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The Politics of low-carbon innovation:

Implementing the European Union's Strategic Energy Technology Plan

Abstract

The EU Strategic Energy Technology Plan (SET-Plan) was adopted in 2008 to steer the funding of low-carbon technology research and innovation in Europe and thus accelerate the development and deployment of such technologies. Examining how and why the Plan attained its objectives, we first find that research and innovation funding came to steer the development of the SET-Plan rather than the converse. Second, we find three main explanations, drawing on theories of EU integration and policymaking: 1) differing research and innovation priorities among state, non-state (industry and research community), and institutional actors within the EU, making the Plan contested and leading to the mobilization of actors whose priorities had not been included in the Plan*;* 2) weak EU-level authority to govern the Plan; 3) diverging alignment between the Plan, constituting EU's low-carbon technology push policy, and EU market pull policies, such as carbon pricing. These observations have relevance to other international efforts, such as Mission Innovation linked to the Paris Agreement.

Keywords

EU, Energy, Climate, Policy, Technology, Innovation

1. Introduction

Further development and deployment of low-carbon technologies is crucial for climate mitigation. Concerted international action is urgently needed to speed up the pace. However, social science research has largely ignored key issues in the international politics and cooperation on low-carbon research and innovation (R&I).[1] Here we present some lessons on pitfalls and opportunities in low-carbon R&I cooperation, based on experiences with the EU Strategic Energy Technology Plan (SET-Plan).

The SET-Plan was adopted by the EU in 2008 to steer research and innovation in low-carbon technologies. The Plan responded to the declining and fragmented funding of energy-research in Europe, and was seen as a crucial element in the EU policy portfolio needed for pooling scarce resources to attain short- and long-term climate and energy targets adopted from 2007.[2] The SET-Plan was to bring low-carbon technologies from ideas to the mass market via large-scale demonstration projects. Concerted EU action was deemed essential, given the scale of investments needed for establishing such projects. Failed demonstration projects could mean that promising technologies would never reach the market [2]. By accelerating the development of low-carbon technologies in Europe, the Plan also aimed at EU leadership in international markets for such technologies.[3]

The SET-Plan was established in order to accelerate and steer EU, national, and industrial research and innovation funding towards prioritized low-carbon technologies and large-scale projects. Here the Plan failed. Paradoxically, instead of steering R&I funding based on initially defined priorities, the SET-Plan's list of prioritized technologies was steered and expanded by actual funding at the EU, national, and industrial levels. We ask how and why this happened, drawing on theories of EU integration and policymaking.

The main objectives of the SET-Plan reflected the desire to break the trend of declining and fragmented energy R&I efforts at EU, national, and industrial levels [3]. The Plan aimed at

[1] See [1] The present article draws heavily on this book.

[2] Targets for 2020 were: 20% cuts in GHG emissions (from 1990 levels), 20% of EU energy to come from renewables, 20% improvement in energy efficiency. The long-term ambition was to reduce greenhouse gas (GHG) emissions by 80–95% by 2050. These targets have now been strengthened for 2030 and 2050.

[3] Space does not permit comprehensive analysis of the relationship between the EU and its main low-carbon technology competitors.

achieving a sharper focus, a strengthening of total efforts, and better coherence of efforts between these levels. Certain promising technologies would be selected for concentrated R&I funding, specifically for demonstration projects on a scale beyond the capacity of single member-states. As that challenged the principle of technology neutrality, whereby the market (not the public authorities) picks the "winners," the Plan was contested among actors who favored other priorities. Moreover, the Plan signaled stronger EU-level authority over energy R&I, challenging established national competence in this policy area. However, when finally adopted in 2008, the Plan was not legalized in a final text, but rested on political support from EU institutions and member-states with differing views on which technologies to prioritize.

The SET-Plan and EU low-carbon technology "push" policies have remained largely unexplored terrain,[4] unlike EU energy and climate "pull" policies, such as emissions trading and carbon pricing [7,8,9,10,11,12]. To help fill this knowledge gap, we highlight the politics of innovation in the literature on EU energy and climate policies, as well as international cooperation on low-carbon R&I in general. Lessons from the EU may also have wider relevance, given the Paris Agreement's Mission Innovation, which emphasizes greater international cooperation on low-carbon energy technology.

Our research approach involves a theoretically informed qualitative case study. Data collection was based on multiple sources, including official EU publications, secondary literature, and 21 semi-structured interviews with key SET-Plan actors.[5]

First, we outline our analytical point of departure for examining implementation of the SET-Plan. After briefly introducing the SET-Plan, we assess and explain its attainment of objectives, before offering some concluding remarks.

