How technology innovation is anticipated to reduce the cost from PV installations.

Webinar
23/05/2016
11:00 – 12:00 CET

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration

Agenda

Item	Speaker
Cost reduction approach in Cheetah project – ongoing work and results.	Ioannis-Thomas Theologitis – SolarPower Europe
Future renewable energy cost series – Solar PV. The KIC InnoEnergy approach	Emilien Simonot – KIC InnoEnergy
Anticipated impact of innovations in cSi cell technologies	Simon Philipps – Fraunhofer ISE
Anticipated impact of innovations in cSi module technologies	Wim Sinke - ECN
Anticipated impact of innovations in Thin Film technologies	Ivan Gordon - IMEC
Q&A	

Chair: Emilien Simonot

Cost reduction approach in Cheetah project – ongoing work and results.

Ioannis Thomas Theologitis, SolarPower Europe

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Cheetah project in a nutshell

CHEETAH

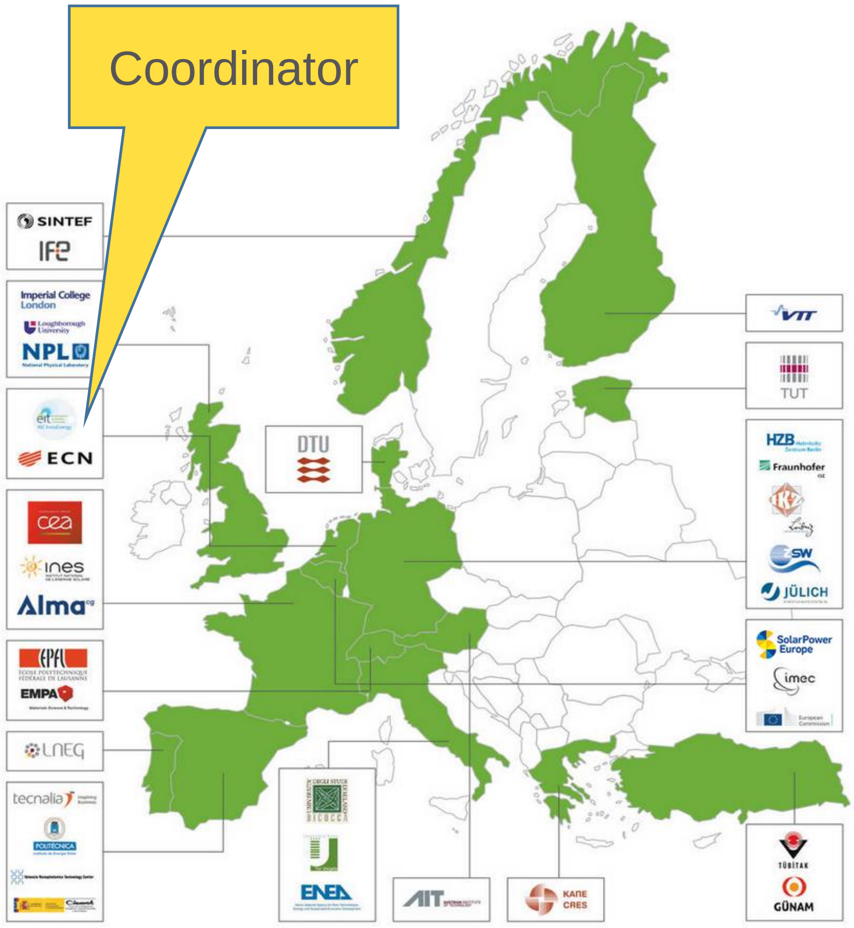
Quick Facts & Figures

- EU funded project (≈75% of the total planned costs – 13.2M€)
- Duration of 48 Months (due 1/1/2018)
- Combination of collaborative research project and coordination actions
- Derive from the European Energy Research Alliance for PV (EERA-PV) and the Strategic Energy Technology Plan (SET-Plan) which aim at **“Accelerating the development and deployment of low carbon technologies (i.e. PV)”** and focus on **Enhancement of performance, Cost reduction of PV systems and low cost products, High throughput manufacturing processes, reliability and lifetime improvement**

