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Advanced SOFC CHP Solution

Presentation to APEC Southern Illinois Chapter

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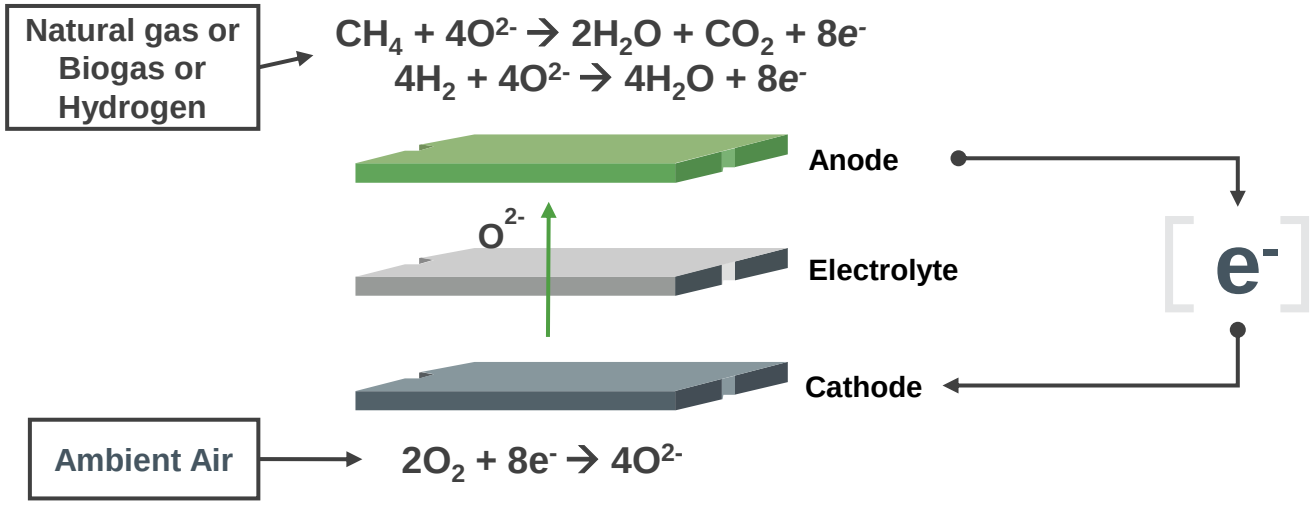
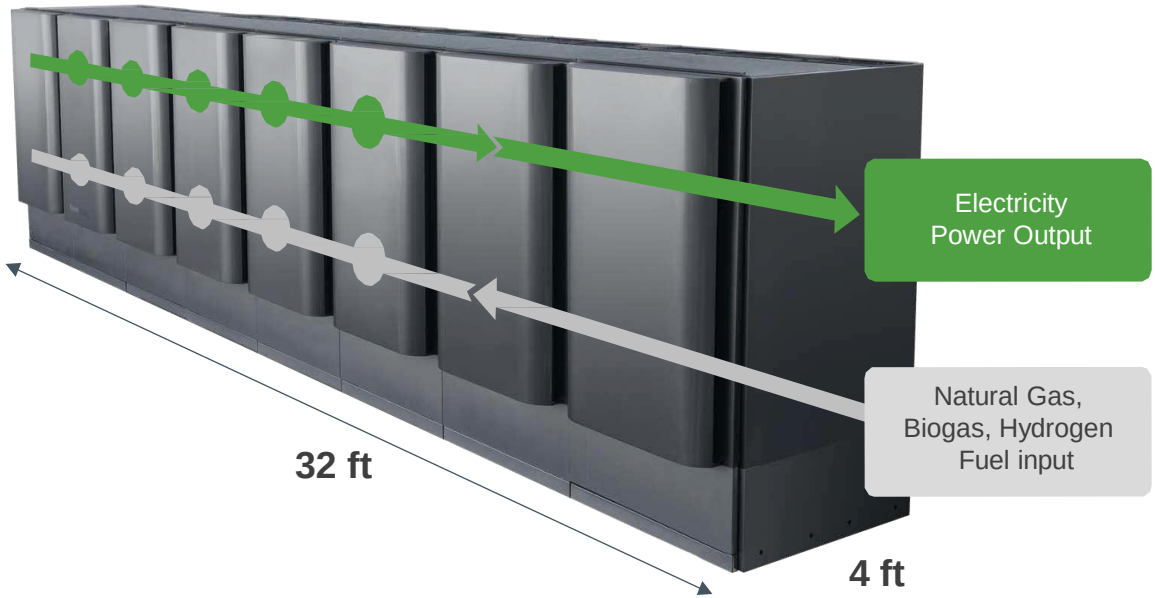
SOFC Technology – How it works

