Research and development of low-carbon and negative-carbon energy systems

Tony Bi
Clean Energy Research Centre
The University of British Columbia
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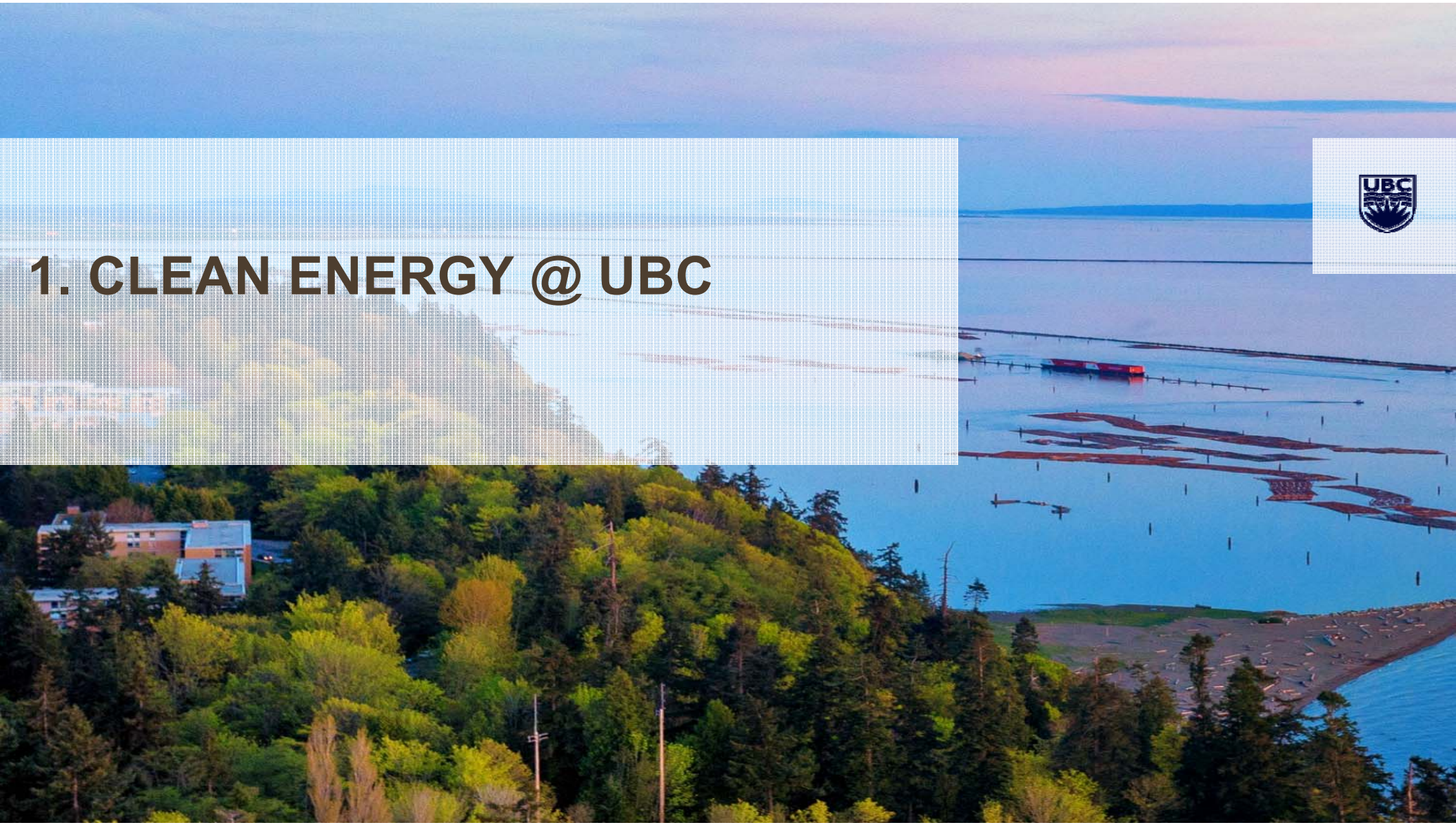
Pacific Energy Innovation Association Energy Breakfasts

CONTENT

1. Clean energy research at UBC
2. Low carbon bioenergy for decarbonisation
3. From low carbon to carbon negative bioenergy systems



1. CLEAN ENERGY @ UBC

CLEAN ENERGY RESEARCH CENTRE

CERC

UBC

2004: $9M Canada Foundation for Innovation (CFI) fund awarded

2005: Opening of CERC research building

2018: $4.5M CFI fund for Biorefining Research and Innovation Centre

2018: $12M CFI fund for Transport Future

VISION

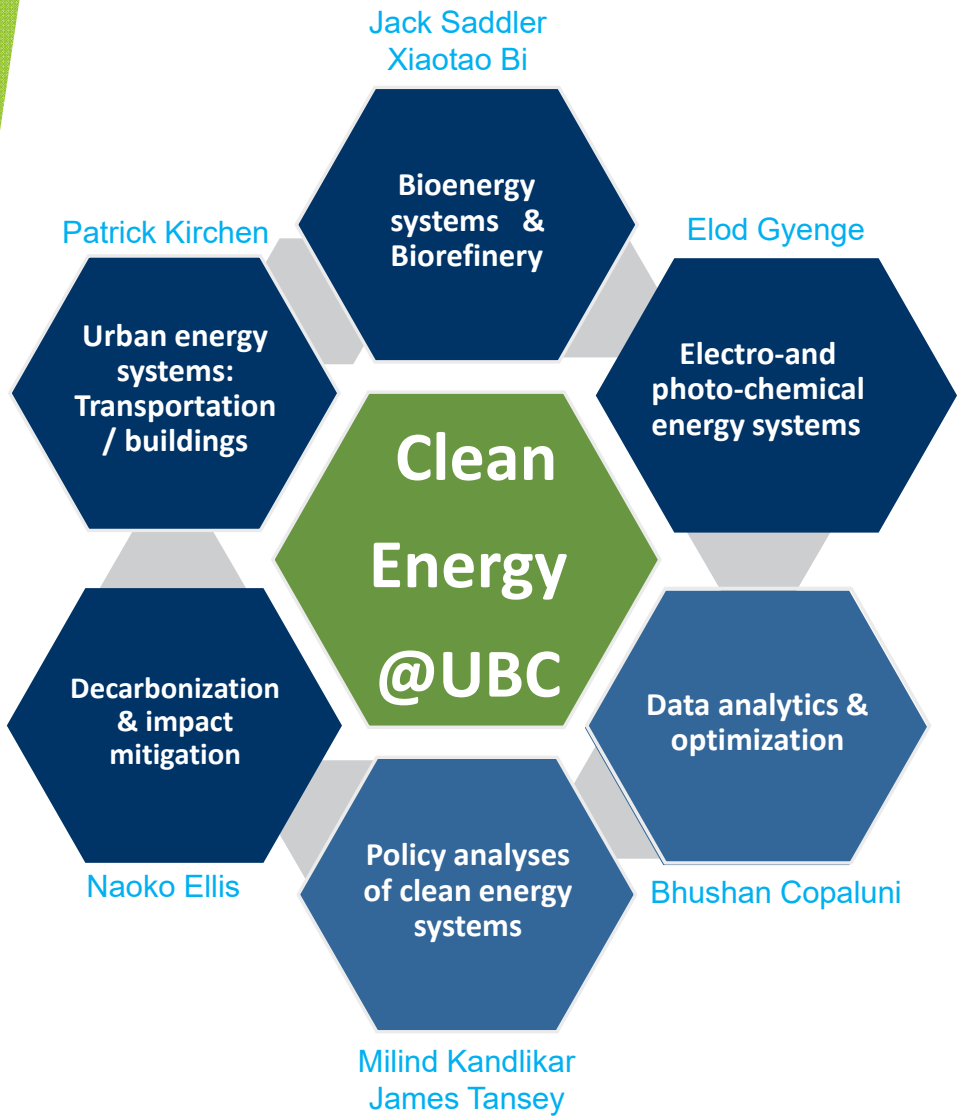
A global leader and powerhouse in R&D&D for innovative clean energy solutions to climate change and regional sustainability.

MISSION

Undertake world-class clean energy research and training that will bring values to UBC, British Columbia, Canada and the World.

CORE RESEARCH ACTIVITIES

- Research & development of clean energy technologies
- Demonstration, validation & optimization of clean energy technologies
- Techno-economic analyses and policy analyses of clean energy technologies



- **Bioenergy systems & Biorefinery**

Pellets, biochar, liquid biofuels, gaseous biofuels

- **Electro- and photo-chemical energy systems**

Fuel cells, batteries, solar, wind, hydrogen

- **Urban energy systems: Transportation/buildings**

Engine, fueling/charging station, green building, district heating, geothermal

- **Decarbonization & impact mitigation**

Carbon capture and utilization, air, water, soil impact mitigation

- **Data analytics & optimization**

Smart grid, energy efficiency, energy supply chain, energy system simulation, optimization & control

- **Policy analyses of clean energy systems**

LCA, TEA, IE, circular economy, policy & regulations

My Research Interests

Multiphase reactors & Particle technology

Clean energy & Green engineering

- Fluidized/spouted beds
- Electrostatics of powders
- Catalytic Reduction of NOx
- Biomass gasification
- Microwave catalytic pyrolysis
- Torrefaction & densification
- Fuel cell water management
- Catalytic tar cracking
- Life cycle analysis
- Industrial symbiosis

UBC clean energy research facilities and collaborations

China-Canada Bioenergy Centre

Korea Institute of Science & Technology - UBC Bio-refinery Lab

Fraunhofer - UBC Projects

$30M

Bioenergy Research and Demonstration Facility

$24M

Campus Energy Center

$9M

Clean Energy Research Centre (CFI, 2004)

$6M

Biorefining Research & Innovation Centre (CFI, 2018)

$12M

Transport Future (CFI, 2018)

BioProduct Institute (Gasification pilot)

Forest Biotechnology & Bioenergy Lab

Biomass & Bioenergy Research Group

FP Innovations - UBC BioAlliance

Highlight of Core Research Activities (I)

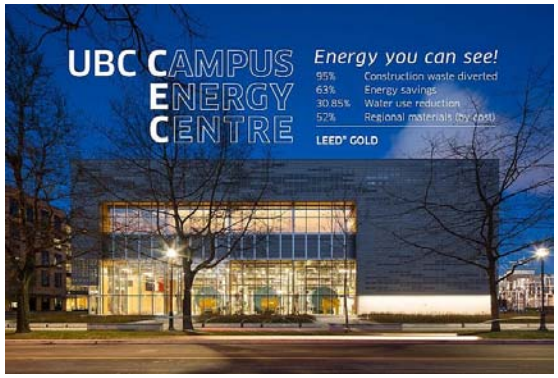
1. Research, development and scale-up of Clean Energy technologies

