SUPERIOR FIRING STABILITY, SUPERIOR CELL PERFORMANCE

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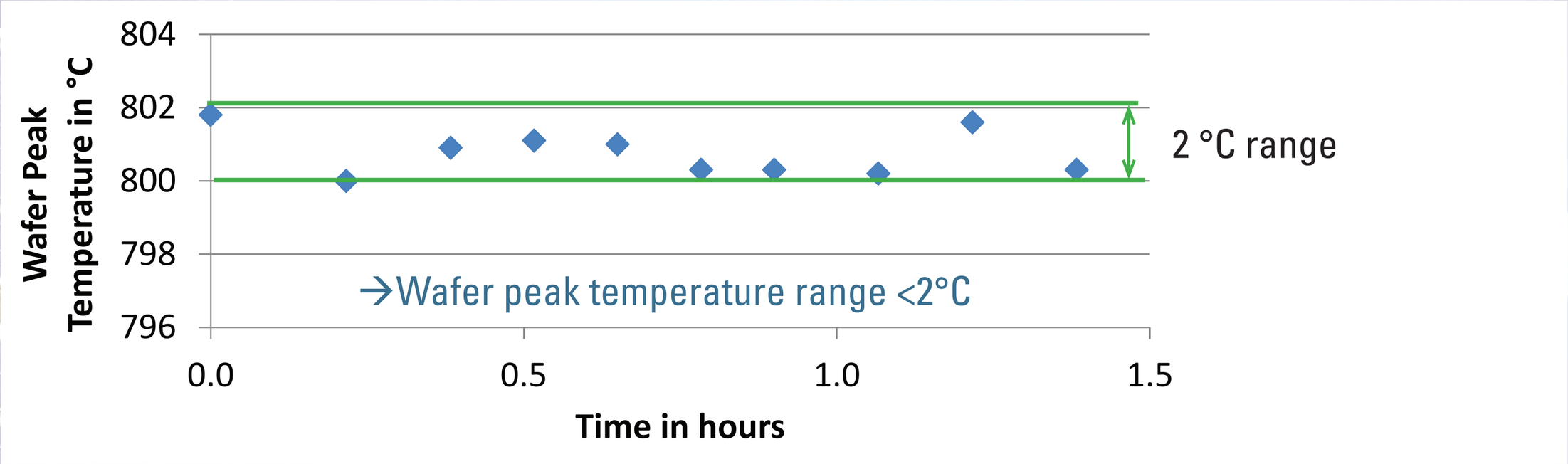
Introduction

Co-firing is the last process step in making a solar cell. It is also one of the most critical as it is the step that determines the final cell-metrics and is the step at which the cost impact of scrap cells is the greatest. The most significant parameter of co-firing is the wafer peak temperature. 'Peak Temperature Repeatability' was the single most important design criteria for building a new firing furnace (Model: Safire). The data below illustrates the stability of this newly developed firing furnace and the impact on cell performance. Building upon stability, Safire has several unique firing features that can further enhance cell performance.

