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A bright solar energy future: global high-quality PV markets

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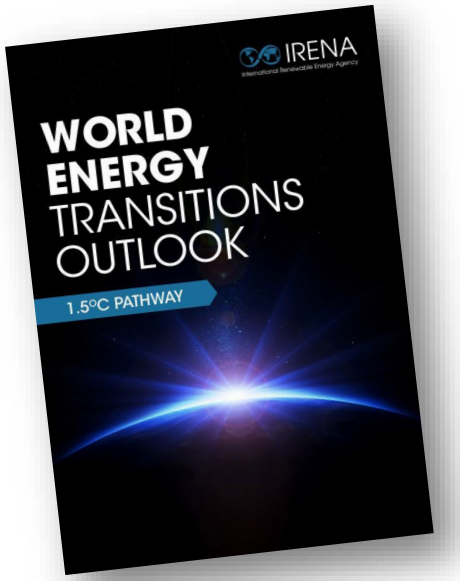
6th IRAN Renewable Energy Conference, 21 November 2021

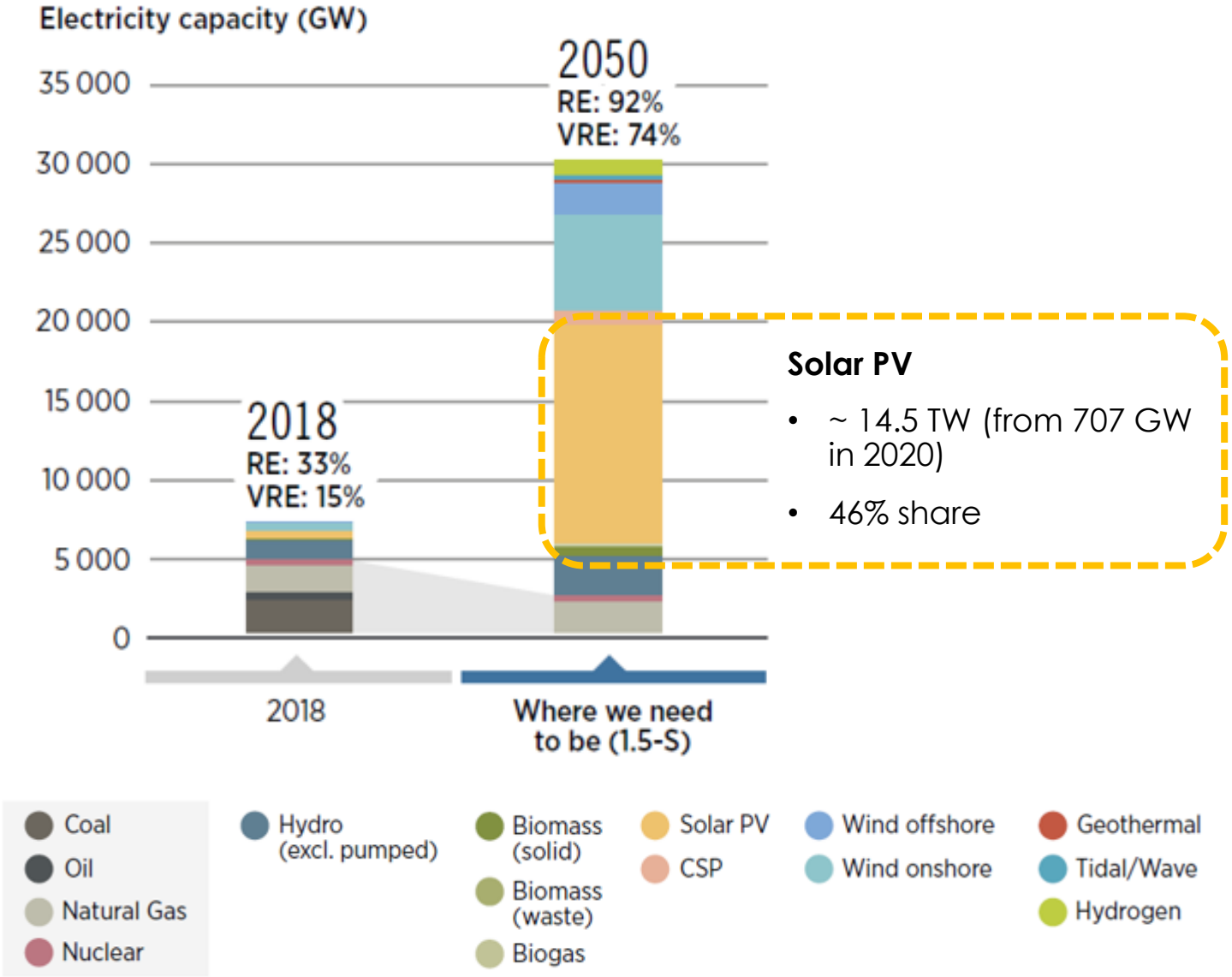
Role of solar PV in the electricity sector in a 1.5ºC scenario

PV sector in the next three decades

- Annual additions ~ 450 GW (from 126 GW last year)
- 360 billion USD/year

Consensus from different actors on the way to go





Solar PV

- ~ 14.5 TW (from 707 GW in 2020)
- 46% share

Source: https://www.irena.org/publications/2021/March/World-Energy-Transitions-Outlook

