UNECE

Fraunhofer

IIASA International Institute for Applied Systems Analysis

Pacific Northwest NATIONAL LABORATORY

ENERGY

Pathways to Sustainable Energy

Exploring and facilitating the transition to sustainable energy systems

26 September 2018, Geneva

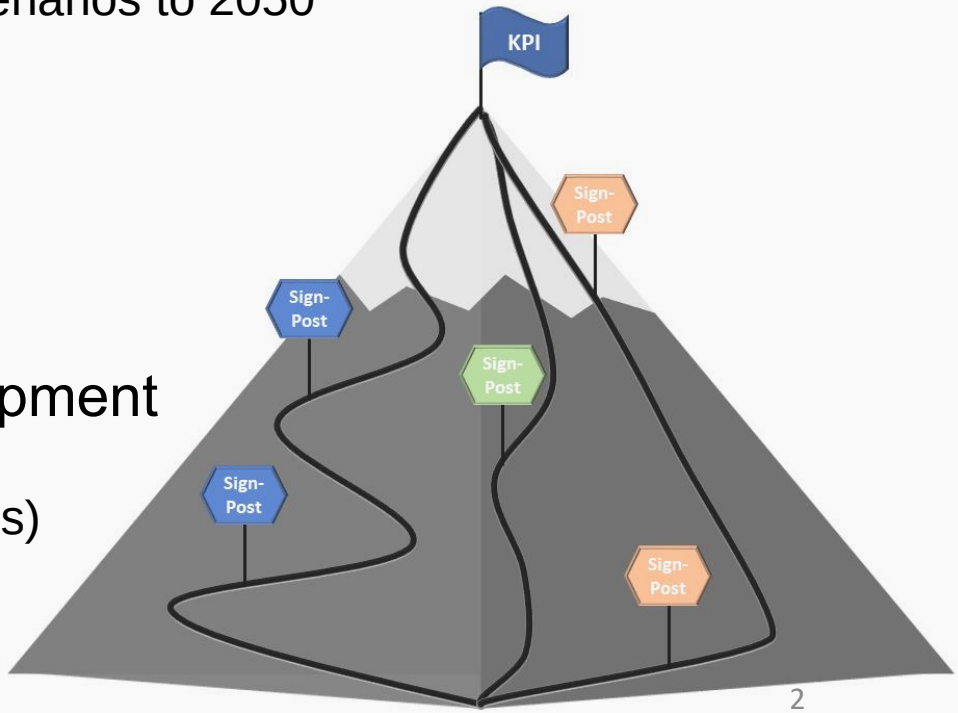
Project Overview

Pathways to Sustainable Energy

ENERGY

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

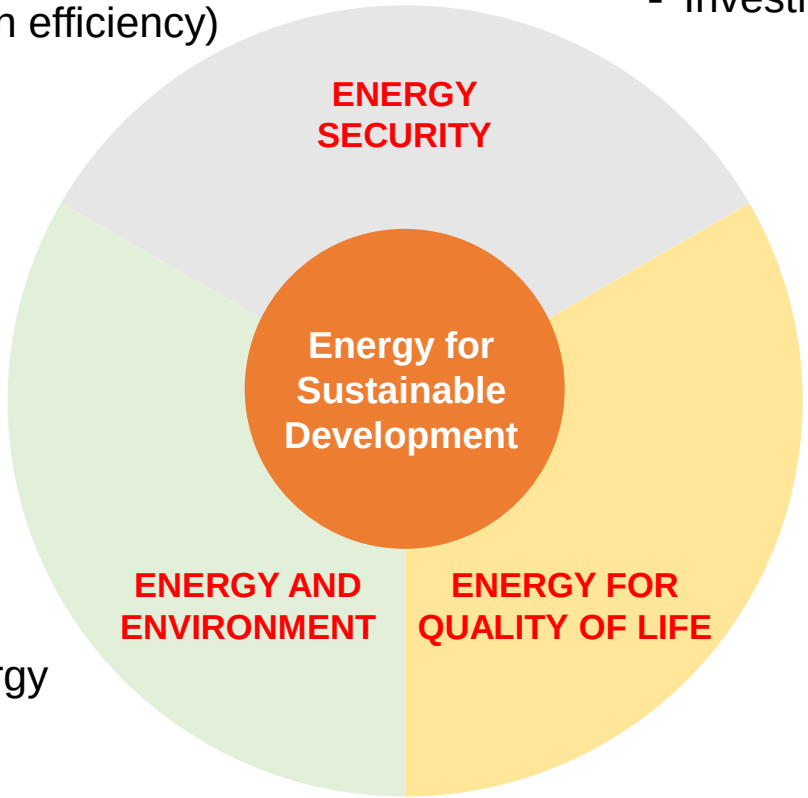
Pathways Project and Sustainable Energy

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)

Methodology

Modelling of Scenarios & Technology Research

ENERGY

- **Two integrated assessment models based on different methodologies**
  - ***GCAM* - *G*lobal *C*hange *A*ssessment *M*odel**
    Equilibrium model clears markets through iterative price adjustments and feedback loops
  - ***MESSAGE*** - ***M*odel for *E*nergy *S*upply *S*ystem *A*lternatives and their *G*eneral *E*nvironmental 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

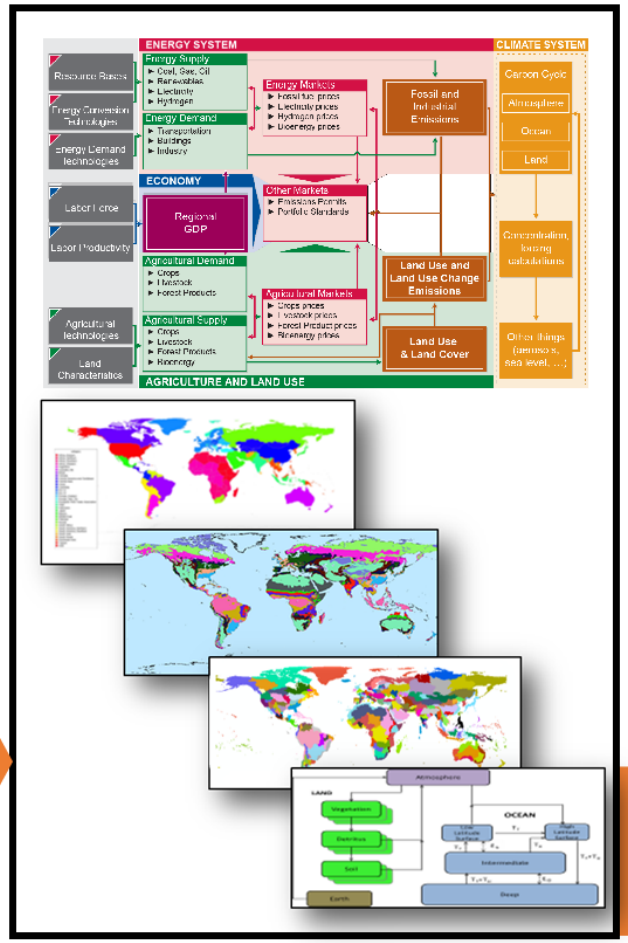
Model Overview

GCAM: **G**lobal **C**hange **A**ssessment **M**odel

ENERGY

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

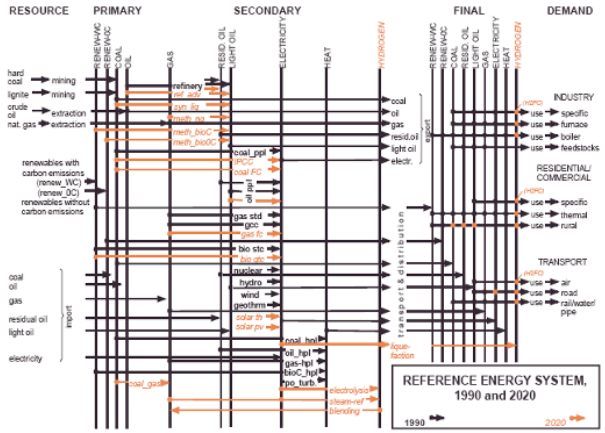
Model Overview

MESSAGE: **M**odel for **E**nergy **S**upply **S**ystem **A**lternatives and their **G**eneral **E**nvironmental Impacts

