Biohydrogen from Alberta's Biomass Resources for Bitumen Upgrading

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BIOCLEANTECH FORUM, OTTAWA, NOV. 1-3, 2016

OUTLINE

- Background
- Overview of hydrogen production
- Biohydrogen pathways
- Comparative economic and environmental metrics
- Key observations

NSERC Industrial Research Chair Program

Research on Energy and Environmental Systems Engineering

Theme Area 1
Integrated Energy-Environmental Modeling

Theme Area 2
Energy Return on Investment (EROI) of Energy Pathways

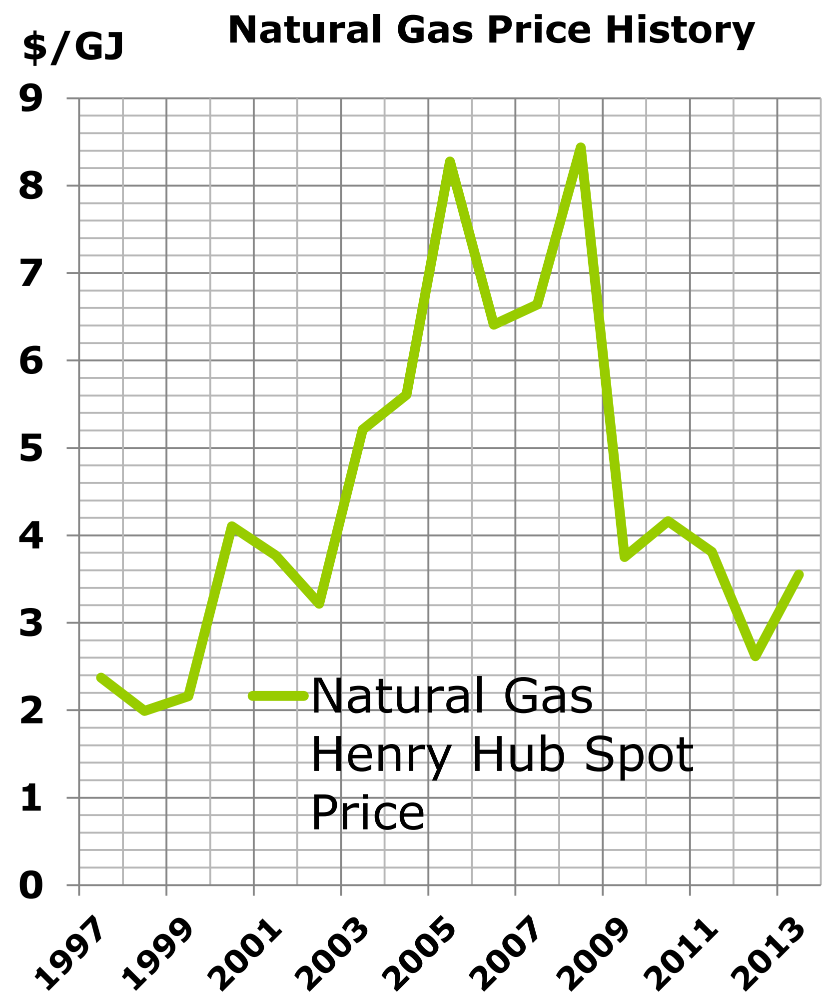
Theme Area 3
Techno-economic Assessment of Energy Conversion Pathways

Background – Need for Hydrogen

- Upgrading of bitumen to synthetic crude oil (SCO) is highly H_2 intensive.
- Based on projections, oil sands (bitumen) production capacity will increase from 2.4 million barrels/day in 2015 to 3.7 million barrels/day by 2030 (CAPP, 2016).
- About 2.4 – 4.3 kg/bbl bitumen of hydrogen is used during the upgrading of bitumen.
- Hydrogen is needed for hydrotreating and hydrocracking.
- The projected hydrogen requirement for oil sands upgrading is about 4 million tonnes/yr by 2040.

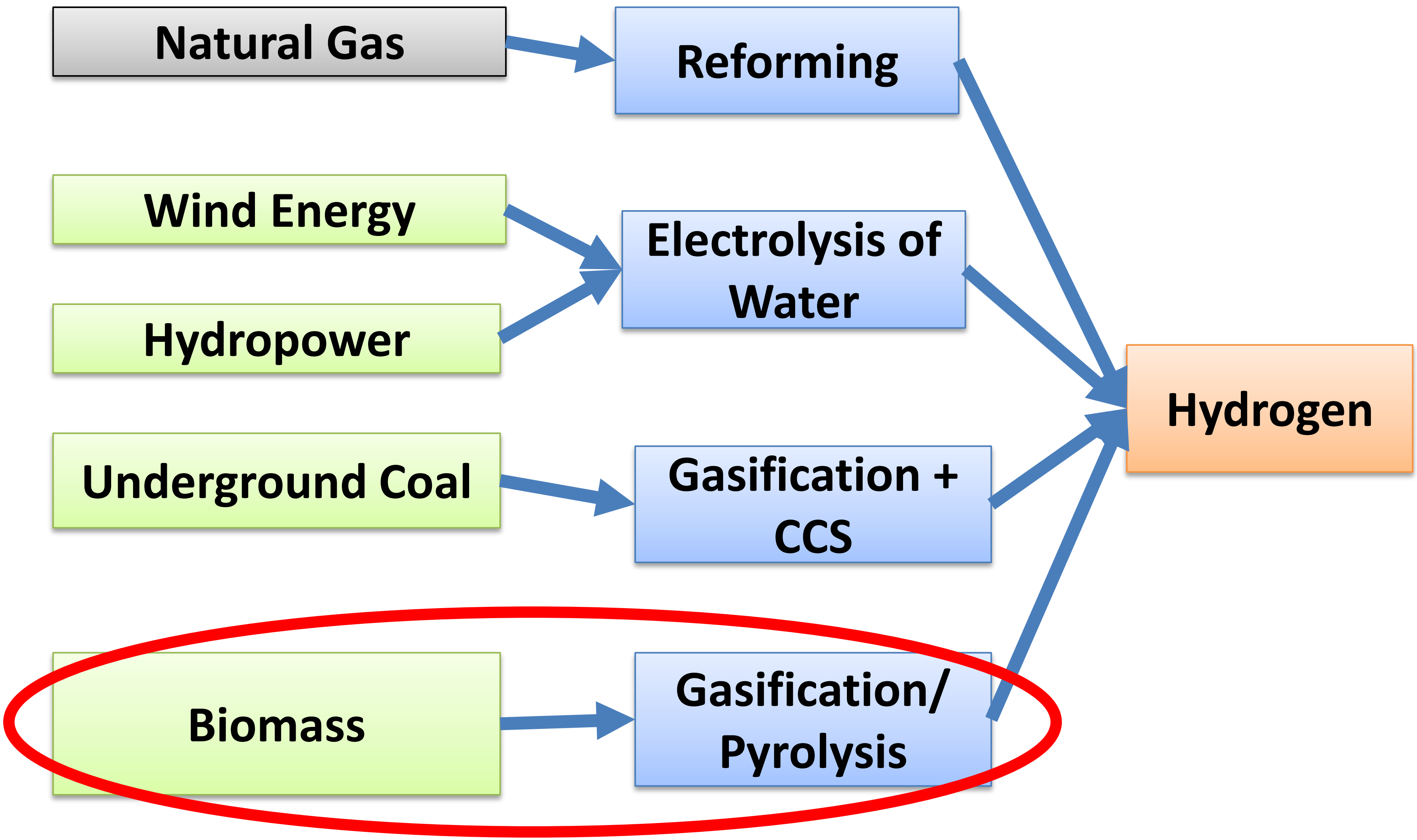
Background – Current Source of Hydrogen

- Steam methane reforming (SMR) is the predominant means of H_2 production - Demerits include: feedstock volatility, greenhouse gas (GHG) emissions, and the use of a premium fossil fuel, i.e., natural gas.
- The energy market is increasingly GHG constrained; there is a growing global consensus that GHG mitigation is a policy imperative.
- Reducing SCO related GHG emissions with respect to other light crudes is a prudent measure for market competitiveness.



