Glossary

Pathways to Sustainable Energy Project

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All terms were defined in the context of the Pathways to Sustainable Energy project and may differ from definitions found elsewhere.

Sustainable Energy

We recognize that the notion of sustainable energy has many aspects and may imply different things to different stakeholders. For the purposes of this project we define Sustainable Energy in terms of three pillars**: energy security**, **quality of life**, and **environmental sustainability,** each of which contributes to achieving sustainable energy, but no one of which individually or even jointly fully describes sustainable energy[1]. For one, the pillars are not independent from each other; there are tradeoffs but also synergies. For another, the pillars are intimately linked with the 2030 Agenda for Sustainable Development (2030 Agenda). Energy underpins achievement of most, if not all, Sustainable Development Goals (SDGs). In turn, the implementation of most non-energy SDGs has bearings on Sustainable Energy. To account for energy-related interlinkages between SDGs, the "energy for sustainable development" framework shall be applied (see below).

Each of the three pillars has many attributes. A major contribution of this study is to assign specific metrics (quantifiable measures, see below) to describe the state of each of the three pillars and to track its evolution.[2]

Objectives

Building upon the definition of the three sustainable energy pillars energy security, quality of life, and environmental sustainability (see "Sustainable Energy"), three objectives are defined in the context of this project. The three objectives describe the **overarching goals in 2050** sustainable energy seeks to achieve.

Long-Term Performance Goals

Long-term performance goals (LPGs) are sustainable energy targets with a clear constraint that can be measured and are inherently globally harmonious. The LPGs are the stated desired state of the world at a specific point in time. They cannot be defined such that the goal of one region (or time period) would be in conflict with the goals of another. By setting a specific, measurable goal, success can be defined as achieving that goal.

For the purposes of this project, the constraints will be defined as **outcomes in 2050** (or 2100). An example of a target is the international agreement to limit global warming to 2 degree Celsius. There will be3-5 LPGs in the context of his project.

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[1] This definition is consistent with, but goes beyond, the scope of the Sustainable Development Goal 7 – Affordable and Clean Energy of the 2030 Agenda for Sustainable Development.

[2] Our approach is similar to the FAO definition of food security, which has four primary attributes (availability, access, stability, and utilization), each of which have multiple indicators that can be measured to track progress toward the overarching attributes.

Metrics

Metrics are quantifiable indicators that are consistent with the attributes of the pillars of sustainable energy. They must be measurable in the real world (e.g., GDP or GDP per capita) and from models' outputs. Metrics are useful because they can help track progress toward goals. Exploring multiple metrics not only gives a more nuanced understanding of sustainable energy, it can also identify synergies and/or tradeoffs between different aspects of sustainable energy.

Metrics will be linked back to energy-related SDGs according to the "energy for sustainable development" framework. Metrics either are consistent with indicators of SDGs, such as the share of renewables in total final energy consumption), or they can become an "proxy indicator" assigned to a specific SDG. Metrics hence help to track progress towards achieving Agenda 2030 (and a view towards 2050).

Key Performance Indicators (KPIs)

Some metrics may be identified as uniquely important. These are called **Key Performance Indicators** (KPIs). Three to four KPIs will be selected for each of the three sustainable energy pillars (see "Sustainable Energy"), and they will play a more visible role in the presentation and analysis of the selected scenarios.

In the context of this project, desirable ranges for selected metrics will be used for most of the KPIs. More than one desirable range for a KPI may be defined, but modeling work may have to focus on each one individually, as desirable ranges are not necessarily harmonious (i.e., achieving one KPI may make achieving another easier or harder). As such KPIs are different from LPGs which define the overall sustainable energy target that is to be achieved by 2050.

Signposts

Signposts are Interim Performance Indicators (IPIs) which are modelled values of metrics at specific points in time along a given pathway. These values can then be used to track regional and global progress toward a KPI or a sustainable energy target, which are articulated at a global level and at more distant point in time. IPIs are not intended to be policy prescriptive – they are not short-term performance goals – but rather to gain insight into whether we are on a path to achieving a policy target or if additional policies need to be implemented. Signposts may be KPI measures or other metrics.

