Long term energy prices – interdependencies between market power, resource availability and demand options:

A sensitivity analysis with the soft coupling of TIAM and LOPEX

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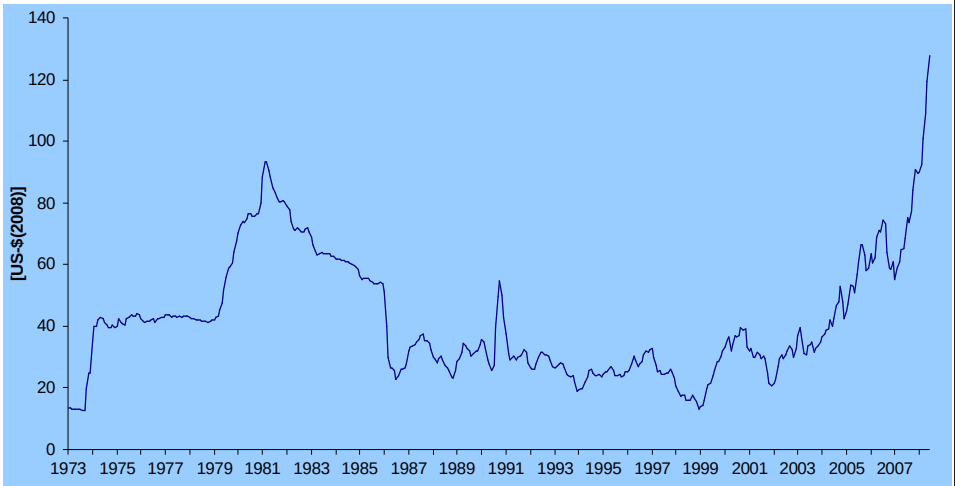
Overview

- Introduction
  i. Factors influencing the oil price
- Methodological approach
  i. Linking an oil market and an energy system model
- Sensitivity analysis on various factors
- Conclusions

Historic development of global oil price



* Oil Price is Saudi Light until Dec 1973 and Refiner Acquisition Cost afterwards, deflated with the CPI to 2008

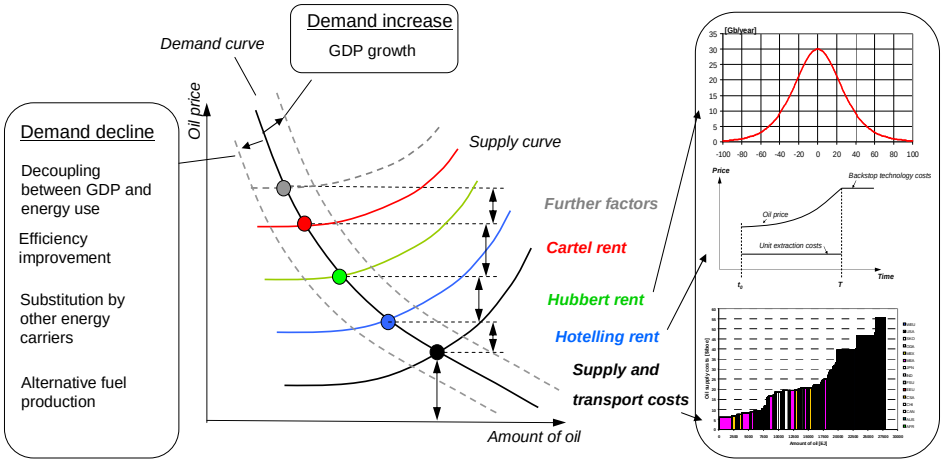
Factors influencing the oil price

- **Short-term price fluctuations caused by:**
  i. Production or transport disruptions
  ii. High degree of capacity utilization in production and processing
  iii. Storage of oil
  iv. Geopolitical instability and risks
  v. Speculation
  vi. Exchange rate fluctuations
- **Long-term factors influencing the oil price:**
  i. Limitations in the temporal availability by restrictions in production rates; decline of new discoveries due to lack of investments in exploration
  ii. Reserve / Resource situation
  iii. Lack of investments in development of new fields
  iv. Market structure:
    1. Cartel behavior
    2. Regulatory framework, taxes, royalties in producing countries
  v. Demand development
  vi. Availability of technologies for production of synthetic fuels or biofuels

