PLANETARY ENGINEERING PEGE GROUP

founder

presents

PEGE energy sim

Simulation with PVGIS data for photovoltaic. BESS battery, export and import of electricity by spot market prices, EMS to avoid high peak-usage grid fees, heating, cooling and DHW by heat pump, charging cars, off-grid and weak-grid systems with a generator and power to methanol. All for the house improvement up to the energy-intensive industry.

All activities of Planetary Engineering Group Earth

Since 1991, striving to lead humanity into the solar age. Our activities are the philosophy Infinitism, WWW movement WorldWide Wealth and the GEMINI next Generation house.

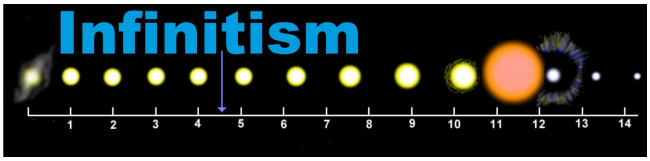
WWW - WorldWide-Wealth Movement

Mankind has the technology for a lasting paradise
but a policy for hell on earth. Our mission is to change that.

It is a politcal party registered in Austria.

Infinitism

Can a civilization develop an unlimited ability to survive?
We think so! Thus, worldwide wealth and a limitless future are possible.



The association to promote infinitism is an association registered in Austria.

GEMINI next Generation Zrt.

Let's make the world a better place! Your investment and our ideas as an unbeatable team to give humanity a future well worth living.

Introduction

There is a big difference between having electricity just as the sun shines, 24-electricity, and 24×365 electricity.

There is a big difference between replacing 8 kWh thermal energy by 1 kWh electricity on scooters (very small gasoline engines have terrible efficiency) and replacing 1.6 kWh thermal energy by 1 kWh electricity by changing cement production from heating the clinker by burning to heating it by electricity. Some decades ago, it was great for the first photovoltaic owners to run the washing machine when the sun shone. Now the target is to run energy-intensive industry even during a dark doldrum at a competitive price.

Many thought about the energy transition, “We have to do it, whatever it costs”. This idea is a sure way to lose. This idea created the present problems in Germany.

How to design an optimal system? The old way was to build, to measure, and to be surprised. The new way is to simulate first. We have data; we have the computing power. Everybody runs today around with a smartphone with far more computing power than a Cray-2 supercomputer in 1985. The smartphone weighs less than 2 t and consumes less than 150 kW.

The first phase of the energy transition was simple: the sun shines, and now we can switch off some caloric power plants. But with more and more photovoltaics, you cannot switch off more caloric power plants than are switched on.

Here starts the second phase of the energy transition: the conversion of solar electricity into 24-electricity by batteries. This gives electricity in the night, but not enough in the winter. Even near the equator, several days with very dense clouds are expensive to cover with more batteries alone.

Here starts the third phase of the energy transition: power to methan/methanol. Power to methan when You have already enough infrastructure with big underground methane storage, and power to methanol for new or additional capacity.

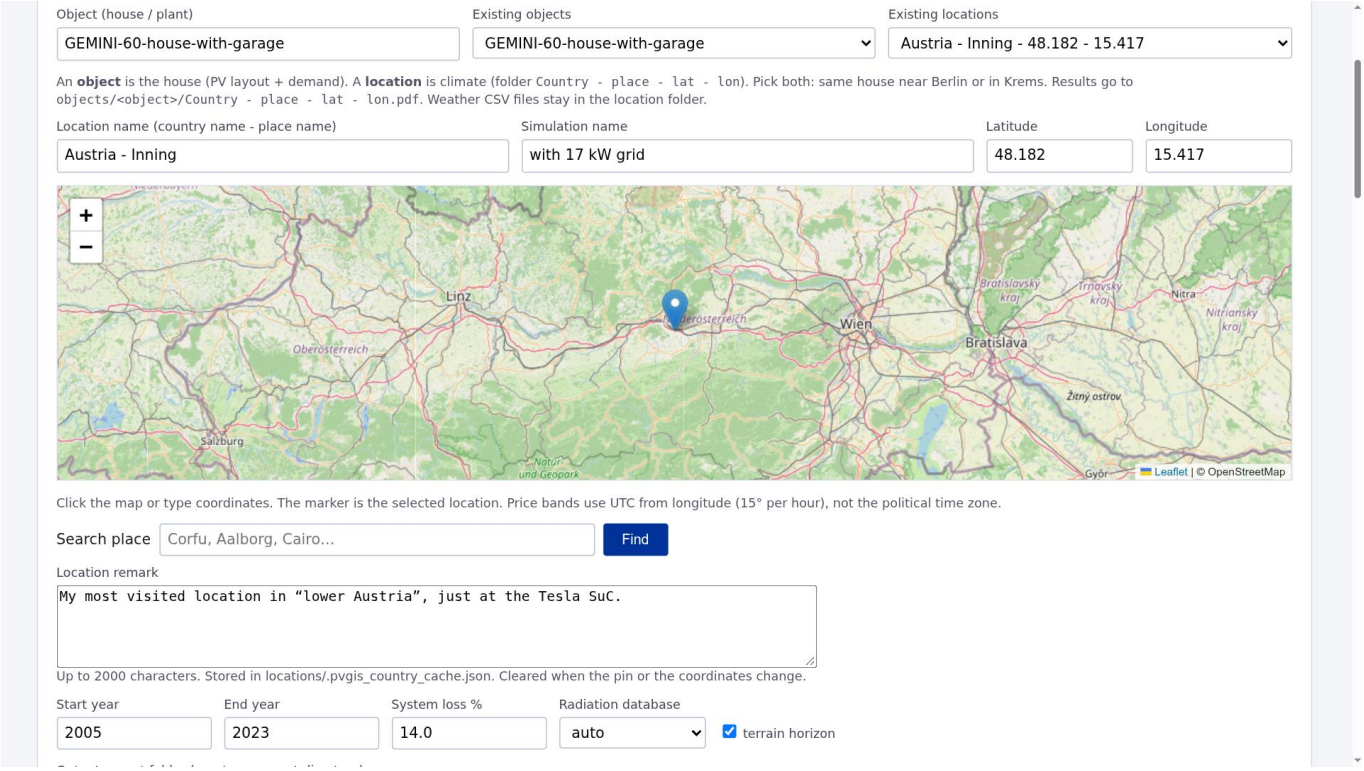
PEGE energy sim is the tool to simulate all ideas and plans against the harsh reality of physics and economics. Find your best solution before the money is spent.

Table of contents

Introduction....2
Menu ⇒ Object House: Location and the system loss....4
Menu ⇒ Object House: Photovoltaic definition....5
Menu ⇒ Object House: Demand - building....6
Menu ⇒ Object House: Demand - DHW....6
Menu ⇒ Object House: Demand - heat pump map....7
Menu ⇒ Object House: Demand - battery and cars....8
Menu ⇒ Object House: Efficiencies....9
Menu ⇒ Object House: Peak import allowance....10
Menu ⇒ Object House: Spot market price model....11
Examples: Just an apartment....12
Examples: Just an apartment - Fixed tariff, no PV, no battery....12
Examples: Just an apartment - Spot tariff, no PV, no battery....12
Examples: Just an apartment - Spot tariff and a 16 kWh battery, still no PV 12
Examples: Just an apartment - Add 3 kWp on the terrace railing....12
Examples: Just an apartment - Add the remaining strips, about 4 kWp in total....13
History: How time changes....13
Examples: Old house to improve....14
Examples: Old house to improve - Old house, first step: Start with an air heat pump only....14
Technic: The 5.6 kW air heat pump....14
Examples: Old house to improve - The Energy Warmth Garage....15

Examples: Old house to improve - EWG, full PV and the special heat pump....15
Examples: Old house to improve - Air-based wall heating....15
Examples: Old house to improve - Ventilation with heat recovery....15
Technic: How the PV is connected....16
Examples: Old house to improve - The whole step....17
Examples: Old house to improve - Hip roof and module geometry....17
Technic: What to do with 780 A?....18
Object house report: Hourly yield records of all PV together....18
Technic: By then, there were only 425 A left 18
Technic: By then, there were only 240 A left....18
Technic: Why at all low-volt 48 V batteries?....19
Technic: What is so great at low-volt 48 V systems?....19
Object house report: Hourly yield records of single PV fields....19
Examples: GEMINI 60 house with garage....20
Examples: GEMINI 60 house with garage - Inning - common example for Lower Austria....20
Examples: GEMINI 60 house with garage - Fürstenbrunn - only diffuse light in winter....20
Examples: GEMINI 60 house with garage - Grünheide - far more north....20
Examples: GEMINI 60 house with garage - Off-grid - just as autarkic test....20
Weather: Are cold days good or bad?....20
Examples: GEMINI 60 house with garage - The taxi driver coming home for lunch....21
Vision: Living near a major highway....21
Examples: GEMINI 60 house part of an energy-optimized settlement....22
Examples: GEMINI 60 house part of ... - Designed to be able to be the only energy source....23
Weather: Do not see it with North Europe in mind....23
Weather: 9 worldwide examples....23
Examples: GEMINI 60 house part of ... - Denmark - Aalborg....23
Examples: GEMINI 60 house part of ... - Austria - Inning....24
Examples: GEMINI 60 house part of ... - Greek - Corfu....24
Examples: GEMINI 60 house part of ... - Egypt - Cairo....24
Examples: GEMINI 60 house part of ... - Uganda Kampala....24
Examples: GEMINI 60 house part of ... - Nepal Kathmandu....24
Examples: GEMINI 60 house part of ... - Indonesia - Timika....24
Examples: GEMINI 60 house part of ... - Argentina - La Quiaca....24
Examples: GEMINI 60 house part of ... - China K2....24
Menu ⇒ Files: Rerun for versions compare....25
Menu ⇒ Object house: Stop a buggy simulation run....26
History: CORP 2025: Energy Optimized Settlements – Enabler for Necessary Civilization Targets....27
History: CORP 2026: Cost optimization – the key to energy transition and climate protection....27

Location and the system loss



The location is the climate. The name is country and place. The marker on the map, or the coordinates, set the place. The search box finds a place by its English name and moves the marker. The remark is stored with the location and appears on page 1 of the PDF.

The start and end year set the weather period. PVGIS returns hourly data for those years. The radiation database is usually left on auto. The terrain horizon uses the PVGIS horizon so nearby hills shade the arrays.

The last change in PVGIS was the period 2005 to 2020. The current version of PVGIS reaches 2023. As soon as a new PVGIS version with more years comes out, a new version of PEGE energy sim will offer to download a new version of all files in the locations folder and to rerun all simulations with the new data, including a compare of the differences.

The system loss is sent to PVGIS. The default is 14 %. PVGIS reduces the hourly yield by that amount before the data reach the simulation. The figure covers cable losses, inverter losses, dirt, and a small allowance for ageing. How much of the 14 % is the inverter is not known. The series is therefore not the first-year output of new modules. It is closer to an average over the life of the system.

The six efficiencies are applied after that. They cover paths PVGIS does not model. The direct PV to AC path overlaps only with the unknown inverter part of the 14 %. The rest of the 14 % is cables, dirt and ageing, which the six efficiencies do not repeat.

Photovoltaic definition

Up to 25 arrays. Empty rows are ignored. Azimuth: 0 = south, 90 = west, −90 = east, 180 = north. Southwest = 225, opposite face = 45. Wall: integer metres, empty = no extra shade. Width is 10× distance. Cache suffix is _s80 = 100 × height/distance (d5h4 and d10h8 are the same file). Bifacial: fills the next row as face 2 (azimuth + 180°, junction-box / rear side). Face 2 Wp = front × bifaciality % (default 80). Both yields are added; nameplate Wp is counted once. Put the front (no junction box) toward the open field; face 2 toward the house.