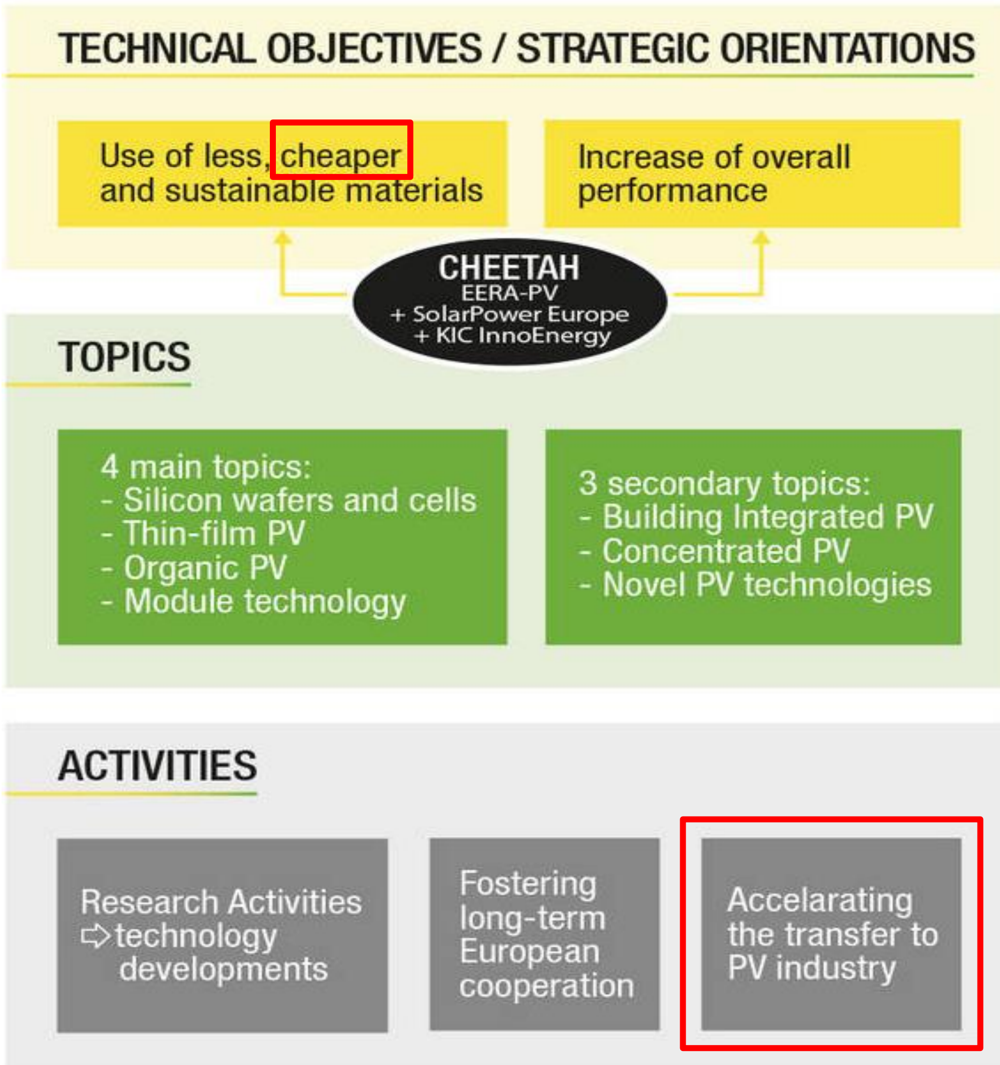
Website

www.cheetah-project.eu

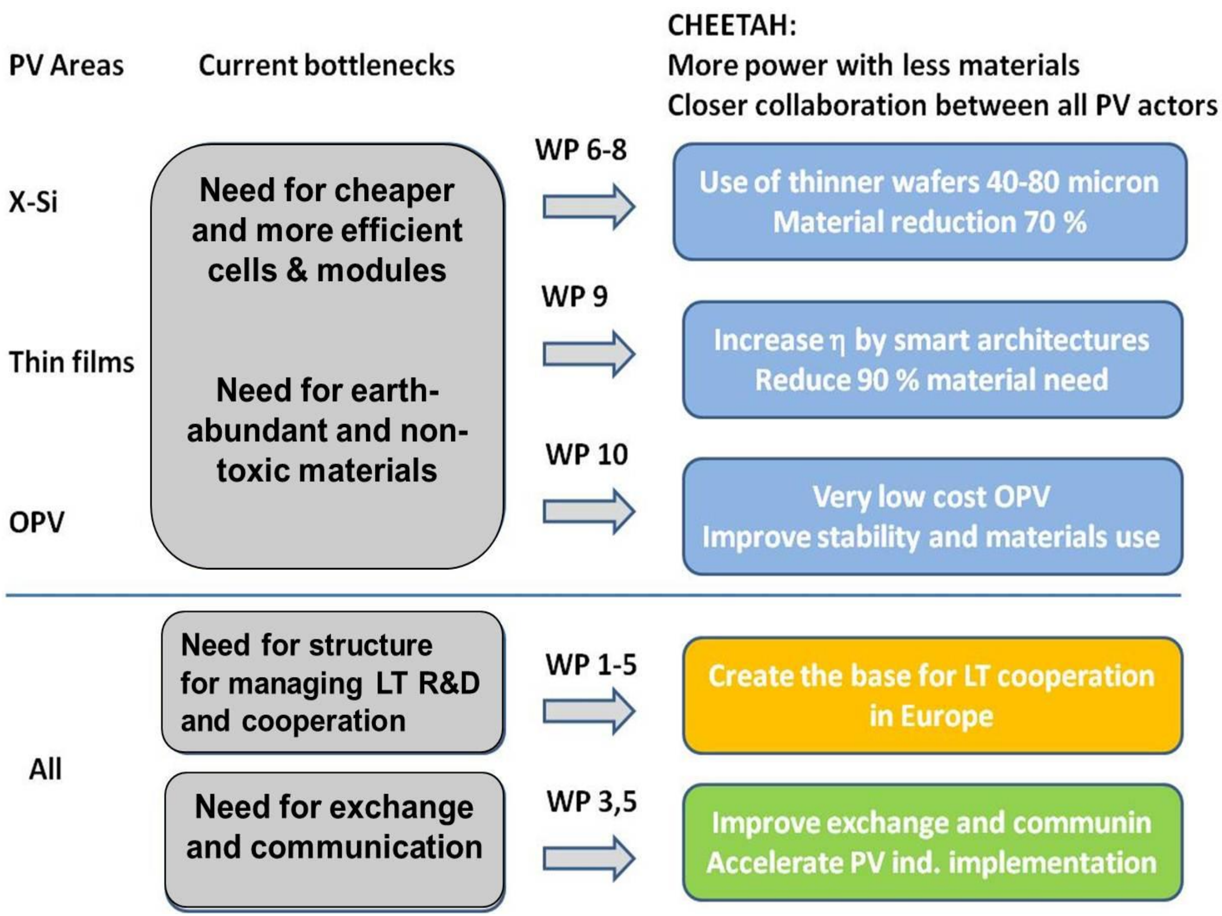
Consortium 34 partners



Objectives


TECHNICAL OBJECTIVES / STRATEGIC ORIENTATIONS
Use of less, cheaper and sustainable materials
Increase of overall performance
CHEETAH
EERA-PV
+ SolarPower Europe
+ KIC InnoEnergy
TOPICS
4 main topics:
- Silicon wafers and cells
- Thin-film PV
- Organic PV
- Module technology
3 secondary topics:
- Building Integrated PV
- Concentrated PV
- Novel PV technologies
ACTIVITIES
Research Activities ⇨ technology developments
Fostering long-term European cooperation
Accelarating the transfer to PV industry

Main Innovations



Proof of potential for further cost reduction and cheaper new PV technologies will accelerate the implementation

Cost reduction work stream in Cheetah

Part 1

- Learning curve analysis
- LCOE analysis

(finalized and soon to be published on project's website)

Part 2

- Assess the cost impact of some quality innovations at LCOE level

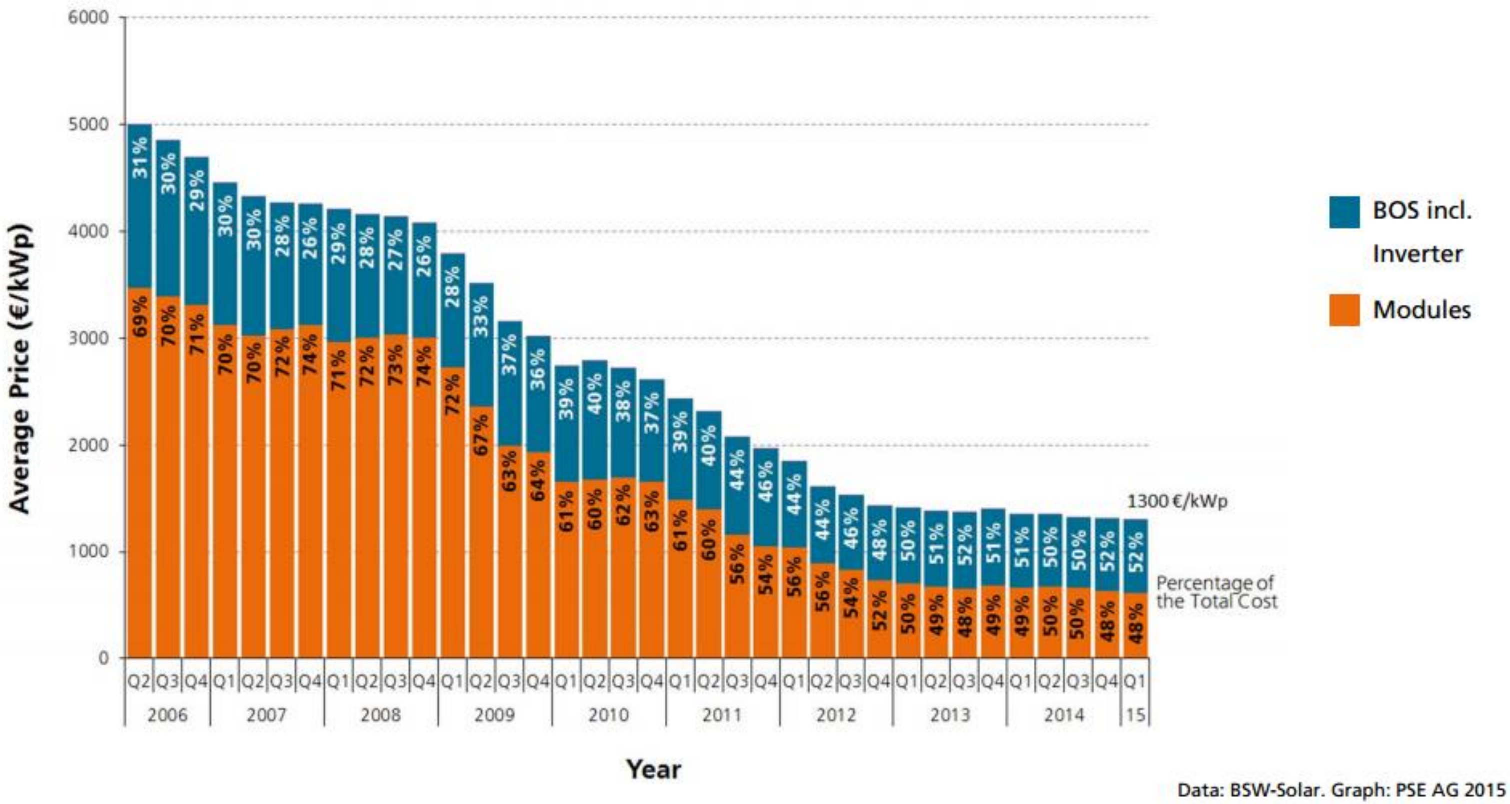
(to be finalized and published on project's website)

Part 3

- Assessment of cheetah innovations
- Incorporating own (cheetah's) experience + industry consultation and trends

