

PV et technologies
propres pour une
Suisse décarbonisée :
tout ce qui devrait
encore arriver

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Innovation by Swiss companies: a collaboration CSEM/EPFL
with les Caves du château d’auvernier.



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Innovation by Swiss companies: a collaboration CSEM/EPFL with les Caves du château d'auvernier and PMI international for sustainable life in Covid-19 times

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Innovation by Swiss companies: a collaboration CSEM/EPFL with les Caves du château d'auvernier and PMI international for sustainable life in Covid-19 times

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Photovoltaic to save the world: what technology can bring



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- The new Phovotovoltaic respirator

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Confidential/patent pending

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Some «scientific» questions for Switzerland and the world ?

- How do I get to install 50 GW cost efficiently and preserving patrimony ?
- How do I make a better use of unconventional places (parkings, railways, roads) ?
- How do I forecast, balance and integrate 50 GW in the Grid ?
- Will value for hydropower and which products for DSO in future
- Will technology still evolve ?
- Is photovoltaic really sustainable ?
- Can tech Swiss companies still play a role ?
- How much more PV do we need at a European or world level ?

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Unique « solar » landscape, for research development, industrialisation and implementation



- Academics and research: CSEM, EPFL, EMPA
- Univ. of Applied-science: ZHAW, SUSPI, BFH, HSLU, SPF,...
- > 50 Industries and Start-up
- >> 200 installers and engineering offices
- A perfect country for mass implementation of fluctuating renewables

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Source BFE

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EPFL Current status of world energy consumption in 2018

reminder : electricity from hydro, solar and nuclear divided by 0.38 to come to primary energy value for BP report

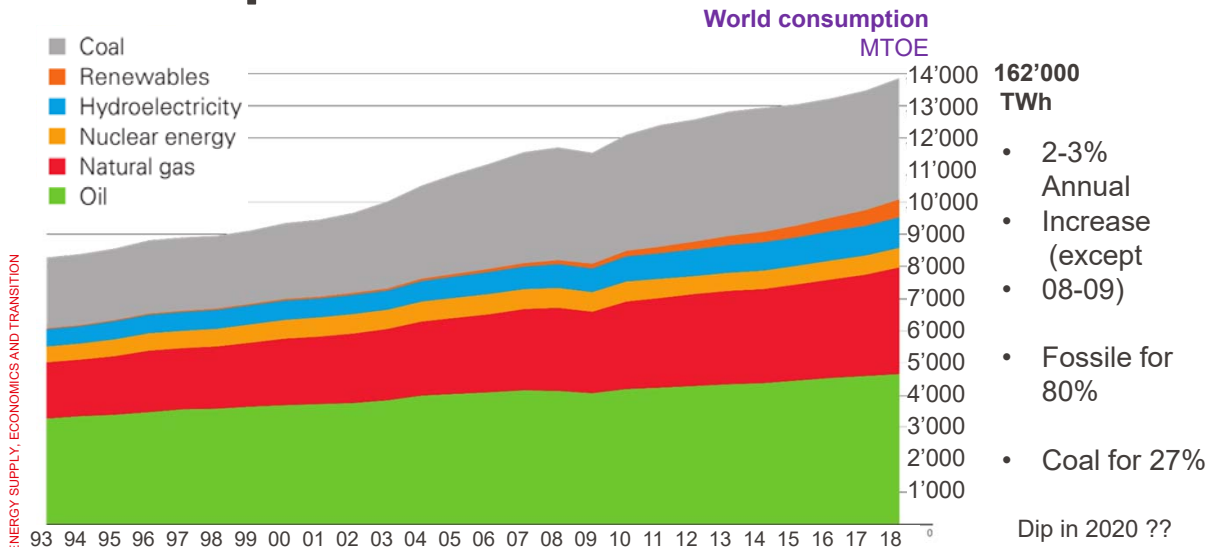
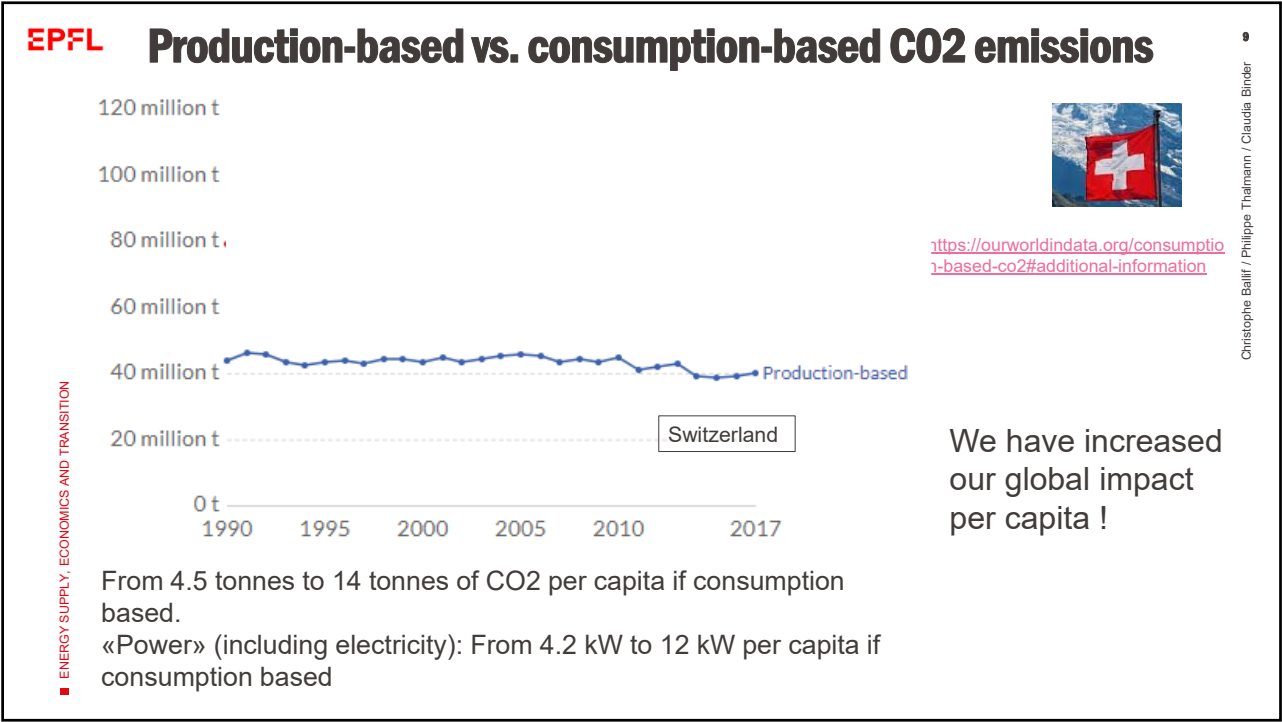
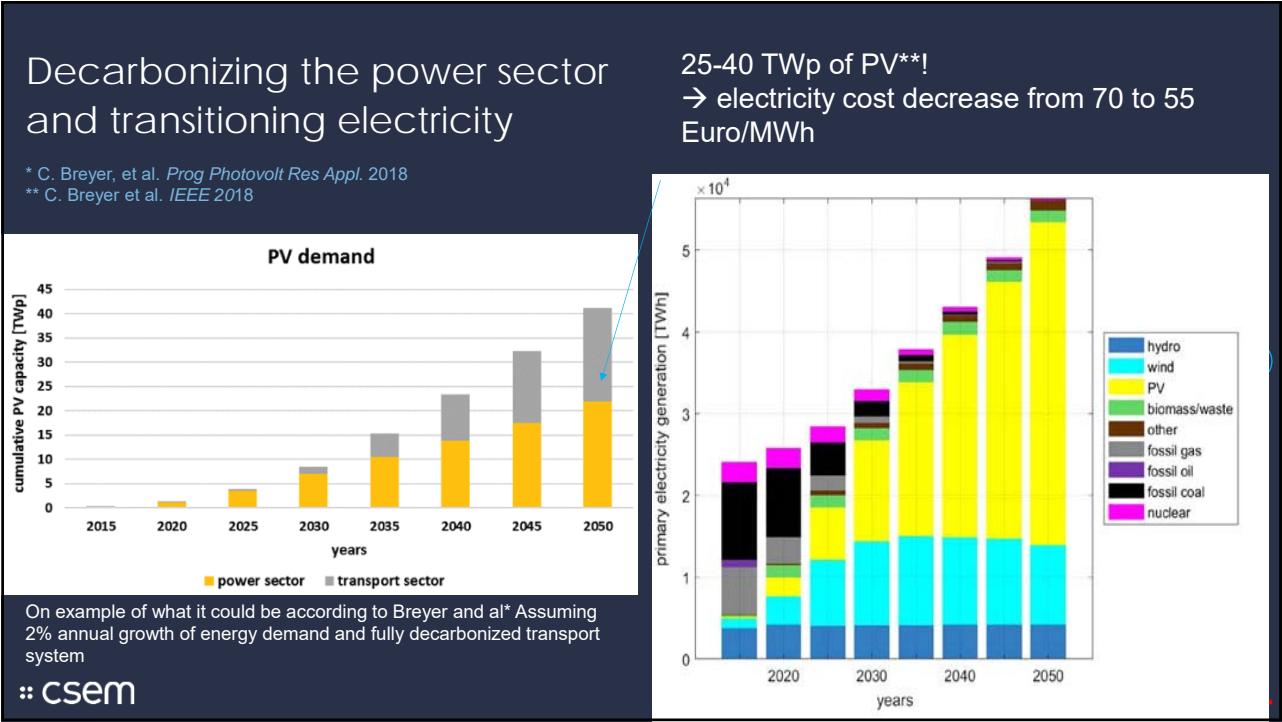


