Cost optimization — the key to energy transition and climate protection

Roland Mösl, PEGE – Planetary Engineering Group Earth, A-5083 St. Leonhard Drachenlochstr 1c/5, founder@pege.org

1 ABSTRACT

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 at 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.

To meet the necessary cost optimization targets, we cannot hold the energy problem separate from all other problems: another major problem is housing. This ranges from demotivation due to having no chance of owning one's own house up to mass homelessness.

My first approach to combining energy production and housing was in 1991 with the “GEMINI inhabited solar power plant”. The transition from the rotating GEMINI inhabited solar power plant to the GEMINI next Generation house with east-west photovoltaics shows what a profitability transition means: in 1992, tracking the sun was cheaper, but from 2010 onwards, a fixed solution became cheaper.

Every component of our civilization must be examined for profitability transitions that have already taken place and those that are yet to come. We cannot design our future based on already outdated conclusions:

- Large apartment buildings vs. single-family homes
- Traditional village layouts vs. the new energy-optimized
- Urbanization vs. reruralization
- Energy from Biomass vs. Power-to-X
- On which latitudes is a high-voltage grid an advantage or a burden?

We designed our GEMINI next Generation house and energy-optimized settlements for maximum cost optimization and for worldwide use. At our research, what could our project do for the energy transition? We encountered many points where profitability transitions had taken place without being noticed. Some are so big that they can be called paradigm shifts.

Keywords: climate protection, energy transition, cost optimization, profitability transition, paradigm shifts, disruption, synergy

1 INTRODUCTION

We got our mobility and transport system not by decreasing the costs of horse breeding. The change from horses to cars is an example of a profitability transition everybody knows. Who could afford a horse for their everyday mobility needs today? It's now an expensive lifestyle item. Big cars now pull horse trailers to events.

Take my lecture as something like a prediction: “Horses will be only for rich people, and rich people will pull their horses in trailers with their cars to distant events.” Unimaginable in 1900, but it happened.

This means cost optimization is far more than reducing the costs of every component of an established system. Cost optimization has to study past and predictable profitability transitions and to evaluate just reducing costs in an existing system vs. an entirely new system.

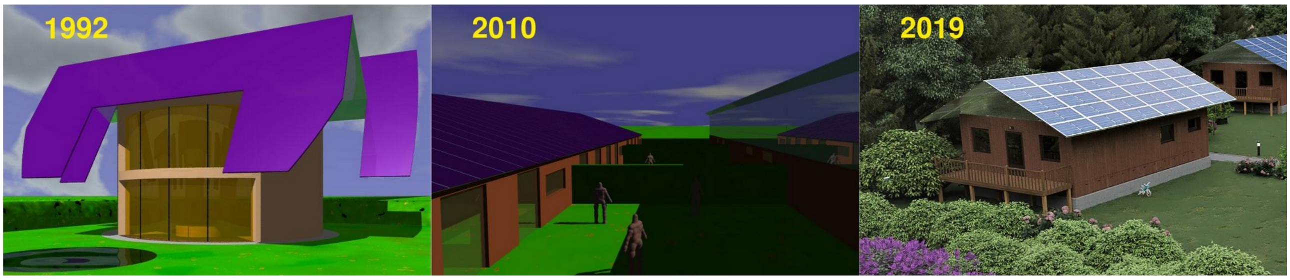
Many imaginations about our future had been created in the past with completely different parameters. Unchecked conclusions from the past endanger our future with unbearable costs.

2 MY PERSONAL EXPERIENCE WITH A PROFITABILITY TRANSITION

I designed the GEMINI next Generation house in February 2019 and tried to figure out in March 2019 why it looks so different from my design in 1992. The design target was in 1992 30 MWh yearly yield in Austria.

This can be done with 30 kW peak south-oriented photovoltaic or 23 kW peak horizontally tracking the sun photovoltaic. Photovoltaics were priced at 7 €/Watt. 30,000 × 7 €/W peak = 210,000 € but 23,000 × 7 €/W peak + 5,000 € for turning the house is only 166,000 €.

In 2019, photovoltaics were already so cheap that 30 MWh/a could be best done by 36 kW peak east-west oriented. Now I tried to figure out in what year the profitability transition took place. It was 2010 and without knowing about the term "profitability transition", I designed exactly in this year low-rise row houses with south-facing photovoltaic panels. The equation had changed to 30,000 × 1 €/W peak = 30,000 € and 23,000 × 1 €/W peak + 7,000 for turning the house is also 30,000 €.



Birds can fly without knowing all the terms of aerodynamics. I reacted with my design change in 2010 to an ongoing "profitability transition" without knowing the term at this time. I realized this concept only 9 years later.

3 ENERGY TRANSITION

The long way from random electricity from sun and wind towards 24×365 electricity. Overseen profitability transitions have to be considered as major accidents.

3.1 Fast load change power plants vs. high efficiency

Here is a current example about increasing costs and CO_2 emissions by ignoring a profitability transition.

Some decades ago, nobody imagined that sun and wind energy could deliver more electricity than all the caloric power plants together. Let's look back into this time to understand the historic context:

There are these peaker power plants; they work mainly at midday. They can change the load fast, so no problem replacing them on a sunny day with solar electricity. Medium-load power plants are also no problem. But maybe we will have so much photovoltaic power in the future that we will even have to switch off the base power plants. But these base load power plants have too slow a decrease to be down until midday and too slow an increase to have full power at sunset. So base load power plants are an enemy of the energy transition; they congest the grid! Really, statements like this were still being made by high-ranking Green politicians in Germany even in 2025. The conclusion: All new power plants have to be for fast load change.

Who killed the electric car at the beginning of the 20th century? The lead-acid battery. My Tesla Y with lead-acid batteries would have 20 kWh capacity and 100 km range, 40 kW peak power, and the battery would need to be replaced every 6,000 km. No joke, painful experience at my first electric scooter test, 2006 to 2009.

The same goes for any thoughts towards grid-scale batteries. So the ideal of the fast-changing power plant was born to deal with the changes in photovoltaic and wind energy.

This was the historic context about 3 decades ago. It is shocking that we are still in the first phase of the energy transition. There are 3 phases of using renewable energy from the sun and wind:

- Random, the sun shines or the wind blows, and we reduce the output of caloric power plants.
- 24-electricity, stable supply in the range of a day; batteries make a cooperation between sun, wind, and caloric power plants possible.
- 24×365 electricity, a stable supply for every day of the year, and the fossil fuel for caloric power plants is replaced by power-to-X.

In the first phase, the idea is, whenever the sun shines or the wind blows, we decrease the output of caloric power plants. In the other direction, to increase the output of caloric power plants as soon as it becomes dark or windless. That was the time when the wish for all power plants to be able to make fast load changes originated.

This method has a limit: it is not possible to switch off more power plants than are just running. Because of this limit and because people were unwilling to think ahead, 70 GW was cited as the expansion target for photovoltaics in Germany for many years. They did not even think that renewable energy has to evolve from random to 24-electricity. Why? Lithium batteries were at this time too expensive for this task, and they were not convinced that this could change. This is despite all the experiences with price decreases in emerging industries.

24-electricity is a cooperation between renewable energy and caloric power plants. There is a weather and demand forecast: the next day we split production on 80% renewable and 20% caloric power plants. When there are 10 caloric power plants, let just 2 of them run with the highest efficiency. All the different yields of photovoltaic and wind power during the day are flattened by batteries. Surprise, the demand for fast load changes at power plants is gone. The batteries make such a slow load change possible that even the slowest-changing base load power plant can follow.

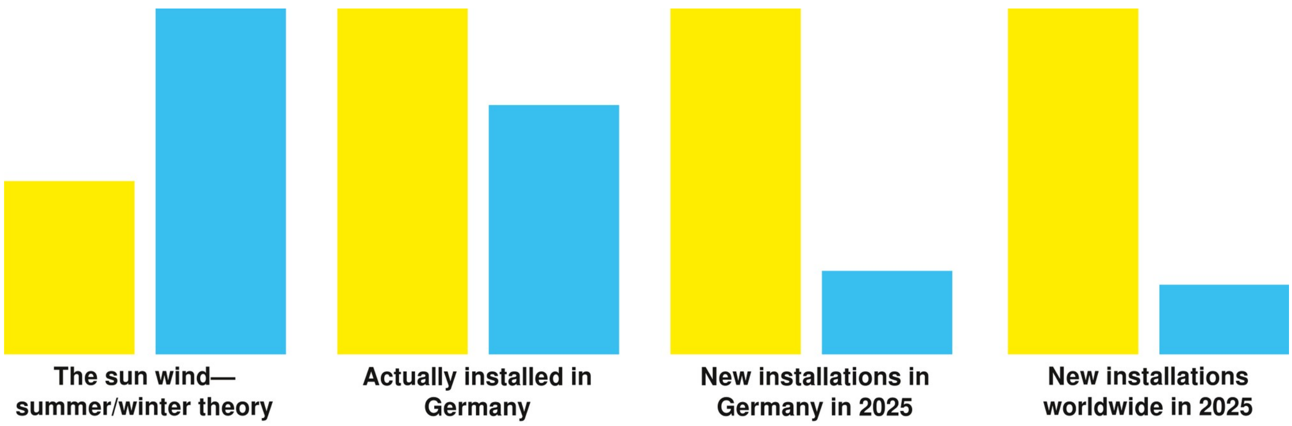
Let's look at the current situation at new power plants to be built in Germany.

400 MW CCPP designed for fast load change	**400 MW CCPP designed for highest efficiency**
800 million € in Germany	**600 million € in Germany**
no batteries	**120 million € for 1,000 MWh sodium batteries**
Can ramp 50 MW/min	**Ramp speed only limited by grid compliance**
60% LHV top efficiency	**64% LHV top efficiency**
53% LHV average efficiency	**59% LHV average efficiency**

10% less CAPEX 10% less natural gas to burn is already a huge difference for the efficiency-optimized battery version. But thinking in the past, they continue to talk about fast load change power plants.

3.2 From 24-electricity to 24×365 electricity

How to refine 24-electricity to 24×365 electricity? There had been the sun-wind theory for three decades: the sun delivers more in the summer, and wind delivers more in the winter. This would require, on average, in Europe, 2 kW wind systems for every kW photovoltaic. Just right now in Germany, 0.72 kW wind for 1 kW photovoltaic, and the gap widens fast: 0.24 in Germany, 0.2 in the EU and worldwide at new installations in 2024 and 2025.



The required ratio according to the 'sun shines more in summer, wind blows more in winter' theory vs. reality.

The next theory was biomass for the winter gap: not enough sun, not enough wind; we would start power plants fueled by biomass. Extremely inefficient land usage. The first border for photovoltaics in Germany was 70 GW: we cannot switch off more caloric power plants than we have running. The next border is at 300 GW photovoltaic and 750 GWh batteries: some sunny summer days, and all Germany is 100% solar-electric all this time.

What to do beyond this next border? Just waste abundant production? Install more batteries? Use it for Power-to-X?

3.3 Simulation of 24×365 systems

We started the simulation in April 2024 to find out if off-grid fast-charging settlements are feasible. We used the EU Photovoltaic Geographical Information System. The start of the design was a 1 ha energy-optimized village with an additional fast-charging area. These are the 1,120 modules with a 25° slope towards the east and west slope on the houses and the 968 modules with an 8° slope east and west covering the central structure. We added a fast-loading area covered with 1,200 photovoltaic modules with a 5° slope facing south at the northern half of Earth and north at the southern half of Earth.

A fast charging station can have very different business. Nearly nothing at the beginning up to beyond the optimal load limit. The simulation tested with 20 kW to 240 kW load in the far north and 80 kW to 400 kW at all other locations in steps of 20 kW. The data was for each hour from 2005 until the end of 2020. For every hour decisions are made, how much should be used for power-to-methanol, and on the other end, do we have to start the generator? The power-to-methanol system is powered during the night by the batteries.

The simulation combined 10 different battery sizes with 10 different power-to-sizes. So a simulation is 16 years × 365.25 days × 24 hours × 10 battery sizes × 10 power-to sizes × 17 different loads = 238,435,200 decisions and calculations. We did the simulation with 50 different places. 35% HHV (Higher Heating Value) efficiency is typical for methanol-powered generators in the 200 kW to 500 kW range. There could be up to 48%, but the additional cost at only some hundred hours of yearly usage makes this high-efficiency option too expensive. The efficiency of a 50 kW to 300 kW power-to-methanol system is assumed to be 50%.

This simulation is with a flat demand over all the year. With a higher demand in winter, would the 24×365 conversion rate be even lower in Aalborg and Salzburg. On the other side, industry with variable production increases the 24×365 conversion rate.

