Baringa

The Corporate Catalyst

How cross-border renewable procurement can deliver a faster, cheaper, and more equitable energy transition

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This report has been commissioned by: amazon

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Foreword

The global transition to sustainable energy is not on track to meet the ambition of the Paris Agreement.

Development in the power sector has been leading the way in this transition, but progress has not been spread evenly – 85% of investment in renewable energy technologies has been made in nations home to less than 50% of the global population.

In this study we have explored how a change to the Greenhouse Gas Protocol, which sets the standards for carbon accounting globally, could help to address both of these issues by relaxing market boundaries for renewable procurement – and allowing corporates to catalyze the energy transition by investing in renewables with the greatest decarbonization potential.

Companies today seeking to buy renewable power must do so within the same 'market boundary' as their demand, typically defined by country borders, if they want it to be recognized.

This means that investment is then concentrated close to corporate demand centres, often in advanced economies that already offer other routes-to-market for renewables – 80% of deals to date have been inked in Europe and North America.

Our work shows that unlocking market boundaries and allowing corporates to invest in renewable projects with the greatest positive impact, regardless of location, could not only save much more carbon, but also help drive billions of dollars into emerging and developing economies each year.

Our study was commissioned by Amazon, a member of the Emissions First Partnership – a global group of companies with a shared goal of maximizing the decarbonization offered by corporate investment.

Amazon set the problem statement for us, but this study has been conducted independently by Baringa's team of experts.

The Corporate Catalyst quantifies the size of the prize that could be realized by prioritizing emissions impact and relaxing market boundaries for carbon accounting, not just the billions of tonnes of CO_2, but also a levelling of the global playing field for renewable investment.

While this change starts with a signature at the bottom of a document, it would need to be followed by a set of enablers such as a carefully designed cross-border mechanism, supportive national policies, and transparent access to data.

If these challenges can be met, our report shows that the substantial reward is a faster, cheaper, and more equitable energy transition.

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Unlocking 'cross-border' corporate procurement of renewables for maximum decarbonization impact could allow for a faster, cheaper, and more equitable energy transition

1.7 billion tonnes of CO_2 could be saved over the next 15 years

This is equivalent to taking **40 million cars off roads today** and **accelerating global power-sector decarbonization by 18 months.**

2040

Redistributed investment can decarbonize the global power sector for less than half the cost.

By 2040 an additional 90 gigawatts of solar and 65 gigawatts of offshore and onshore wind could be deployed, generating 325 terawatt-hours of renewable power each year.

$85 billion of corporate investment could be made into developing economies by 2040

This is **more than the total foreign direct investment** made into India, Indonesia and Vietnam combined in 2022.

825 thousand tonnes of coal could be left in the ground.

If adoption of a cross-border mechanism exceeds our conservative assumptions, billions more tonnes of CO_2 could be saved.

Baringa

1. Executive summary

1. Executive summary

More must be done to ensure a global energy transition that is fast, cost-effective, and equitable

The International Renewable Energy Agency (IRENA) has stated that the world is off-track to meet the climate commitments of the Paris Agreement, and annual investment in renewable energy must more than quadruple to remain on a 1.5°C pathway. To date, investment has been concentrated in a handful of advanced economies, with 85% of global renewable funding changing hands in countries home to less than 50% of the world's population.

Corporations have begun to play an important role in the energy transition, but must be enabled to do more to address these challenges. Last year, corporates supported a record 46 GW of solar and wind capacity via Power Purchase Agreements (PPAs), but almost 80% of these contracts were signed in Europe and the Americas. Emissions reporting standards today are defined by the Greenhouse Gas Protocol. They state that the value of a renewable energy project in decarbonizing scope 2 ('energy-use') emissions can only be recognized if it is in the same geography as the corporate that invests in it, or within a 'market boundary'. This leaves much of the world out of reach.

Our analysis suggests that corporates could help to decarbonize an additional 1.7 billion tonnes of CO_2 over the next 15 years

The amount of CO_2 a renewable project can displace from a market depends on the other generators present. If a market is dominated by carbon-intense coal-fired generation, then renewables will offer greater benefit than in a more decarbonized power grid.

By relaxing market boundaries in the Greenhouse Gas Protocol, and enabling corporates to recognize the value of renewable electricity regardless of where it is produced, 325 terawatt-hours (TWh) of annual corporate demand could be free to make cross-border investments in renewables that offer maximum decarbonization impact, more than the electricity consumption of the United Kingdom.

By accelerating the transition to renewable energy in economies that have seen little investment to date, this change to Greenhouse Gas Protocol policy could unlock 1.7 billion tonnes of CO_2 savings over the next 15 years, equivalent to taking more than 40 million cars off roads today. In 2040 alone, over 200 million tonnes of CO_2 could be avoided, more than the annual emissions from the German power grid last year. This single policy change could accelerate global power-sector decarbonization by 18 months, compared to our current trajectory, and send a strong market signal in geographies where renewable investment is most needed.

More than 80% of the displaced CO_2 is driven from power grids in Asia, as shown in *Figure 1*, with the greatest impact achieved in India (39%), Vietnam (16%), Indonesia (9%), and Malaysia (6%). These markets have attracted disproportionately low investment in renewables to date for their demand, population, and power-sector emissions. Note that China has been omitted from our analysis due to current sanctions restricting the ability of corporates to procure renewables in the country.

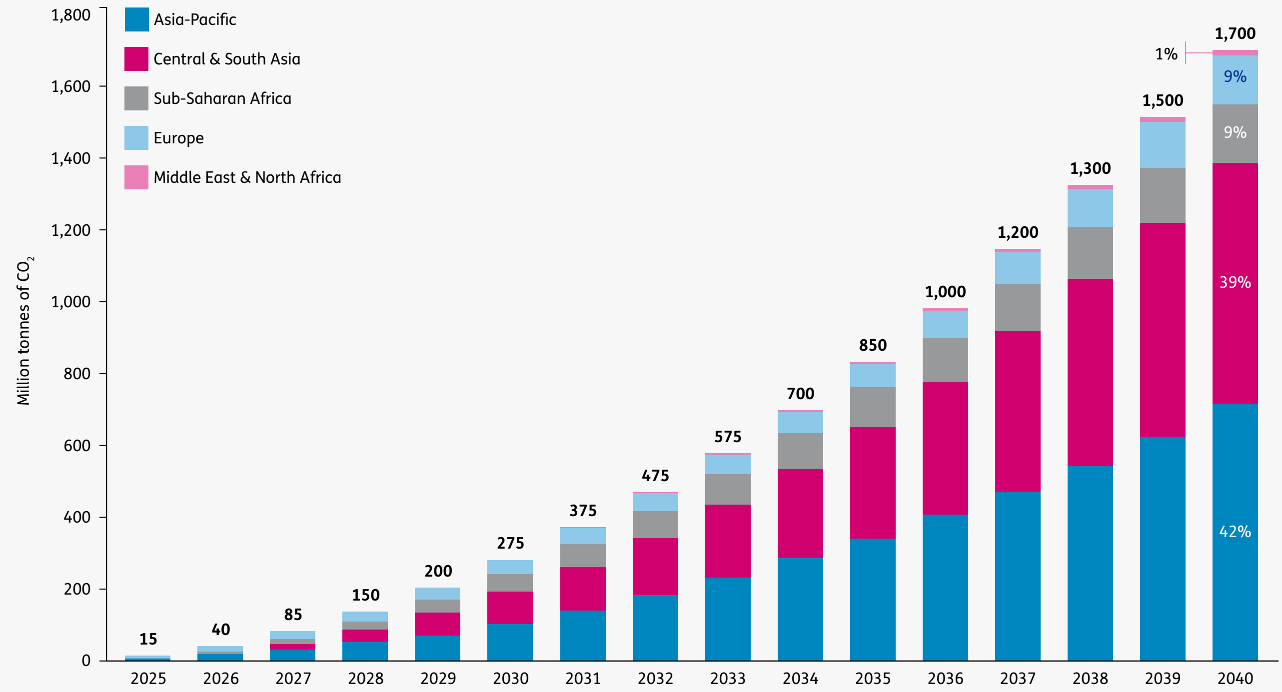


Figure 1: Projected cumulative reduction in CO_2 emissions from relaxing market boundaries, million tonnes of CO_2

Corporate investment could catalyze the global phase-out of coal-fired power stations

Our study suggests that mass decarbonization in South and East Asia would be driven by the displacement of 2,100 TWh of coal-fired power by 2040, leaving 825 thousand tonnes of coal in the ground. Homes and businesses would instead be powered by the output from 155 GW of wind and solar projects. By 2040 these generators are no more than 15 years old, and could go on to produce another 5,800 TWh of zero-carbon electricity.

The scale of these markets, and the dominance of coal on their grids, allows for significant headroom to deploy renewables without causing 'curtailment', which occurs when renewable generation exceeds demand, and some projects must be turned down. Relaxing market boundaries for corporate procurement postpones the need to invest in enabling infrastructure to manage curtailment by at least ten years, allowing time for these technologies, such as energy storage, to scale and mature.

Relaxing market boundaries would unlock a more equitable energy transition, driving $85 billion of investment into developing economies by 2040

This cumulative figure, which only accounts for capital from corporates headquartered in advanced economies, is more than the total foreign direct investment made into India, Indonesia and Vietnam combined in 2022.

Figure 2 presents the redistribution of capital between global corporate demand centres and economies most in need of renewable energy investment. A total of $112 billion is injected into emerging renewable industries in South and East Asia, Africa, and Eastern Europe.

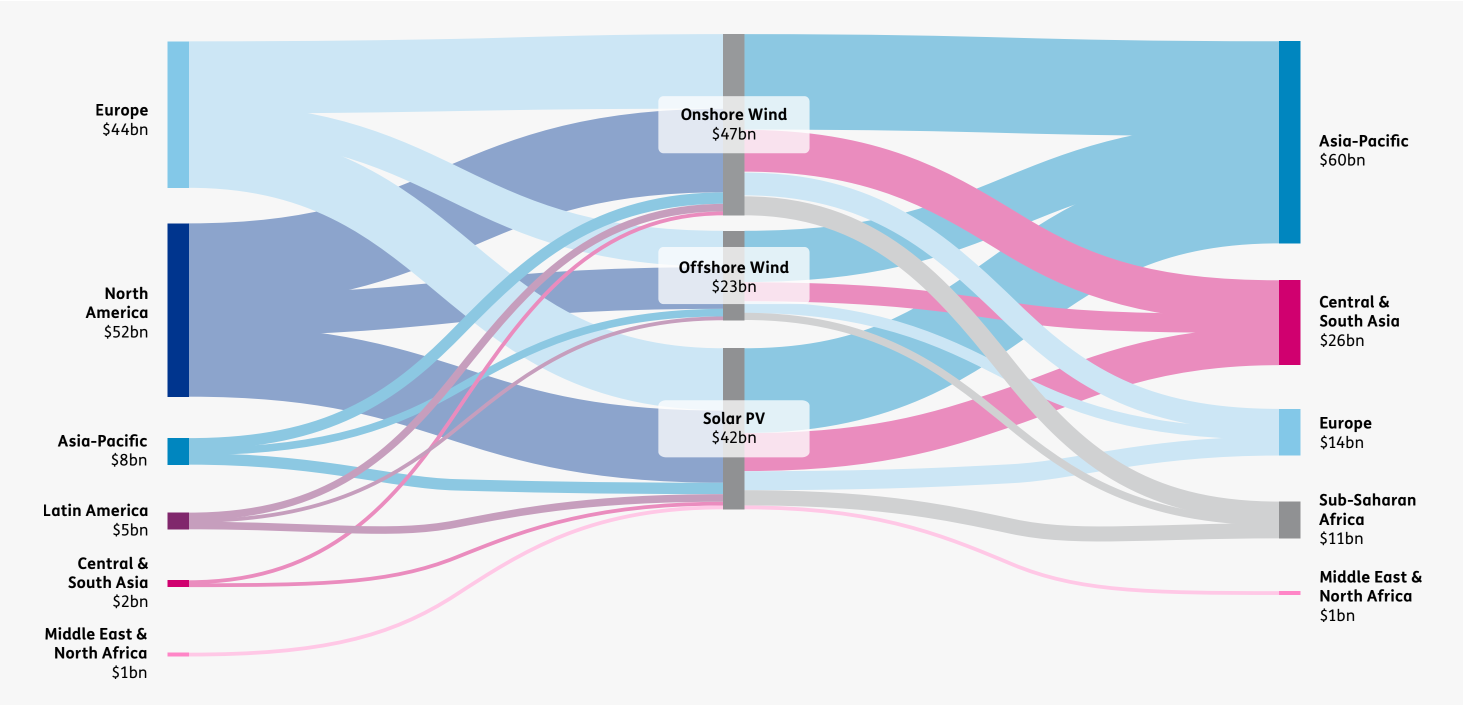


Figure 2: Cumulative capital flow between global regions, billion US dollars

Redistributed investment can decarbonize the global power sector for less than half the cost

As well as shifting investment to currently underserved markets, a borderless approach would also enable a lower-cost energy transition, by offering greater impact for each dollar spent.

The total investment cost of reducing carbon emissions through global cross-border procurement averages $65 per tonne of CO_2, less than half the cost compared to equivalent investment made within today's market boundaries. This is driven not just by the 60% greater decarbonization potential of renewables in these markets, but also a 20% lower cost of available projects per MWh.

The scale of coal use globally offers potential for billions more tonnes of CO_2 to be saved through sustained investment

The findings presented above assume a conservative outlook for corporate appetite for cross-border procurement. An annual demand of 325 TWh by 2040 has been assumed, calculated using the reported demand for renewable energy today by members of the RE100, a global group of companies committed to decarbonizing their energy use. This demand figure is representative of only the largest global corporates, leaving room for increased participation in this potential mechanism.

If corporate adoption reaches 660 TWh annually by 2040, a figure calculated using the total electricity demand of all RE100 members, not just demand for renewable electricity, the cumulative impact would almost double to 3.2 billion tonnes of avoided CO_2 emissions. This is more than the annual power-sector emissions of the European Union today.

Our analysis suggests that there is significant headroom to continue delivering decarbonization beyond this. *Figure 3* shows the further CO_2 savings that could be delivered by increasing addressable demand. Not until around 1,000 TWh of annual demand is reached are less-carbon-intense generation technologies, such as gas, displaced by the procured renewables.

If 6,000 TWh of demand was to be procured cross-border annually, 50% more than the total power demand of the United States today, the last renewables to be added in 2040 would still offer a greater impact than deploying renewables in California, Spain, or the United Kingdom today.

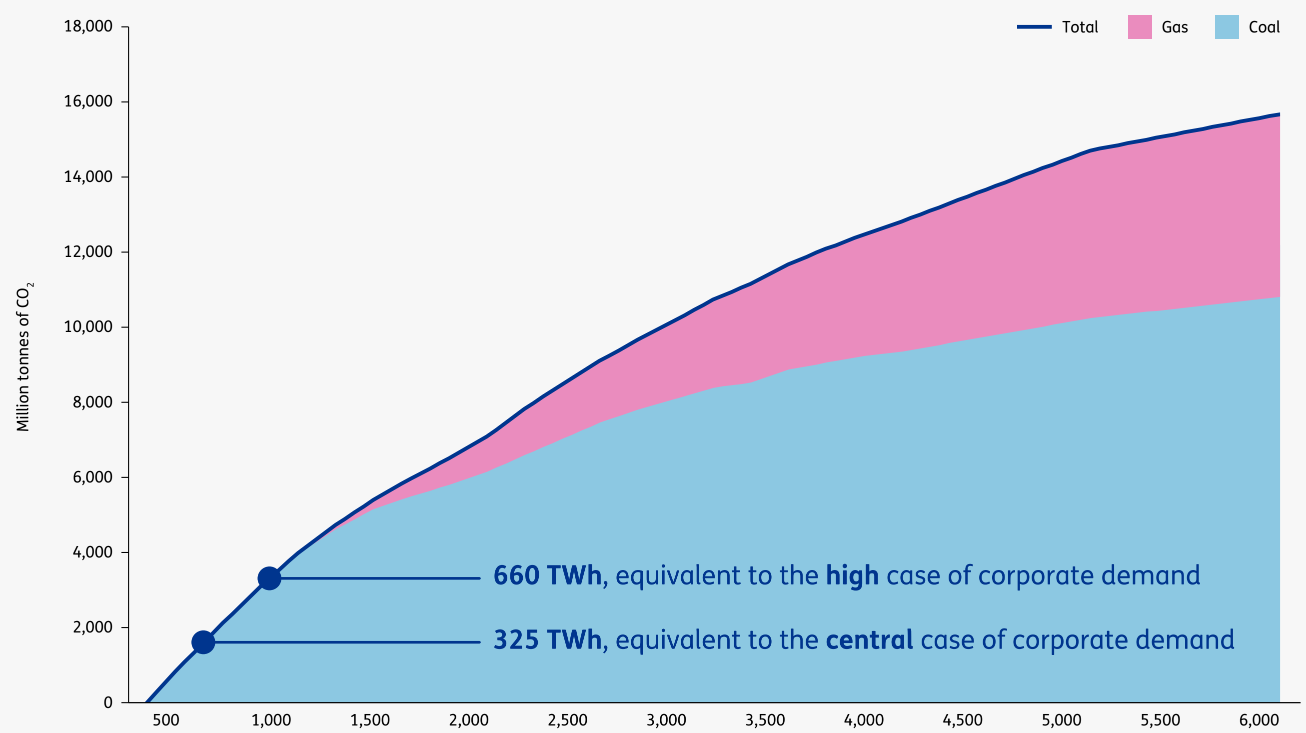


Figure 3: Projected 2025-2040 CO_2 savings as a function of corporate demand in 2040, million tonnes of CO_2

To achieve this impact, markets must adopt supportive policies for renewable development and cross-border investment

Many of the markets with the greatest potential are developing economies. To successfully drive coal from their power grids, these countries must ensure a stable policy and regulatory landscape, supportive of the widespread deployment of renewable assets. This is important to attract not just corporates to invest in renewables in these markets, but also developers, operators, and financial institutions, which all play a part in bringing new renewable projects online.

Another stumbling point for many countries and organizations is the availability of data. The quality and integrity of generation and emissions data is limited in some markets, posing a challenge for corporates wanting to invest and report their emissions.

The design of a cross-border procurement mechanism must consider potential political, market, and climate risks, to ensure the compelling results of this study are realized.

2. Introduction

2. Introduction

2.1 The Greenhouse Gas Protocol

The Greenhouse Gas (GHG) Protocol[1] provides standards, guidance, tools and training for businesses and governments to measure and manage climate-warming emissions. It was founded over 20 years ago from the partnership between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). In 2001 the first edition of the *Corporate Standard*[2] was published, which has since been updated with additional guidance and calculation tools to assist companies in their reporting of greenhouse gas emissions.

The GHG Protocol has become the default emissions accounting standard, with over 90% of Fortune 500 companies reporting to CDP[3] using its standards. The number of organizations using the *Corporate Standard* continues to rise globally as more companies disclose their climate impact, whether voluntarily, or as a result of mandatory reporting regulations.

The *GHG Protocol Corporate Standard* classifies emissions into three 'scopes':

- **Scope 1** emissions are *direct emissions from owned or controlled sources*. They include emissions from the burning of fossil fuels in a company's vehicle fleet.
- **Scope 2** emissions are *indirect emissions from the generation of purchased energy,* including electricity, which is the focus of this study.
- **Scope 3** emissions are *all indirect emissions* (excluding scope 2) *that occur in the value chain of the reporting company, including both upstream and downstream.*

2.1.1 The incumbent scope 2 reporting standards

The guidance for scope 2 emissions reporting was last updated in 2015 when the GHG Protocol introduced dual reporting to cover:

- **Location-based emissions:** The change in emissions as calculated using the annual average carbon intensity of the grid (kilograms of CO_2 per megawatt-hour) in which the organization operates, including any impact from on-site generation.
- **Market-based emissions:** The change in emissions as calculated via the organization's purchased electricity volumes, evidenced through Energy Attribute Certificates (EACs) within the same market boundary. If an organization purchases EACs to cover 100% of their annual electricity consumption, and these EACs are volumetrically matched to the consumption in the same market boundary, then the market based emissions become zero.

1 Greenhouse Gas Protocol
2 A Corporate Accounting and Reporting Standard, GHG Protocol
3 CDP

 |

Energy Attribute Certificates (EACs) are instruments for tracking the production, trade, and consumption of renewable electricity. Each certificate corresponds to a megawatt-hour (MWh) of renewable power, and can be traded between generators and consumers. Different markets use their own certification standards, for example much of Europe uses Guarantees of Origin (GoOs), the United States (US) and Canada use Renewable Energy Certificates (RECs), and countries including the United Kingdom (UK), Poland, Australia, Japan, and New Zealand have national standards.

While location-based emissions reporting can be an accurate method for electricity within a single power grid, and is the most easily applied in markets with limited data availability, it creates little incentive for corporates to invest in renewable energy beyond on-site generation.

To address this, market-based emissions reporting was introduced to create a mechanism for corporates to purchase EACs from generators within the same market boundary. This enabled corporates to report a decarbonization impact through the purchase of certificates, with the aim of driving more investment into renewable energy. The concept of market boundaries was introduced at this stage to ensure a closer link between power demand and generation.

2.1.2 The GHG Protocol consultation

In 2022 the GHG Protocol launched a consultation process to update its four main reporting standards, including scope 2 guidance. Around 400 survey responses were submitted, and 70 detailed proposals received, from a mix of bodies[4] for a new set of scope 2 reporting standards.

