The 247Solar Plant™ is a dream come true for the 21st century—a solar power plant with built in storage to generate electricity economically any time day or night. - S. David Freeman, former head, Sacramento Municipal Utility District (SMUD), Tennessee Valley Authority (TVA), New York Power Authority, and Los Angeles Department of Water and Power (DWP)
Summary: 247Solar Plant™

Target: coal-competitive 24/7 solar electricity

✓ Revolutionary breakthrough in 24/7 Concentrated Solar Power (CSP)
  ✓ MIT originated
  ✓ US Department of Energy funded (USD5 million)

✓ Competitive with solar PV but reliable, grid-stabilizing, 24/7 operation

✓ Soon competitive with coal but flexible operation, minimal outage time, grid optimization; voltage control; frequency control, instantaneous demand response
  ✓ Majority of components factory-made, many locally
  ✓ Rapid permitting, installation, time-to-revenue

✓ Attractive returns with low risks for power project developers and investors
Presenting

40-year solar industry leader and pioneer

Bruce N. Anderson, Co-founder, CEO

- Began solar career in 1973 with Masters degree at MIT
- 40 years as CEO
- 1980 Advisory Board Member, National Renewable Energy Laboratory (NREL)
- 1982 First “Lifetime Achievement Award,” American Solar Energy Society
- Author of 5 solar energy books
- Twice testified to US Congress
- Member, MIT Corporation (Board of Trustees)
Pre-engineered, 300-400 kWe standardized modules (like wind)
Competitive with PV, potential to be competitive with coal

- Mostly well-proven equipment, low risk
- Simple operation, simple maintenance
- Battery-like grid stabilization
- Uses air – no molten salts, oil, water/steam
- Distributed or utility scale
“If you want to make something dirt cheap, make it out of dirt. Preferably dirt that’s locally sourced.”
Donald R. Sadoway, John F. Elliott Professor of Materials Chemistry at MIT
Voted one of Time magazine’s 100 most influential people in the world in 2012
Objective: Next Generation CSP cheaper than fossil fuels

1. See http://www.osti.gov/scitech/search/semantic:%22Brayton-cycle%20baseload%20power%20tower%20csp%20system%22/filter-results:Fr
2. 247Solar purchased the technology from Wilson Solarpower in 2016

Engineering and Cost Study
Brayton-Cycle Baseload Power Tower CSP System
Phase 1 Report, US Department of Energy
July 2011

Brayton-Cycle Baseload Power Tower CSP System
Phase 2 Report, US Department of Energy
September 2014

Funding Opportunity Announcement Number: DE-FOA-0000104
Baseload Concentrating Solar Power Generation
Huge system breakthrough

New AMBIENT pressure operation, not old HIGH pressure

**HIGH pressure system**
- Only 100 kWe
- No thermal storage
- Daytime only

**LOW pressure system**
- 400 - 2000 kWe
- 3 - 24 hours thermal storage
- 24x7 operation
Huge component breakthrough

Scaled up, simplified proven technology

HIGH pressure receiver by DLR
- 60 cm aperture
- ~0.35 MWth
- Pressure vessel
- 3 active cooling systems

AMBIENT pressure receiver
- 200 cm aperture
- ~2.5 MWth
- Ambient pressure
- No moving parts
>100-year-old proven thermal storage system

1. <10% the cost of battery storage
2. 3 - 4 m diameter, 7 - 9 m tall
3. Firebrick* spaced for airflow
4. 970°C operation
5. No moving parts, unlimited cycles
6. >95% round trip efficiency

*For more information about firebrick, see https://en.wikipedia.org/wiki/Fire_brick and http://www.traditionaloven.com/articles/84/firebricks-heavy-dense-fire-clay-bricks
Next generation CSP: 247Solar Plant™

5 Plug-and-play subsystems

1. **OFF-THE-SHELF SUN-TRACKING HELIOSTATS**
   (~4 acres (16,000m²) per 400 kWe)

