De-Carbonizing the Campus: Planning, Tools & Technologies

CampusEnergy2023

February 27 – March 2, 2023

Gaylord Texan Resort & Convention Center | Grapevine, Texas

INTERNATIONAL DISTRICT ENERGY ASSOCIATION

University of Idaho

NLINE ENERGY®
EVERY DROP OF ENERGY

Revolutionizing Campus Energy Plants with Waste Heat Recovery and Microgrids: The Future Is Proven

IDEA
CAMPUS ENERGY 2023

De-Carbonizing the Campus: Planning, Tools & Technologies
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MARCH 1, 2023

Agenda

1. Introduction of Authors:
    - Marc Compton (U of ID)
    - Nate Turner (NLine Energy)
2. University Overview & Energy History
3. Project History
4. Diligence
5. Project Economics
6. Design Challenges
7. Construction & Commissioning
8. Microgrid Lessons Learned
9. Operation / Results

University of Idaho – Background
Moscow, ID

1 U of ID by the numbers:

- Founded in 1889
- Public land grant institution
- State's primary research institution
- Student population = 10,000

2 District Energy System

- 62 buildings on steam (3.2M sq.ft.)
  - 3 miles of tunnel
- 38 buildings on chilled water (2.4M sq.ft.)
  - 7.5 miles of pipe

Teddy Roosevelt @ U of ID (1911)

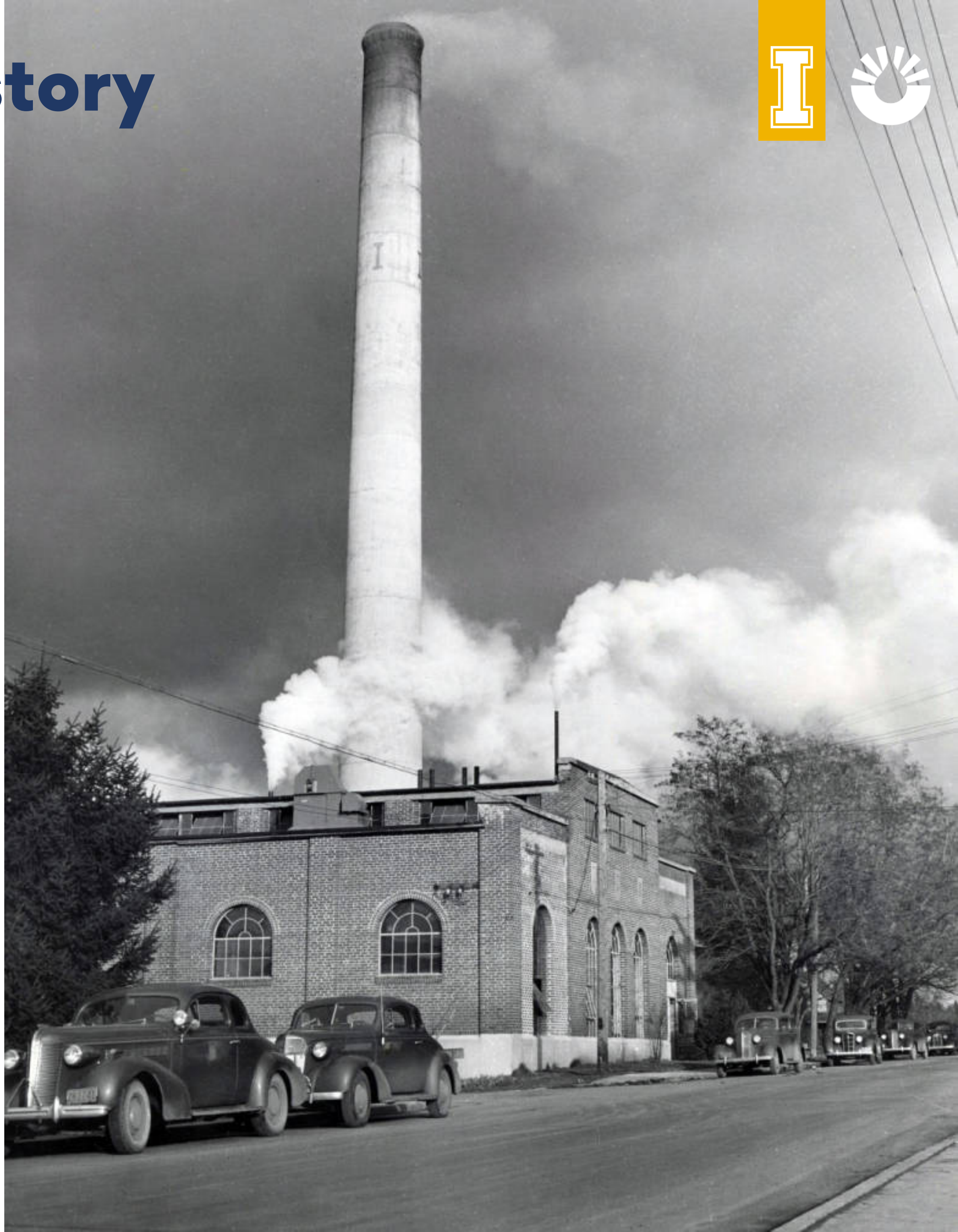
University of Idaho – Energy History

1 Energy Plant Constructed in 1926

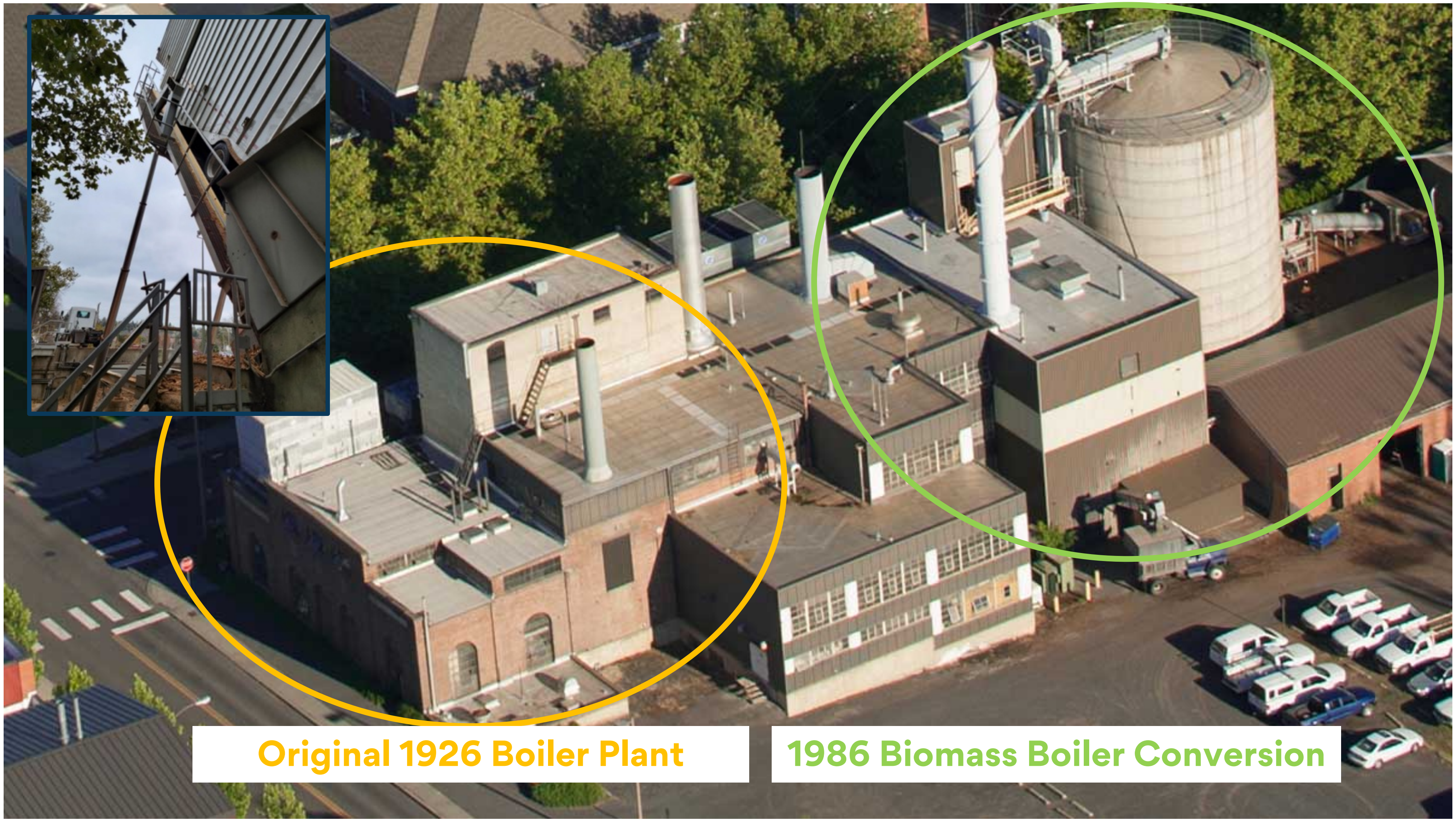
- Originally 3 coal boilers
- Began transition to NG in 1963
- Switched to woody biomass in 1986
- **Biomass Boiler = 90%+ of campus load**
  - **$4.00 per 1000 lb steam**
  - **Environmentally friendly**
- Gas boilers = 10%+ for peak loads and backup
  - $10.62 per 1000 lb steam
- 96% condensate return rate
- PRV station at Energy Plant

