SOLAR AGENTUR
Solar Agentur Schweiz
Agence Solaire Suisse
Swiss Solar Agency

Sonneggstrasse 29
CH-8006 Zürich
www.solaragentur.ch
info@solaragentur.ch

«Solar architecture is not about fashion, it is about survival.»
(Lord Norman Foster, London)

PLUS® ENERGY BUILDING

Solar electricity potential with measured values: 127 to 435 TWh

NF-PEB secure 100–180% of the energy need

- Attractive NF-PlusEnergyBuildings (PEB) fulfil Paris Climate Agreement
- PEB and PSPP guarantee an independent and CO_2-free electricity supply
- Revenues untill 2035: CHF 35 billion - Reduction: 2/3 of CO_2-emissions

Solar Prize Jury / Norman Foster PEB Jury 2021

Editorial

Herausgeberin/Editeur
Solar Agentur Schweiz (SAS)
Agence Solaire Suisse (ASS)
Swiss Solar Agency (SSA)

Sonneggstrasse 29, CH-8006 Zürich
Tel. +41 (0)44 252 40 04
Fax +41 (0)44 252 52 19
info@solaragentur.ch
www.solaragentur.ch

Co-Präsidium
Priska Seiler Graf, Nationalrätin;
Leo Müller, Nationalrat;
Christoph Eymann, Nationalrat;
Dr. Eugen David, e. Ständerat

Geschäftsführer
Gallus Cadonau, Sonneggstrasse 29
8006 Zürich, info@solaragentur.ch
Tel. 044 252 40 04, Fax 044 252 52 19

Finanzdelegierte
Carole Klopfstein, Aarbergergasse 21,
3011 Bern
office@sses.ch, Tel. 031 371 80 00
www.sses.ch

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NF-PEB solar electricity supply: 100-180% with 127 to 435 TWh

Lord Norman Foster, London
Swiss Solar Prize, Geneva (fig. 2)

Art. 89 Federal Constitution (FC): „The Confederation and the cantons shall... advocate a secure, economical, and environmentally compatible energy supply as well as economical and rational energy consumption." The Confederation "shall promote the development of energy technologies, in particular in the areas of energy saving and renewable energies." The principle of proportionality must be considered (Art 5, paragraph 2 FC). In the opinion of the Norman Foster PEB jury, these goals can be optimally implemented in the building sector with the following theses by Norman Foster.[1]

I have never seen a conflict between the pursuit of aesthetic delight and high performance in terms of sustainability. I would go further and say that responding to more demanding criteria should produce more beautiful buildings. (LNF, 2010).

The way we shape our buildings, our neighbourhoods and our global lifestyle has now become even more important than ever - we must ensure that sustainability become as inseparable from our design processes as time, cost, and quality (LNF, 2005)

Short version: Solar electricity potential with measured values secures 127-435 TWh/a

Biggest solar electricity potential is still not taken into consideration: This report is dealing in **part A** with the huge discrepancy between published *estimated values* and *measured values* in the field of modern building technology. Estimates *neglect* more than three quarters of the produced solar electricity and empirically proven and confirmed *energy losses in the building sector of 80%* (Federal Council, IP 10.3873) despite their huge and most cost-effective energy potential. **In part B,** *house owners, tenants, residential cooperatives, and SME* prove with *measured and confirmed values* (confirmed by local electricity companies, see p. 4 and 5) that they can produce **between 127 and 435 TWh** until 2050 or supply CO_2-free solar electricity to cover **100 to 180% of the total energy need**. They also prove that the Paris Climate Agreement can be achieved with Minergie-P/PEB or similar building standards only.

The 182% PEB housing estate with 32 apartments in the **municipality of Tobel-Tägerschen in the canton of Thurgau** (PEB-MFH) illustrates Switzerland's enormous *solar electricity potential* of **435 TWh** or *180% of the present energy consumption* – with rents that are 20% lower than in comparable residential buildings of the region (fig. 4 PEB, p. 4). In **Waltensburg/GR**, a *817% PEB single family house* is producing more than 8 times its total energy need. The PEB solar surplus allows to *drive 10,000 km per year without any CO_2-emissions with 25 e-cars each*. In the **canton of Lucerne**, several SME show how commercial buildings can provide the electricity for 3,000 to 5,200 e-cars completely CO_2-free. And in the **municipality of Affoltern i.E. in the canton of Berne**, a *protected building* dating from 1765 was transformed from a huge energy waster into a **700% PEB MFH** with a solar surplus that allows to power more than 50 e-cars (fig. 3).