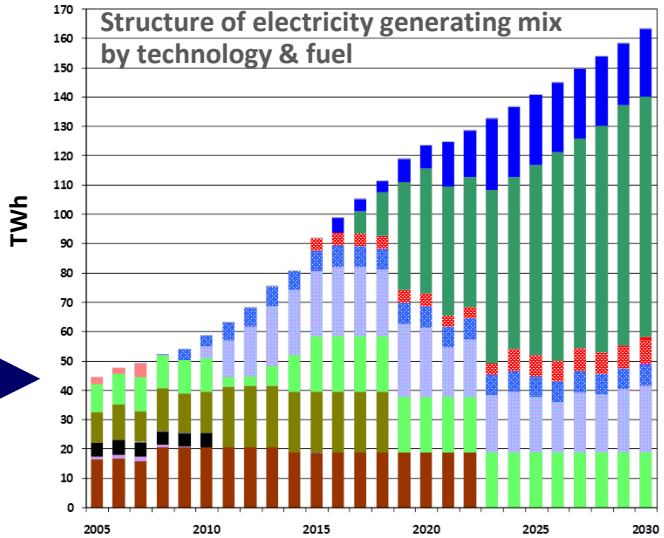
ENERGY

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



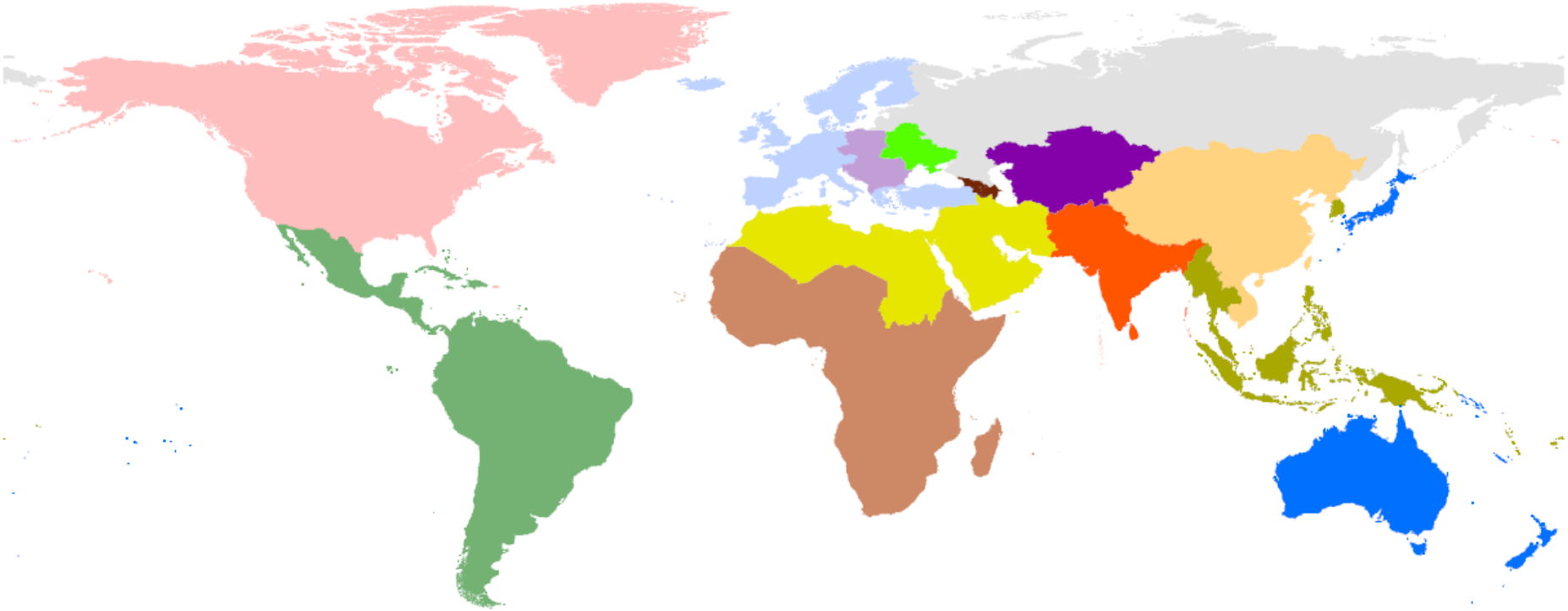
- Primary and final energy mix
- Electricity generating mix, capacity expansion/retirement, investments
- GHG missions, air pollution, wastes
- Health and environmental impacts - via link to GAINS and LCA module
- Resource use - energy, water, land (via link to GLOBIOM), materials
- Trade & import dependence
- Prices

MESSAGE

Regions Modelled

ENERGY

AFR	Sub-Saharan Africa	LAC	Latin America and the Caribbean	RUS	Russian Federation
BMU	Belarus, Moldova, Ukraine	MEA	Middle East and North Africa	SAS	South Asia
CAS	Central Asia	NAM	North America	SCS	South Caucasus
CPA	Centrally planned Asia & China	PAO	Pacific OECD	WEU	Western Europe
EEU	Central and Eastern Europe	PAS	Other Pacific Asia		



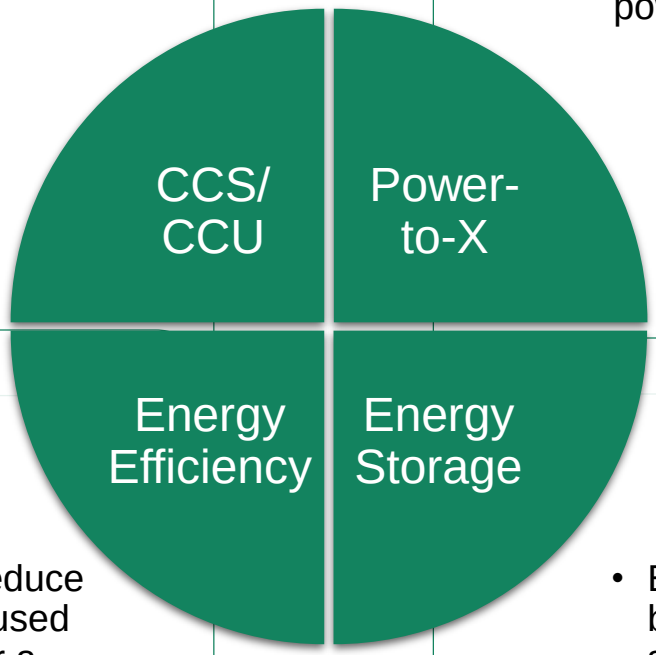
Technology Research

Zoom-ins on possible “game changers”

ENERGY

- To reach a 2°C target most models rely heavily on CCS technologies as they prevent CO_2 releases to the atmosphere

- 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

- Energy storage systems may become indispensable for stable and reliable energy supplies provided by mainly fluctuating supply technologies (wind, solar)

- 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.

Scenario Development

To date: Three sequential steps

ENERGY

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 2ºC -

One key component of SE is the 2ºC 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 2ºC)

→ Input from stakeholders highly appreciated

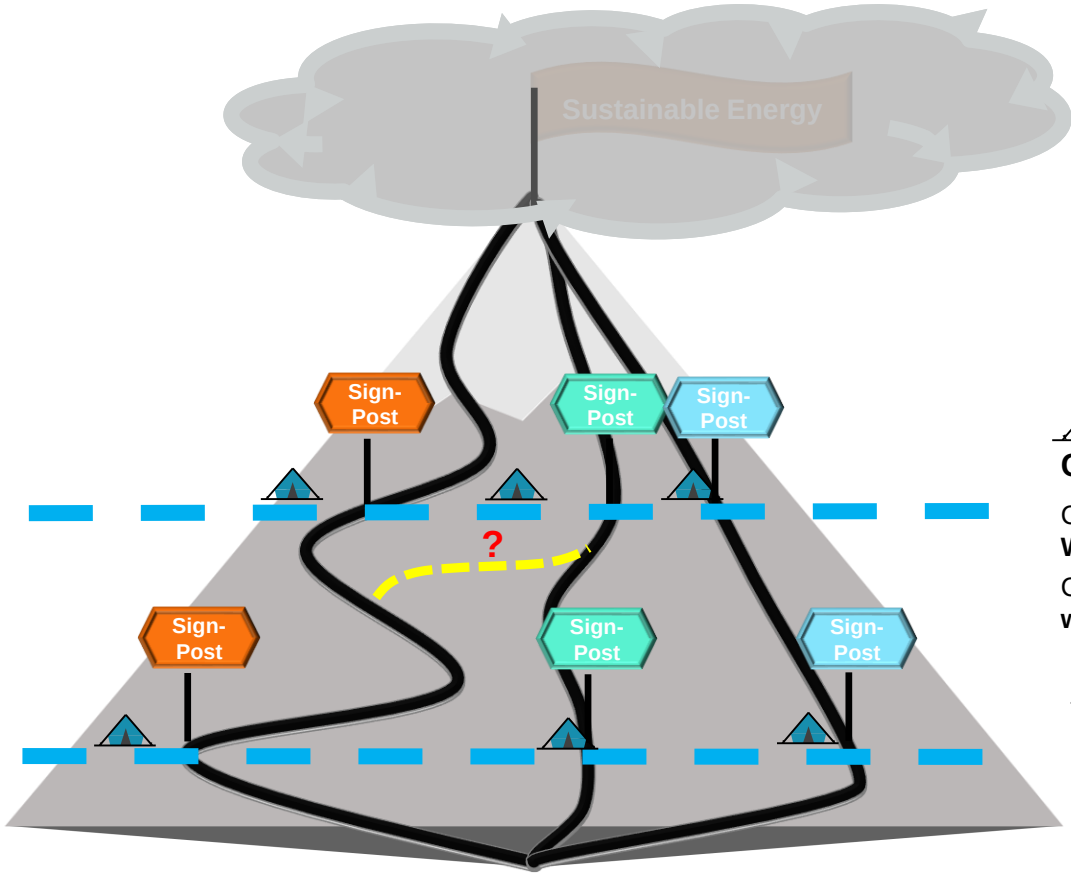
Note: Metrics and KPIs will inform and quantify trade-offs between the three pillars

Early-Warning System

Process and Components Scoping

ENERGY

- **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.



Checkpoint 2040:

Checking **Sign-Post** in 2040. **Where are we?**

Checking **KPI** in 2040: **How well are we doing** ?

Checkpoint 2030:

Checking Sign-Post in 2030. Where are we?

Checking KPI in 2030: How well are we doing?

Same starting point - different pathways represent different policy options

Ongoing. Currently in conceptualization phase.

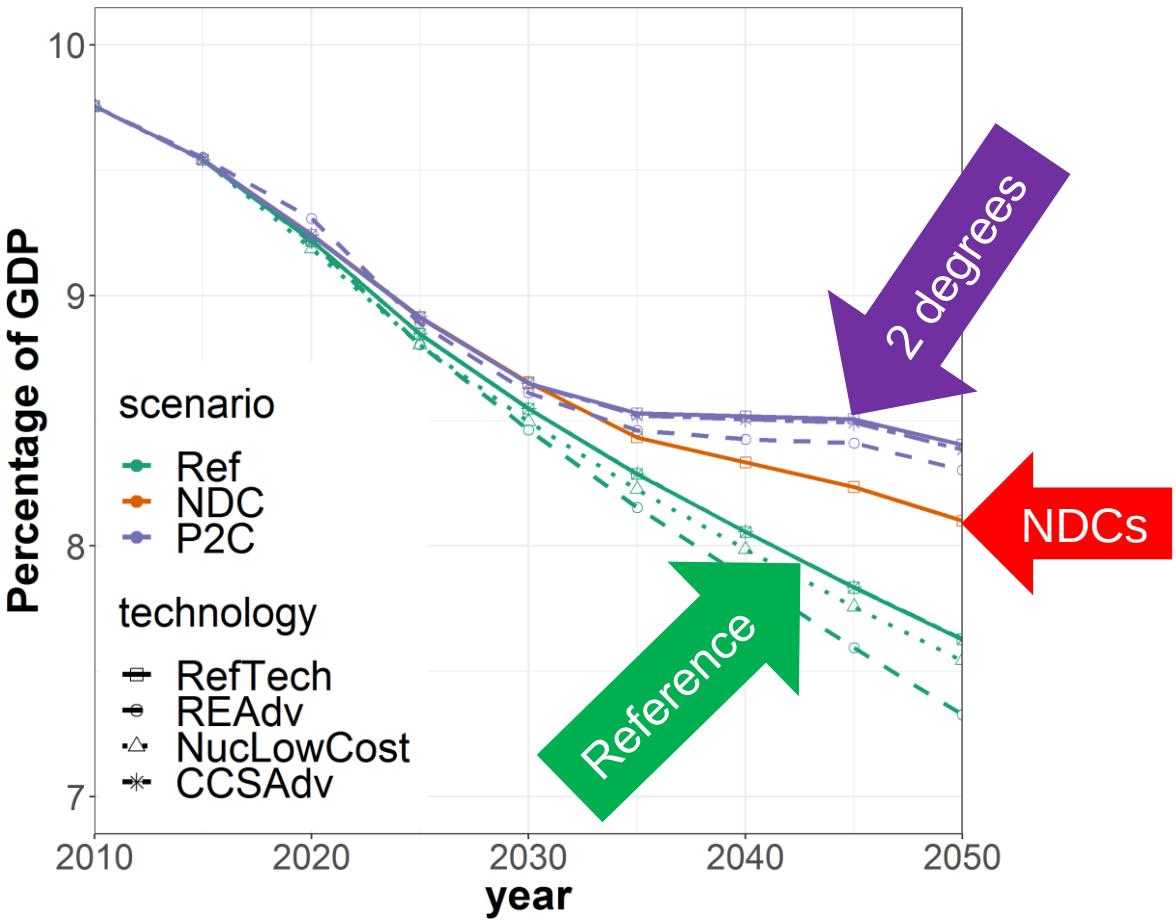
GCAM: Preliminary Modeling Results

Exemplary results: “Energy for Quality of Life”