- A natural gas diesel **engine** for clean transportation (Evans et al. + Westport Technology)
- A membrane reactor for high purity **hydrogen** production (Grace/Lim + Membrane Reactor Technology)
- An electrochemical reactor for converting CO_2 and saline wastewater into chemicals and reusable water (Wilkinson + Mangrove Technology)
- A fluidized bed biomass gasifier for liquid and gaseous biofuels (Bi/Ellis/Grace/Lim /Watkinson + Highbury Energy)
- A biomass torrefaction reactor for torrefied pellets (Bi/Lim/Sokhsansanj + GloGreen Technology)

Highlight of Core Research Activities (II)

2. Demonstration, validation and optimization of global clean energy technologies

- Nexterra biomass gasification technology for **district heating** (Grace/Sokhansanj/Bi/Ellis, Bioenergy Research & Demonstration Facility)
- Transportation Futures: demonstration of integrated infrastructures for clean **transportation** (Merida, Solar/charging/H2-fueling stations)
- Biomass to **biojet** fuels in British Columbia (BC-SMART) (Saddler, Parkland Refinery, NRCan, PNNL, airlines, ports)
- Bio-syngas for **lime kilns** and upgrading to **renewable natural gas** (Bi/Smith/Ellis, Bioalliance + FPInnovation, Pulp & Paper companies)
- Biomass **supply logistics** and pre-processing (Sokhansanj, Wood Pellet Association of Canada, Biofuel Net)

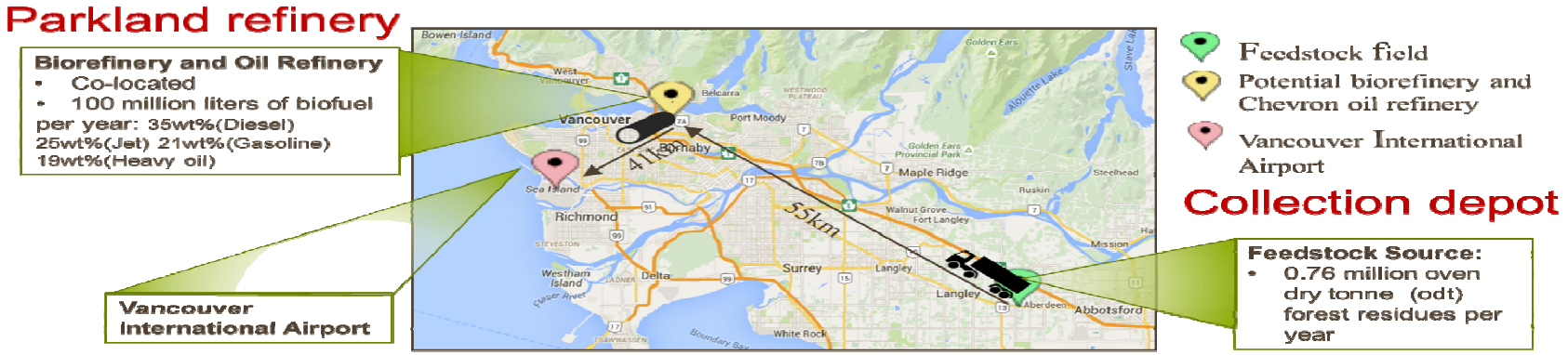


Highlight of Core Research Activities (III)

CERC

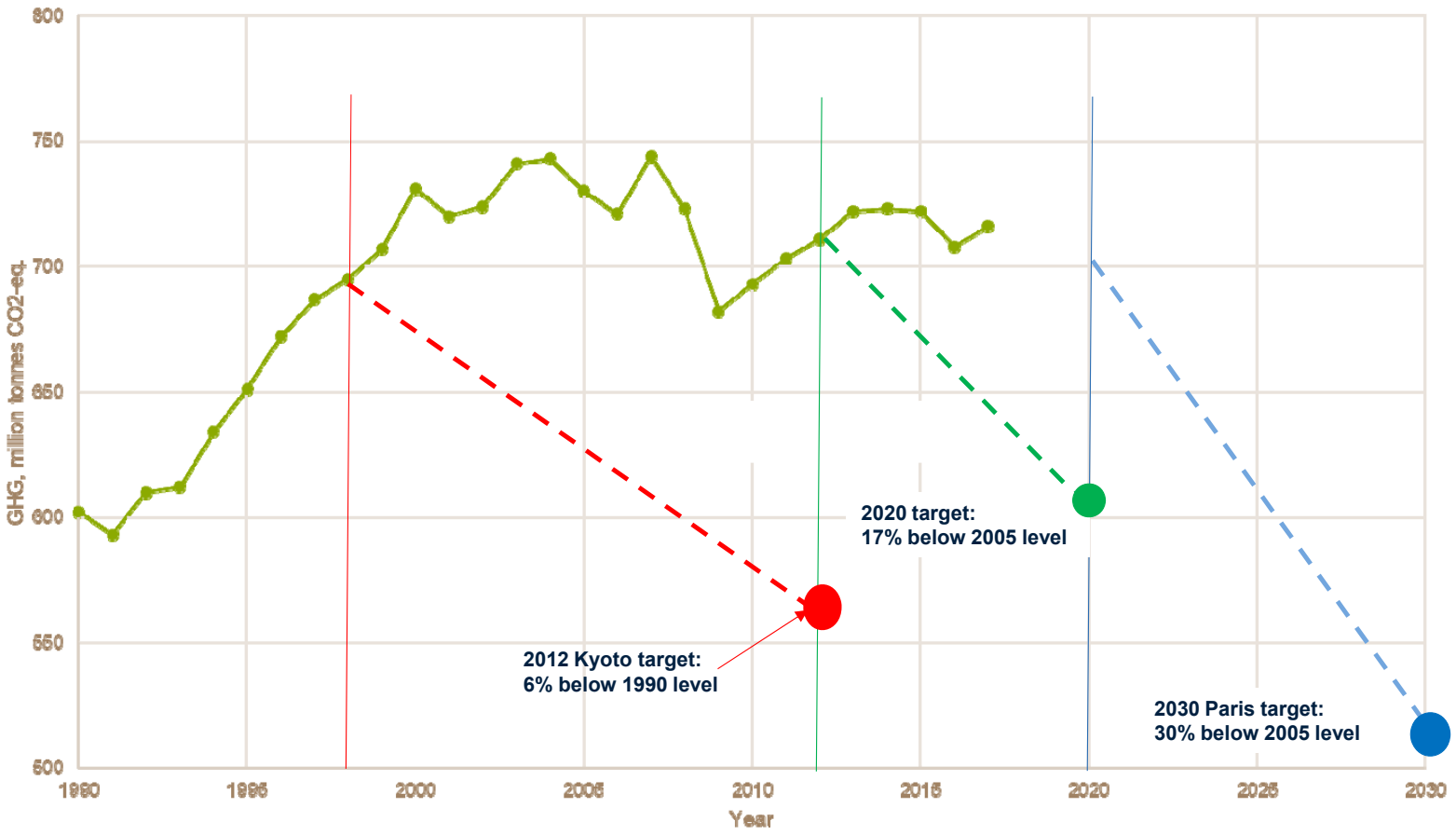
3. Impact assessments and techno-economic analyses of clean energy systems

- GHG reduction potential of BC **forest residues**;
- Canadian **wood pellets** and torrefied pellets
- Biomass-derived **liquid biofuels** in BC
- Bio-syngas for **lime kilns** in pulp and paper industry
- Forest-residues for **renewable natural gas** production