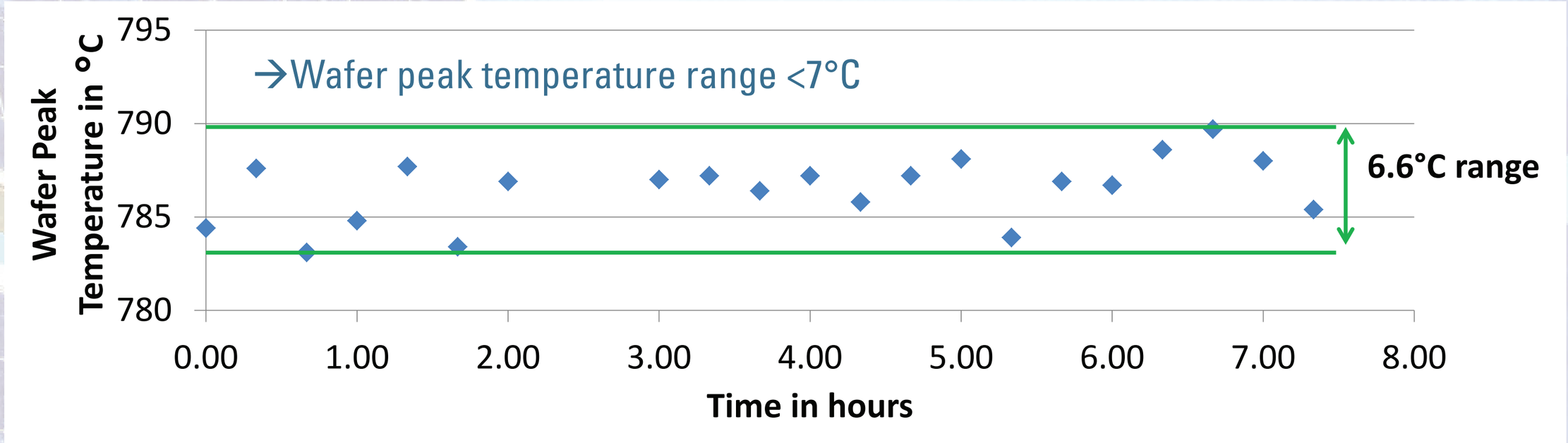
Furnace Stability

The graph below shows Safire's unparalleled peak temperature repeatability. In an unloaded condition the peak temperature range (measured directly on the cell) is less than 2°C. Peak temperature repeatability in an unloaded furnace is an important metric but much more critical is the peak temperature stability in a loaded furnace. The second graph shows peak temperature repeatability of Safire while running high-volume production. Even during a typical production shift with interruptions in loading, the peak temperature range is less than 7°C.

Unloaded Furnace



Loaded Furnace

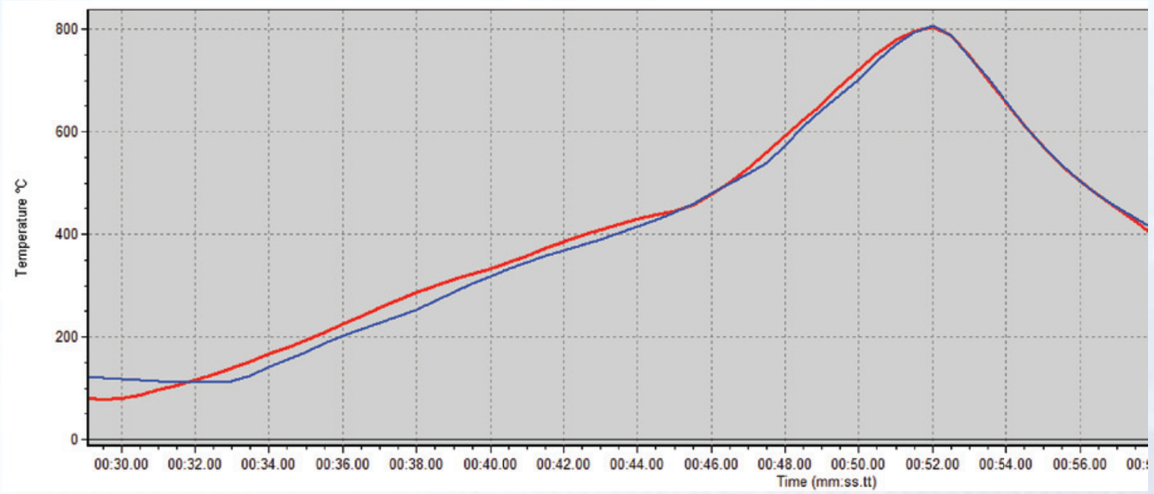


Measurements were taken every 30min while furnace was in full production.
Close to 10,000 cells were produced while this data was collected.

Cell Efficiency

At a cell manufacturer the impact of peak temperature repeatability on cell performance was investigated.

