Invenergy
Energy Storage
We’re North America’s largest privately-held clean energy provider

125 Projects
20,032 Megawatts
$30B+ Capital Raised
900+ Employees

As of 5/11/18; includes projects that are operating, in construction or contracted. Renewables include wind, solar and storage.
We develop, own & operate large-scale renewable projects.

- **Wind**
  - 92 projects
  - 13,246 MW

- **Solar**
  - 15 projects
  - 565 MW

- **Storage**
  - Advanced Energy
  - 6 projects
  - 94 MW

- **Natural Gas**
  - 12 projects
  - 6,126 MW

As of 5/11/18; includes projects that are operating, in construction or contracted. Renewables include wind, solar and storage.
Development

Strategic Siting
Land Acquisition
Permitting
Interconnection

Engineering & Construction

In-House Design
Construction Management

Marketing & Finance

PPAs, Tolls, Hedges
Environmental Commodities
Flexible Structures
$25B+ Capital Raised

Ownership & Operations

Operations & Maintenance
Asset Management
Community Relations
# Developed Storage Projects

**#1 Privately held advanced Energy storage owner/operator**

<table>
<thead>
<tr>
<th>Year</th>
<th>Project Name</th>
<th>Technology</th>
<th>Capacity</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>Grand Ridge IV Energy Storage</td>
<td>Lithium Titanate</td>
<td>1.5 MW</td>
<td>1.0 MWh</td>
</tr>
<tr>
<td>2014</td>
<td>Goldthwaite Energy Storage</td>
<td>Sodium Nickel Chloride</td>
<td>0.6 MW</td>
<td>1.2 MWh</td>
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<tr>
<td>2015</td>
<td>Grand Ridge Energy Storage</td>
<td>Lithium Iron Phosphate</td>
<td>31.5 MW</td>
<td>12.2 MWh</td>
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<tr>
<td>2015</td>
<td>Beech Ridge Energy Storage</td>
<td>Lithium Iron Phosphate</td>
<td>31.5 MW</td>
<td>12.2 MWh</td>
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<tr>
<td>2016</td>
<td>Grand Ridge IV Expansion</td>
<td>Lithium Iron Phosphate</td>
<td>3.0 MW</td>
<td>1.4 MWh</td>
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<tr>
<td>2018</td>
<td>Orangeville Energy Storage</td>
<td>Lithium Iron Phosphate</td>
<td>20 MW</td>
<td>10 MWh</td>
</tr>
<tr>
<td>2019</td>
<td>Eastern Region</td>
<td></td>
<td>6 MW</td>
<td>75 MWh</td>
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</table>
Energy Storage Technology 101
There are multiple methods of storing energy—most of the focus today is around electro-chemical storage.
**Energy Storage 101 Terminology**

A battery stores electricity, as a tank stores water:

- **Flow rate → Power**
  - Units: Kilowatts (kW)
  - Megawatts (MW)
  - Power is limited by the size and number of inverters

- **Size of tank → Energy**
  - Units: Kilowatt-hours (kWh)
  - Megawatt-hours (MWh)
  - Energy is limited by the size and number of battery modules

Amount of available energy at a given time = **State of Charge (SOC)**
Multiple trays are wired in series to form a **Battery String**. Strings can be configured vertically in a single rack, across multiple racks, or horizontally.

Each string has a **Battery Management System (BMS)** that monitors voltage, current, temperature, SOC, et.

The inverter rating dictates how much power can be charged or discharged to the battery (typically max charge power = max discharge power).

The **Battery Tray** or **Module** is the smallest replaceable unit. It is filled with **Battery Cells**.

“Battery” = ...almost anything, depending on who is speaking.
Energy Storage 101 System Duration

Power

1 MW

Energy

0.5 MWh

1 MWh

4 MWh

Duration

30 min

1 hour

4 hours

Invenergy
Battery Costs

Battery costs keep declining rapidly

Battery prices ($/kWh)

Global lithium-ion battery demand (GWh)

- BNEF observed values: annual lithium-ion battery price index 2010-16.
- Implied 2025 lithium-ion battery price: $109/kWh
- Implied 2030 lithium-ion battery price: $73/kWh

ESS lithium-ion demand
EV lithium-ion demand
BNEF observed values
19% learning rate
## Real 2017 $ Benchmark capital costs for a fully-installed energy storage system, of a 1MW/1MWh project.

### Battery Costs

Cost of battery as % of system cost continues to decline.

<table>
<thead>
<tr>
<th>Year</th>
<th>Battery pack</th>
<th>PCS</th>
<th>Balance of System</th>
<th>Energy Management System</th>
<th>Developer overheads</th>
<th>Grid connection</th>
<th>Developer margin</th>
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<tbody>
<tr>
<td>2017</td>
<td>57</td>
<td>27</td>
<td>100</td>
<td>24</td>
<td>49</td>
<td>193</td>
<td>172</td>
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<td>2018</td>
<td>53</td>
<td>25</td>
<td>95</td>
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<td>172</td>
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### Note:
- Excludes warranty costs, which are often paid annually rather than as part of the initial capital expenditure. These costs do not explicitly include any taxes, although due to a lack of transparency in the market, some may be unknowingly accounted for. This is for a brownfield development so excludes grid connection costs. Note * includes a 10% EPC margin. Developer overheads set at 5% of total system costs, and developer margin set at 10%. It also excludes transformer costs which may be added on a project by project basis.
Applications
Applications

Advanced energy storage can be located where it is needed on the grid.
Application: Peak Shaving

Peak Circuit Load with Storage

- Storage Charging
- Storage Discharging
- Peak
- Load with Storage

Confidential & Proprietary
Application: **Optimize Fixed Resources**

Some resources like to run constantly at a fixed output – nuclear, run-of-river hydro, geothermal, etc. Storage can handle variability in the grid so these resources can run more optimally.

- Reduce curtailment when load falls below minimum threshold
- Respond to over- and under-frequency events (no reserve capacity needed)
- Provide spinning reserve
- Fast frequency regulation
Application: T&D Deferral

125 MW demand load cannot be filled without battery, because the substation is limited to 100 MW.

Charge the battery when the load is less than 100 MW and discharge when the load is larger than 100 MW.

Allows load to reach 125 MW.
20 MW solar farm output
4 MW / 1 Hour duration battery

- Smooths variations into hourly firm blocks
- Reduce energy imbalances
Solar + Storage: **Energy Shifting**

In this example from an islanded grid, adding storage to a 15 MW solar project to shift energy would have a benefit of roughly $3.1M

<table>
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<th>Area</th>
<th>Average LMP Price ($/MWh)</th>
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<td>Area A – Solar Only</td>
<td>$110</td>
</tr>
<tr>
<td>Area B – 4 hour storage</td>
<td>$141</td>
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</tbody>
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Below is an example of an island grid with most of its existing baseload generation coming from diesel generation. Storage is being used to shift solar energy to the hours of greatest need.
Actual output of a 90 MW wind facility.

10 MW, 5 MWh battery can provide a firm output in the form of 15 min or 1 hour blocks.
Working towards a clean energy future

Join us.

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