Well-to-Wheel Analysis of Cellulosic Ethanol Produced via Coskata Process

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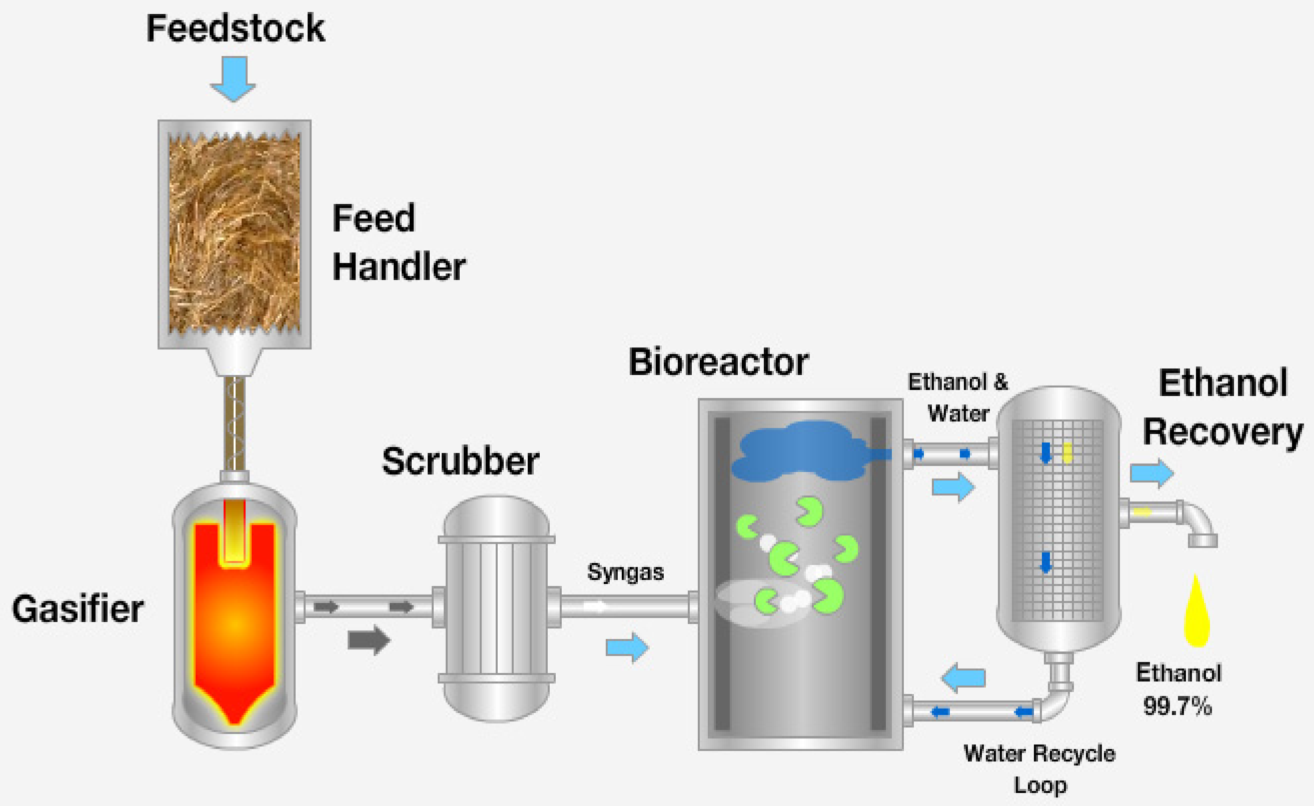
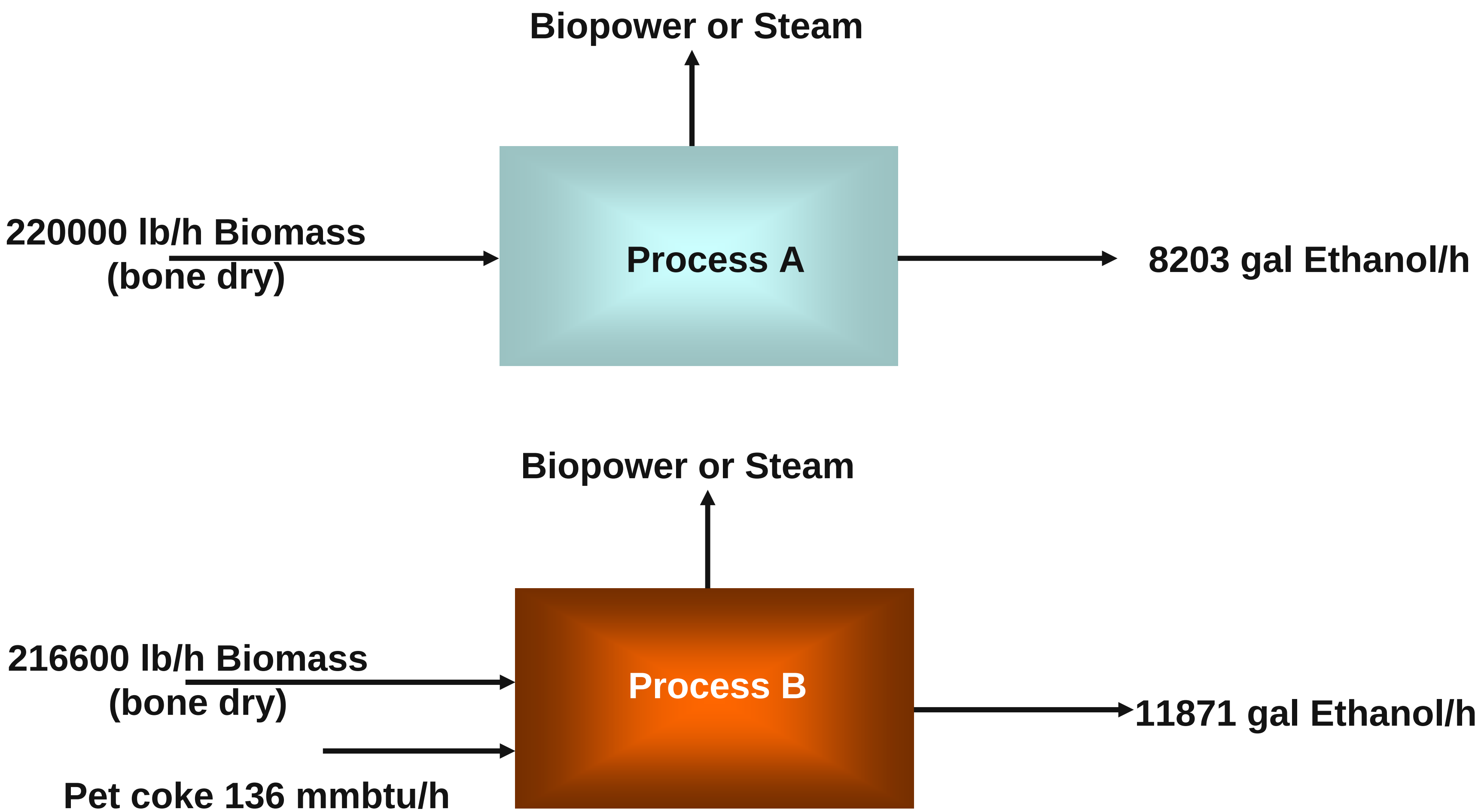
The Coskata Process