3.4 Hydrogen – methane – methanol

Why methanol? It is liquid at room temperature. The other options are methane and hydrogen. Both are only an option at huge underground storages and far too expensive for decentralized energy systems. Here we are suddenly in the power-to-hydrogen, methane, and methanol debate. Hydrogen has the highest power-to-efficiency because no DAC - Direct Air Capture of CO2 is required. From a pipe in the bathroom comes 10 L of water per minute containing 1.11 kg hydrogen. Very simple. But You have to suck 4,400 m^3 air through a filter to capture as much CO2 as containing the 1 kg carbon. This decreases the efficiency.

But the higher power-to-hydrogen efficiency comes at the price of far more storage costs, because the existing 25 km^3 underground gas storage in Germany would contain only a third of the energy when filled with hydrogen. When this 25 km^3 (at standard pressure) underground gas storage in Germany is not enough, additional storage would be far cheaper with methanol.

The 25 km^3 underground gas storage in Germany is designed for the fossil energy system: delivery is constant all over the year, but in summer there is less demand than delivery, and in winter there is more demand than delivery. The difference is covered by the 25 km^3 gas storage.

As the new installation numbers suggest, we are going to a very heavy photovoltaic-oriented energy transition requiring more storage for summer-winter balancing.

3.5 Prices used in the simulation

We used for the simulation 300 €/kW peak photovoltaic total including construction and inverter, 40 €/kWh sodium battery, and 60,000 € for the generator. For power-to-methanol, 10,000 € and 1 € for each Watt. So 50,000 W power-to-methanol is calculated with 60,000 €. These are estimated prices in 2030.

The equipment is different depending on the characteristics of the location. So Aalborg needs far more power to and less battery than Kampala. The chosen equipment for the 6 locations is all a bit above one million €.

Could the 24×365 electricity problem be solved with batteries alone? We added for comparison 3 battery-only scenarios with the same costs, 3-times and 10-times the costs. This means with 5.5, 30 and 120 kWh battery per kW photovoltaic.

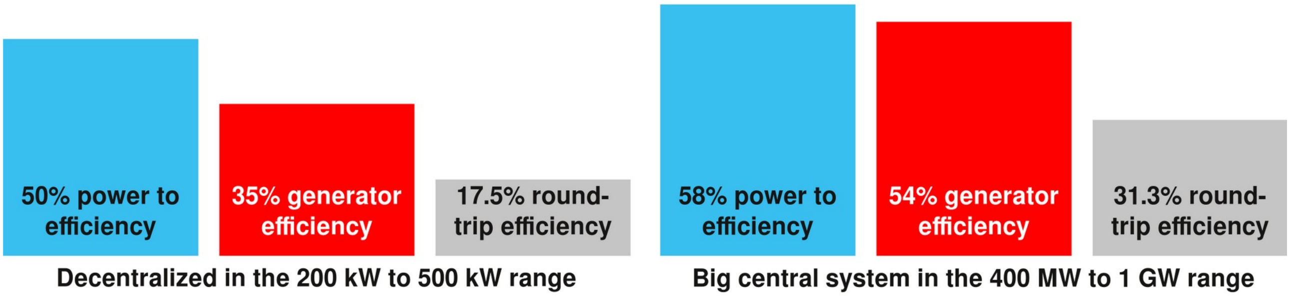
3.6 High voltage grid or no high voltage grid – that is here the question

The high-voltage grid is used to transport electricity over long distances. There are three reasons for this:

- Geographical features for wind energy systems and hydropower plants
- Very efficient central large-scale technology
- Minimum and optimal size requirements from energy-intensive industries

There is more wind in the North Sea than in Bavaria. Austria generates about twice as much electricity from hydropower as Germany, which is much larger. In the past, the centralized large-scale technology counted on the rail connection to bring two freight trains full of coal to the coal-fired power plant every day.

To answer the question, we added to the simulation high-efficiency central systems with 58% at power-to and 54% at generation, grid losses already in the efficiency.



In our assumption, the big central system has 79% more round-trip efficiency.
What remains of this huge difference in the complete system?

There is on the diagrams a red line for the yearly average solar yield, a blue line for a central high-efficiency system, and a green line for a decentralized system. This simulates a solar-only system. It is obvious that they should, in Denmark, mix with wind energy to improve the gross yield vs. 24×365 electricity ratio. Since wind energy is not where most people live, here is the answer: a high-voltage grid to connect all the wind energy with the consumers.

In this simulation, we listed percent improvement against less efficient decentralized systems. This improvement ranges between 5.1% and 26% at the 6 tested locations. Equipment costs × improvement gives the allowed costs for the grid to have equal costs. This is listed as "grid cost allowance" per kW peak photovoltaic. This ranges between 27 € to 151 € maximum grid cost per kW photovoltaic.

The diagram represents the 365 days of a year on the x-axis and the yield in kWh per kW peak photovoltaic installed on the y-axis. For each day of the year are 16 yellow dots for each yield on this day from 2005 to 2020.

3.7 Simulation download and description

The download contains the 6 locations shown in this paper, each in 3 variants:

- "battery only" to show the effect of huge amounts of batteries
- "central" with assumed efficiencies of big central power to and CCPP systems
- "decentral" with assumed efficiencies of 200 to 500 kW systems

The download location is: https://climate.pege.org/2026/solar-yield.7z

Each file starts with a scenario description

Uganda Kampala Latitude: -1.259 Longitude: 29.993

Modules East 25	560
Modules West 25	560
Modules East 8	484
Modules West 8	484
Modules South 5	0
Modules North 5	1,200
Modules Total	3,288
Watt per modul	610
Total Watt PV	2,005,680

Sodium battery efficiency	0.93
Generator Watt	800,000
Generator efficiency	0.35
Generator start penalty hours	0.10
Power to efficiency	0.50
Maintenance	0.02
Methanol buy/sell ratio	0.30

Price fast charging kWh	0.12
Price Photovoltaic per kW	300
Price Sodium battery per kWh	40
Price Generator	60,000

Jump to diagrams with years / methanol price:			
8 / 0.10	12 / 0.10	16 / 0.10	20 / 0.10
8 / 0.15	12 / 0.15	16 / 0.15	20 / 0.15
8 / 0.20	12 / 0.20	16 / 0.20	20 / 0.20
8 / 0.25	12 / 0.25	16 / 0.25	20 / 0.25

Scenario description with Uganda Kampala as an example

Modules East 25: East-facing modules with a 25° slope.

Generator Watt: Why 800,000 W? The average load is tested up to 400 kW, and the daily load profile has 2 hours with twice the average. To keep the simulation simple and avoid complicated ahead planning, we assumed the maximum possible load as the generator size. 200 kW would be the minimum reasonable size.

Generator start penalty hours: The cold start requires additional fuel.

Maintenance: The maintenance costs each year are 0.02 × CAPEX.

Price fast charging kWh: The off-grid fast charging settlement sells fast charging at this price.

Methanol buy/sell ratio: You cannot sell for the same price as you buy. At 20 cents/kWh HHV, 0.3 means you sell for 20 cents × 0.3 buy/sell ratio makes 6 cents/kWh HHV.

Jump to diagrams with years / methanol price: The price per kWh and the balance are calculated with 8, 12, 16, and 20 years of depreciation and 10, 15, 20, and 25 cents/kWh HHV methanol price.

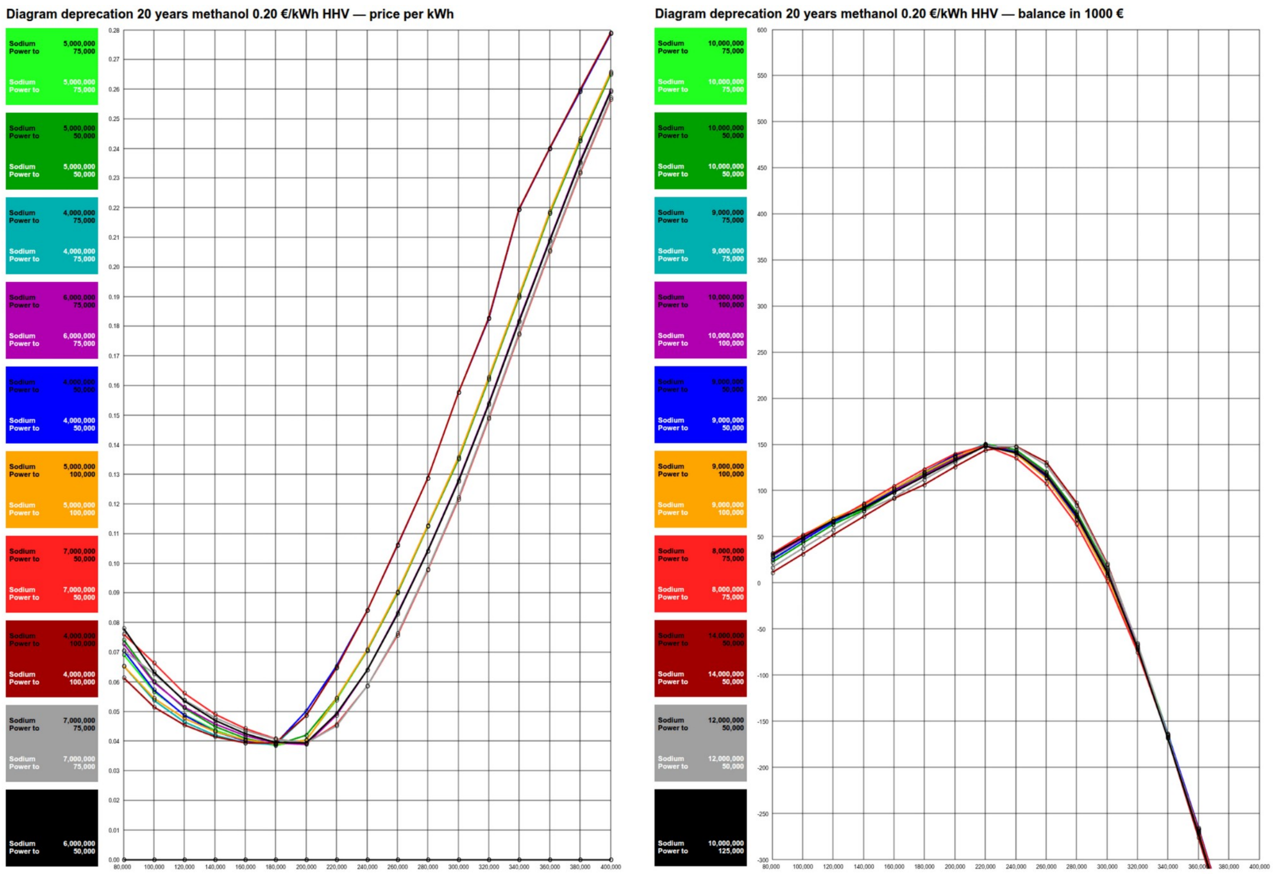


Diagram with the 10 best combinations for the lowest kWh production price on the left side and the 10 best combinations with the best balance on the right side

The lowest production costs do not always bring the best balance. This depends on the sale price. Selling 1 GWh at 4 cents/kWh production costs for 12 cents/kWh brings 80,000 €. But selling 1.2 GWh at 5 cents/kWh production costs brings 84,000 €. This makes the differences between the viewpoint production costs and balance.

At low load, the under-usage of the equipment determines the bad performance in production price and balance. At high load, the fuel usage of the generator determines the bad performance in production price and balance. Purchasing methanol for 20 cents/kWh HHV and converting it with 35% efficiency to electricity means 57 cents in fuel costs per kWh.

