Theme 3: Wholesale Power Markets

This briefing note is drafted by Mike Hogan (RAP) with support from the group of lead authors in the 'Roadmaps to Reality' process. The note serves as the basis for the discussion at the 3rd Core Working Group seminar on 14 November 2012 on theme 3 (wholesale power markets). The options identified in the note are non-exhaustive and put forward to be tested and further developed along with new insights and ideas with the Core Working Group at the seminar and in consultation with the expert panel throughout the 'From Roadmap to Reality' project.

Summary

This briefing note is intended to provide the basis for discussion for the third of three seminars conducted with the Core Working Group of the Roadmaps to Reality project. The two previous seminars have focused on network infrastructure and on carbon pricing and complementary measures. This seminar will focus on the wholesale power markets in Europe and their relationship to the various energy roadmaps published in recent years.

The note is structured around two questions: The first question is what the roadmaps have to say about what wholesale power markets are expected to achieve, or to put it differently: What challenges are posed to markets by the pathways described in the various roadmaps? The second question is: What measures might be taken to improve the chances that the wholesale power markets will be successful in overcoming these challenges?

It is relatively more straightforward to extract a catalogue of the challenges faced by markets as elucidated in the various roadmaps. It is more challenging to arrive at a consensus on what should be done to meet these challenges. In order to bring some structure to our consideration of the wide range of measures that have been proposed, both in the roadmaps and beyond, the discussion will be divided between: (i) those measures intended to preserve and improve upon the market paradigm to which the EU is formally committed (most recently in the form of the Third Energy Package); and (ii) measures that effectively replace that market paradigm in the belief that it cannot or will not succeed in overcoming the challenges elucidated in the various roadmaps.

We have endeavored to present a comprehensive (but brief), objective overview of the issues arising regarding wholesale power markets in Europe. It is not our intention to steer the discussion toward one or another conclusion but rather to foster an open and inclusive debate about the full range of solutions that have been put forward by various stakeholders and experts.

1. Introduction

In Europe as in many regions, energy policy makers have determined that certain subsectors of the electricity industry are no longer natural monopolies. In simplest terms this means that welfare is maximized by having multiple competing suppliers rather than a single monopoly supplier. In reliance upon that determination, and in the belief that competitive markets are inherently more efficient and more innovative than central planning and regulation, governments have moved in the direction of substituting markets for central planning and regulation as the primary "software" that determines where, how and by whom electricity will be produced and sold and what price buyers will pay for it.[1]

At the same time governments retain an overarching interest in the co-equal triad of energy policy objectives – affordability (or competitiveness), security of supply, and environmental sustainability. While it is relatively easy to explain how the market virtues of efficiency and innovation can promote affordability, it is often less straightforward to explain how these virtues, in and of themselves, promote security of supply and environmental sustainability. The electricity industry is uniquely fraught with potential market failures (e.g., the difficulty in storing large quantities of electricity economically for long periods of time, or the lack of transparency between retail pricing and wholesale market conditions). There are numerous examples of centrally administered processes interjected into the electricity market in the belief that market outcomes need to be steered in the interest of one or more of these overarching objectives (feed-in tariffs and capacity markets are two examples). Competitive market tools (such as auctions) are sometimes employed to optimize the outcome of these processes, but that does not change the fact that a central administrator has in some way asserted control over the interaction between buyers and sellers of electricity. Each such intervention, however well justified, increases the risk of suboptimal outcomes and unintended consequences.

The central tension that emerges from the roadmaps, therefore, is between (i) the goal of improving the functioning of the market so that these commonly agreed objectives of energy policy are properly and fully valued in interactions between buyers and sellers, and (ii) the need to intervene administratively in the market out of a concern that it cannot or will not adequately promote one or more of these objectives.[2]

As was stated in a previous note, roadmaps are not predictions but rather ways of exploring the implications of different possible future pathways to the same ultimate objective. The first half of this note will consider what the various roadmaps have to say about the roles markets, and market interventions, are expected to play in shaping those possible future pathways.[3] The second half of the note will then put forward for

[1] These outcomes are also affected by central planning and regulatory processes deployed in the two subsectors that remain natural monopolies: transmission and distribution. These sectors have been treated in a previous seminar.
[2] "Intervention" is not meant here to refer to the types of regulation (of market power, e.g.) customarily considered necessary for markets to function properly; it refers rather to efforts to shape market outcomes in a certain direction.
[3] An especially prominent administrative intervention in the energy market is the Emissions Trading System ("ETS"), an attempt to correct an obvious market failure by internalizing the value of a market externality. The ETS was considered in a previous seminar; it is treated here as an integral market reality and will be addressed only to the extent that the fact of it affects consideration of future choices for market design and market intervention. Also, as discussed in the previous seminar, pre-commercialization support for technologies at the far right of marginal

discussion a non-exhaustive set of options for improving the chances that Europe's wholesale power market will deliver a secure, affordable and decarbonized power sector.

The list of roadmaps we will consider in this note is essentially the same as that enumerated in the briefing note prepared for the seminar on network infrastructure.

2. What the Roadmaps Expect of the Wholesale Market(s)

In broadest terms the operation of a wholesale market for electricity is no different from any other market: It is expected to achieve its objectives of maximizing economic efficiency and promoting innovation by operating across all time scales. It is expected to shape the decisions of buyers and sellers in the short term, and over the long term this is expected to shape resource development and investment decisions. For this to work as intended, essential conditions include transparency, liquidity and regulatory consistency, in both the short term and the long term.

The various roadmaps all acknowledge, to varying degrees, the central role markets and private sector capital are expected to play in Europe's power sector. At the same time, however, each of them also poses specific challenges to the wholesale power markets. This is in the nature of roadmaps – while markets are open-ended affairs roadmaps are employed with a stated destination in mind. In the case of the roadmaps we consider here, the destination they share in common challenges markets to (i) promote a pattern of resource investment that leads to a nearly zero carbon (or, in one case, carbon-neutral) power sector by 2050; and (ii) enable the power system to continue to deliver reliable and affordable electricity as it adapts to this new supply paradigm. The latter expectation (affordability and reliability) is one that clearly applies to market outcomes throughout the transition period to 2050. While the former expectation (decarbonization) is stated in the form of an end-point constraint in 2050 it is recognized in several of the roadmaps that the nature of the climate risks that motivate it also impose expectations on market outcomes throughout the intervening period.

These expectations give rise to a wide range of difficult issues associated with the design and operation of wholesale markets. This section will consider those issues in the context of each of the three fundamental objectives of energy policy against which the performance of wholesale markets will ultimately be measured – environmental sustainability, security of supply, and affordability.

