



# NOTA DI LAVORO

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**Should We Ban Unconventional  
Oil Extraction to Reduce Global  
Warming?**

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By Samuel Carrara, FEEM and CMCC  
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Technology, CESifo and FEEM

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### Summary

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*This research project has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under the grant agreement n°266992 (Global IQ).*

**Keywords:** Unconventional Oil, Climate Mitigation, Energy Policy, European Union

**JEL Classification:** Q35, Q37, Q42, Q48, Q56

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# Should we ban unconventional oil extraction to reduce global warming?

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December 2014

## Abstract

The extraction and processing of unconventional oil is more energy intensive and has larger negative environmental impacts than the extraction of conventional oil. The European Union (EU) estimates that oil sands lead to 22% more emissions than conventional oil. The EU is very concerned by the potential climate and environmental impacts and has considered introducing a tax on imported unconventional oil in order to discourage its production. This study shows that a global ban on the use of unconventional oil substantially reduces global carbon dioxide emissions, but the policy is not efficient. A unilateral ban of the EU on unconventional oil has no climate benefits and it is expensive for Europe.

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# 1. Introduction

The production of unconventional oil<sup>1</sup> has increased more than fourfold between 2000 and 2013, from 1.4 to 6.1 mb/d (million barrels per day) (IEA, 2013 and 2014). The share of unconventional oil over total oil supply has jumped from less than 2% to almost 7%. A decade with high oil prices has accelerated technological diffusion and innovation in the extraction sector. Large untapped resources have been transformed into profitable oil fields, radically changing the geography of oil production. For example, the extraction of extra-heavy oil from oil sands in Alberta (Canada) and the boom of shale oil in North Dakota (USA) have staged the return of North America as a major player in the global oil market.

New infrastructures to connect production areas to refineries or to major shipping ports have been planned. For example, large bottlenecks separate the Canadian province of Alberta from the refineries in the Gulf of Mexico in the south and the coast of British Columbia (and thus Asia) in the west. Two large projects to overcome these barriers are currently under exam: the Keystone XL pipeline towards the Gulf of Mexico and the Enbridge Northern Gateway Pipeline towards the coast of British Columbia.

The International Energy Agency (IEA) projects that unconventional oil production will almost double from 2013 to 2020, covering about 11% of total oil production (IEA, 2014). It is not clear if the observed trend will also continue in the near future. A prolonged period with the oil price below 80 \$ per barrel will compromise the profitability of the existing oil fields and will discourage new investments. The opposition to new oil fields for environmental reasons may also slow down the expansion of unconventional oil.

The extraction of unconventional oil is understandably controversial because it causes large environmental damages. First, the production process is much more disruptive of the environment than the production of conventional oil. For example large volumes of water are used and polluted with chemicals during the extraction phase (IEA-ETSAP, 2010). Second, the extraction and processing of unconventional oil is more energy intensive than the extraction of conventional oil resources. The amount of carbon dioxide emitted during the combustion of oil products (e.g. gasoline) is the same, but the extraction and the refining of unconventional oil needs more energy and thus causes more emissions during the entire life-cycle of oil products (IEA-ETSAP, 2010). The European Union (EU) estimates that a barrel of oil that comes from oil sands leads to 22% more carbon dioxide emissions than a barrel of oil that comes from conventional oil resources (Brandt, 2011). According to the International Energy Agency the difference ranges between 0 and 15% (IEA, 2010), depending on the type of conventional oil used as a benchmark. This means that unconventional oil is responsible for higher local and global environmental damages than conventional oil.

For these reasons the exploitation of unconventional oil resources causes growing tensions. In the United States and in Canada the decision of building the Keystone XL and the Enbridge Northern Gateway pipelines is opposed because of fear of oil spills, but most importantly because the new transportation route will unlock dirty unconventional oil resources in Alberta.

With no domestic production of unconventional oil, local environmental damages are not a primary concern in the European Union. However, the EU is very concerned by the impact of the additional carbon emissions from unconventional oil extraction on global warming. EU regulators have expressed the desire to stigmatize the production of tar sands oil in Canada by labelling it as a “dirty” fuel.<sup>2</sup> The EU also brought

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<sup>1</sup> There is not a precise definition of unconventional oil (Gordon, 2012). According to the IEA (2013) oil sands, extra heavy oil, shale oil (light tight oil), gas to liquids and other liquids are all unconventional oil sources. We follow this convention throughout this paper. The distinction between conventional and unconventional oil is subtle and shifts over time. For instance, light tight oil is substantially a normal type of crude oil, but extracted through unconventional techniques and/or from unconventional geological deposits (IEA, 2013).

<sup>2</sup> See for example (all websites were retrieved on 13<sup>th</sup> December 2014):

to an advanced stage the proposal of taxing oil coming from Canada. The proposed tax would penalize the extra emissions during the extraction of tar sands compared to conventional oil extraction.<sup>3</sup> The EU move would be equivalent to a border tax adjustment, as emissions from the extraction phase would still be counted as part of total Canadian emissions.

