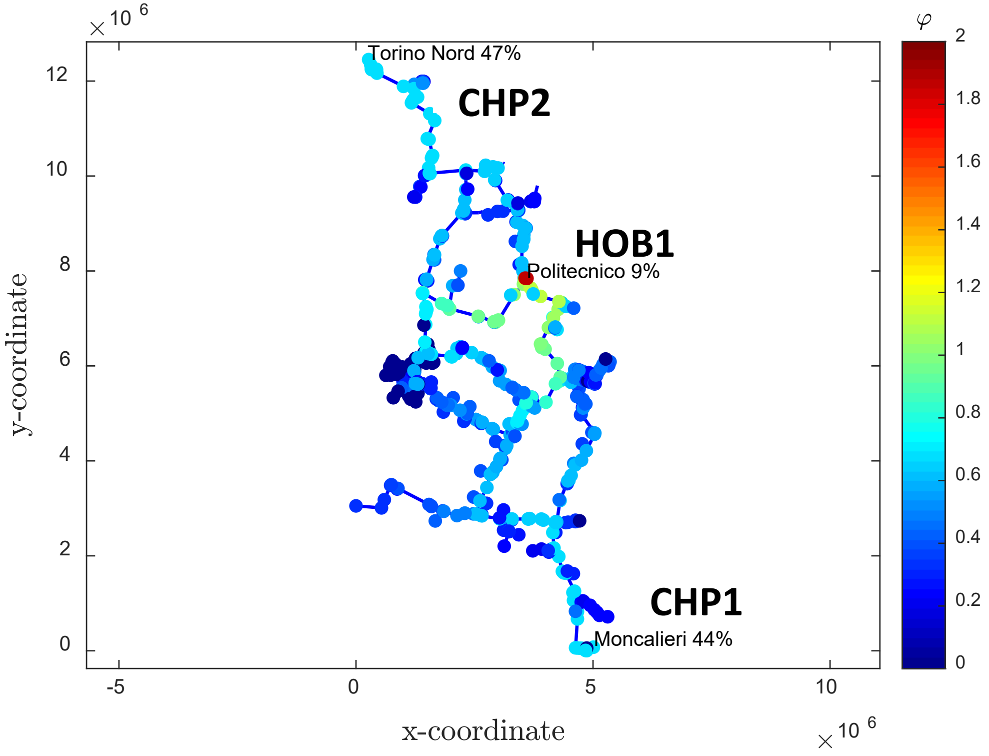


CASE 2a

CHP AND HEAT ONLY BOILER

LOCATION NEAR THE HEAT ONLY BOILER BECAUSE OF:

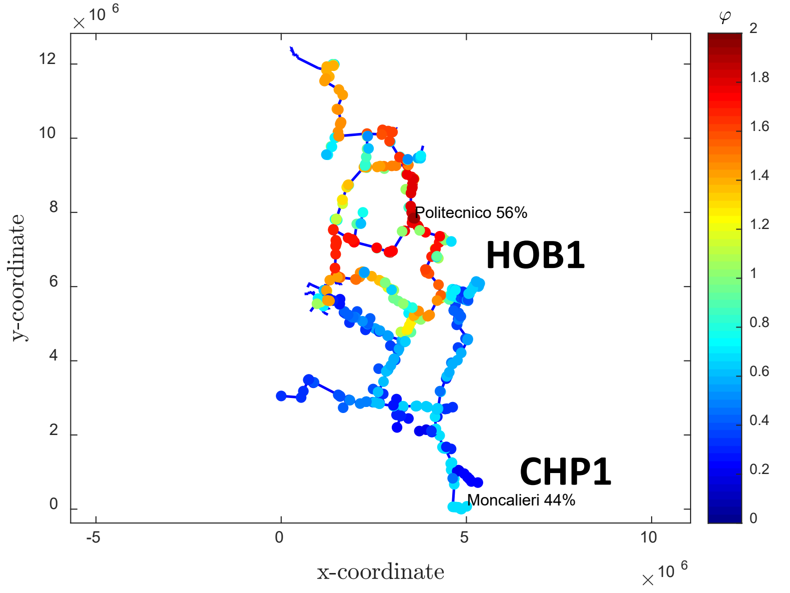
- LOWER THERMAL LOSSES
- NO PERFORMANCES DECREASE OF CHP PLANTS

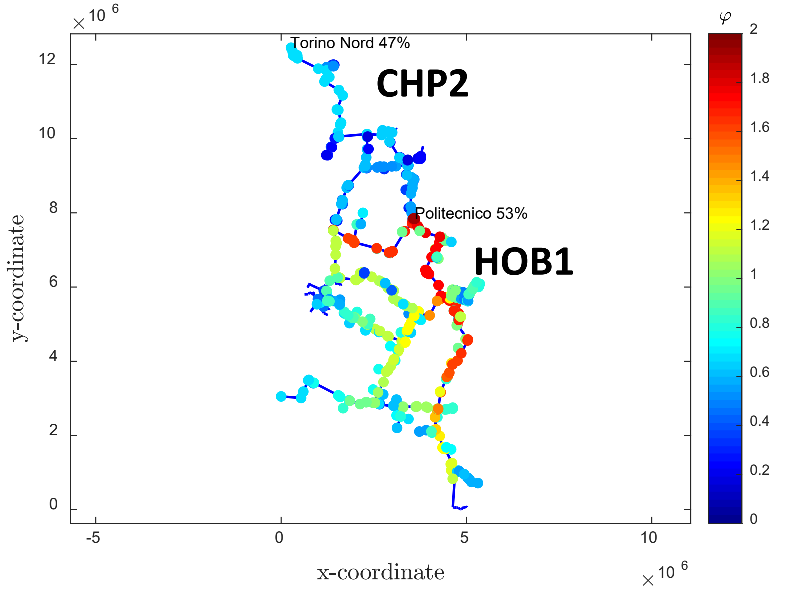


CASE 2b

CHP AND HEAT ONLY BOILER

LOCATION NEAR THE HEAT ONLY BOILER





CASE 3

CHP AND HEAT ONLY BOILER

$\overline{\varphi}$, is defined taking into account the time each scenario occurr:

$$\overline{\varphi} = \sum_{i=1}^{NS} p_i \, \varphi_i$$

where NS is the total number of scenario while p_i is the time percentage the scenario i occurr.

Optimal position for the system considered will be the one with maximum $\overline{\varphi}$.

