The role of energy in the mitigation of climate change

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BC3 Summer School
San Sebastian, San Fermín 2017
The role of energy in GHG emissions (I)

Figure TS.3. Allocation of GHG emissions across sectors and country income groups. Panel a: Share (in %) of direct GHG emissions in 2010 across the sectors. Indirect CO2 emission shares from electricity and heat production are attributed to sector s of final energy use. Panel b: Shares (in %) of direct and indirect emissions in 2010 by major economic sectors with CO2 emissions from electricity and heat production attributed to the sectors of final energy use. Lower panel: Total anthropogenic GHG emissions in 1970, 1990 and 2010 by economic sectors and country income groups. GHG emissions from international transportation are reported separately. The emissions data from Agriculture, Forestry and Other Land Use (AFOLU) includes land-based CO2 emissions from forest and peat fires and decay that approximate to net CO2 flux from the Forestry and Other Land Use (FOLU) sub-sector as described in chapter 11 of this report. Emissions are converted into CO2-

IPCC AR5, WG3 Technical Summary
The role of energy in GHG emissions (II)
Carbon-energy flows

http://www.comillas.edu/Documentos/BP/sankey_energy.html
The role of energy in mitigation

- Reaching atmospheric concentration levels of 430 to 650 ppm by 2100 will require large-scale challenges to global and energy systems over the coming decades [high confidence]
  - 3x – 4x share low-carbon energy in 2050
  - 2100 concentration levels unachievable if the full suite of low-carbon technologies is not available
  - Demand reductions on their own will not be sufficient
  - But will be a key mitigation strategy and will affect the scale of the mitigation challenge for the energy supply side

(AR5 WG3 Technical Summary)
Drivers for GHG emissions (I)

Decomposition of the Change in Total Global CO₂ Emissions from Fossil Fuel Combustion

- Carbon Intensity of Energy
- Energy Intensity of GDP
- Population
- GDP per Capita

Decadal Change in Emissions [GtCO₂]

- 1971-1980: 4.0 GtCO₂
- 1981-1990: 2.9 GtCO₂
- 1991-2000: 2.5 GtCO₂
- 2001-2010: 6.8 GtCO₂

IPCC AR5, WG3 Technical Summary
Drivers for GHG emissions (II)

Figure TS.7. Global baseline projection ranges for Kaya factors. Scenarios harmonized with respect to a particular factor are depicted with individual lines. Other scenarios depicted as a range with median emboldened; shading reflects interquartile range (darkest), 5th – 95th percentile range (lighter), and full extremes (lightest), excluding one indicated outlier in population panel. Scenarios are filtered by model and study for each indicator to include only unique projections. Model projections and historic data are normalized to 1 in 2010. GDP is aggregated using base-year market exchange rates. Energy and carbon intensity are measured with respect to total primary energy. [Figure 6.1]
Access to energy?

<table>
<thead>
<tr>
<th>Table 3: Estimated additional emissions and temperature rise from an energy poverty alleviation program.</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009-2030: Energy poverty alleviation emissions (GtCO2)</td>
<td>Optimistic</td>
<td>Pessimistic</td>
</tr>
<tr>
<td></td>
<td>2.9</td>
<td>2.9</td>
</tr>
<tr>
<td>2030-2060: Use of additional energy infrastructure (GtCO2)</td>
<td>7.9</td>
<td>7.9</td>
</tr>
<tr>
<td>2060-2100: Retirement of additional infrastructure (GtCO2)</td>
<td>5.3</td>
<td>10.5</td>
</tr>
<tr>
<td>2009-2100: Total emissions (GtCO2)</td>
<td>16.1</td>
<td>21.3</td>
</tr>
<tr>
<td>Additional temperature increase (degree C): mean and 10-90 percentile in square brackets</td>
<td>0.008</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>[0.004-0.011]</td>
<td>[0.006-0.014]</td>
</tr>
</tbody>
</table>