2. **Highly innovative**
   **247SOLAR RECEIVER™**
   (air heating, no moving parts)

3. **Conventional**
   **TOWER SYSTEM**
   (~125ft, 35m)

   **AIR FLOW, warm air up, hot air down**

4. **Conventional microturbine**
   **247SOLAR POWER BLOCK™** (outfitted with
   247Solar Heat Exchanger™, 247Solar Combustor™)

5. **100+ year proven**
   **247SOLAR THERMAL STORAGE SYSTEM™**
   (3-24 hours, e.g. firebrick
   no moving parts)
**Daytime solar operation**

Exhaust air from the turbine and the thermal storage are heated in the solar receiver. Some of the air passes through the thermal storage and the remainder powers the turbine.
Night operation from storage

Exhaust air from the turbine passes through the thermal storage in the opposite direction to power the turbine. A combustor heats the air further, if needed.
247Solar Power Block™

Highly proven, most versatile power generator in the world

1. All **factory-produced** for rapid deployment, low cost
2. **Plug-and-play**, includes power electronics for grid connections
3. Powered by solar and/or by a **wide variety of fuels**, including biofuels
4. **Firmly dispatchable** 24/7
5. **Simple**, low cost to operate, maintain
6. **Highly efficient** from 33% electrical (Up to 80% using 1.5-2 million BTU/hr useful industrial grade heat)
7. Multiple **additional benefits** for customers and grids

This article does a good job of covering the many special attributes of microturbines, which is the core component of the 247Solar Power Block:
### Low risk

Mostly proven, off-the-shelf components

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>247Solar Power Block</td>
<td>Off-the-shelf, 1,000,000s of hours of proven performance</td>
</tr>
<tr>
<td>247Solar Thermal Storage System™</td>
<td>&gt;100-year-old proven technology, no moving parts</td>
</tr>
<tr>
<td>247Solar Receiver™</td>
<td>Scaled up but simplified proven technology from DLR, no moving parts</td>
</tr>
<tr>
<td>Heliostats/field</td>
<td>Off-the-shelf proven technology</td>
</tr>
<tr>
<td>Tower</td>
<td>Conventional tower</td>
</tr>
<tr>
<td>Air Transport Subsystem</td>
<td>Conventional low-pressure ducts, blowers, dampers</td>
</tr>
</tbody>
</table>
Technology Roadmap

For continued cost reductions, performances increases

1. Develop larger power sizes of each 247Solar Plant
   • Like wind, from 400 kWe today to ~2 MW in 3 years
   • Cost reduction of ~2 cents/kWh

2. Develop MIT-invented ceramic turbine
   • 35-40% increased turbine efficiency
   • 25-35% system cost reduction
   • Cost reduction of 1-2 cents/kWh

3. Develop other technologies
   • Phase change heat storage materials
   • Modular water purification/desalination
   • High-efficiency coatings
“I strongly believe 247Solar will deliver the cheaper and simpler solution that CSP must have to succeed.”

Jan Drathen
Head of Concentrated Solar Power Fleet at E.ON Climate & Renewables GmbH
Wind, PV make case for standardization:

Rapid, steep declines due to FACTORY production and minimal site construction costs
247Solar Plants win

Lower cost than PV and conventional CSP

(Source: Turning Up the Heat on Advanced Concentrating Solar Power by Lux Research, LLC, May 2014)
Conservatively, costs drop ~7% with each doubling of cumulative production**
(comparres with historical ~15% for PV)

**Costs compiled by WorleyParsons, DLR, Saint Gobain, EZ Klein, Wilson Solarpower for US DOE Feasibility and Cost Study. See http://www.osti.gov/scitech/search/semantic:%22Brayton-cycle%20baseload%20power%20tower%20csp%20system%22/filter-results:F
The Solar Advisor Model (SAM) developed by NREL (the National Renewable Energy Laboratory) was used by WorleyParsons to estimate costs and performance for solar plants, particularly LCOEs
Comparison: PV plus batteries

247Solar Plants are 50% cheaper!

