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

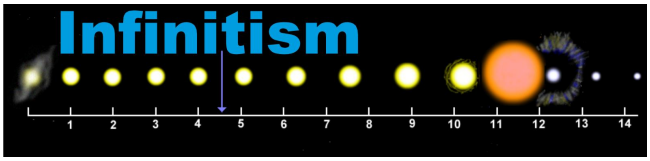


Mankind has the technology for a lasting paradise
but a policy for hell on earth. Our mission is to change that.

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 160 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.

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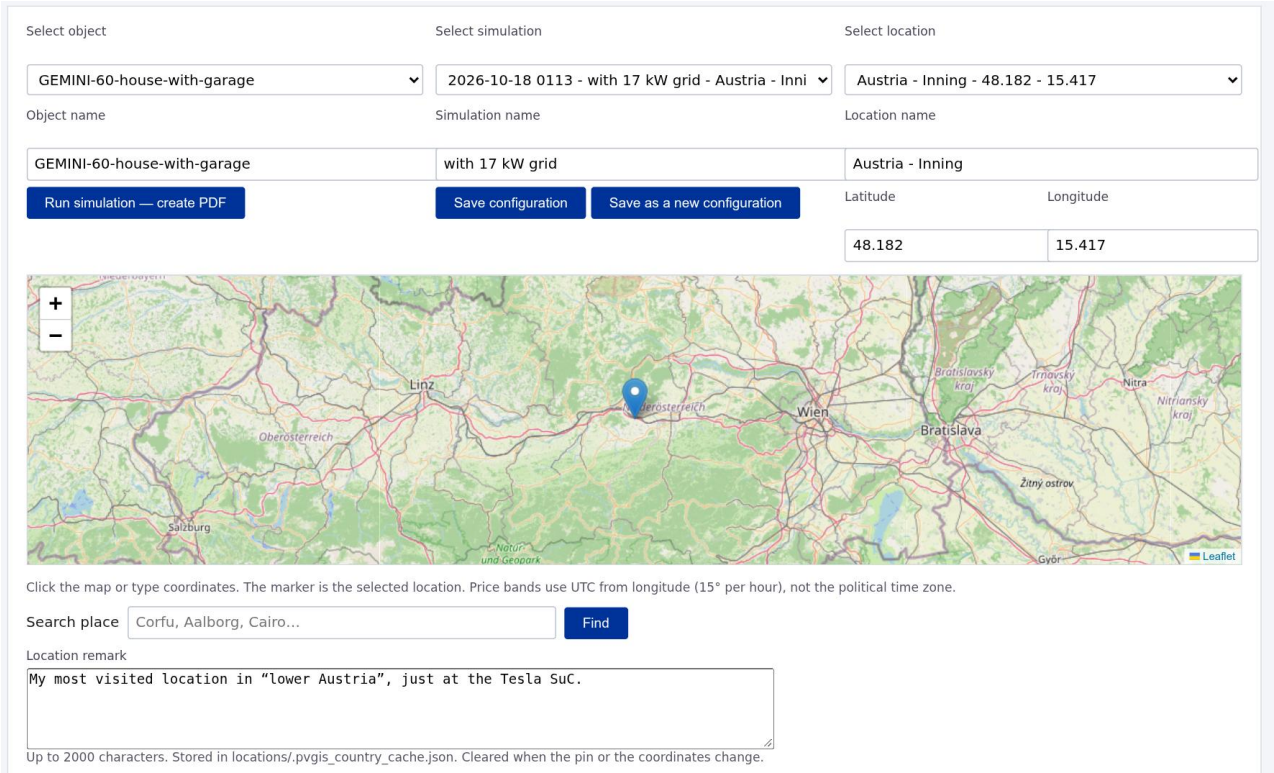
Location and the system loss



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

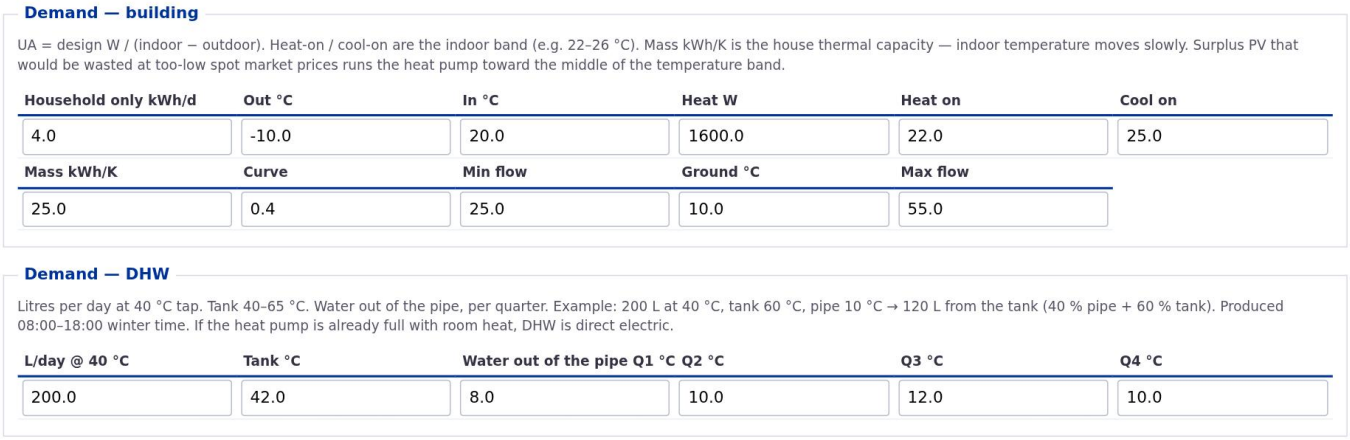
Up to 25 arrays can be entered. Empty rows are ignored. The arrows change the order of the rows. Clearing the name and leaving the field clears the rest of that row.

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

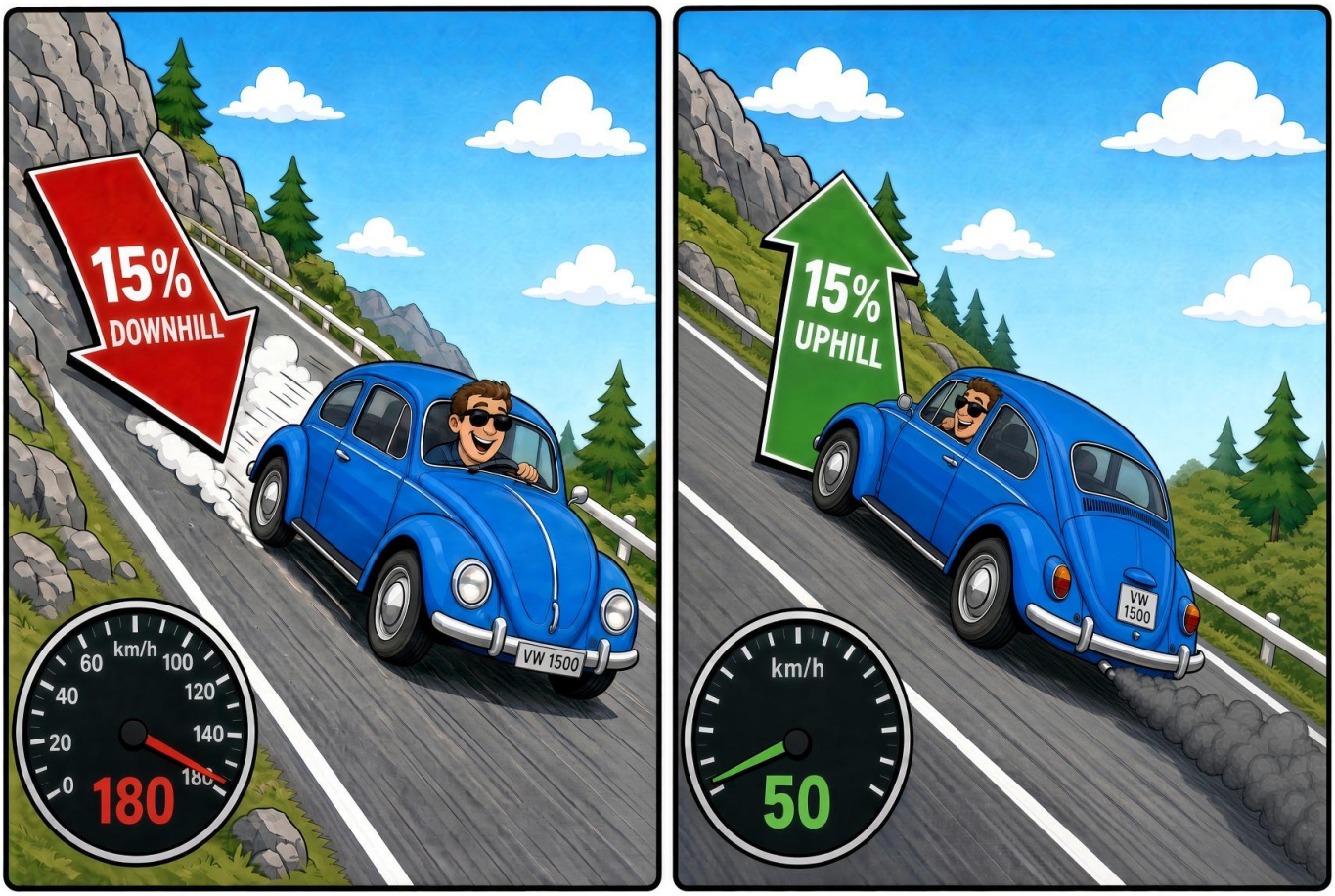
A heat pump's catalogue number is not the heat it delivers on the design day. A 5.6 kW unit is usually rated at A5/W35: 5 °C outside air, 35 °C flow. That is a mild day and a low-temperature floor. It is the downhill figure. A VW Beetle can also be said to do 180 km/h — at 15 % downhill.

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.

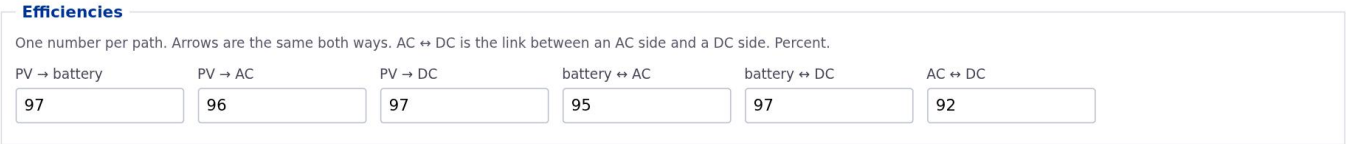
Inverter AC kW is the power the inverters can make on the AC side. Grid connection kW is the power the house may exchange with the grid. These two are not the same. A house can have two inverters and only one of them connected to the grid. The second serves the house and the battery. In that case the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

Naming convention for Objects

To avoid chaos there is a strict naming convention.

objects/{object name}/{stamp} - {simulation name} - {location name} - {latitude} - {longitude}.pdf

objects/{object name}/{stamp} - {simulation name} - {location name} - {latitude} - {longitude}.json

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

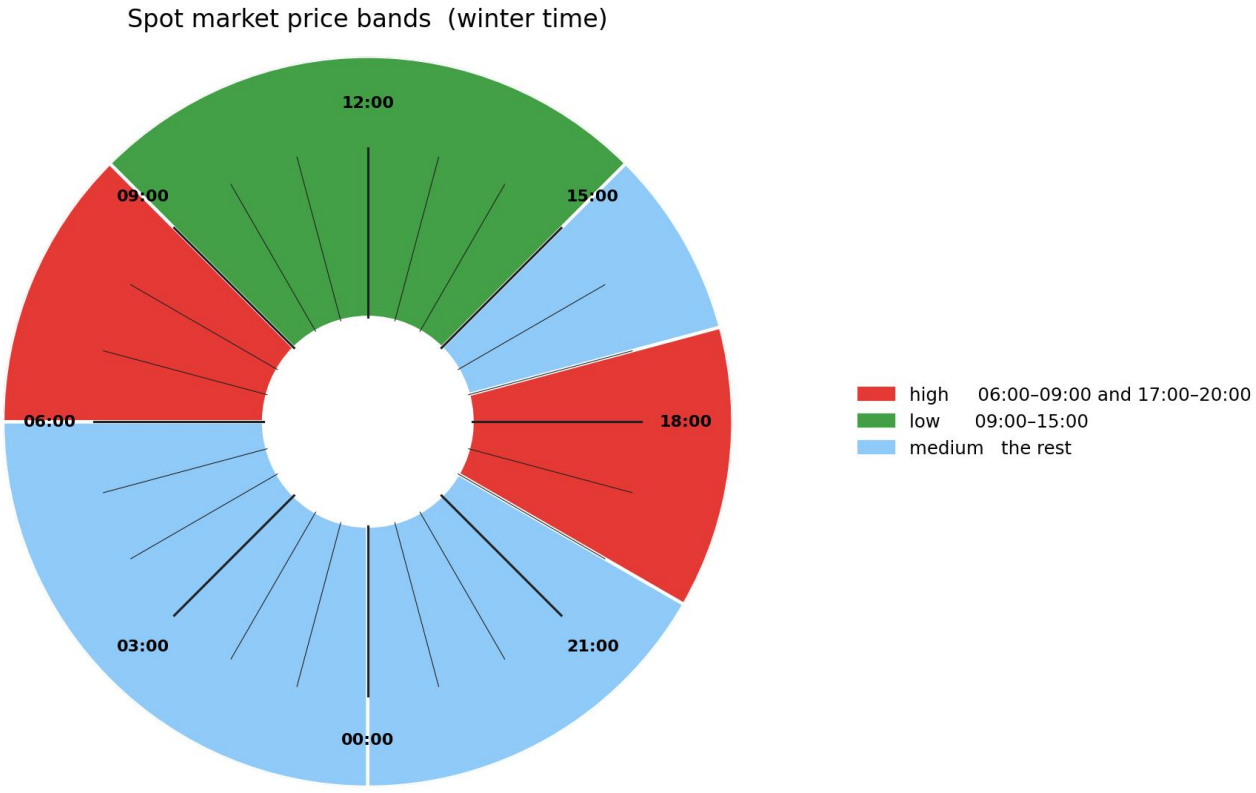
Around 2000, solar was thought to be at its most valuable at noon. Demand peaked then, and that is also when a panel delivers most. The two seemed to meet.

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.

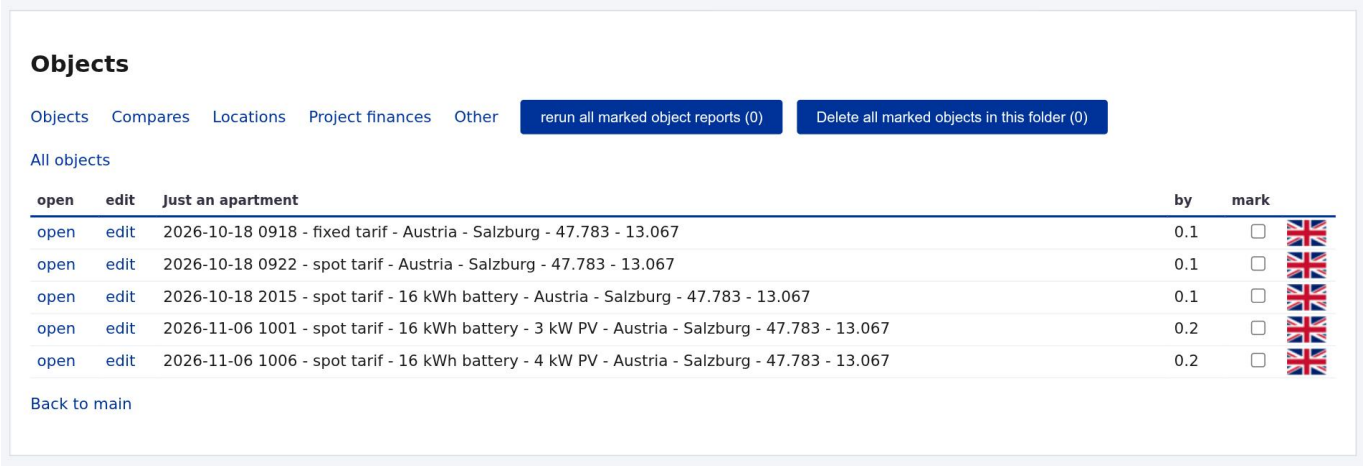
Import and export differ because they are not the same transaction. On top of the spot price sit a handling fee, the balancing charge (something special at Spotty.App), and, on import, the grid fee. A spot price of 2 cent can be 14 cent to buy and −1 cent to sell. The table holds the result, not the 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



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.



