UCL Institute for Sustainable Resources

Modelling greenhouse policies and oil resource production

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Outline

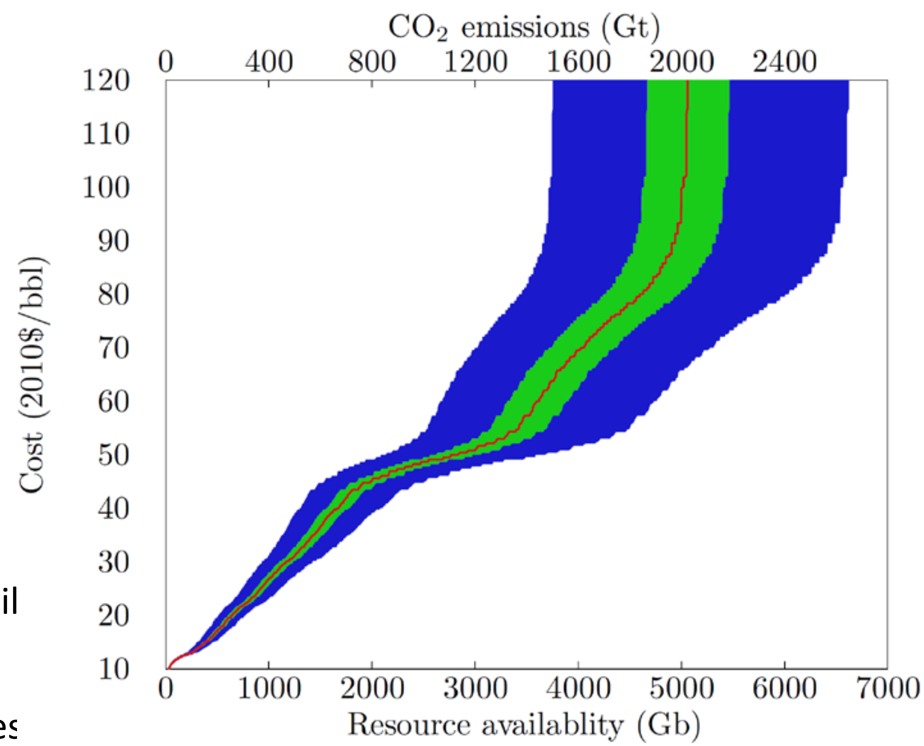
- Motivations and background
- Modelling approaches
  - TIAM-UCL
  - BUEGO
- Results
  - ‘Unburnable’ oil
  - The importance of considering uncertainty over future CO_2 emissions mitigation

Motivations and background

- UNFCCC entered into force in 1994 and recognised the need to prevent dangerous anthropogenic climate change
  - 'Dangerous' is a value judgement, but policy makers concluded that the warming should be limited to below 2°C
  - This has been explicitly included in the Copenhagen Accord of 2009 and the text adopted by the UNFCCC in Durban
- The IPCC has recently related the likelihood of staying within certain levels of average temperature rise to cumulative emissions of CO_2
  - Existing reserves (and resources) of fossil fuels vastly exceed the budgets associated with a 2^{o}C rise
- However, level of future GHG emissions reductions are only one source of uncertainty affecting oil and gas projections
- Many of the existing models aiming to project oil and gas production and consumption choose to focus only on one side of the market
  - Curve fitting
  - Pure demand side modelling
  - Consequently cannot take account of real production and market dynamics
- Need to use models that take account of whole energy system (including emissions) to project future oil and gas production and consumption

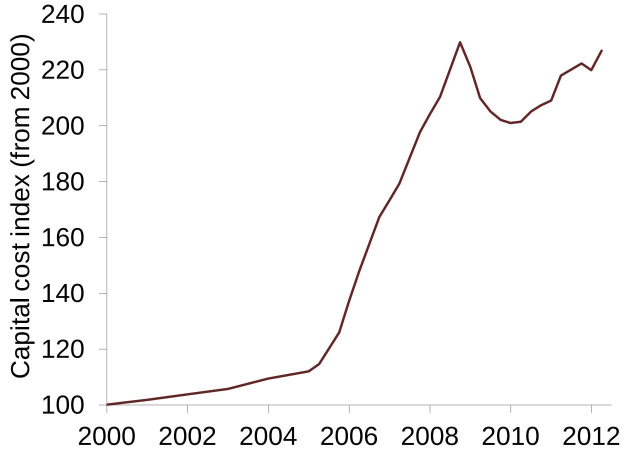
Example of uncertainty: resource estimates

- Uncertainty in resource estimates arises for a large number of reasons…
  - The use of contradictory, ambiguous or inconsistent definitions
  - Problems associated with sources that report reserve data
  - ‘Political reserves’
  - The inclusion of stranded volumes in reserve estimates
  - Estimating current and future recovery factors
  - Differences between methodologies used to estimate undiscovered oil and gas volumes
  - Scarcity of reports estimating volumes of Arctic oil and light tight oil and the prices at which these resources may become available
  - Which unconventional oil production technologies will be utilised
  - Chosen oil richness cut-off yield for kerogen oil
  - Functions utilised to estimate volumes of reserve growth
  - And many more…