Table source: <https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html>

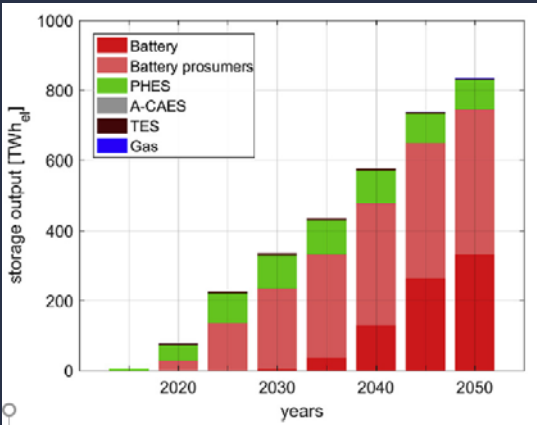
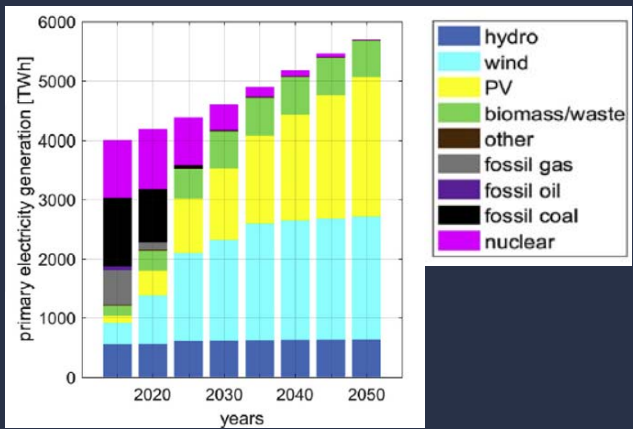
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A short look at Europe (in a area connected scenario)



Michael Child, C. Breyer, et al. Renewable Energy 139 (2019) 80-101

Battery storage and pumped hydro necessary to balance the grid

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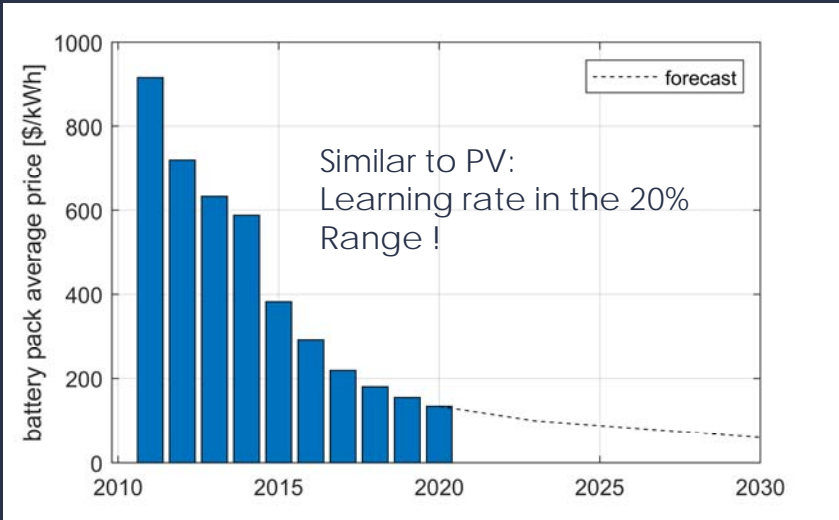
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Electricity storage - lithium ion batteries

Evolution of the battery pack price from 2011 to 2020



- From 135 \$/kWh in 2020 to 60\$/kWh in 2025-2030 ?
- Cost reduction depends on market growth speed. Likely much faster
- Batteries will become much cheaper, thanks to volume effects !
- Prices for li-ion ~600-1000 cycles.
- More cycles more expensive but synergy with car batteries

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BNEF, Battery Price Survey, 2019

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Alternative reading of low oil price crash



Today's barrel at 31\$
(2 cts/kWh thermal)

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Today:
Tesla worth 116 Billions
BP worth 86 Billions (but yield of 9.4%)
Shell 130 Billions

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Alternative reading of low oil price crash

- Discourage energy transition
- Discourage electric cars (and heat pumps)



Today's barrel at 31\$
(2 cts/kWh thermal)

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Today:
Tesla worth 116 Billions
BP worth 86 Billions (but yield of 9.4%)
Shell 130 Billions

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Alternative reading of low oil price crash

- Discourage energy transition
- Discourage electric cars (and heat pumps)



Today's barrel at 31\$
(2 cts/kWh thermal)

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Today:

Tesla worth 116 Billions

BP worth 86 Billions (but yield of 9.4%)

Shell 130 Billions

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Scenario for a decarbonised future

Implication for PV

- If the world is serious: 30-40 TW of PV by 2050 (and 50 for CH)
- Increase production volume to 1 – 1.5 TW annual from 0.13 TW today

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10 X production increase for PV
(IEA scenario: slow, slow, slow....)