Fundamental factors of long-term oil price formation

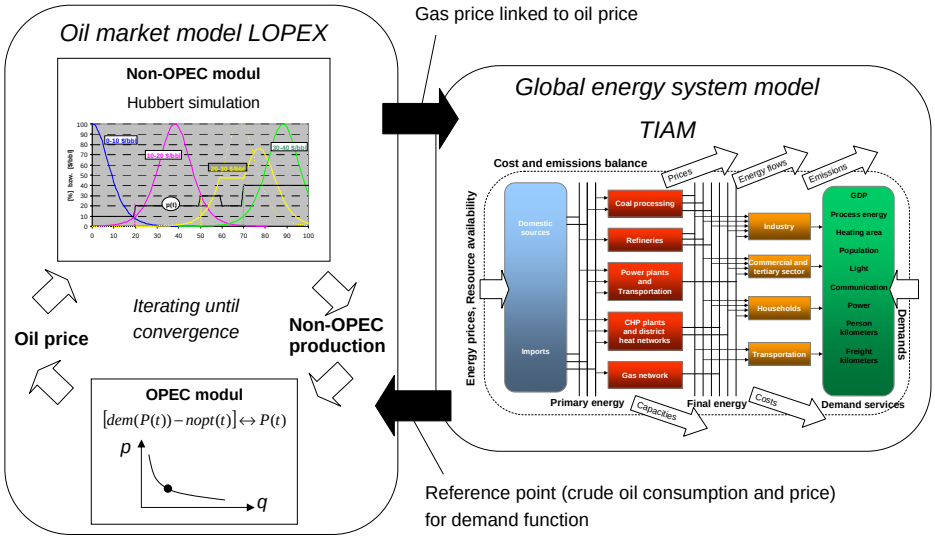
Demand side

Supply side



Modelling approach

Cartel rent for crude oil,
Gas price linked to oil price



Reference point (crude oil consumption and price) for demand function

Oil market model: LOPEX

Periods: 10-year periods from 1980 to 2100 (1976-1985,...,2096-2105).

2 Regions: OPEC = perfect cartel, Non-OPEC = competitive fringe (simulation).

Typ: Optimizing overall discounted OPEC-Revenue under perfect foresight

$$\underset{P(t),\ X_{OPEC}(t)}{Max} \sum_t d(t)\cdot\left(P(t)\cdot X_{OPEC}(t) - SUPPLYCOST\left(X_{OPEC}(t), R_{OPEC}(t)\right)\right)$$

Format: Mixed Complementary Programming (MCP)

Constraints:

- limited resources: $\sum_t X_{OPEC}(t) \le R_{OPEC}(t)$

- OPEC covers demand determined by iso-elastic demand function minus non-OPEC production: $X_{OPEC}(t) = d_{ref}(t)\cdot\left(\frac{P(t)}{p_{ref}(t)}\right)^{\varepsilon(t)} - nop(t)$

- Non-OPEC production modeled by Hubbert curves

Global energy system model: TIAM

- ***T*IMES *I*ntegrated *A*nalysis *M*odel**
- **Based on TIMES model generator:**
  i. Developed by ETSAP
  ii. Dynamic partial equilibrium model approach with inter-temporal objective function (perfect foresight) minimizing total discounted system costs
  iii. Technologically detailed „bottom-up" model for each region
  iv. Covering energy flows from the useful energy demand over end-use sectors and conversion sector to the primary supply
- **Time horizon 2000 – 2100**
- **15 world regions with**
  i. Bilateral trade in hard coal, pipeline gas, LNG, crude oil, petroleum products (distillates, gasoline, heavy fuel oil and naphtha) and bioethanol
  ii. Global trade in emission permits possible
- **Emissions: CO_2, N_2O, CH_4**
  i. Carbon capture and sequestration (power generation and alternative fuel production)
  ii. Mitigation options for N_2O and CH_4
- **Climate module** (3-reservoir model for calculating atmospheric CO_2 concentrations)
- **Multi-stage stochastic programming** (uncertainties in emission targets, demands, bounds)

Scope of scenario analysis

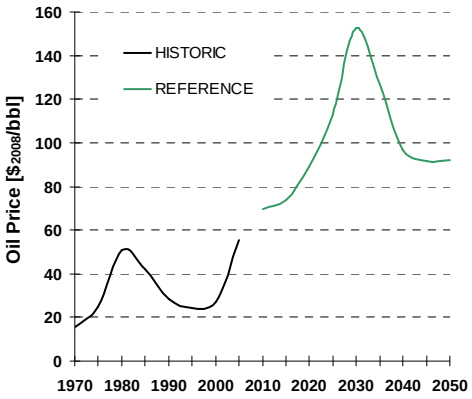
- Scenarios analyzed:
  i. REFERENCE scenario: Long-term equilibrium on oil market incl. OPEC's cartel behavior

