# THE UBC TRANSITION:

## The Evolution of Low Carbon District Energy and Innovative Solutions at University of British Columbia


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IDEA MAIN CONFERENCE JUNE 11-15TH 2018 VANCOUVER

# THE UNIVERSITY OF BRITISH COLUMBIA

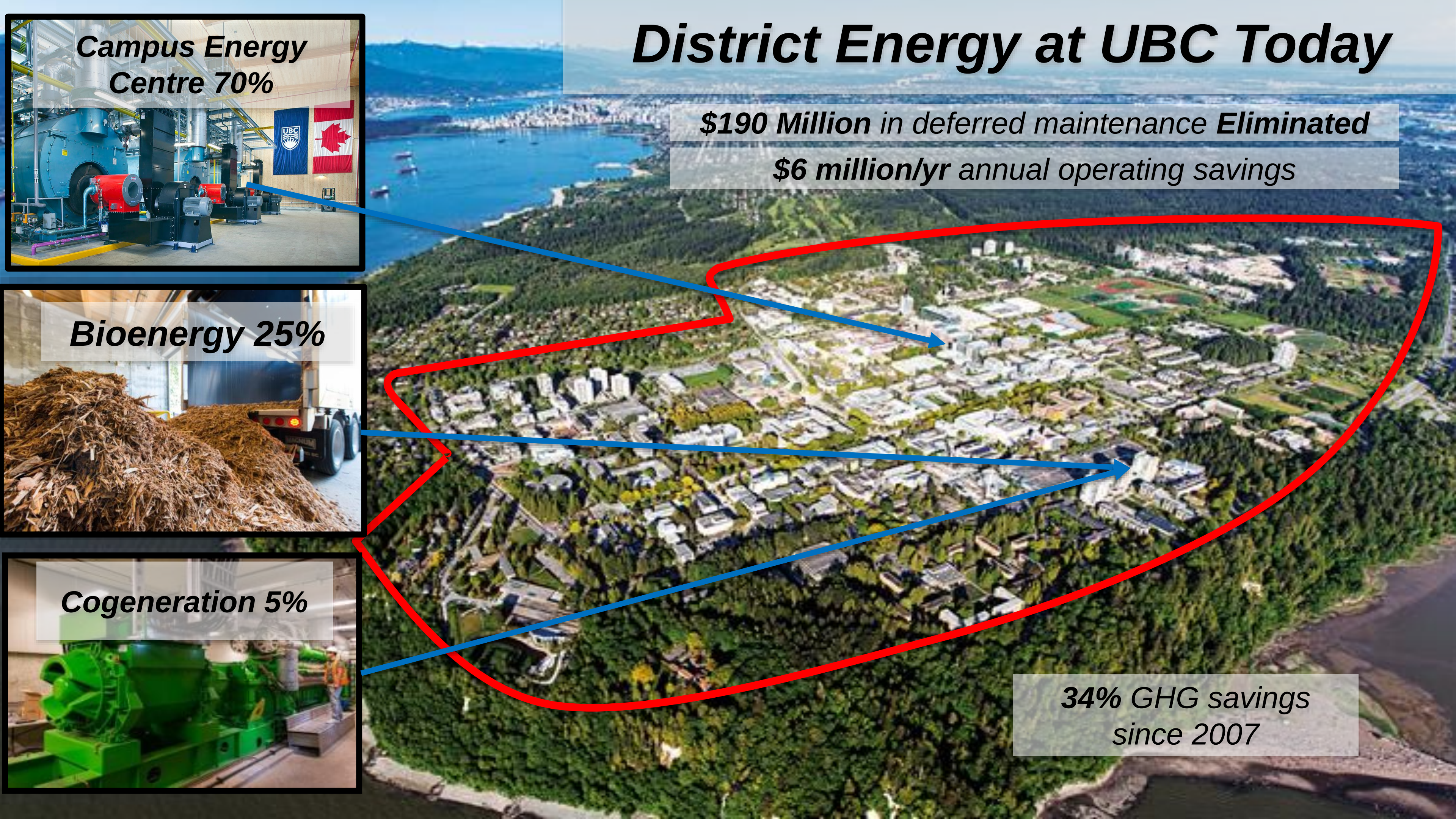
***Single Owner***
***1000 acre campus***

*Day time population* ***69,000***

***17 million sqft*** *of floorspace*

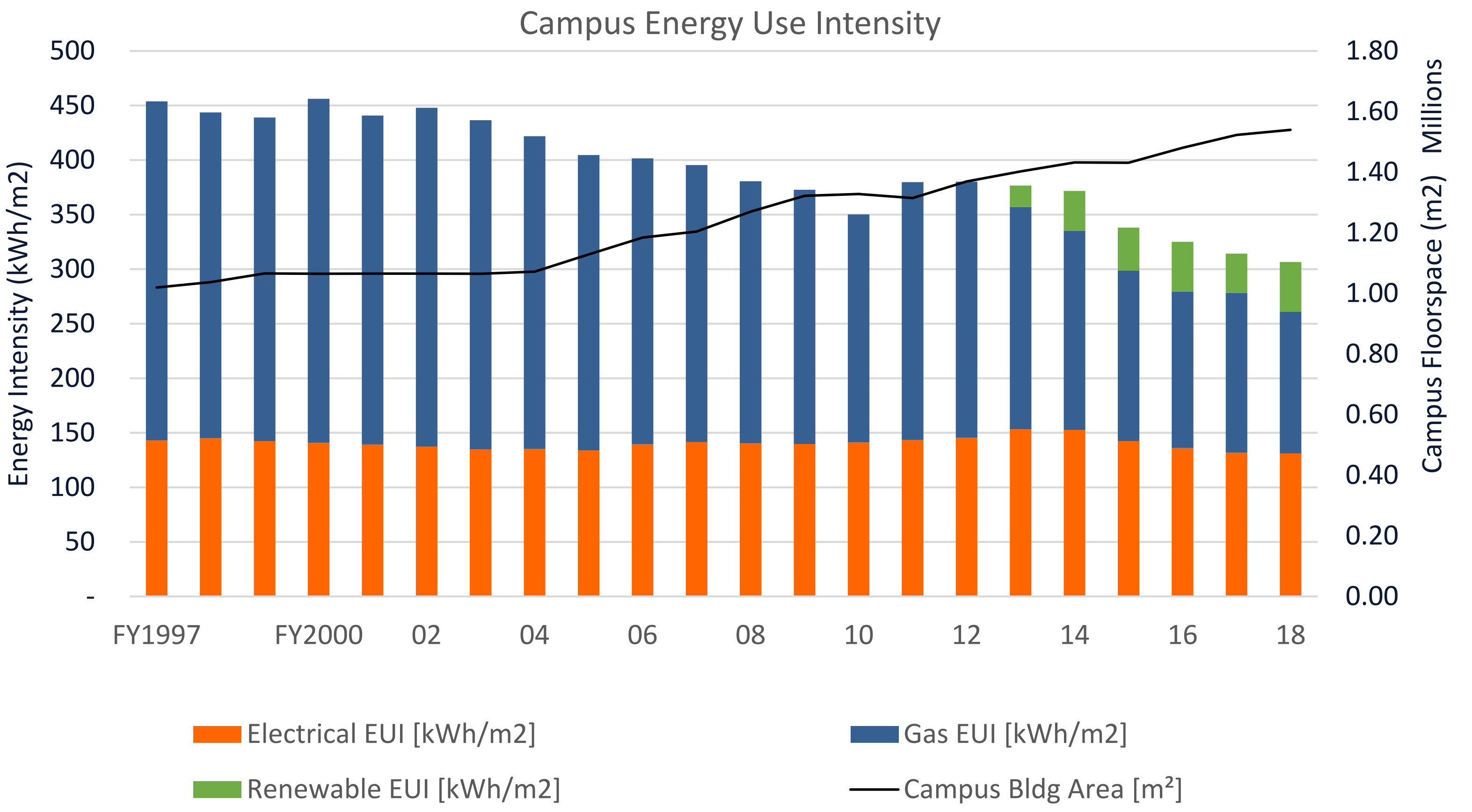
*Average annual growth of* ***200,000 sqft***

***$54 million*** *annual Utility Budget managed by UBC Energy & Water Services*



District Energy at UBC Today
$190 Million in deferred maintenance Eliminated
$6 million/yr annual operating savings
Campus Energy Centre 70%
Bioenergy 25%
Cogeneration 5%
34% GHG savings since 2007
UBC

# UBC ENERGY STORY

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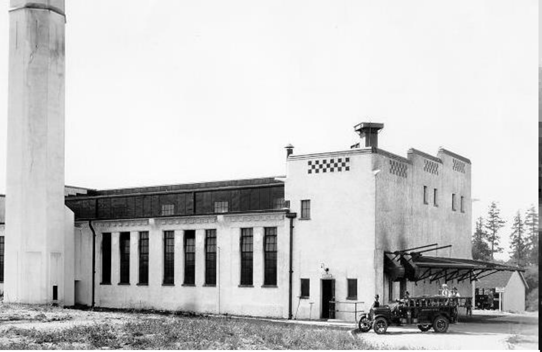
# PROJECT DEVELOPMENT – THE QUESTION

***"Is there a better way"***

*David Woodson Director UBC Utilities circa 2007*

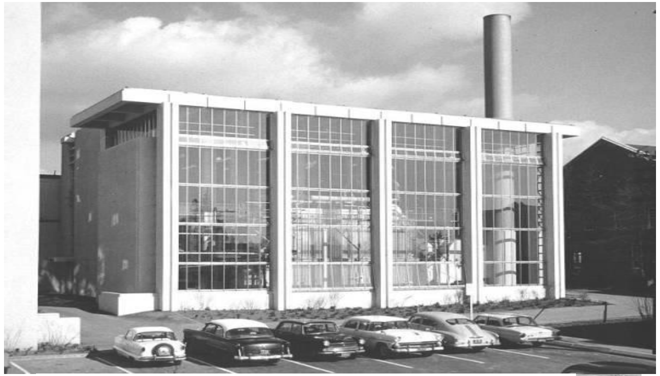
# Brief history of District Energy at UBC



