Achieving energy transitions: Which RES policies are best applied when?

Reducing risk and creating an enabling environment

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Abstract

The transition to a sustainable energy system is desired by many countries around the world. Financial support for the deployment of renewable energy technologies is the choice of policy in most countries. We argue, drawing from transition theory and the multi-level perspective, that an energy transition evolves in two phases: A first phase with a focus on growth of the niche, in which renewables are protected through support policies; and a second phase with a focus on integrating the niche technologies into the regime, once they have become more mature and the market share has reached a significant level. We show, using policy analysis and socioeconomic considerations including uncertainty, that in the first phase, it is beneficial to focus on establishing support policy instruments which reduce risk for investors (such as feed-in tariffs). This will lead to faster and less costly renewable deployment, and will increase the likelihood of achieving a successful transition into the second phase, where policy focus should be on creating an enabling environment (including e.g. infrastructure, market rules, standards, coordinated support of related niches), in order to embed the new technologies fully into the more and more sustainable regime.

Keywords: energy transition; renewable energy; support policy; innovation systems; enabling environment;

1 Introduction

A grand challenge of our age is to transform our global society from one which is dependent on fossils fuels to one which is sustainable and equitable. The transition of the energy system towards sustainability is thus targeted by many policy makers and members of society in many countries throughout the world. Changes in the energy system are ubiquitous, and at any point in time one can talk about an ongoing transition. A transition towards sustainability though generally requires policy intervention, because the new technologies that are desired to form the basis of a new, sustainable energy system (including technologies using renewable energy sources (RES), energy efficiency and demand management appliances) face various barriers to implementation. Therefore, we investigate *managed transitions*, in which policy makers determine targets and timelines for the transition, and actively intervene with certain policies in order to trigger deployment of desired technologies.

In the spirit of Cropper and Oates (1992), who find that "policy structure and analysis is a good deal more complicated than the usual textbooks would suggest", we propose an approach to policy evaluation that goes beyond the 'standard' approach, in which cost-benefit analysis is used to evaluate policies. Using transition theory, we broaden the evaluation perspective to also take into account dynamic processes and related market imperfections. The insight that policies not only have to be effective and efficient in a static sense, but that they also need to deal with long-term normative goals for systemic change, has recently entered innovation systems thinking and policy making (Weber and Rohracher, 2012). Taking this perspective, the question 'which policy is better' cannot be answered anymore – it should rather be 'what policy specifications and combinations are better to achieve which

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targets at what times'? We argue that for a successful energy transition, policies need to be successful not only in achieving low cost deployment of the new technology at micro level, but also in triggering changes of the existing socio-technical system at a macro level. As discussed by Weber and Rohracher (2012), the capability of policies to initiate larger changes in the system is important for a successful transition to a fully sustainable energy system.

This paper draws from two lines of research. First, literature on transition theory, strategic niche management and innovation systems serves as the general frame for our analysis (Rip and Kemp, 1998; Kemp et al., 2001; Smith and Raven, 2012; Meadowcroft, 2009; Verbong and Geels, 2010; Pollitt, 2012; Markard et al., 2012). Second, literature on the assessment of different policy instruments helps us to support our economic argumentation (Weitzman, 1974; Cropper and Oates, 1992; Just et al., 2004; Menanteau et al., 2003; Miller et al., 2013).

Miller et al. (2013) differentiate between 'first-generation' and 'next-generation' drivers for policy in an energy transition. They predict that policies will evolve from being focused on maximum deployment in the beginning towards having more nuanced designs including the reduction of investment risk, minimisation of policy costs and market integration at later stages of the transition. We argue in this paper that it is beneficial for policy makers to focus on these nuances in policy design as early as possible. If flexible policy instruments are chosen, it will increase the likelihood that policies can be adapted to the new needs evolving during an energy transition.

2 Managed energy transitions: Phases, economics and risks

Transitions are gradual, continuous processes in which society (or a complex sub-system of society) changes in a fundamental way over several decades (Rip and Kemp, 1998; Rotmans et al., 2001). Change can occur through a range of possible development paths. Rotmans et al. (2001) emphasise that policy makers can influence, but never entirely control the direction, scale and speed of transitions. As also Solomon and Krishna (2011) point out, the transitions literature tends to be sceptical about *managed* energy transitions, i.e. the ability of governments to create transitions of the energy system according to a targeted development. The authors however show that there are historical examples of successfully managed energy transitions (in Brazil and France).

Transition management can be undertaken by governments when they would like large socio-technical systems to develop in a certain direction, e.g. towards sustainability. Risk analysis and risk management is an integral part of transition management, where policy corridors are created that can ensure key variables remain within acceptable limits (see Rotmans et al., 2001). Successful transition management has four major characteristics: (1) Long-term thinking when shaping short-term policy; (2) Thinking in multi-domain, multi-actor and multi-level terms; (3) Focus on learning and bringing about system innovation alongside system improvement (learning-by-doing and doing-by-learning); (4) Focus on a wide playing field (keeping open a large number of potentially beneficial development paths) (Rotmans et al., 2001).

The multi-level thinking in transitions is often expressed through the multi-level perspective (MLP) (Geels, 2004). The MLP consists of three interlinked levels: (1) Niches: the micro level, where new technologies emerge; (2) Regime: the meso level, consisting of technical infrastructure and other material elements, rules and regulations as well as actor networks and social groups; (3) Landscape: the macro level, the exogenous environment including macro economy, policy making and cultural patterns that all influence the dynamics at the niche and regime levels. From historical experience, we know that transitions only occur when developments at all three levels link up and reinforce each other in feedback loops (Geels, 2004).

Niches are the crucial level for triggering the start of a transition. At niche level, protected spaces can be created in which the new technology can blossom. In niches, the viability of a new technology is demonstrated, a system of providing financial means is created, and interactive learning processes and institutional adaptation are set in motion. All of this is crucial for the wider diffusion of the new technology (Kemp et al., 1998, p. 184). A whole set of literature revolves around 'strategic niche management' (e.g. Kemp et al., 1998; Kemp et al., 2001; Jacobsson and Lauber, 2006; Schot and Geels, 2008). Risk reduction is a central aspect here: Stabilising revenue streams and technology-specific price guarantees are a major source of protection (Finon and Perez, 2007). Niches can break through on regime level in two ways: Either, they eventually become competitive under the selection environment and rules of the existing regime ('fit and conform'); or they challenge the existing regime in ways so that its selecting criteria, rules, and institutions need to be adapted ('stretch and transform') (Smith and Raven, 2012). In this, it is crucial that external developments from landscape level create pressures on the regime that favour the niche technology (STRN, 2010). Such pressures might be policy interventions, but also e.g. changes in world market prices on fuels. In energy transitions, a 'stretch and transform' alignment is generally required due to the very different technical and economic characteristics of RES as compared to conventional thermal power plants (see e.g. Verbong and Geels, 2007). At any point in time, several new technologies (and practices) are developing in different niches. When different related niches start reaching into the regime, they can become either hindrance or leverage for each other. In a successful transition to a sustainable energy system, many of these related niches need to gradually arise, developing and linking together, so that they eventually combine at the regime level into one overarching sustainable energy system.

There have been various criticisms of the MLP (as explored by Geels, 2011), some of which we agree with. Nevertheless, we find the notion of the three levels (niche, regime, landscape), and the inter-linkage between them a useful general description for the purpose of this paper.

2.1 Phases of the transition

The dynamic process of an energy transition is best analysed in different phases. The first to define different phases in technological change was Schumpeter (1939), differentiating invention, innovation, and diffusion. Kemp et al. (2001) describe the transformation process in four steps (p. 271): (1) Frontiers of knowledge shift, (2) New problems emerge, (3) people's preferences changes, (4) old institutions dissolve, while others are created. Rotmans et al. (2001) describe transition phases as (1) Predevelopment, (2) Take-off, (3) Breakthrough, (4) Stabilisation. Strategic niche management analyses changes in a normative phase, a take-off phase and a market phase. In the normative phase of strategic niche management, the main targets for a new technology are achieving reduced investment cost and increased production volume (e.g. in terms of lifetime, operational performance). In the market phase, there is more focus on the deployment and market performance of the technology. Drawing from these approaches, this paper views energy transition in two phases: A first phase with focus on growth of niches (thus comprising the predevelopment or normative phase and the take-off phase), a second phase with focus on efficient integration and enabling innovation (similar to the market phase and thereafter, comprising both breakthrough and stabilisation). Later, there might follow a third phase, in which a society (as a whole) becomes truly sustainable.