Signposts will be linked back to energy-related SDGs according to the "energy for sustainable development" framework. Signposts either are consistent with indicators of SDGs (such as "doubling the rate of energy efficiency improvement by 2030" under SDG 7), or they can become an "informal" indicator assigned to a specific SDG. Signposts hence help to track progress towards achieving Agenda 2030 (and beyond). As such, they will play an important role in the formulation of the early-warning system that shall help countries to stay informed and track progress towards sustainable energy.

Storylines

Storylines are narrative descriptions of alternative futures, i.e., visions of how the world may evolve towards a (desirable future) state or normative objectives. Key are qualitative descriptions of the relationships among different trends and socio-economic developments foreseen for the future. The storylines do not contain strategies for achieving specific goals or outcomes. Storylines also do not assign probabilities to the likelihood of any future.

Within the Pathways project storylines are further used as an organizing framework for the scenarios to be developed as part of the modelling.

Scenarios

In the context of the Pathways projects, the term "**Scenarios**" means quantified descriptions or images of the future (often outlined by a storyline). Note: Scenario quantification is synonymous with making assumptions about the future). In contrast, storylines underpin scenarios by providing a qualitative but internally consistent vision of the future and/or its key developments and events (see below).

There are three major elements that we will use to develop scenarios: Quantified Assumptions, Quantified Relationships, and Quantified Outcomes.

- **Quantified Assumptions**: These are the key drivers of a future sustainable energy system that we take as given for the purpose of scenario development and are inputs to the modelling process. These fall into five broad categories:
  - Demographics—the number of people and their geographic, age, and gender distribution
  - Economic—the evolving economic state of the world, e.g., labor productivity growth rates.
  - Resources—the availability and quality of natural resource assets such as fossil fuels, minerals, uranium, land, wind, solar insulation, water, or geothermal energy.
  - Technology—the set of knowledge and processes that can be used to extract and transform resources to meet energy service demands.
  - Institutions and Policies—the formal and informal rules that govern and direct human decisions.
- **Quantified Relationships**: These are the rule-based interactions between the key energy system components, i.e. the equations of the model that link the scenario drivers (assumptions) and outcomes in a model. These relationships can be either simple or complex. In this exercise, the relationships are embodied in science-based methods, and well-documented, peer-reviewed computer codes.
- **Quantified Outcomes:** These are quantified measures of human and natural systems that are determined by the assumptions and result from the model relationships. Examples include metrics (see below) such as energy extraction, energy supply mixes and shares, demand, imports and exports, land use, food prices, oil prices, pollution, water and withdrawals in specific places and times. Outcomes are contingent on quantified assumptions. If the assumptions change, the outcomes will also change.

Reference Scenario

All analysis begins with a set of baseline assumptions based on historical trends and current policies. It is an evaluation of the world as it stands right now. A reference scenario enables analysis of whether or not the world is likely to achieve specific goals along its current trajectory. This is a vital part of all research. Analysis of specific metrics based on the outcomes of a reference scenario may show that a Long-term Performance Goal (LPG), such as a 25% reduction in energy intensity by 2050, would likely be achieved with our current assumptions about the pace of economic development and the evolving relationships between energy and economic development. The outcomes of a reference scenario may also show that, under the current set of assumptions and relationships, a specific LPG is unlikely to be attained.

The reference scenario for the Pathways project is the Shared-Socio-Economic Pathway 2 (SSP2), a "Middle of the Road" Pathway.

Policy Scenarios

Policy scenarios can take two general forms. In the first, a policy proposal is defined and the modeling and analysis shows what the outcomes are. In the second, a goal is set and the models show what would need to be done to achieve this goal.

- Analysis of specific policy proposals: In the first, the implications of a specific policy proposal, such as a $0.50/kWh subsidy intended to increase deployment of solar, wind, and hydropower, can be analysed. Here, the proposed policy is included in the model on top of the baseline assumptions in the reference scenario. In this type of policy scenario, metrics – such as the cost of electricity, total subsidy cost to the government, renewable share of electricity by 2040, or total consumption of electricity and fossil fuels – can be analyzed to improve the understanding of the broader implications and end result of a policy proposal.

