CAF BANCO DE DESARROLLO DE AMÉRICA LATINA

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PARA LOS PAÍSES ANDINOS

SEMINARIO INTERNACIONAL

LAS ENERGÍAS RENOVABLES HOY

PERSPECTIVAS DE COLABORACIÓN ENTRE AMÉRICA LATINA Y EUROPA

Sede de la Secretaría General de la Comunidad Andina
Av. Andrés Aramburú cdra. 4 ,San Isidro
Lima, 1 y 2 de Marzo de 2012

COMUNIDAD ANDINA

Apoyando

IRD
Institut de recherche pour le développement

UBI VULT SPIRITUS SPIRAT
UNIVERSIDAD PERUANA CAYETANO HEREDIA

Jean-Pierre JOLY
Director General del Instituto Nacional
Para la Energía Solar de Francia
(INES)

Photovoltaics: State of the art and prospective

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Institut National de l'Energie Solaire

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Associated Partners 2006

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CSTB le futur en construction
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Savoie Conseil Général
RhôneAlpes Région

Technologies studied

1 – Phtovoltaics including CPV

2 - Solar thermal including CSP

3 – Storage and batteries

4 – Building applications

Resources end of 2011

Buildings : **10 000 m²**

Equipements : ***50 M€***

Staff : ***350***

Annual Budget : ***40 M€***

Outcome

40 publications per year

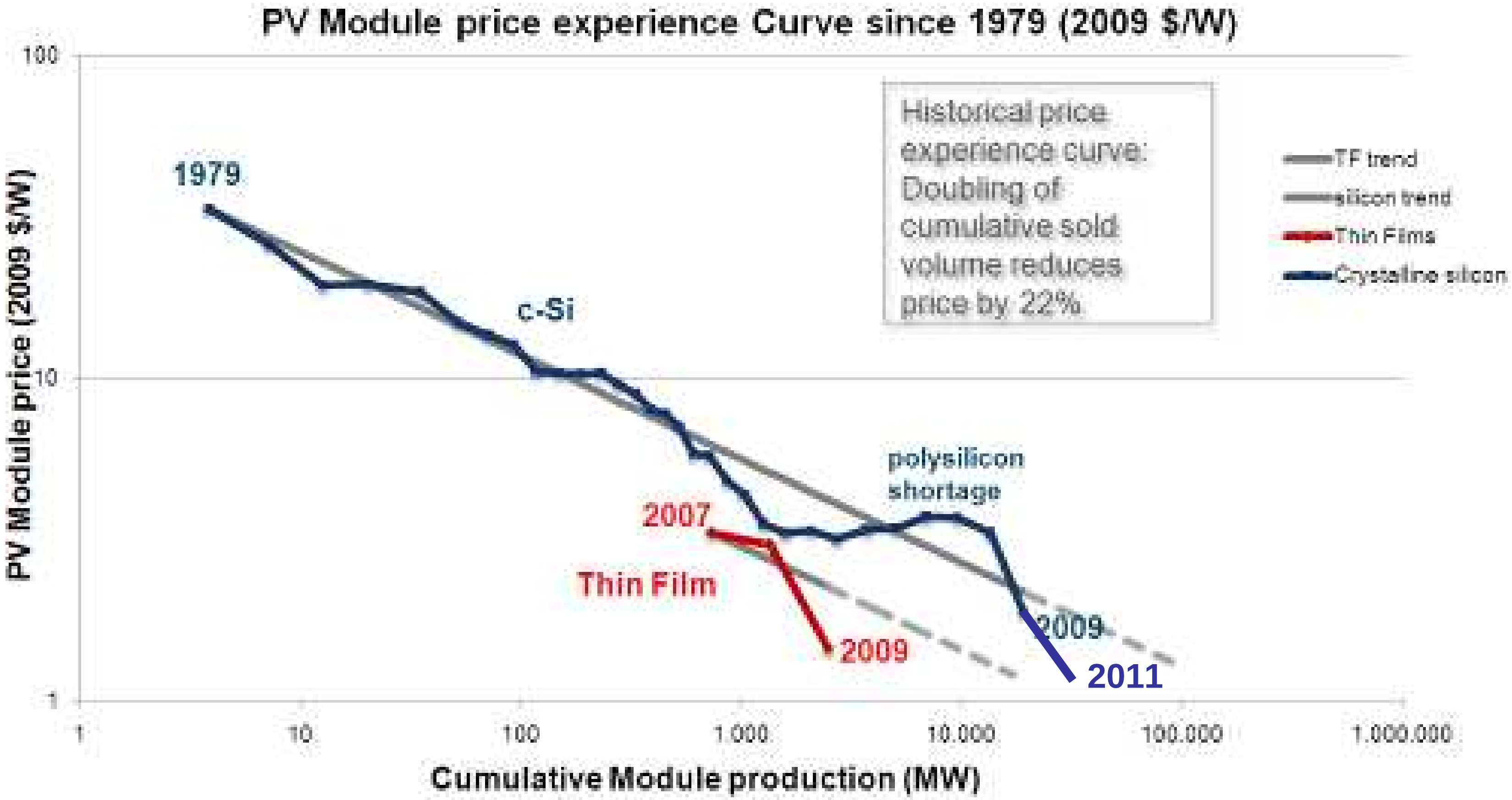
50 patents per year

170 industrial partners :

- **100** SMEs
- **30** big groups
- **40** international

5 start-up created

Very rapid cost decrease



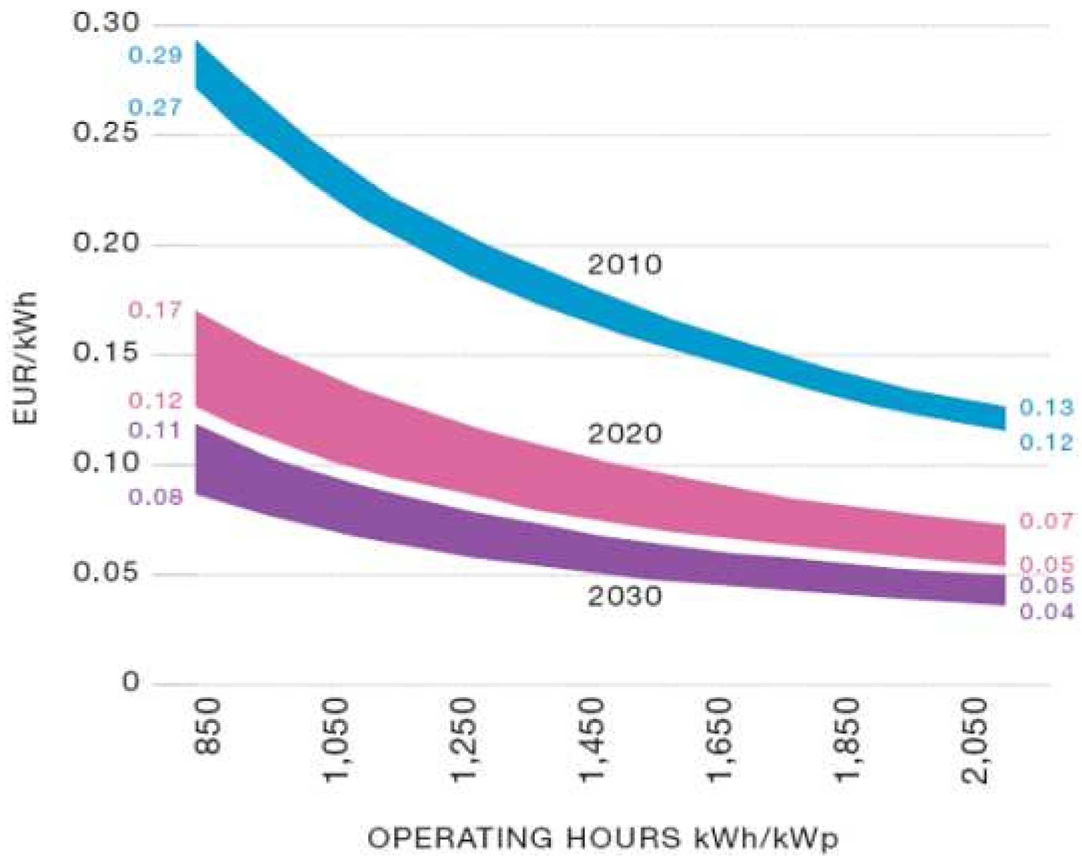
But still a bit more expensive kWh

Prices include 30% federal incentive
Source: Lazard Capital Markets 3/18/2009

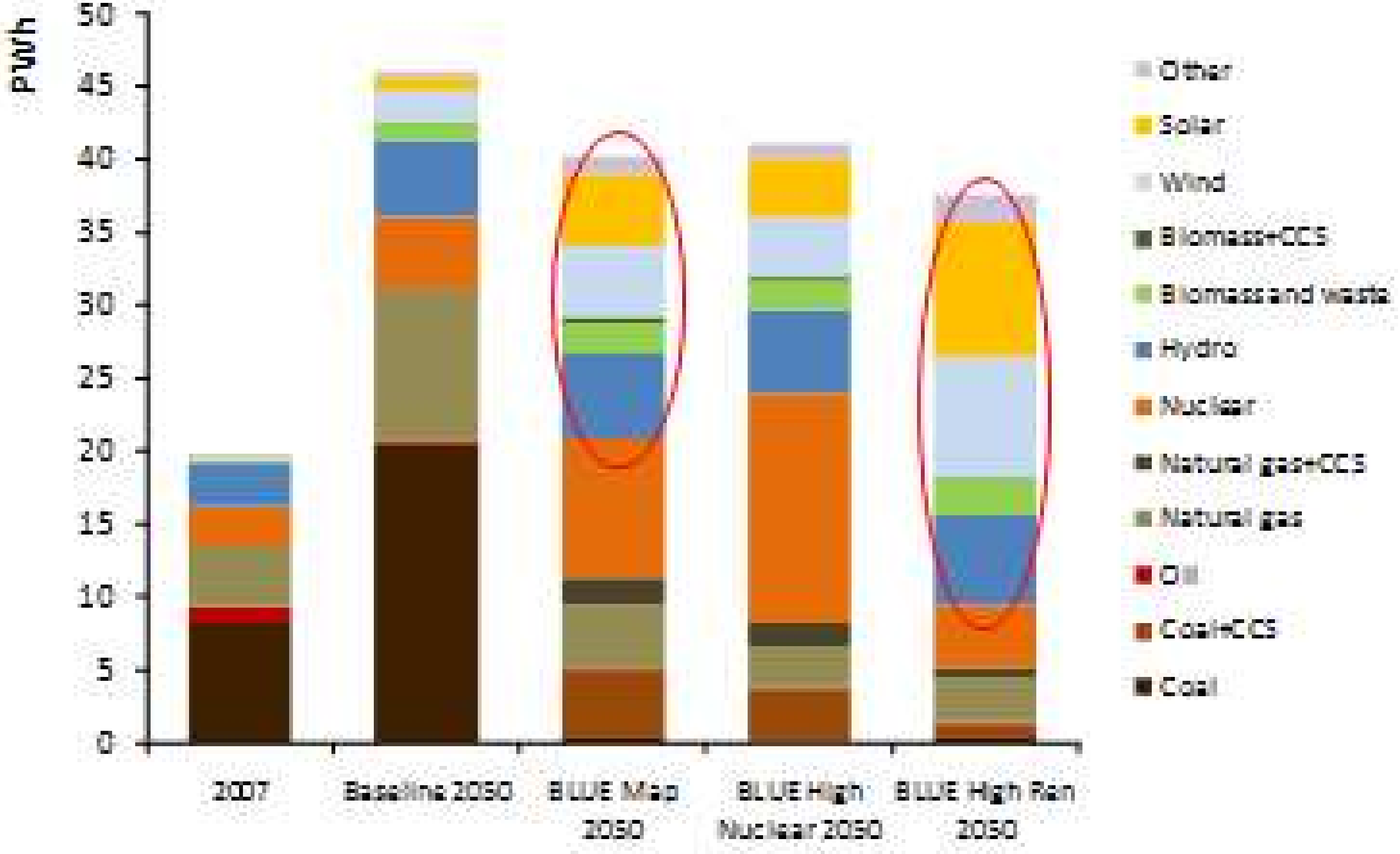
Towards a kWh less than 7€cts stable (no fossile cost fluctuations)

DECREASE OF THE LCOE OF SOLAR PV

LCOE = LEVELISED COST OF ENERGY



The primary role of renewables in the BLUE scenarios



Renewables provide from almost half to three quarters of the global electricity generation in 2050