Chakravarty and Tavoni, 2013
Energy-related mitigation options

- Decarbonization of energy supply
- Final energy demand reductions
- Switch to low-carbon fuels
- Different by sector
  - Decarbonization of electricity generation is a key component: quicker and simpler
  - The transport sector is difficult to decarbonize, and opportunities for fuel switching are low in the short term
  - Large achievable potential in the building sector, but strong barriers
Emissions reductions required (I)

**Figure 2.4**  Cumulative global energy sector investments by sector in the INDC and 450 Scenarios, 2015-2030 (trillion dollars, 2013)

Note: T&D is transmission and distribution.

Emission reductions required (II)

Figure 2.5  ▶  Energy-related CO₂ emissions per capita by selected region in the INDC Scenario and world average in the 450 Scenario, 2030

- United States: 10.9
- Korea: 9.4
- Middle East: 8.2
- Japan: 7.3
- China: 7.1
- Russia: 12.0
- Caspian: 6.0
- European Union: 4.7
- Mexico: 3.4
- Latin America: 2.5
- Southeast Asia: 2.7
- India: 2.1
- Africa: 0.9

1 tonne of CO₂
Effective implementation of the proposed measures in the Bridge scenario would have profound implications for global emissions. Emissions would be 2.1% (or 1%) lower than in the INDC scenario by 2025 and 4.1% (or 13%) lower by 2030, meaning that energy-related emissions would peak and then begin to decline by around 2020 (Figure 3.2).

The largest contribution to global GHG abatement comes from energy efficiency, which is responsible for 4.5% of the savings in 2030 (including direct savings from reduced fossil-fuel demand and indirect savings as a result of lower electricity demand thereby reducing emissions from the power generation). The power sector is the second-largest contributor to global savings, at 2.6% in 2030. While limitations on the use of the least-efficient coal power plants are effective in curbing global GHG emissions until 2020. Tables containing detailed projections results for the Bridge scenario by region, fuel and sector are available in Annex B.

The results take into account direct rebound effects as modelled in the IEA’s World Energy Model. Direct rebound effects are those in which energy efficiency increases the energy service gained from each unit of final energy, reducing the price of the service and eventually leading to higher consumption. Policies to increase end-user prices are one way to reduce such rebound effects, but are not considered in the Bridge Scenario (except for fossil-fuel subsidy reform). The level of the rebound effect is very controversial; a review of 500 studies suggests though that direct rebound effects are likely to be over 10% and could be considerably higher (IPCC, 2014).

Box 2.3 ⊳ Exploring the implications of a “well below 2 °C” or a 1.5 °C emissions pathway

The Paris Agreement does not include a precise definition of what holding the temperature rise to “well below 2 °C”, while also pursuing efforts to limit global warming to 1.5 °C, means as a target for climate action. One interpretation of the goals is as a range spanning a scenario that provides a reasonable chance of staying below 1.5 °C at the lower end, to a scenario that provides a reasonable chance of staying below 2 °C at the upper end. The 450 Scenario, for example, has a 50% chance of limiting the temperature rise to 2 °C and therefore lies at the top of this range. But within this putative range, we can select an illustrative case to explore some of the potential implications for the energy sector of aiming to go beyond the mitigation levels in the 450 Scenario. One such case, for which the “CO₂ budgets” have been examined in detail by the Intergovernmental Panel on Climate Change (IPCC), has a 66% chance of staying below 2 °C. It would imply a 50% chance of a 1.84 °C temperature rise in 2100.

