



Emerging Wafer Sizes in PV Manufacturing

Exploring the Impact and Challenges of Using Emerging Wafer Sizes in PV Manufacturing

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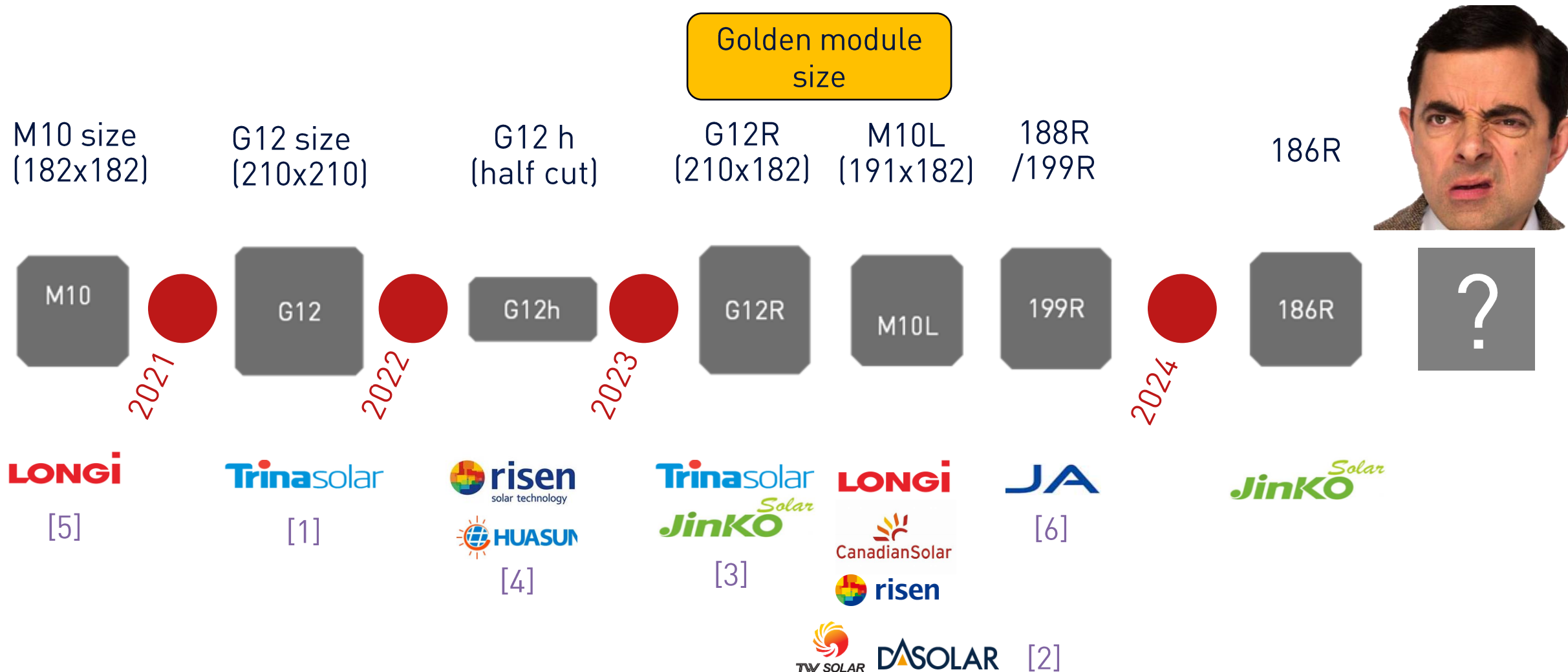
**TOPcon
Edition**



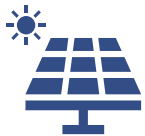
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Latest history of wafer sizes used in industry