2.1 Environmental Sustainability

As has already been stated, each of the three legs of the energy policy triad is of equal importance, and the performance of markets will be evaluated against all three. We will begin with environmental sustainability, and more specifically greenhouse gas abatement, since the primary motivation for creating the roadmaps was rooted in carbon abatement goals adopted in recent years.

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abatement cost curves is meant to bring their costs down in anticipation of the need to deploy them in the market at scale. As such, this type of support will not be considered here as a market intervention. That said, where one draws the line between pre-commercialization and commercial deployment is highly subjective, and such support still has real consequences for effective market operations.

A) An increased need for capital investment

All of the roadmaps recognize the relatively greater capital intensity of a low-carbon power system. The power sector is capital intensive by nature, and even the business-as-usual pathways projected in the roadmaps require very significant capital investment in order to meet acceptable security of supply standards over the same period. Yet in every case the need for capital is greater in the decarbonization pathways[4]. While increased investment in transmission is a key focus of the decarbonized pathways, transmission represents a relatively small share of the overall capital requirements.[5,6] And while transmission investments are entwined with market outcomes (both driving and driven by), transmission itself is expected to remain largely a state-owned or state-regulated monopoly. Thus new low-carbon supply represents both the largest quantum of investment in the decarbonization pathways as well as the investment category most directly reliant on the functioning of the competitive wholesale market. Should the competitive wholesale market paradigm adopted by the European Union be challenged in delivering sufficient and timely investment in long-lived assets under any scenario, that challenge would only be compounded in every decarbonization pathway described in the roadmaps.

B) The importance of energy efficiency to the feasibility of decarbonization

The higher capital needs identified in the roadmaps are based primarily on the greater capital intensity of low-carbon supply relative to the business-as-usual supply portfolios. Still, the need for capital could be even greater. The roadmaps describe in various ways the role electrification is expected to play in the abatement of greenhouse gas emissions in other sectors of the economy, though they take different views on how big that role will be. One consequence of this would be an increase in the demand for decarbonized power. In nearly all of the roadmaps this increase in power intensity is offset by a significant increase in energy efficiency, both in end use and in production and delivery[7].

The primary rationale for increased energy efficiency in the roadmaps is cost, and the role of energy efficiency in ensuring affordability will be addressed below. A second rationale, however, and one that is only lightly touched on in the roadmaps, is the challenge posed to decarbonization of electricity should the expected investments in

[4] According to COM Energy 2050 Roadmap, capita investment in the decarbonisation pathways range between €2.2 and €3.2trillion compared to €2.0trillion in non-decarbonisation scenario (Current Policy Initiatives scenario). The ECF Roadmap 2050 saw a doubling in annual capital expenditure up to 2025 to be required.

[5] ECF Power Perspectives 2030 suggests investments in transmission infrastructure to be less than 10% of overall capital investment costs in 2020 (€46bn versus €567bn overall) and 2030 (€68bn versus €1028bn overall).

[6] Several of the roadmaps allude to the potentially greater need for investment in the distribution system, particularly in pathways relying on large distributed resources. Good quantification of distribution investment needs is mostly lacking from the roadmaps, yet while it might eclipse investments in transmission it is still nearly certain that the largest need for capital under all pathways will be for new low-carbon supply. The COM Energy 2050 Roadmap suggests investments in distribution networks to be close to three times as high as investments in transmission (±€450bn in transmission versus ±€1500bn in distribution by 2050)

[7] ECF Roadmap 2050 suggests that ambitious energy efficiency measures can compensate for the increase in demand from electrification of transport and heat sectors (40% increase in electricity demand by 2050 in stead of 80% increase). The COM Energy 2050 Roadmap suggests an increasing role for electricity with a share of up to 40% of electricity in the energy sector by 2050 in the decarbonisation scenarios. Also in the CPI scenario, the role of electricity increases to almost 30%.

cost-effective efficiency measures not materialize[8]. Most of the decarbonized pathways show demand for electricity rising only to roughly the same level in 2050 as it reaches in the business-as-usual pathways and they assess the feasibility of supply options on that basis. Without significant improvements in energy efficiency, however, the demand for decarbonized power, driven by electrification in other sectors, could be considerably greater. The consequences for decarbonization include the need to access lesser quality renewable resources, greater pressure on land use for renewable production and increased pressure on supply chains and a need for faster technology commercialization in every low-carbon supply category, all of which would translate into disproportionately higher capital needs and greater risk of policy failure. In the second half of this briefing note we will consider whether and how wholesale markets can affect the rate of investment in energy efficiency. Failing to do so may well result in non-linear impacts on the feasibility of achieving the decarbonization objective and the ability to rely on competitive wholesale markets as the primary driver.

C) The role of disinvestment

The flip side of energy efficiency's role in decarbonization is the extent to which it slows the increase in demand and, thus, in demand for investment in new low-carbon sources of supply. The pace of decarbonization, and the pace of technological progress on which decarbonization relies in all pathways, depend on the rate at which carbon-intensive electricity production is replaced by increasingly carbon-free production. Yet the various roadmaps adopt different views on how that transition will occur.

At one end of the range are those roadmaps (e.g.: EGAF, "Making the green journey work", 2011) where abatement proceeds slowly at first and accelerates in the latter part of the period to 2050, resulting in a more gradual rate of disinvestment. These roadmaps tend to rely primarily or exclusively on the ETS to drive price formation and plant obsolescence. One consequence of this approach is to slow the rate of disinvestment and delay further (post-2020) commercialization of various renewables technologies into the latter half of the period when carbon prices will presumably be much higher. Such pathways imply a concentration of risk in one or two critical technology developments up to 2030 and possibly beyond. The European Gas Forum's roadmap, for instance, achieves long-term decarbonization and cost-effectiveness targets by relying on a rapid pace and large scale of gas-with-CCS commercialization by 2030.

At the other end of the range are those roadmaps (e.g.: ECF Power Perspectives 2030) in which not just the 2050 abatement objective but also interim abatement targets employed by the European Commission and some member state governments drive the pace of disinvestment.[9] These roadmaps place more emphasis on both the likelihood of achieving interim power sector abatement targets and on the expected cost and feasibility of continued abatement post-2030. This in turn implies the continued deployment of a portfolio of renewables beyond 2020 (in pursuit of ongoing improvements in cost and performance) accompanied by a commensurately faster rate of disinvestment. One consequence of this would be a greater diversification of technology and resource risk in the 2020-2030 period, with policy risk spread more evenly across nuclear, fossil-with-CCS and a portfolio of four to six leading renewable

[8] ECF Roadmap 2050 suggests that power demand without aggressive efficiency measures could double by 2050 increasing the challenge of meeting demand with zero-carbon power generation. ECF Power Perspectives suggests that more ambitious energy efficiency measures (0.3% increase of electricity per annum in stead of current 1.8%) reduce overall system costs by 30%.

