

Data-to-Deal Series

D2D Component 4

MODELLING: UNDERTAKING DELIBERATIVE MODELLING – A BEST PRACTICE BRIEF

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SUMMARY

This best practice brief presents Component 4 of the Data-to-Deal (D2D) framework, which addresses Modelling. This component focuses on the role of scenario-based, policy-relevant modelling in translating shared national visions into implementable transition strategies that are credible to domestic stakeholders and finance partners. Component 4 comprises six sub-components of successful modelling: (i) establishing governance and institutional arrangements; (ii) choosing fit-for-purpose models aligned with policy questions and national priorities; (iii) ensuring transparency and openness in methods and data; (iv)

integrating demand-side modelling that reflects spatial and socioeconomic realities; (v) communicating results to inform policy and finance; and (vi) translating modelling into endorsed transition plans. Together, these sub-components guide countries from shared visions and targets towards implementable transition plans grounded in evidence, credibility, and ownership. The brief draws on practical experience and case studies, including Ecuador, Kenya, and the Latin America and Caribbean region as a whole to illustrate best practices for developing robust modelling workflows that support financing and implementation.

KEY RECOMMENDATIONS

1. Strong institutional foundations for national modelling should be established through clear leadership and governance arrangements.
2. Modelling frameworks should be anchored in policy questions and grounded in transparency and open access.
3. Demand should be treated as a dynamic lever for sustainable and inclusive development.
4. Communication of modelling results should be clear, inclusive, and action-oriented.
5. Transition pathways should be stress-tested, sequenced, and linked to actionable policy and finance strategies.

CONTRIBUTING INSTITUTIONS



IMPERIAL



D2D
4/7

This document forms part of a series of guidance notes, each focused on one D2D component. The series provides practical advice to governments and their partners on how to integrate D2D into national planning and financing processes.

This series (available [here](#)) is co-authored by leading international organisations, along with contributors from LMIC countries, to reflect a collective perspective on how best to leverage investment for climate-aligned energy and transport transitions.

The primary audience for these briefs includes energy and transport policymakers in LMICs at national and subnational levels, as well as development partners and international organisations that provide technical and financial support. The guidance applies to both mitigation and adaptation priorities, while recognising that the balance between them will differ depending on the specific country context.



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CONTENTS

SUMMARY	2
1. INTRODUCTION	4
1.1. Inter-linkages	4
1.2. Value Proposition	4
1.3. Sub-components	5
2. BEST PRACTICE GUIDELINES	7
2.1. Establishing Governance and Institutional Arrangement	7
2.1.1. Defining formal governance arrangements.	7
2.1.2. Developing coordination mechanisms.	7
2.2. Choosing a Model and Aligning Tools with National Priorities	8
2.2.1. Engaging Iteratively with Stakeholders to Define the Scope of the Modelling Exercise	8
2.2.2. Establishing the Geographical and Temporal Scope of the Modelling Exercise	9
2.2.3. Determining the Sectoral Coverage of the Modelling Exercise	10
2.2.4. Defining the Technological Coverage of the Modelling Exercise	11
2.3. Ensuring Transparency and Openness of the Modelling Process	12
2.3.1. Ensuring High-Quality Data Through QA/QC Procedures	12
2.3.2. Adopting Transparent and Open-Source Modelling Principles	12
2.3.3. Providing Public Access Wherever Possible	13
2.3.4. Addressing Uncertainties Throughout the Modelling Exercise	14
2.3.5. Acknowledging Modelling Limitations	15
2.4. Enhancing Energy System Design through a Demand-Side Focus	15
2.4.1. Integrating Demand-Side Measures into the Model	15
2.4.2. Representing Spatial Variation in Demand	15
2.4.3. Reflecting Variation in Demand Across Socioeconomic Groups	16
2.4.4. Integrating Qualitative Insights that Capture Social and Behavioural Dynamics	17
2.5. Communicating the Results to Domestic and International Audiences	17
2.5.1. Communicating During the Modelling Process Itself	18
2.5.2. Framing Results in Terms of Actions, Timelines, Budgets, and Policies	18
2.5.3. Providing Disaggregation of Results Across Relevant Groupings	18
2.5.4. Reporting Assumptions, Limitations, and Uncertainties	19
2.6. Translating the Modelling Analysis into Transition Plans	19
2.6.1. Embedding Modelling Insights in Existing Planning Instruments	19
2.6.2. Designing Strategies with Clear Policy Levers and Sequencing	19
2.6.3. Linking Results to Financing Strategies	20
2.6.4. Ensuring Adaptability Through Iterative Monitoring and Review	20
3. RECOMMENDATIONS	21
REFERENCES	22

1. Introduction

Low- and middle-income countries (LMICs) are working to transform major economic sectors to advance development priorities, meet climate commitments, and strengthen infrastructure resilience. Achieving these objectives will require accelerated socio-economic change across energy, transport, and other high-emitting sectors. Most countries, however, cannot achieve these transformations without mobilising much higher levels of finance [1]

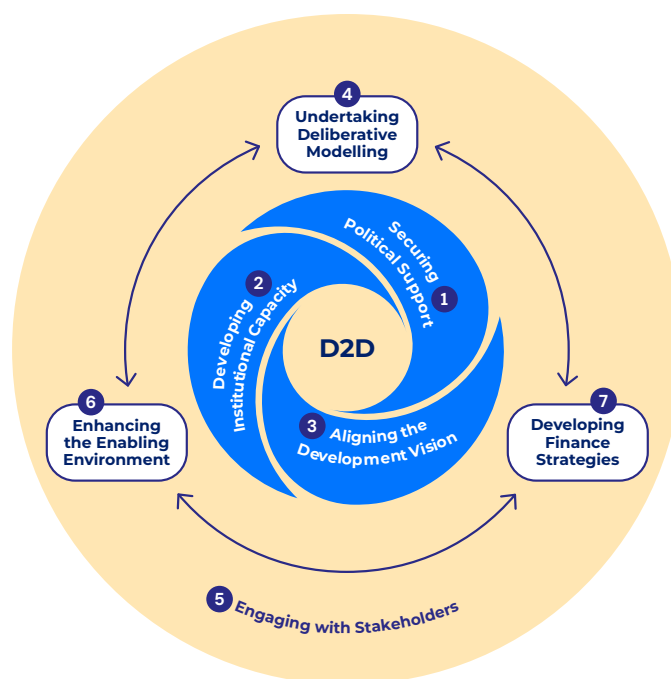
The Data-to-Deal (D2D) framework (**Figure 1**), developed by over 75 global experts, provides a structured, evidence-based approach to help countries close this gap. The framework consists of seven interlinked components – Politics, Capacity, Vision, Modelling, Engagement, Policy, and Finance – that move from political commitment and institutional readiness through to financing. These components are designed to be adapted to national contexts, rather than be followed in strict sequence, and they are underpinned by sustained stakeholder engagement.

