Raising Ambition Through Fossil Fuel Subsidy Reform:

Greenhouse gas emissions modelling results from 26 countries

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Global Subsidies Initiative

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About GSI

The IISD Global Subsidies Initiative (GSI) supports international processes, national governments and civil society organizations to align subsidies with sustainable development. GSI does this by promoting transparency on the nature and size of subsidies; evaluating the economic, social and environmental impacts of subsidies; and, where necessary, advising on how inefficient and wasteful subsidies can best be reformed. GSI is headquartered in Geneva, Switzerland, and works with partners located around the world. Its principal funders have included the governments of Denmark, Finland, New Zealand, Norway, Sweden, Switzerland and the United Kingdom, as well as the KR Foundation.

Global Subsidies Initiative

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Authors:

This working paper was a collaborative effort across the staff and associates of the Global Subsidies Initiative (GSI) of the International Institute for Sustainable Development (IISD). The working paper was edited and managed by Laura Merrill. Andrea Bassi undertook GSI-IF modelling. Anne Geddes provided the update of global reviews of fossil fuel subsidy reform (FFSR) and production of reviews on fossil taxation. Vibhuti Garg contributed India swap information. Ivetta Gerasimchuk gathered producer subsidy information. Peter Wooders provided fossil fuel subsidy indicator information. Philip Gass contributed information about Nationally Determined Contributions (NDCs). Nina Quintas updated the review of country FFSR and produced the subsequent GSI map. Balasubramanian Viswanathan organized subsidies data and country papers. Anna Zinecker initiated the project. The team would also thank those at the International Energy Agency (IEA) and International Monetary Fund (IMF) for sharing their data on subsidies.

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The views expressed within this paper lie with the authors. Any mistakes are our own.

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Executive Summary

This Global Subsidies Initiative (GSI) working paper is designed for policy-makers. It focuses on fossil fuel subsidies and opportunities for greenhouse gas (GHG) emission reductions from reforms as well as co-benefits from switching to sustainable energy via the savings unlocked from such reforms.

Following an internal review of the recent implementation of fossil fuel subsidy reforms (FFSRs), this research found that 50 countries undertook some level of FFSR between 2015 and 2018; these countries are highlighted in a map in Section 1. While many countries have been progressing with reforms, globally, fossil fuel subsidies increased in 2017 (International Energy Agency [IEA], 2018; Coady, Parry, Le, & Sheng, 2019). More can be done to encourage countries to maintain existing reforms and to continue with the job of phasing out both producer and consumer subsidies to fossil fuels in the short term.

Our research reviewed the impact of the reform and removal of consumer fossil fuel subsidies by 2025 on GHG emissions across 26 countries.[1] We found simple country average GHG emission reductions of 6 per cent from 2018 until 2025, compared to business as usual (BAU), from such reforms (detailed country results are available in Section 3 and Annexes 1, 2 and 3). This simple average of GHG emission reductions (from across the countries modelled) improves with modest additions to the modelled scenario, which includes a 10 per cent energy tax from 2025 until 2030 and a shift of 30 per cent of the savings from reforms, and of revenues from taxation, into investments in renewable energy and energy efficiency. In this scenario, GHG emission reductions improve to 13.2 per cent by 2030. Cumulative fiscal savings from FFSR alone by 2030 total USD 2.56 trillion across the countries analyzed, with total cumulative GHG emissions abated from FFSR (alone) of 4.8 Gt of carbon dioxide equivalent (CO_2e) by 2030. FFSR is a policy tool that saves government resources; for every tonne of CO_2e removed through FFSR, governments save an average of USD 93.

This study also undertook a literature review of 60 pieces of research on global GHG emission reductions stemming from negative and positive carbon pricing. We reviewed 40 papers concerned with FFSR and 20 papers focused on fossil fuel energy or carbon taxation. Our review found that global studies of fossil fuel subsidy removal result in emission reductions of between 1 and 10 per cent by 2030 (Delpiazzo, Parrado, & Standardi, 2015; IEA, 2014, 2015; Jewell et al., 2018) and between 6.4 and 8.2 per cent by 2050 (Burniaux & Chateau, 2014; Schwanitz et al., 2014). Removing fossil fuel subsidies and applying appropriate taxation could reduce emissions by a much larger 28 per cent globally (Coady et al., 2019). Fossil fuel subsidies act as a negative carbon price and could also be considered along with carbon pricing discussions.

Our review of the research, and this study, finds that FFSR alone will not meet the Paris Agreement goals nor equal the current level of ambition as identified within Nationally Determined Contributions (NDCs) to the Paris Agreement. Furthermore, many, including the authors of this study, find that FFSR cannot be conducted in isolation from other fiscal (taxes, subsidy swaps) and regulatory (emission caps, bans or moratoriums, especially for coal) measures that are also designed to encourage economies to move away from fossil fuel energy and toward sustainable energy in the long term. Perhaps more importantly, research also identified that it makes little sense to introduce such fiscal and regulatory measures in the presence of conflicting subsidies for fossil fuels that persist in nudging economies in the opposite direction.

[1] The countries modelled were: Algeria, Bangladesh, Brazil, China, Egypt, Germany, Ghana, India, Indonesia, Iran, Iraq, Mexico, Morocco, Myanmar, Nigeria, Pakistan, Russia, Saudi Arabia, South Africa, Sri Lanka, Tunisia, United Arab Emirates, the United States, Venezuela, Vietnam and Zambia. Country-specific briefing papers are available on request.

At the same time, the research also found significant differences in terms of GHG emission reduction estimates when using higher subsidy estimates. Our model, and others, is likely to underestimate the impact of the removal of fossil fuel subsidies on emission reductions, and this highlights the need for better data and information surrounding fossil fuel subsidies, especially for producer subsidies (see Sections 3 and 4). One way forward could be country reporting of fossil fuel subsidies for the SDG indicator 12.c.1, via guidance from a recently published methodology (see Section 2). Another approach could be through self-review or peer review of fossil fuel subsidies, as within the G20.

Overall, this review of the literature found that almost all studies on the matter find that FFSR leads to emission reductions. It is an additional tool that governments have at their disposal in order to meet the goals of the Paris Agreement and for governments that are considering or undergoing reforms and plan for ambitious second-generation NDCs. An internal review of all NDCs found that 8 per cent included FFSR in 2015 (Section 6). Therefore, this working paper recommends that parties seriously consider including FFSR within second-generation NDCs, due in 2020, to raise ambition on climate change.

While many countries have undergone FFSR, this is by no means a straightforward task. The importance of having a sound plan for reform cannot be emphasized enough. While this working paper focuses on the co-benefits of GHG emission reductions from reforms, there are many other important considerations, including the development of social welfare systems via cash transfers that help mitigate the impacts of rising energy prices on vulnerable groups. Broader political economy considerations also remain key. Countries can benefit from international support, learning from one another's successes and devising a strong plan linked to country priorities for action on all fronts going forward.

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Abbreviations and Acronyms

BAU	business as usual
CO_2e	carbon dioxide equivalent
EE	energy efficiency
EU	European Union
FFSR	fossil fuel subsidy reform
FY	fiscal year
G20	Group of 20
GHG	greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GSI	Global Subsidies Initiative
GSI-IF	Global Subsidies Initiative – Integrated Fiscal Model
IEA	International Energy Agency
IISD	International Institute for Sustainable Development
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
LPG	liquefied petroleum gas
NDC	Nationally Determined Contribution
OECD	Organisation for Economic Co-operation and Development
RE	renewable energy
SDG	Sustainable Development Goals
SOE	State Owned Enterprise
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
PRB	Powder River Basin

1.0 Progress on Fossil Fuel Subsidy Reform

During the past decade, there has been widespread agreement as to the benefits of reforming subsidies to fossil fuels, endorsed by international commitments and discussions within international forums. Encouragingly, between 2012 and 2016, fossil fuel subsidies to consumers almost halved, from USD 504 billion to USD 260 billion (International Energy Agency [IEA], 2018). This drop was due to a combination of reform efforts and a decrease in international oil prices, providing a window of opportunity for action and allowing governments to implement long-awaited reform plans.

Figure 1 maps countries implementing some level of fossil fuel subsidy reform (FFSR) between 2015 and 2018, demonstrating real progress at the country level. The map highlights countries in which policy changes have contributed to declining fuel subsidies. Fifty countries implemented some level of policy change, from fuel price changes and deregulation to electricity tariff reforms. And while the map does not provide an exhaustive picture of all subsidy policy change or cover all subsidies within a country, it does illustrate the broad engagement of countries, at a national level, to tackle the issue of fossil fuel subsidies.

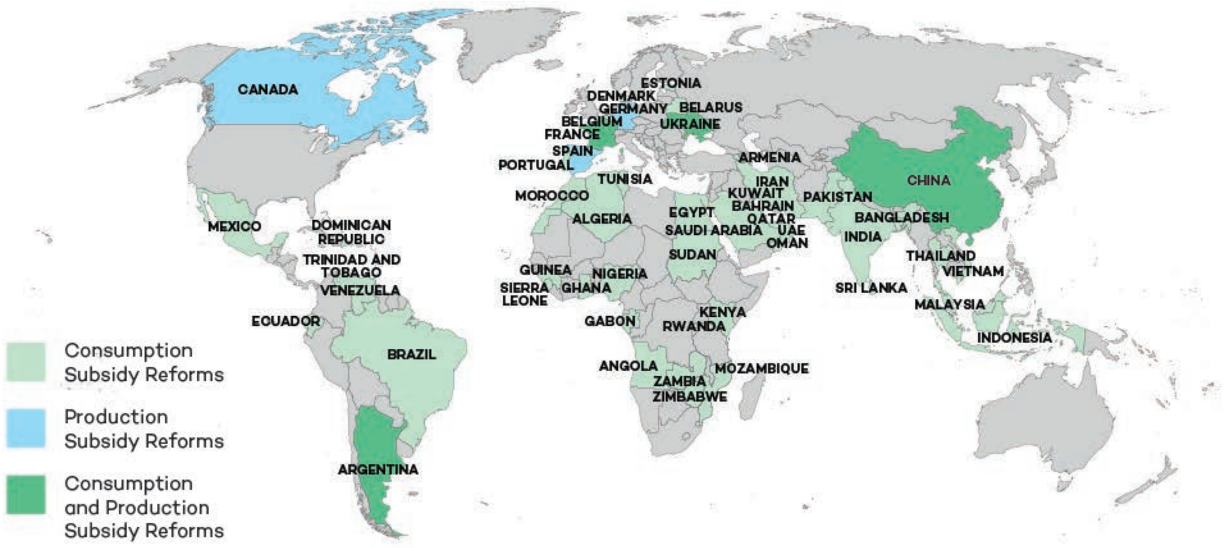


Figure 1. Countries implementing FFSR between 2015 and 2018

Source: Merrill & Quintas, 2019.

Despite these reforms, the latest figures from the IEA (2018) suggest that consumer subsidies actually increased slightly in 2017, reflecting pressure on previously implemented reforms due to the rise of oil prices on the international market (Figure 2). The IEA finds that consumer price support for fossil fuel subsidies increased from USD 270 billion in 2016 to USD 302 billion in 2017. The increase is linked to the increase in the average international crude oil price from USD 42 (2016) to USD 52 (2017) per barrel. However, this 12 per cent rise in consumption subsidies was considerably less than the 25 per cent rise in oil price, and this indicates that there is still a level of ongoing reform that has taken place and is being maintained. In this context, governments need strong encouragement and support to maintain existing, and introduce additional, energy sector reforms, enabling domestic prices to reflect changing international ones. Reforming fossil fuel subsidies and shifting to renewable energy and increased energy efficiency also offers governments protection and greater energy security from the volatility of international oil prices.

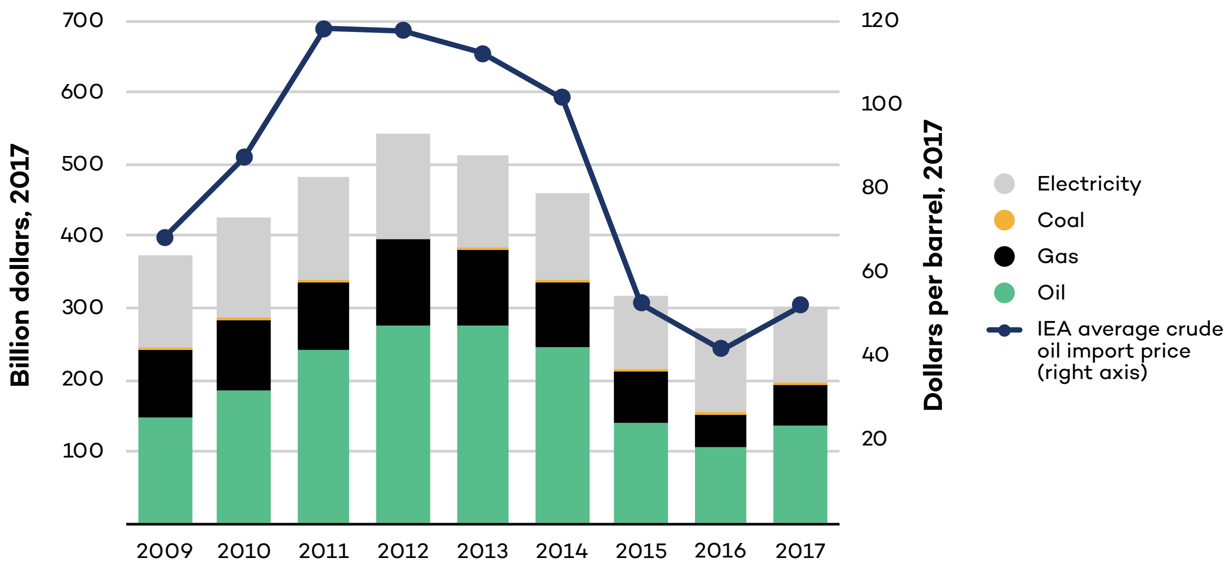


Figure 2. Global fossil fuel consumption subsidies – IEA estimation

Source: Republished with permission from IEA, 2018b.

Moreover, the International Monetary Fund (IMF) recently released a working paper with updated estimates of consumer price support for fossil fuels at a global level using a pre-tax and post-tax methodology (Coady, Parry, Le, & Shang, 2019). The latter differs from the IEA method since it includes some producer subsidies and unpriced externalities arising from fossil fuel usage, such as greenhouse gas (GHG) emissions and emissions of air pollutants, as well as social costs associated with driving (e.g., traffic congestion). According to the Coady et al. (2019), these costs (15 to 20 times larger than pre-tax subsidies, which stood at USD 296 billion in 2017) reached USD 5.2 trillion in 2017, up from USD 4.7 trillion in 2015. This analysis starkly illustrates the far broader negative costs and impacts of fossil fuels on the environment and the economy as a whole. Furthermore, the research highlights that there has not been a sharp increase in the pricing of environmental costs at the global level, despite the 2015 Paris Agreement and implementation of reforms in several countries (Figure 3). Indeed, additional research finds that, globally, the global mean net tax of fossil fuels actually fell by 13.3 per cent from 2003 to 2015, even with a combination of subsidy reform and taxation (Ross, Hazlett, & Mahdavi, 2017).