This renewable revolution anticipated in certain countries

ines
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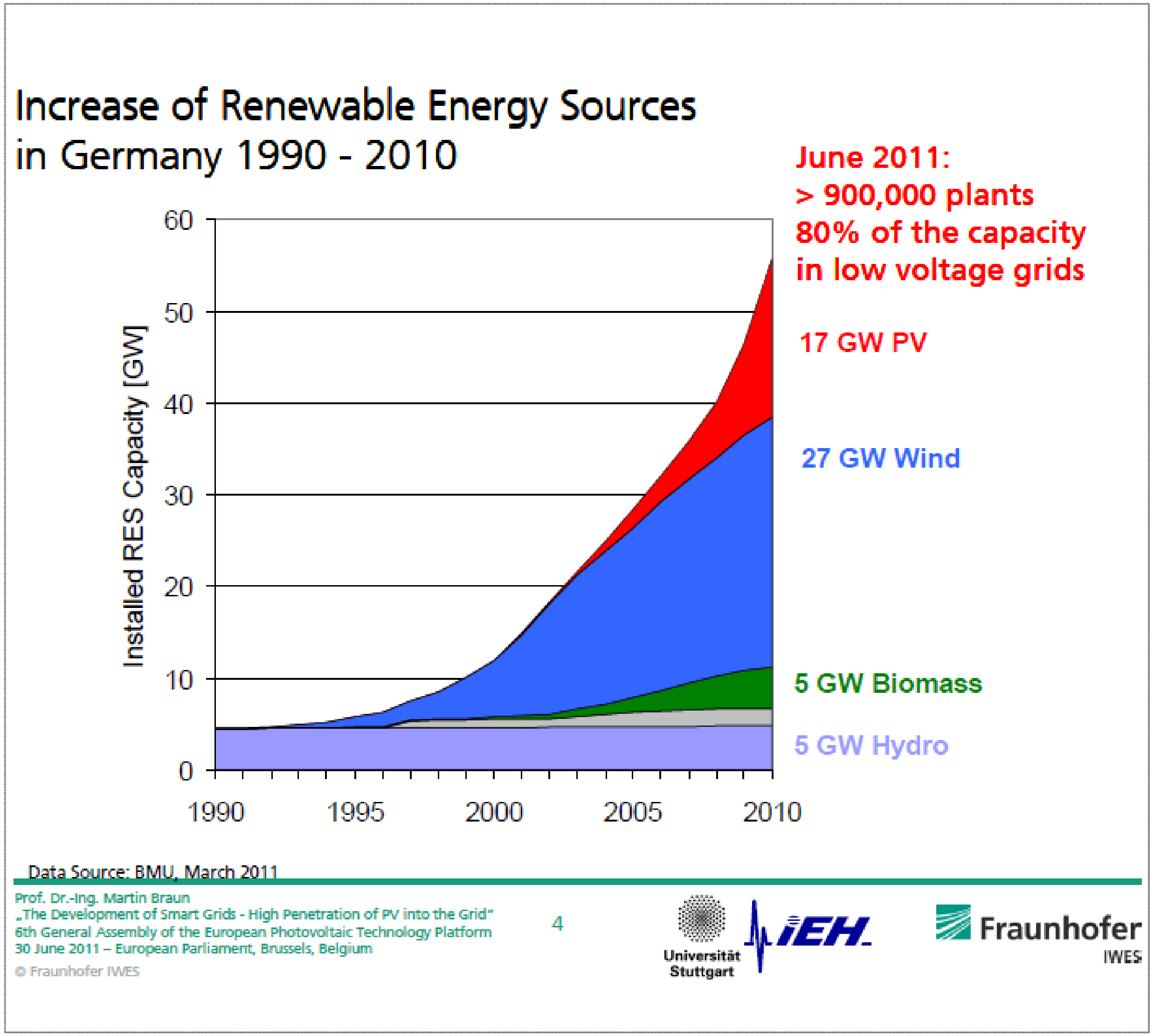
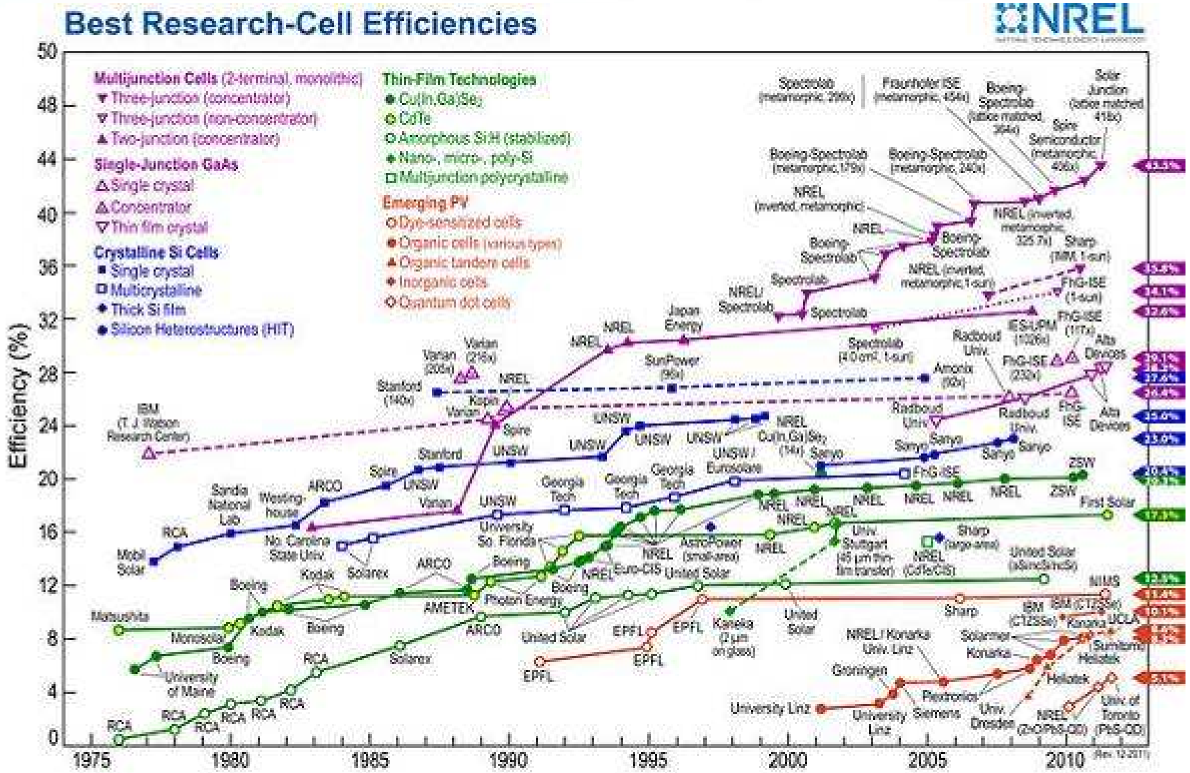


Available technologies

Technologies used or under investigations

	Technology	2008	2010 status	2015 status
Crystalline Silicon	Si Wafer based (Mono and Polycrystalline)	Mass production		
Thin films	Amorphous (a-Si)	Mass production		
	Tandem a-Si / Si Crystalline	Mass production		
	CIS / CIGS	Mass production		
	CdTe	Mass production		
	III V	Industrial research on concentrator; Mass production for cells	Mass production	
	Dye Sensitized	Industrial research and pilot plant	Mass production	
	Full Organic	Experimental research	Industrial research and pilot plant	Mass production
	Hybrid	Experimental research	Industrial research and pilot plant	Mass production

Very long maturing



c-Si

Cu2S
CdTe
CIGS

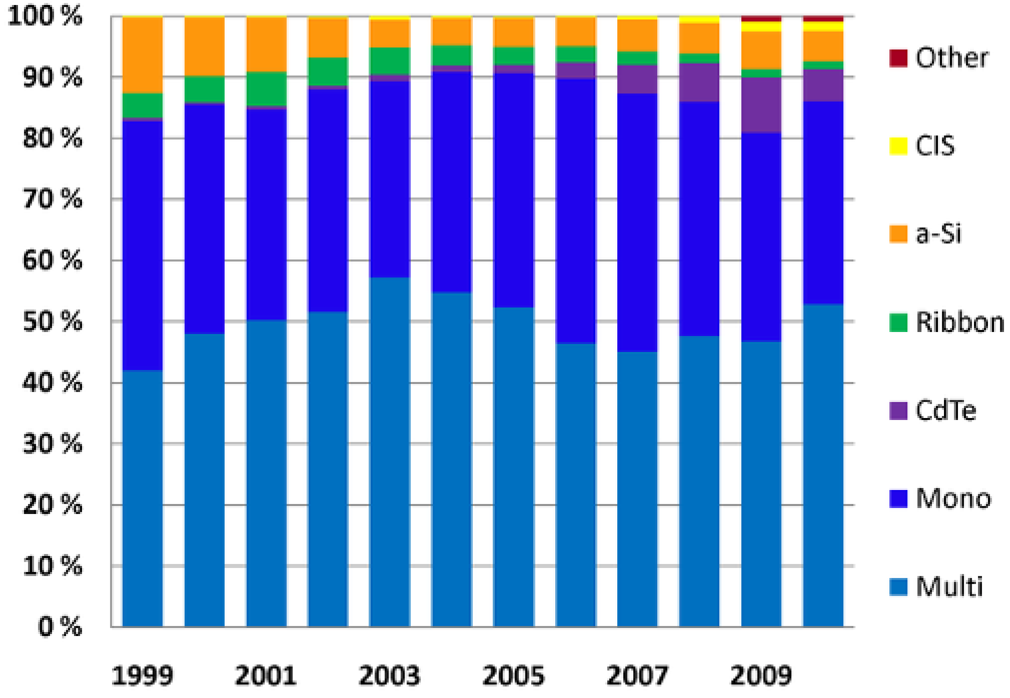
a-Si

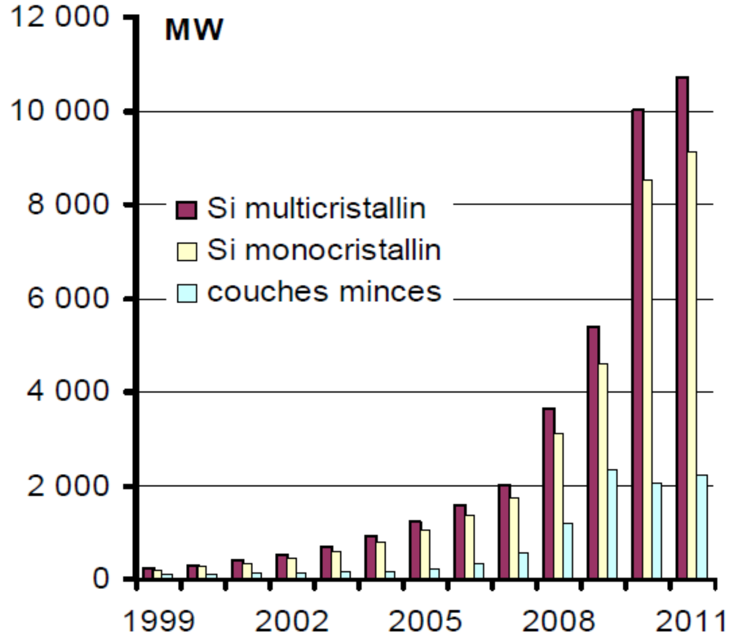
III-Vs

Dye

Organic

Stable market shares between technologies





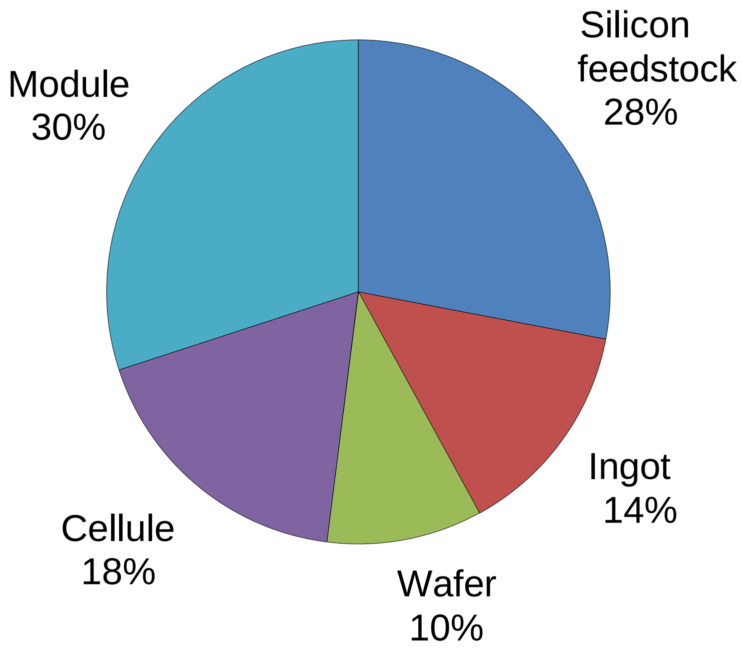
Thin films often presented as the final solution do not confirm at this stage

