

# Future energy systems under resource constraints

A case study on oil resources using the POLES model



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- ▶ **1. The POLES model**
- 2. Oil resources for long-term forecasts
- 3. CO2 policies and the oil market
- 4. Beyond the « oil issue »

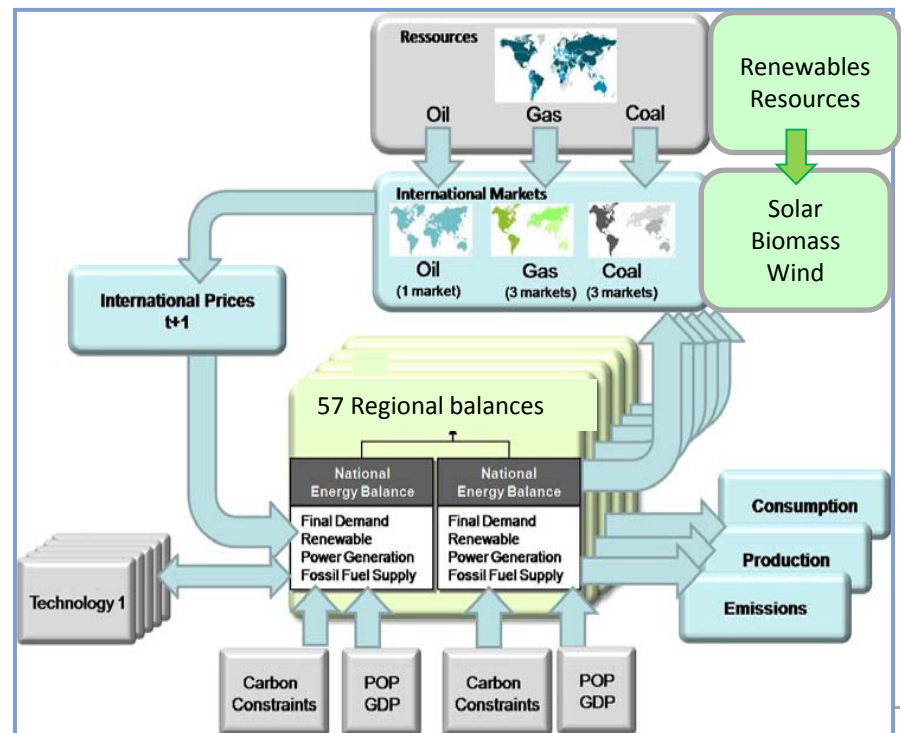
# POLES – An integrated tool to assess the role of energy resources in future energy systems

## ■ Main features

- Projections of energy demand & supply by country and commodity up to 2050 (-2100)
- Projection of international oil, gas, and coal prices and end user prices (inc. power)
- Simulation of GHG emissions, analysis of GHG abatement strategies
- Simulation of future technology developments in the energy sector

## ■ Structure and fonctions

- Yearly dynamic recursive, includes anticipation behaviors
- Simulation of energy balances for 57 countries/regions
- Disaggregation into 15 energy demand sectors, 50 energy-related technologies & technological learning
- **Simulation of oil and gas : 80 countries**
- Full power gen system
- **Uranium & renewables resources**
- International energy prices and markets (oil, gas, coal)



# Oil resources, discoveries & reserves : the creaming curves

## Conventional oil discoveries:

- Resources = Oil in Place x Recovery Rate
- Recovery Rate =  $f(\text{Oil price})$
- Discoveries increase with cumulated drilling
- Reserves = Discoveries – Cum. production

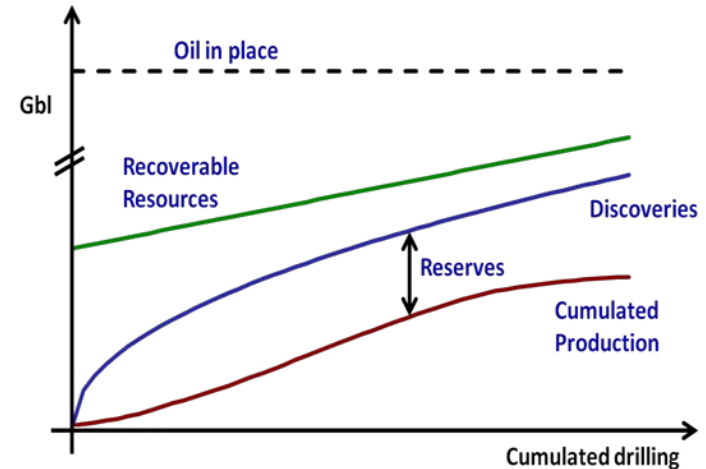
## Unconventional oil supply:

- Reserves = Resource in Place x Recovery rate
- Recovery rate =  $f(\text{Oil price})$
- Production:

