ECN

Energy research Centre of the Netherlands

Prepare(d) for impact

photovoltaics on its way to terawatt-scale use

Wim Sinke

Contents

- **The photovoltaic technology portfolio**
  - wafer-based silicon in perspective
- **Meeting expectations: from gigawatts to terawatts**
  - can wafer-based silicon deliver?
- **Outlook**
  - the benefits of diversity

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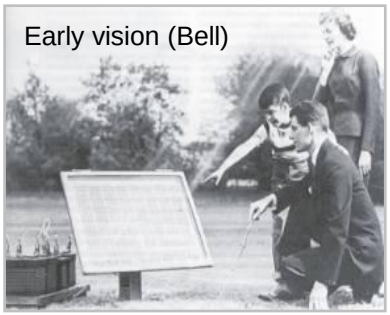
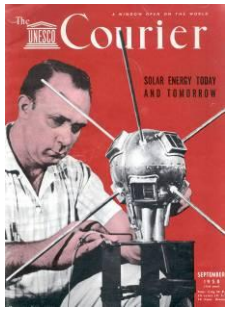
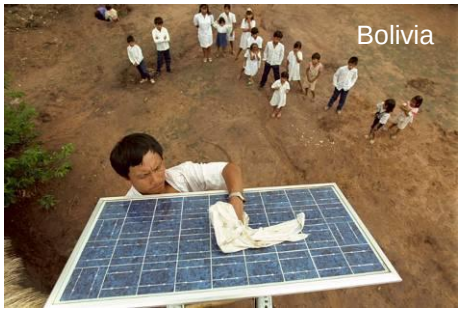
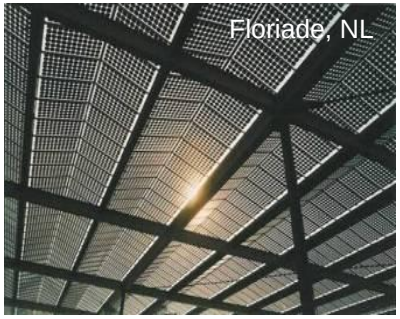
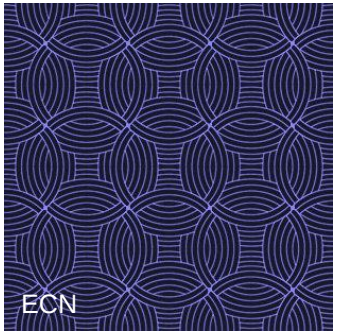
The many faces of wafer-based silicon PV

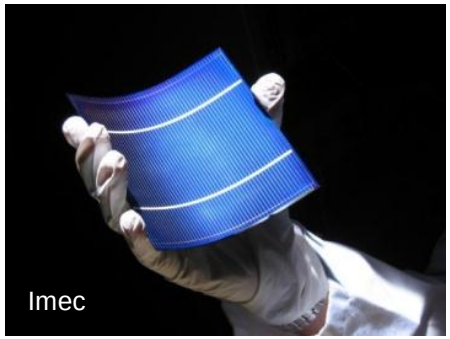








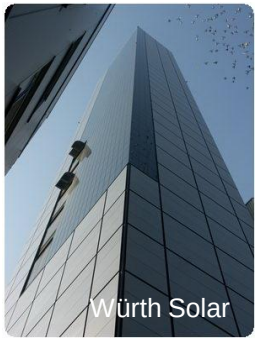




Cell & module technologies (flat plate)

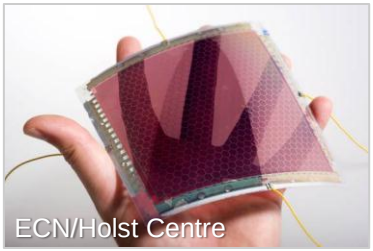
<u>Commercial:</u> wafer-based crystalline silicon
- monocrystalline
- multicrystalline
- ribbons

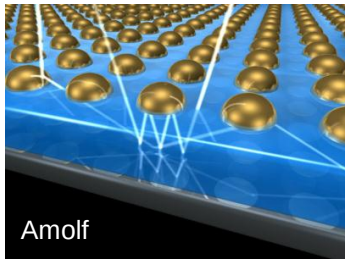
Module efficiencies 13 ~ 19%



<u>Commercial:</u> thin films
- silicon
- copper-indium/gallium-diselenide (CIGS)
- cadmium telluride (CdTe)