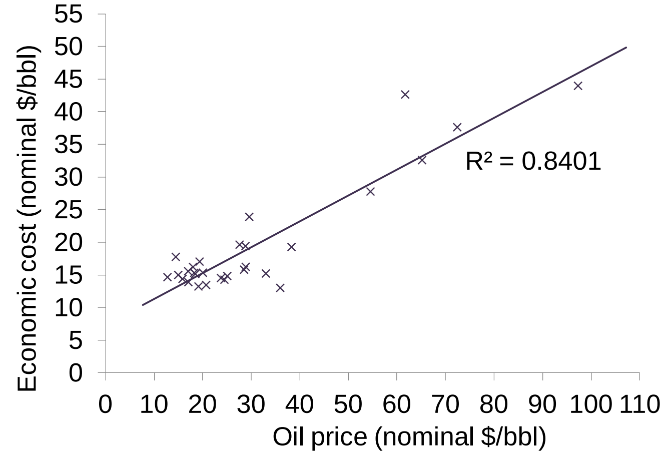
Uncertainty in ultimately recoverable resources of ‘all oil’

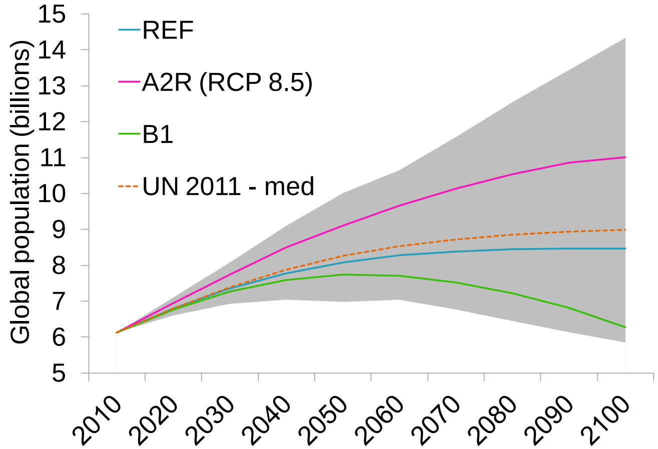
Other examples : Cost and GDP/population uncertainty



Production costs have doubled since 2005

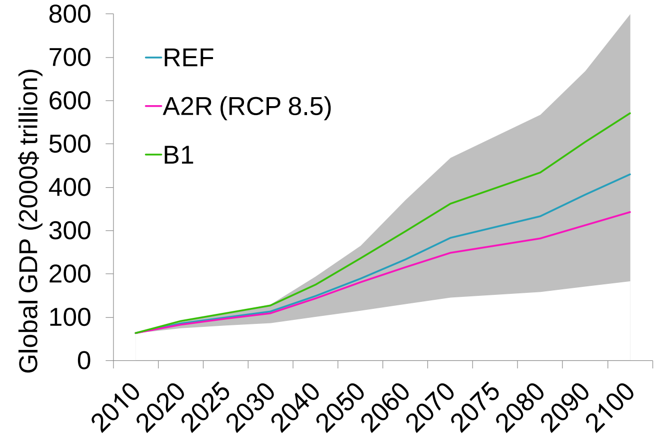
Close correlation with oil price





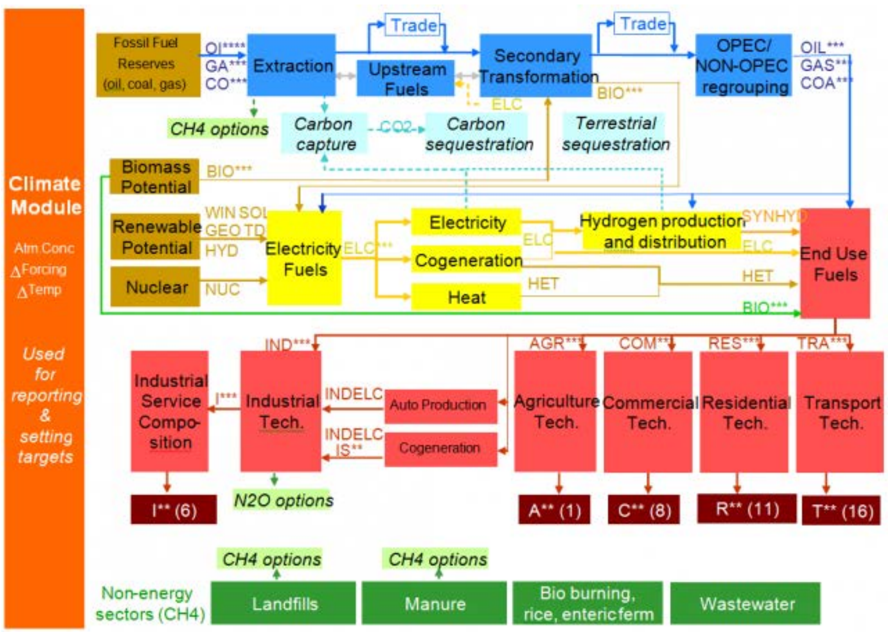
Macro-economic drivers of demand

Huge variation in future projections of population and GDP



- Assumptions over the level of future technological deployment and GHG emissions reduction are also likely to have major effects on projected oil and gas production levels
- Next, how to model these?