Module cost still dominates the CAPEX

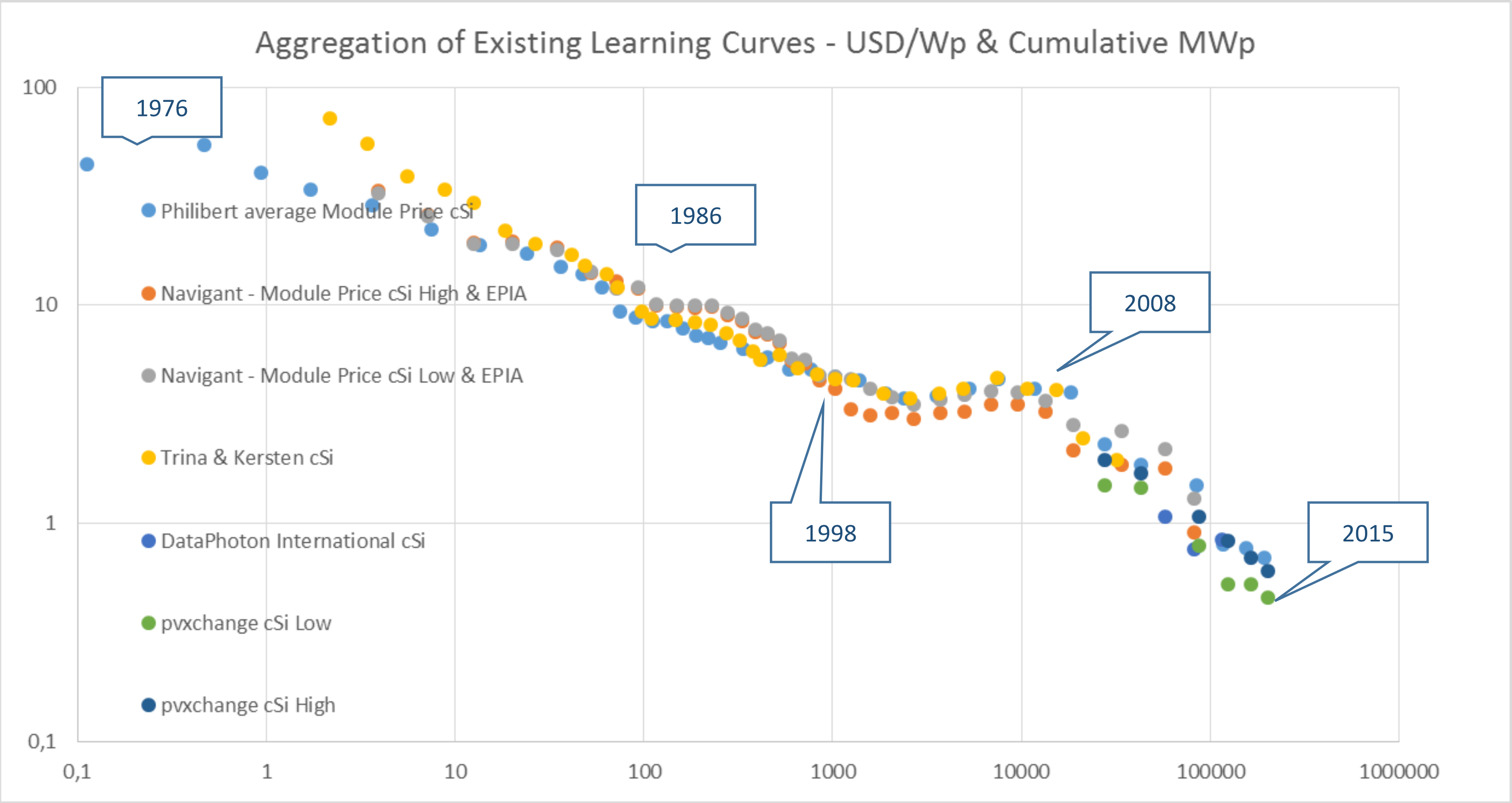
10 – 100 kWp roof tops in Germany



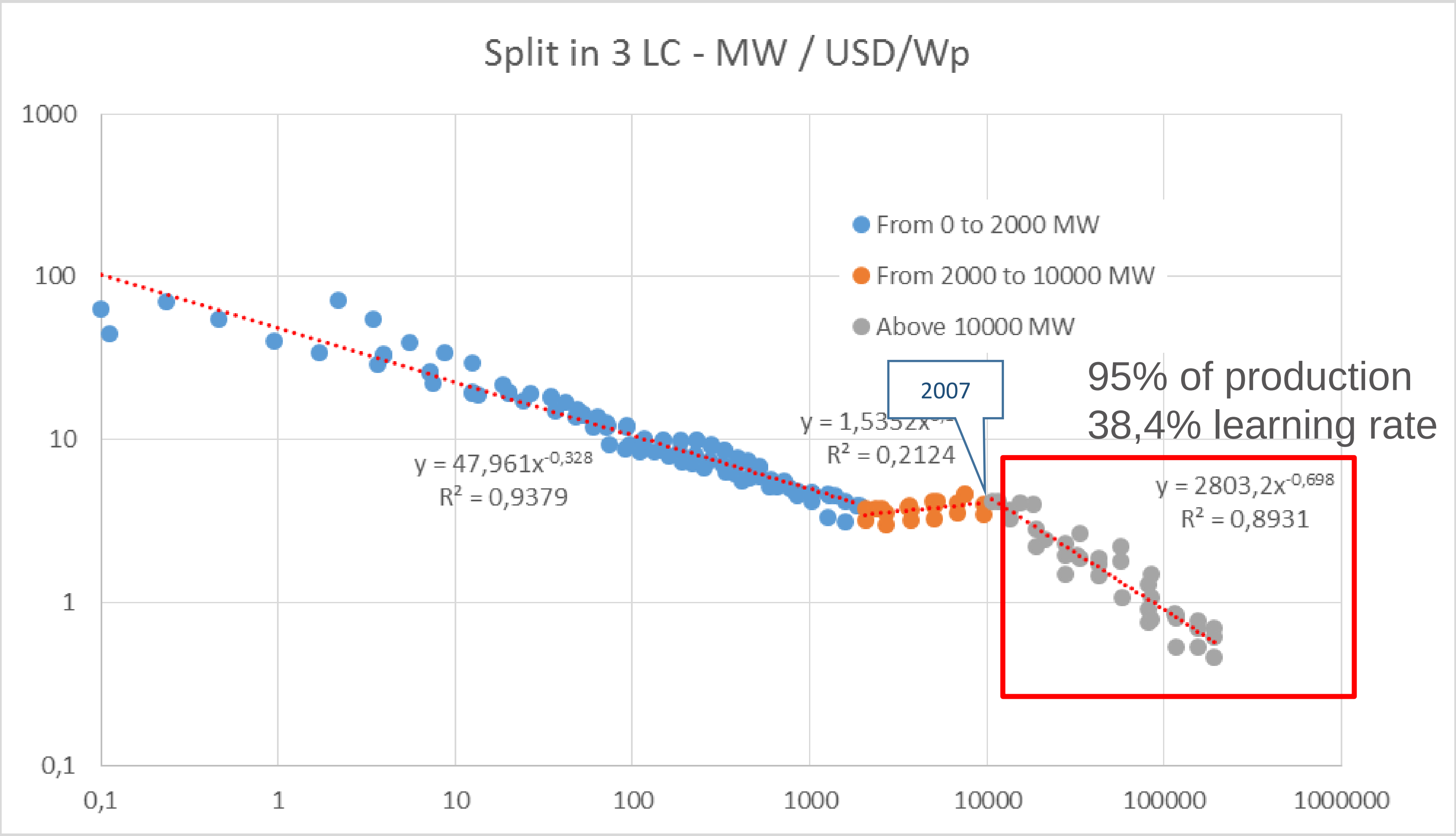
Extracted from Fraunhofer ISE

For utility scale systems is around 1/3 of the CAPEX

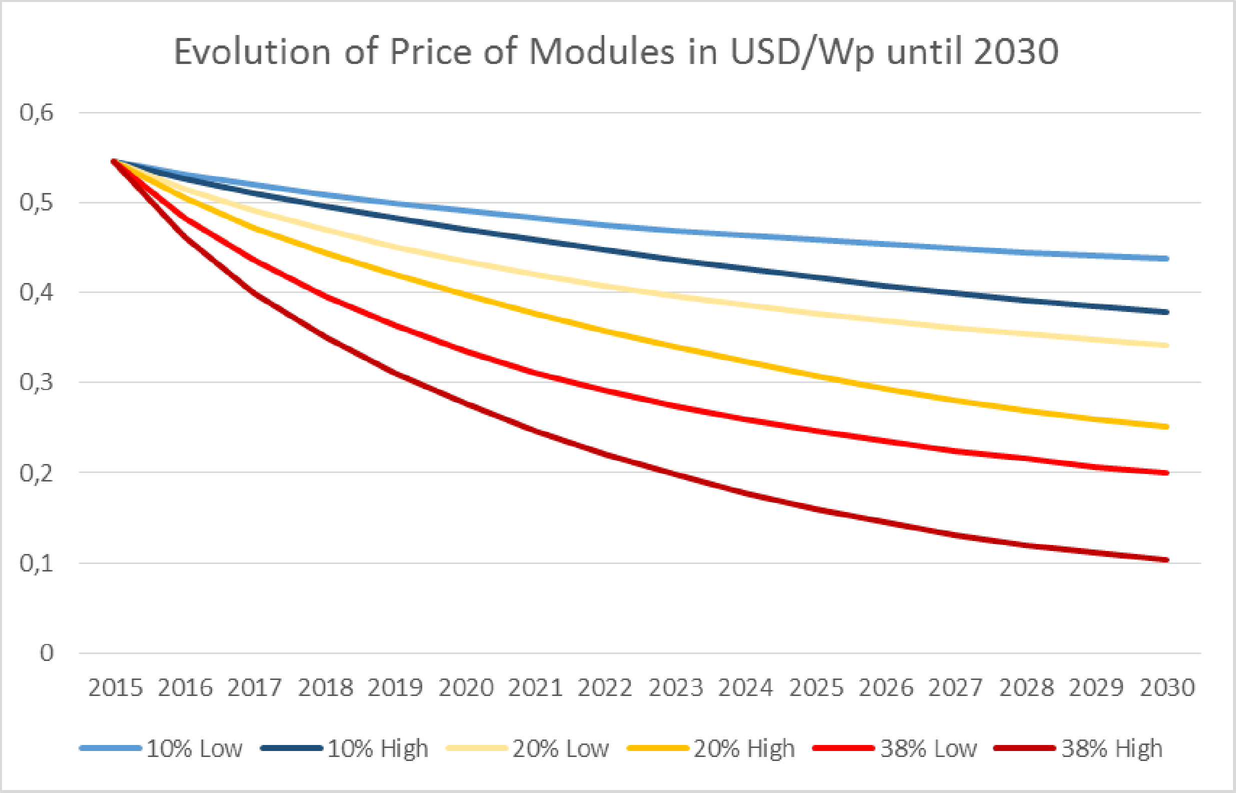
Learning Curve (c-Si only)



Learning curve in segments



From experience to prediction



Assuming different learning rates and scenarios

Low: 50 GW after 2020, c-Si only

High: 15% annual growth after 2020 capped at 250 GW a year, c-Si only

Cost Assessment of Cheetah Innovations

c-Si

- Development of ultra-thin wire-sawn wafers (80µm)
- Development of epi-foil wafers (40µm)
- Respective cell processing
- Respective module development

>90% of the market

Thin Film

- Novel approaches in cell development (e.g. micro-concentrator in CIGS)

around 8% of the market

OPV

- Advanced manufacturing processes such as non-encapsulated cells

no real market

Main assumptions for the c-Si assessment

- Benchmark Technology for comparison: **IBC-SHJ**
  - Reason: State of the art, not yet commercial, no tabbing and stringing
  - Cost: 0.51 USD/Wp
- Point of reference for costs of wafers: second half of 2015
- Point of comparison: when the conditions will allow large scale commercialization of Cheetah innovations
- Costs represent the COGS – no gross margins per value chain step and taxes
- The silicon cost evolution follows reported learning curves
- Breakage rate based on low consolidated volume (to be further addressed in the future)
- Average quality wafers have been considered
- Mono and multi as well as p-type and n-type even
- Cell processing cost: constant
- No major reduction in module assembly material

Main results – wafer level

Substrate	Standard 180µm	Thin 120µm	Ultra-thin 80µm	Epi foil 40µm
Current wafer cost (COGS in USD cents/Watt)	18.0	15.2	13.4	n/a
Ultimate wafer cost (COGS in USD cents/Watt)	13.2	11.0	9.8	5.4
Ultimate wafer cost corrected for yield (COGS in USD cents/Watt)	13.2	11.0	10.0	5.6
Current cell processing cost (COGS in USD cents/Watt)	15.0	15.0	15.0	n/a
Ultimate cell processing cost corrected for yield (COGS in USD cents/Watt)	15.0	15.0	15.3	15.6
Current integral module cost (COGS in USD cents/Watt)*	51.0	48.0	46.0	n/a
Ultimate integral module cost (COGS in USD cents/Watt)*	45.2	42.8	41.4	36.3

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Assumes 0.9 USD/item and an IBC 60 cell module of 20.5% efficiency and 300 Wp power output = 5 Wp per cell/wafer

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Around 25% cost reduction

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Ultimate integral module cost (COGS in USD cents/Watt)*	45.2	[illegible]	[illegible]	5.3

Around 58% cost reduction

Considering a throughput of 3000wafers/h, a mechanical yiled of 99.8%, re-use of the parent wafer and the following steps:

- Reclaim/clean of the parent wafer where the epitaxial Si foil will be grown
- Anodization
- Low hydrogen annealing (H2 anneal) and epitaxial deposition
- Lasering
- Detachment

CHEETAH

Main results – cell level

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Adding the wafer costs this lead to a 25% cost reduction at cell level