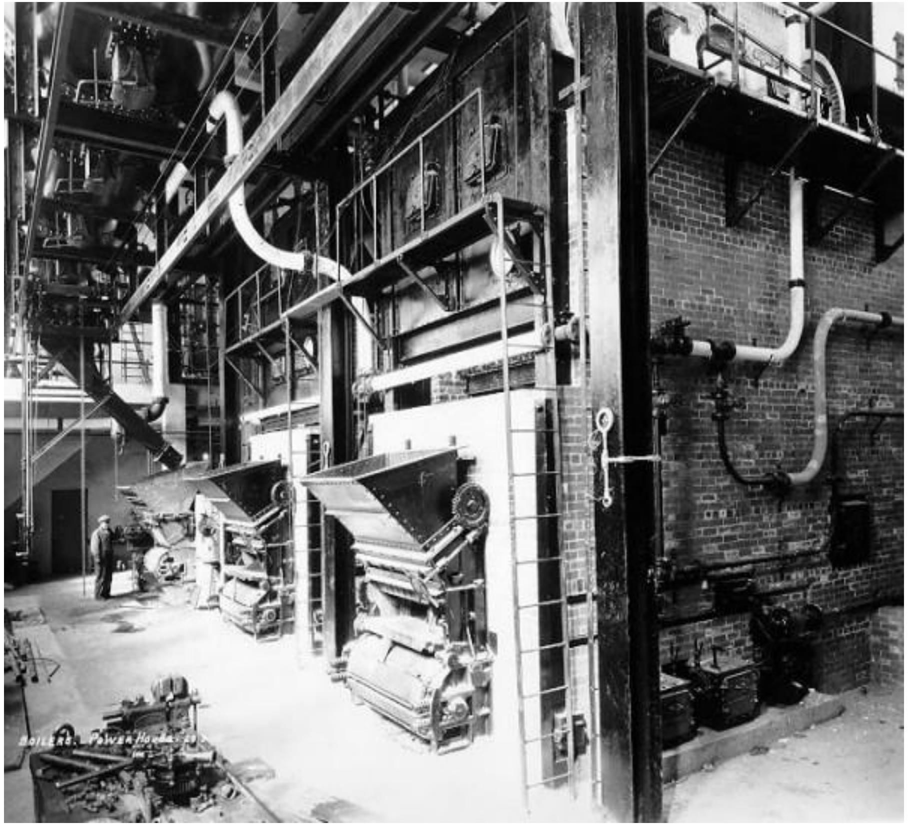
UBC Powerhouse circa 1925
3rd Permanent building
on campus

# BRIEF HISTORY OF DISTRICT ENERGY AT UBC CONTINUED

1925: 3 original Boilers (Coal fired)
1950’s Boilers 1, 2 & 3 replaced (FO)
1961 New wing added and Boiler 4 (NG) installed
1965 Boilers 1, 2 & 3 converted to NG
1969 Boiler 5 installed
1972 Boiler 3 decommissioned (Fire)
Total installed Capacity **120 Megawatts** (Nameplate)



UBC Powerhouse circa 1969



Boiler #1 circa 1925

# 2002 - 2007 UBC ECOTREK PROJECT

- ***Largest project*** of it's kind at a Canadian University
- Saved ***more than*** $2.6 Million/yr.
- Enabled UBC to meet it's ***Kyoto Protocol***

Targeted Projects

- Lighting (T12 to T8)
- HVAC and BMS Controls
- Once-Through Cooling retrofits
- **Steam system upgrades**
  - Boiler Economizers
  - Low NOx burners
  - Condensate Return

2004 Sofame Percotherm installed. Boiler efficiency raised from 70 to 78%

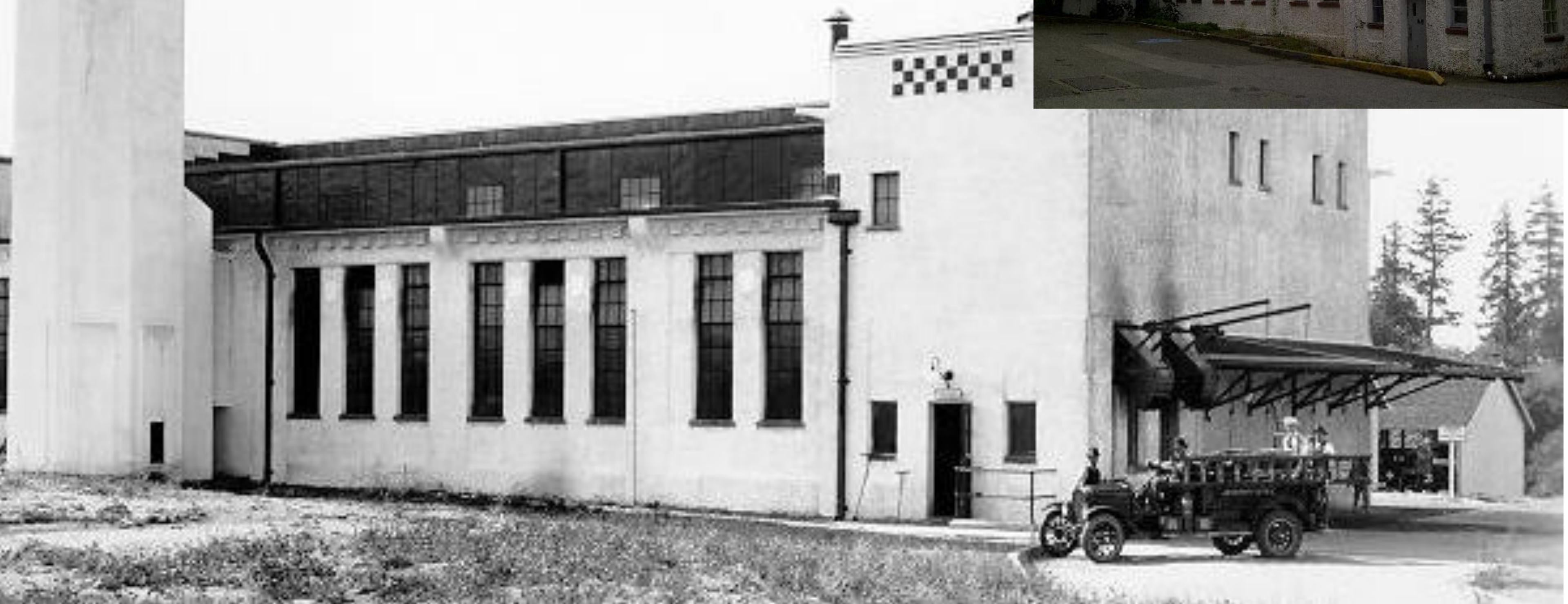
2006 New Low NOx burners and Burner Management System. Boiler efficiency raised by 5%


2005 3,650m trench new condensate return. 80% return

# Drivers for Change

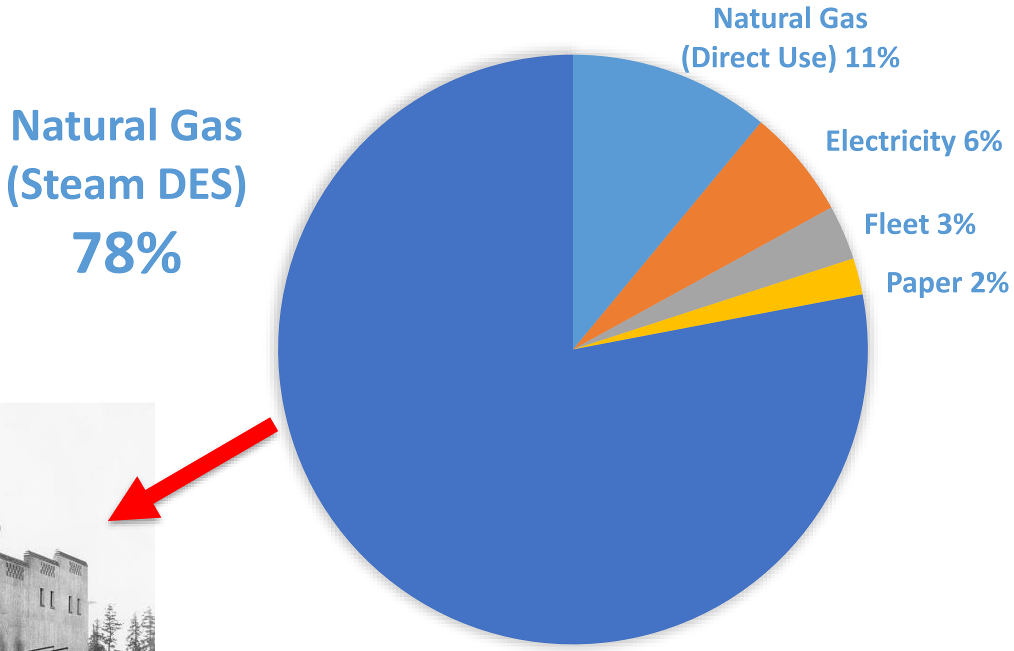
- No.1 Seismic Risk on Campus
- Aging infrastructure
- $190M in deferred maintenance

UBC Powerhouse 2015



# *2007 First Comprehensive Campus Greenhouse Gas (GHG) inventory*

## 2007 BASELINE IS 61,090 TONNES CO2




# Alternative Energy Sources Committee

- A multi-disciplinary committee of experts in their fields
- Developed guiding principles for evaluating Options
- Commissioned Alternative Energy Feasibility Study


Nobel Laureate Dr. John Robinson

CERC | Clean Energy Research Centre

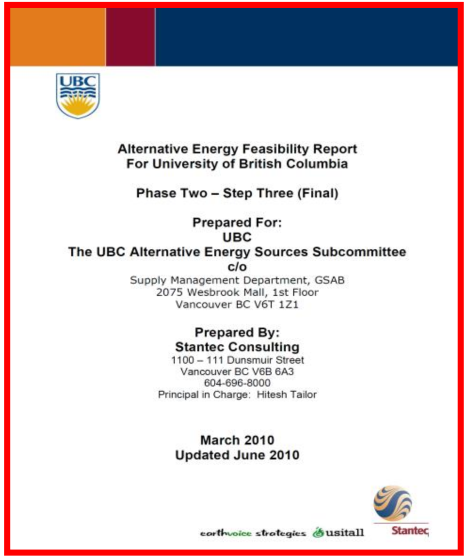
IRES

UBC sustainability

SAUDER School of Business

# ALTERNATIVE ENERGY STUDY - Conclusions

1) Conversion of campus from ***Steam to Hot Water*** is the ***preferred*** delivery option regardless of supply or demand scenarios.
2) Continue implementing all ***cost effective*** demand side measures
3) Further studies required to confirm technical, regulatory and financial viability of preferred supply options i.e. ***Large Biomass*** and/or ***Ocean Source Heat Pump***



**Alternative Energy Feasibility Report**
**For University of British Columbia**

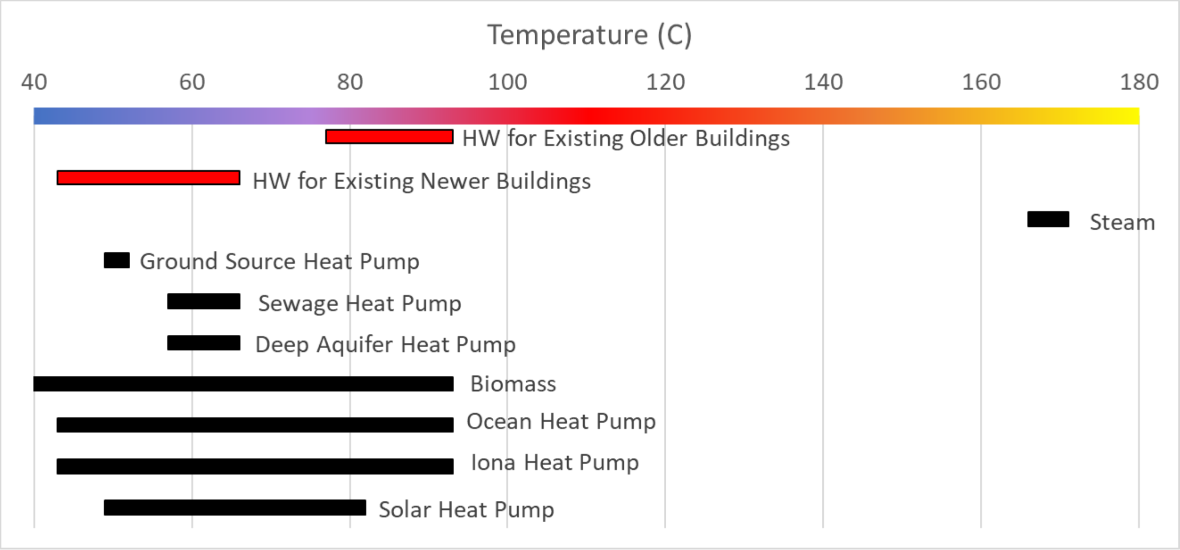
**Phase Two – Step Three (Final)**

**Prepared For:**
**UBC**
**The UBC Alternative Energy Sources Subcommittee**
**c/o**
Supply Management Department, GSAB
2075 Wesbrook Mall, 1st Floor
Vancouver BC V6T 1Z1