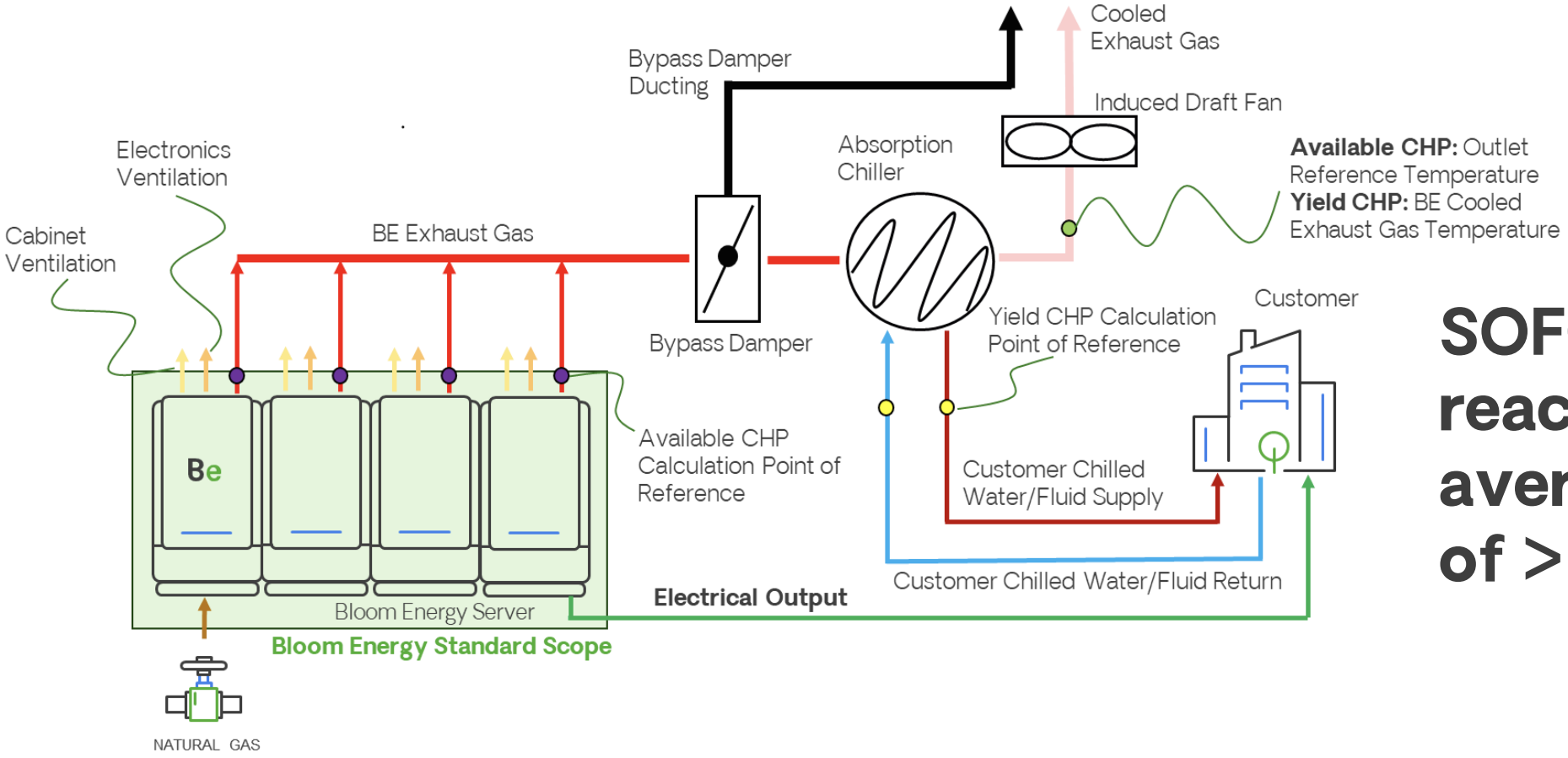




Key advantages

- High efficiency
- UPS quality power
- Clean exhaust
- No water
- No manpower
- Carbon capture friendly and H_2 ready