[9] ECF's Roadmap 2050 report in particular presented an impartial analysis of pathways that span the full range of views described herein.

resource and technology options. Yet there is only limited consideration of exactly how this would happen. While some of the roadmaps specifically exclude "early retirement" in the construction of their pathways,[10] it is evident that there is at best a delicate balance between the rate of retirement of the existing high-carbon supply portfolio and the rate of zero-carbon deployment (and therefore technical progress) projected in these roadmaps. The implication in these roadmaps is that the ETS (or an improved ETS) will be sufficient to drive the required rate of retirement. Given the assumed rate of continued low-carbon resource deployment in these roadmaps versus the assumed rate of growth in demand this outcome is far from certain. The more aggressively cost-effective efficiency is exploited, the slower the growth in demand and the trickier this balance becomes. These roadmaps therefore present a challenge to the market in whether and how it will bring about this more rapid process of high-carbon disinvestment without some form(s) of administrative intervention.

D) Zero-marginal-cost resources in a marginal-price-driven energy market
It is widely expected, though not a given, that out-of-market subsidies or binding targets for the more mature zero-carbon generation options will be phased out at some point beyond 2020 leaving continued deployment to rely on the market. This assumption presents several challenges to decarbonization beyond the simple question of whether low-carbon supply is "competitive," some of which are considered in the roadmaps. One is the oft-cited "merit order effect" in which the addition of more and more zero-marginal-cost resources drives down the average marginal cost of resources on the system and therefore, it is suggested, the system marginal price. Should this be the case in the long term it would present a challenge to all resource investment but particularly to highly capital-intensive resources. A second issue is the impact of large shares of variable renewables on the volatility of system prices. While much higher volatility in prices would be a challenge to investment in general, it presents a specific challenge to investment in variable resources since lower prices would be expected to dominate at times of high variable production and higher prices would be expected to dominate when variable resources are not producing. (Some roadmap analyses – e.g., Power Perspectives 2030 and EC Energy 2050 Roadmap – contradict both of these issues as being necessary outcomes, though they acknowledge that they are at least possible.)

The roadmaps offer a very mixed picture of how continued investment in low carbon resources will play out in the market. In some cases it is explicitly assumed that commercial deployment of low-carbon resources post-2020 will rely entirely on the market (including carbon pricing). In these cases renewables deployment slows until much higher carbon prices materialize post-2030. The same should be true of other low-carbon supply options currently reliant upon support (primarily nuclear and CCS for fossil generation), but this does not come through in those roadmaps that favor this approach. In these roadmaps nuclear investment continues based particularly optimistic assumptions about its economics, while CCS commercialization is assumed to proceed apace though it is not clear how that would happen in the absence of out-of-market support.

In other roadmaps it is recognized that a lull in commercial deployment of low-carbon technologies would have adverse consequences for the long-term feasibility of decarbonization (as well as security of supply and cost). In the ECF Power Perspectives 2030 report the issue of technology S-curves is considered, raising the possibility that a lull in deployment may save cost in the short term but would cause renewable technology learning and supply chain development to atrophy. This would retard the commercialization of renewable technologies and, as a result, place the practical

[10] Amongst others: ECF Roadmap 2050, EC Energy 2050 Roadmap, EGAF 2011

timeline for power sector decarbonization at considerable risk. In these pathways it is assumed that deployment continues apace. The question of exactly what drives that continued deployment is only superficially considered in the roadmaps, but it is a central issue for any discussion of wholesale market.

E) The role of responsive demand
A common feature of all decarbonization pathways is the tension between the variability of some resources (such as wind) and the limits of flexibility in the balance of the supply portfolio. This manifests as a challenge in several ways, but the one that is relevant to the feasibility of achieving the decarbonization objective is the extent to which it constrains the economic deployment of certain zero-carbon supply options. One of the potential measures identified in most of the roadmaps for alleviating this constraint is to make demand far more responsive to uncontrollable changes in supply than has historically been the case. The goal would be to shift consumption of electricity from periods of supply shortage to periods of supply surplus, thus allowing more variable production to be utilized in an economic fashion. The roadmaps identify a number of ways this could be done technically and economically, but there is little or no discussion of the market barriers that have historically inhibited the response of demand to conditions in the wholesale power market. Responsive demand also has an important role to play in ensuring affordability, which is considered section 2.3 below.

2.2 Security of Supply

The second leg of the energy policy triad against which market performance will be measured is security of supply. Concerns identified in the roadmaps encompass a number of specific challenges. Because the most pressing market-relevant issues identified in the roadmaps pertain to the reliability dimension (and because electricity production is overwhelmingly a domestic European activity) this note will focus primarily on challenges both in defining and in delivering an acceptable standard of service reliability. That being said, the roadmaps also identify the potential for security of supply issues to arise due to a lack of diversification, increased (or decreased) import dependence, and technology failure. Of these, the diversification issue is most clearly relevant to the question of market outcomes and thus will also be briefly discussed here.

A) Variability as a challenge to reliable day-to-day operation of markets
All of the pathways in all of the roadmaps reach shares of variable renewable production at some point in the next 15-20 years at which the day-to-day functioning of the power grid will be fundamentally transformed from what it has been over the past century. The rate at which production from some renewable resources can change, combined with the frequency of such changes, can result in a significant increase in the demand for balancing services on the system relative to what most systems have experienced in the past. This may lead to a decrease in system stability and reliability if not addressed in some manner. While this challenge arises to some extent in most pathways analyzed, it is also apparent from some of the roadmaps that greater flexibility in the balance of system resources can significantly mitigate this issue (considered below). Several of the roadmaps also highlight the extent to which greater geographic and resource diversification, combined with more integrated market operations, can mitigate this issue.

Nonetheless, up to now variable renewable resources have been largely insulated from balancing market impacts, though standards have sometimes been used to require variable renewable technologies to mitigate system balancing issues. While there are good reasons for this – such as the desire to remove barriers to commercialization, and the fact that the aggregate impact on system balancing needs is typically far less than the sum of the impacts of individual installations – it can distort wholesale balancing markets in much the same way that out-of-market support schemes distort wholesale energy markets. The challenge facing any discussion of the role of markets going forward is the manner and timing of the integration of variable renewables into the wholesale balancing markets.

