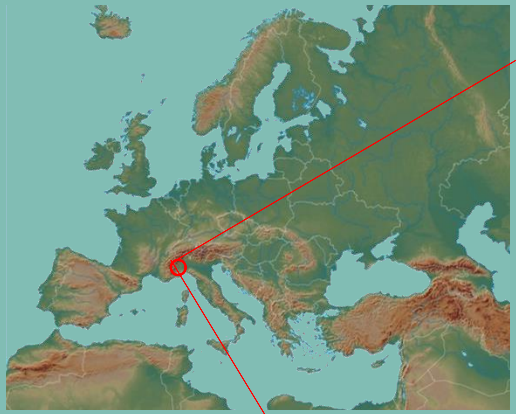
POLITECNICO DI TORINO

EXPERIENCE ON DEMAND SIDE MANAGEMENT APPLIED TO THERMAL NETWORKS

ELISA GUELPA, VITTORIO VERDA

RESEARCH ACTIVITY ON DISTRICT HEATING
POLITECNICO DI TORINO

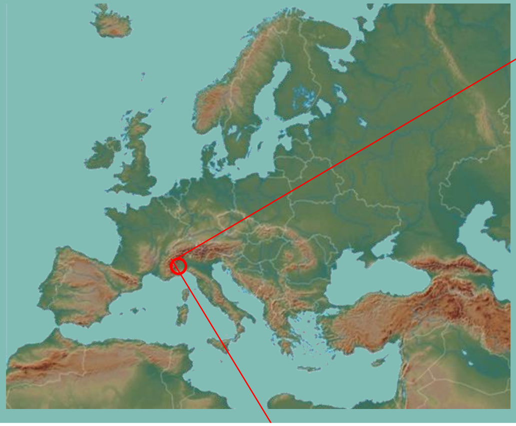
The **Turin** network

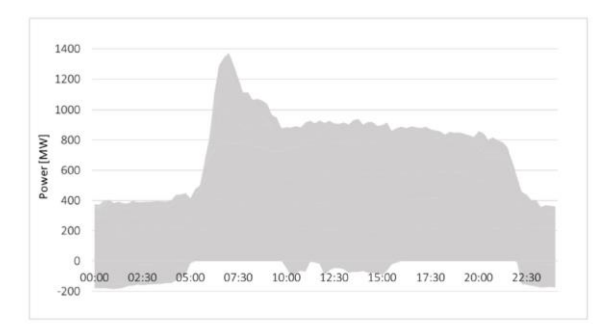


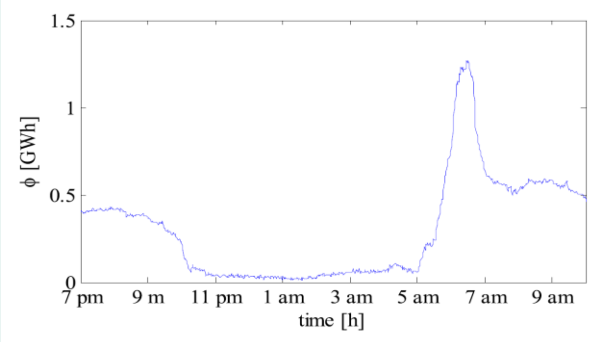
The **largest** district heating network in Italy:

- 55% of the buildings are connected (**700.000 inhabitants**)
- **800 km** of transport and delivering network
- Maximum thermal load of about **1500 MW**

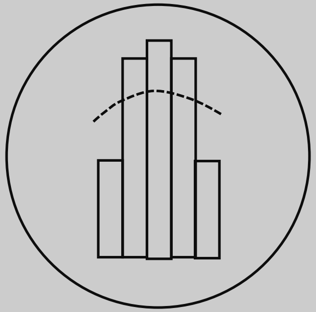
The **Turin** network







WHY ?



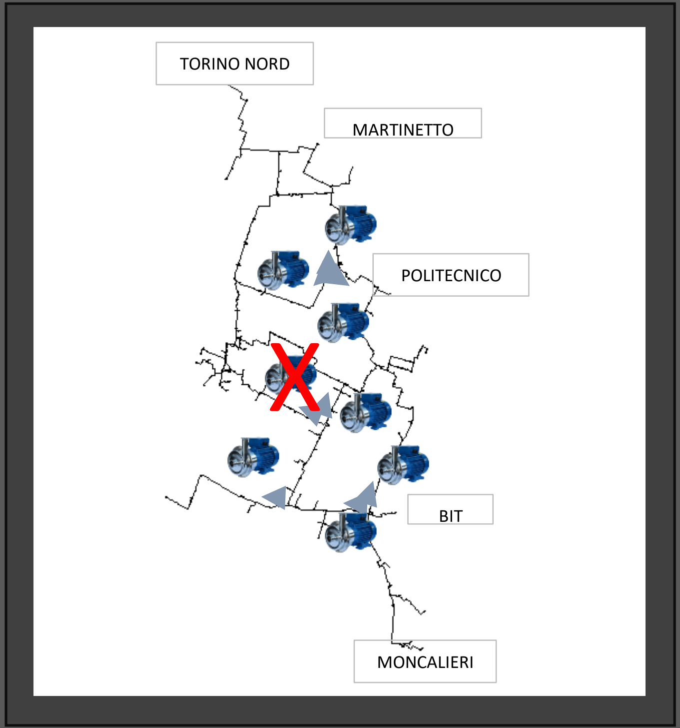
DEMAND RESPONSE IN DISTRICT HEATING

01 New connections

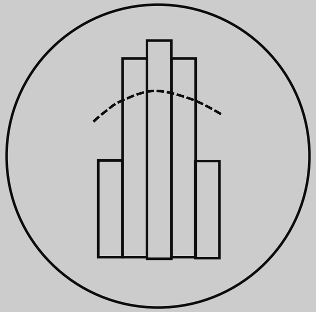
02 Increase plant flexibility

03 Easier malfunction management

03 Decrease the supply temperature



HOW ?

