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D6.5 AN ASSESSMENT OF EU LOW-CARBON ROADMAPS

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[1] The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission

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6.5.1 – Introduction

The scope of this exercise is to demonstrate the improved suitability of the models that participate in ADVANCE project for the assessment of climate and energy policies. The selected set of WP6 scenarios are highly relevant to the current policy debate and are a direct follow-up of the Paris COP21 agreement by providing a first multi-model assessment of the implications of the recent agreement. Moreover, the scenarios will attempt to highlight the relevant area of application and the value added of each improved model by assessing a variety of policy impacts. In order to achieve utmost efficiency, the policy scenarios to be analyzed under WP6 and Task1.4 will be combined.

Low Carbon Roadmaps

In 2011, the European Commission (2011 a,b,c) presented the low-carbon roadmap communication and the Energy roadmap up to 2050 The EU has set itself a long-term goal of reducing greenhouse gas emissions by 80-95% when compared to 1990 levels by 2050. The Energy and low-carbon Roadmaps 2050 explore the transition of the energy system in ways that would be compatible with this greenhouse gas reductions target while also increasing competitiveness and security of supply.

In the following years the focus of the European policy development and global negotiations had turned towards 2030 resulting in the 2030 Framework of Climate and Energy Policies (European Commission, 2014) and its various levels of implementation; as well as the Paris Agreement (UNFCCC, 2016). As a result of the outcome at the COP21 in Paris, there is a renewed momentum to look further towards the mid-century at a (sub-)regional level. (such as Paroussos et al., 2016; Spencer et al., 2016).

Deliverable 6.5 of the FP7 ADVANCE project builds further on the analysis and scenarios in Workpackages 1.4 and 6 (D6.3, D6.4) with of focus on the EU in 2050.

However, the results of this report (D.5) face a number of important caveats:

- **The consortium board in dialogue with DG RTD and DG Clima has decided that the ADVANCE project should focus on a global analysis of the Paris Agreement (for 2030 in the case of Work Package 6; up to 2050 and beyond for Task 1.4)**
- **The CD-Links project has a more (sub-)regional focus, including on the EU. Therefore the CD-Links project is expected to deliver a more mature analysis building on the scenarios developed in and experience gained from the ADVANCE project.**
- **The geographical and sectoral detail of some Integrated Assessment Models may not be perfectly suited yet for an in-depth analysis of an energy and low-carbon roadmap for the EU as was done by the European Commission (2011a, b, c).**

For all these reasons, the results of D6.5 should merely be seen as a first step of a long process, possibly culminating in CD-Links or any possible follow-up of European Commission (2011 a, b, c), and therefore they should not be quoted.

Scenario design and Scenario Protocol

The Scenario Design and Scenario Protocol are identical to the ones described in Deliverable 6.3 of the ADVANCE project.

A consolidated set of policy scenarios enables the assessment of the Paris Agreement in terms of mitigation effectiveness and system transition. A brief description of the 4 scenarios presented in this analysis is found in Table 6.5.1[2].

Table 6.5.1: Brief description of scenarios

Scenario name	Description	Long-term Temperature target
Reference	2020 Cancun pledges / low ambition post-2020 reductions	No
INDC	2020 Cancun pledges / 2030 INDCs / post-2030 fragmented emission reductions of the 2020-2030 intensity	No
2°C	2020 Cancun pledges / post-2020 global action to a 1000 Gt CO_2 carbon budget	2°C
1.5°C	2020 Cancun pledges / post-2020 global action to a 400 Gt CO_2 carbon budget	1.5°C

Reference scenario

The Reference scenario describes the trajectory of key economic, environmental and energy figures under existing, pre-COP21 climate policies. It follows a low ambition mitigation effort that is highly diverse and fragmented across countries. In the post-2020 period it further assumes a continuation of low ambition climate policies, taking stock of the Reference trajectories in Labat et al. (2015).

The building process of a current policies Reference scenario is based on deriving data from many different sources (e.g. UN, OECD, EIA, European Commission, and UNFCCC) and aims for maximum consistency with related projections of international and national institutions. The socioeconomic assumptions of this scenario build upon two main sources in terms of economic growth rates and population assumptions, namely the global Reference scenario as described in Labat et al. (2015) and the SSP2[3] scenario. Harmonization with the above assumptions ensures consistency with the EU28's energy and GHG emissions trends as described in European Commission (2013) and with international publications like the UN (2013).

Table 6.5.2 describes the EU emission reduction targets in 2020, whereas Table 6.5.3 lists the EU energy-related policies and targets in 2020. Table 6.5.6 lists the post-2020 emission and emission intensity growth rates for the reference scenario.

[2] The scenarios are identical to the ones used for D6.3 and D6.4.
[3] http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/SSP_Scenario_Database.html

INDC scenario

The INDC scenario increases efforts after 2020 so as to achieve full implementation of the conditional (high) pledges submitted in COP21 in Paris. This scenario further assumes that the regional mitigation effort in the period beyond the Paris Agreement time-frame will continue equal to the effort of moving from the Cancun to Paris emission levels, i.e. regional emission intensity reduction rates in the post-2030 period are equal to those of the 2020-2030 period. A key feature of the analysis is the harmonized quantification of INDCs. More particularly, the EU is committed to a binding target of an at least 40% domestic reduction in greenhouse gas emissions by 2030 compared to 1990 (Table 6.5.4). This INDC corresponded with the 2030 Framework for Climate and Energy Policies and was supported by the conclusions of the European Council of October 2014. Moreover, the EU ambition covers 100% of the GHG emissions including Carbon Dioxide (CO2), Methane (CH4), Nitrous Oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF6) and Nitrogen trifluoride (NF3).

The INDC Scenario also holds the two other main elements of the 2030 Framework for Climate and Energy Policies, namely, to boost the share of renewables to at least 27% of EU energy consumption by 2030, and an indicative energy savings target of 27% by 2030 (Table 6.5.5).

Table 6.5.7 lists the post-2030 emission and emission intensity growth rates for the INDC scenario.

2°C and 1.5°C scenarios

A set of stylized carbon-budget scenarios enables the comparison of INDC and climate stabilization scenarios. These emission pathways ensure a high probability (above 66%) of achieving a maximum global average temperature increase of 2°C (2°C scenario) and 1.5°C (1.5°C scenario) by 2100. Cost-effective, global, deep-decarbonization action is enabled through immediate reductions (from 2020) and a single carbon price in all countries that limit cumulative CO_2 emissions to 1000 $GtCO_2$ and 400 $GtCO_2$ respectively in the period 2011-2100.

Table 6.5.2: EU Emission reduction targets in 2020 for all scenarios

Region	Metric	Sectoral coverage	Base Year	2020 Target
EU	All GHGs	All excl LULUCF	1990	-20%
EU	All GHGs	ETS	2005	-21%

Table 6.5.3: EU Energy related policies and targets in 2020 for all scenarios

Region	Technology	Objective	Target Year
EU	Renewables	Share of gross final demand 20%	2020
EU	Renewable fuels	Share in transport demand 10%	2020
EU	Private vehicles emissions	Emissions, in g/km 95	2020

Table 6.5.4: Quantification of INDC emission reductions in 2030

Region	2010 emissions	GHG coverage	Sectoral coverage	INDC emission reduction %	INDC Refrence point	INDC rel.to 2010
EU	4421	All GHGs	All sectors	-40%	Emissions by 2030 below 1990	-28%

Table 6.5.5: Other EU policies included in INDC scenario in 2030

Region	Target Year	Policy
EU	2030	at least a 27% share of renewable energy consumption
EU	2030	at least 27% energy savings compared with the business-as-usual scenario

Table 6.5.6: Post-2020 emission and emission intensity growth rates for Reference in EU

Region	Variable	Unit	2000-2010	2010-2020	2020-2030	2030-2050
EU	Emissions|Kyoto gases	Mt CO2	-0.8%	-1.3%	-1.2%	-0.5%
EU	Emissions|CO2	Mt CO2	-0.7%	-1.3%	-1.1%	-0.6%
EU	Emissions intensity|Kyoto gases	t CO2/MUS$2005	-2.3%	-2.3%	-2.6%	-2.0%
EU	Emissions intensity|CO2|Fossil Fuels and Industry	billion US$2005	-2.1%	-2.3%	-2.5%	-2.2%
EU	Emissions intensity|Kyoto excl. Land Use	Mt CO2e	-2.2%	-2.4%	-2.6%	-2.1%

Table 6.5.7: Post-2030 emission and emission intensity growth rates for INDC scenario in EU

Region	Variable	Unit	2000-2010	2010-2020	2020-2030	2030-2050
EU	Emissions|Kyoto gases	Mt CO2	-0.8%	-1.6%	-2.3%	-1.8%
EU	Emissions|CO2	Mt CO2	-0.7%	-1.4%	-2.2%	-2.1%
EU	Emissions intensity|Kyoto gases	t CO2/MUS$2005	-2.3%	-2.5%	-3.6%	-3.3%
EU	Emissions intensity|CO2|Fossil Fuels and Industry	billion US$2005	-2.1%	-2.5%	-3.3%	-3.6%
EU	Emissions intensity|Kyoto excl. Land Use	Mt CO2e	-2.2%	-2.6%	-3.4%	-3.4%

6.5.2 – EU GHG emissions in 2030 and 2050

In 2010 the EU the GHG emissions level stood around 4.9 Gt CO2eq. In the Reference, with all existing policies fully implemented, taking into account the existing global energy and technological evolutions, and without any additional policy measures the EU GHG emissions are assessed to be around 4.15 Gt CO2eq [3.6-4.9] in 2030, which is about 17% [2-27%] lower than in 2010.

