Analysis of long term climate strategies given different possible short-term agreements

TIMES Integrated Assessment Model

06/12/2009

Objective

The main objective of the analysis of climate policies done with the global TIAM is to evaluate the long-term climate strategies (until 2100) to limit the temperature increase by 2°C forever, considering different possible policies implemented in the shorter-term (until 2030).

More particularly, the preferred mitigation decisions are identified, as well as the impacts of the short-term policies on the longer-term decisions and costs of the climate strategies. The feasibility of the long-term climate constraint might even be affected by the short-term (in)action. The analysis of carbon market is not analyzed in detail since GEMINI-E3 focuses more on that aspect.

The trajectory of the CO2 equivalent concentration obtained with TIAM is also used by GENIE to evaluate the impacts of climate change.

Overview of the methodological approach

The implementation of the analysis requires two steps: first, the five policies defined for the period 2005-2030[1], each characterized by different regional emission quotas and different levels and date of participation to the international carbon exchanges, are implemented in TIAM; second, the model is run until 2100 with the appropriate climate target (2°C) and with the decisions taken in each region frozen at their level obtained in the short-term runs. A perfect carbon trade is assumed from 2031, just after the first period agreement.

An additional scenario is evaluated, representing a theoretical case where all countries would fully cooperate from 2010 (called *Perfect World*). This scenario represents a first-best solution and helps understanding the benefits of the full cooperation compared to partial agreements.

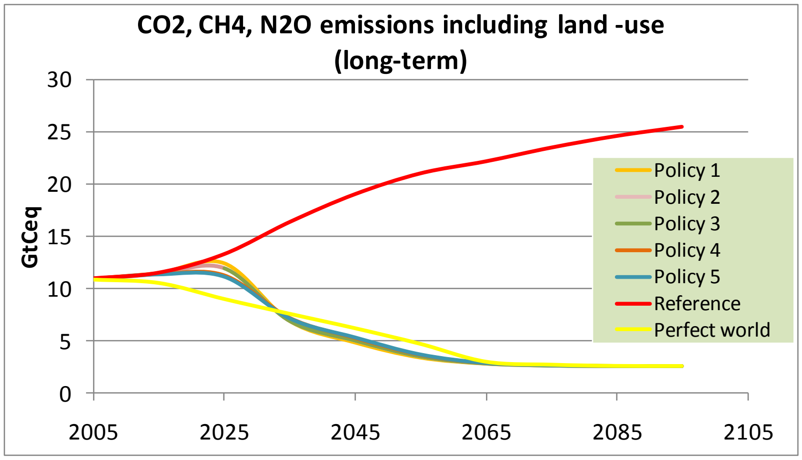
[1] The five policies are: Failure of negotiations, Minimum agreement in OECD, Agreement in OECD plus Russia, Agreement within G20, International agreement (global) – see description at http://synscop15.ordecsys.com (scenario analysis)

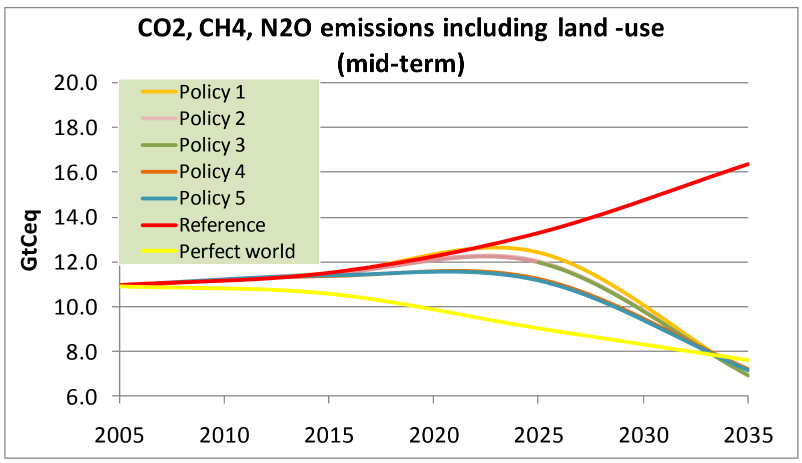
Climate and emissions

First result, the **2°C target requires extreme changes** in all the sectors, including energy and non-energy emitting sectors, given the characteristics of the energy system and the mitigation options represented by TIAM. And this, even in the *Perfect World* situation. The main factor behind the difficulty in satisfying the target in the model in related to the **remaining Non-CO2 emissions** for which no mitigation is available, such as the emissions from agriculture activities, whose only 25% can be reduced by modifying the agricultural practices, following the usual estimations. At the opposite, **net CO2 emissions are reduced to 0 and become even negative** thanks to capture and sequestration in geological sinks of carbon generated by biomass-based power plants and biomass-based Fischer-Tropsch plants (biomass being considered as free of emissions, the CCS applied to biomass-based technologies represents a source of negative emissions, what represent a powerful mitigation option.