Assume dispatchable 24/7 power required

Cost of PV plus batteries
- First 8 hours: $900/kW
- Additional 16 hrs: $1800/kW
- 16 kWh of batteries @$400/kWh: $6400/kW

➢ TOTAL: $9,200/kW
  - Power after a day of no sunshine?
  - Backup diesel genset? Cost? Complexity?

Cost of 247Solar Plant
➢ TOTAL $4500/kW
  - Produces power 24/7, regardless of weather
  - Provides valuable waste heat 24/7 for other uses, increasing the system’s ROI
247Solar responds perfectly to fluctuating demand

No extra storage or capacity required, $$ saved

Eskom load curve (data from autumn 2013)
MW and hours

- South Africa’s load curve has both a morning and evening peak, creating a need for energy storage twice per day
- South Africa’s evening peak is about the size of the Medupi power station
- Building sufficient storage eliminates the need for that extra generation capacity

247Solar in red
## CSP Comparison

### 2nd generation 247Solar compared with 1st generation CSP

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Power Tower</th>
<th>Parabolic Trough</th>
<th>Linear Fresnel</th>
<th>247Solar Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reliability</strong></td>
<td>Conventional reliability</td>
<td>Conventional reliability</td>
<td>Conventional reliability</td>
<td>High 9s reliability due to many modules per system.</td>
</tr>
<tr>
<td><strong>Power costs (US)</strong></td>
<td>&gt;10 cents/kWh, no obvious path to &lt;8 cents</td>
<td>&gt;10 cents/kWh, no obvious path to &lt;8 cents</td>
<td>&gt;10 cents/kWh, no obvious path to &lt;8 cents</td>
<td>Competitive to start (10-13 cents/kWh), highly competitive with mass production, &lt;6 cents</td>
</tr>
<tr>
<td><strong>Permitting to, commissioning</strong></td>
<td>3 - 4 years</td>
<td>3 - 4 years</td>
<td>3 - 4 years</td>
<td>&lt;18 months permitting, erection, commissioning</td>
</tr>
<tr>
<td><strong>Custom vs. standardized</strong></td>
<td>Custom; every plant is unique</td>
<td>Custom; every plant is unique</td>
<td>Custom; every plant is unique</td>
<td>Mostly factory components for quick erection</td>
</tr>
<tr>
<td><strong>Costs</strong></td>
<td>50% of costs in factory, 50% on site, which increase over time</td>
<td>50% of costs in factory, 50% on site, which increase over time</td>
<td>50% of costs in factory, 50% on site, which increase over time</td>
<td>90% of costs in factory, which decrease ~7% with each doubling of output</td>
</tr>
<tr>
<td><strong>Required skill level</strong></td>
<td>Highly-skilled</td>
<td>Highly-skilled</td>
<td>Highly-skilled</td>
<td>Semi-skilled</td>
</tr>
<tr>
<td><strong>Environmental issues</strong></td>
<td>Uses water, oils and/or salts</td>
<td>Uses water, oils and/or salts</td>
<td>Uses water, oils and/or salts</td>
<td>None. Uses air; some water for heliostat cleaning</td>
</tr>
<tr>
<td><strong>Land type requirements</strong></td>
<td>Typically 2-5 sq km, or 2.8 acres/GWh-yr; Flat land ideal; round site</td>
<td>Typically 2-5 sq km, or 2.5 acres/GWh-yr; Requires very flat land; rectangular site</td>
<td>Typically 2-5 sq km, or 1.7 acres/GWh-yr; Requires very flat land; rectangular site</td>
<td>As little as 4 acres, or 1.25 acres/GWh-yr; OK on rolling hills, irregular shapes; even landfills</td>
</tr>
<tr>
<td><strong>Scalability</strong></td>
<td>Large-scale only; ties into transmission system</td>
<td>Large-scale only; ties into transmission system</td>
<td>Large-scale only; ties into transmission system</td>
<td>Small- and large-scale; ties into either transmission or distribution system. Can be standalone, no grid connect</td>
</tr>
</tbody>
</table>
## 247Solar modernizes the power industry