TIAM-UCL: bottom-up energy system model



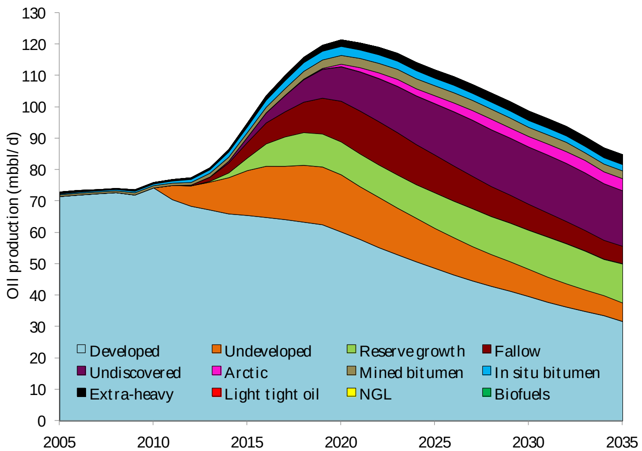
- TIMES Integrated Assessment Model (TIAM)
- Dynamic partial equilibrium model with objective function that minimises total discounted costs
- Technologically detailed bottom-up whoel energy system model with reduced-from climate module
- 16 regions with flexible time horizon through to 2100
- Numerous modifications undertaken to improve fossil fuel modelling including:
  - Improving the resources availability and production costs of all fossil fuels
  - Introduction of region specific constraints on the growth and decline of conventional oil and gas production to model more accurately empirical and geological factors dictating possible rates of production
  - Introduction of new array of Fischer-Tropsch fuels (coal-to-liquids, gas-to-liquids etc.)

The 'Bottom-Up Economic and Geological Oil field production model'

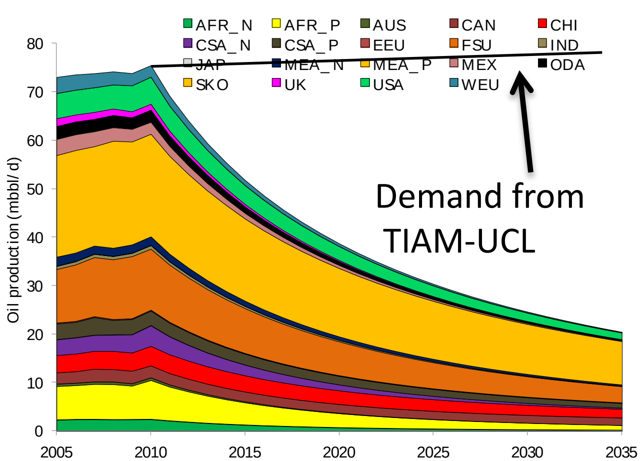
- TIAM-UCL cannot, however, take account of a number of specific sources of uncertainty including smaller-scale, shorter-term, geopolitical, or more oil-sector specific uncertainties
- Have therefore also developed BUEGO, which incorporates the major economic and geological factors driving oil production at a field level
  - Demand levels generated by TIAM-UCL
  - Examine expected behaviour of oil companies developing oil field projects
- Includes 7000 producing, undiscovered, and discovered but undeveloped oil fields
- Existing fiscal regimes of 133 countries
- Oil price generated endogenously