B) Variability and its impact on investment in resources for reliability

Much attention has been focused on the impact of increased shares of variable renewables on investment in the balance of system resources. This pertains both to retention of investment in existing resources as well as investment in new resources. The principal drivers of this concern were discussed in 2.1.D above. The more familiar reliability challenge this presents to markets is that of resource adequacy, i.e., whether or not there are sufficient reliable resources available to meet the maximum demand the system is expected to experience. There is a long-standing debate over whether competitive wholesale energy markets will of their own accord support timely and sufficient investment in firm resources, but the rise in variable production has reinvigorated that debate. The issue of regulatory risk (arising from ambiguity of market rules or from frequent and unexpected rules changes) is often cited as a primary barrier to investment in the liberalized market, and in reflecting on the roadmaps one could conclude that in many of the decarbonized pathways the risk of regulatory and policy uncertainty will only be magnified. Some of the roadmaps offer analysis suggesting that in the medium to long term a properly functioning energy market with high shares of variable production will produce average prices and a level of price volatility that will be adequate to support the needed investment. Other roadmaps take the view that average prices will follow the reduction in average marginal cost and, combined with higher volatility, will undermine needed investment.

While the resource adequacy conundrum is one that markets must be capable of addressing in any case, the rising share of variable production means that markets face an additional challenge when it comes to resource investment. As noted above, the longer-term implication of the increase in variable supply in all of the pathways is the value of investment in greater resource flexibility. Possible sources of resource flexibility identified in the roadmaps include more flexible conventional supply (including fuel supply flexibility), more responsive demand, and energy storage. This is to a great extent a question of affordability (considered below), but it is also a reliability challenge, since a failure to invest in cost-effective means to increase system flexibility is likely to lead to a marked decrease in system stability. The question facing markets, therefore, is not just whether or not they can deliver the quantity of investment needed to meet security of supply expectations, but also whether or not they can properly value the reliability benefits from investments in more flexible resources (and conversely, the reliability penalties associated with investments in less flexible resources).

C) The importance of cross-border resource optimization

Several of the roadmaps rely on the presumption that resources will be deployed to meet system needs in the most effective manner regardless of their location. In other words, they assume that the only constraints on resource deployment are physical limits. Clearly this is not reflective of the way resources are deployed across the European grid today. Political borders constrain resource deployment even in the absence of physical constraints due to scheduling and dispatch rules designed for an era where supply was overwhelmingly dispatchable and relatively proximate to demand. While these rules have in the past resulted in what was considered to be an acceptable degree of inefficiency in the use of system resources, the rising share of variable production increases the scheduling and dispatch demands on system operators in a given control area. There are clear reliability benefits to increasing the size of control areas and improving system operators' access to interconnection capacity between control areas and the resources to which they connect. An important question arising from the roadmaps is therefore how the market can more closely approximate the "perfect" effectiveness of resource deployment and utilization across Europe that is implicitly or explicitly assumed to be the case.

Cross-border issues arise in the roadmaps on a separate dimension of security supply – the question of whether security is measured at the European level or member-state-by-member-state. All of the pathways rely on a significant increase in renewable supply, which challenges a fragmented view of European security of supply in two ways. First, primary renewable resources and feasible siting opportunities are not evenly distributed across Europe and the most efficient distribution of development may conflict with individual member states' views on "import dependency." Second, because any given member state's domestic variable renewable resources, no matter how "secure" on the basis of installed capacity, will ebb and flow with time any member state that is self-sufficient on paper may be a net importer of energy in one hour and a net exporter of power the next. An integrated European wholesale power market would seem well placed to sort these issues out, assuming it is allowed to do so.

D) The value of diversification to security of supply

Diversification of types and sources of resources has long been a central tenet of energy security. How markets can and will properly value diversification is a critical question for markets under any circumstances, but the decarbonization objective at the heart of the roadmaps introduces new security of supply risk categories that place an even higher premium on diversification. These risks include technology commercialization, technology deployment, and the risk of over-dependence on a limited number of lower-carbon fossil fuel sources. These various risks converge to create the risk of creating path dependency in the early phases of the decarbonization process – what appears to be a low-risk pathway today may over the course of the transition turn out to be high risk. The roadmaps present a range of pathways, each of which features market outcomes with a different embedded security of supply risk profile. Those pathways that minimize technology commercialization risk and cost in the early years exhibit high risks associated with fuel concentration, technology deployment and path dependency. Those pathways that emphasize technology commercialization in the early years present a different risk profile. Several of the roadmaps highlight the seemingly obvious conclusion that the lowest risk pathways (for both security of supply and for decarbonization) are those that achieve the greatest diversification of risks at every stage of the transition. It is less obvious how the wholesale power market, left to its own devices, would produce such an outcome.

2.3 Affordability

The final priority in the energy policy triad that markets must satisfy is affordability. Most would agree that while decarbonization and reliability are high priorities they are not goals to be met at any price. At the same time, in a well-functioning market price is inversely correlated to risk, and our desire to pay less is constrained by our appetite for risk when it comes to supply insecurity and environmental degradation. What price is worth paying, how that is determined and who determines it are all extremely important and difficult questions for markets, but these basic principals would not be much in dispute.

Affordability is probably the most subjective and hardest to quantify of the three criteria. While it is often interpreted in terms of the price paid by consumers it is rarely that simple, since the energy price paid directly by consumers often obscures the actual cost incurred by citizens and industry. And what constitutes "affordable" can be assessed in many ways, for instance in a utilitarian fashion – the balance of cost and risk that creates the greatest good for the greatest number – or in a more egalitarian fashion – the balance of cost and risk that minimizes the burden on the most vulnerable populations. To make the problem tractable the roadmaps all evaluate the pathways in terms of their total direct cost. Some of them stress-test pathways for certain risks (e.g., ECF's Roadmap 2050, §6.5), but a more robust discussion of the relationship between total cost and affordability takes place in only a cursory fashion.[11]

Unfortunately for the topic at hand, we must pick up where the roadmaps leave off. While total cost is the only common ground on which the pathways can be compared, the question of how cost and risk relate to price goes to the heart of the challenge in designing and operating markets. Markets, and interventions in the markets, will play a central role in driving what path we take regardless of relative attractiveness of the underlying cost and associated risks. It is easy to say that a well-functioning market would by definition seek the optimum balance between cost and risk, but we must live in the real world, and in the real world the energy sector in general, and the electricity sector in particular is rife with possible reasons why that may not be the case. In considering market design options against the criterion of affordability we must therefore consider the possibility that market failures will frustrate the motivating urge to achieve the optimal balance between cost and risk; in considering market interventions we must consider the possibility that the market, even with all of its imperfections, would have ultimately produced a more beneficial tradeoff between cost and risk if only it were given a genuine opportunity to do so. As will become apparent, many of the challenges facing markets in delivering decarbonization and security of supply are also – in some cases are predominantly – issues affecting affordability.

