Converting Green River oil shale to liquid fuels with ATP and ICP technologies

A life-cycle comparison of energy efficiency and GHG emissions

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Outline

1. Introduction and context
2. Research questions
3. Research methods
4. Results
5. Conclusions and open questions

1. Introduction and context

- Past oil shale development hindered by high risk, uncertain technology, and environmental concerns
- Two prominent technologies appear to be moving forward: Alberta Taciuk Processor (OSEC) and In situ Conversion Process (Shell oil)
- I was hired by Natural Resources Defense Council to study oil shale
  - Have put in an additional year of time on this project (part of Ph.D. dissertation)
- This is a brief outline of two working papers available on my website: http://abrandt.berekley.edu

2. Research questions

- What are the energy inputs and outputs from key above ground and in situ oil shale production processes?
- What are the associated greenhouse gas emissions?

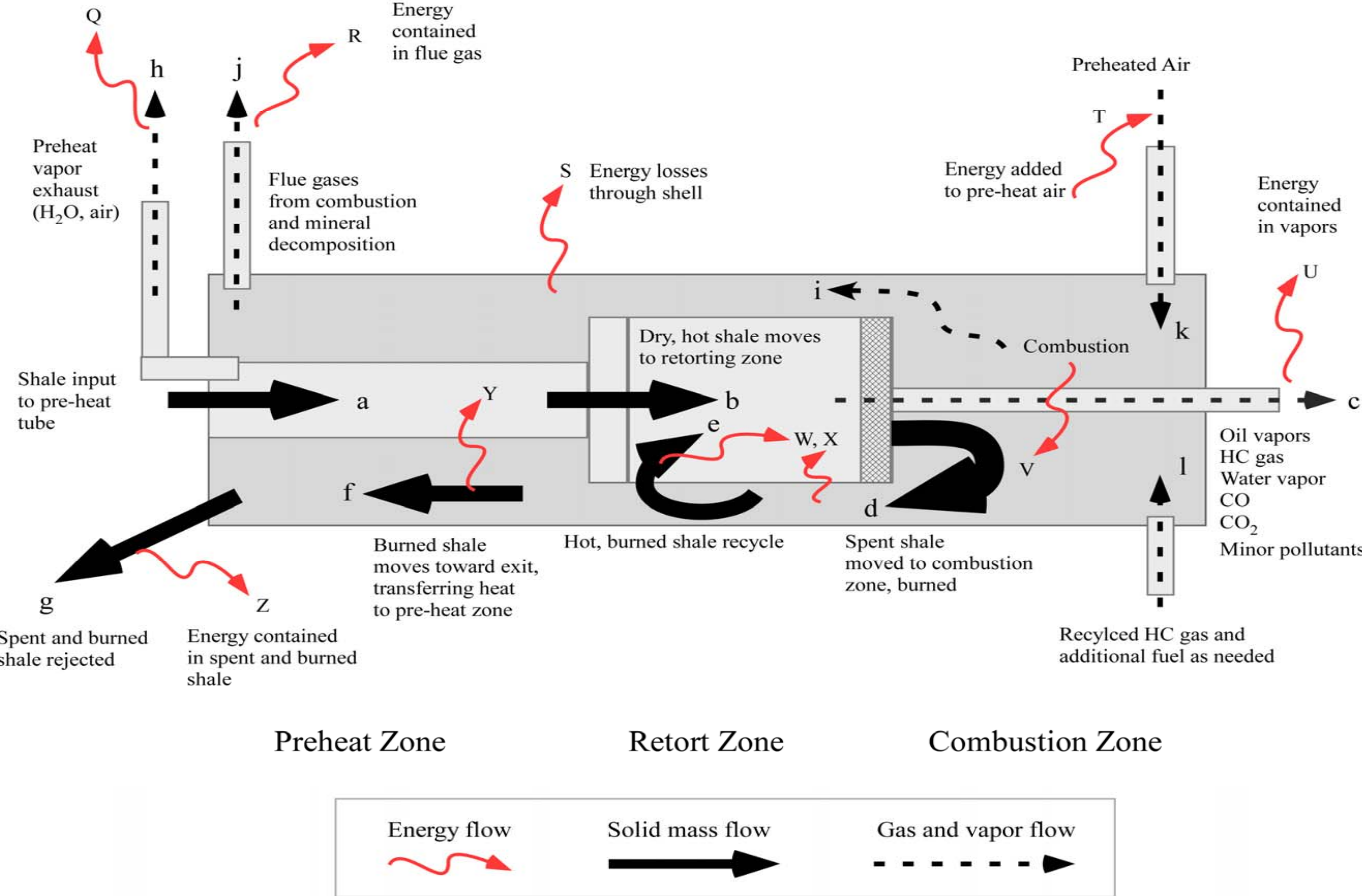
3. Research methods - LCA

- I compare the Alberta Taciuk Processor (ATP) to the Shell In situ Conversion Process (ICP) using **life cycle analysis**
  1. Compute material and energy inputs to stages of each process
  2. Convert material requirements into energy requirements (for prominent materials, e.g. steel, cement)
  3. Sum direct and indirect energy requirements, compare to energy outputs
  4. Compute GHG emissions from direct and indirect energy requirements
- Multiple cases calculated: I will show high and low **primary cases**

ATP modeling

- Define ATP-based process with stages
  - Mining/transporting/crushing
  - Retorting
  - Post-retorting processes (spent shale disposal, upgrading of SCO)
  - Refining SCO into finished liquid fuel
- For each stage calculate materials and energy flows **per tonne**
  - Retorting uses detailed mass and energy balance
- Include material energy embodied in steel, cement, mining equipment

