Shadow price of carbon in economic analysis

Guidance note

This guidance note is intended to help World Bank staff value carbon emissions in economic analysis of investment project financing. The economic analysis is requested under Operational Policy and Bank Procedure (OP/BP) 10.00. The guidance provided in this note aims to enhance the economic analysis by using the shadow price of carbon for applicable projects. It replaces the 2014 "Social Value of Carbon in Project Appraisal Guidance Note". The note will be updated and complemented from time to time, based on new knowledge and feedback from teams.

Applicability

The use of shadow price of carbon in the economic analysis is a corporate commitment[1] for all IBRD/IDA investment project financing that are subject to GHG accounting. GHG accounting is undertaken for IBRD/IDA investment lending projects in Global Practices with Bank approved GHG accounting methodologies. Projects that are not subject to GHG accounting do not have to use the shadow price of carbon in the economic analysis.[2] The corporate commitment to apply shadow price of carbon in economic analysis is effective for projects with concept notes approved on or after July 1, 2017. Projects that are not subject to GHG accounting are invited to use shadow price of carbon in the economic analysis, on a voluntary basis.

Background

In 2015, the world came together and agreed to limit global warming to less than 2ºC by 2100, and make best efforts to limit warming to 1.5ºC. In the Climate Change Action Plan, the World Bank committed to support the achievement of these goals.

The World Bank finances projects that can have impacts on greenhouse gas (GHG) emissions. As such, in economic terms, many projects generate global social benefits from reduced GHG emissions or costs from increased emissions. This guidance note provides a corporate approach to incorporate carbon externalities in scenarios considered in the economic analysis.

GHG emissions are global externalities. As such, we recommend that the scenarios considered in the economic analysis be done both with and without the shadow price of carbon. The analysis with the shadow price of carbon reflects the global impacts of a project, shared with other countries, while the analysis without the shadow price of carbon conveys the impacts of the project without considering climate change.

The economic analysis of projects is one of many factors that enter a decision by the Bank and its clients to undertake a project or not. As such, the purpose of this note is to contribute to greater transparency

[1] See Climate Change Action Plan and IDA 18 commitments. Different documents have been using different terms to refer to the price of carbon used in economic analysis (shadow price of carbon, social cost of carbon, social value of carbon). These terms refer to different approaches to calculate the price of carbon. This guidance note uses the term "shadow price of carbon," which is the price of carbon consistent with a given climate objective, as estimated for the High-Level Commission on Carbon Prices, led by Joseph Stiglitz and Nicholas Stern.

[2] This concerns for instance projects that fall below GP-specific minimum threshold for GHG accounting.

and consistency of the project's global climate impacts to help inform decision making by the Bank and its clients. This note does not provide an automatic rule to select projects – it only provides a methodology to ensure that management and the Board have the information needed to make decisions.

The shadow price of carbon and its impact on the cost-benefit analysis and/or cost-effectiveness analysis of a project is conceptually distinct from the question of how the project should be financed or who should pay for the global external cost or gain from the global external benefit of the project.

Cases may arise where an emission reducing project is economically viable with the global (positive) carbon externality being counted but not viable without it being counted– i.e. the project domestic costs are higher than domestic benefits but lower than the global benefits. In such a case, the country may still decide to pursue the project for strategic or other reasons. Efforts may also be made to find additional external financing to cover a portion of the additional cost of delivering global benefits.

Conversely, it could happen that an emission increasing project is viable from a purely domestic point of view, but is not economically viable when the global (negative) carbon externality is accounted for. This information can encourage Bank teams and its clients to consider realistically available project alternatives, delivering the same benefits with lower global social costs, that enjoy strong country ownership or whose incremental costs can be supported by concessional finance.

However, the financing questions are not covered by this guidance note, which focuses only on the use of shadow carbon price in economic analysis.

Valuation of GHG emissions

The High-Level Commission on Carbon Prices, led by Joseph Stiglitz and Nicholas Stern, concluded based on an extensive review that a range of US$40-80 per ton of CO_2e in 2020, rising to US$50-100 per ton of CO_2e by 2030, is consistent with achieving the core objective of the Paris Agreement of keeping temperature rise below 2 degrees, provided a supportive policy environment is in place.[3]

In line with the High-Level Commission on Carbon Prices, this guidance note recommends that projects' economic analysis use a low and high estimate of the carbon price starting at US$40 and 80, respectively, in 2020 and increasing to US$50 and 100 by 2030. Given that the High-Level Commission report does not prescribe any specific carbon price values beyond 2030, the low and high values on carbon prices are extrapolated from 2030 to 2050 using the same growth rate of 2.25% per year that is implicit between the 2020 and 2030, leading to values of US$78 and $156 by 2050.[4]

Figure 1 shows the low and high values of shadow price of carbon that all projects are recommended to use for the period 2017-2050 period.