2 Campus Energy Consumption

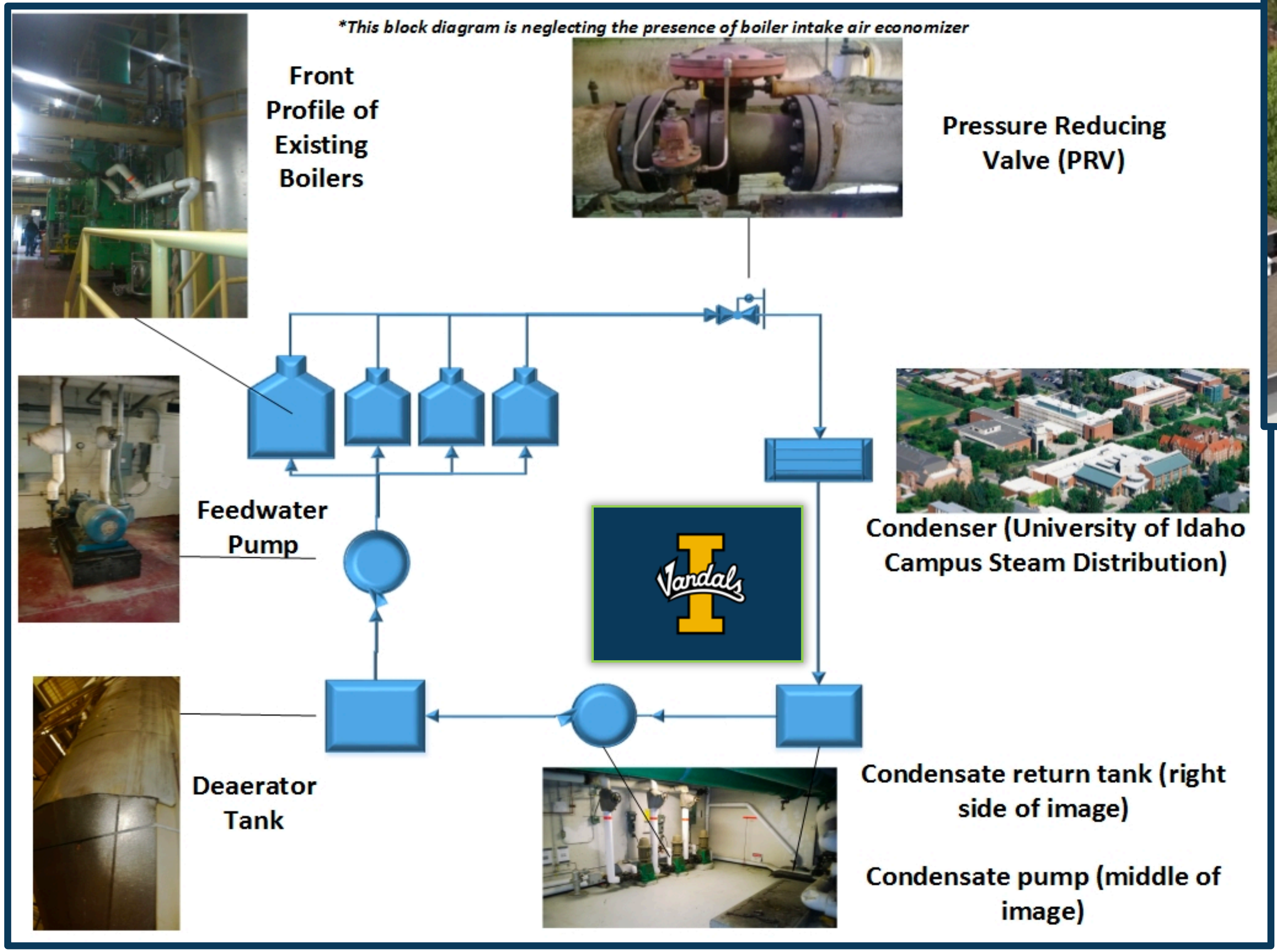
- Steam generation = 284MM lb/year
- Chilled water generation = 4.4MM ton-hrs/year
- Electric demand = 46,000,000 kWh/year



University of Idaho – Energy Overview



University of Idaho – Energy Overview



University of Idaho Energy Goals and Intent

- Capture potential energy savings by installing backpressure steam turbines at the Energy Plant
  - **Reduce or offset the ~$3.0 million annual electric bill**
  - **Reduce the 14,000 metric tons of eCO_2 emissions from electricity consumption *(51% of campus carbon footprint)***

- Establish a campus-wide microgrid to ensure energy independence
  - **Improve resilience to utility outages**
  - **Future load shedding schemes to reduce peak demand charges**

Phased Timeline

CAMPUS-WIDE MICROGRID STRATEGY

ENERGY INDEPENDENCE

SRM Project (Alteration and Repair)

Expanding Energy Projects

Upgrade Grid and Backup Systems

Broadening Energy Projects

Energy Plant Modernization

PHASE I
2008+

Energy Conservation

(CONTINUOUS IMPROVEMENT)

PHASE II
2018+

Install 3x NLine Turbines

Backup Power Generation

IRIC PV Array

PHASE III
2024+

Condensate Return Backup Systems

Transmission Lines

PV Arrays

PHASE IV
2025+

MCC Upgrades

Additional Wood Boiler

PV Arrays

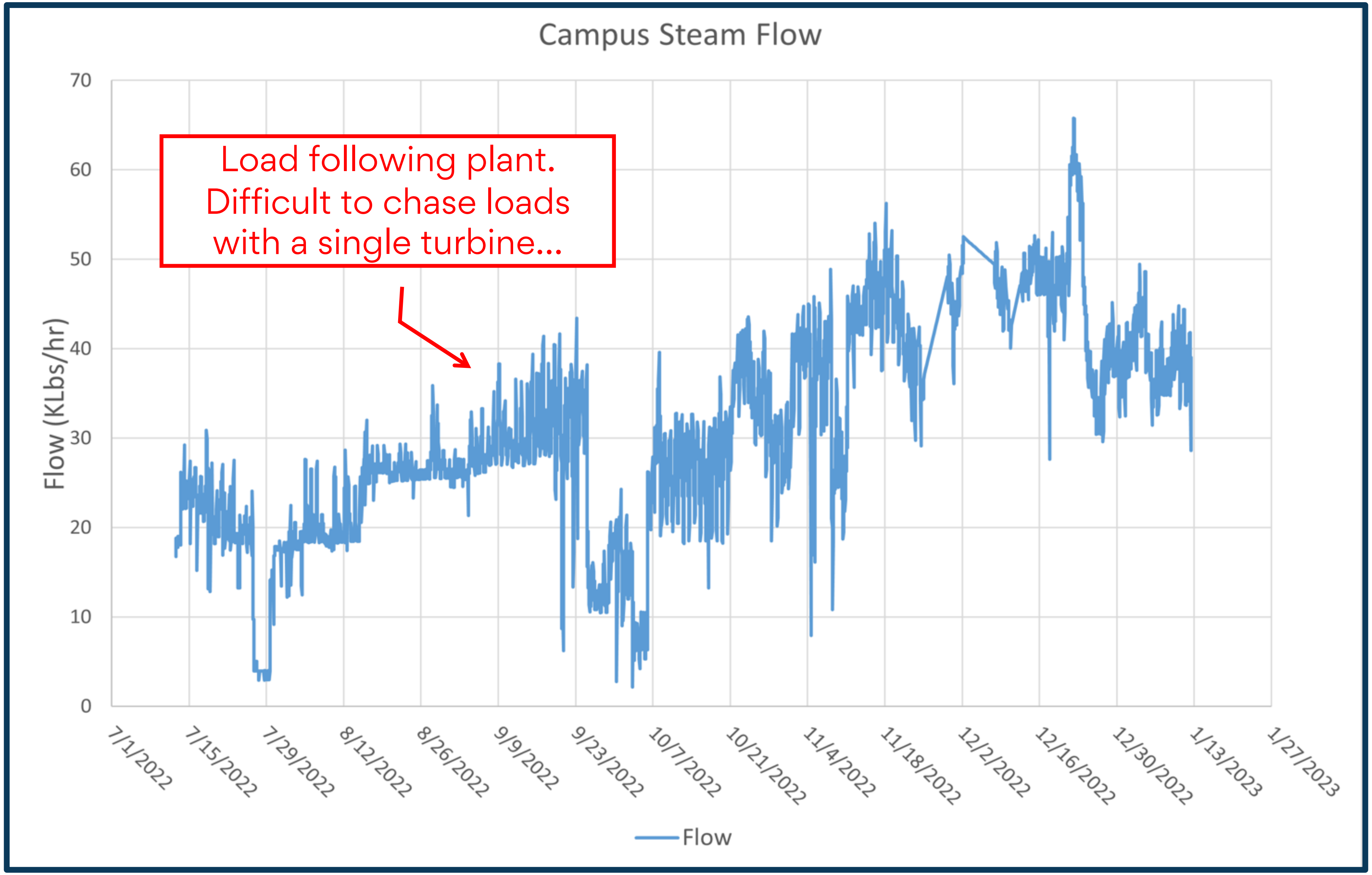
PHASE V
2030+

Plant Improvements

4th Turbine

Battery Storage

U of ID - Steam Flow Fluctuation



U of ID – The Road to CHP

The path towards CHP has spanned decades

- Plant designed for it
  - 600 psig wood boiler
- Multiple feasibility studies
  - Many iterations of student capstone projects
  - DOE CHP TAP program
  - Steam pressure assessments
- Many challenges
  - Small footprint available
  - Meeting electrical demand
  - High efficiency requirement at various steam loads
- The solution:
  - Utilize parallel small turbines
  - Enter NLine Energy