In our first phase, policy makers create protected spaces in niches to trigger the deployment of RES. In a liberalised market such as the electricity system in Europe (and many other regions in the world), adequate investment incentives for private investors must be established, i.e. through support schemes. A focus on growth in the niche is crucial but not sufficient. A steadily growing share of variable RES has implications for power markets, grid operation, and infrastructure needs (Miller et al., 2013; Mitchell, 2014). It is thus important that policy makers as early as possible deal with upcoming requirements to adapt the regime infrastructure (e.g. grid reinforcements), and trigger development in related niches (e.g. flexibility providing technologies). Therefore, a coordinated management of related niches as well as preparation for system adaptation is crucial for the success of the first transition phase and a smooth transition to the next phase.

The crossover to transition phase 2 begins when the niches have grown so that the new technologies significantly challenge or transform the regime. Then the transition stands at a crossroad: Either, the regime will develop resistance to further growth of the niche, preventing it from becoming a fully integrated part of the system; or the regime will embrace the new technologies. Only when a regime has overcome initial resistance to the new technologies (technically, socially and politically), the transition can enter phase 2. We define the start of transition phase 2 so that all of the following three conditions are met: (1) System and network operations have adapted to dealing with a large share of RES; (2) Market design has been adapted to value characteristics that complement the new technologies (such as flexibility); (3) Technology costs of the new technologies have come down significantly to almost competitive levels. The adaptation of the regime in areas that are directly or indirectly related to the niche is thus a crucial characteristic of transition phase 2. System and market integration aspects now become a main focus of policies. Usually, a whole cluster of policies is required to create an enabling environment which allows successful integration.

It should be noticed that the two phases can overlap in a step-wise introduction of different new technologies and with different stages of maturity. Typically, a regime would be in phase 2 for some technologies, whilst still being in phase 1 for others.

2.2 Support policies in managed transition: Does it make sense economically?

From an economic perspective, a prerequisite for justifying an actively managed transition towards a sustainable energy system is the expectation that the promoted new technologies (based on renewable energies) will at some point in the future be more beneficial for society than conventional technologies (based on coal, natural gas) or other known options (such as carbon capture and storage), and that the favourable technologies would not be developed and deployed sufficiently by the market alone (Kumbaroğlu et al., 2008). In sustainability transitions, sufficient development through market forces is not likely. As Jaffe et al. (2004) emphasise, new environmentally friendly technologies are "doubly underprovided by markets" because of two distinct types of externalities: Negative externalities (pollution) of conventional technologies (if not sufficiently internalised) and positive externalities (knowledge spill-over) of new technologies.

Negative environmental externalities are, according to the 'polluter-pays' principle (OECD, 1972), best internalised by increasing the cost of the polluting units – and not by supporting units that avoid the negative externalities. In this line of argument, support of RES is regarded as a 'second-best-solution' as compared to i.e. a carbon tax, because support payments create distortive effects on the market (e.g. consumption would be higher than optimal because external costs are still not visible to consumers) and they consume more than what would be optimal). Others however argue that it might often be necessary to use RES support policies because the 'correct' tax level might not be known or would be required at such high level that public acceptance issues arise. Moreover, the positive externalities of knowledge spill-over and other barriers that new immature technologies face cannot be efficiently overcome by pricing pollution (Jaffe et al., 2002; Menanteau et al., 2003; Finon and Perez, 2007; Kalkuhl et al., 2013). Additionally, other market failures such as incomplete markets play a role.

Acknowledging the necessity of renewable support, one could argue that only research and development (R&D) should be supported. For example, Frondel et al. (2010) use the example of Germany to suggest that it would be beneficial to wait with the deployment of costly RES technologies until costs are brought further down by R&D. On the other hand, energy transitions are often used to combat negative effects from climate change. For this, replacement of conventional pollution technology is crucial - policies are required which can deliver fast deployment of renewables (see e.g. Jacobsson and Lauber, 2006). Moreover, research on innovation systems suggests that without deployment, energy innovation processes are less effective (Gallagher et al., 2012). Thus, the awaited cost reductions might be achieved never, or later, by pure R&D support, impeding the success of an energy transition.

Regarding support for deployment of renewable energies, lump-sum support payments (such as investment grants, paid out as upfront sum, i.e. 500 EUR/kW) generally figure as the most efficient ones in the literature, because they minimise market distortions (see Andor et al., 2012). However, in reality, lump-sum support is often only used as supplementary support. The most commonly applied major support schemes for electricity generation from renewable energy sources (RES-E) in Europe are output based (paid out per generated unit, i.e. 50 EUR/MWh) (European Commission, 2011; Kitzing et al., 2012). Because of their dominance in practical policy implementations, we will focus on the most common output based instruments: feed-in tariffs (FIT) and quota schemes with tradable green certificates (TGC). Traditional FIT schemes are technology-specific price-control mechanisms that offer a guaranteed price to eligible producers, most often in combination with priority dispatch and exemption from participation in balancing markets. Traditional TGC schemes are technology-neutral quantity-control mechanisms that oblige energy suppliers to have a certain quota of renewable energy in their portfolio, which can be acquired in form of green certificates from eligible producers on a dedicated certificates market. More recently, also feed-in premiums (FIP) are coming in use. FIP are guaranteed add-ons to market prices.

2.3 Renewable energy technologies from an investors perspective

Figure 1 describes a typical cost development of a new technology over time as seen by a private investor. The total costs of new projects tend to be high in the early stages of technology development and decrease with increasing deployment of the technology (Jamasb and Köhler, 2007). We have split the total cost into 'technology cost', and 'cost of risk'. We use this distinction, because the two elements, although related, can distinctly be addressed by specific policy measures, and are important to our argument about how technologies should best transfer from phase 1 to phase 2.

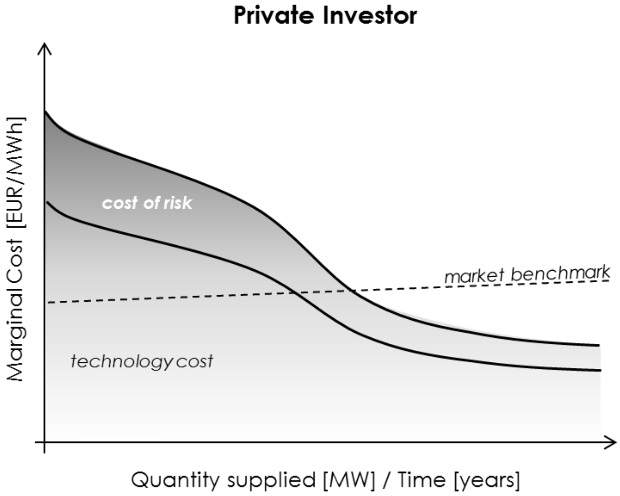

Figure 1: Cost of a technology from an investor's perspective, development over time

Technology cost reductions stem from two different general sources (based on Menanteau et al., 2003): 1) technical change, including falling investment cost, improved technical performance; and 2) systematic effort to benefit from economies of scale, use of very best sites available, operational optimisation, organisational learning, synergies within companies, etc. (also called 'induced progress' in the literature, Finon and Menanteau, 2004). Achieving technical change often requires R&D investment (technological innovations), whereas the more 'organisational' cost reductions are effectively triggered through competition (pressure between projects of available technologies). Menanteau et al. (2003) show that traditional FIT schemes generally provide higher incentives for domestic innovation and R&D, whereas technology-neutral TGC schemes perform better on the 'organisational' cost reductions through their increased competitive pressure.

Traditional FIT schemes tend to have lower competitive pressure, because every good project (i.e. with costs below the tariff) can be developed, independent of the number of other good (or even better) projects. Moreover, because of the long term guarantees, projects are not exposed to competition with future improved technologies (as it is the case with TGC, where all projects receive the same certificate price no matter when they have been built). However, FIT schemes tend to spur more technological innovation, because they provide a real benefit for technology front-runners: The extra surplus that a project with lower costs can generate is predictively collected by the producer, because of the long-term guaranteed tariff (Menanteau et al., 2003). Under TGC schemes, producers are mostly driven by avoiding negative effects of (potentially) falling future prices. It is just this lack of market anticipation, which decreases the incentives for R&D under TGC schemes – it is better to focus on 'organisational' improvements and procure new and improved technologies externally (see Menanteau et al., 2003 and Finon and Menanteau, 2004). Johnstone et al. (2010) have shown with an empirical patent analysis that innovation under TGC schemes is mostly related to technologies close to market-competitiveness, whereas FIT spur innovation in more immature technologies. However, Söderholm and Klaassen (2006) show that the innovation effect of FIT schemes highly depends on efficiently set tariff levels: If they are too high, then FIT provide fewer incentives for cost reductions. In Europe, we have seen that in countries with FIT schemes, strong domestic technology industries have developed (Denmark, Germany, Spain), whereas countries with TGC schemes often procure equipment from abroad (UK), as shown by Söderholm and Klaassen (2006) for wind energy.