**Prepared By:**
**Stantec Consulting**
1100 – 111 Dunsmuir Street
Vancouver BC V6B 6A3
604-696-8000
Principal in Charge: Hitesh Tailor

**March 2010**
**Updated June 2010**

earthvoice strategies usitall Stantec



# STEAM VS HW SYSTEM EFFICIENCY COMPARISON

## Powerhouse

Boilers +
Sofame 89%

Deaerator+
parasitic
losses -9%

## Steam & Condensate Distribution

Insulation losses + steam traps

Condensate 60-70% returned

## Building/ End User

Shell & Tube heat
exchangers

Steam traps +
Hot water
tanks losses

Plant = 80%

Distribution = 80%

End User = 90%

Overall Steam DES Efficiency = 80% x 80% x 90% = **60%**

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## Campus Energy Centre

Boilers +
Condensing
economizer
88%

## Supply & Return Piping

**Insulation losses minimal**

Return Water 100%

## Building/ End User

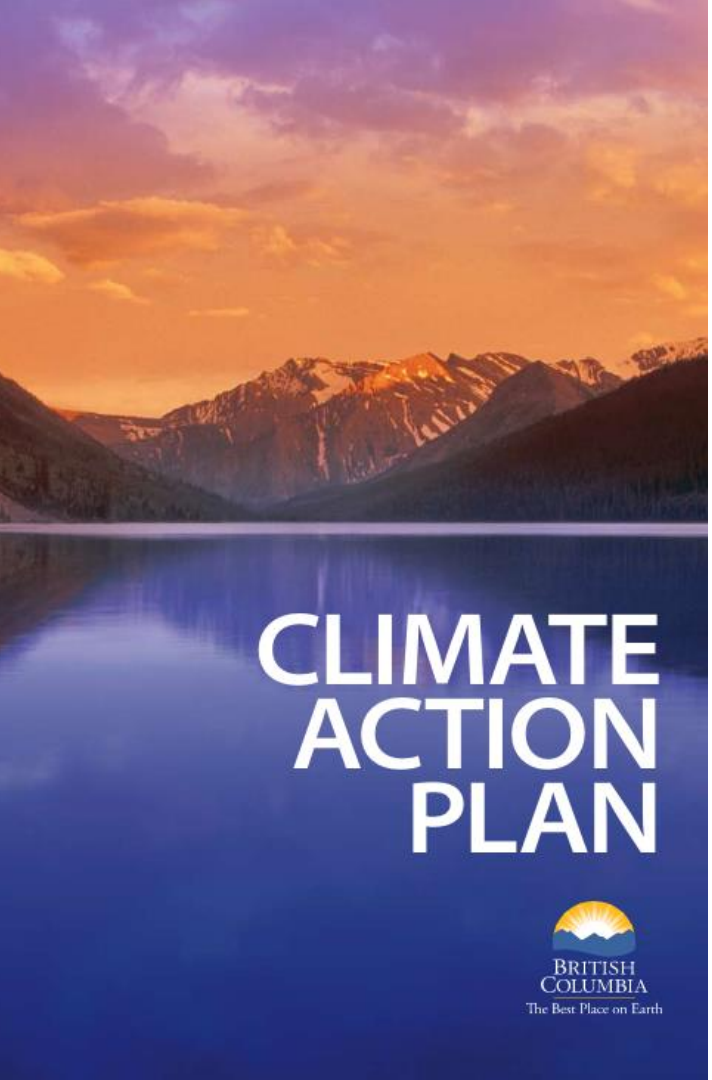
Plate heat
exchangers,
cascaded with
domestic.
No DHW tanks
required

Plant = 88%

Distribution = 97%

End User = 99%

Overall Hot Water DES Efficiency = 88% x 97% x 99% = **84%**




## PROVINCIAL CARBON TARGETS

**33%** below **2007** levels by **2020**

**80%** below **2007** levels by **2050**

- **BILL 44 —** Carbon Neutral Public Sector ($25/tonne$CO_2$)
- **BILL 37 —**Carbon Tax ($30/tonne$CO_2$)
- Combined cost to UBC ($55/tonne$CO_2$)

**$3.4 Million/yr**

# BUSINESS CASE – THE ECONOMICS OF HOT WATER VS. STEAM

| Savings & Cost Avoidance | 30 Year NPV ($ Millions) |
|---|---|
| Energy (Natural Gas) | $27.5 |
| Carbon | $9.0 |
| Water | $1.9 |
| Staff | $19.4 |
| Maintenance | $1.5 |
| Capital Avoidance | $24.4 |
| **Total** | **$83.8** |

# The Stars Align…


UBC 2010 Climate Action:

Greenhouse Gas reduction targets of:

**33%** below **2007** levels by **2015**

**67%** below **2007** levels by **2020**

**100%** below **2007** levels by **2050**

# HOW TO GET FUNDING FOR YOUR HOT WATER PROJECT CHECKLIST

- ✓ Complete a major energy retrofit in advance of your ask ($30M with an average 10 year simple payback).
- ✓ Have a former US President mention your project at an International Conference where your University President and respective peers are present.
- ✓ Have your University President identify Sustainability as one of their core pillars of their presidency.
- ✓ Time the hosting of the Winter Olympics with a Global Energy Conference where your president can announce your university's aspirational & inspirational GHG reduction targets.
- ✓ Seek Executive and Board Approval for the projects (that you've been working on anyways for the last 3 years) that will achieve those targets on the basis that those projects have a sound business case.

# UBC'S 2010 LOW CARBON ROADMAP

## 2015
### 33% GHG Reduction

Supply:

- ✓ Biomass demonstration: (9%)
- ✓ Steam to Hot water conversion (start) (17%)

Demand:

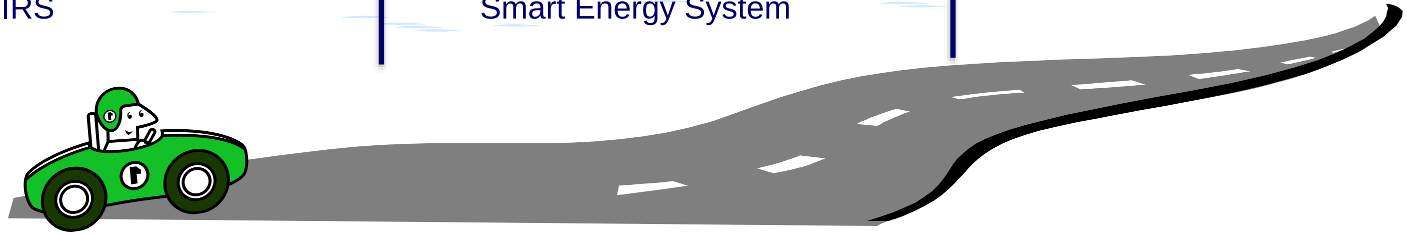
- ✓ Building Tune-ups (10%)
- ✓ New Buildings: Low temperature and energy
- ✓ CIRS

## 2020
### 67% GHG Reduction

- 8.5MW Clean Energy: Biomass II (23%)
- ✓ Steam to Hot water conversion (completion) (5%)
- Triumf?
- Building Tune-ups
- ~~BC Hydro Self-Sufficiency (6.5%)~~
- New Buildings: Low temperature; energy neutral
- Smart Energy System

## 2050
### 100% GHG Reduction

- New clean energy sources: Ocean, Waste, Aquifer?
- Extend District Heating system to all campus buildings
- Building Tune-ups
- New Buildings: energy neutral
- ✓ Transport changes



# Q&A
# PROJECT DEVELOPMENT

# PROJECT DELIVERY

# THE MOTIVATION FOR CHANGE

**Academic District Energy System**

- **Deferred Maintenance** — $190m VFA Audit, $45m for boilers
- **GHG reduction** — UBC CO2 reduction 33% by 2015, ADES achieves 22% of this
- **Economics** — Saves $4m per year: From Fuel, FTE's, Maintenance, Carbon Tax's reductions
- **Efficiency and energy conservation** — 280,000GJ NG reduction per year. 60% Vs 84% DES efficiency
- **Use of new technologies** — E.g. Condex, LED fixtures
- **Demonstration and Leadership** — Industry, Municipalities and Peers
- **Research** — E.g. Energy data Available to all
- **Enabling platform for other technologies** — E.g. Life Sciences Centre, and BRDF Engine HR
- **Resiliency** — Steam Powerhouse is the No.1 Seismic Risk on Campus