It is not possible to predict what will be the outcome of the current tensions in Northern America and what will be the position of the EU towards the Canadian tar sands in the near future. It is also not possible to guess if lower oil prices in the short term will subdue demand of unconventional oil and thus reduce the need for regulation. It is however reasonable to assume that these tensions will persist and possibly grow in the future. On one side unconventional oil will become more and more attractive as conventional oil resources become scarcer and more expensive. On the other side the negative environmental impacts will become larger and larger.

In this paper we abstract from local environmental damages and we focus on the impact of unconventional oil extraction on global warming. We address the following three research questions.

What is the impact of unconventional fossil resources extraction on global warming? By how much would global temperature in 2100 change if the use of unconventional fossil resources was banned globally and what would be the economic cost of this policy? What would be the impact on global warming and the cost of a unilateral ban by a large country or a large group of countries like the EU?

We answer those questions by examining scenarios developed using WITCH, a well-known Integrated Assessment Model. We start by developing pathways of oil demand and supply up to the end of the century without any policy to limit greenhouse gas (GHG) emissions. We use this scenario to estimate carbon dioxide emissions from unconventional oil and their impact on global warming. We then simulate a first experiment in which all world countries agree to ban the extraction of unconventional oil. We assess the impact of the global ban on conventional oil demand, on the oil price, on carbon dioxide emissions, on global mean temperature, and on aggregate consumption. Finally, we assume that Europe takes unilateral measures to ban domestic extraction and imports of unconventional oil. Also in this case we estimate the impact of the ban on unconventional oil on global warming and on European consumption.

The remainder of the paper is structured as follows. Section 2 is dedicated to the description of the WITCH model. Section 3 illustrates the Reference scenario and the impact of a global ban on unconventional oil on emissions, temperature and on the economy. Section 4 presents the results of the experiment in which only the European Union bans the extraction and the use of unconventional oil. Conclusions follow.

## 2. The WITCH model

WITCH (World Induced Technical Change Hybrid)<sup>4</sup> is an Integrated Assessment Model (IAM) used to study the socio-economic impacts of climate change and the economic consequences of climate policies throughout the 21<sup>st</sup> century. It is a hybrid model because it combines a top-down inter-temporal Ramsey-type optimal growth framework, where a social planner maximizes the total discounted welfare (a function of the per capita consumption), with a disaggregated description of the energy sector. The first distinction is between the electric and non-electric sectors, with a progressive refinement down to the single technologies. The hybrid formulation allows investigating global economic and climatic effects related to

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<http://opinion.financialpost.com/2013/08/12/eu-fuel-directive-demonizes-oil-sands/>

<http://www.carbonbrief.org/blog/2014/01/who-killed-the-fuel-quality-directive/>

<sup>3</sup> <http://uk.reuters.com/article/2014/06/05/eu-tarsands-idUKL6N0OC18M20140605>, retrieved on 13<sup>th</sup> December 2014.

<sup>4</sup> See [www.witchmodel.org](http://www.witchmodel.org) for model description and relevant papers.

specific constraints in the energy sector. Technical change is endogenously modeled through innovation (Learning-by-Researching) and diffusion (Learning-by-Doing) processes.

The model is defined on a global scale: world countries are grouped into thirteen regions, which can interact according to two cooperation schemes. In the cooperative scenario, all regions cooperate to find a solution which is globally optimal. In the non-cooperative scenario – the one used for this study – each region maximizes its own welfare and it strategically interacts with the other regions in an open-loop Nash game. The thirteen regions are USA (United States), WEURO (Western EU and EFTA countries), EEURO (Eastern EU countries), KOSAU (South Korea, South Africa and Australia), CAJAZ (Canada, Japan and New Zealand), TE (Transition Economies, namely Russia and Former Soviet Union states and non-EU Eastern European countries), MENA (Middle East and North Africa), SSA (Sub-Saharan Africa except South Africa), SASIA (South Asian countries except India), EASIA (South-East Asian countries), CHINA (People’s Democratic Republic of China and Taiwan), LACA (Latin America and Central America) and INDIA (India).<sup>5</sup>

The base calibration year is 2005; monetary values are expressed in constant 2005 USD and market exchange rates (MER) are used for international comparison. A more detailed description of the model can be found in Bosetti et al. (2006, 2007 and 2009). The Appendix describes oil demand, oil supply and oil trade in WITCH.

### 3. A global ban of unconventional oil

Our Reference scenario – which assumes no constraints on unconventional oil use nor any climate policy – reveals that unconventional oil extraction starts in 2020. Unconventional oil then constantly gains market shares over the century: 50% of global demand in 2070 and 58% in 2100, when global oil demand reaches 316 EJ/yr, after a peak of 385 EJ/yr in 2065 (Figure 1). The pattern of unconventional oil extraction is similar to what found by Mohr and Evans (2009).