2. Analytical point of departure

We assess the outcomes of the SET-Plan by relating the consequences of its institutional setting to its main objectives. Institutional setting refers broadly to the constellation of rights and rules that define social practices, assign roles to participants in those activities, and guide interaction among those who occupy these roles – who deals with what, how, when, and

[4] See, however, [4,5,6].

[5] All interviews are based on confidentiality and used as background information for interpreting written sources.

where? [13] The Plan identifies three objectives [14]: 1) to select and prioritize certain promising low-carbon energy technologies; 2) to provide the resources (financial and human) necessary for realizing the prioritized technologies; 3) to undertake joint research and large-scale demonstration projects which could accelerate the market uptake of selected of low-carbon technologies. These objectives resemble technology-specific policies whereby public authorities at the EU level—not the market—pick the winners [15].

2.1 Explaining implementation

The SET-Plan's institutional setting created new EU arenas for coordination; it institutionalized the roles and distributed competences for actions among actors at various administrative levels. Implementation would require combined initiatives and actions of the supranational EU institutions (Commission and European Parliament), member-states and non-state actors, including industry and the research community. To analyze SET-Plan implementation, we draw on two explanatory perspectives: Liberal Intergovernmentalism (LI) and Multi-Level Governance (MLG). These perspectives are considered alternative but complementary in the "who governs the EU" literature, and are widely applied in the study of EU climate and energy policies [8].

2.1.1 The role of member-states

The LI perspective focuses on the member-state level, explaining EU policy outcomes as largely the result of these states' interests and preferences, constrained by political interests nested within autonomous national areas—leaving scant room for autonomous supranational institutions to influence policymaking significantly [16, 17,18]. According to LI, the principle of national self-determination over the diverse energy mix and related R&I will prevail, and any concentration of resources at EU level for technologies not prioritized by major member-states is unlikely. Basically, it is the member-states who pick the technology winners.

An underlying assumption here is that the intensity and scale of interest mobilization will increase apace with the degree of "winner-picking" efforts by the supranational EU institutions. With narrower priorities, technology areas and related national interests likely to be left out will be expected to mobilize to get in. From an LI perspective, this leads us to assume that national priorities will determine the implementation of SET-Plan priorities, the level and alignment of R&I resources—and ultimately, the realization of large-scale

demonstration projects. We would expect initial EU priorities to be expanded, not concentrated on a few technologies. That would contradict the objectives of the SET-Plan.

2.1.2 The role of EU institutions and non-state actors

Multi-Level Governance (MLG) approaches have been presented as alternatives to state-centered intergovernmentalist approaches to EU policymaking and implementation [19,20]. According to MLG approaches, of which there are many variants, EU member-state governments are not in full control of policymaking in Brussels; European integration has weakened the powers of the state. With high R&I competence at EU level, the EU institutions can harmonize technology selection and related resources across the member-states.

Two mechanisms of influence that "challenge" state R&I control should be noted here. First, the role and influence of the supranational EU institutions, particularly the Commission and the European Parliament. The Commission is the main agenda-setter in the EU, frequently with independent influence beyond its role as agent for national governments [20, 21,22]. Its independent role hinges on its capacity to coordinate internally the R&I initiatives originating in its units, all with their own preferences and cultures [23, 24, 11]. The European Parliament also has a say as co-decider on EU-level R&I programs, together with the Council.

Secondly, non-state actors, like industry and the research community, can influence policymaking and implementation at the EU level in Brussels—and, with the expanding powers of EU institutions, this mechanism is becoming increasingly important [24,11]. EU institutions may prove particularly influential if they can form transnational policy "networks" with non-state actors who generate commitment and allegiance to EU-level policies [25,26].

Given EU level institutional unity and supranational competence, MLG leads us to assume that the EU institutions will be able to prioritize technologies, coordinate and allocate R&I resources, and align resources with SET-Plan priorities to realize demonstration projects. We would expect initial SET-Plan priorities to be concentrated, not expanded in line with the diverse interests of the member-states. That would align with the objectives of the SET-Plan.

2.1.3 Summing up

Table 1 sums up our analytical approach for assessing and explaining SET-Plan implementation according to its objectives. From the theoretical perspectives, we have generated empirically observable expectations. The theories and expectations identify explanatory factors and mechanisms, provide a focus for data collection, and enable us to draw conclusions about the relative merits of alternative explanatory perspectives. We apply pattern-matching and process tracing for making such inferences.