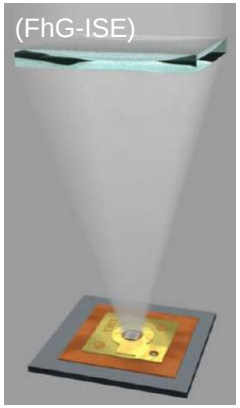
Module efficiencies 7 ~ 13%





<u>Pilot production and laboratory:</u> emerging and novel technologies
- super-low-cost concepts
- super-high-efficiency concepts

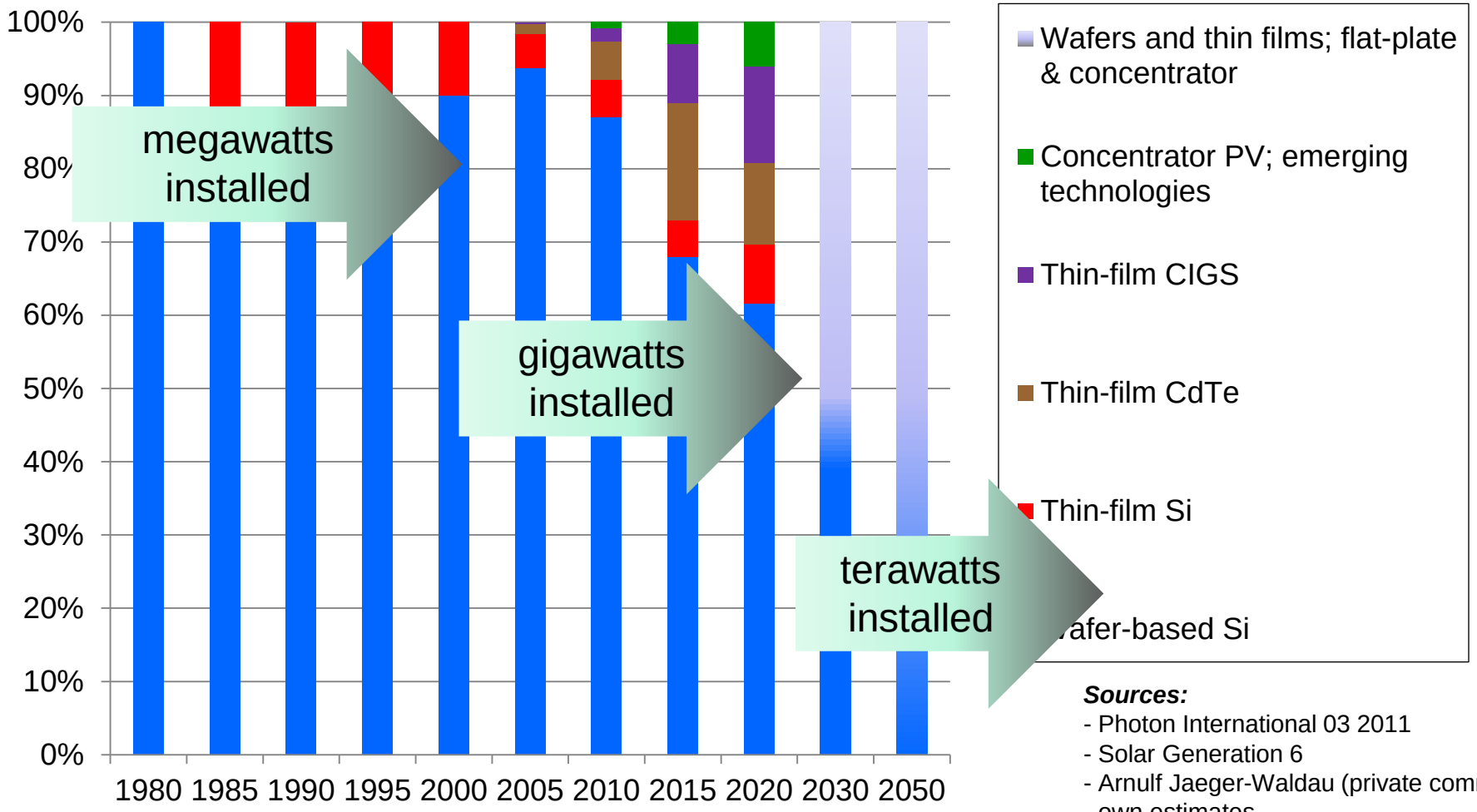
Cell & module technologies (concentrator)