The oil price in WITCH is lower than the oil price observed in the global market in the recent years because the model is not able to replicate short-term frictions. The model provides a better indication of long-term patterns. For this reason unconventional oil is extracted only starting from 2020.

Cumulative oil extraction over the century is equal to about 32,000 EJ, one third of which is of the unconventional type. Oil incidence in the global primary energy portfolio increases from 36% in 2005 to 43% at the middle of the century; in 2070 it starts decreasing.

Figure 2 shows how the cumulative oil extraction is distributed across regions and between conventional and unconventional oil. The largest producers, both of oil in general and of unconventional oil, are Middle East and North Africa (MENA), Transition Economies (TE), Latin America (LACA) and the United States (USA). KOSAU (South Korea, South Africa and Australia), and, unsurprisingly, CAJAZ (Canada, Japan and New Zealand) are the only two regions where unconventional oil extraction is larger than conventional oil extraction. Unconventional oil is of minor importance in Europe. Figure A-1 in the Appendix reports in detail the whole time series of extraction of conventional and unconventional oil for each region.

We then consider two hypothetical scenarios in which unconventional oil extraction is limited. In the first scenario (Global Ban) all world regions agree not to use unconventional oil resources. In the second scenario (EU Ban) we assume that only Europe bans the use of unconventional oil.

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<sup>5</sup> To the purposes of this work, the European Union is given by the sum of WEURO and EEURO, although this is not rigorously correct due to the presence of the EFTA countries in the former region.

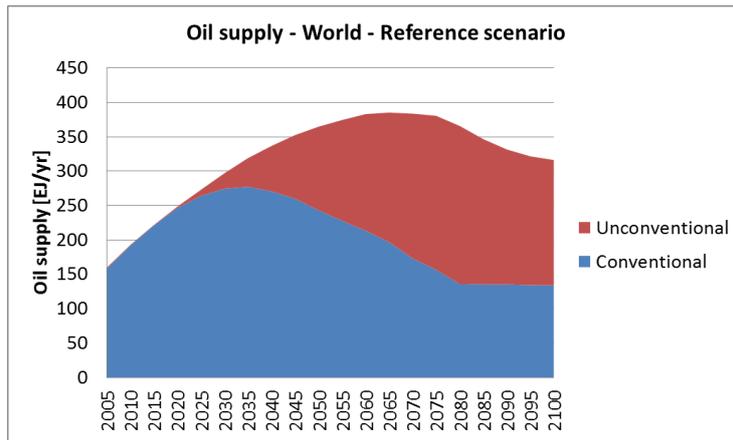


Figure 1 – Conventional and unconventional oil supply (World - Reference scenario).

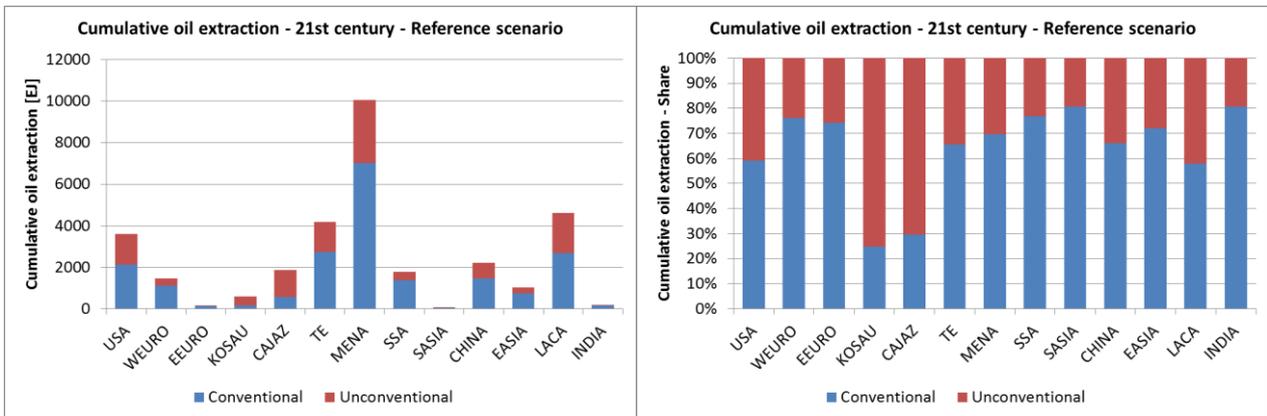


Figure 2 – Conventional and unconventional cumulative oil extraction (Reference scenario).

