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pv magazine webinars

Entering the Terawatt age: A 360° view on solar sustainability

Tuesday, 8 November 2022

9:00 am – 10:00 am | GMT, London
10:00 am – 11:00 am | CET, Berlin
10:00 am – 11:00 am | Morocco
1:00 pm – 2:00 pm | Dubai

Jonathan Gifford
Editor in Chief
pv magazine

Adele Zhao
Head of Product & Marketing
Trina Solar

Dr. Pierre Verlinden
Founder
Amrock

pv magazine webinars

Welcome!

Do you have any questions? ❓

Send them in via the Q&A tab. We aim to answer as many as we can today!

You can also let us know of any tech problems there.

We are recording this webinar today.

We'll let you know by email where to find it and the slide deck, so you can re-watch it at your convenience.

AMROCK

Sustainability of PV Manufacturing at the Multi-Terawatt Level

Pierre Verlinden

PV magazine
Webinar Sustainability
November 8th , 2022

AMROCK Pty Ltd
University of New South Wales
Trina Solar
Yangtze Institute for Solar Technology

AMROCK

Why are we suddenly talking about sustainability?

- PV electricity is clean
  - It should be sustainable
- PV used to be about Cost, Efficiency, Reliability
  - If it is reliable and cost effective against fossil fuels, it should be sustainable
- PV in operation does not use any consumable, …
  - It should be sustainable

We need to talk about sustainability because PV will be **huge**!

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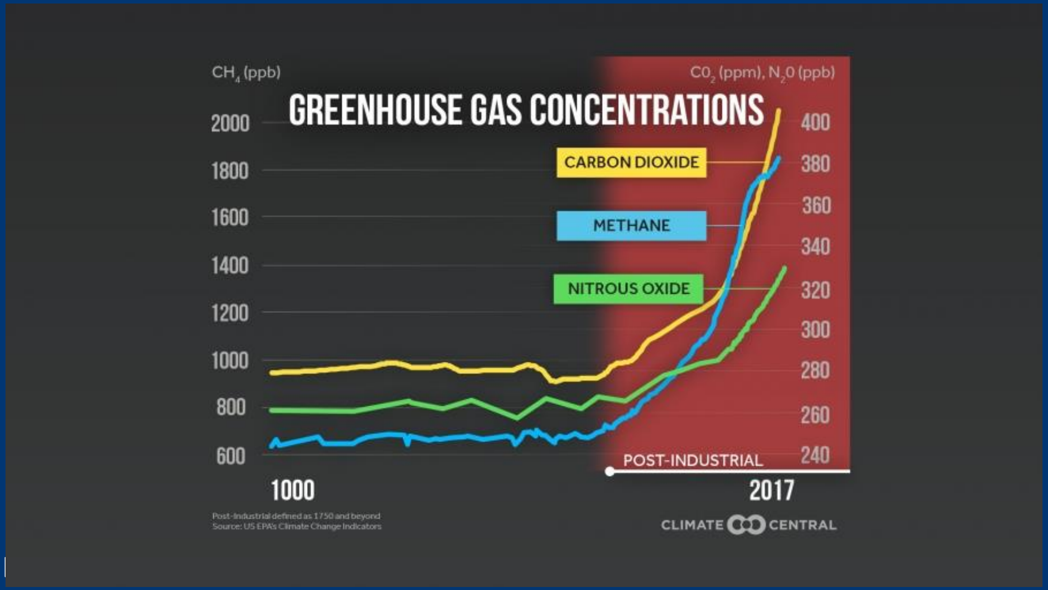
Anthropocene

/ˈanθrəpəˌsiːn/

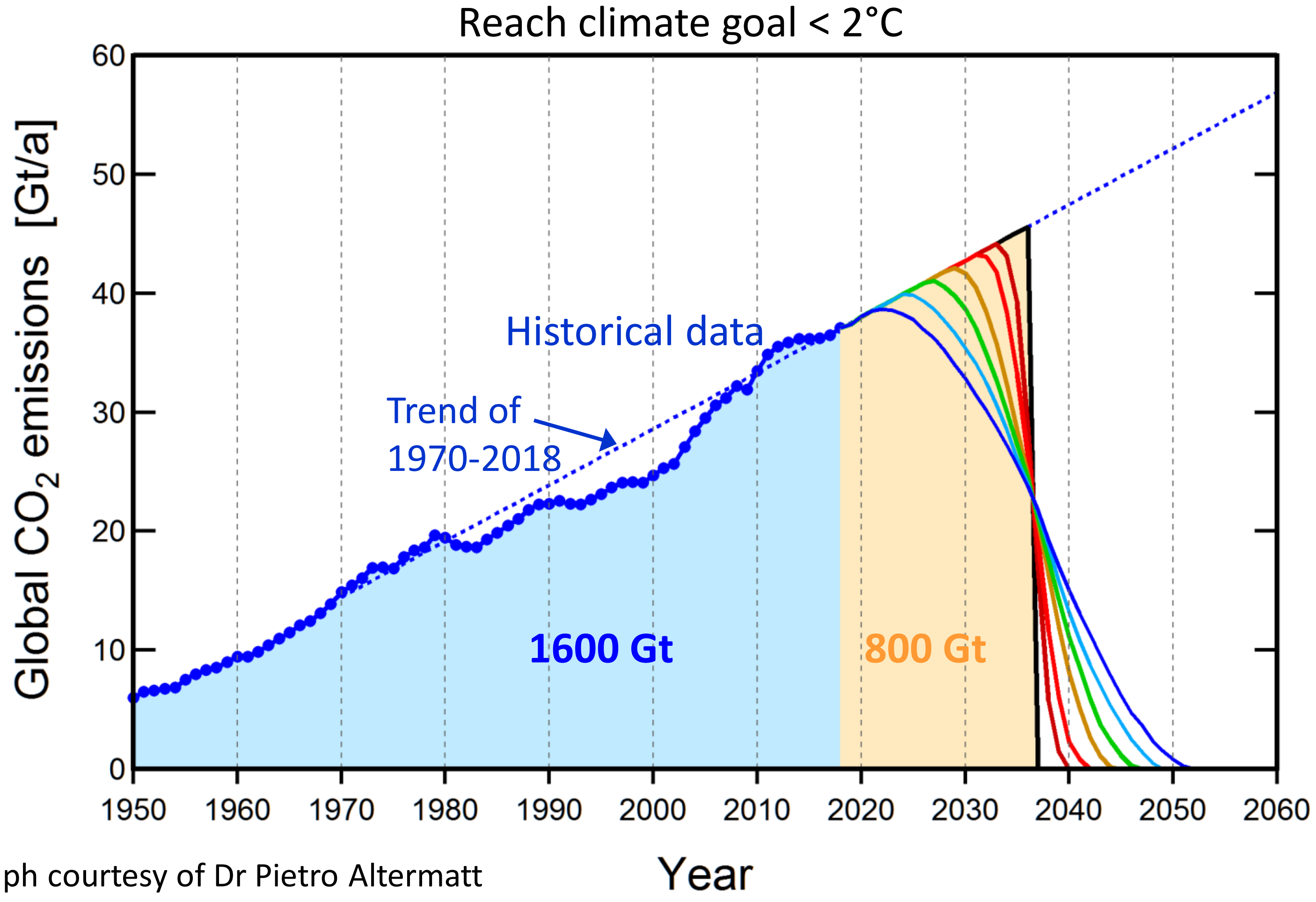
noun

the current geological epoch, viewed as the period during which human activity has been the dominant influence on climate and the environment.

One proposal, based on atmospheric evidence, is to fix the start with the Industrial Revolution, ca. 1780, with the invention of the steam engine.



To fulfill the Paris COP21 Agreement, we are allowed to generate only 800 GT* of CO_2, then zero. The next 10 years will be decisive.



Graph courtesy of Dr Pietro Altermatt

While developing our new PV technologies, when making design, materials and process decisions, we cannot ignore anymore the context of Global Climate Change.

- Can we develop quick enough?
- Is our technology sustainable?
- What is our embedded $C0_2$?

***Note: Only 400GT of CO_2 allowed if target is 1.5°C**

Historical data: U.S. Dep. of Energy (DOE)

[1] G. Luderer et al, Nature (climate change) 8, 262 (2018)

Only fast transition over the next 30 years to net-zero CO_2 emission allows to meet +1.5C -2C

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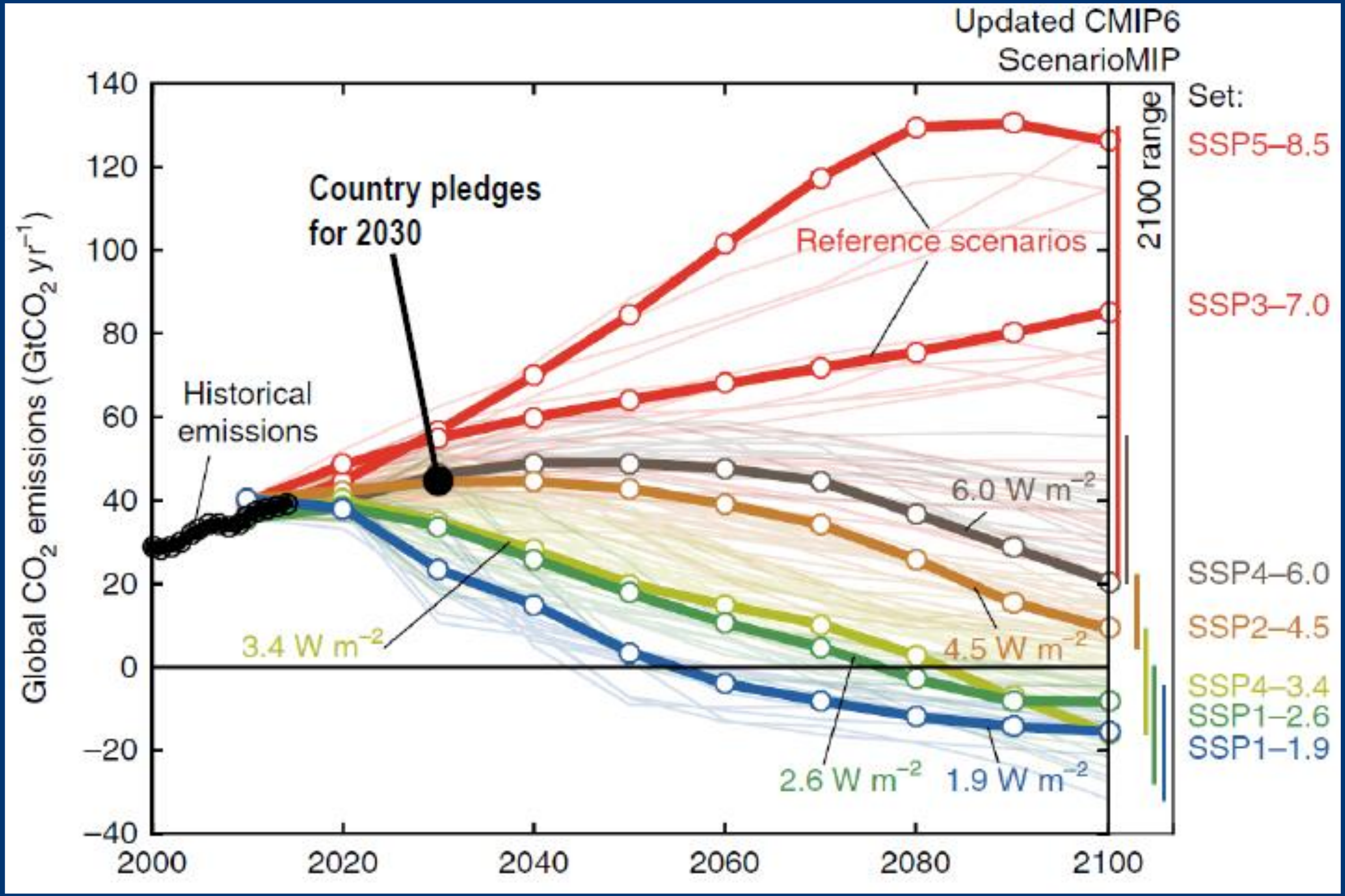

Source: Rogeli et al., Nature Climate Change **8**, pages325–332 (2018)

