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On evaluating success in complex policy mixes: the case of renewable energy support schemes

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Abstract The aim of this paper is to propose the main elements of a theoretical and methodological framework for the assessment of the success of complex policy mixes, to highlight the conflicts between individual instruments and other elements within those mixes and to propose policy recommendations in order to mitigate them. Some criteria are defined, and different levels of analysis are considered. The challenges in evaluating policy packages are illustrated with the case of the coexistence between renewable energy support and emissions trading schemes. It is shown that policy mixes inherently lead to interactions between the different instruments, either in the form of conflicts or synergies. Conflicts are horizontal (i.e., between different types of instruments) and/or vertical (i.e., between different administrative levels). It is suggested that mitigating those conflicts could require administrative coordination. Relevant coordination could take place between different administrative levels and relate to different instruments or different design elements within similar instruments. However, given the trade-offs between different criteria, the role of coordination is necessarily limited.

Keywords Policy design · Policy mix · Renewable energy · Policy interactions · Coordination

Introduction

Policy mixes are generally justified to account for the coexistence of market failures and/or barriers to achieving certain policy goals, following Tinbergen's dictum that multiple market failures require multiple instruments (Tinbergen 1952). Given the presence of more than one market failure, no single policy can correct both simultaneously (Philibert 2011).

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It is frequently assumed in the literature that instruments complement each other in achieving policy goals and/or removing barriers (Mitchell et al. 2011). This assumes that each instrument is isolated from each other, when in reality, the instruments in those policy mixes mutually interact, leading to conflicts ("one plus one is less than two") and synergies ("one plus one is more than two"). The issue becomes even more complicated when the responsibility for the implementation of the instruments in the policy mix falls on different government levels, which are likely to have some common, but also different goals. In particular, attaining a goal at the higher administrative level may lead to winners and losers at a lower level and the interactions between instruments may reflect or even amplify the gains and losses.

The aim of this paper is to propose the main elements of a theoretical and methodological framework to assess the success of complex policy mixes, to highlight the conflicts between individual instruments within those mixes and to provide policy recommendations for mitigating them. We follow an inductive method, whereby we derive our framework and analysis based on previous work carried out on the interactions taking place in the specific policy realm of climate change mitigation and support for renewable electricity (RES-E) (del Río 2007, 2009, 2010, 2012).[1]

The literature on climate change mitigation and RES-E has often proposed combinations of instruments to address different barriers in different sectors and countries (see, for example, IPCC 2007; Mitchell et al. 2011). However, these instruments are not isolated from each other and they interact. These interactions obviously influence the assessment of the success of the policy mix. When these interactions in policy mixes have been assessed, "success" has often been defined too narrowly, i.e., based on a single criterion (cost-effectiveness in attaining the respective targets) and a single administrative level (national) (see, e.g., Braathen 2007; Böhringer and Rosendahl 2010; Lecuyer and Bibas 2011). In contrast, real-world situations, at least in the EU, are characterized by combinations of instruments pertaining to different administrative levels, i.e., the EU (such as the emissions trading scheme, ETS) or national (RES-E support). Furthermore, policy makers may find it relevant to assess the success of policy mixes with additional criteria. A relatively recent literature has considered additional criteria to those of effectiveness and cost-effectiveness. Equity, sociopolitical acceptability, dynamic efficiency and local impacts have received some attention, reflecting the fact that policy makers do take these criteria into account when implementing instruments (see Mitchell et al. 2011; Del Río et al. 2012). In addition, policy makers usually have other goals apart from CO_2 mitigation, such as security of energy supply or reduction in other non-CO_2 pollutants (Philibert 2011). Finally, when analyzing the interactions occurring in the policy mix, some see the conflicts between instruments as unavoidable and usually argue against such instrument combination (Braathen 2007; Frondel et al. 2010; Pethig and Wittlich (2009)). However, the possibility to mitigate or even remove those conflicts through an appropriate coordination of instruments and/or targets is disregarded.

Therefore, taking into account these gaps in the literature, our analysis is based on the following hypotheses:

1. The success of policy mixes depends on the types of interactions between targets and instruments.

[1] This is a similar approach to Braathen (2007) who reviews the common practice of using multiple policy instruments for environmental purposes from household waste management to energy efficiency and derives some principles for determining appropriate environmental policy mixes.

2. "Success" should be defined broadly, to include different criteria and policy goals which are relevant to different administrative levels.
3. The problems (conflicts) resulting from interactions can be mitigated by coordinating targets, instruments and/or design elements.

We base our analysis on the following assumptions:

1. The targets and instruments coexist during a certain period of time. In the EU, RES-E support schemes have been adopted sequentially in some countries. For example, in the UK, a tendering scheme was adopted in the 1990s. This was replaced by a quota with tradable green certificates (TGCs) in the 2000s and by a feed-in tariff (FIT) a few years ago. In contrast, other countries have always used the same instrument (i.e., Germany with a FIT). In the EU, RES-E support instruments were adopted in the 1990s and they have coexisted with the EU ETS since 2005, when the later was implemented.
2. We focus on the interactions of two instruments. The coexistence of more than two instruments in the energy realm is currently the case in the EU, where support for RES-E coexists with energy efficiency instruments, the EU ETS and research and development (R&D) support. However, we only focus on the interactions between two instruments, i.e., RES-E support and the EU ETS for simplicity and given the aim of this paper. This is also the interaction which has received most attention from academics and policy makers on both sides of the Atlantic (see, e.g., Fischer and Preonas 2010; Palmer et al. 2011 and Böhringer and Rosendahl 2010, among others).
3. Instruments interact to attain one target or two instruments attain two targets which partially overlap (CO_2 mitigation in the power generation sector and RES-E penetration).

Accordingly, the paper is structured as follows. The following section proposes a typology of policy mixes and a set of relevant criteria to assess them. Section "Links between crucial elements to assess policy mixes" provides the main elements of a theoretical and methodological framework to assess those policy mixes. Section "Illustrating conflicts, complementarities and synergies in type II policy mixes. The case of CO_2 mitigation and renewable electricity promotion" applies this framework to the combination of a CO_2 emissions mitigation instrument (an emissions trading scheme) and RES-E support schemes. The role and limitations of coordination to improve policy mixes are discussed in Sect. "Policy implications: the role of administrative coordination and policy integration." Section "Conclusions" concludes.

Defining success in complex policy mixes. Different policy mixes and different criteria

Types of policy mixes

Since the interaction can occur either at the level of targets or at the level of instruments, we can identify two broad groups of policy mixes and interactions:

Type I policy mix: There is one target and at least two instruments to achieve this target. The interaction takes place at the level of instruments in order to achieve the single target. The success of type I policy mixes should take into account the interaction between instruments to achieve the single goal. Therefore, the evaluation of this policy mix refers to whether attaining the target is better with two instruments or with only one when there are several barriers and/or market failures.

Type II policy mix: There are at least two targets and at least two instruments. Each instrument is adopted to reach one of those two targets. Either the targets are related to each other to some extent (overlaps) without being coordinated or those two targets are separated but interactions take place at the level of instruments with respect to the overlapping space between targets. Under type II interactions, success refers to whether compliance with both targets (CO_2 and RES-E) with two instruments (i.e., an ETS and RES-E support) scores better than compliance with only one instrument. Recall that, in this case, we have two overlapping targets. We focus on type II policy mixes in this paper, since their complexity is much greater than under type I policy mixes, i.e., it is a more interesting case from an analytical point of view, and this is the case which has also recently received more political attention in Europe and elsewhere.

