<u>Singapore's submission in response to call for inputs for the Belém Mission to 1.5</u>

Enabling International Energy Cooperation through Evidence-Based, Collaborative Mitigation Planning Tools

<u>Introduction</u>

1. Belém Mission to 1.5 was conceived in the context of the Global Mutirão Decision, aimed at enabling ambition and implementation of nationally determined contributions (NDCs) and national adaptation plans (NAPs), to reflect on accelerating implementation, international cooperation and investment.

2. Given the increasing likelihood of overshooting 1.5°C, we cannot afford to waste any of our precious global mitigation resources. Success is not measured solely by reaching net zero, but by minimizing the cumulative emissions released on the pathway to net zero. While NDCs remain the foundation of the Paris Agreement, achieving the fastest and most cost-effective emissions reductions will require accelerating international collaboration alongside domestic action.

3. Most mitigation planning today is largely premised on national-level accounting, i.e. enabling emissions reductions within each country's national boundaries. Each country models its own abatement options, costs, and pathways in isolation. Emissions and the economics of abatement, however, do not respect borders. While regional or bilateral cooperation would lower costs, unlock additional emissions reductions, diversify energy trade, or accelerate technology deployment, those opportunities frequently remain invisible simply because no one has analysed them. To fully unlock global mitigation potential, we must move towards coordinated regional and international planning that enables cross-border solutions. This goes beyond the transfer of carbon credits under Article 6 of the Paris Agreement and includes greater physical integration of low-carbon systems such as electricity grid interconnections, trade in green hydrogen and ammonia, joint renewable energy developments, and trade in low-carbon industrial intermediate products. By planning and acting collectively, countries can access mitigation opportunities that would not be achievable through domestic action alone.

4. A key barrier to advancing international cooperation is the conflation of two fundamentally different questions: who provides mitigation resources and where those resources are deployed. Climate discussions often carry the perception that investing in mitigation abroad is a way of avoiding domestic responsibility. Yet greenhouse gases do not recognize national borders. The climate benefits of emissions reductions are global, regardless of where they occur. We therefore need to decouple the question of who contributes resources, which is fundamentally a question of equity, from where those resources are invested, which is a question of efficiency. Restricting mitigation efforts to domestic action risks wasting scarce global resources at a time when every tonne of avoided emissions matters. By separating these two issues, we can unlock win-win outcomes that enable greater climate ambition, more cost-effective mitigation, and a just transition.

High-impact and innovative solutions are required to support NDC ambition and implementation

5. While the importance of international cooperation for climate mitigation is widely recognized, moving from principle to implementation remains a major challenge. Although advanced energy system and techno-economic models can rigorously evaluate collaborative opportunities, the number of possible cross-country arrangements is immense, each with its own technical, economic, and geopolitical considerations. Most individual collaboration scenarios have a low probability of being realized without further evidence or political engagement, making it difficult to justify the significant time, expertise, and financial resources required for detailed modelling studies. As a result, countries face a "discovery problem": identifying which opportunities are sufficiently promising to warrant deeper analysis and negotiation. This slows progress towards the international cooperation needed to achieve global climate goals.

6. Addressing this discovery problem requires a new class of decision-support tools that can rapidly identify the most promising opportunities for international collaboration before more resource-intensive analyses are undertaken. Such tools should enable countries to efficiently narrow thousands of potential collaboration scenarios into a small number of high-potential options that can then be evaluated using more detailed techno-economic models. To fulfil this role, they should have three key characteristics:

i. **trusted and transparent inputs**, based on data and assumptions that all participating stakeholders can scrutinize and agree upon;
ii. **sufficiently accurate outputs**, providing robust estimates of the techno-economic benefits of collaboration that are reliable enough for prioritization; and
iii. **dynamic, real-time scenario analysis**, allowing stakeholders to explore alternative assumptions and collaboration pathways interactively during discussions and negotiations. By complementing, rather than replacing, detailed modelling, these tools can accelerate the pathway from broad cooperation concepts to actionable international partnerships.