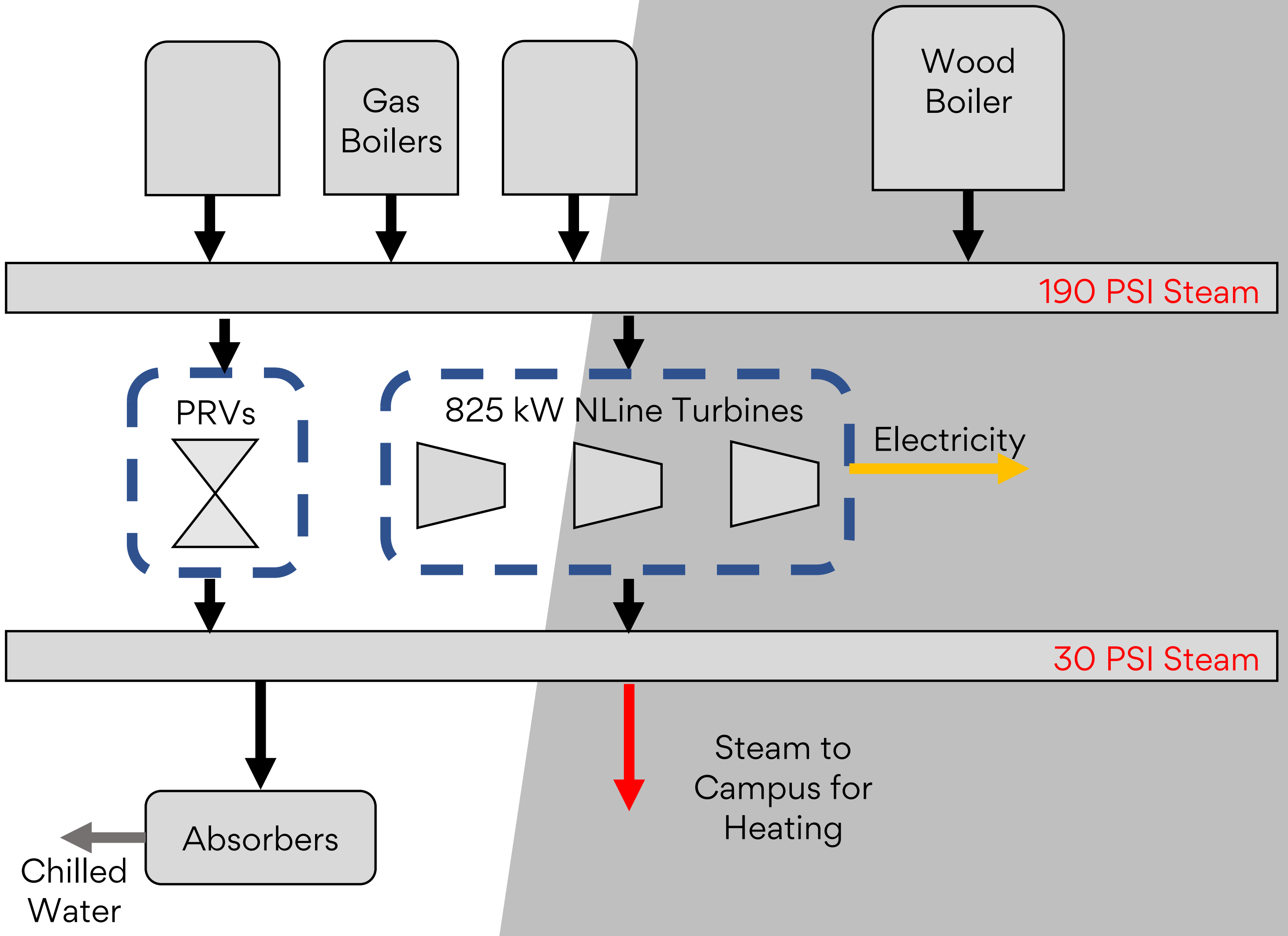
Back Pressure Steam Turbines

PROJECT OVERVIEW

- Three NLine backpressure turbines in the Energy Plant
    - Synchronous generators
    - Total output power: 825 kW (1031 kVA)
    - Annual energy generation: 6,300,700 kWh
- Schweitzer Engineering Labs (SEL) based Microgrid
    - Energy Plant will be able to island itself during power outages
    - Excess power will be pushed onto the UI owned electric grid
- Project completed: February 2022

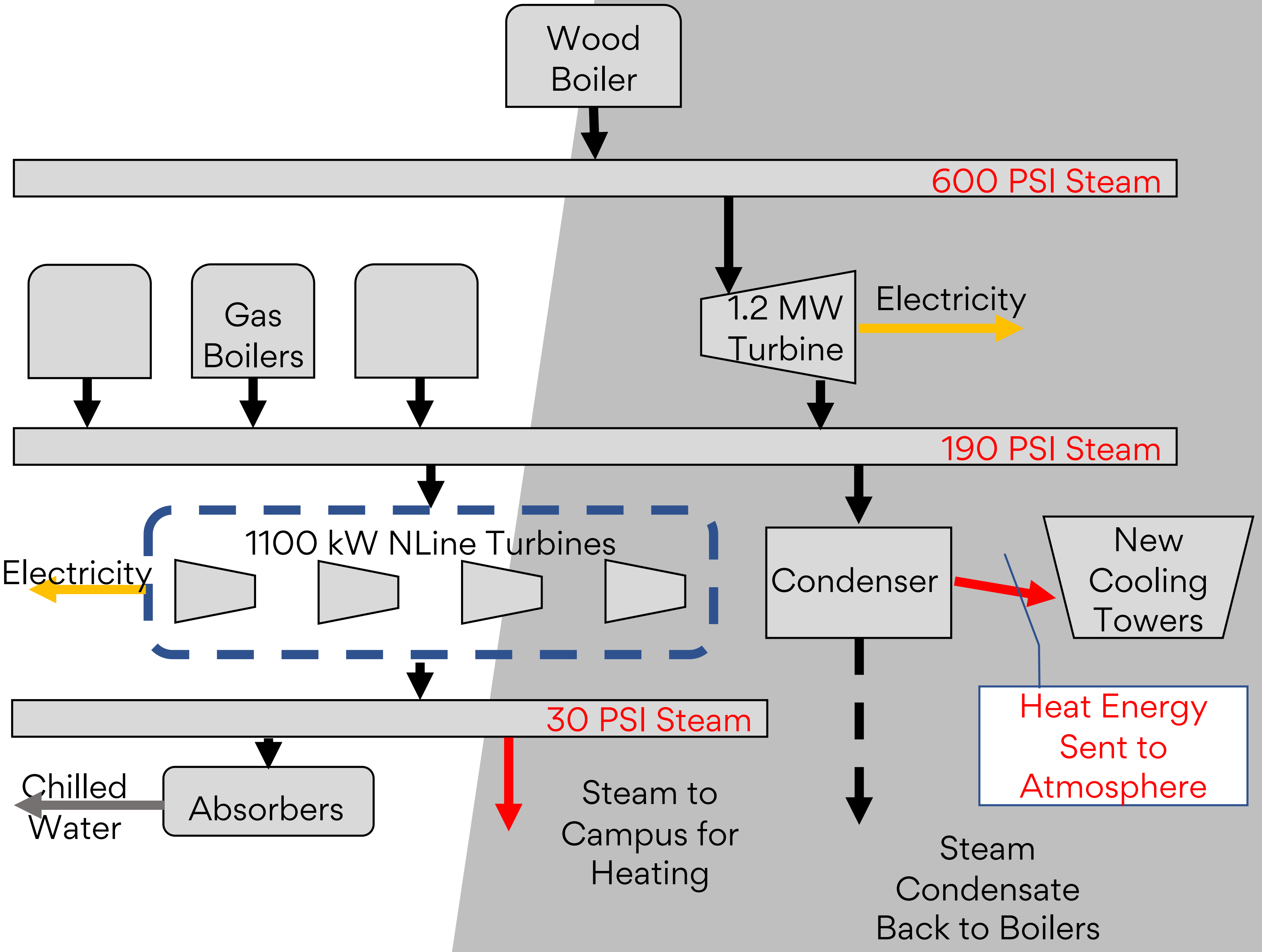
New Steam Plant Configuration

PROJECT OVERVIEW



- PRVs downsized to act as backups
- 3 NLine turbines installed in parallel
  - Turbines follow campus heat load
- The system is built and designed to use **all** the steam produced

