GEOFIT
SMART GEOTHERMAL

Modelling and simulation of the geothermal heat pump system for swimming pool heating using TRNSYS

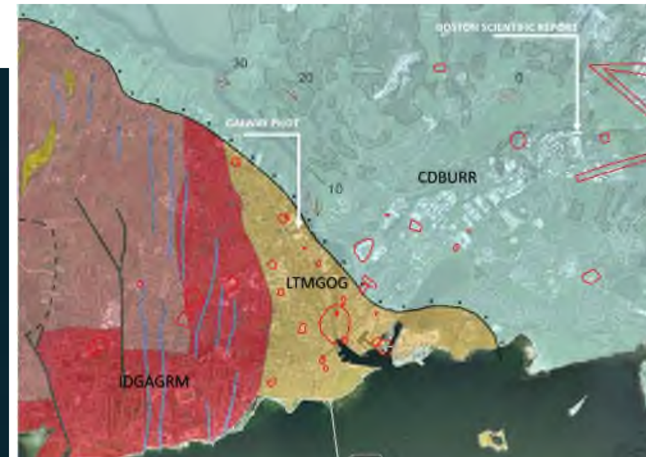
Andrea Frazzica
Giuseppe Dino
CNR ITAE

This project has received funding from the H2020 programme under Grant Agreement No. 792210

Galway GEOFIT system

The TRNSYS model, created by CNR researchers, will simulate the performances of the system installed in the pilot demo-site located in **Galway**.

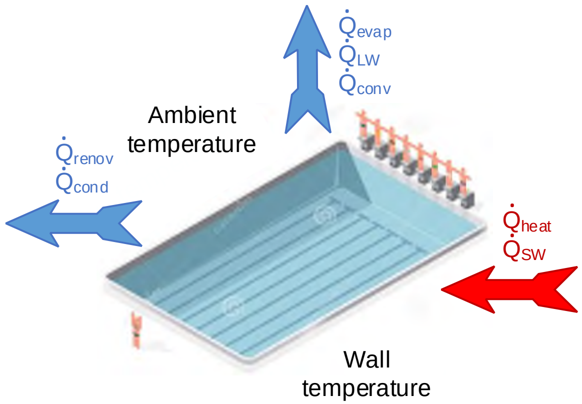
A swimming pool, actually supplied by a gas boiler, will be supplied by a **dual source** heat pump by coupling geothermal and air sources. The system will be integrated to the existing one



Swimming pool modelling and validation

The swimming pool was simulated through TRNSYS type344. It performs an energy balance by considering several contributions:

- Heat flow rate by evaporation
- Heat flow rate by convection
- Heat flow rate by short-wave radiation
- Heat flow rate by long-wave radiation
- Heat loss by fresh water supply
- Heat flow rate by heating

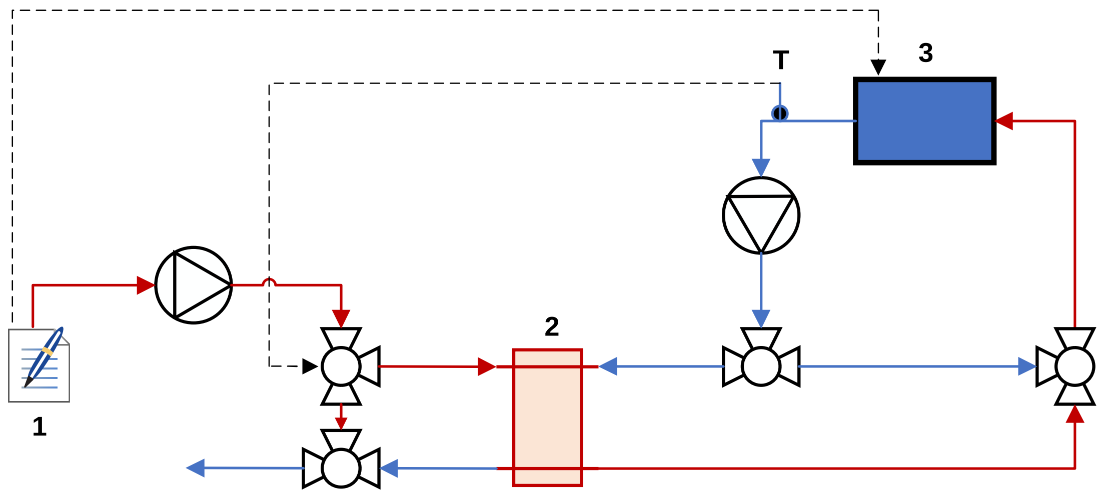


Data collected from the demo-site and from ECOSCADA interface were used to set up the parameters that let to validate the TRNSYS type

Parameter	Value
Pool surface area	300 m^2
Pool volume	800 m^3
Cover emissivity	0.9
Cover absorption coefficient	0.9
Cover thermal conductivity	0.04 W/m·K
Cover thickness	0.29 m
Indoor ambient air	*Variable from input file*
Indoor relative humidity	*Variable from input file*
Temperature of enclosure surfaces	*Variable from input file*
Water surface activity	Function of pool occupancy

TRNSYS pool validation model structure

Existing system simulation



1) Input data file containing data from ECOSCADA, 2) Heat Exchanger, 3) Swimming pool

Variable input data:

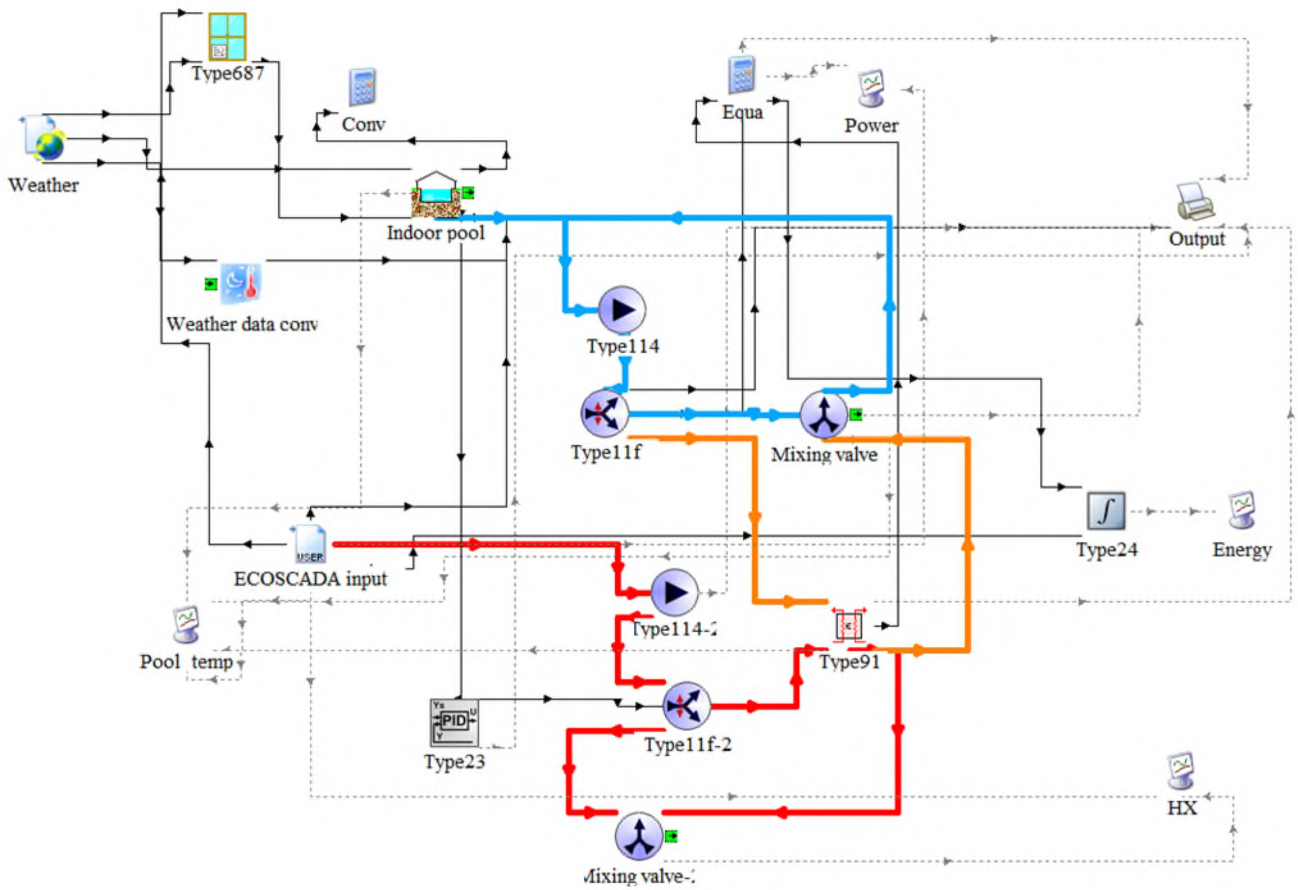
1. Indoor air temperature
2. Indoor relative humidity
3. Temperature of enclosure surface
4. Shortwave radiation gain
5. Temperature inlet to the HX

Fixed parameters coming from measured data:

1. Pool surface area
2. Pool volume
3. Water surface activity
4. Occupancy profile
5. Radiation factors of covering surface

Overview of TRNSYS pool validation model

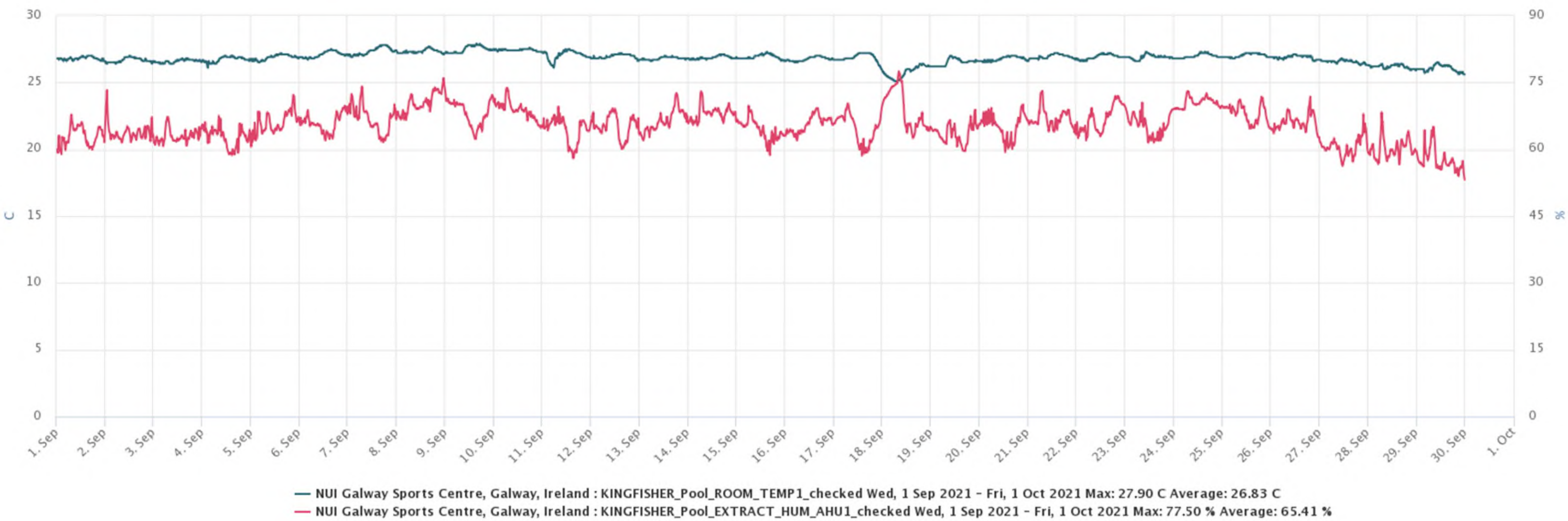
Existing system simulation



Inputs to the validation model

Existing system simulation

The contributions that mostly affect the the pool TRNSYS type simulation are the **evaporation and convection heat transfer** ones. For this reason, it is necessary to know exactly the indoor air temperature and relative humidity that were retrieved from ECOSCADA interface.