Model details

Maximum production

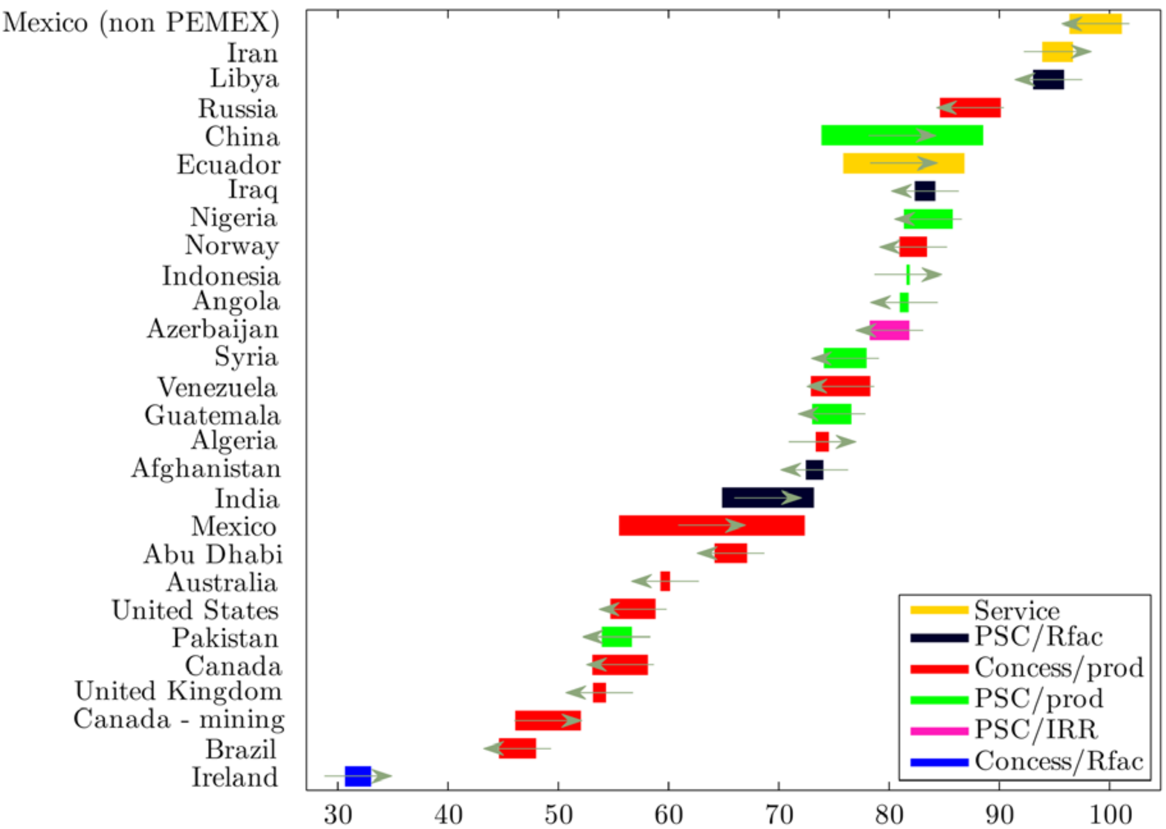


With no capital investment



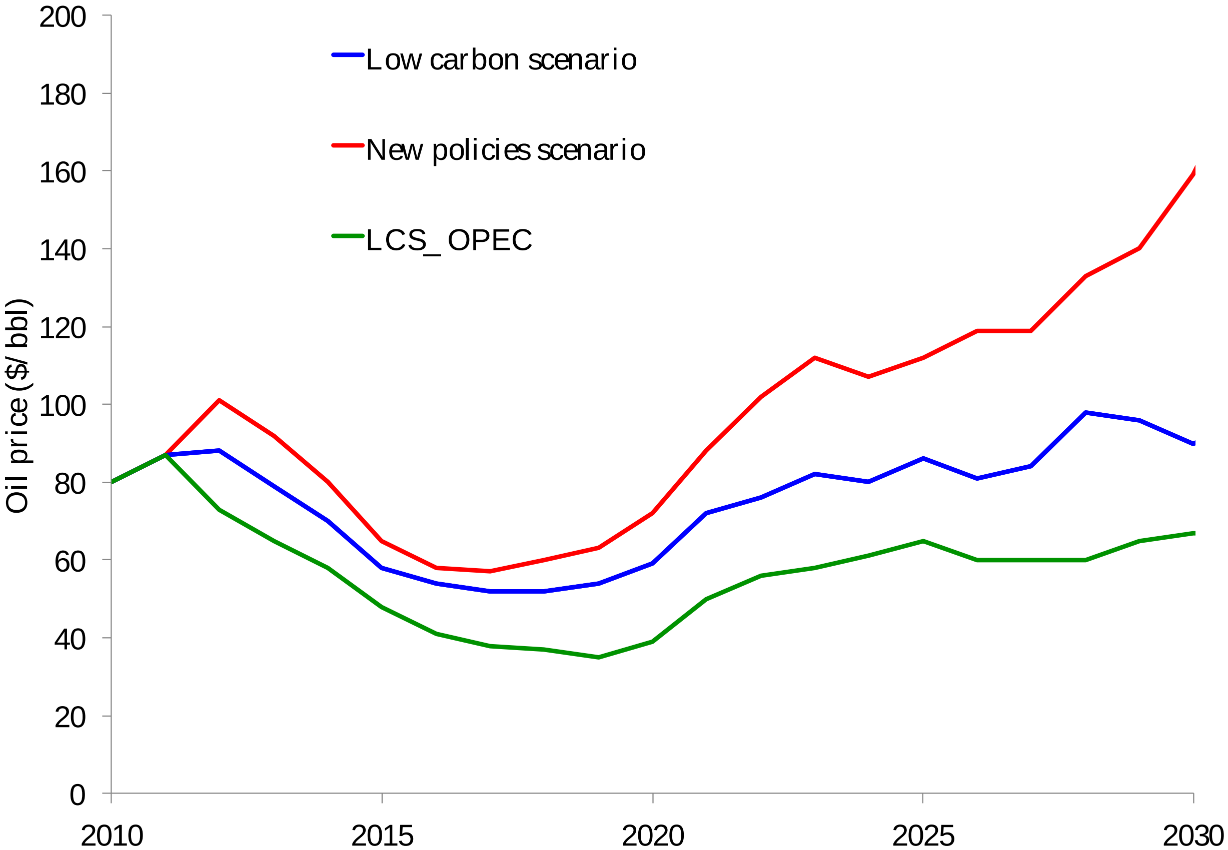
- Relies upon existing geological model containing a detailed representation of each of the 7000 field's:
  - 2P reserves
  - Potential capacity additions
  - Natural decline rates
- Have added field level:
  - Capital costs
  - Operating costs
  - Government tax takes
  - Water depths
- Operation of model
  - Net present value of each field calculated at an initially low assumed oil price
  - Field developed if NPV is positive
  - Oil price is increased (and so new fields will be developed) until demand matches supply in a given year
  - Model moves on to next year and repeats until 2035

