CANDU® Plants for Oil Sands Application

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Advanced Reactor Initiatives

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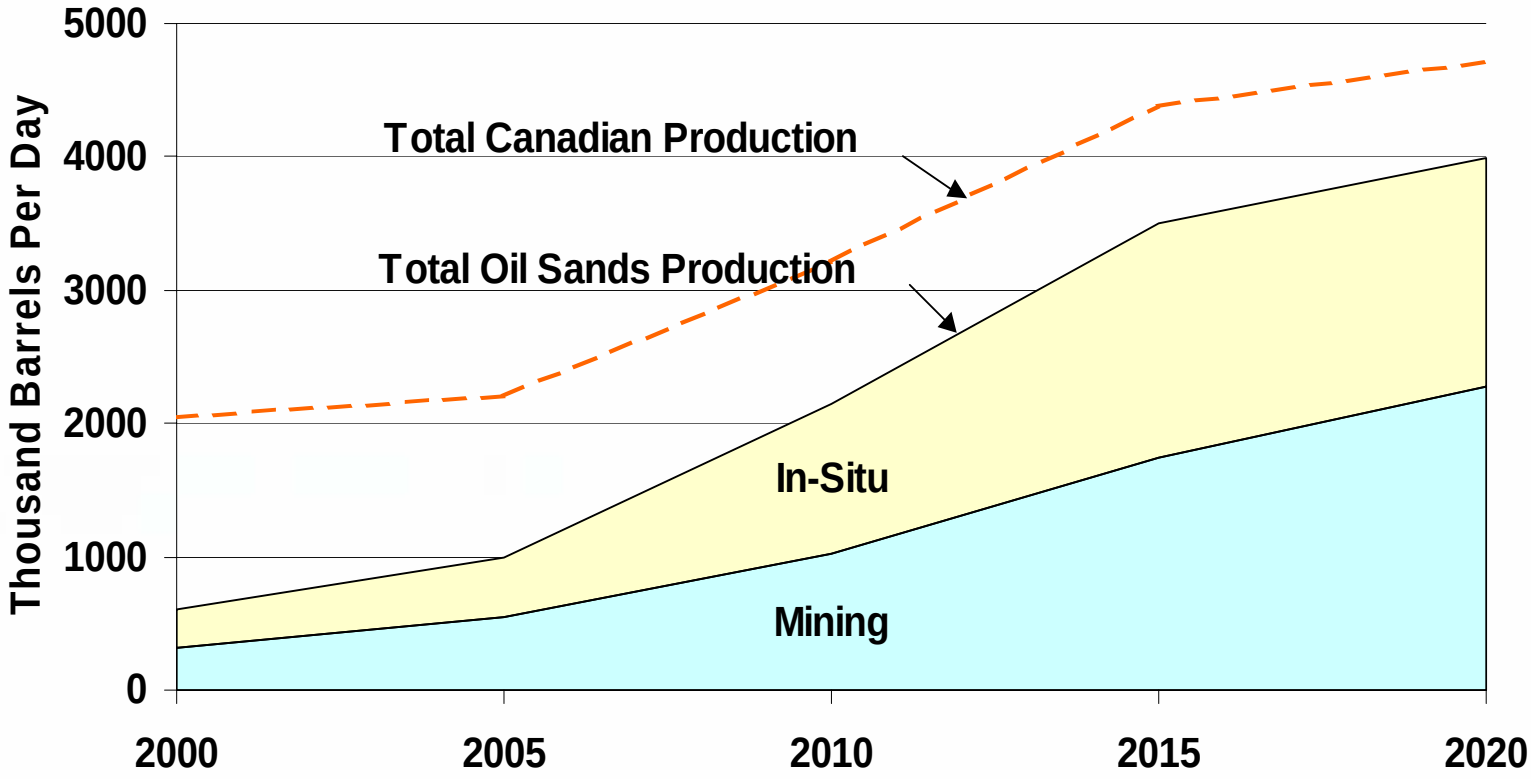
Overview

- Major ongoing long term expansion of Alberta's oil sands production capability is underway.
- Extraction and upgrading are energy intensive. Oil Sands facilities require a 300% increase in energy supply by 2020.
- Depletion of natural gas reserves, green house gas (GHG) emissions and price escalation are major concerns.
- Nuclear reactors are proven large scale thermal energy producers.
- Nuclear plants provide a sustainable solution for oil sands industry energy requirements, and do not produce GHG emissions.

