Green Technology Risks and Benefits: Bioenergy Research & Demonstration Facility, UBC

Pacific Energy Innovation Association

Energy Breakfast 14th January, 2016

Paul Holt CEng, Director, Engineering & Utilities

Agenda

1. UBC Overview
2. The motivation for UBC to build a Green Energy Project
3. Bioenergy Research Demonstration Facility (BRDF)
    a) The original project and priorities
    b) Early performance and challenges
    c) A new direction
    d) BRDF synergies with UBC Steam to Hot Water Project
    e) From demonstration to baseload production facility
4. Conclusions
5. Questions

The University of British Columbia

UBC Stats

- 12 million sq.ft. of institutional buildings
- 3 million sq.ft. residential
- Day time pop. ~ 65,000
- ~ 30% growth over the next 15 to 20 year

UBC Steam Stats

Steam
- 785,000,000lbs/year
- 1.1 million GJ/year NG
- 78% of GHG emissions

Electrical
- 309 GWh/year
- 49 MWe peak load
- 8% of GHG emissions

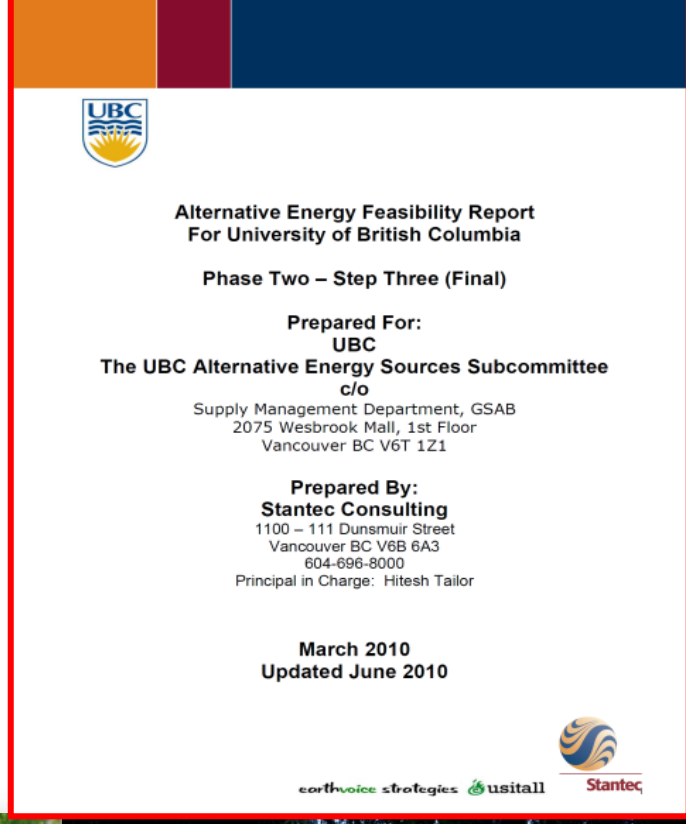
The Motivation for the Project

There were several major drivers and influencers for the project:

1. 2007: Financial: Deferred Maintenance; new Steam boilers required at UBC Powerhouse ($10m), fuel switching to biomass (high NG prices ~$8/GJ)
2. 2008: Alternative Energy Feasibility Study instigated, in line with UBC Sustainability Climate Action Planning process launch and BC bill 28
3. 2008: UBC Faculty and Nexterra propose a biomass demonstration project at UBC
4. 2009: Operational, Industrial & research objectives combine to make BRDF a viable project. “Campus as a Living Lab” concept
5. 2010: Alternative Energy Feasibility Study and UBC CAP completed
6. 2010: UBC’s GHG reduction targets published
7. 2010: BRDF project approved

ACHIEVING GHG AND ENERGY REDUCTION TARGETS

- Alternative Energy Campus wide feasibility study recommends a mix of options
- Out of these recommendations two main projects were developed:
  1. Convert UBC from a Steam to hot water DES (22% GHG reduction)
  2. Bioenergy Research Demonstration Facility (12% GHG Reduction)


Alternative Energy Feasibility Report
For University of British Columbia

Phase Two – Step Three (Final)

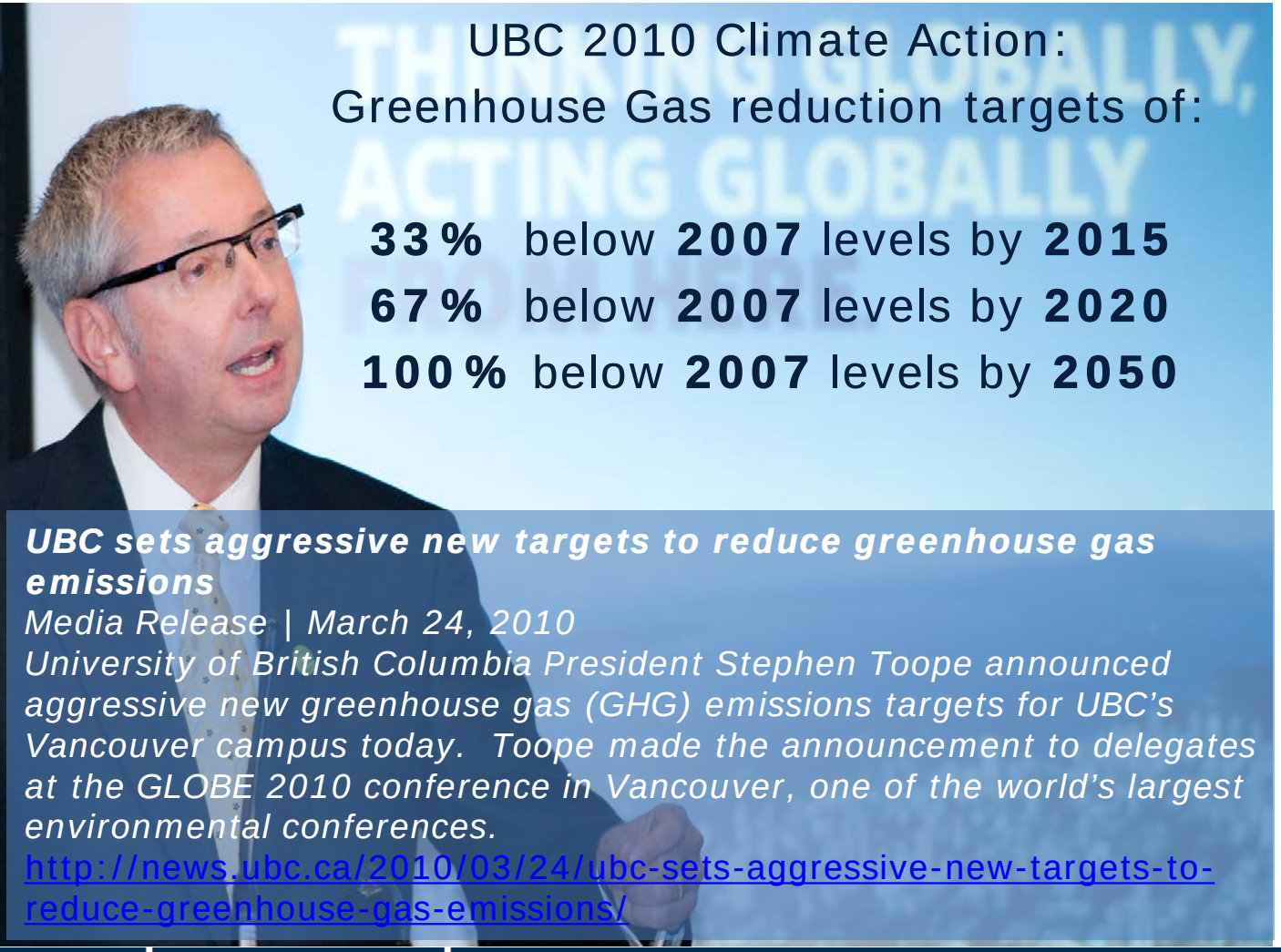
Prepared For:
UBC
The UBC Alternative Energy Sources Subcommittee
c/o
Supply Management Department, GSAB
2075 Wesbrook Mall, 1st Floor
Vancouver BC V6T 1Z1

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

UBC GHG Commitment Confirmed



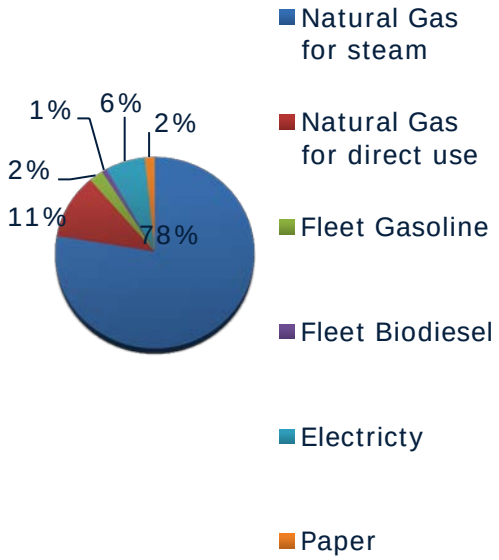
UBC 2010 Climate Action:
Greenhouse Gas reduction targets of:

33% below **2007** levels by **2015**
67% below **2007** levels by **2020**
100% below **2007** levels by **2050**

UBC sets aggressive new targets to reduce greenhouse gas emissions
Media Release | March 24, 2010
University of British Columbia President Stephen Toope announced aggressive new greenhouse gas (GHG) emissions targets for UBC's Vancouver campus today. Toope made the announcement to delegates at the GLOBE 2010 conference in Vancouver, one of the world's largest environmental conferences.
http://news.ubc.ca/2010/03/24/ubc-sets-aggressive-new-targets-to-reduce-greenhouse-gas-emissions/

2007 First Comprehensive campus GHG inventory

Baseline is 61,090 tons Co2 equivalent

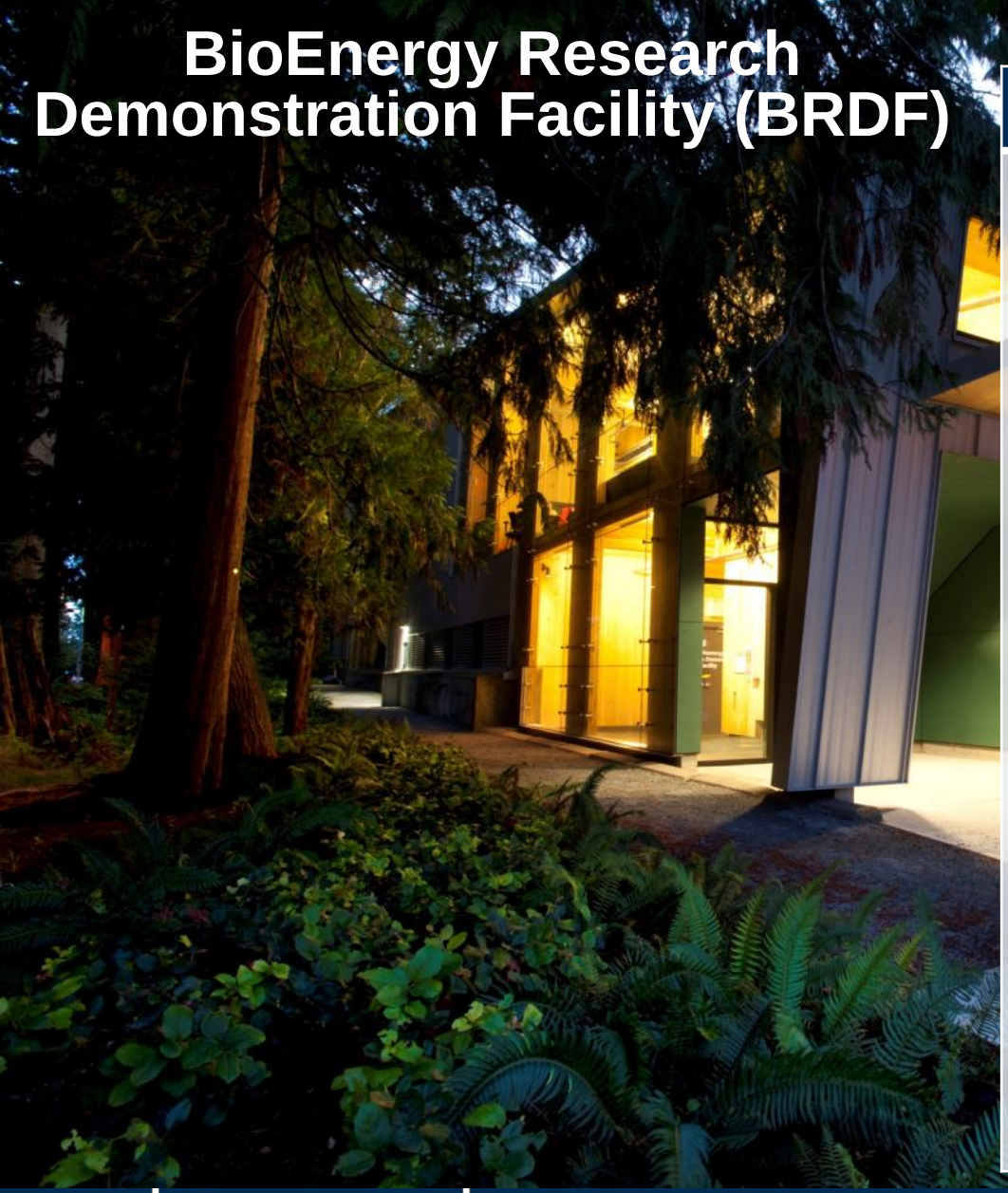


Campus as a Living Lab

To use the physical scale of the campus and its infrastructure for the purpose of:

1. Meets an Operational need:
2. Demonstrates new and innovative technologies: In partnership with industrial partners
3. Has Research opportunities: integrating academic experts, students and operators

BioEnergy Research Demonstration Facility (BRDF)



Summary of Original Concept

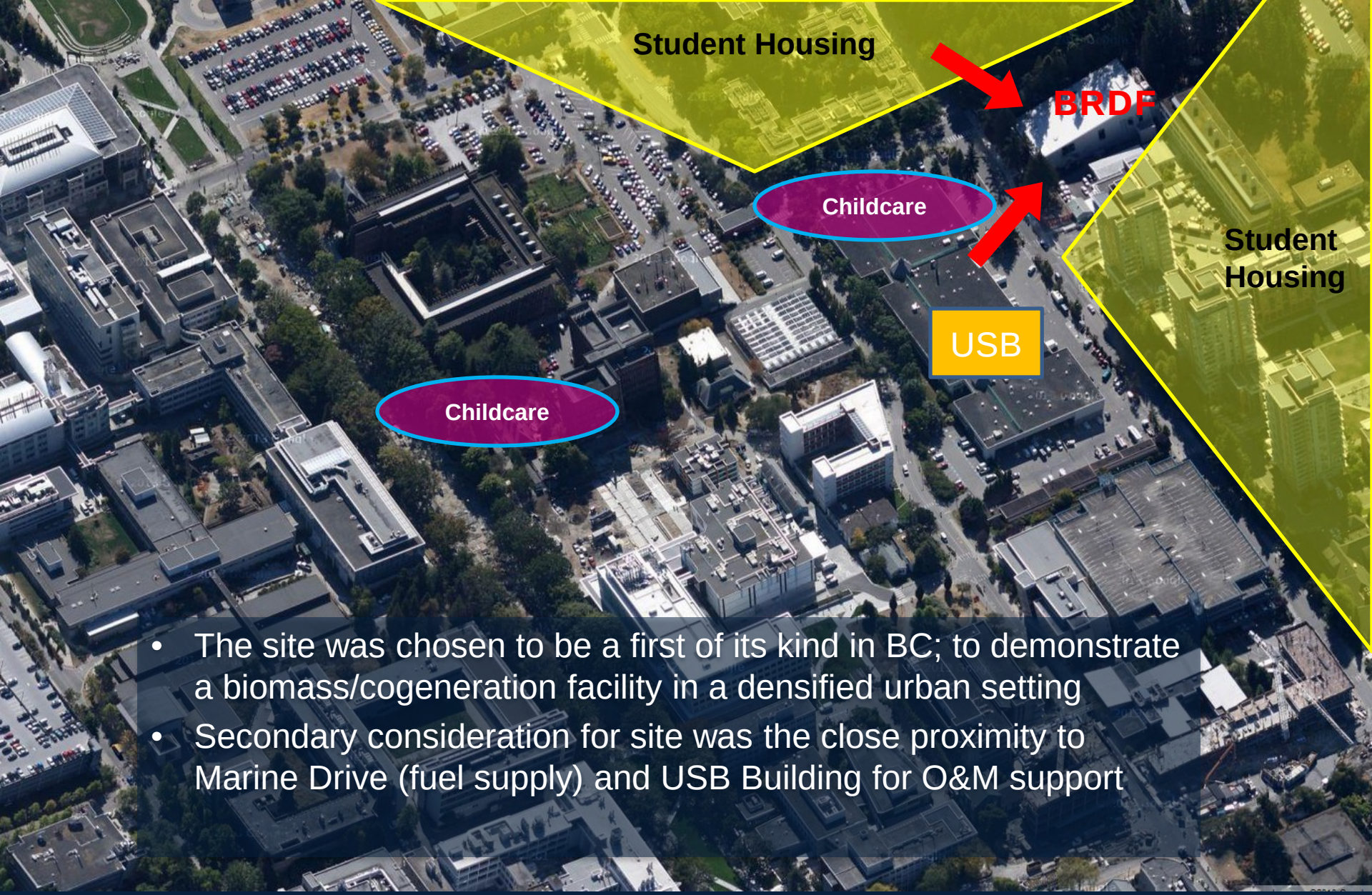
- Biomass cogeneration demonstration project
- A social license demonstration
- Building constructed from Canadian produced Cross Laminated Timber (CLT)
- LEED Gold
- A $28M multi-partnership project
- Thermal & Cogen Modes of operation
- 12% reduction of UBC CO_2 emissions
- “Campus as a Living Lab” collaboration between Faculty, Operations & Industry