Average load:	**220,000 W**
Sodium batteries:	**10,000,000 Wh**
Power to methanol:	**100,000 W**
Price power to:	**110,000 €**

Methanol kWh	0.10 €	0.15 €	0.20 €	0.25 €
8 years	0.0881 €	0.0881 €	0.0880 €	0.0880 €
12 years	0.0628 €	0.0627 €	0.0627 €	0.0627 €
16 years	0.0501 €	0.0501 €	0.0500 €	0.0500 €
20 years	0.0425 €	0.0425 €	0.0424 €	0.0424 €

Less load	**More load**

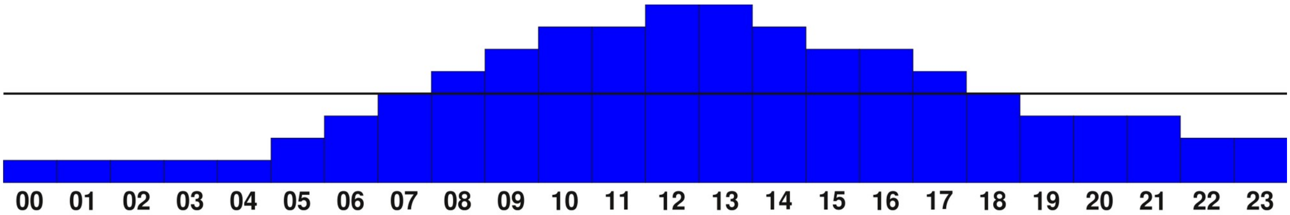
PV total	2,732,774,438
PV direct used	1,110,366,505
PV to sodium battery	1,103,142,700
PV to power to methanol	105,907,054
PV unused production	413,358,179
PV unused hours	894
Sodium battery total	987,684,817
Sodium battery charge hours	2,991
Sodium battery discharge hours	5,775
Sodium cycles	99
Generator starts	6.44
Generator usage hours	33.56
Generator direct used	5,781,875
Generator to sodium battery	21,068,125
Total price investment	1,171,704 €

Power to usage hours		1,657
Power to usage hours > 90%		1,578
Methanol produced l/Wh	16,374	81,869,152
Methanol sold l/Wh	737	3,683,438
Methanol purchased l/Wh	0	0

Methanol	0.10 €	0.15 €	0.20 €	0.25 €
8 years	61,477	61,533	61,588	61,643
12 years	110,298	110,354	110,409	110,464
16 years	134,709	134,764	134,819	134,875
20 years	149,355	149,410	149,466	149,521

For each battery, power-to-methanol and load combination is such a statistic:
1,700 statistics for one location.

PV unused production: The batteries are fully charged, and power-to-methanol runs at maximum power. Sure, it would be possible to reduce the unused production by much more batteries and a much stronger power-to-methanol system. All the simulations show that reducing unused production to nearly zero increases costs per kWh.



Daily load profile is a fast charging station

The simulation was created in April 2024 to research the possibility of off-grid fast-charging settlements in Africa. Future versions will have new possibilities to simulate different load profiles.

Industry with variable production: It will be possible to set a minimum percent of production rate. So the industry will throttle down in low solar yield situations.

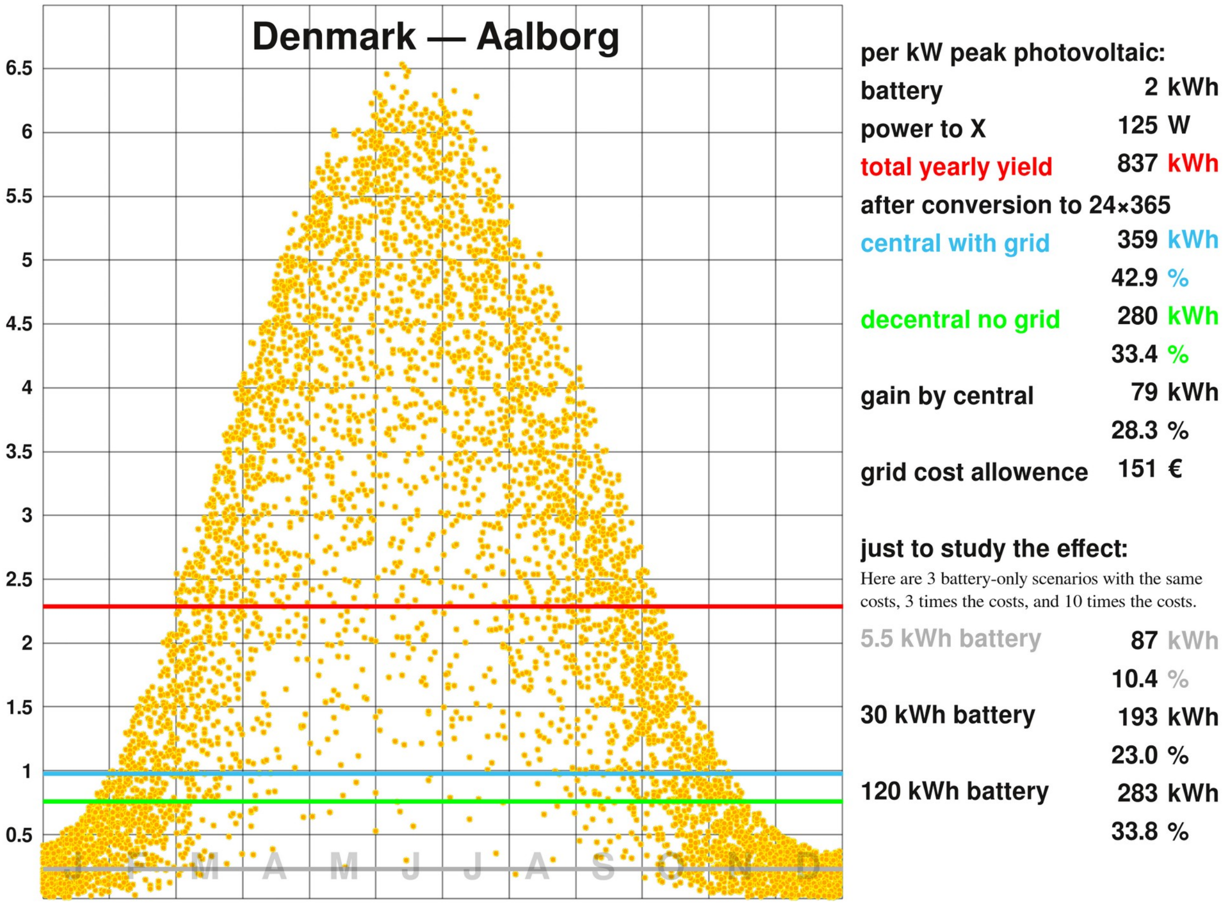
Old town buildings: Old buildings usually have bad thermal insulation. They need much heating in winter and much cooling in summer.

Greenhouse: Growing plants in a greenhouse has several advantages but requires heating or cooling.

3.8 Solar yield and conversion to 24×365 electricity

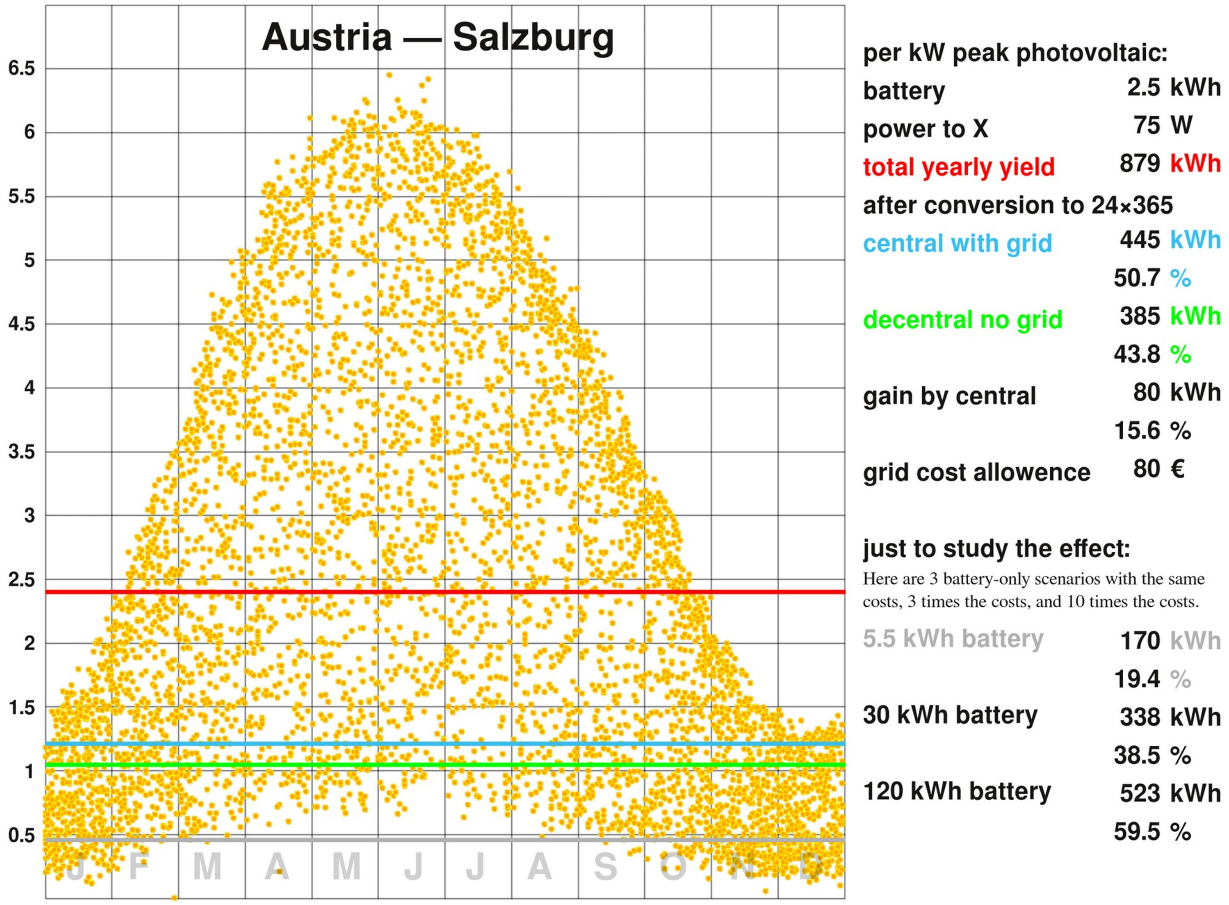
The wide range of solar yield becomes much wider after the conversion of gross yield to 24×365 electricity. 6 examples from our research of 50 locations.

3.9 Denmark – Aalborg



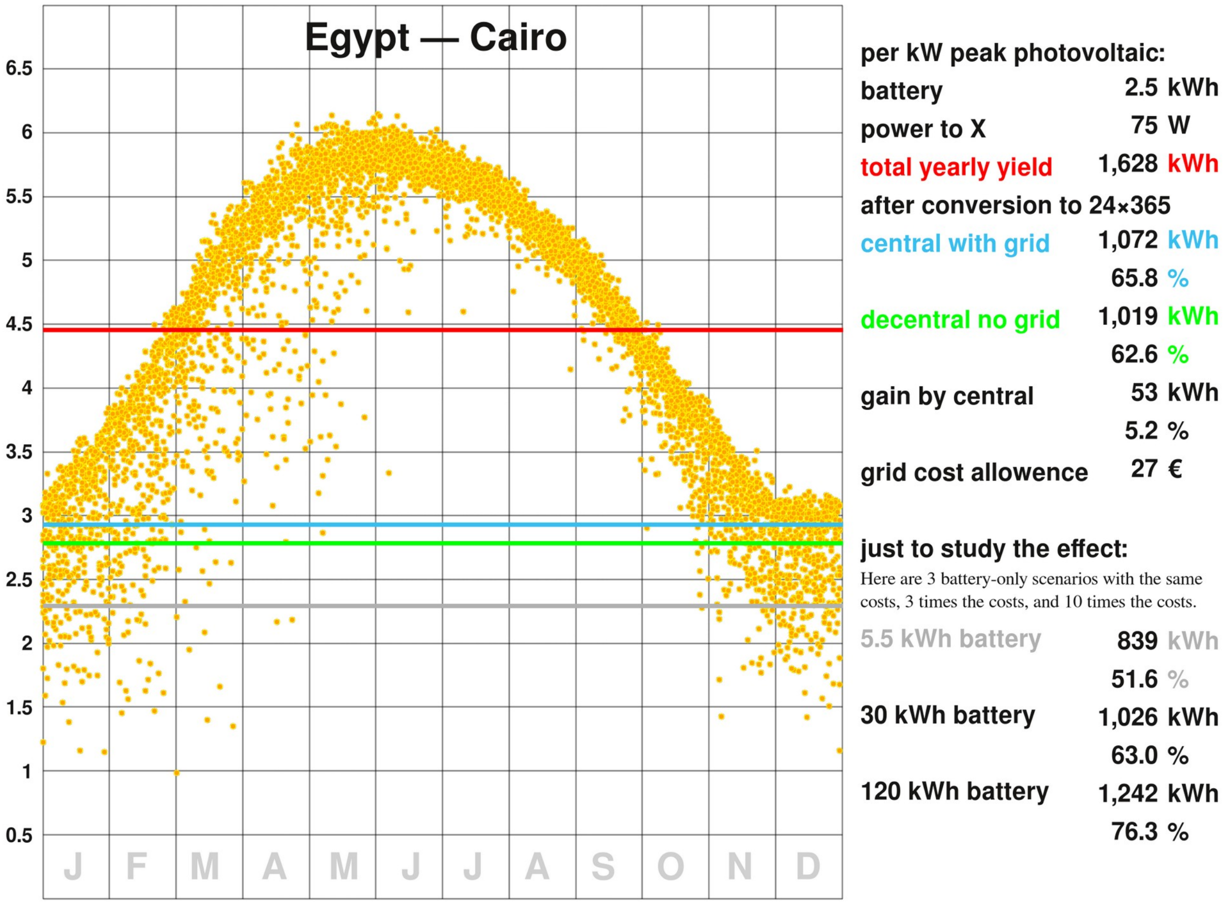
At the winter solstice, the sun is only 9.47° above the horizon at midday. So we have here a very drastic difference between the summer solstice and the winter solstice.