This brief focuses on **Component 4: Modelling** – Undertaking Deliberative Modelling. In the D2D framework, deliberative modelling is the structured, participatory process through which shared national visions are translated into quantified, evidence-based transition pathways. It provides the analytical foundation for transition planning by testing policy options, assessing trade-offs, and identifying robust strategies under uncertainty. The process is typically led by technical ministries or planning agencies, working in close coordination with ministries of finance, utilities, regulators, and research institutions. Component 4 concludes with an endorsed transition plan.

1.1. Inter-linkages

Within the D2D framework, Component 4 builds upon the outputs of other components, as outlined in **Table 1**.

Figure 1: The D2D framework visualised



The interaction among these components is iterative. As Component 4 receives updated data or revised targets, it may trigger adjustments in modelling assumptions, influencing stakeholder engagement processes (Component 5: Engagement), policy design (Component 6: Policy), and finance strategy development (Component 7: Finance).

1.2. Value Proposition

Deliberative modelling plays a pivotal role in translating national visions and targets into credible, evidence-based transition plans. Without such a process, policy and investment decisions risk being fragmented, inconsistent, or detached from national data and realities. The key value propositions of undertaking a robust, deliberative modelling process, which bring multiple benefits, include:

- **Evidence-based policymaking.** Quantitative modelling grounds decisions in national data and transparent analysis, enabling

Table 1: Interactions between Component 4 and other Components of the D2D Framework

D2D Component	Link to Component 4: Modelling
1. Politics: Securing political support	Component 1 establishes the political mandate and institutional leadership needed for a national modelling process. High-level endorsement ensures access to data, inter-ministerial coordination, and alignment between modelling outputs and national policy objectives. Political commitment also signals ownership, helping embed modelling results into formal planning and budgeting cycles.
2. Capacity: Developing institutional capacity	Component 2 strengthens the institutional and technical foundations for modelling by building national the TDG-SIG, data management systems, and analytical capabilities. It assesses and develops skills across ministries, utilities, and research institutions, ensuring that modelling can be conducted, understood, and updated domestically over time.
3. Vision: Aligning the development vision	Component 3 defines the decarbonisation and development targets that guide the modelling process. These targets, derived from national visioning exercises, are translated into assumptions, constraints, and scenarios within the models, forming the analytical link between long-term ambition and implementable pathways.
5. Engagement: Engaging with stakeholders	Component 5 embeds participatory modelling by involving stakeholders throughout the process, from defining questions and collecting data to validating results. Engagement builds trust, improves data quality, and ensures that model assumptions and outputs reflect the perspectives of affected sectors, regions, and communities.
6. Policy: Enhancing the enabling environment	Component 6 draws directly on modelling outputs to identify the policy and regulatory reforms required to deliver transition pathways. These may include sectoral targets, investment incentives, or fiscal measures. The feedback between policy and modelling ensures that scenarios remain realistic, actionable, and responsive to changing policy priorities.
7. Finance: Developing finance strategies	Component 7 uses the outputs of the modelling process, the quantified transition plan, to determine investment requirements, sequencing, and cost trajectories. In turn, finance strategy modelling feeds back real-world financial constraints, such as fiscal space or debt limits, to refine assumptions and ensure consistency between technical and financial planning.

policymakers to assess trade-offs, test policy options, and design realistic transition pathways.

- **Enhanced policy credibility and public trust.** Transparent, participatory modelling builds confidence among domestic stakeholders and international partners, strengthening acceptance of transition strategies and ensuring they are seen as nationally owned.
- **Integration and coordination across sectors and scales.** Modelling connects energy, transport, land-use, and economic systems under a coherent analytical framework, helping to coordinate ministries, regulators, utilities, and other actors around shared assumptions, goals, and pathways.
- **Identification of robust strategies under uncertainty.** Scenario analysis allows governments to stress-test policy choices against uncertain futures, such as shifting technologies, volatile markets, or evolving policy landscapes, and identify strategies that

remain viable, resilient, and affordable across a range of possible outcomes.

- **Foundation for policy and finance design.** By quantifying investment needs, costs, and system impacts, modelling provides the analytical base for subsequent components on policy (Component 6: Policy) and finance (Component 7: Finance), ensuring that strategies are both technically and financially feasible.
- **Capacity development and institutional learning.** Establishing local modelling teams and workflows strengthens long-term analytical capability, supports data governance, and embeds evidence-based planning within national institutions.

1.3. Sub-components

Component 4 consists of six sub-components that collectively lay the foundation for a comprehensive and deliberative modelling process. These sub-

components progress from model and data selection to effective translation of results into transition plans:

1. Establishing Governance and Institutional Arrangements.

Establishing clear leadership, coordination mechanisms, and decision rights to ensure the modelling process is nationally owned, transparent, and embedded in planning and budgeting cycles. Effective governance links technical teams with policymaking institutions, promotes data sharing, and sustains institutional capacity for iterative modelling and policy refinement.

2. Choosing a Model and Aligning Tools with National Priorities.

Selecting models is critical to effectively addressing national development priorities. Understanding the synergies of these priorities across multiple sectors (eg land, water, industrial processes) and capturing socioeconomic aspects is key to maximising the modelling impact and ensuring policy coherence.

3. Ensuring Transparency and Openness of the Modelling Process.

Models are mathematical representations of the real system; thus, they use data. Adequate data is always a challenge, but the use of transparent, validated, and context-relevant input data enhances political acceptance.

4. Enhancing Energy System Design through a Demand-Side Focus.

Prioritising demand-side measures (eg energy efficiency, electrification, behavioural shifts) is necessary for shaping cost-effective and inclusive system development.

5. Communicating the Results to Domestic and International Audiences.

Modelling outcomes and policy recommendations should be presented in accessible formats to engage stakeholders, secure buy-in, and attract financing.

6. Translating the Modelling Analysis into Transition Plans.

The ultimate value of modelling lies in converting analysis into investment-ready transition plans. This involves embedding outputs into existing national frameworks (such as Long-Term Strategies or Nationally Determined Contributions), sequencing policy measures, linking results to financing strategies, and designing adaptive plans that remain relevant under uncertainty.

The remainder of this brief provides in-depth guidance on these six sub-components to support policymakers and their partners in operationalising transition plans through viable financing strategies. Throughout, the brief draws on concise case studies to illustrate practical applications, common pitfalls, and replicable solutions in diverse LMIC contexts.