The use of a range of values (instead of a central estimate) is justified by the uncertainty and the need to consider the country context. Indeed, there is a significant uncertainty around the carbon value that is consistent with the Paris Agreement, linked to the unpredictability of future socioeconomic and

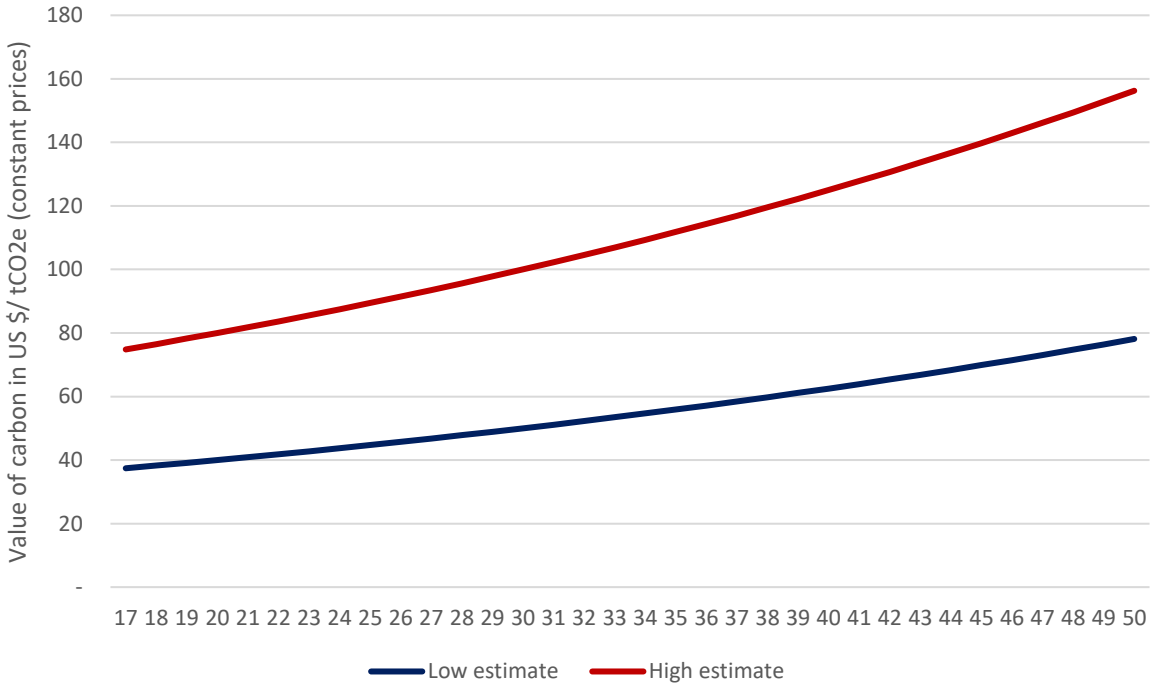
[3] Carbon Pricing Leadership Coalition 2017. Report of the High-Level Commission on Carbon Pricing, Commission chairs: Stiglitz, J.E. and Stern, N., supported by World Bank Group, ADEME, French Ministry for the Ecological and Inclusive Transition. https://static1.squarespace.com/static/54ff9c5ce4b0a53decccfb4c/t/59244eed17bffc0ac256cf16/1495551740633/CarbonPricing_Final_May29.pdf

[4] This is a conservative assumption reflecting a very optimistic forecast of early mitigation action and rapid cost decline of low-carbon technologies

technological trends. To reflect this uncertainty, this note recommends the use of low and high values and an approach to the assessment that is consistent with the presence of uncertainty (see the analysis section below). Further, the report by the High-Level Commission on Carbon Prices acknowledges that uniform carbon prices are optimal only if unlimited resource transfers can be made across countries, so that countries with higher marginal abatement costs can finance abatement measures in countries with lower marginal abatement costs. Given the limitation on such transfers, the High-Level Commission states that prices are better determined at the country level. Such country-specific price levels and pathways depend on many characteristics, such as income level, poverty incidence, economic structure and dependence to fossil fuels, potential of renewable (hydropower, wind and solar resources), and ability of the government to support the transition, especially for the poor and vulnerable.

