Upgrading CHP to Hybrid CHP

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Topics

I. What are some gaps in the value-proposition of CHP?

II. What is a Hybrid system and how will it meet the needs?

1. What are the features?
2. Benefits of Hybrids?
3. Who are seeing the benefits?

III. Modeling outcome to show the value of CHP Hybrids

IV. Conclusions

I. What are some gaps in the usage of CHP?

- **Economics: CHP is not considered economical when there is not sufficient thermal load**
  - **CHP is sized to the thermal or electric load, rarely both. If sized to thermal load, a project could miss the electric opportunity. Many "commercial" clients do not have sufficient thermal load**
  - **Solar and other renewables can be alternates – but they are not 100% ideal solutions either**

- **How can CHP have a higher value proposition for all end-users?**

II.1. Traditional Distributed Energy Resources (DER)

- CHP: "Base Loaded" Application
  - Natural gas, bio-gas, waste-to-energy
  - Reciprocating Engines
  - Turbines – Micro and Combustion
  - Fuel Cells

- Solar: "Variable" Renewable Technology
  - Zero fuel cost and rapidly decreasing capital cost
  - "Passive system" – requires little complex maintainance

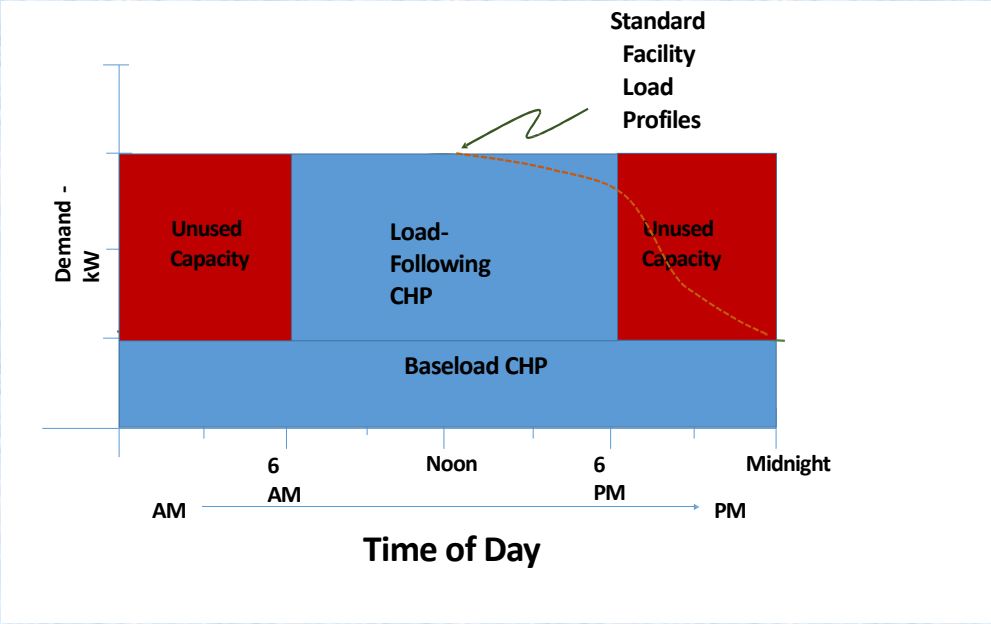
- Energy Storage: "Flexible" Technology
  - Provides an ability to store electricity for later use
  - Capable of providing multiple discharges from 30 min. - 6 hrs.

Majority of DER assets today are targeted at behind-the-meter, facility based benefits.

II. 1. Limitations of Individual DER- CHP

- For electricity "following" systems, CHP is optimized to "baseload" consumption

- However, base-loaded application provides little flexibility for other revenue streams outside its operating profile