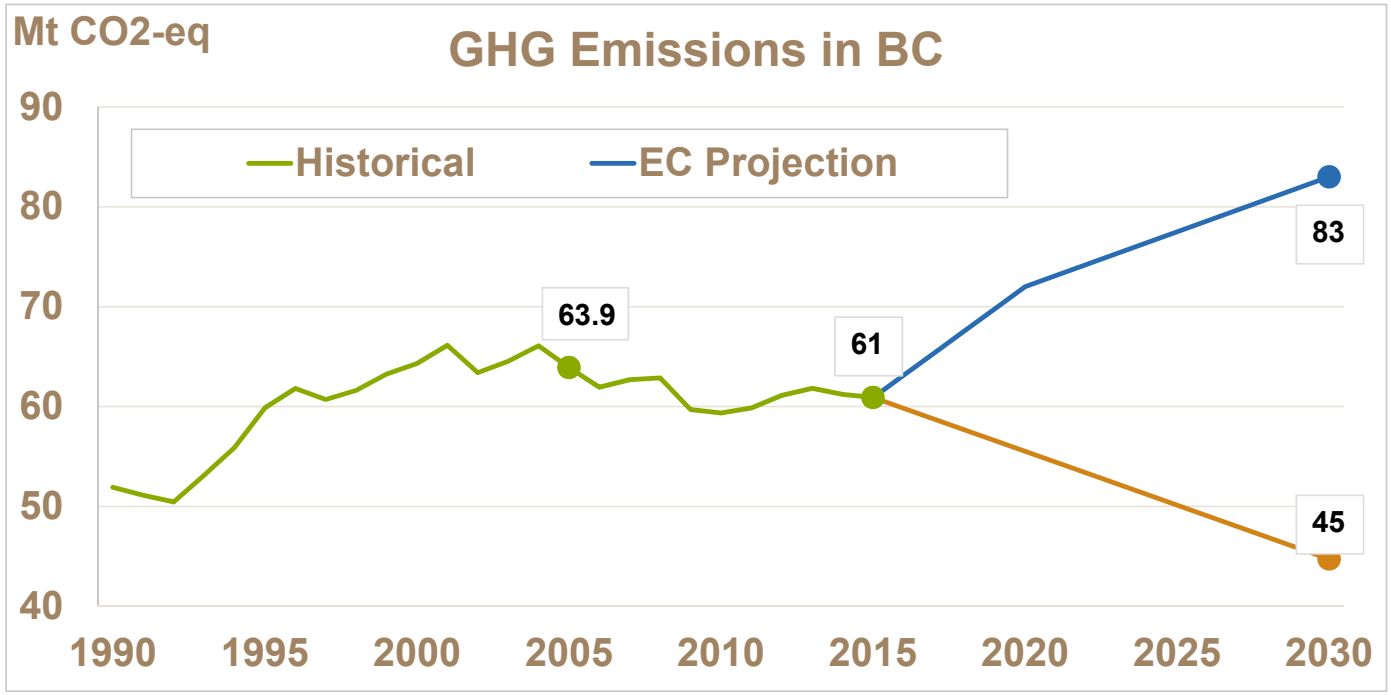
2. LOW-CARBON BIOENERGY FOR DECARBONISATION

Canada's 2012, 2020 & 2030 GHG targets

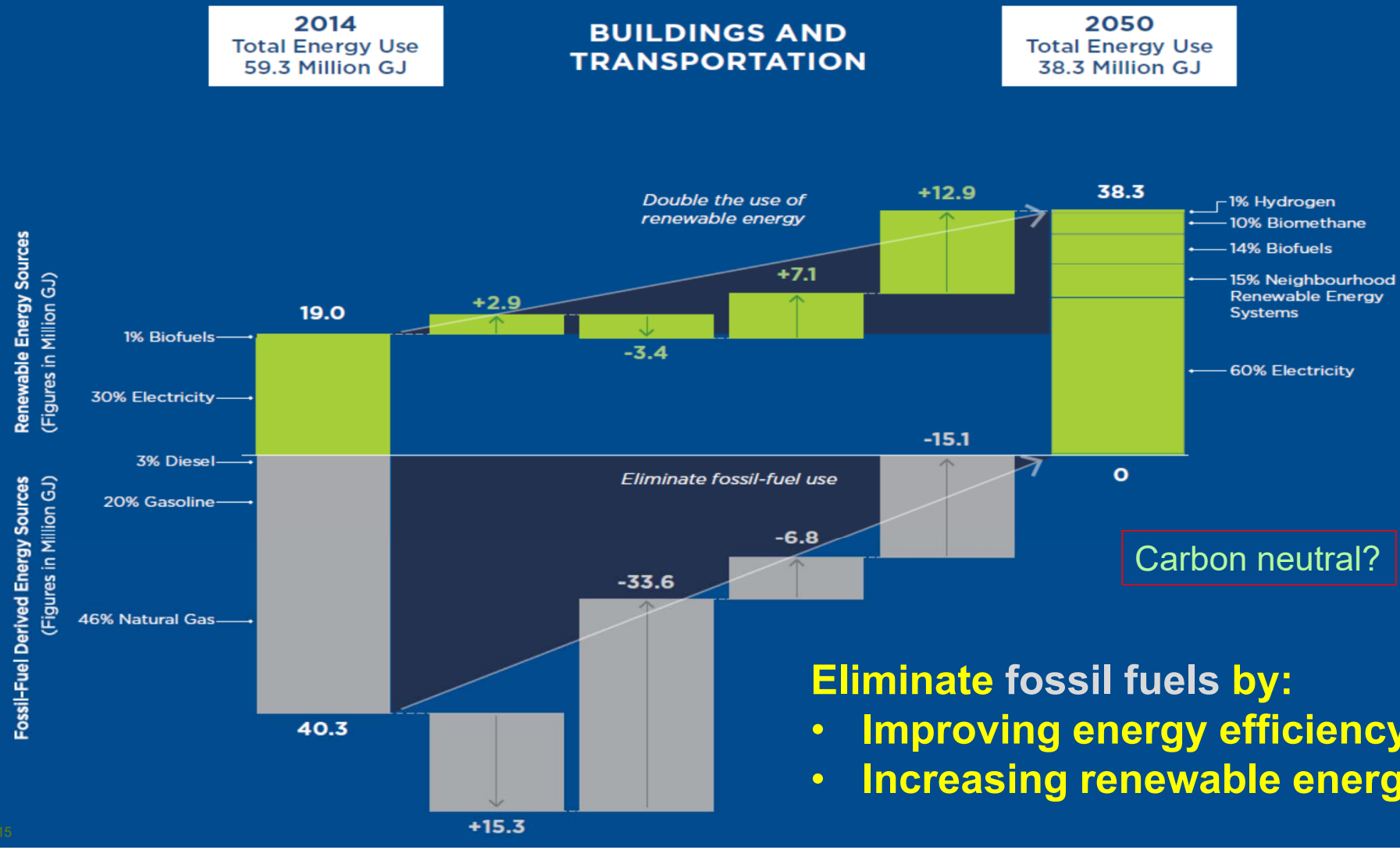


BC'S GHG EMISSIONS TARGET

- **Paris Agreement: 30% reduction from 2005 level by 2030**
- **BC Climate Leadership Plan: 80% reduction by 2050**



Vancouver 2050 "renewable city" target



Carbon neutral?

Eliminate fossil fuels by:

- **Improving energy efficiency**
- **Increasing renewable energy**

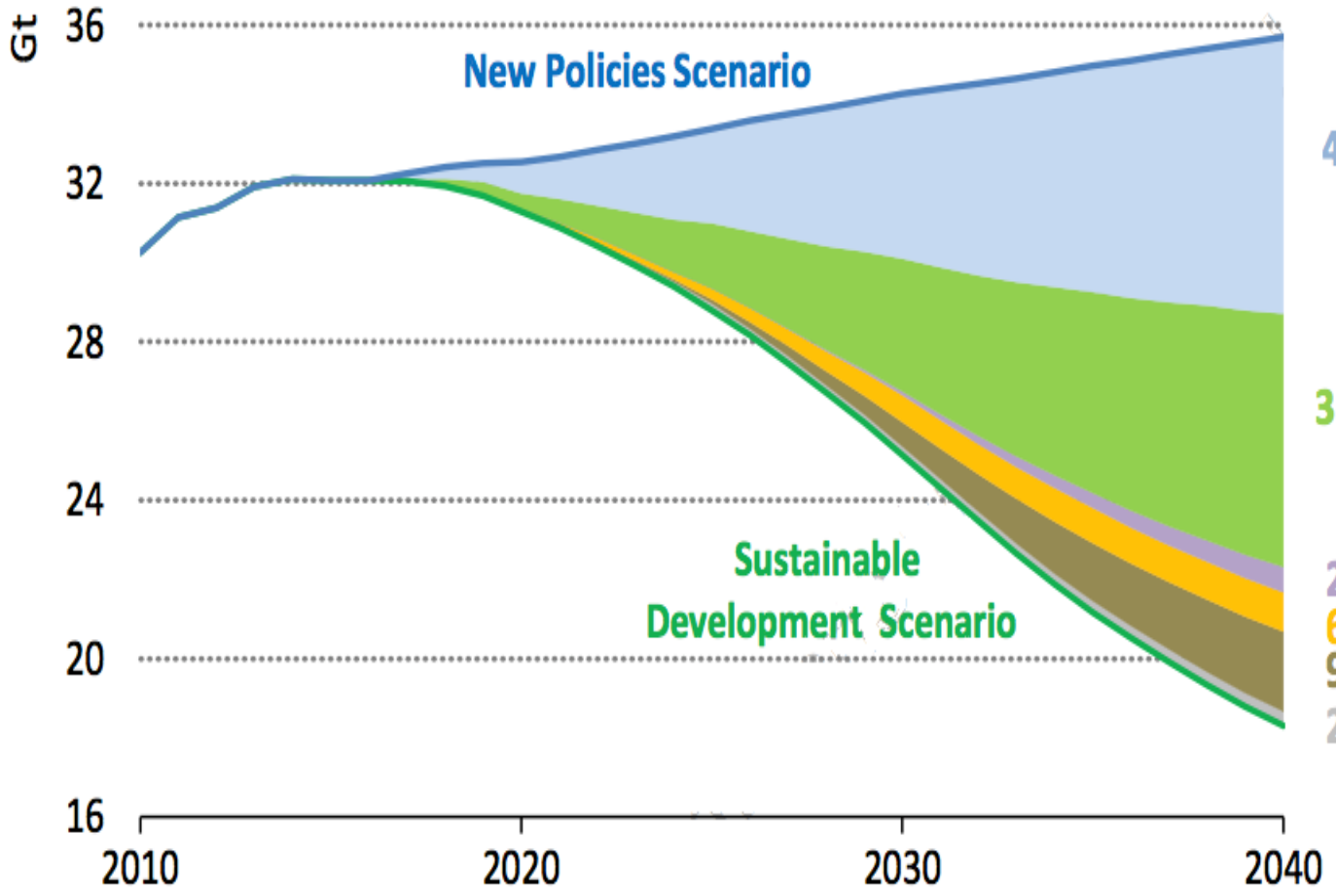
UBC'S GREENHOUSE GAS REDUCTION TARGETS

UBC ADOPTED ITS CLIMATE ACTION PLAN IN 2010, COMMITTING THE UNIVERSITY TO GREENHOUSE GAS (GHG) REDUCTION TARGETS OF:

33% BELOW 2007 LEVELS BY 2015
67% BELOW 2007 LEVELS BY 2020
100% BELOW 2007 LEVELS BY 2050

UBC DECLARED CLIMATE EMERGENCY IN 2019

CLEAN ENERGY FOR GREENHOUSE GAS EMISSION REDUCTION (IEA, 2017)