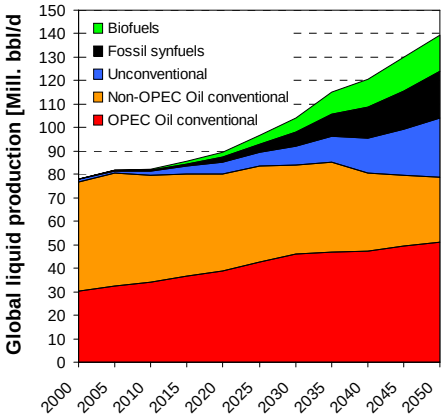
Socio-economic assumptions	2000 - 2010	2010 - 2020	2020 - 2030	2030 - 2040	2040 - 2050
Global GDP growth	3.1%	2.9%	2.8%	2.6%	2.5%
Global population growth	1.1%	0.9%	0.7%	0.7%	0.6%
Maximum liquid supply [million bbl/d]:	**2010**	**2020**	**2030**	**2040**	**2050**
Unconventional	2	5	8	15	25
Alternative fuels	0.6	6	12	25	50

Scope of scenario analysis (contd.)

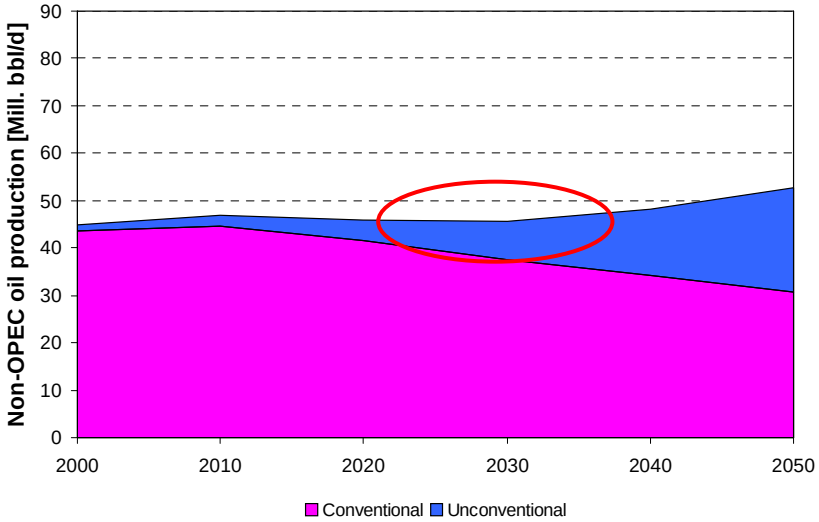
- Scenarios analyzed:
  ii. Sensitivity of oil price on factors on the supply side:
    1. EOR+TPROG: Increasing recovery factor from 50% to 60% plus technological progress in oil supply (cost reduction of 0.5%/year)
    2. UNCONV: More optimistic assumptions on growth in production of unconventional oil (oil sands, oil shale)
    3. FT+BIOFUEL: More optimistic assumptions on growth in production of liquid fuels by Fischer-Tropsch conversion of coal, natural gas or biomass and of methanol/ethanol
  iii. COMBI: Combination of all three supply factors plus option to increase electricity use by increased electricity supply from nuclear power
  iv. Sensitivity of oil price on oil demand (LOW DEMAND): Lower GDP growth
  v. Sensitivity of oil price on OPEC behaviour (OPEC): Disintegration of OPEC
  vi. Sensitivity of oil price on climate policy (CO2): Introduction of a CO_2 price of up to 350 $/t by 2050