3.10 Austria – Salzburg



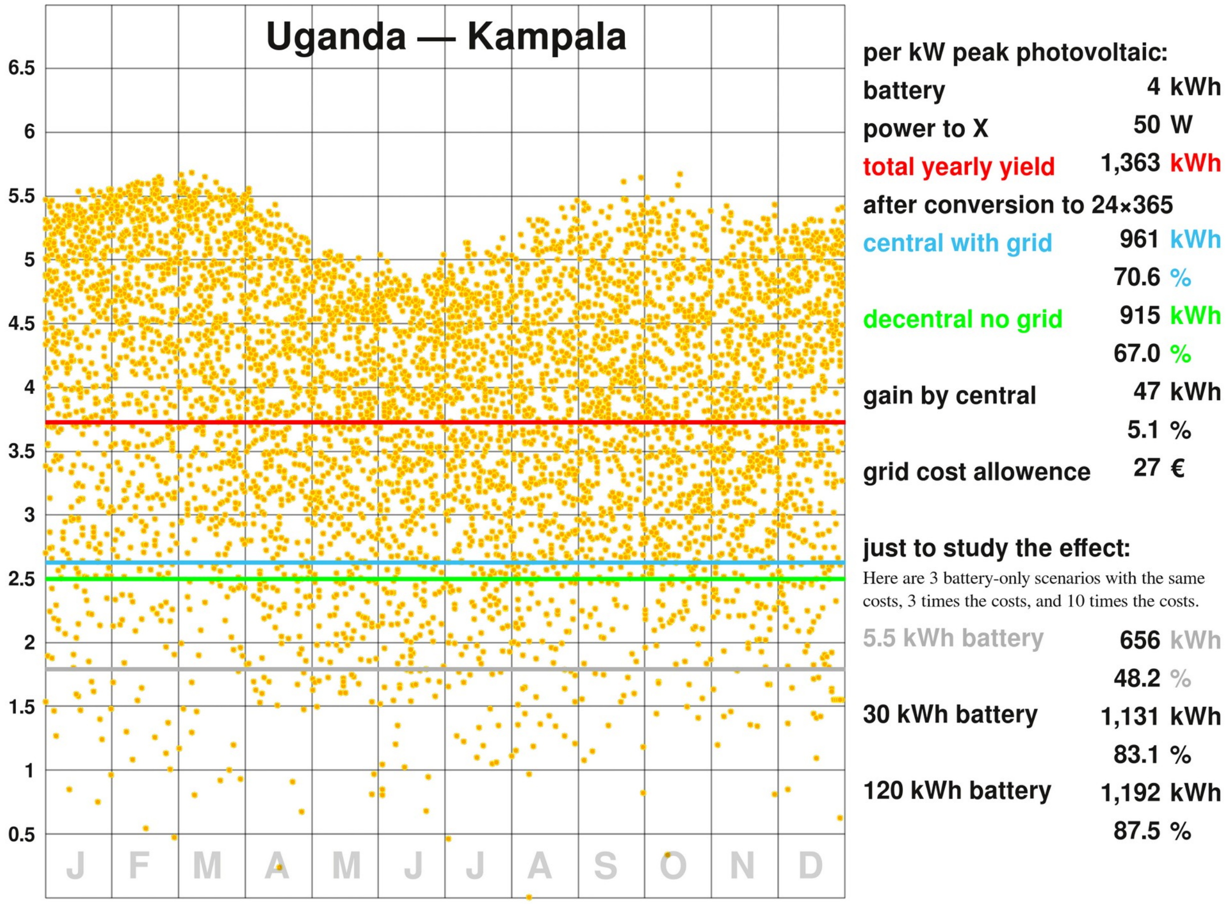
At the winter solstice, the sun is 18.76° above the horizon at noon instead of 9.76° in Aalborg.
This is sufficient for a 37.5% increase in 24×365 yield.

3.11 Egypt – Cairo



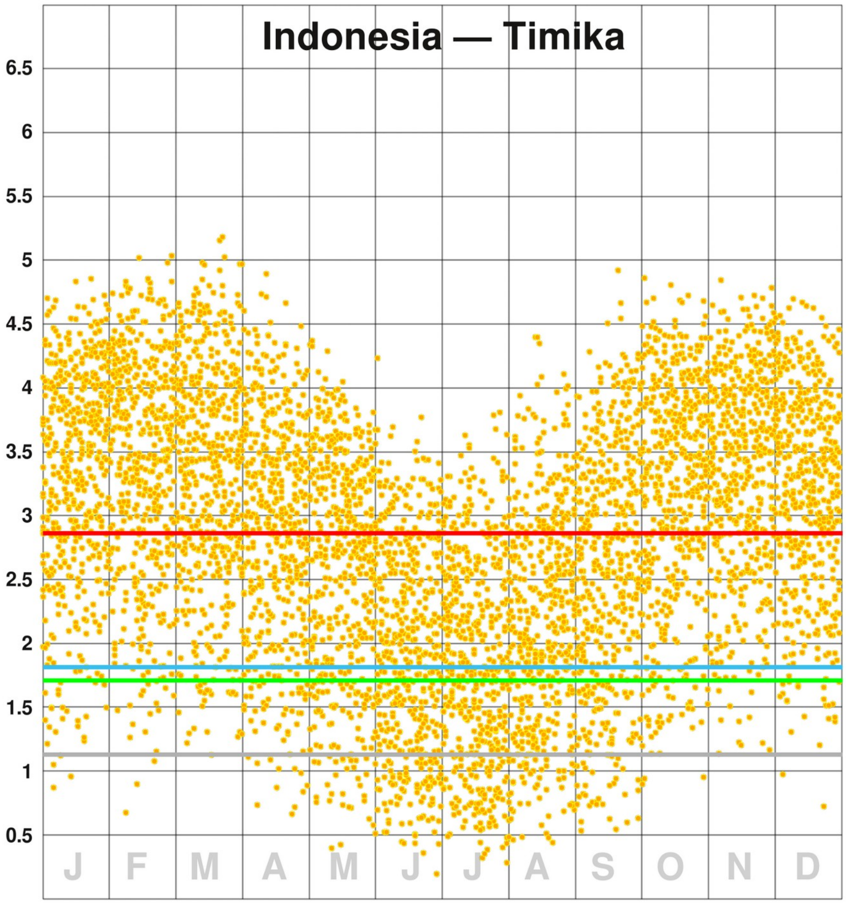
Long-term storage requirements are determined almost exclusively by the tilt of the Earth's axis. This results in 165% more 24×365 yield. Not only is there much more gross yield, but also a much more efficient conversion to 24×365.

3.12 Uganda – Kampala



The weather determines long-term storage requirements. Much less gross yield compared to Cairo, partially compensated by higher 24×365 conversion efficiency.

3.13 Indonesia – Timika



per kW peak photovoltaic:

battery	4 kWh
power to X	50 W
total yearly yield	1,047 kWh
after conversion to 24×365	
central with grid	665 kWh
	63.5 %
decentral no grid	627 kWh
	59.9 %
gain by central	38 kWh
	6.1 %
grid cost allowence	32 €

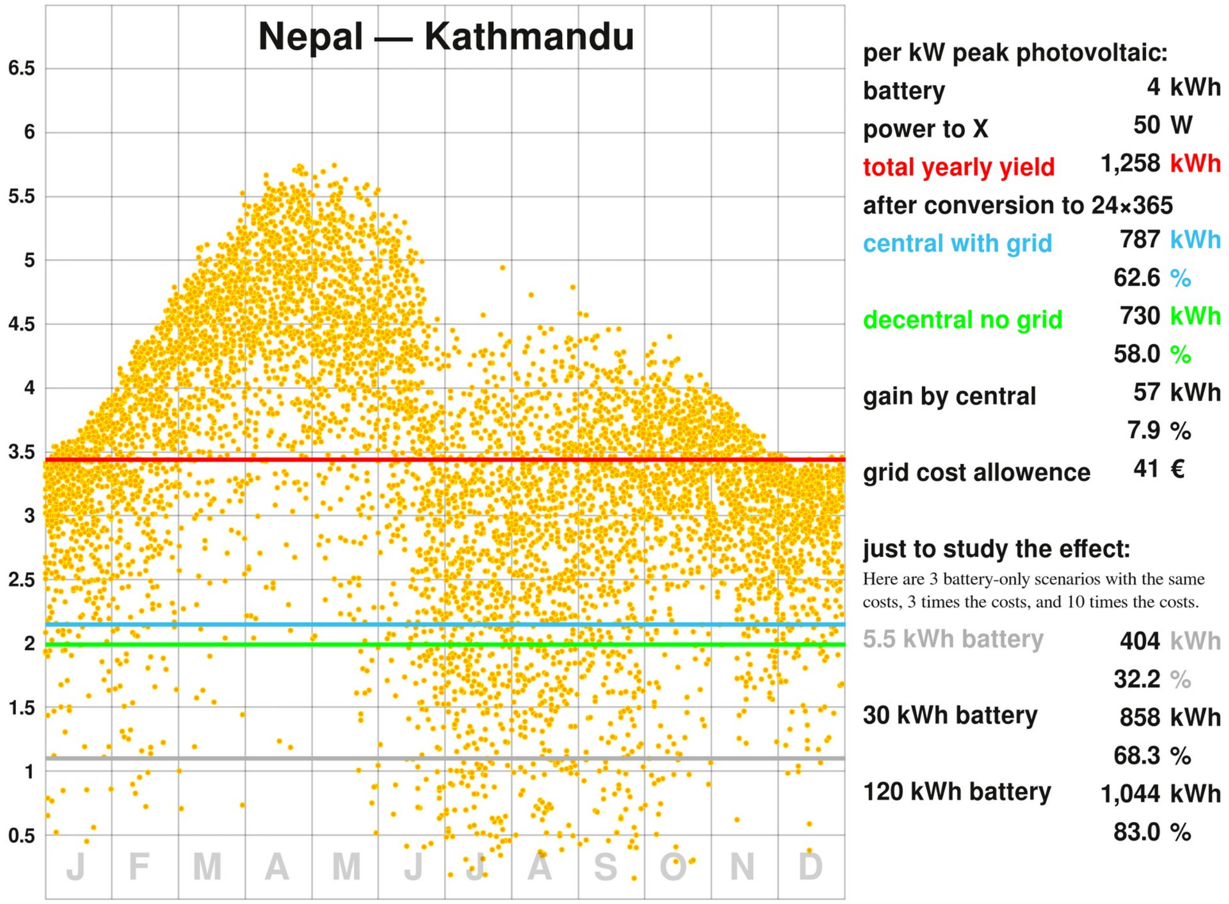
just to study the effect:

Here are 3 battery-only scenarios with the same costs, 3 times the costs, and 10 times the costs.

5.5 kWh battery	415 kWh
	39.7 %
30 kWh battery	686 kWh
	65.5 %
120 kWh battery	940 kWh
	89.8 %

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 2020 not one sunny day from dusk to dawn. Despite this more or less cloudy weather, there is still 63% more 24×365 yield than in Salzburg.

