THE POTENTIAL AND CHALLENGES RELATED TO PHOTOVOLTAIC ELECTRICITY GENERATION AND LOCAL (DC) MICROGRIDS

PROF. J. POORTMANS, IMEC & ENERGYVILLE

OUTLINE

- The Energy system and DC-nano (microgrids)?
- The business case for DC-nano and microgrids
- Technology development enabling DC-nano and microgrids
- Introduction to EnergyVille

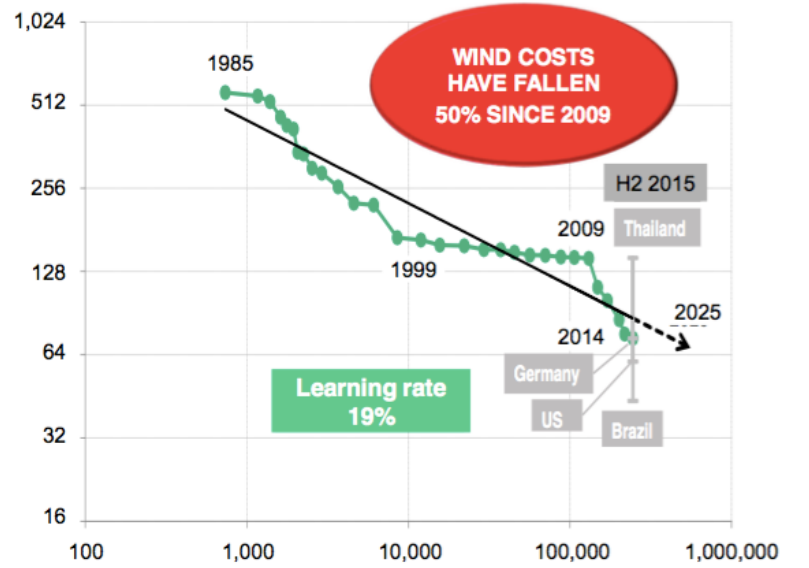
TOWARDS A SUSTAINABLE ENERGY FUTURE

DRIVEN BY (DRAMATIC) COST REDUCTION ...

TOWARDS A MORE DISTRIBUTED SYSTEM

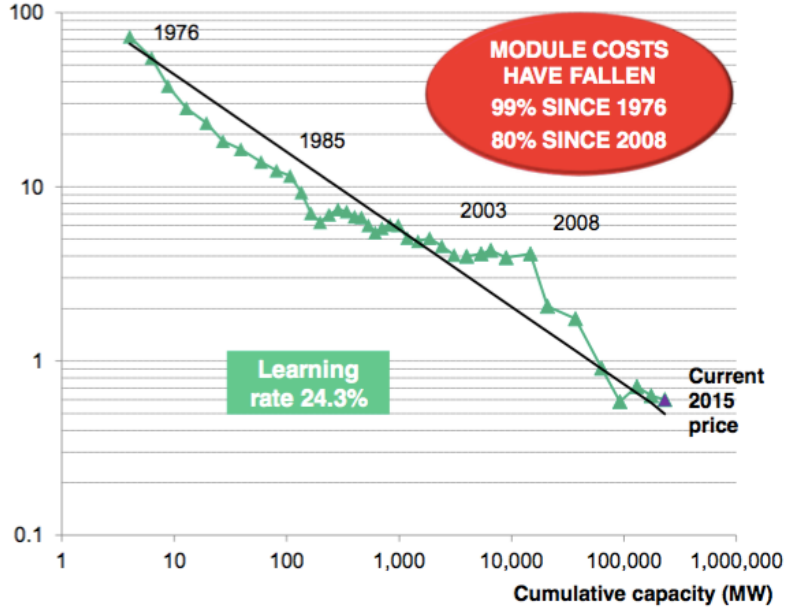
DRIVEN BY (DRAMATIC) COST REDUCTION ...

ONSHORE WIND LEVELISED COST ($/MWh)



Note: Pricing data has been inflation corrected to 2014. We assume the debt ratio of 70%, cost of debt (bps to LIBOR) of 175, cost of equity of 8% Source: Bloomberg New Energy Finance

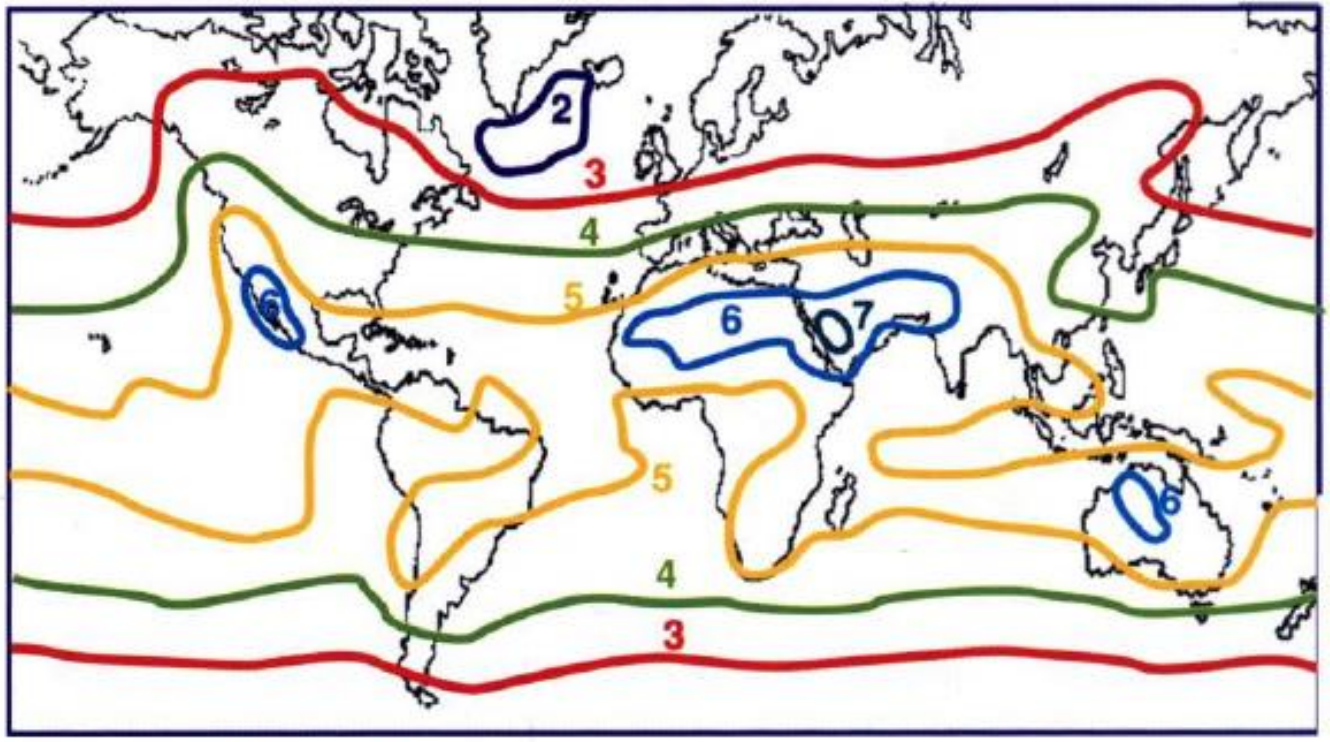
SOLAR PV MODULE COST ($/W)



Note: Prices are in real (2015) USD. 'Current price' is $0.61/W Source: Bloomberg New Energy Finance, Maycock

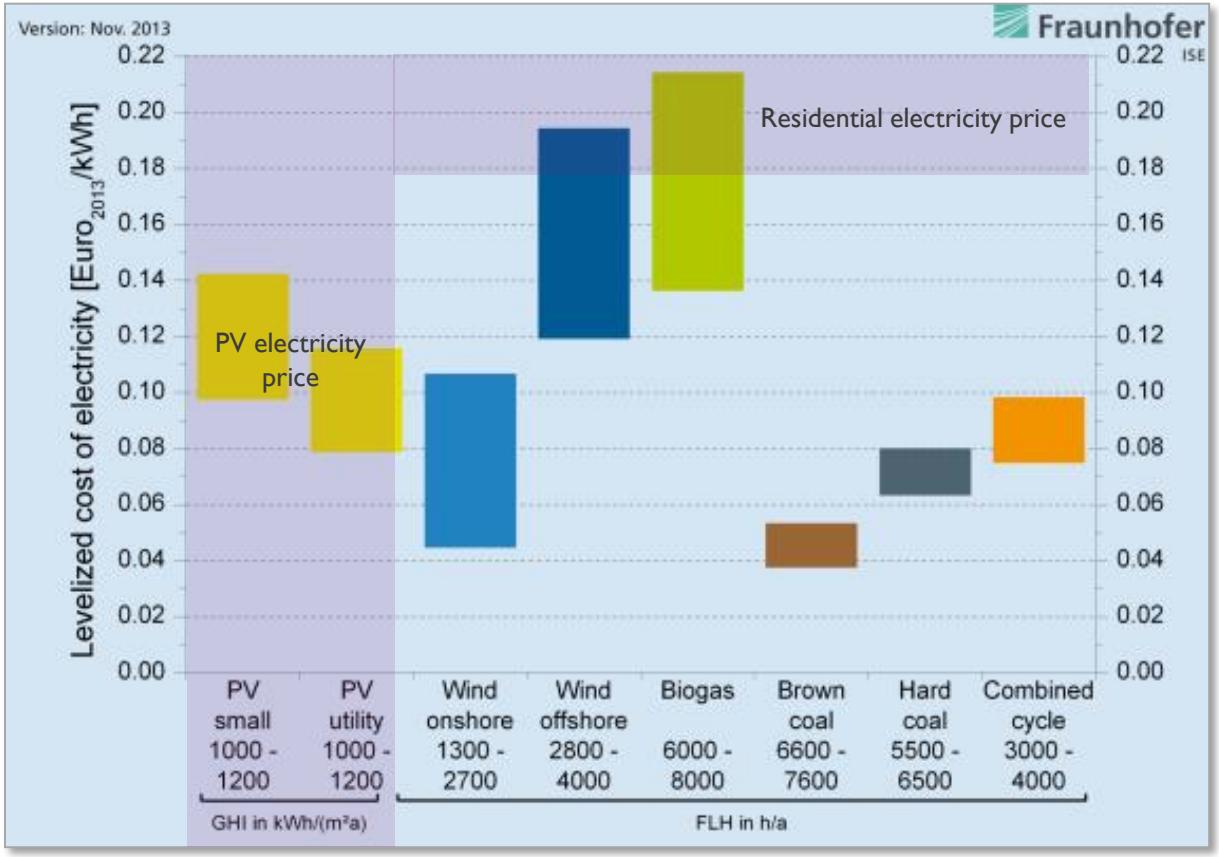
imec Energy Ville

Solar resource



solar irradiation in kWh/m² day
(source: ABB, 1998)