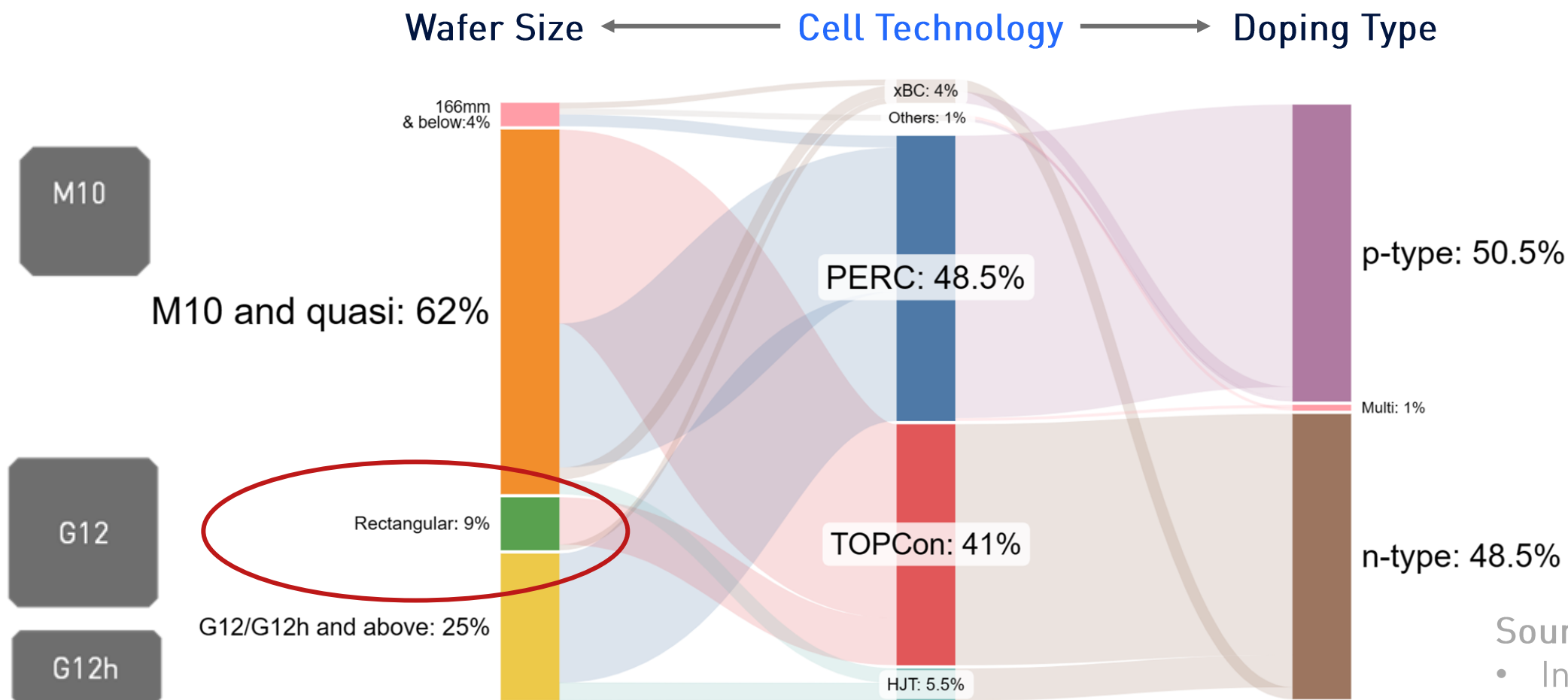


Content – wafer sizes for TOPCon modules



1. Market overview for n-type modules
 - a) Present data on the **current market share of various wafer sizes** and types in 2023.
 - b) Introduce the **top 5 manufacturers** and their **adoption of wafer/cell sizes**, with a focus on **n-type** modules.
2. Challenges in **manufacturing** for **different wafer sizes** from ingot to cell:
3. Factors affecting **module design**
4. Customer value analysis
 1. Methodology
 2. Results
5. Conclusion: **Impact of wafer sizes on TOPCon modules**

What is the status in wafer type & size in 2023?



→ Biggest streams are M10-PERC, G12-PERC and M10 TOPCon wafers

Source:

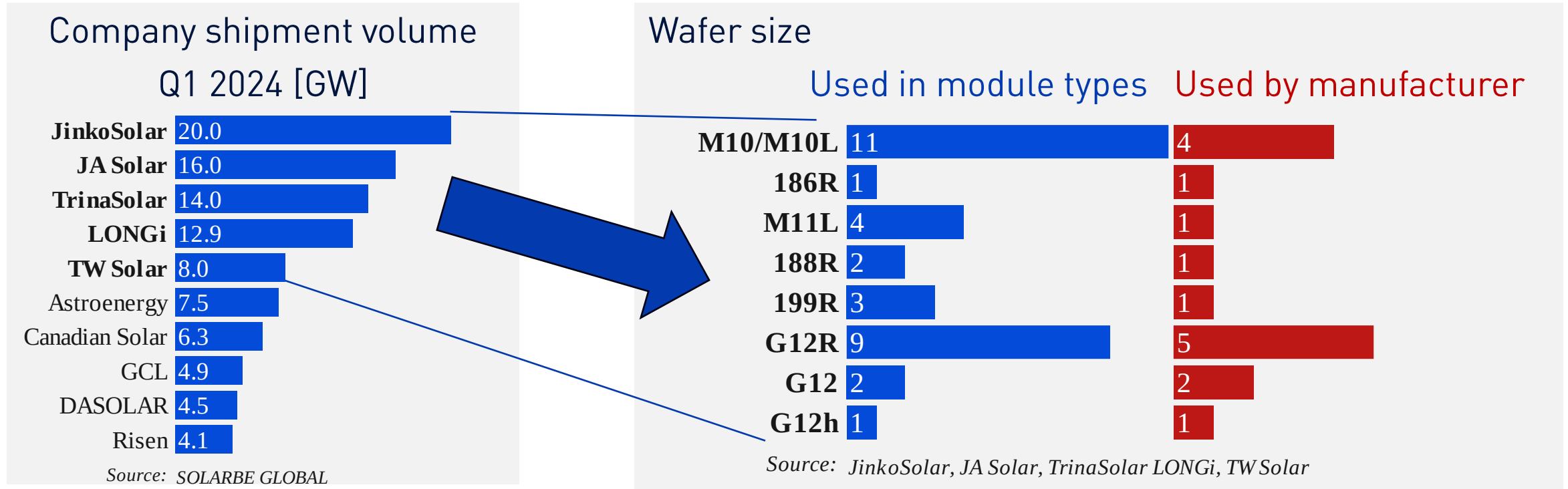
- Internal tracking
- PV Infolink [8]
- CPIA [9]