Assessment criteria

Policy mixes are usually assessed according to different criteria (Table 1). The following are proposed here, based on del Río et al. (2012). See also Fleder and Haut (2008) for a discussion of several assessment criteria. The listed criteria are not necessarily the "right ones." There are multiple criteria, and therefore, policymakers may respond with multiple policy instruments and at multiple government levels.[2] Section "Illustrating conflicts, complementarities and synergies in type II policy mixes. The case of CO_2 mitigation and renewable electricity promotion" illustrates how policy mixes can be assessed according to those criteria.

The definition of common criteria has been based on an in-depth review of the literature, informal stakeholder consultations and analysis and internal discussions within the EU-funded Beyond 2020 project (see del Río et al. 2012 for further details). In order to identify relevant "a priori" criteria, we heavily drew upon existing concepts from both the environmental economics and the innovation economics literatures. This was complemented with insights from other streams of the literature, including studies on learning effects, political science, the empirical literature on RES-E policy support schemes and work on EU harmonization of RES-E support schemes. European Commision documents were also analyzed in order to infer relevant criteria.[3] Furthermore, guidelines and criteria in existing policy documents were also considered. An advanced version of the Report "Assessment criteria for identifying the main alternatives" (del Río et al. 2012) was presented in two public workshops in Brussels and one in Madrid during the fall of 2012. The relevance of the criteria was discussed with stakeholders during these workshops. National and EU policy makers attended these meetings together with other stakeholders (NGOs, utilities, RES-E generators and technology providers). There was a consensus among these stakeholders that those were the most relevant criteria to assess the success of RES-E and CO_2 policies,

[2] I thank an anonymous referee for this remark.

[3] These criteria are common in the declarations of the goals made by climate and energy regulations and instruments in Europe. An example is the recent European Climate and Energy Package. Konidari and Mavrakis (2007) and Oikonomou and Jepma (2008) provide a complete overview of the criteria used in the climate policy literature. Mitchell et al. (2011) discuss relevant criteria in the realm of RES-E support.

Table 1 Brief characterization of the criteria

Criteria	Brief characterization
Effectiveness	It refers to the ability of an instrument to achieve CO_2 and/or RES-E targets
Cost-effectiveness	This refers to the ability of an instrument to reach either RES-E or CO_2 targets at the lowest societal cost. Three sub-criteria can be distinguished: 1. Compliance with the equimarginality principle. According to economic theory, a given CO_2 or RES-E target is achieved with the lowest CO_2 abatement or electricity generation costs, respectively, when marginal costs between different polluters or power plants are equalized (Tietenberg 2008; Field and Field 2008). This means that proportionally greater RES-E deployment or CO_2 abatement is undertaken by those firms and installations with lower RES-E deployment or CO_2 abatement costs, and lower RES-E deployment and abatement by plants or emission sources with higher costs 2. Minimization of policy support costs is a concern of governments everywhere (REN21 2013; IEA 2011). Support costs (whether for the CO_2 or RES-E policy) may be paid either by electricity consumers or taxpayers 3. The administrative costs of the instrument (set-up and running costs) should also be considered
Dynamic efficiency	Impact of deployment instruments on innovation in renewable energy technologies. Promoting a diversity of technologies should be part of this criterion (Sovacool 2010). Encouraging diversity induces innovation because it activates two innovation effects as a result of deployment: private R&D and learning effects. Private R&D refers to the extent to which the RES-E deployment or CO_2 instrument encourages private R&D investments (Watanabe et al. 2000; Rogge et al. 2011). Learning effects indicates the degree to which the instrument induces cost reductions in the technologies by allowing them to advance along their learning curves (Kahouli-Brahmi 2008)
Equity	Instruments have distributive impacts. They may have more or less beneficial effects on different countries and actors within those countries. The fairness of cost sharing and the extent to which the instrument facilitates the market entry of smaller players are key aspects of equity impacts (Mitchell et al. 2011)
Environmental and economic effects	CO_2 abatement and RES-E deployment have unavoidable local impacts (positive or negative) of a different nature: socioeconomic (diversification of energy sources, job creation and regional development opportunities) and environmental (reductions in local pollutants)
Sociopolitical acceptability	Policies may not be socially acceptable and may be rejected by the population. Social rejection may be a general aspect (i.e., civil society is against the deployment of renewables or against deployment support) or may have a local character (the not-in-my-back-yard or NIMBY syndrome). Social acceptability and political feasibility go hand-in-hand

Source: Own elaboration from del Río et al. (2012) (see text)

although different stakeholders attached a different degree of importance to different criteria.[4]

Links between crucial elements to assess policy mixes

Success in policy mixes can be evaluated according to the aforementioned criteria. In addition, there are other critical elements, including market failures, policy areas to address

[4] Notwithstanding, we are aware that stakeholders may behave strategically when selecting and interpreting criteria (Felder et al. 2011).

those failures, goals, targets, technologies, instruments, design elements and different administrative levels. We provide a holistic picture of those elements. In this section, we focus on and describe those elements and try to link them in a coherent manner.

The horizontal level: linking elements to assess policy mixes

Elements to assess policy mixes

The success of complex policy mixes has to take into account the nature of interactions between policies at the same administrative level. In fact, conflicts in policy mixes can take place at different levels, i.e., between targets and/or between instruments and even between technologies. Success in policy mixes can be evaluated according to the aforementioned criteria. In addition, other critical elements should be considered, as mentioned above.

Policy makers have different goals, which materialize in the adoption of targets for those goals, and the implementation of instruments and design elements within specific instruments to achieve those goals. The success in achieving those goals is mediated by the success of policies in triggering the implementation of renewable energy technologies. At the "horizontal level," different policy instruments are implemented by the same government level, and interactions are related to the conflicts or synergies occurring at this level (horizontal interaction). Administrative agencies at the same level of government (i.e., ministries) can have different goals and, thus, support the implementation of different instruments which interact between each other.

Targets may be totally separated between each other, but they may also partially or totally overlap, as with CO_2 and RES-E targets. When overlaps exist, conflicts with respect to different criteria may occur. But even for the same target, there might be interactions at the level of instruments. Combinations of instruments may be justified if they address different goals. But even for the same goal, instruments may be used jointly if they tackle different market failures. In the climate mitigation/renewable energy policy realms, we may envision the existence of a "three-externality problem" (del Río 2010b). Each may justify the implementation of an instrument which tackles each externality.[5]

1. The *environmental externality* refers to firms not having to pay for the damages caused by their greenhouse gases (GHG) emissions.
2. The *innovation externality* is related to spillover effects enabling copying of innovations, which reduces the gains from innovative activity for the innovator without full compensation, meaning that private actors will autonomously conduct less R&D than what is needed overall.
3. The increased deployment of a technology which leads to cost reductions and technological improvements due to learning effects and dynamic economies of scale may result in a positive *deployment externality* (Stern 2006).[6] Even companies that did not initially invest in the new technologies may benefit and produce or adopt the new

[5] Other market failures may exist, including informational problems and market power. However, we have focused on the three which are most relevant to justify the coexistence of CO2 mitigation (ETS) and RES-E support policies.

[6] Since the 1970s, the costs of energy production from all technologies have fallen systematically through innovation and economies of scale in manufacture and use (apart from nuclear power). Technologies such as solar energy and offshore wind all show much scope for further innovation and cost reductions (IEA 2008). The extent of those reductions depends on the maturity of the technology. The costs of the more mature technologies are assumed to fall less than those of new technologies (IEA 2009).

technology at lower costs. Although investors can partially capture these learning benefits, e.g., using patents or their dominant position in the market (Neuhoff et al. 2009), they do not capture all these learning benefits. Thus, investments in the new technology will stay below socially optimal levels.