ENERGY

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.**

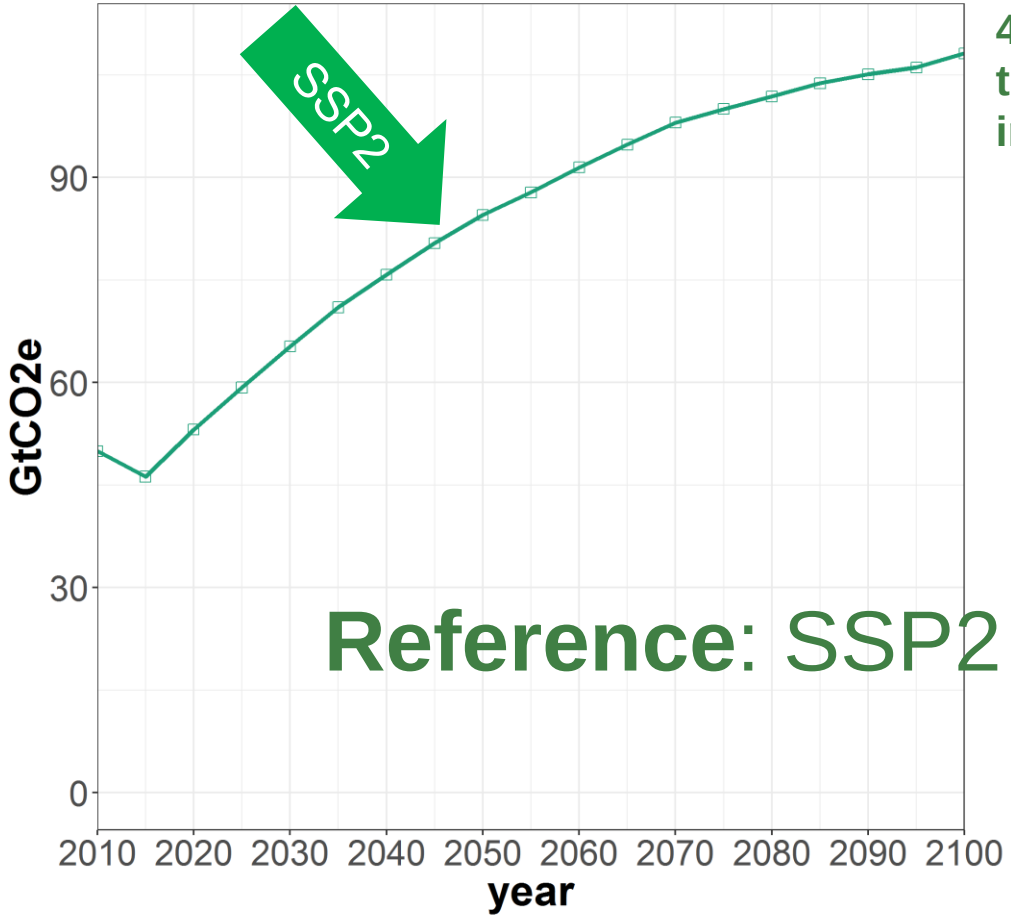
GCAM: Preliminary Modeling Results

Exemplary results: “Energy and Environment”

ENERGY

GHG emissions and temperature rise

Global GHG emissions (GtCO2e)



4.2°C temp increase

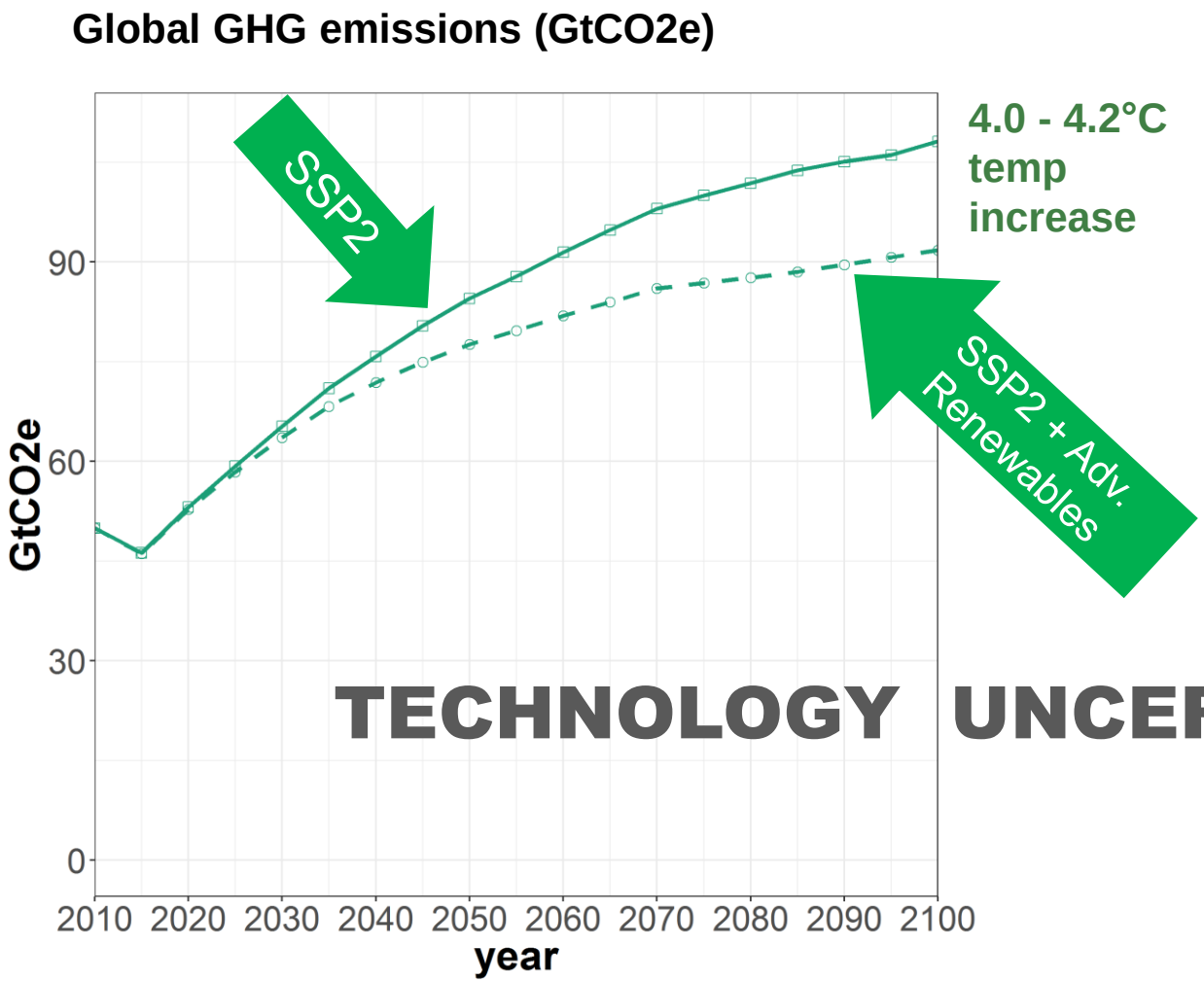
Reference: SSP2 assumptions

GCAM: Preliminary Modeling Results

Exemplary results: “Energy and Environment”

ENERGY

GHG emissions and temperature rise



TECHNOLOGY UNCERTAINTY

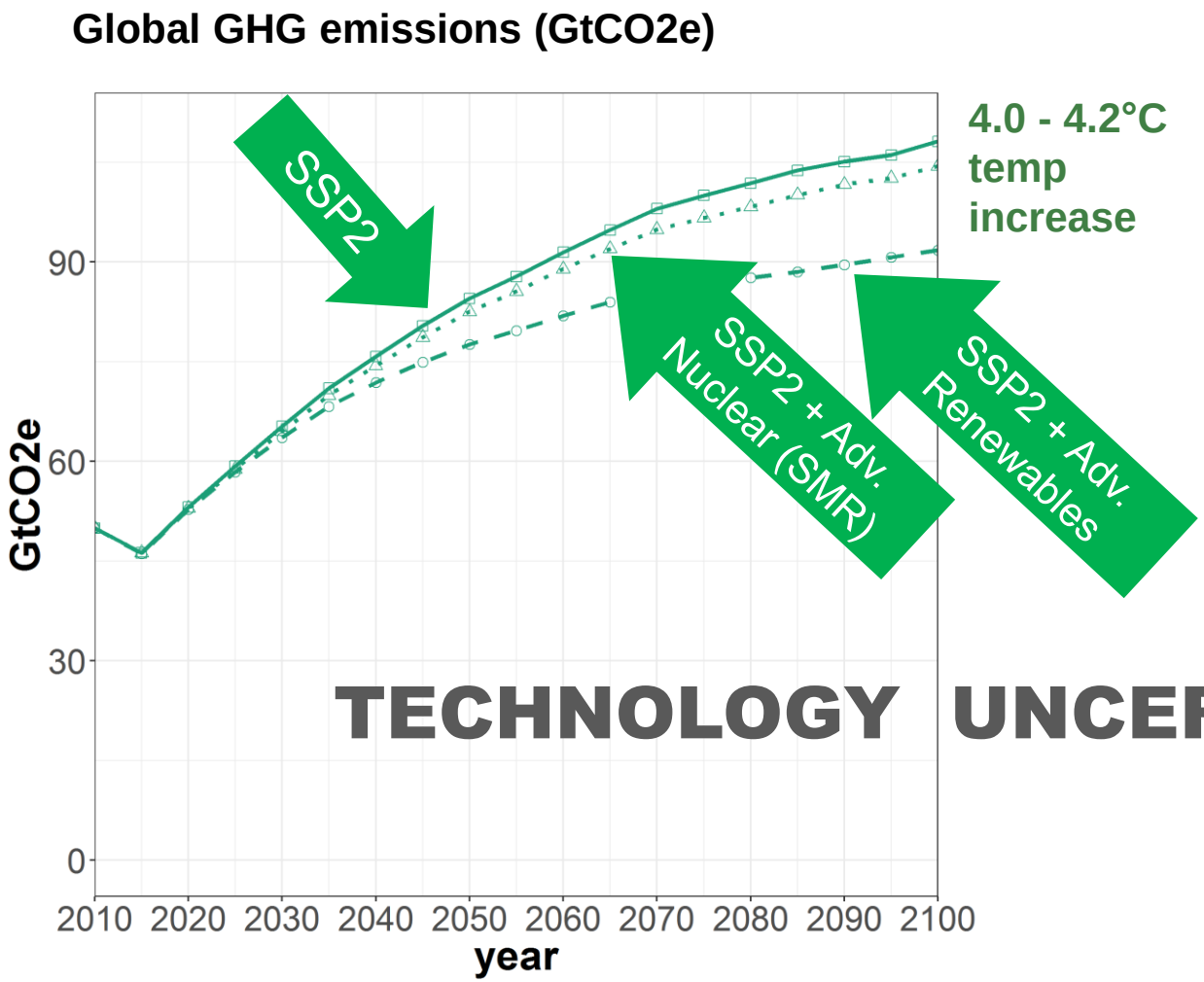
- **Reference**: SSP2 assumptions
  - Reference technology
  - Advanced renewables

