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CUTTING CARBON, NOT THE ECONOMY

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Highlights

- A drastic change in the way we produce and consume energy is necessary to contain the risk of global environmental catastrophe. For its part, the EU has set agreed to a greenhouse gas reduction target of 80-95 percent by 2050, compared to 1990.
- However, with the current fuel mix, even the most ambitious improvements to incumbent technologies are unlikely to be sufficient for reaching the reduction targets. Meeting the targets requires low-carbon transition. However, the process of transition will likely be littered with market failures.
- Hundreds of more-or-less proven low-carbon technologies are competing for market share in the low-carbon system. In order to bring about the transition to a low-carbon energy and transport system at the lowest cost, policymakers should rely as much as possible on private action to choose, develop and deploy low-carbon technologies.
- For those market failures that might only be overcome with technology-specific measures, governments should set up a transparent and predictable mechanism for selecting technologies.

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CUTTING CARBON, NOT THE ECONOMY

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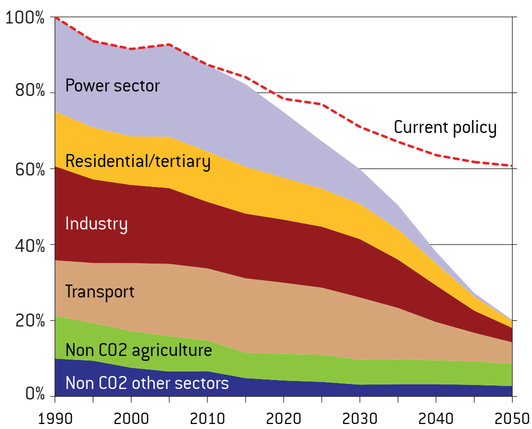
A DRASTIC CHANGE in the way we produce and consume energy is necessary in order to contain the risk of a global environmental catastrophe. For its part, the European Union has set targets for the reduction of greenhouse gas emissions by up to 80-95 percent of 1990 levels by 2050 to keep the global temperature increase below 2°C. However, with the current fuel mix[1], even the most ambitious improvements to incumbent technologies are likely to be insufficient for reaching the reduction targets set by the EU (Figure 1). Meeting these targets requires a transition to an energy and transport system built around low-carbon technologies. However, the process of transition will be fraught with market failures.

Energy system transition is a complex undertaking. Hundreds of more-or-less proven low-carbon technologies are competing for market share in the low-carbon system. Selecting technologies in an administrative or political process is unlikely to be cost-effective. In order to bring about the transition to a low-carbon energy and transport system at the lowest cost, policymakers should rely as much as possible on private action to choose, develop, and deploy low-carbon technologies. The policy challenge is to develop the least distorting instruments for preventing market failures. For those market failures that might only be prevented with technology-specific measures, the difficulty of selecting from technologies of unknown merit should be minimised by setting up a transparent and predictable mechanism.

Figure 1: EU greenhouse gas emissions towards an 80% domestic reduction (1990=100%)



Source: European Commission (2011).

1. Many observers dismiss biofuels based on expected cost (C. Ford Runge & Benjamin Senauer 2007; Lisa Ryan *et al*, 2006; Juan Delgado and Indhira Santos, 2008).

2. Side-benefits include the reduction of local pollutant and noise emissions. Furthermore, decarbonising the economy based on new technologies could induce growth, and may lead to innovation spillovers that can help to reduce emissions even in countries that have no, or less stringent, climate change policies (eg by making green technologies cheaper than dirty alternatives).

BACKGROUND

The current energy and transport system, in its complexity, has developed over centuries. Though it suffers from an extreme degree of inertia, it has undergone a series of transformations in the past: from wood to coal, coal to oil, and to electrification. In each of these cases, the new energy source proved either cheaper or more versatile than the one it supplanted or complemented. Despite the notable advantages of each successive fuel, transitions took time: perhaps 200 years for coal and 75 for both oil and electricity. These very slow transitions were primarily due to path dependencies and market failures.