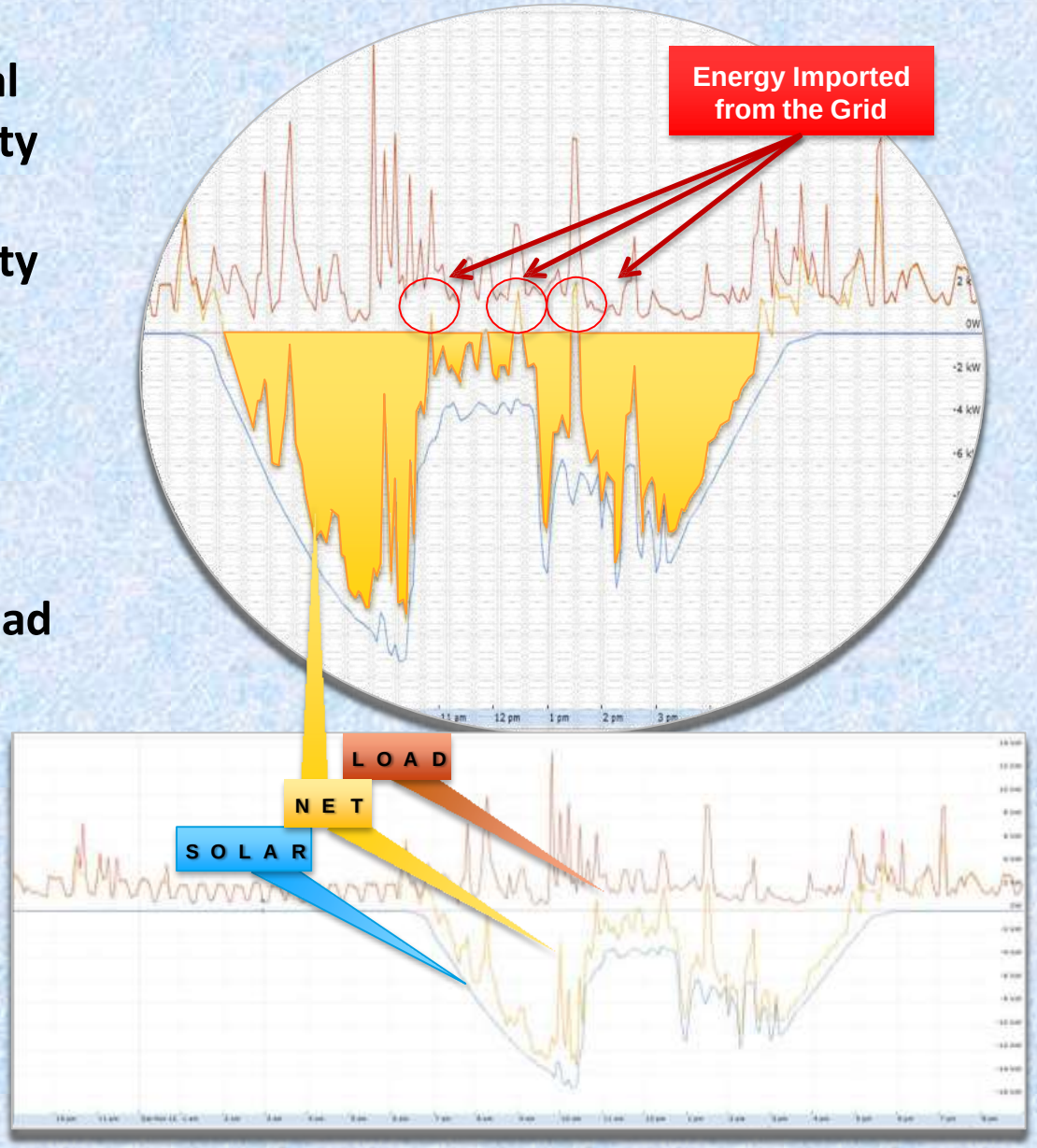


- The unused capacity and capital for that capacity makes the CHP project uneconomical

II.1.Limitations of Individual DER -Solar

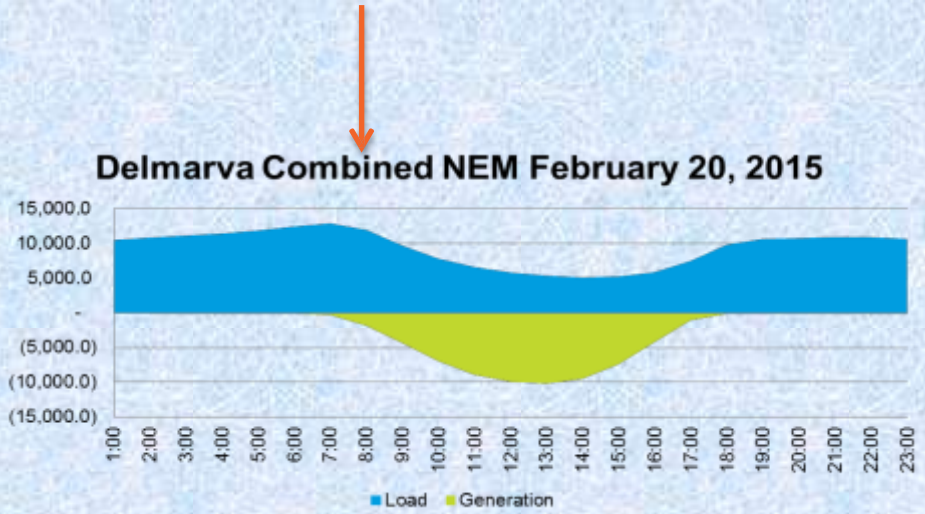
1. Capacity factor – Annual energy a typical PV system is ~14-18% of its rated capacity times 8760 hrs./yr. To produce any significant amount of energy, the capacity of the PV system will be larger than the minimum load of the premise.