Table 1: Explanatory factors, theory foundation, propositions

Explanatory factors	**Theory foundation**	**SET-Plan implementation**
Member-state R&I interests and priorities	Liberal Intergovernmentalism	Member-state R&I interests and preferences will determine SET-Plan priorities. Diverse member-state interests will lead to expansion of R&I resources. That would contradict the objectives of the SET-Plan.
EU institutions and non-state actors	Multi-Level Governance	If unified, EU institutions and non-state actor networks will determine SET-Plan priorities. EU institutions will enable concentration of R&I resources. That would align with the objectives of the SET-Plan.

3. The SET-Plan

In March 2006, the Commission adopted a green paper on future EU energy-policy opportunities, which included the idea of what was to become the SET-Plan: “to accelerate research in promising energy technologies…[and] create the conditions to bring such technologies efficiently and effectively to the EU and the world markets” [27p. 13]. On January 10, 2007, the first SET-Plan communication was issued, together with synchronized

communications on policy strategies for broader energy and climate market "pull" deployment [28, 29,30].

The SET-Plan idea was presented as the EU's key technology "push" instrument for coordinating EU and national R&I funding mechanisms. It responded to declining and fragmented public and private energy-research actions and funds, national and European, which had been "decided and implemented in almost total isolation one from another" [3, p.7].

The key strategic element of the Plan involved identifying and selecting certain low-carbon technologies for concentrated efforts, thus accelerating their development and deployment [30, p. 8]. Special attention was to be devoted to large-scale demonstration projects, beyond the capacity of any single country to realize. The Commission initially listed various energy technologies, without making any definite selection.

In March 2007, the European Council welcomed the Commission's intention of tabling a package of energy and climate policies, including the SET-Plan [31]. The Commission then organized consultations on what technologies to prioritize, before formally proposing the Plan in November 2007 [3,14]. The Commission argued that the plan for concerted EU intervention would help to correct structural weaknesses in the energy innovation process, which had been handicapped by long lead-times in bringing ideas to the mass market due to the scale of investment, technological and regulatory inertia, and fossil-fuel "lock-in." The Commission called for a collective endeavor to achieve what were formulated as objectives of the SET-Plan:

> …the SET-Plan will *focus, strengthen* and give *coherence* to the overall effort in Europe, with the objective of accelerating innovation in cutting edge European low-carbon technologies. In doing so, it will facilitate the achievement of the 2020 targets and the 2050 vision… [14, p. 9, emphasis added].

An institutional setting was proposed to ensure delivery of objectives. The member-states would have a central role in a new Commission-chaired *Steering Group.* High-level government representatives would identify and elaborate joint actions, provide resources through coordination of national programs, and monitor and review the progress of the Plan. *European Industrial Initiatives* (EIIs) would be new arenas for mobilizing industry engagement

in R&I. Industrial initiatives might range from public–private partnerships to coalitions of interested member-states, depending on the nature and needs of the sectors and the technologies. Additionally, the Commission proposed that universities and research institutes should form a *European Energy Research Alliance* to coordinate and elaborate joint research programs, aligning with the EIIs. Further, a European energy technology information system (SETIS), to be developed and administered by the Commission's Joint Research Centre, would collect, report, monitor, and review data on progress.

The Commission now explicitly stated that the Plan should include technologies at various levels of maturity and avoid: "…being perceived as a European level picking winners" [30, p. 8]. However, that would appear to be exactly what the Commission had in mind by "…ensuring that the *right* portfolio of technologies is brought forward to the member states to pick and choose…" (ibid., emphasis added). This "right portfolio" consisted of six European initiatives:

- *wind:* large-scale demonstration of on- and off-shore turbines and their adoption in the energy system
- *solar:* large-scale demonstration of photovoltaics and concentrated solar power
- *bio-energy:* next-generation biofuels within the context of overall bio-energy use
- *CCS:* to prove the viability of zero-emission fossil-fuel power plants at industrial scale
- *electricity grid*: development of smart electricity systems, including storage
- *nuclear fission:* development of "sustainable" Generation-IV technologies.

Main priority would be accorded to decarbonization of electricity generation.[6] Excluded were several technology areas listed in earlier Commission preparatory work, such as clean coal (except for CCS), geothermal, ocean—and, importantly: consumer energy-efficiency technologies.

