IAEA
International Atomic Energy Agency

From Knowledge to Action

IAEA Toolkit for Sustainable Energy Planning

G20 BRASIL 2024
BUILDING A JUST WORLD AND A SUSTAINABLE PLANET

“Energy is the lifeblood of societies. To ensure a secure and sustainable energy future, planning is key. The IAEA supports its Member States in energy planning, enabling them to make better informed decisions when it comes to some of the most critically important choices they have to make in building a better future for their citizens and the wider regional and global community.”

IAEA Director General,
Rafael Mariano Grossi

UN Sustainable Development Goal 7 is to ensure access to affordable, reliable, sustainable and modern energy for all.

Energy is the cornerstone of socioeconomic progress. In our interconnected world, we rely on dependable and affordable energy services. From powering factories to illuminating hospitals and schools, energy is indispensable. Access to stable energy is essential for daily routines, impacting industry, cooking, refrigeration, heating and other vital amenities. UN Sustainable Development Goal 7 emphasizes the need for affordable, reliable, sustainable and modern energy for all. However, 2.3 billion people still use hazardous cooking systems, and 675 million people lack electricity, which hinders development, affects human health and harms the environment [1].

Energy systems vary around the world because of differences in economic development, societal norms, available resources and environmental circumstances. Despite these variations, there is a pressing need for a worldwide transition to low carbon energy to meet the targets set out in the Paris Agreement, aiming to cap the increase in global warming at 1.5 °C. The pace and scale of this energy transition need to accelerate, but modern energy systems are complex and expensive, making rapid changes challenging. To navigate this, it is vital to anticipate social and political developments alongside understanding resources, technologies, financial requirements and capabilities.

Robust energy planning and policy expertise are critical for consistently addressing energy transitions and fostering a favourable environment to mobilize finance for low carbon technologies.

ENERGY PLANNING AND EXPERTISE AT THE IAEA

The International Atomic Energy Agency (IAEA) supports Member States, especially in emerging markets and developing economies, in building and reinforcing national capabilities to conduct energy system analysis and planning. Energy planning serves as the foundation for designing effective policies, guiding the development of the energy sector and its connections to other parts of the energy system, economy and society at large. A national energy plan frames the investment strategies and business targets for both state owned and private energy companies. It helps to leverage funding from foreign and international sources.

An important aspect of national sovereignty is the ownership of the energy planning process, including qualified energy analysts, modern planning tools, as well as comprehensive and reliable data. As energy systems need approaches tailored to local conditions, national expertise in modelling and analysis is essential. This expertise broadly includes competencies in (a) developing energy balances and projections; (b) configuring energy demand/supply and trade scenarios; (c) estimating financing and institutional support; and (d) understanding sustainable development metrics and cross-sector impacts. Without these competencies, national development strategies could be misinformed, leading to unintended outcomes [2].

The IAEA's capacity building programme plays an important role in cultivating local expertise for long term energy system planning to facilitate informed decision making.

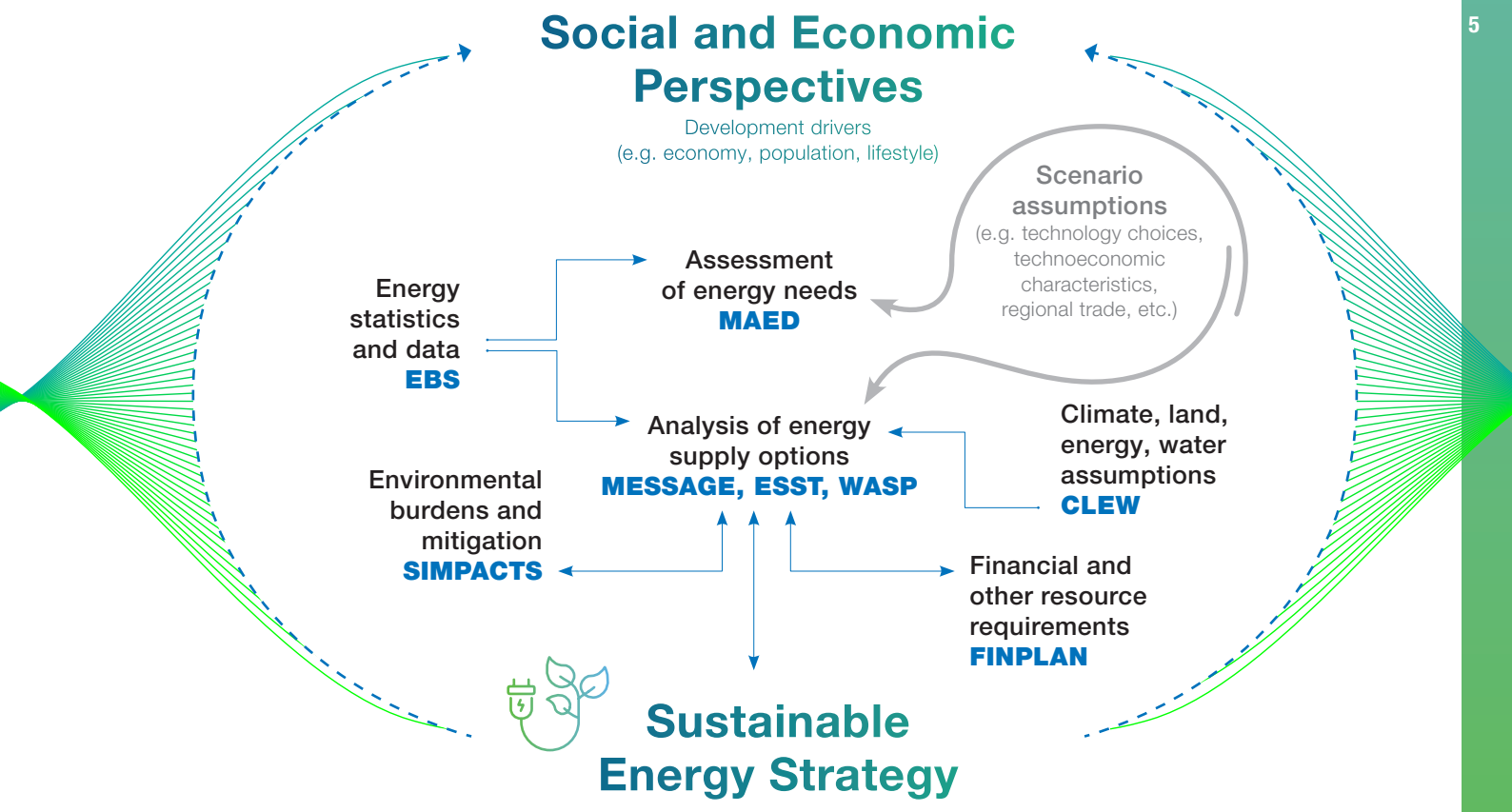
Having extended these services to over 150 countries for more than 40 years, the IAEA can bring tangible contributions to the Global Coalition for Energy Planning under the G20 Presidency of Brazil.

