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CO_2 shadow prices and the social cost of carbon

An analysis of the application in UK, US, France, and Canada

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List of Abbreviations

BEIS	The Department for Business, Energy and Industrial Strategy
BRF	Better Regulation Framework
CO_2	Carbon dioxide
DDS3	Domestic Delivery Services Generation 3
DICE	Integrated Assessment Model used by the IWG
DOT	US Department of Transport
ECS	Equilibrium climate sensitivity
EPA	U.S. Environmental Protection Agency
FPC	French Public Procurement Code
FUND	Integrated Assessment Model used by the IWG
GBP	Pound sterling
GHG	Greenhouse gas
GSA	US General Services Administration
IA	Impact Assessment
IAM	Integrated Assessment Model
IAMC	Integrated Assessment Modelling Consortium
IIASA	International Institute for Applied System Analysis
IPCC	Intergovernmental Panel on Climate Change
IWG	Interagency Working Group
MAC	Marginal Abatement Cost
NEPA	National Environmental Policy Act
PAGE	Integrated Assessment Model used by the IWG
PPN	Procurement Policy Note
PSPC	Public Services and Procurement Canada
RPC	Regulatory Policy Committee
SCC	social cost of carbon
SGPI	Secretariat-General for Investment

TIGER	Transportation Investment Generating Economic Recovery
UK	United Kingdom
UK ETS	UK Emissions Trading Scheme
US	United States (of America)
USG	Government of the USA
yr	year

Summary

The study analyses the application of shadow CO_2 prices in the G7 countries, except for Germany. For four countries – the United Kingdom, the United States (US), Canada, and France – meaningful examples of the application of CO_2 shadow prices could be found. The study consists of factsheets for those countries. We discuss the regulatory history of each country; when were shadow prices enacted and relevant major changes. The current use is presented, including examples and – as far as it exists – scientific evidence for its effectiveness and impact. We discuss the approach for setting shadow CO_2 prices – how targets are set, which modelling approach is used, and any relevant changes. Carbon values may be based on different approaches, but they always require the use of integrated assessment models. The US and Canada use the "social cost of carbon" i.e., estimates of the damage caused by emissions released into the atmosphere. Key inputs include socio-economic parameters / climate sensitivities / damage functions, and importantly the discount rate. The UK and France use marginal abatement costs that are consistent with a given emissions reduction target. Key inputs include the setting of a target and the development of a marginal abatement cost curve. A table is presented with the current estimations or set values of shadow CO_2 prices in 2020, 2030, 2040, and 2050.

1 Country assessment UK

1.1 Regulation in place and current use of shadow CO_2 prices

Regulatory background: Already in 2002, the UK Government proposed to include the social cost of carbon emissions, that was critically received (Watkiss and Downing 2008, p. 1). Further studies were commissioned by the interdepartmental group on the social cost of carbon in 2007, following the publication of the Stern review on the economics of climate change' the methodological approach was changed to incorporate use of the shadow price of carbon (GOV.UK). It was subsequently updated. The Department for Business, Energy and Industrial Strategy (BEIS) publishes GHG emissions values ("carbon appraisal values") which are used for valuing impacts on emissions (GOV.UK 2021). They represent a monetary value that society places on one tonne of carbon dioxide equivalent.

Current use:

Who? All government departments.

When? The regulatory policymaking process in the UK begins with a policy proposal to address a market failure, a limitation in an existing policy, or strategic or distributional objectives that have not yet been achieved. Policy options are then considered to address the issues identified and, if it is necessary to introduce new legislation for the policy change, then it is expected in most circumstances that a full Regulatory Impact Assessment (IA) will be required[1] on the impacts of the legislation (Regulatory Policy Committee 2020).

The IA template (GOV.UK 2011) outlines what is necessary to fully assess a policy proposal, and this is accompanied by further guidance in the Green Book and the Better Regulation Framework (BRF). Within the IA template on the page entitled 'Summary: Interventions and Options', there is a requirement to input the expected change in GHG emissions for the traded (UK ETS) and non-traded sectors. However, there is no differentiation requested to further classify GHG emission change between scope 1, 2 and 3. Supplementary guidance to the HM Treasury Green Book recommends that direct, indirect, and also, to the extent possible, embedded emissions in imported materials should be considered for an IA when valuing energy use and greenhouse gas. However, it is also acknowledged that the reporting of emissions under Scope 3 is challenging as this information is not included in national GHG inventories (Department for Business, Energy & Industrial Strategy UK 2023).

A policy or project that increases or decreases GHG emissions domestically or internationally relative to a "business as usual" scenario is required to quantify the change in emissions, and then apply the carbon appraisal values set by BEIS. This calculation feeds into the overall cost benefit analysis to be considered alongside other quantitative and qualitative evidence in the overall policy appraisal (Department for Business, Energy & Industrial Strategy UK 2023).

Action note PPN 06/21 (Cabinet Office 2021) sets out how to take account of suppliers' Net Zero Carbon Reduction Plans[2] in the procurement of major Government contracts (above 5 million GBP per annum excluding VAT), which applies to all central government departments, their Executive