<u>Commercial:</u> multi-junction III-V semiconductors

Module efficiencies 25 ~ 30%

PV technology shares



Sources:
- Photon International 03 2011
- Solar Generation 6
- Arnulf Jaeger-Waldau (private comm.)
- own estimates

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Wafer-based silicon PV: a personal SWOT

Strengths	Weaknesses
Opportunities	**Threats**

Wafer-based silicon PV: a personal SWOT

Strengths	Weaknesses
• high efficiency • extensive track record reliability & lifetime • synergy with micro- & nanoelectronics industry	
Opportunities	**Threats**

Wafer-based silicon PV: a personal SWOT

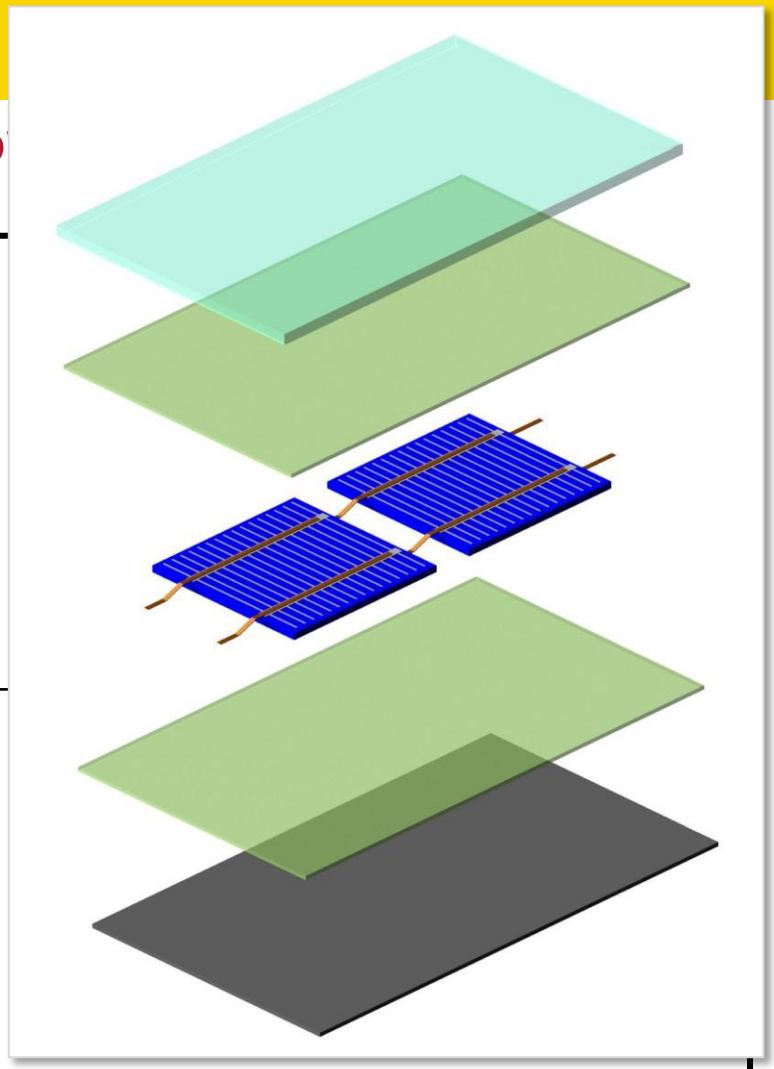
Strengths	**Weaknesses** (current)
• high efficiency • extensive track record reliability & lifetime • synergy with micro- & nanoelectronics industry	• poorly integrated processing • significant materials cost component • suboptimal aesthetics of some products
Opportunities	**Threats**

Wafer-based silicon P

Strengths

- high efficiency
- extensive track record reliability & lifetime
- synergy with micro- & nanoelectronics industry

Opportunities



Wafer-based silicon PV: a personal SWOT

Strengths	**Weaknesses** (current)
• high efficiency • extensive track record reliability & lifetime • synergy with micro- & nanoelectronics industry	• poorly integrated processing • significant materials cost component • suboptimal aesthetics of some products
Opportunities	**Threats**
• further increase total-area efficiency • reduce materials consumption & use low-cost materials • implement advanced device designs & processes	