Note! One could grow an emitter and/or BSF/FSF7 during the epi-foil growth at no extra cost = more cost reduction that could balance the breakage rate and lower efficiency.

Main results – module level

Substrate	Standard 180µm	Thin 120µm	Ultra-thin 80µm	Epi foil 40µm
Current integral module cost (COGS in USD cents/Watt)*	51.0	48.0	46.0	n/a
Ultimate integral module cost (COGS in USD cents/Watt)*	45.2	42.8	41.4	36.3
Module efficiency (%)	20.5	20.5	20	19.5
Ultimate module cost corrected for module efficiency (COGS in USD cents/Watt)	45.2	42.8	42.4	38.2
Ultimate module cost corrected for module efficiency and cell yield (COGS in USD cents/Watt)	45.2	42.8	42.9	39.1

CHEETAH

Main results – module level

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Cost reduction of around 13.5%

For the ultimate costs, the ultimate wafer costs were now taken into account, keeping all other parameters and module efficiency constant and neglecting yield losses. **An additional assumption that was implemented was a cost reduction of 0.01 USD from back sheet material.**

Sensitivity Analysis for epi-foil modules

Module efficiency (%)

Production yield (%)	18,5	18,7	18,9	19,1	19,3	19,5	19,7	19,9	20,1	20,3	20,5	20,7	20,9	21,1	21,3	21,5
80	0,451	0,447	0,442	0,438	0,434	0,430	0,426	0,423	0,419	0,415	0,412	0,408	0,405	0,401	0,398	0,395
81	0,448	0,444	0,439	0,435	0,431	0,427	0,423	0,420	0,416	0,412	0,409	0,405	0,402	0,398	0,395	0,392
82	0,445	0,441	0,436	0,432	0,428	0,424	0,420	0,417	0,413	0,409	0,406	0,402	0,399	0,395	0,392	0,389
83	0,442	0,438	0,433	0,429	0,425	0,421	0,417	0,414	0,410	0,406	0,403	0,399	0,396	0,392	0,389	0,386
84	0,439	0,435	0,430	0,426	0,422	0,418	0,414	0,411	0,407	0,403	0,400	0,396	0,393	0,389	0,386	0,383
85	0,436	0,432	0,428	0,424	0,419	0,416	0,412	0,408	0,404	0,400	0,397	0,393	0,390	0,387	0,383	0,380
86	0,433	0,429	0,425	0,421	0,417	0,413	0,409	0,405	0,401	0,398	0,394	0,391	0,387	0,384	0,380	0,377
87	0,431	0,426	0,422	0,418	0,414	0,410	0,406	0,402	0,399	0,395	0,391	0,388	0,385	0,381	0,378	0,375
88	0,428	0,424	0,420	0,415	0,411	0,407	0,404	0,400	0,396	0,392	0,389	0,385	0,382	0,378	0,375	0,372
89	0,426	0,421	0,417	0,413	0,409	0,405	0,401	0,397	0,393	0,390	0,386	0,383	0,379	0,376	0,373	0,369
90	0,423	0,419	0,415	0,410	0,406	0,402	0,398	0,395	0,391	0,387	0,384	0,380	0,377	0,373	0,370	0,367
91	0,421	0,416	0,412	0,408	0,404	0,400	0,396	0,392	0,389	0,385	0,381	0,378	0,374	0,371	0,368	0,364
92	0,418	0,414	0,410	0,406	0,401	0,398	0,394	0,390	0,386	0,382	0,379	0,375	0,372	0,369	0,365	0,362
93	0,416	0,412	0,407	0,403	0,399	0,395	0,391	0,387	0,384	0,380	0,377	0,373	0,370	0,366	0,363	0,360
94	0,414	0,409	0,405	0,401	0,397	0,393	0,389	0,385	0,381	0,378	0,374	0,371	0,367	0,364	0,361	0,357
95	0,411	0,407	0,403	0,399	0,395	0,391	0,387	0,383	0,379	0,376	0,372	0,368	0,365	0,362	0,358	0,355
96	0,409	0,405	0,401	0,396	0,392	0,388	0,385	0,381	0,377	0,373	0,370	0,366	0,363	0,359	0,356	0,353
97	0,407	0,403	0,398	0,394	0,390	0,386	0,382	0,379	0,375	0,371	0,368	0,364	0,361	0,357	0,354	0,351
98	0,405	0,400	0,396	0,392	0,388	0,384	0,380	0,376	0,373	0,369	0,365	0,362	0,359	0,355	0,352	0,349
99	0,403	0,398	0,394	0,390	0,386	0,382	0,378	0,374	0,371	0,367	0,363	0,360	0,356	0,353	0,350	0,346