Wafer sizes share in 2023

Wafer Size	M10	M11-L	199-R	G12-R	G12h	G12 (210)
Dimensions	182 x 182*	182.2 x 191.6	182 x 199	182 x 210	210 x 105	210 x 210
Introduced	2020: LONGi [5]	2023 : LONGi, Risen, Canadian Solar, Tongwei, DAS, Astronergy [2]	2023: JA Solar [6]	2023: Trina, Jinko [3]	2022: Huasun / Risen [4]	2021: Trina [1]
Share 2023: ITRPV [7] Infolink [8] CPIA [9] RCT	64% 68% 68% 63%	2% Missing 10% 9%			Missing Missing Missing 5%	20% 27% 20% 20%
Used for Technology:	TOPCon / PERC / xBC	TOPCon / xBC	TOPCon / xBC	TOPCon / xBC	HJT	PERC / HTJ

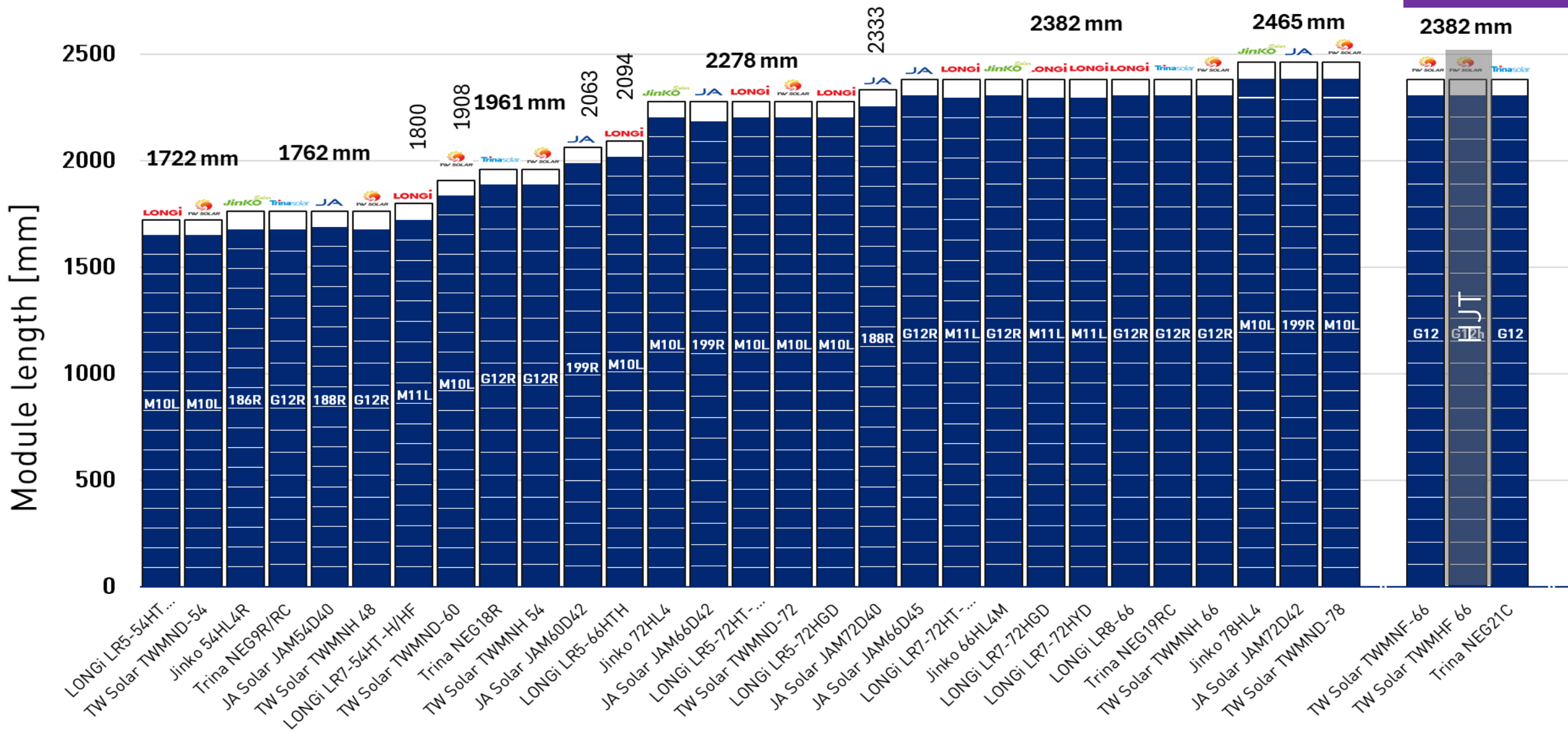
- M10 wafer size dominated the market with a share of ca. 63%-68% in 2023.
- G12 wafer size held a market share of about 20%-29% in the same year.
- Large G12 wafers are primarily used for PERC and HJT technologies.
- Half-cut wafers have become increasingly popular for HJT solar cells (5%).