Without net-negative emissions, energy sector CO₂ emissions fall to zero by 2040 for a 50% chance of 1.5 °C and around 2060 for a 66% chance of 2 °C. The remaining energy sector CO₂ budget between 2015 and 2100 in this illustrative “well below 2 °C” case is 830 Gt, some 250 Gt, or 25%, less than the 450 Scenario energy sector CO₂ budget (Figure 2.9). Multiple emissions trajectories are consistent with this CO₂ budget, but one that avoids relying on global emissions turning net-negative requires energy-related CO₂ emissions to be at net-zero by around 2060. Energy-related CO₂ emissions in 2040 would need to be around 16 Gt, just over 2 Gt lower than emissions in the 450 Scenario. While this might not appear to be an enormous escalation of ambition,
Mitigation potential

450 ppm CO$_2$ eq with CCS

450 ppm CO$_2$ eq without CCS

<table>
<thead>
<tr>
<th>Direct Emissions [GtCO$_2$ eq/yr]</th>
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<tbody>
<tr>
<td>2030 2050 2100</td>
</tr>
</tbody>
</table>

- Transport 22 22 22
- Buildings 22 22 22
- Industry 22 22 22
- Electricity 36 36 36
- Net AFOLU 32 32 32
- Non–CO$_2$ 36 36 36

n= 29 29 29

IPCC AR5, WG3 Technical Summary
But the future may not take us there

...for strictly logical reasons, it is impossible for us to predict the future course of history.

Sir Karl R. Popper
Many possible futures
Many possible futures
Many possible futures
Many possible futures
Many studies
• Large investment needs to keep supply flowing, even more to decarbonize
• The Paris goal (1.5°C) is almost unachievable
Plausible energy mix in an emerging net-zero emissions world
The gradual transition in the fuel mix continues…

*Renewables includes wind, solar, geothermal, biomass, and biofuels

Primary energy consumption by fuel

Billion toe

Base case: Primary energy

- Global resource abundance
- Increased car ownership – but electric cars remain anecdotal
- Oil demand for cars keeps growing
- Resources are not the problem
- Demand revised down, RES revised up
• Renewables rule
• Thanks to technological development
• Decentralized in developed countries, centralized in developing ones

Source: Bloomberg New Energy Finance. Note: Flexible capacity includes power storage, demand response, and other potential resources.
### Large differences in building blocks

#### CAGR (%) 2015-2035

<table>
<thead>
<tr>
<th></th>
<th>Faster transition</th>
<th>Even faster transition</th>
<th>IEA 450</th>
<th>MIT 2° Base</th>
<th>IHS Markit ‘Solar Efficiency’</th>
<th>Greenpeace ‘Revolution’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon emissions</td>
<td>-0.7%</td>
<td>-2.0%</td>
<td>-2.0%</td>
<td>-2.0%</td>
<td>-2.8%</td>
<td>-3.2%</td>
</tr>
<tr>
<td>Total energy</td>
<td>0.9%</td>
<td>0.8%</td>
<td>0.4%</td>
<td>0.5%</td>
<td>-0.7%</td>
<td>-0.1%</td>
</tr>
<tr>
<td>Energy intensity</td>
<td>-2.4%</td>
<td>-2.5%</td>
<td>-3.0%</td>
<td>-2.9%</td>
<td>-4.0%</td>
<td>-3.5%</td>
</tr>
<tr>
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<td>-2.7%</td>
<td>-2.3%</td>
<td>-2.5%</td>
<td>-2.1%</td>
<td>-3.5%</td>
</tr>
</tbody>
</table>

#### Share of total energy, 2035

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<th>Faster transition</th>
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<th>MIT 2° Base</th>
<th>IHS Markit ‘Solar Efficiency’</th>
<th>Greenpeace ‘Revolution’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil &amp; gas</td>
<td>51%</td>
<td>48%</td>
<td>48%</td>
<td>46%</td>
<td>51%</td>
<td>39%</td>
</tr>
<tr>
<td>Renewables†</td>
<td>16%</td>
<td>23%</td>
<td>17%</td>
<td>29%</td>
<td>19%</td>
<td>38%</td>
</tr>
</tbody>
</table>