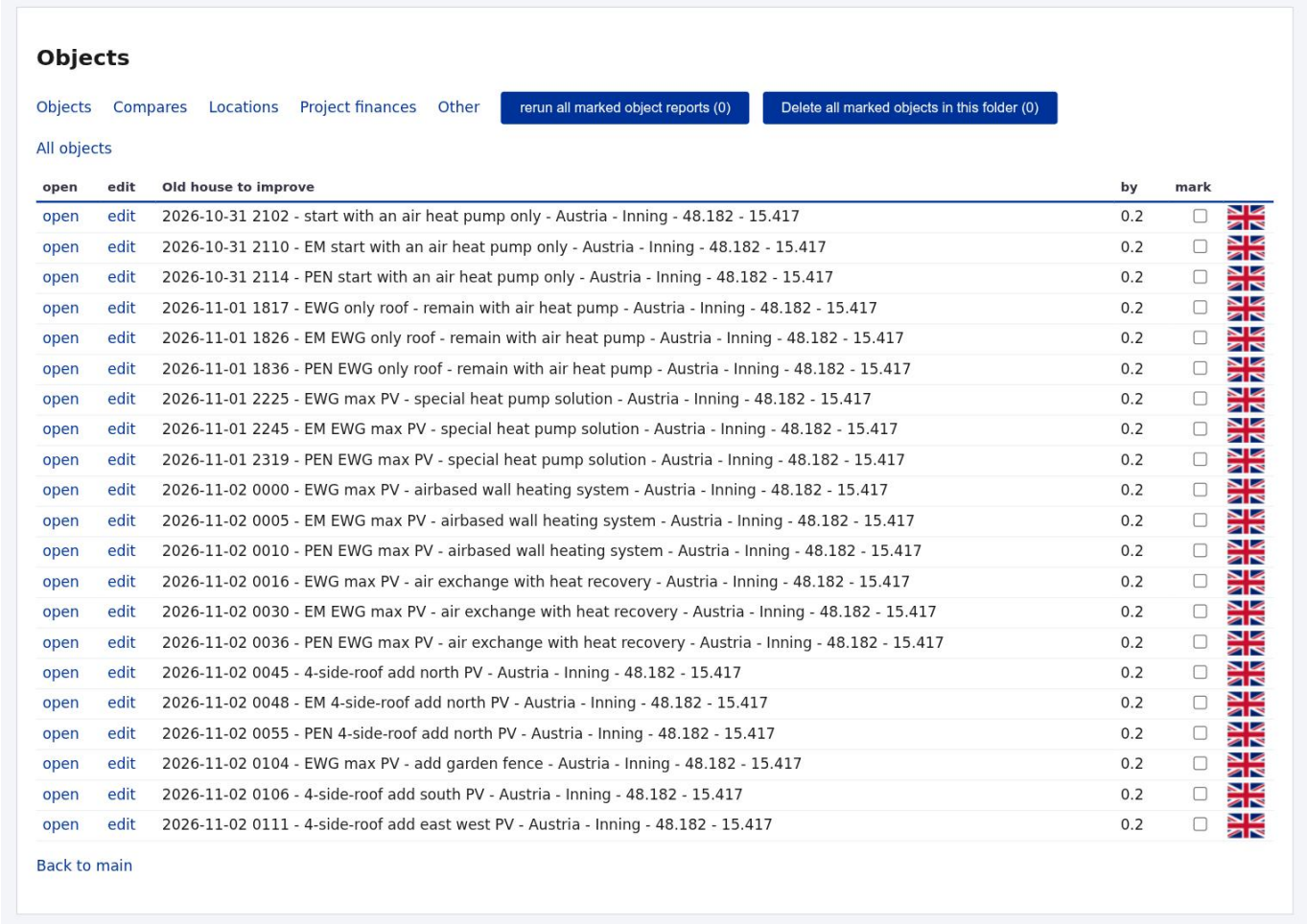
How time changes

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 Project finances Other rerun all marked object reports (0) Delete all marked objects in this folder (0)

All objects

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open	edit	2026-11-01 1817 - EWG only roof - remain with air heat pump - Austria - Inning - 48.182 - 15.417	0.2	
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open	edit	2026-11-02 0055 - PEN 4-side-roof add north PV - Austria - Inning - 48.182 - 15.417	0.2	
open	edit	2026-11-02 0104 - EWG max PV - add garden fence - Austria - Inning - 48.182 - 15.417	0.2	
open	edit	2026-11-02 0106 - 4-side-roof add south PV - Austria - Inning - 48.182 - 15.417	0.2	
open	edit	2026-11-02 0111 - 4-side-roof add east west PV - Austria - Inning - 48.182 - 15.417	0.2	

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.

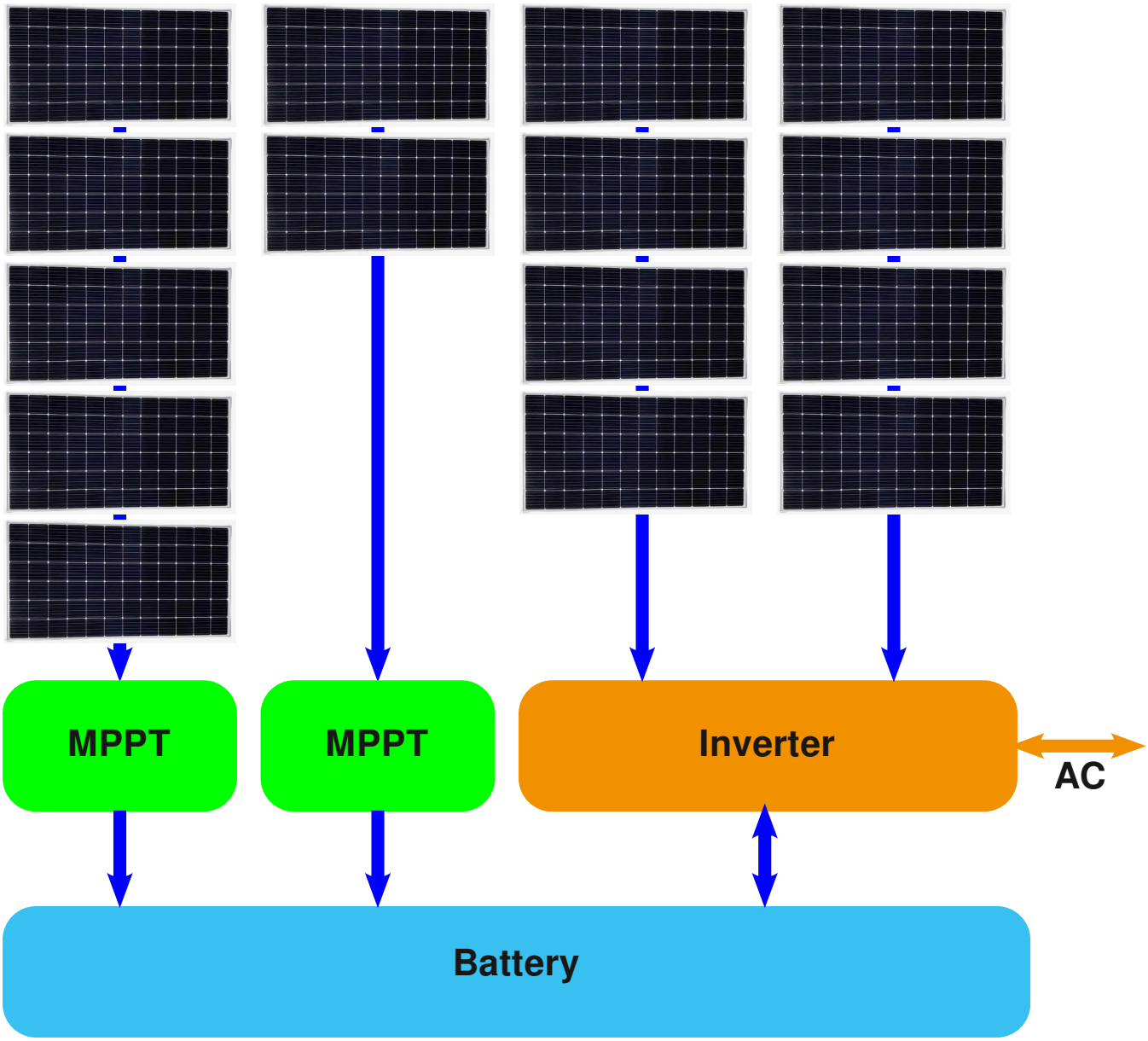
How the PV is connected

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.

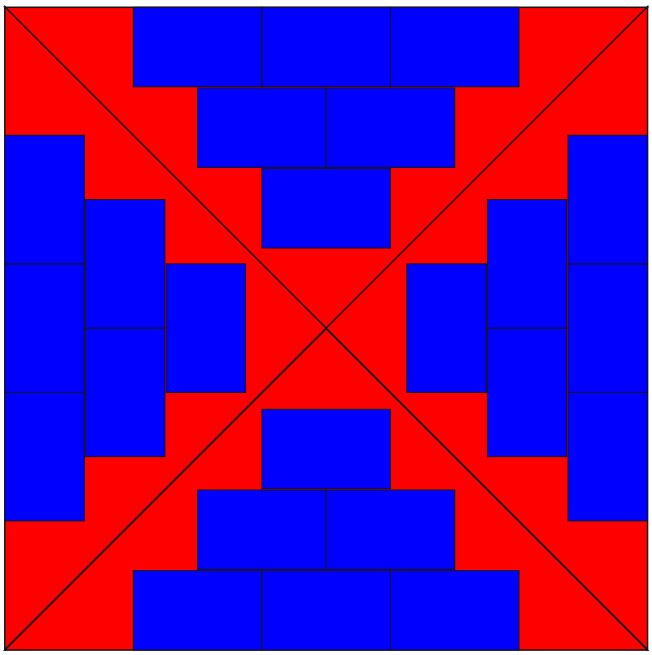
The end of the house story is different. The EWG holds a 60 kWh battery and a water-to-water heat pump with a special air-to-water exchanger and a ground store. Wall heating runs at slope 0.35. Single-room ventilation with heat recovery cuts the design load to 3.3 kW. PV covers the garage, a bifacial 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 do EM and PEN mean, and why 3 versions?

This versions are later used in project finance. Life changes. There can be unexpected emergency situations; EM stands to simulate an emergency situation where it is necessary to reduce expenses. There is maybe the retirement ahead; PEN stands to simulate pension time. Maybe higher room temperature, less car driving, the commuter time is over, and less DHW demand because the children have moved out.

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.

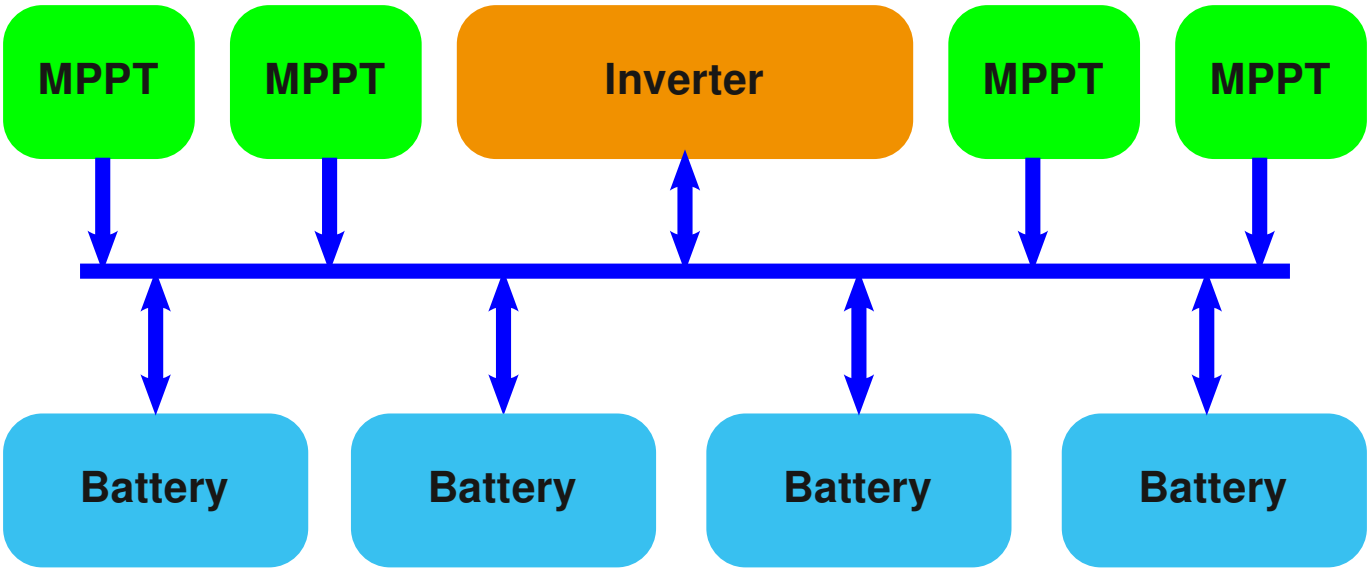
Records 1–10 — contribution of each PV
Austria - Inning 48.182, 15.417

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.

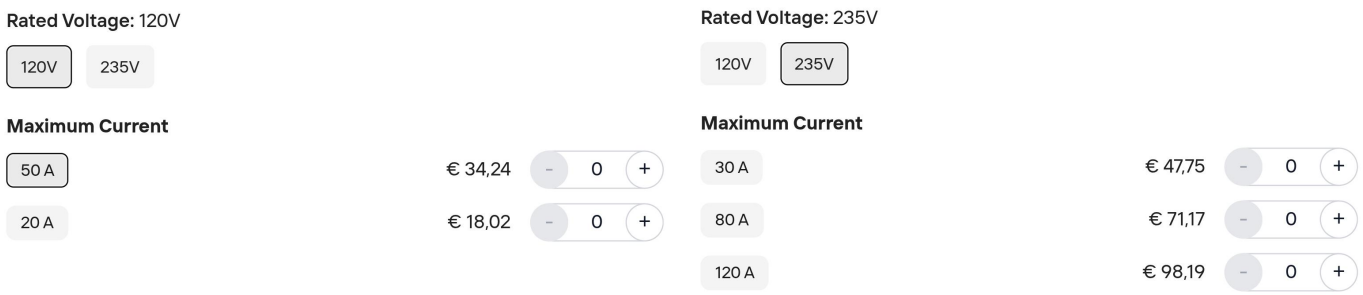
Battery boxes for serial connection have to be certified for serial connection. This makes a battery box more expensive. Serial connected systems also require a combiner box.

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.

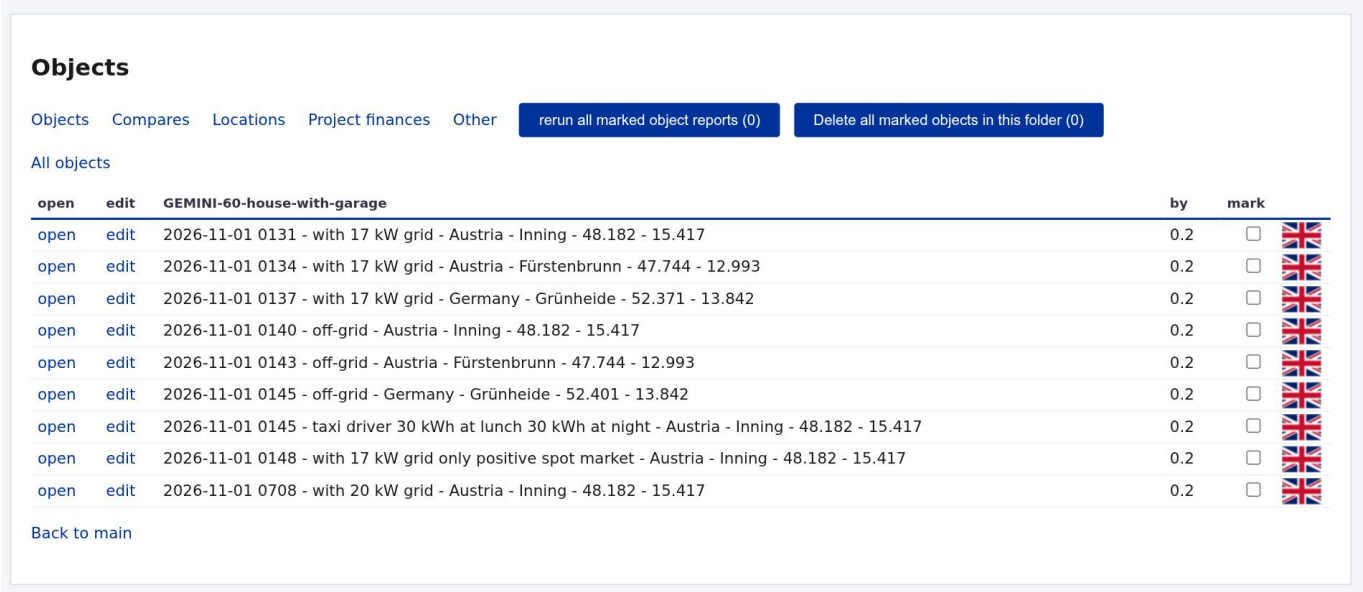
Records of each photovoltaic field
Austria - Inning 48.182, 15.417

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



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 Project finances Other rerun all marked object reports (0) Delete all marked objects in this folder (0)

All objects

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open	edit	2026-11-01 0117 - with 27 kW grid - Greek - Corfu - 39.748 - 19.660	0.2	
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open	edit	2026-11-01 0123 - with 27 kW grid - Uganda - Kampala - 0.399 - 32.767	0.2	
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open	edit	2026-11-01 1459 - with 40 kW grid - China - Talatan - 36.190 - 100.540	0.2	

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.

