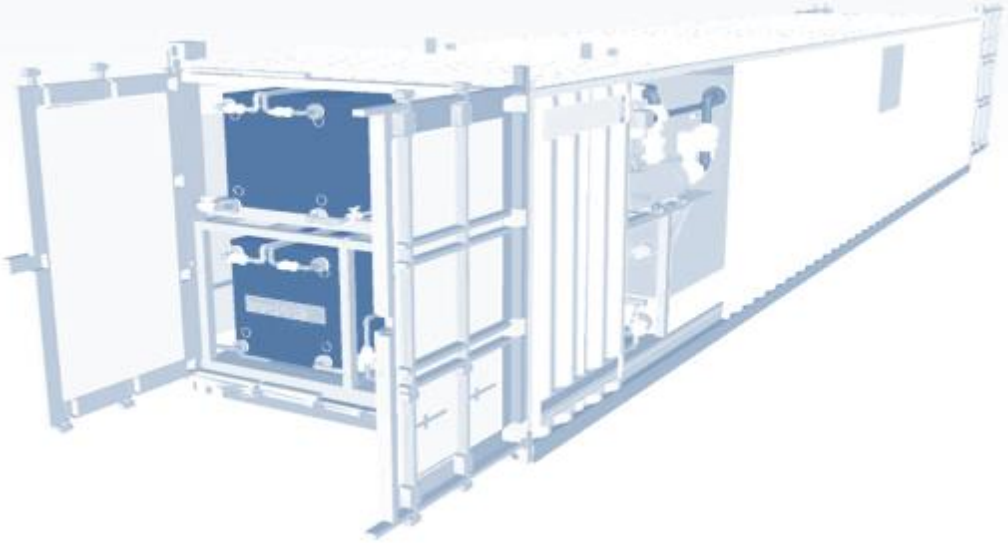

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Dispatchable Solar Power

May 2017

www.pvhstorage.com

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  - History
  - Global Installation Footprint
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- Technology
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  - Design Examples
- Operating Modes
  - Oversizing
  - Alternative configuration of EMS
- Business Models
  - Cash & PPA Structures
- PVH Energy Storage
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Introduction to Gransolar Group

GRS

Distributed Generation
EPC contractor
Operation & Maintenance

ISE

Engineering design
Quality control
Testing and Commissioning

PVH

Tracking systems
Support structure
Controllers

GRS	Distributed Generation	EPC	
ISE	Engineering	Quality control / Commissioning	Independent technical assessment
PVH	Fabrication	Structure assembly	SCADA & Corrective maintenance

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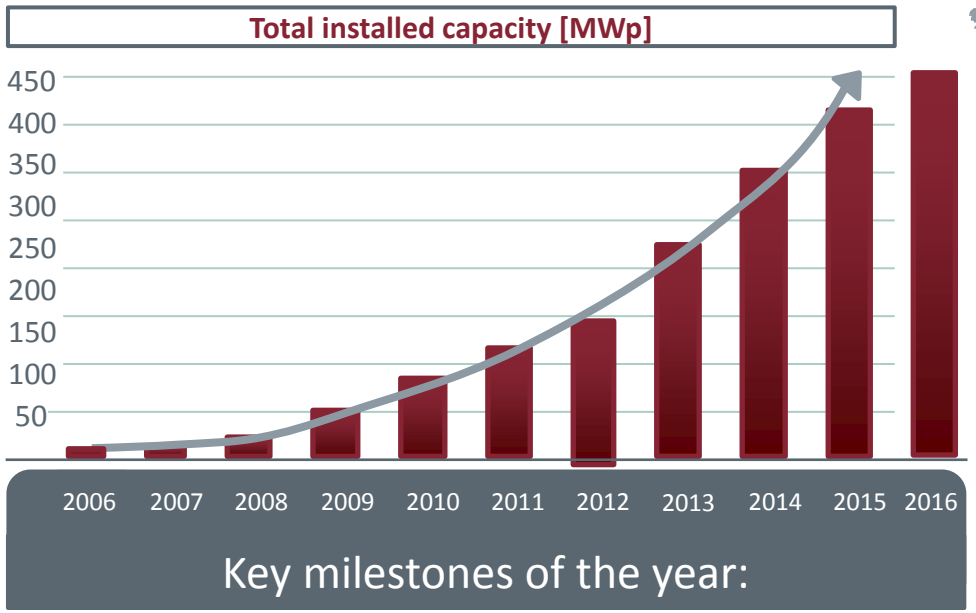
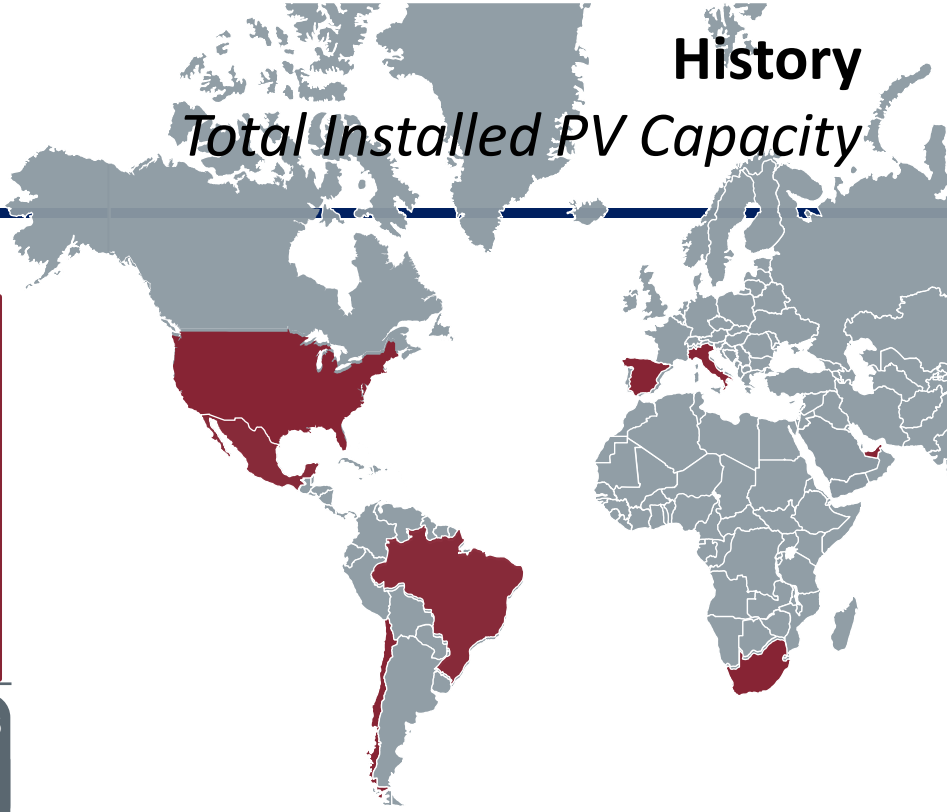
History

Total Installed PV Capacity





Key milestones of the year:

2009
Development **70 MW** in **Italy**
2 new plants in **Spain**

2010
30 MW installed in **Italy**
Incorporation of GRS **Chile** and **US**
10 MW concession contracts awarded in **Portugal**

2011
32 MW installed in **Italy**
PVH incorporated in the **US**
Incorporation of Hypesolar to develop **12 MW** in **Portugal**

2012
Award Lesedi and Letsatsi (**150 MW**) projects in **South Africa**
Incorporation of ISE **South Africa**
Construction of Bailadero (**10 MW**) in **Spain**

2013
Construction of **12 MW** in **Portugal**
Construction of **150 MW** in **South Africa**
Incorporation of GRS **Centro America**

2014
Incorporation of GRS in **Mexico** to develop **100 MW**
Construction of **6 MW** Sibo (**Guatemala**)
Award of **25 MW** in **New Mexico (US)**