The main structure of the SET-Plan was adopted by the Council and European Parliament in December 2008 [1,32]. The Commission received broad political support—

[6] Fuel Cell & Hydrogen was already planned through a Joint Technology Initiative under EU Framework Programme 7.

especially concerning the higher budgets for, and better coordination and prioritization of, low-carbon energy research and innovation efforts. However, the European Parliament and the Council did not fully agree with the Commission on some aspects of SET-Plan governance, the criteria for selecting priorities, or what specific technologies to prioritize [1]. The SET-Plan was not finalized in a legally binding text that settled future directions, priorities, and governance. The Commission was to steer the Plan without any provision for extended competence over R&I funding or legal means to ensure adequate funding for technology priorities and large-scale demonstration projects. This increased the risk that SET-Plan technologies and project types (demonstration) might become derailed due to contestation at the implementation stage. As we shall show, that was exactly what happened when the Plan was implemented.

4. Implementation

The new institutional setting was put in place during 2008: the Steering Group, the European Industrial Initiatives, the European Energy Research Area, and SETIS—the new reporting, monitoring, and review system. In 2009, EIIs teams reported their work on detailed research agendas and demonstration projects in Technology Roadmaps. The European Energy Research Alliance (EERA) launched the first joint programs in 2010. The Steering Group started work on joint actions linked to the six technology priorities.

After this initial phase, implementation encountered serious problems. First, instead of consolidating around the six technology areas, the Plan was expanded to focus on a far wider set of technology areas and individual technologies, 14 in all [1]. The EU was obviously unable to concentrate its R&I efforts.

Second, a main task involved providing the funds needed to realize the SET-Plan, estimated by the Commission in 2009 at €8 billion/year. Although data collected by SETIS indicated that low-carbon R&I funding in the EU had increased, the causal connection with the SET-Plan as steering instrument remained weak. EU-level funding programs were gradually steered towards far wider priorities than first envisaged. Also national research programs and industry research broadened their technology portfolios [33]. The SET-Plan had drifted away

from the original idea of prioritizing specific technologies and project types to accelerate low-carbon innovation.[7]

Opportunities for EU-level funding came with the EU R&I Framework Programme (Horizon 2020), the European Energy Programme for Recovery (EEPR), and NER300, the latter based on revenues from auctioning emissions allowances linked to the EU Emissions Trading System (EU ETS). However, the Commission had limited success in bringing these into line with SET-Plan priorities. New mechanisms applied under Horizon 2020 to incentivize joint actions by the member-states yielded meagre results, indicating problems in ensuring coherence in national funding for SET-Plan priorities [1]. At EU level, differing eligibility criteria for relevant programs, and restrictions on coordinated funding even from thematically overlapping programs, constrained the opportunities for pooling available resources [33]. Notable was the lack of coordination between EERP and NER 300. The latter developed its own procedures for allocating funding, only partly aligned with SET-Plan priorities [2]. Some projects were co-funded, but additionality was not allowed—resources provided from one program led to automatic deduction for funding from the other program.

Third, partly as a consequence of the challenges of focusing, strengthening, and making public programs at EU and national levels more coherent, many large-scale demonstration projects failed to raise enough funding from industry to achieve financial closure [35]. There was variation among the SET-Plan EII technology areas. CCS was poorly served—no pilots or large-scale demonstration projects were realized. Funding mechanisms worked better in generating industry investments in certain more-mature SET-Plan technologies (solar PV, onshore windpower, mass-burned biomass) [35, p. 99]. Industrial investments in demonstration plants for second-generation biofuels and concentrated solar-power experienced problems. Several national-level smart-grid demonstration projects were implemented, but there were few projects coordinated jointly at EU level [35, p. 145].

Summing up, the SET-Plan was established to steer funding of low-carbon research and innovation towards the most promising technologies, to accelerate a transition towards lower emissions. However, in the implementation stage, the SET-Plan was altered and its priorities expanded. The SET-Plan evolved from funding made available at EU, national, and industrial

[7] SETIS documented an initial increase in annual EU funding for SET-Plan technology areas 2007–2011 [1]. From 2010 to 2015, total funding of energy technologies in the SET-Plan increased by 8%, but that also reflected the expansion of priorities under the Plan [34].

levels. Paradoxically, this implied that funding steered SET-Plan development, and not the converse, as initially intended. Coherence problems within and between EU and national energy research programs persisted, and large-scale demonstration projects faced significant challenges. In the next section, we explore why the SET-Plan largely failed to achieve its objectives.

