Basic Concepts in Energy and Environment Planning and Modeling

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Presentation Overview

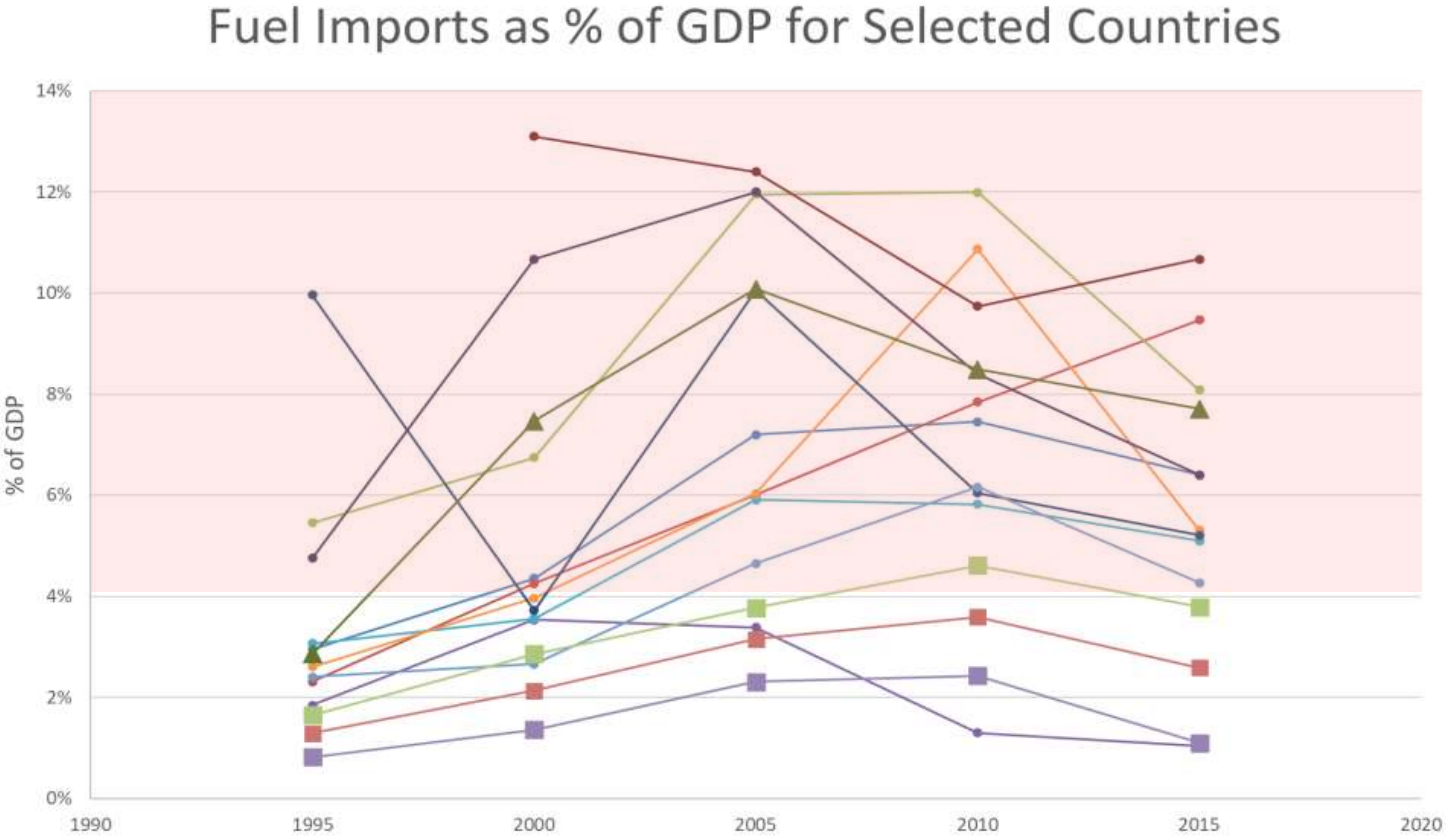
- Energy for Development and the Role of Integrated Planning
- Basics Elements of Energy Systems
- The Role of Models and Scenario Analysis in Integrated Planning

Energy for Development and the Role of Integrated Planning

Energy for Development

- Energy is crucial for development: affordable energy promotes rising living standards and industrial and agricultural development. In increasingly urbanized societies, it is key to meeting the high demand for transport services.
- In oil importing countries, energy costs severely constrain development, both in terms of high operating costs and high capital costs of energy infrastructure.
- Energy systems also cause pervasive environmental externalities including air pollution, climate change, social dislocation, the risks associated with nuclear power, etc.