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Impact on PV

- Mainstream products price will continue to go down thanks to volume increase. If we assume 16% market growth:
- «Standard» typical mono-crystalline module in 2025: 16-18 cts / W
- «Typical module» in 2030 at 13-15 cts/W

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Module (or solar cell): soon less than 0.6 cts/kWh (or 0.4 cts/kWh)

Cheaper than any other energy source. And by a factor 10 -20 compared to oil, if you import

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• Green hydrogen from CH or abroad

Large PV powerplant at 0.3-0.33 cts/W in 2030 (today's best at 0.5 cts/W) → electricity price down to 1.1-1.3 cts/kWh

- Progress in Electrolysers (alkaline or others) → < 500\$/kW with potential cost < 250\$/kW at full power plants level

Potential for hydrogen at 1-1.5\$/kg.

International trade of hydrogen



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H2 as a support to energy management, and industrial process



Hydrospider and Alpiq: →2MW electrolyser for H2 for trucks, in Gösgen

- Or replacement in gas powerplants
- In distribution network



Sustainable manufacturing

In a number of cases, creative companies have figured out sustainable business cases. Swedish power company Vattenfall has calculated that producing a €20,000 car from CO2-free steel (using green hydrogen) rather than regular steel would add just €200 to the price. That suggests premium markets could be developed for consumers willing to pay 1% to 3% more for products manufactured using green hydrogen.

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Photovoltaïque: is it really sustainable ???



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1st major improvement

- Siemens process to create pure polysilicon

Reactors with up to 10 tonnes of Si

Only 40-45 kWh/kg against 200 kWh/kg en 2000 !!!

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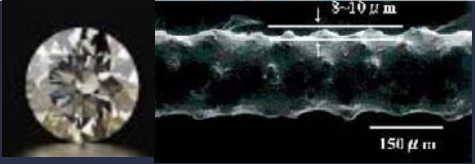
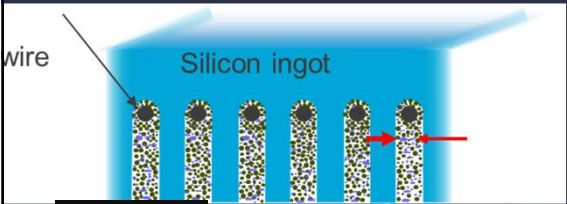


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Second major innovation, made possible by Swiss company



- Yesterday, multi-wire sawing, SiC particles loose 200 microns

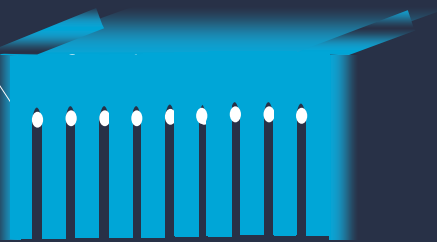


- Today, diamond wire for mono loose 60 microns

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- → 60 % more wafers than 5 years ago !

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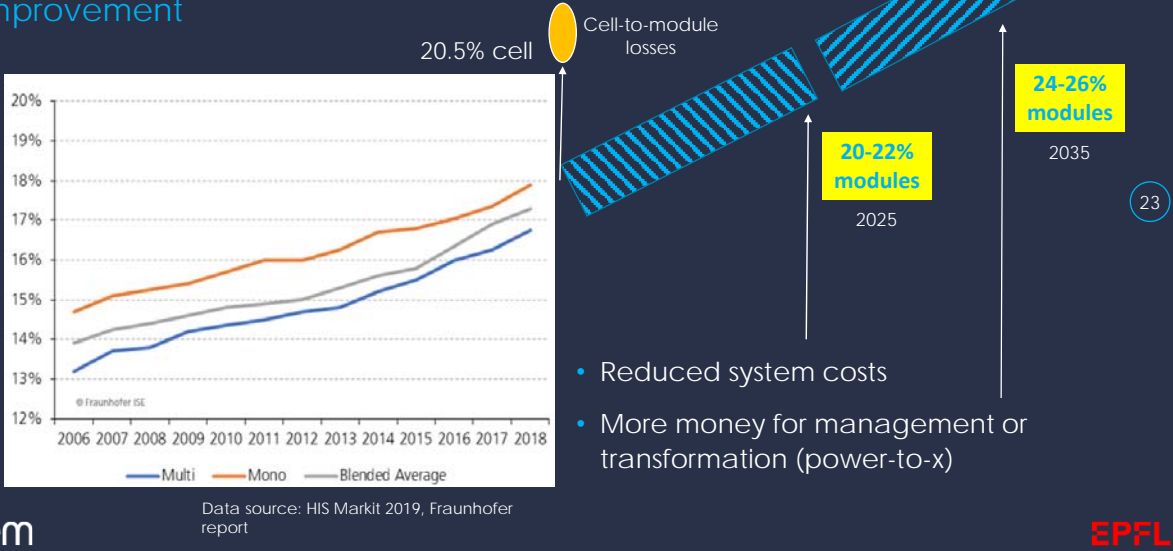


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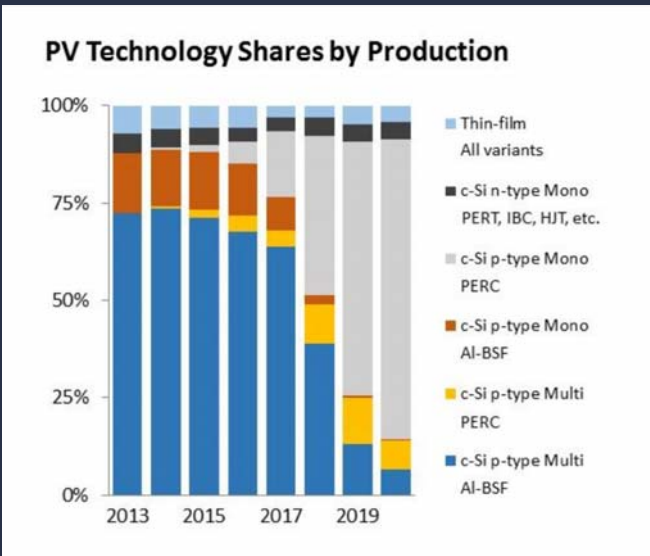
3. PV module efficiency improvement: a necessary trend !

