

# Integrated Carbon Policy Design for Achieving Net-Zero Targets

Abhijeet Acharya<sup>1</sup>

<sup>1</sup> College of Management and Technology, Walden University, Minnesota, USA

Correspondence: Abhijeet Acharya, Walden University, Minnesota, USA.

Received: December 4, 2021

Accepted: January 7, 2022

Online Published: January 10, 2022

doi:10.5539/eer.v12n1p1

URL: <https://doi.org/10.5539/eer.v12n1p1>

## Abstract

Several countries have set net-zero targets, and many more will announce in the next few years. Countries have used carbon pricing as an instrument to cut Greenhouse Gas (GHG) emissions and provide a price signal to attract private investments to achieve net-zero targets. However, current carbon policy in countries with net-zero targets remains inadequate and asymmetrical to overcome net-zero challenges; there are visible gaps in the carbon price level, sectoral coverage, and mechanism to reward carbon-neutral initiatives. This paper proposed an integrated carbon policy design covering economic, technical, and social dimensions and discussed how an integrated policy design approach could be effective in helping countries achieve net-zero objectives. The paper makes recommendations for net-zero policymakers. First, a stable and appropriate carbon price must be in place to attract private investments in carbon offset measures and commercialize clean technologies. Second, governments should use an effective revenue recycling mechanism to engage firms and citizens in mitigating the side effects of the carbon price regime and win their trust. Third, countries should promote behavioral changes and carbon footprint reduction measures through citizen participation.

**Keywords:** carbon price, carbon tax, clean technologies, citizen engagement, net-zero, revenue recycle

## 1. Introduction

### 1.1 Background

Scientists and economists agree that climate change resulted from the industrial revolution when firms released GHG into the atmosphere without being held responsible for the negative impact on the environment. Therefore, one way to curb GHG emissions is to impose a reasonable carbon price on emissions. With effective carbon prices, firms can be made accountable for the social cost and environmental damage arising from their production-related emissions (Burke, Byrnes & Fankhauser, 2019; Stöllinger, 2020). According to OECD (2021), carbon pricing can be an effective decarbonization policy if adequately designed. Supporting a fair carbon price can make renewable energy more competitive than high-carbon energy sources and provide certainty for investors willing to invest in clean and emission abatement technologies. Nordic countries Finland, Sweden, Norway, Denmark implemented carbon policy in the 1990s, followed by central European countries like Switzerland, Slovenia, Estonia, and Canadian provinces of Alberta and British Columbia in the 2000s (World Bank, 2020). However, the current reality of carbon policy implementation is not encouraging; out of 190 countries pledged to the Paris agreement, only 46 nations and 26 subnational jurisdictions have implemented carbon policy which covers just 22% of global GHG emissions (World Bank, 2020). Curbing GHG emissions through higher carbon prices can be difficult for political decision-makers; however, it is possible to design a carbon policy that is effective and acceptable to society (Burke et al., 2019). According to the World Bank (2020), the current level of the carbon price is substantially lower than those needed to be consistent with the Paris Agreement, the estimated carbon Prices of at least US\$40–80/tCO<sub>2</sub>e by 2020 and US\$50–100/tCO<sub>2</sub>e by 2030 are required to reduce emissions in line with the Paris Agreement. Further, IEA estimates a carbon price level of \$63/tCO<sub>2</sub>e in 2025 and \$140/tCO<sub>2</sub>e in 2040 must be in place to incentivize GHG reduction measures to achieve EU's 2030 and 2050 targets (Barnes, 2021). In recent years the issues related to carbon policy design have gained momentum; however, the effectiveness of carbon policy design depends on several factors. According to Barnes (2021), the key elements of effective carbon policy design are a) carbon price level, b) scope and coverage, c) existence of different carbon prices and schemes within a country, d) carbon leakage, and e) credibility of policy design. With many countries moving away from renewable energy subsidies, clean technology must be linked to the carbon market to remain viable and self-sustaining (Edenhofer et al., 2021). An

effective carbon policy design can provide investment incentives to relatively new pollution abatement technologies such as CCS (Carbon Capture and Storage) and green hydrogen that act as a carbon sink.

Finland and Sweden have net-zero targets by 2035 and 2045, respectively, while Denmark, France, Hungary, New Zealand, and the United Kingdom have a net-zero target by 2050. Denmark, France, Hungary, New Zealand, Sweden, and United Kingdom have made their respective net-zero targets legally binding. Countries like Finland, Germany, Ireland, Norway, Switzerland, and the EU commission have included net-zero targets in their policy documents (Climate Action Tracker, 2020). Having set an ambitious net-zero target, countries must have effective policies to achieve the same. Net-zero target allows offsetting carbon emission from the hard-to-treat sector with natural or engineered carbon sinks. Therefore, to achieve net-zero targets, a higher price on positive emissions should create new opportunities for scaling up and funding negative emissions and carbon sinks (Burke et al., 2019). In general, countries use two instruments to set a carbon price: a cap-and-trade mechanism on Emissions Trading System (ETS) or a carbon tax. Both instruments aim to create an additional cost for GHG emitters, discouraging positive emissions and encouraging cleaner technologies that act as emission offset or carbon sink. Among countries that have set net-zero targets, the carbon price level and policy coverage vary drastically. Even within the EU, countries have different carbon price levels and coverage. Sweden has the highest carbon price of US\$127 per tCO<sub>2e</sub>, Finland US \$70, Norway US\$ 59-5, France US\$50, Denmark US\$ 26-23, UK US\$24 while EU ETS at US\$25; in terms of coverage, Norway covers more than 60% of GHG in the jurisdiction, Sweden around 40%, UK about 25% while EU ETS about 46% of GHG emission (World Bank, 2020). Furthermore, a significant difference in carbon price level and coverage may also lead to carbon leakage within the EU countries. Therefore, such anomalies in carbon policy design pose a challenge to countries that have set ambitious net-zero targets.