A) The conditions for markets to deliver economic efficiency

More so than with either of the other two legs of the energy policy triad the desire for affordability (or competitiveness) lays at the heart of the decision to rely on competitive wholesale markets. In order for markets to fulfill this expectation certain conditions must apply. The economic impact of individual choices should be transparent to buyers and sellers, both in the short term as well as far enough into the future to inform investment decisions. Enough of what is bought and sold should be contestable so that entry into and exit from the market by investors is sufficient to ensure effective competition. And the rules by which market participants play in the market should remain stable or evolve in a consistent fashion over time. As we consider changes to or interventions in the wholesale market, the extent to which the market can actually deliver affordable and competitive outcomes will be dependent on the extent to which they promote or obstruct progress toward these criteria.

B) The value of diversification as a cost-control measure

As with security of supply, what appears to be a low-cost pathway in the short term may well turn out to be a very costly pathway. The sequencing of deployment of various categories of resources and its potential impact on the cost of the transition is an issue that arises repeatedly in the roadmaps. Switching from coal to gas is identified as a

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[11] "Because the average costs of the decarbonized pathways over 40 years differ from the baseline cost by less than 15%, other factors, like risk tolerance, …become more important in planning for and implementing a decarbonized power system." *Roadmap 2050: A practical guide to a prosperous, low-carbon Europe", European Climate Foundation, 2010.*

source of added system flexibility and low-cost carbon abatement over the near to medium term but it could delay the commercialization of renewables by a decade or more and its long term viability and cost are contingent on resource depletion rates and large-scale commercialization of CCS technology. Alternatively, full commercialization of a suite of renewables technologies is identified as indispensible to a cost-effective transition in the medium to long term but the near term direct and indirect costs and risks of continued commercialization support beyond 2020 may be higher than alternative pathways. This whole issue of the cost and risk effects over time of various technology and resource deployment pathways presents a critical challenge to the long-term effectiveness of wholesale power markets.

C) The cost of market fragmentation

Cross-border resource optimization is identified as a security of supply issue. While this is certainly the case, most of the roadmaps conclude that reliability can be maintained by building more back-up generation and transmission and incurring higher rates of curtailment of zero-marginal-cost production. In other words, the fragmentation of the European power market is primarily a challenge to the affordability of power sector decarbonization.

Market fragmentation is also seen to have an adverse impact on the cost of expanding the share of production from renewable resources, though the estimated size of that impact varies among the roadmaps. As the targeted share increases there is a cost to inhibiting the option to access production from the highest quality resources wherever they might be.[12] To date member states have variously chosen to emphasize domestic control over electricity supply, parochial industrial policy and the desire to promote small-scale distributed production over the opportunity to optimize the cost of meeting targets. It is impossible to say for sure how that calculus might shift over time. Given the much more significant level of market penetration expected to be at issue post-2020, however, any market reform discussion intended to address post-2020 renewables deployment should consider carefully the cost of continuing to accommodate parochial member state energy and industrial policies.

D) The value of accessing cost-effective demand-side resources

As with market fragmentation, the opportunity to access demand-side resources has been noted as an issue for sustainability and security of supply but in the end it is primarily a question of affordability. "Demand-side resources" is here meant to refer to both energy efficiency and demand response.

The impact of energy efficiency on the scale and feasibility of decarbonization has already been noted, but the primacy of the cost dimension was also acknowledged. Much of the challenge facing greater investment in cost-effective energy efficiency is beyond the reach of wholesale power market design, however as has been seen in markets in North America there are opportunities to capture some portion of the energy efficiency potential through the design of capacity investment mechanisms.

Several of the roadmaps strongly endorse the cost benefits of making demand more responsive to changing conditions in the wholesale power system than is the case today. As with energy efficiency, some of the issues in expanding its role pertain to retail pricing policies (e.g., time-of-use rates or real-time pricing) and are therefore beyond a

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[12] In the pathways with the highest shares of renewables this issue attenuates over time since in many member states the practical limits on domestic renewable production are well below the level of penetration achieved. Also, while there are cross-border options in the existing legislation they are burdensome and have not been widely exploited.

discussion of wholesale market design. However because demand response has the potential to be as valuable to system operators as it is to end-use customers there is a commercial rationale to designing wholesale market instruments that would bridge the gap between retail pricing effects and the long-term system value of investments that would allow demand to be dispatched in response to uncontrollable changes in supply. There is also reason to expect that there are reliability and cost benefits to be had from enabling price-responsive customers and aggregations of customers to participate in the day-ahead and intra-day energy markets.

E) Investments for reliability
The potential effect of decarbonization on resource adequacy was already discussed in 2.2.B above. While this is primarily a security of supply concern the roadmaps point to an emerging dimension of reliability in the decarbonization pathways that has potentially significant cost implications. As noted in 2.2 above the rising shares of variable production drive a marked increase in the demand for balancing services compared to what most system operators have historically experienced. Regardless of how the debate over resource adequacy is resolved, one seemingly clear conclusion from some of the roadmaps is that a failure to increase the overall flexibility of the wholesale system will result in the need for higher costs in the form of a need for more backup generation, more transmission capacity, and higher levels of curtailment of zero-marginal-cost production. An emerging challenge for the wholesale market, therefore, is to illuminate more clearly how much flexibility is worth and to enable the broadest possible range of resources capable of providing it. These include flexible generation, responsive demand, end-use thermal energy storage strategies and grid-scale energy storage.

3. How Can Markets Deliver on Expectations?

As the foregoing review of the messages from the various energy roadmaps makes clear, the wide range of feasible power sector decarbonization pathways present a complex set of challenges to the European commitment to competitive wholesale electricity markets. This section will posit for discussion a set of options for how the design and operation of the wholesale markets might be improved, supplemented or overhauled in order to meet these challenges.[13]

The options presented here will be organized into three categories:

1) Toward a more effective implementation of markets – measures to improve the effectiveness of current wholesale market operations. This includes measures to enlist the buyer side of the market more fully in future market outcomes, a topic that almost warrants its own category.
2) Selective intervention – measures designed to address specific potential market failures such as weak investment signals, political/regulatory hazard, or barriers to commercial deployment of cost-effective resources.
3) Radical surgery – fundamental revisions to the current wholesale power market paradigm.

These categories point to two overarching questions posed to wholesale electricity markets by the challenges identified in the previous section:

[13] A detailed and comprehensive description of the measures referenced herein, along with the many variations that have been proposed, is well beyond the scope of this briefing note. We will instead provide a cursory description of some of the more commonly cited options.