In December 2023, the GHG Protocol published a summary of the survey responses and proposals[5], which showed clear interest in updating the scope 2 accounting methods in three key areas:

1. Improvements to the location-based method to improve locational granularity by using grid-specific carbon intensities, rather than country-wide, for example in the US. The ambition is to also switch to hourly carbon intensities where consumption data is available hourly.
2. Improvements to the market-based method in line with those suggested for location-based. This would mean closer alignment between when and where renewable power is generated, and when and where it is consumed by the corporate. The aim is to ensure that scope 2 reduction claims made via EACs more closely reflect real-world changes in greenhouse gas emissions.
3. Elevation of the role of, and improvements to, emissions impact reporting for projects and interventions, to capture system-wide benefits of electricity-related developments. This seeks greater emphasis on the reporting of project-based assessments and to introduce mandatory emission disclosure regulations.

The third point would signify one of the largest changes to corporate emissions reporting and renewable procurement since the introduction of dual reporting standards in 2015. It could allow companies to recognize avoided emissions from investment in renewable

4 194 companies, 65 consultancies, 40 industry groups, 37 non-profits, 12 academic bodies, 9 government institutions, 4 GHG reporting initiatives, 3 electricity grid operators, and 2 international agencies.

5 Scope 2 Proposal Summary, GHG Protocol

energy projects, alongside induced emissions from energy consumption due to their own operations. It proposes that avoided emissions could be claimed from projects located outside the market boundaries of the company's operations. It is undecided if this will be introduced instead of, or in addition to, incumbent reporting methods.

The aim is to finalize and publish the updated standards and guidance in the next 12 to 24 months. Ahead of this, the GHG Protocol has formed a new governance structure to oversee the standards development process and ratify any decisions, ensuring suitable feedback is gathered throughout.

2.2 The case for change

2.2.1 Corporate demand for renewable energy

To date, corporate investment in renewable generation projects has been concentrated in their markets of operation, with nearly 80% of corporate Power Purchase Agreement (PPA) deals in 2023 signed in Europe and the Americas[6]. One of the key drivers behind this has been the requirement for corporates to recognize their scope 2 decarbonization impacts within the same market boundaries as their demand. Market boundaries are usually defined by country borders, although there are a few exceptions; several markets in Europe are within a single market boundary, as are the US and Canada[7].

This requirement continues to contribute to the enduring geographical inequality in the growth of renewable capacity. Despite global investment in renewables reaching record highs of $358 billion in the first half of 2023[8], the International Renewable Energy Agency (IRENA)[9] reports that there are significant geographical disparities, with over 50% of the world's population receiving only 15% of global investments in 2020[10]. In 2021, European investment per capita in renewables was 41 times that in Sub-Saharan Africa. In North America, it was 57 times more. Availability and accessibility of renewable projects has also influenced the volume and distribution of corporate investment to date.

6 Corporate Clean Power Buying Grew 12% to New Record in 2023, BloombergNEF

7 Cross-border renewable procurement is already recognized through trade of RECs across the US and Canada. GoOs can also be traded across power markets in most of the European Union (EU), as well as Norway, Iceland, Serbia, and Switzerland. Four EU states are currently unable to trade GoOs across markets: Bulgaria; Malta; Poland; and Romania. Limited recognition is in place in other European markets.

8 Renewable Energy Investment Hits Record-Breaking $358 Billion in 1H 2023, BloombergNEF

9 IRENA

10 Global Landscape of Renewable Energy Finance, IRENA

Figure 4 below shows the share of electricity demand met by renewable sources, as reported by members of the RE100[11]. The RE100 is a global corporate renewable energy initiative with more than 400 large businesses as members that together procure over 500 terawatt-hours[12] (TWh) of power annually[13], and are committed to 100% renewable energy by 2050, or before. The RE100's aim is to accelerate the transition towards zero-carbon power at scale, and it encourages members to bring forward their target dates for scope 2 decarbonization.

The figure shows the relativity between the penetration of renewables in Europe and the Americas, compared to much of Africa and Asia. In a number of these markets, it is more difficult to contract with renewables, and, in the case of Africa, fewer corporates have demand.

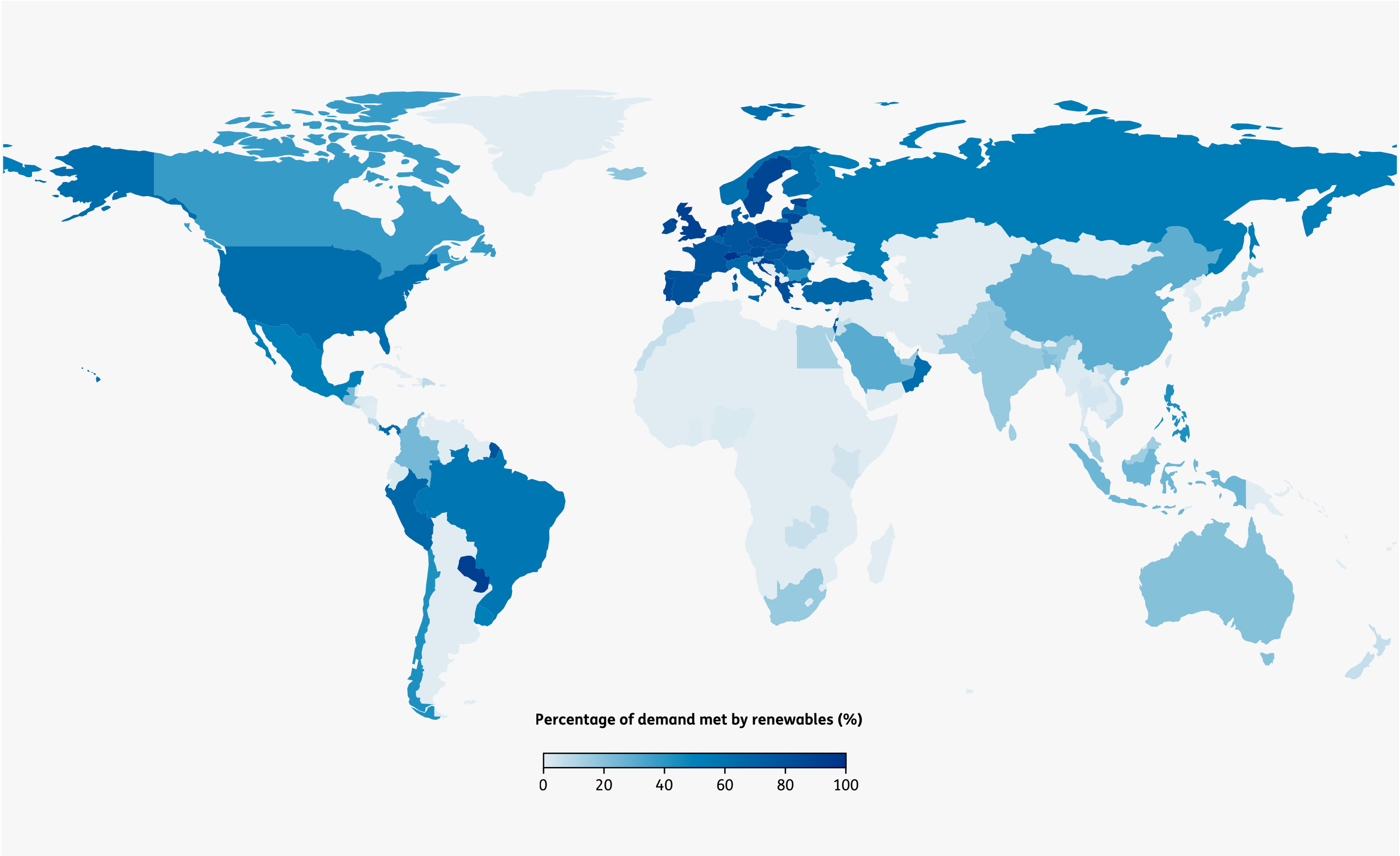


Figure 4: Percentage of RE100 member demand met by renewable sources

To ensure a just and equitable energy transition, there is a need to maximize investment, and redistribute it to markets that have been underserved to date. Corporate investment offers a unique opportunity to drive capital into economies that are most in need, and in which it can have the greatest decarbonization impact.

11 RE100

12 A terawatt-hour (TWh) is equal to a thousand gigawatt-hours (GWh), a million megawatt-hours (MWh), or a billion kilowatt-hours (kWh).

13 RE100 members exceed the annual electricity demand of France, RE100

2.2.2 Rationale for relaxing market boundaries

According to analysis by IRENA, the world is off-track to meet the climate commitments of the Paris Agreement[14]; annual investment in renewable energy must more than quadruple if the world is to remain on a 1.5°C pathway[15]. Climate change requires the world to decarbonize as much as possible, as fast as possible. Due to the fact that fossil fuel-fired assets keep emitting every year, the sooner they are displaced from the global power system, the greater the reduction in cumulative emissions. If the objective is to maximize decarbonization as quickly as possible, then there are two key limitations to current dual reporting standards:

1. Corporate renewable procurement is concentrated in markets in which they operate, rather than in markets that could offer the maximum decarbonization impact.
2. In markets with little renewables development opportunity, or no mechanism to contract with renewables assets (e.g. Singapore), corporates are left with few options to invest in renewables and claim the decarbonization benefits, effectively blocking investment.

Relaxing market boundaries globally, and enabling corporates to procure renewables regardless of geography, could allow corporate investment to be directed to markets that are dominated by carbon-intense generation technologies. An additional MWh of renewable generation in South Africa this year could displace up to 1,100 kilograms of carbon dioxide (kgCO_2) due to the dominance of coal-fired capacity on the grid. An equivalent renewable MWh in the Netherlands would displace around 350 kgCO_2, due to the penetration of renewables and gas-fired generation. By creating a robust mechanism that enables corporates to invest in renewables across borders globally, capital would be redirected to economies with limited renewable build-out to date, helping to achieve a more equitable decarbonization trajectory worldwide.

Arguments against relaxing market boundaries and enabling ‘cross-border’ renewable procurement have tended to focus on a potential ‘race to the bottom’, in which renewable investment in markets with higher costs is replaced by alternative options in lower-cost markets. The concern is that investment would cease in higher-cost markets, which would then slow their pace of decarbonization. However, if the overall objective of renewable procurement is to maximize and accelerate decarbonization globally, then the Greenhouse Gas Protocol accounting system should permit investment in markets that offer the greatest carbon savings per dollar.

14 Paris Agreement
15 World Energy Transitions Outlook 2023, IRENA

2.2.3 The role of corporate PPAs in procuring renewable power

As more companies seek to decarbonize their emissions and manage exposure to volatile power prices (and rising EAC prices), increasing numbers are signing PPAs to contract directly with renewable energy generators. In more mature markets with renewable development already underway, and in which the political and regulatory landscapes are supportive of the widespread deployment of renewable power, PPA markets have expanded rapidly.

A PPA is a long-term contract (usually 10-15 years) between energy buyers and sellers, for example, between a corporate (the energy buyer) and a renewable generator (the energy seller). A PPA serves two key purposes:

1. For the energy buyer (corporate) it secures their access to renewable energy at a fixed price and enables them to claim a reduction on their scope 2 emissions.
2. For the energy seller (renewable generator) it provides a 'bankable' revenue stream that enables them to raise financing, e.g., from a bank, to build the wind or solar asset. This is because it provides a guaranteed revenue stream and therefore de-risks the bank's lending.

For the PPA market, and the renewable market more broadly, to be successful, it is important to have active market participants across buyers, sellers, and financers (the banks and other institutions providing the capital for the renewable projects).

There are two main structures available for PPAs:

- **A physical PPA** where power is 'sleeved', or physically transferred, from the generator to the buyer. This is the most common structure in most markets but requires the power generation and consumption to exist within the same electricity grid, i.e., to have a physical connection.
- **A virtual, or financial, PPA** where the two parties agree to a 'strike price' for the electricity, which is generated and sold into the local wholesale market. If the wholesale power price is below the strike price, then the buyer pays a 'top up' to the strike price. If the wholesale power price is above the strike price, then the generator pays back the extra money to the buyer, therefore always receiving the strike price for the power. The difference compared to a physical PPA is that the buyer does not need to physically receive the electricity from the generator. This allows virtual PPAs (vPPAs) to be suitable for cross-border procurement, in which physical transfer of electricity is often not possible; they have been more common to date in cross-market deals in North America and Europe.

vPPAs have been adopted by corporates and generators as a 'hedge' against physical power exposure in a market, i.e., they act to mitigate risk for both parties by locking in a price for generated and consumed electricity. Adopting vPPAs as a mechanism for cross-border procurement removes some of this benefit, as the corporate becomes exposed to movements in the power price of a second market, which may be less predictable. There are other practical considerations of a cross-border agreement, including international tax and accounting rules for vPPAs, which have already become an obstacle for corporates trying to procure within EAC boundaries today. Political risk, foreign exchange exposure, and climate risk also need to be considered in cross-border arrangements.

In the absence of another mechanism for cross-border renewable procurement that supports the deployment of new assets, we have assumed that vPPAs, or an equivalent, are employed for cross-border procurement. It is vital that the ultimate design of such a mechanism considers and mitigates any potential barriers, points of friction, and risk in cross-border procurement, to ensure the results of this study are realized.

2.3 Overview of this report

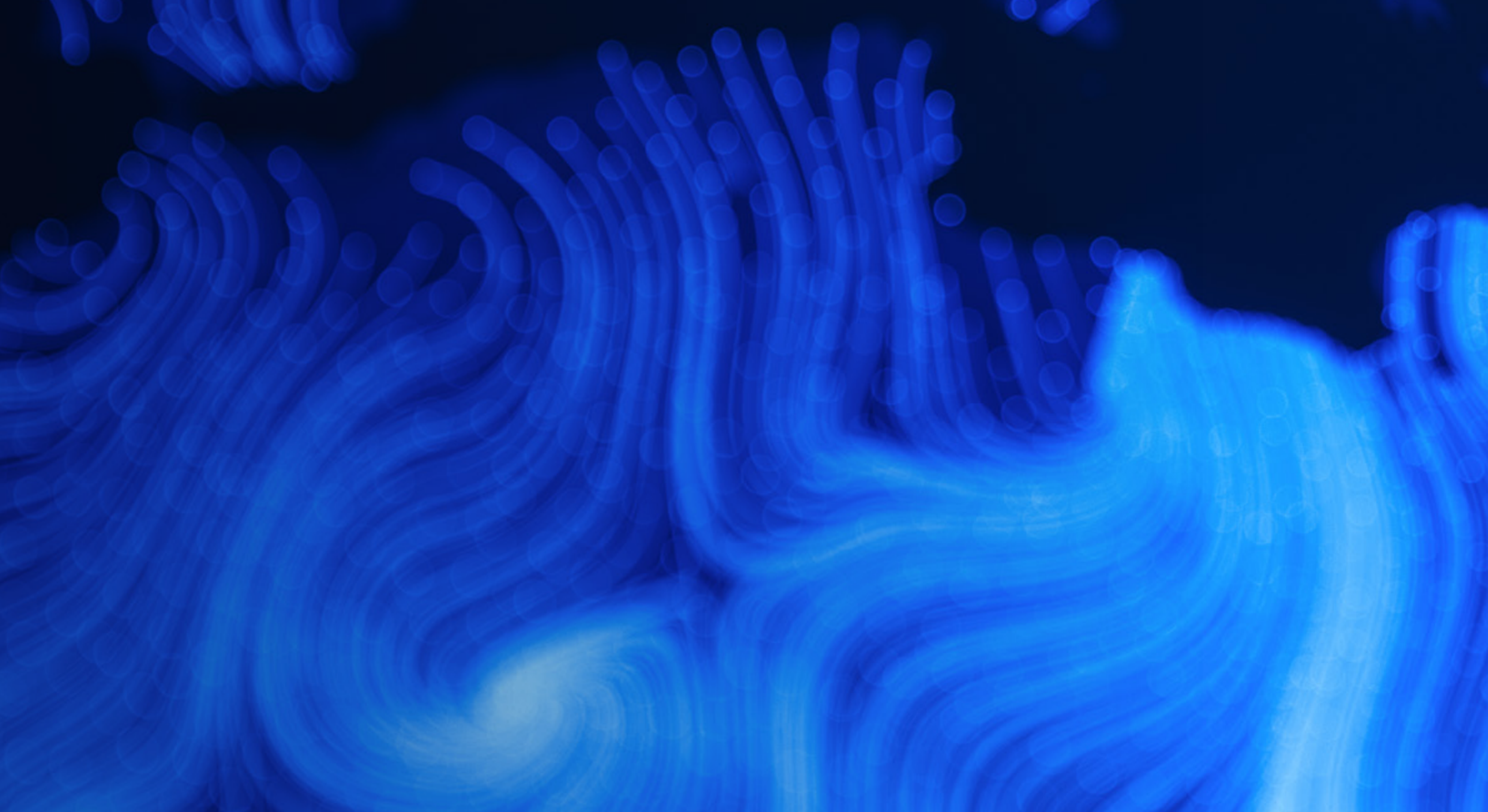
The aim of our study is to quantify the potential decarbonization impact of removing or relaxing market boundaries within scope 2 reporting standards. This could be enabled through a change to the existing market-based reporting standards, or by the creation of a new standard.

To understand the relationship between cross-border renewable procurement and decarbonization, we have modelled the emissions impact of deploying additional renewable capacity in different power markets. This report explores the results and insights gained from our analysis, as well as providing a detailed explanation of the methodology, data inputs, and assumptions that underpin it:

- Section 2 provides an overview of the key assumptions and methodology used in our analysis.
- Section 3 presents the results and insights of our study, including several sensitivities that have been explored to understand the range of decarbonization that might be achieved.
- Section 4 summarizes the key findings of the study.
- Appendix A contains additional information on our assumptions and modelling methodology.
- Appendix B contains supplementary input data presented at a regional level.
- Appendix C provides a selection of our other publications.

Note that all monetary values in this report are presented in real 1st of January 2024 US dollars.

3. Assumptions and methodology



3. Assumptions and methodology

3.1 Input assumptions

3.1.1 In-scope markets

We have identified 64 'in-scope' markets which define the geographies covered by our analysis. These 64 markets make up 95% of global electricity demand outside of sanctioned, or economically or politically fragile jurisdictions. Note that we have excluded China due to current trade restrictions, and sanctions enforced by the EU, UK and US. Throughout this report, 'global' results represent the impact as modelled for these markets.

To assess each in-scope market, we have categorized them into six groups, each characterized by a similar carbon intensity and proportion of renewable generation. One market from each group has been selected as an 'archetype'.

We have then used hourly power market data for the six archetypes, with a series of adjustments, to represent the 64 in-scope markets in our assessment of the decarbonization impact from additional wind and solar capacity.

Figure 5 below presents the results of this market classification, with archetype markets labelled in bold.

Much of the electrical system in the US is managed by seven Independent System Operators (ISOs). These are federally-regulated entities tasked with coordinating, controlling, and monitoring the power grid in specific geographical, multi-state, areas. The ISOs operate distinct competitive wholesale power market arrangements, each of which has been included within this study. Two of the ISO regions, the Southwest Power Pool (SPP) and Pennsylvania-New Jersey-Maryland Interconnection (PJM), have been selected as archetypes in our study and can be seen in Figure 5 on the next page..

Further detail on our market selection and archetype methodologies can be found in Appendix A.1, and additional detail for each in-scope market can be found in Table 3 in Appendix B.

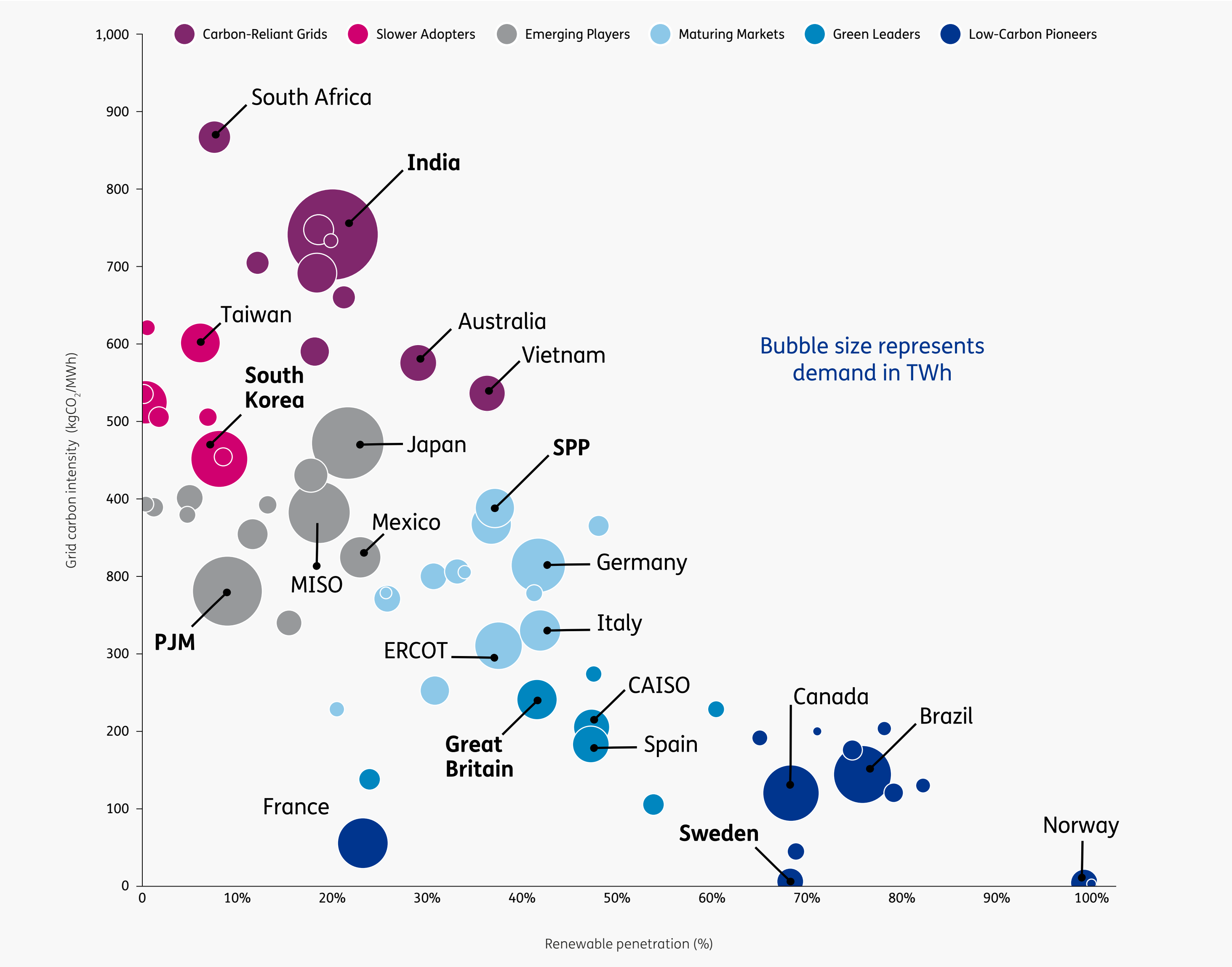


Figure 5: Archetype groups for our in-scope markets, determined by their renewable share (%), carbon intensity (kgCO_2 per MWh) and demand (TWh)[16]

3.1.2 Addressable corporate demand

We have applied a conservative estimate in considering the volume of corporate demand that may participate in a global cross-border procurement mechanism, using data reported by the RE100[17].