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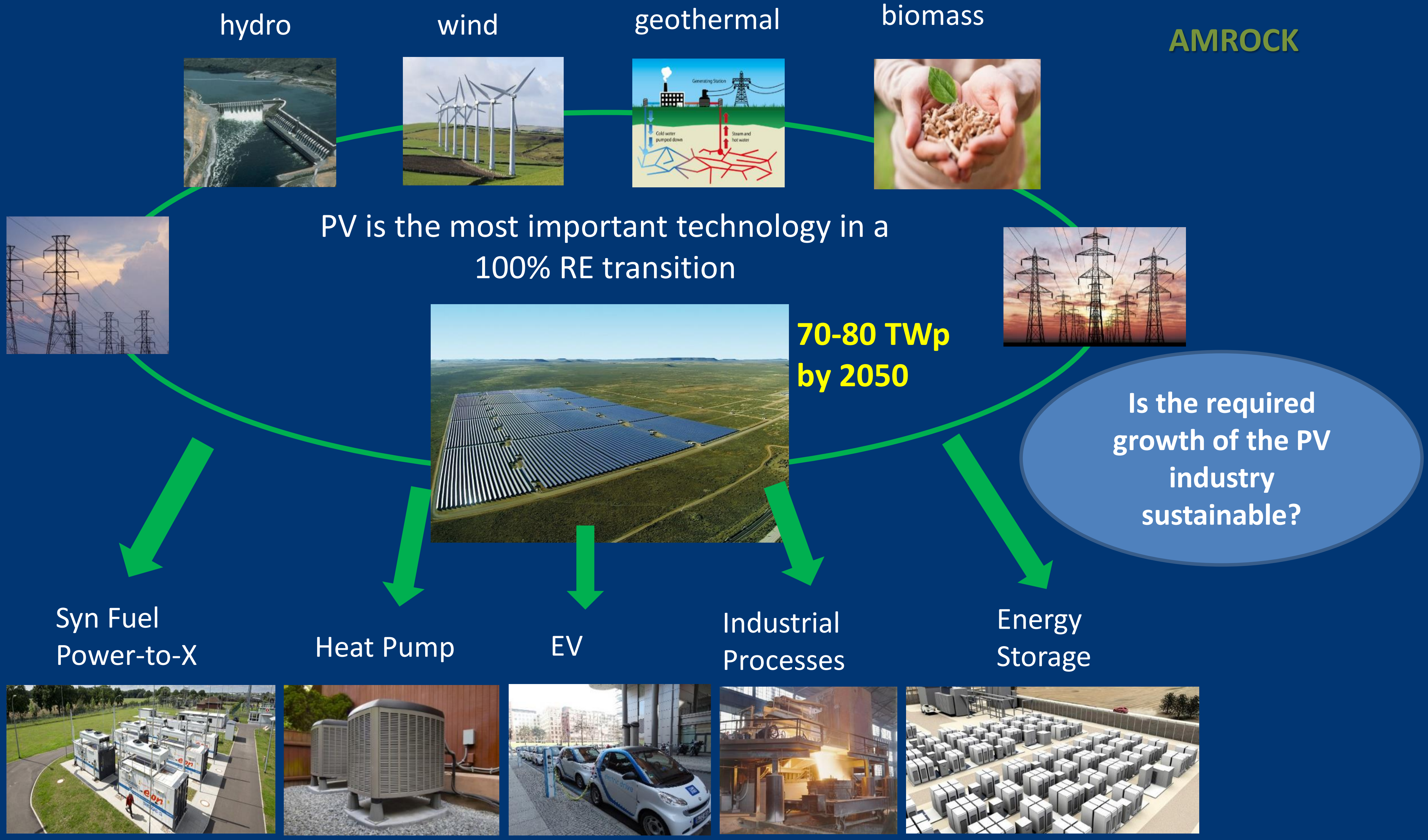
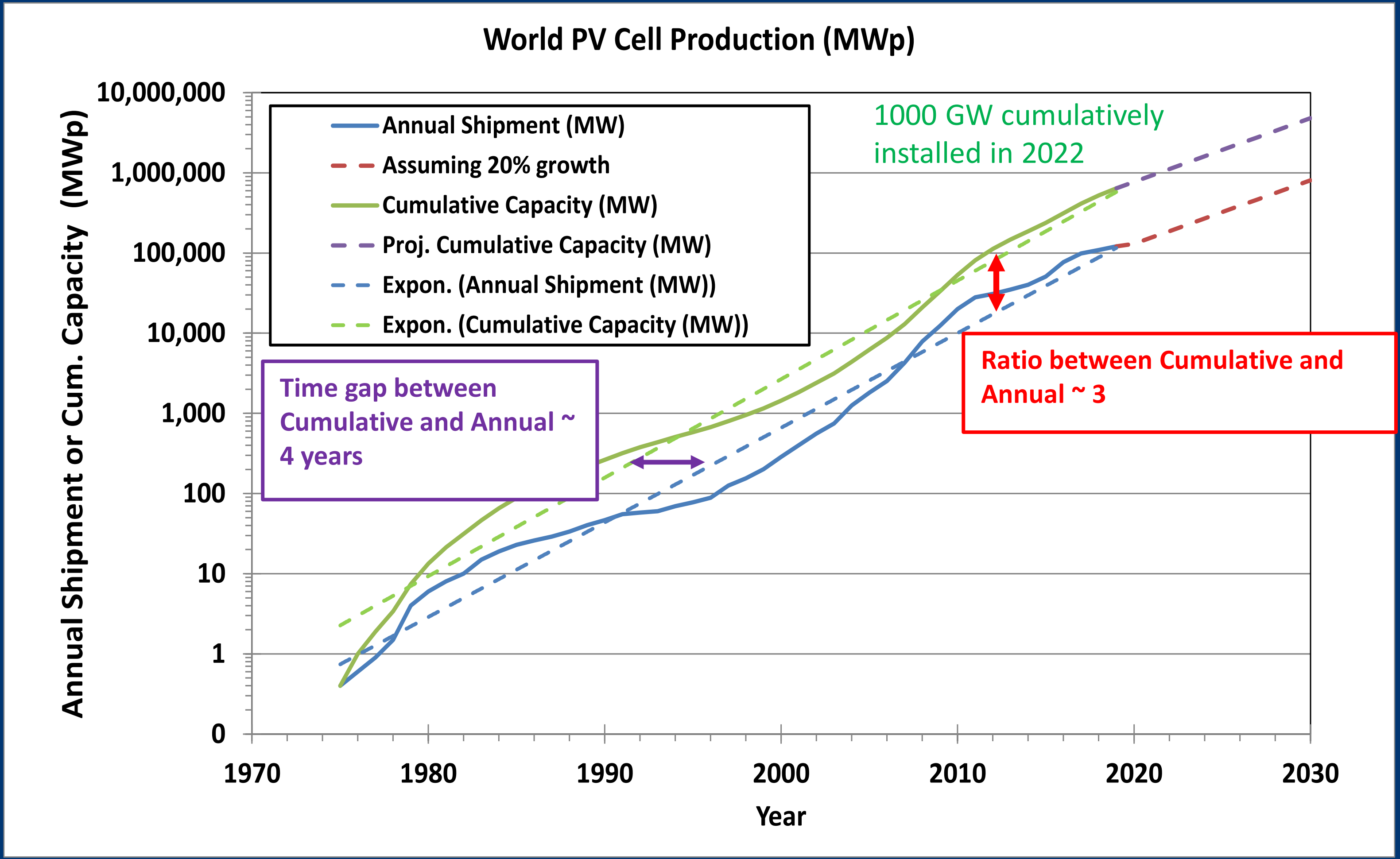

hydro
wind
geothermal
biomass
PV is the most important technology in a 100% RE transition
70-80 TWp by 2050
Is the required growth of the PV industry sustainable?
Syn Fuel Power-to-X
Heat Pump
EV
Industrial Processes
Energy Storage

PV Production Rate and Installed Capacity double every 3 years

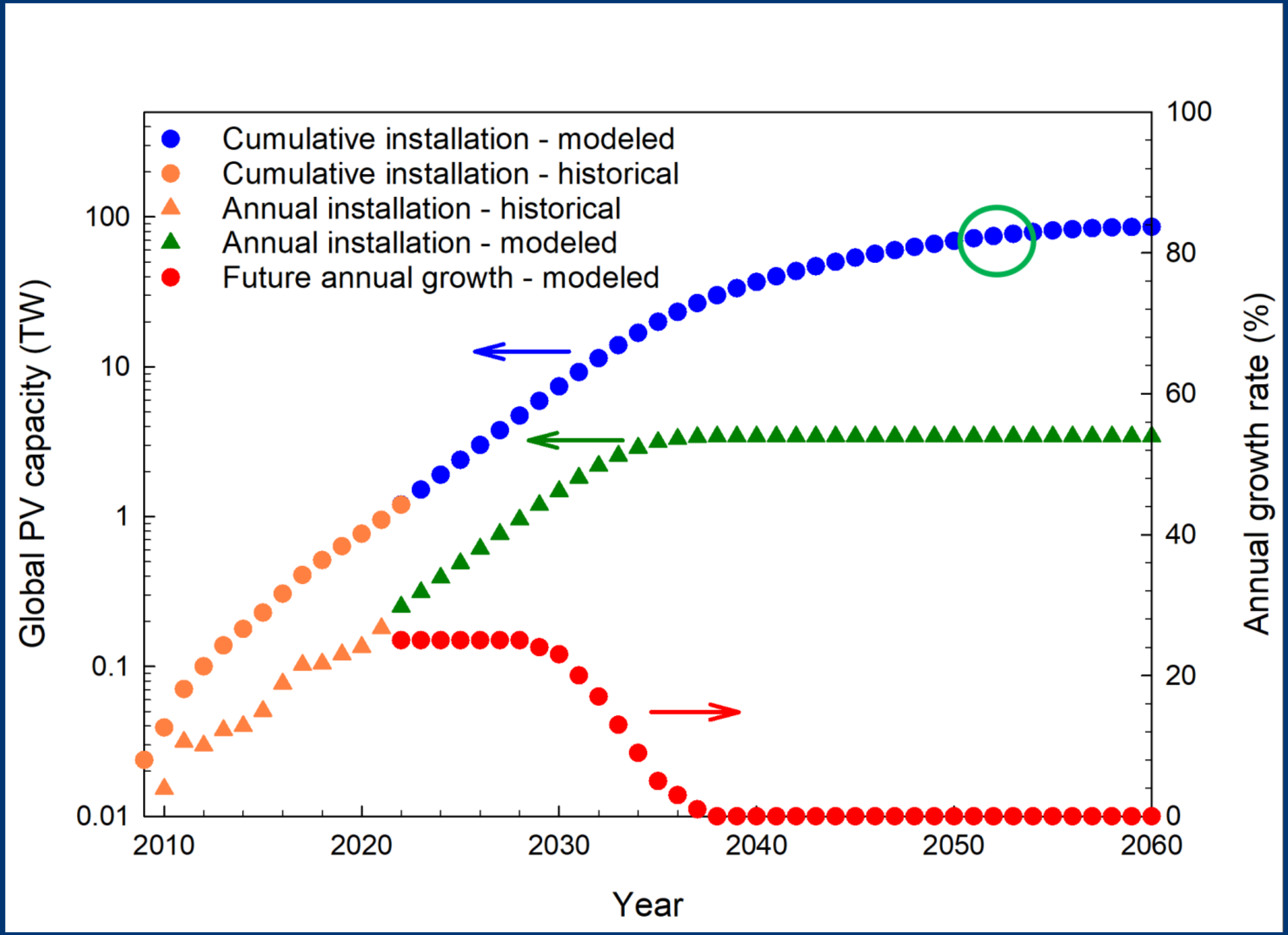


It took ~ 70 years to deploy the first TeraWatt. It will take just 3 years to install the next TW.

In 2022, PV generates 4.5% of Global electricity.

In 2026, PV will generate, worldwide, more electricity than nuclear.