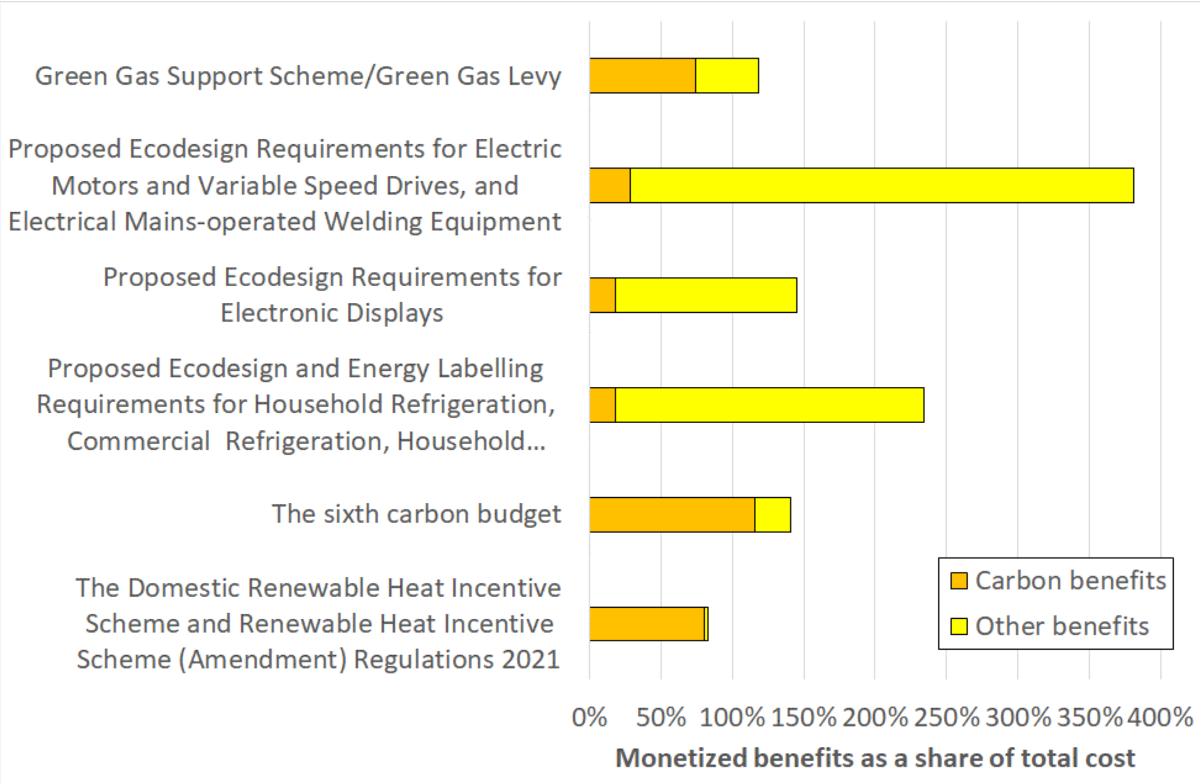
[1] 'With the exceptions of non-regulatory provisions, regulatory provisions with an annual net business impact below ±£5 million (non-qualifying regulatory provisions) and non-qualifying regulatory provisions above de minimis with administrative exclusions around safety in buildings' (Regulatory Policy Committee 2020).

[2] A carbon reduction plan is a statement from suppliers identifying their current carbon footprint and commitment they will make to help the UK achieve Net Zero emissions by 2050.

Agencies and Non Departmental Public Bodies. However, the input of a shadow CO_2 price is not included within the Carbon Reduction Plan Template that needs to be submitted by suppliers with a focus only on baseline emissions and emission reduction targets over a five year period to show progress towards net zero emissions by 2050. It is also necessary to provide information on the mitigation projects already implemented or planned for the future (Cabinet Office 2021).

Impact? The use of carbon values to quantify the monetized benefits of a particular policy or project have been implemented throughout the UK government in recent years. Figure 1 shows a selection[3] of Impact Assessments at the final procedure stage published by BEIS in 2021. The application of carbon values had a positive impact on the net present value of the UK government's preferred policy option for the setting of the sixth carbon budget over 2033-37. The impact assessment estimated a net benefit of 211 billion pounds (Department for Business, Energy & Industrial Strategy UK 2021), with the carbon benefits estimated to exceed the total cost of the policy.

Figure 1: Monetized benefits as a share of total cost estimated in a selection of final Impact Assessments published by BEIS in 2021



Source: https://www.legislation.gov.uk

The application of carbon values to quantify the monetized benefits of the Green Gas Support Scheme / Green Gas Levy were also significant along with other benefits such as generation savings from biomethane displacing the use of natural gas in the grid and fertilizer savings where digestate displaces synthetic fertilizer use in the agricultural sector. The role of carbon values for the impact assessments focusing on energy efficiency policy were less impactful in comparison to the financial savings from a reduction in fuel use. The only policy with a negative net present value was the amendment to the Domestic Renewable Heat Incentive Scheme and Renewable Heat Incentive

[3] Selection includes final impact assessments where carbon values were used to quantify benefits.

Scheme, despite the application of carbon values to determine the benefits of GHG emission reductions. However, the Impact Assessment states that if a number of non-monetised and benefits were able to be quantified (i.e. renewable heat generation, innovation and cost reductions, low carbon heat sector growth and health benefits) it would have a significant positive impact on the net present value (Department for Business, Energy & Industrial Strategy UK 2020).

While it is evident that the benefits of GHG emission reductions are increasingly taken into account in UK policy making, it is nevertheless acknowledged by the UK government that the impact assessment process is not without its limitations. For example, only a ‘proportionate assessment’ of the environmental impacts of a regulatory proposal is required for an IA submission and the Regulatory Policy Committee (RPC) concede that they are unable to provide a ‘fitness for purpose’ rating on the assessment of wider impacts including impacts on the environment. Indeed, some of the most strategically important benefits of climate policy cannot always be quantified (underestimating the true benefits) such as the strengthening of decarbonisation supply chains or increases in the UK’s resilience to deal with extreme climate change events (GOV.UK 2021). Interestingly, it is currently under consideration whether the scope of the RPC should be extended to not only offer independent scrutiny on impacts beyond business such as the compatibility of policies with long-term environmental objectives such as the UK government’s net-zero target by 2050 (Gibson 2021).

1.2 Approach for setting shadow CO_2 prices

In 2009 the government conducted a review of the approach taken to developing carbon values. The conclusion of the review was to move to a “target-consent“ or “abatement cost” approach to carbon valuation rather than a “social cost of carbon” (SCC) approach. The new carbon values are based on a Marginal Abatement Cost (MAC) or “target-consistent” valuation approach. This involves setting the value of carbon at the level that is consistent with the level of marginal abatement costs required to reach the targets that the UK has adopted at a UK and international level (GOV.UK 2021).

