3SUN: Innovative Advanced Technology Factory for PV Module R(e)volution

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3SUN

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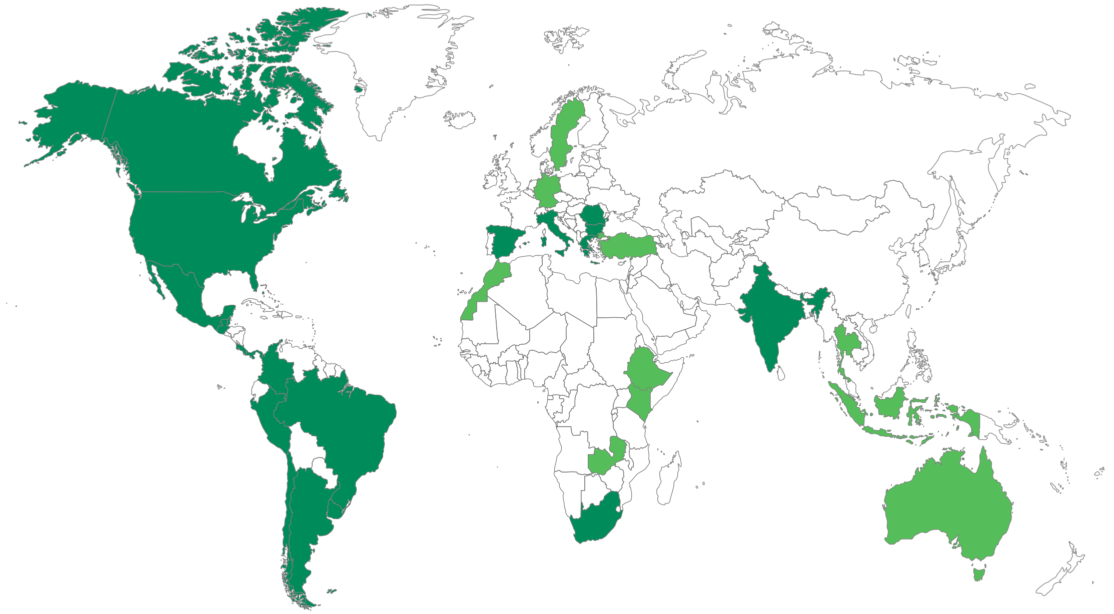
Outline

- EGP positioning and key figures
- Modules cost reduction
- Enel Green Power Core Business
- Business model
- 3SUN Strategic Decision in 2015
- Innovative and Reliable Technology
- Industry 4.0

EGP positioning and key figures



Countries of presence   Countries of interest

Net installed capacity[1] (GW)	6.4	1.2	2.5	0.8	0.1	24.8

Key figures	2016	Old perimeter	Large hydro
Capacity[1] (GW)	35.7	10.9	24.8
Production (TWh)	92.4	37.4	55.0

Key financials (€bn)	2016	Old perimeter	Large hydro
EBITDA	4.2	2.0	2.2
Opex	1.4	0.8	0.6
Maintenance capex	0.4	0.2	0.2
Growth capex[1]	2.8	2.7	0.1

1. Old perimeter capacity and growth capex not including USA projects managed through BSO model (Build Sell and Operate)

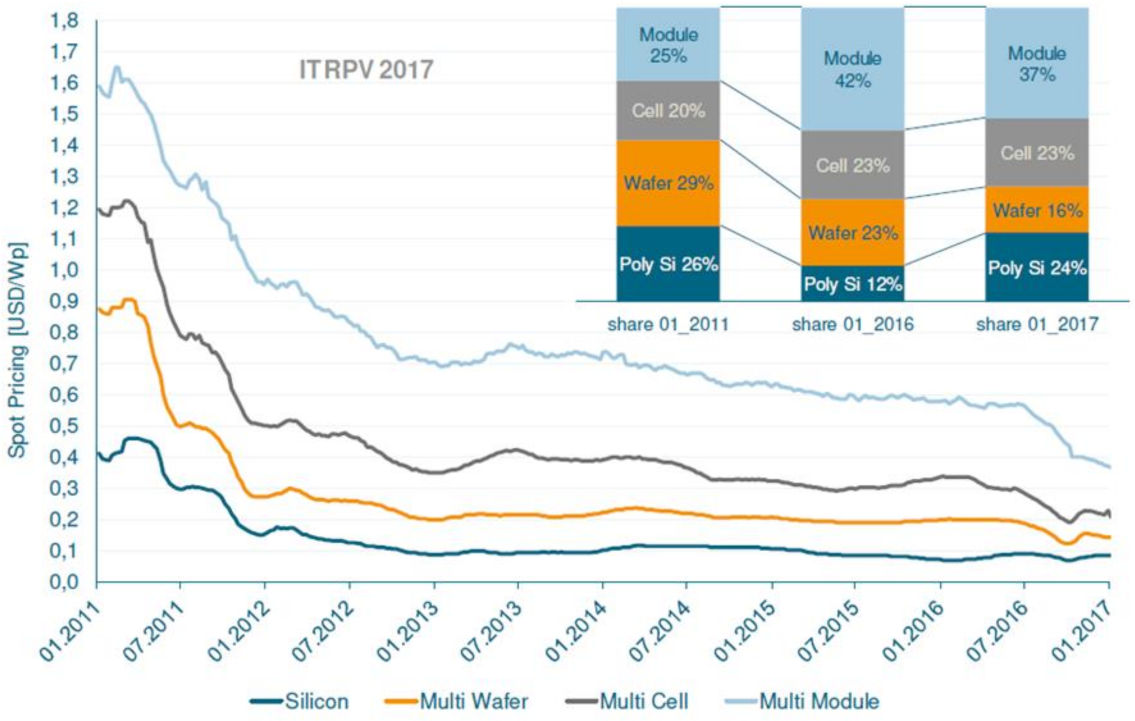
Geo Hydro Wind Solar Biomass Large hydro