Importance of accounting for government tax take



- BUEGO calculates the tax take at each iteration of the oil price for all potential capacity additions in each year
- Tax takes vary markedly both between and within countries
  - E.g. within a given country, tax take can vary for fields of different size, water depth, production potential etc.
- Field-level modelling is therefore needed to understand properly the tax levied by countries (and the NPV of new projects)
- Figure demonstrates the effect of varying the oil price from $70-110/bbl for a field of a fixed size in each country
  - Arrows give direction of change
  - Colours indicate nature of fiscal regime

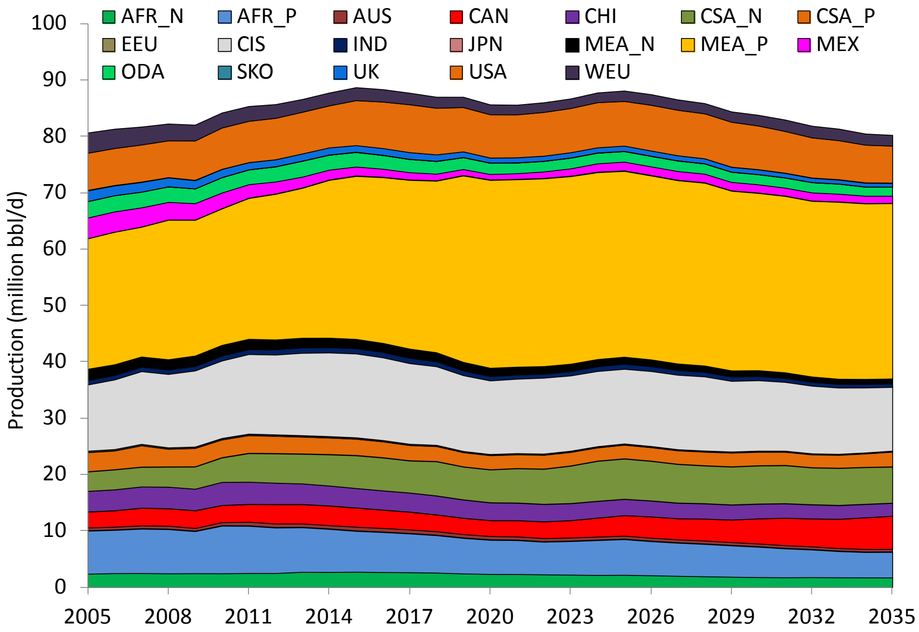
Example output: 'Oil price' generated under a selection of scenarios



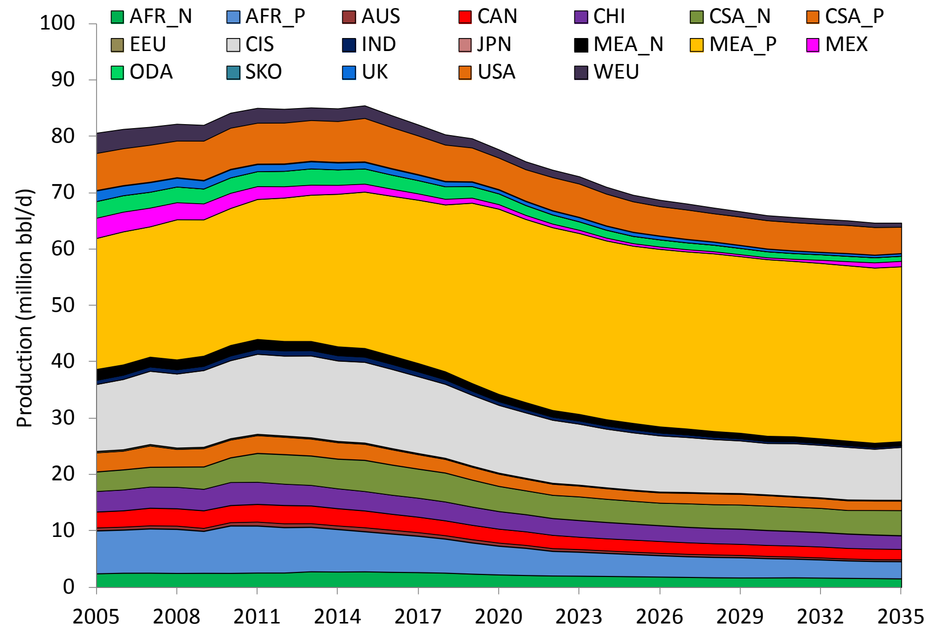
- BUEGO results suggest that following an initial peak in 2012 (results suggest) there will be a softening of prices throughout the 2010s
- Whether this will actually happen is another matter…
- Results also suggest that if OPEC restrictions are removed, the oil price would drops by around $15/bbl in 2010s and $25/bbl in 2025