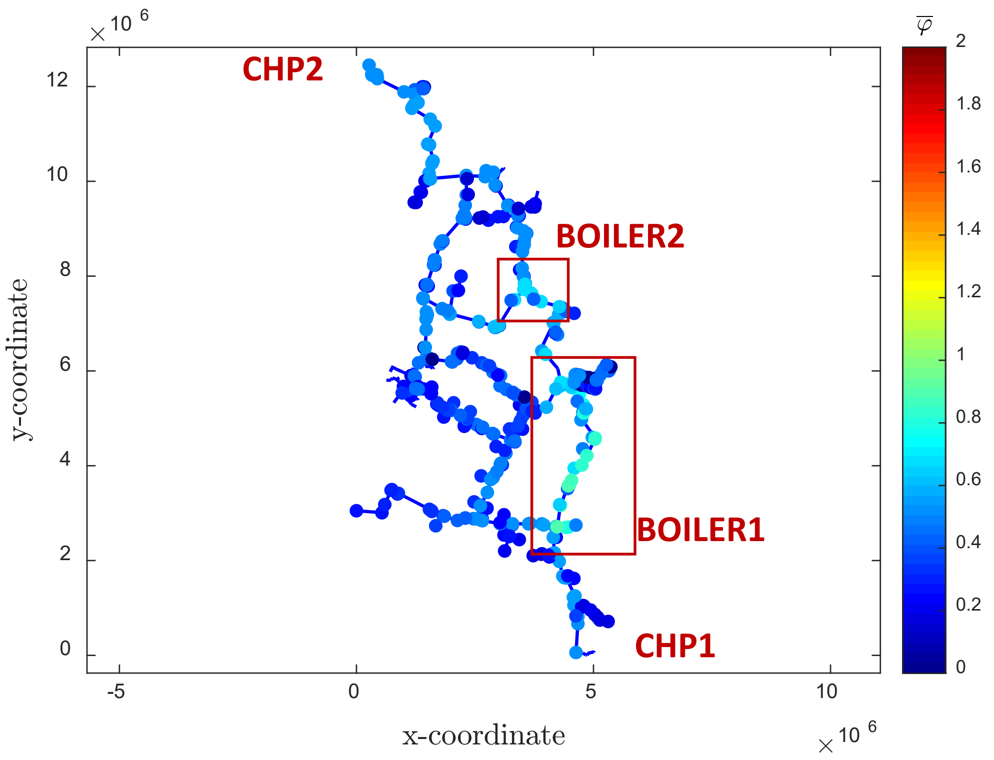
CASE 3 CHP AND HEAT ONLY BOILER

NEAR THE BOILER2

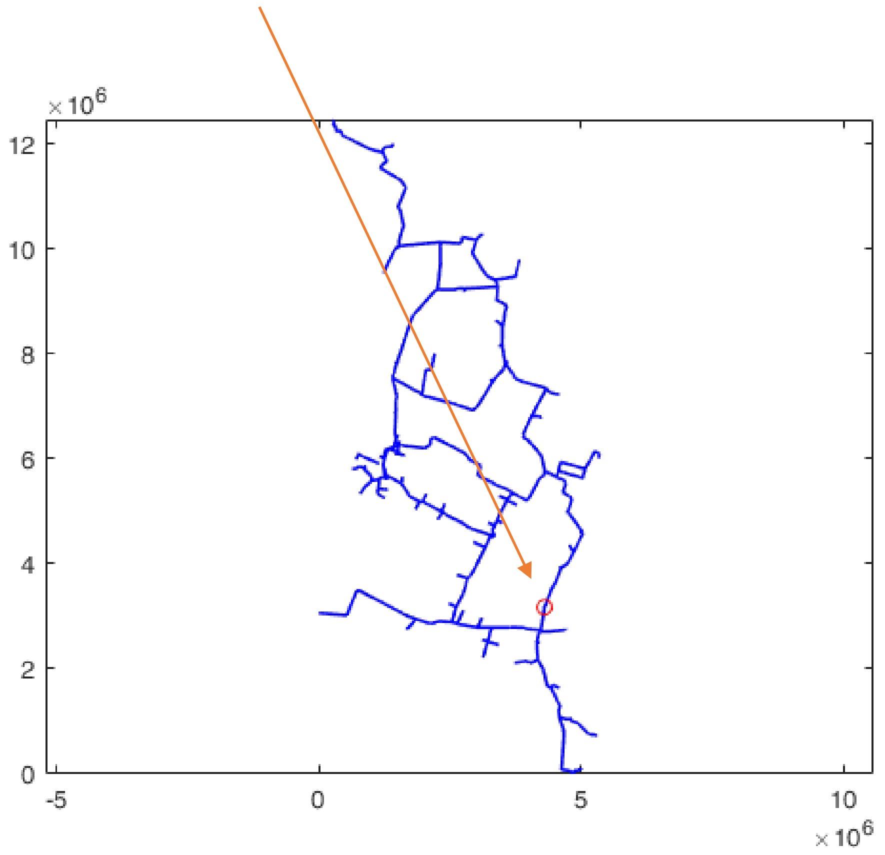
(NO DECREASE IN CHP PERFORMANCES AND LOWER THERMAL LOSSES)

NEAR BOILER1 AND CHP1

(VERY HIGH MASS FLOW RATES AND LOWER THERMAL LOSSES)



- $\overline{\varphi}$ maximum occurs in an intermediate point



CONCLUSIONS

SMART INTEGRATION OF HEAT PUMPS IN DISTRICT HEATING SYSTEMS

INSTALLATION POSITION AFFECTS THE OVERALL PERFORMANCES

THE POSITION OF INSTALLATION SHOULD BE DONE **CONSIDERING ALL THE ANNUAL OPERATING CONDITIONS**

A THERMO-FLUID DYNAMIC MODEL OF THE NETWORK SHOULD BE USED TO EVALUATE MASS FLOW RATE , TEOERATURE AND LOSSES

WHERE MASS FLOWS ARE HIGHER PERFORMANCES ARE HIGHER, BUT THIS IS NOT THE ONLY POINT

INFLUENCE OF THERMAL LOSSES AND TYPE OF THERMAL PLANT ARE NOT NEGLIGIBLE

THANK YOU

FOR THE ATTENTION

This work has been conducted within the European Project H2020-LCE-2016-2017 PLANET (Planning and operational tools for optimizing energy flows and synergies between energy networks)

https://www.h2020-planet.eu/

Analisi dell’installazione di una pompa di calore in una rete di teleriscaldamento

1. Con un modello termo-fluidodinamico della rete si valuta la temperatura dell’acqua che rientra in centrale

$$T_{r,\,centr} \quad [°C]$$

2. Si calcola la potenza termica richiesta dalla centrale

$$\Phi_{centr} = G_{centr} c_p \left(120°C - T_{r,\,centr}\right) \quad [W]$$

3. Si stima l’exergia associata a tale flusso termico

$$E = \Phi_{centr} \left(1 - \frac{T_0}{\frac{120\,°C + T_{r,\,centr}}{2}}\right) \quad [W]$$

