Scraping the bottom of the barrel:

CO_2 emissions consequences of a transition to low-quality and synthetic petroleum resources

Carnegie Mellon Climate Decision Making Center

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Introduction

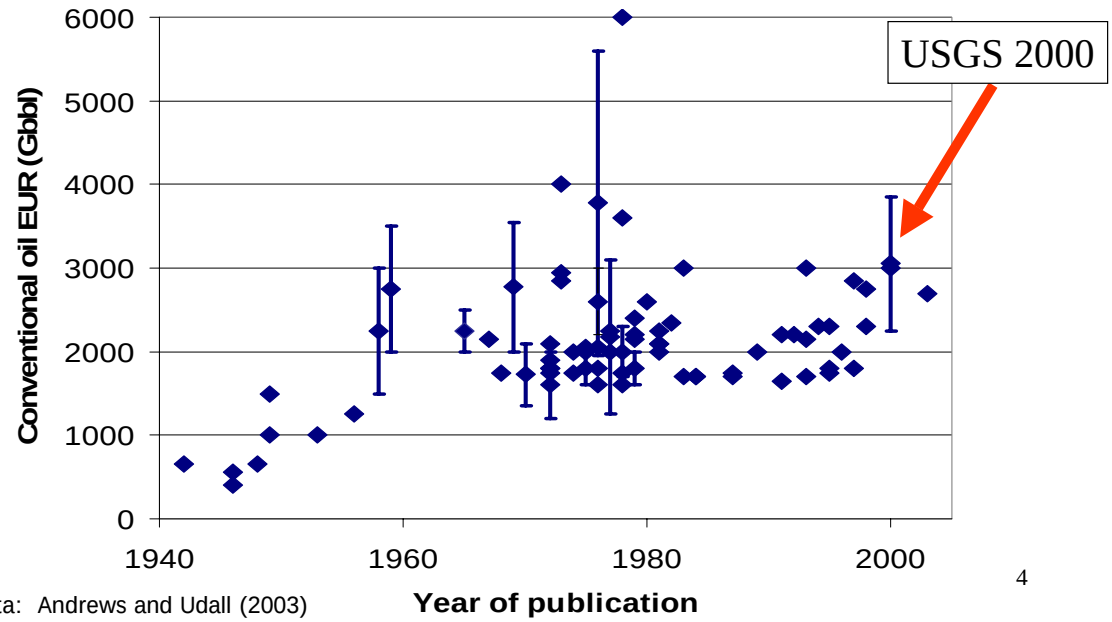
- Many GHG emissions scenarios imply a transition to alternatives to conventional petroleum
- We studied IPCC Special Report on Emissions Scenarios (SRES)
  - SRES is well known and detailed
  - Transition to alternatives is not explicit
  - In many SRES scenarios petroleum production forecasts require development of either:
    - Low-grade petroleum resources (extra heavy oil, tar sands, oil shale)
    - Synthetic liquid fuels to replace petroleum (gas-to-liquids, coal-to-liquids)
- Question: How is this transition modeled?
  - What emissions factors are used?
  - What resource endowments are assumed?
  - What uncertainties are associated with these assumptions?

Method

- Literature review
  - Estimation of fossil hydrocarbon endowment
    - Petroleum, conventional and unconventional
    - Gas
    - Coal
  - Evaluation of production technologies
    - Unconventional petroleum
    - Gas-To-Liquids
    - Coal-To-Liquids
- Review and simulation of some SRES forecasts
  - Scenarios
    - A1F
    - A1B
    - A2
  - Models
    - IMAGE
    - MESSAGE
    - MiniCAM

Estimates of conventional EUR

- Historically many analysts have projected Estimated Ultimate Recovery for conventional oil (EUR)
- This is the amount of oil estimated to be produced over all time