Compared with earlier energy transitions, the transition to a low-carbon energy and transport system suffers from an additional bottleneck – although new low-carbon technologies grant positive environmental externalities and additional side-benefits[2], they are neither cheaper nor more versatile than the technologies they aim to replace. In fact, the substantial expensive downstream changes to the incumbent energy or transport system will require significant investments.

MARKET FAILURES IMPEDE A MEANINGFUL TRANSITION

The environmental benefits that low-carbon technologies provide to society are not automatically internalised by private investors and firms. Markets alone will not encourage the development and deployment of uncompetitive technologies, even if they are necessary for a low-carbon future. Furthermore, a number of market failures impede the success of new low-carbon technologies at different stages of their development (including research and development, demonstration, and deployment).

At the R&D stages, there would be underinvestment without effective policies to protect intellectual property or to alleviate the private costs of investment. Innovation, especially as it pertains to specialised technologies, comes at a cost. Although acquired knowledge may offset the cost of R&D for the investing firm, investments confer a positive externality to outside firms – they may reduce the costs of production through beneficial knowledge spillovers. This results in a situation in which individual firms under-invest in R&D because they cannot fully internalise the social benefits of their investments or because they anticipate costless benefits to be gained from the investments of others.

At both the R&D and the demonstration stages, the costs of exploring and building new markets are high. These costs may not be fully recoverable given that later entrants may reduce profit margins. As a result, early movers might not be willing to take risks and business exploration investments may be hampered or slowed. This is unfortunate as the exploration of new low-carbon technology business models has high social value. It provides important information to consumers, competitors and politicians about the viability of different business models and technologies.

Additionally, deploying and exporting low-carbon technologies might offer business opportunities and increase competitiveness. Under certain conditions, it is even conceivable that economies as a whole might benefit from low-carbon technology industries that were built on early local deployment. For example, Denmark's wind industry benefited from aggressive domestic market expansion[3]. However, the early deployment of still non-competitive low-carbon technologies will typically not occur without public support.

At the deployment stage, even if competitive low-carbon technologies were available, past technology choices might have created a difficult-to-overcome system that could hinder quick rollout of new technologies. Such path-dependence or lock-in, in the market failure sense, is the inability of the market to switch technologies despite the knowledge that the incumbent technology is inferior or undesirable relative to an alternative (Liebowitz and Margolis, 1995)[4]. The market failure may exist for a number of reasons: lock-in due to uncertain payoff functions occurs because incumbent companies prefer to avoid embarking on risky new technologies when incumbent technologies are still profitable; lock-in due to learning-by-doing is happening because incumbent technologies have accumulated significant process innovation over time while new technologies would first need to improve to become competitive; institutional lock-in is due to the evolution of institutions around existing technologies, which creates a symbiotic relationship that is focused on the incumbent technology; and/or network effects that favour incumbent technologies because the number of participants in a system increases the value of the system for all participants. High levels of uncertainty, coupled with positive network externalities, may lead individual firms to converge on a technology or energy system that proves suboptimal *ex post*.

The energy and transport sector is highly capital-intensive. Thus, poor coordination during the transition would be very costly. Due to the high number of interfaces required by energy systems, the many stakeholders involved, and the complexity of the technical questions that need to be answered, complicated negotiations between stakeholders may emerge. These negotiations might take years and consume valuable resources. First-movers who participate in the

'Markets alone will not encourage the development and deployment of uncompetitive technologies, even if they are necessary for a low-carbon future, and a number of market failures impede the success of new low-carbon technologies at different stages.'

3. Huberty and Zachmann (2011).

4. Path-dependence based on insufficient knowledge at the beginning is not *ex-ante* inefficient but can be *ex-post* inefficient.

coordination of standards may therefore impose a positive externality on late-comers by absorbing the costs of standardisation. Due to this market failure, first-movers may prefer to form fragmented networks/markets to avoid laborious and costly coordination. Alternatively, in the absence of stakeholder involvement in the coordination process, a minority of firms might push through a standard clearly not in the best interest of society. Leaving coordination entirely to the market might result in late deployment and fragmented networks and markets.