With the INDC the emissions are 29% lower in 2030 than in 2010, reaching 3.6 Gt CO2eq [2.9-4.6]. The analysis shows that the INDC mitigation effort is consistent with a 2C pathway for the EU in 2030, as under the 2C scenario GHG levels are 36% [27-46%] below 2010 levels. An 1.5C pathway however would need a reduction of 51% [37 – 63%] in 2030 compared to 2010, which corresponds to a 58% [51 – 72%] reduction to 1990.

In 2050 the reference is with 3.9 [3.1 – 4.7] Gt CO2eq at about the same levels as the Reference in 2030.

The emissions in 2050 for a 2C scenario are assessed to be at around 1.6 Gt CO2eq [1 -2.2] which correspond to 73% [62 – 82%] compared to 1990 (or 69% compared to 2010).

A 1.5C scenario, however, reduces the GHG emissions in EU to 0.9 Gt CO2eq [0.12 – 2.04] and requires emissions reductions of about 90% [84 -98%] compared to 1990 (or 82% compared to 2010).

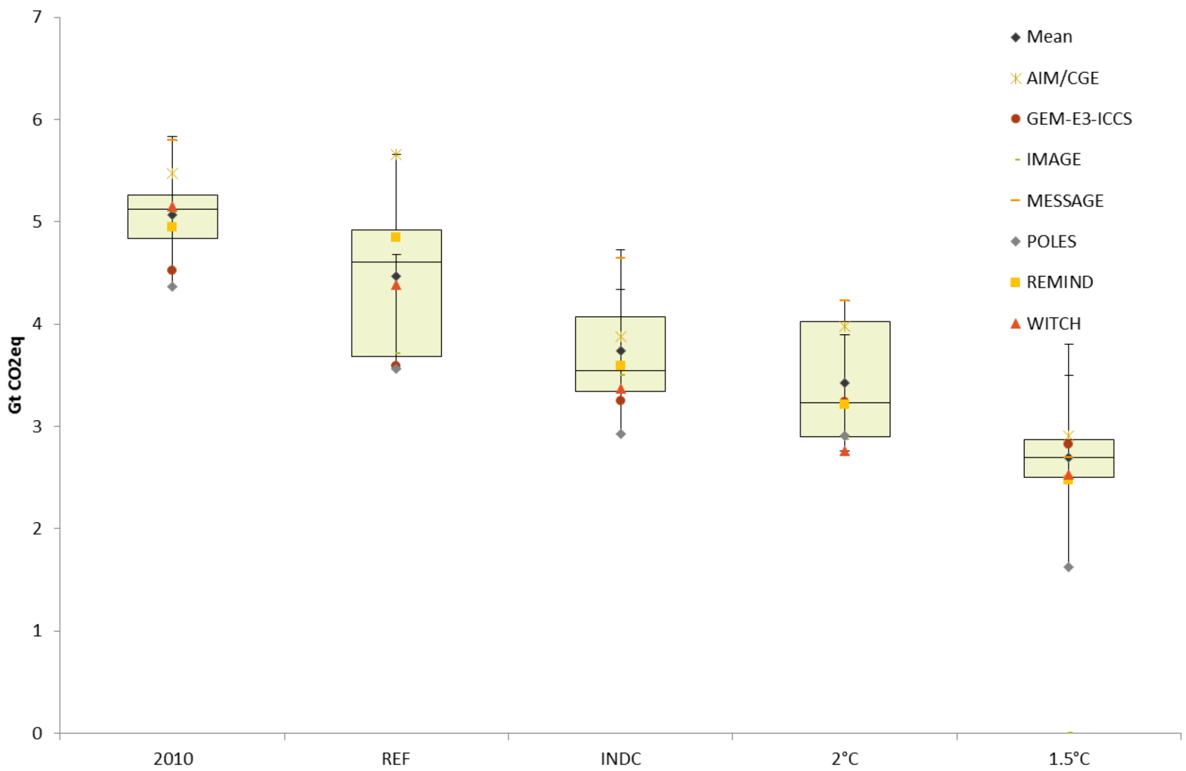

Figure 6.5.1: EU28 GHG emissions in 2030 for all scenarios

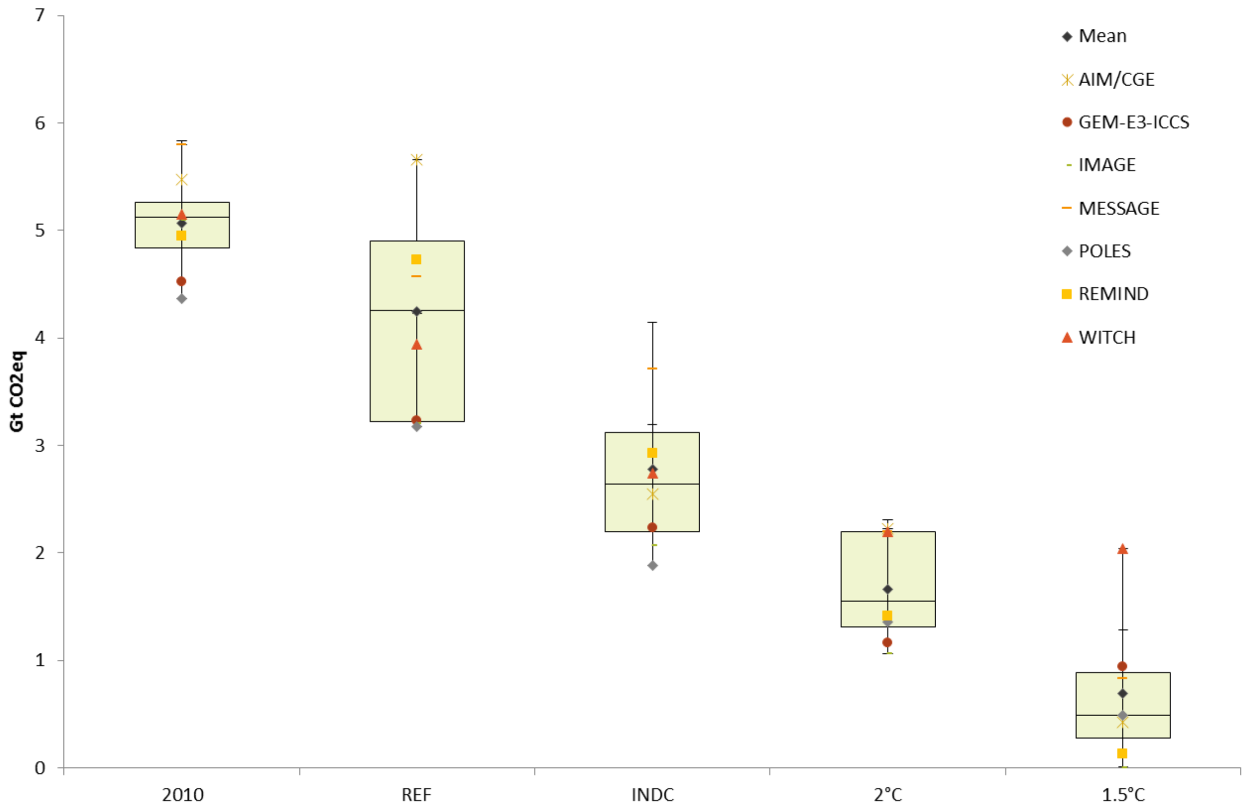

Figure 6.5.2: EU GHG emissions in 2050 for all scenarios

6.5.3 – EU CO_2 emissions in 2030 and 2050

In 2010 the EU the CO2 emissions level stood around 4 Gt CO2. In the Reference, with all existing policies fully implemented, taking into account the existing global energy and technological evolutions, and without any additional policy measures the EU CO2 emissions are assessed to be around 3.4 Gt CO2 [2.9 – 4.2] in 2030, which is about 81% of total GHG.

With the INDC, CO2 emissions are 2.9 [2.4 – 3.7] Gt CO2 in 2030, representing again 81% of total GHG. The analysis shows that this is consistent with a 2C pathway which results in 2.7 Gt CO2 for the EU in 2030. An 1.5C pathway however would reach 1.9 Gt CO2 in 2030, or 80% of total GHG.

In 2050 the reference is with 3 Gt CO2, 32% below 1990 levels. The emissions in 2050 for a 2C scenario are assessed to be at around 1.1 Gt CO2 [0.6 – 1.5] which correspond to 75% compared to 1990 .

A 1.5C scenario, however, reduces the CO2 emissions in EU to 0.5 Gt CO2eq [-0.01 – 1.4] and requires emissions reductions of about 89% compared to 1990 .