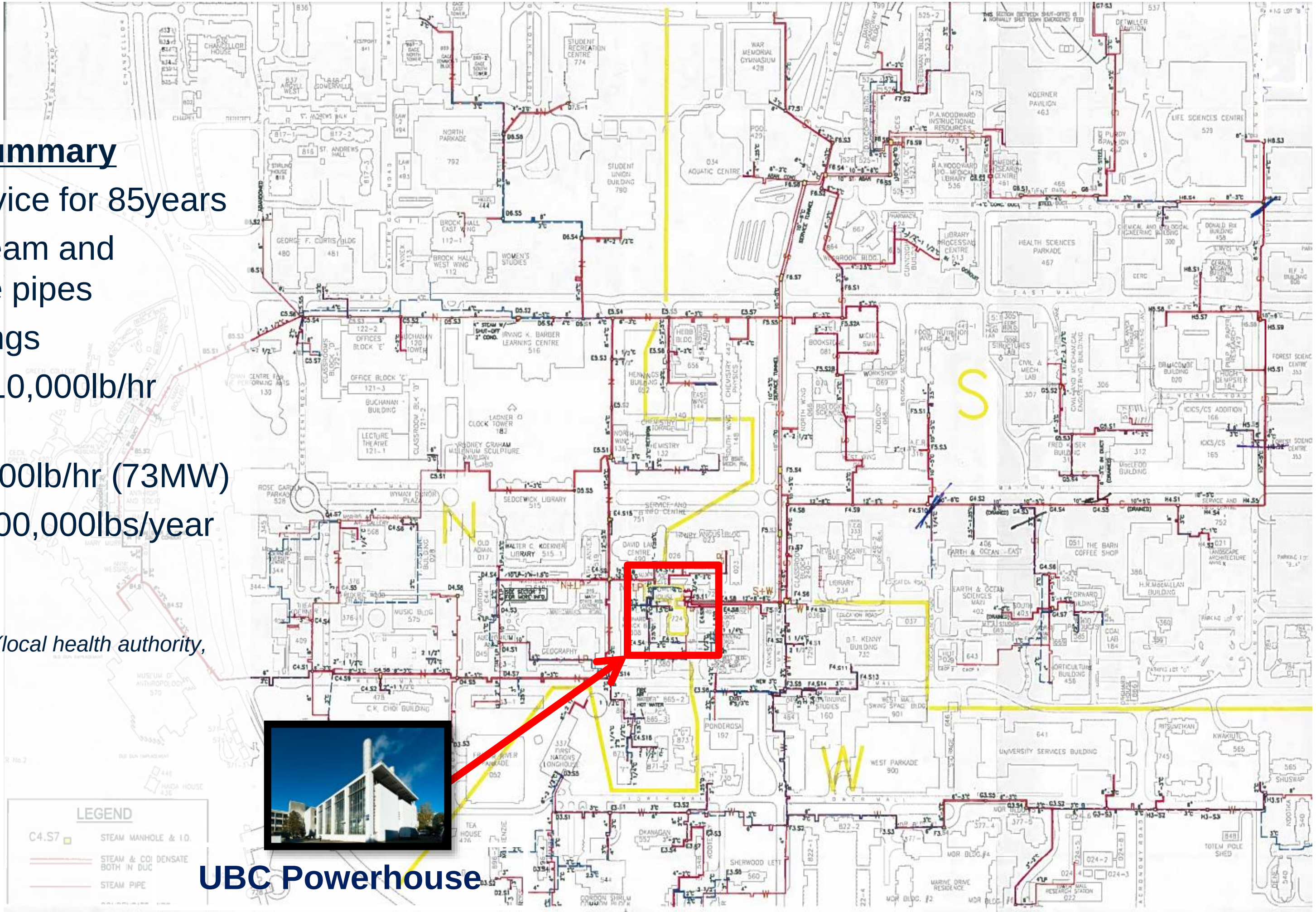
# STEAM ACADEMIC DISTRICT ENERGY SYSTEM JAN 2010

**<u>2010 Summary</u>**

Continuous service for 85years

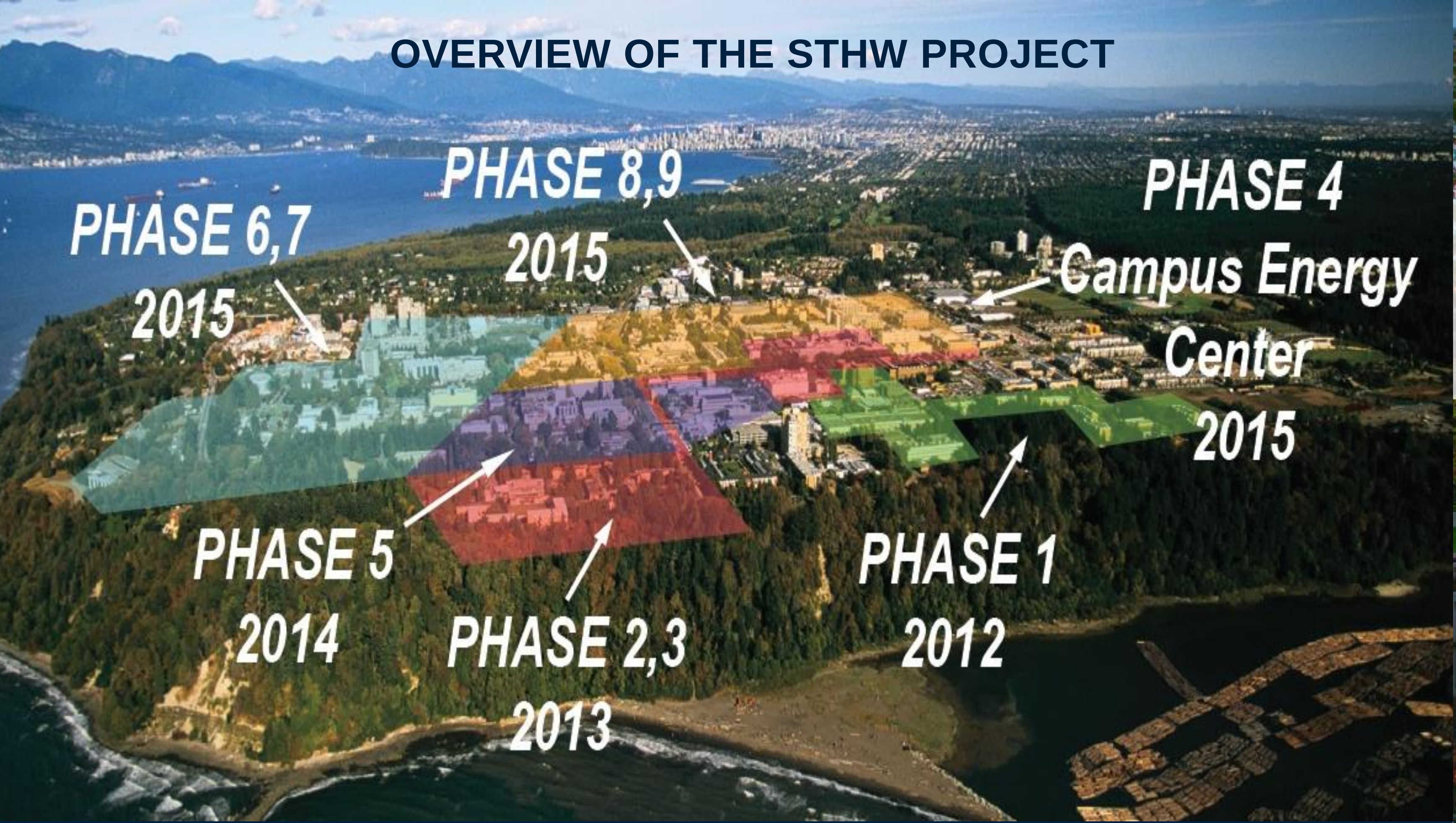
- 28km of steam and condensate pipes
- 133* buildings
- Capacity 410,000lb/hr (120MW)
- Peak 250,000lb/hr (73MW)
- Total 830,000,000lbs/year (242GWh)

**Includes UBC Hospital (local health authority, not UBC)*




**UBC Powerhouse**

# OVERVIEW OF THE STHW PROJECT




$88m, 9 phase, 5 year construction

# STEAM TO HOT WATER CONVERSION: WHO WAS INVOLVED

UBC's Energy and Water Services, Project Services, Building Operations, Risk Management Services, Infrastructure Development, Campus Planning, Finance, Treasury, Legal Services, Human Resources, Sustainability, Communications

FVB ENERGY INC
kwl
CES ENGINEERING
AME Group consulting mechanical engineers
AES
SIEMENS
All Pro Services Ltd.
DIALOG
LOCKERBIE & HOLE
FORTIS BC
CELCO Advancing Automation
LEDCOR GROUP
RISSLING
Trotter & Morton
Division 15 MECHANICAL LTD.
Total Build
FIVE STAR BUILDING MAINTENANCE LTD.

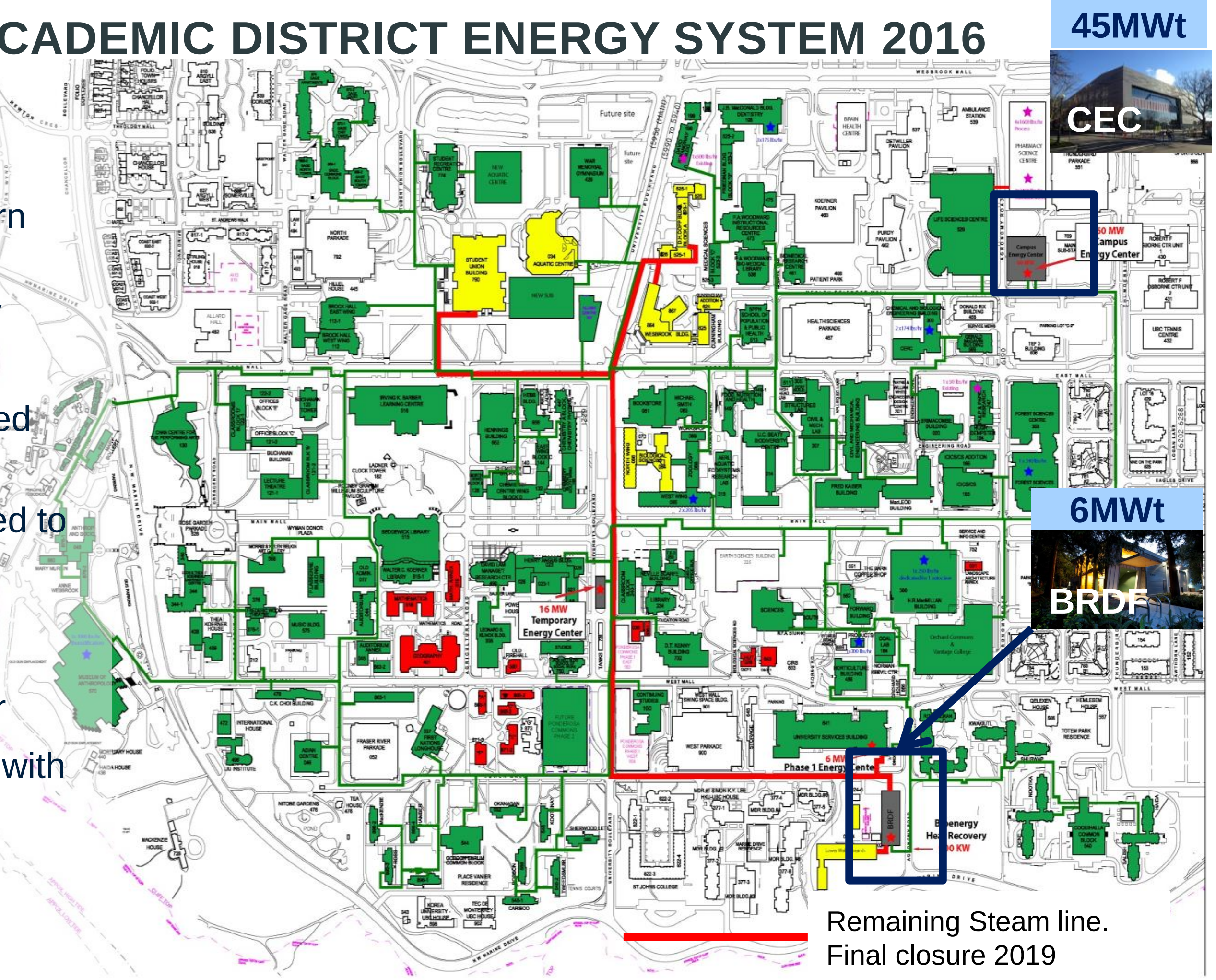
Employed over 3000 people from the above