Use ↑ ↓ to change the order. Clearing a name and leaving the field clears that row.

#	Use	Name	Slope °	Azimuth °	Wp	Wall dist. m	Wall height m	Bifacial	Bi %
↑ ↓	☑	Roof East	22.0	-90.0	19800.0	m	m	☐	80
↑ ↓	☑	Roof West	22.0	90.0	19800.0	m	m	☐	80
↑ ↓	☑	Terrace railing south	90.0	0.0	4620.0	5	4	☐	80
↑ ↓	☑	Terrace railing north	90.0	180.0	4620.0	5	4	☐	80
↑ ↓	☑	Garage roof	1.0	0.0	10740.0	m	m	☐	80
↑ ↓	☑	Garage side wall south	90.0	0.0	3475.0	5	4	☐	80
↑ ↓	☑	Garage side wall north	90.0	180.0	3475.0	5	4	☐	80
↑ ↓	☑	Garage door side west	90.0	90.0	700.0	5	4	☐	80
↑ ↓	☑	Garage back side east	90.0	-90.0	2540.0	5	4	☐	80
↑ ↓	☑	Garden fence east	90.0	-90.0	6000.0	5	4	☑	80
↑ ↓	☑	Garden fence east face2	90.0	90.0	6000.0	5	4	☐	80
↑ ↓	☑	e.g. Garden fence SW				m	m	☐	80
↑ ↓	☑	e.g. Garden fence SW				m	m	☐	80
↑ ↓	☑	e.g. Garden fence SW				m	m	☐	80

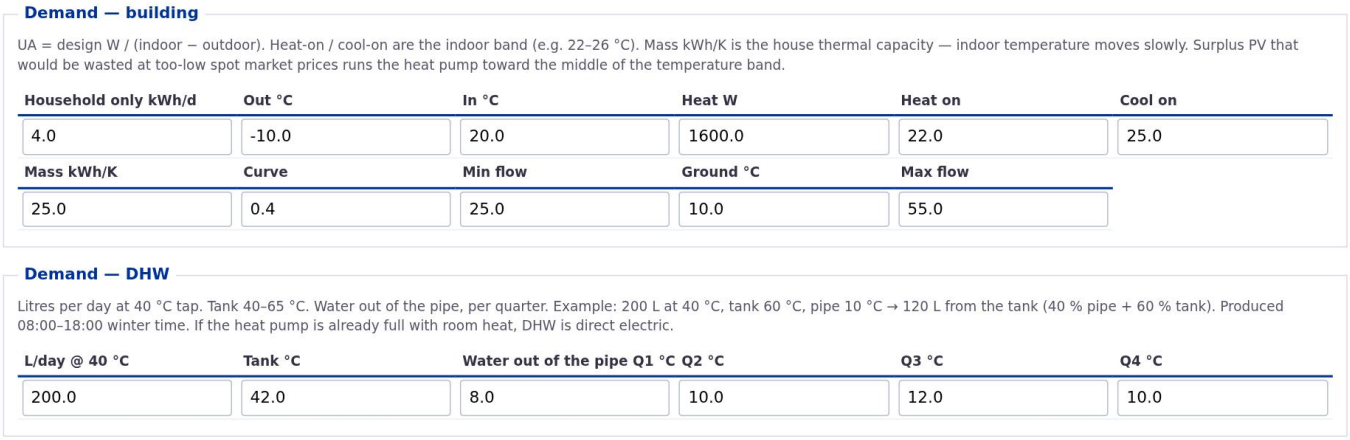
Up to 25 arrays can be entered. Empty rows are ignored. The arrows change the order of the rows. Clearing the name and leaving the field clears the rest of that row.

The slope is the tilt from horizontal. The azimuth is the direction: 0 is south, 90 is west, −90 is east, 180 is north. Southwest is 225. The opposite face is 45 from the front.

Wp is the nameplate power of the array. The wall distance and wall height are integer metres. They are empty when there is no extra shade from a wall. The shade width is ten times the distance. The cache suffix is _s80 when the height is 80 % of the distance. A wall of 5 m distance and 4 m height is the same file as 10 m and 8 m.

Bifacial fills the next row as face 2. Face 2 has the azimuth plus 180° and is the junction-box or rear side. Face 2 Wp is the front Wp times the bifaciality percent. The default is 80. Both yields are added. The nameplate Wp is counted once. Put the front, the side without the junction box, toward the open field. Put face 2 toward the house.

Demand - building



The household field is the electricity used by the house itself, in kWh per day. It does not include heating, cooling, or hot water.

The design outdoor temperature, indoor temperature, and heat demand in watts set the heat loss of the building. UA is the design heat divided by the difference between indoor and outdoor. The heat-on and cool-on temperatures are the indoor band. The heat pump starts when the indoor temperature leaves that band.

The mass in kWh/K is the thermal capacity of the house. A larger mass means the indoor temperature moves more slowly. Surplus PV that would be wasted at too-low spot market prices runs the heat pump toward the middle of the temperature band.

The curve is the slope of the heating curve. A lower slope means a lower flow temperature for the same outdoor temperature. Min flow and max flow limit the flow temperature. The ground temperature is used when the heat pump can take heat from the ground. When the outdoor air is warmer than the ground, the heat pump uses air. When the air is colder, it uses the ground.

If the heat pump cannot cover the room heat, the remaining heat is made by direct electric.

Demand — DHW

The litres per day are at 40 °C at the tap. The tank is between 40 °C and 65 °C. The water out of the pipe is given for each quarter of the year. A mix of cold pipe water and hot tank water reaches 40 °C. The example is 200 L at 40 °C, a tank at 60 °C, and pipe water at 10 °C. That needs 120 L from the tank.

Hot water is produced between 08:00 and 18:00 winter time. If the heat pump is already full with room heat, the remaining hot water is made by direct electric.

Demand - heat pump map

Demand — heat pump map

Source: air, ground, or air and ground (heat uses the warmer, cool the colder). COP and max heat kW at −10 / 0 / +10 °C vs flow 35 °C and 50 °C. Cooling = map at 35 °C, COP × 0.9.

Heat-pump source

air and ground

Source	COP @ 35 °C	kW @ 35 °C	COP @ 50 °C	kW @ 50 °C
-10 °C	2.4	4.0	1.9	3.5
0 °C	3.4	5.0	2.6	4.5
10 °C	4.5	6.0	3.3	5.0

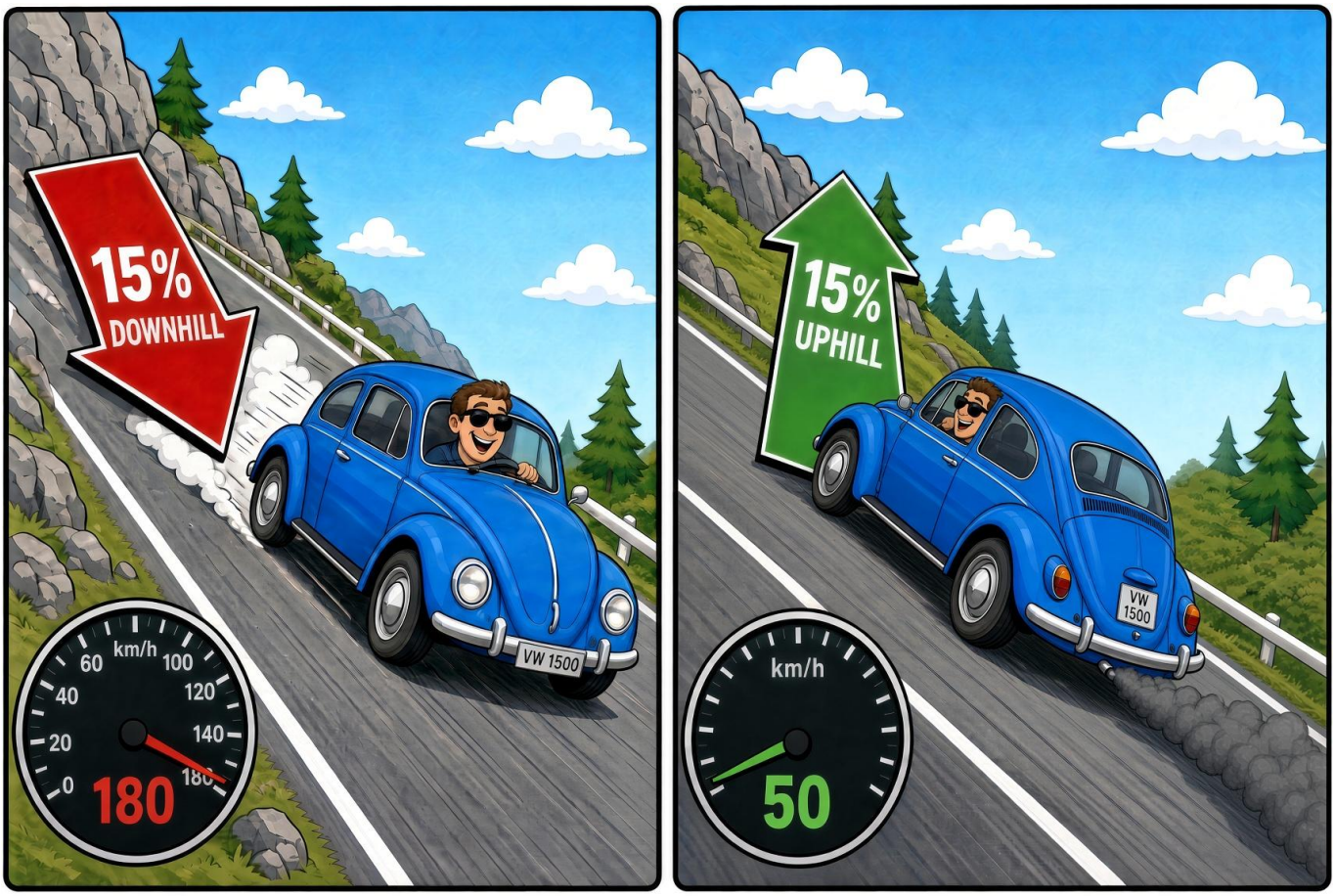
A heat pump's catalogue number is not the heat it delivers on the design day. A 5.6 kW unit is usually rated at A5/W35: 5 °C outside air, 35 °C flow. That is a mild day and a low-temperature floor. It is the downhill figure. A VW Beetle can also be said to do 180 km/h — at 15 % downhill.

The design day is the uphill. The house needs 4 kW at −10 °C outside and 20 °C inside. An old radiator circuit may want 60 °C flow, and a cold night can be −20 °C. For an air heat pump those are exactly the 15 % uphill. Output falls as the source gets colder and as the flow gets hotter. At the design point the same machine may give 3 kW, or less, and the rest comes from the electric backup.

The table shows all situations: uphill, flat and downhill. Three source temperatures, −10, 0 and +10 °C, against two flow temperatures, 35 and 50 °C. Each cell has the COP and the maximum heat in kW. The simulation looks up the hour's source and flow, and takes the heat and the COP from there. Above the map's maximum, the backup heater covers the rest.

The source can be air, ground, or both. Both means heat uses the warmer of the two and cooling uses the colder. Ground stays near its set temperature. Air follows the weather, so an air machine loses output on the coldest hours.

Cooling uses the 35 °C column, with the COP reduced by 10 %.



