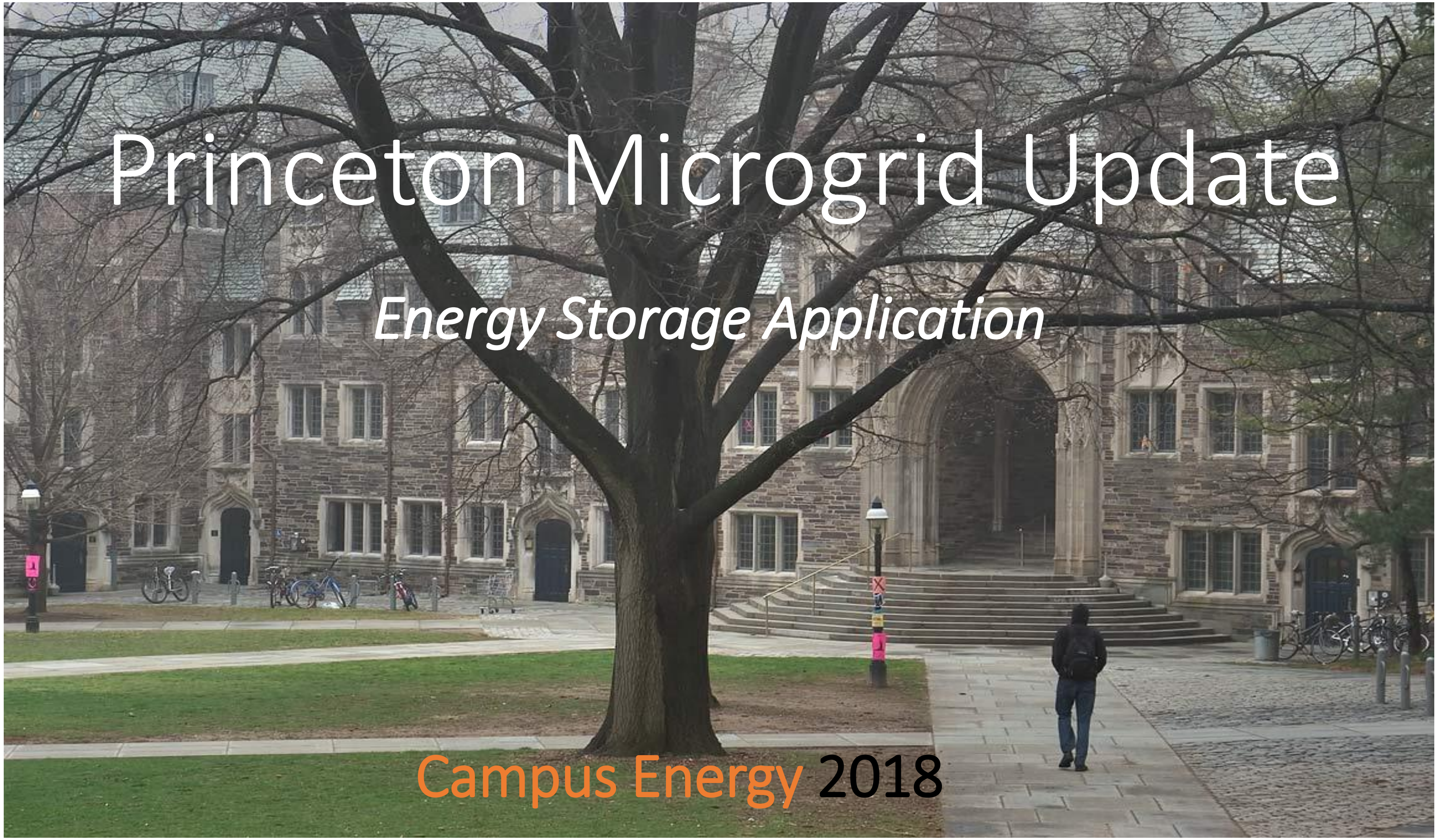
Princeton Microgrid Update

Energy Storage Application

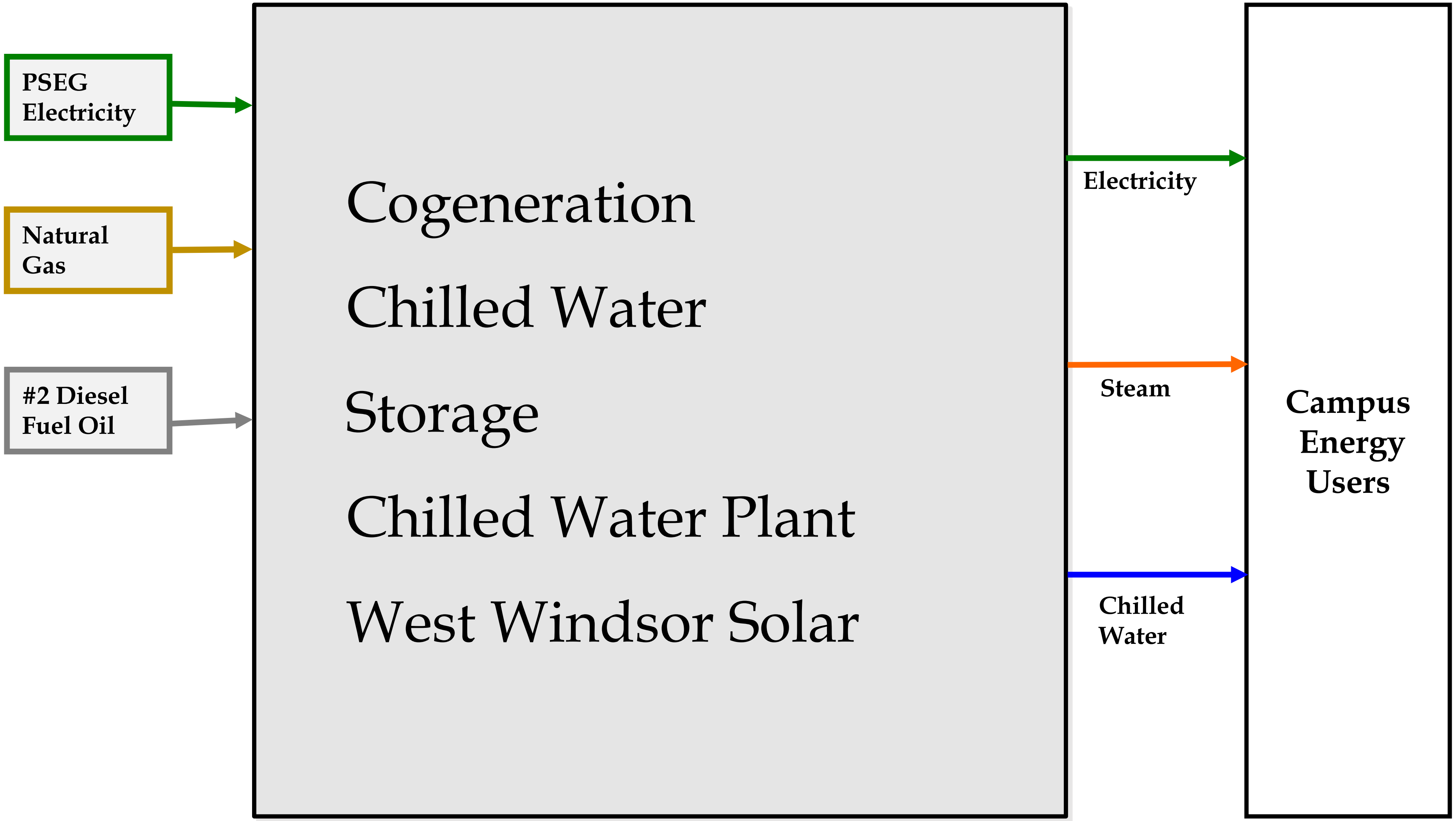


Campus Energy 2018

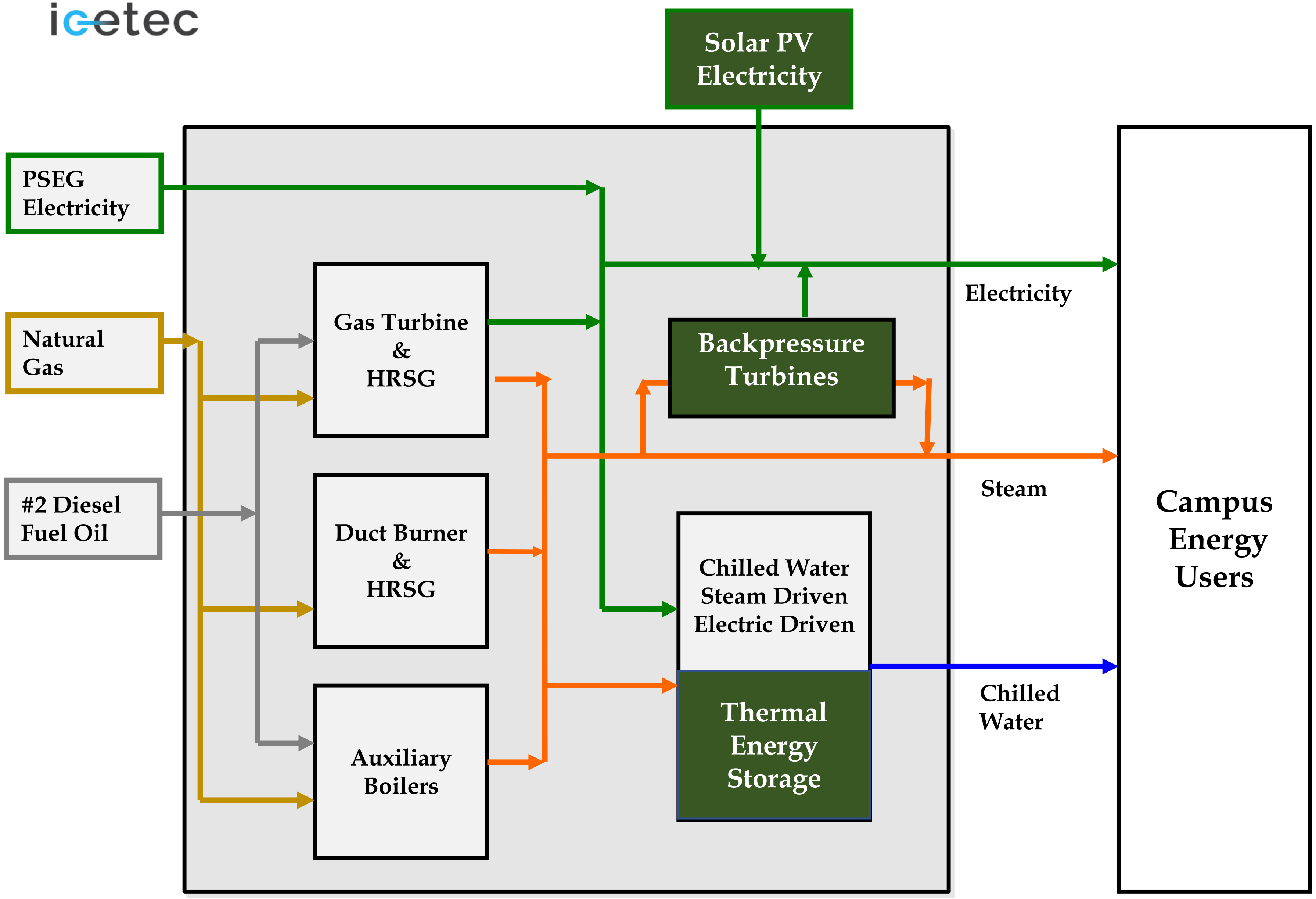
INTERNATIONAL DISTRICT ENERGY ASSOCIATION

Microgrid Resources Coalition

Thermally Designed CHP with TES



Thermally Designed CHP with TES

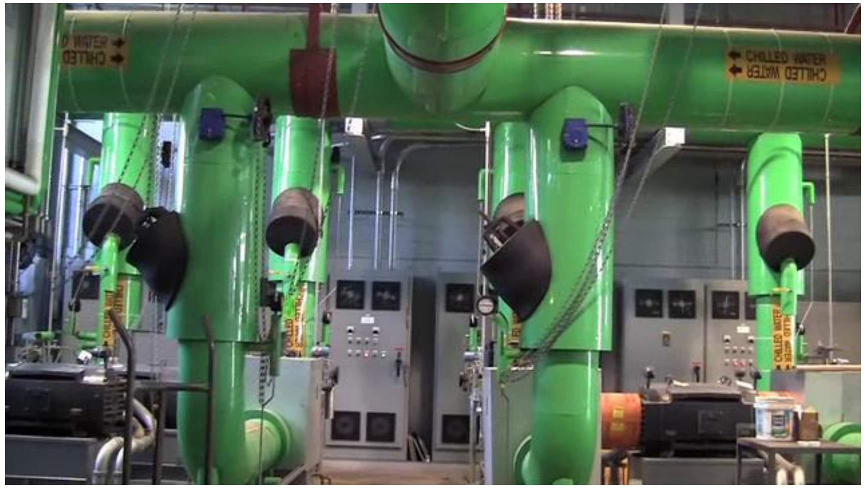


Thermally Designed CHP

15 Mw GE LM1600 combustion Turbine
50,000 LB steam Heat Recovery, 182,000 LB with duct Burning
300,000 lb steam Boiler Capacity

15,000 Ton Electic driven chilled water capacity
10,000 Ton Steam driven chilled water capacity
25,000 Ton Total chilled water plant capacity

Chiller Plant Expansion



Increased chilled water plant capacity to 25,000 tons

2.6 million gallon chilled water thermal
Energy Storage - 40,000 Tonhour capacity

Thermal Energy Storage

Designed for aggressive dispatch -10 hour dispatch to 4 hour dispatch

Economic and Environmental Benefits