7. Energy systems is an important sector that would benefit from international cooperation. This is because renewable resource endowments (e.g. solar, wind, hydro) are widely, yet unevenly distributed geographically, while the grids, interconnectors and green hydrogen corridors needed to share them are physical infrastructure requiring long lead times and large capital commitments. Cross-border energy cooperation can lower system-wide costs by avoiding redundant storage and backup capacity in each country, allow importing countries to access cheaper renewable resources, increase energy access, and unlock abatement that would not be reachable by any single country acting alone. Beyond lowering costs, mapping cooperative options also helps countries diversify their energy trade partners, creating greater freedom to optimise strategic partnerships between countries and across regions. This is a resilience benefit underscored by recent conflict-driven disruptions to global energy, food and commodity supply chains. Thus, cross-border energy cooperation can expand the space of possibilities in the energy trilemma; it can unlock actions that can reduce costs, reduce emissions and increase energy security.

Global Mitigation Potential Atlas (GMPA)

8. A potential tool that can support countries' planning for international cooperation on mitigation efforts is the Global Mitigation Potential Atlas (GMPA), which has been developed by a consortium of international thinktanks[1] with support from Singapore, the Netherlands and other stakeholders. The GMPA is designed to address this discovery problem by providing a fast, transparent, and sufficiently accurate decision-support platform for identifying high-potential international collaborations[2]. The GMPA is a free-to-use web-based platform that quantifies each country's emissions reduction potential across a range of additional mitigation costs relative to business as usual and, by allowing users to combine countries into collaborative groups, reveals new mitigation opportunities that become feasible through cooperation while meeting the same energy demands. Rather than prescribing a specific market mechanism, GMPA first quantifies the total value, or the size of the "benefits pie", created by collaboration. This allows stakeholders to establish whether a collaboration is worth pursuing before addressing how the benefits should be shared. Once a significant win-win collaboration opportunity has been identified, principles such as Shapley value allocation[3] demonstrate that fair and stable distributions of these gains can exist. Finally, a range of policy and market mechanisms, including, but not limited to, carbon markets, infrastructure agreements, and long-term trade arrangements, can be used to realize them in practice.

9. The GMPA currently covers 30 countries across the globe and will be expanded to cover more countries over time.[4] For example, it can highlight the economic optimal constellations of cross-border energy cooperation, incl. green electricity, hydrogen and ammonia, involving all economic sectors. This can then help inform countries seeking to explore new forms of energy diplomacy around the world, adding to emerging roadmaps of greater energy security, while jointly moving towards net-zero emissions. In terms of sector coverage of countries, the GMPA currently covers the power and industrial high temperature heating, covering activity collaborations in ammonia/hydrogen trade and electricity imports. Work is ongoing to increase the sectoral coverage and scope of countries.

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[1] The GMPA consortium comprises: Climate Analytics (Germany), Institute for Essential Services Reform (IESR) (Indonesia), Moya Analytics (a start-up under the Singapore Institute of Manufacturing Technology, which is part of Singapore's Agency for Science, Technology and Research (A*STAR) (Singapore), OSeMOSYS (UK) and Supergrid Consortium (US and Europe).

[2] Data for GMPA was compiled using publicly available sources. Where available, multiple sources and most updated sources of published data was used. Data for certain countries were then further updated through bilateral engagement. This is to ensure the data is transparent, comparable, and representative, thus useful. Renewable energy capacity factors and technical potentials were derived from a pipeline which applies simulation models of the open-sourced python package GLAES (Geospatial Land Eligibility for Energy Systems) and RESKit (Renewable Energy Simulation Toolkit). RE cost projections were obtained from IRENA. Electricity demand data is collected from Climate Compatible Growth (CCG) Starter Data Kits (SDKs) for OSeMOSYS modelling. CCG is a consortium of universities and institutions including Cambridge and Oxford. Grid emissions factors for generic dispatchable power plants in the power sector was obtained from Institute for Global Environmental Strategies. (IGES). Where data was not present in the CCG SDKs, the closest equivalent data was obtained from IEA world energy outlook. Other technology specific data such as for cement or steel production were obtained from literature, and country specific sources were used as available. The full list of assumptions and methodologies can be found on the GMPA website or through contacting the GMPA team.

