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Article

Horizontal and Vertical Reinforcement in Global Climate Governance

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Abstract: This paper is dealing with mechanisms that can accelerate the global diffusion of climate-friendly technologies. The accelerated diffusion of low-carbon technology innovation can possibly be achieved by interactive processes such as: (1) mutually reinforcing cycles of policy-induced domestic market growth, innovation, and policy feedback; (2) lead markets and political lesson-drawing, the reinforced international adoption of innovations from pioneer countries; and (3) interaction between the vertical and horizontal dynamics in multi-level systems of governance. The three mechanisms are not exclusive. They can overlap and reinforce each other. After a theoretical introduction they will be described. The empirical focus is on the European system of multi-level climate governance. The paper draws some final conclusions for policy makers.

Keywords: climate policy; innovation/diffusion; multi-level governance; European Union

1. Introduction

The increase of greenhouse gases and the scientific consensus on the consequences of manmade changes to the atmosphere of the Earth is a dramatic challenge to the governance of necessary climate mitigation. What is needed is a high speed of technological change towards a low-carbon economy, comparable to the industrial revolutions of past centuries, and it can be asked what strategic options exist that can accelerate mitigation efforts. Evidence shows that indeed, there have been cases of accelerated change in the last decade. The international diffusion of renewable energy technologies is a prominent example. This paper deals with mechanisms that can accelerate the diffusion of climate-friendly technologies.

Three types of interactive processes seem to be interesting in this regard:

(1) Mutually reinforcing cycles: the interactive reinforcement of policy-induced domestic market growth, induced innovation, and policy feedback.
(2) Reinforced international diffusion of innovations from pioneer countries, which can be both (a) the diffusion of low-carbon technologies from lead-markets and (b) the diffusion of the supporting policy resulting from "lesson-drawing" by other countries.
(3) Reinforced diffusion by multi-level governance: Multi-level governance can stimulate vertical and horizontal learning at all levels of the global system. This has become particularly relevant regarding horizontal dynamics on the sub-national level being induced by higher levels.

These mechanisms are characterized by a multi-factorial interactive reinforcement of innovation and diffusion processes. A reinforced diffusion of climate-friendly technology can be observed at different levels of the multi-level system of global governance. The following analysis will refer to selected cases of best practice (a pragmatic methodological decision, which excludes the discussion of failures).

2. Economic and Political Mechanisms of Accelerated Diffusion

Mechanisms of acceleration and self-reinforcement are not unknown in economics and in political science. Brian Arthur presented a theoretical discussion on "dynamical systems of the self-reinforcing or autocatalytic type" both in the natural sciences and in economics. According to Arthur, self-reinforcing mechanisms in economics are related to four "generic sources":

- *Large set-up or fixed costs*, giving advantage to increasing economies of scale.
- *Learning effects*, which act to improve products or lower their costs.
- *Coordination effects*, which confer advantages to "going along" with other economic agents.
- *Adaptive expectations*, where increased prevalence in the market enhances beliefs of further prevalence [1].

Arthur mentions "virtuous cycles" and the option of "strategic action" as well as the possible role of policy "to 'tilt' the market" toward certain dynamics [1]. He also mentions an important condition for a new equilibrium: "self-reinforcement (that) is not offset by countervailing forces" but supported by "local positive feedbacks" [1]. Although this is not extended and lacks discussion or empirical analysis, Arthur gives a remarkable early theoretical view of a phenomenon that has become highly important, particularly in environment and climate policy research. We will present empirical cases, which are compatible with the typology of his "generic sources", but the picture is different if the mechanism of policy-feedback is included.

Modern *innovation research*, particularly on eco-innovation, has brought new theoretical and empirical insights into the phenomenon of accelerated technical change [2–5]. Political science has added the dimension of policy feedbacks to the interpretation of interactive dynamics in modern policy-making [6,7]: Policies generate resources, incentives, and information for political actors, which can reinforce the policy.

The present author has contributed to this research by adding the policy cycle to the reinforcing cycles of market growth and innovation in an analytical model for the diffusion of clean energy technology [8]. The policy cycle (agenda setting-policy formulation-decision-implementation-policy outcome-evaluation-new agenda setting, *etc.*) is a mechanism of policy learning and change. It is particularly open to policy feedback, for instance if there are unexpected co-benefits of the policy.

"Lesson-drawing" [9] is another potential mechanism of political reinforcement. It can support the diffusion of policy innovations, for instance if there is a certain "group dynamics" of countries: a collective learning leading to the broad adoption of a certain "trendy solution" [10].

There may be more types of acceleration. Economic but also regulatory competition [11] can reinforce the diffusion of goods or policies. Both economists and political scientists are familiar with the purposeful use of a window of opportunity [12]. Here we find an incidental convergence of "multiple streams" providing a situational opportunity for decision makers [13]. However, this does not necessarily produce a stable result. Windows of opportunity (such as the situation after the Chernobyl catastrophe) often close after a while. Therefore this type of acceleration is excluded from consideration here. This article deals with an accelerated transformation, *i.e.*, change with stable long-term effects [7].

The diffusion of innovative low-carbon technologies and innovative supporting policies are typically interlinked. There is, however, no clear causal relationship, but a pattern of multiple interactions between technology and policy [14]. Policy can support the innovators of a low-carbon technology, and the innovators may provide new technology-based policy options for climate policy. Policy may act as a first mover, and its diffusion by lesson-drawing may support the diffusion of the technology. Often, the technological innovation comes first (as in the case of wind power) and governmental support can reinforce its success in national and global markets. In any case, the interaction between policy and technology can contribute to a reinforced diffusion of both the low-carbon technology and the supporting policy. This is a "coordination effect" in terms of Arthur's classification [1].