Example output: unburnable oil

- To have a reasonable chance of staying below 2°C, going to need to leave some fossil fuels in the ground
- Use BUEGO to help understand that with a global effort to mitigate emissions, how much oil does not need to be used, and where is this located?

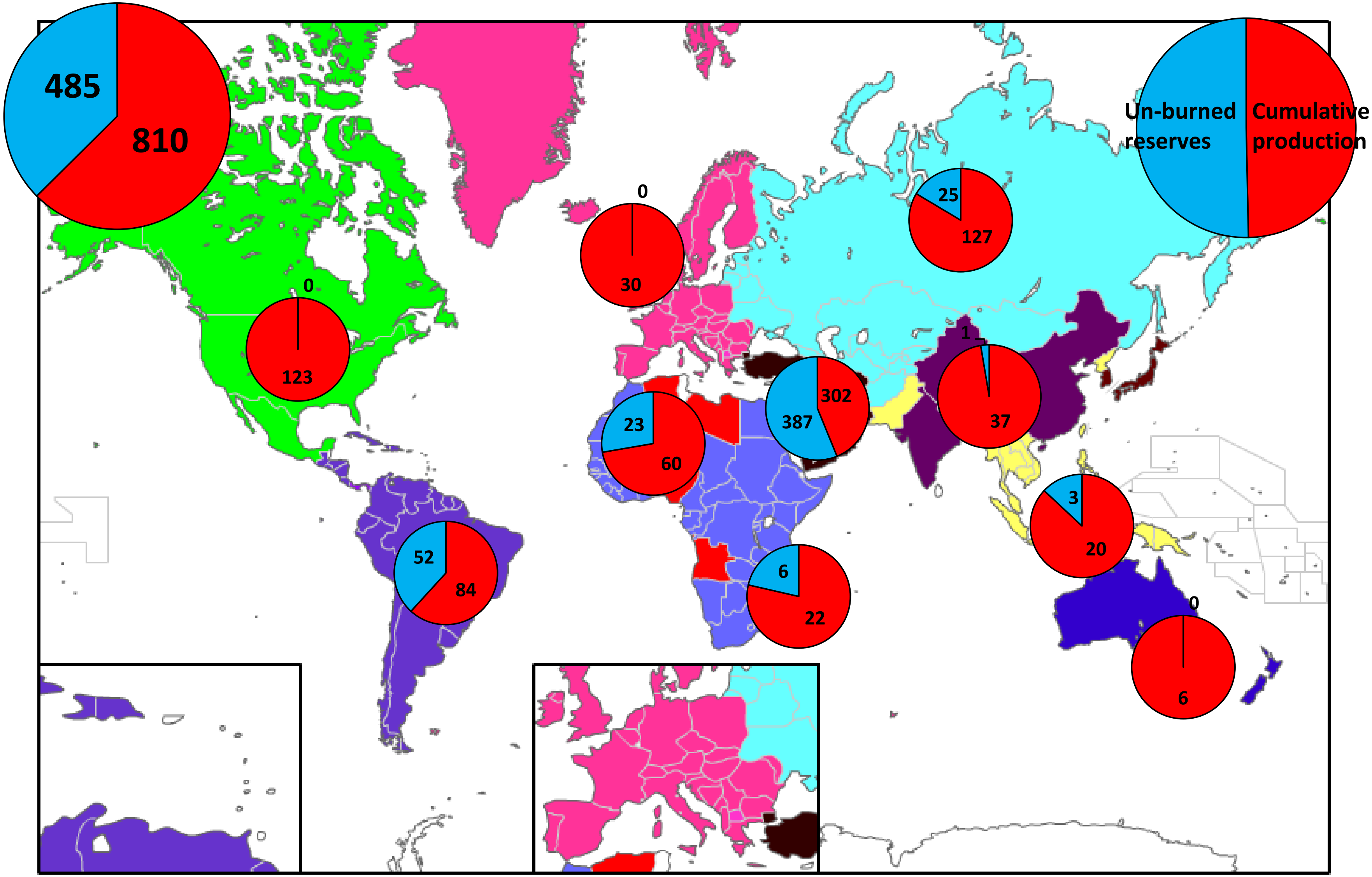


2°C scenario with CCS



2°C scenario without CCS

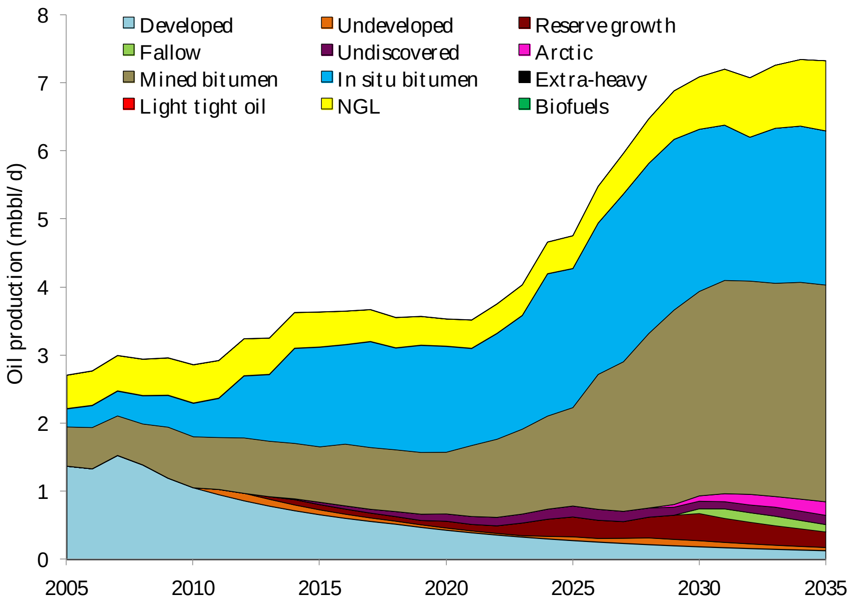