GCAM: Preliminary Modeling Results

Exemplary results: “Energy and Environment”

ENERGY

GHG emissions and temperature rise



TECHNOLOGY UNCERTAINTY

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

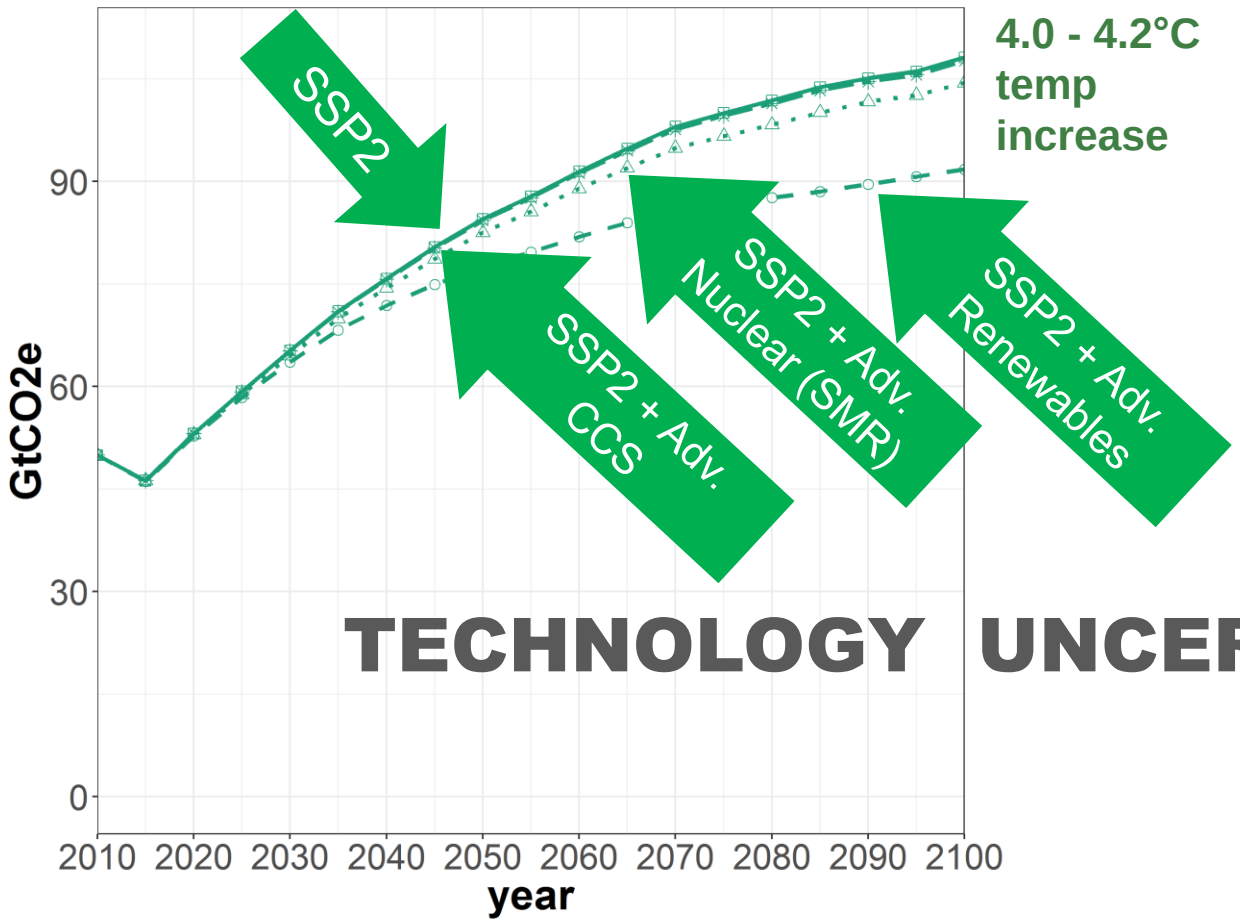
GCAM: Preliminary Modeling Results

Exemplary Results for "Energy and Environment"

ENERGY

GHG emissions and temperature rise

Global GHG emissions (GtCO2e)



TECHNOLOGY UNCERTAINTY

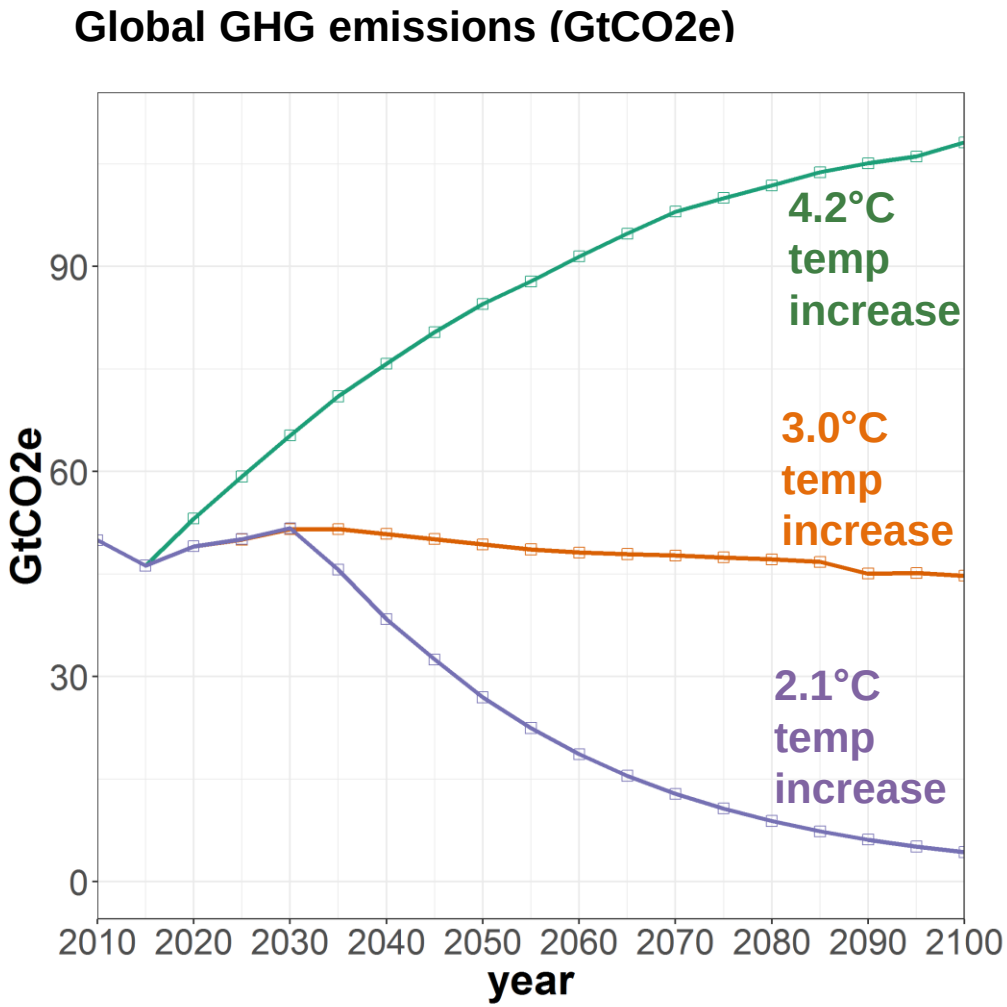
- **Reference**: SSP2 assumptions
  - Reference technology
  - Advanced renewables
  - Low-cost Nuclear (SMR)
  - Advanced CCS

Preliminary Modeling Results

Exemplary Results: "Energy and Environment"