In recent times there has been a rejuvenation of industrial policy [15,16]. It seems that green growth strategies and the designing of environmental and climate protection in terms of industrial policy are prominent examples of this tendency [17–20]. The translation of environmental and climate policy goals into the language of a technology-based economic strategy has become a success story in Germany and other countries such as China. Many governments regard themselves as actors in a highly competitive global market for clean technologies, in which innovation is considered the core of competitiveness [21,22]. From the perspective of climate policy this means that this policy has been able to mobilize economic interests. The following analysis will show that this ability can be observed at all levels of the global multi-level governance system.

3. Interactive Cycles of Climate-Friendly Innovation

It is a basic economic truth that growing markets induce demand for further innovation, which reduces production costs, improves the quality of the end-product and often reinforces market growth again. This is the learning effect in Arthur's classification [1]. Markets for climate-friendly technologies, however, are characterized by the fact that they are typically policy-driven [23].

Therefore, a third dynamic mechanism is relevant: not only the market and the technical innovation cycle, but also the policy cycle (see also [24]). It is essentially a political learning process from agenda-setting and policy formulation to the final outcomes and their evaluation.

Reinforcement by interactive cycles of low-carbon innovation can therefore be described as follows:

- Ambitious targets based on a clean-energy innovation plus effective policy implementation.
- Market growth of the supported clean-energy technology.
- Induced technological learning (secondary innovation).
- More ambitious targets: policy feedback from the new economic interests.

It has been shown that cases of accelerated diffusion of low-carbon technologies can be explained by the interaction of the three cycles (Figure 1). The author has studied 15 empirical cases in which these kinds of dynamic interactions can be observed [8,21]. The example of green power in Germany alongside the successive increase of targets (2020) is shown in Figure 2. As in certain other cases, the policy starts with an ambitious target inducing an unexpected market growth, which again induces innovation and finally a positive policy feedback in the form of an increase in the policy's targets. In 2000, the ambitious (and originally contested) German target was 20% green power by 2020. It was increased after nine years and again only one year later. The target for 2025 is now 40%–45% (compared with 1990).

Even more remarkable is the example of wind and solar energy in China. The target for wind power to be installed by 2020 was several times increased, from 20 GW to 200 GW, due to an unexpected rapid diffusion. The example of installed PV capacity is shown in Figure 3. Here the target increased from 1.8 to 100 GW.

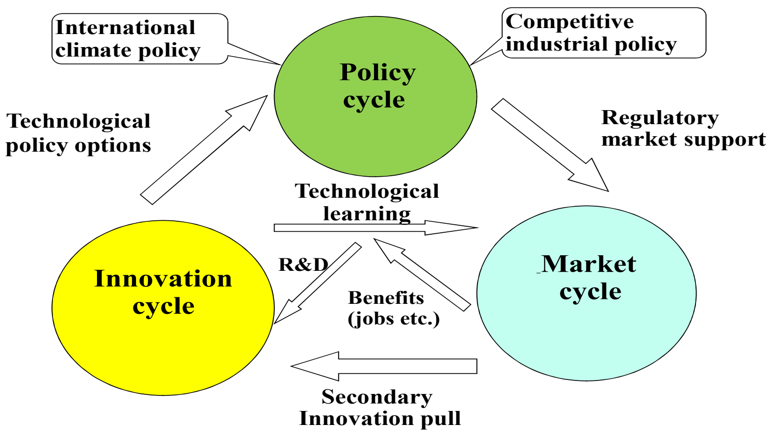

Figure 1. Mutually reinforcing cycles of clean-energy innovation [8].

The Intergovernmental Panel on Climate Change in its Special Report on Renewable Energy Resources and Climate Change Mitigation has drawn the policy conclusion regarding the "virtuous cycles" of clean-energy innovation: "that long-term objectives for renewable energies and flexibility to learn from experience would be critical to achieve cost-effective and high penetrations of renewable energies" [5].

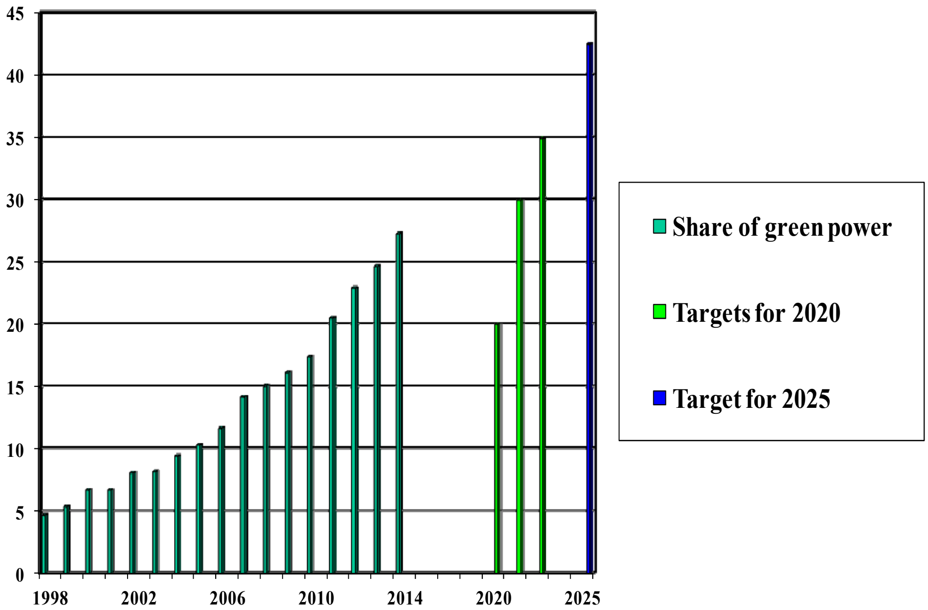

Figure 2. Share of green power 1998–2014 and targets for 2020/2025 in Germany (BMUB 2015).

