



## Deliverable 8.1 (CMCC): Report on the ICES and the GEM-E3 model benchmark scenario for the subsequent analysis

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# Executive Summary

This deliverable describes the main assumptions adopted for the benchmark scenario that will be used for the assessment of planned adaptation using the ICES model and autonomous adaptation using the GEM-E3-CAGE model.

For this purpose ICES has been tailored in two versions considering two different perspectives.

The first one extends ICES to include a more detailed public sector to assess planned adaptation with direct government interventions for sea level rise and floods.

Conversely, the second version considers an improved irrigation module for agricultural activities as a measure of planned adaptation from the private sector.

The GEM-E3-CAGE model was equipped with representation of market mechanisms allowing for occurrence of autonomous adaptation response to a climate change scenario. The mechanisms include control of degrees of capital mobility, labour market rigidities and substitution between domestic and imported products and services.

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# 1. Introduction

This deliverable describes briefly the ICES model, the GEM-E3-CAGE model, the benchmark scenario which will be used for the assessment of planned adaptation actions at the regional level, and how the GEM-E3-CAGE model will be used for the assessment of autonomous adaptation response.

Within the ECONADAPT project, the ICES model is used to assess two different forms of planned adaptation, in a more general context of market-driven adaptation captured by endogenous relative price changes. There are thus two different ICES model versions with the same regional and sectoral detail. The first version extends the impact and adaptation assessments developing a more realistic behaviour of the public sector, and will be referred as ICES-XPS. It enables to consider the effects of public spending in adaptation interventions like sea-level rise and/or floods protection. The second version, from now on code named ICES-Irr, emphasises specific and private actions planned to deal with climate change impacts on agriculture.

For assessment of the market-driven autonomous adaptation a simplified version of the GEM-E3 model named CAGE (Climate Assessment General Equilibrium) has been prepared. The model accounts for various market mechanisms which underpin autonomous adaptation, including capital mobility, labour market rigidities and substitution between domestic and imported products and services.

## 2. The ICES model

ICES is a recursive-dynamic computable general equilibrium (CGE) model based on the GTAP 8 database (Narayanan et al. 2012). The ICES simulation period is 2007-2050 resolved in one-year time steps, with 2007 as the calibration year. Compared to the standard GTAP database and model, in addition to the dynamic in capital stock, it includes renewable energy production. Different versions of the ICES model have been extensively used in past exercises to economically assess many different kinds of climate change policy and impacts for different climatic scenarios and regional aggregations (see e.g. Bosello and Zhang, 2006; Bosello et al., 2006, 2007, 2008, 2011, 2012; Eboli et. al 2010; Parrado and De Cian, 2012).<sup>1</sup>

The two ICES versions which will be used for the assessment of planned adaptation, have been described in Milestone MS12 (Bosello and Parrado, 2015). The first version (ICES-XPS) improves the behaviour of the public sector in the CGE model. It features a more realistic description of the public sector, with the government as a proper agent and detailed information about fiscal accounts. The second version (ICES-Irr) extends the model and database to include irrigation as an explicit action to contrast climate change impacts on agriculture. In this case an explicit irrigation services sector has been included which provides input to irrigation activities in agriculture.

The regional and sectoral model detail used in ECONADAPT project is summarized in Table 1).

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<sup>1</sup> A more detailed description of the core of the model can be found in Parrado and De Cian (2012) and in the ICES website at <http://www.feem-web.it/ices/>.

**Table 1: Regional and sectoral detail of the ICES model**

<b>Regional detail</b>				
<b>Europe</b>	<b>Africa/Middle East</b>	<b>Americas</b>	<b>Asia</b>	<b>Oceania</b>
North Europe	North Africa	USA	Japan	Australia
North_EU15	Sub-Saharan Africa	Canada	South Korea	New Zealand
Med_EU15	South Africa	LACA	South Asia	
Med_EU12	Middle East		India	
East_EU12			China	
Rest of Europe			East Asia	
Rest of FSU				
<b>Sectoral detail</b>				
<b>Sectors</b>		<b>Energy sectors</b>		
Rice		Coal		
Wheat		Oil		
Other Grains including Maize		Gas		
Oil Seeds Including Soy		Nuclear Fuel		
Livestock		Oil Products		
Energy Intensive Industries		Nuclear Electricity		
Other Industries		Renewable Electricity		
Construction		Fossil Electricity		
Road Transport				
Other Transport				
Trade				
Water				
Irrigation Services				
Market Services				
Public Services				

