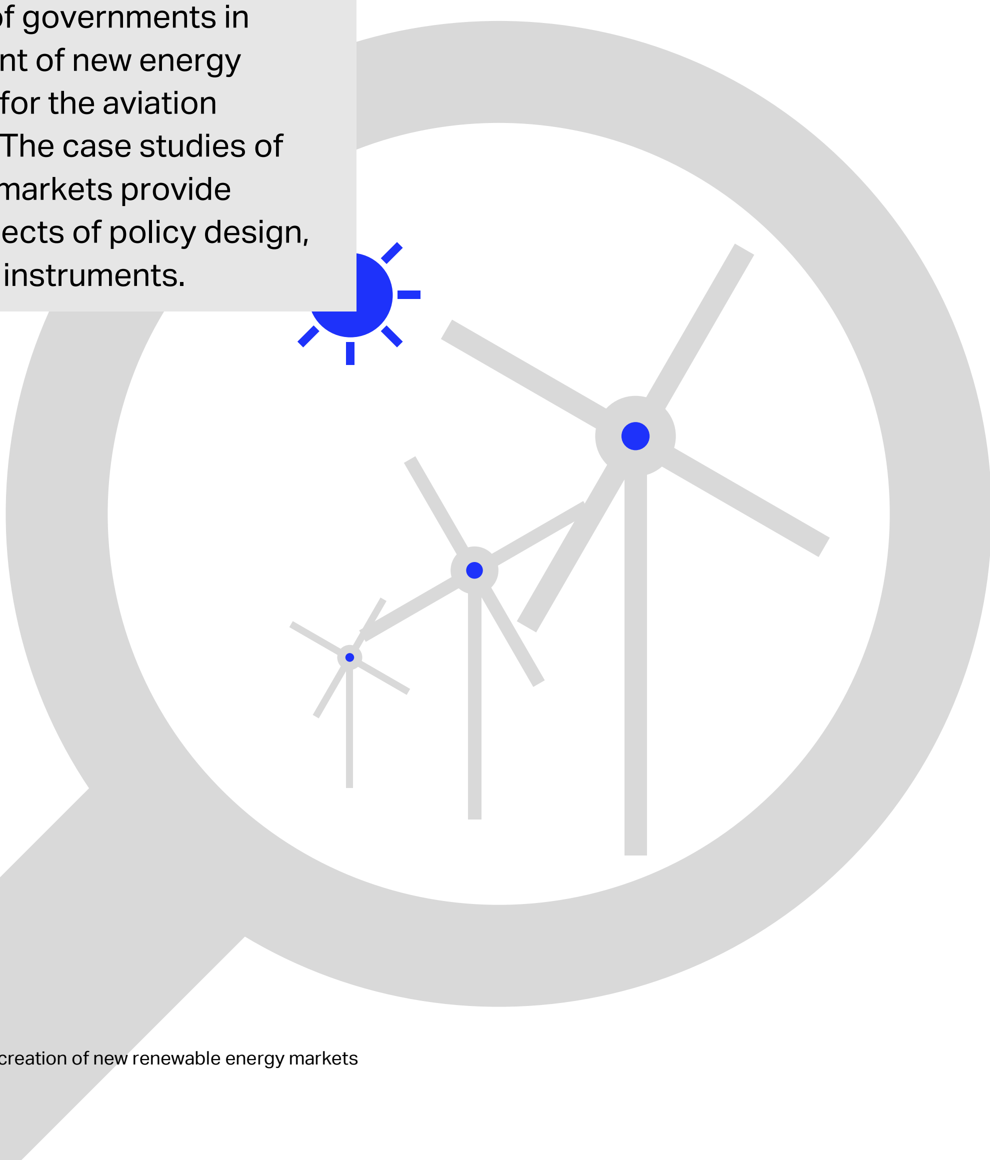
IN-DEPTH

A reflection on policies used to support the creation of new renewable energy markets

Lessons for aviation?

25 July 2024

This document provides an analysis of the policies used to create the wind and solar energy markets. The crucial role of governments in supporting the development of new energy markets is a key takeaway for the aviation sector's energy transition. The case studies of the solar and wind energy markets provide insights into important aspects of policy design, sequencing, and choice of instruments.



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EXECUTIVE SUMMARY

The global shift towards renewable energy, particularly solar and wind, offers valuable insights for the aviation sector's transition to sustainable aviation fuel (SAF). Analyzing the successes and failures of policies supporting these renewable energy markets can guide the development of effective governmental strategies for SAF, although sector-specific considerations and local contexts will always play critical roles.

Over the past 30 years, solar and wind energy have achieved significant growth due to a strategic mix of technology-push and demand-pull policies. This growth has driven innovation, investment, cost reductions, and the widespread deployment of renewable energy infrastructure, making solar and wind viable alternatives to conventional fossil fuels.

The analysis highlights the importance of well-designed policies in developing renewable energy markets. Key lessons for the aviation industry's energy transition include:

- The importance of creating energy policy frameworks tailored to local conditions and supported by international cooperation.
- The positive impact of strategic policy sequencing on the creation of a new energy market, with technology-push policies leading and demand-pull measures following.
- The importance of early and substantial governmental R&D support, a crucial element to foster competition and diverse solutions, with market-based policies implemented as technologies mature.
- The necessity for all supply chain stakeholders to be subjected to predictable, long-term, and as globally harmonized as possible policies.
- The urgent and substantial practical and financial need to support emerging economies in the development of new energy markets.

These observations are essential for the widespread production of SAF, which is crucial for the decarbonization of the air transport industry, necessitating coordinated efforts and urgent government support to achieve this goal.

1. INTRODUCTION

Policy frameworks implemented across the globe in support of the creation and scale-up of renewable energy— notably solar and wind energy— share much common ground. Analyzing the policy successes and failures around these renewable energy markets can provide insights for the aviation sector's energy transition and the necessity to create a new market in sustainable aviation fuel. Sector-specific considerations and local context will always matter in policy design, and the complexities involved mean that it is not possible to simply copy and paste policies from one case to another. Nevertheless, understanding past experiences is a prerequisite for any future policy design.

Early initiatives to develop the wind and solar energy markets date from the 1970s, prompted by the energy crises of that decade. These caused substantial oil price increases and supply shortages which prompted a shift in policy towards energy-saving and in favor of fossil fuel-saving technologies. Moreover, a heightened awareness of environmental costs emerged, as well as of the potential local economic benefits of developing alternative energy sources. Policymakers liberalized energy markets and adopted a host of policy measures designed to create new renewable energy markets.