Demand - battery and cars

Demand — battery and cars

Battery kWh	Charge C-rate	SOC min %	Plan SOC min %	SOC max %	Start SOC %
176.8	0.5	5	12	95	50

Nameplate: 11 x 51.2 V x 314 Ah

Inverter AC kW	Grid connection kW	DC charger kW	Night AC charger kW	Max export kW	Lunch 12–13 kWh DC	Night 20–07 kWh AC
34.0	17.0	40.0	11.0	17.0	0.0	10.0

The battery size is the usable kWh. The C-rate is how fast it may be charged and discharged: 0.5 on 176.8 kWh is about 88 kW. SOC min is the floor the battery is never taken below. Plan SOC min is the target the EMS keeps for ordinary days. SOC max is the ceiling. Start SOC is only the state at the first hour of the run.

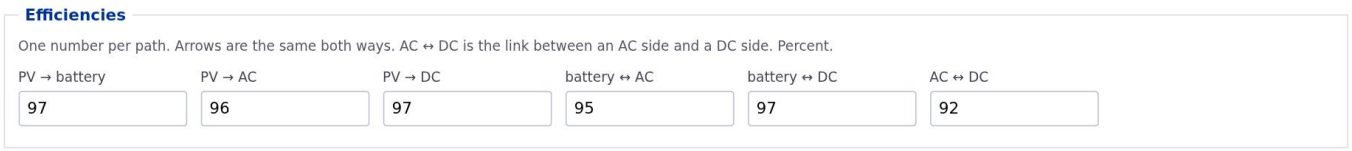
The nameplate is a note, for example 11 modules of 51.2 V and 314 Ah. It is not used in the calculation.

Inverter AC kW is the power the inverters can make on the AC side. Grid connection kW is the power the house may exchange with the grid. These two are not the same. A house can have two inverters and only one of them connected to the grid. The second serves the house and the battery. In that case the inverter figure is larger than the grid figure. Here, 34 kW of inverter and 17 kW of grid connection.

Max export kW is a further limit on what may leave the house. A grid operator can cap the feed-in below the connection size. In Lower Austria that cap can be 4 kW, even on a larger connection. Set Max export to that number. The simulation will not sell more than this, whatever the inverter and the grid connection allow.

DC charger kW is the fast charger at lunch, 12 to 13. Night AC charger kW is the wall box, 20 to 07. The two kWh fields are the energy those chargers take: lunch on DC, night on AC. A taxi that comes home at noon and plugs into 50 kW puts that load on the lunch field. The night field is the slow charge.

Efficiencies



Every path the energy takes has its own loss. One number would hide that. PV into the battery is a DC-DC step. PV onto the AC side passes an inverter. PV onto a DC bus is another converter. The battery leaving toward AC, or toward a DC charger, is not the same step either. AC into DC, the link between the two sides, is usually the least efficient of the set.

Each field is that one path, in percent. An arrow is the same in both directions. 97 means 3 % is lost on the way.

The split matters once the house is no longer the only object. A community can have a DC bus between houses, a DC charger, and an AC grid. Energy can then take more than one route to the same load, and the route decides the loss. Charging a car from PV over the DC path is not the same as charging it from the battery over AC and back. The six numbers keep those routes apart, so a later community run can add them instead of inventing a new model.

Peak import allowance

Grid targets and prices

Monthly import kW is a design target. Grid is unlimited; overflow = emergency import. Currency in Your units. No currency sign is drawn. Prices are cent per kWh. Summer April–September, winter October–March. Workday Monday–Friday, weekend Saturday–Sunday, clock is winter time. High 06:00–09:00 and 17:00–20:00, low 09:00–15:00, medium the rest. Example: spot 2 cent → export 2 − 2 handling − 1 Ausgleichsenergie = −1, import 2 + 2 handling + 10 grid = 14. Do not sell when export is negative. At 0 cent, export PV yield only, not the battery. Peak fee is per kW per month of the highest import hour (hourly stand-in for the 15-minute peak). Burgenland 76 / 12 = 6.33. It is added to that month's import. Fixed tariff > 0: no export, import only at this price. 0 = use the spot table.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

Peak fee / kW / month	Fixed tariff cent/kWh	
6.33	0.0	>0 = no export, import only at this price. 0 = spot table.

For a long time, only industry paid for peak demand. A factory that drew a high load for a few minutes a month forced the grid to build lines and transformers for that peak, so the bill had two parts: energy in kWh, and a fee per kW of the highest quarter-hour in the month. A steady load was cheap. A short spike was expensive.

That rule is now reaching private households. Heat pumps, car chargers and electric cooking can push a house over the same kind of limit that used to apply only to workshops. More countries add a monthly fee on the highest import of the month, measured over 15 minutes.

Burgenland is the example used here, because its peak fee is among the steepest. €76 a year per kW is €6.33 a month.

The twelve fields are the import the EMS should schedule, one kW cap per month. Planned import stays inside that cap. Import above it is emergency import, and it sets the peak fee for the month.

An air heat pump needs a higher cap in winter. In deep cold its output falls, and it can fall back to plain electric heating. A summer cap that is right for the house will then be too low, and the winter months will be full of emergency import. Raise the cold months, and leave the mild months low.

Below the twelve fields is the monthly fee per kW of peak. If every month of the year hits the same peak, the year is twelve times that number.

Spot market price model

Peak fee / kW / month: 6.33

Fixed tariff cent/kWh: 0.0

>0 = no export, import only at this price. 0 = spot table.

Season	Day	Flow	High	Medium	Low
Summer	Workday	Import	40.0	25.0	18.0
Summer	Workday	Export	22.0	7.0	3.0
Summer	Weekend	Import	30.0	22.0	12.0
Summer	Weekend	Export	12.0	4.0	-3.0
Winter	Workday	Import	40.0	27.0	24.0
Winter	Workday	Export	22.0	9.0	6.0
Winter	Weekend	Import	30.0	24.0	21.0
Winter	Weekend	Export	12.0	6.0	3.0

Around 2000, solar was thought to be at its most valuable at noon. Demand peaked then, and that is also when a panel delivers most. The two seemed to meet.

The hourly day-ahead prices in Germany showed the first small dent at noon in 2009. Each year after that the dent grew. By now it is a deep solar valley: the middle of a sunny day is often the cheapest hour, and on some days the price goes to zero or below. The old argument has turned around. Noon is no longer the scarce hour. The scarce hours are the morning and the evening, when the panels give little and the demand is still there.

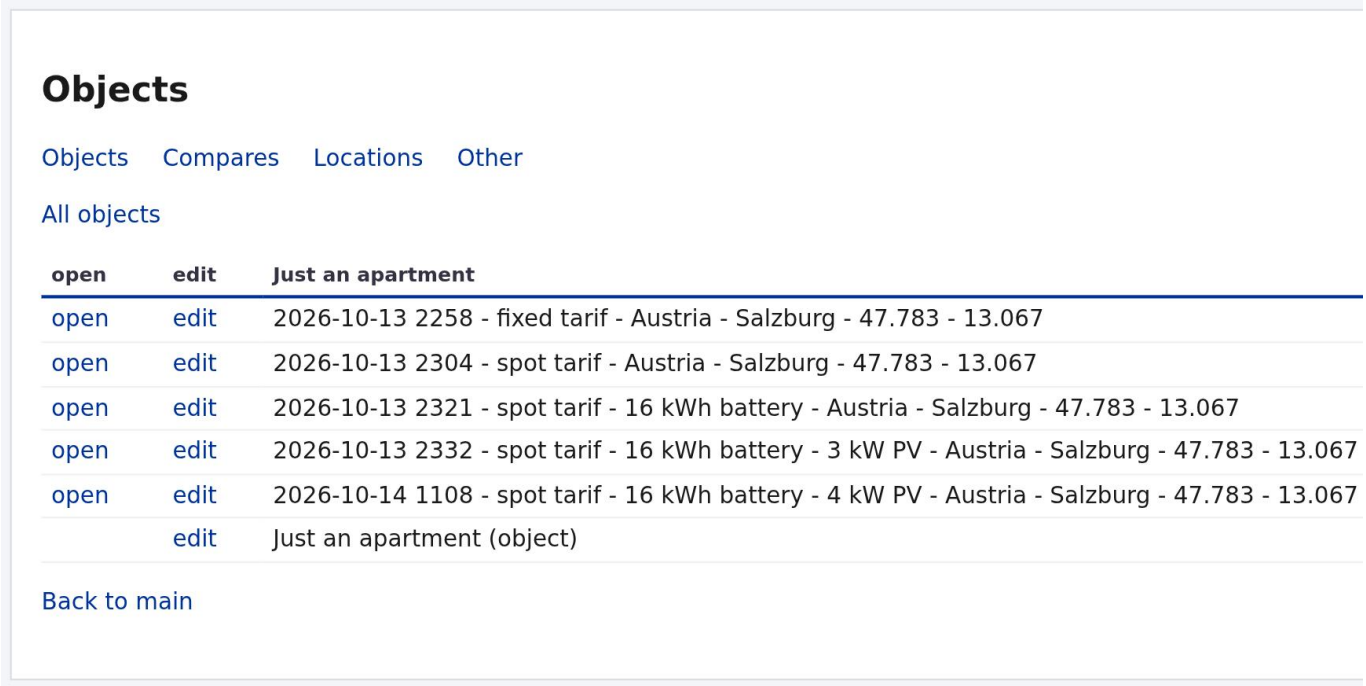
The table has 24 prices: summer and winter, workday and weekend, import and export, high, medium and low. Summer is April to September. A negative export price means the house would pay to push energy out.

Import and export differ because they are not the same transaction. On top of the spot price sit a handling fee, the balancing charge (something special at Spotty.App), and, on import, the grid fee. A spot price of 2 cent can be 14 cent to buy and −1 cent to sell. The table holds the result, not the spot price itself. Fixed tariff is the alternative: one price, no table, for a run that should be compared with a plain contract.

The EMS sells only when the export price is above zero. At zero, only PV yield leaves, never the battery. A negative price is not sold.

Just an apartment

Menu Files ⇒ Just an apartment



Objects

Objects Compares Locations Other

All objects

open	edit	Just an apartment
open	edit	2026-10-13 2258 - fixed tarif - Austria - Salzburg - 47.783 - 13.067
open	edit	2026-10-13 2304 - spot tarif - Austria - Salzburg - 47.783 - 13.067
open	edit	2026-10-13 2321 - spot tarif - 16 kWh battery - Austria - Salzburg - 47.783 - 13.067
open	edit	2026-10-13 2332 - spot tarif - 16 kWh battery - 3 kW PV - Austria - Salzburg - 47.783 - 13.067
open	edit	2026-10-14 1108 - spot tarif - 16 kWh battery - 4 kW PV - Austria - Salzburg - 47.783 - 13.067
	edit	Just an apartment (object)

Back to main

Fixed tariff, no PV, no battery

Import is about 97 000 kWh over 19 years, roughly 5 100 kWh a year. At 38 cent the bill is about 2 025 currency units a year, including the peak fee. The car is charged at the same price as every other hour.

Spot tariff, no PV, no battery

The same electricity costs about 1 431 a year. The main gain is the car. Night charging is allowed from 20:00 to 07:00. The preferred hours are the medium-price hours 00:00 to 06:00. A 2 kW charger and 10 kWh fit entirely in that window. The fixed tariff has no such window. That is most of the difference between 2 025 and 1 431.

Spot tariff and a 16 kWh battery, still no PV

The battery is charged at low-price hours and used at high-price hours. Import rises from about 97 100 kWh to about 103 100 kWh over 19 years. The extra kilowatt-hours are the round-trip losses of the battery. The peak fee also rises, because the battery still has to be filled in a few hours. The yearly bill falls only from about 1 431 to about 1 361. That is roughly 70 a year. The main reason for so little gain is the efficiency: more electricity is imported than is used. A 16 kWh battery does not save enough to pay for itself when there is nothing to store except the price difference. The car was already charged in the medium-price hours without a battery.