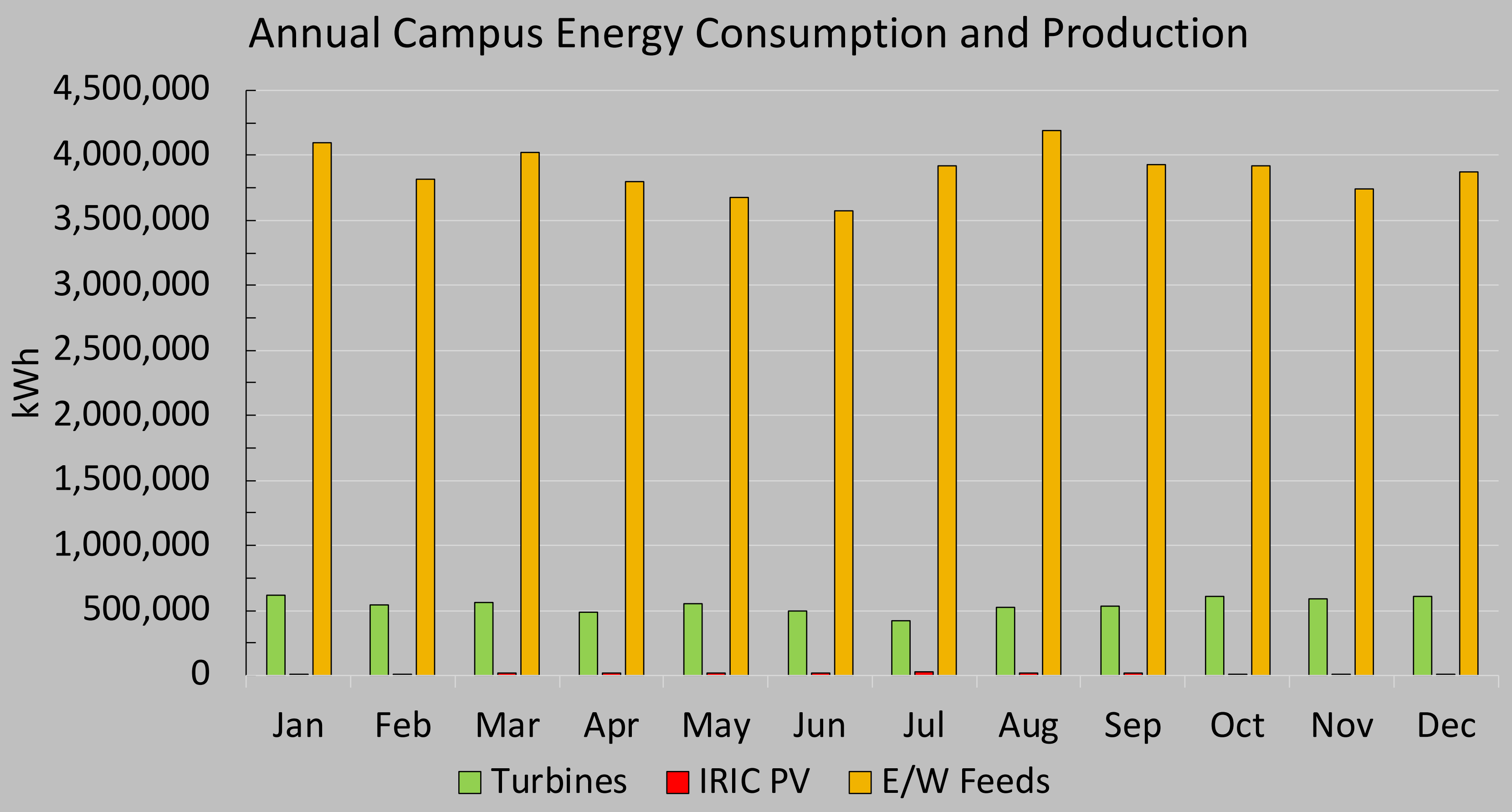
Future Steam Plant Configuration



- The system will be redesigned to maximize power at the expense of wasting steam energy
  - 1.2 MW steam turbine
  - 4th NLine turbine
  - Additional absorber
  - Cooling towers req.
- All turbines will run at full capacity

Anticipated Electric Production vs. Consumption

- The turbine project does not exceed the campus consumption at any time of the year
  - Avoids net metering/PPA complications with Utility Provider
- Peak Energy Generation:
  - 622,214 kWh in October ***(16% of campus)***
- Lowest Energy Generation:
  - 446,832 kWh in July ***(11% of campus)***



NLine Energy – Thermal Energy Developer

Clean, reliable power from existing infrastructure

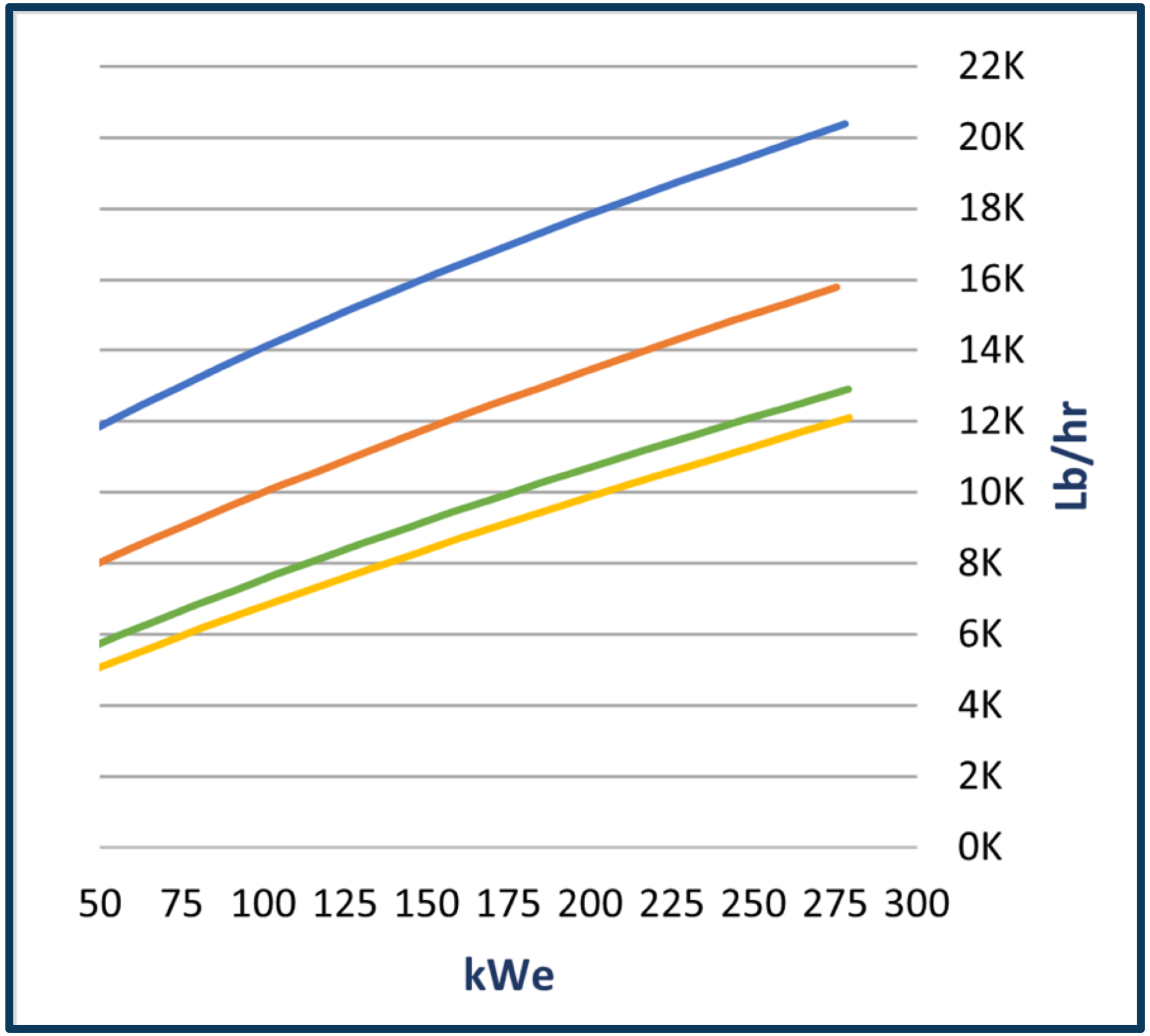
- Power generation from existing steam systems
- Can utilize readily available or excess renewable fuel sources (including biomass applications)
- OEM of the versatile Microsteam® Turbines
    - Ultra-efficient rotor design (60-80%)
    - 1.5x – 2x increased output efficiency
- Create energy saving opportunities for plant upgrades
- Reduced GHG emissions realize sustainability goals

The MST form factor is compact and unique

Project Data Request:

1. Boiler process delivery pressures (pressure produced at boiler)
2. Process use pressure (PRV outlet pressure)
3. Steam Flow Rates: Please provide one or more calendar years steam flow data (hourly if possible)
    - Steam Flow Alternative: Boiler feedwater flow data
    - Steam Flow Alternative: Amount of fuel consumed per month/year by boilers
4. Electric bill: One month sample or one calendar year to validate total kWh load and cost (used in proforma to provide accurate payback analysis, IRR, Total Savings, and NPV)
    - Electric Bill Alternative: Price paid for electricity ($/kWh + $/kW demand)
5. Boiler Fuel Type (NG, Biomass, #2, etc.)
6. Fuel Bill: Price of fuel charged or accounted for internally ($/Ton or $/MMBtu)
7. Basic system steam layout to determine number of headers, PRV's, etc.
8. Number of boilers
9. Boiler Nameplate (a photo is most helpful)