ATP retort mass and energy flow diagram



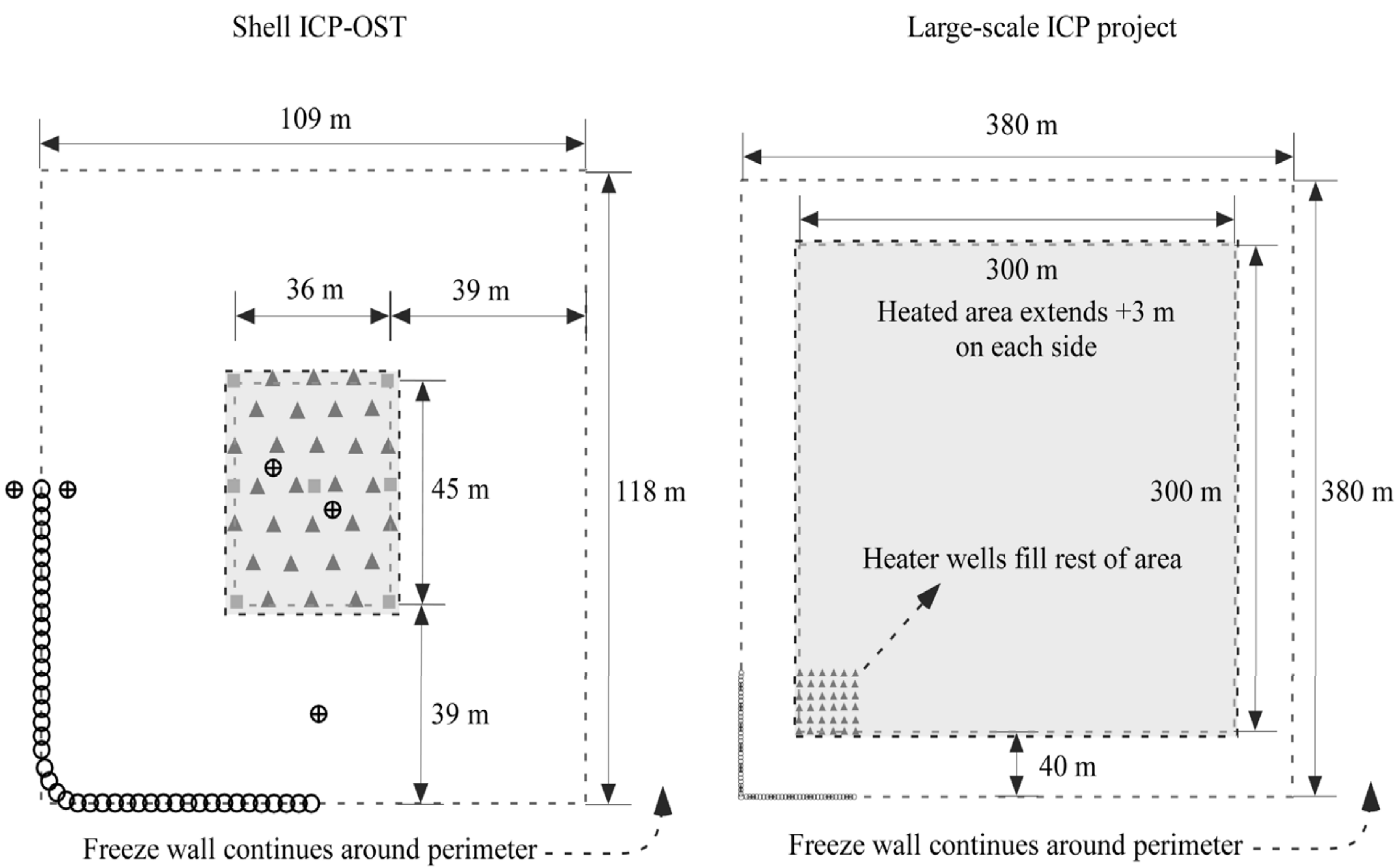
ATP difficulties and uncertainties

- Mining inputs are uncertain, as no large-scale industry exists
  - Use tar sands (Johnson et al.) and coal mining as analogues
- Retort process is tunable to meet different criteria
  - Use data from patents (Taciuk et al.) and published sources to estimate temp. for different retort chambers – allows recycle rate and energy balance calcs.
  - Retort could be run at lower temperature/slower to reduce carbonate decomposition
- Waste heat capture is possible, but uncertain how economics would play out