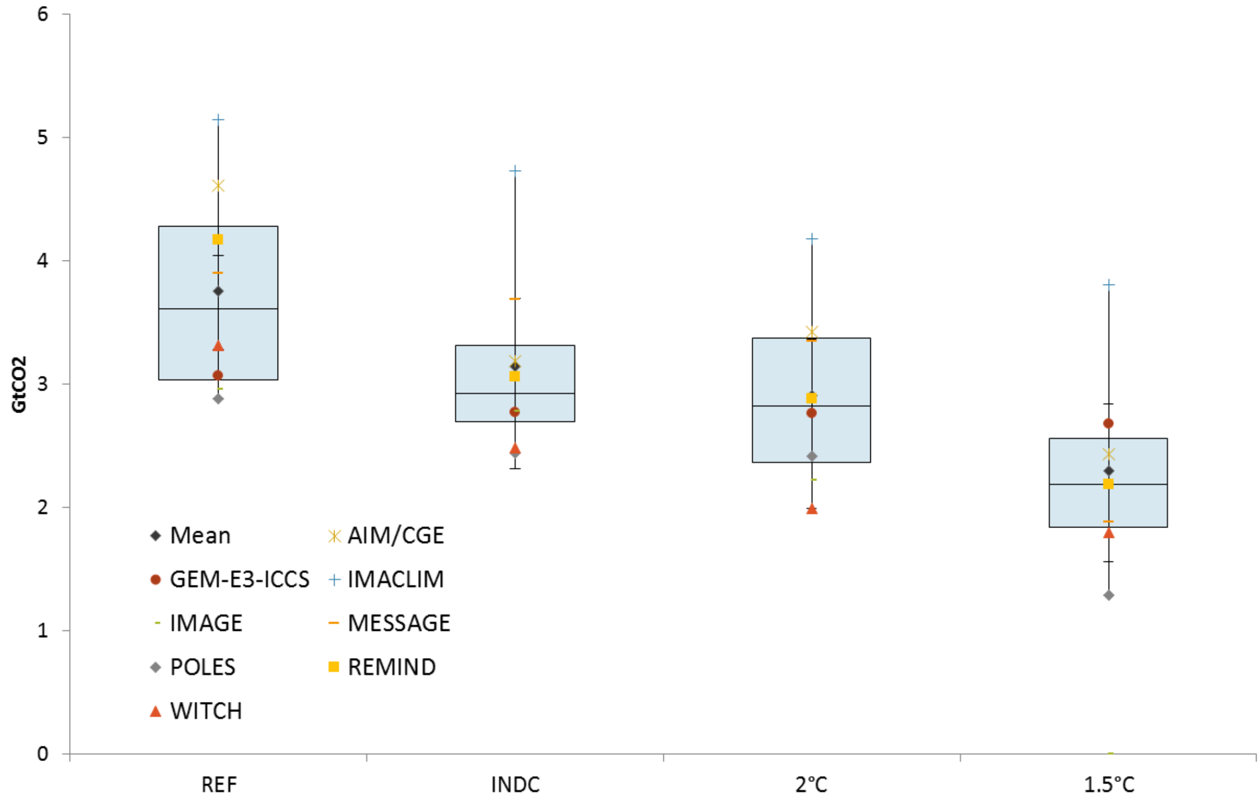

Figure 6.5.3: EU CO2 emissions in 2030 for all scenarios

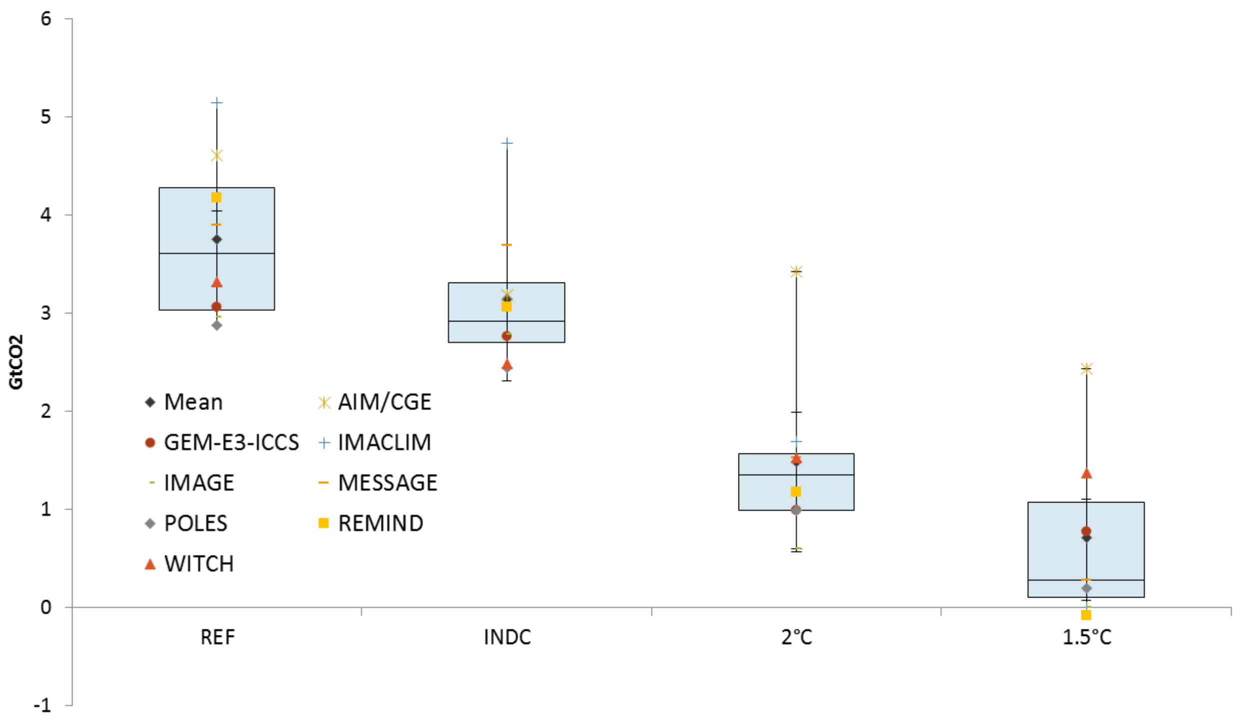

Figure 6.5.4: EU CO2 emissions in 2050 for all scenarios

6.5.4 – Sectoral CO_2 emissions in EU in 2030 and 2050

Figure 6.5.5 shows the CO2 emissions for the power sector, industry, transport, building sector and LULUCF in the EU for 2010 and the reference, 2C, and 1.5C in 2030.

In the reference for 2030, the Power sector (1064 MtnCO2 [769 - 1399]) and the Transport sector (1175 MtnCO2 [702- 1853]) are the sectors with the highest CO2 emission levels in the EU. Whereas the Industry and Building account for almost the same level of emissions, an average of 694 and 642 MtnCO2 respectively. The net emissions of LULUCF are already considered negative in 2030, with an rather low with an average of -55 MtnCO2 [-201 – 125].

In 2030 the reference emissions of the power sector have decreased already by 17% [-37 - +13%] compared to 2010 levels. This reflects the ongoing trend in the EU of the higher use of low carbon technologies in power supply. Further CO2 reductions are needed in the INDC scenario, when Power sector emissions are reduced by 37% [23-48%] from 2010 levels, while these reductions are significantly higher in the 2C (-46% [33-60%]) and 1.5C scenario 2C (-64% [42% – 85%]).

In 2030 the emissions of the transport sector are lower by an average 20% in the EU than in 2010 (in contrast to what is observed at the global level). The additional contributions of the transport sector to reach the INDC levels are projected to reach 25% below 2010 while 2C and 1.5C levels are on average 33% and 38% below 2010 respectively and thus are significantly lower in both absolute and relative terms than the contributions of the Power sector. Similarly, in 2030 the emissions of the Industrial sector is lower in 2010 for the EU in the Reference scenario by 11% while in the INDC industrial CO2 emissions fall by 21% compared to 2010 levels. The additional contributions of the Industrial sector to reach 2C and 1.5C levels are -23% and -39% respectively.

Something similar can be observed for the Building sector (heating and cooling etc.) in the EU. In 2030 the emissions of the building sector in the Reference are lower 8% compared to 2010 for the EU while under the INDC this reduction doubles with the increased energy efficiency measures and reaches -19% from 2010 levels. The additional contributions of the Building sector to reach the 2C levels and 1.5C levels bring emissions to -21% and -37% from 2010 levels.

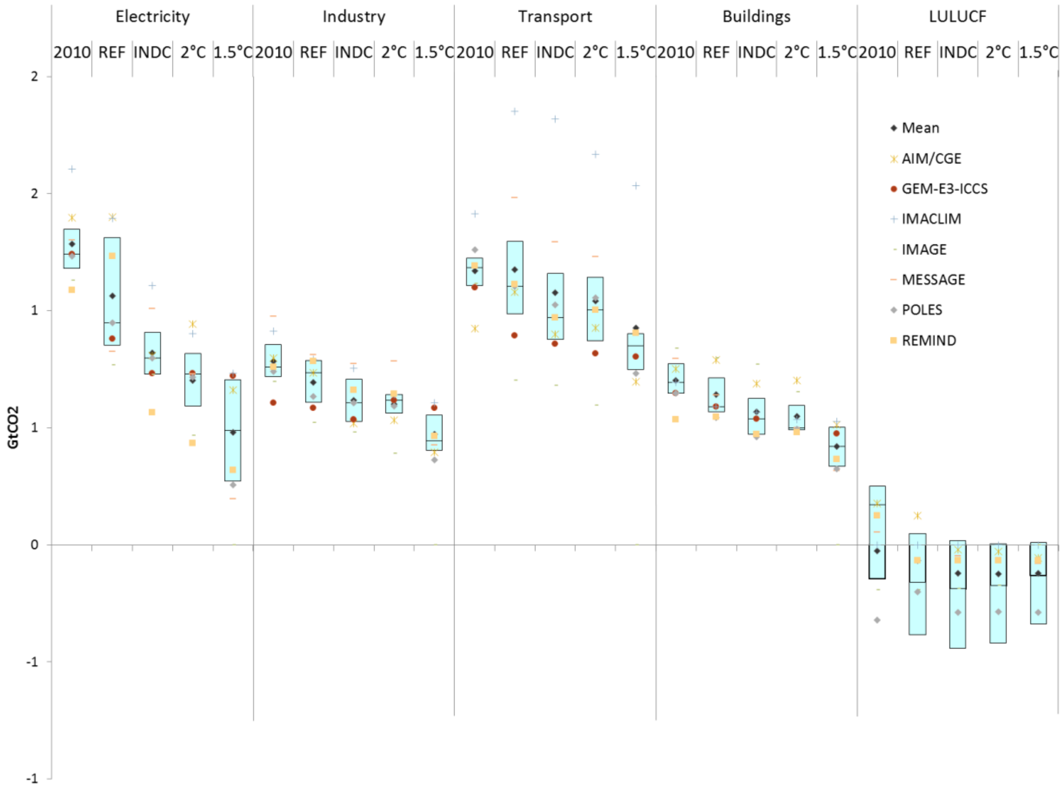

Figure 6.5.5: EU Sectoral CO2 emissions in 2030 for all scenarios

Figure 6.5.6 shows the CO2 emissions for the power sector, industry, transport, building sector and LULUCF in the EU for 2010 and the reference, 2C, and 1.5C in 2050.