$\ln(\text{Prod}) = f(\text{Oil Price} - \text{ProdCost})$ , with:  $\text{ProdCost} = f(\text{Env constraint})$

*Production cost increases with carbon value and past production due to increasingly stringent environmental norms on producers (inc. CO2 emissions)*

**Oil price** =  $f(\text{R/P World, Utilisation rate in Gulf})$

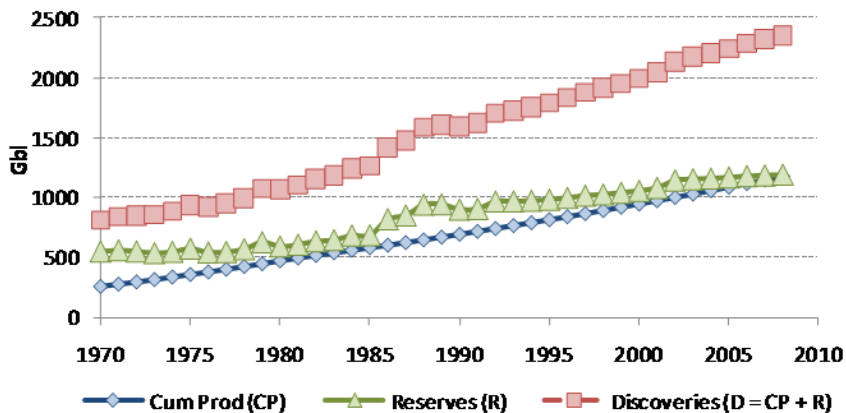


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# Historical picture – Very contrasted views on discoveries and reserves.. *(sources : Enerdata, IEA, BP, Laherrere 2010)*

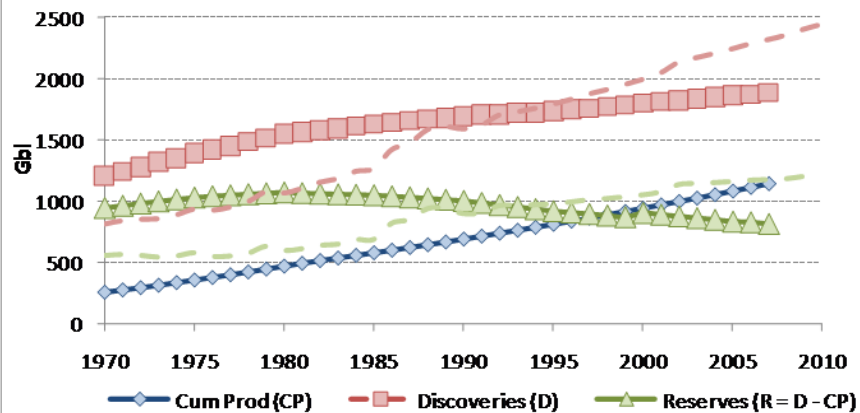
## 1. Declared reserves, corresponding discoveries