Crystalline Silicon : Continuous innovations

Technology drivers

Decrease the material cost impact

Decrease the purification cost



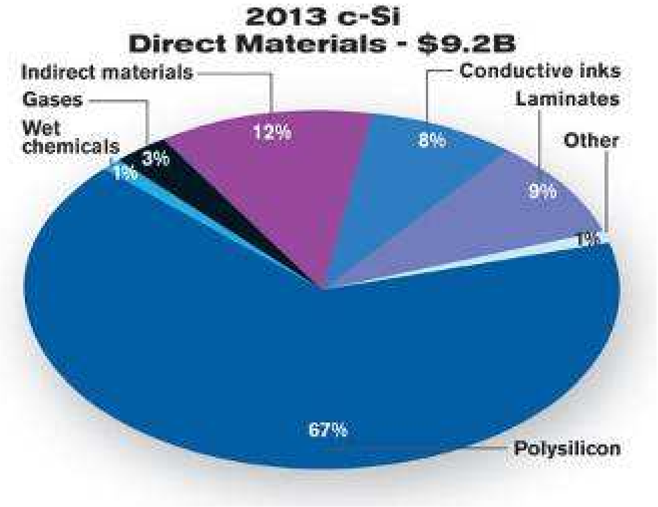
Increase Conversion efficiency

Decrease material losses

Increase material usage and crystal quality

Feedstock and Wafer roadmap

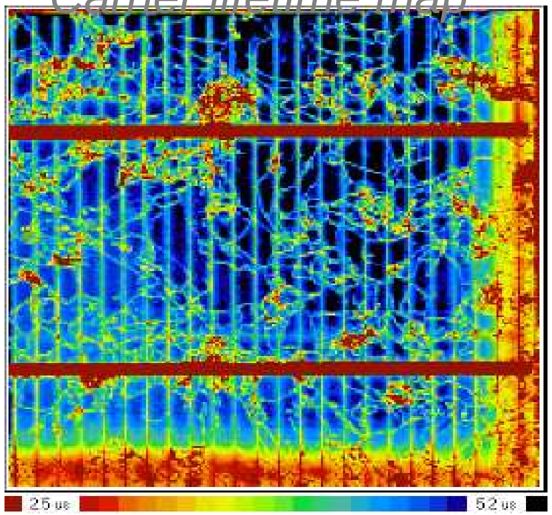
c-Si



Echéance	2008-2013	2013-2020	2020-2030
Consommation	5 g/Wc	< 3 g/Wc	< 2 g/Wc
Coût feedstock	15-25 €/kg	13-20 €/kg	10-15 €/kg
Epaisseur wafers	< 150 μm	< 120 μm	< 100 μm

Material quality

Carrier lifetime map



Purification technologies

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1

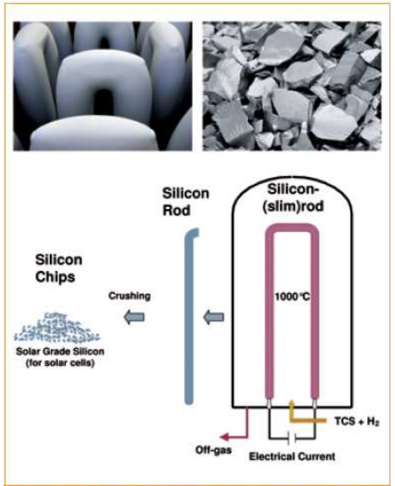
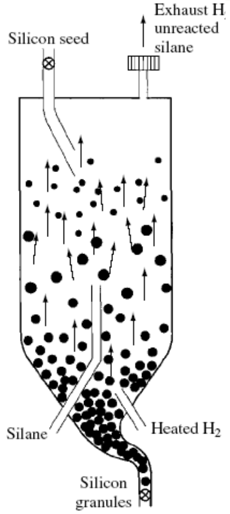


Figure 7. Schematic representation of the rod deposition process.

2



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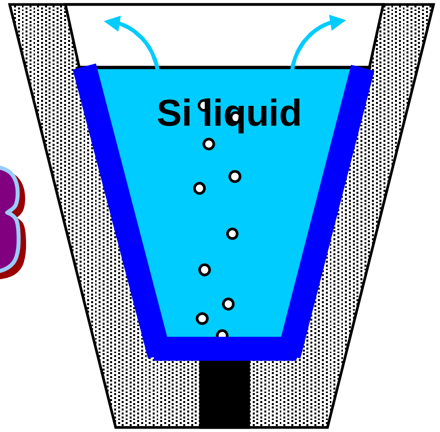
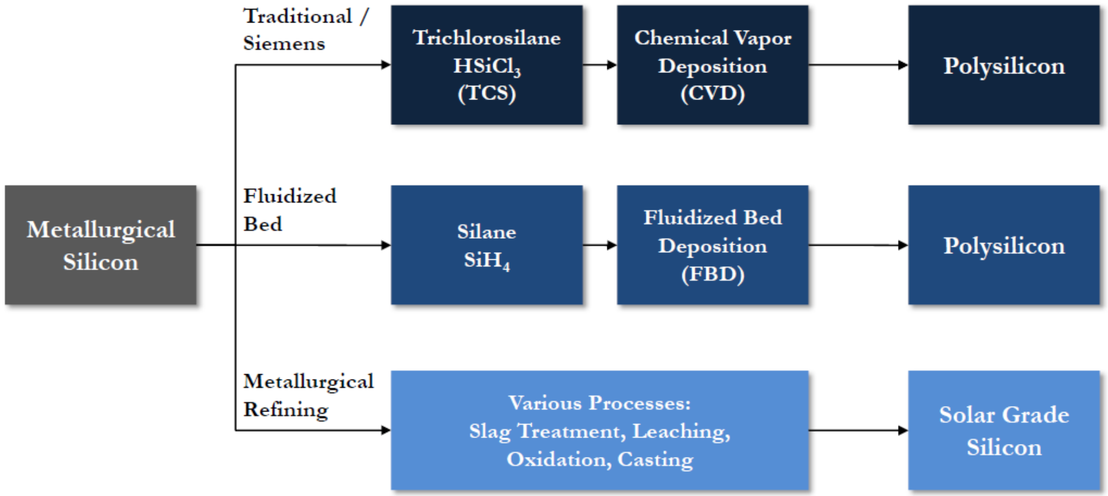
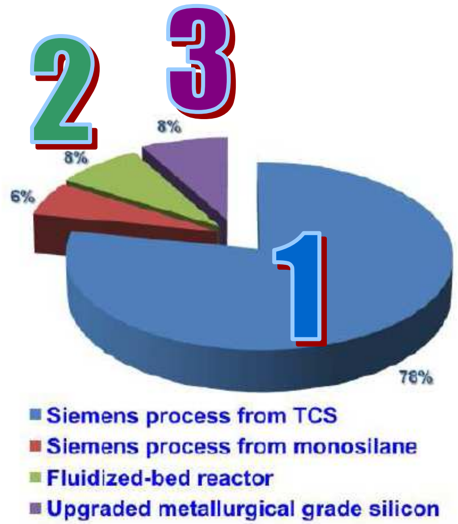
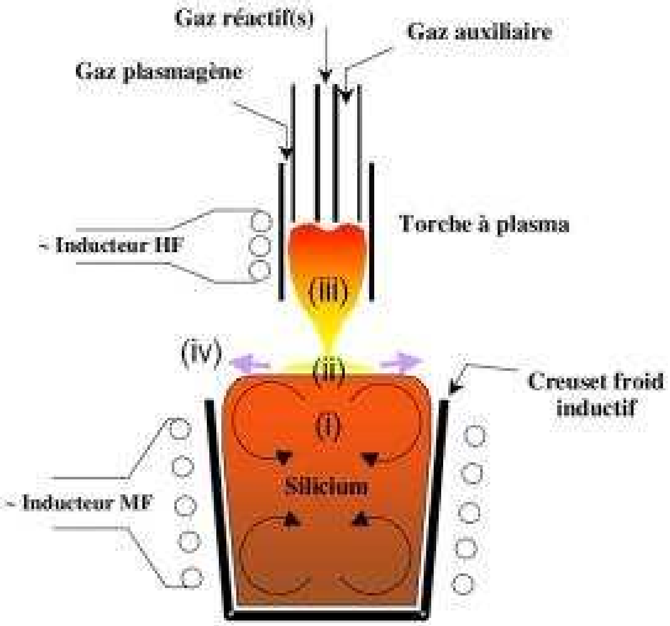






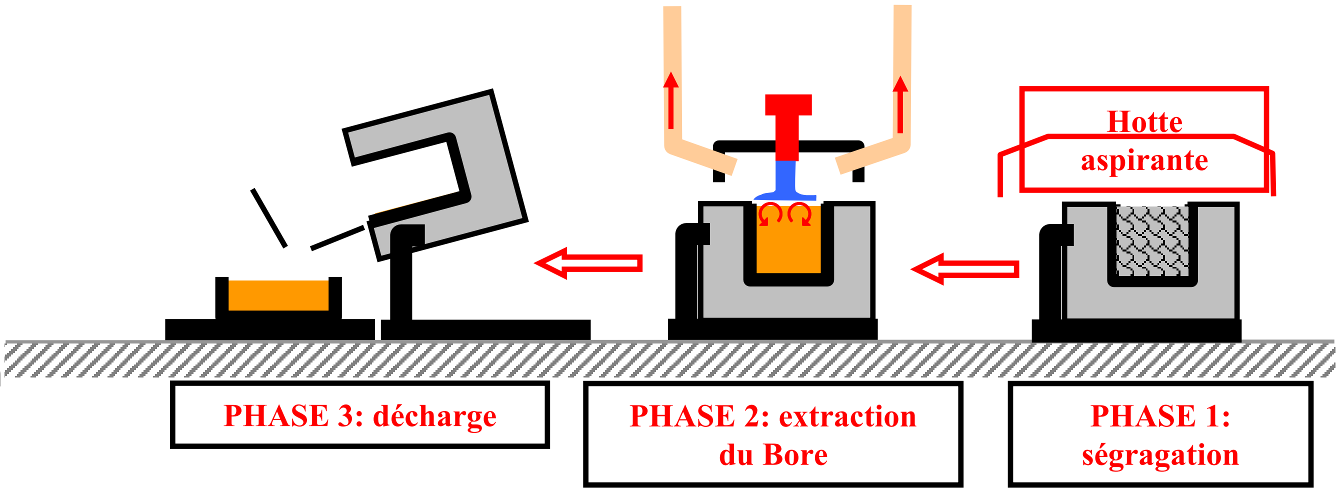
New purification process developped at INES



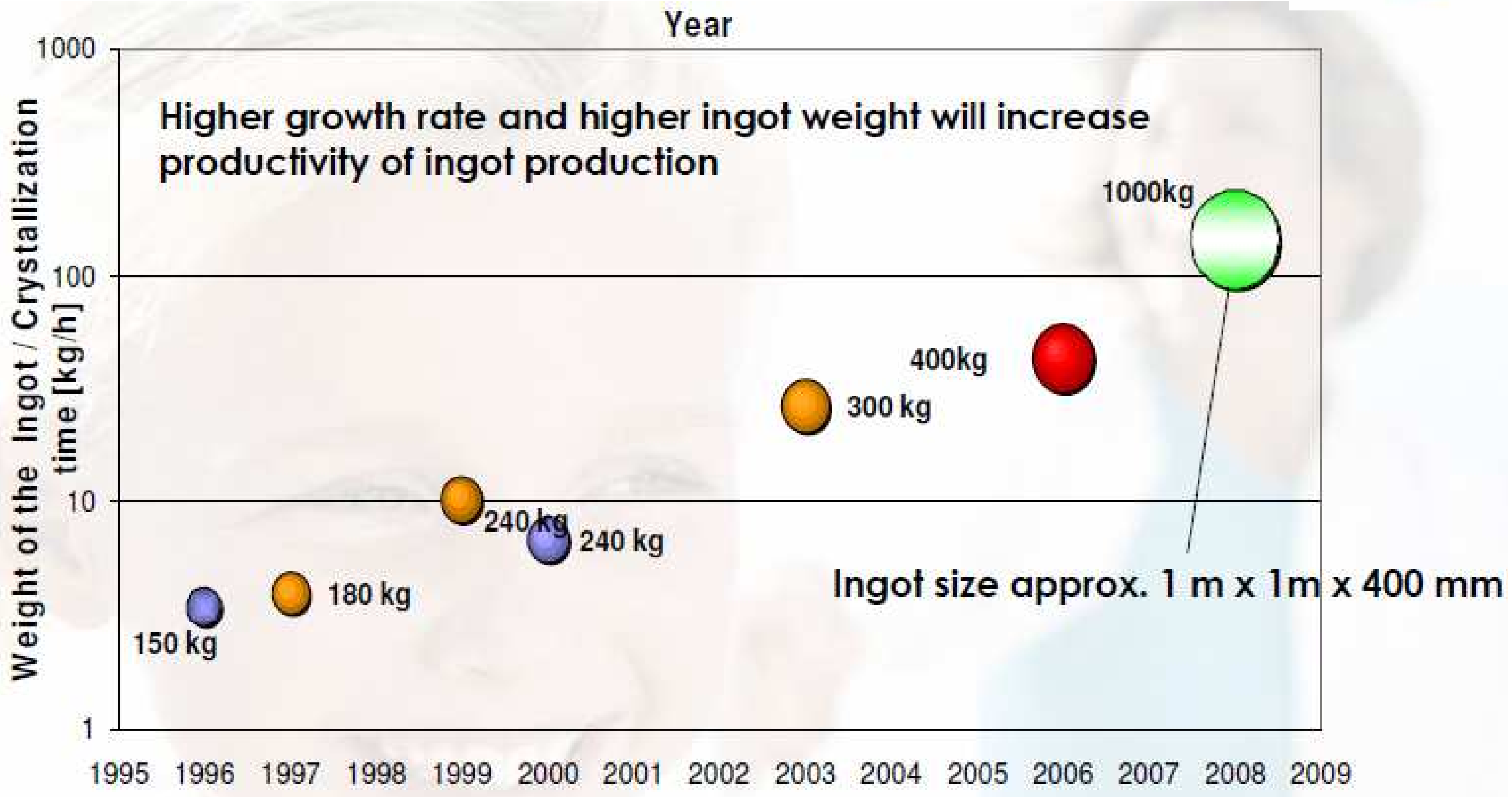
(i) Transport du bore à la surface
(ii) Réaction et volatilisation du bore
(iii) Génération des espèces réactives
(iv) Evacuation des produits de réaction