- Analysis of a Long-term Performance Goal: In the second type of policy scenario, a LPG is implemented as a constraint in the model, with the technology and development assumptions defined in the reference scenario. In this type of policy scenario, a goal is defined – such as achieving a 100% share of renewable electricity generation by 2050 – and the models determine what would need to change in order to achieve this goal. The same general set of metrics as above can also be analysed, with the difference being the models determine what level of effort and types of changes need to occur to achieve this goal.

The difference between these types of policy scenarios is subtle, but important. In the first, the question is: If I change X in this way, how close to Y do I get? In the second, the question is: If I want to achieve Y, how does X need to change? It is essential to understand the answers to the two types of questions may be incompatible with each other. The first type of policy analysis can inform as to whether a renewable subsidy of $0.50/kWh is sufficient to achieve the goal of 100% renewable electricity by 2050 or not. It will also inform policy makers on the unintended consequences of a policy action, such as increases in fossil fuel consumption in regions without such a policy. In the second type of analysis, a model will achieve the goal at the least total economic cost (within the context of the reference assumptions and relationships). In this case, who bears the burdens and in what ways (e.g., changes in food prices or export revenues) is an important part of the analysis. Ultimately, policy makers determine what the final goal is and what types of costs are acceptable in working toward that goal. The models can show whether a goal is achievable within these constraints, but not determine what the “right” level of a target or acceptable costs to society should be.

The modelling of policy scenarios will lead to the formulation of policy pathways. See “pathways” for more information.

Pathways

Pathways are alternative possible trajectories within the overall context of a scenario. They assess the feasibility and implications of a strategy to reach an objective, say, sustainable energy (meeting a range of sustainability objectives simultaneously). They also envisage different means of dealing with incomplete knowledge, uncertainty, highlighting and responding to the different aspects of risk such as lock-in effects and stranded assets.

Pathways and scenarios are intimately related as pathways are means of meeting scenario objectives. Policy scenarios within the model will become policy pathways used within the project. See “policy scenarios” for more information.