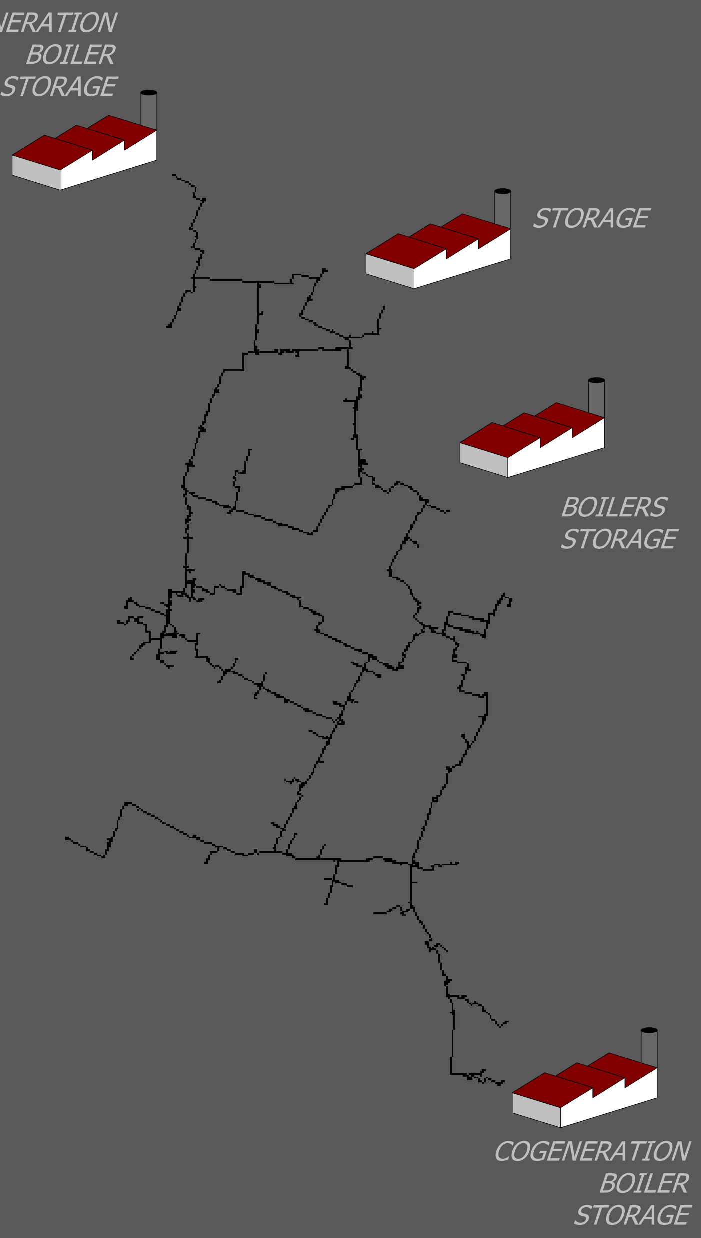


DEMAND
RESPONSE
IN DISTRICT
HEATING

DEVELOP A SPECIAL PLATFORM
WORKING IN DIFFERENT STEPS
APPLYING DEMAND SIDE MANAGEMENT

THE PLATFORM HAS BEEN TESTED ON A
DISTRIBUTION NETWORK IN THE TURIN
NETWORK

Turin DHN



DATA MANAGEMENT

0,383009	0,007536	0,458115	0,7305	0,464257	0,9840
0,240762	0,149886	0,764717	0,338687	0,621064	0,8721
0,130933	0,922002	0,223229	0,863496	0,537065	0,3534
0,740849	0,004821	0,534199	0,569883	0,184574	0,4985
0,338363	0,540476	0,831135	0,6438	0,984606	0,4871
0,299399	0,719533	0,977963	0,294893	0,241031	0,2706
0,880117	0,7318	0,416266	0,530702	0,118131	0,1315
0,943695	0,438742	0,224095	0,62798	0,882203	0,5737
0,698269	0,915042	0,439371	0,70066	0,682891	0,2111
0,12684	0,597248	0,909929	0,56208	0,60241	0,2777
0,773526	0,425906	0,44806	0,716161	0,543693	0,4861
0,6786	0,559858	0,760599	0,516307	0,547431	0,6788
0,443486	0,386355	0,134702	0,325792	0,025583	0,1326
0,187758	0,757642	0,389147	0,712915	0,120392	0,355
0,603888	0,258116	0,285958	0,565441	0,143153	0,885
0,236112	0,91907	0,969045	0,493904	0,550691	0,961
0,593149	0,249459	0,878485	0,780751	0,724867	0,6048
0,918011	0,931491	0,76319	0,432733	0,025838	0,4400
0,52286	0,94532	0,918952	0,627694	0,901968	0,7102
0,884585	0,01145	0,997395	0,635106	0,935585	0,5565
0,835181	0,049511	0,14788	0,148215	0,475657	0,9372
0,486827	0,784039	0,939939	0,997849	0,144975	0,7880
0,459609	0,441546	0,449554	0,935894	0,983458	0,1563
0,129387	0,269903	0,747338	0,229071	0,335637	0,0813
0,832997	0,367975	0,621328	0,181819	0,845056	0,0995
0,639369	0,252093	0,501254	0,331849	0,485977	0,0311
0,777931	0,26818	0,616885	0,249616	0,423878	0,8398

1

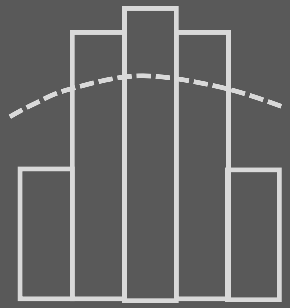
REQUEST FORECAST

2

FOULING DETECTION

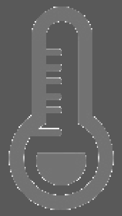
3

PEAK SHAVING



4

INDOOR COMFORT CONTROL

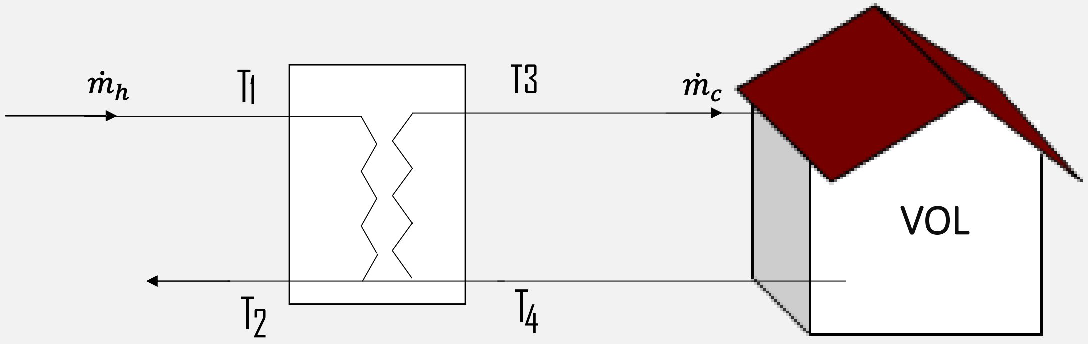


5

DATA MANAGEMENT

ADVANCED CONTROL SYSTEMS

DATA MANAGEMENT

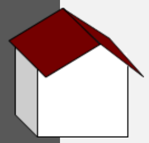


DATA OFTEN AT DISPOSAL IN LARGE DH NETWORKS:

T1, T2, T3, T4, mh, Φ VOL, ANNUAL ENERGY

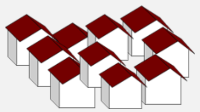
T1, T2, T3, T4, mh, Φ

TIME STEP= 5MIN



1 BUILDING

6 data/mis* 12 mis/h *24 h/day * 200 day/year *3 years = $1 * 10^6$ data/build



TEST AREA

$1 * 10^6$ mis/build * 100 build = 10^8 data

ENTIRE NETWORK

$1 * 10^6$ mis/build * 8000 build = $8 * 10^9$ data

1

DATA MANAGEMENT

LOADING

Automatic loading of data of interest (6 files per day)

