Silane-Based Fluidized Bed Reactor (FBR) Technology Development
International Silicon Industry, Xi’an, China
September 29, 2016
Mr. Tore Torvund, President & CEO
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About REC Silicon

FBR Technology Leader: largest Fluid Bed Reaction (FBR) production in the world
› Annual FBR-A capacity of 16,000 MT
  - FBR-A: multi quality granular polysilicon
  - FBR-B: mono quality granular polysilicon (used at Yulin)

› Largest silane gas producer in the world

› Over 30 years of experience in the polysilicon and silicon gas industries
What We Do

› REC’s manufacturing process utilizes readily available metallurgical grade silicon, which is transformed into silane and polycrystalline silicon (polysilicon).
Where REC Silicon is Located: Production Facilities

Two polysilicon production facilities in the U.S.

2015 Production

- 14,098 MT Granular Polysilicon
- 18,695 MT Silane Gas

Moses Lake
- ~366 employees

- 3,274 MT Silane Gas Loaded
- 7,233 MT Silane Gas Produced
- 2,843 MT Siemens Polysilicon

Butte
- ~245 employees
Over 30 Years of Polysilicon Experience

1980-1999
• 1984: Moses Lake Plant commissioned by Union Carbide
• 1990: Purchased by Komatsu Ltd., creating ASiMI
• 1998: Butte Plant Start up

2000-2009
• 2002: Moses Lake plant becomes Solar Grade Silicon LLC
• 2005: ASiMI purchased by REC, creating REC Silicon

2009-Present
• 2009: Silane III, Silicon III, FBR commercial reactor
• 2010: Start-up of Silane IV
• 2015: Joint Venture breaks ground in Yulin China
Global PV demand is expected to continue to grow year on year.

Global PV demand will more than double from 2020 to 2040.

By 2040, global PV demand will be over 200 GW annually.

China, India and the US will be the largest markets.

Demand > 200 GW by 2040

Source: Bloomberg (June 2015)
2016 IHS China and ROW Installation Forecast Comparison

China Installs Compared to ROW

Source: IHS Technology Markit PV Demand Market Tracker – Q3 2016

Results based on IHS Technology Markit PV Demand Market Tracker – Q3 2016. Results are not an endorsement of REC Silicon. Any reliance on these results is at the third party's own risk. Visit www.technology.ihs.com for more details.
GTM: China Remains Top Solar Market in 2016

- China leads 2016 global demand at 26.4 GW, reaching a peak in its annual installation rate
  - In line with its 143 GW by 2020 solar goal

- US is the second-largest 2016 market at 14.5 GW
  - Record installations tied to the previously expected expiry of the federal Investment Tax Credit, which has now been extended

- Major shifts in the global solar market in H1 2016:
  - 1. China: FIT pullback of 11% and major grid curtailment
  - 2. U.S.: Total solar installations surpassed 1 million = 27.5 GW
  - 3. Japan: Scaling back FIT support – 12% drop in 2016 demand
  - 5. India: 23 GW tender pipeline – 148% spike in 2016 demand
China and US PV Demand Development 2015-2021E

China Annual Installations 2015-2021E (GW)

US Annual Installations 2015-2021E (GW)

GTM Research, Demand Monitor, Q3 2016
By 2021, Shift in Demand Share as ROW, US and India Increase Appreciably

GLOBAL DEMAND SHARE 2016E

73 GW Expected to be installed

GLOBAL DEMAND SHARE 2021E

105 GW Expected to be installed

GTM Research, Demand Monitor, Q3 2016
FLUIDIZED BED REACTOR (FBR) TECHNOLOGY
Development of FBR: FBR-A in Moses Lake and FBR-B in Yulin

- 1976: JPL / UCC FBR Study & Pilots
- 1996: ASiMi/Komatsu, FBR Pilots
- 2004: FBR-A Pilot Reactors • Feasibility • Modeling/Validation/Operability
- 2009: FBR-A Commercial Process • Supply to Multi Market
- 2010: FBR-B Pilot • Demonstrated Enhanced Quality & Operability at Reduced Cost
- 2017: Yulin Joint Venture Start-up • Semiconductor quality • Supply Mono Market

Continual Process Improvement

N E X T   G E N E R A T I O N
Fluid Bed Reactor (FBR) is the Most Efficient Way to Produce Polysilicon

<table>
<thead>
<tr>
<th>Siemens Reactor TCS Based</th>
<th>Fluid Bed Reactor Silane Based</th>
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</thead>
<tbody>
<tr>
<td>Fluid Silane Deposition</td>
<td>SiH₄ → Si + 2H₂</td>
</tr>
<tr>
<td>Low energy efficiency - High cash cost</td>
<td>High energy efficiency - Lowest cash cost</td>
</tr>
<tr>
<td>Batch Process</td>
<td>Continuous production</td>
</tr>
<tr>
<td>Requires post processing</td>
<td>Ready for use</td>
</tr>
<tr>
<td>Mature technology</td>
<td>New Technology</td>
</tr>
</tbody>
</table>