[3] The Shapeley value is a concept from cooperative game theory that provides a principled method for allocating the total benefits of cooperation among participants according to their respective contributions.

[4] The coverage of the GMPA comprises: Australia, Brazil, Brunei Darussalam, Cambodia, China, Chile, Colombia, Egypt, France, Germany, India, Indonesia, Japan, Kenya, Laos, Malaysia, Morocco, Myanmar, Nigeria, Peru, the Philippines, Russian Federation, Saudi Arabia, Singapore, South Africa, South Korea, Thailand, Türkiye, Vietnam and the US.

10. GMPA can potentially enhance the workflow of international cooperation by enabling stakeholders to explore potential collaboration scenarios dynamically and in real time. Through an interactive visual interface, users can quantify the emissions reductions achievable under different mitigation budgets, or conversely determine the investment required to achieve specific emissions targets, for individual countries or groups of countries. This provides a rapid, top-level assessment of the theoretical benefits of proposed interconnections, energy trade arrangements, or other collaborative initiatives before significant resources are committed to detailed feasibility studies. By combining transparent estimates of the total benefits from cooperation with fair and symmetric benefit-allocation approaches, GMPA provides a practical starting point for discussions on cost and benefit sharing, while helping countries identify which opportunities merit deeper analysis using more detailed national models and data. The box story in the Annex illustrates some of the GMPA's features.

11. **The Belem Mission to 1.5 report should give due focus to encouraging countries to pursue cross-border energy cooperation, e.g. facilitating grid interconnection, green hydrogen and ammonia trade, joint renewable projects and trade in green industrial intermediate products**. **It should recognise and profile the usefulness of decision-support tools that can quantify mitigation potential and costs arising from international cooperation**. Without such tools, negotiators, financiers and technical agencies working on cooperative NDC implementation are often working blind: existing high-level policy platforms surface many options with a low probability of success, while existing technical and implementation tools are too costly to use for open-ended, exploratory evaluation. Tools that bridge this gap allow parties to narrow a large option space down to a shortlist of cooperative pathways worth pursuing before committing significant technical or financial resources.

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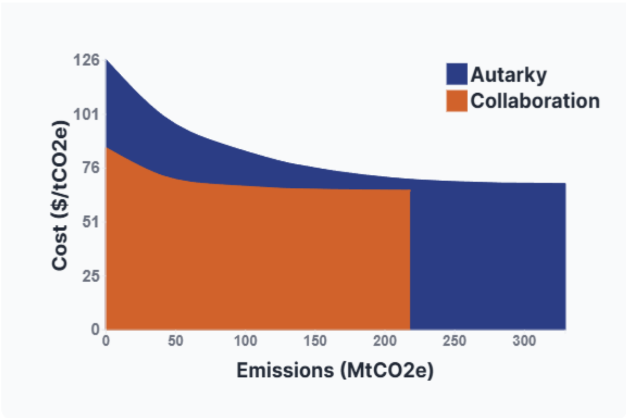
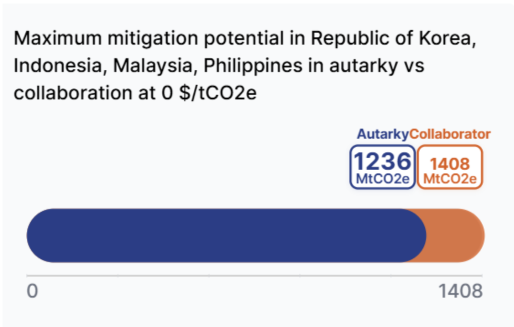
<u>Box Story: Example from the GMPA on quantifying mitigation cooperation opportunities between Southeast Asian countries and the Republic of Korea</u>

Pareto Abatement Cost (PAC) Curve of Korea-Indonesia-Malaysia-Philippines with and without collaboration.

(Note: The GMPA platform allows users to generate mitigation potential insights based on any combination of countries. The countries featured in this box story were selected to illustrate the GMPA's interactive features.)