An **independent electricity supply – also during winter – can be guaranteed by PEB in combination with pump storage power plants** (PSPP). How it works, is shown in fig. 5 in **part C** if *idle PSPP* capacities in the GW range *are used* in accordance with the constitution instead of over-promoting *"ineffective subsidies"*. In **part D to G**, *house owners, tenants, residential cooperatives, and SME* show with their already **realised PEB** how *127 to 435 TWh/a* of the necessary **electricity** can be **generated with solar energy** until 2050 (fig. 6-13) with best-integrated solar installations. In 23 of 26 Swiss cantons, dozens of PEB already have a far better installed performance in kW than needed to implement the *Paris Agreement*. **Part H** explains finances, **part I** the universal implementation and **part K** the building law. For building implementation, please refer to **NF-PEB theses 1-8**, Solar Prize 2021, p. 21.

For the Norman Foster PlusEnergyBuilding (PEB) Jury

Prof. Reto Camponovo	Gallus Cadonau	Prof. Dr. Roland Krippner	Prof. Georg W. Reinberg
Pres. Jury Prix Solaire Suisse	Jurist/GF SAS	TH Nürnberg	TU Vienna

Geneva/Munich/Vienna/Zurich, April 2022

[1] **Norman Foster PEB Jury video statement** of May 30, 2021, esp. Stefan Cadosch, Vice President NF-PEB-Jury dipl. Arch. ETH/e, president SIA and further NF-PEB Jury members support the NF theses of PEB solar architecture.

NF-PEB secure 100-180% of Switzerland's energy need

Federal Council: Switzerland's biggest energy potential with 157 TWh/a (IP 10.3873)

1. 700% PEB refurbishment Anliker, Affoltern i.E./BE

Norman Foster PlusEnergyBuilding Solar Award 2019, European and Swiss Solar Prize for PEB: The following fig I-IV are the basic Min.P/PEB

Total energy	%	kWh/a
Need before refurb.:	750	196,800
Need after refurb.:	100	13,000
Self-supply:	700	90,500
Energy surplus:	600	77,500
For 55 CO_2-free e-cars		

Fig. 3: The 700% PEB double family house Anliker dating from 1765 and refurbished in 2015 had an energy need **before** PEB refurbish-ment of almost **200,000 kWh/a;** with its Min-P refurbishment, **93.4% of energy losses were eliminated,** and the two families have an actual energy need of **13,000 kWh/a**, while the MFH produces **90,500 kWh**; the **PEB solar surplus** amounts to **77,500 kWh/a** *of CO_2-free solar electricity.* This allows to drive 10,000 km per year with 55 e-cars each without any CO_2-emissions. **Electricity need in winter is barely 8,000 kWh/a – Solar electricity production in winter amounts to 21,000 kWh/a.**

2. 182% PEB housing development Thurgau

Norman Foster PEB Solar Award 2019
European and Swiss Solar Prize for PEB

Total energy:	%	kWh/a
Energy need:	100	129,500
Self-supply:	182	236,300
Energy surplus:	82	106,800
For 76 CO_2-free e-cars		

Fig. 4: The 182% PEB housing development in Tobel/TG with 32 units is covering 100% of its total energy need of **129,500 kWh/a** and generating a solar surplus of about **106,000 kWh/a**, i.e., the total production amounts to **236,300 kWh/a** allowing to drive 10,000 km per year with 76 e-cars each without any CO_2-emissions; The rents are *20% cheaper* than for comparable apartments. **Electrici-ty supply in winter** is **85%** – with **PV-facades facing East-West** it would even be **115%** of needed winter electricity.

3. 800% PEB-SFH in 7158 Waltensburg/GR

Norman Foster PEB Solar Award 2020 and Swiss Solar Prize for PEB 2020

Total energy	%	kWh/a
Energy need:	100	4,900
Self-supply:	817	40,200
Energy surplus:	717	35,200

For 25 CO_2-free e-cars

Fig. 5: The PEB-SFH Brunner-Bapst built in 2019 in Waltensburg/GR produces **40,200 kWh/a**. Thanks to its Minergie-P-insulation it consumes only **4,900 kWh/a**. Its 817% energy self-supply leads to a **solar surplus of 35,200 kWh/a**. This allows to drive 10,000 km per year with **25 e-cars** each without any CO_2-emissions and to avoid 65 t of CO_2-emissions. The building meets the target of the Paris Agreement for an energy turnaround by far (Swiss and Norman Foster PEB Solar Prize 2020; p. 26-34).