**Cumulative**

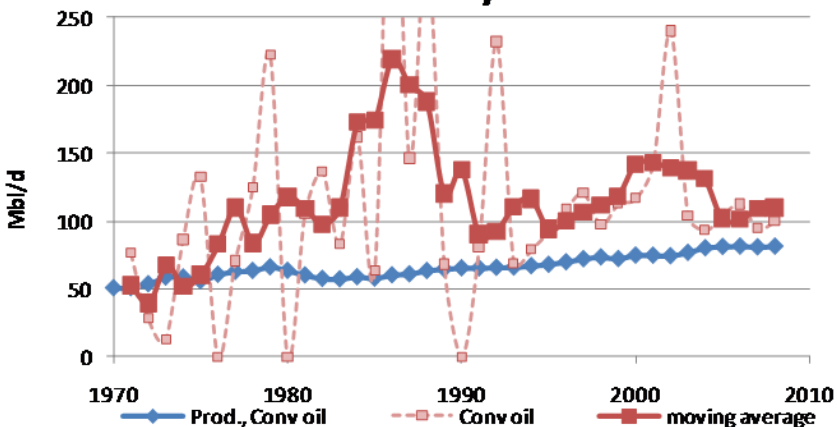


## 2. ASPO : from discovery estimates to reserves

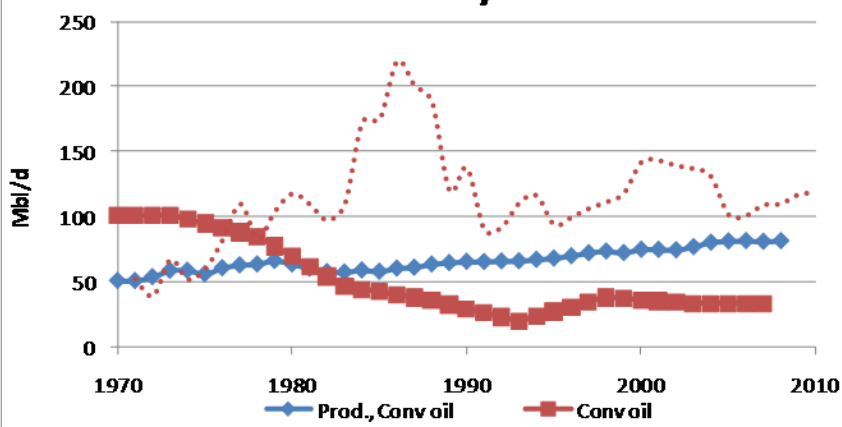
**Cumulative**



**Yearly**

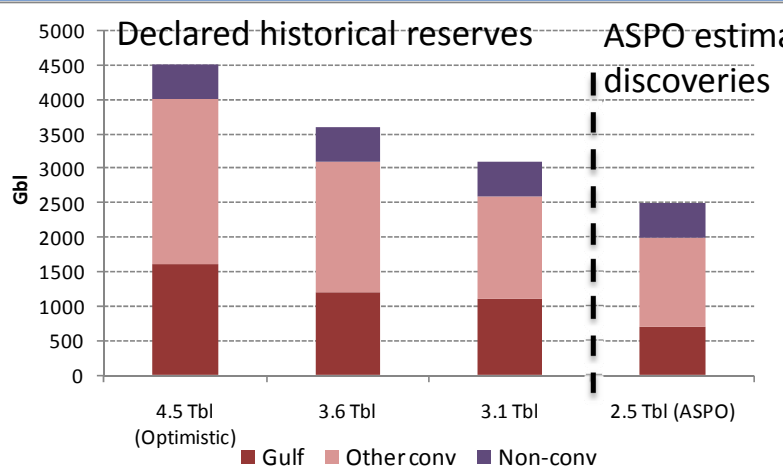


**Yearly**



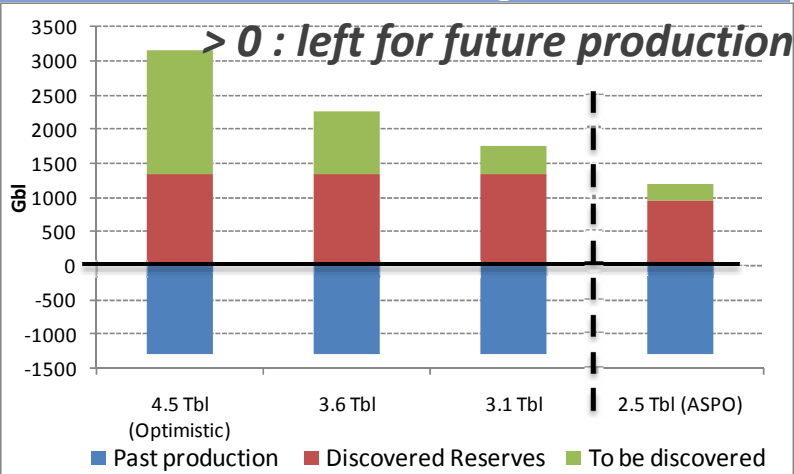
# 4 Scenarios on available oil resource

Resources, by category



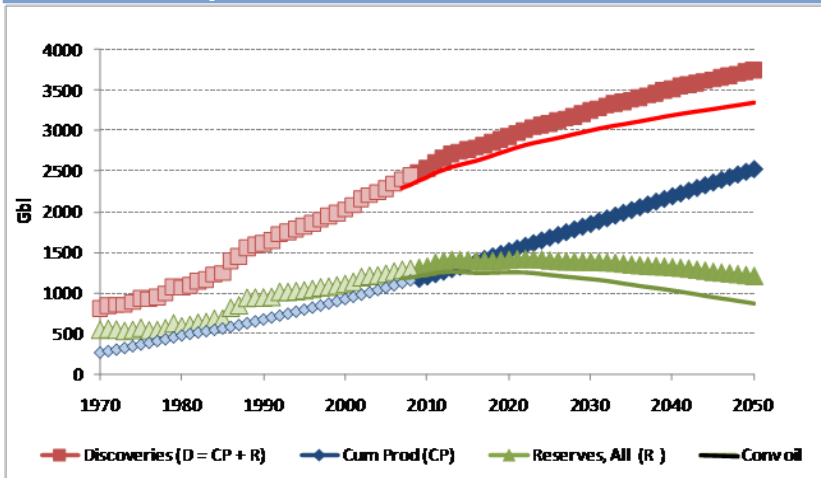
- Very contrasted assumptions on conventional oil resources.
- “4.5”, “3.6” and “3.1” are differentiated along yet-to-find resources
- Noticeable difference between the *ASPO case* and the other scenarios using declared reserves : the Gulf oil resources are significantly lower.
- Volumes left for future production ranges from twice past production (*4.5 Tbl case*), to less than already produced (*ASPO case*).