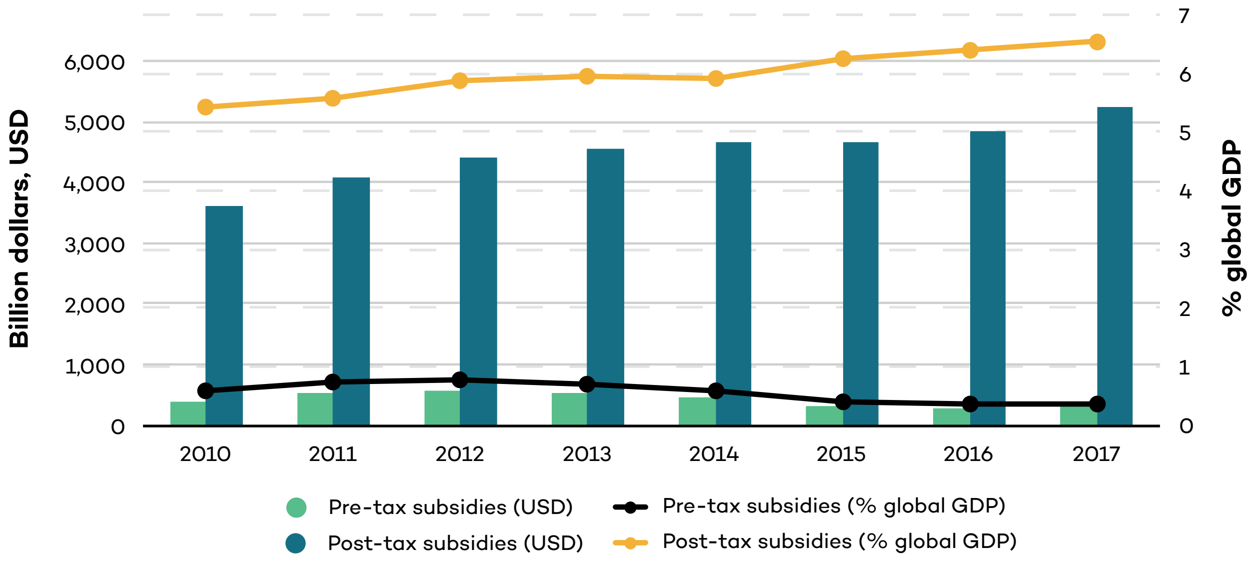


Figure 3. **IMF estimates of global pre-tax and post-tax energy "subsidies," 2010–2017**

Source: Republished with permission from Coady et al., 2019, p. 20.

The combined IEA and Organisation for Economic Co-operation and Development (OECD) estimates for fossil fuel support among 76 economies totals between USD 370 billion and USD 620 billion annually for 2010-2015 (OECD, 2018b). OECD found more than 1,000 policies across 44 countries that support the use or production of fossil fuels, often policies that were introduced decades ago. The Global Subsidies Initiative (GSI) estimates that the scale of subsidies to fossil fuels is significant, at around USD 400 billion (Bridle et al., 2018) in 2017: USD 300 billion per year for consumer subsidies (IEA, 2018) and between USD 70 billion and 100 billion for producer subsidies, which are consistently underreported (Bast et al., 2015; Laan, 2010). Consistent with subsidy estimates for other sectors, this estimate does not include the global cost of fossil fuels on the environment and society, but it is still significant—especially for countries that use a large percentage of the national budget to pay for fossil fuels via subsidies.

This paper focuses on carbon emission reductions from the removal of consumer price support for fossil fuels, for which subsidy data are more available.

Box 1. Measuring fossil fuel subsidies in the context of the SDGs

A transition toward clean energy is crucial to achieving the goals of the United Nations (UN) 2030 Agenda on Sustainable Development. The importance of measuring fossil fuel subsidies has been recognized in the SDG process with a dedicated indicator (12.c.1 – "Amount of fossil fuel subsidies per unit of GDP [production and consumption]") (SDG Knowledge Platform, n.d.). However, until recently, there was no agreed methodology to report on fossil fuels subsidies, and consequently their reform has been held back by a lack of consistent and comprehensive data. A recent methodology is the first agreed upon globally. It was developed by UN Environment, IISD and OECD with three case studies from Egypt, India and Zambia with reference to 30 technical experts. It establishes a methodology for countries to follow when it comes to measuring fossil fuel subsidies in light of the SDGs. The first step to providing a consistent approach was establishing definitions that would enable a common understanding of fossil fuel subsidies. The price-gap approach, which compares domestic energy prices to the international market, though very effective, was considered too narrow, as it reflects only subsidies to consumers. The main discussion among the experts concerned how to include producer subsidies, because, while they may not affect the price of a product immediately, they incentivize extra exploration and production.

The proposed methodology includes all fossil fuel subsidies and splits them into four categories:

1. Direct transfer of funds – payments made by governments to individual recipients
2. Induced transfers – energy prices regulated by government
3. Tax expenditure, other revenue foregone, and underpricing of goods and services – for example, tax reductions, allowances, rebates or credits
4. Risk transfers – direct involvement of a government in the fossil fuel industry, by taking on risks on behalf of parts of the industry

The categories listed above were examined against data availability, their complexity and their acceptance. The methodology asks countries to identify, measure and report against three of the aforementioned categories: direct transfers, induced transfers and tax expenditures. For the first category, the methodology argues for a phased approach, moving gradually from global to national datasets. Recognizing the complexity and data availability issues around the third category in many countries, the methodology recommends that countries report against it progressively. The fourth category—transfer of risks to a government—presents serious issues on data availability and complexity. The methodology therefore concludes that reporting against this should be optional. In common with all SDG indicators, UN members are asked to report annually, from 2020 to 2030. Many organizations are available to help countries complete the vital task of identifying, measuring and reporting their fossil fuel subsidies. Sharing experiences between countries, potentially at a regional level, appears valuable.

Table 1. Assessment of subsidy categories for monitoring of SDG Indicator 12.c.1

Subsidy category	Data availability	Complexity	Acceptance	Recommendation for SDGs	
				National	Global
Direct transfer of funds	++	++	++	Yes	Yes
Induced transfers (price support)	+	+	++	Yes	Yes
Tax expenditure, other government revenue foregone, and under-pricing of goods and services	+	O	+	Yes, but optional*	Yes, but optional*
Transfer of risk	-	-	O	No	No

++ (green) means "excellent" or "low degree of complexity"

\+ (yellow) means "good" or "moderate degree of complexity"

O (orange) means "neutral"

\- (red) means "poor" or "difficult"

* Countries are invited to report existing information and build up information on this category progressively. In 2025 it should be considered whether this indicator can be fully included.

Source: UN Environment, OECD, & IISD, 2019; Wooders & Mlynarska, 2019

It is crucial to implement and acknowledge the importance of both FFSR and the correct pricing of fossil fuels, even more so when the world is made aware of the high costs that fossil fuels imply. Countries are realizing that fossil fuel subsidies are known to be socially regressive, failing as a social welfare policy tool and potentially preventing government funding of more sophisticated social security nets, including investment in health and education. Furthermore, such subsidies lock us into a high-carbon future, and their elimination could contribute to reducing carbon emissions, as stated in the Paris Agreement.

Despite considerable efforts to reform subsidies, the absolute value of subsidies increased in 2017, both subsidies captured within the economy and those yet unpriced, bringing massive broader costs to society (the externalities). It is therefore crucial that countries persist with efforts to phase out subsidies to fossil fuels and usher in more efficient social welfare and sustainable energy systems and are supported strongly by the international community in their endeavours to do so.

This paper sets out what we know about the *co-benefits of carbon emission reductions* from FFSR, particularly from consumer subsidies, specifically the removal of around USD 300 billion to fossil fuels as identified by the IEA (2018). It models emission reductions from across 26 countries and provides an in-depth literature review of global research on emission reductions associated with FFSR and fossil fuel taxation. The working paper sets out this information in the hope that countries will consider including FFSR as part of their updated Nationally Determined Contributions (NDCs), not only as a potential fiscal instrument to save domestic resources, but also as an emission reduction co-benefit, based on existing country plans to undergo energy sector reforms.

2.0 Global Subsidies Initiative – Integrated Fiscal Model 2019: Results

The Global Subsidies Initiative – Integrated Fiscal Model (GSI-IF model) was created to analyze the effects of FFSR and the subsequent reallocation of savings from subsidies toward investments in renewable energy and energy efficiency (a subsidy swap). The GSI-IF model was initially produced to support countries with Intended Nationally Determined Contributions (INDCs) in the lead up to the Paris Agreement. The model was updated in 2019 to support countries who are building ambition within their updated NDCs. In 2019, the GSI-IF model outlines the impacts of (i) complete FFSR, (ii) followed by a modest 10 per cent energy tax, and (iii) the reallocation of funds to investments in energy efficiency and renewable energy (from both subsidy removal and taxation) on GHG emissions. The model is bounded at the national level, and results are compared with a business-as-usual (BAU) scenario.

The GSI-IF model is a causal-descriptive partial equilibrium model that uses semi-continuous simulations to forecast energy demand and corresponding GHG emissions. The model is built using the System Dynamics methodology (Sterman, 2000). GSI-IF was first created in 2015 (Merrill, et al., 2015) and has been updated (with new and more up-to-date data), expanded (to cover more countries) and improved (to capture subsidy removal as well as modest energy taxation) for this study. The aim is that those countries modelled in this research consider the emission reduction co-benefits that FFSR and taxation afford within forthcoming NDCs.

The GSI-IF model estimates energy consumption from 1990 to 2040 using differential equations calculated with an annual time step. Historical data (based on IEA World Energy Balance data) are used to parametrize the model in 1990 and to validate model results from 1990 to 2017. Future scenarios forecast energy demand until 2040 using various assumptions, including FFSR. The model forecasts energy consumption by sector (residential, commercial, industrial and transport) and source (oil, natural gas, coal, biomass and waste, and electricity), using elasticities associated with GDP, population, energy price changes and energy efficiency (for which various scenarios can also be tested). GDP growth is based on the IMF *World Economic Outlook*, and population is based on the UN World Population Prospects database (medium variant). The price of energy is based on data from the IMF (regional coal and natural gas prices) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (national gasoline and diesel prices) and national databases (electricity prices). The effects of subsidies and taxation are manifest through energy prices. Subsidy reform or increased energy taxation, leading to higher prices for a particular source, can cause a drop in domestic consumption due to a price response and the substitution for consumption of other, comparatively cheaper, fuels. Emission factors are applied to determine total national emissions from the use of energy. As a result, GHG emissions are affected by both the drop in demand and the change to the fuel mix. Demand and fuel mix are also influenced by other policy interventions, namely the reallocation of subsidy savings and tax revenues to investments in energy-efficiency improvements (assumed to be 20 per cent of subsidy savings and additional revenues) and in renewable energy equipment (assumed to be 10 per cent of subsidy savings and additional revenues).

A graphical representation of the process for the GSI-IF model is shown in Figure 4.

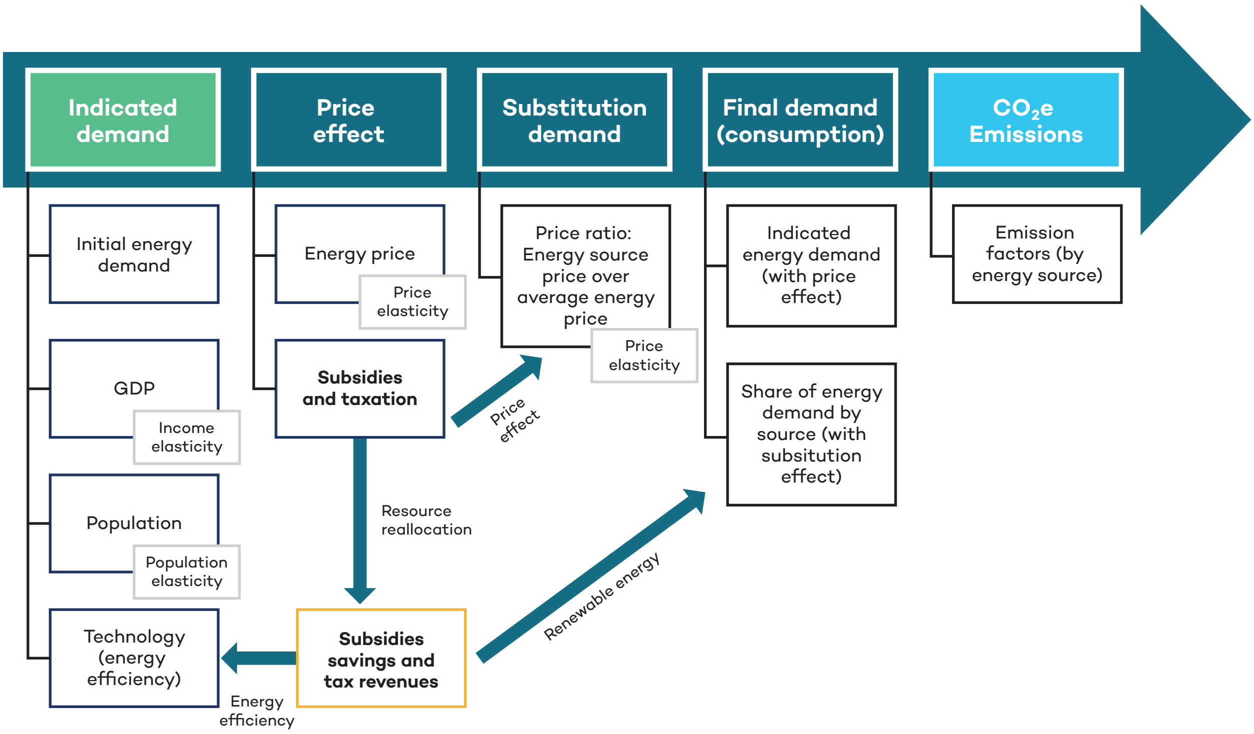


Figure 4. GSI-IF model sketch, highlighting the main steps considered for estimating carbon dioxide equivalent (CO_2e) emission reductions resulting from FFSR

In summary, the model performs these key functions across each of the 26 countries reviewed:

- Estimates the impact of the phased removal of fossil fuel subsidies on GHG (CO_2e) emissions starting immediately and with complete removal by 2025.
- Quantifies the impact on emission reductions from the introduction of a subsequent, modest, energy tax (applied to fuels and electricity) equivalent to 10 per cent of the price of the energy.
- Calculates the fiscal savings from subsidy removal and increased taxation during the period.
- Explores the impacts on GHG emission reductions from the reallocation of 30 per cent of subsidy savings and subsequent tax revenues to other programs—in this case toward energy efficiency and renewable energy promotion.
- Assumes that a much larger 50 per cent of the savings from FFSR and subsequent revenue generated from energy taxation are reallocated to develop or strengthen targeted social safety nets to communities and sectors of society likely to be hardest hit from an increase in energy prices.

The 26 countries modelled in the research are: Algeria, Bangladesh, Brazil, China, Egypt, Germany, Ghana, India, Indonesia, Iran, Iraq, Mexico, Morocco, Myanmar, Nigeria, Pakistan, Russia, Saudi Arabia, South Africa, Sri Lanka, Tunisia, United Arab Emirates, the United States, Venezuela, Vietnam and Zambia. These countries were chosen to provide a globally diverse range of countries with a mix of larger and smaller GDPs where fossil fuel subsidies were found to be significant and where there was interest from the governments themselves in the results. Countries were modelled where fossil fuel subsidies exhibited either a high percentage within national budgets (often in the case of smaller economies) or where there were significant potential emission co-benefits (often in the case of larger economies). The countries modelled also build on the modelling of 20 countries in 2015, prior to the Paris Agreement.

Fossil fuel subsidy data used within the model were drawn from both the IEA and the IMF (pre-tax) for 2016 (data available at the time of modelling), across coal, electricity, gas and oil. The analysis considered three scenarios that build on each other: (i) complete fossil fuel subsidy removal by 2025 (following a linear trend from 2018), (ii) the introduction of energy taxes for an amount of 10 per cent of current energy prices (following a linear trend from 2025 and reaching 10 per cent by 2030) and (iii) the reallocation of 20 per cent of subsidy savings and increased tax revenues to investments in energy-efficiency improvements and 10 per cent to investments in renewable energy plants (from 2018 and continuing through 2030). The research found that the combination of actions could lead to an average national emission reduction of 13.2 per cent by 2030 compared to a BAU baseline (Figure 5). When weighting reductions by the size of the economy of the countries using GDP, the decline in emissions reaches 7.3 per cent by 2030.

The results found that, specifically, the average emission reduction of 13.2 per cent (Table 2, column 1) is obtained from:

- Emission reductions from fossil fuel subsidy removal: 6 per cent by 2025 and remaining the same in 2030, as against BAU.
- Fossil energy tax: starting in 2025 and reaching 2.17 per cent by 2030.
- Recycling of savings from reform and fossil energy tax into energy efficiency (EE): 2.26 per cent by 2025 and 3.14 per cent by 2030.
- Recycling of savings from reform and fossil energy tax into renewable energy (RE): 1.14 per cent by 2025 and 1.91 per cent by 2030.

The cumulative savings from across all countries from FFSR amounts to 2.08 gigatonnes (Gt) of CO_2e by 2025 and 4.8 Gt of CO_2e by 2030; when adding fossil energy taxation from 2025 onwards, emissions are reduced by an additional 6.66 Gt of CO_2e by 2030. Investments in EE and RE increase emission reductions further, to a total of 3.09 Gt of CO_2e by 2025 and 10.63 Gt of CO_2e by 2030.

