Assessing the potential and costs of reducing energy demand

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The relevance of energy savings (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.

The relevance of energy savings (II)

**Figure 3.2** Global energy-related GHG emissions reduction by policy measure in the Bridge Scenario relative to the INDC Scenario

The largest contribution to global GHG abatement comes from energy efficiency, which is responsible for 49% 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 25% 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 projection 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).

The relevance of energy savings (III)

**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

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 4.3% 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 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$_2$-eq (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 December 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 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.
But...is it as cheap as we are told?
Assessing reductions in energy demand is not straightforward

- Public vs Private perspective
  - Discount rates
  - Taxes
- The choice of the counterfactual
- Interactions between measures
- Rebound effect
- Bottom-up vs. Top-down
Tools to estimate potential and costs

- **Marginal cost curve**
- **Expert evaluation**
- **Model-based**
  - **Top-down**
  - **Bottom-up**
  - **Partial Equilibrium**
    - **General Equilibrium**
      - **CGE**
    - **Optimization models**
    - **Simulation models**
Advantages and Disadvantages

• Model-based:
  – Accounts for interactions, and for optimal investments
  – But may be opaque and biased by assumptions

• Expert-based:
  – More transparent: important in the face of uncertainty and lack of rationality
  – Easier: two relevant parameters
  – Investments need to be determined exogenously

• Hybrids
Our expert-based approach

• For each measure:
  – We determine the long-run marginal cost
  – And we identify the alternative measure

• We calculate the cost of the EE measure as the difference between it and the alternative

• We estimate energy savings as the difference between energy intensities x penetration rate

• Finally, we determine the cost per MWh saved
Graphic representation

Block length: 
$(E_{ref} - E_{new}) \Delta \text{Penetration}$

Block representing the additional installation of an energy saving technology

Block height: 
$(LRMC_{new} - LRMC_{ref}) / (E_{ref} - E_{new})$
Our improvements

• We compare against the BAU
• We account for interactions
  – Within measures in the same sector
  – Between the electricity sector and the rest
  – We obtain an 5-10% of overestimation
• Public vs private cost
  – Discount rate
  – Taxes
Some limitations

- Lack of data
- Uncertainty about the future
  - Technological advance
  - Policies and behavioral changes
- We only look at technology, not behavioral changes
Sectors and measures

• 80% of primary energy in Spain
  – Residential
  – Commercial
  – Transport
  – Power sector
  – Industrial: aluminum, ammonia, bricks, cement, steel, ceramics, petrochemical, oil refining

• 15-50 measures per sector
Scenarios for 2030

- BAU
- Policy-intensive
- Technology-intensive
Results: BAU

26% savings compared to BAU
2% less than 2010
Results: Policy-intensive

Efficient vehicles and modal change

Wind
Heat pumps

19% additional savings
50% at negative cost
Results: Technology-intensive

15% additional savings
40% at negative cost
Why do we still have negative-cost measures? The paradox of energy efficiency

- Possible explanations
  - Market failures
  - Lack of rationality
  - We are not as dumb as we seem

- That is also the reason why the potential is so large
## Reasons for the EE paradox

<table>
<thead>
<tr>
<th>Reason</th>
<th>Is it a market failure?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low energy prices</td>
<td>Not as such. Yes if prices are not efficient (due to externalities or over-subsidies)</td>
</tr>
<tr>
<td>Hidden and transaction costs</td>
<td>Not the first, yes the second</td>
</tr>
<tr>
<td>Uncertainty and irreversibility</td>
<td>No, unless the risk is socially diversifiable</td>
</tr>
<tr>
<td>Information failures</td>
<td>Yes</td>
</tr>
<tr>
<td>Bounded rationality</td>
<td>No</td>
</tr>
<tr>
<td>Slowness of technological diffusion</td>
<td>Not as such, yes if there are positive externalities not accounted for</td>
</tr>
<tr>
<td>Principal-agent problem</td>
<td>Yes</td>
</tr>
<tr>
<td>Capital markets imperfections</td>
<td>Yes, although not significant</td>
</tr>
<tr>
<td>Heterogeneity of consumers</td>
<td>No</td>
</tr>
<tr>
<td>Divergence with social discount rates</td>
<td>Not necessarily</td>
</tr>
</tbody>
</table>
Why some measures seem so costly?