MST Generation: varying pressures and flows

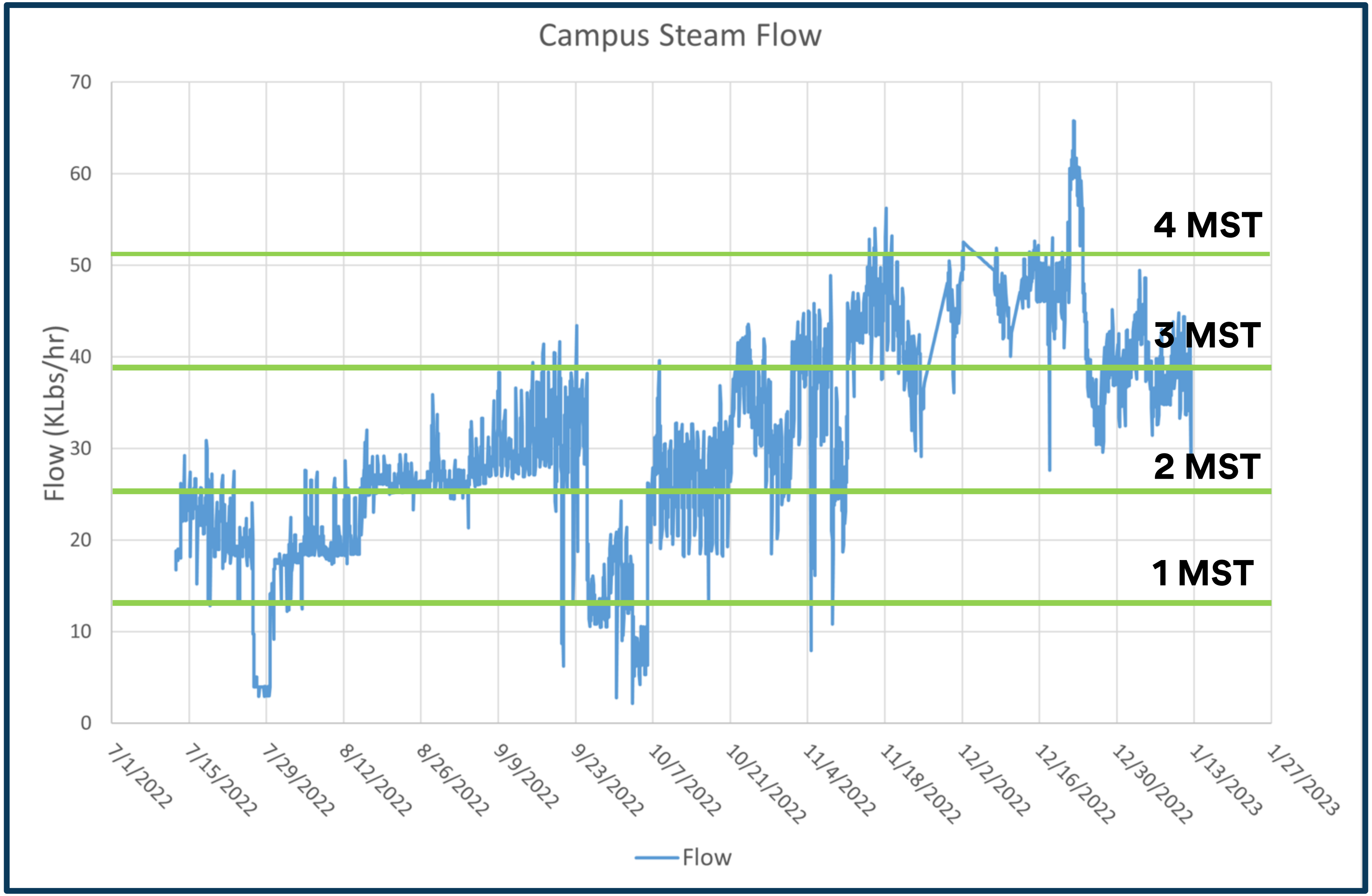


Sample Pressure Drop Scenarios*

- 150 to 50 psig
- 170 to 35 psig
- 190 to 30 psig (U Idaho)
- 150 to 15 psig

*** Limitless pressure drop and flow combinations available (not all shown here)**

U of ID – Identifying MSTs to Match Flows



Incentives

Numerous grants and incentives to support energy recovery

Avista Utilities: Custom Efficiency Incentive

- Avista sees removal of kWh from grid as efficiency
- Lesser of 23 ¢/kWh or 70% CAPEX
- No Grant Value Limit
- Provided >$1.5MM to projects

USFS: Wood Innovation Grant

- Wood Innovation incentivizes unique use of wood products / biomass
- Project received $250,000 Grant from USFS

IRS: Investment Tax Credit

- *Not available for this project (project completed too soon)*
- Currently 30% for Biomass or Waste Heat Recovery Property
- 10% Bonus for Local Content (Buy America)
- Direct Pay to not for profits

U of ID - Project Economics

PRV station at Energy Plant

1. **Steam power generation + microgrid**
   - 29,000 – 95,000 PPH
   - Augmenting pressure drop to increase generation (190 to 35/25 psig)
   - 3 MSTs @ 825 kWe capacity (Future 4th turbine)
   - Showpiece and teaching tool for College of Engineering
   - Resiliency for campus heating system

2. **Payback 3.3 years incl. microgrid (Turbines <1 year)**
   - Design Build Delivery
   - Total CAPEX (with microgrid) = $3.2M
   - Incentives = >$1.8M
   - $427,000 savings per year (6.1¢/kWh)
   - 5,630 tons CO2e /yr offset

U of ID - Diligence Proved MST was a good solution

DOE's CHP TAP provided technical assistance on technology

The Microsteam turbine is certified in the US Department of Energy's eCatalog and CHP TAP, as a recognized CHP Packaged System

Pre-approved provider of certified technology by the New York State Energy Research and Development Authority

Officially acknowledged by the State of California Air Recourses Board as a zero-emission technology through DG-017 certification

U of ID - Diligence Proved MST was a good solution

Northampton, MA

Portland, OR

Split skid – turbine package only (controls & switchgear located locally)