The 2°C climate target remains feasible whatever the short term climate agreement is. However, the delayed agreements result in delayed emission reductions (Figure 1), and thus more expensive climate strategies (Figures 2 and 3) compared to the theoretical "*Perfect World*" situation. Hence the interest in acting as soon as possible.

Mid-term emission trajectory follows the definition of the policies: the increasing number of countries participating in the climate agreement result in decreasing emissions. **"Some" emission leakage** is observed in countries not participating in the climate agreement (remains small in comparison to total emissions, and concerns only the period before 2030 - not visible in the curves): a slight increase of gas extraction is observed in countries not involved in the agreement, motivated by the increase of gas consumption at the World level and by some displacement of gas extraction mainly from Europe to other regions. No increase of oil consumption in these countries resulting from the decrease of oil price (**no oil rebound**) is observed.





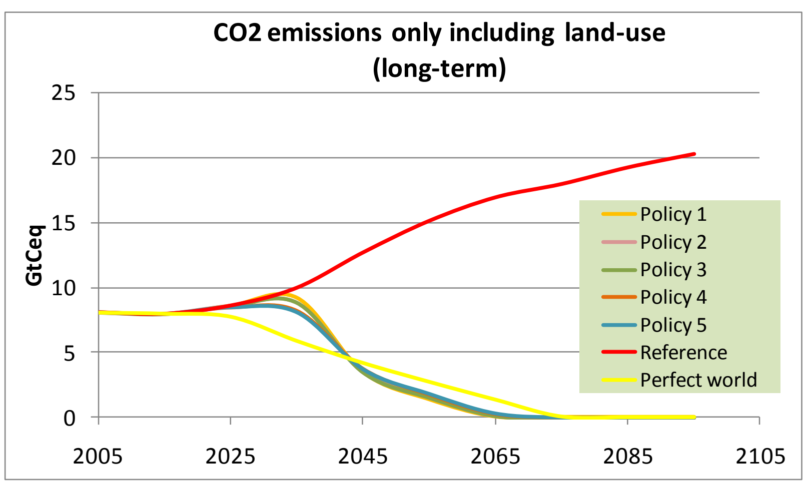


Figure 1. CO2, CH4 and N2O emissions

Impact of mid-term climate agreements on long-term mitigation costs and carbon prices

Enlarging the climate agreement helps reducing the mid-term carbon price observed in Europe (Figure 2). Europe is used for illustrative purpose here, since it is the only region committed to early targets in all scenarios (more details on the mid-term carbon price are provided by the analysis done by GEMINI-E3). Indeed, larger coalitions allow a larger volume of trade of CO2 permits exported by regions where the mitigation potential is high and/or cheap, or also where the allocated quota is relatively high.

The CO2 price reaches high values of up to 1400 $\$_{2000}$/tCO2 in the middle of the time horizon, before decreasing again in the second part. Two remarks apply.
First, sensibility analyses done with less stringent climate targets shows that such a peak is **delayed with less stringent targets and disappears** when the climate target is around 2.5°C (Figure 3). No easy and unique reason explains this dynamic. Amongst the factors probably playing a role, the climate dynamics themselves, the endogenous constraints of the model (for example, the fact that several parameters of the model change after 2050 and might offer easier long-term mitigation potential- some technology characteristics, curves of the final demands, relaxation of constraints making the model more flexible after 2050, etc.).
Second, the peak is **reduced when early and large climate agreements are implemented**. The peak observed again in the *Perfect World* case illustrates an interesting **trade-off** between the level of the carbon price (not minimized in this scenario: several of the mid-term policies result in lower CO2 price peak) and the total cost of the climate strategies (minimized in the *Perfect World* case)

The long-term CO2 prices in the different scenarios converge to very similar values.