GRID PARITY IS REACHED …

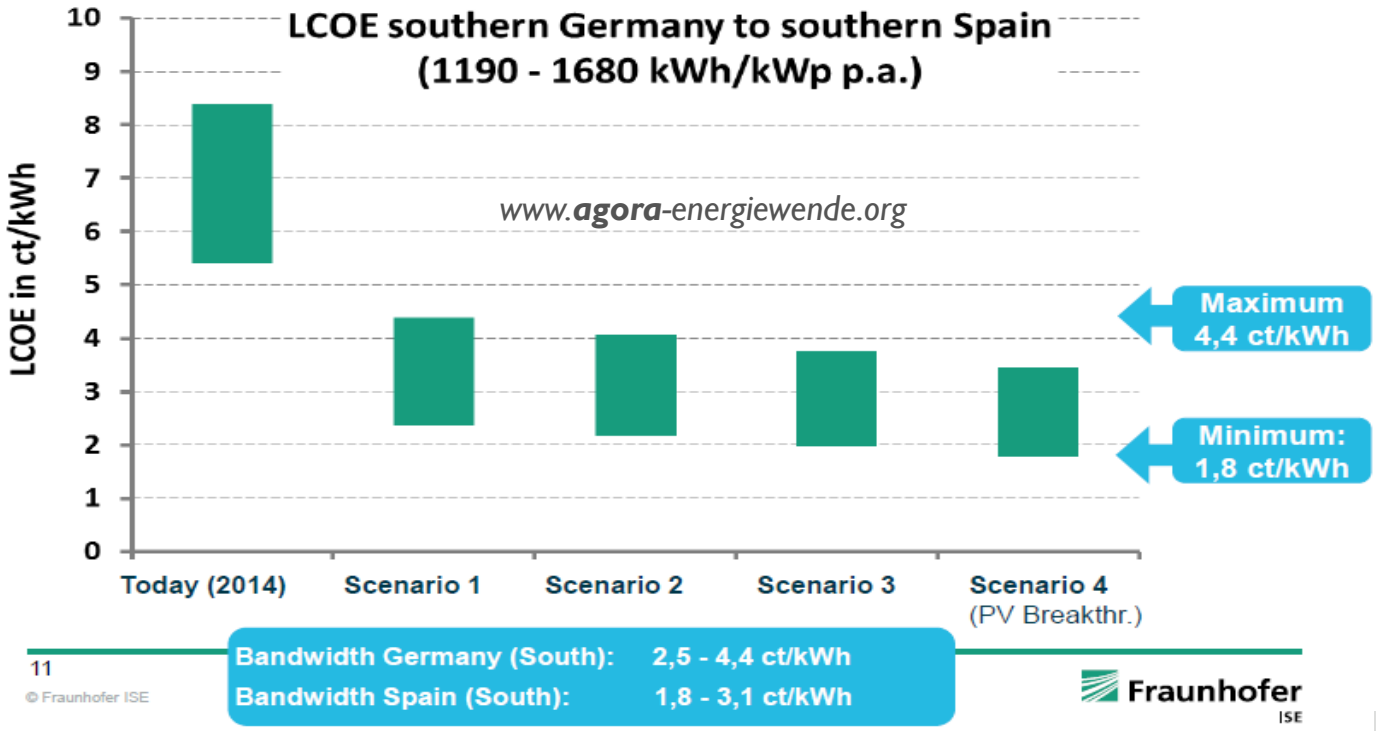


Fraunhofer ISE, 2014

LEADING ULTIMATELY TO …

Cost of power produced by Ground-Mounted PV in 2050

Levelized Cost of Electricity, ct/kWh

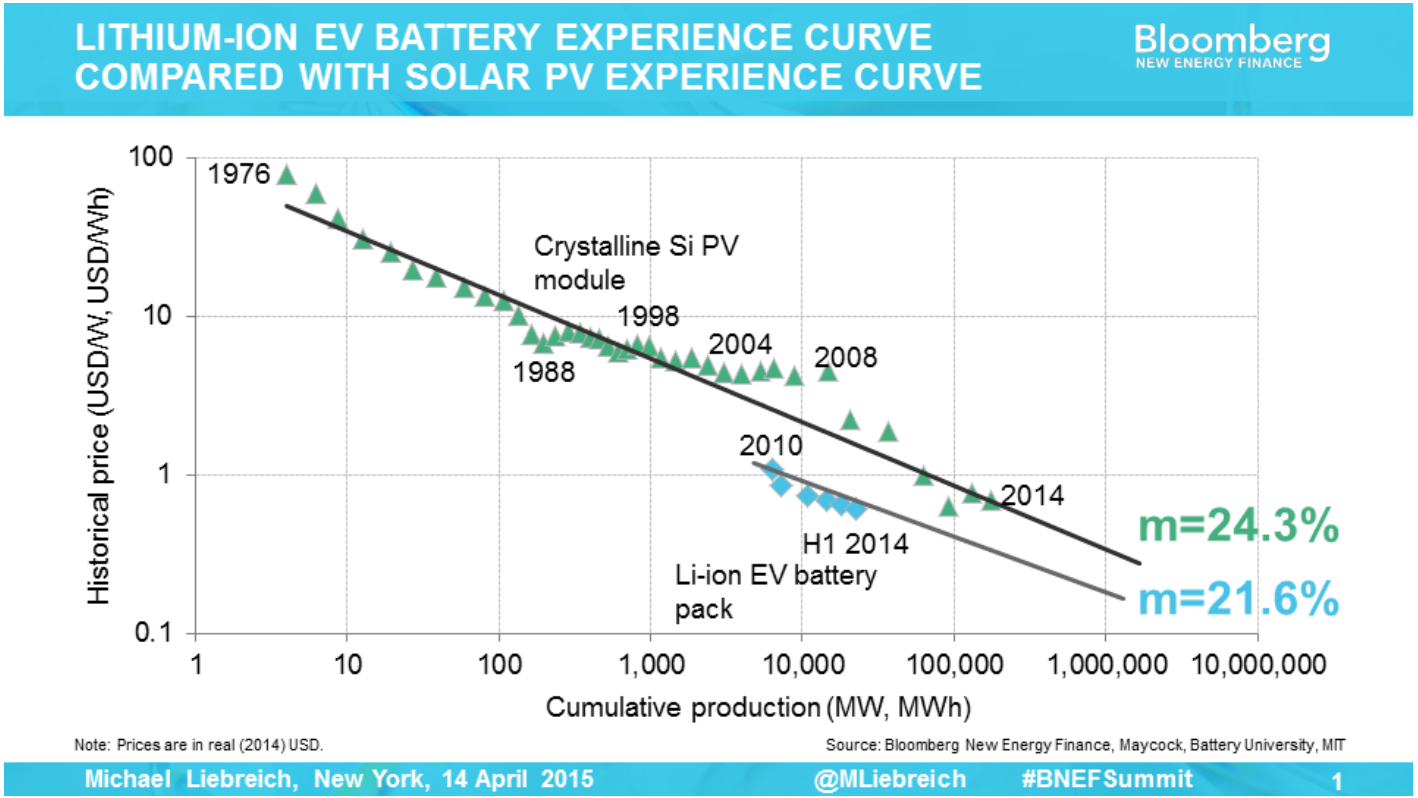


11

Fraunhofer ISE

TOWARDS A MORE DISTRIBUTED SYSTEM

DRIVEN BY (DRAMATIC) COST REDUCTION ...ALSO FOR STORAGE



imec Energy Ville

OUTLINE

- The Energy system and DC-nano (microgrids)?
- The business case for DC-nano and microgrids
- Technology development enabling DC-nano and microgrids
- Introduction to EnergyVille

