Multi-Path Transportation Futures Study

Analysis of Fuel Production Pathways

A Collaboration Between Argonne National Laboratory and the STEPS Program

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Introduction

The DOE/Argonne Multi-Path Study is aimed at comparing alternative ways to make significant reductions in oil use and carbon emissions from U.S. light vehicles from now to 2050. A key goal of the study is to make these comparisons on as common a ground as possible, with analytic robustness.

The Study has been carried out in two phases.

- Phase 1
  - Conducted entirely by Argonne National Laboratory
  - A scoping study aimed at identifying key analytic issues and constructing a study design.
- Phase 2
  - Examines multiple scenarios aimed at illuminating the issues and impacts associated with a national effort to reduce U.S. dependence on foreign oil.
    - More focus on costs: vehicle costs and cost of producing fuels
    - Analysis of oil security impacts of scenarios
    - Risk analysis
    - Examination of the interactive effects of multiple pathways and interactions with the rest of the economy
  - **Collaboration with STEPS Program, ITS-Davis**
    - More detailed fuel production pathway characterizations
    - Cross-comparison using various metrics (e.g., costs, efficiencies, water/land use)

The main task performed at ITS-Davis has been to undertake a literature review of reports on fuel pathways with the following objectives:

- Establish a database of economic and environmental data and estimates for each of these fuel pathways;
- Estimate environmental and energy impacts and costs of the fuels pathways;
- Characterize uncertainties and controversies about key factors affecting the magnitude of estimated environmental and energy impacts and investment and operating costs of the fuel pathways, including uncertainties in R&D outcomes, feedstock choices, selection of centralized vs. local fuel production, and so forth.

Fuel Production Pathways Characterized:

. ***Gasoline and diesel fuel from:***

- Conventional Petroleum (including EOR)
- Unconventional Petroleum (Oil Sands, Oil Shale, Heavy Oil)
- Coal (Coal-to-liquids, CTL)
- Natural Gas (Gas-to-liquids, GTL)
- Biomass (Biomass-to-liquids, BTL)

Hydrogen from

- Coal
- Natural gas
- Biomass (several types)
- Electrolysis

Ethanol from

- Corn
- Cellulosic Biomass

Electricity from

- Fossil fuels (coal, natural gas)
- Biomass
- Nuclear
- Renewables

Information Contained in Pathways Characterizations:

➢ **Description of Pathway**

- Each fuel pathway is described in a narrative noting the potential feedstock sources, collection methods, fuel production technologies and scale options, distribution methods, fuel station characteristics, and so on.

➢ **Production Efficiency**

- The production efficiency is estimated for each given transportation fuel pathway.

➢ **Costs**

- Various types of costs are estimated
  - Capital Costs
  - Feedstock Costs
  - Levelized Production Costs

➢ **Emissions**

- Lifecycle emissions are estimated for each fuel production pathway.
  - Greenhouse Gas Emissions
  - Criteria Air Pollutant Emissions

➢ **Water Use**

- Water use is estimated for both fuel and feedstock production.
- Water use for transportation fuels production has not been extensively studied on a full fuel cycle basis.
- Water requirements can be substantial, especially for biofuels production.

➢ **Land Use**

- Land use is estimated for both fuel and feedstock production.
- The land requirements of biofuels production, in particular, can be significant, as recent studies have shown.

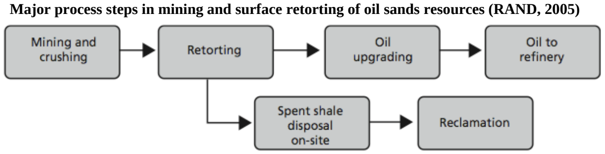
➢ **R&D Needs**

- Key research areas are identified, especially those that may contribute to improvements in costs, efficiencies, and emissions.

Example Results from Pathways Characterizations

➢ Pathway Narrative Description

Major process steps in mining and surface retorting of oil sands resources (RAND, 2005)



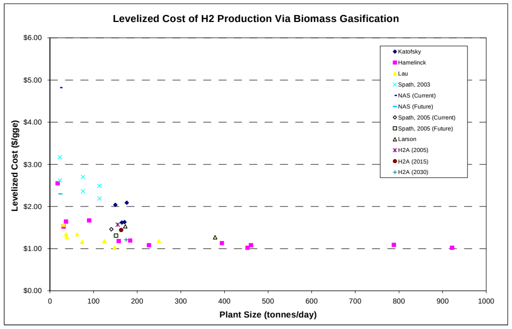
RAND *MG414-3.1*

➢ Production Efficiency

A typical yield and product distribution from CTL plant (National Petroleum Council, 2007)

	CTL plant	*Direct liquefaction*		*Indirect liquefaction*
Typical yield (C3+)	bbl/ton of moisture-free bituminous coal	3		2.2
	mmBTU of coal/bbl liquid product	9		11
Typical product distribution	C3-C4 LPG	11%		14%
	Naphtha	28%		21%
	distillate	11% light distillate	31% heavy distillate	18%
	other	19% gas oil		47% wax

➢ Costs



Levelized cost estimates of biomass-to-H2 production from various studies, LHV basis

➢ Emissions

Type of Estimate	WTT GHG Estimates From Corn Ethanol Production		
	g CO2-eq/MJ	*g CO2-eq/mmBtu*	*g CO2-eq/gge*
Extreme Low	60	63,304	7349
CO2-light	68	71,145	8329
Mid-range	71 – 77	74,480 – 81,241	8646 – 9431
CO2-intensive	91	96,012	11,146
Extreme High	121	127,664	14,821
Including land use changes[1]	*+104*	*+109,727*	*+12,738*

Well-to-tank greenhouse gas emissions for corn ethanol production, LHV basis (various sources)

➢ Water Use

Category	Plant Type	Water Consumption *(gal H2O/mmBtu electricity)*		
		Feedstock Production[1]	Electricity Production[2]	TOTAL
Coal	Subcritical PC – Steam	3 – 93	147 – 343	150 – 436
	Subcritical PC – Steam, with CCS	4 – 127	176 – 755	180 – 882
	Supercritical PC – Steam	3 – 83	132 – 305	135 – 388
	Supercritical PC – Steam, with CCS	4 – 109	158 – 644	162 – 753
	IGCC	3 – 83	59 – 241	62 – 324
	IGCC, with CCS	3 – 103	71 – 386	74 – 489
Nuclear	Pressurized Water or Boiling Water – Steam	4 – 14	29 – 440	33 – 454
Natural Gas	Combined-Cycle	6	29 – 146	35 – 152
	Combined-Cycle, with CCS	7	35 – 175	42 – 182
Biomass	IGCC	0	?? (see text)	?? (see text)
Renewables	Geothermal	0	0 – 1589	0 – 1589
	Solar thermal	0	220 – 270	220 – 270
	Solar photovoltaic	0	~0	~0
	Hydroelectric	0	0	0
	Wind	0	~0	~0
	Ocean	0	0	0

Water consumption for different electricity production pathways (various sources)

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