Setting the target: The UK has committed to the targets agreed under the Paris Agreement with a particular focus on limiting the global temperature increase to 1.5°C. Domestically the UK has legal targets for achieving net zero emissions by 2050 (GOV.UK 2021).

Modelling approach: The shadow CO_2 prices were calculated based on global marginal abatement costs derived from a series of freely available (IAMC and IIASA 2018-2019) Integrated Assessment Models (IAMs), which produced a range of carbon price trajectories consistent with the UK’s national and international climate commitments. The carbon values are “anchored on long-run global abatement costs rather than UK costs” but the IPCC trajectory selected reflects the UK’s “relatively front-loaded domestic targets” (GOV.UK 2021). The modelled carbon prices and emissions projections were based upon the “1.5°C low overshoot pathway class of modelling scenarios (including a constraint on Kyoto gas emissions in 2010 being sufficiently close to observed values)” (GOV.UK 2021). In the modelling of the 2030 and 2040 abatement necessary to achieve emissions that correspond to the median emissions projected for 1.5LowOS, the median of the corresponding IPCC carbon price was 163 GBP and 326 GBP respectively (GOV.UK 2021).

The UK government adopted the IPCC’s evidence base rather than their own internal modelling as it has been widely peer-reviewed. The 2040 median carbon price was selected as an ‘anchor point’ (justified by the fact that marginal carbon costs can be subject to large fluctuations between years modelled) around which a constant rate of 1.5 % of annual real growth (based on internal assessments on the development of marginal costs over time taking into account increased emission reduction ambitions and reductions in technology costs) was applied to determine annual shadow

CO_2 prices. An uncertainty range of plus or minus 50 % was deemed appropriate to apply around the central value (GOV.UK 2021).

1.3 Shadow CO_2 prices

The carbon values below were updated in 2021 to take into account the latest evidence, targets and wider context and will be subsequently reviewed every 5 years in line with setting the UK's carbon budgets. The review will take into account a broad evidence base (GOV.UK 2021).

Table 1: Carbon values in 2020 GDP prices per tonne of CO_2

Year	Low series	Central series	High series
2020	120	241	361
2025	130	260	390
2030	140	280	420
2035	151	302	453
2040	163	326	489
2045	176	351	527
2050	189	378	568

Source: GOV.UK 2021

2 Country assessment US

2.1 Regulation in place and current use of shadow CO_2 prices

Regulatory background: Introduced in 2008 thanks to a Court ruling, federal agencies began applying different valuations of shadow prices (US terminology: the social cost of greenhouse gases) as part of the cost benefit analyses (Wright 2017). The Obama administration formed an Interagency Working Group (IWG) for a uniform methodology and application and the development of methods for nitrous oxides and methane (Lovells 2021). This methodology was then subsequently factored into decisions such as “energy efficiency of consumer appliances, and requirements for the fuel economy of cars and trucks” (Early 2021). The Trump administration introduced a number of changes that resulted in a shadow price as little as $1 a ton (Early 2021): as only the domestic effects were considered and up to 7 % discounts applied. The Biden administration reinstated the IWG and set an initial price of $51 a ton (Cho 2021). Biden plans to extend it to new areas such as government procurement (amendment of the Federal Acquisition Regulation started in October 2021) (Volcovici 2021) and the permitting of highways and pipelines (Cho 2021). The IWG should also revise the social costs of greenhouse gases (still forthcoming)[4] and update its methodologies “to the extent that current methodologies do not adequately take account of climate risk, environmental justice, and intergenerational equity” (Wright 2021). Furthermore it should recommend which areas of decision-making, budgeting and procurement shall be covered (Interagency Working Group on Social Cost of Greenhouse Gases 2021). Currently 12 states (Institute for Policy Integrity) use SCC, e.g., as a base for carbon taxes or subsidies.[5]

Current use:

Who? Federal Government agencies.

When? As part of the Regulatory Impact Assessment, under the subpoint Cost Benefit Analysis (Wright 2017), it is mandatory for “economically significant” regulatory proposals of Federal Agencies (The White House; The White House 2021). It has also been used in federal procurement, grant programs, National Environmental Policy Act (NEPA) analysis,[6] though this application has been uneven due to contrary judgments.[7] The inclusion in Environmental Impact Assessments on a project level base is disputed.[8]

Legal basis? For Impact assessments: Executive Order 12291--Federal regulation (Office of the Federal Register 1981).

Examples?

4 There was originally an expectation that the SCC would be updated by January 2022, however it is likely that this has been delayed due to Republican attorneys general challenged Biden's February 2021 executive order that restored the approximately $51 per metric ton number set by former President Barack Obama's administration. On the 21 October 2022, a U.S. appeals court upheld the SCC calculation used by President Joe Biden's administration (Mindock 2022).

5 For example, subsidies in Minnesota for rooftop solar energy producers, subsidies for nuclear power plants in New York and Illinois (Cho 2021).