0.3- 0.4% annual module absolute efficiency improvement



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A drastic change in the PV industry



csem Source : PV tech

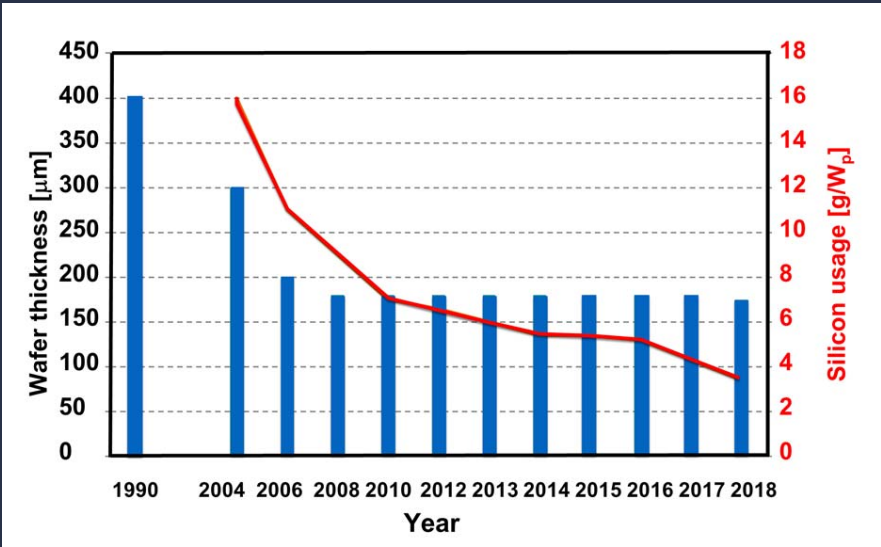
- The market is shifting very, very quickly to monocrystalline silicon (progress in crystal pulling and sawing, need for quality for high eff.)
- PERC solar cells are taking 95% of the market
- TOPCON, Heterojunction as high efficiency products pulling (extending) PERC ?
- But new products with new challenges ... (e.g. degradation modes)

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Silicon usage per watt



Improved processes
Sawing
Efficiently



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From 17 to 3.5 g/W
in 20 years,
With low grey energy

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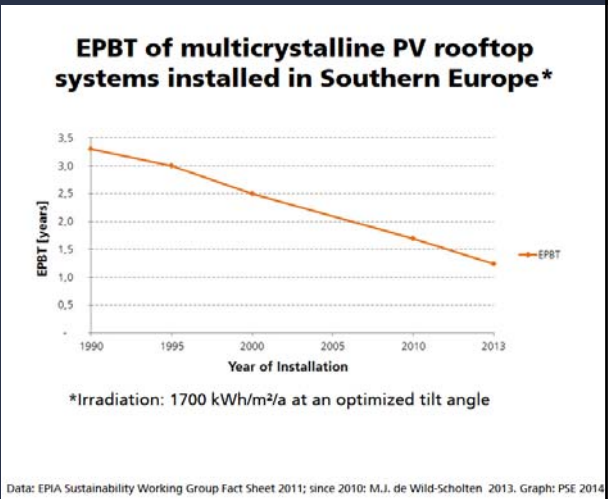
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Summary grey energy

- A modern monocrystalline module takes likely 0.6-1 kWh to produce (estimates)
- In CH E-payback time for system down to 1-1.5 years (estimates)

!!! La plupart des études LCA (Life cycle assesment) ont 5-8 ans de retard



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Empreinte CO2 d'un module



Les modules Hanwha Q CELLS obtiennent une nouvelle certification en faible empreinte carbone pour les appels d'offres solaires en France

- Empreinte carbone de 300 kg-eq/CO²/kWc atteinte pour les séries de modules Q.PEAK et Q.PEAK DUO.
- Les objectifs ambitieux de la France en matière d'énergie solaire sont fixés par le marché des appels d'offre CREqui favorise

300 g/W: Sur 25 ans, 25 kWh

→ **8-10 g CO2 par kWh**
au niveau du module

→ Contre 400 g/kWh pour centrale au Gas et 900g/kWh pour centrale au charbon

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Some examples of (upcoming) product changes



- 1/3 rd cells with 210 mm wafers! (Eg. Announced Trina product with 500 Watts)



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½ cells smart wire modules over > 21% available with Meyer Burger heterojunction technology

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The world's first installation of REC Group's Alpha solar panels

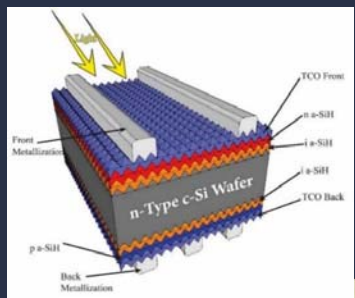
Munich, Germany, October 8, 2019 – [REC Group](#), an international pioneering solar energy company with a Scandinavian Heritage, is proud to announce the world's first installation of its [innovative Alpha solar panels](#) on a home near Venice, Italy. Harnessing power from the sun enables home owners to reduce carbon emissions while saving on their electricity bills – with REC Alpha's industry-leading power output even small roofs can make a difference. This helps the environment and thus preserves places like Venice and many other UN heritage cites whose very existences are threatened by climate change.



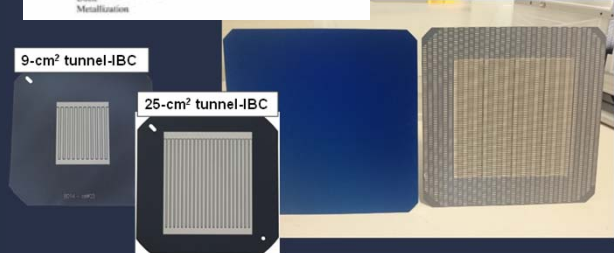
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Powerpure development at CSEM/EPFL

Technologies for lowest cost solar electricity beyond PERC SOLAR cells



- Passivating contacts devices for PERC upgrade
- Silicon Heterojunction
- Back-contacted solar cells



- Few process steps
- High(er) efficiency
- Higher energy yield
- Work with 100 micron wafers
- Bifacial

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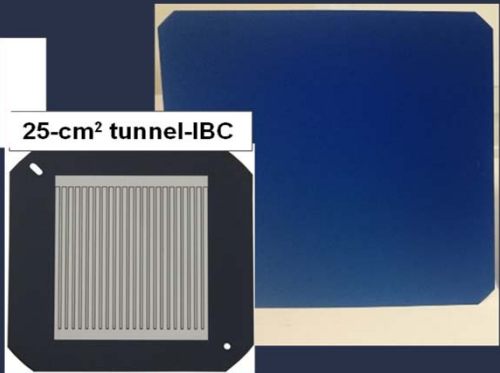
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HETEROJUNCTION: UPGRADE SCENARIO to IBC-HJT

- TUNNEL IBC-HJT process of EPFL/CSEM
- Selective local epitaxial growth:
- SIMPLE PROCESS FLOW, MINIMIZE MATERIALS (Indium-free)

In 9 process steps

Tomasi et al. Nature energy 2017



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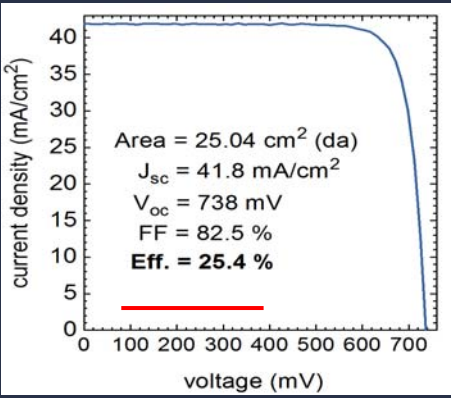
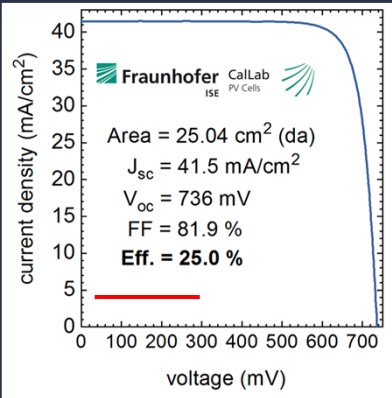
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HETEROJUNCTION: UPGRADE SCENARIO to IBC-HJT