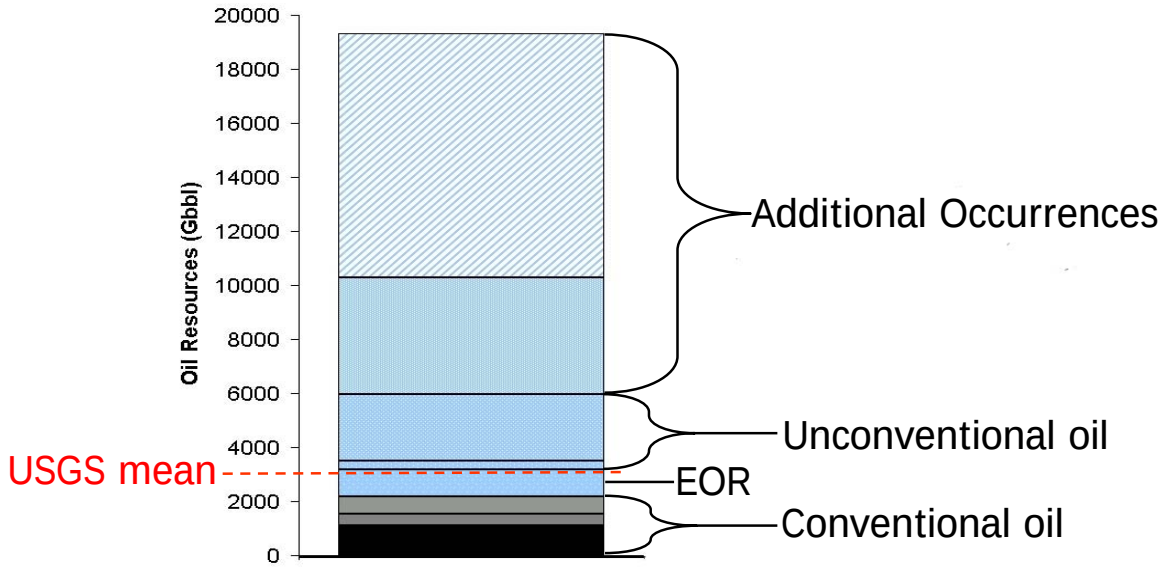
Data: Andrews and Udall (2003)

Definitional problems

- Reserves or EUR ?
- What is petroleum?
- Resources or capacity?
- Stability of supply?

Rogner's estimates (1997)

- All SRES modeling teams used Rogner (1997) for resource endowment
  - Rogner is "optimistic" - broad resource definition



SRES oil production

- We can compare this to the oil consumed in 3 SRES modeling efforts

Scenario	Cumulative Oil Production (Gbbl 2000-2100)		
	IMAGE	MESSAGE	MiniCAM
A2	3900	2900	1600
A1B	4500	3900	3800
A1F	5200	5400	4600

Rogner's estimates (1997)