The yellow part of the figure reflects the scenarios where the epi-foil module will reach values above our result (0.391 USD/W) but lower than the standards product (0.452 USD/W) while the green areas are the scenarios where costs could decrease further. **What is promising to see is that even in worst case scenarios (80% production yield and 18.5% module efficiency) the final product (epi-foil) is cheaper.**

Conclusions

- Ultra-thin and epi-foil based products show significant potential for further cost reduction at high rates – consequent impact on LCOE
- The innovations reduce the silicon material use and the kerf loss (in improved wire sawing) - which is on average around 140 µm - along with a reduction of energy and other consumables required for the crystallization and the wafering process
- Investigation will continue on the c-Si and expand to other technologies
- There are many factors and components that are still unclear and will be subject to supply chain logistics and other macroeconomic factors such as global economic environment, EU competitiveness etc.
- Standardization around materials and also processes and equipment for these innovations require updates and improvements that will match with the specifications of those new products. This will substantially impact the cost and quality of those products.
- Industry involvement at early stages is important and planned within Cheetah.

Future renewable energy cost series, Solar PV. KIC InnoEnergy approach

Emilien Simonot, KIC InnoEnergy
Simon Philipps, Fraunhofer ISE
Wim Sinke, ECN
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KIC InnoEnergy cost reduction analysis toolbox

Future renewable energy costs series

How technology innovation is anticipated to reduce the cost of energy in Europe

www.kic-innoenergy.com/reports

Developed in collaboration with BVGassociates

Online LCOE model for evaluation of impact of innovation
www.kic-innoenergy.com/delphos

Provide:

→Reference cost breakdown of renewable energy power plants (EU representative)

→List of innovations + impact description

→Fully customisable

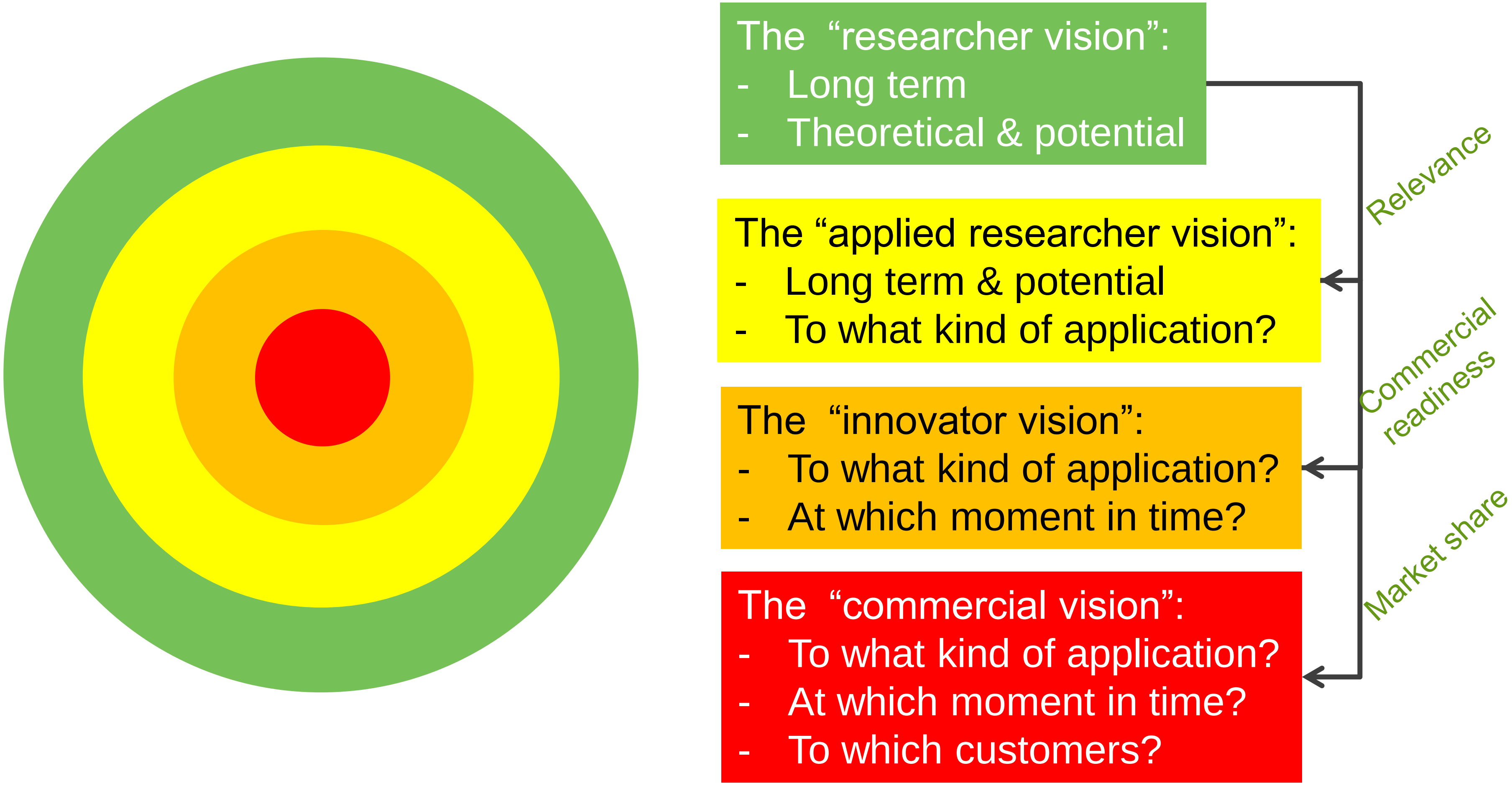
Objective: understand the impact of what we do

→Prioritize
→Invest
→Take decisions

→Serve as reference

From LAB to Market, modelling the impact of an innovation

(the biggest the circle, the highest the impact of the innovation)



Summary - headlines

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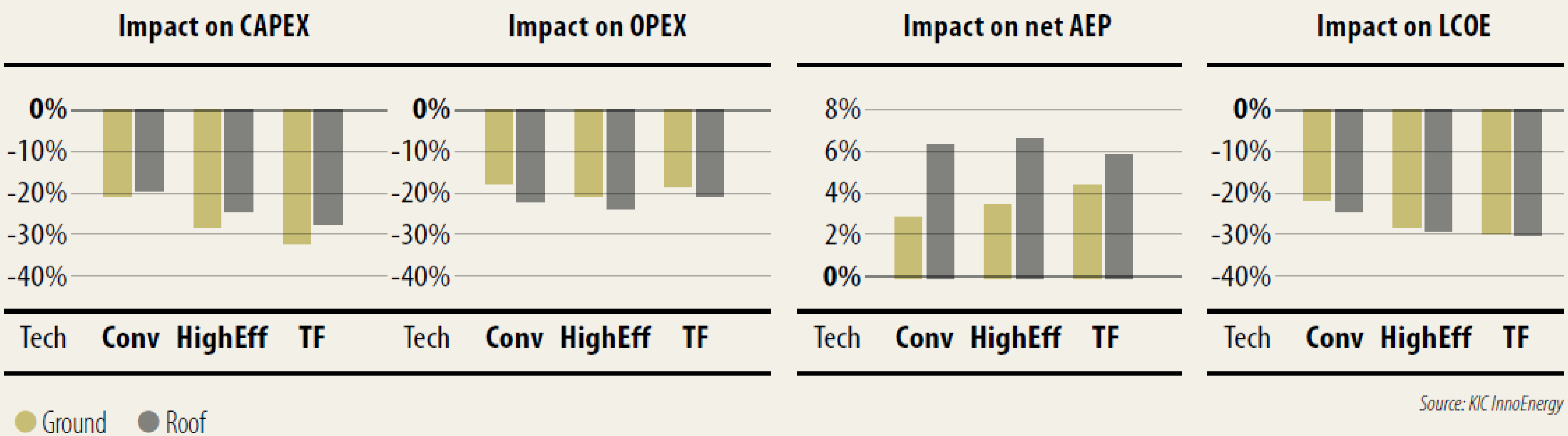
Wim Sinke, *ECN*