2. Intermittency – because solar is intermittent, we see greater load/gen swings than with only the diversity of load



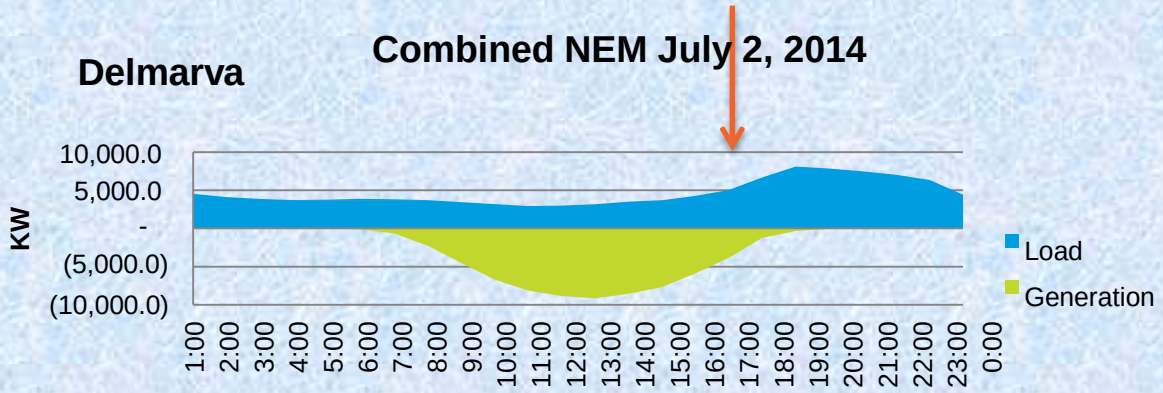
II.1.The Limitation of Solar (contd.)

System Winter Peak @ :08:00Hrs



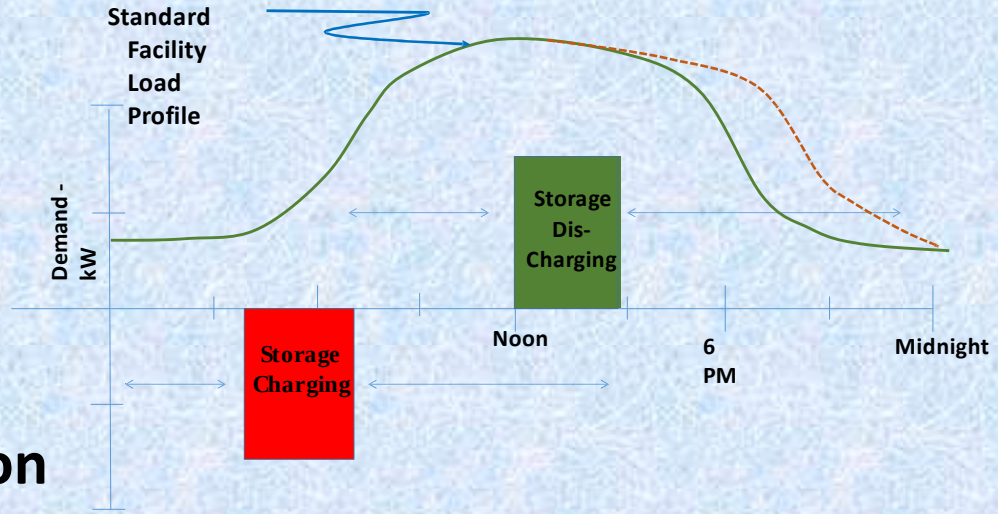
3. Output Profile – the output profile doesn't match the load profile of the premise or aggregate system load (shown)