UBC

# HOT WATER ACADEMIC DISTRICT ENERGY SYSTEM 2016

## 2016 Summary

- 22km supply and return piping laid
- CEC in service 45MW installed Capacity
- BRDF ~8MW's installed thermal capacity.
- 115 buildings converted to Hot Water
- 14 buildings + 4 UBC Hospital Buildings not converted to hot water
- 12 research buildings with steam process loads requirements




Remaining Steam line.
Final closure 2019

Buildings on DES | Temporary Orhan Steam | Permanent Orphan Steam

# PROJECT RISK MITIGATION STRATEGY

2011 Board of Governors (BOG) approves the $88m project in principle and deploys the following strategy:

- A step by step approach with main funding approval contingent upon the pilot or phase 1 performance evaluation and verification.
- Stop No-Go or off ramp options available up to phase 4 i.e. the construction funding approval for the CEC:

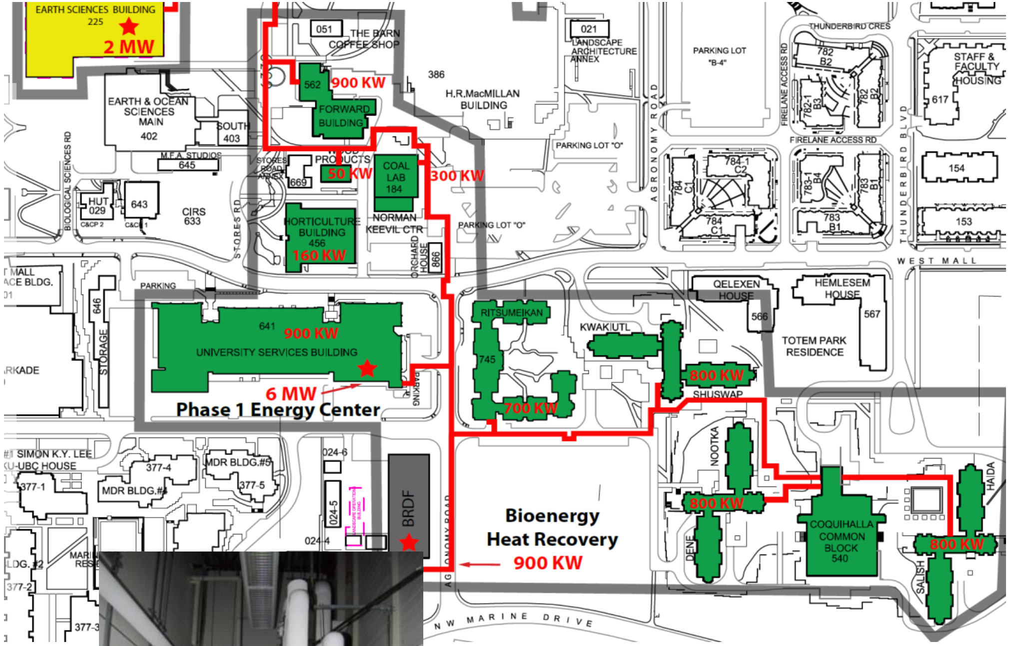
Timeline

- 2011 Funding approval for phase 1 to provide proof of concept
- 2012 Approve funding phase 2 & 3
- 2013 Phase 4 CEC funding approved
- 2013 Phase 5-10 full funding approved

# PHASE 1 PILOT PROJECT

**Phase 1 Summary**

- 1,100 trench meters of District Piping System (DPS) laid
- 13 buildings converted
- Successfully repurposed the existing oversized heat exchangers at USB (5MW).
- Connection for BRDF HR (1MW)
- Subsequently becomes the USB Energy Center (USBEC) (6MW total) (USB + BRDF HR)
- Phases 1 completed on budget and on time
- Concurrently 1km of trench steam lines decommissioned (insulation worse than expected)
- **Confirmed Phase 1 energy savings of 12,00 GJ's NG and 600 tonnes of $CO_2$ emissions**





# FOUR MAIN PROJECT CATEGORIES

1. District Piping System (DPS)
2. System Energization
    a. Temporary Energy Centre (TEC)
    b. Campus Energy Centre (CEC)
3. Building Conversions & Energy Transfer Stations (ETS)
4. Orphan Steam Buildings & Process Steam

# DISTRIBUTION PIPING (DPS)

# DISTRIBUTION PIPING

- Laid 22 km (11km trench) of Logstor pre-insulated piping with leak detection
- Pricing was $2000/m on average
- Moved from batch to bulk procurement strategy to reduce cost
- Innovative routing to reduce length (13km trench original plan)
  - Optimized route plan reduced 1km of trench piping
  - Internal team worked with designers to identify groups of buildings that could be fed from a central ETS
    - Additional 1km of DPS reduced by running secondary side Schedule 40 piping through buildings

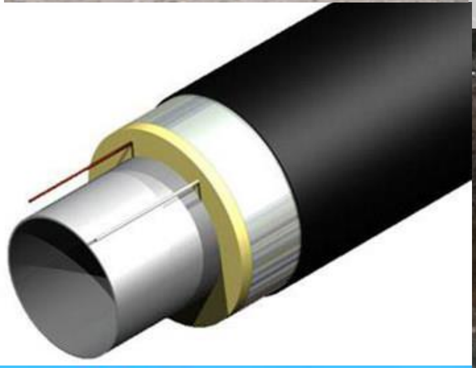
# PIPE SPECIFICATION

European piping (EN 253)

- Fully welded system including, buried values, jump tees, air vents, joint kits and leak detection.
- Temperatures 65-120C supply 45-75C return

Utilizes unsheathed Logstor piping. Early VE decision to save cap costs, offset by optimizing system to operate at lower temps

Supply and return piping selected over combined piping as local market not mature enough to implement.



# SYSTEM ENERGIZATION

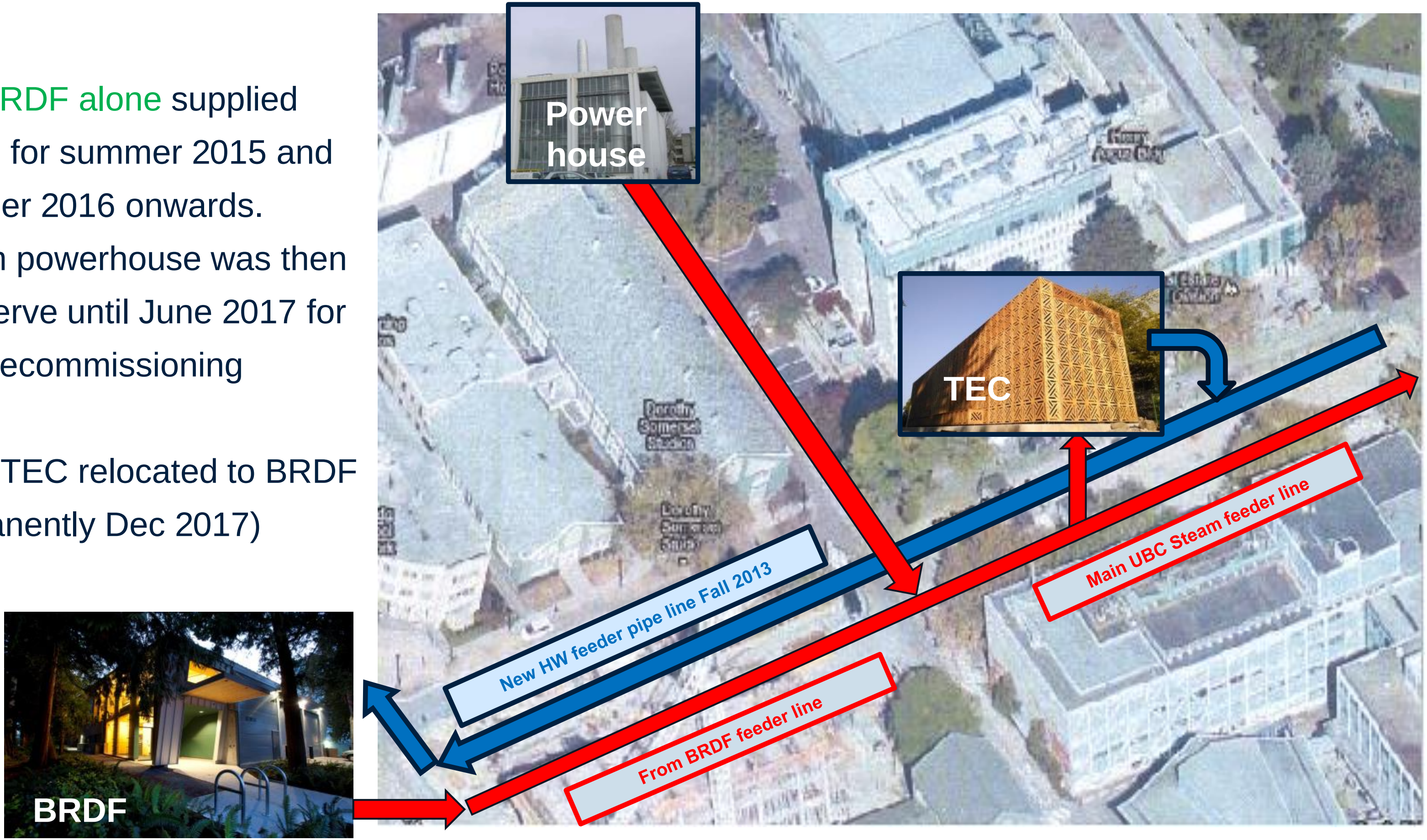
# INSTALLATION OF THE TEMPORARY ENERGY CENTRE

- Phase 1, 2 & 3 converted 17 buildings and laid 4 trench km’s of DPS energized by the USBEC
- USBEC at maximum peak capacity after phase 3
- Phase 4: the CEC was a two year build
- Temporary Energy Centre (TEC) was developed:
    - 2 x 7.5MW Steam to Hot Water Heat Exchangers (15MWt total)
    - The TEC + USBEC gave a total 23MWt capacity for the system whilst the CEC was being built which enabled 85 building conversions to be completed prior to Campus Energy Centre coming into service
    - Delivered energy savings of 125,000 GJ’s NG and reduced $CO_2$ emissions by 6,250 tons 2014/15


# BIOENERGY FACILITY (BRDF) AND THE TEC

The BRDF alone supplied steam for summer 2015 and summer 2016 onwards. Steam powerhouse was then in reserve until June 2017 for final decommissioning

(Note TEC relocated to BRDF permanently Dec 2017)



# CAMPUS ENERGY CENTRE

# CAMPUS ENERGY CENTRE (CEC) IN SERVICE NOV. 20TH, 2015

- LEED Gold Certified
- Constructed using Canadian cross laminated timber (CLT)
- $24 million CAD

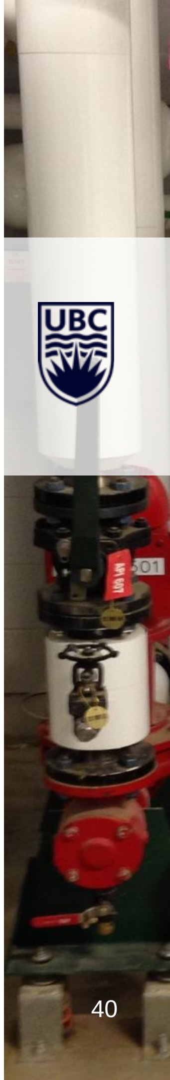
- Built for 4 boilers
- Initial Installation 3x15MWt natural gas boilers (45MWt)
  - Backup provided by #2 diesel
- To match UBC thermal load growth profile over next 20 years
  - Each boiler bay is sized for 4 x 22MW boilers (88MWt) ultimate expansion