Add 3 kWp on the terrace railing

The railing is vertical, 90°. Import falls to about 852 a year including the peak fee. Export earns about 17. The net bill is about 835. Compared with the spot tariff alone, that is roughly 600 a year less. The PV is profitable. The battery now has something to store: the midday yield that would otherwise be exported at a low price, or wasted. The terrace railing is south facing and unshaded, but it is only 3 kWp. That is the limit of the place.

Add the remaining strips, about 4 kWp in total

The strip above the windows is better than the railing: 60° instead of 90°. The wall toward the neighbour is again 90° and turned away. Import falls further, to about 755 a year including the peak fee. Export earns about 46. The net bill is about 709. The extra kilowatts still help, but the gain is smaller. The additional faces are smaller, and one of them faces the neighbour. The apartment is south facing and free of shadow, and still the useful area is small. PV is profitable. It is also limited by the building.

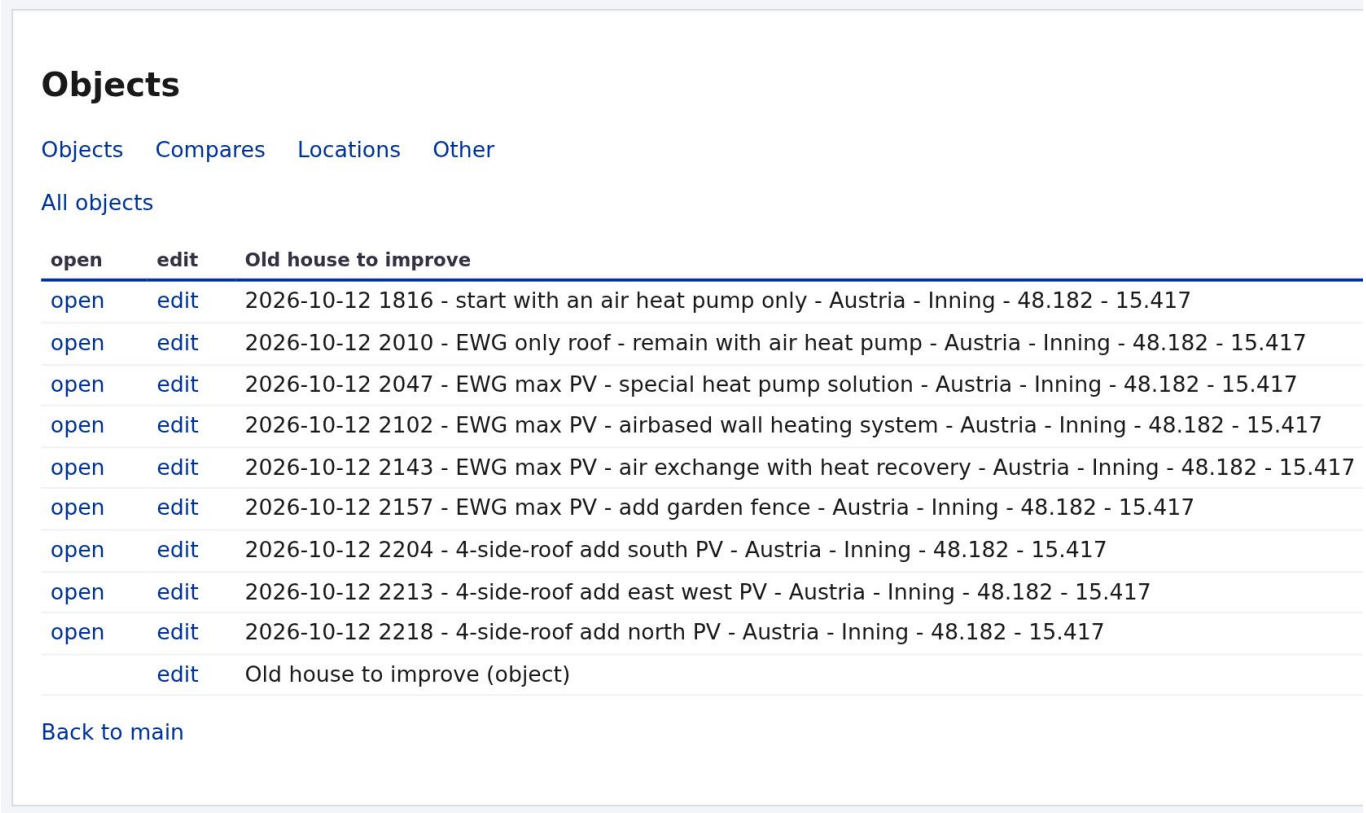
How time changes

In 1998 a solar pioneer in South East Styria built a zero-energy house in Halbenrain. The south roof carried 48 m^2 of solar collectors and, below them, 24 modules that made 2.1 kWp of PV. That PV cost as much as a small car. The house was oriented for the sun, the south pitch was 48° for the winter, and two large tanks stored heat for the season. The electricity bill was negative. There had been a very different price model.

Today we look at a one-room apartment and call 4 kWp far too little. The limit is not the price of the modules. The limit is the usable surface: a terrace railing, a strip above the windows, a wall toward the neighbour. In 1998, 2.1 kWp was a statement. In 2026, 4 kWp on an apartment is what the building allows, and it is still not enough to cover the year. The modules have become cheap. The roof has not grown.

Old house to improve

Menu Files ⇒ Old house to improve



Objects

Objects Compares Locations Other

All objects

open	edit	Old house to improve
open	edit	2026-10-12 1816 - start with an air heat pump only - Austria - Inning - 48.182 - 15.417
open	edit	2026-10-12 2010 - EWG only roof - remain with air heat pump - Austria - Inning - 48.182 - 15.417
open	edit	2026-10-12 2047 - EWG max PV - special heat pump solution - Austria - Inning - 48.182 - 15.417
open	edit	2026-10-12 2102 - EWG max PV - airbased wall heating system - Austria - Inning - 48.182 - 15.417
open	edit	2026-10-12 2143 - EWG max PV - air exchange with heat recovery - Austria - Inning - 48.182 - 15.417
open	edit	2026-10-12 2157 - EWG max PV - add garden fence - Austria - Inning - 48.182 - 15.417
open	edit	2026-10-12 2204 - 4-side-roof add south PV - Austria - Inning - 48.182 - 15.417
open	edit	2026-10-12 2213 - 4-side-roof add east west PV - Austria - Inning - 48.182 - 15.417
open	edit	2026-10-12 2218 - 4-side-roof add north PV - Austria - Inning - 48.182 - 15.417
	edit	Old house to improve (object)

Back to main

Old house, first step: Start with an air heat pump only

The example is a 1960 house, 8.5 × 8.5 m, Walmdach. Before any work it needed 16 kW at −10 °C outside and 20 °C inside. After 12 cm EPS WLG 32 on the walls, 20 cm mineral wool under the roof, and very good new windows, that falls to 4 kW.

We start after the thermal improvement, because the other order makes no sense.

A heat pump sized for the old house would be about 20 kW. Its inverter range is roughly 5 to 20 kW. After the insulation the house needs 4 kW, which is below the minimum the machine can run. It would cycle all winter, loud and inefficient, and the investment in the large unit would be wasted.

So the sequence is fixed by the physics. First reduce the demand. Then size the heat pump to what remains. A machine chosen for 16 kW cannot serve a 4 kW house.

The 5.6 kW air heat pump

This run is the house after the thermal improvement, with nothing else: no PV, no battery, only an air heat pump. The design load is 4 kW at −10 °C outside and 20 °C inside. The machine is a 5.6 kW unit, the size that looks right on a catalogue.

The map shows why it is not. At −10 °C and 50 °C flow it delivers 3.5 kW, at a COP of 1.9. The design day already exceeds it. The rest is direct electric.

Over the years the backup averages 1228 kWh, and in a hard year 2612 kWh. January alone averages 408 kWh of direct electric, with a worst day of 69 kWh. The heat pump's own electricity averages 4437 kWh a year. There is no PV and no battery, so all of it is import: about 2790 kWh a year on average, up to 3325 kWh, and the peak-fee months follow the cold.

The 5.6 kW choice is the downhill number again. A5/W35 says 5.6 kW. The design day says 3.5 kW. The gap is the direct electric, and it is large enough that the small machine does not save the house from a heavy winter bill. A larger unit, or a ground source, would close it. The next steps of the improvement add PV and a battery, which can cover part of the backup, but they cannot change the fact that the heat pump itself is short on the coldest hours.

The Energy Warmth Garage

There is room beside the house for an EWG, an Energy Warmth Garage. The first PV goes on its roof, 10.7 kWp, nearly flat, facing south. A 45 kWh battery sits in the garage, with a 12 kW inverter.

Why not the house roof first? A 45 kWh battery has strict fire rules. It does not belong in the living space or in an ordinary attic. The EWG is built for it: the battery, the inverter and the chargers are outside the house, in a space made for the heat and the risk. The house roof can wait. Its Walmdach is also the harder place to cover, with four slopes.

This step leaves the heat pump as it was. The 5.6 kW air unit is still short on the cold days, and the direct electric is unchanged: about 1228 kWh a year on average, up to 2612 kWh. What changes is where the electricity comes from. The garage roof covers a large part of the import, and the battery shifts it out of the expensive hours and under the monthly kW cap. The peak-fee months shrink. The backup itself does not.

So the improvement is real, and incomplete. The PV and the battery attack the bill. They do not fix the machine that is too small for the design day. That is the next decision: a larger heat pump, or a ground source, once the EWG is in place.

EWG, full PV and the special heat pump

All four walls of the garage now carry PV, on top of the roof. South and north walls 3.5 kWp each, the back 2.5 kWp, the door side 0.7 kWp. With the 10.7 kWp roof that is 20.9 kWp. The battery stays 45 kWh.

The air heat pump is replaced by a water-to-water heat pump built into the garage, with a special air-to-water heat exchanger. The ground under the garage is a low-temperature store. When the air is warmer than the ground, the machine uses air. When the air is colder, it uses the ground.

The software does not yet model this in detail. Later versions will. For now the ground is held at the temperature you type, here 10 °C, and the machine takes the warmer source for heat and the colder for cooling. On a −10 °C day it no longer sees −10 °C air. It sees 10 °C ground, so the COP and the output stay near the mild column of the map. The direct electric shrinks, and the import caps can be set lower.

Air-based wall heating

The old radiators are replaced by an air-based wall heating system. Radiators cannot cool. A floor used for cooling gives cold feet. Walls, and ceilings, can do both.

The heat curve slope falls from 1.0 to 0.4. A slope of 1.0 means the flow rises one degree for every degree the outside falls. At −10 °C that pushes the flow toward 50 °C or more, which is where an air heat pump loses output and COP. A slope of 0.4 keeps the flow lower on the cold days. The same heat leaves the wall at a lower temperature, so the heat pump stays in the better part of its map.

The design load is still 4 kW. What changes is the temperature at which that heat is delivered. Lower flow, higher COP, less direct electric on the cold days. Cooling becomes possible in summer without a separate system.

Ventilation with heat recovery

The next step is controlled ventilation. Fresh air still enters, but the heat in the exhaust is kept. The design load falls from 4 kW to 3.3 kW at −10 °C outside and 20 °C inside.

The units are single-room, not a central plant. A central system with ducts belongs in a new building drawn around it. An old house gets a small unit in the outside wall of each room that needs air.