5. Explaining implementation

5.1 Member-states

Before 2008, the EU member-states displayed significant variation in capacities and responsibilities for energy R&I [36]. France, Germany, and Italy accounted for 73% of total EU energy-research spending; the new member-states from Central and Eastern Europe, less than 3%. Nearly half of the member-states had no special national or regional energy R&I programs, and few had dedicated programs for demonstration projects. The six initial EIIs (wind, solar, bioenergy, CCS, nuclear fission, grid) were based largely on priorities already made or planned in the major energy-research countries [36].

SET-Plan implementation required continuous member-state commitment and agreement adopted at the newly established arenas for coordination at EU level. The Council emphasized, however, that the Plan should allow member-states to pursue R&I in line with their own national situations, and to determine their own energy mixes [32, p.2].

The Steering Group (SG) served as the major arena for member-states to start implementing the Plan.[8] The SG was intended to reinforce coherence among national, European, and international efforts by facilitating joint actions, including coordination between the EIIs and EERA. The intention was to create close links between the SG, national and EU sources of funding aligned to Plan priorities. Each member-state would designate two high-level representatives from its energy and research authorities with "…sufficient authority and knowledge to take positions on Community and national research and innovation investments" [37, p.3].

[8] The SG was composed of representatives from the Commission, from the 28 EU member-states, and from non-EU members Iceland, Norway, Switzerland, and Turkey.

As the minutes from early meetings show, the SG was becoming a forum for exchange of information among a select few member-states, not an arena for strategically steering low-carbon technology priorities. A few member-states presented their own low-carbon R&I projects and informed on national approaches for improving R&I cooperation [38]. However, less than half of the member-states gave presentations to the assembled SG members [39]. Commission representatives did most of the talking; national representatives tended to remain silent, especially those from energy R&I resource-poor Central and Eastern European countries.

The SG failed to get high-level representation—many national representatives in the group had no authority to take investment decisions. This weakened the link between the SG and national R&I funding authorities. Only a few member-state representatives were committed to joint actions; and even this small group proved unable to commit to any substantial resources, resulting in few and poorly resourced joint initiatives in the period 2008–2013 [1]. Moreover, certain member-states held that national funding for joint actions should be distributed exclusively to national actors.

Dissatisfaction with the workings of the SG surfaced at its meeting in September 2012, and member-states agreed that revision of SG management was needed [40]. As this was restated by the Commission in 2015, problems appeared to persist. The SG was rapidly running out of steam.

The European Industrial Initiatives (EIIs) constituted another implementation arena where member-states were represented. Under SG guidance, they were led by "EII Teams" composed of, and appointed by, member-states, industry, and the Commission. These teams were to serve as a platform for planning actions and identifying investment needs in Technology Roadmaps; they were to develop implementation plans, put these into operation, and monitor the progress. Further, they should address cross-cutting issues and synergies with other EII teams, to ensure coherence (see Table 2).

Table 2: Member-state involvement in the EIIs

Low-carbon technology initiatives	Member-state involvement
Wind	Key member-states not engaged
Solar	NA

Bioenergy	Key member-states with resource potential are not engaged
Electricity Grids	NA
Sustainable Nuclear	Limited direct participation of member-states with nuclear in their energy mix
CCS	Limited active involvement of member-states

Source: [40].

The member-states generally failed to commit to joint strategic planning, investment, or coordinated implementation of the EIIs [41, p.8]. Implementation was further hampered by unclear sharing of competences between member-states and the Commission, and between the SG and the EII teams. Lack of financial resources from the member-states obstructed the realization of large-scale demonstration projects [41].

The EIIs were to be supported by EERA—the arena for European public research centers and universities—to coordinate activities and propose joint programs. Member-states should agree on coordinated funding of EERA joint programs. EERA contributed to the consolidation of national research capacities for, *inter alia,* windpower—but links with most EIIs were weak, and joint programs remained largely "virtual" [41]. In 2015, the Commission concluded: "…EERA and the…EII are not delivering to the level required to move the SET-Plan forward" [42, p.5]. Moreover, member-states lacked commitment to build up SETIS as an effective SET-Plan steering instrument. A key challenge was the unwillingness or inability of member-states to report national research and innovation priorities and investments to SETIS [41, 42 p.4].