Segregation + Boron extraction using Plasma torche

World record for UMG: 18%

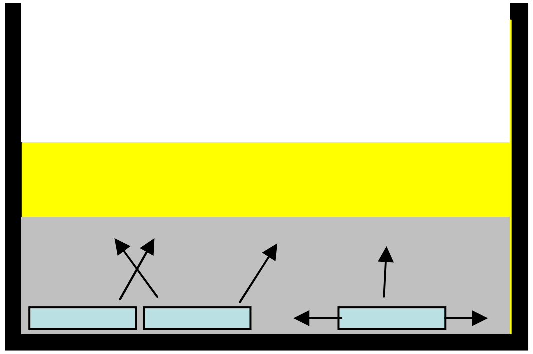


Towards larger and larger ingots



« Mono-Like » crystallization

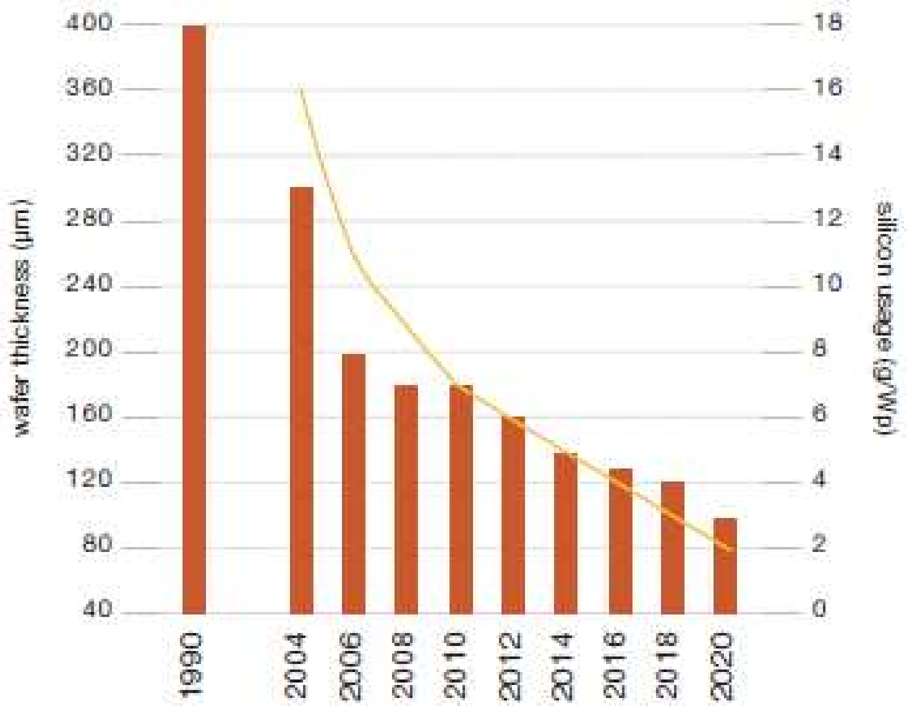
Recent results Schott Solar: 19,9%



Use single crystal seeds atthe bottom of the crucible

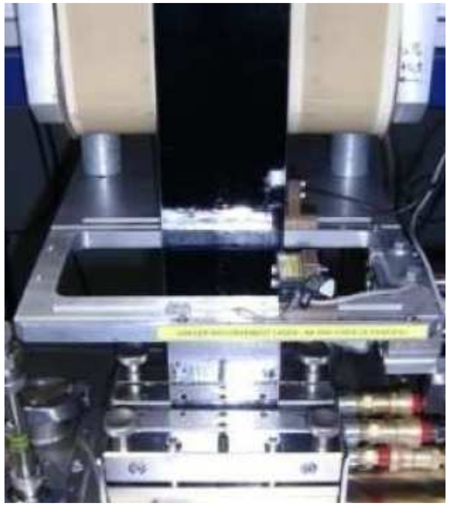
c-Si SOLAR CELL DEVELOPMENT

wafer thickness in µm &
silicon usage in g/Wp



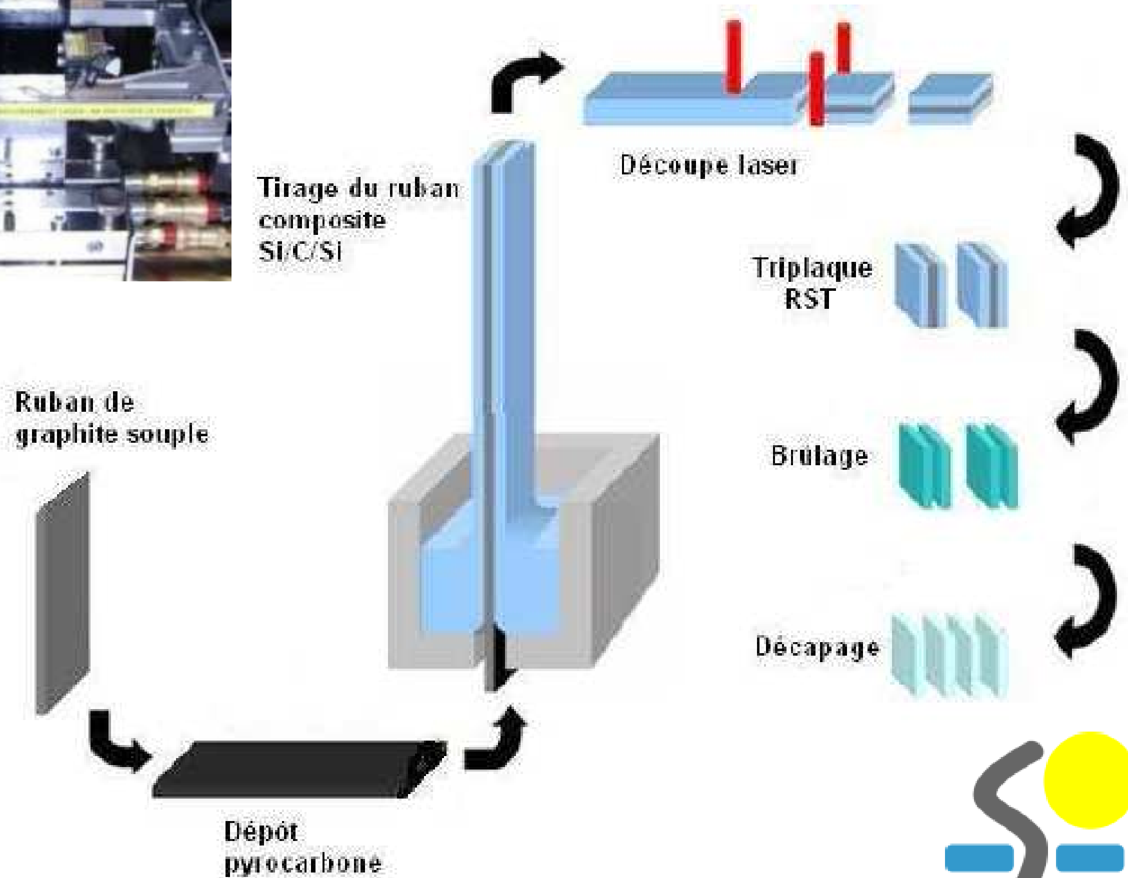
source: EU PV Technology Platform Strategic Research Agenda, C-Si Roadmap ITPV, EPIA roadmap 2004.

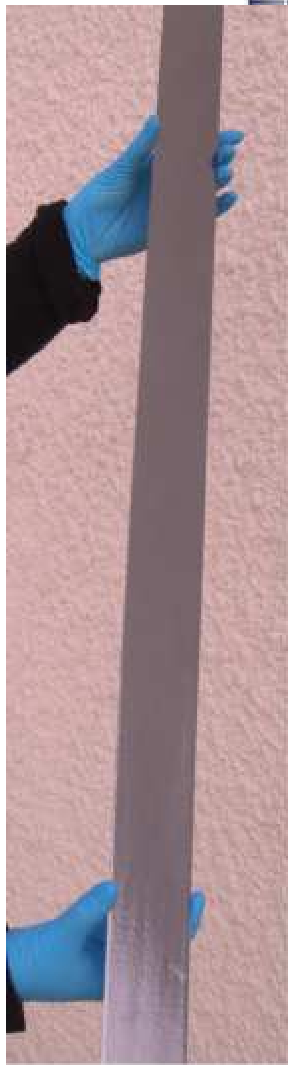
Get read of sawing?



Ribbons: 60 to 120 μm

1 to 2 g of Silicon per Wc !!!!