Inputs to the validation model

The short wave heat gain is due to the visible solar radiation that, transmitted through the windows, is absorbed by pool water. Matterport virtual tool was used to estimate the windows surface, than it was simulated by type 687 in TRNSYS by knowing azimuth orientation

Inputs to the validation model

Existing system simulation

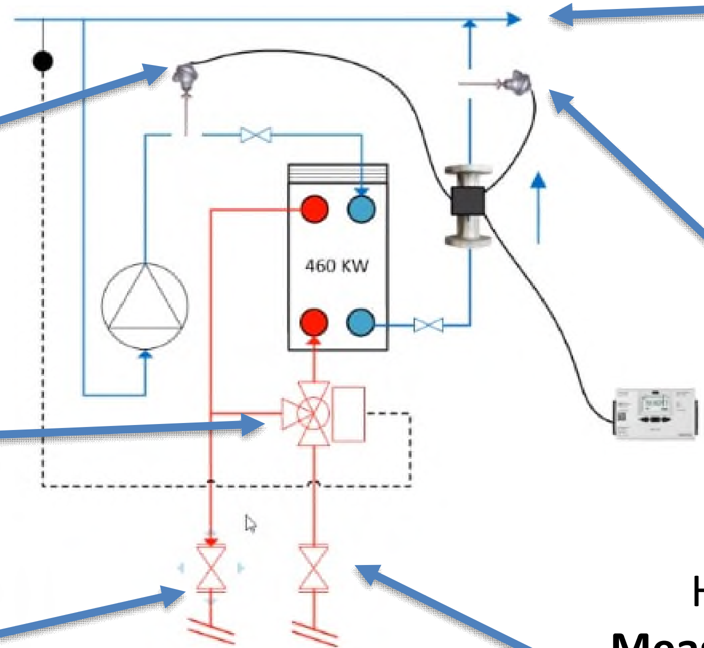
Only HX primary inlet measured temperature was given as input to the hydraulic loop model. The other data retrieved from ECOSCADA were used to made the comparison between simulated and measured values.

HX secondary inlet (pool outlet temperature) SIMULATED

Pool inlet temperature SIMULATED

HX secondary outlet (pool temperature) SIMULATED

Position of diverting valve SIMULATED



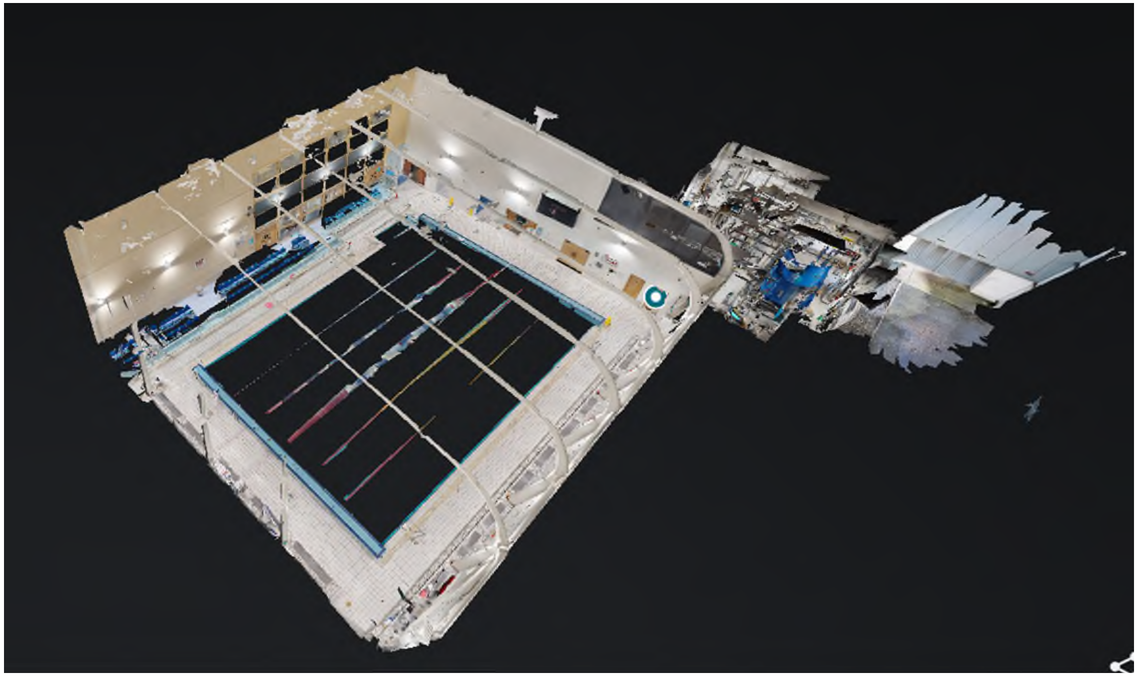
HX primary outlet SIMULATED

HX primary inlet **Measured temperature-** input to the model from ECOSCADA data

Validation model simulation

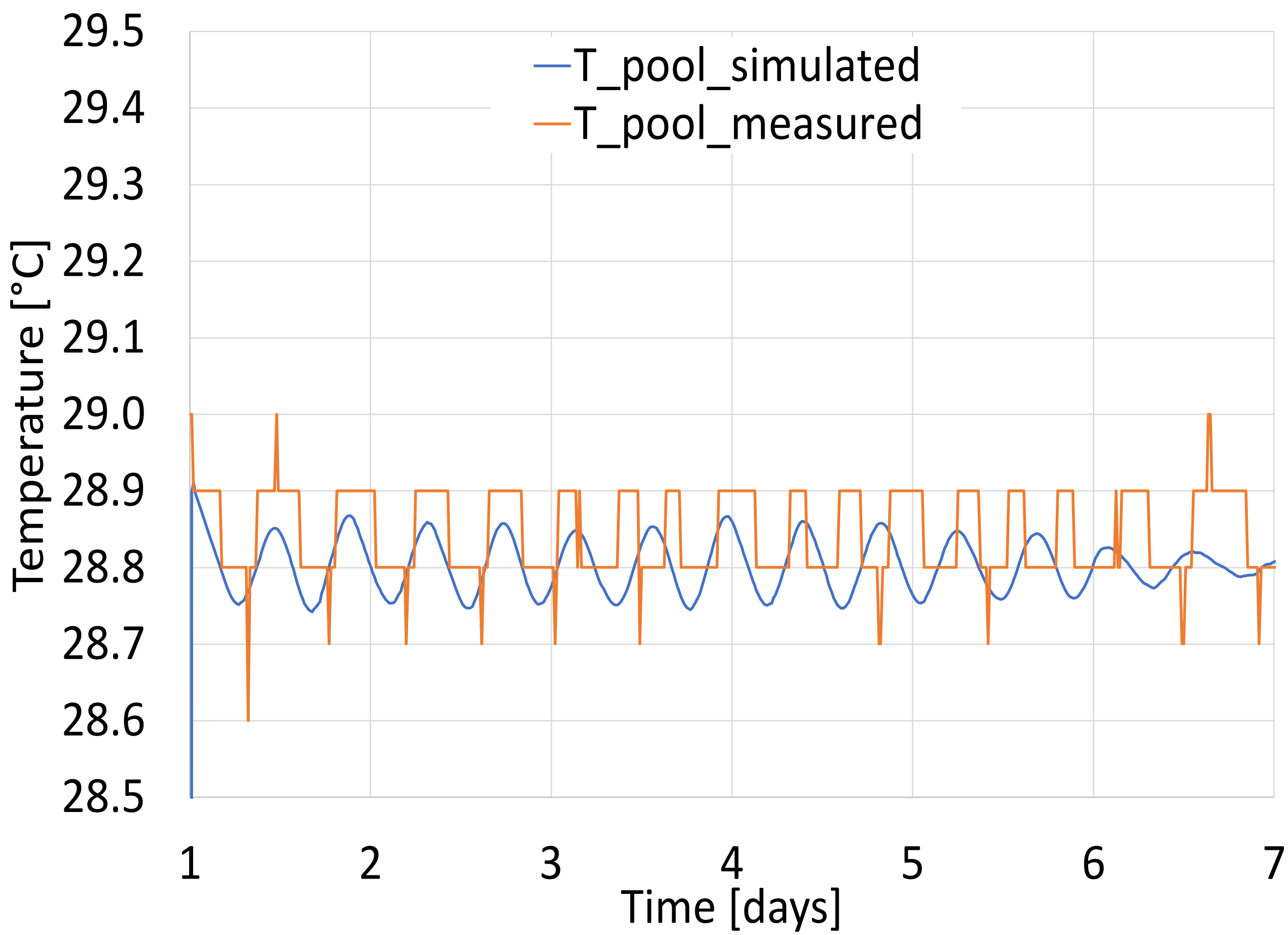
ECOSCADA platform, developed within GEOFIT project, provides all the monitoring data for the demo-sites, data available from **28th January 2022 to 21st July 2022** were chosen for the model validation.