### 3. The CAGE model

The CAGE model is a simplified version of the GEM-E3. It features the standard CGE structure with a nested production where output is produced by combining capital, labour, energy and intermediate inputs (in the CAGE model the energy comprises electricity and three fuel inputs: coal, gas and energy); the consumption is based on utility maximising representative household with minimum consumption on the commodities level and with welfare defined as change in real consumption above the subsistence level; the international trade follows the Armington specification; closure rules allow for different macroeconomic assumptions. The model is calibrated to 2007 base year (GTAP 2008 database, Narayanan et al. 2012). The sectoral and regional aggregation of the CAGE model will be adapted to ensure maximum possible consistency between the CAGE and the ICES models, as presented in Table 1 above.

For the ECONADAPT project the CAGE model was tailored to explore the implications of the various possible autonomous adaptation mechanisms which relate to factor mobility (capital and labour), both across sectors and regions, and the degree of substitutability between capital and labour in the production function. The adaptation-related mechanisms include: (1) control of mobility of factors of production for capital and labour which allows for specifying three different degrees of sluggishness separately for each factor: they can be set as sector-

specific, region-specific, or inter-regional (full global mobility); (2) control of labour market rigidities by assuming labour mobility (as in the previous point) and by modifying substitution possibilities between capital and labour; (3) control of degree of substitution between domestically produced and imported goods and services (Armington elasticity).

The regional and sectoral aggregations of the CAGE model appear in Table 2 and Table 3, respectively.

**Table 2. CAGE geographical aggregation.**

<i>Region</i>	<i>List of countries</i>
China	China
Japan	Japan
Korea	Korea
Indonesia	Indonesia
Russia	Russia
India	India
USA	USA
Canada	Canada
Mexico	Mexico
Brazil	Brazil
South Africa	South Africa
UK & Ireland	UK, Ireland
Northern Europe	Denmark, Estonia, Finland, Lithuania, Latvia, Sweden
Central Europe (North)	Poland, Netherlands, Luxembourg, Germany, Belgium
Central Europe (South)	Austria, Czech Republic, France, Hungary, Romania, Slovakia, Slovenia, Croatia
Southern Europe	Bulgaria, Cyprus, Spain, Greece, Italy, Malta, Portugal
Australasia	Australia, New Zealand, rest of Oceania
South Asia	Bangladesh, Iran, Sri Lanka, Nepal, Pakistan, rest of South Asia
Sub-Saharan Africa	Botswana, Cote d'Ivoire, Cameroon, Ethiopia, Ghana, Kenya, Madagascar, Mozambique, Mauritius, Malawi, Namibia, Nigeria, Senegal, Tanzania, Uganda, South Central Africa, Central Africa, rest of Eastern Africa, Rest of South African Customs Union, Rest of Western Africa, Zambia, Zimbabwe
Rest of Europe	Albania, Switzerland, Norway, Rest of Eastern Europe, Rest of EFTA, Rest of Europe
Rest of South-east Asia	Cambodia, Laos, Mongolia, Malaysia, Philippines, Singapore, Thailand, Taiwan, Vietnam, Rest of East Asia, Rest of Southeast Asia, Rest of the World
Rest of Former USSR	Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Ukraine, Rest of Former Soviet Union
Middle East & North Africa	United Arab Emirates, Bahrain, Egypt, Israel, Kuwait, Morocco, Oman, Qatar, Saudi Arabia, Tunisia, Turkey, Rest of North Africa, Rest of Western Asia
Central. America & Caribbean	Costa Rica, Guatemala, Honduras, Nicaragua, Panamá, El Salvador, Rest of Central America, Caribbean, Rest of North America
Rest of South America	Argentina, Bolivia, Chile, Colombia, Ecuador, Peru, Paraguay, Uruguay, Venezuela, Rest of South America