In the reference for 2050, the power sector (970 MtnCO2 [457 - 1388]) and the Transport sector (1144 MtnCO2 [547 - 2264]) are the sectors with the highest CO2 emission levels in the EU, with transport taking the lead as ambitious decarbonization polices for the power sector have already been put in place. Whereas the Industry and Building account for an average of 648 and 602 MtnCO2 respectively. The net emissions of LULUCF are already neutral, with an average of -17 MtnCO2.

In 2050 the reference emissions of the power sector have decreased already by an average of 25% compared to the situation in 2010, while transport emissions are only marginally reduced by 3% compared to 2010 and emissions from the Building sector by 13% accordingly. In the mitigation scenarios the Power sector is still dominant in the mitigation effort but the transport and Buildings sectors are contributing significantly more than in the previous period. In the INDC scenario the average sectoral reductions compared to 2010 levels are 77%, 22% and 31% respectively. Further CO2 reductions are needed in the 2C and 1.5C scenario in 2050. The power supply sector reaches zero CO2 emissions while Transport moves to 42% and 67% below 2010 levels respectively, and the building sector to 52% and 77% respectively. Similar to the Buildings sector, Industrial CO2 emissions move from 17% below 2010 levels in the Reference, to -36% in the INDC scenario and to 62% and 75% for the 2C and 1.5C scenarios respectively.

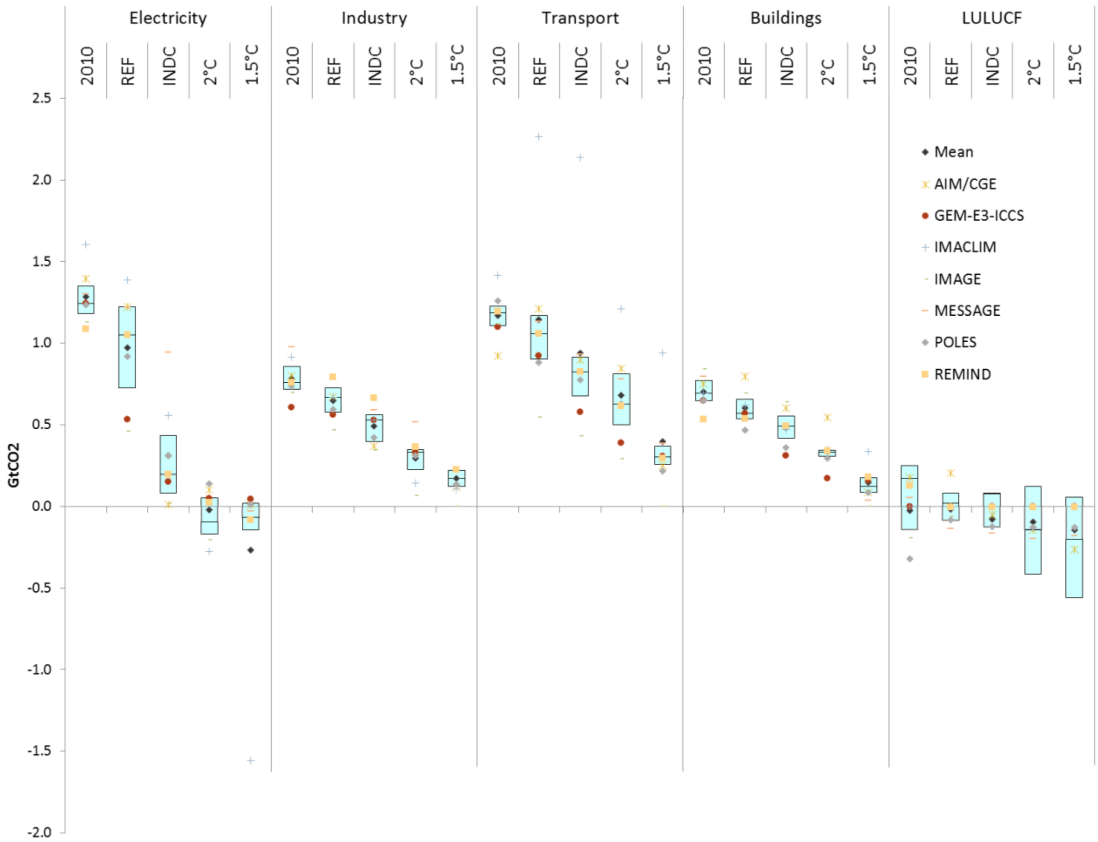

Figure 6.5.6: EU Sectoral CO2 emissions in 2050 for all scenarios

6.5.5 – Sectoral final energy demand in EU in 2030 and 2050

In the EU for 2030 the INDCs imply a rather moderate change from current trends in the energy system. The transformation of the energy system is limited even when considering the energy-related targets provided in the INDCs. Nevertheless, energy is used more efficiently than today economy-wide already in the Reference scenario, with energy intensity in 2030 falling by 24% [18-31%] below 2010 levels. The implementation of INDCs brings only marginal improvements in the energy efficiency of the EU economy, getting energy intensity in 2030 only 28% [22-32%] below 2010 levels. On the contrary, to achieve the 1.5-2°C targets, the economy changes the way it uses energy, as already in 2030 energy intensity levels fall by 31% [25-40%] and 37% [27-49%] below 2010 levels in the 2C and 1.5C scenarios respectively.

In the EU for 2050 the INDCs imply a more significant change from current trends in the energy system. The transformation of the energy system is more pronounced. Energy intensity in 2050 falls by 42% [32-54%] below 2010 levels. The implementation of INDCs brings only marginal improvements in the energy efficiency of the EU economy, getting energy intensity in 2050 only 47% [41-57%] below 2010 levels. On the contrary, to achieve the 1.5-2°C targets, the economy changes the way it uses energy, as already in 2050 energy intensity levels fall by 54% [42-63%] and 59% [47-67%] below 2010 levels in the 2C and 1.5C scenarios respectively.

In the INDC scenario final energy demand is reduced by only 5% [2-9%] in 2030 compared to the Reference, while in the 2C and 1.5C scenarios it is reduced by 9% [3-21%] and 17% [6-26%] respectively. In the INDC scenario final energy demand is reduced by only 8% [6-11%] in 2050 compared to the Reference, while in the 2C and 1.5C scenarios it is reduced by 21% [13-35%] and 31% [21-43%] respectively.

Figure 6.5.7**Error! Reference source not found.** shows the EU final energy demand per sector for each model[4], giving an insight on which sectors contribute the most in the drop of demand, either due to efficiency measures or due to a fall in sectoral activity. In the INDC scenario the Transportation and Buildings sectors have the highest and almost identical contributions in absolute terms, reducing demand by 5% [1-14%] and 5% [2-8%] relative to Reference. To get to 2C consistent pathways, Transportation and Buildings sectors reduce by 9% [3-13%] and 8% [5-16%] respectively, while for 1.5C pathway they reduce by 18% [7-32%] and 15% [5-21%] respectively. Industry is contributing relatively less to total final energy savings, reducing its final energy demand from Reference levels by 3% [9-+3%] in the INDC and by 5% [11-+3%] in the 2C and by 14% [25-+1%] in the 1.5C scenarios respectively.

Respectively, Figure 6.5.8**Error! Reference source not found.** shows the EU final energy demand per sector for each model[5] for 2050. In the INDC scenario the Buildings sector has the biggest reduction in demand in absolute levels (10% [4-20%] relative to Reference), followed by Transportation (8% [1-19%]) and Industry (6% [1-11%]). To get to the 2C consistent pathway, Transportation contributes the most, reducing energy demand by 25% [16-34%] compared to

[4] Excluding WITCH model that does not provide results in this sectoral detail.

Reference, while the same holds for the 1.5C, with a reduction of 40% [27-50%] from Reference levels.