2. Best Practice Guidelines

2.1. Establishing Governance and Institutional Arrangement

The first sub-component of Component 4 is establishing governance and coordination arrangements. Clarifying institutional roles and coordination structures is essential to ensure that modelling activities are credible, nationally owned, and directly connected to policy and investment decisions. In practice, this means defining who leads, who contributes, and how different institutions work together throughout the modelling process. It also requires aligning technical modelling teams, such as the TDG-SIG, with policymakers and the Ministry of Finance so that analytical outputs feed seamlessly into decision-making. This subcomponent identifies two key elements that influence the effectiveness of governance for deliberative modelling:

- **Defining formal governance arrangements.**
- **Developing coordination mechanisms.**

2.1.1. Defining formal governance arrangements.

Establishing clear governance arrangements will ensure both the effective conduct of modelling and the credibility of the transition plan that follows. The Governing Coordination Function (GCF), established under Component 1: Politics, sits at the centre of the governance architecture for Component 4. Its role is to convene and sequence the work, ensuring that policy questions are translated into scenarios, that results are framed as actions and timelines, and that the plan emerging from Component 4 responds to the priorities identified under Component 3: Vision. The GCF also ensures that modelling outputs are framed as actionable inputs for Component 6: Policy and Component 7: Finance.

In many countries, the GCF is located close to the centre of government, such as the Presidency, Prime Minister's Office, or a national planning commission, to secure high-level

authority across line ministries while remaining connected to the lead technical institution that manages modelling activities. Because modelling outputs must ultimately inform fiscal choices, the Ministry of Finance should be formally embedded in the arrangement even when day-to-day authorship rests with an energy, planning, or environment ministry.

Responsibility for technical modelling is often housed in a lead ministry or specialised energy-planning agency. However, best practice is for governance arrangements to establish a shared mandate that links this technical function with the institutions responsible for policy, regulation, and finance. This approach ensures that modelling remains aligned with national development and fiscal strategies and that its outputs carry the legitimacy required for political endorsement.

Governance frameworks should be formalised through mandates, ministerial decrees, or memoranda of understanding that define institutional roles, decision rights, data-sharing protocols, and principles of transparency. These instruments should also specify requirements for model documentation, peer review, and version control to preserve analytical integrity and reproducibility. Embedding the governance framework within existing planning and budget institutions, rather than creating parallel structures, supports sustainability and coherence with established policy processes. Over time, such governance provides the foundation for iterative modelling cycles that are institutionally embedded, transparent, and nationally credible.

2.1.2. Developing coordination mechanisms. **Coordination mechanisms should be put in place to operationalise governance by translating institutional mandates into a functioning modelling process.** Effective coordination enables information to flow between technical

teams and decision-makers, ensuring that modelling responds to policy needs and that analytical results are transformed into actionable plans.

Within this framework, two groups deliver the work. At the strategic level, the Political Steering Committee – Special Interest Group (PSC-SIG) provides political direction, approves model scope and scenario design, and validates key milestones so that the modelling effort remains aligned with national priorities and international commitments. In many contexts, a pre-existing country platform can be designated to play this role, providing a single interface for development partners and investors while avoiding fragmented, project-by-project engagement.

At the operational level, the Technical Delivery Group – Special Interest Group (TDG-SIG) undertakes the analytical work. It translates political guidance into model specifications, compiles and validates datasets, runs scenarios, coordinates quality-assurance procedures, and conducts uncertainty analyses. Membership of the TDG-SIG should combine government planners, utilities and regulators, the national statistics office, and at least one domestic university or research centre to anchor capacity, reproducibility, and methodological continuity. Sub-groups may be convened for specialised tasks, for example on data and assumptions, systems modelling, gender and inclusion, or links to public investment, provided that all activities adhere to a shared calendar aligned with national planning and budget timetables.

These mechanisms should also extend beyond government. Structured touchpoints with the private sector, civil society, and academia during scoping, assumption review, and co-interpretation of results will strengthen data quality, improve the realism of scenarios, and

build legitimacy for the plan. Over time, regular interaction between the PSC-SIG and TDG-SIG, convened and sequenced by the GCF, creates an iterative feedback loop between evidence generation and decision-making, ensuring that deliberative modelling remains responsive, transparent, and embedded within national planning systems.

2.2. Choosing a Model and Aligning Tools with National Priorities

The second sub-component of Component 4 is model choice. A key aspect of effectively studying national development goals and international climate targets relates to the selection of the model that will help answer these simultaneous questions. Trade-offs will need to be made, and in several cases, various models may be needed. In general, the model should aim to address one or several well-defined problems or questions that guide the analysis based on the vision defined in Component 3: Vision. These questions will guide the scoping of the modelling process. This subcomponent outlines four key elements that shape effective model choice:

- **Engaging iteratively with stakeholders to define the scope of the modelling exercise**
- **Establishing the geographical and temporal scope of the modelling exercise**
- **Determining the sectoral coverage of the modelling exercise**
- **Defining the technological coverage of the modelling exercise**

2.2.1. Engaging Iteratively with Stakeholders to Define the Scope of the Modelling Exercise

Stakeholders should be engaged early and throughout the process to define the scope of the model and ensure that assumptions, data, and questions remain policy-relevant.

Stakeholder engagement is a cross-cutting element of the Data-to-Deal framework, as emphasised in Component 5: Engagement. Specifically in Component 4, stakeholders play a

critical role in data collection, model architecture design, and the formulation of assumptions. Openly addressing trade-offs between model complexity and practical constraints, such as data availability and computational resources, is essential to setting realistic expectations. While detailed, feature-rich models are ideal, they may not be feasible in all contexts. For instance, a country with limited data availability on technology costs and performance may opt for a simplified model that only includes aggregated categories like “solar PV”, “diesel standalone”, and “imports”. Therefore, it is important to build a shared understanding between modellers and stakeholders about both the ambition and the limitations of the modelling process [2].

To carry this out, governments and their partners should initiate early consultations with relevant institutions, such as energy ministries, utilities, regulators, academia, and civil society, to identify priority questions and expectations. These consultations can be structured through workshops, interviews, or working groups. Throughout the modelling process, stakeholders should be invited to review assumptions, validate inputs, and interpret preliminary results. This iterative engagement helps refine the model scope and ensures that outputs remain relevant to evolving policy needs. It also builds trust and ownership, which are essential for implementation.

In addition, the modelling workflow should span multiple levels of governance. Including representatives from national, regional, and local institutions ensures that the model reflects diverse perspectives and improves its relevance across planning scales [3]. This multi-level involvement supports stronger alignment with national goals and more inclusive policy design. Coordination across different geographical scales also allows for nested modelling approaches, where subnational insights inform national

scenarios, and vice versa (see section 2.2.2). This strengthens ownership, coherence, and implementation across levels of government.

To implement this, the TDG-SIG should work to define modelling boundaries, facilitate data sharing, and ensure that outputs are usable across planning contexts, with the PSC-SIG providing strategic endorsement where scope decisions have policy implications. Where feasible, subnational models can be linked to national ones to reflect local realities and improve scenario accuracy.