2015
60 MW PPA awarded in tender process in **Brazil**
50 MW in **Philippines** (Project management and PVH supplier)

2016
Capital increase
800 MW awarded in Dubai
43 MW awarded in USA
120 MW awarded in Chile
Construction of **El Paseo** and **Cangrejera** (El Salvador)
Construction of **Camargo** (Mexico)
Construction of **Mont Choisy** (Mauricio)

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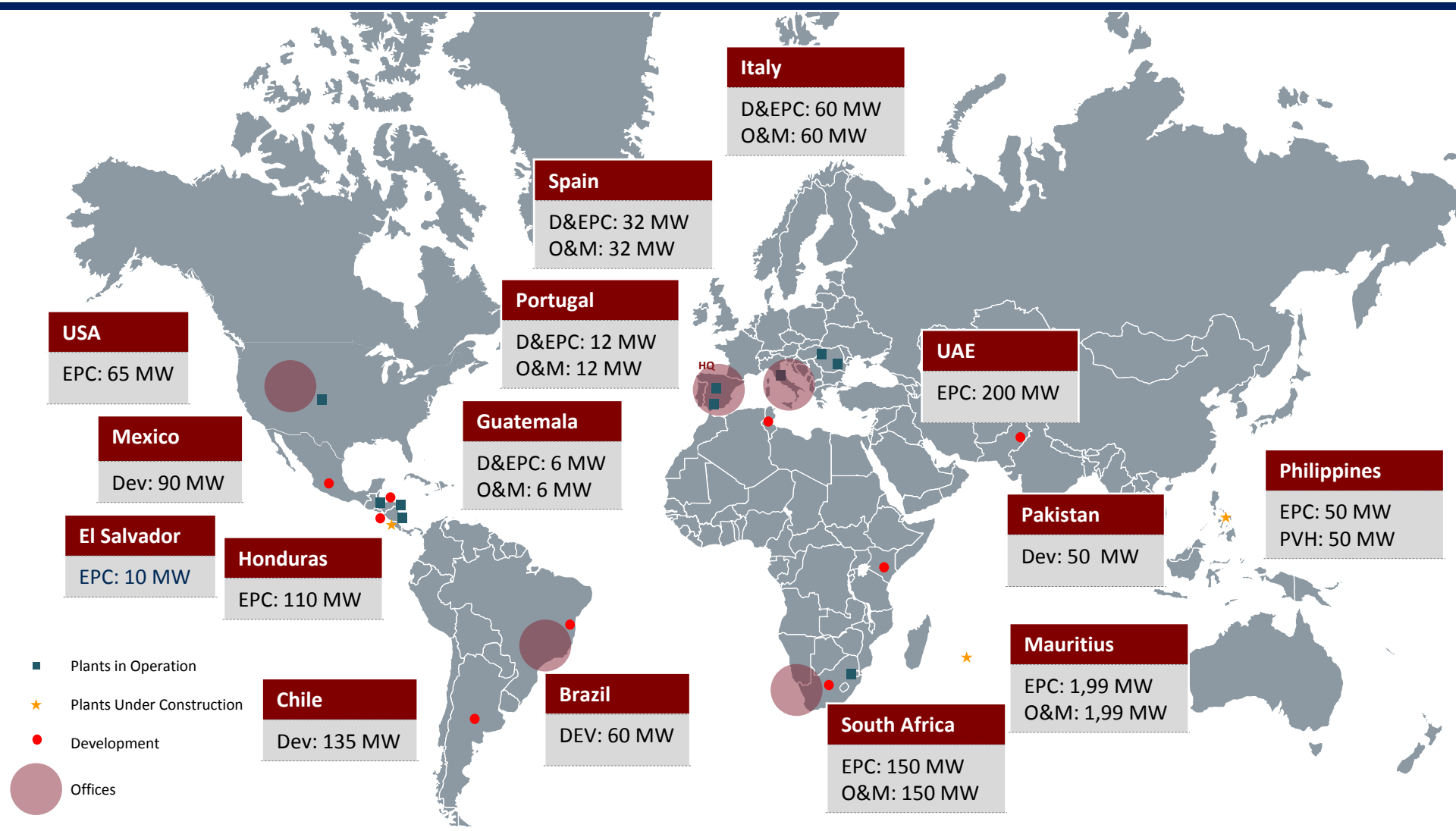
Global Installation Footprint



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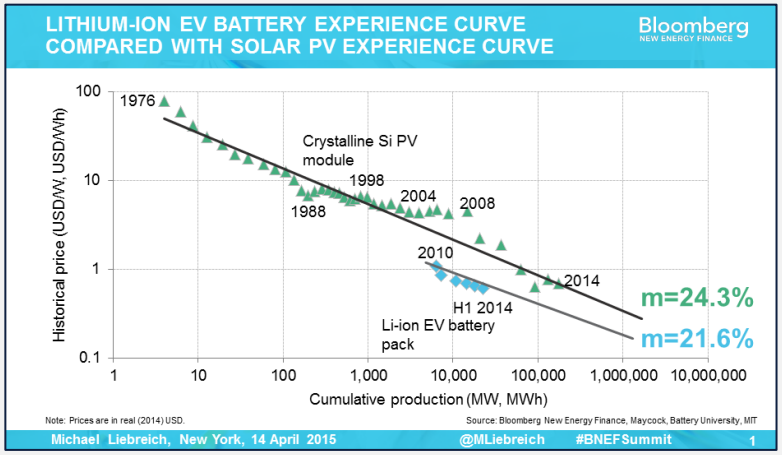
Market Status

Current vs Projection

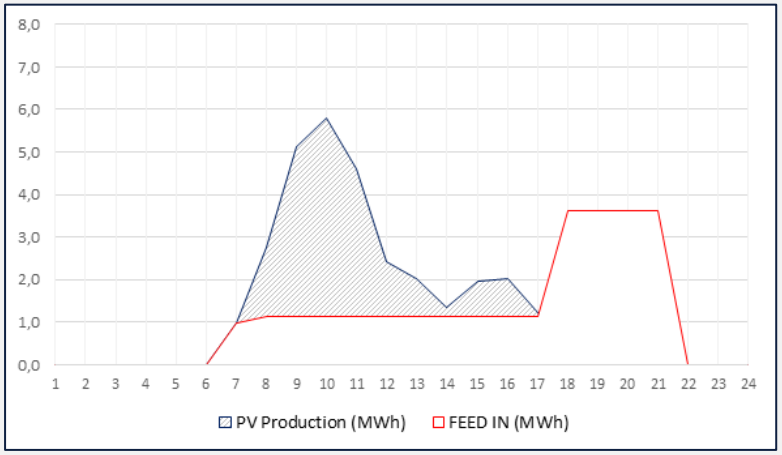
Current Status



One of many cost projections (Li-Ion cost)

- Traditional clients: off grid lead acid <30 kW size in remote or rural locations
- Load Levelling (Li-Ion) 2016 increase with multiple EU tenders
- Catastrophes driving storage implementation (South African load shedding, South Australia blackout)
- Islanded grid first users of load shifting (2 x PV w/storage on Hawaii 2016-17)

Market Projection



PVH battery in use on PV plant (simulation)

- Load shifting taking form with hybrid business cases of **price arbitrage** and **capacity/demand reduction** as main drivers
- Large PV and Wind projects being planned with storage
- Large utility **capital investment deferral** projects with storage to avoid grid upgrades
- Industrial clients taking lead on storage (data centres, mines, large users)