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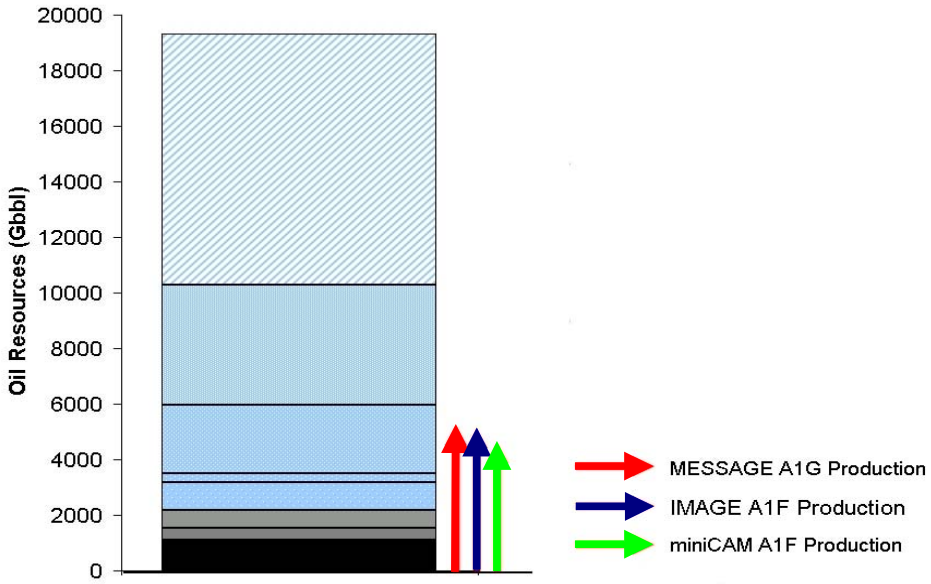
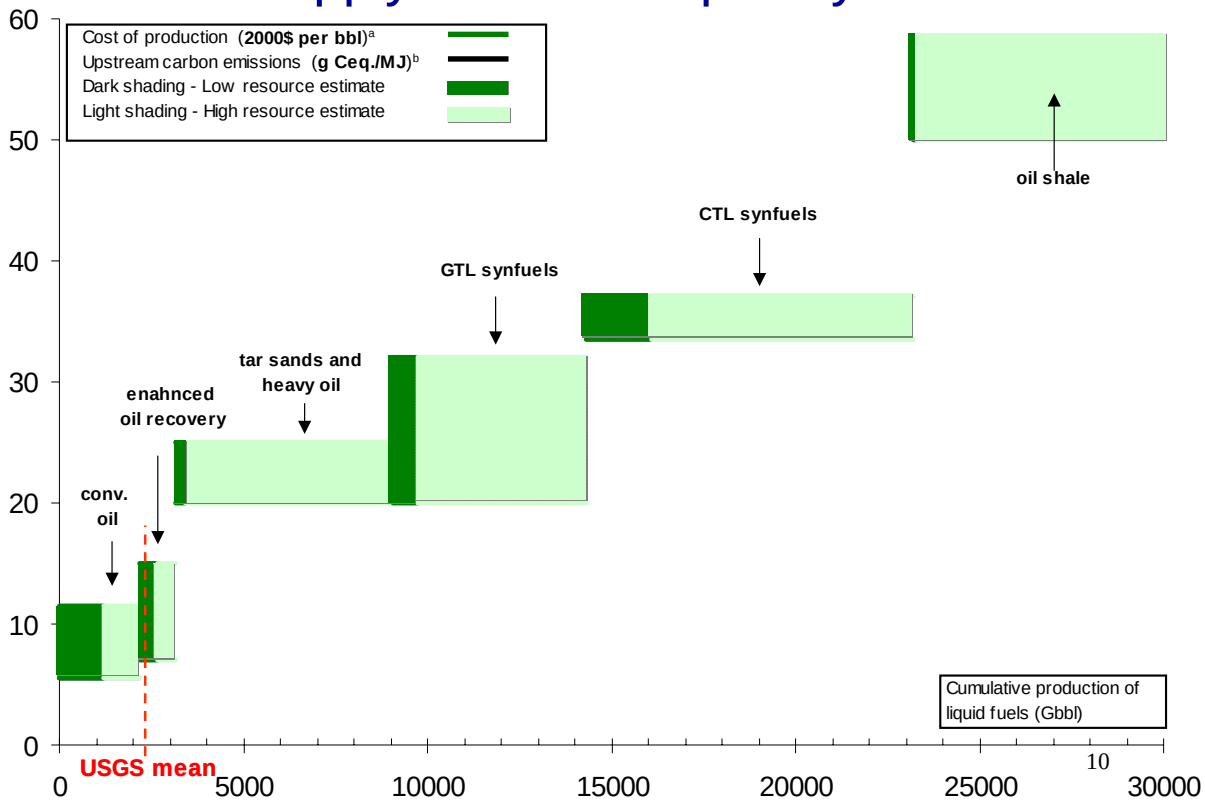