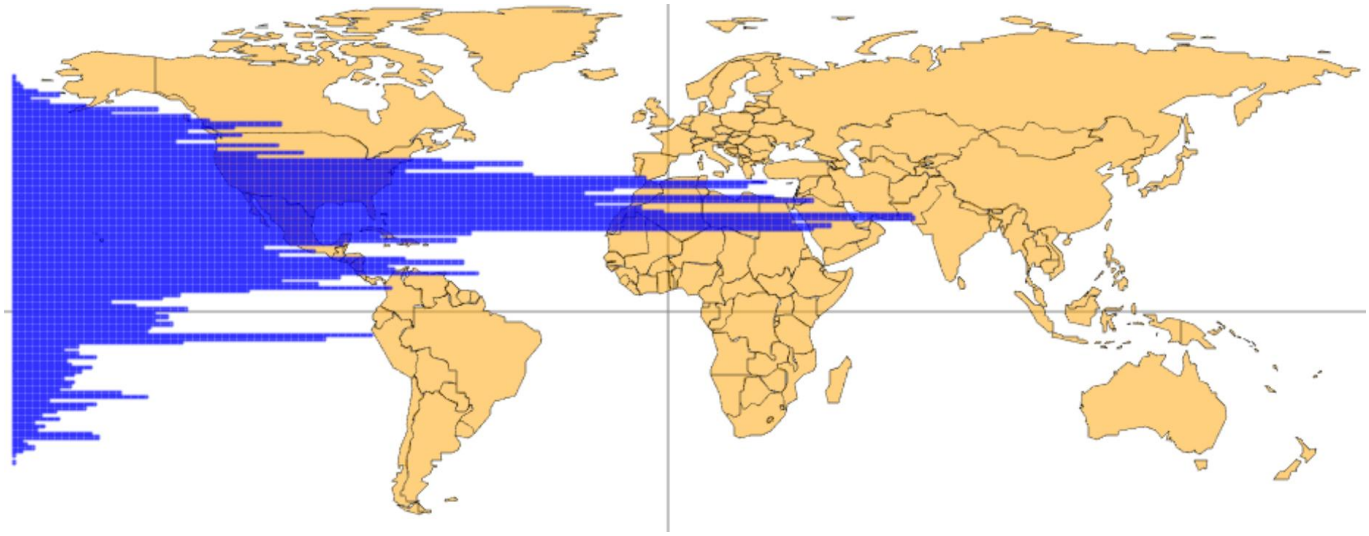
Part of an energy-optimized settlement means each house has a share of this middle structure. 60 solar modules as the own roof, 62 as a share of the middle structure. This gives nearly 50% more yield than the house with the garage only.

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.

12 worldwide examples

We have 12 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.

China - Talatan

For decades in Europe, the idea was huge photovoltaic fields in Africa to supply electricity to Europe. Same idea in China from the dry and very high West towards the densely populated East Coast of China.

Sure, no place to settle; it is for energy only.



Seen from 51 km height: huge photovoltaic fields in Talatan

China - Shenzhen

I found a ground price limit for the GEMINI next Generation house: about €200/m^2. At higher ground prices, as much useable space per square meter of ground becomes the most important target.

All around Shenzhen are the prices beyond this threshold. Otherwise, energy-optimized settlements would bring a good all-year-round yield.

Mexico - Mexico City

Worldwide the highest town with more than 10 million inhabitants. With this solar yield maybe the most easy big city to run with solar energy alone.

Simple house in rural off-grid Africa

Menu Files ⇒ Simple house in rural off-grid Africa

Objects

Objects Compares Locations Project finances Other rerun all marked object reports (0) Delete all marked objects in this folder (0)

All objects

open	edit	Simple house in rural off-grid Africa	by	mark
open	edit	2026-11-06 0930 - We start with 3 kW PV and 16 kWh battery - Kenya - Kirinyaga County - -0.469 - 37.303	0.2	
open	edit	2026-11-06 0932 - Now 6 kW PV and 16 kWh battery and small electric car - Kenya - Kirinyaga County - -0.469 - 37.303	0.2	
open	edit	2026-11-06 0933 - Better increase battery to 32 kWh - Kenya - Kirinyaga County - -0.469 - 37.303	0.2	
open	edit	2026-11-06 0935 - We start with 3 kW PV and 16 kWh battery - Ghana - Nadowli - 10.370 - -2.658	0.2	
open	edit	2026-11-06 0946 - We start with 3 kW PV and 16 kWh battery - Namibia - Tsumkwe - -19.592 - 20.503	0.2	

Back to main



We start with 3 kW PV and 16 kWh battery in Kenya

Both sides of the house have 3 × 500 Watt PV. A typical battery size is 16 × 314 Ah LFP cells for 16 kWh storage. As a basic good living standard: induction cooking, fridge, scooter, and air condition.

How could somebody in a poor countryside region effort this? Heavy cost optimization. The EXW prices from China double towards rural Kenya by ship transport, customs, VAT, road transport, and the necessary wins for the seller. Here we are in 2026 in the US$ 8,000 range for the end-user price for all.

The photovoltaic charges the battery directly with MPPT. For higher efficiency are induction cooker, fridge, scooter charging, and air conditioning directly 48 V DC powered. Nothing exotic; all available, cheap products, easy to source on Alibaba.com.

Building a grid is far too expensive

How to build a grid connection to a rural village? Simply this would be a waste of money, unable to compete against modern off-grid technology.

It makes no sense to try to sell potatoes to a potato farmer. It makes no sense to try to sell grid electricity to a house like that if the residents can generate their own electricity very cheaply.

Strategy to incredible low electricity costs

The electricity consumption is on average 1,840 kWh per year. That matches my own experiences at the long-time electric scooter test in 2008: 2,100 kWh per year, but with tungsten light bulbs at home and other more inefficient technology.

2,160 kWh on average wasted per year: battery full, no grid to sell. Any better use? Not under the known circumstances. We have a waste-to-use ratio of 54:46. With an estimated end-user price of US$ 8,000 and half of it for energy generation, that is, at 5 %, 10 %, or 15 % interest, US$ 37, 48, or 60 per month. Counting only the used electricity, this makes US$ 0.24, 0.31, or 0.39 per kWh.

Those are just common electricity prices paid in many countries. The difference is that after the credit is finished, he still owns the photovoltaics and the battery. Maybe demand increases. Maybe a second electric scooter and more appliances in the house.

So 12 years later, after the first credit is finished, the system is increased by a new 16 kWh battery pack in parallel and 6 additional modules. Same credit, same down payment, but now for 3,000 kWh consumed per year. The kWh price in terms of down payment divided by consumption shrinks to US$ 0.15, 0.19, or 0.24 depending on interest.

Now it is 24 years later, and the second credit is finished. The now 24-year-old battery is down to 60 % and the now 12-year-old second battery is down to 80 %. Photovoltaics are fine, with only some percent lost. This time only a third battery is purchased for US$ 2,000 and mounted again in parallel.

The smaller credit is paid in only 5 years. He changes sides; he no longer borrows money from the bank; he builds up his bank account now. 7 years at US$ 50 a month with 3 % gives US$ 4,620.Now it is 36 years later. The 36-year-old first battery pack is now to be replaced. Purchase for US$ 2,000; US$ 2,620 remains in the bank account. 12 years US$ 25 a month with 3 % interest increases to US$ 8,070.

This means US$ 0.10 per kWh. Who wants to compete with a grid against US$ 0.10 per kWh? Only the start is difficult with the down payment of the credit, with a far shorter run time than the usability of the equipment.

Double PV, double battery for a car

Some years later, it will be like around in 1960 in Germany: the scooter will be replaced by a car. Is it enough to just double the photovoltaic? No, better to double also the battery.

The grid imports shown in the simulation are “The battery is empty; we would have needed so much more”. Nothing dramatic; only very few days when less heating, less cooking, less DHW, and less electric scooter charging would have solved the problem.

Heating? Yes, heating—I wanted to bring an example for air conditioning is no problems at sunny days and had to find out 0 hours with cooling demand, but a little warmer in the rain time feels fine.

In many countries, people have far more problems with an unreliable grid than these few days every some years with “Our system cannot deliver the full demand.”

We start with 3 kW PV and 16 kWh battery in Ghana

Now we have the perfect "air conditioning does not matter because when it is hot it is also sunny" example. Same equipment; the consumption increased from 1,840 kWh in Kenya to 2,287. The wasted solar yield decreased from 2,160 kWh to 2,072 kWh kWh.

The better waste-to-use ratio of 48:52 is caused by the air-conitioner.

We start with 3 kW PV and 16 kWh battery in Namibia

This marks the outer border away from the equator, where a simple solution with more photovoltaics and more batteries works for a cheap off-grid house. Only 19.6° down from the equator.

Sure, there is the GEMINI next Generation house simulated in Grünheide 52.4° north of the equator. But this is not designed as a cheap off-grid house but to sell much to the grid.

Calculating US$ 60,000 for the energy equipment and a 15-year 5% credit is US$ 475 a month. At a consumption of only 6,907 kWh/a, this is US$ 0.83/kWh.

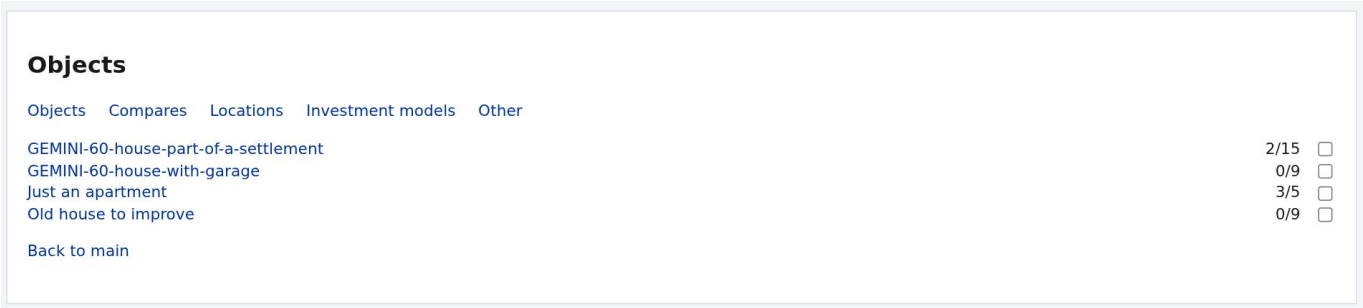
So compared to near-equator regions and this simple off-grid house, 4 times the consumption and 15 times the energy equipment. To find for any region and any demand the most cost-efficient solution is the name of the game.

Rerun for versions compare

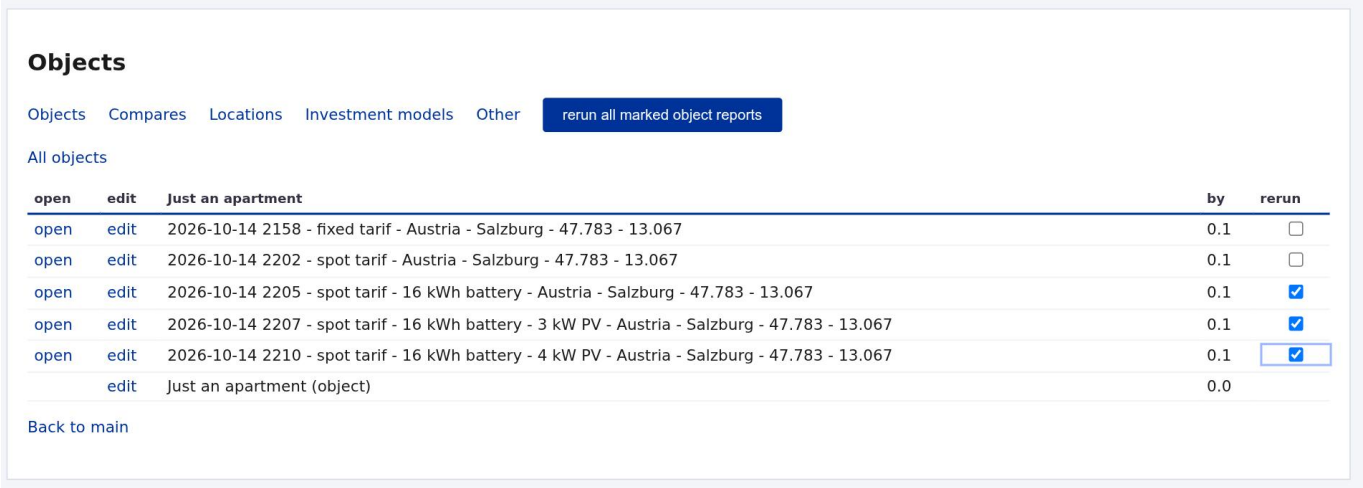
Why are there 32 export hours per day? This led to the discovery that the 29th of February was mishandled. Rerun all simulations manually and compare where the results differ?

No, this should the software do!

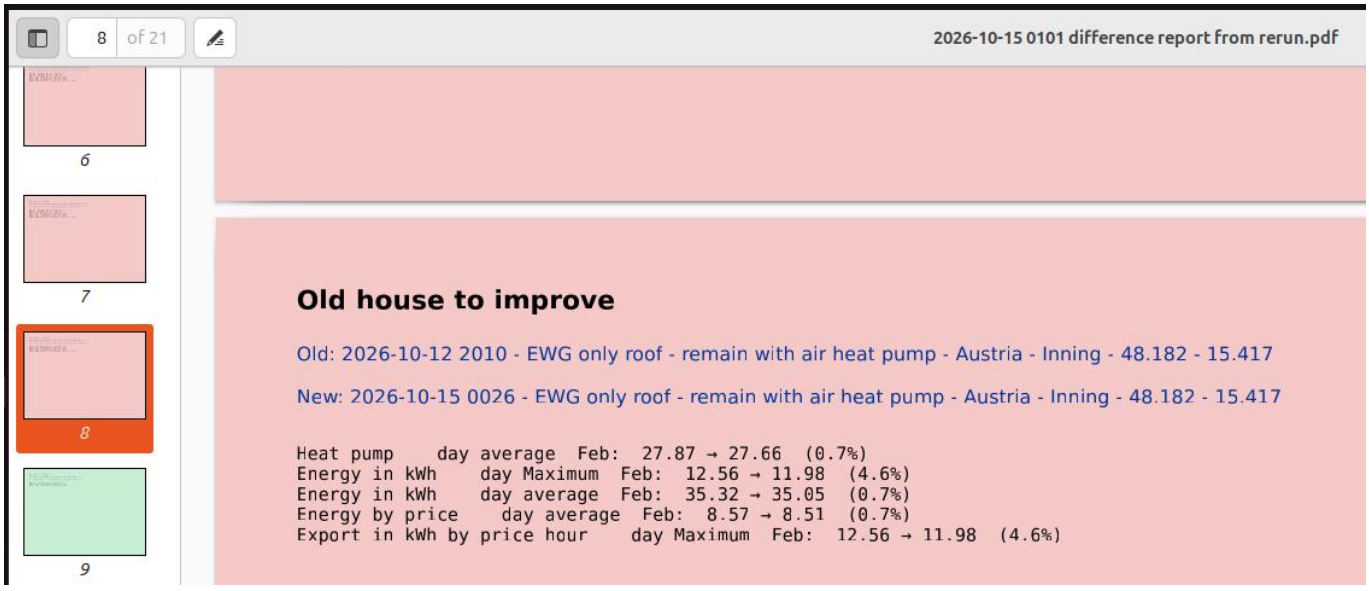
Menu ⇒ Files



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.