Wafer-based silicon PV: a personal SWOT

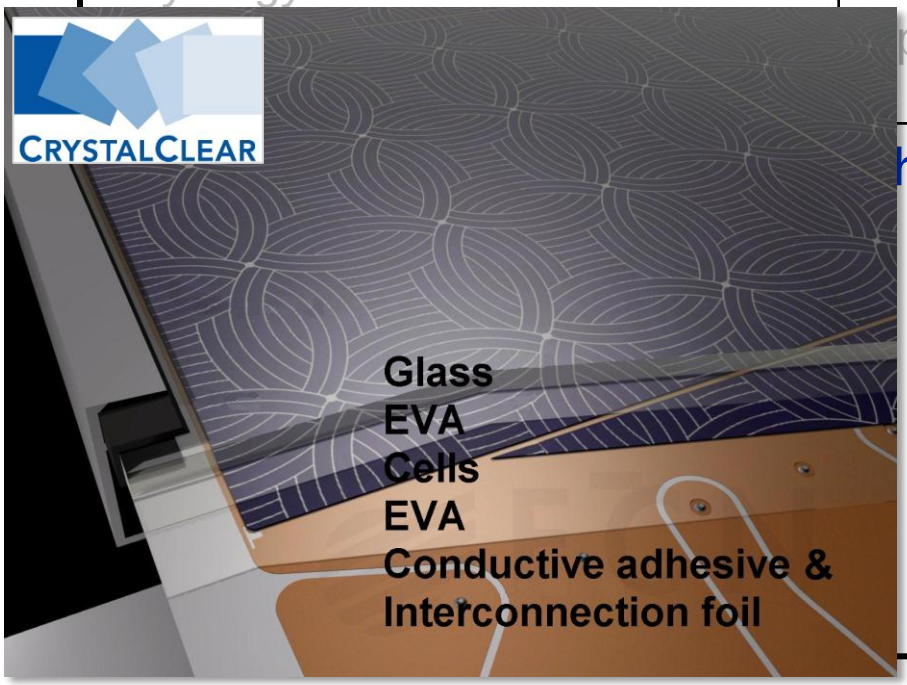
Strengths

- high efficiency
- extensive track record reliability & lifetime
- synergy with micro-

Weaknesses (current)

- poorly integrated processing
- significant materials cost component
- suboptimal aesthetics of some products

hreats



Wafer-based silicon PV: a personal SWOT

Strengths

Selected options for improvement:

- heterojunctions
- rear-contact /rear junction cell designs
- n-type silicon
- Al_2O_3 surface passivation
- kerfless wafer cutting
- advanced light trapping
- seeded ingot casting
- high quality solar grade silicon
- Cu replacing Ag
- new encapsulants
- tandems
- more

Weaknesses (current)

- poorly integrated processing
- significant materials cost component
- suboptimal aesthetics of some products

Threats

Wafer-based silicon PV: a personal SWOT

Strengths	**Weaknesses** (current)
• high efficiency • extensive track record reliability & lifetime • synergy with micro- & nanoelectronics industry	• poorly integrated processing • significant materials cost component • suboptimal aesthetics of some products
Opportunities	**Threats**
• further increase total-area efficiency • reduce materials consumption & use low-cost materials • implement advanced device designs & processes	• innovations remain in the lab • cost reduction curve saturates at too high level *(what is needed for very large scale use?)* • image of “technology of the past”