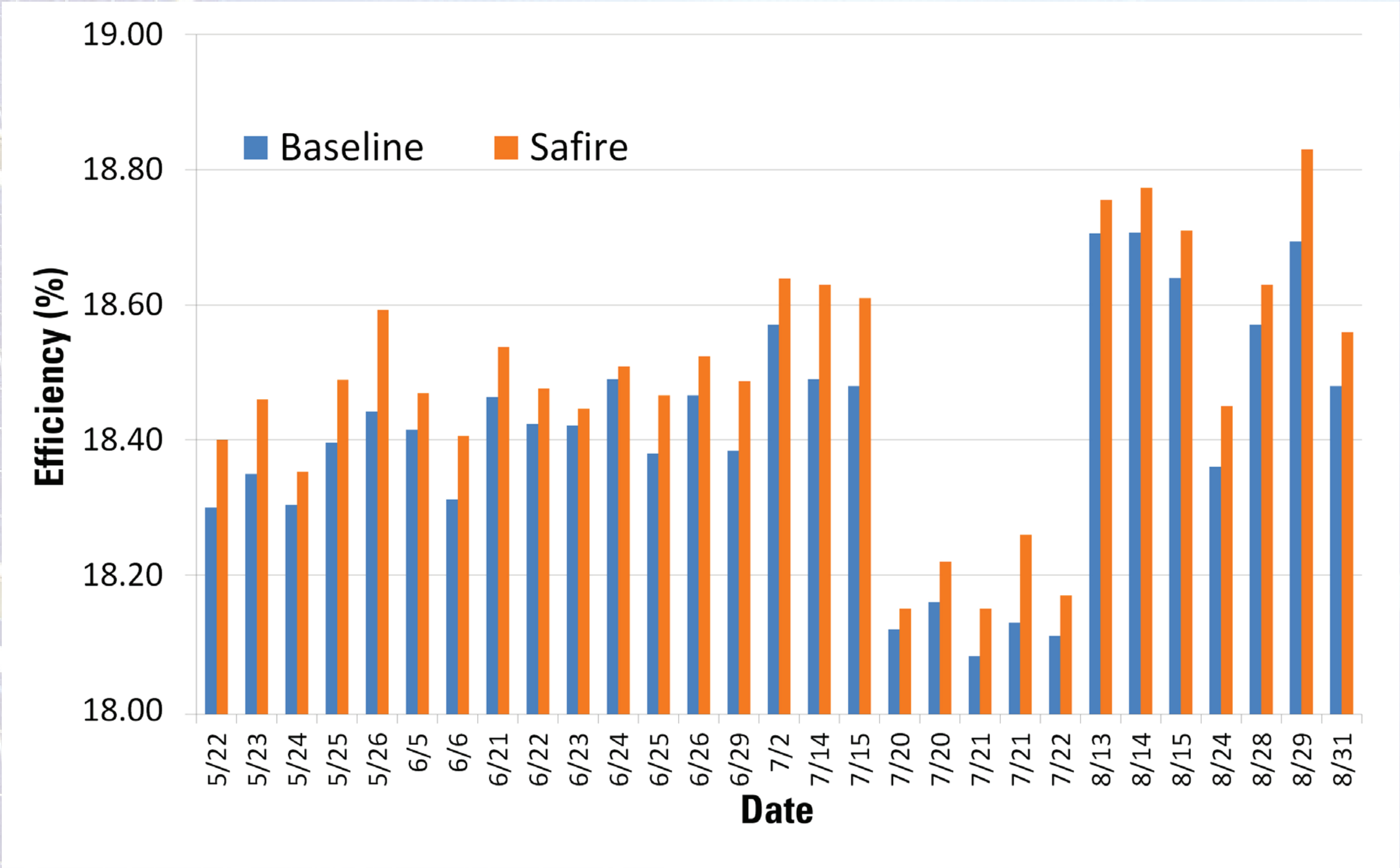
In order to analyze the influence of furnace stability on cell performance the thermal profiles of Safire and traditional firing furnace were set to be as close to each other as possible (see graph on right).



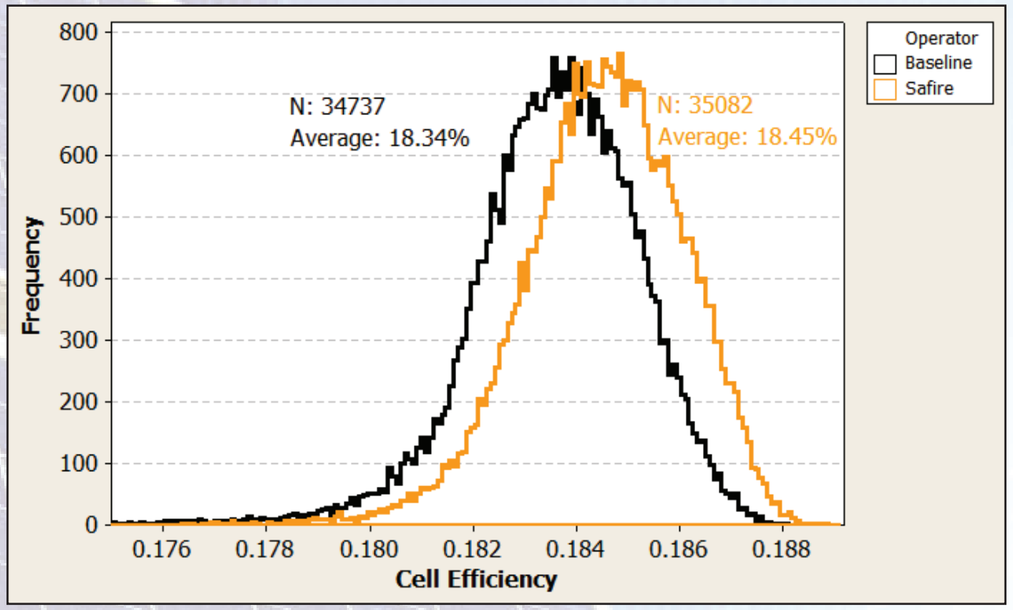
500,000 cells of various types were analyzed over a 3 month production period. Safire demonstrated an average efficiency benefit of 0.1% abs over baseline and up to 0.13% abs on some product types.