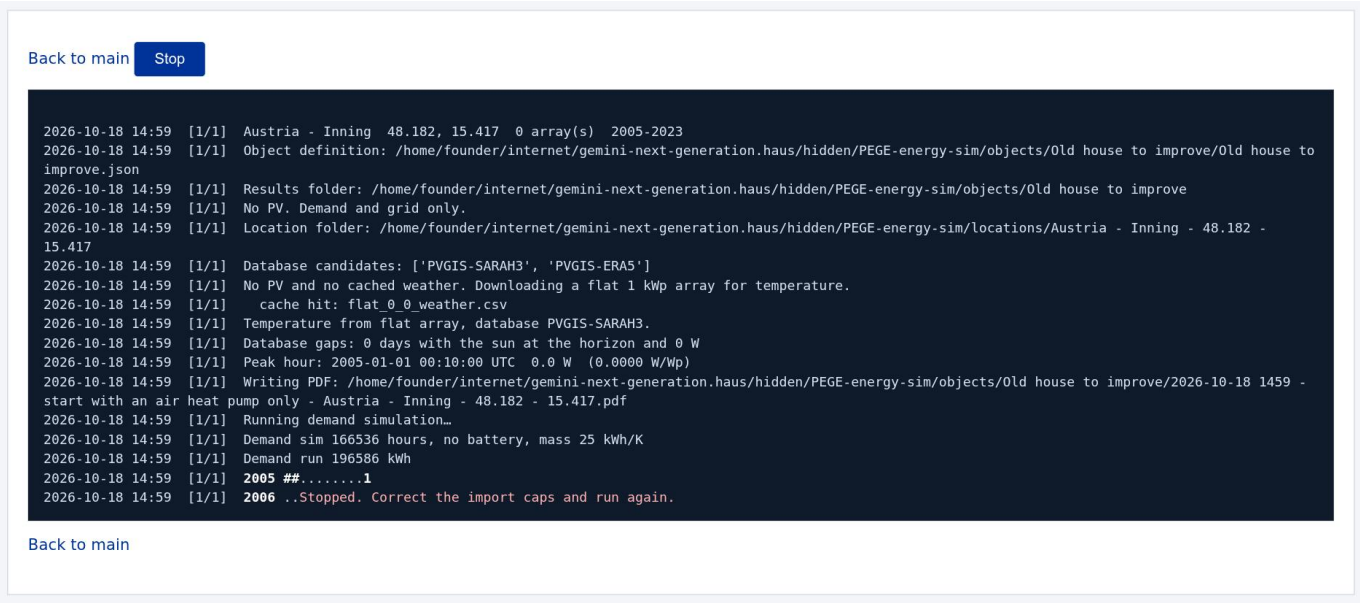
Stop a buggy simulation run

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.

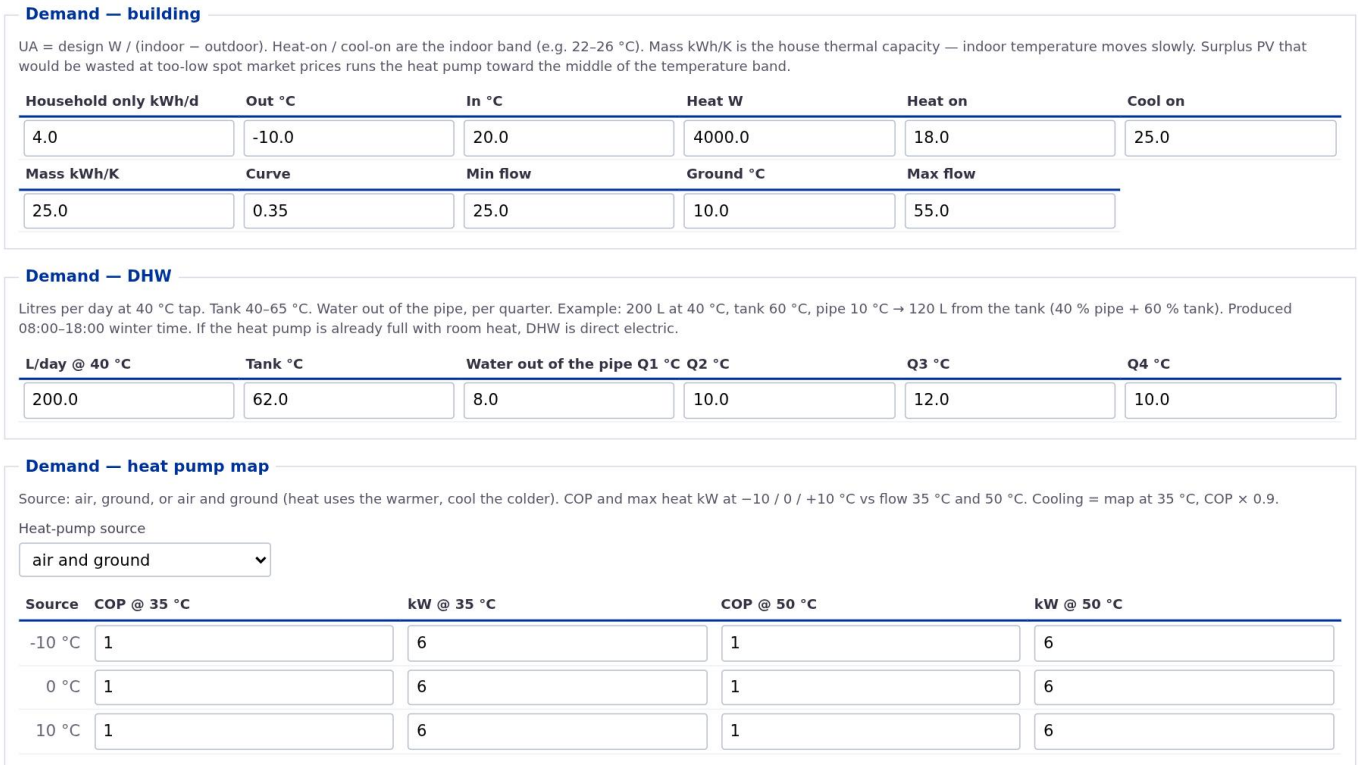
.	All okay, no emergency import hour in this month
1..9	There are 1..9 emergency import hours in this month
#	There are more than 9 emergency import hours this month

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



How to simulate infrared heating?



Demand — building

UA = design W / (indoor − outdoor). Heat-on / cool-on are the indoor band (e.g. 22–26 °C). Mass kWh/K is the house thermal capacity — indoor temperature moves slowly. Surplus PV that would be wasted at too-low spot market prices runs the heat pump toward the middle of the temperature band.

Household only kWh/d	Out °C	In °C	Heat W	Heat on	Cool on
4.0	-10.0	20.0	4000.0	18.0	25.0

Mass kWh/K	Curve	Min flow	Ground °C	Max flow
25.0	0.35	25.0	10.0	55.0

Demand — DHW

Litres per day at 40 °C tap. Tank 40–65 °C. Water out of the pipe, per quarter. Example: 200 L at 40 °C, tank 60 °C, pipe 10 °C → 120 L from the tank (40 % pipe + 60 % tank). Produced 08:00–18:00 winter time. If the heat pump is already full with room heat, DHW is direct electric.

L/day @ 40 °C	Tank °C	Water out of the pipe Q1 °C	Q2 °C	Q3 °C	Q4 °C
200.0	62.0	8.0	10.0	12.0	10.0

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	1	6	1	6
0 °C	1	6	1	6
10 °C	1	6	1	6

Sellers of infrared heating claim that the room temperature can be lower for the same comfort. Just set the minimum room temperature lower as far as you believe this claim. Maybe by 3° for strong believers and 0° for I do not believe this.

Set the heat pump fields' COP to 1 and the output to the maximum of the infrared heating. The direct electric report will show if the infrared heating was too weak.

How to simulate without peak grid fees?



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
11	11	11	11	11	11	11	11	11	11	11	11

Peak fee / kW / month	Fixed tariff cent/kWh	
0	38.0	>0 = no export, import only at this price. 0 = spot table.

Set the maximum of your grid connection in the monthly allowance field. Set Peak fee / kW / month to 0.

Project finance

The Big Bet. You bet that you'll pay your loans on time every month for decades. The stakes: a house. That is true at purchasing a house with a credit but also at extensive home improving.

Decide between “let it be like it is” as the baseline and 5 variants of improving. What happens in case of an emergency? Unemployment or your company going bankrupt? The stress test. Find it out in our simulation!

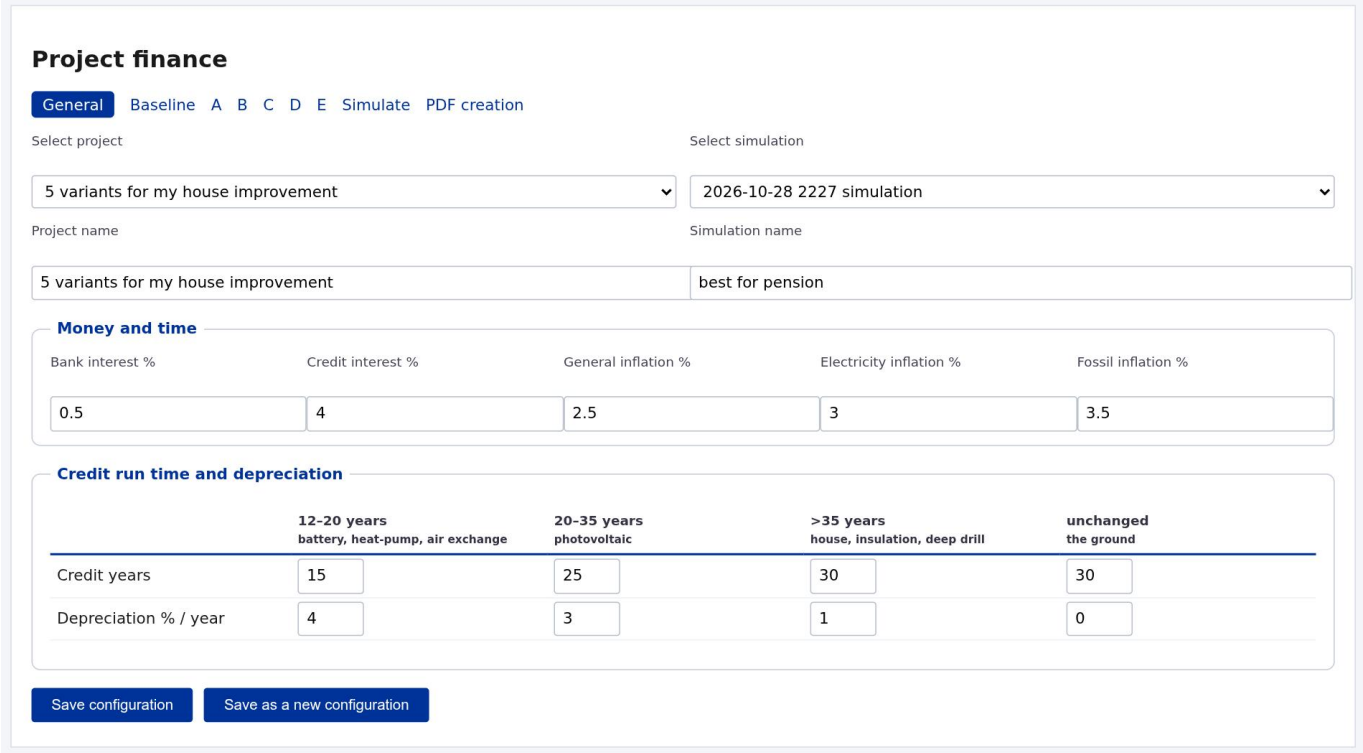
Find out about the effects of different inflation in different sectors and the effects of nominal money value and real inflation-corrected money value. Your credit down payment remains the same in terms of nominal value but shrinks in terms of real inflation-corrected value as long as there is an inflation. Deflation? Oh no, if you are deep in debt, because the real burden of the fixed payment rises.

How to save the situation in an emergency? Run the house simulation with less minimum room temperature, less DHW, and less car driving. How does it change the risk by taking more credit despite some money on your bank account?

How will your living standard be in the pension? Maybe less car driving, as in your work life as a commuter, and a higher minimum room temperature. It is law in Salzburg to make an energy certificate with 20° C for normal houses and 25° C at senior residents. Test it in another simulation.

The same house configuration can use different simulations for normal, emergency, and pension. Explore any possibility to make the best decision for your financial future.

Project finance - General situation



The General page holds the parameters that apply to every variant of the project.

Project and simulation. Select an existing project or type a new name. Each project contains one or more simulations. The simulation name appears in the file list as YYYY-MM-DD HHMM name.

Interest and inflation

Bank interest %	—	the rate paid on a positive bank balance.
Credit interest %	—	the rate charged on the loans.
General inflation %	—	the rate used to convert nominal values to real values, and to inflate maintenance and replacement costs.
Electricity inflation %	—	the rate applied to energy sold and energy purchased.
Fossil inflation %	—	the rate applied to fossil energy costs when no simulation is linked.

Credit run time and depreciation.

Four columns cover the typical lifetimes of the investments:

12–20 years: battery, heat pump, air exchange.

20–35 years: photovoltaic.

35 years: house, insulation, deep drill.

Unchanged: the ground.

Credit years is the loan duration. Depreciation % / year is the annual maintenance and replacement cost on the investment amount. It rises with general inflation, so the real cost stays constant while the nominal cost grows.

You do not get a 30-year loan for a car, but it is usual for long-lasting investments like houses and grounds. You decide over the credit runtimes in the simulation. When You think you can get a € 300,000 loan for a house where €50,000 is for PV, batteries, and a heat pump, test it. Hope it works.

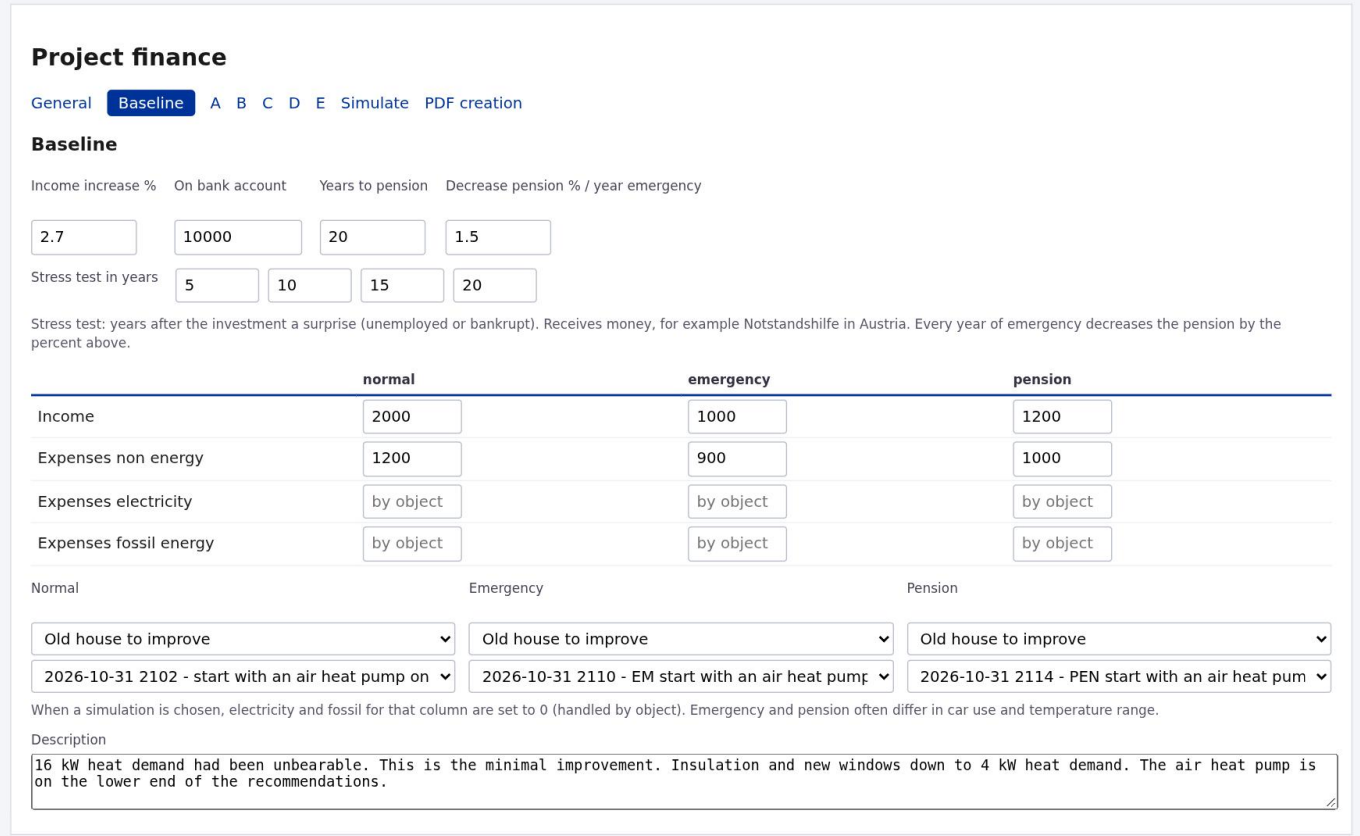
Electricity inflation and an old sellers trick

Before 2020 many home batteries still cost more than 1 000 € per kilowatt-hour. Many sellers calculated with 5 % higher electricity prices every year for decades. That was not a cautious estimate. It was consultation fraud.