Distribution of unburnable reserves when CCS is allowed



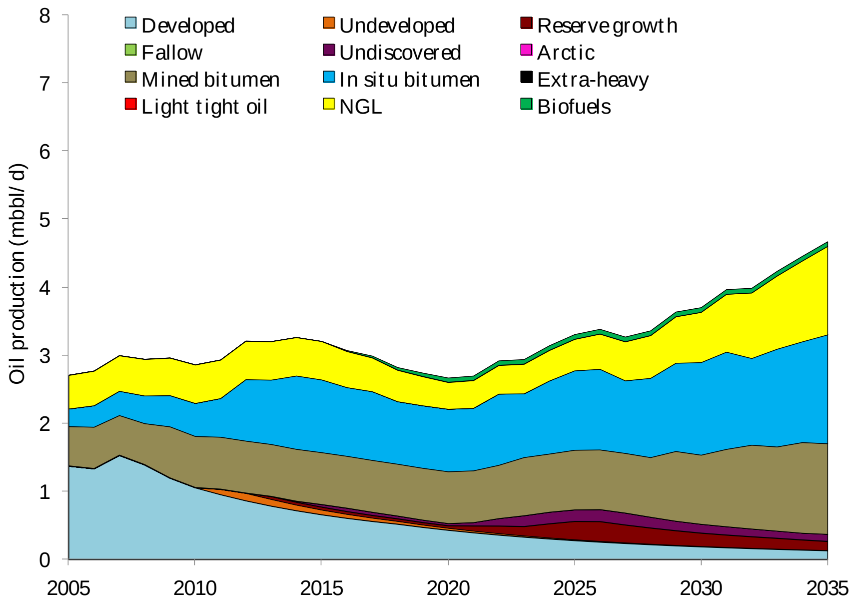
Unconventional oil

- Assuming different demand levels affects production both on a global level and within certain countries
- E.g. in Canada the switch from a 3.5°C scenario to 2°C severely constrains oil production
  - Even then this assumes CCS is available and there is a rapid decarbonisation of the energetic inputs to unconventional oil production.

