Renewable Energy Hub Optimizer

June 2023

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1. Introduction

This report offers an energy analysis of 4 buildings, using the *QBuildings* and *Renewable Energy Hub Optimizer* (REHO) tools developed within from the *Industrial Process and Energy Systems Engineering* (IPESE) laboratory at EPFL.

The figure below shows the selected buildings for this use case.

Figure: Chosen buildings for study case.

2. Methodology

In this section the two main tools to generate a building scale energy scenario, QBuildings and REHO, will be explained. Following this, the input data for the model will be presented.

2.1 Qbuildings

2.2 REHO

2.3 Data

In order to run the model, several input parameters are required.

Optimization parameters

In the present case, a building scale optimization is performed with as objective function the minimization of the total cost (TOTEX) of the energy system for the given building. For this case study, it was decided to enforce no units. In addition, it was decided to exclude NG_Cogeneration, DHN_in, DataHeat_DHW from the optimization.

As REHO makes use of typical days for its optimization a weather cluster is needed. Here, the weather cluster is used which has the following characteristics: TODO

Building

The building parameters are used to define the energy demand of the building. The following parameters are the values used for this case study:

- 868.6 [m2] of reference energy surface (= SRE). That corresponds to the total heated floor area all dwellings
- 1604.9 [m2] of available solar area
- 1193.6 [kWh/m_2/yr] average annual solar irradiation for all the buildings
- 47.4 [capita] estimated people living in the chosen district

Studied scenarios

The different energy configurations studied for this case study are:

1. **TOTEX:**the optimal system according to the excluded and enforced energy systems described above.

Investment

The optimization is based on an investment made from a bank loan over a period of n years (which corresponds to the lifetime of the equipment) with a specified interest rate i specified. The annualization factor can therefore be expressed as :

Here is an example of a display formula:

$$\tau = i * \frac{(1+i)^n}{(1+i)^n - 1}$$

Cost of resources

A number of energy prices and specific CO_2 emissions factors are used for the optimization. They can be found in the following table:

Resource	Cost [CHF/kWh]	Carbon footprint [kgCO2-eq/kWh]
Electricity (buying)	0.2790	0.13
Electricity (selling)	0.1645	0.13
Fuel oil	0.1400	0.28

3. Results

In this section the results generated from REHO are presented.

3.1 Total Energy Demand

The total energy demand for the different services (Space heating (SH), Domestic hot water (DHW), Electricity) is proposed in the figure below

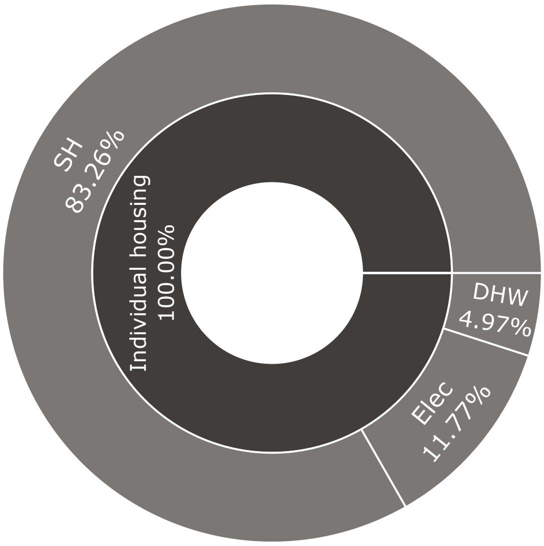

Figure: Energy demand by class of building and by use.

Table: Energy demand by class of building and by use.

Energy Use	Building Type	Energy demand [MWh/yr]
Individual housing	Total	154.35
SH	Individual housing	128.51
DHW	Individual housing	7.67
Elec	Individual housing	18.17