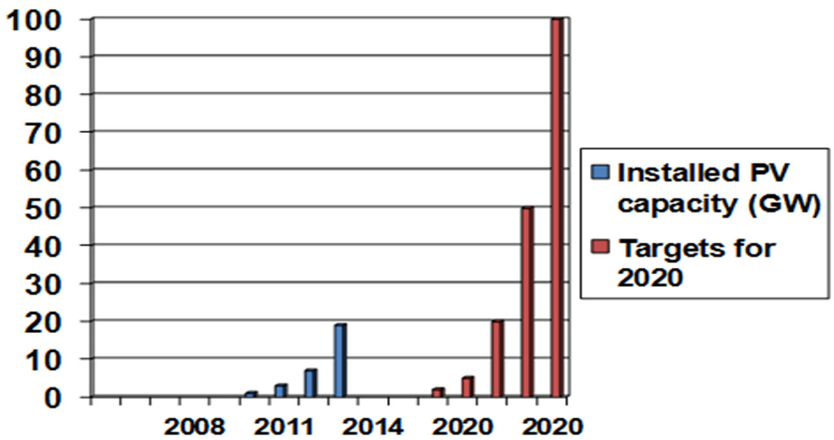

Figure 3. Installed PV capacity in China and targets for 2020 (Data basis REN21 2014).

4. Enforced Diffusion from Pioneer Countries: Lead Markets and Political Lesson-Drawing

A second mechanism of enforced diffusion is provided by national pioneers and trend setters [25]. The creation of a lead market for low-carbon technologies in a pioneer country together with political lesson-drawing [9] by other countries has been a prominent mechanism for the international diffusion of such technologies. Both mechanisms are independent, but they can reinforce each other.

Enforced diffusion of clean-energy innovation by lead markets can be described as follows:

- Lead markets are the national "runway" to start into the global market, where an innovative technology finds supportive conditions such as price, demand, or market structure.
- National lead markets for clean-energy innovations are specific because they are "policy-driven" and provide a regulatory advantage by political support.
- The international diffusion of the supporting policy ("lesson-drawing") can create an additional transfer advantage.

The economic mechanism is the enforced diffusion of climate-friendly technologies via lead markets. A national lead market is, according to Beise *et al.*, "the core of the world market where local users are early adopters of an innovation on an international scale" [26]. Well-known general cases are lead markets for mobile phones (Scandinavia), fax (Japan) or the Internet (USA). They originated in markets with special market advantages, such as price, market structure, demand, or export advantages.

Lead markets in pioneer countries have played a special role in the diffusion of low-carbon technologies. They re-financed the costs for technological learning until the product was sufficiently cheap and effective to diffuse into international markets. In addition, they had a demonstration effect showing how a certain climate-related problem could be solved, often including an economic advantage. This mechanism has become an important pathway for translating climate policy objectives into global markets. Examples encompass the development of wind power in Denmark and Germany, photovoltaic installations in Japan and Germany, heat pumps in Sweden, hybrid motors in Japan, and fuel-efficient diesel cars in Germany [26]. Examples for lead markets in emerging economies include solar water heating in China and bio-fuel technology in Brazil.

Lead markets for climate-friendly technologies arise in countries with a "regulatory advantage" and a "transfer advantage" [27]. This means that the technology and their international diffusion are supported by policy [28]. "Lesson-drawing" by other countries supports policy diffusion. This political "lesson-drawing" is the second mechanism of reinforced international diffusion. In the context of lead markets it refers to the process of learning how to support markets for a specific climate-friendly technology and results in the diffusion of a specific supporting instrument or policy mix. Lesson-drawing is similar to Arthur's mechanism of "adaptive expectations"—although it is *policy* learning. Similar to enforced technology diffusion, reinforced policy diffusion depends to a high degree on expectations, where increased prevalence in the global policy arena "enhances beliefs of further prevalence" [1].

Reinforced international diffusion by "lesson-drawing" can therefore be described as follows:

- "Trendy solutions" of pioneer countries are adopted by other countries, e.g., as a strategy to avoid domestic trial-and-error.
- "Adaptive expectations": increased diffusion enhances beliefs in further diffusion.
- Effect of "critical mass", *i.e.*, the stage in the process at which diffusion becomes self-perpetuating.

The anticipated probability that a certain regulation will become an international standard (also supported by international harmonization) has become a strong driver of policy diffusion [29]. A critical mass of countries adopting a certain trendy solution [10] reinforces the diffusion (see also [30]). At this stage, the process achieves sufficient momentum to become self-perpetuating.

The speed of diffusion and lesson-drawing in technology-based climate policy has been in many cases remarkable. The diffusion of the instrument of feed-in tariffs may be used as an illustration (Figure 4 [31]). The diffusion of targets for green electricity occurred even faster. By early 2014, 144 countries had introduced targets for green power, a number that doubled since 2007 [32]. Even policies to support energy efficiency, which is often regarded as the more difficult part of climate policy, can have a high speed of international diffusion: out of 85 countries analyzed by the French institute ADEME, the share of countries with national targets for energy efficiency doubled within only five years to 80% [33]. This speed of diffusion is in clear contrast to the slow progress in international climate negotiations. Lesson-drawing has been characterized as "governance by diffusion" [34]. It is remarkable that it is a completely voluntary process, significantly different from global climate governance through legally binding international obligations [22].