Canadian Crude Oil Production



Areas of Opportunity

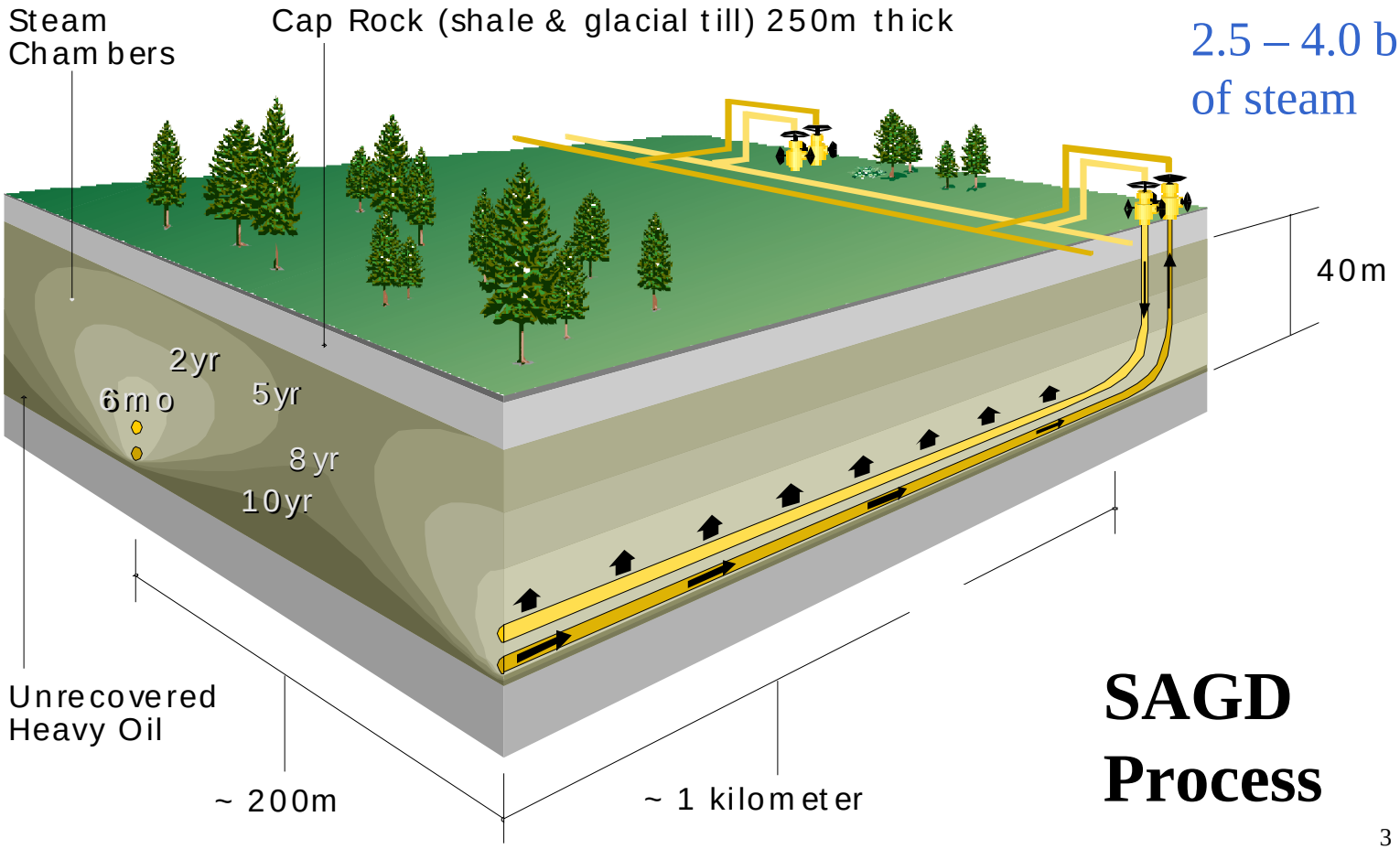
- **Bitumen/Oil Extraction**
  - **Steam Assisted Gravity Drainage (SAGD)**
  - **Carbonate**
  - **Mining**

- **Upgrading/Processing**
  - **Hydrogen**
  - **Electricity**

  (Projects could be combinations of above)

