Biomass Powered ORC Turbine at Dalhousie University

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INTERNATIONAL DISTRICT ENERGY ASSOCIATION

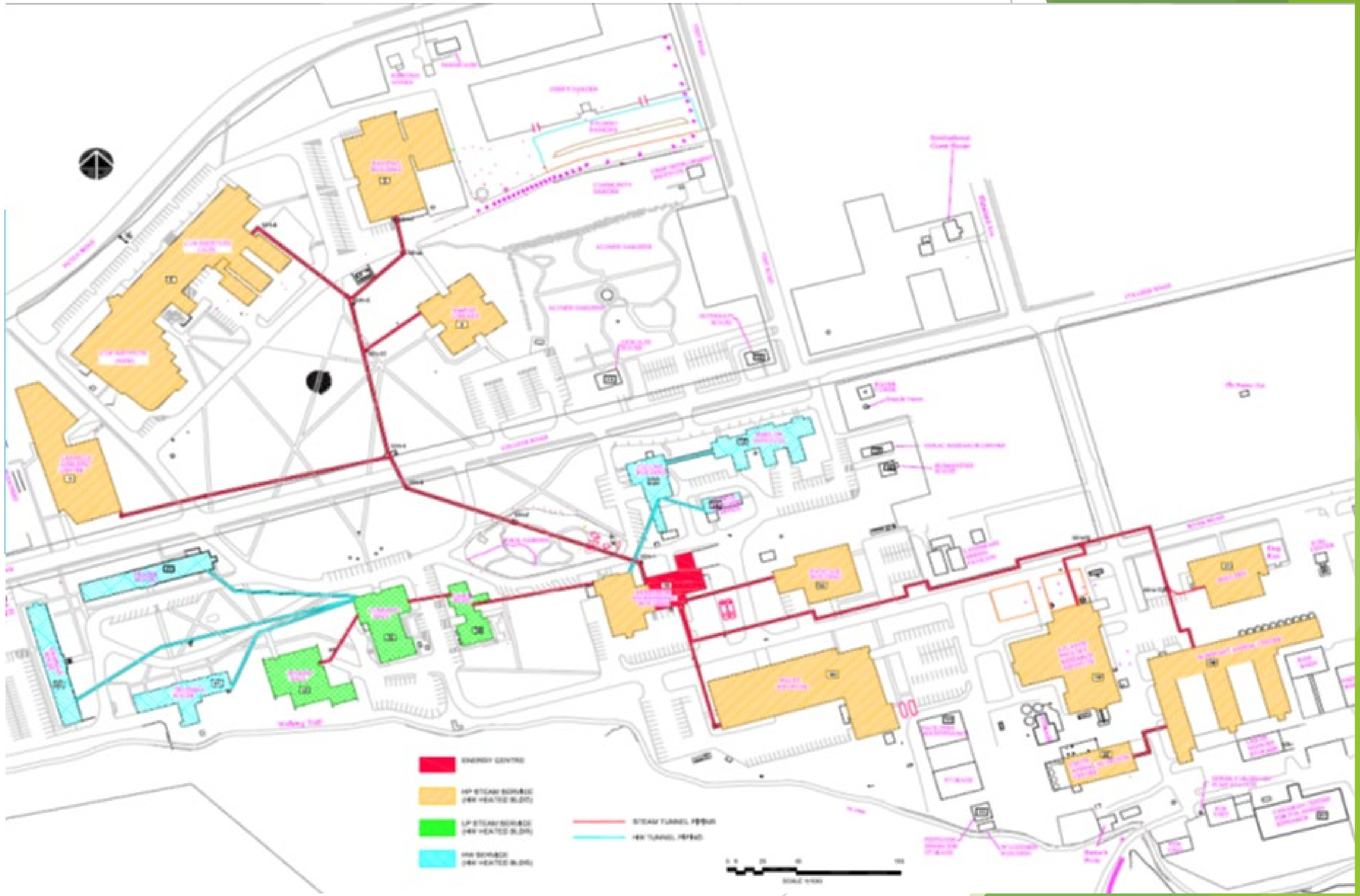
Agenda

- PART 1: Pre and Post District Energy System
- PART 2: How the Project was Executed and Lessons Learned
- PART 3: ORC Technology Description

Where is Dalhousie University?

Dalhousie Agricultural Campus

- Dalhousie University: 18,000 students
- Truro Campus:~ 1,000 students
- Truro Campus:
  - 8 MW Thermal (27,500 PPH)
  - 8,000 metric tonnes of Biomass Annually