3.5°C scenario – production exceeds 7 mbbl/d in 2035

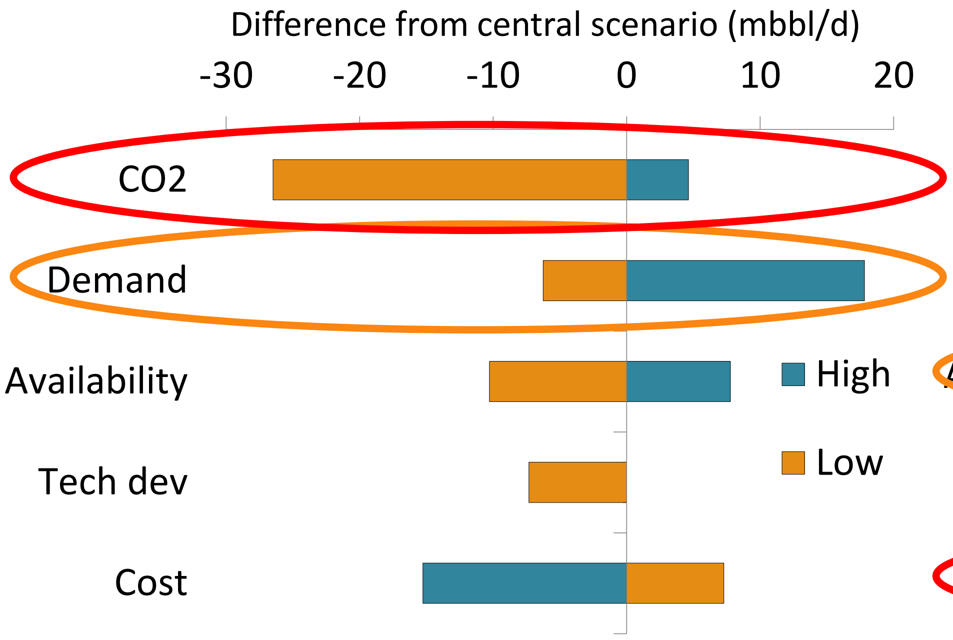


2°C scenario with CCS – production fails to reach 5 mbbl/d in 2035

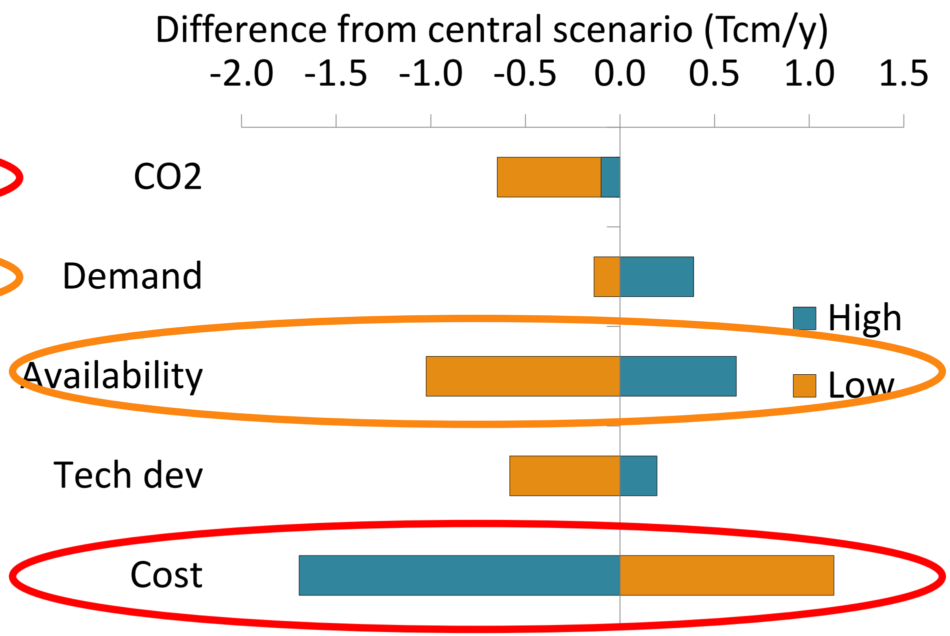


Effects of uncertainty on production levels

- Can test the importance of different major sources of uncertainty using TIAM-UCL



Differences in oil production in 2050



Differences in gas production in 2050

Conclusions and lessons for new oil and gas models

- There are numerous uncertainties that can have a major effect on oil and gas projections
  - Need to focus on scenarios and not 'predictions', particularly changes between different scenarios
  - Understanding these uncertainties and mitigating them to the extent possible will lead to more robust outlooks
  - Of all sources of uncertainty examined, uncertainty over future emissions reductions have the most significant effect on oil production projections. This therefore cannot be ignored.
  - Different sources of uncertainty have the largest impact on oil and gas projections. Different scenarios need to be implemented to explore future potential levels for the two commodities
  - By considering some areas of uncertainty, it may be possible to reduce the sensitivity to other sources of uncertainty (e.g. if CO_2 emissions reduction is considered, then uncertainty over resource potential is less important since much of the reserve base must remain unused)
- Need for a whole systems approach to modelling oil and gas production and consumption within the global energy system
  - Curve fitting or simple demand-side modelling are not suitable for producing robust outlooks
- Disaggregated (i.e. field-level) modelling is the best method for producing reliable projections
  - Tax-take varies on a field-by-field basis. Difficult to calculate what the specific tax take (and hence price required for development to proceed) will be for new projects if modelling at a country or regional scale
  - Cost data is more reliable at the field level and easier to model how it depends on components and so might change in the future
  - Quality of crude produced is field-specific
- Modelling at a more aggregated level (e.g. country or regional) is nevertheless possible, but requires careful calibration with field-level models
  - Need to ensure natural decline rates or depletion rate constraints are properly specified
  - Need to ensure different categories of oil (developed reserves, undeveloped reserves, reserve growth, undiscovered, Arctic, unconventional, deepwater, NGL etc.) are specified separately (as have very different characteristics and potentials)

Thank you

Any questions?

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