Solar PV industry propelled by its cost competitiveness

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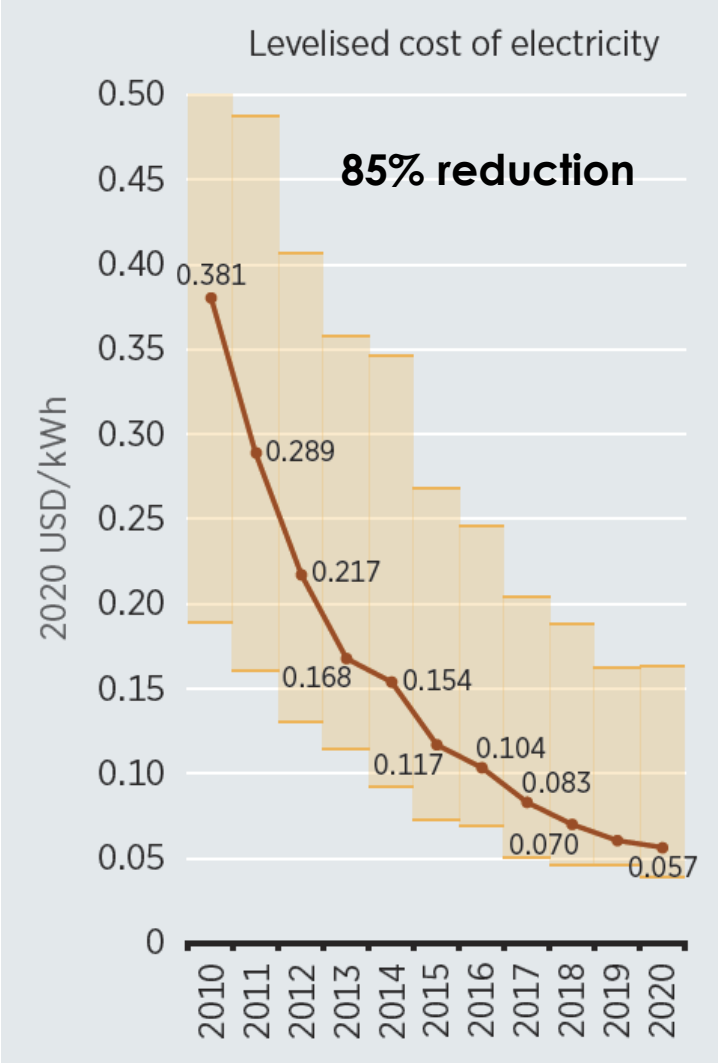
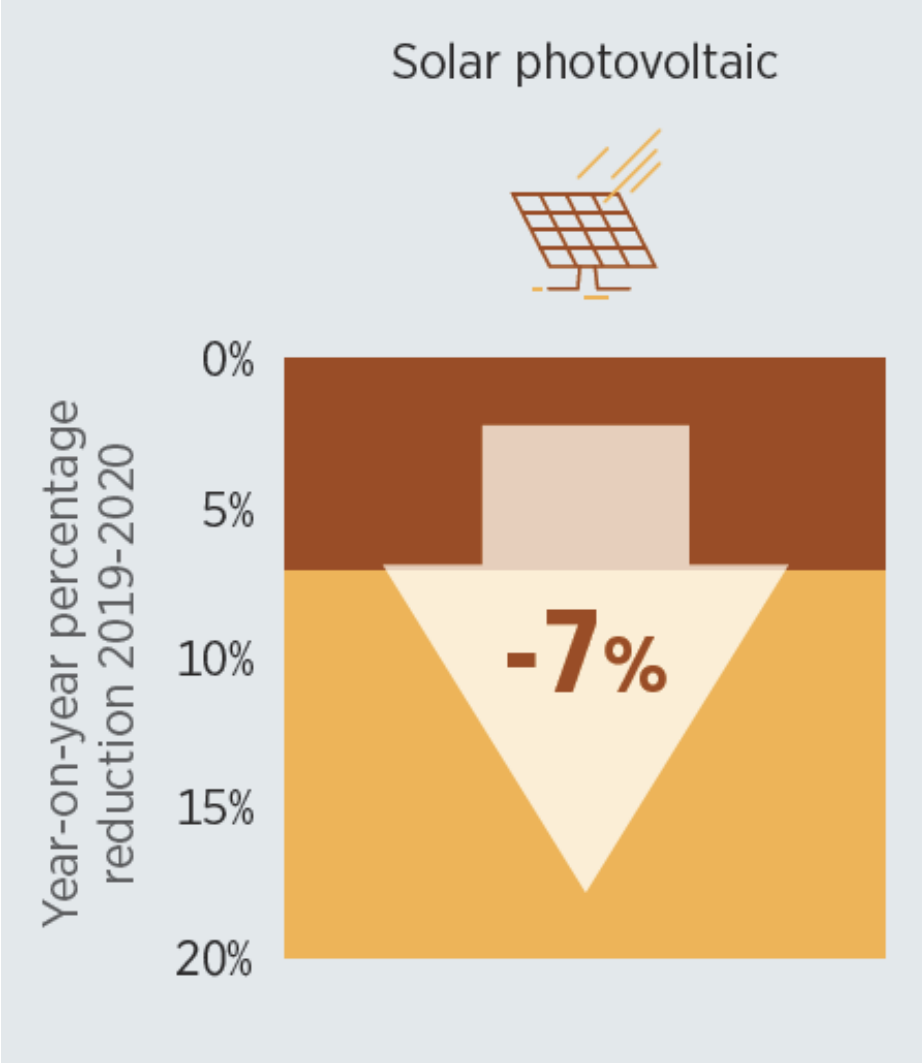
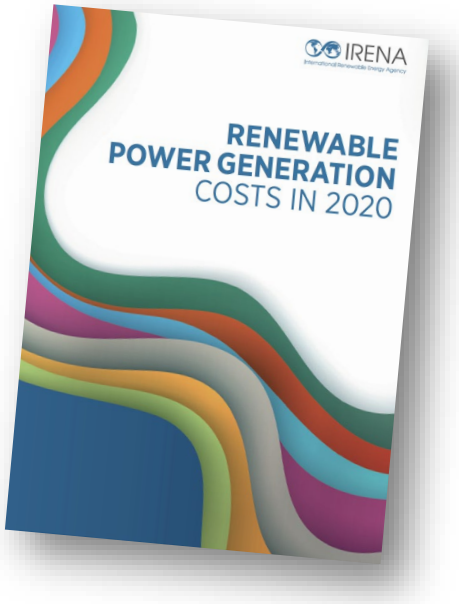
2010 – 2020



2019 – 2020





- Brazil < 2 USD ct/kWh
- Portugal < 1.4 USD ct/kWh
- Middle East < 1.2 USD ct/kWh

Source: https://www.irena.org/publications/2021/Jun/Renewable-Power-Costs-in-2020