We have considered market-level corporate demand met by procurement of PPAs and EACs, as well as total reported consumption, and projected these values forward to 2040. We have applied a 20% uplift to our figures to account for large corporates that are not members of the RE100, but that are committed to decarbonizing their scope 2 emissions.

16 GB refers to Great Britain, and MISO and ERCOT denote the Midcontinent Independent System Operator and Electric Reliability Council of Texas respectively, two of the US ISO zones.

17 Driving renewables in a time of change, RE100

Our assumptions account for participation from only the largest corporates; we have excluded any potential demand from small- and medium-sized businesses that could add significant uplift to our findings.

Figure 6 below presents the three corporate demand scenarios we have modelled in this study.

Further detail on our addressable demand methodology can be found in Appendix A.2 and a breakdown of demand values by region and archetype group are presented in Table 4 in Appendix B.

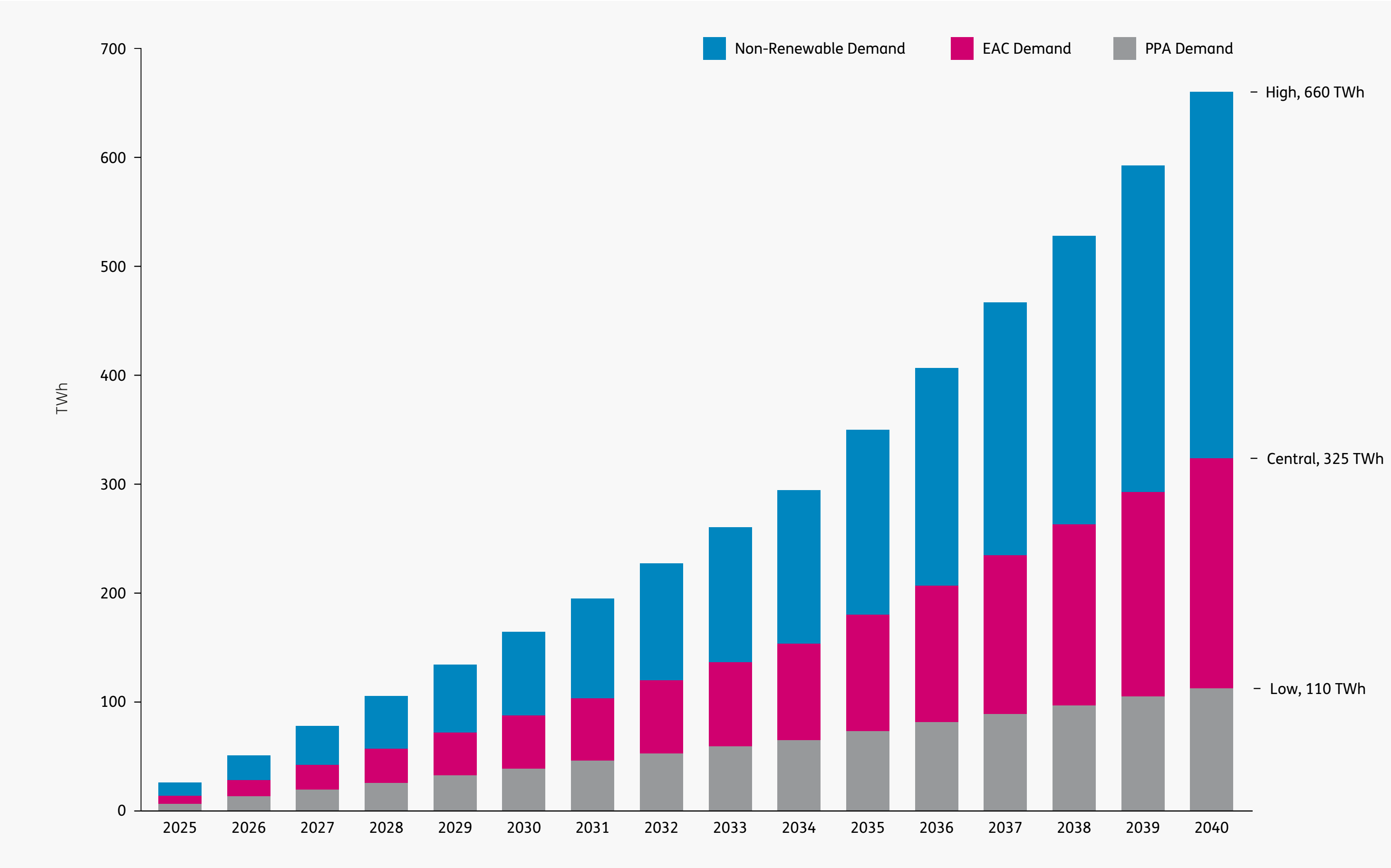


Figure 6: Projected addressable demand by historical procurement method, TWh

3.1.3 Defining the counterfactual and 'additionality'

We have modelled the impact presented in this study relative to a counterfactual projection of future generation mix in each market, including renewable build-out. This counterfactual is based on government policy, market economics, and trends in corporate procurement, and is represented by the 'Baringa Reference Case', our central view for the evolution of power markets globally.

The Reference Case applies a critical lens to ambition towards renewable capacity development and power-sector decarbonization, overlaying a view of constraining factors based on real policies today. This counterfactual assumes that the current scope 2 emission reporting standards continue.

Any incremental renewable volume procured by corporates in our analysis has been considered 'additional' to this counterfactual view. We have assumed that a mechanism is in place that allows for cross-border procurement of additional renewables, analogous to a vPPA, which provides a bankable revenue stream that enables the renewable project to be funded and exist. This is described in more detail in Section 1.2.3.

It is possible that by moving to a global cross-border procurement framework, markets in Europe and North America, which would otherwise receive the majority of corporate capital, would see reduced investment. In this case it is assumed that, given the number of routes-to-market available for renewables in these markets, reduced corporate investment does not materially impact their power-sector decarbonization.

Further detail on our counterfactual scenario, and the power market data used in this study, can be found in Appendix A.3.

3.1.4 Renewable deployment constraints

We have applied market-level development constraints for renewables to ensure that our model does not exceed practical limits. These constraints, projected using historical trends and Reference Case data, are applied to both the total renewable generation, and to the ratio of solar photovoltaics (PV), onshore wind and offshore wind in each market.

Our model also prevents corporates from procuring renewables in 13 markets until 2030, reflecting the fact that PPAs have yet to be signed in these geographies, and time is likely required for PPA offerings to mature. We have excluded these markets based on data published by the RE100.

Further detail on our deployment constraint methodology can be found in Appendix A.4, and a summary of indicative constraint values is presented in Table 5 in Appendix B.

3.1.5 Cost assumptions

To estimate the financial investment required to unlock the decarbonization benefits calculated in this study, and the flow of capital between economies, we have taken a levelized cost of electricity (LCOE) approach. This is a measure of the overall cost per MWh of generation over a project's lifetime, and can be calculated by adding up all costs, from financing through construction, operation, and decommission, and dividing by the lifetime electricity production. We have not accounted for any cost savings from displaced generation, e.g., the fuel costs of a coal-fired generator, or the cost of any infrastructure besides the renewable projects.

Our LCOE assumptions have been sourced from publicly available data, market intelligence, and internal modelling.

Further detail on our cost assumptions can be found in Appendix A.5, and a summary of LCOEs is presented in Table 6 in Appendix B.

3.2 Modelling methodology

3.2.1 How do we work out the impact of renewables?

Wind and solar assets have zero associated 'fuel cost' and therefore are effectively free to run once they have been built, setting aside any maintenance costs. This zero-marginal-cost nature incentivizes them to bid into power markets at a value of, or around, 0 $/MWh, as this is their breakeven price.

A merit order is the stack of power generators within a market, ranked from lowest to highest bid price, that are available to supply power over a given period[18]. The 'marginal' generator is the plant with the highest accepted bid price in that period, i.e., the most expensive generator needed for electricity supply to match demand. In power markets globally, the marginal generator is typically a fossil fuel-fired asset in most periods. As fuel costs increase with decreasing efficiency, the marginal generator typically has a carbon intensity greater than the average of generating assets in that hour, i.e., the 'marginal carbon intensity' of a market is usually higher than the average carbon intensity.

Adding renewable generation to the bottom of the merit order stack will displace generation at the top of the stack, as the level of demand has not changed. This pushes the marginal generator, and potentially generators below it, 'out of merit'. If any of these displaced generators are fossil fuel-fired, then the total CO_2 emissions from power generation in that time period is reduced.

We have recreated this process in this study, evaluating the CO_2 emissions displaced from the marginal generator, and any below it, from deployment of renewables. This analysis is performed on an hourly basis for each for the in-scope markets between 2025 and 2040, one year at a time.

The volume of displaced CO_2 emissions we have calculated is known as the 'Locational Marginal Emissions' (LME). This approach more closely matches the real-world impact of deploying intermittent renewable generation compared to an assessment using average carbon intensities, which do not consider the variable generation profiles of wind and solar projects, or the specific generators being displaced. Note that this value has been calculated at the day-ahead market stage and at the market or system level, rather than for individual nodes. Our calculation considers the evolution of each market's marginal carbon intensity over time, accounting for external factors such as government-backed renewable deployment and retirement of carbon-intense plant, and the sustained impact of renewables procured by corporates in this study. Our results therefore include what is known as the 'Build Margin' (BM), alongside the 'Operating Margin' (OM), and represent the 'Long-Run Marginal Emissions' (LRME) impact of deployed renewables. Note that this does not consider 'embedded' emissions associated with construction and decommission of assets.

18 Note that not all power market arrangements have auctions that result in merit orders in this way, though this remains a good approximation for the impact of incremental renewables under other mechanisms.

Figure 7 below shows this process occurring in a representative hour of one of our model simulations. The merit order is that of SPP, one of the regional markets of the US. Before the impact of corporate procurement, the average carbon intensity of generation stands at 550 kgCO_2 per MWh but the marginal generator, a coal-fired asset, emits 925 kgCO_2 per MWh. Corporate procurement results in 6,000 MWh of renewable generation being added to the merit order in this hour, displacing almost 6,000 tonnes of CO_2 (tCO_2) from the market.

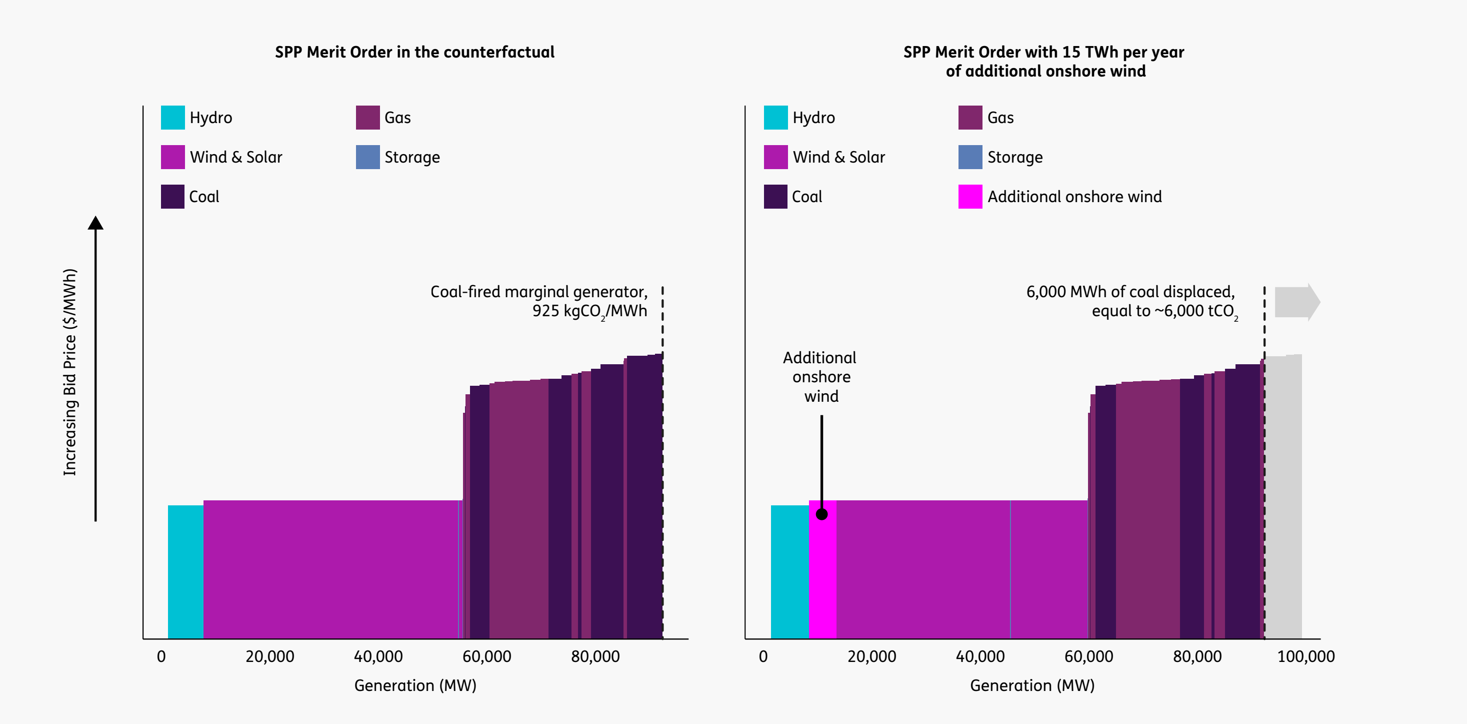


Figure 7: The impact of incremental renewables on the SPP merit order in a representative hour

3.2.2 How does our model work?

We have developed the **Scope Two Emissions Accounting Model (STEAM)**, with the aim of assessing the emissions impact of corporate renewable procurement across geographies. We have used STEAM to quantify the findings of this study and calculate the global decarbonization unlocked by a global approach to renewable procurement.

We have configured STEAM with the assumptions presented throughout Section 2.1, and simulated the global deployment of renewables under a cross-border mechanism. The model process runs in two key steps:

1. STEAM first calculates the marginal carbon intensities of each market for a given year, and assigns corporate procurement volumes (totalling the addressable demand in that year) to markets from most to least carbon-intensive, i.e., starting with the markets that offer the greatest decarbonization potential.
2. STEAM then determines the hourly generation, and CO_2 emissions, that the incremental renewables displace from each market in that year.

A detailed account of the model architecture and optimization process of STEAM can be found in Appendix A.6.

3.3 Notable exclusions

STEAM considers the deployment the renewable assets only and does not consider any requirement to upgrade grid infrastructure that may be necessary to bring additional renewable assets online. Similarly, we have not included any deployment of enabling technologies, such as energy storage, interconnection, demand-side flexibility, or synchronous condensers. We have assumed that much of the associated costs will be paid and accounted for via other mechanisms, for example via energy bills or government subsidies, as a result of growing pressure on governments around the world to decarbonize their power sectors. We have assumed that, with the right market signals, this will persist even in the absence of widespread cross-border procurement. These costs therefore sit outside the remit of our analysis.

We have assumed that additional corporate renewable procurement is enabled through deployment of solar PV, onshore wind, or offshore wind. Corporate procurement of hydro, biofuel, or nuclear generation has not been considered in this study, and neither has the deployment of carbon capture, utilization and storage (CCUS) technologies.

All results presented in this report are calculated from day-ahead market schedules, without consideration of energy balancing, ancillary services, or network constraints.

Detail on additional out-of-scope assumptions for this study can be found in Appendix A.7.

4. Results and implications

4. Results and implications

4.1 Cross-border procurement

4.1.1 Decarbonization impact

The International Energy Agency[19] (IEA) estimates that annual global energy-related CO_2 emissions reached their highest ever level of 37.4 billion tonnes in 2023[20]. This represents an increase of 410 million tonnes ($MtCO_2$) from 2022, with emissions from the burning of coal accounting for two-thirds of this increase. Conversely, the growth in low-carbon electricity sources (including wind, solar, and nuclear) since 2019 has prevented 2023's total from increasing by a further 2.7 billion tonnes.

In our counterfactual, based on our Reference Case and the archetype methodology described in Section 2.1.1, power-sector CO_2 emissions for the in-scope markets decrease by almost 45% from 2024 to 2040. This steady decrease is primarily driven by the deployment of renewable generation across each archetype group. However, more must be done to accelerate and deepen the transition, if the world if to stay on track for Paris climate commitments and decarbonize power grids globally.

Our study has explored the role that corporates can play in accelerating this transition through cross-border procurement of renewables. We have quantified the decarbonization impact of deploying additional renewable capacity in geographies of maximum impact, accelerating the reduction of global emissions relative to this baseline.

Figure 8 below presents the annual carbon abatement, or reduction in carbon emissions, achieved in different global regions by the additional deployment of wind and solar capacity, enabled through a cross-border procurement mechanism. In 2040 alone, a total of around 205 $MtCO_2$ is avoided, equating to a 6% reduction of the global counterfactual scope 2 emissions in that year, and more than the 2023 power-sector emissions of Germany[21].

The cumulative carbon abatement impact of cross-border procurement totals more than 1.7 billion tonnes of CO_2 by 2040, enough to accelerate global power-sector decarbonization by around 18 months.

Due to the scale and dominance of coal use in their power sectors, around 80% of the decarbonization impact across the horizon is concentrated in five countries:

- **India:** 37% of the total scope 2 decarbonization, around 640 $MtCO_2$.
- **Vietnam:** 16% of the total, or 280 $MtCO_2$.
- **South Africa:** 10% of the total, or 170 $MtCO_2$.
- **Indonesia:** 9% of the total, or 160 $MtCO_2$.
- **Poland:** 9% of the total, or 150 $MtCO_2$.

19 IEA
20 CO_2 Emissions in 2023, IEA
21 Electricity Generation in Germany in 2023, Fraunhofer Institute for Solar Energy Systems (ISE)

The remaining 20% of the benefit comes from Australia, Malaysia, the Philippines, Kazakhstan, and Morocco; the other markets within the Carbon-Reliant Grids, the archetype group that offers the greatest potential carbon saving due to the prevalence of coal-fired generation. A full breakdown of in-scope markets and region classifications is provided in Table 3 in Appendix B.

The results have been calculated using the 'central' demand assumptions presented in Section 2.1.2, being projected based on RE100 member demand for renewable power demonstrated using PPAs and EACs. There is the potential for the cumulative decarbonization impact to almost double to 3.2 billion tonnes by 2040, should addressable demand increase to the equivalent of the RE100's total electricity demand. In Sections 3.2 to 3.4, we explore a range of possible outcomes, depending on the level of corporate demand, and the definitions of market boundaries.