Safire achieved a higher cell efficiency EVERY day.

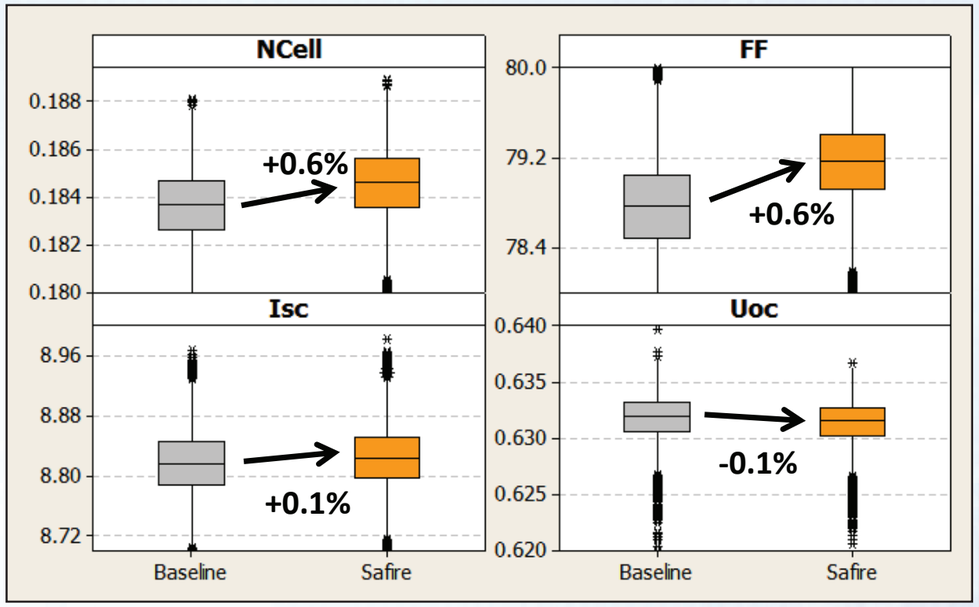
Efficiency of Safire vs Baseline



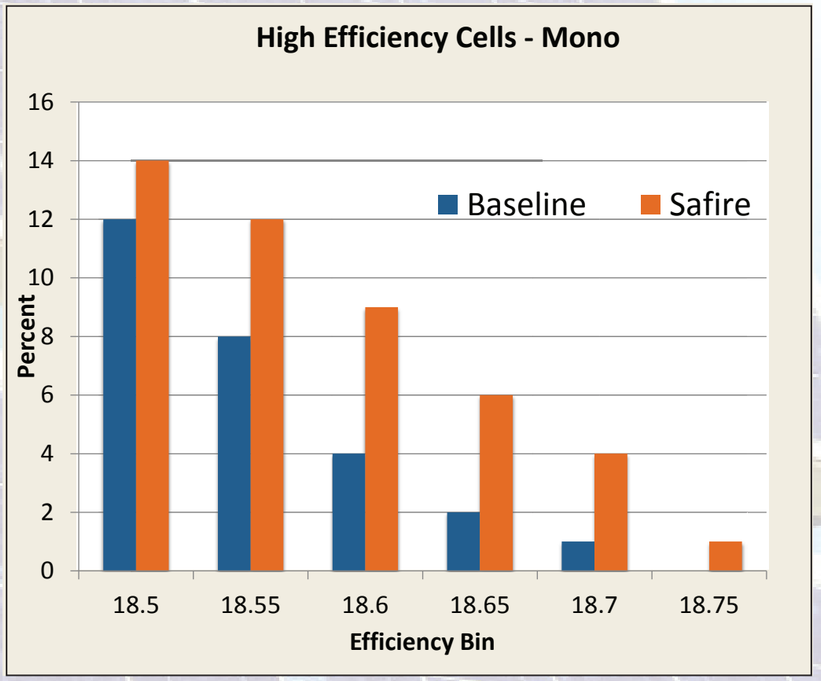
Cell Efficiency Detail from One Day (5/23)



