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ITRPV | International Technology Roadmap for Photovoltaics

VDMA

ITRPV 10th edition 2019 - report release and key findings

Markus Fischer

PV CellTech Conference, March 13 2019

Penang, Malaysia

Outline

1. ITRPV – Status and PV learning Curve
2. ITRPV – Results 2018
   - Wafer - Products, Materials, Processes
   - Cell - Products, Materials, Processes
   - Module - Products, Materials, Processes
   - Systems
3. Outlook and Summary

Outline

1. ITRPV – Status and PV learning Curve

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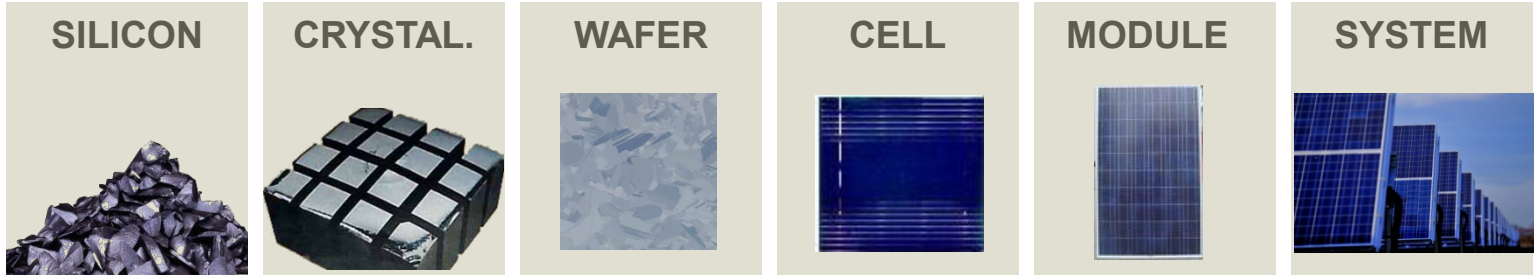
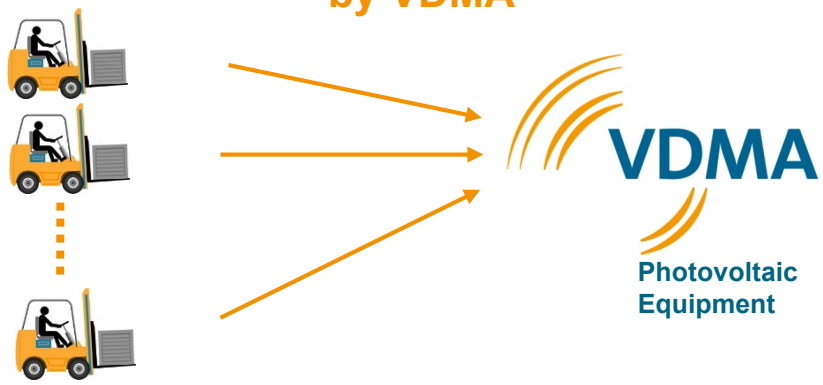
ITRPV – Methodology / Statistics

10th edition: 55 contributors from Asia, Europe, and US

Figures o/a: 90 (71)
Materials: 19 (16)
Processes: 29 (21)
Products: 20 (14)
PV systems: 9 (8)

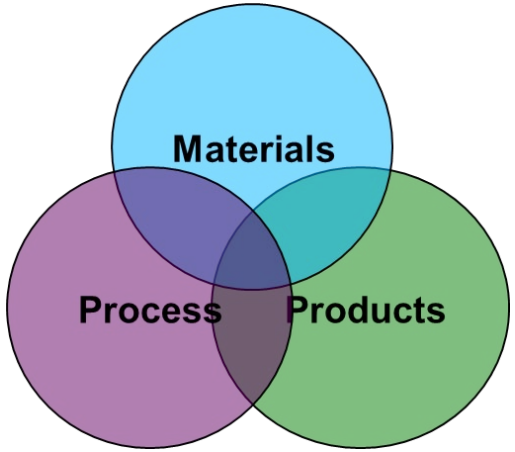


Participating companies → **Independent data collection / processing by VDMA** → **Review of data Preparation of publication → regional chairs** → **Next ITRPV edition**



- Chairs US
- Chairs PRC
- Chairs TW
- Chairs US

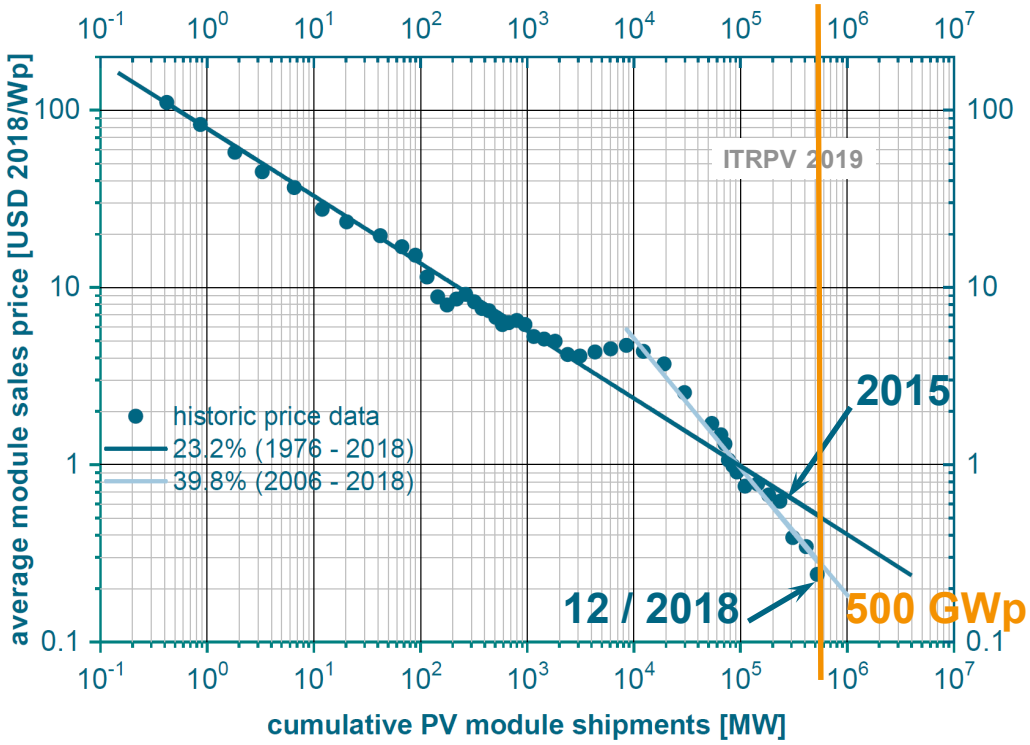
VDMA



Parameters in main areas are discussed → Diagrams of median values

PV learning curve

Learning curve for module price as a function of cumulative shipments



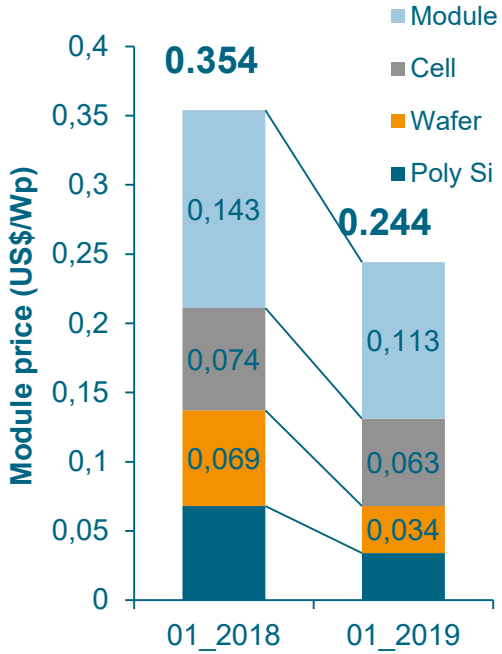
Shipments /avg. price at years end:

2017: 105 GWp / 0.35US$/Wp
2018: 109 GWp / 0.24 US$/Wp

o/a shipment: ≈ 523 GWp
o/a installation: ≈ 504 GWp

0.5 TWp milestone passed!

LR ≈23 % (1976 …. 2018)
LR ≈40 % (2006 …. 2018)



→ Stable volume shipped with **huge** price deterioration

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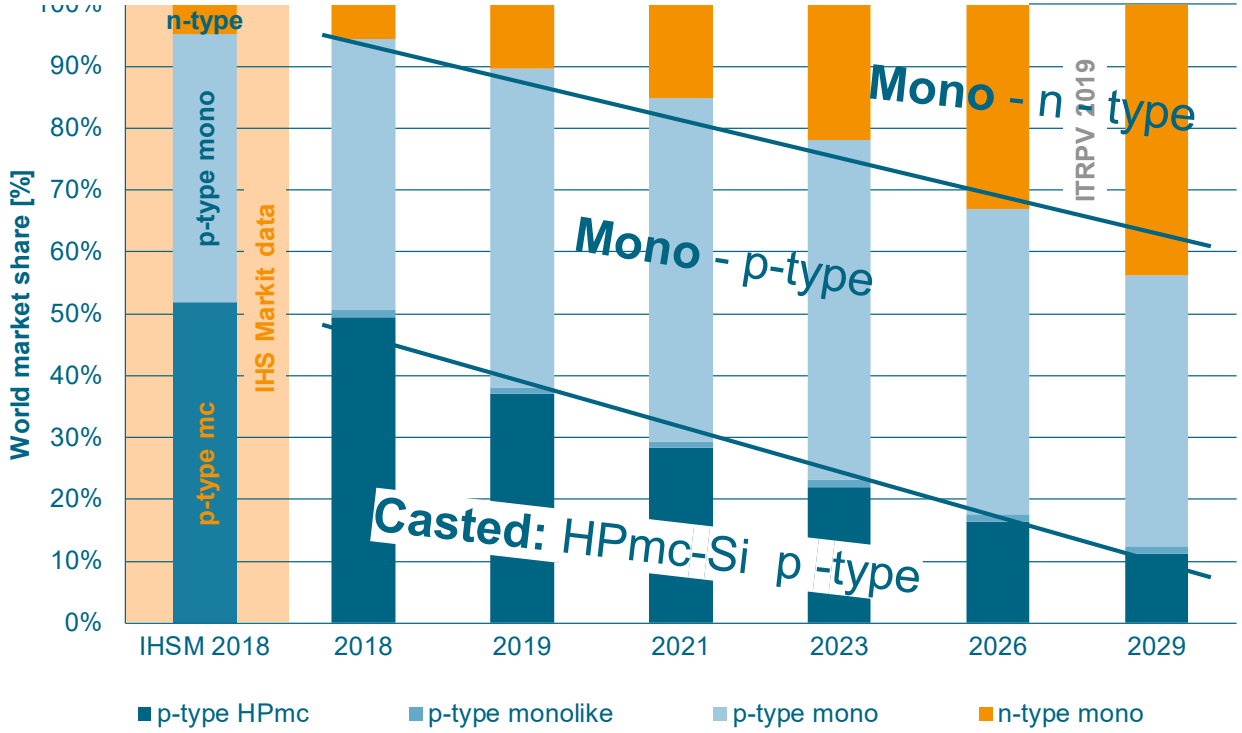
Wafer: Product –market share of wafer type