●●> One PEB in Lucerne can provide CO_2-free energy for 3,100 to 5,350 e-cars

4. 230% PlusEnergy industrial building, Perlen/LU

Swiss Solar Prize for PlusEnergyBuildings (PEB): allows to operate 3,000 to 5,200 e-cars without any CO_2-emissions

Total energy	%	kWh/a
Energy need:	100	3,150,900
Self-supply:	233	7,300,200
Energy surplus:	133	4,200,000

For 3,000 CO_2-free e-cars or
for 5,200 CO_2-free e-cars ≈ small town

Fig. 6: The perfectly roof-integrated solar installations of the logistics centre in Perlen with a capacity of 6.4 MW produces **7.33 GWh/a** which is *more than* **4** *small hydropower plants*. With its **solar surplus of 4.2 GWh/a,** it is possible to drive 10,000 km per year with **3,000 e-cars** each without any CO_2-emissions. The total solar electricity production is even enough for **5,200 e-cars** corresponding to the **number of cars in a small town.**

Building park secures 100-180% of the energy need with 127-435 TWh

1. **PV capacity for 435 TWh already installed multiple times:** The installed PV capacity per MFH, SFH and SME is decisive for a country's CO_2-free solar energy supply. The measurements of the NF-PEB Jury for Switzerland generally apply for all OECD countries and beyond. In part E of the NF-PEB **study on the solar electricity potential,** which is based on measured and confirmed values, the building park is divided into three main categories. It has been known for years that SFH and SME are able to produce much more solar electricity than they need in the annual average. It seems more difficult to supply the total amount of energy needed for MFH since they need an installed capacity of **6 kW per apartment** to cover an energy need of 127 TWh and **8 kW** for 435 TWh.[2] The following table, however, proves that **PEB-MFH** have been built for **38 years** where this is no problem at all. On the contrary: They produce much more solar electricity than they averagely need to secure 435 TWh (see basic PEB fig.1-4).[3]

Multiple family houses (MFH): Installed capacity, solar electricity production, and PEB surplus

	PEB-MFH	kWp	Pro-duktion	Über-schuss		PEB-MFH	kWp		PEB-MFH	kWp
1	349%-PEB, 6004 Luzern	45.90	38'259	27'296	17	157% PEB, 1226 Thônex/GE	12.68	33	130%-PEB, 6253 Uffikon/LU	8.82
2	700%-PEB, 3416 Affoltern i.E./BE	44.70	45'247	32'127	18	130%-PEB, 9244 Niederuzwil/SG	12.50	34	110%-PEB, 3814 Gsteigwiler/BE	8.79
3	510% PEB, 7742 Poschiavo/GR,	33.30	22'944	19'030	19	118%-PEB, 3315 Bätterkinden/BE	11.47	35	108%-PEB, 9650 Nesslau/SG	8.65
4	166% PEB, 6204 Sempach/LU	19.75	16'100	6'450	20	126% PEB, 8049 Zürich	11.23	36	252%-PEB, 3322 Urtenen-Schönbühl/BE	8.55
5	300% PEB, 1955 Chamoson/VS	16.74	17'500	15'000	21	250% PEB, 9248 Bichwil/SG	11.20	37	172%-PEB, 8487 Zell/ZH	8.37
6	170%-PEB, 8610 Uster/ZH	16.50	12'876	5'312	22	128%-PEB, 9500 Will/SG	10.85	38	139%-PEB, 8620 Wetzikon/ZH	8.07
7	110%-PEB, 6147 Altbüron/LU	15.30	15'000	1'360	23	151% PEB, 1226 Thônex/GE	10.55	39	131%-PEB, 3612 Steffisburg/BE	7.93
8	237%-PEB, 8843 Oberiberg/SZ	15.13	14'796	8'544	24	117%-PEB, 8038 Zürich	10.30	40	131%-PEB, 8102 Oberengstingen/ZH	7.82
9	280% PEB, 5615 Fahrwangen/AG	14.54	10'860	7'264	25	124%-PEB, 9050 Appenzell/AI	10.18	41	136%-PEB, 9445 Rebstein/SG	7.81
10	174%-PEB, 8570 Weinfelden/TG	13.93	5'764	2'448	26	130% PEB, 6374 Buochs/NW	10.10	42	184% PEB, 5616 Meisterschwanden/AG	7.65
11	105%-PEB, 6274 Eschenbach/LU	13.75	18'315	948	27	147%-PEB, Unterengstingen/ZH	9.97	43	150%-PEB, 9500 Wil/SG	7.50
12	120% PEB, 3645 Gwatt/Thun/BE	13.74	10'735	2'843	28	187%-PEB, 7023 Haldenstein/GR	9.80	44	157%-PEB, 9555 Tobel/TG	7.27
13	222%-PEB, 3855 Brienz/BE	13.45	12'065	6'638	29	103%-PEB, 8049 Zürich	9.59	45	127% PEB, 8877 Murg/SG	7.25
14	174%-PEB, 7418 Tomils/GR	12.95	15'685	8'415	30	113%-PEB, 6074 Giswil/OW	9.20	46	118%-PEB, 8006 Zürich	6.98
15	232%-PEB, Säriswil/BE	12.85	13'318	7'566	31	210% PEB, 9050 Appenzell/AR	8.90	47	150% PEB, 3855 Brienz/BE	6.83
16	234%-PEB, 6056 Kägiswil/OW	12.73	12'142	6'951	32	182%-PEB, 9555 Tobel/TG	8.88	48	118%-PEB, 8700 Küsnacht/ZH	6.15
Durchschnitt ab 8 kW		14.05	12'103	5'723						