Modelled PV Production to reach net-zero emission by 2050



- Fast growth rate (25%) until 2035
- Stabilise production around 3 TW p.a. before 2040
- Reach ~70 TW by 2050-2055
- The next 10 years will be decisive

There are many ways to look at Sustainability

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- **Energy**: How many kWh consumed per kWp installed?
  - To manufacture PV modules, inverters, BOS
  - To transport, to install
  - Energy Pay Back Time (EPBT)
  - How fast can we grow this industry? (energy, supply chain, infrastructure, land)
- **CO_2 emissions**: How many kg of CO_2 equivalent per PV module? Per kWp? Per kWh?
- Water and chemical **consumption**, solid waste, gas and liquid effluents, pollution
- **Material usage**: availability, scarcity, risk of price increase, speculation
- **Recycling** and Capturing valuable material
- **Financial** sustainability of PV manufacturers
  - Generate enough earning to grow, to build the next production lines
- What is impacting the sustainability of PV systems?
  - Reliability, performance degradation, system lifetime (often depending on climate)
  - Efficiency, PR, Annual irradiance, orientation, partial shading (also impacts reliability)
  - Energy yield, Bifacial or not, tracking or not

Life Cycle Assessment of PV Systems

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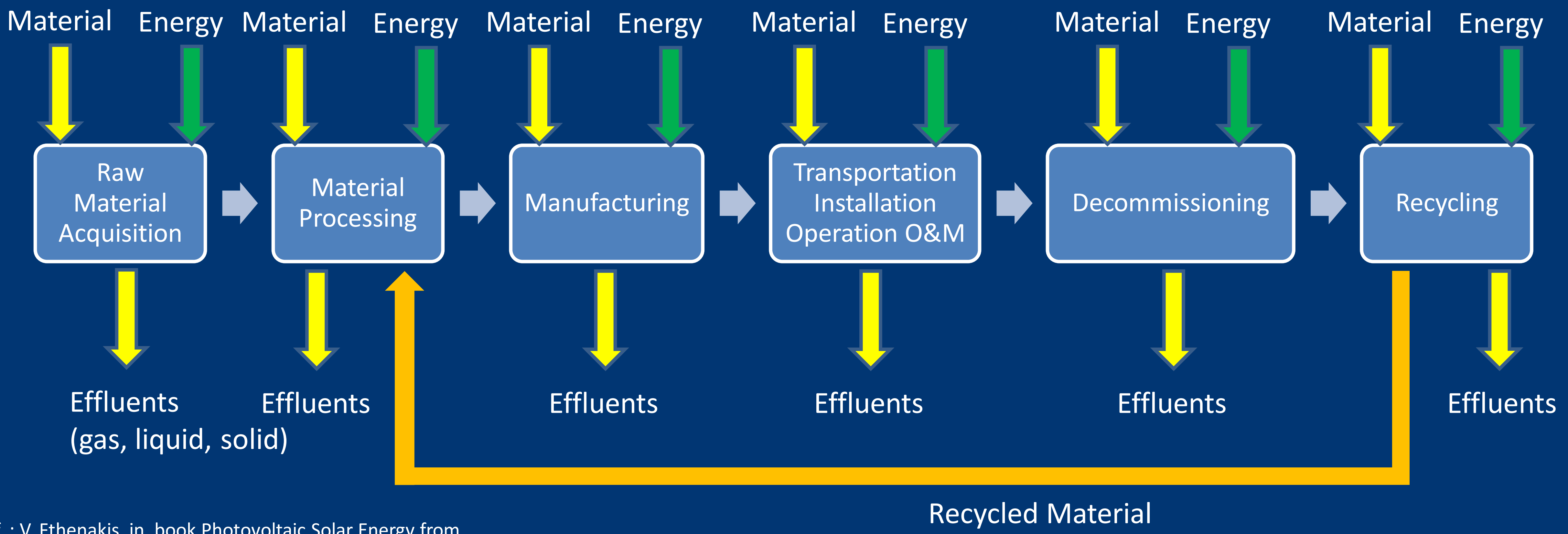
Cumulative (Primary) Energy Demand : **CED** $= E_{mat} + E_{manuf} + E_{trans} + E_{inst} + E_{EOL}$

Energy Payback Time : **EPBT** $= CED / \left((E_{agen} / \eta_G) - E_{O\&M} \right)$

Energy Return on Investment : **EROI** = System Lifetime / EPBT



Ref. : V. Fthenakis, in book Photovoltaic Solar Energy from Fundamentals to Applications, Wiley 2017

EPBT and Greenhouse Gas Emissions of PV Systems

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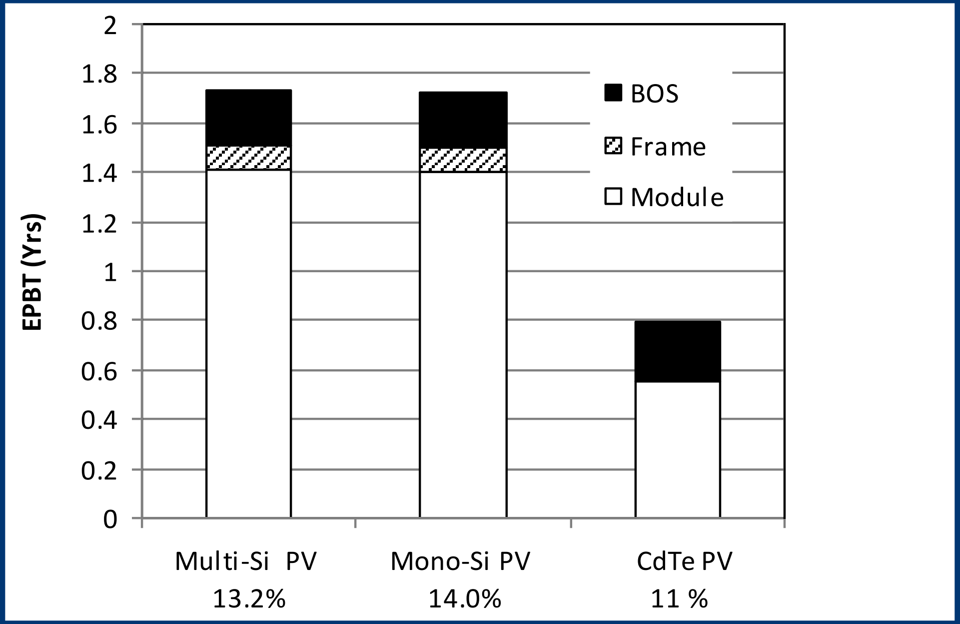

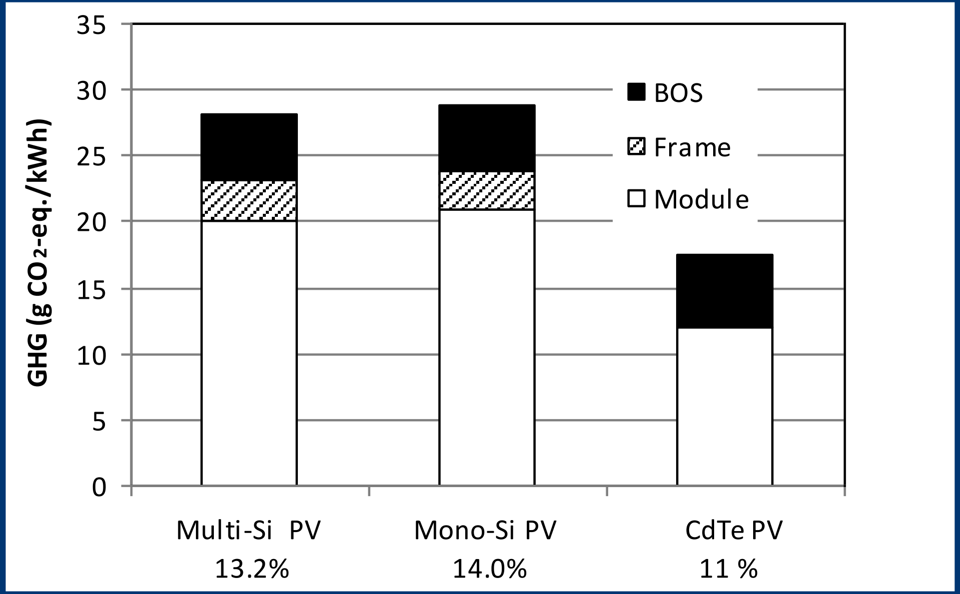

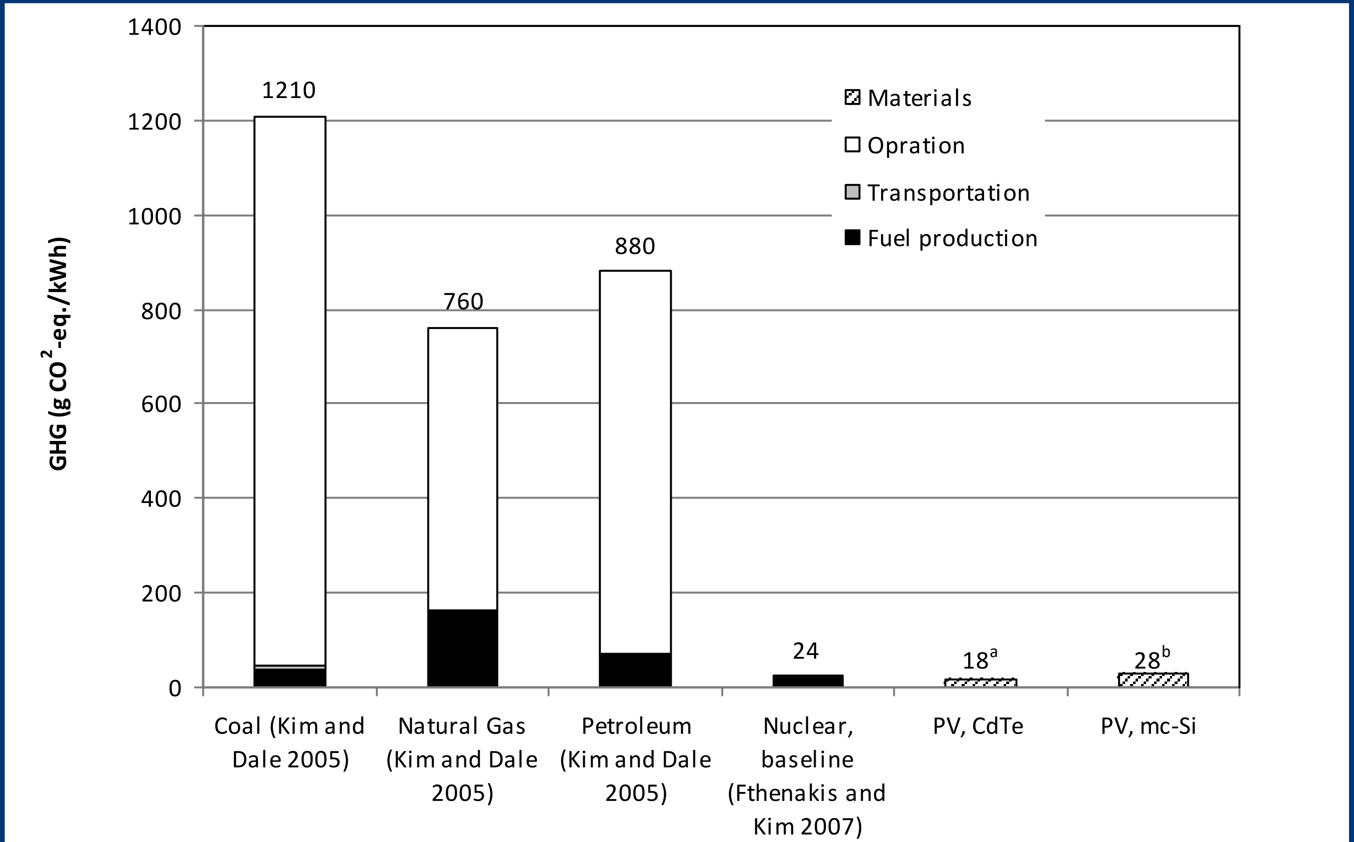

Ref. : V. Fthenakis, in book Photovoltaic Solar Energy from Fundamentals to Applications, Wiley 2017

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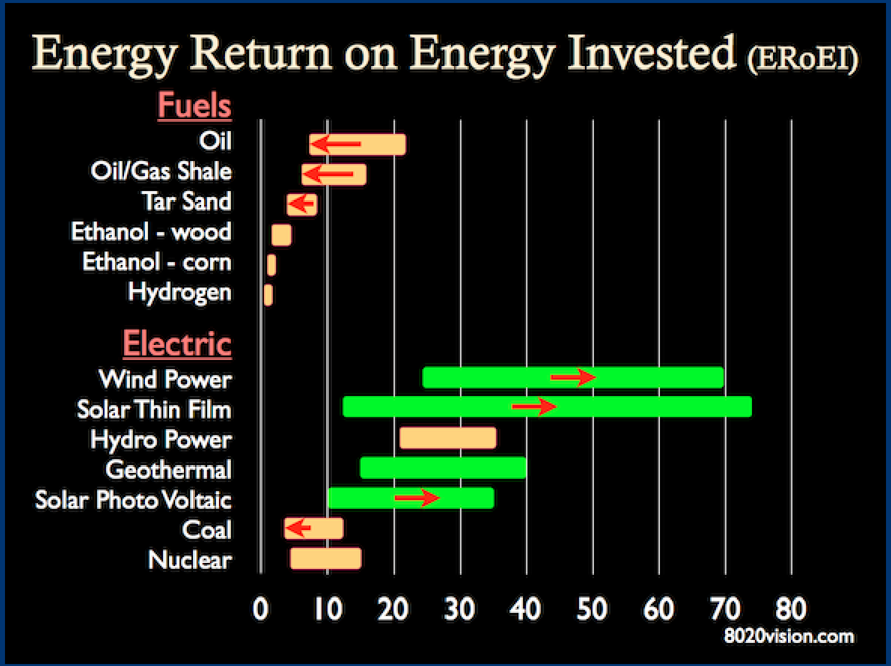
How fast can we grow the PV industry?