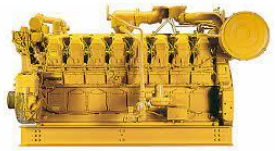
Advanced SOFC CHP Solution



SOFC with CHP reaches a lifetime average efficiency of >90%

Clean Electricity | **Steam** | **Cooling** | **Hot Water**

Advantages of SOFC CHP solutions



	Gas Engines/Turbines	Fuel Cell	
Application	Backup and Continuous Power	Baseload Continuous Power	Ideal for 24x7 operations… data centers, pharma, manufacturing
Electrical Efficiency	25% to 45%	54% lifetime guarantee	Very high lifetime electrical efficiencies
Exhaust Temp.	High ~380 to 500 ˚C	Moderate High ~360 to 435 ˚C	High quality exhaust heat
CHP Efficiency	Up to 85%	~85 to 93%+	Very high CHP efficiency
Emissions	NOx in Flue Gas, High CO_2	No NOx & SOx, Low CO_2	High sustainability benefits and simpler permitting
Others	Expensive carbon capture, limited H2 flexibility, noisy	Carbon capture friendly, 100% H2 capability, no rotating parts	Futureproofed for zero carbon generation

Advanced CHP solutions of SOFC are perfect fit for balanced Electrical & Thermal efficiency

Evolution of SOFC CHP solution

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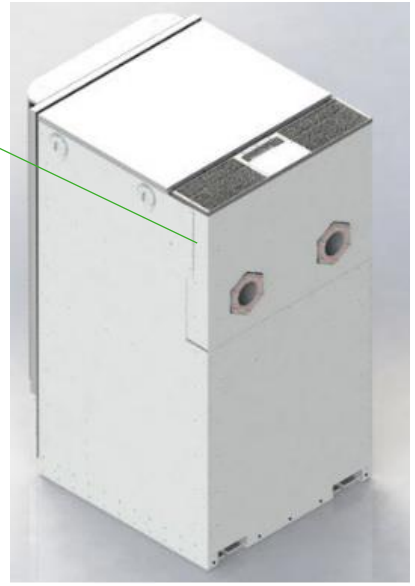
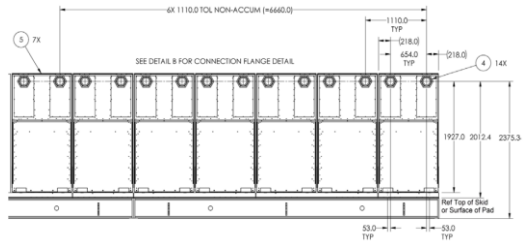
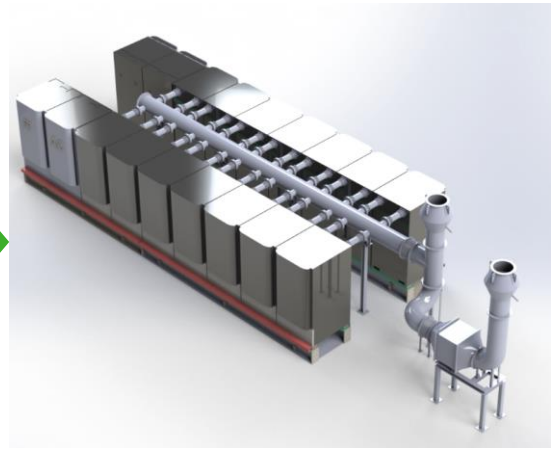
Rear side of fuel cell