SAGD - Overview of Technology

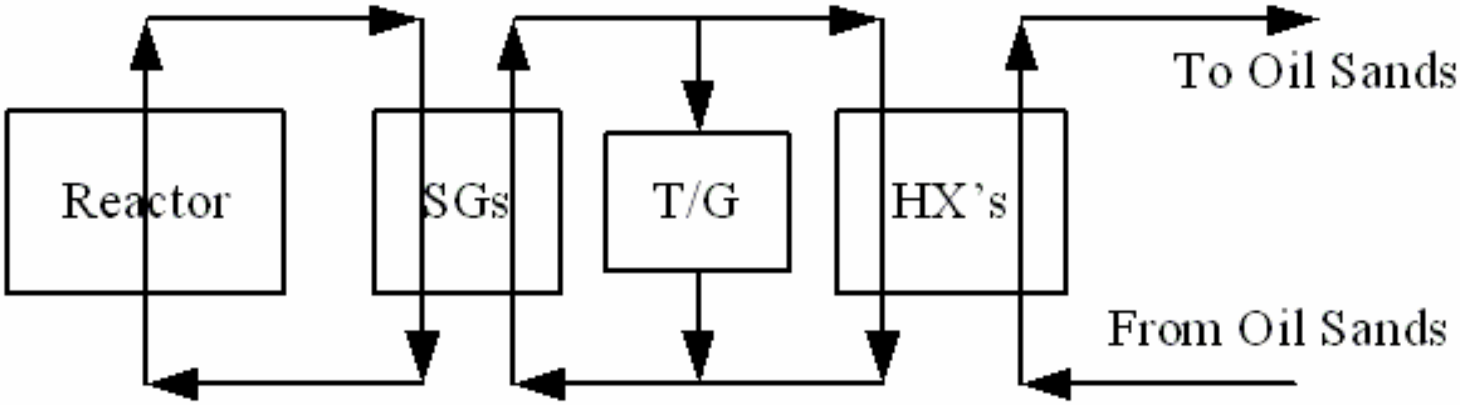
Each barrel of bitumen requires 2.5 – 4.0 barrels of steam