Low commitment to SET-Plan implementation was noted in a period where the potential for effective implementation increased, with more member-states funding low-carbon energy research and innovation [43]. Resources remained highly concentrated in the North, but also countries like Slovakia, Poland, and the Czech Republic increased their funding. This higher potential remained largely unexploited for SET-Plan steering, however: "…although MS do share common industrial and research interests, their commitment to the SET Plan is suboptimal" [42, p. 4]. Member-states essentially supported many of the initial

SET-Plan technology areas but also wanted to include other technology areas not in the initial Plan, like demand-side energy-efficiency technologies [32].

In summary, national R&I priorities were broader than the Commission's SET-Plan priorities; this contributed to mobilization for and actual expansion of priorities for the Plan, as expected from the LI perspective. Moreover, most member-states lacked commitment; many did not participate actively in the Steering Group, the EIIs, or EERA, or in providing the resources necessary to make SETIS a proper steering instrument. All this weakened implementation of the SET-Plan and reduced achievement of its objectives.

5.2 EU institutions and non-state actors

5.2.1 The Commission

The Commission served as Secretariat for the SET-Plan, took an active role in chairing the Steering Group, in drafting the EII roadmaps, and in facilitating the establishment of EERA. However, the Commission failed to muster commitment from public and private actors.

The Commission was also to draft EU-level funding programs and align these with the SET-Plan. Horizon 2020 represented one opportunity that partly failed, as the Commission initiated the program with a far broader portfolio of energy technologies than the SET-Plan. This broader portfolio had been agreed by the Council and European Parliament when deciding on the program. The link between the SET-Plan priorities and funding was weak—incoherence remained, within and between EU-level programs [44, p. 798].

Moreover, priorities differed within the Commission between directorates with shared responsibilities in energy R&I. DG Research, responsible for drafting Horizon 2020 and administering its implementation, catered to broad European research institutions and societal needs to promote long-term scientific research, steering funds towards broader energy priorities than the SET-Plan. DG Energy catered primarily to large energy-industry interests, to secure more total EU funding for industrial demonstration projects.

The lack of coherence also affected other EU-level programs. NER300, funded by auctioning of EU ETS emissions allowances and administered by DG Environment/Climate, targeted demonstration of CCS and renewable energy technologies. The EEPR, aimed at countering the effects of the financial crisis, was administered by DG Energy, and focused on

demonstration of large-scale CCS and windpower plants. Together, the two programs might have been combined to increase EU-level funding, thus leveraging industry commitments to co-fund demonstration projects, but such coordination was blocked by various eligibility criteria: additionality was not allowed [1].

Summing up, the Commission embraced a leading role in implementing the SET-Plan. However, this proved difficult. The Commission was granted insufficient competence in steering and funding R&I efforts; differing eligibility criteria prevailed among various EU funding programs; and diverging R&I priorities remained a problem within the Commission. Poor internal unity in the Commission weakened its capacity to align the SET-Plan with EU funding programs, rendering it vulnerable to conflicting demands from other implementing actors.

5.2.2 The European Parliament

Although the European Parliament had no formal role in the SET-Plan institutional setting, it would affect implementation through its role as co-decider of EU-level funding programs. The Parliament thus had decisionmaking authority to influence energy R&I priorities, the extent to which various EU-level funds would be directed towards co-funding SET-Plan technologies and towards realizing large-scale industrial demonstration projects.

However, the European Parliament clearly preferred prioritizing EU R&I funding to an extended list of technologies, including energy efficiency, transport, energy systems, and energy customer solutions for energy-system decentralization. Debates and voting in the Parliament revealed disagreement as to the role of the SET-Plan in steering future energy technology R&I and which specific technologies, project types, and actors should be favored [45,46].

The Parliament successfully demanded clearer priority for a wider range of low-carbon energy technologies to be funded under the Horizon 2020 Programme than initially selected by the SET-Plan. It insisted that funds be earmarked for small and medium-sized enterprises (SMEs) and less-mature technologies, against concentrating resources on demonstrating only a few, mature, low-carbon technologies [47,48]. The Parliament made similar changes to the EERP in negotiations with the Council. The program would include smaller-scale energy efficiency and a larger portfolio of renewable energy projects, in addition to the initially proposed CCS and offshore wind demonstration projects. The Parliament argued that energy

efficiency and renewables would be superior in creating jobs by SMEs at the local level. Additionally, MEPs were instrumental in extending the scope of NER 300 beyond the priorities of the SET-Plan [2].