Five percent per year for 30 years multiplies the price by $1.05^{30} \approx 4.32$. Electricity that costs 30 ct/kWh today would be assumed to cost about 1.30 €/kWh in 30 years. No serious long-term planning starts from that number.

Electricity has often risen faster than general inflation. That is a reason to give it its own rate in the simulation, In the Global settings you choose both rates yourself. The simulation then shows the effect.

Project finance: Baseline



The Baseline describes your situation without further investment. All later variants (A–E) are compared against it.

Personal parameters

Income increase % — expected yearly rise of your income. Different professions and skill levels have different wage development. This value belongs to the Baseline because it describes you, not the house.

On bank account — money already available at the start of the simulation.

Years to pension — years from now until retirement.

Decrease pension % / year emergency — every year spent in emergency (unemployment or bankruptcy) reduces the later pension by this percentage.

Stress test

Years after the investment a surprise can occur (unemployed or company bankrupt). You receive reduced income, for example Notstandshilfe in Austria. The four fields set the years in which the stress tests start.

Income and expenses

Three columns: normal, emergency, pension.

Income — monthly income in that phase.

Expenses non energy — living costs that are not energy (food, insurance, transport, etc.).

Expenses electricity and Expenses fossil energy — normally left at “by object”.

When a house simulation is chosen below, these costs are taken from that simulation.

House simulations

For each phase you select an object and a simulation:

Normal — your everyday life (commuting, usual room temperature, usual hot water).

Emergency — reduced standard (lower room temperature, less hot water, less car driving).

Pension — often less driving, sometimes a higher room temperature.

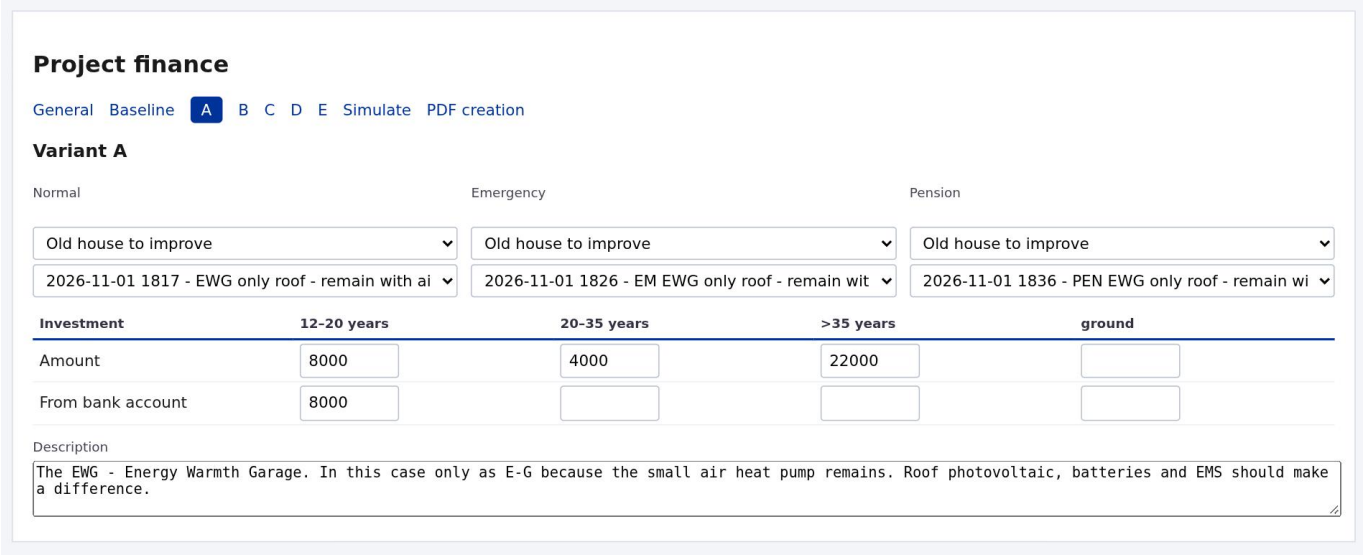
The same house configuration can be run with different settings for the three phases. The simulation then uses the matching energy costs for each phase.

If you leave Emergency or Pension empty, the simulation uses the Normal house run for that phase. Energy costs do not drop to zero. Choose a separate Emergency or Pension simulation only when the house is run differently (lower temperature, less hot water, less driving).

Description

Free text. It appears in the changes list when you save, so you can record why this Baseline was chosen.

Project finance: Variants A to E



Each of the five variants describes one way to improve the house. The baseline is “leave it as it is”. A variant is a concrete package of investments plus the simulations that show how the house behaves after those investments.Normal / Emergency / Pension

For every variant you choose three house simulations:

Normal — everyday operation (working life, usual driving, usual room temperature).

Emergency — the reduced mode used when money becomes tight (lower minimum room temperature, less hot water, less driving).

Pension — the mode after retirement (often less commuting, sometimes a higher room temperature).

The same house configuration can have different simulations for the three phases. The project-finance simulation switches between them according to the rules for emergency and pension.

Investment table

The four columns are the credit durations already defined on the General page:

12–20 years

20–35 years

more than 35 years

ground (land)

Amount is the credit taken for that duration

From bank account is the part paid from your own money instead of a new credit.The monthly down-payment of each credit is calculated from the usual credit formulas and appears in the simulation.

Taking money from the own bank account for less credit is cheaper but riskier. In the case of an emergency, it could be very difficult to get a loan to cover the next years when expenses are higher than the income during the emergency.

I would suggest testing both variants to see the differences in the outcome at the stress tests.

Description

A free-text field for this variant. It is stored with the project and appears in the changes table when you save. Use it to note what the investments are (for example “Energy Warmth Garage – roof photovoltaic, batteries and EMS; small air heat pump remains”).

Income and non-energy expenses stay the same across all variants; only the house-related investments and the energy simulations change.

DIY and/or professionals

This simulation gives no prices for photovoltaic modules or battery storage. You decide for every part whether you do it yourself or hire a professional, and you enter the cost that matches your choice.A garden-fence or railing photovoltaic array is often a good candidate for do-it-yourself work: the modules are easy to reach, the height is low, and the electrical work stays simple. Work on the house roof is different. Falling risk, roof sealing, and the weight of the modules make it a job many people prefer to leave to a professional.

Enter the price that belongs to the way you actually plan to build it.

At “old house to improve” is an example: a 6 kW photovoltaic array as a garden fence, done by yourself, can cost less than a 3 kW array on the south roof installed by professionals. The fence is easy to reach, and the work is simpler; the roof needs scaffolding, sealing, and higher labor rates.

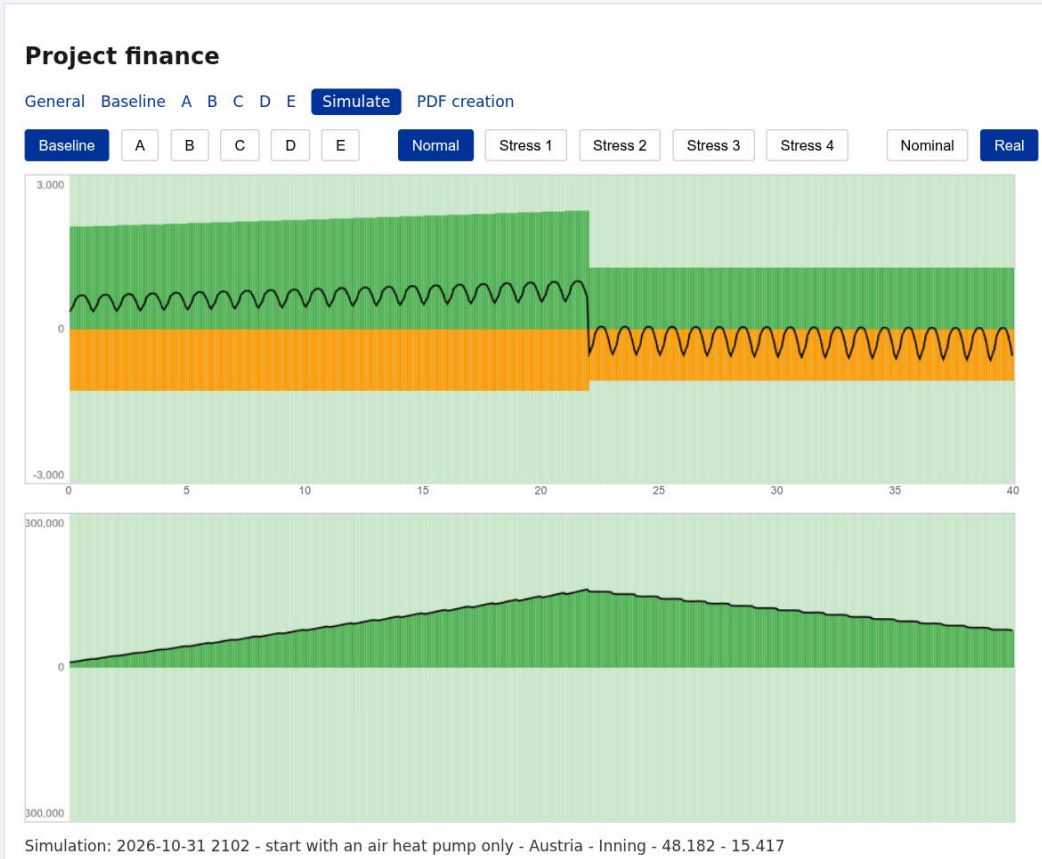
Variants A to E are not only to compare different improvements. They are also to compare different DIY or professional combinations.

Estimate hours DIY, maybe by asking Grok with a description of the project and your skill levels to get an estimate of working hours.

Find out in the simulation how much the financial outcome improves by DIY.

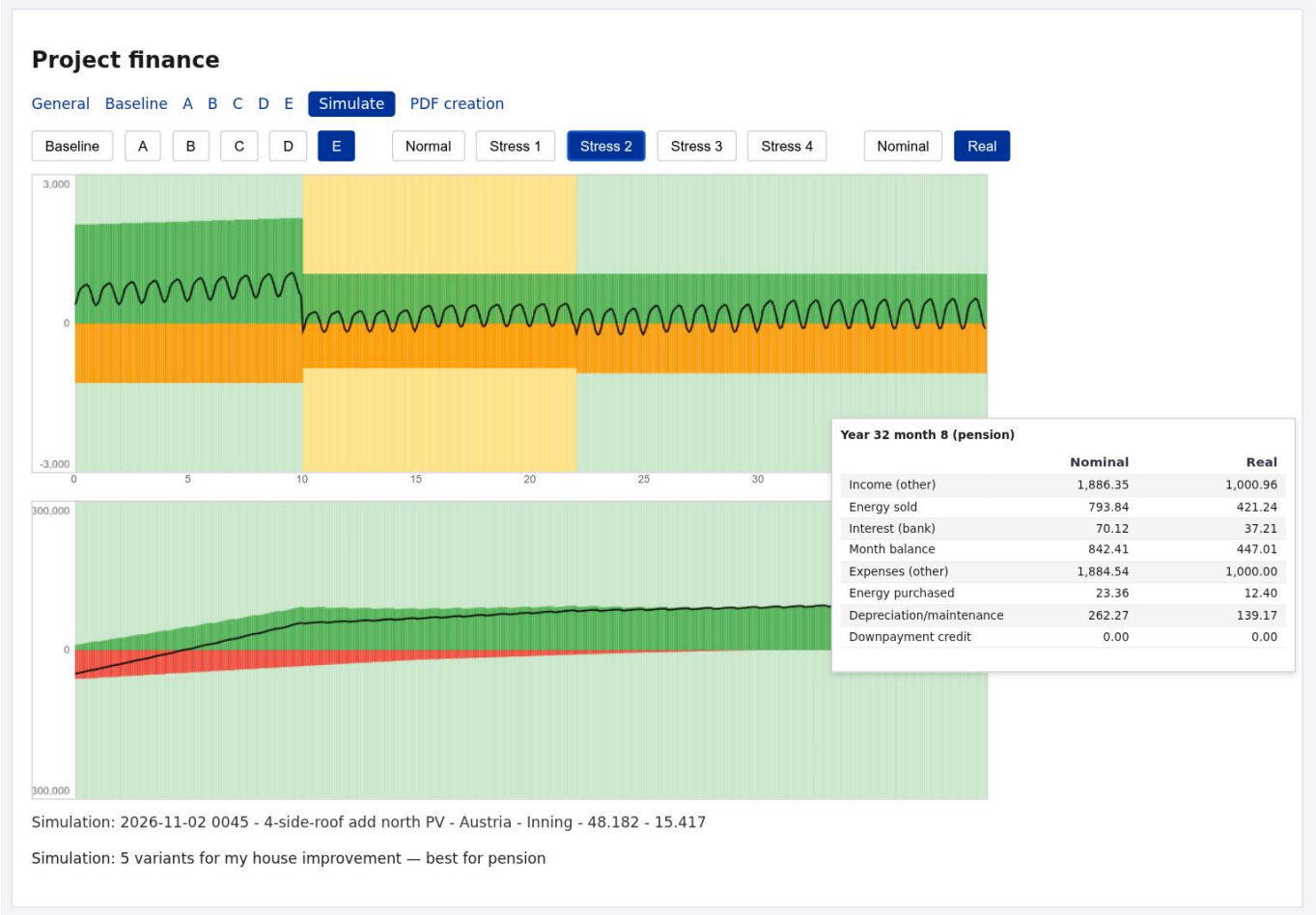
Project finance: Simulate: Nominal Real





Buy a car for US$ 440? This is the nominal value of a Ford T in 1915. The real inflation-corrected price in 2026 is US$ 14,700. The difference between nominal and real over 111 years is 1:33.4, stating an average inflation of 3.2%.

Project Finance: Simulate: Income Expenses



Move the pointer over a month on either chart. A table appears for that month.

The header shows the year, the month, and the phase (normal, emergency or pension).