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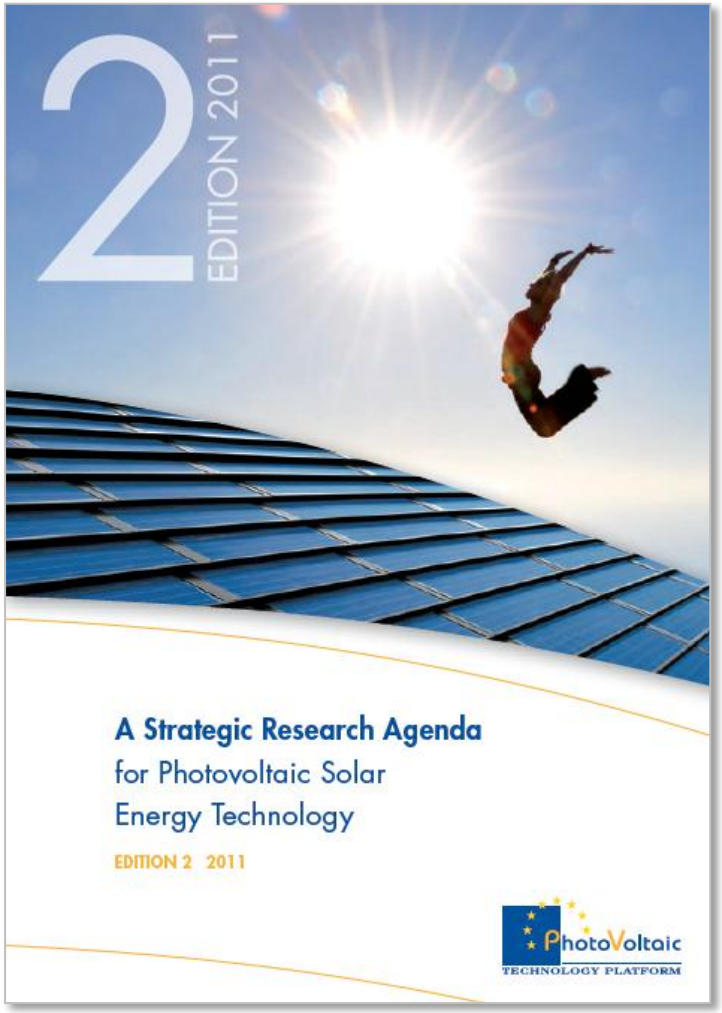
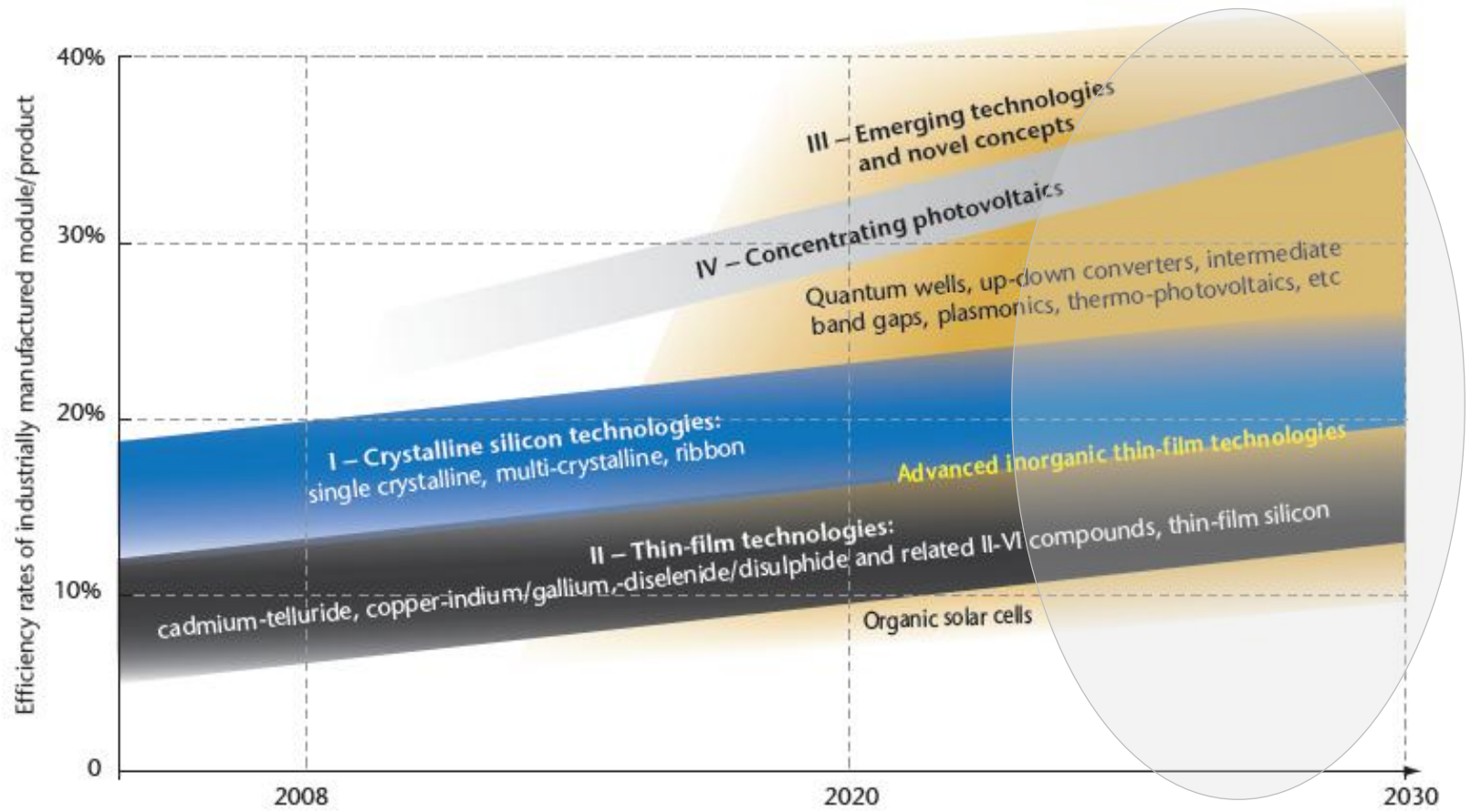
The benefits of diversity