Cost of risk tends to be highest in the beginning of a technology learning curve. It will be reduced throughout the learning process. We consider two different types of risks: market risks and non-market risks. We can distinguish between three different energy-related markets (Klessmann et al., 2008): (1) (future) power markets, (2) balancing markets, (3) support markets (if existing). All three markets entail two kinds of risks: price volatility and volume risk, as also discussed in Mitchell et al. (2006). Additionally, RES-E investors also operate on the capital market to secure financing for the investments. Non-market risks are either technical, social or political. Risks emerge from the technology itself (e.g. efficiency, yield, reliability, hazards), the project and firm (schedule, contract strategy, competence of employees, safety issues, etc.), the social environment (labour availability and skills, employment law, public acceptance), regulatory issues (permitting procedure, system rules), the legal framework (laws, recourse, remedy, income taxation, allowances) and political initiatives (regime stability, changes in energy and climate policy, provision of infrastructure, etc.) (adapted from Michelez et al., 2011).

Most risks are common to many investors in a country (e.g. regime stability, taxation rates, etc.) and will not be changed in light of a managed energy transition. There are however a number of risks that can be addressed to increase the success likelihood of an energy transition, as discussed below.

2.4 Renewable energy technologies from a societal perspective

The costs of a new technology differ for society and private investors. This is because the latter is concerned only with direct project costs whereas society also incurs all related development and system costs. Ueckerdt et al. (2013) have developed a comprehensive framework for estimating system integration cost of variable renewable energies. These include expenses for grid infrastructure, balancing services, reserve requirements and additional flexibility from thermal power plants. Ueckerdt et al. (2013) calculate that integration cost steadily rise with increasing shares of variable renewable energies (up to 40% market share). Their analysis relates though mostly to a static environment. When taking system adaptation effects and technology learning into account, we argue that, conceptually, a turning point should be expected in the cost development, after which system integration cost and grid infrastructure are marginally decreasing with more deployment of the new technology. We illustrate this effect conceptually in Figure 2.

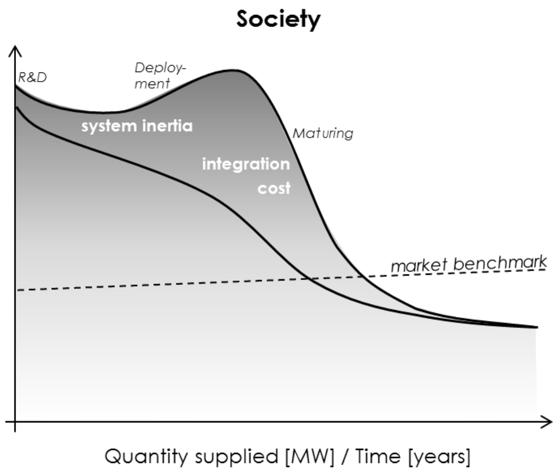

Figure 2: Cost of a technology from a societal perspective, development over time

The risks that society is concerned with are quite distinct from private investors' risks. E.g. contractual issues or market price volatilities are generally of no concern on a societal level unless they would affect either economic output, social welfare or efficiency of a market. Society is more concerned with the stability of state income and budget, so that social services can be upheld. Political risks are not so much related to the stability of the support regime (as is the concern of a private investor), but more to the incentive structure that the policies provide and the distortions that they might cause. There are risks related to the evaluation of pollution effects and related health and other costs. Society may be concerned about a healthy domestic industry, about unemployment and a good trade balance. Policies are often used to mitigate these concerns. Societal risk of support policies tends to be either (1) that the best technology options are not promoted, thus foregoing the opportunity to a higher welfare; or (2) that the technologies are not supported in the optimal way, thus leading to net social welfare loss as compared to the social optimum.

3 Efficiency and effectiveness of policies in managed transitions

Often, the effectiveness and efficiency (or cost-effectiveness) of policies is evaluated on the basis of static cost-benefit considerations. We argue that especially two aspects should not be neglected in policy evaluation: Risk aspects and dynamic processes. Risk aspects are an area of increasing attention in policy making (see e.g. Gross et al. 2010). Klessmann et al. (2008) show that the level of exposure to risk is a significant factor for differences in effectiveness and efficiency of different renewable policy instruments.

In this section, we present some conceptual considerations regarding risk aspects and dynamic processes for a policy evaluation framework, which we then develop in section 4. We focus mainly on the question of how far the reduction of investor's exposure to risks can help to achieving a successful energy transition. We first look at market risks and discuss how different policy instruments perform in terms of risk reduction. We then show that the reduction of market risks can help to increase deployment rates of RES-E. Subsequently, we explore if this increased effectiveness comes at the expense of lower efficiency. Finally, we briefly discuss non-market risks.

3.1 Reduction of market risks

In power markets, the future price is unknown and (currently) no perfect hedges exist to secure prices through financial contracts (Forwards are traded only for 3-6 years into the future). RES-E producers also face volume risks if there is a probability that they are not able to market their whole generated power, either through constraints in market design (bidding sizes and time blocks) or in the physical grid infrastructure. Traditional FIT schemes provide guaranteed grid access and priority feed-in to RES-

E, so the volume risk is minimised. Also the price risk is decreased to a minimum thanks to the guaranteed price level. In FIP and TGC schemes, RES-E producers are fully exposed to power market risks.

Balancing markets have also unknown future prices (which typically cannot be hedged at all) and the volume risk is especially high for intermittent renewable energies. Depending on the market design, the RES-E producers are exposed to more or less imbalances from forecasting errors or performance issues (depending e.g. on the gate-closure time of spot markets). Traditional FIT schemes exempt RES-E producers from participating in balancing markets. In some more recent implementations of FIT (sliding premium systems), as well as in FIP and TGC schemes, RES-E producers are fully exposed to balancing market risks.

Support markets only exist when created by a respective RES support scheme. For FIT, FIP and supplementary support schemes, no support markets are necessary. For TGC schemes, a market to trade green certificates is established. On this market, RES-E producers are exposed to price risk (at which price they can sell their received certificates to obligated suppliers) and to volume risk (demand of certificates is depending on the quota set by government).

On the capital market, risk reduction can happen through 'financing support' measures, as described by Kitzing et al. (2012): provision of reimbursable equity or venture capital from governmental institutions, low interest loans, equity guarantees, loan guarantees and securisation products. Weiss and Marin (2012) find that providing long-term revenue stability (as in traditional FIT price-control schemes) is critical for facilitating the financing of capital-intensive renewable energy projects and thus for their successful deployment.

Traditional FIT schemes are thus usually the policies that reduce market risk most, due to their inherent risk reducing characteristics. Therefore, the literature describes the implementation of FIT schemes often as 'low risk' approach, and TGC schemes as 'high risk' approach (see e.g. Klessmann et al., 2008). However, these inherent characteristics can be substantially altered by design specifications (e.g. sliding premiums or caps and floors), so each instrument can also be implemented in a 'low risk' or 'high risk' way. In fact, Ragwitz et al. (2011) show that a gradual convergence of key properties in FIT and TGC implementations can be observed in Europe, with trends to provide differentiated technology-specific support, to enact quantity controls, and to introduce elements of market exposure.

Whatever policy is employed, it should be flexible enough to be slowly adapted according to the changing requirements in the different transition phases. In transition phase 2, system integration becomes important, which implies two things: (1) the protection of niche technologies must be slowly reduced, so that RES-E become a more and more 'normal' part of the overall energy system, (2) the regime level has to be adapted, so that it accommodates the needs of the new technologies. Conceptually, technology-neutral support schemes seem to be more difficult to adapt slowly, in small steps, to new policy criteria. The success of TGC depends on a well-functioning market. Implemented changes almost always affect the whole market. Too many changes can have disturbing effects on the functioning of the market. The risk of interruption of deployment is rather large for these systems. Policy makers have strong control over the specific technologies in FIT schemes. Changes can be implemented step-wise and if announced timely, they will not disturb the market place in the same way as in TGC schemes. More research on this issue would be beneficial e.g. to support this point with analytical or empirical evidence.