Solar and wind energy have emerged as the twin titans among renewable energy sources. Their growth has been unparalleled, though heterogeneous, over the past 30 years during which their development took place. Thanks to a strategic mix of technology-push and demand-pull policies, the development of the solar and wind energy sectors accelerated, and the transformative effects of these policies have been profound. They have ignited innovation, stimulated investment, reduced both costs and investment risk, and facilitated the widespread deployment of renewable energy infrastructure across continents. Consequently, solar and wind energy have transitioned from niche energy sources to more mainstream contenders in the global energy landscape, providing sustainable alternatives to conventional fossil fuel energy sources.

For instance, wind energy generated 7.8% of the world's electricity in 2023, more than double its share in 2015 (3.5%)[1]. Similarly, solar photovoltaic (PV) capacity has expanded globally, generating 5.5% of the world's electricity in 2023, up from just 1.1% in 2015. More than 30 countries now generate at least 10% of their electricity from solar energy[2]. The growth in both wind and solar energy was propelled by governments' efforts in many countries across the globe, without which the steady and significant reduction in their cost of production would likely not have materialized.

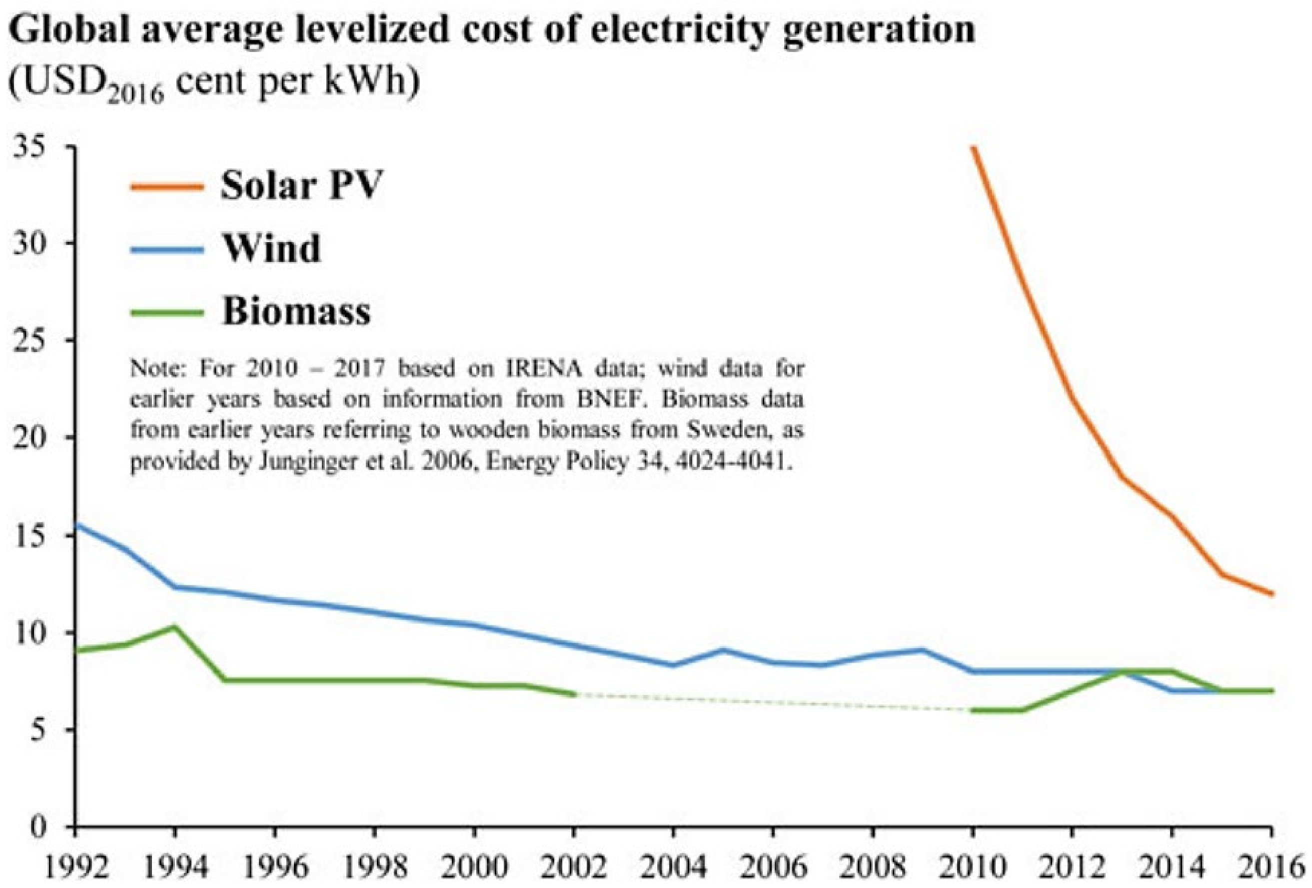
These cost reductions, underpinned by the innovation-driven policy mix described below, have translated into substantially reduced prices for consumers, ensuring broader access to, and take-up of, renewable energy worldwide. According to the International Renewable Energy Agency[3], in 2022 alone the global electricity sector saved USD 520 billion in fuel costs thanks to the use of renewable energies. The recent high fossil fuel prices have enhanced the competitiveness of renewable energies further. Approximately 86% of newly commissioned renewable power installations in 2022 generated electricity at a lower cost than electricity generated from fossil fuels. The global weighted average cost of photovoltaic solar electricity plummeted by 89% over the decade from 2009-2019 while for onshore wind, the decline was 70%[4].

More specifically, global deployment drives technological learning, leading to wide-spread spillover effects in the form of reduced technology costs. This phenomenon is particularly evident in the case of solar PV (see Figure 1). However, the effect weakens with increased product complexity. Design-intensive technologies, such as wind farms, typically require a higher proportion of locally adapted or sourced components. As a result,

[1] Ember Electricity Data Explorer. Accessible here.
[2] Ember Electricity Data Explorer, Accessible here.
[3] International Renewable Energy Agency (IRENA) (2023), Renewable power generation costs in 2022, Abu Dhabi. Accessible here.
[4] Data from Lazard Levelized Cost of Energy (LCOE) Analysis v13.0. Accessible here. Electricity prices are expressed in LCOE which includes the infrastructure cost of building the power plant along with the ongoing costs of fuel and operation over the plant's lifetime.

while some components can come from global supply chains, a significant portion of technological learning depends on developing local technological capabilities. That can represent very challenging and steep learning curves, and correspondingly more muted cost reductions, spread over a longer time horizon. Biomass is arguably an even more complex product than wind energy, and its electricity generation has seen a more limited cost reduction since 1992 (see Figure 1).

Figure 1 Average levelized cost of electricity generation per technology



Source: Bjarne Steffen, Tyeler Matsuo, Davita Steinemann and Tobias S. Schmidt, "Opening new markets for clean energy: The role of project developers in the global diffusion of renewable energy technologies", Business and Politics 2018; 20(4): 553–587. Accessible here.