System Summer Peak @ 17:00 Hrs



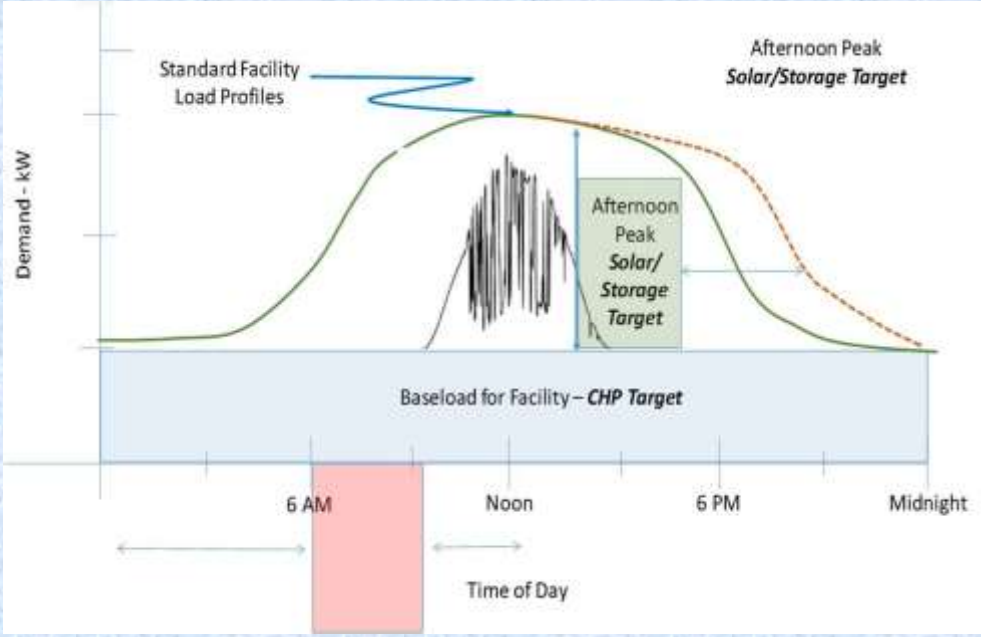
II.1. Limitations of Individual DER -Battery Storage

- Storage can charge during off-peak; Discharge at “needed” time
- Pay-back is through energy-shifting, demand reduction and short duration back-up power
- Drawback is output is for a shorter duration mostly
- Units are still cost prohibitive