3.2 Reduction of market risks: effective in delivering deployment

Effectiveness is one of the most important success criteria for policies, generally defined as the ability of a policy (or policy package) to deliver the desired outcome at the desired time. However, the desired outcome can be defined in different ways. Two of the most usual definitions are: (1) Targets can be set or perceived as minimum levels (deployment over the set target is still desirable). In this case such policies are considered most effective that deliver *maximum deployment* within a given time period (this corresponds to the definition of the European Commission (2008); and RES targets of many countries; see also Haas et al., 2011); (2) Targets can be set as fixed, or even maximum levels. In this case, such policies are considered most effective that deliver *exact target achievement*. Such target setting often occurs in situations where other policy objectives (such as cost-effectiveness or system integration) become dominant.

Some economic studies conclude that there should be no difference in deployment quantity from different policy instruments (such as TGC or FIT) at a given support level (see also Menanteau et al., 2003), as long as the support levels are set efficiently. Those studies base their argumentation mostly on classic welfare economics and implicitly neglect issues such as incomplete markets, risk-aversion and transaction costs.

In real energy systems, markets are often incomplete: No perfect hedges are available for RES-E developers and investors, leaving them most often involuntarily exposed to certain market risks. Assuming risk-aversion of investors and other market agents, the involuntary exposure to market risks will entail costs. A reduction of these risks will have several effects for investors (see also Simkins and Simkins, 2013, p. 385f): A firm with lower risk projects can generally achieve greater debt capacity and lower cost of debt. Alternatively, the cost of equity could be reduced. A firm with more stable income flows has lower cost of liquidity management and other measures that shall avoid financial and economic distress[1]. When assuming imperfect markets, the reduction of market risks can also help to reduce transaction costs and reduce the exposure to risks that cannot be hedged.

The emerging field of 'transaction cost economics' tries to assess private costs and risks associated with transactional complexity, which in reality can be substantial. As Finon and Perez (2007) have analysed, FIT schemes offer a maximum of clarity and simplicity for transactions between producers and purchasers, because much is defined by the regulatory arrangement. This reduces overall transaction costs. In TGC and also FIP schemes, producers and (obligated) buyers are forced to seek long-term contracts or vertical integration to avoid market risk. This can be costly and lead to an efficiency loss if transaction costs are taken into the economic assessment (Finon and Perez, 2007). Based on an empirical analysis for European countries between 2002-2010, Jaraitė and Kažukauskas (2013) have shown that in TGC schemes more market imperfections are present than in FIT schemes, because of higher investment risks, higher capital constraints and higher transaction costs.

Another often neglected factor is that firms are not always ex-ante rational decision makers. Also firms have to go through a learning process and understand how to assess and cope with the risks associated with new technologies (see Ramesohl and Kristof, 2002). Especially in the beginning of this learning phase, perceived risks may be significantly higher than actual risks. This could be prohibitive for some projects and costly for others. Risk reducing policies can also help to give a comforting signal to developers, investors and financial partners in times when the risk assessment of new technologies is still in the learning phase. More investors can dare to take up the endeavour, because less upfront knowledge is necessary, less risk capital is required etc.

The cost reducing effect of less exposure of investors to market risks is illustrated in Figure 3 on the left hand side. However, market risks do not disappear when reduced for private investors: they are merely transferred to other actors. A net cost reduction on societal level would be very small if present at all, as conceptually illustrated in Figure 3 on the right hand side.

[1] In classic economic theory, active liquidity management and related costs of risks are not recognised as relevant part of investment considerations of firms (Modigliani and Miller, 1958). Empirical studies however show that this is common practice in firms to incur additional cost from activities targeted at avoiding financial and economic distress (Acharya et al., 2012).

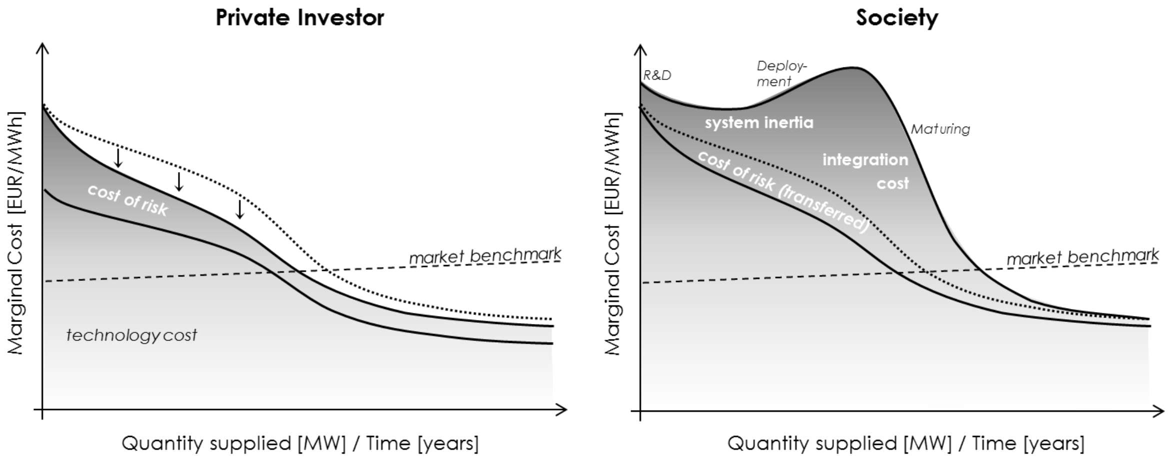

Figure 3: Transfer of market risks from investor to society

The risk reducing effect of policies influences private decisions so that investors more readily invest at lower risk premiums. The private costs of investment becomes lower and more investment takes place for a given support level (compare also Miller et al., 2013). Figure 4 illustrates the effect of increased deployment quantity from a 'low risk' as compared to a 'high risk' policy. Many studies have shown that FIT schemes can lead to an increased deployment as compared to TGC schemes, based on empirical policy analysis (Mitchell et al., 2006; Butler and Neuhoff, 2008; Klessmann et al., 2008; Haas et al., 2011), and also more theoretically based on finance theory and a real option approach (Boomsma et al., 2012; Kitzing et al., 2014).

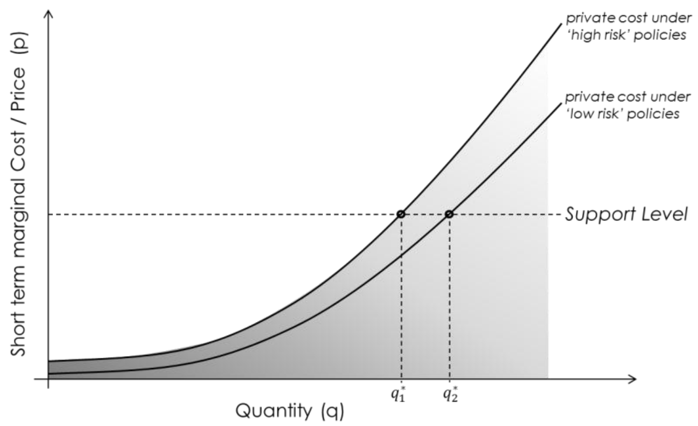

Figure 4: Illustrative marginal direct cost curves for a certain technology under different policies, resulting in different deployment quantities for a given support level

Risk reduction is thus clearly a policy strategy to achieve maximum deployment at given support levels. If maximum deployment is targeted for a given time period, then those policies reducing most risk are often the most effective ones. As discussed in 3.1, FIT schemes generally reduce most risk for RES-E. A large part of the risk reduction stems from the power price stabilisation. But does this effectiveness come at the expense of reduced efficiency? In the next section, we deepen our analysis by exploring efficiency effects of the different policy instruments.

3.3 Reduction of market risks: is it also cost-effective?

Rio (2014) discusses two different understandings of efficiency (or 'cost-effectiveness') in the RES-E literature: Some scholars adhere to neo-classical welfare economics, where the efficient mix of technologies is the one with the lowest production cost, evolving from market forces and competition. Studies adhering to this line of thought tend to favour technology-neutral, competitive instruments with volume caps (like traditional TGC schemes). Others find those policies 'efficient' that minimise support cost (see also the definition of the European Commission, 2008), implicitly assuming that not only net social welfare matters but also the allocation of welfare between producers and consumers (as an equity issue). These studies tend to favour technology-specific, price-guaranteeing instruments (like traditional FIT schemes). Much of the economic literature analyses the difference between quantity-control (in our case TCG) and price-control (in our case FIT) policies. In this section, we will also use this terminology. We will start from a simple classical welfare economic argument and will then broaden our perspective to incorporate effects from dynamic processes that are central to the transition framework.