3.2 Economic performance

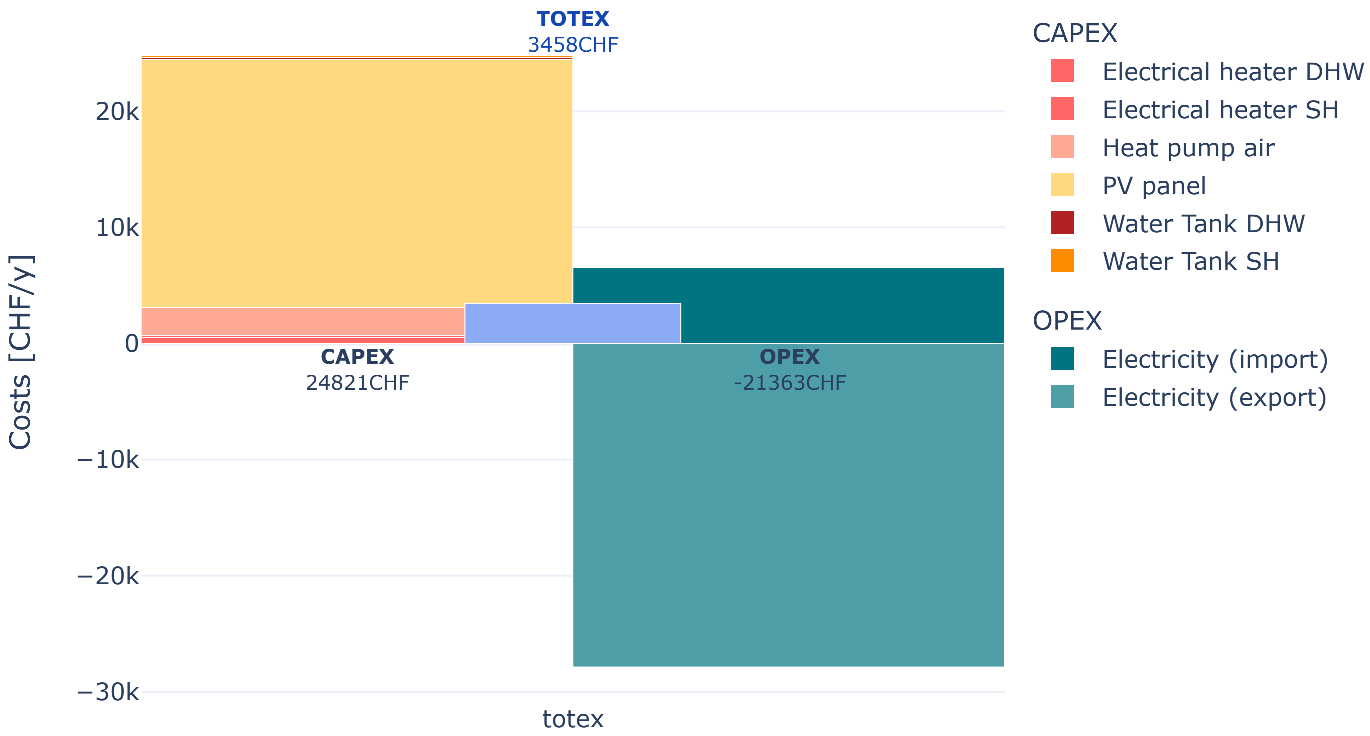

Figure: Total cost (TOTEX) distribution for all scenarios studied. The total cost is split into the capital cost (CAPEX) and the operating cost (OPEX) for each unit.

Table: Distribution of costs for each unit for all studied scenarios in CHF/yr.

Unit	totex
ElectricalHeater_DHW	497.21
ElectricalHeater_SH	254.16
HeatPump_Air	2324.75
PV	21313.63
WaterTankDHW	152.03
WaterTankSH	279.66