2. Policies used to create the wind and solar energy markets

2.1. The role of government

There are many situations when market forces, or "laissez-faire" policies, are ill-suited or otherwise fail to deliver the outcomes sought. This is frequently the case with respect to emerging technologies, and it has certainly been the case regarding developing alternative energies to those reliant on fossil sources. Stepping in when the market fails to fill the needs of the economy is a key role of government, and as such, any market failure is a clarion call for government policy intervention.

What form such policy intervention should take regarding creating new energy markets has been discussed in a broad body of literature covering different experiences, all of which provides several general guidelines and considerations.

A categorization of policy instruments

The broad categories of policy instruments involve whether they are aimed at technology or at demand, and whether they are market based, or not. Policymakers often implement a mix of policy instruments from these different categories to support the development of a new energy market. Indeed, if there are multiple policy goals to be achieved over several time horizons, it is unlikely that a single policy instrument will be sufficient. This sparks the need to understand what the appropriate policy mix might be, and how that mix should be implemented over time.

Technology versus demand[5]:

- Focusing on technology-push instruments, which include fiscal incentives, and support for research and development (R&D) to stimulate innovation and to bring new technology solutions to the market. Such policies are instrumental in terms of scaling up new technologies and bringing about the associated cost reductions. They might, however, only bear fruit a few years down the line once the new technology has been developed and reached sufficient maturity to be commercialized.
- Focusing on demand-pull instruments, which include downstream interventions, such as feed-in tariffs, subsidies, mandates, and tax credits for end consumers to stimulate demand. These policies encourage the increased use of recent but existing technologies and do not necessarily incentivize innovation and technological change. To the extent that the technology already exists, benefits can accrue very rapidly.

Market-based versus non-market based[6]:

- Market-based instruments utilize market forces to transform the energy system, such as carbon pricing, support for renewable energy (RE) deployment, investment, and energy efficiency (EE) measures.
- Non-market-based instruments include legislative standards, such as those applied to building codes and vehicle efficiency, public investment in R&D, and mandated production or use.

These policy categories can be used separately or together. When used in combination, the policies are not always mixed in equal parts, and the relative intensity of their use will also influence the outcome. For example, in Germany, demand-pull policy funding for PV technologies under the feed-in tariff regime exceeded the

[5] HEC Paris Professors Sam Aflaki and Andrea Masini, and East West University Professor Syed Abul Basher. (2022). What's the Best Way for Governments to Support Renewable Energy? Accessible here.
[6] IRENA; IEA. Renewable Energy Policies in a Time of Transition Heating and Cooling. vol. 53. 2018; IRENA; IEA. 2020. REN21.

funding for public R&D by a factor of 40, so there was a clear bias toward demand-pull and not much of a policy mix in actual fact[7].

Local context considerations

Geographic considerations, and thus local context, are paramount when analyzing policy developments for transitioning to new energy markets. The more complex the new market or technology is, the more the local context will be determinant in terms of the optimal policy mix, potentially compounding the challenges[8]. This is undoubtedly the case in many emerging economies where current levels of investment in renewable energies are too low. Investment needs in such economies are also often greater because, in addition to the question of technology transfer, there may be a general lack of infrastructure and skilled labor, including systems for processes and administration. Hence, certain policy options might not be possible to implement unless a whole host of prerequisite conditions are tackled first. This will impact, furthermore, the pace and sequencing of policy choice and implementation across countries. Nevertheless, it is encouraging that 222 gigawatts of the 341 gigawatts new wind and solar additions in 2022 were realized in emerging economies[9].

Matching policy objectives and policy instruments

Any analysis of how successful policy instruments have been depends on the stated objective of the policy in question. If multiple objectives are pursued simultaneously, the success or failure of the policy mix can depend on from which perspective the outcome is considered.

For instance, Germany targeted the reduction of carbon emissions, the improvement of technologies, and the creation of industries and jobs simultaneously, all of which the feed-in tariff scheme in support of solar, biomass, and wind generation aimed to address[10]. Consequently, there are unsurprisingly many views in the literature[11] regarding how successful Germany's policy was.

A selection of policy instruments and the policy objectives they targeted is outlined in Table 1.

[7] Hoppmann, Joern & Peters, Michael & Schneider, Malte & Hoffmann, Volker. (2013). The Two Faces of Market Support – How Deployment Policies Affect Technological Exploration and Exploitation in the Solar Photovoltaic Industry. Research Policy. 42. 989-1003. 10.1016/j.respol.2013.01.002. Accessible here.
[8] Bjarne Steffen, Tyeler Matsuo, Davita Steinemann andTobias S. Schmidt. Opening new markets for clean energy: The role of project developers in the global diffusion of renewable energy technologies. Business and Politics 2018; 20(4): 553–587.
[9] BloombergNEF Climatescope 2023 – Power Transition Factbook. Accessible here.
[10] IWR, 2016. Erneuerbare Energien Gesetz (EEG), Accessible here.
[11] IWR, 2016. Erneuerbare Energien Gesetz (EEG), Accessible here ; Alejandro Nuñez-Jimenez,Christof Knoeri, Joern Hoppmann, Volker H. Hoffmann. Balancing technology-push and demand-pull policies for fostering innovations and accelerating their diffusion. ETH Zurich, Group for Sustainability and Technology, 2019.

Table 1 Key policy objectives, strategies, and instruments used to create new energy market[12].

POLICY OBJECTIVE AND RATIONALE	POLICY STRATEGY	POLICY INSTRUMENTS
Attract investment	Tech-push policies	▪ State-funded R&D programs ▪ Public-private R&D partnerships ▪ R&D subsidies ▪ Grants ▪ Buyer of Last Resort (BOLR) ▪ Ensure free access to public R&D facilities ▪ Tax incentives, benefiting producers ▪ Contracts for Difference (CfDs) ▪ Revenue Certainty Mechanism ▪ Loans and credit enhancements ▪ Standard setting and new regulatory frameworks, at the national, regional, and international levels
Scale-up production, lower production costs	Tech-push policies	▪ Tax incentives, benefiting producers ▪ Contracts for Difference (CfDs) ▪ Grants ▪ Direct government production ▪ Price regulation ▪ Policy harmonization at the international level
Ensure, with no additional cost, access to new energies, mainly to lower their market price and therefore facilitate their commercial scale deployment	Mix of tech-push and demand-pull policies	▪ Regulation promoting free competition and preventing cartels and other competitive distortions ▪ Tax incentives, benefiting producers ▪ Public-private partnerships ▪ Administrative incentives (simplified local procedures), benefiting end consumers ▪ Auctions
Drive demand, reduce risk for producers, accelerate uptake	Demand-pull policies	▪ Mandates ▪ Subsidies ▪ Advertising ▪ Government procurement ▪ Public promotion campaign ▪ Energy efficiency labelling ▪ Tax incentives, benefiting to end consumers ▪ Mandates ▪ Auctions