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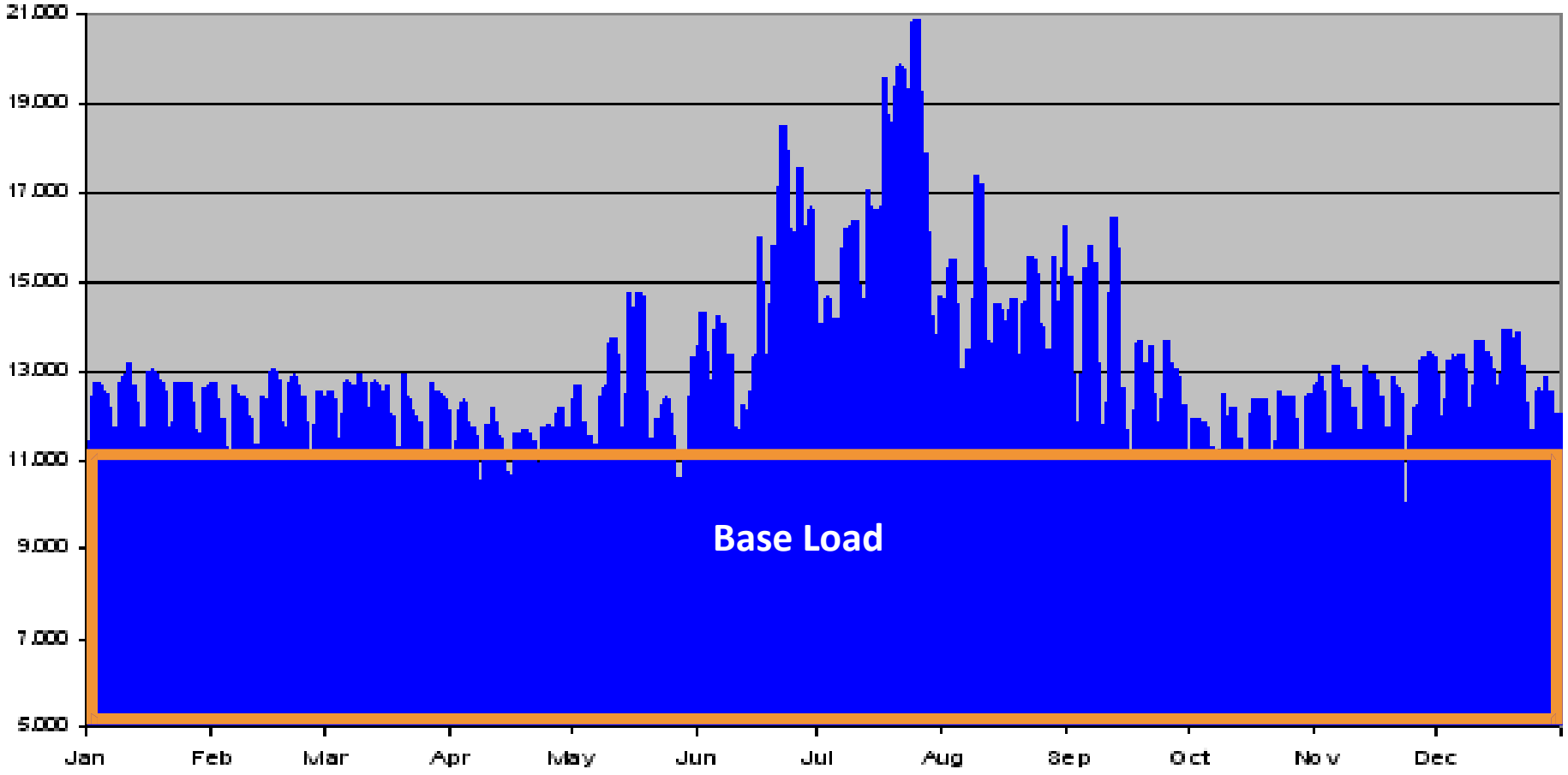
Electricity Terminology

Base Load

Typical Season Load Profile



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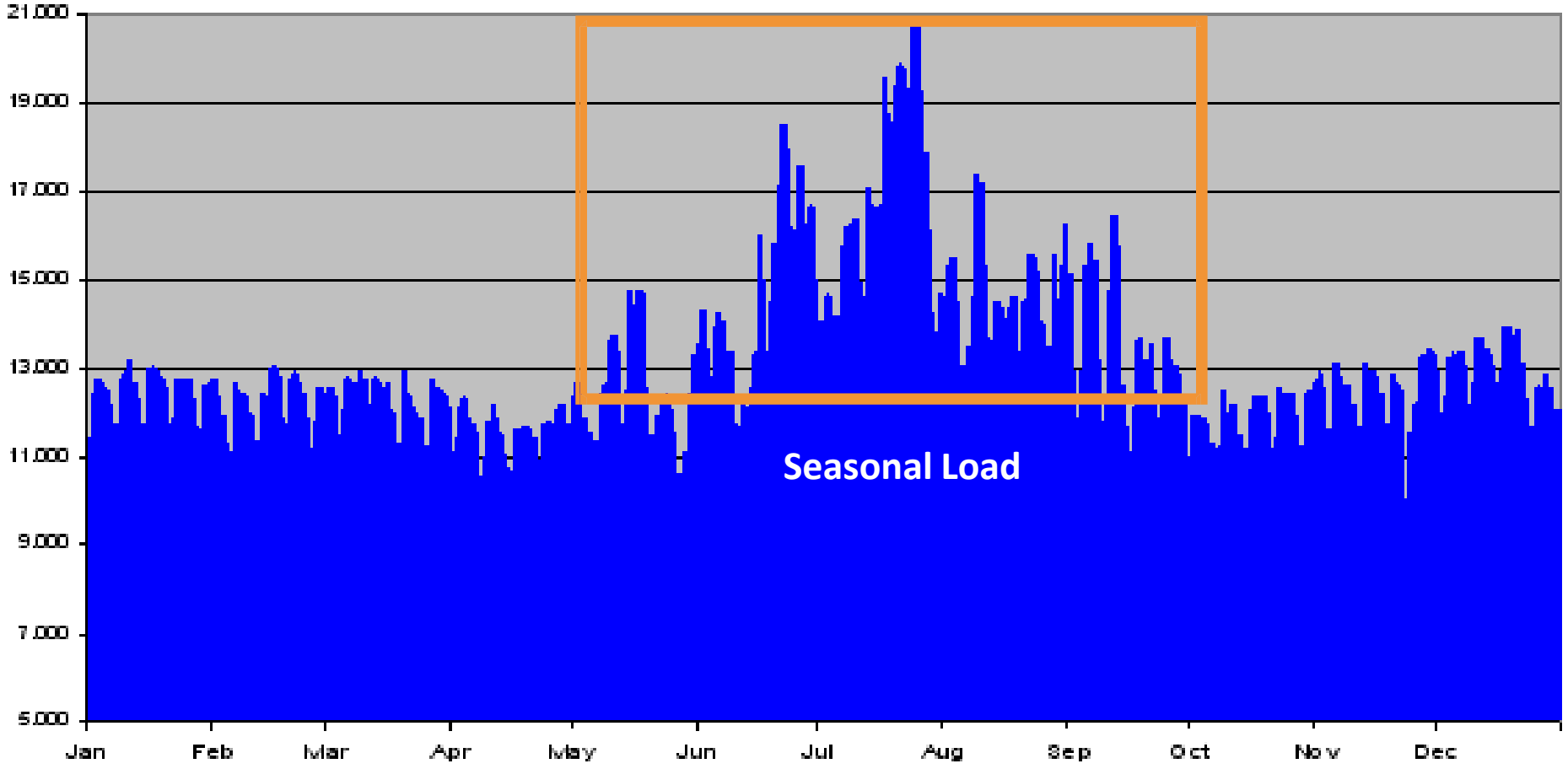
Electricity Terminology