- Integrated with plant assets. TES helps to reduce PLC
  - Zero Capacity or Transmission tag
- Increased Economic performance
- Increased bid size in Economic market (FERC 745)
- Used to reduce emissions by offsetting steam driven chillers

Qualitative Benefits

- Provided stable and reliable operation
- Backup capacity
- Can be called on to correct disturbances or to quickly ramp in cases of equipment failure giving operators time to correct or re-dispatch thermal equipment
- Provides resiliency and reliability for thermal plant…

Sound familiar?

Behind the meter solar farm

4.5 Mw solar generation

Dynamic Operation and Market Participation

Behind the meter benefits

- Significant increase in economic performance
- Significant reduction in fixed cost
- Significant reduction in emissions
- Ability to leverage plant flexibility in commodity markets

Ahead of the meter benefits (market participation)

- Participation in energy markets (745)
- Participation in ancillary services (755)
  - -Real time participation in the regulation market

Market Participation - Regulation

Energy Storage

- Renewable penetration
- ITC credit changed to include storage and solar apps … game changer
    - About 7 Years ago, Regulators and Bankers had this Ah-Ha! Moment
    - “If you pair solar with storage, anything is possible!”
        - Can you store the solar energy and use it at night or when its cloudy
        - Can you can arbitrage your solar
        - Can you Be your own Microgrid
        - “Wirecutting!”

    - However, the first Solar+Lithium ion battery configurations presented a learning curve for the industry.
        - Designed around power.
        - Very Expensive to have battery big enough to discharge for hours
        - Manufacturers wanted to limit SOC.
        - Will always need the grid → and you should want the grid for market reasons
        - Regulation

Energy Storage

- Invest based on value today… but
- Need to track developments that affect value in future
- Rare to have <u>Four Major FERC Proceedings</u> that may affect a technology:

1. **Energy Storage NOPR** from the FERC
   - Smarter bidding for energy limited resources … Impact on capacity value of storage
   - PJM / ISO *should* make sure you are dispatched for highest priced hours of the day
   - Matching your incentives with what the grid wants
2. **DER technical conference**
   - Better interconnection procedures
3. **Resiliency NOPR** is the name of the game.
   - Grids need to define resiliency
   - -> higher compensation for resources that add to resiliency
   - Need to emphasize the impact on customers...
4. **Primary Frequency Response NOPR**
   - Regulators are realizing that **<u>storage is a critical part of the renewable future</u>**.
   - Fast Start capability when clouds roll in
   - Solar installations to have response capability… Perfect application for storage.
   - Power Quality
   - Delay Substation work for 10-20 years

Energy Storage

This is what markets want!