→0.11% absolute efficiency improvement



→Efficiency improvement driven by Fill Factor



→21% more high efficiency cells

In order to gain a deeper understanding of the improvement, the data from one production day was investigated in more detail. The shift in efficiency distribution can have a large impact on profitability.

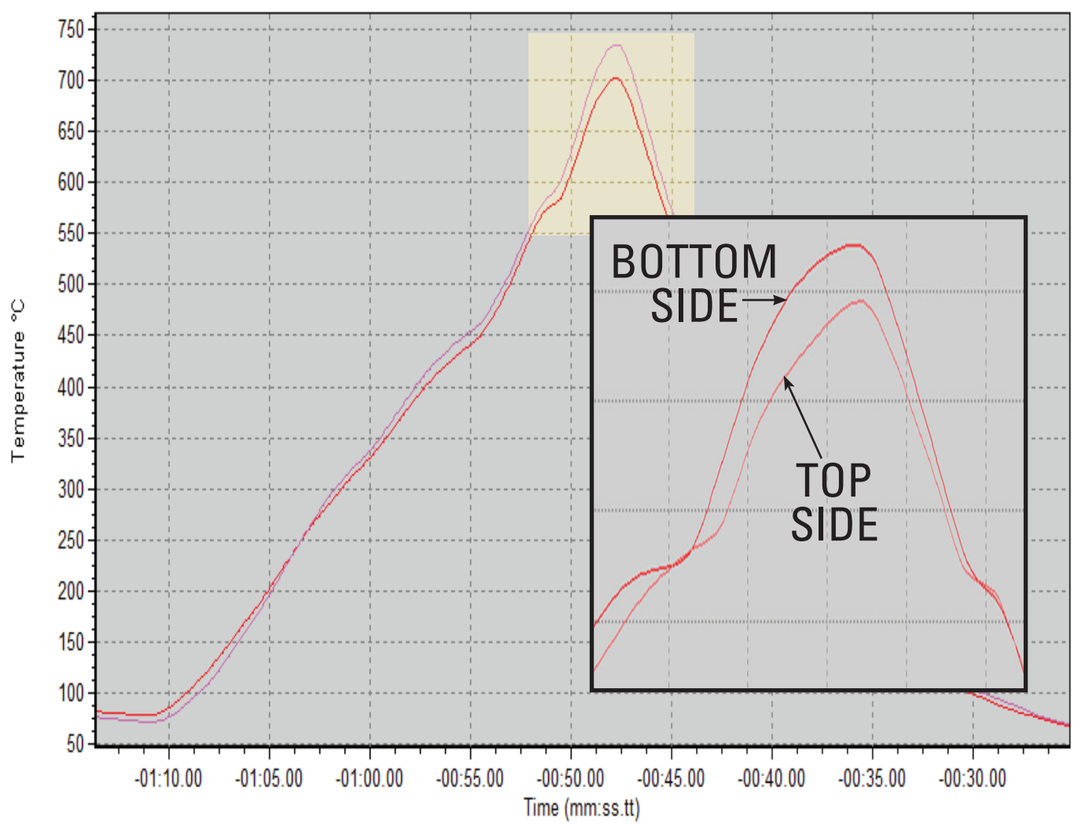
21% more high efficiency cells resulted in considerably less low efficiency cells and 0.57% abs fewer scrap cells.

