Webinar powered by DSM Advanced Solar

24 September 2020
4 pm – 5 pm | CEST, Berlin
3 pm – 4 pm | BST, London
7 am – 8 am | PDT, Los Angeles
10 am – 11 am | EDT, New York

Back-contact’s move to the front

Mark Hutchins
Editor | pv magazine

Hugo Schoot
DSM Advanced Solar

Paolo Maccario
Silfab Solar

Radovan Kopecek
ISC Konstanz
Back-contact’s move to the front

9/24/20 PV Magazine Webinar

Paolo Maccarlo
1) Who is Silfab
2) Why back-contact (the product)
3) Why back-contact (the process)
4) The results
Who is Silfab Solar Inc.

• Silfab is a leading North American manufacturer of solar modules with over 35+ years of global experience in the PV industry.

• Silfab is consistently one of the top 3 quoted residential brands* in the USA and sells to at least 10 of the top 15 residential solar installers and top distributors in US, Canada and Mexico.

*EnergySage
### Timeline/Milestones

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>Monocrystalline Cell Production</td>
</tr>
<tr>
<td>1986</td>
<td>Delphos PV Solar farm still producing 80% output after 30+ years</td>
</tr>
<tr>
<td>1999</td>
<td>SOLARIS</td>
</tr>
<tr>
<td>2000's</td>
<td>Helios technology enters the Kerself Group listed on Milan Stock exchange</td>
</tr>
<tr>
<td>2004</td>
<td>Silfab SPA $110M USD JV</td>
</tr>
<tr>
<td>2007</td>
<td>Silfab Ontario, fully-automated PV manufacturer opens with 60 MW capacity</td>
</tr>
<tr>
<td>2008</td>
<td>Equity Partnership</td>
</tr>
<tr>
<td>2010</td>
<td>Silfab delivers solar modules for Nike Headquarters</td>
</tr>
<tr>
<td>2011</td>
<td>30 years experience Toronto facility expands to 90MW</td>
</tr>
<tr>
<td>2013</td>
<td>114 MW / year capacity reached Purchased ATS / Photovolt equipment</td>
</tr>
<tr>
<td>2014</td>
<td>Supplies 5 solar farms totaling over 65MW Delivery of largest rooftop portfolio in Canada (18.1 MW) Return rate below 40 parts per million (PPM) Name change to Silfab Solar and launching into the US Market Purchased Flextronics Canada solar production line</td>
</tr>
<tr>
<td>2015</td>
<td>First Bifacial module 180 MW / year capacity reached Silfab achieves AVL financing approval by SunSage Financial, Mosaic, Sunnova, and Hanwha Solar Silfab co-develops and produces first Lumos GSX modules for carports</td>
</tr>
<tr>
<td>2016</td>
<td>Exporter of the year award EDC Silfab Bifacial installed on largest US rooftop project 16.9 MW 95% export volumes achieved Silfab delivers solar modules for Nike Headquarters</td>
</tr>
<tr>
<td>2017</td>
<td>350 MW / year capacity Silfab receives OSEA manufacturer of the year award Silfab is recognized as #6 quoted solar brand in US by energySage Silfab achieves AVL approval by Sun Run</td>
</tr>
<tr>
<td>2018</td>
<td>Winner of Bronze Stevie® Award for Large Manufacturer / American Business Awards Silfab COO, Paolo Maccario &amp; Franco Traverso, awarded for environmental leadership by ICCO Silfab supplies modules to Puerto Rico Certification of ISO9001:2015 Extends Product Warranty to 25 years and Performance Warranty to 30 years Silfab and DSM enter exclusive North American Alliance to develop and launch Back-Contact PV Solar Module Silfab ranked number 30 on Canadian Business Growth 500 for fastest growing companies Silfab jumps to 3rd most quoted solar brand in US by Silfab purchases manufacturing facility in Bellingham, WA becomes largest manufacturer in North America Silfab achieves AVL and DSM Solar Launch First Generation Back-Contact MWT production line in Bellingham, WA using DSM's Conductive Backsheet (CBS) Manufacturer of the Year in the WA manufacturing Awards by Seattle Business Magazine</td>
</tr>
<tr>
<td>2019</td>
<td>Silfab Solar and DSM Solar Launch First Generation Back-Contact MWT production line in Bellingham, WA using DSM’s Conductive Backsheet (CBS)</td>
</tr>
</tbody>
</table>

**Silfab Solar Inc.**
In 2019, Silfab Solar and DSM created a JV to develop, mass produce, market and sell PV solar modules. We were the first to bring this technology to North America.

