Technology of photovoltaic cells and modules

Armin ABERLE
Solar Energy Research Institute of Singapore (SERIS)
National University of Singapore

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armin.aberle@nus.edu.sg
www.seris.sg

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Outline

1. Market leading PV technologies
2. Silicon wafer PV
3. Thin-film PV
4. Summary

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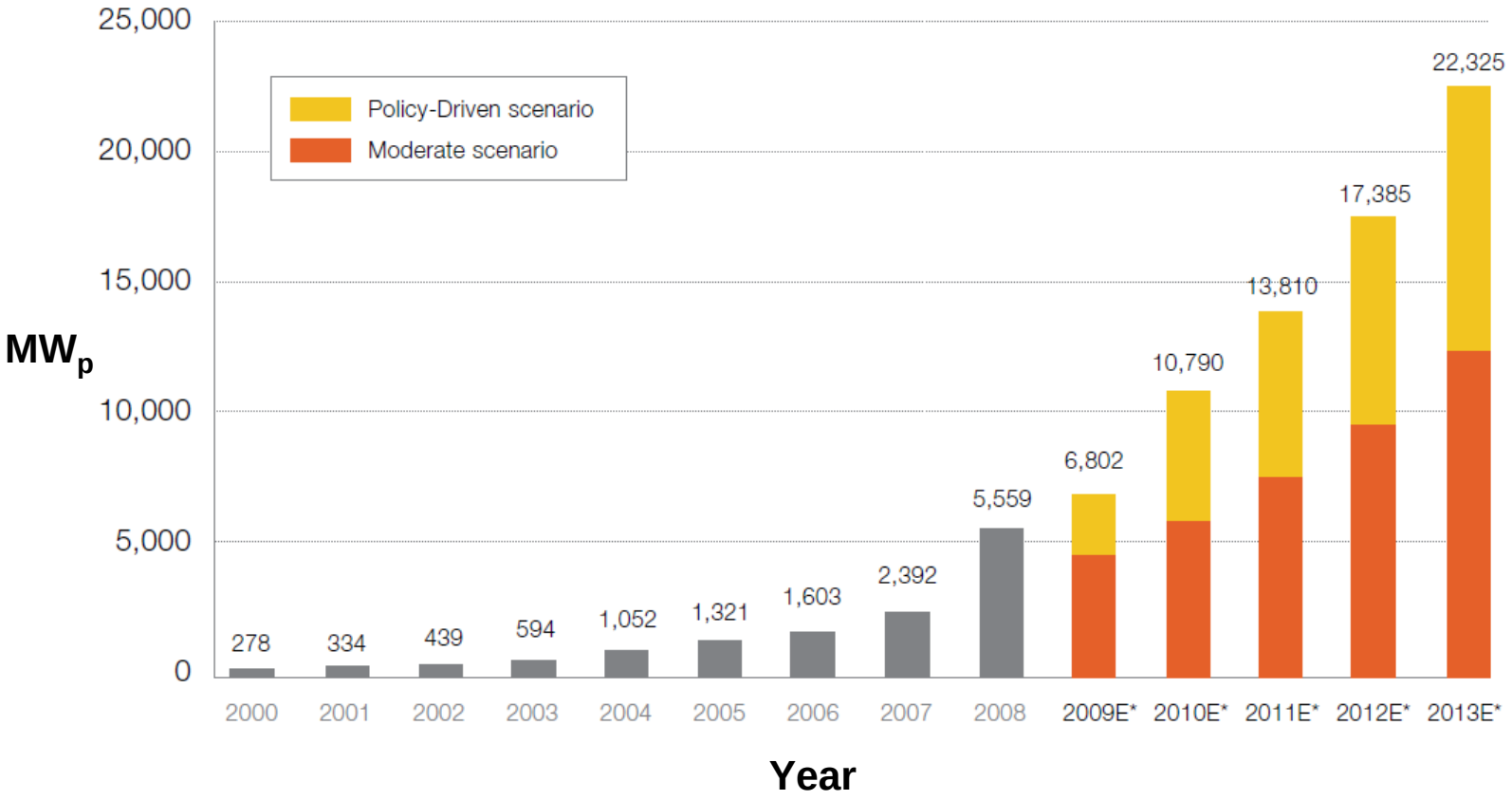
Global PV market