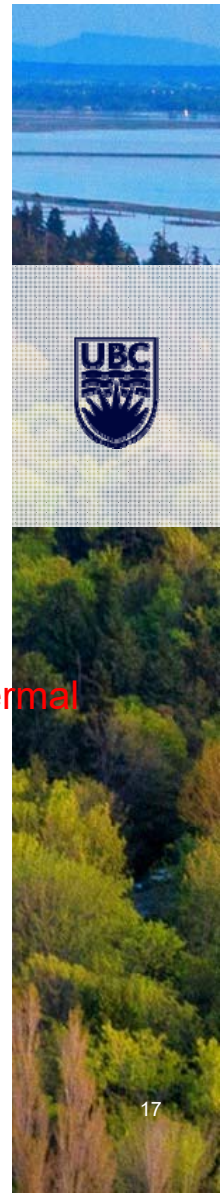
44% Efficiency

-UBC Hot water;
-Green building

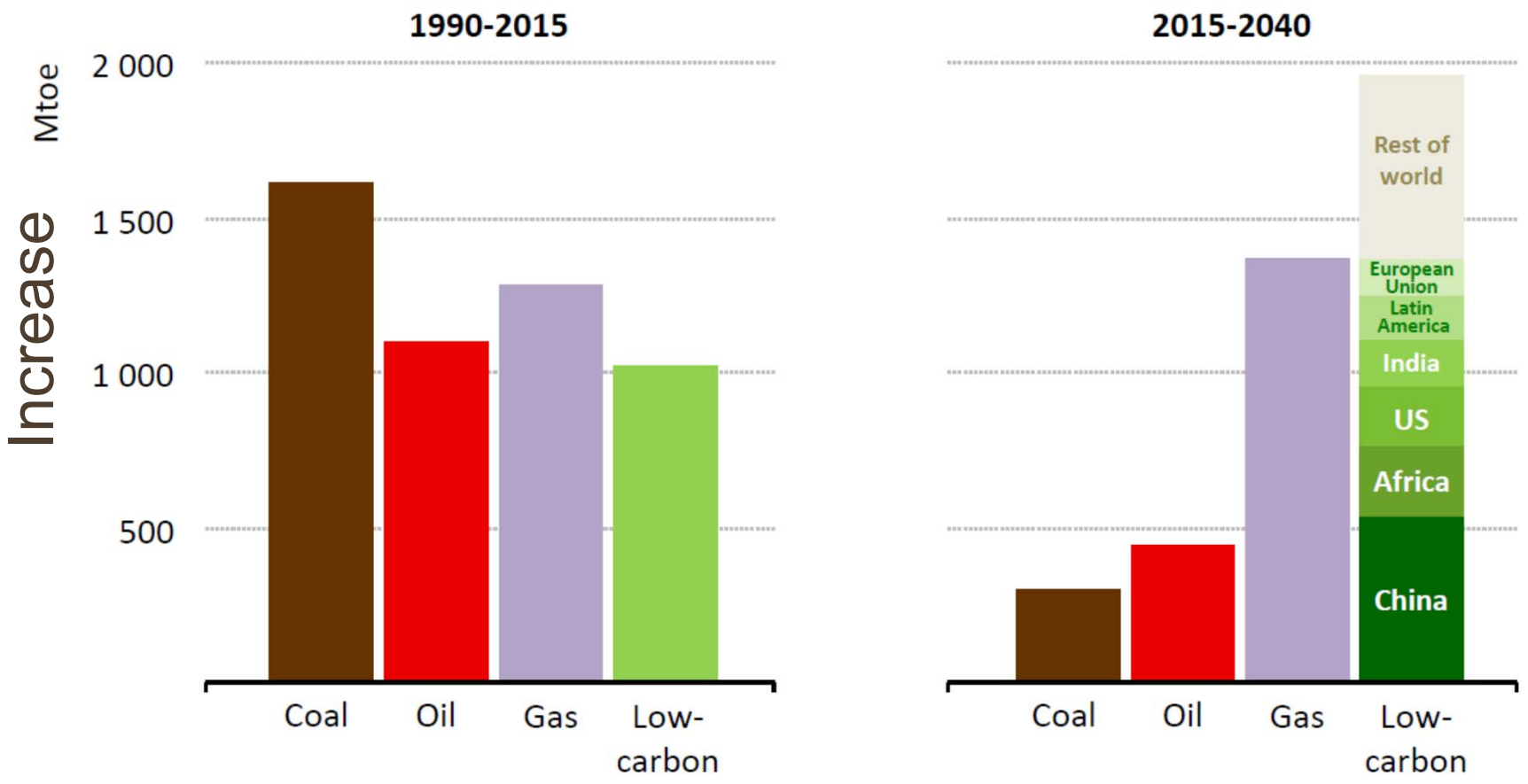
36% Renewables

-Solar/wind/geothermal
-Bioenergy

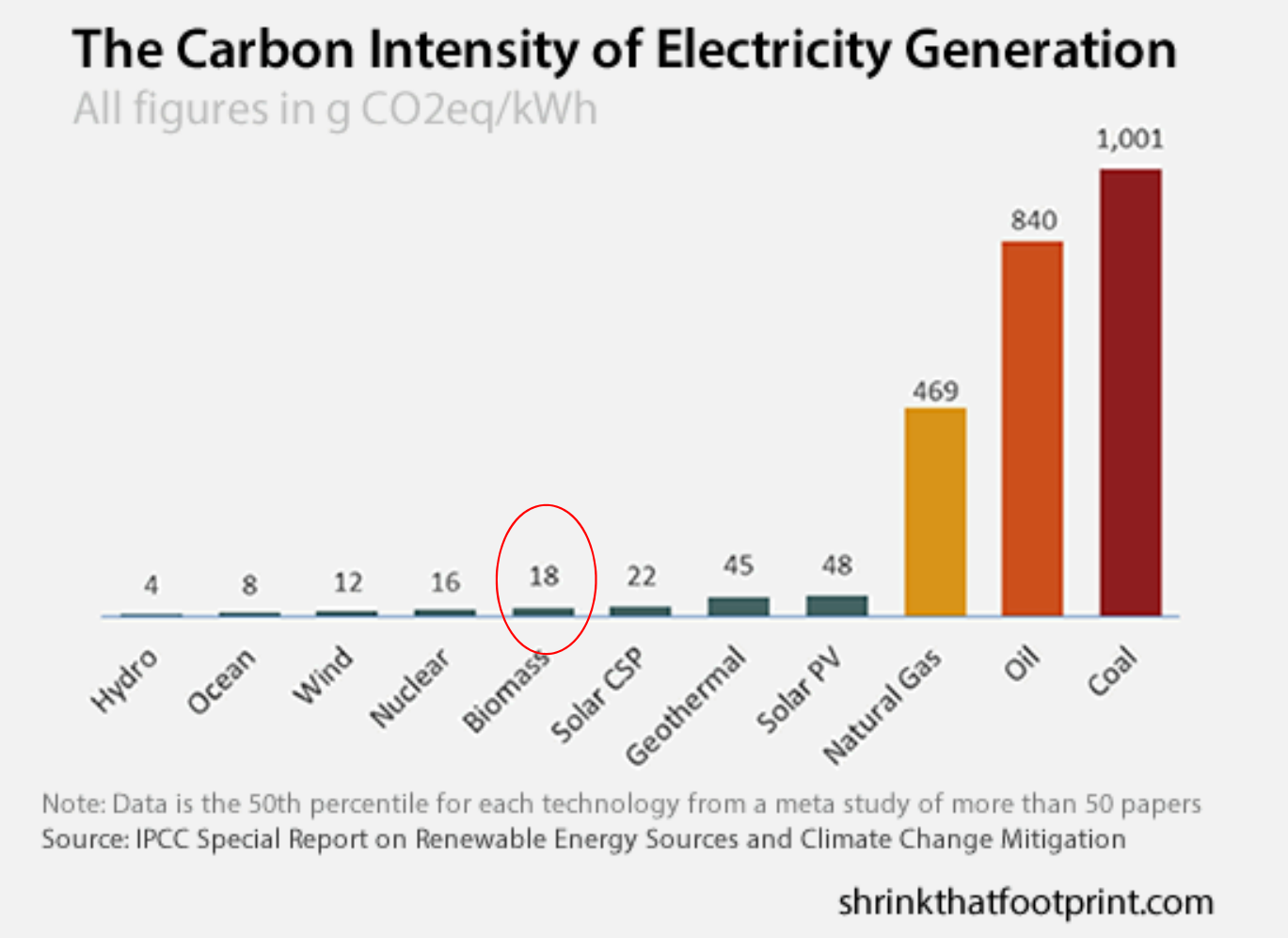
2% Fuel-switching
6% Nuclear
9% CCS
2% Other



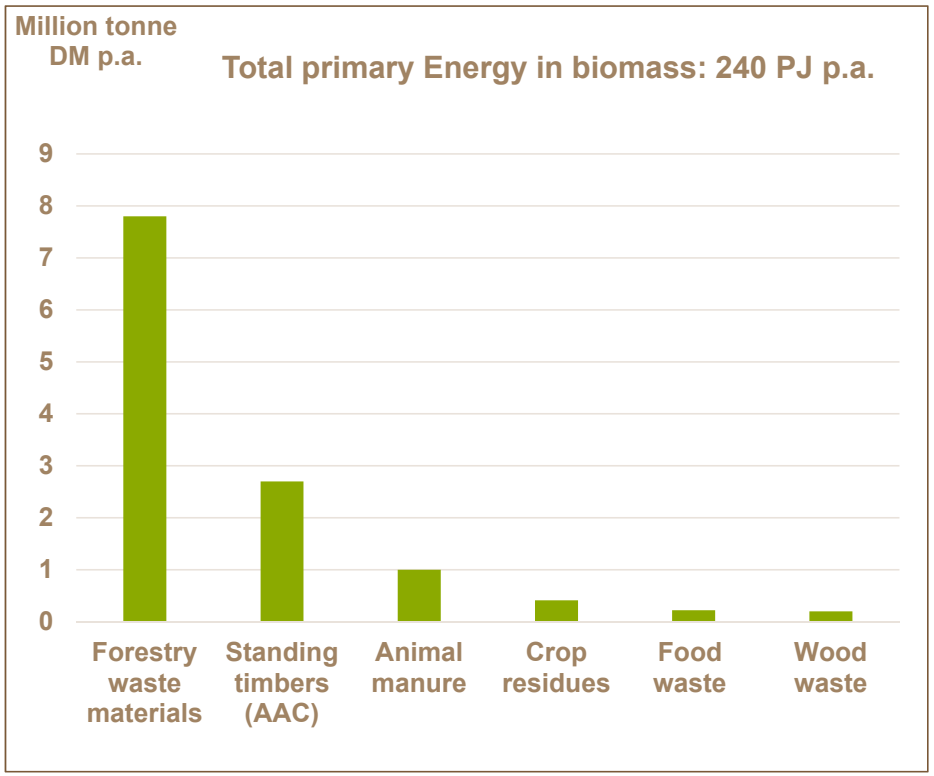
Low-carbon clean energy potential (IEA, 2016）