An energy system consists of an energy supply sector, energy end-use technologies needed for everyday life activities, and an associated infrastructure that converts energy commodities provided by an energy sector into energy services.

MODEL BASED ANALYSIS

Model based analysis is the main component of informed decision making. Energy planning models serve to create quantitative and consistent scenarios for a country's energy sector development to comprehend the necessary institutional, incentive, technological and financial needs. Quantified results facilitate the harmonization of energy policies and the planning across different resource systems and provide information on energy and technology trade.

The IAEA offers a suite of tools and methodologies that are designed to cover the various stages of the energy planning process: data collection, statistics, energy demand analysis and projections, energy supply simulation/optimization, power generation expansion, simplified environmental impacts and financial analysis of power projects. These tools are developed in-house and are distributed free of charge to the IAEA Member States. They are technology neutral and can be tailored to the needs, priorities or policy questions of any country.



The diagram shows a framework for comprehensive energy planning using the IAEA's tools and methodologies.

IAEA TOOLS AND METHODOLOGIES FOR ENERGY PLANNING

EBS

The Energy Balance Studio (EBS) is a tool that helps to create initial energy balances, starting from raw data sets, aligning with the United Nations Statistics Division's Annual Questionnaire on Energy Statistics. It easily adapts to changes in energy form definitions, energy flows, various source databases and operating systems. EBS simplifies the process of energy balance compilation, by incorporating consistency checks and metadata collection in line with the International Recommendations on Energy Statistics (IRES).

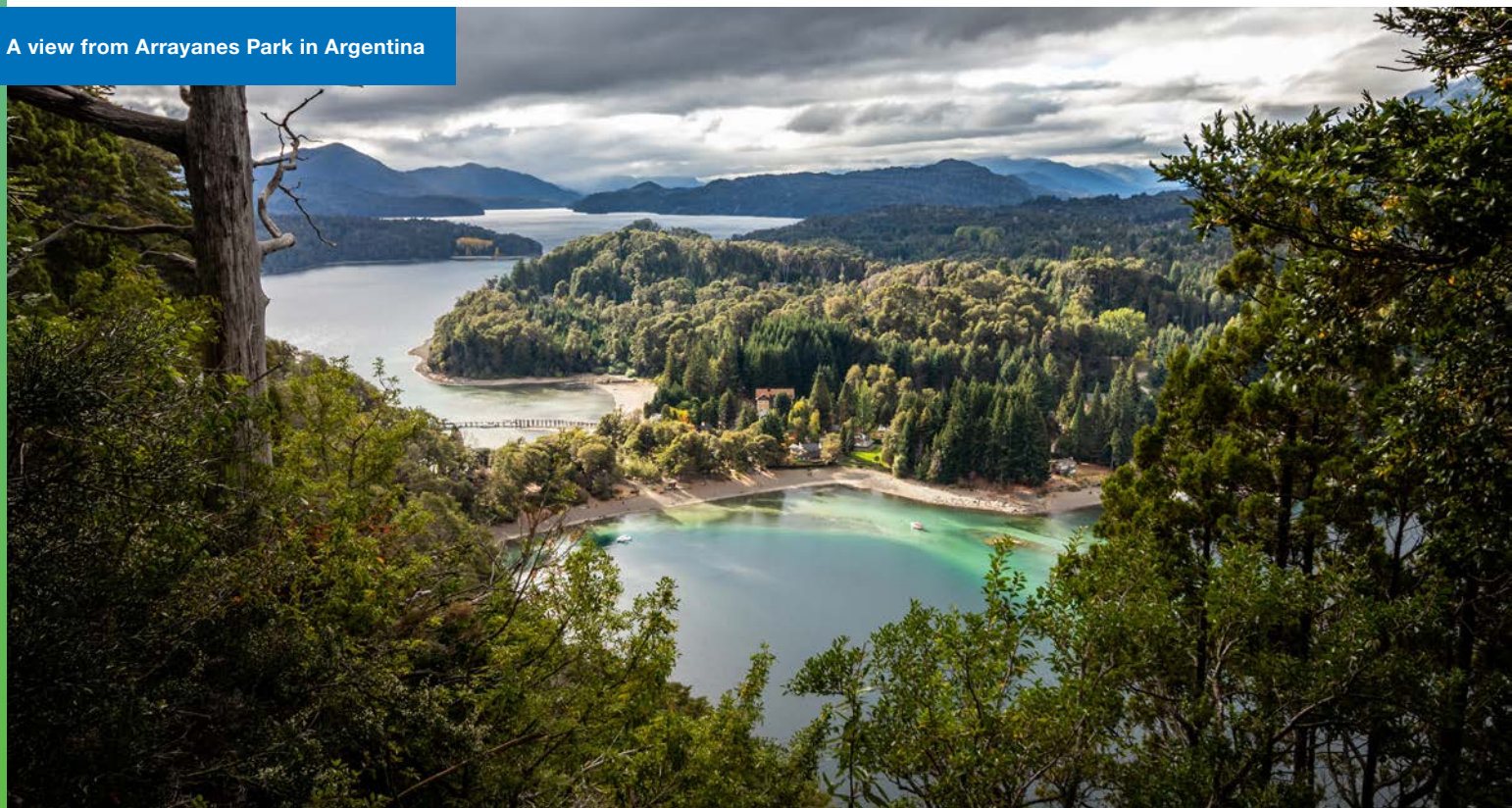
MAED

The Model for Analysis of Energy Demand (MAED) assesses future energy demand based on consistent assumptions about socioeconomic, technological and demographic factors. It connects energy needs to goods, services, technology, income driven lifestyle changes and mobility. MAED systematically maps trends and anticipates energy needs under different socioeconomic scenarios.