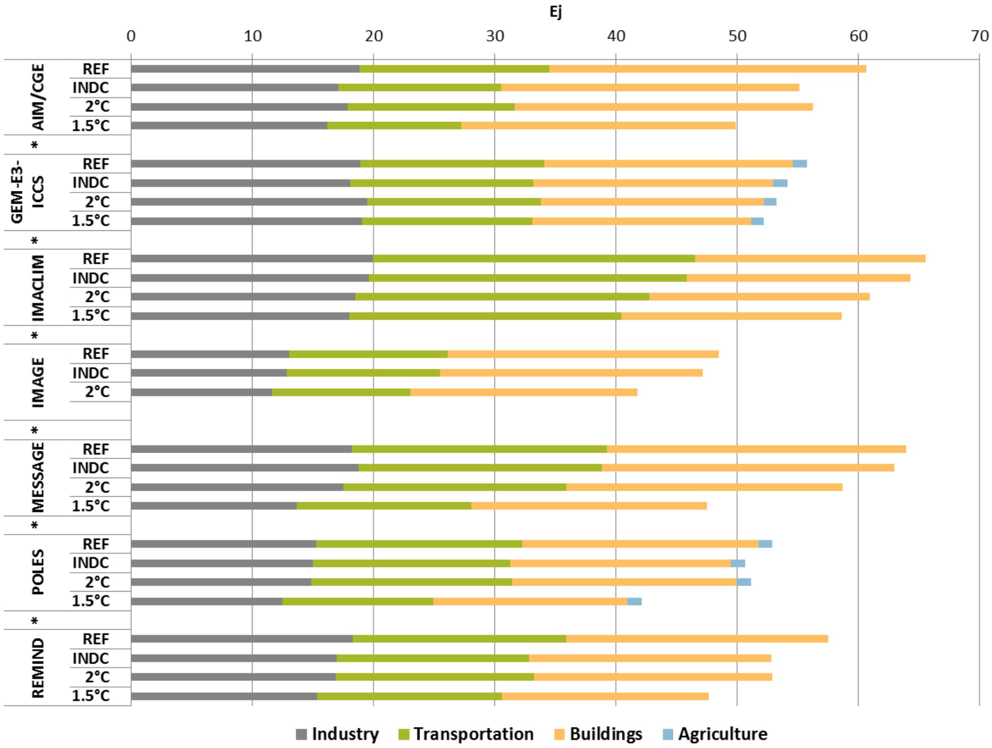

Figure 6.5.7: EU sectoral final energy demand in 2030 for all scenarios

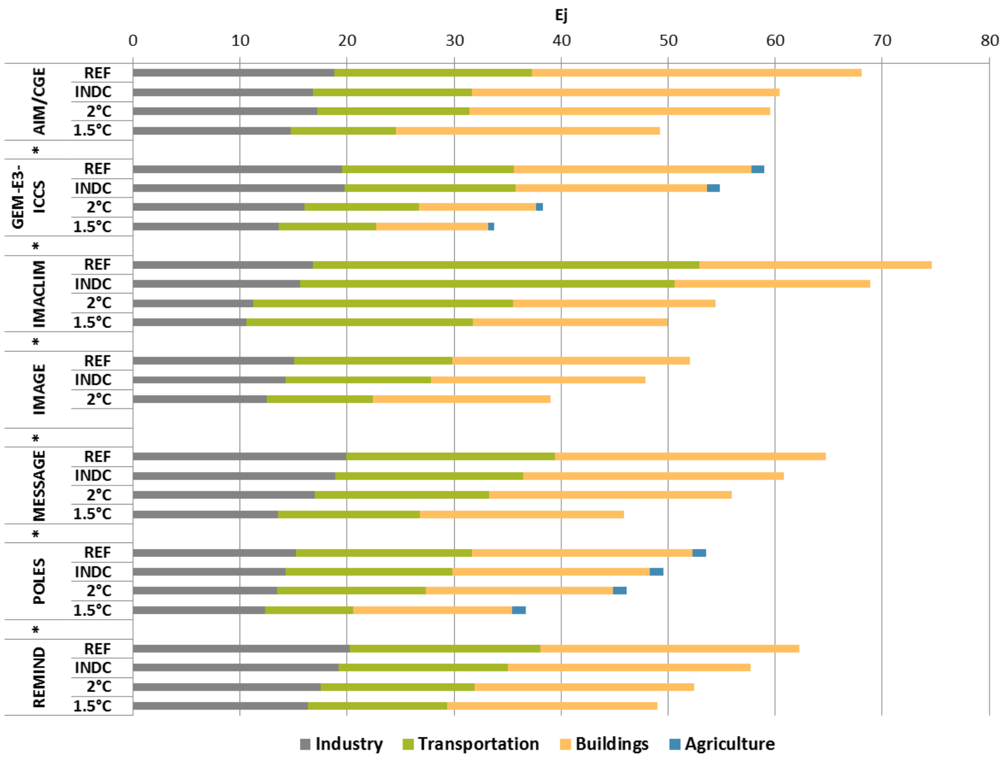

Figure 6.5.8: EU sectoral final energy demand in 2050 for all scenarios

6.5.6 – Zero Carbon Power Supply in EU in 2030 and 2050

The decarbonization of the power sector is dominant in the transformation of the energy system and in the mitigation effort, contributing with half of CO2 emission reductions in all scenarios in both 2030 and 2050.

Figure 6.5.9 shows the shares of zero-carbon production in the EU power system in 2030 while Figure 6.5.10 shows the respective shares in 2050. In 2030, zero carbon power supply moves from an average 62% in the Reference to 69% with the implementation of INDCs. However to reach the 1.5C emission pathway, zero carbon power supply reaches on average 80% already in 2030. In 2050, respectively, the share in the Reference scenarios is already 70%, indicating that strong climate policies are already in place for the power sector in EU28. Nevertheless, a 2C consistent pathway involves an average of 87%, which increases to 91% for the 1.5C scenario.

Figure 6.5.11 and Figure 6.5.12 provide an insight on specific zero-carbon technologies that enter the system for all different scenarios in 2030 and 2050 respectively. Although nuclear power maintains a share close to that of 2010 in all scenarios, solar power in the EU increases from an 1% in 2010 to around 6% in the Reference, INDC and 2C scenarios and to 8% in the 1.5C in 2030. Wind has an even deeper penetration, going from an average of 6% in 2010 to 19% in 2030 in the Reference scenario and to 29% in the 1.5C scenario, indicating the high potential of this technology in the mitigation effort.

In 2050 in the Reference and INDC scenarios nuclear loses its position in the power mix compared to 2010 (26%), moving to 10%, while in the 2C and 1.5C scenarios the share is still lower than in 2010, increasing to 16%. Solar in 2050 moves to around 13% in all scenarios, while wind has an average 33% penetration in the Reference scenario and reaches almost 40% in the 2C and 1.5C scenarios.

The importance of zero-carbon power technologies differs widely across models. This can be explained, among others, by differences in the abatement effort and emission gap in 2050, by differences in the costs of each technology but also by the size of the cost-effective contribution of other sectors and gases, which in turn is determined by different abatement options and costs and by the sector responsiveness of each model.