1. Energy Payback Time EPBT << PV System Lifetime

$$EROI = \frac{System\ Lifetime}{EPBT} >> 1$$

2. Energy Consumed to manufacture < Energy generated by PV systems installed the previous year

$$Growth\ Rate < \frac{1}{EPBT}$$



http://8020vision.com/tag/eroei/

Financial Sustainability

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The PV Industry ability to grow is limited by the EBIDTA and CAPEX

$$\boldsymbol{Growth \leq \frac{ASP}{CAPEX} \times EBITDA(\%)}$$

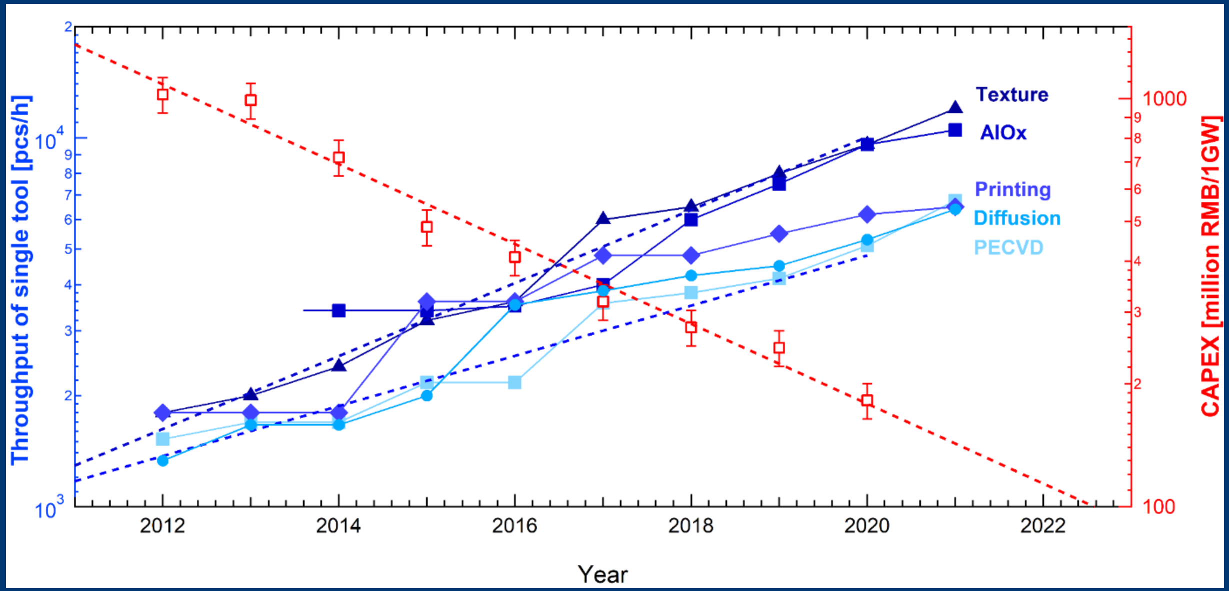
- ❑Current typ. EBITDA ~ 15%
- ❑Current typ. ASP ~ US$0.26/W
- ❑Current typ. CAPEX ~ US$0.18/W

MG Silicon to Module, for mono PERC

⇒ Maximum sustainable growth ~ 22%

⇒Low CAPEX is key

Reduction of CAPEX



Cost of new manufacturing line (CAPEX) decreases by 50% every 3 years

*ASP = Average Sales Price
CAPEX = Average Cost to Build (+/-10%)
EBITDA = Earning Before Interest, Tax, Depreciation and Amortization

Energy and CO_2 Embedded in a 1 TW PV Modules

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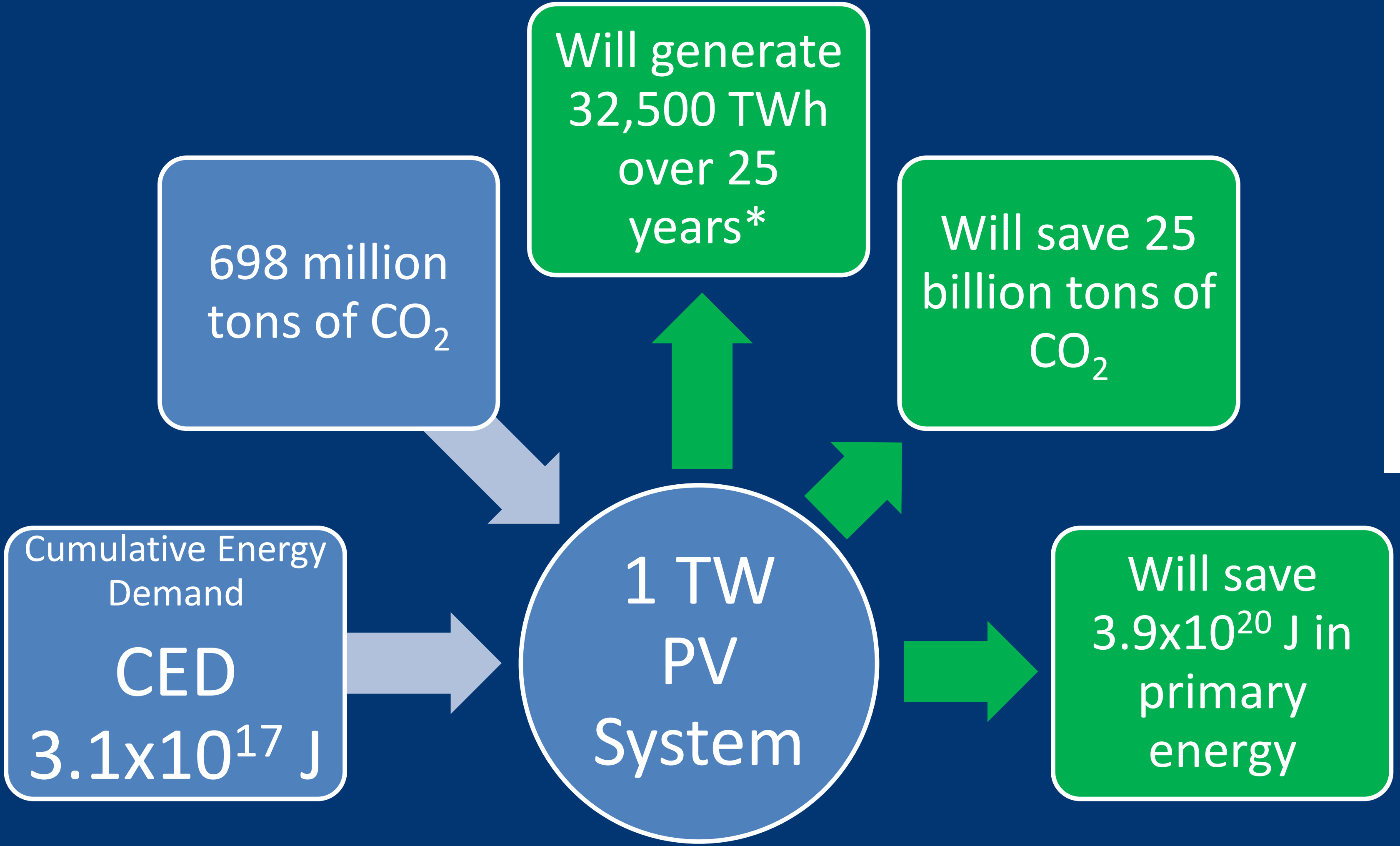
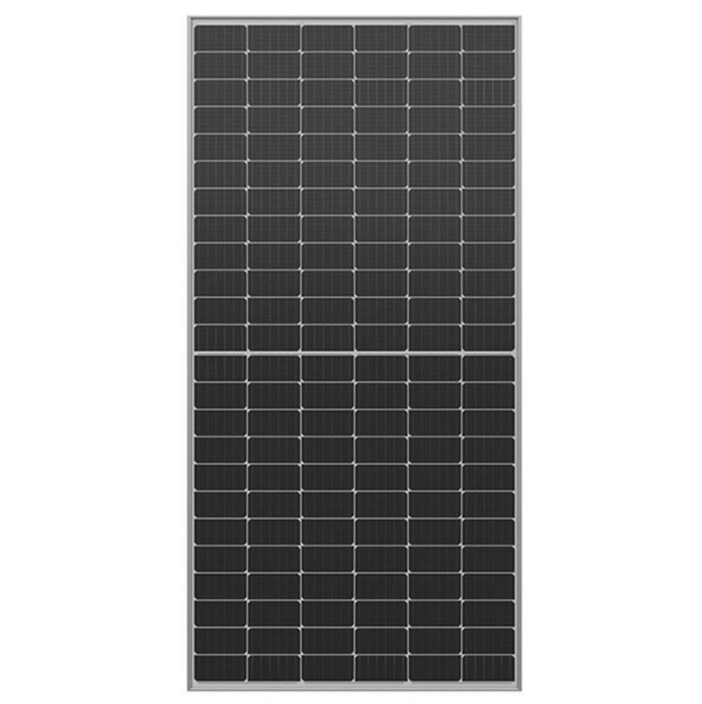




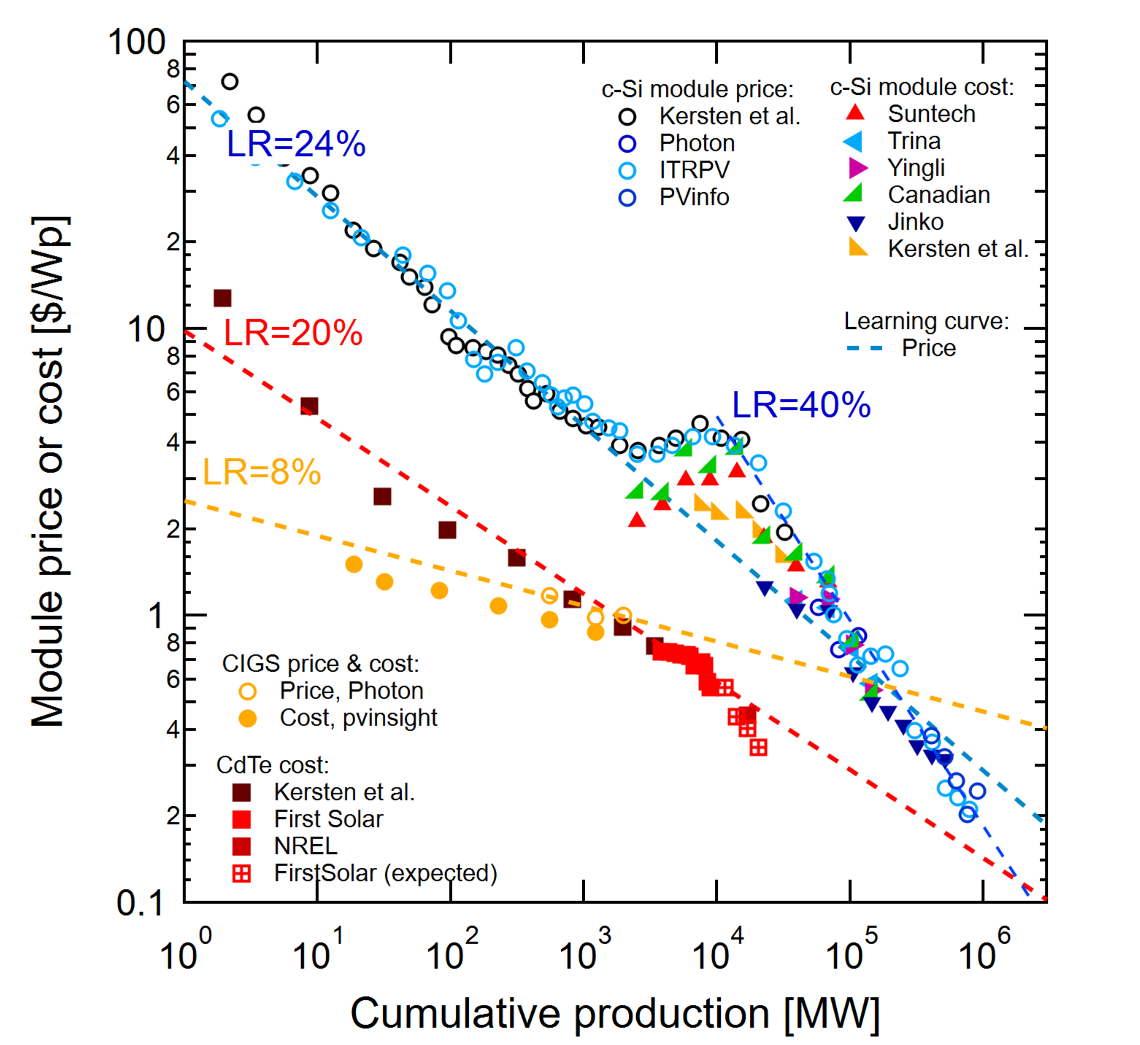
One 400W PV panel (~US$100) will produce the same amount of electricity as 6.9 tons of coal (~US$280)

