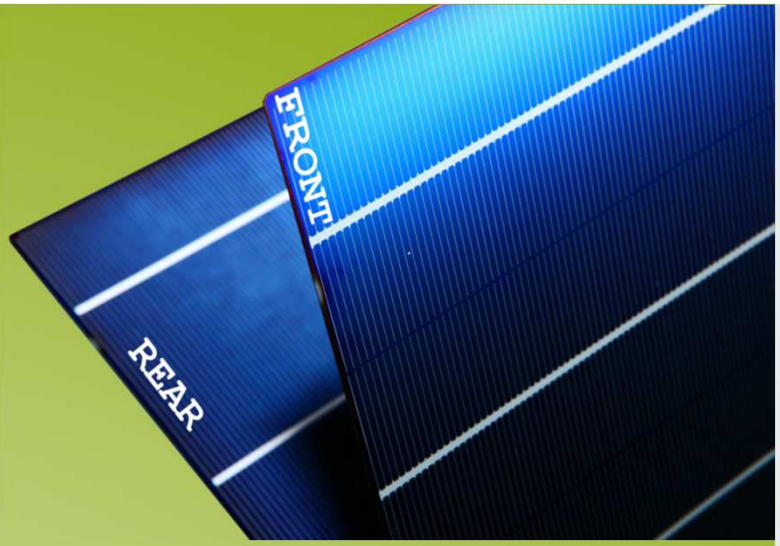



# ECM Group

## PV production equipment leader

*Technologies for*
***high efficiency solar cells***

ECM Greentech
109 rue Hilaire de Chardonnet
38100 Grenoble - France

Benjamin Deneux | Sales Manager | Crystallization focus | 6th of September 2016

# ECM GROUP

320 EMPLOYEES – 80 M€ REVENUES

## AUTOMOTIVE NUCLEAR

ECM TECHNOLOGIES

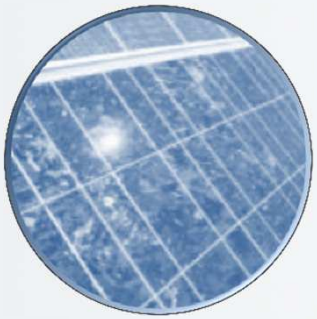
ICBP®
Vacuum furnace
Induction furnace
Special furnace

## AEROSPACE

SERTHEL INDUSTRIE ECM GROUP

Conventional furnace
VPA furnace
Retrofit

## PHOTOVOLTAICS



ECM GREENTECH

Ingot and cell production equipment
Crystallization Furnace
Diffusion furnace
PECVD
Turnkey line