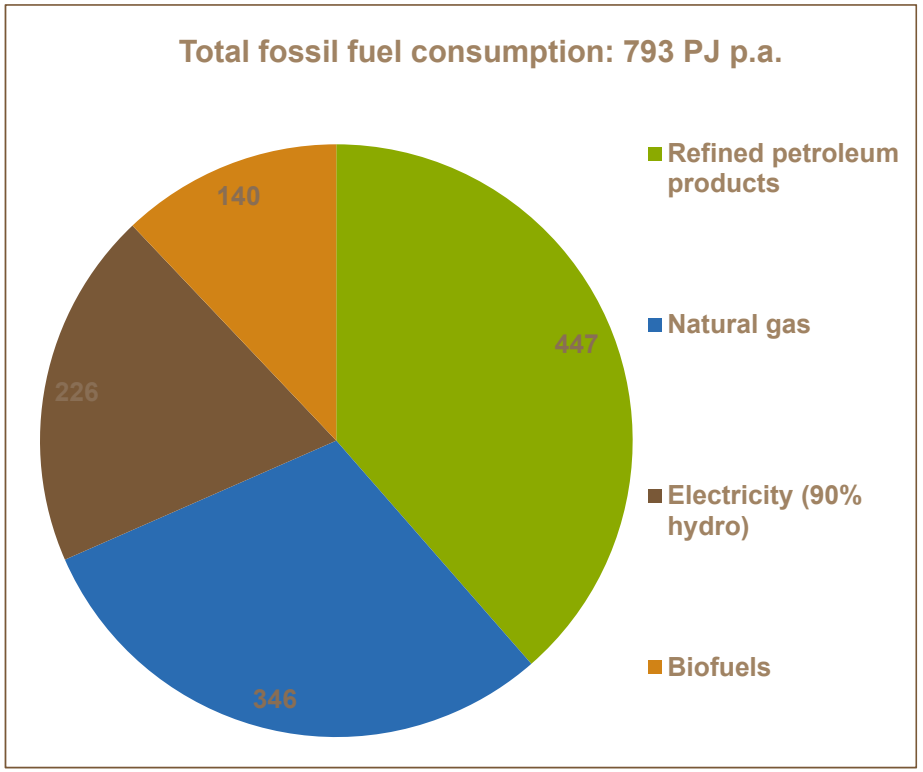


CARBON INTENSITY OF ENERGY SOURCES



Bioenergy potential at British Columbia

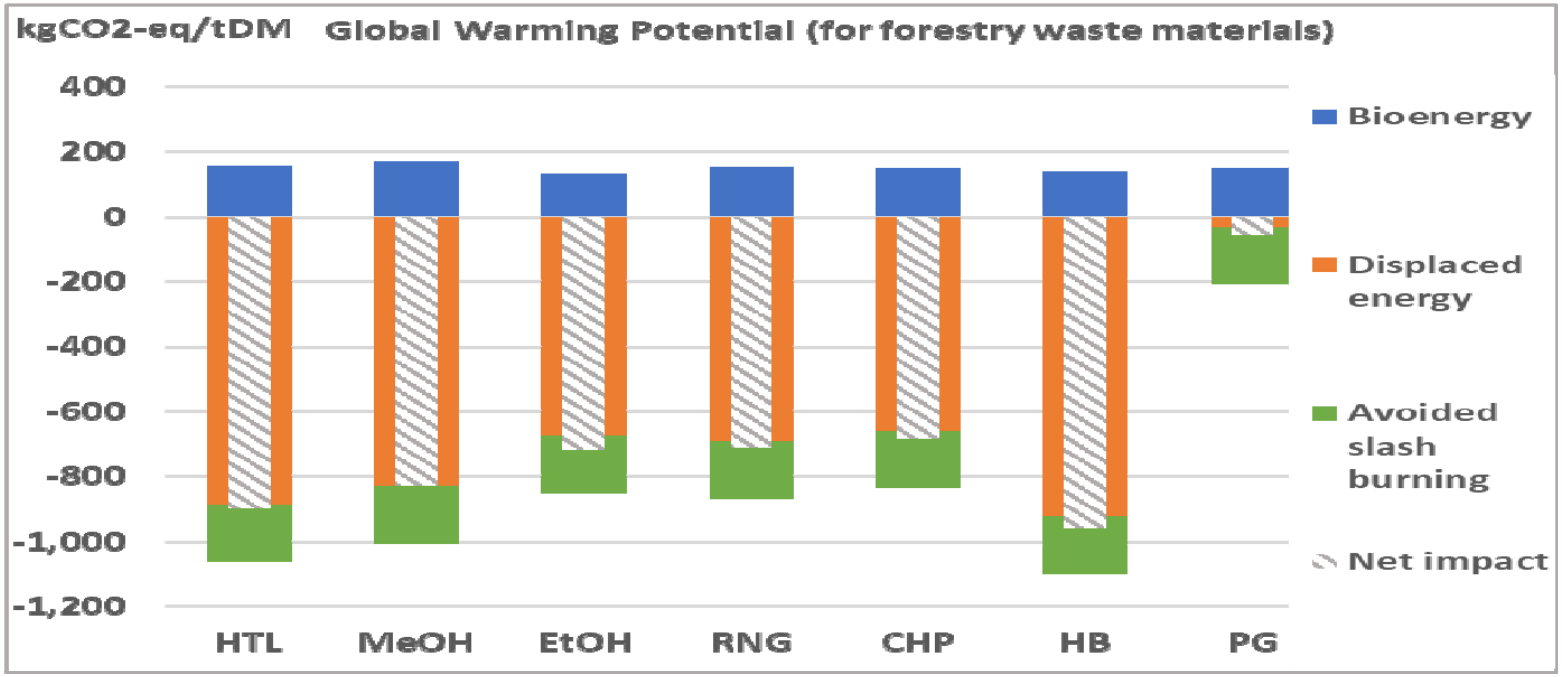




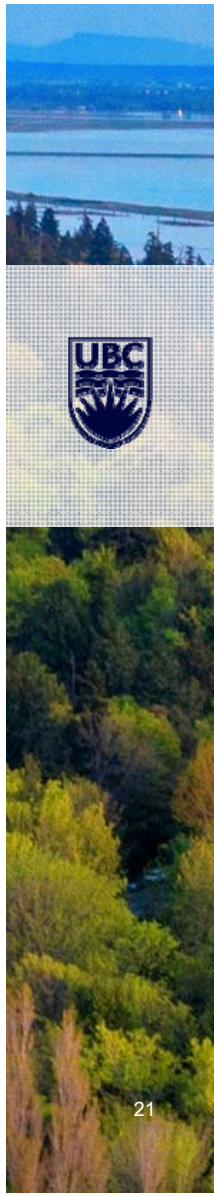
Wang, Zhang, Clift & Bi, Energy Policy (2020)

Source: https://www.cer-rec.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/bc-eng.html

GHG reduction potential from different conversion pathways

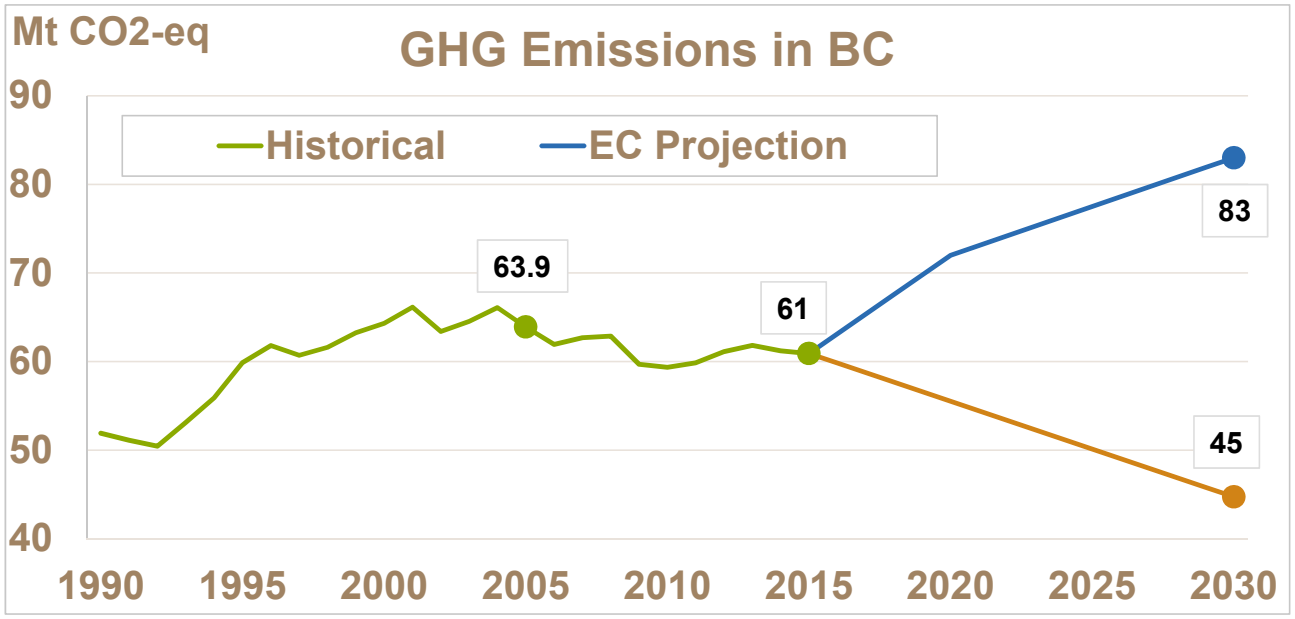


Wang, Zhang, Bi, Clift, Energy Policy, 138, 111285, 2020.

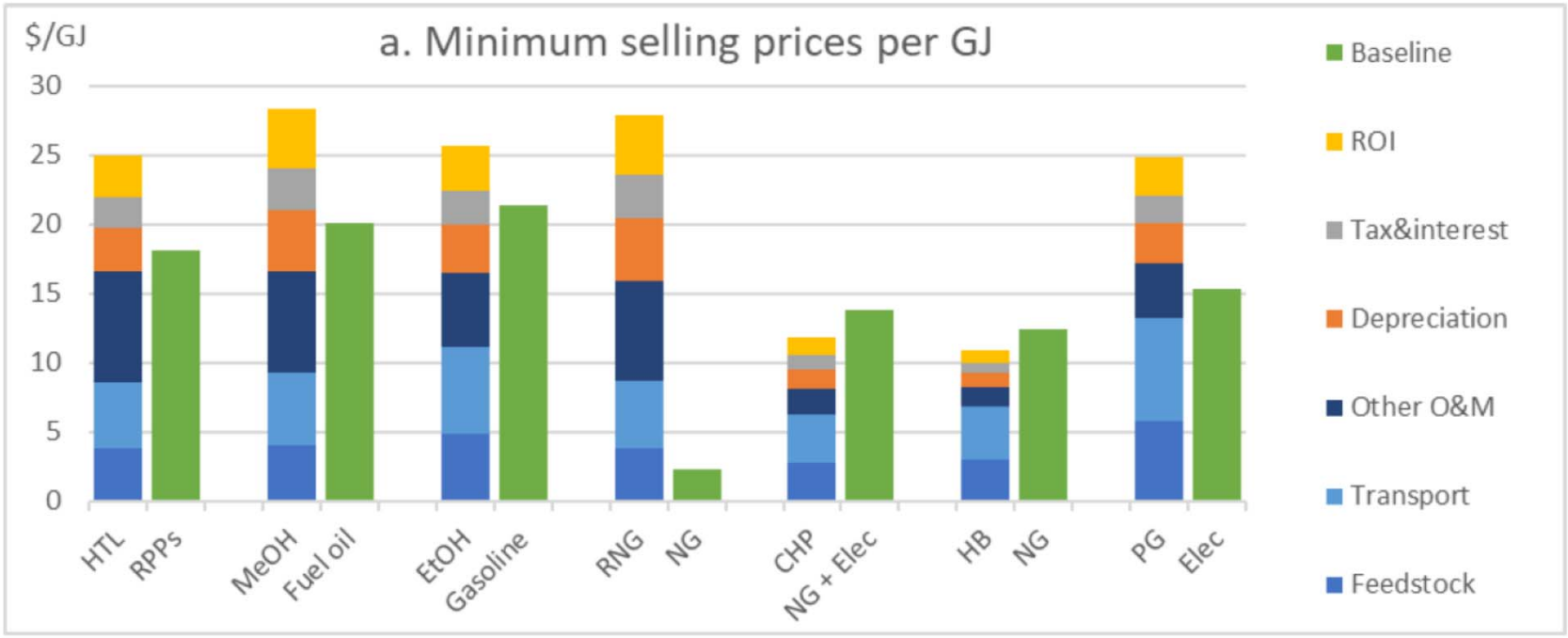


GHG REDUCTION POTENTIAL BY BIOENERGY IN BC

- Total GHG emissions in BC in 2005: **63.9 MT** CO_2-eq
- BC GHG reduction target by 2030: **19.2 MT** CO_2-eq reduction, **30%** below 2005 level
- Total bioenergy potential: **7-10.1 MT** CO2-eq., **11-16%** reduction from 2005 level (contribution of **35-50%** to the 2030 30% reduction target).