Reference scenario

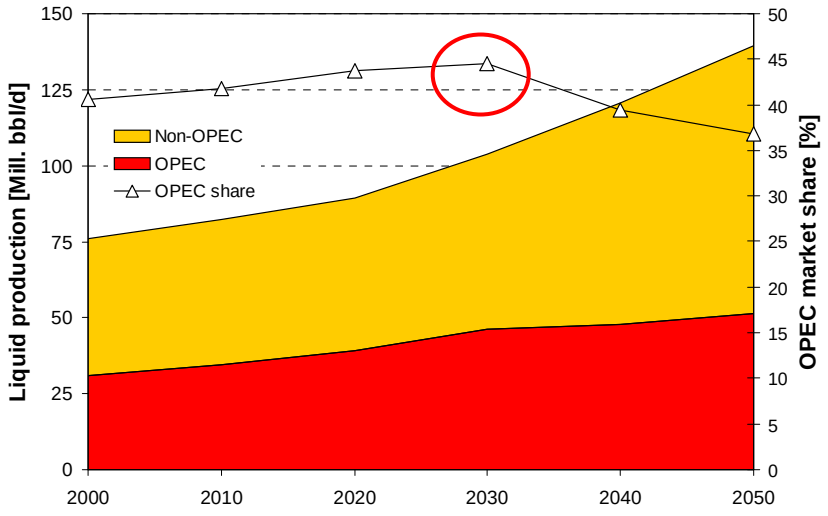




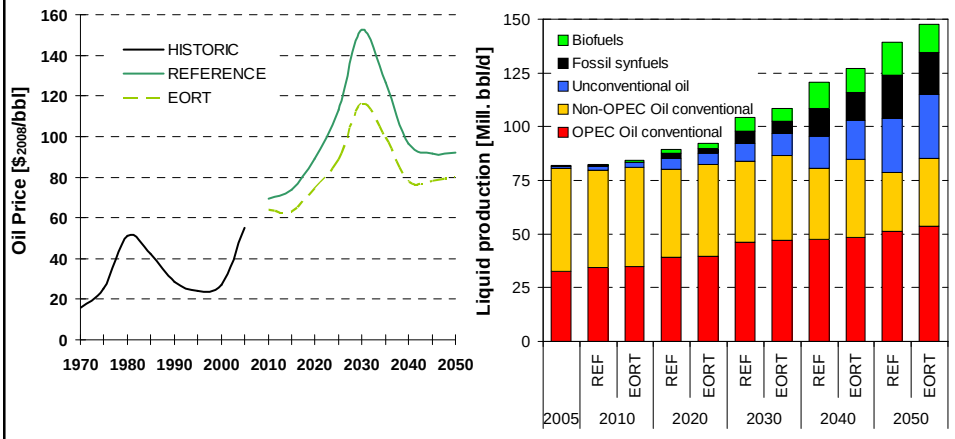
Non-OPEC production



Reasons for oil price increase in 2030

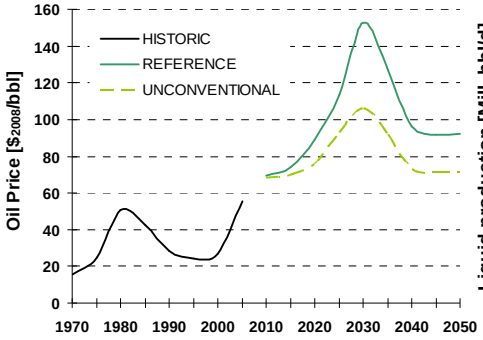


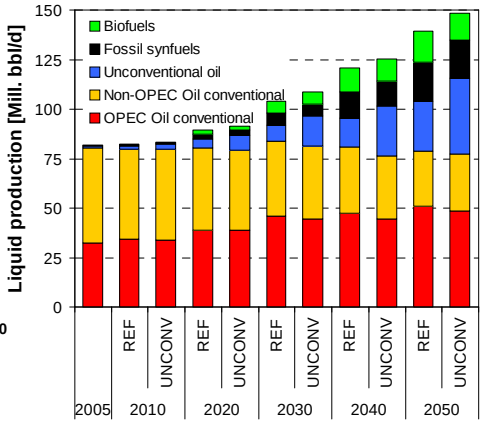
Better use of resource base



- Assumptions:
  - i. Increased recovery factor for conventional oil from 50 % to 60 %.
  - ii. Technical progress: Oil supply costs decrease by 0.5%/yr