The **total cost of the climate strategies**, decreasing when more countries participate in the coalition, and minimized in the *Perfect World* case (Figure 4), confirms that given the severity of the climate target, **any "lost" mitigation option in the short-term makes the required long-term efforts higher (for example, more renewable, more nuclear) and more expensive**. Let's remind here that the climate target is considered very severe according to the mitigation options available in the model.

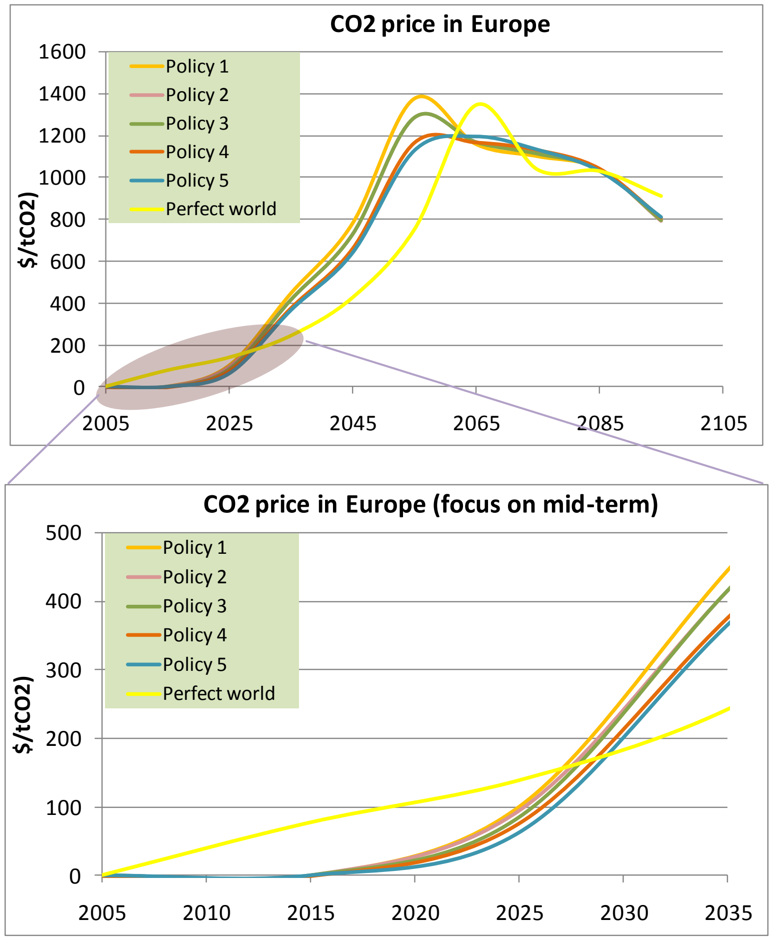


Figure 2. Carbon price in Europe

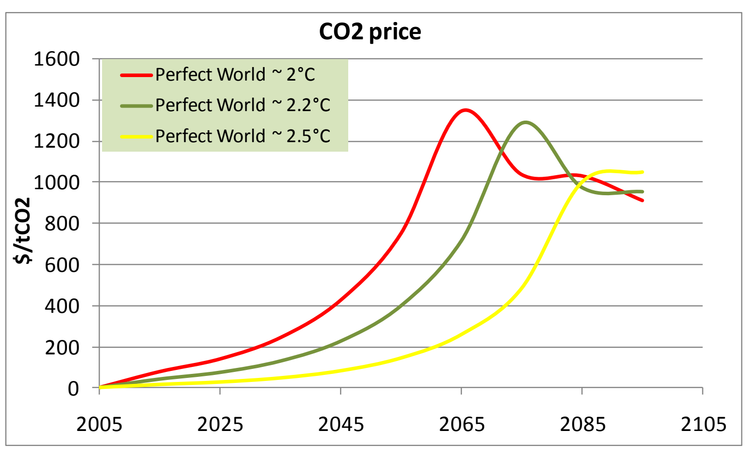


Figure 3. Carbon price under the *Perfect World* case (full cooperation) for three different climate targets