Source: EPIA

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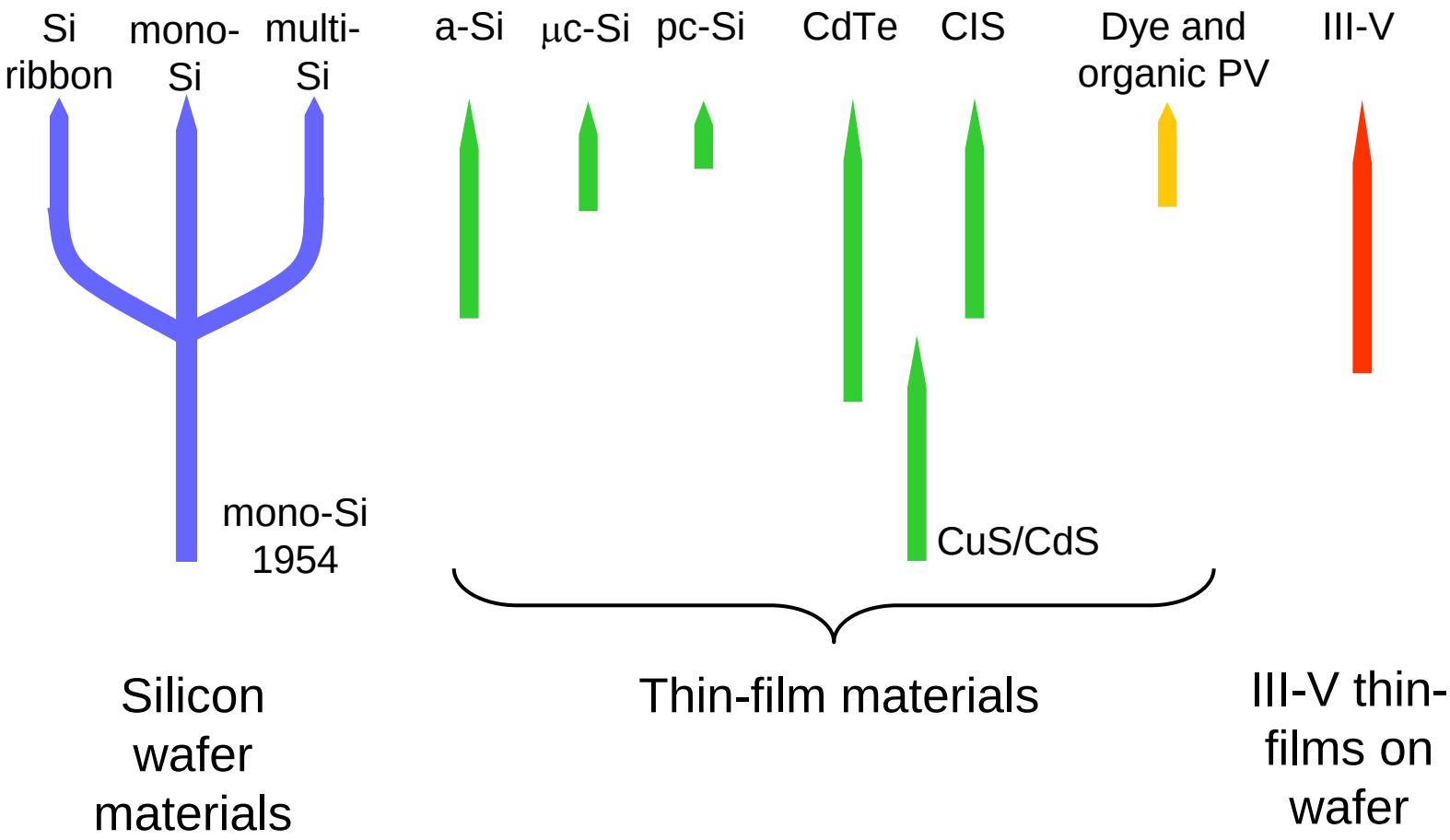
Materials for PV energy conversion