### *1.2 Aim of the Paper*

This paper aims to propose an integrated carbon policy design covering economic, technical, and social dimensions and discuss how an integrated policy design approach could be effective in helping countries achieve net-zero objectives. In section 1, we briefly discuss the relevance of carbon policy in the abatement of GHG emissions; we also discussed issues and challenges in designing an effective carbon policy. In section 2, we discuss the methodology. Section 3 discusses the carbon pricing concept, evolution of the carbon market, effective carbon policy design elements, including issues related to the floor price level, scope, coverage, and carbon leakage. We also discussed the significance of effective carbon policy design in achieving net-zero targets in the EU. Section 4 discussed an integrated carbon policy design underpinning economic, social, and technological dimensions that will help countries achieve net-zero. We conclude our paper in section 5 with recommendations that net-zero policymakers must incorporate in carbon policy design to help countries achieve their net-zero targets.

## **2. Materials and Method**

We conducted a literature review on papers related to carbon policy design issued within the last five years. The literature review helped us develop a conceptual understanding of carbon policy implementation in achieving net-zero targets; we also identified key elements of carbon policy design and challenges in implementing the same. To gain insight into the EU's carbon policy design, we conducted literature reviews on status reports related to carbon policies issued by international bodies. In the discussion section, we used the cross-country comparison between countries with net-zero targets to bring out key differences in carbon policy design. We also analyzed best practices followed by countries in rewarding net-zero initiatives using carbon revenue recycling.

## **3. Carbon Price Concept**

The concept of carbon price emerged in the 1990s when Nordic countries wanted to develop a market mechanism to support GHG reduction measures. It was further extended in 1997 by the Kyoto Protocol when 38 industrialized nations agreed to use a carbon trading mechanism to support climate change initiatives (Michaelowa, Shishlov, & Brescia, 2019). Under the Kyoto Protocol, countries could earn carbon credits against GHG reduction measures; this resulted in the institutionalization of the carbon market in Europe. The EU saw strong growth in carbon market development between 2005 to 2011 when many European countries agreed to join ETS in 2005 (Michaelowa et al., 2019). The EU ETS, established in 2005, is the first major carbon market globally, included 27 EU states (Barnes, 2021). The EU ETS saw high demand for carbon credits when firms wanted to participate in GHG reduction measures; a high carbon credit demand with a cap on emission limits resulted in healthy carbon prices. In 2008, EU ETS saw a carbon price of approx US\$30/tCO<sub>2e</sub>; however, the price went below US\$ 15/tCO<sub>2e</sub> in 2012 due to lower carbon credits demand that resulted from the global recession and renewable energy diffusion (Michaelowa et al., 2019).

Countries use two main instruments to set a carbon price: a cap-and-trade mechanism on ETS or a carbon tax. The coverage and purpose of two different instruments vary with country. In contrast to ETS, where the carbon price is driven by the supply and demand of carbon credits, the carbon tax, at a predefined price level, is directly applied to firms on their GHG emissions (Barnes, 2021). Usually, carbon taxes are applied to the sectors that are not covered under ETS. There are two main differences between these mechanisms. First, under a carbon tax, the carbon price is stable as it is set directly by the regulatory authority; on the other hand, in ETS based on a cap-and-trade system, the price is established by supply and demand dynamics of carbon credits (Goulder & Schein; 2013). Second, there is no certainty that carbon tax leads to actual GHG reduction, while ETS based on cap-and-trade assures emission reduction. Both mechanisms have pros and cons; therefore, an alternative to pure ETS or carbon tax countries could apply a hybrid mechanism supported by floor and ceiling prices.

A stable carbon price can reduce GHG emissions without impacting firms’ competitiveness and incentivize abatement initiatives; however, the regulators must provide price floor and ceiling limits on a long-term basis. To support floor price, the regulator can 1) remove allowance from the market through buybacks or 2) set a fee that allowance purchasers must pay in addition to the allowance price when carbon prices drop below the stipulated floor (Goulder & Schein, 2013). On the other hand, a higher ceiling price can limit a firm’s economic performance. According to Goulder and Schein (2013), regulators can control the ceiling prices in two ways 1) by circulating additional emission allowances in the market whenever the ceiling price is reached or 2) allow firms to pay a fee on additional emissions when carbon price crosses the threshold limit.

3.1 Carbon Price and Net-Zero Targets

Countries that have set net-zero targets have implemented both ETS and Carbon tax within their jurisdiction, except Germany and Hungary who implemented only EU ETS. Switzerland has its own ETS, while post-Brexit UK has set up UK ETS, both countries plan to integrate their ETS with EU ETS (World Bank, 2020). Most EU member states have their carbon and energy taxes in addition to the EU ETS; however, the carbon price level for these taxes and the extent of coverage varies across countries (Barnes, 2021). The Carbon tax levied on GHG emissions varies in terms of covered gases (such as carbon dioxide, methane, and fluorinated gases), thereby resulting in a different share of coverage (refer to Table 1).

Table 1. carbon pricing status in countries with net-zero targets

Countries	Target	Status	Mechanism	Carbon (US\$/tCO <sub>2e</sub> )	Price	Coverage
Denmark	2050	law	ETS & Carbon Tax	Carbon Tax US\$ 26-22 EU ETS		40%
Finland	2035	Policy doc.	ETS & Carbon Tax	Carbon Tax US\$ 68-58 EU ETS		38%
France	2050	law	ETS & Carbon Tax	Carbon Tax US\$ 49 EU ETS		35%
Germany	2050	In policy doc.	ETS	EU ETS		As per EU ETS
Hungary	2050	law	ETS	EU ETS		As per EU ETS
Ireland	2050	In policy doc.	ETS & Carbon Tax	Carbon Tax US\$ 28-22 EU ETS		47%
Norway	2050	In policy doc.	ETS & Carbon Tax	Carbon Tax US\$ 53-3 EU ETS		65%
Switzerland	2050	In policy doc.	Swiss ETS & Carbon Tax	Carbon Tax US\$ 99 Swiss ETS		33%
Sweden	2045	law	ETS & Carbon Tax	Carbon Tax US\$ 119 EU ETS		40%
United Kingdom	2050	law	UK ETS & Carbon Tax	Carbon Tax US\$ 22 UK ETS		23%

EU commission      2050      Proposed Legislation      ETS & Carbon Tax      EU ETS- US\$ 19      46%

Terminology- tCO2e: Tons of CO2 emissions

In 2020, Sweden had set a carbon price level of US\$119 per tCO2e, followed by Switzerland with US\$99, while the UK, Denmark, and Ireland had carbon price levels in the range of US\$26-22 (World Bank, 2020). Regarding GHG emission coverage in their respective jurisdictions, Norway has the highest coverage of 65%, while the UK has the lowest coverage with 23% (World Bank, 2020). Additionally, methane and other transport fuels, which are significant contributors to GHG emissions, are not covered by EU ETS; therefore, countries use different mechanisms to tax them (Barnes, 2021).