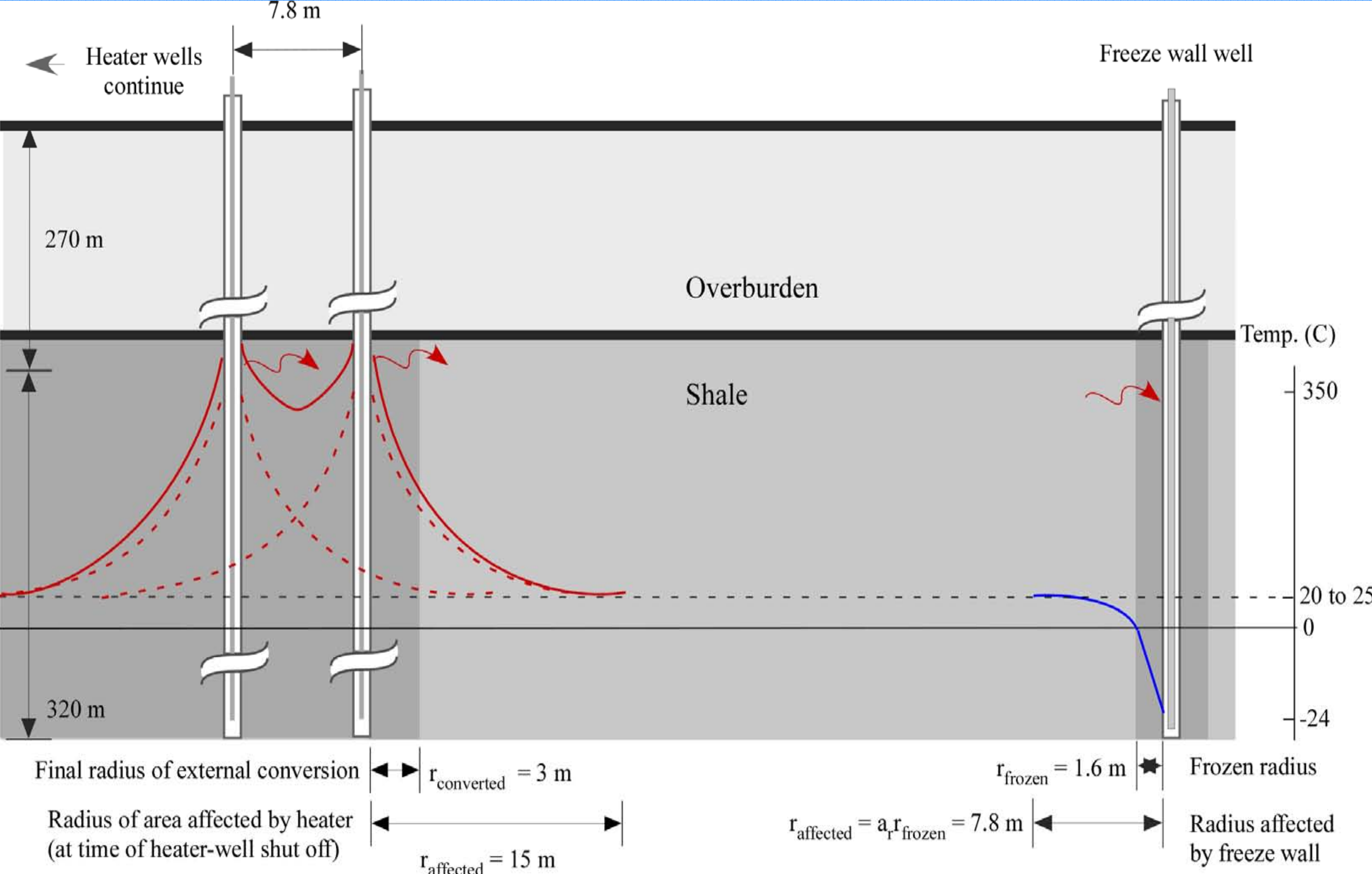
ICP Modeling

- Divide ICP process into stages
  - Preliminary ops./freeze wall const./dewatering
  - Heating
  - Production/upgrading
  - Restoration and remediation
  - SCO refining
- LCA again performed per tonne
- Processes reported in patents/reg. doc. are small-scale – **scaling required**