Dynamic Adaptive Policy Pathways

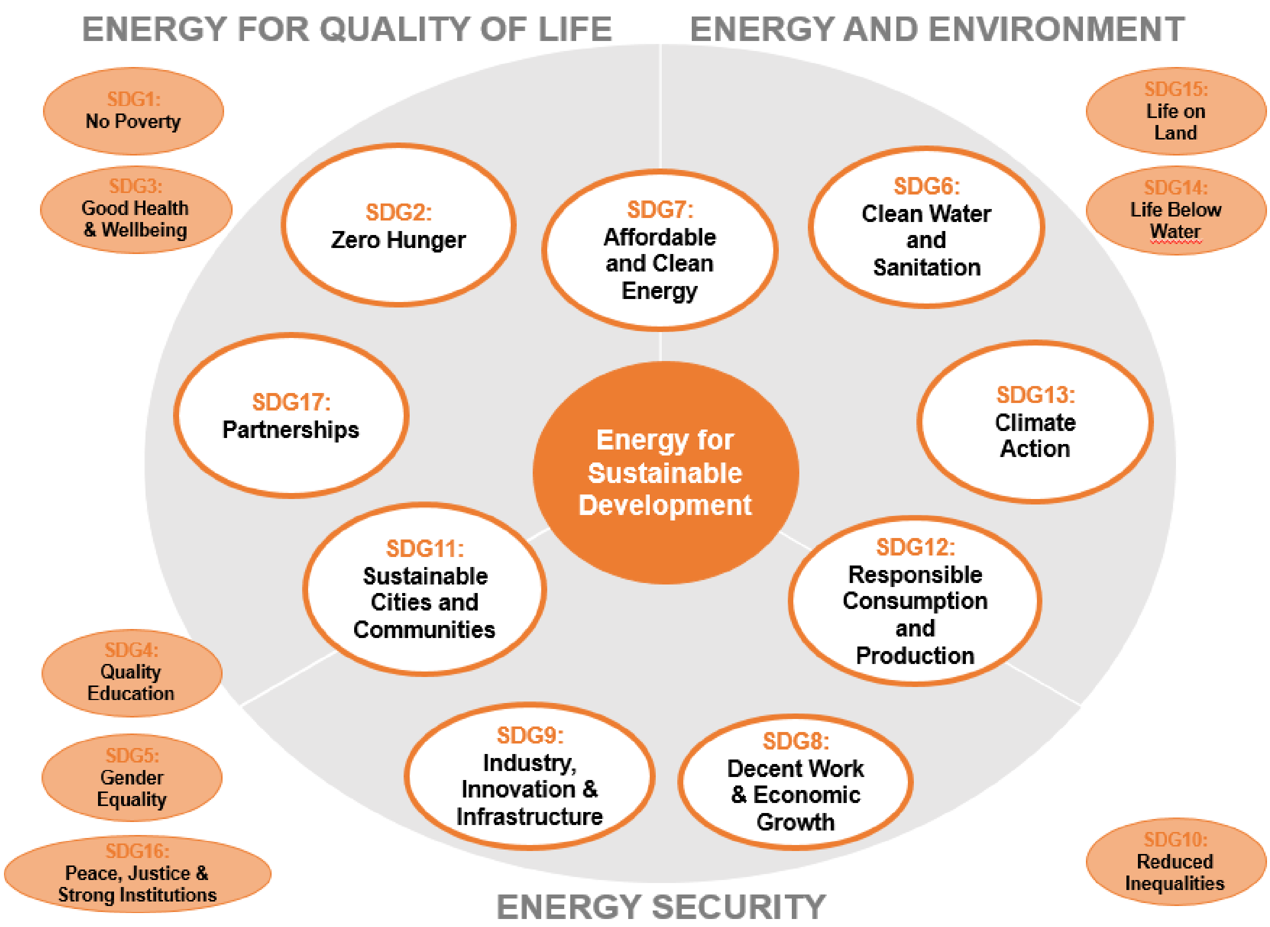
As the future is inherently unknowable, hence uncertain, analysts resort to storylines and scenarios to deal with uncertainty. Dynamic Adaptive Policy Pathway analysis deals with near-term decision making under deep uncertainty. It is a specific protocol for arriving at near-term actions that are intended to be adjusted as time passes and the uncertain future resolves or initial decisions prove flawed or ineffective. The near-term actions are intended to leave the decision maker with the ability to respond to a wide range of future realizations. It is similar in approach to Robust Decision Making, Real Options Analysis, decision trees, and roadmaps and draws on two existing methods, Adaptation Pathways and Adaptive Policy Making. The approach assumes a single decision maker with a long-term strategic vision of the future, but poor knowledge of how the future will evolve. That decision maker undertakes sequential short-term actions intended to implement the long-term goal in a way that is robust against multiple future states.

In this project we will consider the time-evolution of policies needed to achieve sustainable energy targets and selected desirable ranges of KPIs. An exploration of the implications of uncertainty is not part of this project.

Energy for Sustainable Development

The framework "Energy for Sustainable Development" was developed a part of the "Global tacking framework: UNECE Progress in Sustainable Energy" report. The conceptual basis for the development of the framework is that energy underpins achievement of Agenda 2030, and hereby goes beyond the energy goal SDG 7 towards a reflection of the cross-cutting interconnections among the SDGs. Using this framework shows the need to develop indicators to track energy for sustainable development beyond those for SDG 7.

Metrics, KPIs and signposts shall be linked back to this framework to allow analysis and insights on consequences of scenarios on achieving (energy related aspects of) Agenda 2030.