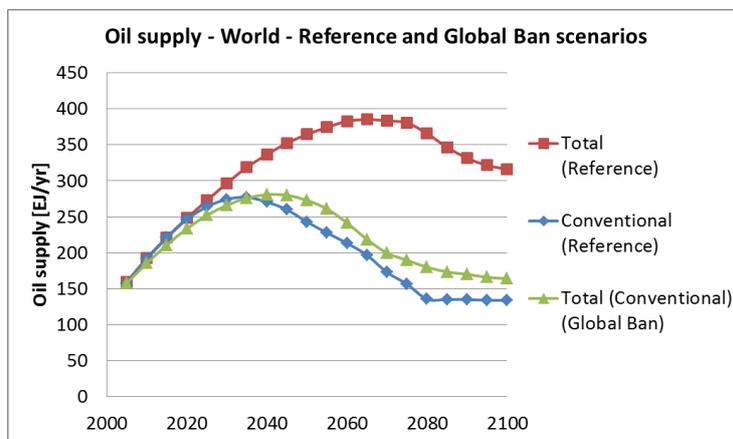


Figure 3 – Conventional and unconventional oil supply (World - Reference and Global Ban scenarios).

In the Global Ban scenario demand of oil is shifted from unconventional to conventional sources. Conventional oil production is expanded by exploiting more expensive traditional oil fields. As a result, the price of oil substantially increases (+17% in 2030, +54% in 2050 and +128% in 2100) and global oil supply decreases (-25% in 2050, -48% in 2100) (Figure 3). The contraction of oil consumption is only partially compensated by increased demand of other fuels. Total primary energy use declines: -10% in 2050 and -12% in 2100. This implies that the carbon dioxide emissions into the atmosphere decline by 5% in 2030, by 11% in 2050 and by 20% in 2100 in the Global Ban scenario compared to the Reference scenario.

The cumulative reduction of CO<sub>2</sub> emissions is equal to 122 GtCO<sub>2</sub> from 2010 to 2050 and to 906 GtCO<sub>2</sub> from 2010 to 2100. In relative terms, emissions decline by 6% in 2050 and 16% in 2100 compared to the Reference case. In order to put these figures in perspective, the Fifth Assessment Report of the IPCC (IPCC, 2014) finds that global fossil-fuel related CO<sub>2</sub> emissions reached 32 (±2.7) GtCO<sub>2</sub>/yr in 2010. The overall reduction of emissions from 2010 to 2050 thus corresponds to about four 2010-equivalent years' worth of fossil fuels emissions; from 2010 to 2100 it would be worth about twenty-eight 2010-equivalent years.

These results suggest that unconventional oil may become one of the major sources of carbon dioxide emissions in the future. However, this remarkable contraction of emissions, being mostly concentrated in the second half of the century, has a limited impact on the global concentration of greenhouse gases and even more limited impact on global mean temperature over the 21<sup>st</sup> century due to the inertia of the climate system. In the Global Ban scenario the concentration level of GHG in 2050 is only 2% lower than in the Reference case (624 ppm CO<sub>2</sub>eq against 636 ppm CO<sub>2</sub>eq). The policy basically does not change global temperature in 2050. In 2100 the ban of unconventional oil extraction reduces GHG concentrations by 9% (from 960 ppm CO<sub>2</sub>eq to 873 ppm CO<sub>2</sub>eq) and reduces the increase of global mean temperature by 0.3°C, from +4.1°C to +3.8°C.

We thus find that unconventional oil extraction is responsible for about 10% of the extra warming that will be recorded at the end of this century. This is a non-negligible effect of the policy. We find that the new pattern of emissions is consistent with the temperature trajectory generated by WITCH in the Representative Concentration Pathway 6.0 (RCP6.0)<sup>6</sup> scenario (Van Vuuren et al., 2011).

What is the cost of achieving this benefit? Is the unconventional oil ban an efficient policy? Would it be possible to obtain the same climate benefits using different policy tools?

The global ban on unconventional oil increases oil prices globally, thus negatively affecting importing regions and it subtracts an important source of revenues to exporting regions. Regions with high conventional resources benefit from the new oil geography and from higher oil prices.

We find that the net global welfare effect is negative. From 2010 to 2050 the undiscounted sum of global consumption loss is equal to 11.5 USD trillion (0.32% of aggregate consumption in the Reference scenario); from 2010 to 2100 the loss is equal to 277 USD trillion (1.7%). Consumption losses are thus concentrated in the second half of the century, when reliance on unconventional fossil fuels is strongest in the Reference scenario.

These welfare losses are largely unnecessary. The ban of unconventional oil extraction is not an efficient policy tool. The same environmental benefit could be achieved using more flexible market-based instruments, like carbon emission permits and carbon taxes. We find that the cost of achieving the same level of greenhouse gases concentrations (RCP6.0) with a uniform – over sectors, gases and countries –

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<sup>6</sup> The number 6.0 indicates the level of global radiative forcing in 2100, in watts per square meter. The RCP scenarios have been used by climatologists to prepare the IPCC AR5 climate change scenarios (Ebi et al., 2014, and Van Vuuren et al., 2014).

carbon tax is fifteen times less expensive. The global ban of unconventional oil concentrates all the efforts in one sector, exponentially increasing marginal abatement costs while missing cheap mitigation options.