Although scientists and economists agree that an effective carbon price is vital to support net-zero initiatives, there is a lack of consensus on calculating an appropriate carbon price. The most prevalent method is the social cost of carbon derived from the integrated assessment model based on uncertain assumptions; therefore, estimate varies widely (Pezzey, 2019). The social cost of carbon is widely criticized for overly focusing on delivering maximum benefits to society. It does not provide practical value to policymakers in deciding the appropriate carbon price level required for GHG targets (Kaufman et al., 2020). Scholars agree that an alternate method based on a pathway approach can be more practical to policymakers in arriving at abatement cost, which is socially acceptable (Pezzey, 2019). According to Kaufman et al. (2020), estimating carbon pricing based on net-zero pathways is a more practical approach as this allows policymakers to set a carbon price level with the following in mind a) selection of technology options, b) addressing market imperfections, and c) incentivizing climate innovations.

3.2 Competitiveness and Political Inertia

A major concern for carbon-intensive sectors under the carbon pricing system is the loss of competitiveness. The EU ETS induction raised concerns in member states about the competitiveness of European firms due to production cost increase resulting from buying additional emission allowance (Stöllinger, 2020). The carbon pricing system can increase production costs both directly and indirectly. In a direct way, a firm requires to buy emissions allowances; indirectly, the increased costs of inputs such as electricity will impact downstream consumers. Therefore, carbon pricing can affect the relative competitiveness, sector, or firm (Ellis, Nachtigall & Venmans; 2019). Various policy options are available to protect against competitiveness impacts; these include grandfathering to exempt a sector, providing a free allowance, tax credits, transition assistance, and border adjustments (CPLC, 2019). With a focus on EU ETS, there have been several empirical studies related to the impact of emission trading on a firm’s competitiveness. Most studies do not find a statistically significant effect of carbon pricing on proxy variables related to competitiveness. Therefore, it is possible to suggest that the current carbon pricing design has no detrimental impact on proxies for competitiveness (Ellis et al., 2019).

Table 2. carbon price impact on competitiveness

Competitiveness Proxies	Carbon Price Impact
Employment	No statistically significant impact
Innovations	Positive impact
Investments	Positive impact
Productivity	Positive impact
Profits	No statistically significant impact
Turnover	Positive impact

*This is based on empirical studies done between 2011 to 2019 to find impact of carbon pricing on proxies of competitiveness (Source: Ellis et al., 2019)*

Generally, the higher cost of carbon pricing is passed on to consumers, leading to inflation. Governments, in such situations, can bring complementary policies to ease away pressure on consumers (Burke et al., 2019). In fact, due to political inertia, governments are unwilling to increase carbon floor prices as such moves could face political resistance from citizens. Climate researchers agree that the policies related to carbon pricing should be long-term, consistent, and credible. Governments are known for policy withdrawals and making U-turns when faced with political resistance. In 2018, the French government took a U-turn when met with political resistance against fuel tax increases (Barnes, 2021). A well-coordinated multidisciplinary approach with a strong political

will is required to swiftly mobilize policy responses that are necessary to achieve net-zero targets (World Bank, 2020).

### *3.3 Carbon Leakage*

The biggest challenge of asymmetrical and unilateral climate policy design is carbon leakage. The carbon leakage occurs when firms relocate carbon-intensive activities from counties with stricter emission regulations to regions with less stringent regulations. More rigorous emission regulations in one region fail to reduce overall emissions unless coordinated between the regions (Zachmann & McWilliams; 2020). According to Droege and Fischer (2020), the carbon policy landscape within the EU, based on uncoordinated and divergent carbon prices with limited geographic and sectoral coverage, undermines the effectiveness of carbon policy design and leads to carbon leakage. Carbon leakage is a policy risk, and policymakers must be aware of the sectors which could lead to carbon leakage. Usually, policymakers identify industrial sectors having a risk of carbon leakages, such as mining and oil production, chemical production, pulp, paper manufacture, etc., and provide free allowances or reduce the carbon price level to these sectors (Barnes, 2021). However, with most countries having set ambitious net-zero targets, governments should start gradually withdrawing the free allowance or increasing the carbon price level applicable to these sectors (Droege & Fischer; 2020). With net-zero targets in place, countries within The EU can overcome the free-riding of polluters by having a well-coordinated carbon pricing regime across the EU. A well-coordinated carbon policy design in terms of pricing, scope, and sector coverage within the EU can help policymakers overcome carbon leakage challenges (Baranzini et al., 2017).

### *3.4 Carbon Revenue Usage*

With more countries and jurisdictions working towards implementing carbon tax or carbon ETS, the revenue collection will likely increase in many folds in the coming years. Due to a steady increase in the carbon price, carbon revenue collection increased 30% from US\$ 33 bn in 2017 to US\$ 44,6 bn in 2018 (World Bank, 2019). As a result of new carbon pricing initiatives and reforms by governments, the carbon revenue collections continue to rise; in 2019, nearly US\$45bn was collected globally (World Bank, 2020). Although such an increase in carbon revenue collection is a positive sign for policymakers, the bigger question is how effectively this collected revenue is circulated and used to achieve net-zero targets. Scholars agree that the effective use of carbon revenue could help governments win the trust of the common public, thereby showing credibility and consistency in carbon policy design. Different countries have used carbon revenue differently. In 2018, an estimated 42% of global carbon revenues were allocated to environmental projects, 38% diverted to the general budget, 11% for non-climate related topics, and only 3% sent to households and business beneficiaries as direct transfers (World Bank, 2019). According to Klenert et al. (2018), when carbon revenues are diverted towards the general budget, the public acceptance of policy is lower. On the other hand, if carbon revenues are earmarked for a specific purpose, such as targeted green investments or direct transfers to affected groups, it has greater acceptability. A significant part of carbon tax collection in many countries with net-zero targets, such as France, Sweden, and the UK, is allocated to the general budget (World Bank, 2019). However, such practices are less transparent and ineffective; instead, the government should do earmarking or hypothecation to use revenue effectively. Using a revenue recycling mechanism, policymakers can earmark the tax collection and effectively return it to society. Effective recycling can help close the gap between current carbon prices and required price levels to achieve net-zero by enhancing public acceptance (Klenert et al., 2018). Beiser-McGrath and Bernauer (2019) found that revenue recycling could win citizen support for carbon tax levels of \$50 to \$70 per tCO<sub>2</sub>e and suggested that revenue recycling can increase citizen willingness to pay the higher tax required to stimulate significant emission cuts.