Dalhousie's Dilemmas

- Aging Steam Energy Infrastructure

Dalhousie's Dilemmas

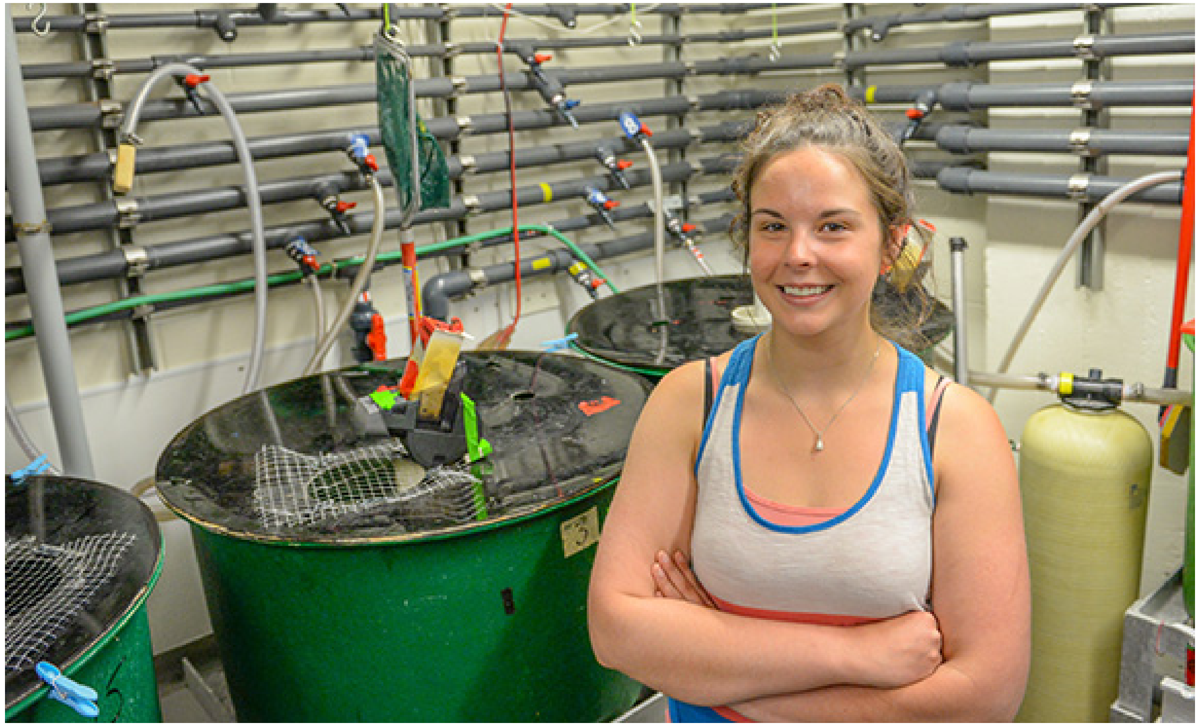
- Condemned Biomass Boiler

Dalhousie’s Dilemmas

- Biomass Fuel Delivery Challenges; Site Constraints; Fuel Type Limitations

Dalhousie's Dilemmas

- Sensitive Research Facilities



Dalhousie’s Opportunities

- **Provincial Feed-in Tariff Program**
- Dual Steam Lines
- Existing Biomass Operations
- Facilities Maintenance and Sustainability Synergies

$100 million
spent in local communities on project-related costs

220 MW
of renewable energy capacity approved under the COMFIT program

125
project approvals issued under the COMFIT program

85%
of electricity capacity approved under the program is from wind energy

$40 million
invested by Nova Scotians for COMFIT projects expected to be online by 2015