2.2.2. Establishing the Geographical and Temporal Scope of the Modelling Exercise

Align the model's geographic and temporal resolution with the decisions it is intended to inform, to capture key system dynamics without overcomplicating the model. Defining the geographical scope of an energy system model requires a balance between analytical depth and practical feasibility. Best practices recommend aligning the model's boundaries with the specific policy or research questions it seeks to address [4]. For example, national-level models are appropriate for long-term energy planning and assessing commitments under international agreements, whereas regional or subnational models can capture localised dynamics such as renewable resource availability, grid congestion, or urban energy demand. A clear justification of the chosen boundary is crucial, as overly broad scopes may introduce data and computational challenges, while overly narrow ones risk overlooking cross-border flows or interregional dependencies in terms of imports and exports of energy. Where possible, models should also represent interconnections between regions or countries, especially in contexts where electricity trade or shared resources significantly influence system outcomes.

Equally important is the temporal scope, which determines both the time horizon and the

resolution of the analysis. A long-term horizon, often extending 20 to 50 years, is typically needed to reflect technology lifetimes, infrastructure planning cycles, and decarbonisation pathways. Within that horizon, temporal resolution should capture variations in demand and supply, such as daily load curves or seasonal resource availability, without overburdening the model with unnecessary complexity. Best practice is to tailor the temporal detail to the research question: for instance, hourly time slices may be essential for analysing flexibility options like storage or demand response, while annual or seasonal resolution may suffice for strategic policy assessments.

To implement this, modelling teams should consult with planners and technical experts to determine the appropriate time horizon and resolution. These decisions should be based on the types of technologies being assessed and the planning questions being addressed. The rationale for both geographical and temporal choices should be documented and shared with stakeholders to ensure transparency and confidence in the modelling process.

2.2.3. Determining the Sectoral Coverage of the Modelling Exercise

The major sectors that shape or are shaped by energy use should be modelled to capture real-world synergies, trade-offs, and policy coherence. Intersectoral linkages are crucial for creating a comprehensive and integrated approach to energy planning [5]. Linking energy systems with other sectors, such as transport, industry, and agriculture, ensures that the interactions and dependencies between sectors are properly accounted for, leading to more accurate and robust models. This interconnection helps to identify synergies, optimise resource allocation, and develop strategies that enhance system resilience and sustainability. Furthermore, it supports the design of policies that are aligned

with broader socioeconomic goals, such as environmental protection, economic growth, and social equity, promoting a holistic and adaptable energy transition.

To carry this out, modellers should begin by identifying which sectors significantly influence or are influenced by the energy system. This includes mapping energy demand across sectors and understanding where emissions reductions are most feasible. Coordination with sectoral ministries is essential to align modelling assumptions with existing plans and data sources. Where feasible, models should be integrated across sectors or linked through shared parameters and scenarios. For example, energy models can be connected with land-use models to assess bioenergy potential or with transport models to evaluate electrification pathways. Assumptions for each sector should be transparently documented, and limitations clearly stated, to avoid misinterpretation of results.

Best practices from integrated resource modelling stress that models should align with policy cycles and planning tools used in other sectors, such as transport, agriculture, or water so that outputs can feed into cross-sectoral strategies. See **Box 1** for more details.

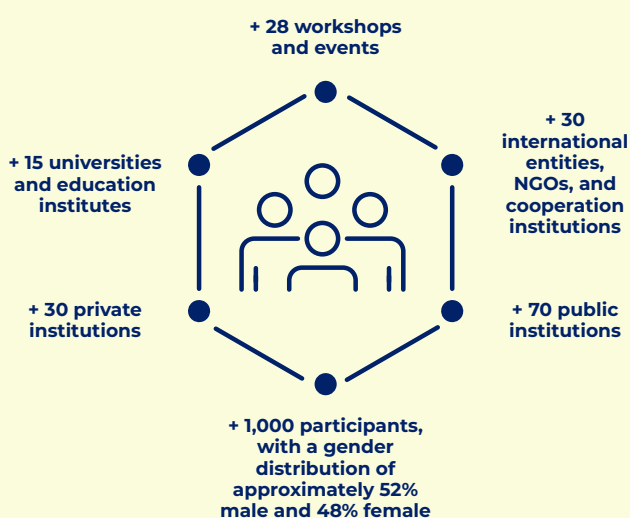
BOX 1. Case Study: Building Credible Climate Pathways through Participatory Modelling in Ecuador

In line with the commitments outlined in Ecuador's 2015 Nationally Determined Contribution (NDC), the government has developed the National Plan for Climate Change Mitigation (PLANMICC) 2024–2070. PLANMICC serves as a strategic policy document aimed at achieving net-zero emissions beyond mid-century. The plan encompassed cross-sectoral interlinkages for five key sectors: Energy; Agriculture; Land Use, Land-Use Change and Forestry (LULUCF); Industrial Processes and Product Use (IPPU); and Waste. This holistic approach –

developed by the University of Costa Rica (main modelling team) and University of San Francisco of Quito – demonstrated the relevance of analysing synergies and trade-offs in the implementation of mitigation measures.

PLANMICC illustrates how participatory and transparent modelling can strengthen credibility and ownership of long-term strategies. PLANMICC engaged over 1,000 stakeholders from government, civil society, academia, and industry across the five main emitting sectors to co-design a pathway to net-zero emissions beyond the mid-century point. Stakeholders reviewed modelling outcomes to identify enabling conditions, stronger national–local coordination, fiscal policy alignment, and mobilisation of international support. The open-source framework reinforced transparency and institutional capacity, transforming modelling from a technical exercise into a durable policy platform for implementation and monitoring. See [Ministerio de Ambiente y Energía](#) for more information [6].

Figure 2. Summary of participation statistics in the formulation of the PLANMICC. Source: Authors.



2.2.4. Defining the Technological Coverage of the Modelling Exercise

Models should cover all relevant technologies, balance completeness with simplicity,

and reflect uncertainty over time. When defining technological coverage in energy system modelling, best practices emphasise balancing comprehensiveness with relevance to the research or policy question at hand. The coverage should be broad enough to capture the diversity of technologies across supply, demand, storage, and transmission, while avoiding unnecessary complexity that may obscure insights. Models should also incorporate both mature and emerging technologies, with parameter ranges that reflect technological uncertainty and potential learning curves. Additionally, aligning the scope of technological coverage with national or regional policy objectives, data availability, and stakeholder priorities helps strengthen the usefulness of the model as a decision-support tool. Finally, periodic review and updating of the technology set ensures that the model remains relevant in light of evolving energy systems and innovation trends.

To implement this, modelling teams should begin by compiling a technology inventory that includes existing infrastructure, planned projects, and emerging options. Where data is limited, parameter ranges should be used to reflect uncertainty in costs, efficiency, and performance. Emerging technologies and fuels should be incorporated in ways that reflect country-specific readiness. End-use innovations like electric mobility, hydrogen for industry, direct air capture, and synthetic fuels must be assessed in terms of infrastructure requirements, policy support, and societal acceptance. These should be endogenously modelled (ie within the system) wherever possible to explore their role under different scenarios. Recent studies encourage embedding innovation pathways into scenario analysis to test how scaling technologies (eg distributed solar, electric cooking) interact with affordability [7, 8].