ICP plan – OST and modeled cases



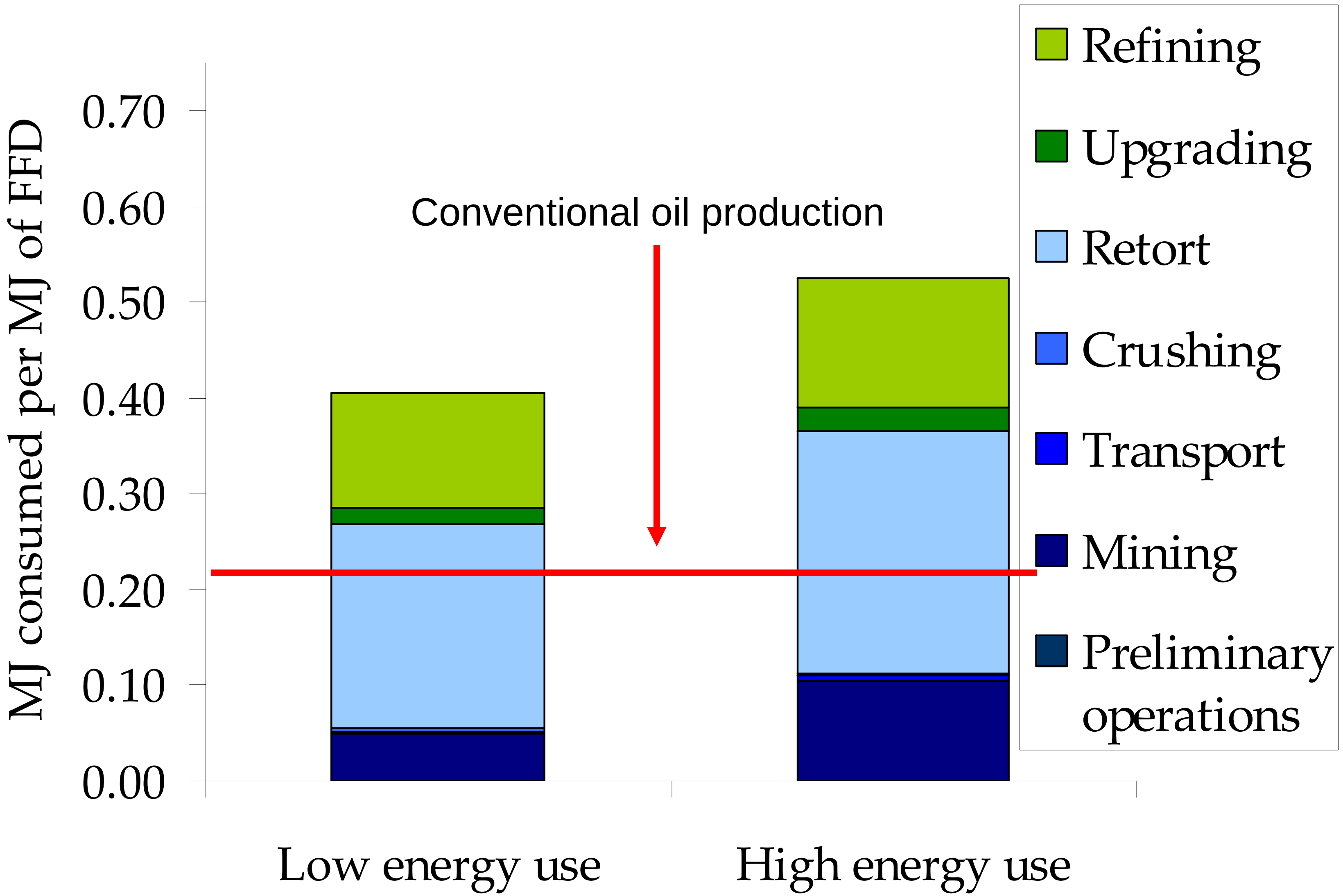
ICP side-view



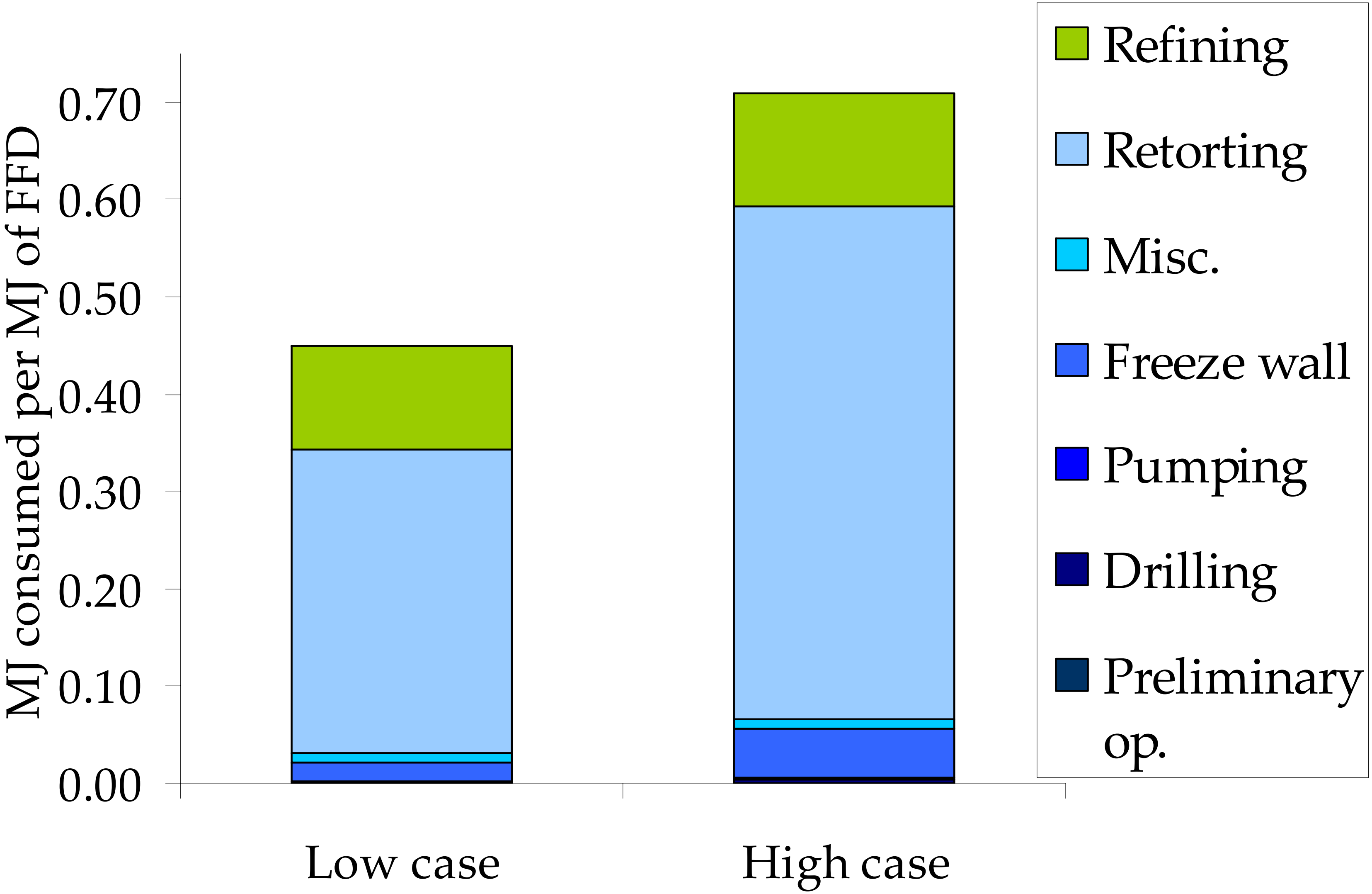
ICP difficulties and uncertainties

- Little empirical, publicly available work done at retorting temperatures, speeds, and pressures used in ICP
  - Work from LLNL is best source (Burnham, Braun, Singleton et al.)
- Operating pressures are uncertain, effect of pressure accounted for roughly in my model
- Difficult to reconstruct ICP from patents
- Inherent flexibility of ICP creates variability