Data Credits: US EIA

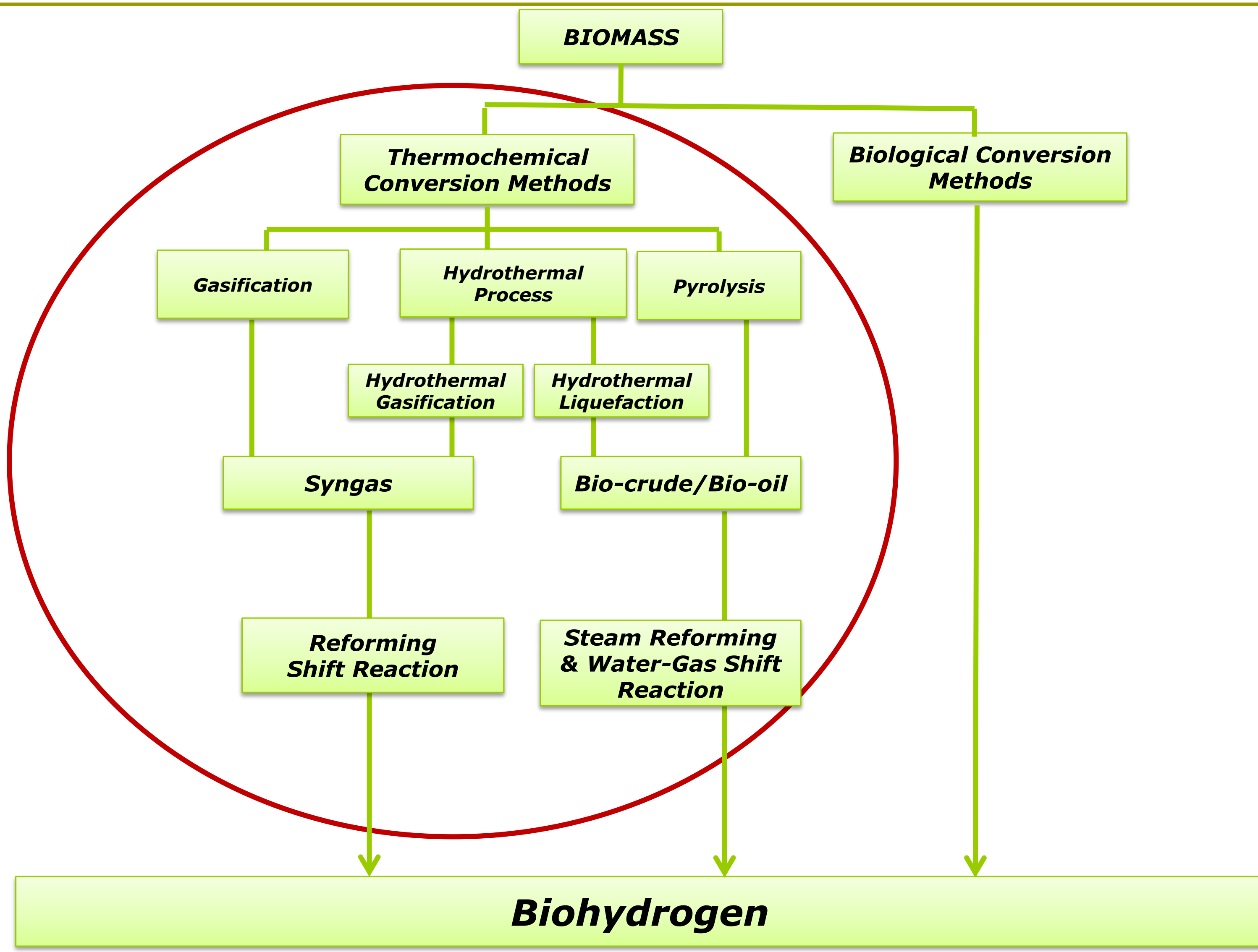
Systems Approach to Hydrogen Production from Alternative Sources



Feedstocks for Biomass-based Hydrogen (Biohydrogen) Production

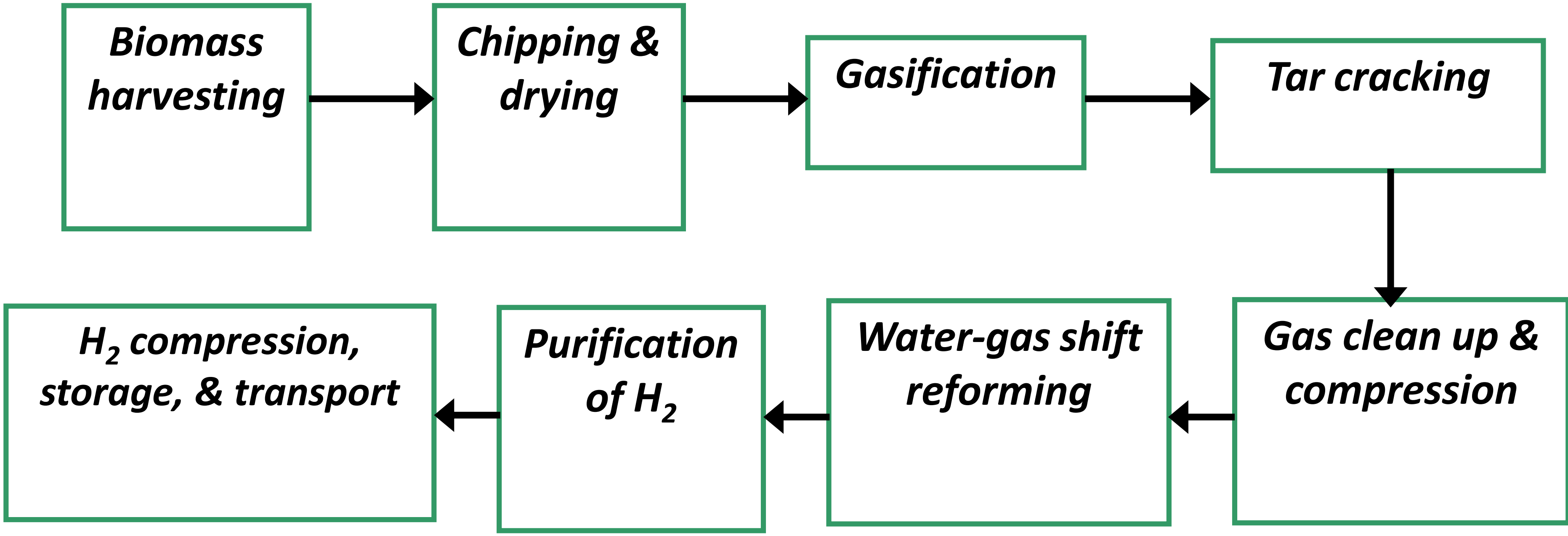
- Considered biomass feedstocks:
  - **Whole forest** – whole-tree biomass.
  - **Forest residues** – tree tops, branches, needles which are left after the logging operation.
  - **Agricultural residues** – blend of straw from wheat and barley crops.

Biohydrogen Production Pathways

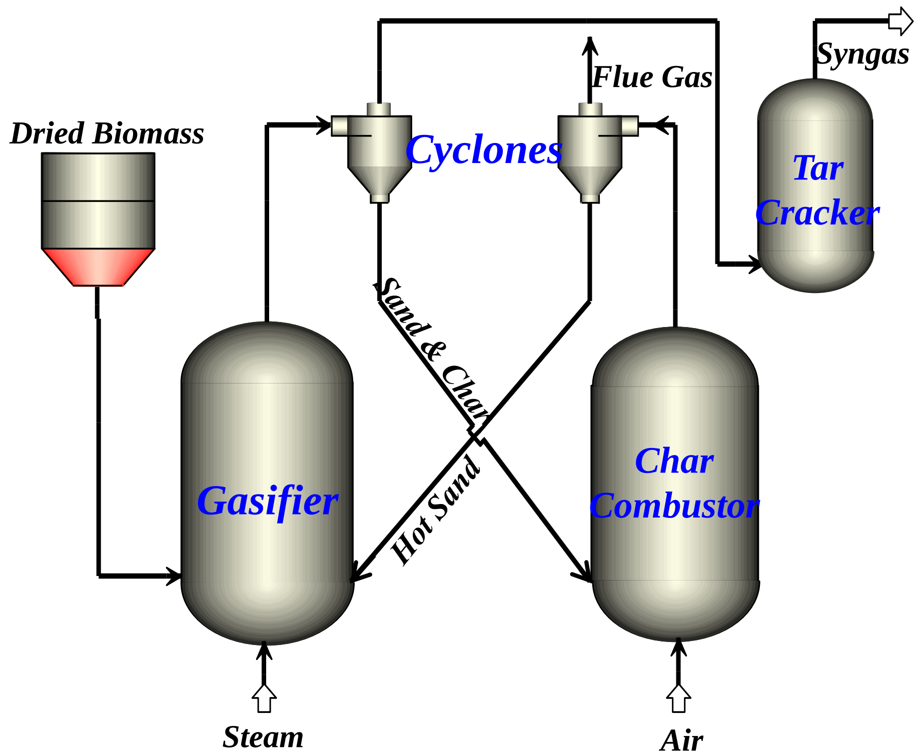


Biohydrogen Production Pathways: Gasification

- ***Biomass gasification of whole-tree-based biomass forest residues and agricultural residues***