Produced vs. Remaining resources

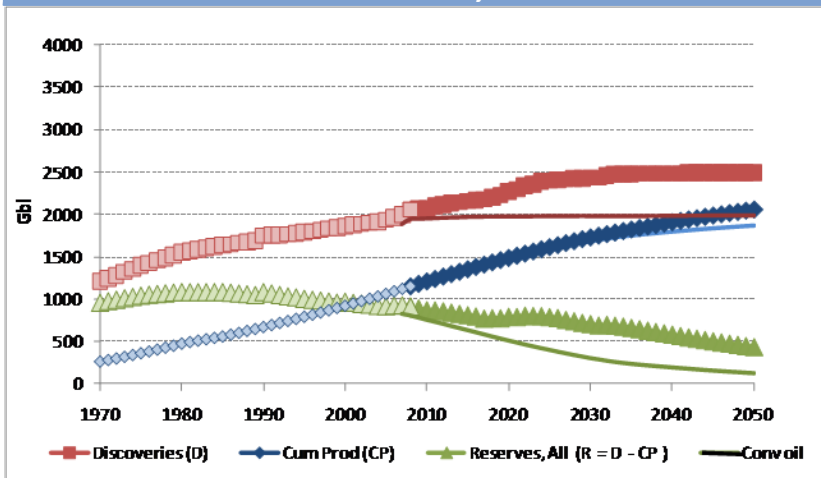


# Future oil discoveries & production – Cumulative profiles

Optimistic scenario, 4.5 Tbl



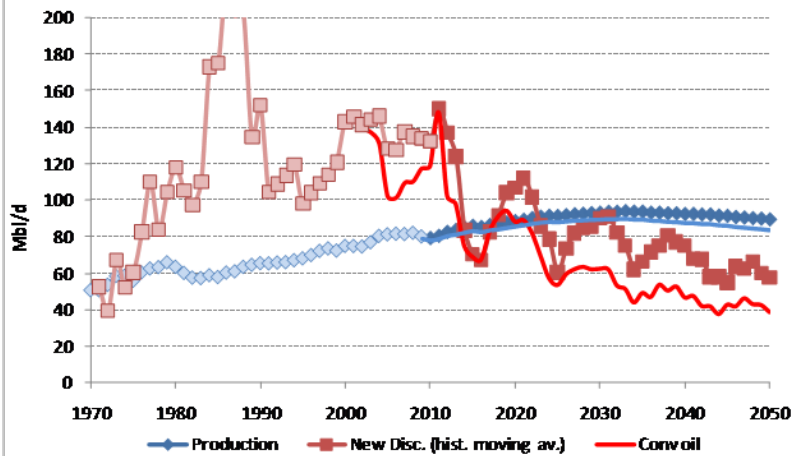
ASPO scenario, 2.5 Tbl



- In the Optimistic case, conventional ensure most of the total production, with non-conventional adding to reserves
- In the *ASPO case*, there is no room for new discoveries of conventional oil, leading to fast decreasing reserves
- In the *ASPO case* only non-conventional oil allows to keep reserves and production

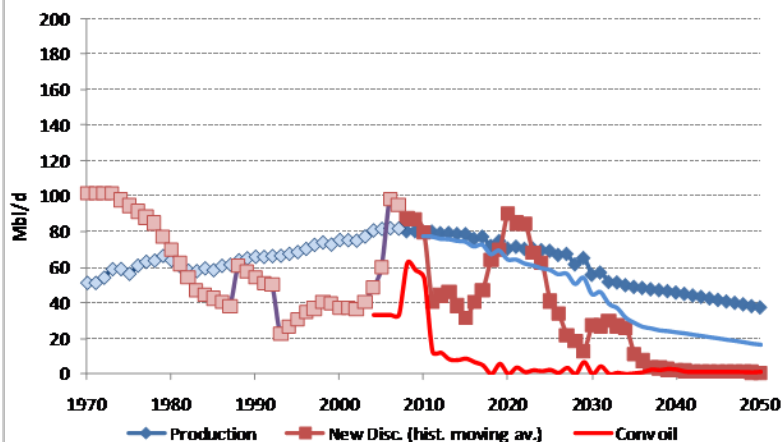
# Future oil discoveries & production – Yearly volumes

## Optimistic scenario, 4.5 Tbl



- In the Optimistic case :
  - there are discoveries of both conventional & non-conventional oil,
  - production plateaus at 90 Mbl/d during 2020-2040.