Table 2. Average percentage and cumulative GHG emission reductions across 26 countries, GSI-IF 2019

	Percentage of national emission reductions as against BAU (2030)				
Average across 26 countries	**Simple average**	**Weighted by GDP**	**Weighted by emissions**	**Cumulative CO_2e by 2025 (Gt)**	**Cumulative CO_2e by 2030 (Gt)**
FFSR: Emission reductions from fossil fuel subsidy removal 2018–2025	6	1.76	2.22	2.08	4.8
Tax: 10% fossil energy tax 2025–2030	2.17	2.27	2.28	-	1.85
Swap: Recycling of 30% savings from reform and 30% of revenue from fossil energy tax into EE (20%) and RE (10%), 2018–2030	3.14 (EE) and 1.91 (RE)	2.16 (EE) and 1.15 (RE)	2.25 (EE) and 1.16 (RE)	1.01	3.98
Total across all policies (2030)	13.2	7.33	7.91	3.09	10.63

Because FFSR is a policy tool that saves government resources, it is estimated that for every tonne of CO_2e removed through FFSR, governments save an average of USD 93. These findings are discussed in more detail below and are consistent with previous research from GSI that reviewed the international literature, finding global emission reductions of between 6 and 13 per cent by 2050 (Merrill et al. 2015).

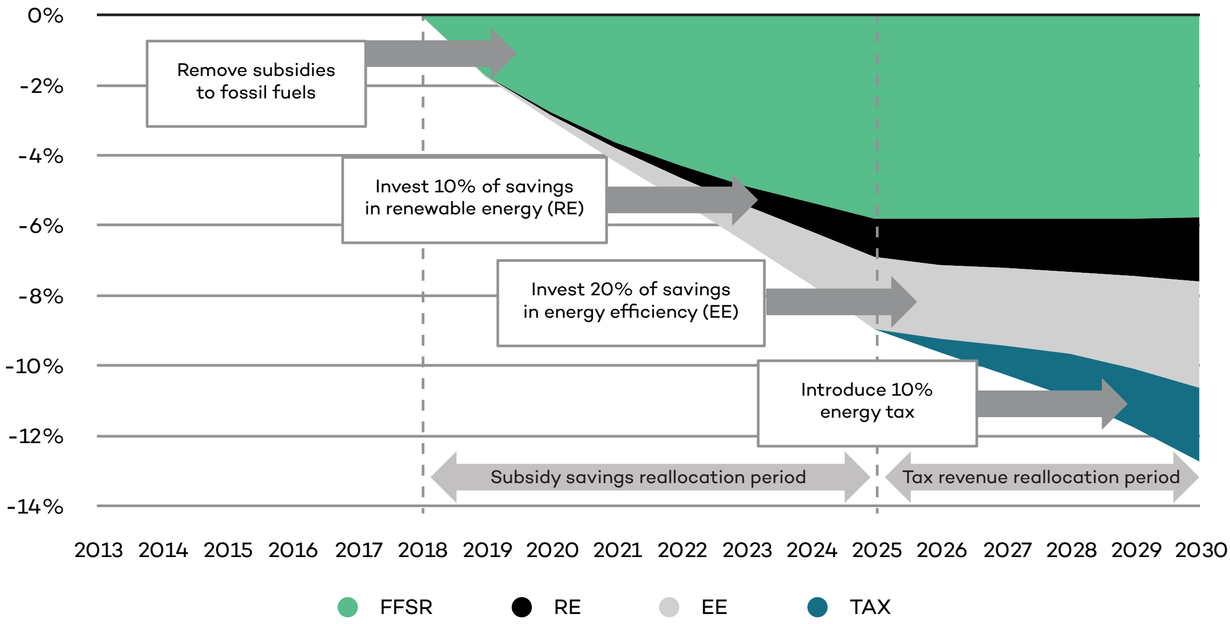


Figure 5. Average percentage of carbon equivalent emission reductions over time from consumer FFSR and 10 per cent energy taxation across 26 countries, with 10 per cent of savings and revenues invested in RE and 20 per cent in EE.

Source: Author-generated data

When analyzing the results by country, interesting insights emerge. Countries with the highest percentage reduction in emissions are Venezuela, Iraq, Saudi Arabia, Algeria and the United Arab Emirates, with an average emission reduction above 20 per cent in the year 2030 (Figure 6). These countries are characterized by the highest relative amounts of subsidies as a share of GDP among those considered for this study. As a result, FFSR leads to large price changes in these countries, which affects energy demand and fuel switching. Further, the presence of large subsidies implies, in our scenarios, that a significant amount of additional revenues raised from the reforms could therefore be reallocated to improving EE (20 per cent) and expanding the availability of RE (10 per cent). The model found that, under this scenario the largest component of emission reductions in these countries is FFSR and removal.

On the other hand, the countries with the largest absolute reductions in emissions are China, the United States, India, Saudi Arabia, Russia and Indonesia. These countries are characterized by high energy intensity and consumption, relatively low energy prices, high carbon intensity (and hence high reliance on subsidized fossil fuels), or a combination of these conditions. The model found that, under this scenario and for these countries, FFSR is not the largest contributor to emission reductions. Rather, it finds that a subsequent fossil fuel energy tax and investment in energy efficiency based on savings or revenues from FFSR or taxation can lead to larger absolute emission reductions than FFSR. That is to say, in countries such as China or India, the biggest effects would arise from the impact that a 10 per cent tax has on energy prices, rather than subsidy removal, and the comparatively larger amount of resources reallocated to EE (due to the disproportionately higher demand compared with other countries). Detailed country results are set out in Annexes 1, 2 and 3.

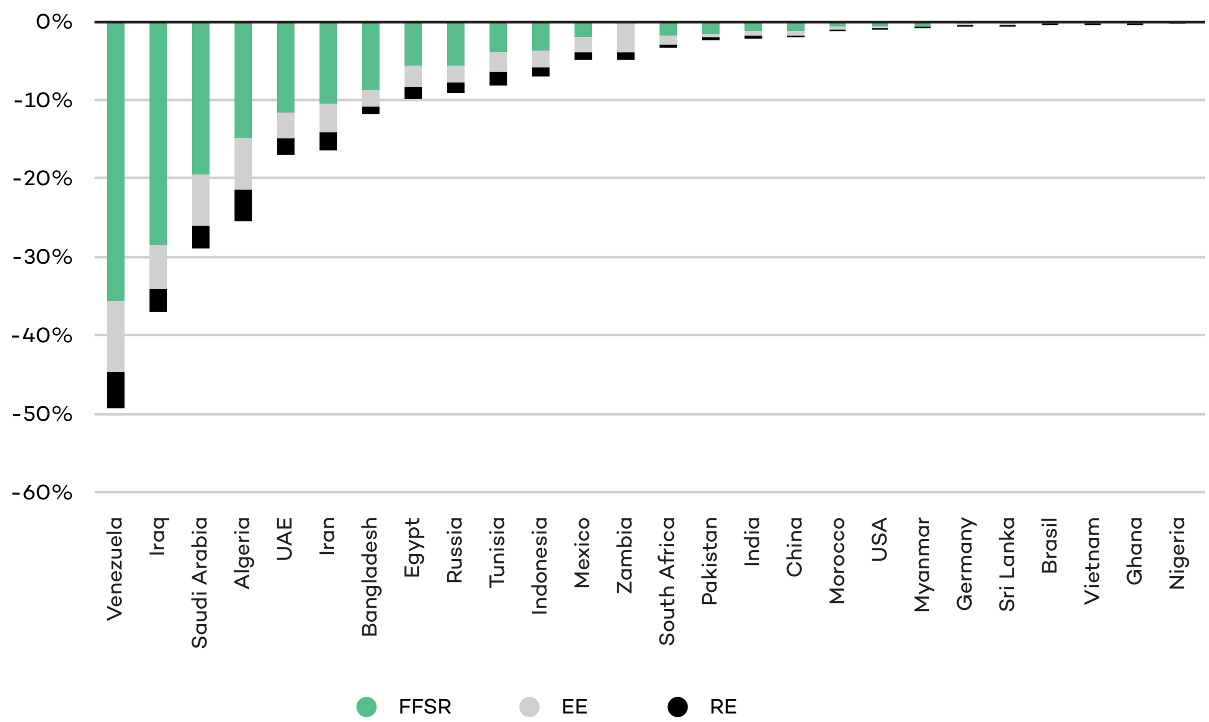


Figure 6. Percentage of emission reductions in the year 2025 from FFSR by country, with 10 per cent of savings invested in RE and 20 per cent in EE

Source: Author-generated data

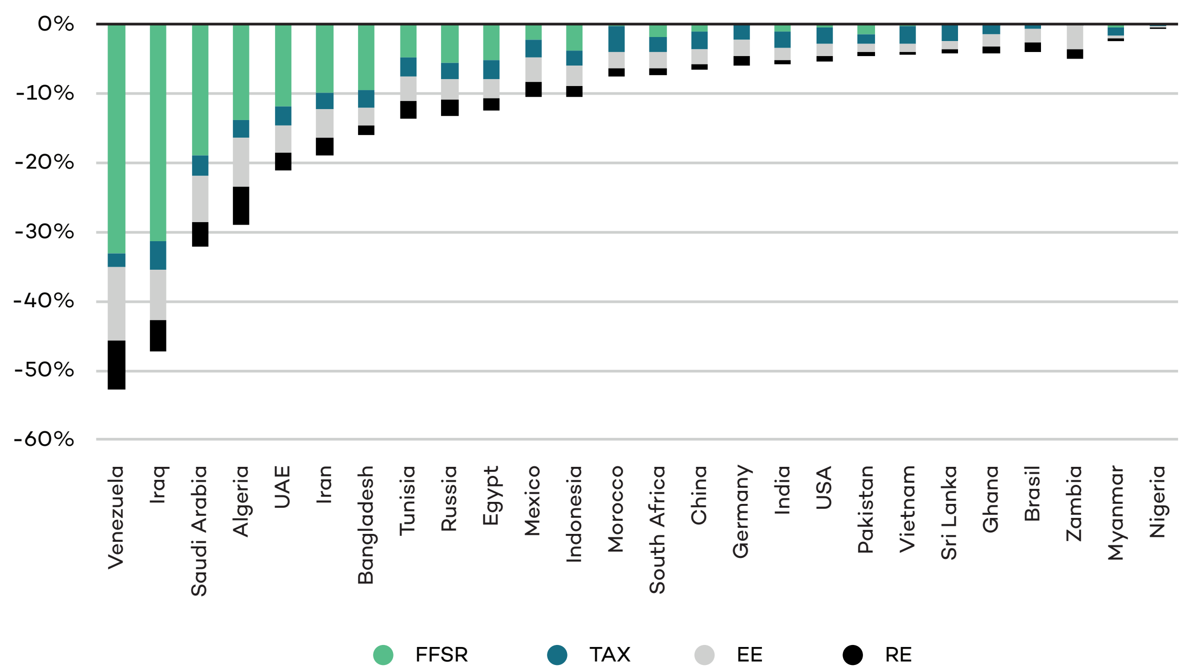


Figure 7. Percentage of emission reductions in the year 2030 from FFSR and energy taxation by country, with 10 per cent of savings invested in RE and 20 per cent in EE

Source: Author-generated data

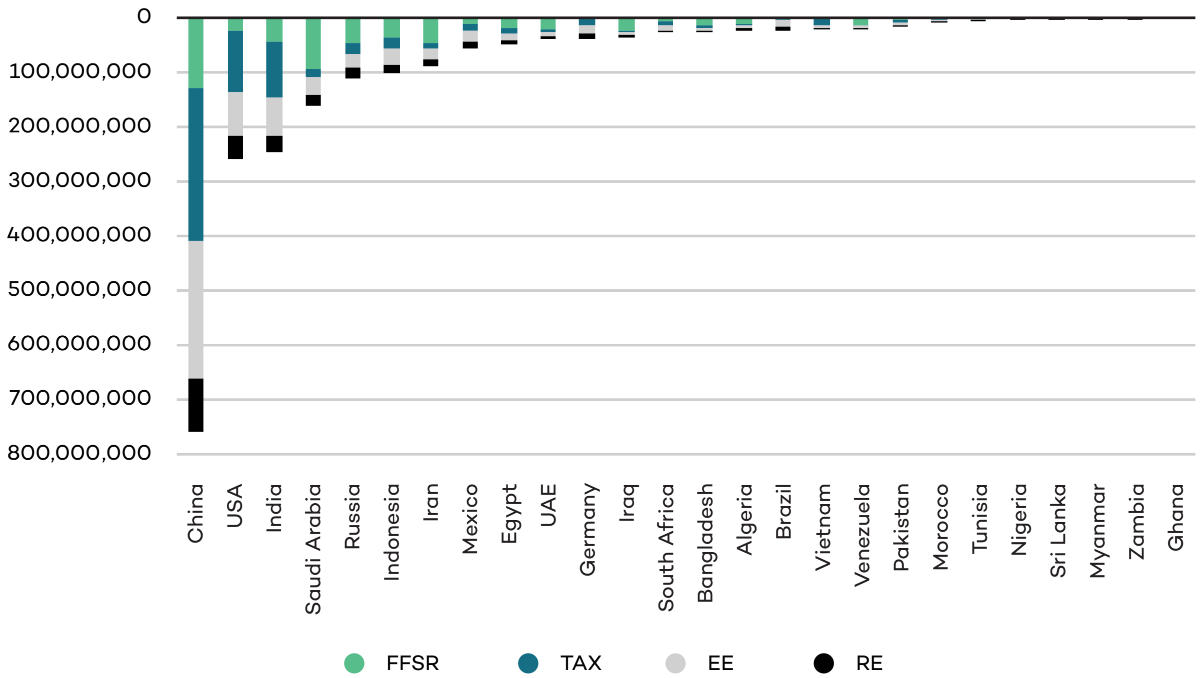


Figure 8. Absolute emission reductions in the year 2030 from FFSR and energy taxation by country, with 10 per cent of savings invested in RE and 20 per cent in EE

Note: This graph presents emission reductions compared to the baseline for the year 2030 only. The unit is CO_2e/year (in the year 2030).

Source: Author-generated data

The amount of subsidies provided by the 26 countries analyzed totalled USD 256.7 billion in 2016. Taking into account forecasted energy consumption and assuming that the subsidy provided per unit of energy consumed remains constant in the future, the cumulative subsidy savings through to 2030 amounts to USD 2.56 trillion for the 26 countries analyzed. Fossil fuel energy tax revenues are forecasted to reach USD 1.94 trillion cumulatively by the year 2030. This leads to a total of USD 4.5 trillion raised via subsidy savings and tax revenue. Thirty per cent of this (USD 1.35 trillion) would be shifted toward investments in renewables and energy efficiency within the model by 2030.

When compared to the results from a previous GSI-IF modelling exercise undertaken in 2015, a number of key differences arise. The first is that this modelling exercise included an additional six countries to those modelled in 2015. The second is the scale of subsidies inputted into the 2015 model, which were higher than in 2016, due both to effective reforms but also higher oil prices. Furthermore, the scenarios from 2015 did not include the additional 10 per cent energy taxation. Given these differences, we now forecast a simple average for national emission reductions from FFSR across 26 countries of 6 per cent by 2030 compared to the BAU baseline. In 2015 the value of emission reductions forecasted was higher—10.9 per cent by 2020 and 9.85 per cent by 2025—as the simple average across 20 countries.

The cumulative emission savings from across all countries is similar to results from 2015. The total emission reductions from FFSR alone, across all 26 countries in 2019 amounts to 2.08 Gt of CO_2e by 2025 and 4.8 Gt of CO_2e by 2030 in the current study. The results from the 2015 study came to 2.82 Gt of CO_2e by 2020. The amounts in this case are different for two main reasons: (a) fossil fuel subsidies have declined but energy consumption has increased, and (b) the list of countries included in the study has increased, from 20 to 26.

