IAM COMPACT

Expanding Integrated Assessment Modelling: Comprehensive and Comprehensible Science for Sustainable, Co-Created Climate Action

Cost of capital evolution effects on regional mitigation pathways:

Financing renewable investments in low- and middle-income countries

20/03/2025

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1 Introduction

IAM COMPACT is a Horizon Europe research project, with the objective to support the assessment of global climate goals, the collective progress towards them, and the feasibility space in delivering on those goals. It aims to involve relevant stakeholders in the process to help promote acceptable, robust, sustainable transitions, as well as to enhance trust on both ends, yielding outputs intelligible in terms of real-world implications and actionable in terms of concrete policy recommendations.

Participatory approaches have been argued to bring a more diverse range of views into the IAM process, by building a better understanding of the social context and supporting more inclusive decision-making. In IAM COMPACT, we have designed a Policy Response Mechanism (PRM), a co-creation process that facilitates collaboration among modelling teams and with stakeholders. The PRM dynamically responds to changing policy priorities, aiming for policy relevance, knowledge exchange, and enhanced trust, by providing different layers of inputs and making modelling socially/politically realistic. Stakeholder engagement in IAM COMPACT is organised into themes (for stakeholders within the EU) and regions (for stakeholders outside the EU). The themes and regions were collaboratively determined within the project, with Bruegel coordinating the process. For the themes, the aim was to have a broad enough coverage to capture a range of issues, but also sufficiently selective to lead a clear research agenda later in the project. Overall, 23 questions emerged from high-level exchanges with policy stakeholders (forming the Policy Steering Groups), which we grouped into proposals for seven modelling studies. These proposals were in turn grouped into four overreaching themes and discussed with a wider policy audience (forming the Core Working Groups) selected on geographical and sectoral criteria. The consultative process helped us evaluate the relevance of policy issues, refine the scope of research questions, and establish a balanced group of stakeholders to participate. We conducted one workshop under each theme alongside the corresponding core working group to consult stakeholders on our scenario design and co-define desired outputs as well as a key set of joint input assumptions.

This policy brief is part of the theme *Global Effects*, which considers trade and macroeconomic issues and their effects on European decarbonisation. During the workshop conducted under this theme, we sought feedback on the scenario design, inputs, and projections of two proposed modelling studies. Following an in-depth discussion on uncertainty factors and how these may play out, the 20 participating stakeholders—among others from DG Trade, DG ECFIN, the European Central Bank, and the National Bank of Belgium—were asked to also fill out a survey on how perceived costs may evolve for different technologies and countries around the world. The study presented here looked at how regionally and technologically differentiated cost of capital projections could affect decarbonisation pathways in Europe and around the world.

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2 Assumptions

When it comes to climate change mitigation, reliable data and improved understanding of the composition of the cost of capital of energy technologies and its drivers are essential to effectively mobilising substantial low-carbon investments as well as to developing support mechanisms and market designs that appropriately consider varying technology and country risks. These are commonly represented in the weighted average cost of capital (WACC), a cost-of-capital case that considers the proportion of debt and equity in a company's capital structure. Essentially, WACC is a weighted average of the cost of debt and the cost of equity, where weights are determined by the proportion of each in a company's total capital.

Most model-based scenario exercises—e.g., using energy-system models or integrated assessment models (IAMs), among those used to underpin climate change mitigation strategies—often use uniform WACC values across technologies and/or regions over time, which can disproportionately impact mitigation pathways for developing economies. Although efforts in the literature and among international organisations have recently focused on the development of empirically calibrated WACC databases, differentiated by region and technology, there remains a challenge of understanding how these may evolve in the future. To this end, IRENA recently released short-term cost-of-capital trends, which were partially informed by expert insights. Here, we took one step further and combined the empirical estimates of baseline WACC values with an expert-based approach to produce plausible, forward-looking, long-term projections of evolving costs of capital over time. Using a global IAM, we explored the implications of regional decarbonisation pathways under alternative technological and policy choices, with particular emphasis on de-risking clean energy and risking fossil-fuel technologies. We drew experts' insights on how much investment risks may change for a set of technologies by 2050 in high-, middle-, and low-income countries, considering finance and policy derisking or divestment mechanisms that may play out, to determine the final risk percentage change.