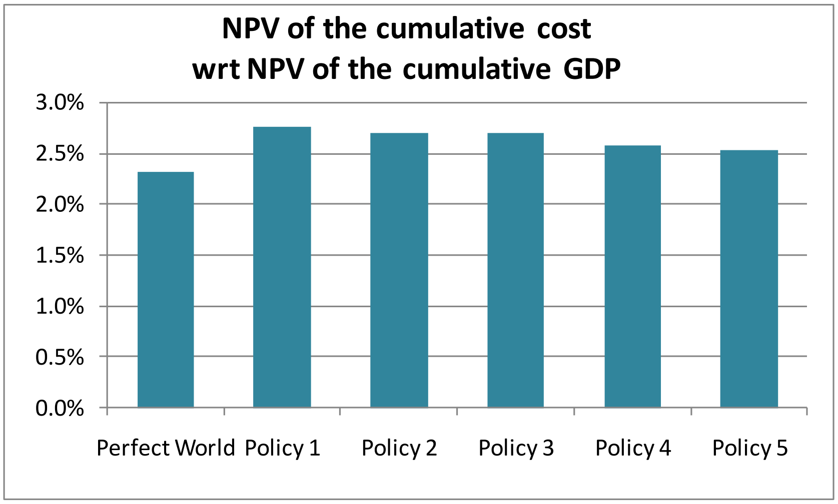


Figure 4. Total cost of the energy system

Preferred mitigation options: end-use sectors

The different policies **don't differ in the long term energy consumed in end-use sectors** (Figure 5)**:** a drastic increase of **electricity** is observed, substituting mainly coal in the energy-intensive industry sectors, and gas in the residential / commercial sectors; in transport (Figure 6), the penetration of **biofuels** is accelerated (with the penetration of CCS in the generation of biofuels), and **electricity as well as hydrogen vehicles** enter the market. The reduced climate agreements result in **faster changes required in the middle of the century** (2040-2060) in order to compensate for the lower mitigation options implemented in the first part of the horizon.

It is also interesting to note the decrease of biomass consumed in the residential sector as an effect of the climate policies, because **biomass is preferably used in processes where capture and sequestration is possible** (power plants, production of synthetic fuels) since these options are equivalent to negative CO2 emissions, very important in severe climate policies.

Globally, the energy consumption by the end-use sectors decreases, reflecting the penetration of **more efficient fuels and technologies**, as well as the **decrease of the demands for final energy services** (up to 20% reduction for some energy services), elastic to their own prices (see more details in the online description on TIAM).