Carbon implications

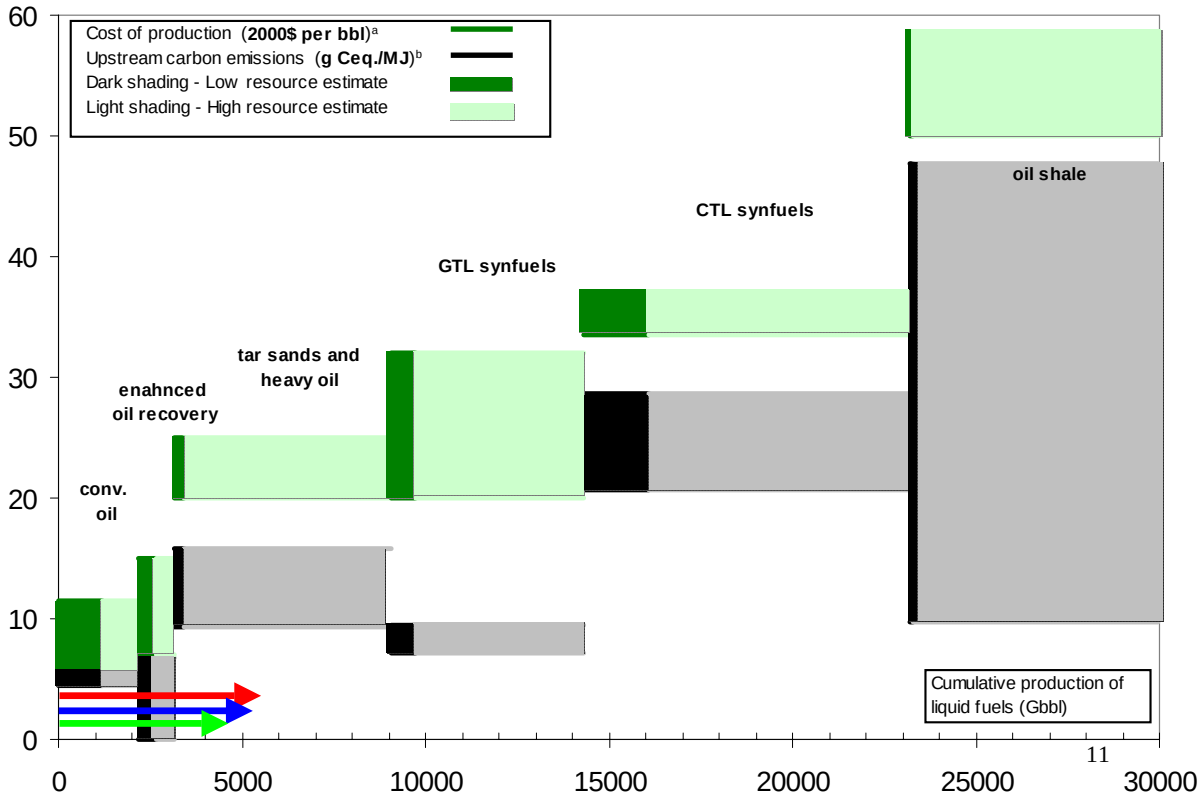
- These unconventional resources are more expensive and environmentally damaging
  - Supply curve with variable cost is included in Rogner, thus in SRES
  - However, Rogner does not describe excess emissions from substitutes

	Emissions (gCeq./MJ of refined product)					
	Gasoline		Tar sands and extra-heavy oil			
			Low emissions		High emissions	
Upstream	5.6	(21%)	9.3	(31%)	16	(44%)
Combustion	20	(78%)	20	(69%)	20	(56%)
Total	26		29		36	
Normalized	**1**		**1.14**		**1.39**	

Global supply curve for liquid hydrocarbons



Global supply curve for liquid hydrocarbons



3 types of uncertainty

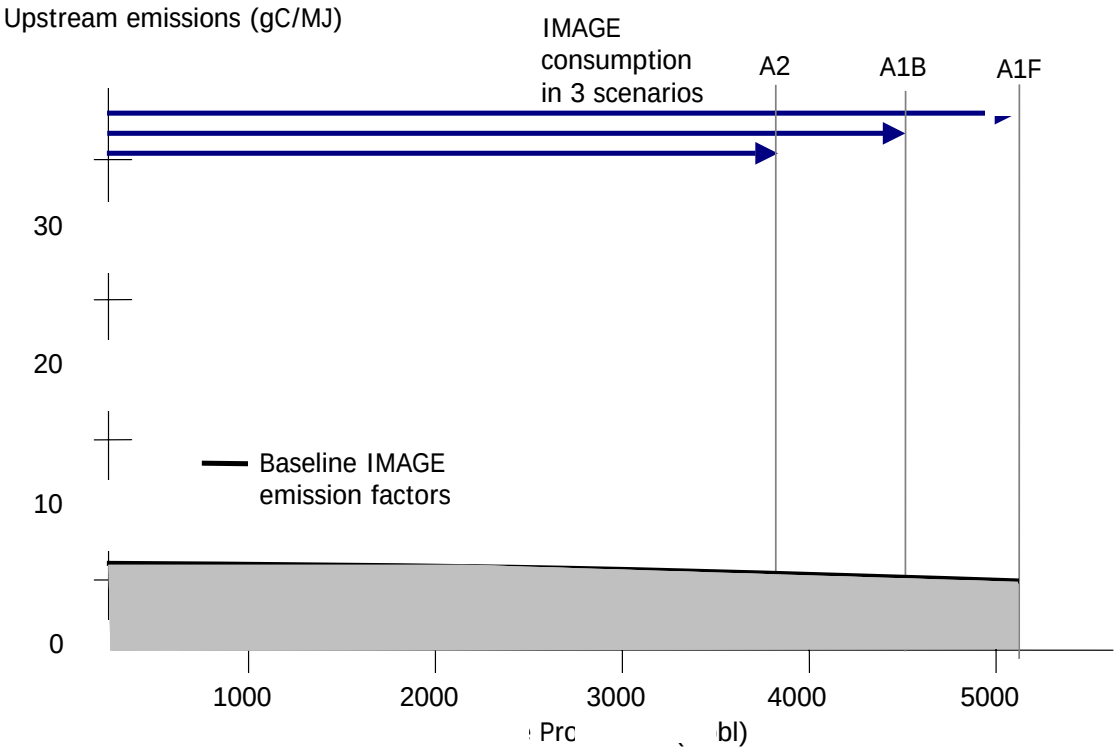
- Using this supply curve, we can study 3 types of uncertainty in SRES modeling of transition