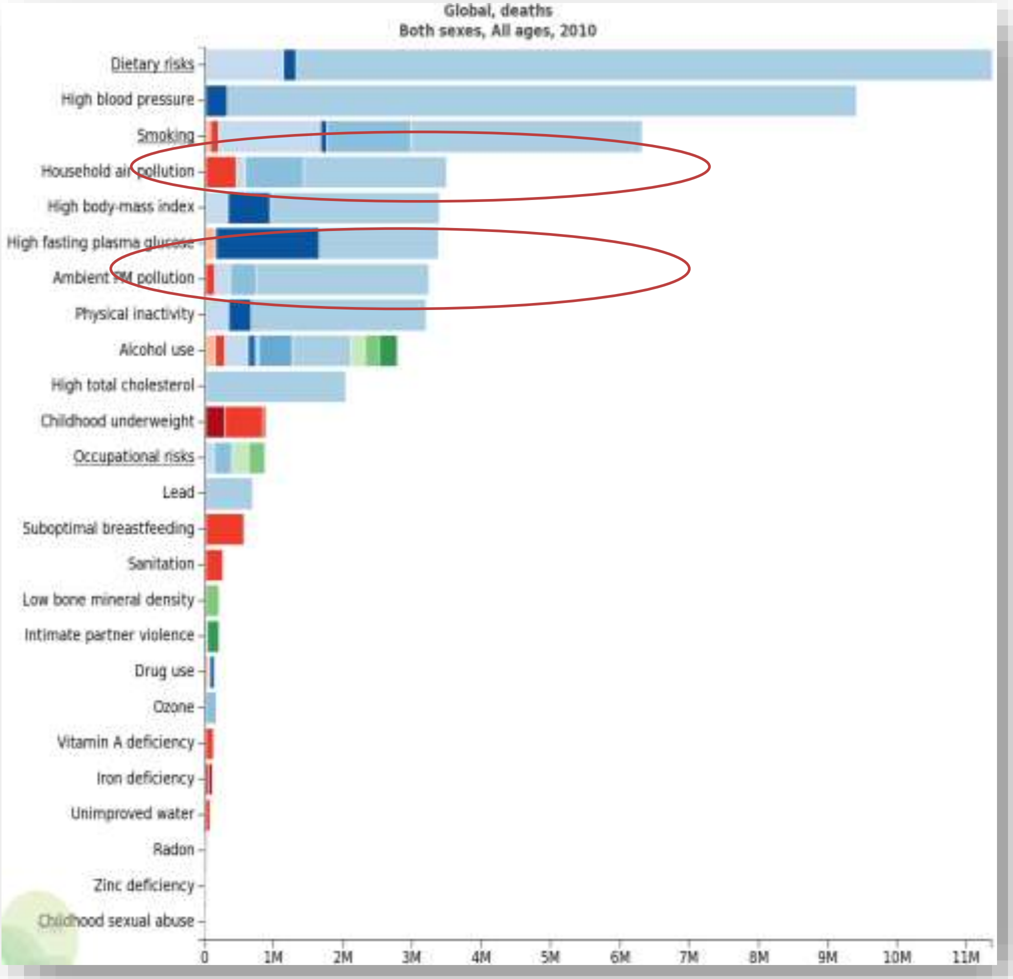
CARICOM Countries Particularly Vulnerable



Based on data from World Bank World Development Indicators (2021)

Environmental Impacts: Air Pollution

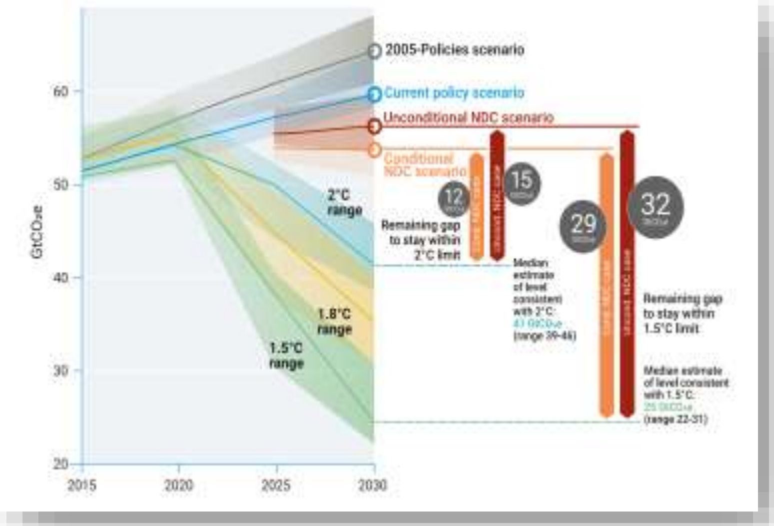
- The 2010 Global Burden of Disease study ranked indoor air pollution and ambient air pollution resulting from the combustion of fuels as the 4th and 7th most important disease risk factors.
- Particularly important issue in countries where traditional fuel use and indoor air pollution remain important.

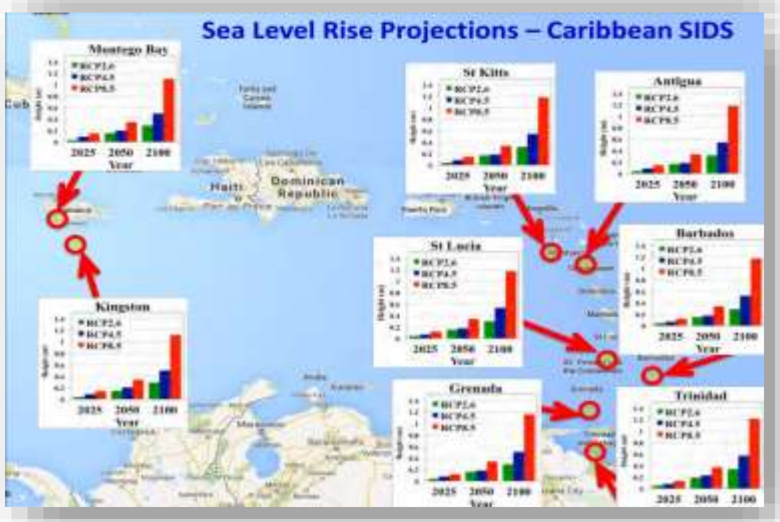


Source: Global Burden of Disease (2010)

Environmental Impacts: Climate Change

- Present trends put us on a path of 3-5°C warming or more this century. Even with current commitments, there is a high likelihood of exceeding 4°C by 2100. Further warming to over 6°C, with several meters of sea-level rise, will likely occur over the following centuries.
- A 4°C world would be one of unprecedented sea level rise, heat waves, severe droughts, major floods, and serious impacts on human systems, ecosystems, and associated services. No certainty that adaptation to a 4°C world is possible.
- Avoiding catastrophic climate change requires a rapid global transition away from the use of fossil fuels and significantly net negative emissions globally by the end of the century.
- Important unanswered questions about climate justice: how to fairly share the burden for GHG mitigation effort among countries, considering that the majority of emissions have been generated by the richest countries.