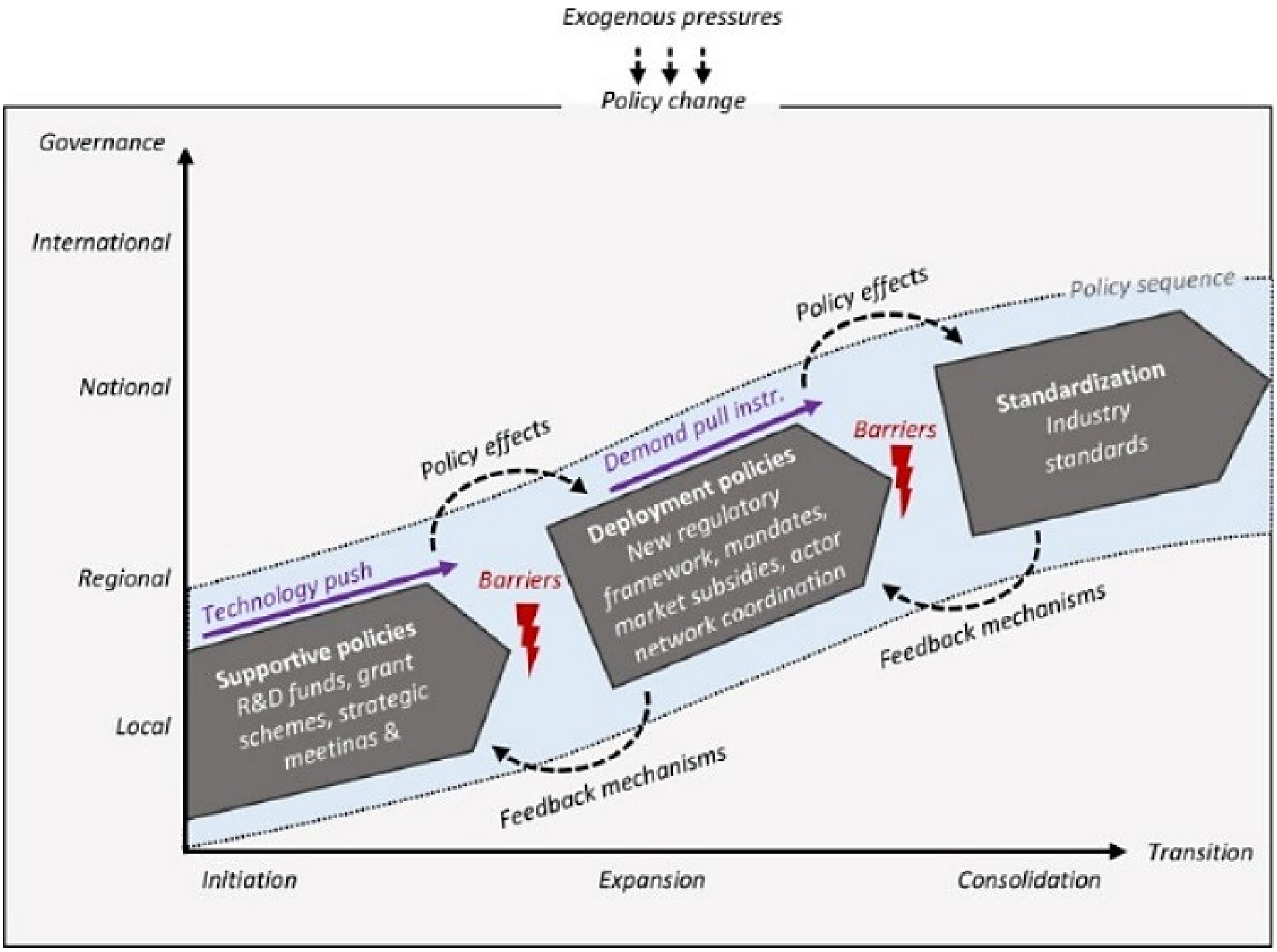
Source: IATA – Sustainability and Economics Division – 2024

[12] Table 1 provides a non-exhaustive overview of the potential policy objectives, strategies, and instruments available for policymakers planning to implement new policies to support the development of new energy markets in the context of sustainable development.

The sequencing of policy implementation.

In addition to aligning the objective, the strategy, and the policy instruments, it is essential to analyze how these interact, and how they do so over time. Temporal considerations should also be explicit as to whether the goal is to show the desired results in the short- or in the long-term[13]. The technology itself might determine the time horizon for the desired outcomes as some new energy technologies might benefit from swift access to global supply chains and develop rapidly, whereas other more complex technologies, or those more dependent on local factors, might require different policies and be viable only on a longer time horizon. The issue of how to implement policy over time and which policy instrument to use when is commonly referred to as policy sequencing[14]. There are two types of sequencing: strategic policy sequencing, and reactive policy sequencing.

Figure 2 Generic process model of strategic policy sequencing



Source: Katrin Pakizer, Eva Lieberherr, Megan Farrelly, Peter M. Bach, David Saurí, Hug March, Miriam Hacker, Christian Binz, Policy sequencing for early-stage transition dynamics – A process model and comparative case study in the water sector, Environmental Innovation and Societal Transitions, Volume 48, 2023,100730, ISSN 2210-4224, https://doi.org/10.1016/j.eist.2023.100730.