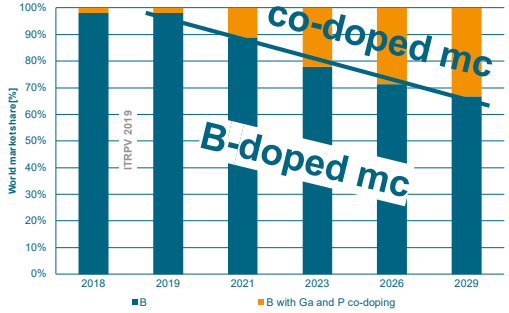
Trend: share of c-Si material types



→ **Mono will dominate** (further boost by n-type)

- **p-type material will stay mainstream until 2029**
  → base for p-PERC technology

- **casted-Si share shrunk to 50%:**
  → Dominance is gone,
  → p-type **HP** mc-Si is dominating
  → mono-cast @ 1%
  → **co-doping with Ga/P** will improve ingot quality

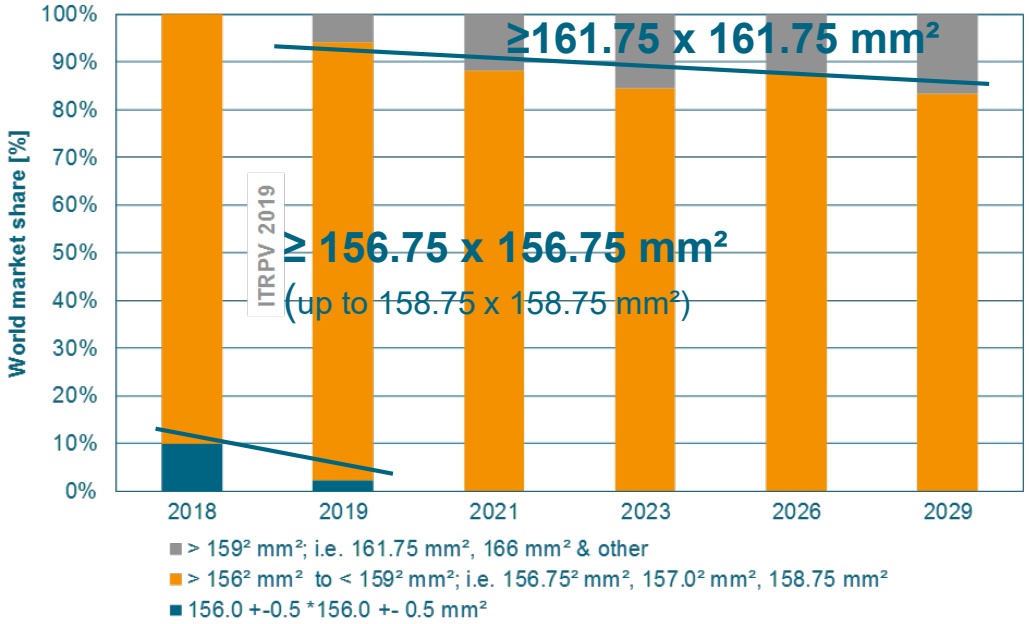


- **Mono technology will fast gain market share:**
  → n- + p-type ≈60% in 2019
  → n-type material share will increase (HJT, Topcon)
  → p-type will stay mainstream
  Ga doping expected to improve

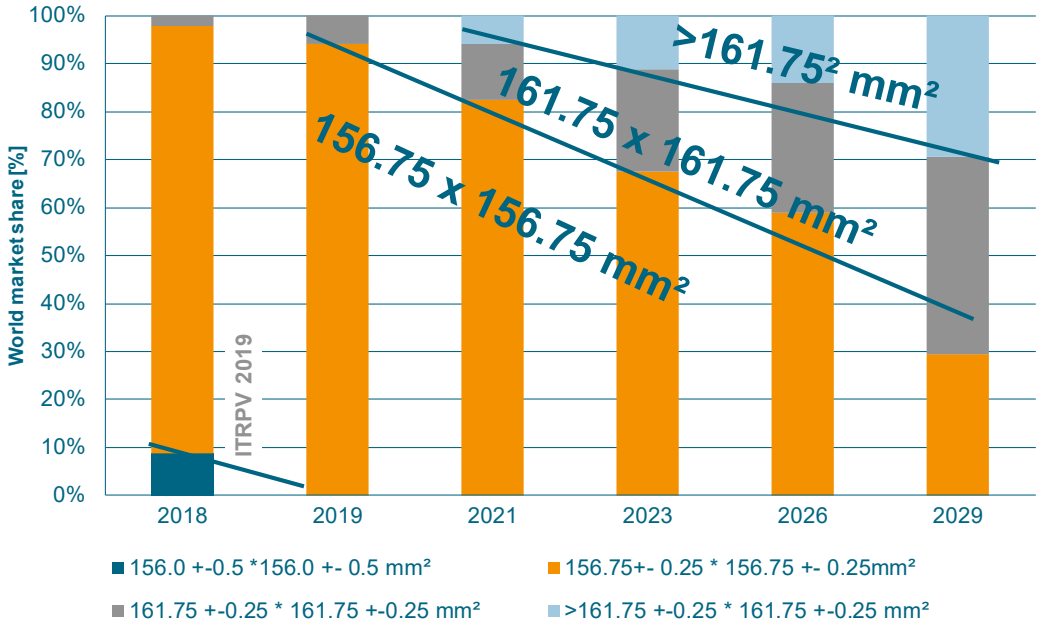
- **2018 values in line w/ IHS Markit analysis**

Wafer: Product - market share of wafer sizes

Trend: mc-Si wafer size
→ several new formats appear



Trend: mono-Si wafer size
→Mono will soon use ≥161.75x161.75mm²

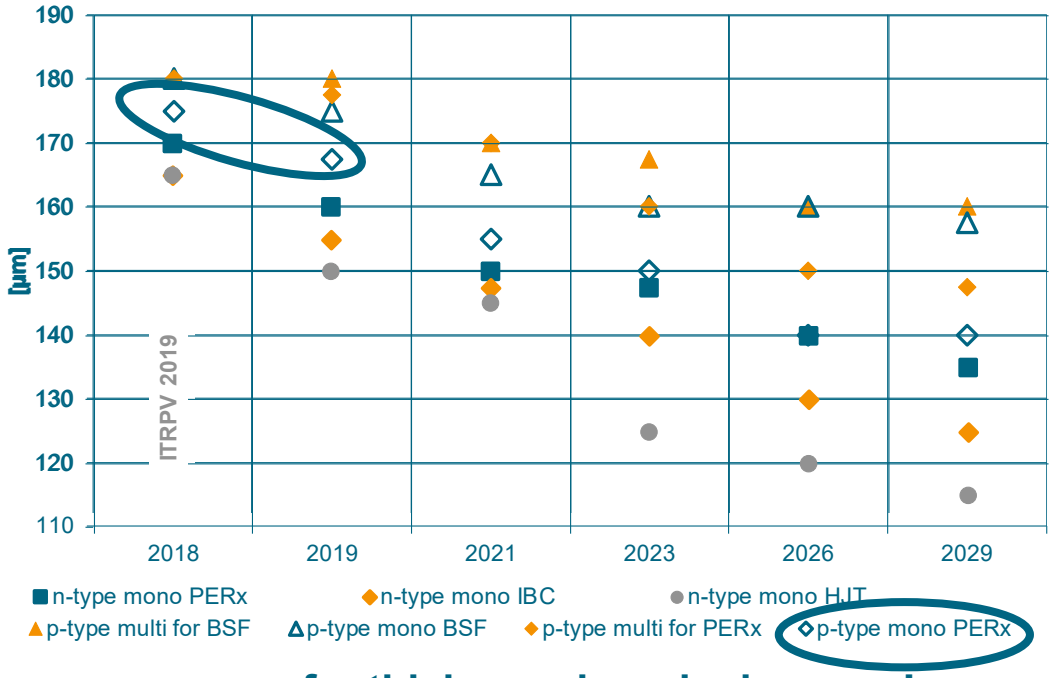


- **≥156.75 x 156.75 mm² is mainstream now!**
  →156 x 156 mm² - disappeared
  161.75x 161.75 mm² require upgrades of existing lines and larger modules
  → new tools/fabs for even larger wafers

Standardization is required

Wafer: Process – crystallization / wafering technology

Trend: wafer thickness



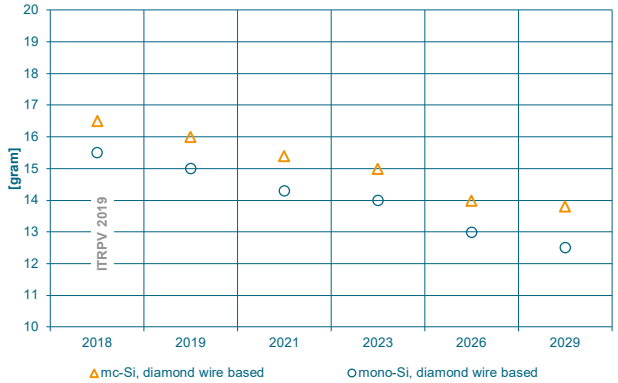
- **mono wafer thickness is reducing now!**

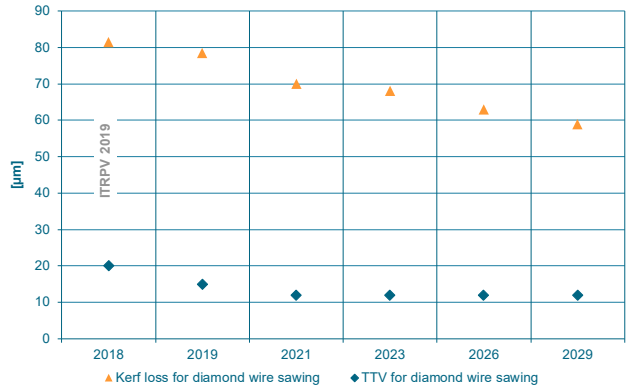
  2019 2029

  →p-type ≈170µm today, →140µm driven by PERx
  →n-type ≈150µm today, →115µm HJT leads
  →mc-Si still delayed