New cell recently measured in-house

Certified measurement

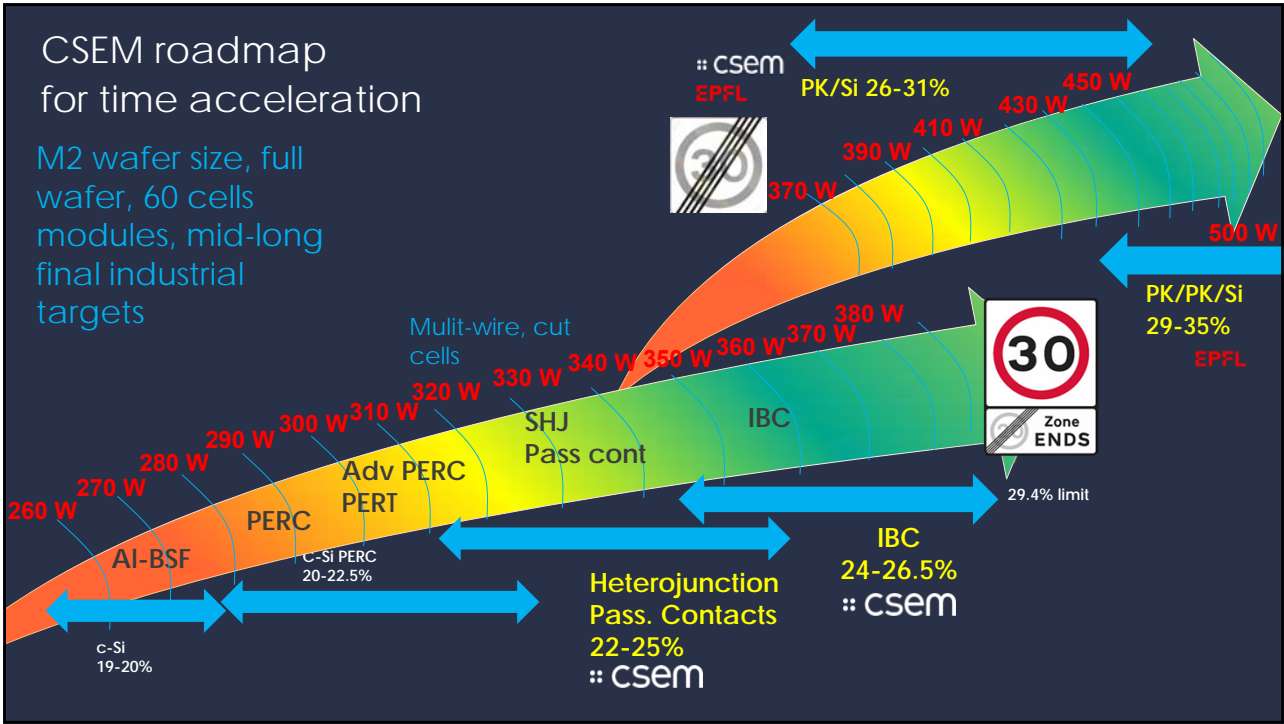


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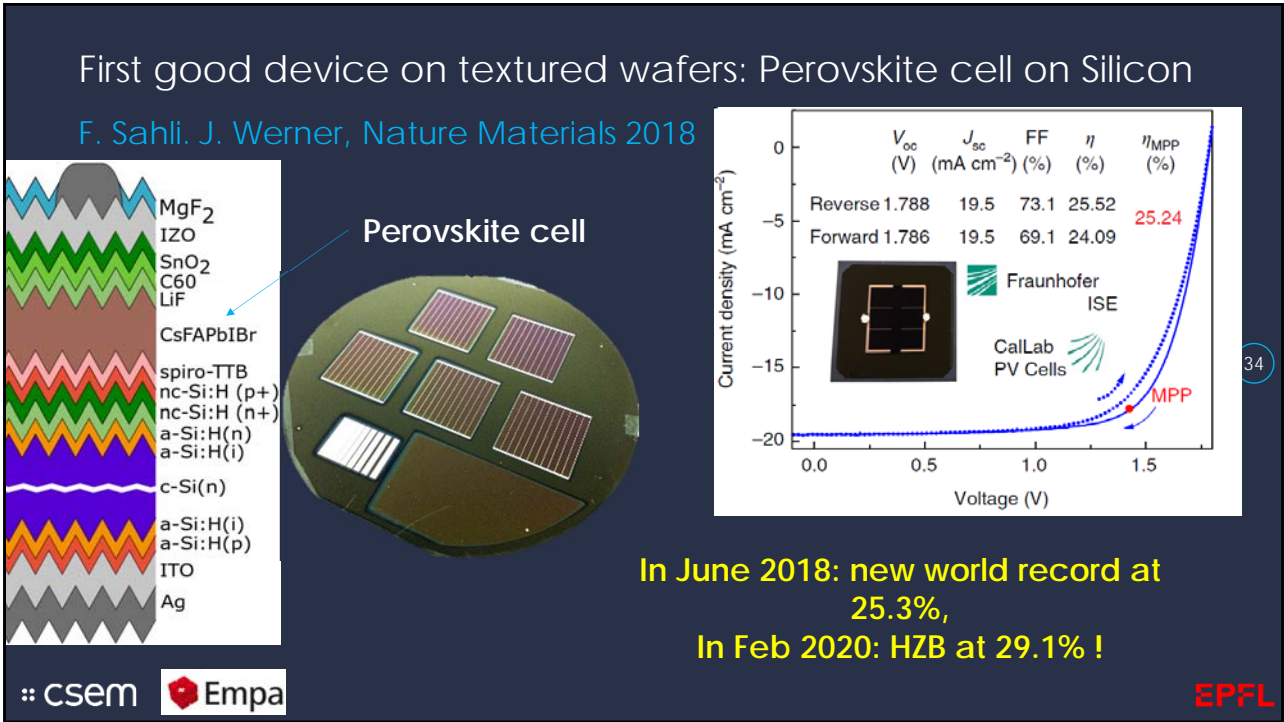
Goal 26-27%

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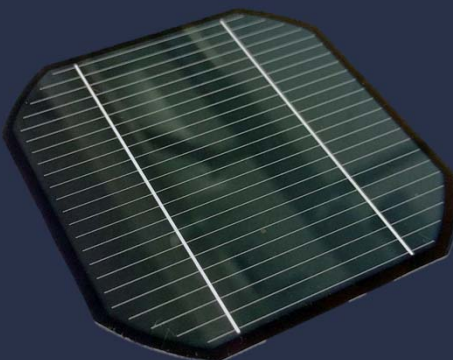
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Towards industrialisation with Perovskites

Talk by
Q. Jeangros tomorrow




Upscaling structure at CSEM
Tandem solar cells:
First 4 inches Perovskite on silicon
> 24.3 %

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Static conentration, based on space solar cells but captures diffused light