Who's Involved

UBC Operations, Faculty, Students, Researchers, with industry partnerships; Nexterra, General Electric, BCHydro and the local community UNA and SHUSH

UBC project partners include:

- BC Bioenergy Network
- BC Ministry of Energy, Mines
- BC Ministry of Forests
- BC Hydro
- Ethanol BC
- City of Vancouver
- FP Innovations
- GE Energy
- Natural Resources Canada
- Nexterra Systems Corp.
- Sustainable Development Technology Canada



- The site was chosen to be a first of its kind in BC; to demonstrate a biomass/cogeneration facility in a densified urban setting
- Secondary consideration for site was the close proximity to Marine Drive (fuel supply) and USB Building for O&M support

Social License: BRDF Siting

Public Engagement

- Early engagement with the local community was key to project acceptance and ultimate success
- Three public open houses, consultations, regular updates and website releases
- Addressed all stakeholder concerns for air emissions, noise, traffic, tree preservation, and biomass quality
- Formed ongoing Community Relations & Emissions Committee: Membership made up of private & UBC residents, students, researchers and operations staff

- Canadian Cross Laminated Timber (CLT) sourced and manufactured in BC: FP Innovations
- McFarland Marceau Architects
- Mechanical Consultant Building: Stantec
- Mechanical Process: Turnkey by Nexterra
- General Contractor: Ledcor

Photo Credit: Don Erhardt

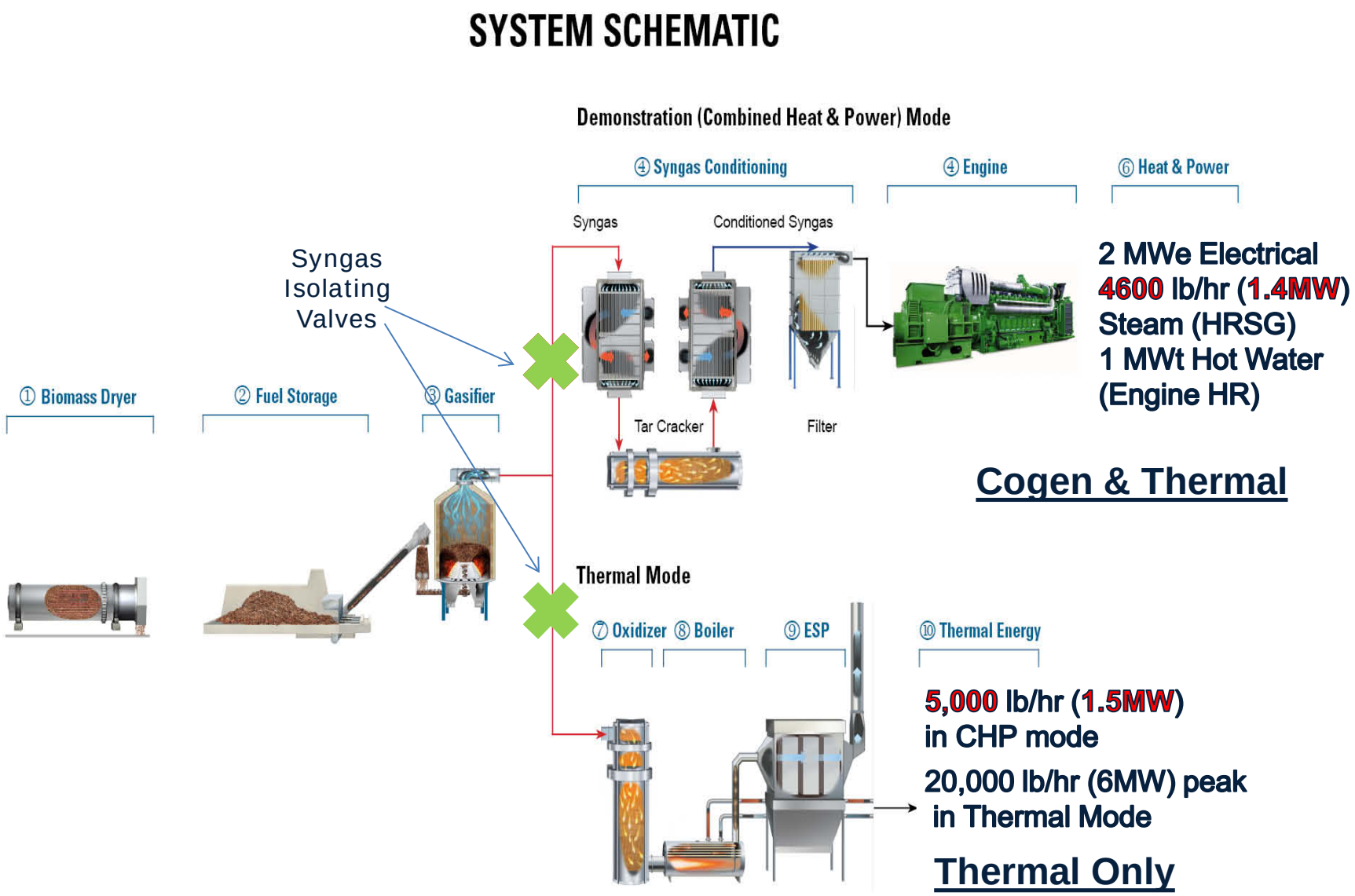
Construction

Photo Credit: Don Erhardt

Construction Cont’d

Original Project Roadmap

- Spring 2009 — BRDF Concept devised
- Spring- Fall 2010 — Public Engagement
- April 2010 — UBC Board Approval
- Feb. 2011 — Groundbreaking
- July 2012 — Thermal Mode Commissioned
- Sept 2012 — Grand Opening Ceremony
- Oct. 2012 — CHP Mode Commissioned
- Nov. 2012 — Full Operation



BRDF Original Modes of Operation

The Fuel: Biomass

- Fuel is ground & chipped waste wood:
  - Sawmill residuals
  - Furniture/carpentry offcuts
  - Municipal trimmings
  - Land clearing operations
- Delivery of 2-4 truck loads per day for 12,500 dry tonnes per year.

BRDF Air Emissions

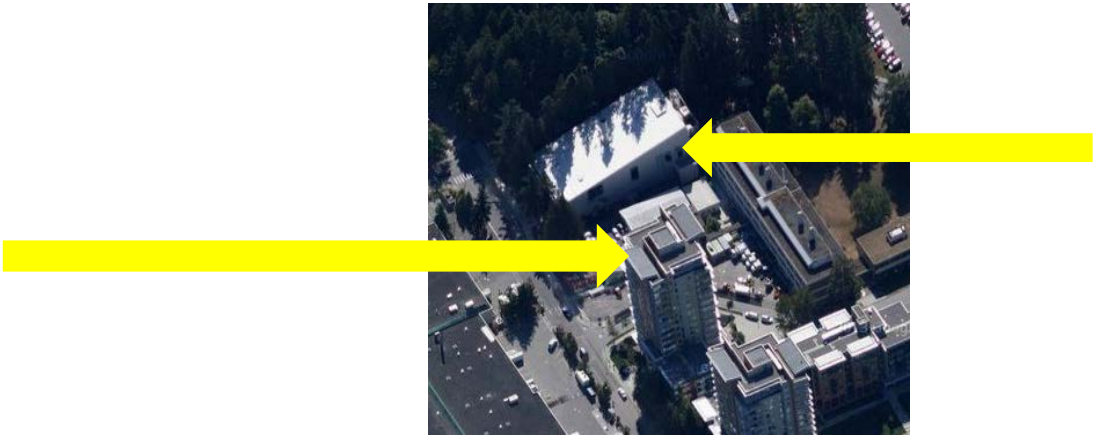
Permit Requirements	Dryer		Boiler		Engine	
	Permit	Test	Permit	Test	Permit	Test
PM Particulate Matter	15	5.9	15	0.7	15	1.3
NO_x Nitrogen Oxides	-	-	209	183	249.7	105
VOC Volatile Organic Compounds	10.4	<2	10.5	<2	40.9	31
Opacity	5%	<5%	5%	0	5%	<5%

- Verified by 3rd party testing (Al Franco)

Above & beyond: Ambient Air Monitor

Air monitor

- Emission Dispersion Study showed Marine Tower 5 as the most likely residential building for air emission impact
- June 2012, UBC proactively installed a real time Ambient Air Monitor on Marine Tower 5