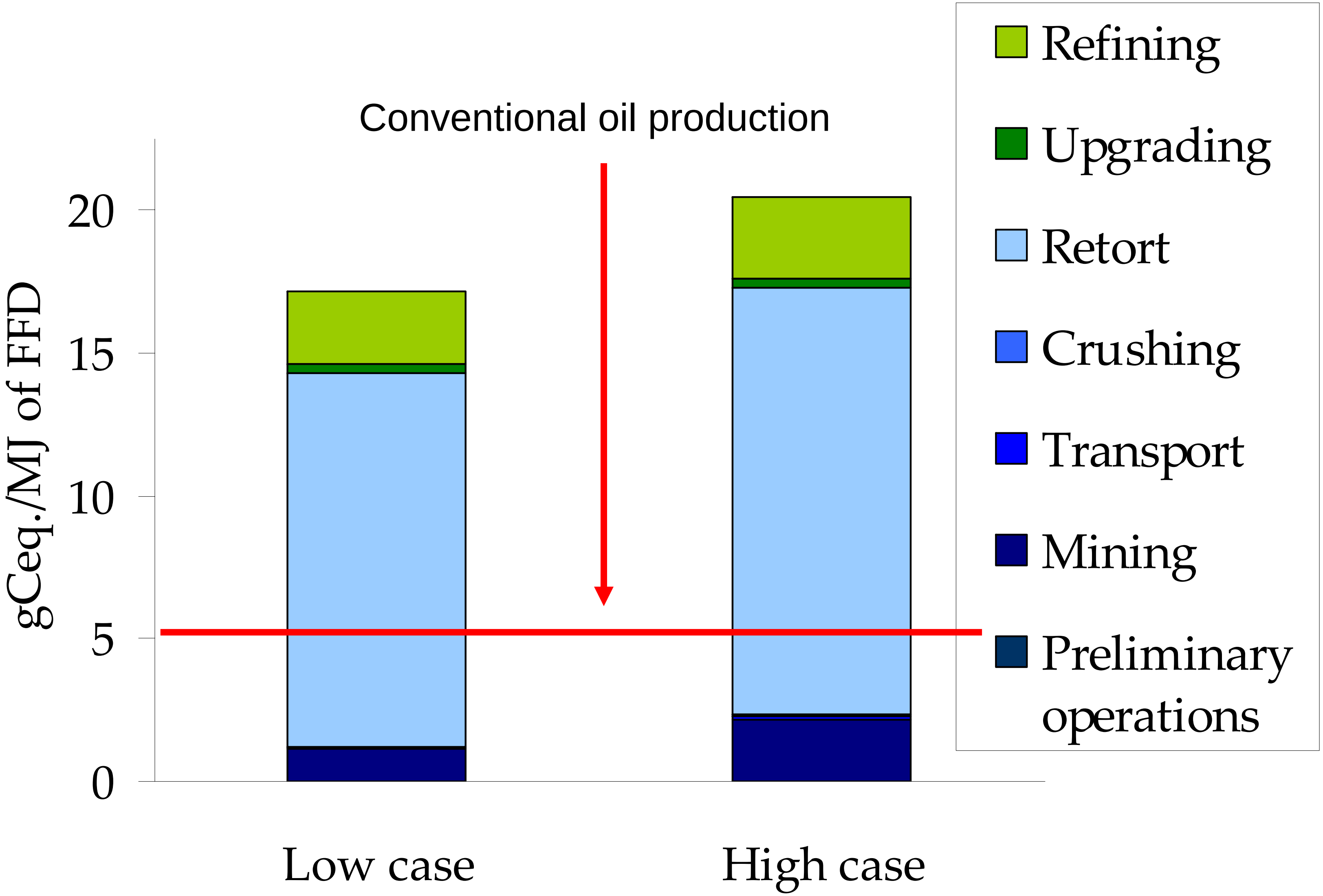
4. Results – Energy inputs ATP



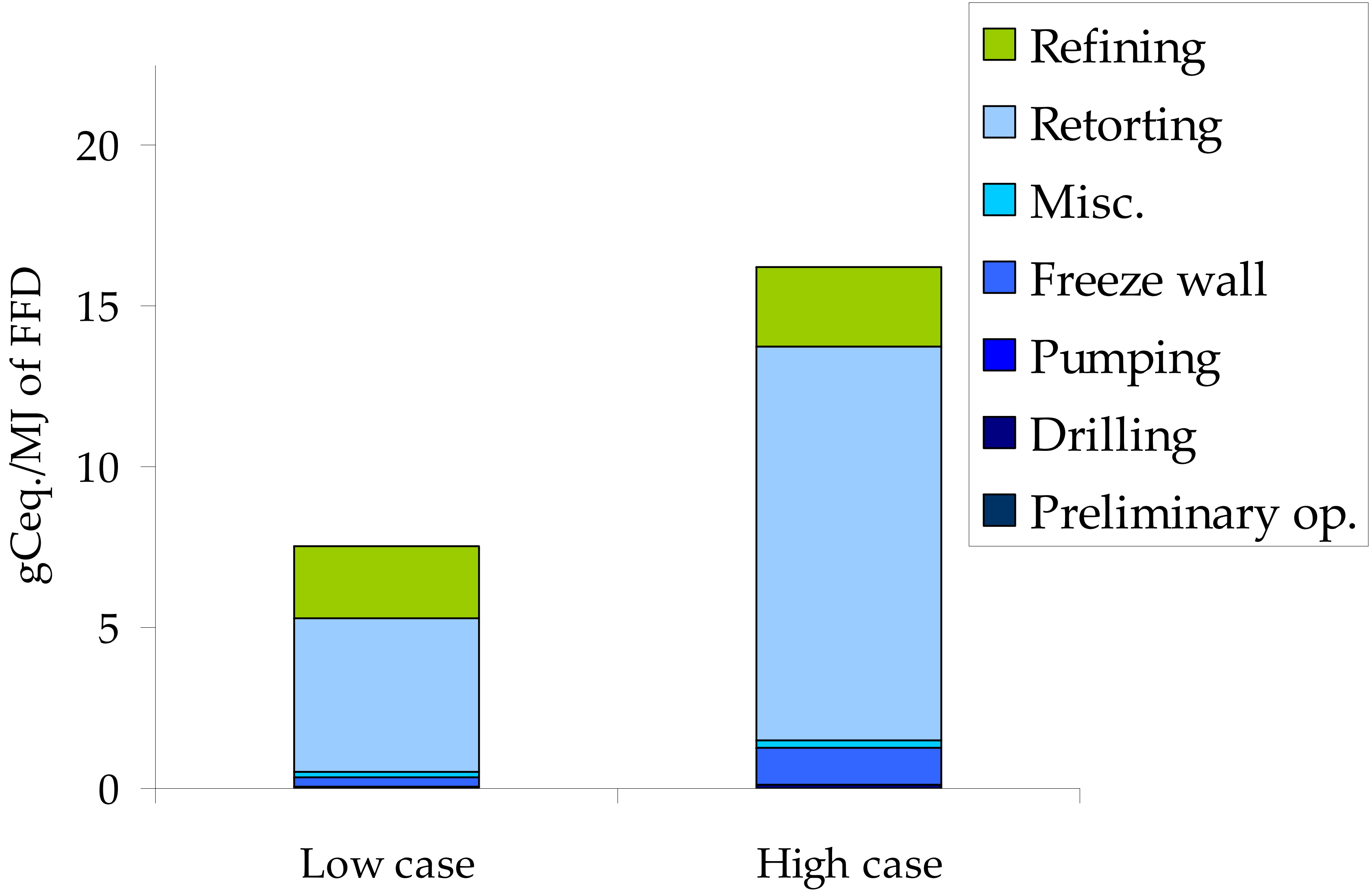
4. Results – Energy inputs ICP



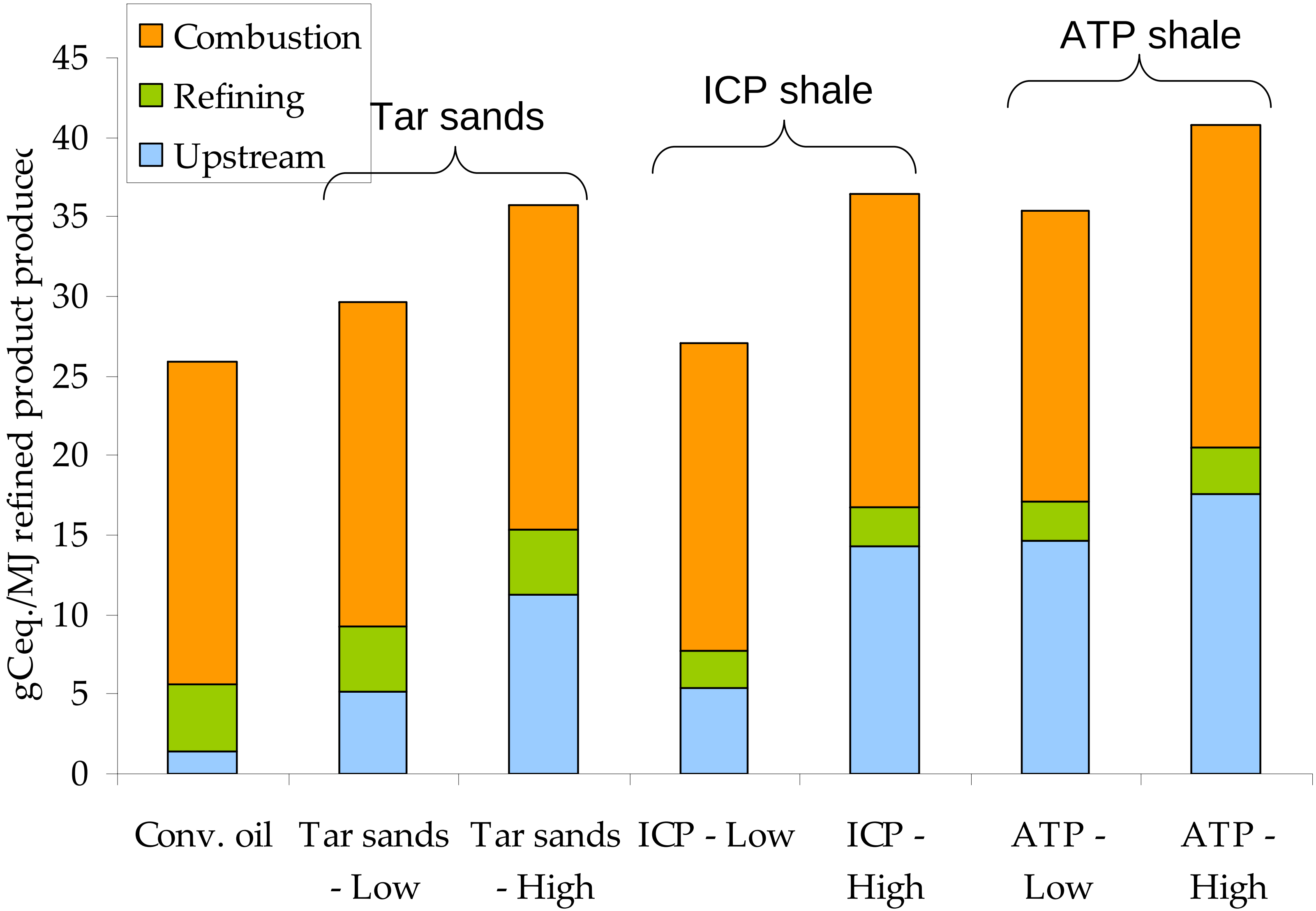
4. Results – Upstream GHGs ATP



4. Results – Upstream GHGs ICP



4. Results – GHGs comp. to other fuels



5. Conclusions and open questions

- Both processes very energy intensive
- GHG emissions comparable to or possibly higher than tar sands emissions
- ICP is more energy intensive than ATP, even given scale (e- use)
- Fuel flexibility gives ICP potential for lower carbon emissions
  - ICP could use renewable power to greatly reduce emissions

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