- How can markets be made to function more effectively as intended in order to meet these challenges? The first two categories above respond to this question.
- Is the current market paradigm simply unfit for purpose under the most likely set of decarbonization pathways and, if so, how should it be reconsidered in order to address these challenges? The third category above responds to this question.

3.1 Toward More Effective Market Operations

Even the most ardent advocates of competitive markets would likely agree that the wholesale power market could never expect to be entirely independent of government and regulatory administration. With that said, proponents can point to a number of areas where the reality of implementation currently fails to match what is necessary or optimal for the market to function as intended. Fix these problems, in this view, and the market (including the internalization of the cost of greenhouse gas emissions via the ETS)[14] will most efficiently deliver a power sector that supports the EU's stated carbon abatement goals with the level of security desired by European consumers and at a price they are willing to pay.

Whether or not one endorses such a purist viewpoint, many would agree there are a number of measures that could enable Europe's wholesale power markets to accomplish the tasks that have been set for them far more effectively than is the case today. Broadly speaking, these measures would improve transparency, increase liquidity, ensure full and effective competition, reduce regulatory risk and remove artificial cross-border barriers to efficient utilization of the synchronized European power grid.

A) Consolidate larger control areas
A number of recent studies of power systems with large shares of variable renewables have illuminated the economic and reliability benefits of operating as a single market over a large geographic area.[15] Indeed most of the roadmaps rely, at least implicitly, on an assumption that this is effectively the case. The benefits include: better utilization of existing transmission infrastructure; an aggregate reduction in intermittency of supply; less variability in aggregate demand; real-time access to a wider pool of operating and contingency reserves; a reduction in the need for investment in backup generating capacity; greater liquidity; less price volatility; more competition; and higher rates of utilization of investments in variable resources. Where system operation has been vested in an independently chartered body, as is the case with regional independent system operators in most North American markets, market governance can be more stable and transparent creating a more attractive investment environment.

This is not yet the reality of the European power market. With the exception of Nordpool "the market" is actually a collection of separate member-state-based control

[14] As noted in several of the roadmaps' discussion of markets, the ETS currently falls well short of the carbon market implicit in this view. The ETS was covered in the previous seminar. Issues relevant here include the fact that the ETS covers only part of the European economy and does not include some of the sectors with the greatest abatement potential, or the fact that the trajectory of the cap even in the covered sectors supports neither the 2050 goal of an 80-95% reduction nor the interim abatement imperatives identified by climate science and recognized by the European Commission and several member states.
[15] ECF Power Perspectives 2030 suggests that a pan-European approach with optimal cross-border cooperation could reduce overall system costs with up to 11%.

areas.[16] While steps toward such a structure can be seen in the Target Model that is intended to be the basis for implementing the Internal Electricity Market (discussed below), the European Union cannot force member states to take the process to its logical conclusion. This can only be achieved through a bottom-up process driven by the member states themselves. While there are signs of progress in this direction (e.g., the North Seas Countries Offshore Grid Initiative) parochial national energy politics, including a chauvinistic approach to energy security, represent a significant hurdle in most countries.

B) Implement the IEM and the Target Model; improve the Target Model?

The EU has mandated the completion of an internal market for cross-border trade in electricity (commonly referred to as the Internal Electricity Market or "IEM"). While this falls short of creating a single European electricity market, or a series of regional markets covering multiple member states, it does require member states to open their electricity markets to cross-border trade and imposes a set of requirements on that cross-border trade.

In order to provide a blueprint for regional market integration, ENTSO-E is engaged in the drafting and implementation of network codes in accordance with framework guidelines drawn up by ACER that would harmonize the rules for cross-border trade. These framework guidelines and network codes together will constitute the Target Model for regional electricity market integration.

If properly designed and implemented the Target Model has the potential to deliver many, though not all of the benefits of a true single market such as those enumerated in 3.1.A above. For this reason it carries important implications for the effectiveness of the wholesale power market in delivering the decarbonization pathways described in the roadmaps in a reliable and economic fashion, even though decarbonization of the power sector was not stated to be one of the primary objectives of the Directive. If implemented successfully it may provide the groundwork for the eventual creation of true regional electricity markets with closely coordinated (or merged) multi-member-state market governance and regulation.

Proper design and implementation of the Target Model, however, faces many similar hurdles to those facing consolidation of market control areas, since a truly effective Target Model would impose a number of comparable obligations on member state electricity markets (e.g., locational price signals, dynamic transmission capacity allocation and congestion management, and harmonization of rules governing energy and balancing markets). For this reason progress has been uneven and there is significant risk that the rules, when finally written, will fail to deliver the level of benefits anticipated.

C) Upgrade system operations

An implicit assumption embedded in many of the roadmaps is that the day-to-day operation of the wholesale market will adapt to the operational characteristics of the evolving supply portfolio. As with consolidation of market areas, a number of recent studies have shown that certain upgrades to system operations would pay significant economic and reliability benefits to power systems with high shares of variable renewables.[17] In essence, many of the issues arising today as the share of variable

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[16] Luxembourg is split between the German and Belgian control areas because of its size; Denmark is split between the German and Nordic control areas because of its geography.

[17] Perez-Arriaga, I., Batlle, C., *Impacts of intermittent renewables on electricity generation system operation* , Jan. 2012

production grows in some markets can be traced to this failure to upgrade system operations as appropriate to this new supply paradigm. Two of the more beneficial upgrades are (i) shorter and more frequent scheduling of system resources, and (ii) improved weather forecasting (related both to demand and to variable production) and scheduling algorithms.

In one sense (relating to cross-border coordination) the scheduling issue may be addressed in the implementation of the Target Model, but the specific issue of shortening scheduling intervals is uniquely beneficial to decarbonized pathways with high shares of variable renewables. Improvements in forecasting and scheduling algorithms are unlikely to be taken up in the implementation of the Target Model because they are of value specifically in decarbonization pathways. As shown in a number of studies[18] centralizing weather forecasting, adopting better forecasting methodologies and updating forecasts more frequently in concert with scheduling intervals can significantly mitigate the cost and reliability of integrating variable production. Taking this a step farther, growth in distributed variable renewables would be facilitated by updating on a regular basis the scheduling algorithms used by system operators to estimate demand day-ahead and within-day.

D) Ensure full and effective competition to mitigate market power

Scale and capital intensity are inherent barriers to greater competition in the wholesale electricity market, but it is also the very scale of the capital investment needs arising in the roadmaps that, *inter alia,* gives such urgency to the need to facilitate entry into the market by new investors and technologies, including investment at very small scale in distributed low-carbon production. As noted earlier, consolidation of larger control areas can contribute to the increased liquidity needed for this to happen, as can the provisions of the Target Model supporting unencumbered grid access.