kWp pro Wohnung | Energieproduktion pro Wohnung | Solarstromüberschuss pro Wohnung

Fig. 7 PEB: The *first column* shows the *installed PEB capacity* **per PEB-MFH apartment** in 23 cantons; the *second column* lists the **total annual production** in kWh/a; the *third column* confirms the *PEB solar surplus per year.* From 48 PEB-MFH *80% have a capacity of more than 8 kW* per apartment.

2. **Solar electricity potential: at least 180% or 435 TWh:** Based on fig. 7, the question if the mentioned solar electricity potential exists or not can easily be answered. The NF-PEB Jury has been checking all these PEB-MFH since 2010 (incl. PEB-SFH and PEB-SME). So far, no irregularities or wrong figures from owners, tenants, SME, or the respective local electricity companies have ever been found.

3. **For a solar electricity potential of 435 TWh, a capacity of 8 kW is necessary - for 127 TWh only 6 kW:** In fig. 7, 80% of the already realised PEB-MFH (new buildings or refurbishments) with more than 8 kW per apartment prove that owners, tenants, residence cooperatives, and SME are producing more solar electricity than needed for 435 TWh or for 180% of the actual energy consumption of 240 TWh/a. 20% or 10 PEB-MFH (no. 39 – 48) have an installed capacity of 6.15 to 7.93 kWp per apartment (only). This is enough to produce 127 TWh. And if these buildings are realised or refurbished according to **Minergie-P/PEB building standard** until 2050, Switzerland can reach the goal of the Paris Agreement easily.

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[2] **Fig. 10 and 12 in the study on the solar electricity potential.** Acc. to fig. 10 only an installed capacity of 6 kW is needed for 127 TWh (see fig. 10 and 11 NF-PEB study on the solar electricity potential).

[3] **Fig. 7** shows that 38 PEB-MFH have a far **higher installed capacity** from 8.07 **to 45.9 kWp** per apartment. If future PEB-MFH owners will install more than 8 kW per PEB apartment as well, the potential to achieve the Paris Agreement would be far more than 435 TWh/a.

Until 2035: 35 billion CHF of revenues and reduction of CO_2-emissions by $^2/_3$

Total energy	%	kWh/a
Energy need:	100	129'500
Self-supply:	182	236'300
Energy surplus:	82	106'800
For 76 CO_2-free e-cars		

1. Overview: **Min.P/PEB solar electricity and CO_2-free transport**: The 182% PEB settlement in Tobel/TG with 32 Min.P/PEB apartments has a total energy need of **129,500 kWh/a** ≈ 4,050 kWh/a per apartment. With the full-surface roof installation and partially solar-used facades, it generates **236,300 kWh/a** ≈ *7,380 kWh/a* per unit – *3,300 kWh/a* more than its own need. With the PEB solar electricity surplus of 106,800 kWh, CO_2-free transport is guaranteed for *all tenants* (see basic PEB fig. 4). Only measured and *confirmed* energy values in kWh/a apply.

2. NF-PEB and finances: **Revenues:** Within 15 years, the Min.P/PEB Tobel produces for its own use or grid feed-in (236,300 kWh/a x 15 y) ≈ **3.54 GWh** at 15 cts./kWh **≈ 531,675 CHF**. With **MuKEn/Minergie** building standard only, the **costs** for tenants are (4,025 m² EBF à 65 kWh/m²a ≈ 261,625 kWh/a x 15 cts. ≈ 39,243.75 CHF/year; in 15 years **≈ 588,600 CHF** (see fig. 4 above).