This coexistence of instruments may lead to negative interactions (i.e., conflicts) or positive ones (either complementary or synergistic effects). A consensus on the terms and definitions of conflicts, complementarities and synergies does not exist in the literature on interactions (del Río 2007). We can define the types of interaction taking into account their impact on one specific criterion as follows. Obviously, conflicts refer to criteria and can be assessed either in qualitative or quantitative terms:

- Strong conflict: where the addition of an instrument (X) leads to a reduction in the effect of a second instrument (Y) in the combination: $0 < X + Y < 1$.
- Weak conflict (partial complementarity). The addition of X to Y lead to a positive effect on the combination, but the impact of the combination is lower than in case both instruments are used separately: $1 < X + Y < 2$.
- Full complementarity. X adds fully to the effect of Y in the combination: $X + Y = 2$.
- Synergy. Adding X to Y magnifies the impact of the combination: $X + Y > 2$.

Linking elements to assess policy mixes

The challenge is to relate those elements to each other, in order to find causal links which allow us to assess the impact of different instruments and design elements on policy goals within policy mixes, according to different criteria. Figure 1 represents the sequence and links between the different elements.

Starting with policy areas and goals, in the climate and energy realm these usually include the three traditional dimensions of energy sustainability, i.e., environmental sustainability (CO_2 mitigation and reductions of other pollutants), security of energy supply (diversification of energy sources) and economic sustainability (a competitive energy system, i.e., affordable energy).[7] But governments also have other relevant goals (and policies serving those goals), including employment and industry creation, regional and rural development and support for innovation.

Policy goals and the three types of externalities provide justification for governments to implement policies to address them. The implementation of these policies takes place in practice through the adoption of three types of policy components: targets, instruments and design elements. The contribution of instruments and design elements to the policy goals is mediated by the extent to which they trigger the development and diffusion of specific technologies and can be evaluated according to relevant assessment criteria.[8] In other words, technologies are considered as means to an end (i.e., the goals) and their deployment is affected by the policy components.[9] Note that the criteria should assess the

[7] See, for example, EC (2012a).

[8] In turn, this contribution depends on how the instruments and design elements are implemented. Policies that are easy to understand, transparent in terms of eligibility and compliance and stable in duration and statute (Sovacool 2010) are more likely to achieve those goals.

[9] Obviously, given their qualitative differences, different technologies contribute differently to those goals and their contribution can be evaluated with the assessment criteria. Different renewable energy technologies may be promoted, leading to interactions (synergies, complementarities and conflicts) between them in attaining the targets/goals.

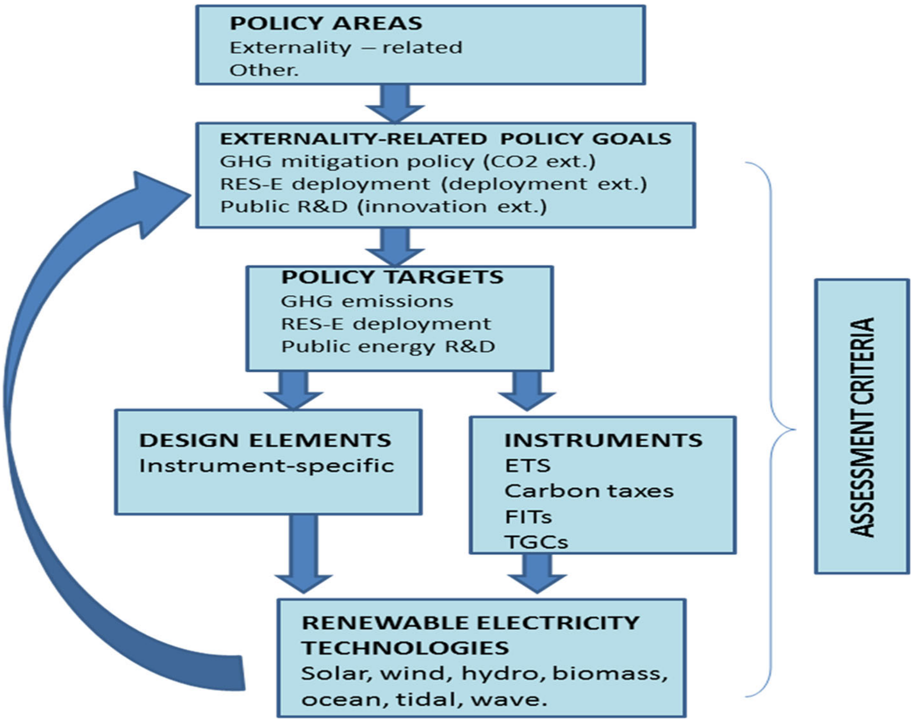

Fig. 1 Relating different elements to assess policy mixes in the climate and energy realm. *Source* own elaboration

functioning of the entire policy mix and, in particular, the contribution of instruments and design elements to all the policy goals, and not only the contribution to a single goal.

The vertical level

Obviously, the existence of different administrative levels complicates the assessment since it adds another layer to the analysis of the links between different elements of the policy mix. Goals can be defined by different administrative levels, and they may overlap, leading to interactions (conflicts or synergies). Additional conflicts may arise since the benefits and costs of achieving those targets are shared by actors at different administrative levels. Thus, considering different government levels is crucial for this analysis. Conflicts can take place at the level of targets or at the level of instruments.

The assessment of the success of the policy mix is affected by the choice of the boundaries of the system and the existence of different administrative levels. For instance, an increase in RES-E deployment in a given country might be perceived as beneficial by the national policy makers if the local benefits outweigh the local costs, but may be considered detrimental from a supranational (EU) perspective if it leads to higher costs of complying with the CO_2 or RES-E targets at the EU level (because the best EU-wide locations in terms of renewable energy resources are not used). And the other way around: A combination of an EU ETS and an EU-wide harmonized RES-E support system would create winners and losers at the country level and, thus, could be perceived as beneficial at the EU but not at the national level (see also Sect. "Illustrating conflicts, complementarities and synergies in type II policy mixes. The case of CO_2 mitigation and renewable electricity promotion").[10]

There are different alternatives for target setting under type II policy mixes when considering the involvement of national and supranational administrative levels. Either both targets are set at a supranational level or one of the targets is set at the supranational, and the other is set at the national level. There are also different possible decisions about instruments in type II interactions, i.e., at the supranational level (alternative A), national level with minimum requirements from the supranational level (B) and entirely at the national level (C). We analyze alternative A and focus on the most complex case, i.e., alternative B, in Sect. "Vertical interactions in the policy mix."

Illustrating conflicts, complementarities and synergies in type II policy mixes. The case of CO_2 mitigation and renewable electricity promotion

Goals, targets, instruments and technologies

Two targets in the climate change mitigation and RES-E penetration realms have been adopted by the EU and its member states (MS): a 20 % reduction in GHG and a share of 20 % of RES in gross inland energy consumption by 2020. The EU emissions trading scheme (EU ETS) and domestic RES-E support schemes are two instruments currently applied in Europe to comply with those targets.

Although the European Commission sets an overarching policy framework on renewables, the MS have the ability to apply specific policies to support RES-E. European support for RES-E deployment has traditionally been based on two main mechanisms, whose costs are usually borne by consumers (see Ragwitz et al. 2007 for further details):

- *Feed-in tariffs* are subsidies per kWh generated and combined with a purchase obligation by the utilities. RES-E generators receive either a premium payment added to the electricity price or an absolute amount of support.
- *Tradable Green Certificates* are certificates that can be sold in the TGC market, allowing RES-E generators to obtain revenue. This is additional to the revenue from their sales of electricity fed into the grid. The issuing (supply) of TGCs takes place for every MWh of RES-E, while demand generally originates from an obligation on electricity distributors. The TGC price is set as a result of the interaction of supply and demand.