MINIMUM SELLING PRICES PER GJ BIOFUELS/BIOENERGY



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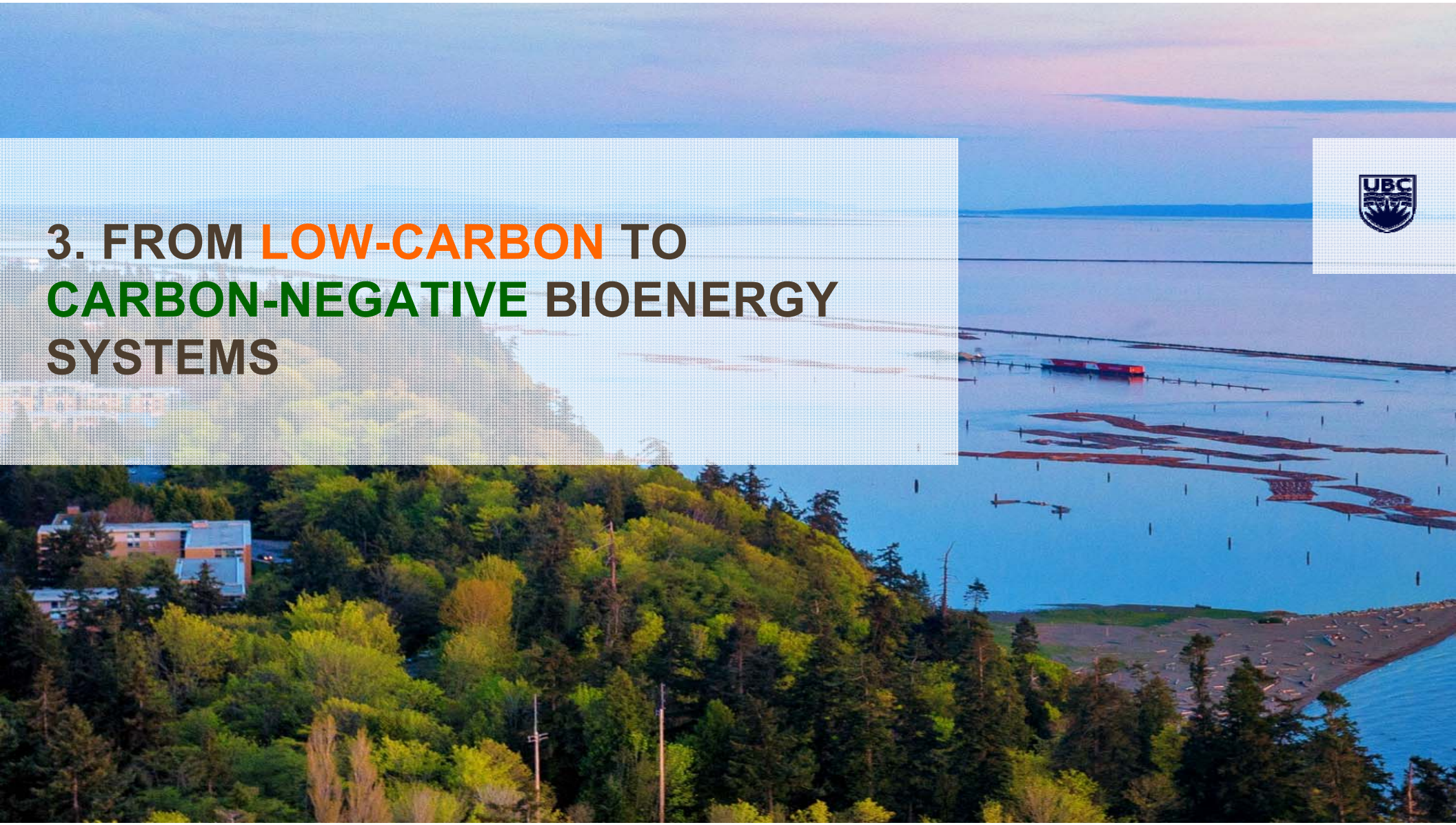
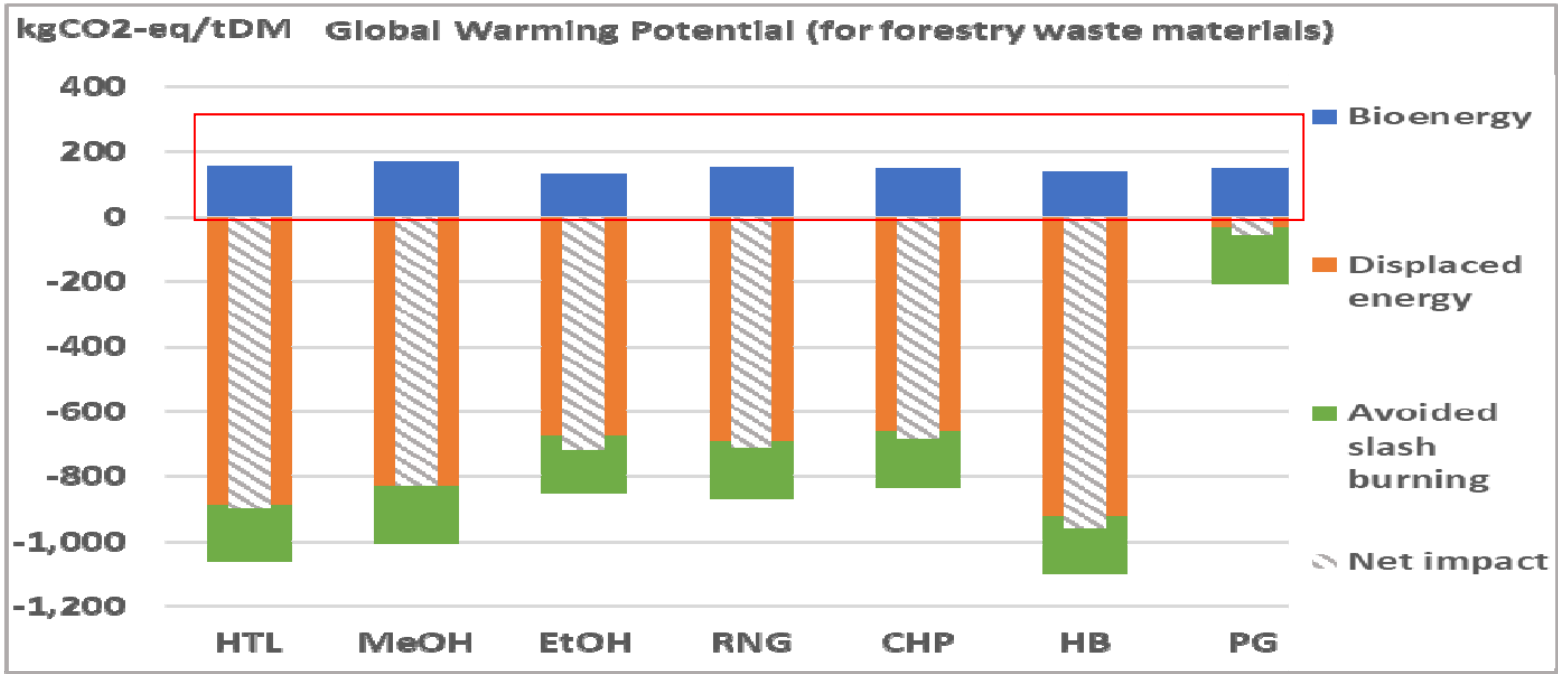


3. FROM LOW-CARBON TO CARBON-NEGATIVE BIOENERGY SYSTEMS

GHG reduction potential from different conversion pathways



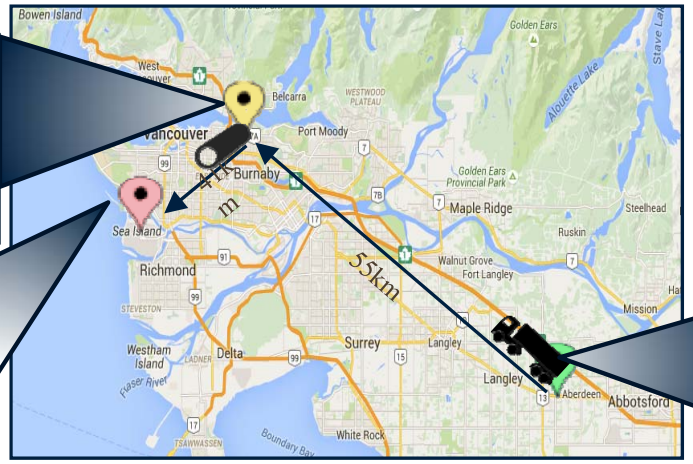
Wang, Zhang, Bi, Clift, Energy Policy, 138, 111285, 2020.

Local supply chain of biomass residues at BC

100,000 liters per year liquid biofuel

Parkland refinery

Biorefinery and Oil Refinery
- Co-located
- 100 million liters of biofuel per year: 35wt%(Diesel) 25wt%(Jet) 21wt%(Gasoline) 19wt%(Heavy oil)



Feedstock field

Potential biorefinery and Chevron oil refinery

Vancouver International Airport

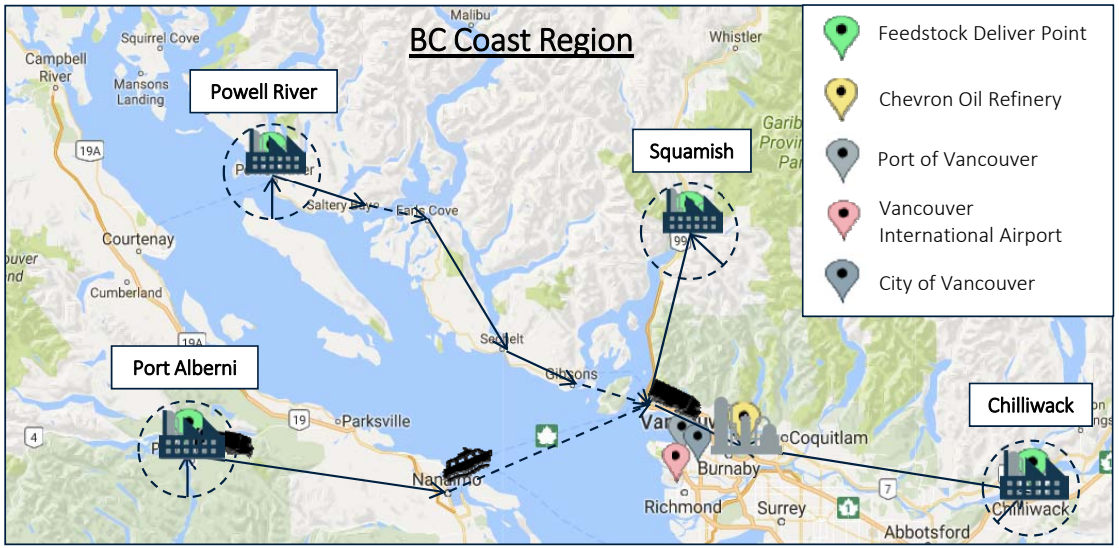
Collection depot

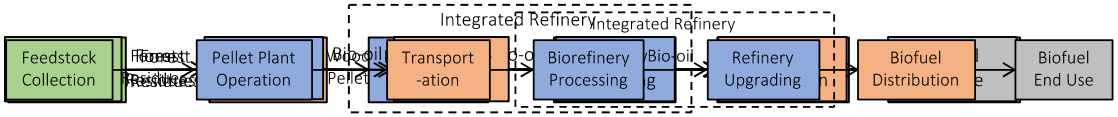
Vancouver International Airport

Feedstock Source:
- 0.76 million oven dry tonne (odt) forest residues per year

Three Scenarios

Case Study: 100 million liters per year HTL biofuel system





Scenario 1 (Fr-CIR)