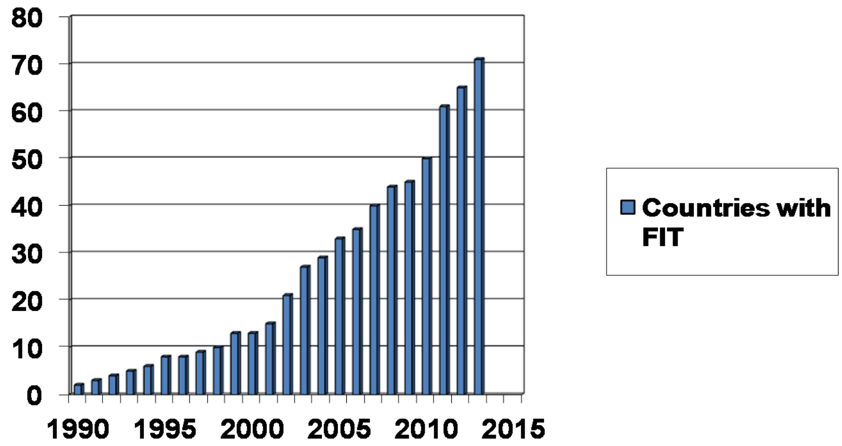

Figure 4. International diffusion of feed-in tariffs 1990–early 2013 (data basis [31]).

A special reinforcement of a lead-market process takes places when feedback from the international markets occurs, which is driven by second-mover countries now entering the original lead market by successfully producing similar products at lower prices. The Chinese solar industry and its booming exports to Europe may be taken as an example [35]. The case marks a situation where a former lead market has to find a new role in the competition for innovation. This may create difficulties for the former pioneer. However, in terms of climate protection, this reinforcement of diffusion based on lower prices is a clear advantage.

So far, lead markets in rich countries have provided the basis for clean technologies to diffuse from industrialized and emerging economies into international markets. A more recent development is the role of lead markets in emerging countries like India, where the lag markets are developing countries. Most interestingly for a sustainable energy future are lead markets for frugal innovations [36]. Frugal innovations are cheap, simple and robust. Beyond that they also try to save resources at all stages of the supply chain [37]. They are worth mentioning here, because, due to a generally low profit share, they depend on large-scale markets. The existence of such large markets in emerging economies can lead to the advantage of falling unit costs to increased output as a mechanism of reinforcement [1].

5. Multi-Level Governance: the Vertical Reinforcement of Horizontal Diffusion

5.1. The Multi-Level System of Global Climate Governance

Multi-level governance "characterizes the mutually dependent relationships—be they vertical, horizontal, or networked—among public actors situated at different levels of government" ([38], see also [39,40]). The multi-level perspective (MLP) is "a middle-range theory that conceptualizes overall dynamic patterns in socio-technical transitions" [41]. Multi-level reinforcement is a particularly interesting aspect (Figure 5). Schreurs and Tiberghien have used this terminology to explain the dynamics of climate policy in the European Union and its member states ([42], see also [43]). However, it is also relevant in the global context. Here it is used to explain the dynamic interaction between the national and the sub-national levels.

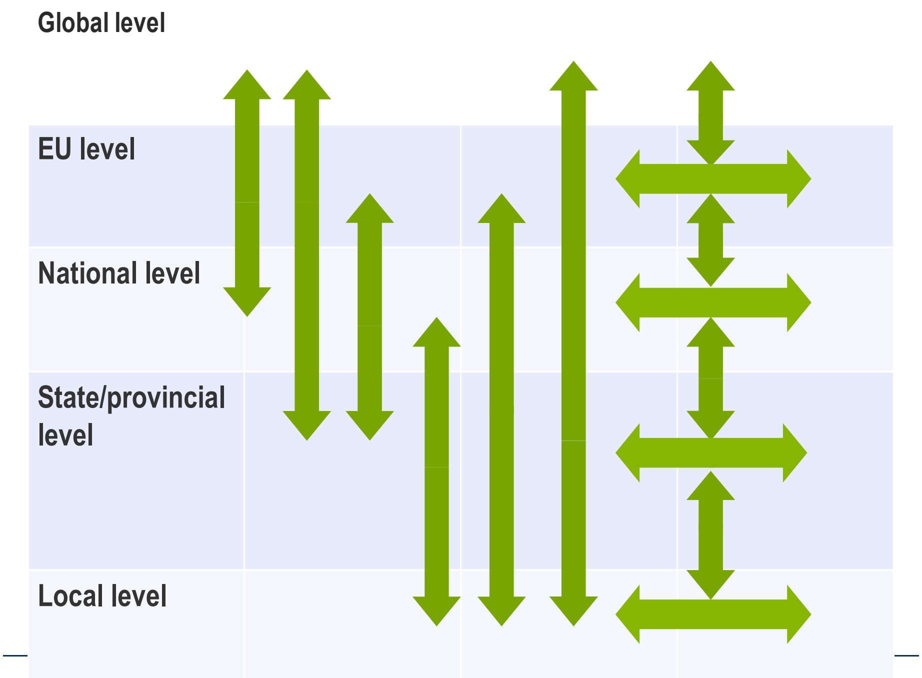

Figure 5. Multi-level governance: possible horizontal and vertical interactions.