3. **NF-PEB refurbishment Anliker Affoltern i. E.** (fig.3): **Revenues:** Within 15 years, the refurbished Min.P/PEB MFH produces (90,500 kWh/a x 15 y) ≈ **1.3575 GWh** of solar electricity at 15 cts./kWh **≈ 203,600 CHF** for two families. **Without refurbishment the costs** were (196,000 x 15 y ≈ **2.952 GWh/a** at 15 cts./kWh **≈ 442,800 CHF**

4. **Energy scenario C – If-then decision:** In the PEB study 2019 in part V, lit. C,[4] the *solar electricity potential* until 2050 is determined with *measured values* and according to "if-then scenarios". If a majority of the parliament decides for Min.P/PEB measures incl. PSPP, Switzerland can count on **435 TWh** of solar electricity – a sum which is based on already *applied* PEB building technology *according to confirmed measurements of owners, tenants, residence co-operatives, and SME.* With an *installed capacity of* **6 kW** *for PEB-MFH,* the total sum amounts to **127 TWh** *and* with **8 kW** *for PEB-MFH* to *approximately* **435 TWh** of solar electricity (see lit. E to G). However, if billions of consumers' money continues to be wasted on "ineffective subsidies"[5], the targets of the **Paris Agreement** will *never be achieved.*[6]

5. **Minergie-P/passive houses also ensure emission-free transport:** Residential and commercial buildings with Minergie-P/passive house insulation are *reducing energy losses* by an average of 80% (IP RW 10.3873). By doing so, such insulation is the *most important prerequisite* for **energy-efficient PEB** *with a high CO_2-free* **solar surplus** *of up to 800% per Min.P/PEB*. This drastically reduces **CO_2-emissions in the building and transport sector**.[7] The present study on the solar electricity potential can be applied **universally** (see part B, item 16, and part I).

6. **Revenues of CHF 35 billion in 15 years:** Both examples of item 2 and 3 above show how NF-PEB not only guarantee a **CO_2-free energy supply in the building and transport sector,** but also **net revenues of up to CHF 35 billion,** provided that *80% of energy losses in the building sector* and about *70% in the transport sector* are reduced with highly efficient Min.P/PEB and PSPP.[8] Such Min.P building investments are normally amortised after **5 to 9 years** (see lit. **H** item 5 ff. ≈ **CHF 35 billion** until 2035)**.**[9]

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4 **If-then energy scenario C:** see PEB study 2019, part II item 2 and part V annexe 3, item 2, as well as PEB motion Eymann 19.4202.

5 **Tages-Anzeiger:** Three billion of CHF for "inefficient subsidies" in small hydropower plants (TA, 21. Okt. 2020).

6 **Statement of Federal Council 21.047** to the revision of the EnL and Electricity Act of June 18, 2021, p. 85: The Federal Council envisages **2 TWh** by 2040 to replace the approximately **170 TWh** of fossil-nuclear energy sources by 2050 and to comply with the Paris Climate Agreement.

7 **CO_2-elimination in terrestric transport** is possible, however not (yet) in the aviation sector (see also basic PEB fig. 1-4).

8 **Min.P/PEB means enough CO_2-free energy and more comfort** *instead of useless wasting of energy and money,* i.e., clean air and biodiversity instead of consumer costs of **CHF 8 billion each year for fossil-nuclear** energies and „inefficient billions of CHF for small hydro power plants" see basic PEB fig. 1-4 and part **B** fig. 4 and 23, part **C** 17 and **G** item 2.

9 **Exempt** are the energy-intensive companies and nationally protected monuments (see PEB building study 2019, energy scenarios C).

7. **Conclusion:** After 15 years and based on the arithmetic series of order two, 55.5 TWh of solar electricity are generated and 37.2 TWh/a of energy losses are reduced. Total 92.73 TWh/a substituted incl. a reduction of approx. 39 million t (of ≈ 50 million t) of CO_2 -emissions. Of the cumulative CHF 111 billion (40% of CHF 111 billion ≈ savings), CHF 45 billion are for building investments. This results in (CHF 111 - 44.4 billion) ≈ CHF 66 billion in revenue from electricity sales or own consumption at 15 cents per kWh per year. Of this, CHF 30.5 billion must be substituted for incentive investments. Net electricity revenues or saved expenditure for electricity consumption after 15 years therefore are (CHF 66 billion - 30.5 billion = 35.5) ≈ **CHF 35 billion.** Because these scenarios require a certain start-up time, the mentioned energy figures are realised with a slight delay.