1. HTL Biorefinery **co-locates** with oil refinery to form an **integrated refinery system**
2. **Forest residues** are transported directly to integrated refinery

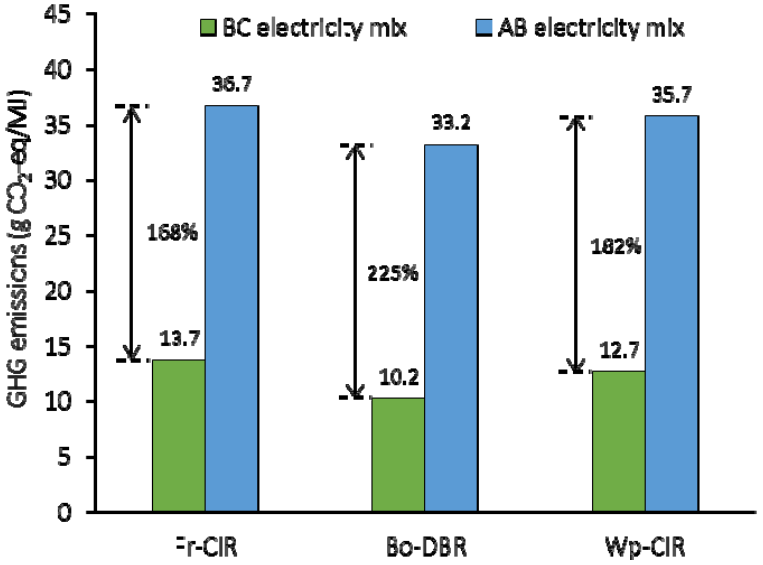
Scenario 2 (Bo-DBR)

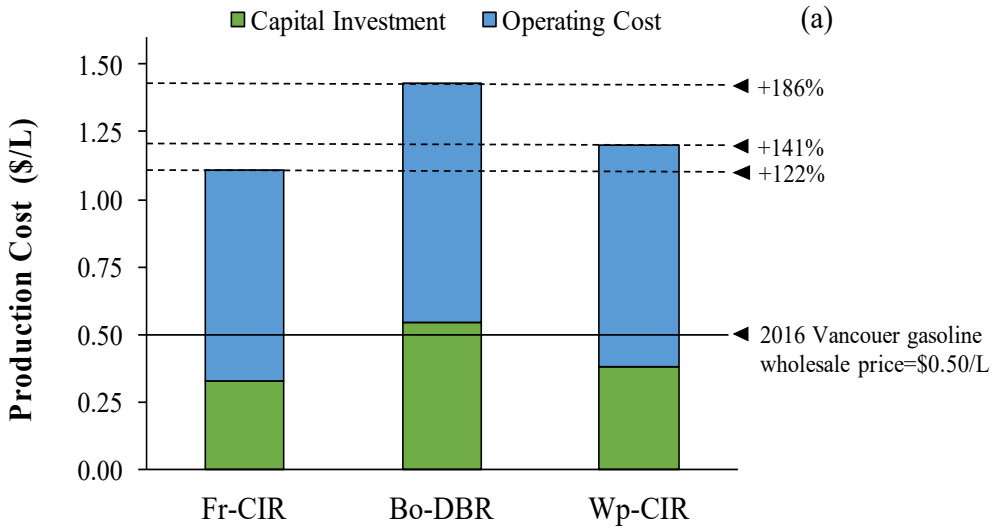
1. **HTL Biorefineries** locate at feedstock delivery points to convert forest residues to bio-oil
2. **Bio-oil** is transported to refinery

Scenario 3 (Wp-CIR)

1. **Wood pellet** plants locate at feedstock delivery points
2. **Wood pellet** is transported to **integrated refinery**

GHG EMISSIONS AND PRODUCTION COST OF HTL BIOFUELS





Nie and Bi, Biotechnology for Biofuels, 11-23, 2018.

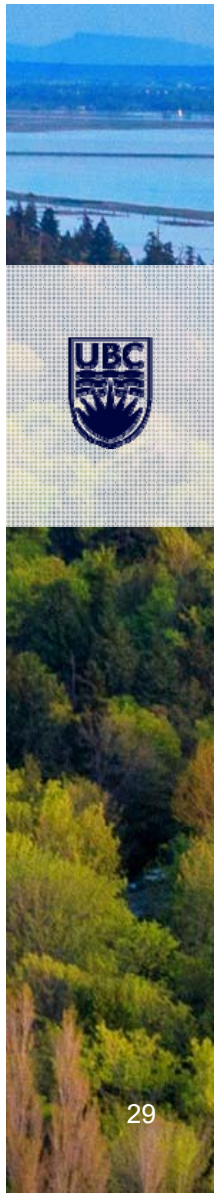
UBC AS A CARBON-NEUTRAL CAMPUS BY 2050

Unit: Tonne-CO_2-eq per year

Sources	2007	2015*	2018	2020* (Target)	2050 (Target)
Heating (NG+biomass)	54160	39221	34359	(~17130)	(0) ~5400
Liquid fuels (transport)	1970	1094	943	(~900)	(0) ~200
Electricity	3970	2071	2247	(~2000)	(0) ~2000
Total	60100	42386	37549	20030	(0) **~7600?**

*BRDF bioenergy: Phase 1 (~15% reduction); Phase 2 (~30%)

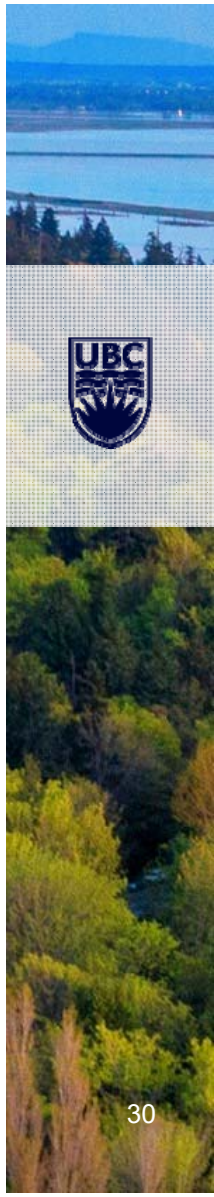
Negative carbon emission technologies are needed

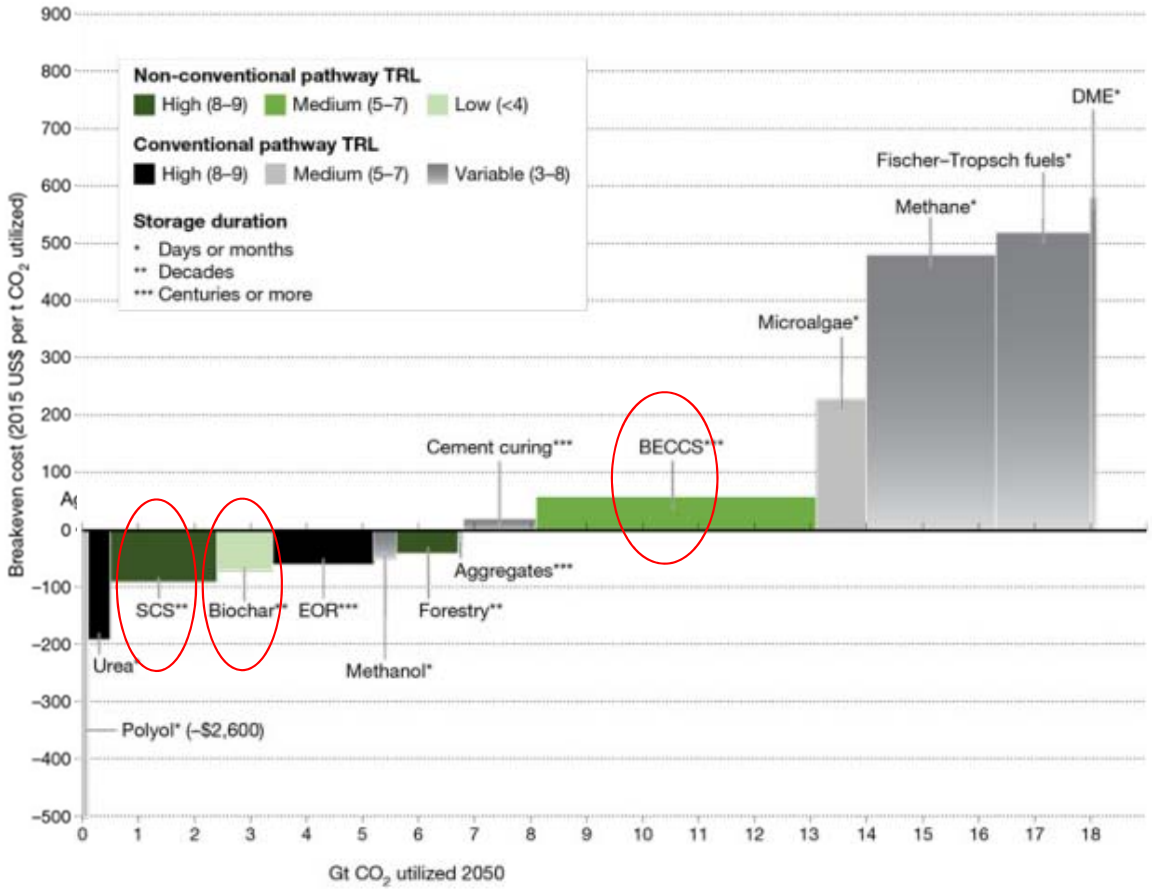


NEGATIVE CARBON EMISSION TECHNOLOGIES

1. **Afforestation and reforestation**
2. **Land management**
3. **Bioenergy with carbon capture and storage (and utilization) (BECCSU)**
4. **Enhanced weathering**
5. **Direct air capture and carbon storage (and utilization) (DACCSU)**
6. **Ocean fertilization**
7. **Carbon capture and storage (and utilization) (CCSU)**