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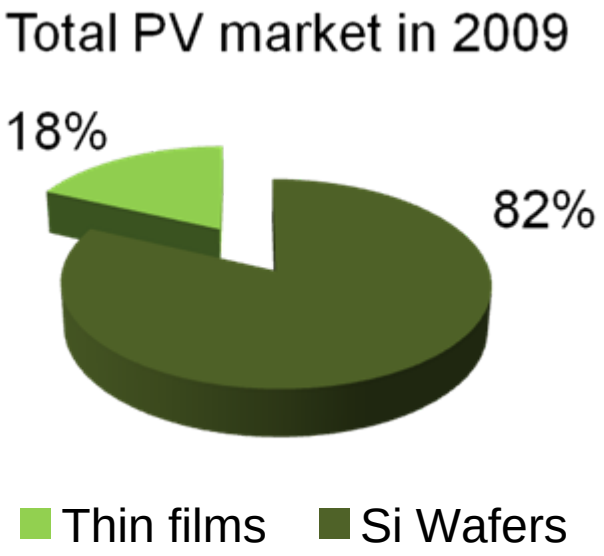
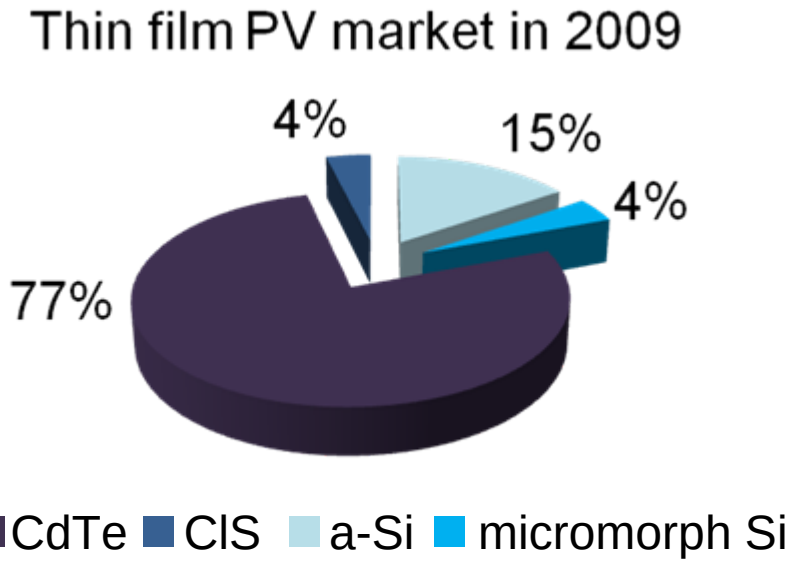
Market shares of PV technologies





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Efficiencies of major PV technologies

Technology	Best Eff in lab (cells)	Eff in industry (modules)	Remarks
Mono-Si	25.0%	14-20%	Pseudo-square wafers (125 mm)
Multi-Si	20.4%	13-18%	Square wafers (156 mm)
CIS (CIGS)	20.1%	9-13%	Uses indium (scarce)
CdTe	16.7%	9-11%	Uses tellurium (scarce)
Micromorph Si	11.7%	7-10%	Tandem cell (a-Si/µc-Si)
Amorphous Si	10.1%	5-7%	Very thin cell (Si ~300 nm)

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Silicon wafer photovoltaics

Status 2010

- Production of silicon wafer PV is growing rapidly (> 30% p.a.)
- Module efficiencies 13 - 20 %
- Proven technical lifetime of > 20 years
- Applications: All market segments, in particular those with limited space availability (high efficiency required)

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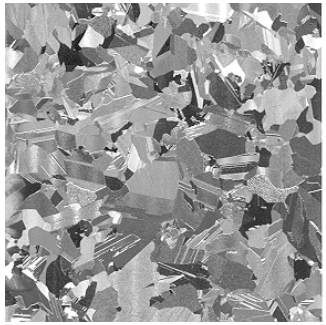
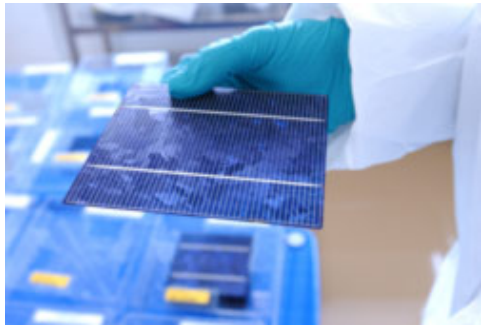
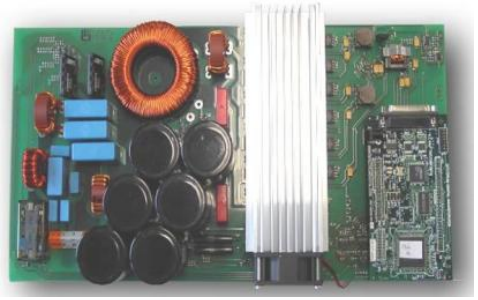
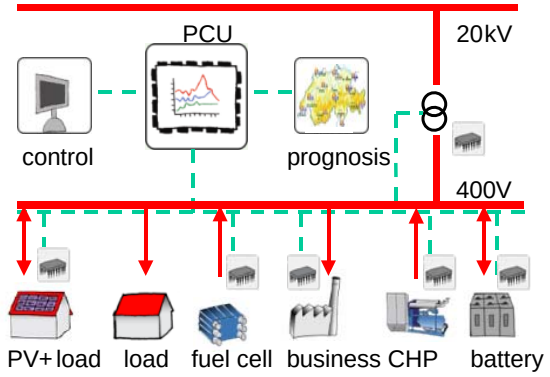
Silicon wafer photovoltaics