MESSAGE

The Model of Energy Supply Strategy Alternatives and their General Environmental Impacts (MESSAGE) constructs energy chains, mapping flows from resource extraction to energy services. It aids in designing long term energy supply strategies by analysing cost optimal energy mixes, investment needs and other costs for new infrastructure, energy security, new technologies and environmental constraints.

A view from Arrayanes Park in Argentina



WASP

The Wien Automatic System Planning Package (WASP) facilitates optimal power generation expansion plans within constraints, which could include limited fuel availability, emissions restrictions and system reliability. It explores all feasible capacity addition sequences to meet demand and reliability requirements while accounting for the costs of existing and new technologies, reserve capacity and unserved electricity.

ESST

The Energy Scenarios Simulation Tool (ESST) assesses future aggregate energy balances and provides a first screening of alternative energy strategies in terms of capacity expansion, investment schedule, costs and emissions. It can be used to present complex energy analysis concepts in a simple, transparent and intuitive way.

FINPLAN

The Model for Financial Analysis of Electric Sector Expansion Plans (FINPLAN) is used for financial analysis of electricity generation projects by considering financial sources, expenditures, revenues, taxes, interest rates, and capital costs. It aids in exploring the long term financial viability of projects and preparing financial statements.

SIMPACTS

The Simplified Approach for Estimating Impacts of Electricity Generation (SIMPACTS) quantifies health and environmental damage costs of electricity generation technologies, supporting comparative analyses and environmental policy decisions.

ISED

The Indicators for Sustainable Energy Development (ISED) offer a flexible framework to understand national energy situations, policy impacts and progress. The indicators reflect energy's interaction with economic, social and environmental aspects in the past and helps to explore future scenarios and strategies in terms of common indicators for sustainable development.

CLEW

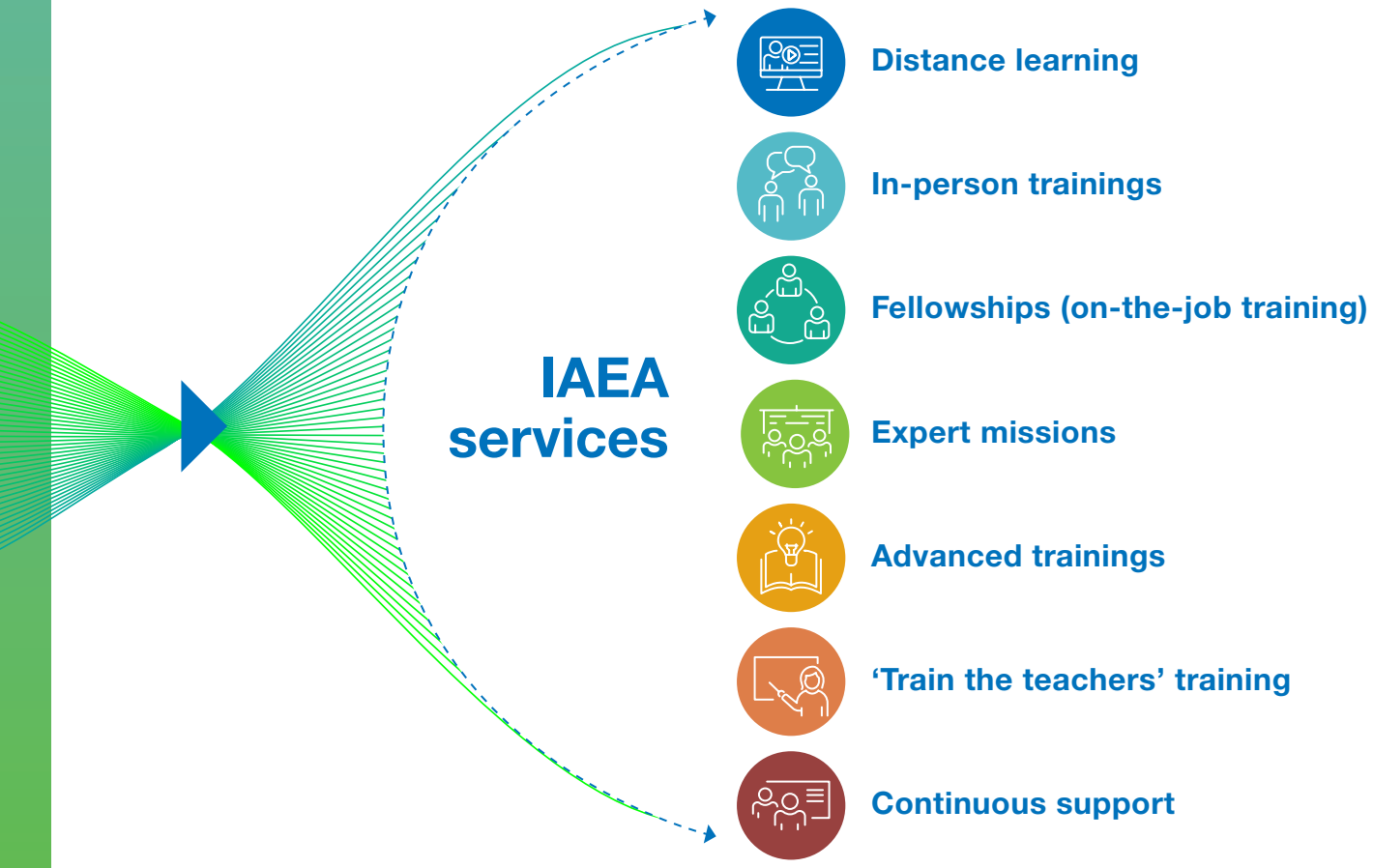
The Climate, Land, Energy, and Water (CLEW) framework supports integrated assessments of resource systems, addressing food energy and water security while considering climate impacts. It helps to align energy planning with broader development policies for cohesive decision making.

COMPREHENSIVE CAPACITY BUILDING: THE IAEA EMPOWERS COUNTRIES TO MANAGE THEIR ENERGY FUTURE

IAEA Member States get free access to tools for energy analysis and planning. These user friendly tools come with manuals and guidelines, but this is just a first step. The IAEA offers a comprehensive and tailored training programme to bridge the knowledge gap and make sure that Member States are using the tools effectively. Training is organized through various channels and events. Distance training and online courses provide a learning space that can be adjusted to the trainees' paces and time. In-person training brings hands-on experience through various workshops and seminars. Regional events allow direct collaborations among experts from other countries about real-world energy challenges.