Symmetrically, we find that for the same level of consumption losses found in the Global Ban scenario it is possible to limit the increase of temperature to about 3°C in 2100 (1.1°C lower than in the Reference scenario). The 3°C temperature increase in 2100 is roughly consistent with the RCP4.5 scenario generated by WITCH. Thus, banning unconventional oil has the same impact on global temperature as the RCP6.0 scenario but it costs as much as the RCP4.5 scenario.

Figure 4 compares the relative discounted aggregate consumption losses from 2010 to 2100 in the Global Ban scenario to the RCP6.0, RCP4.5 and RCP2.6 scenarios (Massetti et al., 2014). In the comparison we use three discount rates: 0%, 3% and 5%. The corresponding temperature increases in 2100 with respect to the pre-industrial level are reported near each scenario. The diffusion of unconventional oil is mainly relevant in the second half of the century, thus consumption losses are highly discounted. Also emission reductions in the RCP scenarios are concentrated in the second half of the century.

Figure 5 summarizes the percentage aggregate consumption changes in all regions, without discounting. Results are reported for the Global Ban scenario and the equivalent efficient global carbon tax scenario.

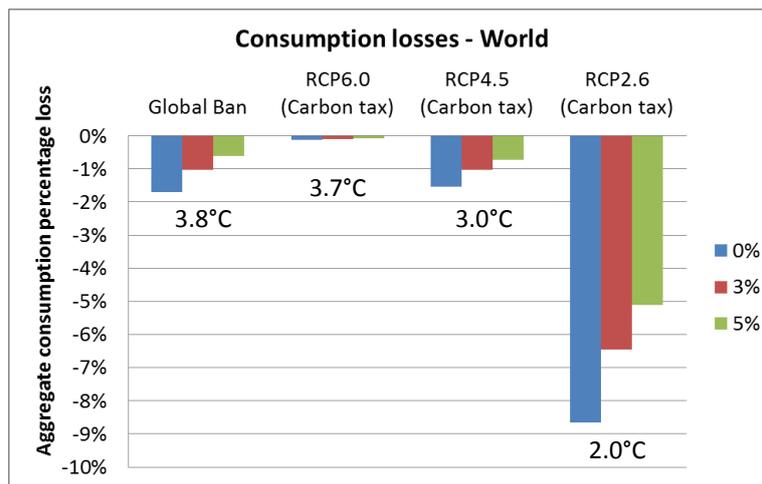


Figure 4 – Consumption losses at different discount rates (Global Ban and RCP scenarios).

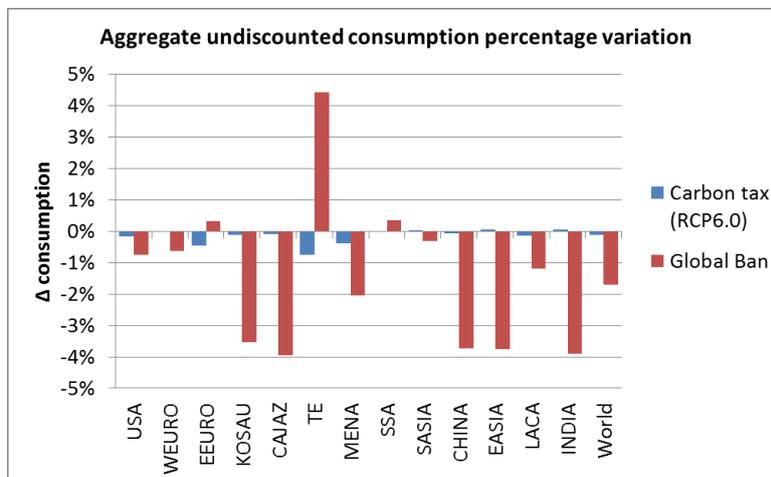


Figure 5 – Regional cost (Global Ban and RCP6.0 scenarios).

The carbon tax would have a minor impact on consumption levels in almost all regions, while the global ban has large regional effects. The biggest negative impact is in the largest producing regions (KOSAU, CAJAZ, MENA and LACA) and in the main oil importers (CHINA, EASIA, INDIA). A completely peculiar behavior is instead shown by Transition Economies, which are characterized by a considerable aggregate consumption gain. This result is in part due to the ability of the region to extract large quantities of conventional oil at a relatively modest cost when the global price of oil is instead high. The result is also explained by a faster transition of domestic consumption from oil to biomass. Figure A-2 in the Appendix provides an overview of oil consumption, extraction and import/export in all regions in the Reference and Global Ban scenarios.