The two columns are Nominal and Real. Nominal is the money of that year. Real is the same amount corrected for general inflation, so it can be compared with today's prices.The rows are:

Income (other) — income that is not from energy or interest

Energy sold — electricity exported to the grid

Interest (bank) — interest earned on a positive bank account

Month balance — income minus expenses for that month

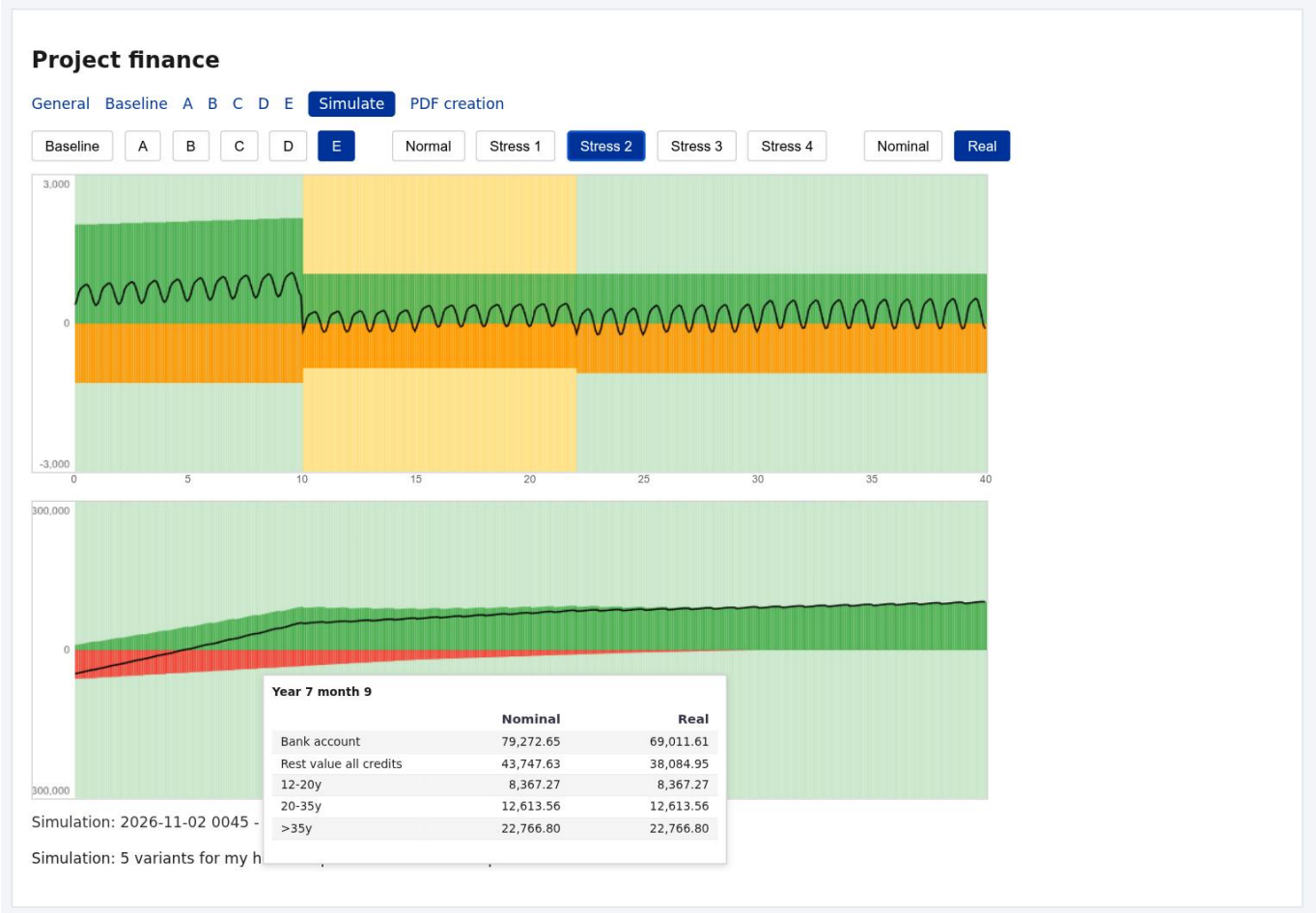
Expenses (other) — non-energy living costs

Energy purchased — electricity and fossil energy bought

Depreciation/maintenance — the annual allowance for replacement and upkeep, spread over the months

Downpayment credit — the monthly credit payment

Project finance: Simulate: Bank account credits



The lower chart shows the bank account and the remaining credit balances. Move the pointer over a month to see the values for that month.The header shows the year and the month.The two columns are Nominal and Real. Nominal is the money of that year. Real is the same amount corrected for general inflation.The rows are:

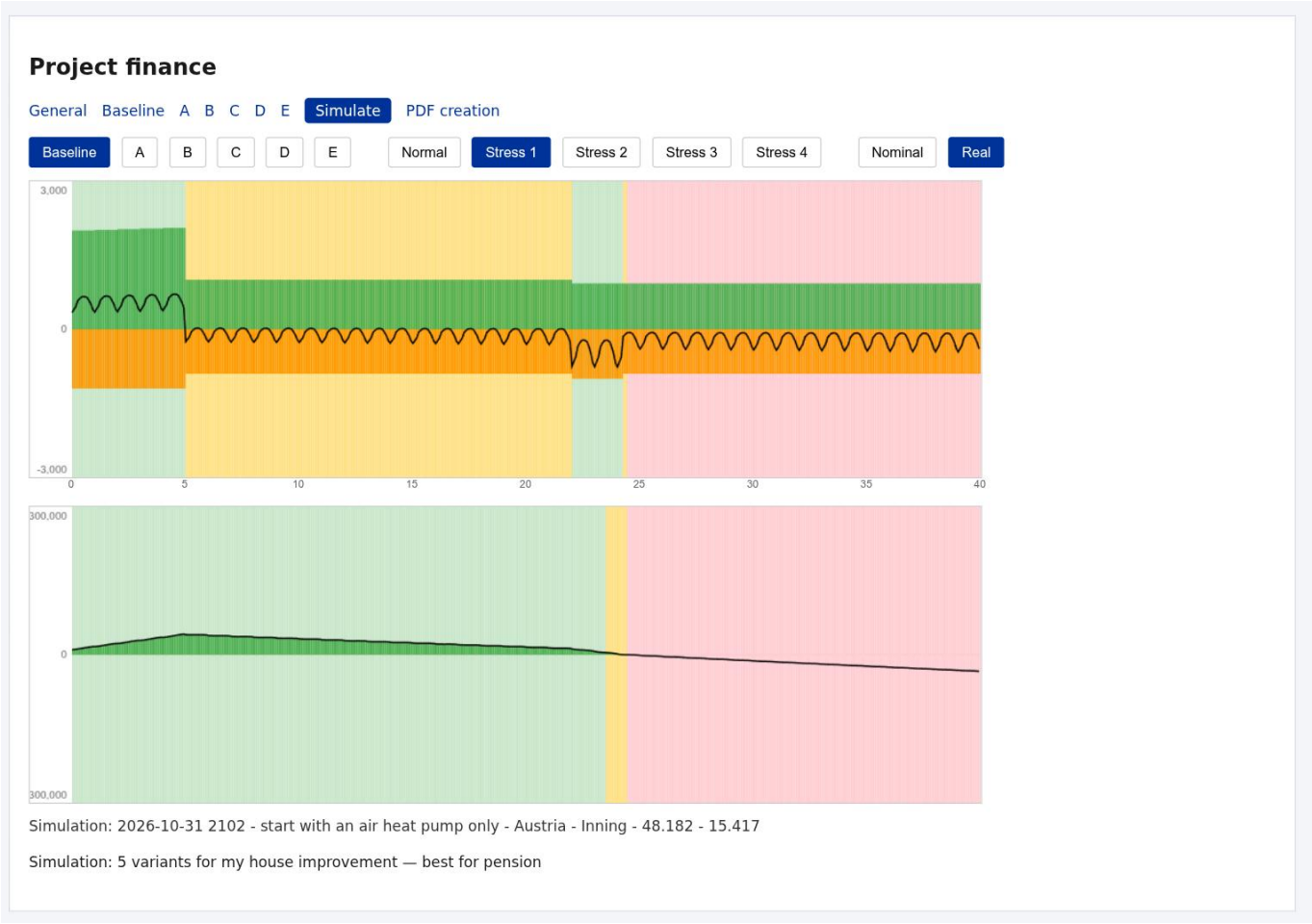
Bank account — the money on the account at the end of that month

Rest value all credits — the sum of all remaining credit balances

One row for each credit that is still open. The label (12–20 years, 20–35 years, more than 35 years) is the life span of the investment that was paid with that credit, not the length of the loan itself.

A credit that has been fully repaid no longer appears.

Project finance: Simulate: Status background



The background of both charts shows the financial condition of each month.

Upper chart

Light green — normal conditions. Income and expenses follow the normal (or pension) figures, and the bank account stays positive.

Yellow — emergency. The house runs in the reduced mode (lower temperature, less hot water, less driving). This happens in a stress-test year, or when expenses exceed income and the current monthly loss would drive the bank account negative within twelve months. In pension, the switch to emergency is made only if the emergency expenses are lower than the pension expenses.

Light red — the bank account is already below zero.

Lower chart

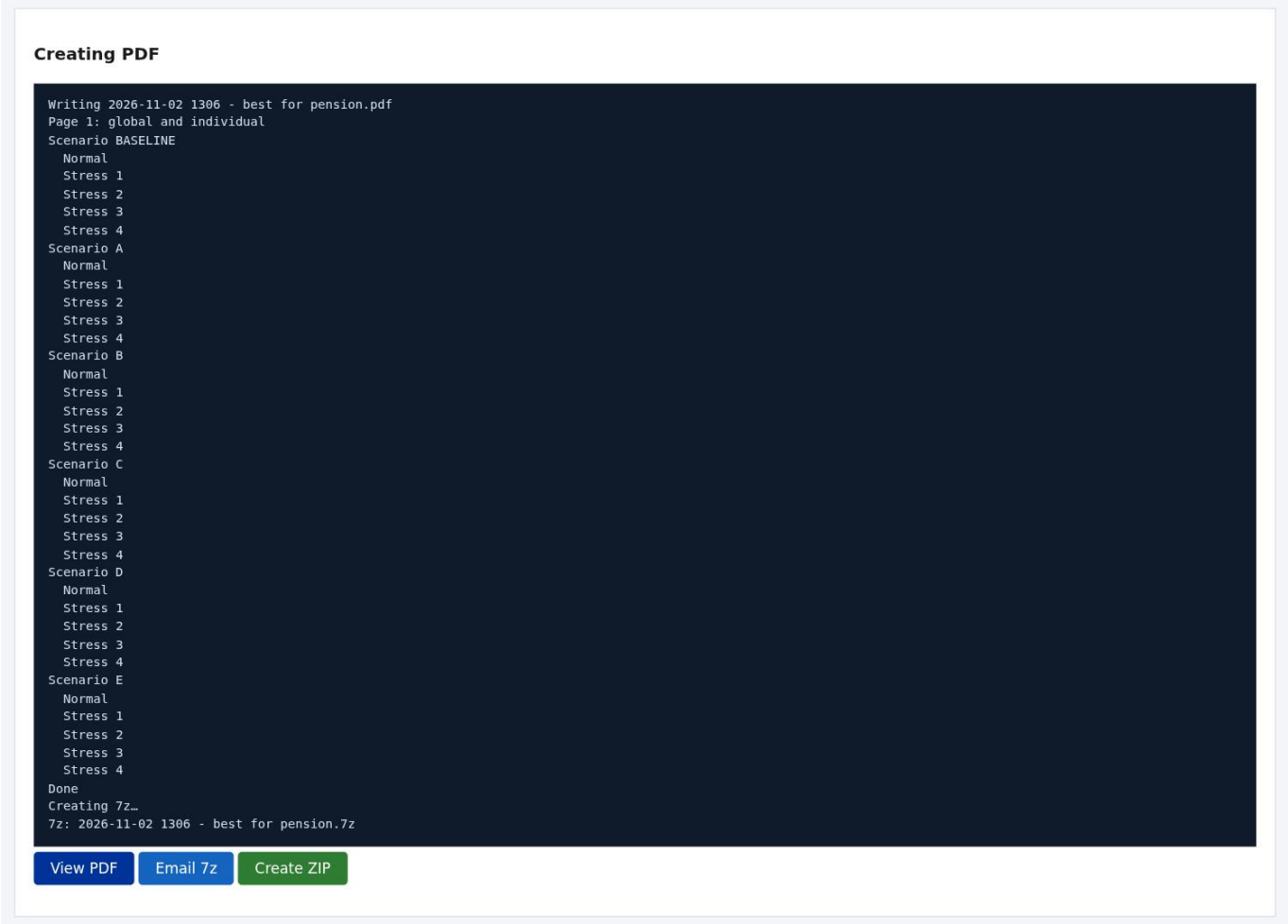
Light green — the bank account is positive and the current monthly balance does not threaten it within the next twelve months.

Light yellow — the bank account is still positive, but the current monthly loss would drive it negative within twelve months.

Light red — the bank account is already negative.

The black line on the upper chart is the monthly net cash flow. The black line on the lower chart is the bank-account balance.

Project finance: Create PDF



Click PDF creation. The progress window opens and shows each step as it happens: the global page, each scenario, and each stress level.When the PDF is finished, the 7z archive is created automatically and stored next to the JSON and the PDF. The 7z is about half the size of a ZIP, which matters when you send it by email.

Three buttons appear below the progress:

View PDF opens the finished PDF in a new tab.

Email 7z opens your default email program with the 7z already attached.

Create ZIP builds a ZIP of the same files, if you prefer that format.

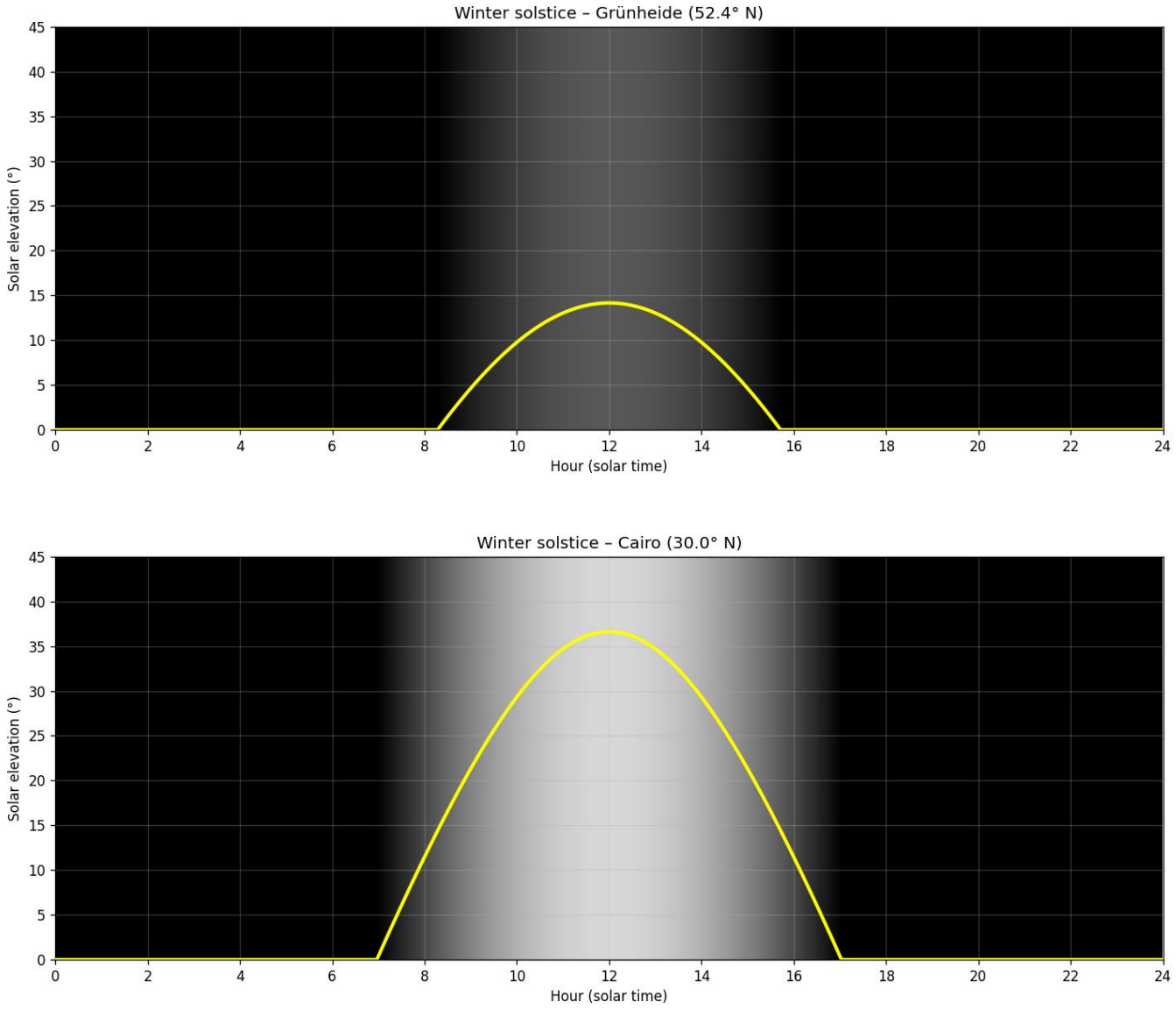
The 7z and the ZIP contain the project-finance JSON and PDF, and the object-house JSON and PDF for every scenario that is linked (normal, emergency, pension). The folder structure inside is project-finance/ and objects/, so the recipient can place the folders next to each other and the links in the PDF still work.