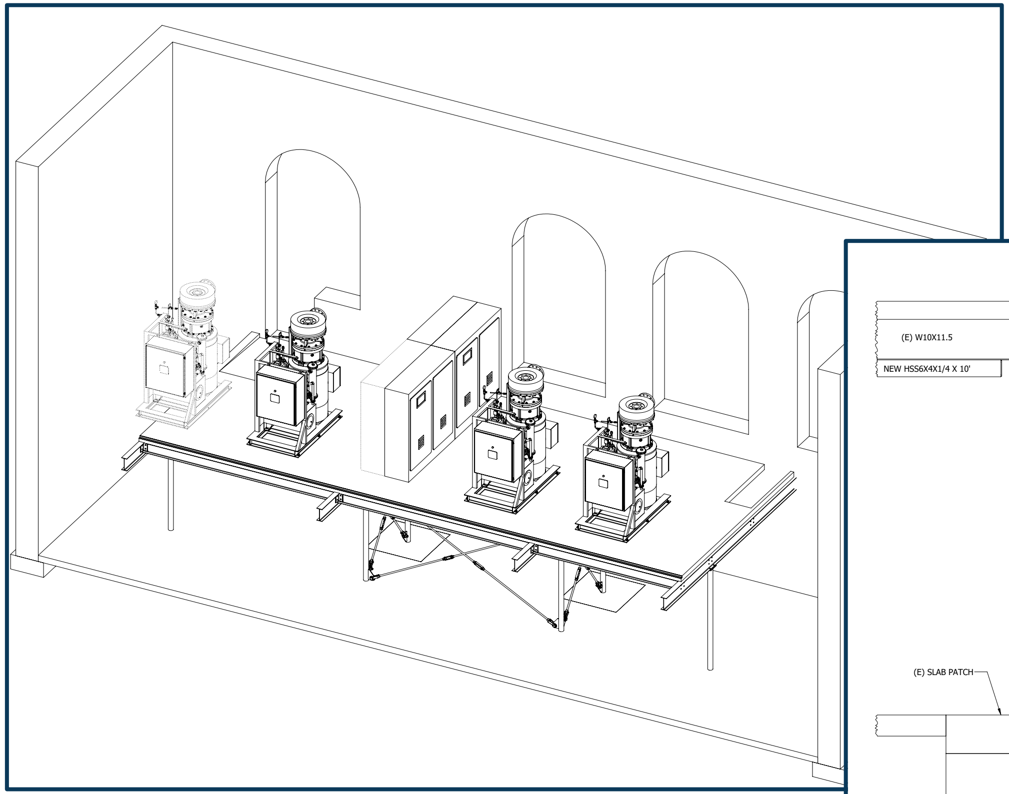
New York, NY

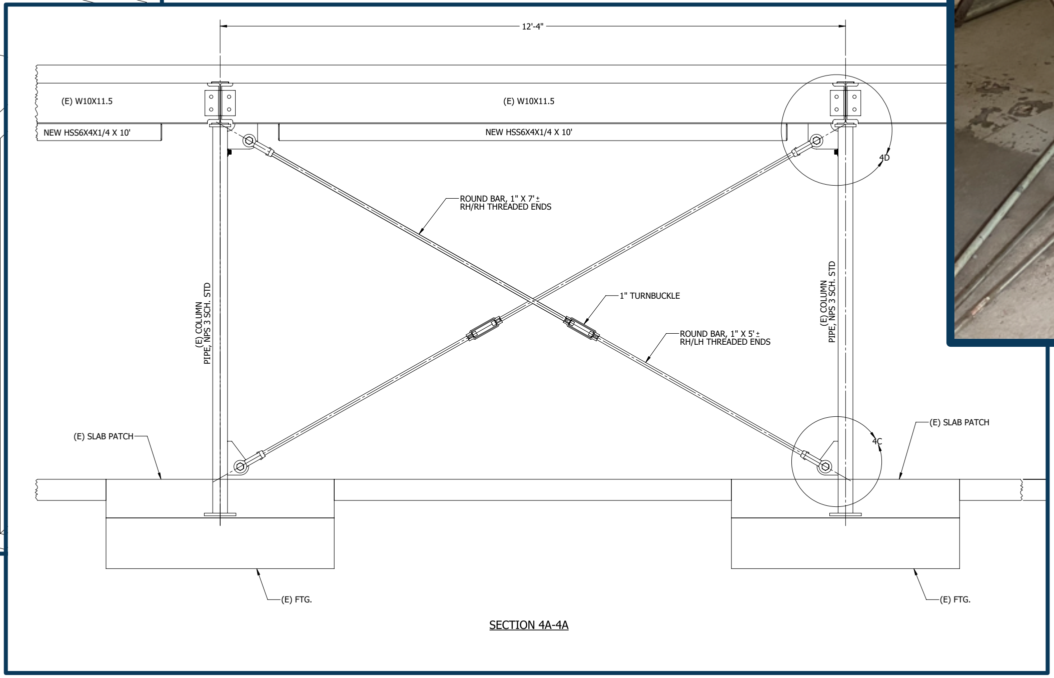
Single skid – turbine package, controls & switchgear mounted on skid

Princeton, NJ

Design Overview- Structural

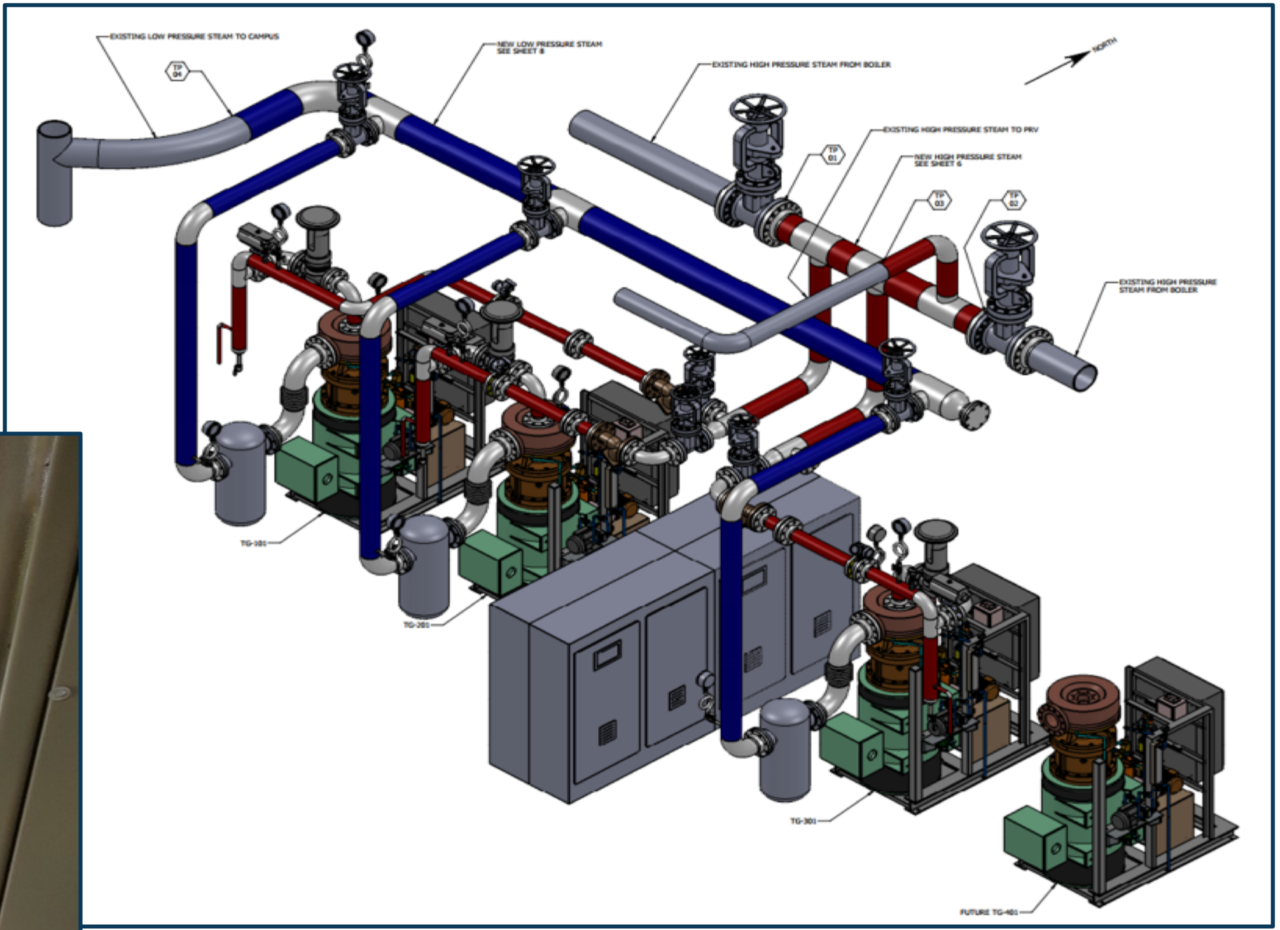
1. 1926 Building
2. Turbines located on elevated mezzanine, resonance concern
3. Tight footprint





Design Overview- Mechanical

1. Cutting into Old & Congested Piping
2. New PRV Configuration needed
3. Small Footprint available
4. ***Steam plant never shut down…***