In the past, FITs have promoted renewable energy technologies with different maturity levels and costs (Mitchell et al. 2011). TGCs mostly promote the deployment of the most mature, low-cost renewable energy technologies, whereas ETS promote the cheapest low-

[10] For example, simulations with the ADMIRE-REBUS model showed that an EU ETS combined with an EU-wide tradable green certificate system for the promotion of RES-E would be the least-cost system to deploy renewables in the EU, since the cheapest technologies and locations would be used first with this technology-neutral scheme (Uyterlinde et al. 2003). However, it was also shown that it would lead to some countries (such as Spain) being importers of certificates, which would be created by deploying RES-E elsewhere. These results were rejected by Spanish policy makers. They argued that they would better spend such money in deploying renewables in Spain and grasping the local benefits of so doing.

carbon technologies, which usually do not include renewables (except the cheapest ones) (IEA 2008, 2011).

Justification for the policy mix

From an economic point of view, there are basically two reasons to justify policy mixes in general and the combination of an ETS with RES-E deployment support in particular (Matthes 2010): the existence of different market failures to reach one policy goal and the existence of several goals, which cannot be achieved with only one instrument.

Both RES-E deployment and an ETS share one common goal (CO_2 emissions reductions), but RES-E deployment contributes to other goals in addition to CO_2 reduction, including the diversification of energy sources leading to a lower fossil-fuel dependence, a goal which is mentioned seven times in the current RES Directive (Directive 28/2009/EC). But the Directive also mentions other goals: the promotion of innovation and the creation of opportunities for employment and rural and regional development (see also EC 2012a). This is also the case in other, non-EU countries.[11]

However, several authors argue that there might be other alternatives to RES-E deployment which may achieve the non-CO_2 targets and goals in a more effective and/or cost-effective manner (Frondel et al. 2010, Fischer and Preonas 2010). While this might be true, there is clearly a role for RES-E deployment in achieving the CO_2 and non-CO_2 goals, i.e., their potential contribution to those goals, and particularly to the security of energy supply, should not be disregarded, as shown by IEA (2010).

In addition, a main justification for the policy mix lies in the market failures tackled by each instrument. Both instruments address different externalities, and thus, the combination of policies is welfare-improving. While the ETS internalizes the environmental (CO_2) externality, deployment support addresses the deployment externality (Fischer and Preonas 2010; del Río 2010). The innovation externality is addressed by a third instrument, i.e., public support for R&D (Newell 2010).

Horizontal interactions in the policy mix

The interaction between both policy realms has been judged as negative by some authors, who claim that their combination should be ruled out (Braathen 2007; Frondel et al. 2010; Pethig and Wittlich 2009). It has been argued that adding a RES-E support instrument to an already existing ETS does not make much sense, given that RES-E is an expensive way to tackle CO_2 emissions, and since CO_2 emissions are covered by a cap in an ETS, RES-E deployment triggered by RES-E policies does not lead to additional CO_2 emissions reductions (Braathen 2007; Frondel et al. 2010; Felder 2011). Renewable energy technologies are generally more expensive low-carbon technologies, and RES-E policies allow them to take part in the electricity generation mix (McKinsey 2009). This leads to higher compliance costs with the CO_2 target than would be the case in the absence of RES-E policies.[12]

[11] Recent legislation in both chambers of the US Congress has sought to create a similar "package" of federal policies to reduce emissions and stimulate renewable energy production. The House and Senate bills share the same goal: "to create clean energy jobs, achieve energy independence, reduce global warming pollution and the transition to a clean energy economy" (Fischer and Preonas 2010).

[12] Several studies find that TGC quotas substantially increase the social costs of the EU ETS (Böhringer and Rosendahl 2010; Abrell and Weigt 2008; Unger and Ahlgren 2005).

Furthermore, it is claimed that "green promotes the dirtiest" (Böhringer and Rosendahl 2010). With a given CO_2 cap, additional RES-E in the system reduces the CO_2 price in the ETS (Felder 2011). The lower CO_2 price benefits conventional fossil-fuel generators, i.e., it leads to an increased production from the most CO_2-intensive power generation technologies (typically coal power) than would be the case with an ETS alone. Furthermore, this lower price decreases innovation efforts aimed at low-emission technologies in the electricity generation sector (Matthes 2010).[13] Many authors share this traditional view, which calls into question the need to adopt RES-E support policies.[14] However, it is often forgotten that CO_2 prices do not necessarily have to be lower if the RES-E and CO_2 targets are coordinated (see Sect. "Policy implications: the role of administrative coordination and policy integration"). Furthermore, this argument fails to consider the non-CO_2 benefits of RES-E support, which might be significant (IEA 2010). In turn, an ETS cannot achieve both targets (CO_2 and RES-E deployment) cost-effectively (Jensen and Skytte 2003; Fischer and Newell 2008; Huber et al. 2004).[15]

Conflicts in the RES-E support and CO_2 mitigation realms may also exist at the level of assessment criteria. For example, if national policy makers give priority to the local benefits of RES-E deployment, they will implement a more stringent RES-E target. Obviously, this will mean that CO_2 emissions reductions will be achieved at greater abatement costs (since, as mentioned above, renewable energy technologies are a relatively expensive CO_2 abatement option). And the other way around: For the same reason, overemphasis on short-term cost-efficiency in achieving CO_2 targets makes it unlikely that ambitious RES-E targets will be adopted. Obviously, these trade-offs have to be taken into account when setting targets.

Another area of potential conflict is between cost-efficiency (equimarginality) in achieving CO_2 emissions and dynamic efficiency[16] Overemphasis on cheap emissions reductions in the short term may lock in the adoption of other, currently more expensive technologies which will be needed in the future to comply cost-effectively with ambitious CO_2 emissions reduction targets (Huber et al. 2004, 2007). If those technologies are not adopted, they will not have the necessary demand-pull which allows them to advance along their learning curve and reduce their costs. This is obviously a vicious circle which can be broken through RES-E support. In this context, a negative interaction (conflict) at the level of technologies may occur if policy makers only promote the most mature and cheapest renewable energy technologies (i.e., wind on-shore), whereas the more expensive ones (i.e., solar photovoltaics) are not supported. This would lock in the most expensive ones, which will be needed in the future to reach those targets cost-effectively (Río 2010). In fact, some instruments are more likely to promote only the least-cost technologies. This is the case of quotas with TGCs. In contrast, a wide array of technologies is supported with FITs (Sovacool 2010).

[13] However, the low CO2 prices in the EU ETS are not fundamentally related to RES-E deployment, but to lenient targets and the economic crisis (Ellerman 2013a).

[14] See Abrell and Weigt (2008); Braathen (2011); Fisher and Preonas (2010); Böhringer and Rosendahl (2010); De Jonghe et al. (2009); Lecuyer and Bibas (2011); Tsao et al. (2011); Pethig and Wittlich (2009) and Palmer et al. (2011).

[15] Using an ETS to reach a RES-E quota leads to higher consumer costs than using RES-E deployment instruments for that purpose, due to the strong emission restriction needed to increase RES-E deployment with an indirect mechanism such as an ETS (Jensen and Skytte 2003, Fischer and Newell 2008, Huber et al. 2004).

[16] See also Sovacool (2010) and del Río et al. (2012).

While it is obvious that the combination of RES-E and CO_2 targets leads to greater CO_2 abatement costs (Möst and Fichtner 2012), this narrow, static view suggests that we only have one goal (CO_2 emissions reductions) and one market failure (the CO_2 externality). Obviously, if this was the case, we should only apply one instrument. In reality, policy makers usually have several goals and there are different market failures. The additional costs of CO_2 abatement resulting from the combination of targets and instruments could be interpreted as the costs of achieving those non-CO_2 goals plus the dynamic efficiency benefits of RES-E deployment.[17]

Thus, we should not look at the costs of attaining one target with only one market failure, but different goals and market failures simultaneously. In other words, the combination may result in higher compliance costs with the CO_2 target but not necessarily to higher costs to reach all the goals jointly. In reality, the issue becomes not only whether different instruments should be combined, but also what types of instruments and design elements should be applied in order to achieve the different targets jointly but cost-effectively, i.e., at the lowest possible cost.[18] To this issue, we now turn.