Source: Nova Scotia Department of Energy

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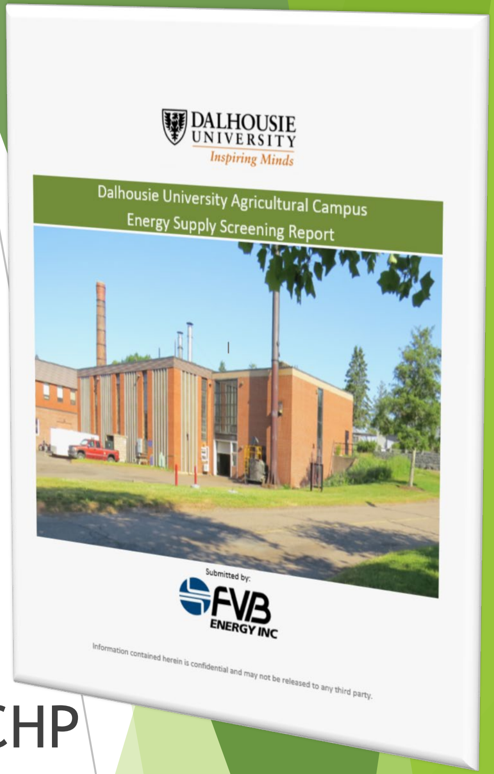
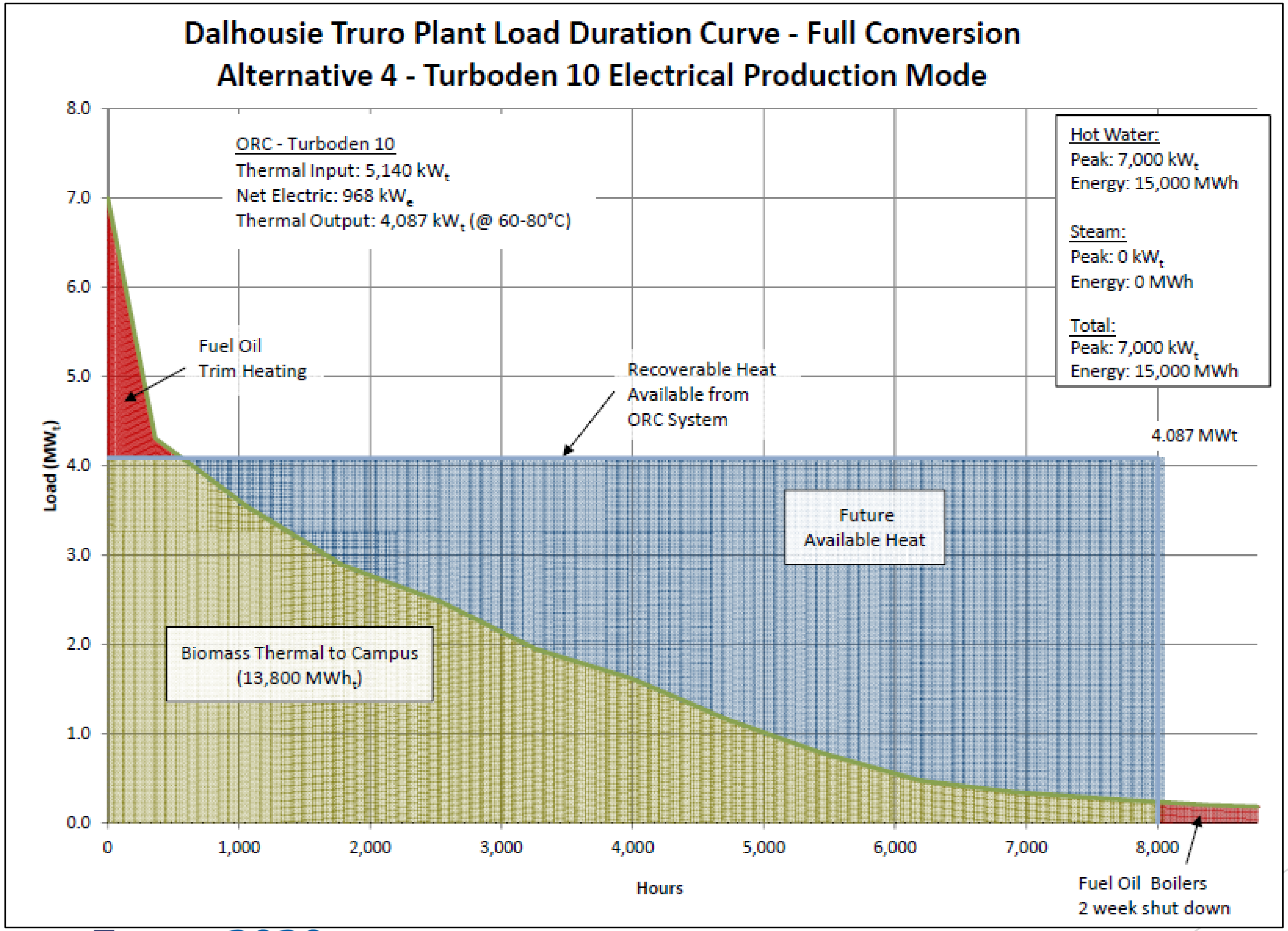
Screening Study

- FVB was hired in 2015 to Complete a Detailed Screening Study
  1. Replace Biomass Steam Boiler (Status Quo)
  2. Biomass Superheated Steam Boiler w/ Extraction Steam Turbine
  3. Biomass Thermal Oil Boiler w/ 700 kWe Organic Rankine Cycle CHP
  4. Biomass Thermal Oil Boiler w/ 968 kWe Organic Rankine Cycle CHP
  5. Biomass Superheated Steam Boiler w/ Back Pressure Steam Turbine



Screening Study- Load Duration Curve



Campus Hot Water Conversion

- **Repurpose Duel Steam Lines**
- New EN 253 Pre-insulated Hot Water Lines
- Steam Humidification Replacement
- New Water to Water ETS
- Transition Planning Meant No Interruptions

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Biomass CHP Concept

- **New Dual Fuel Biomass Storage Bin with Improved Truck Access**
- New Upsized Thermal Oil Heater
- 1.0 MWe Organic Rankine Cycle Generator
- Convert the Backup Boilers from Steam to Hot Water
- Staffing Requirements Were Reduced

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Project Approval & Timelines

- October 2015 – The Board approved the Schematic Design phase for a biomass cogeneration system at the AC campus to replace the steam boiler.
- On April 29, 2016 the Board approved to commence detailed design and construction
- Total Project Budget: $ 26.45 Million
- Per COMFIT, Must Achieve Commercial Operation at Rated Capacity by June 10, 2018
- Less than 2.5 Years to Design and Construct the Project