3.14 Nepal – Kathmandu



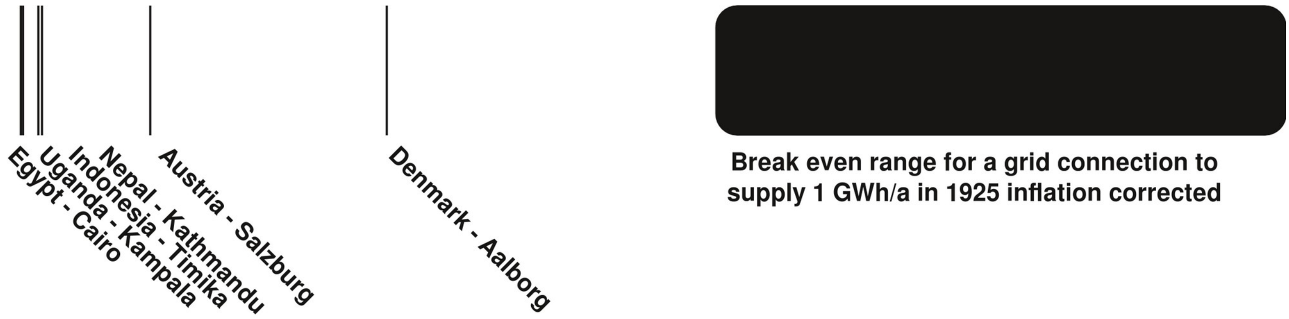
Guess which months are the rainy season. Despite this very pronounced weather phenomenon, 90% more 24×365 yield than in Salzburg.

3.15 Grid development in the past vs. today

Let's look back one century, to the twenties of the 20th century. Independent from the political system, electrification was a high priority. Here in the West: “electricity to the last mountain farming village” and Lenin wrote, “Communism is Soviet power plus the electrification of the whole country”.

Parameters had been entirely different. The grid was to connect to distant coal power plants or hydropower. Was local production an option? Really not! Diesel engines were at this time no option. Large coal power plants had 18 to 20% efficiency. In the 200 kW range, only 8 to 12%. This means not only nearly double the coal but also higher transportation costs. There is the big coal power plant with its own railroad and a freight train full of coal every few hours. The next point is labor cost. Manual coal/ash handling was dominant in small plants; central benefited from scale and emerging automation.

Assuming a small consumer, industry, or settlement with 1 GWh/a electricity demand, the grid cost allowance had been 1 to 1.8 million € inflation-corrected. No question, grid expansion was a great idea. We just showed the range is 27 € to 151 € per kW photovoltaic. For the assumed 1 GWh/a consumer, this translates to a range of 27 to 534 thousand €. Denmark and Austria are “we already have a great grid” countries. Without these 2 countries in the examples, the range is only 27 to 56 thousand €.

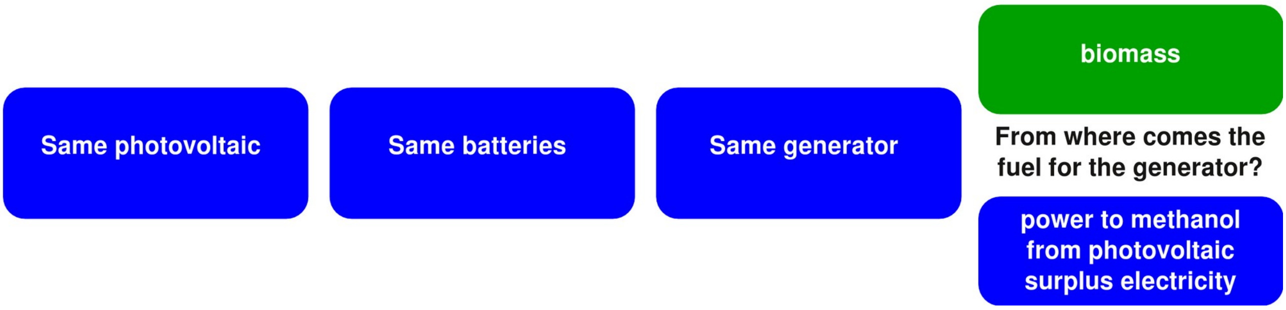


Different time, different places, completely different outcome. When one century and a location more close to the equator changes the high voltage grid from a “must-have” to an “unnecessary, too expensive”.

3.16 Energy from biomass loses against surplus electricity

The batteries are full; what to do with the surplus electricity? When you have nothing to use surplus electricity for, it is simple waste. Power-to-X becomes, in this situation, simple waste utilization.

Components like large storage of chemical energy and caloric power plants are necessary, regardless of the system. So all the energy from biomass competes against only one component: the Power-to-X system. All the other components are necessary, regardless of the usage of biomass.



This duel is for the biomass impossible to win. It is unavoidable that fuel generated from power-to-X from surplus solar electricity will expel biomass from the energy market.

4 THE GEMINI PRINCIPLE: DOUBLE USAGE OF LAND

No better solar power plant, no better housing possible on the same ground is the ultimate target of the GEMINI principle.

4.1 Single family homes vs. big houses

Houses built around 1960 in Germany had been a horror in nonexistent insulation. A typical 16-apartment block had been, at this time, between 160 and 220 kWh/a/m² heat demand and 60 to 80 m² per apartment. On the other side had been a single-family house with 250 to 300 kWh/a/m² heat demand and between 100 and 120 m² living space. So a family living in an apartment block had between 9,600 and 17,600 kWh heat demand, while the family in the single-family house had 25,000 kWh to 36,000 kWh heat demand.

In addition to the heat demand problem, owners of single-family houses had been more likely to have a car and to drive more km a year than people living in apartments. All energy had come in 1960 from distant power sources: hydropower plants and coal power plants. Coal power plants supplied by coal mines, and the cars supplied by refineries supplied by distant oil wells. There was only one thing a house could do about energy: consume less energy.

Based on these numbers evolved the idea that apartment blocks are good and single-family houses are bad. The first thermal insulation regulation was introduced in 1977 in Germany. All concentrated only on the heat energy demand: the passive house and the low-energy house. All the efforts had been towards nearly zero heat demand, with nearly no thought beyond.

Range of typical single family homes in Germany	1960		2025	
Size	100 m²	120 m²	140 m²	152 m²
Heat demand per m²	250 kWh	300 kWh	40 kWh	60 kWh
Heat demand total	25,000 kWh	36,000 kWh	5,600 kWh	9,120 kWh
Range of typical 16-apartment block				
Size	60 m²	80 m²	70 m²	85 m²
Heat demand per m²	160 kWh	220 kWh	30 kWh	50 kWh
Heat demand total	9,600 kWh	17,600 kWh	2,100 kWh	4,250 kWh

Both apartments and single-family homes are now bigger but have improved much at lowering the heat demand.

4.2 Contemporary 16 apartment building block

Space and material for a 16-apartment building block in Germany:

Brick/Masonry Construction (Ziegel-Mauerwerksbau) Traditional and common (highest market share in Germany): Load-bearing brick walls, concrete floors/slabs.

- Standard range: 1,200–2,400 m² (0.12–0.24 hectares)
- Bricks/masonry (load-bearing walls, often high-insulation filled bricks like Poroton): 500–700 kg/m² BGF → 1,200–1,680 tons total. (Higher mass due to thicker walls ~30–42 cm for thermal performance.)
- Concrete (mainly floors/ceilings, basement/garage): 250–350 kg/m² BGF → 600–840 tons total. (Less than pure concrete build, as walls carry load.)
- Steel reinforcement: 40–60 kg/m² BGF → 96–144 tons total.
- Only 20 to 40 kW photovoltaic.

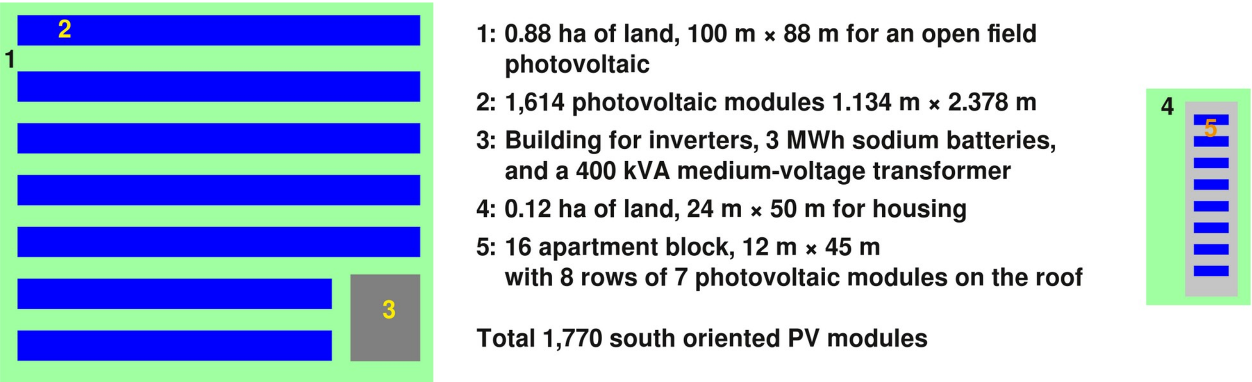
We have to end the time when our energy came mostly from coal mines, oil wells, and gas extraction. So from where should all the energy come from?

I predicted in 1992 that the electricity demand in Germany would increase from 500 TWh to 1,200 TWh because we have to change all the use of thermal energy to electricity; the yield of biomass is magnitudes too low to continue with burning to produce heat or mechanical energy.

Prof. Volker Quaschning wrote in 2016 in “Sektorkopplung durch die Energiewende” (Sector coupling through the energy transition) that the electricity demand will increase from 600 TWh to 1,300 TWh. Some new studies predict more, some less, but let's see what 1,300 TWh means: 1,300 TWh divided by 83.5 million inhabitants is 15,687 kWh per inhabitant. With an average of 2 inhabitants per apartment: 31,138 kWh. With 16 apartments in this block: 498 MWh.

4.3 Conventional usage with housing and open field PV seperated

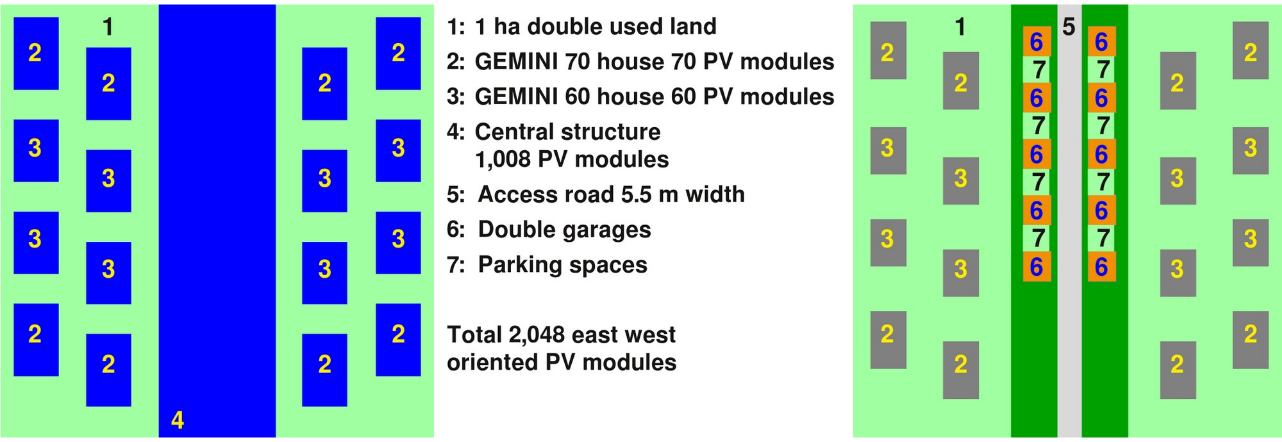
Let's put the 16 apartment block somewhere on 0.12 ha of land and somewhere else 0.88 ha of open-field photovoltaic systems. 1,670 south-oriented photovoltaic modules with 1.094 MW peak.



Let's put the 16 apartment block somewhere on 0.12 ha of land and somewhere else 0.88 ha of open-field photovoltaic systems. 1,670 south-oriented photovoltaic modules with 1.094 MW peak.

4.4 Optimized usage for better housing, more energy, and fewer costs

Now let's compare this with an energy-optimized village like the one presented in my paper for CORP 2025.



Left is seen all the photovoltaic from above; right is seen what is below all the photovoltaic.

The single-family home is dead; long live the new single-family home, which makes a major contribution to energy transition and climate protection.

Who would trade living here for the canyon-like streets of a big city?

For a complete energy transition, including the electrification of heavy industry,
it is necessary for about one-third of the population to live in this way.

