PROCESS for BIO NATURAL GAS PRODUCTION from FORESTRY RESIDUE

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Overview

- **Bio-natural gas as a meaningful bio-energy pathway**
- **Size, siting and production considerations**
- **G4 approach**
- **Market uses for bio-natural gas**

G4 Insights Team

- **Multi-disciplinary technology & commercial development**
- **Bio-natural gas technology under development with commercially driven focus**
- **Current external support by:**
  - **National Research Council Canada (IRAP)**
  - **Ethanol BC, a BC government and forest industry fund**

G4 Experience

- Founders, senior management and R&D roles in QuestAir Technologies Inc.
- <u>Technology:</u> Developed and commercialized gas separation equipment for industrial gas and petro-chemical industries

QuestAir Prototypes

Liquid Hydrogen Plant, Japan

Natural Gas Business

- **125 Billion GJ/yr world consumption**
- **Supplies ~23% of world energy requirements**
  - **Electricity** → Natural gas generates 21% of all electricity
  - **Heating/combustion** → a growing, preferred fuel source
  - **Transportation** →Currently accounts for only ~ 1% of transportation fuel
- **World-wide commodity with mature and broad distribution**
  - Low transportation/distribution losses over large distances
  - Economical large-scale energy storage
  - Large & accepted infrastructure
  - Infrastructure continuing to be developed
  - Robust trading/displacement/wheeling to allocate gas to buyers

SNG & Bio-Natural Gas

- **Synthetic & bio-natural gas:**
  - Must meet gas utility defined heating values and quality specifications
  - Injected into natural gas pipelines or regional distribution network
  - Can be used by any natural gas equipment, appliance or vehicle
- **Proven methods: anaerobic digester gas, landfill gas**
  - Low-cost purification is key
  - Limited resource: estimate maximum production of 0.4 Billion GJ/yr
- **Emerging methods: biomass gasification with methanation**
  - Low-cost biomass transportation is not well developed
  - Large central plants needed for cost reasons
    → funding, permitting and time-to-market hurdles
- **New Method: G4 Bio-Natural Gas Process**

Biomass Availability

- **350 million dry tonnes/year sustainable forestry residue biomass available in US and EU**
  → a ~ 7 Billion GJ/yr source of carbon neutral energy available **now**
  → an impressive ~15% of current US+EU natural gas use
- **Does NOT include harvest for sole purpose of energy generation**
- **Does NOT include agricultural residues with seasonal availability**
- **Does NOT include regional degradation issues**

Biomass Availability

- **Near-Term Challenges**
  - Difficult to secure long-term biomass supply contracts
  - Unstable and rising feedstock costs ($10-100/dry tonne)
  - Additional forestry jobs to harvest/transport residues
- **Long-Term Challenges**
  - Low-cost methods of residue harvesting & transport
  - Forest industry needs to think/act like an energy provider
  - Energy crops are a long-term investment
  - Seasonal availability & use patterns