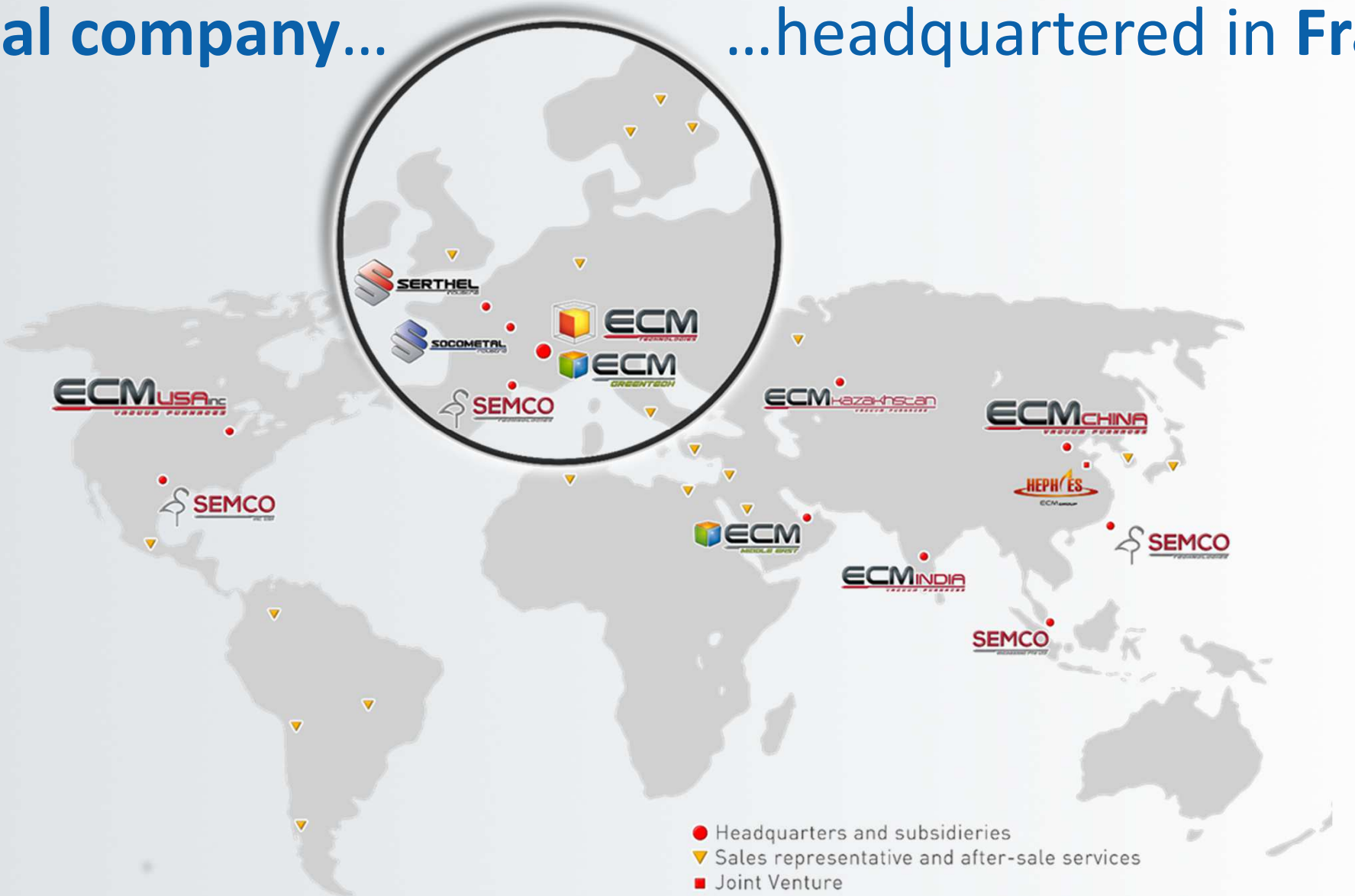
## MICROELECTRONICS

SEMCO TECHNOLOGIES ECM GROUP

Photovoltaic
Silicon treatment
Electrostatic Chucks
Gas flow components

# A **global company**… …headquartered in **France**

**Offices in:**
- France
- USA
- China
- India
- UAE
- Kazakhstan
- Singapore
- Taiwan






ECM TECHNOLOGIES

## 8 000 m² of workshop

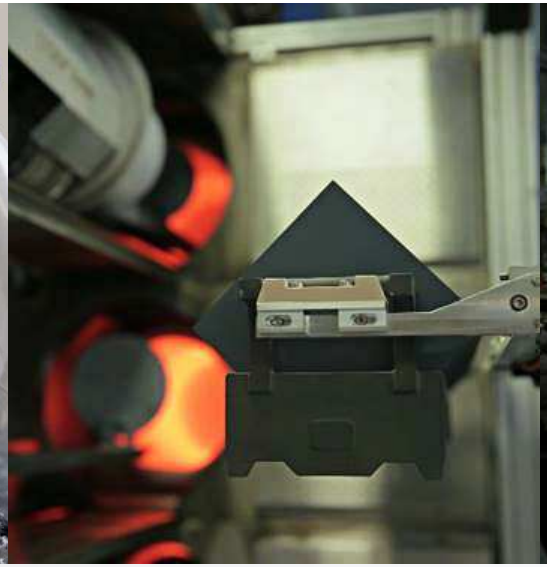
Boilermaking – Welding – Moly – Refractory brick lining – Piping – Machining – Assembling

## Engineering Office

Expertise Process – Electronical Automatism – Mecanic – Thermal

## 2 metallurgical testing facilities

In France and in US


ECM GREENTECH

SEMCO TECHNOLOGIES

ECM GROUP

## ECM GREENTECH

1 agency in Grenoble

## SEMCO Technologies

2 agencies in Montpellier, North and South

## 1 000 m² of workshop

## Engineering Office

Process Expertise – Electronical Automatism – Mecanical – Thermal

## 1 Laboratory of equipment development and clean room process

# ECM: A leading vacuum furnace maker

- **>3000** vacuum furnaces in production (Photovoltaic, automotive, aeronautic, electronic, nuclear)
- **1000 carburizing ICBP Cells** in the automotive industry (WORLD LEADER)
- More than **50 crystallization furnaces** in the field (France, China, Germany, Norway, Kazakhstan). Expert in Silicon crystallization since **1983**