1. Upstream emissions factors for unconventional production
   - Unaccounted for in IMAGE and MESSAGE
   - Partially represented in miniCAM

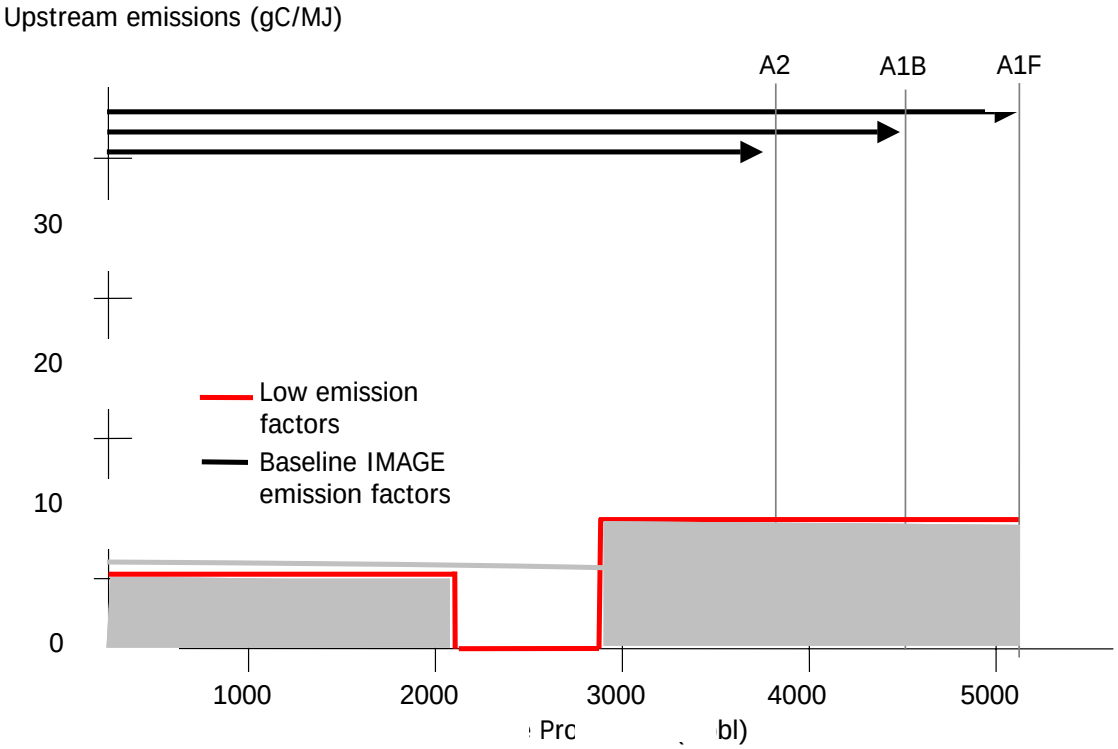
2. Varying estimates of conventional EUR
   - Not included in any SRES model
   - Possibly implicit in different scenarios