* Average lifetime of PV power plants is actually 32.5 years

Material Sustainability

- "Bumps" in Learning Curve are generated by Supply Constraints

- Supply Constraints are due to:
  1. Inability of suppliers to grow as fast as demand (ex.: Polysilicon in 2005-2010)
  2. Temporary interruption of supply: Accident, Fire, Floods, Hurricane, Strike, Earthquake
  3. Material Scarcity (Ag, In, Bi, Te, …)



Material Sustainability – The Silver Issue

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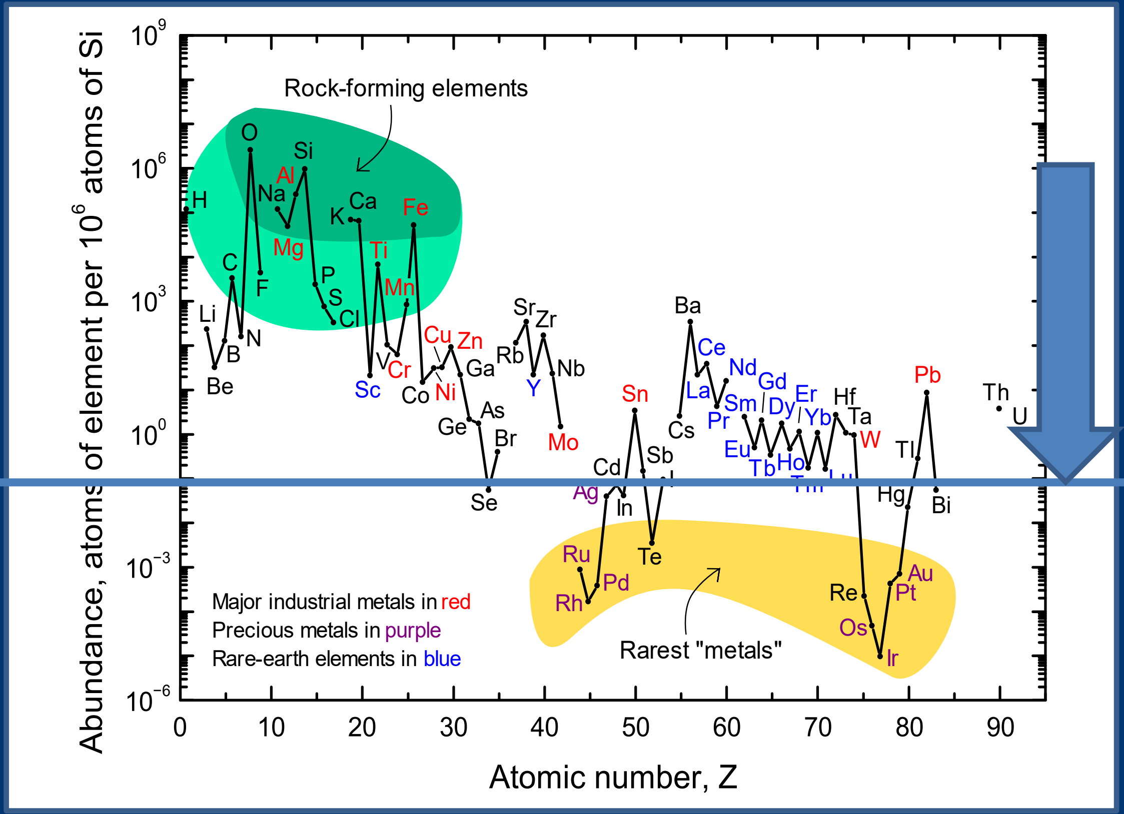
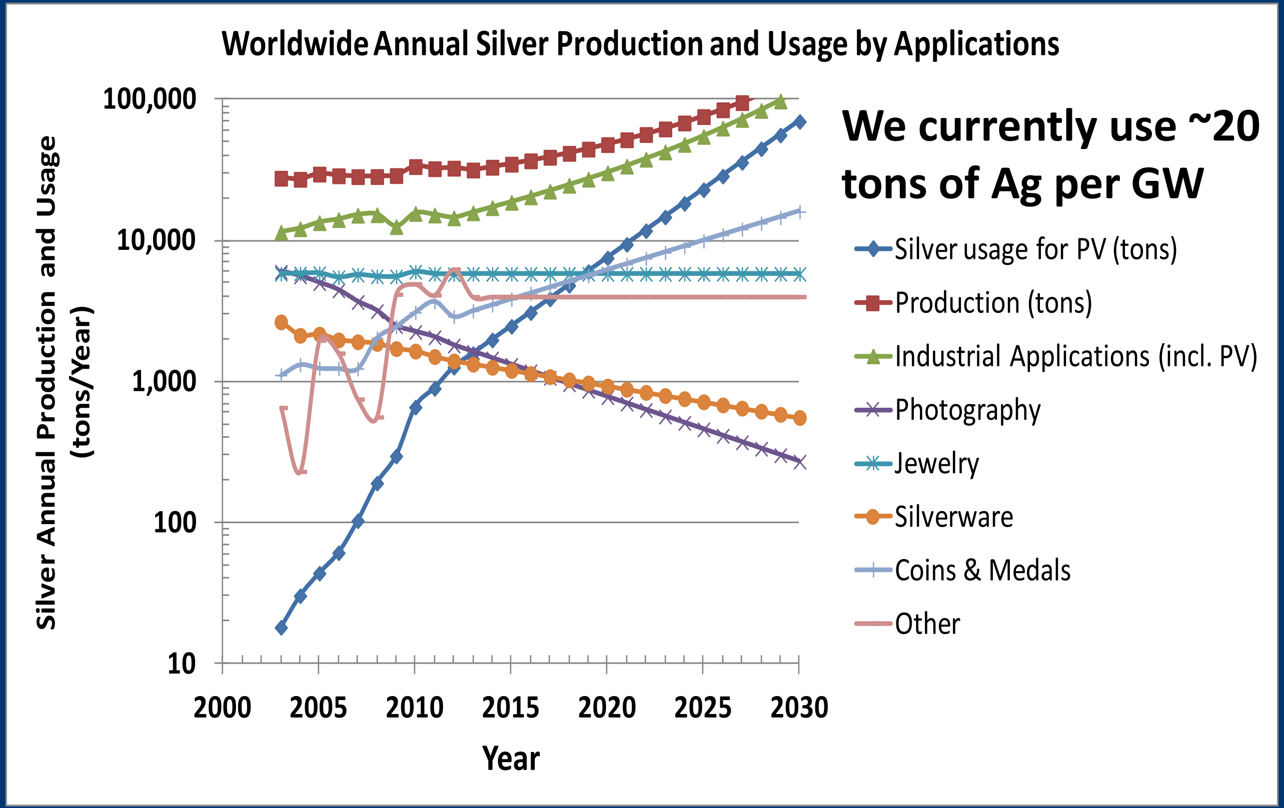
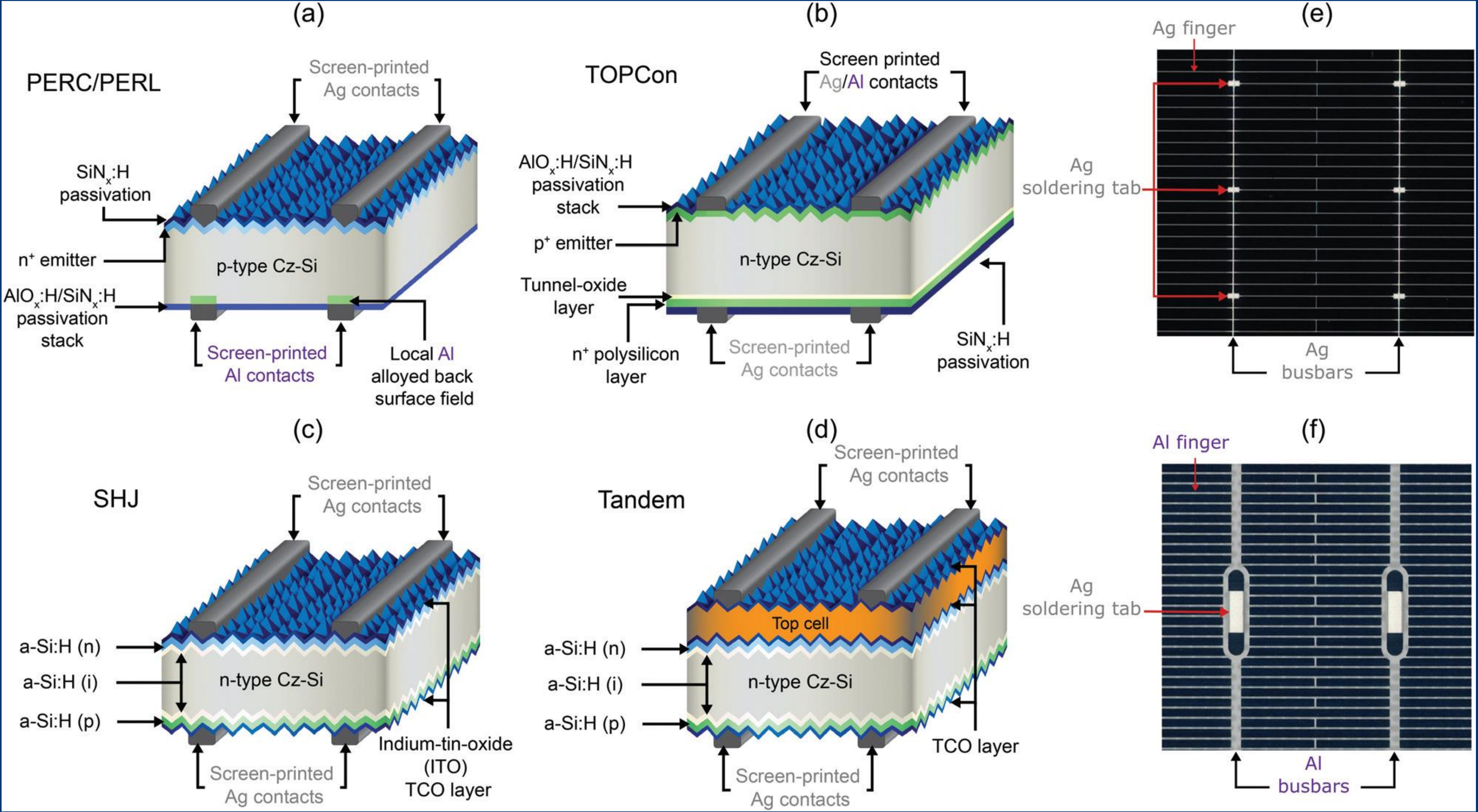


https://en.wikipedia.org/wiki/Abundance_of_elements_in_Earth%27s_crust



Source: www.silverinstitute.org for historical data and projections, except for PV

World Production of Ag ~ 30,000 Tons p.a. Recycling does not become significant until 2050.
At 3TW p.a. (~2040) , the usage of Ag must be < 2mg/W (currently ~ 20mg/W in average. Best in class 15mg/W)



Y. Zhang et al., Energy Environ. Sci., 2021, **14**, 5587

Silver consumption

	Ag (mg/cell) 166mm	Eff. (%)	Ag (mg/W)	% of global Ag supply for 1TW
PERC	96	22.8	15.4	53%
TOPCon	163	23.2	25.6	88%
HJT	218	23.5	33.9	117%

Y. Zhang et al., Energy Environ. Sci., 2021, **14**, 5587

- Assuming that 1TW market will be reached before 2030, and 3TW market by 2035,
- Assuming that a sustainable level of Ag should be kept below 20% of global Ag supply (currently ~30,000 metric tons),

⇒Ag consumption should be reduced to 5mg/W at 1 TW and 2 mg/W at 3 TW per year

⇒We need to reduce the Ag consumption by 3 to 8 (PERC), by 5 to 13 (TOPCon) and by 7 to 17 (HJT)

Indium and Bismuth consumption

	Mass Fraction (kg/kg)	Global reserves (tonnes)	Total supply in 2019 (tonnes)
Ag	7.5 x 10-8	560,000	29,000
In	2.5 x 10-7	15,000 to 50,000	2,100
Bi	8.5 x 10-9	320,000	21,000

Y. Zhang et al., Energy Environ. Sci., 2021, **14**, 5587

- Indium is used in TCO (ITO) for HJT cells
  - Typical consumption of In ~ 4 to 10 mg/W