8. **Paris Agreement can be achieved until 2050 thanks to the theses of Norman Foster**

Scenario C	Building per year	Incentive [10]	Accum. incentives	Install. capacity	**Electricity and reduced e-losses**	Revenues/ savings per y. (with 15 cts./kWh)	Accum. revenues /savings (with 15 cts./kWh)	**accum. reduction of CO_2-emissions**[11]	Imports	Reduction of dependency on foreign c.
	in 1,000	in billion CHF	in billion CHF	in GW[12]	**in TWh/a**	in billion CHF	in billion CHF	in mio. t	in TWh/a	
after 1 y	84.9	2.44	2.44	3.7	**6.18**	0.93	0.93	**2.63**	195	78%
after 5 y	424.5	2.44	12.2	18.5	**30.91**	4.65	14.0	**13.15**	164	65.6%
after 10 y	**849**	1.22	24.4	37	**61.82**	9.30	51.2	**26.3**	133	53.2%
after 15 y	1'274	1.22	**30.5**	**55.5**	**92.73**	14.0	**111.6**	**39.45**	102	40.8%
after 20 y	1'698	0	36.6	74	**123.6**	18.6	195.3	**43.8**	71	28.4%
after 25 y	2'123	0	36.6	92.5	**154.5**	23.3	302.3	**48.2**	40	16%
after 30 y	2'547	0	36.6	111	**185.5**	27.9	432.5	**52.6**	10	4%

Fig. 9 shows the energetic, ecological, and economical effects of **incentive investments of 30%** of the respective building investments. In 25 years, **154.5 TWh/a** could be substituted; in 30 years, **185 TWh/a**. CO_2-emissions would decrease enormously, in the first 10-15 years by 2.63 million tons annually; from the 15th year, the decrease would be only 1/3 or 0.87 million t per year. This corresponds to a reduction of (39.45 + [5 x 2.63 x 1/3) ≈ 4.38 million t of CO_2-emissionen in **five years**. With yearly adjustments of the reduced CO_2-emissions as in fig. 15, the figures could be more precise – however, this would be at the expense of predictability and legal security. The incentive investments will be paid back in 25 years about 8 times (CHF 36.6 billion ≈ CHF 302 billion) – mainly as savings and reimbursements, the rest as revenues from electricity sales. Assumption: Successful energetic, ecological, and economical implementation of the Paris Agreement. (Fig. 4 corresponds to fig. 113 of the PEB study 2019, part V (A), item 10 et seq. and (C), see p. 121 et seq.).

9. **Climate protection: CO_2 tax "almost ineffective".** The fact that the climate protection goals are unattainable with today's measures is proven by countless studies.[13] *"Achieving the Paris climate goals seems further away than we previously thought. This should not be glossed over".*[14] About **170 TWh/a** of today's total energy need of **240 TWh/a** are covered with fossil-nuclear energies. They must be substituted to achieve the goals of the Paris Agreement. To date, no comparable measures are evident to have the same or similar impact as Min.P/PEB investments. The well-known Swiss climate scientist Prof. Dr. Thomas Stocker, University of Bern, explains: "The current system of the CO_2 tax is indeed practical from an administrative point of view. But in terms of climate protection, it is almost ineffective."[15]

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[10] **Minergie-P/passive house standard:** Energetic, ecological, and economical effects are according to fig. 36/38/43/45 of the PEB study 2019.

[11] According to fig. 104 and 109, it is assumed that **from the 15th year** CO_2-reduction is only about 1/3 (more efficient buildings, PEB and increased e-mobility).

[12] **Installed capacitiy in GW**: Energetic, ecological, and economical effects are according to fig. 36/39/42 of the PEB study 2019.

[13] **Council of States Damian Müller,** CS commission speaker, Sept. 23, 2019 and statement of the Federal Council of Dec. 1, 2017, p. 253: *"The **climate targets** would probably be **missed** by the cantons by far if **only the MuKEn 2014** were implemented in the future".*

[14] **NZZ am Sonntag**, August 15, 2021, p. 25; *Dr. Jérome Haegeli***,** chief economists Swiss Re.

[15] **NZZ am Sonntag**, Sept. 5, 2021, p. 8, *Prof. Dr. Thomas Stocker*, University of Berne.

NF-PEB: CO_2-free solar electricity potential of 127 TWh to 435 TWh

1. For 127 TWh, only 50% of the buildings per category are considered

127 TWh/a	no. of buildings in %	Best integrated capacity in kWp	**necessary kW** for **127 TWh/a**	in % of already installed capacity:	annual production in **TWh/a** per building category
a) PEB-**MFH**	**50%**	46 kW	**6** kW	≈ 13%	**≈ 10**
b) PEB-**SFH**	**50%**	48 kW	**15** kW	≈ 31%	**≈ 10**
c) PEB-**SME**	**55%**	6425 kW	**150** kW	≈ 2.3%	**≈ 107**
Average of all building categories			**15%**	**≈ 15%**	**≈ 127**

Fig. 10: Number of buildings: To get a solar electricity potential of 127 TWh/a until 2050, only **50% of the PEB-SFH** and **PEB-MFH** are considered. For **PEB-SME** it is **55%.**