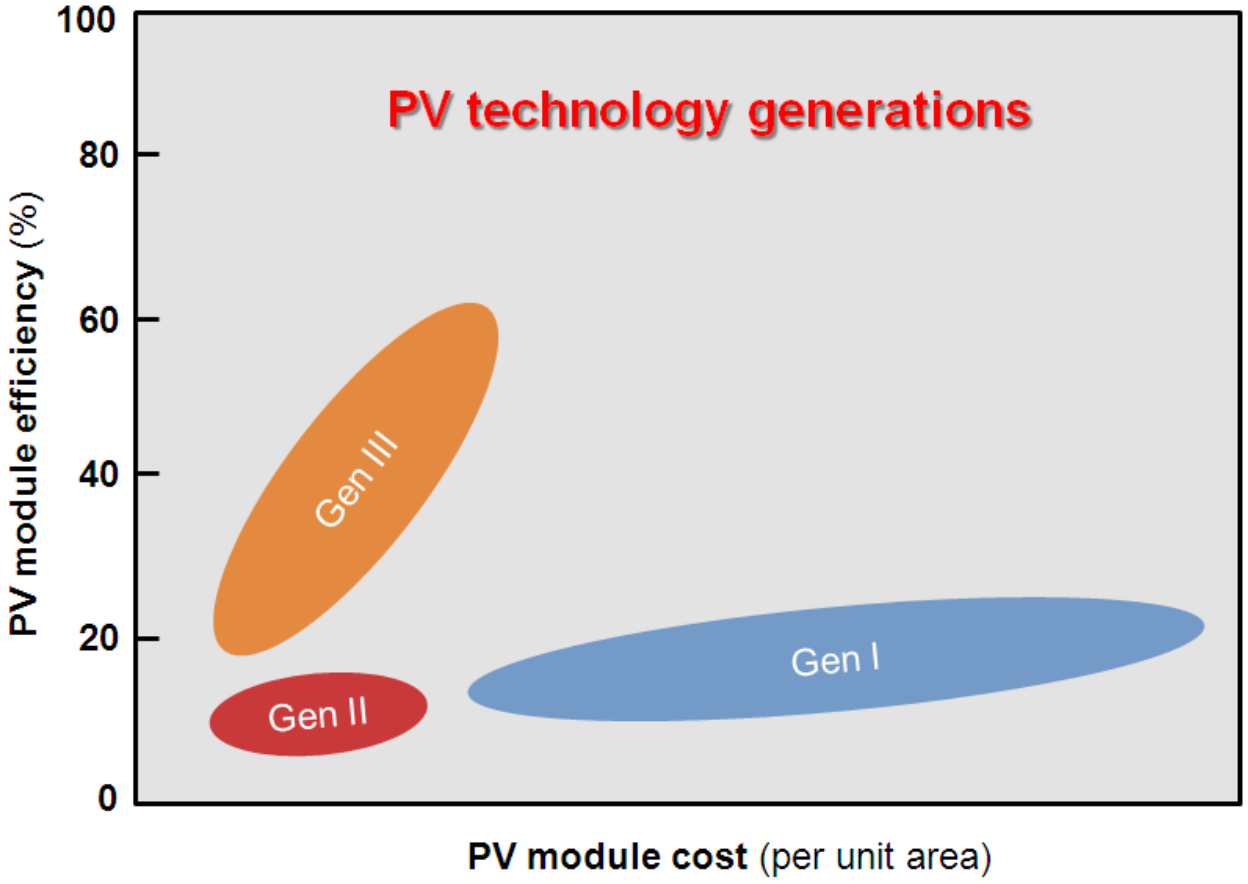


Evolution of technology portfolio and module efficiencies *(IEA PV Roadmap, 2010)*