Multi-level governance—from the global to the local level—can be regarded as a general mechanism of reinforcement. The broad variety of possible vertical and horizontal interactions makes it possible that innovation take place at different parts of the governance system (Figure 5). Furthermore, they can be adopted in other parts of the system. Lesson-drawing (peer-to-peer learning) from pioneers is possible at all levels. Horizontal up-scaling of de-central innovations and best practice is another mechanism. The resulting policy of higher levels (nation state, the European Union) can stimulate horizontal dynamics at lower levels. This aspect of multi-level reinforcement will be exemplified by the case of the European Union.

The multi-level system of climate governance is a global system because it has a global base of climate-related knowledge, motivation, and legitimacy. Moreover, it is a global system because a global market for climate-friendly technology has been established together with the global arena of climate policy. An important condition of its innovation dynamics is the leadership role of the higher levels.

At each level of the multi-level system of global climate governance, a broad variety of motives and opportunities can be observed. At the level of provinces/regions or federal states, the following motives to support or to adopt climate-friendly technologies exist: rich regions can be motivated to transfer their successful economic policy to the new field of climate policy. Poor regions, on the other hand, can try to support renewable energies or energy-saving investments in the housing sector to overcome unemployment. Another driver may be opposition of the region against the national government (as in the case of Scotland, Quebec or California). Geographical advantage might provide another condition to support renewals (as with wind energy in coastal zones). Political scientists often point to the party constellation of a certain regional/state government [44]. In the EU, there are several responsibilities for climate and energy—beyond emission trading—at the regional level [45]. The EU has a regional commissioner and a regional committee, which has recently issued a multi-level governance convention (2014). There exist international horizontal networks such as the R20 Regions, or the Network of Regional Governments for Sustainable Development, which has been established at the World Summit in Johannesburg (2002).

Cities and local communities have important responsibilities in policy areas that are relevant to climate policy. Housing and the energy consumption of households, transport regulations and infrastructures, land-use and urban planning, or waste policy are important policy fields in this regard. Most important is the responsibility for local energy supply, where cities in Europe or the US can have strong influence [38]. The fact that 80% of EU greenhouse gases emissions are related to urban activities illustrates the importance of the local level. Thus, cities are also important places for climate policy experiments and innovations [46]. Horizontally active international networks such as ICLEI or the Covenants of Mayors play an important role [47]. In addition, national networks such as the City Energy Project (USA) or the Chinese Low Carbon Eco-Cities Association can play a role [48]. The German "100%-Renewable Energy" network (Figure 6) is a remarkable example of horizontal dynamics at the lowest level being supported by climate policy activities at higher levels.

Local climate mitigation and horizontal lesson-drawing between cities is being generally supported by the EU Commission and also by the central government in India and China.

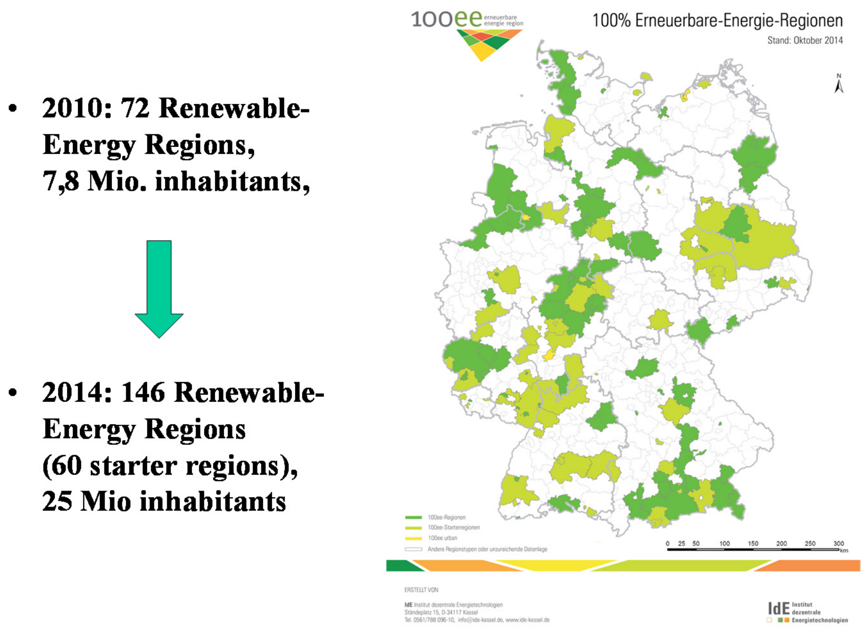

Figure 6. "100%-Renewable-Energy" Regions in Germany 2014 (2010) (Umwelt 12/2012, IdE 2015).

5.2. Horizontal Dynamics Induced by Higher Levels

The reinforcement at lower levels by multi-level governance can be described as follows:

- Experimentation, innovation and best practice at different levels.
- Local and regional best practice being scaled up and supported by the higher level.
- Support from the higher level inducing horizontal dynamics at the lower level: pioneers become relevant as benchmark, partners or competitors.

Political leadership on the higher levels can impose the up-scaling and generalization of experiments, innovations and best practices from lower levels. If the higher levels take the lead, providing regulatory financial or informational support to the lower levels, they will strengthen the role of pioneers at the lower levels and induce horizontal lesson-drawing, cooperation, or competition at the same level (Figure 7). Pioneer cities or provinces/states at the lower levels become benchmarks for others. Support from above therefore provides new means and opportunities for the diffusion of climate-friendly innovation. From an economic perspective this includes the potential broadening of markets to a supra-regional scale. The mobilization of economic interests and the translation of climate policy goals into the language of market dynamics is an integrating common factor at all levels.