2.3. Ensuring Transparency and Openness of the Modelling Process

The third sub-component of Component 4: Modelling is ensuring transparency and openness. Component 4 of the Data-to-Deal framework recognises that no single model can address all national priorities or sectoral complexities. Instead of prescribing specific software or platforms, it encourages countries to select or adapt modelling approaches based on transparency, usability, institutional capacity, and alignment with national decision-making needs.

To operationalise this, modelling teams should begin by assessing institutional capacity and identifying the transparency principles to follow during the modelling process. This helps determine the need for openness in data and code. Where possible, teams should prioritise models that allow for public scrutiny and stakeholder engagement and ensure that documentation is clear and accessible. Transparency should be embedded from the outset, not treated as an afterthought, so that the modelling process builds trust and supports long-term institutionalisation. This subcomponent identifies five key elements of transparent and open modelling processes:

- Ensuring high-quality data through QA/QC procedures.
- Adopting transparent and open-source modelling principles.
- Providing public access wherever possible.
- Addressing uncertainties throughout the modelling exercise.
- Acknowledging modelling limitations.

2.3.1. Ensuring High-Quality Data Through QA/QC Procedures

Establishing disciplined data governance and routine QA/QC across inputs, code, and outputs will ensure model credibility. Trustworthy modelling requires high-quality data, information that is consistent, timely, comprehensive, and

aligned with the decision-making needs of the analysis. The well-known saying "Garbage in, garbage out" underscores the importance of data integrity throughout the modelling process [4]. To this end, quality assurance (QA) and quality control (QC) procedures, such as version control, peer review, analyst-led testing, and independent audits, should be standard practice. QA/QC must also extend to model architecture itself, with unit and integration testing used to detect and correct structural errors [9].

To implement these practices, the TDG-SIG should establish a formal QA/QC protocol at the start of the project. This includes assigning responsibility for data validation, maintaining version histories, and conducting regular peer reviews of both inputs and outputs. Where feasible, independent audits can be commissioned to verify model structure and assumptions. These steps help ensure that results are credible and defensible, especially when presented to policymakers or external stakeholders.

2.3.2. Adopting Transparent and Open-Source Modelling Principles

Open, well-documented models should be developed so that decisions rest on evidence that can be seen and tested by all. Equally important is the openness and transparency of the modelling process [10]. Public access to model inputs, outputs, and code allows for validation and reuse, but transparency also requires full documentation of assumptions, data sources, and methodological choices. To support this, the TDG-SIG should establish clear licensing terms, choose transparent programming frameworks, and foster a community of users and contributors. Additionally, the role of stakeholder visioning in Component 3: Vision is critical for reaching agreement on data requirements and assessing the real possibilities for data sharing among different actors. For

instance, active stakeholder engagement can build trust with industry actors, which in turn facilitates access to sensitive or proprietary data that might otherwise remain unavailable, such as technology cost structures, operational constraints, or investment plans.

To carry this out, the TDG-SIG should select platforms that support open-source development and ensure that all documentation is made publicly available. This includes publishing model assumptions, input datasets, and code repositories with clear instructions for replication. Stakeholder engagement should be used not only to validate assumptions but also to negotiate data-sharing agreements, especially with private sector actors. Embedding transparency throughout the modelling process helps build legitimacy and encourages broader participation.

To ensure the modelling process meaningfully supports national development and decarbonisation goals, the design and execution of models must be guided by the Openness principles known as U4RIA: Ubuntu [Community and Collaboration], Retrievalability, Reusability, Repeatability, Reconstructability, Interoperability, and Auditability [11]. These principles are not peripheral; they are foundational to Component 4: Modelling of the Data-to-Deal framework, shaping both the technical architecture and institutional engagement strategies. Embedding U4RIA ensures that models are not only technically sound but also socially anchored, transparent, and fit for iterative policy use. By grounding the modelling approach in openness, reproducibility, and contextual relevance, countries can foster trust among stakeholders, enable capacity development, and support long-term institutionalisation of modelling practices. In doing so, the modelling process becomes more likely to yield successful

outcomes in the subsequent stages of the Data-to-Deal framework (particularly Component 6: Policy and Component 7: Finance) where scrutinised, transparent models enhance accuracy and credibility, underpin evidence-based and explainable policy decisions, and provide investors with confidence in the robustness and longevity of national energy transition plans.

2.3.3. Providing Public Access Wherever Possible

If data and results are publicly accessible, this will strengthen national ownership, accelerate innovation, and support long-term capacity development. To promote capacity sharing and sustainability, open-source models and collaborative platforms such as data repositories should be prioritised where possible. These foster model reuse and co-creation, especially among local institutions. Projects that combine public accessibility with technical co-ownership, such as Energy Access Explorer, OnSSET, or Geographic Information Systems (GIS) tools in Kenya and Tanzania show how transparency and co-creation accelerate innovation and build institutional memory [7, 8, 12].

To implement this, the TDG-SIG should publish model inputs and outputs in accessible formats, accompanied by metadata that explains sources, assumptions, and limitations. Where possible, the TDG-SIG should use collaborative platforms such as Github, Zenodo, or CKAN (Comprehensive Knowledge Archive Network) that allow local institutions to contribute data, run scenarios, and adapt models to their own needs. This not only strengthens national capacity but also ensures that modelling remains relevant and responsive to local realities. When full openness is not feasible – due to proprietary data or institutional constraints – detailed metadata and explanatory documentation should be made available.

2.3.4. Addressing Uncertainties Throughout the Modelling Exercise

Embedding uncertainty analysis from the outset will identify strategies that remain robust under a range of possible futures. Another best

practice is incorporating uncertainty analysis into the modelling framework from the start [13]. Key uncertainties, such as technology costs, fossil fuel prices, or demand trajectories, should be identified with stakeholder input and tested through sensitivity or scenario analysis. Methods from Decision-Making under Deep Uncertainty (DMDU) such as Robust Decision Making (RDM), Dynamic Adaptive Policy Pathways (DAPP), and Stochastic or Distributionally Robust Optimization (SRO/DRO) are alternatives to integrate uncertainty analysis in the modelling process [14, 15]. An outstanding example is SiSePuede, a modelling framework for testing

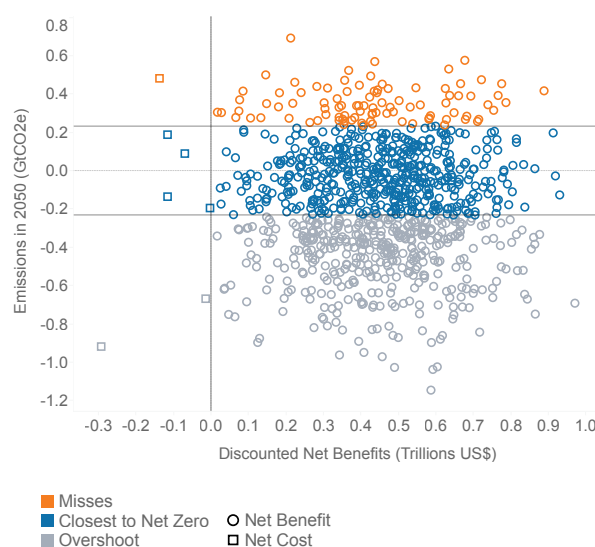
decarbonisation strategies under deep uncertainty in Latin America and the Caribbean (see **Box 2** for more details).