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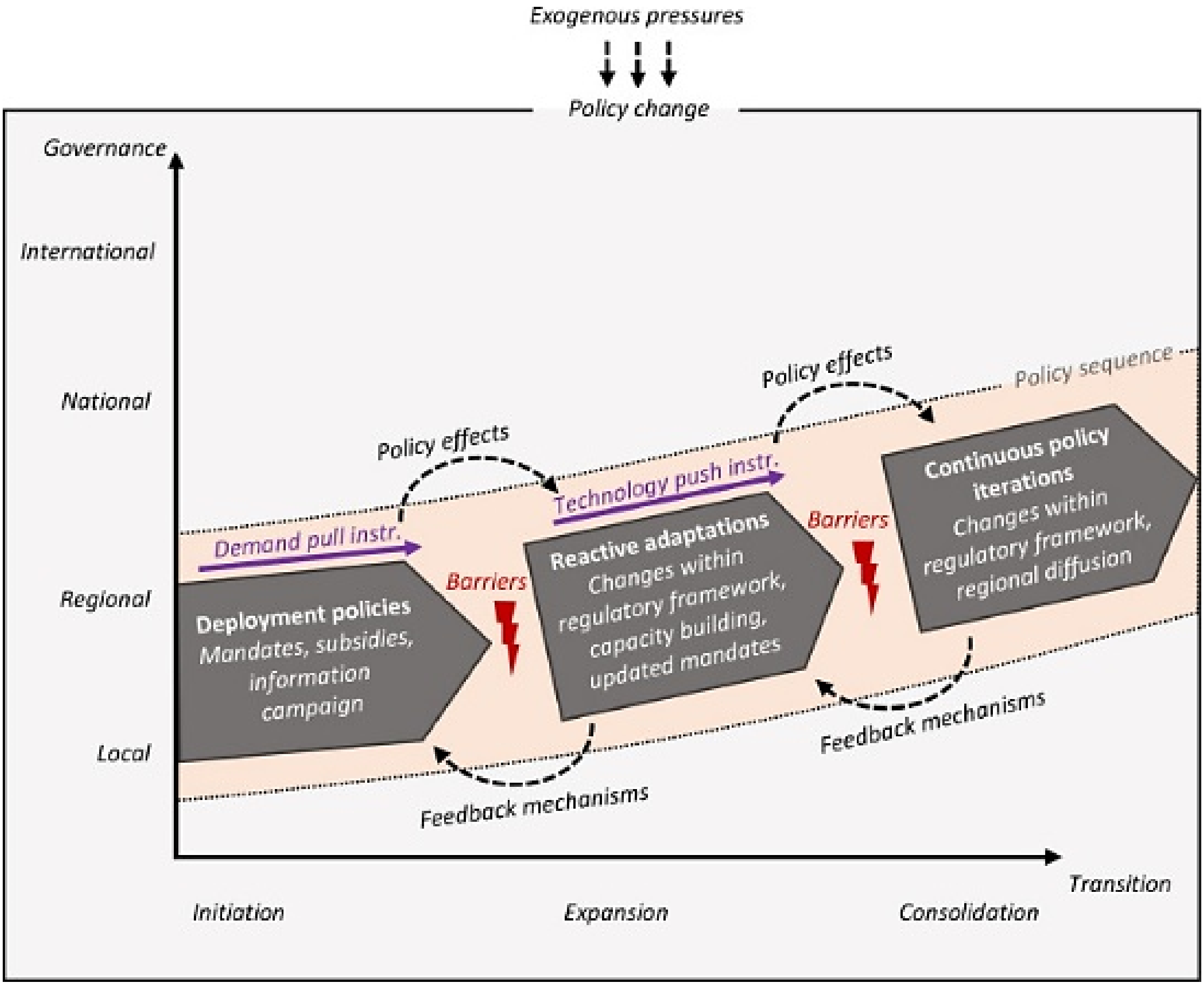
[13] Alejandro Nuñez-Jimenez,Christof Knoeri, Joern Hoppmann, Volker H. Hoffmann. Balancing technology-push and demand-pull policies for fostering innovations and accelerating their diffusion. ETH Zurich, Group for Sustainability and Technology, 2019.
[14] Katrin Pakizer, Eva Lieberherr, Megan Farrelly, Peter M. Bach, David Saurí, Hug March, Miriam Hacker, Christian Binz. Policy sequencing for early-stage transition dynamics – A process model and comparative case study in the water sector, Environmental Innovation and Societal Transitions, Volume 48, 2023,100730, ISSN 2210-4224. Accessible here.

Strategic policy sequencing (Chart 2) emphasizes the importance of considering technology-push as a critical first step because it tends to lower costs of new technologies rapidly, and broaden their political support, helping to address potential economic and cultural-cognitive barriers more swiftly[15].

In the absence of strategic policy sequencing, policy formulation often resorts to becoming reactive (Chart 3), focusing on certain key bottlenecks by developing an improved regulative and legal framework[16].

Figure 3 Generic process model of reactive policy sequencing



Source: Katrin Pakizer, Eva Lieberherr, Megan Farrelly, Peter M. Bach, David Saurí, Hug March, Miriam Hacker, Christian Binz, Policy sequencing for early-stage transition dynamics – A process model and comparative case study in the water sector, Environmental Innovation and Societal Transitions, Volume 48, 2023,100730, ISSN 2210-4224, https://doi.org/10.1016/j.eist.2023.100730.

In both cases, the literature is unanimous regarding the need for policy stability and predictability. An uncertain policy environment can prevent stakeholders from investing or, more generally, from taking any action to

[15] Katrin Pakizer, Eva Lieberherr, Megan Farrelly, Peter M. Bach, David Saurí, Hug March, Miriam Hacker, Christian Binz. Policy sequencing for early-stage transition dynamics – A process model and comparative case study in the water sector, Environmental Innovation and Societal Transitions, Volume 48, 2023,100730, ISSN 2210-4224. Accessible here.

[16] Katrin Pakizer, Eva Lieberherr, Megan Farrelly, Peter M. Bach, David Saurí, Hug March, Miriam Hacker, Christian Binz. Policy sequencing for early-stage transition dynamics – A process model and comparative case study in the water sector, Environmental Innovation and Societal Transitions, Volume 48, 2023,100730, ISSN 2210-4224. Accessible here.

develop a new market. This applies, of course, to how the policy is implemented as well, including administrative and legal frameworks and means of enforcement[17].

Case studies of solar and wind energy development policies

Technology-push (TP) and demand-pull (DP) policies have both played a role in the development of the wind and solar energy markets. On the one hand, this suggests that R&D policies and tax incentives aimed at fostering the creation of pertinent technological knowledge have proven to be effective in expediting industry-level technological advancements. On the other hand, it also suggests that public communication campaigns, tax incentives for end consumers, and mandates aimed at fostering the use of solar and wind energies have proven to be effective in boosting demand.

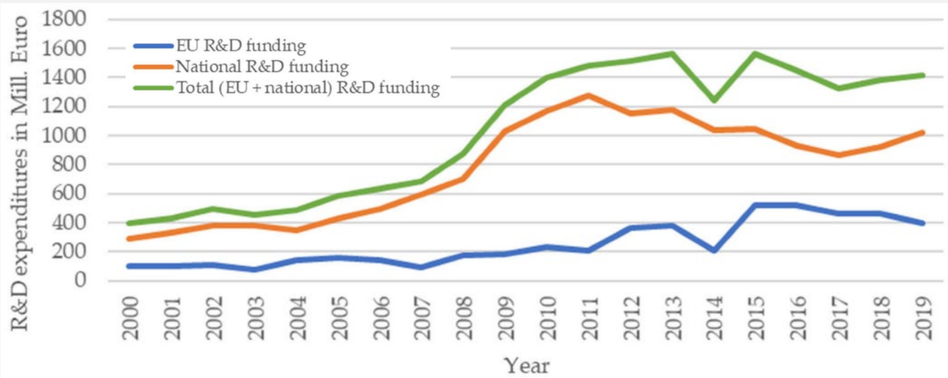
Striking the right balance between TP and DP, both in terms of duration and intensity, has been essential in pursuing industry policy objectives. Notably, initial TP action helped offset the higher costs associated with early-stage development and deployment, thereby spurring market adoption.