The goal is for countries to become self-sufficient in using these tools. This empowers them to make informed decisions about their energy futures, leading to the design of better energy systems – secure energy supplies for homes and businesses, sustainable and cleaner environments and improved efficiency through the optimized use of energy resources.

With the IAEA's support, countries can unlock their energy potential and build better futures for their societies.



Recipients of Capacity Building Programmes

The IAEA's tools cater to a diverse audience, including national governments and their entities, regulatory agencies, the energy industry, academic institutions, the general public, non-governmental organizations (NGOs), international bodies and consulting firms. These stakeholders benefit from capacity building programmes and models offered by the IAEA for enhancing energy planning, regulatory effectiveness, market analysis, investment planning, and academic research and teaching. The tools also serve the public and NGOs in addressing broad societal concerns, while international organizations leverage IAEA models for global and regional scenario analyses to inform policy decisions and negotiations.

The IAEA's Technical Cooperation Programme

The capacity building programme in energy planning is facilitated through the Technical Cooperation (TC) Programme. The TC Programme is the IAEA's primary mechanism for transferring nuclear techniques to Member States, aiding them in addressing vital development areas such as health, agriculture, water, industry and nuclear knowledge. It primarily aids emerging markets and developing economies through jointly managed projects funded by voluntary contributions, extrabudgetary funding and government cost sharing. Member States submit project proposals reviewed for technical feasibility and safety by the IAEA Secretariat. The IAEA Technical Assistance and Cooperation Committee assesses projects for approval by the Board of Governors. National Liaison Officers facilitate coordination and act as the primary contacts between the IAEA and a country. Participants in TC activities for capacity building in energy planning receive technical guidance through national, regional and interregional projects.

BOX 1: SUPPORTING MEMBER STATES EXPLORE PATHWAYS TO NET ZERO: THE IAEA'S ATOMS4NETZERO INITIATIVE

At COP27 (the 2022 UN Climate Change Conference, held in Sharm el-Sheikh, Egypt) IAEA Director General Rafael Mariano Grossi announced the Atoms4NetZero initiative. Building on decades of supporting Member States to develop capacity in sustainable energy planning, through this new initiative the IAEA is providing its analytical tools and expertise to help countries model how nuclear power can contribute to reducing greenhouse gas emissions to as close to zero as possible by 2050. The Atoms4NetZero initiative is helping countries assess the potential of innovative nuclear technologies, including small modular reactors, to support their long term strategies to decarbonize electricity generation and other carbon intensive sectors. The initiative will develop credible scenarios through the IAEA's analytical tools, including MESSAGE (the Model for Energy Supply System Alternatives and their General Environmental Impacts), which is used by more than 100 countries. Atoms4NetZero is one example of IAEA initiatives in energy planning tools, capacity building and regional cooperation, which can support the Global Coalition for Energy Planning under the G20 Presidency of Brazil.

Explore the Atoms4NetZero website.

BOX: 2 **IAEA SUPPORT FOR JUST TRANSITION ANALYSIS**

In assessing the impact of energy strategies on both national and local economies, employing tailored macroeconomic analysis and models is essential. Recognizing the diverse conditions of Member States, the IAEA is developing a tool to facilitate such analysis and comparison – the Extended Input-Output Model for Sustainable Power Generation (EMPOWER). Reliable data on a country's or a region's economic activities are essential for using tools such as EMPOWER effectively.

The tool can assess the macroeconomic effects of various energy investments, including the deployment of nuclear power, as well as evaluation and comparison of broader energy strategies. It is also adept at analysing the complex issues surrounding Just Transitions arising from the retirement of fossil fuel facilities, thereby alleviating the added social and economic strains on local communities. A prime example is the coal-to-nuclear transition, entailing the establishment of a nuclear reactor in lieu of a recently decommissioned coal power plant. By integrating with energy planning tools, EMPOWER can provide quantitative insights into pivotal questions regarding Just Transition. These include identifying the factors that render a coal community suitable for transition, assessing the technological, cost and timeline considerations that underpin the economic viability of such a shift and evaluating its repercussions on local societies and economies.

EMPOWER can facilitate the analysis of Just Transition from fossil fuels to alleviate social and economic strains on communities.

BOX 3. **IAEA SUPPORT FOR ASSESSING NUCLEAR ENERGY SYSTEMS**

For Member States that are interested in advanced analysis of nuclear energy, the IAEA offers tailored technical support. The planning and the development of nuclear energy systems are focused on the analyses of their enhanced sustainability. This support comes through education and training in the use of the following methods and tools [3, 4]:

The MESSAGE-NES model for material flow analysis in complex nuclear energy systems representing different countries with different nuclear fuel cycles and nuclear reactors, allowing to model cooperation (nuclear trade) among countries at any stage(s) of the front-end and back-end nuclear fuel cycle.

The NEST tool for comparative economic evaluation of reactor and nuclear fuel cycle alternatives.

The KIND-ET tool for comparative evaluation of nuclear energy systems and evolution scenario alternatives based on key indicators defined in a variety of areas.

The ROADMAPS-ET tool represents a structured approach for globally enhancing nuclear energy sustainability, providing models for international cooperation and the framework for documenting actions, scope of work and timeframes for specific efforts by particular stakeholders.

Kori Nuclear Power Plant, Republic of Korea

COOPERATION, COLLABORATIONS AND PARTNERSHIPS

A robust network of global, regional and national partners enables tailored support and training to address the unique needs of each country. Collaboration amplifies impact beyond the efforts of individual institutions. In the realm of energy planning capacity building, the IAEA joins forces with entities such as the United Nations Department of Economic and Social Affairs (UNDESA), the International Renewable Energy Agency (IRENA), the Latin American Energy Organization (OLADE), the International Energy Agency (IEA), the United Nations Statistics Division (UNSD) and UN regional commissions, as well as research institutions, universities and donor organizations.

Basic cooperation involves the exchange of crucial information and data on energy consumption, resources, technologies, environmental impacts and the broader socioeconomic context. Deeper cooperation entails partners jointly developing and applying energy planning tools. These tools could be upgraded versions of existing ones or entirely novel frameworks, methodologies or models designed to tackle evolving energy planning challenges, such as climate change adaptation and mitigation. Collaborative training events are also part of the joint efforts, with multiple institutions co-organizing and delivering sessions. The IAEA may support other organizations in hosting training events, or reciprocally, other organizations may assist the IAEA.