Monitoring data were mainly used for calibration of the parameters of the swimming pool type and the booster heat exchanger ones



HX secondary loop – inlet temperature (pool outlet)

Good matching between measured and simulated value



Energy balance comparison

Measured heat capacity on the HX secondary side (booster heat exchanger) was retrieved from ECOSCADA. The analogous simulated one was retrieved from TRNSYS model results

The energy exchanged during the considered validation period was calculated by the expression:

$$\mathrm{Q} = \int_{t_1}^{t_2} \dot{Q}\, \mathrm{dt}$$

Measured and simulated heating energy were compared

The simulated heat capacity and energy exchanged shows a <u>good matching</u> with HX secondary side values:

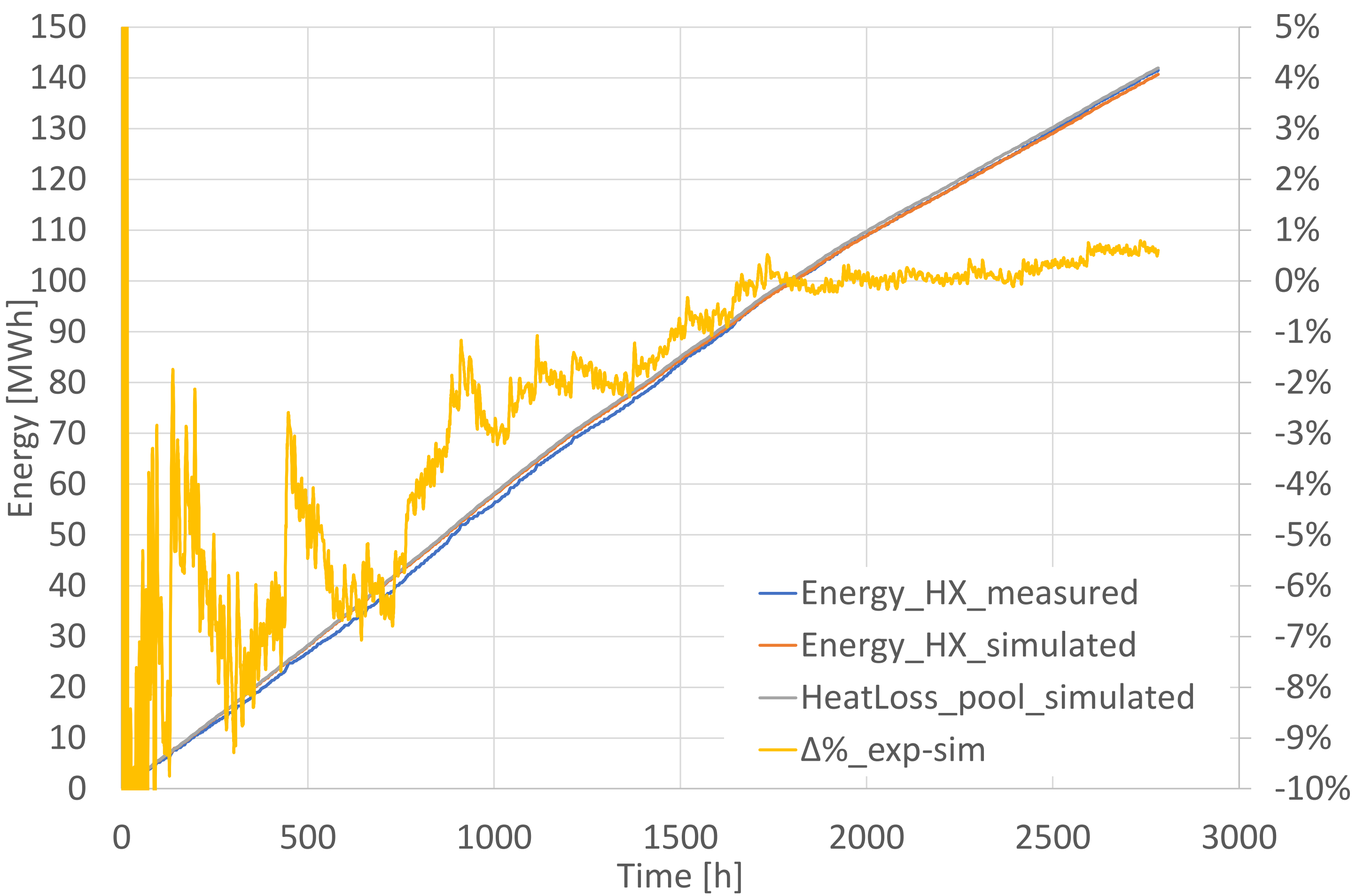
- $Q_{measured}$=**141.5 MWh**
- $Q_{simulated}$=**140.7 MWh**

The previous two values were compared to the simulated heat losses from the swimming pool