**Table 3. CAGE sectoral aggregation**

<b>Sector</b>	<b>Description</b>
Agriculture	Bovine cattle, sheep and goats, horses, animal products, raw milk, wool, silk-worm cocoons, fishing
Crops	Paddy rice, wheat, cereal, grains, vegetables, fruit, nuts, oil seeds, sugar cane, sugar beet, plant-based fibres, crops
Forestry	Forestry
Coal Mining	Coal
Crude Oil Extraction	Oil
Natural Gas	Gas, gas manufacture, distribution
Refined Oil	Petroleum, coal products
Electricity	Electricity
Metals	Ferrous metals, metals, metal products
Chemicals	Chemical, rubber, plastic products
Energy Intensives	Minerals, paper products, publishing, mineral products
Electronic equipment	Electronic equipment
Transport Equipment	Motor vehicles and parts, transport equipment
Other Equipment	Machinery and equipment, manufactured goods
Consumer Goods	Bovine meat products, meat products, vegetable oils and fats, airy products, processed rice, sugar, food products, beverages and tobacco products, textiles, wearing apparel, leather products, wood products
Construction	Construction
Transport	Transport, water transport, air transport
Market Services	Water, trade, communication, financial services, insurance, business services, dwellings
Non-market Services	Recreational and other services, public administration, Defence, Education, Health

## 4. Benchmark scenario

The social-economic reference for the analysis for the ECONADAPT project with ICES is based on one of the scenarios proposed as Shared Social Economic Pathways (O'Neill et al., 2014). Specifically, the ICES benchmark scenario is based on the SSP2 – “Middle of the Road or Dynamics as Usual” scenario. This scenario assumes a socio economic development in line with that of recent decades, with reductions in resource and energy intensity at historic rates and a slowly decreasing fossil fuel dependency. Quantitatively, the ICES reference baseline for both versions described in Milestone MS12 assumes:

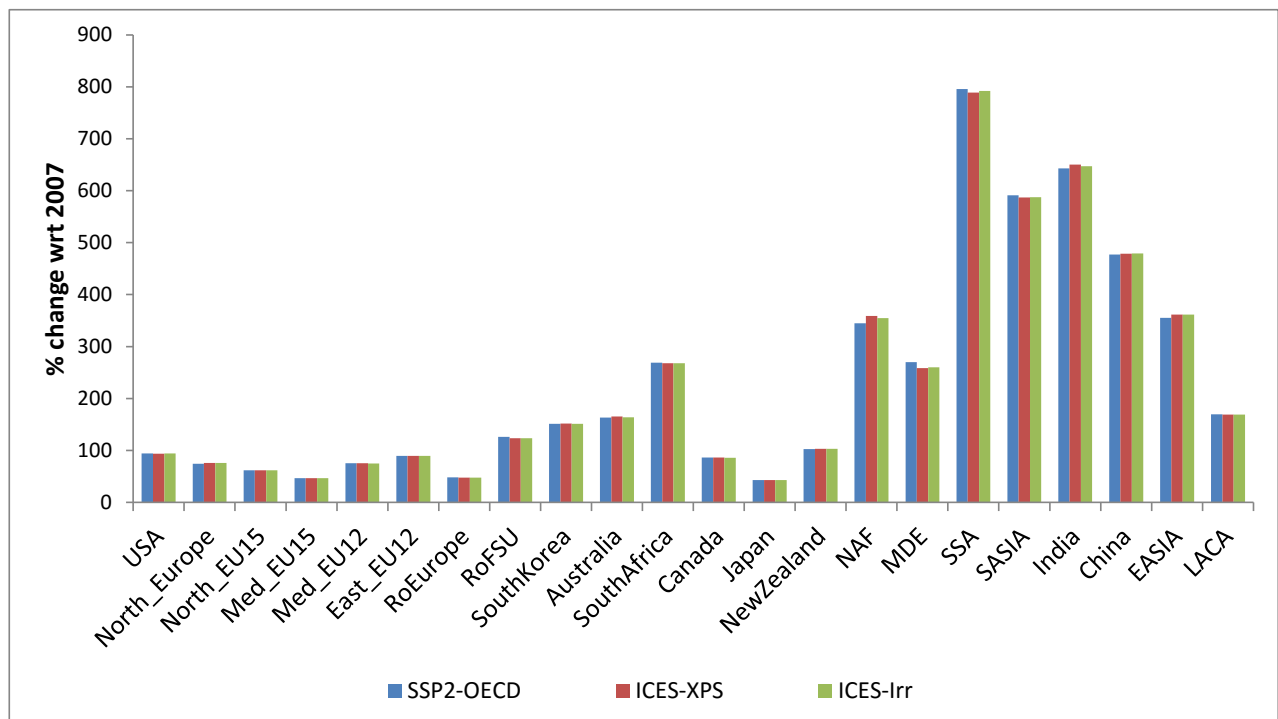
- GDP and population growths as those reported for the SSP2 in the “OECD version” (see Figure 1 for GDP, and Figure 2 for population).<sup>2</sup>