<table>
<thead>
<tr>
<th>247Solar Plant™</th>
<th>PV and wind</th>
<th>New conventional power</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electricity price</strong></td>
<td>Inflation free and predictable because most of the costs are upfront.</td>
<td>Fuel costs, the largest portion of electricity costs, are volatile, unpredictable, and prone to rise.</td>
</tr>
<tr>
<td><strong>Project costs</strong></td>
<td>Higher CAPEX but 4 to 5 times more electricity produced per year than PV due to economical storage and fuel backup. Significant room for cost reductions, &gt;50%. Reduces cost of grids.</td>
<td>Lower CAPEX but intermittent energy so overall electric costs similar. Compared with 247Solar Plants, little room for further cost reductions. Redundant power plants, grid storage required.</td>
</tr>
<tr>
<td><strong>Storage</strong></td>
<td>Low cost, high-efficiency thermal storage allows for on-demand 24/7 power. Small, hot-air turbines nimbly respond to demand changes.</td>
<td>Battery storage is possible but very expensive and inefficient – remains intermittent; Only 19-23% capacity factor (CF).</td>
</tr>
<tr>
<td><strong>Grid benefits</strong></td>
<td>Stabilizes the grid with battery-like responsiveness to demand changes and voltage fluctuations; both a distributed and central solution.</td>
<td>Their unpredictability, intermittent and variable output, and non-dispatchability add to grid operational challenges.</td>
</tr>
<tr>
<td><strong>Scalability</strong></td>
<td>From mini-grid to industrial to utility scale, 400 kWe to 1000s MW.</td>
<td>Large scale only.</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td>Minimal environmental impact.</td>
<td>Huge environmental impact, especially CO2.</td>
</tr>
<tr>
<td><strong>Power Plant Redundancy</strong></td>
<td>No backup power plants or spinning reserves required; modularity guarantees output 24/7.</td>
<td>Requires backup power plants when the sun isn’t shining or the wind isn’t blowing. Requires backup power plants &amp; spinning reserves during planned and unplanned outages.</td>
</tr>
<tr>
<td><strong>O&amp;M</strong></td>
<td>Low because of few moving parts and high MTBFs (1.5-2.5 cents/kWh); also, a low-pressure air system.</td>
<td>PV has few moving parts, high MTBFs (1 - 2 cents/kWh). Panel efficiency degrades ~1.5%/yr. Wind has low MTBF problems. Highest O&amp;M because of high-pressure steam systems, fuel requirements (3-5 cents/kWh).</td>
</tr>
<tr>
<td><strong>Project Cycle</strong></td>
<td>Comparatively short due to modularity, all-factory production, and rapid on-site assembly of standardized modules.</td>
<td>Comparatively short due to modularity, all-factory production and rapid on-site assembly of standardized modules. Very long, 5 - 8 years.</td>
</tr>
<tr>
<td><strong>Localization</strong></td>
<td>Significant % of supply chain can be manufactured &quot;in-country&quot;.</td>
<td>Local content is small, except in very large markets.</td>
</tr>
<tr>
<td><strong>Industrial Integration</strong></td>
<td>Generates 24/7 electricity and heat/steam for industrial processes, desalination, refrigeration, drying, and other applications.</td>
<td>Electricity generated by PV, wind can support industrial processes but need a base load source to offset intermittency and, also, to provide heat. CHP with smaller turbines is common but require backups during down times.</td>
</tr>
</tbody>
</table>

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Localization of components

Typically >60% local initially

- Heliostats (~30%)
- Thermal Storage (~15%)
- Tower and Balance of Plant (~10%)
- Logistics, Construction & Manufacture (~15%)

~ 16,000 m² (400 kW)

24 m
“This (247Solar) CSP solution is a revolution waiting to happen.”
Belen Gallego, founding CEO
New Energy Update (formerly CSP Today, PV Insider)
Veteran Leadership Team

>200 years of technical and business success

Bruce N. Anderson, Founder, CEO, 40-year solar industry leader and veteran
- Began solar career in 1973 with Masters degree at MIT
- 1980 Advisory Board Member, National Renewable Energy Laboratory (NREL)
- 1982 First recipient “Lifetime Achievement Award,” American Solar Energy Society
- Author of 5 solar energy books
- Twice testified to US Congress on energy matters
- Member, MIT Corporation (Board of Trustees)
- 35-year career CEO including 15 with Wilson Solarpower and 247Solar Inc.