Biomass Plant

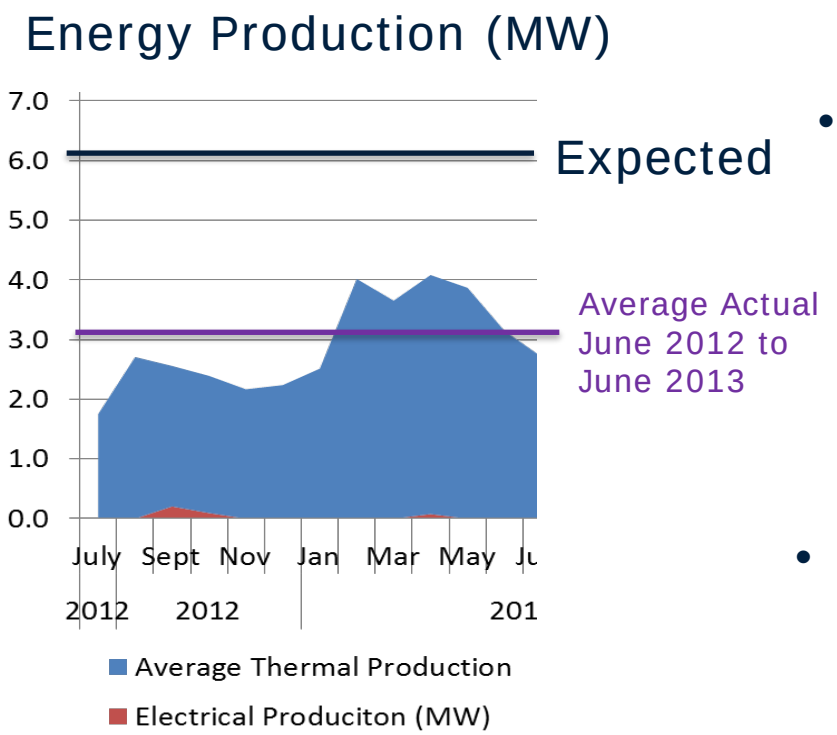
- Automatic emails alerts if air quality limits are exceeded
  - **24 hour average PM 2.5 < 25 µg/m³ or**
  - **1 hour NO_2 < 107 ppb**
- **Air emissions remain well below Metro Van limits**

1st Year Successes:

- **Best in class air emissions** (well below permitted levels and on par with Natural Gas)
- **Noise Emissions below guidelines**
- **Emissions committee**
- **1st LEED Gold facility made from BC CLT**
- **100+ of tours**
- **Achieved 2 MW electrical production using syngas**
- **Strong engagement with faculty and students**

Photo Credit: Don Erhardt

1st Year Challenges



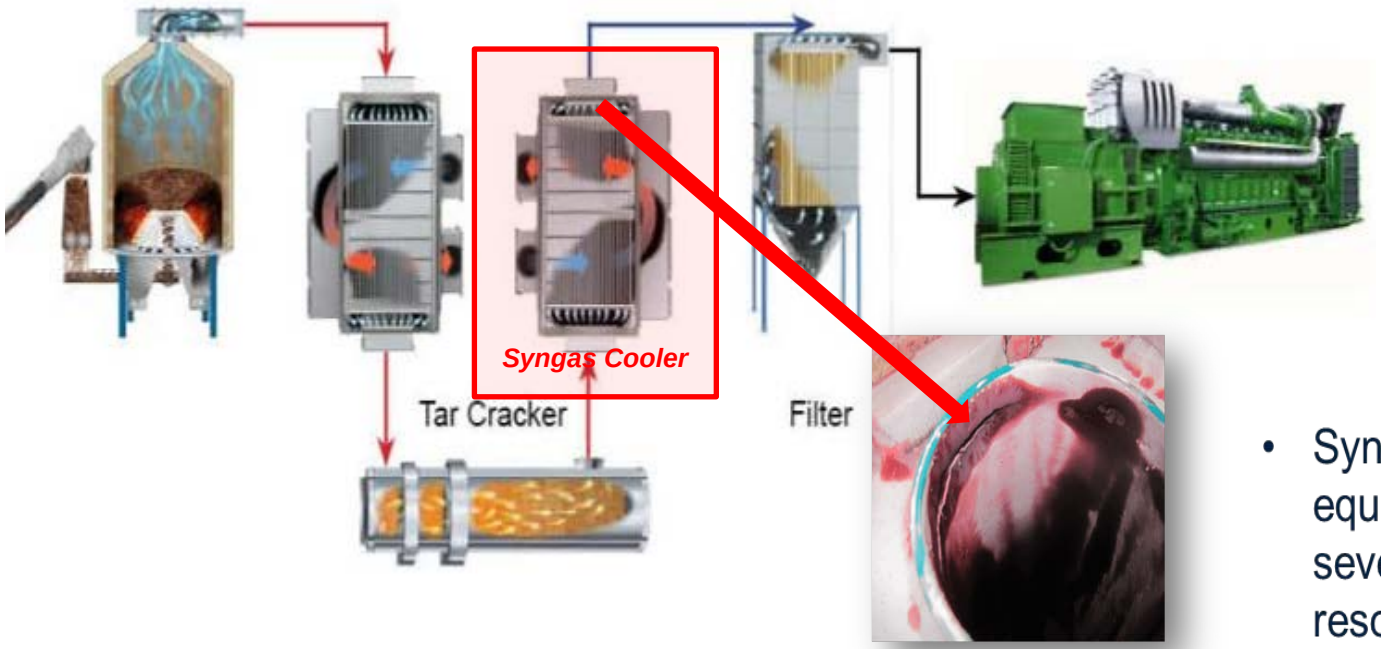
Note ~6MW = 20,000lbs steam production

- Syngas clean up process for Cogen operations

- Requires a higher fuel quality than expected (Needs ~30% MC)

- Higher operational costs than expected e.g. people, maintenance and materials

CHP Performance with Biomass Syngas

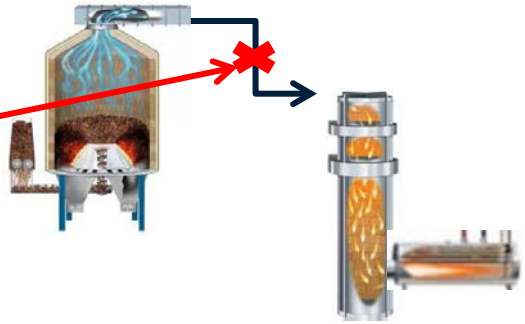


- Syngas clean up process equipment failures. Requires several system upgrades to resolve

- CHP demonstration Trials: Fall 2012 and Spring 2013
- 406 hours of clean engine grade Syngas Produced
- 220MWh of Electrical Production
- Spawned multiple UBC Masters and PhD level research projects
- Challenges with Syngas Cleaning Equipment and Process

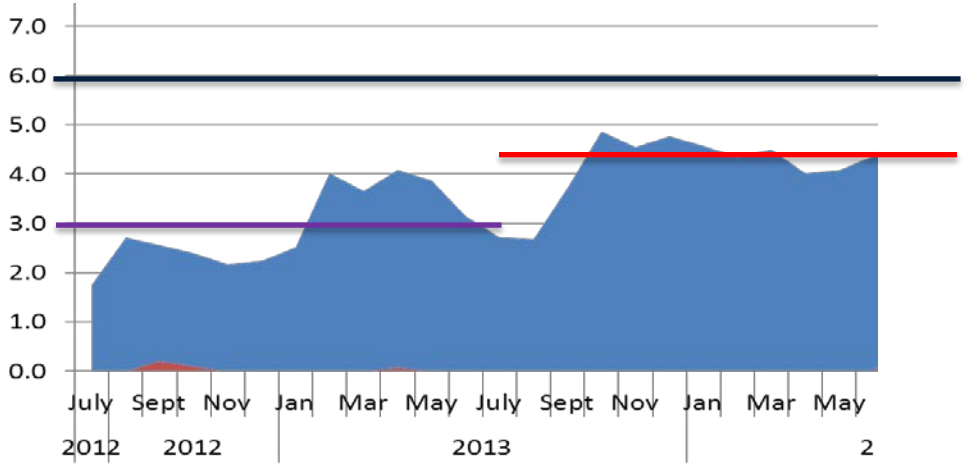
2nd Year Successes

- 33% lift in thermal energy production
- Employee engagement
- 200's + tours
- Multiple Research projects ongoing



- Removal of routinely fouling Syngas isolation Valve
- Wood quality improved to regularly meet new fuel spec MC ~30%. Consumption down to 10,000BDT
- Concurrently fine tuned main Powerhouse boiler turn down ratio's from minimum 20kpph to 10kpph
- BRDF firing table/curves optimized

Energy Production (MW)