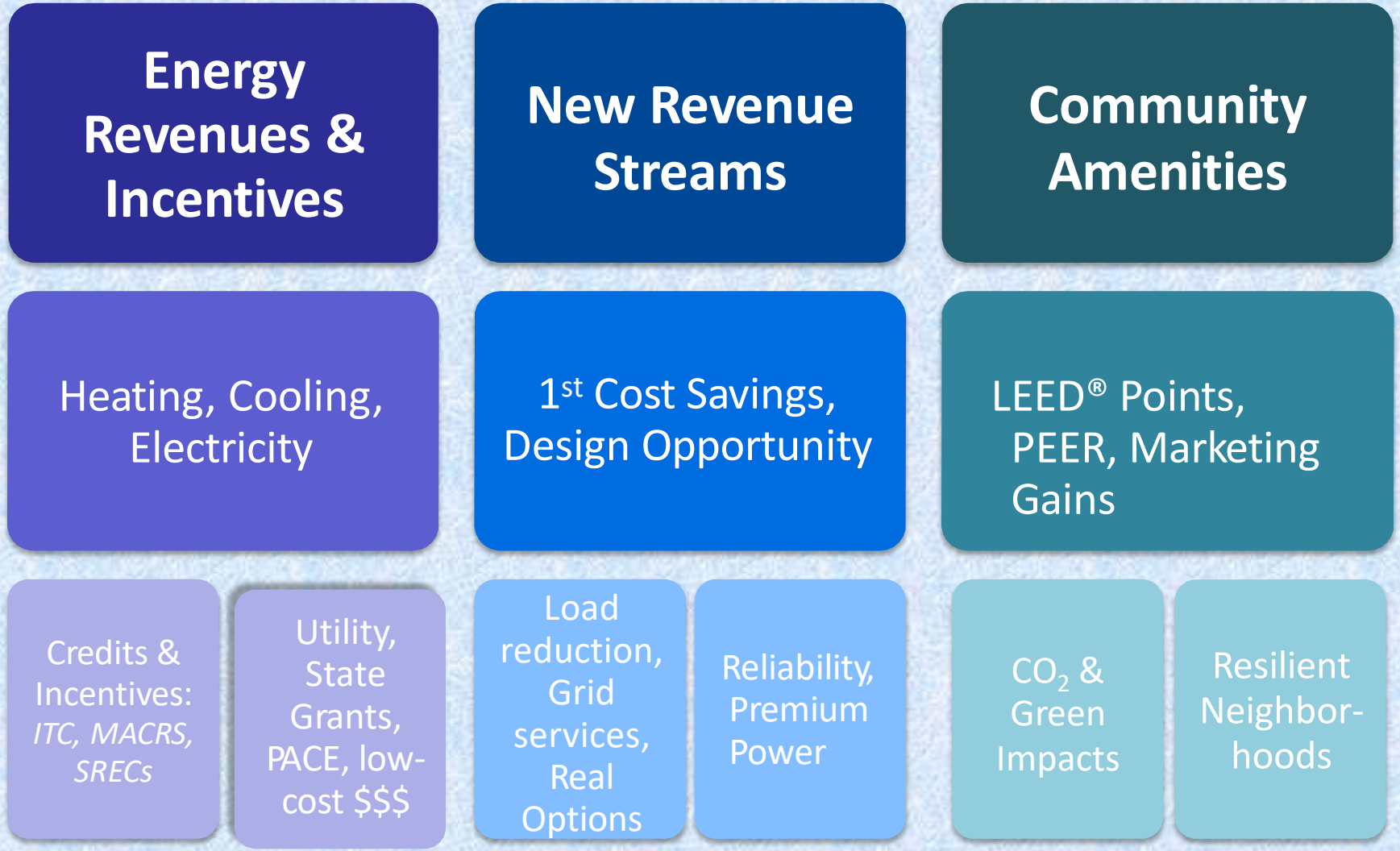
II.2. Benefits of Hybrid Systems

- **Hybrids are combination of technologies to extend the system benefits:**
  - **CHP + Solar**
  - **CHP + Storage**
  - **CHP + Storage + Solar**
  - **CHP + Storage + Energy Efficiency**



- **Hybrid provides additional grid services through frequency response, voltage control, and ramping capabilities. ➔ Major benefit**

II. 2. Benefits of Hybrid Systems - Value Stacks



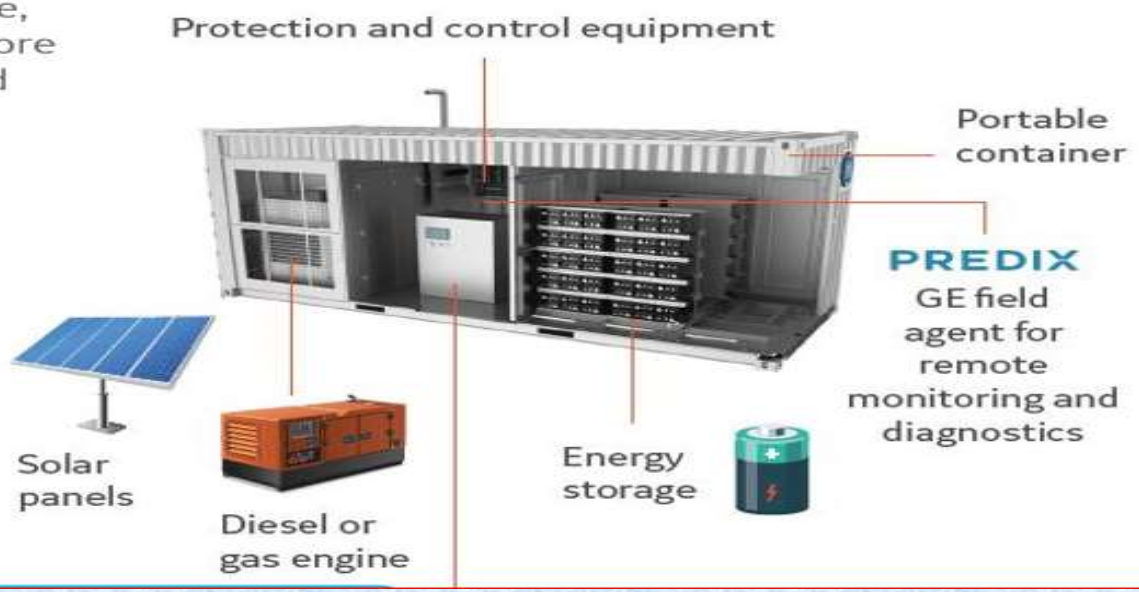
II. 3. Who Is Building Hybrid CHP's?

- **Packaged digitally-connected CHP hybrid systems are available for clients with installation and financing challenges !**

Modular, containerized, digitally-connected power solution

Benefits

- Lower installation and commissioning time and expenditures
- Reduced operating cost and emissions versus diesel systems
- Quickly scale output to capture growing demand
- Achieve higher uptime, identifying issues before they cause unplanned downtime
- Enhanced ability to monitor and control multiple installations
- Operate reliably through a variety of environmental conditions