Steven Walsh, COO, power project expert
- VP Middle East/South Asia and VP Government & Legislative Affairs, AES Corporation
- Principal, Tier One Capital Management LLC
- CEO/Chief Re-structuring Officer, TPG Power Holdings
- Program manager to rebuild Iraq’s electric grid in Iraq under US Mission, Baghdad
- Over 35 years in military and civilian leadership roles
- 1979 graduate, US Naval Academy

Joseph Z Perry, VP Corporate Development
- President and CEO, CHROMx, CPV Solar cells
- President and CEO, FlexEnergy, Gas turbine and low quality methane e.g. landfill gas capabilities
- President and CEO, WaveCrest Laboratories, electric vehicle transportation
- Westinghouse, Pressurized light water reactors
- President and CEO at CCI and a number of computer system, software and hardware companies

Dr. Boris Maslov, CTO
- CEO, CTO, Ener-Core, continuous energy from ultra-low quality gas.
- President and CEO, Energy One, renewable energy project developer
- CTO, WaveCrest Laboratories, electric vehicle transportation
- Senior member of IEEE and holds more than 30 US and international patents
- Moscow Institute of Physics &Technology: Ph.D., Electrical Eng; B.S., M.S., Electrical Eng and Computer Science

Bill Treece, VP Engineering
- 45-year engineer of microturbine and related technology development & project management
- Solar Turbines, Gas Turbine Product Engineering Manager
- Holds seven U.S. patents, plus four patents pending in gas turbines and two in CSP
Key Global Partners

German Aerospace Center (DLR) - Germany
- World’s largest, most experienced center of excellence for Brayton power towers
- Principal partner to develop 247Solar Receiver™

WorleyParsons – Australia
- Global utility engineering firm
- Did costing and LCOEs

Saint-Gobain – France
- Global construction products manufacturer
- Principal partner to develop 247Solar Thermal Storage System™

Oak Ridge National Laboratory – US
- US government’s premier materials-testing lab
- Cycle tested super alloy for 247Solar Heat Exchanger™
Board of Advisors

Respected veterans volunteer their support

- **David M. Walker**, Senior Vice President of Bechtel Group (retired)

- **S. David Freeman**, former head of the Sacramento Municipal Utility District (SMUD), the Tennessee Valley Authority (TVA), the New York Power Authority, and the Los Angeles Department of Water and Power (DWP)

- **Robert Hemphill**, former CEO of AES Solar and Executive Vice President of AES Corp (retired)

- **Dave Belote**, former Commander of Nellis Air Force Base

- **Kymus Ginwala**, former CEO of Northern Research and Engineering Corporation (NREC), a global advanced technology development company and part of the worldwide Ingersoll-Rand group
Status

The commercialization process is accelerating

- Two pilot 247Solar Plants in process in two different countries
- MOU with first customer for a 10 MW commercial power project
- MOUs with exclusive commercialization partners in two of the three largest CSP markets
- Signed MOU to build commercial Plants in South Africa
- Active discussions throughout Africa, the MENA region, and Australia to build commercial Plants
The 247Solar Plant™ is a dream come true for the 21st century---a solar power plant with built in storage to generate electricity economically any time day or night. - S. David Freeman, former head, Sacramento Municipal Utility District (SMUD), Tennessee Valley Authority (TVA), New York Power Authority, and Los Angeles Department of Water and Power (DWP)

2nd generation baseload solar