Do different instruments and design elements matter?

Discussions of the energy and climate policy mix have taken place at a very abstract level, without considering specific instruments and design elements. In reality, the interaction between the ETS and RES-E support can be affected by different types of RES-E support instruments (Del Rio 2009) and by different design elements within specific instruments (del Río 2012).

With respect to instruments, the analysis of the interaction between ETS and RES-E support has mostly been based on TGC schemes in the past. However, the results of the interactions might be different when, instead of a TGC scheme, a FIT is used. When we add an ETS to preexisting RES-E support schemes, as was the case in the EU in 2005, this increases wholesale electricity prices, whatever the RES-E instrument being implemented (NERA 2005; Jensen and Skytte 2003; Felder 2011). This is so because complying with the CO_2 target under an ETS represents an additional cost for conventional electricity generators (Reinaud 2003). With a TGC scheme, no impact of the ETS on RES-E deployment can be expected because an increase in the wholesale price triggers a reduction in the TGC price, leaving total support for RES-E generators constant (Jensen and Skytte 2003; Morthorst 2003). Under a FIT premium, RES-E generators receive the wholesale electricity price plus a premium. In contrast to TGC schemes, an increase in the wholesale electricity price does not lead to a reduction in the premium, the total support received by RES-E generators or the amount paid by electricity consumers. Therefore, the retail price increases under a FIT premium (Del Rio 2009).

We may generalize this result and argue that the results of the interactions depend on whether the instruments are quantity-based or price-based. This is not only the case with RES-E support instruments, but also with CO_2 mitigation instruments. For example, the aforementioned impact of RES-E deployment on the reduction in CO_2 prices in an ETS

[17] Möst and Fichtner (2012) empirically show that the combination increases the costs to reach the CO2 target but that it fulfills other goals.

[18] This does not rule out the need to make RES-E deployment policy as efficient as possible. In particular, we should assess the extent to which the non-CO2 goals and the deployment externality justify the additional costs of RES-E deployment. These benefits should be compared to the costs of RES-E promotion. A reasonable level of support for RES-E deployment would then be justified, but this is neither cero nor excessively generous.

does not occur under a carbon tax and, thus, the problems attributed to such reduction would not take place (Ellerman 2013a). In other words, under a carbon tax, the carbon price (tax rate) is not affected by RES-E deployment, whereas RES-E deployment does affect the CO_2 allowance price under an ETS. The possibility for coordination could also be different under different types of instruments. It would be easier under quantity-based instruments (i.e., quotas with TGCs) than under price-based ones (FITs) because, in the former case, the maximum amount of RES-E generation is given by a quota, while there is in principle no maximum generation eligible for support under FITs. In other words, the future amount of RES-E generation (and, thus, the CO_2 emissions avoided) is uncertain. This makes it easier to calculate the CO_2 emissions avoided under TGCs than under FITs and to adjust the CO_2 cap accordingly.

Specific impacts of a RES-E support instrument are mediated by the instrument design elements, For example, the Spanish government implemented a cap-and-floor FIT system in 2007 for renewable energy installations participating in the market (i.e., under the premium option). If the addition of the market price plus the premium was above the cap, then RES-E generators would only receive the cap price. If it was below the floor, they would receive the floor price (del Río 2008). Thus, the combined impact of the EU ETS and the FIT on the retail price was capped. A price cap also limited the amount of RES-E deployment and, thus, the aforementioned “negative” impact on CO_2 prices. Therefore, a cap on FIT levels mitigates the need for coordination between both instruments and the impact on consumer costs.

On the other hand, different design elements of emissions trading schemes would also affect the outcomes of the policy mix. For example, a floor price for CO_2 allowances would put a limit on the reduction in CO_2 prices which comes as a result of RES-E deployment.

Vertical interactions in the policy mix

Vertical interactions occur whenever we have horizontal interactions between targets and instruments whose responsibility lies at different government/administrative levels. In the EU, there is a coexistence of targets/instruments at the supranational (ETS) and national levels (RES-E support). In the USA, federal air emission caps for SO2 or NOx coexist with regional CO_2 caps and state level renewable portfolio standard requirements. While some targets/instruments should have a supranational scope (such as CO_2 emissions reductions), the implementation of other policy instruments is more relevant at a national level, since they can incorporate national priorities and/or bring local benefits (such as RES-E deployment). The negative results of horizontal interactions are aggravated with vertical interaction because, then, the difficulty to coordinate targets/instruments is greater than under horizontal coordination with only one government level.

Have there been vertical interactions at the EU and Member State level? Before the EU Climate Change Package was implemented, a Renewable Electricity Directive (Directive 77/2001/EC) with (indicative) targets for 2010 was in force, combined with the ETS since 2005. MS could use whatever instrument they decided in order to comply with those RES-E targets. On the other hand, the overall ETS cap (target) was the addition of MS CO_2 targets. These national targets were specified in the so-called National Allocation Plans (NAPs), and according to the emissions trading Directive (Directive 87/2003/EC), they should put the country on a path to comply with its Kyoto Protocol target (European Commission 2003). However, countries had in fact a lot of leeway in interpreting what was meant by “a path to comply with their Kyoto Protocol target,” and they were quite generous in granting allowances, which resulted in an overall non-stringent CO_2 target for the EU and very low allowance prices (Ellerman and Buchner 2008). Thus, RES-E deployment is unlikely to have reduced CO_2 prices in the first compliance period 2005–2007 (Ellerman 2013a).

The negative interactions between both instruments have been mitigated in the third EU ETS compliance period (from 2013), because targets for both RES-E and CO_2 effectively lie at the EU level. A greater degree of EU harmonization has occurred after 2009 with the Climate Change Package, which included CO_2 and RES targets for both the EU and its MS for 2020. According to Ragwitz (2013), the EU CO_2 target took into account the EU RES-E target, and thus, RES-E deployment cannot be argued to have reduced CO_2 prices, leading to the aforementioned negative consequences. We return to this issue in the next section (Table 1).

Table 2 illustrates the above discussion on interactions by providing a matrix which scores the different alternatives according to key criteria and sub-criteria with respect to a situation (baseline) in which CO_2 and RES-E deployment targets are not adopted. While it is based on the results of simulations in the RES-E and CO_2 realms using the GREEN-X and PRIMES models (Huber et al. 2004, 2007; Resch et al. 2009; EC 2008), it can be adapted and used in other studies on interactions. The table lists relevant assessment criteria and sub-criteria in the first column. We focus on the three main criteria of effectiveness, cost-effectiveness and dynamic efficiency, which can be analyzed using the results of the aforementioned simulations. Columns (1)–(3) show the score regarding different criteria when only CO_2 mitigation instruments (such as an ETS), but no dedicated RES-E support is used (1), when only RES-E support, but no ETS is implemented (2) and when both types of instruments are combined (3). In these three columns, responsibility for the instruments lies at the national level. The same structure is reproduced in columns (4)–(6) which refer to a situation in which the CO_2 instrument (ETS) is the responsibility of a supranational entity (the EU), but RES-E support falls in the realm of national policy makers. In columns (7)–(9), the responsibility for all instruments falls on the supranational (EU) level. Therefore, the impact of policy combinations on those criteria with respect to the use of single instruments for different alternatives of responsibility for CO_2 or RES-E deployment instruments (either national or supranational) is shown in columns 3, 6 and 9. It is shown whether attaining both targets (CO_2 and RES-E) with two instruments (ETS + RES support) scores better in each criteria compared to the use of a single instrument (ETS or RES support).