In a classical economic view, only those outcomes are efficient that adhere to the equi-marginal principle (all technologies are deployed until the same marginal cost). In TGC, this occurs implicitly by controlling the total quantity (q) of deployment from the desired technologies. All potentially eligible RES-E projects have to compete for their share in the support market, and eventually all projects with costs below q* will be realised (see Figure 5). The resulting support market price is p* for all RES-E production. On the other hand, the price levels in a FIT scheme are exogenously determined by government. To achieve a comparably efficient outcome, the levels have to be designed so that no technologies above p* or q* are being deployed. In reality, this is not always the case, for example there might be a strategic interest in promoting photovoltaics even if they are still expensive. We will be setting this aside for the moment, assuming that governments only deviate from this principle of staying below q* and p* as a conscious decision at the expense of short-term market efficiency.

In both cases shown in Figure 5, generation costs are minimised. Net social welfare (shaded areas combined) is the same in both cases. So, following classic welfare economics, one would be indifferent regarding instrument choice at this stage. This conforms with textbook teaching that risk reduction in form of price stabilisation (as in FIT schemes) is neutral on overall welfare under price uncertainty with predetermined volumes (Just et al., 2004, p. 470f).

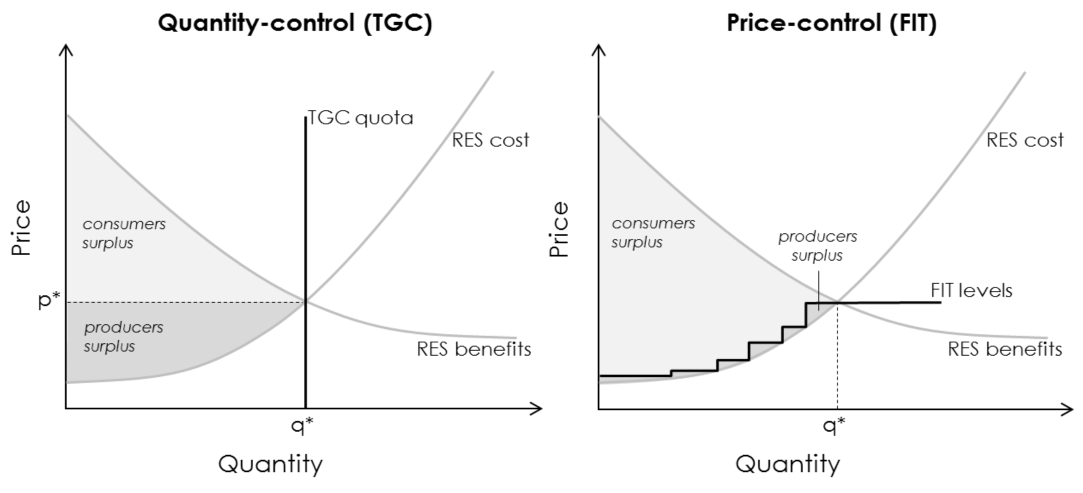

Figure 5: Marginal cost and benefit curves, distribution of social welfare between producers and consumers for the two major generation support instruments FIT and TGC (see also Haas et al., 2011).

However, the two policies differ significantly in their allocation of welfare (surplus) to consumers or producers, respectively. In the FIT scheme, consumer surplus is much larger than in the TGC scheme. This reallocation is achieved by minimising support payments, while keeping up the investment incentive (thus minimising the difference between the respective FIT level and the RES cost). As a result, FIT minimises support costs as well as producer surplus, whereas the TGC doesn't.

This effect matters if equity (in terms of economic welfare and socially) is considered an issue in regards to choosing support policies. Contrary to general recommendations by welfare economists, policy makers are in reality often concerned about re-allocation effects, and will try to minimise producer surplus to the benefit of consumers (del Río and Cerdá, 2014). Then, a technology-specific price-control mechanism should be chosen because it can best mirror the specific costs at any time. The empirically experienced efforts to minimise support costs (see e.g. the discussion in Germany, as described in Lauber and Jacobsson, 2013) could be due to public acceptance issues, but could also stem from the legitimate argument that not all producers will use the excess profits for related R&D investment (as is necessary for a continuingly improving sector and to achieve dynamic efficiency) (Finon and Perez, 2007).

We have not yet taken into account uncertainty related to the cost and benefit functions. The risk of setting the quota or the tariff at an inefficient level is apparent. In this case, the optimisation problem changes from finding the right price level or quota that maximises net social welfare to finding the policy that maximises the *expected* net social welfare while minimising society's exposure to undesired outcomes. When price levels or quotas are set at an incorrect level, they can lead to net welfare losses (also depicted as 'regulator's regret'). Weitzman (1974) has developed a framework for analysing this effect for quantity- and price-control instruments of environmental policy. We illustrate his findings in Figure 6 adapted to renewable support instruments.

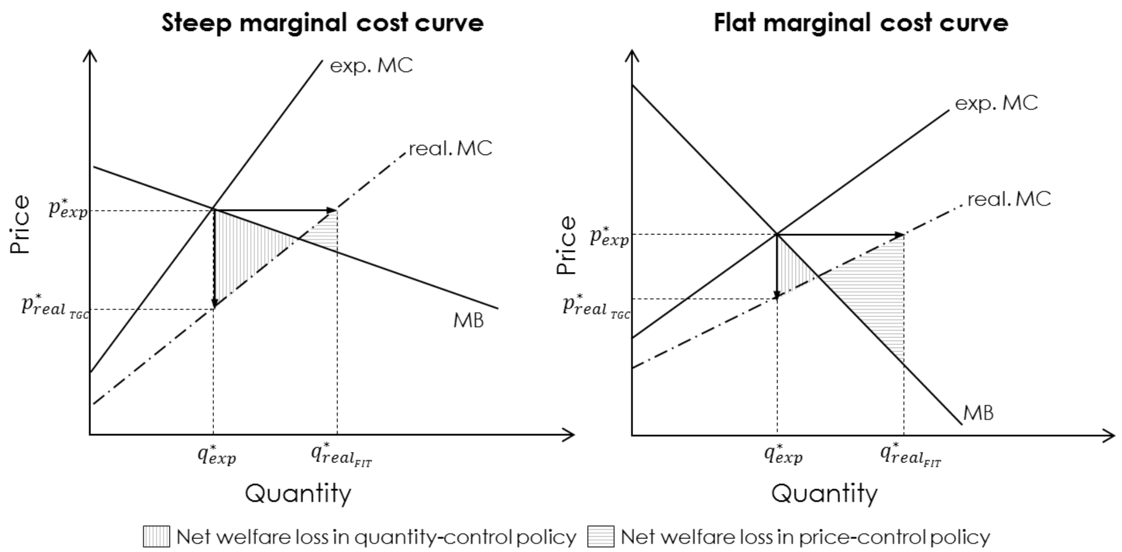

Figure 6: Risk of net welfare loss under cost uncertainty for quantity- and price-control policies, for a marginal cost curve steeper than the benefit curve (left), and vice versa (right) (based on Weitzman, 1974)

Figure 6 shows the welfare implications of uncertainty described by Weitzman (1974) for two relations between marginal cost curve (MC) and marginal benefit curve (MB): A relatively flat MC curve (on the left hand side) and a relatively steep MC curve (on the right hand side). In both cases, we compare the net welfare losses for a price-control (FIT) and a quantity-control (TGC) policy. If the realised marginal costs (real. MC) are lower than expected (exp. MC) (which is a reasonable assumption from recent experiences with RES-E cost developments), then a FIT will lead to higher than expected quantities deployed ($q^*_{real_{FIT}} > q^*_{exp}$), whereas a TGC will lead to lower than expected prices ($p^*_{real_{TGC}} < p^*_{exp}$). Both effects cause net welfare loss.

However, the amount of net welfare loss differs significantly: If the MC curve is steeper than the MB curve, the TGC leads to larger net welfare loss (in Figure 6 on the left hand side, the shaded triangle for TGC is larger than for FIT). If the MC curve is flatter than the MB curve (right hand side of Figure 6), the FIT leads to larger net welfare loss and thus higher 'regulator's regret'.