The IAEA offers targeted energy planning tools that are used by over 135 countries and 20 international organizations.

Energy Modelling Platforms

The Energy Modelling Platform – Joint Global Training School (EMP-G), organized by the United Kingdom's Climate Compatible Growth Initiative and multiple UN and international organizations and hosted by the Abdus Salam International Centre for Theoretical Physics (ICTP), aims to transfer skills in models and tools for energy planning needs supporting human and institutional capacity for integrated energy modelling and investment planning. Similarly, but acknowledging region specific context, there are Energy Modelling Platforms for Africa (EMP-A) and for Latin America and the Caribbean (EMP-LAC). These schools are examples of collaboration and offer training segments led by the IAEA. These include energy balances and demand projections using tools such as MAED and EBS and financial analysis of power projects using FINPLAN. As part of the schools, participants engage in discussions and hands-on exercises, present case studies and have high level dialogues with experts [5–7].

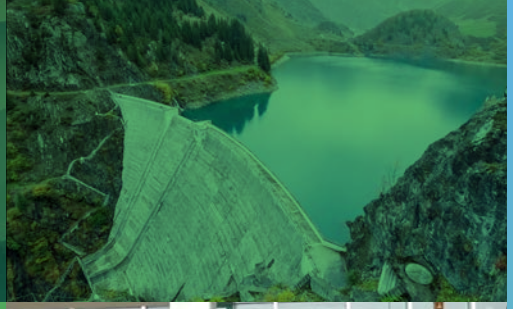
Participants of the EMP-A at the University of Namibia in 2023. (Courtesy of the IAEA)

Energy Modelling Platforms have so far delivered 12 successful schools involving more than 500 policy and energy professionals worldwide.

BUILDING STRONGER ENERGY TEAMS: EXAMPLES OF IAEA SUPPORT

On average, every year the IAEA trains over 350 professionals representing over 60 Member States around the world. While national projects are essential for knowledge building and skills enhancement, the IAEA is working on bringing countries together. Many countries face similar energy hurdles; therefore, by cooperating regionally, they can learn from each other and find solutions and synergies that work for everyone.

On average, IAEA conducts 50 trainings and workshops annually to support capacity building in energy planning.



skills enhancement

Participants at the 2023 Regional Training on the IAEA's MESSAGE Tool in Jakarta, Indonesia. (Courtesy of the IAEA)

Workshop on Energy System Modelling for Planning held at the Croatian Energy Institute of Hrvoje Pozar in 2019. (Courtesy of the IAEA)

bringing countries together

Sample Case Studies Generated Using IAEA Tools and Methodologies

Energy Planning Support to Europe and Central Asia: Case Studies
International Atomic Energy Agency

Kingdom of Eswatini Energy Masterplan 2034
Ministry of Natural Resources and Energy, The Kingdom of Eswatini

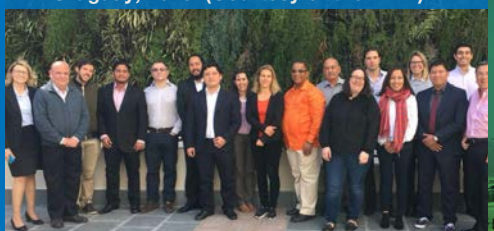
Plan Nacional Indicativo de Desarrollo de Infraestructuras Energéticas Crítica
Gobierno de la República Dominicana, Energía y Minas, Viceministerio de Seguridad Energética e Infraestructura

Prospectiva Energética: Adopción de la Electromovilidad
Secretaría de Estado en el Despacho de Energía,
Honduras Energía Goblerno de la Republica

Rwanda Least Cost Power Development Plan (LCPDP) 2019–2040
Rwanda Energy Group

knowledge building

Regional Workshop on finalising Subregional Energy Demand Studies held in Uruguay, 2018. (Courtesy of the IAEA)



Powering Up Africa: A Continent Wide Power System Development Plan

A unified electricity grid, bringing clean and reliable power to every corner, is an ambitious goal of the African Continental Power Systems Master Plan (CMP Africa).

Building Power Together

The IAEA and the IRENA joined forces under the leadership of the African Union, through the African Union Development Agency and the New Partnership for Africa's Development (AUDA-NEPAD) and regional power pools, to support the development of CMP Africa. The resulting plan is a blueprint for connecting Africa's five power sub-regions into a single, continent-wide grid. The overall activity was coordinated by the European Union (EU).

Tools and Models Deployed

The IAEA and the IRENA acted as official modelling partners and supported key activities through a dedicated capacity building programme and provision of tools and models. These powerful platforms were used to match supply and energy needs and identify the most cost effective solutions, helping countries to visualize the best mix of clean energy sources and interconnections of the systems.

During almost three years, more than 20 African energy experts were trained in power generation expansion planning and transmission system analysis. This exemplary case of knowledge and skills transfer ensures that Africa can continue developing its own energy solutions in the future.

The energy sector in Africa is powering the transformation of economies and societies. By providing the necessary supply and through a more efficient energy system, CMP Africa offers more power for everyone:

- Job creation in building and maintaining the new generation and transmission assets;
- Investment opportunities in clean energy sources across Africa;
- Sustainable development by gradually reducing reliance on fossil fuels, protecting the environment and mitigating climate change.

Wind turbines near Nairobi, Kenya

SPLAT MESSAGE Africa

The SPLAT MESSAGE Africa model demonstrates an effective in-field cooperation between two major agencies. The IAEA offered its Model for Energy Supply System Alternatives and their General Environmental Impacts (MESSAGE), while the IRENA complemented the tools by offering the System Planning Test model (SPLAT). The tools, numerous newly generated data sets and computational capabilities were used to support the development of CMP Africa.

The overall initiative aimed at establishing a long term continent-wide planning process through:

- Increased use of energy system assessment tools for the evaluation of sustainable energy supply and demand paths and support in decision and policy making;
- Comparative assessment of supply and trade options for meeting electricity demand;
- Evaluation of alternative sustainable development scenarios;
- Meeting the goals of integration, increased accessibility and affordability and security of supply while minimizing adverse environmental impacts.