In the end, however, there is no substitute for aggressive regulatory oversight and enforcement of the competitive landscape. It is primarily the suspicion (perhaps in some cases the fact) of market power exercised by a small number of producers that drives the tendency to impose caps on wholesale power prices that in many cases are too low to allow the legitimate scarcity pricing essential to the operation of a competitive wholesale energy market. Partly as a result self-supply arrangements by a few large retail suppliers have come to dominate many markets. This in turn reduces liquidity and inhibits new entry.

The establishment of independent member state regulators has been a central objective of European market liberalization, as has the establishment of a stronger European regulatory body (ACER). In reality the effectiveness of member state regulators in ensuring sufficient liquidity and competition has been uneven and constrained by limited resources, and the scope and authority of ACER's remit remain limited. As a result market liquidity is extremely limited in many markets. The blunt instrument of wholesale price caps to mitigate market power is inevitably subject to political manipulation, causing uncertainty and undermining investor confidence. If market liberalization in general is to succeed, but in particular if the market is ultimately expected to be the primary driver of the decarbonization pathways, stronger regional or pan-European bodies for competition oversight and enforcement will be required.

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[18] Lew et al. 2011, The Value of Wind Power Forecasting

E) Aggressively enable participation by end-users in market outcomes

One of the most commonly cited challenges facing the effectiveness of wholesale electricity markets is the passivity of demand. In the absence of real-time price information and the hard and soft infrastructure necessary to enable consumers or aggregators of consumers to act effectively on that information, demand is largely passive in the face of changing conditions in the wholesale power system with the exception of a few large industrial consumers. In most cases the only practical "demand response" to short-term scarcity is involuntary load reduction (i.e., blackouts), and there is little practical incentive or opportunity for most consumers to respond to short-term surplus. In the longer term there are multiple market failures that mute the response of consumers to increases in average wholesale prices (driven by the need for new investment or a rise in input costs) by investing in cost-effective end-use efficiency measures.[19] The overwhelming reliance on fully dispatchable thermal generating resources and decades of government policy in the electricity sector has encouraged this inelasticity of demand.

Demand response ("DR") can participate in market outcomes in at least two ways. First, price-responsive demand (or more likely aggregations of remotely activated responsive demand) can bid into day-ahead and intra-day energy markets. This would not only enable system operators to better cope with uncontrollable changes in supply but will encourage a more economic and equitable determination of what the traditional notion of service reliability is actually worth to different types of consumers. Second, DR can bid into balancing services markets. The direct benefits to the average consumer from doing so are less obvious than in the case of energy markets, however the benefits to system operators are potentially significant and DR providers can be compensated for that value in the same way as are supply-side providers of such services.

Several of the roadmaps illuminate the costs and risks of failing to address this issue. Beyond its impact on growth in peak demand and total demand, the stubborn inelasticity of demand complicates the task of reliably and affordably integrating larger shares of low-carbon supply resources. Bi-directional demand response (increasing purchases electricity during periods of surplus – and perhaps storing it as thermal potential or in EV batteries – and reducing purchases during periods of scarcity – including the use of energy converted and stored earlier to provide the related energy services) has the potential to be one of the lowest cost sources of flexibility available to system operators.

As with new supply-side resources considerable investment is required to access the greater proportion of this demand-side potential, and as with supply-side options it is possible that administrative intervention will be required to overcome market barriers to such investment. These issues will be addressed in section 3.2.

3.2 Selective Intervention

All of the roadmaps acknowledge to varying degrees a central role for markets in the future of the power sector. In the face of the substantial challenges facing the markets, however, nearly all of them end up embracing some form of direct administrative

[19] The focus of this note is on wholesale power markets. For this reason measures at the retail level to remove barriers to investment in cost-effective end-use efficiency will be left for discussion in other forums. There are measures that can be employed at the wholesale level and these will be considered in section 3.2 below.

intervention in one or more dimensions of the market, some more grudgingly than others. In nearly every case these are justified (explicitly or implicitly) on the basis of a perceived market failure.

A) Forward market mechanisms to encourage needed investment
Much has been said and written about whether energy-only wholesale power markets can attract a sufficient amount of investment in a timely manner to ensure an acceptable standard of supply security. That is not a debate that is unique to the decarbonization pathways described in the roadmaps. Nonetheless, the roadmaps point to two aspects of decarbonization pathways that change the complexion of the debate. The first is the variability of a considerable portion of the likely low-carbon supply options identified in all the roadmaps. This raises the question of the impact that variability may have on the clarity and volatility of the price signals available to investors from the energy and balancing services markets. The second aspect is the very low marginal cost, very capital-intensive nature of most of the likely low-carbon resources identified in the roadmaps. This raises the question of whether the marginal clearing price will remain high enough for enough hours of the year to support the long-term marginal cost of the resources required for a decarbonized power sector.

Several roadmaps endorse the view that the energy-only wholesale market is fully capable of supporting the needed investment even in the decarbonized pathways. Others take the view that the nature of the decarbonization pathways is such that centrally administered mechanisms are required to provide clearer, longer-term, more stable investment signals to investors. The theory is that these mechanisms can be constructed in such a way that the economic efficiency of the wholesale market will be preserved. The value of energy would continue to drive investment, but a portion of the revenues system resources would otherwise have expected to receive from the sale of energy will be replaced by a comparable revenue stream from another source. The most common substitute revenue source is from the forward sale of firm capacity, based either on a central clearing auction or on an obligation imposed on retail energy providers to commit forward to the resources required to meet their reliability obligations. An alternative to this is the forward sale of non-energy services required by the system operator and retail energy providers to balance supply and demand reliably. These two options are not mutually exclusive.

In considering the design of such mechanisms the roadmaps as well as experience in other regions highlight several two important issues to be addressed in any decarbonization pathway. First is the value of ensuring that all qualified energy efficiency and demand response resources can compete on an equal footing. Second is ensuring that need for and value of investments in greater resource flexibility is fully reflected in the design of these mechanisms, Flexibility in the mechanisms themselves is equally important, as the administratively developed forward views of demand and related sources of distributed supply upon which these mechanisms rely are far more vulnerable to unforeseen advances in information and communication technologies than has ever been the case in the history of the electricity industry.

B) Technology/resource deployment support mechanisms
As mentioned earlier it is not the intention to debate here the justification for pre-commercial technology support, including early deployment support. This issue was discussed at some length in the previous seminar. There remains, however, the question of whether or not commercialized and otherwise competitive low-carbon resources will nonetheless continue to require some alternative means of participating in the wholesale market. One category of reasons offered is that there are intractable inequities in areas such as grid access and in the allocation of system balancing costs.