Finon and Perez (2007) report that, although the shape of the marginal cost curve cannot be known precisely, several studies suggest that marginal cost curves of RES-E are rather flat (near the equilibrium where it matters). This would imply that a TGC scheme should be preferred. However, we have a more differentiated view. Acknowledging that the shape of the marginal cost and benefit functions are very difficult to estimate, because they comprise different elements, not all of which are revealed as market prices, we argue the following: A small niche comprising different and still immature technologies has most probably a comparably steep marginal cost function: Not many different equipment manufacturers or project developers are active. Plant capacities for producing equipment and available, still relatively few sites for renewable energy are developed. The total amount of available projects is thus limited and partly only realisable at very high cost. It takes time to build up related infrastructure. On the other hand, the marginal benefit curve is rather flat as often, the marginal benefits from positive externalities are rather stable (Cropper and Oates, 1992). The steepness of the marginal cost curve however decreases with the development of the technology and the growth of the niche. More manufacturers and investors enter the market, more sites are explored, knowledge will be shared. The marginal cost curve may thus *become* flatter after certain time of niche development. Given this, a FIT scheme would be preferable in the first phase of a transition, at least until the relation of MC and MB curves has changed. Given concerns of consumer welfare, it is not certain that a TGC scheme would become preferable at all.

In light of the uncertainties about the marginal cost and benefit functions, as well as about the relative positioning of the curves towards each other (uncertainty about which curve is steeper at what times), Roberts & Spence (1976) and Weitzman (1978) have shown that the expected and realised net social welfare might be best optimised by using price- and quantity-control instruments in tandem, where each policy acts as a 'safeguard' against the potential pitfalls of the other.

Moreover, the validity of the above conclusions regarding efficiency properties of the different policy instruments depends heavily upon the degree to which a perfectly competitive equilibrium exists for the market (see Cropper and Oates, 1992). In reality, a number of market imperfections exist that distort the outcome. Market imperfections may exist in form of monopolies or oligopolies, imperfect information and transactions costs, as well as complex objective functions.

One straight-forward example for complex objective functions might be that policy makers place different values on the effects from the policies. If an important political target is to achieve as much renewable deployment as possible within a certain time horizon, then the perceived benefit from additional deployment might more than compensate the net welfare loss associated with a too high price paid. Also other (external) payment obligations may be relevant, such as in Europe potential infringement penalties if a Member State cannot achieve its binding renewable targets by 2020.

Transaction costs are most often not considered relevant in the analysis of economic efficiency (Griffin, 1991). We have discussed the implications of neglecting transaction costs in section 3.2 above. As also mentioned above, real energy markets are often incomplete. In the state-preference model of economic theory, if differences stemming from risk exposure occurred, individuals would trade with each other until differences are eliminated ('balance of the states') (Just et al., 2004). However, if market imperfections exist and these trades cannot be fully conducted, competitive markets cannot converge in the one market price that is required to reach the social optimum. In this case, it might be socially beneficial to take risk away from individuals and re-allocate them to other individuals that have better hedging options or to combine it into one socialising pool. In an energy transition, this could for example be protecting renewable energy producers from market price risks with a price guarantee. However, this kind of risk reduction can entail a situation of moral hazard and adverse selection problems, in which the beneficiaries adopt socially adverse behaviours because of their protection (Just et al., 2004). In our case, renewable energies that are fully protected from market signals will not decrease their production in situations of oversupply and negative market prices. A pooling of risk to the benefit of private investors can thus only be accepted for a limited time in a controlled niche in order to achieve certain important targets.

Until now, we have implicitly assumed that there are no differences in how the different agents evaluate risks. When assuming differences in risk-aversion by investors, it suddenly matters which risks the different agents are exposed to and how they personally evaluate it. A way to economically analyse such effects is by using utility theory, and calculating the specific benefits to each individual (see e.g. Just et al., 2004). Without going into detail with this, many applications of utility theory have shown that the classical argumentation does not hold, and it often does matter for overall welfare if surplus is allocated to producers or consumers, or where risks fall (see e.g. Just et al., 2004).

Finally, the question of what is efficient in the short term differs significantly from the question of what is efficient in the long term. This is often referred to as the difference between 'static efficiency' and 'dynamic efficiency' (Finon and Menanteau, 2004). The different incentives to reduce technology costs are important here (see section 2.3). Weber and Rohracher (2012) define it as 'directionality failure', if policies fail to contribute to a particular direction of transformative change. To avoid this failure, often technology specific policies are needed to provide more targeted impulses (Jacobsson and Bergek, 2011). Another failure of systemic rather than market character is the policy coordination failure, as discussed in section 3.4.

We can conclude that politically set targets, market failures (imperfections, externalities), different maturity levels, systemic failures, adoption processes and the uncertainty about all of these issues make the analysis of energy policy more complicated than suggested by many economic studies that compare different support policy instruments. We started the section by saying that technology-neutral, quantity-control policies (like TGC) are often by economic analyses considered more efficient. However, having reviewed the arguments and conceptually analysed several related issues, we cannot agree with this unconditionally. In contrast, we find that, at least for the economics of early niche development, price-control instruments (which are also reducing most risks for investors) can be equally as and maybe even more efficient than quantity control instruments. But this also depends on the definition and political interests (e.g. if equity is an issue). Moreover, it also depends on wider social and non-market goals as discussed below.

3.4 Reduction of non-market risks and societal costs

In addition to the market risks discussed above, which are often the subject of economic analyses, there are a number of non-market risks that affect investment decisions and which need to be considered in policy evaluation. Many of these risks can be influenced by policy makers. Typical non-market risks are related to policy stability and predictability, permitting procedures, public acceptance issues, etc. The interesting thing about reducing non-market risks is that it reduces costs for private investors without transferring too much risk to society. This means that this can result in an overall cost reduction. Many of these private non-market risks are either of no concern from a societal perspective or relate to overall inefficiencies to which society is exposed to as a whole (e.g. the delayed connection of a wind park). Finon and Perez (2007) argue further that it may be cheaper for society (considering a period of 15-20 years) to "bring down technologies rapidly down their learning curves, and thus reduce costs quickly, rather than to introduce RES-E relatively slowly".

Weber and Rohracher (2012) argue that 'policy coordination failure' can lead to inefficiencies in transition processes, referring both to niche policies (e.g. support of technologies), sectoral policies (e.g. energy market regulation) and cross-cutting policies (e.g. taxation). Concrete policy actions and initiatives need to be coordinated so that the necessary goal-oriented transformative changes can be achieved. Taking this argument further, we argue that such coordinated management can also decrease overall costs. For example the introduction of smart grid infrastructure and demand-side management technology is beneficial for an improved electricity market operation anyway (Riesz et al., 2013). If timed in a smart way to support the integration of variable renewable technologies, the overall social cost of both developments can be minimised.

Building further on the economic theory and arguments laid out in section 3.3, Figure 7 conceptually illustrates these overall cost reductions on societal level.

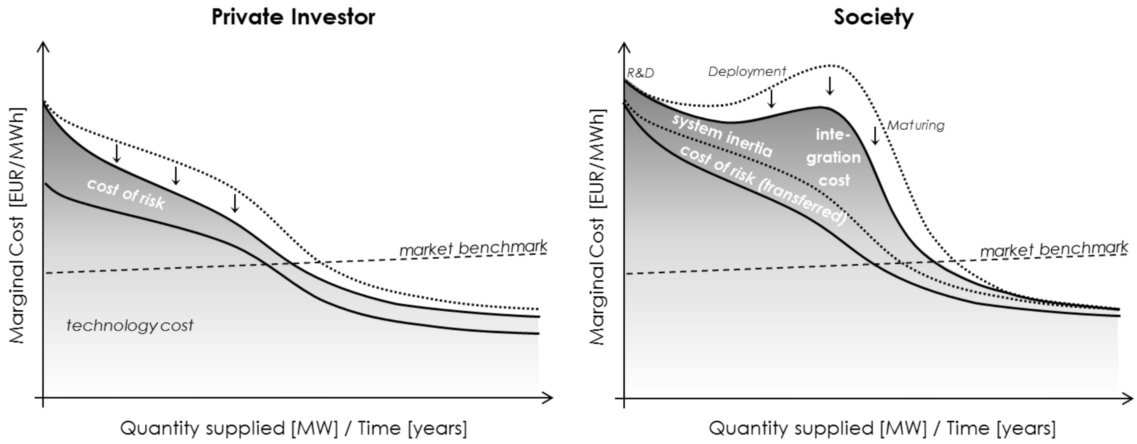

Figure 7: Absolute cost reductions are possible on societal level through reducing non-market risks

In other words, as analysed above, reducing risk increases the effectiveness of a policy to society over the long term; and it also has advantages regarding the dynamic efficiency of an energy transition. Scholars promoting the use of technology-neutral, competitive policies, in which new technologies are exposed to a lot of market risk right from the start of niche development base their analysis mostly on static considerations and do not take dynamic processes and specific characteristics of the different transition phases into account. Also, they do not recognise re-allocation of welfare from consumers to producers as an issue, although it is consumers who ultimately have to pay for the (temporarily) additional cost of an energy transition.