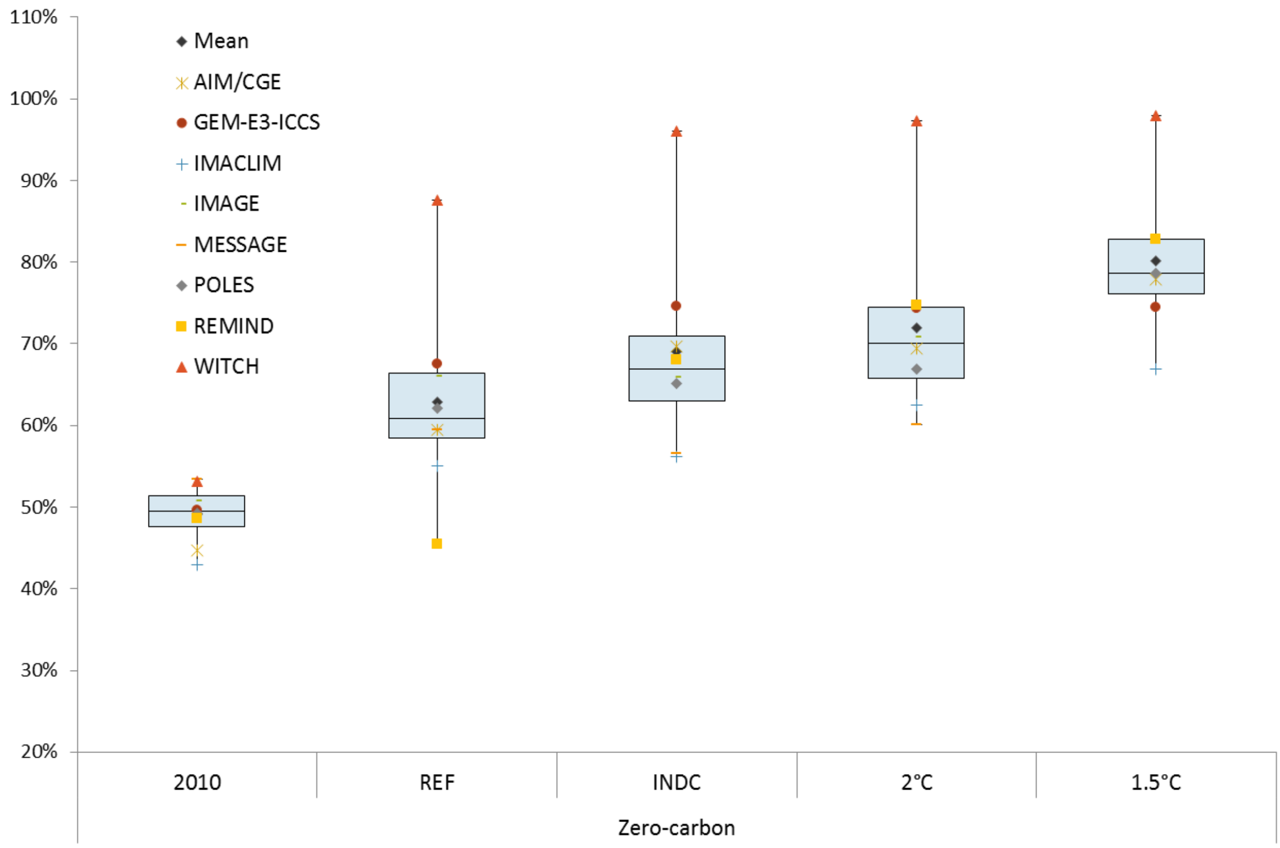

Figure 6.5.9: Share of EU zero carbon power supply in 2030 for all scenarios

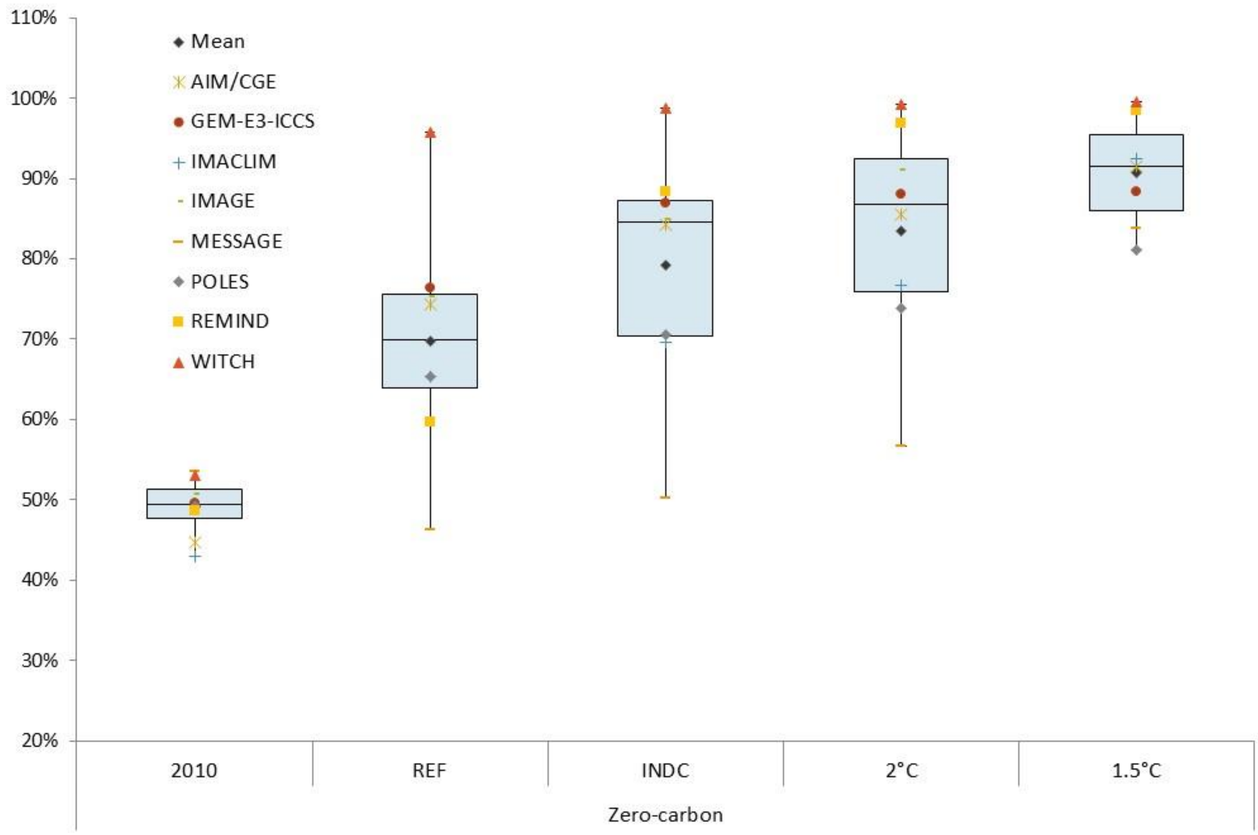

Figure 6.5.10: Share of EU zero carbon power supply in 2050 for all scenarios

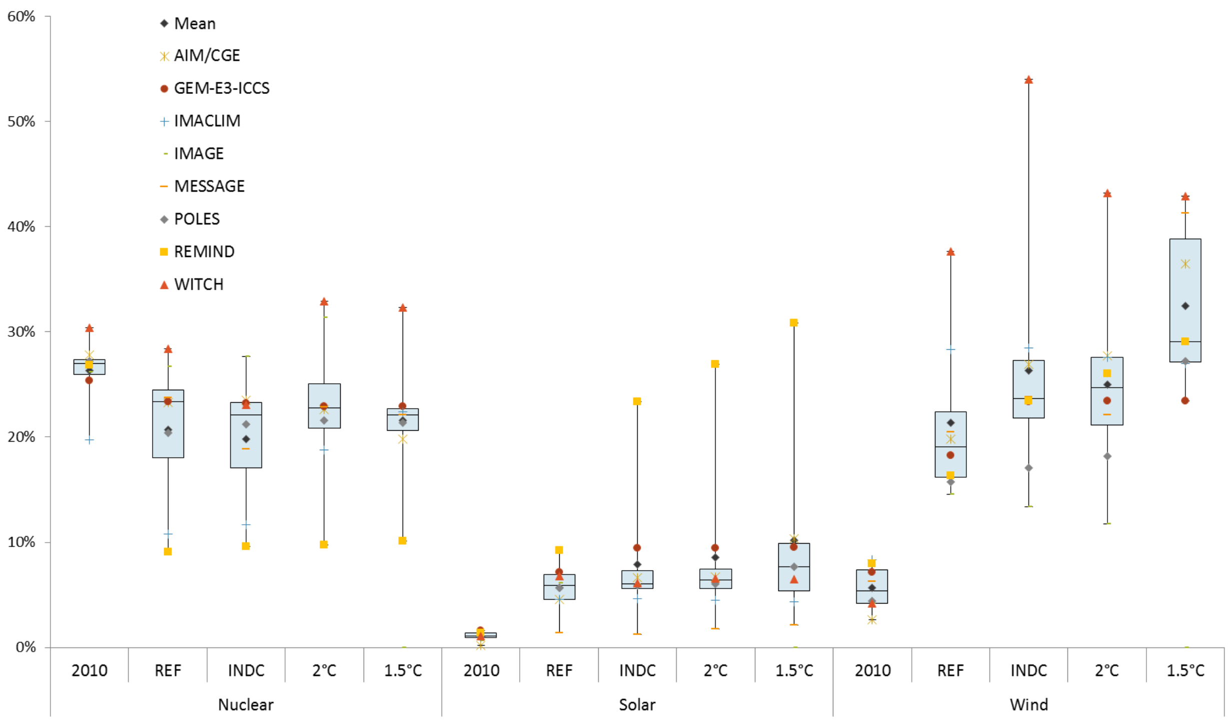

Figure 6.5.11: Technology share in EU power supply in 2030 for all scenarios

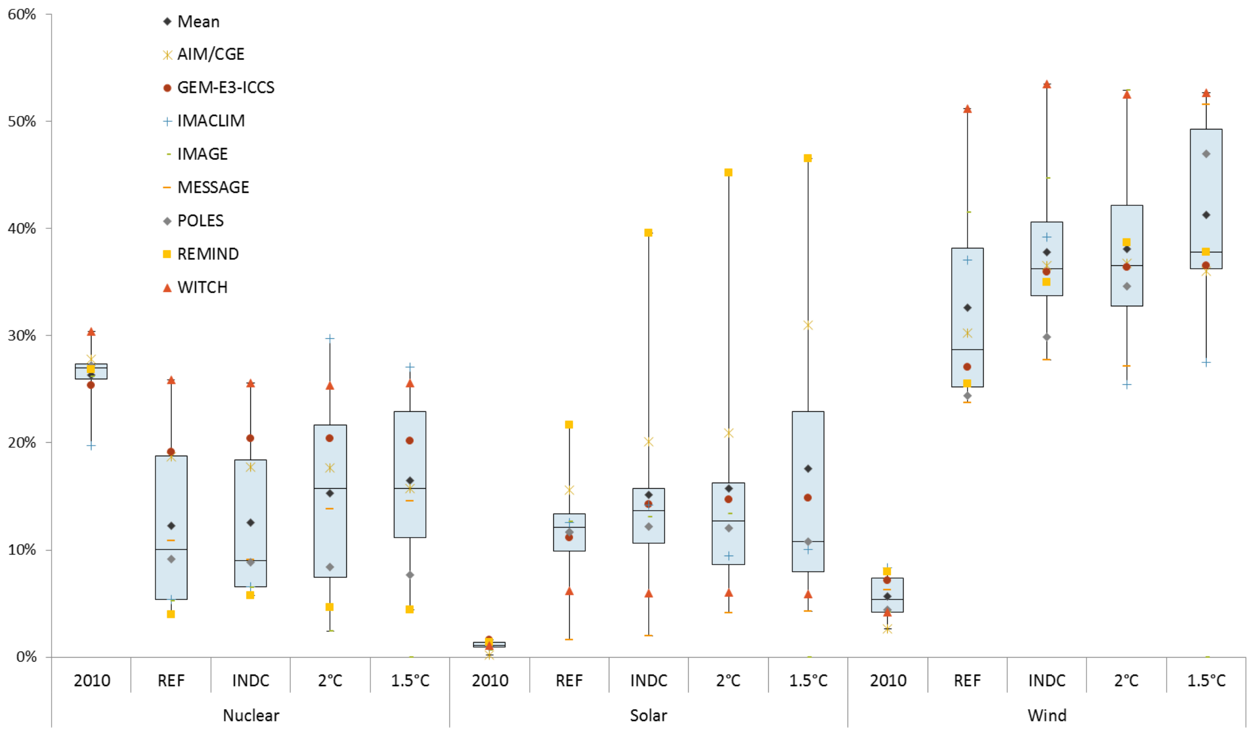

Figure 6.5.12: Technology share in EU power supply in 2050 for all scenarios

6.5.7 – Low-carbon transportation in EU in 2030 and 2050

Low carbon transportation is close to 4% in 2010 and reaches a share of about 8% in Reference and 10% in the INDC and 2C scenarios in 2030, while for the 1.5C this share is only marginally higher to 13%. In 2050, the transport sector is undergoing a transformation, as the low carbon share reaches 38% and 49% in the 2C and 1.5C scenarios from the 17% that is already seen in the Reference. Figure 6.5.13 and Figure 6.5.14 present these trends for all scenarios and models.