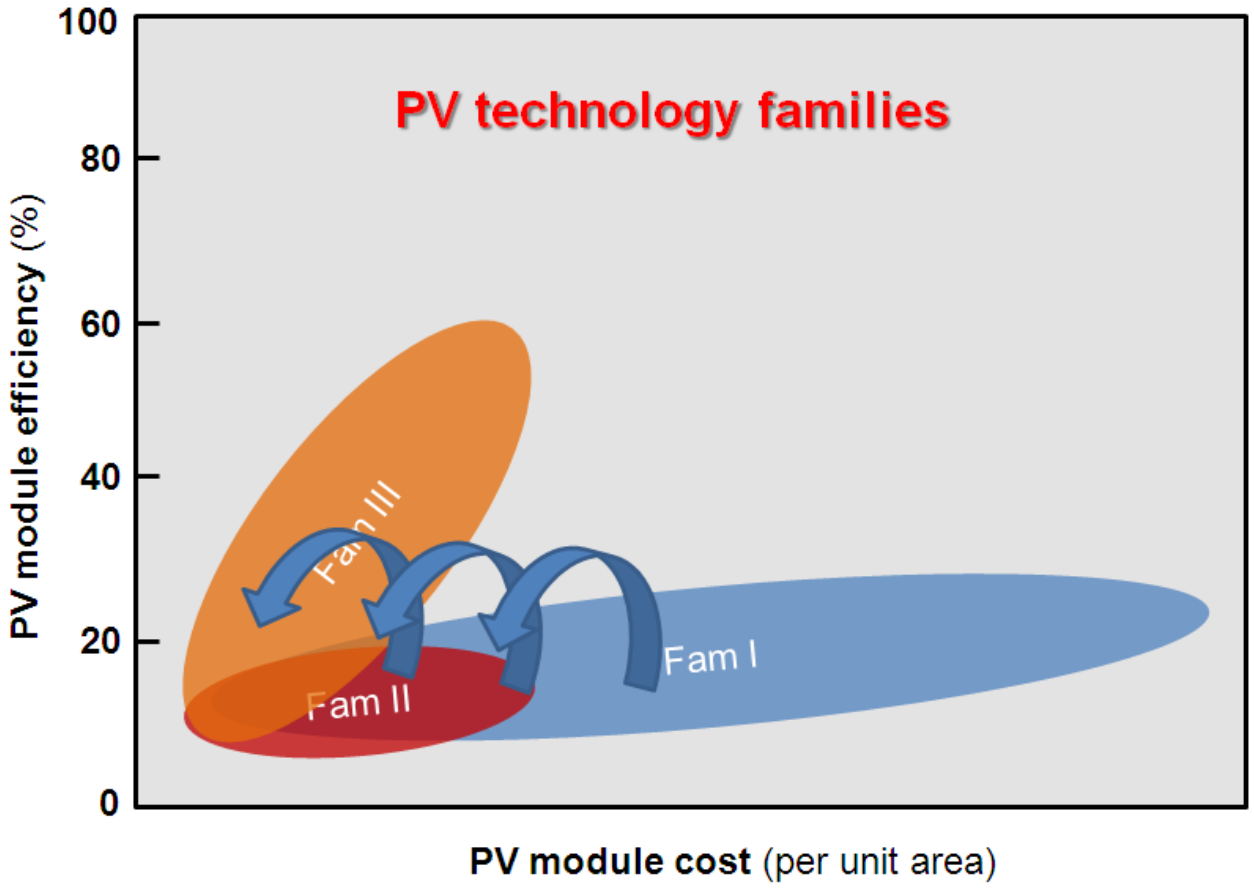


Source: IEA PVPS.

Crystalline silicon: first generation PV?