Utility-scale solar PV from 2010 to 2020

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COSTS

-93% PV module prices

-81% Total installed costs

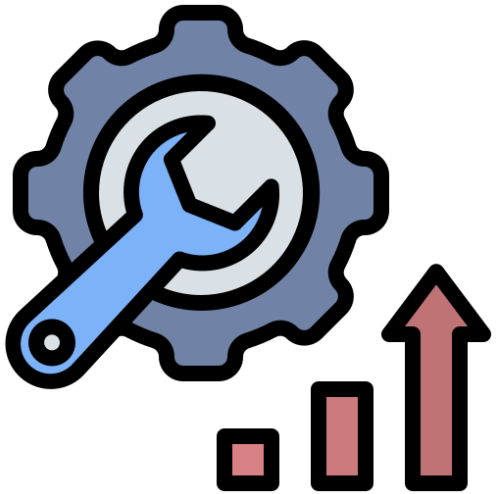
-85% Levelised cost of electricity

PERFORMANCE

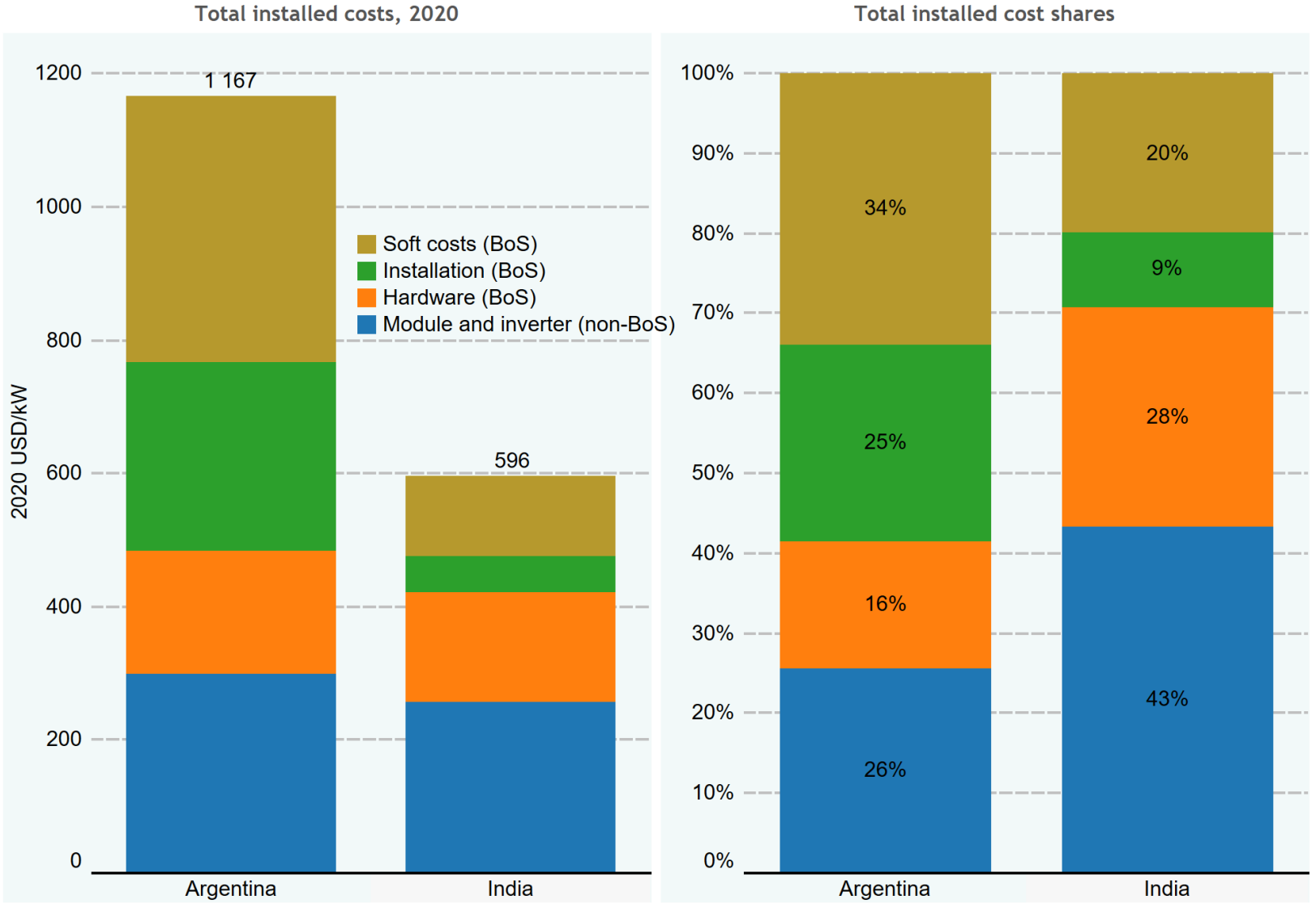
Module efficiency +24%

Module power (watts) +55%

Capacity factor +17%



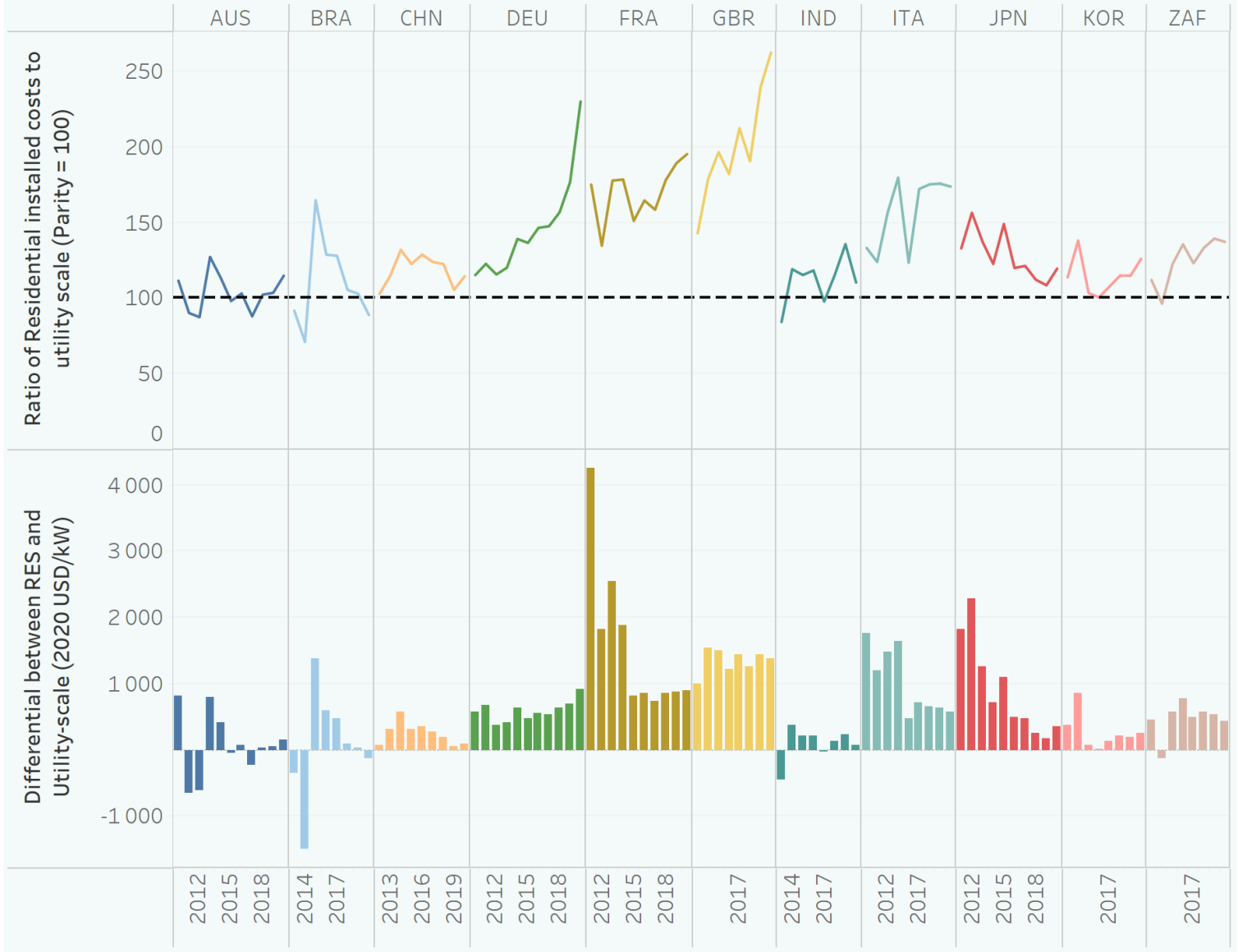
Typical utility scale project cost breakdown – its not about modules



Source: IRENA

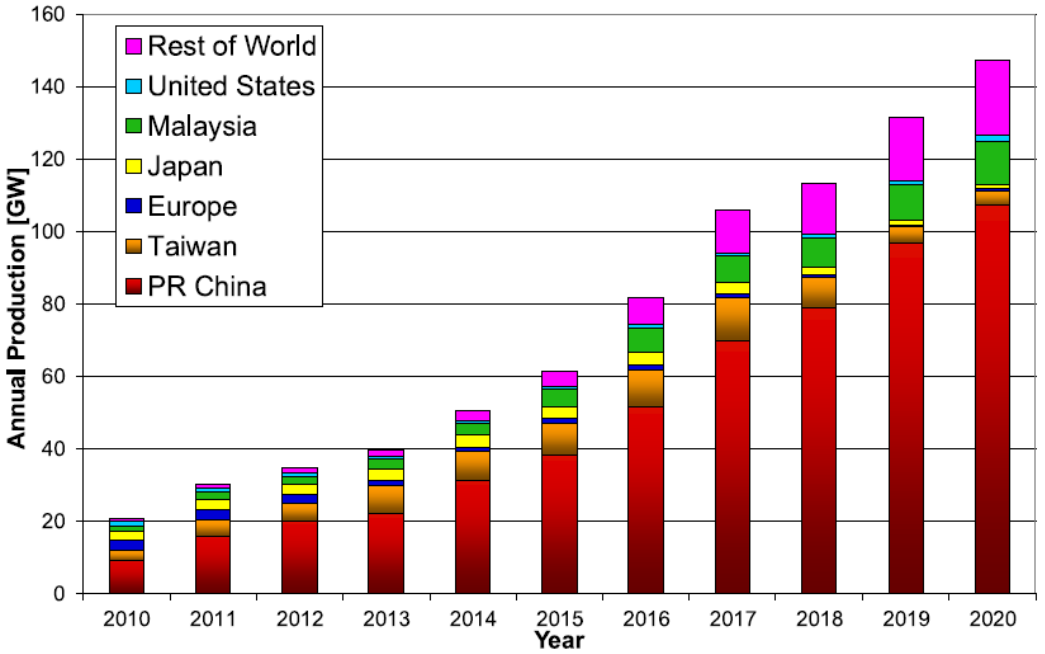
Residential solar PV vs utility scale: installed cost comparison