6 Interagency Working Group on Social Cost of Greenhouse Gases 2021, see for the limitations under NEPA Raduazo 2018.

7 See Wright and Doelle 2019 on NEPA, as well as Raduazo 2018.

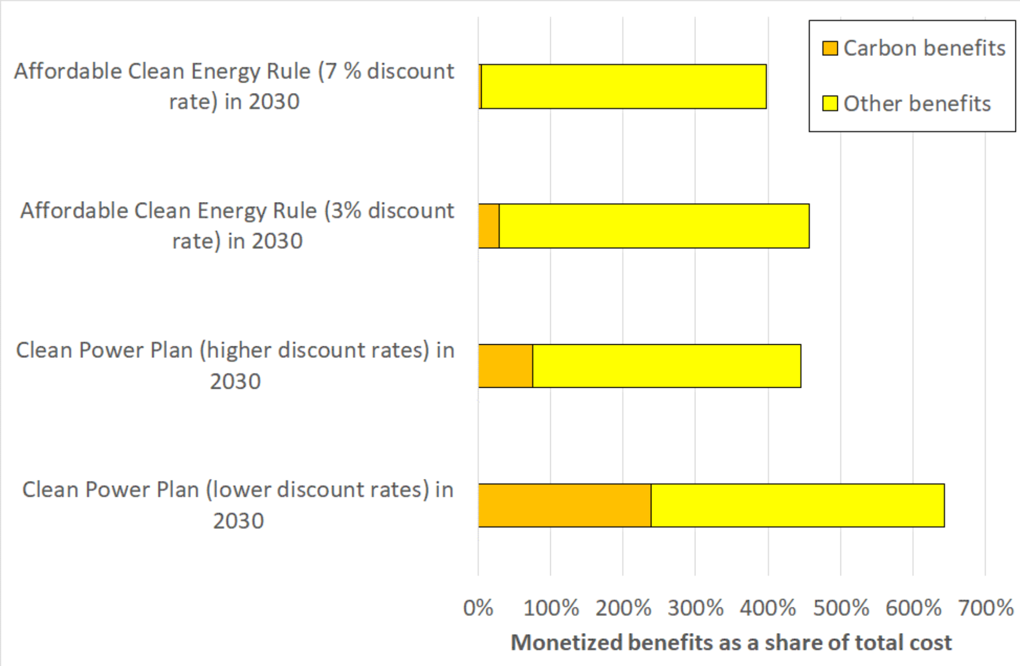
8 “Emerging practice” see Wright 2021 though in Wright and Doelle 2019 it seems to be very sporadic.

- *Regulatory Impact Assessments*: 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards (Wright 2017) and Final Standards of Performance for Greenhouse Gas Emissions from New, Modified, and Reconstructed Stationary Sources: Electric Utility Generating Units it is noted that the Power Plant standards are lower than in Canada and therefore the SCC not too effective (Wright 2017).
- *Procurement*: Domestic Delivery Services contracts for USG parcel shipping. For example, the US General Services Administration (GSA), which is the government's purchasing arm, has previously proposed that "vendors competing for a $1.5-billion government-wide contract for package delivery services beginning in 2014 (Domestic Delivery Services Generation 3, DDS3), [should] be assessed on their ability to meet annual targets for fuel efficiency, greenhouse gas intensity and alternative fuel use as well as delivery prices" (Green Car Congress 2013).
- *Grant Programmes*: 2016 DOT's Transportation Investment Generating Economic Recovery (TIGER) discretionary grant program required a demonstration that benefits justify costs for proposed projects, and the guidance DOT provides to applicants for how to conduct such an analysis specified that they should use the US government's social cost of CO_2 estimates (U.S. Department of Transportation 2016).

Impact? According to Rose 2016), the SCC was applied in 65 federal rules and 81 sub-rules between 2008 and 2016 in areas such as "energy efficiency, fuel economy standards, emissions standards for hazardous air pollutants, power plants and performance standards for solid waste incineration facilities" (Cho 2021). Interestingly, the analysis finds that CO_2 reduction benefits are portrayed as the primary driver of benefits in only 20 % of the federal rules and only when higher discount rates are applied to non-climate benefits. Energy savings and reduced air pollution benefits account for the majority of the benefits quantified in the sample of impact assessments. Rose (2016) suggests that as a consequence of the research, it appears that CO_2 reduction benefits were not essential for positive net benefits in impact assessment calculations. However, due to several fundamental issues with regards to the application of the SCC in US regulatory impact assessments (i.e. such as inconsistencies in the use of reference socio-economic and emission assumptions and the use of multiple SCC values) Rose (2016) caveats their findings with regards to the influence of monetizing CO_2 reduction benefits on policy decision making. Thus, limiting the extent to which strong conclusions can be made from the assessment.

Figure 2 provides a comparison of the monetized benefits of CO_2 reductions as a share of the total cost of both the Clean Power Plan advocated by the Obama administration and the subsequent Affordable Clean Energy Rule advanced by the Trump administration as a legislative replacement. The different estimates of carbon benefits reflects, fundamentally, a significant difference in the level of ambition of the two legislative proposals with regards to emission reductions. Indeed, the "EPA had projected that the original Clean Power Plan would reduce CO_2 emissions by approximately 415 million tons relative to a no-action baseline, whereas the Affordable Clean Energy rule would only reduce CO_2 emissions by 14-27 million tons relative to a no-action baseline" (Wentz 2018). However, the difference is also due to changes in the methodology (based on discount future impacts and focusing only on domestic impacts) (Newell 2017) by the Trump administration that resulted in a significantly lower SCC value than applied under the Obama administration. This provides an example of how the cost benefit analysis and the assumptions underlying it in an impact assessment can currently be manipulated for political purposes.

Figure 2: Monetized benefits as a share of total cost estimated in a selection of Regulatory Impact Assessments



Note: Different discount rates were applied for the regulatory impact assessment of the Clean Power Plan. The higher (lower) discount rate of 5% (3 %) was applied for carbon benefits, a 7 % (3 %) discount rate was applied for other benefits (highest value taken) and the compliance cost assumes a discount rate of 5 %.

Source: U.S. Environmental Protection Agency 2015

2.2 Approach for setting shadow CO_2 prices

Since 2009, the US government's Interagency Working Group (IWG) has determined shadow CO_2 prices based upon the social cost of carbon (SCC) approach (i.e., by estimating the marginal global damage caused by global emissions released into the atmosphere). The IWG used three Integrated Assessment Models (IAMs), DICE, PAGE and FUND and the results from each were given equal weighting to create the SCC estimates (Interagency Working Group on Social Cost of Greenhouse Gases 2021). The IWG input harmonized assumptions into the three IAMs in order to estimate the temperature effects and the damages in each year resulting from the baseline pathway of emissions for a given scenario. An additional unit of carbon emissions was then added in each model in year t and the temperature effects and damages were recalculated for this adjusted pathway of emissions. The difference in marginal damages between the baseline and the adjusted pathway of emissions were then subsequently discounted back to the year of emissions.

The following harmonized assumptions were input into the three IAMs to estimate a range of shadow CO_2 prices:

Socio-economic scenarios:

Socio-economic assumptions are required to determine a baseline climate trajectory. The following five socio-economic scenarios below (based on a previous exercise by the Stanford Energy Modelling Forum) were input into the three IAMs to set the baseline for emissions, GDP and population developments (Interagency Working Group on Social Cost of Carbon 2010).