Box 2. The importance of detailed subsidy data, including producer subsidies

Though we used consistent consumer price support data available from 2016 from the IEA and IMF for consistency, we recognize that these figures are often underestimated and do not capture producer subsidies. Therefore, when we inputted subsidy data collected via a bottom-up inventory approach into the GSI-IF model, we found substantial differences in the level of emission reductions available from subsidy reform. A country example is provided below:

Country X /X per cent emission reductions from FFSR alone by 2030:

- IMF pre-tax subsidy data: 0.04 per cent reduction in emissions
- Peer review subsidy data: 1.37 per cent reduction in emissions
- Inventory approach from external researchers: 2.08 per cent reduction in emissions

This highlights that the emission reductions from the GSI-IF modelling undertaken in 2019 (this report) are very likely to be significant underestimates due to the lack of a consistent, detailed set of subsidy estimates at the global scale covering both consumer and producer fossil fuel energy for every country. For more information on producer subsidies and the impact of their removal for a reduction in GHG emissions, see Box 3.

3.0 Review of Global Modelling of GHG Emission Reductions From FFSR

Economists have acknowledged the importance of FFSR for over 30 years: for example in the 1980s, Kosmo outlined that by "removing such energy subsidies, governments can encourage energy efficiency, cut the costs of producing and using energy, reduce costly energy imports (or, in the oil-exporting countries, increase oil exports), minimize environmental damages and risks, and reduce their own fiscal burdens" (Kosmo, 1987, p. 1). In the 1990s, Larsen further asserted that "the removal of fossil fuel subsidies has been advocated as the first order of priority in instituting economic policies to protect local and global environments" (Larsen, 1994, p. 2). Many studies have sought to quantify emission reductions from the removal of fossil fuel subsidies, but their results vary widely due to many factors: the geographical scope, how subsidies are defined and calculated and the type of subsidy under consideration (consumer or producer), the baseline assumptions, which sectors and fuels are investigated (often electricity is ignored in consumer studies, for example), the time frame of reform and the model employed for the study.[2] (Annex 4 summarizes a literature review of 40 global and national studies on potential emission reductions due to phasing out fossil fuel subsidies.)

For example, research by Jewell et al. (2018)[3] uses five models to describe how a single policy instrument, consumer and producer FFSR, leads to global reductions of 0.5–2 $GtCO_2e$, or 1–4 per cent, by 2030. This reduction accounts for around a quarter of the combined effort currently proposed by countries' NDCs from the Paris Agreement of between 4 and 8 Gt. Earlier work on consumer subsidy removal alone found global emission reductions of between 6.4 and 8.2 per cent by 2050 (Burniaux & Chateau, 2014; Schwanitz et al., 2014).

GSI-IF modelling across 26 countries, as undertaken for this working paper, was found to be commensurate with these findings. When weighting reductions by the size of the economy of the countries using GDP, the average decline in GHG emissions from FFSR, a modest tax and reallocation of the savings to investments in energy efficiency and renewable energy reaches 7.3 per cent by 2030 compared to BAU. Of those studies that focused on regional or country-level efforts of subsidy reform, Mundaca et al. (2018) estimates that reductions in subsidies to both gasoline and diesel consumption by about USD 20 cents per litre will lead to reductions in emissions from 10 to 90 per cent by 2029, depending on the country and type of fuel. In a backward-looking study, Stefanski (2014) determined that emissions would have been 36 per cent lower in 2010 in a world without both consumer and producer fossil fuel subsidies. In one of the few global producer subsidy reform studies Gerasimchuk, Bassi et al. (2017) found that a complete removal of subsidies to fossil fuel production globally would reduce the world's emissions by 37 Gt of CO_2e over 2017–2050, roughly equivalent to eliminating all emissions from the aviation sector (see the Box 3 below on producer subsidies).

However, the external costs of fossil fuels are not fully accounted for in current fossil fuel prices, nor are they reflected in the studies above. The IMF found that removing consumer price support[4] and charging "optimal" taxes on fossil fuels and electricity would have resulted in a 28 per cent reduction in emissions[5] in 2015 (Figure 1) and a 21 per cent reduction in 2013 (Coady et al., 2019). These higher emission reductions reflect these studies' attempts to price fossil fuels appropriately.

[2] For example Sampedro, Arto, & González-Eguino (2017) determine that partial or general equilibrium models tend to give higher expected emission reductions than integrated assessment models because their fuel-switching possibilities are more optimistic.

[3] Widely sourced datasets used in this study feature some significant exclusions (e.g., many large-scale subsidies to coal and gas power generation are absent).

[4] Both consumer and producer subsidies are included in the IMF's work on "pre-tax subsidies," but producer subsides are relatively small.

[5] The same study found that fossil fuel air pollution deaths would have been 46 per cent lower, tax revenues would have been higher by 3.8 per cent of global GDP, and net economic benefits (environmental benefits less economic costs) would have amounted to 1.7 per cent of global GDP (Coady et al., 2019).

In particular, the authors note that consumer price support ("pre-tax subsidies" per the IMF) for coal is negligible, but once one takes into account consumption-related externalities, "coal is the most important fuel, accounting for 44 percent of the global subsidy in 2015, reflecting the underpricing of its large carbon and local air pollution costs" (Coady et al., 2019, p. 20). Almost 80 per cent of all emission reductions result from the correct pricing of coal and associated reduction in its use (Coady et al., 2019). Parry, Mylonas and Vernon (2018) found that a carbon price of EUR 30 (USD 35)/tonne (t) of CO_2 would lead to between 6 and 30 per cent emission reductions and a price of EUR 60 (USD 70)/tCO_2 would lead to between 10 and 40 per cent emission reductions, depending on the country, by 2030. For the G20, a carbon price of USD 35 per tonne in 2030 would be consistent with the total current emission reduction efforts from NDCs (Parry et al., 2018).

During 2008–2011, British Columbia's emissions associated with carbon-taxed fuels declined by 10 per cent, and its reductions outpaced those in the rest of Canada by 9 per cent (Elgie & McClay, 2013). In that same period, emissions from the transport sector in Sweden were reduced by 11 per cent in an average year after the implementation of a carbon tax and a value-added tax, with a 6 per cent reduction from the carbon tax alone (Andersson, 2015). (Annex 5 summarizes over 20 studies on potential emission reductions due to various fossil fuel taxes.)

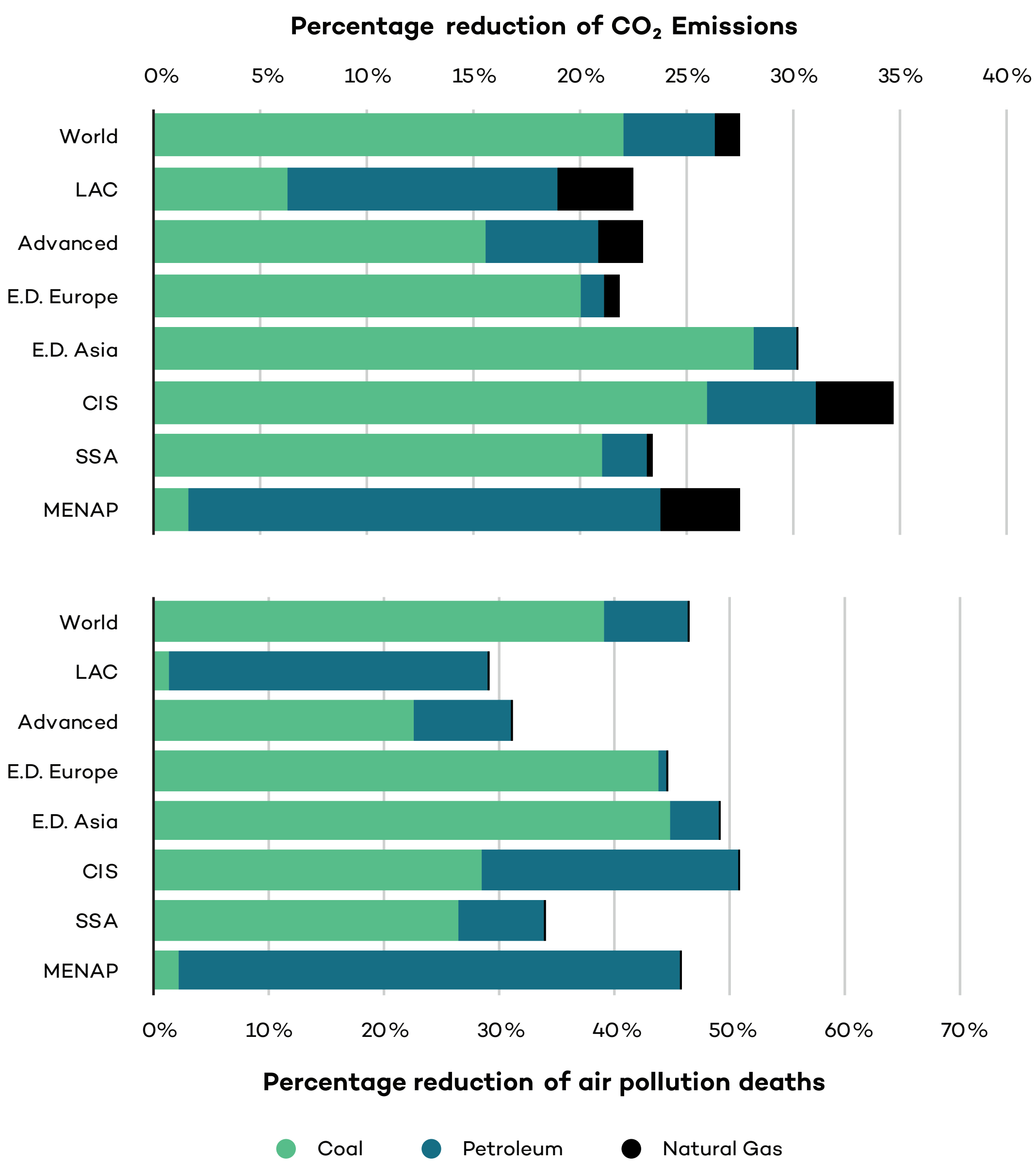


Figure 9. **Environmental gains from correct pricing of fossil fuels (2015)**

Source: Coady et al., 2019.

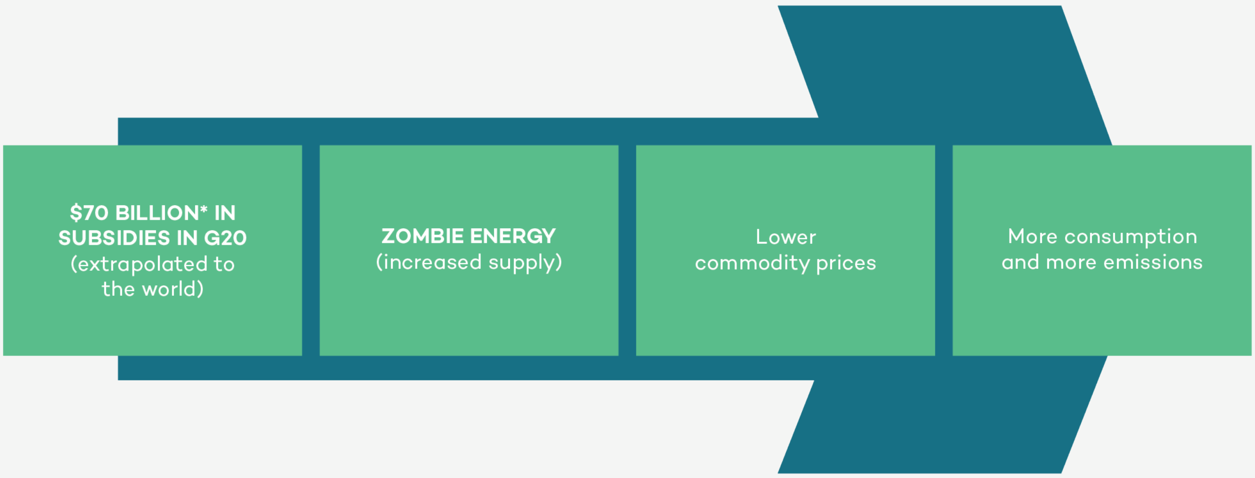
Countries could start to price fossil fuels correctly: not just via a carbon tax (excise tax) but also via a basic value-added tax, a goods and services tax and producer taxes. European countries that introduced a long-run policy of high transport fuel taxes have cut carbon emissions by more than half between 1978 and 2003 and have moved from low to high-tax scenarios for the entire OECD for all fuel, resulting in 10 per cent of total global fossil carbon emissions from all sources (Sterner, 2007).

Davis & Killian (2011) determine that a 10 cent/gallon increase in the U.S. federal gasoline tax would reduce carbon emissions from the transport sector by 1.5 per cent and from the United States as a whole by 0.5 per cent.

A globally levied tax rate of USD 10/tCO_2 on all thermal coal production could reduce annual emissions by 1.9 GtCO_2, or over 19 per cent of current global emissions from coal use in the power sector (Richter, Mendelevitch, & Jotzo, 2018). Production taxes have been found to "consistently yield higher tax revenues and have greater effects on global coal consumption with smaller rates of carbon leakages" than a unilateral export tax (Richter et al., 2018, p. 43). Other research finds that production subsidy reform alone will not achieve emission reductions consistent with limiting warming to 2°C, whereas a mine moratorium beginning in 2020 would reduce global coal consumption by limiting coal availability, strongly increasing prices and enabling a coal consumption path consistent with the 1.5–2°C target (Mendelevitch, 2018). McGlade and Ekins (2015, p. 187) finds that "globally, a third of oil reserves, half of gas reserves and over 80 per cent of current coal reserves should remain unused from 2010 to 2050 in order to meet the target of 2°C."

Box 3. Producer subsidies and the need for transparency

It is not only consumer subsidies that create an artificial decrease in fossil fuel prices and thus lead to additional emissions. Subsidies to producers of oil, gas and coal, as well as electricity and heat generated by these fuels, have the same consequences for both prices and climate (see below).



* Incomplete, but best available dataset (Bast et. al., 2015) for direct spending and tax breaks to fossil fuel production by G20 countries on annual average in 2013 and 2014, also excluding estimated:
• USD 286 billion in SOE investment • USD 88 billion in public finance

Figure 10. How fossil fuel production subsidies lead to more emissions (first-order impacts)

Source: Gerasimchuk, Bassi, et al. (2017).

Fossil fuel producer subsidies come in many forms, for example, direct budget spending and preferential loans; company bailouts and equity injections by governments; reduced rates of royalties and other taxes on production; access to land, water, subsoil resources, roads and other government-owned infrastructure for free or on conditions better than the market; liabilities for oil spills and other pollution assumed by the government.

Unlike consumer subsidies, most producer subsidies cannot be measured on the basis of observed price gaps alone, and not all expert organizations cover them in their analysis of fossil fuel subsidies. Instead, it is necessary to make an inventory of producer subsidies for each country and quantify each of them individually using different methods (Jones & Steenblik, 2010). The OECD publishes inventories of budgetary transfers and tax expenditure to producers and consumers for 44 countries, including by subnational governments (OECD, n.d.). Inventories undertaken by non-governmental expert organizations such as GSI, Overseas Development Institute and Oil Change International have added further to the body of work on production subsidies, particularly those provided through credit support (GSI, n.d.; Bast et al., 2015).

In the G20 countries, direct spending and tax breaks supporting fossil fuel production were estimated at USD 70 billion on average annually between 2013 and 2014 (Bast et al., 2015). But for most other countries in the world, there are no datasets of fossil fuel producer subsidies.

Global fossil fuel producer subsidies were estimated in the mid 2000s as probably being at least USD 100 billion a year (Laan, 2010).

Electricity, coal and, especially, oil and gas projects are very capital-intensive. Many producer subsidies are provided to cut these capital costs and attract investors (Gerasimchuk, Bassi et al., 2017). Therefore, producer subsidies often determine whether or not a particular field, mine or plant will come online. In the United States, depending on prevailing oil prices, several tax reductions at the development stage were found to be the decisive factor for up to half of all new oil fields (Erickson, Down, Lazarus, & Koplow, 2017).

In most cases, the introduction or removal of consumer subsidies has immediate impacts on energy prices. By contrast, for most fuels, introduction or removal of producer subsidies affects energy prices only in the medium and long terms. For example, the oil market is global. If oil becomes more expensive to produce because of producer subsidy removal and several production projects do not develop as a result in one country, producers from other countries with lower costs can fill in most or all of the gaps.

