Pathways to Sustainable Energy
Exploring and facilitating the transition to sustainable energy systems

26 September 2018, Geneva
How can the UNECE Region attain Sustainable Energy (SE)?

- **Current Phase:** May 2017 – Oct 2019 (further phases planned)

- **Outputs**
  - Pathways and Scenario Development
    - Sub-regional modelling of SE scenarios to 2050
    - Policy and technology options
  - Policy dialogue
    - Adaptive policy pathways
    - Policy dialogues
    - Sub-regional workshops
  - “Early-warning system” development
    - SE Targets
    - Key Performance Indicators (KPIs)
    - Signposts

[https://www.unece.org/energy/pathwaystose.html](https://www.unece.org/energy/pathwaystose.html)
Pathways Project and Sustainable Energy

Three Pillars

ENERGY

“Secure the energy needed for economic development”

- Energy Efficiency (energy intensity of economy, rate of improvement of energy intensity, conversion efficiency)
- Fuel mix
- Net energy trade
- Investment requirements

“Minimize adverse energy system impacts on climate, ecosystems & human health”

- GHG emissions from the energy system
- Energy-related air pollution, water use & water stress

“Provide affordable energy that is available for all at all times”

- Access to energy services
- Energy affordability
- Food security (biomass use)
Two integrated assessment models based on different methodologies

- **GCAM** - Global Change Assessment Model
  Equilibrium model clears markets through iterative price adjustments and feedback loops

- **MESSAGE** - Model for Energy Supply System Alternatives and their General Environmental Impacts
  Optimization model: Supply must meet predetermined demand at minimum system costs (partial equilibrium)

**Why two different models?**

- Better delineation of uncertainties inherently associated with
  - Methodological fundamentals
  - Spatial, sectoral and temporal resolution
  - Energy technology and infrastructure resolution
  - Data
  - Assumptions
  - Complexity

**Technology zoom-in**

- Technology Research assessing the status and prospects (availability, performance, costs) of current and future energy system technologies

*Note: Models will be at the disposal of the UNECE’s Committee on Sustainable Energy*
Model Overview
GCAM: Global Change Assessment Model

Scenario Assumptions
- Socioeconomic assumptions (population, GDP)
- Energy, land use, and water technologies
- Policies
- Resources

Scenario Outputs
- Prices and production quantities:
  - Energy sectors
  - Transportation
  - Primary energy resources
  - Agricultural products
- Land use
  - Crops (by type)
  - Pasture
  - Unmanaged
- Water demand
  - Raw demand by sector
  - Response to scarcity
- Atmosphere-Climate
- Economic indicators
  - Economic losses
  - Income transfer
MESSAGE: Model for Energy Supply System Alternatives and their General Environmental Impacts

**INPUT**

- Energy system structure (including vintage of plant and equipment)
- Base year energy flows and prices
- Energy demand (e.g., via link to MACRO)
- Technology and resource options & their techno-economic performance profiles
- Technical and policy constraints

**OUTPUT**

- Primary and final energy mix
- Electricity generating mix, capacity expansion/retirement, investments
- GHG missions, air pollution, wastes
- Health and environmental impacts - via link to GAINS and LCA module
- Resource use - energy, water, land (via link to GLOBIOM), materials
- Trade & import dependence
- Prices
Each Zoom-in describes the state of the art of a set of different technology options.

Includes assessment of future deployment potentials and barriers and cost analysis based on literature review.

Currently under stakeholder consultation.

- To reach a 2°C target most models rely heavily on CCS technologies as they prevent CO₂ releases to the atmosphere.
- Energy storage systems may become indispensable for stable and reliable energy supplies provided by mainly fluctuating supply technologies (wind, solar).
- Decarbonization of certain sectors such as the heating or the transport sectors may require large scale use of power-to-X technologies.
- Efficiency measures reduce the amount of energy used to produce a service or a unit of economic output, and thus reduce related emissions.
I. **Reference Scenario**
Based on SSP 2 as point of departure, i.e., without dedicated sustainable energy or climate policies.

II. **NDC scenario**
A scenario that implements by 2030 the NDCs under the Paris Agreement but maintains the NDCs beyond 2030 – *kind of NDCs forever*. It also includes other current policies towards sustainable energy.