Tracking TOP 5 module manufacturers **wafer/cells** for **n-type module** variants (August 2024)

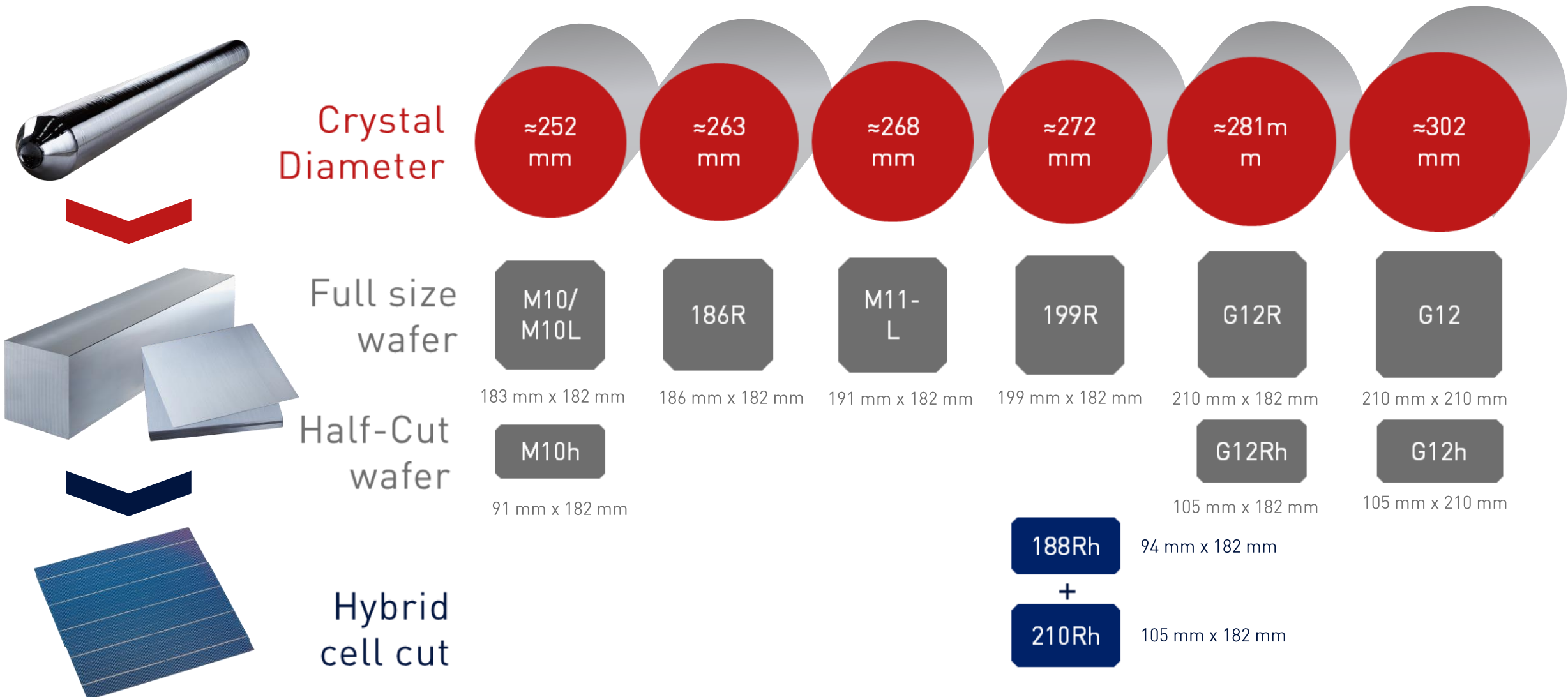


- The top five manufacturers using **8 distinct cell sizes**
- **M10** and **G12R** are the most used formats, appearing 11 and 9 times in products
- **G12R** is adopted by all the TOP 5 manufacturer
- 2-4 different wafer sizes per manufacturer