IMEC'S ENERGY ACTIVITIES

in partnership with EnergyVille

High efficiency PV panels

Energy storage

Building integrated PV

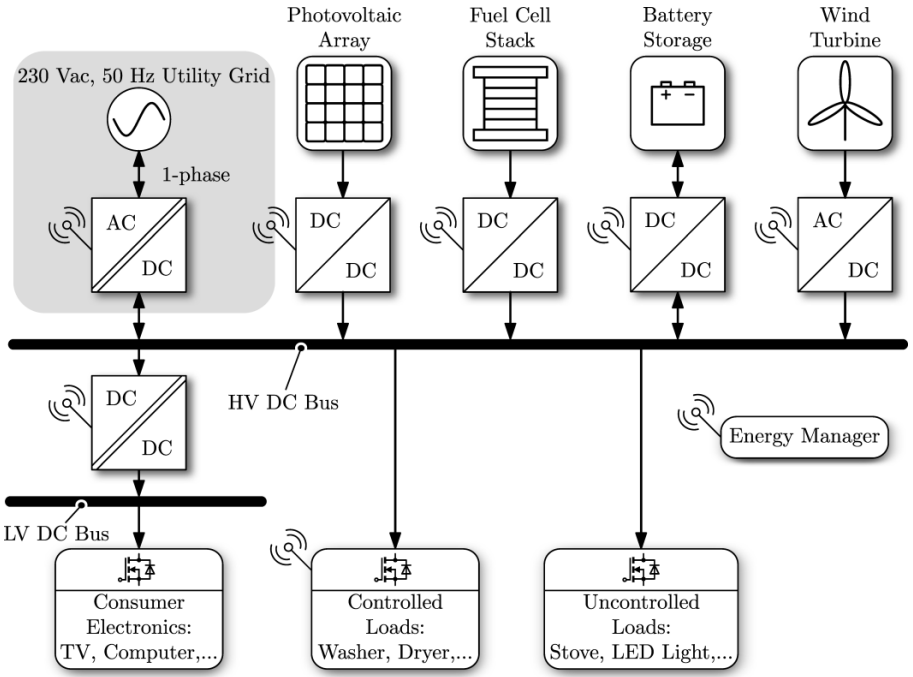
Energy yield optimization

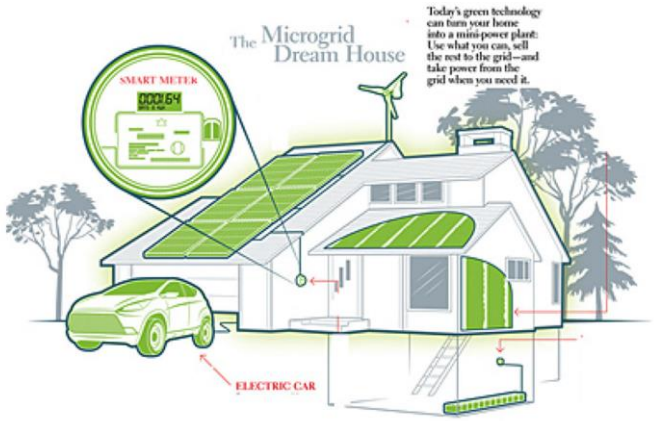
Controllable applicances, smart homes / IoT

imec EnergyVille

EXTENDING THE IMPACT TOWARDS SYSTEM

THE RETURN OF… THE DC GRID ?





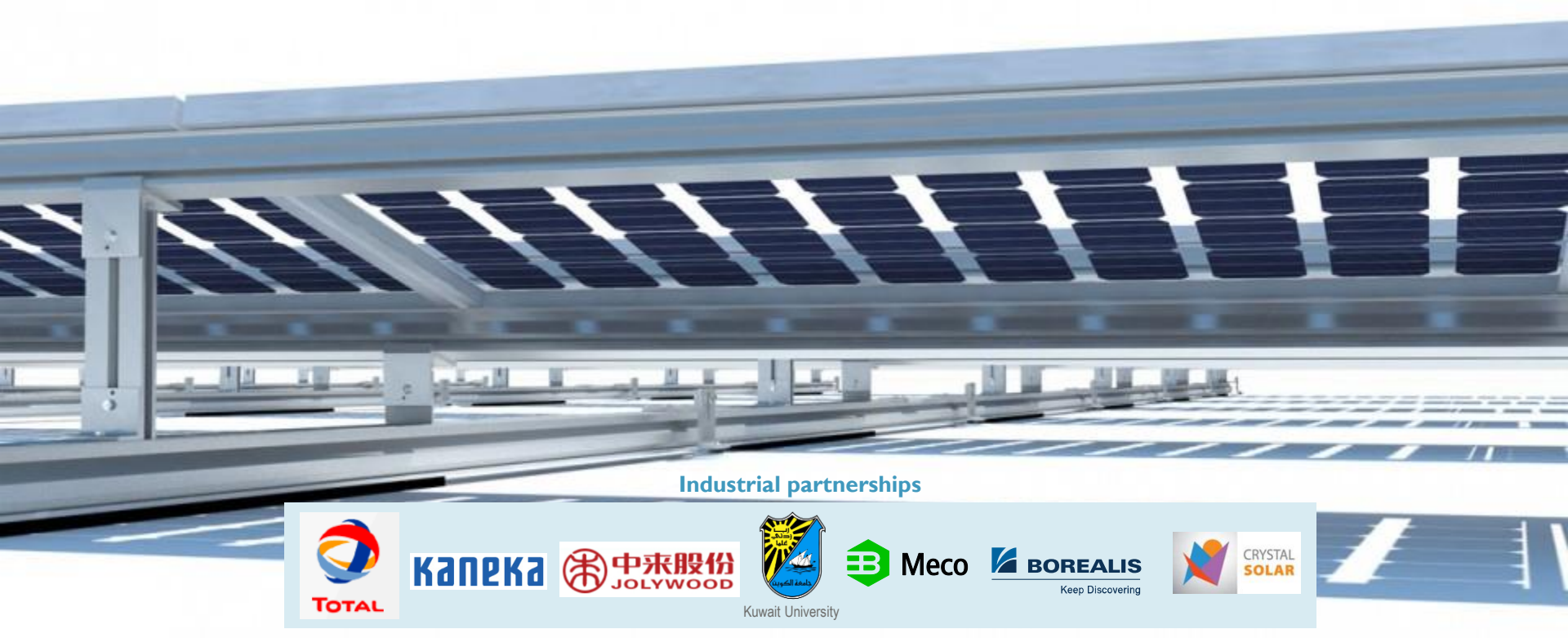
- Growing number of DC sources
  - PV, batteries, fuel cells
- Growing DC usage
  - LED's, storage, electric vehicles, consumer electronics, ...
- Move to DC-microgrids ?
- Need improved power converters

OUTLINE

- The Energy system and DC-nano (microgrids)?
- The business case for DC-nano and microgrids
- Technology development enabling DC-nano and microgrids
- Introduction to EnergyVille

PHOTOVOLTAICS

FOCUS ON THIN BI-FACIAL CELLS AND GLASS-GLASS MODULES FOR INCREASED ENERGY YIELD (KWH/KWP) AND IMPROVED RELIABILITY.



Industrial partnerships

TOTAL

kaneka

中来股份 JOLYWOOD

Kuwait University

Meco

BOREALIS
Keep Discovering

CRYSTAL SOLAR

CURRENT RESULTS

RECORD EFFICIENCY 22.8%, PLATED

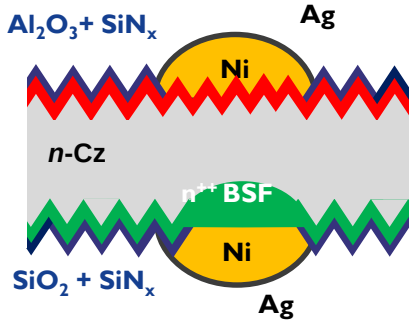
Results

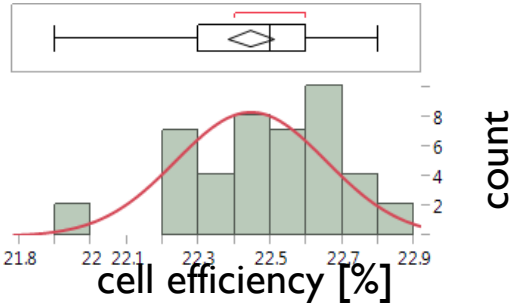
- Rear ju

...91±2 mV

Ni/A co-plat	...ficiency
	[%]
25 wfr cassettes	...4±0.2
	...8

239 cm², 5 Ωcm,
front STC (1000W
j_{sc} *calibration based*





imec

Energy Ville

imec

PRESS RELEASE

Imec develops bifacial n-PERT solar cell with a record 22.8% front-side efficiency

Leuven (Belgium) – April 17, 2017 – Imec, the world-leading research and innovation hub in nano-electronics, energy and digital technology and partner in EnergyVille today announced it has realized bifacial n-PERT solar cells using an industrially-compatible process with a record-setting front-side conversion efficiency of 22.8 percent. Used bifacially under standard front illuminations conditions in conjunction with an additional 0.15 sun rear illumination, these cells can produce the equivalent energy of 26.2 percent monofacial cells. With a projected potential low cost-of-ownership at module level (< 0.30 $/Wp), the newly developed bifacial cell technology allows a further reduction of the levelized cost of electricity (LCOE) of large photovoltaic (PV) installations.

Featuring a transparent backside and comparable front- and back contact schemes, bifacial solar cells capture light on both sides of the cell. As a result, they also profit from indirect light, light reflected by the ground and buildings, diffuse light on overcast days, and even direct light at sunrise or sunset, incident on their rear surface. Tests indicate that, over the course of their lifetime, such cells may generate 10-40 percent more electricity than traditional monofacial cells, depending on their bifaciality, the PV installation properties and the reflection or albedo of the location. This may result in an estimated LCOE reduction for PV installations of 10 up to 30 percent.