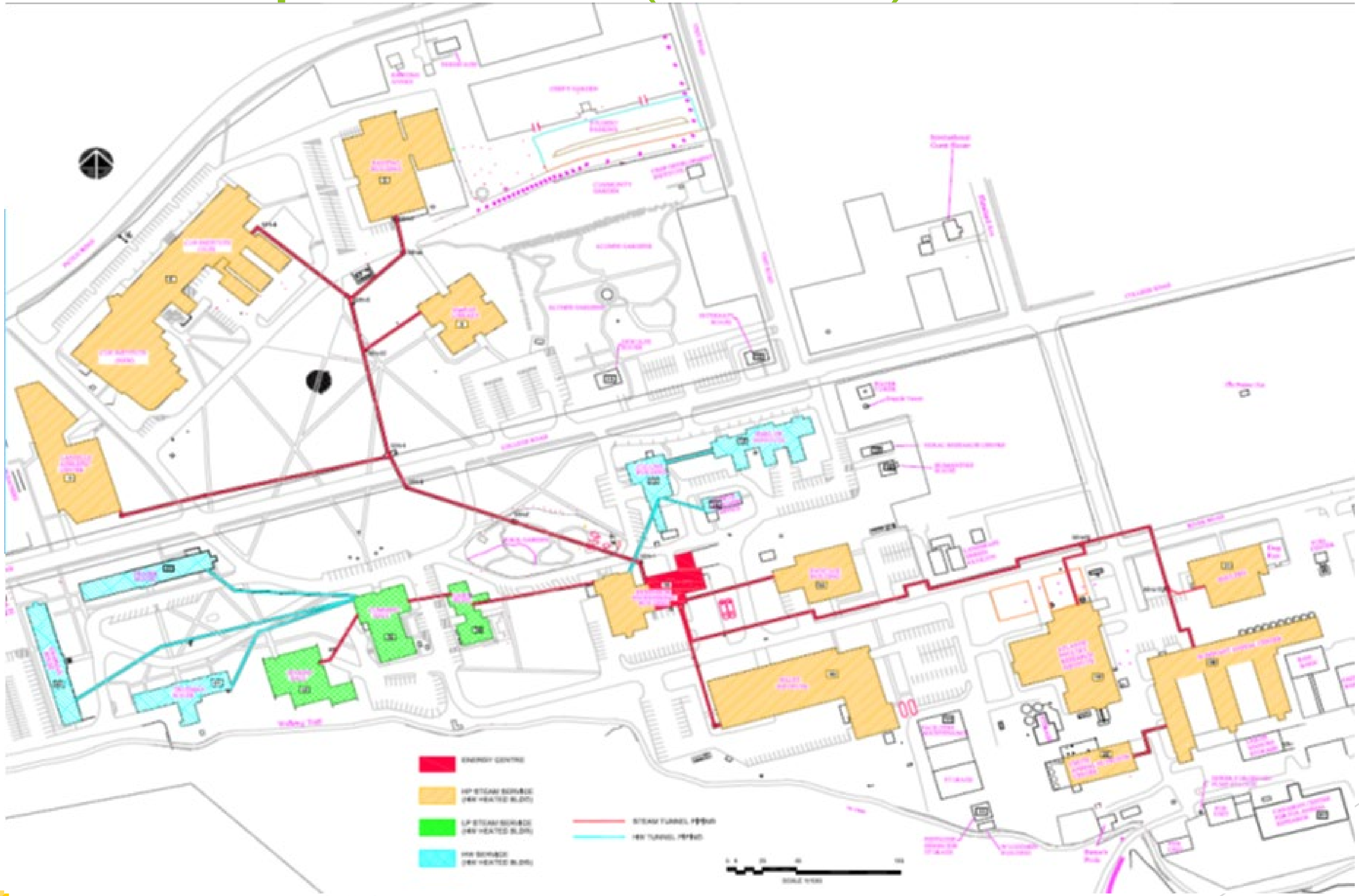
Engineering, Procurement, Construction & Commissioning Method

- Design-Bid-Build
- Detailed Design was completed by FVB Energy and Dillon Consulting
- Major Equipment was Pre-purchased by Dalhousie and Assigned to the General Contractor
- Construction was Completed by General Contractor under a Stipulated Price Contract
- Dalhousie Retained an *Integrated Systems* Commissioning Agent