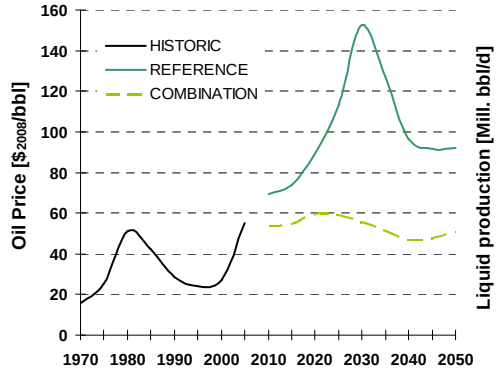
Development of unconventional resources

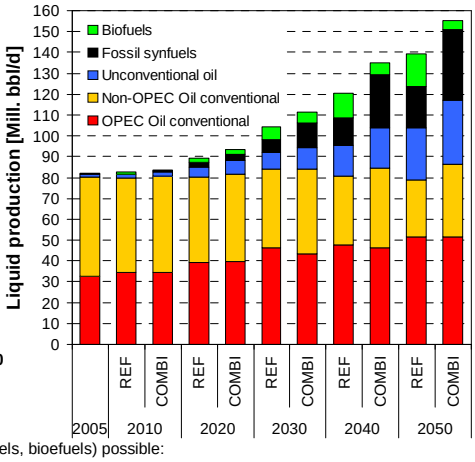




Max. unconventional oil production [million bbl/d]:	2010	2020	2030	2040	2050
Reference scenario	2	5	8	15	25
Unconventional scenario	3	8	15	25	38

Combination of supply side options

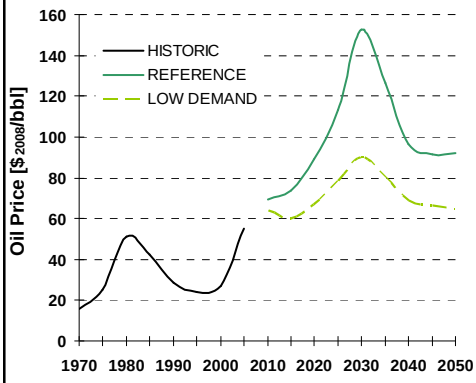


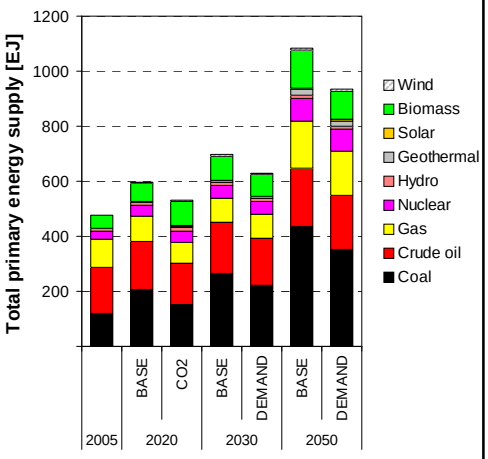


- Assumptions:
  - i. EORT + UNCONV + Option to use more electricity
  - ii. Increased production of alternative fuels (fossil synfuels, bioefuels) possible:

Max. alternative liquid production [million bbl/d]:	2010	2020	2030	2040	2050
Reference scenario	0.6	4.3	12.0	26.0	40.0
COMBI scenario	1.1	6.5	22.0	50.0	67.0

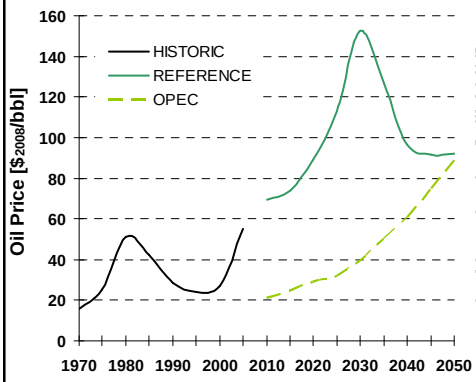
Lower economic growth

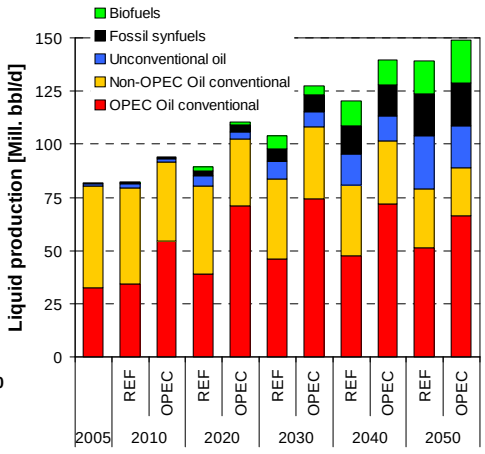




Global GDP growth	2000 - 2010	2010 - 2020	2020 - 2030	2030 - 2040	2040 - 2050
Reference	3.1%	2.9%	2.8%	2.6%	2.5%
Low demand	2.7%	2.4%	2.4%	2.3%	2.2%