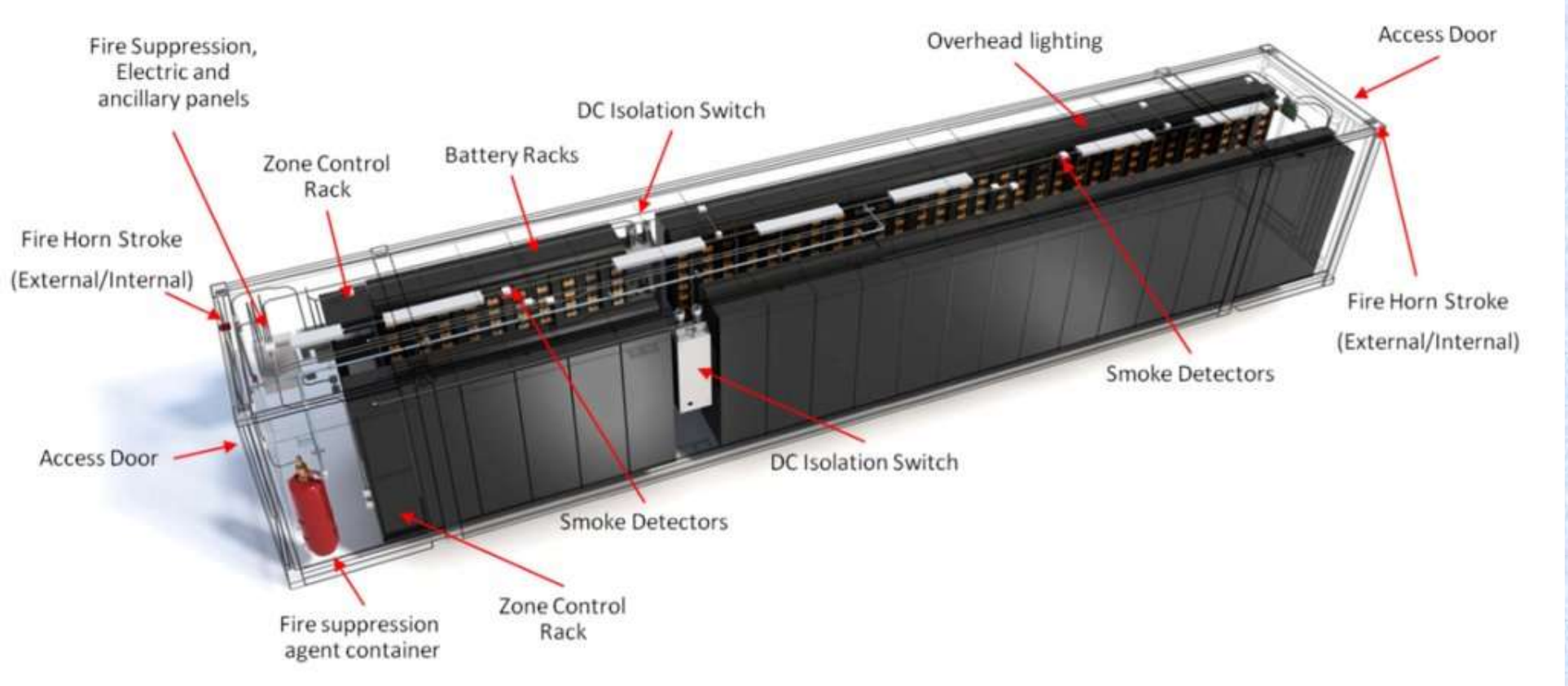
II.3. Who Has Seen The Benefits?

Brigham & Womans BBF Project

Caterpillar 4.0 mw Natural Gas Engine
Hot Water Heat Recovery
Exhaust Steam Boiler
SCR/CO System
Three Fire Tube Boilers
In Service spring 2016

Reference: Brigam and Woman's BBF Project; Waldron Engineering and Construction – Terence Waldron, 3,'18