Today Silfab Solar operates one dedicated Eurotron line in Bellingham (WA) and sells to the US residential market.
1) Who is Silfab
2) Why back-contact (the product)
3) Why back-contact (the process)
4) The results
Why Does Back-contact Conductive Backsheet (CBS) Technology Exist?

**PROS**

- Highest power density of any module technology (even shingling!)
- Can be adapted to *any* kind of back-contact solar cell. IBC/n-type/EWT/MWT/etc.
- Highly-automated manufacturing (eliminates stringers and robotic lay-up operations)
- Highly customizable layout of electrical circuit
- Robust durability against thermo-mechanical stress (contacts are on the back).
- Low stress due to back contact can enable MFG with thinner cells. Individual small contact points, more robust than traditional back-contact module designs. No wire/ribbon at all!
- Better thermal performance (lower NOCT, 3rd party validated)
- Lower CTM losses
- Design of half-cell can easily be optimized for balanced high and low light performance

**CONS**

- Learning curve (any new manufacturing technology)
- Non-conventional supply chain
  - Rear Perforated Insulator (RPI)
  - Patterned CBS
1) Who is Silfab
2) Why back-contact (the product)
3) Why back-contact (the process)
4) The results
- ITRPV is quite conservative and may have temporarily lost its crystal ball in 2019.
- 2020-2022 predictions may also be quite conservative with only 35% anticipated wafer volumes in the >/= M6 (166mm) category.
Examples of metal-wrap through back-contact solar cells based on p-type PERC technology.
Conventional PV cell interconnection (copper/solder/silver pad/Si)
- Solder joint formed at very high temperatures >220°C
- Frontside busbar connection sandwiched between glass and cell.
- The bigger the CTE mismatch between the solder/Cu and solar cell/glass, the greater the damage induced by thermo-mechanical stress.

Back-Contact/CBS PV cell interconnection (copper foil/conductive paste/silver pad/Si)
- Contacts are formed at lower temperatures (~150°C)
- All contacts are on the back, far away from the glass
- Contact points are 2-3 mm in diameter. CTE mismatch between conductive paste + silicon results in minimal to no damage since contact is free to expand/contract.
- FLEXIBLE SUBSTRATE ALLOWS MOVEMENT. PROXIMITY TO GLASS, ON THE OTHER HAND, LIMITS MOVEMENT AND TRANSLATES STRESS TO CELL.
1) Who is Silfab
2) Why back-contact (the product)
3) Why back-contact (the process)
4) The results
1) DML (dynamic mechanical load): 1000 cycles at +/- 1000Pa, 3 cycles/min at 25°C (IEC 62782)

2) TC50: 50 thermal cycles from -40°C to +85°C with current injection at Imp

3) HF10: 10 humidity freeze cycles from -40°C to +85°C at 85% R.H.

4) Then TC600.

- Even after 4 different types of testing, the degradation was less than 0.5% relative to time zero.
1) Low Light Performance

- 126cell (3rd party PAN file measurements) = 3.0% rel. loss @ 200W/m²
- Typical half-cell on the market (3rd party) = 4.5% - 7.0% loss @ 200W/m²
Spaces between solar cells stay quite cool...polymers are poor thermal conductors and represent ~10% of the module area not covered by cells

Thermal IR Image of conventional PV module

2) NOCT
- 3rd party measured (two different RTL’s) = 40.6°C (60cell), 43.5°C (126cell)
- Typical black/black (BoB) module NOCT = 47-50°C
- Temp Coeff for Pmax ~0.4%/°C (That’s 6°C x -0.4% = 2.5% increase to instantaneous energy production!!)
- MWT/structure foil PV modules have ~10% more area to laterally spread heat for optimized heat transfer
*Note, simulations done with PVSyst Version 7.0.0

**PAN file for Silfab is based on fitting model data to measurements made by ISO 17025 accredited 3rd party lab according to IEC 61853-1,-2

***PAN file for conventional 120cell module was acquired from a 3rd party lab with ISO 17025 accreditation. Manufacturer was not disclosed, however data is representative of a typical 5BB half-cell module.