→ 29% efficiency



- EPFL start-up



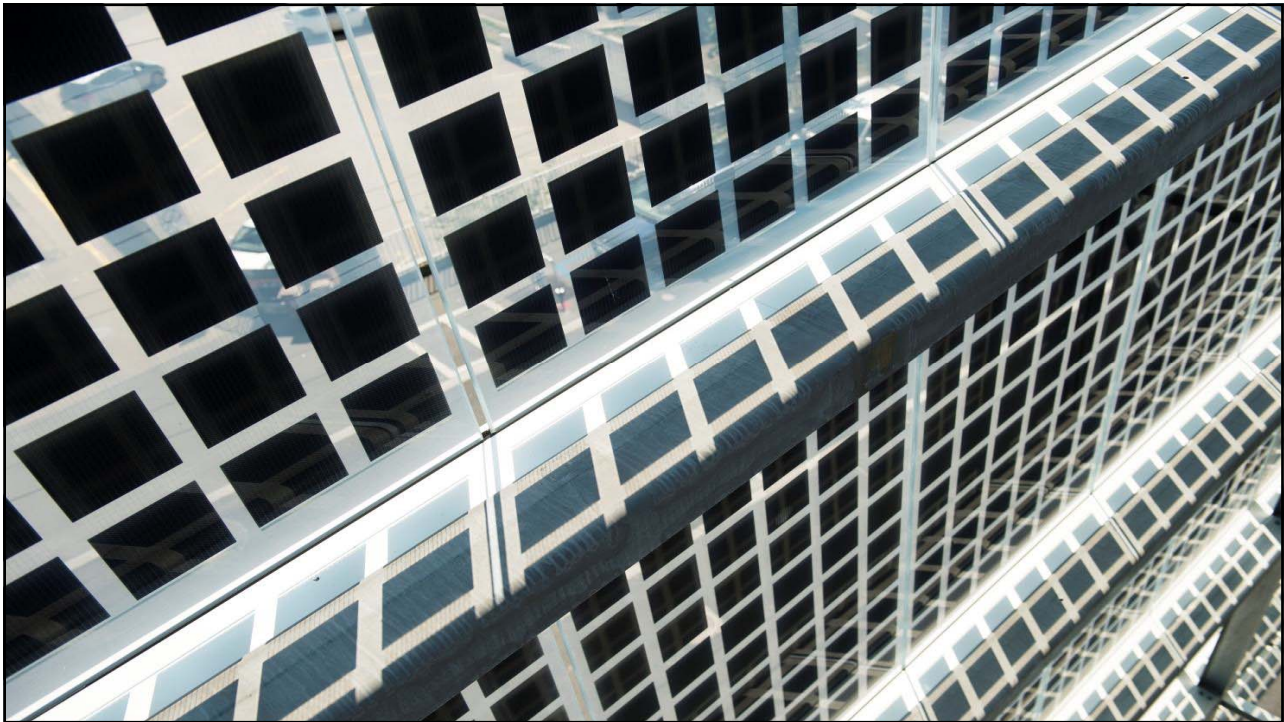
Hyperion: large EU project around Insolight just started !
CSEM manages project and to hosts pilot line.

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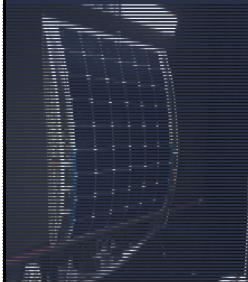


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Polymers and specialty films for PV: towards ultra-reliable PV



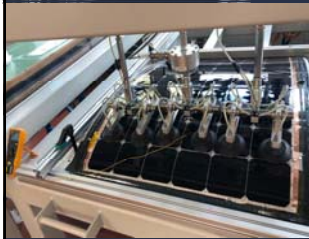
Airplane
and drones




Light weight aerospace



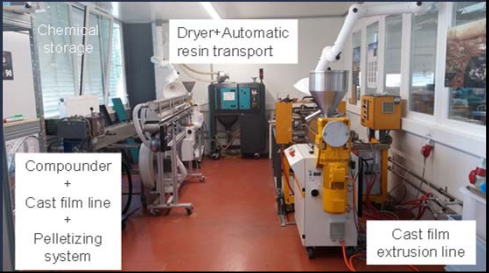
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Nautical



Chemical storage
Dryer+Automatic resin transport
Compounder + Cast film line + Pelletizing system
Cast film extrusion line

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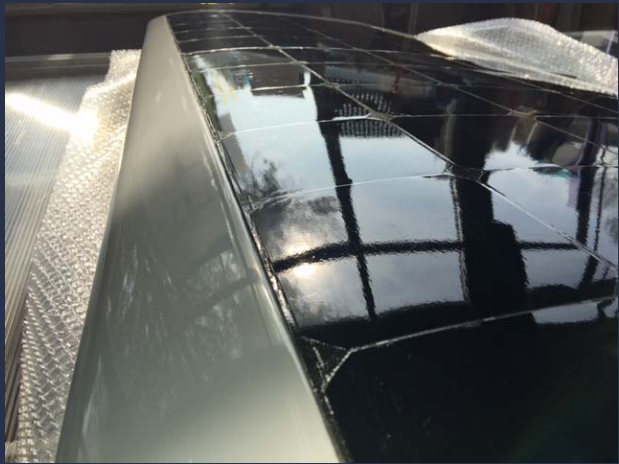


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Lightest weight

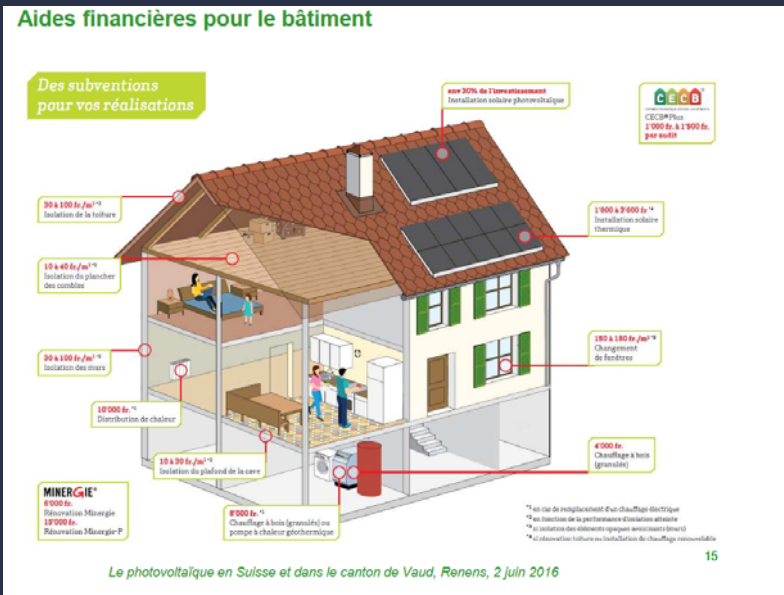


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PV onto buildings: what we should not do in Switzerland !



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Small PV systems
on a large roof
Should be
discouraged

All good roof
surfaces should be
covered with PV

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When required: make PV integrated and better looking system



One of my Neighbour:
Full roof renewal

More expensive to integrate
PV than to add PV
how to solve that ?