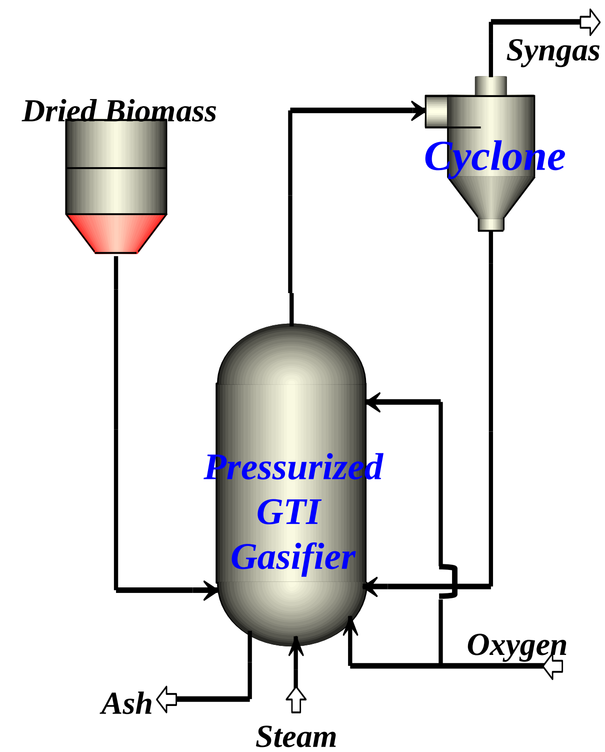


Biohydrogen (Gasification)



BCL Gasifier

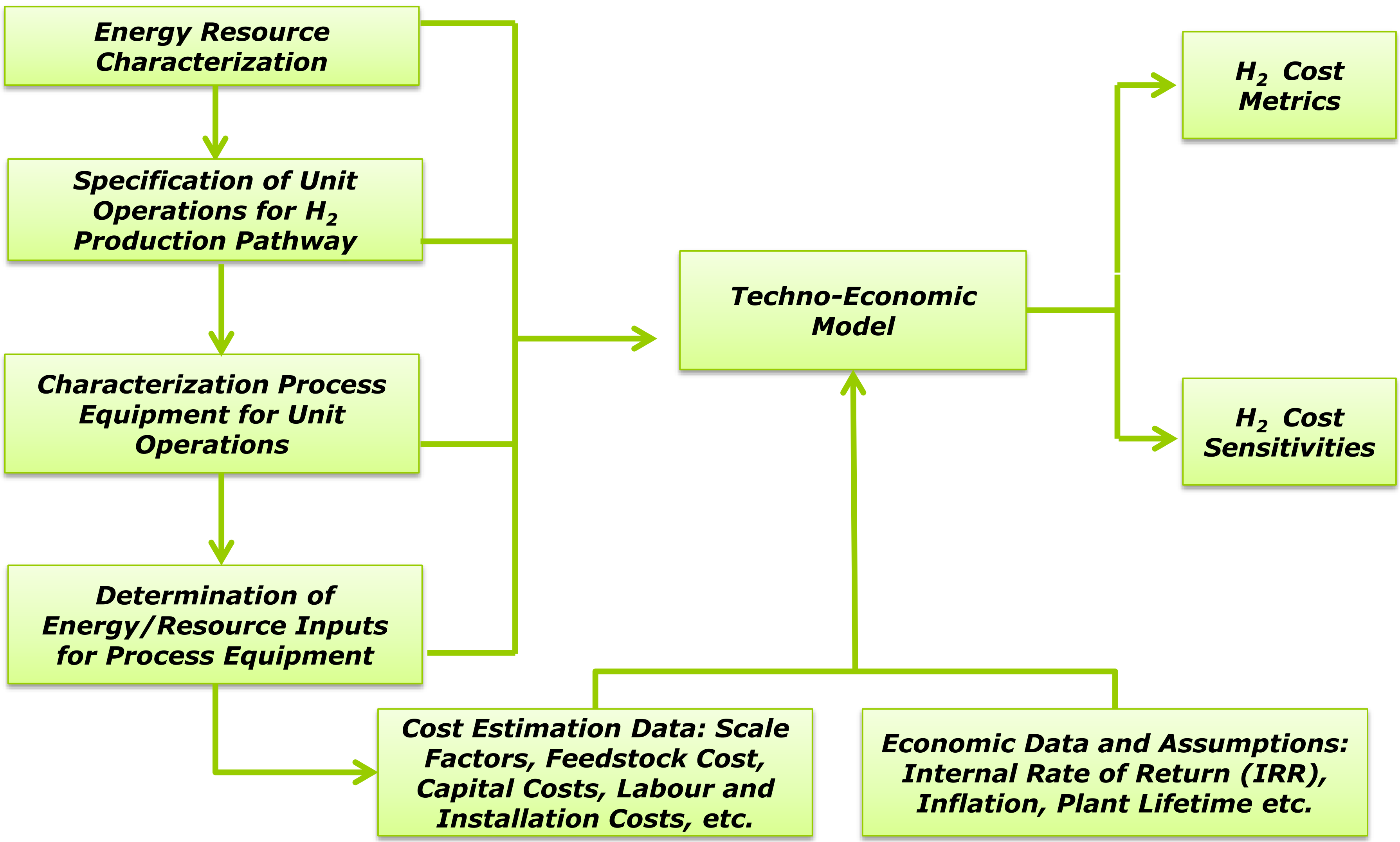
- No air-flow in gasifier
- Atmospheric pressure