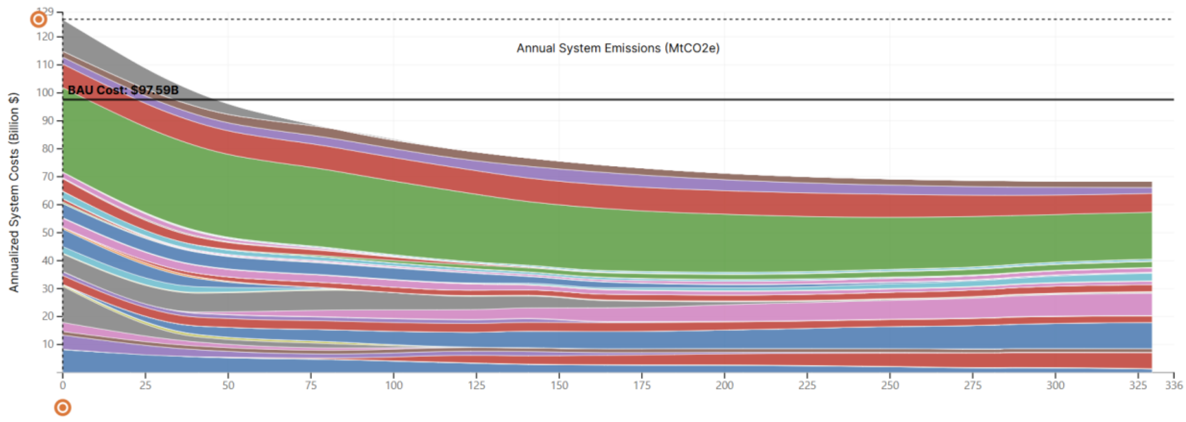


This shows the trade-off between costs and emissions to build a new system to meet 2050 demands for 30 years. The current system only models electricity end-use demand and high-temperature heating end-use demand to illustrate interplay between easy-to-abate and hard-to-abate sectors. The x-axes shows the annual emissions of the system, the y-axes shows the annualized costs of building the system. If we build a system with lower emissions, it will cost more, and vice versa. The PAC curve shows the pareto-frontier. "Autarky" curve shows the pareto-frontier without any physical trade of energy. The "Collaboration" curve shows the pareto-frontier with physical trade of energy. With collaboration, the pareto-frontier shifts to the bottom and to the left, creating strictly better solutions. Thus, systems with the same emissions can be built with lower costs. Furthermore, systems with the same costs can be built with lower emissions.

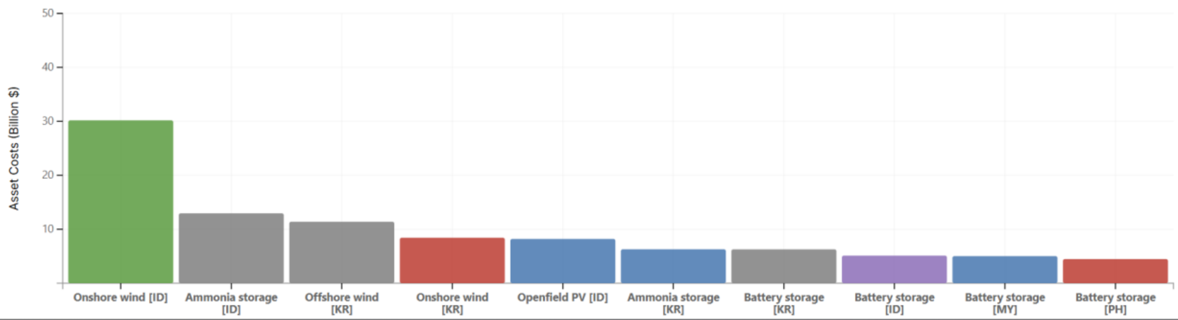
Preliminary results from the GMPA modelling indicate that:

- Cooperation between Indonesia, Malaysia, Philippines and Korea could raise the mitigation outcomes in the electricity and high temperature heating end-uses at no additional average cost by up to 12%. This translates to about 172MtCO2e mitigation per year (from 1236 MtCO2e p.a. to 1408 MtCO2e p.a.).
- The overall cost of net-zero systems can be reduced by up to 35% compared to fully siloed national pathways. This translates to about USD 45 billion reduction in annualised costs (from $129 billion p.a. to $84 billion p.a.).
- In this cooperation the costs of building a net-zero system were up to 14% lower than the cost of business-as-usual (from $98 billion to $84 billion)this translates to about $14 billion reduction in annualized costs..
- Thus, international cooperation can unlock simultaneously reaching net-zero and cost reduction.