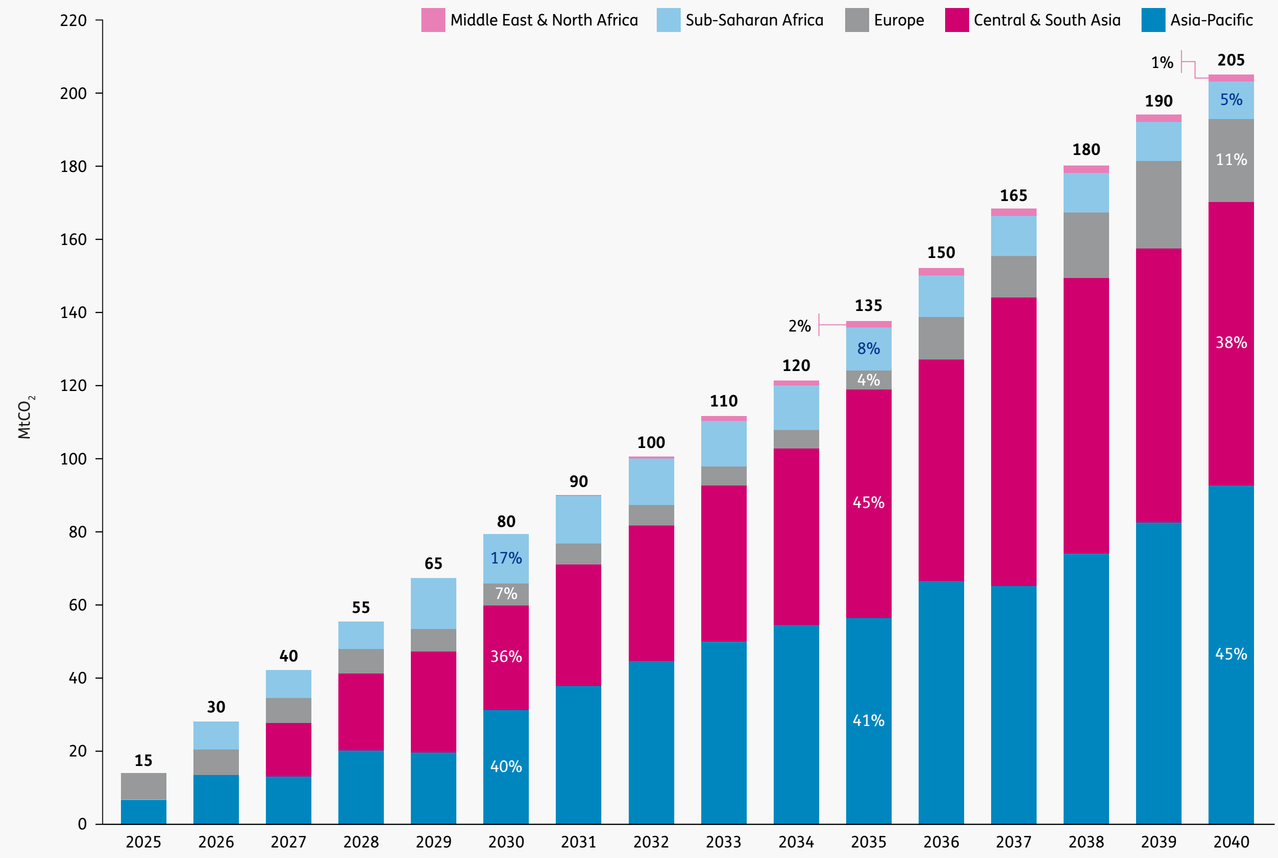


Figure 8: Annual abatement in power-sector CO_2 emissions from cross-border procurement, $MtCO_2$

Despite the increasing penetration of zero-carbon generation technologies in the Carbon-Reliant Grids over the horizon, enabled through sustained corporate procurement, the relative scale of the markets compared to the global addressable demand means that the model does not need to build renewables in other archetype groups. In 2021, the total power demand of the Carbon-Reliant Grids totalled almost 3,000 TWh, more than nine times the central addressable corporate demand projected for 2040.

The particularly large market size of many of the Carbon-Reliant Grids leads to two key effects:

1. The renewable build constraints are rarely reached in the model optimization, allowing relatively free choice of market for renewable build by the model. In cases where limits are reached for a given market, there is 'space' in other Carbon-Reliant Grids.
2. The margin of coal-fired generation is thick, i.e., large volumes of renewable generation can be added before the marginal carbon intensity of a market decreases.

Markets in North America and Latin America are absent from this archetype group, being characterized by gas-fired generation on their margins more so than coal. Although the *average* carbon intensity of some of these markets remains high throughout the horizon, greater decarbonization can be achieved in the Carbon-Reliant Grids, in which coal use leads to the highest *marginal* carbon intensity.

Figure 9 below presents the carbon abatement over the horizon on a cumulative basis.

1.7 billion tonnes of avoided CO_2 is equivalent to taking more than 40 million mid-size cars off roads today[22]. All of this reduction is achieved through the displacement of coal-fired generation.

40% of this CO_2 reduction is achieved in Central & South Asia, with an additional 40% in the Asia-Pacific region. This represents an 11% acceleration in power-sector decarbonization in these regions compared to our counterfactual, helping work towards a more equitable energy transition globally by driving development of renewables into markets of highest impact.

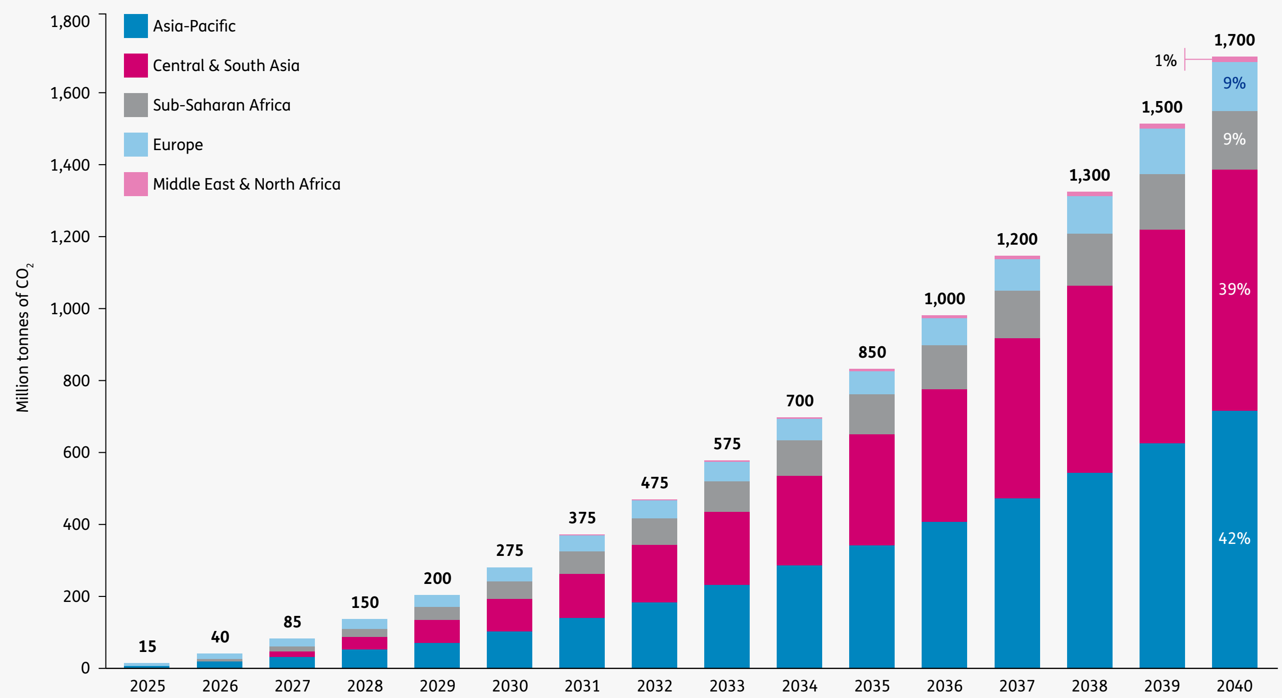


Figure 9: Cumulative reduction in power-sector CO_2 emissions by cross-border procurement, $MtCO_2$

22 Comparative life-cycle greenhouse gas emissions of a mid-size BEV and ICE vehicle, IEA

4.1.2 Challenges in certain markets today

To realize the decarbonization illustrated above, it is vital that a cross-border procurement mechanism be recognized and enabled by governments and power markets globally. Although the exact mechanism may ultimately differ, the hurdles currently faced by virtual PPAs in some markets must be addressed to unlock the full potential of cross-border procurement. This is particularly important in a handful of Asia-Pacific markets, found by STEAM to offer significant decarbonization opportunity:

- **Vietnam (16% of total CO_2 saving):** Although the Vietnamese Government has been accelerating plans for a Direct Power Purchase Agreement (DPPA) mechanism, the launch of this vPPA approach has been delayed in the past. The optimized result from STEAM includes deployment of renewables in Vietnam from 2026, with a total of around 3 GW of corporate-backed capacity commissioned by 2030. Corporate procurement volumes in this year total 8 TWh, around 1.5% of projected power demand in the Baringa Reference Case. Given the relatively modest ramp up of corporate procurement to 2030, we have assumed that the DPPA, or a borderless equivalent, will be in effect to enable this deployment. Vietnam's Power Development Plan VIII[23] (PDP8) sets out an ambitious goal for 23 GW of new-build wind capacity by 2030, including 6 GW of offshore wind. There are a range of challenges to clear if these targets are to be met, including availability of contracts for renewable projects, and grid stability concerns. A cross-border procurement mechanism for corporates, if adopted globally, would offer an alternative route-to-market.

- **Indonesia (9% of total):** Indonesia's power system operates under regulated market arrangements, and no corporate PPAs have been recorded by the RE100 to date. We have therefore excluded Indonesia from our modelling optimization until 2030. The 160 $MtCO_2$ saving quantified in this study is unlocked by procurement of around 200 TWh of renewable energy between 2030 and 2040.
- **Malaysia (6% of total):** Malaysia also operates a regulated power market, and although 2023's Corporate Green Power Programme[24] (CGPP) initiative successfully awarded over 500 MW of corporate vPPA capacity, the direction of future policy appears to be towards physical PPAs. Our view however is that the Malaysian Government would, in time, follow a change in approach announced by the GHG Protocol, acting to enable cross-border procurement by corporates if this was to become the new global standard. This assumption reflects the recent move to put renewable energy at the forefront of the economic agenda, and the opportunity for foreign direct investment offered in this respect. Our modelling suggests renewable deployment beginning in 2026, with just under 3 GW of incremental solar PV capacity built by 2030. This capacity produces 4 TWh annually, less than 3% of the projected market demand.

23 Vietnam's $135 billion power plan for 2030, World Economic Forum
24 CGPP Information Guide, Suruhanjaya Tenaga Energy Commission

4.1.3 Generation mix

As described in Section 2.2.2, STEAM procures a volume of renewable generation equal to the global addressable corporate demand. The makeup of the newly procured renewable generation adheres to a defined ratio for each market, as described in Section 2.1.4. *Figure 10* below presents the resulting annual procured volumes by technology.

Between 2025 and 2040, a total of 2,300 TWh of renewable generation is procured across the ten markets, including:

- Around 1,000 TWh of onshore wind generation, produced by 50 GW of installed capacity.
- 300 TWh of offshore wind generation, through 15 GW of capacity.
- 1,000 TWh of solar PV generation, through 90 GW of capacity.

By 2040, the 155 GW of additional renewable capacity is at most 15 years old, with 75% being under ten years old. Assuming a technical lifetime of 25 years for each technology, these assets could go on to produce another 5,800 TWh of zero-carbon electricity.

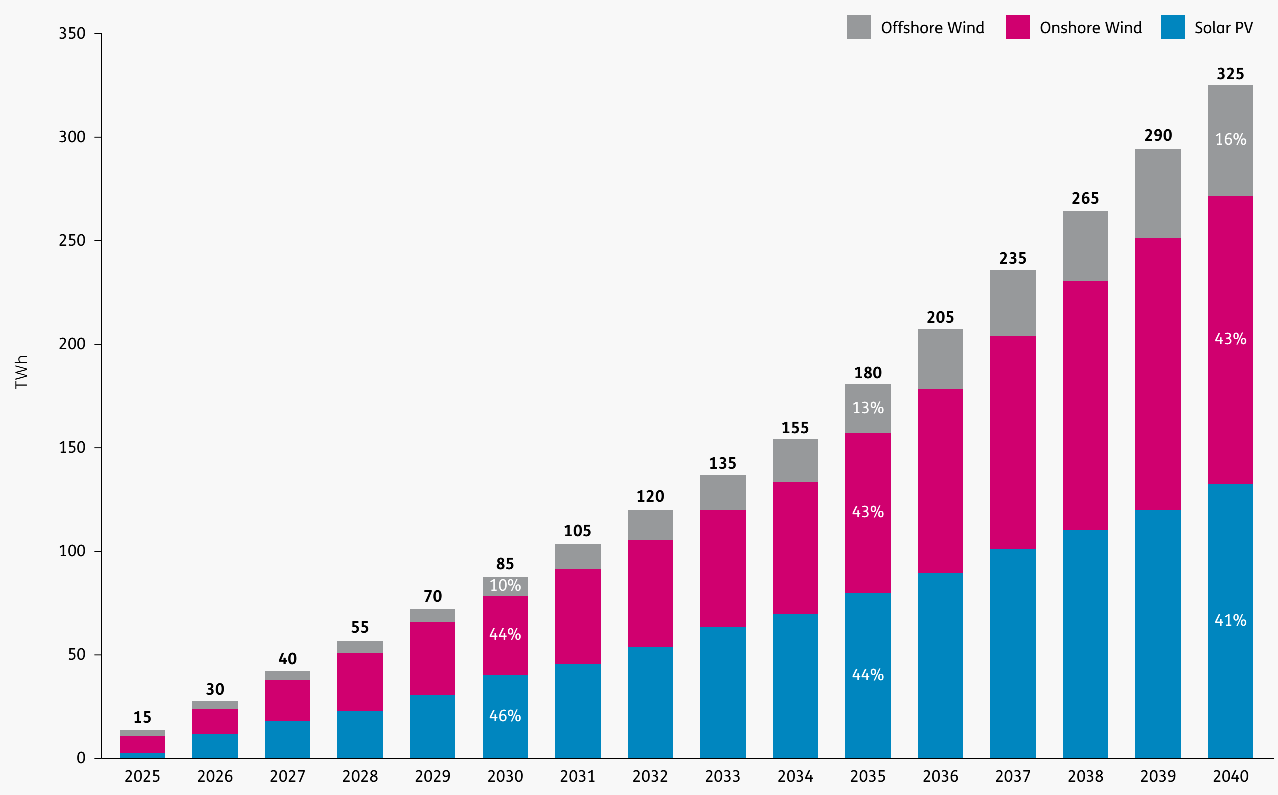


Figure 10: Annual procured renewable volumes by technology, TWh

Figure 11 below presents the total volume of generation displaced from global merit orders annually. As all renewables are procured within the Carbon-Reliant Grids, represented by the coal-dominated domestic generation mix of the Indian archetype, this carbon-intense fuel makes up effectively 100% of the carbon abatement. Between 2025 and 2040, 90% of the procured renewable generation volume directly displaces coal-fired generation, a total of 2,100 TWh.

This displacement of coal-fired power enables 825 thousand tonnes of coal to be left in the ground, delivering a decarbonization benefit of around 750 $kgCO_2$ per MWh of renewable generation in the Carbon-Reliant Grids, compared to a value of 90 $kgCO_2$/MWh achievable in GB, the archetype for the Green Leaders.

The accelerated shift away from coal-fired generation, while delivering significant carbon savings, requires careful management from a social responsibility perspective. Many communities rely on income provided by the coal industry, and policies will be required to support the switch away from coal if this is to be a truly equitable transition.

Around 65 TWh of the procured volume acts to displace imports through interconnectors, and discharge from storage assets. Each of these is assumed to have no carbon impact, i.e., we are not accounting for any reduction of CO_2 emissions that may occur in neighbouring markets, or from the energy in storage. A non-zero, but negligible, volume of gas- and oil-fired generation is displaced.

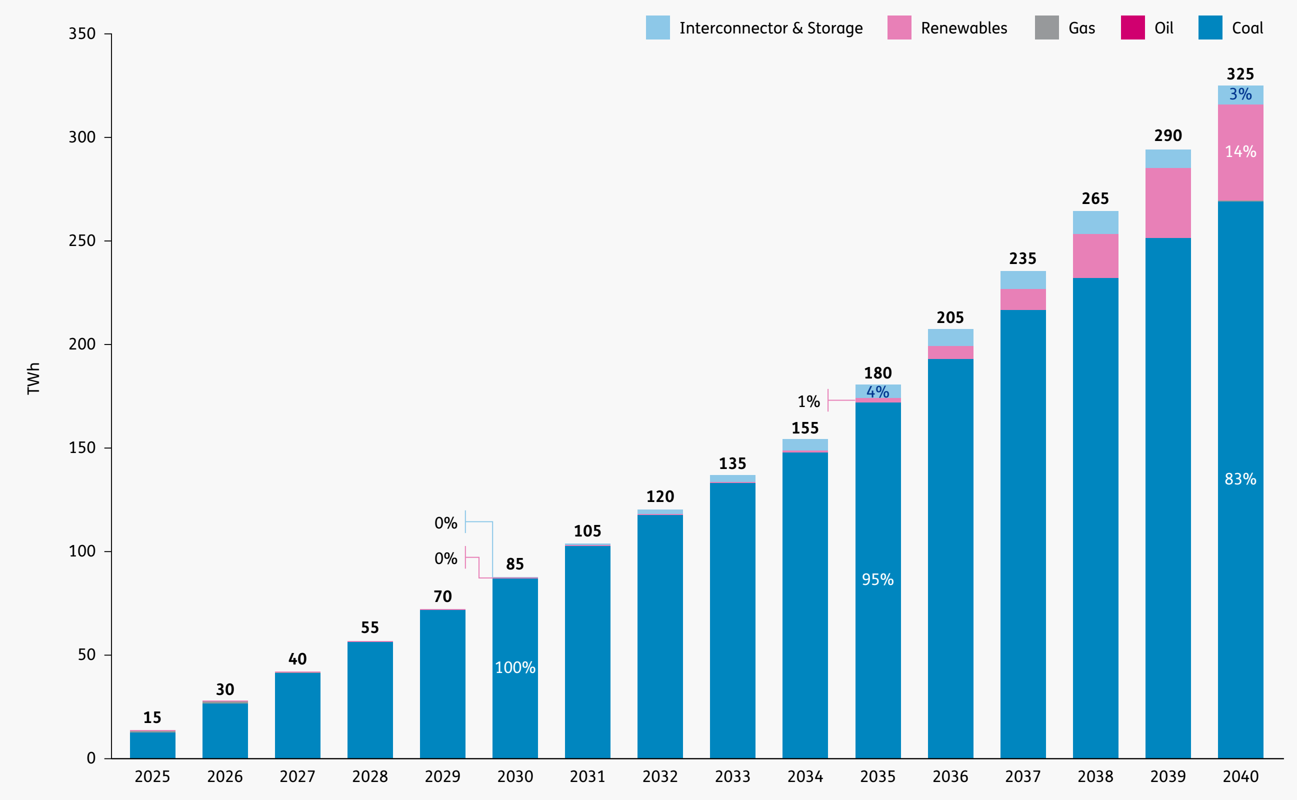


Figure 11: Annual displaced generation volumes by technology, TWh

In 2040, the 325 TWh of incremental renewable generation displaces 270 TWh of coal-fired generation, and around 10 TWh of generation from storage assets. The remaining 45 TWh, around 14% of generation, is produced in hours in which other renewable generation is on the margin, including wind, solar, hydro, and biomass. In presentation of results, we have assumed that during these hours it is renewable generation already present in the counterfactual that is displaced by the corporate procurement. Although some generation from other renewable assets will be displaced in these hours, a portion of the potential generation from the contracted assets will be curtailed[25]. Neither outcome will result in a net carbon saving, as has been assumed. Between 2025 and 2040, around 120 TWh of curtailment is induced, either for the contracted assets, or renewables already on the system. This represents around 6% of the displaced volume of coal-fired generation.

The generation mix of the Carbon-Reliant Grids, with initially lower renewable penetration than typical markets in Europe or North America, allows for more of the potential zero-carbon generation from the contracted assets to displace carbon-intense generation, rather than other renewables.

In markets that have seen significant investment in renewables to date, including Europe and North America, it has become increasingly necessary to deploy enabling technologies to avoid curtailment. These include sources of 'system flexibility' such as energy storage, interconnection, or demand-side response.

Less than 1% of procured renewable generation under a global cross-border mechanism is 'lost' due to curtailment until 2035. This result is achieved without the deployment of energy storage, demonstrating that large-scale investment in flexible assets is not required to manage intermittent generation for at least ten years.

4.1.4 Capital investment and energy equity

Given the optimum deployment of renewable capacity to maximize decarbonization is within the Carbon-Reliant Grids, the financial impact of this procurement is driven by the evolution of technology costs in largely developing economies.

We have not attempted a comprehensive cost-benefit analysis of this procurement for the corporates. We have instead quantified the implied cost at the system level using the levelized costs of each technology.

Between 2025 and 2040, the total cost of procurement under this definition totals:

- $112 billion of investment in renewable projects globally.
- An average cost of $49 per MWh of renewable power, more than 20% less than the equivalent procurement within existing market boundaries at 61 $/MWh.
- An abatement cost of $65 per tonne of CO_2, more than 50% less expensive than the equivalent achievable through domestic procurement; 135 $/t$CO_2$.

The average cost of renewable procurement across each scenario is presented in Table 6 of Appendix B.

25 This form of curtailment is known as 'economic curtailment', which occurs during hours of oversupply of renewables in the market, i.e., when supply exceeds demand. This does not include 'grid curtailment', from congestion on the transmission network, or 'technical curtailment', from a need to maintain system stability.

The lower cost of cross-border procurement relative to a domestic equivalent reflects the lower technology costs in markets such as India. Even with the impact of the Inflation Reduction Act[26] (IRA) on the cost of delivering renewable electricity in the US, LCOEs in some Central & South Asia and Asia-Pacific markets remain competitive, before becoming the least expensive options outright at the end of the IRA's tenure.