4. Infine, attraverso il rendimento di secondo principio, si calcola l’exergia associata al combustibile utilizzato

$$E_{fuel} = \frac{E}{\eta_{II}} \quad [W]$$

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INFLUENCE OF TEMPERATURE OF WATER AFFECT A LOT THE POSIZION OF THE HP (BECASUE OF THE DIFFERENT COP)

Analisi dell'installazione di una pompa di calore in una rete di teleriscaldamento

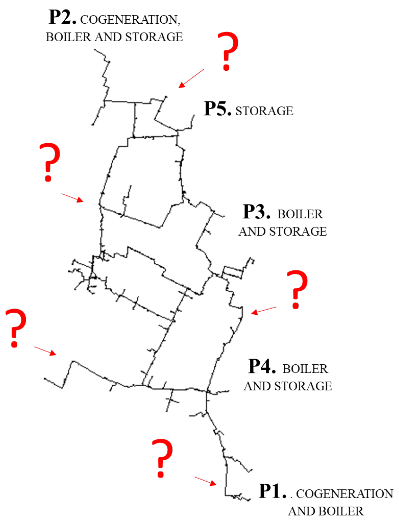
- Il rendimento di secondo principio viene assunto costante.
- Per le centrali cogenerative di Moncalieri e Torino Nord:

$$\eta_{II,\,CHP} = \frac{W_{el} + \Phi\left(1 - \frac{T_0}{\overline{\overline{T}}}\right)}{E_{fuel}} = 56{,}3\ \%$$

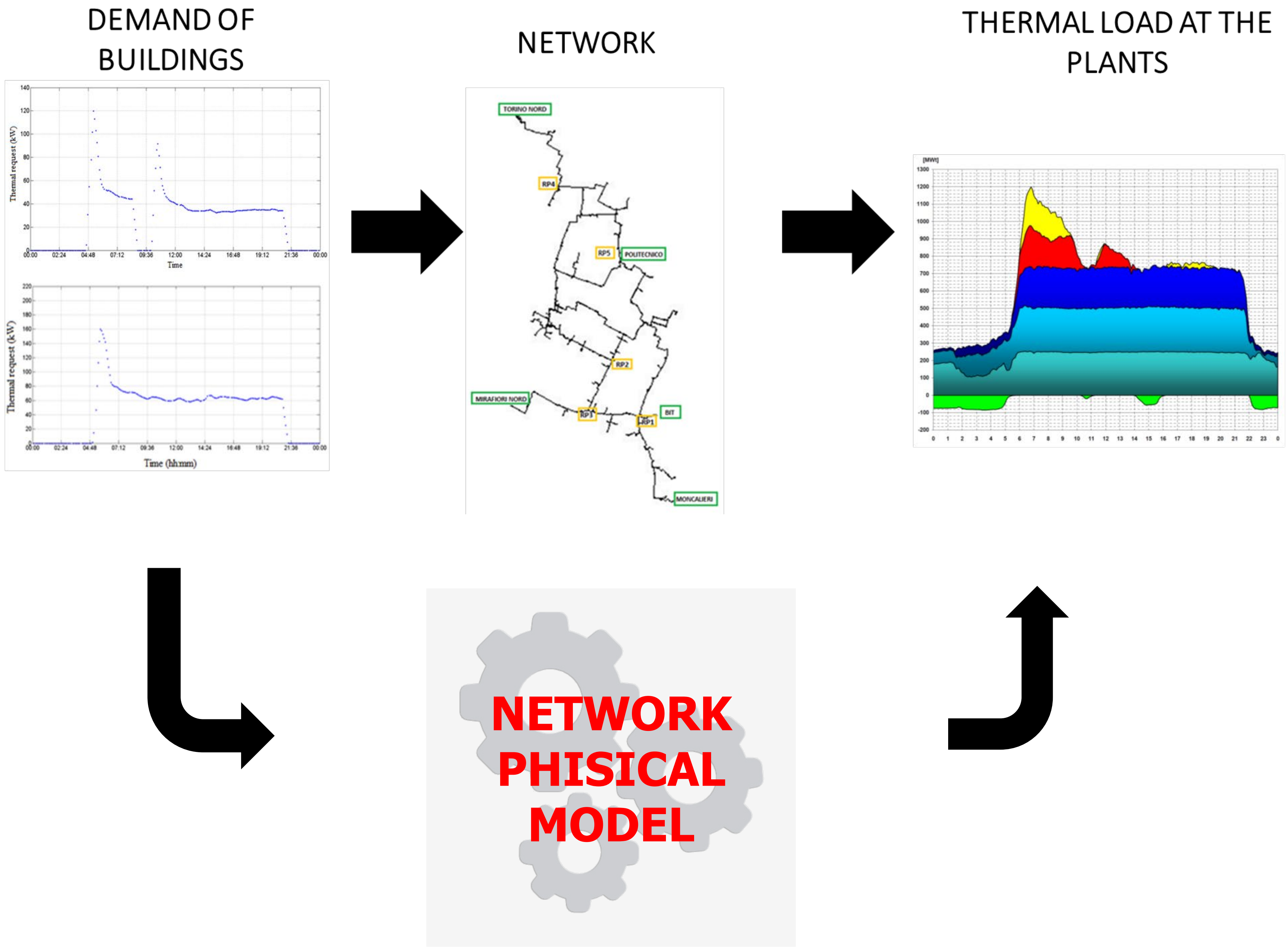
- Per l'impianto di integrazione del Politecnico:

$$\eta_{II,\,Boiler} = \frac{\Phi\left(1 - \frac{T_0}{\overline{\overline{T}}}\right)}{E_{fuel}} = 19{,}6\ \%$$

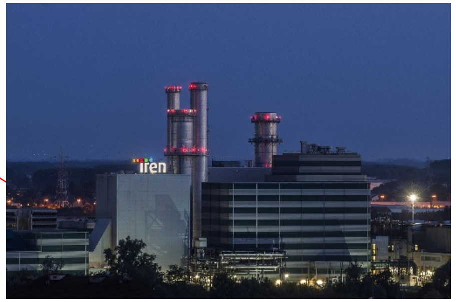
OPTIMIZATION APPROACH TO FIND THE BEST LOCATION FOR THE HEAT PUMP



STORAGE


DEMAND OF BUILDINGS
Thermal request (kW)
Time
Time (hh:mm)
NETWORK
TORINO NORD
RP4
RP5
POLITECNICO
RP2
MIRAFIORI NORD
RP3
RP1
BIT
MONCALIERI
THERMAL LOAD AT THE PLANTS
[MWt]
NETWORK PHISICAL MODEL

TEST CASE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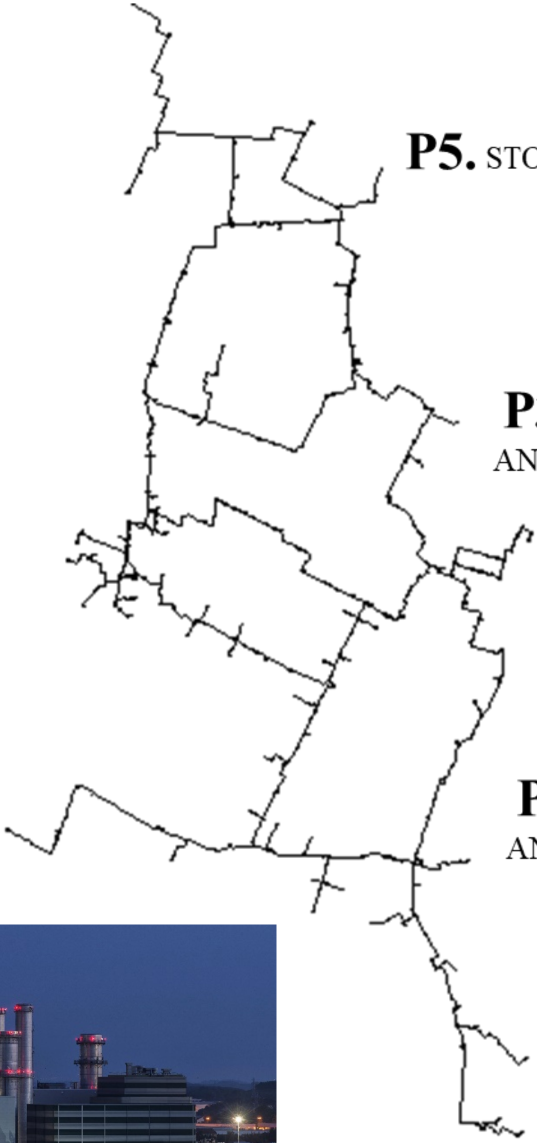
P2. COGENERATION,
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P5. STORAGE
P3. BOILER
AND STORAGE
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AND BOILER