### *3.5 Carbon Policy Design*

Technology policies aimed at developing clean technologies (like solar, wind, biogas) and pushing them into the market has been a game-changer that helped the EU to achieve the EU2020 target of 20% reduction in emission level by 2020 (Edenhofer et al., 2021). However, such efforts were limited to the energy sector. On the other hand, the net-zero concept is about offsetting carbon emissions with natural or engineered carbon sinks. Therefore, it has a much broader scope in terms of sector coverage and poses complexity in selecting and implementing emission abatement technologies.

Net-zero targets pose immense and immediate challenges to policymakers in terms of choice of the energy mix, sector to be covered, energy efficiency measures; there is no simple end-of-pipe solution, hence requiring a multidisciplinary approach (Baranzini et al., 2017). GHG reductions alone will not help countries to achieve the net-zero target. The net-zero strategy should prioritize carbon offset measures that mandate developing carbon sinks. Several technologies like CCS (Carbon capture and storage) and green hydrogen are at the developing

stage that can play a significant role in carbon removal. These technologies require high upfront capital costs and, to remain operational, must be supported with a continuous revenue stream. The bigger question is who should bear the carbon offsetting cost; there is no single answer to this, although many economists agree that polluters should pay. An effective decarbonization policy could be the answer to this question. The governments need to establish long-term policies that ensure the GHG emission reductions and carbon removal for achieving the net-zero target through a policy mix strategy that is acceptable to industries and society (Honegger et al., 2021).

Incentivizing the carbon-negative potential of clean technologies is an essential part of carbon policy design. Relying on technology push policies without incentivizing carbon negative potential may lead to market failures. New technologies like Anaerobic Digestion (AD) that produce biogas face market failures compared to fossil gas; the carbon-negative potential of AD technology is not recognized and internalized in the competitive energy market (Acharya & Cave, 2021). A Policy-mix package can help overcome market failures when carbon policy is complemented by other technology-specific policies (Baranzini et al., 2017). Carbon leakage through borders is another relevant issue within the EU due to the variability of carbon policy design among member states. Faced with anomalies and variability in carbon policies among member states, the EU proposed European green deals in 2019 to address carbon leakage through borders as part of a long-term strategy. Under the European green deals, the EU aims to decarbonize its economy by 2050; this strategy calls for an effective carbon policy design (Stöllinger, 2020). Without further delays, in the next few years, net-zero policymakers should implement effective carbon policy to address market failures and carbon border leakage as policy impacts can only be observed in the 2030s and 2040s (Edenhofer et al., 2021).

#### 4. Discussion

This paper aims to propose an integrated carbon policy design covering economic, technical, and social dimensions and discuss how an integrated policy design approach could be effective in helping European countries achieve net-zero objectives. Section 3 discussed the concept of the carbon price, price levels, and coverage in countries that have declared a net-zero target. We also discussed issues and challenges in the present carbon policy design that policymakers must address to improve policy effectiveness in achieving the net-zero target. We observed carbon policy design plays an essential role in achieving the net-zero target; however, effective policy design requires a multi-disciplinary approach covering technical, economic, and social aspects. This section proposed an integrated carbon policy design covering technical, economic, and citizen perspectives. From an economic perspective, we discussed how countries in the EU should shift to a carbon neutral economy by stabilizing carbon price and widening the coverage scope. Such a move will help policymakers address carbon leakage within the EU, also address competitiveness issues. From a technical perspective, we discussed how policymakers should develop strategies to support clean technologies that are required to create carbon sinks. From a citizen perspective, we discussed how governments could effectively use revenue recycling mechanisms to benefit citizens and businesses; also win their support and establish policy credibility.

Due to the entanglement of social, economic, and technical issues in the net-zero target, policymakers should have a multidisciplinary approach in developing carbon policy design. Addressing complex social-technical challenges like climate change requires a paradigm shift in the policy approach that will help to recognize the interaction between various elements and subsystems. In contrast to the traditional policy design approach, an integrated approach helps overcome cross-cutting issues and siloed policies for subsystems (Biesbroek, 2021). Policy integration is a strategy to overcome policy fragmentation to address problems emanating from cross-established administrative and jurisdictional boundaries (van Geet et al., 2021). The integrated policy design is not just about setting an overall goal but also aims to understand how different instruments interact with each other and enable policymakers to adjust them to achieve the most effective result (Cejudo & Michel, 2021).

##### 4.1 Wider Carbon Coverage in Economy

Under the EU2020 strategy, European Union successfully achieved a 20% GHG emission reduction in the energy sector by 2020 using effective renewable energy policies. While the net-zero strategy calls for a more expansive and multidisciplinary policy approach to shift towards a carbon neutral economy where negative carbon externalities are accounted for, monitored, and internalized. Developing a carbon-neutral economy requires expanding the present carbon price regime to include carbon-intensive sectors like transport, industry, and building sectors supported by a stable carbon price and wider coverage of GHG. The climate action plan among 27 EU member states has significant variation in their national policies and strategies. Within the EU, climate policies depend on country-specific factors that include institutional culture, power structure, political systems, and socio-economic development. Many EU members are either foot-dragging or fence-sitting when it

comes to developing an effective climate action plan; only a few member states like Denmark, France, Germany, Italy, Sweden can be categorized as pacesetter (Maris & Flouros, 2021). Further, other two non-member states, Switzerland and the UK, have been proactive in developing and pushing climate policies.