3.3 Environmental performance

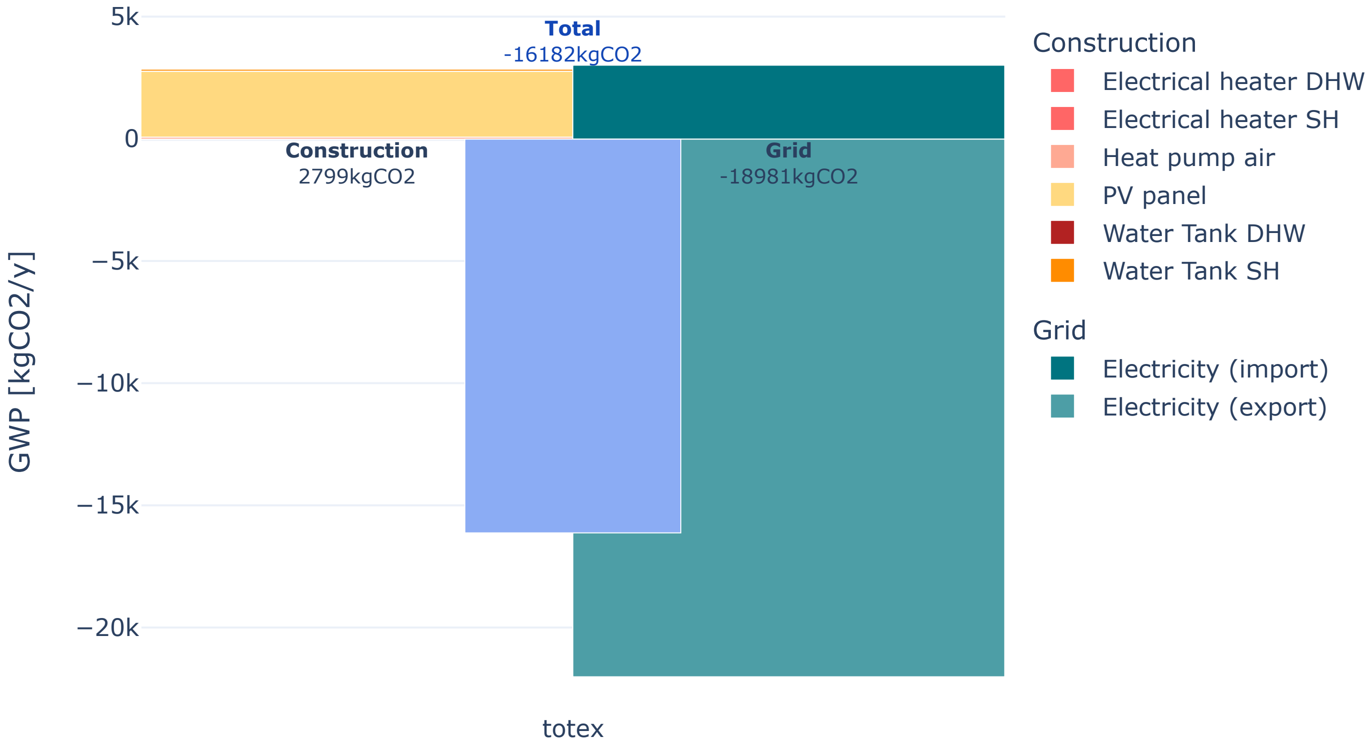

Figure: Carbon dioxide emissions distribution

Table: Carbon dioxide emissions distribution

Unit	totex
ElectricalHeater_DHW	0.04
ElectricalHeater_SH	0.18
HeatPump_Air	83.59
PV	2649.76
WaterTankDHW	15.52
WaterTankSH	50.78

Sankey diagrams

A Sankey diagram allows you to visualize the different flows of energy within a building:

- The building's final energy demand can be read to the right of the diagram: *Domestic Electricity*, *Heating*, *Water domestic hot*.
- Imported energy (*Oil*, *Electricity - purchase*) or produced locally (*Solar panels*) can be read on the left.
- Between these two extremes are the different conversion technologies (e.g. *Oil boiler*, *Heat pump*) and energy storage (e.g. *Hot water tank*).

The diagrams below show the annual energy balance for each of the scenarios studied.