Seasonal Load



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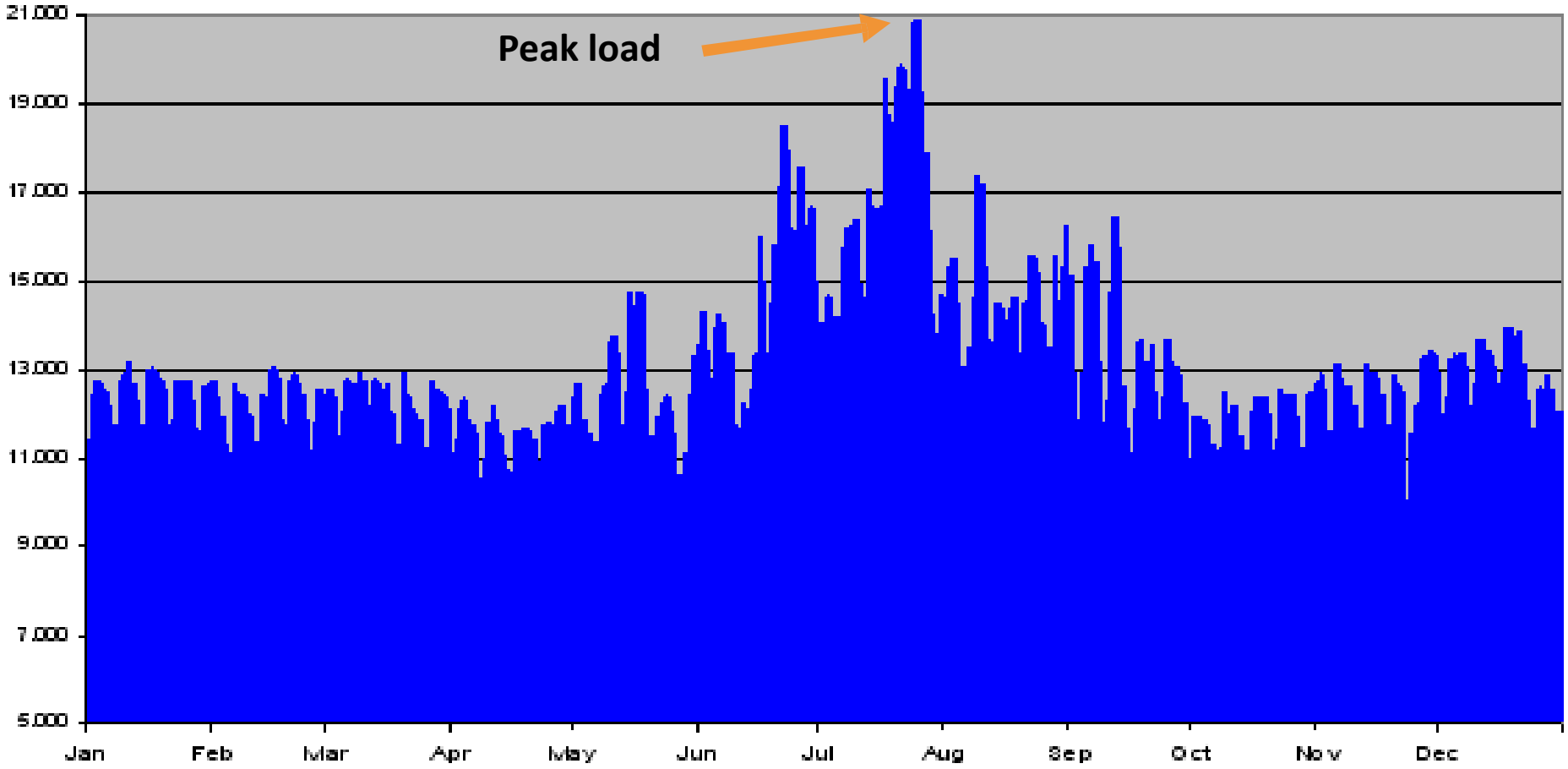
Electricity Terminology

Peak Load



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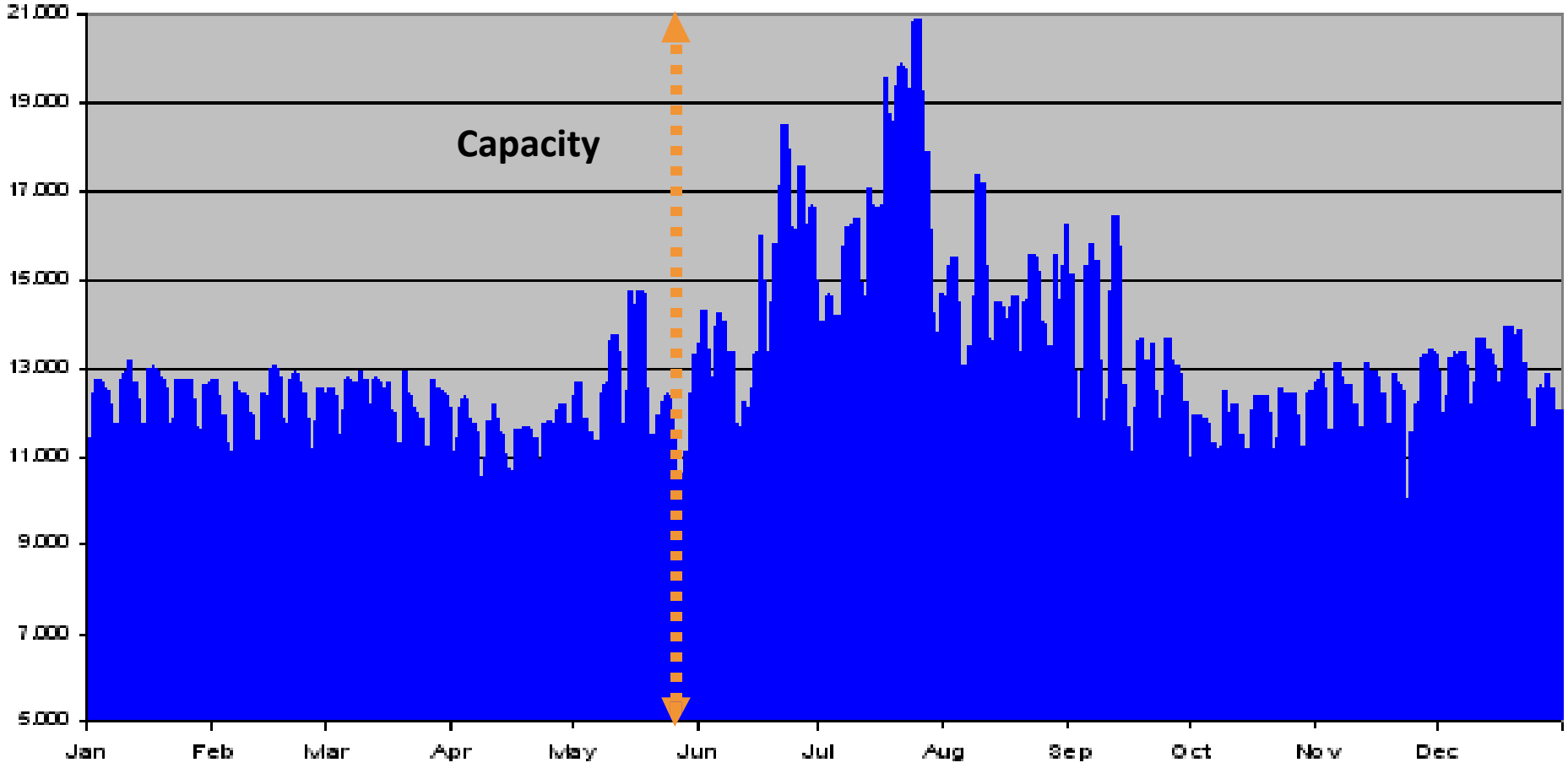
Electricity Terminology