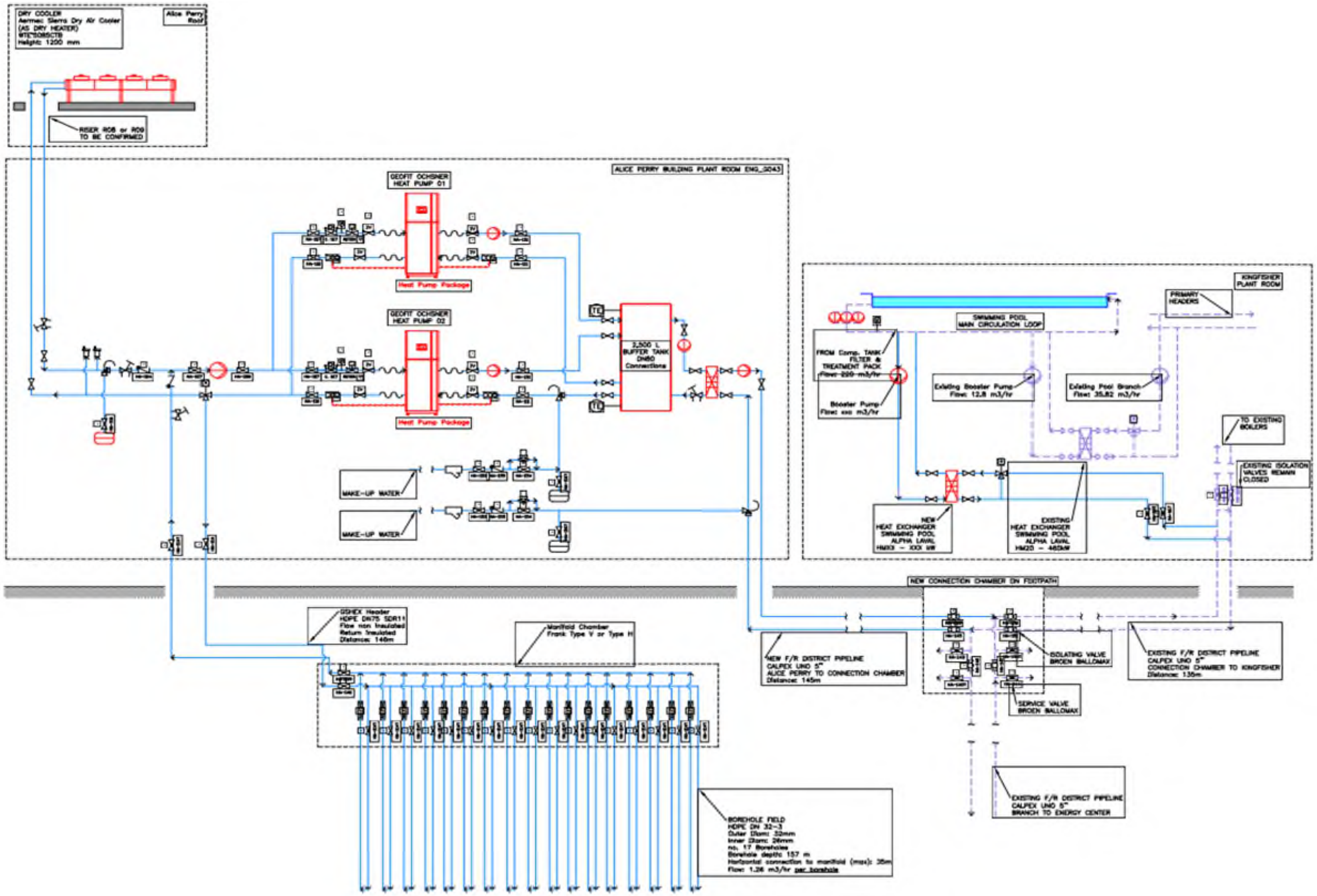
Energy balance comparison

Relative error

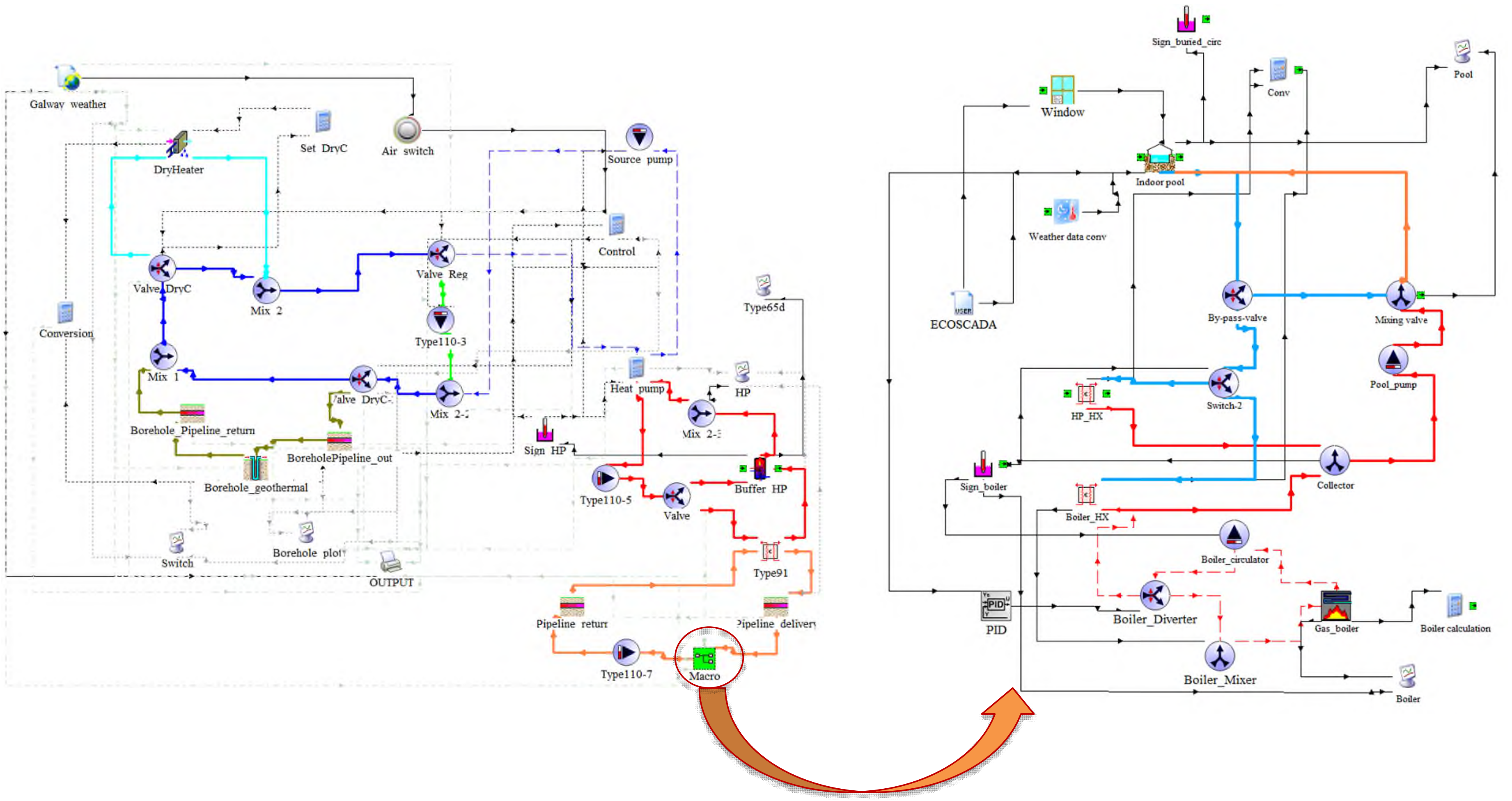
$$\frac{Q_{exp} - Q_{sim}}{Q_{exp}} \%$$