In 2020, the transport sector emitted around 7.0 Gt of CO<sub>2</sub> globally; with 2050 net-zero targets in place, the CO<sub>2</sub> emissions from the transport sector must be reduced to about 5.5 Gt in 2030 and 0.7 Gt by 2050, a 90% drop relative to 2020 levels (IEA, 2021). The EU transport sector is no different, and the sector, still heavily dependent on fossil fuels, contributes to around one-quarter of the total EU's GHG emissions (EEA, 2021). Therefore,

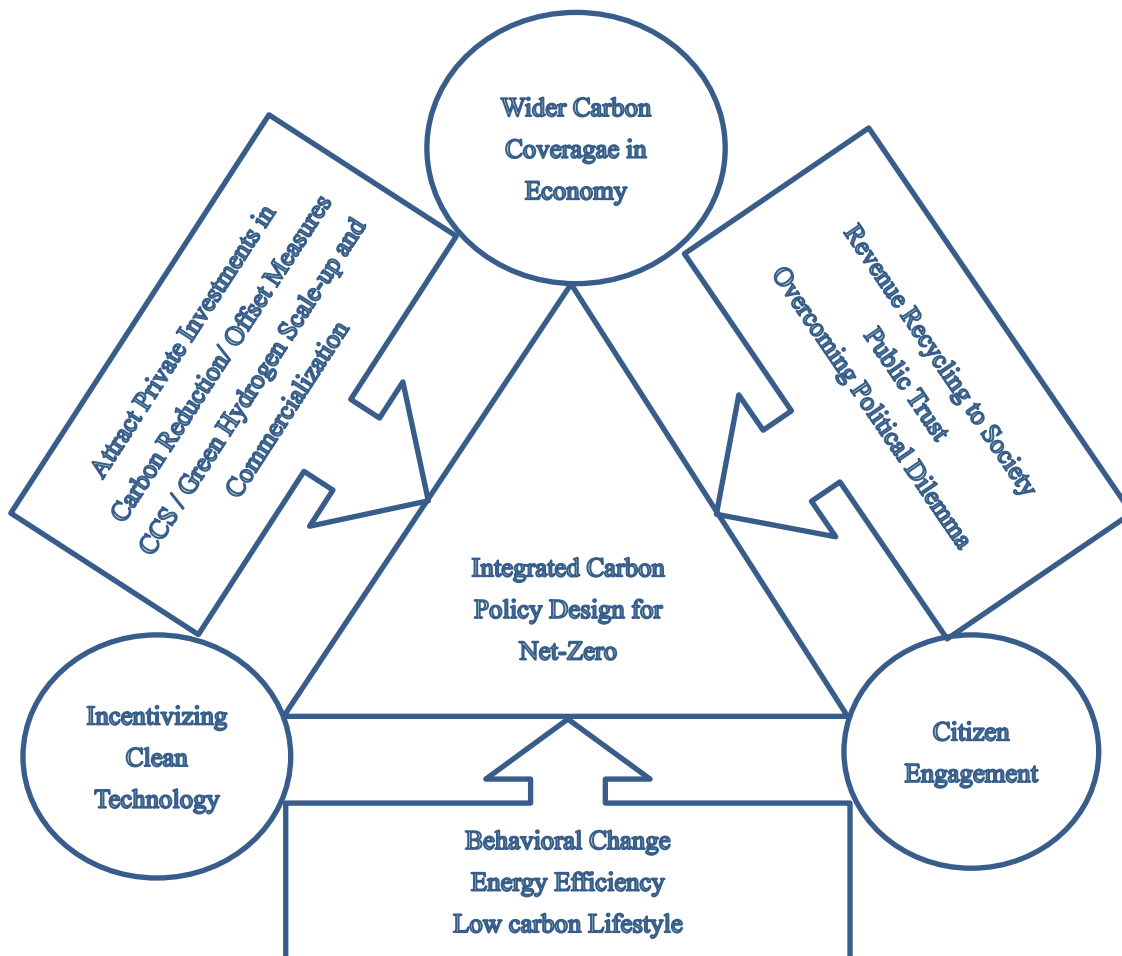


Figure 1. Integrated Carbon Policy design for Net-Zero

polymakers should gradually move away from fossil fuel dependency to biofuel or electric mobility. Achieving carbon neutrality in the transport sector within the EU will need a 90% reduction from the current transport emission level by 2050 (EEA,2021). Such drastic reduction in emissions within the EU will require effective carbon policy complemented with technology push policies to incentivize biofuel and electric mobility. EU's renewable energy directive (2009/28/EC) had set a target of 10 % share of renewable energy in the transport sector for each Member State by 2020. But in reality, the renewable energy share in the transport sector remains below the 10% target in many member states. The share of renewable energy in transport varied across countries: from 32 % (Sweden) to close to 0.4 % (Estonia); only two countries with net-zero targets, Finland, and Sweden, could achieve 10 % renewable energy use in transport by 2020 (EEA, 2021). There are three main reasons why countries cannot reduce dependency on fossil fuels and push renewable energy use into the transport sector. First, the transport sector is not covered under a structured carbon price regime; second, lack of complementary policies to incentivize and scale-up renewable energy use in transportation. Third reason is that methane, a constituent in natural gas-based transport fuel, is not covered under the carbon price regime.

The transport sector in countries with ambitious net-zero targets is not covered by any structured carbon tax or trading schemes; instead, countries apply energy or fuel taxes on transport fuels in their jurisdictions. Therefore, the implicit carbon price varies widely in the range of US\$100/tCO<sub>2</sub>e to less than US\$1/tCO<sub>2</sub>e. Varying tax

rates could be attributed to political inertia, which fails to keep fuel tax at an adequate level required to decarbonize the transport sector. Therefore, it raises a question on the credibility of the government's policy design in achieving a net-zero target (Barnes, 2021). In the proposed global pathways to achieve net-zero in the transport sector, IEA (2021) estimated biofuels should cover 14% of global transport fuel demand in 2050, hydrogen-based fuels meet a further 28% of transport energy needs by 2050. Additionally, hydrogen fuel generation from water electrolysis must increase from less than 1 GW in 2020 to 850 GW in 2030 and 3585 GW in 2050; this up-scaling of hydrogen generation requires substantial investment (IEA, 2021). Biomethane upgrade facilities and hydrogen generation from water electrolysis need high capital costs. One way to push renewable energy adoption into the transport sector is to incentivize these carbon-neutral technologies by providing a stable and adequate carbon pricing.