Each unit has a ceramic core and a reversible fan. The fan pushes room air out. The core takes the heat. Then the fan reverses, pulls fresh air in, and the core gives the heat back. A typical unit moves 20 to 64 m^3/h, uses about 12 W, and recovers up to about 97 % of the heat. Filters keep dust and insects out. Noise stays low.

Because less heat leaves with the air, the heat curve can be flattened again, from 0.4 to 0.35. The wall system delivers the remaining 3.3 kW at a still lower flow temperature. On the cold days the heat pump stays further from the bad corner of its map.

The import cap can now be 3 kW in every month. The house, the heat pump and the ventilation together fit under it on ordinary days. Emergency import becomes rare. The EWG, the PV, the battery and the special heat pump are already in place. This step only reduces what they have to cover.

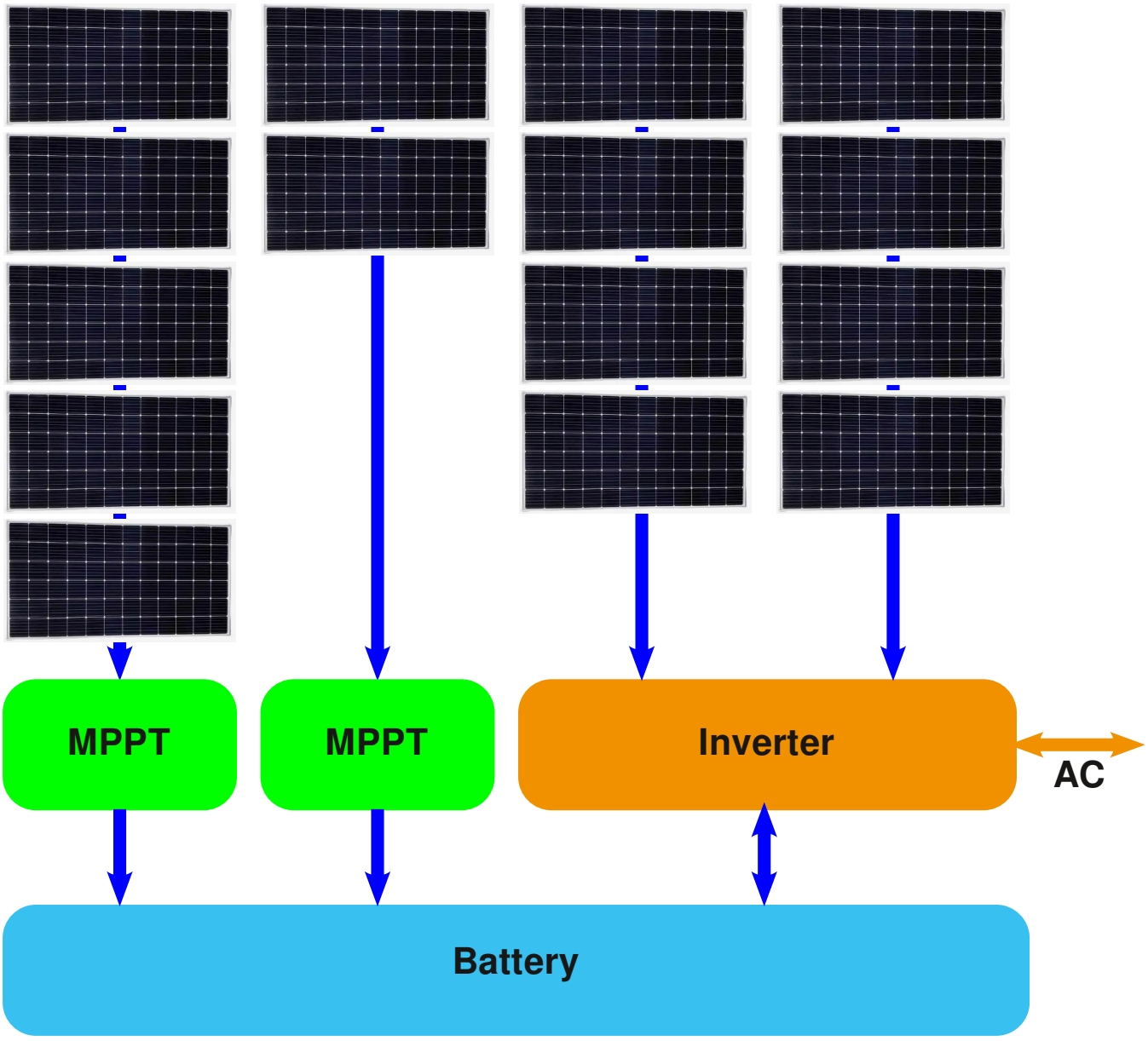
How the PV is connected

An inverter has only a few PV inputs. At 20.9 kWp on a 12 kW inverter, most of the modules cannot go there. The limit is not only the power. It is the number of strings the inverter will accept.

Most of the PV is therefore connected by an MPPT straight to the battery. An MPPT is a DC-DC converter. It takes the voltage and current of its string and sets them to what the battery needs. The energy never passes the inverter on the way in. Several MPPTs can feed the same battery, so the number of strings is no longer limited by the inverter.

The inverter still has its own PV inputs. It also links the battery to the AC side, for the house and for export. The orange arrow right on the diagram is that link.

This is why more PV can be added later, on the fence or elsewhere, without a larger inverter. Each new field gets its own MPPT to the battery. The inverter stays at 12 kW, which is also the grid connection and the export limit.



The whole step

The house starts after the thermal improvement: 4 kW design load, a 5.6 kW air heat pump, no PV, no battery. On a cold day the machine sees cold air and needs direct electric. The highest import day is 113 kWh. Average import is about 10 300 kWh a year. There is no export.

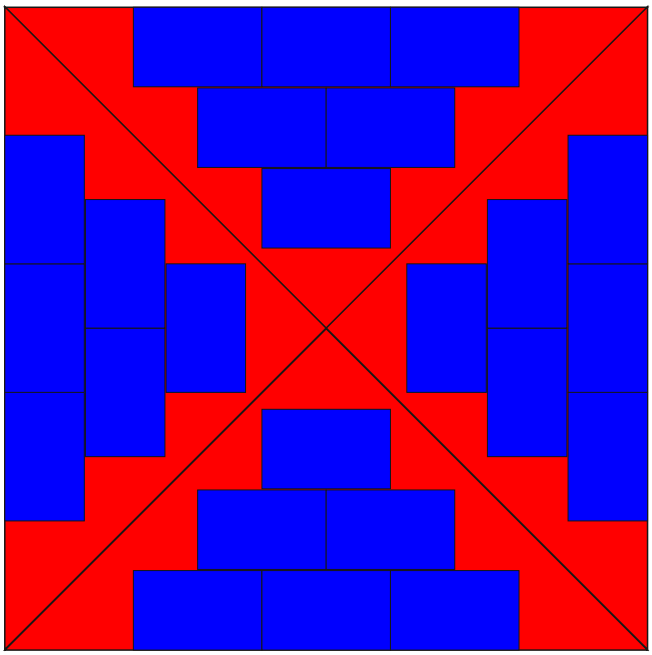
The end of the house story is different. The EWG holds a 60 kWh battery and a water-to-water heat pump with a special air-to-water exchanger and a ground store. Wall heating runs at slope 0.35. Single-room ventilation with heat recovery cuts the design load to 3.3 kW. PV covers the garage, a bifacial garden fence, and all four faces of the hip roof. Counted peak is 38.9 kWp. Average export is about 15,900 kWh a year, import about 1 280 kWh. The money balance is about € 1,490 a year: export earnings minus import including the peak fee. The highest import day falls from 113 kWh to 36 kWh.

If every house kept a small air heat pump on a cold day, the grid would need new lines for those hours, and the hours would no longer be few. Peak fees price that load. A house that stays under a low cap on the cold day does not ask for the extra line.

Summer export is larger than winter import. Version 1.0 will add community runs: power to methane or methanol, underground storage, and a combined-cycle plant. The chain is house to grid, to power-to, to storage (with the energy to press methane), to the plant, to the grid, to the house. That answers whether the summer surplus of one house is large enough, after the losses, to cover its own winter import.

Hip roof and module geometry

A “Walmdach” is a hip roof. All four sides slope to the walls. The hips are the diagonal lines where two faces meet. On an 8.5 × 8.5 m house at 22° the four faces are trapezoids, wider at the eaves and narrower at the ridge.



The modules are rectangles, 1.134 × 1.700 mm, 500 W each. A rectangle does not fill a trapezoid, and it does not cross a hip. Each face is cut by two diagonal boundaries. Modules that would cross a hip are left out. The corners of each face, and the strips along the hips, stay empty. That is the red area.

Six modules fit on each face, 3 kWp per face, 12 kWp on the roof. The wasted area is the price of the shape: four sloping faces, four hips, and rectangular modules that cannot be cut. A gable roof with two large rectangles would take more modules on the same floor area. The hip roof takes fewer, and leaves the red triangles.

What to do with 780 A?

With all the garage, garden fence, and roof, 38,930 Wp installed. Handling this in a low-voltage 48 V system seems to be insane. What cable to handle 780 A?

Really 780 A? The PV-modules are in many different directions. What could be the highest possible yield at the same time? We see this in the objects simulation report PDF.

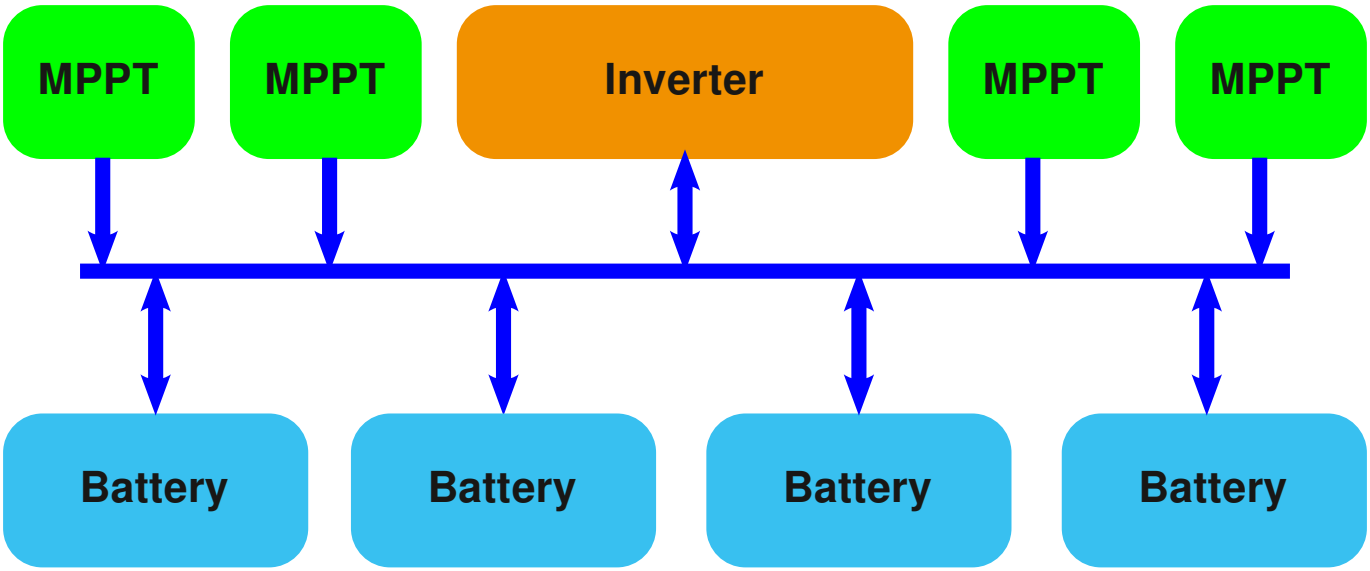
Records 1–10 — contribution of each PV
Austria - Inning 48.182, 15.417

PV	2012-05-18 09:10	2016-05-17 09:10	2013-05-13 09:10	2006-05-25 09:10	2009-06-13 09:10	2020-05-07 09:10	2021-05-26 09:10	2009-06-03 09:10	2009-06-04 09:10	2017-04-30 09:10
Garage roof	7617	7574	7581	7713	7701	7489	7689	7640	7498	7365
Garage side wall south	1509	1520	1561	1424	1299	1625	1409	1339	1342	1723
Garage side wall north	178	202	171	137	175	155	111	168	228	141
Garage door side	36	41	34	28	35	31	22	34	46	28
Garage back side	1114	1115	1118	1098	1102	1124	1094	1086	1086	1146
Garden fence east	2632	2634	2642	2595	2604	2654	2585	2564	2566	2708
Garden fence east face2	245	279	236	190	242	214	154	232	315	195
Roof south	2331	2321	2341	2343	2304	2341	2329	2301	2251	2330
Roof east	2335	2323	2333	2363	2357	2318	2351	2338	2288	2290
Roof west	1626	1621	1604	1643	1654	1563	1640	1638	1629	1519
Roof north	1637	1629	1602	1673	1721	1544	1672	1687	1677	1478
Watt at record	21261	21257	21223	21206	21194	21058	21057	21028	20926	20923
Percent of installed peak	54.6	54.6	54.5	54.5	54.4	54.1	54.1	54.0	53.8	53.7

By then, there were only 425 A left

This is from the object simulation report PDF. The record of all PV-fields together is only 21,261 W. So only 425 A instead of 780 A.