Sources: UNEP Emissions Gas Report (2019), Nurse, L. (2017)

Different Perspectives on Energy Systems

Decision-making in the energy sector is highly dependent on how it is perceived:

- **As a Commodity:** energy companies and large consumers (e.g., industry) tend to view energy as a commodity or factor of production, based on the buyer-price-seller relationship inherent in commercial transactions.
- **As a Cause of Environmental Impact:** energy systems are increasingly viewed in terms of social and environmental impacts (e.g., through air pollution and induced climate change) . Achieving a rapid transition to near zero GHG emissions is now seen as perhaps the most important challenge for the planet this century.
- **A Social Necessity:** the provision of basic energy services (access to electricity and clean cooking fuels) is now widely seen as a social priority as reflected in the UN's Sustainable Development Goals (SDGs). These priorities are pursued through policies such as electrification programs and the subsidizing of fuels to low-income groups.
- **A Vital Element of Political Strategy:** Many oil importing countries are particularly dependent on expensive energy imports and are highly vulnerable to the increasing volatility of international energy prices. Exporting countries are increasingly concerned that their energy extraction and processing facilities may become "stranded assets" if the rest of the world embarks on a raid transition away from fossil fuels. Overall, energy concerns are a key security issue and have contributed to multiple military interventions in the past decades.

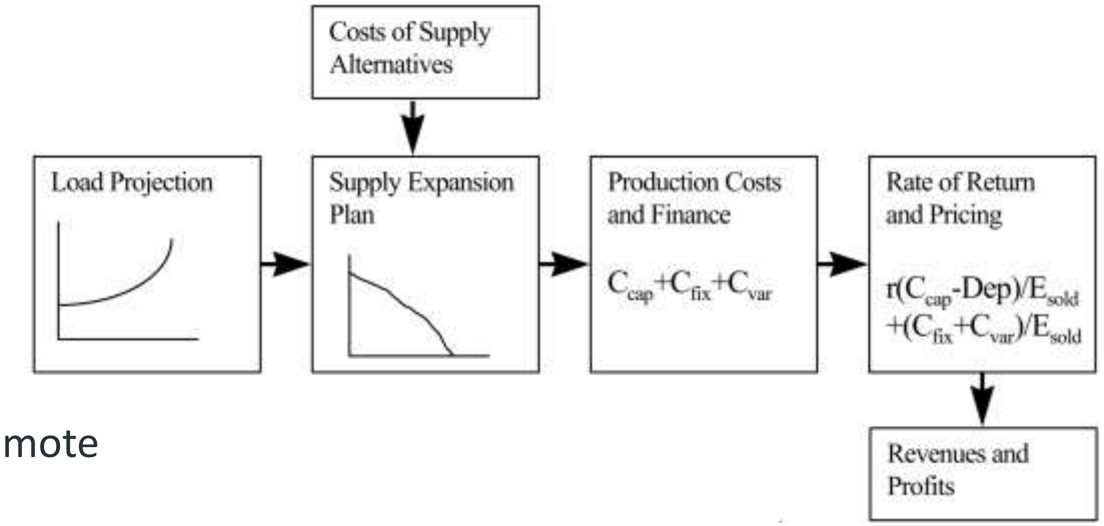
Adapted from: Swisher, Jannuzzi, Redlinger (1997)

The Need for Good Energy Policy

- New cost-effective energy-efficient technologies, dramatic reductions in the cost of wind, solar and other renewable technologies spurred on by the climate protection imperative have led to a growing realization that economic development can be decoupled from the growth in the use of fossil fuels.
- Many of these technologies are now cheaper than traditional fossil-based technologies. Moreover, they tend to be less “lumpy” and have shorter lead times, meaning that capital investments can be put to work more quickly.
- However, such technologies tend to be more capital intensive per kWh and are often harder to implement for a variety of reasons, such as distortions in energy prices, lack of access to capital, differences in incentives between energy consumers and producers (often reinforced by market liberalization), and the lack of internalization of important environmental externalities.
- Thus, while being clearly beneficial from a national social cost-benefit perspective, current energy systems fail to adequately promote these new cleaner technologies.

Traditional Approaches to Planning

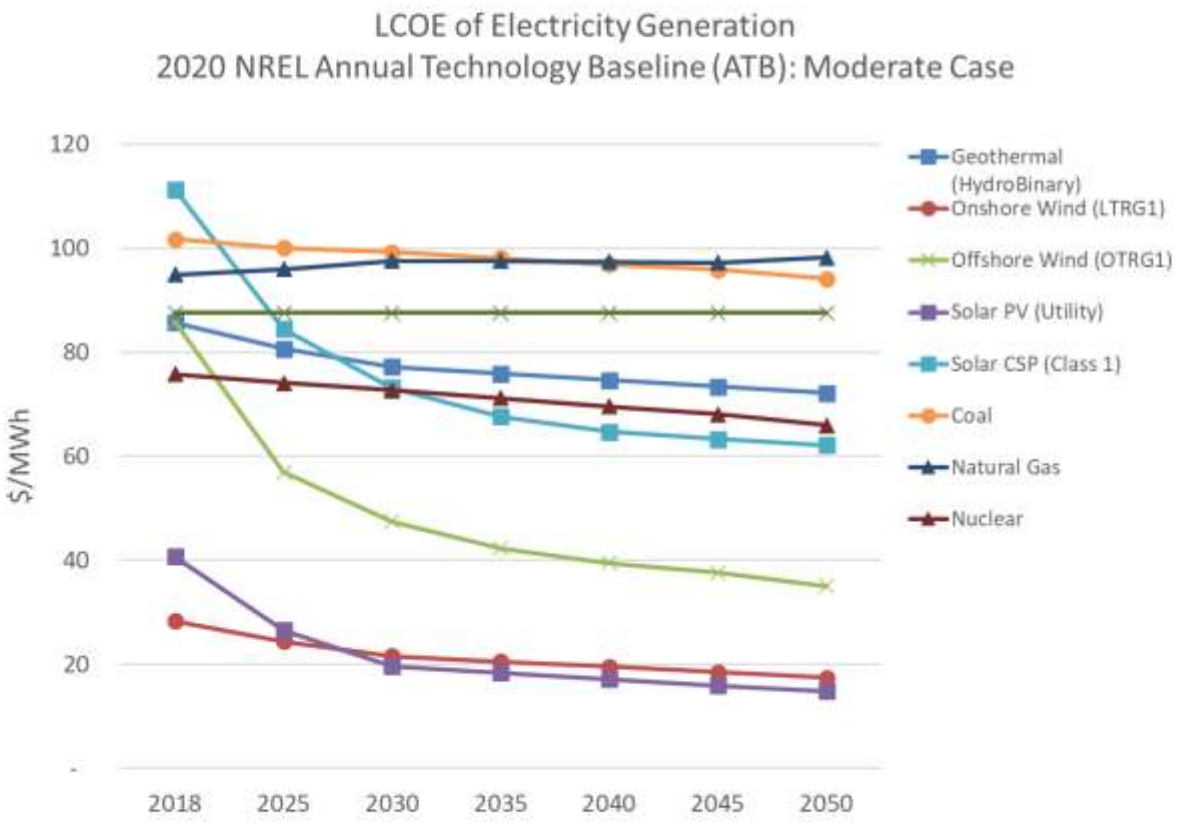
- Traditional approaches to planning relied on top-down forecasting of demands coupled with least-cost generation planning: seeking to expand supplies to meet anticipated demand growth with high reliability at minimum economic cost.
- This worked reasonably well when energy systems had:
  - Stable prices, reliable supplies.
  - Large, centralized utilities and a growing customer base.
  - Supply dominated by large power plants, predictably dispatched
  - Long plant lifetimes and build times.
  - Externalities largely ignored.
- Governments often used their energy systems as a vehicle to promote development: cross-subsidizing electricity for poorer consumers.
- Parastatal utilities were often directed to help meet goals, regardless of financial viability, so often under-capitalized and unprofitable.