Additionally, in order to deploy, some technologies require a completely new underlying infrastructure. Infrastructure comes at a high cost, which may not be fully recoverable for the initial providers, especially if the business is regulated *ex post* or late entrants face lower costs. To recoup their initial investment, providers might have an incentive to capture customers by implementing artificial barriers to prevent switching. This can also lead to fragmented markets and slow adaptation of new technologies.

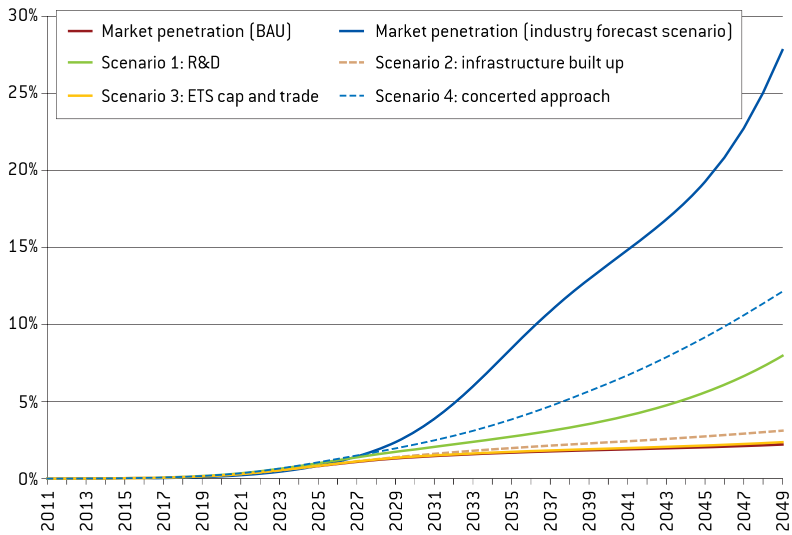
The result of these market failures is that, though private investment into new low-carbon technologies provides many positive spillovers for society, companies will be reluctant to make the necessary investments. Without public intervention, the transition will either happen too slowly to achieve the desired result, or may not take place at all.

ILLUSTRATIVE EXAMPLE OF GAPS

The preponderance of market failures associated with an energy transition, if not addressed at least partially, will prevent certain low-carbon technologies from entering the market. We use the case of Fuel Cell Electric Vehicles (FCEVs) as an example of such a technology. FCEVs have the potential to become a breakthrough low-carbon transport technology (due to their range advantage over current battery vehicles), but their deployment is stymied by very high initial cost (about €100,000 for a mid-class vehicle) and the absence of the required dedicated infrastructure (only about 100 hydrogen fuel stations in the EU27). FCEVs are more sensitive to the infrastructure externality than technologies such as battery electric vehicles, and illustrate the problems faced by similarly infrastructure-sensitive technologies[5]. According to modeling results[6], under the existing framework conditions, FCEVs will be virtually absent from the vehicle market in 2050, while incumbent technologies will still play a major role.

Figure 2 shows the results of the simulation exercises. The results suggest that a comprehensive package of measures could close the gap between hydrogen fuel cell and other established or emerging propulsion technologies. Indeed, the results indicate that only a concerted approach is likely to lead to any significant increase in the market

Figure 2: Simulation results, FCEV market share



Source: Bruegel based on ESMT (2011) and McKinsey & Company (2010). See Zachmann *et al* (2012)

5. Hybridisation and a large niche market (suburban commuters with home-charging) could allow battery electric vehicles an initial deployment without substantial public infrastructure investment.