A powerful tool

Participants at one of the meetings to implement CMP Africa. (Courtesy of the IAEA)

Building Botswana's Energy Future

The vision behind Botswana's integrated resource plan (IRP), developed with the IAEA's support in 2019, is to provide Botswana with a secure and affordable energy supply, powered by a mix of clean and reliable sources.

Botswana's IRP is a plan for its energy future. It considers different scenarios for energy needs and explores the most cost effective ways to meet them. The IRP considered three key areas:

- Improving demand side efficiency by using better end-use technologies and energy forms;
- Boosting supply side efficiency by orienting Botswana's energy sector towards the latest power plant technologies;
- Expanding supply options by exploring clean energy sources.

Botswana aimed to achieve several goals using its IRP:

- Diversification: reduce its reliance on a single energy source and diversify its energy mix;
- Competitive prices: keep electricity costs affordable for businesses and households;
- Reliable power: ensure a steady supply of electricity to meet the growing demand;
- Energy independence: become less reliant on energy imports and consider regional market trade opportunities;
- Clean and green: reduce greenhouse gas emissions and protect the environment.

The IAEA's Role

The IAEA provided Botswana with the MAED and MESSAGE tools to analyse energy scenarios. Botswana's energy team was trained in the use of these tools, ensuring that the country can continue developing its own energy solutions in the future. Botswana's IRP is a blueprint for a better energy future, with a focus on security, affordability and sustainability.

“Integrated Energy Planning and developing an Integrated Resource Plan (IRP) are an integral part of the energy planning process in Botswana as guided by its 11th National Development Plans (NDP 11) and other sector policies and ambitions.”

Botswana Energy Regulatory Authority,
Integrated Resource Plan for Electricity for Botswana

Solar panels in Gaborone, Botswana

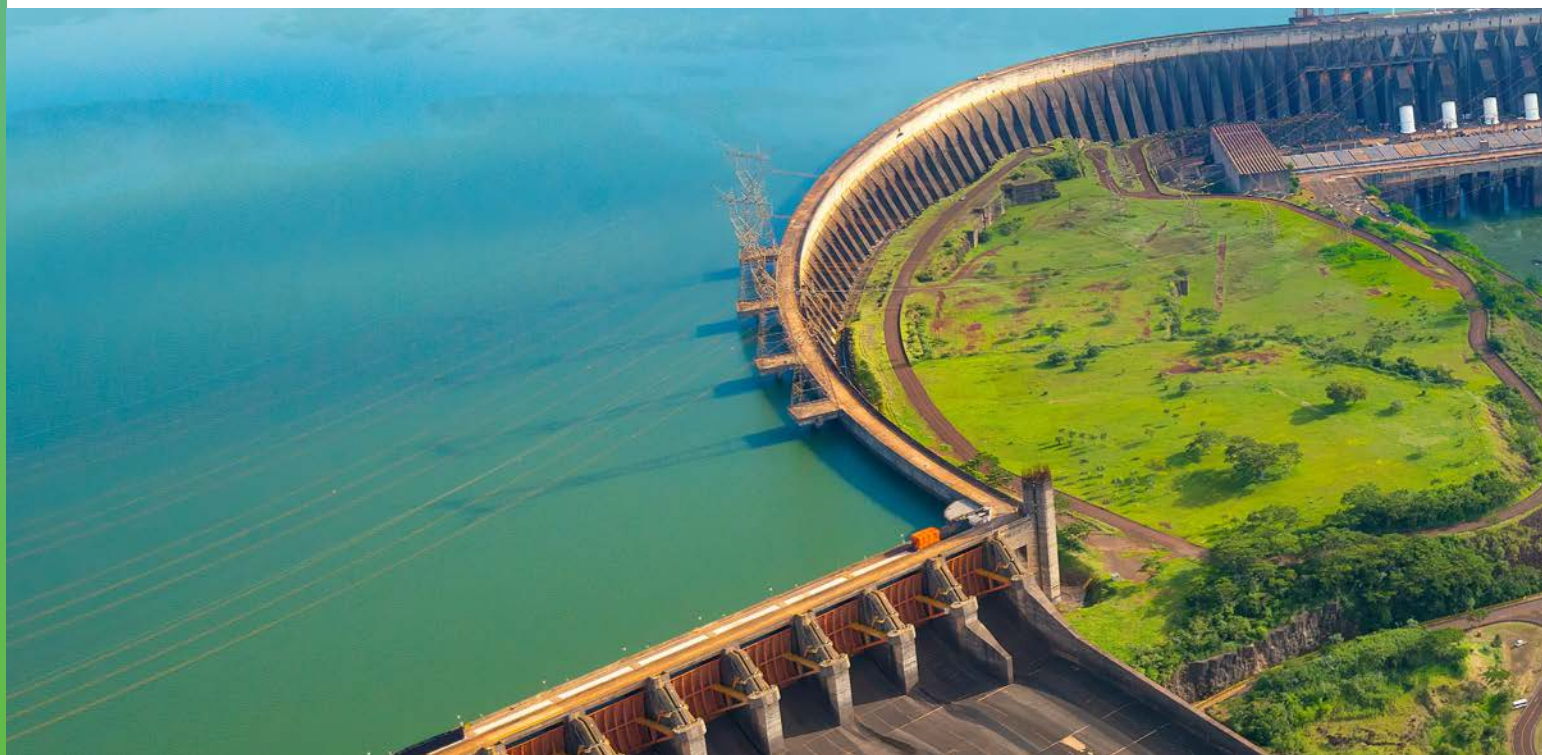
CLEW for the Future: Planning Sustainable Energy in Latin America and the Caribbean