→ **Diamond wire** sawing is the only wiring technology

Trend: poly-Si utilization / kerf loss





- Poly-Si utilization:
  → ≈16.5g / mono-Si wafer
  → ≈ 15.5g mc-Si wafer

- kerf loss
  → ≈80µm 2019
  → ≈60µm 2029
- TTV
  → will improve to 10µm

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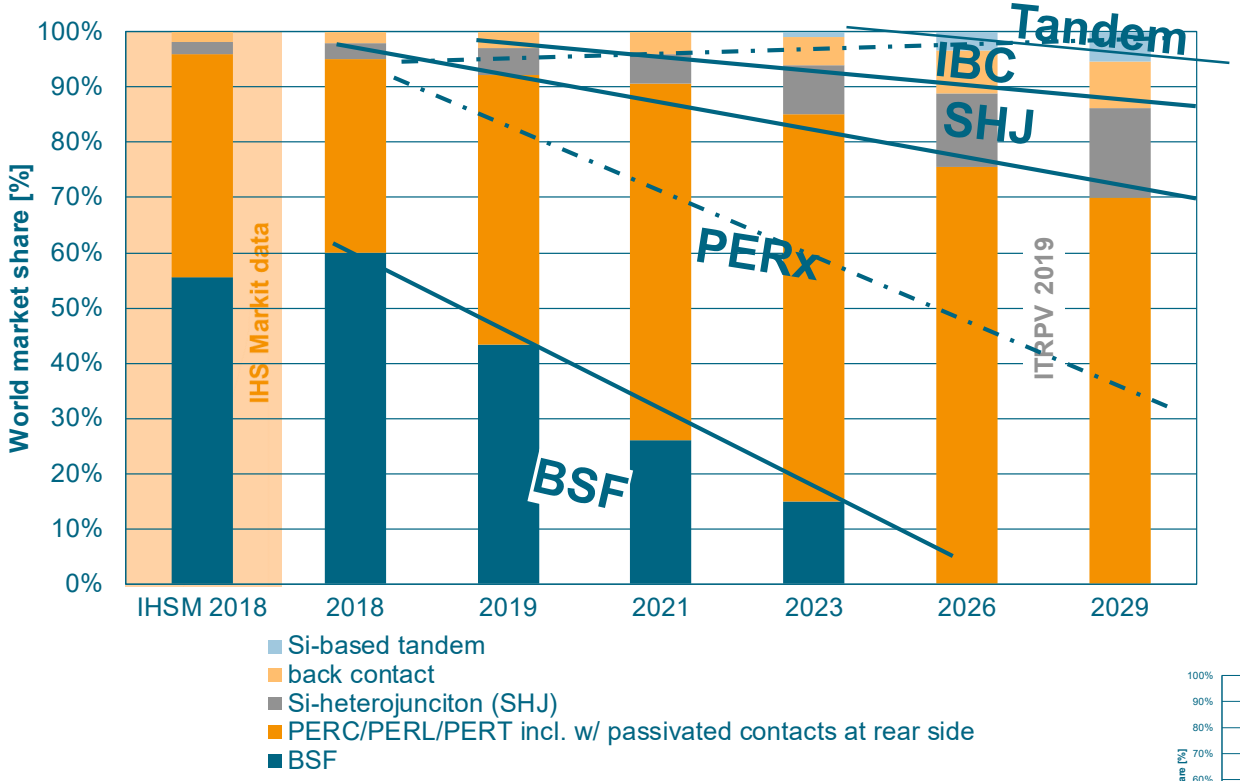
Cell: Product – market share of cell technologies

Trend: share of cell technologies

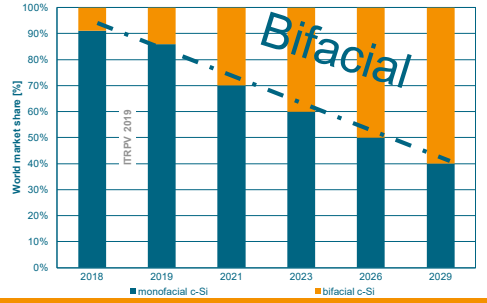


→ **PERx - technologies will dominate**
(2018 ITRPV data are close to IHS Markit)

- **BSF**
  → ≈40% share in 2019
  → focus on mc-Si BSF
  → will disappear after 2025

- **PERx (incl. passivated contacts)**
  → >50% share in 2019
  → market mainstream in coming years
  → on p- and n- type
- **Si- heterojunction (SHJ)**
  → ≈2% in 2018 → >15% in 2029
  → on n-type only
- **Back contact concepts**
  → ≈2 % in 2018 → 10% in 2029
- **Si-Tandem** expected from 2023 onwards

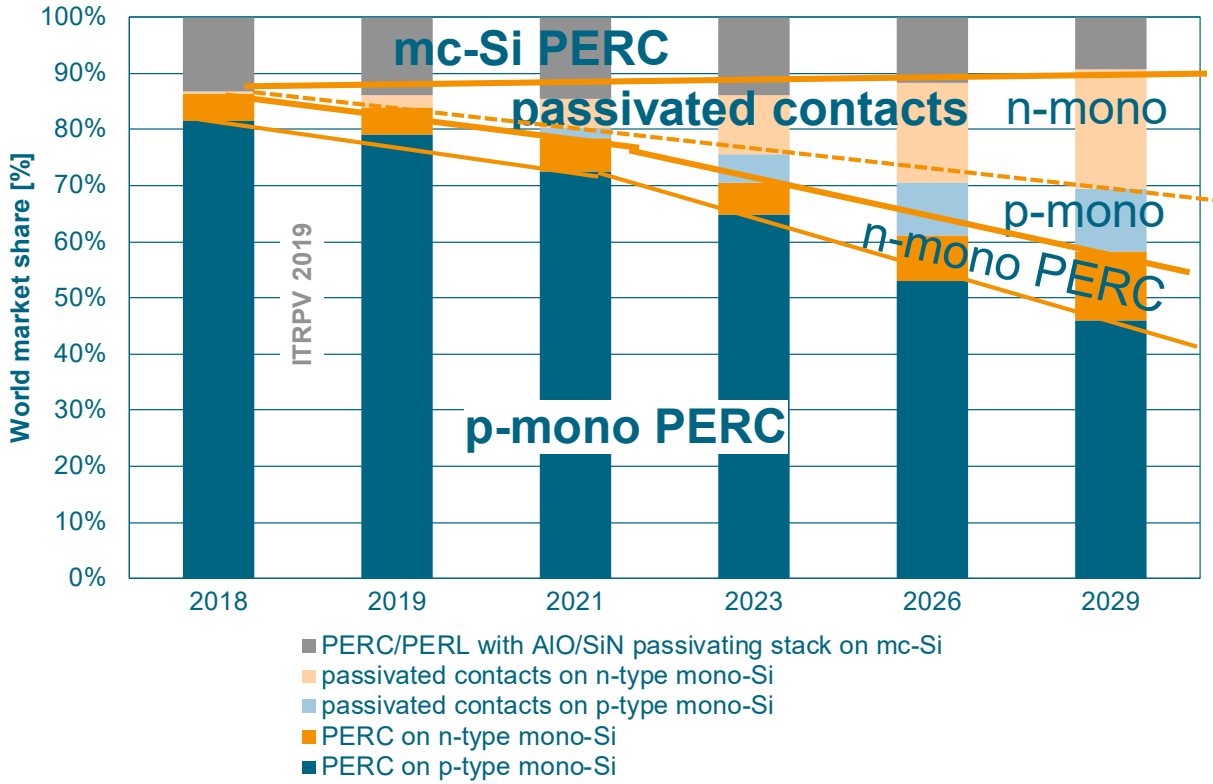
fit for **Bifacial**



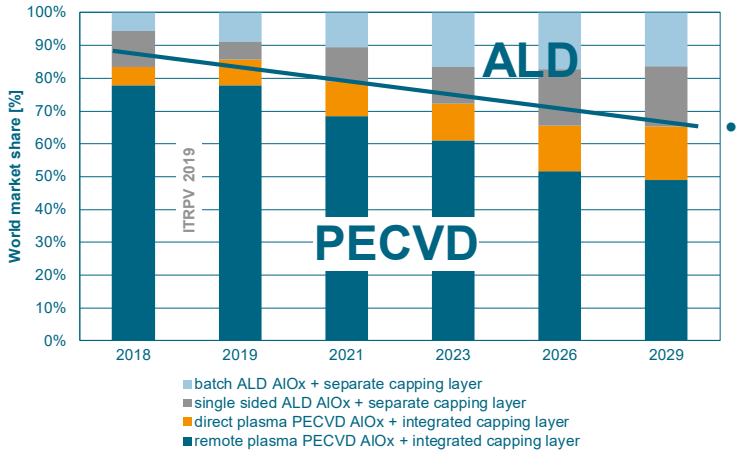
Bifacial cells will gain share
→ ≈15% in 2019
→ ≈60% in 2029

Cell: Process – market share of PERx cell technologies

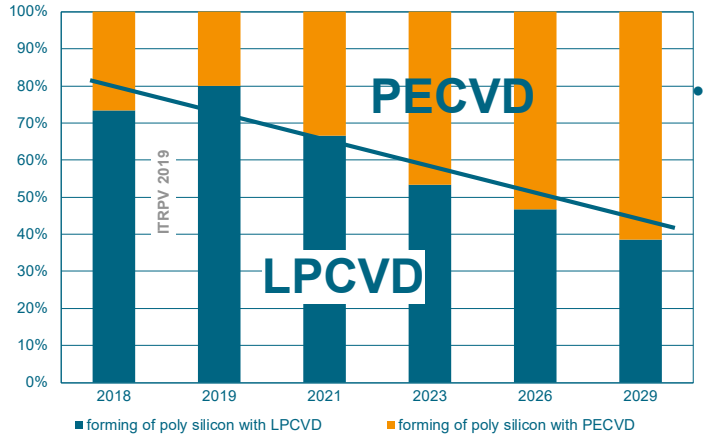
Trend: Passivated Emitter and Rear concepts



Trend: rear passivation processes



PERC (with contacts)
→PECVD (AlOx/SiN)
= mainstream
→ ALD AlOx
= will gain market