To apply this approach, the TDG-SIG should begin by identifying key uncertainties in consultation with stakeholders. These may include fuel price volatility, technology learning rates, or climate impacts. Once identified, these variables should be tested using sensitivity analysis or scenario modelling in order to assess how changes in these key input parameters affect model's outputs. Where feasible, the TDG-SIG can adopt DMDU methods to explore a wide range of futures and identify strategies that perform well under diverse conditions. This helps increase transparency and trust in results while policymakers make informed decisions even when future conditions are uncertain.

BOX 2. Case Study: Advancing Uncertainty Analysis for Energy System Modelling in Latin America and the Caribbean

Uncertainty is a central challenge in developing credible long-term strategies. To address this, a regional study across 18 Latin American and Caribbean countries developed SiSePuede, an open-source model that applies Robust Decision-Making (RDM) to explore hundreds of “what-if” scenarios on emissions, costs, and co-benefits. Workshops with national experts identified key uncertainties and informed scenario design. The analysis found that robust strategies consistently centre on three pillars: expanding renewable electricity, electrifying transport, and enhancing land as a carbon sink, delivering up to \$2.7 trillion in net regional benefits. By combining openness with deep uncertainty methods, SiSePuede shows how to design resilient, evidence-based transition pathways. See [IDB](#) and [SiSePuede](#) for more information [16, 17].

Figure 3. Net benefits and emissions in 2050 for critical action strategies under uncertainty: Source [16, p. xix].



2.3.5. Acknowledging Modelling Limitations

Model limitations should be explicitly stated to preserve credibility and reinforce modelling as a guide for strategy rather than prediction.

Finally, it is essential to acknowledge modelling limitations [2]. The TDG-SIG should provide clear guidance on how results should and should not be interpreted. Doing so builds trust and ensures that modelling remains a collaborative tool for informed decision-making, rather than a black box (where inputs and assumptions are unclear or hidden) that undermines policy credibility.

To implement this, modelling outputs should be accompanied by explanatory notes that clarify assumptions, highlight uncertainties, and define the scope of applicability. Policymakers should be briefed on the strengths and limitations of the model, including what it can and cannot predict. This transparency helps ensure that modelling is used appropriately, as a guide for strategic planning rather than a definitive forecast, and reinforces its role as a tool for inclusive and adaptive policymaking.

2.4. Enhancing Energy System Design through a Demand-Side Focus

The fourth sub-component of Component 4: Modelling is enhancing energy system design through a demand-side focus. Traditionally, energy system models have centred on supply-side optimisation, but effective transition planning requires recognising demand as a dynamic driver shaped by policy, behaviour, and socioeconomic trends. Integrating demand-side measures enables countries to identify more inclusive, affordable, and resilient pathways towards decarbonisation. In practice, this involves embedding demand interventions early in model design, reflecting spatial and social variation, and incorporating qualitative insights that capture behavioural and institutional dynamics. This subcomponent identifies four key elements of a demand-side-focused modelling process:

- Integrating demand-side measures into the model.
- Representing spatial variation in demand.
- Reflecting variation in demand across socioeconomic groups.
- Integrating qualitative insights that capture social and behavioural dynamics.

2.4.1. Integrating Demand-Side Measures into the Model

Incorporating efficiency, behavioural, and structural demand measures early will shift transition pathways towards lower costs and more inclusive outcomes. Demand-side decarbonisation measures should be included early in model development to capture their transformative potential [18]. These include reducing industrial material use through circular economy practices, shifting transport demand via modal changes, improving building efficiency, and reducing service demand through digitalisation (eg teleworking). These interventions often have co-benefits for air quality, affordability, and inclusion.

To integrate these measures, modellers should begin by identifying relevant demand-side policies and behavioural trends that are likely to influence future energy use. These can be translated into model parameters such as reduced energy intensity, altered demand trajectories, or technology adoption rates. Where possible, demand-side interventions should be linked to specific policy levers, such as building codes, transport incentives, or digital infrastructure investments, to test their impact under different scenarios. Treating demand as a dynamic variable allows the model to reflect shifts in consumption patterns and improve realism and inclusivity.

2.4.2. Representing Spatial Variation in Demand
Geospatial models can capture spatial diversity, improving infrastructure planning and equity in access. Demand centres and energy sources vary across a country, especially in countries

with uneven infrastructure development or urban–rural disparities. Geographic Information Systems (GIS) can strengthen spatial modelling and inform infrastructure planning, particularly in distributed or off-grid settings [19]. GIS also supports engagement with diverse subnational stakeholders, improving equity in model inputs and usability. For instance, in Kenya, high-resolution data was integrated to identify the least-cost, location-specific energy solutions – see **Box 3** for more details. By visualising demand, supply, and infrastructure gaps, GIS methods enabled data-driven planning in Narok County, highlighting their value for effective and equitable infrastructure development.

To reflect spatial variation, the TDG-SIG should incorporate geospatial data on population density, economic activity, and infrastructure access. This can be used to map demand hotspots and identify underserved areas. GIS tools can also support scenario development by visualising the impact of different infrastructure investments or policy interventions. Engaging subnational stakeholders during this process helps validate assumptions and ensures that spatial modelling reflects local realities. To implement this, the TDG-SIG should collaborate with social researchers, community organisations, and national statistics offices to gather disaggregated data.

2.4.3. Reflecting Variation in Demand Across Socioeconomic Groups

Incorporating gender, income, and regional differences will ensure modelling reflects social realities and supports just transitions. Gender Equality and Social Inclusion (GESI) dimensions are also critical at this stage. Demand patterns often differ by gender, income, ability, and geography. Inclusive engagement with affected groups can help identify overlooked demand types, such as energy for informal work, unpaid care work, or community services. Incorporating these dimensions strengthens both accuracy

BOX 3. Case Study: GIS-Driven Energy Planning for Universal Access: The Case of Narok County, Kenya

Narok County, Kenya, used open-source GIS tools to develop a least-cost County Energy Plan (CEP) under the 2019 Energy Act, which mandates all 47 counties to prepare such plans. The process integrated KoboCollect surveys, Energy Access Explorer (EAE), and OnSSET modelling to map demand and design electrification scenarios for achieving universal access by 2026. Scenario 2, combining grid expansion with solar, hydro, and wind mini-grids, proved the most balanced and cost-effective. A local GIS data repository and customised EAE platform strengthened data quality, institutional capacity, and affordability analysis. By embedding transparency and spatial precision in planning, Narok's CEP bridged the gap between modelling and implementation, offering a replicable model for decentralised, inclusive energy transitions across Kenya and other Global South contexts. See [WRI](#) for more information [12] and [KoboCollect](#), [EAE](#), and [OnSSET](#) for tools [20–22].

and justice in model design. Emerging practices recommend collecting gender- and income-disaggregated data to more accurately reflect differentiated energy service profiles. Integrating GESI perspectives throughout scenario design helps ensure the results are not only technically viable but also socially just [23].

