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“ The basic materials produced by heavy industry will still be in high demand by 2050 if we are to build a low-carbon society, but industry’s role and the market environment will change dramatically. ”

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The global objective to limit human-induced warming to 2°C requires that global emissions are reduced by 50% by 2050. However, industrialized countries need to do much more. The principle of burden sharing embedded in the global climate negotiations implies that industrialized countries should be set on a path towards a complete decarbonization up to 2050 and beyond. The EU has adopted a target of 80–95% reduction by 2050 and the USA had similar targets in 2009; however, these never passed legislation. Several countries have adopted even stricter targets for 2050 such as Denmark, Norway, Iceland, New Zealand and Costa Rica.

The first set of climate policies introduced across European countries in the early 1990s resulted in substantial reductions in the power, housing and agricultural sectors, and curbed the growth of emissions in the transport and industry sectors. Even more important is that climate policy induced the development of a range of innovative low-carbon technologies that enable future decarbonization.

For heavy industry, with a large part of emissions originating not from combustion, but from the process itself, the prospects for decarbonization are still

relatively unexplored. Part of the reason is that industry has been sheltered from policy intervention due to concerns for lost competitiveness and carbon leakage. With continued process efficiency and fuel shifts, it seems possible to attain combined reductions of 10–40% within the next 10–20 years. For further reductions, industrial CCS has been proposed as the remaining back-stop option. However, recent investigations have shown that retrofitting CCS to existing industrial facilities is complicated, potentially very costly and will not result in a complete decarbonization [1].

It is against this backdrop that governments and industry associations in the EU have begun to develop ‘roadmaps’ for assessing the potential for decarbonizing industry in the long term. In 2011, the European forest-fiber industry released a roadmap for 2050 [2] and in 2012 our group at Lund University (Sweden) published a report assessing a decarbonization of heavy industry in Sweden by 2050, as an input to the Swedish Government’s low-carbon roadmap [3]. Several other industrial roadmaps are currently being developed by European industry associations and governments and will be published in the next 2 years.

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The roadmaps are not developed to forecast the future but to serve as a platform for discussing future challenges among the relevant actors involved (e.g., industry, government and NGOs). The focus when developing roadmaps and visions are thus normally not on carbon costs (derived from climate–economic models) but on the potential structural changes in markets, the complexity of technology dynamics and the need for institutional reforms. The analysis can include exploration of potential ‘game changers’ or ‘disruptive’ technologies.

The futures outlined by the emerging roadmaps are interesting. The basic materials produced by heavy industry will still be in high demand by 2050 if we are to build a low-carbon society, but industry’s role and the market environment will change dramatically. Decarbonizing society by 2050 will induce systemic changes to the whole energy system. The structural changes necessary for a decarbonized energy system could induce a stronger integration with heavy industry supplying peak power, load management and even being a major electricity producer. As an example, increased supply of variable renewable electricity could induce ‘power-to-gas’ solutions that will increase integration between the energy, transport and industry sectors.

“ The roadmaps are not developed to forecast the future but to serve as a platform for discussing future challenges among the relevant actors involved... ”

A transformation towards a decarbonized society will create both winners and losers among industries. Refineries in their present form are set to decrease as an effect of climate policy itself with less demand for fossil fuels. This will also have severe effects on the chemical sector relying on refinery byproducts (naphtha) as feedstock. This change is already apparent and pushing the introduction of bio-based chemicals. Industries involved in the transformation of biomass are in the midst of a very dynamic development with strong competition and focus on innovation of new products. Emerging bioeconomy solutions for producing biofuels, chemicals and electricity could induce the merger of industrial sectors, such as the food and chemical sector.

From a mitigation point of view, the results from the work on roadmaps are clear. Retrofitting current production systems with increased efficiency, fuels shifts or ‘end-of-pipe’ solutions such as CCS will be insufficient. More radical shifts focusing on the core industrial processes are needed for a complete decarbonization beyond 2050. Some examples of radical technology shifts are the electrowinning or HIsarna-concepts for steel (replacing the blast furnace), the magnesium- or oxygen-based process with CCS replacing current cement kilns, and bio-based platform chemicals via gasification or hydrolysis.

Apart from these specific process technologies, there is also a need to develop more general-purpose technologies such as electrothermal technologies for industrial heating and industrial CCS. Decarbonizing industry will thus depend on strong innovation that requires a major effort to develop, demonstrate, pilot and eventually to invest in novel process designs that are currently not available on the market.

Decarbonizing industry by 2050, or soon thereafter, may seem like a daunting task. However, major technology shifts and transitions in industry have occurred before. Examples include the shift from open hearth to basic oxygen furnaces in the iron and steel industry, and from batch digesters to continuous cooking in pulp mills, or the conversion to chlorine-free bleaching. Cost reductions, productivity and quality improvements, but also regulation and consumer demand, have been important drivers behind such changes. In addition, economies of scale have driven some of the structural changes towards fewer and larger plants and mills. Although the capital intensity of basic industries may lead us to assume that change is difficult, history shows that it is constantly evolving.

Investment strategies in the asset-intensive heavy industry need also to consider the large sunk cost in existing facilities and the complexity of operations. Core industrial processes change only gradually over the years and the investment cycles in heavy industry are extremely long. Decarbonization of industry will affect the core processes in a sector that is at the same time exposed to fierce global competition. For big companies, 2050 is only one or two major investment opportunities away. Heavy industry must thus aim at being ‘zero-emission ready’ by 2040 in order to be able to make the sensible low-carbon investment decisions that will have effect by 2050 and beyond. Being ‘zero-emission ready’ means that technology needs to be proven and economically predictable for sound investment decisions.

“ A transformation towards a decarbonized society will create both winners and losers among industries. ”

Work on roadmaps so far has identified several promising technologies that could radically cut emissions; the remaining question is how a transition may unfold and how it can be governed. Overcoming the numerous barriers for radical future technologies in the industrial sector, and at the same time managing the inherent risk of carbon leakage embedded in the climate change convention, requires a comprehensive and systemic policy strategy for technology development and deployment. This may include consideration of trade agreements and border carbon-tax adjustments.

Targeted support for specific technologies is necessary and needs to include funding for research development and demonstration, but also for market development support in a broad sense. Now, this development must be up-scaled for assessing industrial feasibility.

The major obstacle identified for up-scaling and moving breakthrough technologies beyond the demonstration phase is the lack of financing and risk sharing. Here, institutional reforms are needed for creating a mechanism that could fill the financing gap between demonstration and market readiness for developing core technologies for heavy industry.

The risk of deploying new technologies and processes is not only technological but also political (i.e., will climate policy persist and will there be any global mitigation effort easing the carbon leakage issue?). For that reason it is legitimate that public funds are used to ease the risk and help finance demonstration, pilots and even early market deployment. Under what circumstances, with what guarantees and with what sunset clauses this is done, is something that roadmaps also need to discuss in order to create long-term clarity and trust between government and industry while

maintaining flexibility. The EU scheme of financing renewable energy and CCS pilots with revenues from a small pot of reserved ETS allowances (NER300) offers an interesting start but needs to be scaled up, to be broadened and integrated into a wider innovation policy and made more permanent, in order to match long-term ambitions with the EU climate policy.

Financial & competing interests disclosure

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