Thus, the European Parliament contributed to increasing the level of EU low-carbon R&I funding but weakened the opportunities for consolidating the SET-Plan around its initial selection of technologies and large-scale demonstration projects. MEPs remained divided concerning the transition of the EU energy system—whether resources should be allocated to assist the development of small-scale de-centralized technology investments, or large-scale projects that could secure a future role also for conventional and centralized large-scale fossil-fuel-based plants. The result was a political compromise: the initial priorities and criteria of the SET-Plan were retained while new priorities and criteria were added.

5.2.3 Industry and the research community

Research institutions, industrial companies, and their EU-level associations had important roles in implementing the SET-Plan.[9] As the principal funders of EU energy R&I, industrial companies were necessary for bringing research from the lab to the market. Research institutions and companies were key connecting links to national R&I programs.

The six initially prioritized technology areas mirrored established European Technology Platforms (ETPs) set up under industry leadership. The Commission utilized these transnational ETP networks to underpin the SET-Plan priorities [1]. Several major industry associations wanted the Plan to cover a wider range of technologies. Business Europe, representing European industry broadly, argued that demand-side/energy-end-use technologies should be included, especially those that could help make energy-intensive industries more competitive [49]. The Council and European Parliament heeded these demands, thereby adding to SET-Plan consolidation problems: extending the priorities meant diverting funds at the EU and national levels away from initially prioritized technologies and large-scale demonstration projects [35]. Public resources available for co-funding industry investments remained more scattered than envisioned and less useful for mitigating industry

[9] They possessed resources valuable for achieving agreement on and implementing the Plan: first-hand knowledge about research frontiers at global, EU and national levels; about knowledge gaps to advance various technologies to innovation, and about the factors impeding such innovation in several national systems.

risk-aversion. Moreover, the economic crisis unfolding from the fall of 2008 made industry increasingly averse to investing in new and riskier technologies.

The role of the research community in the SET-Plan was mainly to assist industry with research tasks through EERA. This did not work as intended because the research community was divided as to what technologies and projects should be given priority. Some opposed the focus on large-scale industrial demonstration projects, holding that EU funding programs should serve smaller actors rather than big industry [50]. The research community favored more EU support of low-carbon technology R&I at lower stages of maturity as a point of departure for the SET-Plan, as reflected in the position of DG Research and supported by the European Parliament.

Much of the variation in industry investments among technology areas (the EIIs) can be explained by variations in EU and national market deployment "pull" policies. Close-to-market low-carbon demonstration projects related to the SET-Plan were deemed increasingly risky for private investors if wider market deployment "pull" policies were weak or unstable and expected to remain so [51]. SET-Plan alignment with EU climate and energy market "pull" policies was weak, varying roughly in line with the performance of the different EIIs [2, 8]. Low carbon prices related to the EU ETS offered few incentives for investment in low-carbon technologies and reduced the available funds expected under NER300. This affected some technology areas and project types more than others, in particular CCS and large-scale projects. Additional EU renewable-energy policies proved instrumental in pulling the market for smaller-scale solar PV and on-shore windpower technologies, but could not stimulate advanced biofuel technologies. Biofuels became increasingly contested, and EU renewable energy policies failed to settle the role of biofuels in the mix of renewable energies: which biofuels, from which feedstock, how to calculate climate benefits, and the specific design of support schemes for advanced biofuels. Political wrangling fueled the uncertainties for investors, who cancelled or postponed large-scale biofuel demonstration projects [2].

The upshot is that initially excluded industrial interests contributed to the expansion of the SET-Plan, resulting in scattered public funding and low realization of large-scale demonstration projects, exacerbated by the financial crisis. Also the research community favored expansion of the Plan, although some were strongly against the focus on large-scale industrial demonstration projects. Much of the unevenness in performance among the EIIs can be explained by variation in EU and national market deployment "pull" policies.

6. Conclusions

In examining why the SET-Plan encountered significant challenges in achieving its objectives, we have sought to fill a knowledge gap in the study of EU climate/energy policies. The SET-Plan largely failed on its three initial objectives—to focus, strengthen, and give coherence to accelerating innovation for a selection of cutting-edge European low-carbon technologies. First, instead of prioritizing scarce resources on key low-carbon technologies, the Plan was expanded significantly in scope. Second, it failed to coordinate and pool resources and fund large-scale demonstration projects of European value. Third, although low-carbon energy R&I funding increased, alignment to SET-Plan priorities remained weak. Funding came to steer the development and priorities of the Plan, rather than the converse.