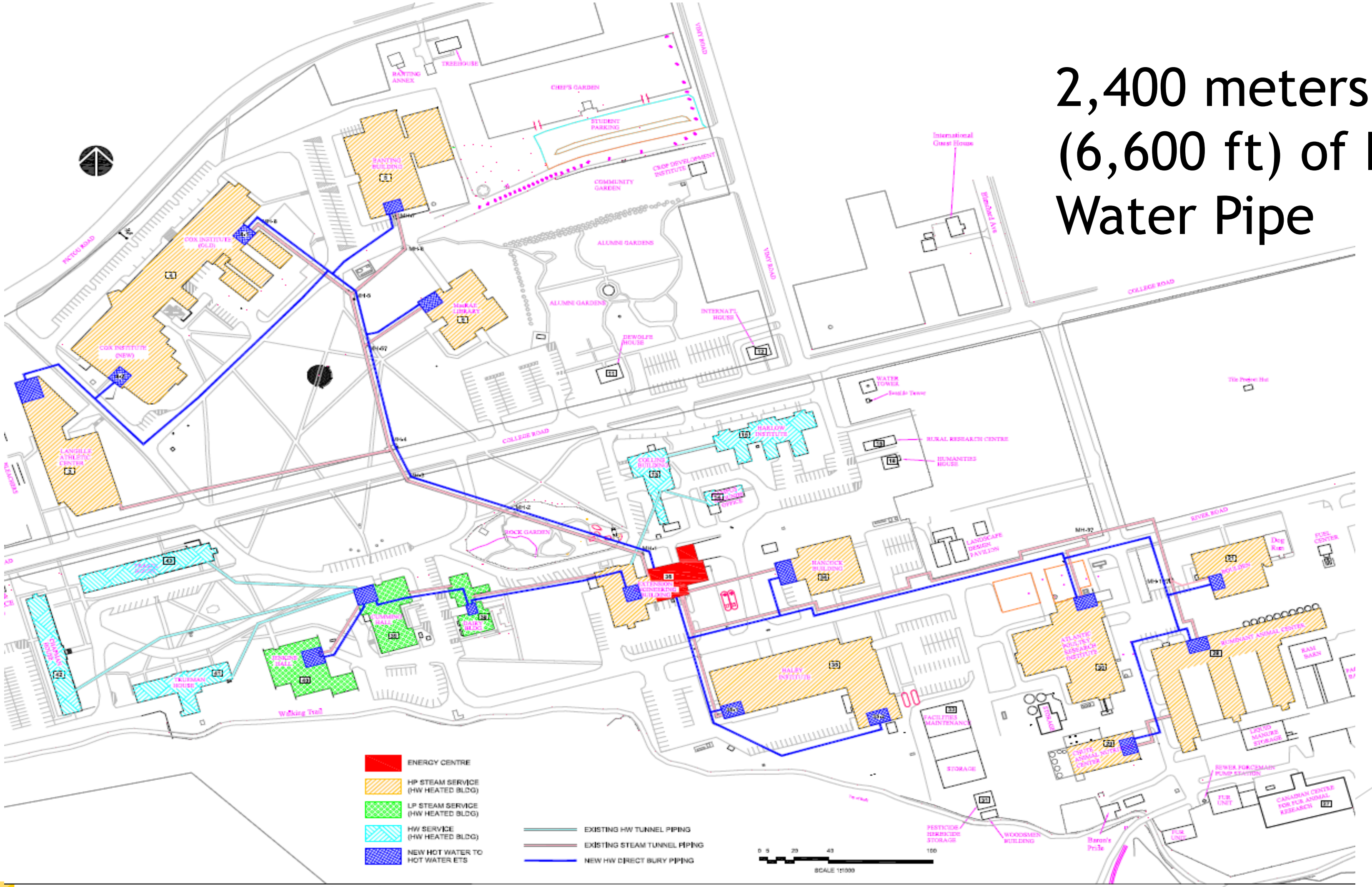
Project Results Summary

- The Hot Water Conversion was successfully executed over the period of two summers. No campus interruptions. There was no loss to any Research.
- The University was able to satisfy its commercial obligations with the province/utility and export 1 MW on May 7, 2018.
- Substantial completion of the CHP facility was granted on July 18, 2018
- The project came in slightly over budget (2%)
- Performance of the new Thermal Boiler and ORC Generator are both exceeding their nominal output ratings

System Map- Before (Steam)



System Map- After (Hot Water)



2,400 meters (6,600 ft) of Hot Water Pipe

Load and Energy Summary

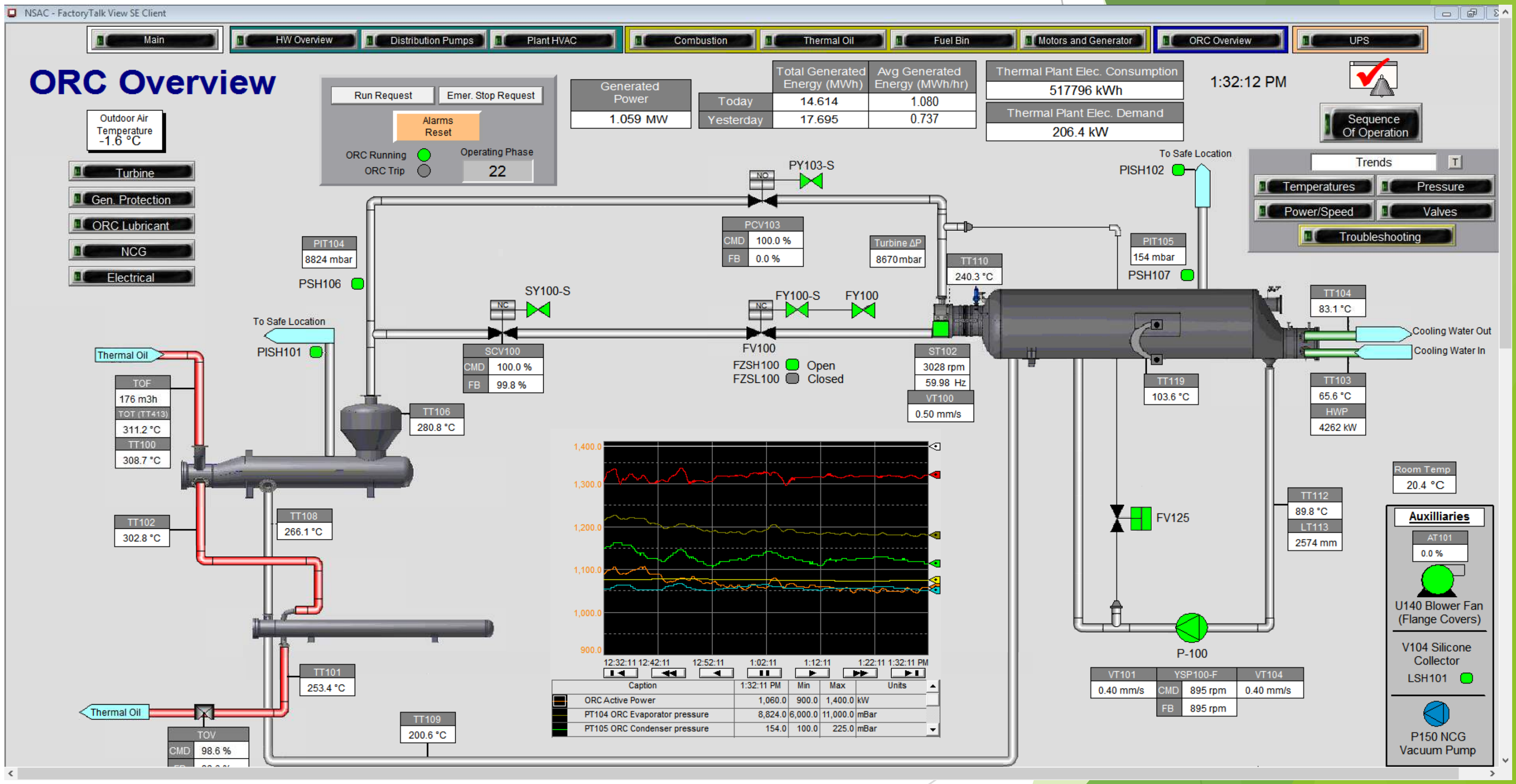
As a Result of the Steam to Hot Water Conversion:

Thermal Load/Peak Reduced by 25%

Thermal Energy Reduced by 25%

Biomass Boiler and ORC Performance

- Peak Electrical Power To Date of 1.3MWe
  - Achieved Through Unusually Low M.C. Fuel (35% vs 48%) and Optimal ORC Cooling Water Temps (55°C)
- On average, we predict we will overperform by 12% annually



Lessons Learned- Part 1

- Leave yourself longer than 2.5 years to execute a project of this scale. Particularity with a hard COMFIT or PPA deadline and a large steam to hot water conversion.
- The Owner needs to play the role of Construction Manager
  - Too complicated and inter-related to leave to a single or group of contractors
  - The GC did not have significant experience with the Biomass Boiler and ORC Equipment that was selected.

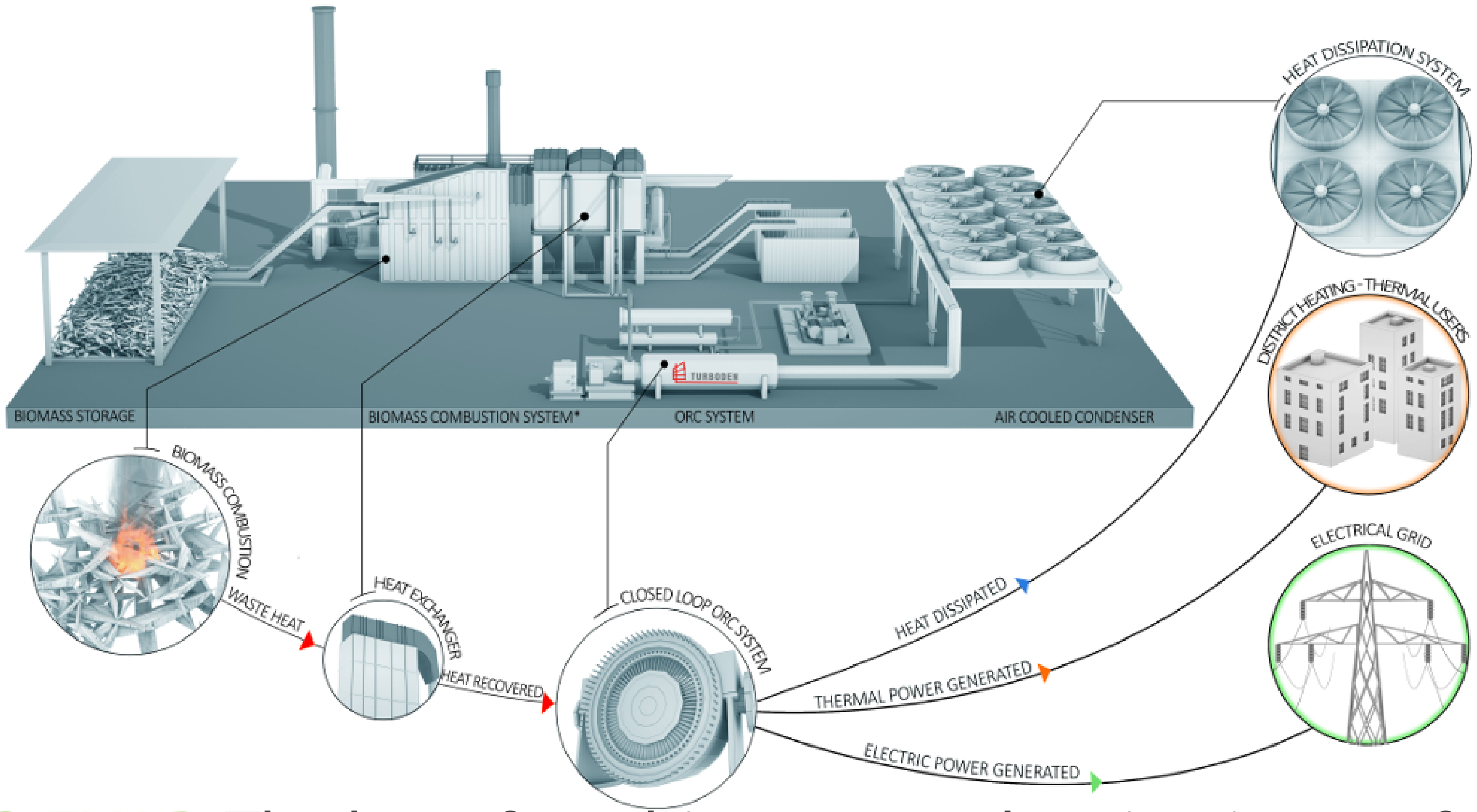
Lessons Learned- Part 2

- If schedule permits, avoid pre-purchasing equipment wherever possible to avoid holes in scope. If you pre-purchase, have strong language for contactor receipt and handling.