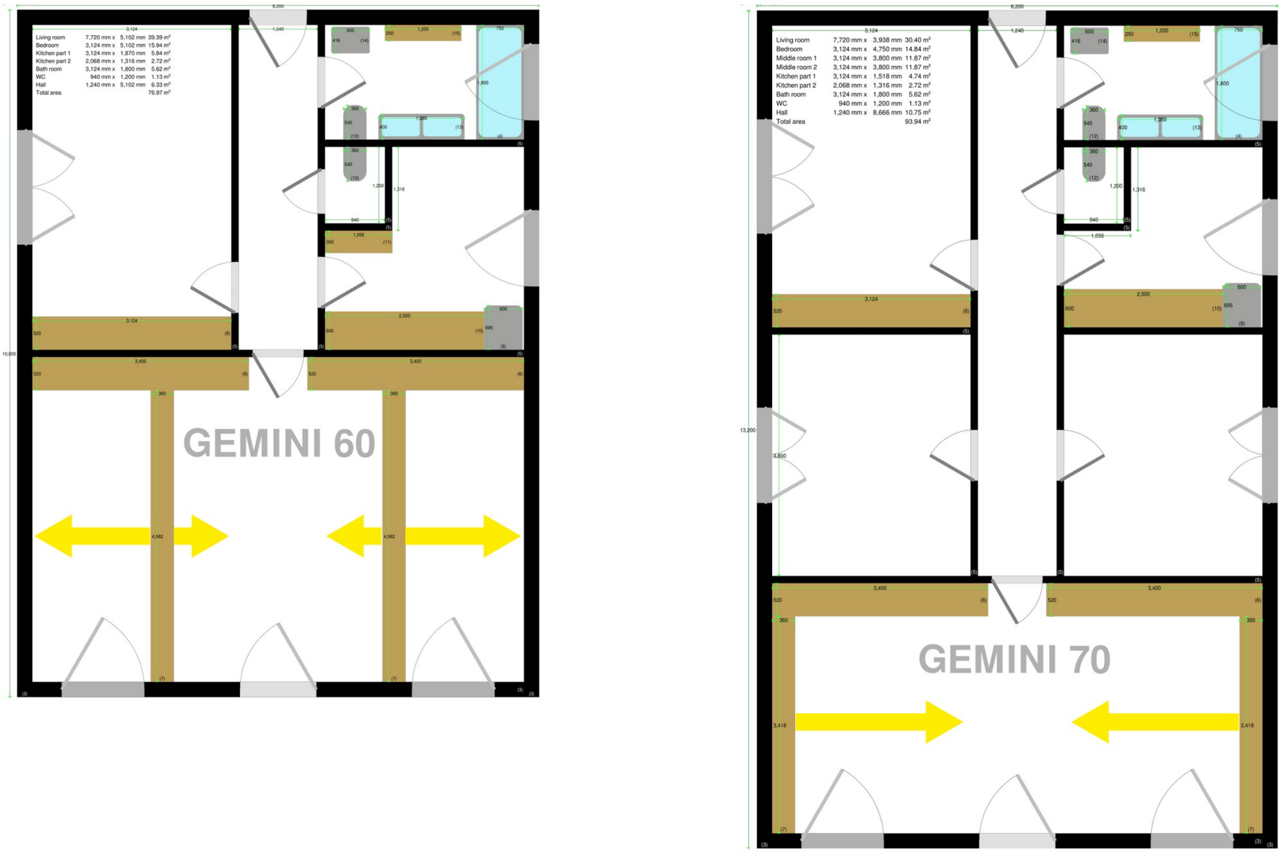
Anyone who generates so much electricity should also be able to use a small portion of it for luxury items:
for example, using a swimming pool in Central Europe from April to October.

The area covered by photovoltaic panels is almost 27 m wide. That's enough for much more than just garages and parking spaces.

40% of the area protected from sun and rain by photovoltaics is communal space
for sports, children's playgrounds, and shared activities.

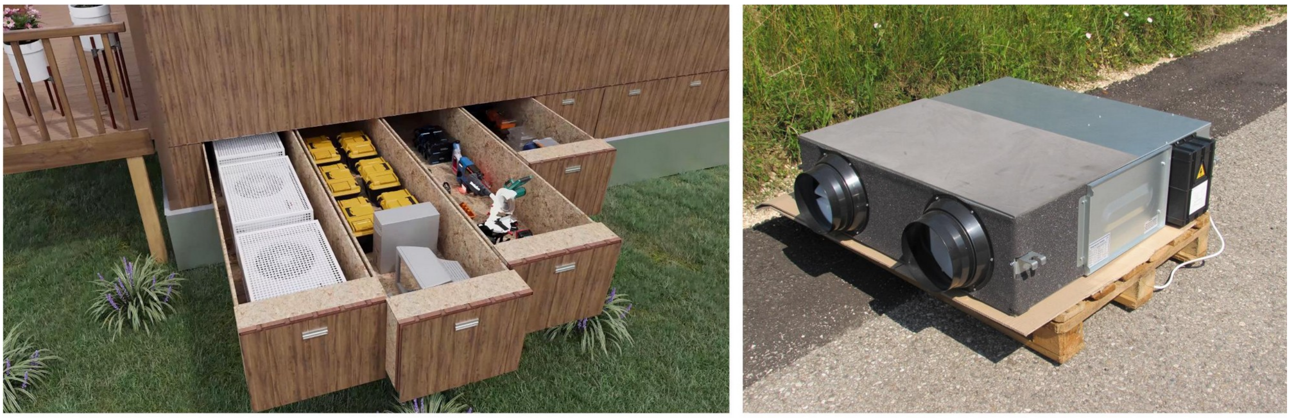
4.5 GEMINI next Generation house type 60 and 70

The number in the house type represents the number of 1,134 mm × 2,378 mm solar modules. We have designed types 50, 60, 70, 72, 80, and 84. However, we think types 60 and 70 will be the most used types. As we made the photos of the settlement, there had been only what are now types 60 and 80. On the site plan is a mix of types 60 and 70.



Slideable wall/furniture elements for a variable usage as one big living room or a small living room and two additional rooms.

We did cost optimization not only at the energy system. Affordability is a key point in every design decision.



Left: drawers instead of basement. Right: air ventilation system with heat and humidity recovery

We have shrunk the basement. Drawers that are within the thermal envelope of the house. Perfect conditions for long-term storage. Lots of space; perhaps a homeowner in financial difficulty might even consider renting out some of the drawers as storage space.

Biodiversity is only beautiful outside. The ventilation system with heat and humidity recovery not only saves energy but also keeps unwanted intruders away. HEPA filters can also be used.

Left: This machine can produce the frame of a GEMINI 60 house in 3 hours. Right: The steel comes from this coil.

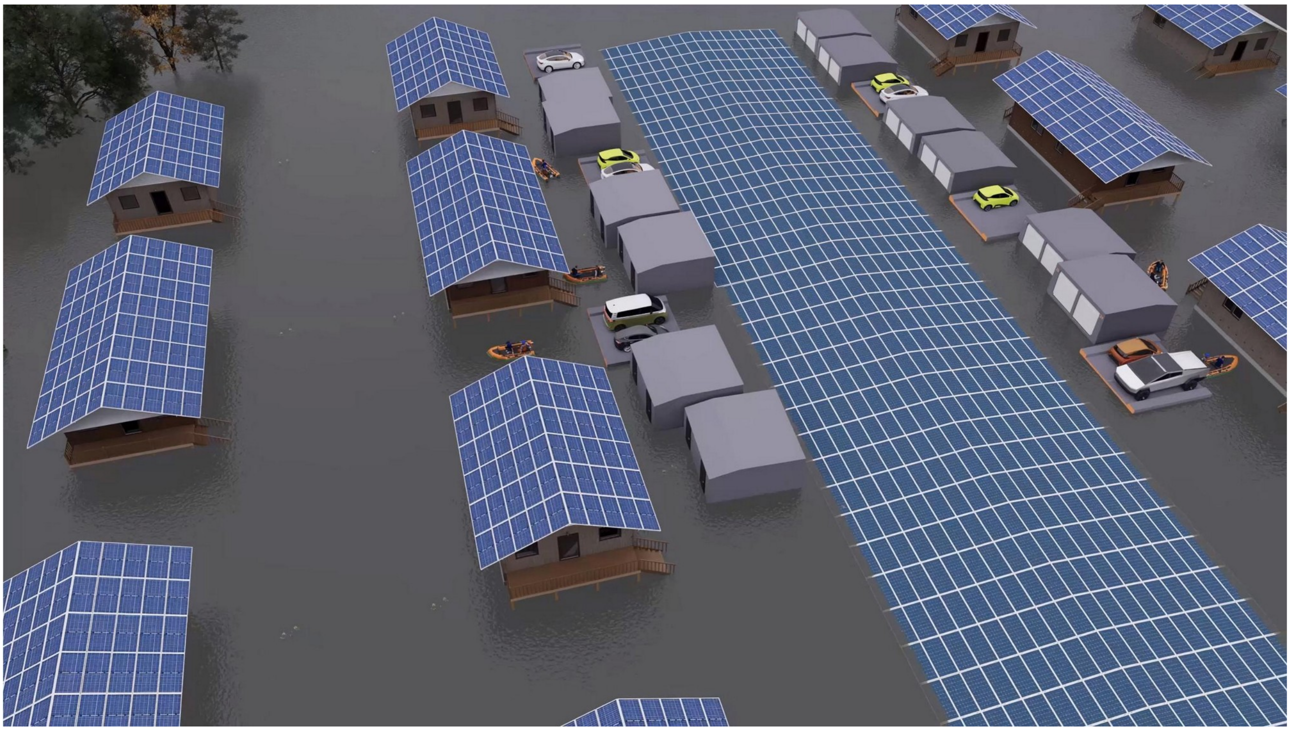
4.6 Other advantages: floodproof up to 70 cm and "Option Venezia"

Climate change increases flood risk globally. Far more incidents in low-risk and moderate flood-risk areas. The GEMINI next Generation house is floodproof up to 70 cm and will be able to swim for a 20,000 € upgrade called "Option Venezia". Most homeowners will make the decision based on insurance tariffs: What is cheaper, the down payment for "Option Venezia" or the flood insurance?

BTW, we thought about a special possibility to make the photovoltaic hailproof. The idea was dismissed after it turned out that this design would be 10 times pricier than the hail insurance. Studying risks is a main job of running an insurance company, so any design avoiding a risk can only be successful when it is cheaper than insurance.

On the other side, fire insurance in California is so expensive that an advanced fire protection system would be far cheaper. When we will be there, we will call it "Option California."

4.7 Compare conventional vs. energy optimized settlements



The settlement, shown before, at 4.5 m flood. All houses swim. The central structure is fixed, so all garages and parking platforms had been brought outside to swim.

4.8 Compare conventional vs. energy optimized settlements

Point-for-point compare why the energy-optimized settlement is far cheaper than the conventional approach. Let's start underground with the garage. Makes 32,000 € to 42,000 € per place in middle Europe, but it is common that 2 places have to be for one apartment. Here are the first 64,000 € to 84,000 € for the apartment.

At the energy-optimized settlement, there are garages and parking places below the central photovoltaic structure. Garages below 10,000 € per place, the central photovoltaic is like a huge carport. Let's have one garage place and one parking place. What to do with the difference? Let's have 80 kW photovoltaic and 240 kWh batteries!

We only finished to compare the underground, and we have already discovered the money for the energy transition. But we are far away from finished.

Only mass helps against impact sound. In a multi-story residential building, such a ceiling is 300 to 350 mm thick throughout. One square meter weighs 500 kg to 600 kg. But that is not one square meter of living space, because in buildings of this type, only 70% of the total area is living space. So that's 700 kg to 850 kg just for the ceiling for one square meter of living space. At the GEMINI house, the floor separating the living area from the drawer system below is less than 5% of this weight.

How do you stop noise over the shortest distance? Sound insulation is a decisive factor for residential satisfaction. Again, this can only be achieved on short distances with mass, a lot of mass. Because the neighbor's stereo system can be louder than the traffic noise outside, the partition walls between apartments are also heavier than the exterior walls. The partition walls between apartments weigh 300 kg to 550 kg per m², while the exterior walls weigh only 180 kg to 350 kg per m² of wall space. We use some optimizations for acoustic insulation between rooms inside the GEMINI house, but in a single-family house, no strong acoustic separation is required. The outside wall is less than 30 kg/m².

A Boeing 747 carrying a space shuttle makes 322 tons of takeoff weight. Or the weight of 5 Abrams M1 main battle tanks.
An 100 m² apartment with 2 places in the underground garage can also be up to 322 tons of construction material..

This is an enormous material battle to make it reasonably bearable for people to live together in a very small area. Can we continue to afford this type of newly built housing, or must it be considered a luxury for private buyers?