Integration of the existing system in the GEOFIT concept

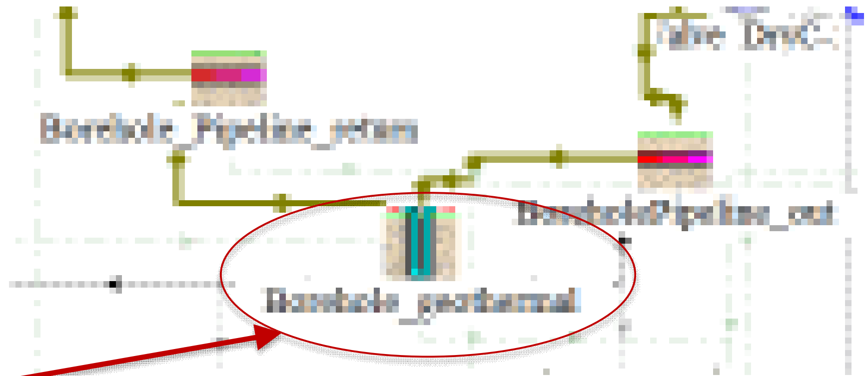


Overview of the GEOFIT TRNSYS model



The geothermal side

The boreholes were modeled through type 557 that considers the Duct Ground Heat Storage Method (*Hellstrom, Goran, "Duct Ground Heat Storage Model, Manual for Computer Code", Department of Mathematical Physics, University of Lund, Sweden.)*



This subroutine models either a U-tube ground heat exchanger or a concentric tube ground heat exchanger. A heat carrier fluid is circulated through the ground heat exchanger and either rejects heat to, or absorbs heat from the ground depending on the temperatures of the heat carrier fluid and the ground. The program assumes that the boreholes are placed uniformly within a cylindrical storage volume of ground. There is convective heat transfer within the pipes, and conductive heat transfer to the storage volume.

GeoFit - Funded by the EC - G.A. 792210

The geothermal side

The buried piping that connect heat pump with geothermal field and heat pump with pool supply side were modeled through type 952

Borehole-HP loop connection (evaporator loop)

HP-Kingfisher loop connection (condenser loop)

Heat pump model

The heat pump was modelled by a black box approach. The model is composed by a set of equations (Eq. 1,-6) obtained from the datasheet provided by the technology supplier (Ochsner).

The equations contain statistical regressions calculated from the experimental performance maps performed for the heat pump

- $\dot{Q} = f(T_{inlet}, T_{outlet})$ (1)
- $COP = f(T_{inlet}, T_{outlet})$ (2)
- $T_{source,out} = T_{source,in} - \Delta T_{source}$ (3)
- $T_{sink,out} = T_{sink,in} + \Delta T_{sink}$ (4)
- $\dot{m}_{sink} = \frac{\dot{Q}_{sink}}{c_p \cdot \Delta T_{sink}}$ (5)
- $\dot{m}_{source} = \frac{|\dot{Q}_{source}|}{c_p \cdot \Delta T_{source}}$ (6)

A time-dependent performance degradation of heat pump was introduced

$$COP = COP_{base} \times (1 - \beta)^{\tau}$$

For heat pump β=0.1[1], τ is expressd in years

1) Georgios Eleftheriadis, Mohamed Hamdy, Impact of building envelope and mechanical component degradation on the whole building performance: a review paper, Energy Procedia, 2017

Dual source mode

The dual source system foresees three different operation modes:

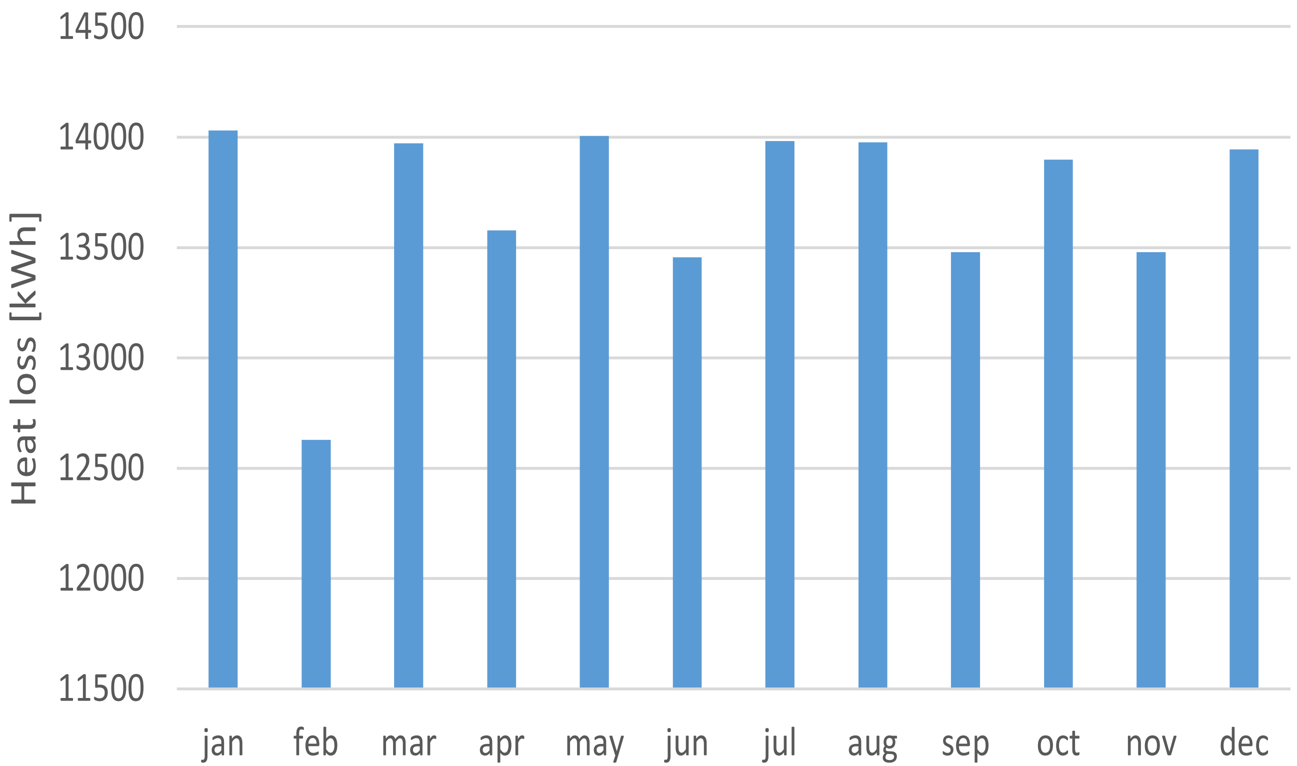
1. Ground mode: if $T_{air}<T_{switch}$
2. Air mode: if $T_{air}>T_{switch}$
3. Regeneration mode: if $T_{air}>T_{switch}$ AND HP switched off