2. Min.P/PEB: 127 TWh/a of solar electricity and avoidance of 113 TWh/a of energy losses

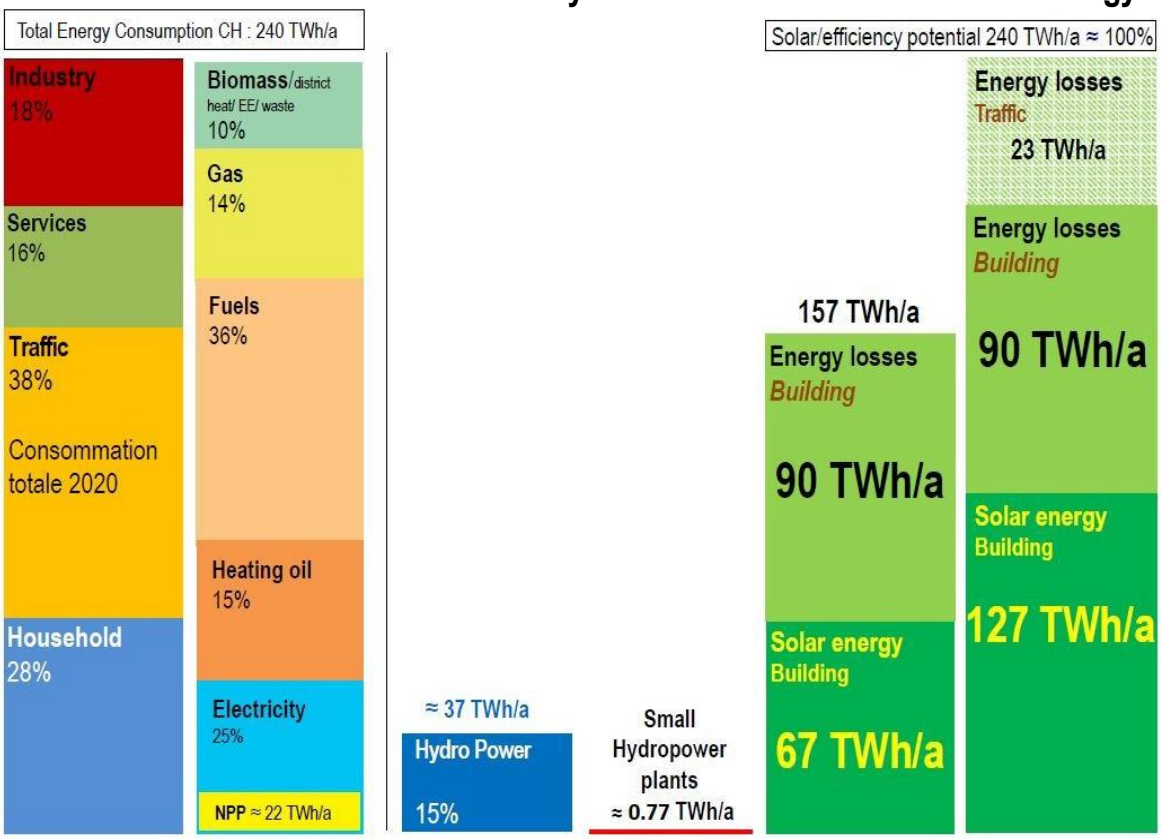

Fig. 11: Overall energy use 240 TWh: 1st column: purpose of use; 2nd column: energy source; 3rd column 3: hydropower **37 TWh/a**; 4th column: small hydropower plants **0.77 TWh/a**; 5th column: energy losses of buildings **90 TWh/a** (Federal Council: IP RW10.3873); solar electricity potential **67 TWh/a** (BFE 15.4.2019). Total potential on buildings according to **Federal Council ≈ 157 TWh/a**. 6th column: with 15% increase ≈ **127 TWh/a** of PEB solar electricity; **90 TWh** of electricity losses on buildings could be eliminated. PEB substitute **50 TWh/a** of fossile fuels, from which ≈ **23 TWh/a** have been considered (from 127 TWh ≈ at least 80 TWh of PEB surplus). Conclusion: 127 TWh of solar electricity + 90 TWh/a of energy losses that can be eliminated + 23 TWh of substituted fossil fuels ≈ 240 TWh/a which can replace or substitute the whole actual fossil-nuclear energy need (top right: solar potential + efficiency in buildings/transport ≈ 240 TWh/a ≈ 100%). With Min.P/PEB investments, the Paris Climate Agreement can be met until 2050 (Swiss Solar Prize 2020, p. 26 and following and 2021, p. 34, 35, and 86- 90)

3. For 435 TWh, 80% of the buildings per category is enough

435 TWh	no. of build-ings in %	Best integrated capacity in kWp	**necessary kW** for **127 TWh/a**	in % of already in-stalled capacity:	annual produc-tion in **TWh/a** per building category
a) PEB-MFH	80%	46 kW	**8** kW	≈ 17%	**≈ 23**
b) PEB-EFH	80%	48 kW	**25** kW	≈ 52%	**≈ 20**
c) PEB-KMU	86%	6425 kW	**350** kW	≈ 5.4%	**≈ 392**
Average of all building categories			**25%**	**25%**	**≈ 435**
No. of buildings according to BFS: *SFH* appr. 1 mio.; *MFH* 3.6 mio. apartments; *SME/commercial buildings about* 1.3 mio.					