Capacity



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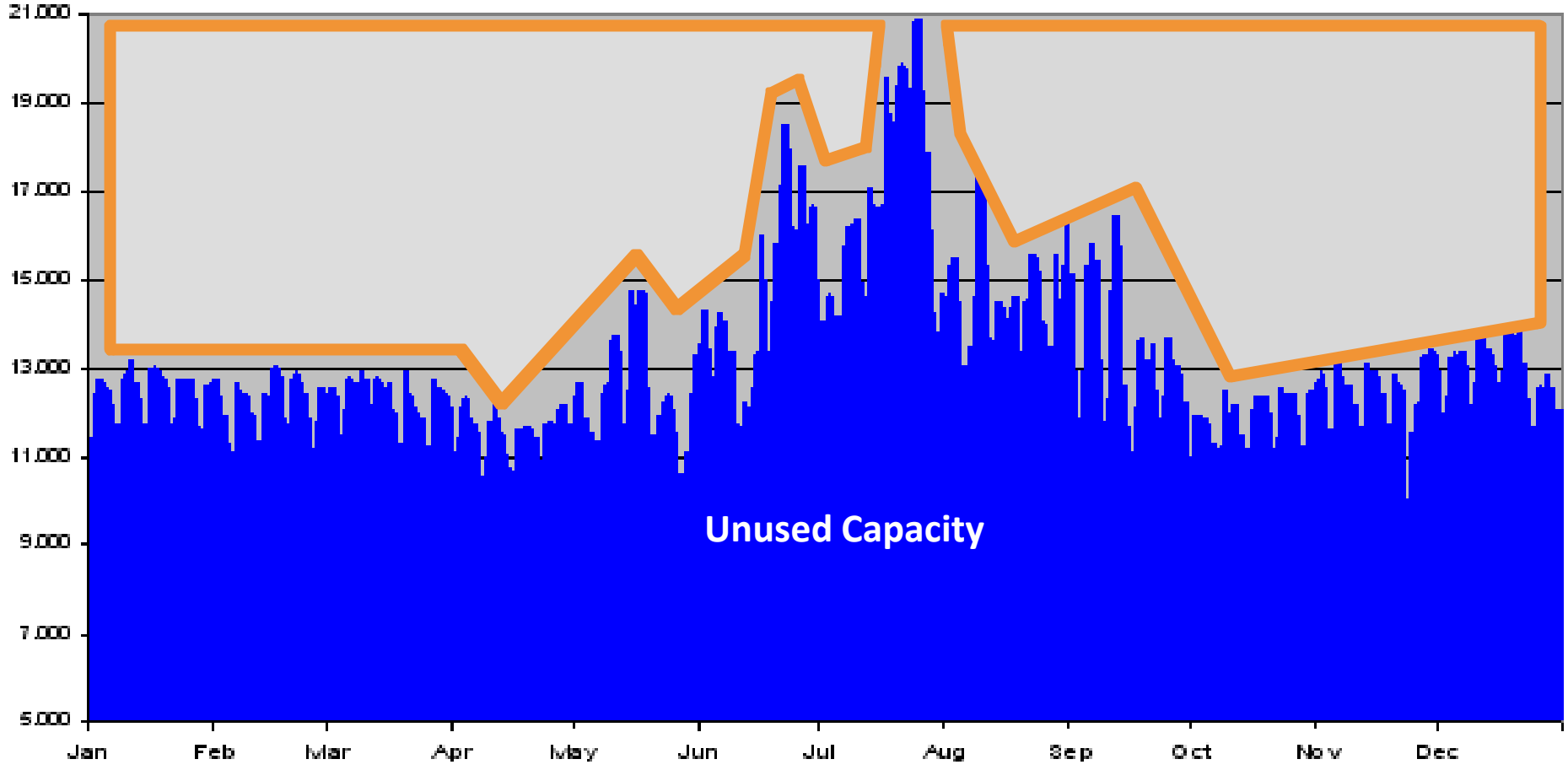
Electricity Terminology

Unused Capacity



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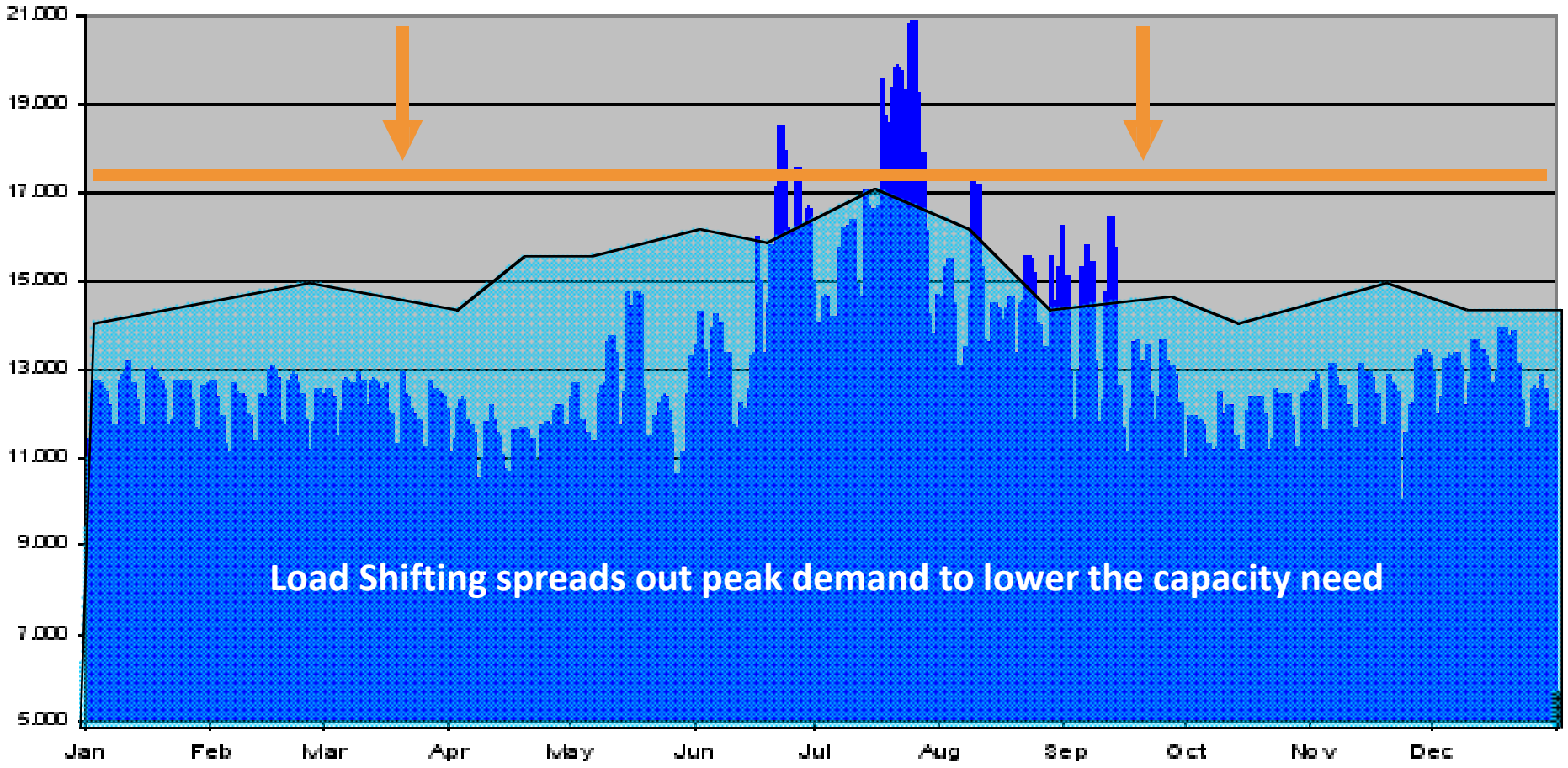
Electricity Terminology