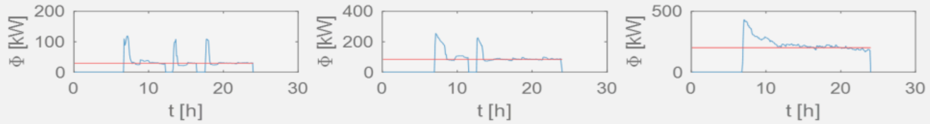
RE-ORGANIZATION

Automatic allocation of loaded data in proper matrices

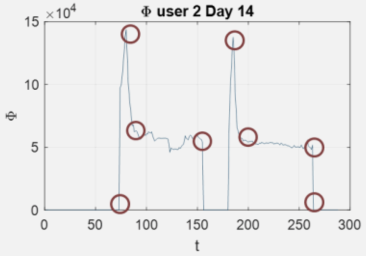
$$\begin{matrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{matrix}$$

AUTOMATIC PROBLEM DETECTION

STEADY STATE CONDITIONS



MAIN CHARACTERISTICS



MANAGEMENT

Automatic saving and loading of the various step of the software

2

FOULING DETECTION

AUTOMATIC TOOL FOR HELPING OPERATORS TO EVALUATE FOULING LEVEL

2 FOULING DETECTION

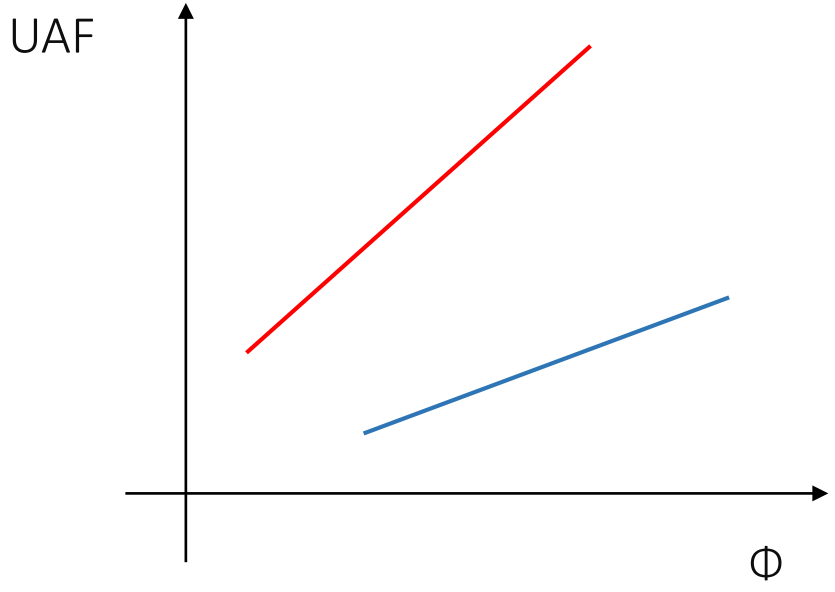
$$UAF = \frac{1}{\frac{1}{A_i h_i} + \frac{Rf_i}{A_i} + \frac{s}{Ak} + \frac{Rf_o}{A_o} + \frac{1}{A_o h_o}}$$

UAF(Φ) HIGH ➔ CLEAN CONDITIONS

UAF(Φ) LOW ➔ FOULED CONDITIONS

HISTORICAL DATA

UAF(Φ) ESTIMATION FOR **CLEAN** HEAT EXCHANGER



CURRENT DATA

UAF(Φ) ESTIMATION FOR **CURRENT** HEAT EXCHANGER CONDITIONS

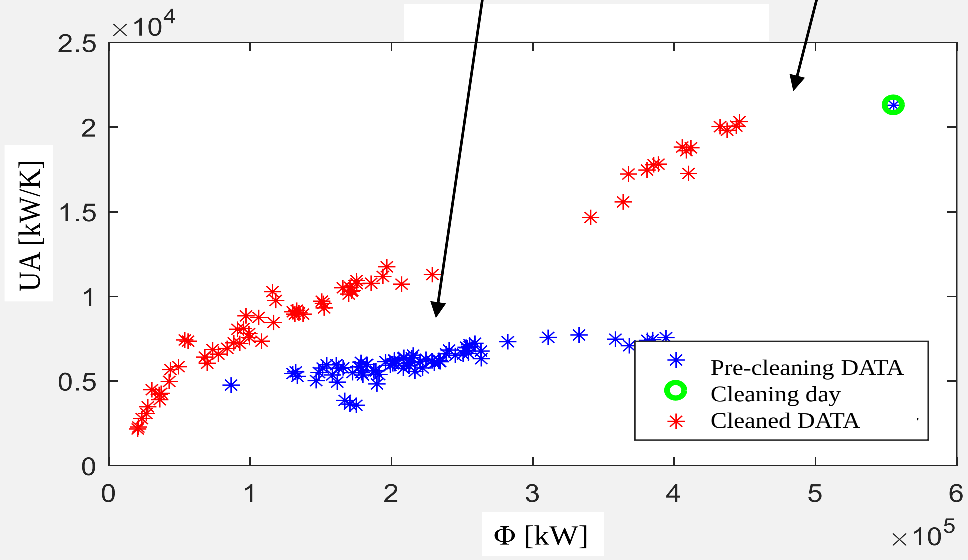
Guelpa, E., & Verda, V. (2020). Automatic fouling detection in district heating substations: Methodology and tests. *Applied Energy*, *258*, 114059.