1. **IMAGE** – Reference fossil and industrial CO_2 emissions of 40, 45 and 60 Gt CO_2 / yr in 2030, 2050 and 2100 respectively / Reference GDP (using market exchange rates in trillion 2005$) of 97, 156 and 396 in 2030, 2050 and 2100 respectively.
2. **MERGE** – Reference fossil and industrial CO_2 emissions of 45, 67 and 118 Gt CO_2 / yr in 2030, 2050 and 2100 respectively. Reference GDP (using market exchange rates in trillion 2005$) of 77, 123 and 268 in 2030, 2050 and 2100 respectively.
3. **MESSAGE** – Reference fossil and industrial CO_2 emissions of 42, 44 and 43 Gt CO_2 / yr in 2030, 2050 and 2100 respectively. Reference GDP (using market exchange rates in trillion 2005$) of 91, 154 and 335 in 2030, 2050 and 2100 respectively.
4. **MiniCAM** – Reference fossil and industrial CO_2 emissions of 45, 58 and 80 Gt CO_2 / yr in 2030, 2050 and 2100 respectively. Reference GDP (using market exchange rates in trillion 2005$) of 79, 125 and 370 in 2030, 2050 and 2100 respectively.
5. **550 Average** - Reference fossil and industrial CO_2 emissions of 32, 20 and 12 Gt CO_2 / yr in 2030, 2050 and 2100 respectively. Reference GDP (using market exchange rates in trillion 2005$) of 86, 137 and 338 in 2030, 2050 and 2100 respectively.

Climate sensitivity:

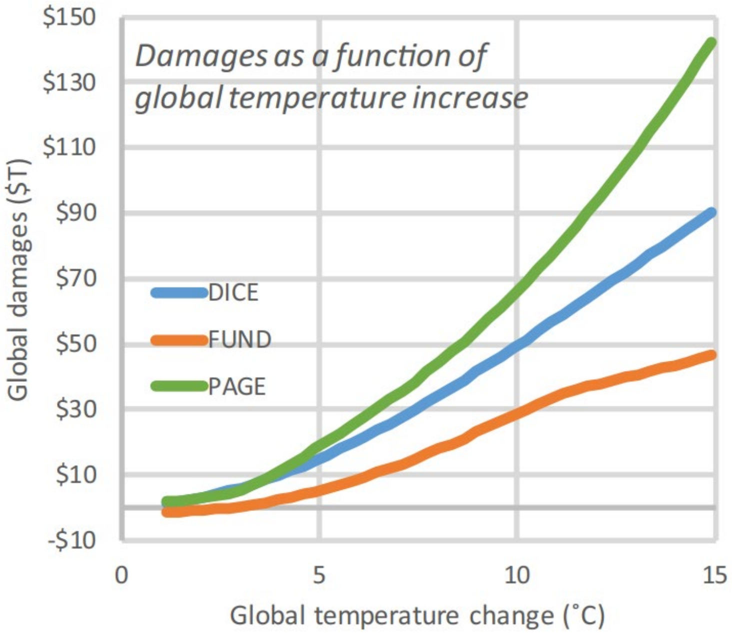
The equilibrium climate sensitivity (ECS) is defined as “the long-term increase in annual global-average surface temperature from a doubling of atmospheric CO_2 concentration relative to pre-industrial levels” (Interagency Working Group on Social Cost of Carbon 2010). Informed by the IPCC (at the time of the IWG assessment), the climate projections were based upon a Roe and Baker (2007) distribution for the climate sensitivity parameter bounded between 0°C and 10°C with a median of 3°C and a cumulative probability between 2°C and 4.5°C of two-thirds (Interagency Working Group on Social Cost of Carbon 2010).

Damage function:

The damage component within a social cost of carbon IAM estimates monetized damages over time based upon both socio-economic and physical climate variables. These damages are represented in the IAMs in terms of fractions of global or regional GDP and therefore scale with the overall size of the economy.

All three SC-IAMs that were used in the IWG assessment have damage components that take global mean temperature, global mean sea level, and socio-economic projections (global population and GDP) as inputs for calculating damages. However, “the models differ in their use of the drivers of damages with respect to other climate variables (e.g., CO_2 concentrations, regional temperature), regional socioeconomic projections and sectoral detail (e.g., the agricultural share of the economy, energy efficiency of space cooling and heating), demographic detail (e.g., population density), and other factors” (National Academies of Sciences, Engineering and Medicine 2017).

Figure 3: Damages as a function of global temperature increase



Source: Download: Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide | The National Academies Press (nap.edu)

Figure 3 shows damage as a function of global temperature increase in each of the three IAMs assessed by the IWG when estimating the SCC. It is evident that "DICE and PAGE yield higher damages for a given level of warming and income and are much more responsive to both temperature change and income than FUND" (National Academies of Sciences, Engineering and Medicine 2017).

The differences in model characteristics drive these differences in results, with specific characteristics playing a prominent role. Examples (National Academies of Sciences, Engineering and Medicine 2017) of these key modelling differences include:

- In DICE, "damages are based on quadratic functions of temperature and sea level rise";
- In FUND, "net benefits in the agricultural sector result at lower warming levels, adaptation addresses much of the risk from sea level rise, cooling energy demand costs are a large fraction of damages, and "catastrophic" damages are not included"; and,
- In PAGE, "regional damages are computed by scaling damages between regions, and a large fraction of damages are from those that do not directly impact GDP and an unspecified discontinuity damage."

The IAMs assessed were last updated in 2013 and the damage functions are limited by the fact that it does not take into account more recent studies from the scientific literature on monetizing damages over time.

Discounting: The discount rate refers to "the reduction ("discount") in value each year as a future cost or benefit is adjusted for comparison with a current cost or benefit" (National Academies of Sciences, Engineering and Medicine 2017) To determine carbon values for use in cost-benefit analysis, the IWG decided to use three different discount rates. The aim of using three discount rates was to cover a plausible range, between 2.5 % and 5 %, with a central rate of 3 %.