That is why, to have a significant effect on emission reductions, producer subsidy reform has to be undertaken in several large fossil fuel-producing countries and be combined with consumer subsidy reform and other climate policies such as coal and fossil fuel phase-outs. In particular, producer subsidy reform is an organic component of coal phase-outs in Canada, Europe and several other countries. As coal extraction costs increased in these countries, mines struggled to remain competitive, leading to calls for subsidies to safeguard the industry. Eventually, the high cost of these subsidies, climate concerns and local pollution created pressure on governments to remove coal subsidies, commit to coal phase-outs and thus achieve significant emission reductions (Bridle at al., 2017).

A recent launch of the SDG 12.c.1 methodology (UN Environment, OECD, & IISD, 2019) should encourage countries to actively consider and report on producer subsidies as part of their commitment toward progress against the SDGs. The indicator for all countries is to report the "amount of fossil fuel subsidies per unit of GDP (production and consumption)" (p. ix). The method for reporting against this indicator clearly lays out elements to consider, including for producer subsidies (UN Environment, OECD, & IISD, 2019) (see Box 1).

While many agree, including the authors of this report, that subsidy reform can lead to reductions in emissions, it is also becoming clear that subsidy removal *alone* is not enough to achieve our long-term climate objectives. There are several reasons for this. First, there are other drivers of emissions, with Schwanitz et al. (2014) observing that, in the long term, "all phase-out scenario emissions are returning to the same level as the reference case, since the effects of the phase-out [of fossil fuel subsidies] are less important than other effects that drive emissions like population, GDP growth, or resource depletion" (p. 886). Second, fuel substitution can occur where lower-carbon-intensive fuel is switched out for higher-carbon-intensive fuel. This is of particular concern in countries that have limited options for fuel switching to lower-carbon activities.

In some regions and countries, global subsidy removal could lead over the medium or long term to an increase in emissions, due to lower-carbon oil and natural gas being replaced by cheaper and higher-carbon coal (Jewell et al., 2018; Schwanitz 2014). Li and Sun (2018) saw overall emission reductions from a removal of fossil fuel subsidies in China from 2003 to 2014, but many of the years modelled saw an increase in carbon dioxide emissions due to fuel substitution from lower-carbon oil or gas to high-carbon coal. The authors indicate that they do not believe that removing fossil fuel subsidies would promote a transition to a low-carbon economy in this case unless the action is accompanied by additional policies, such as obligations to use an increasing share of renewable energy in the electricity mix and funding to help support that expansion (as is proposed and modelled in this paper). Work by Gerasimchuk, Bassi et al. (2017) on producer subsidies shows that "maximum emissions mitigation effect is achieved if subsidies are removed for all fossil fuels, because otherwise fuels can partially substitute for each other and production will shift toward fuels that are subsidized the most" (p. 37).

Finally, carbon emissions leakage can occur across borders, minimizing the mitigation effects implemented by a reform in one country or region. Delpazzio et al. (2015) found overall emission reductions of 2.3 per cent in 2030 from world-wide removal of fossil fuel subsidies, but also showed shifts in international trade to those regions that did not undergo subsidy reform, including gains in GDP and slight increases in emissions, indicating the emissions leakage effect. Similar results were observed in earlier work where the phase-out of fossil fuel consumption subsidies led to a reduction in trade volumes in oil-exporting countries that was compensated by an expansion of trade flows in OECD countries (Burniaux, Chateau, & Savage, 2011).

Studies show that fossil fuel subsidy to clean energy "swaps" can overcome some of these problems and could result in greater emission reductions. Under the IEA's Sustainable Development Scenario,[6] a phase-out of consumer fossil fuel subsidies by 2035 plus implementation of energy efficiency results in a 37 per cent reduction in emissions by 2040 compared to the New Policy Scenario (IEA, 2018b).

Li et al.'s (2017) study on China evaluated eight fossil fuel reform scenarios based on 2007 data: one set of four reform scenarios looked at partially or fully removing fossil subsidies and the other set of four reform scenarios also swapped subsidies into clean energy. The authors found that total carbon emissions would be reduced by an additional 15.5–19.1 per cent in the swap scenarios compared with the FFSR only scenarios. Sampedro (2017) found that, by recycling the revenues from European Union fossil fuel subsidy removal into investment in solar photovoltaic installations resulted in an emission mitigation increase from 1.8 to 2.2 per cent by 2030. The GSI-IF modelling agrees with these findings, showing that combining subsidy reform and a 10 per cent tax along with a shift that redirects 30 per cent of the savings to investments in improving energy efficiency and expanding renewable energy capacity leads to improving emission reductions from 4.03 to 7.33 per cent by 2030 (weighted by GDP). The practical application of such a shifting of expenditure is described in Section 6, using an example from India.

In order to harness the longer-term impacts of subsidy reform and benefits from more permanent emission reductions, countries will need to do three things. First, they need to remove their fossil fuel subsidies; and second, they need to start taxing their fossil fuels correctly. Fossil fuel subsidy removal combined with the application of appropriate taxation could reduce emissions by a much larger 28 per cent globally (Coady et al., 2019). Finally, countries need to shift to using cleaner, low-carbon fuels (Merrill et al., 2017). Governments can choose to invest in improving energy efficiency, expanding renewable energy and lower-carbon public transport schemes, and other mitigation measures in order to help move away from energy systems built on fossil fuels and toward those based on sustainable energy.

[6] The IEA's Sustainable Development Scenario is a trajectory based on the goals of the Paris Agreement, whereas the New Policy Scenario is a trajectory based on policies and targets announced by governments (IEA, 2018).

In short, subsidy reform is an important tool within the government's fiscal tool-box for the emission reductions associated with this fiscal measure, but also in that reform and removal of fossil fuel subsidies helps to create the necessary enabling environment, to allow the acceleration and take off of other technologies that will appear comparatively more attractive in the absence of fossil fuel subsidies. In fact, recent modelling by Monasterolo and Raberto (2019) shows that subsidy reform contributes to improvements in macroeconomic performance through "higher capital accumulation in the domestic economy and the creation of green jobs and capital investments" (p. 365). Removal of fossil fuel subsidies would provide governments with the opportunity to reallocate the savings unlocked from reforms to be reallocated toward specific policies to promote and accelerate sustainable energy, such as renewables and energy efficiency. FFSR enables a shift in investments to low-carbon energy production, creating the conditions that support a low-carbon transition (Monasterolo & Raberto, 2019).

Therefore, FFSR saves government resources while simultaneously reducing emissions. The GSI-IF model estimates that, for every tonne of carbon dioxide removed through FFSR, governments save on average USD 93, whereas other policy tools to mitigate GHG emissions often usually incur a cost. The OECD (2013, 2018) estimates that effective carbon prices for various policies in the electricity sector range from USD 53 (EUR 40) for renewable portfolio standards to USD 232 (EUR 175) for feed-in tariffs per tonne of carbon dioxide abated in 2010. These prices highlight the potential for subsidy reform to be an effective tool for governments in the fight against climate change, and therefore the co-benefits of reform must be seriously considered and included within country NDCs as part of the Paris Agreement.

4.0 Social Protection and the Economy

4.1 Social Protection and FFSR[7]

Fossil fuel subsidies do a poor job of assisting the poor effectively. IMF research covering 35 countries and fuel price subsidies finds that "on average, the top income quintile receives more than six times more in total subsidies than the bottom quintile" (Coady, Flamini, & Sears, 2015, p. 12, see Figure 1) and that fossil fuel subsidies are very regressive: "nearly 93 out of every 100 dollars of gasoline subsidy 'leaks' to the top three quintiles" (Coady et al., 2015, p. 12). Subsidies to gasoline perform badly: the bottom two quintiles receive on average 7.4 per cent of benefits and the top two quintiles receive on average 83.2 per cent of benefits (Coady et al., 2015). Country-level data are also striking. Even with kerosene, where the IMF study finds that benefits are equally distributed across the quintiles, national surveys find real variations on the ground. One study in India finds that for every six rupees the government spends on kerosene subsidies, only one rupee reaches the poorest 20 per cent of consumers (Clarke, 2014). This substantial leakage of subsidy benefits to the top income groups means that blanket fuel subsidies are an extremely costly and thus inefficient way to provide assumed targeted welfare to poor households.

The last few years have seen impressive progress by a number of governments in phasing out fossil fuel subsidies and investing instead in social safety nets, education, health care and development priorities. To mitigate the impact of gasoline and diesel subsidy reforms, Indonesia used a basket of social protection policies covering education, health insurance, food subsidies, cash transfers and infrastructure programs. Indeed, Indonesia's first large-scale unconditional cash transfer system was created in only six months in order to compensate for subsidy reforms.

Brazil started to gradually increase prices on fossil fuels in the early 1990s with deregulation in 2002 across gasoline, diesel and liquefied petroleum gas (LPG). From 2001 onward, Brazil developed better-targeted LPG voucher subsidies and a national conditional cash transfer scheme aimed at covering education and energy outcomes (Adeoti, Chete, Beaton, & Clarke, 2016). Ghana reformed subsidies to gasoline and diesel; it also developed a livelihoods program to support families. India put in place a direct benefit transfer for LPG, which has since become one of the largest cash transfer programs in the world (Adeoti et al., 2016). Morocco expanded a national conditional cash transfer, education and health insurance scheme at the same time as reforming (Merrill et al., 2016). The Philippines used targeted cash transfers to help build a national safety net and lifeline tariffs to protect the poor in the process of reforms (Mendoza, 2014). Peru expanded a conditional cash transfer program and introduced an improved cookstove distribution scheme (Merrill et al., 2016).

Reform presents an opportunity for governments to switch from relatively simple and easy-to-administer subsidies designed to provide welfare benefits via cheap fossil fuels toward more administratively complex, but better-targeted (and often cheaper) social welfare systems and safety nets via direct cash payments and targeted measures. A recent World Bank report (Inchauste & Victor, 2017, p. 9) finds that the link between reforms and the development of social protection schemes is important in that "improvements in social protection systems are critical to the success of reforms" because they make it possible to target assistance to those most in need. Furthermore, it finds that a switch away from fossil fuel subsidies and toward better-targeted assistance can also promote better tracking and governance of the subsidies via smart cards or micropayment schemes.

[7] Broad ideas in Section 4.1 are drawn from Merrill et al., 2017.

4.2 Fossil Fuel Subsidies and the Economy[8]

The scale of subsidies means that they can occupy a large proportion of government budgets, especially in times of high oil prices. Thus, their removal can lead to substantial fiscal savings and free up resources for governments to invest in sectors such as health, education and sustainable energy for all. Ebeke and Ngouana point out that "public expenditures in education and health were on average lower by 0.6 percentage points of GDP in countries where energy subsidies were 1 percentage point of GDP higher" (2015, p. 1). Research from the IMF finds that reform of fossil fuel pricing and accurate taxation of fossil fuels could provide an average revenue stream to governments of around 2.6 per cent of GDP globally (Parry, Heine, Lis, & Li, 2014). Furthermore, the economic distortion from transport fuel subsidies has been estimated at USD 44 billion in deadweight loss (2012), where the buyer's willingness to pay is below the opportunity cost across 10 countries with the highest subsidies (Davis, 2013). Furthermore, a review of 37 countries found that fossil fuel subsidies had a significant and negative impact on growth (Sulistiowati, 2015, p. viii).

Reforming subsidies to fossil fuels unlocks savings to governments. Recently, Indonesia was able to free up around 10 per cent of state expenditure (USD 15.6 billion) through a combination of fossil fuel subsidy reforms (largely removing significant gasoline and diesel subsidies) and falling world oil prices (Pradiptyo, Susamto, Wirotomo, Adisasmita, & Beaton, 2016). Pricing reforms in India, mainly to gasoline (2010) and diesel (2014), cut the country's subsidies bill in 2014 by USD 15 billion (IEA, 2015), while subsidy reforms have led to the parallel implementation of one of the largest cash transfer programs in the world.

Not only are significant portions of government budgets ring-fenced for government subsidies, crowding out investment in other areas of the economy, but fossil fuel subsidies are also associated with weaker institutions. Their reform could be a step toward strengthening institutions to deliver targeted social welfare and tax systems. There are strong links between countries that have energy resources and the presence of subsidies, and particularly so for oil. There are clear negative associations between subsidies to GDP and a measure of government effectiveness, rule of law, regulatory quality and freedom from corruption (Commander, 2012). Numerous studies suggest that fossil fuel subsidies can also act as a barrier to the development and deployment of renewable energy technologies. Bridle and Kitson (2014), for example, identified three impacts of the presence of fossil fuel subsidies on renewable electricity generation. First, subsidies reduce the costs of fossil fuel-powered electricity generation and thereby impair the cost competitiveness of renewable energy. Second, they create an incumbent advantage that reinforces the position of fossil fuels within the electricity system. Finally, subsidies create conditions that favour investments in fossil fuel-based technologies over renewable alternatives.

4.3 Shifting Fossil Fuel Subsidies to Sustainable Energy

Energy is at the fulcrum of economic development in India, and India relies heavily on fossil fuels to meet its energy requirements. But there is a shift taking place toward a clean energy transition. India has been succeeding in many different aspects when phasing out fossil fuel subsidies. Between fiscal year (FY) 2014 and FY 2017, subsidies to oil and gas dropped by 76 per cent (Soman et al., 2018), from USD 26.1 billion to USD 5.5 billion, thanks to various reform efforts and a decrease in international oil prices. During the same period, the government support to renewable energy grew almost six times, from INR 2,608 crore (USD 431 million) in FY 2014 to INR 15,040 crore (USD 2.2 billion) in FY 2017 (Soman et al., 2018). This support is backed up with a target to generate 175 GW from renewable energy sources by 2022.

[8] Broad ideas in Section 4.2 are drawn from Merrill et al., 2017.

India uses several levers to shape its energy mix, including fiscal incentives, regulated energy prices and other forms of government support. In FY 2019, the central government of India spent over INR 46,000 crore (USD 6.6 billion) on subsidies for liquefied propane gas, which is mainly used for cooking and for kerosene (Business Standard, 2019). Since 2015, there have been efforts to better target LPG subsidies with the redirection of subsidies straight to the consumers' bank accounts—establishing the world's largest benefit transfer scheme (Jain, Agrawal, & Ganesan, 2016)—as a way to avoid diversion and eliminate duplicate connections and non-existent users. Moreover, the country has also implemented communication campaigns to assess consumers' views (Sharma, 2018) and to encourage high-income consumers to voluntarily surrender their subsidies.

In addition to targeting LPG subsidies, the Indian government has initiated several measures to enable households to switch away from kerosene to LPG and electricity, resulting in subsidies for kerosene falling significantly between FY 2014 and FY 2017 (IISD & Council on Energy, Environment and Water, 2018). The reduction in kerosene subsidies and replacement with clean cooking and lighting options is a good example of a fossil fuel subsidy to clean energy swap in India.

A recent report by Laan et al. (2019) notes that making the switch from kerosene to off-grid solar energy would significantly reduce fiscal and household expenditure: many off-grid solar products are now cheaper than kerosene over the lifespan of the technology. A cost comparison establishes that the government could save INR 129 (USD 2) per month on each household if a solar lantern replaced kerosene as a lighting source. Monthly savings would be an estimated INR 41 and INR 37 for every household should the government supplant kerosene with a solar home system and micro grid, respectively. Given the high upfront costs of the solar products, the study suggests a three-pronged strategy to overcome the concern (India Climate Dialogue, 2019). The solar subsidy would be provided to either households or manufacturers, or as credit through financial institutions.

In light of GSI research, India's Ministry of New and Renewable Energy has requested that the Ministry of Petroleum and Natural Gas divert a part of the cooking gas and kerosene subsidy (around INR 25,000 crore per year) to solar photovoltaic cook stoves (Financial Express, 2019). This will enable the government to help fund the energy transition for economically marginalized households, improve energy access for households and reduce indoor pollution.