See supplemental material for further information on how these prices were derived and Annex 1 for the difference with the 2014 guidance note.

Figure 1: Recommended shadow price of carbon in US$ per 1 metric ton of CO_2 equivalent (constant prices)



Year	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Low	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	55	56	57	58	60	61	63	64	65	67	68	70	71	73	75	76	78
High	75	77	78	80	82	84	86	87	89	91	94	96	98	100	102	105	107	109	112	114	117	120	122	125	128	131	134	137	140	143	146	149	153	156

Calculation

To incorporate carbon externalities into the economic analysis either in the form of cost benefit analysis or cost-effectiveness analysis, the annual shadow price of carbon (US$/$tCO2_e$) is multiplied by the annual GHG emissions (tCO_2e) over the economic lifetime of the project. The value of shadow price of carbon (SPC) can be used either in a cost-effectiveness or in a cost-benefit setting.

The task team will calculate the relevant indicators of economic analysis (i) without SPC, (ii) with the low value of SPC, (iii) with the high value of SPC, and (iv) with the switching SPC when relevant. The interpretation of these results will be presented in the project document along the guidelines provided in the "Analysis" and "Reporting" sections below.

In the case of cost effectiveness analysis, the costs of different realistically available project alternatives that provide the same result ("same level of service") are compared. For example, in a comparison of thermal power with variable renewable energy, it would be important to ensure that the latter project incorporates the system cost of adequate storage, back-up or other flexibility services to provide the same degree of energy reliability as the former. For this comparison, the annual gross (or absolute) GHG emissions of the proposed project and of its realistically available alternatives are to be multiplied by the shadow price of carbon of the respective year. The cost associated with the carbon externality (and any other relevant externality) is added to the costs of each project alternative.

In the case of cost benefit analysis, the benefits and costs associated with the carbon externalities are added to the net present value of the costs and benefit streams that can be calculated as:

$$NPV = -Fixed\ Cost_0 + \sum_{t=1}^{T} \frac{Benefits_t - Costs_t - (\boldsymbol{SPC_t * GHG\ emissions_t})}{(1+Discount\ Rate)^t}$$

The following considerations need to be included in the calculation:

- **Shadow price of carbon.** The value (SPC_t) is increasing each year in real terms over the economic lifetime of the project, consistently with the pathways detailed in Figure 1.
- **GHG emissions.** If annual benefits and costs in the cost-benefit analysis are expressed in comparison to a baseline/counterfactual scenario, the annual GHG emissions are calculated as the difference between gross/absolute GHG emissions of the project and the gross GHG emissions of baseline/counterfactual scenario used in the economic analysis (i.e. annual net GHG emissions).
- **Consistency in baseline.** All benefits and cost in the economic analysis (including GHG emissions) need to refer to the same baseline/counterfactual scenario(s).[5] The choice of counterfactual scenarios used to calculate the GHG emissions caused by the project needs to be consistent with the counterfactual scenario used to calculate other costs and benefits of the project. In particular, if the baseline used in the economic analysis differs from the baseline used for GHG accounting, then the emissions from GHG accounting cannot be used directly in the economic analysis and needs to be adjusted.[6]

[5] Economic analysis in the project document may be carried out "with and without project" to assess the net development impact of the World Bank's resources (OPCS 2014). In that case, the costs and benefits of the project are calculated compared with a scenario in which no project is implemented, and the GHG emissions need to be calculated compared with the same no-project scenario. However, the Energy Sector Directions Paper endorsed by the WBG Board of Executive Directors in 2013 specifies that – in the energy sector – global externalities be assessed comparing alternatives delivering the same level of service within the same time frame as the proposed project. Therefore, in energy projects where economic analysis to assess the project's net development impact uses the traditional "with and without project" approach, an additional set of economic analyses will be carried out to capture the shadow price of carbon. The additional set of analyses will compare alternatives, all of which will deliver the same level of service as the proposed project within the same time frame. This is to ensure consistency with the Energy Sector Directions Paper.

[6] For example, if the proposed project is the gas-fired CCGT, the alternative project scenarios in the economic analysis could include meeting the same level and quality of energy service by coal power plant or by renewable power plants, while the baseline for the purpose of GHG accounting would be the combined (operating and build) margin in the entire power sector.