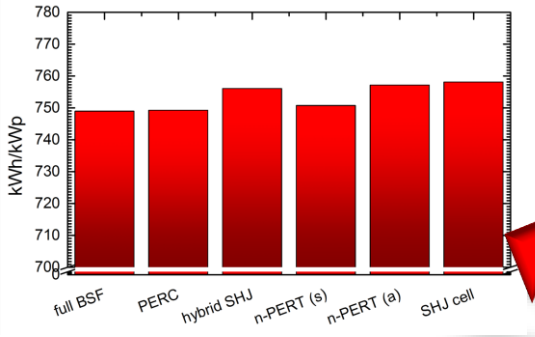
Imec's bifacial n-type PERT cells (Bi-PERT) have thin and narrow (< 20 µm) nickel-silver (Ni/Ag) plated fingers on both the n⁺ and p⁺ side of the cell. The cells' contacts were fabricated in a patented process of simultaneous plating both cell sides.. This cell plating is performed on cassette level (simultaneous plating on a full cassette of wafers in a chemical bath) without the need for an electrical contact to be made to the substrates. This resulted in a solar cell batch with an average conversion efficiency of 22.4 percent, with the best cell topping 22.8 percent, which is a record for this type of cell. These outcomes were measured internally, based on an ISE CalLab calibrated reference cell, with a GridTOUCH system under standard test conditions using only front side illumination and a non-reflective chuck.

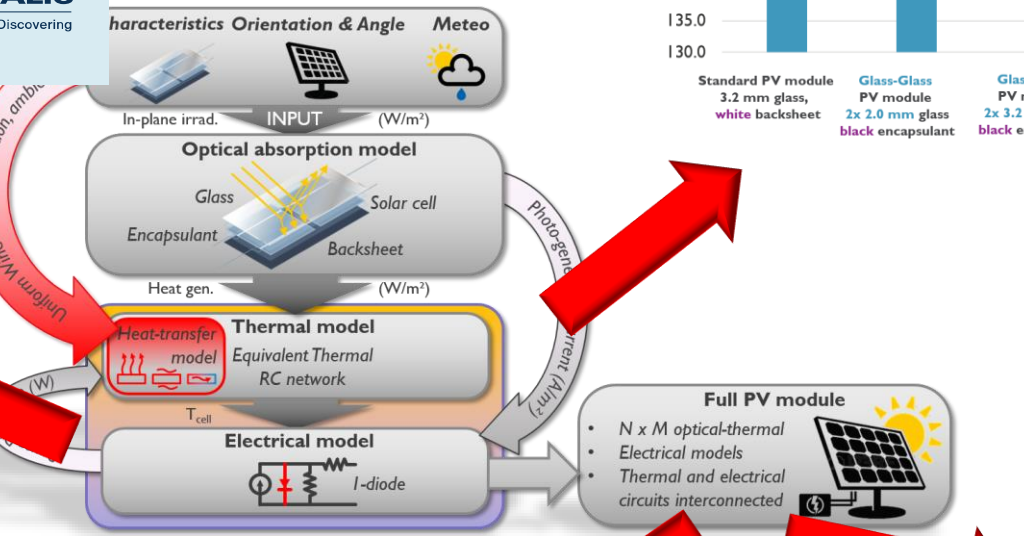
Filip Duerinckx, principal engineer at imec, said: "Our Cost-of-ownership calculations indicate that this new cell technology has the potential for an exceptionally low cost-of-ownership at module level (< 0.30 $/Wp). This results from the low-cost patented metallization, the fine finger contacts, and the essential of multi-wire interconn... Especially the very limited use of silver compared to screenprinted bifacial ... impact on the cost. As for the bifacial aspect: our ... bifacial gain. We are now working to ... connection, which we expect will ...

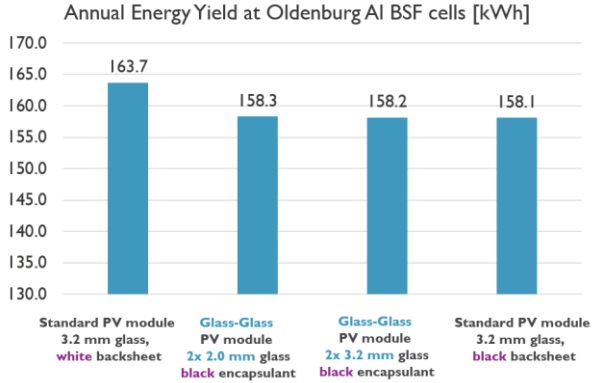
see: http://www.imec-int.com/en/articles/imec-develops-bifacial-n-pert-solar-cell-with-a-record-22-8-percent-front-side-efficiency

ENERGY YIELD SIMULATIONS

APPLICATIONS MODELLING FRAMEWORK

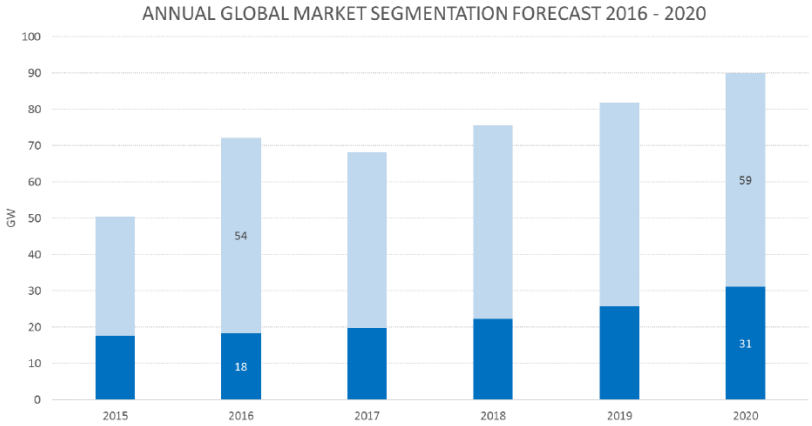


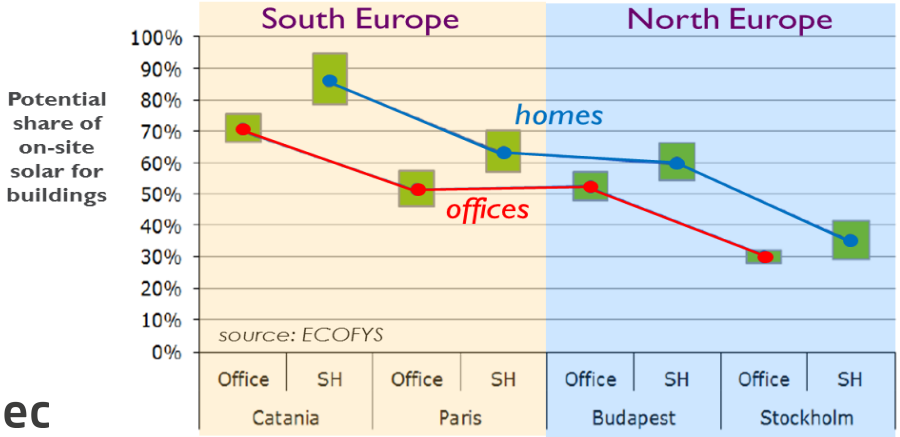




GENERAL ENERGY CONTEXT

2 PV-FLAVORS: PV POWER PLANTS VERSUS BIPV





NZEB "has a very high energy performance. [ ]. The nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby."

All new **public** authorities buildings:
nearly zero-energy buildings by end 2018

All new buildings:
nearly zero-energy buildings by end 2020

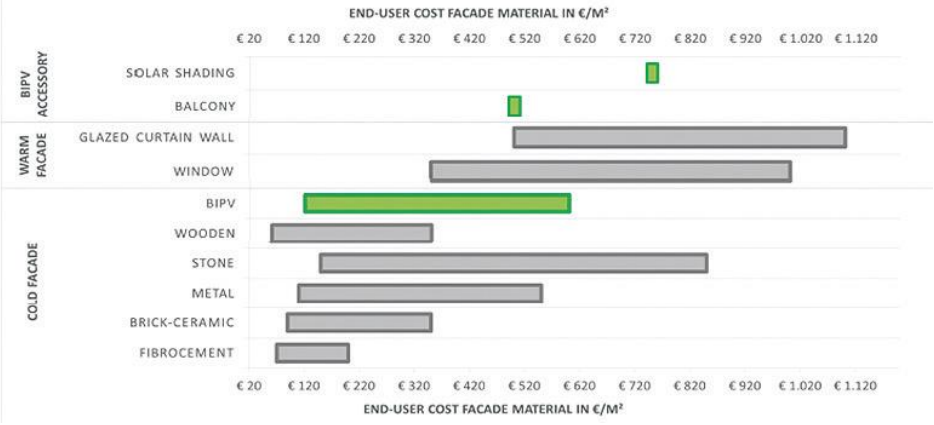
imec

How would you like your BIPV, Sir ?