# BUILDING CONVERSIONS



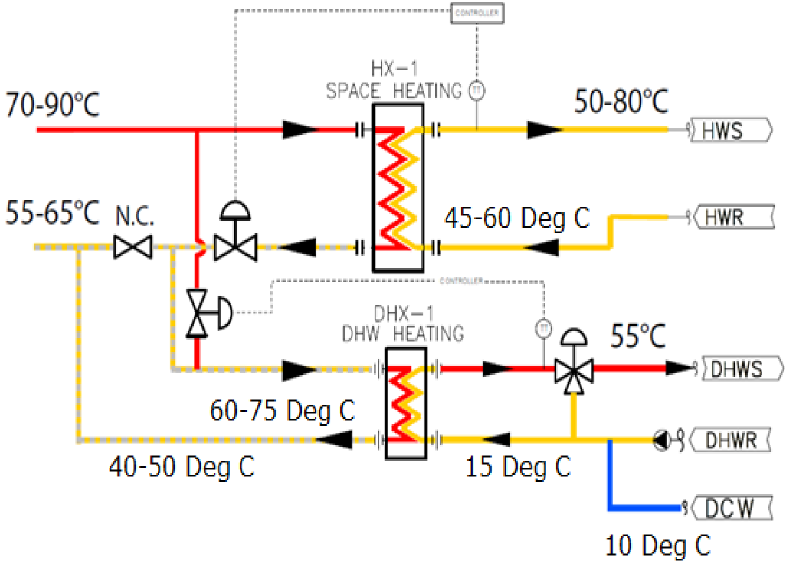

# BUILDING CONVERSIONS

- 115 buildings, 102 Energy Transfer Stations (ETS)
- Each building was their own project
  - Could be a simple Hex exchange only
  - Or AHU coils needing exchanging
  - VAV Box coils etc.
- Strategy on building conversions
  - Generally a like for like replacement (STHW Hex to HWHW hex)
  - Look at historical metered data and right sized oversized hexes (1MW may go down to 600kW based on actuals)
  - Centralize ETS to feed multiple buildings where possible to reduce DPS piping (Scarfe & Buchanan)
- Strategy on secondary side
  - To minimize disruption – typically added hot water coil and decommission steam coil
  - In some cases repurposed existing steam coil or cooling coil for hot water
  - Only two buildings required service shutdown to remove steam coil and replace with hot water
- Several original 1930s buildings with steam on secondary side were too costly to convert and were taken off DES



# ENERGY TRANSFER STATIONS (ETS)

- Heating: Single-walled brazed plate & frame
- Domestic: Double-walled brazed plate & frame with leak detection
- Cascading ETS design with hotter temperature first to meet heating then domestic.





http://www.technicalguidelines.ubc.ca/Division_23/UBC_DPS-ETS_Design_Basis_6March2017.pdf

# ORPHAN STEAM BUILDINGS & PROCESS LOADS

# PERMANENT LEGACY STEAM BUILDINGS

<u>Original Project Scope:</u>

8 original 1930's buildings were directly heated by steam on their secondary sides and deemed too cost prohibitive to convert to hot water. They were to be converted to electric baseboard.

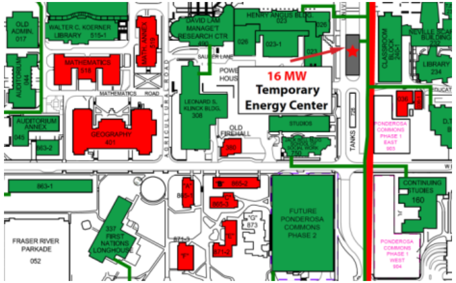
During the 5 year project, 6 additional buildings that were due for demolition were reprioritized by the university and kept.

<u>Additional Scope:</u>

1 x 1930's building: HW boiler installed and existing steam radiators were repurposed to use Hot Water

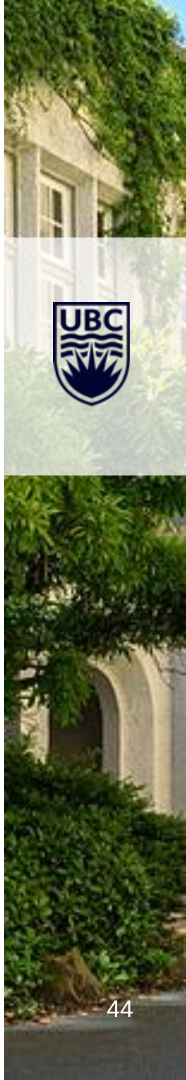
3 x 1960's buildings were on an existing small hydronic distribution grid with an original primary STHW Hex supplying this mini HW district. We replaced the STHW Hex with a new HW boiler.

2 x 1960's buildings using a forced air system. Here we replaced the original AHU steam coils with NG coils

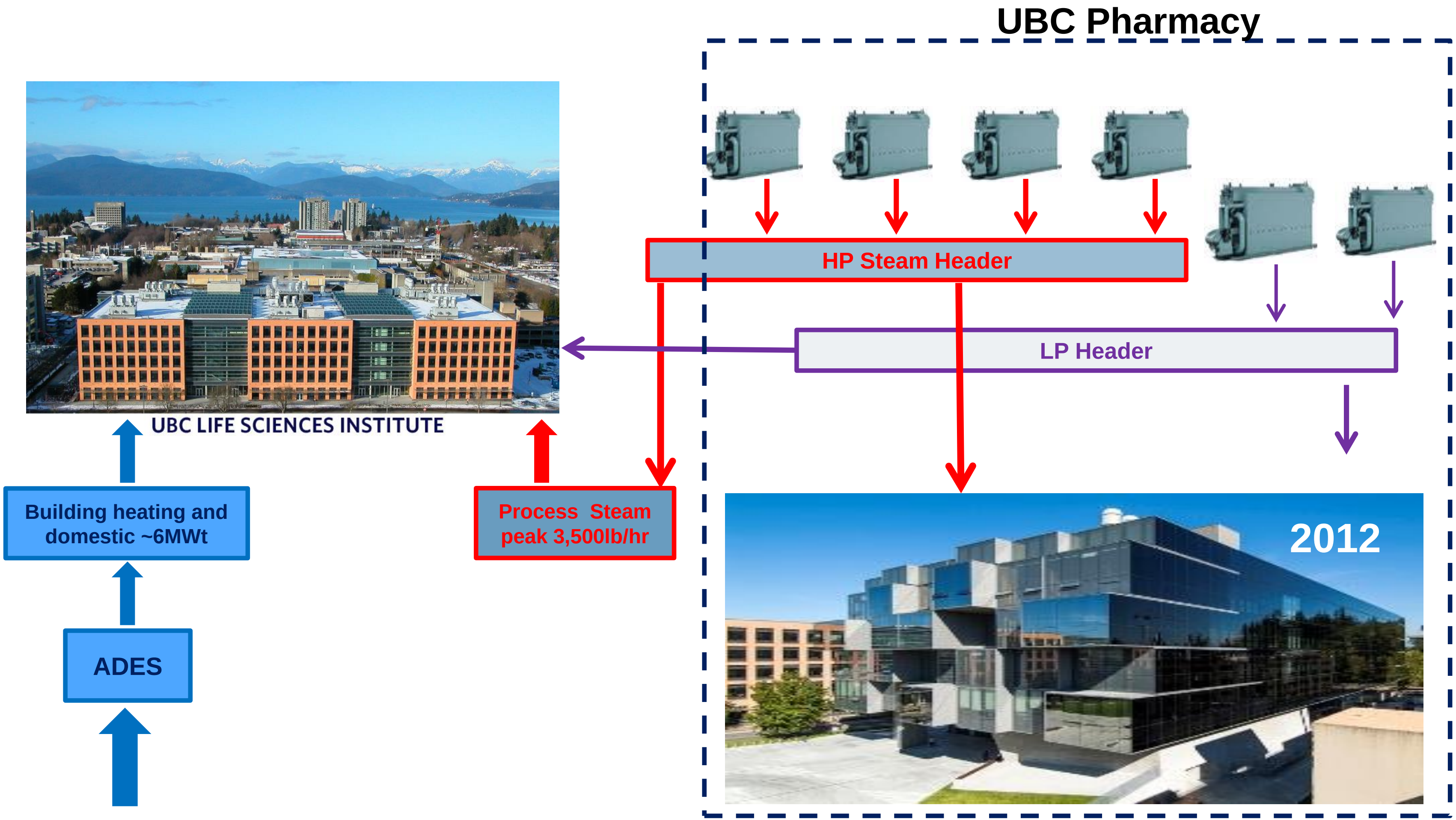


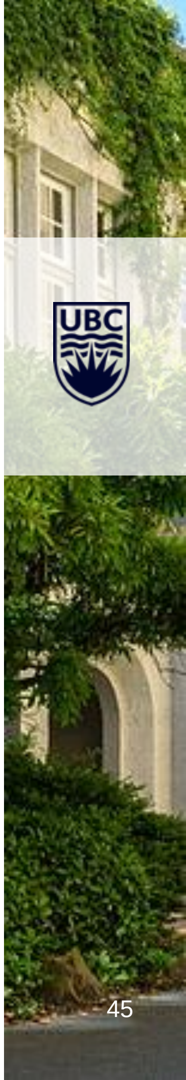

# PROCESS STEAM LOADS

- 12 buildings with sterilization requirements (Autoclaves, cage washers)
- 6 buildings require steam for humidification
- Most researchers already had clean steam generators
- 3 x Steam absorption chillers replaced
- Kitchens – Dishwashers and steam kettles

# LSC AND PHARMACY: PROCESS STEAM MICROGRID



# OPERATING A HOT WATER VS STEAM DISTRICT ENERGY SYSTEM

| | Steam (2007) | Hot Water (2017) |
|---|---|---|
| Floor space | 9.5 million square feet | 9.7 million square feet |
| Plant Efficiency | 80% | 87% |
| Distribution Efficiency | 75% | 97% |
| Installed Capacity | **120MWt** (410MMBTU/hr) | **55.4MWt** (189MMBTU/hr) |
| Winter Peak | **73MWt** (250MMBTU/hr) | **44MWt** (150MMBTU/hr) |
| Summer Min. Load | **7.6MWt** (26MMBTU/hr) | **3MWt** (10MMBTU/hr) |
| Annual Thermal Energy | **242GWh** (830,000MMBTU) | **129GWh** (440,000MMBTU) |
| Water (Makeup & Quenching) | 270,000,000 liters | 130,000 liters |
| FTE | 33 | 18 |
| Regulatory | 1st Class Plant | 4th Class Plant |
| Carbon | 50,000 tCO2e | 27,000 tCO2e |
| % Renewable | 0% | 31% |