SAGD Process

3

Simplified SAGD Configuration

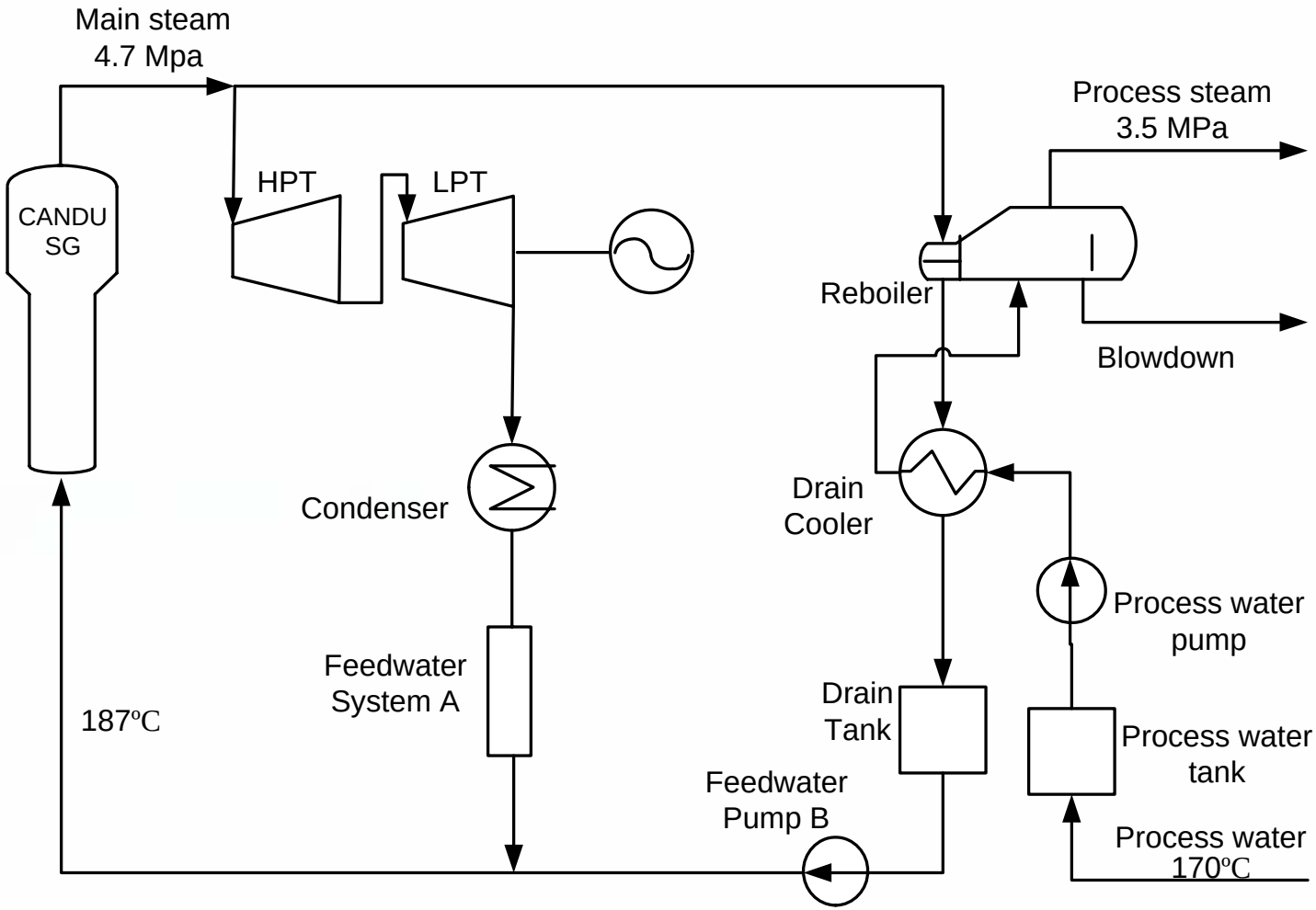


SAGD - Potential Configurations

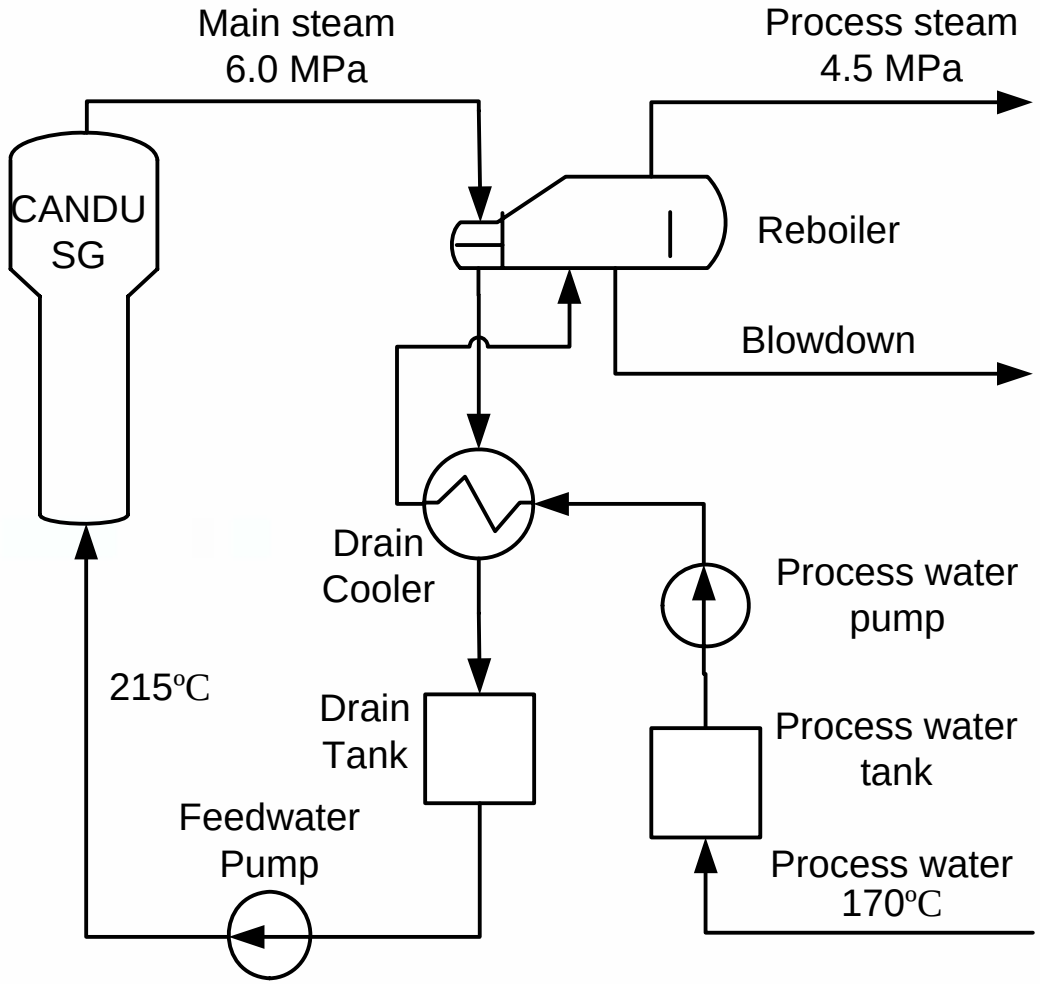
- **<u>Option 1</u>: Limited amount of electricity (150-200MWe), the remainder steam**
  - **Hybrid design**
  - **Flexible in energy product delivery (steam/electricity ratio)**