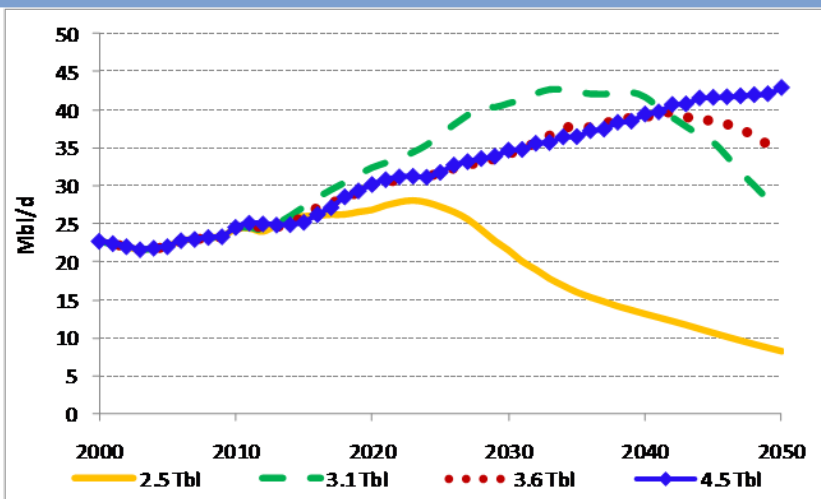
## ASPO scenario, 2.5 Tbl



- In the ASPO case :
  - total production peaks around 2010,
  - conventional oil production falls to 50 Mbl/d in 2030 and 20 Mbl/d in 2050,
  - “dirty” non-conv oil represents half the total production over the long-term.

# Possible (huge) tensions on markets....

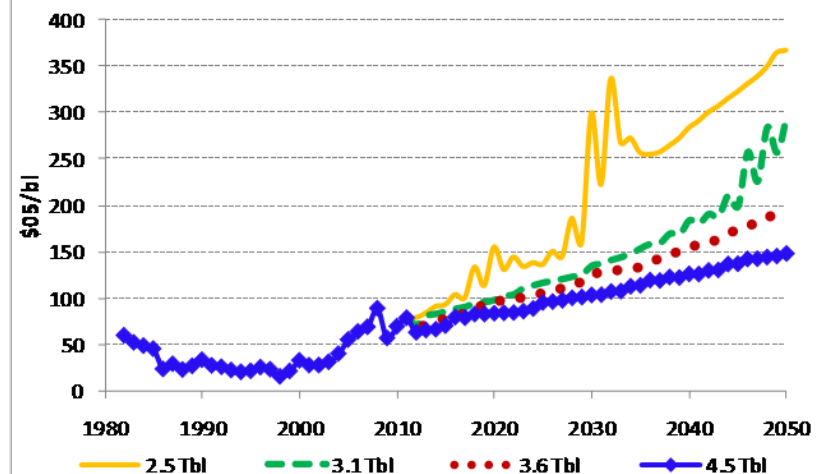
Gulf production capacity



- 4.5 Tb : increases steadily, no shock
- 3.6 Tb : stronger increase
- 3.1 Tb : stronger increase, structural instability in the long-run
- 2.5 Tb : increase in line with 2003-2008, permanent instability, potentially extreme peaks

