Policy Brief

Identifying technology opportunities in the low carbon energy transition

Our 2050

This is one of a series of policy briefs to summarize ongoing findings related to the research project, 'Our 2050 – Opportunities for Ireland in a Low Carbon Economy', which is on the economic and societal opportunities arising from the transition to a low carbon economy and the policies needed to achieve this transition

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The Our 2050 project is addressing four key questions:

1. What will Ireland's future energy use look like? In particular, how will we generate electricity? How will we heat our buildings? What modes of travel will we use?
2. What technologies are most likely to play leading roles in Ireland's transition to a low carbon economy?
3. What strengths can Ireland play to, and what opportunities can Irish-based firms avail of?
4. What policies are needed? What do government, firms, universities and individuals need to do, individually and collectively, to achieve the transition?

This policy brief addresses the critical challenges faced when answering the first and second questions.

Marginal Abatement Cost Curves:

Assessment of key mitigation technologies with MACCs based on energy systems modelling

Policy Background

As a member state of European Union, Ireland has a national target to reduce green house gas emissions by 80%-95% relative to 1990 levels by 2050, with mandatory intermediate reduction target of 20% by 2020 and at least 40% reduction by 2030. The Paris Agreement aims to further limit the global temperature rise to "well below 2°C" above pre-industrial levels and contains the ambition to "limit the temperature increase to 1.5°C".

Marginal Abatement Cost Curves

It is important for policy makers to understand how low carbon energy future should look like and which carbon mitiation measures are likely to play critical roles while remaining resilient under a range of different uncertain circumstances. A well established analytical tool that advises policy making in mitigation measures is the marginal abatment cost curve (MACC). Marginal abatement cost measures the additional costs accrued for an additional unit of carbon abatement. A MACC presents the costs and potentials of carbon mitigation options by graphically relating the marginal abatement costs with the carbon reduction potential of mitigation technologies. MACC is usually derived through an expert-based method, which assesses the cost and emissions reduction potential of a portfolio of policy measures individually ranked by cost from lowest to highest. Such MACCs are presented in a step-wise graph that relate abatement quantity to cost. The most famous example is the global MACC published by the McKinsey and Company. These expert-based MACCs have received criticism due to insufficient treatment in uncertainty, inter-temporal dynamics and interactions among different sectors.

Energy systems modelling

The energy systems optimization model (ESOM) is another widely used energy policy tool. ESOMs are linear models that encompass all energy related technologies and commodities from primary resources through the chain of processes that transform, transport, distribute and convert energy into the supply of energy services demanded by energy consumers. The objective is to solve for least cost solution subject to emission constraints, resource potentials, technology costs, technology activity and capability to meet individual energy service demands. At University College Cork (UCC), the Energy Policy and Modelling Group (EPMG) has developed the Irish TIMES energy systems model. Scenario analysis has been used to support policy making process for Ireland by generating a technologically and economically robust evidence base and inform the development of national legislation on climate change and energy policy.

Deriving MACCs from energy systems model

Using the Irish TIMES model, the MACC is derived by imposing increasingly more stringent mitigation targets and run the model multiple times. The MACC contains over 100 scenarios, from the REF scenario where no climate policy is imposed to 100% with a 1% step change in 2050 emission level (relative to 1990 level). Intermediate climate targets in 2020, 2030 and 2040 are linearly interpolated.

Key Policy Insights

MACC

The system-wide MACC (Fig. 1) demonstrates the tradeoff between decarbonization ambitions and economic feasibility. The upward shape of the MACC reflects the increased marginal efforts when aiming for more ambitious carbon mitigation targets. Compared to the MACC, the total system cost does not increase tremendously. The impact of 80% reduction target on the total energy system cost represents less than 1% of total GDP in 2050.