The outlook for renewables

Investments	Decoupling between installations and investments
Solar	Solar costs down 90% since 2009
Wind	Performance improvement coupled with repowering opportunity
Storage	Cost of lithium-ion cells have plunged from $1,000/kWh in 2007 to $300/kWh now
Private sector	Commercial, financial and risk management skills remain key factors to win in a fast changing market
Innovation	Pervasive and unstoppable. Leading the change is key to support marginality

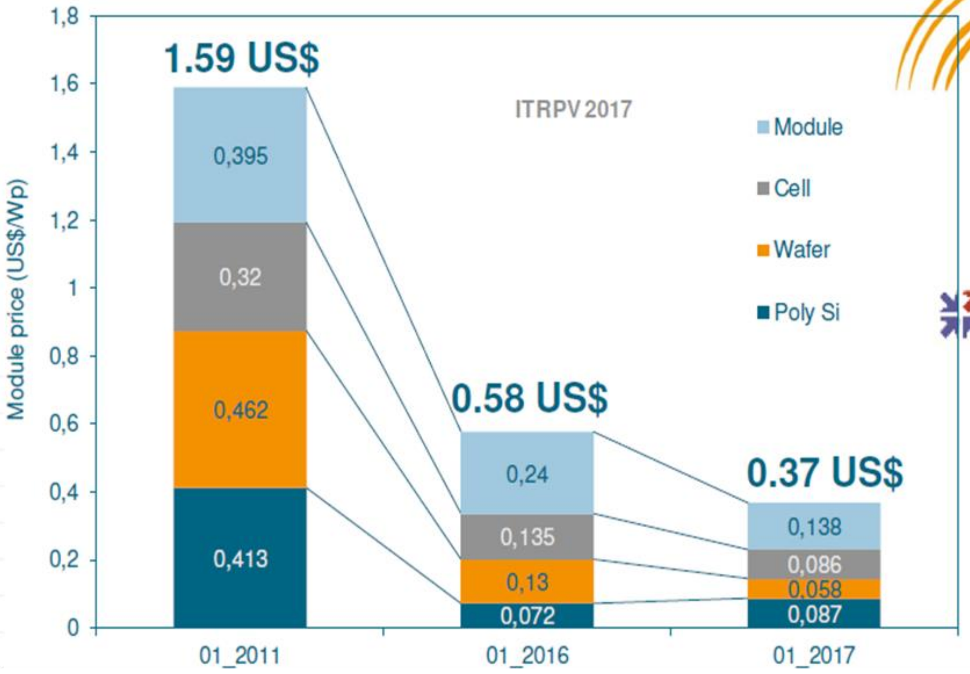
Costs

ITRPV 2017



01/2011 → 01/2016 ~ 64%
01/2016 → 01/2017 ~ 36%

Module price break down [US$/Wp]



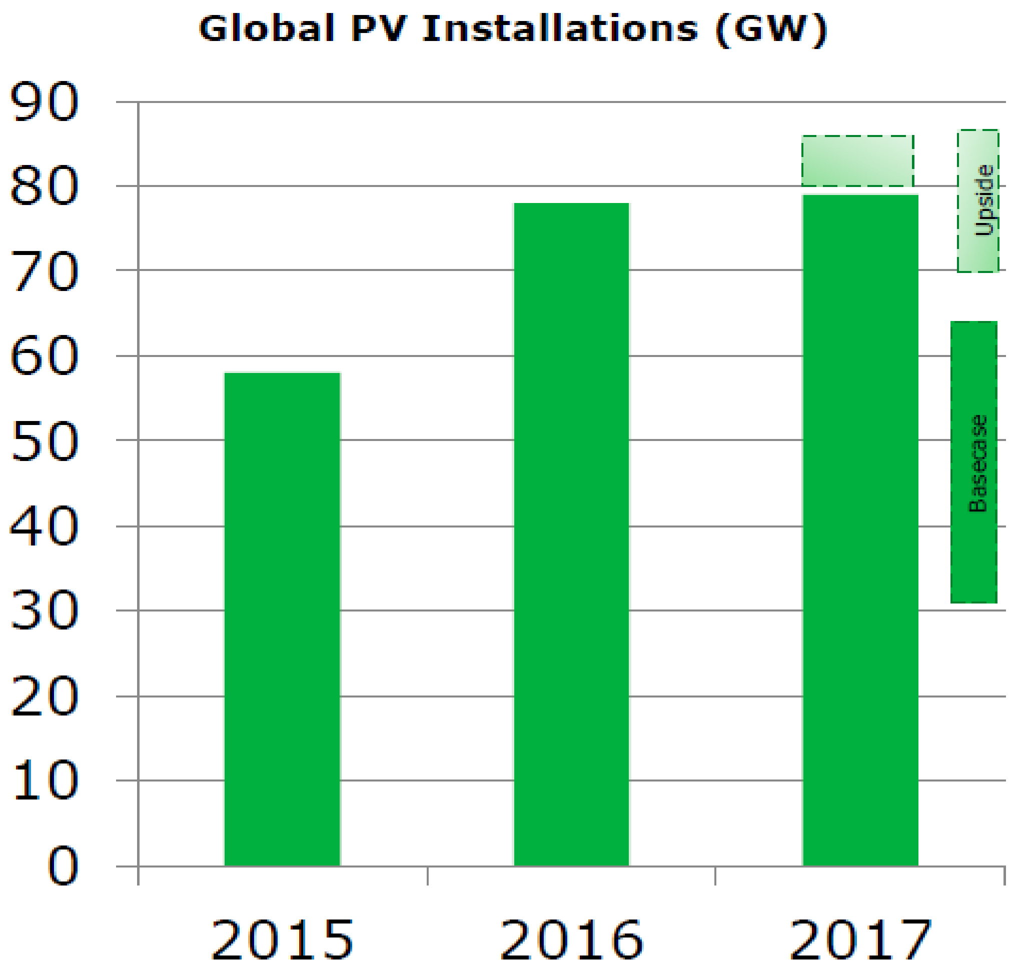
Dramatic price drop during 2nd half of 2016