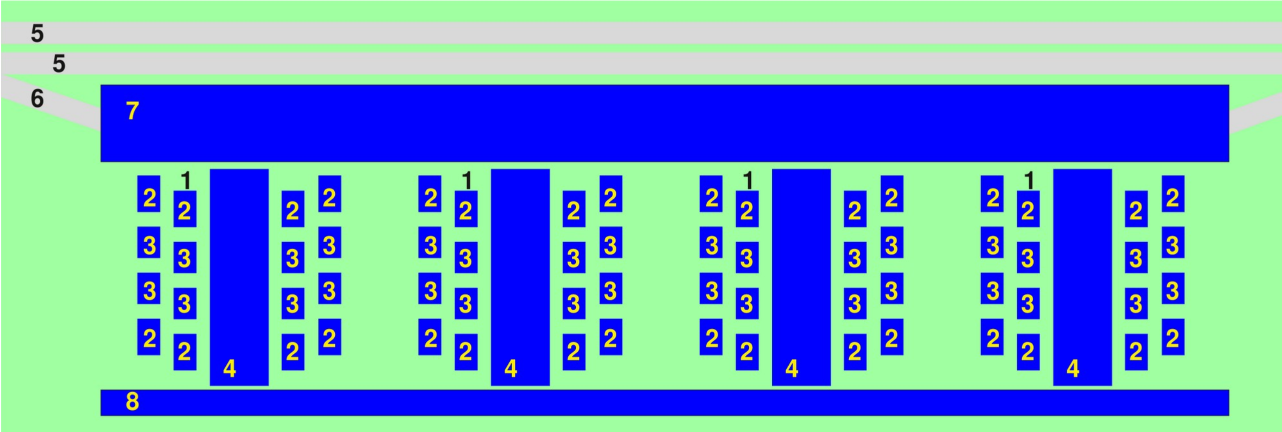
Do we want an energy transition? Do we want climate protection? Then such material battles must be called into question.

5 OFF-GRID FAST CHARGING SETTLEMENTS

Being able to reach all the areas with no electricity is most important for the change to electric cars and trucks in Africa. As shown before, a high-voltage grid is far too expensive. It makes absolutely no sense to transfer the power of a photovoltaic over some hundred kilometers when a photovoltaic there can do the job also without this grid. There are even more advantages: DC direct by a battery-powered fast chargers are cheaper and more efficient than AC-powered fast chargers.

It can start small, somewhere in a village, with a single GEMINI house with a big PV carport and 100 kW DC charging. This can expand to several houses and a generator to also provide service in very dense cloudy weather conditions. Maybe at a group of 16 houses, a power-to-methanol system will be added.

And the off-grid fast charging settlement grows, and 20 years later it is the size of a usual European highway station.



Typical 24×365 capability for 80 trucks 300 kWh charging and 300 cars 30 kWh charging.

1.) 1 ha double used land

2.) GEMINI 70 house 70 PV modules × 32 = 2,240

3.) GEMINI 60 house 60 PV modules × 32 = 1,920

4.) Central structure 1,008 PV modules × 4 = 4,032

5.) Highway

6.) Street to the fast chargers

7.) 460 × 15 = 6,900 modules above fast charging and gastronomy

8.) 460 × 5 = 2,300 modules above a connection street behind the village

Total 17,392 modules with 11 MW peak. The inhabitants work in the gastronomy of the fast-charging station and as farmers to utilize the surrounding land.

6 ENERGY-INTENSIVE INDUSTRY

I once developed a scale for off-grid solar possibilities depending on photovoltaic size, 3 Wh battery per Watt peak assumed:

1.) 5 to 100 W information and light (smartphone, laptop, LED)

2.) 200 to 300 W refrigerator (less rotten food)

3.) 500 to 1,000 W electric cooking and electric scooter

4.) 3,000 to 6,000 W air conditioner and electric car

But now is to make a big jump upwards on this scale:

5.) 80,000 W to 160,000 W house in a workers village designed to contribute to the extreme electricity demand of electric-only running, energy-intensive industry.

These houses are beyond what a simple worker in a poor country could afford, even with selling much electricity to the company. It is for the company to balance house prices, the price of electricity, and the wages to pay.

6.1 Operating mode for energy intensive industry

There is an investment, and it should run all year. This is the standard approach. Would a taxi operator cease operations in winter simply because electricity prices are higher in winter than in summer and consumption is slightly higher? Sure not!

Exactly this question is a main question in energy-intensive industry. There is an investment, there are workers and there are different amounts of available energy and resulting energy prices. Look at the solar yield graph of Cairo, Egypt. Here it is completely predictable; we run the factory with 200 workers in June and with 100 workers in December. Look at Kampala, Uganda. Here it is completely unpredictable for more than some days weather forecast.

At low battery prices, is the conversion from random electricity to 24-electricity always a win. The conversion from 24-electricity to 24×365 electricity comes at a price. This price is shown at the conversion ratio. In our examples, this conversion ratio is between 33.4% and 65.8%. No problem for everyday electricity use, like for car driving or heat pumps.

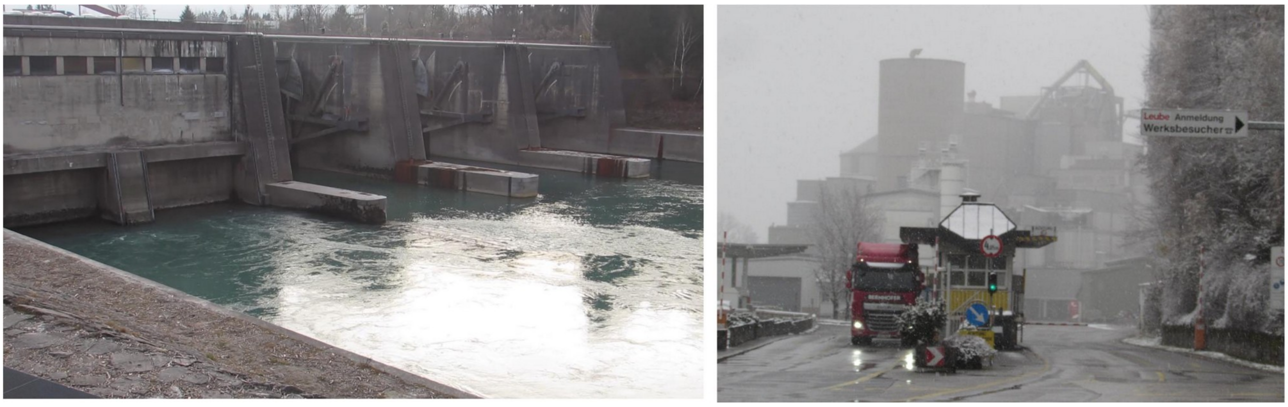
But it is a huge problem when 9,000 kWh are required to produce 1 t of a product where the fossil energy-using competition is at €300/t on the market. 9,000 kWh can propel an electric car more than one time around Earth or produce 1 t of urea fertilizer.

So we show for each energy-intensive industry 3 modes:

- Constant all the year
- Moderate changing of production for cost optimization
- Running on 24-electricity, no conversion to 24×365

Remember, 2 centuries ago, steel production emerged only close to coal mines delivering hard coal. It was possible to heat a house with hard coal 1,000 km distant from a coal mine, but not to build a steel factory there.

6.2 Electric-only production of cement



Left: hydropower plant Urstein - right; cement factory LEUBE

At the hydropower plant Urstein at the Salzach is a sign: 120 GWh/a, we supply to 35,000 households. Only 2.5 km distant is the cement factory LEUBE: 110 GWh electricity and 400 GWh heat for 600,000 t cement per year. Making a fire to bring the clinker to the required reaction temperature could be replaced by electric-only heating. The 400 GWh heat could be replaced by 250 GWh electricity. So the cement factory would be fully electric with 360 GWh/a fully electric, and the shield at the hydropower plant should be replaced with: 120 GWh/a, we supply 90 workers in the energy-intensive industry.

The non-SI unit "household" translates in middle Europe usually to 3,500 kWh/a electricity; the heating of the household is by burning, and they have only ICE cars. But even when we correct "household" to 8,000 kWh/a, the difference between 15,000 households and 90 workers in the energy-intensive industry is two orders of magnitude.

600 kWh per ton for electric only cement production	Aalborg Denmark	Salzburg Austria	Cairo Egypt	Kampala Uganda	Timika Indonesia	Kathmandu Nepal
Usual market price for 1 t	134 €	140 €	66 €	148 €	87 €	89 €
Electricity for the production of 100 € market price	448 kWh	429 kWh	909 kWh	405 kWh	690 kWh	674 kWh
If 70% of the price would be energy, this would be €/kWh	0.156	0.163	0.077	0.173	0.102	0.104
Constant production all the year aound	red	red	yellow	green	green	green
Moderate production changes for cost optimization	green	green	green	green	green	green
Runing only on 24-electricity to be competitive	red	red	green	red	red	red

The energy subsidies in Egypt are running out. Electric-only cement production by photovoltaics is possible in all example locations.

What moderate production changes in Denmark and Austria? Simple 30 to 45 days break around the winter solstice.

6.3 Electric-only mineral wool production

There are Heat Degree Days (HDD). You can calculate the heat demand of a house with the energy certificate and the HDD of a location. 100 W/K and 3,900 HDD means 100 W/K x 24 hours x 3,990 HDD = 9,360 kWh/a heat demand. Most extreme permanent inhabited locations in Austria have 5,300 HDD. For example, Obergurgl. Permanent used houses there have good thermal insulation. Vienna has only half of the Obergurgl HDD.

There are also Cool Degree Days (CDD). Manila has as many CDD as Obergurgl, the highest permanently inhabited village in Austria, has HDD. Single glass windows and no insulation. Rich people brag there that they spend for electricity as much as for 4 housemaids, most of the energy for this insanity is imported fossil energy.

So the production of thermal insulation is something very important for hot areas. As we signed an NDA with a construction company in Ghana, my first reaction was to search for electric-only production equipment for mineral wool because insulation material is more expensive in Ghana than in Austria.

2,000 kWh per ton for electric only mineral wool production	Aalborg Denmark	Salzburg Austria	Cairo Egypt	Kampala Uganda	Timika Indonesia	Kathmandu Nepal
Usual market price for 1 t	2,200 €	2,200 €	1,800 €	1,200 €	1,000 €	900 €
Electricity for the production of 100 € market price	91 kWh	91 kWh	111 kWh	167 kWh	200 kWh	222 kWh
If 70% of the price would be energy, this would be €/kWh	0.770	0.770	0.630	0.420	0.350	0.315
Constant production all the year aound						
Moderate production changes for cost optimization						
Runing only on 24-electricity to be competitive						

I kept hearing from building biologists about the energy required for production,
but now it turns out that this is completely uncritical.

6.4 Scrap to steel by electric melting

Approximately 29% of global crude steel production is made via electric arc furnace (EAF) melting, which is the primary method for recycling steel scrap (electric melting). So this is an established technology.

450 kWh per ton for electric only scrap to steel recycling	Aalborg Denmark	Salzburg Austria	Cairo Egypt	Kampala Uganda	Timika Indonesia	Kathmandu Nepal
Usual value change for 1 t	250 €	250 €	280 €	160 €	50 €	100 €
Electricity for 100 € market price gain from scrap to steel	180 kWh	180 kWh	161 kWh	281 kWh	900 kWh	450 kWh
If 70% of the price would be energy, this would be €/kWh	0.389	0.389	0.436	0.249	0.078	0.156
Constant production all the year aound						
Moderate production changes for cost optimization						
Runing only on 24-electricity to be competitive						

Seems there is a price anomaly in Timika.

6.5 PEM or AEL electrolyzer

PEM electrolyzers have a stable efficiency over a wide range of power input and follow load changes in seconds. You can even connect PEM to photovoltaics directly without any electronics in between. Sounds great, but there are severe disadvantages: shorter usage of the equipment and high prices due to extremely expensive materials like iridium and platinum.

The world production of gold is 3,000 to 3,500 t/a, and platinum is 180 to 200 t/a. We have only 7 to 8 t/a Iridium. Even the complete world production of iridium would be only 11 GW PEM electrolyzers.

Type		—— PEM ——			—— AEL ——	
Year		2010	2030		2010	2030
Photovoltaic	1 kW	1,500 €	300 €	1.2 kW	1,800 €	360 €
Batteries				3.6 kWh	1,800 €	144 €
Electrolyser	0.8 kW	1,600 €	1,600 €	0.25 kW	200 €	200 €
Total		3,100 €	1,900 €		3,800 €	704 €

Surprise, we have again detected a missed profitability transition.

There had been a time when photovoltaics and batteries had been extremely expensive. No batteries are necessary at a PEM electrolyzer, making the best usage of the expensive photovoltaic. In this scenario, the high price per kW of PEM electrolyzers did not matter. In this scenario, the scarcity of iridium did not matter. But here again, we have a missed profitability transition. How can this happen so often in the area of the energy transition?