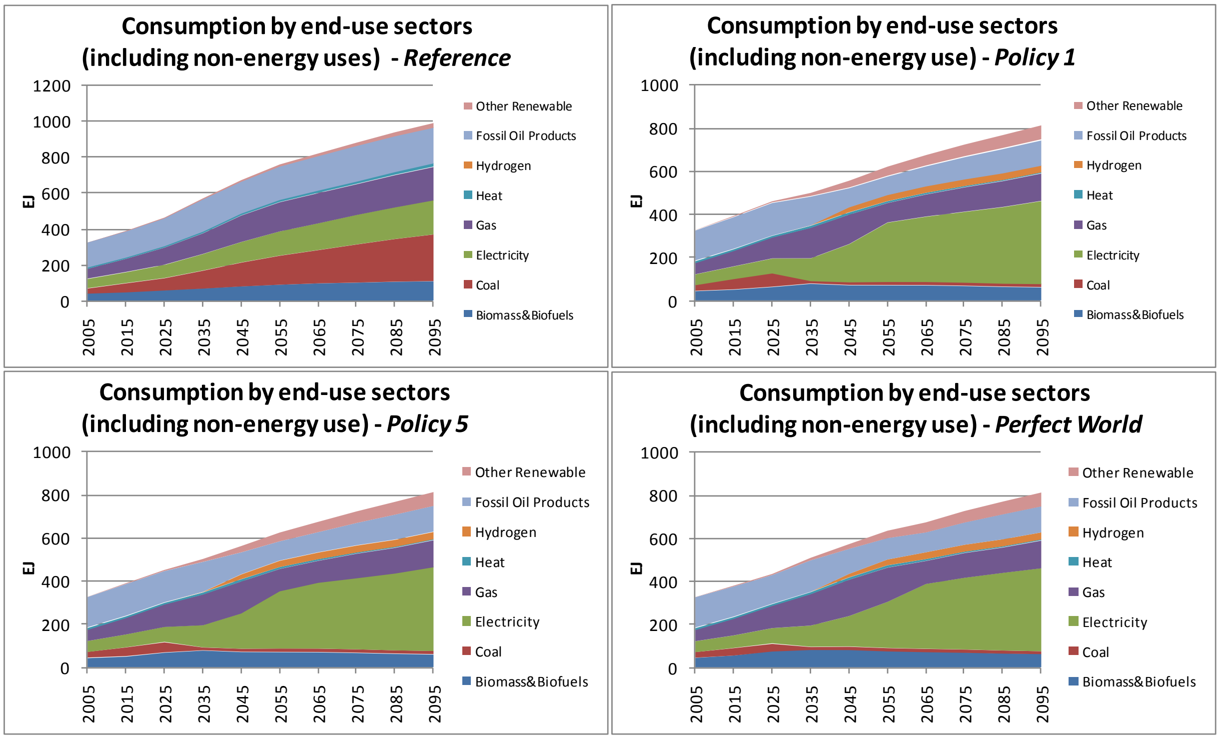


Figure 5. Consumption by End-use sectors

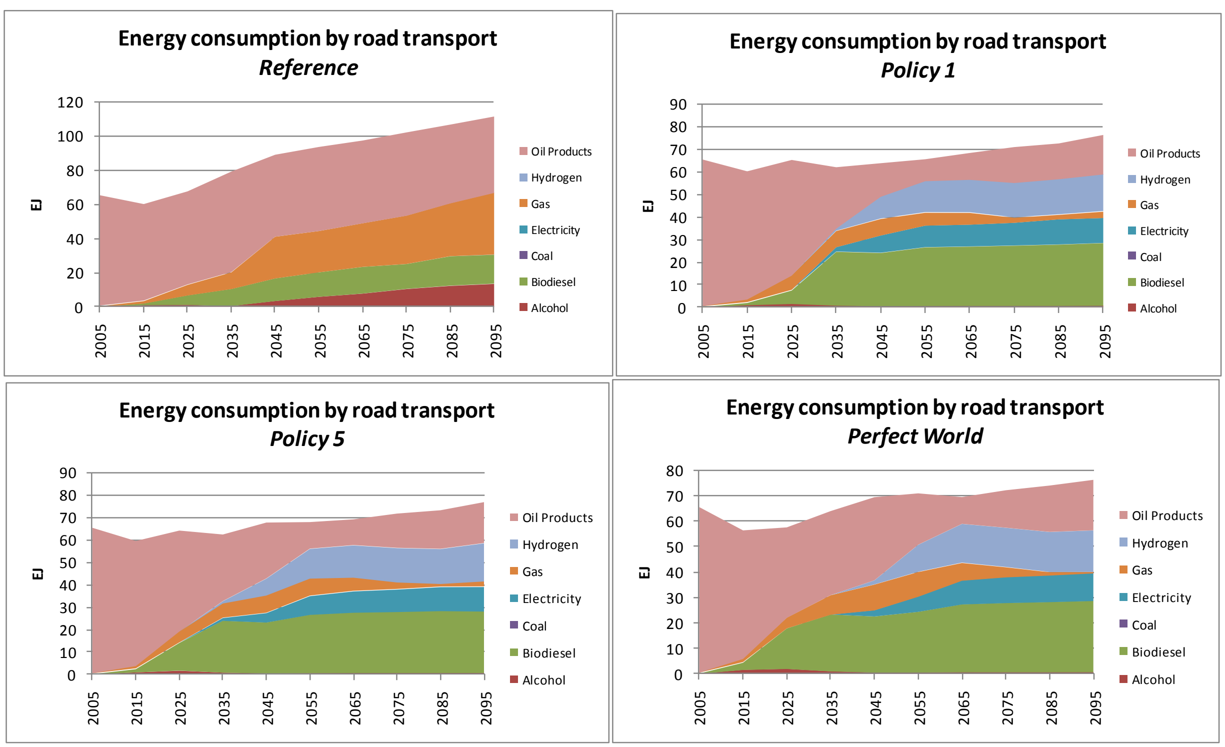


Figure 6. Consumption by road transport

Preferred mitigation options: electricity generation

Electricity generation plays a crucial role in climate mitigation. **Carbon capture and sequestration** is the preferred strategy until **renewable power plants** become available and cheaper. It is interesting to note the **preference for gas-power plants with CCS to coal-power plants** although the latter are less expensive. This is explained by the lower remaining emissions of the gas plants. Indeed, coal power plants with CCS penetrate much more in sensibility analyses done with less stringent carbon target. Let's also remind that afforestation was not included as a mitigation option in the current application given its large uncertainties; it was observed in other applications that when afforestation is allowed, coal power plants with CCS are preferred to gas plants, the remaining emissions being able to be sequestrated by afforestation mitigation. The penetration of **biomass-based power plants with CCS** also deserves attention: as explained previously, the CCS applied to biomass-based technologies represents a source of negative emissions, in other word, a very powerful mitigation option.