- **<u>Option 2</u>: No electricity generation, all steam**
  - **Simpler design**
  - **Reduced water requirement**
  - **Favorable thermodynamics (best economics)**

SAGD Design Concept for CANDU 6
(Steam and Electricity)



SAGD Design Concept for ACR 1000
(Steam Only)



Design Challenges(1)

- **Coexistence with Oil Sands Operator**
  - **Energy demand dependant on oil sands operations**
  - **Process steam/ return water link**
  - **SAGD complexity**
- **Steam Transport**
  - **Distance, delta P, pipe size and isolation etc.**
- **Reboilers**
  - **Detailed design, fouling and cleaning etc.**
  - **Heat sink for upset conditions and isolation requirements**
- **Cooling Water**
  - **Distance and availability**
  - **Water return temperature**

Design Challenges(2)

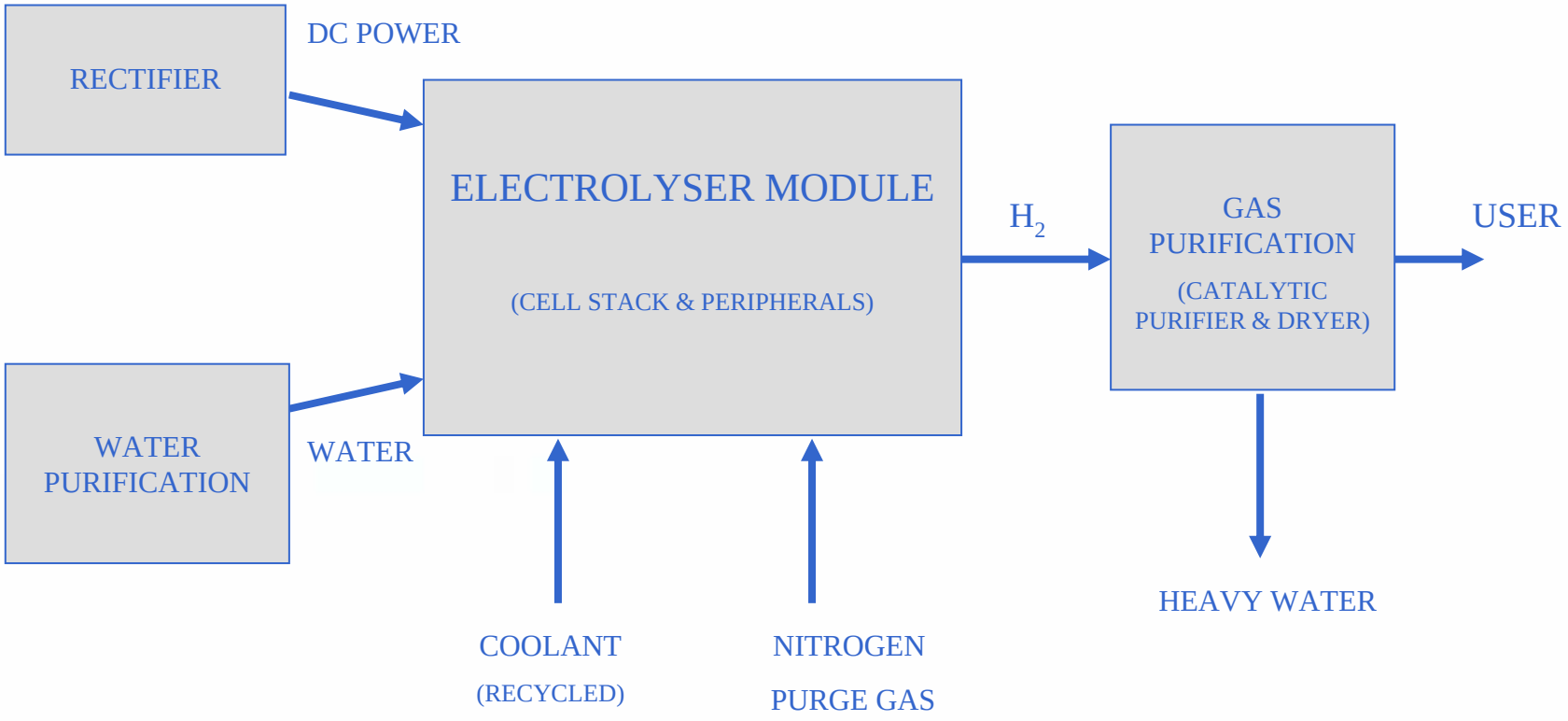
- **Electrical Power**
  - **Grid reliability**
  - **Plant operational stability**