Non-CHP solution

Exhaust mixed with cold air and vented to atmosphere

CHP solution with flanges to recover hot exhaust

New development to recover exhaust heat

Multiple modules design

Multi module design including validation for backpressure sensitivities

Heat recovery equipment and control logic integration

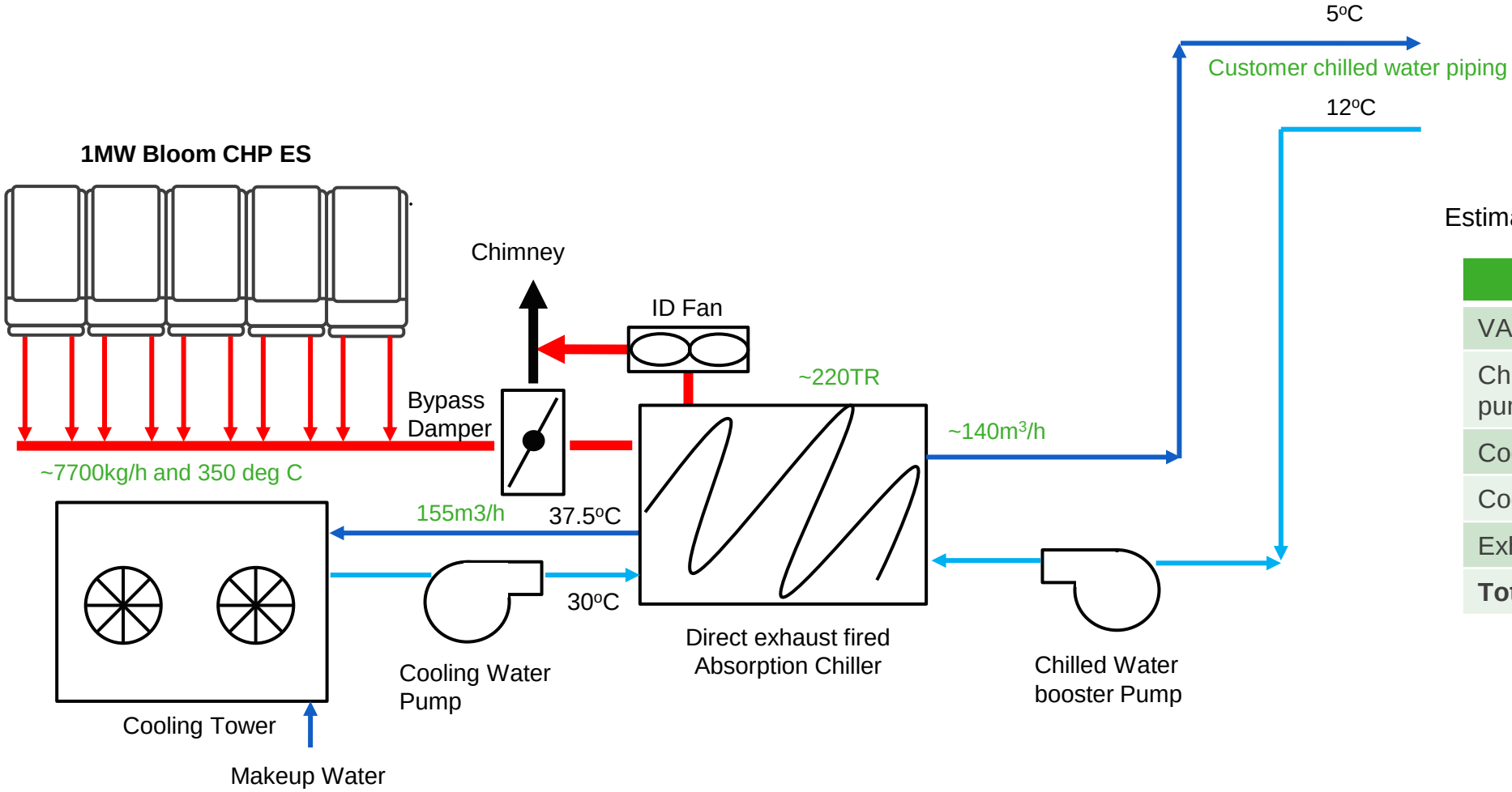
Full plant solution including system integration for high pressure drop applications

Developed & validated solution reaching high downstream backpressure ensuring safe SOFC operation

SOFC CHP installation - Italy

SOFC CHP installation South Korea

SOFC CHP cooling use case



Estimated auxiliary power consumptions

Equipment	kW
VAM chiller	5
Chilled water booster pump	8
Cooling water pump	15
Cooling tower fans	12
Exhaust ID fan	15
Total Aux power	**55**

Indicatory values. Subject to project specific evaluation

Electrical savings of approx. 1.5Mil kWh/yr & Co_2 reduction of approx. 1200 tons/yr

SOFC CHP Performance

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Electrical output= 1010 kW_e (from SOFC data)

Thermal output = 220 x 3.5 = 770 kW_{th} (from VAM performance data)

Aux consumption = 55 kW_e (from aux. equipment sizing data)

Fuel input = 1909 kW (From SOFC data)

$$\text{CHP efficiency} = \frac{\text{Electrical output} + \text{Thermal output} - \text{Aux consumption}}{\text{Fuel input}}$$