BUILDING-INTEGRATED PV
A DIFFERENT BALL GAME

- Traditional PV (PV power plants)
  - Highly standardized
  - Cost-driven
  - Reliability to ensure Return-on-Investment

- Building-integrated PV
  - Need for flexibility
    - Dimensions
    - Color
  - Link with specific building project
  - Additional drives:
    - Aesthetics
    - Cost/m^2



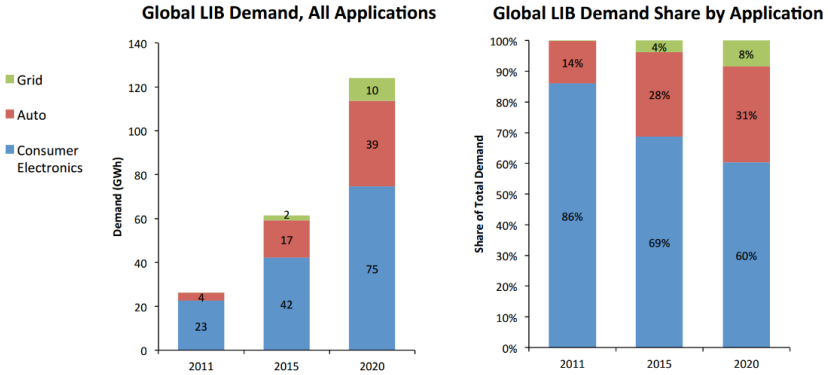
SOLID STATE BATTERY R&D

BATTERY MARKET AND EVOLUTIONS

HUGE MARKET GROWTH, ALL SOLID STATE IS THE NEXT BIG THING

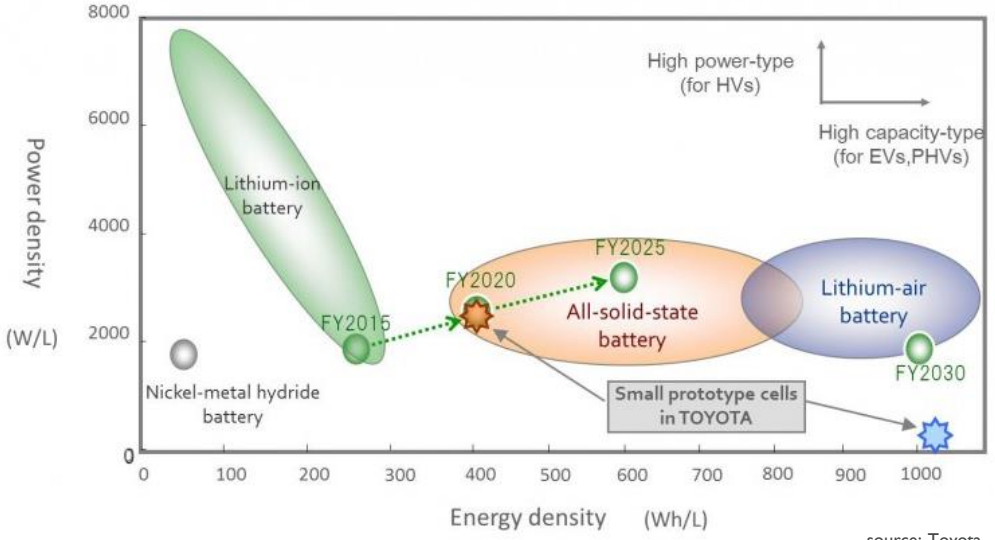
Overview of Global LIB Markets and Supply Chain

Consumer Electronics Represent the Majority of Demand for LIBs



- Competitive advantages for automotive LIB producers emerged from incumbent firms supplying consumer electronics (CE) applications; these advantages may persist, at least in the near-term.
- While automotive demand is expected to grow, the majority of demand for LIBs may continue to be driven by CE applications.

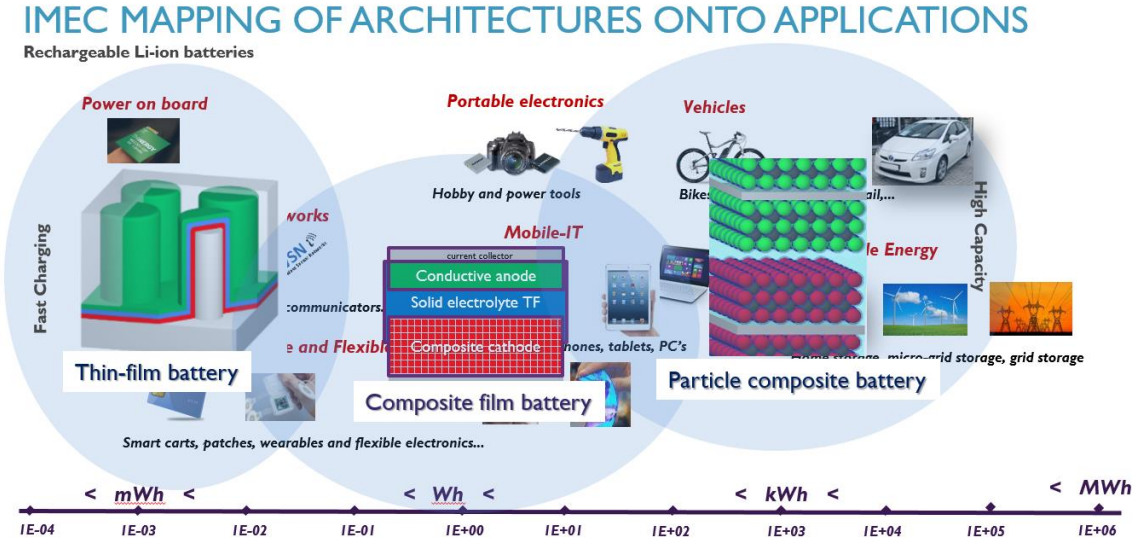
Sources: Roland Berger (2012); Pike Research (2013); AAB (2013); CEMAC analysis



source: Toyota

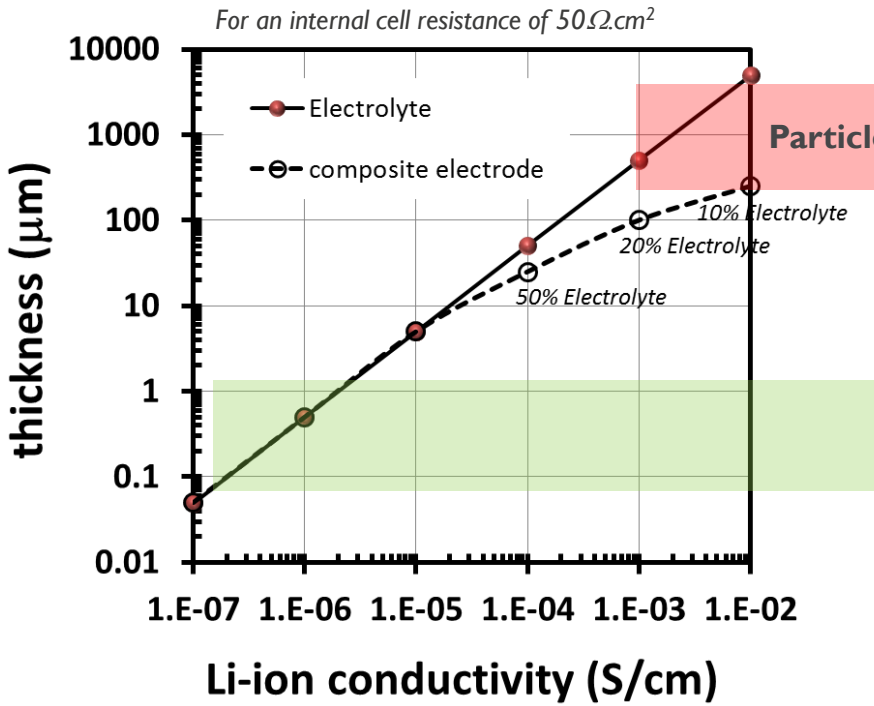
SOLID STATE BATTERIES

- Advantages
  - Safer
  - More energy
  - Faster Charging
  - Longer life-time
- Key features
  - Nano-composites
  - Very high conductive solid electrolyte

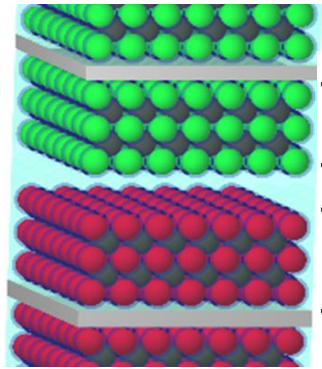


CONDUCTIVITY OF SOLID-STATE ELECTROLYTES

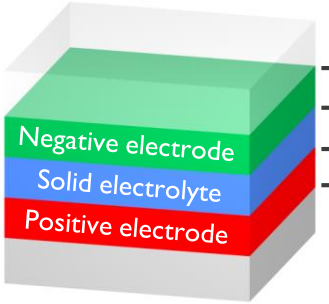
HIGH IONIC CONDUCTIVITY NEEDED (> 10 mS/cm) FOR LARGE STORAGE SOLID-STATE BATTERIES