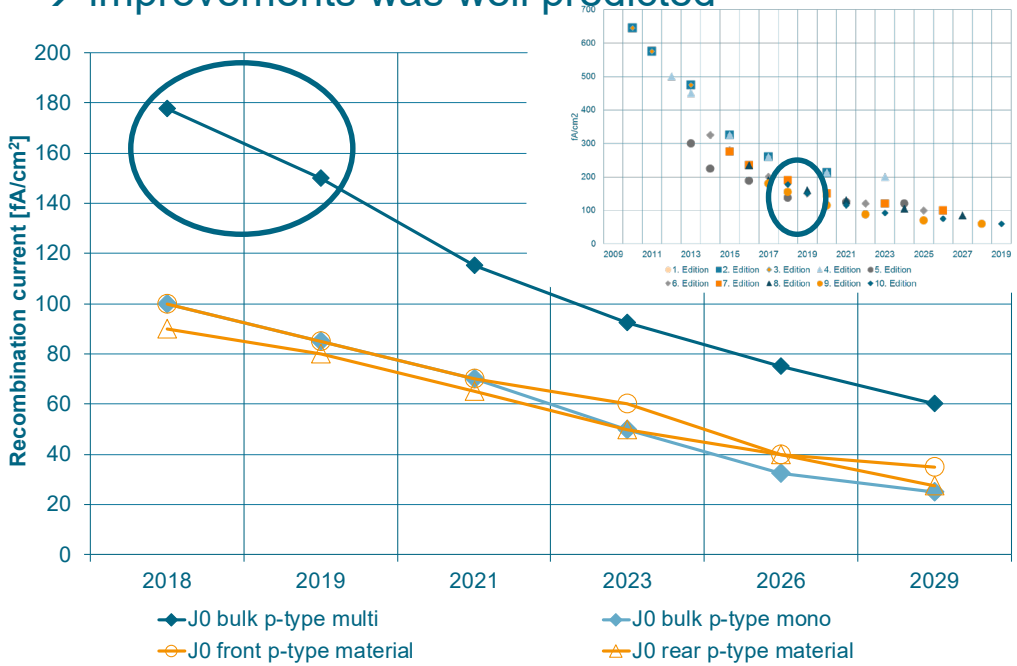
Passivated contacts
- poly-Si deposition:
→ LPCVD vs. PECVD
- tunnel oxide forming
→ in-situ preferred
- poly-Si doping
→ in-situ preferred

→ **PERC with AlO/SiN stack is mainstream**
→ **Passivated contact concepts will gain market share**

Cell: Process– recombination losses

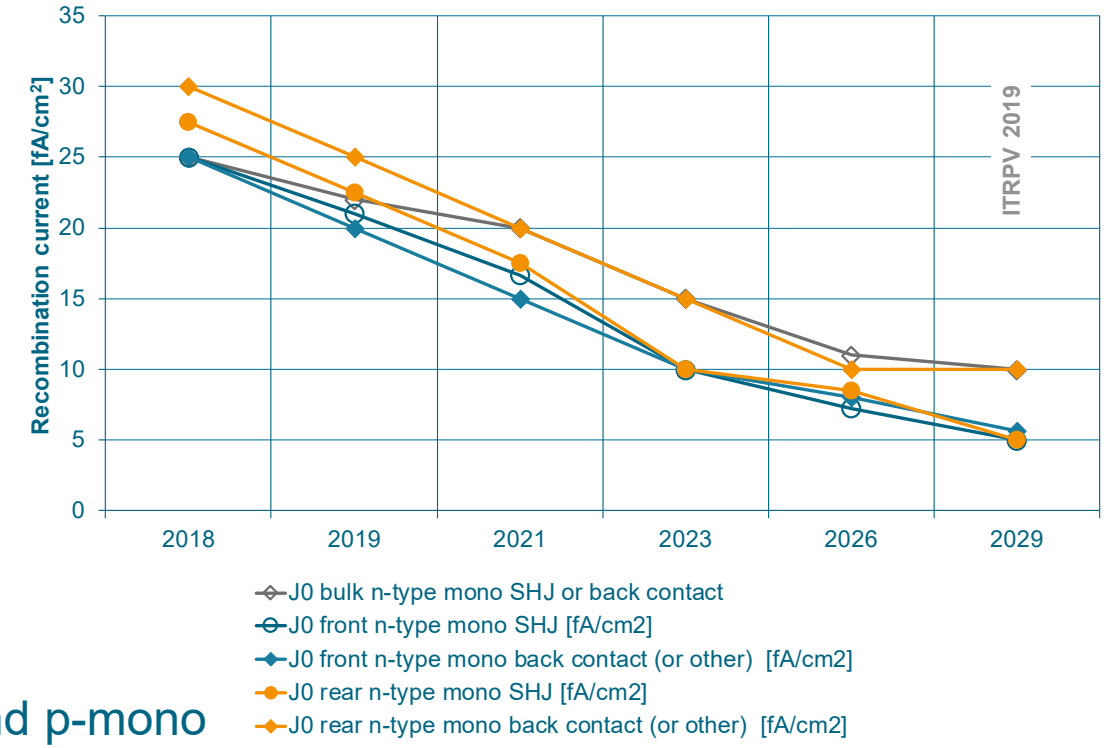
Trend: J0 p-type materials

→ improvements was well predicted



Trend: J0 n-type materials

→ n-type has much lower J0



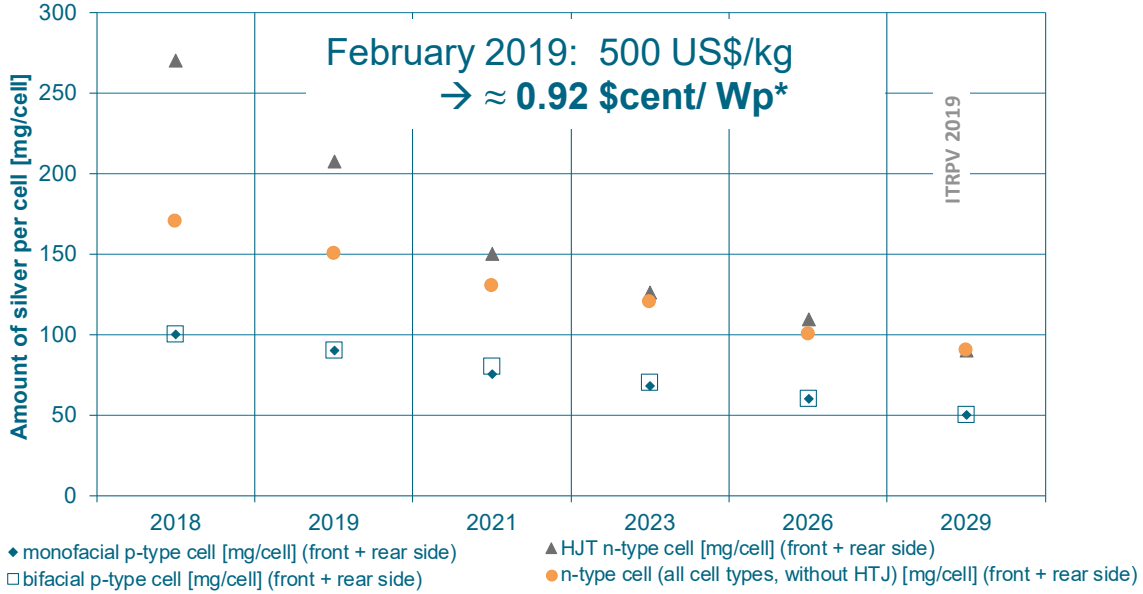
	2018		2023
J0 bulk:	p-mc-Si 178 fA/cm²	→	90 fA/cm² ≈ 5y behind p-mono
	p-mono 100 fA/cm²	→	50 fA/cm² ≈10y behind n-mono
	n-mono 25 fA/cm²	**→**	**10 fA/cm²**

J0 front/rear → close to mono bulk values

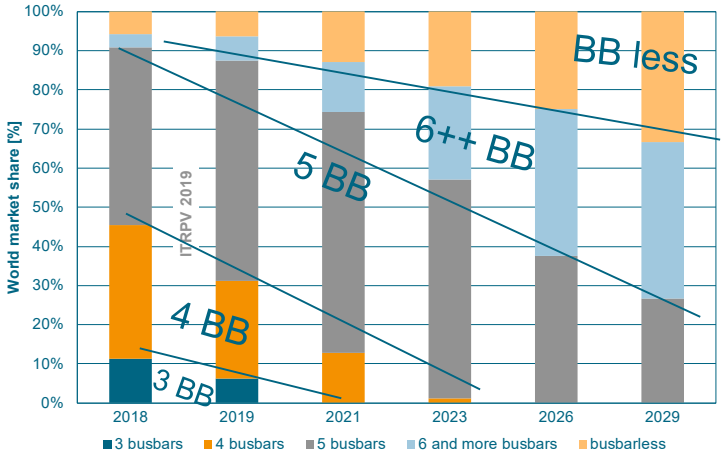
Cell: Process – metallization trends

2019: 20.25% x 0.987 (CTM) ≈ 4.91W/ cell *
→ ≈ 18.3 t / GWp
→ ≈ 18300 t @100GW = 6.3 % of world Silver market 2017**
Photography 1996: 40% of annual Silver market**

Trend: remaining Silver (predictions were met)

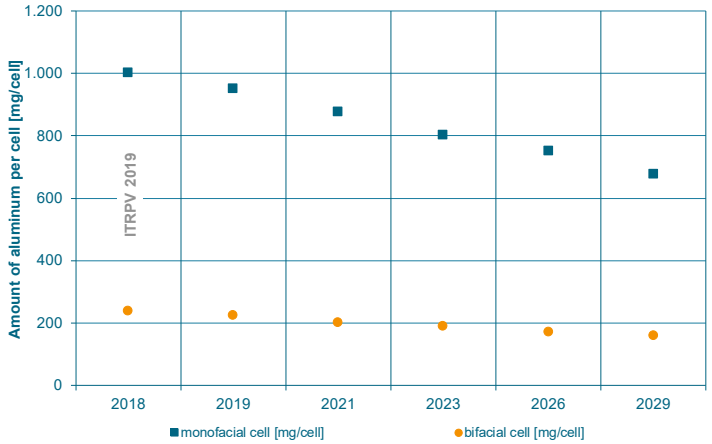


Trend: number of bus bars



- **BB trend:**
  →5 BB+ is mainstream
  → 3/4BB will disappear

Trend: remaining Aluminum



- **Rear side Al trend:**
  →1 g for mono-facial
  →Bifacial uses 20% only

Silver reduction will continue

→ 90mg Ag for p-type cells
→ n-type concepts use more Ag

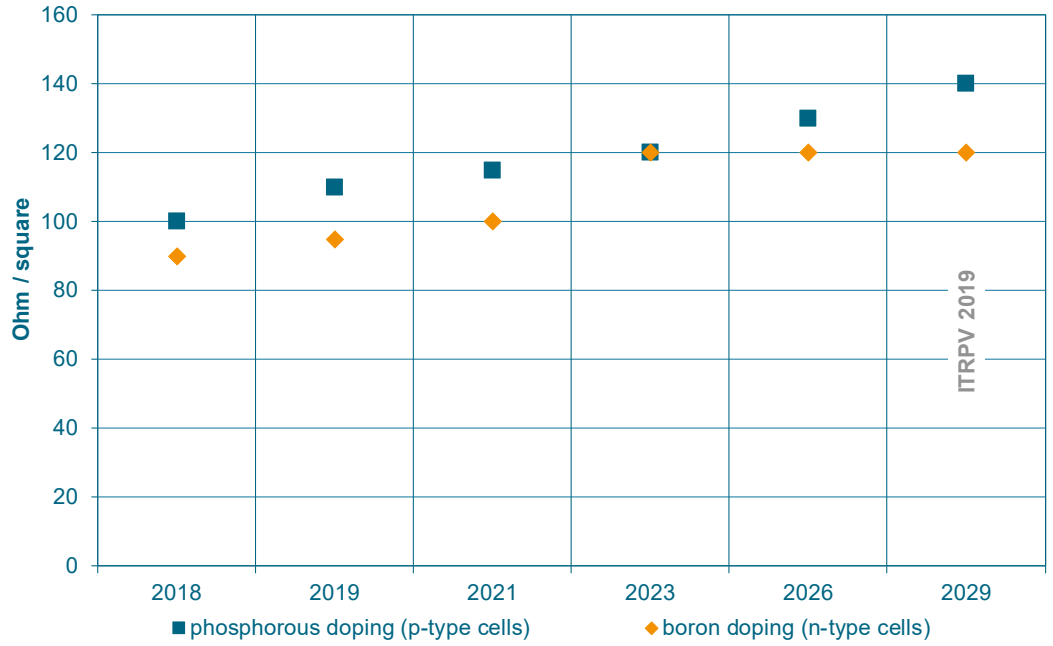
Measures: - reduction of finger width → more bus bars
- finger width 40µm → 20µm in 2029
- Single print will remain mainstream