4 Policy implications for the transition phases

In this section, we use the conclusions from our above considerations to describe some policy implications for the two phases. The definition of our transition phases is given in section 2.1. In the first phase of an energy transition, policy makers create protected spaces to help new technologies grow. A fast and cost-effective deployment is desirable. A further development of the technologies and the initiation of a dynamic transition process are crucial for this phase to lead to a successful transition. In the second phase of the transition, the niche is grown so that it needs to become more and more embedded into the regime. The aim of this phase is to make the new technology become a fully-fledged part of the regime. Miller et al. (2013) list the policy goals in a system with high shares of renewable energies as (1) to facilitate investment in RES-E technologies, (2) to enable efficient and reliable system operation, (3) to enable cost-effective service delivery, and (4) to enable continued public acceptance. The policies applied in the previous phase need to be adapted to cope with the new aims of this phase. A more holistic approach is required.

Table 1 illustrates the potential success criteria that policy makers might have in the first and second transition phases. It adds some potentially successful strategies which we have identified from the above analysis. All elements are discussed in detail below.

Table 1: Potential success criteria and successful policy strategies in transition phases 1 and 2

Success criteria	**Successful strategies in transition phase 1**	**Successful strategies in transition phase 2**
Dynamic transition process	Initiate dynamic processes: - minimise entry barriers and risks - reduce private risks - create an enabling environment	Control dynamic processes: - focus on predictability and stability - introduce policy safeguards - maintain an enabling environment

Effectiveness (deployment achieved)	Maximum deployment achieved: - accelerate growth rate - reduce private cost of risk	Deployment targets exactly achieved: - control growth rate - control support costs - introduce safeguards on price and volume
Efficiency (cost-effective deployment)	- Minimise generation cost - minimise regulator's regret - keep open options of promising immature technologies	- Minimise generation cost - minimise regulator's regret - keep open options of promising immature technologies
Preparation for phase 2	- Coordinated management of related niches - ensure flexibility of the policies to adapt to new challenges	
Integration of new technologies into regime		- Exploit synergies from related niches - empower new technologies - adapt regulations and rules of regime to accommodate new technologies
Technology cost reduction	- Maximise technological learning - accelerate growth rate - introduce modest competitive elements	- Maximise organisational learning - uphold technological learning - introduce more competition
Public acceptance	- Increase equity - minimise support costs	- Increase equity - minimise support costs
Preparation for discontinuation of policy support		- Adapt market rules to provide adequate investment incentives - Adapt the support policies for slow phase-out

4.1 Initiation and control of a dynamic transition process

In the first phase, the transition process is not yet dynamic or self-sustained. Development still depends mostly on political initiative and support schemes. Here, policies should be designed to remove entry barriers. Entry barriers could be removed through tackling non-market issues (e.g. simplified permitting procedures), and also market issues (e.g. price stabilisation and dispatch priority to reduce perceived and actual risk). The entry of new firms is central to initiating a more dynamic process: New entrants bring additional knowledge, capital, other resources, and transfer innovative ideas from other sectors (Jacobsson and Lauber, 2006). More entrants strengthen the 'political' position of a niche: their opportunity to influence the institutional set-up increases (Jacobsson and Lauber, 2006). With creating an *enabling environment,* a strong and diverse group of firms will develop around the new technologies, and a later adaptation on regime level becomes more likely.

When the energy transition has successfully gone through phase 1, dynamic processes have been started that ensure continued technology innovation and market deployment. These often autonomous dynamics can however at later stages make the outcomes quite unpredictable (Rotmans et al., 2001). For example, faster than anticipated cost reductions could increase the deployment significantly under FIT schemes (see section 3.3). Therefore, often policy makers feel that 'safeguards' need to be employed in policy instruments to retain some control over the process (Finon and Perez, 2007), because of effectiveness and efficiency concerns.

It is however crucial that, as soon as policy targets begin to change from initiating a dynamic process to controlling it, policy makers should have a prepared and predictable way forward for policy changes. The dynamic processes should be controlled and guided in a certain direction but not completely stopped. Agnolucci (2008) shows that it is in the best interests of consumers and governments to reduce risks related to regulatory and policy changes. In this light, it is important that the changes to policy are not too abrupt and radical. However, this also requires that reasonably good policies are in place to build upon. In this case, small stepwise adjustments of existing schemes are often better in the long-term than radical switches to another support scheme, because ex-ante transaction costs of switches can (over)compensate the gains from the new incentives in the long run (Finon and Perez, 2007).

4.2 Effectiveness (Deployment achieved) and public acceptance

In transition phase 1, generally those policies that deliver the highest deployment rates are considered most effective (see section 3.2). Rapid growth is required in an early phase for new technologies to *'take-off'* and set in motion a chain reaction of powerful positive feedback loops (Jacobsson and Lauber, 2006), i.e. to start the dynamic development process. As discussed above, the reduction of private risks, both market and non-market risks, can lead to accelerated growth. Policies that focus on reducing risks perform thus better under this success criterion.

However, there is empirical evidence that with increasing shares of renewables, policy makers start to be concerned about total support costs (del Río and Cerdá, 2014). Therefore, the success criteria for transition policies might change during the transition from achieving maximum deployment (overachieving of targets is desirable) to achieving the targeted deployment exactly (under- or overachievement of targets to be avoided). Driving factors for this change in target setting are ensuring continued public acceptance, stabilising the use of state budget, and ensuring that renewables and regime can develop alongside each other in a timely manner (e.g. to provide sufficient time for large infrastructure reinforcements, changes in market rules, etc.). While these are legitimate concerns, a too strong focus on minimising support costs might exaggerate the 'burden' of support payments for today's citizens and neglect inter-generational equity problems (Lauber and Jacobsson, 2013).

To ensure that the targeted deployment is exactly achieved (no more or less), several control mechanisms, or safeguards, can be established. Miller et al. (2013) speak of introducing 'cost aware' policies. For FIT schemes, these could include: (1) Regular, predictable adjustment of tariff levels; (2) introducing a total cap on support payments (in monetary terms) or maximum supported amount (in capacity); (3) introducing other quantity-control elements, such as auctioning out of support, as seems to be suggested by the European Commission (2013). In TGC schemes, a quantity-control is already established. However, the total support costs are not minimised. With a uniform certificate price, the cheapest technologies will receive much higher support than required (see Figure 5). The significance of this issue depends on the energy mix and resource availability of a specific country, but if the deployment targets are ambitious, often a diverse set of renewable technologies is required. In order to limit support costs and increase public acceptance of TGC schemes, policy makers can minimise total support cost by introducing 'banding', a differentiation in the number of certificates the different technologies receive.

4.3 Efficiency (cost-effective deployment)

Transition phase 1 is characterised by high barriers and transaction costs for new technologies as well as high uncertainties about today's and potential future costs and benefits. The level of protection against competition and market risks needs to be relatively high to overcome initial inertia, barriers, and uncertainties. Equipment manufacturers, project developers, investors, financing partners, etc. need yet to go through a learning process. An industry branch has to evolve. Even small risks can be prohibitive for new entrants and for project investments because of the high risk perception. Remaining risks are priced at high premiums. This might lead to inefficient developments, as private choices do not match societal interests anymore. In such environment, competitive market forces are less effective in providing high deployment rates at minimum costs for society (see section 3.2). Protection from overly strong competition and reduction of risk can lead to success until the first major barriers are overcome and market forces become more applicable. The principle of minimising regulator's regret suggests that price-control instruments may be more appropriate in this phase if it is characterised by steep marginal cost curves and rather flat marginal benefit curves (see section 3.3).

Barriers and inertia become less important in transition phase 2, because substantial private and institutional learning has occurred; risks are better anticipated and can be better dealt with. This means that competitive market forces are more likely to lead to efficient outcomes. Miller et al. (2013) speak of "changing investment environments" from declining capital costs. Due to changes in the marginal cost function or renewable energies (might become flatter), a quantity-control element in policies might in this phase become important to minimise the regulator's regret (see section 3.3). Because renewable technologies have now reached a significant market share, not only total support costs become significant, but also the integration cost. In order to minimise these, renewable producers must become better integrated into the regime (Riesz et al., 2013).