Limitations of the approach: According to Stern et al. 2022), the Integrated Assessment Models (IAMs) do not consider “the global cost of reaching any particular temperature or emissions target and rely on assumptions, that, when altered, provide widely varied estimates”. As a consequence, it is argued that the current approach results in the estimation of an SCC that is not aligned with international temperature targets or domestic emissions targets. Given that a review of the SCC is currently underway it is possible that, under the Biden administration, an alternative target-consistent approach may be applied that would ensure higher SCC values that would most likely have a positive impact on more sustainable decision making.

2.3 Shadow CO_2 prices

Table 2 provides an overview of the social cost of carbon values currently estimated by the IWG. In addition to the three average SCC values, a fourth value was also introduced to reflect higher than expected climate-related damages. Each annual figure is generated from thousands of runs of the IAMs under different socioeconomic scenarios. The fourth value is based on the 95th percentile of the SCC values generated for the central SCC value (i.e., 3 % discount rate).

Table 2: Social Cost of CO_2 in 2020 dollars per metric ton of CO_2

Year	5 % Discount (average)	3 % Discount (average)	2.5 % Discount (average)	3 % Discount (95th percentile)
2020	14	51	76	152
2025	17	56	83	169
2030	19	62	89	187
2035	22	67	96	206
2040	25	73	103	225
2045	28	79	110	242
2050	32	85	116	260

Source: Interagency Working Group on Social Cost of Greenhouse Gases 2021

3 Country assessment Canada

3.1 Regulation in place and current use of shadow CO_2 prices

Regulatory background:

The federal government of Canada introduced the Social Cost of Carbon (SCC) in 2010, basically following the US approach (Wright 2017). It is part of the cost-benefit analysis that must be provided in the Regulatory Impact Analysis Statement (RIAS) (Government of Canada). Like in the US, other greenhouse gases were subsequently included. Plans exist to update the methodology and maybe expand to areas such as the "the proposed federal climate accountability regime, the new federal impact assessment regime, and the federal carbon pricing regime" (Wright 2021). As part of the "Greening the Canadian Government Initiative" a shadow price for carbon of C$300 was introduced as part of the life-cycle assessment of all major property funding decisions (Treasury Board of Canada Secretariat 2020).

Current use:

Who? Federal agencies and departments.

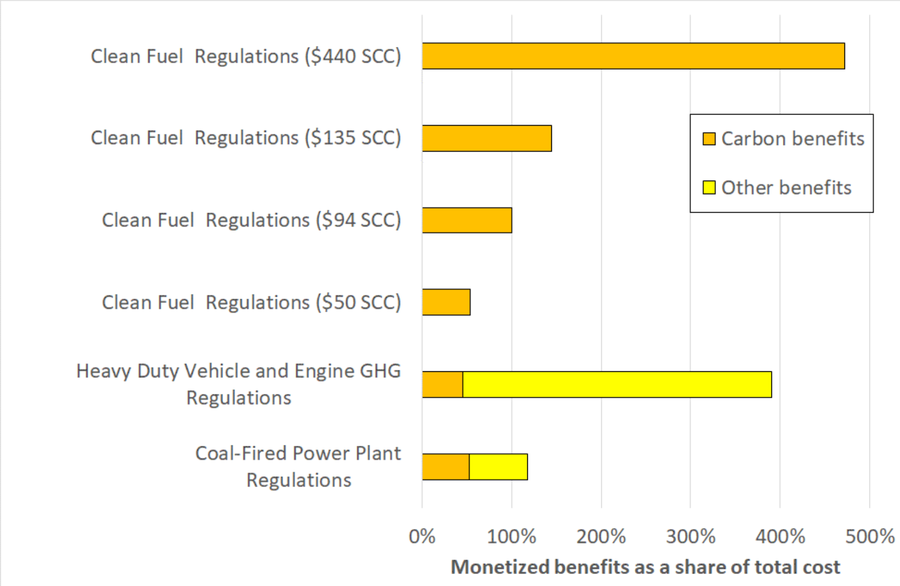
When? Part of the Regulatory Impact Analysis Statement, in the subpoint Cost Benefit Analysis (Wright 2017).[9]

Legal basis? Cabinet Directive on Regulation Treasury Board of Canada Secretariat 2018.

Impact? Research from Wright 2021) states a "quite limited deployment" of the use of SCC values in order to inform policy decision-making. Indeed, the use of SCC values have not been frequently or consistently applied in impact assessments in the past. For example, a published impact assessment on the proposal to regulate emissions from coal-fired electricity generating plants (illustrated in Figure 4) showed that the government would not have deemed the regulation as 'economically justified' in 2011 without taking into account the projected benefits of CO_2 emission reductions using the SCC concept (Heyes et al. 2013). The influence of the SCC was less for the cost benefit assessment of the Heavy Duty Vehicle and Engine GHG regulations, whereby the driver of the economic viability of the measure was the savings in fuel costs (Government of Canada 2018). However, in the Impact assessment of the 2020 proposal of the Clean Fuel Regulations, updated interim values to the \$50 /tCO_2 applied were also considered (Wright 2021). Indeed, Figure 4 shows that the use of a higher range of SCC values (i.e. \$135 / tCO_2 and \$440 / tCO_2) was necessary to show that the monetized benefits of the proposed Regulations would exceed its costs once the SCC value was updated to better reflect damages from CO_2 emissions (Wright 2021).

[9] Wright 2017 p. 521.

Figure 4: Examples of the use of SCC values in impact assessments by the Canadian government.



Source: Government of Canada 2020, 2018), Heyes et al. 2013

Since 2006, the Canadian government have implemented the Policy on Green Procurement with the objective of “integrating environmental performance considerations into the procurement decision making process” (Government of Canada o. J.). The Policy requires that departments “establish green procurement targets and monitor and report on their green procurement performance” (Government of Canada o. J.) and applies to all departments and agencies.