6. We use the Market Model Electric Mobility (MMEM) – a simulation tool developed by the European School of Management and Technology (ESMT, 2011). While the underlying assumptions are based on the German car market, the results can generally be transferred to the European context.

share of FCEVs in the foreseeable future. Employing a package that would combine infrastructure support, R&D funding, and accounting for the emission cost of conventional vehicles is likely to lead to a market share approaching 12 percent in 2050 (Scenario 4, light blue line)[7]. While this is still below the industry forecast scenario of 25 percent in 2050, it would serve to establish FCEVs as a mass-market technology. Consequently, policy is clearly key to bridging the gap for new technologies. Whether this is the most efficient policy intervention package depends, however, on the cost of the policy mix.

Table 1 shows that the increasing share of FCEVs under the concerted approach scenario are accompanied by a reduction in the market share of conventional (-1.8 percent for diesel and -2.5 percent for gasoline) and hybrid technologies (-2.8 percent for hybrids, -2.8 percent for plug-in hybrid electric vehicles). Consequently, if the hydrogen is produced by low-carbon technologies, the replacement of the (partly) fossil-fuel based technologies by FCEVs would result in greenhouse gas reductions.

CONCLUSION

To incentivise the private sector to make the necessary investments in low-carbon technologies, policymakers should build on existing policy instruments to address the gaps in support. We propose some complementary instruments.

Inclusion of all forms of transport in the EU emissions trading system

As vehicles become more fuel-efficient, a rebound effect might become apparent. Consumers might use cars more often when fuel consumption savings lead to lower driving costs relative to other modes of transport. Lower fuel bills may also mean more money to be spent on transport. A price on carbon for fossil fuels is necessary to stimulate efficient emissions-mitigation behaviour on the part of consumers.

An arbitrary price on carbon is, however, not efficient. The proposed carbon component in the fuel tax is insufficient for ensuring efficient economy-wide greenhouse gas mitigation. A carbon tax would be different from the volatile marginal abatement costs in ETS-regulated sectors. Transport fuels produced in different sectors would then face different carbon costs. For example, the electricity used in electric vehicles (or for electrolysis to produce hydrogen) is covered by the ETS, while gasoline production is not covered by the ETS. Hence, fossil fueled transport would abate too much/little if the carbon tax is higher/lower than the ETS price. In addition, taxes are a less good incentive for long-term investment decisions because they can easily be changed by policymakers[8]. Only a broad scheme providing a single carbon price across sectors would ensure cost-optimal abatement. Including transport in the ETS could achieve this. Furthermore, inclusion of transport in the ETS would increase the depth of the carbon market and make the system more resilient.

Implementation could be done by obliging fuel outlets to buy emission allowances for the fuel they sell. This would result in the harmonisation of the carbon price across sectors and create an incentive for the use of the cheapest available abatement options.

Lock-in of a long-term carbon price (government credibility)

In addition to aligning the carbon cost across the different transport sectors, governments can reduce uncertainty for investors by providing assurance that carbon would be sensibly priced beyond 2020.

Table 1: Market penetration (%)

	Diesel	Gasoline	Hybrid	LPG/CNG	Biofuels	Hydrogen	BEV	PHEV	RE
2011	42.0	54.2	0.2	3.1	0.5	0.0	0.0	0.0	0.0
2050 BAU	12.3	15.8	21.2	1.5	2.5	2.2	2.4	19.1	23.0
2050 Concerted	10.5	13.3	18.4	1.4	1.9	12.1	2.2	16.3	23.9

Source: Zachmann (2012). Note: LPG/CNG = liquid petroleum gas/compressed natural gas; BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicles.

7. At this stage, modeling results cannot indicate an optimal mix of measures, as the costs of the individual policies are not considered.

8. The volatility of national fossil fuel taxation is a telling example of the volatility of taxation.

Currently, the EU emission cap for 2020, the sectoral coverage, the institutional setting beyond 2020 and other key elements of the ETS, are subject to change. As investors cannot predict the direction that likely political changes will have, the ETS lacks credibility in the long-run, and thus fails to provide clear long-term investment signals.