  => Maximum PV annual production to stay below 20% of In supply ~ 37 to 95 GW

- Bismuth is used for low-temperature soldering (Sn-Bi alloy) of HJT cells
  - Typical consumption of Bi with 12BB ~ 7.8 mg/W
  - Typical consumption with SmartWire™ ~13mg/W

  => Maximum PV production ~ 330 GW (SWCT) to 560 GW (12BB)

Embedded in a 1 TW PV System (Mono PERC, fixed tilt)

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14% of today's worldwide production

42 million tons of glass

94% of today's worldwide production

29,000 tons of Ag

32% of today's worldwide production (of MG Silicon)

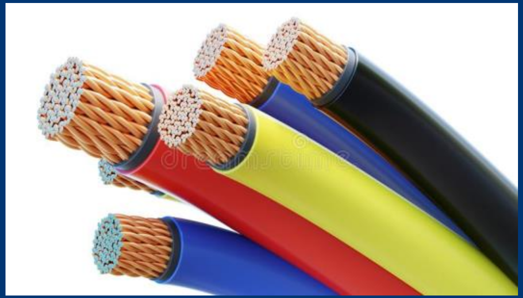
2.3 million tons of silicon

19% of today's worldwide production

12.5 million tons of Al

35% of today's worldwide production

7 million tons of Cu



3% of today's worldwide production

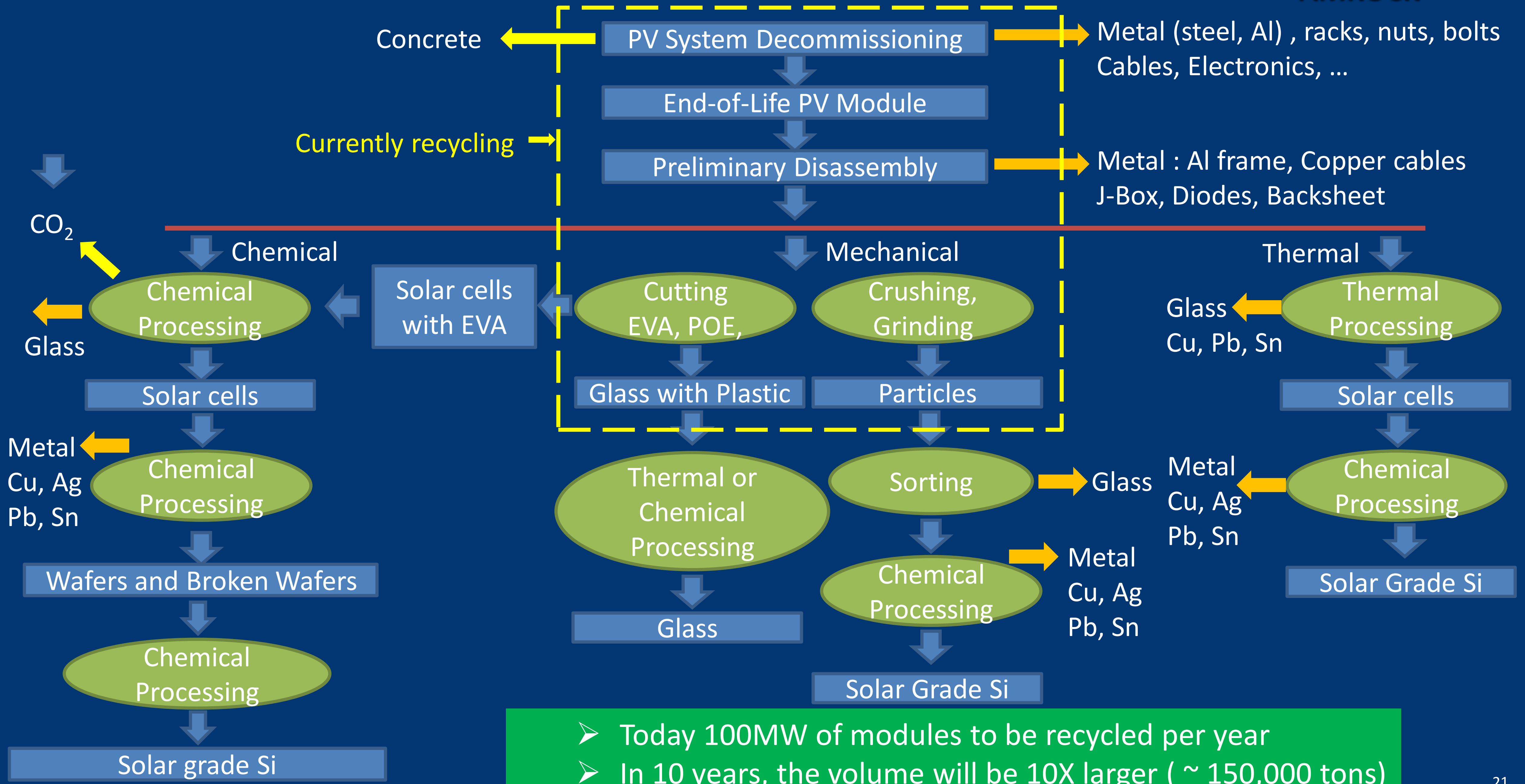
56 million tons of steel

1 TW PV System

47 million tons of concrete

1% of today's worldwide production

Recycling of PV Systems and Modules



- Today 100MW of modules to be recycled per year
- In 10 years, the volume will be 10X larger (~ 150,000 tons)

Conclusions

- PV Manufacturing will have to ramp-up quickly (25% growth p.a.) to reach about 3.5 TW p.a. by ~ 2035, and cumulative capacity should reach ~ 70 TW by 2050
- No issue with EPBT, EROI
- Keep reducing energy and water consumption, and reducing emissions
- Ability to grow is limited by EBIDTA and CAPEX of new production lines
  - CAPEX decreases by 50% every 3 years
- Temporary Supply Constraints (supply chain, fire, floods, …) are not fundamental issues
- Material Sustainability due to Material scarcity:
  - Ag: reduce to less than 2mg/W, or switch to Cu plating
  - In, Bi, Cd, Te, … should not be used for mainstream PV technology
- Recycling technology to be improved to recycle critical material: Ag, Cu, Al, Glass, Si, …

Thank You

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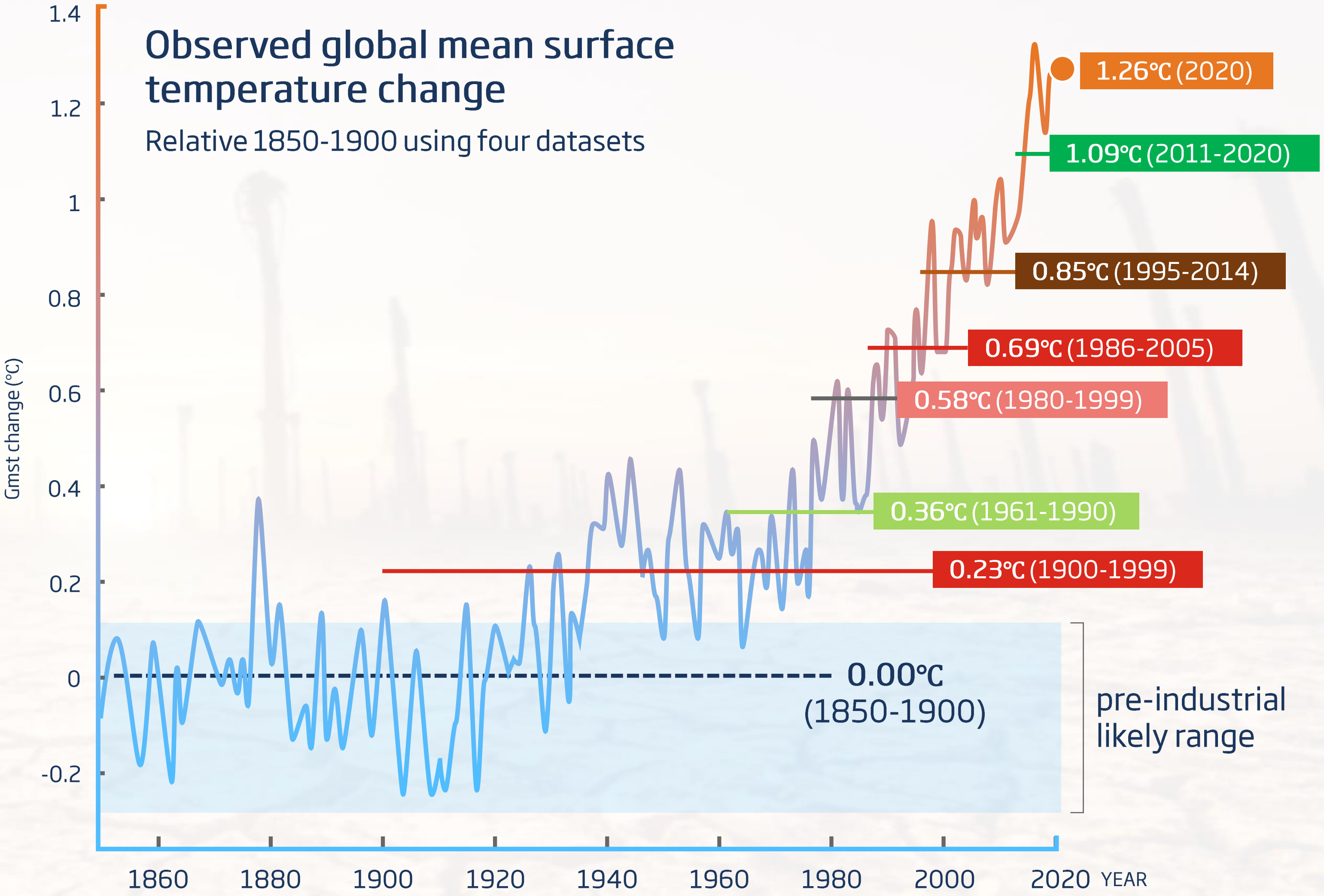
The Road To A Sustainable Future

Adele Zhao
Head of Product Solutions & Marketing
Trina Solar Europe

November 2022

Global Warming



Source: IPCC, 2021. The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. In Press.

The World Calls for Cooperation and Accelerated Shift towards Clean Energy

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

"The Parties shall strengthen the global response to the threat of climate change, by holding the increase in the global average temperature to well below 2℃ above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5℃. Parties aim to reach global peaking of greenhouse gas emission as soon as possible and to achieve net-zero emission of green house gas by the second half of the century."

—— Paris Agreement

UN CLIMATE CHANGE CONFERENCE UK 2021
IN PARTNERSHIP WITH ITALY

"Major economies" will phase out coal by 2030s.

For the past 25 years, Trina Solar has stayed true to its purpose

Solar Energy for All

Our Vision

We are committed to lead the way

in smart solar energy solutions for a

net-zero future

Driving Transformation from the Top

We pledge

that Trina Solar conducts all business in a manner that ensures compliance with applicable laws, regulations and industry standards, and integrates environment, health, safety and corporate social responsibility into all stages of our product life cycle.

天合光能

2022 Reconfirmation of the Product Stewardship Policy

- Trina Solar conducts business in a manner that ensures compliance with all applicable regulatory requirements and industry standards. We are committed to integrating environmental, health, safety, and social responsibilities into all stages of our product life cycle.
- We believe that product stewardship, the ongoing performance improvement of products in terms of environmental, health, safety and social aspects, is one of the cornerstones of sustainable business. We act in a responsible manner to protect our employees, customers and the communities in which we operate.
- Trina Solar pledges to implement effective product stewardship management programs, and shows our commitment and leadership to meet the customers' increasing demands on safer and more environmentally sustainable products.
- Trina Solar actively strives to develop new raw materials and products in a responsible manner by assessing their risks for current and future generations. We commit to conflict-free materials and products, and work diligently to promote sustainable development by way of ethical and green sourcing.
- Trina Solar offers product guidance to customers, distributors and users so that our products are safely transported, stored and used. We voluntarily participate in take-back and recycling program for defective and/or end-of-life (EOL) solar modules.
- We pledge to actively engage in fighting against climate change by way of continuously enhancing energy efficiency and reducing greenhouse gas emission.
- Trina Solar continuously keeps vigilant in its commitment to safeguard workers' rights in global supply chains. We commit to no use of child labor and forced labor, including prison labor, indentured labor, bonded labor or other forms of forced labor.
- Trina Solar engages with stakeholders to review periodically the policy to ensure that it remains adequacy and continues to meet stakeholders' expectations.