## 4. A unilateral European ban of unconventional oil

In our second experiment we assume that the European Union unilaterally introduces a ban on unconventional oil. This scenario is inspired by the recent position taken by the European Commission, which has repeatedly considered the possibility of imposing penalties on unconventional oil extracted in North America.<sup>7</sup>

Our results indicate that this policy is neither climate effective nor efficient. The increase of global mean temperature is virtually unchanged at the end of the century (+4.03°C instead of +4.06°C). Europe has not the scale to significantly affect global oil markets and the reduction of demand from Europe is almost completely offset by an increase of demand from the other regions, which benefit from the resulting lower oil price.

The European cumulative oil demand from 2010 to 2050 decreases by 11%, while global demand declines only by 1%; from 2010 to 2100 the cumulative demand reduction is equal to 33% in Europe, while it is less than 3% globally. As a consequence of the European policy, the global price of oil declines (up to 5% at the end of the century) and oil demand outside Europe increases.

The left panel of Figure 6 shows the progress of oil demand at global level and in Europe in the Reference and the EU Ban scenarios. The right panel of Figure 6 shows the evolution of CO<sub>2</sub> emissions from fuels combustion.

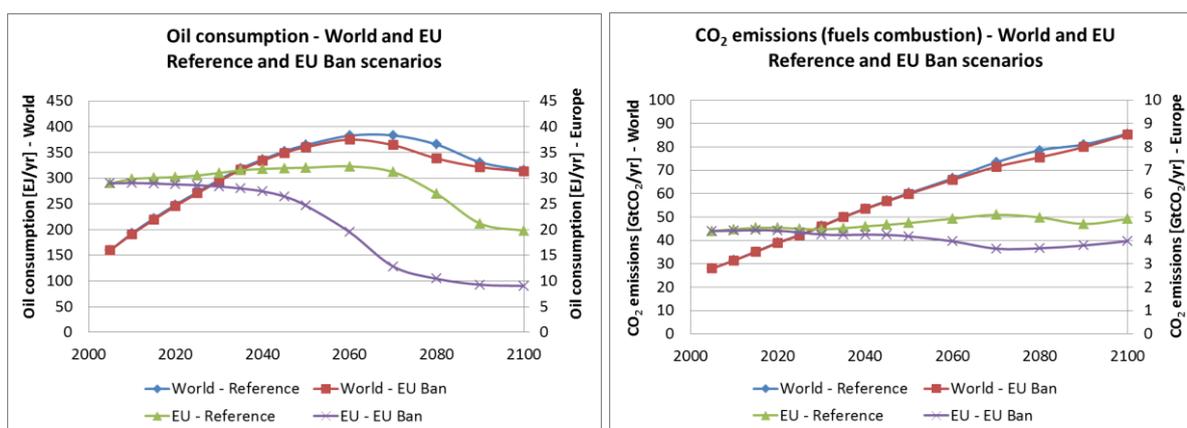


Figure 6 – Oil consumption and CO<sub>2</sub> emissions (Reference and EU Ban scenarios).

<sup>7</sup> We assume that there is no domestic extraction of unconventional oil and that Europe does not change the total amount of oil imports from the scenario in which all regions implement the unconventional oil ban. Explicitly imposing a ban on imports of unconventional oil is not possible because traded oil is a homogenous good.

## 5. Conclusions

We presented two scenarios to study the climate effectiveness and the economic efficiency of a hypothetical ban of unconventional oil extraction to reduce global warming. In the first experiment we considered a global ban while in the second experiment we considered a unilateral ban by the European Union. Both these experiments are extremely naïve. However, they are instructive because they reveal how inefficient at best, or inefficient and ineffective at worst these policies can be if their primary goal is to control global warming.

Our results reveal that a global ban on the use of unconventional oil has non-negligible climate benefits but it is a very inefficient climate mitigation policy. Not using unconventional oil resources slows global warming by 0.3°C (from +4.1°C to +3.8°C in 2100 with respect to the pre-industrial level). Despite a rebound effect in conventional oil extraction, the global ban is effective because it substantially reduces oil demand, carbon dioxide emissions and the increase of temperature. However, the policy is terribly inefficient. We find that an efficient, global uniform carbon pricing mechanism would achieve climate benefits almost four times larger, at the same cost. Analogously, an efficient pricing scheme would deliver the same climate benefit being fifteen times cheaper.

A unilateral European ban of unconventional oil is both inefficient and ineffective. If the main goal is carbon mitigation, the European Union should avoid unilateral aggressive policies against unconventional oil. Diverting trade routes may be expensive for oil producers and a short-term victory is possible. However, in the long-run, with rising energy prices and technological progress in oil extraction and transportation, it is likely that unconventional oil will flow where demand is and Europe alone will have a negligible impact on global patterns. Starting trade wars to achieve virtually null environmental benefits may be counterproductive.

We have not simulated scenarios in which other regions unilaterally decide to ban unconventional oil extraction but we expect results similar to those found for the EU: the policy would be inefficient and ineffective.