- **Project boundary.** The scope of the calculation of the economic costs and benefits, and the calculation of the GHG emissions also needs to be the same within the economic analysis. If the considered costs and benefits include indirect (out-of-project) costs and benefits, such as induced investments outside of the project scope financed by the Bank, then the emissions generated out of the project (scope 2 and 3 emissions) also need to be considered in the analysis.
- **Explicit carbon prices.** If a borrowing country has a domestic explicit carbon price or tax or receives carbon payments/ credits for the emissions reduction delivered by a project, and it has been already included in the financial projections, the carbon price or tax should be subtracted from the recommended shadow prices of carbon in the economic analysis, so that the carbon externality is not accounted for twice.
- **Switching value.** The switching value can be calculated by finding the shadow price of carbon for the first year of calculation (and increasing at a constant rate of 2.25% throughout) that changes the sign of economic viability of a project.
- **Discounting** – All shadow prices of carbon need to be discounted at the same discount rate used for all other costs and benefits considered in the economic analysis.

For further information on the calculation, please see supplemental material and excel templates to facilitate the calculation.

Analysis

The results with no, low and high shadow price of carbon as well as the switching value can then be analyzed depending on whether the project increases (e.g., a new road or thermal power plant) or decreases (e.g., energy efficiency, afforestation or renewable energy displacing thermal generation) GHG emissions:

- For projects that **increase GHG emissions** and are viable (and least cost when compared to other realistically available alternatives) without the shadow price of carbon, the results with the high and low shadow price of carbon can be interpreted as follows (see Figure 2):
    - If the project remains viable (or least-cost among realistically available alternatives) even with the high shadow price of carbon, then there is a strong economic case for the project despite the increase in emissions.
    - If the project is not economically viable (and no longer least cost when compared to other realistically available alternatives) with the high shadow price of carbon, but is economically viable (least-cost) with the low shadow price of carbon, the team should report the switching value, which is the shadow price of carbon, at which the low carbon alternatives to the proposed project become more economically viable (and cost-competitive). Lower switching values are appropriate in countries with lower capacity to reduce emissions (either because of lower GDP per capita, low endowment in renewable energy potential, weak energy system or grid, high poverty, highly carbon-intensive economic structure). In addition, the project team may consider providing more information, for instance on other non-monetized project benefits or constraints to alternatives.
    - If the project becomes economically unviable (and not least cost when compared to other realistically available alternatives) even with the low shadow price of carbon, the project team may provide more information to explain why the project may still be desirable, or

describe constraints to alternatives. It may also be relevant to consider lower-carbon alternatives that enjoy strong country ownership (for example, through inclusion in a country's NDCs), or whose incremental costs can be supported by concessional finance.

- For projects that **reduce GHG emissions** and are unviable (and not least cost when compared to other realistically available alternatives) without the shadow price of carbon, the results with the low and high shadow price of carbon can be interpreted as follows (see Figure 3):
    - If the project remains economically unviable (and not least cost when compared to other realistically available alternatives) even with the high shadow price of carbon, then there is no strong economic case for the project despite the reduction in emissions.
    - If the project is economically unviable (and not least cost when compared to other realistically available alternatives) with the low shadow price of carbon, but is economically viable with the high shadow price of carbon, the team should report the switching value which, in this case, is the minimum shadow price of carbon required to make the project viable (and least cost when compared to other realistically available alternatives). Lower switching values are appropriate in countries with lower capacity to reduce emissions (either because of lower GDP per capita, low endowment in renewable energy potential, weak energy system or grid, high poverty, highly carbon-intensive economic structure). In addition, the project team may consider providing more information, for instance on other non-monetized project benefits or constraints to alternatives.
    - If the project becomes viable (and least cost when compared to other realistically available alternatives) with the low shadow price of carbon, it remains important to verify whether this low-carbon project either enjoys strong country ownership (for example, through inclusion in a country's NDCs), or is able to cover its incremental costs through concessional finance.