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3 Scenario co-design

We designed four alternative futures, in terms of cost-of-capital projections. The first explicitly reflects the results of the survey (scenario *Sv* in the figures below). Seeing how our experts' responses showed two tendences in terms of cost-of-capital projections across technologies, namely increased risk of fossil-fuel investments and derisking of renewable energy technologies, we disaggregated these trends and formulated two more futures. The first sticks to the experts' opinions on fossil fuels becoming less competitive in the future; to reflect this, we used the survey values for these technologies, while keeping non-fossil technologies constant over time in line with the employed empirical dataset (scenario *Sv-F*), overall reflecting a world of fossil fuel divestment. The second used the WACC value projections provided by the experts for the non-fossil fuel technologies to portray a world of de-risking non-fossil fuel technologies: WACC values for renewables, green hydrogen, hydropower, and CCS decrease over time, while those for nuclear and biomass increase, and fossil-fuel values are kept constant and identical to the empirical dataset (scenario *Sv-NF*). The fourth scenario reflects a fragmenting world, in that a variety of economic, financial, and geopolitical factors lead to increasing divergence of costs of capital between high-income countries and low- and middle-income countries (LMICs) (scenario *Frag*).

A high-level summary of all scenarios is available in **Table A1**, while **Figure 1** shows a representation of baseline and future aggregated WACC values by region and technology for each scenario.

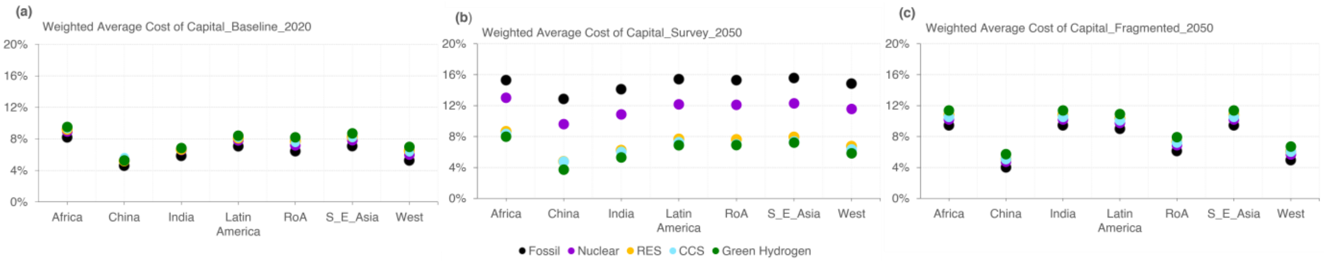

Figure 1: Baseline and projections of WACC values per scenario and windfall profits. *WACC values aggregated by aggregated region and technology (fossil fuels, renewables, nuclear, CCS, and green hydrogen),* ***(a)*** *in the baseline year;* ***(b)*** *in 2050 based on the survey results (Sv, Sv-F, Sv-NF scenarios);* ***(c)*** *and in 2050 for the Frag scenario. Scenarios are explained in* ***Table A1.***

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4 Model insights

4.1 Changes in the energy system

By building on and expanding empirical values reflecting investment risks, our modelling exercise shows that, especially for developing economies (e.g., in Africa), policies aimed at derisking renewables could prove an effective lever for reaching net-zero targets. However, regions with extensive fossil-based infrastructure would face structural challenges, with declining costs of capital driving clean energy investments but not sufficiently to entirely replace fossil fuels (e.g., in China). Temporal dynamics highlight limited additional reductions by 2030 across all regions, which is indicative of the relatively small changes in WACC values compared to the baseline (**Figure 1b-c**).

The highest emissions decrease (**Figure 2a**) would happen in the case of fossil fuel divestment (*Sv-F*) (i.e., reflected through higher fossil-fuel WACC values), whereby fossil (coal, oil, and gas) secondary electricity would be replaced by renewables, biomass, and nuclear—with the latter more evident in China (+65TWh RES and +46TWh nuclear in 2050 relative to *B-NDC*) and countries in South and East Asia (+95 TWh nuclear and +22TWh biomass in 2050 relative to *B-NDC*) (**Figure 2c**). This is also the scenario with decarbonisation gains consistently across the globe in the longer term, although Western countries (-11%) and India (-8%) showcase the largest achievements in terms of mitigation, with extensive reductions in fossil electricity and capacity additions mostly in solar and wind. Countries in Africa and South and East Asia would exhibit smaller emission reductions (-2%), indicative of slower transitions rather than transformative shifts, due to economic or infrastructure constraints.