Source: Swisher, Jannuzzi, Redlinger (1997)

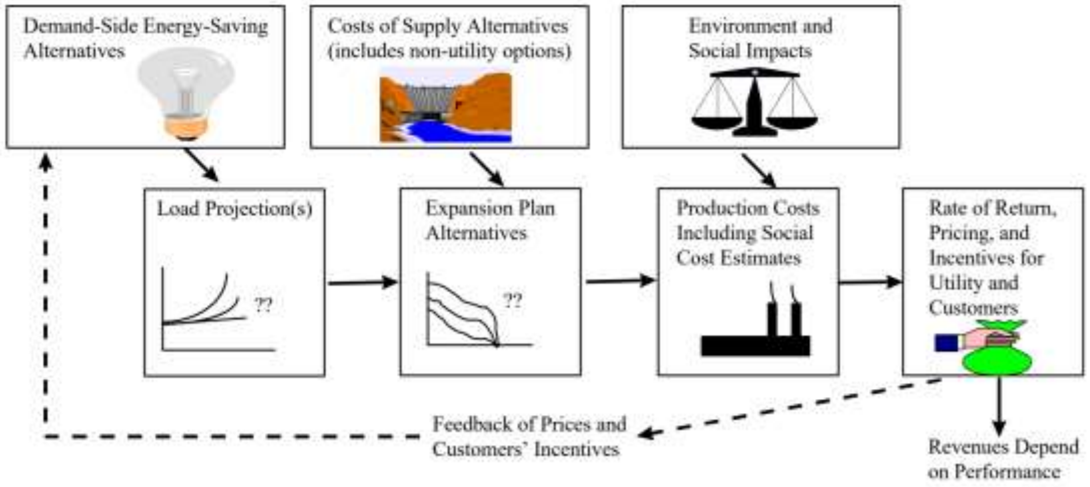
Emerging Trends Make Traditional Approaches Unsuitable

- Unprecedented improvements in cost and performance of EE and RE technologies.
- Competition to utilities from private & behind the meter solar “prosumers”.
- Volatility in fuel prices.
- Emerging technologies for managing load and for energy storage.
- New markets for electrification (vehicles, heat pumps, etc.) that may have significant impact on overall demands and the shape of electric loads.
- Utilities risk losing highest paying customers. Using cross-subsidies for social policy increasingly difficult.
- Air pollution and climate change from fossil generation require strong role for Government in planning.



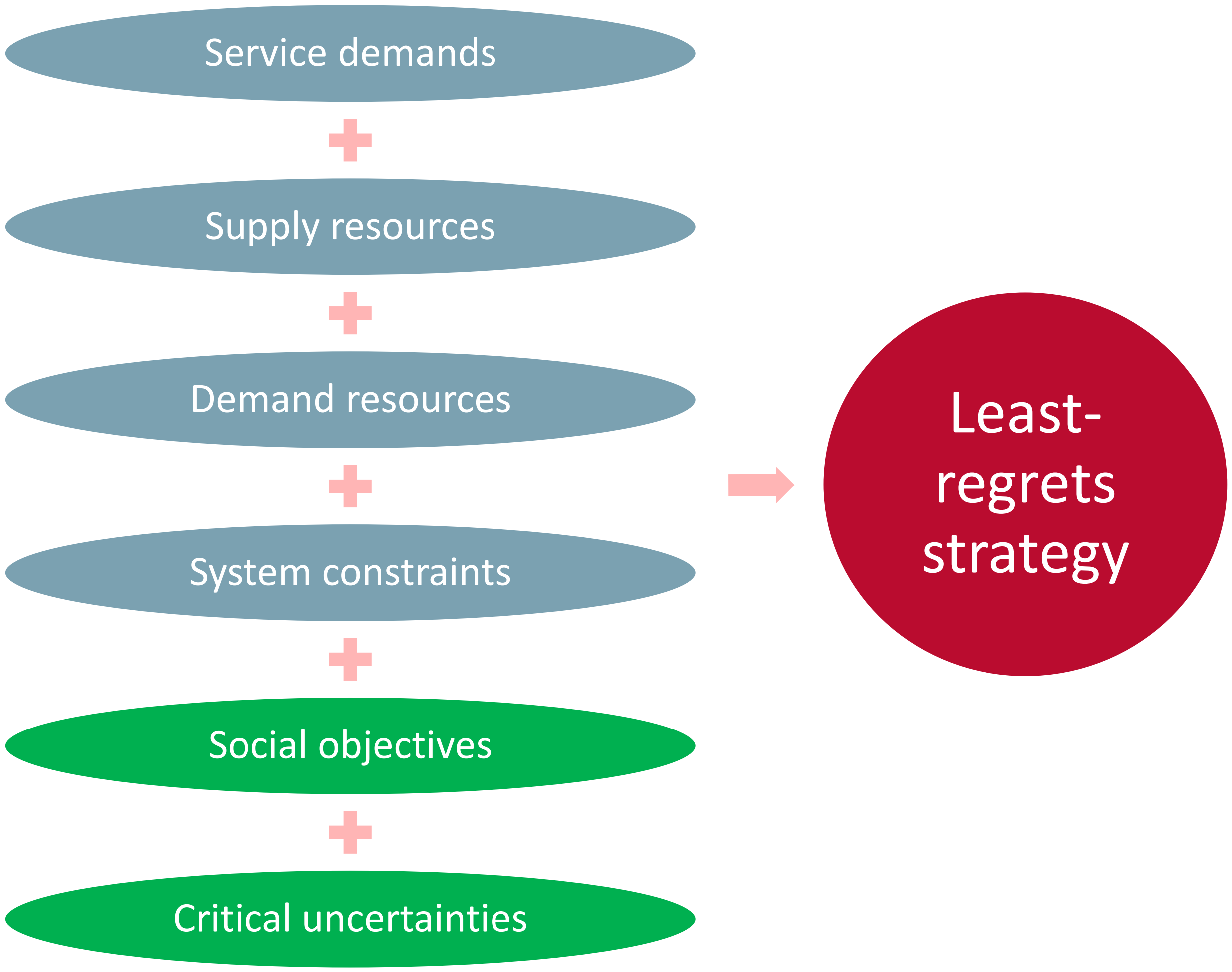
Integrated Resource Planning (IRP)