Methane, a constituent in natural gas-based transport fuel, is considered a potent GHG after carbon dioxide. In the energy and transport sector, methane leakage occurs from storage, transmission & distribution systems, and incomplete combustion. However, despite the high climate change impact, the methane emission in the EU is not covered by EU ETS currently (Barnes, 2021; European Commission, 2020a). Covering methane emissions under ETS will help reduce methane emissions from the natural gas supply chain; this will also create an incentive for companies to take abatement action (IEA, 2021). In 2019, the EU Commission proposed the European Green Deal strategy considering inclusion of methane under EU ETS and providing an initial roadmap of the necessary key policies and measures. The EU green deal aims to transform the EU into a resource-efficient and competitive economy with net-zero GHG emissions by 2050, where economic growth is decoupled from resource use (Siddi,2020). However, the main challenge for member states in implementing the EU green deal is choosing priorities between EU and national policies.

The aviation sector in the EU is covered under EU ETS but mostly enjoys free allowance allocation. In the EU ETS, 85% of aviation allowances are given free, while only 15% are auctioned (Barnes, 2021). Aviation emissions are considered hard to abate due to specific technical requirements for aviation fuel (IEA,2021). One way to offset aviation related emissions is to gradually reduce free allowance and increase auction allowance and make carbon offset measures mandatory for all airlines operating within the EU (Barnes, 2021). Many countries with net-zero targets have already contemplated levying taxes on jet fuel, and air tickets also implemented measures to offset aviation-related emissions (World Bank, 2020).

In addition to the transport sector, other sectors like building, construction, and heavy industries give rise to GHG emissions. UNEP (2019) reported globally, the buildings and construction sector accounted for 39% of carbon dioxide (CO<sub>2</sub>) emissions in 2018. The main reason for the high carbon footprint is the non-accessibility to renewable energy resources and the lack of low-carbon design initiatives in buildings. The heavy industrial sectors like steel, chemical, and cement are considered hard-to-abate; therefore, GHG emissions from these sectors are provided free allowance. However, globally, heavy industrial sectors like steel, chemical, and cement are responsible for 70% of GHG within the industrial sector (IEA,2021). In the EU, the industrial sector is covered under EU ETS but mostly enjoys free allowance. The competitiveness concern of production getting transferred from the EU and the risk of carbon leakage to countries with relaxed GHG regulation are the main reasons for free allowance given to the industrial sector in the EU (Barnes; 2021).

Widening carbon coverage of the economy is not adequate to achieve a net-zero target; it needs to be complemented by the other elements in policy design. Countries must bring significant investments to develop carbon sinks and support technologies towards net-zero targets through the 2030s and 2040s. One way to get new investments is to partner with private organizations. Therefore, emission abatement measures led by private organizations need to be incentivized suitably. Also, the carbon revenue collected must be recycled back to society to create social engagement to win public trust and credibility.

#### *4.2 Incentivizing Clean Technology*

This decade, countries will need large-scale diffusion of clean technologies such as electric mobility, bioenergy, and hydrogen fuel in different sectors to reduce GHG emissions. Further, abatement technology such as CCS effectively captures carbon from emissions and can generate cheaper hydrogen fuels; therefore, it acts as an artificially engineered carbon sink (Global CCS Institute,2020). According to IEA (2021), due to increased economic activities, global energy uses are likely to increase by 50% in 2050; measures to improve energy efficiency can play a significant role in reducing energy demand. Lower energy consumption driven by innovative technologies and efficient processes leads to GHG reductions; therefore, energy efficiency measures in domestic or industrial activities should be incentivized and credited (World, bank, 2020).



In fact, clean technologies and energy efficiency measures will need substantial capital investment through private participation. The private sector is central to finance higher investment needs through enhanced collaborations and partnerships with governments; the next five to ten years are critical for developing large infrastructure projects and scaling up today's prototype phase of hydrogen and CCS technologies (IEA,2021). The UK government (2021) proposed their net-zero strategy leveraging private investments and expects to bring in an average investment of £50-60bn per year through the late 2020s and 2030s. According to European Commission (2020b) large-scale diffusion of hydrogen fuel can be a cost-effective way to achieve EU's climate targets through private participation and aims to develop a hydrogen ecosystem by 2030. Large-scale diffusion of bioenergy, hydrogen fuel, CCS technologies, and other energy efficiency measures will require per unit cost in parity with fossil fuels. Currently, except for wind and solar energies, non of the renewable sources are comparable with fossil. Most technologies are still immature and evolving. According to the European Commission (2020b) presently, renewable hydrogen is not yet cost-competitive compared to fossil fuels. Further, CCS technologies are at an early stage of commercialization (IEA, 2021). the unit costs for CCS depend on economies of scale, which means that as the capacity (tonnes per year) of a CCS facility increases, the capture costs go down (Global CCS Institute,2020).

Technology immaturity and high cost of operation are barriers to scaling up and commercialization, therefore, pose a challenge to countries with the net-zero target. One way to overcome this challenge is to develop a carbon price regime with an appropriately higher floor price, sector-wide coverage and internalize the negative emission potentials of these technologies through carbon credits. To overcome such uncertainties related to clean technologies, Governments should develop a policy framework to provide certainty that can bring investments through strategies such as carbon contracts for difference, public procurement, and carbon credits to private participants on deploying cleaner technologies (IEA, 2021). The UK and Sweden, with market-driven economies, have recognized climate action related market failures in their net-zero strategies. The UK government (2021), in their net-zero strategy, plans to apply fair carbon pricing to make polluters pay for the transition and provide a price signal for future investments in clean technologies. Further, recognizing the potential CCS as an engineered carbon sink for heavy industry, the UK plans to initiate consultation in 2022 to learn how incentives for CCS technologies can be linked with carbon pricing policies. The Swedish climate policy (2020) recognizes the market failures as reasons for insufficient incentives to develop clean technologies and advocates the significance of economic instruments as fundamental drivers of the net-zero targets. Therefore, a carbon pricing regime should be designed to address market failures and strengthen the price signal for investments in clean technologies.