Load Shifting



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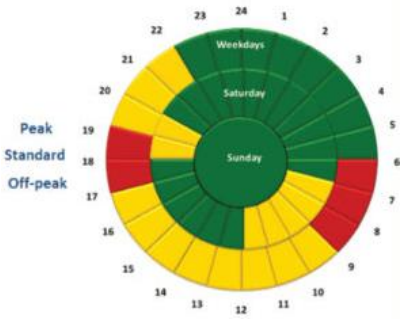
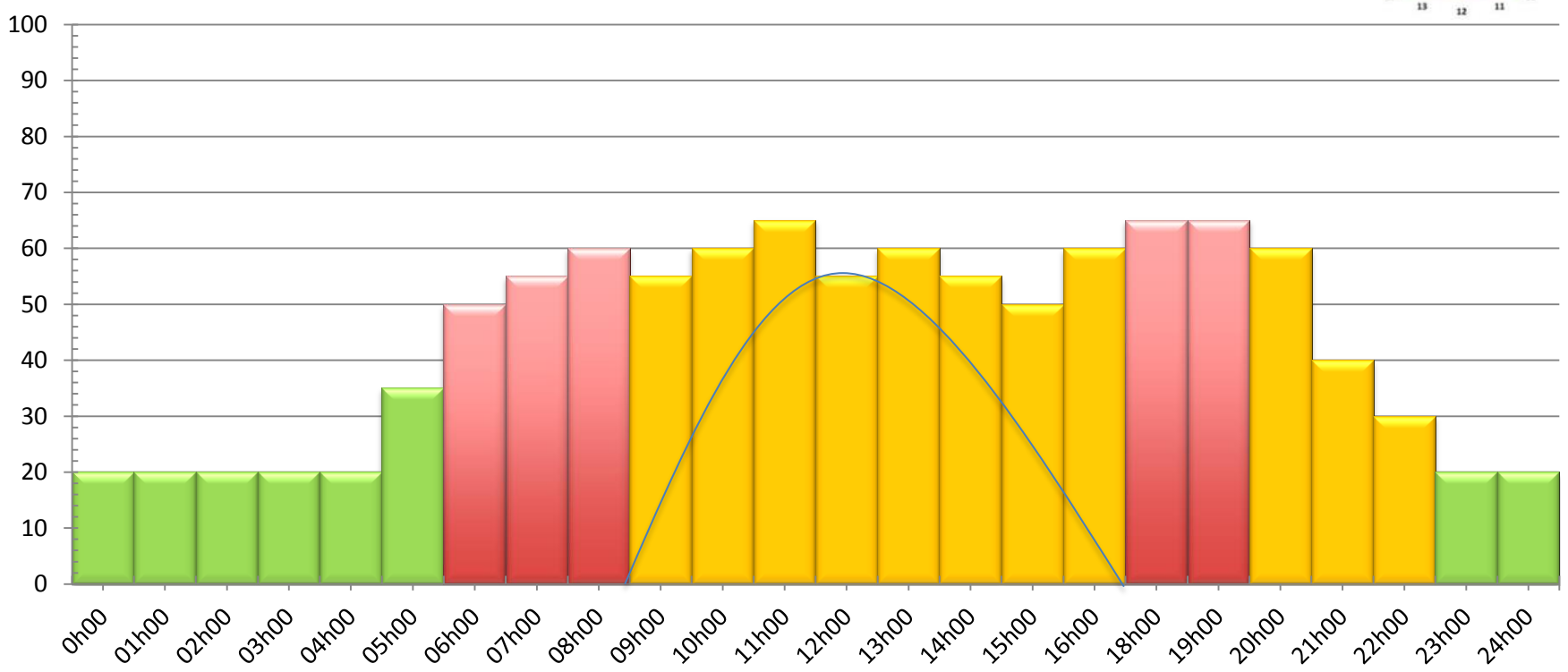
Time of Use Tariffs

Electricity Consumption vs Solar Production



Illustrative Load Profile over 24 hours



Photovoltaic System Sizing

- Imagine a car:
  - 300HP is the MAXIMUM horsepower the 3.7L V6 engine can deliver at its peak **power** output / performance **(power = kW)**
  - 1000kWp PV System refers to the 1MWp peak MAXIMUM output the system will produce in full sunlight **(kWp – Kilowatt Peak)**

- System sizing is described as the PEAK output in full sunlight under ‘Standard Test Conditions’ and can refer to **AC (kW)** or **DC (kWp)**

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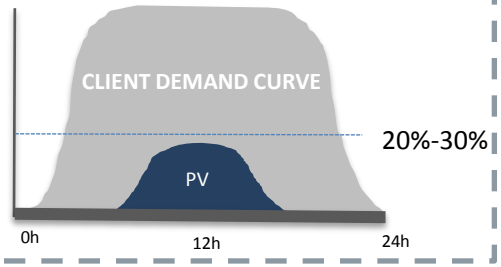
Technology
Introduction to PV

Typical Design Methodologies

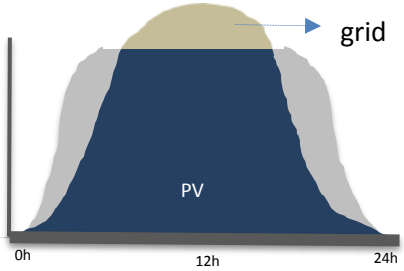
Type 1: Self Consumption.

Solar System dimensioned to 20-30% of client consumption
No interference with Grid
Can be larger depending on load profile analysis



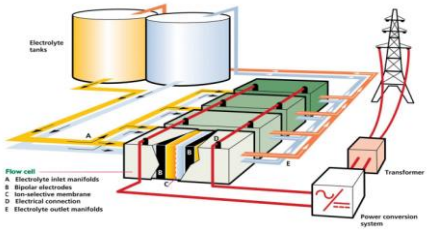
Type 2: Excess to be injected in the grid

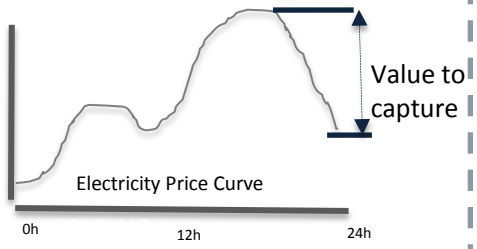
Optimize solar system with production excess injected back to the grid
Requires Net Metering and agreement with Utility



Type 3: Solar + Storage

Solar System + Storage ideal for large base loads
Capture high tariffs during peak hours 18:00 to 20:00





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Technology

Introduction to Storage

Power vs Capacity

- Imagine another car:
  - The **power** is the horsepower of the engine, the bigger engine the faster acceleration **(power = kW)**
  - The range you can drive is determined by the size of the fuel tank (or for EV's the size / capacity of battery), the bigger the tank, the longer the range **(capacity = kWh)**

- Traditional PV Plants: **kW** defines **power output** only. **kWh** defines the **volume of power output** delivered over **time**
- Energy Storage Plants: **kW** defines **charge/discharge power**. **kWh** defines the **time** one can deliver a set **kW power output**