Day of Interest
6,541.1 kWh – Daily Sum (Conventional 120 half-cell)
6,702.7 kWh – Daily Sum (Silfab MWT, 126cell)
2.54% more energy production

Annualized
Silfab MWT/126cell array = 1924kWh/kWp
Conventional 120cell array = 1873kWh/kWp
2.72% more AEP (annualized energy production)

Breakdown
square 1.5% attributable to lower operating temp.
square 1.2% attributable to performance at low irradiance
**PVsyst Simulations – Cool, Cloudy/Low Irradiance in Boston**

*Note, simulations done with PVsyst Version 7.0.0*

**PAN file for Silfab is based on fitting model data to measurements made by ISO 17025 accredited 3rd party lab according to IEC 61853-1,2**

***PAN file for conventional 120cell module was acquired from a 3rd party lab with ISO 17025 accreditation. Manufacturer was not disclosed, however data is representative of a typical 5BB half-cell module.**

**Day of Interest**

1,924.9 kWh – Daily Sum *(Conventional 120 half-cell)*

2,008.4 kWh – Daily Sum *(Silfab MWT, 126cell)*

*4.3% more energy production*

**Annualized**

Silfab MWT/126cell array = 1408kWh/kWp

Conventional 120cell array = 1365kWh/kWp

*3.15% more AEP (annualized energy production)*

**Breakdown**

- 1.2% attributable to lower operating temp.
- 2.0% attributable to performance at low irradiance

---

**PVSyst Simulations – Cool, Cloudy/Low Irradiance in Boston**

*Note, simulations done with PVsyst Version 7.0.0*

**PAN file for Silfab is based on fitting model data to measurements made by ISO 17025 accredited 3rd party lab according to IEC 61853-1,2**

***PAN file for conventional 120cell module was acquired from a 3rd party lab with ISO 17025 accreditation. Manufacturer was not disclosed, however data is representative of a typical 5BB half-cell module.**

**Day of Interest**

1,924.9 kWh – Daily Sum *(Conventional 120 half-cell)*

2,008.4 kWh – Daily Sum *(Silfab MWT, 126cell)*

*4.3% more energy production*

**Annualized**

Silfab MWT/126cell array = 1408kWh/kWp

Conventional 120cell array = 1365kWh/kWp

*3.15% more AEP (annualized energy production)*

**Breakdown**

- 1.2% attributable to lower operating temp.
- 2.0% attributable to performance at low irradiance

---

**PVSyst Simulations – Cool, Cloudy/Low Irradiance in Boston**

*Note, simulations done with PVsyst Version 7.0.0*

**PAN file for Silfab is based on fitting model data to measurements made by ISO 17025 accredited 3rd party lab according to IEC 61853-1,2**

***PAN file for conventional 120cell module was acquired from a 3rd party lab with ISO 17025 accreditation. Manufacturer was not disclosed, however data is representative of a typical 5BB half-cell module.**

**Day of Interest**

1,924.9 kWh – Daily Sum *(Conventional 120 half-cell)*

2,008.4 kWh – Daily Sum *(Silfab MWT, 126cell)*

*4.3% more energy production*

**Annualized**

Silfab MWT/126cell array = 1408kWh/kWp

Conventional 120cell array = 1365kWh/kWp

*3.15% more AEP (annualized energy production)*

**Breakdown**

- 1.2% attributable to lower operating temp.
- 2.0% attributable to performance at low irradiance

---

**PVSyst Simulations – Cool, Cloudy/Low Irradiance in Boston**

*Note, simulations done with PVsyst Version 7.0.0*

**PAN file for Silfab is based on fitting model data to measurements made by ISO 17025 accredited 3rd party lab according to IEC 61853-1,2**

***PAN file for conventional 120cell module was acquired from a 3rd party lab with ISO 17025 accreditation. Manufacturer was not disclosed, however data is representative of a typical 5BB half-cell module.**