Emilien Simonot, *KIC InnoEnergy*
Antoni Martínez, *KIC InnoEnergy*

Summary - headlines

Figure 0.1 **Anticipated impact of all innovations by Technology Type with FID in 2030, compared with a plant with the same nominal power with FID in 2015[1].**



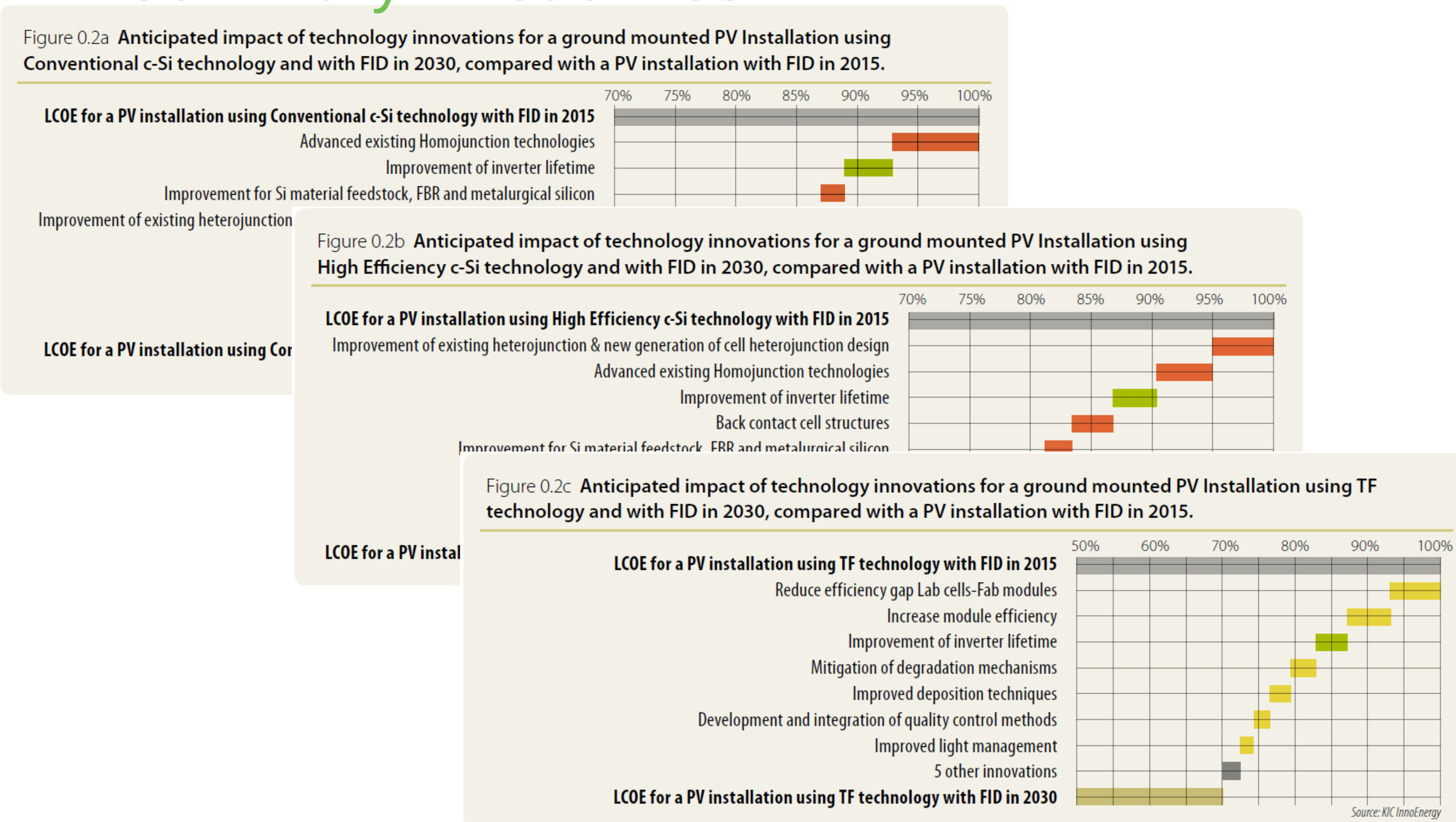
30 innovations screened – impact mid term 10/15 years

2 sites: ground mounted (multi MW range) & roof top (below 100kW range)

Representative EU average conditions

3 technology types: conventional (multi-c), high efficiency (mono-c) & thin film

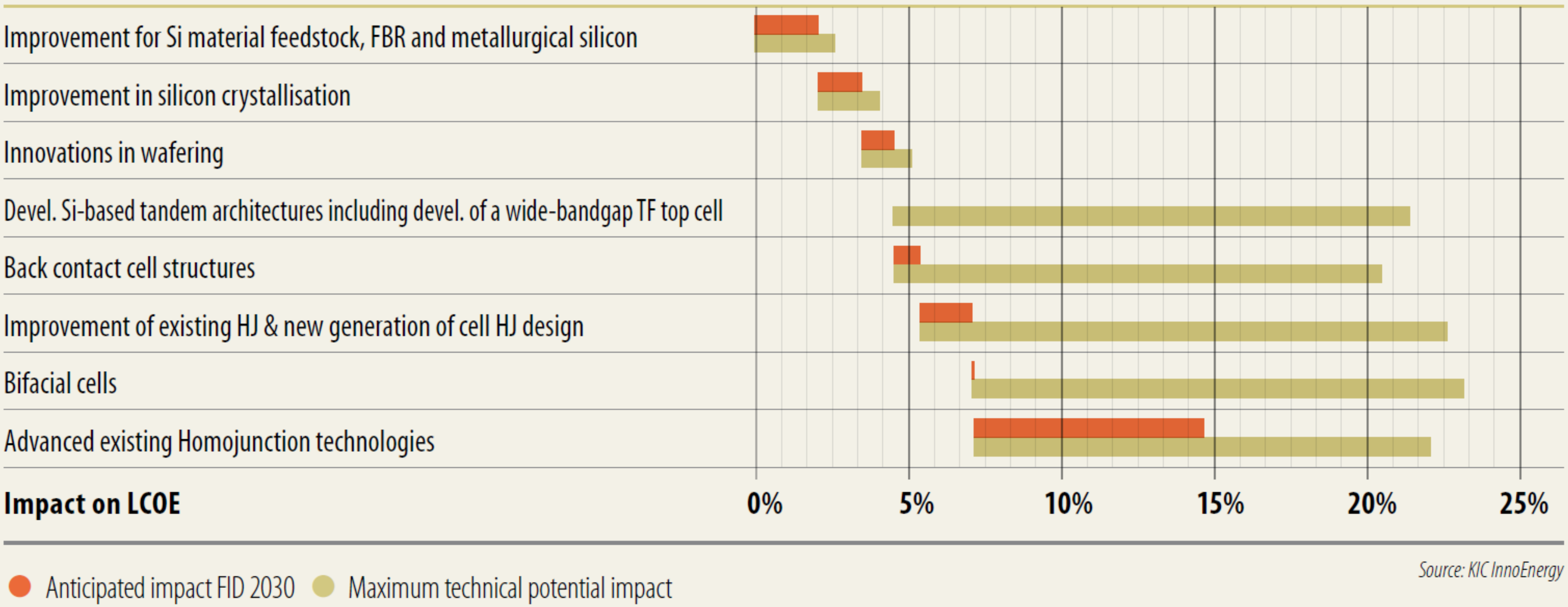
Summary - headlines



Innovations for cSi cell technology

Conventional cSi (multi-c)