5.0 Including FFSR in an NDC

5.1 Is FFSR Included Within Current NDCs?

At present, there are a number of measures related to fiscal policies that have been included in NDCs. An initial assessment of INDCs, prior to the Paris Conference of the Parties in 2015, indicated that 13 countries had referenced FFSR as a means to meeting their contribution toward the Paris Agreement (Terton, Gass, Merrill, Wagner, & Meyer, 2015). There was little detail in these initial INDCs as to how much FFSR was expected to deliver in terms of GHG mitigation, but GSI modelling of seven of the 13 countries that had indicated FFSR as a tool for GHG mitigation indicated a potential of between 1 and 15 per cent emission reductions below BAU levels for these countries (Terton et al., 2015). In 2015, most countries that had indicated a role for FFSR were developing countries, with only one or two exceptions. There were some updates to these documents as they evolved from INDCs to NDCs. A review of the registry of NDCs in its current state (United Nations Framework Convention on Climate Change [UNFCCC], 2019) indicates that there has not been a significant change in the number of countries with FFSR referenced within their NDCs. A recent assessment counts a collection of 14 countries referencing FFSR in the current version of their NDCs, largely the same countries as in 2015 with some minor changes. As with FFSR, there is a similar story regarding the inclusion of fossil energy taxation within NDCs. Taxation of carbon or fossil energy is referenced in a number of NDCs but often without too much detail and with very little information about the quantified impact that taxation of fossil energy would have on the ability of countries to meet their NDCs.

IISD and GIZ's initial assessment of INDCs in 2015 did not look at taxation at a broad level but did examine which NDCs contained references specifically to carbon pricing. In 2015, 13 NDCs were found to contain explicit references to carbon pricing, the same number that referenced FFSR. The fundamental difference is that, while only 13 NDCs referenced carbon pricing, this also included the NDC of the European Union and its 28 member states, so the actual total of countries including carbon pricing as part of their NDC reached 40. Very little detail was provided as to how these tools would be implemented, the impact they might have on national GHG emissions or how they might interact with other policies.

Currently in 2019, and again reviewing the list of current NDCs, the number of references to carbon pricing increases to over 50 countries (depending on the exact criteria used to assess the NDCs), but again very little detail is given in most cases on how carbon pricing would work and for several developing countries the reference to carbon pricing could be considered aspirational.

More broadly, on taxation, there are other references to tax reform beyond just carbon pricing in the NDCs. For example, Eswatini's NDC references the use of resource pricing as a means to encourage water use efficiency (Kingdom of Swaziland, 2016). In its NDC, the Government of Sri Lanka speaks to the development of tax structures to promote sustainable technologies (Government of Sri Lanka, 2016). However, the majority of references to taxation are with regard to taxation of GHG emissions, with very little detail about these measures on the whole.

5.2 How Can Parties Include FFSR in their NDC?

As of early 2019, 183 countries had submitted their first NDC to the UNFCCC secretariat (UNFCCC, 2019). The vast majority of these NDCs include references to either 2025 or 2030 targets for GHG mitigation. There has been some movement in terms of updating these NDCs to increase ambition during this first commitment period, but for most countries the initial INDC that they presented in 2015 largely moved unchanged into their current NDC under the Paris Agreement. For this reason, it is unlikely that there will be a great deal of change in terms of adding ambition to the current NDCs, or much prospect for additional countries to amend their current NDCs to include references to FFSR as part of their emission mitigation strategies. For the most part, first-generation NDCs (from 2015) are solidified, and roughly 8 per cent of current NDCs contain FFSR as a specifically noted action in support of GHG mitigation.

The Paris Agreement stipulates that "Each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions" (Article 4.2) (United Nations, 2015). Furthermore, the approach is that the "Party's successive nationally determined contribution will represent a progression beyond the Party's then current nationally determined contribution and reflect its highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances" (Article 4.3). Regarding the time frame, all parties are requested to submit NDCs (new or updated) by 2020 and every five years thereafter. Parties that submitted an NDC up to 2025 in the first generation are to communicate a new NDC in 2020, and those that submitted with a time frame up to 2030 need to communicate or update their NDCs in 2020 (Hackmann, 2016). In 2019 and 2020, countries could increase ambition by submitting updated or new NDCs, 9–12 months prior to the Conference of the Parties. There is a current opportunity for countries to consider the inclusion of mitigation measures and emission reductions stemming from FFSR or fossil energy taxation within second-generation NDCs.

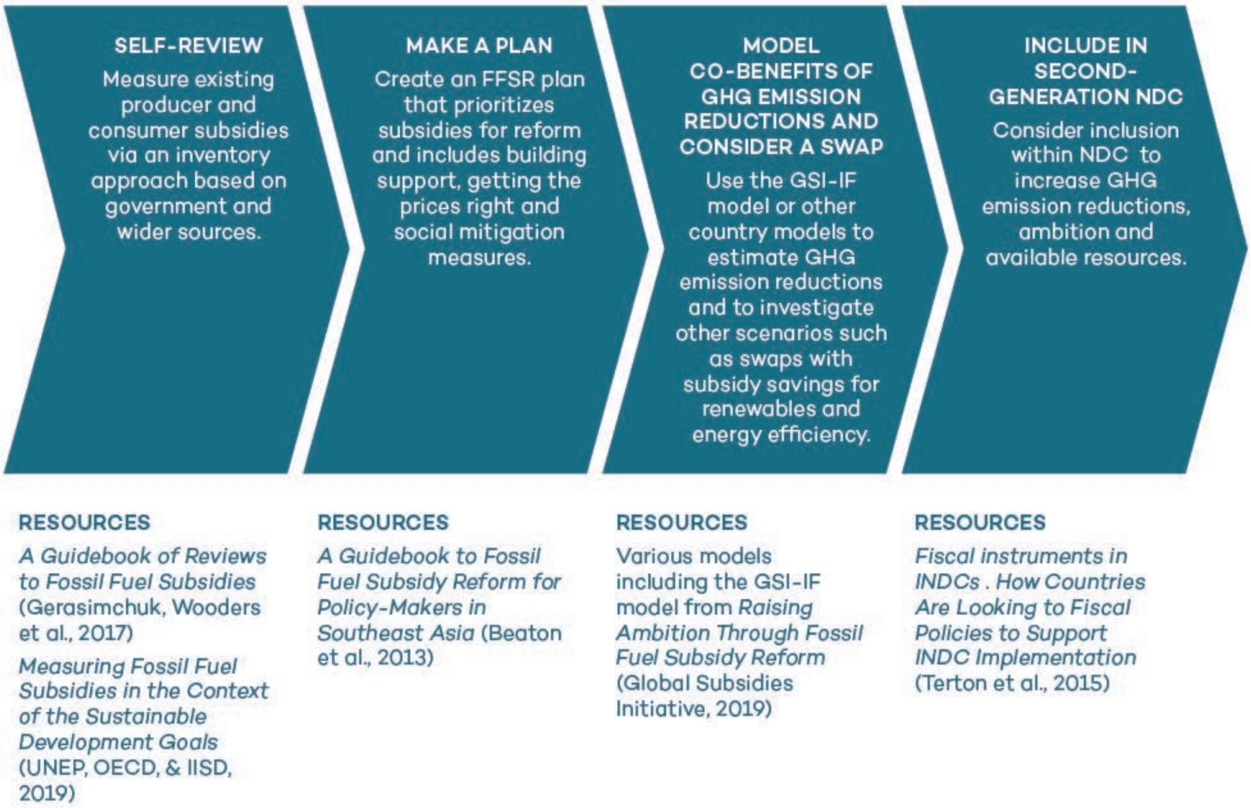


Figure 11. Including FFSR within second-generation NDCs, steps and resources

Source: Author's representation

Many countries are beginning to think of the components and ambition they will present in the next generation of NDCs. As of May 2019, only one country (Marshall Islands) has submitted its second NDC, which sets out its vision on future GHG emission mitigation aspirations for 2035 and 2050 (Republic of the Marshall Islands, 2018). With as many as over 180 additional NDCs to be developed over the coming years as countries begin to look past the initial 2025 or 2030 time frame, the current time frame is ideal for the additional consideration of the co-benefits (in terms of emission reductions) stemming from FFSR or a modest fossil energy tax as an additional action to assist countries in meeting their contributions to the Paris Agreement and for increased ambition.

The timeliness of discussion as it relates to the second set of NDCs to the Paris Agreement is also backed by a strong amount of research that says that the level of ambition in the current set of NDCs is not high enough to avoid a rise in temperatures that could be devastating for many parts of the world. In the Paris Agreement, countries agreed to limit global warming to below 2°C and pursue ways in which to limit it below 1.5°C. However, analysis of the current NDCs indicates that they would lead to warming of between 2.7 and 3.7° C (Fransen & Northrop, 2017). With this in mind, there is obviously a significant ambition gap between the current NDCs and the effort needed to bring projections for climate change in line with the requirements of the Paris Agreement.

Given the potential for FFSR to contribute to GHG mitigation and the current situation that it is only referenced in 8 per cent of NDCs, there is a timely opportunity to bring together the need for enhanced ambition for GHG mitigation and the process for the development of the second generation of NDCs. There is a strong case for a much wider consideration of FFSR in the NDCs as a significant contributor to the enhanced ambition for GHG mitigation. Locking it into the second generation of NDCs would enhance its prominence and also see it as a significant contributor to post-2025 GHG mitigation activity.

A better understanding of the potential for GHG mitigation from FFSR could help make the case for adding it to the range of actions that could be undertaken by the 92 per cent of countries that do not currently consider FFSR as one tool toward the delivery of GHG mitigation contributions. FFSR cannot be the answer to the ambition gap alone, but it could form a significant part of the solution within second-generation NDCs and should remain top of mind for those countries looking to increase their NDC ambition.

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ANNEX 1: GSI-IF Results: Total National % Emission Reductions by Country (2030)

Table A1. Percentage of emission reductions in 2030 from FFSR, energy taxation (TAX), investment in energy efficiency (EE) and renewable energy (RE), by country

	Subsidies (2016) USD million	FFSR	TAX	EE	RE	Total
Venezuela*	13791.0	-33.08%	-1.93%	-10.65%	-7.15%	-52.81%
Iraq*	5511.0	-31.37%	-4.01%	-7.27%	-4.63%	-47.27%
Saudi Arabia*	35576.9	-18.89%	-3.05%	-6.60%	-3.66%	-32.20%
Algeria*	10336.4	-13.90%	-2.45%	-7.17%	-5.46%	-28.99%
United Arab Emirates *	7584.8	-11.84%	-2.75%	-3.87%	-2.66%	-21.12%
Iran*	29036.6	-9.91%	-2.43%	-4.01%	-2.68%	-19.02%
Bangladesh*	1034.8	-9.58%	-2.52%	-2.42%	-1.37%	-15.90%
Tunisia^	1062.6	-4.79%	-2.74%	-3.51%	-2.50%	-13.54%
Russia*	32052.1	-5.65%	-2.24%	-3.02%	-2.36%	-13.27%
Egypt*	7961.5	-5.18%	-2.73%	-2.74%	-1.86%	-12.50%
Mexico*	10391.1	-2.25%	-2.49%	-3.51%	-2.22%	-10.46%
Indonesia*	18466.4	-3.75%	-2.10%	-2.95%	-1.58%	-10.39%
Morocco^	303.4	-0.34%	-3.64%	-2.41%	-1.14%	-7.53%
South Africa*	3561.9	-1.78%	-2.16%	-2.46%	-0.97%	-7.37%
China*	41726.0	-1.11%	-2.41%	-2.18%	-0.84%	-6.53%
Germany^	3319.5	-0.04%	-2.12%	-2.37%	-1.33%	-5.87%
India*	15393.4	-1.02%	-2.38%	-1.67%	-0.71%	-5.78%
United States^	13395.93	-0.52%	-2.35%	-1.64%	-0.89%	-5.41%
Pakistan*	1522.90	-1.43%	-1.44%	-1.06%	-0.66%	-4.59%
Vietnam*	154.2	-0.27%	-2.58%	-1.08%	-0.51%	-4.43%
Sri Lanka*	67.5	-0.15%	-2.21%	-1.21%	-0.57%	-4.13%
Ghana*	27.9	-0.05%	-1.42%	-1.69%	-0.97%	-4.12%
Brazil^	1848.6	0.01%	-0.67%	-1.93%	-1.43%	-4.03%
Zambia^	2416.2	1.34%	-0.10%	-3.58%	-1.24%	-3.57%
Myanmar^	102.8	-0.38%	-1.24%	-0.47%	-0.30%	-2.39%
Nigeria*∞	44.0	0.00%	-0.28%	-0.18%	-0.07%	-0.52%
		-6.00%	**-2.17%**	**-3.14%**	**-1.91%**	**-13.22%**

Note: * indicates subsidy data taken from IEA, 2018b; ^ Indicates subsidy data taken from IMF pre-tax subsidy estimates, 2017 (raw data from IMF shared with GSI). ∞For Nigeria more detailed subsidy information available from GSI gives greater emissions reductions: Subsidies 2016 (USD) million: 2,100; FFSR 0.10%; TAX:0.28%; EE:0.67%; RE:0.32%; TOTAL: 1.37%.

ANNEX 2: GSI-IF Results: Total Absolute Emission Reductions by Country (2030)

Table A2. **Absolute emission reductions in 2030 from FFSR, energy taxation (TAX), investment in energy efficiency (EE) and renewable energy (RE), tonnes of CO_2e by country.**

	FFSR	TAX	EE	RE	Total
China	-128,947,200	-279,864,320	-253,844,734	-97,354,752	-760,011,006
United States	-24,923,648	-112,617,984	-78,803,849	-42,646,016	-258,991,497
India	-43,875,328	-102,366,976	-71,592,004	-30,340,608	-248,174,916
Saudi Arabia	-94,984,160	-15,350,240	-33,206,655	-18,386,080	-161,927,135
Russia	-47,398,912	-18,827,520	-25,317,727	-19,763,456	-111,307,615
Indonesia	-37,004,736	-20,690,496	-29,089,857	-15,583,168	-102,368,257
Iran	-46,316,512	-11,360,416	-18,730,246	-12,522,688	-88,929,862
Mexico	-12,289,152	-13,596,864	-19,150,514	-12,106,944	-57,143,474
Egypt	-20,271,808	-10,681,728	-10,730,226	-7,277,280	-48,961,042
United Arab Emirates	-22,378,112	-5,192,944	-7,321,582	-5,029,376	-39,922,014
Germany	-278,272	-13,966,656	-15,607,760	-8,772,608	-38,625,296
Iraq	-24,334,300	-3,108,384	-5,635,956	-3,587,544	-36,666,184
South Africa	-6,603,072	-7,997,568	-9,116,981	-3,576,064	-27,293,685
Bangladesh	-16,034,576	-4,220,496	-4,054,303	-2,289,312	-26,598,687
Algeria	-12,357,280	-2,180,448	-6,374,735	-4,855,080	-25,767,543
Brazil[9]	49,088	-4,224,512	-12,157,032	-8,990,784	-25,323,240
Vietnam	-1,392,288	-13,351,392	-5,590,641	-2,636,992	-22,971,313
Venezuela	-13,826,004	-807,420	-4,450,557	-2,988,698	-22,072,679
Pakistan	-5,020,800	-5,085,184	-3,734,080	-2,321,536	-16,161,600
Morocco	-347,384	-3,753,680	-2,492,686	-1,176,664	-7,770,414
Tunisia	-1,663,380	-951,904	-1,219,914	-869,064	-4,704,262
Nigeria	-13,568	-1,546,880	-984,872	-387,776	-2,933,096
Sri Lanka	-88,320	-1,326,368	-727,133	-340,500	-2,482,321
Myanmar	-319,248	-1,035,224	-392,760	-247,232	-1,994,464
Zambia[10]	641,792	-47,360	-1,707,464	-593,028	-1,706,060
Ghana	-15,200	-462,796	-552,044	-316,650	-1,346,690

[9] Annex 2 presents emission reductions compared to the baseline for the year 2030 only. The unit is CO_2e/year (in the year 2030). This scenario of FFSR shows a potential increase in emissions for Brazil and Zambia. This is because (1) for these two countries only, electricity subsidies are identified within IMF pre-tax subsidy data, (2) an increase in electricity prices stimulates fuel switching toward other energy sources, and (3) these energy sources (e.g., petroleum products and biomass) are more carbon-intensive than electricity (85 per cent of which is hydropower in the case of Zambia and 77 per cent for Brazil). Practically, what the results show is a pessimistic scenario for emission reductions from electricity subsidy reform in these examples. The model assumes that there is no lock-in effect for technologies and that fuel switching can take place immediately to go from electricity to diesel generators or burning biomass. In reality, if industries and other consumers use electricity from the grid, switching to another source would not be a seamless process. This is because these economic actors will need to purchase new infrastructure (e.g., a stand-alone diesel generators) to replace purchasing electricity from the grid.