CHP efficiency = (1010 + 770 – 55)/1909 = 90.3%

Indicatory values. Subject to project specific evaluation

SOFC CHP Sustainability advantage

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Heat Capture
~400°C

819 lbs. CO_2/MWh

	Emissions reduction	CHP Efficiency
25 TPH Hot water	System-wide emission reduction of **284 lbs. CO_2/MWh (-35%)**	**~90%+**
or		
0.9 TPH Steam	System-wide emission reduction of **253 lbs. CO_2/MWh (-30%)**	**~85% to 90%**
or		
220 TR Chilling	System-wide emission reduction of **155 lbs. CO_2/MWh (-20%) + ~5% from HFCs**	**~90%+**

Equivalent to ~20% extra electrical efficiency

24x7 reliable power & heat + lower overall emissions profile…
…even compared to grids with high renewable penetration

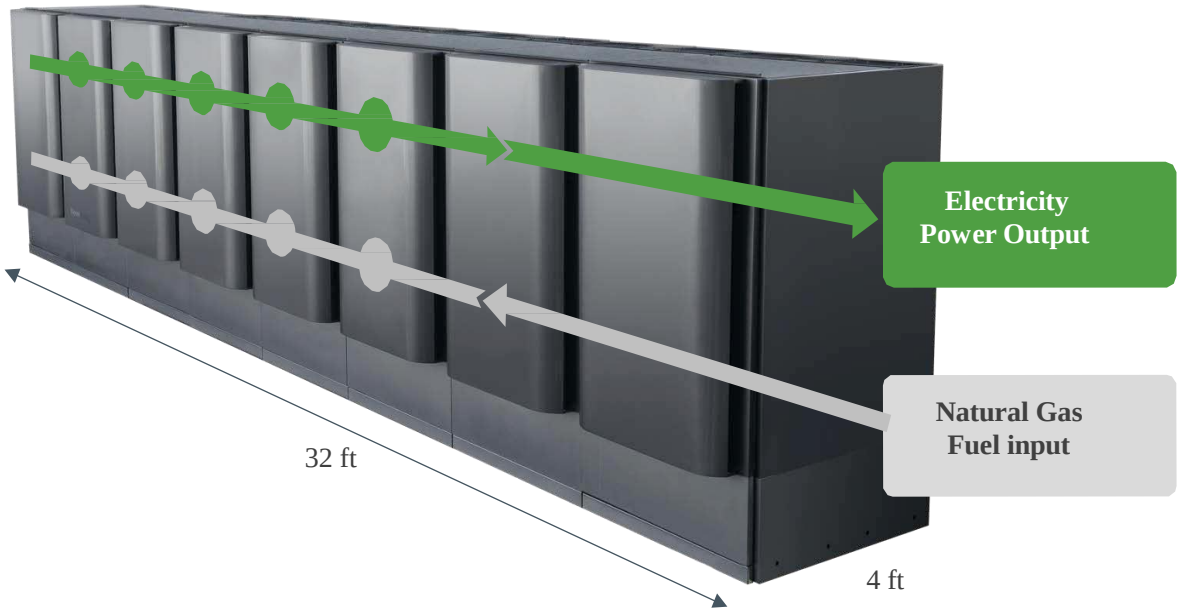
Status quo solution assumptions: Hot water: 70C in 90C out 95% HX eff, (5 deg duct loss), Steam: 6 bar (g) saturated, 90% boiler eff.; Electric chiller 0.8kw/ton. 2% of CHP efficiency reduction attributed to aux power requirements. Grid emissions at 880 lbs Co_2/Mwh. Condensing economizer not considered.

Bloomenergy®

What
Powers
You

The Bloom Energy Server

- **Delivers Always-On, Onsite Power** Hot-swappable and redundant design availability >99%
- Converts Natural Gas/Biogas/hydrogen to Electricity **without Combustion**
- **World Leading Efficiency >60%** Beginning of Life and Lifetime Average Contracted Efficiency 54%
- Mission Critical Reliability in cases where **uninterrupted power** is required
- **Clean:** Low/no CO2, Virtually no NOx, SOx or Particulate Emissions
- **No water is required** during operation
- **No Man Power** requirement for operation, system is Remotely managed and monitored by Bloom Energy
- Electrical tie-in at 400, 415V or 480V, 50Hz/60Hz



Modular and Reliable

Always On

Clean