



CrystalMax ingot of 650Kg – Intersolar 2015

CrystalMax

Advanced crystallization



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Benjamin Deneux | Sales Manager | Advanced crystallization | 21st of December 2016

CRYSTALMAX: Ultra High Performance

<100> oriented wafers at the cost of multicrystalline



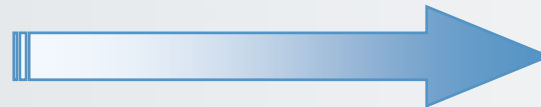
Traditional technologies:



Multicrystalline- 450Kg
Low cost
Average efficiency



Monocrystalline - 180Kg
High cost
High performance



INNOVATION ECM:



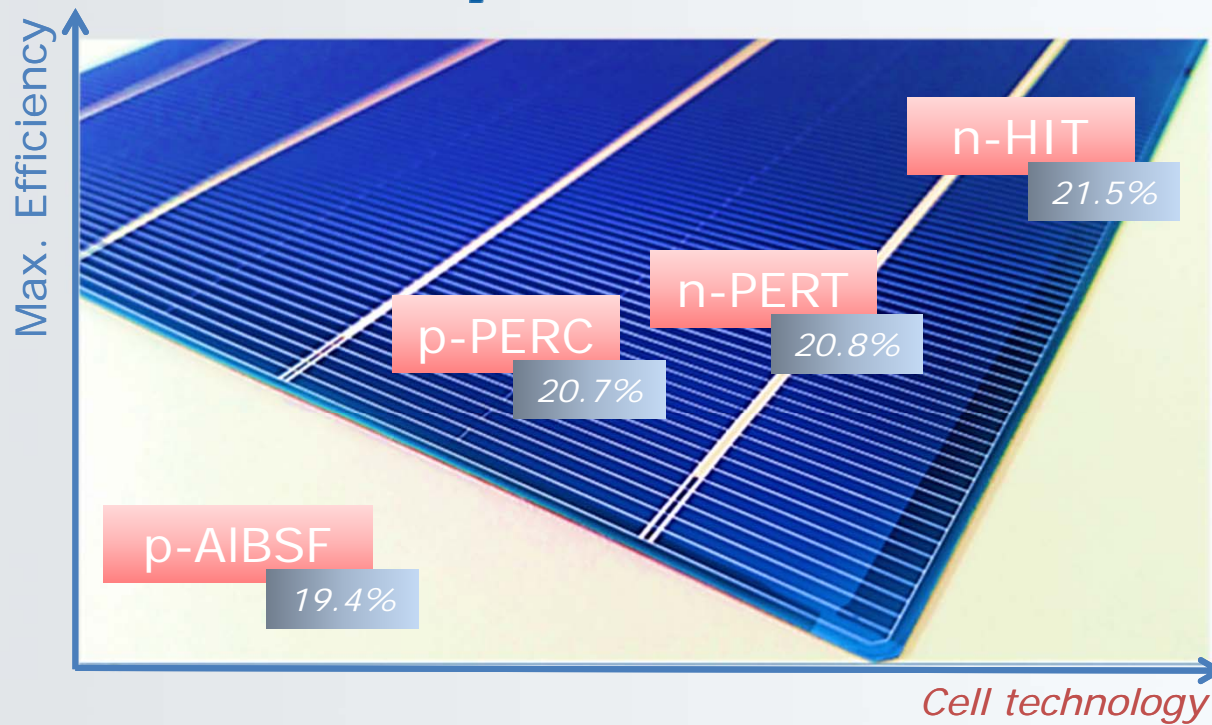
CrystalMax - 650Kg
Low cost
High performance