→ Market driven
→ Poly-Si share increased
→ High pressure on manufacturers

Global Solar Demand in 2017

IHS 2017

- **79 GW of global installations** with upside potential of 85 GW.
- **More** than 90% is c-Si or mc-Si
- **China** maintains its position as **the largest end market*.**
- **Lower system costs support** demand **growth in new regions** and emerging markets

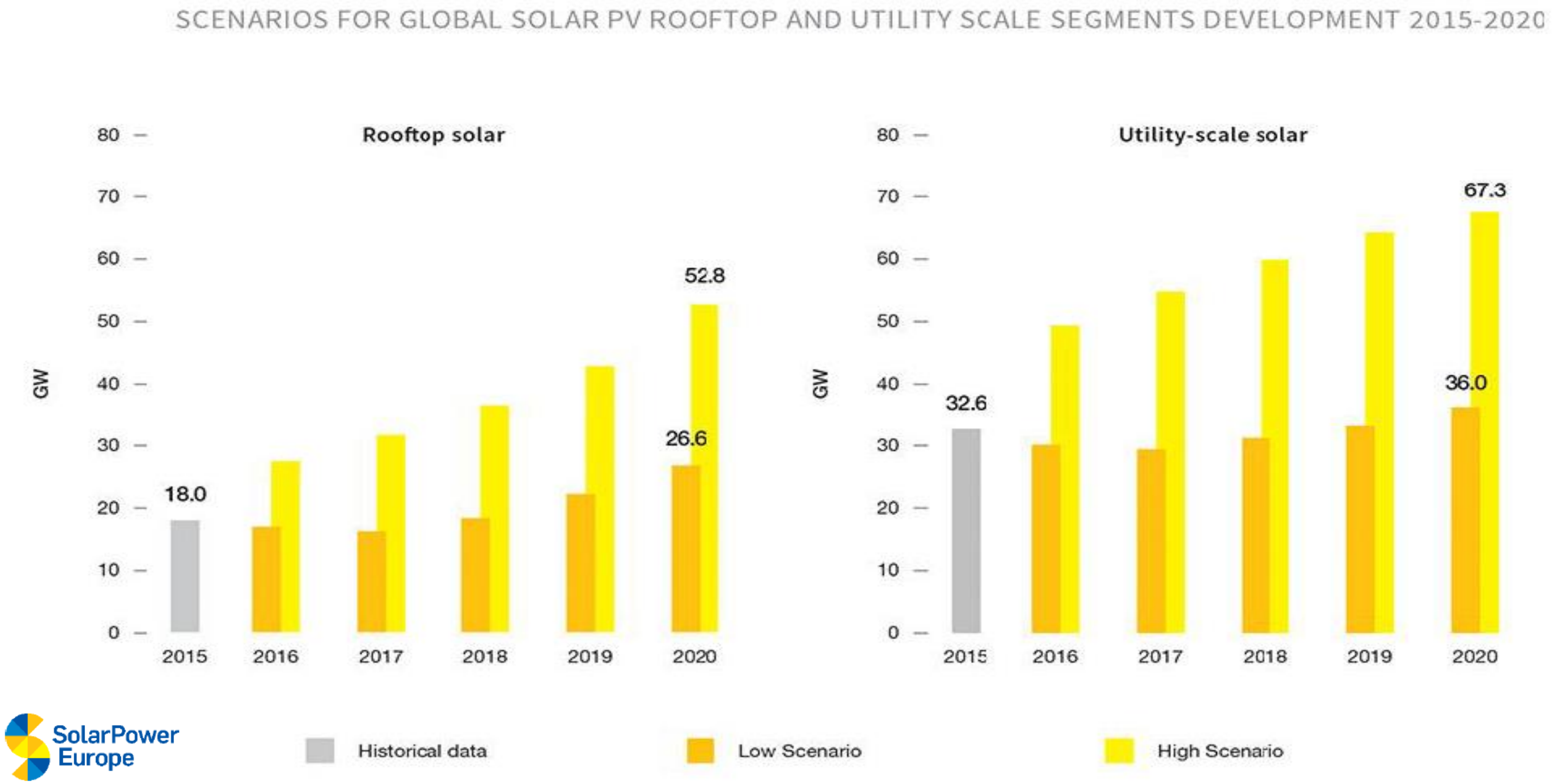


IHS Markit 2017

(*) Final global demand numbers will be heavily influenced by policy evolution in China in the second half of the year

Enel Green Power Core Business

The Utility Scale Market



SolarPower Europe

EPIA 2016

The **“utility scale”** market (Power Plants) dominates the market, continuously growing, as growth mainly comes from emerging markets. It is mainly represented by hot climate geographical areas