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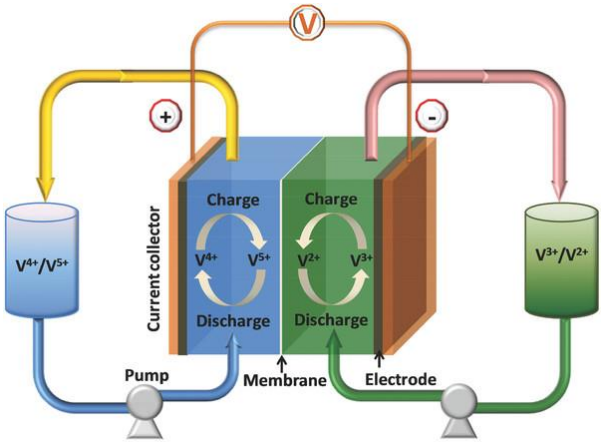
Technology

Introduction to Storage



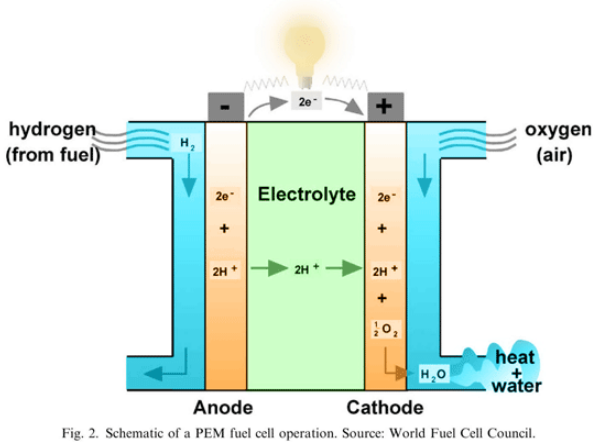


Fig. 2. Schematic of a PEM fuel cell operation. Source: World Fuel Cell Council.

Rechargeable Batteries

- Lead Acid
- NiCd, NiMh
- Li-Ion
  - Lithium Iron Phosphate
  - Lithium Manganese Oxide
  - Lithium Nickel Manganese Cobalt Oxide

Flow Batteries

- *Vanadium*
- Zinc Bromide
- Iron
- Future Technology - Organics (Hydrocarbon)

Fuel Cell (Chemical)

- Hydrogen & Oxygen

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Technology
Design Examples

Spinning Reserve *10% Power @ 15 minutes* **Value Proposition:** Off-grid applications – allows generators to start up or be taken off line. Ramp rate control – Fill solar PV production gaps on cloudy days.	**Load Levelling** *10-25% Power @ 2-4 hours* **Value Proposition:** Intermittency - Day time PV plant production levelling (ramp rate control). Therefore offsets daytime consumption only. Helps increasing renewable penetration.
Load Shifting (Base Load Plants) *25-40% Power @ 4-6 hours* **Value Proposition:** Solar + Storage offers a stable output for up to 16 hrs/day acting as a base load. Helps increase renewable penetration.	**Peak Hour Plants** *>50% Power @ 4-6 hours* **Value Proposition:** Offers a priority of early evening feed in from the Storage, typically after sunset. Includes Dual Cycling capability of day time charging with solar and off-peak night time charging from the grid.

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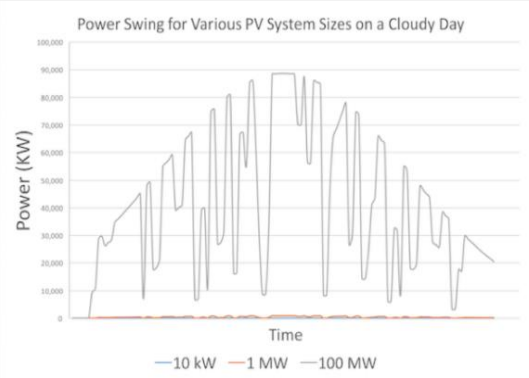
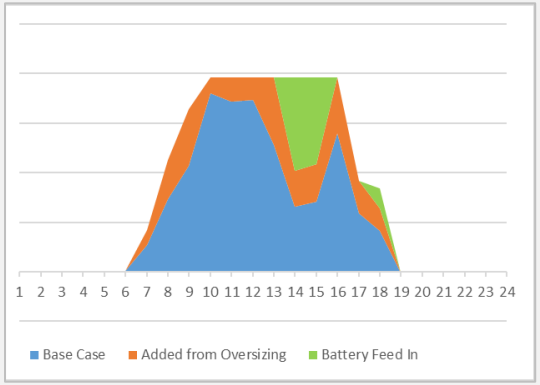
Technology
Design Examples

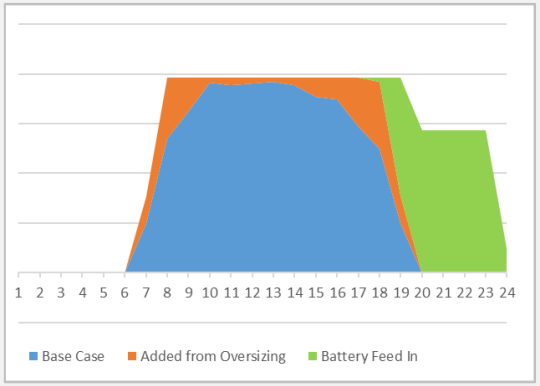
Spinning Reserve



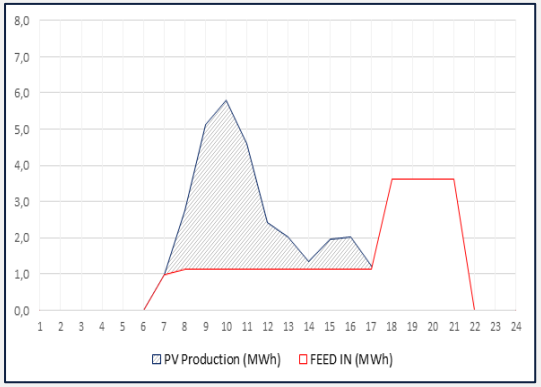
Load Levelling



Load Shifting (Base Load)



Peak Hours Plant



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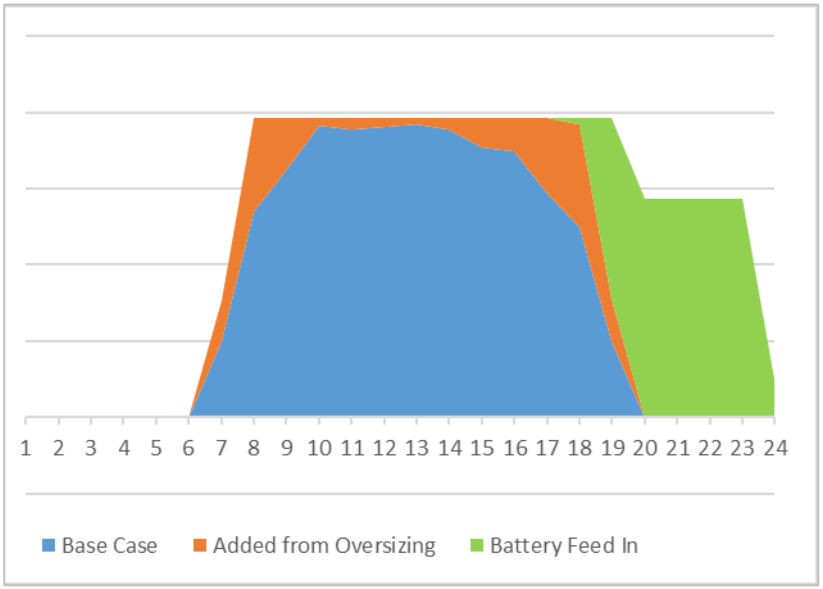
Operating Modes
Oversizing



Solar PV with no Storage (Blue Only)	Solar PV with Storage (all colours)
Slide shows 7th of May production with average solar output; no cloud cover but reduced output in the morning and afternoon and below the baseload requirement at midday peak.	
Bell shaped production curve	No intermittency due to oversizing and storage
No evening production	Evening production is stable and predictable
A majority of days would have no intermittency and a large evening production	