III. **Designing pathways towards sustainable energy - Paris to 2°C -**
One key component of SE is the 2°C target of the Paris Agreement by 2100 (Environment pillar). The other two pillars “energy security” and “quality of life” to follow – but models require quantified targets (similar to Paris to 2°C)

→ Input from stakeholders highly appreciated

*Note: Metrics and KPIs will inform and quantify trade-offs between the three pillars*
• **Key performance indicators (KPI)** assess the sustainability of the system. KPIs are to likely differ by scenario and over time.

• **Sign-posts** identify the scenario that we are in. The most characteristic results of each scenario serve as sign-posts in order to identify the path we are on.

Same starting point - different pathways represent different policy options.

**Checkpoint 2030:**
Checking Sign-Post in 2030. Where are we? Checking KPI in 2030: How well are we doing?

**Checkpoint 2040:**
Checking Sign-Post in 2040. Where are we? Checking KPI in 2040: How well are we doing?

Ongoing. Currently in conceptualization phase.
GCAM: Preliminary Modeling Results
Exemplary results: “Energy for Quality of Life”

Energy affordability

Global energy expenditures as share of GDP (percent)

- Energy expenditure share of GDP decreases to 2050.
- Increased Paris ambition increases energy share of GDP.
- Advanced technologies help lower costs and reduce the policy impact.
Global GHG emissions (GtCO2e)

4.2°C temp increase

Reference: SSP2 assumptions
GCAM: Preliminary Modeling Results
Exemplary results: “Energy and Environment”

GHG emissions and temperature rise

Global GHG emissions (GtCO2e)

- Reference: SSP2 assumptions
  - Reference technology
  - Advanced renewables

4.0 - 4.2°C temp increase

TECHNOLOGY UNCERTAINTY
GCAM: Preliminary Modeling Results

Exemplary results: “Energy and Environment”

**GHG emissions and temperature rise**

Global GHG emissions (GtCO2e)

- **TECHNOLOGY UNCERTAINTY**
- **Reference**: SSP2 assumptions
  - Reference technology
  - Advanced renewables
  - Low-cost Nuclear (SMR)

- **4.0 - 4.2°C temp increase**

- SSP2
- SSP2 + Adv. Renewables
- SSP2 + Adv. Nuclear (SMR)
Global GHG emissions (GtCO2e)

- Reference: SSP2 assumptions
  - Reference technology
  - Advanced renewables
  - Low-cost Nuclear (SMR)
  - Advanced CCS

GHG emissions and temperature rise

- 4.0 - 4.2°C temp increase
Preliminary Modeling Results
Exemplary Results: “Energy and Environment”

**GHG emissions and temperature rise**

- **Reference**: SSP2 assumptions
  - Reference technology

- **NDCs**
  - Regional GHG emissions caps based on national Paris pledges
  - Continued ambition post-2030

- **Paris to 2C**
  - Regional GHG emissions caps based on national Paris pledges
  - Enhanced ambitions post-2030 to achieve 2°C goal

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MESSAGE: Preliminary Modeling Results

Final Energy Mix

Final energy mix, UNECE Reference Scenario

- Except for district heat, the demand for all other forms of final energy grow between 2020 and 2050

- Liquids driven by demand for transportation services
Final energy mix, UNECE NDC Scenario

- Climate mitigation policies affect overall final energy demand (at constant supply of energy services)
- Higher share of electricity displaces lower efficient fossil fuels (see next slide)
The NDC Scenario introduces hydrogen as of 2030

The decline of district heat is slowed down

Natural gas seems to be the swing fuel in meeting final energy demand
MESSAGE: Preliminary Modeling Results
Electricity Generation

Electricity generation by technology, UNECE Reference

- Large penetration of natural gas
- Quick reduction in the use of coal
- Steady decline of nuclear power
**MESSAGE: Preliminary Modeling Results**

**Electricity Generation**

Electricity generation by technology, UNECE NDC

- Higher total electricity generation due to increase demand
- Large penetration of natural gas delayed
- Faster take-up of low carbon emitting technologies
- Introduction of CCS
- Temporary increase of nuclear power followed by decline
MESSAGE: Preliminary Modeling Results
Electricity Generation

Difference in electricity generation, UNECE NDC versus Reference
MESSAGE: Preliminary Modeling Results
Cumulative Energy Sector Investments

UNECE Region – NDC Scenario
2020 – 2050 in billion US$\textsubscript{2010}

Extraction fossil fuel  Electricity Supply (including T&D)

- Extraction fossil fuel
- Coal
- Oil
- Gas CCS
- Nuclear
- Biomass
- Biomass CCS
- Solar
- Wind
- Coal CCS