Best explanation is the “It doesn't make economic sense” trauma. In the time before 2009, people working for the energy transition heard again and again, “It doesn't make economic sense”. Over several years, this developed into a severe trauma. The reaction was, “We have to do it, whatever it costs”. This trauma-induced reaction brought the energy transition in a bad situation.

6.6 Iron ore to steel only by electricity

Iron ore is actually rust mixed with stones. The formula FeO(OH) for rust is a significant simplification: rust is a complex mixture of many different oxides and hydroxides of iron. Some of them have names like Hematite Fe_2O_3 or magnetite Fe_3O_4. If you want iron, you first have to remove the oxygen. This can be done either with carbon or hydrogen. With carbon, you get 2 kg of CO2 emissions per kg of iron, while with hydrogen you have to use about 4 kWh of electricity to produce the necessary hydrogen.

4,000 kWh per ton for electric only steel production from ore	Aalborg Denmark	Salzburg Austria	Cairo Egypt	Kampala Uganda	Timika Indonesia	Kathmandu Nepal
Usual market price for 1 t	650 €	650 €	670 €	550 €	450 €	500 €
Electricity for the production of 100 € market price	615 kWh	615 kWh	597 kWh	727 kWh	889 kWh	800 kWh
If 70% of the price would be energy, this would be €/kWh	0.114	0.114	0.117	0.096	0.079	0.088
Constant production all the year aound						
Moderate production changes for cost optimization						
Runing only on 24-electricity to be competitive						

Changing the production of steel by ore: 2 kWh of electricity replaces 1 kg of CO2 emissions.

6.7 Fertilizer production by electricity

At the beginning of the 20th century, Haber was celebrated as the man who made bread from air, thanks to the Haber-Bosch process for producing artificial fertilizer. Earlier sources of fertilizer were guano bird droppings and Chilean nitrate, both of which were limited resources. These limited resources were replaced by a new limited resource: fossil fuels. The best conventional plants emit 1.5 kg of CO2 per kg of urea fertilizer.

Since the production of 1 kg of fertilizer costs 9 kWh of electricity, the least favorable ratio for replacing CO2 emissions with clean electricity is 6 kWh to avoid 1 kg of CO2 emissions.

Replacing a moped with a 2-stroke engine with an electric scooter meant replacing 4 liters of gasoline/100 km with 10 kg of CO2 emissions with 5 kWh of electricity: only 0.5 kWh of electricity to avoid 1 kg of CO2 emissions.

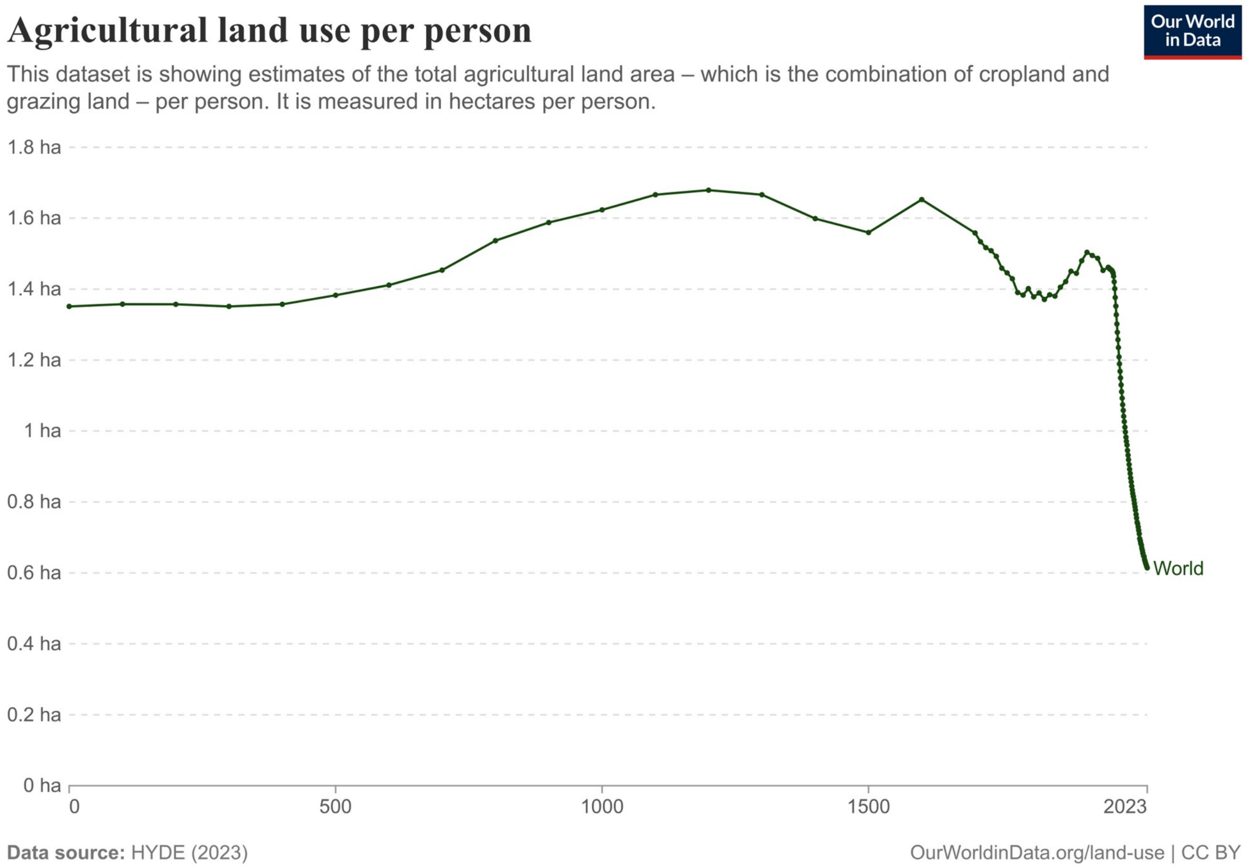
9,000 kWh per ton for electric fertilizer (urea) production	Aalborg Denmark	Salzburg Austria	Cairo Egypt	Kampala Uganda	Timika Indonesia	Kathmandu Nepal
Usual market price for 1 t	445 €	470 €	300 €	430 €	300 €	150 €
Electricity for the production of 100 € market price	2,022 kWh	1,915 kWh	3,000 kWh	2,093 kWh	3,000 kWh	6,000 kWh
If 70% of the price would be energy, this would be €/kWh	0.035	0.037	0.023	0.033	0.023	0.012
Constant production all the year aound						
Moderate production changes for cost optimization						
Runing only on 24-electricity to be competitive						

The greatest challenge: cheaper than steel but more than twice the electricity for production.

At least one green field in the “Run only 24-electricity” mode, but this is more than enough, because Cairo, Egypt stands for the Sahara, the Arabic peninsula and many more very sunny deserts.

7 AGRICULTURE: HOW MANY SQUARE METERS DOES A HUMAN NEED FOR HIS FOOD?

Mankind started as hunters and gatherers. 12,000 years ago, 500,000 m^2 to 2,500,000 m^2 per human. With the agricultural revolution, the land use was reduced by 2 magnitudes.



Our World in data: https://ourworldindata.org/grapher/total-agricultural-land-use-per-person

But is this reduction enough? 9 billion × 0.6 ha are 54 million km². A new revolution in reducing required space for food growing could be used first in areas with extreme conditions.

7.1 Food growing: electricity instead of land and water

Jordan has approximately 61 cubic meters of renewable freshwater available per capita per year. This is far below the international threshold of 500 cubic meters per person per year, which defines absolute water scarcity.

To grow food, you need water. This limits Jordan's food production. It is possible to reduce water usage drastically by using much electricity.

Scenario: tomato production	Yield per m²	Usage per m²		Usage per kg	
		L water	kWh	L water	kWh
Open Field near Vienna	8	480	1.6	60	0.2
Open Field near Amman	6.8	476	2	70	0.3
Advanced Greenhouse in Vienna with LED light in winter	200	400	900	2	4.5
Advanced Greenhouse in Vienna without artificial light	140	280	650	2	4.6
Advanced Greenhouse in Amman	200	400	1,400	2	7.0

How could the greenhouse in Vienna be improved? Maybe a winter break? How long should the winter break be?

Advanced greenhouse: Very low air exchange. The air exchange is controlled by holding the oxygen level below 25%. At the air exchange, humidity recovery is used. CO2 is blown into the greenhouse to achieve the 800 ppm CO2 optimal level for growing tomatoes. The CO2 can be provided by DAC - Direct Air Capture or from cement factories heating the clinker electrically, only providing pure CO2 from the chemical reaction.

Water for cooling is cooled down during the coldest hours of the day to improve the COP of the heat pumps. A GEMINI 60 house has 40 m³ water as low-temperature heat storage, which can be used for this optimization.

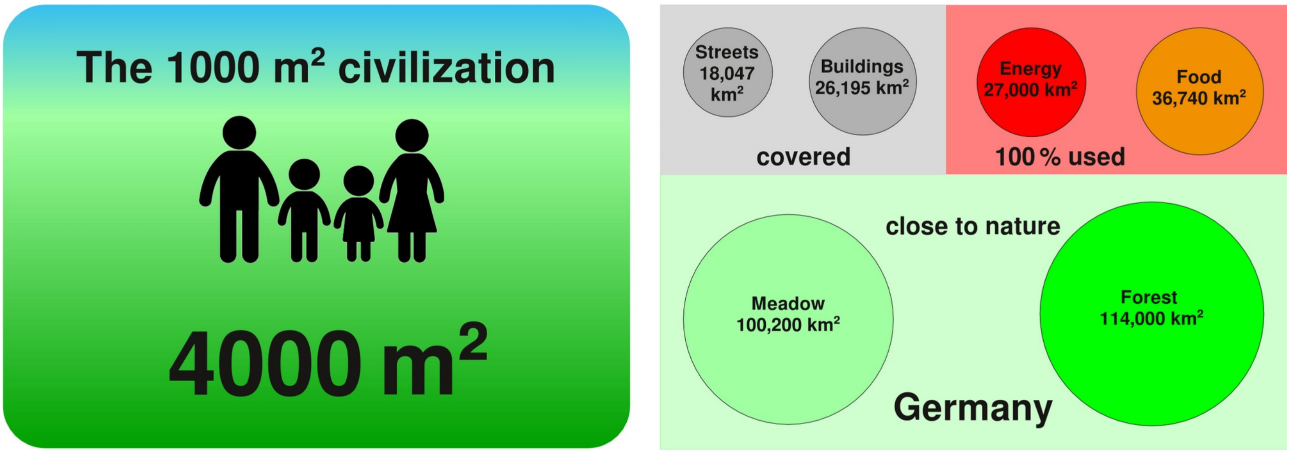
In aeroponic/hydroponic setups, the recirculating solution concentrates salts over time as plants transpire pure water. To prevent toxicity (maintaining EC <2.5–3 dS/m for tomatoes), a fraction must be periodically discharged and replaced with fresh water. For a further reduction of water usage, this water is also recycled as well as economically feasible.

Vacuum glass is decreasing in price, so it will soon be a solution to reduce the heating demand at greenhouses in winter.

LED usage: Amman has enough light all year to grow tomatoes. In Vienna is the decision is to supplement natural light in winter with LED light for optimal plant growth. The outcome in kWh/kg tomatoes is nearly the same, but using much more electricity in winter would further decrease the 24×365 conversion ratio.

7.2 The 1000 square meter civilization

More room for nature, more biodiversity—let's have a space-optimized civilization. Meadows and forests can mostly be considered nature. The main obstacle is not buildings and streets, but agricultural land for food and energy production. Intensive agricultural fields have zero biodiversity and are 100% not nature.



The 1000 square meter civilization would mean 83,500 km² of land usage in Germany and the rest more or less close to nature.

The easiest to resolve in Germany is the area wasting energy from biomass. One hectare of maize for biogas creates only 17 MWh/a, while one hectare of energy-optimized settlement has, even after the 24×365 conversion, about 550 MWh. With the new possibilities, there could be 50,000 km² more meadows and forests while having a very comfortable housing and living standard.

8 CONCLUSION

Thinking new about something important over and over again. All parameters are in a constant state of change. We have to check all the parameters and predict the development for the predictable future. What could be more important than the future of our civilization?

That is far more than just science; it is the foundation of ethics—the science of survival.

1. Knowledge is a prerequisite for ethics.
2. Knowledge is thus able to change the bases of decisions laid by ethics.
3. Ethics force us to verify knowledge.

Let's start to see the future of our civilization in a new, optimistic way!

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