The results show that combinations generally score better than the use of single instruments. However, if policy makers strongly favor a specific criterion over others, then the combination may not look so attractive. In particular, the combination generally scores worse than the use of single instruments regarding the cost-effectiveness of the combination according to the equimarginality criterion (whether to reach the CO_2 or the RES-E target). As mentioned above, with a RES-E target, RES-E deployment (a relatively expensive abatement option) is made part of the combination of alternatives which is used to comply with the CO_2 target, and it is not cost-effective in this context. Regarding the effectiveness criterion, a single CO_2 target does not guarantee fulfillment of the RES-E target and a single RES-E target does not guarantee compliance with the CO_2 target (Jensen and Skytte 2003). Thus, a combination of targets is superior. Concerning dynamic efficiency, a CO_2 target would not encourage the diffusion of the less mature/more expensive renewable energy technologies, unless the target was set at a very ambitious level, leading to very high CO_2 allowance prices, which is not realistic for political economy reasons (Del Río 2010). Lack of deployment would not activate the learning effects and private R&D investments which would lead to innovation. Thus, combining a CO_2 and a RES-E deployment target would also be superior.

Table 2 Structuring the discussion on type II interactions for the overlapping target

Criteria/sub-criteria	Responsibility for the instrument								
	National			National/International			International		
	CO_2 (1)	RES-E (2)	Combination (3)[a]	CO_2 (int.) (4)	RES-E (nat.) (5)	Combination (6)	CO_2 (7)	RES-E (8)	Combination (9)
Cost-effectiveness									
Equimarginality									
CO_2 target	++	=	+	+++	=	+	+++	=	+
RES-E target	++	+/= [b]	+	+++	+/=[b]	+	+++	++/=[b]	++
Policy costs									
CO_2 target	++	=[b]	+	+++	=	++	+++	=	++
RES-E target	=	++/0[b]	++/=[b]	=	++/=[b]	++	=	++/=	++
Administrative costs									
CO_2 target	+	++	+ (>than (1))	++	++	+	++	++	+
RES-E target	+	+/=[b]	+ (>than (1))	++	+/=[b]	=	++	+/=	=
Effectiveness									
CO_2 target	++	0	++	++	=	++	++	=	++
RES-E target	=	++	++	=	++	++	=	++	+++
Dynamic efficiency									
Private R&D	=	+	+	=	+	+	=	+	+
Learning effects	=	+	+	=	+	+	=	+	=/+ (less effective for immature tech. than under 7)

Source: Own elaboration based on simulation models (see text). (++) means strong positive impact on the respective criteria/sub-criteria with respect to the absence of any CO_2 or RES-E support instrument; (+) positive impact; (=) no impact

[a] Combination means that there are, both, a CO_2 and a RES target. [b] This result depends on the instrument being chosen

Policy implications: the role of administrative coordination and policy integration

Horizontal and vertical coordination

As mentioned before, the traditional perspective on the interactions between ETS and RES-E support is based on the idea that if RES-E support is added to an ETS, the reduction in the allowance price will negatively affect cost-effectiveness. Again, we are not dealing with instruments trying to achieve one target (CO_2 emissions), but with the simultaneous attainment of two targets (CO_2 and RES-E deployment) with those instruments, considering different criteria. Most studies simplistically tackle this issue as if it was one of type I interactions, when in reality it is a more complex one, i.e., it is one of type II interactions.

The alleged problem of reducing CO_2 emissions as a result of RES-E deployment can be mitigated by ex-ante coordinating the CO_2 and RES-E targets, so that the expected CO_2 emissions reductions due to RES-E deployment are considered when setting the CO_2 target, i.e., the ETS cap. A more stringent CO_2 cap (and, thus, a higher CO_2 allowance price) would then result.

Of course, due to uncertainty about how much CO_2 emissions will be reduced due to an additional amount of RES-E, it is not an easy task to make a precise adjustment to the emissions reduction target (Skytte 2006, p. 9). A baseline for the CO_2 emissions that would have been emitted in the absence of a RES-E target has to be defined, which is always subject to major uncertainties (Philibert 2011).[19] However, this problem is similar to the calculation of the emissions reductions for projects under the Clean Development Mechanism (CDM) of the Kyoto Protocol, and a methodology has been designed by the United Nations Framework Convention on Climate Change (UNFCCC) to make this calculation (see UNFCCC 2011).[20]

It might be argued that for political economy reasons (i.e., given the associated benefits and costs), it is difficult to achieve coordination when the targets and instruments fall on different jurisdictions, and thus, the respective policy makers have different interests and views on coordination. This could have been a problem in the first ETS compliance period (2005–2007), but not currently. At that time, guidelines for coordination between both targets were set in a Communication from the European Commission (EC 2004), which required that CO_2 allowances were allocated by each country in their NAPs taking into account the CO_2 emissions reduced as a result of the national RES-E deployment. Since both RES-E deployment and ETS targets (through the aforementioned NAPs) were to some extent in the hands of countries, coordination between both targets was in reality quite imperfect (Rathmann 2007).[21]

[19] RES-E is particularly challenging: It requires an assessment of the CO2 content of the kWh it displaces, which depends on the merit order (i.e. the last production capacity required to fulfill the demand at every moment). These elements typically differ from one country to another (Philibert 2011).

[20] The CDM methodology for determining a baseline emission factor usually takes a weighted average of existing capacity (operating margin) and newly invested capacity in a country, thereby assuming that the weighted capacity in the baseline is a reflection of policy instruments implemented in the country. The instruments themselves are not directly included in the baseline methodology; they are more specifically addressed in the CDM additionality tool. I thank an anonymous reviewer for this remark.

[21] For example, the rise in RES-E and the corresponding emission reductions were not anticipated in the German NAP (Rathmann 2007), although this seems to have changed later since, according to Matthes (2010), the expected CO2 reductions in Germany due to RES-E promotion were taken into account in reducing the cap accordingly.

A greater degree of EU harmonization has occurred after 2009 with the Energy and Climate Package. CO_2 and renewable energy targets for both the EU and its member states were set at EU level for 2020. The EU RES-E target has been taken into account in the setting of the CO_2 target, according to the Annex of the impact assessment of the Energy and Climate Package (EC 2008) and the opinion of some climate change and energy experts (Ellerman 2013b; Ragwitz 2013).[22] However, it is not totally clear that the targets were set taking into account the respective interactions between both targets. Although the impact of the RES-E target on the CO_2 price was analyzed (EC 2008), a different issue is whether the CO_2 target was set considering the expected CO_2 price reduction due to the RES-E target.

The limited role of coordination with conflicts between criteria

While coordination between the agencies responsible for the setting of targets might be useful to increase the possibility of success of policy mixes, there might be inherent conflicts and trade-offs between instruments with respect to specific criteria or goals, i.e., improving one criterion could worsen another. Thus, it is difficult to fulfill all the goals and criteria simultaneously, as shown above. A multi criteria framework would make those conflicts explicit.

Horizontal coordination requires vertical coordination if responsibility for targets and instruments in different yet overlapping policy areas lies at different administrative levels. The fine-tuning of those targets and instruments would require agreement between European and national policy makers for their smooth coexistence. However, the existence of different jurisdictions responsible for each instrument adds further complications. Thus, the coexistence of instruments aimed at different goals and with different territorial scopes may lead to conflicts which are difficult to mitigate through coordination.

Policy integration, meaning co-visioning and implementation of several policies (Ashford and Hall 2011) are difficult as long as instruments and targets bring benefits and costs to specific territories.[23] Policies at higher administrative levels tend to create winners and losers at lower levels. If this is the case, as with the costs and benefits of RES-E promotion, there is an incentive for national governments to keep responsibility for policies at a national level.[24] Therefore, integration of policies is likely to be more of a hope for the future that something that can be achieved in the short run, at least in the EU.[25] Thus, it is less ambitious but more pragmatic to aim at enhanced coordination between administrative

[22] A quantitative assessment of the interaction between the RES and GHG targets but also between CO2 prices and RES support level is provided in EC (2008). The scenarios show that a carbon price of 49 €/tCO2 is required to achieve the 20 % GHG reduction commitment if no RES policies are put in place. But if RES policies are introduced to achieve the RES target, a carbon price of 39 €/tCO2 would achieve the same GHG reduction target. A 20 % GHG target only would result in a RES penetration of 15.8 % in 2020 (far from the 20 % RES target). A 20 % RES target only would reduce GHG emissions by 9.3 %, i.e., also far from the 20 % GHG emissions reduction target.