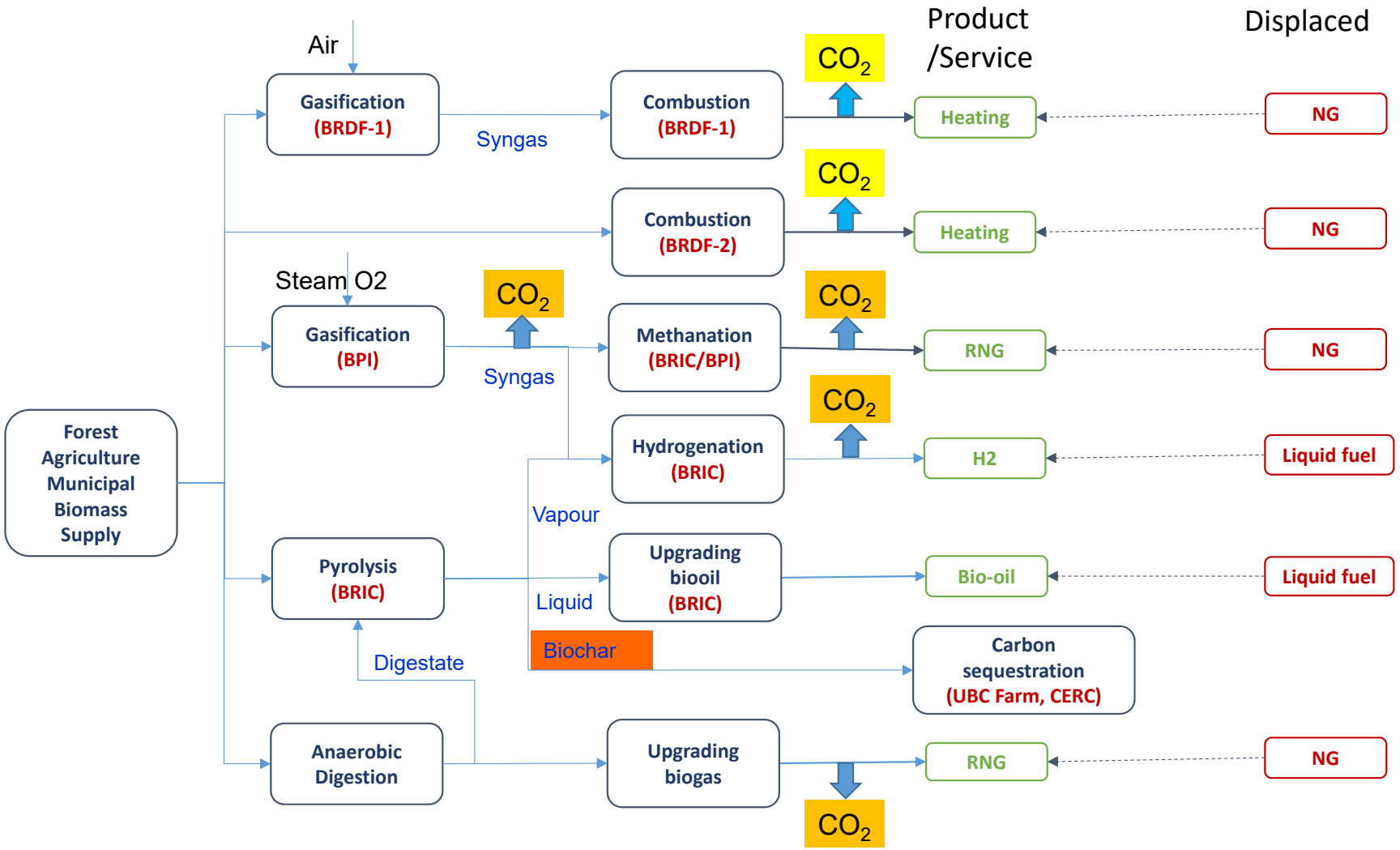
Adapted from European Academies Science Advisory Council (2018)

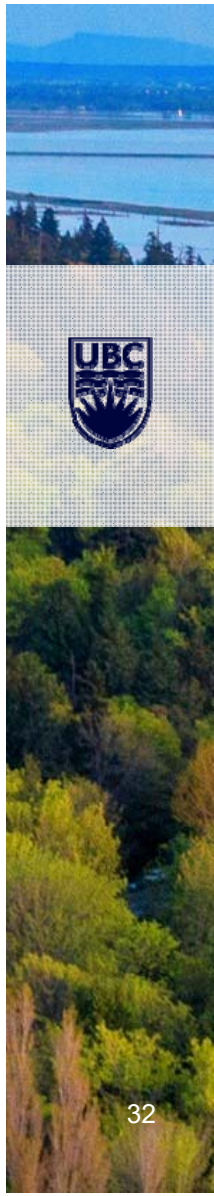




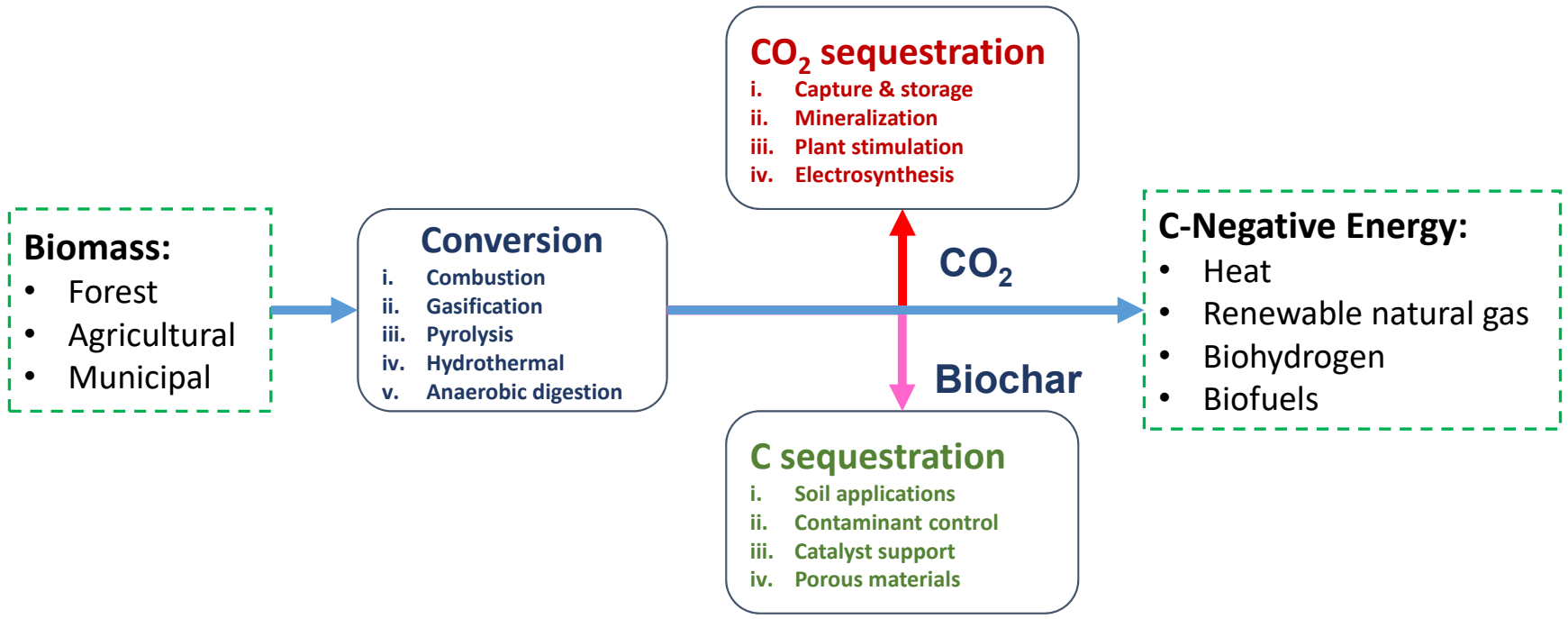
Ella Adlen and Cameron Hepburn, 10 carbon capture methods compared: costs, scalability, permanence, cleanness Energypost.eu, November 11, 2019.

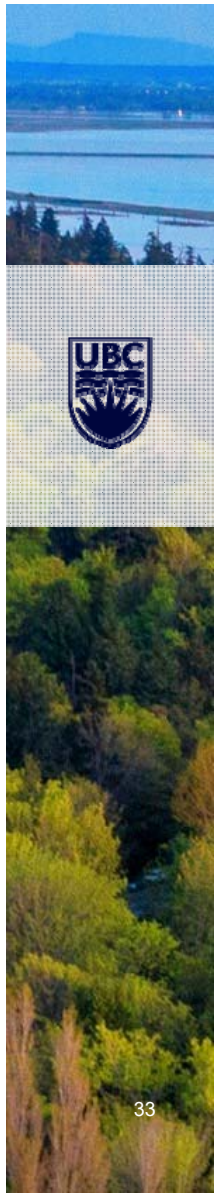
CNES: Biomass-CCSU





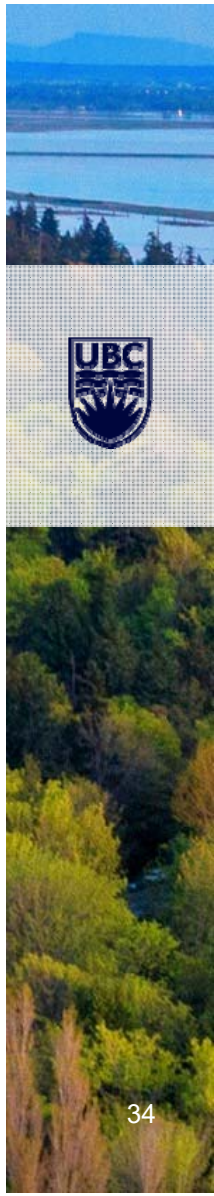
CARBON NEGATIVE BIOENERGY SYSTEMS





SUMMARY

1. Integrated approaches are needed for clean energy technology research, development, scaleup, demonstration and deployment, based on environmental-economic-social impacts assessments and policy support.
2. Bioenergy integrated with carbon capture, storage and utilization (**BECCSU**) shows a great potential as a negative carbon energy system for BC to reach its 2050 carbon neutral target.
3. There is a need to establish a clean energy platform to bring together researchers and practitioners in clean energy and carbon capture & utilization, industrial partners, NGOs, and government agencies to develop and demonstrate carbon negative technologies.



Low-carbon + Carbon-negative → Carbon-neutral