3. Failing to include synfuels
   - Not included in any SRES model

Uncertainty 1) upstream emissions factors



Uncertainty 1) upstream emissions factors



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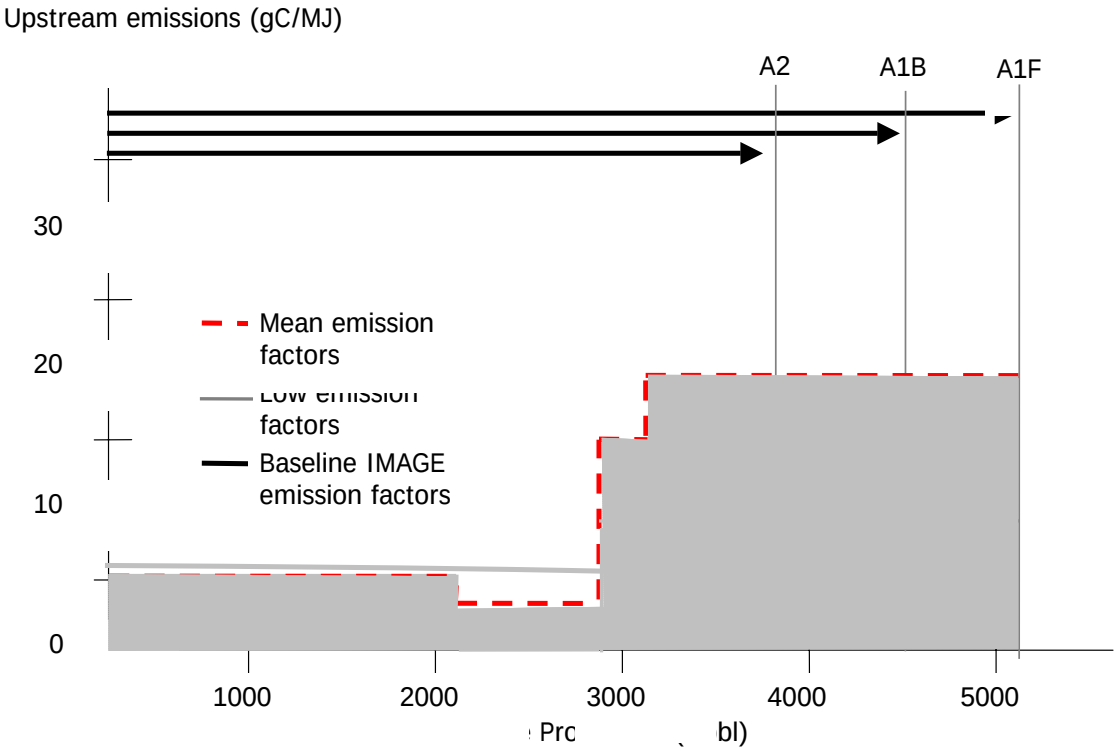