- IRP expands traditional planning to consider a broader range of technological options, and in particular emphasizes demand-side management (DSM) measures:
  - Energy efficiency options for reducing demand growth
  - Seasonal and diurnal load control
- IRP also tends to emphasize a broader perspective on cost analysis:
  - Integration of environmental and social costs
  - A focus on the national social cost-benefit perspective (not just utility costs, revenues, and profitability).
- Since these perspective often lie outside of the immediate interests of utilities and consumers (whether in liberalized markets or nationalized parastatal companies), broader planning and regulation of markets is generally required to incentivize market behavior.



Source: Swisher, Jannuzzi, Redlinger (1997)

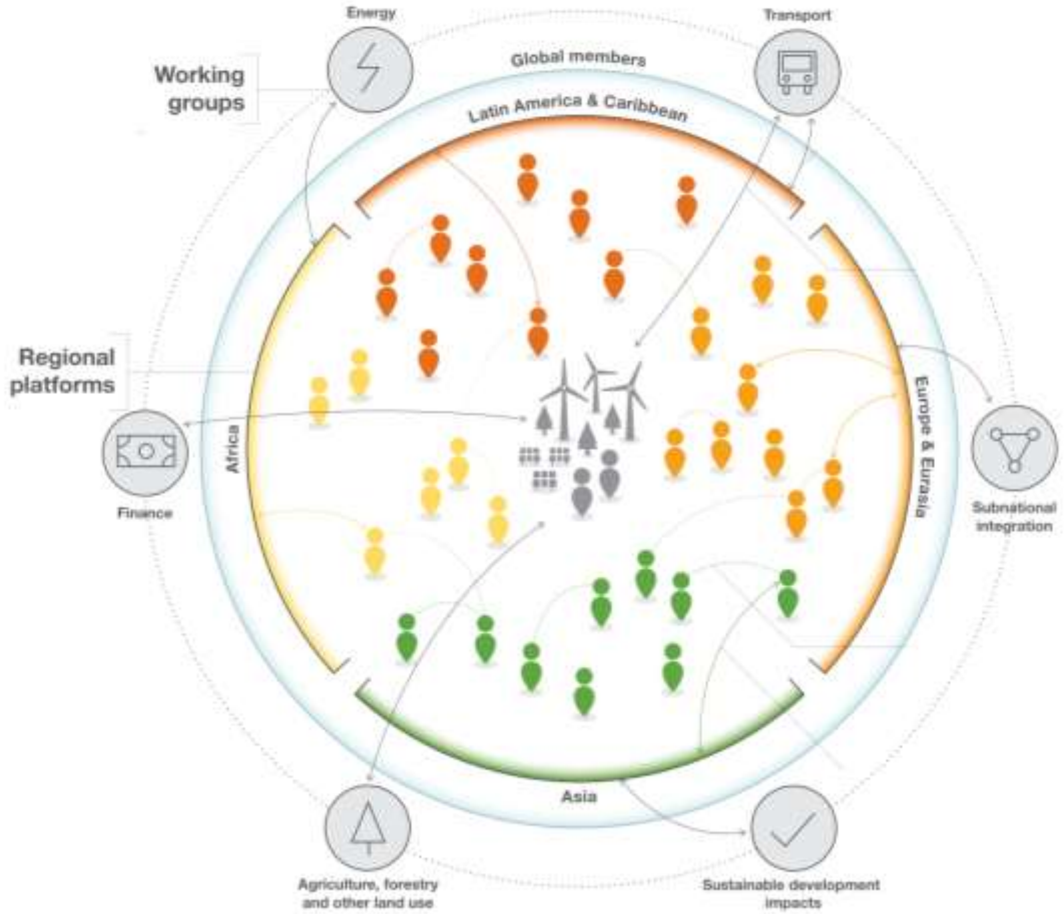
Integrated Resource and Resilience Planning (IRRP)



- A response to the limitations of traditional IRP.
- Seeks plans that do a good job of meeting multiple social objectives given a broad range of future uncertainties and risks.
- Builds on IRP by integrating analysis of climate vulnerability and often emphasizes the need to resist and/or rapidly recover from natural hazards such as hurricanes, floods and heatwaves.
- Moves away from single objective least-cost planning and toward multi-objective approaches that also consider social and environmental co-benefits. Energy policy no longer seen as an objective exercise that can be entrusted purely to technical experts.
- Utilizes new analytical approaches such as large ensemble analysis and multi-stakeholder engagement.
- Tip: "what can be counted" is not the same thing as "what really counts": Non quantifiable (or hard to quantify) aspects of energy systems also important (social inclusion, gender considerations, protection of biodiversity and wilderness areas, etc.)