- Sometimes we don’t have good data
  - Data availability in diffuse sectors
  - Large heterogeneity
- They not only serve energy and environmental purposes
  - Difficult to allocate costs
- They lose profitability due to interactions
MACs are helpful to identify measures

<table>
<thead>
<tr>
<th>VERY NEGATIVE COST</th>
<th>VERY NEGATIVE COST</th>
<th>LOW POTENTIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>Wind onshore</td>
<td>Commercial LED lighting</td>
</tr>
<tr>
<td>Transport</td>
<td>Freight transport by train</td>
<td>Transport Electric vehicle</td>
</tr>
<tr>
<td>Transport</td>
<td>Efficient passenger train</td>
<td>Ind - refining Process improvements</td>
</tr>
<tr>
<td>Ind. - cement</td>
<td>Improvements in processes and wastes</td>
<td>Residential Fluorescent lighting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Residential LED lighting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transport Plug-in electric vehicle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Commercial Climatization management</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transport Biodiesel truck</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transport Electric bus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transport Hybrid bus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Residential Biomass water heater</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ind - steel Energy management EAF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ind - ammonia Energy management</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ind - aluminum Process improvements</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Commercial Biomass water heater</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ind - steel Energy management BOF</td>
</tr>
<tr>
<td>LOW COST</td>
<td>LOW COST</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>Low-resistance tyres</td>
<td>Residential Efficient fridges</td>
</tr>
<tr>
<td>Power</td>
<td>Solar thermoelectric</td>
<td>Power Tidal energy</td>
</tr>
<tr>
<td>Residential</td>
<td>Solar water heater</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>Solar PV</td>
<td>Residential Climatization management</td>
</tr>
<tr>
<td>Commercial</td>
<td>Wall insulation</td>
<td>Commercial Solar water heater</td>
</tr>
<tr>
<td>Power</td>
<td>Wind offshore</td>
<td>Residential Geothermal heat pump</td>
</tr>
<tr>
<td>Ind. - cement</td>
<td>Precalciners</td>
<td>Residential High-efficiency induction kitchen</td>
</tr>
<tr>
<td>HIGH COST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential</td>
<td>Wall insulation</td>
<td>Commercial Efficient heat pump</td>
</tr>
<tr>
<td>Residential</td>
<td>Advanced heat pump</td>
<td>Commercial Double glazing</td>
</tr>
<tr>
<td>Commercial</td>
<td>Efficient electric appliances</td>
<td>Commercial Geothermal heat pump</td>
</tr>
<tr>
<td>Residential</td>
<td>Double glazing</td>
<td>Residential Efficient washing machine</td>
</tr>
<tr>
<td>Residential</td>
<td>Double glazing</td>
<td>Residential Efficient dishwasher</td>
</tr>
<tr>
<td>Residential</td>
<td></td>
<td>Residential Efficient oven</td>
</tr>
</tbody>
</table>
Another example: Active Demand

- Normal Demand in other markets:
  - Consumers respond to variable prices
  - And in the process allocate resources efficiently
- But this was not feasible in the power sector
Hourly prices for electricity

17/01/2013 - Precio horario del mercado diario

- Precio marginal español
- Precio marginal portugués
- Energía total Mercado Ibérico

- Media Aritmética Precios Marginales
- Sistema eléctrico portugués 52,10 EUR/MWh
- Sistema eléctrico español 52,11 EUR/MWh
- Energía total Mercado Ibérico 751,928,70 MWh
Demand and supply in the power sector
Welcome smart meters (and smart grids)

- Now we can measure
- And consumers can respond
- 16% increase in DR between 2009 and 2010, 10.5% of peak demand in PJM
- But this has a cost
## Types of response

- Load shifting
- Load conservation (largest part)

<table>
<thead>
<tr>
<th>Classification criteria</th>
<th>Dualities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Reliability</td>
</tr>
<tr>
<td>Trigger factor</td>
<td>Emergency-based</td>
</tr>
<tr>
<td>Origin of signal</td>
<td>System-led</td>
</tr>
<tr>
<td>Type of signal</td>
<td>Load response</td>
</tr>
<tr>
<td>Motivation method</td>
<td>Incentive-based</td>
</tr>
<tr>
<td>Control</td>
<td>Direct load control</td>
</tr>
</tbody>
</table>
Benefits from Active Demand programs

- **Generation**
  - Reduced fuel costs, emissions (?)
  - Reduced/Delayed investments
  - Better balance – Reduced reserves
  - Increased penetration of RES

- **Transmission & Distribution**
  - Relieve congestion, outages
  - Manage contingencies, better operation
  - Reduced/Delayed investments

- **Other**
  - Reduced market power
  - Less volatility
  - Better consumer awareness
Some preliminary numbers - Spain

<table>
<thead>
<tr>
<th>NPV (9%, 10 years)</th>
<th>Costs in BS</th>
<th>Savings with respect to BS</th>
</tr>
</thead>
<tbody>
<tr>
<td>[M€]</td>
<td>DR-0%</td>
<td>DR-25%</td>
</tr>
<tr>
<td>Investment cost</td>
<td>12,327</td>
<td>0</td>
</tr>
<tr>
<td>Fuel cost</td>
<td>41,330</td>
<td>232</td>
</tr>
<tr>
<td>CO₂ allowances</td>
<td>8,939</td>
<td>39</td>
</tr>
<tr>
<td>TOTAL</td>
<td>62,596</td>
<td>270</td>
</tr>
</tbody>
</table>