- **Australia and Brazil** - modest differentials between the two systems but evidence that utility-scale systems are becoming more competitive.
- **France, Germany and UK**: residential systems increase as utility-scale costs fall faster than residential systems leading to a growing percentage difference
- **Japan**: the only market where residential system cost declined strongly in absolute and percentage terms.

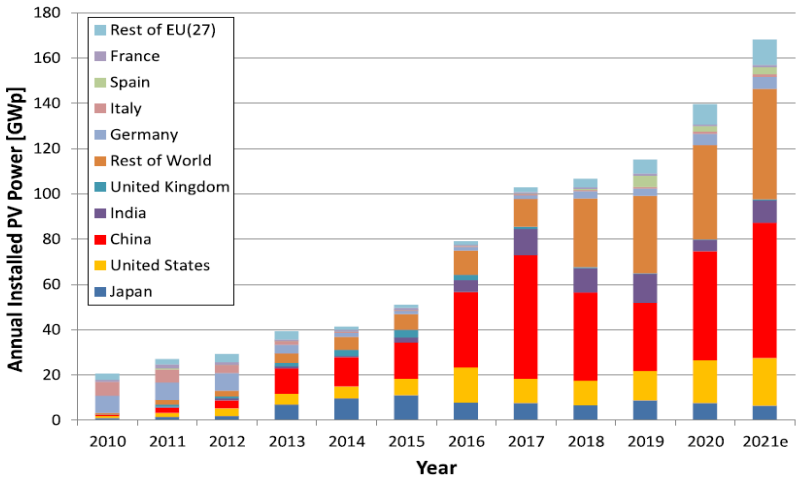


Solar PV trends

- **707.5 GW installed capacity** end 2020
- **856 TWh** solar PV generation in 2020
- **China dominates** world **production** of cells and modules
- **Wafer size increased** enabling larger PV module size allowing power range +600 W per module
- **Material usage for silicon cells reduced** significantly in the last 16 years from 16 g/Wp to 3 g/Wp due to increased efficiencies, thinner wafers and diamond wire saving and larger ingots
- **Efficiencies** continue to **increase**



Source: Jäger-Waldau, 2021

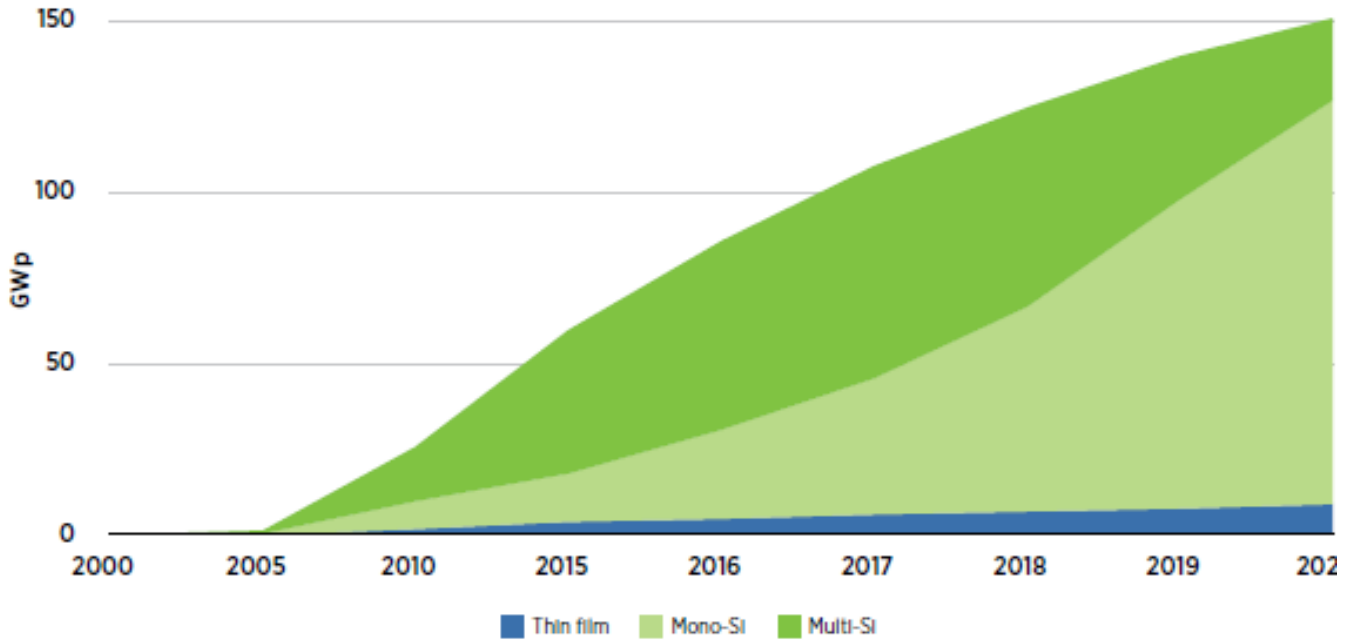


Trend towards mono-Si

- Trend away from multicrystalline silicon and thin film **towards monocrystalline silicon**

- **Silicon multijunction solar cells** (IIIV/silicon, IIVI/silicon, chalcopyrite/silicon, perovskite/silicon)
  - popular and **closer to economic competitiveness**
  - **but will change the materials requirements** (e.g. increase demand for silver substantially)

Figure 4: Trends in PV module manufacturing, 2000-2020



Mono-SI = monocrystalline silicon; Multi-SI: multicrystalline silicon.