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Elegance and architecture

Prix solaire

Transforming building and cities, renovating houses

Suisse 2018





Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Ecuvillens

- 27 kWp
- 28 000 kWh during 1st year of operation

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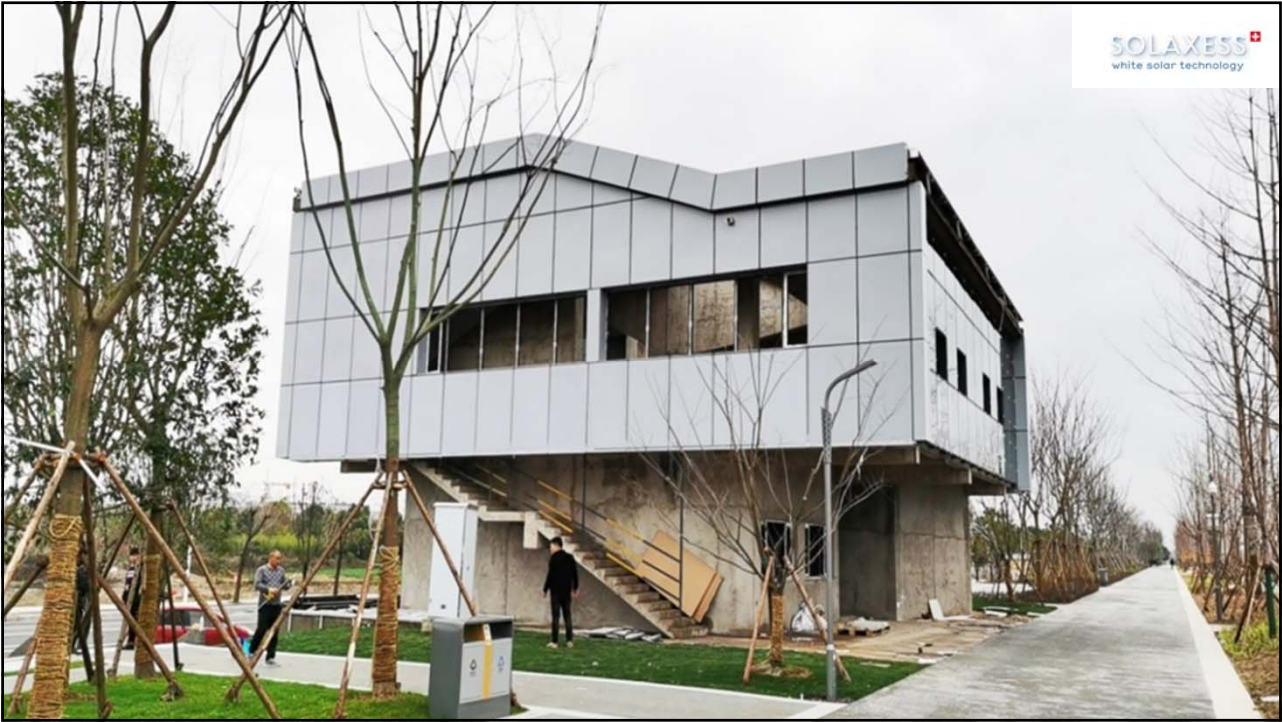
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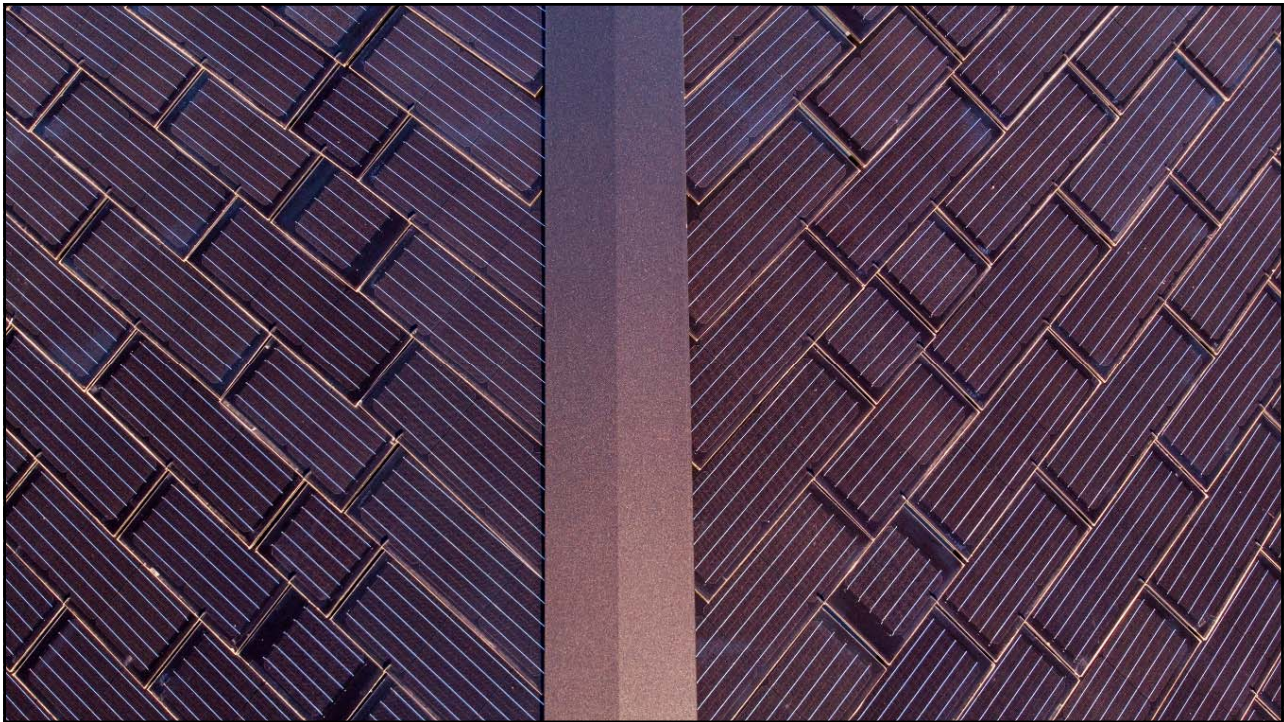
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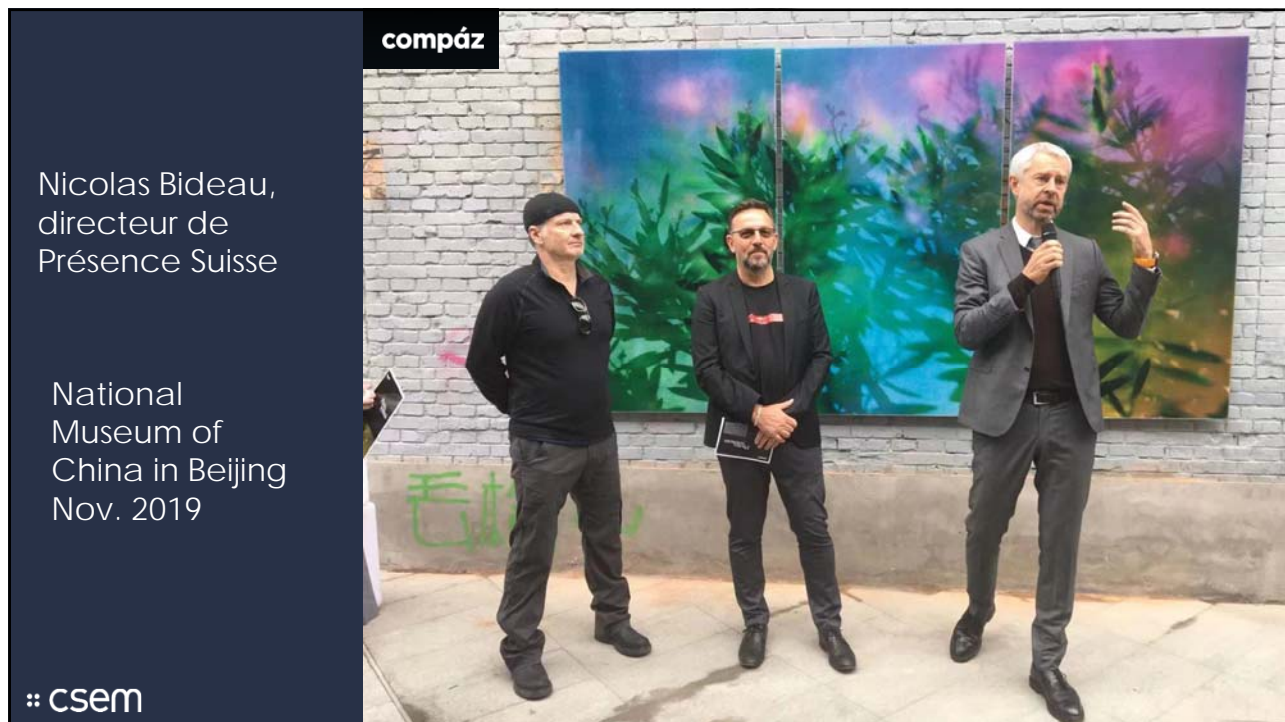
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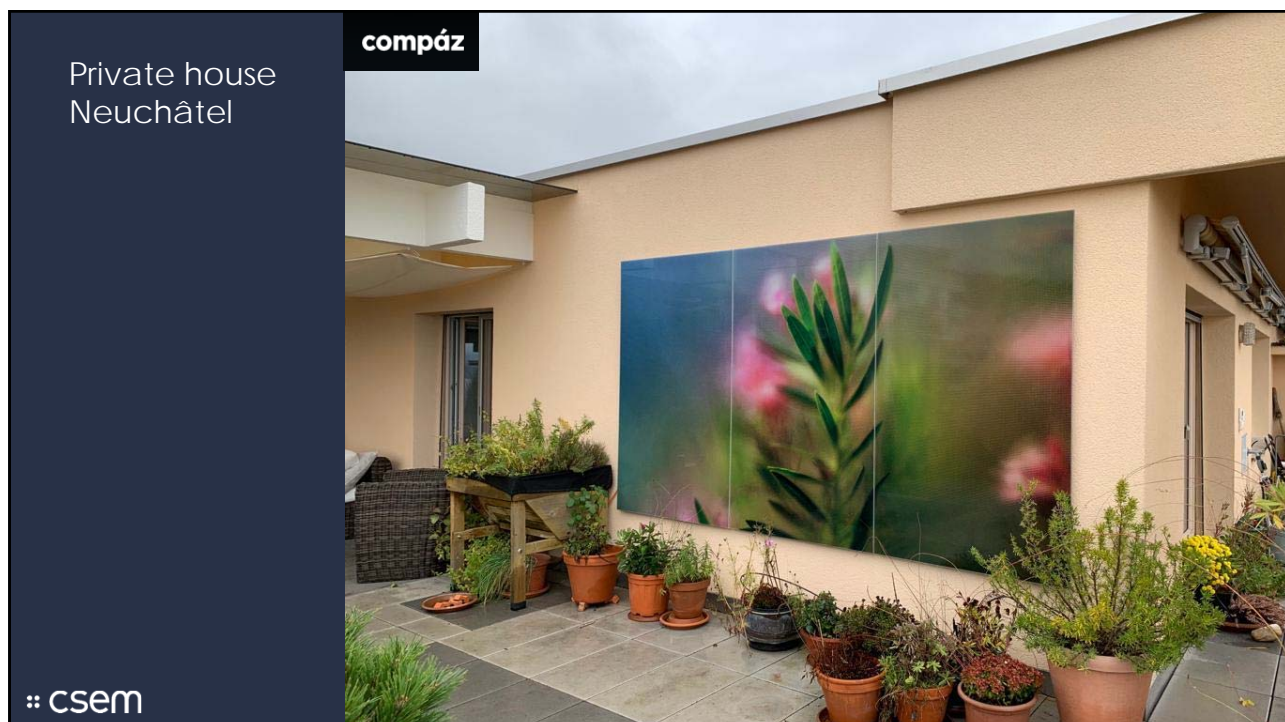
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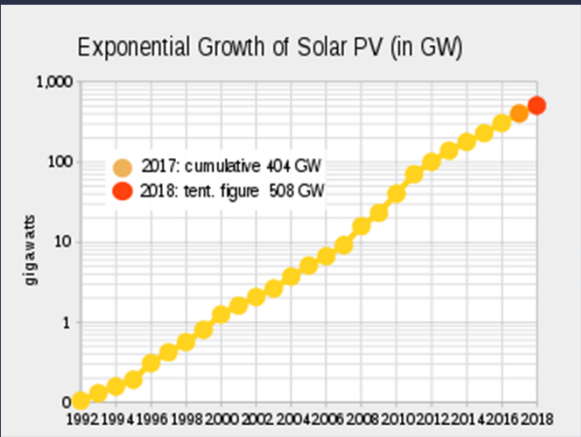
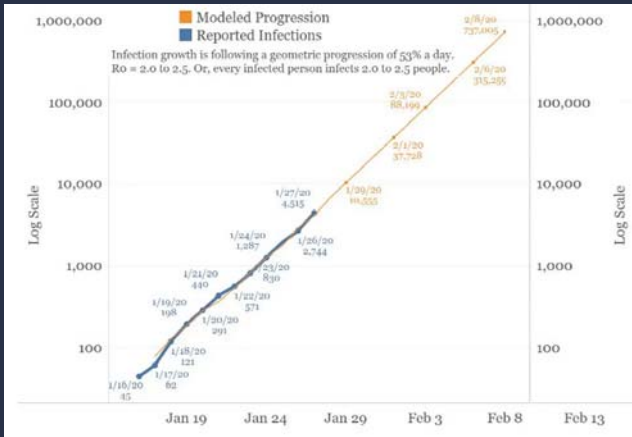
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Coronavirus

vs PV



Only one curve should continue to show a «linear» behavior for sometimes.

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Conclusion

- Globally PV is the cheapest source of electricity with 30-40% less within next decade. Products will continue to improve steadily
- 120 GW/year is a joke: by far not enough
- In Switzerland: either high RU, or compulsory on all roofs and parts of façade.
- More and more solutions available to make buildings with PV, but not fully exploited yet
- Many key technologies available in Switzerland, for Switzerland and the world....

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"Jamais le soleil ne voit l'ombre"
Léonard de Vinci

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