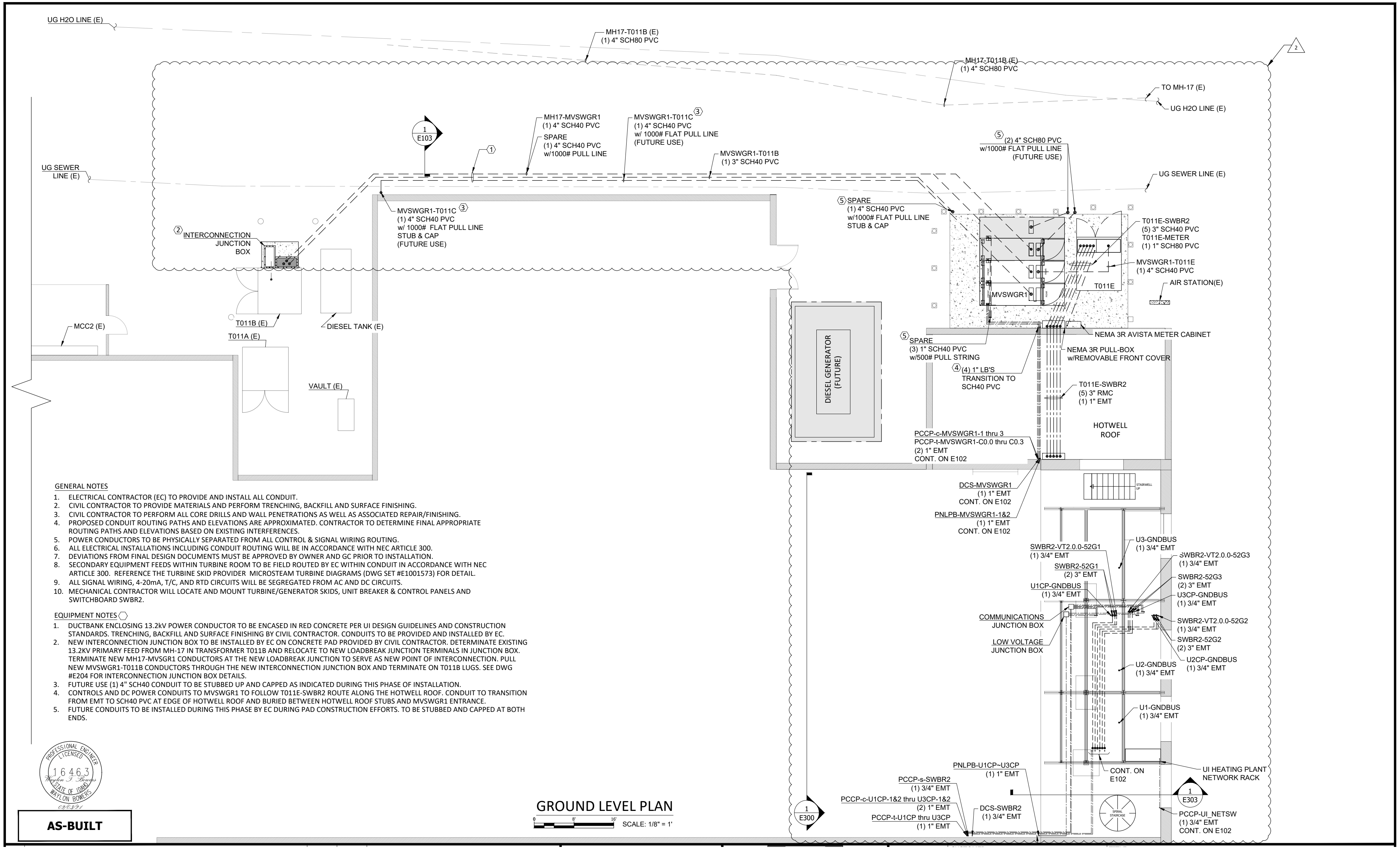


Design Overview- Electrical

1. Microgrid based on an active steam system
   - Power output is of secondary importance
2. Power demand wasn't well known at time of design
3. Point of common coupling aggregated turbine activity into a single brain
4. Curtailment of power generation based on steam valve closure
   - Steam systems do not react as fast as microgrid controls
   - Risk of overspeed
5. Load shedding capable, however not needed until future microgrid expansion
6. Schweitzer Engineering Labs (SEL) provided expertise and design/programming

Point of Common Coupling (PCCP)

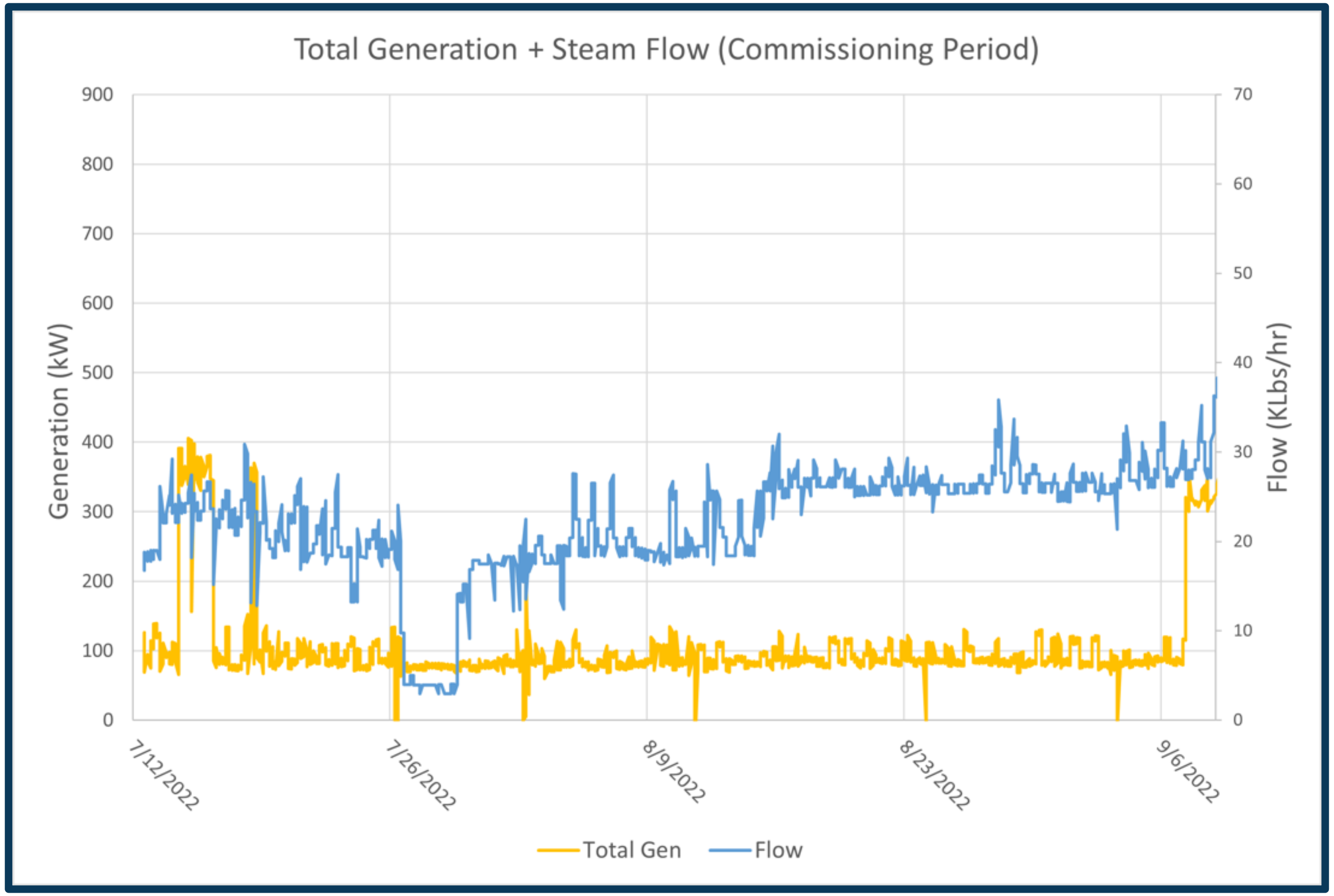
Design Overview- Electrical/Microgrid



Construction & Commissioning

1. Heavy investment in design paid off.
2. Turbine install & commissioning was easy.
3. Microgrid presented challenges.

MST Package Delivered to University of Idaho



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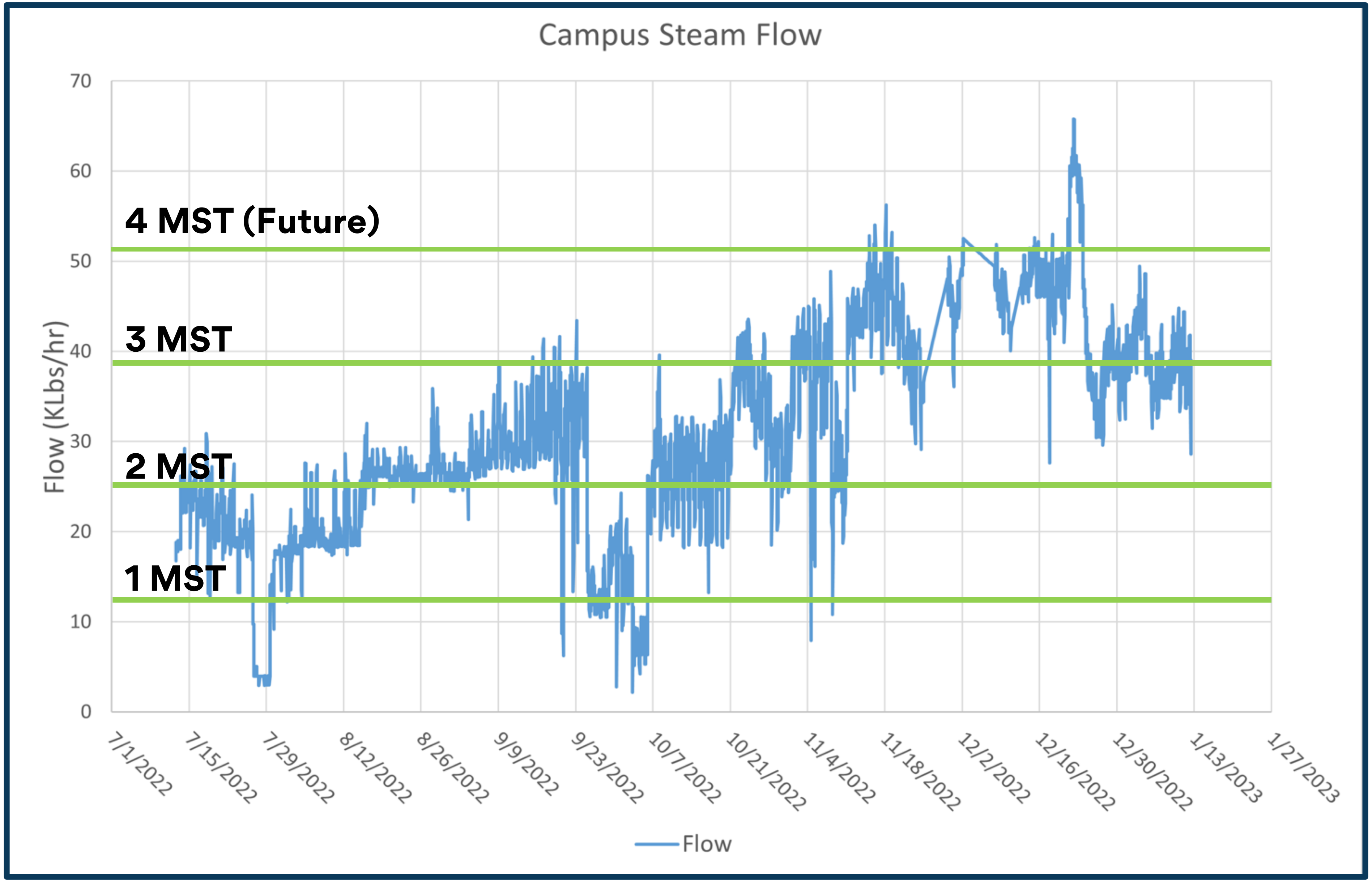