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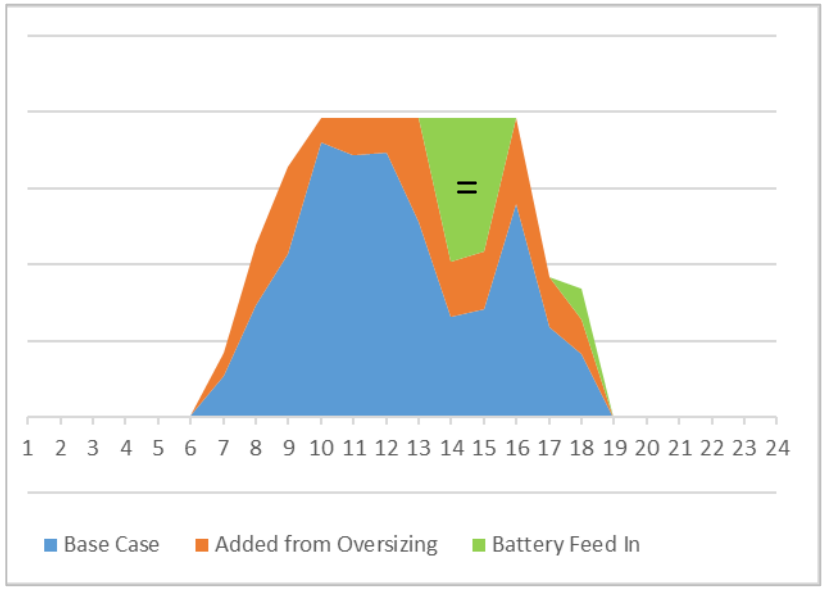
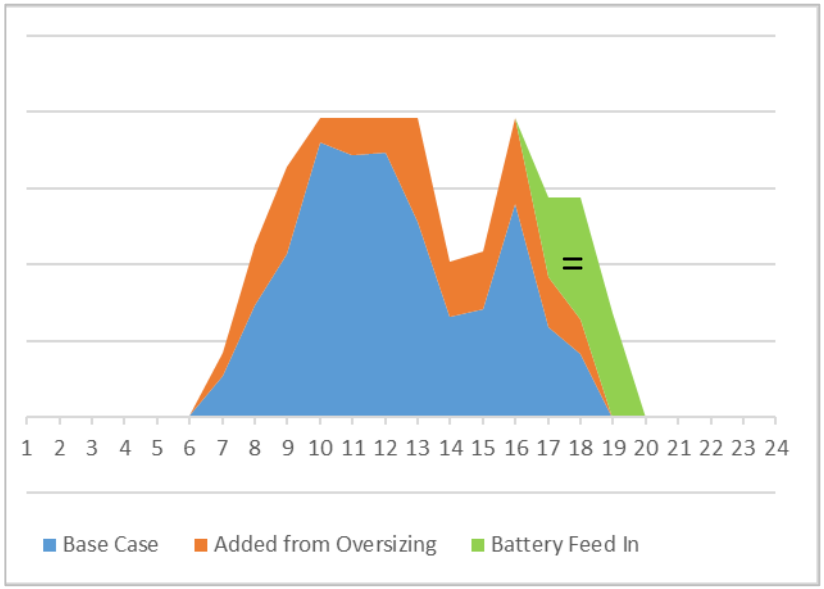
Operating Modes

Alternative configuration of EMS





Intermittency Prioritized	Evening Prioritized
Both graphs show April 25th production; a below average day with low solar production due to early-midday and an afternoon cloud cover reducing output significantly (50% reduction)	
When Intermittency is prioritized the battery discharges most of it's power during normal sun hours to avoid variations in daytime production	When evening is prioritized the plant has intermittent daytime production but a stable and predictable evening production
Flexibility in operations: the prioritization can be changed as required by the off taker (daily)	

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Business Models

CASH vs

Power Purchase Agreement

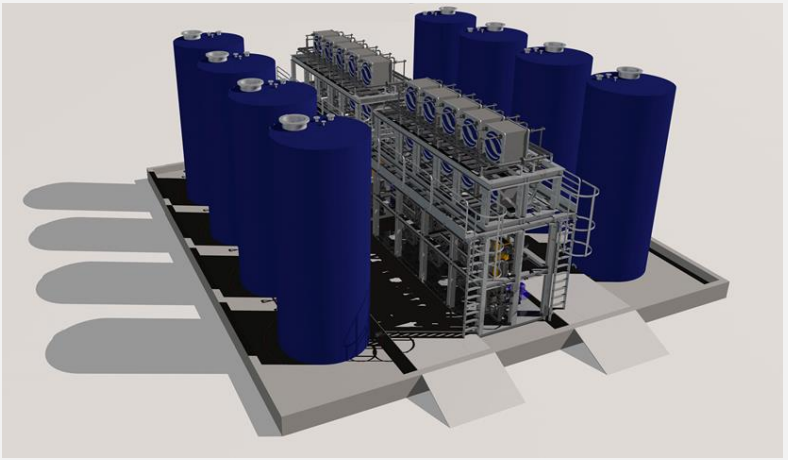
		Intermittency	Load Shifting
Flat Rate	- Rate based on stable baseload consumption applications - Daytime production is prioritised (no intermittency) - Storage reacts to poor day time weather conditions caused by cloud cover.		
Peak Hours	- Rate based on peak hour consumption applications - Evening (peak hours) production is prioritised (no intermittency) - Storage does not react to poor day time weather conditions caused by cloud cover.		

PVH Energy Storage
Product Line-up

Containerized

- 200 kW power
- 1000 kWh capacity
- Ideal for off grid or C&I projects
- Matches well with 400-500 kW solar PV plant
- Simple installation on site
- Delivered complete with DC/AC inverters and SCADA system
- Life expectancy >20 years or 20.000 cycles
- Temperature range without cooling/heating: -5 to 50 degrees

Large Scale



- 500 - >1000 kW power
- 4000-6000 kWh capacity
- Ideal for large scale PV plants and utility interconnections (substations)
- Requires rodent proof and water tight building (simple industrial building)
- AC MV connection, SCADA included in EMS
- Life expectancy >20 years or 20.000 cycles
- Temperature range without cooling/heating: -5 to 50 degrees

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PVH Energy Storage

Pipeline

PVH Energy Storage

Contact

CONTACT

www.gransolar.com
www.pvhstorage.com

DYLAN TUDOR-JONES

dtudor-jones@gransolar.com

+27 (0) 82 450 4619

MADRID
Sepulveda, 17, Pª Baja 1 y 2
Alcobendas Madrid 28108
España
+34917 364 248
España
madrid@gransolar.com

EEUU
222 Sutter St; # 410
San Francisco, CA 94108
Tlf: +1 (415) 243-4469

MEXICO
Avenida Paseo de la Reforma
412 Planta 7
Colonia Juárez, Delegación
Cuauhtémoc CP 06600
Mexico D. F.
Tel. +52 (1 55) 41235148

BRAZIL
Rua Antonio Christi, 453
Parque Industrial Jundiaí 3
Cep 13213-183 – Jundiaí / SP

SOUTH AFRICA
Unit 102A, 1st Floor Atterbury
House Hampton Office Park
20 Georgian Crescent East
Bryanston, Johannesburg
+27 (0) 104 920 558

ALMERÍA
Antonio Cano, 140
1º Izda
04009 ALMERIA
España
Tel: +34 950 278 020

VALENCIA
Polígono Industrial Castilla,
Vial 1, nº 13
46380 Cheste (Valencia)
España

DUBAI
Damac Smart Heights
23rd Floor, Suite 2311 P.O.Box
393578, Dubai, UAE