<sup>2</sup> The SSPs database is available at: <https://secure.iiasa.ac.at/web-apps/ene/SspDb/>

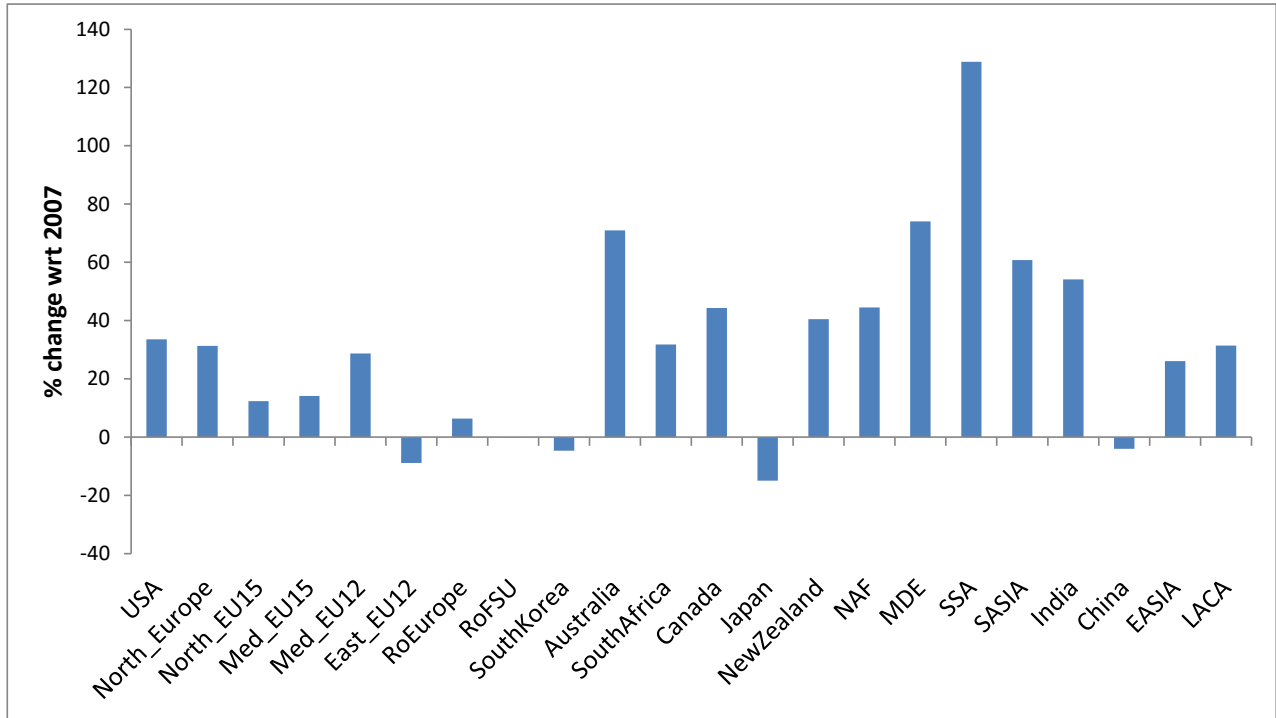


- Labour force growth the same as that of population.
- World fossil fuel prices growth trends of the 25%, 73% and 18% for coal, oil and gas respectively within the period 2007 to 2050. These price trends are derived from simulations performed with the WITCH integrated assessment dynamic optimization model (Bosetti, et .al. 2009) applied to the SSP2. WITCH, among other features, offers a detailed description of the energy system and therefore an endogenous energy price formation (see Figure 3).
- Energy efficiency yearly increases between 0.28% and 0.56% in developed countries and 0.63 % in developing countries. We set these average growth rates for energy efficiency based on information from IEA (2011, 2012). For 2011 the World Energy Outlook 2011 shows an annual average reduction of energy intensity about 1.3% and almost 1.5 % for OECD and Non-OECD countries in the period 1985-2009. In the following edition of the WEO 2012, the annual average percentage change of world energy intensity is reported to be only -0.5% for the period 2000-2010. Accordingly, we impose higher growth rates of energy efficiency for developing countries (0.63%) and lower rates for developed countries (0.56%)
- Land productivity following changes in crop yields according to information from Nelson et al. (2010) for both irrigated and rain fed land.