**Heat treatment experts since 1928...**

DESIGN | BUILD | DEVELOP PROCESS | TRANSFER TECHNOLOGY | LONG TERM SUPPORT

# Experience in crystallization: ECM pioneer

**1983** — First industrial 60Kg DSS furnace

**1989** — First worldwide Bottom loading DSS furnace with graphite heating

**1992** — Capacity increase 150Kg – G3

**1997** — First worldwide 300Kg furnace

**2001** — Additional 22 furnaces sold to Deutsche Solar in Germany

**2009** — Design of G5/G6 flexible furnace 450 – 800Kg

**2009** — Development of CrystalMax Technology (Ultra High Performance multi)

**2012** — Turnkey wafer line 60 -100MW **In Kazakhstan**
Turnkey module line 30MW **In Morocco**

**2012** — Creation of **ECM Greentech**

**2015** — First G8 furnace sold





# References crystallization furnace




FESIL SUNERGY SOLARWORLD REAL VALUE KAZATOMPROM Photowatt TECHNOLOGIES cea ines INSTITUT NATIONAL DE L'ENERGIE SOLAIRE 潞安集团 LU'AN GROUP معهد قطر لبحوث البيئة والطاقة Qatar Environment & Energy Research Institute عضو في مؤسسة قطر Member of Qatar Foundation مؤسسة قطر Qatar Foundation Unlocking human potential.