Given the weighting of corporate demand centres towards Europe and North America, and the optimal locations for investment being largely in South and East Asia, relaxing market boundaries for renewable procurement would allow for sustained flow of capital towards less-developed economies.

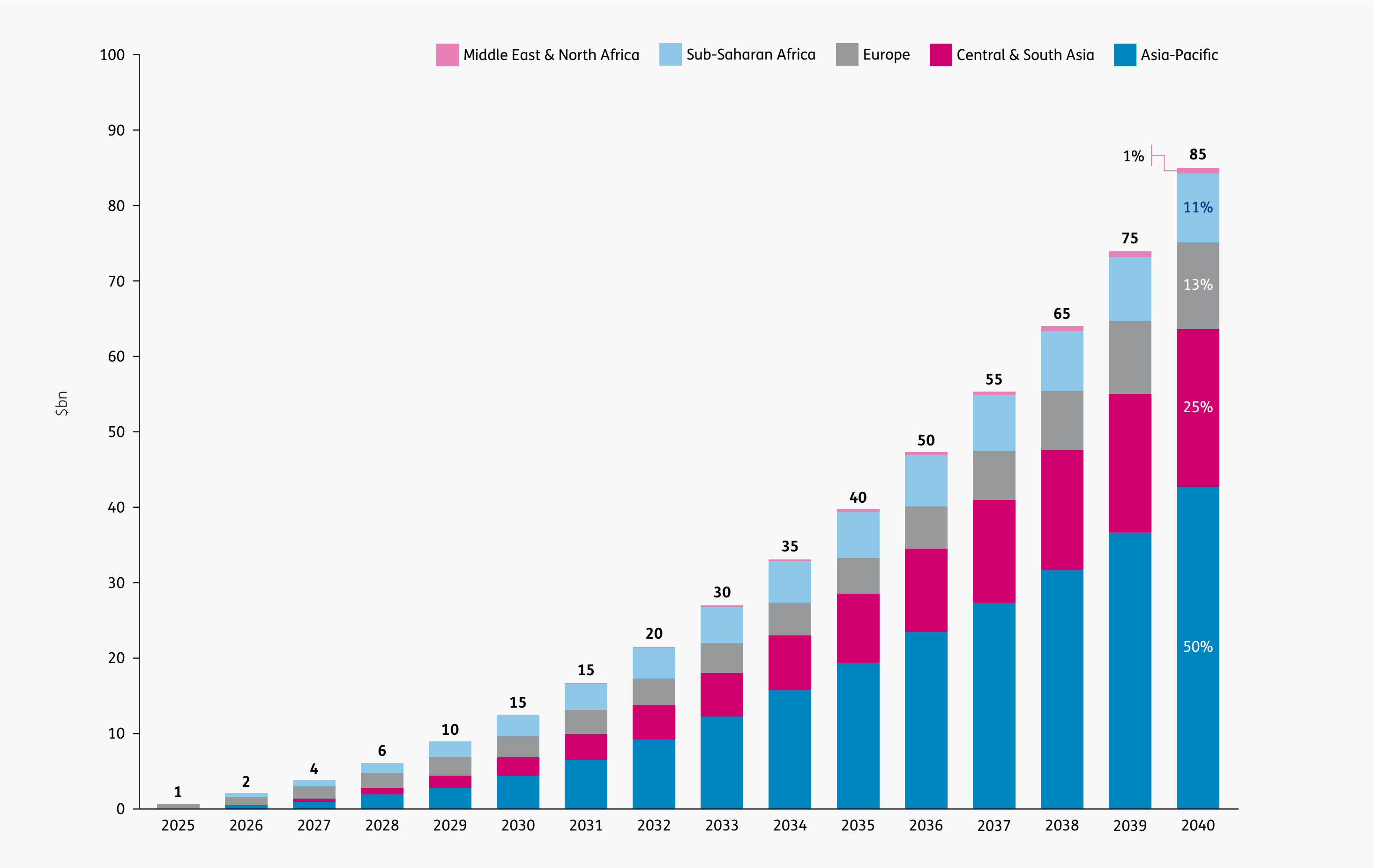


Figure 12: Cumulative capital investment from advanced to emerging & developing economies, $bn

Figure 12 above illustrates the cumulative capital investment made by corporates in advanced economies that results in development of renewables in emerging and developing markets, as defined by the International Monetary Fund[27] (IMF).

A total of $85 billion of corporate investment flows from advanced to developing economies in Asia-Pacific, Central and South Asia, Sub-Saharan Africa, Eastern Europe, and North Africa, helping to enable a more equitable global energy transition. This contribution is more than the total foreign direct investment made into India, Indonesia, and Vietnam combined in 2022[28].

26 Building a Clean Energy Economy, The White House
27 Country Composition of World Energy Outlook Groups, IMF
28 World Bank Open Data

This flow of capital is presented in *Figure 13* and *Figure 14* below, split into economy classifications and global regions respectively. Around $23bn of investment is made into offshore wind in developing economies, helping to kick-start the nascent industry in new geographies.

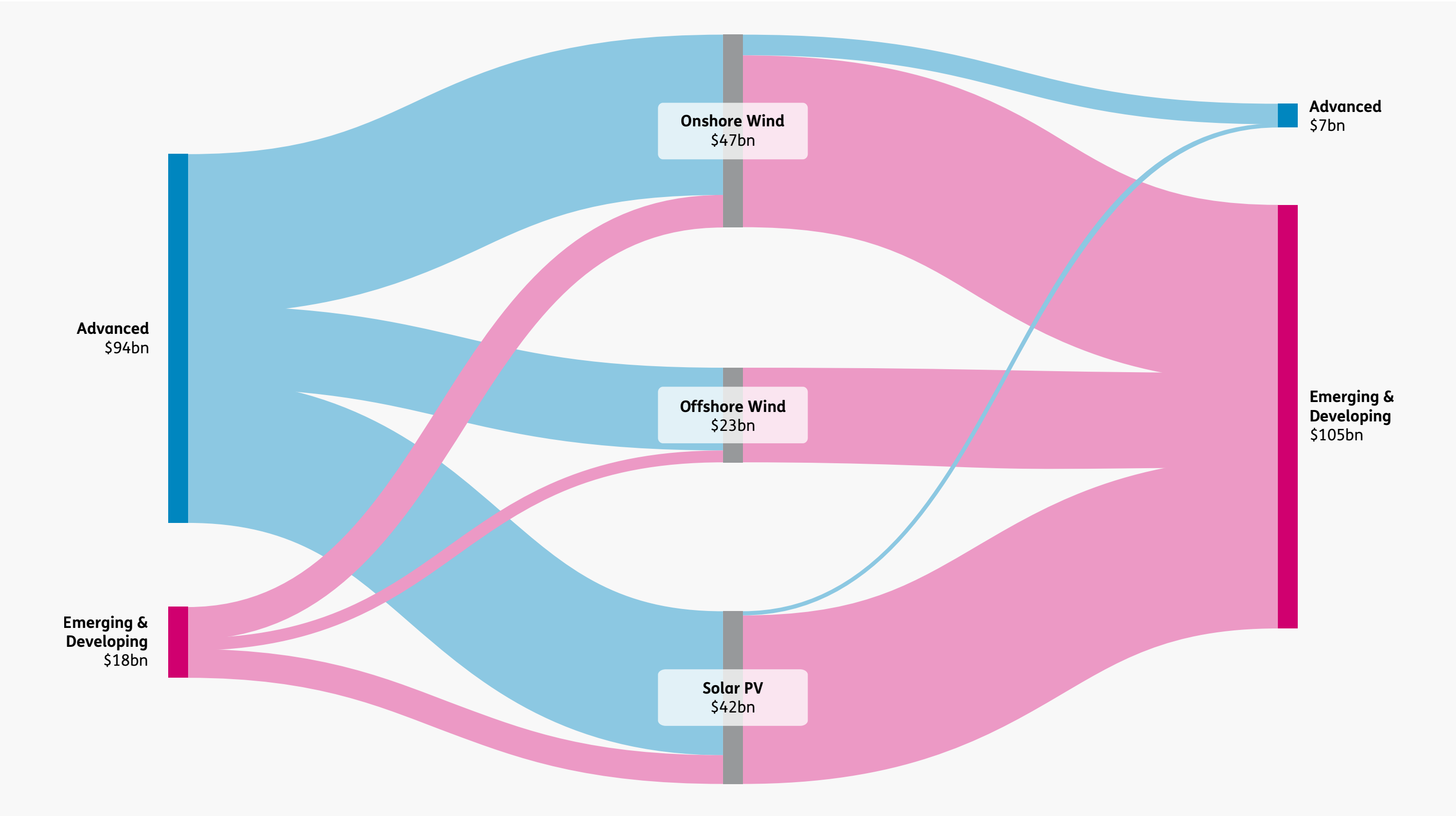


Figure 13: Cumulative capital flow between IMF economy classifications, $bn

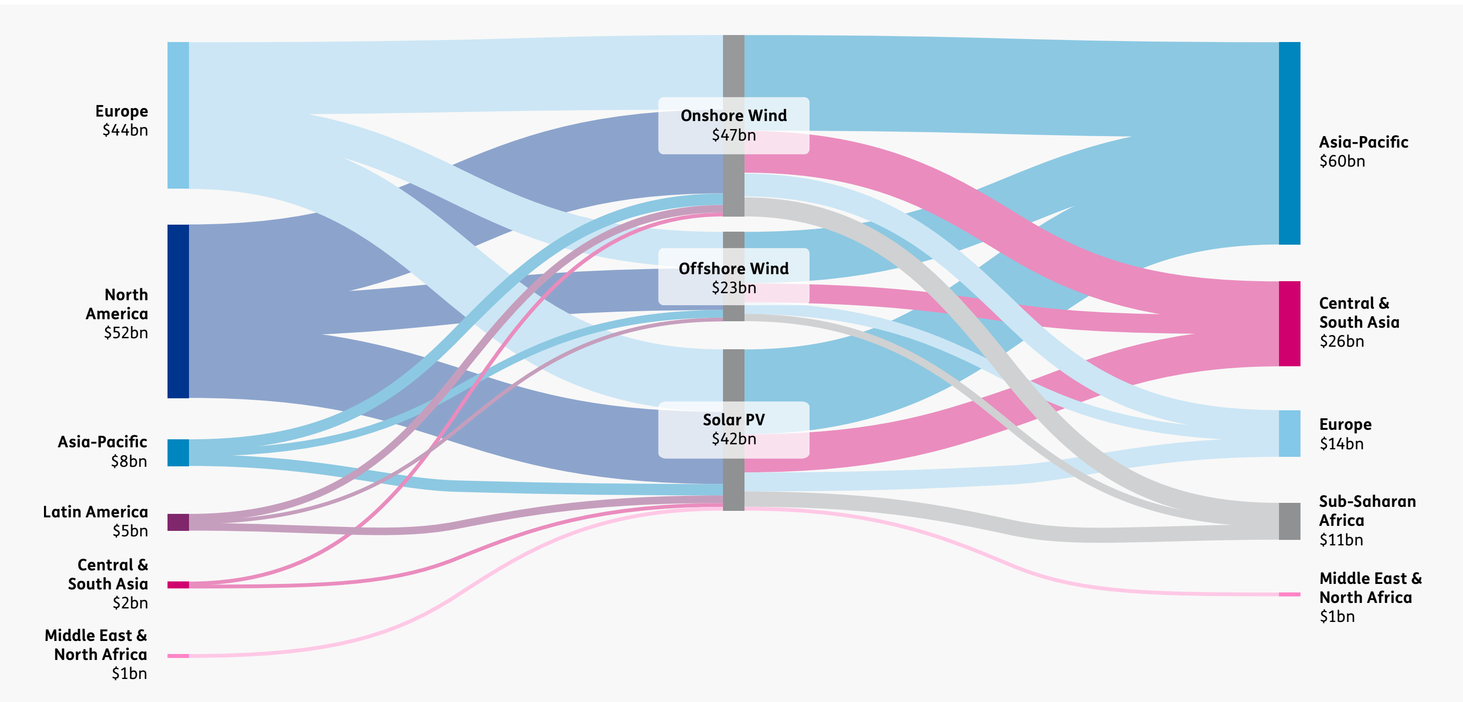


Figure 14: Cumulative capital flow between global regions, $bn

4.2 Exploring the range of outcomes

The results explored above have been calculated using a 'central' demand assumption of 325 TWh of annual addressable corporate demand by 2040, based on RE100 member demand for renewable (PPA- and EAC-backed) power. It has then been assumed that this power is procured in markets that will deliver the greatest decarbonization impact irrespective of location, and with a freedom to optimize across geographies globally to maximize impact.

The realities of how much addressable demand would be applicable to this type of procurement, as well as the underlying preferences of corporates to procure renewables in grids in which they operate, are unknown; there may be upside to the impact presented above. We have used STEAM to explore the sensitivity of the results above to changes in these assumptions, to illustrate the potential range of outcomes.

Figure 15 below presents the evaluated range of cumulative decarbonization unlocked through different assumptions for addressable corporate demand, and the market boundaries within which it can contract with renewable projects.

The extent of global carbon abatement unlocked is heavily dependent on the volume of participating corporate demand; cumulative savings total 3.2 billion tonnes of CO_2 if all members of the RE100 participate by 2040, almost double the benefit found in Section 3.1.

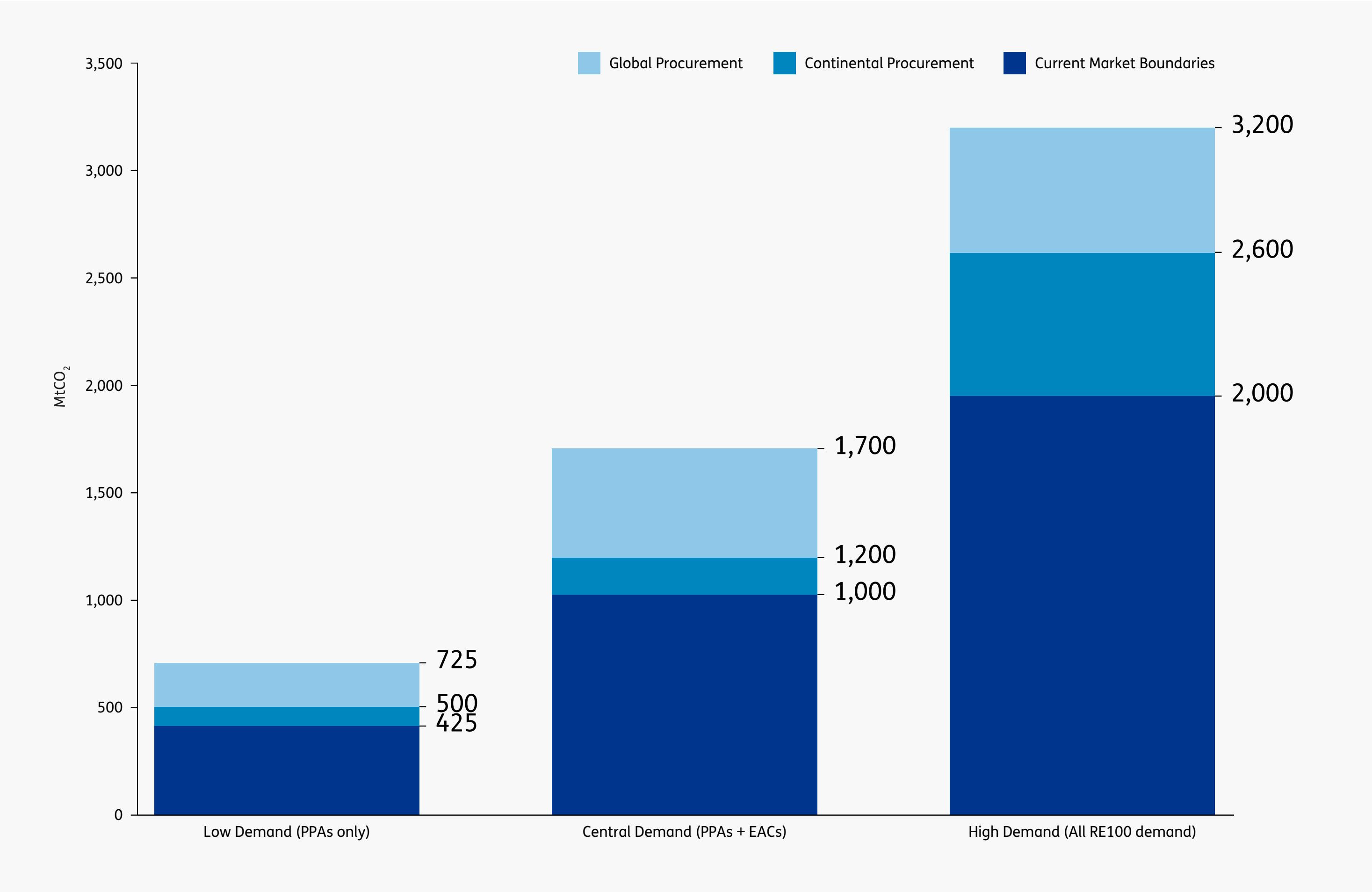


Figure 15: Cumulative carbon abatement under different scenarios for demand and cross-border procurement, $MtCO_2$

In Section 3.3, we present the relative merits of restricting market boundaries for renewable procurement compared to a fully borderless approach (denoted by the different shades of bar in the figure above):

- **Current Market Boundaries:** Corporates are limited to procuring renewables within boundaries currently recognized by the GHG Protocol for 'market-based' emissions. Corporates in the US and Canada are free to contract with projects anywhere across the region, as are corporates across a number of European markets. All other market boundaries are drawn along national borders, e.g., corporates in India can only procure domestic renewables, and no investment from corporates in other geographies is possible.
- **Continental Procurement:** Procurement is unlocked within continental regions, but market boundaries are not unwound entirely. For example, corporates in Asia-Pacific markets can contract with projects in any other Asia-Pacific market, but not beyond. A corporate in New Zealand could partner with a project in Vietnam to unlock a greater carbon benefit, but not with one in Poland.

In Section 3.4, we explore the impact of varying the assumed addressable demand, for which there could be significant upside if a cross-border procurement approach is adopted more widely (denoted by the bars left-to-right in the figure above):

- **Low Demand:** Corporate participation in procurement of renewables is limited to RE100 members currently engaging with PPAs to demonstrate renewable electricity. Corporate demand currently procuring EACs, or not demonstrating renewable electricity consumption, do not participate. Addressable demand ramps up over the horizon, reaching 110 TWh in 2040, about a third of the demand in our central scenario.
- **High Demand:** Addressable demand in the model is expanded to include all RE100 members, including those whose electricity consumption is currently considered non-renewable. A total of 660 TWh of annual demand is addressable by 2040, roughly double that of our central scenario.

The following sections explore the impact of each assumption in isolation, including changes in generation mix, cost of carbon abatement, and distribution of corporate investment. All other model assumptions remain unchanged.

 |

4.3 Restricted procurement boundaries

4.3.1 Relative carbon impacts

The results presented in Section 3.1 assume that cross-border procurement of renewables is unlocked globally, and corporates are free to invest in projects that offer the greatest decarbonization potential, irrespective of location. However, we recognize that corporates may have a bias towards procuring closer to home, so that renewable generation can be more closely linked to their demand. This is particularly relevant in markets that are constrained, such as Ireland, where any additional large energy user demand requires new energy assets to be built.[29] It can also be relevant to corporates that do not want to take on the basis risk that current cross-border arrangements require in terms of power price correlation and currency variation between the markets in which the generator and corporate demand reside.

Figure 16 below presents the relative cumulative carbon abatement achievable if current market boundaries remain in place, or if a 'continental' approach is taken, analogous to the current arrangements in North America and the EU.

A more restrictive approach to market borders would reduce the overall impact of renewable procurement, given the decoupling of corporate demand centres from the most coal-dominated markets. However, the move to PPAs, whether virtual or otherwise, would still result in around 1 billion tonnes of CO_2 emissions being avoided out to 2040 if market boundaries remain as they stand today.