Today mc-Si dominate the market → **need of competitive innovative technology**

The 3SUN Factory

Green Power

3SUN

The biggest PV Italian fab and one of the biggest in Europe

Core Process: amorphous + µ-cristalline silicon deposition

- Two production lines working in parallel
- 8 PECVD (Plasma-enhanced chemical vapor deposition) clusters per line
- Total 96 deposition chambers with 8 slots per each
- Deposition process rate is 2 panels every 43 seconds
- ~4.000 PV Modules/day as annual average

The Plant size:

- 240.000 m^2 surface area
- 115.000 m^2 of usable surface
- 50.000 m^2 Fab area
- 3 floors of 16.000 m^2 each
- 300+ permanent employees
- 200 MW/year production capacity
- ~ 7 millions of modules since Dec 2011

Efficient and Fully Automated Production Lines

Green Power

10hrs from
Glass input
to Pallet Output

International expansion with products manufactured by 3SUN

… just few examples!

Altomonte (Italy)

Istia (Italy)

Brazil

South Africa

Chile

Business Model

Higher margins possible at the system level for electricity companies in many regions

- **Reducing the cost of energy (LCOE)**
- **€/Wp → €/kWh**

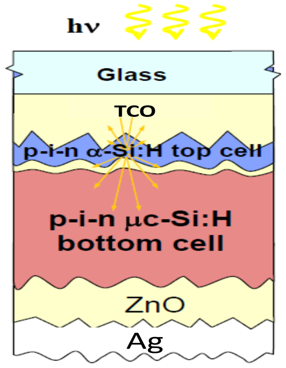
- Within this model thin film technology has problems of competitiveness
- mc-Si is advantaged by higher efficiency, higher materials standardization and economy of scale

Strategy of 3SUN integrated within the EGP value chain:

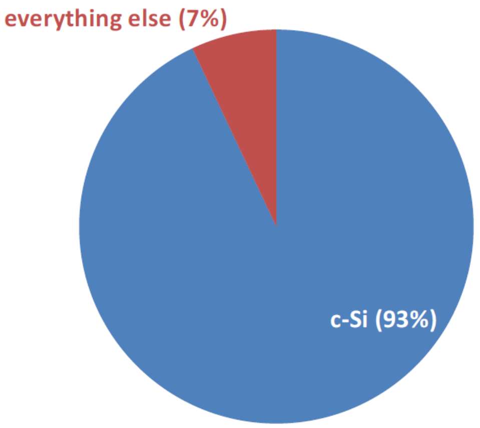
- To convert the a-Si technology to innovative wafer based technology
- Achieving higher energy production in solar plants
- To take advantage from economy of scale and standardization (of materials)

3SUN Strategic Decision in 2015

Green Power

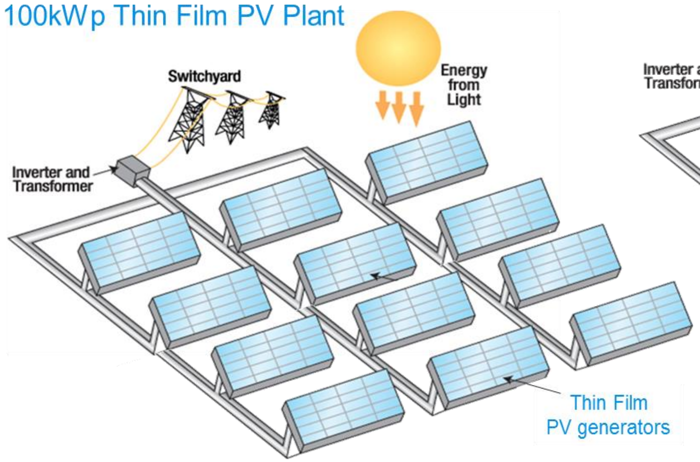


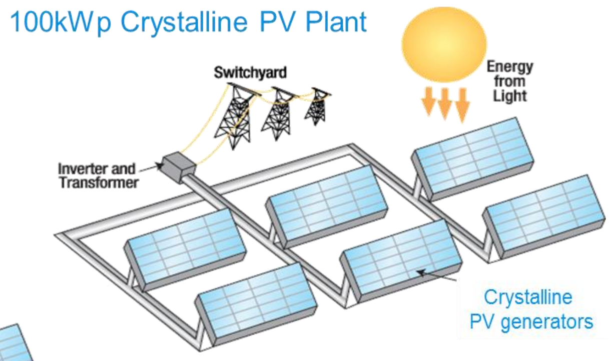
Thin Film Si
Eff. = 10 ÷11%
Different size
Non std materials
mc-Si
Eff. 15÷17%
Wafers
Standard materials



ITRPV Working Group, ITRPV: 2015 Results (SEMI PV Group, 2016).

Thin Film lower efficiency means larger surface…





…to obtain the same peak power capacity.