- Regulation Markets want a quick resource that's not necessary energy neutral….
  - Sized for energy, a flow battery can follow the signal in either direction for hours

- Campus/Investors want a diversified income stream –
  - A flow battery can participate in energy, regulation, Sync and capacity markets – Simultaneously…

It is an upgrade to an already state of the art Microgrid

- Hours of islanding
- Instantaneous - Black start resource
  - Great application for hospitals for that reason.
- Paired with CHP, can increase our bid size, let CHP handle step change and storage fine tune (1+1=3)
- Can provide solar smoothing / power quality support, but primary purpose is to derive value from markets

More Energy Storage ??

- What if we added energy storage to the mix?
- Where would we locate the storage?
- What could we expect to gain?
- What additional behind the meter benefits could we expect?
- What grid benefits could we provide and what revenue could we expect?
- What battery technology would be best for the asset mix already in use?
- Could we provide an asset that provides critical services to the grid, lowers cost, can generate additional revenue, can operate in multiple modes, improve reliance and reliability to the Princeton microgrid?

Energy Storage

- We (Icetec) have experience with solar/storage applications as well as cars to grid.
- We understood that for energy storage to make economic sense and prove to be a good investment, it would need to spend most of the time actively doing something. ~~If we so this, we will use it . A lot.~~
- We wanted a solution that would increase the value of what we were already doing.
- We wanted a solution that would provide power and energy capability with near instantaneous ramp, and sustained output.

Energy Storage

We concluded that a flow battery would be the best fit for the Princeton microgrid.

Why Flow – Economic Reasons?

- As an energy resource capable of prolonged output, it can be used to further reduce capacity and transmission cost
- It can participate in the energy markets and increase performance thru the optimization of bidding strategies
- It be used optimize the solar output and offset swings associated with weather and cloud cover.
- It can be used in regulation markets to increase the bid size greater than the instantaneous output thru integration of the existing turbine. Using the turbine for slower step change response and the flow battery for fine control will result in much higher participation rate. It can also be used for regulation or or additional energy participation when the turbine is dispatched in energy market.
- It can participate in multiple markets simultaneously.

Energy Storage

We concluded that a flow battery would be the best fit for the Princeton microgrid.

Why Flow – Technical Reasons?

- Flow batteries are expected to have an equipment life of 20-25 years with minimal degradation of output. They don't wear out.
- They are safe.
- They do not incur a parasitic load for conditioning of the storage area.
- They do not require fire suppression system
- They require very little maintenance
- They require very little downtime
- Full span 0-100% of rated capacity