产品监管政策

- 天合光能确保所有开展的业务都符合相关法律法规和行业标准的要求，我们承诺将环境、健康、安全和企业社会责任落实到我们产品生命周期的每一个阶段。
- 我们坚信对产品的持续监管和在环保、健康、安全及社会责任方面所做的持续改进是企业可持续发展的基石和核心。我们承诺始终以负责任的态度和方式来保护我们的员工、客户和社区。
- 天合光能承诺全面实施有效的产品监管，以展现我们对可持续发展的承诺和领导力，从而满足客户对产品安全和环境保护越来越高的要求。
- 天合光能积极开发新材料、新产品，并本着负责任的态度评估其对目前和未来的潜在风险，我们努力实施道德和绿色采购，承诺不使用冲突矿产，促进产业链可持续发展。
- 天合光能为客户、分销商和用户提供产品指导性文件，从而确保我们的产品安全运输、安全储存和安全使用，我们自愿参加产品回收计划，对有缺陷的和寿命结束后的太阳能组件进行回收和再利用。
- 我们承诺不断提高能源利用效率，降低温室气体排放，积极参与应对气候变化。
- 天合光能承诺在全球供应链中持续关注和保护员工权益，我们承诺禁止雇佣童工，禁止强迫劳动，包括监狱劳动、契约劳动、抵债劳动或其他形式的强迫劳动。
- 天合光能定期和利益相关方共同回顾产品监管政策，从而确保其合适性，以始终满足利益相关方的期望。

Chairman & CEO of Trina Solar (Jifan Gao):

Date :

Trina Solar CEO

Message from Mr. Gao Jifan

Link to Trina Solar CSR reports and certificates:
https://www.trinasolar.com/en-glb/our-company/sustainability-downloads

Our Sustainable Development Path

Environment

Society

Products & Solutions

Environment

Sustainable Development Goal:
100% Renewable Energy Use
in Manufacturing and Operation by 2030

2020	2025			2030		
Baseline year	-50%	-40%	-20%	100%	"3Rs"	100 Million
	50% reduction for Category 1 and Category 2 GHG emissions intensity (tCO_2e/MW) of solar PV products	40% reduction for integrated energy consumption (tce/MW) of solar PV products	20% reduction for water consumption (t/MW) of solar PV products	100% renewable energy in global production and operations	"3Rs" (Reduce, Reuse and Recycle) policy established and improved to achieve the goal of "zero" waste land fill by 2030	100 million kWh of power consumption saved in global manufacturing and operation from 2021 to 2030

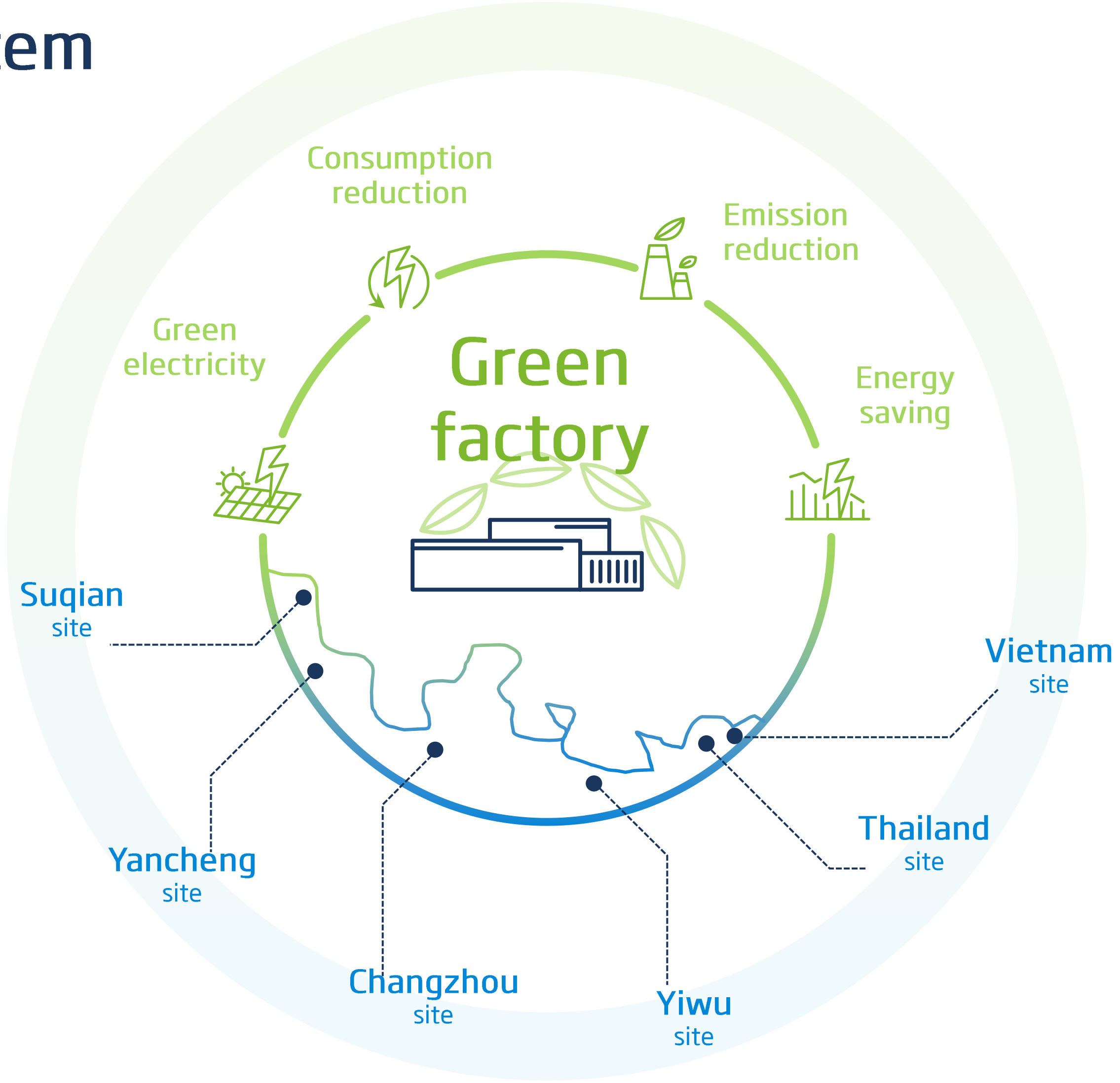
Sustainable development goals are set for 2025 and 2030 against the base year of 2020.

Building Green Factories
with a High Development Standard and an Environmental Management System

Trina Solar has established and implemented an environmental management system based on the requirements of the international standard ISO 14001. Trina Solar commits to sustainable development by creating a green and low-carbon ecological environment throughout the entire product life cycle from production R&D, raw material procurement, and manufacturing, to energy and resource utilization and waste management.

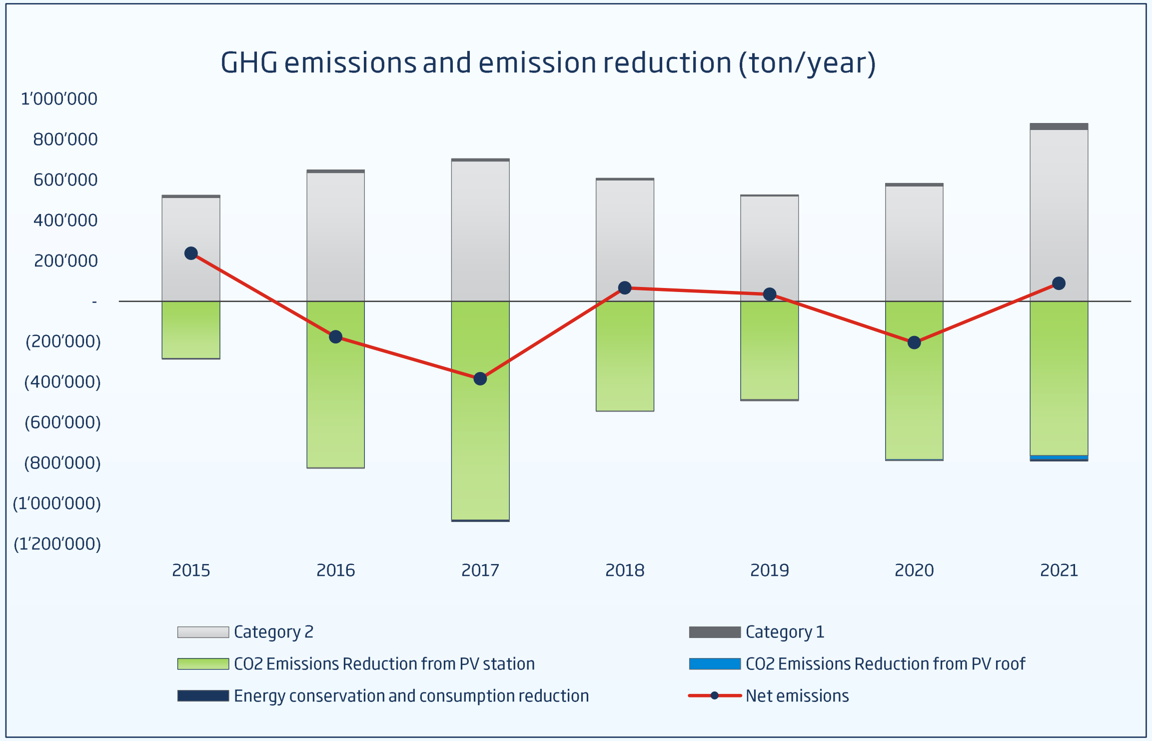
ISO 14001:2015
Environmental management systems

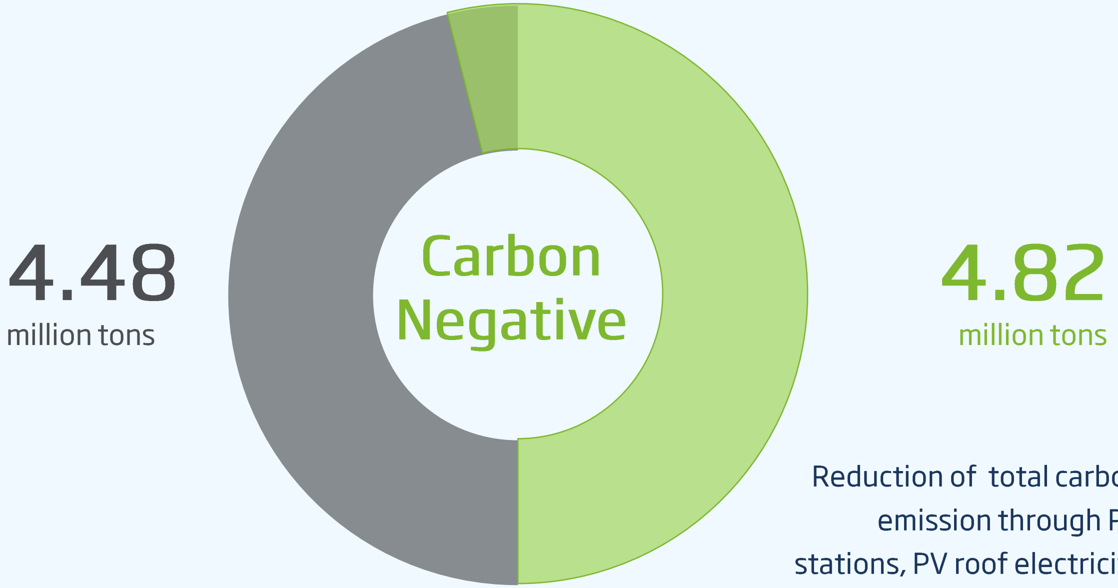
In 2010,
Trina Solar became the first solar industry shaper at the Davos World Economic Forum.



Contributing to a Zero-Carbon Planet

through Measures such as PV Stations, Green Electricity Use, Energy Conservation and Consumption Reduction





Total carbon emissions during production, operation and R&D of all manufacturing bases:

4.48 million tons.

Reduction of total carbon emission through PV stations, PV roof electricity generation, green electricity purchase, energy conservation and consumption reduction:

4.82 million tons.

PV roof electricity generation

Green electricity purchase

Energy conservation and consumption reduction

* Data collection period: 2015 - 2021
* White bars represent emissions, green bars represent emission reductions

100GW+

Data source: Trina Solar's total global shipment of modules as of April 2022

4.4 Three Gorges Hydropower Stations

7.29 billion Trees

135 billion kWh

134.6 million tons Total CO_2 Emission Reduction

4.05 million tons Total SO2 Emission Reduction

36.72 million tons Total Carbon Dust Emission Reduction

Trina Solar has formally joined the global initiative of Science Based Targets initiative (SBTi) ››› "contributing to the global 1.5℃ goal

BUSINESS AMBITION FOR 1.5°C

SCIENCE BASED TARGETS

DRIVING AMBITIOUS CORPORATE CLIMATE ACTION

Society

We pledge

to constantly focus on and protect employees' rights in global supply chains.

Transparency

Suppliers must open up for audits by Trina Solar or independent third parties.

Traceability

Trina Solar set up an IT traceability system for its customers.

Supplier Selection

Suppliers unwilling to cooperate or to be transparent towards Trina Solar will not be selected.