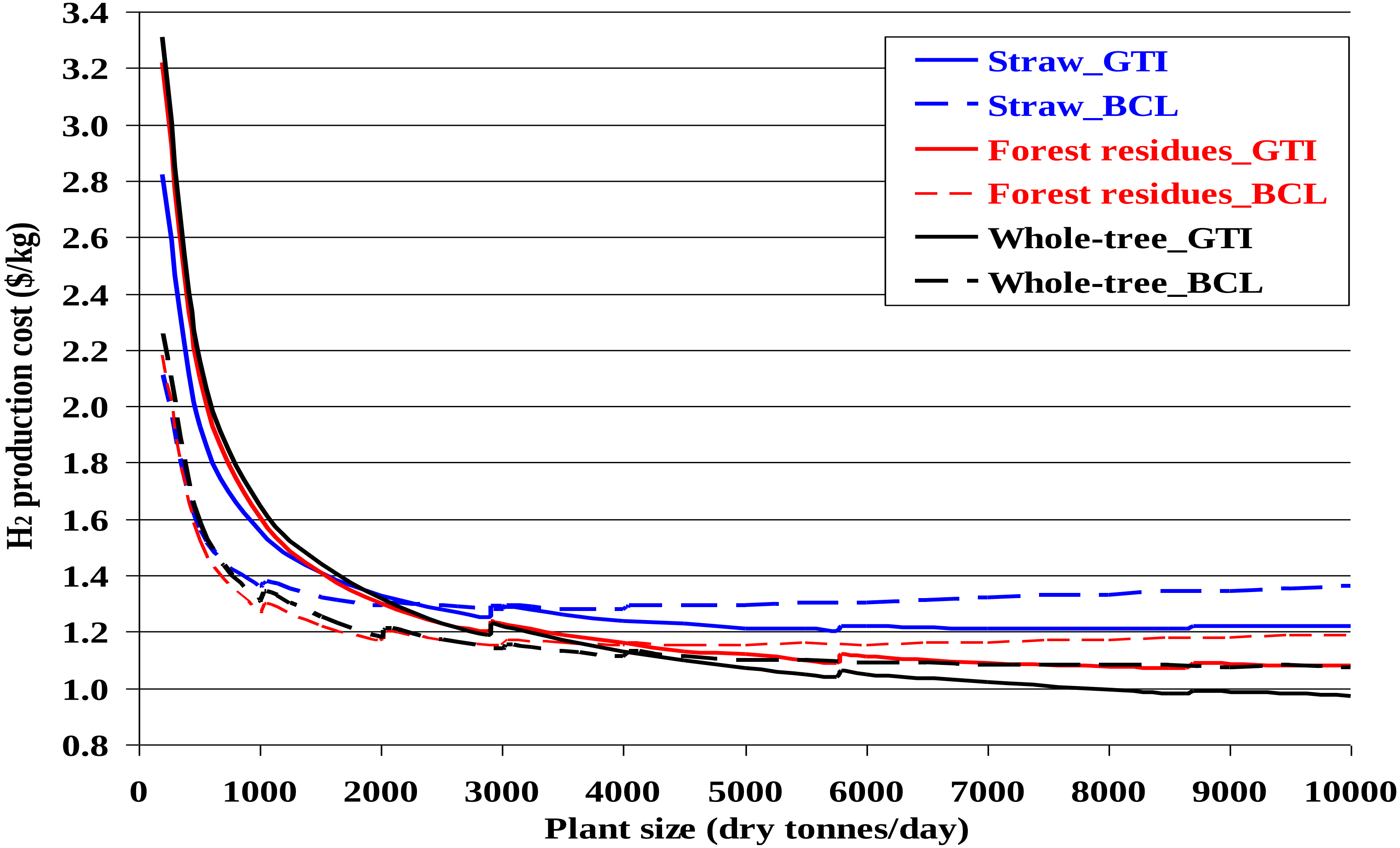
GTI Gasifier

- Oxygen-flow in gasifier
- High pressure

Generalized Modelling Methodology



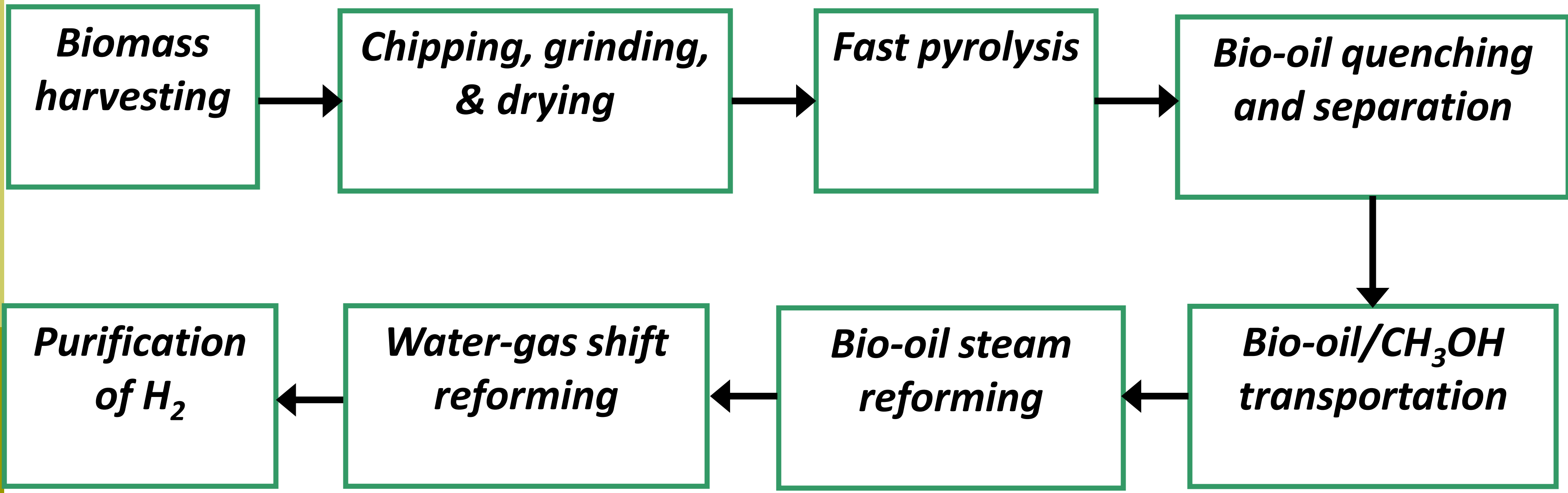
Biohydrogen (Gasification) Production Cost



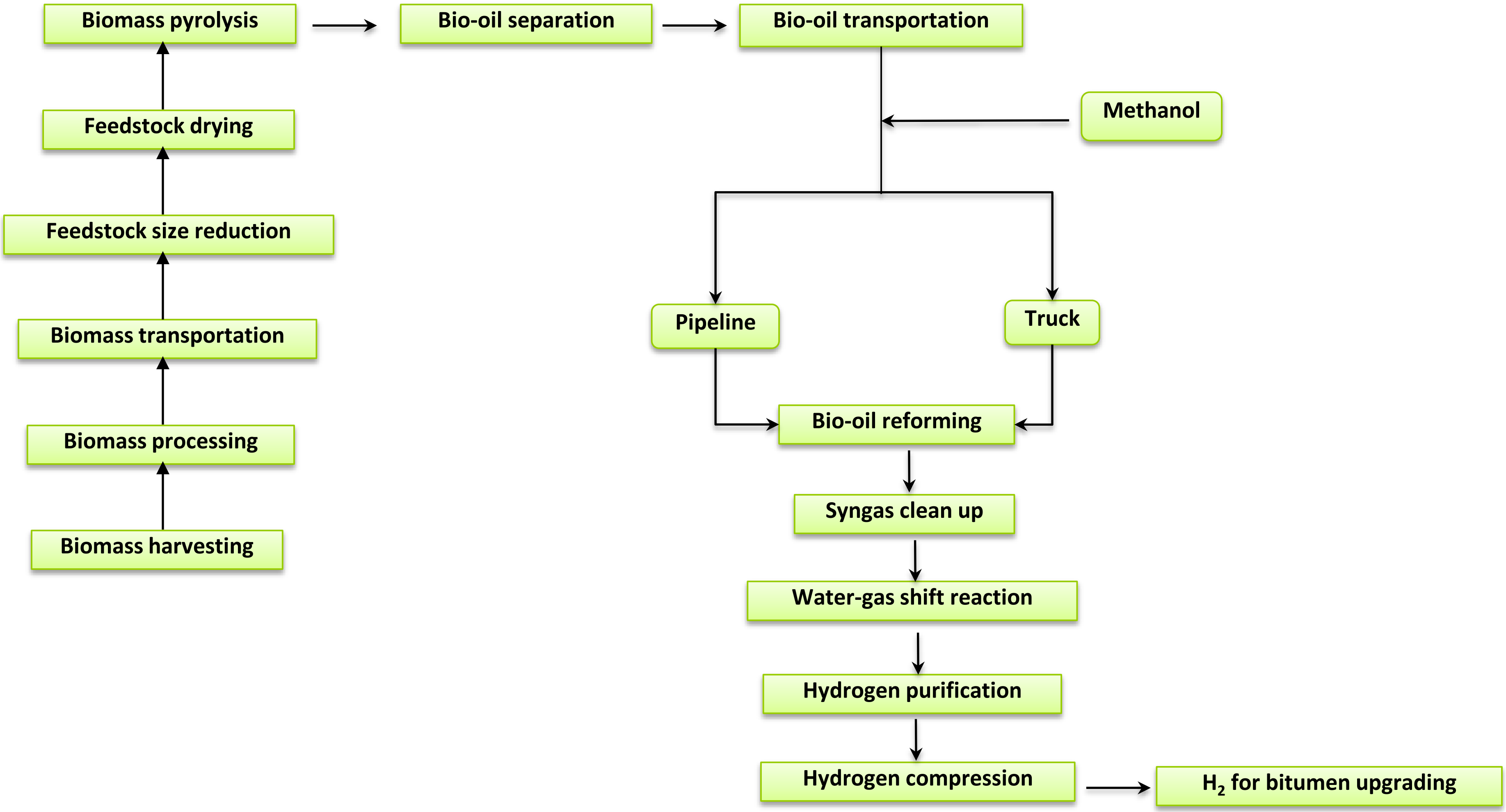
Source: Sarkar and Kumar, Energy, 2010, 35(2), 582-591; Sarkar and Kumar, Trans. of ASABE, 2009, 52(2), 1-12.