Biomass & Energy Transport

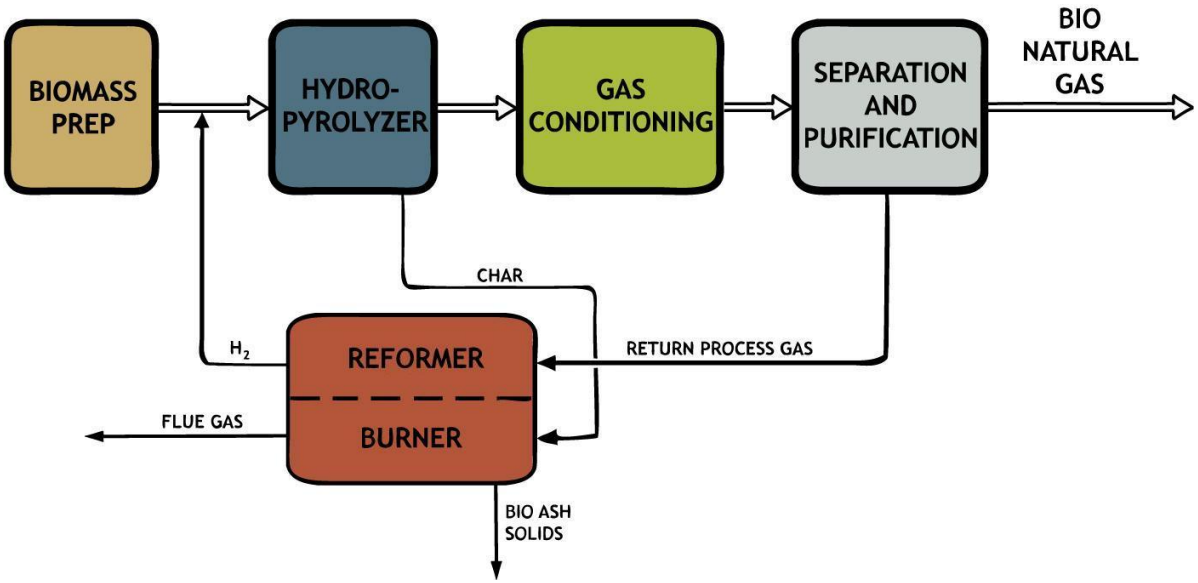
- **Low density of biomass increases transport costs**
  →Largest factor of raw material costs
  →Distributed plant model keeps transport costs reasonable
  →Transport the 'energy' in existing infrastructure
- **Are forests close to pipelines?**
  →Compressor station spacing averages about 100 km
  →Utilization of existing distribution systems
  →Match the sustainable forest harvest practice area with spacing
  →Typical 60km radius biomass supply for each G4 BNG plant
  →Plant feed volumes similar to small/medium sawmill

Logical Conclusion:

- Distributed conversion plant is the most appropriate model
- Appropriate where NG use or distribution infrastructure exists

G4 BNG Process

- Proprietary process to convert biomass into Bio-Natural Gas
- Wood and wood waste is size reduced, dried and thermally vaporized
- Vapors preferentially converted to methane in hydrogen atmosphere
- Gas separation to produce BNG product and re-use other gases
- Reformer generates hydrogen required for the process



G4 BNG Process

- **Industrial Plant:**
  - Similar site considerations as current forest processing plants
  - Use all parts: cellulose, hemi-cellulose, lignin & avoid waste streams
- **Environmental:**
  - Bio-ash from inorganics in wood for redistribution back to forest
  - Carbon neutral CO_2 in flue gas
  - Process water, cooling water optional re-use
  - No contaminated liquid discharge
- **High Energy Conversion Yields**
  - Selling price: US$8 - 10/GJ with US$40 - 50/BDT wood
    (Using typical Independent Power Producer economics and mature design)

Markets

- **G4 BNG with Natural Gas Power Plants:**
  - Large fleet of existing and new power generation stations
  - Purchase “green certificates” and use pipeline gas for immediate renewable power for ANY natural gas powered plant
  - No additional risk or operational impact to power plants
  - Potential biomass heat value to electricity conversion of 40% to 50% when used in new combined cycle (NGCC) plants
  - Lowest cost, large scale production of renewable electricity

GE 9H NGCC @ 400 MW

Markets

'Renewable Premium' Natural Gas

- **Bio-Natural Gas sold by gas utility companies**
  - Residential/commercial users buy premium Bio Natural Gas
  - Use with existing appliances, no need to convert
- **Bio-Natural Gas for CNG vehicles**
  - Existing supply distribution technology and infrastructure
  - Current: limited adoption, primarily used by fleets
  - Emerging consumer market
    → room for incentives for adoption: both $/GJ & $/gasoline equiv.
  - Mainstream CNG & dual-fuel automotive technology