Derisking renewable energy investments—e.g., by reallocating, sharing, and/or reducing existing potential risks associated with those investments—would cut global CO_2 emissions through capacity additions in RES (**Figure 2d**) and increased green electrification. Our results highlight the impact of rising WACC values on the deployment of nuclear power generation; its high upfront costs and long lead times would contribute to the observed significant drop in its share in the energy mix in regions with high baseline nuclear capacity. Despite the lower risk of renewables, emissions would increase in the West for a multitude of reasons. Notably fossil fuels would remain cost-competitive and still get deployed, the use of nuclear energy and BECCS would decrease, and a shift from wind to solar would be observed, with the latter two reasons contributing to a decrease in total electricity produced, hampering electrification efforts in other sectors (**Figure 1c-d)**.

Future WACC pathways according to our survey results (*Sv*), which essentially combine the assumptions of both cases discussed above, could contribute toward bridging the 2050 emissions gap between extrapolated NDCs and long-term targets (*B-LTT*) by as much as 18% in Africa, and 6% globally (**Figure 2b**); interestingly, the largest chunk of this reduction (5%) could be attributed to increased fossil-fuel risks alone. A significant gap would however remain, indicating that lowering WACC values alone is not sufficient to scale up decarbonisation in line with long-term emission targets. The opposite is observed in the West, as emissions increase most notably in the US owing to lower deployment of negative CCS-based technologies (i.e., BECCS with the risk of biomass almost doubling in the country, and DACCS). In regions like Latin America, where the RES share in electricity generation is already high and grows further in the baseline scenario, lower WACC values in these technologies would only moderately increase solar and wind electricity, eventually contributing to bridging the emissions gap towards their LTTs by about 3%.

Finally, a world where investment risks between high- and low-/mid-income countries (LMICs) further diverge (*Frag*) would instead feature decreased deployment of renewable energy for power generation in most developing nations in Africa and Asia, with coal and/or gas gaining ground and leading to a 5-10% increase in CO_2 emissions.