The model considers feedback effects within the power sector

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<tr>
<td>[000 €]</td>
<td>DR-0%</td>
<td>DR-25%</td>
</tr>
<tr>
<td>Investment costs</td>
<td>72,979</td>
<td>204</td>
</tr>
<tr>
<td>Maintenance costs</td>
<td>14,916</td>
<td>39</td>
</tr>
<tr>
<td>TOTAL</td>
<td>87,894</td>
<td>243</td>
</tr>
</tbody>
</table>
Some preliminary numbers - Europe

![Bar chart showing cost comparisons for different scenarios in Europe.](chart.png)
But there may be a rebound

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Power sector</th>
<th>General Eq</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM10</td>
<td>-3,1%</td>
<td>-2,91%</td>
</tr>
<tr>
<td>SOx</td>
<td>-1,8%</td>
<td>-1,04%</td>
</tr>
<tr>
<td>CO2</td>
<td>-3,1%</td>
<td>-0,95%</td>
</tr>
<tr>
<td>NOx</td>
<td>-2,9%</td>
<td>-0,66%</td>
</tr>
<tr>
<td>CH4</td>
<td>-</td>
<td>-0,01%</td>
</tr>
<tr>
<td>N2O</td>
<td>-</td>
<td>0,02%</td>
</tr>
<tr>
<td>CO</td>
<td>-</td>
<td>0,03%</td>
</tr>
<tr>
<td>SF6</td>
<td>-</td>
<td>0,05%</td>
</tr>
<tr>
<td>VOC</td>
<td>-</td>
<td>0,05%</td>
</tr>
<tr>
<td>NH3</td>
<td>-</td>
<td>0,06%</td>
</tr>
<tr>
<td>HFC</td>
<td>-</td>
<td>0,07%</td>
</tr>
<tr>
<td>PFC</td>
<td>-</td>
<td>0,11%</td>
</tr>
</tbody>
</table>
The cost-benefit analysis is not clear

- Depends on the business model
  - Degree of automation
- On the evolution of technology
  - Cost of the smart grid
- On the prices of electricity
  - Increasing? Or not?
  - Shape of the load/price curve
- And on the response of consumers
How will consumers respond?

• Studies have shown that there is some elasticity
  – 10-15% reductions in peak loads
  – Similar reductions in energy demand
• This depends on how signals are sent
  – CPP better than TOU, TOU better than RTP
  – Technology doubles the response
• And on the equipment / consumption
  – Low-income consumers are more responsive
  – Higher-volume consumers are more responsive
What if we just provide feedback?

- Low cost, low response
  - OPOWER (comparison with peers)
    - 2% reduction
    - Half is lost between invoices (Bounded attention)
    - Higher-income saves more than lower-income
  - GOOGLE (Self-reference)
    - 6% reduction
    - Only lasts 4 weeks
    - Mostly change in habits
Some conclusions from our studies

- Large potential for energy demand reductions
  - Stabilization of energy demand growth
  - With even additional reductions: 15-19%
- Very low cost (60%), or even negative (40%)
  - Largely dependent on energy costs
  - Several non-monetary barriers
But many challenges

- Internalisation of external costs
- Split incentives (EE vs retailers)
  - Decoupling does not work here
- Lower economies of scale / access to credit
- Lower technical competence
- Decentralized market and regulation
- Measurement and verification issues
- Flexible customer portfolios
Some may be addressed by specific policies

- Internalisation of external costs
- Split incentives (EE vs retailers)
  - Decoupling does not work here
- Lower economies of scale / access to credit
- Lower technical competence
- Decentralized market and regulation
- Measurement and verification issues
- Flexible customer portfolios
Measurement and verification issues

- The choice of the baseline
- The treatment of free riders
- The rebound effect
- The use of uplift factors

EFFICIENCY VS SAVINGS
### TWC vs Energy Saving Funds

- In theory, they might be equivalent
- In practice, they are not:

<table>
<thead>
<tr>
<th>TWC</th>
<th>ESF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficient price setting and investment (thanks to the market)</td>
<td>Easier measurement of savings</td>
</tr>
<tr>
<td>Measurement is very difficult</td>
<td>Regulated price (but more certain)</td>
</tr>
<tr>
<td>More complex setting</td>
<td>Traditional investment (subsidies)</td>
</tr>
<tr>
<td>Less efficient, higher risk (price volatility)</td>
<td>Higher prices for customers</td>
</tr>
</tbody>
</table>
Conclusions

• We need several instruments to promote energy efficiency
  – But we definitely don’t want some of them

• Liberalized markets require adaptation in some of these instruments
  – We need savings, not only efficiency: measured vs deemed savings
  – But we also want cost-efficiency and the right incentives

• As usual, the devil is in the details
  – E.g., TWCs do not need to be necessarily better than ESF, it is a question of good design
Thanks for your attention

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