2 FOULING DETECTION

EXPERIMENTAL TEST

FOULED BEFORE CLEANING

CLEAN AFTER CLEANING

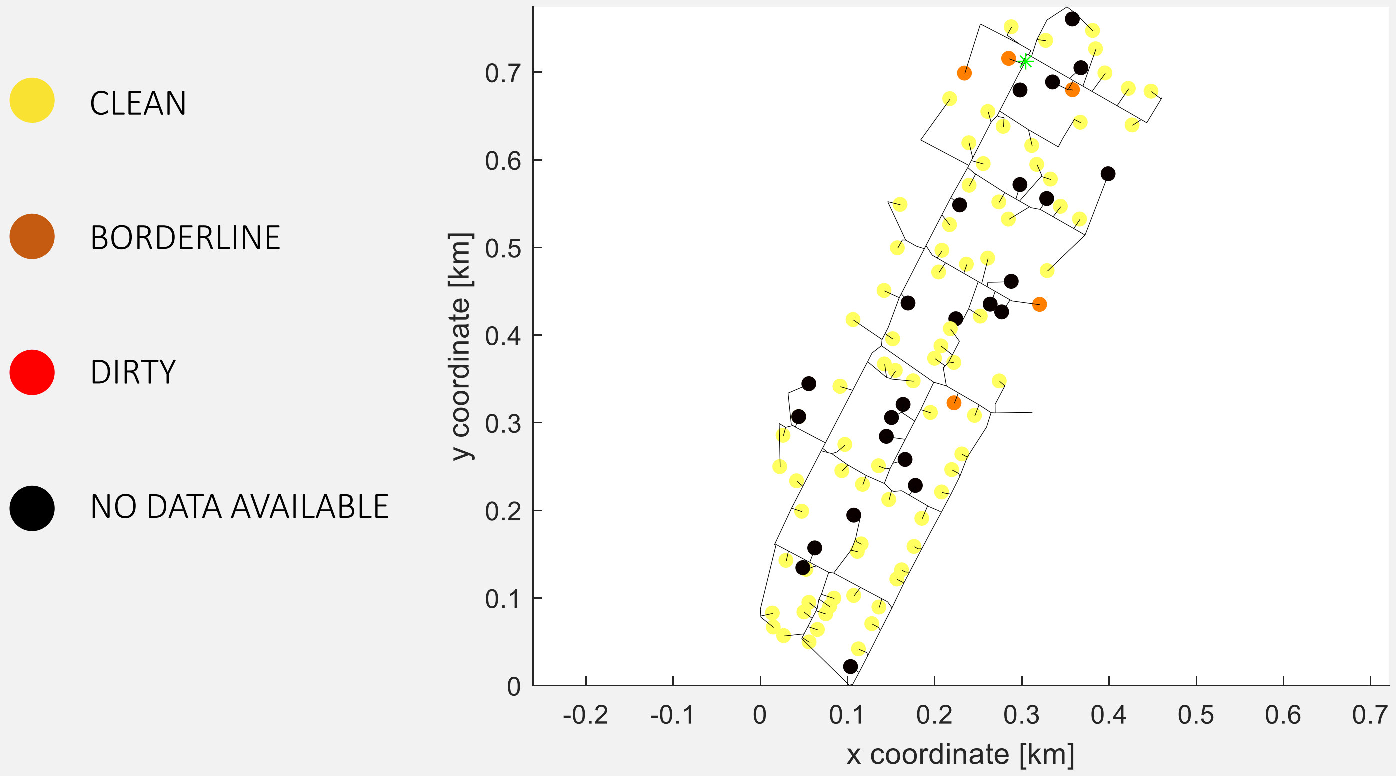


THE CHANGE IN THE BEAVIOR IS EVIDENT

Guelpa, E., & Verda, V. (2020). Automatic fouling detection in district heating substations: Methodology and tests. *Applied Energy*, *258*, 114059.

2 FOULING DETECTION

FOULING MAPS FOR OPERATORS



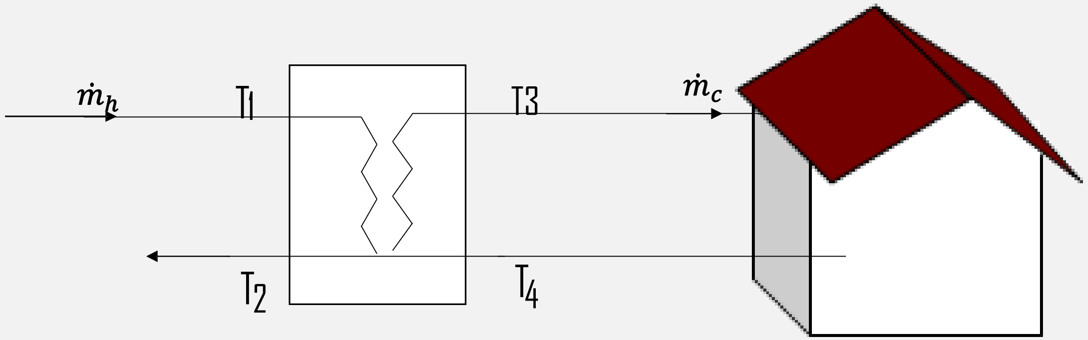
Guelpa, E., & Verda, V. (2020). Automatic fouling detection in district heating substations: Methodology and tests. *Applied Energy*, *258*, 114059.

3

REQUEST FORECAST

AUTOMATIC TOOL FOR EVALUATE THE DAILY THERMAL REQUEST EVOLUTION OF EACH BUILDING

3 REQUEST FORECAST



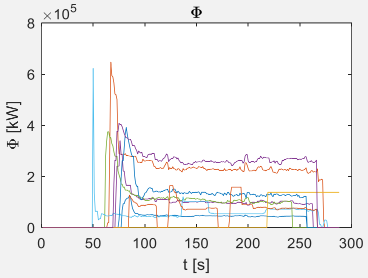
WHICH DATA WE HAVE AT DISPOSAL

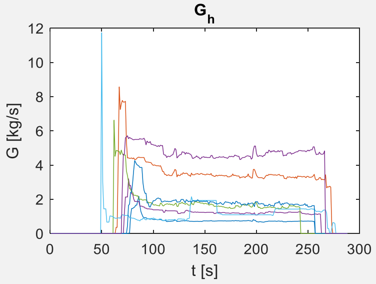
FOR BUILDINGS CONNECTED TO DISTRICT HEATING