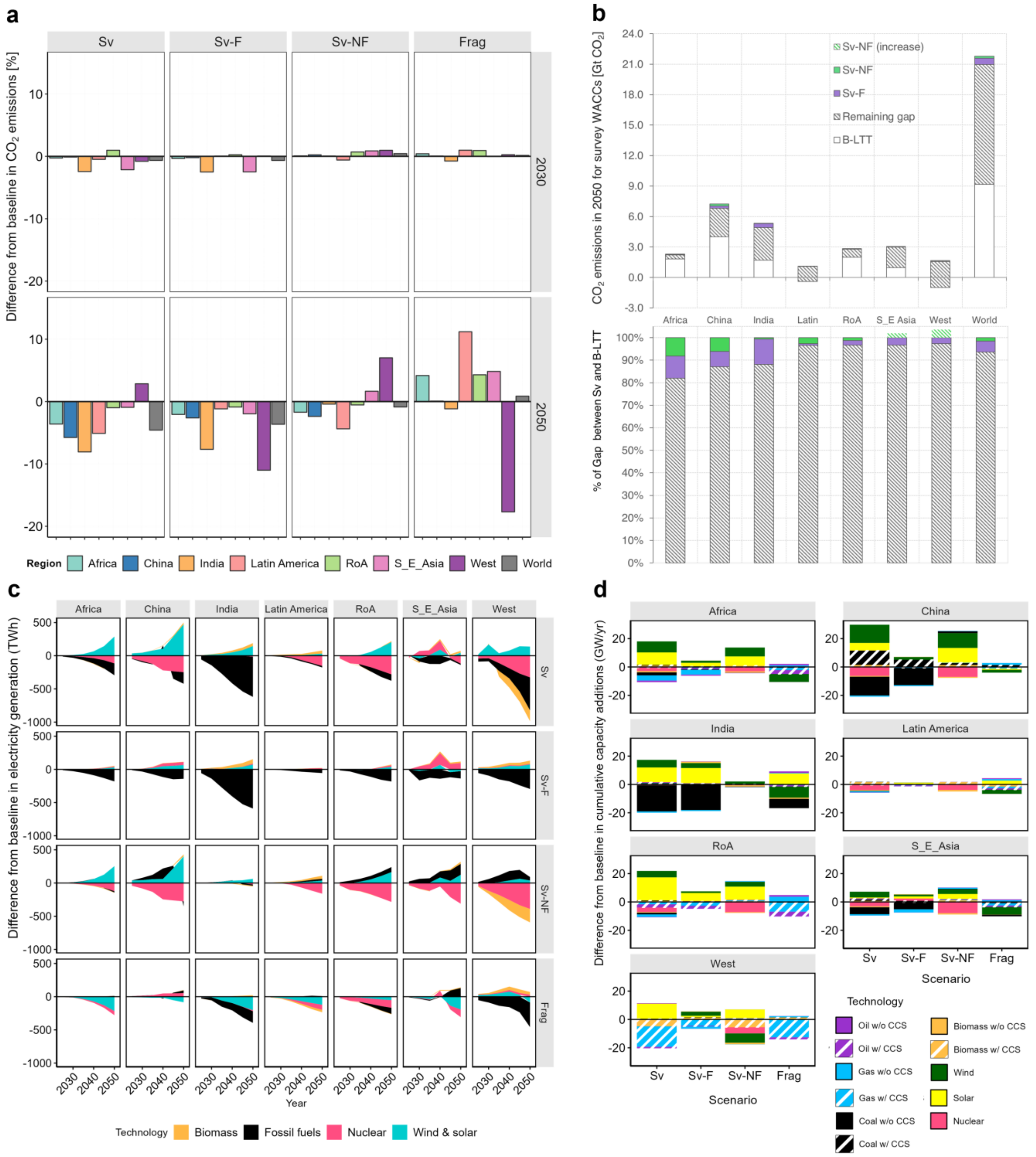

Figure 2: Regional energy-system implications of different WACC projections on top of NDCs. *(**a**) Percentage change of CO_2 emissions from energy and industrial processes by scenario and region compared to B-NDC in 2030 and 2050; (**b**) Gap between B-NDC and B-LTT CO_2 emissions in 2050 when survey WACCs are applied, Fossil & Non-Fossil contribution is shown separately; (**c**) Electricity generation by technology relative to B-NDC; (**d**) Cumulative capacity additions by scenario, technology, and region during 2025 – 2050 relative to B-NDC. Scenarios are explained in **Table A1.***

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4.1.1 Highlights

- Cost-of-capital trends, such as those informed by our stakeholders and discussed above, could help close the emissions gap by 6% globally, and up to 18% in Africa.
- 5% of these global emissions reductions would come from increased fossil fuel risks alone.
- Derisking renewables would reduce CO_2 emissions in Latin America, China, and Africa through capacity additions in RES, and increased green electrification.
- Lowering WACC values alone is insufficient to meet long-term climate targets, indicating the need for additional policy measures.
- Polarisation, reflected in diverging costs of capital among countries, would decrease the diffusion of renewables in power generation in LMICs, reinforcing coal or gas, therefore increasing CO_2 emissions.

4.2 Regionally differentiated impacts on electricity investments and prices

Higher costs of capital would partially discourage investments in new fossil fuel capacity due to lower expected returns. Despite increasing WACC values, nonetheless, fossil fuel technologies would still get deployed, leading to electricity price spikes across all regions. The increased LCOE of fossil fuels would feed directly into electricity market prices—especially in fossil-dominated grids such as India's, where prices could rise by up to 15% compared to the baseline (**Figure 3a**). This would in turn reduce demand and thus investments towards fossil-fuel electricity infrastructure (**Figure 3b**).

Lower WACC values could boost investments in capital-intensive renewables, especially in China (+$6.4 billion), other Asian countries (South and East Asia +$5.1 billion, +$3.1 billion elsewhere), and Africa (+$3.3 billion), in 2050 (**Figure 3b,** Scenario *Sv-NF*). In regions with already favourable investment frameworks (e.g., in the West), where RES investments are less risky, an incremental risk reduction of WACC values would not incur significant investment shifts. However, when combined with riskier fossil fuels (*Sv*), more than $13 billion/yr investments could flow towards solar, and $4.6 billion towards transmission & distribution in 2030—a much quicker response to costs of capital compared to other regions where investments occur mostly towards mid-century. Renewables' falling WACC values would only moderately reduce electricity prices towards 2050, due to the simultaneous increase of WACC values for nuclear—a capital-intensive technology that is highly susceptible to such variations: financing risks would affect the affordability of nuclear power investments all over the world, more prominently in South and East Asia, where investments could drop by $12 billion in 2050.