Low Emission Development Strategies (LEDS)

- First emerged at the UNFCCC in 2008.
- LEDS are country-led processes designed to:
  - reduce greenhouse gas emissions
  - increase resilience to climate change impacts
  - achieve social, economic and environmental development goals
- The LEDS Global Partnership (LEDS GP) supported countries developing LEDS.



Source: LEDS Global Partnership

Basic Elements of Energy Systems

Energy Sources, Carriers and Uses

National energy systems consist of 5 major activities:

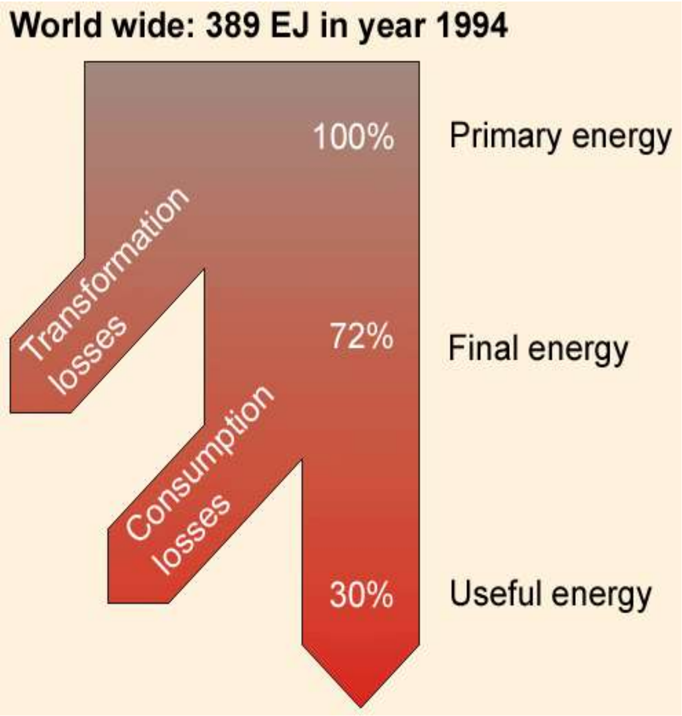
- The production of *energy sources*
- The conversion of energy sources into *energy carriers.*
- The import and export of energy sources and/or energy carriers.
- The storage and distribution of energy carriers
- The consumption of energy carriers

- Energy sources (depletable or renewable) are the form in which energy is found in nature such as coal, crude oil, natural gas, wind, solar, hydropower, biomass and geothermal energy.
- Energy carriers are the form in which energy is consumed such as oil products, charcoal, heat or electricity.

Primary, Final and Useful Energy Consumption

- **Primary energy** measures the gross amount of energy used in an energy system measured *before* any conversion or distribution losses and net of any imports, exports and stock changes.
- Somewhat arbitrary conventions exist for measuring primary energy. EG: nuclear power is typically measured as though it is produced by a 33% efficient thermal power plant, whereas wind, solar and hydro are measured in terms of electricity produced. This tends to understate the importance of RE in primary energy statistics.

- **Final energy** measures the amount of actually consumed in energy using technologies (e.g., in the transport, services, industrial, residential, and agriculture sectors). It is measured after all conversion and distribution losses.
- **Useful energy** is the amount of energy actually demanded by end-users to provide the services society needs such as cooking, heating, lighting, air conditioning and mechanical power. It is measured after the losses incurred in any end-use technologies.



Source: Heinloth (1997)

The Role of Models and Scenario Analysis in Integrated Planning

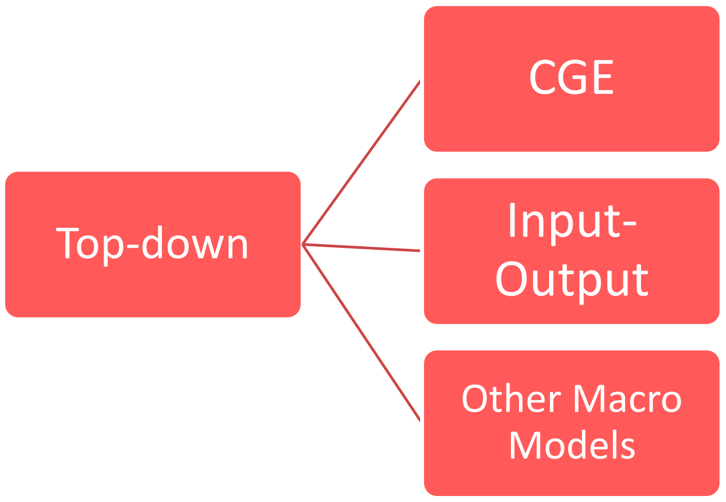
The Role of Models

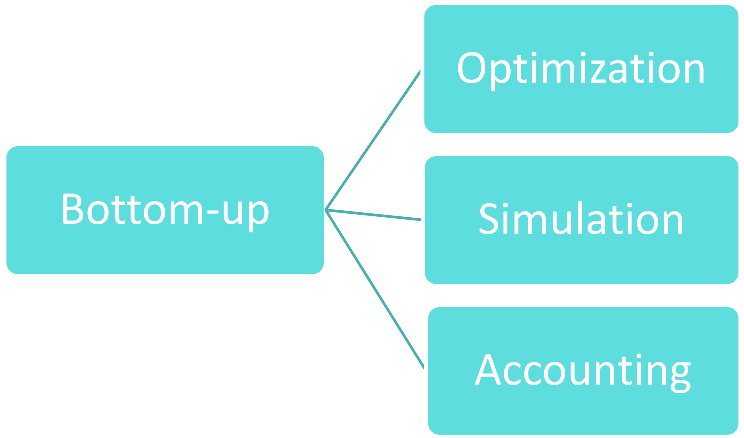
- Models can help national decision makers understand how energy systems may evolve into the future under a range of different assumptions about both external factors (oil and other commodity prices, global climate action) and internal factor (GDP and population growth, policy choices, etc.)
- Can help answer a range of ex-ante and questions, such as:
  - How is energy currently being consumed and produced and where does data need to be improved?
  - What might future energy requirements and GHG emissions be?
  - What level of GHG mitigation can be achieved in the future and how much will it cost to do so?
  - How far can dependency on imported energy be reduced in the future?
  - How can energy systems be managed to help meet important social goals such as providing access to electricity for poorer households or providing clean cooking fuels to all?
- Models cannot provide definitive answers about what system is best, but they can facilitate conversations among stakeholders with different valid perspectives: helping to ensure that future plans are based on the best available science.