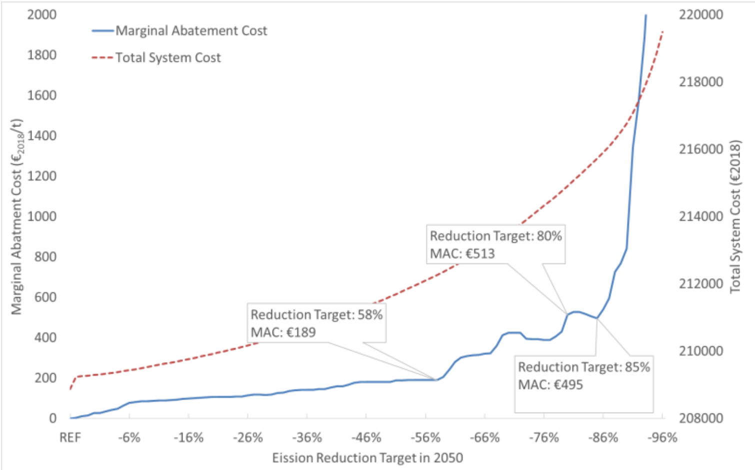

Figure 1. Marginal abatement cost in 2050 and overall total system cost. Tipping points can be identified at 58% and 85% CO_2 reduction levels

Tipping points can be identified on the MACC. At cost levels with steady and low rate of increase, the model is able to deploy and expand the capacities of many cost-effective mitigation options. As these cheaper sets of technologies reach their maximum potential, more expensive options need to be deployed. This causes tipping points where marginal abatement cost increase drastically.

Certain technologies have limited mitigation options in the model (such as passenger trains and cement production) and some mitigation technologies (such as plug-in hybrid vehicles and gas CCS) are not completely carbon free. It is impossible to reach carbon neutrality without negative emission technologies such as BECCS

Energy Systems

Analysis on the scenario ensembles that form the MACC shows the sectoral energy system patterns in response to the change in decarbonization ambitions. Each sector requires different levels of economic efforts for mitigation and may not decarbonize at the same rate with increased emission stringency. For example, the the first half of CO2 in power sector (Fig. 2) can be mitigated by switching from coal/peat to gas with low cost. The rest of CO2 decarbonization requries CCS and biomass technologies.

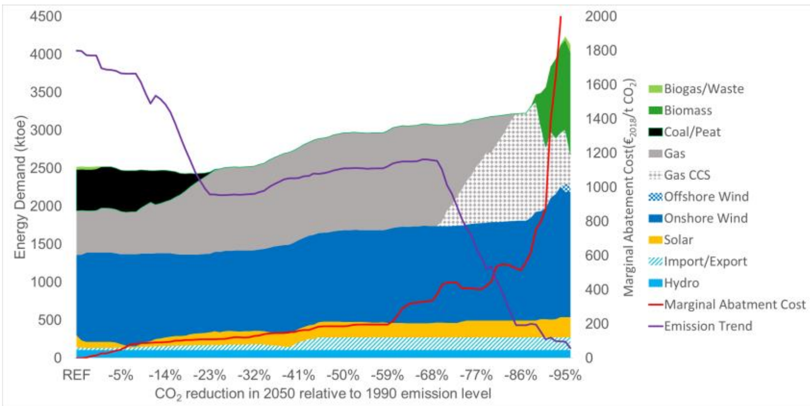

Figure 2. Electricity generation energy demand, emission trends and system-wide MACC in 2050.

Key mitigation options

Using decarbonization analysis, the emission reductions from phasing out carbon intensive technologies are attributed to the contributions from mitigation measures. By associating the marginal abatement costs with the emission reductions from low carbon technologies, key mitigation measures are identified and ranked according to the economic merits.

The MACCs indicate that energy efficiency measures, wind and solar power are cost effective even without any climate policy measures imposed. Electric vehicles, CCS power plants, bioenergy for industry and freight transport penetrate at lenient reduction targets and low MACs, and are categorized as resilient technologies. Beyond 85% reduction target, further mitigation requires electrification of residential heat and commercial heat requires with expansion in power generation, which significantly drives up MACs. High electrification of residential and commercial sectors is therefore categorized as a tipping point measure. Ocean energy and hydrogen transportation are categorized as niche technologies as they do not penetrate in any of our scenarios, implying that cost reduction is required to make them economic appealing compared to other renewable generation.

Conclusions

Combining MACCs with energy systems modelling comes with several advantages. The MACCs derived stenghten the shortcomings of expert-based MACCs as technologies across different sectors over the entire time horizon are assessed in an integrated manner. Analysis on the scenario ensembles that form the MACCs also provide more robust policy insights than focusing on current climate policy scenarios only.

It should be noted that MACC only serves as a basis for evaluating carbon mitigation technologies and is not sufficient for decision making by itself. The assessment based on energy systems modelling mainly captures techno-economic inputs including technology performance data and energy service demands. Decision making requires additional considerations on social and political factors such as public acceptance, political barriers and appropriate policy instruments.

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