STUDIES INDICATE THE NPP APPROACH IS TECHNICALY AND ECONOMICALY FEASIBLE

Carbonates - Background

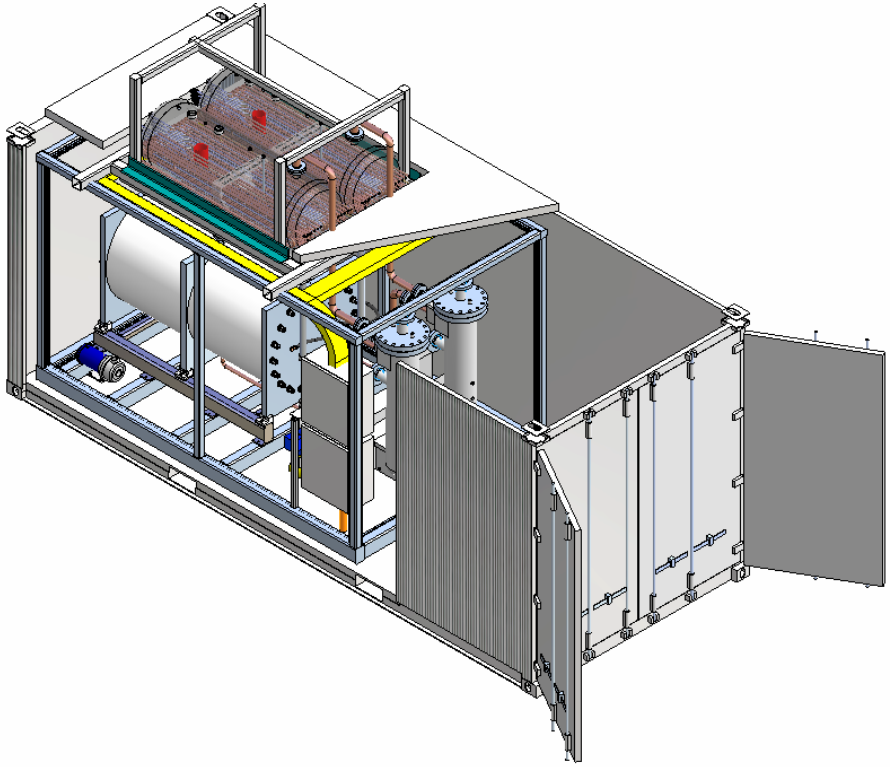
- Carbonate zones have bitumen locked in rock-like formations similar to Colorado oil shales
- Significant development effort over the last 30 years
- Extraction Technology is highly protected
  - Use of electrical heaters in 1000 feet long vertical tubes to heat rock formations
  - Takes up to three years of heating up to 600 C to separate gas and light oil from the rock (so-called in-situ conversion)
- Requires large amounts of base-load electricity
- Oil extracted by conventional oil pumps