T_{switch} is a fixed reference temperature assumed equal to the ground undisturbed temperature. In this case (Galway) it was fixed at 9.8°C

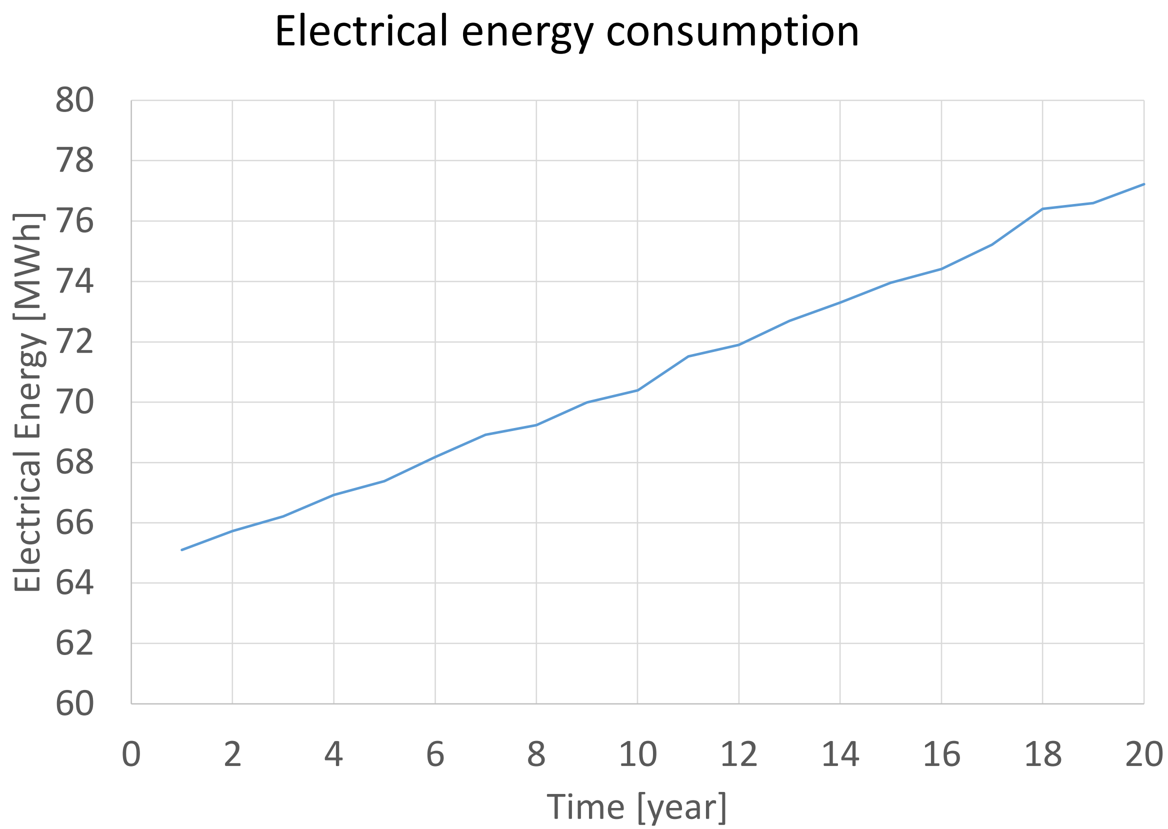
The results of the simulation performed for a long-term period of 20 years were evaluated by considering the yearly energy consumption