Designing Operational Modes

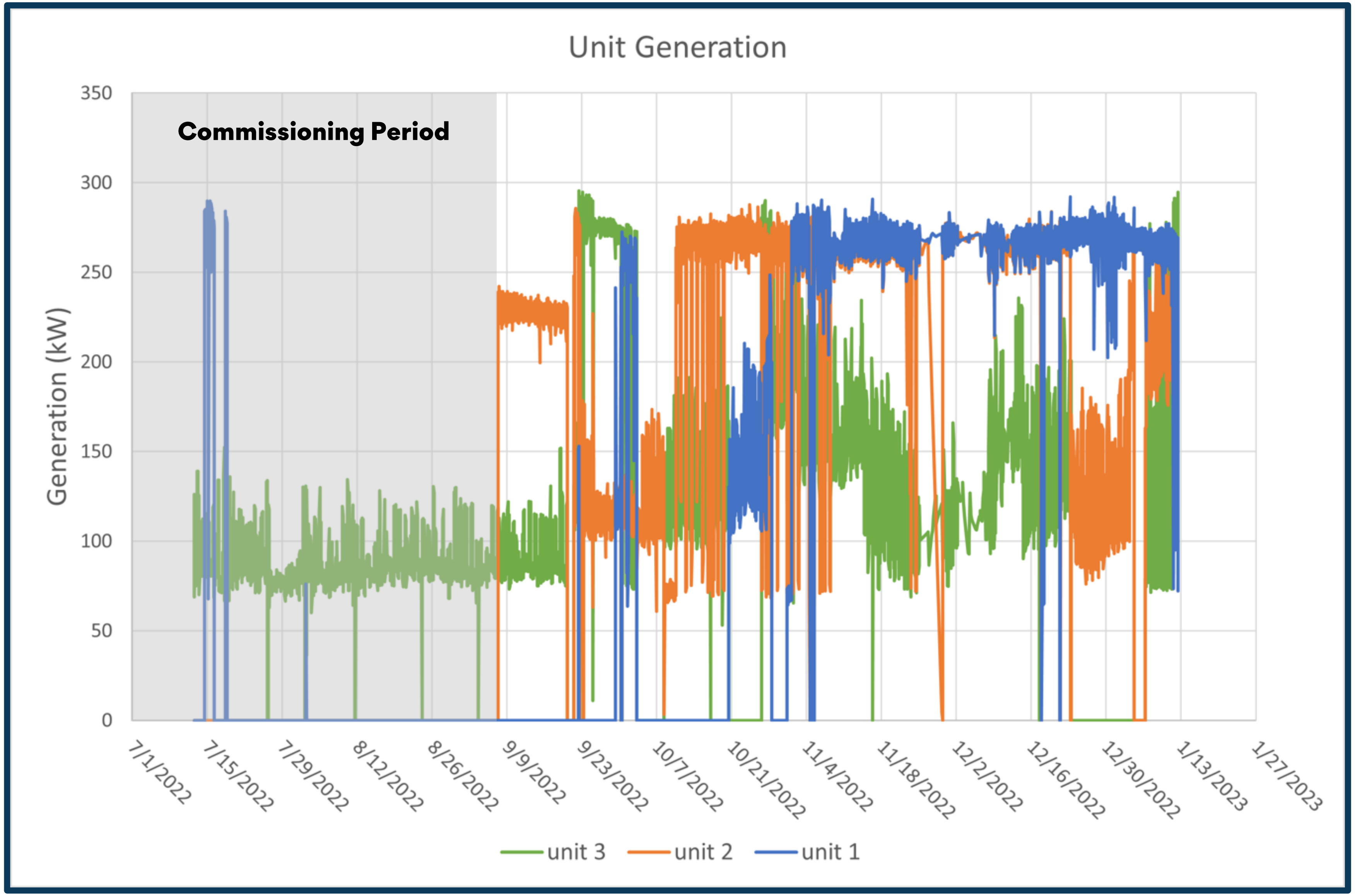
Commissioning proved that electric demand inside the island was well below capacity of 1 turbine- How will we survive a trip?

1. **Load Following-** To catch the grid, one turbine needed to be within 50 kW to catch a trip, but 20 kW determined to be safer.
   - 1 Turbine follows plant electric demand (ex.- 120kW if plant @ 100kW)

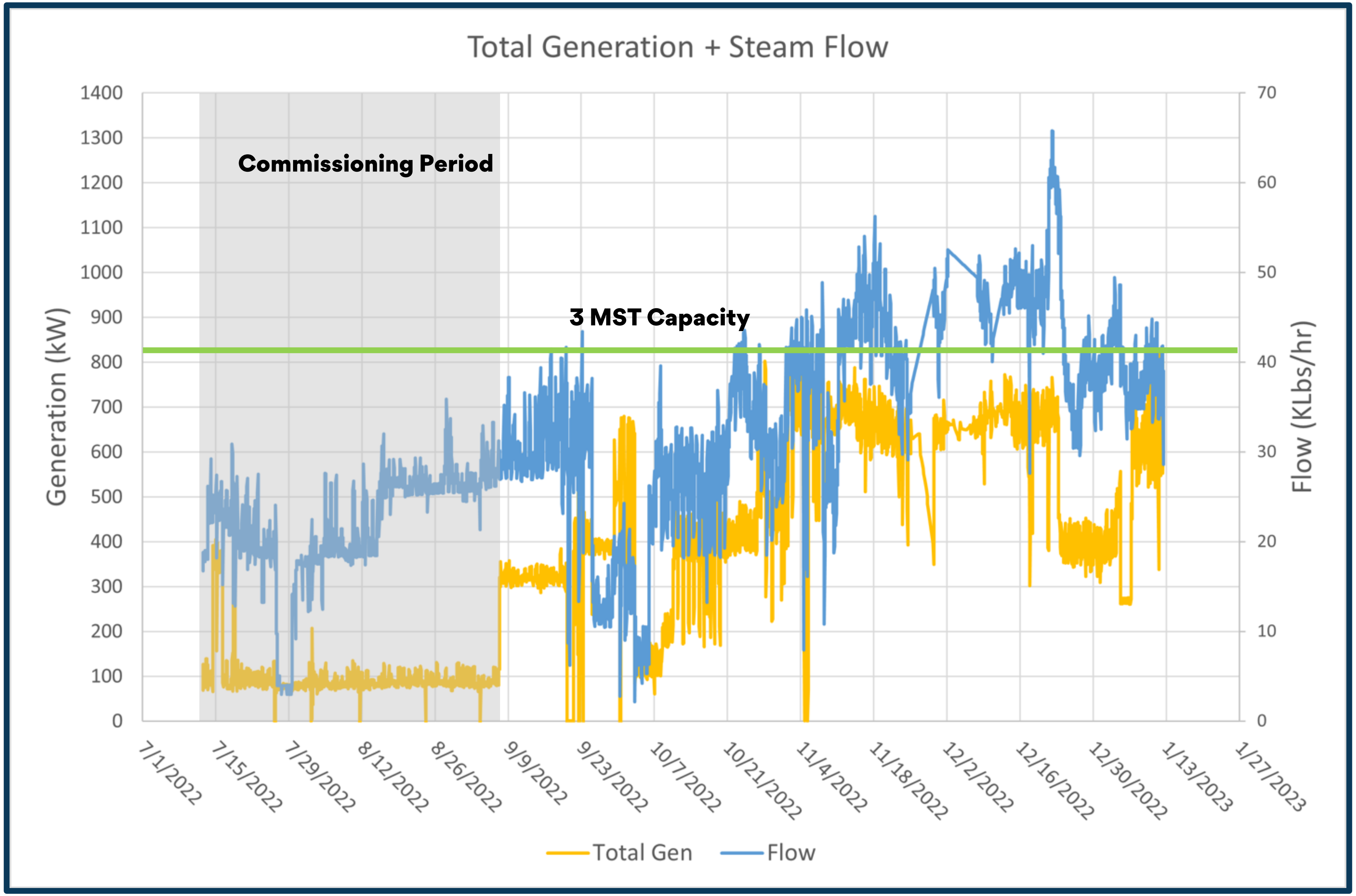
2. **Steam Following-** Regulating header pressure.
   - PRVs maintain pressure slightly above turbines (1/2-1 psig)

3. **Base Load-** Running full on, hitting pre-determined kW output.
   - Looking at capacity kW, not steam flows

Results- Turbines are Cranking!



Steady-State Operation Achieved



Summary

1. Careful, thorough analysis throughout the project, proved successful.
2. Project delivered mid-COVID (2021/22) with minor supply chain delays and cost increases.
3. Turbines generating @ 81% capacity due to unexpected load following requirement.
4. Microgrid is picking up outages, but not yet 100%.
    - Refinement takes time as trips aren't daily occurrence.

Lessons Learned & Next Steps

1. Microgrids are NOT “Copy-Paste.”
2. Load shedding easier than curtailment. Rule: Add more electric load! This was cut out early in the project for budgeting purposes.
3. Huge potential for load following steam plants looking to increase performance.
    - Additional absorbers being explored.
4. 4^{th} Turbine already planned.
5. Follow-on project in development to expand the microgrid.

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