#### Share of abatement vs. 2015

<table>
<thead>
<tr>
<th></th>
<th>Faster transition</th>
<th>Even faster transition</th>
<th>IEA 450</th>
<th>MIT 2° Base</th>
<th>IHS Markit ‘Solar Efficiency’</th>
<th>Greenpeace ‘Revolution’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power sector</td>
<td>&gt;100%</td>
<td>89%</td>
<td>77%</td>
<td>74%</td>
<td>58%</td>
<td>35%</td>
</tr>
</tbody>
</table>
Large differences among regions (I)
Large differences among regions (II)

**Figure 3.4** Energy-related GHG emissions reduction in CO$_2$-eq terms by policy measure and region in the Bridge Scenario relative to the INDC Scenario, 2030

- **China**: 1,346 Mt
- **Middle East**: 553 Mt
- **India**: 395 Mt
- **United States**: 362 Mt
- **Southeast Asia**: 302 Mt
- **Russia**: 280 Mt
- **Africa**: 260 Mt
- **Latin America**: 247 Mt
- **European Union**: 213 Mt

Notes: The relative shares of emissions savings by policy measure have been calculated using a logarithmic Dean Divisia Index ($DDI_I$) decomposition technique. In regions where fossil-fuel subsidies hinder energy efficiency investments today, the existing subsidy level in each sector was used to quantify the impact of fossil-fuel subsidy reform on emissions savings.

Although the strong growth in energy demand in China over the past decade has locked-in a relatively carbon-intensive energy infrastructure, an earlier peak in CO$_2$ emissions (including process emissions) can be achieved than in the INDC scenario: in the Bridge scenario, it is achieved in the early 2020s, as China’s carbon intensity (i.e., the amount of CO$_2$ emitted per unit of gross domestic product (GDP)) drops by 5.4% per year between 2013 and 2030, compared with 4.5% in the INDC scenario. The share of non-fossil fuels in primary energy demand rises to 23% by 2030, three percentage points above the target in the INDC scenario. In India, planned energy sector policies have a focus on large-scale solar power deployment. Taking more use of the energy efficiency potential across all sectors could help to cost-effectively reach India’s energy sector targets and support a total reduction of GHG emissions by 400 Mt CO$_2$ (or 11%) in 2030, relative to the INDC scenario.

As in the case of China and India, most other countries had not submitted their INDCs for COP21 by 14 Day 2015, but their existing and planned policies give a good indication of the likely level of ambition of their targets. In Japan, for example, the existing and announced 2030 value is calculated using the coal-equivalent approach in Chinese statistics, which is likely to be the basis of the Chinese INDC. Using IEA definitions, the share of non-fossil fuels is 20% in 2030 in the Bridge scenario.
And climate changes: hydro

Box 3.1. Projected Changes in Hydropower Generation

Modeling by the Norwegian University of Science and Technology examined climate impacts on river flows and hydropower generation to 2050. Systems at highest risk had both a high dependence on hydropower generation for electricity and a declining trend in runoff. South Africa is quoted as one example with a potential reduction of 70 GWh per year in generation by 2050. Afghanistan, Tajikistan, Venezuela, and parts of Brazil face similar challenges.

And not all technologies use the same water...
Common themes

- The economy grows fast (3-4% pa)
- Energy demand continues growing (30-35% by 2040)
  - In non-OCDE countries
- Electricity grows faster
- Fossils maintain their rule
  - Decarbonization is not fast enough
  - Increasing role of gas and renewables
    - Renewables increase due to technological advances
  - But climate goals cannot be achieved
- Geopolitical changes
Some points for discussion

- Many scenarios are plausible
  - But demand growth is critical
- Gas vs Coal: Leaks and atmospheric emissions
- Electrification seems the cheaper way
- The role of nuclear
- The role of CCS
- Transport: NatGas vs Biofuels vs Electricity
- Do we need more storage?
And some additional questions

- How to deal with bridge technologies (and the associated infrastructure)?
- How to deal with networks (and their fixed costs)?
- Markets vs Regulation?
Thanks for your attention

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