FOR MOST OF THE BUILDINGS

- TEMPERATURE
- MASS FLOW RATES

ARE MEASURED BY SMART METERS

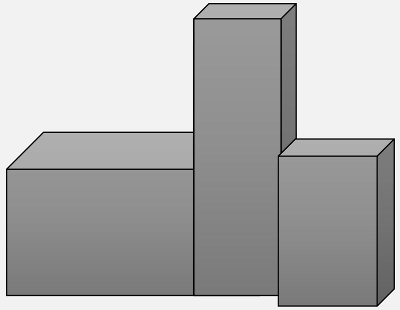


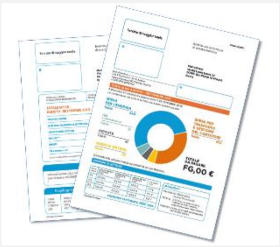


FOR ALL THE BUILDINGS

- VOLUME
- ANNUAL ENERGY REQUEST
- ANNUAL WORKING HOURS

ARE AVAILABLE





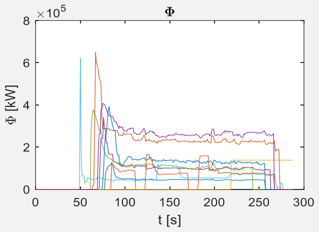
3

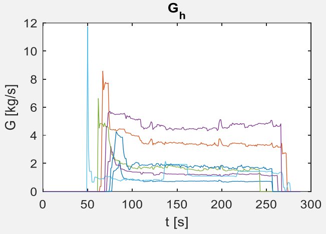
REQUEST FORECAST

FOR MOST OF THE BUILDINGS

- TEMPERATURE
- MASS FLOW RATES

ARE MEASURED BY SMART METERS

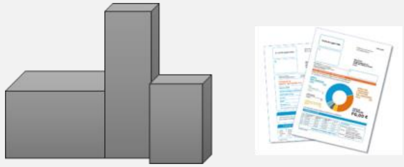


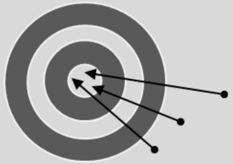


FOR ALL THE BUILDINGS

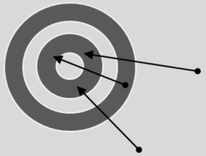
- VOLUME
- ANNUAL ENERGY REQUEST
- ANNUAL WORKING HOURS

ARE AVAILABLE

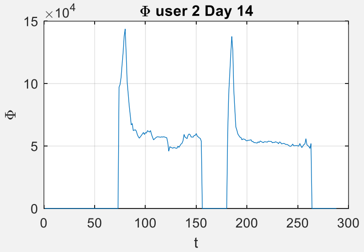




DETAILED MODEL



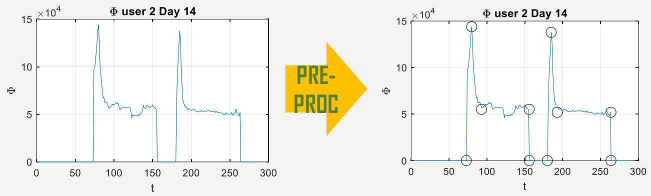
BASIC MODEL

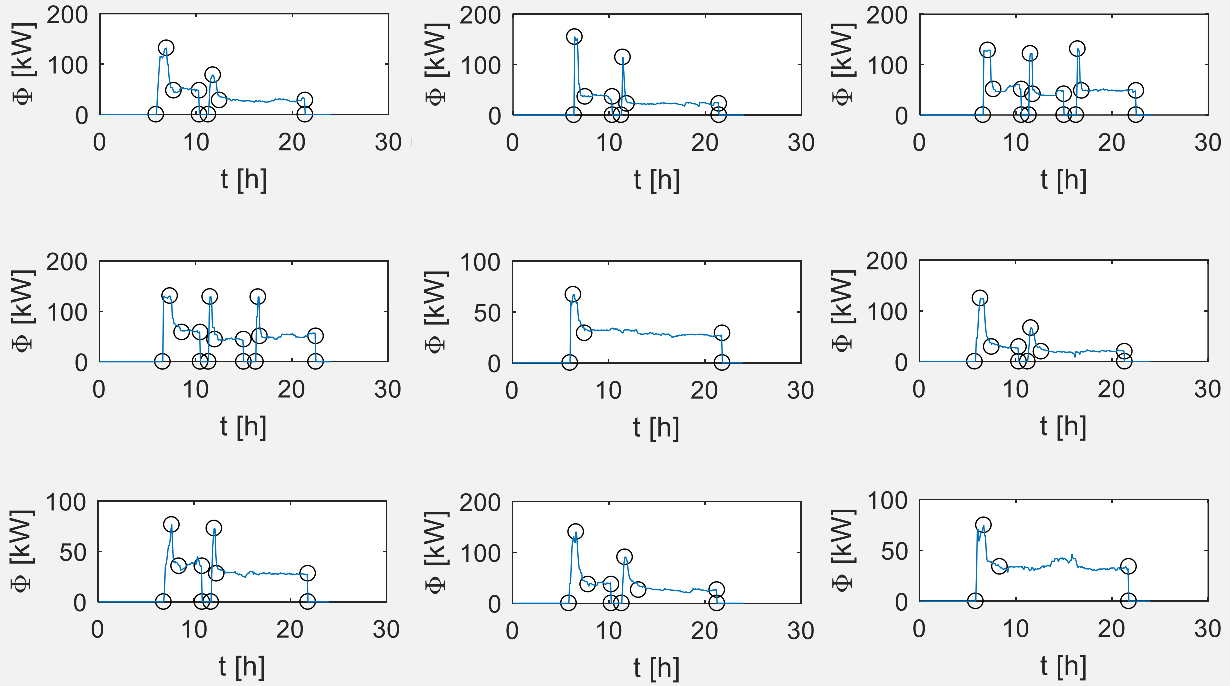


DAILY THERMAL PROFILE PREDICTION

REQUEST FORECAST

AUTOMATIC TOOL FOR MAIN POINT DETECTION

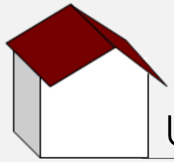




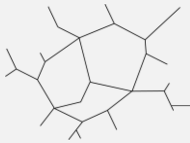
POINTS WELL DETECTED

Guelpa, E., Marincioni, L., & Verda, V. (2019). Towards 4th generation district heating: Prediction of building thermal load for optimal management. *Energy*, *171*, 510-522.

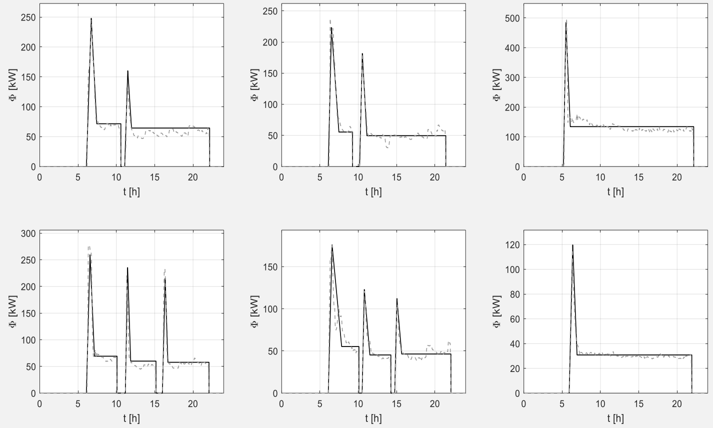
THERMAL PROFILE PREDICTION

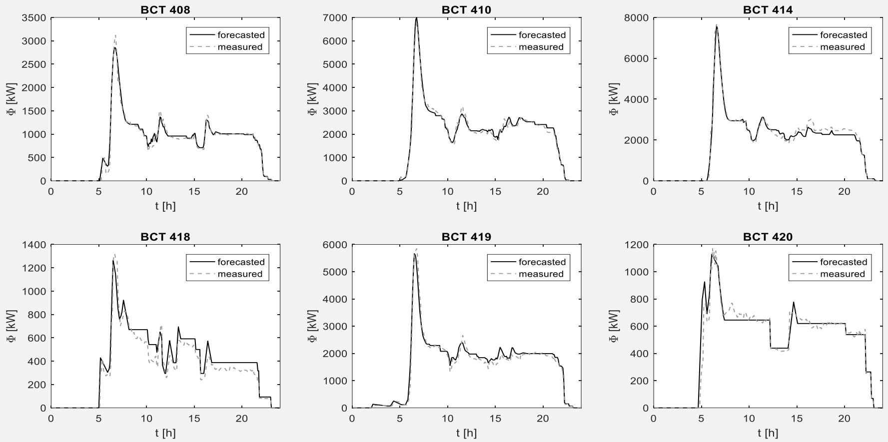


USER LEVEL



DISTRIBUTION NETWORK LEVEL





PROFILES WELL DETECTED

Guelpa, E., Marincioni, L., & Verda, V. (2019). Towards 4th generation district heating: Prediction of building thermal load for optimal management. *Energy*, *171*, 510-522.