[23] See Jordan and Lenschow (2010) and Nilsson and Eckerberg (2007) for a review of the literature on environmental policy integration.

[24] The failure to create an internal electricity market due to the rejection of some countries, in spite of the 1996 Directive on the internal energy market, seems to confirm this pessimistic expectation (see European Commission 2012b). The initial, failed attempts to fully harmonize RES-E support schemes in the EU by the European Commission (Resch et al. 2013) also confirm this statement.

[25] According to Ashford and Hall (2011), integration requires (1) addressing multiple goals (e.g., economic development, employment, environment and public health) in the same piece of legislation or at least passing a group of complementary laws in parallel fashion, (2) planning regulatory and programmatic

levels on different topics and choose instruments and design elements which facilitate an "automatic coordination" of targets.

Conclusions

Some messages can be derived from this analysis for the assessment of the success of policy mixes more generally.

1. *A broad view of elements in policy mixes is needed.* Appropriate policy evaluations cannot be conducted in a narrow context. The focus should not be on the functioning of specific instruments with respect to one specific criterion, but on the functioning of the whole policy mix and the conflicts and synergies with respect to several goals and criteria in this mix. This is particularly challenging with overlapping policies. What might be regarded as conflictive with respect to the interactions between two instruments might not be so problematic when a broader picture is considered, i.e., different goals/instruments. Furthermore, it is virtually impossible to satisfy all the assessment criteria with different instruments for one or more targets. The best way to identify inherent trade-offs and conflicts between criteria is to adopt a multi criteria framework which makes those conflicts explicit. This allows policy makers to give weights to those criteria and decide on the trade-offs according to their preferences.
2. *Analyses are policy-mix dependent* . While a general theoretical and methodological framework for the analysis of interactions can be built, there are too many differences between policy mixes to provide a general prescription. Thus, extrapolations to other policy mixes are necessarily limited. The analysis of "success" is necessarily policy mix specific.
3. *The devil is in the details.* Policy mixes can be assessed at a general level by identifying spaces of conflicts, complementarities and synergies between policy fields, but those interactions also depend on the type of instrument being adopted and the specific design elements of the instruments adopted within those policy fields. The choice of specific instruments and design elements within the interacting policy fields may contribute to mitigate conflicts and promote complementarities and synergies. Coordination is easier under certain instruments and design elements than under others.
4. *Design of policy mixes vs. design of specific instruments.* The focus should move from the design of specific instruments to the appropriate design of instrument mixes. As argued by Sovacool (2009), policy mechanisms must be implemented comprehensively, not individually. However, this is more difficult to do when responsibility for the instruments lies in different administrative/territorial levels.
5. *Limited role of horizontal and vertical coordination.* There is certainly a role for coordination between targets and instruments to mitigate conflicts and to promote complementarities and synergies in policy mixes. But owing to the aforementioned trade-offs, the role of coordination is necessarily limited even at the same administrative level. It cannot achieve the highest score in conflicting criteria, and balances are unavoidable. The existence of different goals at different administrative

Footnote 25 continued
initiatives with participants from different governmental authorities and (3) deliberate simultaneous or staged implementation and monitoring involving different governmental authorities.

levels complicates the role that coordination can play in successful policy mixes. Different goals may create winners and losers at different levels and, thus, lead to unacceptable distributional effects.

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References

Abrell, J., & Weigt, H. (2008). *The interaction of emissions trading and renewable energy promotion, economics of global warming, WP-EGW-05*. Dresden: Dresden University of Technology.

Ashford, N., & Hall, R. (2011). The importance of regulation-induced innovation for sustainable development. *Sustainability, 3*, 270–292.

Böhringer, C., & Rosendahl, K. (2010). Green promotes the dirtiest: On the interaction between black and green quotas in energy markets. *Journal of Regulatory Economics, 37*, 316–325.

Braathen, N. A. (2007). Instrument mixes for environmental policy: How many stones should be used to kill a bird? *International Review of Environmental and Resource Economics, 1*, 185–235.

Braathen, N. A. (2011). Interactions between emission trading systems and other overlapping policy instruments. OECD Green Growth Papers 2011–02.

De Jonghe, C., et al. (2009). Interactions between measures for the support of electricity from renewable energy sources and CO_2 mitigation. *Energy Policy, 37*, 4743–4752.

del Río, P. (2007). The interaction between emissions trading and renewable electricity support schemes. An overview of the literature. *Mitigation and Adaptation Strategies for Global Change, 12*, 1363–1390.

Del Río, P. (2008). Ten years of renewable electricity policies in Spain: An analysis of successive feed-in tariff reforms. *Energy Policy, 36*(8), 2917–2929.

Del Rio, P. (2009). Interactions between climate and energy policies: The case of Spain. *Climate Policy, 9*, 119–138.

Del Río, P. (2010a). Analysing the interactions between renewable energy promotion and energy efficiency support schemes: The impact of different instruments and design elements. *Energy Policy, 38*(9), 4978–4989.

Del Río, P. (2010b). Climate change policies and new technologies. In E. Cerdá, X. Labandeira, & X. Labandeira (Eds.), *Climate change policies: Global challenges and future prospects* (pp. 49–68). Cheltenham: Edward Elgar.

Del Río, P. (2012). The dynamic efficiency of feed-in tariffs: The impact of different design elements. *Energy Policy, 41*, 139–151.

Del Río, P., Ragwitz, M., Steinhilber, S., Resch, G., Busch, S., Klessmann, C., De Lovinfosse, I., Van Nysten, J., Fouquet, D., Johnston, A. (2012). Assessment criteria for identifying the main alternatives. D2.2 report under the beyond 2020 project, funded by the Intelligent Energy—Europe program http://www.res-policy-beyond2020.eu/.

EC. (2004). Communication from the Commission on guidance to assist Member States in the implementation of the criteria listed in Annex III to Directive 2003/87/EC. COM (2003) 830 final.

EC. (2008). Annex of the European commission impact assessment document of the energy and climate package.

EC. (2012a). Energy roadmap to 2050. http://ec.europa.eu/energy/publications/doc/2012_energy_roadmap_2050_en.pdf.

EC. (2012b). Communication COM (2012) 663 of 15 November 2012: Making the internal energy market work.

Ellerman, D. (2013a).What to expect from the third phase of the EU ETS, workshop economic challenges for energy, Madrid. January 11th 2013.

Ellerman, D. (2013b). Personal communication. Madrid, January 11th 2013.

Ellerman, D., & Buchner, B. (2008). Over-allocation or abatement? A preliminary analysis of the EU ETS based on the 2005-06 emissions data. *Environmental & Resource Economics, 41*(2), 267–287.

European Commission (EC). (2003). Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC.

Felder, F. (2011). Examining electricity price suppression due to renewable resources and other grid investments. *The Electricity Journal, 24*(4), 34–46.

Felder, F., Andrews, C., & Hulkower, S. (2011). Global Energy Futures and Their Economic and Environmental Implications. In F. P. Sioshansi (Ed.), *Energy Sustainability and the Environment: Technology, incentives, behavior* (pp. 30–61). Amsterdam: Elsevier Press.

Felder, F., & Haut, R. (2008). Balancing alternatives and avoiding false dichotomies to make informed US. *Electricity Policy, Policy Sciences, 41*, 165–180.