Here also, the reduced climate agreements result in **faster changes required in the middle of the century** (2040-2060) in order to compensate for the lower mitigation options implemented in the first part of the horizon: more renewable, more nuclear

The **cumulative carbon sequestrated by geological sinks** over the horizon remains stable and below 420 GtC (Figure 8), what is relatively optimistic, but within the range usually observed (60-600 GtC) [2].

Nuclear generation also deserves some comments. Nuclear increases in climate scenarios, of course, and reach relatively high installed capacities (around 3800 GW at the end of the horizon). It is important to understand that the penetration of nuclear in TIAM is controlled by lower and higher bounds, reflecting that the decision to invest in nuclear power plants are based on many non-economic factors that are not well reflected in techno-economic models like TIAM, such as the socio-political acceptation, the level of risk associated to the investments, etc. (need for long term and stable policies). The chosen values until 2030 were inspired by the WEO-2008 and EIA-IEO2009. However, it is important to understand that any assumptions on nuclear bounds are part of a scenario, and not meant to be a prediction or forecast. As for any scenario, it is only one possible picture of the future. Finally, the possible penetration of the Generation IV reactors would probably relax the pressure on the uranium resources.

[2] IPCC (2005). IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [Metz, B., O. Davidson, H. C. de Coninck, M. Loos, and L. A. Meyer (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 442 pp.