Particle composite battery



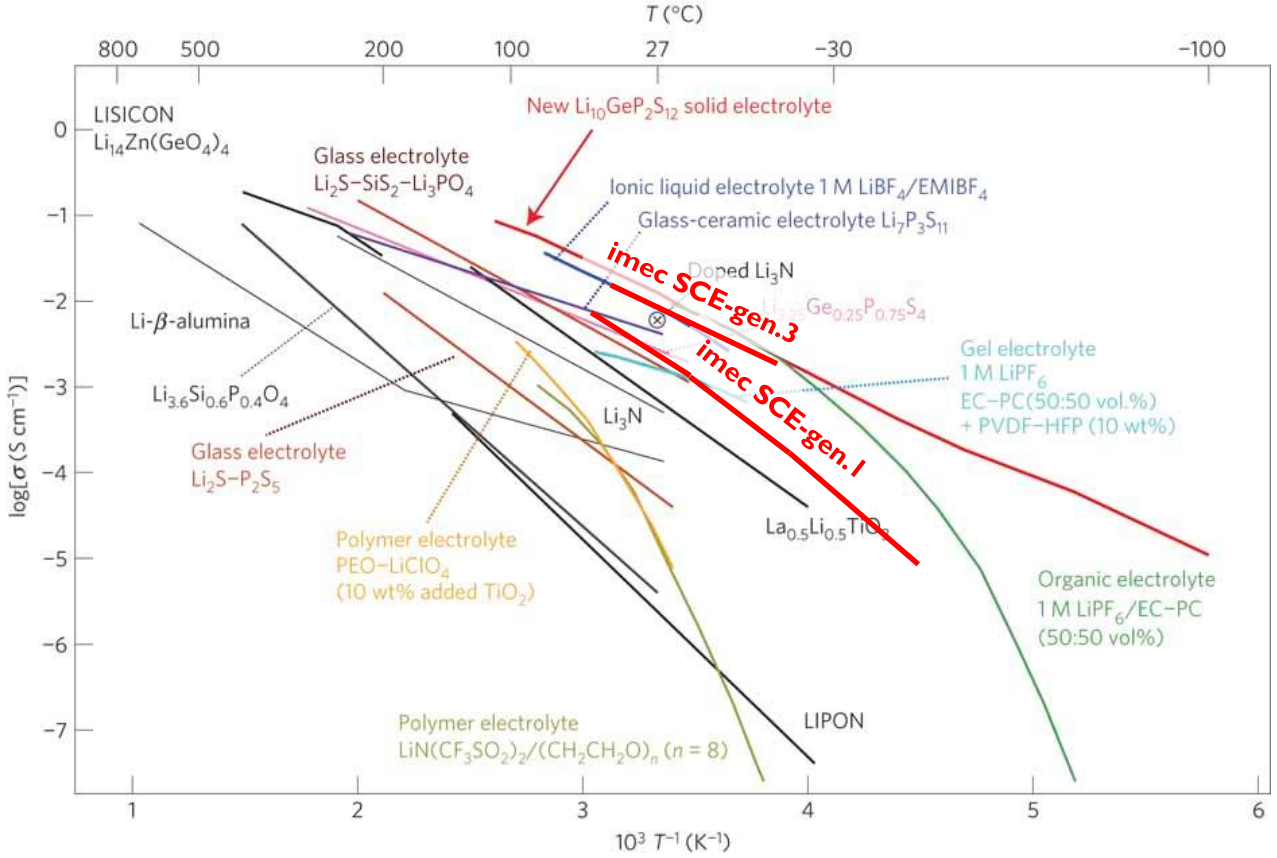
Thin-Film battery



imec Energy Ville

IMEC'S SOLID NANOCOMPOSITE ELECTROLYTES (SCE)

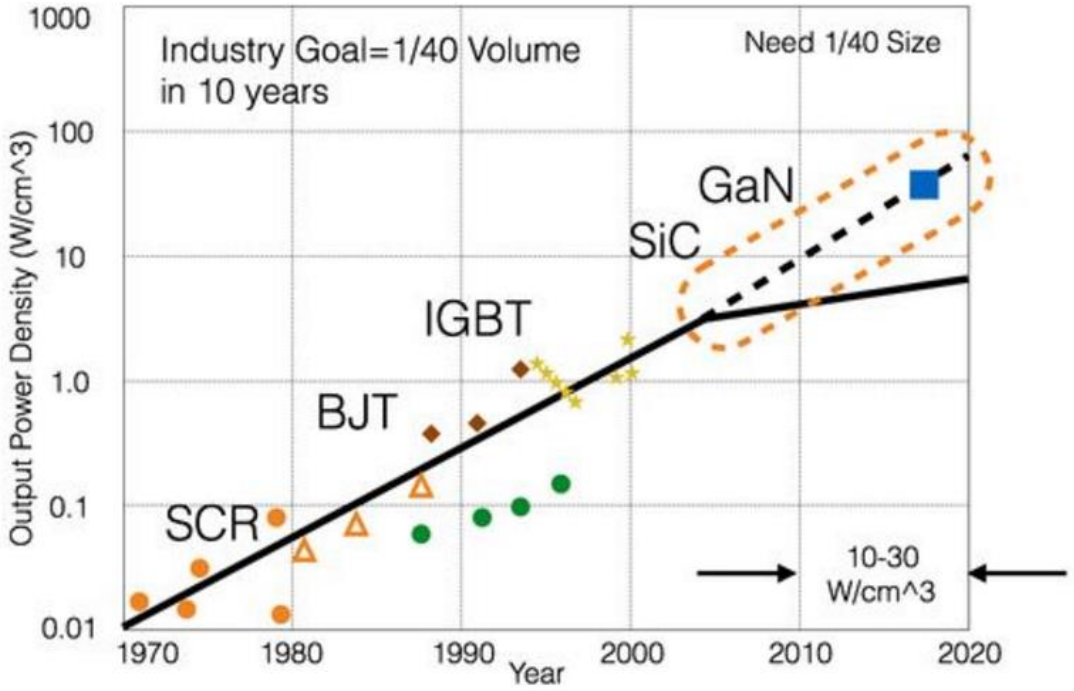
IONIC CONDUCTIVITY APPROACHING WORLD RECORD VALUES



POWER ELECTRONICS

EVOLUTION OF POWER DENSITY

WIDE BANG GAP TECHNOLOGIES (SIC AND GAN) ALLOW SCALING OF POWER DENSITY

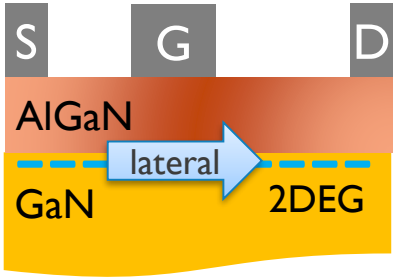


Source: Transphorm, APEC 2014

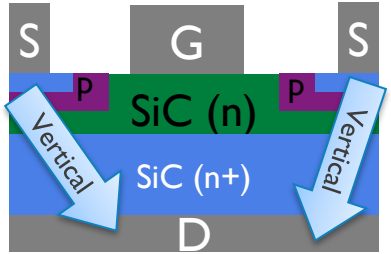
TWO MAIN WIDE BAND GAP MATERIALS: GAN AND SIC

GAN AND SIC OVERCOME THE INTRINSIC LIMIT OF SI

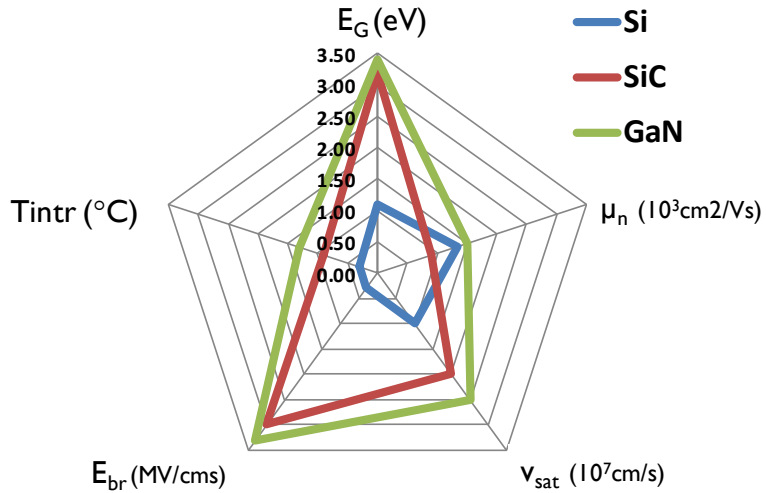
	Si	SiC	GaN
Eg (eV)	1.1	3.2	3.4
μ_n (cm2/V s)	1350	600	900 (Bulk) 1500 (2DEG)
ν_{sat} (10^7 cm/s)	1	2	2.5
E_{br} (MV/cm)	0.3	3	3.3
Tintrinsic (°C)	300	800	1300



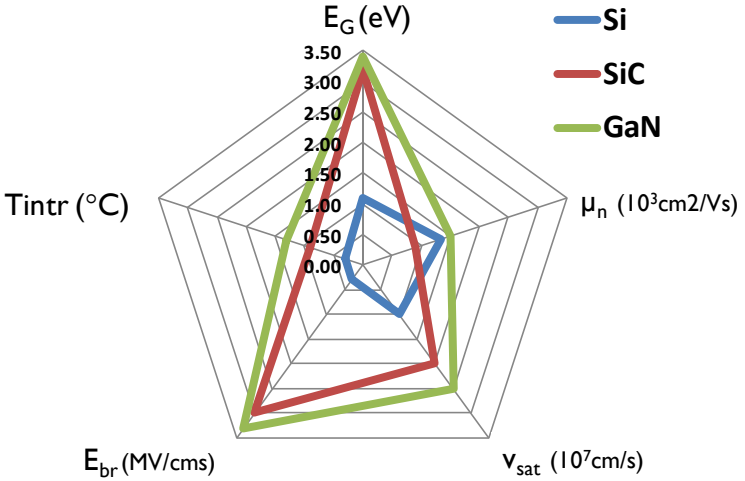
GaN HEMT



SiC MOSFET



WHICH IS THE BEST WIDE BAND GAP MATERIAL?



Comparison on...