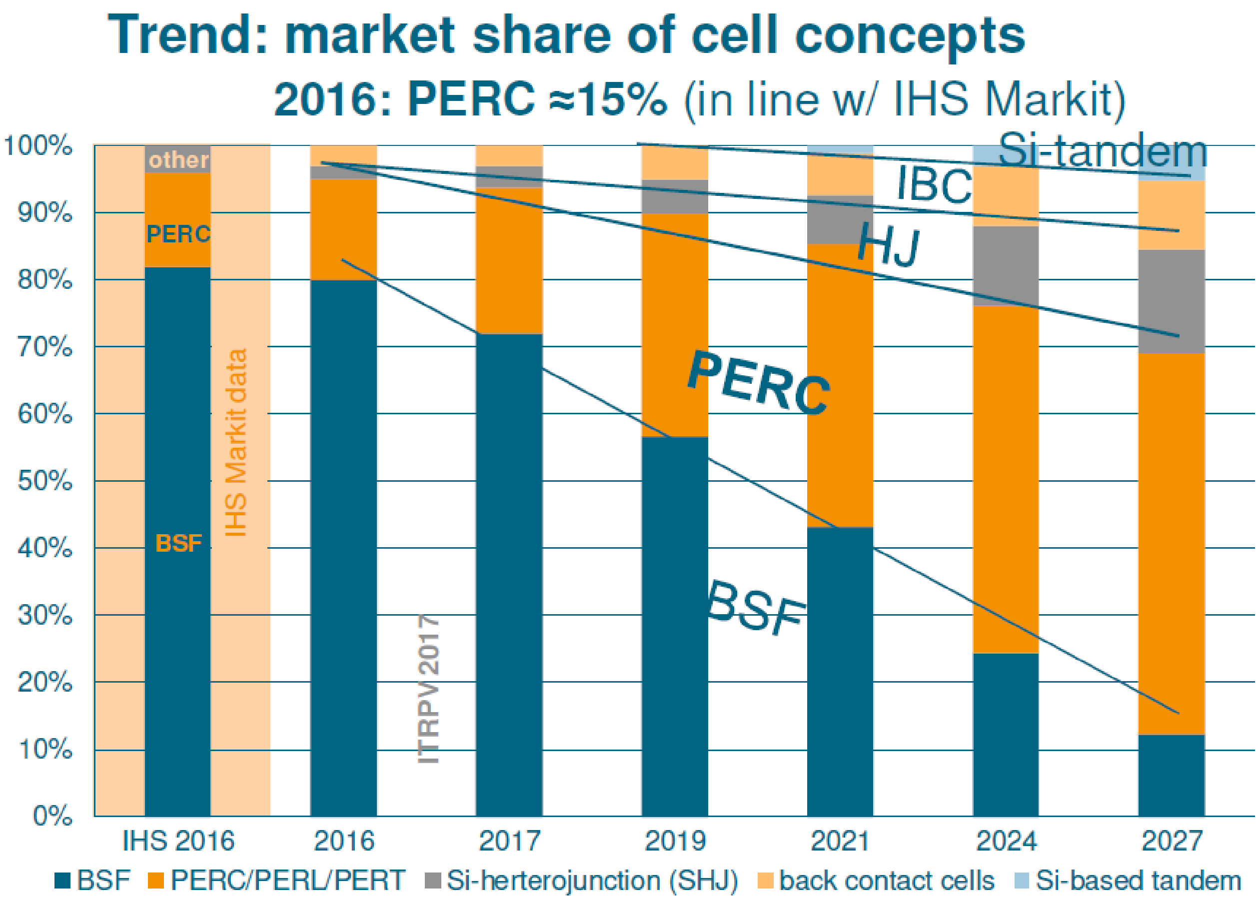
Larger surface means larger costs of installations!!!

Thin film Si, about 7 millions modules so far but…
…cannot compete with mainstream technologies!

Innovative approach: Competitive technology that can reduce the cost of energy

Cell Technologies

ITRPV 2017

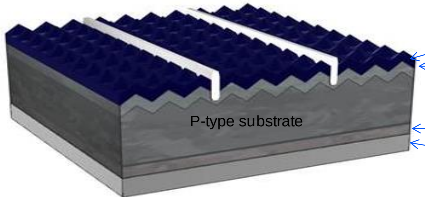


- BSF share is shrinking
- PERC is gaining market share (20% 2017)
- Back contact and HJ: slow increasing share
- c-Si tandem: under development