To implement this, the TDG-SIG should collaborate with social researchers, community organisations, and national statistics offices to gather disaggregated data. Critically, adding these dimensions to energy system modelling often necessitates different models (eg computable general equilibrium and distributional models). Participatory methods, such as focus groups or household surveys, can help uncover GESI dimensions that are not captured in conventional datasets. These insights should be embedded into model assumptions and used to design scenarios that

reflect diverse energy service profiles. Doing so ensures that modelling supports inclusive policy outcomes and avoids reinforcing existing inequalities.

2.4.4. Integrating Qualitative Insights that Capture Social and Behavioural Dynamics

Integrating qualitative insights will bridge the gap between technical feasibility and social and political plausibility. Aligned with GESI principles, integrating qualitative insights into quantitative energy system models is essential for capturing complex, non-technical drivers such as behavioural change, social acceptance, and policy dynamics [24]. For example, understanding consumer reluctance to adopt electric vehicles can be translated into delayed technology uptake rates or adoption ceilings within the model. Likewise, expert interviews or participatory workshops can shape narratives that guide scenario framing, stress-test model outputs, or identify plausible transition pathways that go beyond purely techno-economic considerations. This integration enhances the realism and relevance of modelling, especially in contexts where social, political, or behavioural dimensions strongly influence energy outcomes.

To carry this out, the TDG-SIG should design scenario development processes that incorporate qualitative evidence from stakeholder consultations, expert interviews, and literature reviews. These insights can be used to define behavioural parameters, adoption thresholds, or policy feasibility constraints. Where possible, qualitative narratives should be translated into model logic, for example, by adjusting technology diffusion curves or limiting certain interventions in politically sensitive contexts. This approach ensures that models reflect not only what is technically possible but also what is socially and politically plausible.

2.5. Communicating the Results to Domestic and International Audiences

The fifth sub-component of Component 4: Modelling is communicating the results to domestic and international audiences. Strong communication transforms modelling from a technical exercise into a policy-enabling tool. It ensures that complex outputs are translated into clear, actionable messages that inform decisions, align institutions, and build trust among policymakers, financiers, and the public. Effective communication is essential for uptake and credibility: it connects evidence to action, enabling scenarios to evolve into strategies and strategies into plans. This subcomponent identifies four key elements of effective communication of modelling results:

- **Communicating during the modelling process itself.**
- **Framing results in terms of actions, timelines, budgets, and policies.**
- **Providing disaggregation of results across relevant groupings.**
- **Reporting assumptions, limitations, and uncertainties.**

Table 2. Communication Tools for Modelling Outputs.

Tool	Purpose	Best Use Case
Technical Reports	Provide comprehensive documentation of methods, assumptions, and results.	For policymakers, researchers, and auditors needing full transparency.
Policy Briefs	Summarise key findings and implications in non-technical language.	For decision-makers who require concise, actionable insights.
Presentations	Communicate highlights with visuals and structured narratives.	For stakeholder workshops, conferences, or public consultations.
Dashboards/Portals	Enable interactive exploration of scenarios and results.	For ongoing policy processes and engagement with diverse stakeholders.
Infographics	Translate complex outputs into simple visuals for broad audiences.	For public communication, advocacy, or media outreach.
Academic Articles	Share validated methods and findings with the research community.	For peer-reviewed dissemination and advancing methodological standards.

2.5.1. Communicating During the Modelling Process Itself

There should be ongoing conversation through the TDG-SIG and PSC-SIG to build shared understanding and institutional ownership of results. Communication begins with the modelling process itself. Stakeholder engagement should extend beyond initial consultations to include co-interpretation of results and iterative feedback that refines outputs and strengthens legitimacy (see also Component 5: Engagement). This can be facilitated and convened through the TDG-SIG, which manages assumptions and reviews results, while the PSC-SIG validates milestones to keep outputs aligned with national priorities and submission calendars. This approach ensures that modelling is not a one-off exercise but a collaborative process that builds shared understanding and ownership.

Outputs should be tailored to match decision-making timelines and institutional formats. For example, aligning model results with the structure and language of national development plans, climate finance proposals, or investment prospectuses increases their relevance and usability. Early engagement with ministries and funders helps ensure that modelling insights are embedded in planning cycles and funding strategies.

2.5.2. Framing Results in Terms of Actions, Timelines, Budgets, and Policies

Frame results as actions, costs, and timelines to transform technical outputs into implementation roadmaps. To effectively inform decision-making, modelling outputs must be translated into clear, concise, and actionable insights [25]. This means going beyond technical graphs or spreadsheets to highlight what the results imply for investment needs, policy trade-offs, and development goals.

To support this, the TDG-SIG should distil key messages, such as cost-optimal pathways, sectoral emissions trajectories, or the impact of demand-side measures, into formats tailored for policymaker audiences. These include executive summaries, dashboards, briefing notes, and infographics that clearly articulate:

- what actions are needed
- by when they must be taken
- at what cost
- which policy instruments are required (eg tariffs, subsidies, public investment priorities)

This framing helps bridge the gap between analysis and implementation. Best practice also encourages *co-dissemination*, working with local champions, technical ministries, or community leaders to share results in culturally relevant ways. Participatory dissemination increases local buy-in and ensures that messages are understood, trusted, and acted upon.

2.5.3. Providing Disaggregation of Results Across Relevant Groupings

Disaggregating results across groups and geographies will ensure communication is inclusive and equity-focused. Inclusive communication is essential. Modelling outputs should reflect the differentiated impacts and opportunities across communities, sectors, and geographies. This includes disaggregating results by gender, income, region, or livelihood group to ensure that transition plans are equitable and responsive.

Communicating results in accessible formats, such as plain-language summaries, local languages, or community-level workshops, helps ensure that underrepresented groups can understand and act on modelling insights. When engaging with communities and interest groups, collaborating with communication professionals can be highly effective in simplifying modelling outputs to better address the specific needs

of the target audience. This aligns with GESI principles and broadens ownership of climate and development strategies.

2.5.4. Reporting Assumptions, Limitations, and Uncertainties

Ensuring that assumptions and limitations are transparent will maintain credibility and support informed policy debate. As discussed previously, transparency is critical to credibility. The TDG-SIG should clearly communicate the assumptions, limitations, and uncertainties embedded in their scenarios, especially where results depend on aspirational targets, emerging technologies, or uncertain policy environments. Acknowledging limitations helps manage expectations and fosters informed debate. It also frames modelling as a tool for exploration and learning rather than prediction, highlighting the continuous opportunities for improvement in subsequent iterations of the planning process.