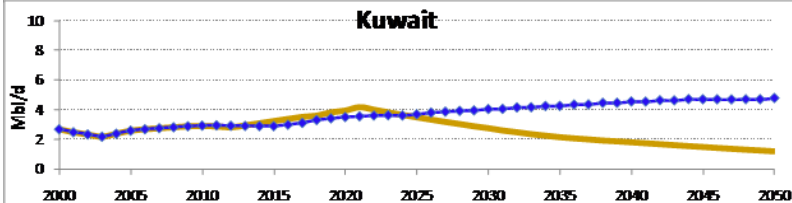
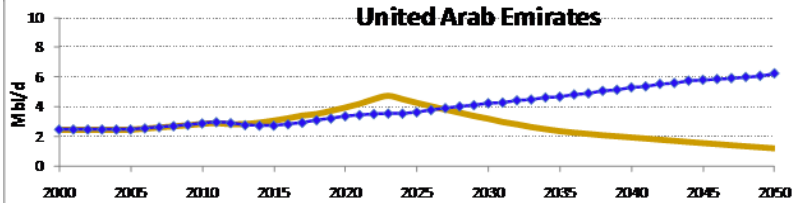
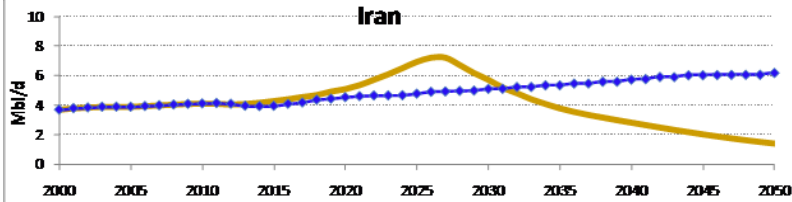
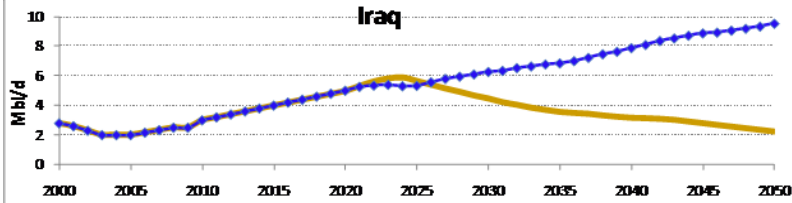
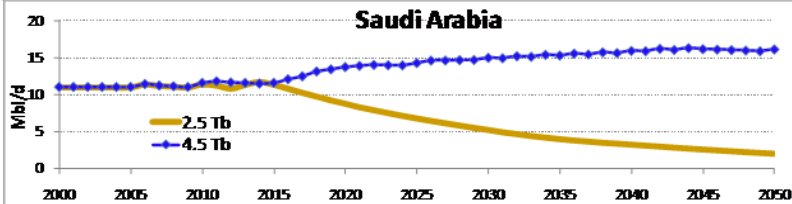
- All scenarios are “market friendly”, and capacities are only limited by R/P
  - 4.5 Tb : keeps increasing
  - 3.6 Tb : declines after 2040
  - 3.1 Tb : first compensates for decline in non-Gulf regions, then decreases sharply from 2040
  - 2.5 Tb : cannot be increased, decreases rapidly from 2025

Oil price



# National oil production capacities in Gulf

Production capacity by country

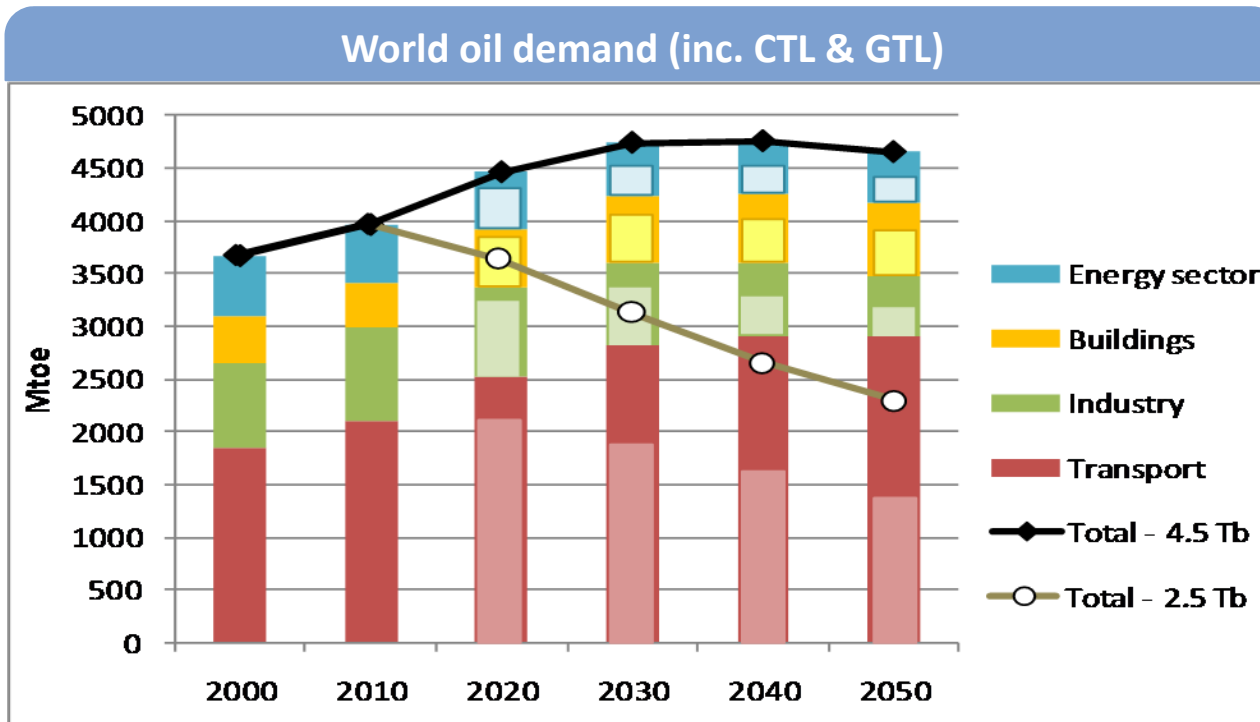


- Saudi Arabia capacities declines rapidly in the 2.5Tb scenario (vs. 15 Mbl/d in the 4.5 Tb, close to official announcements)

- It is partially compensated by Iran, Iraq and UAE in 2010-2025, after which these capacities also decline

- *Caveat* : results are based on favorable assumptions regarding investment and willingness to compensate SA decline. Different hypothesis could lead to different results on the short term (but not in the long run...).