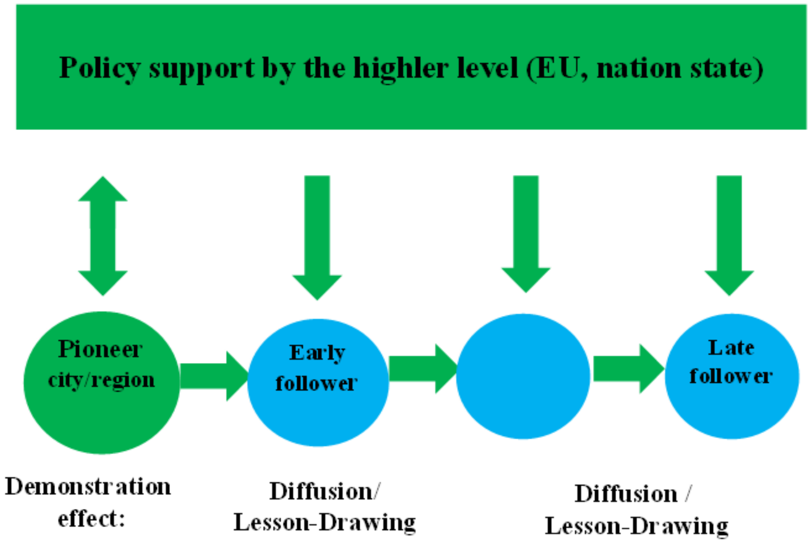

Figure 7. Horizontal dynamics induced by the higher policy level.

6. The Case of the European Union

The EU has provided the best practice in climate mitigation and multi-level climate governance. As a regional system of climate governance it is unique compared with other world regions (NAFTA, African Union, ASEAN *etc.*). Regarding to the global 2° K target the achievements may not be sufficient. Nevertheless, they are remarkable because they have not been expected before. Greenhouse gases have been reduced by nearly 20% from 1990 to 2012. Moreover, the target for 2020 has already been nearly achieved (Figure 8). The accelerated speed of greenhouse gas reduction may be partly explained by the economic downturn. However, the diffusion of renewable energies had a similar tendency. By 2013 renewable energies accounted for 70% of new electric power capacity (Figure 9). One year later, the share was 79%—a significant increase from 57% only five years before [31,32].

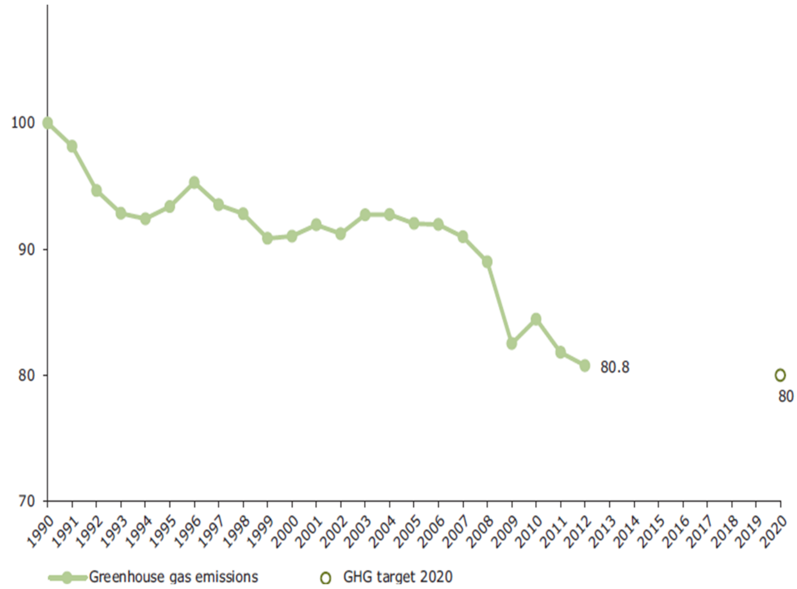

Figure 8. EU-28 greenhouse gas emissions, 1990–2012 (EEA 2014).

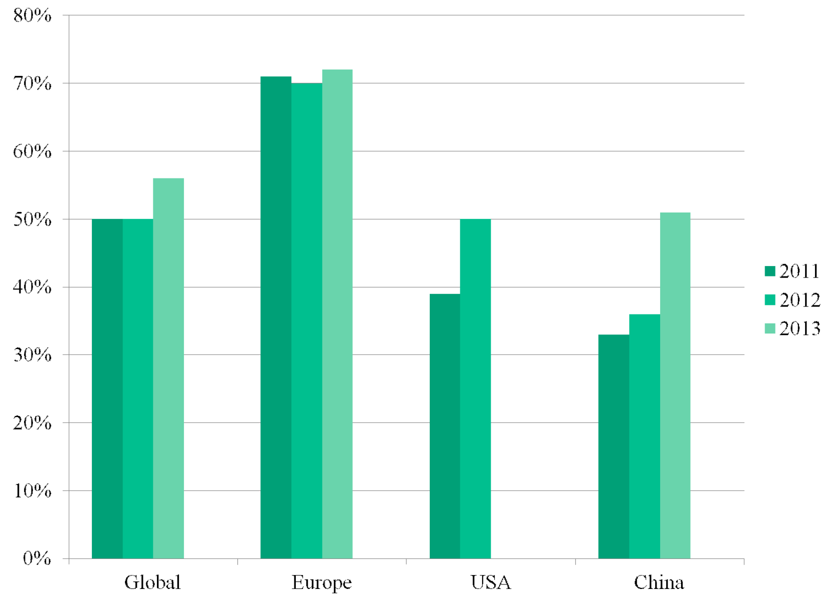

Figure 9. Green power as share of new power capacity, 2011–2013 [31].