4

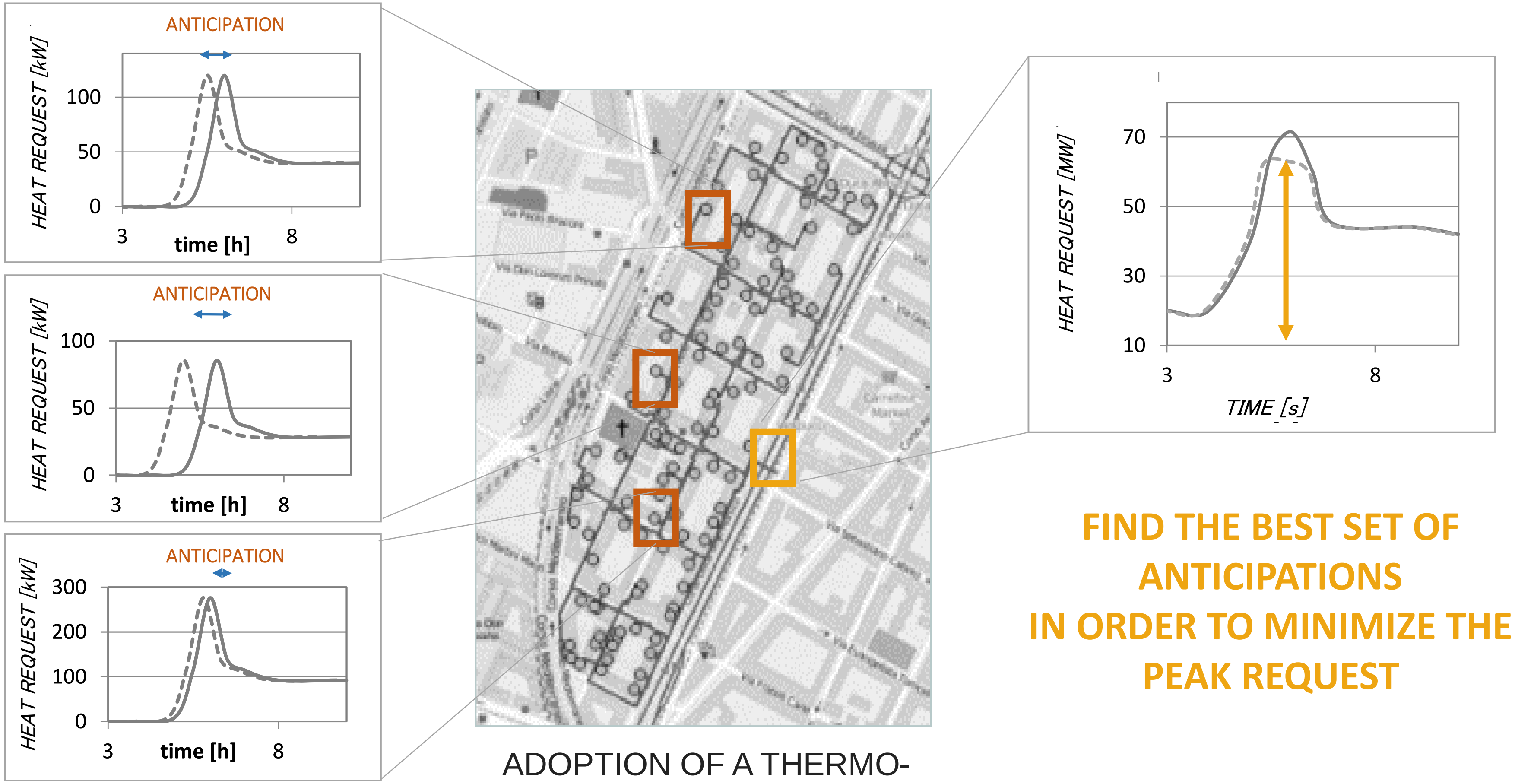
PEAK SHAVING

AUTOMATIC TOOL FOR OPTIMALLY SHAVE THE THERMAL PEAK

4

PEAK SHAVING

PEAK SHAVING THROUGH USER RESCHEDULING



ADOPTION OF A THERMO-FLUIDYNAMIC MODEL

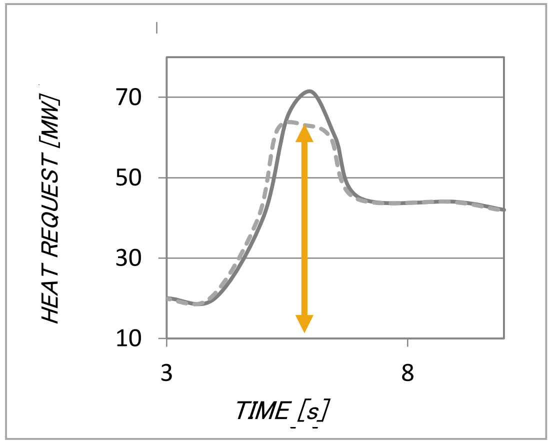
FIND THE BEST SET OF ANTICIPATIONS IN ORDER TO MINIMIZE THE PEAK REQUEST

4

PEAK SHAVING

PEAK SHAVING THROUGH USER RESCHEDULING

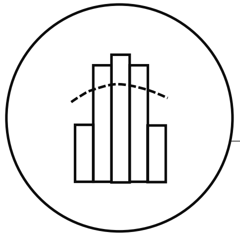
ENTITY OF THE THERMAL PEAK REDUCTION?



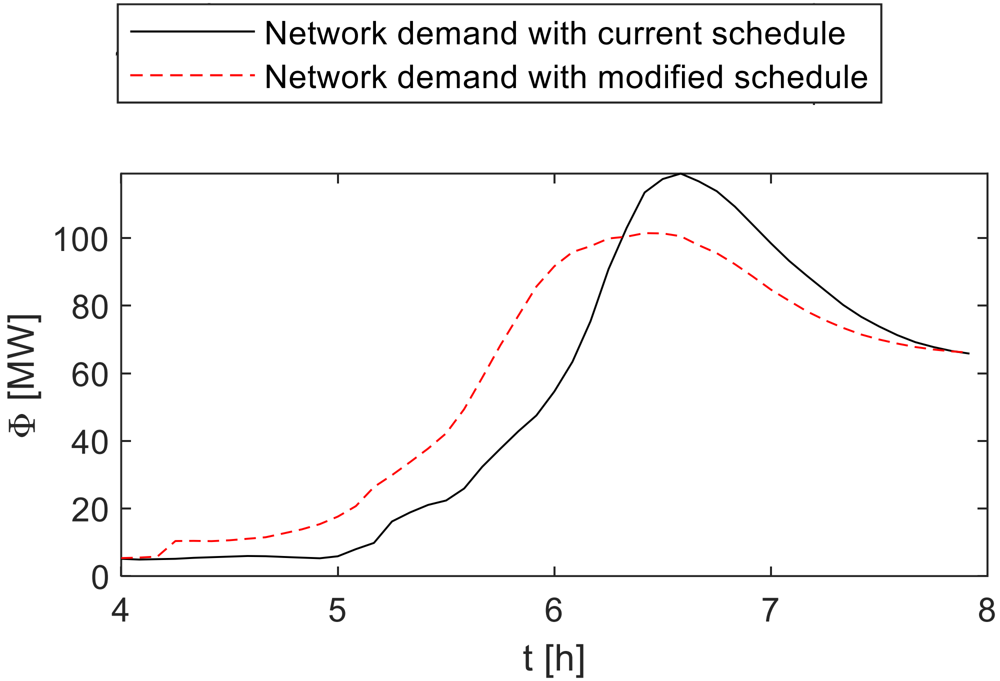
- NUMBER OF USERS WITH ADJUSTABLE SCHEDULE
- LIMITATIONS IN THE MODIFICATION OF THE SWITCHING ON TIME

4

PEAK SHAVING



PEAK SHAVING THROUGH USER RESCHEDULING



Guelpa, E., Deputato, S., & Verda, V. (2018). Thermal request optimization in district heating networks using a clustering approach. *Applied Energy*, *228*, 608-617.