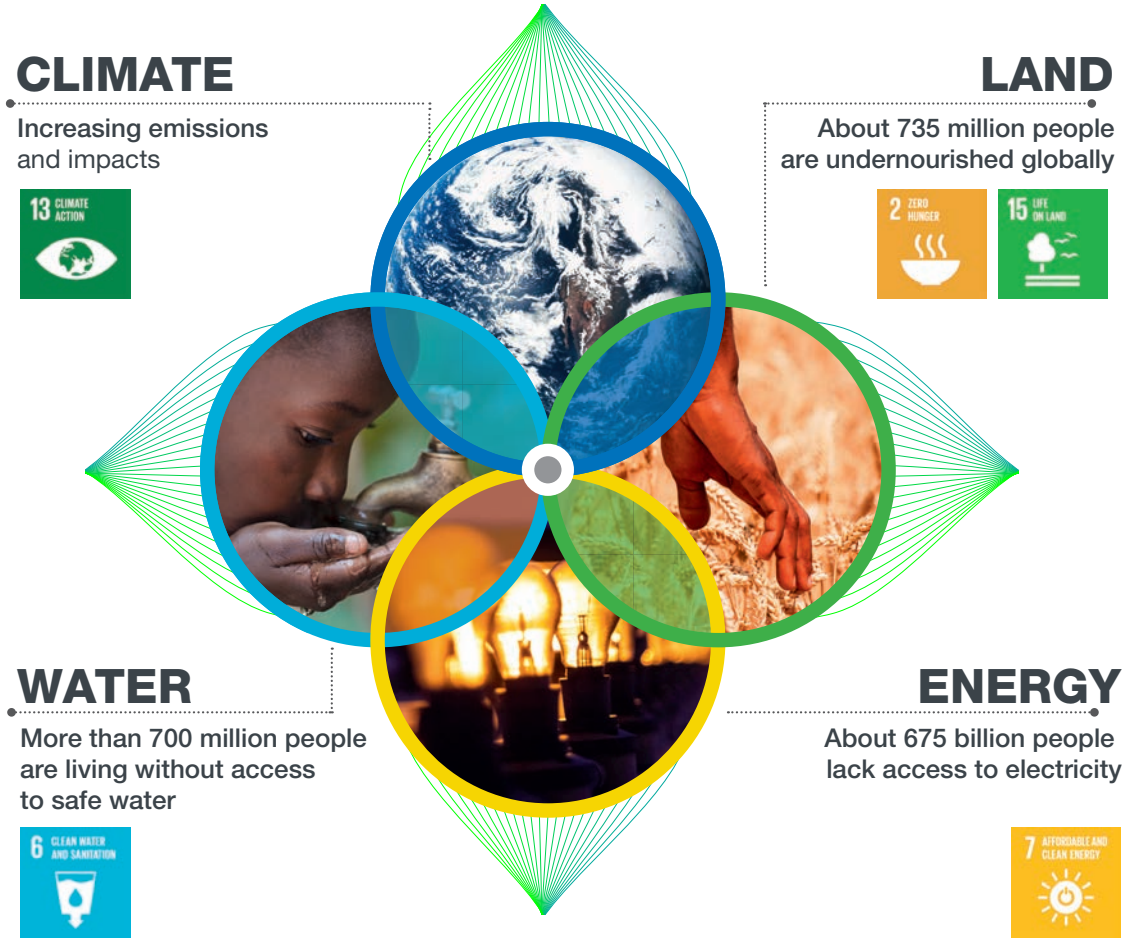
The global energy revolution is already underway, but it should not be simplified to merely searching for and using clean energy sources. The energy shift must be sustainable, as the resources used for energy, such as water and land are also crucial for growing food. The interwoven nature of climate, land, energy and water uses is known as the CLEW nexus.

This is especially true in Latin America and the Caribbean (LAC), a region that has made impressive strides in electricity availability, but facing challenges in water access and the consequences of climate change. The region boasts high electricity access rates, yet sanitation coverage remains uneven among countries of the region. As the population grows and economies develop, energy and water demands will continue to increase substantially. Climate change further complicates the situation, with increased droughts jeopardizing water availability for hydropower plants, a crucial source of clean energy in the region. This growing competition for resources underscores the need for a comprehensive approach to energy planning.

Building on the previous projects for capacity building in energy planning, the current (2024–2027) project, involving 17 countries in the LAC region, aims to enhance capacities in CLEW methodology integration for long term energy planning. Currently, energy planning approaches in LAC often operate in silos, failing to account for the interconnectedness of CLEW factors. By developing a common, unified CLEW approach in collaboration with regional institutions such as OLADE and the Inter-American Development Bank (IDB), the project aims to build strong capacity and cooperation in energy planning. This will involve creating a set of interconnected models that optimize energy planning by considering the complex interplay of these vital resources.

Through the establishment of inter-institutional CLEW project teams, the project will provide targeted training on the CLEW methodology and the IAEA's energy planning tools. By implementing a CLEW approach, LAC can move towards a future with more sustainable and secure energy supplies, reduced competition for water resources and enhanced food security and climate resilience.