Expected

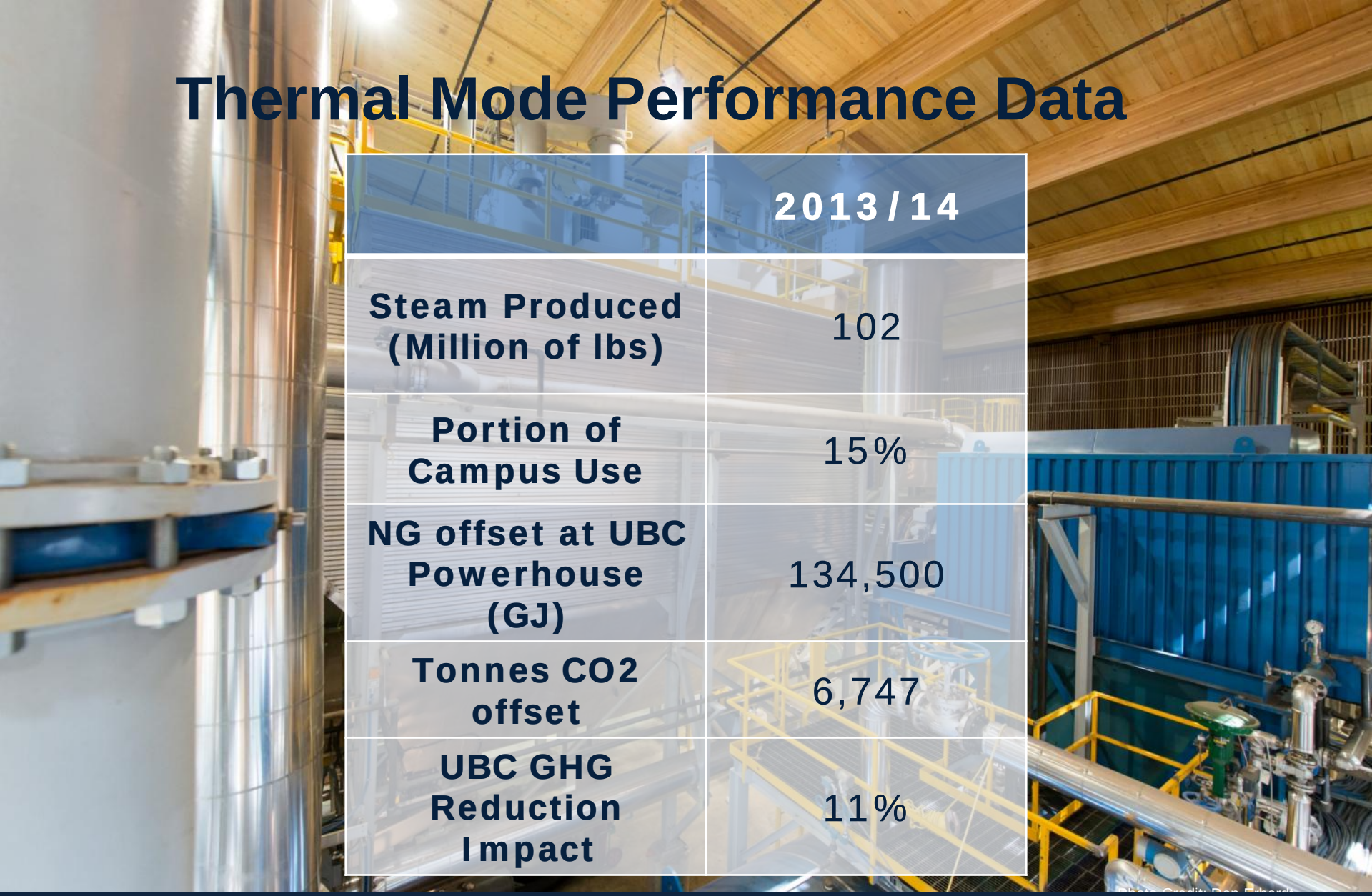
Average Actual June 2013 to June 2014

Average Actual June 2012 to June 2013

2nd Year Successes

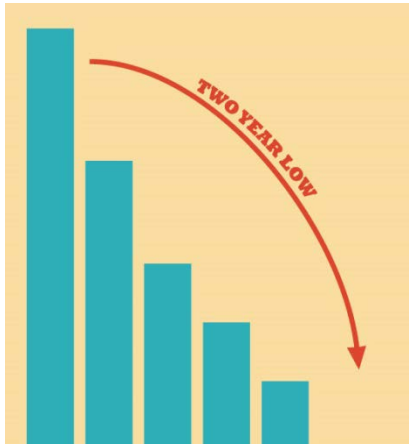
Thermal Mode Performance Data

	2013/14
Steam Produced (Million of lbs)	102
Portion of Campus Use	15%
NG offset at UBC Powerhouse (GJ)	134,500
Tonnes CO2 offset	6,747
UBC GHG Reduction Impact	11%

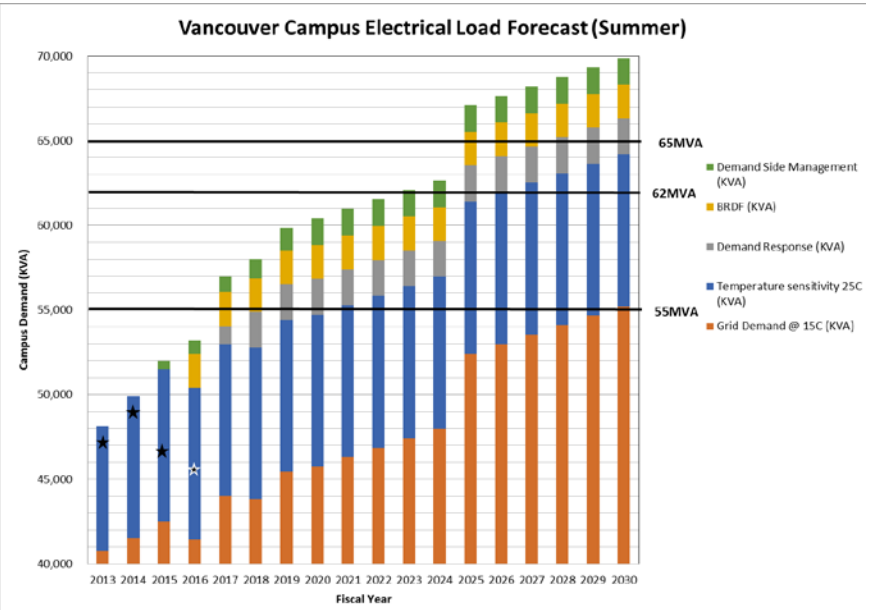


2nd Year Successes

2nd Year Challenges



- Economic: Lower then expected natural gas prices and loss of electrical revenue



- Loss of Electrical production to reduce UBC's Peak demand exposure
- Desire to make use of stranded assets with out compromising research or GHG objectives

Moving Forwards 2014/15
"A New Direction"

RENEWABLE NATURAL GAS

CHP: A Solution is Required

- Provide reliable engine uptime and electrical generation
- That improves the business case and is cash flow positive
- Provides a firm (N-1) 2.4MW thermal capacity
- Aligns with UBC's Climate Action Plan and GHG targets
- That continues Academic research opportunities
- That respects industry partnerships

Renewable Natural Gas

- Renewable Natural Gas (RNG) is upgraded biomethane captured from sources such as landfill sites, agriculture waste and wastewater treatment facilities
- RNG is a certified carbon neutral fuel in BC,
- UBC has Secured 100,000GJ annually of RNG
- Convert engine to dual fuel capability (Natural Gas or Biomass Syngas)

BRDF with RNG utilizes the full installed capacity and provides firm thermal supply

Renewable Natural Gas

Engine & HRSG

2 MW Electrical
4600 lb/hr (1.4MW) Steam from HRSG
1 MW Hot Water HR

AND

Biomass Gasifier

Syngas

Steam Boiler

Steam → 20,000 lb/hr (6MW) peak

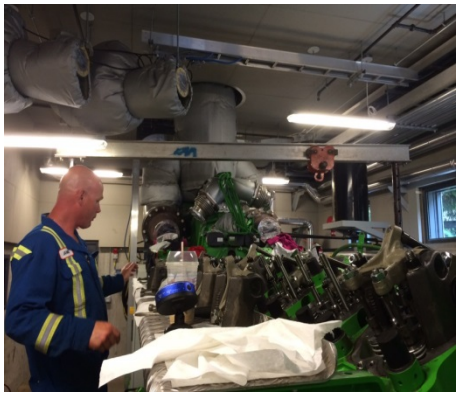
Benefit of Better Use of Capacity

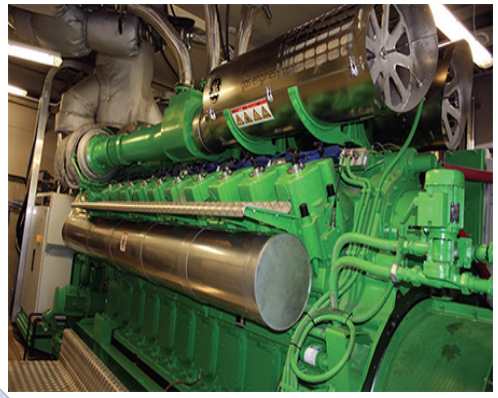
BRDF	Biomass Thermal	Biomass Cogen	Biomass Thermal & RNG Cogen
Steam Boiler	6.0 MWt (20,000lbs)	1.5 MWt (5,000lbs)	6.0 MWt (20,000lbs)
Heat Recovery Steam Generator (HRSG)	-	1.4 MWt (4,600lbs)	1.4 MWt (4,600lbs)
Hot Water Engine Heat Recovery	-	1 MWt	1 MWt
Electrical Energy	-	2 MWe	2 MWe
TOTAL	**6 MW**	**5.9 MW**	**10.4 MW***