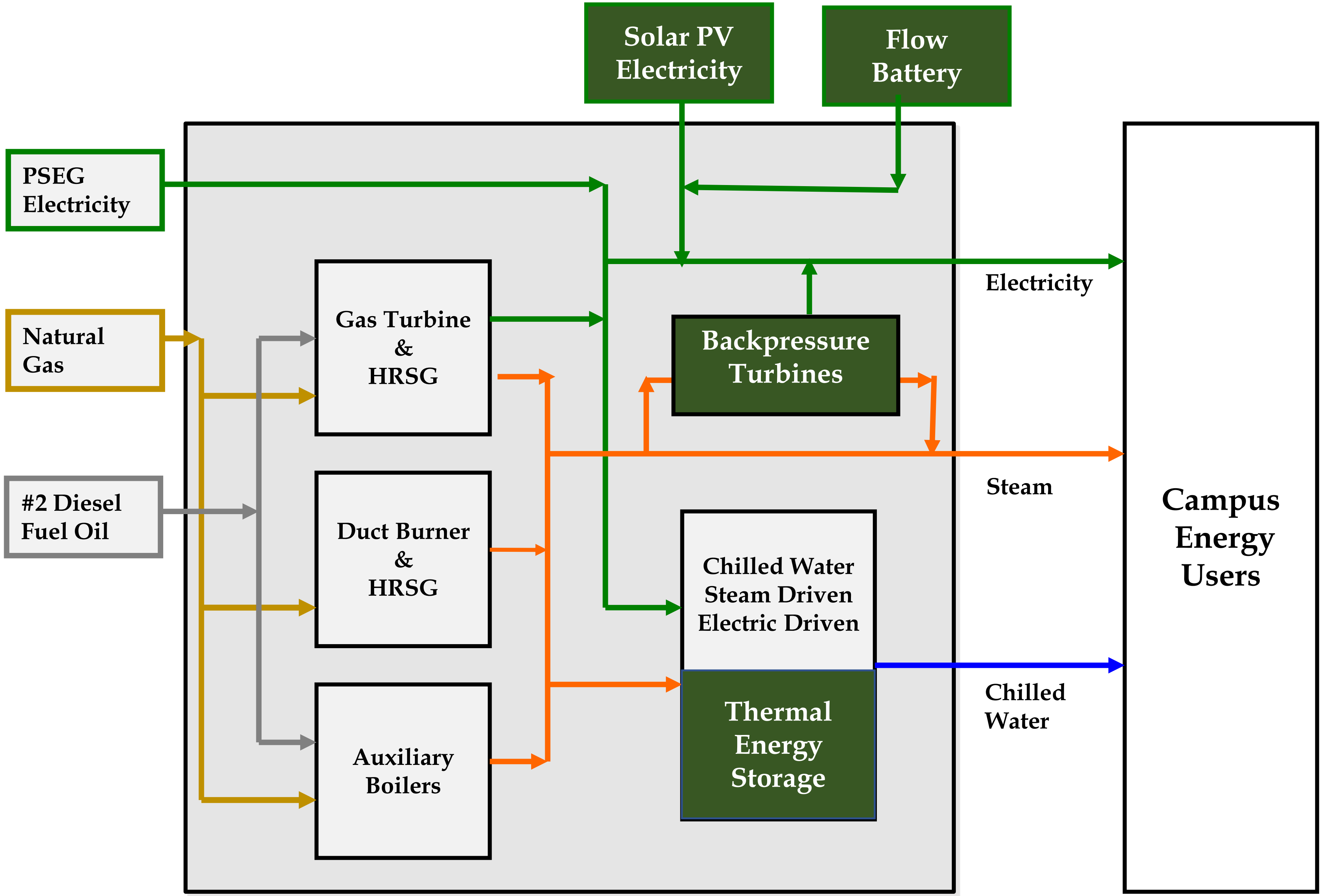
Energy Storage

We concluded that a Zinc Iron flow battery would be the best fit for the Princeton microgrid.

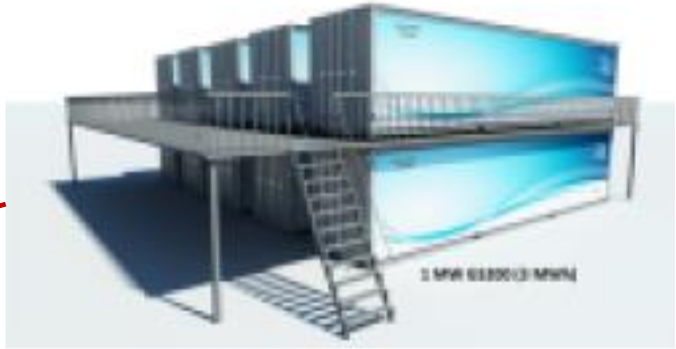
Why Zinc Iron Flow?