Source: Fraunhofer ISE, 2021

Changes to mainstream c-Si wafer, cell, & module technology over time

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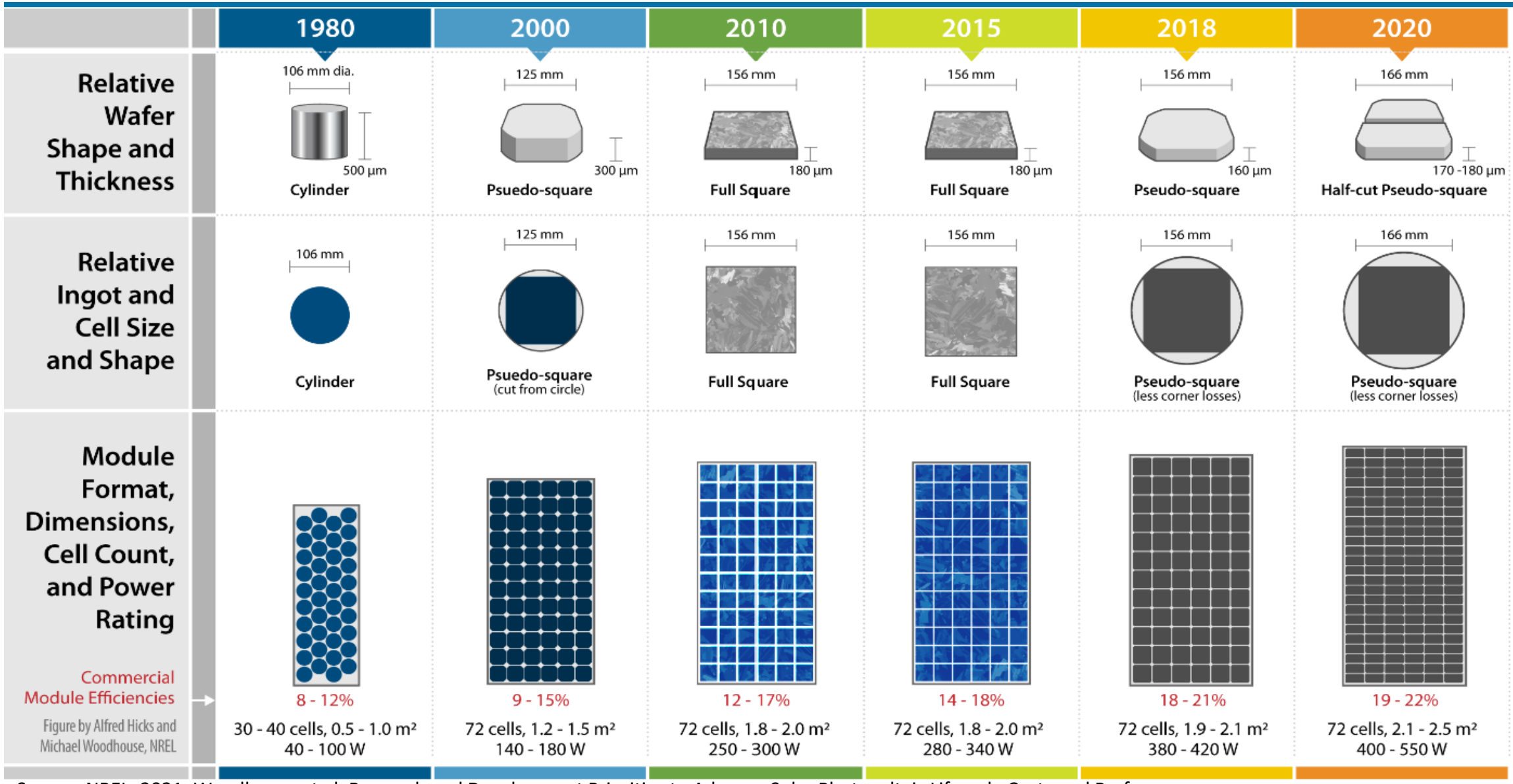
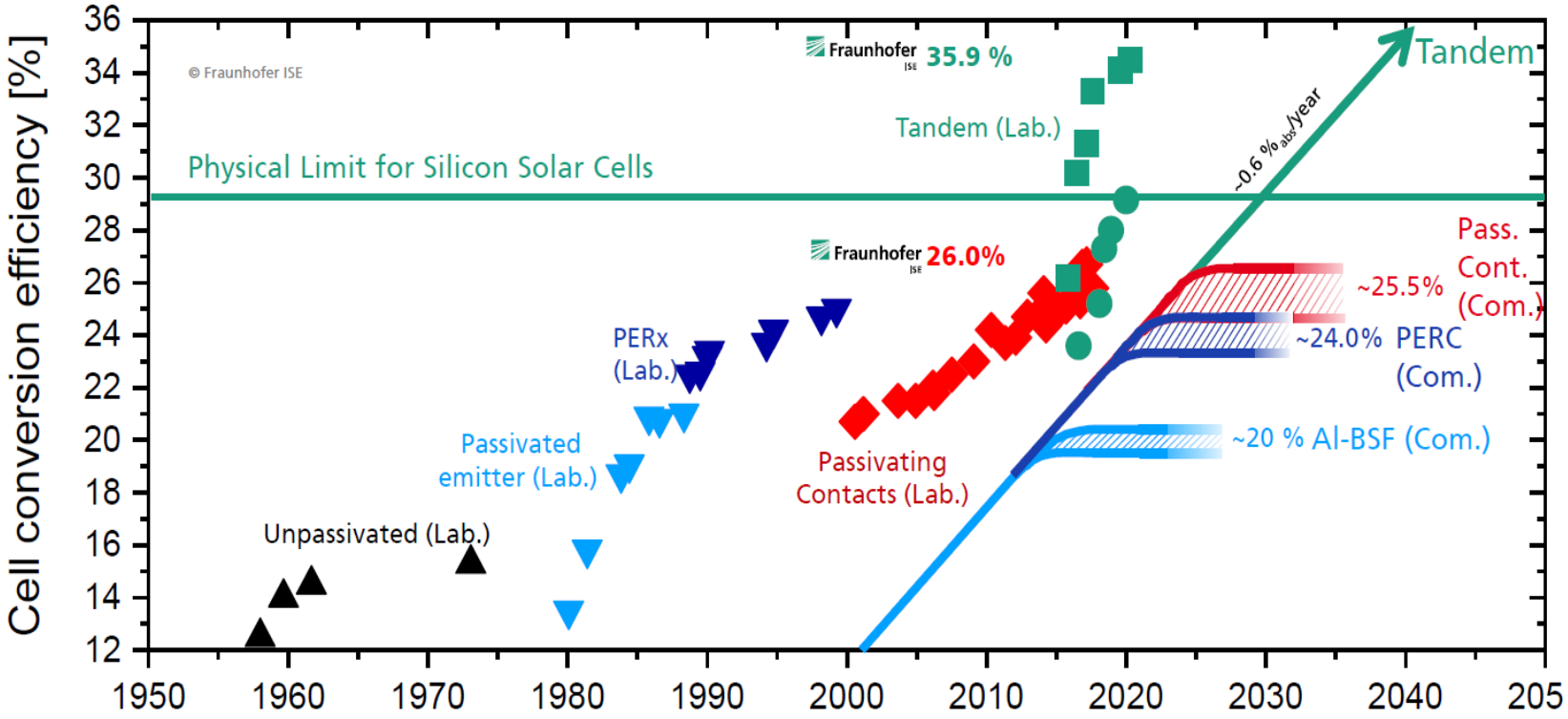
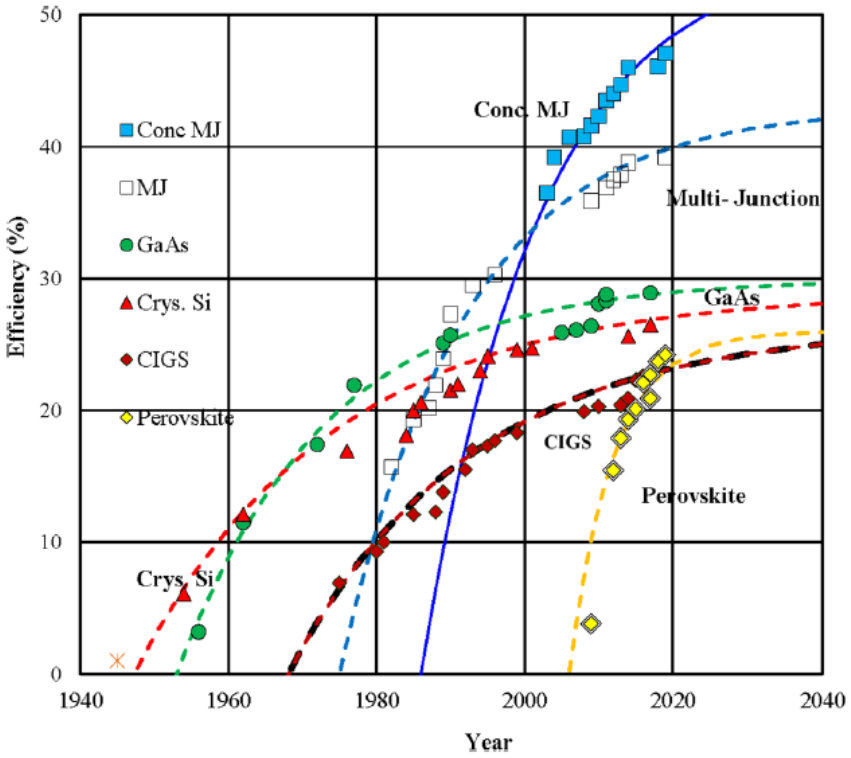