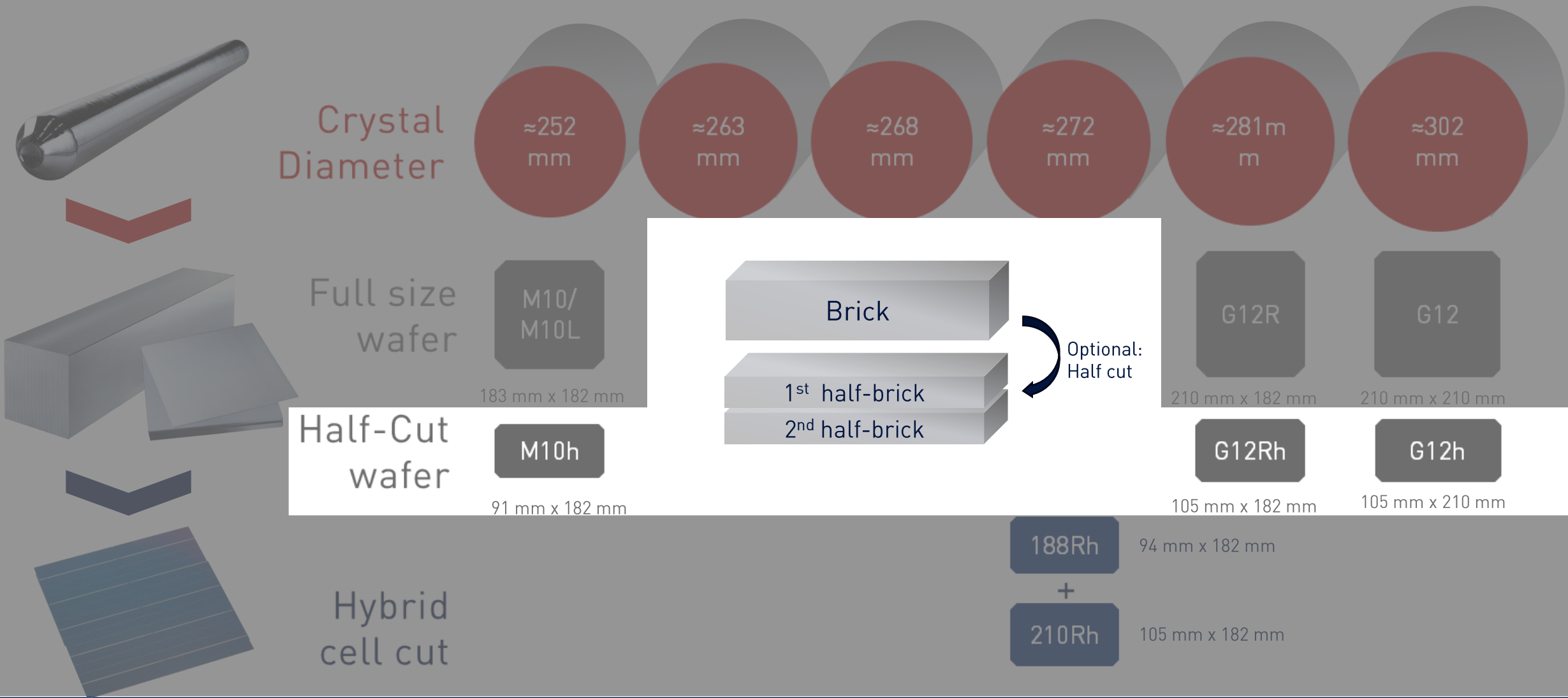
Most n-type modules are 1134 mm wide ↔ / length differing ⇅