Biohydrogen Production Pathways: Pyrolysis

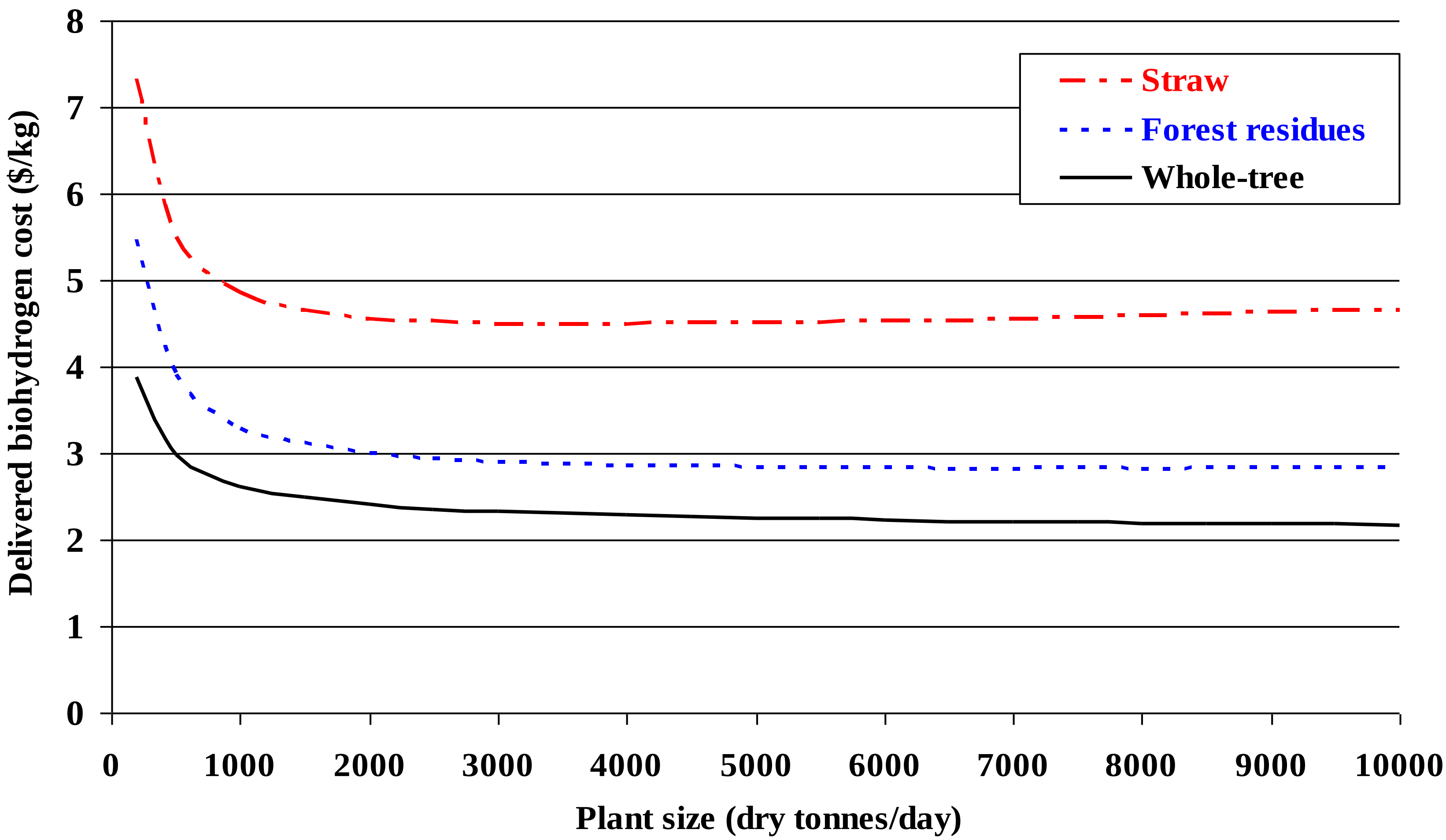
- ***Biomass pyrolysis of whole-tree-based biomass, forest residue, agricultural residue***



Biohydrogen (Pyrolysis): Unit Operations

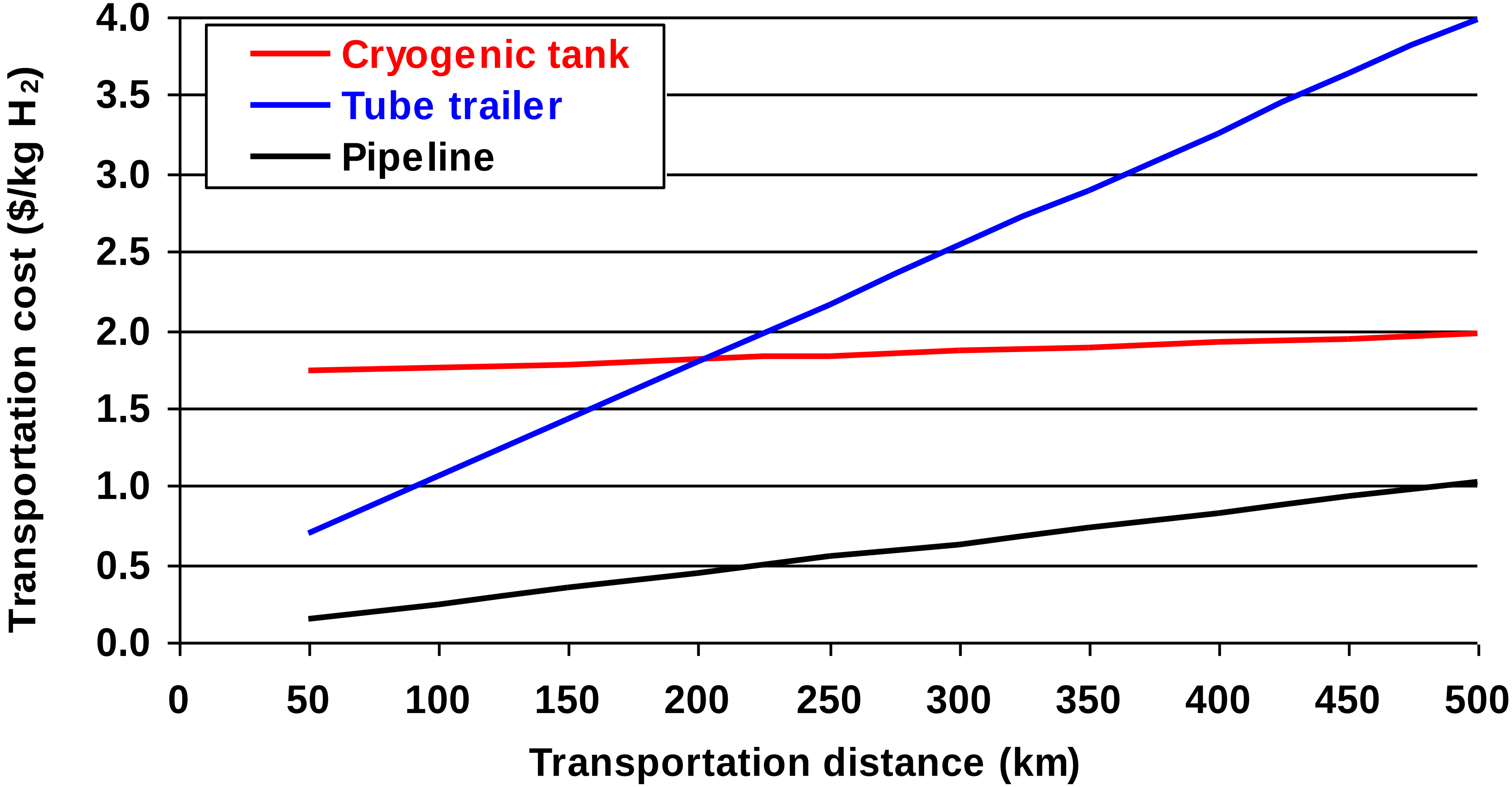


Bio-Hydrogen (Pyrolysis): H_2 Cost



Source: Sarkar and Kumar, Bioresource Technology, 2010, 101(19), 7350-7361.