Industrial sectors of silicon wafer PV



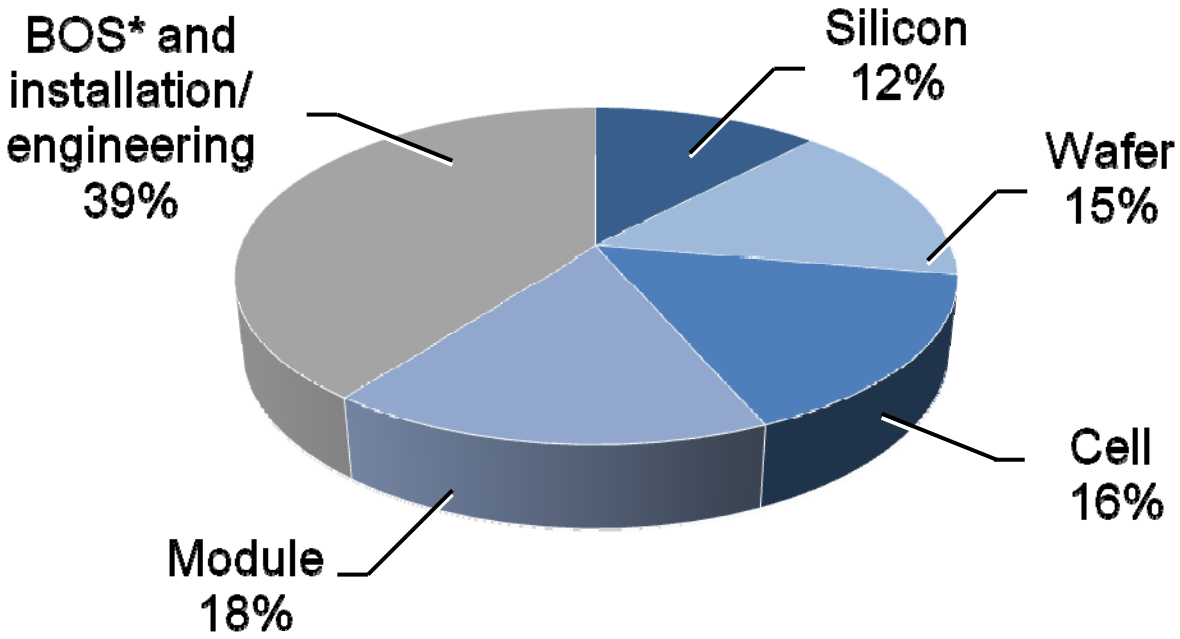






Silicon wafer photovoltaics

Cost breakdown of Si wafer based PV system, 2009



* BOS – balance of system (inverters, mounting system, cabling, etc)

Sources: Barclays Capital, industry sources, SERIS market research 2010

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Thin-film photovoltaics

Status 2010

- Thin-film PV production is growing rapidly (> 30% p.a.)
- Module efficiencies 5 - 13 %
- Semiconductor material consumption is about 100 times lower compared to Si wafer PV
- Warranted technical lifetime of 20 years
- Main applications: Green-field power plants, BIPV