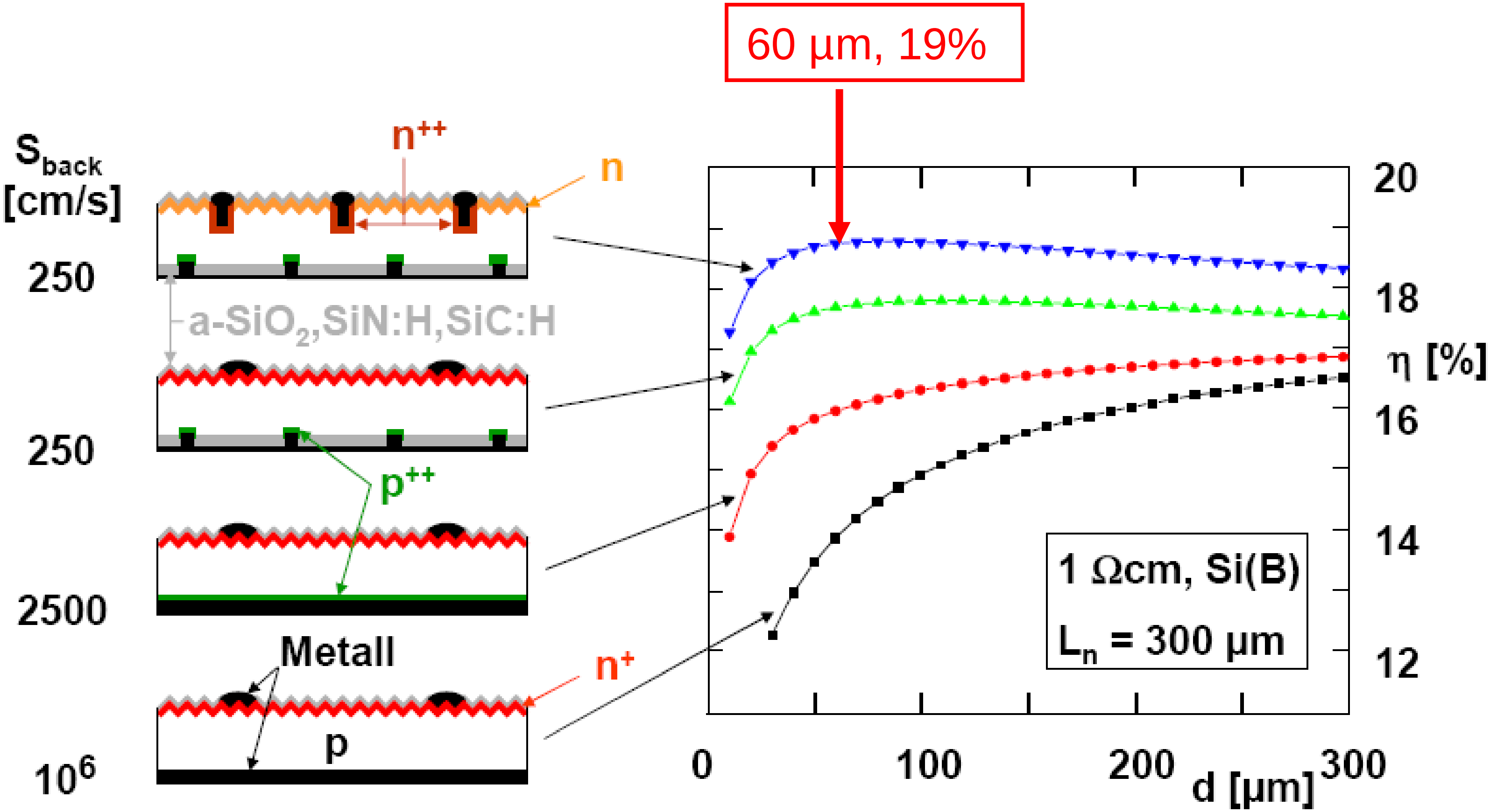




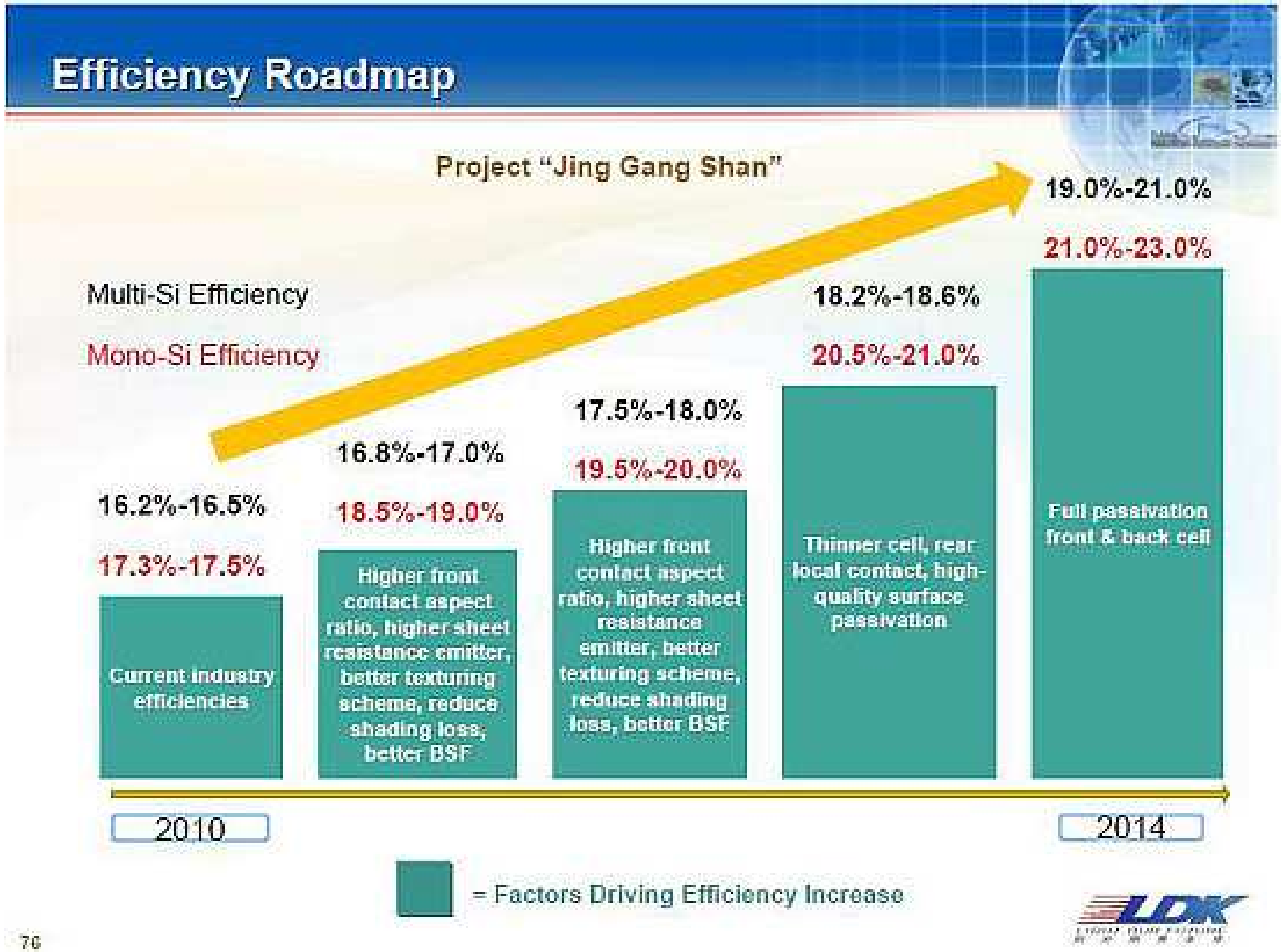
Cell efficiencies: power residual losses

Cell 29.8% / Loss/η =	Optical Surface loss	Metal optical loss	Surface recomb	Volume recomb	Resistive losses
Record η = 24.7%	3%	3%	10%	0%	2%
Std: Si mono η = 17.6%	5%	11%	20%	0%	5%
Std: mc-Si η = 16.1%	8%	11%	16%	6%	6%

New cell architectures (less surface recombinations) ➔very good efficiencies on thin wafers

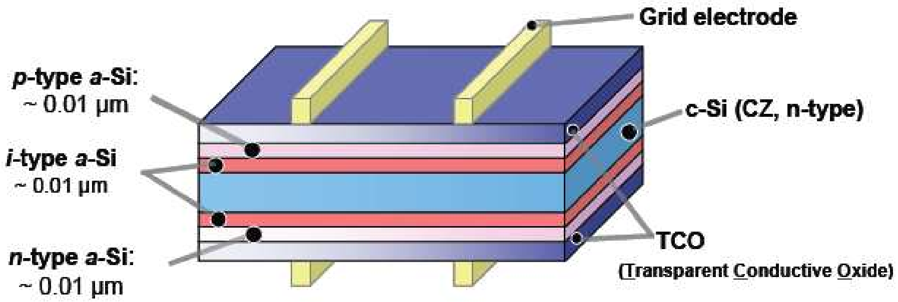


Silicon cells roadmap

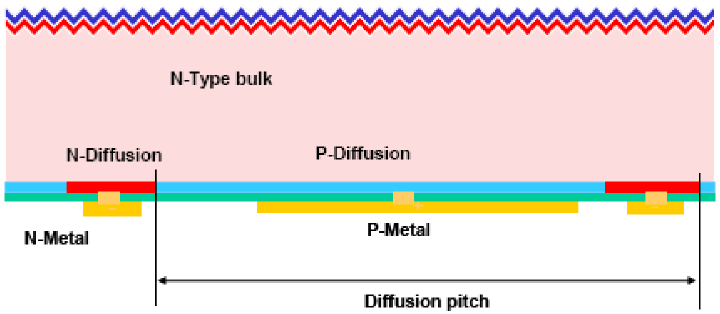


High efficiencies architectures

Heterojunction
HET ou HIT
Type Sanyo: modules à 18%



Rear Contact Cell
RCC
Type Sunpower: modules à 20%

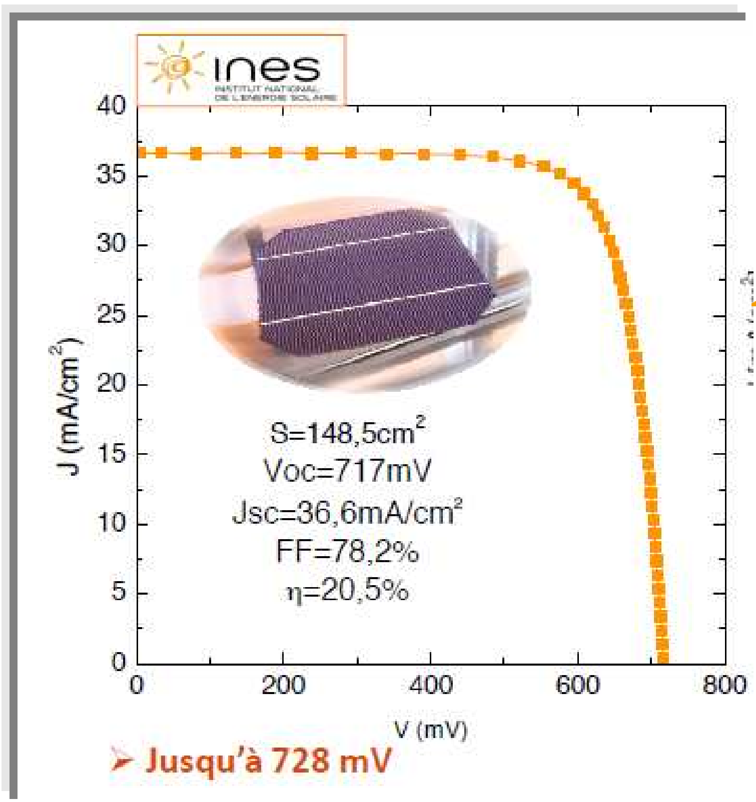


Less sensibles to temperature in operation

Compatibles with thin wafers

Possibilities to get specific modules:ex bi-facials for HET

Resuts of INES on heterojunctions



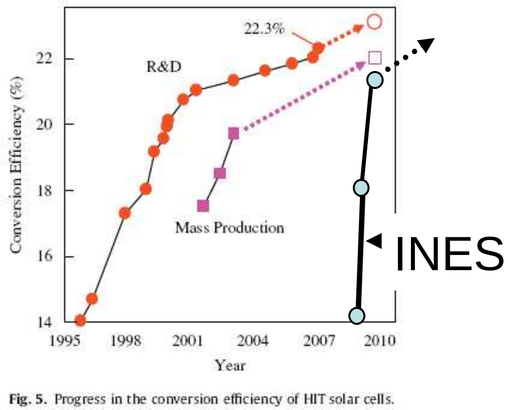
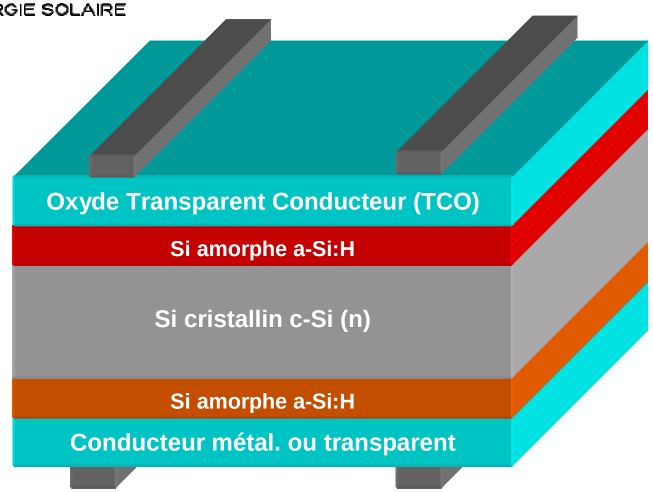


Fig. 5. Progress in the conversion efficiency of HIT solar cells.



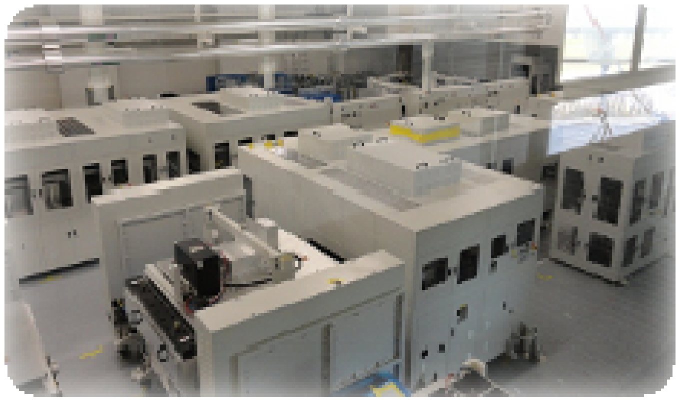
Record Cell 20,7%
Industriel Process 20 %

2 years of development

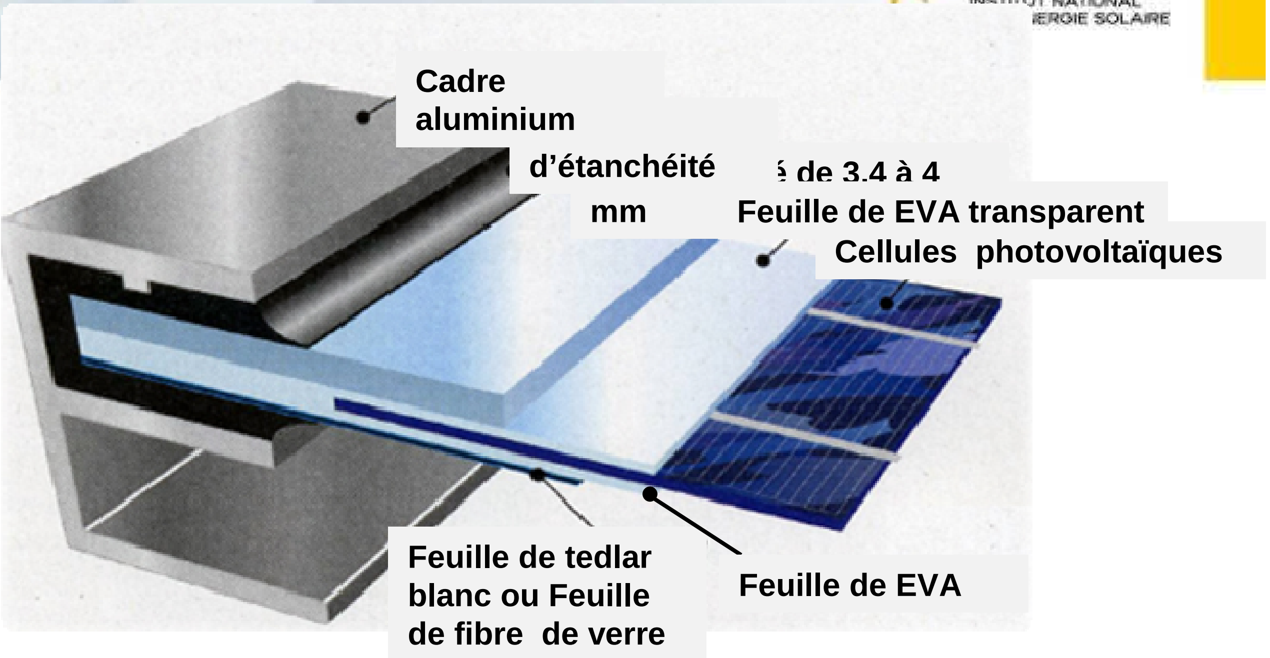
HET: Prototype line installed at INES

CARACTERISTICS:

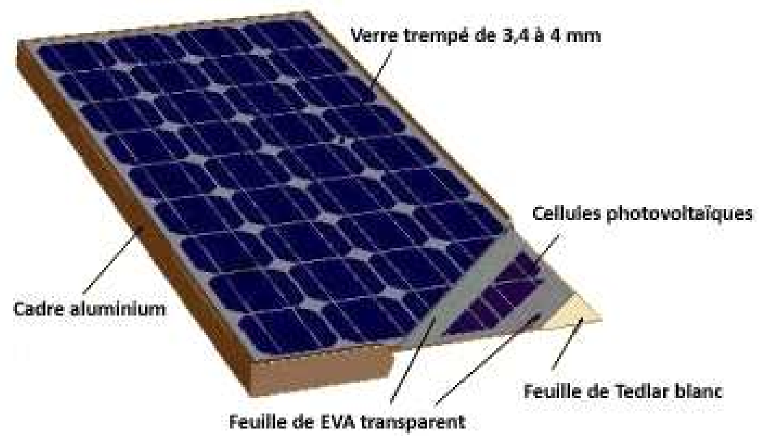
- Nominale Capacity 30-35 MWp/y
- Productivity 1500 cells/hr
- Cells 125 mm or 156 mm
- Clean Room ISO8 1200 m2
- Conversion efficiencies more than 20%



The module encapsulation

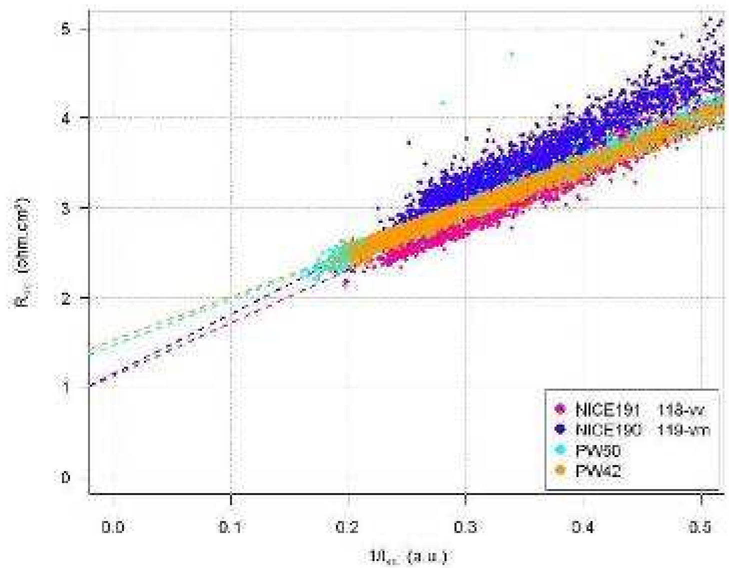


- *Should be adapted to new cells*
- *Decrease losses and increase quality*
- *Integrate the ease of recycling*
- *Automatise*