* avg. module power 290W labeled ; ** Assumption ≈ 29,000t / 1018 MOz 2017 market https://www.silverinstitute.org/publications/

Cell: Process – emitter doping

Trend: emitter sheet resistance

Sheet resistance will increase further



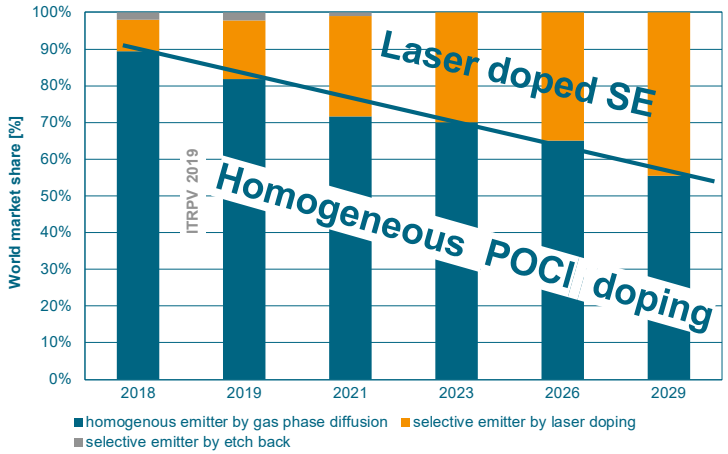
P-doping: 2018: 100 Ω/□ → 2029 140 Ω/□

→ selective emitter use will be intensified

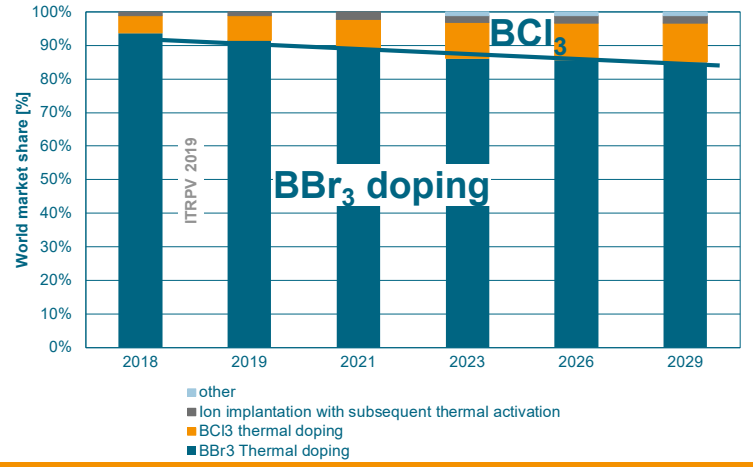
B-doping: 2018: 90 Ω/□ → 2029 120 Ω/□

Trend: doping processes

→ P-doping: selective emitter will gain



→ B-doping: BBr_3 is mainstream

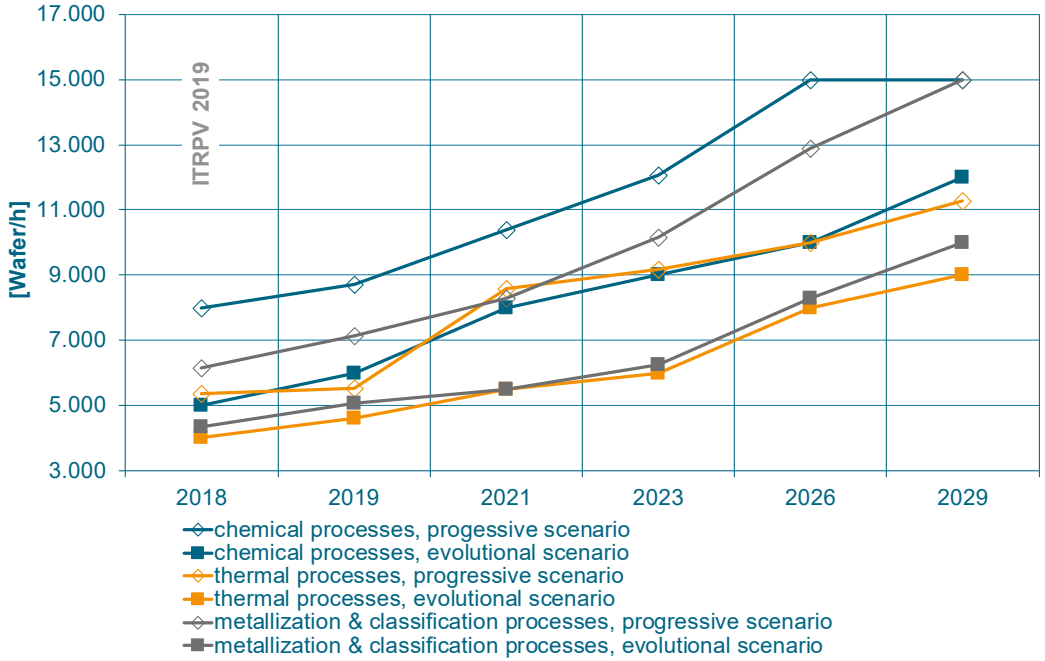


Cell: Process – throughput / OEE / smart fab trends

Trend: cell process tool throughput

→ wet will lead the throughput increase

→ metallization will impressively improve

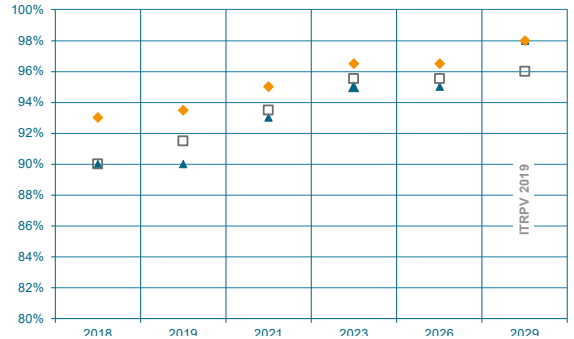


→ **Thermal processing is behind**

Trend: OEE 2018/ 2025

→ chemical is leading: 93% / 96%

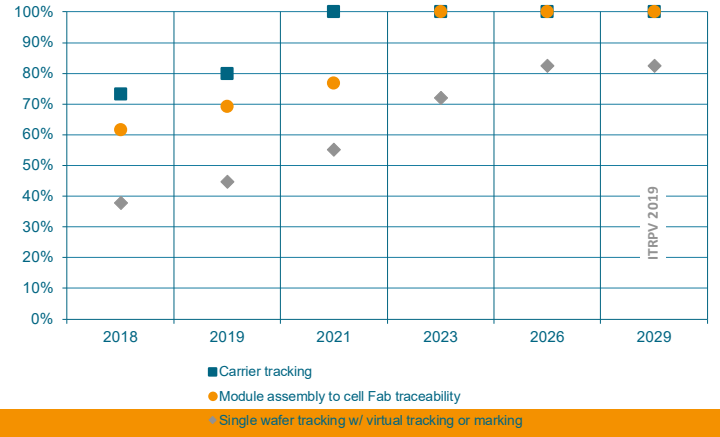
→ thermal and metallization: 90% / 95%



Trend: WIP tracking standard

→ carrier and wafer tracking

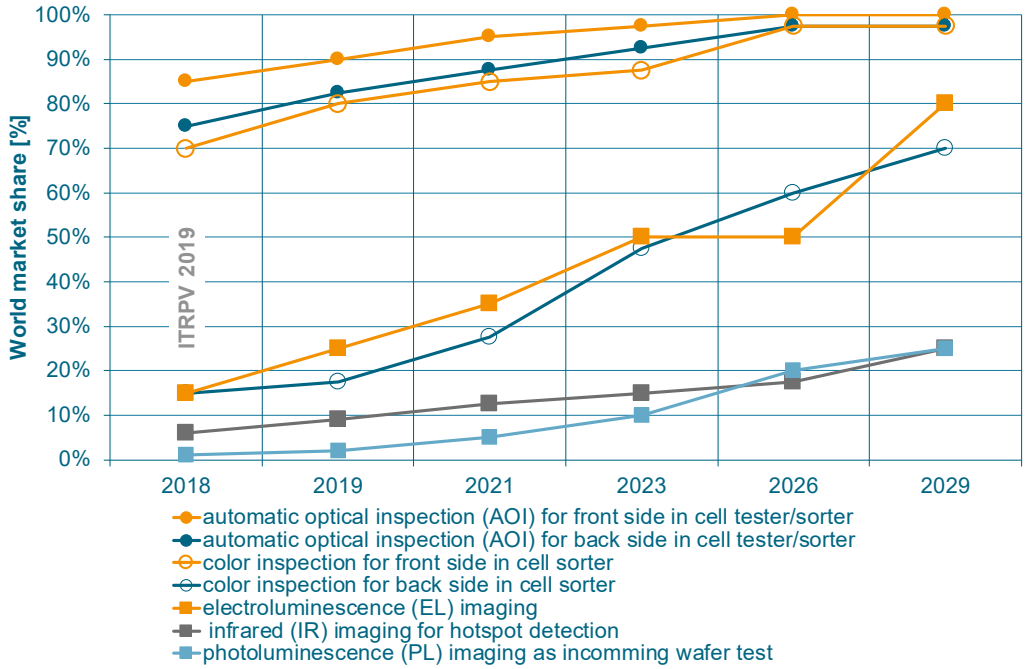
→ link cell to module tracability



Cell: Process – in-line process control /MES