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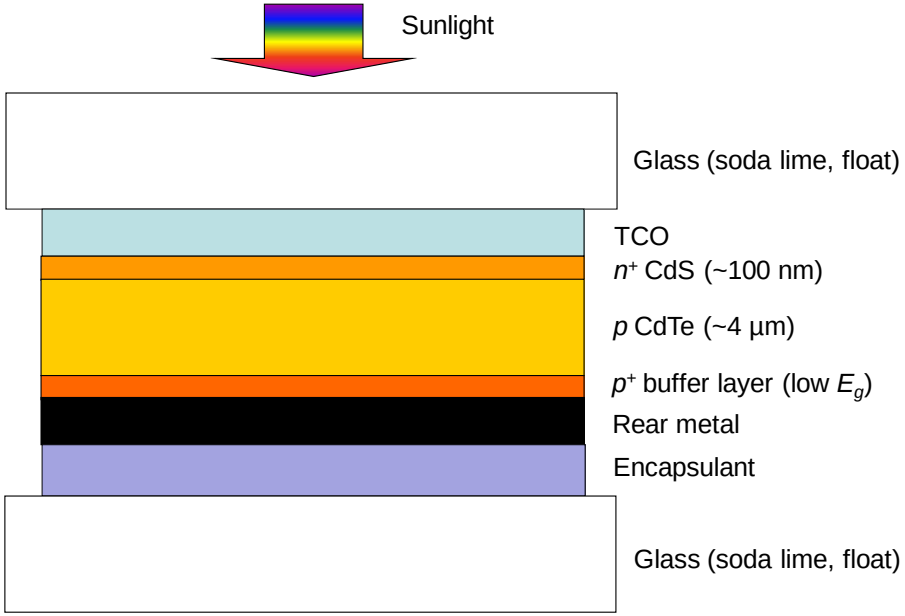
Thin-film photovoltaics

Example: Cadmium telluride technology

- Process: Clean front glass → TCO → Scribe 1 → CdS window layer (heterojunction) → CdTe absorber (~4 µm) → Activation step (annealing at ~450ºC in $CdCl_2$) → Scribe 2 → Back contact → Scribe 3 → Rear glass
- Entire process takes less than 3 hours



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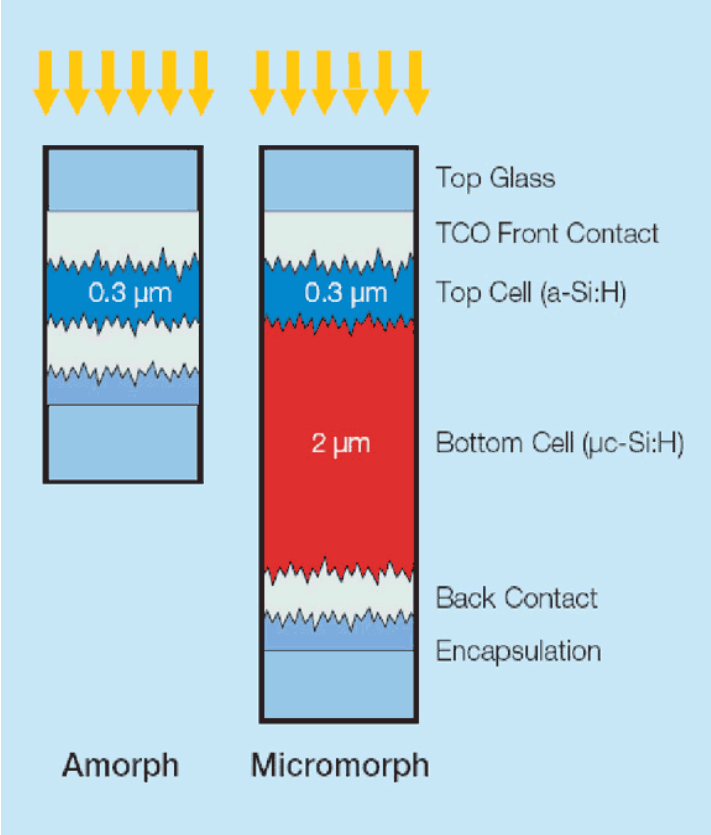
Thin-film photovoltaics

Example: Micromorph silicon technology



Source: Oerlikon Solar

- University of Neuchatel, 1994: Efficient a-Si/µc-Si tandem solar cell on a soda-lime glass superstrate
- Voltages of up to 1.4 V
- Concept has been taken up by industry (Kaneka, Sharp, Bosch, …)
- Turn-key lines for micromorph PV modules available