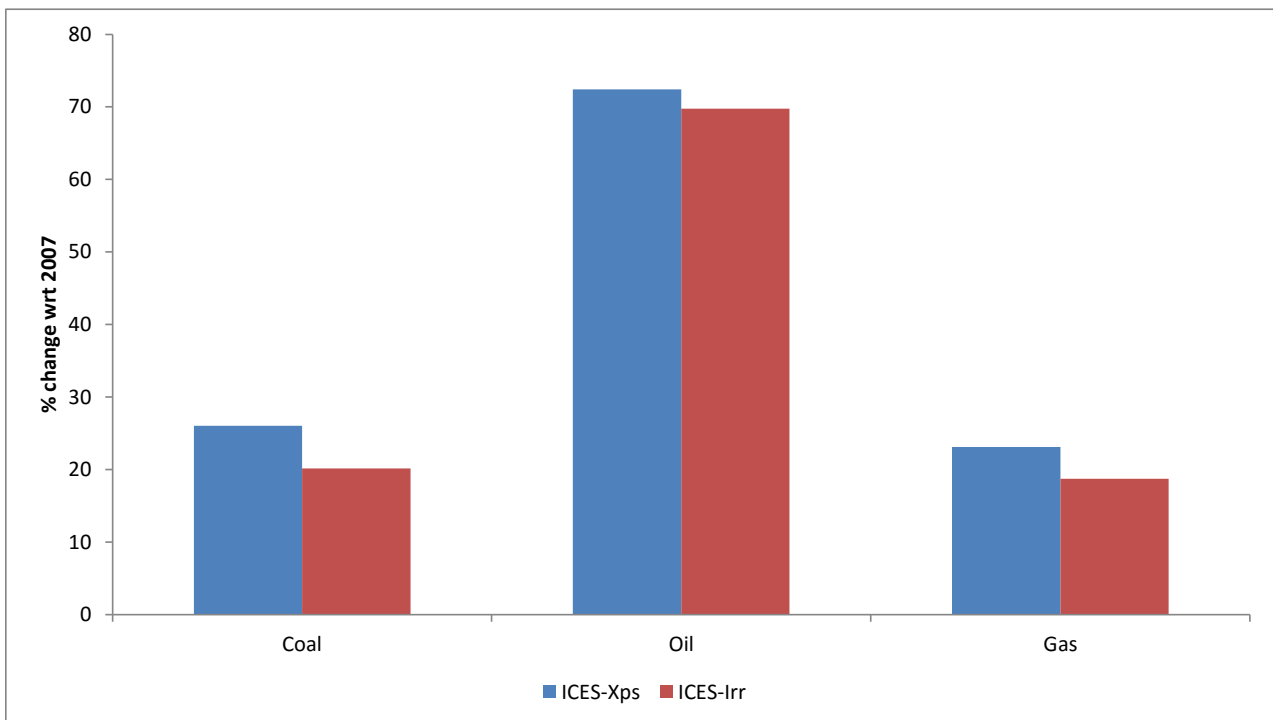
**Figure 1. ICES Benchmark scenario: GDP growth for the period 2007-2050**



**Figure 2. ICES Benchmark scenario: Population growth for the period 2007-2050**



**Figure 3. ICES Benchmark scenario: World fossil-fuel prices growth for the period 2007-2050**



The CAGE model is implemented in a static comparative mode, which assumes that the policy scenario (shock) is occurring under the current socioeconomic conditions, and therefore shocking the current economy. The disadvantage of the static comparative approach is, at the same time, its main advantage: the static-comparable perspective ignores future changes that will occur in the economy (disadvantage) while it allows removing from the results any uncertainty due to forecasting the future baseline needed for the dynamic approach (advantage).

In order to explore possibilities of both the static-comparable and the dynamic approaches JRC develops a method to estimate future base data (Social Account Matrix). The method to update and balance the SAM is based on the Cross Entropy approach (Robinson et al 2001). The methodology has its background in probability theory. Given a set of prior probabilities of some events, the occurrence of one event provides information on the probabilities. The value of the information received with this event can be measured by the 'cross entropy' distance between the distribution of probabilities before and after the event. The Cross Entropy approach to update a SAM minimizes the cross entropy distance between the available SAM and the new SAM, given a set of conditions. Mathematically, this is a constrained optimization problem. In simple words, the Cross Entropy method finds a SAM that is as 'close' as possible to the original SAM – where the Cross Entropy distance is a measure of 'closeness'.

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