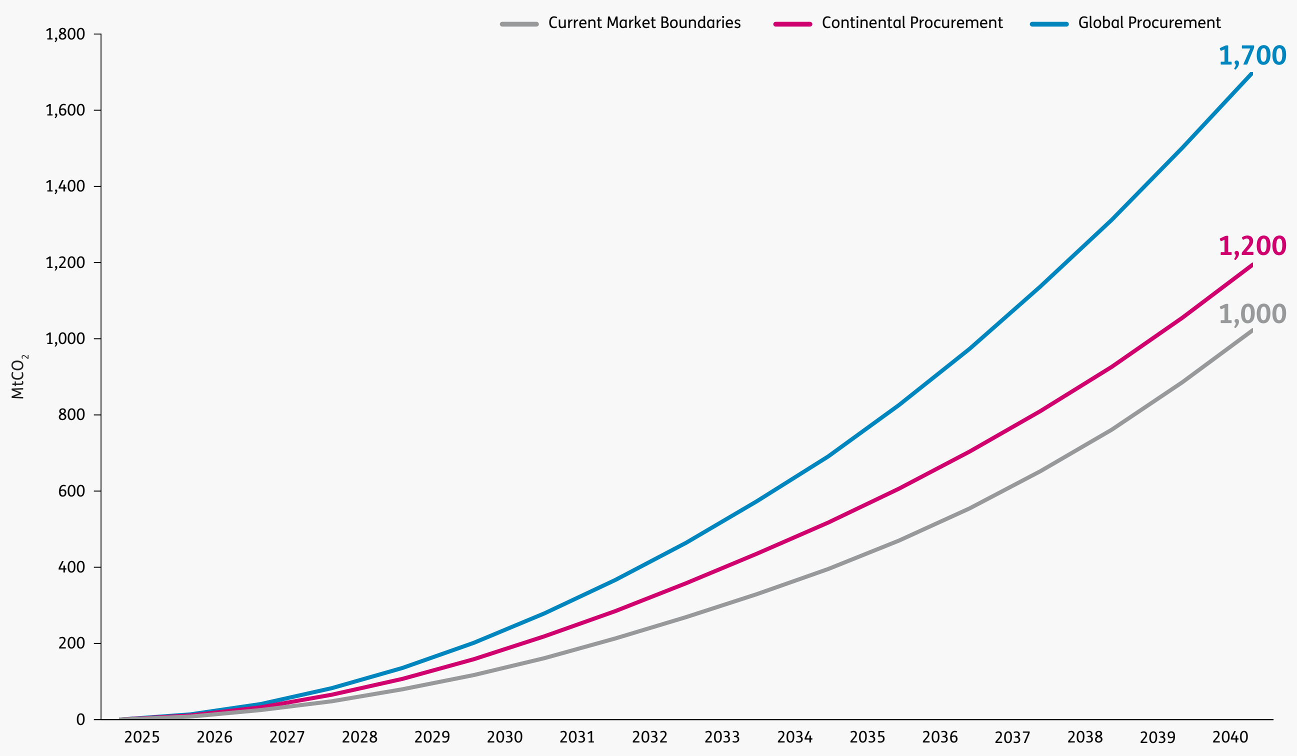


Figure 16: Cumulative carbon abatement through three market boundary arrangements, $MtCO_2$

29 CRU/21/124, The Commission for Regulation of Utilities (CRU)

4.3.2 Current market boundaries

If current market boundaries are retained, i.e., cross-market procurement is available in the US and Canada, and the EU, but is off-limits for all other markets, the geographical impact becomes concentrated in markets according to the size of their addressable corporate demand.

Figure 17 below presents the annual global carbon abatement achieved under these boundaries in each region. Around half of the cumulative decarbonization occurs in North America, driven by displacement of coal- and gas-fired generation from ISO regions of the US including PJM and MISO. The ability to procure renewables across several European markets results in significant corporate investment in relatively carbon-intense markets including Germany, the Netherlands, and Italy, members of the Maturing Markets archetype group, as well as Czechia, one of the Emerging Players. Poland, the most coal-dominated geography in Europe and the only member of the Carbon-Reliant Grids, is outside of the European cross-border market boundary, and so is considered unavailable for procurement by corporates in other markets throughout the time period of our analysis. Post-Brexit arrangements force corporates in GB to procure domestically, limiting the decarbonization achievable.

More than 85% of the decarbonization impact is seen within European and North American markets, mostly advanced economies with existing access to government and corporate capital for investment in renewables.

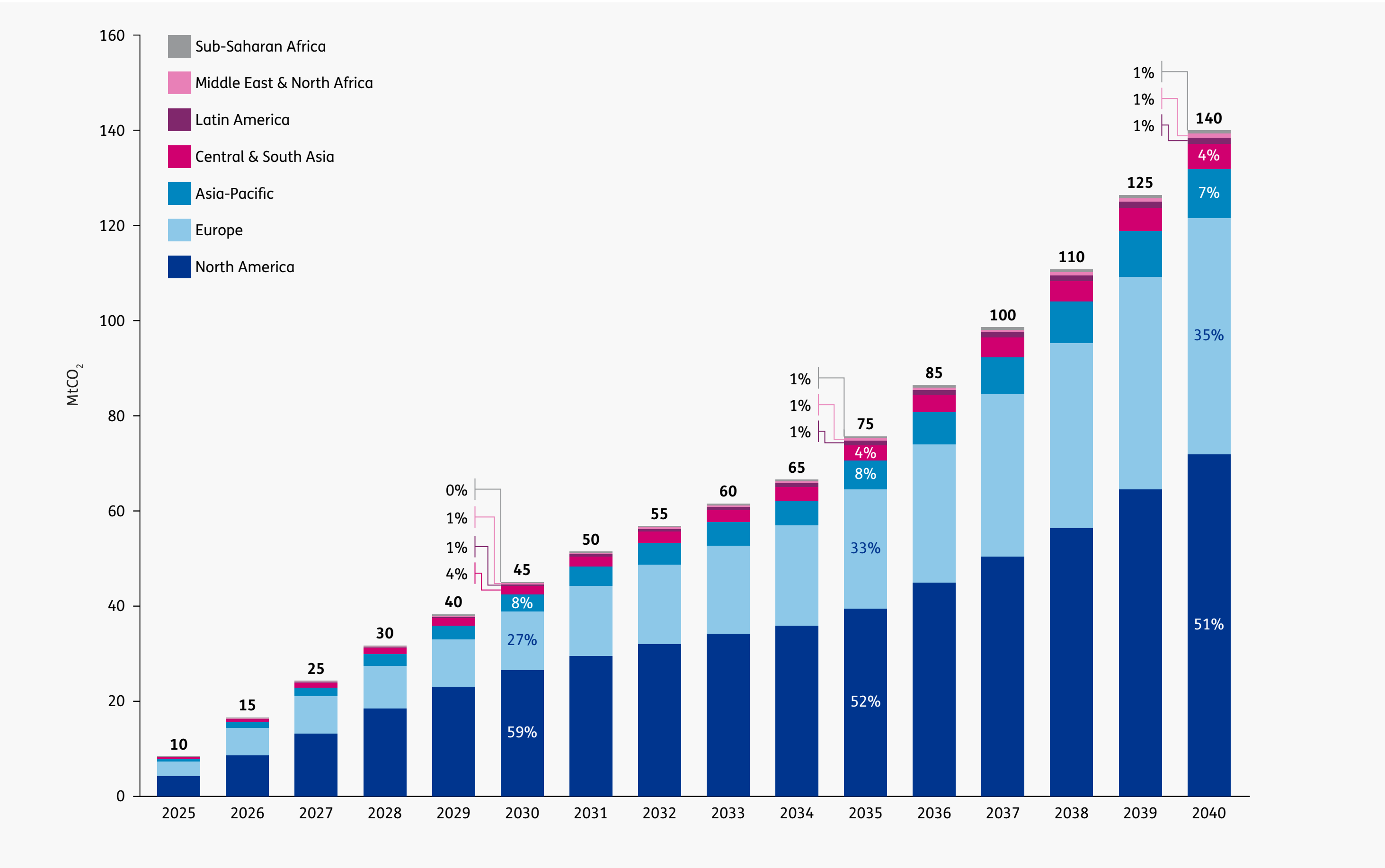


Figure 17: Annual carbon abatement under existing market boundaries, $MtCO_2$

As presented in *Figure 18* below, coal-fired generation makes up 30% of the displaced volumes if market boundaries remain unchanged from today to 2040. Displaced gas-fired generation, largely absent from the results of cross-border procurement, makes up around 45% of volumes in this scenario between 2025 and 2040.

Around 22% of the procured renewable generation is produced during hours in which other renewable sources are at the margin in their respective markets, bringing no decarbonization impact. By 2040, this proportion makes up around 30% of the displaced generation globally. More than 500 TWh of zero-carbon electricity is ultimately curtailed between 2025 and 2040, implying a greater need to deploy flexible technologies such as energy storage to manage the intermittency of renewable generation.

In the absence of cross-border arrangements, addressable corporate demand in markets without access to PPAs are unable to make contributions to decarbonization through electricity procurement. In our analysis this results in a relatively marginal impact; around 15 TWh over the horizon is unable to be fulfilled, but this poses a risk to future demand for renewable electricity in these markets.

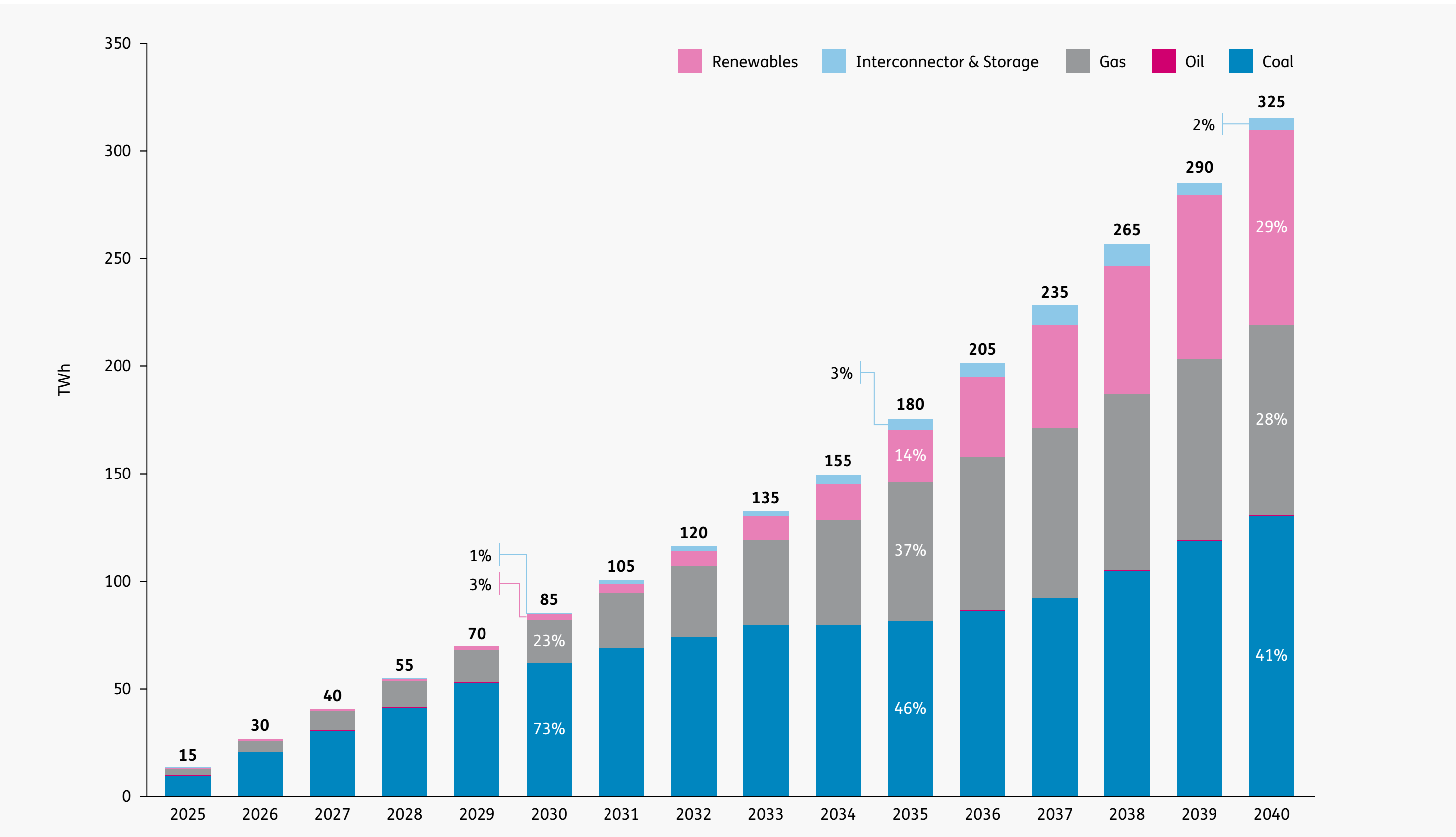


Figure 18: Annual displaced generation volumes globally under current market boundaries, TWh

4.3.3 Continental procurement

If market boundaries are adjusted to include broad continental regions, as illustrated in Table 1 below, a degree of freedom is unlocked for markets outside of Europe and North America to target their procurement in geographies that could deliver greater decarbonization impact.

However, without the option for global cross-border procurement, a disconnect remains between the location of addressable corporate demand, and the markets that would most benefit from renewable procurement.

Over 85% of addressable corporate demand is located in Europe and North America, where only one of the ten Carbon-Reliant Grids, Poland, is available for procurement. A total of 1.2 billion tonnes of CO_2 emissions are avoided with continental borders, with around 175 million tonnes being saved by the switch to partially unwound market boundaries. This policy would close about 25% of the gap in carbon savings between current market boundaries and global cross-border procurement.

Due to the majority of addressable corporate demand remaining locked in the two regions, the results most resemble those of the 'current market boundaries' scenario. Around 17% of renewable generation occurs during hours in which other renewable sources are at the margin, offering no decarbonization benefit. Around 50% of displaced generation is coal-fired, with 30% being gas-fired. This result reflects increased access to coal-driven markets for some corporates, e.g., Poland in Europe, but highlights that global access to coal-fired generation is required to maximize the impact of cross-border renewable procurement.

Table 1: List of in-scope markets by assigned continental region

Continental Regions (Market list)	Countries
Asia-Pacific	Japan, South Korea, Indonesia, Taiwan, Australia, Vietnam, Thailand, Malaysia, Philippines, Singapore, Hong Kong, New Zealand
Central & South Asia	India, Pakistan, Kazakhstan, Bangladesh, Uzbekistan
Europe	Germany, France, Italy, Great Britain (GB), Türkiye, Spain, Poland, Norway, Sweden, Netherlands, Finland, Belgium, Austria, Czechia, Switzerland, Greece, Romania, Portugal, Hungary, Denmark, Ireland, Iceland, Croatia
Latin America	Brazil, Argentina, Chile, Colombia, Peru
Middle East & North Africa	Saudi Arabia, Egypt, United Arab Emirates (UAE), Algeria, Kuwait, Israel, Qatar, Morocco
North America	PJM, MISO, Canada, ERCOT, Mexico, SPP, CAISO, NYISO, ISO-NE
Sub-Saharan Africa	South Africa, Nigeria

4.4 Impact of corporate participation

4.4.1 Addressable corporate demand from the RE100

Throughout the analysis presented in Sections 3.1 and 3.3 above, we have employed consistent assumptions for the level of addressable corporate demand, being the sum of the projected PPA- and EAC-backed demand of the RE100. As pressure increases on corporates to take action to address climate change and reduce greenhouse gas emissions, it is possible that addressable demand exceeds our central scenario assumption, unlocking significantly more decarbonization.

Figure 19 below presents a range of cumulative carbon abatement between 2025 and 2040, and highlights the near doubling in the decarbonization impact that a 'high demand' scenario could deliver, as well as the risks posed by a reduction in addressable demand.

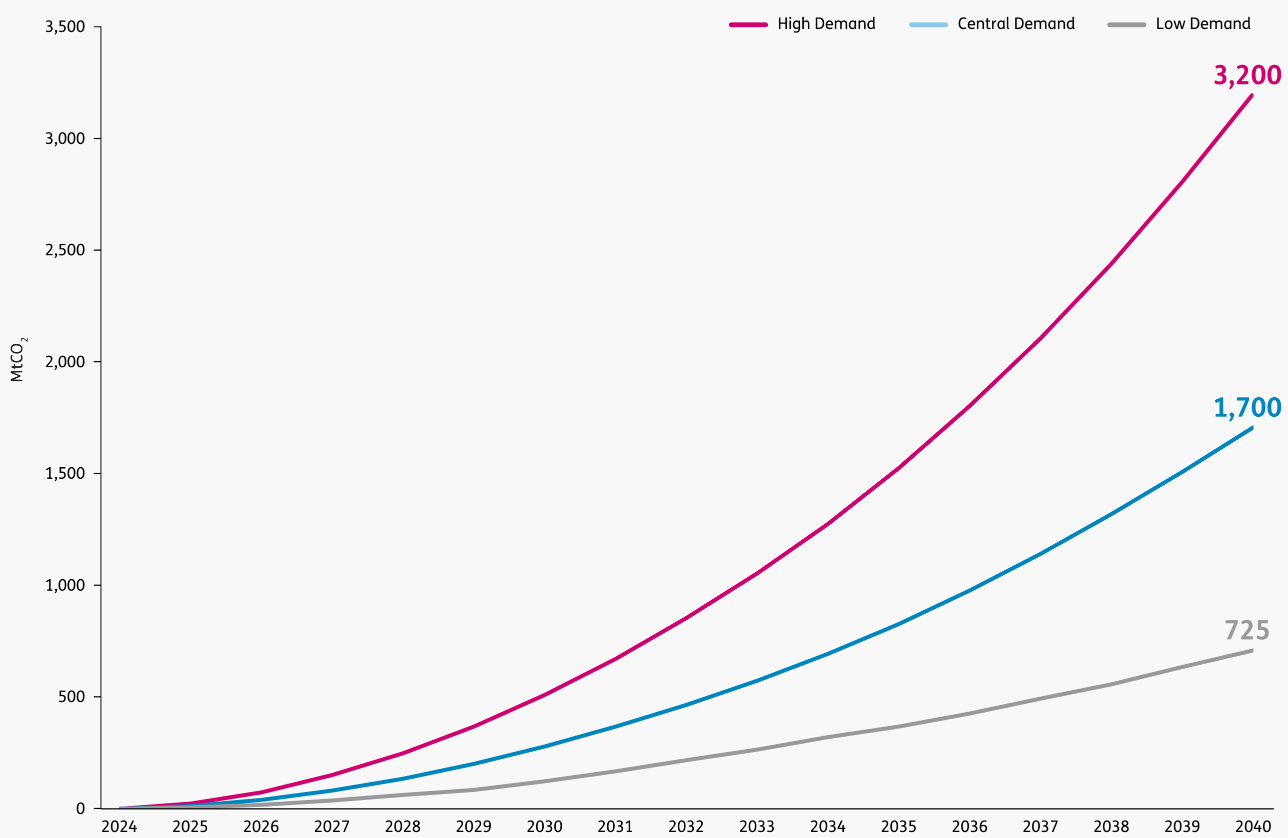


Figure 19: Cumulative carbon abatement achieved through a range of addressable demand, $MtCO_2$

If action is restricted to corporate demand met via PPAs, around 110 TWh by 2040, a total of 725 million tonnes of CO_2 emissions are avoided over the horizon, equivalent to an acceleration in the counterfactual decarbonization rate of the global power system of six months. If the entirety of the RE100 acts through this mechanism to decarbonize their scope 2 emissions by 2040, a total of almost 3.2 billion tonnes of CO_2 can be avoided globally.

This result, equating to a three-year acceleration in global power-sector decarbonization, arises from the abundance of coal-fired generation on the margins of the Carbon-Reliant Grids. Even after doubling the 2040 addressable demand to 660 TWh, coal-fired assets make up more than 80% of the displaced generation volumes. The scale of the Carbon-Reliant Grids also enables the build of the 330 GW of renewables required to match this demand, without needing to procure in other less carbon-intense archetype groups. The 2040 annual carbon abatement totals around 400 million tonnes of CO_2, more than the economy-wide emissions of the UK in 2023[30].

The additional corporate demand in this scenario brings further investment to developing economies. More than $165 billion of corporate investment flows from advanced economies into markets classified as emerging and developing. *Figure 20* below presents the breakdown of the $222 billion capital investment in renewable technologies globally.

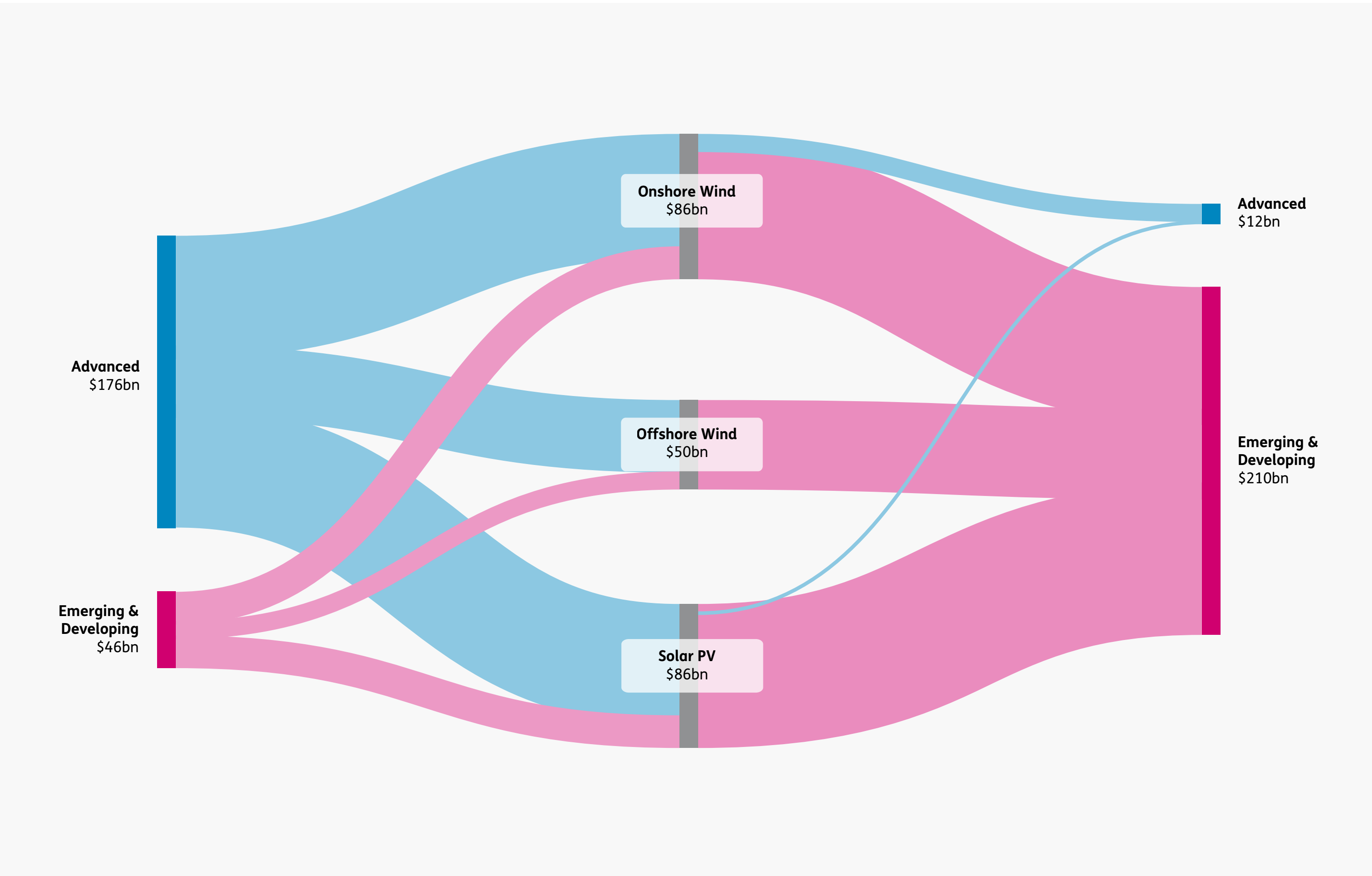


Figure 20: Cumulative capital flow between economy classifications with high demand, $bn

30 UK emissions in 2023 fell to lowest level since 1879, CarbonBrief

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4.4.2 The limit of decarbonization

As explored above, 660 TWh of annual cross-border corporate procurement by 2040 does not exceed the possible rate of renewable build in the Carbon-Reliant Grids, or fully remove coal from their margins. We have further tested the relationship between increasing corporate demand and the resulting carbon abatement to understand how the relationship evolves, and whether any limit exists before increased investment offers diminishing returns.