Figure 4.2 **Anticipated and potential impact of PV cell manufacturing innovations for a ground mounted utility scale PV plant using conventional c-Si technology with FID in 2030, compared with an installation with the same nominal power on the same Site Type with FID in 2015.**

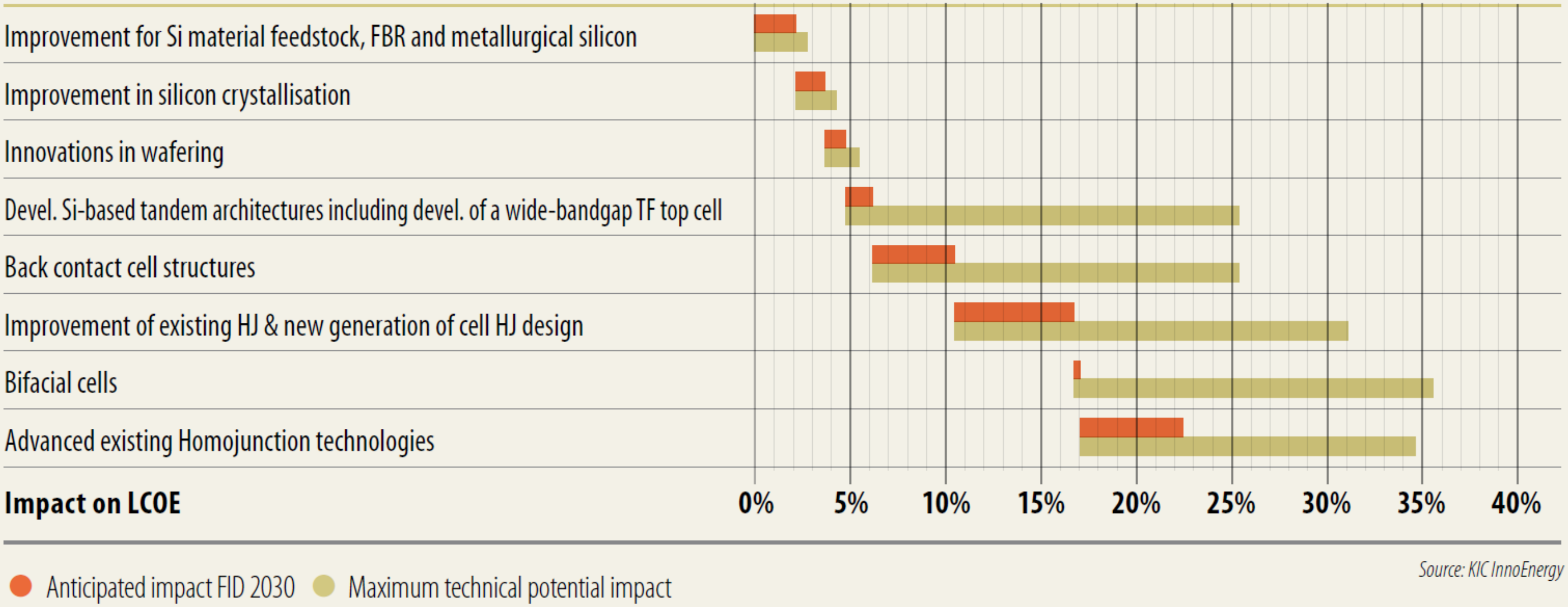


Source: KIC InnoEnergy

Innovations for cSi cell technology

High efficiency cSi (mono-c)

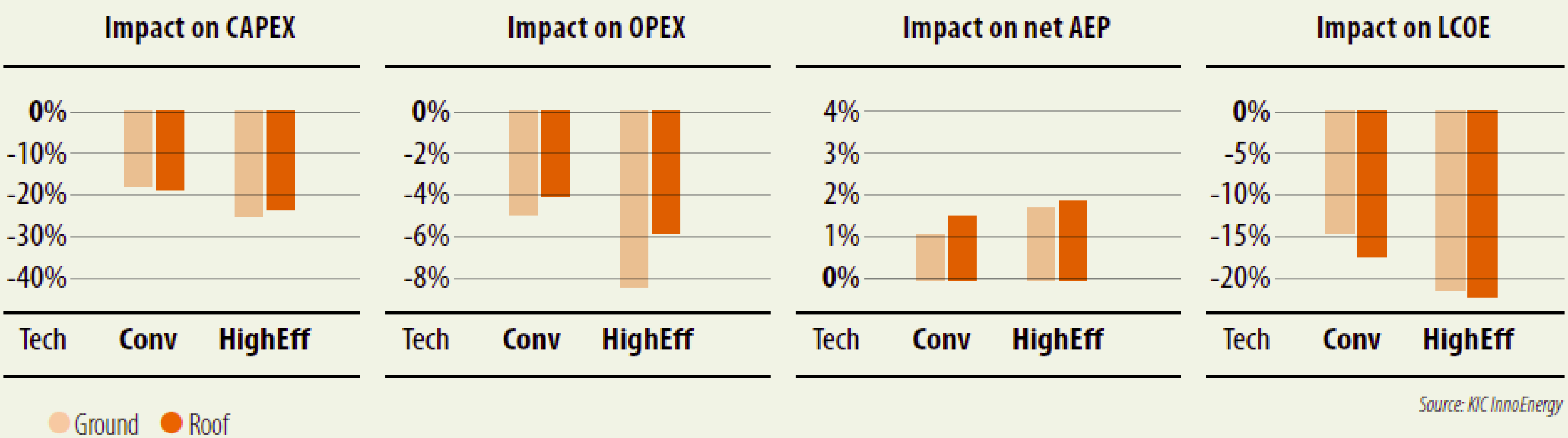
Figure 4.3 **Anticipated and potential impact of PV cell manufacturing innovations for a rooftop PV installation using High Efficiency c-Si technology with FID in 2030, compared with an installation with the same nominal power on the same Site Type with FID in 2015.**



Source: KIC InnoEnergy

Innovations for cSi cell technology

Figure 4.1 **Anticipated impact of PV cell manufacturing innovations by Technology Type with FID in 2030, compared with a plant with the same nominal power with FID in 2015.**