Exemple of rupture: NICE

Lowe Contact Resistance compared to standard welding



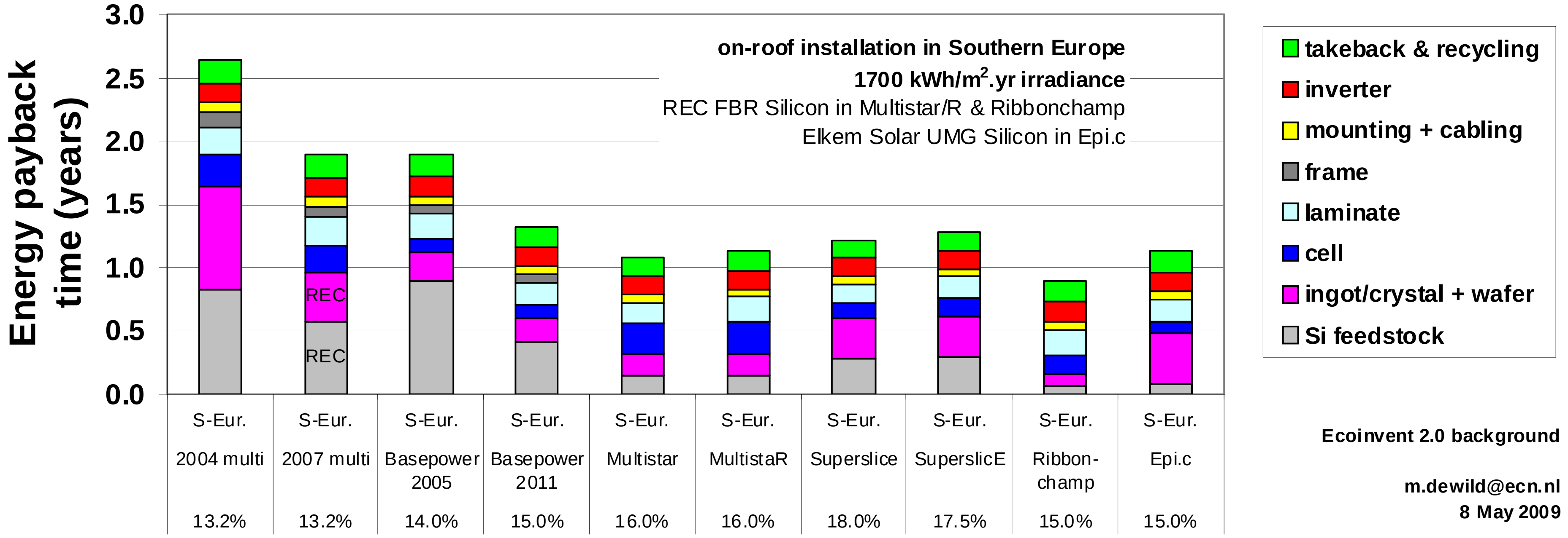
No more encapsulant

Tightness through a peripheral sealing

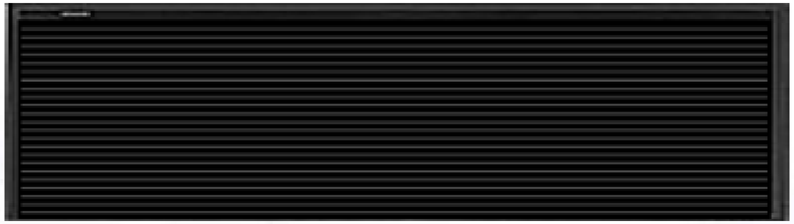
Very easy module fabrication

Very easy recycling

The innovations will reduce the residual environment inpact

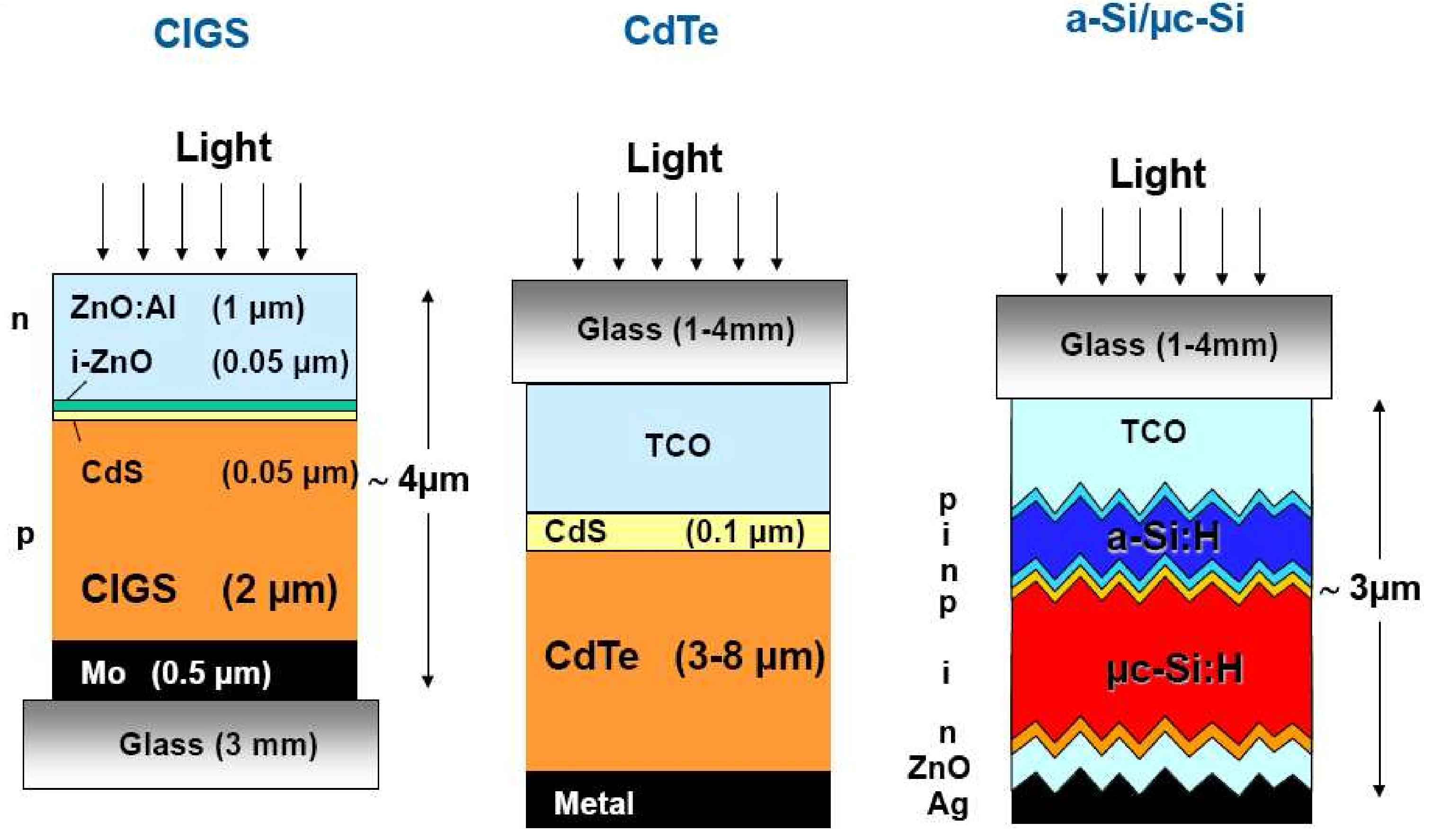


Résultat Projet Crystal Clear



The thin film alternative

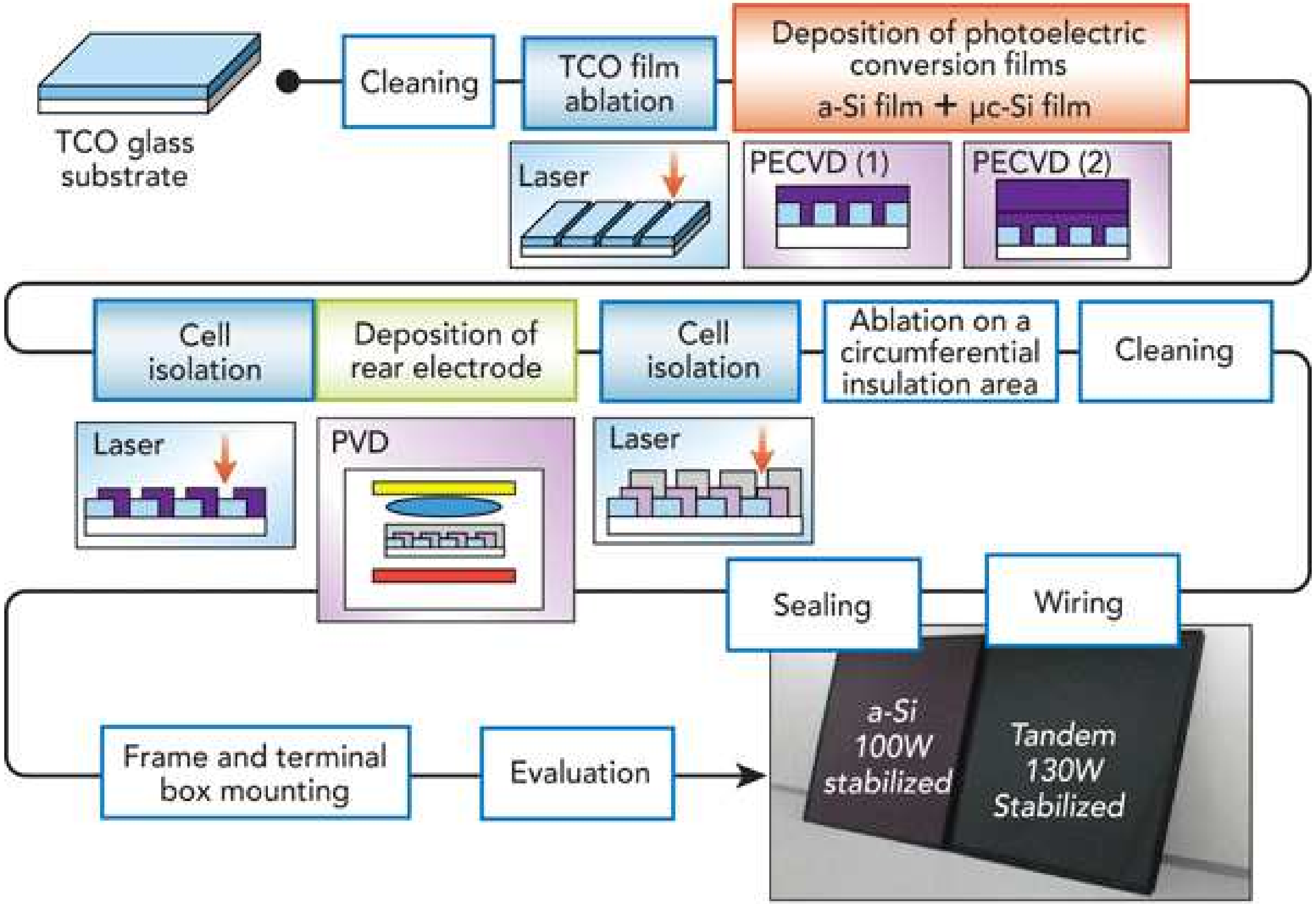
Three technologies in competition



Best commercial products

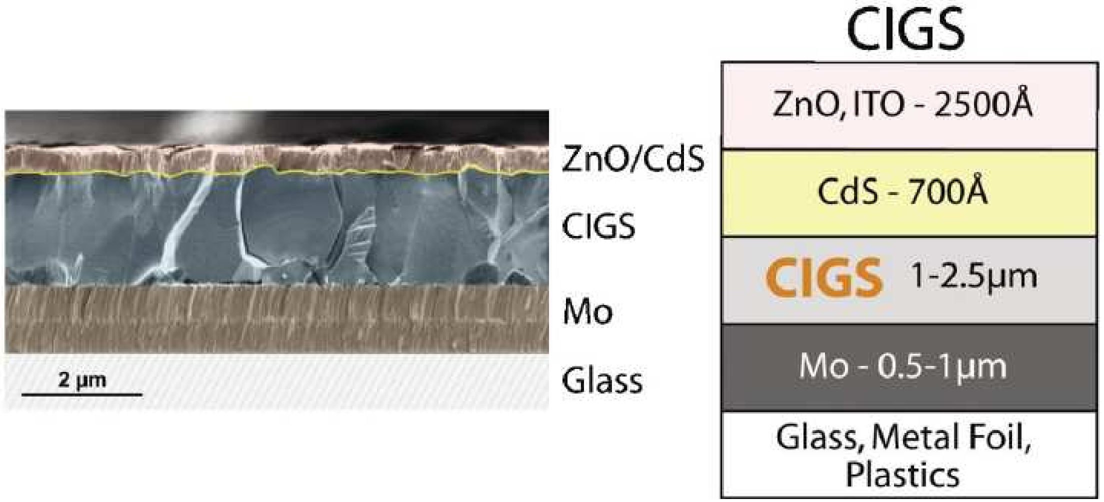
CIGS	CdTe	a-Si/µc-Si
13%	11,5%	10%

A process simple and fully integrated



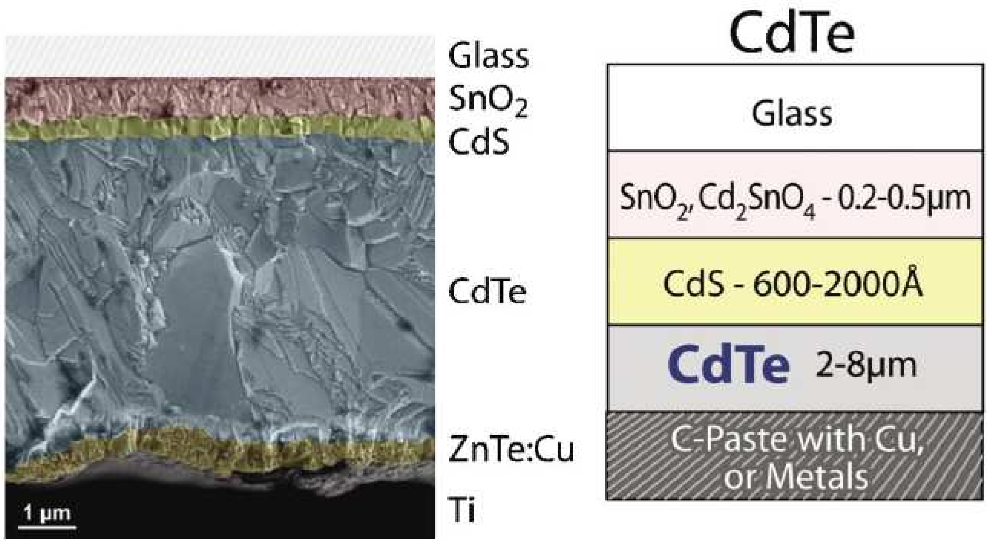
The chalcogenide routes

Best products/ Best lab cells (%)



13/

21



11/

17.5

Cu(InGa)Se2 or CIGS : Good promises

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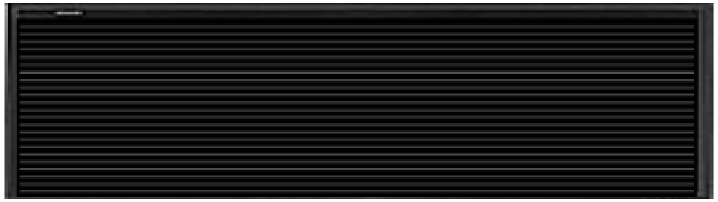
Advantages :



- Very good conversion efficiencies at lab scale
- Not very sensitive to composition

Residual difficulties:

- Indiu and Gallium resources?
- Replace CdS as buffer layer (⇨ remplacement by ZnS, ZnO…)
- Deposition process still not mature →

Ways of Making CIGS

DEPOSITION METHOD	COMPANY
Coevaporation	Würth
Selenization	Showa Shell
Sputtering	MiaSolé
Nanoparticle sintering	Nanosolar
Electroplating	SoloPower
FASST (reactive transfer)	HelioVolt

Tendency: Try to remove rare elements

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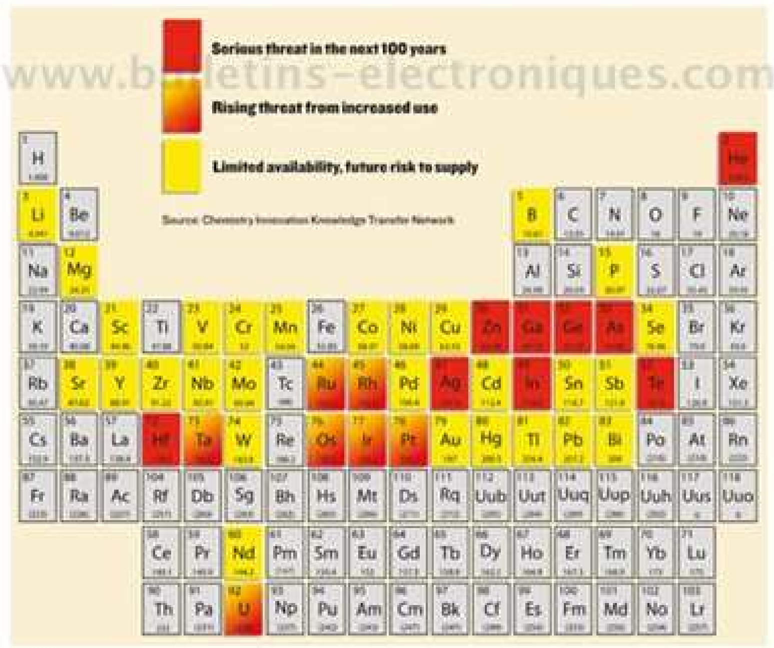
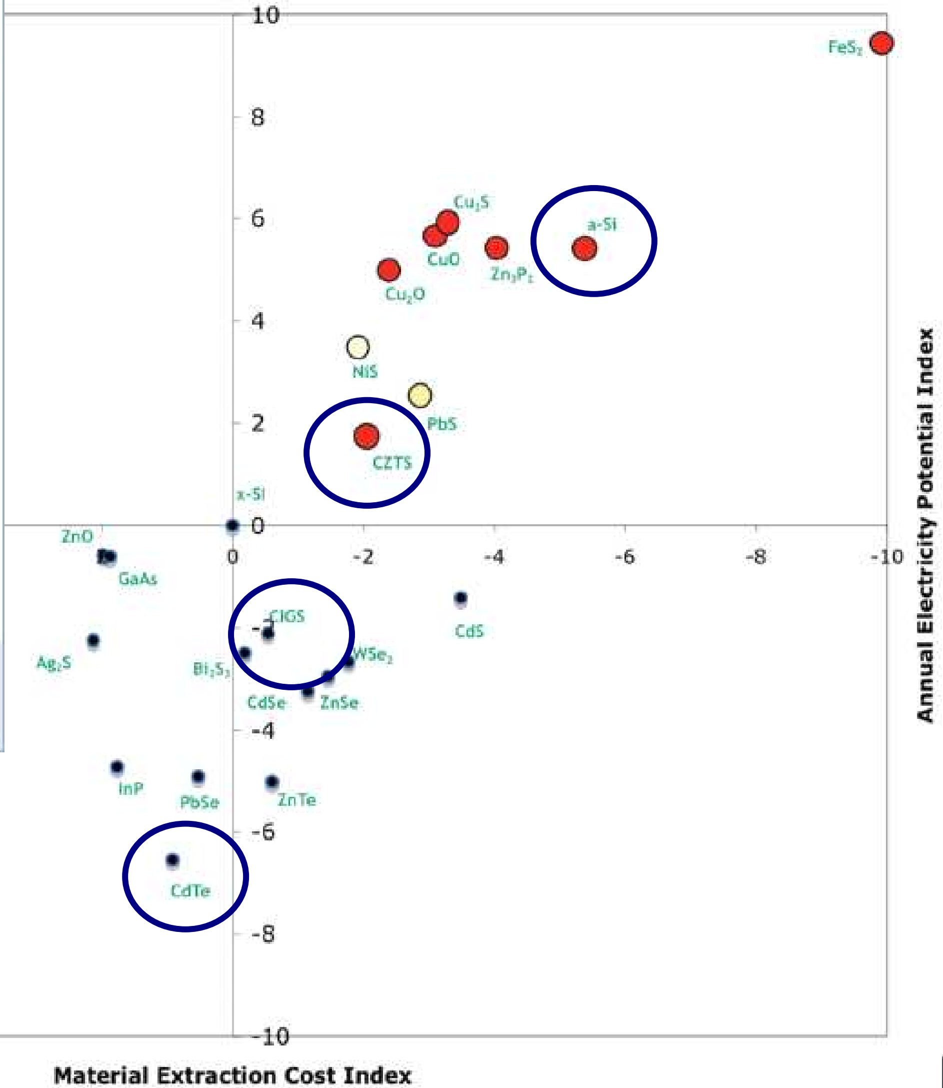


Tableau périodique des éléments 'en danger'
www.bulletins-electroniques.com/actualites/66180.htm
Crédits : Chemistry Innovation Knowledge Transfer Network
FM



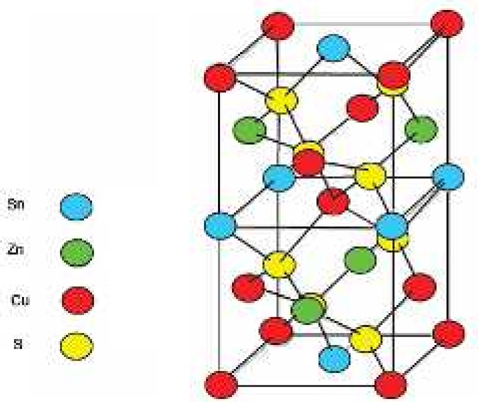
A new challenger: CZTS (kesterite)