LITERATURE REVIEW

Pathways

Global Energy Assessment

http://www.iiasa.ac.at/web/home/research/Flagship-Projects/Global-Energy-Assessment/GEA_Chapter17_pathways_lowres.pdf

- Pathways: Qualitative and quantitative descriptions of demand- and supply-side energy system transformations falling within the overarching GEA scenario
- Pathway groups: Groups of pathways distinguished by their level of energy demand and used as an organizing framework for the modeling of specific supply-side pathways

Fifth Assessment Report: Annex incl. Glossary

https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_annex-i.pdf

- Representative Concentration Pathways (RCPs): Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use / land cover (Moss et al., 2008). The word representative signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. The term pathway emphasizes that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome (Moss et al., 2010).
- RCPs usually refer to the portion of the concentration pathway extending up to 2100, for which Integrated Assessment Models produced corresponding emission scenarios. Extended Concentration Pathways (ECPs) describe extensions of the RCPs from 2100 to 2500 that were calculated using simple rules generated by stakeholder consultations, and do not represent fully consistent scenarios.
- Four RCPs produced from Integrated Assessment Models were selected from the published literature and are used in the present IPCC Assessment as a basis for the climate predictions and projections presented in WGI AR5 Chapters 11 to 14:
- RCP2.6 One pathway where radiative forcing peaks at approximately 3 W m – 2 before 2100 and then declines (the corresponding ECP assuming constant emissions after 2100);
- RCP4.5 and RCP6.0 Two intermediate stabilization pathways in which radiative forcing is stabilized at approximately 4.5 W m – 2 and 6.0 W m – 2 after 2100 (the corresponding ECPs assuming constant concentrations after 2150);
- RCP8.5 One high pathway for which radiative forcing reaches greater than 8.5 W m – 2 by 2100 and continues to rise for some amount of time (the corresponding ECP assuming constant emissions after 2100 and constant concentrations after 2250).
- For further description of future scenarios, see WGI AR5 Box 1.1. See also Baseline / reference, Climate prediction, Climate projection, Climate scenario, Shared socio-economic pathways, Socio-economic scenario, SRES scenarios, and Transformation pathway.
- Transformation pathway: The trajectory taken over time to meet different goals for greenhouse gas (GHG) emissions, atmospheric concentrations, or global mean surface temperature change that implies a set of economic, technological, and behavioural changes. This can encompass changes in the way energy and infrastructure is used and produced, natural resources are managed, institutions are set up, and in the pace and direction of technological change (TC). See also Baseline / reference, Climate scenario, Emission scenario, Mitigation scenario, Representative Concentration Pathways (RCPs), Scenario, Shared socio-economic pathways, Socio-economic scenarios, SRES scenarios, and Stabilization.

- Shared socio-economic pathways (SSPs): Currently, the idea of SSPs is developed as a basis for new emissions and socio-economic scenarios. An SSP is one of a collection of pathways that describe alternative futures of socio-economic development in the absence of climate policy intervention. The combination of SSP-based socio-economic scenarios and Representative Concentration Pathway (RCP)based climate projections should provide a useful integrative frame for climate impact and policy analysis. See also Baseline / reference, Climate scenario, Emission scenario, Mitigation scenario, Scenario, SRES scenarios, Stabilization, and Transformation pathway

Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world

- Adaptation Pathways provide insight into the sequencing of actions over time, potential lock-ins, and path dependencies. An example of a family resemblance between concepts used by these two approaches is the concept of an adaptation tipping point (Kwadijk et al., 2010) used in Adaptation Pathways and the notion of a trigger from Adaptive Policymaking. An adaptation tipping point is the point at which a particular action is no longer adequate for meeting the plan's objectives. A new action is therefore necessary. A trigger specifies the conditions under which a prespecified action to change the plan is to be taken.
- Central to adaptation pathways are **adaption tipping points** (Kwadijk et al., 2010), which are the conditions under which an action no longer meets the clearly specified objectives. The timing of the adaptation point for a given action, its sell-by date, is scenario dependent. After reaching a tipping point, additional actions are needed. As a result, a pathway emerges.
- Key principles of the Dynamic Adaptive Policy Pathways approach are: the use of transient scenarios representing a variety of relevant uncertainties and their development over time; anticipating and corrective actions to handle vulnerabilities and opportunities; several Adaptation Pathways describing sequences of promising actions; and a monitoring system with related actions to keep the plan on the track of a preferred pathway.