Figure 2: Interpretation of no, low, high and switching values to inform decision making for projects that increase GHG emissions

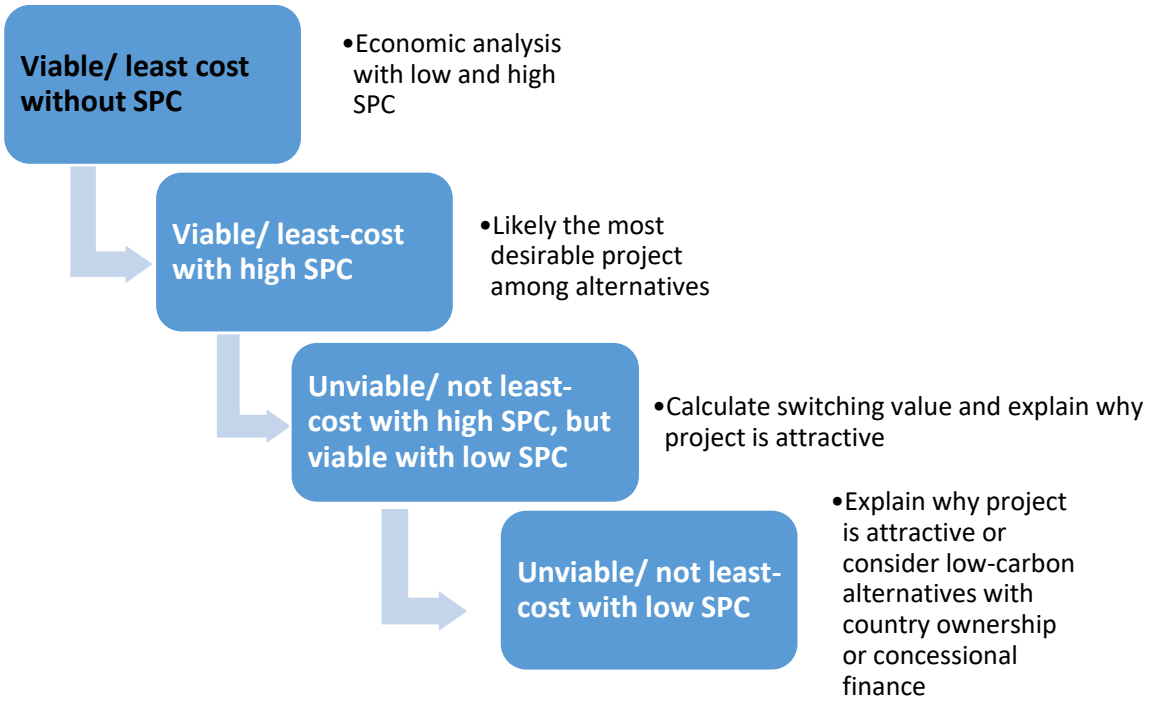
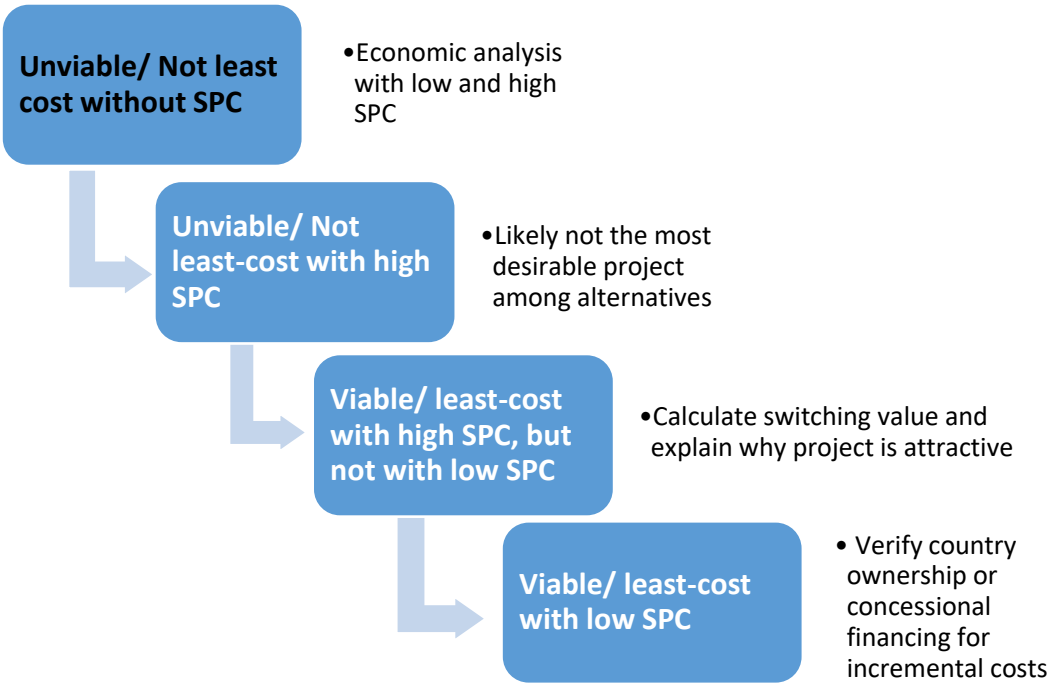


Figure 3: Interpretation of no, low, high and switching values to inform decision making for projects that decrease GHG emissions



Sector-specific strategic notes of the WBG*, such as the Energy Sector Directions Paper for instance*, may provide further guidelines on the use of economic and financial considerations in decision making during project appraisal.