4

PEAK SHAVING

PEAK SHAVING THROUGH USER RESCHEDULING

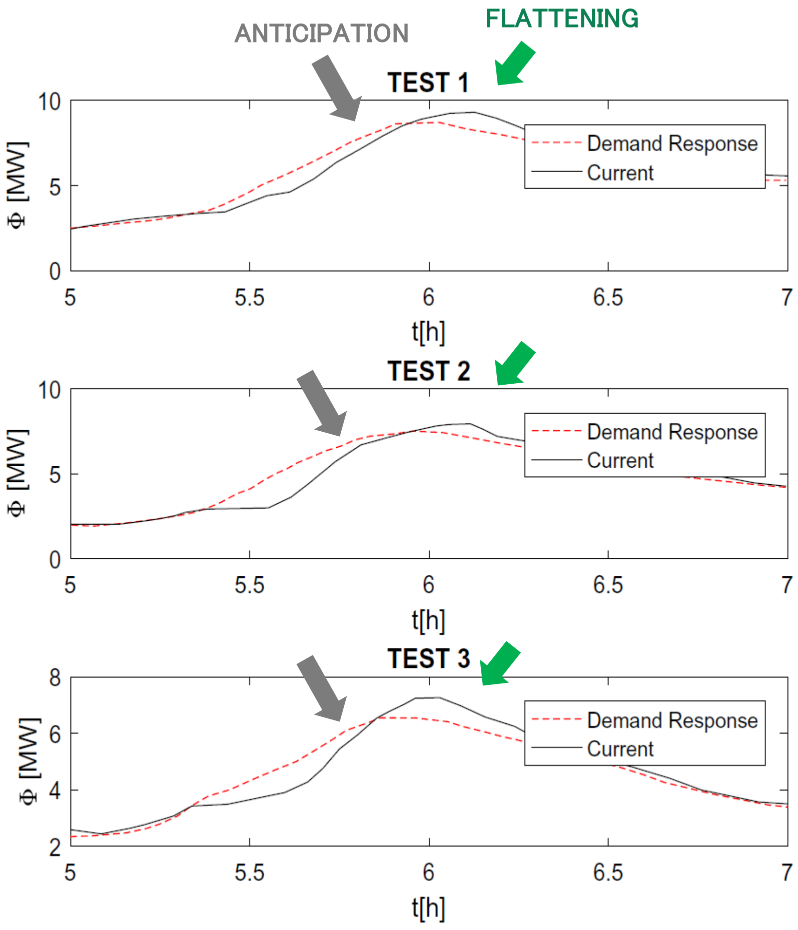


Fig. 6. Thermal request evolution in case with and without demand response (comparison between similar days).

MEAN REDUCTION OF THE THERMAL PEAK:

–15 %

(less than 30% build, max 20 min antic)

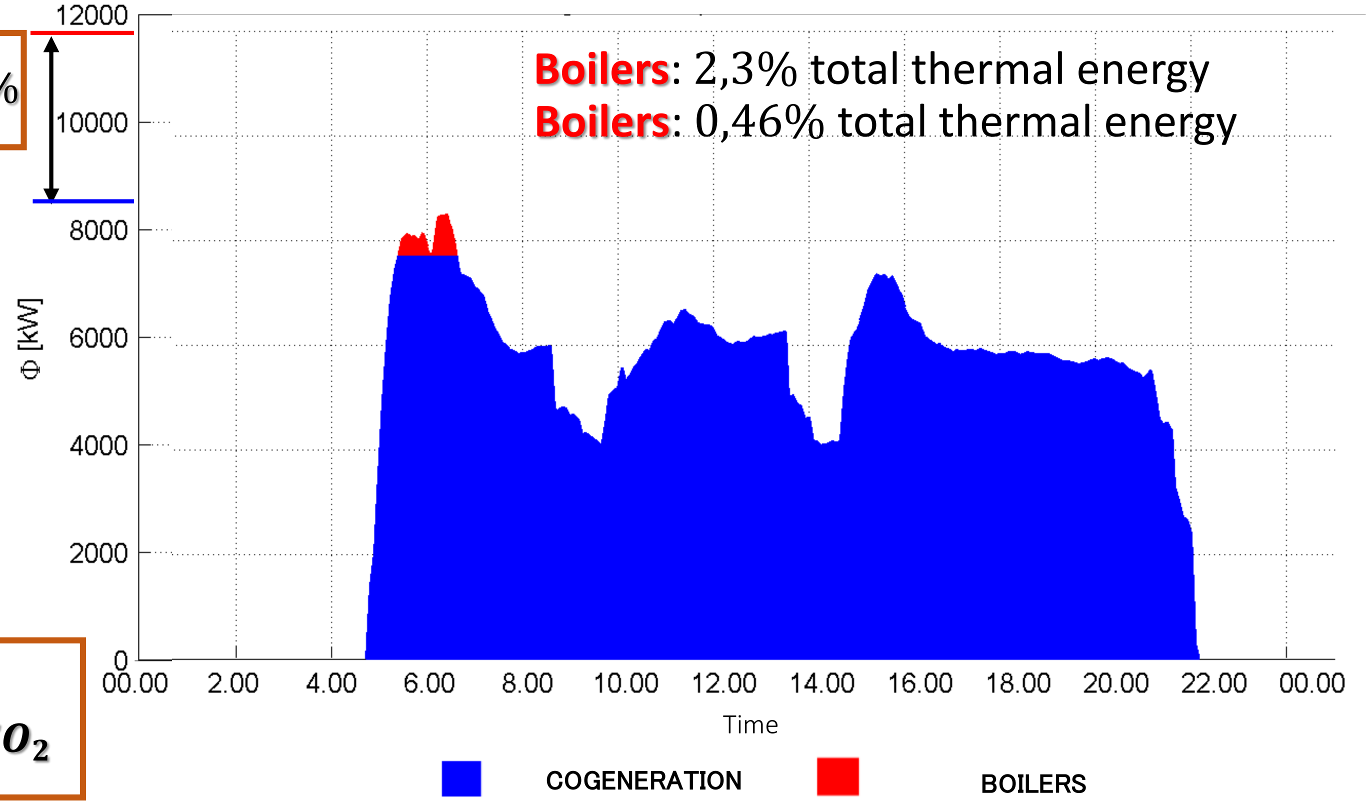
Guelpa, E., Marincioni, L., Deputato, S., Capone, M., Amelio, S., Pochettino, E., & Verda, V. (2019). Demand side management in district heating networks: a real application. *Energy*, *182*, 433-442.