Note 1MWt = 3,412lbs steam

***75% increase in energy production**

BRDF RNG Conversion Road Map



Dec 2013
Project Funding Approval

March 2014
Installed natural gas line to engine

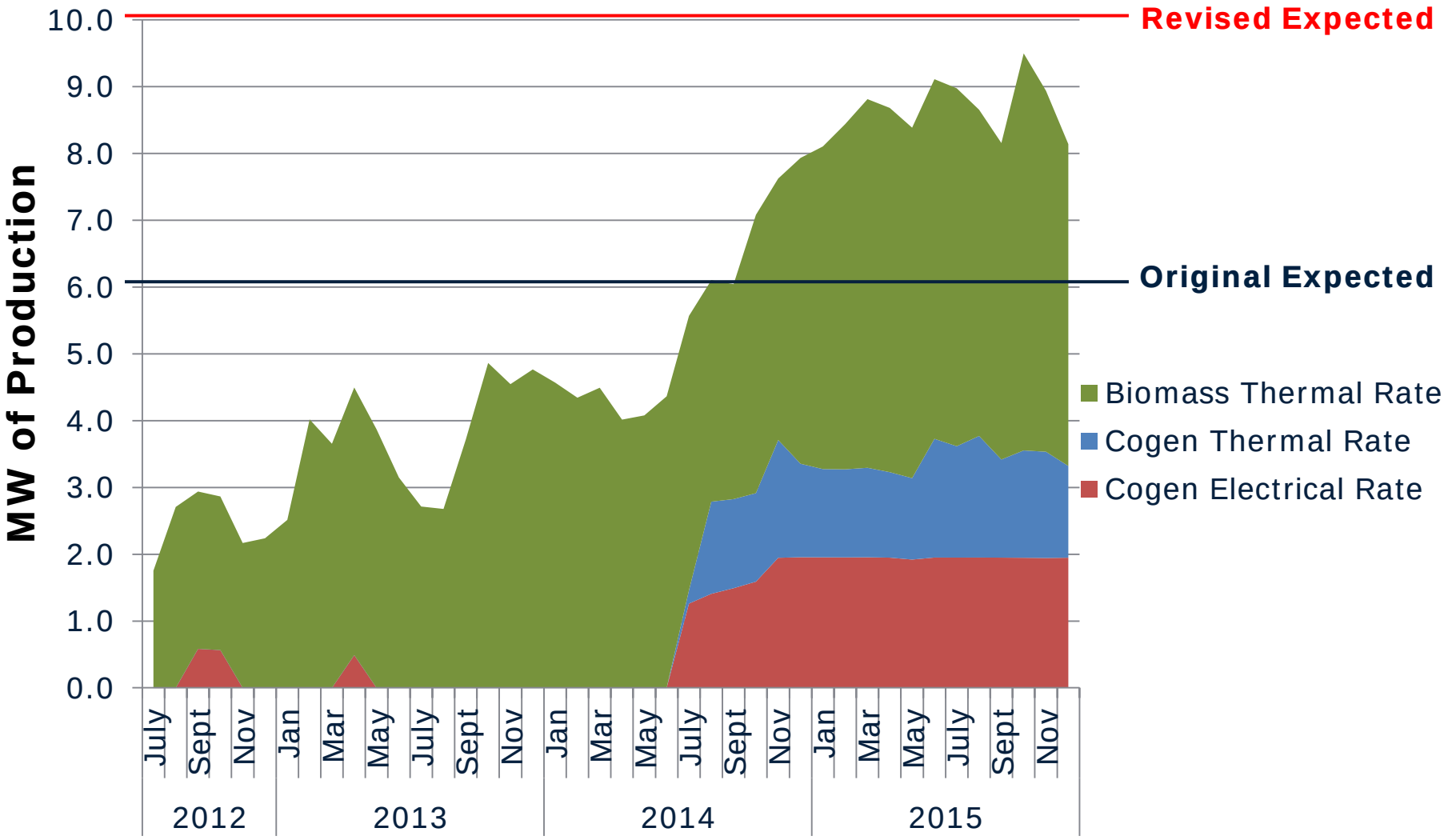
June 2014
Engine converted to dual fuel capable

October 2014
Engine Turbo Upgrades

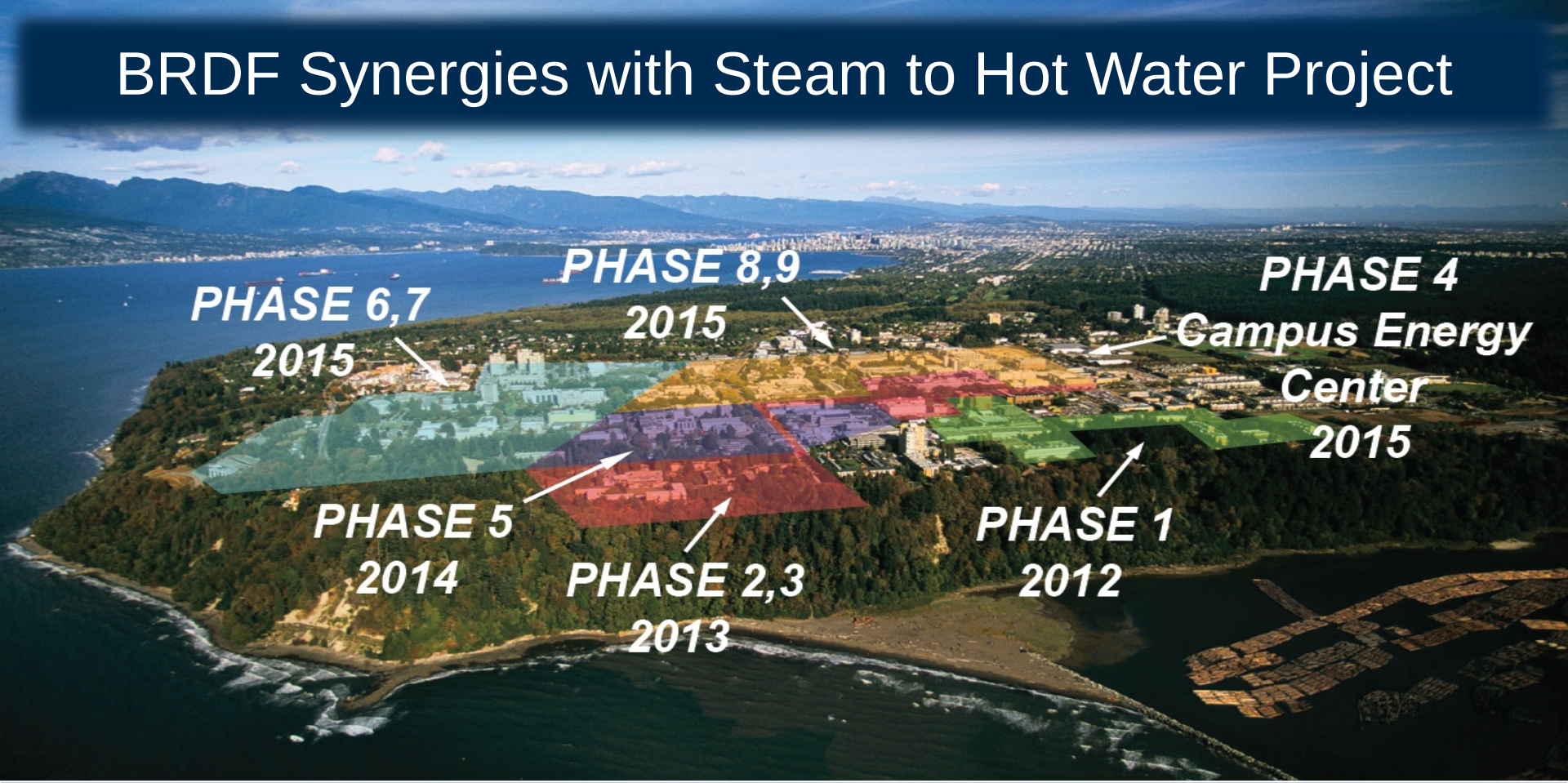
Cogen Performance to Date Since Conversion:
The first 16 Months Aug 2014 – Dec 31 2015

	Cogen Syngas (First 2 years)	Cogen RNG (Aug 2014 to date)
% Engine Uptime	3%	96%
Electrical Generation (MWh)	205	22,426
Peak Power (MW)	1.89	1.98
HRSG Steam (lbs)	199,000 (59MWh)	41,945,000 (12,294MWh)
Hot Water (MWh)	0	5,374

BRDF Average Monthly Production - By Source



BRDF Synergies with Steam to Hot Water Project



Concurrent to the BRDF project, UBC has been undertaking an $88m, 9 phase, Steam to Hot water conversion project: Academic District Energy System (ADES)

- BRDF supplies the ADES temporary energy center (TEC) using steam to hot water heat exchangers to energize the ADES. “First time the Powerhouse had been off load since 1925”.
- Enables an orphan steam project at Lower Mall Research Station (LMRS). New steam microgrid created.