Some caveats apply to our analysis. First, we have focused on the climate externality of unconventional fuels. Local negative environmental externalities from unconventional oil extraction are large and may justify a more conservative approach. However, local externalities require local policies. Using climate policy to address also local environmental effects is not efficient. In order to maximize efficiency, policy makers must use as many policy tools as externalities. Second, although WITCH features a complex description of green technological innovation, with endogenous technical progress in both backstop and non-backstop green technologies, if a temporary ban of unconventional oil shifts the pattern of technological development from a “dirty” to a “clean” equilibrium that is not captured by our model, the conclusions of our study may be different.

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## Appendix – Oil extraction and trade module

Oil extraction and trade are endogenous in WITCH. Oil demand comes from a small residual fraction of power plants and, predominantly, from final consumption in the transportation sector.<sup>8</sup> In each time period  $t$  and in each region  $n$ , oil demand (OIL) is met by means of domestic extraction ( $OIL_{prod}$ ) of eight different categories of oil resources, denoted with  $oilg$ , or by net oil imports on the international markets ( $OIL_{imp}$ ):

$$OIL(t, n) = \sum_{oilg} OIL_{prod}(t, n, oilg) + OIL_{imp}(t, n) \quad (1)$$

In oil-importing regions, oil demand is higher than domestic production and indeed there is a net oil import; in oil-exporting regions, domestic production is higher than demand, and the excess is exported ( $OIL_{imp}$  is thus negative). Of the eight oil categories three are of conventional type and the rest is considered to be unconventional oil.<sup>9</sup> Emissions during the extraction of the first category of oil are assumed to be equal to zero. Emissions during extraction of other categories increase up to a maximum of about 50 kgCO<sub>2</sub>/GJ.

At each point of time the international price of oil is adjusted in order to clear the global oil market:<sup>10</sup>

$$\sum_n OIL_{imp}(t, n) = 0 \quad (2)$$

The international price of oil is thus endogenous and it emerges as the outcome of a non-cooperative game among the thirteen world regions.<sup>11</sup>

One of the strengths of WITCH is the possibility to model investments in energy technologies. Electricity generation is the outcome of investments in power generation capacity that cumulate over time. Oil production is the outcome of investments in oil extraction capacity ( $OIL_{cap}$ ). Oil capacity grows as the result of new investments ( $I_{OIL_{cap}}$ ) and it depreciates over time at the rate  $\delta$ :

$$OIL_{cap}(t + 1, n, oilg) = OIL_{cap}(t, n, oilg) \cdot (1 - \delta) + \Delta OIL_{cap}(t, n, oilg) \quad (3)$$

$$I_{OIL_{cap}}(t, n, oilg) = COST_{OIL_{cap}}(t, n, oilg) \cdot \Delta OIL_{cap}(t, n, oilg) \quad (4)$$

Oil extraction cost is not determined using an exogenous supply schedule. It is rather perceived by the model as the opportunity cost of lost consumption. The benefit of the investment is given by the available production of oil, which can be consumed domestically or sold internationally at the global price. Regions with a low extraction capacity costs have more incentive to trade oil internationally than regions with higher extraction costs. At the equilibrium, the model guarantees that the marginal utility of investments across all sectors and the marginal utility of consumption are equal. The oil sector contributes to the formation of the GDP of each region. A contraction/expansion of extraction activities determines a contraction/expansion of the economy.

Oil production cannot exceed the amount of oil capacity built in each region; besides, cumulative extraction cannot exceed regional resources (which, by definition, are fixed and independent of economic factors).

More details on the oil extraction and trade module can be found in Massetti and Sferra (2010).

<sup>8</sup> A module dedicated to the modeling of Light Duty Vehicles has not been used for this work.

<sup>9</sup> Oil resources are derived from Rogner (1997).

<sup>10</sup> WITCH does not model bilateral oil trade because the reproduction of the observed trade flows would require a large number of arbitrary assumptions. Net oil imports (or exports) for each region are calibrated in the base year using data from Enerdata (2007).

<sup>11</sup> A region-specific cost mark-up (positive or negative) is then added to it in order to take into account local factors which determine the final cost for local consumers.