Figure 21 below presents the cumulative carbon abatement achieved as a function of addressable corporate demand in 2040. Growth of addressable demand from 2025 to 2040 has been assumed to progress at the same rate as presented in Section 2.1.2, but scaled up linearly.

The figure demonstrates the headroom that exists to continue delivering significant decarbonization in the global power sector. As more corporate procurement is added, the volume of coal in the Carbon-Reliant Grids, including India, Indonesia, and the Philippines, is sufficient to offer sustained impact.

The decarbonization impact of additional renewables procured cross-border is almost linear, with 500 TWh of annual renewable generation offering more than nine times the decarbonization benefit of 50 TWh. Coal continues to represent more than 99% of the displaced CO_2, and around 90% of displaced generation, up to 850 TWh of addressable corporate demand in 2040. Gas-fired generation is not meaningfully displaced until around 1,000 TWh of annual demand is reached.

With 6,000 TWh of cross-border procurement in 2040, almost 20 times the volume in our initial analysis, and 50% more than the total power demand for the US today[31], the last renewables to be added would displace 130 kilograms of CO_2 per MWh, still 40% more than is achieved by deployment of renewables in GB without cross-border procurement.

We have been conservative in defining addressable corporate demand in our study, and this result demonstrates that, should global cross-border procurement be adopted more widely, significant decarbonization can continue to be delivered. If the standard is adopted beyond large energy users, expanding to mid-market companies and even small businesses, their demand would continue to provide sustained value globally.

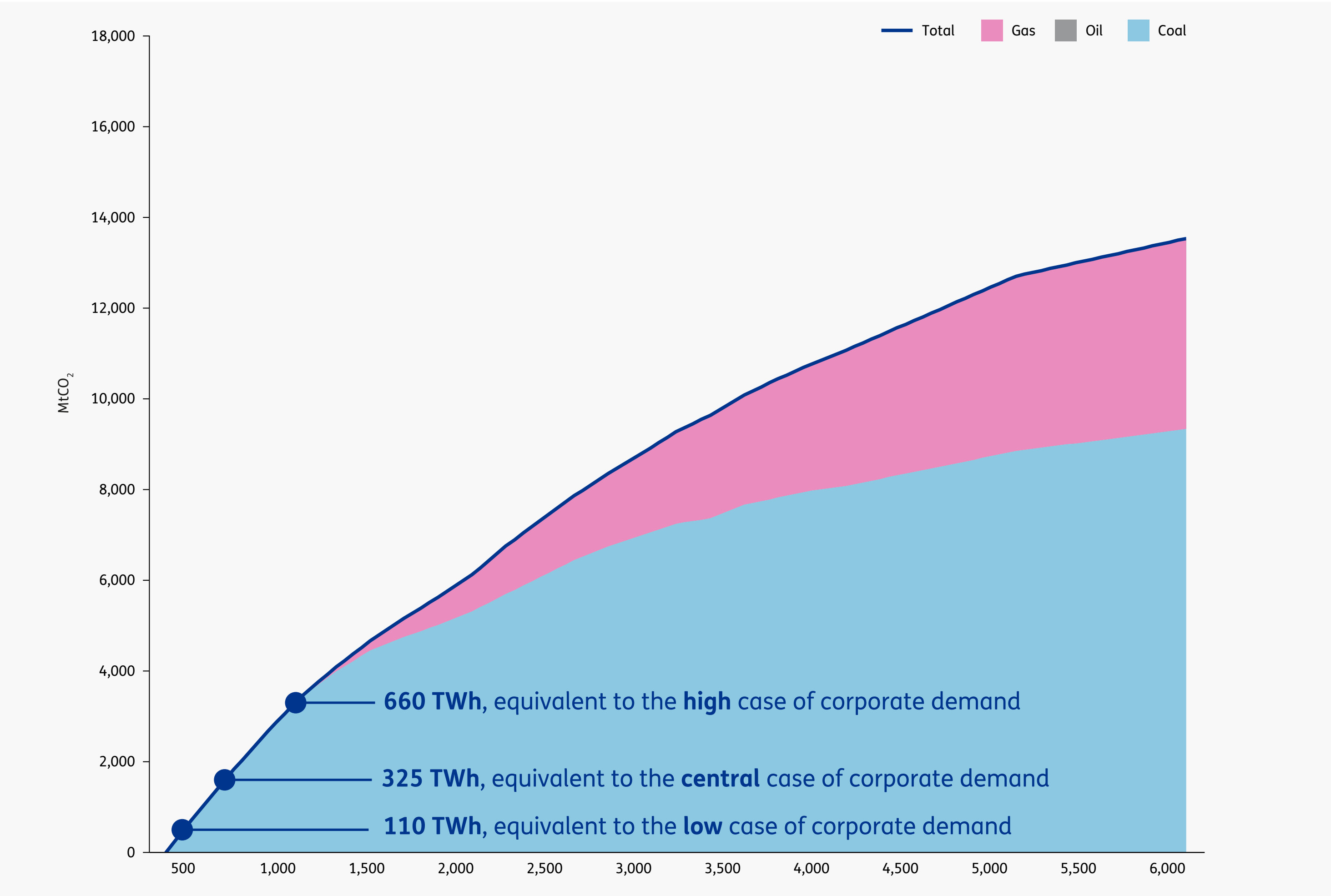

Figure 21: Cumulative 2025-2040 carbon abatement as a function of corporate demand in 2040, $MtCO_2$

31 Electricity, US Energy Information Administration (EIA)

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5. Conclusion

5. Conclusion

Our analysis suggests that corporates could help to decarbonize an additional 1.7 billion tonnes of CO_2 over the next 15 years. Our study has quantified the potential benefits of relaxing market boundaries for corporate renewable procurement. Doing this within continental regions could avoid 1.2 billion tonnes of CO_2 by 2040, rising to 1.7 billion tonnes if market boundaries are relaxed entirely, accelerating the global pace of power-sector decarbonization by 18 months.

Corporate investment could catalyze the global phase-out of coal-fired power stations. Our study suggests that 2,100 TWh of coal-fired generation would be displaced, mostly in South and East Asia, leaving 825 thousand tonnes of coal in the ground. Less than 1% of procured renewable generation would be lost through curtailment until 2035, allowing time for enabling technologies such as energy storage to scale and mature, before becoming essential when curtailment is more significant.

Relaxing market boundaries would unlock a more equitable energy transition, driving $85 billion of investment into developing economies by 2040. Corporates in advanced economies would play a role in contributing a volume of capital more than the total foreign direct investment made into India, Indonesia, and Vietnam combined in 2022, helping to drive a more equal transition.

Redistributed investment can decarbonize the global power sector for less than half the cost. Greater impact is achieved per dollar of investment, with $65 needed per tonne of CO_2, compared to $135 for equivalent investment in a corporates' market of operation. Each project achieves 60% more decarbonization on average, and costs 20% less than a domestic equivalent per MWh.

The scale of coal use globally offers potential for billions more tonnes of CO_2 to be saved through sustained investment. We have calculated the above results using a conservative outlook on addressable demand volumes, based on RE100 members' demand for renewable power (325 TWh by 2040). If all members' demand participated in borderless procurement (660 TWh by 2040), a total of 3.2 billion tonnes of CO_2 emissions could be avoided, more than the annual power-sector emissions of the European Union today.

To enable such an impact and level of investment in these markets, structural changes will need to take place across political and regulatory landscapes. The relaxing of market boundaries sends a strong demand signal to address other critical enablers that would underpin increased investment in these markets, and a growing maturity to renewable investment. It is important to attract not just corporates to invest in renewables, but also developers, operators, and financial institutions, which all need confidence in a market's stability to manage their risk and play a part in bringing new renewable projects online.

Corporates must also have equal and consistent access to data for making investment decisions and accurately reporting emissions. A stumbling point for many countries and organizations is the accessibility of data, which can impede decision-making and speed-of-action. The quality and integrity of generation and emission data is limited in some markets, posing a challenge for corporates wanting to invest and report decarbonization.

The design of a cross-border procurement mechanism must consider potential political, market, and climate risks, to ensure the compelling results of this study are realized. It is imperative that any standard focuses on how to robustly incentivize additional renewable deployment in markets where there is greatest decarbonization potential.

Appendices

Appendix A Methodology details

A.1 In-scope markets

A.1.1 Applicable markets

We have modelled 64 in-scope global power markets in this study, to ensure comprehensive coverage of the markets most likely to be host to corporate renewable procurement under a global cross-border framework. Based on an initial list of 211 markets from US Energy Information Administration[32] (EIA) data, we have excluded 54 due to their being categorized as 'alert' or above within the Fragile States Index[33], or being currently under US, UK, or EU sanctions. This excludes a handful of large markets, including China, Russia, Iran, Iraq, Venezuela, and Ukraine, on the basis that corporates would be disincentivized from contracting with renewable projects in them, by legal restrictions or perceived risk.

Of the remaining 157 we have filtered out the 'low demand' markets where opportunity for large-scale renewable deployment is lower, leaving the largest 60 markets that make up 95% of global out-of-sanction demand. Finally, we have re-introduced four markets (Ireland, Iceland, Nigeria, and Croatia) due to their current and future importance for corporate power demand.

Table 3 in Appendix B contains detail on all 64 of the in-scope markets.

A.1.2 Market archetypes

To accurately represent the impact of renewable procurement in each market, we have defined six archetypes. The aim of these archetypes is to represent a group of markets with similar generation mix characteristics, specifically their marginal generators and renewable penetration. We have chosen market archetypes that are modelled within the Baringa Reference Case and have historical data readily available.

To assign each market to an archetype group, we have first assessed them on a matrix of renewable penetration (including wind, solar, hydro, biofuels etc.) versus average carbon intensity (as a proxy for the carbon intensity of their marginal generators, e.g., coal- or gas-dominated). Each datapoint has been calculated from EIA data for 2021, to ensure consistency across all markets.

We have used K-means clustering[34] to divide the markets into six groups, in which markets most resemble each other for these two variables. We have made two manual adjustments to the result of the cluster analysis; France and Belgium have been assigned to Low-Carbon Pioneers and Green Leaders respectively. These markets each have low average carbon intensities driven by nuclear generation rather than renewables, and most resemble the markets in these groups in terms of the impact that renewable procurement would have on CO_2 emissions.

32 EIA

33 Fragile States Index

34 K-means clustering divides the markets into a fixed number of groups, ensuring that they belong to the group with the closest mean value for both properties.

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Table 2 below presents a summary of the six archetype groupings, including a comprehensive list of markets within them.

An archetypal market with a representative generation mix has been selected to portray each group: Sweden; Great Britain (GB); the Southwest Power Pool (SPP) and Pennsylvania-New Jersey-Maryland Interconnection (PJM), two of the US ISO regions; South Korea; and India.

Table 2: Summary of the six archetype groups

Archetype Groups	Low-Carbon Pioneers	Green Leaders	Maturing Markets	Emerging Players	Slower Adopters	Carbon-Reliant Grids
Archetype Market						
Archetypal country	Sweden	GB	SPP	PJM	South Korea	India
Archetypal zone	SE3	-	All	All	-	West
Market Features (2021)						
Number of markets (#)	13	7	14	12	8	10
Total demand (TWh)	2,200	1,025	2,252	3,575	1,475	2,925
Renewable penetration (%)	64%	45%	37%	16%	12%	21%
Average carbon intensity (kg/MWh)	95	184	352	432	659	732
Renewable Procurement (2021)						
PPA-backed RE100 demand (TWh)	3	8	11	16	0	2
EAC-backed RE100 demand (TWh)	14	16	24	25	2	6
Other RE100 demand (TWh)	7	4	12	45	45	22

Market List	
Low-Carbon Pioneers	Brazil, Canada, France, Norway, Sweden, Colombia, Austria, Switzerland, Portugal, New Zealand, Denmark, Iceland, Croatia
Green Leaders	Great Britain (GB), CAISO, Spain, Finland, Belgium, Peru, Romania
Maturing Markets	Germany, ERCOT, Italy, Türkiye, SPP, NYISO, Pakistan, Argentina, Netherlands, Chile, Greece, Hungary, Nigeria, Ireland
Emerging Players	Japan, PJM, MISO, Mexico, Thailand, Egypt, United Arab Emirates (UAE), ISO-NE, Algeria, Czechia, Singapore, Qatar
Slower Adopters	South Korea, Saudi Arabia, Taiwan, Bangladesh, Kuwait, Israel, Uzbekistan, Hong Kong
Carbon-Reliant Grids	India, Indonesia, Australia, Vietnam, South Africa, Poland, Malaysia, Philippines, Kazakhstan, Morocco

A.1.3 Temporal adjustments

To account for the difference in decarbonization trajectory between markets in each group, we have applied adjustments to the mapping of archetype data. For example, Chile, in the Maturing Markets, is perceived to be 'one year ahead' of SPP, its archetype, in 2040. We have therefore used SPP power market data for 2041, to represent Chile in 2040. Conversely, Pakistan is perceived to be two years behind SPP in 2040, and so archetype data from 2038 is used to represent this year.

We have determined the size of these adjustments using historical data for demand and generation by technology from IEA, and EIA for the US ISO zones, as well as projected equivalent data from the Baringa Reference Case. We have calculated the annual penetration of low-carbon generation sources, including renewables and nuclear, and used this value to map each year for a market against the year for the archetype with the closest value. The annual difference in years between a market and its archetype has been configured within STEAM, with a maximum difference of three years either way maintained throughout.

A.2 Addressable corporate demand

We have defined the addressable demand as the corporate load that we believe would participate in cross-border procurement of renewables, using data published by the RE100.

RE100 members have publicly reported their 2021 electricity consumption met through the procurement of PPAs or EACs, and any remaining 'non-renewable' demand, which collectively totalled 376 TWh. Of the 260 TWh of annual consumption within our in-scope markets, 40 TWh was PPA-backed, 85 TWh was EAC-backed, and the remaining 135 TWh was served by non-renewable sources. We have applied an incremental scalar of 20% to these figures, to provide a high-level representation of large corporates outside the RE100.

By projecting forward RE100 data for 2021, plus a 20% uplift, we are taking a conservative approach to defining addressable corporate demand. In January 2023 the total annual demand of RE100 members reached 437 TWh, with 500 TWh being passed by that November. If growth continues at this rate, the demand of the group will exceed the conservative projection modelled in this study.

We have made four further assumptions in projecting growth in addressable demand out to 2040:

1. Growth in commercial and industrial demand for a market can be predicted using projections of gross domestic product (GDP) and population[35]. Historical power market data from IEA and EIA, along with historical and projected economic data from the World Bank[36], has been used in this calculation.
2. The three components of RE100 member demand increase in line with the overall growth of commercial and industrial demand in the market they are headquartered in. This assumption conservatively assumes that corporate demand growth does not outpace that of commercial and industrial demand as a whole, despite expected growth in areas such as artificial intelligence (AI). A minimum growth of 2% has been applied to all markets in all years.

35 This correlation has been derived from a mathematical relationship between carbon dioxide emissions and four factors (population, GDP per capita, energy intensity, and carbon intensity) known as the Kaya identity.
36 World Bank Open Data

3. The annual volumes of corporate demand currently served by EACs or non-renewable sources that participate in global cross-border procurement ramp up linearly from zero in 2024, to the projected figures from step 2 in 2040. For corporate demand currently served by PPAs, new demand is assumed to participate in cross-border procurement immediately, i.e., corporates currently using PPAs choose to be compliant with the new protocol from the outset for growth in their demand. Demand currently locked into existing PPAs participates in cross-border procurement from the expiry of their contracts, assumed to occur steadily over the first ten years of the horizon.
4. Finally, we have assumed that vPPA contracts made between corporates and renewable projects last an average of ten years[37]. After the expiry of their initial agreements, the corporates are assumed to contract with new projects, remaining compliant with the current GHG Protocol and RE100 rules on project vintage[38].

We consider our corporate demand assumptions to be conservative and may expect further uplift in demand as market mechanisms mature, and organizations become more familiar with cross-border contracting arrangements. We are aware of many companies, including data centre players and chip manufacturers in the technology sector, which are not currently members of the RE100, but that prioritize renewable procurement and grid decarbonization. These corporates are likely, given time for the mechanism to mature, to participate in this type of renewable procurement.

Table 4 in Appendix B presents a breakdown of our addressable demand assumptions.

A.3 Defining the counterfactual

A.3.1 The Baringa Reference Case

Baringa has developed a suite of in-house wholesale power market models covering more than 60 markets globally. These models sit within PLEXOS, a third-party commercial software that is widely used in the power and utilities industry for power price projections, asset dispatch modelling, network analysis, and other purposes. Our models are configured with key inputs and scenario assumptions such as commodity prices, plant build and retirement, and hourly demand, wind, and solar profiles, and have detailed representations of generator technical parameters and interconnection between markets. The models recreate the dispatch of generators in power markets from these fundamental inputs and calculate the resulting wholesale power prices.

The results produced by these models, in Baringa's central view, or 'Reference Case', have been assumed as the counterfactual in this study. This represents a self-consistent scenario reflective of our central view of decarbonization, demand growth, commodity prices, and technology costs, and considers current government policy and corporate commitments. Our central view is not a purely targets-met scenario, instead taking a critical lens on renewable development and decarbonization ambition presented by governments, corporates, and transmission system operators (TSOs), factoring in connection availability, supply constraints, and other factors.

37 How Europe's energy crisis has impacted corporate renewable PPAs, Energy Monitor

38 The GHG Protocol and RE100 state that for procurement of electricity to be considered renewable, it must be sourced from projects no more than 15 years from their commission, or latest repowering.

Being grounded in a view of current policy, with announcements being incorporated only once clear and realistic plans are evident, the Reference Case assumes that the GHG Protocol's scope 2 accounting framework persists as it is specified today. Corporates can demonstrate procurement of renewable electricity as long as projects are located in the same market boundary as their demand.

A.3.2 Power market data

The methodology underpinning STEAM, as presented in Appendix A.6 below, relies on access to hourly power market data from the counterfactual for each archetype, so that merit orders can be studied. Under a day-ahead market structure, the merit order is determined by the volumes and bid prices of all units that clear in the market, including generators, energy storage assets, and interconnectors.

To build up archetypal merit order curves within STEAM, we have used the following hourly datapoints from the Reference Case wholesale market models:

- Generation volume by generator or storage asset (MWh)
- Bid price by generator or storage asset ($/MWh)
- CO_2 emissions by generator (tCO_2)
- Net import volume by interconnector (MWh)
- Day-ahead power price by bordering market ($/MWh)

Additional data series from the Reference Case power market models have been used for other aspects of the methodology:

- Hourly renewable output profiles by geography (%); used to calculate the hourly generation from procured renewables.
- Annual projected market demand (TWh); used to scale the merit orders of markets within a group relative to their archetype.
- Annual counterfactual renewable generation (TWh); used to define renewable build constraints, and temporal adjustments between markets.

A.4 Renewable deployment constraints

In order for STEAM to distribute renewable procurement volumes between markets that do not exceed likely practical limitations, we have assigned annual procurement constraints and set the ratio of build between technologies at the market level.

We have set the maximum annual increase in renewable generation volumes for each in-scope market as a proportion of demand, based on the single largest relative annual increase in each continental region since 2010. This calculation has been performed using datasets from IEA, with EIA data for the US ISO zones. For example, the largest step change in renewable generation in the European in-scope markets occurred in Denmark in 2019, an increase of around 7% of demand.

Our key assumption has been that markets in each continental region typically feature similar characteristics in terms of connection processes and supply chain constraints, leading to a similar maximum practical rate of renewable deployment. Where details of a market suggest that this is not the case, we have made individual adjustments to this assumption, either relaxing or tightening the constraint.