#### *4.3 Citizen Engagement*

Citizen engagement in net-zero policymaking has two objectives. First, engaging them in the policymaking process about reaching net-zero targets, and second, involving them in net-zero actions through cognitive and affective processes (Demska, 2021). An effective carbon price regime calls for a stable and higher carbon price with more comprehensive carbon coverage; however, such actions from governments could lead to inflation and result in political resistance. In such situations, there is a need to build public support and find legitimacy for action; citizen engagement in policymaking can help governments and policymakers gain backing for strict measures (Chwalisz, 2017). Engaging citizens in net-zero actions through behavioral changes is another important aspect of carbon policy design. Net-zero actions will require low-carbon lifestyle change through comprehensive and system-wide approaches (Demska, 2021).

With carbon pricing bound to increase in countries with net-zero objectives, policymakers in these countries should effectively use carbon revenues to help citizens and firms to deal with the impacts of carbon pricing through direct transfers or other policies and programs (World Bank,2019). Among countries with net-zero targets, Norway and Switzerland have implemented recycling mechanisms to benefit citizens and firms. Norway provides corporate tax cuts to firms while Switzerland transfers two-thirds of carbon revenue to firms and households affected by the tax; further, both countries use almost one-third of carbon revenue in green infrastructure development (Klenert et al.,2018). Similarly, the British Columbia province in Canada uses its carbon tax revenue effectively to gain policy acceptability by lowering other corporate taxes and providing technology innovation assistance for specific sectors (World Bank, 2019). On the contrary, several countries such as France, Sweden, and the UK with net-zero targets allocate carbon tax collection to the general budget (World Bank, 2019). Earmarking carbon revenues for a specific purpose, such as green infrastructure projects, tax cuts, and transferring to citizens, will improve the transparency and effectiveness of policy design (Klenert et al.,2018).

Achieving a drastic reduction in GHG emissions over the next 30 years will require behavioral changes and energy efficiency measures. Such paradigm shift is not possible without their active and willing participation in the process. Renewable energy adoption and energy efficiency measures must be prioritized and reduce nearly 70% of building-related emissions if the global net-zero 2050 target is to be met in the energy sector (IEA, 2021). Within the EU, buildings account for 40% of energy consumptions and 36% of GHG emissions; under the European green deal, the EU proposed that by 2030, member states must achieve renewable energy use of 40% and energy saving of 36% in the buildings (European Commission, 2021). Therefore, citizens must actively participate in net-zero actions. Countries with net-zero targets must create a broad vision about net-zero strategy and justify which pathways to be selected by involving citizens and private organizations through accountability, openness, and transparency (Demski, 2021).

## 5. Conclusions

Our analysis observed that the current carbon pricing in countries with net-zero targets is way below the required price level to reduce GHG emissions and incentivize clean technologies effectively. The current carbon policy lacks comprehensiveness due to gaps in sector coverage and GHG definition. Further, clean technologies like CCS and green hydrogen, required for emission abatement and offsetting, are still immature and evolving. Countries have varying degrees of response to net-zero targets. Countries like Denmark, Sweden, Switzerland, and the UK have been proactive in developing and pushing climate policies. In contrast, other countries with net-zero targets still lack policies and strategies to achieve the net-zero target. This paper attempts to fill visible policy gaps by proposing an integrated carbon policy design covering economic, technical, and social dimensions. The paper posits carbon pricing regime alone can't be effective in GHG reduction unless it is complemented by other policies related to technology push and citizen engagement. The paper makes three recommendations for net-zero policymakers to improve carbon policy effectiveness. First, policymakers using a stable and appropriate carbon price level should provide a price signal to attract private investments and incentivize clean technologies. Second, policymakers should use revenue recycling mechanisms to benefit citizens and firms to win their trust and bring transparency to the policy design. Third, using a system approach, policymakers should promote citizen participation and energy efficiency measures to achieve low carbon lifestyle and carbon footprint reductions.

## References:

- Acharya, A., & Cave, L. A. (2021). Evaluating Elements of Demand-Side Policy Imperatives for Biogas from Waste Scheme Diffusion in the UK. *Journal of Sustainable Development*, 14(5). <https://doi.org/10.5539/jsd.v14n5p13>
- Baranzini, A., Van den Bergh, J. C., Carattini, S., Howarth, R. B., Padilla, E., & Roca, J. (2017). Carbon pricing in climate policy: seven reasons, complementary instruments, and political economy considerations. *Wiley Interdisciplinary Reviews: Climate Change*, 8(4). <https://doi.org/10.1002/wcc.462>
- Barnes, A. (2021). The challenges and prospects for carbon pricing in Europe. *Oxford Institute for Energy Studies*. Retrieved from <https://www.oxfordenergy.org/wpcms/wp-content/uploads/2021/05/The-Challenges-and-Prospect-for-Carbon-Pricing-in-Europe-NG-168.pdf>
- Beiser-McGrath, L. F., & Bernauer, T. (2019). Could revenue recycling make effective carbon taxation politically feasible?. *Science advances*, 5(9). <https://doi.org/10.1126/sciadv.aax3323>
- Biesbroek, R. (2021). Policy integration and climate change adaptation. *Current Opinion in Environmental Sustainability*, 52, 75-81. <https://doi.org/10.1016/j.cosust.2021.07.003>
- Burke, J., Byrnes, R., & Fankhauser, S. (2019). How to price carbon to reach net-zero emissions in the UK. Policy Report, London School of Economics, London.
- Cejudo, G. M., & Michel, C. L. (2021). Instruments for Policy Integration: How Policy Mixes Work Together. *SAGE Open*, 11(3). <https://doi.org/10.1177/21582440211032161>
- Chwalisz, C. (2017). Citizen engagement in politics and policymaking: Lessons from the UK. Retrieved from <https://www.oidp.net/docs/repo/doc214.pdf>
- Climate Action Tracker. (2020). Paris Agreement turning point. Retrieved from [https://climateactiontracker.org/documents/829/CAT\\_20201201\\_Briefing\\_GlobalUpdate\\_Paris5Years\\_Dec2020.pdf](https://climateactiontracker.org/documents/829/CAT_20201201_Briefing_GlobalUpdate_Paris5Years_Dec2020.pdf)
- CPLC. (2019). High-level commission on carbon pricing and competitiveness. Retrieved from