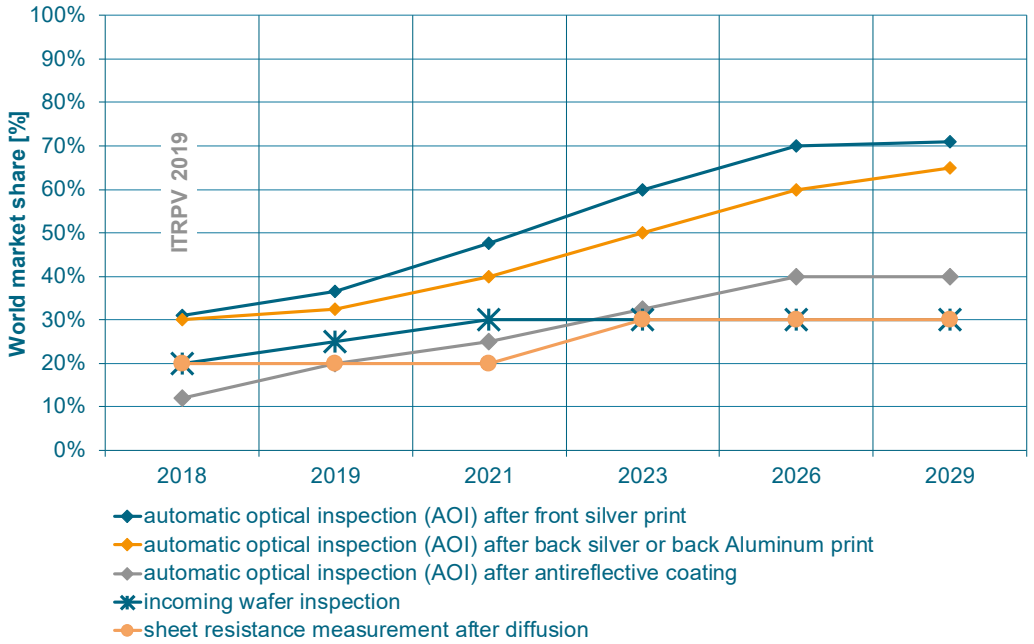
Trend: inspection at cell test

- AOI in cell test is standard → 100% in 2025
- EL on cell level is increasing market



Trend: in-line process control

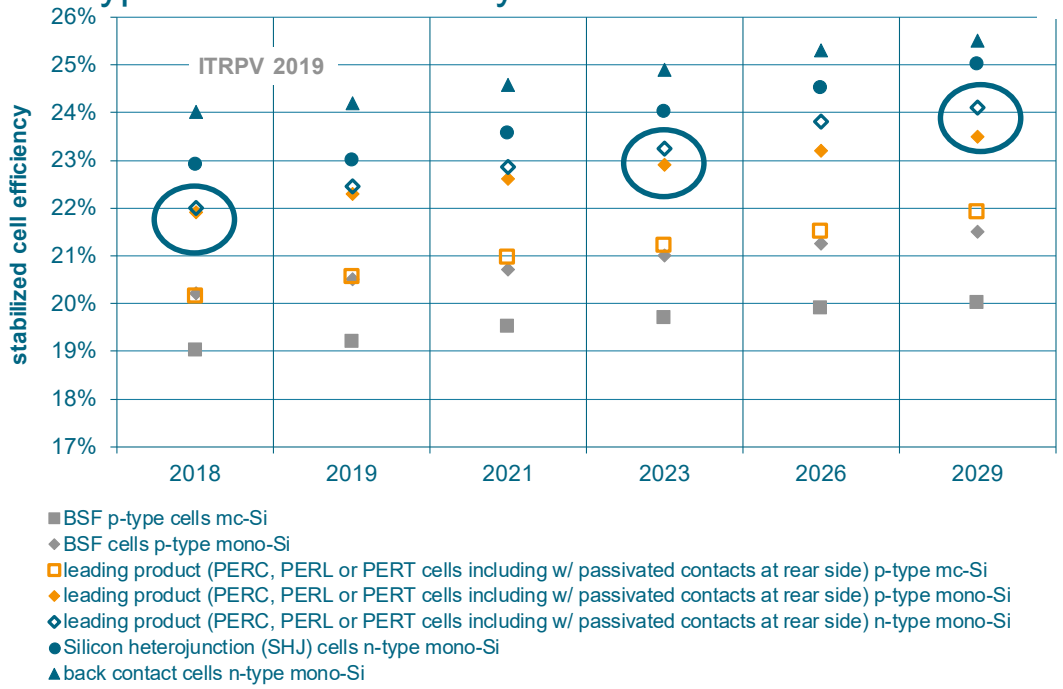
→ printer inspection will gain share
→ other inspection at low share



Cell: Product – cell efficiencies in mass production

Trend: cell efficiency

→ n-type leads in efficiency with SHJ and IBC



Trend: Cell fab size

→ 2GW will be min. Fab size

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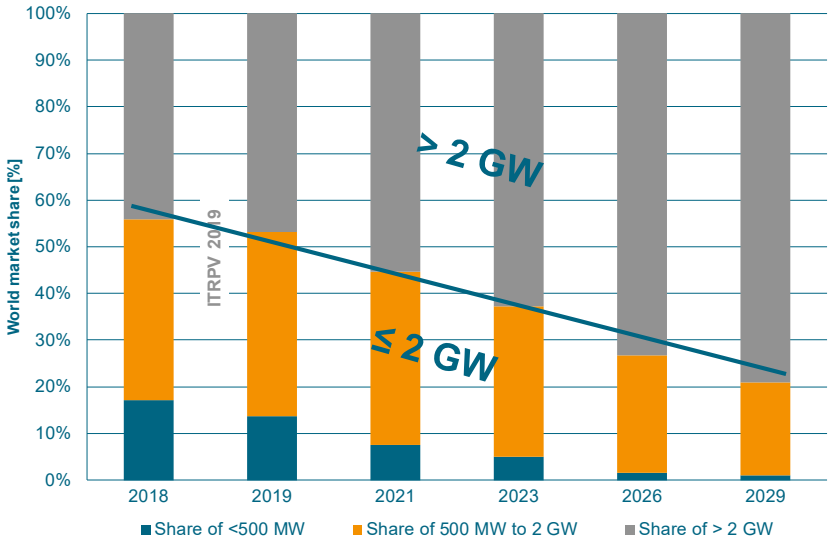

	2018	2023	2029	
mc-Si PERC:	20.2%	21.0%	22.0%	
p-mono PERC:	22.0	23.0	23.5%	
n-mono PERX:	22.0%	23.2%	24.0%	→passivated contacts
SHJ:	23.0%	24.0%	25.0%	

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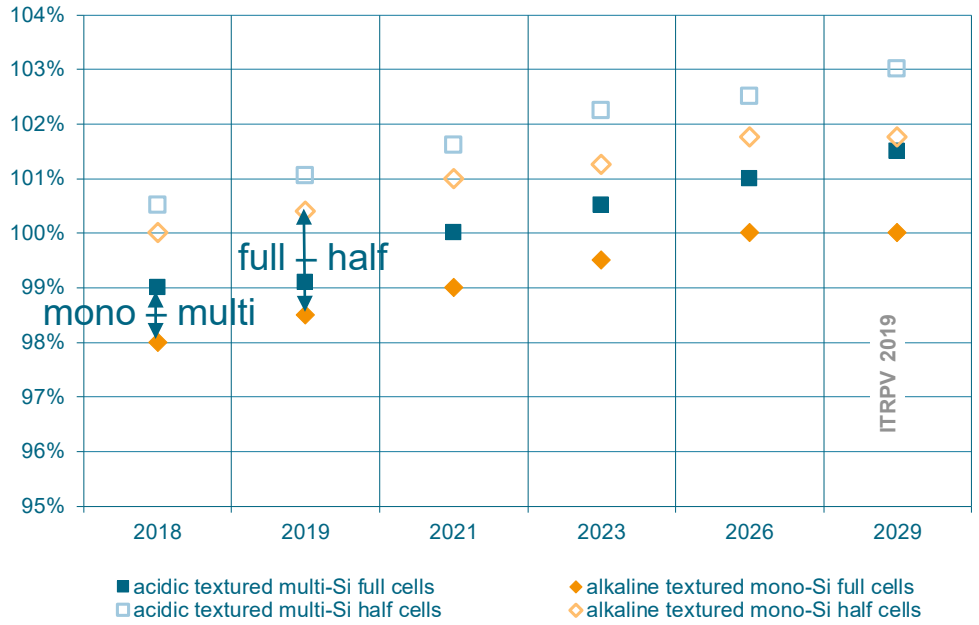
Module: Product – CTM and module power in mass production

Trend: CTM

→ ≈1% difference mc- / mono Si

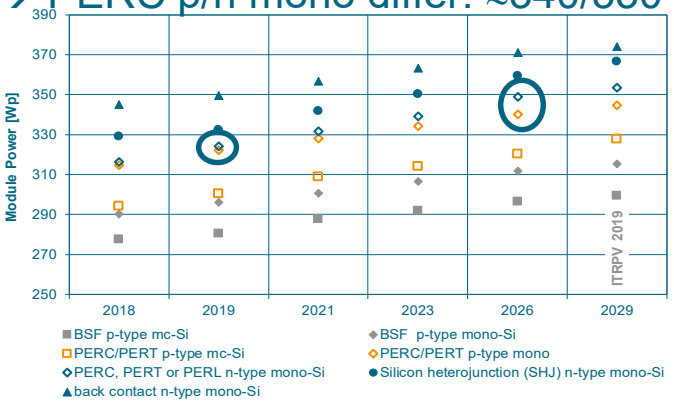
→ ≈2% CTM boost for half cell modules



Trend: Module power 60 (full) cell modules

2019 → PERC p/n mono closely: ≈320/320 Wp

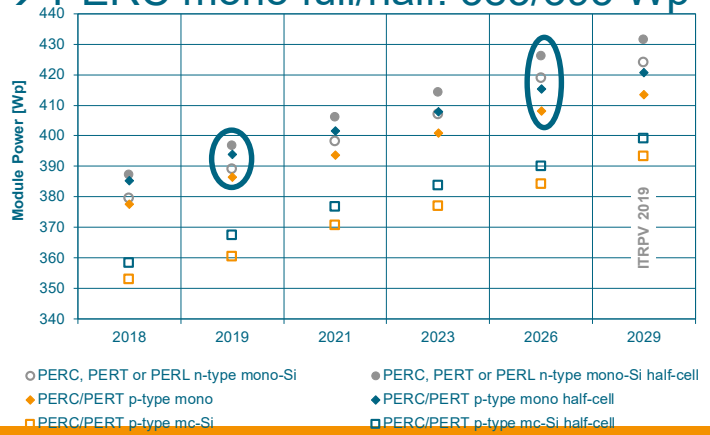
2026 → PERC p/n mono differ: ≈340/350 Wp