# Additional Figures

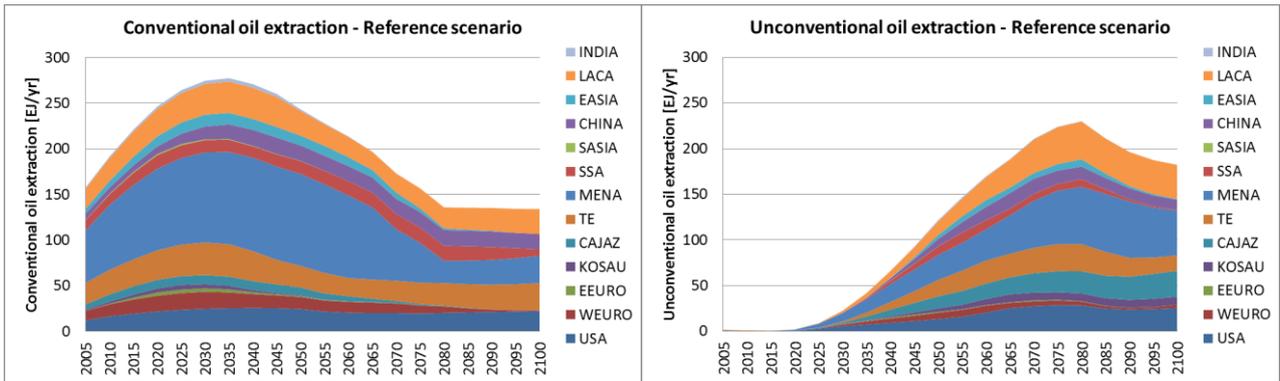


Figure A-1 – Conventional and unconventional oil extraction (Reference scenario).

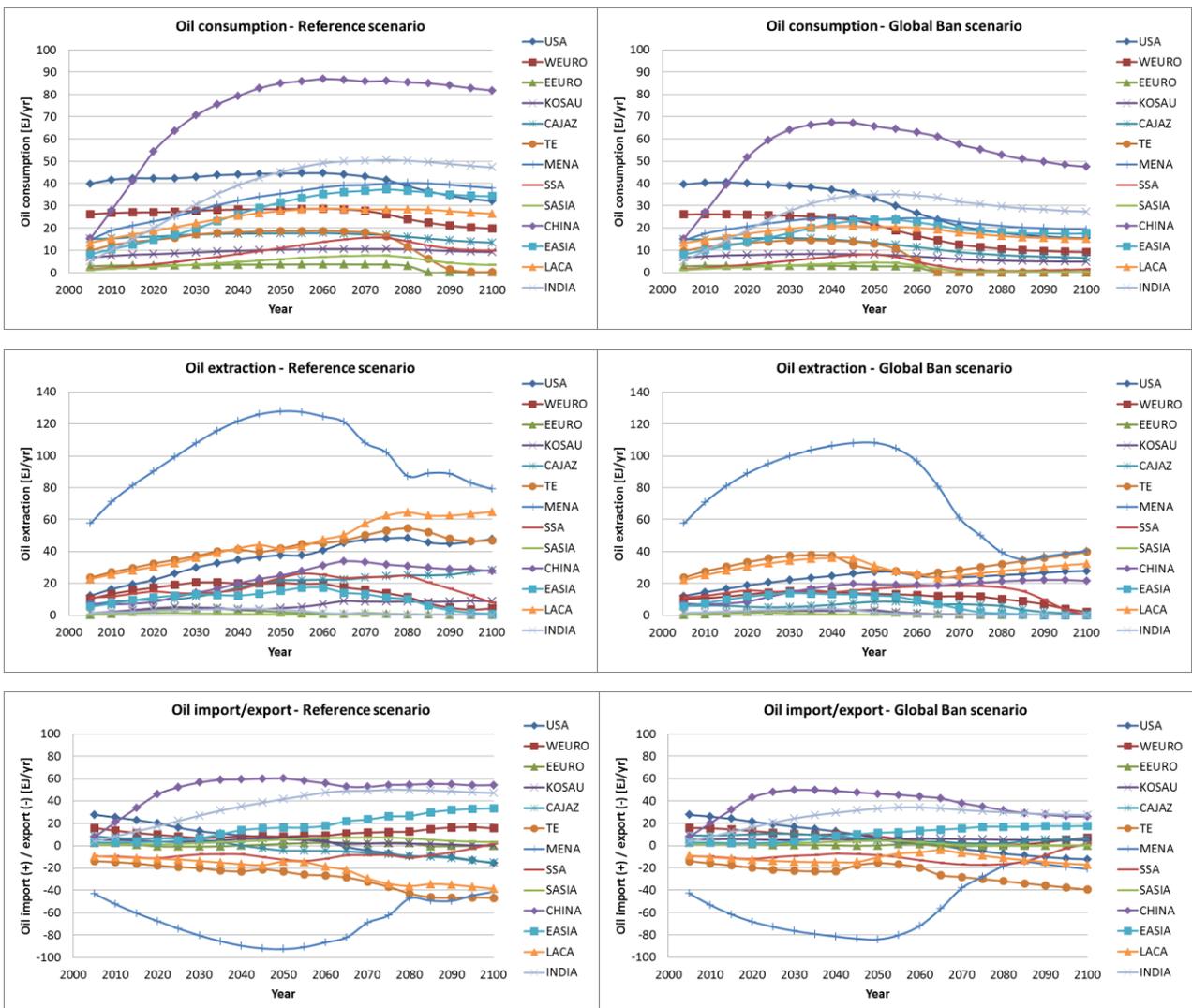


Figure A-2 – Oil consumption, extraction and import/export (Reference and Global Ban scenarios).

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