Simplified Flow Diagram of H_2 Production System

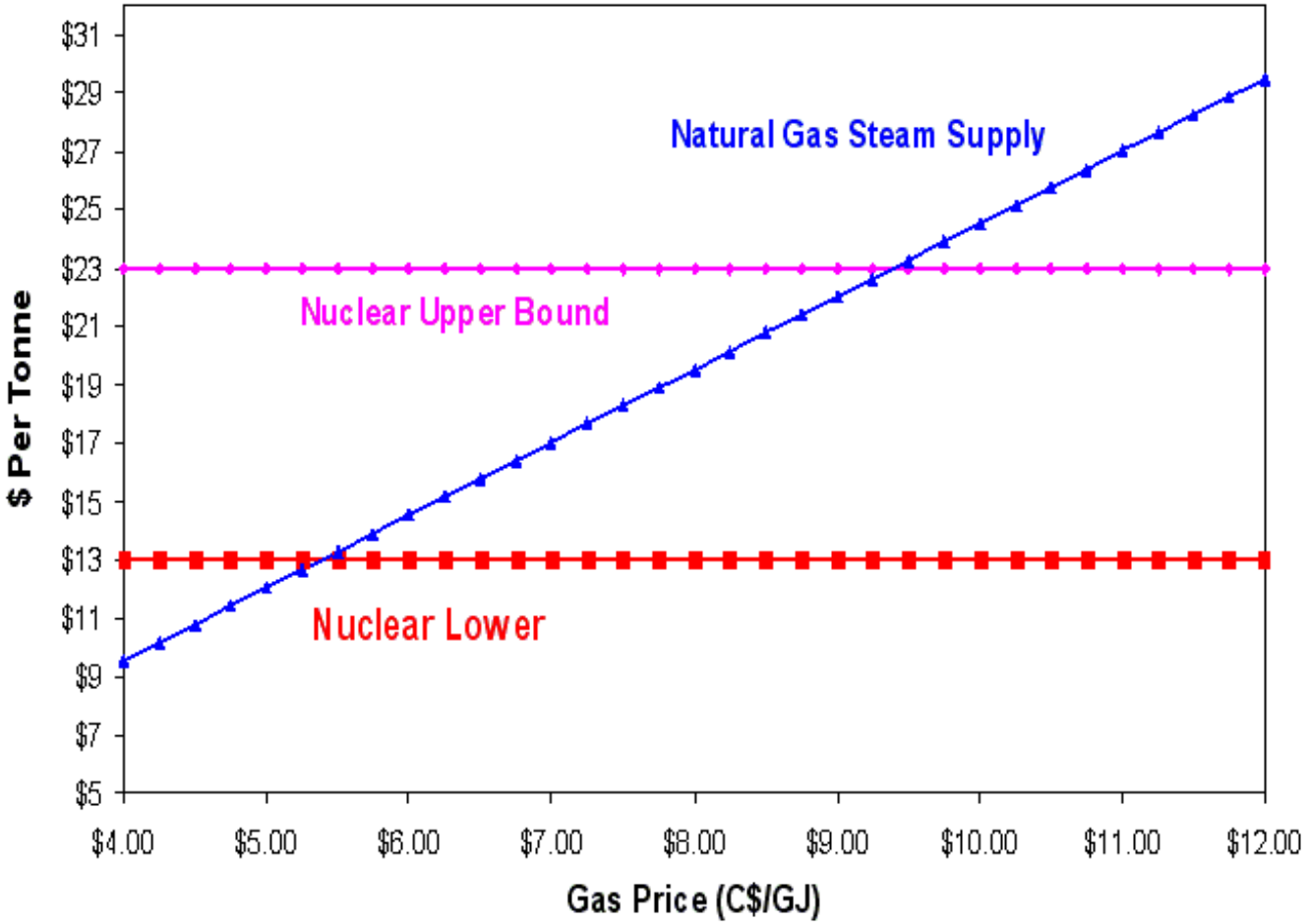


Electrolysis Modules

- **Standard electrolysis modules simplify shipment, installation and servicing**



Cost Comparison – Natural Gas and Nuclear Power for Steam Generation



Summary

- Each oil sands project is somewhat unique.
- Secondary side design adaptation for specific projects will be needed.
- Nuclear power plants are competitive and reliable. They have no CO_2 emissions and therefore offer a sustainable long term solution for oil sands energy requirements.