Trend: module power 72 cell modules

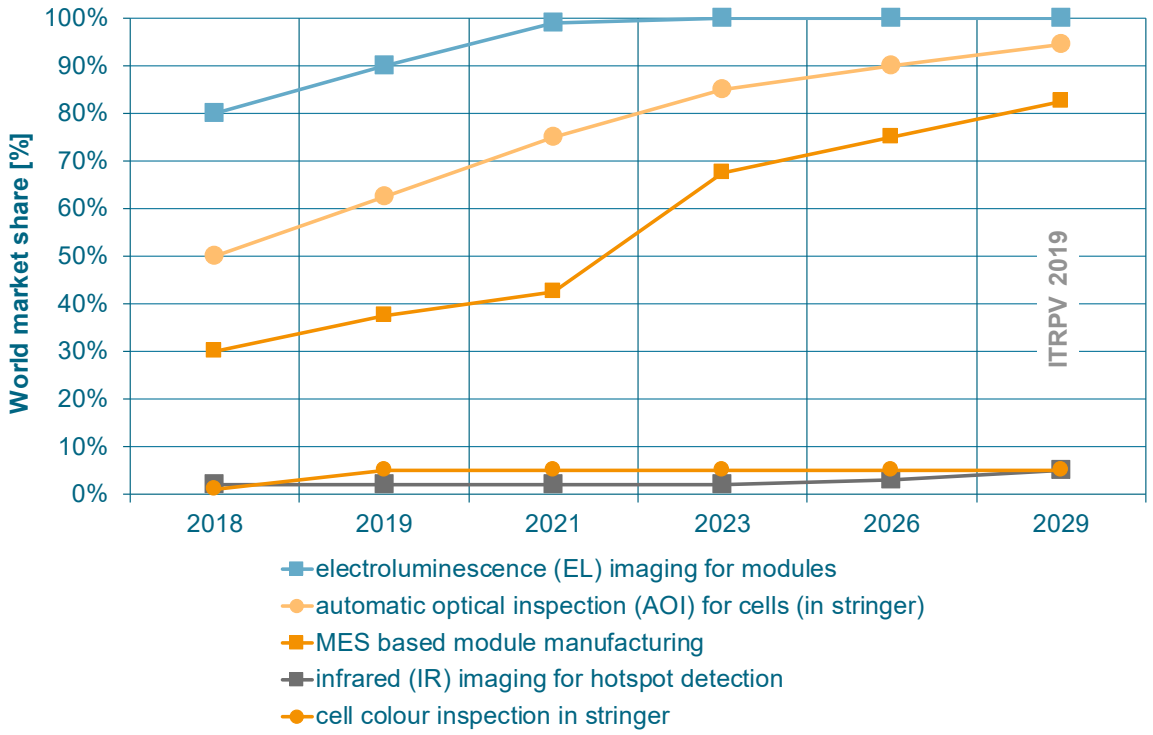
→ half cell: + 1..2 class more power

2019 → PERC mono full/half: 385/395 Wp → **2026: n half: 425Wp**

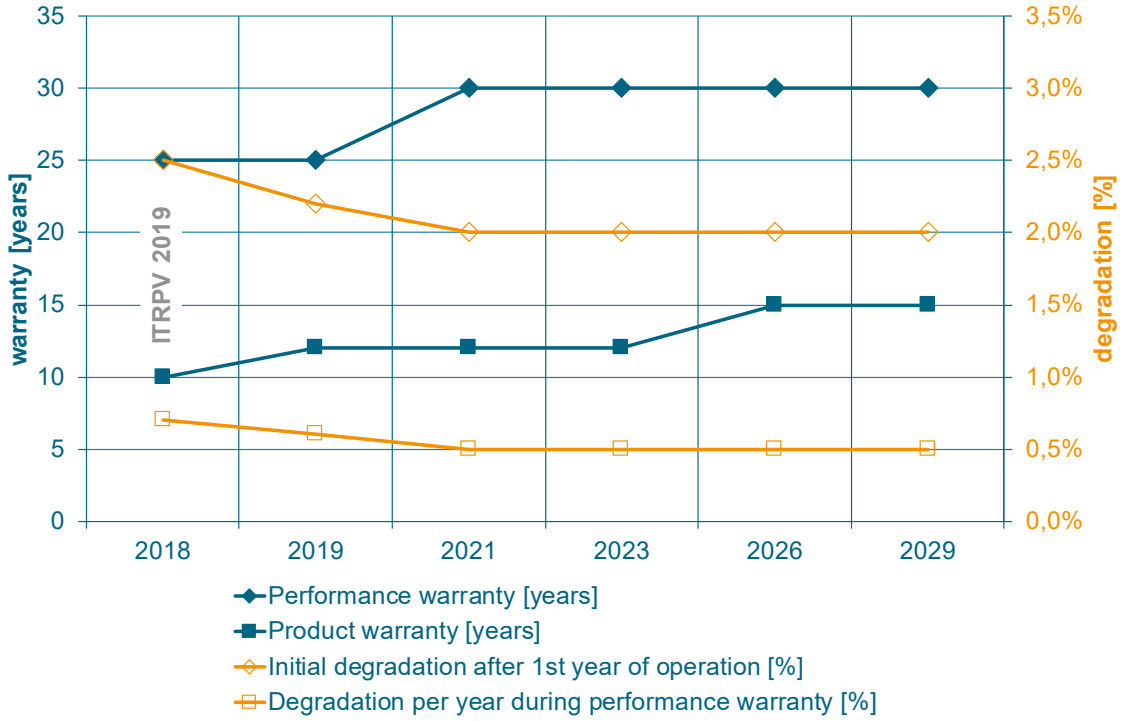


Module: Product – MES / product warranty

Trend: in-line inspection in module lines
→ EL is standard
→ AOI is in implementation



Trend: product warranty
→ 1st year warranty: 2% in 2021
→ performance warranty: 30y in 2021
→ product warranty: 15y in 2021



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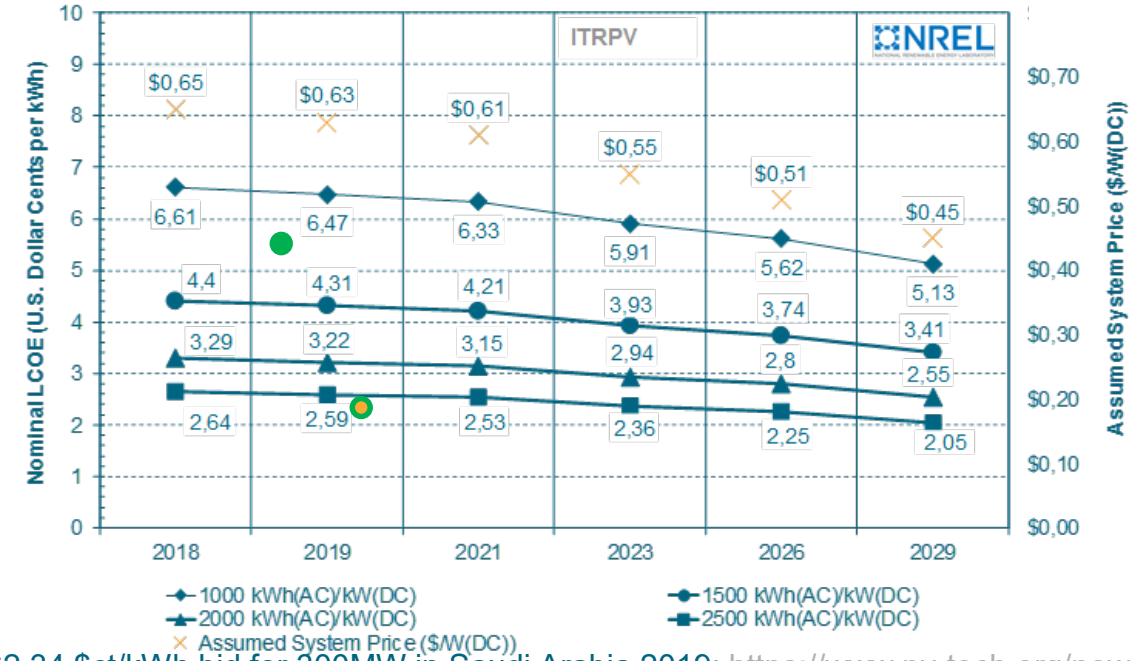
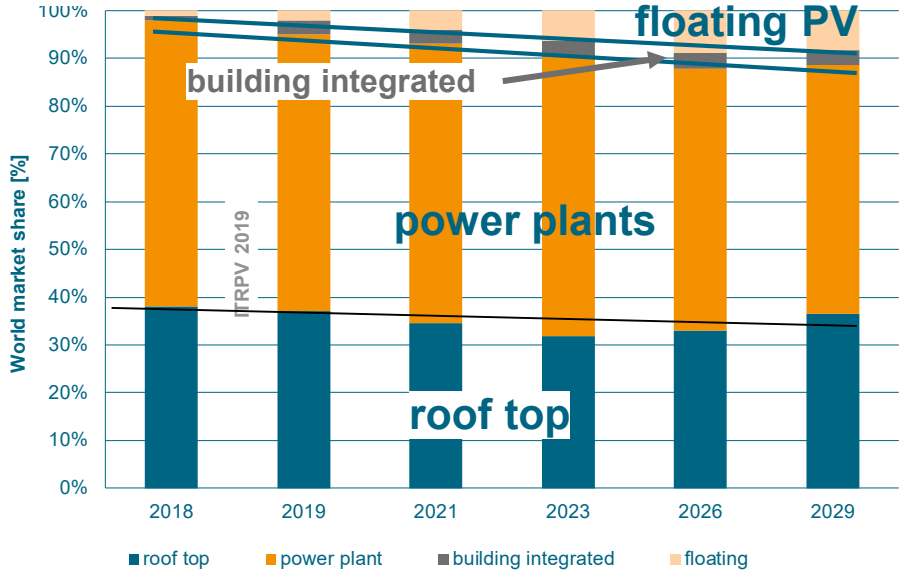
Systems: LCOE and system trends

Trend: LCO in different insolation regions



Trend: systems market

→ PV power plants stay dominating
→ roof top market will stay at ≈35%
→ floating PV will grow



● * ~$2.34 $ct/kWh bid for 300MW in Saudi Arabia 2019: https://www.pv-tech.org/news/acwa-power-wins-saudi-300mw-solar-project

● ** 5.7 $ct/kWh (4.8 €ct) avg. bid February in Germany (≈1000 kWh/kWp)
/https://www.pv-magazine.de/2019/02/15/24-zuschlaege-in-ersten-photovoltaik-ausschreibung-2019-vergeben-zuschlagswerte-erhoehen-sich-weiter-leicht/