We pledge

to always act in a responsible manner to protect our employees, customers, and the communities in which we operate.

Yearly Supplier Assessment and Management

Collect Quality, Cost, Delivery, Service, Innovation data as well as business ethic and release the final assessment results.

Review the result and push suppliers to do improvement accordingly.

Yearly Supplier EHS Management Procedure

EHS & CSR Performance Investigation.

Deliver audit report to supplier within 10 working days after audit.

The audit result and improvement will be one of the basic supplier assessment requirements.

Commitment Letters

Trina's suppliers promise to strictly comply with labor laws and regulations in their country of operations, not be involved in any illegal employment, child labor, forced labor.

ecovadis

Granted for Global Corporate Social Responsibility Achievement from EcoVadis for multiple years in a row.

Products & Solutions

Driver of Sustainable Development:
Most Reliable Products and Strongest Commitment

With a history of 25 years and a minimum 25-years performance warranty commitment for module power performance, Trina Solar's growth spans the entire product life cycle.

- Trina Solar has been recognized as "Top Performer" among global PV module manufacturers for eight consecutive years by PVEL, a world-renowned third-party reliability testing laboratory.

- Trina Solar has been nominated as Overall High Achievement for module manufacturing by RETC three years in a row.

Guaranteed Power Generation through the Life Cycle of the PV System

Extended Reliability Tests

*Extended reliability tests refer to tests that have more strict requirements than IEC / UL basic certification tests.

IEC/UL basic cert tests	DH1000 Damp heat	TC200 Thermal cycling	SML Static mechanical load	DML Dynamic mechanical load	HF Humidity freeze	PID 96h
Extended reliability tests	DH 1500/2000	TC 400/ 600	Compound test sequences with SML , DML , TC , HF			PID 192h

Standard static load

Uneven snow load
Able to withstand 2.8m uneven snow load

Extreme low temperatures
Remains safe and reliable at -40 ℃

Hail impact
Able to easily withstand 35mm hail impact

Dynamic load
Passed ±1500Pa @20,000 dynamic load tests

High wind limits
Passed category 17 hurricane test

210 Vertex Modules Achieve the
Lowest Carbon Emission per Unit in the Industry

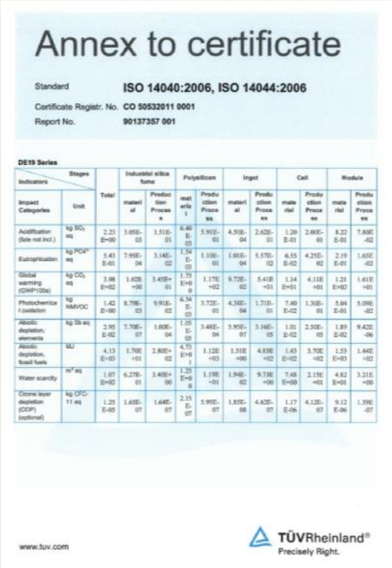
ISO LCA and Carbon Footprint

210 Vertex family products (410 - 670W) have achieved an industry leading low carbon emissions assessment by "Cradle to Gate" ISO LCA and Carbon Footprint qualification.

TÜVRheinland Precisely Right.

ISO 14040:2006
Life cycle assessment

ISO 14044:2006
Carbon footprint of products


Annex to certificate

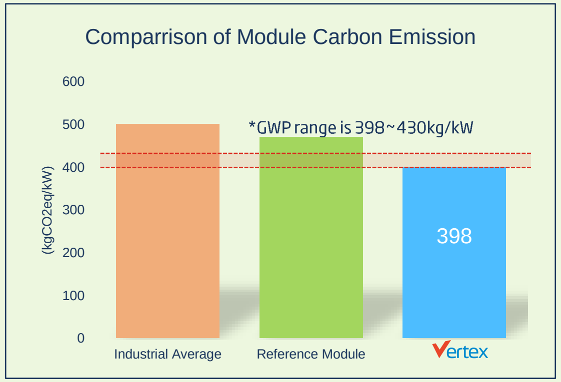
Standard ISO 14040:2006, ISO 14044:2006
Certificate Registr. No. CO 50532011 0001
Report No. 90137357 001

DE19 Series

www.tuv.com
TÜVRheinland® Precisely Right.

Lowest carbon emissions per unit during production in the industry:

within 400g per watt.



Certisolis (France)

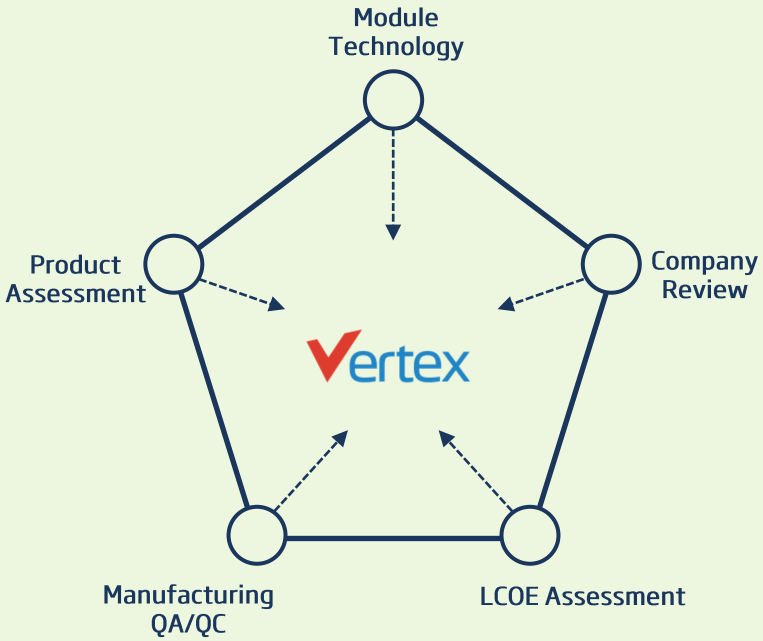
Trina Solar is one of the **first** PV module manufacturers certified by Certisolis (France) with the verified carbon footprint <550kg/kW.

UL/EPD

Trina Solar is the first PV manufacturer to have obtained UL and Italy EPD certifications. More popular types are pending on EPD certification.

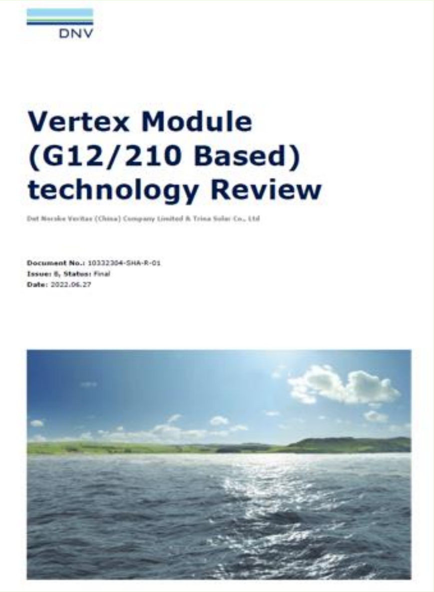
210-Vertex Series Modules

100% Bankability



Trina Solar entrusted world leading independent advisory, testing, inspection and certification organizations: DNV and UL (Underwriters Laboratories) in 2022 with **independent bankability assessment** for Trina Solar's Vertex series modules.

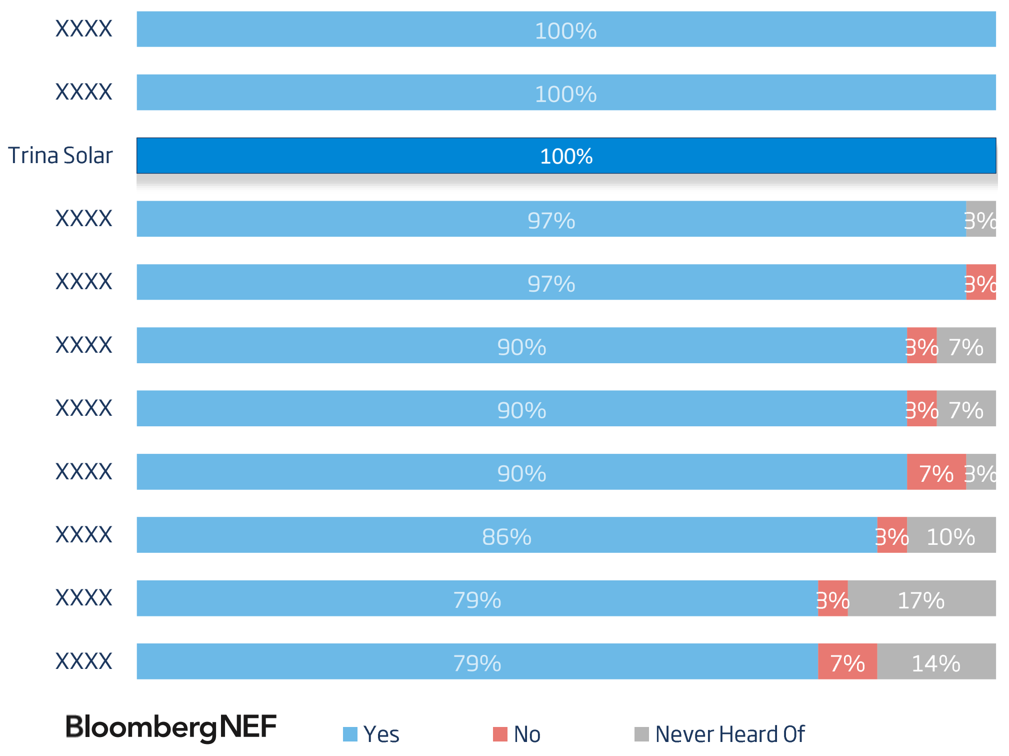
The **assessment proves** that all Vertex series modules have excellent performance in reliability, compatibility and lowering LCOE and high-standard quality management system.



210-Vertex Series Modules

100% Bankability

BloombergNEF's 2021 PV module bankability survey results, top 10



Source:
BloombergNEF. Note: stars** indicate the top performers in PVEL's 2021 PV Module Reliability Scorecard.
PVEL did not test all the manufacturers listed above, so a missing star is not indicative of poor quality.

2021 BloombergNEF

Bankability Rating

Trina Solar has been recognized as bankable by all survey respondents in the 2021 PV Module and Inverter Bankability report issued by BloombergNEF.

Trina Solar is now the only module manufacturer to be rated as bankable for 6 consecutive years by 100% of the industry respondents participating in the annual BloombergNEF survey.

Vertex Modules

Trinasolar 25

Ultra-high-power modules significantly reduce project costs

65GW
2022 module production capacity

40+GW
Vertex 210 series production capacity

No. 1
World's largest 210 module production scale

Wide product range for utility projects

Compared with same-class products on the market

0.01-0.04 USD/W ▾
Lower system costs

1%-3% ▾
Lower LCOE

P type
PERC

Vertex
575W+

Vertex
670W+

N type
i-TOPCon

Vertex N
590W+
Delivery Q1 2023

TrinaTracker

Efficiency booster in the era of grid parity

3%-8% ▲

Higher power generation with smart tracking control system

2.4%-4.5% ▼

Lower electricity cost per watt-hour compared with traditional trackers

30%

Adjustable tilt angle enabled by patented spherical bearing

High safety and stability

Wide applications, resilient to extreme weather conditions

Global project design, capacity planning and service

7GW+

Global installations

5GW+

Annual capacity

400+

Tracker projects

Trina Storage

A vertically integrated BESS solution provider

Trina Storage is a business unit of Trina Solar, a company with 20+ years of solar experience. Trina Storage combines deep technical expertise, quality, safety and agility to meet the unique needs of every customer. We help our clients to build large-scale solar+storage and standalone storage projects that are highly bankable, highly flexible, and cost-competitive.


Trinasolar
25TH
The Road To A
Sustainable Future

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Entering the Terawatt age: A 360° view on solar sustainability

Q&A

Tuesday, 8 November 2022

9:00 am – 10:00 am | GMT, London
10:00 am – 11:00 am | CET, Berlin
10:00 am – 11:00 am | Morocco
1:00 pm – 2:00 pm | Dubai

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Chinese PV Industry Brief: Canadian Solar starts production of independently developed inverters

by Vincent Shaw

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Coming up next...

Thursday, 10. November 2022
8:00 AM – 9:00 AM PST, LOS ANGELES
11:00 AM – 12:00 PM EST, NEW YORK CITY

Monday, 14. November 2022
9:00 AM – 10:00 AM EST, NEW YORK CITY
3:00 PM – 4:00 PM CET, BERLIN

Many more to come!

Learning from PV module manufacturing nonconformities

How a centralized monitoring platform makes your solar asset the center of attention

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Editor in Chief
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Thank you for joining today!