From house to community simulation

Here is the border between house and community simulation. Untils now was everything a house with photovoltaics and batteries where electricity was consumed for household, heating, cooling, DHW, and charging electric vehicles.

The only interaction with the outside world had been buying and selling electricity by a spot market price model.

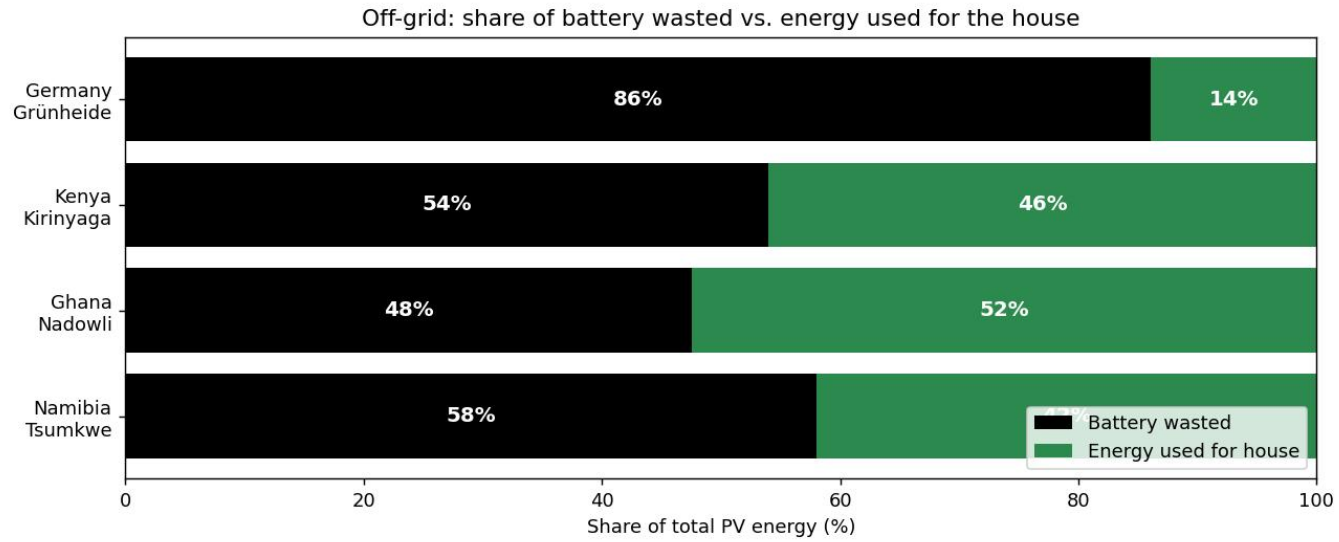
We simulated houses off-grid near the equator. Half of the photovoltaic yield wasted, half of the yield used. We simulated also the GEMINI next Generation house off-grid in Grünheide 52.4° N. (90° - 52.4°) - 23.44° equals 14.16°.



Winter solstice – solar elevation and horizontal irradiance. The yellow line shows the height of the sun above the horizon through the day (solar time). The background shows how much solar energy reaches a horizontal surface just by geometry. White means the sun is 45° above the horizon; black means the sun is below the horizon or at the horizon. Between these extremes the brightness follows the sine of the elevation angle.

Averaged over the whole day, a horizontal surface at Cairo receives roughly 3.3 times as much solar energy as the same surface at Grünheide. No atmosphere involved in the calculation, just geometry; atmosphere nearly doubles the difference from 1:3.3 to 1:5.6. These two pictures show why winter yield is so different between northern and southern locations.

In all these off-grid simulations occured small shortages. Nothing dramatic, just in the range of less DHW or less electric vehicle charging. The GEMINI next Generation house in Inning - Austria did not qualify for this chart, because it was in the off-grid test far away from a shortage.

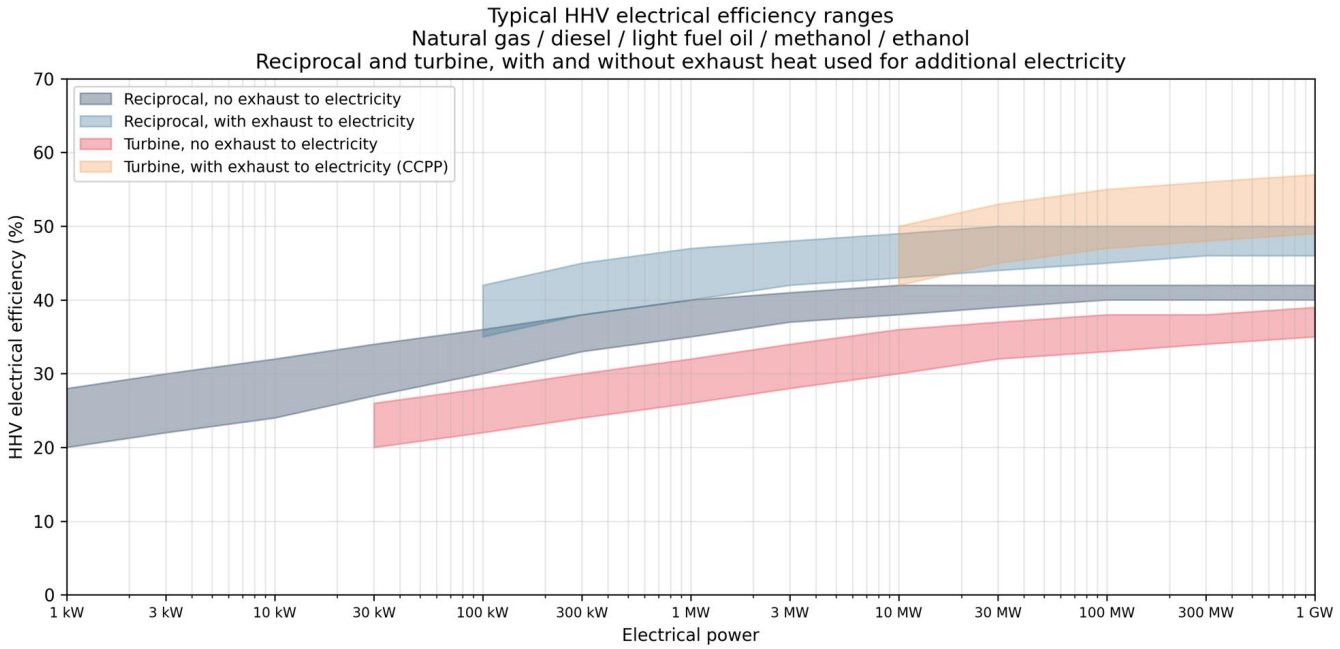


Off-grid: wasted energy versus energy used for the house

The African examples show what is possible with the simplest and cheapest technology that still delivers a good living standard. A basic house in the countryside, a few kilowatts of PV, a modest battery, and an EXW US$ 200 air-conditioning unit. Under these conditions roughly half of the PV energy is used by the house and half is wasted because the battery cannot store more.

The Grünheide example is the opposite: a very advanced house with very good thermal insulation, air ventilation with heat recovery, an extreme flat heating curve and a dual-mode heat pump. Even with this high-end configuration the waste-to-use ratio is already 86 : 14. Anything worse – less insulation, no heat recovery, a steeper heating curve or a less efficientair heat pump – increases electricity demand exactly where it hurts most: in December and January. A less efficient house could easily push the ratio to 90 : 10 or worse.

Electrical efficiency of generators



The diagram shows typical ranges of electrical efficiency (HHV) for reciprocal engines and turbines. The same bands apply to natural gas, diesel, light fuel oil, methanol and ethanol. The difference between these fuels is only 1–3 percentage points for the same machine.

Four cases are shown:

Reciprocal engine without additional electricity from exhaust heat

Reciprocal engine with additional electricity from exhaust heat (for example ORC)

Turbine without additional electricity from exhaust heat

Turbine with additional electricity from exhaust heat (combined-cycle plant, CCPP)

Reciprocal engines are available from 1 kW upward. Turbines start to become practical from roughly 30 kW. Combined-cycle plants appear from about 10 MW. Systems that turn exhaust heat into additional electricity (ORC modules, steam bottoming cycles, etc.) are commercially available from roughly 100–200 kW upward. Below that size the extra equipment is usually not economical, so the light-blue band starts at 100 kW. Simple heat recovery for heating or hot water exists at all sizes, but that does not raise electrical efficiency and is therefore not shown in the diagram.

Why turbines if they are less efficient?

In the simple-cycle range, reciprocal engines are more efficient. Turbines are still used for other reasons:

At multi-MW scale a single turbine is simpler and cheaper to maintain than many reciprocal engines.

Combined-cycle plants (from roughly 10 MW) overtake reciprocal efficiency.

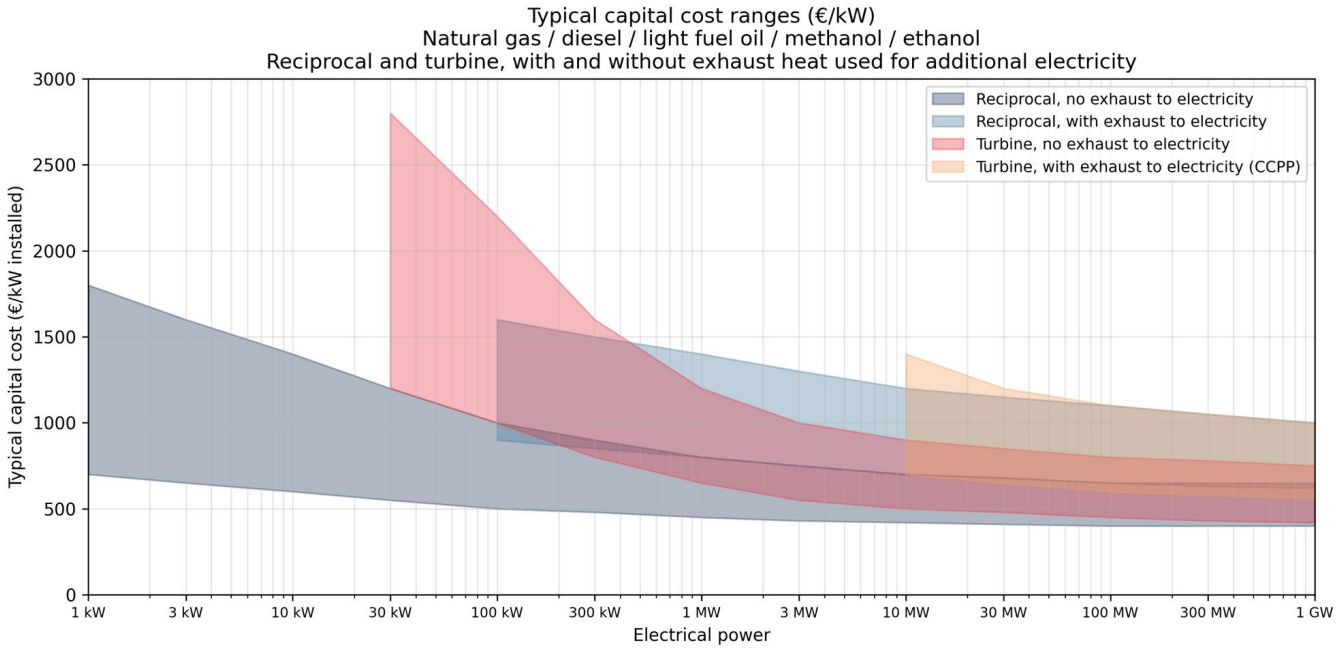
Turbines have lower vibration, higher power density and better exhaust quality for large continuous base-load plants.

At very large sizes (100 MW+) only turbines exist in practice.

For sizes below a few MW, reciprocal engines remain the more efficient and usually cheaper choice.

Capital costs follow the opposite pattern. Reciprocal engines are cheaper at small sizes. Turbines and especially CCPP become competitive only above several megawatts.

Prices of generators



Costs fall with size for all types

Reciprocal with exhaust-to-electricity is more expensive than simple reciprocal.

Simple-cycle turbines are expensive at small sizes; CCPP becomes competitive from roughly 10 MW.

Actual project costs vary with location, grid connection, emissions equipment and current market conditions. The bands show typical ranges only.

Understanding our current electricity system

This simulation is about to design a new electricity system based on renewable energy. We have to understand the design and limitations of our current electricity system to change from the current system to the new.

There is no sudden change like H-Day in 1967 in Sweden to change from left lane traffic to right lane traffic. It is a change over several decades where parts of the old system have to be used together with the new system.

This simulation is about to design the change step by step. What to phase out first? What to keep for as long as possible? Until we are at 100% renewable energy, it is about to design the most efficient coexistence of both systems.

Overview: Steam-powered electricity production

Most thermal power plants (coal, gas, nuclear fission, and proposed fusion) convert heat into electricity with a steam cycle. The process is the Rankine cycle:

Water is heated in a boiler or heat exchanger until it becomes high-pressure steam.

The steam expands through a turbine and drives a generator.

The low-pressure steam is condensed back to water in a condenser.

The condensate is pumped back to the boiler.

Typical efficiencies

Modern large plants reach 35–42 % net efficiency with conventional steam parameters. Advanced supercritical or ultra-supercritical plants can exceed 45 %. Nuclear fission plants usually stay in the 33–36 % range because the reactor coolant temperature is limited. Fusion concepts that use a conventional steam cycle are expected in the same range (~33 %).

Typical terminology

Power plants are commonly classified by the role they play in covering electricity demand. Base-load plants run most of the time and cover the permanent minimum demand. Intermediate-load plants follow the regular daily variation in consumption. Peak-load plants are started only for short high-demand periods or as reserve. The boundaries are not sharp; a modern combined-cycle plant can be used in more than one role depending on the market and the rest of the generation fleet.

Characteristic	Base-load	Intermediate-load	Peak-load
Typical capacity factor	70–90 %	30–60 %	usually < 20 %
Typical plants	Nuclear, lignite, older hard-coal, run-of-river hydro	Combined-cycle gas turbines (CCGT), hard-coal units designed for cycling	Open-cycle gas turbines (OCGT), diesel engines, limited hydro reservoirs, batteries
Cost structure	High fixed costs, low variable costs	Balanced	Low fixed costs, high variable costs
Operating pattern	Run continuously for days or weeks once started	Start and stop more frequently; follow daily load	Start quickly, run only during high-price or shortage periods
Cold start time	8–48 h (nuclear longer)	1–4 h (CCGT typically 2–3 h)	5–20 min
Warm start time	2–8 h	30–90 min	2–10 min
Cold / warm start cost	High (fuel + wear)	Medium	Low
Ramping speed	Slow (typically 1–3 %/min)	Medium (5–10 %/min for modern CCGT)	Fast (10–20 %/min or essentially instantaneous for batteries)
Role in system	Cover the permanent minimum demand	Cover the bulk of the daily variation	Cover short peaks and provide reserve

Heat rejection

Only the fraction of heat that is converted to electricity leaves the plant as useful work. The rest must be rejected to the environment. At 33 % efficiency the plant rejects roughly two units of heat for every unit of electricity. At 40 % efficiency the ratio falls to about 1.5.

The rejected heat is carried away by cooling water (once-through river or sea cooling) or by cooling towers. In summer, low river flow and high water temperature frequently force plants to reduce power so that environmental temperature limits are not exceeded. This effect is stronger for plants with lower efficiency because they reject more heat per kilowatt-hour.

Relevance for different heat sources

Coal and gas plants can choose higher steam temperatures and therefore higher efficiency.

Fission plants are constrained by fuel and coolant temperature limits.

Fusion plants that use a steam cycle face the same temperature limit plus the additional internal electricity consumption of the plasma heating and magnet systems. The result is a higher ratio of heat rejected to net electricity delivered to the grid.

The steam cycle itself is mature and reliable. Its efficiency and cooling demand are fixed by the temperature of the heat source and by the ambient conditions at the site. These physical limits remain the same whether the heat comes from coal, fission, or fusion.

Supercritical CO_2 instead of steam

In a classical thermal power plant the heat from the boiler or the gas-turbine exhaust is used to produce steam that drives a steam turbine (Rankine cycle). An alternative is to use carbon dioxide above its critical point as the working fluid (supercritical CO_2 or sCO_2 cycle, normally a closed Brayton cycle).

The sCO_2 cycle can reach a higher electrical efficiency at the same turbine inlet temperature, the machinery is much more compact, and water consumption is lower. The technology is still at the pilot and demonstration stage; commercial use in large plants is expected mainly in the 2030s. It is most attractive for high-temperature heat sources (advanced coal, high-temperature nuclear, concentrated solar or future hydrogen/methanol combined cycles). For today's light-water reactors the temperature is too low for a clear advantage over steam.