ENERGY

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 2ºC goal

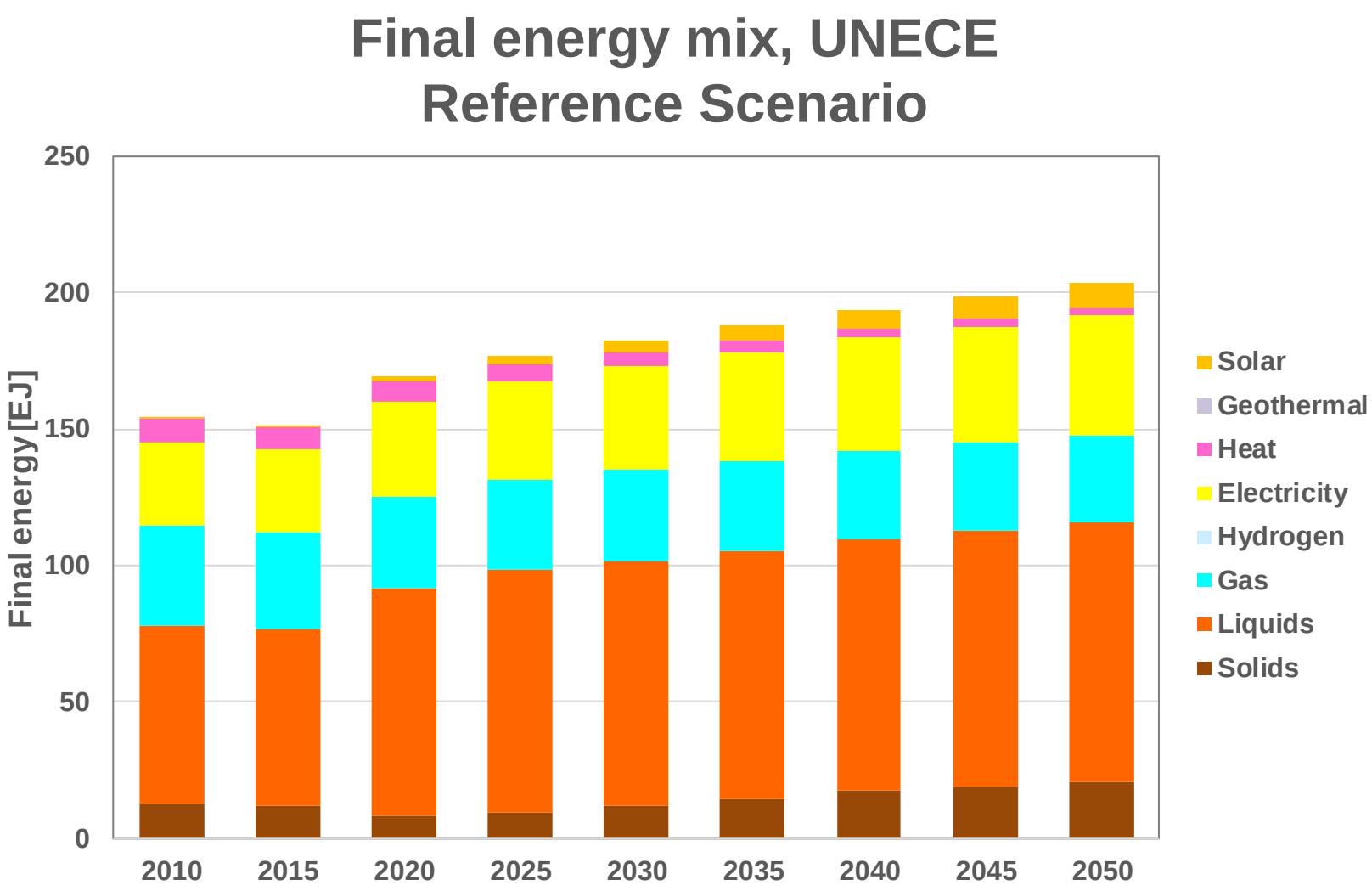
ALTERNATTIVE AMBITIONS

* Fawcett AA *et al.* (2015) Can Paris pledges avert severe climate change? *Science (80)*

MESSAGE: Preliminary Modeling Results

Final Energy Mix

ENERGY

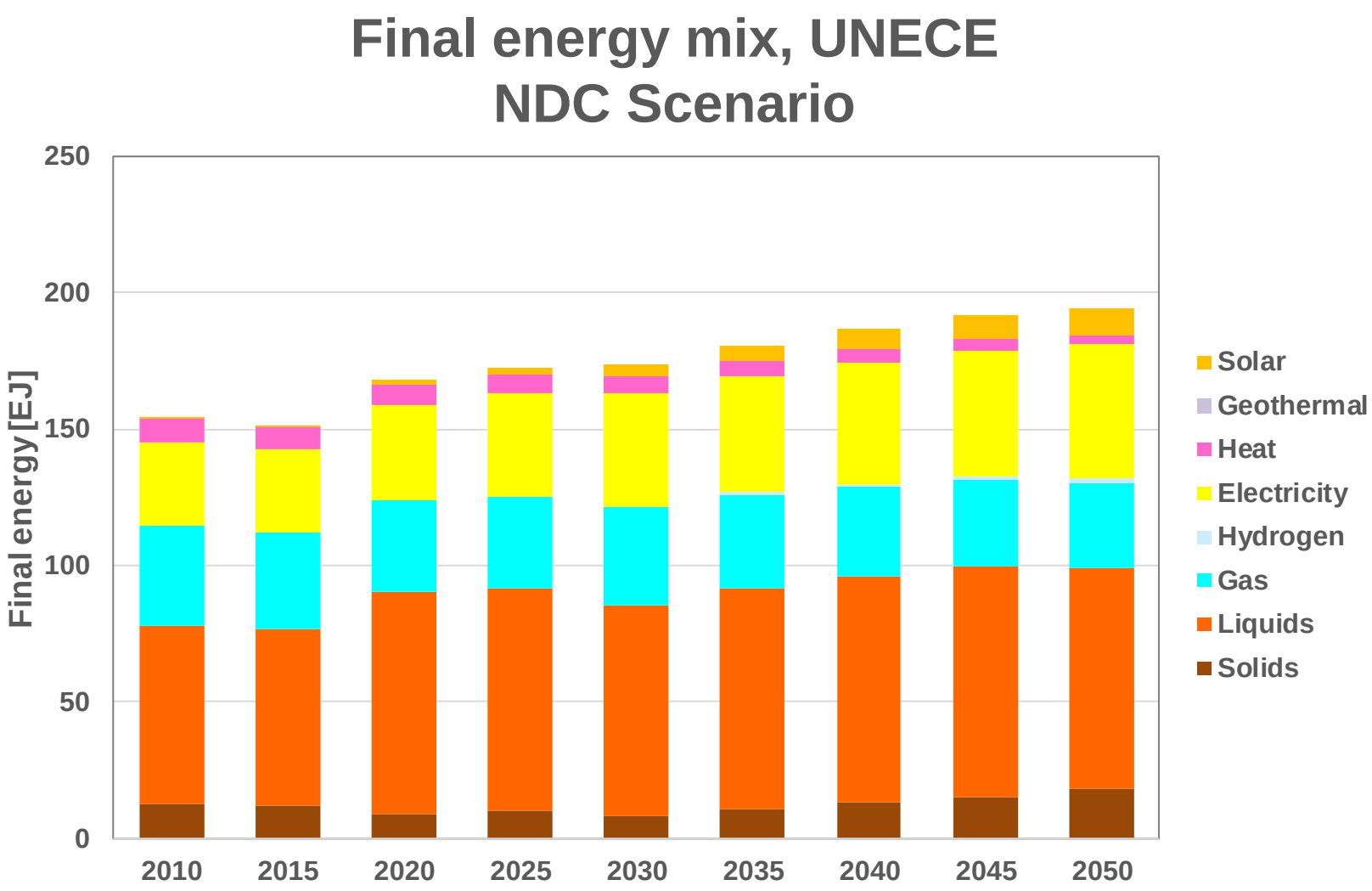


- *Except for district heat, the demand for all other forms of final energy grow between 2020 and 2050*
- *Liquids driven by demand for transportation services*

MESSAGE: Preliminary Modeling Results

Final Energy Mix

ENERGY

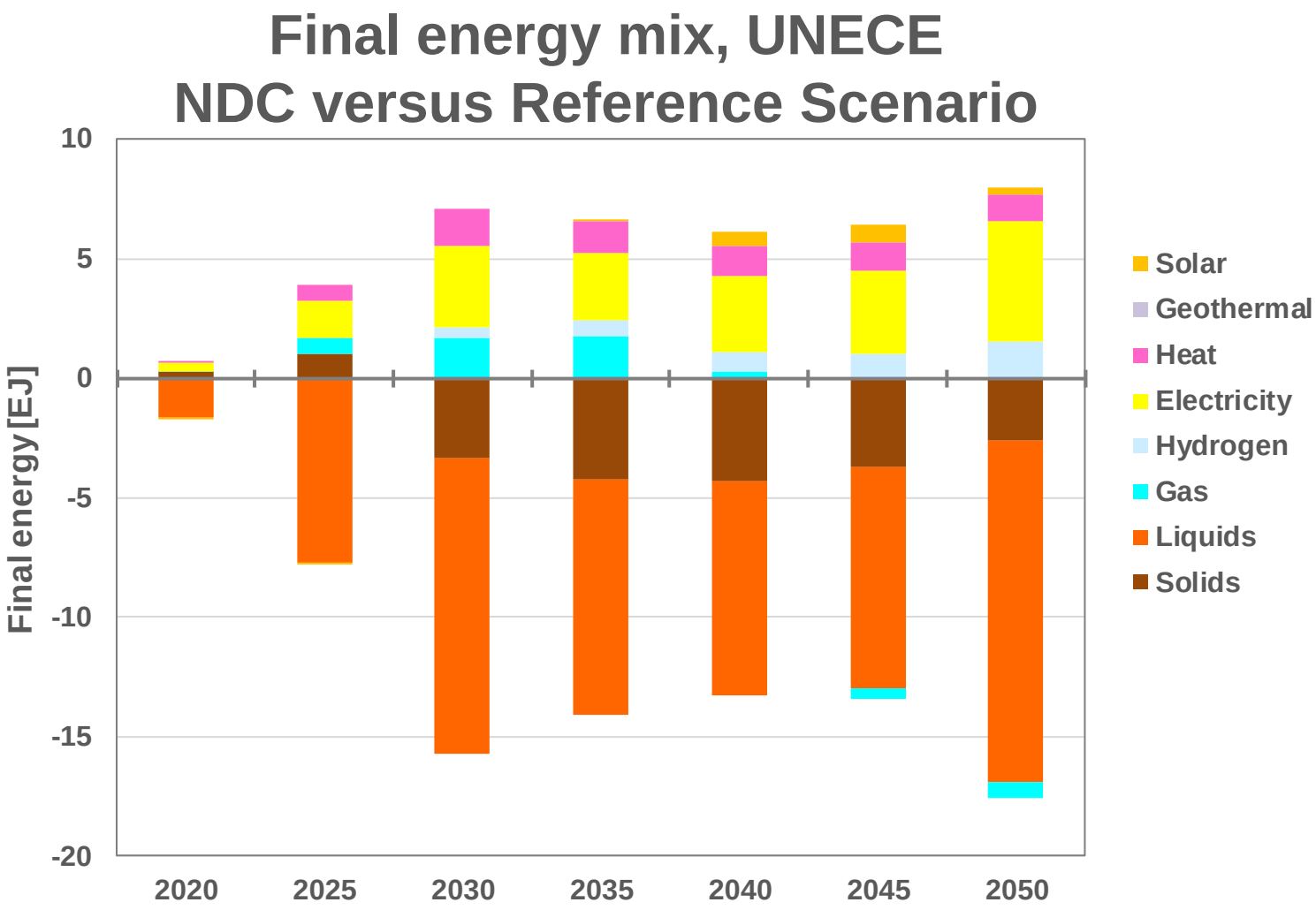


- *Climate mitigation policies affect overall final energy demand (at constant supply of energy services)*
- *Higher share of electricity displaces lower efficient fossil fuels (see next slide)*