**Day of Interest**

1,924.9 kWh – Daily Sum *(Conventional 120 half-cell)*

2,008.4 kWh – Daily Sum *(Silfab MWT, 126cell)*

*4.3% more energy production*

**Annualized**

Silfab MWT/126cell array = 1408kWh/kWp

Conventional 120cell array = 1365kWh/kWp

*3.15% more AEP (annualized energy production)*

**Breakdown**

- 1.2% attributable to lower operating temp.
- 2.0% attributable to performance at low irradiance

---

**PVSyst Simulations – Cool, Cloudy/Low Irradiance in Boston**

*Note, simulations done with PVsyst Version 7.0.0*

**PAN file for Silfab is based on fitting model data to measurements made by ISO 17025 accredited 3rd party lab according to IEC 61853-1,2**

***PAN file for conventional 120cell module was acquired from a 3rd party lab with ISO 17025 accreditation. Manufacturer was not disclosed, however data is representative of a typical 5BB half-cell module.**

**Day of Interest**

1,924.9 kWh – Daily Sum *(Conventional 120 half-cell)*

2,008.4 kWh – Daily Sum *(Silfab MWT, 126cell)*

*4.3% more energy production*

**Annualized**

Silfab MWT/126cell array = 1408kWh/kWp

Conventional 120cell array = 1365kWh/kWp

*3.15% more AEP (annualized energy production)*

**Breakdown**

- 1.2% attributable to lower operating temp.
- 2.0% attributable to performance at low irradiance

---

**PVSyst Simulations – Cool, Cloudy/Low Irradiance in Boston**

*Note, simulations done with PVsyst Version 7.0.0*

**PAN file for Silfab is based on fitting model data to measurements made by ISO 17025 accredited 3rd party lab according to IEC 61853-1,2**

***PAN file for conventional 120cell module was acquired from a 3rd party lab with ISO 17025 accreditation. Manufacturer was not disclosed, however data is representative of a typical 5BB half-cell module.**

**Day of Interest**

1,924.9 kWh – Daily Sum *(Conventional 120 half-cell)*

2,008.4 kWh – Daily Sum *(Silfab MWT, 126cell)*

*4.3% more energy production*

**Annualized**

Silfab MWT/126cell array = 1408kWh/kWp

Conventional 120cell array = 1365kWh/kWp

*3.15% more AEP (annualized energy production)*

**Breakdown**

- 1.2% attributable to lower operating temp.
- 2.0% attributable to performance at low irradiance

---

**PVSyst Simulations – Cool, Cloudy/Low Irradiance in Boston**

*Note, simulations done with PVsyst Version 7.0.0*

**PAN file for Silfab is based on fitting model data to measurements made by ISO 17025 accredited 3rd party lab according to IEC 61853-1,2**

***PAN file for conventional 120cell module was acquired from a 3rd party lab with ISO 17025 accreditation. Manufacturer was not disclosed, however data is representative of a typical 5BB half-cell module.**

**Day of Interest**

1,924.9 kWh – Daily Sum *(Conventional 120 half-cell)*

2,008.4 kWh – Daily Sum *(Silfab MWT, 126cell)*

*4.3% more energy production*

**Annualized**

Silfab MWT/126cell array = 1408kWh/kWp

Conventional 120cell array = 1365kWh/kWp

*3.15% more AEP (annualized energy production)*

**Breakdown**

- 1.2% attributable to lower operating temp.
- 2.0% attributable to performance at low irradiance
• Instantaneous AC Power = 7% higher (rel.)! for MWT 320Wp modules. 4% due to better thermal management and 3% due to higher STC (320Wp vs. 310Wp)

• Total kWh so far from July to September 2020 = 6% higher than the conventional 310Wp modules

• 3% is attributable to the higher relative STC rating, but the remaining 3-4% increase is due to better thermal performance (rel.)
Silfab Solar/DSM Joint Venture was the first to bring back contact CBS PV modules to North America.

Back contact /CBS PV Module Designs offer many advantages and are already seeing GW scale manufacturing volumes globally.

Operationally, the level of simplicity in the design and automation are unparalleled which allows for lower CapEx/OpEx and an efficient use of manufacturing space.

Durability of back contact/CBS PV modules against thermo-mechanical stress is intrinsic to the design. As validated by extensive accelerated stress testing.

Performance of back contact/CBS PV modules is superior to conventional designs using p-type mono-PERC cells and rivals more expensive hetero-junction (HJT) cell-based modules. A combination of better thermal and low-irradiance performance.