As of March 31, 2021, 42.6% of Public Services and Procurement Canada (PSPC)’s standing offers and supply arrangements included green goods and services that have a reduced environmental impact (Public Services an Procurement Canada 2022). For example, PSPC’s Ontario Region took into account environmental considerations in a national Food and Beverage Request for Standing Offer template. These considerations included elements such as “sustainable packaging, food waste reduction and management, as well as greenhouse gas (GHG) reduction in suppliers’ operations and transportation” (Public Services an Procurement Canada 2022).

3.2 Approach for setting shadow CO_2 prices

Methodological approach:

The approach recommended by the Canadian Group uses the U.S. model results to estimate the SCC, with three minor adjustments (Environment and Climate Change Canada 2016):

1. “Instead of using three discount rates, the Canadian group recommended using only the 3 % central rate”;
2. “For the Canadian calculation of the 95th percentile estimates, the results of the FUND model are not included, as the model does not incorporate the low-probability, high-cost events that the 95th percentile value is meant to address. In Environment and Climate Change Canada cost-benefit analysis, the 95th percentile SCC values are used to estimate the sensitivity of the results to higher SCC values.”

3. “U.S. SCC estimates are then updated to reflect inflation through to 2012 using the U.S. GDP deflator and then converted into Canadian dollars. The Canadian values are updated regularly with the Canadian GDP deflator in order to correct for ongoing inflation.”

Limitation in approach: According to Heyes et al (2022) “calculations of the social cost of carbon require the use of highly parameterized integrated assessment models, which contain a large amount of uncertainty, and which rule out by assumption some of the impacts of climate change that are of concern.” Furthermore, they suggest that the SCC applied by the Canadian government in cost benefit analyses are “significantly lower” that the shadow price associated with the country’s international commitments. Heyes et al (2022) therefore advocate the application of a target consistent approach so that the shadow CO_2 price is aligned with the ambition of the country’s environmental policy objectives.

3.3 Shadow CO_2 prices

The carbon values outlined below in Table 3 were updated in 2016. However, since then there has been a recognition from the Canadian government of the need to review and increase the shadow CO_2 price. Indeed, the new federal climate plan (entitled ‘A Healthy Environment and a Healthy Economy’) that was published in December 2020 commits to updating the social cost of carbon so that it aligns with the best international climate science and economic modelling.

Table 3: Carbon values in 2012 C$ prices per tonne of CO_2

Year	Central series
2020	45
2030	55
2040	65
2050	75

Source: Environment and Climate Change Canada 2016

4 Country assessment France

4.1 Regulation in place and current use of shadow CO_2 prices

Regulatory background: In 2009, the Quinet Commission I set the methodology for the first set of shadow prices. They were re-evaluated and changed in 2019 by the Quinet Commission II (France Stratégie 2019). It is used as part of the socioeconomic evaluation, that needs to be done for investments of the Federal State above a certain threshold. According to the French Climate Action plan it is also intended to be used as a basis for developing and assessing the various measures that promote carbon-free choices and private investments (explicit carbon pricing, investment subsidies, regulations, etc.), without setting a level or a rate on a case-by-case basis. The shadow price of carbon serves as a point of reference for comparing the cost of different public policies per tonne of greenhouse gas avoided, which is one of the factors to be taken into consideration when designing measures (Ministère de la Transition Ecologique et Solidaire 2020). [10]

Current use:

Who? Only federal State/public institutions, public health establishments and healthcare cooperation bodies (not regional or local authorities)

When? if the above mentioned actors contribute a threshold of €20M net of tax. If it is over €100M and represents at least 5% of project total value net tax, an independent second assessment overseen by the Secretariat-General for Investment (SGPI) must be made.

Legal basis? Article 17 of the Public Finance Programming Law of 31 December 2012. Decree 2013-1211 of 23 December 2013

Impact? Between 2013-2018 Q2 there were 55 projects over the €100M threshold that needed a counter assessment by the SGPI. The majority of these projects, in terms of median value, were associated with the transport sector with smaller representation from hospitals and higher education and research (France Stratégie 2019). Figure 5 illustrates the influence of quantifying carbon benefits in the evaluation of major public investment projects in France. For example, the carbon benefits estimated for a modernization project to electrify the Serqueux-Gisors line exceeded the projected costs. In contrast, the increased CO_2 emissions expected for the Castres-Toulouse Motorway link reduced the net present value by adding to the overall costs of the project during the counter-assessment.

According to the Quinet Commission II the impact of shadow pricing has been limited in the country due to the too low price and limited applicability (no local/regional authorities) (France Stratégie 2019). It is expected that the increased carbon values recommended by the Quinet Commission II (refer to Table 4) will address the limitations with the application of shadow pricing previously experienced in the country. Furthermore, the scope of the application of shadow pricing is also expected to broaden compared to in the past.

Indeed, an amendment to the French Public Procurement Code (FPC), which was issued on the 3rd of May 2022, introduced new provisions concerning the award criteria for government contracts. Specifically, Decree n°2022-767 amends article R. 2152-7 of the FPC to consider "the environmental criterion in public procurement contracts and concession contracts' awarding process" (Martor and