Do we need a 425 A wireing for this? No.



By then, there were only 240 A left

The 12 kW inverter is the strongest single connection from all. These are the 240 A. Less than 30% of the first estimation. Down to a recommended 30 × 5 mm copper or 40 × 6 mm aluminum.

In the simulation “Old house to improve”. was the change from 3 × 15 kWh to 4 × 15 kWh batteries at starting with the house roof.

Why at all low-volt 48 V batteries?

The most common battery box has 16 cells and 51.2 V nominal. This battery boxes can be organized with a serial connection or parallel connection.

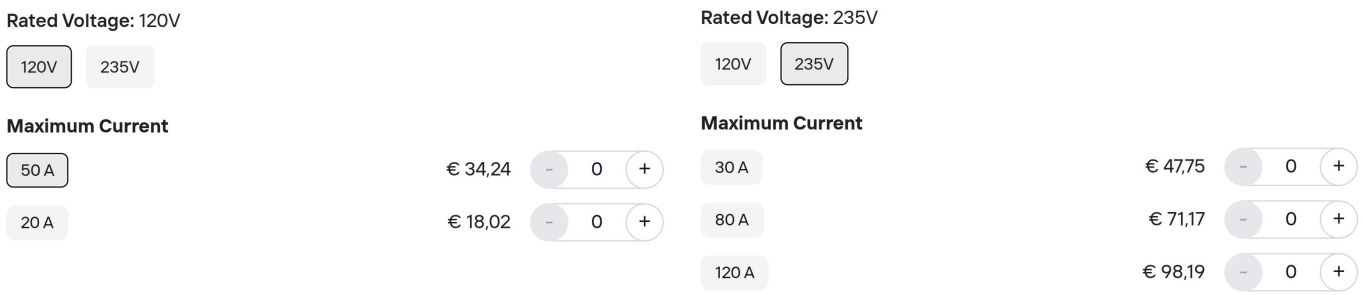
Battery boxes for serial connection have to be certified for serial connection. This makes a battery box more expensive. Serial connected systems also require a combiner box.

So my personal design decision is 60 kWh as the border between low-voltage and high-voltage BESS.

BTW, the first design of the GEMINI next Generation was designed for a low-voltage BESS. The house was smaller and carried only 23 kW photovoltaic. As the photovoltaic increased beyond 32 kW, I changed the design to high-voltage BESS.

What is so great at low-volt 48 V systems?

A huge market for MPPT. I tried summer 2026 to find MPPT for high voltage BESS. No success. It would be easy to produce it. Common technic. Each inverter has several MPPT built in. They are simple not on the market.



Rated Voltage means the maximum allowed VOC (open-circuit voltage) from the photovoltaic. 120 V means 2 standard 1134 × 2378 mm solar panels in series. 235 V means 4 standard 1134 × 2378 mm solar panels serial.

The A means charging current towards a 48 V battery. Take the price times 3 as end user price. You find somewhere a place for 2 × 1134 × 2378 mm 660 W solar panels? Just connect them with a maybe € 54 end user price MPPT to the battery.

But 50 V × 20 A are only 1000 W and 2 × 660 W is 1320 W. What now? Find out on the next object simulation report page.

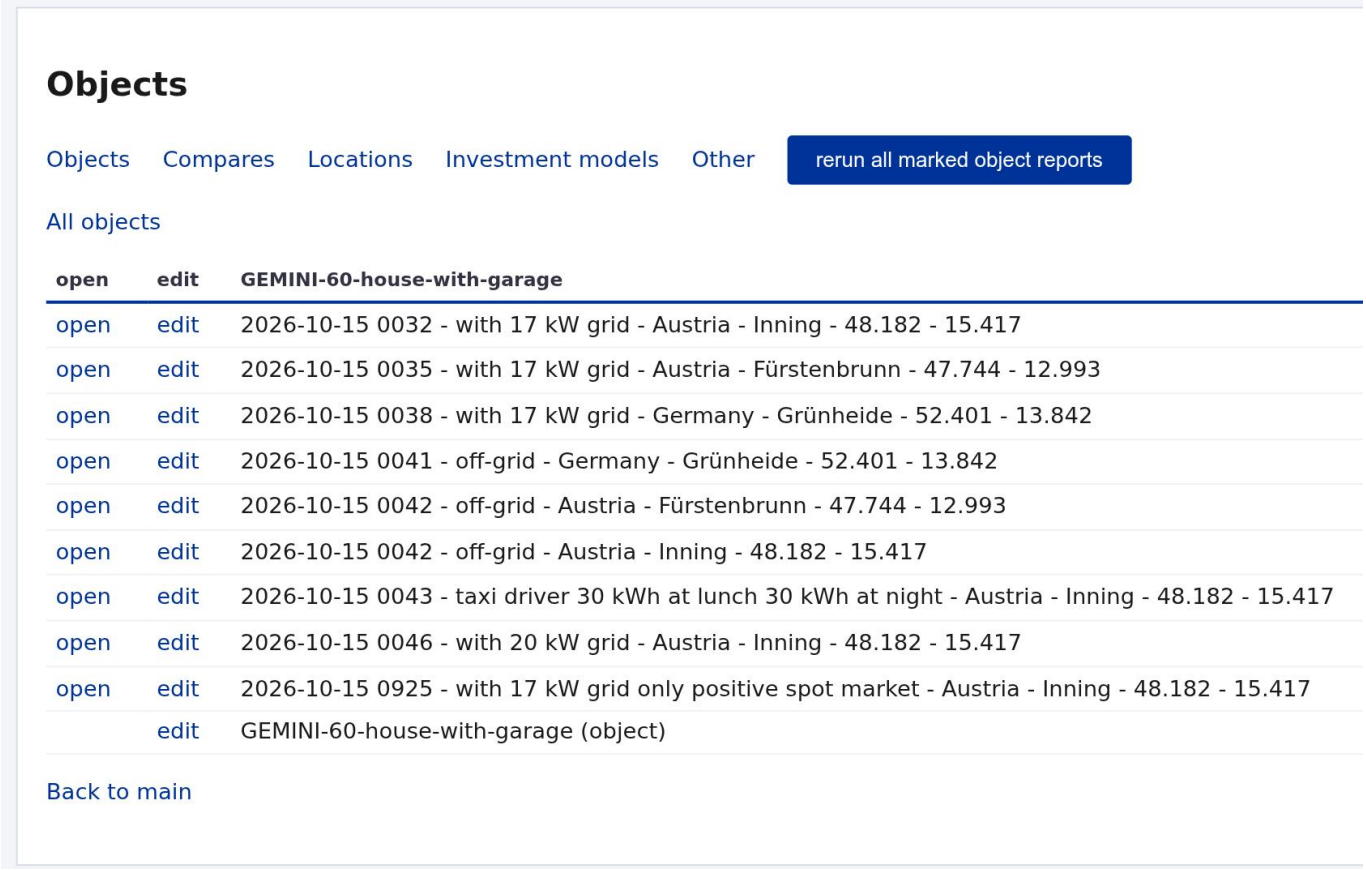
Records of each photovoltaic field
Austria - Inning 48.182, 15.417

PV	Date	Watts	%	h ≥98%	h ≥96%	h ≥94%	h ≥92%	h ≥90%
Garage roof	2009-06-13 11:10	8369	77.9	8	33	112	320	671
Garage side wall south	2009-03-22 11:10	2638	75.9	8	17	26	45	75
Garage side wall north	2023-06-13 05:10	611	17.6	1	8	25	50	108
Garage door side	2005-05-08 14:10	473	67.6	1	3	5	16	49
Garage back side	2009-06-13 07:10	1695	66.7	3	8	16	44	84
Garden fence east	2009-06-13 07:10	4197	70.0	3	10	18	47	102
Roof south	2005-04-22 11:10	2645	88.2	2	11	52	161	376
Roof east	2006-05-25 09:10	2363	78.8	11	38	156	391	806
Roof west	2016-05-15 12:10	2411	80.4	3	12	30	118	333
Roof north	2009-06-13 11:10	1822	60.7	2	17	86	282	654

1000 / 1320 = 67%. Imagine you have a place for 8 × 660 W modules on a north-facing facade. Organized in 4S2P (4 serial times 2 parallel), even the 30 A MPPT could be enough in many regions.

GEMINI 60 house with garage

Menu Files ⇒ GEMINI 60 house with garage



Objects

Objects Compares Locations Investment models Other rerun all marked object reports

All objects

open	edit	GEMINI-60-house-with-garage
open	edit	2026-10-15 0032 - with 17 kW grid - Austria - Inning - 48.182 - 15.417
open	edit	2026-10-15 0035 - with 17 kW grid - Austria - Fürstenbrunn - 47.744 - 12.993
open	edit	2026-10-15 0038 - with 17 kW grid - Germany - Grünheide - 52.401 - 13.842
open	edit	2026-10-15 0041 - off-grid - Germany - Grünheide - 52.401 - 13.842
open	edit	2026-10-15 0042 - off-grid - Austria - Fürstenbrunn - 47.744 - 12.993
open	edit	2026-10-15 0042 - off-grid - Austria - Inning - 48.182 - 15.417
open	edit	2026-10-15 0043 - taxi driver 30 kWh at lunch 30 kWh at night - Austria - Inning - 48.182 - 15.417
open	edit	2026-10-15 0046 - with 20 kW grid - Austria - Inning - 48.182 - 15.417
open	edit	2026-10-15 0925 - with 17 kW grid only positive spot market - Austria - Inning - 48.182 - 15.417
	edit	GEMINI-60-house-with-garage (object)

Back to main

Inning - common example for Lower Austria

Just a good example location in Lower Austria. How much of this houses could power the Tesla SuC Super Charger at this location?

Fürstenbrunn - only diffuse light in winter

North of mount Untersberg. Around the winter eclipse some month no sun shine. This demonstrates how much of the winter yield is diffuse light.

Grünheide - far more north

Nearly 5° more in the north. What has more effect? The shadow of mount Untersberg or to be nearly 5° more in the north?