Results

Simulated monthly profile of swimming pool heat losses for one year



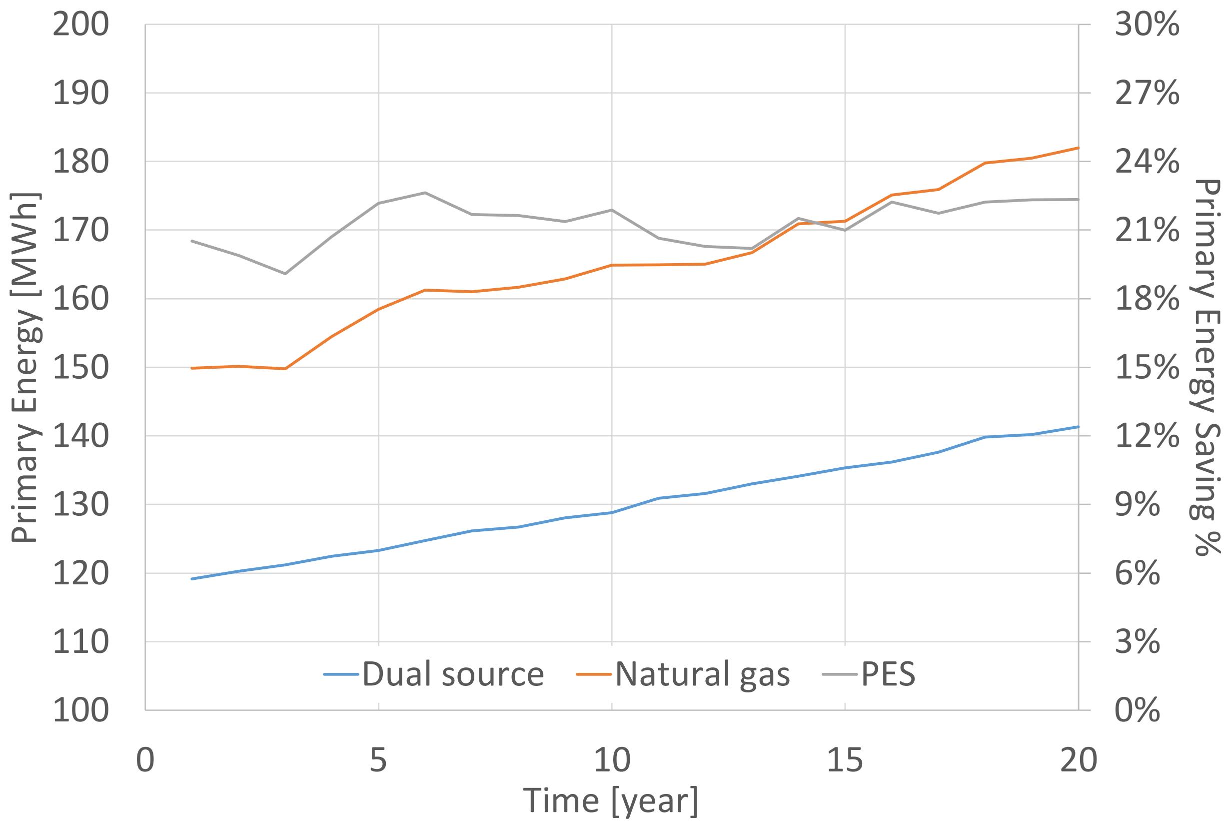
Results



Operation mode	Ratio on total amount of electrical energy consumption
Air mode	39%
Ground mode	51%
Regeneration mode	10%

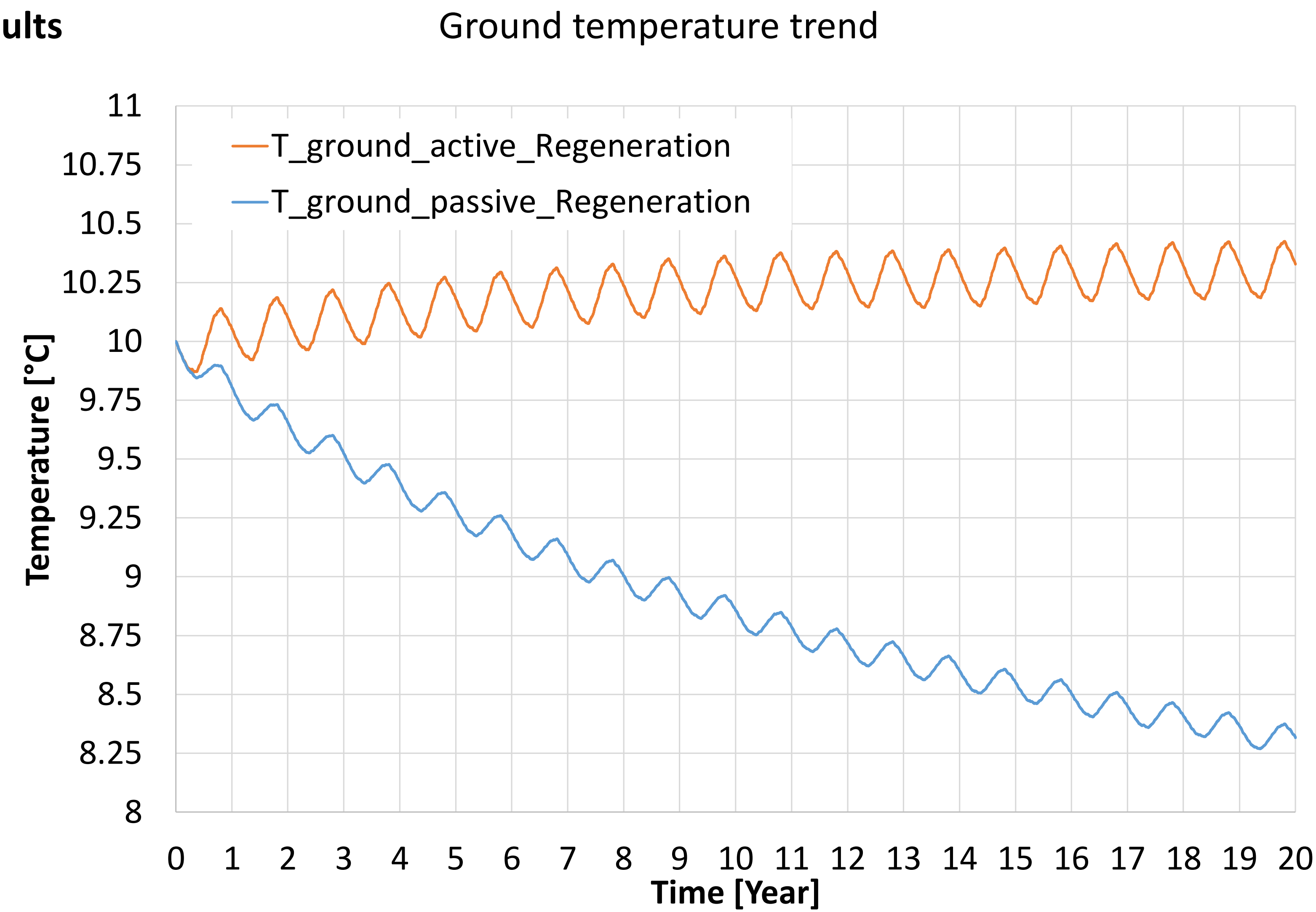
Results

Primary Energy Saving



Energy source	Primary Energy factor (SEAI Ireland)
Electricity	1.83
Natural Gas	1.1

Results



Ground temperature trend
T_ground_active_Regeneration
T_ground_passive_Regeneration
Temperature [°C]
11
10.75
10.5
10.25
10
9.75
9.5
9.25
9
8.75
8.5
8.25
8
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time [Year]

Thanks for your attention

Andrea Frazzica
Giuseppe Dino
CNR ITAE

This project has received funding from the H2020 programme under Grant Agreement No. 792210