- Breakdown
- R_{ON}
- Q_G
- Frequency
- ...
- cost

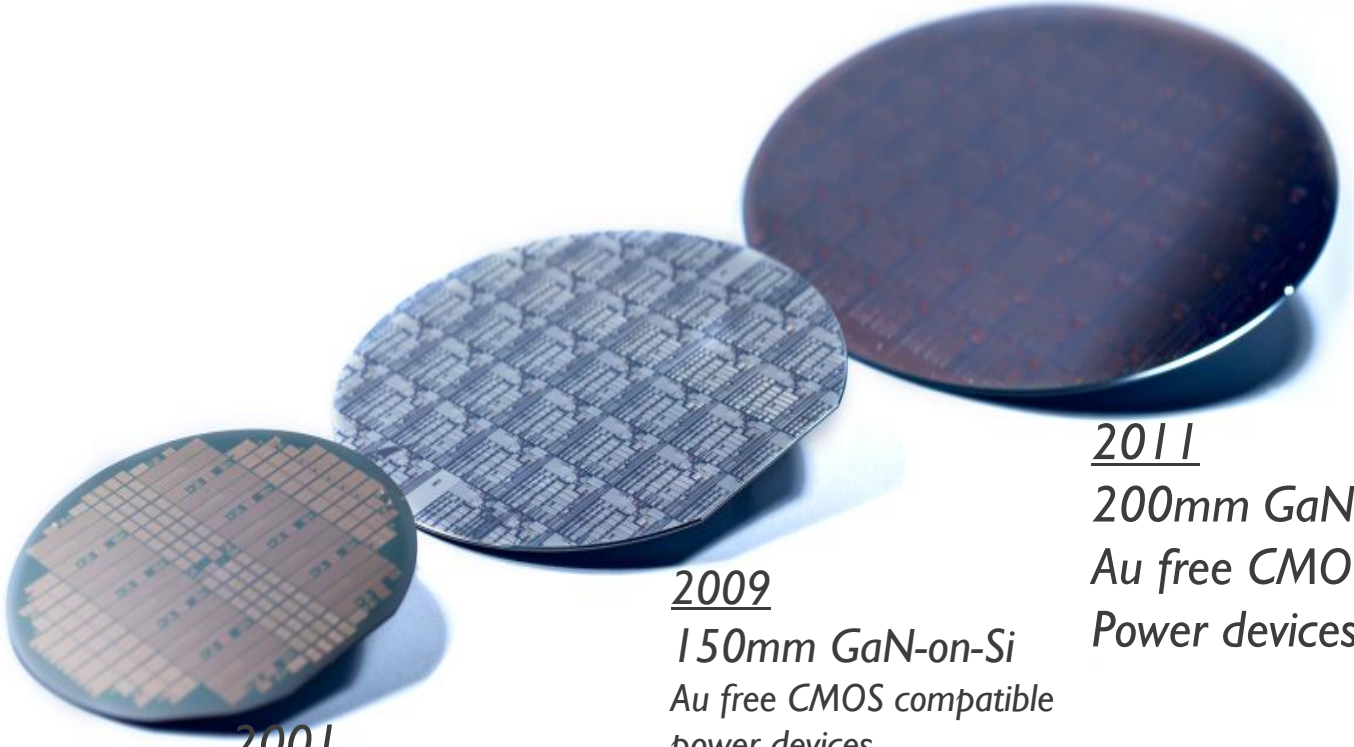
SiC is intriscially very expensive and yet limited in size...

...GaN epilayers can be grown on cheap and large size Si substrate (up to 200mm/8-inch) and processed in a highly productive CMOS fab.

GaN is a cost effective solution

IS IT TRUE THAT GAN CAN BE GROWN ON LARGE SI SUBSTRATE AND PROCESSED IN A CMOS FAB?

IMEC WAS THE FIRST TO SHOW 200MM GAN-ON-SI CMOS COMPATIBLE DEVICES



2001
100mm GaN-on-Si

2009
150mm GaN-on-Si
Au free CMOS compatible power devices

2011
200mm GaN-on-Si
Au free CMOS Compatible Power devices

EVOLUTION OF 200MM GAN-ON-SI E-MODE TECHOLOGY

	Target	..	2011
Voltage ratings (V)	**200/650**	Research	• CMOS compatible modules (Au free ohmics etc...) • 200mm GaN-on-Si epitaxy dev't • E-mode exploration
Vth(V)	**>2V**		
Ron (ohm mm)	**<10 (200V)** **<20 (650V)**		
Dynamic R_{DSon}	**<20%**		

- **Several years of R&D**
- Main challenge is to achieve **simultaneously high Vth and low Ron**
  - High Vth is also mandatory for reliability purposes
- **Dynamic Rdson – Dispersion reduction** is the **last and toughest 10% of optimization**
  - Epi-buffer needs to be optimized
  - Device processing needs to be optimized
  - Device design needs to be optimized

OUTLINE

- The Energy system and DC-nano (microgrids)?
- The business case for DC-nano and microgrids
- Technology development enabling DC-nano and microgrids
- Introduction to EnergyVille

ENERGYVILLE VISION

Combining energy and ICT

The **concurrent spectacular technology innovation and cost reduction of both ICT and distributed energy resources** creates a unique opportunity for the transition towards a sustainable energy system. This **decentralized multi-energy system will be characterized by a dominance of electricity** as energy vector **strongly coupled with other carriers** as for instance thermal energy. The deployment of this energy system in a **highly complex urban context**, ensuring **security of supply, resilience and sustainability** will be the cornerstone of the Sustainable City.

EnergyVille: Energy research partnership by

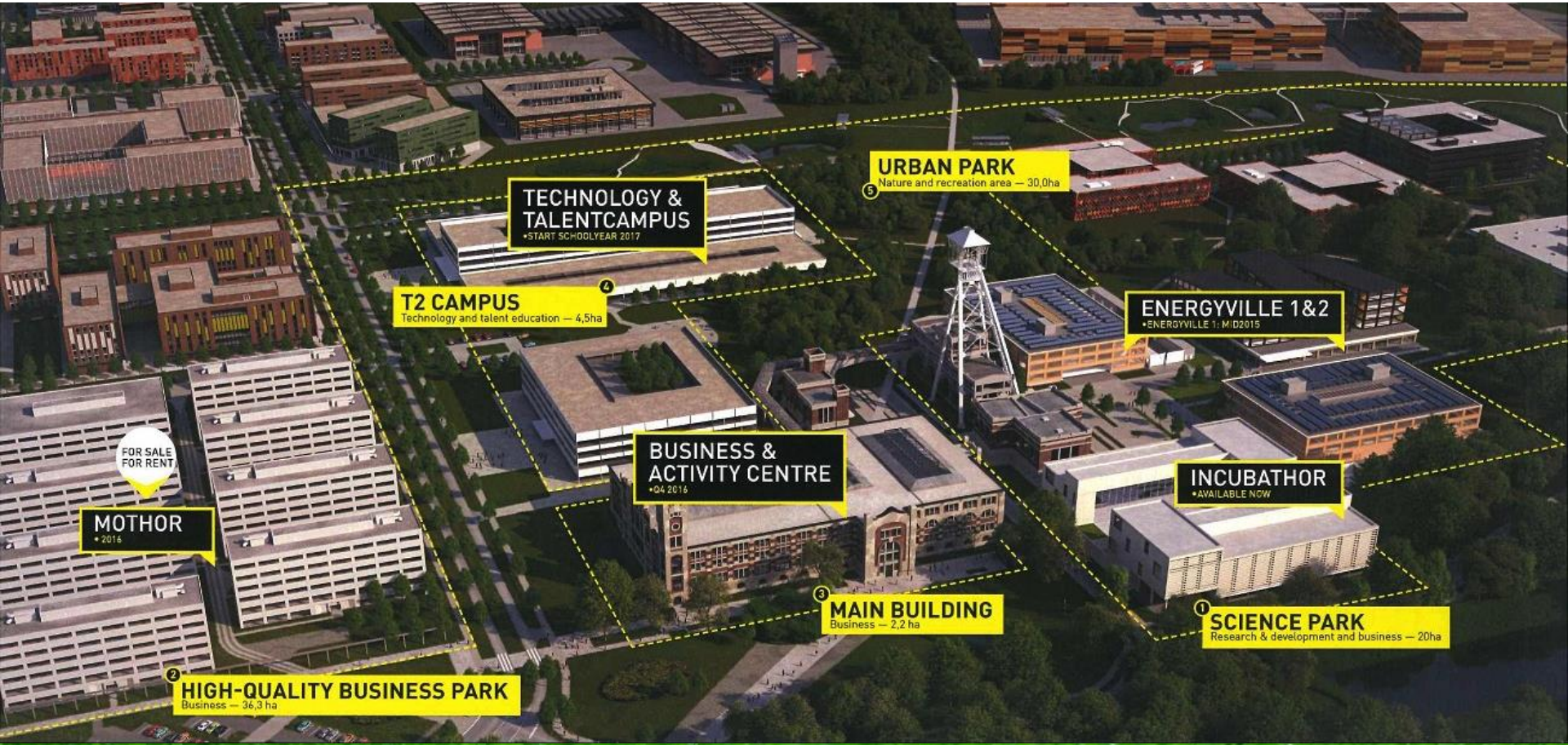
VITO
- Energy Technology
- Sustainable Cities

KU Leuven
- Electa
- Building Physics
- Mechanics

imec
- Photovoltaic Research
- Solid-state batteries
- Power devices
- Energy yield forecasting