MESSAGE: Preliminary Modeling Results

Final Energy Mix: Scenario differences

ENERGY



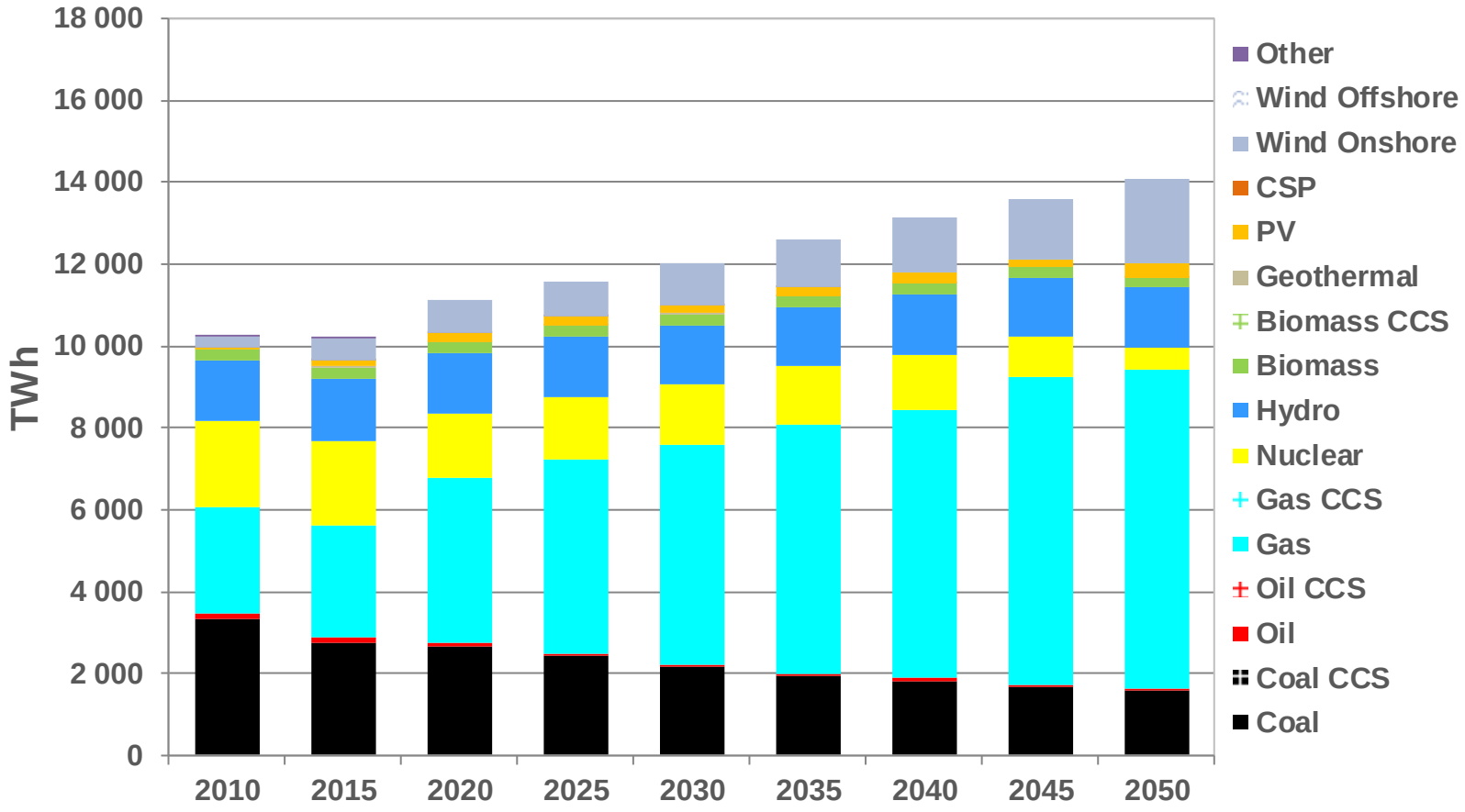
- *The NDC Scenario introduces hydrogen as of 2030*
- *The decline of district heat is slowed down*
- *Natural gas seems to be the swing fuel in meeting final energy demand*

MESSAGE: Preliminary Modeling Results

Electricity Generation

ENERGY

Electricity generation by technology, UNECE Reference



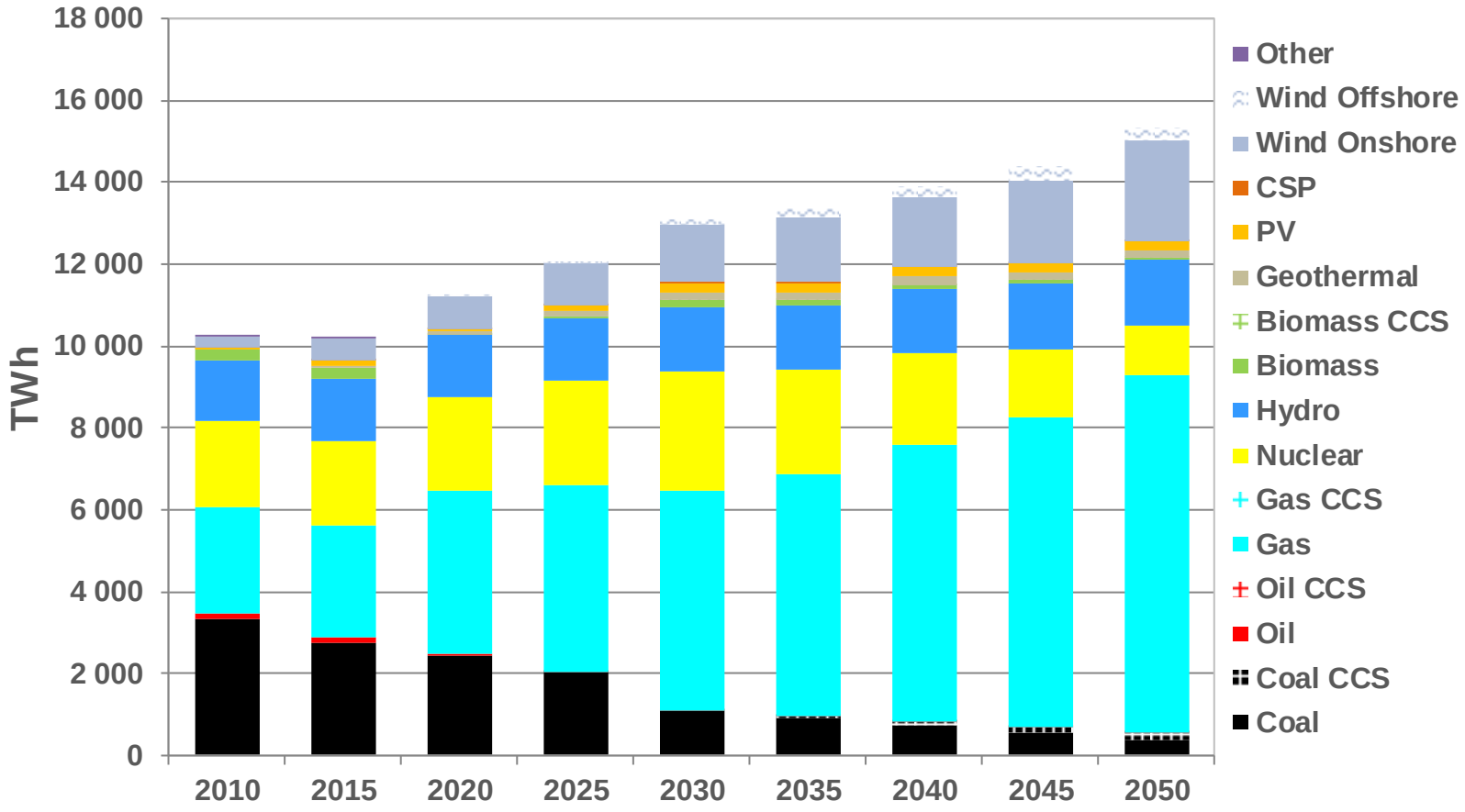
- *Large penetration of natural gas*
- *Quick reduction in the use of coal*
- *Steady decline of nuclear power*

MESSAGE: Preliminary Modeling Results

Electricity Generation

ENERGY

Electricity generation by technology, UNECE NDC



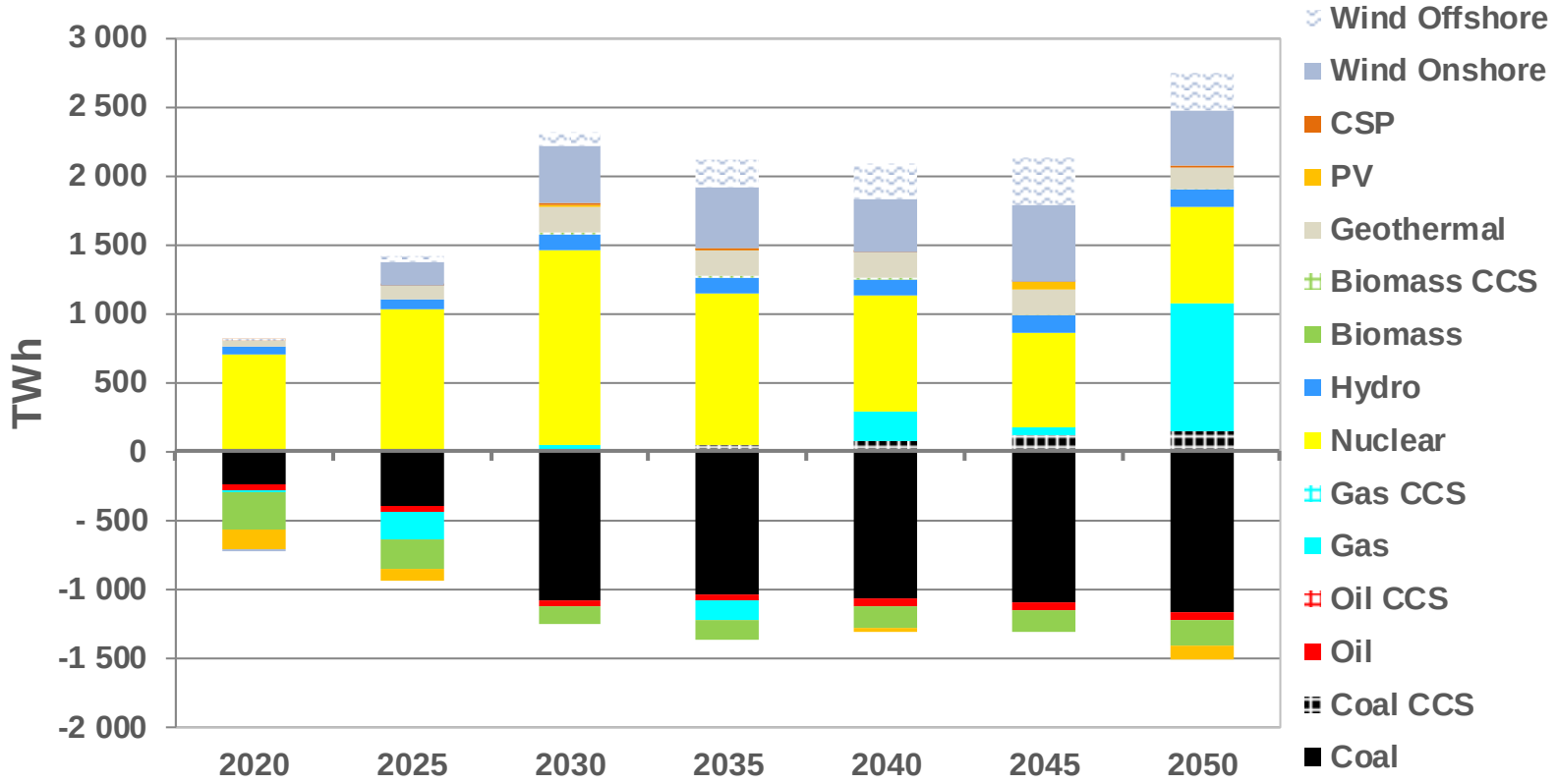
- *Higher total electricity generation due to increase demand*
- *Large penetration of natural gas delayed*
- *Faster take-up of low carbon emitting technologies*
- *Introduction of CCS*
- *Temporary increase of nuclear power followed by decline*