*New furnaces delivered in 2016

# Reference in PV turnkey line

**ECM has successfully delivered and started up an ingot and wafer manufacturing line in Kazakhstan**

Technology: **Multicrystalline**

Capacity: **60MW**, extendable to 100MW

Location: **Ust-Kamenogorsk, Kazakhstan**

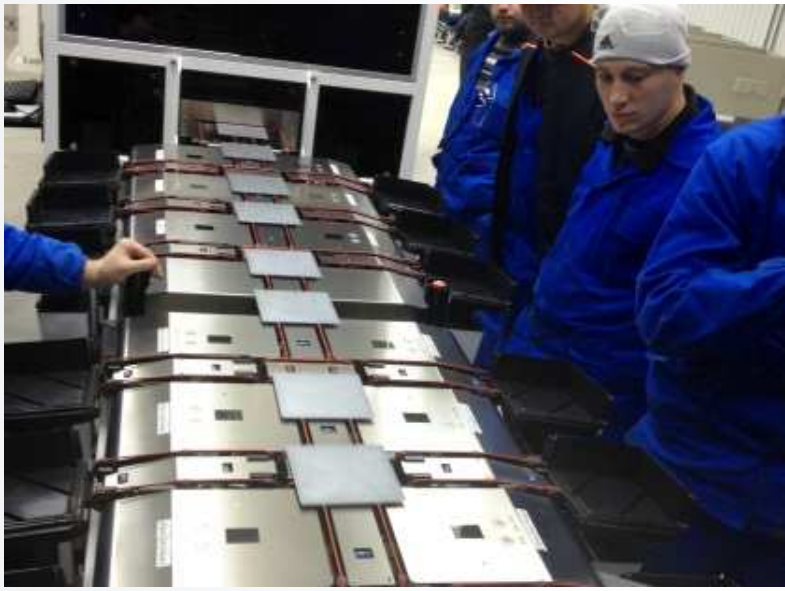
Contract type: **Turnkey**

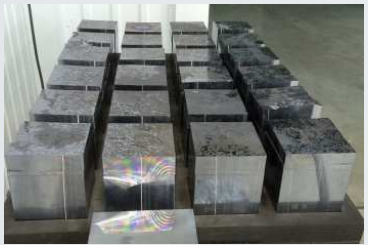
KAZ ATOM PROM

# Reference in PV turnkey line

**ECM is the only equipment supplier whom has successfully delivered such I&W line.**







# Reference in PV turnkey line


# ECM PV600 : Crystallization furnace

**ECM Furnace**


**3 processes**

- Std. multi
- HP multi
- CrystalMax: Ultra High Performance multi

**3 sizes**

G5 25 Bricks

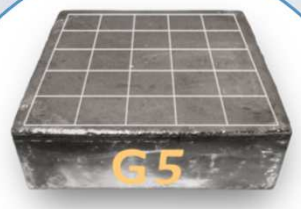
G6 36 Bricks

G8 64 Bricks

# CRYSTALMAX: Ultra High Performance

*<100> oriented wafers at the cost of multicrystalline*

## Traditional technologies:




Multicrystalline- 450Kg

**Low cost**

**Average efficiency**

Monocrystalline - 180Kg

**High cost**

**High performance**

## INNOVATION ECM:

**>20,5%**
Cell efficiency


CrystalMax - 650Kg

**Low cost**

**High performance**

CONFIDENTIAL

# R&D Partner: CEA INES

***CRYSTALMAX*** is a technology jointly developed with the leading solar institute **CEA INES**

INSTITUT NATIONAL DE L'ENERGIE SOLAIRE

400 researchers dedicated to photovoltaics

# Furnace productivity for CrystalMax

**ECM PV 600 *CrystalMax***


| | |
|---|---|
| **Furnace output** | **≥11 MW per year**<br>Assuming 20% cell efficiency and 190µm thickness for mono wafers with 120µm kerf |
| Ingot size | 100 x 100 $cm^2$ |
| Ingot weight | 650 Kg |
| Mass ingot yield (MIY) | ≥63% |
| Cycle time | ≤78 hrs |


Crystalmax

A **1 GW** mono wafer line would require about **330** Czochralski pullers

or **only 90 ECM furnaces** with the CrystalMax process

# CrystalMax production ingots


# CRYSTALMAX: Ultra high efficiency

*<100> oriented wafers at the cost of multicrystalline*

| Cell technology | Efficiency average with CrystalMax | Maturity |
|---|---|---|
| Std Al BSF | 19.0% | Production |
| PERC | >20.0% | Production |
| Bifacial n type | >20.0% + rear side | Production |
| HIT | 21.3% | R&D |

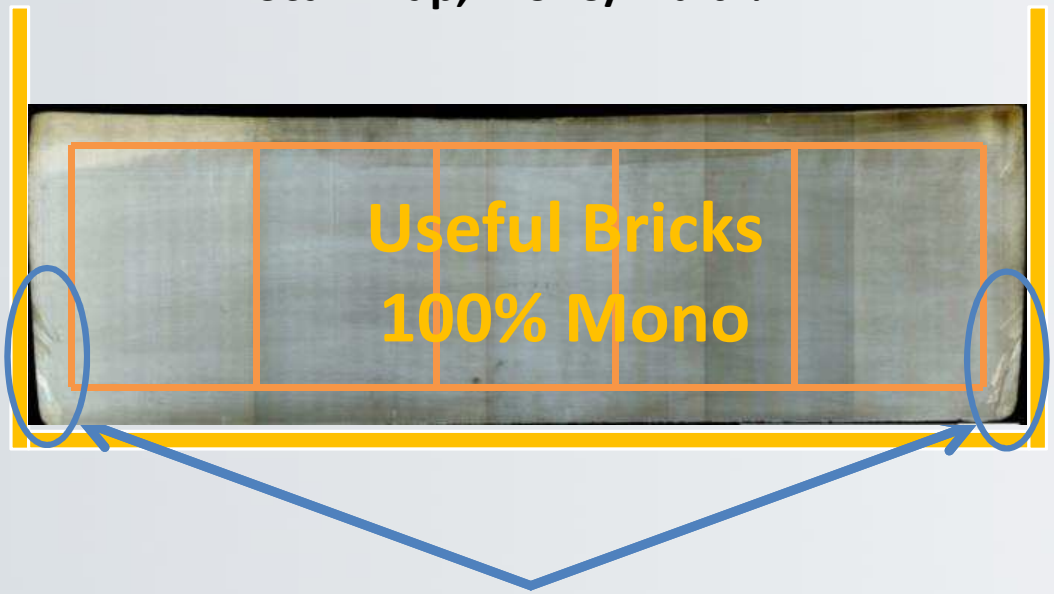
"**CrystalMax** wafers are **oriented <100>** which make it compatible with **alkaline etching**