UHasselt
- Materials
- Reliability

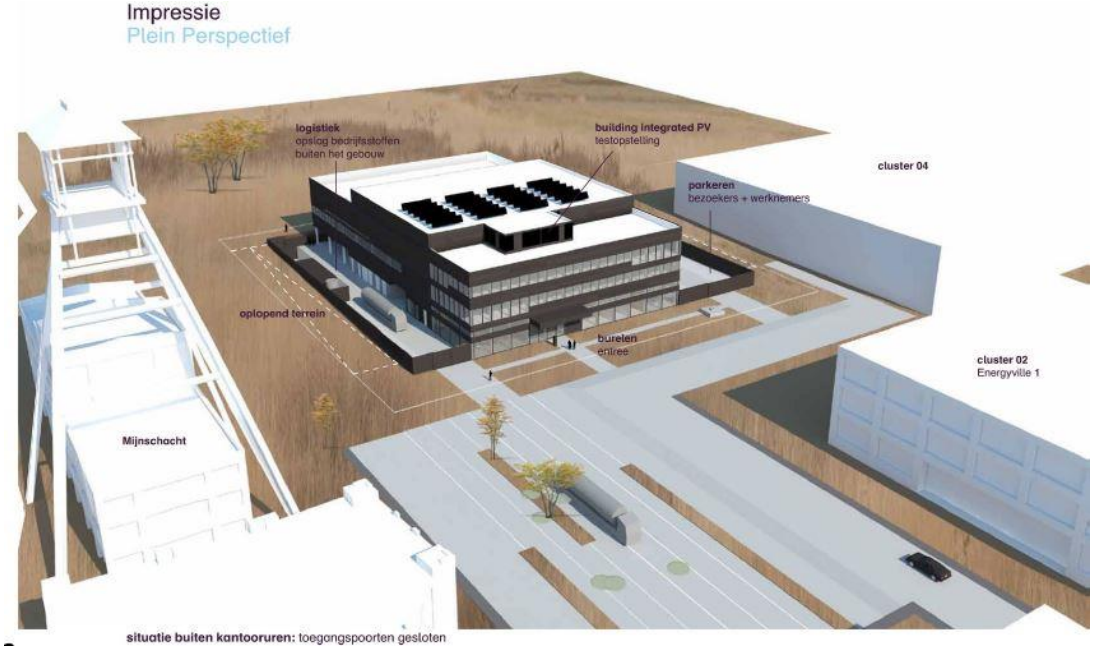
Embedded in an eco-system



ENERGYVILLE

A FLEMISH RESEARCH PARTNERSHIP

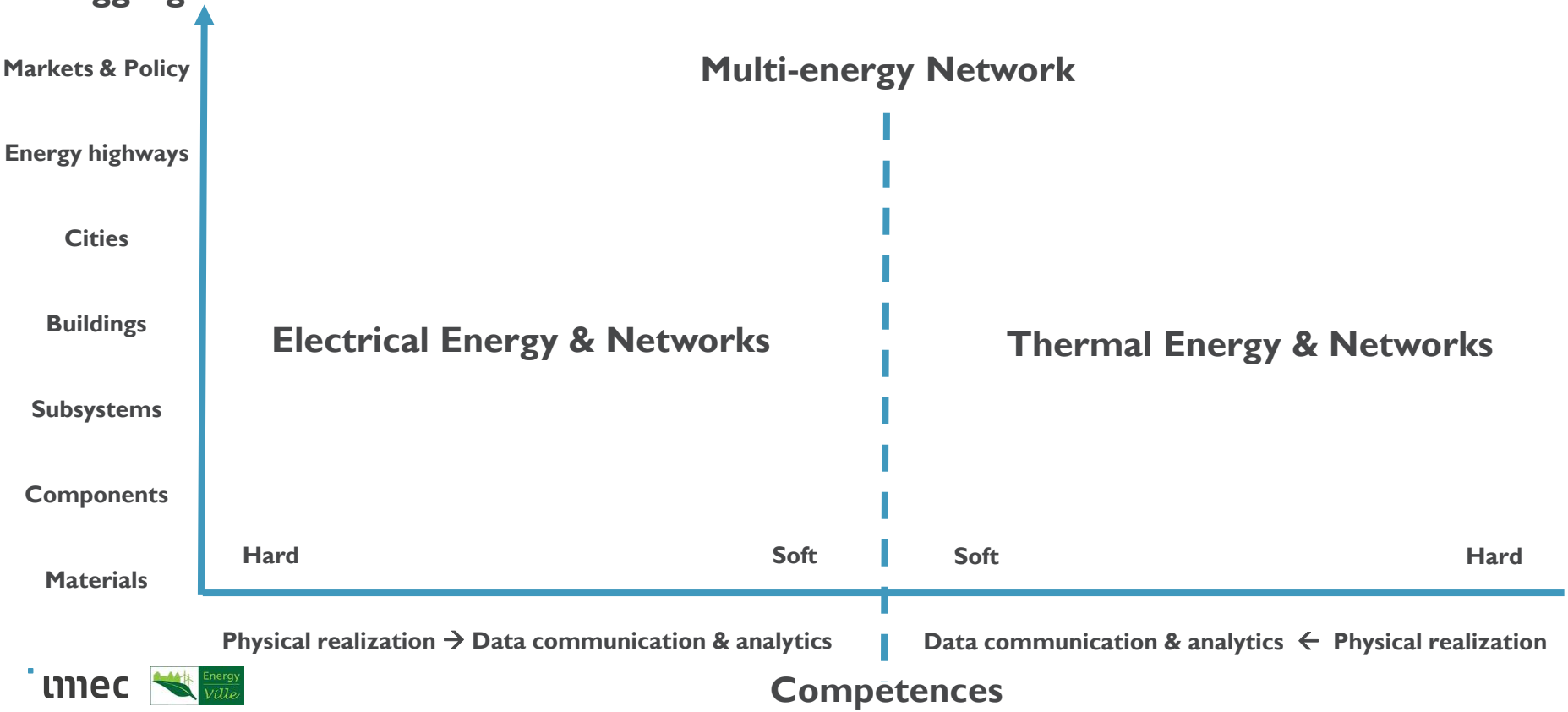
imec VITO KULeuven UHasselt



imec Energy Ville

ENERGYVILLE IN A GLANCE

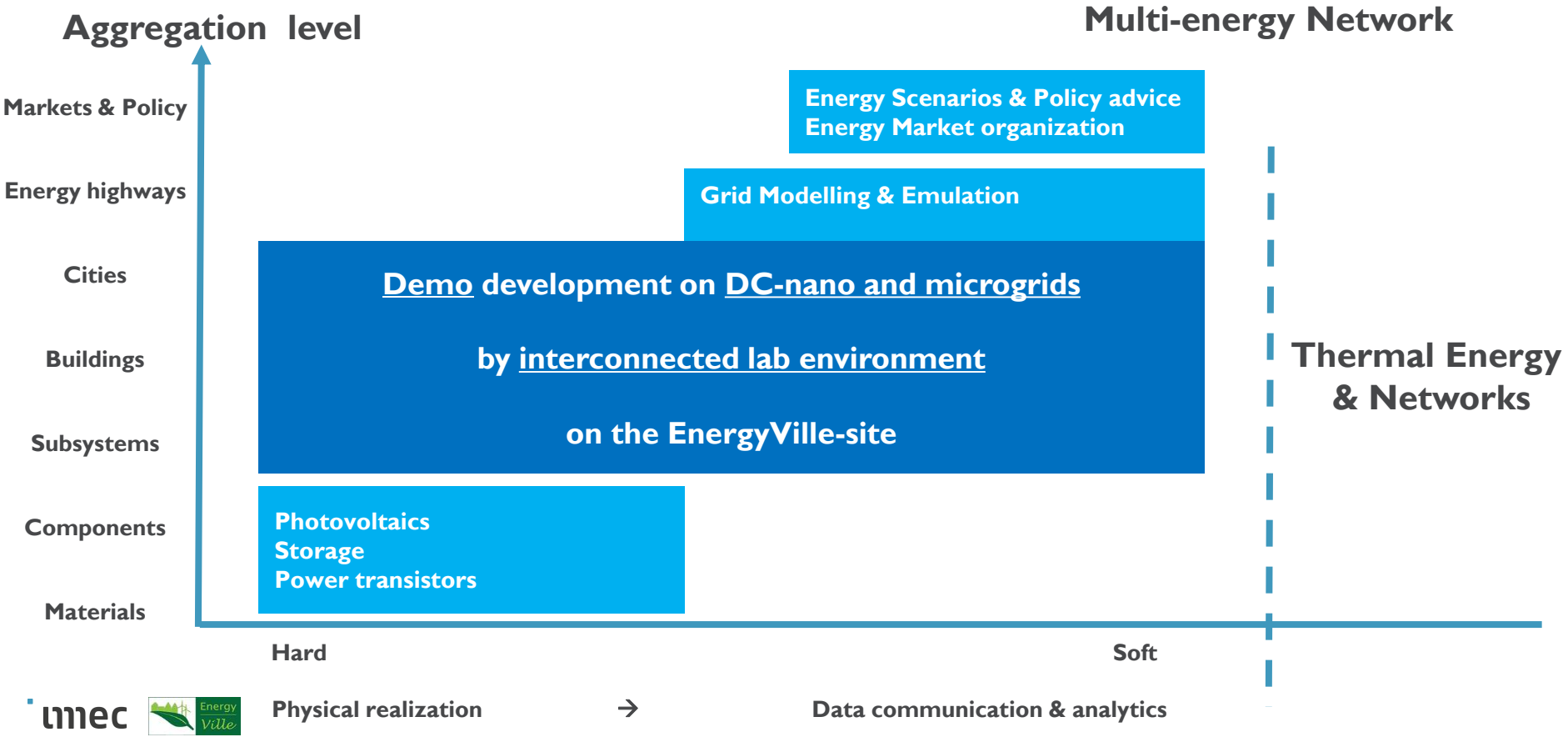
THE ENERGYVILLE "NAVIGATION MAP"



imec Energy Ville

ENERGYVILLE IN A GLANCE

THE ENERGYVILLE "NAVIGATION MAP"



KEY MESSAGES

- Transition to a more sustainable energy system is also the most **cost-effective solution**
- DC-nano and microgrids would enable **significant reduction of investment and operational costs**
- DC-nano and microgrids development is supported by **generic technology development** on
  - (BI)PV
  - More reliable and safe batteries
  - More reliable power electronics
- EnergyVille infrastructure perfectly suited for **hard- and software development, demo and training for DC-nano and microgrids**

imec EnergyVille