Exploring the new wave of wafer/cell sizes



Exploring the new wave of wafer/cell sizes

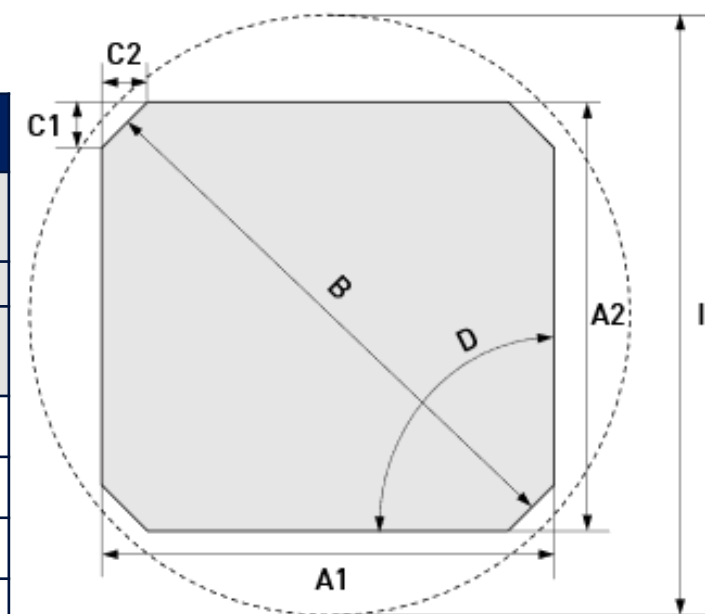


Solar wafer specifications – considered dimensions

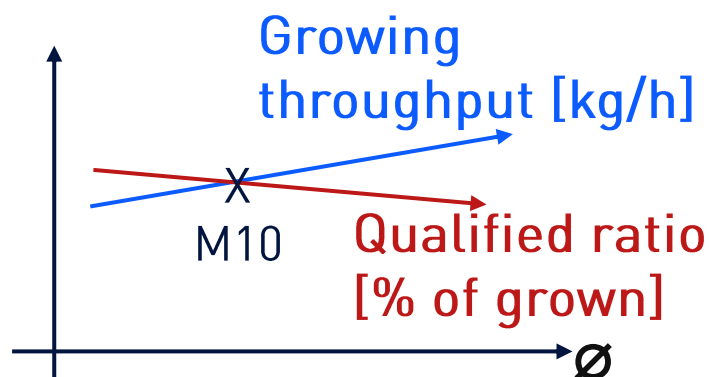
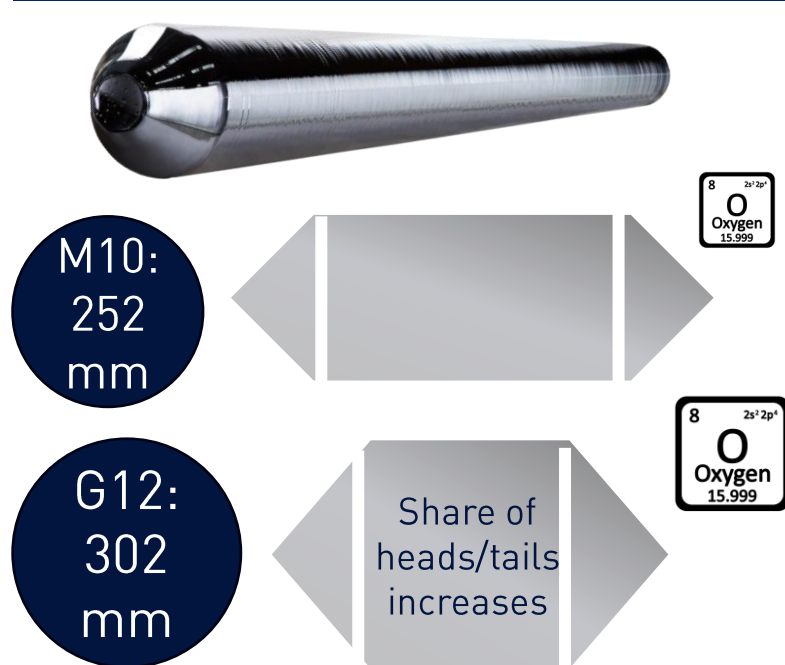
- Most common wafer size M10 (182 x 182 mm) with 63% in 2023
- Wafer size and thickness are selected based on the cell and module technology selected
- Exact sizes can differ according to each manufacturer's preference



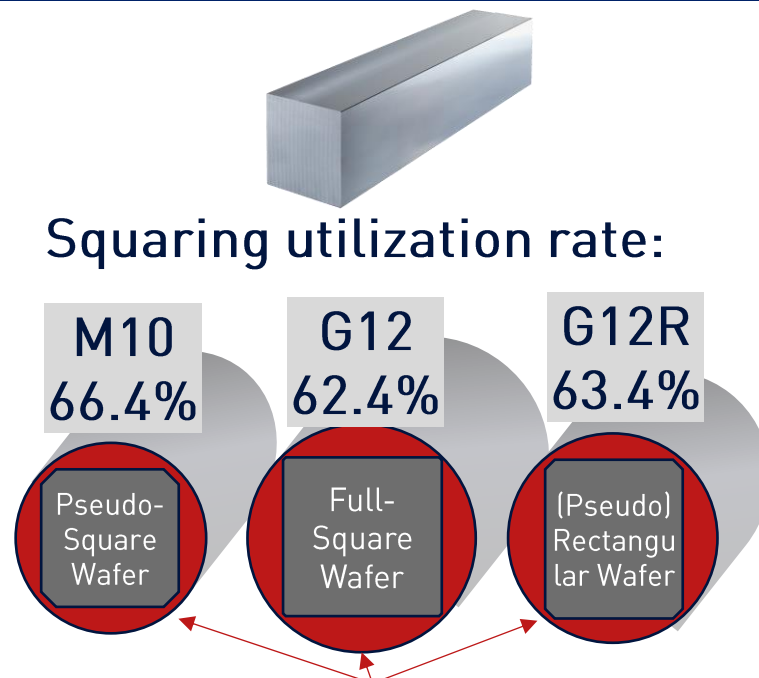
Wafer size	M10	M11-L	199-R	G12-R	G12h	G12 (210)	Tolerance
Introduced	2019/2020	2023			2022	2021	
Share 2023:	63%	9%			5%	20%	
Used for Cell Technology:	All	TOPCon / xBC	TOPCon / xBC	TOPCon / xBC	HJT	PERC / HJT	
Width (A1) [mm]	182.2	182.2	182.2	182.2	105.0	210.1	± 0.25 m
Height (A2) [mm]	182.2	191.6	199.0	210.0	210.1	210.1	± 0.25 m
Diagonal (B) [mm]	247.0	262.5	267	272.0	233.0	295.0	± 0.35 m
Area [mm^2]	≈ 330.8	≈ 349.0	≈ 362.5	≈ 382.2	≈ 220.4	≈ 440.9	N/A
Thickness (T)	110 - 150	120 - 140	120 - 140	110 - 130	100 - 130	130 - 150	± 8 - 10



Challenges in the ingot and wafer factory

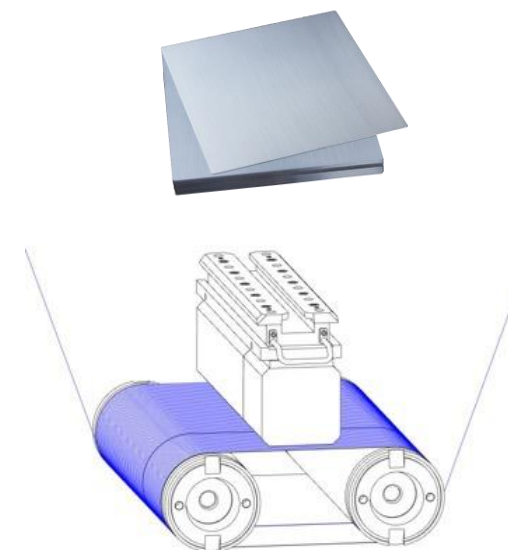


Squaring utilization rate:



Downside of recycling material

1. Energy and material were wasted for growing this part of the ingot
2. During recycling for reuse, losses occur



Slicing:

- Set-up time share to cutting time reduced if brick side length increases
- Feed rate increases, with shorter

Thermal tube processes, diffusion

- Bigger wafers needs to be spaced wider in boats
- Quartz tubes optimized for rather M10 or G12 diameter
- Impact on space, electricity and gas consumption

Wet chemical batch process:

- Due to capillary effects, bigger wafers needs to be spaced wider in cassettes

Single line inline processes:

- + Firing and printing line benefits from bigger wafers

Factors to consider to define a module

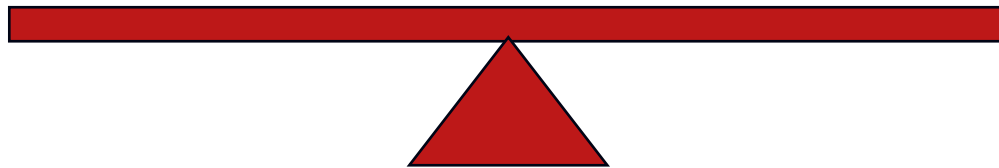
Module size/power:

Width of module usually fixed

- 1134/1303 mm due to inline manufacturing of glass

Height of the module:

- Resolves in **weight, mounting differences and shipping differences**
- Together with the package density and cell technology → module voltage and power is determined



Supply chain availability:

- Do I get the right wafer / cell sizes?
- Do I get the right module glasses?
- Do I get the right sized equipment?
- Is there a competing market for all these items?

→ Strategical portfolio decision required

Somehow the wafer sizes have adapted ←

Module efficiency [%]	Module heights used by TOP 5 Manufacturers									
	1722 x 1134	1762 x 1134	1800 x 1134	1961 x 1134	2063 x 1134	2094 x 1134	2278 x 1134	2333 x 1134	2382 x 1134	2465 x 1134
182	22.5%	22.0%	21.5%	21.9%	20.8%	22.6%	22.6%	22.1%	21.7%	22.7% M10
183	22.6%	22.1%	21.6%	22.0%	21.0%	22.7%	22.8%	22.2%	21.8%	22.8%
184	20.2%	22.2%	21.7%	22.2%	21.1%	20.8%	21.0%	22.4%	21.9%	21.2% M10L
185	20.3%	22.3%	21.8%	22.3%	21.2%	20.9%	21.1%	22.5%	22.0%	21.3%
186	20.4%	22.4%	22.0%	22.4%	21.3%	21.0%	21.2%	22.6%	22.1%	21.4%
187	20.5%	22.6%	22.1%	22.5%	21.4%	21.1%	21.3%	22.7%	22.3%	21.5%
188	20.6%	22.7%	22.2%	22.6%	21.5%	21.2%	21.4%	22.8%	22.4%	21.6% 188R
189	20.7%	20.3%	22.3%	22.8%	21.6%	21.3%	21.6%	21.0%	22.5%	21.7%
190	20.8%	20.4%	22.4%	20.6%	21.8%	21.4%	21.7%	21.2%	22.6%	21.8%
191	21.0%	20.5%	22.6%	20.7%	21.9%	21.5%	21.8%	21.3%	22.7%	22.0% M11L
192	21.1%	20.6%	22.7%	20.8%	22.0%	21.7%	21.9%	21.4%	22.8%	22.1%
193	21.2%	20.7%	20.3%	20.9%	22.1%	21.8%	22.0%	21.5%	21.1%	22.2%
194	21.3%	20.8%	20.4%	21.0%	22.2%	21.9%	22.1%	21.6%	21.2%	22.3%
195	21.4%	20.9%	20.5%	21.1%	22.3%	22.0%	22.2%	21.7%	21.3%	22.4%
196	21.5%	21.0%	20.6%	21.2%	22.4%	22.1%	22.4%	21.8%	21.4%	22.5%
197	21.6%	21.1%	20.7%	21.4%	22.6%	22.2%	22.5%	21.9%	21.5%	22.7%
198	21.7%	21.2%	20.8%	21.5%	22.7%	22.3%	22.6%	22.0%	21.6%	22.8%
199	21.8%	21.3%	20.9%	21.6%	22.8%	22.4%	22.7%	22.2%	21.7%	22.9% 199R
200	21.9%	21.4%	21.0%	21.7%	20.6%	22.6%	22.8%	22.3%	21.8%	21.1%
201	22.1%	21.6%	21.1%	21.8%	20.7%	22.7%	20.8%	22.4%	21.9%	21.2%
202	22.2%	21.7%	21.2%	21.9%	20.8%	22.8%	20.9%	22.5%	22.0%	21.3%
203	22.3%	21.8%	21.3%	22.0%	20.9%	20.6%	21.0%	22.6%	22.1%	21.4%
204	22.4%	21.9%	21.4%	22.1%	21.0%	20.7%	21.2%	22.7%	22.3%	21.5%
205	22.5%	22.0%	21.5%	22.2%	21.1%	20.8%	21.3%	22.8%	22.4%	21.6%
206	22.6%	22.1%	21.6%	22.3%	21.2%	20.9%	21.4%	20.9%	22.5%	21.7%
207	19.9%	22.2%	21.7%	22.4%	21.3%	21.0%	21.5%	21.0%	22.6%	21.8%
208	20.0%	22.3%	21.8%	22.5%	21.4%	21.1%	21.6%	21.1%	22.7%	21.9%
209	20.1%	22.4%	21.9%	22.7%	21.5%	21.2%	21.7%	21.2%	22.8%	22.0%
210	20.2%	22.5%	22.0%	22.8%	21.6%	21.3%	21.8%	21.3%	22.9%	22.1% G12R