Field, B., & Field, M. (2008). *Environmental Economics*. New york: McGraw-Hill.

Fischer, C., & Newell, R. (2008). Environmental and technology policies for climate mitigation. *Journal of Environmental Economics and Management*, *55*(2), 142–62.

Fischer, C., & Preonas, L. (2010). Combining policies for renewable energy: Is the whole less than the sum of its parts? *International Review of Environmental and Resource Economics, 4*, 51–92.

Frondel, M., Ritter, N., Schmidt, C., & Vance, C. (2010). Economic impacts from the promotion of renewable energy technologies: The German experience. *Energy Policy, 38*, 4048–4056.

Huber, C., Ryan, L., O′Gallachoir, B., Resch, G., Polaski, K., & Bazilian, M. (2007). Economic modeling of price support mechanisms for renewable energy: Case study on Ireland. *Energy Policy, 35*(2), 1172–1185.

Huber, C., et al. (2004). *Green-X: Deriving Optimal Promotion Strategies for Increasing the Share of RES-E in a Dynamic European Electricity Market*. Vienna: Vienna University of Technology Energy Economics Group.

IEA. (2009). World energy outlook. Paris.

IEA. (2010). World energy outlook. Paris.

IEA. (2011). Deploying renewables. Paris.

Intergovernmental Panel on Climate Change (IPCC). (2007). Fourth assessment report, working group III. Summary for policymakers. Geneva.

International Energy Agency (IEA). (2008). Deploying renewables. Paris.

Jensen, S. G., & Skytte, K. (2003). Simultaneous attainment of energy goals by means of green certificates and emission permits. *Energy Policy, 31*, 63–71.

Jordan, A., & Lenschow, A. (2010). Environmental policy integration: A state of art review. *Environmental Policy and Governance, 20*, 147–158.

Kahouli-Brahmi, S. (2008). Technological learning in energy–environment–economy modelling: A survey. *Energy Policy, 36*, 138–162.

Konidari, P., & Mavrakis, D. (2007). A multi-criteria evaluation method for climate change mitigation policy instruments. *Energy Policy, 35*(12), 6235–6257.

Lecuyer, O., Bibas, L. (2011). Combining climate and energy policies: Synergies or antagonism? FEEM Nota di lavoro 98/2011.

Matthes, F. C. (2010). *Greenhouse Gas Emissions Trading and Complementary Policies Developing a Smart Mix for Ambitious Climate Policies*. Berlin: Oko-Institut.

McKinsey. (2009). *Pathways to a low-carbon economy*. New york: McKinsey & Company.

Mitchell, C., Sawin, J. L., Pokharel, G. R., Kammen, D.,Wang, Z., Fifita, S., et al. (2011). Policy, financing and implementation. In: IPCC special report on renewable energy sources and climate change mitigation, Cambridge, Cambridge University Press, available at http://srren.ipcc-wg3.de/report/IPCC_SRREN_Ch11.pdf.

Morthorst, P. E. (2003). National environmental targets and international emission reduction instruments. *Energy Policy, 31*(73), 83.

Möst, D., & Fichtner, W. (2012). Renewable energy sources in European energy supply and interactions with emission trading. *Energy Policy, 38*, 2898–2910.

NERA. (2005). *Interactions of the EU ETS with Green and White Certificate Schemes*. London: NERA Economic consulting.

Neuhoff, K., Dröge, S., Edenhofer, O., Flachsland, C., Held, H., Ragwitz, M., et al. (2009). Translating model results into economic policies RECIPE Working paper, available online at www.pik-potsdam.de/recipe.

Newell, R. (2010). The role of markets and policies in delivering innovation for climate change mitigation. *Oxford Review of Economic Policy, 26*(2), 253–269.

Nilsson, M., & Eckerberg, K. (Eds.). (2007). *Environmental Policy Integration in Practice: Shaping Institutions for Learning*. London: Earthscan.

Oikonomou, V., & Jepma, C. (2008). A framework on interactions of climate and energy policy instruments. *Mitigation and Adaptation Strategies for Global Change, 13*(2), 131–156.

Palmer K., Paul, A., Woerman, M. (2011). Federal policies for renewable electricity: Impacts and interactions. RFF DP 10–53.

Pethig, R., Wittlich, C. (2009). Interaction of carbon reduction and green energy promotion in a small fossil-fuel importing economy. CESIfo Working Paper no. 2749. Munich.

Philibert, C. (2011). *Interactions of Policies for Renewable Energy and Climate. Working Paper*. Paris: International Energy Agency.

Ragwitz, M. (2013). Personal communication. January 10th 2013.

Ragwitz, M., Held, A., Resch, G., Faber, T., Haas, R., et al., (2007). OPTRES—assessment and optimisation of renewable energy support schemes in the European electricity market. Supported by the European Commission (D.G. Energy and Transport), Brussels.

Rathmann, M. (2007). Do support systems for RES-E reduce EU-ETS-driven electricity prices? *Energy Policy, 35*, 342–349.

Reinaud, J. (2003). *Emissions trading and its possible impacts on investment decisions in the power sector*. Paris: IEA information paper.

Renewable Energy Policy Network for the 21st Century (REN21). (2013). Global status report 2013. Paris. Available at: www.ren21.net.

Resch, G., Gephart, M., Steinhilber, S., Klessmann, C., del Rio, P., & Ragwitz, M. (2013). Coordination or harmonization? Feasible pathways for a European RES strategy beyond 2020. *Energy & Environment, 24*(1–2), 147–170.

Resch, G., Rawgitz, M., Panzer, C., & Haas, R. (2009). *20% RES by 2020*. Viena: European Congress of the International Association for Energy Economics.

Rogge, K., Schneider, M., & Hoffmann, V. (2011). The innovation impact of the EU emission trading system—findings of company case studies in the German power sector. *Ecological Economics, 70*(3), 513–523.

Skytte, K. (2006). Interplay between environmental regulation and power markets. European University Institute Working Papers no 2006/04, San Domenico, Italy.

Sovacool, B. K. (2009). The importance of comprehensiveness in renewable electricity and energy efficiency policy. *Energy Policy, 37*(4), 1529–1541.

Sovacool, B. K. (2010). A comparative analysis of renewable electricity support mechanisms. *Energy, 35*(4), 1779–1793.

Stern, N. (2006). *Stern Review Report on the Economics of Climate Change*. HM Treasury: Cambridge University Press.

Tietenberg, T. (2008). Environmental and natural resource economics: International Edition, 8/E Pearson Higher Education.

Tinbergen, J. (1952). *On the Theory of Economic Policy*. Amsterdam: North-Holland.

Tsao, C., Campbell, J., & Chen, Y. (2011). When renewable portfolio standards meet cap-and-trade regulations in the electricity sector: Market interactions, profits implications, and policy redundancy. *Energy Policy, 39*, 3966–3974.

UNFCCC (United Nations Framework Convention on Climate Change). (2011). Tool to calculate the emission factor for an electricity system. Version 02.2.1. Sep, 2011. Available: http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v2.2.1.pdf. Accessed September 7, 2012.

Unger, T., & Ahlgren, E. (2005). Impacts of a common green certificate market on electricity and CO_2 emission markets in the Nordic countries. *Energy Policy, 33*, 2152–2163.

Uyterlinde, M. A., Daniels, B. W., deNoord, M., de Vries, H. J., de Zoeten, C., Skytte, K., et al. (2003). Renewable electricity market developments in the European Union—final report of the ADMIRE REBUS project.

Watanabe, C., Wakabayashi, K., & Miyazawa, T. (2000). Industrial dynamism and the creation of a virtuous cycle between R&D market growth and price reduction. The case of photovoltaic power generation (PV) development in Japan. *Technovation, 20*(6), 299–312.