Innovative and Reliable Technology

mc-Si vs HJT

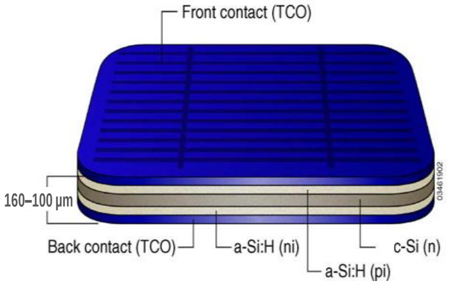
Mc-Si Cell mono facial

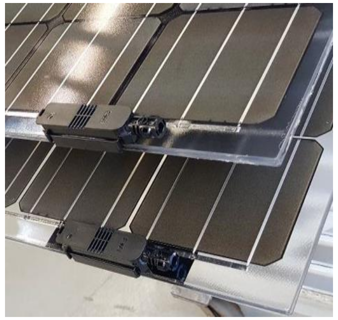


mono facial Glass- Backsheet module

HJT Cell bifacial

Bifacial glass glass module





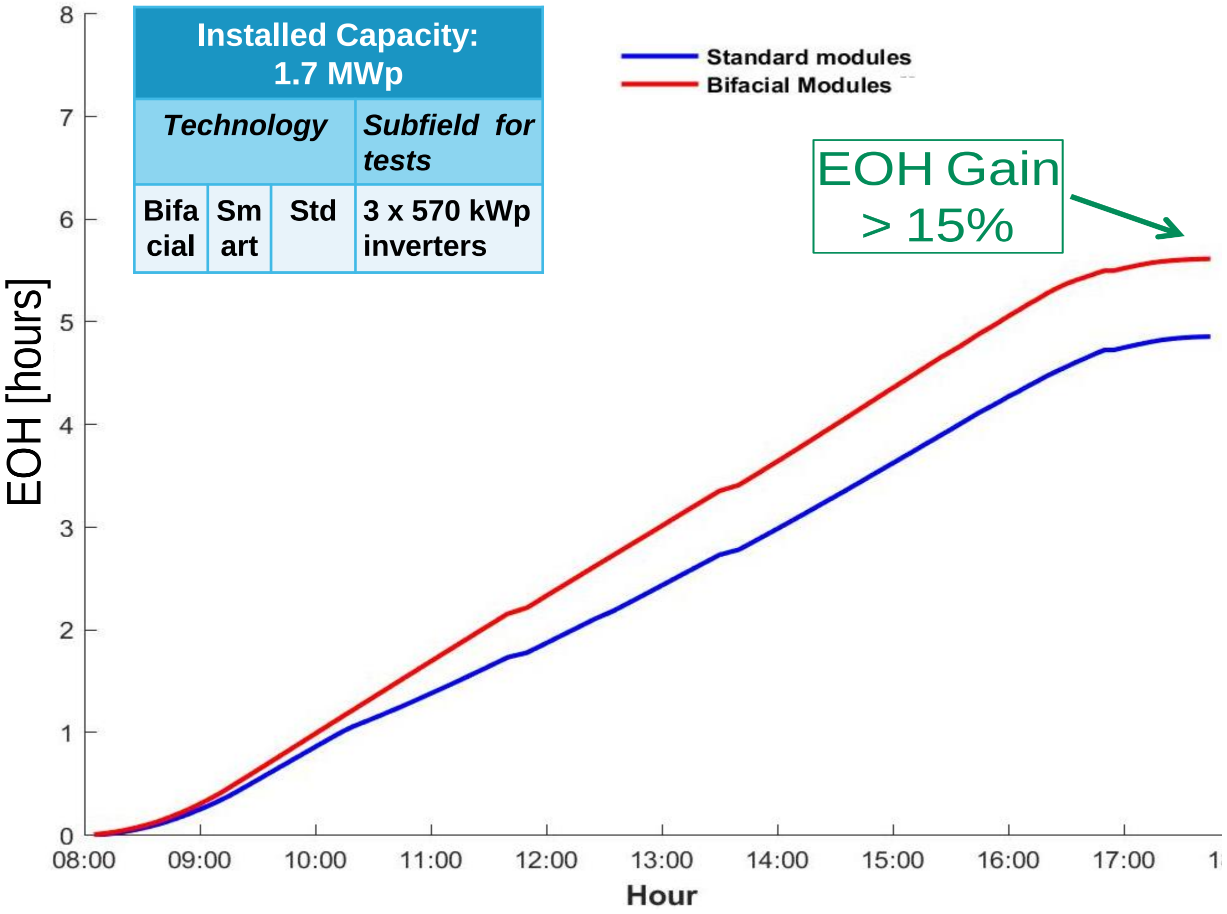
Properties	mc-Si	Bifacial HJT
Efficiency at cell level	18%	22%
Thermal coefficient	0.45 % / °C	0.25 % / °C
Overall energy gain	-	From +12% to +25%
Lifetime	30 years	40 years
Annual degradation rate	0.5 % / year	0.3 % / year 0.25% / year
PID issue	high	Very low due to TCO barrier to Na^+ and glass-glass configuration
LID issue	high	Absent (n-type cell: no B-O complexes

Bifacial for Utility Scale

Experimentation on field

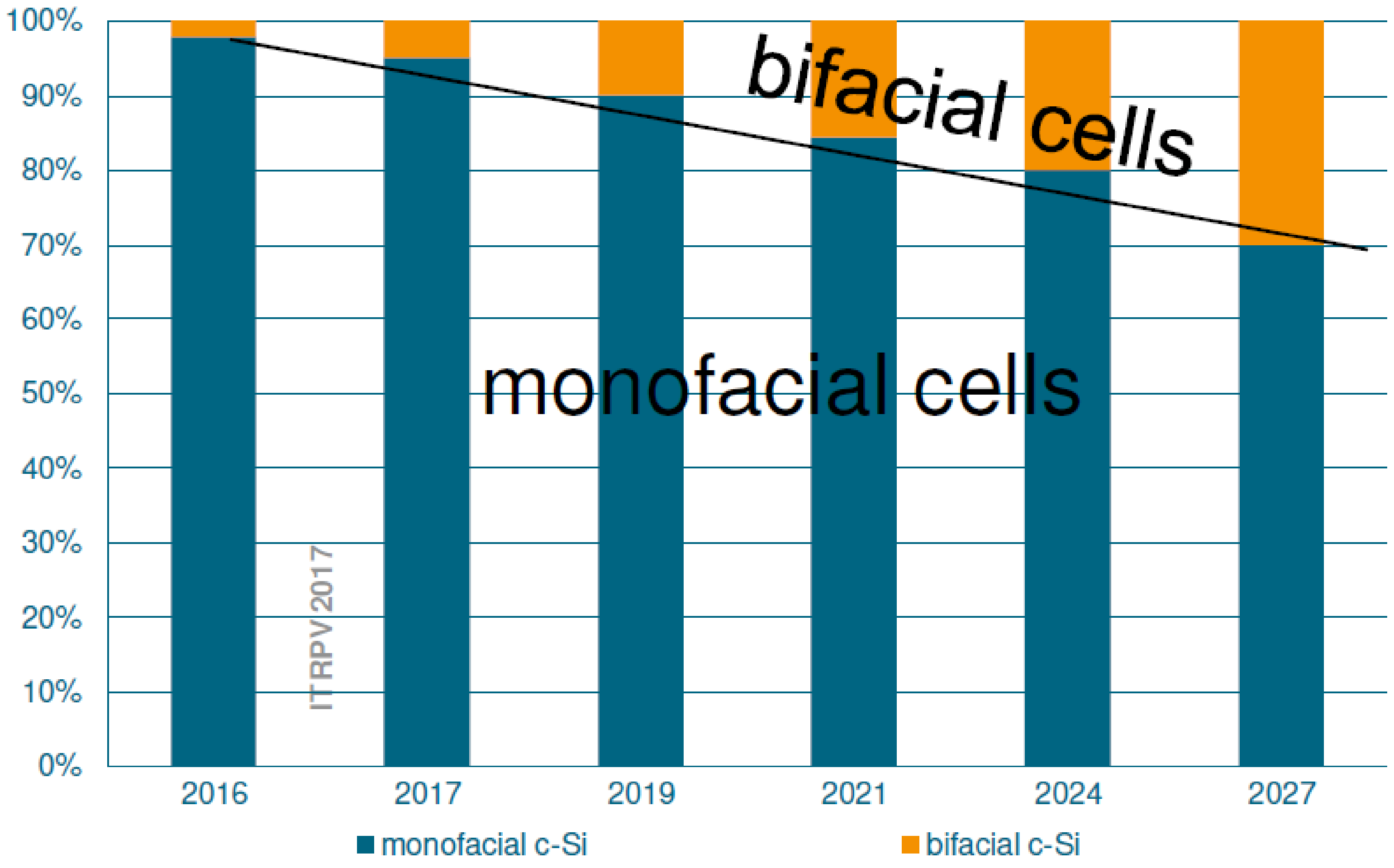
La Silla (Chile): Bifacial glass-glass modules PERT solar cells