We also observe an increase in investments related to CCS, with coal in Asia (amounting to +$12.5 billion in total)—including the two highest emitters from coal in power generation (China and India)—and with gas in the West (+$1.9 billion), despite the rising cost of capital of fossil fuel technologies; as new fossil-fuel capacity additions become riskier while CCS becomes more competitive, investments are increasingly directed towards new coal capacity with CCS (**Figure 2d**). Similarly, in the case of de-risking non-fossil fuel technologies, our analysis suggests a large flow of investments towards BECCS ($14.6 billion total) in most parts of Asia, Africa, and Latin America, even if biomass WACC values instead increase over time.

Deepening inequality, in cost-of-capital terms (*Frag*), would yield the highest electricity price increases in all regions, except for Western countries (where WACC values do not increase) and China, hampering electrification of end uses as well as overall investments in the electricity sector, and leading to higher emissions in 2050, especially in regions with high price spikes (Africa, Latin America, and all Asian countries apart from China).

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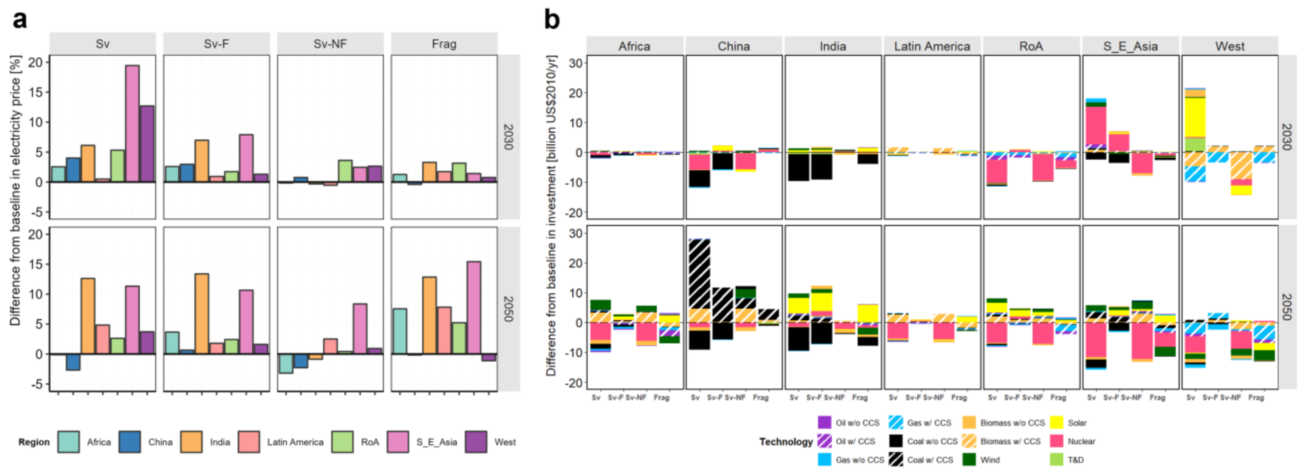

Figure 3: Regional implications of different WACC projections for electricity prices and energy investments, on top of NDCs. *(a) Percentage change of weighted average electricity prices by final electricity consumption per region and scenario (**Data S6**) compared to B-NDC in 2030 and 2050; (b) Difference of investments in electricity supply technologies compared to B-NDC by scenario and region, in 2030 and 2050; T&D: transmission & distribution. Scenarios are explained in **Table A1.***

4.2.1 Highlights

- Increased costs of capital would discourage new fossil fuel investments due to lower expected returns.
- However, fossil fuel technologies would still get deployed, causing electricity price spikes globally.
- Falling WACC values for renewables would not fully offset price increases, as nuclear financing risks would increase overall electricity costs
- Cost-of-capital divergence between high-income and other countries could worsen regional disparities, hindering electrification and sectoral investments in Africa, Latin America, & Asia (excluding China)

5 Policy Implications

Our study, suggests that exploring how realistic costs and perceived investment risks may evolve in the future is also critical to understanding how energy systems could shape in response to different financing developments and in pursuit of climate targets: different cost-of-capital developments for different technologies and across regions could mean vastly different winners and losers in the race to climate neutrality—in terms of major (or earlier) shifts in electricity and energy systems, stickiness and sensitivity of certain technologies to financing conditions, infrastructure lock-ins or stranding, and emissions. Policies aimed at improving financing conditions and facilitating access to affordable finance could bridge the cost-of-capital gap between developed and developing economies and help promote decarbonisation pathways aligned with climate policies and targets.