Fig. 12: 1st column: PEB building type; 2nd column: Number of PEB per category in %; 3rd: Best installed capacity for Min.P/PEB; 4th: **Installed capacity needed** per Min.P/PEB **for 435 TWh** in kW; 5th: installed capacity in % considered per category; 6th: Annual PEB solar electricity production per building category and total in **TWh/a** until 2050. Fig. 3 to 5 and further prove, that NF-PEB are architectonically appealing and elegant and fulfil the goals of the Paris Agreement incl. 435 TWh already today by far.

4. Min.P/PEB: 435 TWh of solar electricity and 140 TWh of avoidable energy losses

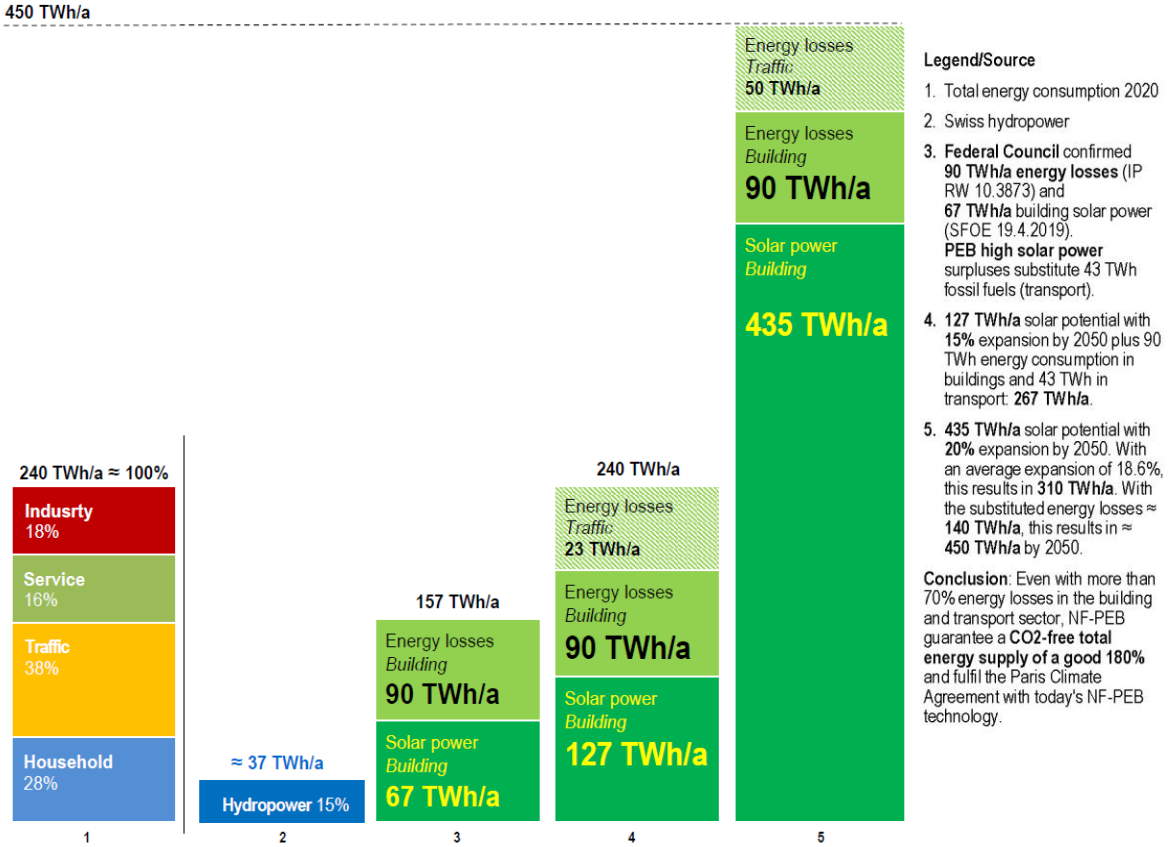

Fig. 13: See text to the right of the graphic; actual examples in fig. 3 to 5 above and according to Swiss Solar Prize 2010/21.