The effect of the EU climate package (2008) cannot be disputed. It seems remarkable that this package was partly motivated by ideas of a policy-driven dynamic market for low-carbon technologies. Already in 2007, the EU Commission proposed a comprehensive lead market and innovation strategy "to create a virtuous cycle of growing demand, reducing costs by economies of scale, rapid product and production improvements and a new cycle of innovation that will fuel further demand and a spinout into the global market" [49]. After 2007 the European market was indeed the lead market for wind and solar power. Innovation and lesson-drawing took place at a high level throughout Europe. In some sense an interaction of the described mechanisms of reinforcement—a syndrome of reinforcement—could be observed at that time. Although the EU top level lost some of its dynamics in recent time, the European system of multi-level climate governance remained a strong driver for climate-friendly modernization [43]. This needs to be explained more broadly.

Multi-level climate governance was a purposeful strategy of the European institutions. There is a special institutional framework for regions/provinces and also a climate governance strategy for cities. Other characteristics of EU countries that provide a green opportunity structure include green political parties and public media. The EU has turned a "free market" into a market with strong environmental framework conditions. The World Bank recently confirmed that the EU has a specific "environmentally sustainable growth model" [50].

Beyond that there is a specific European mechanism of multi-level reinforcement: the interaction of national environmental policy innovation with the European harmonization mechanism in the context of the common market. The EU commission can under certain conditions authorize member states to maintain or introduce stricter measures of environmental policy. When a member state is authorized to do this, "the Commission shall immediately examine whether to propose an adaptation to that measure" (Treaty on the Functioning of the European Union, Art. 114.7; 193). Environmental policy innovation in member states can with a certain probability become a European regulation, which follows the principle of a "high level of environmental protection". Climate policy is part of the EU environmental policy (Art 191). This mechanism can stimulate regulatory competition between member states to become the frontrunner of a European regulation [11,42]. It can be regarded as lesson-drawing by the EU Commission: learning from empirical best practice, avoiding time consuming experimentation and being supported by certain national governments, which can also provide competent advice. The UK emissions trading scheme (2002) can be taken as an example. It was also intended to deliver "first mover advantages" to UK companies before the introduction (2005) of the EU emissions trading scheme [51]. Other examples are the UK Energy Efficiency Commitment (2002) and the German Renewable Energy Law (2000), both being followed by EU Regulations (2001 and 2012).

Climate policy as a process started in the EU at the national and sub-national level. Pioneer countries like Germany, Denmark, and the United Kingdom (UK) generalized and integrated many political and economic experiments and best practices that had already taken place at lower levels, paving the way for their adoption at a higher level. Thus, the process of climate policy has moved bottom-up to the European and global levels. Extending the national policy innovations to the European Union has often been a governmental strategy of member states to stabilize the national pioneer role, but also to create a European market for domestic innovations in climate-friendly technologies.

The Europeanization of climate policies was accompanied by the establishment of lobby organizations, which articulated an economic interest for clean energy at the EU level. Examples include the European Renewable Energy Council, the European Alliance to Save Energy, the European Insulation Manufacturers Association, Lighting Europe and the European Heat Pump Association.

Meanwhile feedback can be observed at the local level, reinforcing earlier initiatives: cities and local communities, often organized as networks [47], use national and European policies and incentives—whether regulations, subsidies, or public procurement—to mobilize economic interests for climate-friendly technologies. These can be investments in the form of renewable energies or low-energy buildings.

Most remarkable is the role of the Covenant of Mayors with about 6400 (2015) participating local communities. It was launched by the European Commission together with the EU climate and energy package in 2008. Within this network, the participating local authorities have to present action plans and a GHG reduction target of at least 20%. The economic dimension is underlined by the fact that the European Investment Bank is involved in the financing of implementation measures. The Smart Cities Partnership Initiative of the EU Commission is a similar economic mechanism. The horizontal dynamics—particularly the competition between cities—are stimulated by an official Benchmark of Excellence, which is also a database of best practice [52].

Private ownership of green power seems to be a strong driver of change at the local level in several countries. In Germany, more than half of the green power installations are owned by private person. Europe, when compared with other global regions, has not only the advantage of a strong supra-national level of climate governance, but it also started early with a high proportion of decentralized and local ownership of green power installations (Bloomberg New Energy Finance 4/2014).

It seems that the local level now has become the most dynamic driver of technical change towards a low-carbon energy system. An evaluation of the Covenant of Mayors shows that 63% of the local communities being assessed by the EU are planning to reduce GHG emissions by more than 20%. A reduction of about 370 million tons is expected by 2020 (ENDS Europe 24 June 2013). The database of the Covenant provides empirical evidence that in recent years, the climate policy process has mobilized strong economic interests at the local level, mainly in the building sector (44% of the activities) and in local energy production.

The former policy initiative at the higher levels has created the necessary preconditions for this booming development at the sub-national level. The EU Directive on Energy Performance of Buildings, for instance, has stimulated a strong activity among local communities with pioneer cities such as Freiburg, Manchester, Copenhagen, and Malmö playing an important role.