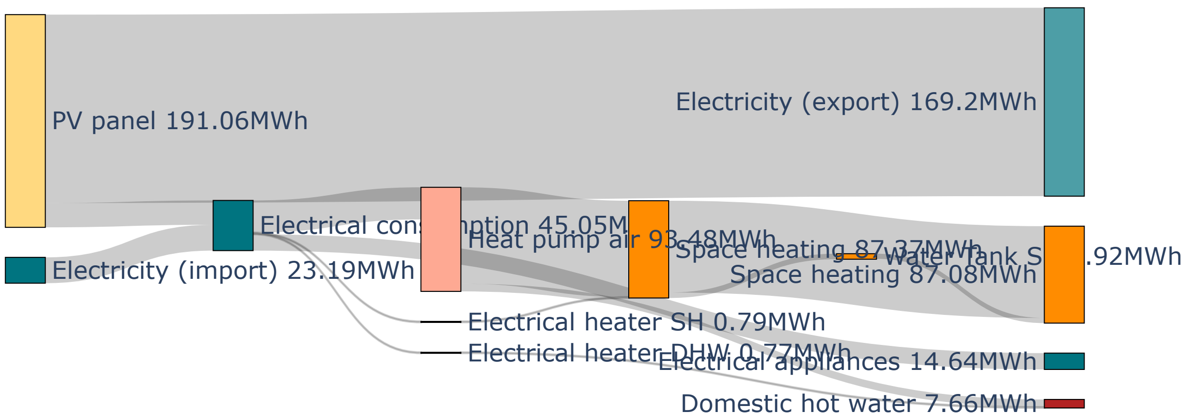

Figure: Sankey diagram of energy systems for the building for the TOTEX scenario.

Table: TOTEX scenario

source	target	Energy demand [MWh/yr]
Electricity (import)	Electrical consumption	23.19
Electrical consumption	Electrical appliances	14.64
PV panel	Electricity (export)	169.20
PV panel	Electrical consumption	21.86
Water Tank SH	Space heating	4.62
Space heating	Water Tank SH	4.92
Space heating	Space heating	82.45
Electrical consumption	Heat pump air	28.85
Heat pump air	Domestic hot water	6.89
Heat pump air	Space heating	86.59
Electrical consumption	Electrical heater DHW	0.77
Electrical heater DHW	Domestic hot water	0.77
Electrical consumption	Electrical heater SH	0.79
Electrical heater SH	Space heating	0.78

Time profiles

The graphs below show the hourly profiles (smoothed with a weekly average) of production and consumption of energy of the building for each of the studied scenarios.

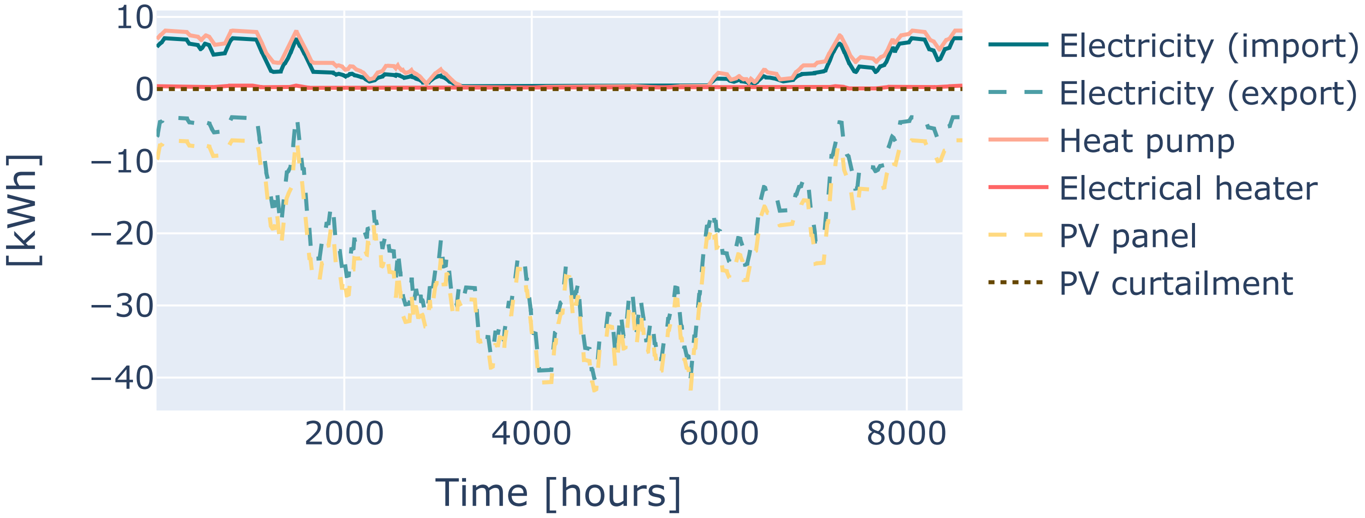

Figure: Profile plot for the building for the TOTEX scenario.

Table: TOTEX scenario