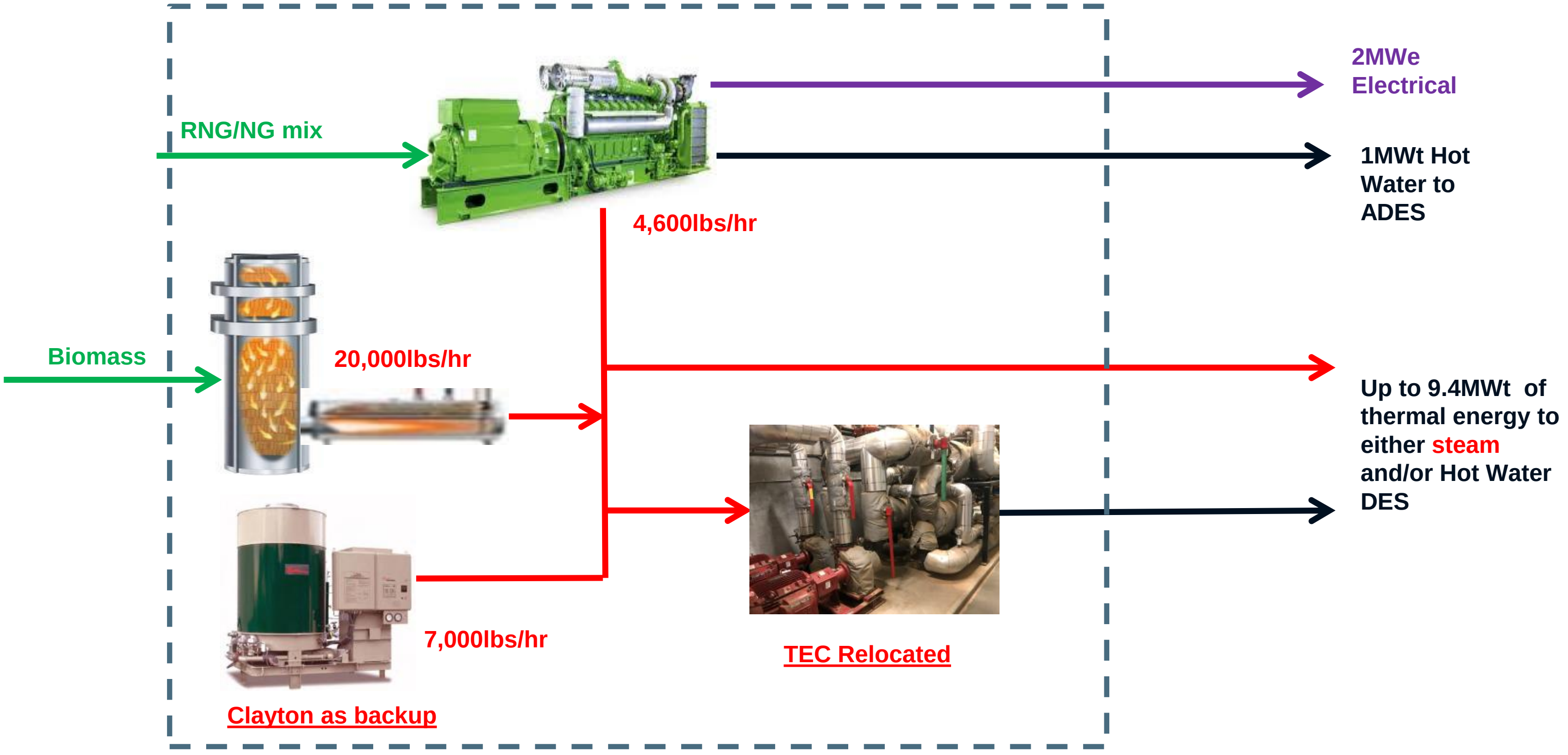

Before


After

# Q&A
# PROJECT DELIVERY

# WHAT’S NEXT– A GROWING SYSTEM

# 2017 TEC RELOCATION TO BIOENERGY FACILITY

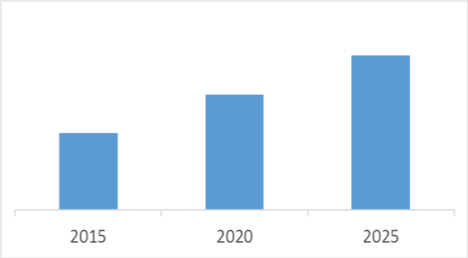


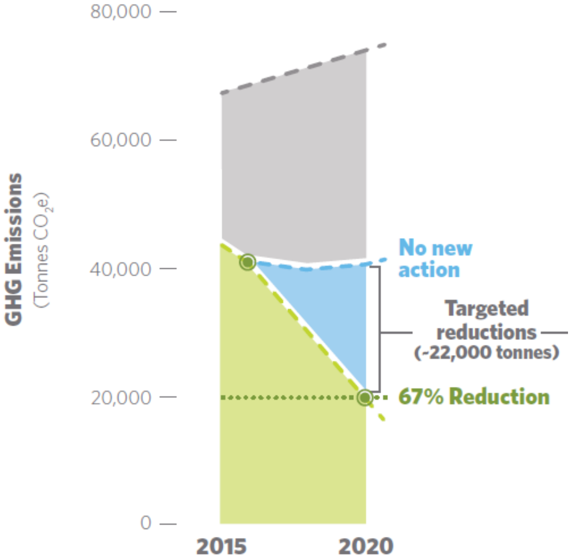

Current Bioenergy Facility

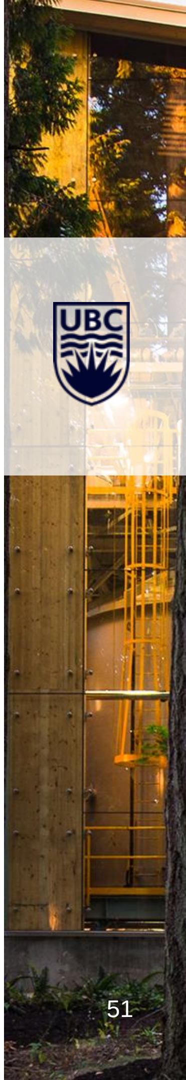
# CURRENT CHALLENGES

- Address Rapid Campus Growth
  - 25% of additional floor space connect to HW DES by 2025.
  - Maintain N+1 thermal redundancy.
  - Business as usual would be to add a 4th natural gas boiler to the CEC

- Meet UBC's 2020 Climate Action Plan
  - 2020 67% GHG reductions targets



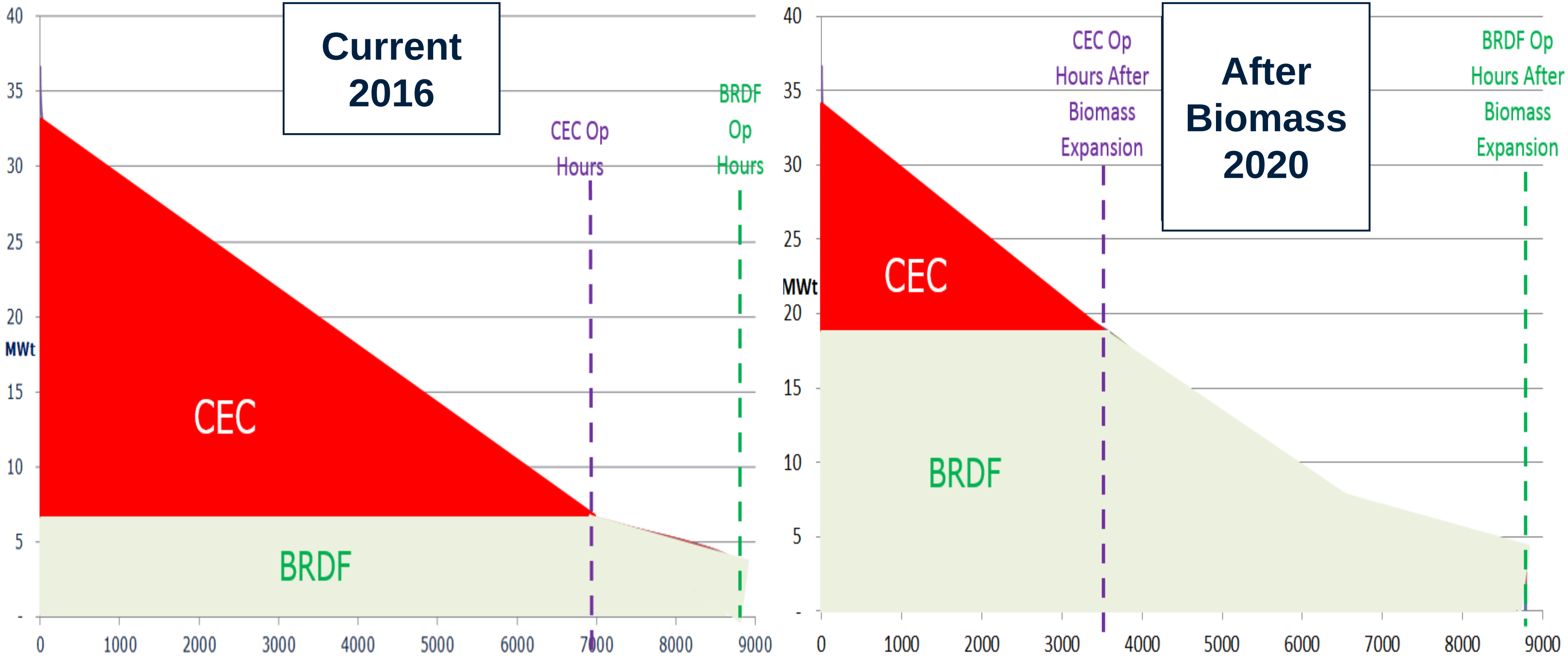



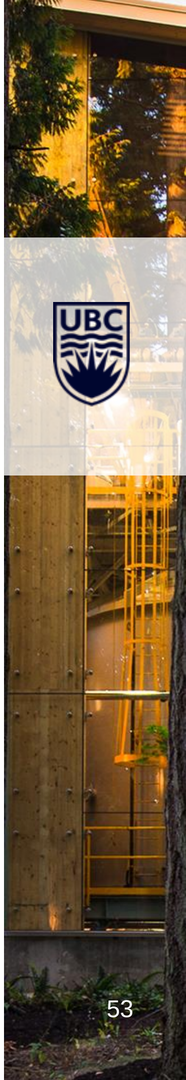
# NEW BIOMASS CAPACITY

- New 12MW Biomass Hot Water Boiler to be installed at the current Bioenergy Facility
- Currently under design
- Technology has yet to be determined
- Will be operational spring of 2020
- Annual average cost savings of $1.3 million vs BAU
- Reduction of 13,000 $tCO_2$/yr of carbon
- Biomass will produce ~67% of UBC total annual thermal district energy load requirements