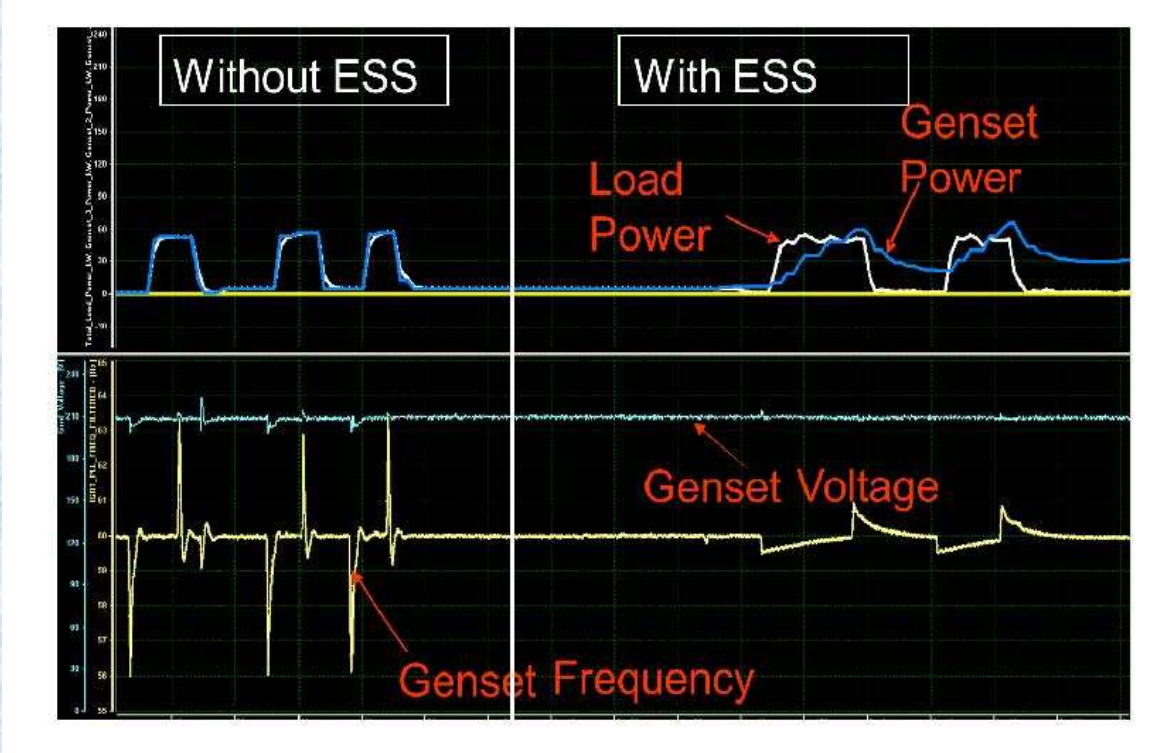
Typical ESS Container



Reference: Brigam and Woman's BBF Project;
Waldron Engineering and Construction – Terence Waldron, 3,'18

System Benefits – Contd.

- **Allows for step changes that many prime movers cannot handle**
- **Provides voltage stability**
- **Provides frequency stability**
- **Provides peak power control**