State-funded R&D programs – a European example[18]

The European Union (EU) and its member States widely acknowledged the importance of public R&D support for renewable energy technologies. For example, they committed to double public R&D investment from 2015 until 2020 and to increase the renewable energy share to at least 35% by 2030.

From 2000 to 2020, the EU's total R&D contribution for renewable energy technologies increased by a factor of approximately 5. The largest economies received most of the R&D funding for RE technologies and Germany, for example, received 20% of the total funds available, at around EUR 1 billion of the EUR 5 billion total. While regional policies targeting R&D have been confirmed to be effective drivers of green innovation, national policy support remains critical for the emergence of a new energy market.

Figure 4 EU and national R&D expenditure for renewable energy technologies, 2000 – 2020, Euro million, 2020 prices



Source: Gasser, M.; Pezzutto, S.; Sparber, W.; Wilczynski, E. Public Research and Development Funding for Renewable Energy Technologies in Europe: A Cross-Country Analysis. Sustainability 2022, 14, 5557. https://doi.org/10.3390/su14095557.

[17] Dr Valentina Dinica and Prof. Dr. Hans Bressers. Center for Clean Technology and Environmental Policy, Universite of Twente. The implementation of renewable energy policies: theoretical considerations and experiences from Spain, Netherlands and United Kingdom. Accessible here.
[18] Gasser, M.; Pezzutto, S.; Sparber, W.; Wilczynski, E. Public Research and Development Funding for Renewable Energy Technologies in Europe: A Cross-Country Analysis. Sustainability 2022, 14, 5557. Accessible here.

US Solar Investment Tax Credit (ITC)

The ITC is a dollar-for-dollar credit for expenses invested in renewable energy properties, most often solar developments.

The Inflation Reduction Act extended the ITC from 2022 through 2032 as a 30% credit for qualified expenditures. This extension has provided market certainty for companies to develop long-term investments that drive competition and technological innovation, which in turn lowers energy costs for consumers. Under current law, the tax credit will drop to 26% for systems installed in 2033 and to 22% for those installed in 2034, before it is eliminated in 2035[19].

Overall and to date, the residential and commercial solar ITC has helped the US solar industry grow by a factor of more than 200x since it was implemented in 2006, with an average annual growth of 33% over the past decade alone (2014-2024)[20]. Since the Solar Investment Tax Credit was passed in 2006, more than 170,000 American solar jobs have been created, and USD 66 billion has been invested in solar installations nationwide[21].

Countries have adjusted their policy mixes periodically to align with the latest market dynamics. For instance, as technologies mature, a shift towards a blend of market incentives, including feed-in tariffs (FITs), and local content requirements were introduced across diverse markets such as China, Brazil, Portugal, and Spain[22].

Feed-in-tariffs have been frequently paired with Renewable Portfolio Standards (RPS). Indeed, during the initial stages of RPS implementation, policymakers often maintained FITs to offer subsidies for photovoltaic power[23].

These incentives created an enabling environment for renewable energy deployment by providing market certainty and stimulating private-sector investment.

[19] Solar Energy Industries Association (SEIA), Solar Investment Tax Credit (ITC). Accessible here.
[20] Solar Energy Industries Association (SEIA), Solar Investment Tax Credit (ITC). Accessible here.
[21] Solar Energy Industries Association (SEIA), The Case for the Solar Investment Tax Credit (ITC). Accessible here.
[22] IRENA-GWEC, 30 Year of Policies for Wind Energy: History of Policy Development, 2013 edition, accessible here.
[23] Zhang, Y.; Zhao, X.; Zuo, Y.; Ren, L.; Wang, L. The Development of the Renewable Energy Power Industry under Feed-In Tariff and Renewable Portfolio Standard: A Case Study of China's Photovoltaic Power Industry. Sustainability 2017, 9, 532. Accessible here.

Renewable portfolio standards (RPS)

One of the most common demand-side policy options employed in supporting energy market development is renewable portfolio standards (RPS). These standards mandate that a certain proportion of electricity must be sourced from renewable sources by a specified date.

By creating demand for renewable energy, RPSs stimulate competition in the market for clean technologies. RPSs directed at the wind energy sector have been implemented in numerous states across the US, the UK, Japan, and Australia, and played a pivotal role in driving its expansion and diversification of projects.

The EU stands out as a notable example in the solar energy sector by imposing a mandate to enforce the installation of rooftop solar energy systems. By 2026, all new public and commercial buildings with a useful floor area exceeding 250m2 are required to have rooftop solar panels installed. Similarly, existing public and commercial buildings of the same size must comply by 2027. Furthermore, all newly constructed residential buildings are mandated to meet this requirement by 2029.[24]

Feed-in tariffs

The feed-in tariff (FIT) is one of the most prevalent and effective policies within the wind energy sector. It offers a fixed price for electricity generated by wind turbines over a specified timeframe, ensuring stable and predictable revenue streams for wind energy producers. This certainty reduces risk, fosters investment, and spurs innovation in the sector.

FITs have seen widespread adoption in countries including Germany, Spain, China, and India, significantly contributing to the growth in wind energy capacity and market share.

However, a pivotal challenge associated with FITs lies in determining the optimal pricing level. Balancing this aspect is crucial to ensure that incentives remain aligned with sustainable development goals while avoiding undue burdens on consumers or strains on governmental budgets.

Guidance regarding the legality of feed-in tariffs for RE development with respect to WTO (World Trade Organization) rules can be drawn from the decision pertaining to the Canada Renewable Energy case[25].

Local content requirements were also often introduced to support domestic industries and job creation. These requirements included setting long-term targets for renewable energy deployment, facilitating access to Power Purchase Agreements (PPAs), and leveraging abundant local resources, such as favorable wind conditions.

However, a comprehensive analysis[26] run from 1995 to 2017 of 124 countries, among which 17 introduced local content requirements in wind and solar PV showed that, for most countries, local content requirements have not led to a significant increase in exports of solar and wind energy components. The exceptions are

[24] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Social Committee and the Committee of the Regions EU Solar Energy Strategy, COM/2022/221 final. Accessible here.
[25] World Trade Organization – Dispute settlement DS412 – Canada – Certain Measures Affecting the Renewable Energy Generation Sector. Accessible here.
[26] Scheifele, Fabian & Bräuning, M. & Probst, B.. (2022). The impact of local content requirements on the development of export competitiveness in solar and wind technologies. Renewable and Sustainable Energy Reviews. 168. 112831. 10.1016/j.rser.2022.112831. Accessible here.