Reporting

Concept stage: The OPCS guidance on economic analysis for investment lending projects advises task teams to recommend in the project concept note the form (methodology) of economic analysis they will use. This guidance note on shadow price of carbon provides further guidance to task teams of applicable projects. Teams are invited to note that shadow price of carbon will be used in the economic analysis and identify the multiple project alternatives that will be considered in the economic analysis with and without the shadow price of carbon.

Appraisal stage: Task teams of applicable projects should present the economic analysis for the main project alternatives with and without the shadow carbon price in the project appraisal document (PAD) and or project paper (PP) to allow management and the Board to take this information into consideration. This guidance note recommends that the PAD states the results of the economic analysis with high and low shadow prices of carbon values, and if relevant to provide the switching value.

In addition, task teams should, before appraisal, report in the Appraisal Data Sheet under Institutional Data (can be found under Roadmap in the Operations Portal) whether they have used the shadow price of carbon in the economic analysis (yes, no, or not applicable).

Roles and responsibilities

Task teams can seek support from GHG help desks that are available in each applicable Global Practice for the design of the baseline scenario and the review of the calculation of economic analysis with shadow price of carbon. GHG focal points in the Climate Change Group are available to support GP GHG focal points and task teams in the analysis of projects that face exceptional circumstances.

Annex 1 – Difference with the 2014 guidance note

This departs from the 2014 "Social Value of Carbon in Project Appraisal Guidance Note" for four main reasons:

- **Paris agreement.** In 2015, the world came together and agreed to limit global warming to less than 2ºC by 2100, and make best efforts to limit warming to 1.5ºC. In the Climate Change Action Plan, the World Bank committed to support the achievement of these goals. Therefore, the recommended values are consistent with the core objective of the Paris Agreement of keeping temperature rise below 2 degrees, and are based on the concept of marginal abatement cost only (while the 2014 guidance note also used the social cost of carbon, the value of climate change damages that can be avoided thanks to reduced emissions).
- **Higher values.** Marginal abatement cost estimates are increasing over time (and will continue to do so) if short-term action is below what the models consider cost-efficient. Hence, values in this guidance note are higher than the values of the 2014 guidance note.[7]
- **Uncertainty.** There is a significant uncertainty around the carbon value that is consistent with the Paris Agreement, and this uncertainty increases, the further we go into the future. To reflect this uncertainty, this note recommends the use of low and high values (instead of a central estimate) and an approach to the assessment that is consistent with the presence of uncertainty (see the analysis section below).
- **Differentiated shadow prices of carbon.** Published in 2017, the report by the High-Level Commission acknowledges that uniform carbon prices are optimal only if unlimited resource transfers can be made across countries, so that countries with higher marginal abatement costs can finance abatement measures in countries with lower marginal abatement costs. Given the limitation on such transfers, the High-Level Commission report states that prices are better determined at the country level. Such country-specific price levels and pathways depend on many characteristics, such as income level, poverty incidence, economic structure and dependence to fossil fuels, potential of renewable (hydropower, wind and solar resources), and ability of the government to support the transition, especially for the poor and vulnerable. There are two (interlinked) reasons why lower-income countries may choose lower carbon prices than higher-income countries: (1) low-income countries tend to have less ambitious objectives for emission reductions; and (2) low-income countries tend to a lower carbon price to achieve a given level of emission reductions. Hence, the range between low and high values can be interpreted as the uncertainty combining technical uncertainty (what price level is level to achieve a given level of reduction in a country?) and equity considerations (how fast should and could different countries reduce their emissions?).
- **At the request of task teams the "Analysis", "Reporting" and "Roles and Responsibilities" sections were added,** to clarify interpretation of, and operational context for the calculation of the shadow price of carbon.

[7] While not relevant here, the shadow price of carbon estimates have also increased due to updated analyses using recent evidence of climate change and variability impacts.