# Impact on oil demand



- Oil demand almost disappears in Industry and the Energy sector.
- It is divided by 2 in Buildings and Transportation (partly compensated by higher biofuel & electricity).

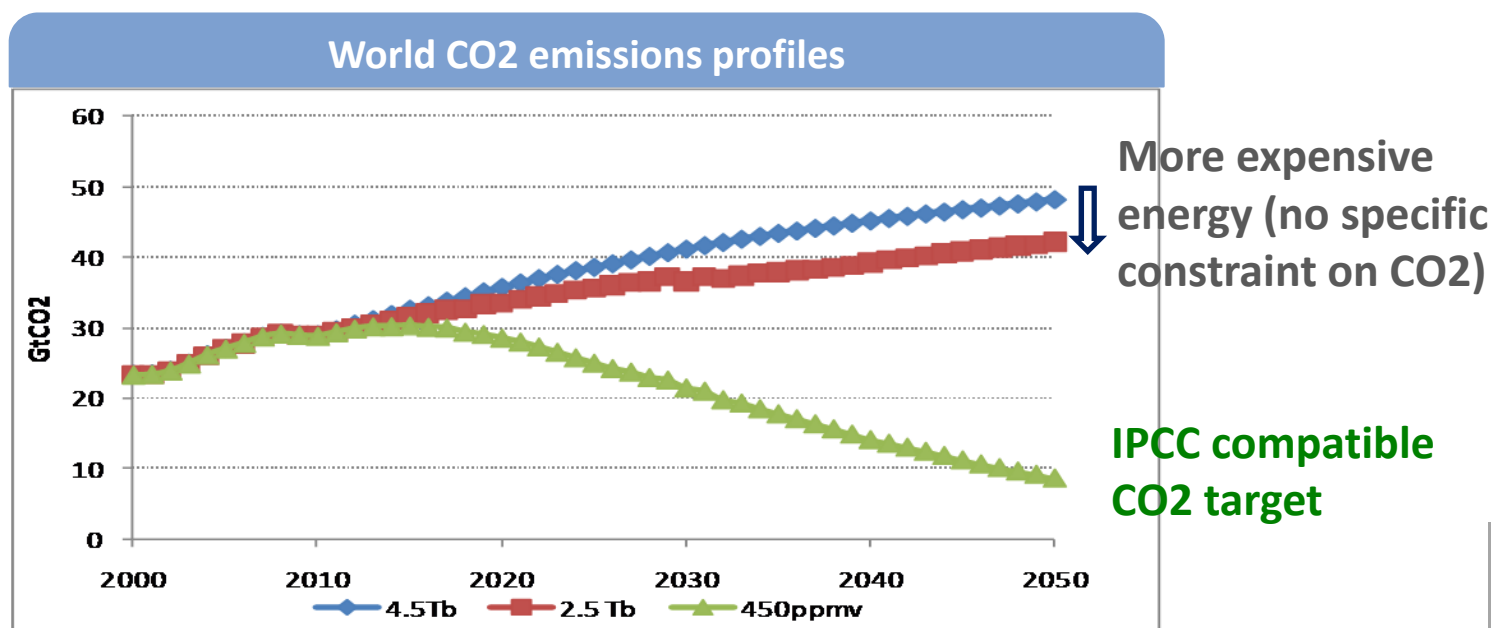
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# CO2 emissions & IPCC recommandations

Table SPM.5: Characteristics of post-TAR stabilization scenarios [Table TS 2.3.10]<sup>a)</sup>

Category	Radiative forcing (W/m <sup>2</sup> )	CO <sub>2</sub> concentration <sup>c)</sup> (ppm)	CO <sub>2</sub> -eq concentration <sup>c)</sup> (ppm)	Global mean temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity <sup>b), c)</sup> (°C)	Peaking year for CO <sub>2</sub> emissions <sup>d)</sup>	Change in global CO <sub>2</sub> emissions in 2050 (% of 2000 emissions) <sup>d)</sup>	No. of assessed scenarios
I	2.5-3.0	350-400	445-490	2.0-2.4	2000-2015	-85 to -50	6
II	3.0-3.5	400-440	490-535	2.4-2.8	2000-2020	-60 to -30	18
III	3.5-4.0	440-485	535-590	2.8-3.2	2010-2030	-30 to +5	21
IV	4.0-5.0	485-570	590-710	3.2-4.0	2020-2060	+10 to +60	118
V	5.0-6.0	570-660	710-855	4.0-4.9	2050-2080	+25 to +85	9
VI	6.0-7.5	660-790	855-1130	4.9-6.1	2060-2090	+90 to +140	5
Total							177