As it might be politically and institutionally impossible to lock-in a credible long-term commitment to a tight emissions trading system in the absence of an international agreement, second-best options for creating investment certainty should be considered.

A carbon floor price might seem attractive to today's low-carbon investors. However a general floor price is a rather inflexible tool. In case future carbon reduction potential turns out to be much cheaper than anticipated (eg because of new technologies or lower economic growth) a high floor price could result in carbon reductions becoming needlessly expensive. In addition, a politically set floor is subject to change and hence not credible in the long term.

A more targeted alternative would be the establishment of bilateral option contracts between public institutions and investors. The public institutions would guarantee a certain carbon price to an investor. In case the realised carbon price is below the guaranteed price, the public institution (the option writer) would pay the difference to the investor (the option holder). Hence, in case of a low carbon price, potentially detrimental to the competitiveness of a low-carbon investment, the investor gets some compensation.

Thus, the investor's risk is reduced. At the same time, if the public institution issues a large volume of option contracts, it creates an incentive to future policymakers not to water down future climate policies. Policies that reduce the carbon price will have a direct budget impact by increasing the value of the outstanding options. This would tend to increase the long-term credibility of carbon policies.

Schemes to drive supply-side investments

It has been argued that consumers do not properly account for future fuel savings, because buyers of new cars who shape the future car fleet are typically less price sensitive than buyers on the secondary market. In the absence of a global price on carbon, the demand for low-carbon vehicles (on both the primary and secondary market) is too small to encourage massive investments in low-carbon technologies. In this context, setting vehicle fleet emission standards is an effective second-best incentive for the provision of low-carbon technologies. Tightening thresholds in predictable way ensures that producers have incentives to invest in clean alternative technologies. For many consumers, reasonable vehicle emission standards will come at little additional cost, as the higher purchase price of less-carbon intensive vehicles is largely compensated for by fuel savings associated with emission reductions. Thus, average emission standards would play a key role in driving supply-side provision of low-carbon technologies.

Encouraging private provision of infrastructure

In the phase after their installation, most stations for newly introduced low-carbon fuels (such as hydrogen, exchangeable batteries, biofuels, natural gas) will see limited use. Due to the initial low load, most stations might only be able to cover their variable costs in the first decade. Without a clear prospect of recovery for their fixed costs, private companies would refrain from installing new fuelling stations. Public support for new refuelling infrastructure is currently mainly coming from local and regional initiatives. The corresponding trials and demonstrations are so far unable to break the chicken-and-egg problem of vehicles and infrastructure. To provide the refuelling stations for new fuels, that markets alone would not deliver, we suggest the establishment of temporary infrastructure consortia for the different low-carbon fuels. Each consortium would plan and organise the deployment of its respective fuelling-station infrastructure. For this purpose, each consortium would be given the exclusive right to auction local concessions for new fuel stations to interested retailers. This would ensure competition between different low-carbon fuels and

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different retailers. Finally, each consortium might organise internal cross-subsidisation between the different parts of the value chain (eg fuel and vehicle producers might support infrastructure), and between different fuel stations (eg fuel outlets in remote areas might obtain support from fuel outlets in densely populated areas), if it finds that this encourages a quicker rollout of their technology. To avoid abuse, all stakeholders should participate in the consortia, the consortia should be time-limited and their constitution should be cleared *ex ante* by competition authorities.

Public procurement mechanisms

One major improvement to current deployment policies would be to make public procurement more oriented towards the long-term by using it strategically for experimenting with alternative technologies. We suggest that publicly financed trials (eg for municipal vehicle fleets) be allowed to fail commercially. Using public procurement to conduct real-world experiments could uncover valuable information and avoid focusing only on low-risk technologies. Such a scheme requires that the responsible local, municipal or regional public authorities are able to accept failures in the trials they are conducting. Consequently, federal or European compensation mechanisms might be necessary.