Plant type	Steam Rankine	sCO_2 cycle
Coal (advanced)	45–47 % HHV	48–52 % HHV
Natural gas / methane CCPP	58–62 % LHV / 52–56 % HHV	60–65 % LHV / 54–59 % HHV
CCPP H_2	58–62 % LHV / 49–52 % HHV	60–65 % LHV / 51–55 % HHV
Methanol CCPP	55–60 % LHV / 50–54 % HHV	57–63 % LHV / 52–57 % HHV
Fission (LWR)	33–36 % HHV	≈ same or slightly lower HHV
Fission (high-temperature)	40–45 % HHV	45–52 % HHV
Fusion (conceptual)	42–48 % HHV	45–55 % HHV

The higher CCPP figures assume a modern large gas turbine plus an sCO_2 bottoming cycle under favourable cooling conditions. The absolute gain remains in the 2–4 percentage-point range; the relative improvement is smaller than for pure high-temperature Rankine or Brayton plants because the gas turbine already operates at very high efficiency. For future systems in which combined-cycle plants are the main remaining thermal generation, this incremental gain is still relevant.

The HHV Higher Heat Value – LHV Lower Heat Value trap

Even the author of this manual fell into the HHV–LHV trap. In Calculation ERROR (written 2012–2013) the BMW Hydrogen 7 was used as an example. The intention was to show how unfavorable the liquid-hydrogen internal-combustion concept is compared with an electric car of the same size. There had been the assumption that a BMW 7 sized car would consume 25 kWh/100 km. The goal was to demonstrate that the hydrogen car was roughly eight times worse.

The comparison used the LHV value for hydrogen and underestimated the energy required for liquefaction. As a result, the hydrogen car appeared far better than it really was. It was not eight times worse, it was ten to eleven times worse.

A consistent calculation changes the picture. Electrolysis efficiency is normally stated relative to the higher heating value. Liquefaction then adds another 10–15 kWh per kilogram. When both effects are included, the well-to-wheel energy demand is substantially higher than the already unfavorable figure that was published.

The same error can appear in power-to-X studies. An efficiency is almost always given on an HHV basis for the power to part. If that figure is later compared with the LHV efficiency of an engine or a combined-cycle plant, the overall result looks several percentage points better than it is. For hydrogen the gap is especially large. Using either HHV or LHV consistently throughout the whole chain is therefore essential.

Mixing LHV and HHV in the literature

The difference between lower heating value (LHV) and higher heating value (HHV) is not a minor technical detail. It appears with every fuel that contains hydrogen. For pure hydrogen the ratio LHV/HHV is approximately 0.845. For natural gas it is about 0.90, for methanol and other oxygenated fuels it lies in between.An efficiency of 60 % on an LHV basis is therefore only about 51 % on an HHV basis for hydrogen, and roughly 54 % for natural gas.Despite this, a large number of peer-reviewed papers report electrolyser, fuel-cell, power-to-X or combined-cycle efficiencies without stating whether the figure is based on LHV or HHV. Some studies even mix both values inside the same calculation chain. A 2020 review in the Journal of Power Sources documents how frequently the basis is omitted or switched for electrolysis, producing results that cannot be compared and that occasionally exceed 100 %.

The error is amplified in round-trip calculations:

Consistent LHV chain: $60\ \% \times 60\ \% = 36\ \%$

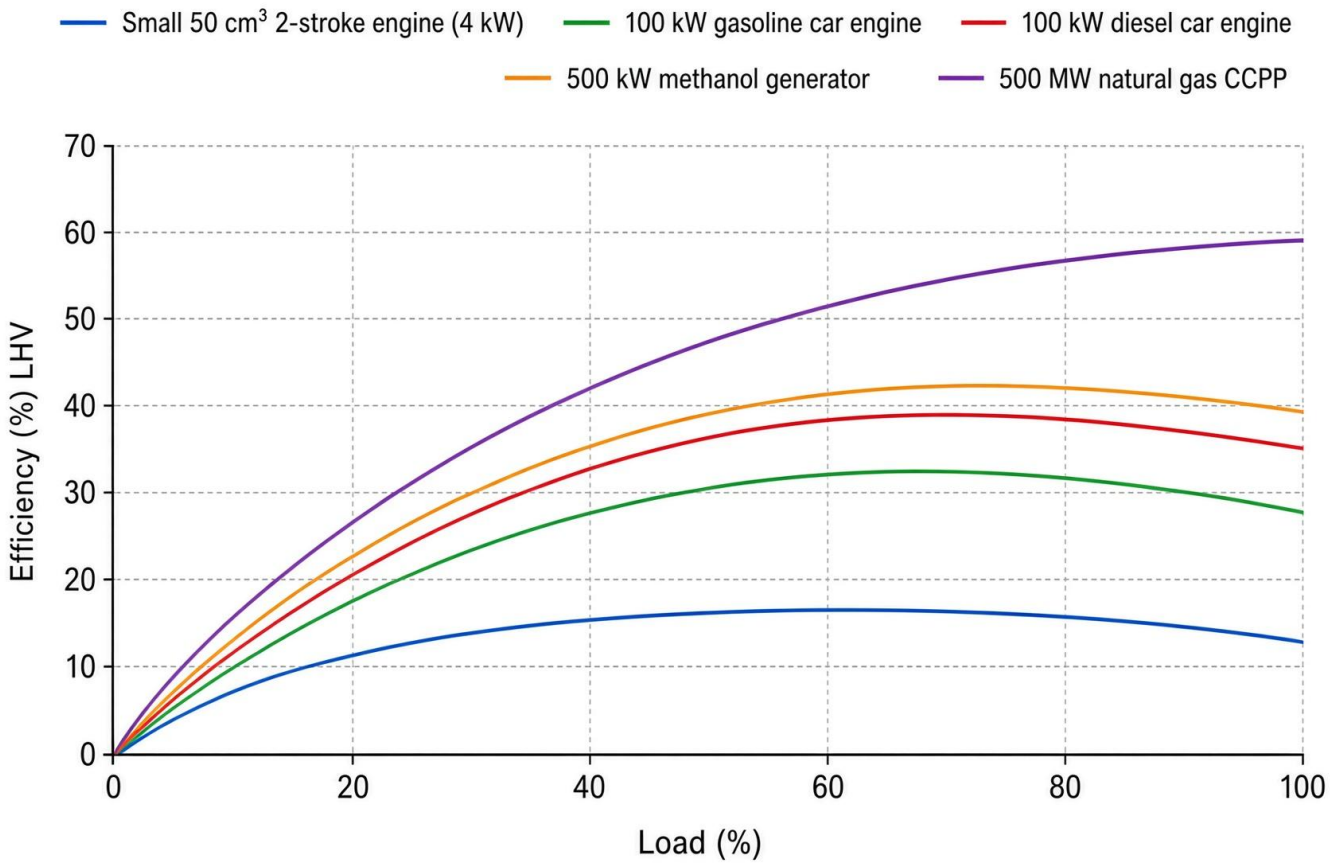
Consistent HHV chain for hydrogen: $50.7\ \% \times 50.7\ \% \approx 25.7\ \%$

The results differ 1:1.4. The same physical plants appear dramatically better simply because the lower reference value was used for “100 %” in both steps.

European literature almost always uses LHV; North-American boiler and some electrolysis papers use HHV. Direct numerical comparison without conversion is therefore invalid. When reading any efficiency claim that involves hydrogen-containing fuels, the first question must be: which heating value was used?

Partial load penalty or battery round trip?

This is a new question based on high-efficiency batteries with many thousand cycles. When all you have is a lead battery with 300 cycles and 70% round-trip efficiency, this is a complete senseless question.



This is only an example for efficiency curves. Details may vary, but the basic principle remains. Here are some effects about what do these curves tell us?

Same ICE car, different engines, different consumption

Same ICE car with a 100 kW and a 200 kW engine drives on the highway with 40 kW. 40 kW is 40% of 100 kW and 20% of 200 kW. Look at the curves; this is a major reason for the huge engine penalty at ICE cars.

Why did China start with electric scooters?

China began policy support for electric scooters in the early 1990s under Deng Xiaoping. The first Five-Year Plan that listed electric two-wheelers as a technology priority came in that period. This time was far away from lithium batteries. Only lead batteries are available. A 45 km/h limited electric scooter consumes roughly 4 kWh/100 km with lithium batteries and 5 kWh/100 km with less efficient lead batteries. A 2 stroke engine scooter consumes about 4 liters of gasoline/100 km. The highest kWh electricity replaces fuel ratio despite ICE super sports cars.

VW CEO and where does the electricity for electric cars come from?

VW CEO Dr. Winterkorn questioned in June 2008 the electric car in an interview with “Bild”: from where should the electricity for all the electric cars come from?

My answer for 2008: multiply the efficiency of a CCPP with grid efficiency, charging efficiency, and electric car efficiency. Surprise: Only half of all the oil and natural gas burned instead in ICE cars in CCPP would produce enough electricity for 100% electric street traffic.

Only half of the fossil fuel imports and CO2 emissions are the baseline of all electric vehicles. Every renewable energy system improves the situation further.

What makes an hybrid ICE car more efficient than an ICE only car?

The 2 major reasons: recuperation at deaccelerating, no ideling of the ICE engine when stopped and the answer to this chapters headline: Partial load penalty or battery round trip?

For example in a traffic jam. Some meters with 10 km/h, stop, some meters with 5 km/h. Look at the chart, where the efficiency is at 1 kW to 5 kW load at a 100 kW engine. Look at the efficiency at 50% load and multiply with 90% efficiency for a battery roundtrip.

Same answer as at an hybrid ICE car

When not enough renewable energy is available and the battery has not enough charge: run the generator at the highest possible efficiency. Highest generator efficiency times battery roundtrip efficiency is most times far better than generator partial load efficiency.

Battery wear? A huge problem at lead batteries. Who killed the electric car? The lead battery. I had to make this experience peronaly at my first electric scooter long time test 2006 to 2009: 3 packs of lead batteries scrapped down to 30% original capacity in only 17,300 kms. High discharge rates accelareted the aging from 300 cycles down to only 100 cycles.

There is calendaric aging and cycle aging at batteries. When there are only 2,000 to 5,000 cycles in 20 years, calendaric aging makes the main part at an 10,000 cycle LFP or sodium battery.

Historic example: the West Berlin lead-acid battery

While West Berlin was an electrical island, BEWAG operated a large lead-acid battery in Steglitz (commissioned 1986, decommissioned end of 1994). It was rated at approximately 17 MW / 14 MWh and served for frequency regulation and spinning reserve. At the time it was the world's largest lead-acid battery installation.

The plant illustrates the practical limits of lead-acid technology for grid use. Flooded lead-acid batteries of that era were typically limited to a depth of discharge of about 50 % if cycle life was to be preserved. High discharge rates further reduced life, exactly as seen later on electric scooters: a battery rated for 300 cycles at C = 0.2 could drop to roughly 100 cycles under sustained high-C discharge. After Berlin was reconnected to the western European grid in 1993 the frequency-control task disappeared and the battery was taken out of service.

The same fundamental constraints — limited depth of discharge and sensitivity to high C-rates — explain why early electric vehicles and the few large lead-acid grid batteries of the 1980s and 1990s never scaled. Modern LFP and sodium-ion cells have removed these restrictions.

PDF Output



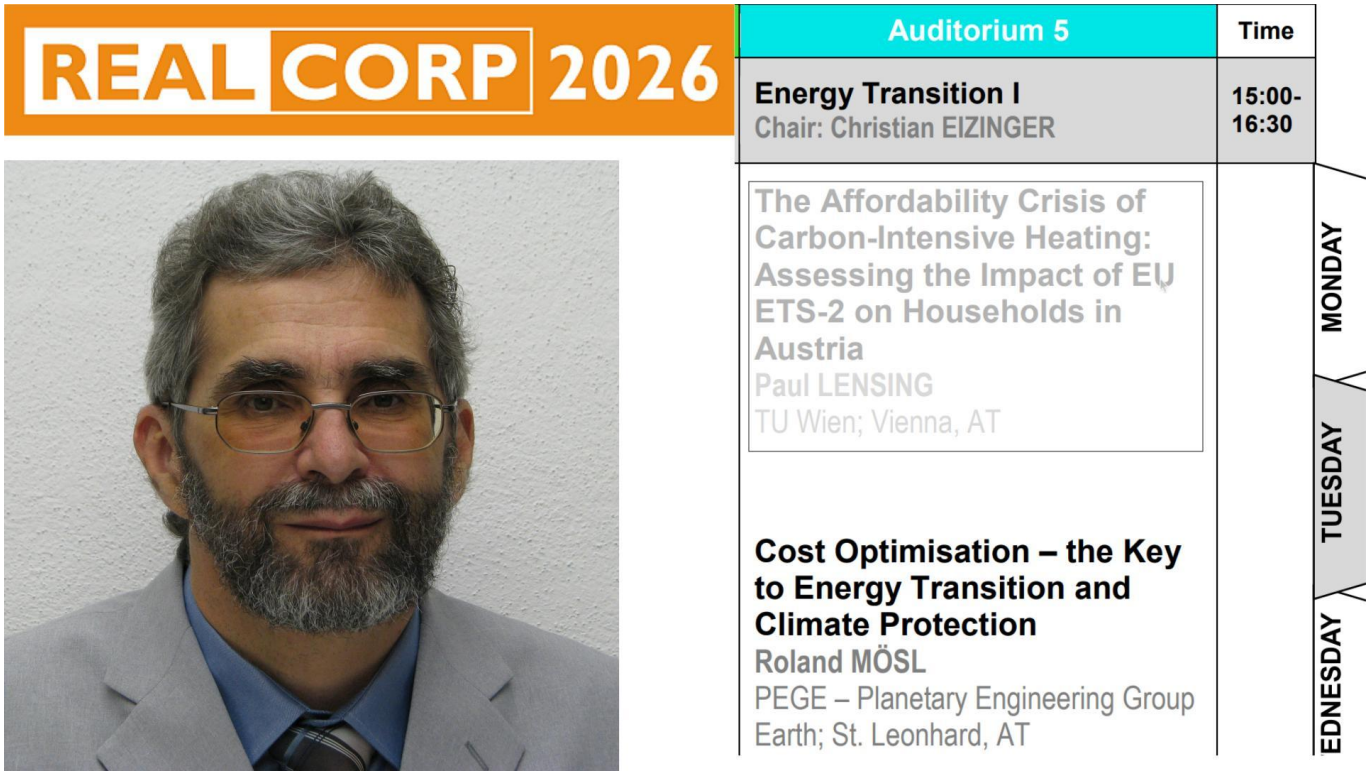
The program interface and this manual are in English only.

PDF output can be generated in other languages. The language files used for the PDFs are not part of the public GitHub repository. They are included only in the download package available from the PEGE website.

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.

PEGE Energy Simulation: A Practical Tool for Energy System Design

My paper from CORP 2026: Cost optimization — the key to energy transition and climate protection. It is easy to say, but how do you actually do it? After outlining the broader problem space at CORP 2026, this contribution presents a working tool that lets users explore and quantify solutions in this domain—solutions that will help determine the future of our civilization.

The first industrial revolution marked the point at which biomass, together with limited hydro and wind power, was no longer sufficient for a world of roughly one billion people. Today, with eight billion people, we must phase out fossil fuels. The reasons go beyond climate change. As Fatih Birol, then Executive Director of the IEA, stated in 2009: “We have to leave oil before the oil leaves us.”

Because biomass could not meet the needs of far fewer people with far lower living standards, the long-term solution must rely on high-efficiency conversion of sunlight into electricity. The remaining question is how to cover the differences between day and night, sunny and heavily clouded conditions, and summer and winter.

The PEGE energy simulation lets users test combinations of systems against 19 years of real hourly data (2005–2023) from PVGIS 5.3, which provides solar yield and temperature. Users can begin with individual houses—varying PV area sizes and orientations, batteries, heat pumps, EV charging, and interaction with spot-market prices for buying and selling electricity.

Beyond houses, the tool includes other objects such as continuous 24/365 processes (power-to-X, chemical storage with generators), charging stations, and factories with different load profiles, all connectable by transmission lines. These objects can be combined into communities—for example 60,000 houses of one type, 30,000 of another, 20 fast-charging stations,

and several different factories. Parts of a community may be located in different regions, requiring appropriately dimensioned transmission capacity between them.

The aim is to enable users to become more expert in the design of future energy systems and to discuss concrete, data-backed findings with other experts.