Markets

Remote Energy Supply

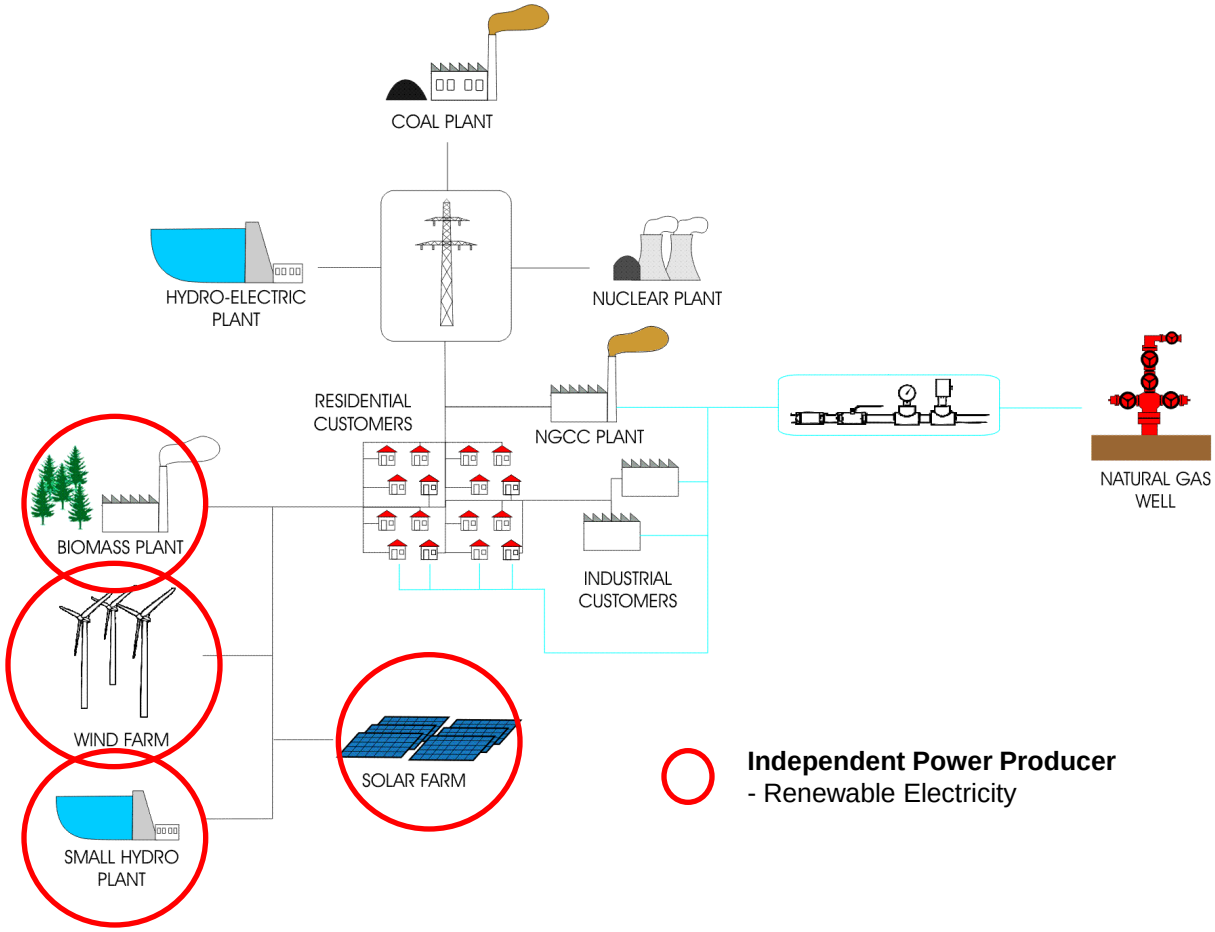
- Remote communities, mining and forestry operations
- Total self sufficiency with high efficiency:
  - coupled with standard NG genset for CHP
  - A stream of BNG for CNG transport fuel
  - Third use of BNG for residential/commercial uses
  - Local employment for energy generation

On-site Industrial Natural Gas Displacement

- BNG is direct substitute for natural gas
  - No burner/boiler modifications required
  - No backup equipment required
  - Can be used for NG space heating, CNG forklifts and vehicles
  - Export BNG if not consumed on-site