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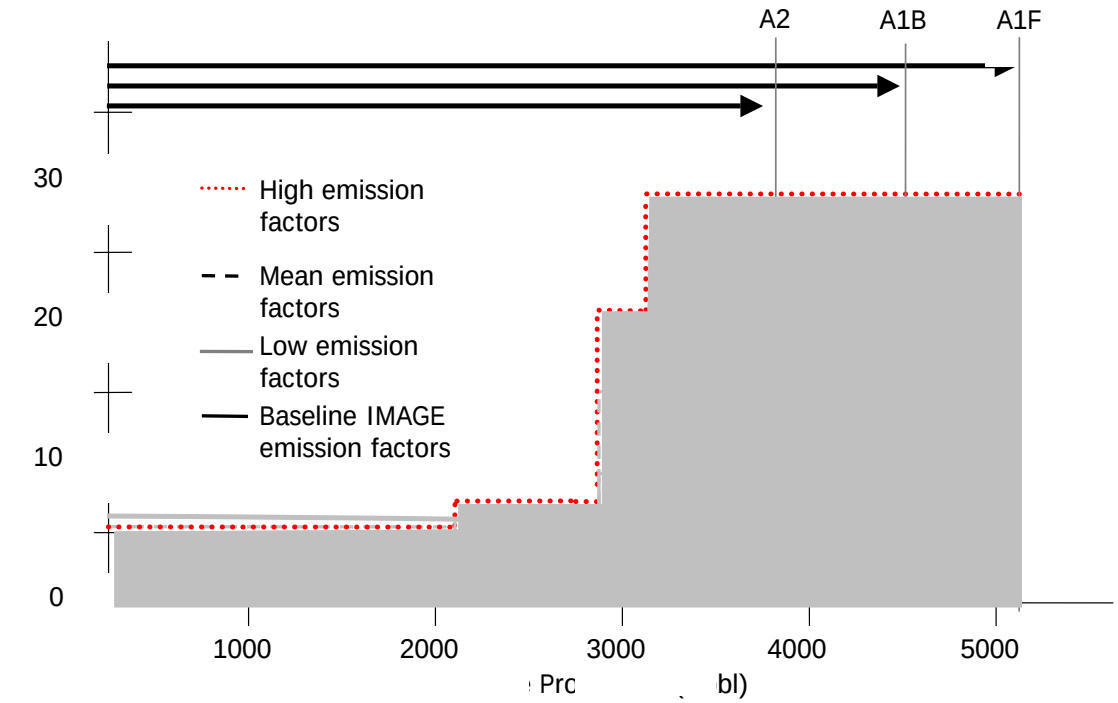
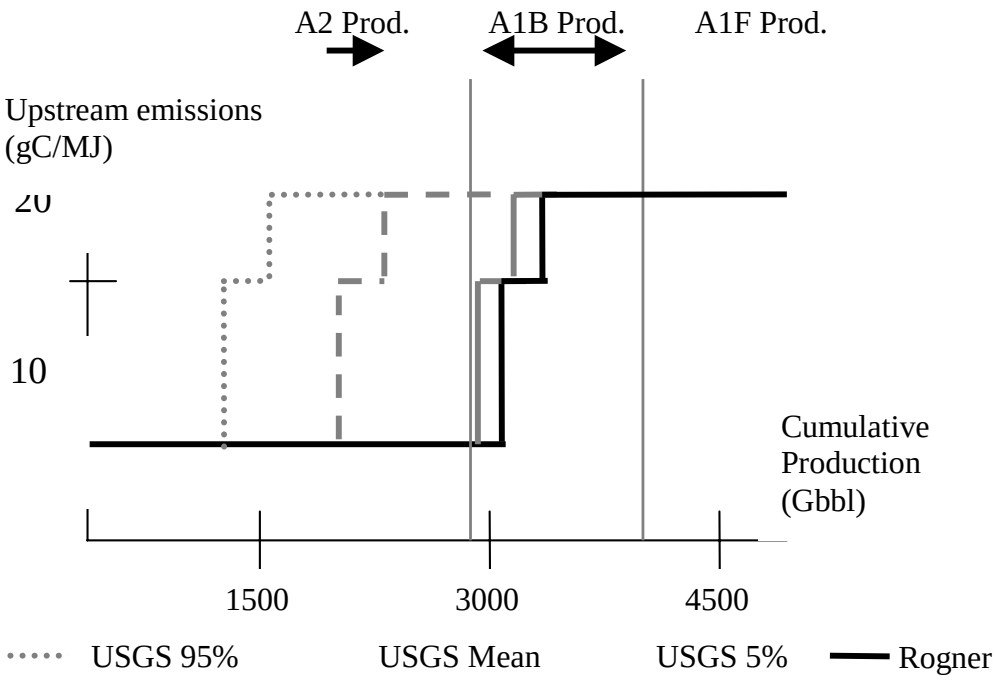


Uncertainty 1) upstream emissions factors

- Using mean emission factors for unconventional oil, cumulative upstream emissions could be 20-130 GtC higher extra emissions relative to the baseline IMAGE results, depending on the scenario.

Uncertainty 2) varying estimates of conv. EUR



Uncertainty 2) varying estimates of conv. EUR

Cumulative upstream emissions using MESSAGE (GtC 2000-2100)

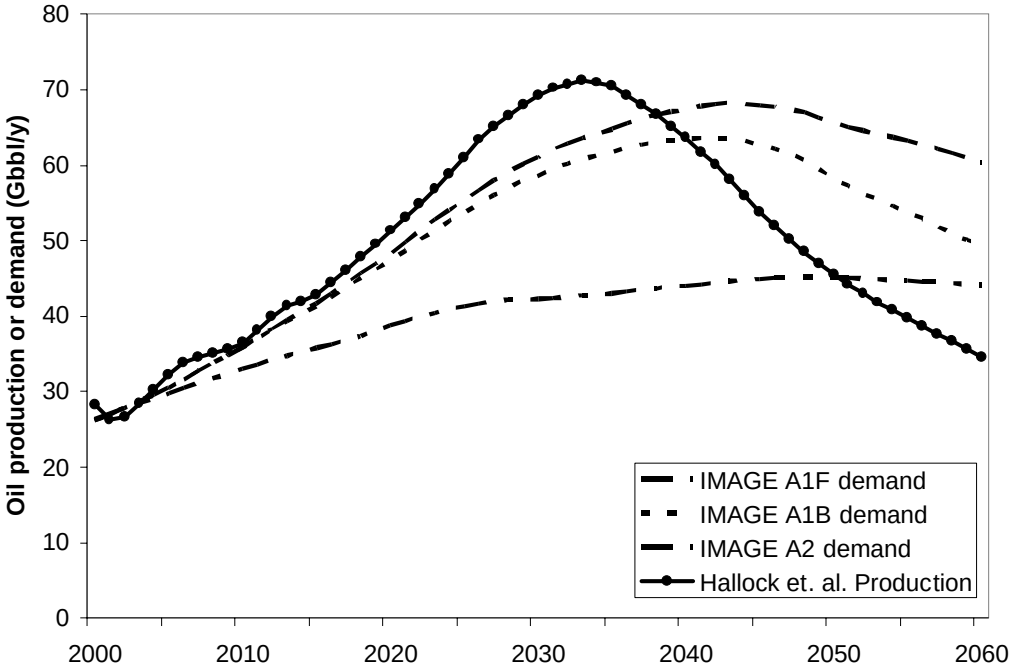
	A2	A1B	A1F
Rogner[a]	93	180	358
USGS 5% Probability	93	195	373
USGS 50% Probability	152	273	451
USGS 95% Probability	224	344	522