Types of Models for Integrated Planning

Modeling tools for energy and environmental modeling are usually divided into two types:

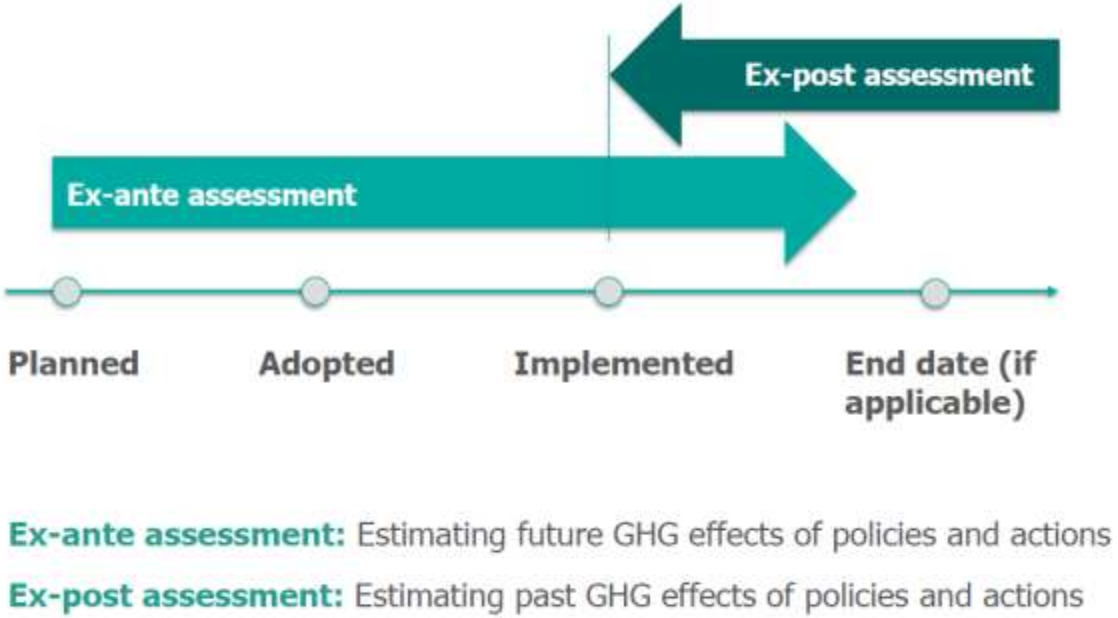
- **Top-down modeling tools** are based on observations of how energy systems behave in relation to other key economic indicators such as GDP and energy prices.
    - Often used for forecasting energy demands and for studying broad macroeconomic and fiscal policies such as carbon or other environmental taxes.
    - Typically lack detailed description of technologies and end-uses, so tend to overlook the potential for energy efficiency and demand-side management but are valuable for capturing sectoral interactions and price effects.
    - Types include: Computational General Equilibrium (CGE), Input/Output (I/O) models and other econometric and macroeconomic models.
- **Bottom-up modeling tools:** focus on the alternative technologies that could potentially provide the energy services demanded by society. Generally better able to represent detailed sectoral and technological policy options, but less well-suited for considering fiscal policies. Typically classified by their solution methodologies:
    - **Optimization:** Use mathematical programming to identify configurations of energy systems that minimize the total cost of providing services.
      Examples: MARKAL/TIMES, MESSAGE, LEAP.
    - **Simulation:** Simulate behavior of consumers and producers under various signals (e.g., price, income levels) and constraints (e.g., limits on rate of stock replacement).
      Examples: ENPEP-BALANCE, LEAP.
    - **Accounting Frameworks:** Account for physical stocks and flows in systems based primarily on engineering relationships and explicit user-driven assumptions about the future (technology improvement, market penetration rates, etc.).
      Examples: LEAP, GACMO
- Important to distinguish between models and modeling tools. Some modeling tools provide a choice of methodologies. Some tools such as LEAP can be used for both top-down and bottom-up modeling.





Ex-ante and Ex-post Modeling

- **Ex-ante:** Estimates the expected future effects of a planned policy or action (before the event).
- **Ex-post:** Estimates what effects an implemented policy or action had on GHG emissions (after the event).



Source: Word Resources Institute (WRI)

Modeling and Scenario Analysis

- Scenarios should be plausible self-consistent stories told in words and numbers about how an energy system might evolve over time.
- They can be used to explore alternative external factors (sensitivity analysis) and to explore the pros and cons of alternative policy choices.
- Many scenarios can be explored: helping to identify robust and resilient futures, rather than single "optimal" solutions.
- Particularly techniques exist for exploring very large number of scenarios (e.g., Monte Carlo analysis and large ensemble analysis).
- At a minimum, energy and climate analyses typically involve the development of at least two scenarios:
  - **A Baseline Scenario** representing the likely future *in the absence* of new policies or measures.
  - One or More **Policy Scenarios** representing the implications of the policies and measures being considered.
- Some modeling tools like LEAP allow individual measures to be considered separately and then automatically combine them to form overall mitigation strategy scenarios.
- Since many countries often need to estimate the effect of already existing measures, they now typically choose to consider at least three scenarios in their climate plans:
  - WOM: Without Measures
  - WEM: With Existing Measures
  - WAM: With Additional Measures

Framing Climate Mitigation Scenarios

In conducting climate mitigation modeling, it is important to frame your mitigation scenarios so that stakeholders understand their purpose and perspective. Framing of Scenarios Includes Setting:

- **Emissions Scope**: CO2 only, all GHGs, all pollutants including local air pollutants, or a broader assessment of sustainability and development goals
- **Sectoral Scope:** Energy sector emissions only or all GHGs (i.e. including LULUCF, agriculture, industrial processes and waste) or a study of a particular sector (e.g. transport or the electricity sector).
- **Accounting Basis:** Territorial (the standard used for UNFCCC reporting), consumption-based or extraction based.
- **Time frame:** including what base year and end year for your analysis. Important here to consider how the mitigation analysis will be coordinated and calibrated with GHG inventory studies. We recommend including historical data in analyses so that future scenario trends can be compared to past trends.