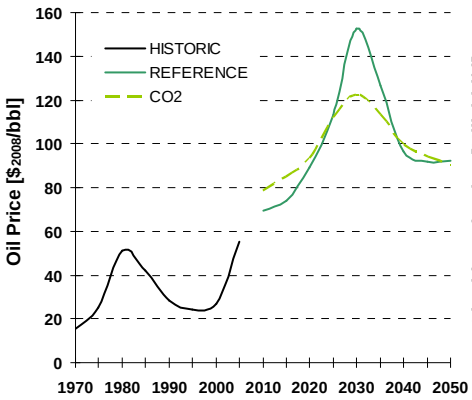
Disintegration of OPEC

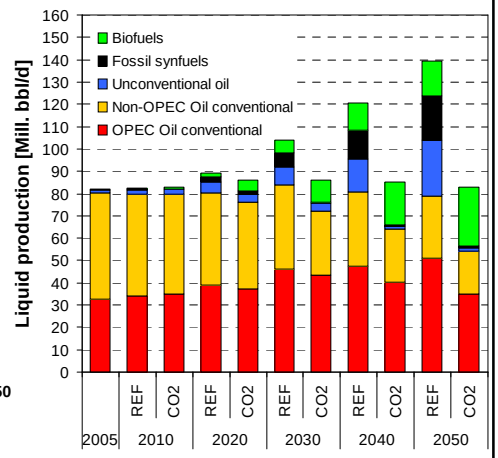




- Assumption:
  i. Current OPEC members do not act as cartel anymore after 2010.

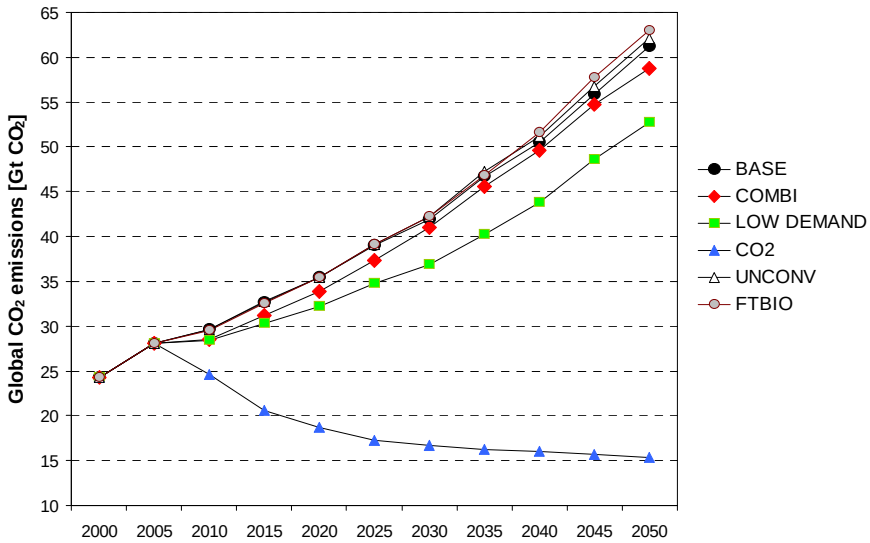
Climate Policy





- Assumption:
  i. Global CO_2 price increasing from 25 $/t to 350 $/t in 2030 and afterwards staying at that level.

CO_2 Emissions



Conclusions

- **Reference scenario: Price peak in 2030 of 150 $/bbl caused by**
  i. decline in conventional non-OPEC production and
  ii. at the same time non-sufficient supply from unconventional oil and alternative liquids allowing OPEC to exercise market power;
  iii. after 2030 OPEC's influence decreases by increased production from unconventional (oil sands) and alternative fuels (FT fuels).
- **OPEC cartel behavior largest price component.**
- **Improvements in oil recovery reduce scarcity and lead thus to lower prices.**
- **Rate by which unconventional and alternative fuels can be introduced also critical for price reductions, since:**
  i. Conventional oil can be saved -> scarcity rent becomes lower (smaller price impact),
  ii. OPEC's market power shrinks (major price impact).
  iii. But, lower prices also imply higher overall liquid fuel demand.
- **Factors reducing price and at the same time demand are:**
  i. Substitution options for oil on the demand side,
  ii. Lower economic growth,
  iii. CO_2 mitigation measures (however, overall price for burning oil increases).