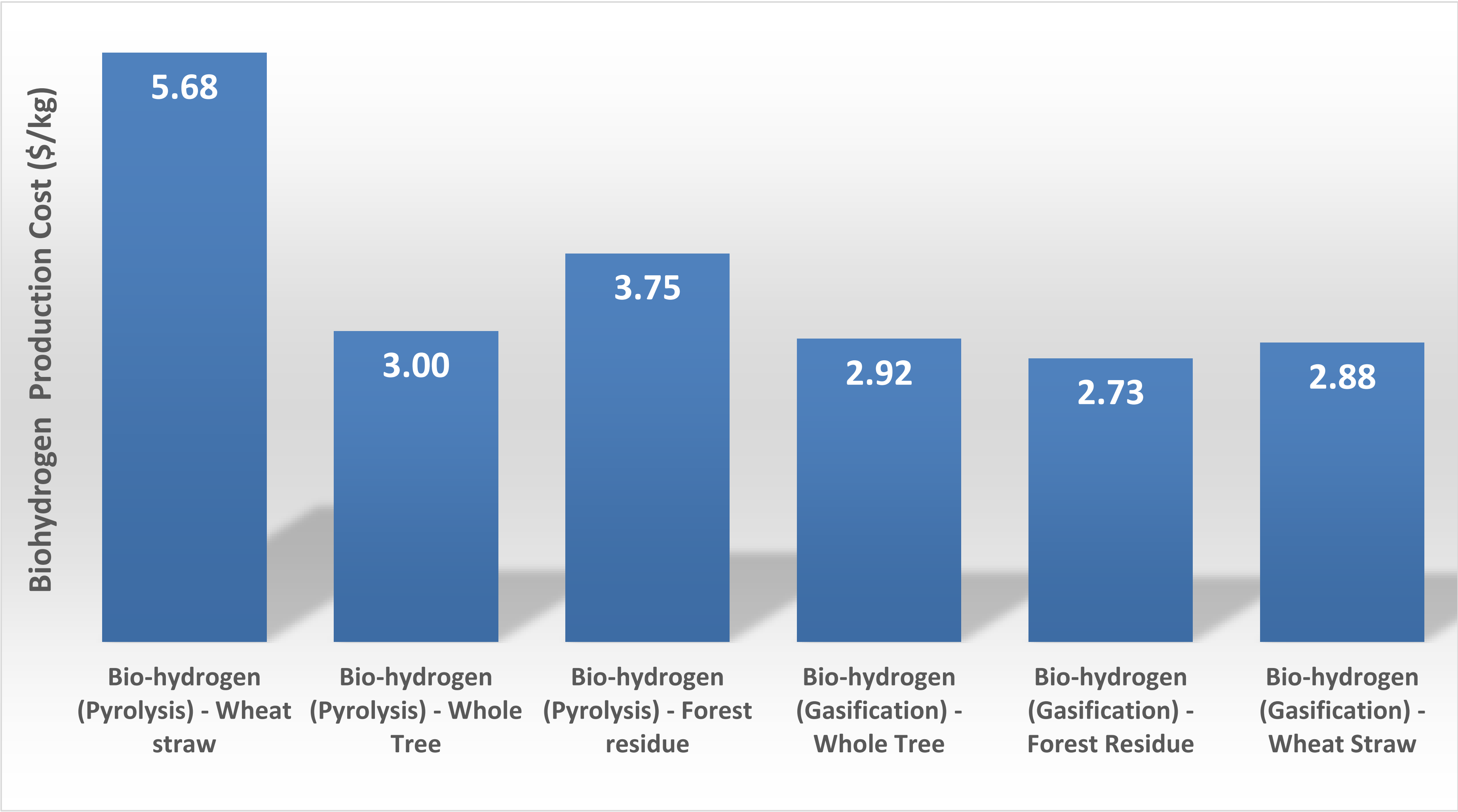
Transportation cost of Biohydrogen



** For 167 tonnes of H_2/day*

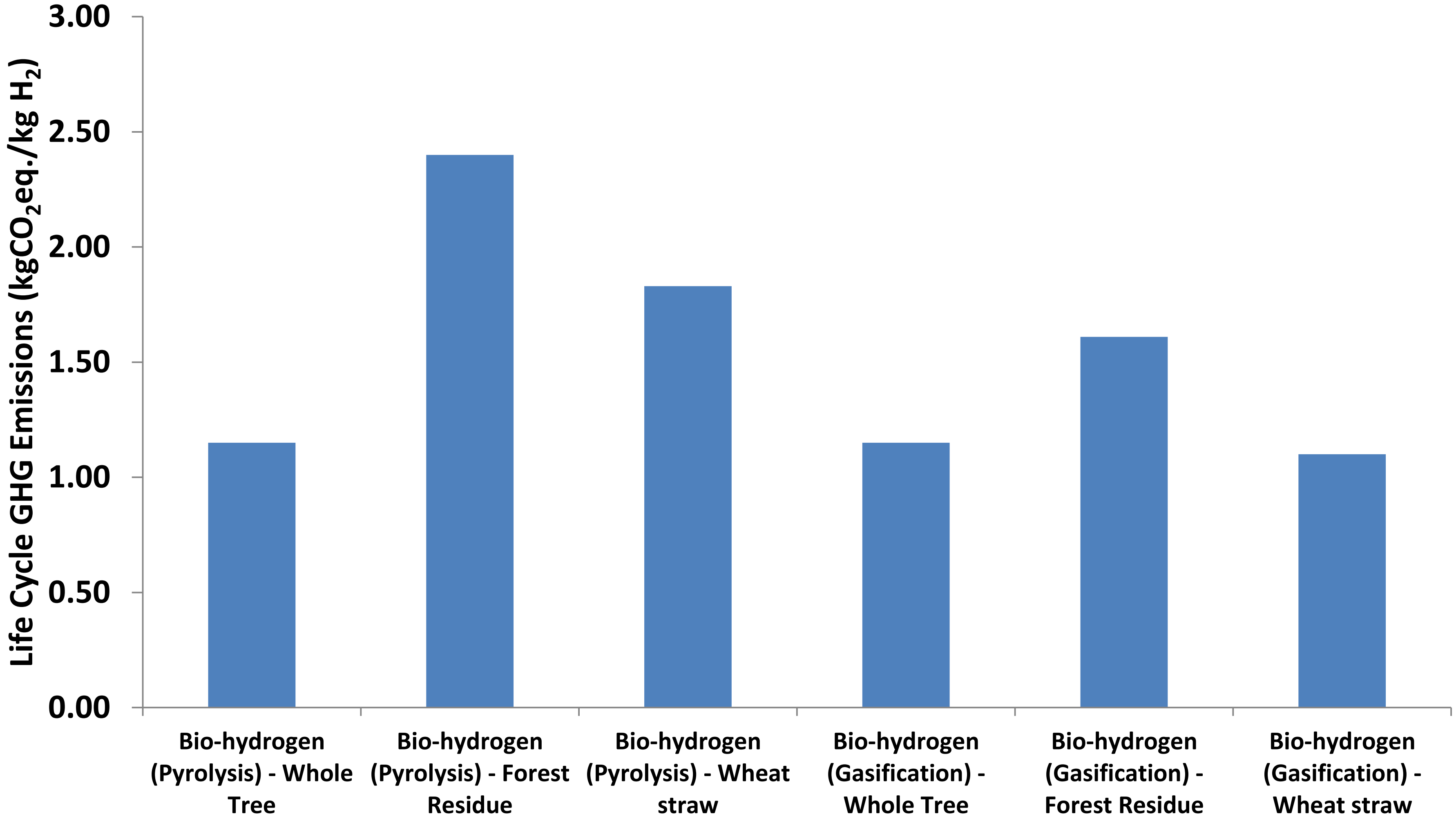
Source: Sarkar and Kumar, Trans. of ASABE, 2009, 52(2), 1-12.