We set out to explain these observations in terms of the role of the EU member-states, EU institutions, and non-state actors. As expected from Liberal Intergovernmentalism, the SET-Plan priorities were expanded. Expansion of initial technology priorities was partly related to the diverse energy R&I interests and preferences among major member-states. However, the low member-state commitment to the SET-Plan had more to do with preserving national self-determination over energy research and innovation than specific R&I priorities. With more member-states becoming increasingly engaged in SET-Plan low-carbon technologies, the potential for enhanced cooperation in implementing the Plan was greater than what was achieved.

Diverging member-state priorities and low member-state commitment cannot fully explain implementation challenges and poor achievement of SET-Plan objectives. The Multi-Level Governance approach draws attention to the roles played by EU institutions and non-state actors. However, expectations from the MLG perspective generally do not match our observations of low goal achievement, partly as our ‘unified EU institutions’ qualifier is not met.

The Commission was internally split over what technologies and project types to prioritize, making it susceptible to demands from technology interests not included in the initial Plan. The European Parliament had formal competence to co-decide EU-level R&I funding programs, but favored wider priorities than the SET-Plan. Whereas DG Research, the research community, and parts of the European Parliament pushed for more resources to long-term basic R&I in less-mature energy technologies that would benefit smaller industries,

DG Energy, industry, and other parts of the European Parliament wanted more resources to short-term applied R&I in mature technologies that would mainly benefit major companies.

We have also found other related reasons why the EU institutions did not manage to counterbalance diverse member-state interests and stimulate commitment to SET-Plan realization. The Commission's capacity to promote implementation was restricted by lack of legal authority to align R&I priorities to funding—indicating an institutional weakness affecting implementation. Instead, the member-states, the European Parliament, industry, and the research community all mobilized successfully to get initially-excluded technology priorities into the SET-Plan. The Plan was expanded significantly, to reflect diverse energy R&I interests, instead of serving as a consolidated, strategic steering instrument towards initially selected priorities. This resulted in scattered funding, low coordination and resource pooling, and weak but varying funding/realization of large demonstration projects—precisely the situation that was meant to be remedied, indeed the rationale for adopting the SET-Plan in the first place. Diverging alignment between SET-Plan priorities and EU climate- and energy-market deployment "pull" policies can also explain much of the variation in performance among the EIIs as regards realizing demonstration projects for CCS, solar, wind, and advanced biofuel technologies.

Lessons from the SET-Plan cannot automatically be transferred to other international low-carbon R&I initiatives, as the actors, institutions and context will differ. Still, this study shows that "picking winners" in low-carbon technology innovation is extremely difficult without a designated authority equipped with adequate powers to allocate R&I funding. As a supranational institution, the EU has more authority to do this than conventional international cooperation. Still, it largely failed to "pick winners". Thus, we can expect that it will be more difficult to select and fund specific low-carbon technologies in other international cooperative efforts, such as Mission Innovation. Mission Innovation was launched at the 2015 Paris Climate conference by 22 countries and the EU. This initiative aimed (like the SET-Plan) to accelerate clean-energy innovation by doubling public funding in some selected technology areas.

This study has made clear the many challenges involved in implementing the SET-Plan, but alternative or complementary analytical approaches are also possible. Groups of public and private actors share common interests across various levels of EU governance and organizational boundaries: some favor funding long-term basic and applied energy research; others, large-scale demonstration of more mature technologies. Systems of innovation

approaches could help explain why some technology areas have progressed differently from others [52,53]. Based on the Europeanization literature, implementation of the SET-Plan could also have been examined more from the perspective of domestic politics and policies and EU adaptation pressure [54]. Additionally, future research on international R&I could examine the relationship between cooperation and competition for new energy "green tech" market shares.

The EU has retained low-carbon energy research and innovation as an integral pillar of the European Green Deal (EGD) and continues its efforts to secure funding for the extended SET-Plan. To ensure longer-term success in line with the 2050 net-zero emissions target and international energy research and innovation leadership, coordination of low−carbon technology "push" policies should be improved. Push policies should also be better aligned with climate- and energy-market "pull" policies. The EGD provides a new opportunity for better coordination and alignment of climate, energy and R&I policies to meet the new 2030 target [55]. The target is to reduce net GHG emissions by at least 55% compared to 1990 as a steppingstone towards net-zero emissions. The EU's attempt to pick winners in low carbon R&I has been politically contested and largely failed. More technology-neutral policies should help to reduce political conflict—but weak prioritization may impair the prospects of achieving net-zero emissions by 2050.

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