- Chemistry was the safest we found and completely non-toxic
- Instrumentation and analytics were very deep
    - Down to the cell level
    - “self healing” capabilities
- We require 10 year system and performance guarantee
- Challenge is not capability but physical size (footprint). Probably not the best fit for some sites.
- Market Integration with Inverters and battery system investigated and found to be very doable
- Robust real time insight to all aspects of battery management
- Market compliance issues minimized due to robust data and connectivity

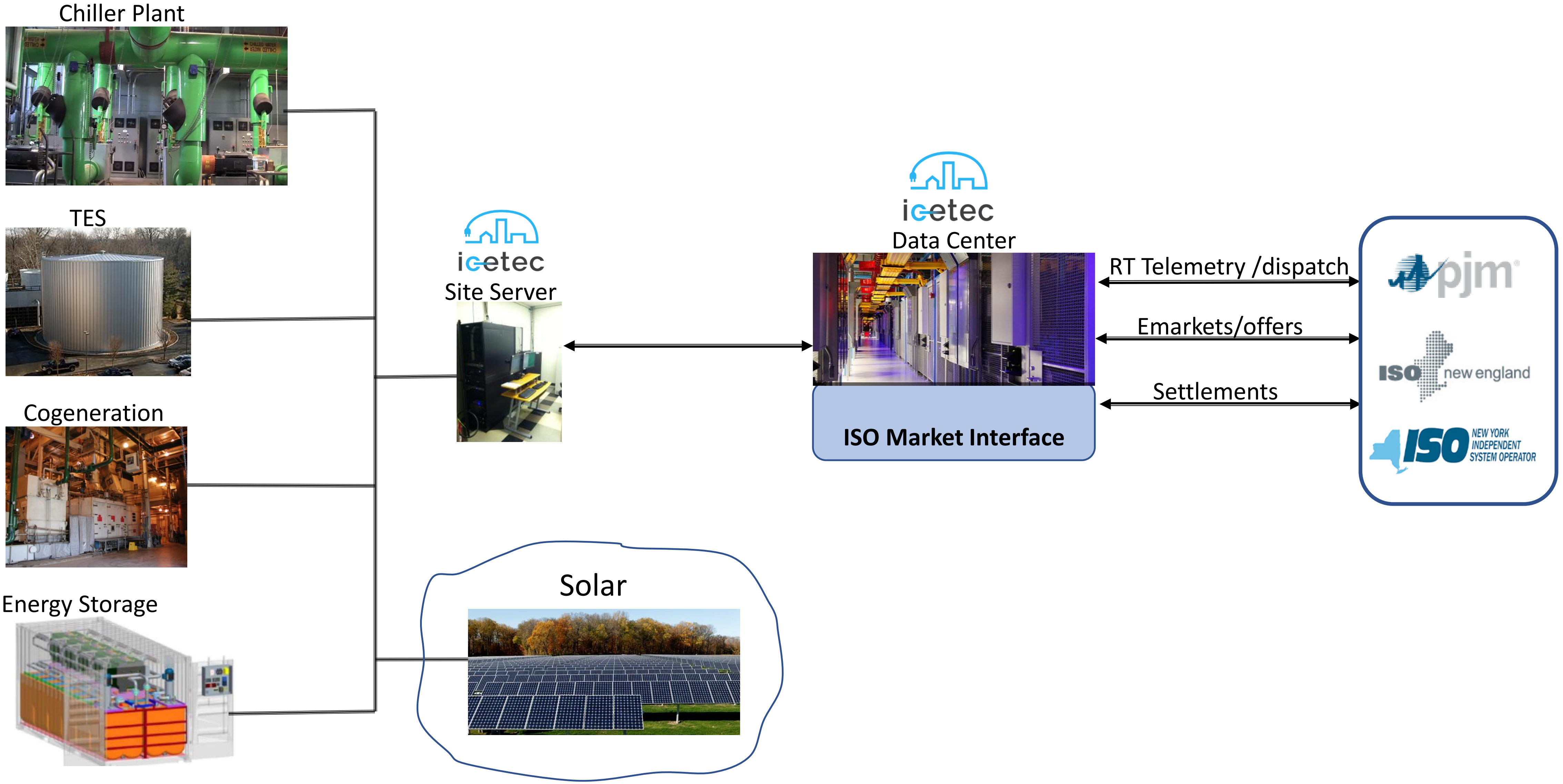
Thermally Designed CHP with TES and Solar Farm and Energy Storage



Proposed Location for the Flow Battery



Market Integration



Thank You

Questions ??