2.6. Translating the Modelling Analysis into Transition Plans

The final sub-component of Component 4: Modelling is translating the modelling analysis into transition plans. The ultimate value of modelling lies not in technical outputs alone but in their conversion into actionable strategies and investment-ready plans. This process bridges the gap between analytical results and policy frameworks, ensuring that modelling informs real-world decisions aligned with national priorities, institutional capacities, and financing realities. This subcomponent identifies four key elements for translating modelling outputs into plans:

- **Embedding modelling insights in existing planning instruments.**
- **Designing strategies with clear policy levers and sequencing.**
- **Linking results to financing strategies.**
- **Ensuring adaptability through iterative monitoring and review.**

2.6.1. Embedding Modelling Insights in Existing Planning Instruments

Integrating modelling into existing national plans will ensure alignment, uptake, and policy coherence across institutions. Modelling insights should be output in a format that can be embedded directly into existing planning instruments such as Long-Term Strategies (LTS), Nationally Determined Contributions (NDCs), development plans, or investment prospectuses [26, 27]. Preparing policy-ready outputs at this stage ensures that the results of Component 4 can be taken forwards seamlessly through the policy design process in Component 6: Policy and into financing strategy development under Component 7: Finance. By explicitly mapping modelling results onto policy commitments, governments can demonstrate how pathways are consistent with international obligations and domestic development goals.

2.6.2. Designing Strategies with Clear Policy Levers and Sequencing

By sequencing policies and assigning clear institutional responsibilities, scenarios can be turned into credible implementation pathways. Strategies should be designed with clear policy levers and sequencing, informed by discussion with the PSC-SIG. Modelling outputs delivered through the TDG-SIG must identify which measures deliver the greatest benefits, the trade-offs involved, and the enabling conditions required for success. For example, electrification pathways may only be feasible if grid investments are accelerated, regulatory barriers addressed, and fiscal instruments aligned.

Turning scenarios into strategies therefore requires policymakers to prioritise measures, assign institutional responsibilities, and establish time-bound milestones [28]. This sequencing helps transform abstract scenarios into credible implementation roadmaps. Where possible, sequencing should be informed by

the relative readiness of sectors, technologies, or institutions, validated through the PSC-SIG to ensure political feasibility, allowing governments to phase reforms and investments in a way that balances ambition with feasibility.

These policy levers and sequences provide the bridge between modelling and the enabling environment set out in Component 6: Policy. Component 6 translates these identified measures into concrete policy frameworks that make implementation possible. In turn, feedback from the policy process should inform future modelling cycles, allowing governments to test the feasibility and system-wide impacts of proposed reforms before they are enacted.

2.6.3. Linking Results to Financing Strategies

Modelling should be used to quantify investment needs, highlight cost-saving opportunities, and assess distributional impacts. When translated into financing terms, such as projected investment volumes, potential risk-sharing mechanisms, or opportunities for concessional finance, modelling outputs become powerful tools for engaging ministries of finance, development banks, and private investors.

This connection between technical pathways and financial planning is a prerequisite for moving from ambition to implementation. It also directly links Component 4 to Component 7: Finance, where detailed financial strategies are developed. The investment requirements, timing, and sectoral cashflows identified in Component 4 form the analytical foundation

for financial structuring. This enables the use of specialised financial models in Component 7: Finance, such as MINFin, to design financing instruments and determine the mix of public and private capital. In turn, feedback from financial analyses under Component 7: Finance can inform model refinement, helping ensure that future scenarios remain economically and fiscally viable.

2.6.4. Ensuring Adaptability Through Iterative Monitoring and Review

Conduct regular reviews and model updates to embed adaptability and keep transition plans responsive and credible over time. Plans derived from modelling should be adaptable. Given the uncertainty inherent in long-term transitions, strategies must include mechanisms for regular review, learning, and course correction [29]. Establishing iterative monitoring frameworks, linked to updated modelling cycles, allows governments to incorporate new data, technologies, or policy developments. In practice, the TDG-SIG maintains the monitoring framework and model update cycle, feeding new evidence into successive iterations, while the PSC-SIG validates when system changes warrant strategic adjustment of the transition plan.

An adaptive design ensures that strategies remain robust and relevant in dynamic contexts. It also builds institutional learning: each iteration of the model strengthens the data ecosystem, policy alignment, and technical capacity required for future scenario development. Embedding periodic review points within national planning or budget cycles helps maintain political momentum and transparency.

3. Recommendations

Drawing on the most effective modelling practices, key case studies, and the collective experience of the co-authors, the following recommendations distil key insights into actionable lessons for governments and line ministries to integrate into their processes. Designed to align with the broader D2D framework, these recommendations aim to support the development of transition plans that attract and secure the required funds for implementation.

1. Strong institutional foundations for national modelling should be established through clear leadership and governance arrangements.

Effective modelling requires nationally anchored leadership and coordination mechanisms that connect technical teams, such as the TDG-SIG, with policy and finance institutions through the PSC-SIG. Embedding modelling within established planning and budgeting systems strengthens continuity, accountability, and data integration. Clear governance, overseen by the GCF at the centre of government, enhances institutional ownership, supports sustained capacity development, and ensures modelling remains a core part of long-term decision-making.

2. Modelling frameworks should be anchored in policy questions and grounded in transparency and open access.

Modelling should begin with the key decisions governments must make, selecting tools that best inform those decisions rather than those that simply exist. Transparent, open-access approaches following the [U4RIA principles](#) enable shared learning, build stakeholder trust, and enhance reproducibility. This approach strengthens credibility and ensures results are readily adaptable to new contexts and priorities.

3. Demand should be treated as a dynamic lever for sustainable and inclusive development.

Integrating demand-side dynamics within modelling allows policymakers to identify efficient, equitable, and locally grounded transition pathways. Reflecting spatial, behavioural, and socioeconomic diversity provides a more realistic picture of how people and businesses use energy and transport. This enables countries to design strategies that reduce costs, expand access, and promote inclusive growth while advancing national decarbonisation goals.

4. Communication of modelling results should be clear, inclusive, and action-oriented.

Strong communication transforms technical analysis into practical decision support. Presenting results in accessible, audience-specific formats, such as dashboards, policy briefs, and community engagement tools, enables shared understanding and alignment across ministries, financiers, and local stakeholders. Co-dissemination with domestic institutions enhances credibility, accelerates uptake, and strengthens policy and investment dialogue at both national and international levels.

5. Transition pathways should be stress-tested, sequenced, and linked to actionable policy and finance strategies.

Applying Decision-Making under Deep Uncertainty (DMDU) methods ensures that strategies remain robust under a range of future scenarios. Embedding results into sequenced policy and finance roadmaps connects modelling with Components 6: Policy and Component 7: Finance, supporting coherent implementation. This alignment allows governments to design strategies that are technically feasible, fiscally sustainable, and responsive to evolving national priorities.

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