Another is that variable resources operating purely on the basis of spot energy prices would incur prohibitive revenue volatility and a perpetual price bias (because of the impact of their operating profile on the price levels available at the times when their energy sales are highest). EWEA, for instance, has recently taken the position[20] that it will take longer to sort out the inadequacies of the current market design than it will for wind power to become competitive with other sources and therefore binding targets or other forms of deployment support will continue to be warranted for some period beyond 2020. Others[21] have proposed that variable resources participating in the market without out-of-market support have the option to be paid for their energy based on average wholesale prices over a given period or in some other manner that redresses what is seen as a structural disadvantage for variable resources in an energy-based market.

In considering selective interventions it is also worth considering areas where market-based decarbonization of the power sector might benefit from the modification or withdrawal of existing, otherwise well-intentioned interventions. Two examples of this are prohibitions on the burning of oil in combustion turbines and the forced decommissioning of older non-retrofitted solid fuel plants under the Large Combustion Plant Directive. In the case of combustion turbines the limited ability to switch from natural gas to on-site stores of low-sulfur oil would greatly relieve the multiple hurdles facing expansion of gas transportation and storage infrastructure as would be needed to support a gas-only strategy for combustion turbine backup generation. In the case of older coal plants slated for retirement under the LCPD it is worth giving serious consideration to selective exemptions to plants willing to survive as very deep backup resources. These exemptions could take the form of one-time options, with a no-return condition, to be paid a modest but adequate fee to remain operational (including an on-site inventory of fuel), with severe restrictions on operating hours, to provide backup for those rare but expected longer-term meteorological events that can leave the system short of energy.

C) Mechanisms to reinforce the internalization of climate externalities

Carbon pricing was addressed in a previous seminar and as noted has been assumed to be an embedded feature of the competitive wholesale market. Some have proposed interventions specific to the power market, however, driven by a concern that (i) even the signals from a well-designed carbon market will be insufficiently clear and compelling to discourage investments likely to become unsustainable within their economic lifetimes; (ii) cross-sectoral abatement opportunities relying on a more rapid decarbonization of power cannot or will not materialize simply by relying on the ETS as it has been or will be implemented; or (iii) the nature of the way the power market operates means that the most economically efficient way to decarbonize the sector is not to rely exclusively on a carbon price built into the marginal cost of carbon-based resources but rather to supplement carbon pricing with performance standards.[22] The most common form of such an intervention is to introduce emission performance standards, such as a limit on grams of carbon per kWh generated, gradually over a specified period of time.

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[20] "Creating the Internal Energy Market in Europe", EWEA, September 2012

[21] Perez-Arriaga, I., Batlle, C., Florence School of Regulation, *Impacts of intermittent renewables on electricity generation system operation* , Jan. 2012

[22] Hausman et al., Synapse Energy Economics, *Productive and Unproductive Costs of CO2 Cap-and-Trade: Impacts on Electricity Consumers and Producers*, 15 July 2009

3.3 Radical Surgery

At some point the imposition of centrally administered measures into the wholesale market becomes so pervasive as to fundamentally undermine the rationale for adopting the competitive wholesale electricity market paradigm in the first place. Looking beyond the current suite of roadmaps, there are some who conclude that the current market paradigm, centered as it is on markets for energy and balancing services as the primary driver of both short-term resource deployment and long-term resource investment, is simply not fit for purpose. In this view it is not possible (or, given the complexity involved, not practical or efficient) to sustain the business case for investments needed to satisfy simultaneously the objectives of decarbonization, supply security and affordability on the marginal clearing price of the marginal resource on the system, particularly in those pathways with very large shares of variable, zero-marginal-cost supply resources. For these market observers only a radical re-thinking of the market paradigm will suffice. Two alternatives are briefly summarized here.

A) Switch from an energy-based market to a capacity-based market

Many experts and stakeholders would prefer to preserve the discipline of markets to the greatest extent possible while looking for alternative paradigms to drive the market along decarbonization pathways. The model most often cited for doing so is the Brazilian market model. A full description of a Brazilian-style market paradigm is beyond the scope of this paper (see, e.g., Nivalde et al., *Market design for electrical systems where renewables are a growing presence,* May 2011). In essence this model takes the forward capacity markets discussed above a step beyond to where the value of a resource is no longer based on the value of the energy it produces. Instead it is based on the long-term value of productive capacity as determined by an auction process driven by administrative assessments of the resource requirements of competitive retail suppliers. The marginal cost of production is reimbursed as a cost of doing business. The attraction of this model is not so much in its ability to drive economic and reliable decarbonization (indeed it faces many of the same challenges as does an energy market in doing so) but rather in its ability to sustain adequate levels of investment in a power sector that has been largely or fully decarbonized.

B) Return to centrally administered integrated resource planning

All of the roadmaps examined here accept competitive markets as the principle (though not the exclusive) driver of investment in and operation of the European power sector. This is not surprising since this has been the accepted basis for and trajectory of energy policy in Europe for several decades. Nonetheless there are those who see decarbonized, reliable and affordable electricity as an indispensible *commodity* for a sustainable modern economy and one that is too important to be left to the whims of a competitive market. For these stakeholders the only answer is to return to a centrally planned electricity sector. In this view the role of market forces is limited to determining the lowest cost provider of products and services specified through a long-term integrated resource planning process. This approach is sometimes advocated on the basis that it is ultimately the most economically efficient way to deliver reliable electricity to consumers. For the purposes of this discussion we will take the position that this is not a compelling rationale. However in the context of the decarbonization roadmaps there is an argument to be made it is ultimately the most efficient way to deliver *decarbonized*, reliable electricity to consumers.

4. Conclusion

Europe is committed to the implementation of a competitive internal market for electricity, a policy trajectory that has evolved over decades on the basis of a vast body of work by an army of competent and diligent experts and administrators. Now comes a new imperative for policy in the electricity sector – the abatement of carbon emissions in line with broader European climate policy. We have attempted here to survey the main themes posed by various recent energy and decarbonization roadmaps with respect to the role wholesale electricity markets can and should play in delivering a decarbonized power sector. It would be impossible in a 20-page note to comprehensively describe all of the challenges markets face and all of the potential measures proposed by various stakeholders to surmount those challenges. If we have failed to touch on a critical issue or a potential solution that should have been addressed here we welcome critical input. It is also difficult to construct such a note without betraying bias, or conversely trying so hard not to do so that a bias emerges in the other direction. If we have failed in our effort to avoid either of these pitfalls, we welcome critical comments to that effect. We look forward to a productive discussion.