$0.03 more per wafer =
>$600,000 per year per Safire

Advanced Firing Features

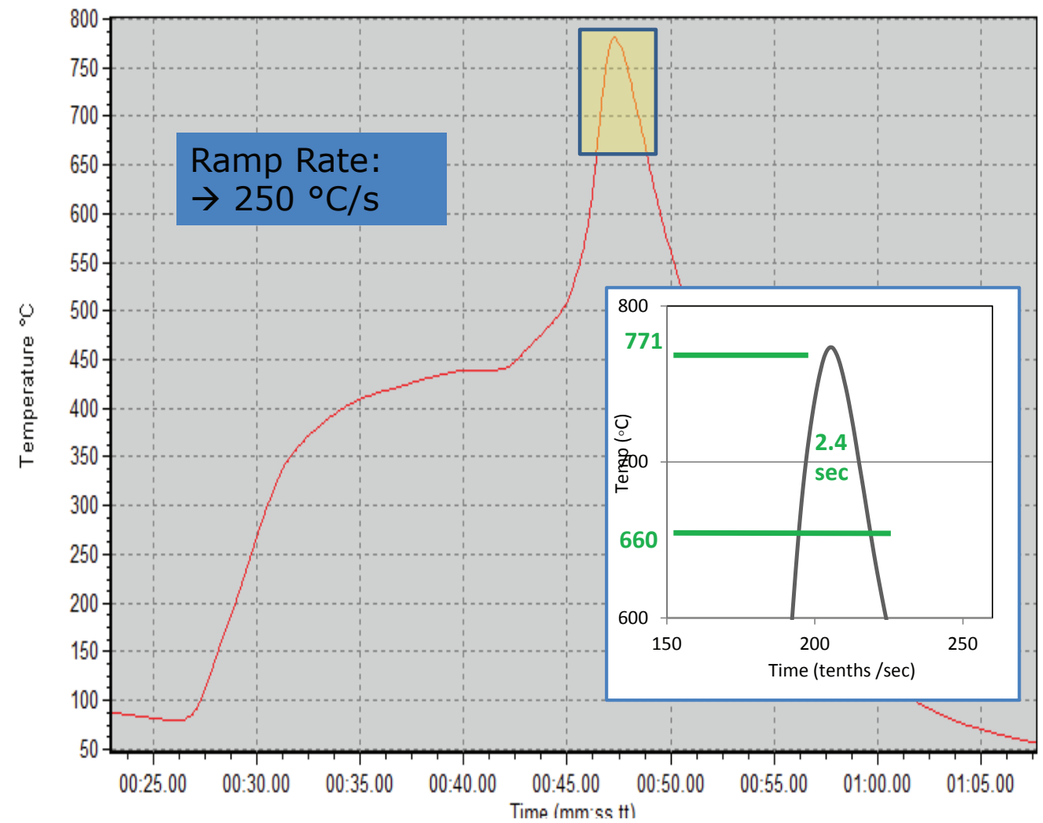
Building upon this stable firing platform the advanced firing features of Safire can be utilized to increase the efficiency further. These features can improve the efficiency of standard cells but are especially advantageous for advanced cell architectures like selective emitter, PERC or MWT cells.