Steam Powerhouse

TEC Summary

- Commissioned Jan 2014
- Allowed 63 buildings to be commissioned prior to CEC completion
- Delivered energy savings of 125,000 GJ's NG and reduced CO2 emissions by 6,250 tons 2014/15
- BRDF only, supplied steam for summer 2015
- In Reserve November 2015

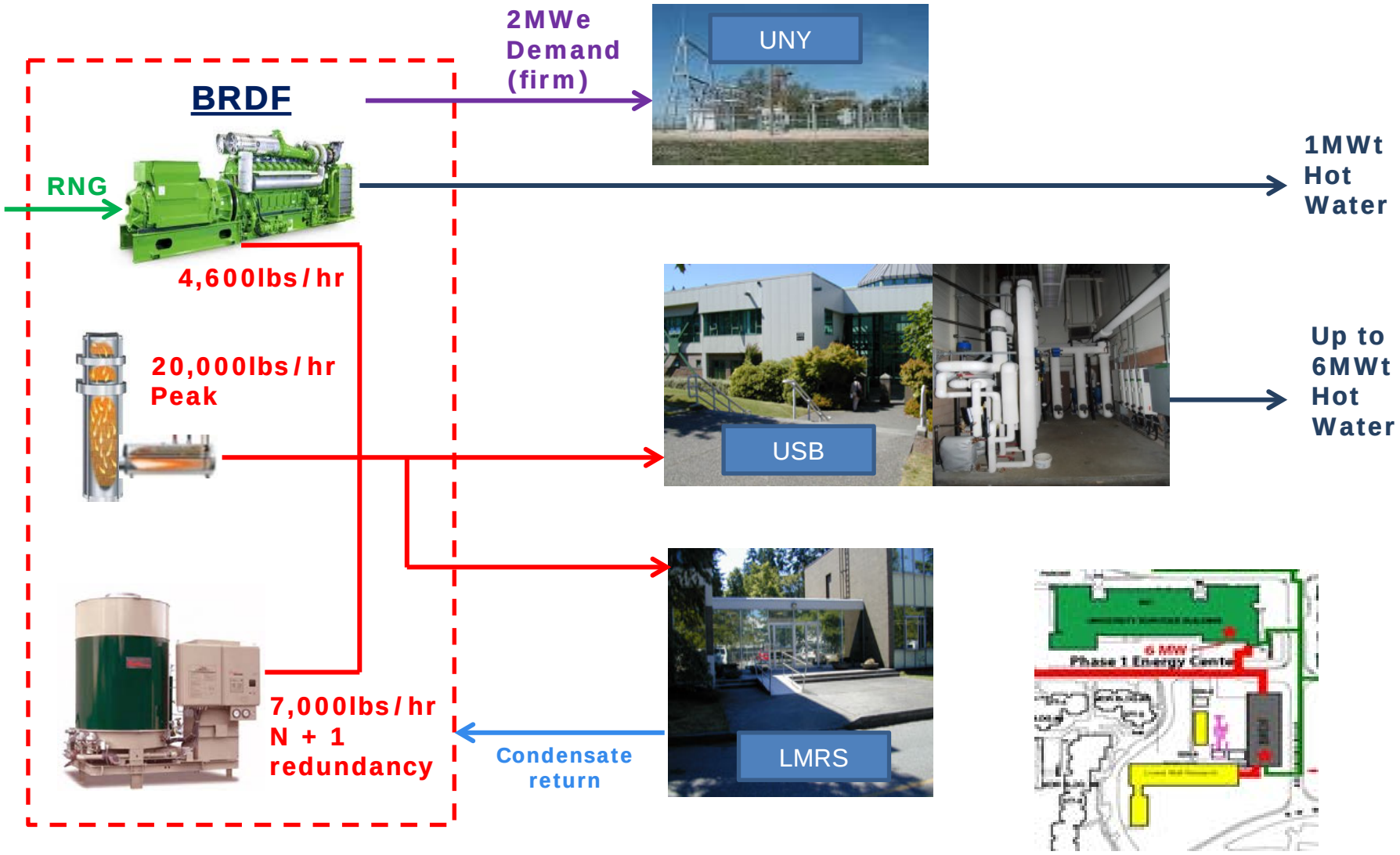
New HW feeder pipe line Fall 2013

From BRDF feeder line

Main UBC Steam feeder line

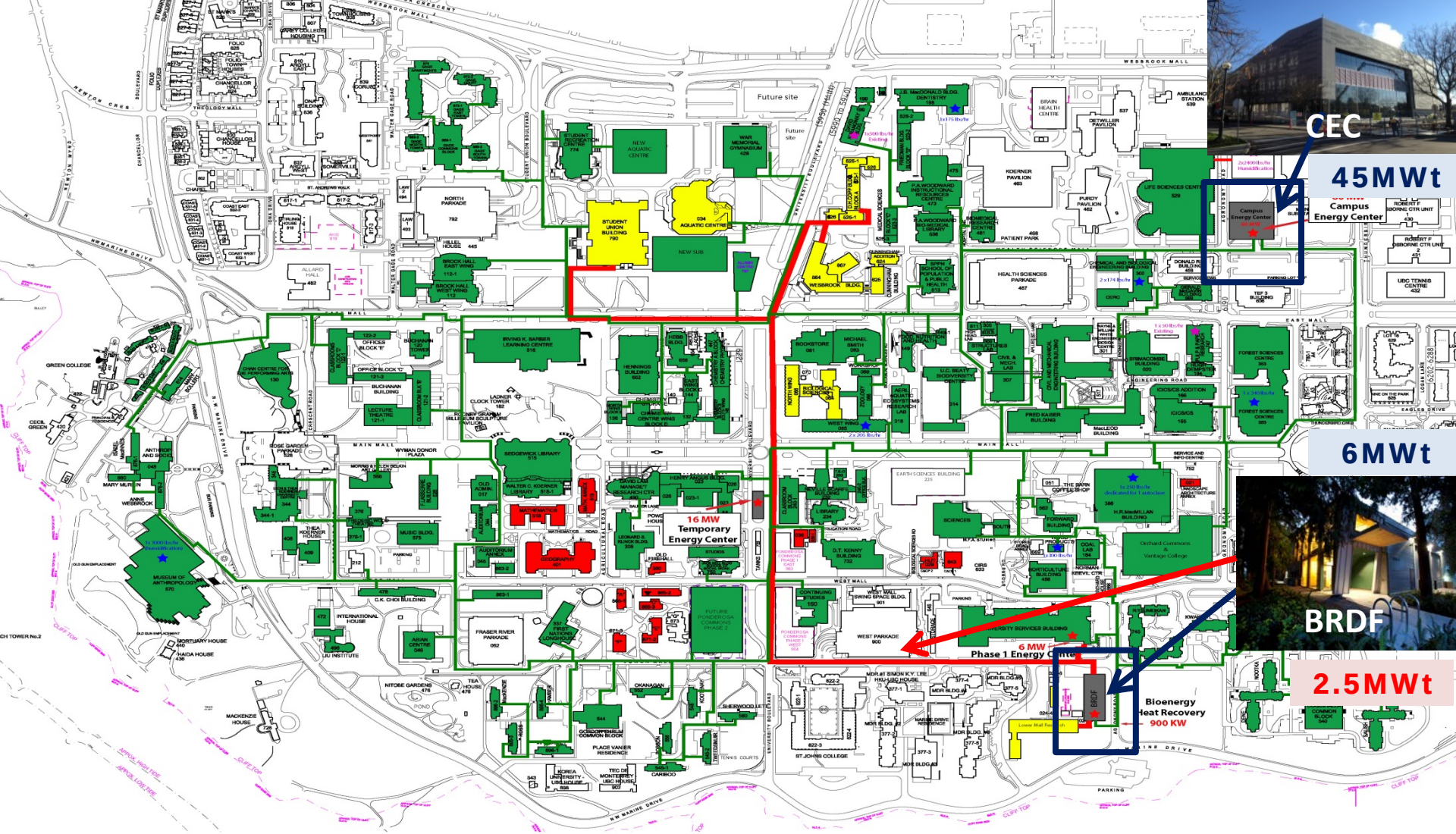
ADES Temporary Energy Center (TEC)