Fossil fuel vs. renewable energy costs of capital

- Increasing risks in fossil fuels would consistently benefit the entire world, leading to divestments in coal, oil, and gas and lowering CO_2 emissions globally—and more prominently in developed and some rapidly emerging economies.
- Favourable conditions for low-carbon technologies alone—e.g., with policies mitigating or reallocating investment risks—could decrease emissions in Latin America, China, and Africa through renewable energy capacity additions and increased green electrification.

Combined cost-of-capital trends

- Modelling the effects of both trends perceived by our experts (i.e., derisking RES and increased fossil-fuel risks) hints that informing energy planning models with better financing assumptions and conditions could unlock a mitigation potential that helps bridge the long-term ambition gap vis-à-vis increasing investment flows in the developing world.
- With mitigation efforts fixed, future cost-of-capital values according to our survey results would contribute towards achieving LTT targets, closing the NDC-LTT gap by as much as 18% in Africa, and 6% globally.
- A significant gap would however remain, indicating that addressing the gaps between developed and developing economies in costs of capital alone is not a sufficient incentive to help deliver on Paris Agreement-compatible targets.

Geographic disparities

- Exacerbated differences in the costs of capital between regions would limit access to climate finance and in turn hamper decarbonisation efforts in LMICs, thereby delaying achievement of global climate goals.
- As the main source of WACC variation lies in each region's local context and framework conditions, our exercise illustrates the importance of international and regional support alike for the reduction of the assumed cost of capital. This in turn highlights the need for policy and regulatory support towards reducing the real and perceived investment risks, and thus the premiums and costs of capital, as well as providing adequate financial support in LMICs.

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Annex: Scenario Protocol

Table A1: Scenario protocol

Name	WACC trends and climate policies assumptions
B-NDC	Based on 2030 emission targets pledged in NDCs submitted or announced by June 2023, capturing all mitigation ambition updates during and after COP26 in Glasgow, implemented on top of current policies. In model regions with current policies exceeding NDC mitigation targets, no additional emission constraints are applied; emissions reductions are therefore never less ambitious than implied in current policies. Empirical WACC values are used and kept fixed for the entire time horizon.
B-LTT	For regions that have expressed an LTT—e.g., net-zero commitments or other targets for 2050 or later—emission constraints linearly decline from 2030 levels from the NDC target towards the LTT. For regions without LTTs, post-2030 the applied policy targets are maintained as minimum levels beyond 2030 to avoid backtracking of achieved policies. Empirical WACC values are fixed for the entire time horizon.
Sv	Empirical WACC values are used as baseline (2020), while future WACC values change for all technologies linearly in 2018-2050, according to our survey results. Carbon prices are taken from *B-NDC*.
Sv-F	Empirical WACC values are used as baseline (2020), while future WACC values for fossil fuels increase linearly in 2018-2050, according to our survey results. Carbon prices are taken from *B-NDC*.
Sv-NF	Empirical WACC values are used as baseline (2020), while future WACC values for RES, green H_2, hydro, and CCS decrease, and those for biomass and nuclear increase linearly in 2018-2050, according to survey results. Carbon prices are taken from *B-NDC*.
Frag	Empirical WACC values are used as baseline (2020), while future WACC values of high-income countries further diverge from those in LMICs, linearly in 2018-2050: for high-income countries (incl. China), WACC values converge to the 25th percentile of the average baseline empirical WACC value per technology; for LMICs, WACC values converge to the 75th percentile of the average baseline empirical WACC value per technology. Carbon prices are taken from *B-NDC*.

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Policy Brief

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In a nutshell

IAM COMPACT supports the assessment of global climate goals, progress, and feasibility space, and the design of the next round of Nationally Determined Contributions (NDCs) and policy planning beyond 2030 for major emitters and non-high-income countries. It uses a diverse ensemble of models, tools, and insights from social and political sciences and operations research, integrating bodies of knowledge to co-create the research process and enhance transparency, robustness, and policy relevance. It explores the role of structural changes in major emitting sectors and of political, behaviour, and social aspects in mitigation, quantifies factors promoting or hindering climate neutrality, and accounts for extreme scenarios, to deliver a range of global and national pathways that are environmentally effective, viable, feasible, and desirable. In doing so, it aligns climate action with broader sustainability goals, while developing technical capacity and promoting ownership in non-high-income countries.

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