WTW Analysis for Coskata Process

- Feed moisture content: 20% and 40%
- Process design variation: Process A and B
- Production options
  - Stand alone plant
    - *No co-gen: produce ethanol, purchase electricity from grid*
    - *Co-gen: produce ethanol and electricity generation through flue gas heat recovery*
  - Co-locate – excess steam export to a co-locating plant
  - Co-feeding
    - *Forest residue woodchips with supplemental fuels*
      - pet coke (9% btu share)
      - coal (8% btu share)
- Conventional gasoline (baseline case)

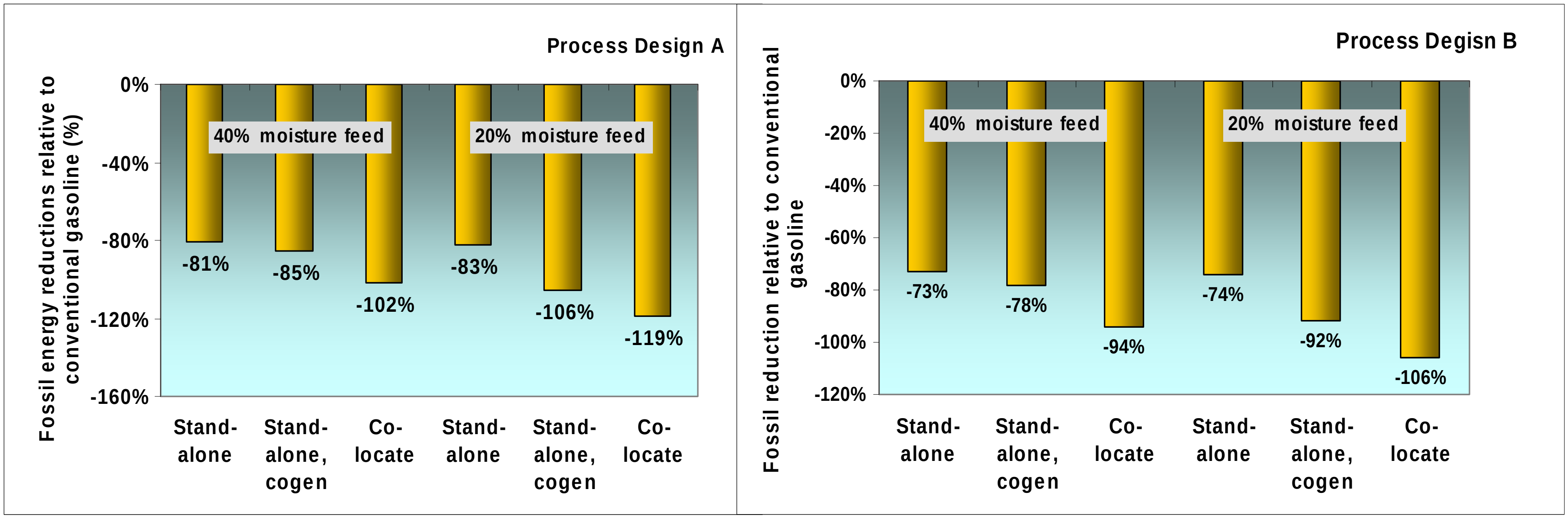
Syngas-to-Ethanol Production Process Energy Input/Output



Major Assumptions

- Forest wood residue as feedstock
- Feedstock collection and transport using GREET default feedstock pathway for forest wood residue
- Petroleum, natural gas, and coal production process based on GREET default value
- Electricity: US average mix
- Electricity generation from off-gas via gas turbine with 40% efficiency
- Electricity generation from steam turbine with 75% efficiency
- Excess electricity is exported to replace US average mix electricity
- Steam is generated using a natural gas (NG) boiler with 80% efficiency
- Excess steam to be exported to displace steam generated from NG fired boiler
- Results are expressed as million Btu of ethanol to examine the effect of fuel ethanol alone without the influence of vehicle fuel economy nor gasoline denaturant
- Time frame: Year 2010

Fossil Energy Reduction Profile from Coskata Process Represents Typical Second Generation Fuel Ethanol

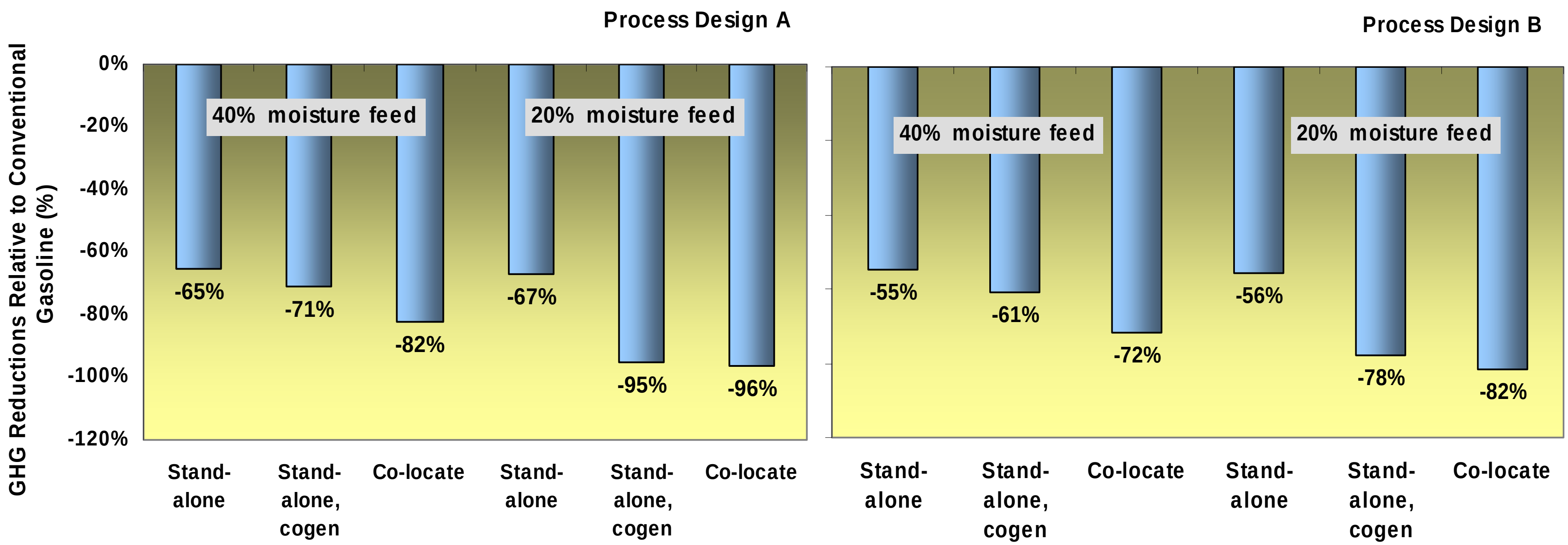


- Oil Reduction:

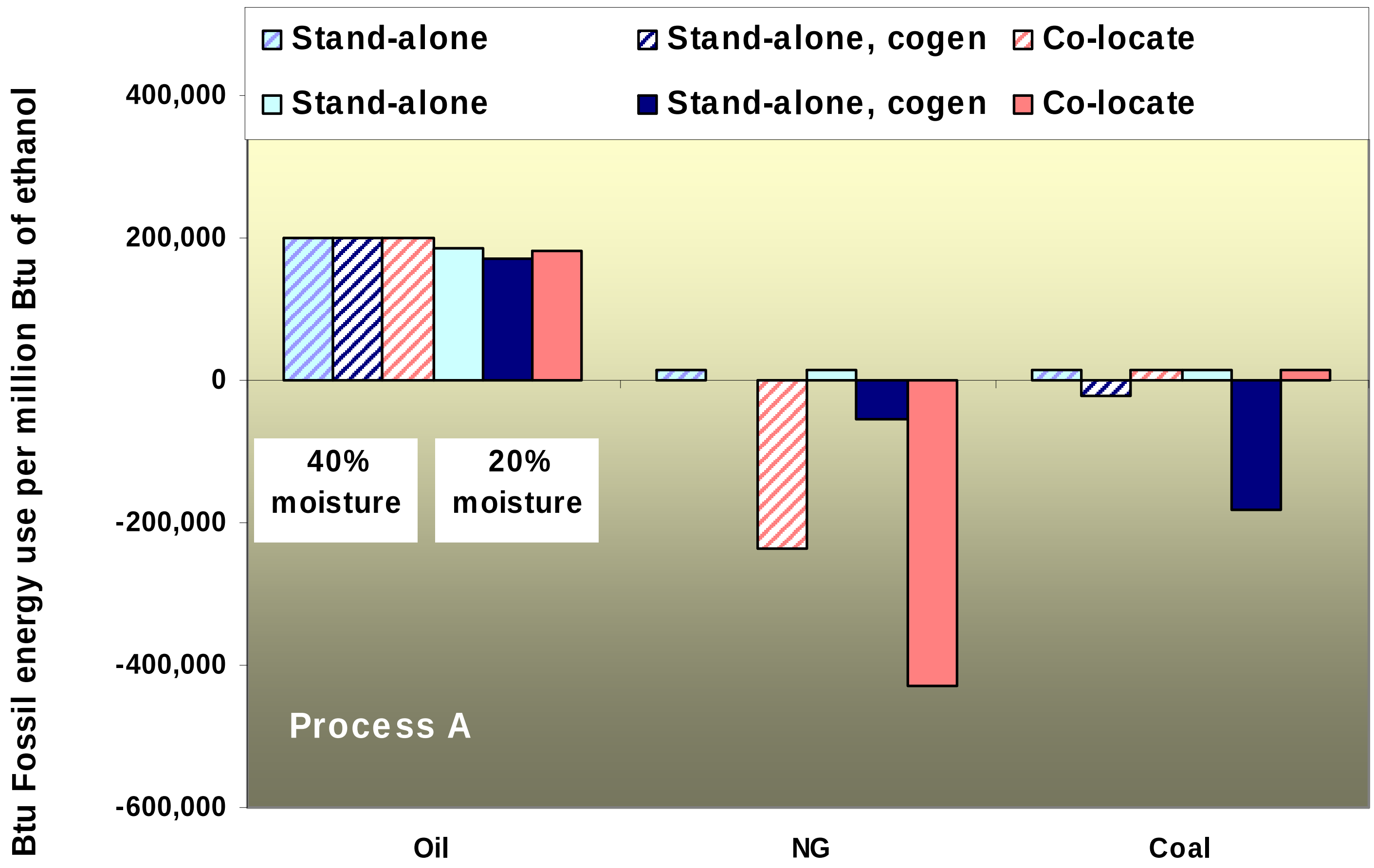
Process Design A 81% -84%

Process Design B 71% - 74%

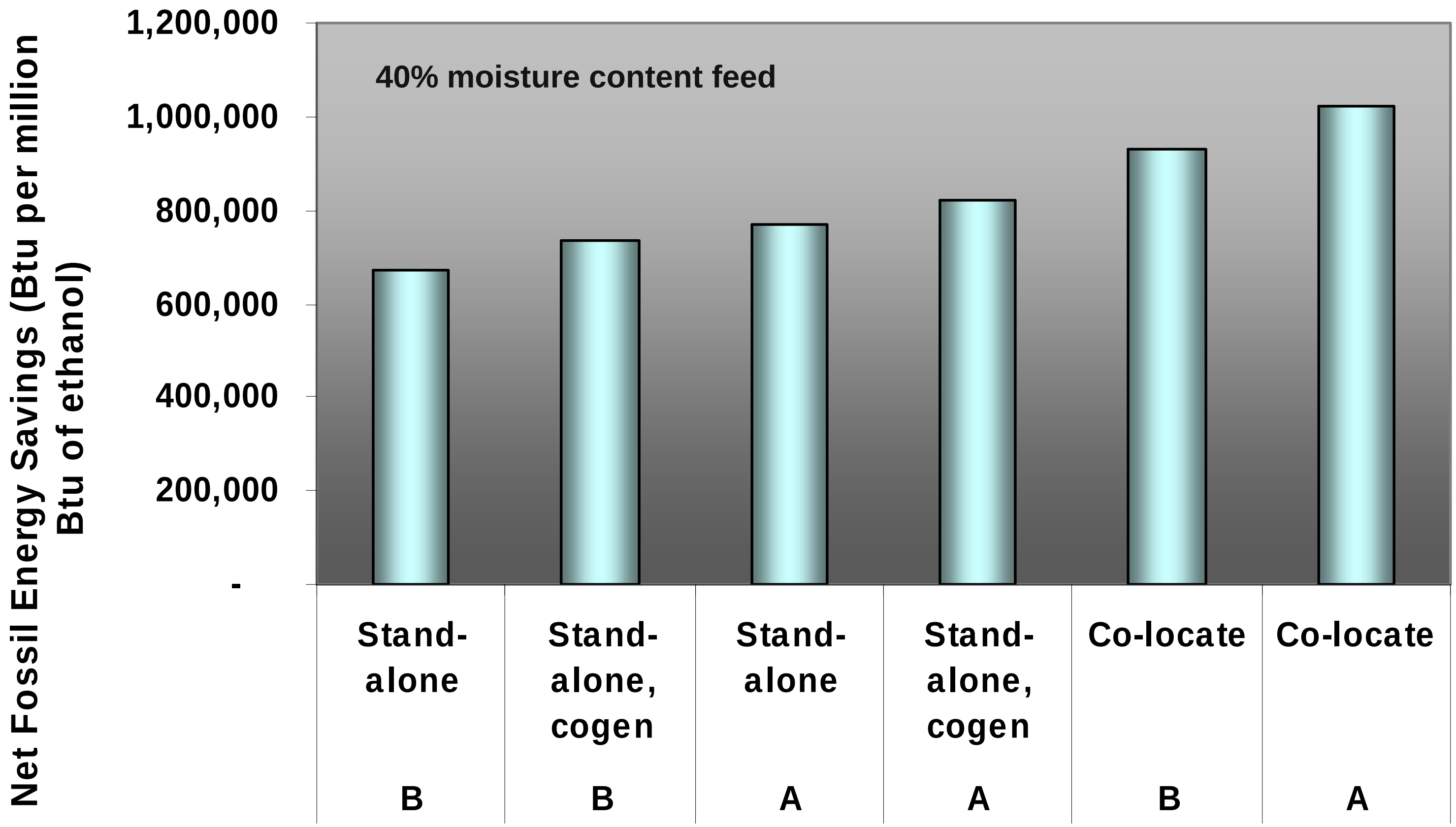
Electricity Co-Generation and Steam Export Avoided 61%-96% of Greenhouse Gases Burden



The Amount and the Type of Fossil Energy Savings are Sensitive to the Choice of Production Options



Syngas-to-Ethanol Process Design and Production Options Achieved Positive Net Energy Balance



Net Energy Balance defined as one million Btu fuel ethanol – Btu of fossil inputs to produce ethanol

Conclusions

- Both Stand alone with co-gen and Co-locate with steam export cases can achieve substantial oil and fossil savings from wells to wheels
  - Oil: 71% - 84%
  - Fossil: 73% - 100%

- The cases examined are able to avoid significant greenhouse gas burdens 61% - 96% in comparison with conventional gasoline, when co-gen or steam export is selected.

- The syngas-to-ethanol fermentation process represents a typical second generation biofuel energy and emission profile and is comparable with other woodchip based biofuel production process.