Biohydrogen Cost of Production – Different Biomass & Pathways



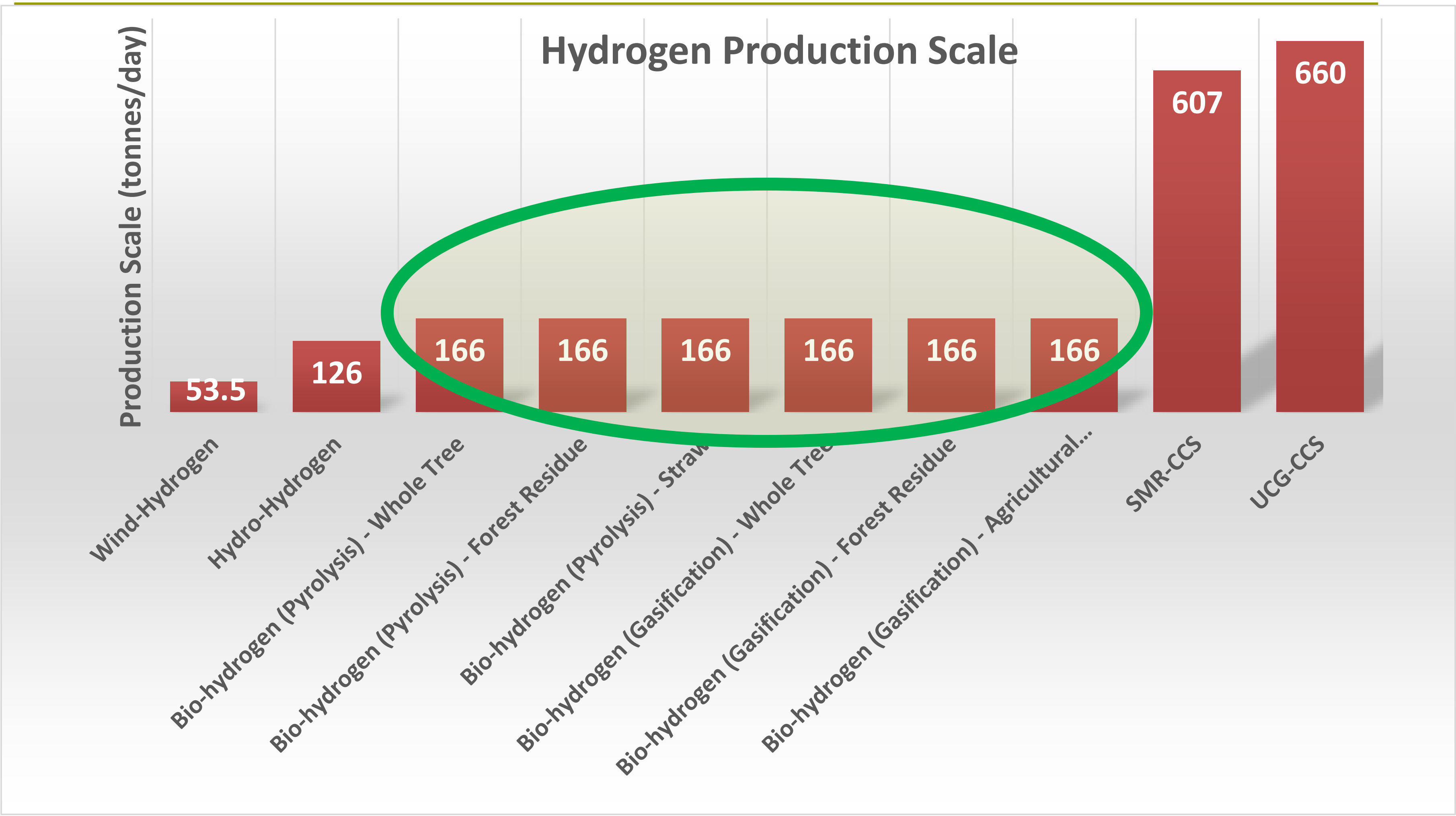
Sarkar and Kumar, 2010. All costs in 2016 C$.