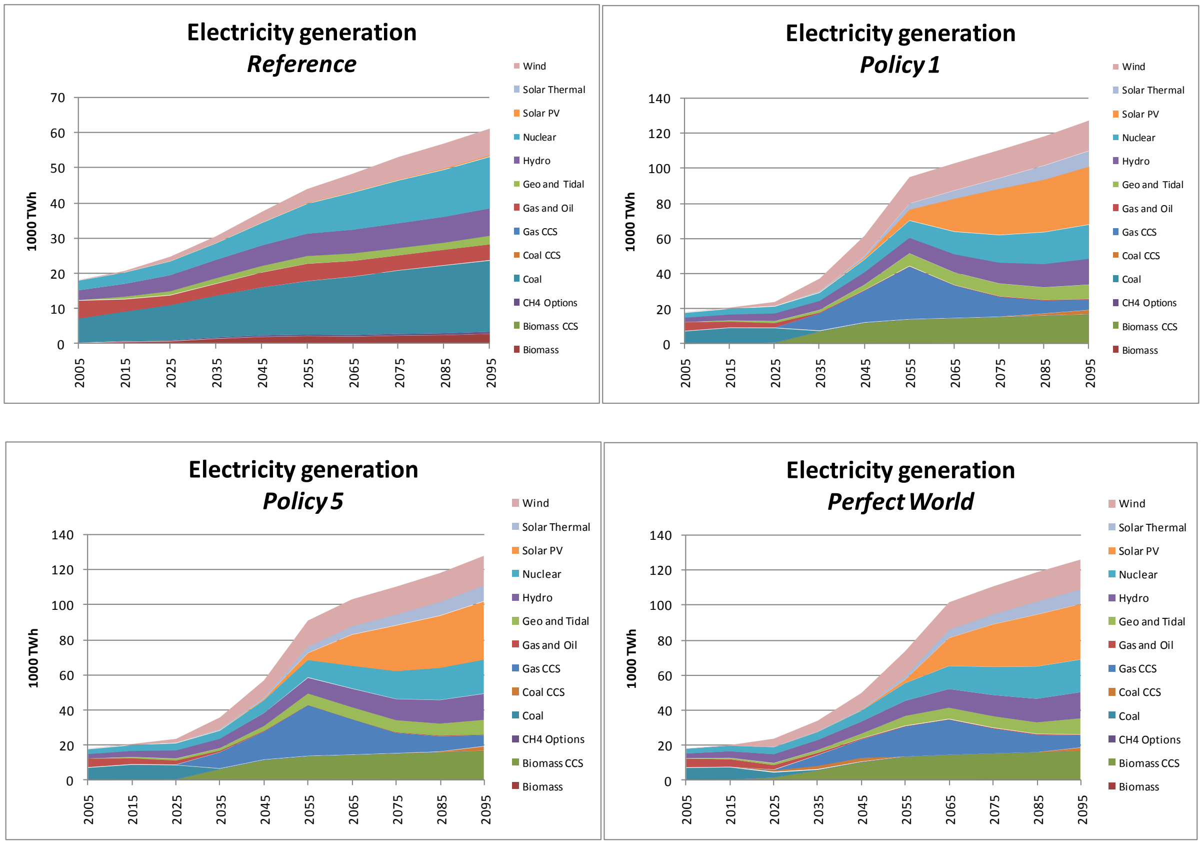


Figure 7. Electricity generation

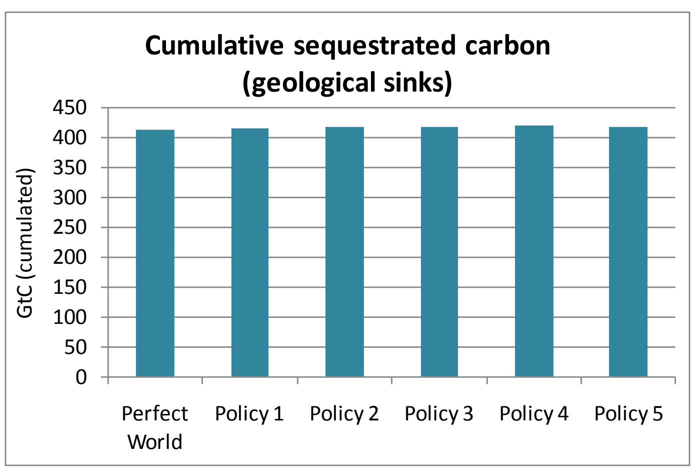


Figure 8. Sequestrated carbon (geological sinks)

Preferred mitigation options: impacts on primary energy

The primary energy (Figure 9) reflects the different energy changes described above. Primary coal appears higher than what can be observed in the final consumption because part of this coal is transformed to synthetic fuel (Fischer-Tropsch) and therefore appears as fossil-oil in the final energy consumption.

It is interesting to evaluate the impact of climate strategies on the **energy security** or energy independence of countries (Figure 10). Differences between policies are rather small, and we observe a mid-term increasing and long-term decreasing dependency of primary energy to imports in climate scenarios compared to the Reference. While coal trade decreases, due to the decrease of its consumption, the increase of electricity generated by plants with CCS results in an increase of gas trade in the middle of the horizon compared to the reference, followed by a decrease when renewable electricity penetrates more in the second part of the horizon.