Transparent and predictable policy response

Existing horizontal policies, including carbon prices or patent legislation, and the approaches proposed in this Policy Contribution, are not technology-specific. However, existing and proposed measures will not eliminate all externalities. In the absence of horizontal first-best solutions for some market failures, the public sector might want to return to technology-specific support instruments for R&D and deployment[9]. In this context, the question of technology choice is critical.

Industrial stage R&D, demonstration projects and support for deployment are not technology-neutral. Publicly funding large-scale demonstration and deployment projects for all technologies would not only be extremely expensive, it would also ignore the fact that different technologies are contemporaneously in different stages of their development. Undifferentiated co-financing could create significant windfall profits and wastage. In the presence of multiple new technologies which compete not only for a market but also for production factors, excessive support to one technology might even slow development. Government action may provide a focal point for a 'less efficient' technology, not only directing its own financial resources but also other production factors (skilled labour, capital, etc) away from the more efficient technologies.

Thus, the public needs to select which technology to support, when and how. This decision is extremely difficult as it involves evaluating technologies of unknown future merits. Due to the high uncertainties inherent in an energy and transport system transition, it is likely that some technologies will not live up to their promises. Selecting a portfolio of technologies is warranted, in order to make the vital transition resilient to unexpected shocks. Furthermore, coordination among member states is crucial for avoiding costly incompatibilities of national energy and transport systems. The EU should adopt a choice mechanism that is dynamic, adaptive and able to digest new information. This mechanism should optimise support in a quick, reliable and effective manner. In order to enable both industry and consumers to form the right expectations over the direction of technology, mechanism transparency is critical. The only way to control the potential impacts of public policy on industry investment choices, and promote fair competition, is through a transparent policy clearly communicating government priorities and decision parameters.

Predictability and technology-neutrality can only be ensured when technology choice is based on transparent and defined metrics and priorities. Stakeholders need to have incentives to provide

9. And as a matter of political reality policymakers find it easier to demonstrate the visible 'success' of technology-specific interventions (eg a milestone of 1 million electric vehicles).

unbiased forecasts of the capabilities of their technology[10]. These forecasts should be processed in an open multi-technology model to provide guidance for the targeting of support. A corresponding model should be built, maintained, extended and published by an independent public institution. This transparent mechanism would ensure that stakeholders can predict public technology decisions, and thus find it easier to commit to the long-term and risky investments needed to make the low-carbon energy and transport system transition a reality.

Along these lines, the European Commission has put some effort into devising a support methodology. The Strategic Energy Technology Plan (SET Plan) and independent technology reviews by the EU Joint Research Centre are two key instruments developed by the Commission. However, the SET Plan does not answer the essential questions: which technology should be supported? When and how? A comprehensive multi-technology view is currently lacking in policy decisions. In the same vein, the EU's new innovation funding programme, Horizon 2020, slated to distribute some €80 billion between 2014 and 2020[11], will not rely on an open multi-technology model to guide the targeting of support. If the EU continues along this path, major technology choices will be at best backed-up by the non-transparent and proprietary energy models currently used by the Commission, and at worst largely at the mercy of shifting politics.

In contrast to a 'shot-in-the-dark' definition of thresholds or numbers (such as 50-50 co-financing or one-million cars in 2020), a transparent choice mechanism may promote more coordination between regions, nations, and firms. The cost of the transition is put at several percentage points of GDP[12]. Therefore, large-scale government intervention will be unavoidable. To avoid extensive inefficiencies, a structured approach, adapted to the complexity of the challenge, is warranted.

10. Developers of different technologies may have an interest in overstating the capabilities or understating the cost of their respective technologies in order to attract more support (or even lock out competitors).

11. According to the European Commission (COM (2011) 808) "around 35 percent of the Horizon 2020 budget will be climate related expenditure".

12. According to the German Council of Economic Experts, in 2011 the net present value of all feed-in tariff obligations alone amounts to €80 billion. This is about 2 percent of Germany's GDP.

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