- <https://www.carbonpricingleadership.org/highlevel-commission-on-carbon-pricing-and-competitiveness>
- Demski, C. (2021). Net zero public engagement and participation. Retrieved from <https://www.gov.uk/government/publications/net-zero-public-engagement-and-participation>
- Droege, S., & Fischer, C. (2020). Pricing carbon at the border: Key questions for the EU. *ifo DICE Report*, 18(01), 30-34. Retrieved from <https://www.econstor.eu/bitstream/10419/225220/1/ifodice-2020-01-p30-34.pdf>
- Edenhofer, O., Kosch, M., Pahle, M., & Zachmann, G. (2021). A whole-economy carbon price for Europe and how to get there. *Bruegel-Policy Contributions*.
- EEA. (2021). Transport: increasing oil consumption and greenhouse gas emissions hamper EU progress towards environment and climate objectives. Retrieved from <https://www.eea.europa.eu/publications/transport-increasing-oil-consumption-and>
- Ellis, J., Nachtigall, D., & Venmans, F. (2019). Carbon pricing and competitiveness: Are they at odds?. *OECD Environment Working Papers No. 152*. <https://dx.doi.org/10.1787/f79a75ab-en>
- European Commission. (2020a). An EU strategy to reduce methane emissions. Retrieved from [https://ec.europa.eu/energy/sites/ener/files/eu\\_methane\\_strategy.pdf](https://ec.europa.eu/energy/sites/ener/files/eu_methane_strategy.pdf)
- European Commission. (2020b). A hydrogen strategy for a climate-neutral Europe. Retrieved from [https://ec.europa.eu/energy/sites/ener/files/hydrogen\\_strategy.pdf](https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf)
- European Commission. (2021). Delivering the European Green Deal. Retrieved from [https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal\\_en](https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en)
- Global CCS Institute. (2021). The Global Status of CCS 2021 report. Retrieved from <https://www.globalccsinstitute.com/resources/global-status-report/>
- Goulder, L. H., & Schein, A. R. (2013). Carbon taxes versus cap and trade: a critical review. *Climate Change Economics*. National Bureau of Economic Research
- Honegger, M., Poralla, M., Michaelowa, A., & Ahonen, H. M. (2021). Who is paying for carbon dioxide removal? Designing policy instruments for mobilizing negative emissions technologies. *Frontiers in climate*, 3, 672996. <https://doi.org/10.3389/fclim.2021.672996>
- IEA. (2021). Net Zero by 2050 A Roadmap for the Global Energy Sector. Retrieved from <https://www.iea.org/reports/net-zero-by-2050>
- Kaufman, N., Barron, A. R., Krawczyk, W., Marsters, P., & McJeon, H. (2020). A near-term to net zero alternative to the social cost of carbon for setting carbon prices. *Nature Climate Change*, 10(11), 1010-1014. <https://doi.org/10.1038/s41558-020-0880-3>
- Klenert, D., Mattauch, L., Combet, E., Edenhofer, O., Hepburn, C., Rafaty, R., & Stern, N. (2018). Making carbon pricing work for citizens. *Nature Climate Change*, 8(8), 669-677. <https://doi.org/10.1038/s41558-018-0201-2>
- Maris, G., & Flouros, F. (2021). The green deal, national energy and climate plans in Europe: Member States' compliance and strategies. *Administrative Sciences*, 11(3), 75. <https://doi.org/10.3390/admsci11030075>
- Michaelowa, A., Shishlov, I., & Brescia, D. (2019). Evolution of international carbon markets: lessons for the Paris Agreement. *Wiley Interdisciplinary Reviews: Climate Change*, 10(6). <https://doi.org/10.1002/wcc.613>
- OECD. (2021). Effective Carbon Rates 2021. Retrieved from <https://www.oecd.org/tax/tax-policy/effective-carbon-rates-2021-brochure.pdf>
- Pezzey, J. C. (2019). Why the social cost of carbon will always be disputed. *Wiley Interdisciplinary Reviews: Climate Change*, 10(1), e558. <https://doi.org/10.1002/wcc.558>
- Siddi, M. (2020). The European Green Deal: Assessing its current state and future implementation. Retrieved from [https://www.fiia.fi/wp-content/uploads/2020/05/wp114\\_european-green-deal.pdf](https://www.fiia.fi/wp-content/uploads/2020/05/wp114_european-green-deal.pdf)
- Stöllinger, R. (2020). Getting Serious About the European Green Deal with a Carbon Border Tax. Policy.
- Swedish Climate Policy. (2020). Report of the Swedish Climate Policy Council 2020. Retrieved from [https://www.klimatpolitiskaradet.se/wpcontent/uploads/2020/05/2020reportoftheswedishclimatepolicy\\_council.pdf](https://www.klimatpolitiskaradet.se/wpcontent/uploads/2020/05/2020reportoftheswedishclimatepolicy_council.pdf)

- UK Government. (2021). Net Zero Strategy: Build Back Greener. Retrieved from <https://www.gov.uk/government/publications/net-zero-strategy>
- UNEP. (2019). Global Status Report for Buildings and Construction. Retrieved from <https://www.worldgbc.org/news-media/2019-global-status-report-buildings-and-construction>
- van Geet, M. T., Verweij, S., Busscher, T., & Arts, J. (2021). The importance of policy design fit for effectiveness: a qualitative comparative analysis of policy integration in regional transport planning. *Policy Sciences*, 54, 629-662. <https://doi.org/10.1007/s11077-021-09429-z>
- World Bank. (2019). Using Carbon Revenues. Retrieved from <https://openknowledge.worldbank.org/bitstream/handle/10986/32247/UsingCarbonRevenues.pdf>
- World Bank. (2020). State and Trends of Carbon Pricing 2020. Retrieved from <https://www.carbon-cap.com/uploads/2zzpbxRF/StateandTrendsofCarbonPricing2020WorldBank.pdf>
- Zachmann, G., & McWilliams, B. (2020). A European carbon border tax: much pain, little gain (No. 2020/05). Bruegel Policy Contribution. Retrieved from <https://www.econstor.eu/bitstream/10419/237637/1/1694817660.pdf>

### Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (<http://creativecommons.org/licenses/by/3.0/>).