[10] As above.

ANNEX 3: GSI-IF Results: Cumulative Absolute Emission Reductions by Country (2025, 2030)

Table A3. Cumulative absolute emission reductions by 2025 and 2030 from FFSR, by country[11]

	CO_2e reduction, cumulative			
	2025 FFSR (tonne)	**2030 FFSR (tonne)**	**2025 FFSR (Gt)**	**2030 FFSR (Gt)**
Saudi Arabia	**404,540,352**	**874,922,304**	0.405	0.875
China	**387,832,832**	**1,008,887,808**	0.388	1.009
Russia	**192,734,272**	**431,050,432**	0.193	0.431
Iran	**189,525,568**	**419,168,768**	0.190	0.419
India	**141,204,992**	**346,887,168**	0.141	0.347
United States	**114,741,248**	**243,155,456**	0.115	0.243
Indonesia	**106,678,080**	**279,055,104**	0.107	0.279
Venezuela	**106,328,418**	**183,276,986**	0.106	0.183
Iraq	**101,020,476**	**218,037,176**	0.101	0.218
United Arab Emirates	**79,248,448**	**185,700,560**	0.079	0.186
Algeria	**62,782,376**	**127,519,544**	0.063	0.128
Egypt	**62,541,520**	**155,723,056**	0.063	0.156
Bangladesh	**41,804,728**	**111,668,776**	0.042	0.112
Mexico	**32,134,048**	**88,768,736**	0.032	0.089
South Africa	**24,683,168**	**59,012,064**	0.025	0.059
Pakistan	**20,005,312**	**44,346,976**	0.020	0.044
Tunisia	**4,094,396**	**11,554,570**	0.004	0.012
Vietnam	**2,691,136**	**8,574,976**	0.003	0.009
Morocco	**1,935,200**	**3,801,784**	0.002	0.004
Germany	**1,528,960**	**3,044,544**	0.002	0.003
Myanmar	**1,473,324**	**3,105,212**	0.001	0.003
Sri Lanka	**520,256**	**997,744**	0.001	0.001
Brazil	**505,536**	**360,768**	0.001	0.000
Nigeria	**107,104**	**186,464**	0.000	0.000
Ghana	**95,632**	**180,870**	0.000	0.000
Zambia	**- 941,360**	**- 3,857,908**	-0.001	-0.004
Sum	**2,079,816,022**	**4,805,129,938**	**2.080**	**4.805**

[11] Annex 3 presents emission reductions compared to the baseline that are cumulative, in that this is the total emission reduction between 2018 and 2025 (first column) and 2018 and 2030 (second column). The unit of measure is therefore CO_2e (cumulative). In comparison, Annex 2 only presents emission reductions in the year 2030 (not the sum of all the years prior to this).

ANNEX 4: Studies on Fossil Fuel Subsidy Reform and Associated Emission Reductions[12]

Name	Scope	Description	Emission Reductions	Methodology
Production and Consumption Subsidy Studies				
Coady, Parry, Le, & Shang, 2019; Coady, Parry, Sears & Shang, 2017 & 2015; Parry, Heine, Lis & Li, 2014	Global removal with appropriate taxation	The series of studies by the IMF estimates that a global removal of post-tax subsidies (subsidies arising when consumer prices are below supply costs plus environmental costs and general consumption taxes) would have resulted in a 28% reduction in emissions in 2015 (Coady et al., 2019), a 21% reduction in 2013 (Coady et al., 2017), between a 18.1 and 22.9% reduction in emissions in 2013 (Coady et al., 2015) and a 23% reduction in 2010 (Parry et al., 2014). In the 2019 study, fossil fuel air pollution deaths would have been 46% lower, tax revenues higher by 3.8% of global GDP, and net economic benefits (environmental benefits less economic costs) would have amounted to 1.7% of global GDP. The authors note that "pre-tax subsidies for coal are negligible but for post-tax subsidies coal is the most important fuel, accounting for 44 percent of the global subsidy in 2015, reflecting the underpricing of its large carbon and local air pollution costs. Petroleum is close behind, however, accounting for 41 percent of the global subsidy, largely reflecting the failure of excises on petroleum products to fully reflect environmental costs" (Coady et al., 2019, p. 20).	28% in 2015 21% in 2013 18.1–22.9% in 2013 23% in 2010	IMF model
Monasterolo, & Raberto, 2019	Theoretical high-income country	This study finds that the phasing out of fossil fuel subsidies in a theoretical high-income country enables a shift in investments to low-carbon energy production, creating the conditions that support a low-carbon transition. It also shows that reform contributes to improvements in macroeconomic performance through "higher capital accumulation in the domestic economy and the creation of green jobs and capital investments" (Monasterolo & Raberto, 2019, p. 365).	Removal of subsidies enables a stable low-carbon energy transition	EIRIN model

[12] Studies are listed by type of subsidy studied, starting with production and consumer subsidy studies, followed by consumer subsidy studies and producer subsidy studies then date of publication. This table builds on previous work on the studies on FFSR and associated emission reductions that can be found in Merrill et al. (2017) and Gerasimchuk et al. (2017).

Name	Scope	Description	Emission Reductions	Methodology
Jewell et al., 2018	Global, excludes coal	The study uses five models to estimate global emission reductions due to subsidy removal from 2020 to 2030. Results show reductions of 0.5–2 Gt or 1%–4% by 2030 under both low and high oil prices. Widely sourced datasets, however, feature some significant exclusions (e.g., many large-scale subsidies to coal and gas power generation are absent). The impacts of subsidy removal vary by region: in oil- and gas-exporting regions (MENA, Russia+ and Latin America), subsidy removal leads to the largest emission reductions, in line with their NDCs; in all other regions, emission reductions are less than their NDCs (Jewell et al., 2018).	0.5-2 $GtCO_2$ abated, reflecting a 1–4% decline by 2030	Study uses five integrated assessment models: (GEM-E3, IMAGE, MESSAGE, REMIND, WITCH)
Stefanski, 2014, 2016	Global	20.7% lower global carbon emissions between 1980 and 2010 if countries had not subsidized fossil fuels (2014). 36% lower emissions in 2010 in a world without fossil fuel subsidies (Stefanski, 2014).	In 2010, a world without subsidies would have had carbon emissions 36% lower than they actually were.	Backward-looking emission intensities
Wang, Ali Almazrooei, Kapsalyamova, Diabat, & Tsai, 2016	Abu Dhabi, subsidies to electricity utilities only	This study looks at removing subsidies to both electricity and water utilities, jointly and separately. A full removal of subsidies to electricity utilities results in a 6.67% reduction in carbon emissions, which corresponds to a decrease of 6.51 $MtCO_2$. Findings show that, since both water and electricity subsidy reductions increase GDP and decrease carbon emissions, joint subsidy reduction has greater macroeconomic and environmental effects than single subsidy reductions.	6.67% reduction or 6.51 $MtCO_2$	CGE model
Anderson & McKibbin, 2000	Global coal	An 8% reduction in carbon dioxide emissions from a phase-out of coal subsidies (production and consumption) in OECD and non-OECD countries (Anderson & McKibbin, 2000).	8%	CGE model

Name	Scope	Description	Emission Reductions	Methodology
		Consumption Subsidy Studies		
Global Subsidies Initiative (2019) (data compiled for this report)	26 countries	Average of 6% reductions from FFSR by 2030 from across 26 countries (as a percentage of national emission reductions): Algeria (13.9%), Bangladesh (9.58%), Brazil (0.01%), China (1.11%), Egypt (5.18%), Germany (0.04%), Ghana (0.05%), India (1.02%), Indonesia (3.75%), Iran (9.91%), Iraq (31.37%), Mexico (2.25%), Morocco (0.34%), Myanmar (0.38%), Nigeria (0.00%), Pakistan (1.43%), Russia (5.65%), Saudi Arabia (18.89%), South Africa (1.78%), Sri Lanka (0.15%), Tunisia (4.79%), United Arab Emirates (11.84%), the United States (0.52%), Venezuela (33.08%), Vietnam 0.27%), and Zambia (+1.34%). Average annual government savings of USD 93 per tonne of carbon dioxide abated.	Average of 6% by 2025 and 2030 from 26 countries, total of 2.08 GtCO_2 equivalent by 2025.	GSI-IF model
IEA, 2018	Global removal by 2040 plus EE	Under the IEA's Sustainable Development Scenario (SDS—the trajectory implied by the goals of the Paris Agreement) a phase-out of fossil fuel subsidies in net-importing countries by 2025 and in net-exporting countries by 2035 plus implementation of energy efficiency results in a 37% reduction in emissions by 2040 compared to the New Policy Scenario (includes policies and targets announced by governments).	37% reduction when combined with efficiency improvements by 2040	World Energy Model
Li & Sun, 2018	China	Removing fossil fuel subsidies from 2003 to 2014 reduces carbon dioxide emissions by 152 Mt. However many of the years saw an increase in carbon dioxide emissions due to fuel substitution from lower-carbon oil/ gas to high-carbon coal. The authors indicate that they do not believe that removing fossil fuel subsidies would promote the transition to a low-carbon economy, if their removal encourages the substitution from low-carbon oil/gas to high-carbon coal.	Carbon dioxide emissions reduced by 152 Mt from 2003 to 2014	Various
Li et al., 2017	China, excludes electricity	This study on China evaluates eight FFSR scenarios, excluding electricity, based on 2007 data: one set of four reform scenarios looks at partially or fully removing fossil subsidies and the other set of four reform scenarios also swaps subsidies into clean energy subsidies. The emission changes range from a gain of 0.8% to a reduction of 22%. Authors find that a policy combining the removal of fossil energy subsidies and addition of clean energy subsidies would be most effective in greatly reducing any rebound effect, and in benefiting both the economy and environment.	Emissions range from an increase of 0.8% to a reduction of 22% on 2007 data	CGE model

Name	Scope	Description	Emission Reductions	Methodology
Mundaca, 2017.	Various World Bank regions & country-level, gasoline & diesel	This study estimates that reductions in subsidies to both gasoline and diesel by about USD 0.20 per litre will lead to reductions in emissions from 90% to 10%, depending on the country and type of fuel, by 2029, focusing on countries and regions of the World Bank. For example, in Iran the reductions could be up to 90% and 50% of current emissions generated from diesel and gasoline consumption, respectively, and for Saudi Arabia, approximately 70% and 40%, respectively.	Various reductions in carbon dioxide emissions from 90% to 10%, depending on the country and type of fuel, by 2029	Price-gap approach
Sampedro, 2017	European Union (EU), excludes electricity consumption	The study analyzes carbon dioxide reductions in the EU arising from firstly removing fossil fuel subsidies and then swapping part of these revenues to promote solar photovoltaic. Recycling the revenues into solar photovoltaic results in a carbon dioxide reduction increase from 1.8% to 2.2% by 2030. Results are based on fossil fuel subsidy estimates for coal, gas and petroleum but not electricity consumption (using IMF pre-tax subsidy data).	Carbon dioxide reduction would increase from 1.8% to 2.2% by 2030 if the fossil fuel subsidy revenues were recycled to promote solar	Integrated assessment model (the Global Change Assessment Model, GCAM)
Delpiazzo et al., 2015	Global	This study analyzes the consequences of a complete phase-out of fossil fuel subsidies between 2015 and 2020 and finds it achieves a reduction in emissions of 2.32% in 2030 compared with the baseline. Authors also find that removal of subsidies may induce emission leakage effects.	2.32% emission reductions by 2030	CGE model
Durand-Lasserve, Campagnolo, Chateau, & Dellink, 2015	Global & 37 non-OECD countries and Korea and Mexico	A multilateral phase-out of energy consumption subsidies leads to 3% global GHG emission reductions at horizon 2020 relative to the baseline (Durand-Lasserve, et al., 2015, p. 53.)	3% by 2020	OECD ENV-Linkages General Equilibrium model
IEA, 2014, 2015	Global partial removal by 2030	A 10% reduction in energy sector emissions by 2030, from accelerating the (partial) phase-out of subsidies to fossil fuel consumption (part of the IEA's Bridge Scenario, which also includes improvements in energy efficiency [49%], limiting construction and use of least-efficient coal-fired plants [9%], minimizing methane emissions from upstream oil and gas production [15%] and renewables investment [17%]) (IEA, 2015). FFSR moderating the growth in demand as well as supporting energy efficiency and the only end user price considered in this scenario of energy sector measures (IEA, 2014).	10% by 2030 (energy sector emissions only)	World Energy Model

Name	Scope	Description	Emission Reductions	Methodology
Li & Lin, 2015	Country, China	This paper estimated the subsidies to 22 Chinese sectors from 2006–2010, adopting the price-gap approach to analyze the impacts of subsidy removal on energy consumption and carbon dioxide emissions for the various sectors and energy types. "The potential carbon dioxide emissions reduction after subsidies removal was about 2.85% of the aggregate carbon dioxide emissions during 2006–2010. The top three sectors with the highest potential carbon dioxide emission-reduction rates are 'transport, storage and post', 'leather and footwear' and 'electricity, gas and water supply'" (Li & Lin, 2015).	2.85% emissions reduction during 2006–2010	Price-gap approach
Merrill et al., 2015	20 countries	Average of 11% in 2020 from across 20 countries (country, as a percentage of national emission reductions: Algeria (22%), Bangladesh (9%), China (1%), Egypt (15%), Ghana (3%), India (3%), Indonesia (7%), Iran (18%), Iraq (41%), Morocco (2%), Nigeria (2%), Pakistan (3%), Russia (6%), Saudi Arabia (30%), Sri Lanka (2%), Tunisia (6%), United Arab Emirates (14%), United States (0.2%), Venezuela (34%), and Vietnam (2%)). This average across 20 countries rises to 18% by 2020 with modest recycling of saved revenues toward renewables (10%) and energy efficiency (20%). Average annual government savings of USD 93 per tCO_2 abated (Merrill et al. 2015).	Average of 11% in 2020 from 20 countries, total of 2.82 Gt of carbon dioxide equivalent	GSI-Integrated Fiscal model (GSI-IF)
Burniaux & Chateau, 2014, Table 2, p. 83	Global & 37 non-OECD countries and Korea and Mexico	A 2.5% reduction in global GHG emissions by 2020 and an 8% reduction of 6.1 $GtCO_2$ by 2050 from a staggered removal of consumer fossil fuel subsidies based on 2008 subsidy figures. An emissions cap on OECD countries and Brazil increases the reduction to 10% (Burniaux & Chateau, 2014, Table 2, p. 83).	8.2% by 2050, 2.5% by 2020	OECD ENV-Linkages, CGE model
Schwanitz et al., 2014	Global	The report confirms "the short-term benefits of phasing out fossil fuel subsidies as found in prior studies. However, these benefits are only sustainable to a small extent in the long term if dedicated climate policies are weak or non-existent" (Schwanitz et al., 2014, p. 882). "Over the whole time frame, until 2100 the cumulative savings range from 50.6Gt (0.6%) in the G20 phase-out scenario to 220.8 Gt (2.7%) in the scenario Zero2020" (p. 886).	0.6%–2.7% by 2100 depending on the scenario	REMIND (intertemporal energy-economy model)