With 17 kW grid, sometimes the EMS gambles away

The EMS scheduling import and export of electricity uses a limited weather forecast. In the attempt to export as much as possible, it can happen to gamble away. At such an gamble away event, some kWh have to be imported.

Off-grid - just as autarkic test

Is the GEMINI house to weak to be 100% autarc or did only the EMS gamble away sometimes? The off-grid test gives the answer. Remember, this simulation is with every day 10 kWh car charging. Some days in winter not charging at home would have solved the problem.

Are cold days good or bad?

In winter have cold days a clear sky: the sun shines. This is an advantage in Inning and Grünheide but a disadvantage in Fürstenbrunn: No sunshine in the shadow of mount Untersberg. A cloudy sky is in most cases brighter than a clear blue sky. So most likely less yield than at a cloudy day.

The taxi driver coming home for lunch

Charging 60 kWh per day should be enough for a taxi driver on the countryside. During lunch are 30 kWh added by a DC powered fast charger directly powered by the battery. Such a 30 kW DC powered CCS fast chargers are available in 2026 for less than 5.000 €. The comfort of coming home for lunch, having the car charged while eating and use mostly self produced solar electricity.

Living near a major highway

The battery of the house could even power an 80 kWh fast charger. Imagine You have a GEMINI house near an highway exit of the A8 and You sell on a good day 350 kWh to car drivers driving to their summer holiday destination or back.

How to motivate car drivers to recharge at Your home? simple the price. Only € 0.30/kWh would be a horror for all over priced charging stations but 105 € turn around for You. Selling for 0.30/kWh to car drivers while the spot market prices are negative.

GEMINI 60 house part of an energy-optimized settlement

Menu Files ⇒ GEMINI 60 house part of an energy optimized settlement

Objects

Objects Compares Locations Investment models Other

All objects

open	edit	GEMINI-60-house-part-of-a-settlement
open	edit	2026-10-17 1529 - with 34 kW grid - Argentina - La Quiaca - -22.100 - -65.585
open	edit	2026-10-17 1538 - with 27 kW grid - Austria - Inning - 48.182 - 15.417
open	edit	2026-10-17 1542 - with 27 kW grid - Denmark - Aalborg - 57.033 - 9.844
open	edit	2026-10-17 1547 - with 27 kW grid - Greek - Corfu - 39.748 - 19.660
open	edit	2026-10-17 1552 - with 27 kW grid - Egypt - Cairo - 29.953 - 31.153
open	edit	2026-10-17 1556 - with 27 kW grid - Uganda - Kampala - 0.399 - 32.767
open	edit	2026-10-17 1601 - with 27 kW grid - Nepal - Kathmandu - 27.708 - 85.262
open	edit	2026-10-17 1605 - with 27 kW grid - Indonesia - Timika - -4.534 - 136.867
open	edit	2026-10-17 1610 - with 44 kW grid - China - K2 - 35.882 - 76.513
	edit	GEMINI-60-house-part-of-a-settlement (object)

Back to main

There are 16 houses, and this structure is in the middle. Below this big photovoltaic in the middle are the access road, parking lots, garages, and community places like a playground.

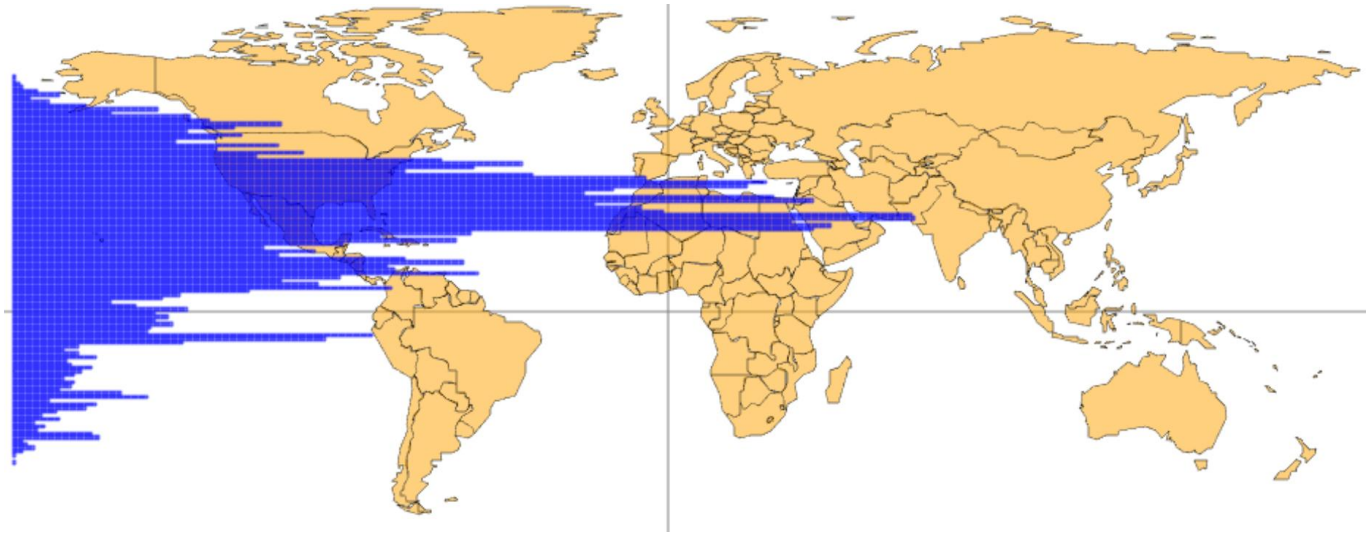
Part of an energy-optimized settlement means each house has a share of this middle structure. 60 solar modules as the own roof, 62 as a share of the middle structure. This gives nearly 50% more yield than the house with the garage only.

Designed to be able to be the only energy source

We think photovoltaics will dwarf any other energy source in the next decades. Not outperforming, dwarfing. We think the best for our whole future is to combine housing and energy production. Can all the energy our civilization needs be produced where we live? Not all of us, only 1/3 of us living in energy optimized settlements?

This design is the answer to this question: Yes, it is possible. Yes, we can discuss every other energy source. Hydro power, wind power, energy from biomass, nuclear power, and all these tiny niche energy sources. Would this new hydropower plant be really a benefit for us? Do we have to sacrifice forests for more wind power? Are 26,000 km^2 for energy from biomass not a senseless waste of valuable ground?

Look at the yields and the low self-consumption in different regions. Multiply this number by a billion. This dwarfs total worldwide electricity production. We need this for worldwide wealth, recycling, and AI. Planet renovation back to 350 ppm falls under recycling.



Do not see it with North Europe in mind

North Europe, with huge differences between summer and winter, is the exception. Only made possible by the Gulf Stream. Somewhere else so far in the north is the climate in winter so harsh that only a few people live there.

9 worldwide examples

We have 9 examples with typical yield/weather patterns. There are 5 pages in the object report PDF showing yield, highest temperature, average temperature, and lowest temperature each day and the difference from lowest to highest temperature each day.

Could be a nice quiz game: I show you these 5 graphs, and you guess where they are taken. For example, Aalborg. Very low yield in winter, so high in the north. Mild climate in winter, so it can be only at the north coast of Europe warmed by the Gulf Stream. Very low differences between the highest and lowest temperature of a day, so it is near the sea.

Denmark - Aalborg

At the winter solstice, the sun is only 9.47° above the horizon at midday. So we have here a very drastic difference between the summer solstice and the winter solstice.

Austria - Inning

A typical central-European site. Yield is limited by the short winter days and the frequent low cloud cover of the Alpine foreland. The battery and the import caps matter most in December and January. The place is used as the baseline for house-improvement examples.

Greek - Corfu

A Mediterranean island site. Summers are long and clear; winters are mild and wet. The tilt of the Earth's axis still sets the storage need, but the winter demand is lower than in Austria. The place is typical for the northern Mediterranean coast.

Egypt - Cairo

Long-term storage requirements are determined almost exclusively by the tilt of the Earth's axis.

The place is typicall for North Africa.

Uganda - Kampala

The weather determines long-term storage requirements. Much less gross yield compared to Cairo, partially compensated by higher 24×365 conversion efficiency. The only place to discuss more batteries vs. power to methanol.

The place is typicall for Africa near the equator. This is a reason to speak from North Africa and Sub-Saharan Africa.

Nepal - Kathmandu

Guess which months are the rainy season. The same weather pattern is also seen more south in India. It is worldwide the most extreme rainy season.

Indonesia - Timika

Timika has a tropical rainforest climate (Af) with heavy to very heavy rainfall year-round. It seems Salzburg is a very sunny city compared to this. It seems from 2005 to 2023 not one sunny day from dusk to dawn. In all these years, only 4 days with a highest temperature above 30°.

Argentina - La Quiaca

3442 m above sea level. The highest mountain in Austria, Mount Großglockner, is only 350 m higher. You thought Egypt - Cairo has a very high yield? La Quiaca has 21% more yield.

Can this high yield be used for energy-intensive industry there?

China - K2

Just to explain climate, it is colder high in the mountains and GHG column above. Here is 0° C the highest temperature, and the solar yield is record high. So much sun and so cold, how is this possible? Earth would have an average temperature of -18° C without atmosphere.

Venus would have an average temperature of 63° C with the same atmosphere as Earth. Venus is nearly 400° C hotter, because of so huge amounts of GHG above the ground.

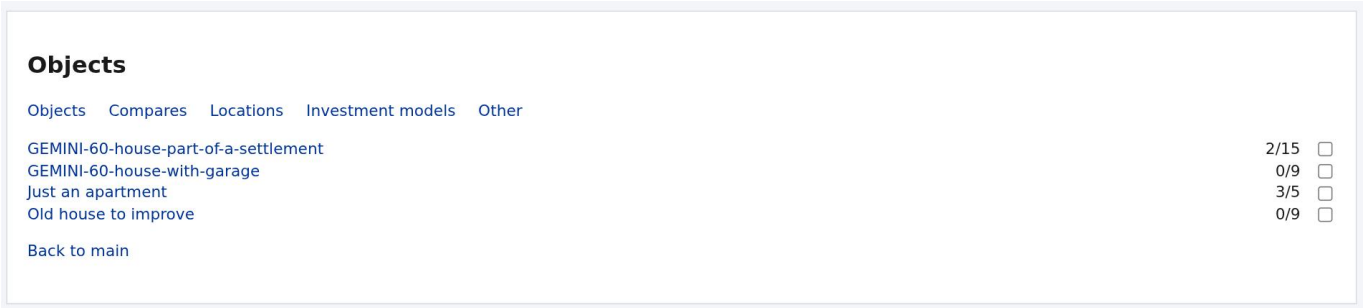
There is less and less GHG above moving up a mountain, and the conditions are more and more like without atmosphere. We have 1000 W/m^2 at 25° C as the standard test condition for photovoltaics. The solar constant is 1361 W/m^2 in space above Earth.