BRDF & LMRS Steam Microgrid (In service May 15)



- **Separation of thermal and Cogen Steam Processes: Now becomes units 1 & 2 (6MW & 1.4MW steam respectively)**
- **New 7kpph (2MW) steam boiler: Unit 3 added 2014**
- **BRDF now has 11kpph (3.4MW) steam redundancy**

From Demonstration to Baseload



Academic District Energy System Dec 2015

Conclusions

- BRDF is a valuable baseload production unit to UBC
- CHP with Biomass Syngas has been proven, but did not provide reliable energy production due to operational challenges
- Cogen RNG fuel conversion provides:
  - Increased total energy production by 75% above BAU
  - Provides additional thermal capacity & fuel diversification
  - Provides 2.4 MWt firm (N-1) thermal capacity i.e. redundancy
  - Provides reliable power production
- BRDF now performs as baseload ADES thermal energy production unit
- BRDF electrical production reduces UBC electrical demand challenge by 2MWe, with an up time of 96%
- 400+ tours to date
- Multiple research projects completed and ongoing.
- UBC continues to benefit from in-kind world attention to BRDF through sustainability agendas, tours, CLL and research

BRDF: RESEARCH ACTIVITIES

The active commercial operation of the UBC system spawned the development of 11 spin-off R&D projects at UBC engaging 14 UBC faculty and a larger number of students

Catalytic Tar Cracking - Primary Investigator: Dr. John R Grace, Dr. Tony Bi

High Temp. Hydrogen Membrane Extraction - Primary Investigator: Dr. John R Grace, Dr. Jim Lim

CLT Life Cycle Study - Primary Investigator: Dr. Alberto Cayuela

MetroVancouver Fuel Study - Primary Investigator: Dr. Shahab Sokhansanj, Dr. Anthony Lau

Implication on testing of pipeline materials exposed to hydrogen - Primary Investigator: Dr. Chad Sinclair, Dr. Matt Roy

Added Value Ash Study - Primary Investigator: Dr. Tom Troczynski

Examination of Corrosion Mechanisms in Steel Vessels - Primary Investigator: Dr. Akram Alfantazi

Metallurgical Investigation of Materials Issues at the BRDF - Primary Investigator: Dr. Steve. Cockcroft

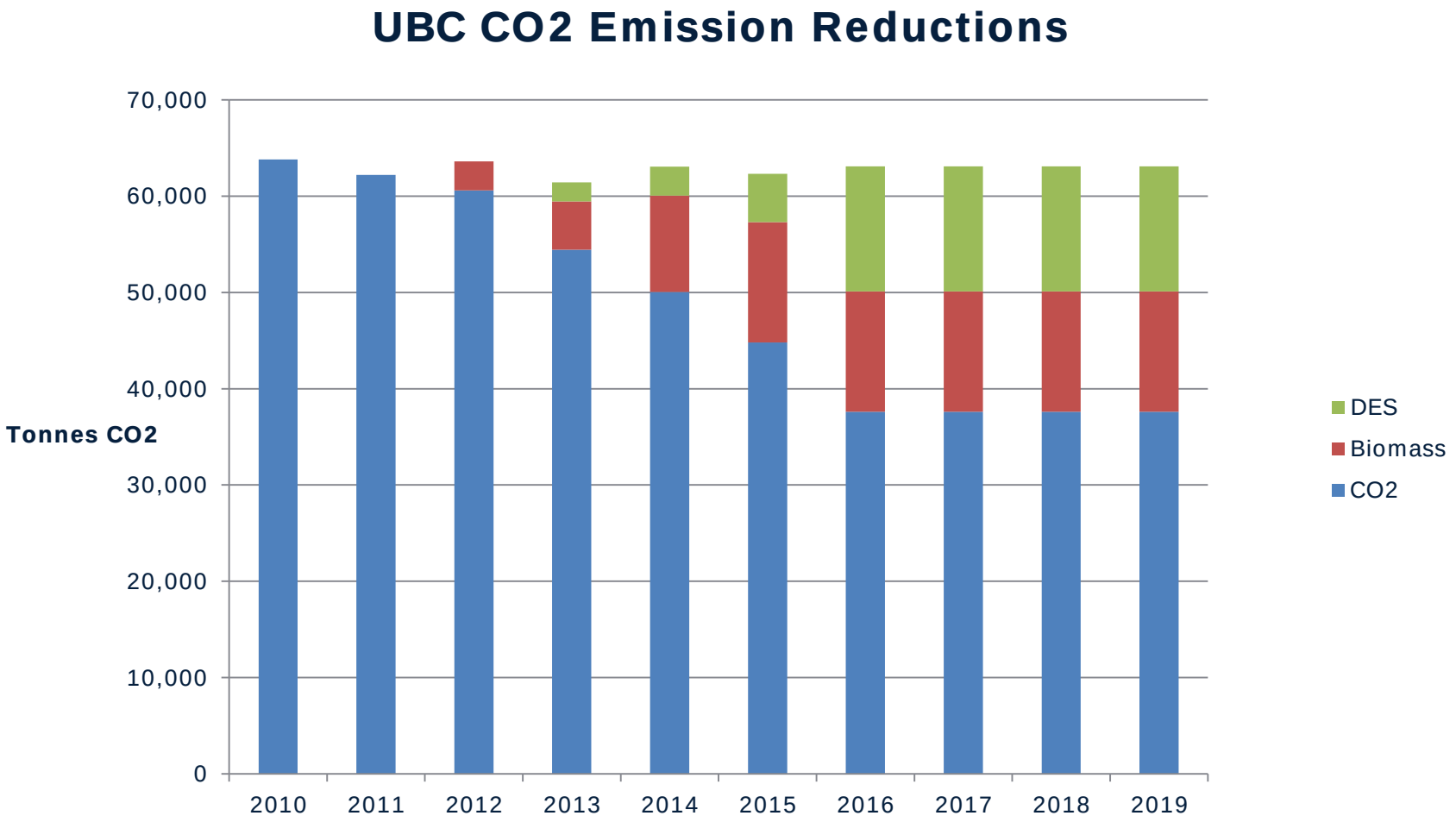
B2H Advanced Gas Program - Primary Investigator: Nexterra/UBC/Fortis/Quadrogen

Electro-Chemical Energy Storage (ECES) - Primary Investigator: Dr. Martin Ordonez

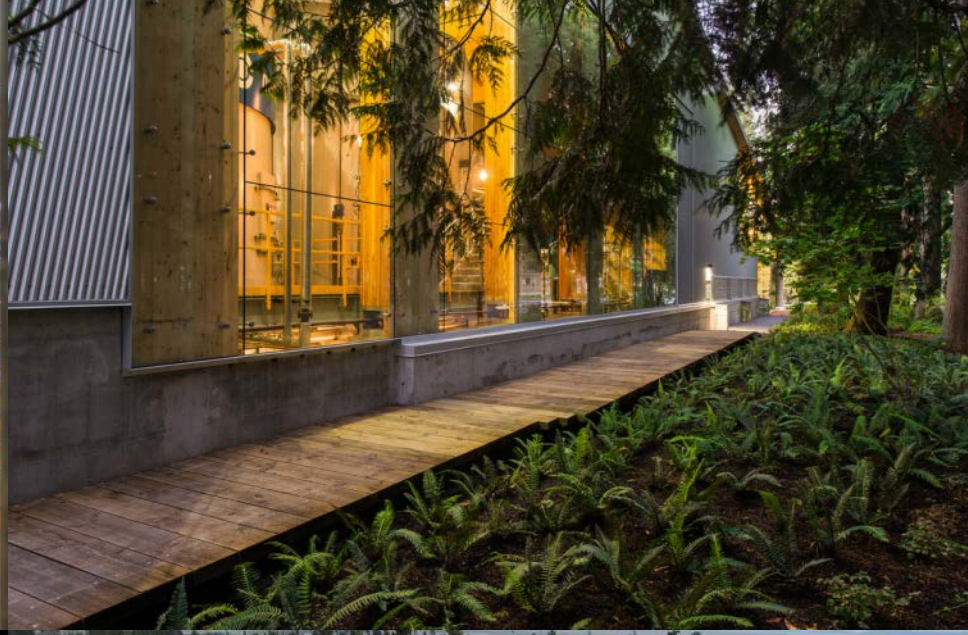
Advanced Integrated AC-DC Systems - Primary Investigator: Dr. Juri Jatskevich

Photo Credit: Don Erhardt

UBC GHG Emissions Post Projects



Early reports indicate UBC achieved a ~31% CO2 reduction for 2015 from 2007 baseline



Paul Holt, paul.holt@ubc.ca