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Summary

- PV is booming (growth > 30% per year)
- Costs of PV modules:
  - Have been halved in the last 5 years
    (Si wafer modules now cost ~2 USD/W_p, thin-films ~25% less)
  - Likely to be halved again during this decade
- Silicon wafer based technologies will very likely remain the locomotive of the PV sector during the next 10 years
- Thin-film based technologies are gaining momentum:
  - CdTe will very likely remain strong during this decade
  - Upscaling of CIGS and micromorph is underway
- Also: Optical concentrator PV is gaining momentum

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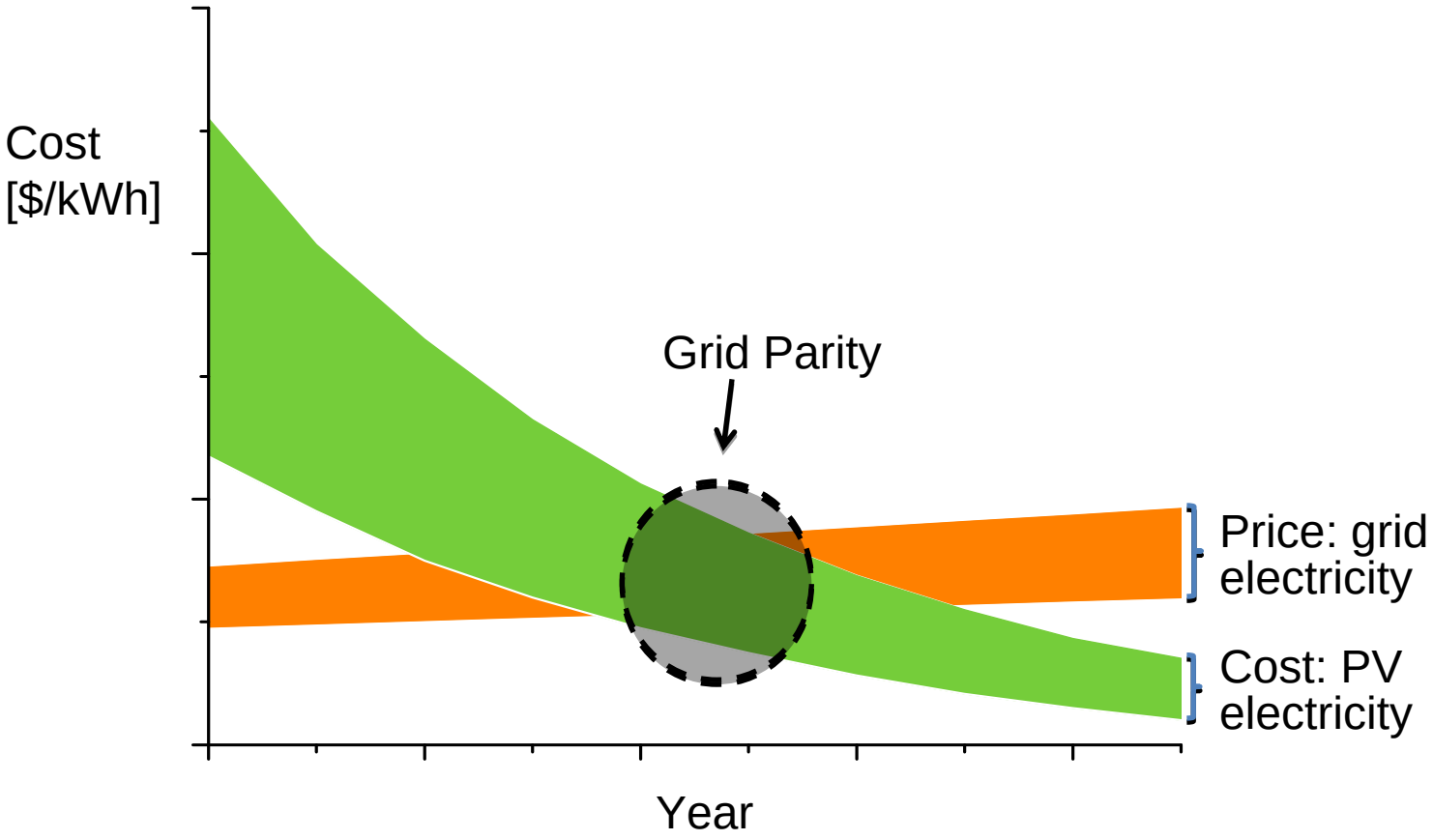
Grid parity in photovoltaics



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