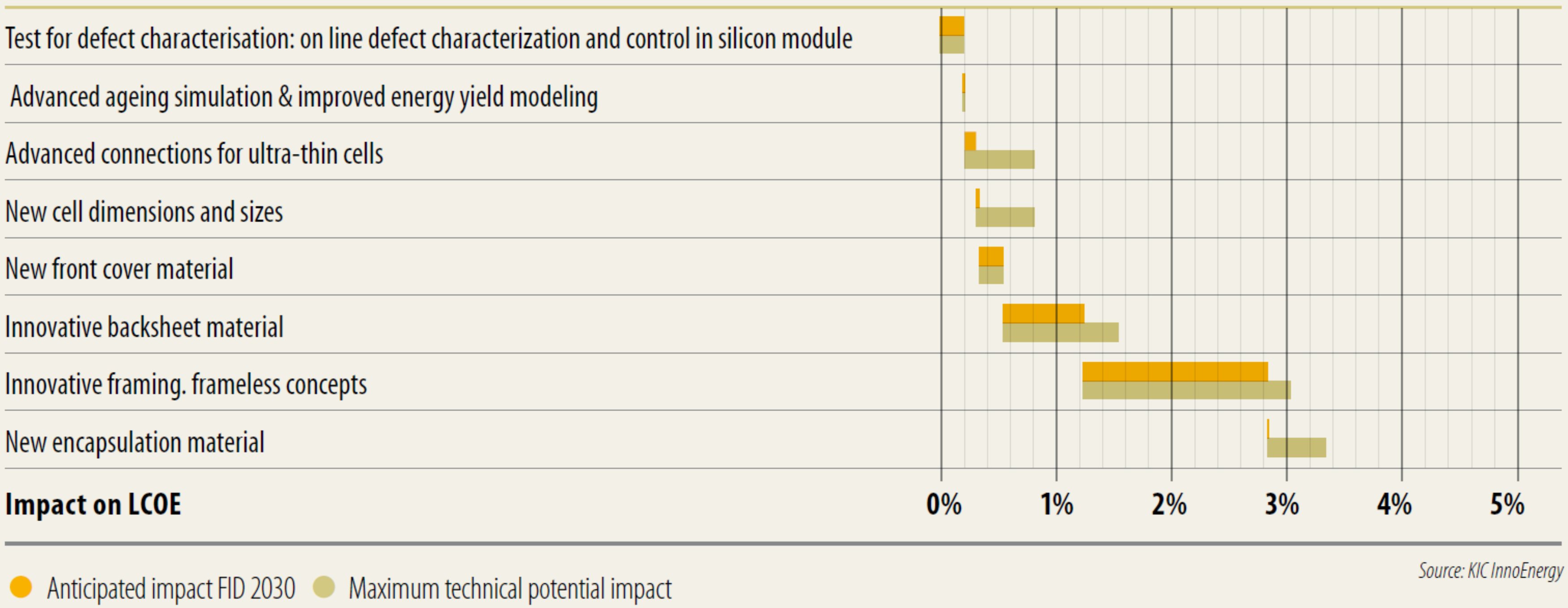


Source: KIC InnoEnergy

Innovations for cSi module technology

Multicrystalline Si

Figure 5.2 **Anticipated and potential impact of PV module manufacturing innovations for a ground mounted utility scale PV plant using Conventional c-Si technology with FID in 2030, compared with an installation with the same nominal power on the same Site Type with FID in 2015.**



Source: KIC InnoEnergy

Innovations for cSi module technology

Monocrystalline Si

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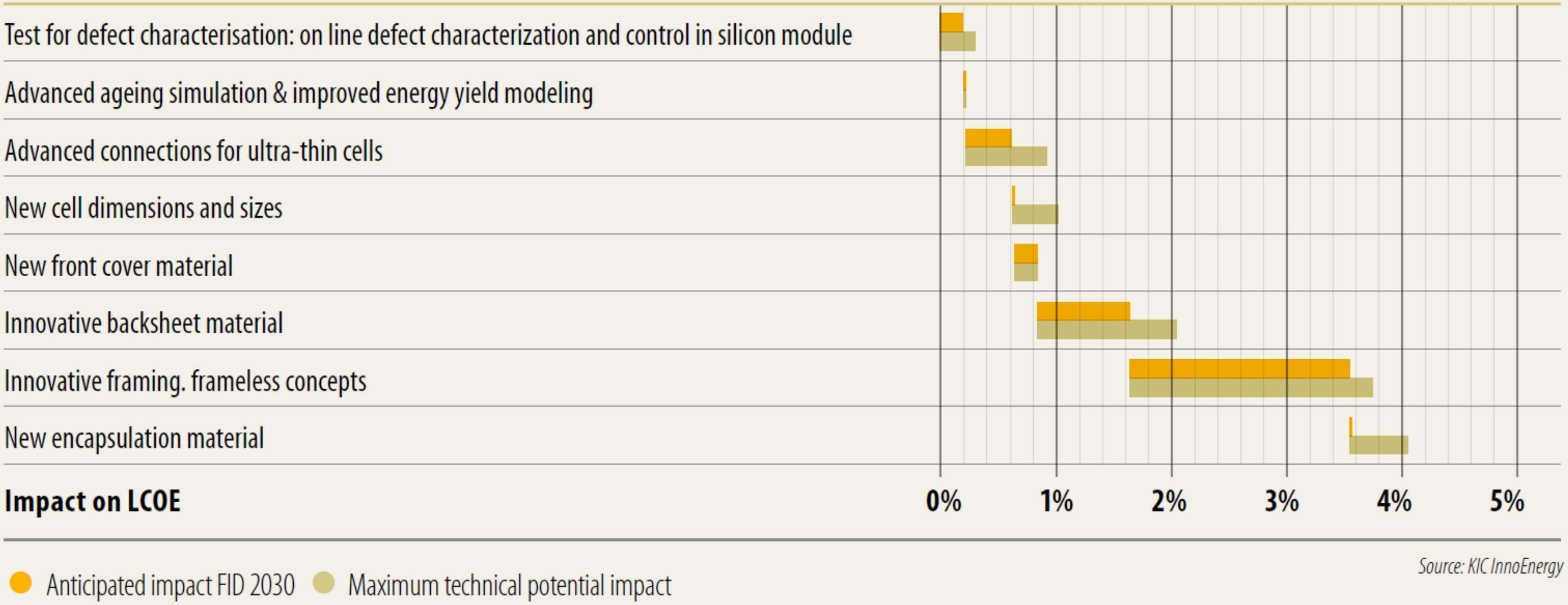


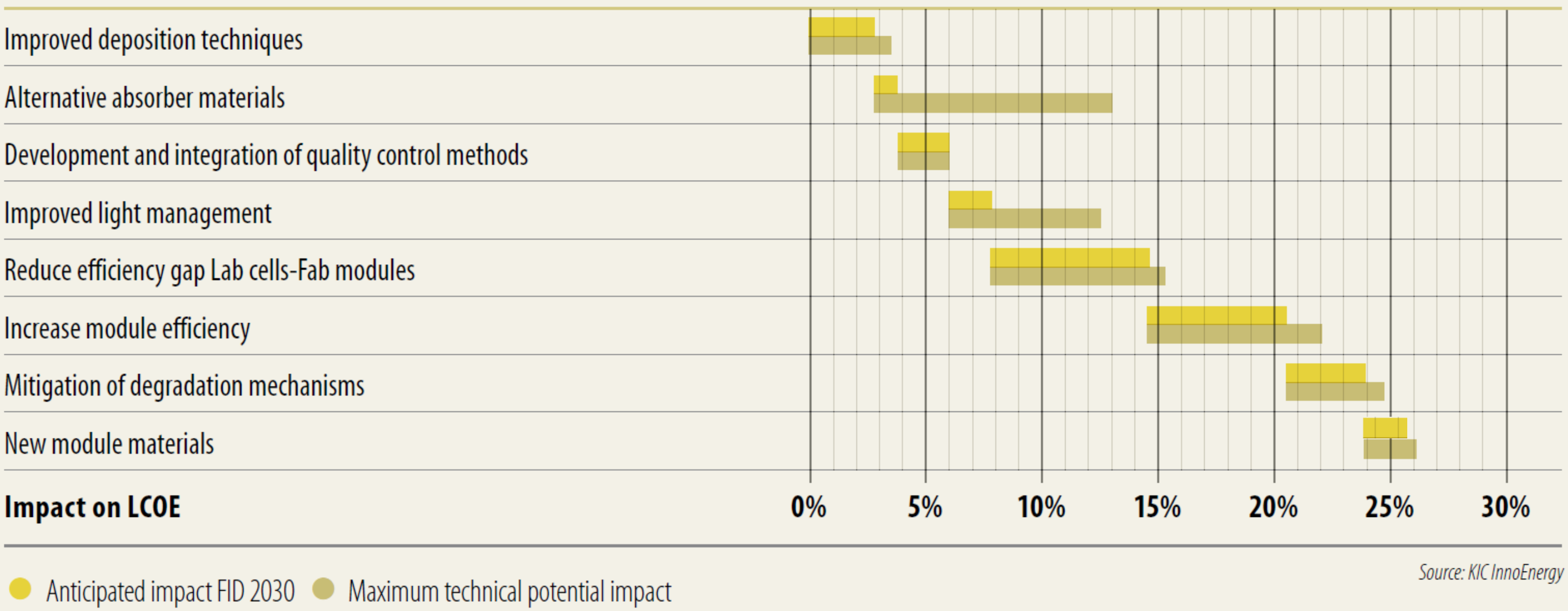
Source: KIC InnoEnergy

Innovations for Thin Film technology

Technologies considered:

- CdTe (ground mounted)
- CIGS (rooftop)

Figure 6.2 **Anticipated and potential impact of TF module innovations for a ground mounted PV installation using TF technology with FID in 2030, compared with an installation with the same nominal power on the same Site Type with FID in 2015.**



Innovations for Thin Film technology

The main LCOE reduction comes from increased module efficiencies due to:

- Reduction in gap between lab and fab efficiency by improved manufacturing processes
- Increased device efficiencies due to improvements in absorber, interfaces, passivation, light management, ...

Other important innovations will be:

- Better quality control leading to increased yield
- Mitigation of degradation mechanisms leading to higher AEP

Q&A

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