China[27] and Spain, which built significant export capacities in wind and solar energy. A central reason for those policy to under-deliver is likely that countries target wind and solar components that are too challenging with respect to existing industrial structures. Countries that have succeeded in breaking into solar or wind exports had already exhibited export capabilities in related industries before the introduction of local content requirements, such as electronics for solar PV.

Power Purchase Agreement (PPA)

A Power Purchase Agreement (PPA) is a contractual arrangement between two parties: an electricity producer and an off taker, which can be an electricity consumer or trader. This agreement details all terms, including the quantity of electricity to be supplied, the agreed-upon price, risk allocation, necessary accounting procedures, and penalties for contract breaches. Being a bilateral agreement, a PPA can be tailored to the specific needs of the parties involved, allowing for various forms of supply contracts.

Typically, a PPA is a long-term contract, often spanning 10 to 15 years. It mitigates the risk of electricity market fluctuations, making it attractive for large, debt-financed projects. PPAs are also used to sustain the operation of renewable energy installations after government subsidies have expired. Indeed, without subsidies, there is a lack of financial security for lending institutions, such as banks, to invest in a renewables project. As a result, lenders require a new way to secure their investment. A PPA can prove that the renewable asset concerned has already found a long-term buyer at a fixed price.

Furthermore, the efficient use of administrative policies has played a key role in facilitating the deployment of new energies.

For instance, the latest EU renewable energy policies focus on streamlining procedures for technology providers to facilitate easy access to innovation by simplifying permit and other patent procedures for all stakeholders within the supply chain.

[27] Kuntze, Jan-Christoph & Moerenhout, Tom. (2012). Local Content Requirements and the Renewable Energy Industry - A Good Match?. SSRN Electronic Journal. 10.2139/ssrn.2188607. Accessible here.

EU Renewable Energy Directive III

The EU Renewable Energy Directive III (EU REDIII) incorporates[28] provisions aimed at simplifying permit processes to expedite the initiation of renewable energy projects. More explicitly, the recently adopted EU Commission action plan in September 2023 introduced[29].

- - Expedited permitting[30]: The Commission announced the launch of the "Accele-RES" initiative, which includes specific actions aimed at facilitating the deployment of wind power. These actions comprise the development of a dedicated online tool to aid Member States in the permitting process. Additionally, the initiative involves updating the Commission Recommendation[31] on expediting permit-granting procedures for renewable energy projects and prioritizing the digitalization of national permitting processes across the EU. Furthermore, support will be provided for implementing training programs for national permitting authorities.
- - Enhanced predictability: In collaboration with member States, the Commission has expressed its commitment to enhancing the visibility and predictability of national plans for renewable energy deployment by implementing pertinent provisions within the EU RED and deploying transparent digital tools. For instance, the Commission intends to establish an interactive EU digital platform where member States' auction planning will be made publicly available. This platform will enhance the visibility of upcoming auctions and expected deployment volumes, enabling companies to access information regarding all planned EU auctions from a centralized source[32].

In addition, EU policymakers seek to implement well-defined procedures for public engagement in policy-setting. Public engagement and participation, including consultations, communication, education, and empowerment, play pivotal roles in the development of new energy markets, but are often overlooked. These can bolster social acceptance and support for renewable energy projects by addressing concerns and fostering a sense of ownership among local communities and stakeholders. Inclusive policy-setting procedures are instrumental in facilitating the transition to renewable energy.

[28] The revised Renewable Energy Directive (EU) 2018/2001, as amended by Directive (EU) 2023/2413. Accessible here.
[29] For instance, see articles 16 and of the revised Renewable Energy Directive (EU) 2018/2001, as amended by Directive (EU) 2023/2413. Accessible here.
[30] " Unlocking existing projects in the authorization phase and accelerating new projects requires more efficient and transparent permitting processes, better staffing and training of the national permitting authorities and faster implementation of the new regulatory framework on permitting. To address these obstacles, the Commission will focus on rolling out the digitalization of the permitting process across all the EU Member States. Better exchange between Member States on existing practices to gain acceptance of local communities will also bring additional value to the process." – Source: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, European Wind Power Action Plan. Accessible here.
[31] Commission Recommendation C/2022/3219 final. Accessible here
[32] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, European Wind Power Action Plan. Accessible here.

EU Solar PV Industry Alliance

For example, in 2022, the EU Commission launched the EU Solar PV Industry Alliance[33], in collaboration with industrial actors, research institutes, associations, and other relevant parties to advance the objectives of the EU's Solar Energy Strategy.

This alliance serves as a platform for stakeholders in the sector, with a focus on facilitating investment opportunities, diversifying supply chains, retaining more value in Europe, and promoting the development of efficient and sustainable solar PV products. Moreover, it provides policy recommendations to reduce Europe's vulnerability to supply disruptions and bolster domestic industry.

Interestingly, the policies discussed above were crafted to adapt and evolve in response to developments in the solar and wind energy markets.

For instance, as the wind energy sector has matured and technologies have become more accessible, a recent and emerging policy approach has focused on market design, involving the implementation of auction or tender systems. Also, in the United States, in August 2022, Congress passed the Inflation Reduction Act (IRA), which extends the Production Tax Credit (PTC) and the Investment Tax Credit (ITC) for wind projects through 2024. Moreover, the IRA introduced increased credit amounts and bonus tax incentives for projects meeting specific criteria. By 2025, the existing PTC and ITC will transition to technology-neutral versions, slated for a gradual phase-out by 2032 or when total greenhouse gas emissions in the power sector decline to at least 75% below 2022 levels, whichever occurs later[34].

While this approach has maintained coherence and relevance within the broader policy framework, it has also sometimes jeopardized the critical predictability needed to encourage investment.

Auction and tender systems

These mechanisms entail competitive bidding for contracts to supply renewable energy at the most competitive price, thereby reducing the cost of energy while enhancing its efficiency and transparency. Auctions and tenders have been successfully adopted in countries including Brazil, Mexico, South Africa, and Morocco[35], resulting, for instance, in record-low wind price and significantly enhancing its competitiveness against fossil fuels and other renewable energy sources.

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[33] https://solaralliance.eu/
[34] **WINDExchange, Wind Energy Policies and Incentives. Accessible here.**
[35] **IRENA, Preliminary Findings, Renewable Energy Auctions, Status and trends beyond price. Accessible here.**

3. Key take-aways for aviation's energy transition

The air transport industry's quest to decarbonize has been given explicit support by the International Civil Aviation Organization (ICAO)'s commitment through its member States to produce 5% of jet fuel in the form of sustainable aviation fuel (SAF) or other cleaner energies as per the CAAF/3[36] vision for 2030[37]. This commitment also puts a spotlight on the urgency to scale up SAF production, as it currently represents a mere 0.5% of total jet fuel consumption.