- Engage the Commissioning Agent early in the process. Have them focus on integrated systems and balance of plant.
- Engage the Electric Utility Early and Don’t ‘settle’ on their design. Look for synergies and cost savings.
- Positively pressurize your electrical & ORC rooms.
- Equipment redundancies and/or critical spare parts on site.

Next Steps For Dalhousie

- Efficiency & Cost Reporting
- Find a use for available excess heat
- Continue to work with Biomass Fuel Suppliers to fine tune the fuel performance.
- Look for opportunities to monetize the ash that is produced.
- Establish Standard Operating Procedures for when to produce what amounts of power for best thermal & economic efficiency

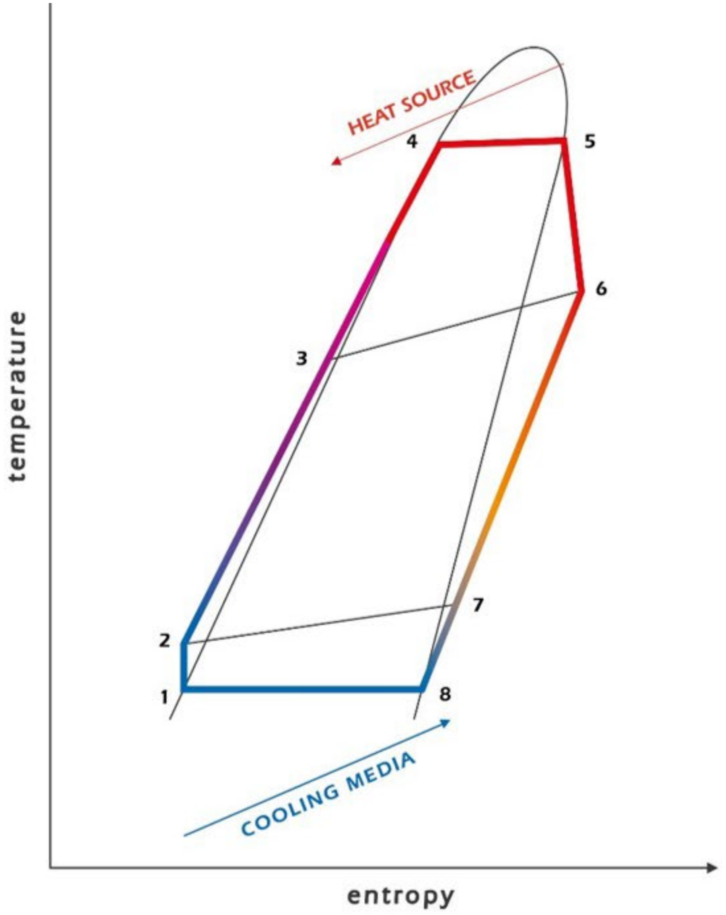
ORC Biomass Plant

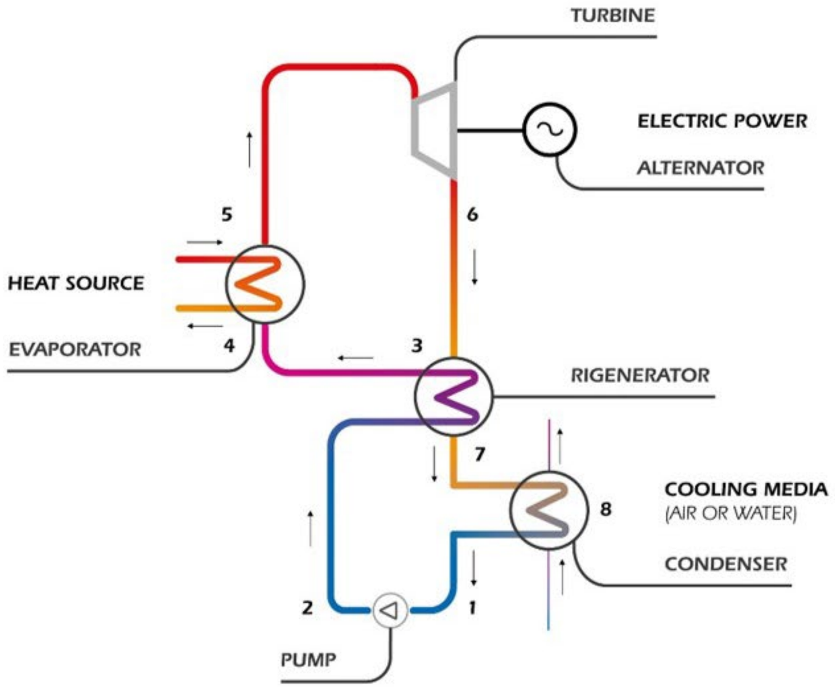


HEAT TRANSFER FLUID The heat from biomass combustion is transferred to the ORC working fluid by means of an intermediate circuit or directly via the combustion gases in direct exchange systems. The media used in the intermediate circuits are thermal oil, saturated steam or superheated water.