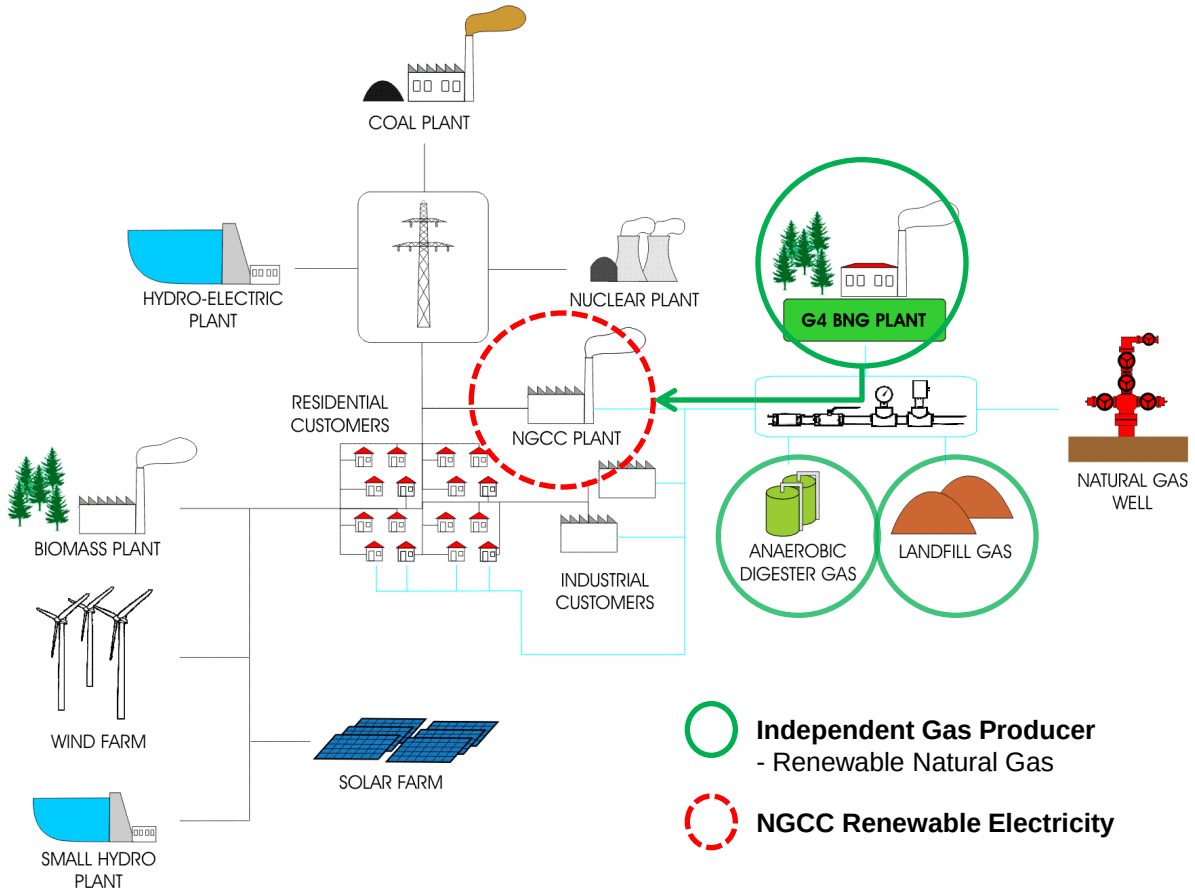
G4 BNG - Distribution

- Current Renewable Electric Power Generation



G4 BNG - Distribution

- G4 BNG into pipeline for renewable power generation



Summary

G4 Bio-Natural Gas

- **Nearly 15% of current NG consumed in US +EU can be displaced by renewable Bio Natural Gas with:**
  - **No change in technology or infrastructure**
  - **Additional sustainable forest-related jobs**
  - **No change to consumer preferences**
- **More can be displaced with advanced forest practices**
- **Low cost renewable electricity**
- **Most expedient way to make fleets 100% green**