MESSAGE: Preliminary Modeling Results

Electricity Generation

ENERGY

Difference in electricity generation, UNECE NDC versus Reference

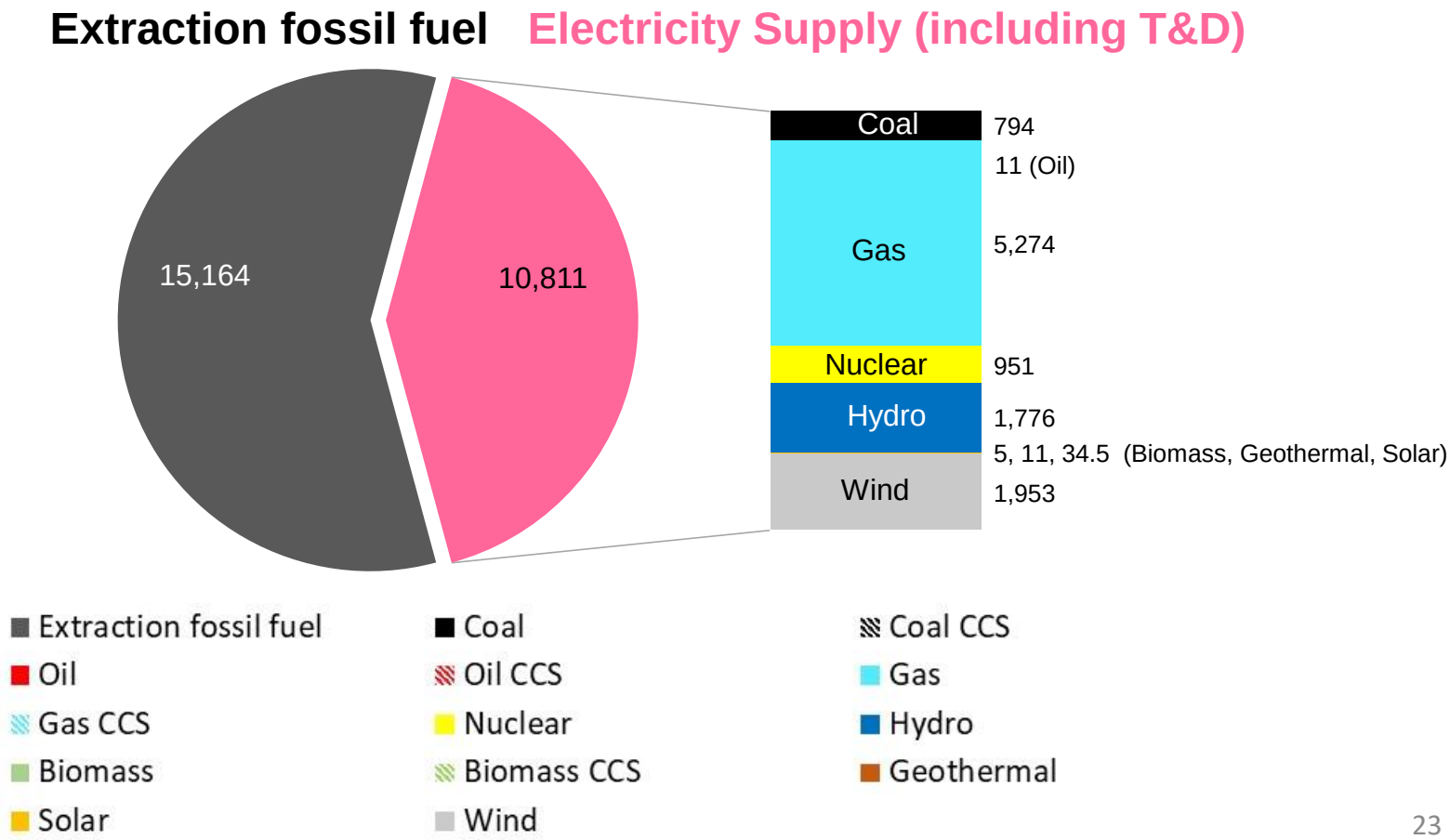


MESSAGE: Preliminary Modeling Results

Cumulative Energy Sector Investments

ENERGY

UNECE Region - Reference Scenario
2020 – 2050 in billion US$$_{2010}$$

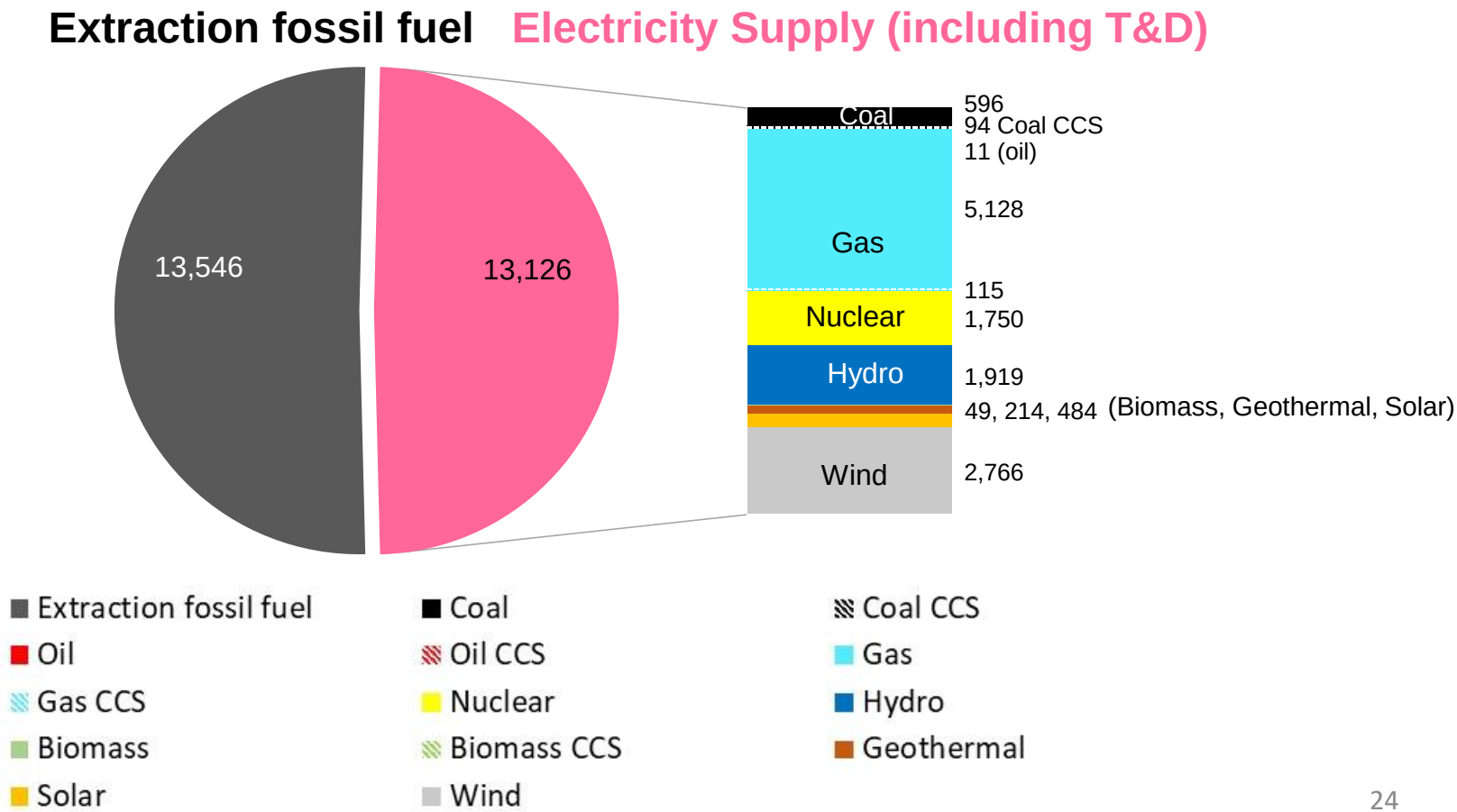


MESSAGE: Preliminary Modeling Results

Cumulative Energy Sector Investments

ENERGY

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



Summary Remarks

Lessons learned and the way forward

ENERGY

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. **STAKEHOLDERENGAGEMENT IS KEY AND WE DEPEND ON YOUR PARTICIPATION**

Outlook: Project Timeline

Engagement with the Pathways Project Community

ENERGY

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

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

Policy Dialogue Geneva, 26 Sep 2019

Consultation Period on Scenarios

Development of Phase II Project Idea

End sep 2019 | Dec | Mar | Jun | Oct 2019

UNECE-wide Policy Dialogue Geneva, 26 Sep 2018

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

Consultation and Information Workshop Geneva, 25 Sep 2018

High-level Political Dialogue Q3 (2019) ???

CSE = Committee on Sustainable Energy
IFESD = Internat. Forum on Energy for Sust. Dev.

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Pacific Northwest NATIONAL LABORATORY

ENERGY

Thank you!