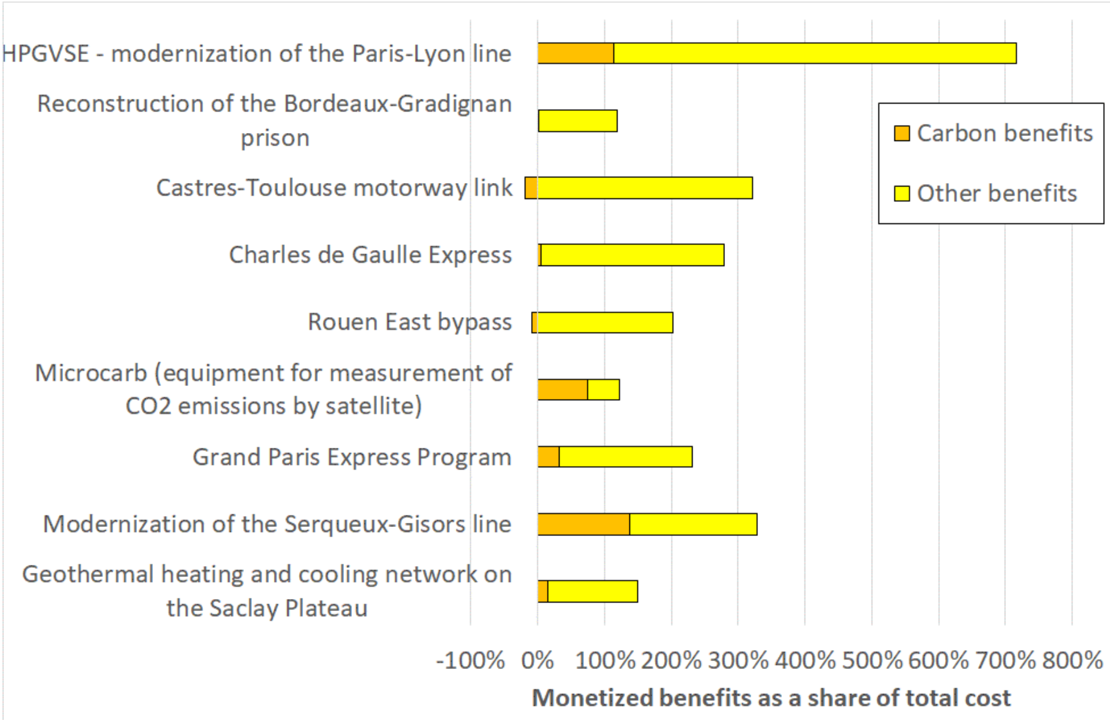
10 French Climate Action Plan p. 86.

Weiss 2022). From the 21st of August 2026, procurement and concession contracts will no longer be awarded on the basis of price along but will be based on:

- Either a price criterion considering the environmental aspects of the tender submitted;
- Or multiple criteria, which may be either the price, the cost, or other criteria. Each criterion shall consider the environmental aspects of the offer.

However, the definition of environmental aspects is not as yet clearly defined (Martor and Weiss 2022) and will therefore require further clarification to see the extent to which a CO_2 shadow price is included in any future considerations for the award of government contracts in France.

Figure 5: Monetized benefits as a share of total cost estimated in a selection of counter assessments of major public investment projects



Source: France Stratégie 2019) own illustration

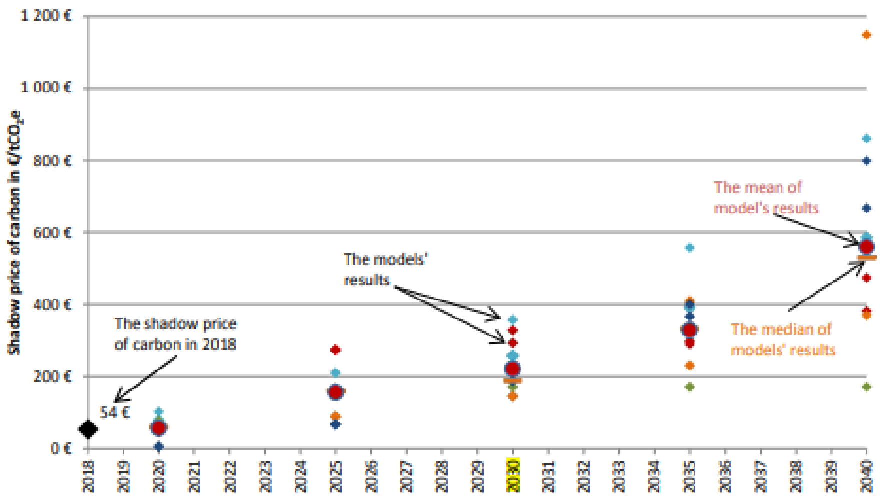
4.2 Approach for setting shadow CO_2 prices

The recent carbon values published by France are based on a Marginal Abatement Cost (MAC) or “target-consistent” valuation approach.

Setting the target: France has set a net-zero GHG target for 2050 and estimated the monetary value of carbon as part of the policy making process. The modelling reflected a domestic economy-wide net zero target in 2050 (Evans et al. 2021).

Modelling approach: The Value for Climate Action Commission applied five different models to estimate the mitigation costs associated with achieving its GHG reduction target. By using multiple models, the aim of the approach was to develop a range of costs that were not dependent on a particular model specification. In order to achieve a net-zero emissions goal by 2050, France set itself a smoothed emission reduction trajectory with an intermediate point in 2030 (-43% of gross emissions compared with emissions in 1990). Based upon the modelling runs, a carbon value of 250 EUR has been adopted for 2030. The 2020 carbon value is estimated by applying a linear rate of growth between 2018 and 2030 to “catch up” for earlier inaction (Figure 6).

Figure 6: Carbon values obtained by models up until 2040



Source: France Stratégie 2019

For calculating the carbon value after 2030, two complementary approaches were considered.

1. *Forecasting the costs of technological developments* required to fulfil the decarbonisation coal. For example, between 2040 and 2050, the carbon value was partly based on forecasting the potential cost (ranging between 600 and 900 € /tCO_2e) of a portfolio of enabling technologies to cost-effectively achieve the net-zero goal.
2. *Applying the Hotelling rule* to gradually align the shadow CO_2 price by ensuring that the carbon value grows at the public discount rate of 4.5 %. This reflects the fact that the carbon values projected in models grow at a much faster pace towards the end of the time horizon due to modelling limitations in reaching full decarbonisation.

4.3 Shadow CO_2 prices

The Quinet II Commission reviewed carbon values after the 2015 Paris Agreement and announced in 2019 that the carbon value should be increased to €250/tCO_2e in 2030 (refer to Table 4). This is significantly higher than the carbon value of to €100/tCO_2e in 2030 advocated by the previous Quintet I Commission in 2008.

Table 4: Carbon values in 2018 EUR prices per tonne of CO2

Year	Central case
2020	87
2030	250
2040	500
2050	775

Source: France Stratégie 2019

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