Source: NREL, 2021: Woodhouse et al. Research and Development Priorities to Advance Solar Photovoltaic Lifecycle Costs and Performance.

Lab and commercial cell efficiencies feature continuous gains that can be extended



Source: Fraunhofer ISE, 2021



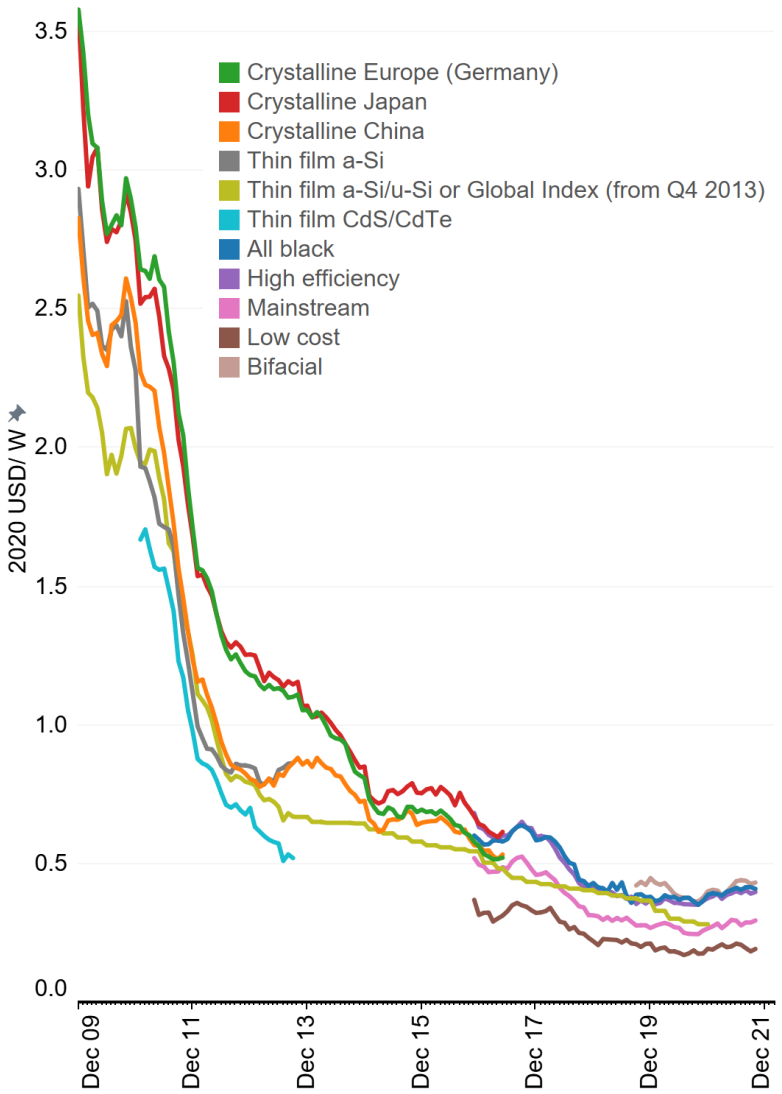
Source: Yamaguchi, 2020

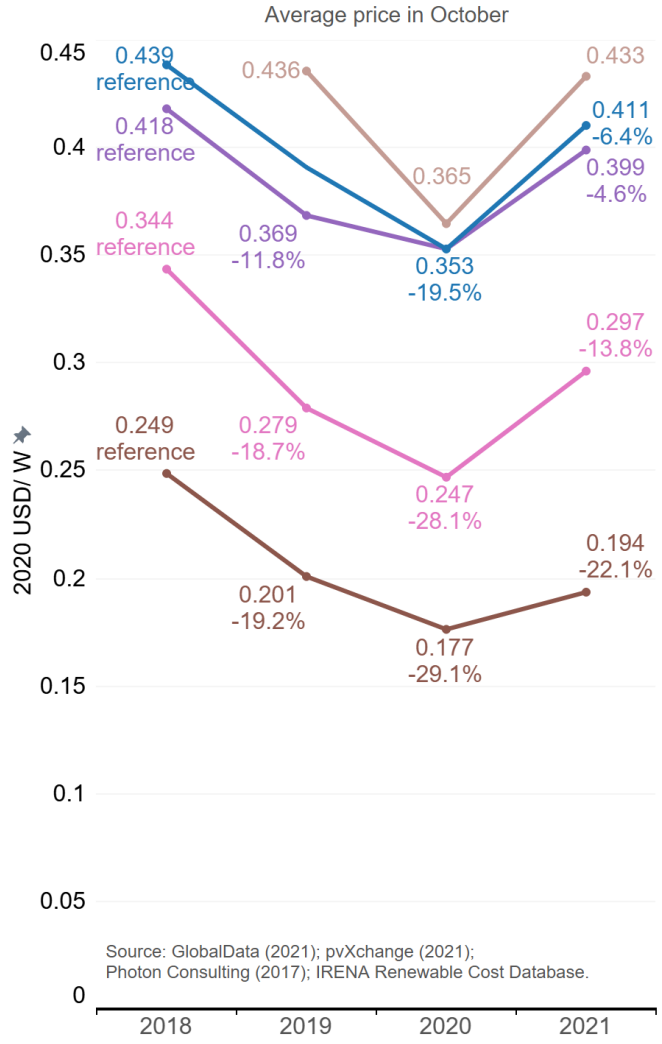
Multijunction cells promise significant efficiency gain

Record solar cell efficiency: III-V MJ (conc.) / mono-Si / CIGS / multi-Si / CdTe	47.1 / 26.7 / 23.4 / 24.4 / 21.0%