**CrystalMax** wafers are compatible with all **high efficiency cell processes**

# Unique thermal control for growing mono ingot

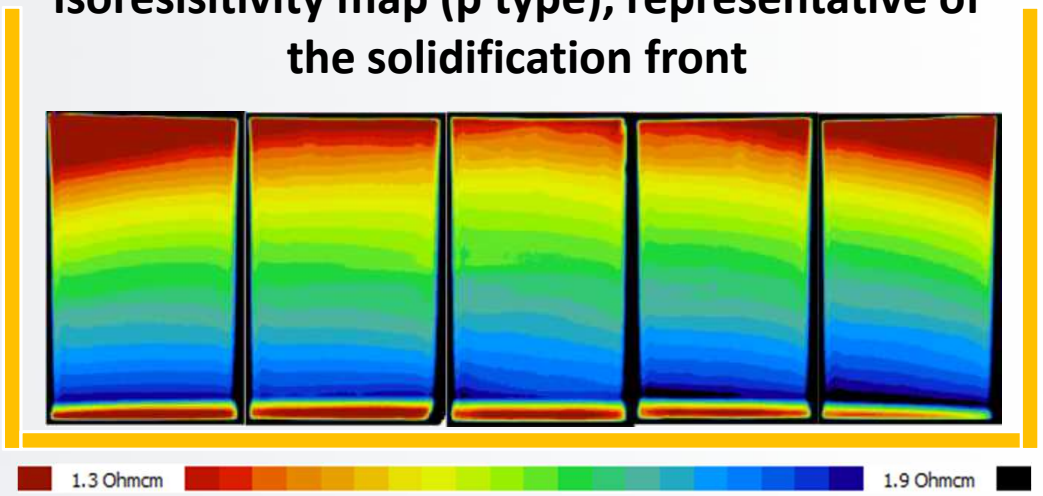
***ECM design is unique on the market, achieving unmatched results in CrystalMax technology***

**Scan map, Mono/Multi %**




Remaining multicrystalline Zone on the sides only.
The useful part of the bricks are 100% mono

**Isoresisitivity map (p type), representative of the solidification front**



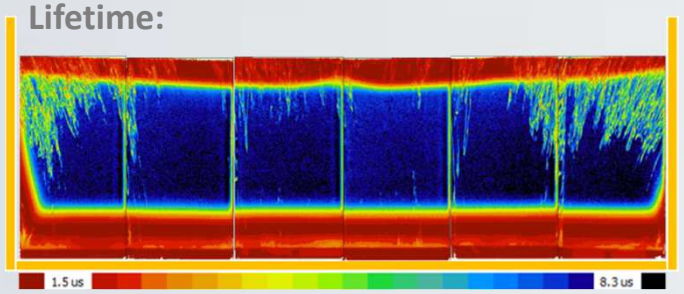

The resistivity mapping shows a uniform and slightly convex shape for the front of solidification which enables segregation of impurities on the sides and top part of the ingot and a proper control of initial crystal growth on mono seeds

# **CrystalMax**: Characterization Gen 6

## Gen 6 ingot: 36 bricks <100>

Visual:

Lifetime:




Infrared:

**100% of bricks oriented <100>**

➔ *Reproducibility*

**Low dislocation density**

➔ *high cell efficiency*

**IR defects free ingot**

➔ *Diamond slicing*

# CrystalMax with diamond wafering

CrystalMax is a material which is compatible with **diamond** based wire sawing process.

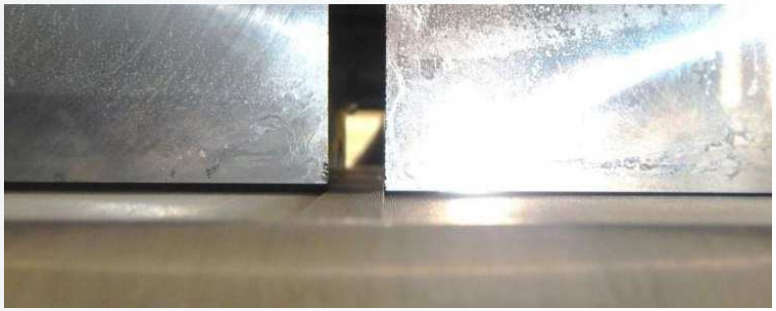
This enables CrystalMax to follow current and future **cost reductions** that roadmaps are displaying thanks to diamond cutting (thinner wafers, reduced kerf, reduced cost, no slurry management)