- Gas
- Hydro
- Geothermal

- 13,546
- 13,126
- 596
- 94 Coal CCS
- 11 (oil)
- 5,128
- 115
- 1,750
- 1,919
- 49, 214, 484 (Biomass, Geothermal, Solar)
- 2,766
Summary Remarks
Lessons learned and the way forward

I. Models can be useful tools in assessing policy options
   - While always representing only simplified images of reality, models help assess the impact of policy changes systematically in a transparent and repeatable manner
   - However, models are complex tools and require expertise to apply

II. Extension of assessments beyond the Environmental Pillar
   - The model applications to date highlight the need for stakeholder input regarding KPIs in the context of sustainable energy

III. Technological change is essential
   - There is considerable technological change and innovation in the pipeline which needs further scrutiny with the Pathways analyses

IV. Regional approaches
   - An alignment of policies on global issues to increase the impact of measures

But most importantly:

1. MORE JOINT EFFORTS ARE NEEDED TO DELIVER A SUSTAINABLE ENERGY FUTURE
2. STAKEHOLDER ENGAGEMENT IS KEY AND WE DEPEND ON YOUR PARTICIPATION
Outlook: Project Timeline

Engagement with the Pathways Project Community

Expert Workshop at 9th IFESD Ukraine, 12-15 Nov 2018

Consultation Period on Scenarios

Sub-Regional Workshop(s)?
Q1-Q2 2019 (tbc)

Development of Phase II Project Idea

High-Level Policy Dialogue, Preparatory Meeting & Phase II definition Geneva, 16 May 2019

High-level Political Dialogue Q3 (2019)

Policy Dialogue Geneva, 26 Sep 2019

Consultation and Information Workshop Geneva, 25 Sep 2018

ENECE-wide Policy Dialogue Geneva, 26 Sep 2018

Energy Outlook: Project Timeline

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Energy Outlook: Project Timeline

CSE = Committee on Sustainable Energy
Thank you!

Holger Rogner on behalf of the Pathways Project Team
rogner@iiasa.ac.at
Date 03 I 09 I 2018, Geneva
BACK-UP SLIDES
Sustainable Energy – not an isolated issue

Energy-related SDGs

**ENERGY FOR QUALITY OF LIFE**
- SDG1: No Poverty
- SDG2: Zero Hunger
- SDG7: Affordable and Clean Energy
- SDG11: Sustainable Cities and Communities
- SDG13: Climate Action
- SDG17: Partnerships

**ENERGY AND ENVIRONMENT**
- SDG3: Good Health & Wellbeing
- SDG6: Clean Water and Sanitation
- SDG12: Responsible Consumption and Production
- SDG9: Industry, Innovation & Infrastructure
- SDG14: Life Below Water
- SDG15: Life on Land

**ENERGY SECURITY**
- SDG4: Quality Education
- SDG5: Gender Equality
- SDG8: Decent Work & Economic Growth
- SDG10: Reduced Inequalities
- SDG16: Peace, Justice & Strong Institutions

Energy for Sustainable Development

ENERGY
GCAM is a **global integrated assessment model**

GCAM links **Economic, Energy, Land-use, Water, and Earth** systems

- Runs in **5-year time-steps**
- Meant to analyze consequences of policy actions and interdependencies
- Used to evaluate impacts of these threads:
  - *Socioeconomic development*
  - *Climate treaty compliance*
  - *Technology and resource developments*
  - *Energy policies*

GCAM is an open-source community model

Documentation available at: [wiki.umd.edu/gcam](http://wiki.umd.edu/gcam)
PNNL’s GCAM
What’s inside GCAM?

ENERGY SYSTEM
- Energy Supply
  - Coal, Gas, Oil
  - Renewables
  - Electricity
  - Hydrogen
- Energy Demand
  - Transportation
  - Buildings
  - Industry
- Energy Markets
  - Fossil fuel prices
  - Electricity prices
  - Hydrogen prices
  - Bioenergy prices

CLIMATE SYSTEM
- Carbon Cycle
  - Atmosphere
  - Ocean
  - Land

ECONOMY
- Regional GDP
- Other Markets
  - Emissions Permits
  - Portfolio Standards

AGRICULTURE AND LAND USE
- Agricultural Demand
  - Crops
  - Livestock
  - Forest Products
- Agricultural Supply
  - Crops
  - Livestock
  - Forest Products
  - Bioenergy
- Agricultural Markets
  - Crops prices
  - Livestock prices
  - Forest Product prices
  - Bioenergy prices
- Land Use and Land Use Change Emissions
- Land Use & Land Cover
  - Other things (aerosols, sea level, …)
IIASA Integrated Assessment Framework