# UBC THERMAL LOAD PROFILES BEFORE AND AFTER BIOMASS



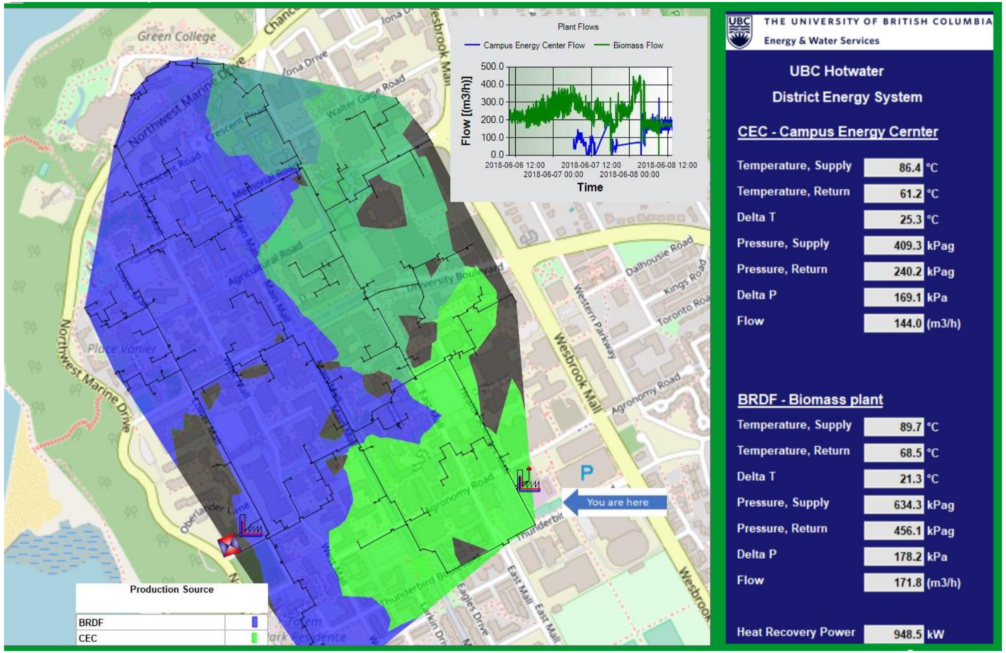

Annual Operating hours (8,760 hours = 365 days)

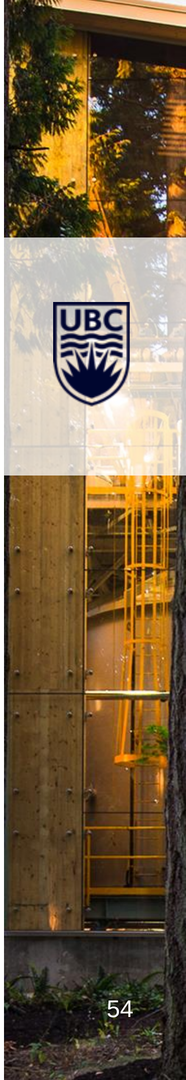


# OPTIMIZING THE HOT WATER DES

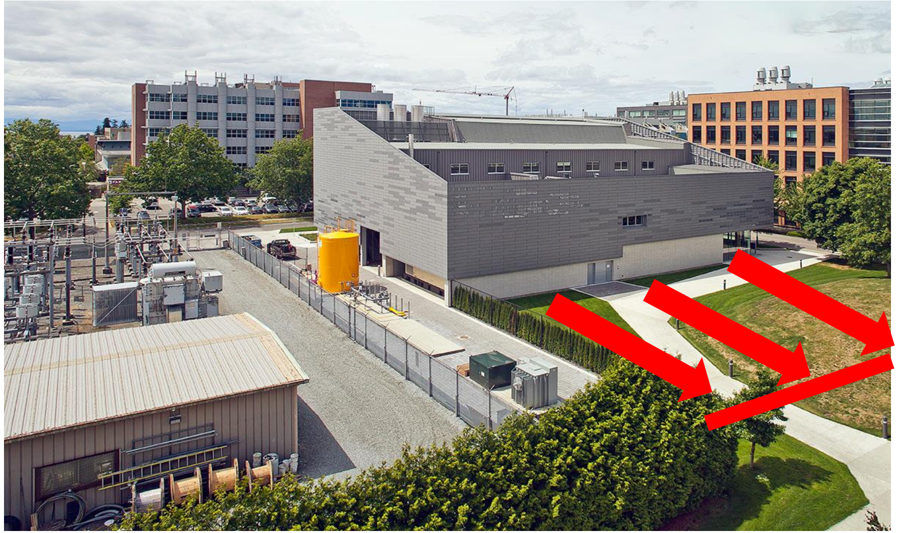
- Implementing Termis' District Energy optimization software
  - Ability to see whole DES system in real-time (Plant, Distribution and ETS)
  - What-if scenarios, expansion planning, pressure & temperature optimization

- Increase automation of system's industrial controls



# FUTURE CONSIDERATIONS
# CEC COGENERATION & RENEWABLE NATURAL GAS



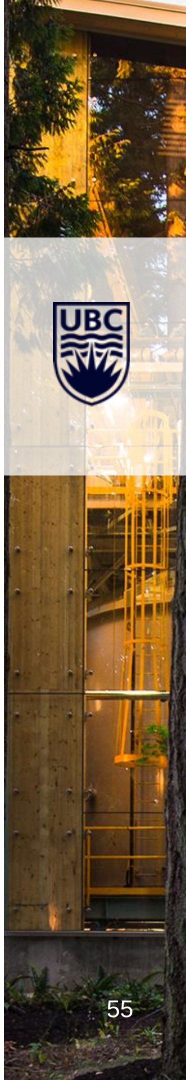
## Renewable Natural Gas (RNG) Development

- RNG is biogas upgraded to natural gas quality
- Allows for cogeneration to be carbon neutral
- Production of renewable electricity
- Looking to secure biogas source

## CEC Cogeneration Option

- CEC Site chosen to allow for a cogeneration expansion
- Total potential CEC capacity: CEC phase 1 + Cogeneration phase 2 at maximum build out will be 110MWt and 25MWe

| Raw Biogas | Upgrading Plant | Biomethane |
|---|---|---|
| 40% - 60% $CH_4$ | | >96% $CH_4$ |
| 30% - 50% $CO_2$ | | <2% $CO_2$ |
| 0% - 2% $O_2$ | | <0.4% $O_2$ |
| 0-2000+ ppm $H_2S$ | | Sulphur free |



# LESSONS LEARNED
# HINDSIGHT IS 20/20

# BUSINESS CASE ASSUMPTIONS VS. ACTUAL TO DATE

| | 2010 OBC Assumption | Actuals |
|---|---|---|
| **Capital Cost** | $88 million | $92 million |
| **Price of Natural Gas** | $5.22/GJ flat for 5 years then 2% escalation | ~$2.76/GJ |
| **Price of Carbon** | $55/tonne | Increase to $75/tonne by 2022 |
| **Operational Savings** | $4 million/yr | Achieved in fiscal 2017/18 |
| **Capital Avoidance** | $34 million PV<br>VFA Audit ($190m vs $42m) | Funding for this portion did not happen. Shortfall made up by energy conservation program |

# WHAT WE MISSED

- Transition period… what to do with new buildings that can't connect to hot water (isn't ready) yet shouldn't connect to steam (being eliminated).
- Economies of scale impact of a 24% efficiency improvement. Rate structure wasn't split between fixed and variable. So, the 24% reduction impacted our ability to recover our fixed costs.
- The other side of the meter… cold mechanical rooms…an unexpected 10% savings.
- Process steam scoping… several labs and or process requirements not captured under original scoping
- Growth… we thought new buildings would be more energy efficient.

# WHAT WE GOT RIGHT ☺

- Phase 1 pilot
  - Allowed for lessons learned to be incorporated into later phases
  - **Verified** costs estimates and delivered energy and cost **savings** from phase 1 onwards
  - Confirmed original business case assumptions e.g. existing steam piping was found to be very **poorly insulated**
- Carbon pricing (to date)
- Energy savings on pace for 280,000 GJ / year savings
- Links with public realm improvements and new construction
- New campus energy centre staffing requirements
- New campus energy centre location
- ETS cascading for domestic hot water
- Lower operating temperature
- CEC has expandability to meet all future thermal load growth for the ADES and NDES
- Open dialogue with peers (IDEA)

# LESSON LEARNED OR ADJUSTMENTS MADE DURING THE PROJECT

## Year 3: We went from summer only to year round construction/ implementation

- 4 DPS construction crews
- 2 ETS construction companies

## 3 different approvals from the Board (not 10)

- Phase 4 approval CEC

## Pre-purchased district energy pipe

- 2012 CN rail strike leaves DPS stuck in Montreal for 6 weeks
- Strong CAD vs Euro

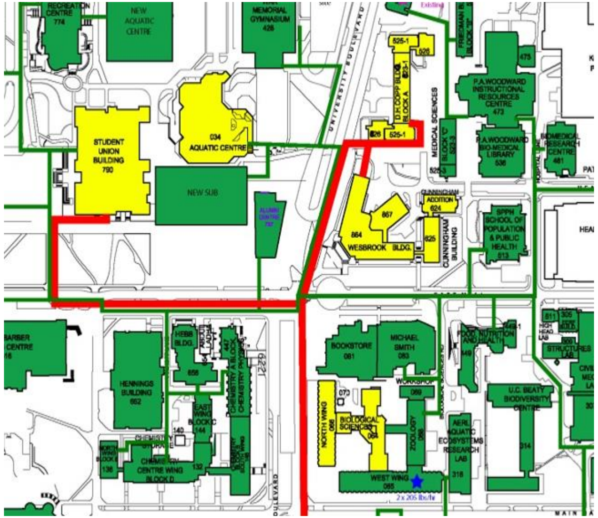
## Sales Tax Change

- Political shift from HST to PST/GST - $1M impact to business case

# LESSON LEARNED OR ADJUSTMENTS MADE DURING THE PROJECT

## Enabled buildings with pending renovation projects to remain on steam.

- Several buildings either awaiting renew programs or scheduled demolitions delayed.



## Modified phases to accommodate new building construction

- Ponderosa II; student housing project (1,000 bed)
- Orchard Commons: Student Housing and academic joint project (1,000 bed)

# LESSON LEARNED OR ADJUSTMENTS MADE DURING THE PROJECT

Allowed for buildings, which were originally planned for demolition prior to the project, to be incorporated into DES plan or new orphan steam projects developed to compensate

# LESSON LEARNED OR ADJUSTMENTS MADE DURING THE PROJECT

## Process steam scoping

- Several earlier assumptions or missed equipment in original scoping identified
- Led to standardization of equipment selection

## Communication plan refined

- PM's, Communications, C&CP, Facilities Managers fully engaged to give continuous updates to community e.g. road closures, classroom & laboratory interruptions etc., etc…

## Project Management team

- PM's increased from 1 to 6 by end of the project

## Team Meetings

- Weekly meeting between PM's, key owner group and associated post project owner groups

# CONCLUSIONS

- Phased implementation:
  - Allowed for lessons learned in earlier phases to be incorporated into later phases
  - **Verified** capital costs and delivered energy and cost **savings** from phase 1 onwards
- Developing a TEC and the use of existing steam to hot water HEX's, allowed for energization of the DPS and for 80 building conversions to be completed prior to Campus Energy Centre coming into service.
- Energy reduction targets achieved and now expected to exceed forecasts
- **UBC Achieves a 34% GHG reduction in 2016**
- CEC has expandability to meet all future thermal load growth
- 14 separate UBC departments, 18 different consultants and contractors firms: Altogether over 3,000 people worked on the ADES project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