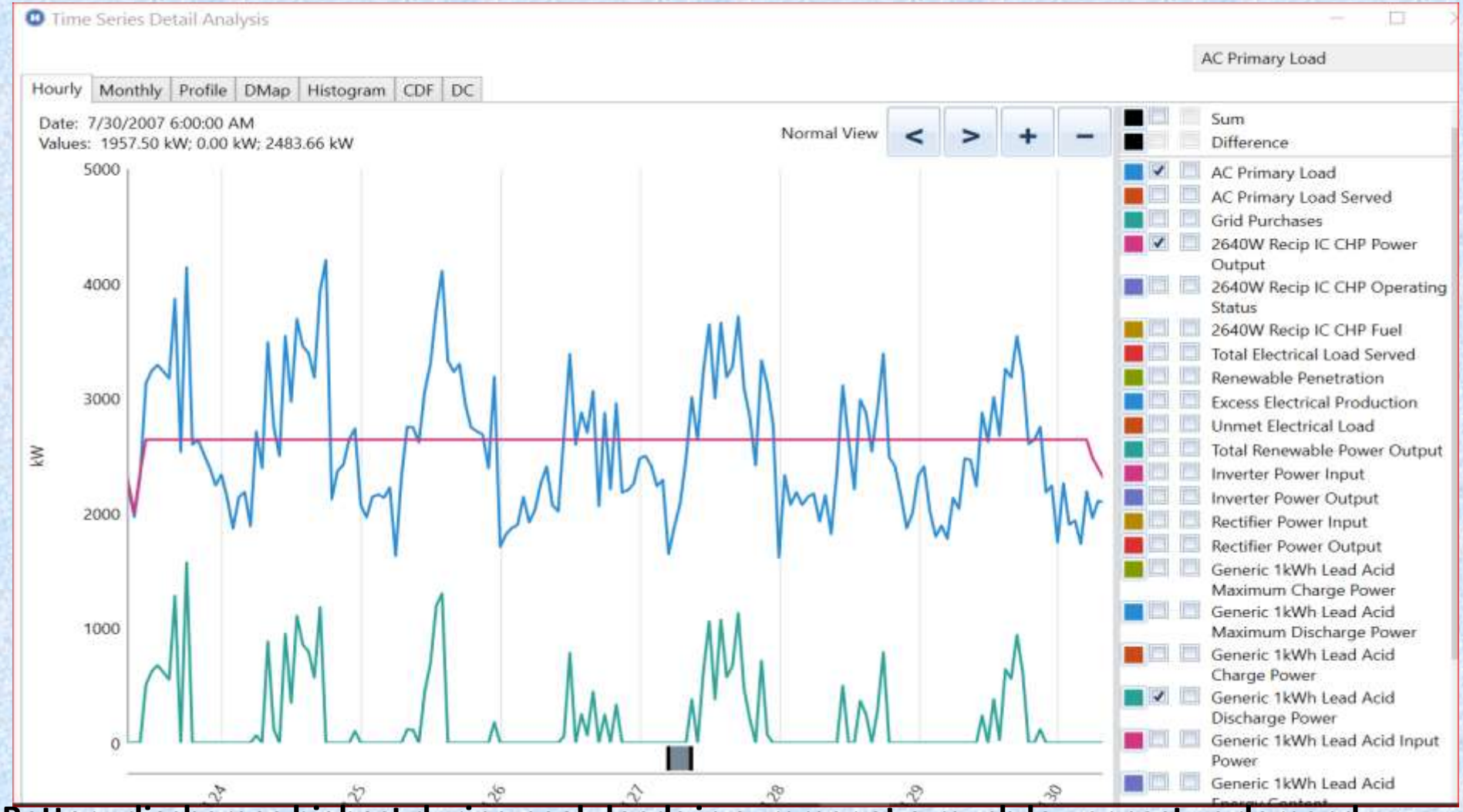


Reference: Brigam and Woman's BBF Project; Waldron Engineering and Construction – Terence Waldron, 3,'18

III. Hybrid CHP– Modeling Methodology

- Modeled a large commercial 2000 kW facility such as a large university campus with grid only as the baseline
- Modeled same with 1) CHP only 2) CHP with battery storage, 3) CHP with solar 4) CHP with battery and solar
- Conclusion:
- For an university campus, CHP with PV and battery provides additional benefits at a slightly expensive system cost. The resiliency and peak-shaving benefits will overweigh the cost difference.

HYBRID CHP WITH BATTERY – POWER OUTPUT



Battery discharges highest during peak-loads in summer at a much lower cost vs demand charges. Due to this the yearly reserve for the site is reduced and hence the overall yearly electricity bills by 20-25%.

HYBRID CHP AND BATTERY – NET PRESENT COST

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
2640W Recip IC CHP	$4,752,000.00	$0.00	$3,409,993.28	$9,172,203.07	$0.00	$17,334,196.35
Generic 1kWh Lead Acid	$5,266,500.00	$2,878,284.12	$1,617,805.63	$0.00	($254,124.08)	$9,508,465.67
Generic Boiler	$0.00	$0.00	$0.00	$1,883,369.07	$0.00	$1,883,369.07
Grid	$0.00	$0.00	$20,172.45	$0.00	$0.00	$20,172.45
System Converter	$515,625.00	$126,784.51	$0.00	$0.00	($16,586.95)	$625,822.57
System	$10,534,125.00	$3,005,068.63	$5,047,971.36	$11,055,572.14	($270,711.03)	$29,372,026.11

Conclusion: Net Present Cost for 15 year for the system is $29.3 million from capital costs of CHP and battery. Highest expenses for this comes from fuel for CHP and O&M as in the break-down of expenses in the table.

BENEFIT OF HYBRID VALUE STACKS

Large Commercial, Comparison of Financials with and without Renewable Sources							
System	Type	Net Present cost	Rebates-utility	Grant-State	Federal Tax Credits	Net after financial assistance, $	Comment
100% Grid	Layer 1	20,328,240	None	None	None	20,328,240	Baseline
2640 CHP + 10 kW grid	Layer 2	22,038,060	2,500,000	499,999	475,200	19,038,061	Good Option 1 Vs 100% grid Baseline
2640 kW CHP+806 kW PV+6631 kWh battery	Layer 3	26,207,160	2,500,000	499,999	1,824,888	21,382,273	Good Option 2 Vs 100% grid Baseline
2640 kW CHP + 17555 kWh battery, no grid, no solar	Layer 4	29,372,030	2,500,000	499,999	2,055,150	24,316,881	Good Option 3 Vs 100% grid Baseline
					Nandini Mouli, eSai LLC, 12,11,17		

IV. Conclusion

Hybrid assets stack to meet multiple stakeholder needs:

- **Customer:**
  - **Energy bill savings: $/kWh savings; $kW savings**
  - **Grid services**
  - **Reliable power**
- **Society:**
  - **Higher GHG reduction**
- **Utilities/Implementers:**
  - **Higher CHP project adoption**
  - **Opportunity to reduce project development timeline**
  - **More developers to work with; cost-competitive**
  - **Development of streamlined hybrid interconnection/permitting**
- **Hybrid solutions mitigate economic risks currently faced by CHP !!**

THANK YOU !!

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