Solectfire



→Top and bottom side of cell can be fired at different temperatures

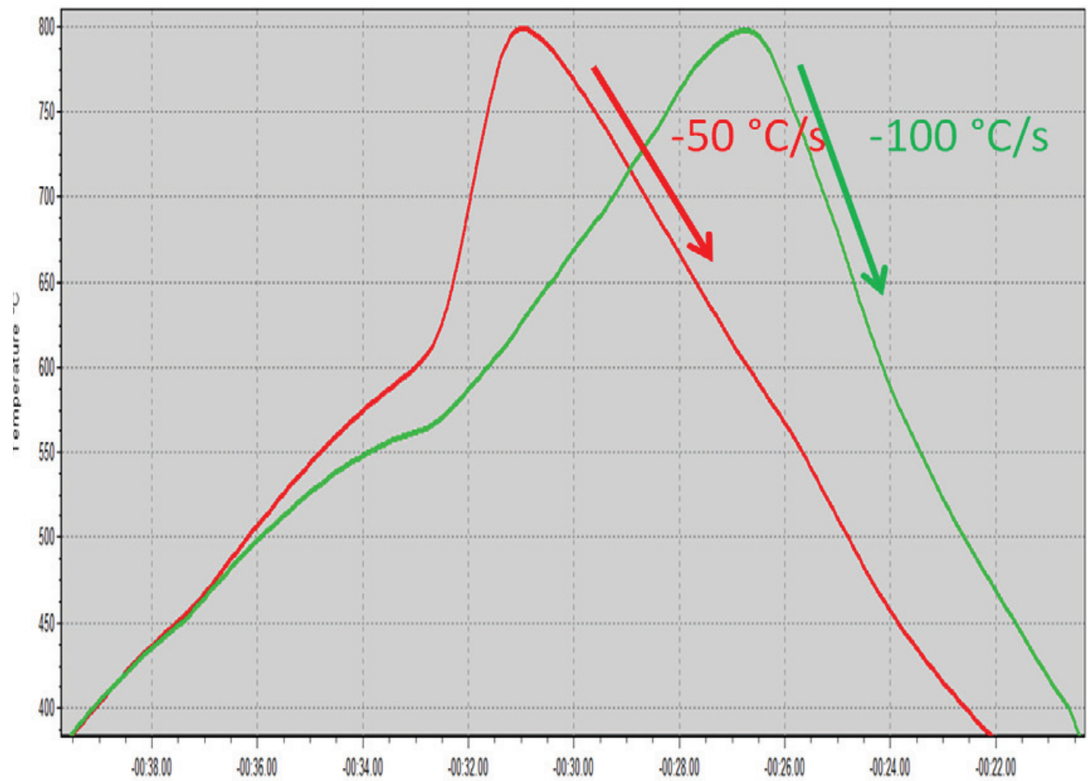
Fast Firing



→Fast firing feature enables high ramp rates and short times above 660°C

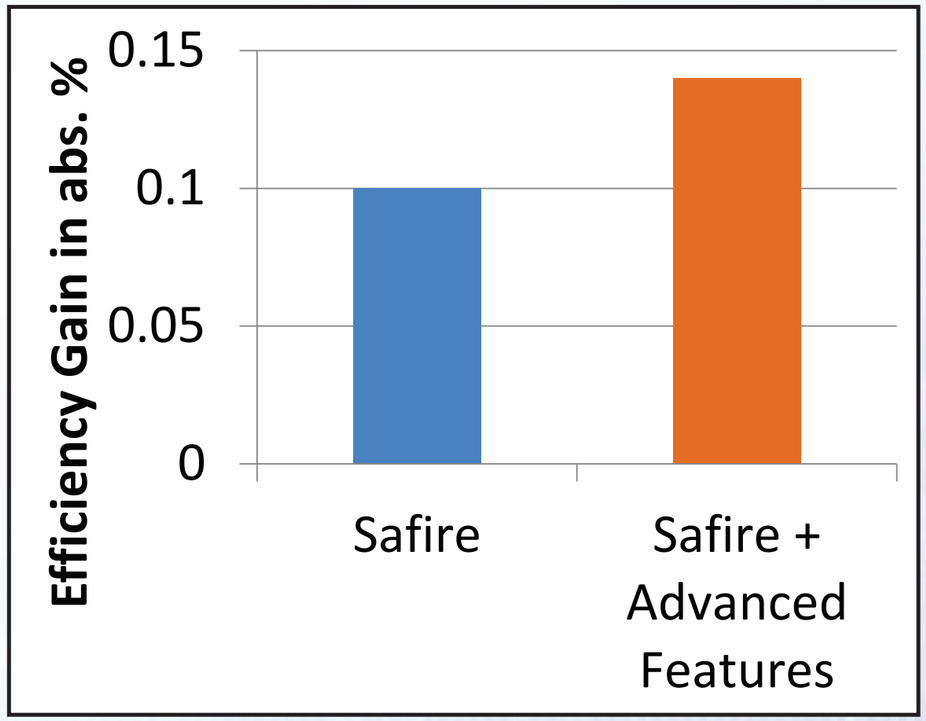
Advanced firing features continued

Tunable Cooling Rate



→Without changing belt speed or peak temperature the cooling rate can be varied between -50 °C/s and -100 °C/s which can be especially beneficial for wafer bow control

Advanced Firing Features Impact Cell Efficiency (Selective Emitter Cells)



→Results at high volume manufacturer showed an efficiency gain of 0.14% abs. for selective emitter cells with advanced firing features

Conclusions

High-volume production data have shown that the newly developed Safire co-firing furnace exhibits unparalleled peak temperature stability under real-world high-volume production conditions. This stability leads to an efficiency improvement of 0.1% abs. when averaged over three months and 0.5 million cells. Advanced firing features such as Solectfire, Fast Firing or Tunable Cooling Rate have the ability to further increase this efficiency gain. High volume production data has shown a 0.14% abs. efficiency gain by using advanced firing features on selective emitter cells. It is expected that especially new cell architectures like PERC or Metal-Wrap-Through will benefit from these firing capabilities.