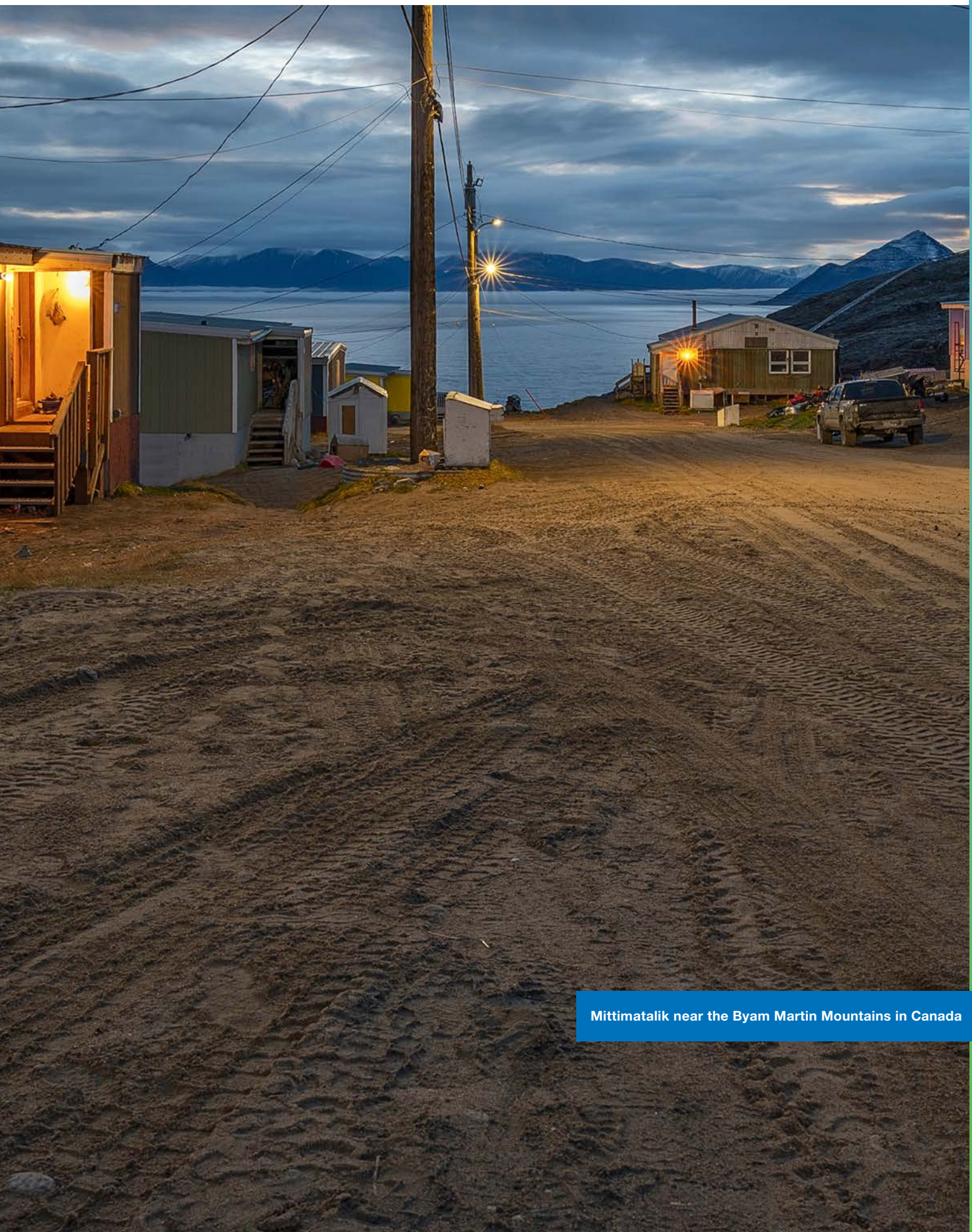


IAEA Framework for Integrated Assessment of Climate, Land, Energy and Water

Itaipu Dam located between Brazil and Paraguay

“Building better energy infrastructure requires strengthening key pillars like financing, technology and skills. It also needs supportive policies and regional collaboration. Planning is key when it comes to providing more energy and more low-carbon energy around the world. The IAEA assists its Member States with their energy planning, whether they plan to include nuclear or not.”

IAEA Director General,
Rafael Mariano Grossi



Mittimatalik near the Byam Martin Mountains in Canada

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SAINT VINCENT AND THE GRENADINES
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SPAIN
SRI LANKA
SUDAN
SWEDEN
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TAJIKISTAN
THAILAND
TOGO
TONGA
TRINIDAD AND TOBAGO
TUNISIA
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TURKMENISTAN
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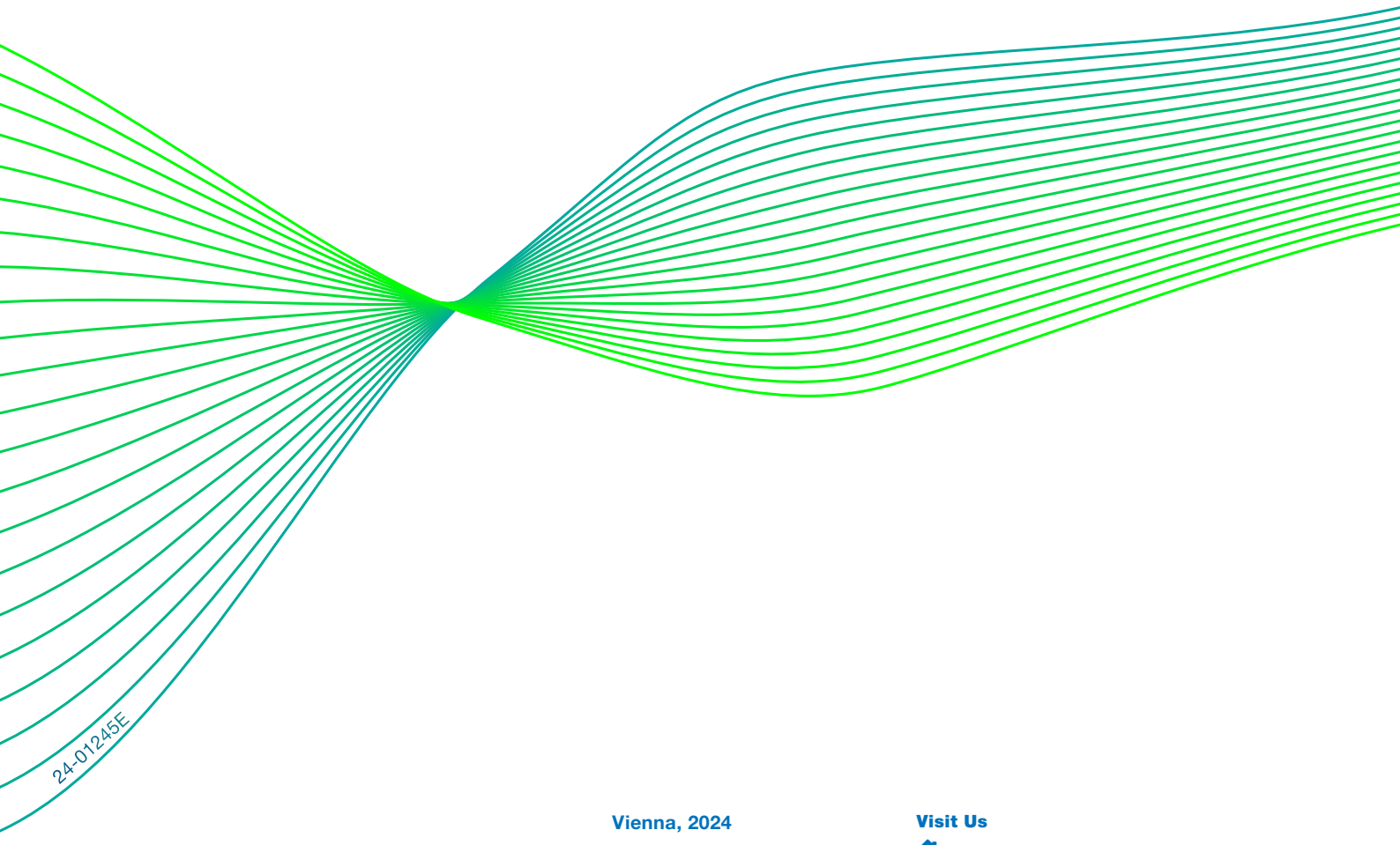

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