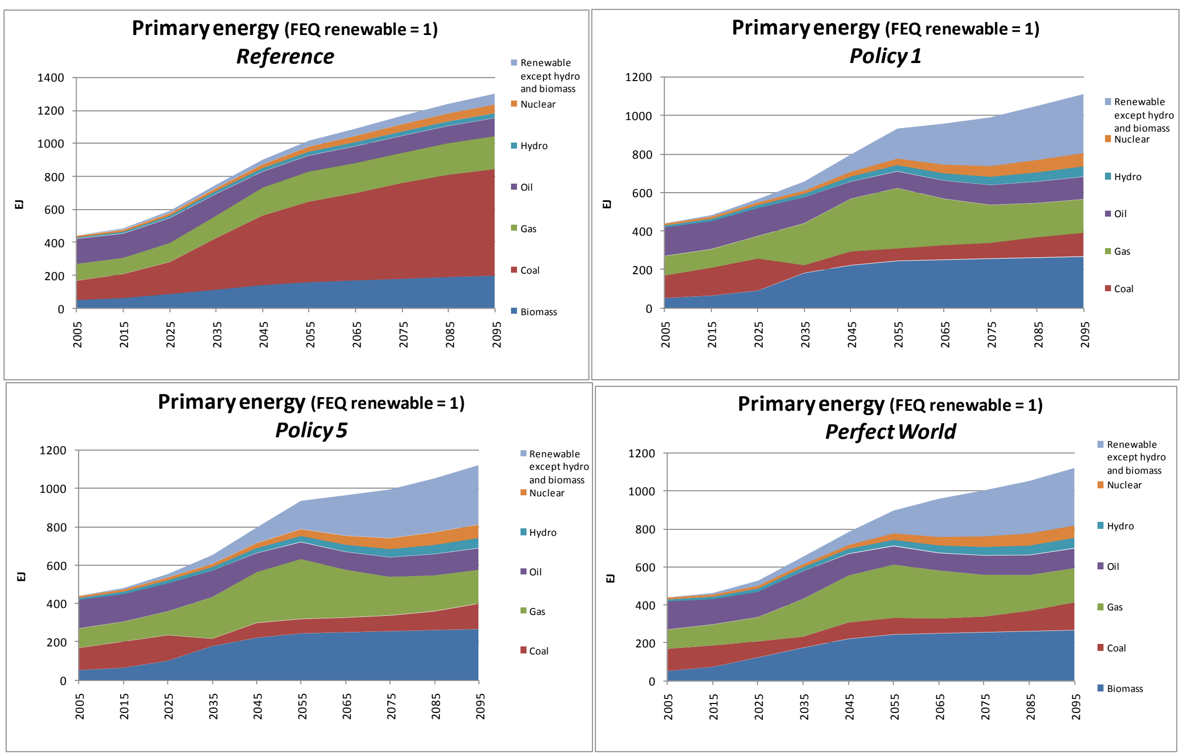


Figure 9. Primary energy

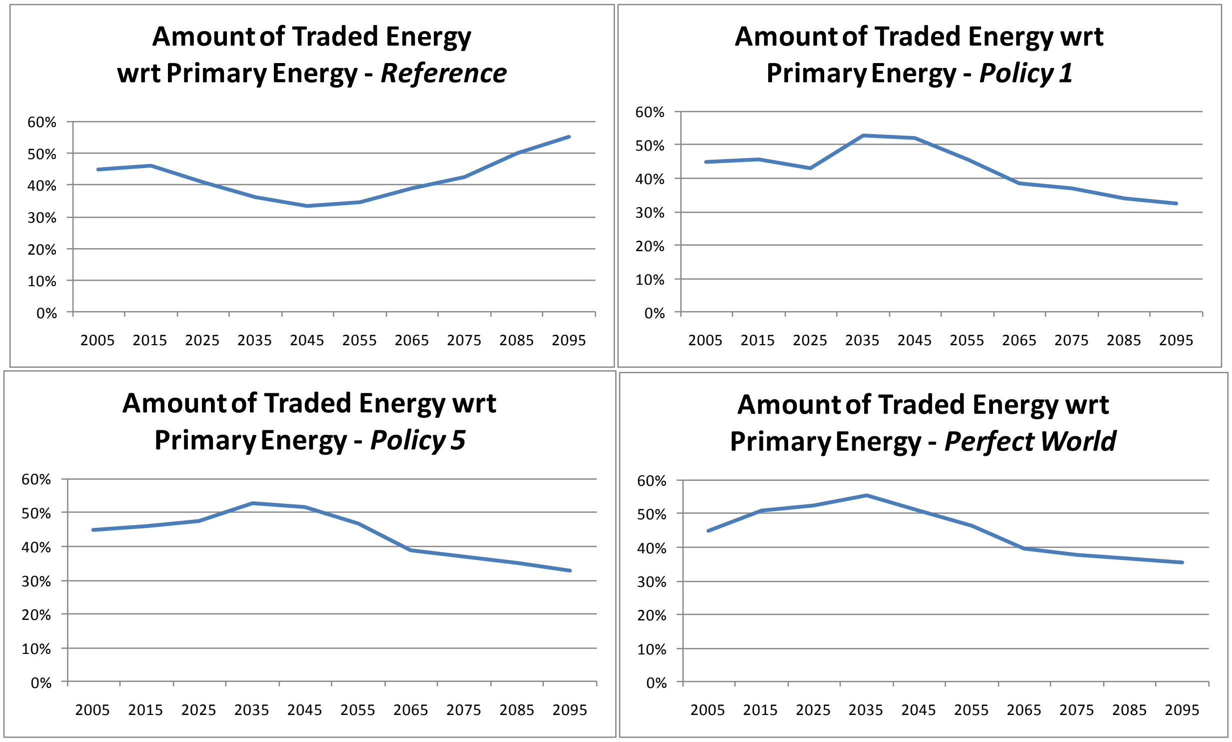


Figure 10. Traded energy