Solar PV module price trends, 2009-2021

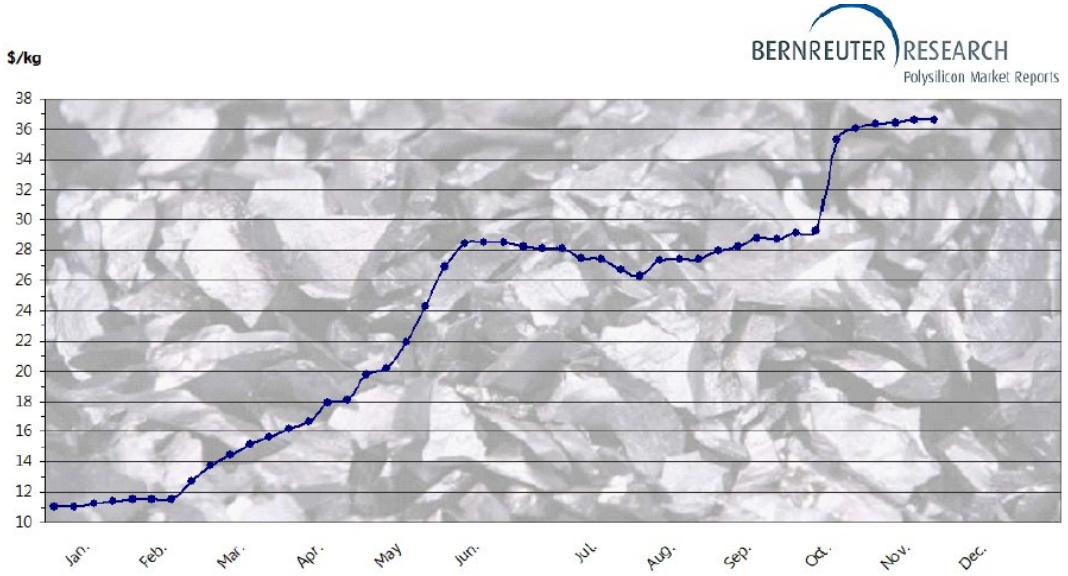
- Solar PV module costs – important driver for **improved competitiveness**
- Crystalline silicon module **prices declined** between **89% and 95% in Europe**
- **Factors**:
  - ❖ Increased economies of scale in manufacturing,
  - ❖ reduced labour costs,
  - ❖ falling material prices
  - ❖ materials use efficiencies,
  - ❖ process optimisations
  - ❖ continuous increase in module efficiencies
- **2021 supply chain disruptions** led to higher material costs or lower availability and is pushing up prices

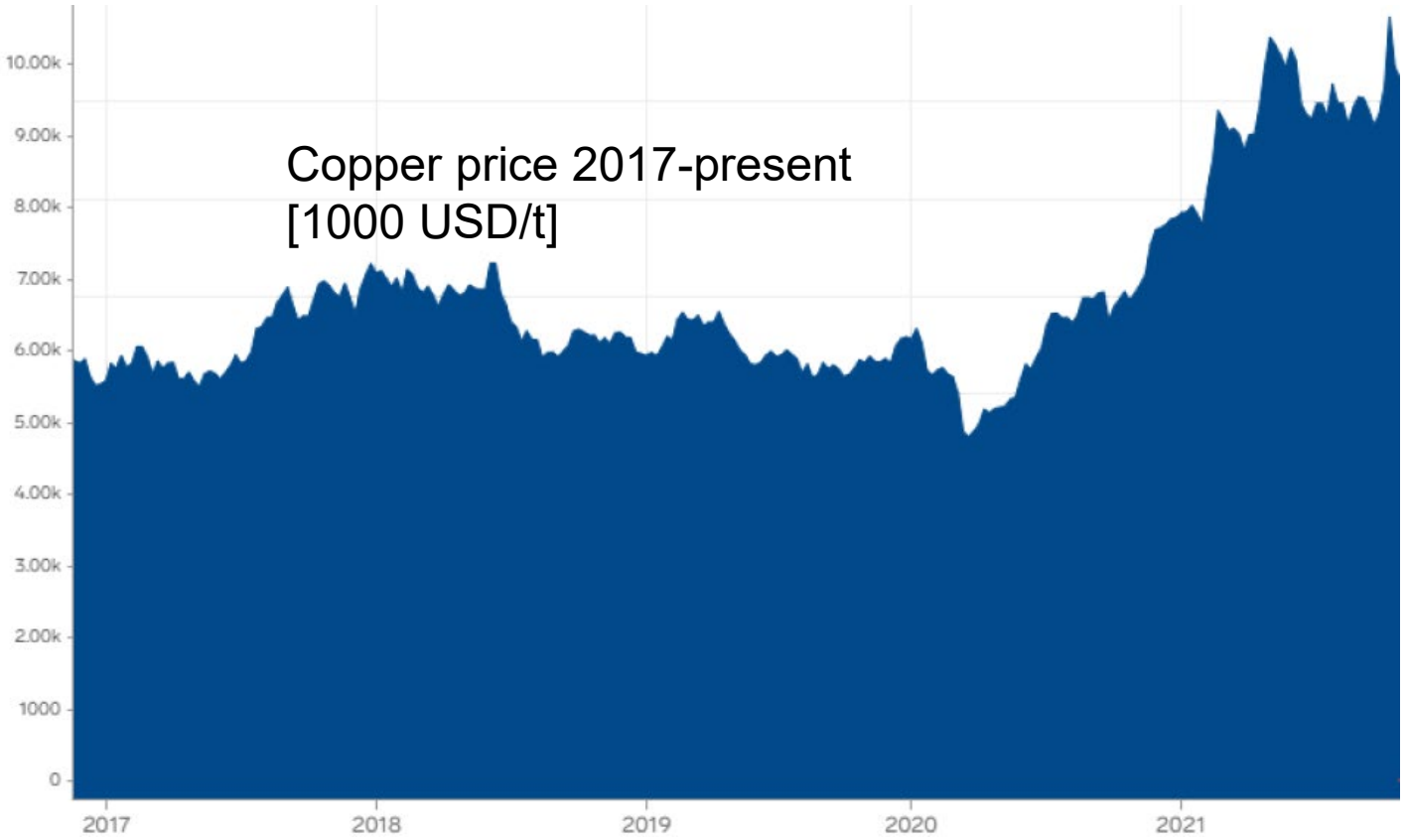




Critical materials for the energy transition
Materials price increase weighs on solar PV installation cost

- Rising materials prices are driving up
- Silicon & copper price rise
- 10% of silver is used for solar PV
- Copper use for connections
- Growing solar PV will require more glass