Overview

ENERGY

- MAGICC
  - simple climate model

- GAINS
  - GHG and air pollution mitigation model

- MACRO
  - Aggregated macro-economic model

- MESSAGE
  - systems engineering model (all GHGs and all energy sectors)

- Scenario Storyline
  - demographic change
  - economic development
  - technological change
  - policies

- National level projections

- Population

- Economy

- GLOBIOM
  - integrated agricultural, bioenergy and forestry model

- G4M
  - spatially explicit forest management model

Socio-economic drivers

- carbon and biomass price
- consistency of land-cover changes (spatially explicit maps of agricultural, urban, and forest land)

Iteration

Energy service prices

Demand response

Air pollution emission coefficients & abatement costs
Comparison of **annualized cost** shows similar internal cost rankings

Comparing model reference data with literature (grey areas) to show uncertainty.

**Currently under stakeholder consultation.**
**SSP2: “Middle of the road”**

**Reference Scenario**

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**Why the SSPs?**

- **SSPs¹** are widely used in the Sustainable Development (SD) and Climate Change (CC) communities. They represent well described and ‘agreed’ development pathways.
- **Peer reviewed and vetted** - No knowledge gain by adding yet a new set of scenarios

**Why SSP2 out of five SSPs?**

- **“Middle of the road”** scenario deemed most suitable analyzing the four scenario spaces developed by UNECE expert network between 2015 and 2016
- Social, economic, and technological trends proceed along historical patterns
  - Moderate population development
  - Economic development and income growth proceed unevenly
  - Technological development follows an evolutionary path (no revolutionary breakthroughs)
  - No reluctance to use unconventional fossil resources
  - Fossil fuel dependency decreases slowly
  - No explicit climate change policies
  - Environmental systems experience degradation
- **In Summary:** Slow progress on reaching the SDGs

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¹Adapted from B. van Ruijven (2015); K. Riahi (2017); and O’Neil (2017)
Preliminary Modeling Results

Energy Security - Metric: Decrease energy intensity of economy

- Energy use per unit of GDP decreases, with higher rates under policy scenarios
- Technology variations have marginal impact
Preliminary Modeling Results

Global energy expenditures as share of GDP (percent)

- Energy expenditure share of GDP decreases to 2050.
- Increased Paris ambition increases energy share of GDP.
- Advanced technologies help lower costs and reduce the policy impact.
Energy expenditures as share of GDP by region (percent, RefTech)

- Energy expenditure share of GDP decreases through 2050.
- Although energy intensity is lower under policy scenarios, energy expenditure share of GDP is higher due to increasing prices.
- Developing countries tend to have larger impacts under policy scenarios.
GCAM. Preliminary Modeling Results
Exemplary results: “Energy Security”

Decrease energy intensity of economy

Energy intensity by region (GJ per thous 2010USD)

- Energy use per unit of GDP decreases, with higher rates under policy scenarios
- Several regions (e.g., Eastern Europe, Russia, Central Asia) may still be above the 2010 global average level by 2050
Current NDCs are a modest step on the bumpy road to a 2°C target

MESSAGE: Preliminary Modeling Results
Energy
Global GHG emissions in different Scenarios

- Global CO₂ emissions [Gt/yr]
**Stakeholder Community: Pathways to Sustainable Energy**

**DIRECTING THE PROJECT**
- Strategic decision making at defined project implementation stages
- Outcome Monitoring

- **Project Board**
  - 4 members, representatives of CSE Bureau, UNECE, Modeller, Advisory Board

- **Project Manager**
  - Lisa Tinschert, UNECE Sustainable Energy Division

**MANAGING PROJECT IMPLEMENTATION**
- Day to Day Management
- Delivery of Work Packages (Outputs) incl. supplier coordination
- Progress Reporting
- Stakeholder Engagement
- Communication

- **Experts**
- Other Groups: Policy, Technology, Communication
- Six UNECE Expert Groups Secretaries of Groups

- **Modeller Team**
  - Technological Zoom-In
  - Geographical Zoom-In
  - Global & regional dive-ins
  - PNNL
  - IIASA
  - FRAUNHOFER

**MANDATE PROVISIONING**

- **Committee for Sustainable Energy**