While there is no "one-size-fits-all" set of policies that will guarantee carbon emissions-free flights everywhere simultaneously, we outline below some lessons learned from the renewable energy sectors regarding the policies that can be implemented to create a global market for SAF[38].

Strategic policy intervention is immediately required to lower SAF market prices

The SAF market today is in its utter infancy, and the meagre quantities produced are sold through private deals[39]. As a result, prices are estimated from the production cost side rather than from observed and traded prices, and both supply and demand volumes remain opaque. Policy intervention is sorely needed to address this market failure and to mitigate the effects of inaction.

In this context, governments should design policy mixes that enhance innovation across the entire supply chain and that scale up SAF production urgently. Indeed, given that SAF currently costs around 2 to 5 times more than fossil-based jet fuel, scaling is necessary to drive prices lower, and the immediate policy emphasis needs to be on technology-push instruments for rapid results in this domain.

Learning from the most effective policy instruments implemented to support the development of wind and solar energy markets, tech-push policies can include tax incentives and subsidies benefiting producers, as well as Contracts for Difference (CfDs) and the Buyer Of Last Resort (BOLR) mechanisms to increase supply, reduce production costs, and lower market prices. These should be coupled with maximum support for R&D across a broad technological spectrum to foster innovation and to avoid the risk of trying to pick the "winner" too soon. Moreover, as regards aviation's energy transition, multiple solutions will be needed and should be developed simultaneously.

Effective policy is driven by sound economic principles; financial and environmental sustainability go hand in hand

The most effective policies with respect to promoting wind and solar energies were those driven by sound economic principles that enabled and promoted economic activity and growth.

Aviation's energy transition must not compromise the overall economic health of the supply chain or create market or sub-market monopolies or oligopolies which add to existing or create new market distortions and failures. The so-called "unintended consequences" of some appealing policy actions – including their

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[36] The Third Conference on Aviation Alternative Fuels (CAAF/3) hosted by the International Civil Aviation Organization (ICAO) agreed a global framework to promote SAF production in all geographies for fuels used in international aviation to be 5% less carbon intensive by 2030. To reach this level, about 17.5 billion liters (14Mt) of SAF need to be produced.

[37] The aim is that aviation fuel in 2030 is 5% less carbon intensive than fossil fuel used today by the industry.

[38] Note that detailed policy recommendations will be provided in IATA's upcoming Net Zero Carbon Roadmap, which will be released in September 2024.

[39] In 2022, global SAF production is estimated to have been between 240 and 380 thousand tonnes (300 to 450 million liters), covering only around 0.1% to 0.15% of total jet fuel demand. – IATA, SAF Deployment, accessible here – In 2023, SAF volumes reached over 600 million liters (0.5Mt), double the 300 million liters (0.25 Mt) produced in 2022. SAF accounted for 3% of all renewable fuels produced, with 97% of renewable fuel production going to other sectors. In 2024 SAF production is expected to triple to 1.875 billion liters (1.5Mt), accounting for 0.53% of aviation's fuel need, and 6% of renewable fuel capacity. The small percentage of SAF output as a proportion of overall renewable fuel is primarily due to the new capacity coming online in 2023 being allocated to other renewable fuels – IATA Press Release n69, accessible here.

interaction with other policy initiatives or levers – cannot be neglected. Therefore, policymakers do need to consider impacts beyond the immediate policy target. For instance, neither incentives nor mandates are neutral with respect to their effects on broader markets. Of course, economic, and financial incentives will tend to encourage the targeted behavior while taxes, restrictions, and obligations will weigh on the activity concerned.

With regards to fuel, if policymakers wish to reduce the use of fossil fuel, they should not subsidize their production and exploration as is the case currently. On the contrary, if they wish SAF to be produced at scale, they should sponsor and support R&D and innovation and provide subsidies to produce SAF and related feedstock. Such a policy mix would improve environmental outcomes, generate more jobs, improve energy independence, and boost economic activity.

Moreover, air transportation is a uniquely global industry and is therefore particularly sensitive to policy fragmentation. Even small divergences in policies across countries can create radically different competitive environments and potentially render compliance impossible. International harmonization of policies is consequently of utmost importance to our industry.

Leaving no economy behind; developing countries' crucial role in decarbonization

All airlines in the world must have access to SAF, and all SAF producers in the world must have access to airlines' demand for SAF globally. As discussed regarding the wind and solar energy markets, policy support is key in enabling such global dynamics.

However, the Declaration from ICAO's Third Conference on Aviation Alternative Fuels (CAAF/3) in November 2023, made clear that "certain States have the capacity to progress at a faster pace, and that others do not", referring to developing countries' local context considerations. Considering this statement, the CAAF/3 participants agreed that technology transfer should be facilitated, recognizing that the involvement of developing countries in SAF production requires context-specific solutions, i.e., tailor-made policies aligned with international standards.

Technology transfer can be facilitated by policy changes, global partnerships, and focused capacity-building efforts[40]. For instance, public-private partnerships, supported by key international cooperation schemes, partnerships with international organizations, donor agencies, and multilateral development banks, are all needed to provide access to technical skills, and help close the finance gap.

It is nevertheless certain that mature economies will need to financially support emerging economies if a truly global SAF market is to emerge.

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[40] Falcone, P.M. Sustainable Energy Policies in Developing Countries: A Review of Challenges and Opportunities. Energies 2023, 16, 6682. Accessible here.

4. Conclusion

Just as it was in the 1970s, ahead of the renewable energy boom, the global economy remains concerned with energy security. Today, the world also faces increasingly urgent choices regarding addressing climate change. These factors are important catalysts for structural change in global energy markets. Scaling up renewable energy production to unprecedented levels is essential to reduce our dependence on fossil fuels. Every industry, including aviation, requires a fair allocation of this uncertain future renewable energy production.

The aviation sector's goal of achieving net-zero carbon emissions by 2050 is ambitious and demands coordinated efforts on multiple fronts for successful implementation. While airlines are committed to this objective and equally committed to meeting the obligations imposed upon them by ICAO and by States, the tools with which to achieve this are not available. Urgent government support is necessary.

The analysis presented in this paper underscores the critical role of well-designed policies in fostering the development of new renewable energy markets. While there is no universal set of policies to ensure decarbonization globally, by examining different policy instruments and their impacts on the wind and solar energy sectors, valuable lessons emerge for the aviation industry's energy transition. These include the need to strive for overall energy policy frameworks that are tailored to local contexts and supported by international cooperation. In the sequencing of policies, technology-push should lead, and demand-pull should follow. Support for R&D should also be stacked up front to ensure competition and the multiplication of solutions. More market-based policies can follow as technologies mature. Policies need to be predictable, long-term, and harmonized globally to every extent possible. Emerging economies require both urgent and additional practical and financial support. All this will be essential for achieving widespread production of SAF, which is indispensable for the air transport industry's decarbonization.