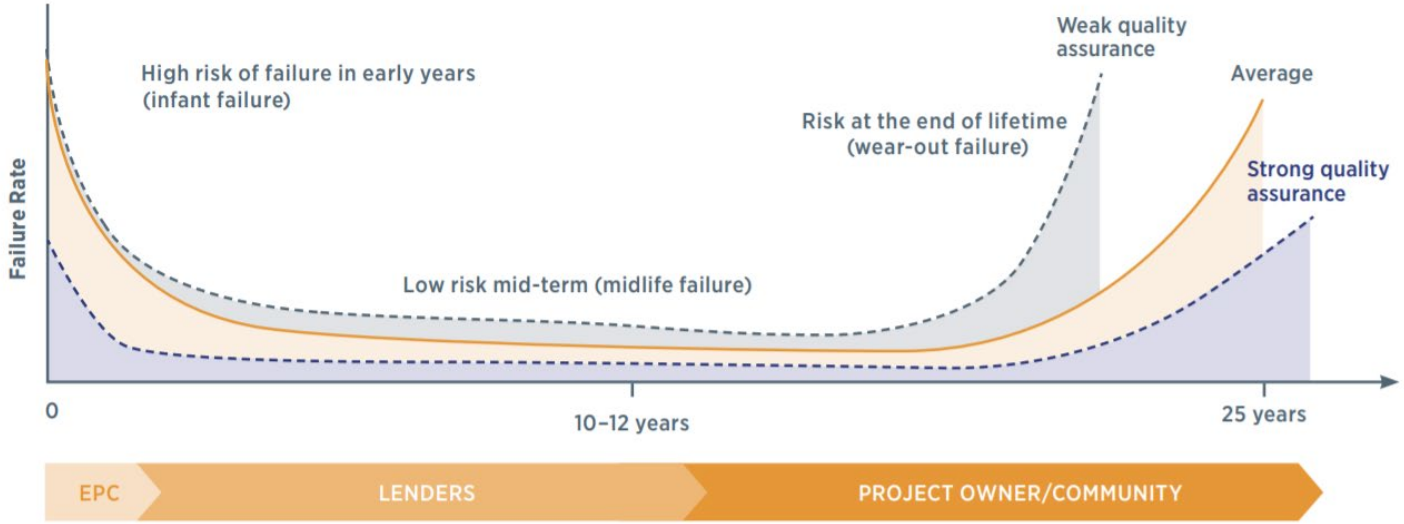
Inverters

- Inverter **efficiency** for state-of-the-art brand products is **98% and higher**
- **String** inverters:
  - market share 64%
  - Used in residential, small and medium commercial applications in PV systems up to 150 kWp
- **Central** inverters:
  - Market share: 34%
  - Used in large commercial and utility-scale systems
- **Trends:** Digitalisation, repowering, new features for grid stabilization and optimization of self-consumption, storage, utilisation of innovative semiconductors (SiC and GaN) which allow very high efficiencies and compact designs; 1500 V maximum DF string voltage

Emerging markets in locations with different weather conditions – need to consider new standards

Importance of Quality Infrastructure to Ensure Healthy Markets

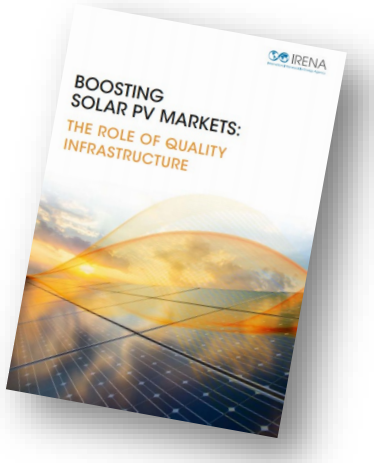
Figure 1.4. Failure curve of solar photovoltaic system



Weather Impact	Issue
Extreme Temperature	Reduced efficiency, affects PID
Temperature variations	Broken interconnects, broken cells, solder bond failures, junction box adhesion problems, open circuits leading to arcing, open circuits of the module connection, etc.
Dust storms	Abrasion, soiling, cementation, hot spots, etc.
Drought	Affects ventilation systems (transformer)
UV Irradiation	EVA-browning, encapsulant adhesion or delamination; damage to (cable) isolation

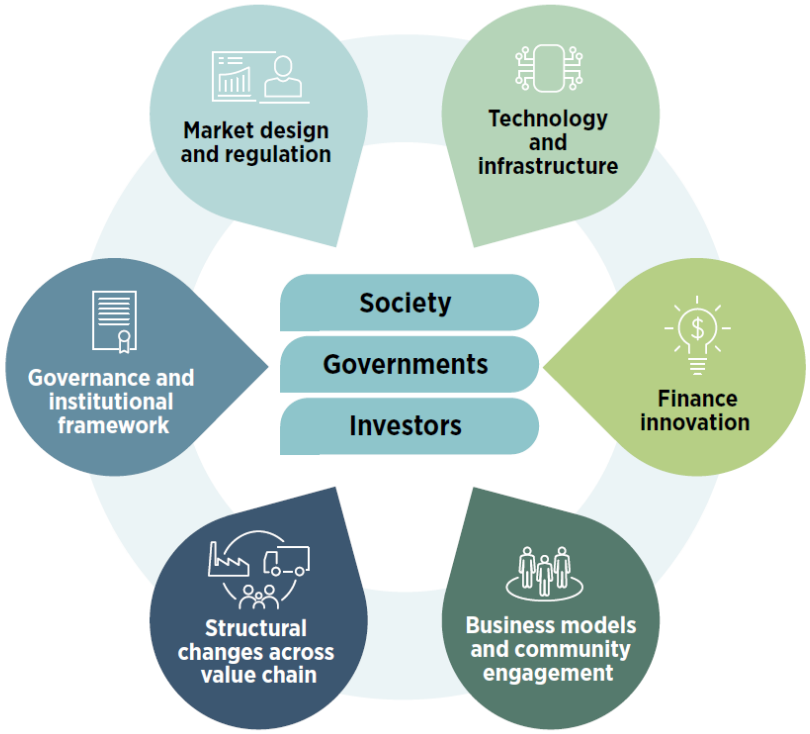
Standardisation & Conformity Assessment

- IEC 61701/62716 (salt/ammonia corrosion)
- IEC TS 62782 (mechanical load)
- IEC TS 62804 (PID)
- DIN 52348 (sand abrasion test)
- IEC 62892: Additional tests to reflect different climates and applications (thermal stress, UV, high humidity)

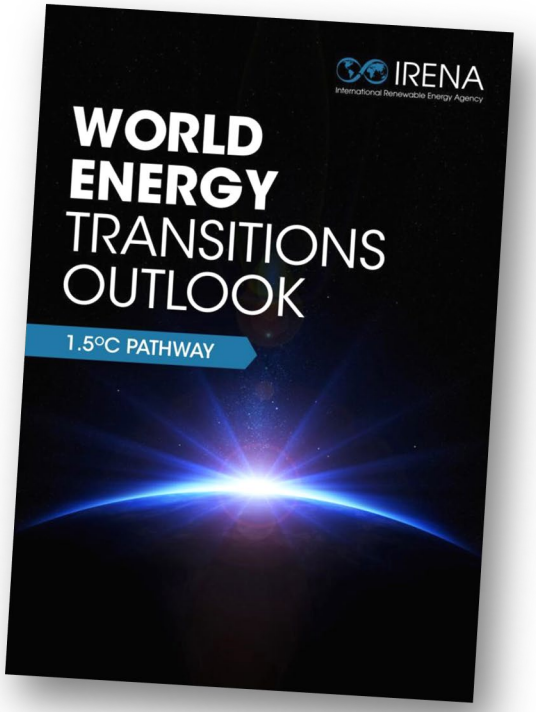


Source: https://www.irena.org/publications/2017/Sep/Boosting-solar-PV-markets-The-role-of-quality-infrastructure

Considerations for a successful industrial energy transition



- Net zero ambitions yes, but net zero implementation?
- Access to renewable energy & enabling infrastructure
- Additional cost, competitiveness and carbon leakage – certification for green commodities
- Systemic innovation – flexibility, adjusted global value chains
- Social acceptance
- International quality infrastructure considering context of new markets
- Stranded assets and retrofit potentials for integrated production processes



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