Framing also considers which mitigation measures will be included in your analysis.

- One approach involves setting a top-down reduction target and identifying measures required to meet that target. Targets may be set as:
    - An absolute target for emissions (e.g., net zero studies)
    - A percentage reduction relative to some historical year.
    - A percentage reduction relative to future baseline emissions.
    - A performance target for chosen indicators (e.g., CO_2/person, CO_2/$ of GDP, RE deployment, targets for access to electricity, etc.)
- Alternatively, mitigation scenarios may include all options up to a certain unit cost (e.g., “no regrets” scenarios including all cost-effective options).
- Scenarios may also be developed by asking stakeholders to define which options they think are politically plausible. This approach is common but rarely leads to ambitious targets, since it inevitably emphasizes short-term political viability.
- Parties may also wish to develop multiple mitigation scenarios with multiple alternative framings.

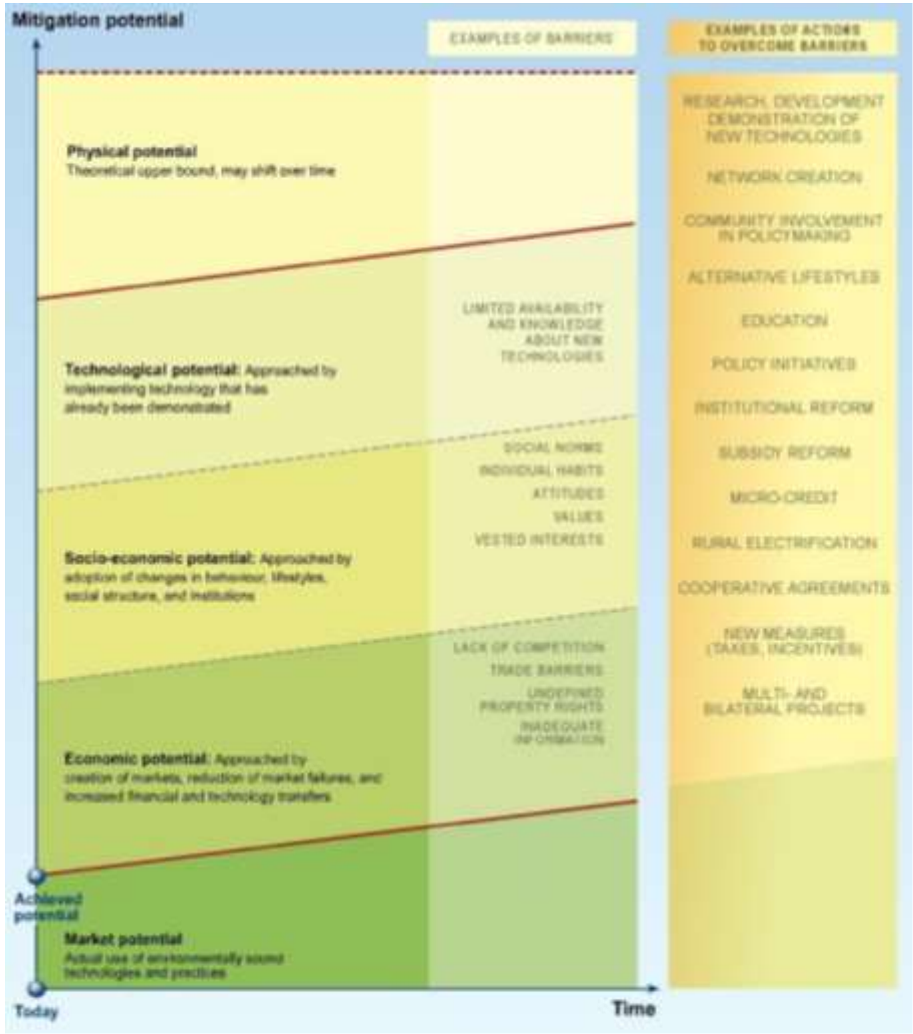
Modeling in the Energy & Climate Planning Process

- Mitigation modeling is sometimes thought of as a separate & distinct task in the climate planning process. But it is more useful when used to help guide and manage the overall process:
  - It is informed by and calibrated to GHG inventories.
  - It is reliant on data collection but can also help to set priorities for improving data.
  - It can help to establish priority policies & measures
  - It can monitor and verify success or failure of implementation (MRV).
  - It can help in communicating strategies and engaging with stakeholders.
  - It can help to set goals and targets: not just for GHGs but also for co-benefits and wider development goals.

  Overall – modeling can help to keep processes on track to meet targets.

Barriers to Climate Mitigation

- Many barriers need to be overcome on the path from theoretical to actual use of low-emission technologies and practices.
- Overcoming barriers requires a wide variety of policies, measures and instruments, which must be tailored to national and local circumstances.
- Taking advantage of capital stock turnover and periods of rapid social change can minimize disruption and mitigation costs.
- National responses to climate change can be more effective if deployed as a portfolio of policy instruments to limit or reduce greenhouse gas emissions.
- Effectiveness and acceptability can be enhanced when climate policies are integrated with non-climate objectives (e.g., reducing impacts of air pollution, increasing employment opportunities, promoting social cohesion, etc.).
- Coordinated actions among countries and sectors may help to reduce mitigation costs, address competitiveness concerns, and carbon leakage.
- Early action can increase flexibility in moving towards stabilization of atmospheric concentrations of greenhouse gases.



Source: IPCC (2001) TAR WGIII

Questions?

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