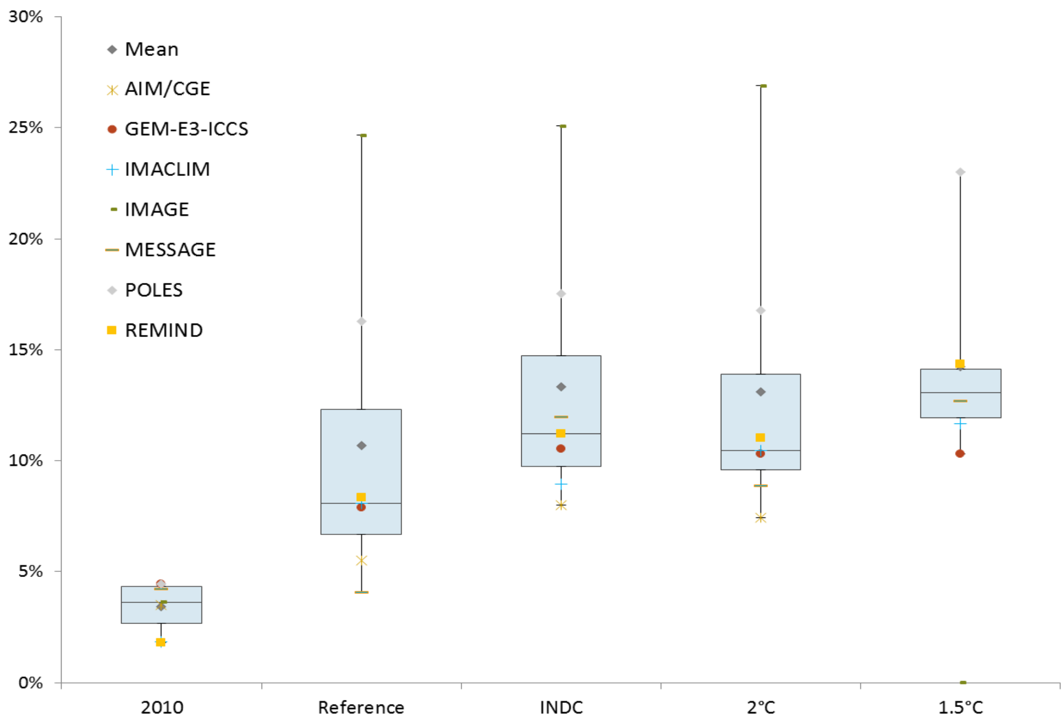

Figure 6.5.13: Share of low-carbon transportation in total EU in 2030 for all scenarios

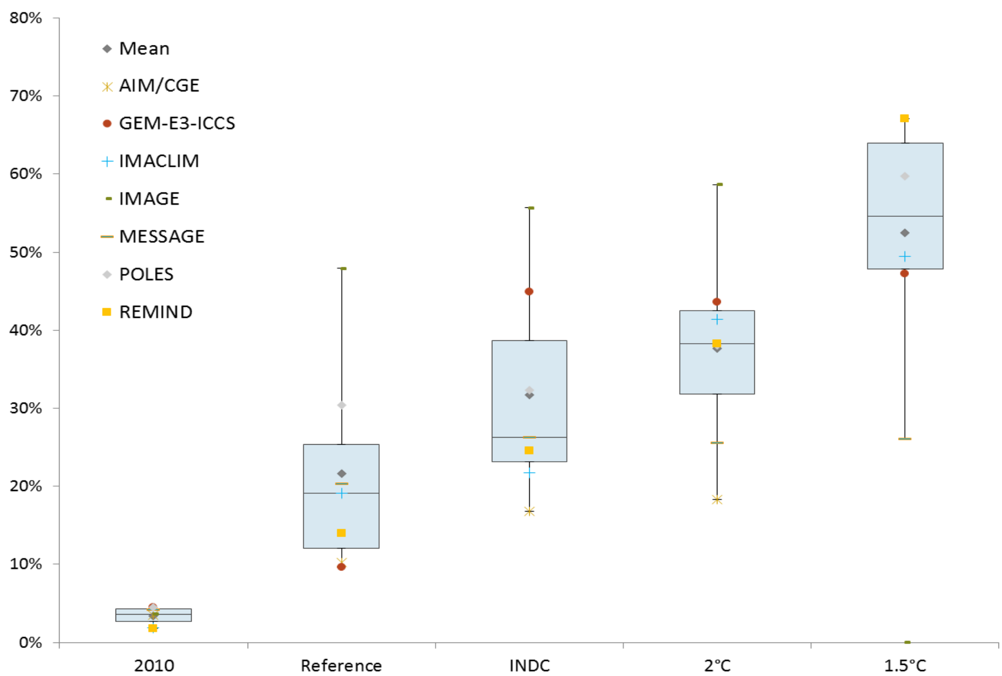

Figure 6.5.14: Share of low-carbon transportation in total EU in 2050 for all scenarios

6.5.8 – GDP impacts in EU in 2030 and 2050

Hybrid general equilibrium models are used to assess the INDC, 2C and 1.5C scenarios. Moving to a low carbon system is capital intensive and requires a reallocation of resources that may result in economy-wide policy costs. In general, costs rise with more ambitious climate mitigation policies.

However, the allocation of efforts is also an important driver of costs, as those are minimized in a global mitigation framework where reductions are undertaken by sectors and countries with the lowest marginal abatement cost. On the contrary, a fragmented action, like under the INDC scenario, may results in sub-optimal burden sharing. Further, the way of implementing the emission reductions is almost as important as a driver for policy costs than the ambition levels itself.

This analysis does not take into account the eventual avoided damage costs from pollution (e.g. air quality) and climate change impacts, or other positive feedback effects of the mitigation policies. Hence, the (negative) GDP impacts are high-end estimates and can be considered as conservative.

We assess the costs of implementing the EU's INDC in a global Paris Agreement context, and find a policy cost in 2030 in terms of loss of GDP equal to 0.4% [0.0-1.2%] of Reference GDP (Figure 6.5.17). Closing the “emissions gap”, i.e. moving from INDC to deep-decarbonization pathways, reduces further GDP by 0.9% [0.3-1.9%] and 1.9% [1.2-3.0%] from Reference levels for the 2°C and 1.5°C scenarios respectively. Comparing the EU28 costs with global costs as reported in D6.3, we see that on average, EU28 costs are higher than global (in relative terms of reductions from Reference) for the INDC scenario, but lower for the deep decarbonization scenarios as other countries present cheaper mitigation potentials.

To put these numbers into context, the EU annual GDP growth rate for the 2020-2030 period is presented in Table 6.5.8, indicating that sustainable growth can be ensured even under the 1.5C scenario. Growth rates are only marginally reduced, even if the avoided climate impacts and other potential co-benefits are not included in this assessment of costs.

GDP growth rate 2020-2030	Reference	INDC	2°C	1.5°C
AIM/CGE	1.7%	1.6%	1.6%	1.5%
GEM-E3-ICCS	1.3%	1.3%	1.3%	1.2%
IMACLIM	2.4%	2.4%	2.2%	2.2%
MESSAGE	2.3%	2.3%	2.2%	2.1%
REMIND	1.6%	1.6%	1.6%	1.6%
WITCH	1.6%	1.5%	1.4%	1.3%

Table 6.5.8: EU28 yearly growth rate for 2020-2030 under all scenarios

Figure 6.5.18 shows the GDP costs for the INDC, 2C and 1.5C scenarios for the EU in 2050. In 2050, the INDC and 2C scenario are no longer compatible, and Figure 6.5.16 shows GDP costs of 0.6% [0.1-1.4%] and 2.2% [0.7-4.7%], for the INDC and 2C scenario respectively. The 1.5C scenario shows a higher cost in 2050, reaching 4.6% [1.4-8.3%], as the transition to a low-carbon system is deepening. While these costs are substantial compared to the reference (which does not take into account the costs of unstainable levels of air pollution and higher impacts of climate change, and other co-benefits), the GDP growth reductions are modest when annualized over the period 2020-2050, as seen in Table 6.5.9.

GDP growth rate 2020-2050	Reference	INDC	2°C	1.5°C
AIM/CGE	1.6%	1.6%	1.6%	1.5%
GEM-E3-ICCS	1.5%	1.4%	1.3%	1.2%
IMACLIM	2.5%	2.4%	2.3%	2.2%
MESSAGE	2.2%	2.2%	2.1%	2.1%
REMIND	1.6%	1.6%	1.6%	1.6%
WITCH	1.5%	1.5%	1.4%	1.4%

Table 6.5.9: EU28 yearly growth rate for 2020-2050 under all scenarios

Figure 6.5.15 and Figure 6.5.16 provide the GDP costs illustrating that costs differ across models due the different abatement efforts in 2030 and 2050 in relation to the Reference, as both Reference emission trajectories and cost-efficient pathways for the 1.5-2°C targets differ across models.

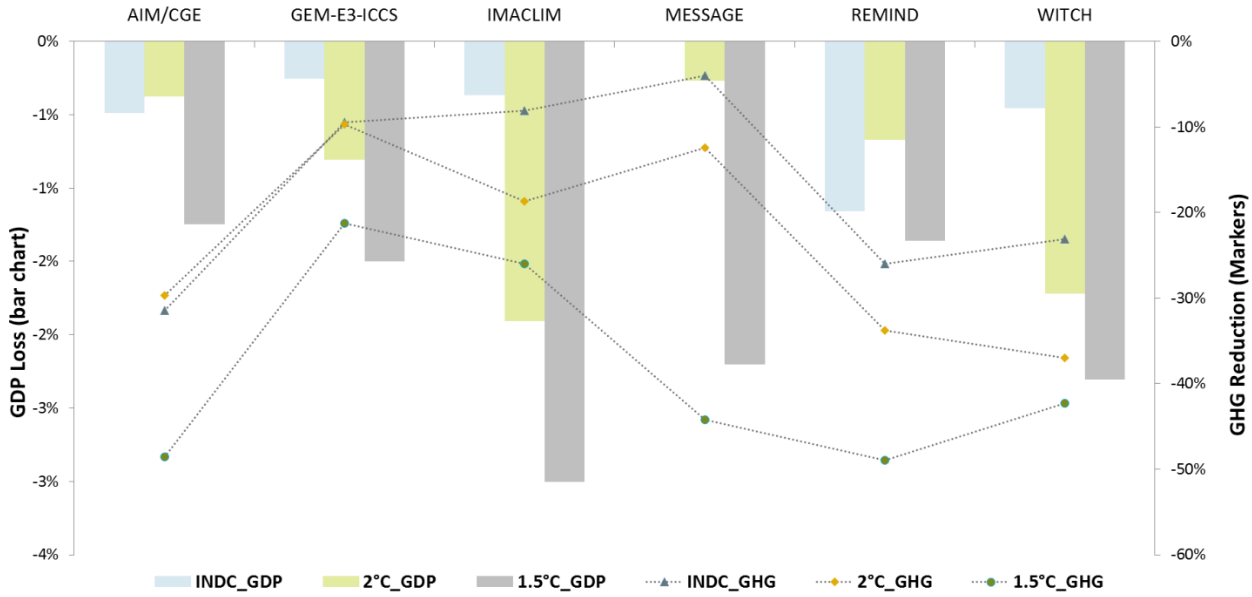

Figure 6.5.15: EU GDP loss in relation to GHG reductions in 2030, all scenarios compared to Reference