The ORC Cycle

- Preheat + vaporize organic working fluid in the evaporator (4>5).
- Vapor rotates the turbine (5>6), coupled to the electric generator.
- The exhaust vapor flows into the regenerator (6>7),
- Condensed + cooled by the cooling circuit (7>8>1).
- The organic working fluid is then pumped (1>2) into the regenerator and evaporator, completing the closed-cycle operation.





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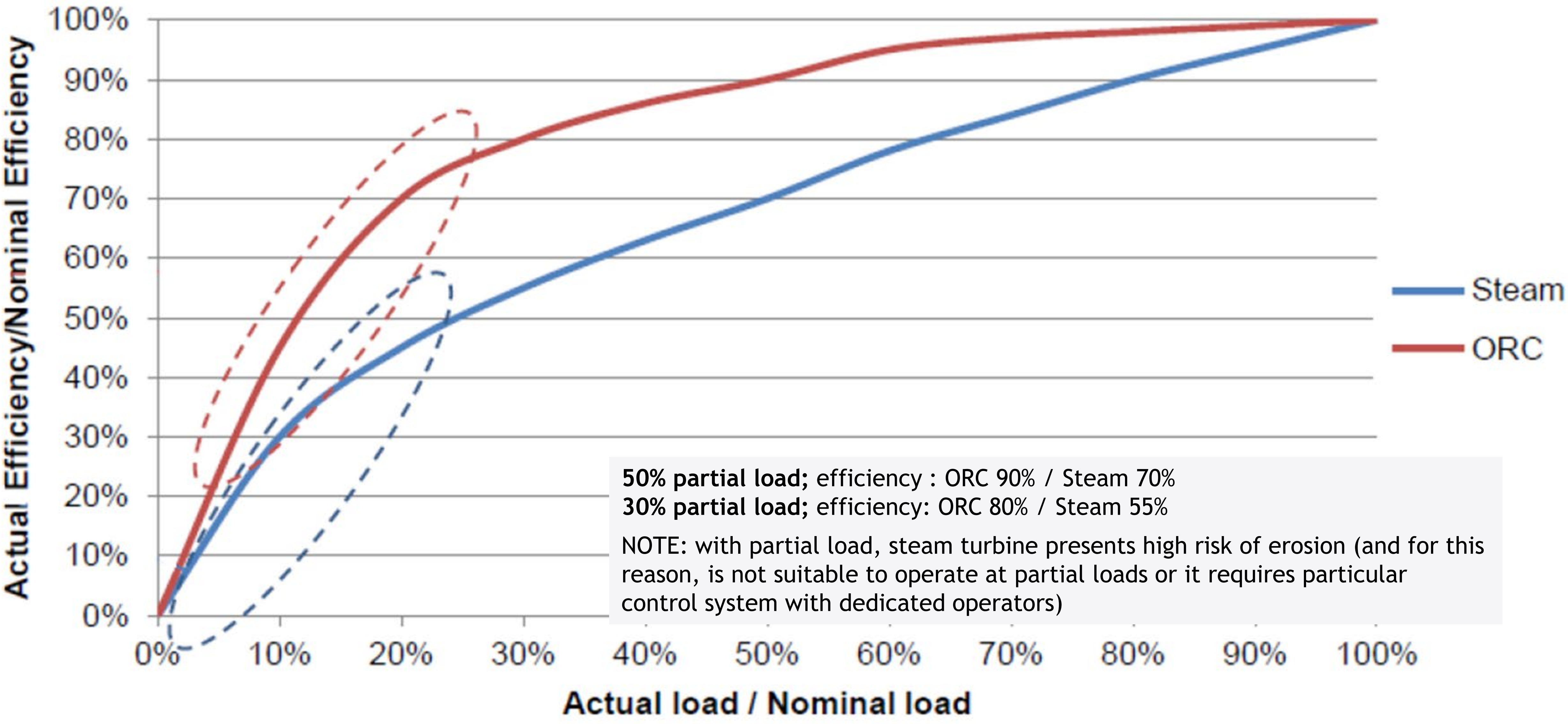
The Principle

The ORC system vaporizes an organic fluid, characterized by a molecular mass higher than water, which leads to a slower rotation of the turbine and lower pressure and erosion of the metallic parts and blades.

Advantages

- Low Temperature,
- Simple start up procedure
- High availability
- Partial Load operation down to 10% of nominal power
- Low operation & maintenance requirements



50% partial load; efficiency : ORC 90% / Steam 70%
30% partial load; efficiency: ORC 80% / Steam 55%

NOTE: with partial load, steam turbine presents high risk of erosion (and for this reason, is not suitable to operate at partial loads or it requires particular control system with dedicated operators)

Thank You!

Questions?