Rerun for versions compare

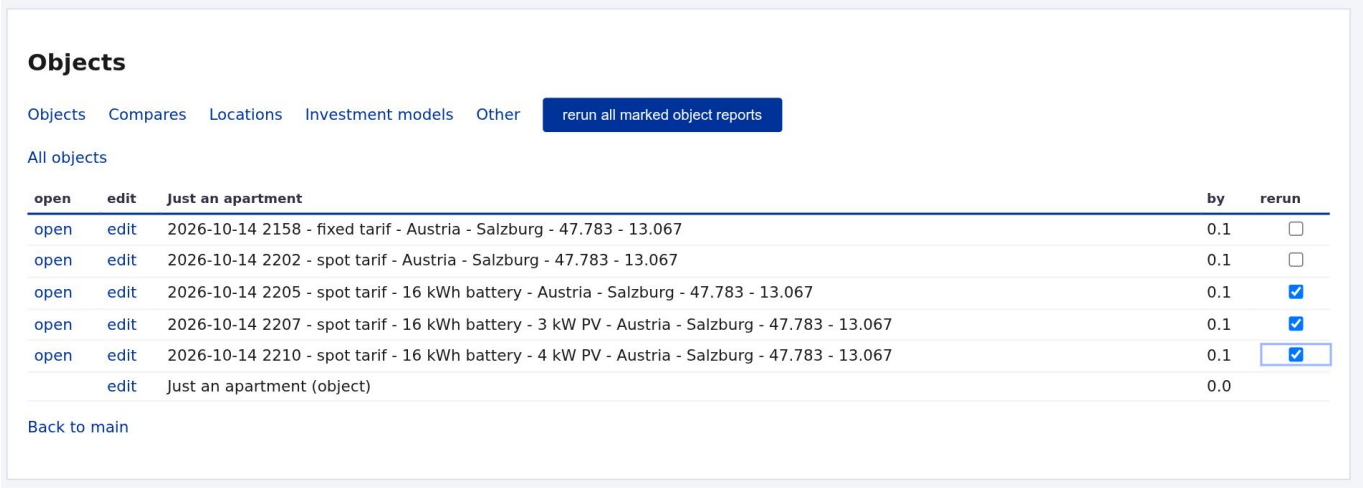
Why are there 32 export hours per day? This led to the discovery that the 29th of February was mishandled. Rerun all simulations manually and compare where the results differ?

No, this should the software do!

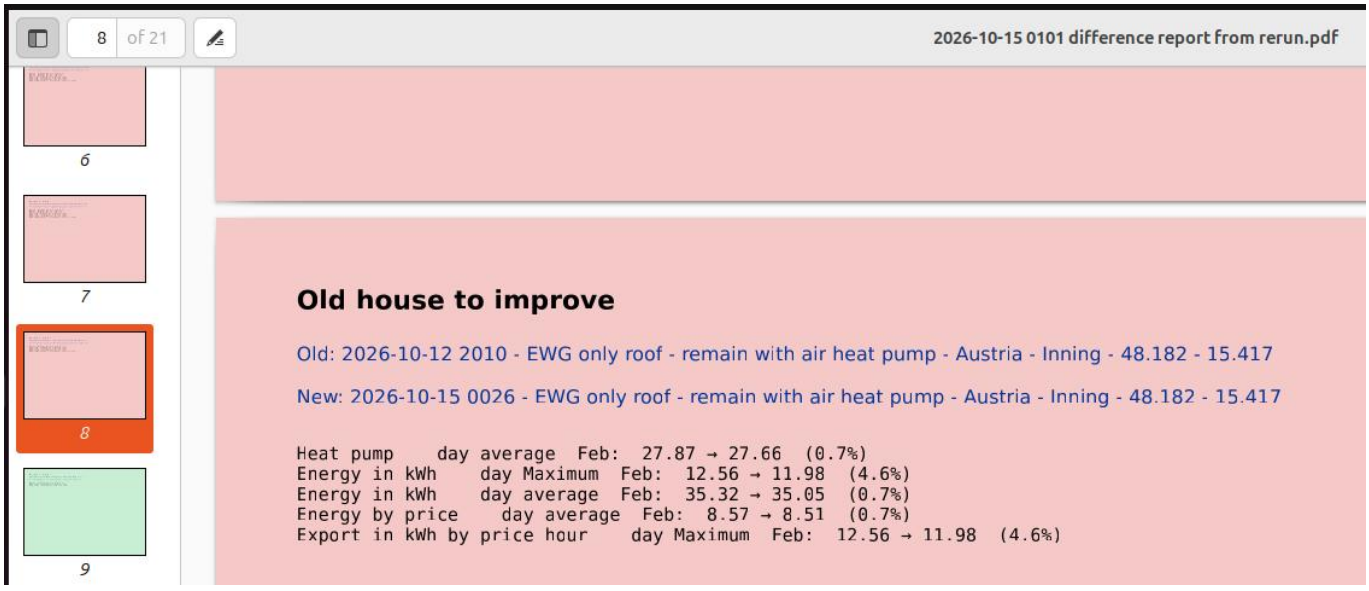
Menu ⇒ Files



You see at the right side: the number of simulations to rerun at this object/total number of simulations in this folder. Right a check box to select or deselect all simulations in this folder.



On the right side: by showing what version of PEGE energy sim created this simulation. Mark or unmark for rerun.



You can see in the thumbnail sidebar where simulations with differences are: green for nearly no difference, yellow for medium differences, and red for big differences.

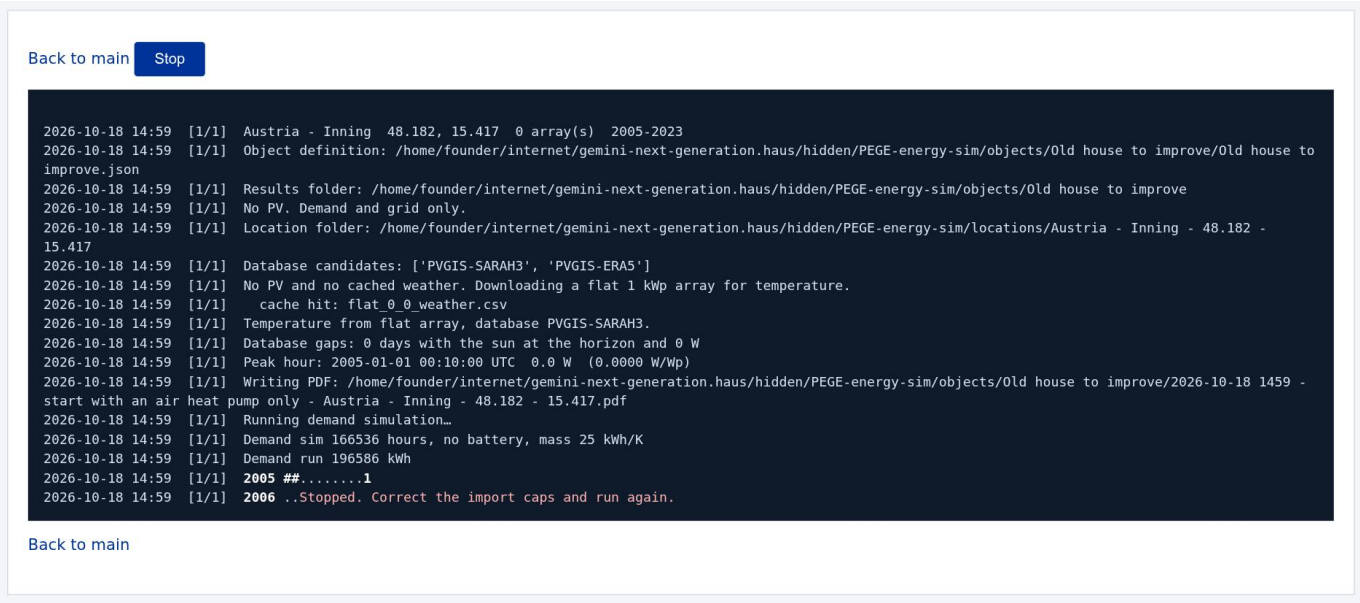
Stop a buggy simulation run

Are 4 kW import allowance in December enough? Import limits are not something obvious to set. They can be tested out by simulation runs. The progress display of the simulation runs shows not only each year and month.

.	All okay, no emergency import hour in this month
1..9	There are 1..9 emergency import hours in this month
#	There are more than 9 emergency import hours this month

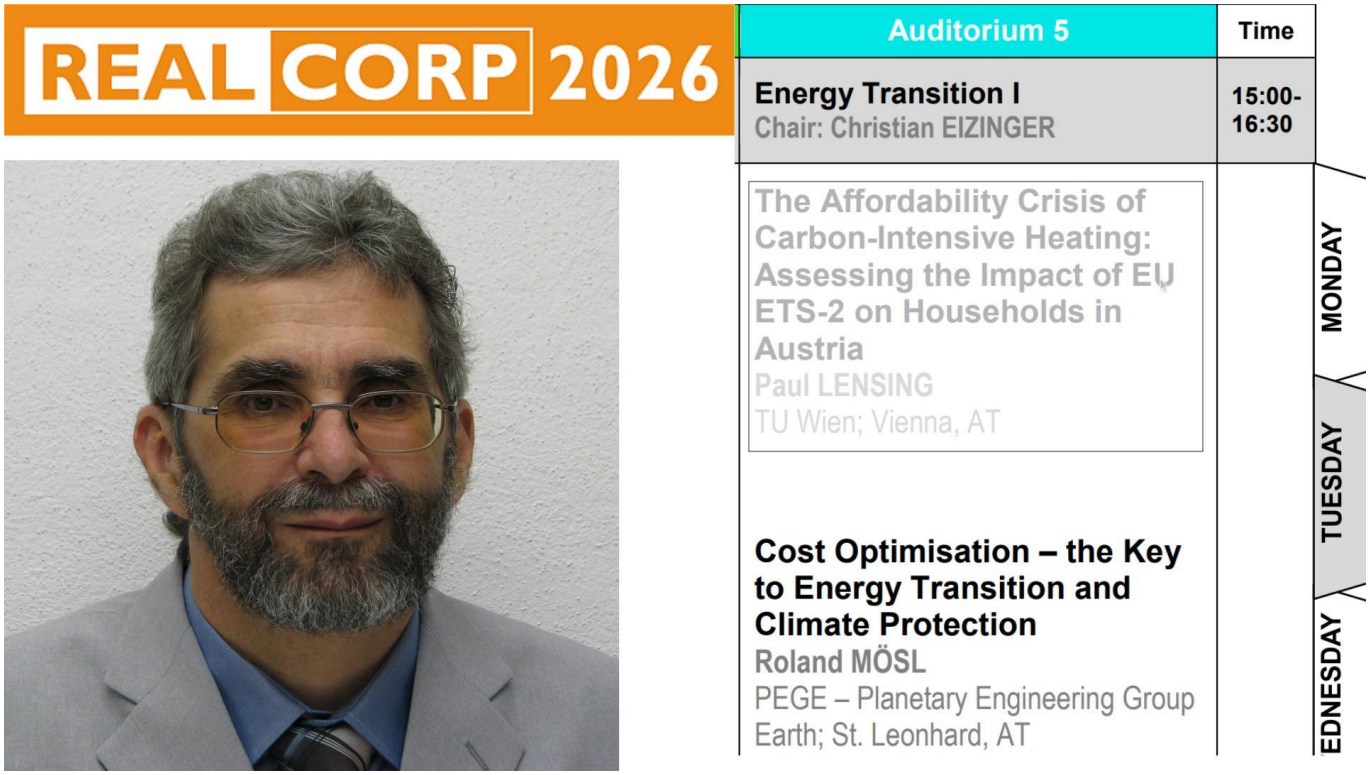
Why waste time to run the rest of the simulation when it is bugged in 2005? Just stop it with the stop button.

Menu ⇒ Object house



Energy Optimized Settlements – Enabler for Necessary Civilization Targets

Cost optimization – the key to energy transition and climate protection



The findings in the paper “Cost optimization — the key to energy transition and climate protection” for the CORP.at conference, 22–25 March 2026 in Vienna, were made with the old Perl version of this software. The paper is at https://climate.pege.org/2026/.

Energy-intensive industry is covered at https://climate.pege.org/2026/industry.htm. Typical energy-intensive industry will be objects in version 1.0.

At the next CORP conference I will show at least version 1.0 of PEGE energy sim and the findings from using it.