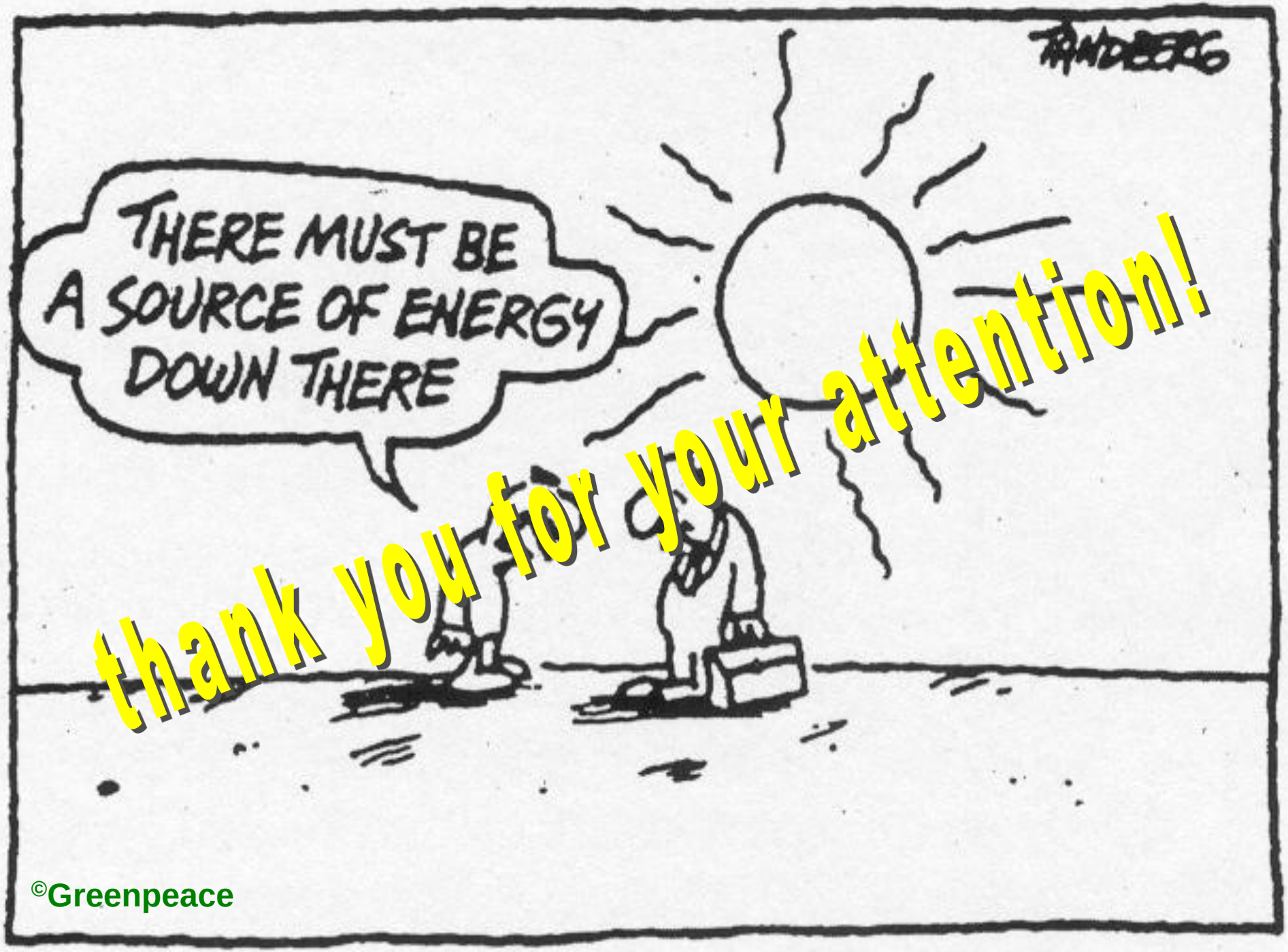
Crystalline silicon: first generation PV?



Summary

Thank you:

- my colleagues at ECN and at Utrecht University
- the members of the European Photovoltaic Technology Platform
- the people at EPIA, WIP, Eurec and JRC
- the CrystalClear team
- the Becquerel committee
- the European Commission and the Dutch Ministry of Economic Affairs
- my family: Ineke, Koen, Pelle and Corijn
- you, the audience
- all other PV advocates around the world


THERE MUST BE A SOURCE OF ENERGY DOWN THERE
thank you for your attention!