Uncertainty 3) Synthetic petroleum

- Assume USGS 5% likelihood EUR value
  - Close to Rogner's conventional oil resource categories I-IV, which includes EOR
- Calculate "shortfall" between IMAGE implied production scheduel and a forecast production schedule based on USGS 5% (Hallock et al. 2004)
- Estimate additional GHG emissions from filling the shortfall
  - GTL
  - CTL

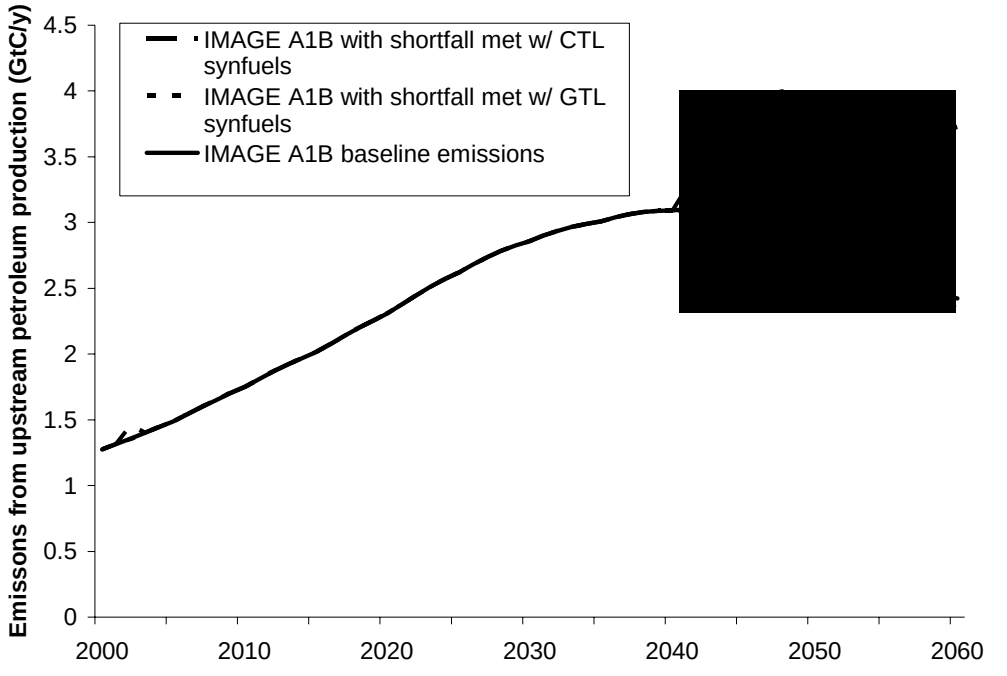
Uncertainty 3) Synthetic petroleum

Calculate the shortfall



Uncertainty 3) Synthetic petroleum

Estimate additional GHG emissions



Conclusions and further work

- Scenarios that include persistent shortages or persistent, exceptionally high oil prices (>$50/bbl) seem implausible.
- The potential for additional emissions in SRES scenarios is clear.
- Additional detail should be incorporated into future emissions models to ensure proper understanding of the potential emissions from oil substitutes.
- If liquid hydrocarbon production does not follow the least cost supply curve, these effects could be observed sooner and in greater degree.

- Simple model of global supply of liquid hydrocarbons (17 regions).

But, don't clap yet...

Acknowledgements

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