PEAK SHAVING

PEAK SHAVING THROUGH USER RESCHEDULING

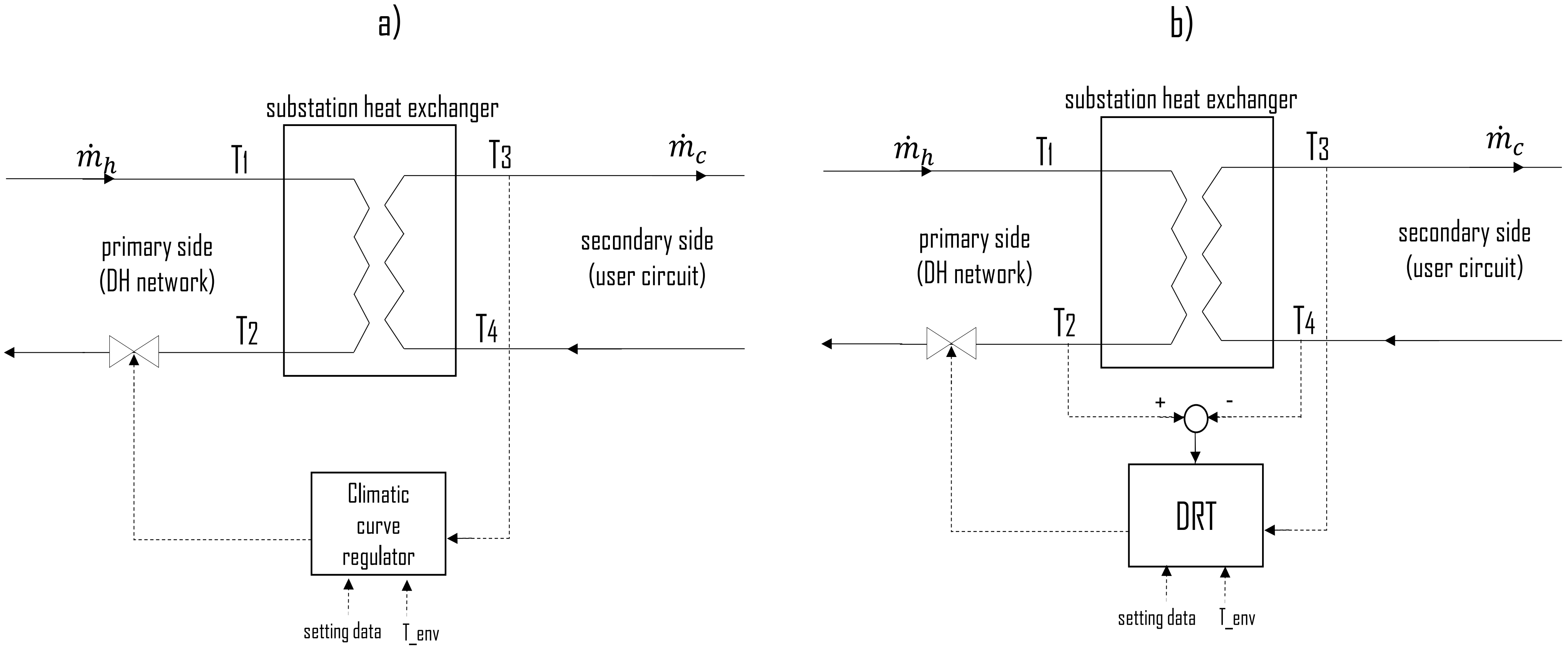
$$\Delta P_{morning\ peak} = 26,98\ \%$$

$$\Delta EP = -3.8\%$$
$$\Delta Emission = -268\ kgCO_2$$



PEAK SHAVING

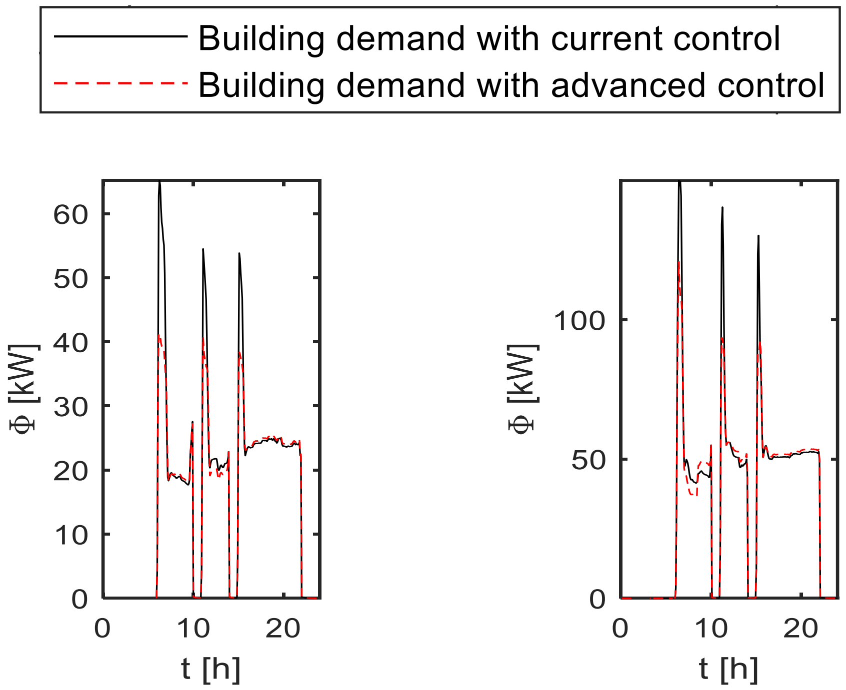
PEAK SHAVING THROUGH CHANGE IN CONTROL STRATEGY



Guelpa, E., & Marincioni, L. (2019). Demand side management in district heating systems by innovative control. *Energy*, *188*, 116037.

PEAK SHAVING

PEAK SHAVING THROUGH CHANGE IN CONTROL STRATEGY



Guelpa, E., & Marincioni, L. (2019). Demand side management in district heating systems by innovative control. *Energy*, *188*, 116037.

5

COMFORT CONTROL

AUTOMATIC TOOL FOR EVALUATING THE INDOOR COMFORT (WITHOUT EXTRA DATA)

INDOOR COMFROT CONTROL

A model ONLY RELY ON:
available data from the thermal substations
the building volume

Building thermal capacity

Building overall transmittance

Average indoor temperature evolution

This is a simple model aimed at evaluating the modification in the indoor temperature (comparing before and after the demand side management)

CONCLUSIONS

SUBTASK A (Collaboration models):
Discussion/collaboration with agencies

SUBTASK B (Technology at the building level):
Platform/new control strategy devices and test on water storage in substations

SUBTASK C (Methods and Tools):
Methods for fouling detection/load prediction/best rescheduling

SUBTASK D (Case studies):
Test Case Turin

THANK YOU

FOR THE ATTENTION