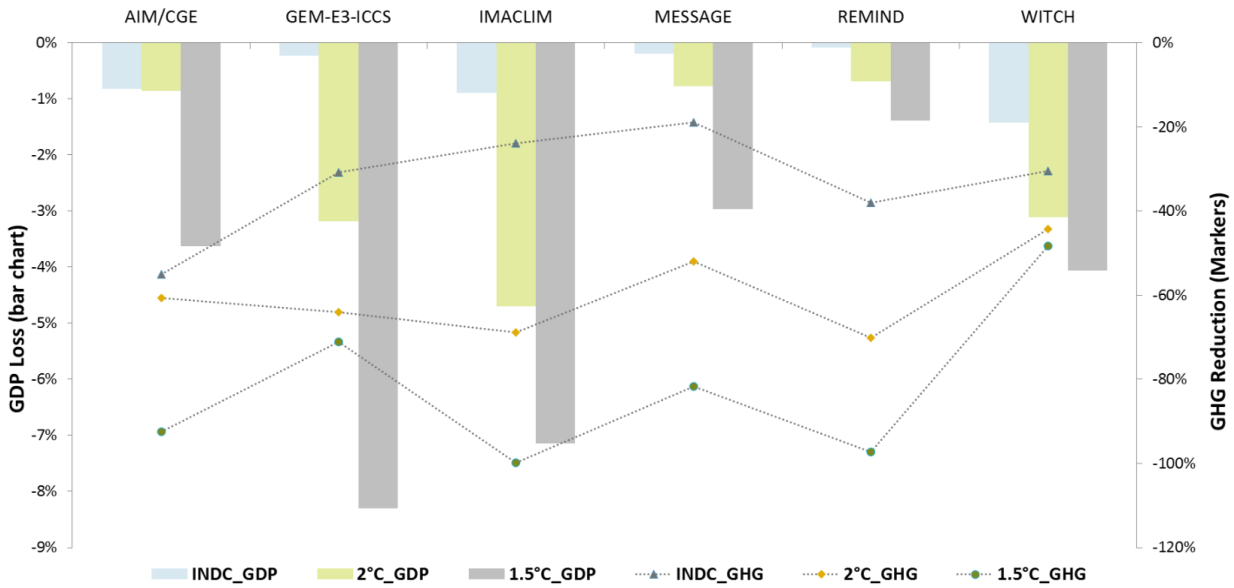

Figure 6.5.16: EU GDP loss in relation to GHG reductions in 2050, all scenarios compared to Reference

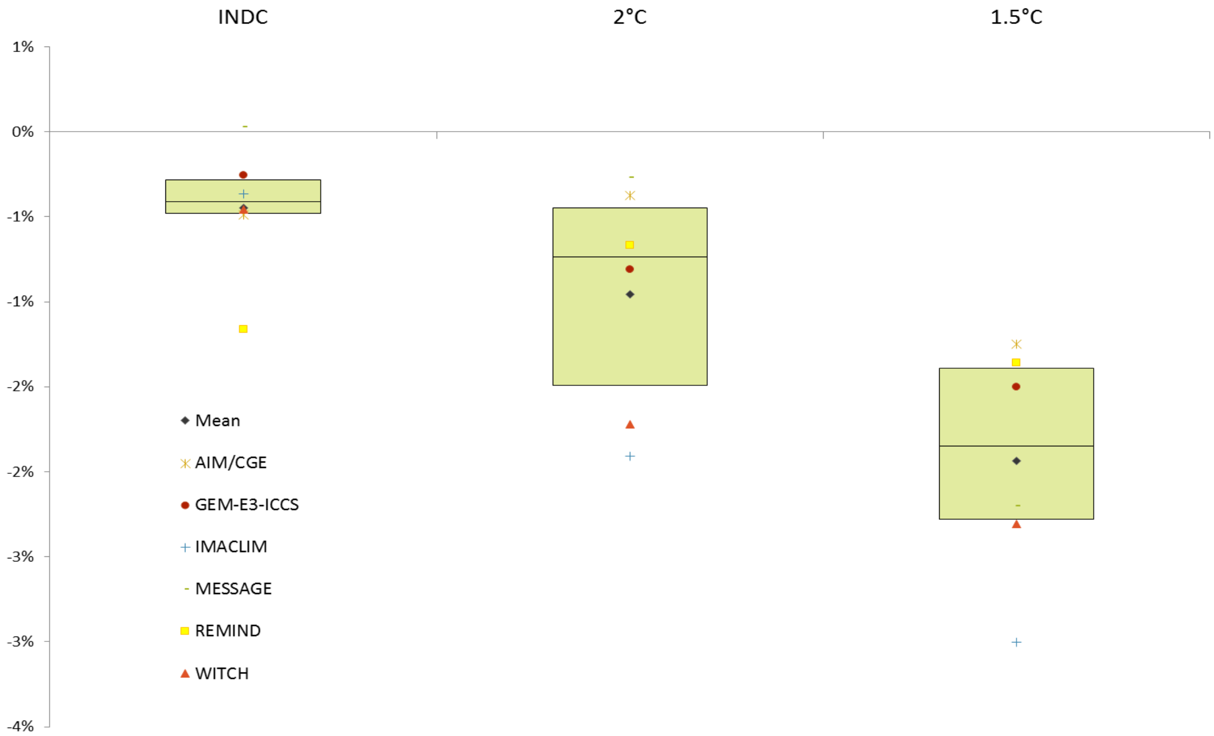

Figure 6.5.17: EU GDP loss in 2030, all scenarios compared to Reference

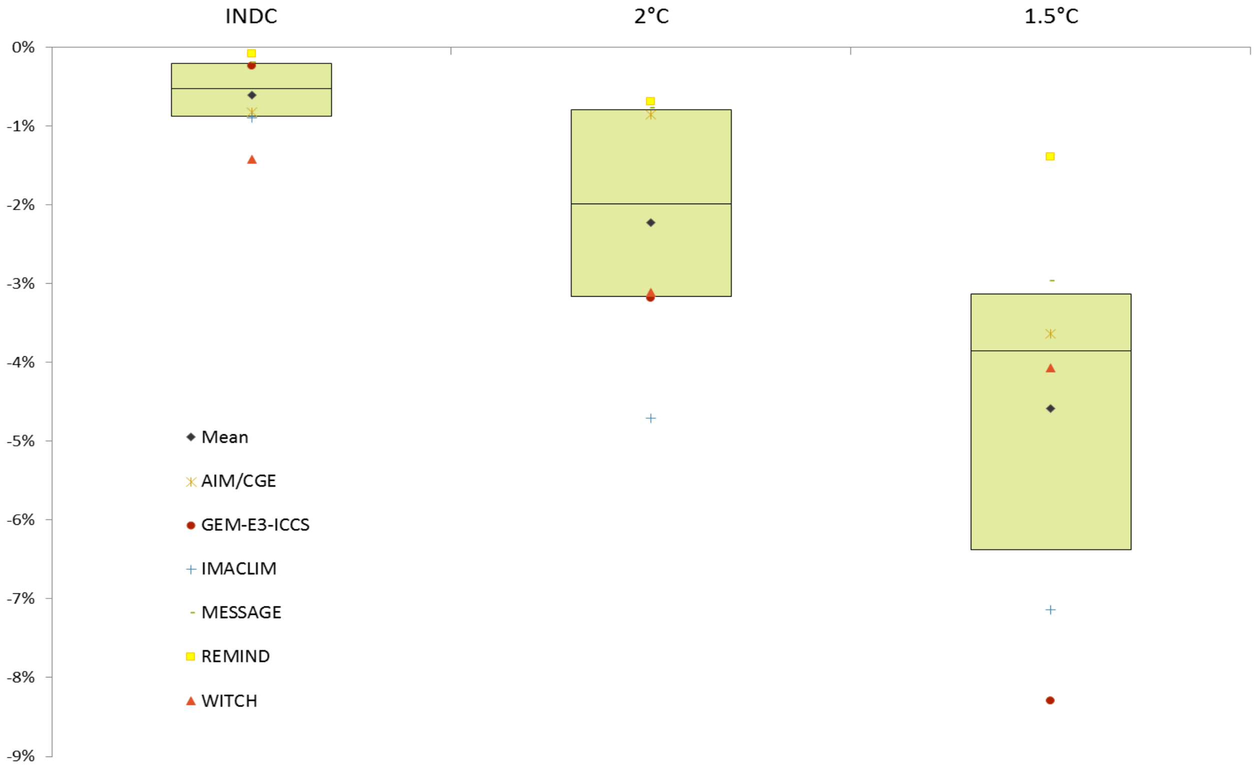

Figure 6.5.18: EU GDP loss in 2050, all scenarios compared to Reference

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