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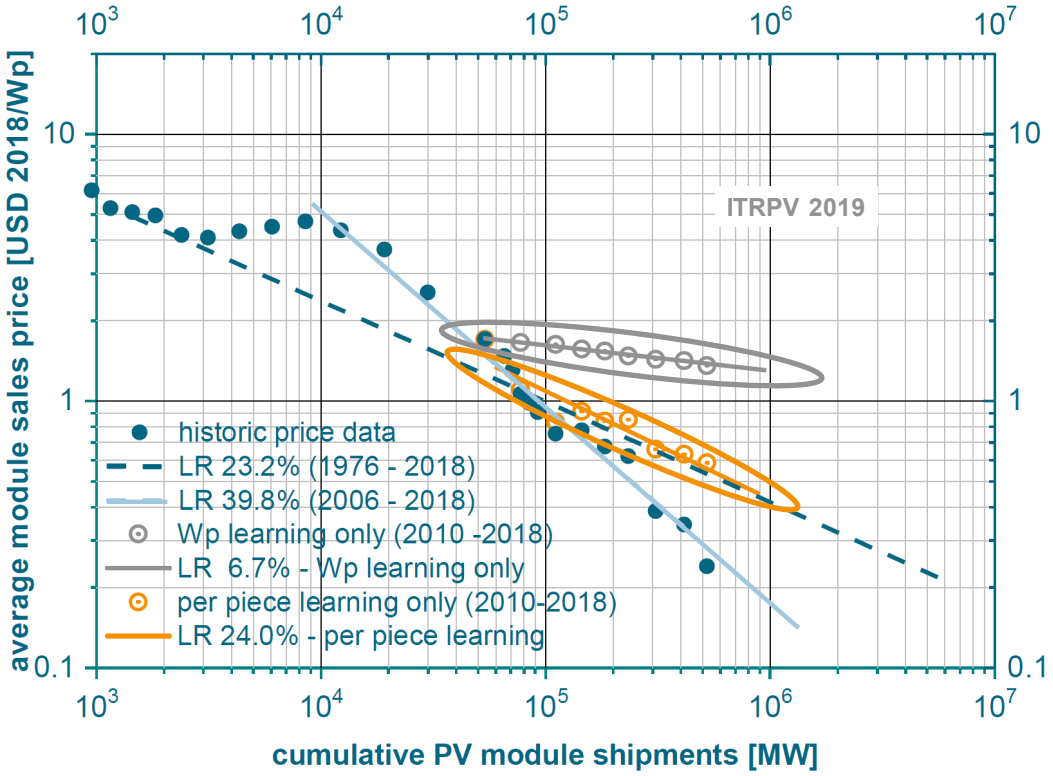
   - Cell - Products, Materials, Processes
   - Module - Products, Materials, Processes
   - Systems
3. **Outlook and Summary**

Outlook: a look at PV today and in future

Learning curve:



ITRPV finding:

2010-2018 Wp and per piece updated:

Wp learning rate: ~ 6.7% (last year 4%)
per piece learning rate: ~ 24.0% (last year 7%)

conclusion:
→ Learning was and will be always a combination of

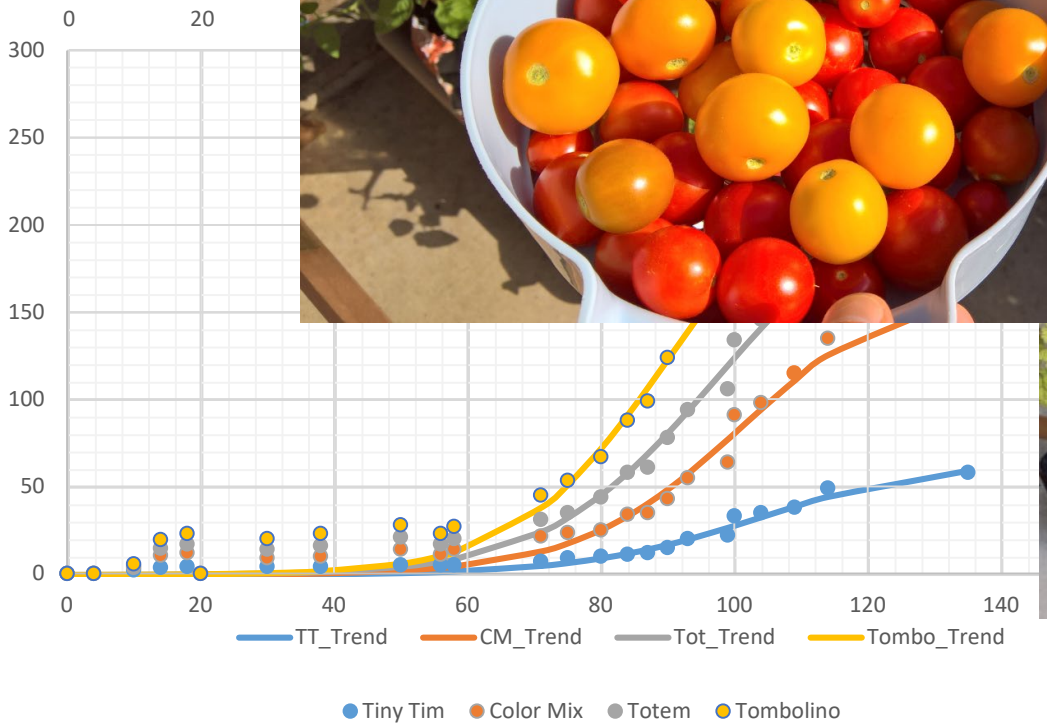
efficiency increase
+ continues cost reduction per piece
= cost reduction of PV generated electricity

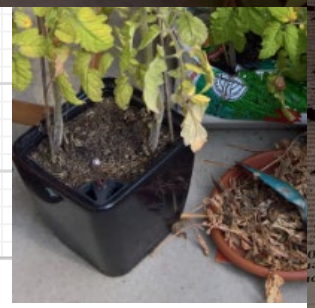
→ Wp increase w/o cost increases will remain challenging

→ But how will PV proceed in future?

logistic growth approach is limited

Outlook: status on PV growth experiments





→ I continue logistic growth studies but with larger diversification ☺

Outlook and summary - PV today and in future

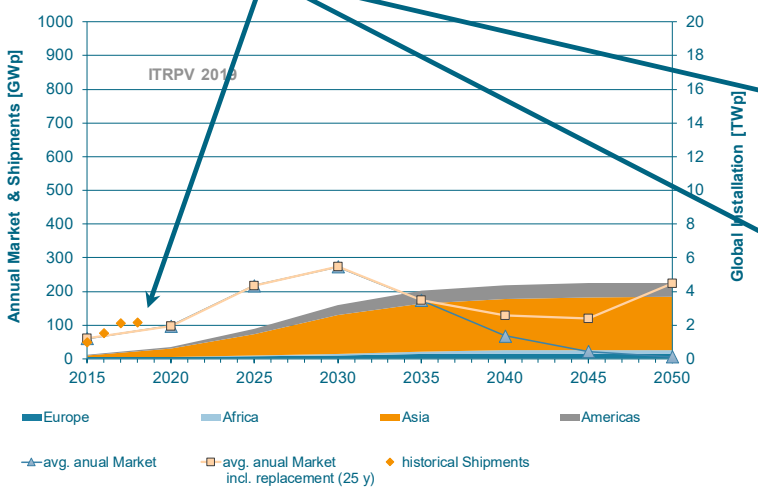
Different calculated scenarios in 10th edition:

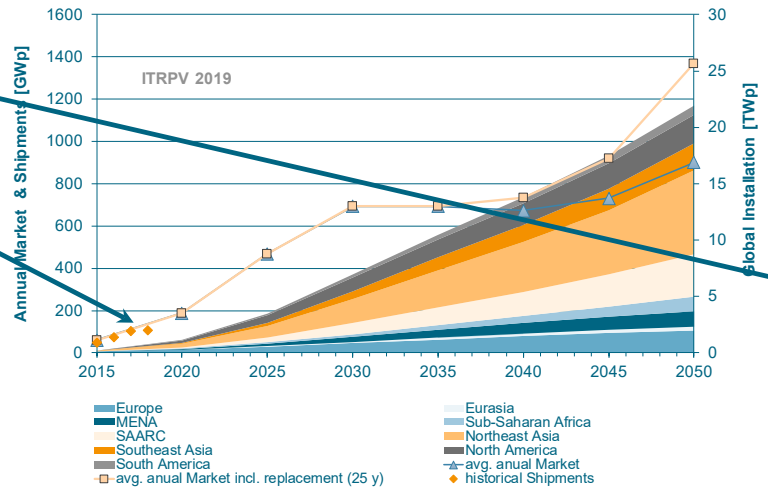
IEA
low: 4.5 TWp/ 7 PWh (16% global electricity)
market peak:300+GWp / 2030

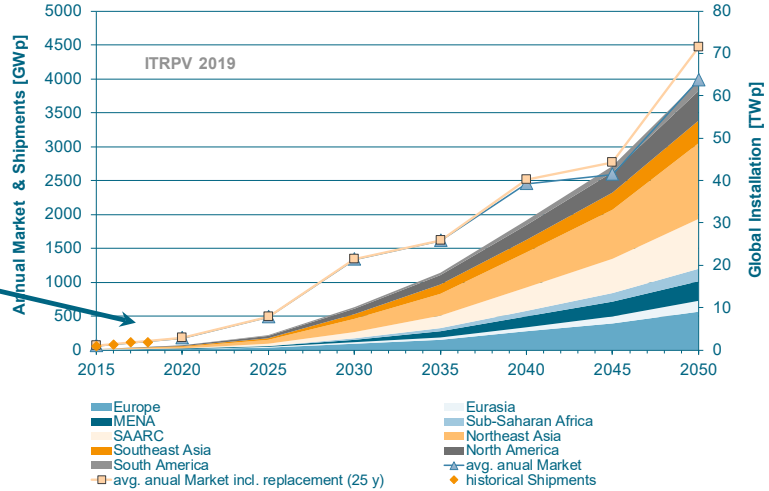
Breyer ("Electricity")
high: 22 TWp/ 38 PWh (69% global electricity)
market peak: 1,400+GWp /2050

Breyer ("Broad electrification")
mix: 63 TWp/ 104PWh (69% global energy)
market peak:4,500+ GW/ 2050

→ Shipments 2018 were close to approaches!







ITRPV finding:
- PV learning continues and progresses but market will remain volatile
→ Several 100GW markets are ahead, and can be served based on todays PV technologies
→ Further effort is required to meet 2030+ / xTWp market requirements!

ITRPV provides a guideline to handle the technology challenges


Source: www.siemens.com/presse

Thank you

Thank you

for your attention!

to all contributors!

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