CrystalMax | Champion cells



Crystalmax



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

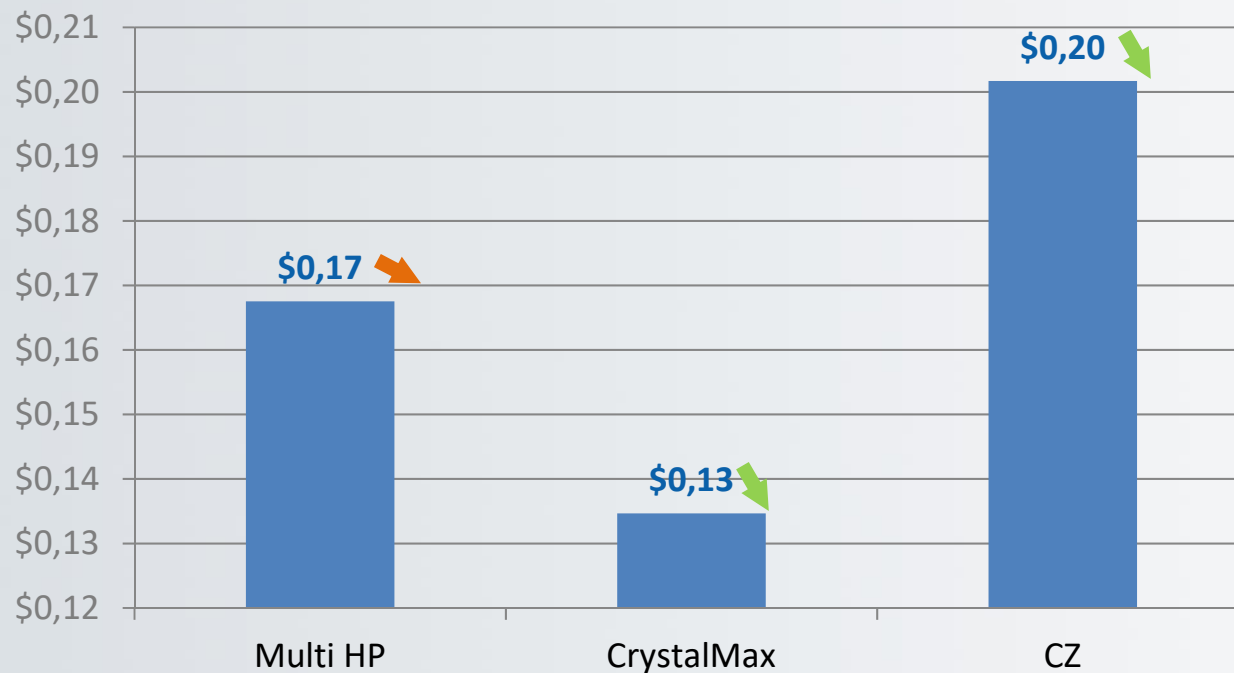
“CrystalMax wafers are **oriented <100>** which make it compatible with **alkaline etching**”

CrystalMax wafers are compatible with all high efficiency cell processes

CrystalMax Competitiveness per Wp



Manufacturing cost per Wp (PERC cells)



Mono & **CrystalMax** wafers have a clear path for cost reduction through diamond sawing, reduction of kerf loss, wafer thickness, etc.

Thanks to high cell efficiency and DS furnace productivity, **CrystalMax** is and will remain **more competitive** than CZ wafers.

Cost from ingot to brick



Basic assumptions for calculations:

Silicon cost = 15 USD/Kg

Electricity cost = 0,08 USD/kWh

- **CrystalMax** (Current technology status available to newcomers)

650Kg ingot Gen 6

79 hrs cycle time

- **Mono CZ** (Roadmap target, not available from start)

Advanced recharge CZ technology

2 pulls per crucible ; total charge weight 200Kg

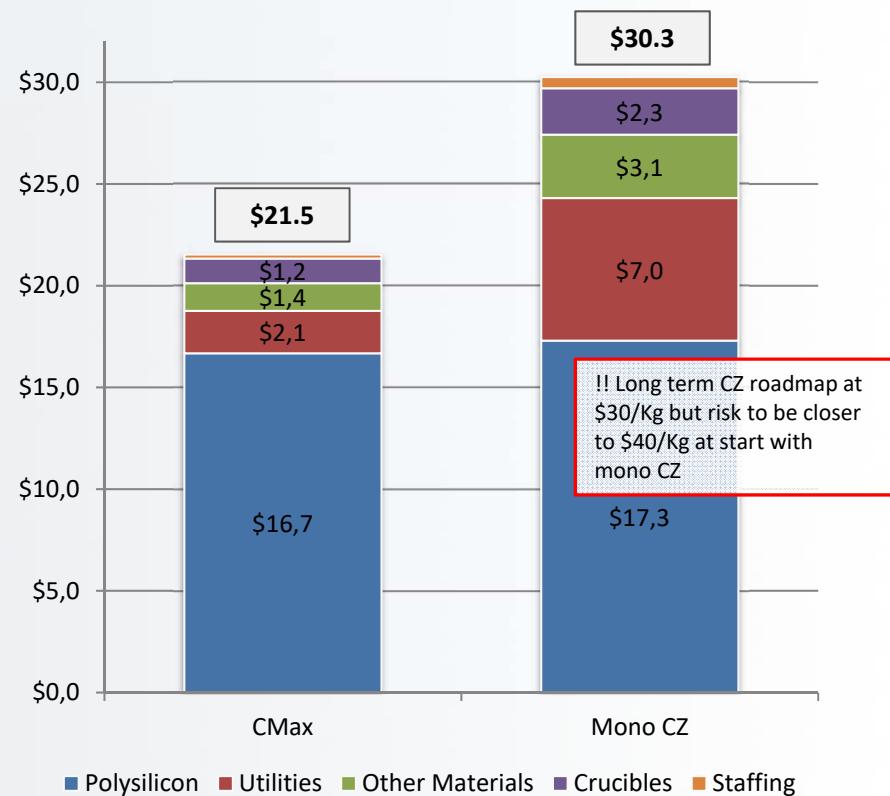
60 hrs cycle time per pull

Focus on electrical consumption:

	Cmax	Mono CZ
Consumption per cycle (kWh)	6,500	5,180
Kg of useful brick per cycle	414	153
Consumption per Kg (kWh)	16	34
Cost per Kg	1.3	2.7

Mono CZ crystallization method consumes **twice as much electricity** than what is required for **CrystalMax** !

Cost per Kg of useful brick (OPEX):



Total cost of ownership

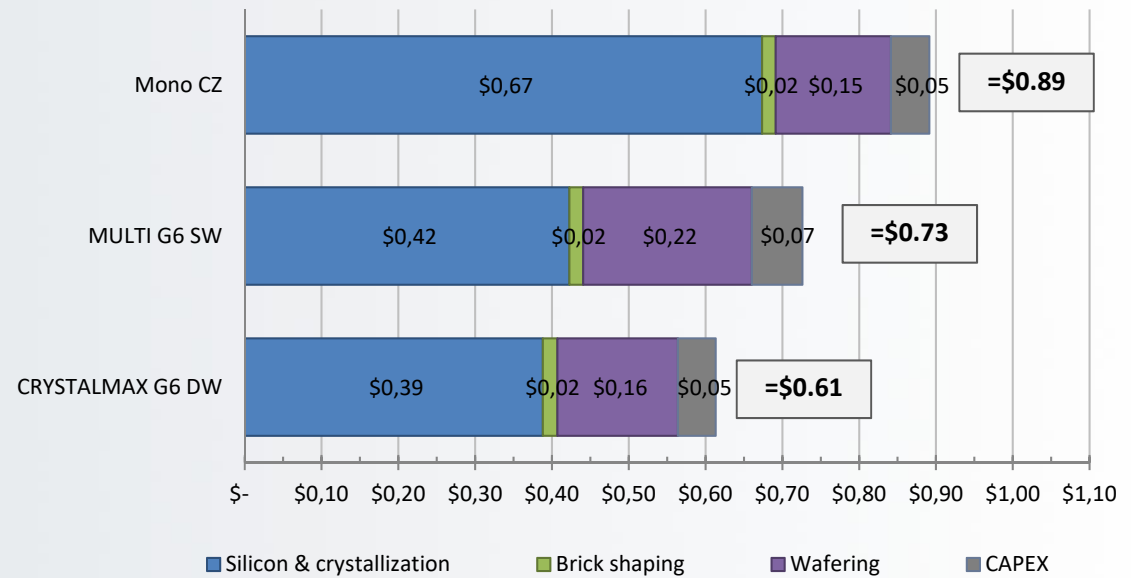


Mono CZ = \$0.89

CrystalMax wafers are about **-31%** cheaper to manufacture

CMax = \$0.61

TOTAL COST PER WAFER:



Assumptions: Si = \$15/Kg – Electricity = \$0,08/kWh – Depreciation 10 years – wafering pitch 280µm – RCZ technology 2 ingots per crucible

Extra surface = free energy !



Increasing wafer size standards:

From M0 to M2 (156 to 156.75mm)

For Mono CZ wafer size = + \$0,03/wafer

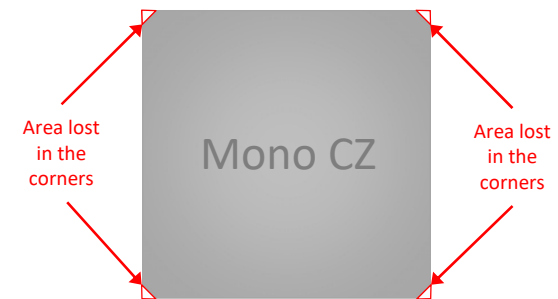
For CrystalMax = Free

Source: Longi March 16th 2016

Extra power from full square surface:

CrystalMax wafers benefits from **+1.8%** surface area to convert light into power.

It correspond to **+0,4%** in cell conversion rate !



Why invest in CrystalMax ?



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

- Mono full square wafers **cheaper than multi** with ECM furnace
- **Very 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)



Most current and future cost reductions for wafers are coming from the diamond wafering process which is only attractive on CrystalMax/mono ingot, not multi.

Our references in Photovoltaics...



Thank you



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