Installed Capacity: 1.7 MWp			
Technology			***Subfield for tests***
Bifacial	**Smart**	**Std**	**3 x 570 kWp inverters**



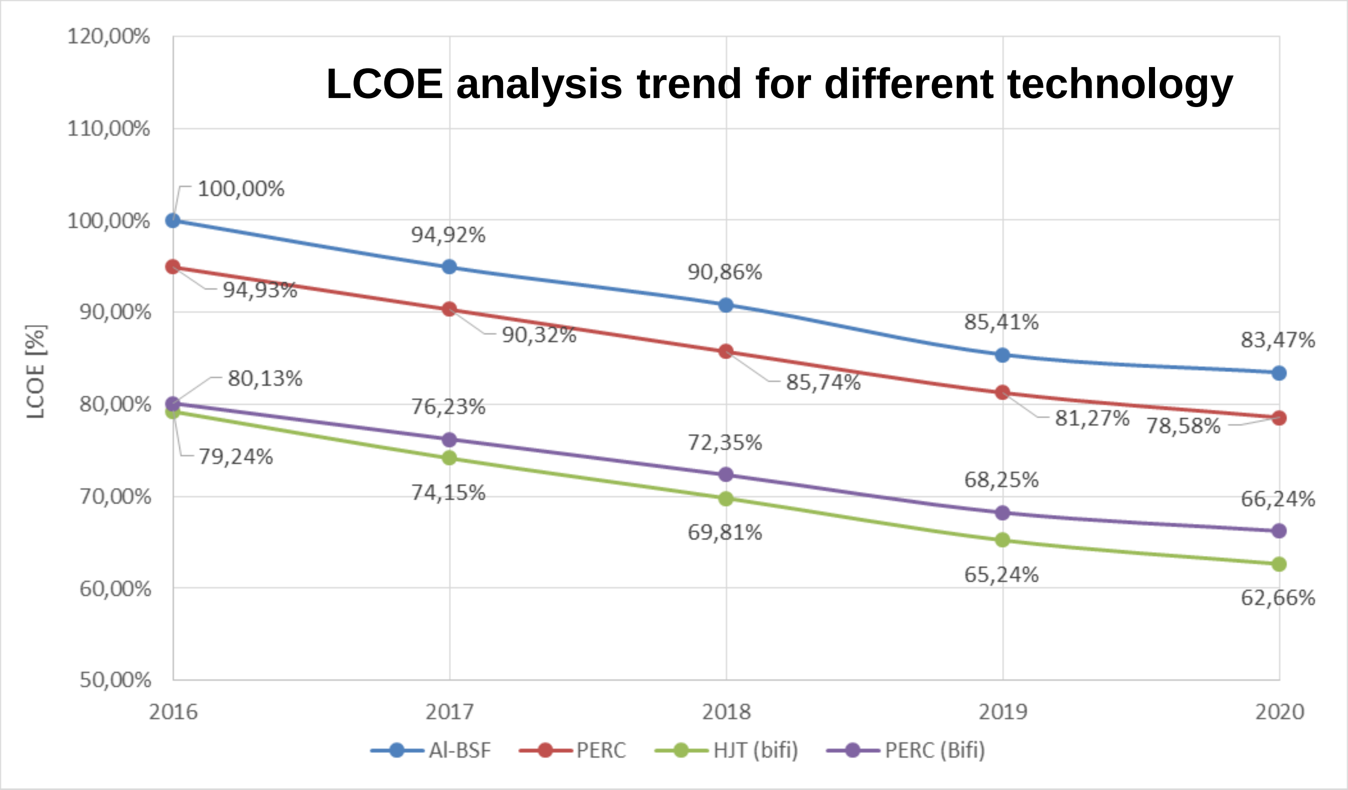
Bifacial vs Monofacial Market Trend

ITRPV 2017



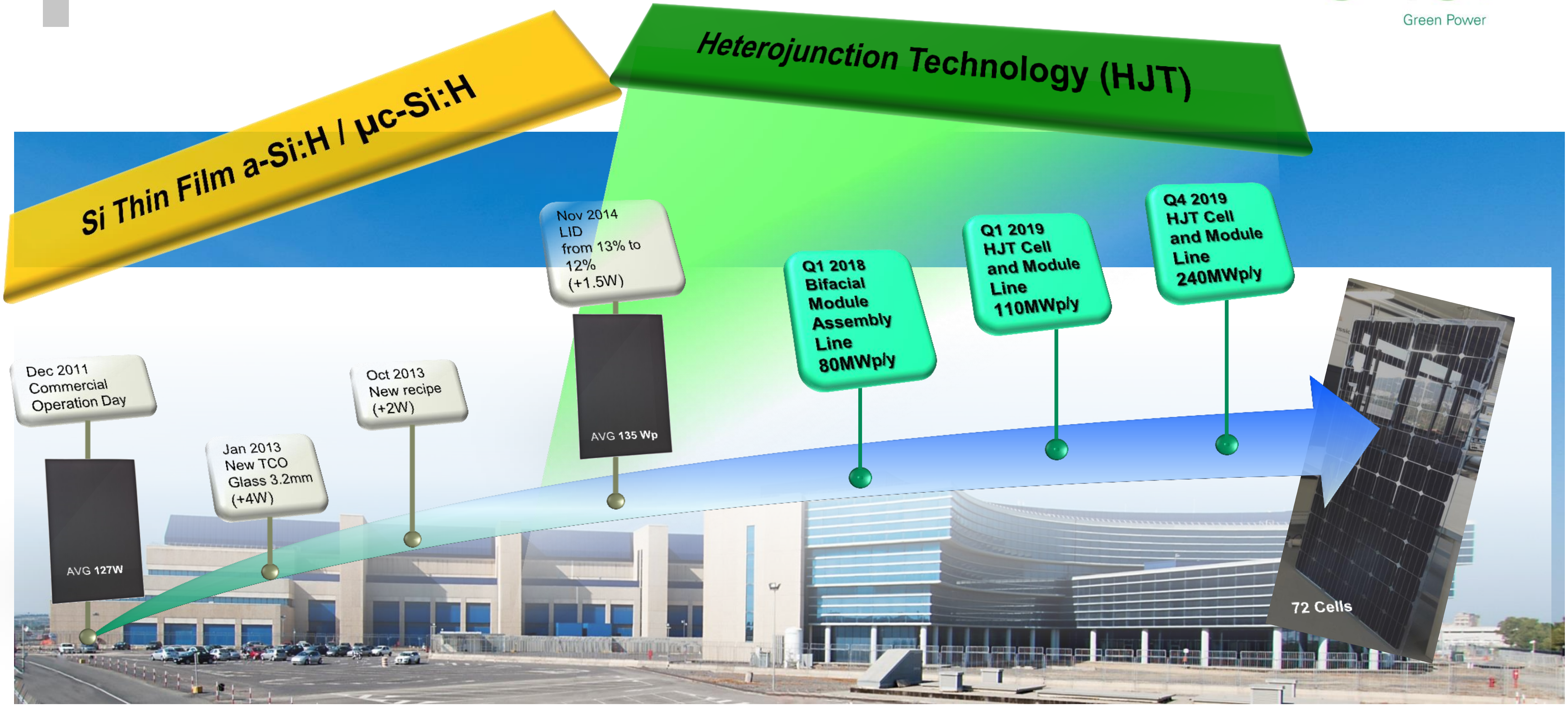
How to compete

We need to compete in a tough world → LCOE reduction



Bifacial hJT is the best option for reducing LCOE

3SUN 2.0 Technology Roadmap



The 3SUN 2.0 Program

Innovative PV module factory based on HJT bifacial technology

3SUN

enel Green Power

3SUN 2.0 Project Phases

Phase 1: Bifacial modules assembly line – 80 MWp/year.
✱ COD → Mar 2018

Phase 2: HJT Cell line and integration with module line– 110 MWp/year.
✱ COD → Q1 2018

Phase 3: Extension of the manufacturing line to 240 MWp/year.
✱ COD → Q4 2019 (Q3 2019)

Pmax=395W

Workforce

3SUN will continue to compete with the main technology players
Keeping the workforce (300+ employees and 600+ in subcontractor companies)

Technology

Regain the technology leadership with innovative bifacialPV modules

Strategic

Reuse of existing facilities and building
Leverage on the high industrial skill on PV of 3SUN and EGP.

International collaborations with research centres

HORIZON 2020

cea tech
ines
Fraunhofer ISE
ENEA
Consiglio Nazionale delle Ricerche
csem
EPFL ECOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
iit ISTITUTO ITALIANO DI TECNOLOGIA
INRIM ISTITUTO NAZIONALE DI RICERCA METROLOGICA
BAPVC BAY AREA PHOTOVOLTAIC CONSORTIUM
Caltech

Industry 4.0

Directions for the new fab development

High automation level: robots and automatic conveiors. Manufacturing automation system

Data: big data, open data, internet of things, machine-to-machine and cloud computing for centralization of information and storage

Analytics: extract values from collected data. Example: machine learning, optimizing machine performances and yield by «learning» from collected and analyzed data

Man - machine interaction: «touch» interfaces and «augmented reality» using tools such as i-glasses, tablets, smart phones. Application to manufacturing and maintenance

From digital to real: robotics, communications, machine-to-machine interactions, new technologies to store and efficiently use energy, optimizing costs and performances

Many Thanks for your attention