Polysilicon rods

Electrical contact

Cooling medium

Reactor inlet

Reactor outlet

Cooling medium

Silane

Hydrogen

Granular Product
FBR Greatly Increases Energy Efficiency

Note 1: REC silicon data based on 2014 measured energy consumption and actual production. This includes consumption for operations, maintenance, and analytical functions.
Note 2: REC data includes the buildings (lights/HVAC) along with processing, packaging, treatment, and support equipment.
Note 3: Competitive technology data appears to be based on simulations of power consumption for only the process equipment to manufacture Polysilicon when it is operating at 100% utilization.
FBR Growth Expected, but Siemens Polysilicon Dominance Will Remain

- Approximately 10% current FBR market share
- FBR growth reflects potential for cost reduction
- Increase of FBR market share expected in long term
- Siemens polysilicon still expected to have majority of market share in long term

Source: ITRPV Seventh Edition Vers 2
Yulin JV
TianREC: Youser Group and REC Silicon’s JV

› Ideal Partners:
  - Established Chinese SOE Youser Group
  - US Proven Technology Leader REC Silicon

› 51% - 49% Partnership

› REC transferred technology to TianREC

› TianREC benefiting from Youser Group experience in China

› Construction of TianREC plant currently well underway

Yulin JV Signing Ceremony
February 2014
Capacities and TianREC Plant Layout

Yulin Plant Production Capacity:

- 19,000 MT Granular Polysilicon
- 300 MT Siemens Polysilicon
- 500 MT Silane Gas Loading

Hydrogenation Steel Structure

FBR Reactor Building

Siemens Reactor Building
Current View of the TianREC Project Site

Administration
FBR Unit
Silane Units
Siemens Unit
TianREC’s Focus on Health, Safety, and Environmental

Zero project incidents to date

Training

Personal Protective Equipment

Personal Protective Equipment

Safety Signs

截止当前，项目安全事故发生率为零
Cooperation in Action: TianREC Employees Training at REC Silicon’s US Plants

“It’s exciting to be a part of an organization that is the first of its kind, not only in China, but worldwide. A lot of time has been spent on training and along the way, I have been grateful not only for the valuable knowledge and experience, but also for the comradery. REC Silicon staff have been very supportive and encouraging during the training process.”
– Mr. Wei Wujie TianREC

Around 50 TianREC trainees are in the process of undergoing extensive training at REC Silicon’s Moses Lake and Butte facilities.
MARKET APPLICATIONS
Granular Polysilicon Enhances Efficiency for Wafer Producers

<table>
<thead>
<tr>
<th></th>
<th>Only Siemens</th>
<th>Siemens and Granular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crucible Loading Time</td>
<td>48.5 mins.</td>
<td>28.5 mins.</td>
</tr>
<tr>
<td>Crucible Weight</td>
<td>63.8 kg</td>
<td>82.5 kg</td>
</tr>
</tbody>
</table>

- 40% improvement in filling time
- 30% increase in charge weight
FBR Granular Can Increase Productivity in Mono Through Continuous Feeding

- Continuous feeding reduces non-productive down-time between the standard batch processes

- 50% crucible cost reduction with one refill process

Source: Cost effective growth of silicon mono ingots by the application of mobile recharge system in cz-puller, presented at the 32nd European PV Solar Conference and Exhibition, 20-24 June 2016 Munich Germany
Silane Based Siemens: 300 MT of Ultra Pure Polysilicon

- 300 MT of high resistivity Siemens chunk (Float Zone)

- Market segments will be semiconductor industry in China

FZ Float Zone Puller

IGBT dies-on-wafer
Silane Loading Capacity: 500 MT

› 500 MT of silane loading

› Market segments will be semiconductor and PV industry in China
Summary

› REC is the leading silane based FBR producer on a global basis

› FBR Technology is the most cost effective way to produce polysilicon

› TianREC will supply Chinese customers with semiconductor grade granular polysilicon at competitive prices

› Granular polysilicon will improve efficiency and reduce cost in the manufacturing process of mono and multi wafers

› 300 MT of ultra-pure Siemens chunk (Float Zone) will be available for the high-end semiconductor industry

› 500 MT of silane gas will be available for the semiconductor/PV market in China
The TianREC JV is a perfect example of the collaboration between the US and China to produce clean and sustainable solar energy for the world, and it will bring the best and most efficient polysilicon manufacturing technology to China.
Thank You

Learn more: www.recsilicon.com