It seems that pioneer countries like Germany, Denmark, and the United Kingdom are also leading countries when local dynamics are concerned. These three countries have achieved the highest GHG reduction rates. They also have the most ambitious GHG reduction targets for the period 1990–2025 (Germany 40%–45%, UK 50%; Denmark 40% by 2020). In all three countries this is the result of policy-induced reinforcing cycles of innovation and market growth with policy feedback. They are also cases of best practice regarding the mobilization of economic interests for climate governance at the sub-national level.

7. The Advantage of a Polycentric Approach

As we have seen, it is no disadvantage that the implementation of climate policy takes place under the condition of a broad variety of actors, dimensions, and levels. On the contrary: a "polycentric approach" [53] can be a real opportunity [54]. It should be mentioned that this polycentric approach includes not only governments and businesses, but also societal actors. Civil society—with networks of all kinds and at all levels of the multi-level game—seems to be the indispensable context of the energy transformation, although its highly complex causality is not easy to assess in terms of empirical research.

The extremely high complexity of multi-level climate governance may cause the problem of final responsibility: if everybody is responsible, in the end there might be a situation in which nobody actually takes responsibility. So far, reaching a solution is still primarily the final responsibility of national governments acting within broad networks, often as collective players (e.g., G20). National governments, if compared with the small administration of global regimes, such as under the United

Nations Framework Convention on Climate Change, have more human and financial resources. They can impose sanctions and penalties. They act under comparably higher pressure to provide legitimacy for their actions. They are the first responders in the event of extreme weather and other crises and they are observed more intensively by the public than government actors at other levels of the global multi-level governance system [21].

8. Conclusions

This article has shown that the acceleration of the diffusion of clean-energy technologies is a potentially strong option for climate policy (see also [22]). As Arthur stated long ago, mechanisms of reinforcement can be found in natural as well as in economic systems. Although his typology was abstract and theoretical, it shows many similarities with the empirical dynamics in climate governance that have been presented in this paper. It is, however, necessary to include the role of government in this analytical perspective to explain the special dynamics of climate-related governance.

Three mechanisms of reinforcement have been presented: (1) the dynamics of policy-driven domestic markets and innovation processes, that lead to a policy feedback, due to unexpected success but also due to the creation of a new interest base; (2) the dynamics of both the global climate policy arena and the global markets for clean-energy technologies: lead markets supported by country-to-country lesson-drawing; and (3) the dynamics of multi-level reinforcement, which is based on vertical and horizontal interaction and learning. It includes the up-scaling of decentralized innovations and the top-down implementation of climate policy measures on lower levels. In this paper we have focused on the horizontal dynamics of sub-national levels (such as networking, benchmarking, or competition between cities) being induced by top-down climate policy support. The three mechanisms are highly likely to support each other. In the EU they have sometimes (particularly after 2007) led to a syndrome of reinforcement. The list of possible accelerators may be longer than those presented. One additional likely mechanism of acceleration is the break-even point of simultaneously rising prices for fossil energy and the falling prices of renewable energies.

It seems that the accelerators discussed can best be understood within the system of global multi-level climate governance. The governance system of the EU can be regarded as the most advanced sub-system. Meanwhile the multi-level system of global climate governance seems to have achieved its own inherent logic. It can be characterized by typical horizontal and vertical dynamics as well as long-term stabilization mechanisms, based on institutional change, new economic interests, and policy feedback. This governance system has created opportunities for innovation and its diffusion. The broad variety of agents and possible interactions (Figure 5) could be seen as one of its main characteristics. The interaction between levels is another one; such vertical interactions are often connected with horizontal dynamics at different levels: pioneer activities and lesson-drawing, networking, and cooperation, as well as competition. They have become increasingly important, particularly at the sub-national level (Figures 6 and 7).

Several policy measures can be used to support this process and to stimulate acceleration, although a comprehensive strategy still needs to be developed. Thus far, these processes are mainly the result of an interactive learning-by-doing. The dynamics in most cases have been induced by competent practitioners. This means that they are not the result of scientific design; instead, they are most often unintended and unexpected.

The IPCC stated in its 5th Assessment Report that "…institutional and governance changes can accelerate a transition to low-carbon paths" [55]. However, there can be no doubt about the difficulty of translating the complex task of multi-level governance into a comprehensive strategy. There needs to be more research on best practices to draw better and more comprehensive conclusions for government strategies. The main general conclusions of this explorative analysis can be summarized as follows:

1) Translating climate policy objectives into the language of industrial policy and ecological modernization [21] is a strong option for climate policy (while it is not the only solution, since there are limits to technological approaches).
2) Ambitious goal-oriented climate policies can induce market growth and interactive technological learning (secondary innovation). Successful learning by doing, increased capacity, and the creation of new interests could lead to a policy feedback with even higher ambition.
3) Multi-level governance is a highly important institutional opportunity structure for the innovation and diffusion of clean-energies and their supporting policies. Best practice can arise and lesson-drawing can take place at quite different points of the system of multi-level climate governance.
4) Therefore base policy on existing best practices at different levels and provide channels for lesson-drawing and interactive learning. Apply ambitious but realistic targets and credible implementation programs. Raise ambitions and targets in cases of unexpected success.
5) Give targeted support to sustainable R&D initiatives; use the lead market mechanism where possible.
6) Support lower levels of government and stimulate horizontal dynamics through bench-marking, competition, lesson-drawing, cooperation, and networking.
7) National governments—both as single and collective actors—so far exhibited the strongest capacities and therefore should lead with ambitious climate policies.

Conflicts of Interest

The author declares no conflict of interest.

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