Biohydrogen GHG Emissions – Different Biomass & Pathways



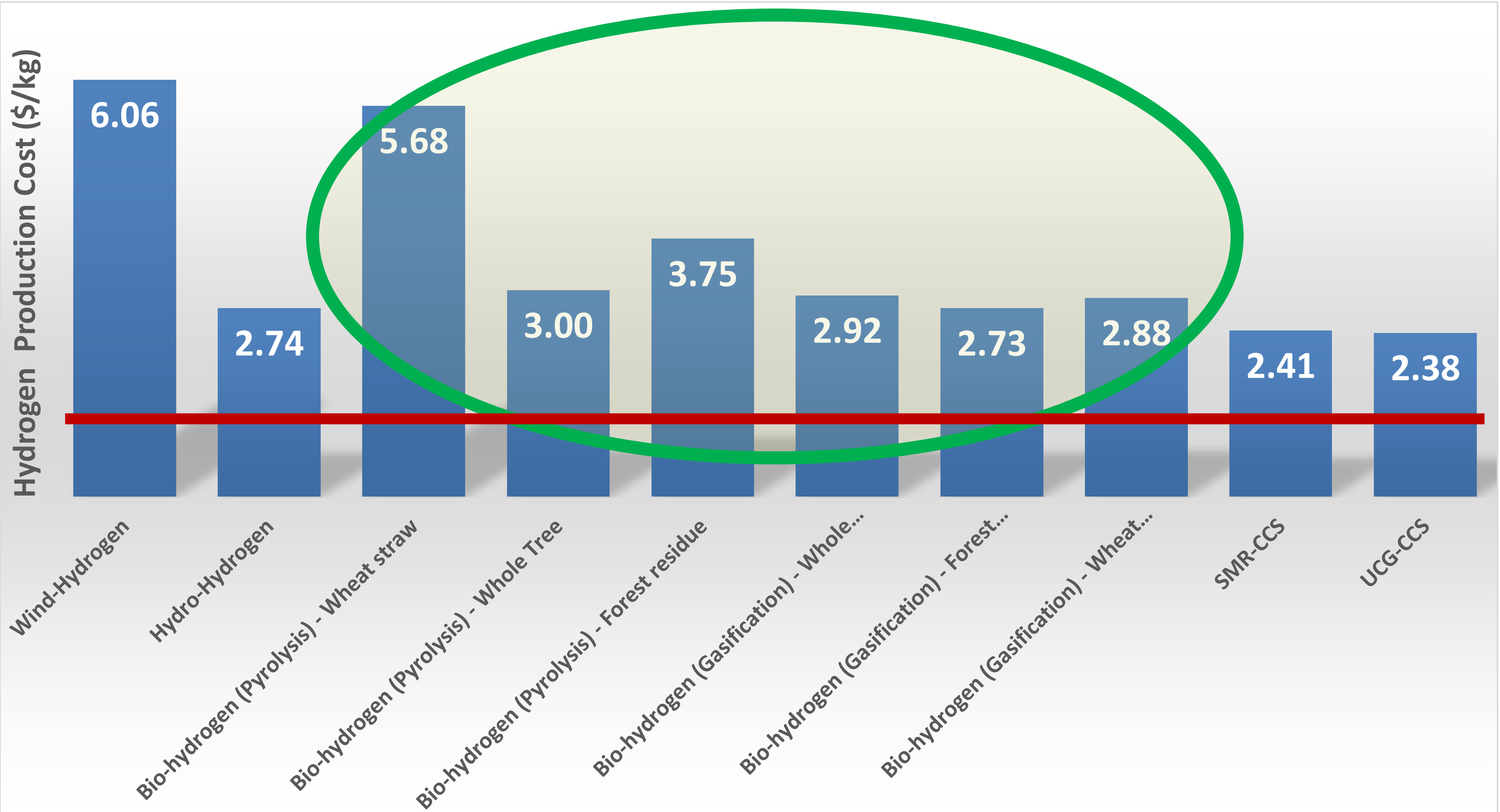
HYDROGEN PATHWAYS: COMPARATIVE ECONOMIC AND ENVIRONMENTAL METRICS

Comparative Techno-Economics



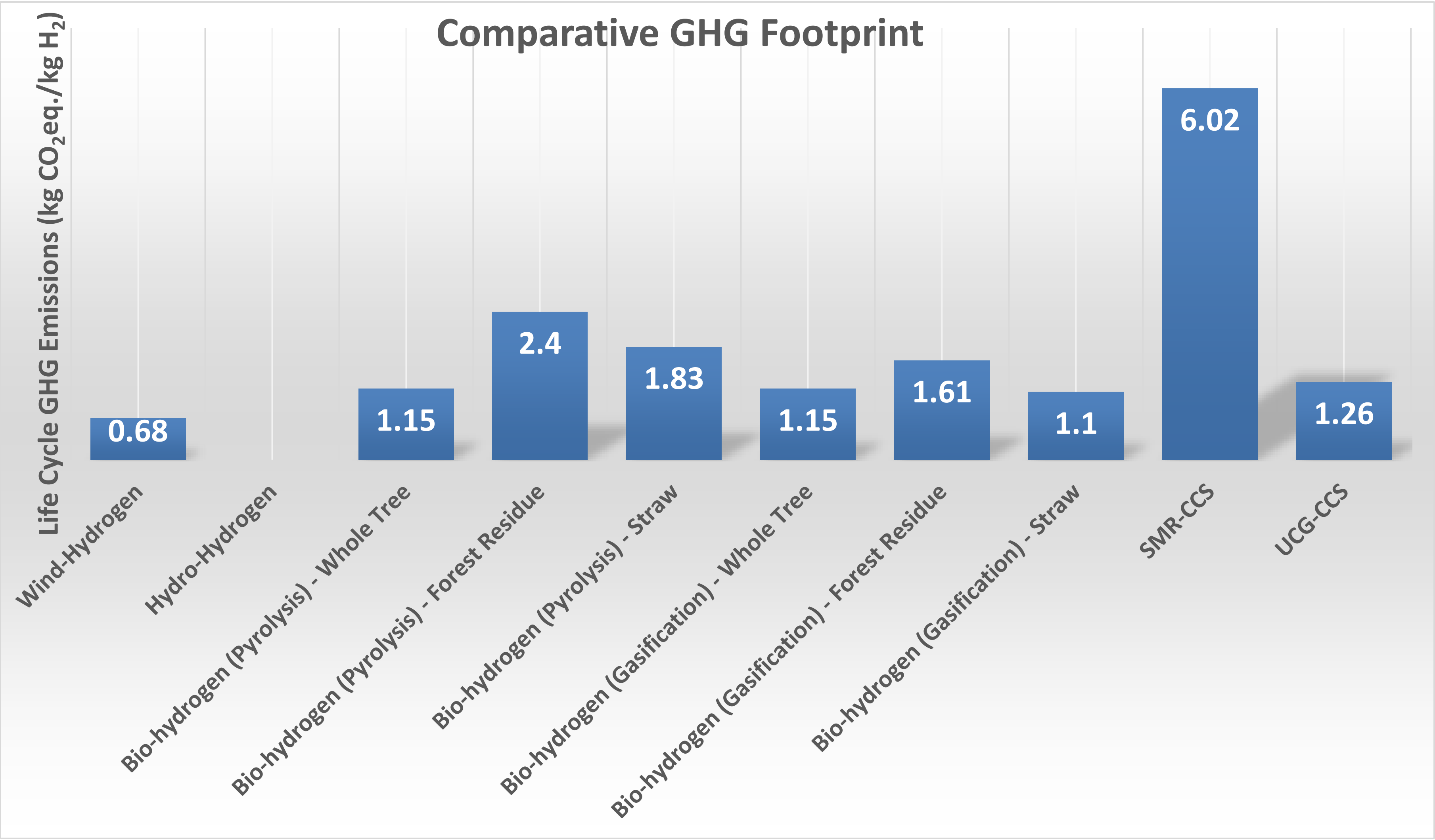
* ***Data for Wind-Hydrogen, SMR-CCS and UCG-CCS from Olateju and Kumar, 2015***

Comparative Techno-Economics – Hydrogen Production Cost

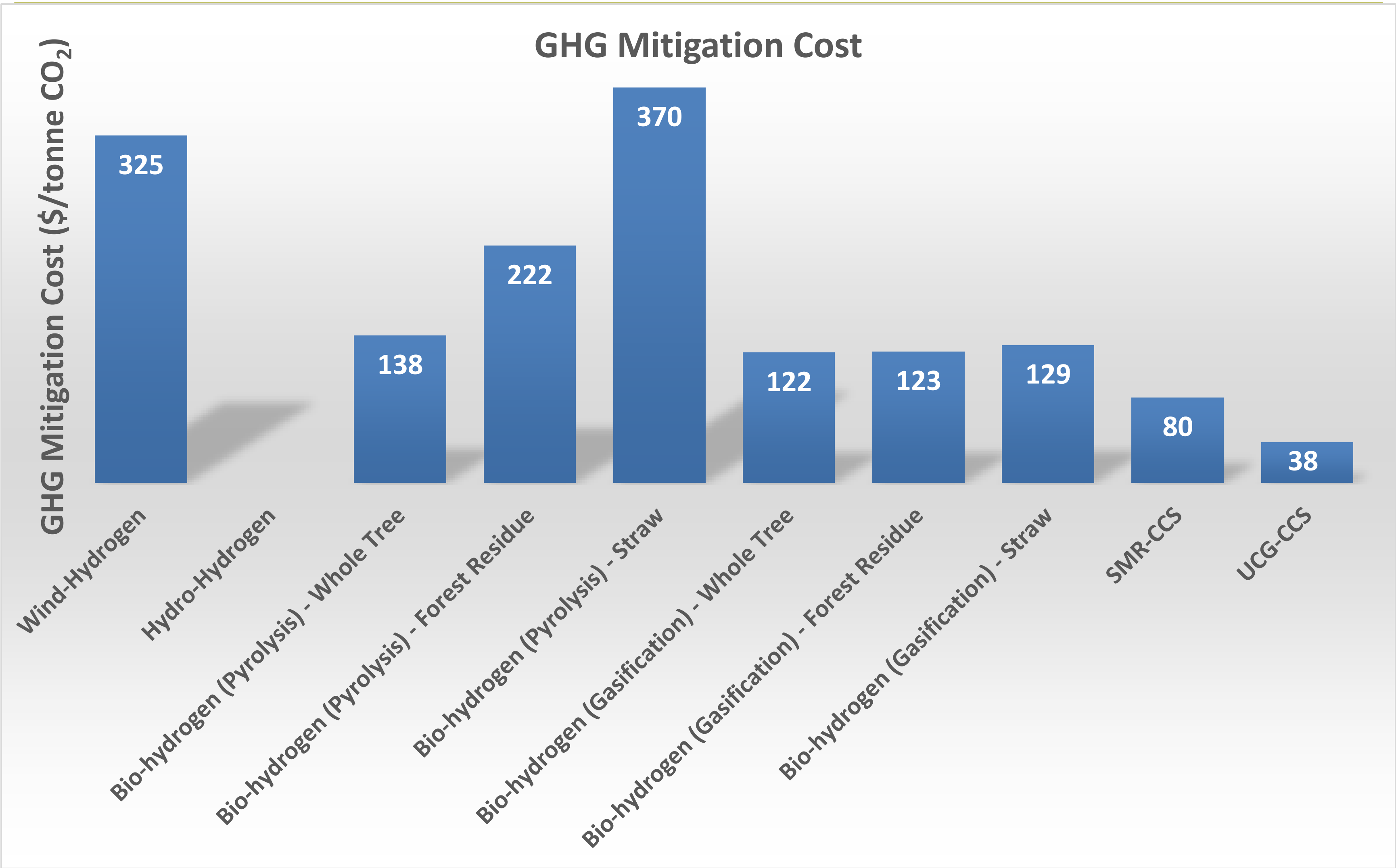


All production costs have an Internal Rate of Return (IRR) of 10%, other than UCG at 15%. All costs in $CAD 2016.

Comparative GHG Economics/Footprint



Comparative GHG Abatement Cost



Key Observations

- Biomass-based hydrogen has low GHG footprint compared to hydrogen from natural gas sources.
- Biomass-based hydrogen is more cost-efficient compared to other renewable source like wind.
- Biomass can provide baseload hydrogen production similar to natural gas.
- GHG abatement cost is higher than $100/tonne of CO2 mitigated.
- Biohydrogen could be one of the GHG mitigation pathways for oil sands with technology improvement and incentives.

Acknowledgment

- NSERC/Cenovus/Alberta Innovates Associate Industrial Research Chair Program in Energy and Environmental Systems Engineering.

- Cenovus Energy Endowed Chair Program in Environmental Engineering.

- A number of other organizations, industry and individuals for their inputs with data and feedbacks including Alberta Innovates – Bio Solutions, Alberta Innovates – Energy and Environment Solutions, Cenovus Energy Inc. and Suncor Energy Inc.

THANKS

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