Scenarios

Global Energy Assessment

www.iiasa.ac.at/web/home/research/Flagship-Projects/Global-Energy-Assessment/GEA_Chapter17_pathways_lowres.pdf

- GEA Scenario: An overarching storyline of energy system transformation to meet normative sustainability objectives

Fifth Assessment Report: Annex incl. Glossary

https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_annex-i.pdf

- Scenario: A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e. g., rate of technological change (TC), prices) and relationships. Note that scenarios are neither predictions nor forecasts, but are useful to provide a view of the implications of developments and actions.
- Socio-economic scenario: A scenario that describes a possible future in terms of population, gross domestic product (GDP), and other socioeconomic factors relevant to understanding the implications of climate change
- SRES scenarios: SRES scenarios are emission scenarios developed by Nakićenović and Swart (2000) and used, among others, as a basis for some of the climate projections shown in Chapters 9 to 11 of IPCC (2001) and Chapters 10 and 11 of IPCC (2007) as well as WGI AR5. The following terms are relevant for a better understanding of the structure and use of the set of SRES scenarios:

- Scenario family: Scenarios that have a similar demographic, societal, economic and technical change storyline. Four scenario families comprise the SRES scenario set: A1, A2, B1, and B2.
- Illustrative Scenario: A scenario that is illustrative for each of the six scenario groups reflected in the Summary for Policymakers of Nakićenović and Swart (2000). They include four revised marker scenarios for the scenario groups A1B, A2, B1, B2, and two additional scenarios for the A1FI and A1T groups. All scenario groups are equally sound.
- Marker Scenario: A scenario that was originally posted in draft form on the SRES website to represent a given scenario family. The choice of markers was based on which of the initial quantifications best reflected the storyline, and the features of specific models. Markers are no more likely than other scenarios, but are considered by the SRES writing team as illustrative of a particular storyline. They are included in revised form in Nakićenović and Swart (2000). These scenarios received the closest scrutiny of the entire writing team and via the SRES open process. Scenarios were also selected to illustrate the other two scenario groups.
- Climate scenario: A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate projections often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as the observed current climate.
- Baseline / reference: The state against which change is measured. In the context of transformation pathways, the term ‘baseline scenarios’ refers to scenarios that are based on the assumption that no mitigation policies or measures will be implemented beyond those that are already in force and / or are legislated or planned to be adopted. Baseline scenarios are not intended to be predictions of the future, but rather counterfactual constructions that can serve to highlight the level of emissions that would occur without further policy effort. Typically, baseline scenarios are then compared to mitigation scenarios that are constructed to meet different goals for greenhouse gas (GHG) emissions, atmospheric concentrations, or temperature change. The term ‘baseline scenario’ is used interchangeably with ‘reference scenario’ and ‘no policy scenario’. In much of the literature the term is also synonymous with the term ‘business-as-usual (BAU) scenario,’ although the term ‘BAU’ has fallen out of favour because the idea of ‘business-as-usual’ in century-long socioeconomic projections is hard to fathom.

Sign-posts

Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world

- Signposts: Signposts specify information that should be tracked in order to determine whether the plan is meeting the conditions for its success. In addition, critical values of signpost variables (triggers) beyond which additional actions should be implemented are specified.

Storylines

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https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_annex-i.pdf

- Storyline: A narrative description of a scenario (or family of scenarios), highlighting the main scenario characteristics, relationships between key driving forces and the dynamics of their evolution.

Plotting Your Scenarios

http://www.meadowlark.co/plotting_your_scenarios.pdf

- Scenarios are narratives of alternative environments in which today’s decisions may be played out. They are not predictions. Nor are they strategies. Instead they are more like hypotheses of different futures specifically designed to highlight the risks and opportunities involved in specific strategic issues.

- To be an effective planning tool, scenarios should be written in the form of absorbing, convincing stories that describe a broad range of alternative futures relevant to an organization's success. Thoughtfully constructed, believable plots help managers to become deeply involved in the scenarios and perhaps gain new understanding of how their organization can manage change as a result of this experience