Once each market has a maximum relative build limit, we have then subtracted the generation from new-build renewables each year in the counterfactual, representative of new generation from government-backed and merchant plant. The result leaves an annual volume of renewable generation that can be procured by corporates in each market through a global cross-border mechanism.

We have also made the high-level assumption that renewable build enabled through global procurement by corporates results in the same generation ratio of onshore wind, offshore wind, and solar PV as in the counterfactual.

An indicative summary of these constraints is presented in Table 5 in Appendix B.

A.5 Cost assumptions

To estimate the investment required to unlock the decarbonization benefits of this study, and the flow of capital between economies, we have taken an LCOE approach.

Although this method provides an indication of the total investment made in renewable technologies, it is not a comprehensive cost-benefit analysis for the corporates investing in them. The cost of a PPA is typically dependent on a number of factors, including the contract length and expected merchant revenue of the asset, not just the LCOE. Additionally, a cross-border vPPA would lead to a physical disconnect between the renewable generation and the corporate demand. In this case, the electricity generated could be sold back into the local market, with the corporate needing to purchase electricity from their domestic market or supplier. The costs and revenue streams opened up to the corporate are highly dependent on the design of the mechanism, as well as external factors such as day-ahead and retail power prices.

We have sourced LCOE assumptions for each market and technology from two facets of Baringa's modelling framework. For power markets that are modelled as part of the Reference Case, we have aligned our LCOE assumptions with those used in their respective market models. This includes all in-scope markets in Europe and the US, and the majority of markets in Asia and Latin America. For in-scope markets not currently modelled in the Reference Case, we have aligned our assumptions with the less granular regional data used in Baringa's Global Transition Model, a model designed to explore global climate transition scenarios.

LCOE assumptions from both models have been developed from publicly available data, market intelligence, and internal modelling.

Table 6 in Appendix B presents the average LCOEs of procured renewable technologies across each scenario. Note that these values are weighted averages across markets according to the optimization of STEAM in each scenario. They are not inputs to the model, or global averages.

A.6 STEAM

A.6.1 Model architecture

Figure 22 below provides an overview of the model architecture behind STEAM, showing the flow of data through the model execution process. Fixed inputs remain constant between different simulations of the model, with variable inputs changing depending on the parameters being tested.

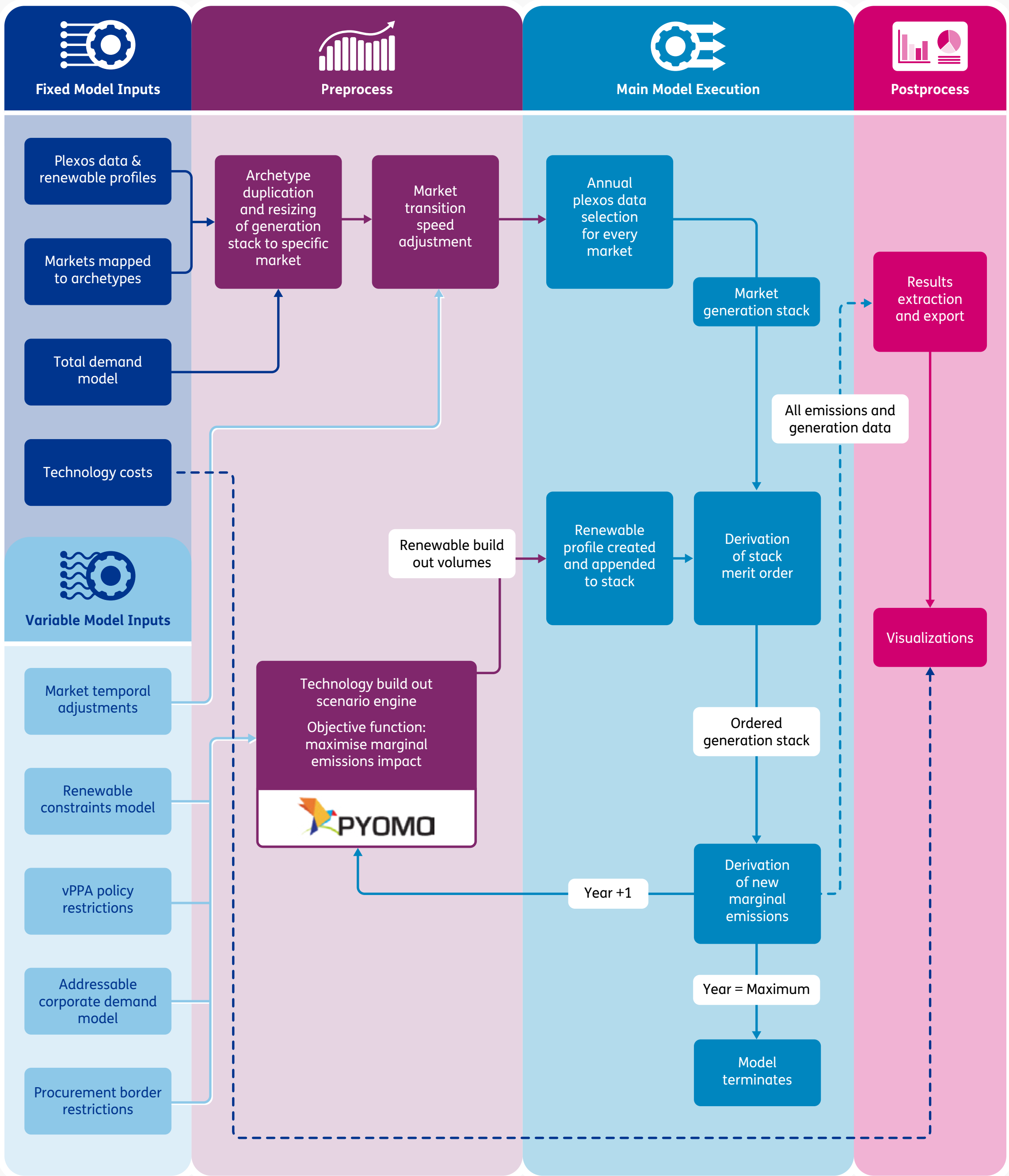

Figure 22: Process flow diagram for STEAM, from inputs to optimization and model execution

A.6.2 Preprocess

The first step in the model is to build counterfactual hourly merit order stacks for each of the in-scope markets, based on data for their archetypes:

1. Asset-level day-ahead market data (Appendix A.3.2) from the results of the Reference Case power market models is used to define the hourly merit order stacks for each archetypal market between 2024 and 2040. This data includes hourly generation, accepted bid price, and CO_2 emissions for each generator and energy storage asset. Interconnector flow data and day-ahead prices in neighbouring markets are used to insert imports into their respective positions in the merit order stacks. Discharge of energy storage assets and imports through interconnectors are not assigned CO_2 values, i.e., they are assumed to offer no carbon benefit if displaced by corporate-backed renewables[39].
2. Once hourly merit orders have been created for the six archetypes, a copy is made for each market within their group. These copies are then linearly scaled up or down using projected annual demand data for each market in the Reference Case, relative to their archetype. For example, Poland's archetypal market is India, and so the Indian merit order data is scaled down until annual demand matches that projected for Poland.
3. To reflect differences in renewable energy transitions between markets and their archetypes, temporal adjustments (Appendix A.1.3) have been made based on IEA, EIA, and Reference Case data. Taking the example above, in 2030, Poland's renewable penetration is projected to be higher than that of India, and so data from later in the horizon (2031) has been used to represent it.

A.6.3 Main model execution

Once the counterfactual merit order data has been calculated for each market, STEAM is tasked with optimizing the geographical procurement of renewables to achieve maximum global carbon abatement. Note that the model optimization does not account for other factors, such as cost.

The optimization is bounded by several constraints, including available procurement volumes, maximum renewable build by market, and procurement boundaries, allowing the relative impacts of different scenario assumptions to be tested. The model optimization proceeds in iterative annual steps, with the deployment of contracted renewables factoring into decision making for subsequent years. In this design, the model is reactive to the ongoing decarbonization achieved by renewable procurement and can adjust deployment location accordingly. With cross-border procurement unlocked globally, the model optimization proceeds as follows:

1. STEAM first calculates the carbon intensity of the marginal generator in every hour of 2024, for each of the 64 markets. The average of this value over the year is used to rank the markets from most carbon-intense marginal generation to least, i.e., most to least potential decarbonization from renewables. Any markets without PPAs to date (based on RE100 data) are removed from the optimization until 2030.

39 In reality, displacement of imports through interconnectors may displace fossil fuel-fired capacity from the margins of neighbouring markets, and storage assets may have CO_2 emissions associated with charging.

2. Renewable procurement volumes for 2025 are defined as equal to the addressable corporate demand in that year (Appendix A.2). This volume is assigned first to the market with the highest marginal carbon intensity in the previous year, subject to a fixed assumed ratio between technologies, and a maximum build constraint (Appendix A.4). This repeats down the hierarchy of markets until the required volume has been procured.
3. The model then inserts the procured renewable volumes into the merit orders according to the distribution calculated in step 2. Market-specific renewable output profiles for each technology are used to convert annual volumes into hourly production data, and the total cost of procurement is evaluated from technology cost data (Appendix A.5). The resulting displaced generation from the top of the merit order is recorded for each market, along with any associated CO_2 emissions.
4. The model then calculates the average marginal carbon intensity of each market in 2025, factoring in the impact of deployed renewables, and steps 1 to 3 repeat until the end of the model horizon is reached after 2040.

A.7 Additional exclusions

A.7.1 China

We have excluded countries and jurisdictions under US, UK, and EU sanctions from the scope of this study, including China. Given the current macro-economic and political environment, we have deemed it reasonable to exclude China from our analysis given potential disincentives for investment from companies in Europe and North America, which account for most of the in-scope corporate demand.

Renewable investment in China is likely however to play a major role in global power-sector decarbonization, as the Chinese power grid accounts for around half the world's coal-fired generation today, and 95% of new coal plant construction[40]. Cross-border investment in Chinese renewable projects, including from growing corporate demand in other Asian markets, is therefore likely to offer additional decarbonization to the results presented in this study.

A.7.2 Cost-based optimization

STEAM optimizes the location of renewable procurement based decarbonization impact and does not consider the relative cost to build renewables in each market. It is therefore possible that comparable decarbonization could be realized for a lower cost than reported, though this has not been explored as part of this study.

40 Global Coal Plant Tracker, Global Energy Monitor (GEM)

Appendix B Tabulated assumptions

In this Appendix we present a selection of the key input data used within our modelling of the global power system:

- Table 3 summarizes the 64 markets we have included within our analysis.
- Table 4 presents the addressable demand volumes assumed.
- Table 5 presents renewable build constraints by region, and indicative technology ratios.
- Table 6 presents the average LCOEs of procured renewables.

Table 3: Summary of global markets included within our analysis

Studied Markets	Archetype Group	Current Boundary	Continental Region	Economy Class
Algeria	Emerging Players	-	Middle East & North Africa	Emerging & Developing
Argentina	Maturing Markets	-	Latin America	Emerging & Developing
Australia	Carbon-Reliant Grids	-	Asia-Pacific	Advanced
Austria	Low-Carbon Pioneers	Europe	Europe	Advanced
Bangladesh	Slower Adopters	-	Central & South Asia	Emerging & Developing
Belgium	Green Leaders	Europe	Europe	Advanced
Brazil	Low-Carbon Pioneers	-	Latin America	Emerging & Developing
CAISO	Green Leaders	North America	North America	Advanced
Canada	Low-Carbon Pioneers	North America	North America	Advanced
Chile	Maturing Markets	-	Latin America	Emerging & Developing
Colombia	Low-Carbon Pioneers	-	Latin America	Emerging & Developing
Croatia	Low-Carbon Pioneers	Europe	Europe	Advanced
Czechia	Emerging Players	Europe	Europe	Advanced

Table 3 (continued)

Studied Markets	Archetype Group	Current Boundary	Continental Region	Economy Class
Denmark	Low-Carbon Pioneers	Europe	Europe	Advanced
Egypt	Emerging Players	-	Middle East & North Africa	Emerging & Developing
ERCOT	Maturing Markets	North America	North America	Advanced
Finland	Green Leaders	Europe	Europe	Advanced
France	Low-Carbon Pioneers	Europe	Europe	Advanced
Great Britain (GB)	Green Leaders	-	Europe	Advanced
Germany	Maturing Markets	Europe	Europe	Advanced
Greece	Maturing Markets	Europe	Europe	Advanced
Hong Kong	Slower Adopters	-	Asia-Pacific	Advanced
Hungary	Maturing Markets	Europe	Europe	Emerging & Developing
Iceland	Low-Carbon Pioneers	Europe	Europe	Advanced
India	Carbon-Reliant Grids	-	Central & South Asia	Emerging & Developing
Indonesia	Carbon-Reliant Grids	-	Asia-Pacific	Emerging & Developing
Ireland	Maturing Markets	Europe	Europe	Advanced
ISO-NE	Emerging Players	North America	North America	Advanced
Israel	Slower Adopters	-	Middle East & North Africa	Advanced
Italy	Maturing Markets	Europe	Europe	Advanced
Japan	Emerging Players	-	Asia-Pacific	Advanced
Kazakhstan	Carbon-Reliant Grids	-	Central & South Asia	Emerging & Developing

Table 3 (continued)

Studied Markets	Archetype Group	Current Boundary	Continental Region	Economy Class
Kuwait	Slower Adopters	-	Middle East & North Africa	Emerging & Developing
Malaysia	Carbon-Reliant Grids	-	Asia-Pacific	Emerging & Developing
Mexico	Emerging Players	-	North America	Emerging & Developing
MISO	Emerging Players	North America	North America	Advanced
Morocco	Carbon-Reliant Grids	-	Middle East & North Africa	Emerging & Developing
Netherlands	Maturing Markets	Europe	Europe	Advanced
New Zealand	Low-Carbon Pioneers	-	Asia-Pacific	Advanced
Nigeria	Maturing Markets	-	Sub-Saharan Africa	Emerging & Developing
Norway	Low-Carbon Pioneers	Europe	Europe	Advanced
NYISO	Maturing Markets	North America	North America	Advanced
Pakistan	Maturing Markets	-	Central & South Asia	Emerging & Developing
Peru	Green Leaders	-	Latin America	Emerging & Developing
Philippines	Carbon-Reliant Grids	-	Asia-Pacific	Emerging & Developing
PJM	Emerging Players	North America	North America	Advanced
Poland	Carbon-Reliant Grids	-	Europe	Emerging & Developing
Portugal	Low-Carbon Pioneers	Europe	Europe	Advanced
Qatar	Emerging Players	-	Middle East & North Africa	Emerging & Developing
Romania	Green Leaders	-	Europe	Emerging & Developing
Saudi Arabia	Slower Adopters	-	Middle East & North Africa	Emerging & Developing

Table 3 (continued)

Studied Markets	Archetype Group	Current Boundary	Continental Region	Economy Class
Singapore	Emerging Players	-	Asia-Pacific	Advanced
South Africa	Carbon-Reliant Grids	-	Sub-Saharan Africa	Emerging & Developing
South Korea	Slower Adopters	-	Asia-Pacific	Advanced
Spain	Green Leaders	Europe	Europe	Advanced
SPP	Maturing Markets	North America	North America	Advanced
Sweden	Low-Carbon Pioneers	Europe	Europe	Advanced
Switzerland	Low-Carbon Pioneers	Europe	Europe	Advanced
Taiwan	Slower Adopters	-	Asia-Pacific	Advanced
Thailand	Emerging Players	-	Asia-Pacific	Emerging & Developing
Türkiye	Maturing Markets	-	Europe	Emerging & Developing
United Arab Emirates (UAE)	Emerging Players	-	Middle East & North Africa	Emerging & Developing
Uzbekistan	Slower Adopters	-	Central & South Asia	Emerging & Developing
Vietnam	Carbon-Reliant Grids	-	Asia-Pacific	Emerging & Developing

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Table 4: Addressable corporate demand assumptions

Addressable Demand	Units	2025	2030	2035	2040
Projected Addressable Demand					
PPA-backed demand	TWh	5	40	75	110
EAC-backed demand	TWh	5	50	105	210
Non-renewable demand	TWh	10	75	170	335
Modelled Assumptions					
Central demand	TWh	15	85	180	325
Low demand	TWh	5	40	75	110
High demand	TWh	25	165	350	660
Central Demand by Archetype					
Low-Carbon Pioneers	TWh	0	10	20	40
Green Leaders	TWh	5	15	35	60
Maturing Markets	TWh	5	25	50	90
Emerging Players	TWh	5	30	60	110
Slower Adopters	TWh	0	0	5	5
Carbon-Reliant Grids	TWh	0	5	10	20
Central Demand by Region					
Asia-Pacific	TWh	0	5	10	20
Central & South Asia	TWh	0	0	5	10
Europe	TWh	5	35	70	130
Latin America	TWh	0	5	5	15
Middle East & North Africa	TWh	0	0	0	5
North America	TWh	5	40	85	150
Sub-Saharan Africa	TWh	0	0	0	0

Table 5: Modelled renewable build constraints, and build proportions for select markets

Renewable Constraints	Units	2025	2030	2035	2040
Maximum Annual Renewable Build by Region					
Asia-Pacific	TWh	120	110	145	185
Central & South Asia	TWh	45	20	40	70
Europe	TWh	135	145	200	230
Latin America	TWh	30	40	45	60
Middle East & North Africa	TWh	30	30	35	45
North America	TWh	170	155	215	250
Sub-Saharan Africa	TWh	10	10	15	20
Illustrative Set of Renewable Build Proportions[41]					
Sweden - Onshore Wind	% of TWh	85%	80%	65%	30%
Sweden - Offshore Wind	% of TWh	15%	20%	30%	60%
Sweden - Solar PV	% of TWh	0%	0%	5%	10%
GB - Onshore Wind	% of TWh	30%	25%	30%	30%
GB - Offshore Wind	% of TWh	55%	70%	60%	65%
GB - Solar PV	% of TWh	15%	5%	10%	5%
SPP - Onshore Wind	% of TWh	75%	85%	60%	5%
SPP - Offshore Wind	% of TWh	0%	0%	0%	0%
SPP - Solar PV	% of TWh	25%	15%	40%	95%
PJM - Onshore Wind	% of TWh	20%	15%	15%	0%
PJM - Offshore Wind	% of TWh	20%	25%	35%	40%
PJM - Solar PV	% of TWh	60%	60%	50%	60%

41 Note that these values correspond to the archetype markets themselves, not the groups they represent, and so are an illustrative subset of our assumptions.

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Renewable Constraints	Units	2025	2030	2035	2040
South Korea - Onshore Wind	% of TWh	20%	15%	20%	20%
South Korea - Offshore Wind	% of TWh	30%	55%	35%	35%
South Korea - Solar PV	% of TWh	50%	30%	45%	45%
India - Onshore Wind	% of TWh	35%	50%	40%	30%
India - Offshore Wind	% of TWh	0%	0%	5%	5%
India - Solar PV	% of TWh	65%	50%	55%	65%

Table 6: Average levelized cost of procured renewable volumes across scenarios

Average LCOE of Procured Renewables[42]	Units	2025	2030	2035	2040
Global Cross-Border Procurement					
Onshore wind	$/MWh	63	52	45	44
Offshore wind	$/MWh	115	87	77	70
Solar PV	$/MWh	55	46	42	38
Current Market Boundaries					
Onshore wind	$/MWh	66	54	49	49
Offshore wind	$/MWh	100	87	86	76
Solar PV	$/MWh	75	52	49	43
Continental Market Boundaries					
Onshore wind	$/MWh	60	52	54	49
Offshore wind	$/MWh	105	87	84	74
Solar PV	$/MWh	58	47	47	42
Low Demand					
Onshore wind	$/MWh	73	62	59	48
Offshore wind	$/MWh	115	81	80	71
Solar PV	$/MWh	83	50	49	41
High Demand					
Onshore wind	$/MWh	68	55	52	42
Offshore wind	$/MWh	119	77	74	60
Solar PV	$/MWh	69	51	41	34

42 Note that these values are optimized outputs of STEAM, and not inputs to the model.

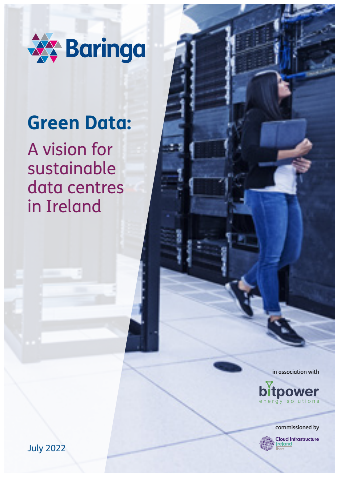
Appendix C More from Baringa

UK renewables deployment supply chain readiness study

Read our latest study conducted for the Department for Energy Security & Net Zero, to discover why achieving the renewables deployment ambitions outlined in the British Energy Security Strategy will be very challenging without significant coordination across industry and Government to resolve supply chain constraints. The study includes analysis of offshore wind, onshore wind, solar PV and transmission and distribution network supply chains.

Read our report

Green Data



Read our landmark study and explore the role of data centers in modern Irish society, including the social and economic value that the industry brings to Ireland, and the essential role they play in helping Ireland to meet its climate goals. The report, commissioned by Cloud Infrastructure Ireland, sets out a vision for the future of the industry, and the actions that must be taken by the sector, Government, and other stakeholders, to ensure a sustainable future for Ireland.

Read our report

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The Corporate Catalyst – Report commissioned by Amazon

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