Factors after shipping and other BOS cost

40ft container Capacity [kW]		Module dimensions used by TOP 5 Manufacturers [mm]										
		1722 x 1134	1762 x 1134	1800 x 1134	1961 x 1134	2063 x 1134	2094 x 1134	2278 x 1134	2333 x 1134	2382 x 1134	2465 x 1134	2382 x1303
Wafer Size	M10L	408					421	418			362	
	186R		416									
	M11L			394						438		
	188R		419						429			
	199R					417		417			364	
	G12R		415		431					439		
	G12											456
	G12h											456

1303 mm width
(35 mm frame→ 416 kW)

0.7236 Voc - 72.44 mA/cm² - 83.15% FF - 24.5% Efficiency - CTM 98.7%

All modules considered with 30 mm frame

- The right module voltage is key, to optimize the usage of the Inverter
- Higher module efficiency results in more effective use of area
- Longer modules with longer strings show higher voltage, resulting in less ohmic losses

Assessing customer value variations due to wafer size differences.

The **Customer Lifetime Value (CLV)** - estimate the total net profit a business can expect from a customer over the duration of their relationship:

$$CLV = \sum \left(\frac{\text{Revenue per period} - \text{Cost per period}}{(1 + \text{Discount rate})^{\text{period}}} \right)$$

Simplified approach used:

$$\text{Customer Value} = \text{Total Customer Benefits} - \text{Total Customer Costs}$$

Sufficient if **no time-dependent factors** required for the comparison, e.g.:

- Rental costs for land
- Differences in degradation
- Performance under high-temperature
- Performance under low light

Assessing customer value variations due to wafer size differences.

Value chain step	Differences by wafer Sizes investigated	Potential positive impact of change	Total customer cost
Polysilicon	Differences in polysilicon consumption	OPEX reduction	$\Delta \text{ Customer cost} = \Delta \frac{\text{Module cost}}{\text{power output}}$
N-type ingot	Differences in qualified throughput	Reduced OPEX + CAPEX	
N-Type wafer	Differences in qualified throughput	Reduced OPEX + CAPEX	
TOPCon cell	Higher power output per cell	Enhanced power output	
TOPCon module	Changes in packaging density	Enhanced power output	

Module is sold

Value chain step	Differences by wafer sizes investigated	Impact of change	Total customer benefits
Distribution	Container package density	Reduced transportation costs	$\Delta \text{ Customer benefits} = \Delta \frac{\text{BOS cost}}{\text{power output}}$
Module installation	Change in module efficiency	Reduction of area-related BOS cost	
Inverter installation	Optimized module voltage	Reduction of inverter cost	

Module is operating

Power generation	Change in module efficiency	Reduction of area related running cost	Customer benefits differences
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Assessing customer value variations due to wafer size differences.

COO [$\Delta\%$] of BOS		Module Sizes used by TOP 5 Manufacturers [mm]										
		1134 x 1722	1134 x 1762	1134 x 1800	1134 x 1961	1134 x 2063	1134 x 2094	1134 x 2278	1134 x 2333	1134 x 2382	1134 x 2465	1303 x 2382
Wafer Size	M10L	1.4%					0.3%	0.0%			1.1%	
	186R		1.4%									
	M11L			1.5%						-0.5%		
	188R		1.0%						-0.4%			
	199R					-0.1%		-0.1%				
	G12R		0.9%		0.5%					-1.2%		
	G12											-2.4%
	G12h											-1.5%

1. COO differences shown here depends more on module- than on wafer size ($\rightarrow$ equipment and module design more efficient for larger modules, known fact)
2. Rectangular wafers reduce the cost especially in larger scale modules, which is the most important market for the producers
3. Only slight improvement for going to bigger + rectangular in the smaller sized modules
4. Going for G12 and larger would be beneficial, but the wafers are currently not fitting into the standard glass sizes
5. Producing half-wafers will start benefiting, if the wafer thickness can be reduced in advance (here similar with 130 μm)! and the cell production equipment is adapted

Recommendation:

- As the cost difference is small, we recommend to **follow the market** and take a solution with a diverse Supply chain.
- We highly recommend emerging markets to **achieve standardization**.
 - ➔ This will **reduce conversion cost and productivity loss**
due to production line changeover caused by different products
- Still, we need to **investigate each individual case**:
 - Which **steps on the value chain** we are considering (Ingot, Wafer, Cell or/and Module)
 - Where we source the **feedstock and materials**?
 - Who will be our **final customer**?
 - What will be the **cell technology**?

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