4.4 Preparation for phase 2 and integration of new technologies into the regime

Even though in transition phase 1, system integration issues are not pressing, they will arise with an increasing market share of variable renewable technologies. Two issues will become important (1) securing grid infrastructure, (2) enhancing system flexibility (see Riesz et al., 2013). To ensure a smooth and successful transition, these issues should be dealt with as early as possible in the process. Grid infrastructure projects will be required if renewable energy production cannot use existing infrastructure, e.g. due to location of resources. The development of grid projects takes a very long time; challenges such as planning and coordination, securing rights of way, public acceptance, allocating costs and more need to be overcome (Miller et al., 2013), and should thus be taken on as early as possible. Enhancing system flexibility will become an issue if the conventional energy system is not built to deal with the variability coming from e.g. wind and solar energy. We know from empirical evidence that high shares of variable renewable energies can have significant influence on market prices (Klinge Jacobsen and Zvingilaite, 2010). To fully utilise the energy produced from variable renewable energies, system flexibility becomes crucial to minimise curtailments (spilled energy), supply shortages (scarcity, peak prices), and system stability (balancing, frequency control) (see also Miller et al., 2013). The technologies required for delivering additional flexibility are typically not being developed in the conventional energy system, where they are not demanded. Supporting niches must be initiated already in the early phase 1 of the transition and nurtured, so that the appropriate technologies can develop and mature. These technologies include e.g. innovative storage options, demand-side management technologies, automated demand response etc.

With a successfully coordinated management of related niches during transition phase 1, the newly matured technologies (of storage, demand response etc.) can be exploited in phase 2. The additional flexibility required in phase 2 can be provided by these technologies. However, the usefulness of the new technologies in regards to the energy transition will depend on how they are supplemented with changes in market design and regulation on regime level (i.e. price signals to consumers, faster market operation and shorter gate closure time, participation on balancing markets, etc.; see Riesz et al., 2013).

Also the renewable energy producers can be incentivised to contribute to the flexibility issue. Miller et al. (2013) call this concept 'market aware' policies. They are necessary for the power markets to continue to operate efficiently also with high shares of RES-E (p. 8). After they have overcome the first phase of learning, RES-E produces have to be prepared to become a 'normal' market player with the same responsibilities as every other power producer in the regime. More concretely, this can be (1) being part of the balancing process; and (2) incentivising reaction to market signals.

Following the concept of risk reduction, RES-E have in the early stages of development been exempted from balancing requirements. After the energy system has successfully moved from transition phase 1 to phase 2, meaning that all of the three conditions laid out in section 2.1 are fulfilled, it can be beneficial to bring RES-E producers closer to the market by including them in the balancing process. Under FIT schemes, this can e.g. be done through modifying the price guarantee from fixed tariffs into sliding premiums (or 'target price FIT', see Kitzing et al., 2012). The higher risk involved with the additional responsibility does however entail costs for RES-E producers, so the support levels need to be adjusted accordingly. Another option would be to switch the support instrument from a traditional FIT scheme to a FIP. In this situation, it is crucial that the demand of more market integration of RES-E occurs with complementary changes in market design (e.g. shorter times to gate closure etc.), so that new barriers and unexpected exposures can be avoided (Bauknecht et al., 2013). Several countries in the European Union have introduced FIP schemes in the past decade (Kitzing et al., 2012), although this in our opinion might have been done too early, because of being in transition phase 1 and without there being the necessary adjustments in market operations.

The second issue is related to reaction to market signals. Traditional FIT schemes grant a price guarantee that shields RES-E producers from market signals, so that they sometimes experience production incentives which are not socially optimal: whenever market prices are below the marginal production cost of the respective RES-E technology, it would be beneficial to stop production. With a guaranteed price, producers however have no incentive for to do so (Andor et al., 2012). With an increasing share of RES-E in the system, this issue worsens and significant net social welfare losses could be incurred. In transition phase 2, it may therefore be beneficial to expose RES-E to more market signals. This can be done by small adjustments in the FIT, e.g. through excluding production from support payments at times where market prices are below zero (as in Denmark for offshore wind; DEA, 2009), but also with more radical solutions, such as switching to FIP. Again, this should go hand in hand with respective changes in market design.

4.5 Technology cost reduction

As discussed in section 2.3, cost reduction stem from technical change and from 'organisational' improvements. In the early stages of technology development, the technology is still immature and rapid technological learning is required to bring down costs. A focus on technical improvements can be desirable in the first transition phase to accelerate technological learning and create an environment of technical leadership in a country (see section 2.3). Attention needs to be directed towards overcoming initial barriers and developing working systems. Overly strong competitive forces can be destructive for this. Risk reduction and protection from overly strong competition can help to re-direct efforts from 'organisational' learning towards technological progress. As discussed earlier, FIT schemes have generally the most risk reducing characteristics. But also TGC schemes can be adapted to remove some competitive risks, e.g. by differentiating support for different technologies (banding), and establishing price floors. However, the benefit of reducing risk in terms of cost reductions can only be temporary, as in the long run, competitive incentives are necessary to ensure market efficiency. Also, the benefits that countries might have from technological leadership, e.g. in form of a better trade balance through increased technology export, will decrease with the maturing of the technology and its spreading throughout the world. In transition phase 2, more competitive elements can and should be slowly introduced into the transition policies, thus bringing the different RES-E technologies and projects into competition with each other, and expose RES-E producers to market signals, as discussed above.

4.6 Preparation for discontinuation of policy support

Towards the end of phase 2, the energy transition will reach a point, at which the new technologies are (part of) the new 'normal' on regime level. It becomes crucial that the regime is adjusted so that the technologies can develop on a self-sustained basis. No support policy should be needed forever. Which instruments are better in terms of exit strategies has not been subject to much research yet.

Conceptually, we would expect that FIT schemes can rather easily be adapted by slowly reducing the support level until the guaranteed price has reached the market price. Then, RES-E producers will voluntarily opt out of the support. This is not the case with FIP or TGC schemes, where no producer will voluntarily give up an add-on to the market price. Here, the policy makers will have to forecast the market price developments and anticipate at which time the premium can be stepped down to zero, or the certificate market can be closed for new projects. Another complicating issue in the TGC is that it needs a certain market size with liquid trades to function efficiently. As soon as no new projects will enter the market anymore, its size will slowly decrease with the decommissioning of old plants. The price setting in an illiquid market will become more and more problematic. This shows that even in the last stages of an energy transition, new solutions have to be found and policies need to be adapted to cope with the new requirements. In general, it would be beneficial for the planning of an energy transition to have the different exit options in mind when selecting the appropriate support instruments, so that a smooth and successful transition without disruptions from unnecessary instrument switches can be ensured.

5 Conclusions

We have provided a broader evaluation framework that goes beyond 'standard' cost-benefit policy evaluation of 'which policy is better'. We have shown that in the early stages of an energy transition, it is beneficial to design policies so that they reduce risk for private investors. Considering market risks, we could show that risk reducing policies lead to faster deployment without compromising on efficiency in the early stages of the transition. When considering non-market risks, risk reducing policies and a coordinated management in regards to network and system integration have overall cost benefits.

We have shown that the conclusions about which RES-E support policy instrument is best for making an energy transition successful depend heavily on the assumptions taken in the economic assessment (e.g. if transaction cost and risk-aversion are considered). It also depends on local conditions: Energy mix, resource availability, technology cost structure, market structures, existing regulation, policy making practices and public opinion all contribute to the weighting of the different policy criteria and affect the success likelihood of the potential policy strategies. We have tried to give a somewhat comprehensive discussion of different perspectives. After all, policy making is often not a purely rational technocratic process but may depend on visions and values for society, influence by pressure groups, beliefs of 'how things work' and deeper historical and cultural influences (Jacobsson and Lauber, 2006). Although the presented approach adopts a broad perspective, many areas are still excluded from the evaluation, such as the interplay between different sectors of energy (electricity, heat, transport) or the interactions of an energy transition and its related policies with other measures (taxes, emission trading schemes, etc.) or other sectors of society (i.e. health and education).

However, a general conclusion that we can draw seems to be that in the first phase of an energy transition a focus on risk reduction efforts and creating an enabling environment for the new technology is a successful policy strategy. FIT schemes inherently reduce market risk, so they seem to be best suited for the purpose of fast deployment in niches. Also they can rather easily be adapted to cope with changing policy needs. If TGC schemes are chosen by policy makers, they can also be adapted to incorporate significant risk reduction elements. Overall, an avowedly strategic framework approach by policy makers will lead to more success. There should be a clear way forward for technology developers, investors and consumers. Tailoring the policies to the specific needs of each phase means to start with a focus on growth and accelerated deployment with reducing investor risk as the major success strategy and then evolve those policies to create an enabling environment for system integration. This will not only make the transition more likely to become reality, it will also reduce overall costs.

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