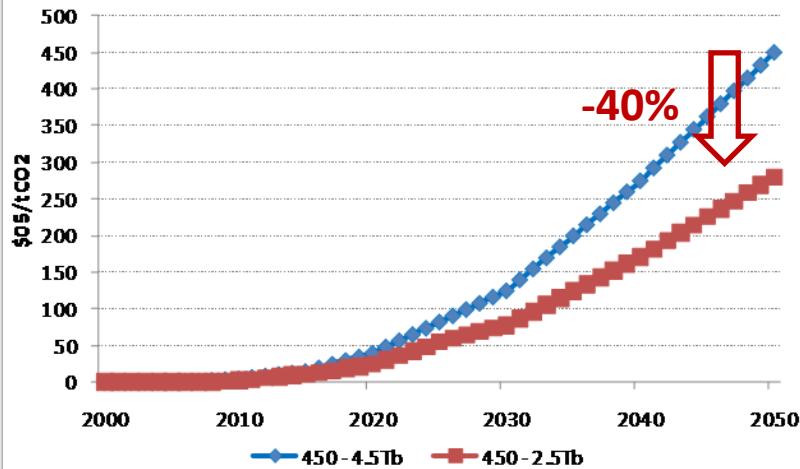
# CO2 emission objective for a +2°C increase



- The constraint on oil resources leads to lower CO2 emissions (**energy price effect**) / -13% in 2050.
- Constrained profile corresponds to a 450ppmv concentration of CO2e, in line with the IPCC recommendations (+2°C) :
  - 2030 : -10% 2000
  - 2050 : -65% 2000

# Required carbon value & impact on the oil price

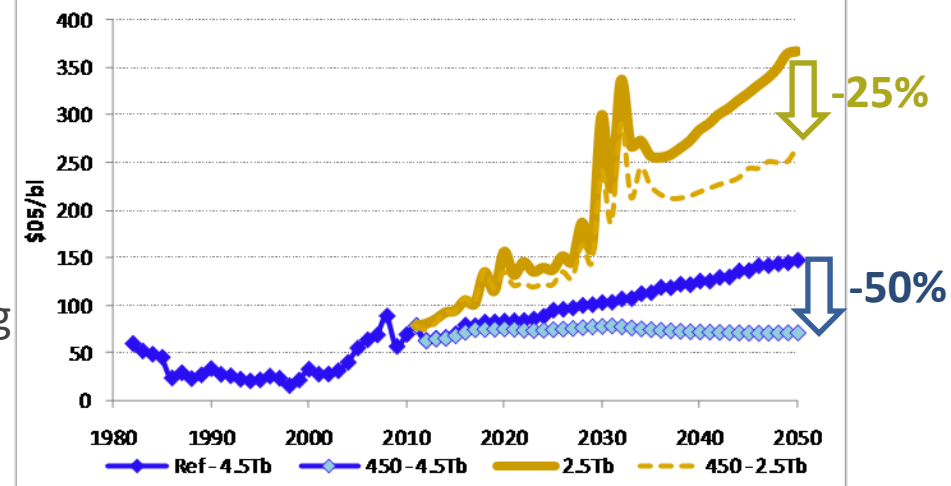
Required CO2 price



- The constraint on oil resources leads to lower CO2 emissions w/o any carbon price: low oil resources 'facilitates' mitigation efforts

- Tensions on the oil market are lowered in the case of high oil resources (-50% in the long run)
- In the 2.5Tb scenario :
  - the resource constraint remains strong
  - the CO2 constraint limits the development of non-conventional oil

Resulting oil price



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# Other factors on future supply & demand

## Supply

- Political role of **swing producers** in capacity development
- Unconventional oil (tar, shales, ..) :
  - Actual resource and potential future production
  - Environmental impact & sustainability of the production effort

## Demand

- Policies & measures on oil demand : CO2 limitation, mobility, ..
- Competitors to oil in **transportation**
  - Biofuels, gas, electricity

# Competing with other energy sources

Integration within a larger energy picture, considering the role of & constraints on other energy resources :

- **Gas**
  - Actual resources, including shale gas
  - Environmental impact & sustainability of the production effort
- **Coal**
  - Actual resources, costs & environmental impact
  - Potential role of CCS
- **Nuclear**
  - Actual resources
  - What will be the primary limitation to a large scale deployment of nuclear : industrial accidents or resources ?
- **Renewables**
  - Biomass potential for energy purposes vs. competition with other uses and land management
  - Wind and solar : land, network management, demand for new materials



Thank you for your attention !

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