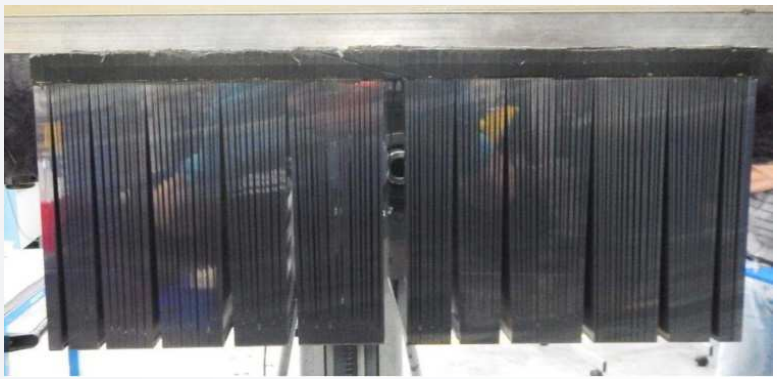
**CrystalMax:**

Inclusion free ➔ **Easy cut with diamond**

<100> crystal orientation ➔ **Alkaline texturing**

*Monolike bricks cut on diamond platform*

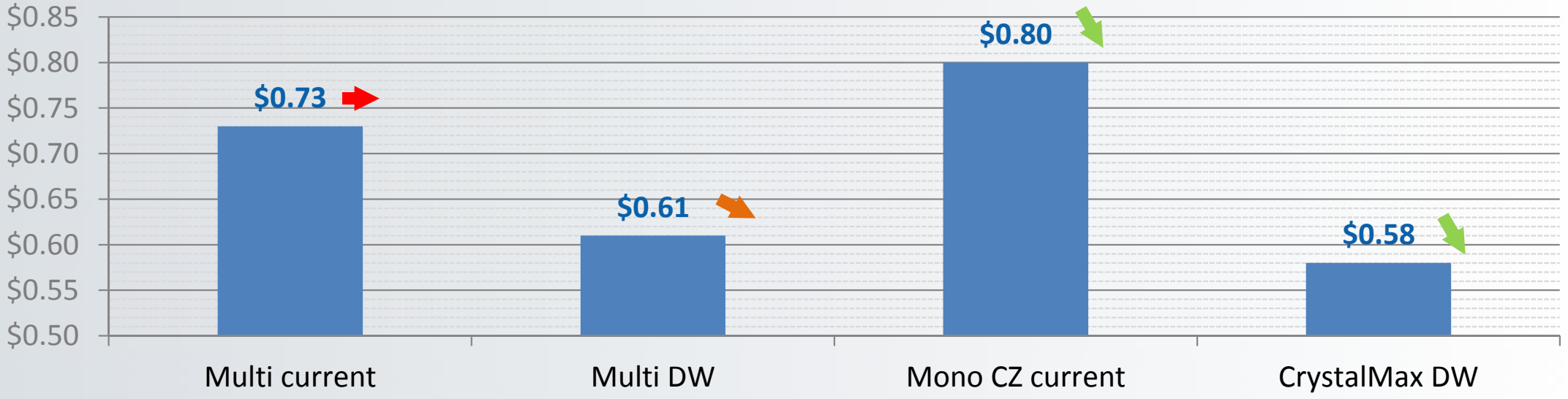




# CrystalMax Competitiveness per wafer

**Manufacturing cost per wafer (OPEX+CAPEX)**

*DW= Diamond wire wafering*



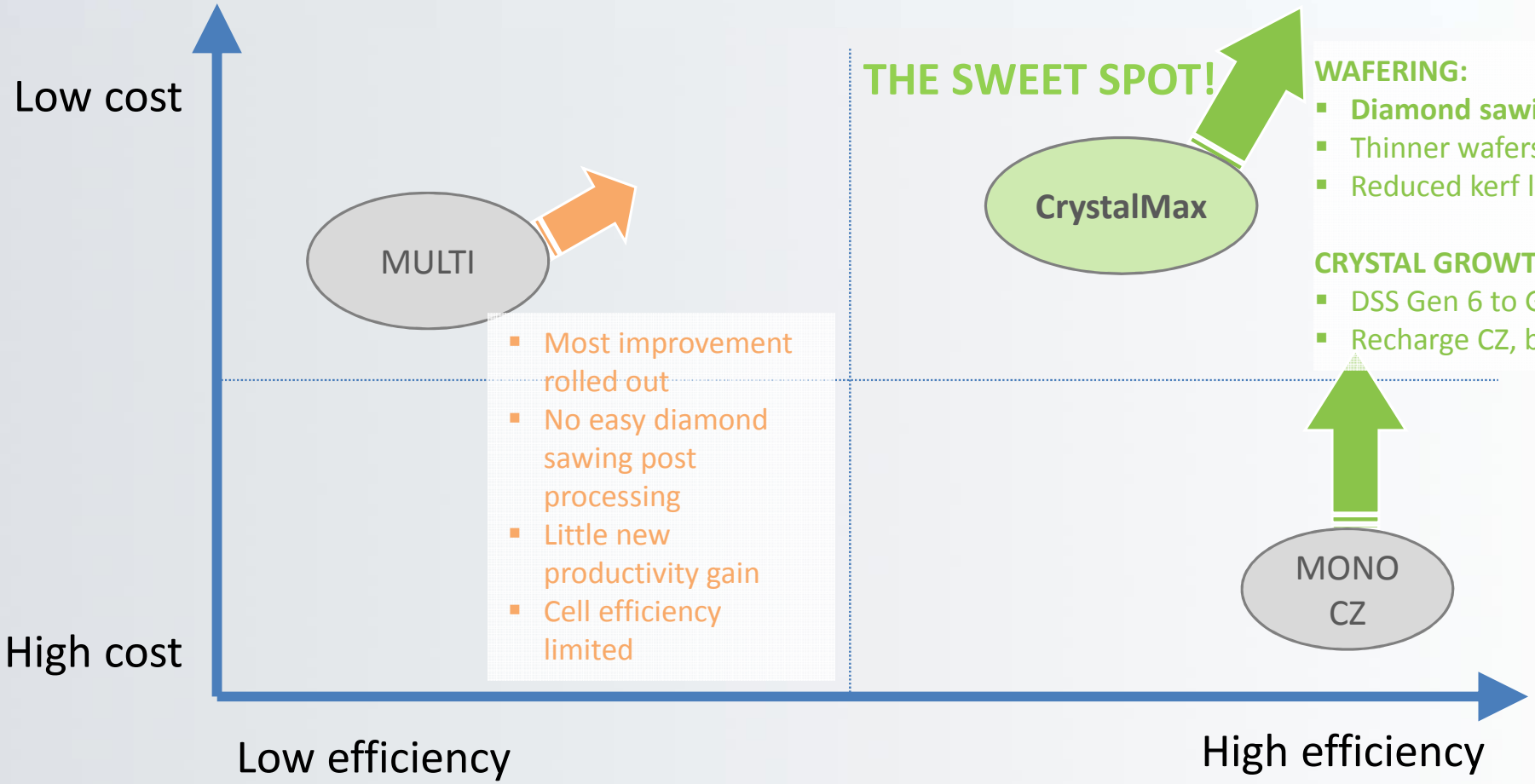

Multi current installed based stalling with slurry cutting = no to little cost improvement

Diamond wafering shows potential improvement for multi, yet not mature for mass production

Diamond wafering mature for mono ingot, being rolled out in the industry, but expensive crystallization cost

**CrystalMax** is mature for diamond wafering and has unmatchable low crystallization cost structure compared to Mono CZ

# Competitiveness mapping



# Why invest in CrystalMax ?

**ULTRA HIGH EFFICIENCY WAFER PROCESS:** Crystalmax *A technology backed up by CEA-INES*

- Mono full square wafers **cheaper than multi** with ECM furnace
- **High cell efficiency** (e.g. >20% average in PERC)
- **Diamond** wafering solution + KOH texture (reduced kerf, thinner wafers, no slurry)
- **Automatic** process, easy to integrate in a new fab
- Enabling production of **n type** mono wafers for **bifacial** application
- **Low CAPEX** and **safe** investment (Flexible and high productivity multi furnace)
- **Highly productive furnace** = savings on building requirement, utilities and manpower

# Our references in Photovoltaics…

# Thank you

**M. Benjamin DENEUX**
Sales Manager
+33 6 30 92 61 22
b.deneux@ecmtech.fr

ECM GREENTECH

Photovoltaic Division
109 rue Hilaire de Chardonnet
38100 Grenoble
France