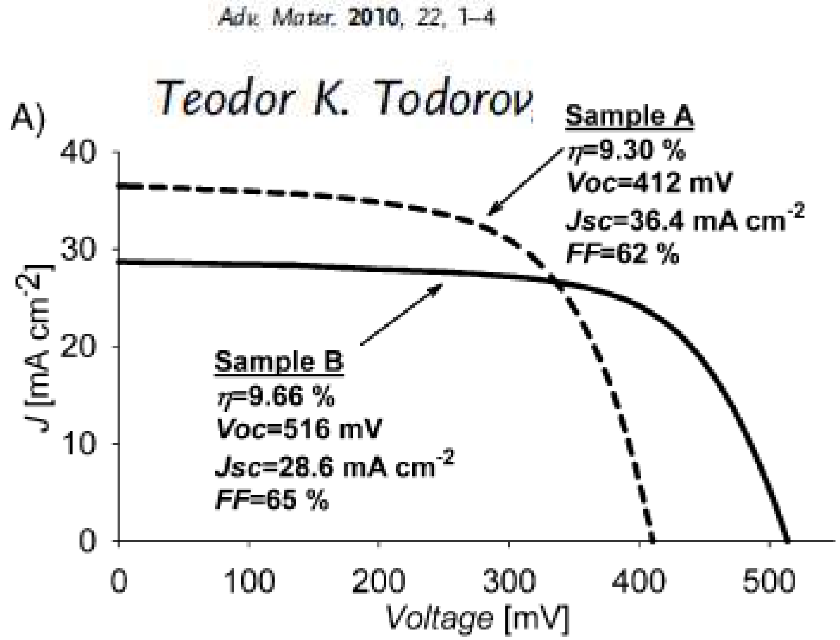
Si

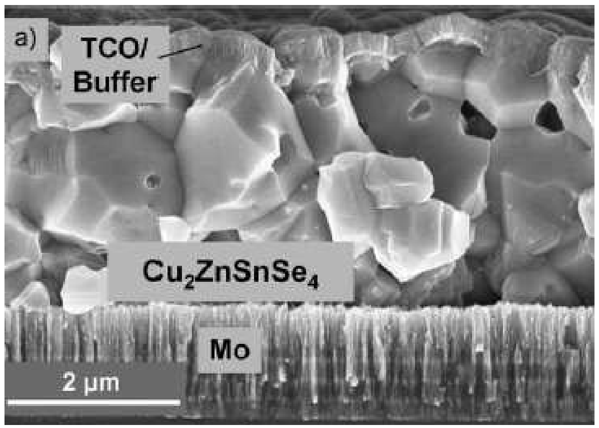
Zn^{2+} S^{2-} — CdTe

Cu^{1+} In^{+3} $2S^{2-}$ — CIS

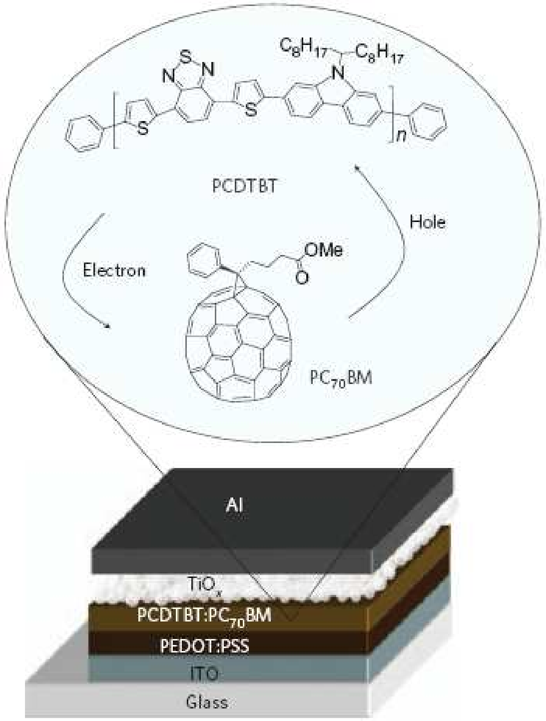
$2Cu^{1+}$ Zn^{2+} Sn^{4+} $4S^{2-}$ — **CZTS**



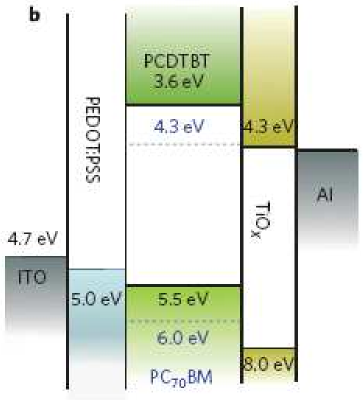


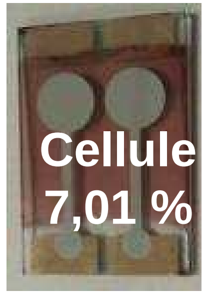


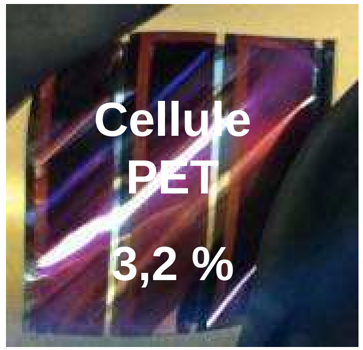
Organic cells: constant progress



Colloïdale Sol of TiO2



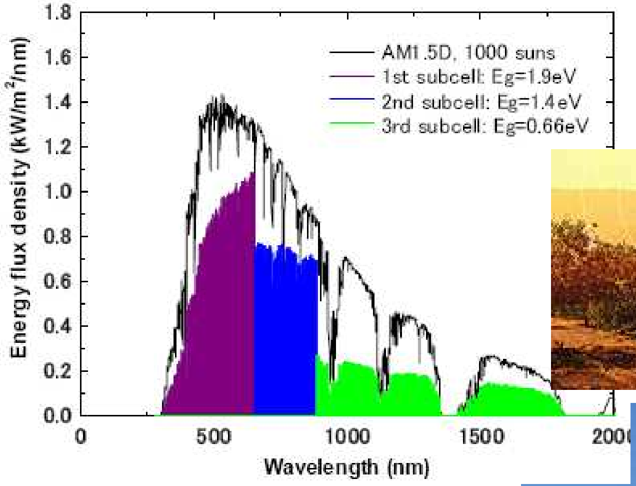




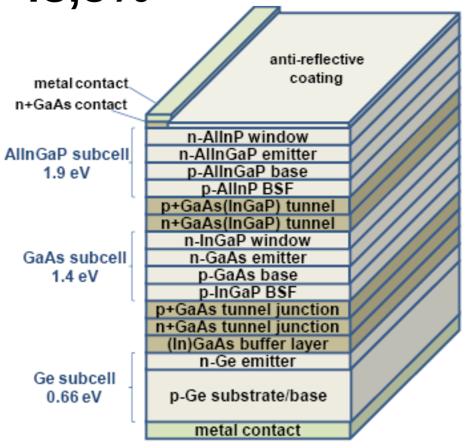
Record 8,4%: UCLA

Première certification IEC: Konarka

High concentration PV



Cellules Record: 43,5%



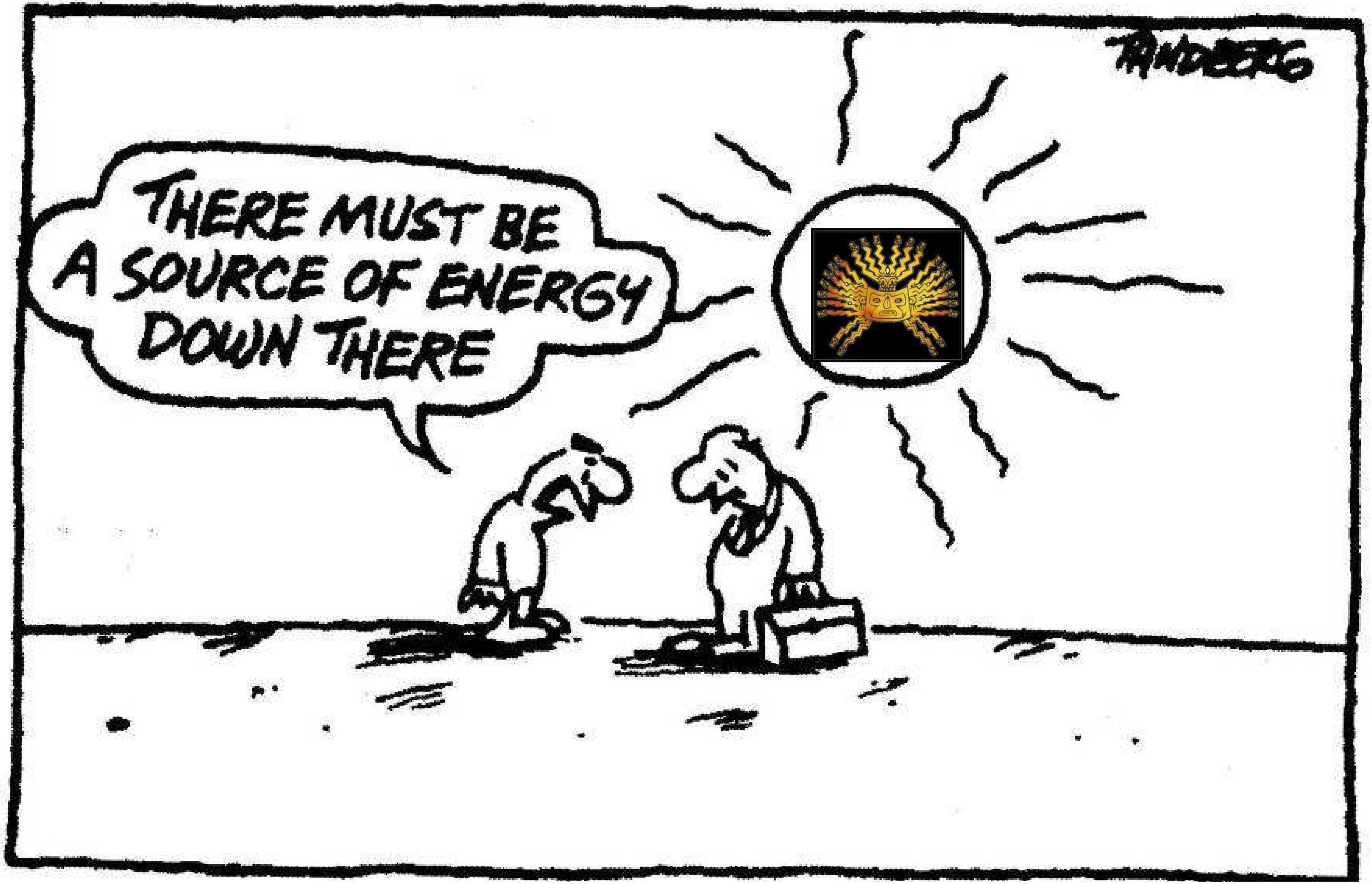
Rendement Système record (Semprius): 33,4%

Visé: 36%

A summary about the PV roadmap

		2007	2010	2015	2020
Turn-key price large systems (€/Wp)		5	2,5	2	1,5
PV electricity generation cost in Southern EU (€/kWh)		0.30	0.13	0.10	0.07
Typical PV module efficiency range (%)	Crystalline silicon	13-18%	15-20%	16-21%	18-23%
	Thin films	5-11%	6-12%	8-14%	10-16%
	Concentrators	20%	20-25%	25-30%	30-35%
Inverter lifetime (years)		10	15	20	>25
Cost of PV + small-scale storage (€/kWh) in Southern EU (grid-connected)		--	0.35	0.22	<0.15
Energy pay-back time (years)		2-3	1-2	1	0.5

Applications: adapt the module technology to buildings


THERE MUST BE A SOURCE OF ENERGY DOWN THERE
TANDBERG

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Jean-Pierre JOLY

- *El señor Jean-Pierre Joly es diplomado del Instituto Nacional Politécnico de Grenoble en Francia (PHELMA) y doctorado en ingeniería de la Universidad Joseph Fourier de la misma ciudad. Es presidente del Instituto Nacional de Energía Solar de Francia (INES) desde 2009 y director de investigación en la Comisión para la Energía Atómica y las Energías Alternativas (CEA). Se dedicó en investigar en el campo de las energías solares en varios laboratorios e instituciones francesas (CEA, INES, LITEN, CEA LETI). Se destacó, en particular, por sus trabajos sobre materiales semiconductores y sus usos en las técnicas fotovoltaicas.*
- Contacto : jean-pierre.joly@cea.fr

- El INES ha sido fundido en el 2006 con destino de hacerse el centro francés y europeo de referencia en el campo de la energía solar. Abarca hoy más de 350 investigadores, y seguirá creciendo durante los próximos años.
- Se ubica en el polo *Savoie Technolac* en Chambéry, Francia.
- Mayor Información en http://www.ines-solaire.org/

La Corporación Andina de Fomento y la Cooperación Regional para los Países Andinos dan las gracias a los expositores por haber compartido su peritaje, al público por su presencia y a todas las personas que trabajaron para que este acontecimiento tuviera el éxito que conoció.

Coporación Andina de Fomento (CAF)

IGARCIA@caf.com

www.caf.com/

Cooperación Regional para los Países Andinos

clement.larrauri@diplomatie.gouv.fr

http://www.franceamsud.org/site/