Dynamic Pareto Abatement Cost Curve

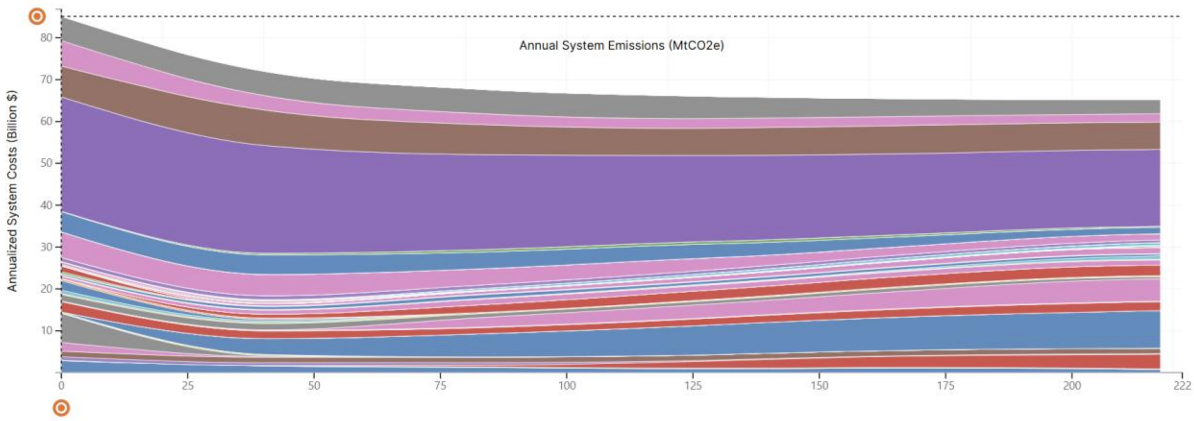


Assets in Cost-Optimal Technology Mix



Dynamic Pareto Abatement Cost Curve that shows the breakdown of the costs of actions to build system to meet demands. This graph shows the breakdown of actions for systems in Autarky, with no physical trade of energy.

Dynamic Pareto Abatement Cost Curve



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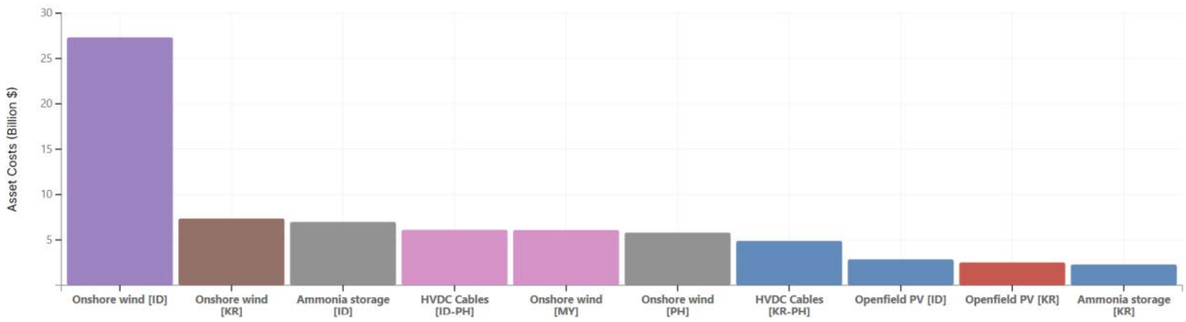

Dynamic Pareto Abatement Cost Curve that shows the breakdown of the costs of actions to build system to meet demands. This graph shows the breakdown of actions for systems in Collaboration, with physical trade of energy. E.g. trade of electricity through high voltage electricity lines from Indonesia to Philippines to Korea.