Name	Scope	Description	Emission Reductions	Methodology
Larsen, 1994	Global	9% reduction globally assuming no change in the oil price and a 5% reduction globally assuming a change in the oil price from removal of USD 230 billion in subsidies. An equivalent reduction in carbon emissions could be achieved by an OECD carbon tax in the order of USD 50–90 per tonne (Larsen & Shah, 1992). A 7% reduction in emissions from removal of USD 210 billion in subsidies, accounting for interfuel substitution. Reduction of national carbon emissions by more than 20% relative to the baseline emissions in some countries (Larsen, 1994).	5–9% and 7% by 2010	Model with interfuel substitution
Various	Country specific	Country-specific reductions: China, a 3.72% carbon dioxide reduction between 2006 and 2010 (Lin & Ouyang, 2014); India: 1.3–1.8%, Indonesia: 5.1-9.3%, Thailand: 2.8% by 2030 (Asian Development Bank, 2015); Indonesia 7.9–8.3% 2020 (Durand-Lasserve et al., 2015); Ukraine, 3.6% reduction or 15 million tCO_2 (Ogarenko & Hubacek, 2013); Mexico, 34 million tCO_2e saved every year between 2014–2035 from a mix of Green Growth transport measures including FFSR giving a net present value of USD 193,300 million in that period (Ibarrarán, Bassi, & Boyd, 2015).	Various, depending on the country	Various
		Production Subsidy Studies		
Mendelevitch, 2018	Global, coal	Mendelevitch models the removal of coal production subsidies and finds a reduction of global emissions of 82 $MtCO_2$ annually from 2020–2050 which still leaves a gap of 4.6 $GtCO_2$ to achieve emission reductions consistent with 2°C. A mine moratorium also beginning in 2020 would reduce global coal consumption by effectively limiting coal availability and strongly increasing prices, inducing a coal consumption path consistent with the 1.5–2 °C target.	2020-2050 subsidy removal leads to reduction of 82 $MtCO_2$ annually	COALMOD-World
Erickson et al. (2017)	U.S. producer subsidies	Erickson et al. (2017) show that billions of dollars in federal and state subsidies could enable large amounts of oil and gas production in the United States that would not otherwise be economic. At USD 50 per barrel, roughly the January 2017 oil price, 45% of discovered (but not yet producing) U.S. oil would depend on subsidies to reach minimum returns acceptable to investors. The additional oil produced due to subsidies would emit 8 billion tCO_2 abated once combusted.	8 $GtCO_2$ abated through the removal of subsidies to oil production in the United States	Various

Name	Scope	Description	Emission Reductions	Methodology
Gerasimchuk, Bassi et al., 2017	Global producer subsidies	Research finds a complete removal of subsidies to fossil fuel production globally would reduce the world's emissions by 37 $GtCO_2$ over 2017-2050	37 $GtCO_2$ over 2017–2050	GSI-IF (p)
Acar & Yeldan, 2016	Turkey	An academic study looks at the impacts of eliminating two groups of subsidies in Turkey: subsidies to coal production and regional investment subsidies benefiting the coal mining and coal-fired electricity generation. The value of these subsidies was estimated at USD 730 million in 2013, or USD 11 per MWh of generation. Eliminating coal production subsidies would lead to a 2.5% decline in total CO_2e by 2030. Additionally, removal of regional investment subsidies would reduce emissions by 5.4%. The impacts on the economy are estimated to be insignificant (Acar & Yeldan, 2016).	5% by 2030 in Turkey	CGE model
Metcalf, 2018	United States	A study models firm behaviour in response to the potential loss of each of the three major tax preferences for oil and gas producers in the United States, including the intangible drilling credit (see the preceding example). It finds that removing these three tax preferences in the United States would increase the global price of oil by 1% by 2030. U.S. oil production could drop 5% and global consumption could fall by less than 1% in that time frame. Meanwhile, domestic natural gas prices could rise between 7% and 10%, and both domestic gas production and consumption could fall between 3% and 4%, with insignificant impacts on emissions (Metcalf, 2018).	Insignificant impact on emissions of removing three oil and gas production subsidies in the United States through 2030	Various
Carbon Tracker Initiative, 2015	Basin	A Carbon Tracker Initiative assessment looks at thermal coal subsidies in two major producing regions: the U.S. Powder River Basin (PRB), estimated at USD 8 per tonne and Australia, estimated at USD 4 per tonne. According this analysis, the removal of the U.S. PRB subsidies would result in an 8%–29% reduction in demand for U.S. PRB coal, with associated cumulative reductions of 0.7 to 2.5 $GtCO_2$ to 2035. Further, over the same time period, the removal of Australia's coal subsidies would lead to a 3%–7% reduction in demand for Australian Seaborne coal, though with smaller carbon reductions due to substitution of coal from other (often also subsidized) producers.	0.7–2.5 Gt CO_2 abated through an 8%–29% decline in demand for U.S. PRB coal	PE model

ANNEX 5. Studies on Fossil Fuel Taxation and Associated Emission Reductions

Name	Scope	Description	Emission Reductions	Methodology
Coady, Parry, Le, & Shang, 2019; Coady, Parry, Sears & Shang, 2017 & 2015; Parry, Heine, Lis & Li, 2014	Global removal with appropriate taxation	The series of studies by the IMF estimates that a global removal of post-tax subsidies (subsidies arising when consumer prices are below supply costs plus environmental costs and general consumption taxes) would have resulted in a 28% reduction in emissions in 2015 (Coady et al., 2019), a 21% reduction in 2013 (Coady et al., 2017), between an 18.1 and 22.9% reduction in emissions in 2013 (Coady et al., 2015) and a 23% reduction in 2010 (Parry et al., 2014). See Annex 4 for more details.	28% in 2015 21% in 2013 18.1–22.9% in 2013 23% in 2010	IMF model
Liu, Huang, Huang, Baetz, & Pittendrigh, 2018	Regional, Saskatchewan	This study simulated and analyzed the impacts of five different carbon taxes on the socioeconomic system of the Province of Saskatchewan, Canada, based on 2011 as a benchmark year. It found that a carbon tax rate of CAD 40/t would reduce GHG emissions by 7.3%, or 4.8 Mt.	GHG emissions will reduce by 7.3% (4.8 Mt) when carbon tax rate is CAD 40/t, based on 2011 benchmark	CGE
Parry et al., 2018	Global	This paper computes environmental, fiscal, and economic welfare impacts of carbon pricing and other mitigation instruments, providing consistent comparisons across a broad range of countries. A carbon price of EUR 30 (USD 5)/tCO_2 will lead to a 6–30% emission reduction and EUR 60 (USD 70)/tCO_2 will lead to a 10–40% emission reduction depending on the country by 2030. At the international level, the study assesses whether countries are likely to fall short, meet or exceed their targets under (explicit or implicit) carbon price scenarios: for the G20, a carbon price of USD 5/t in 2030 is consistent with the total of current NDCs.	CAD 30 (USD 35)/tCO_2 will lead to a 6–30% reduction and EUR 60 (USD 75)/tCO_2 will lead to a 10–40% reduction, depending on the country, by 2030	IMF model
Richter et al., 2018	Global, thermal coal	This work studies the impact of a tax on thermal coal in Australia alone, on a coalition of major exporting countries, on all exporters and on all producers. The study finds that "production taxes consistently yield higher tax revenues and have greater effects on global coal consumption with smaller rates of carbon leakages" than a unilateral export tax (Richter et al., 2018, p. 43). A globally levied tax rate of USD 10/tCO_2 on all thermal coal production could reduce annual emissions by 1.9 GtCO_2, or over 19% of current global emissions from coal use in the power sector.	Global coal production tax of USD 10/tCO_2 results in a reduction of 1.9 GtCO_2, or over 19% of current global emissions from coal use in the power sector	COALMOD- World, a multi-period partial equilibrium model of the international steam coal market

Name	Scope	Description	Emission Reductions	Methodology
Dong et al., 2017	China	This study forecasts the possible impacts of various carbon tax rates on emission reductions in 30 Chinese provinces up to 2030. Seven scenarios, including business as usual (BAU) and carbon prices from USD 20/t to USD 120/t up to 2030 are simulated. Results show that carbon dioxide emissions will be reduced from between 1.8 billion to 5.2 billion tCO_2.	Carbon prices of USD 20/t and USD 120/t lead to emission reductions of 1.8 billion and 5.2 billion tCO_2, respectively, by 2030	CGE
Andersson, 2015	Sweden, transport sector	This paper empirically analyzes emission reductions from 1990 to 2005 using a quasi-experimental study of the implementation of a carbon tax and a value-added tax on transport fuel in Sweden. The results show that emissions from the transport sector are reduced by 11% in an average year, with a 6% reduction from the carbon tax alone. The total cumulative reduction in emissions for the period is 40.5 million tCO_2.	11% reduction in emissions for the 1990–2005 period	Various statistical empirical methods
Cheng, Chang, & Lu, 2015	Kaohsiung City, Taiwan	The study models several urban transportation management policies—fuel tax, motorcycle parking management policies and free bus service policies—and estimates their potential to reduce vehicular fuel consumption and carbon dioxide emissions. To start, a fixed fuel tax is levied per year according to the engine capacity of vehicles and an additional TWD 1 per litre of fuel tax is considered in the next 10 years. The researchers conclude that the fuel tax policy is the most effective method to reduce emissions, with a 9.9% reduction by 2025.	Emissions in 2025 are predicted to be 9.9% lower	Simplified system dynamics model
Murray & Rivers, 2015	Regional, British Columbia	This paper reviews existing evidence on the effect of a carbon tax, starting at CAD 10/tCO_2 in 2008 and rising to CAD 30/t by 2012, on GHG emissions in the Province of British Columbia, Canada. "Empirical and simulation models suggest that the tax has reduced emissions in the province by between 5% and 15% since being implemented" (Murray & Rivers, 2015).	Reductions of 5–15% below the counterfactual reference level since 2008	Various models, time series analysis, CGE, etc.

Name	Scope	Description	Emission Reductions	Methodology
Rivers & Schaufele, 2015	Regional, British Columbia	This study uses various econometric results to construct counterfactual scenarios to calculate the change in gasoline-related emissions due to the carbon tax. The carbon price was found to reduce emissions by more than 2.4 million tonnes during its first four years. "Of this total, 74.5%, or 1.8 Mt, is due to the additional salience of the carbon tax—it is an environmental bonus that would not have been achieved if individuals responded to carbon taxes in the same way as to identical changes in gasoline prices caused by other factors" (Rivers & Schaufele, 2015).	Carbon price led to emission reductions of 2.4 Mt from 2008 to 2012	Wide range of econometric specifications
Deetman et al., 2013	Europe	Deetman et al. (2013) study various emission reduction options including various taxes, up to 2050, in order to identify the potential of each policy and trade-offs between sectoral policies in achieving emission reduction targets. Together, the options in this study lead to a reduction of 65% of 1990 CO_2e emissions by 2050. In addition: a 50% tax increase on fossil fuel combined with a 35% subsidy on electric cars leads to a 3% reduction in emissions, a 25% subsidy on high-speed rail combined with a departure tax for air travel leads to a 1.4% reduction in emissions. In the transport sector they see a 13% reduction in sectoral emissions compared to baseline, 2050.	Various: from 1.4–65% of 1990 CO_2e emissions by 2050.	TIMER energy model of the IMAGE Integrated Assessment modelling framework
Elgie & McClay, 2013	Regional, British Columbia	This paper reviews changes in fuel use in British Columbia since the introduction of a carbon tax, starting at CAD 10/tCO_2 in 2008 and rising to CAD 30/t by 2012, and compares them with changes that occurred in the rest of Canada during the same period. It finds that from 2008 to 2011 British Columbia's emissions associated with carbon-taxed fuels declined by 10% and its reductions outpaced those in the rest of Canada by 9%.	10% emission reductions from 2008–2011	Examines the changes in fuel use during tax period and compares to the rest of Canada during the same period
Meng, Siriwardana, & McNeill, 2013	Australia	This paper investigates the short-run implications of a carbon tax policy of AUS 23/tCO_2 on emission reductions in Australia. Emissions decrease by 70 Mt, or 12%, but results show that the AUS 23 carbon price achieves less than half of the emission reduction target.	Emissions decrease by 70 Mt, or 12%	CGE Model based on ORANI-G

Name	Scope	Description	Emission Reductions	Methodology
Withana et al., 2013	Australia, British Columbia (Canada), Denmark, Finland, Germany, Ireland, Netherlands, Norway, Sweden, United Kingdom	In terms of environmental impacts, insights from past experiences indicate that, while there have been substantial variations across countries, carbon and energy taxes have led to carbon dioxide savings of up to 1 per cent per year for some of the regions examined, with not dissimilar though generally slightly lower levels of energy savings. In Denmark for example, total carbon dioxide emissions decreased by 24% between 1990 and 2001, with Danish industry reducing its carbon dioxide emissions by 25% per produced unit from 1993 to 2000. In Sweden, average 2008–11 emissions were 12.6% lower than 1990 levels, while in Finland energy and carbon taxes were found to have reduced carbon emissions by over 7% in 1990–1998. Carbon and energy taxes have also been found to contribute to reductions in fossil fuel use in some counties, for example in British Columbia (Canada), consumption of petroleum fuels fell relative to levels in the rest of Canada (as did the province's GHG emissions).	Various reductions due to carbon pricing and taxes (pp. 31–33)	Various
Mao et al., 2012	China, transport sector fuels	This work studies the impact on emissions of implementing various policy instruments—carbon tax, energy tax, fuel tax, clean energy vehicle subsidy and reduction in ticket price—in China's transport sector from 2008 to 2050. The authors report a wide range of tax rates and associated emissionsreductions: carbon tax scenarios of CNY 10 to CNY 300 per tCO_2 lead to emission reductions of 0.9 and 19.8%, respectively; fuel taxes of 10% to 100% lead to emission reductions of 7.4% and 47.9%, respectively; and energy taxes of 10% to 100% lead to emission reductions of 7.4% and 45%, respectively.	Various	CIMS Model
Davis & Kilian, 2011	United States, gasoline	Davis and Killian (2011) use a variety of methods to estimate the GHG emission reductions of a gasoline tax in the United States. Their results show that a USD 0.10 per gallon increase in the gasoline tax would reduce carbon emissions from vehicles in the United States by about 1.5%, or a 0.5% decrease in total U.S. carbon emissions, based on 1989–2008 data.	USD 0.10/gallon included in gasoline tax would reduce emissions by 1.5% in the transport sector or a 0.5% decrease in total U.S. carbon emissions	Various

Name	Scope	Description	Emission Reductions	Methodology
Lin & Li, 2011	Finland, Netherlands, Norway, Denmark and Sweden	Lin and Li (2011) empirically estimate the real mitigation effects of carbon taxes levied in Denmark, Finland, Sweden, Netherlands and Norway by 2008. The tax in Finland imposed a significant and negative impact on the growth of its per capita emissions (1.69%), but the mitigation effects in other countries were weakened due to the tax exemption policies on certain energy-intensive industries.	1.69% reduced emissions growth per capita in Finland; limited effect in other countries	Empirical analysis using the difference-in-difference method
Andersen, 2010	Sweden, Denmark, Netherlands, Finland, Slovenia, Germany and the United Kingdom	This study accounted ex-post for the impacts of carbon-energy taxation under revenue-neutral environmental tax reform on emissions in six EU member states: Sweden, Denmark, Netherlands, Finland, Slovenia, Germany and the United Kingdom. The European environmental tax reforms led to reductions in GHG emissions of 3.1% on average for the six member countries, with the largest drop for Finland (5.9%). The results also suggest that these countries did not experience marked impacts on economic growth (GDP).	EU environmental tax reforms led to reductions of 3.1% by 2004	E3ME model - macro-econometric European model
Barker, Junankar, Pollitt, & Summerton, 2009	Sweden, Denmark, Netherlands, Finland, Slovenia, Germany and the United Kingdom	Barker et al. (2009) estimates the emission reductions due to (carbon) tax shifts implemented in the 1990s in Sweden, Denmark, Netherlands, Finland, Slovenia, Germany and the United Kingdom. GHG emission reductions range from 2 to 7% over a decade or more.	2–7% emission reductions	E3ME model - macro-econometric European model
Sterner, 2007	OECD/ EU/global gasoline taxes	Sterner (2007) shows how European countries that introduced a long-run policy of high transport fuel taxes have essentially cut carbon emissions by more than half, basically the difference between the United States and Europe. The study also shows that "the difference between the low and high-tax scenarios for the whole of the OECD for total fuel actually makes a difference of around 10% of total global fossil carbon emissions from all sources. The difference between the hypothetical use with high/low prices for total fuel is about 750 Mt of fuel per year. A decade of such differences would correspond to emissions of roughly 25 billion tCO_2 or a carbon content of 3 ppm" (Sterner, 2007).	High-tax scenario for OECD countries leads to 10% reduction in global carbon emissions	Uses average elasticities to calculate the equilibrium fuel consumption with lower or higher prices
Bruvoll & Larsen 2004	Norway	This paper estimates the impact of a carbon tax (average USD 21/ tCO_2) on emissions, indicating a reduction of 2.3% between 1991 and 1990. The small effects are shown to be related to a range of fossil fuel-intensive industries being exempt from this tax, such as the process industry.	2.3% reduction due to carbon tax between 1991 and 1999	Disaggregated general equilibrium model (AGE simulation)

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