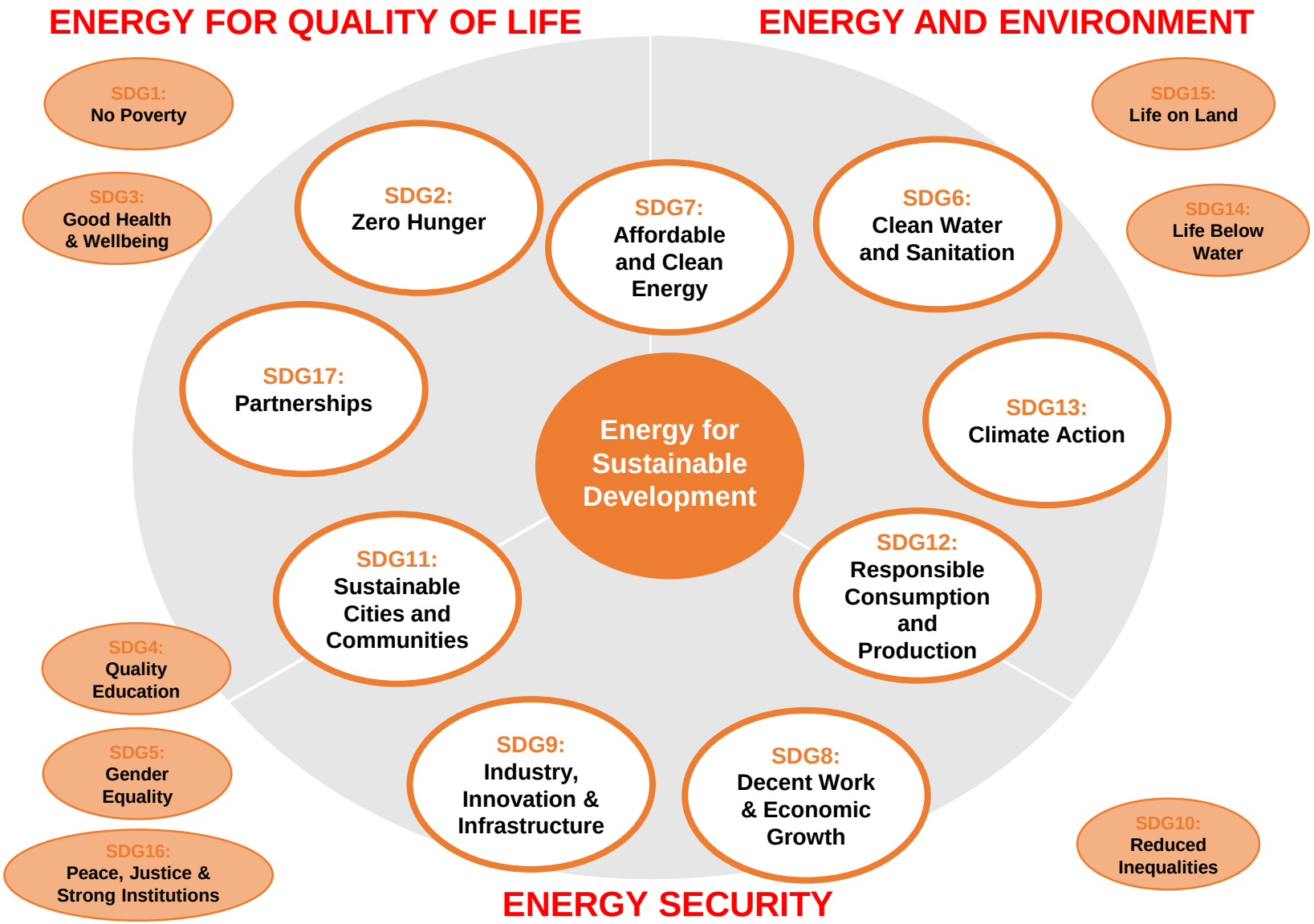
Holger Rogner on behalf of the Pathways Project Team
rogner.@iiasa.ac.at
Date 03 I 09 I 2018, Geneva

BACK-UP SLIDES

Sustainable Energy – not an isolated issue

Energy-related SDGs

ENERGY

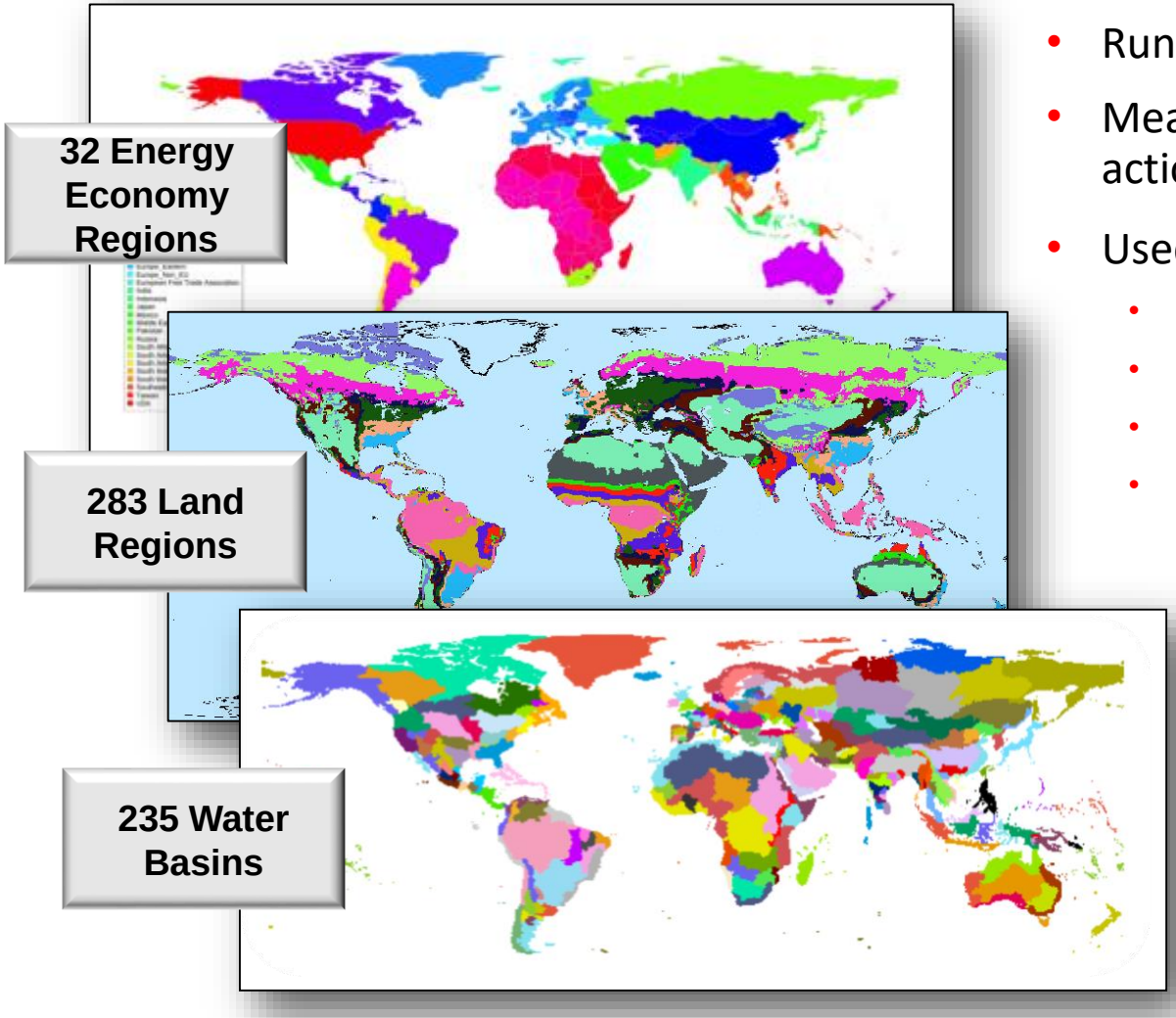


PNNL's GCAM

Overview

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*

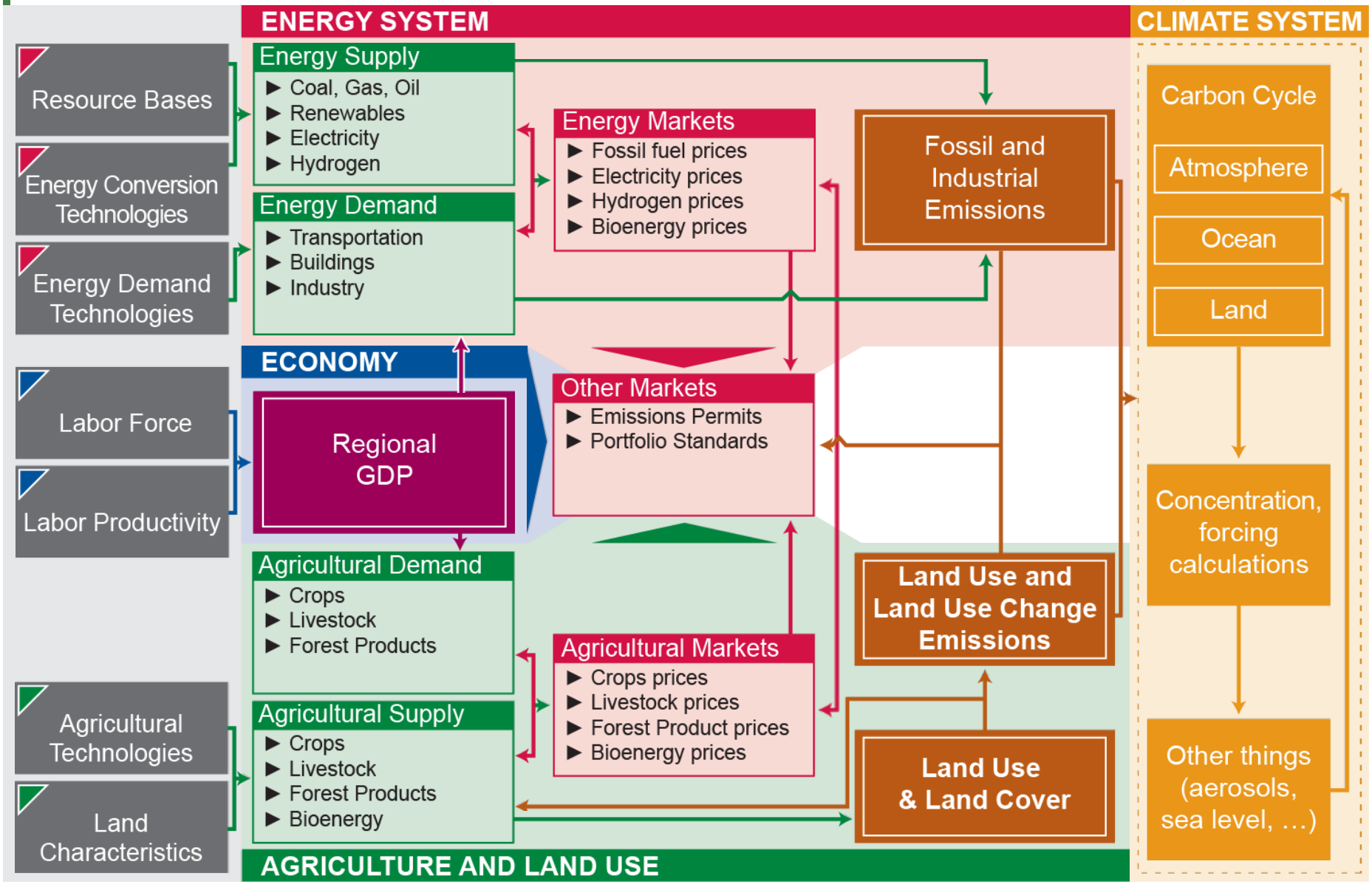
GCAM is an open-source community model

Documentation available at: **wiki.umd.edu/gcam**

PNNL's GCAM

What's inside GCAM?

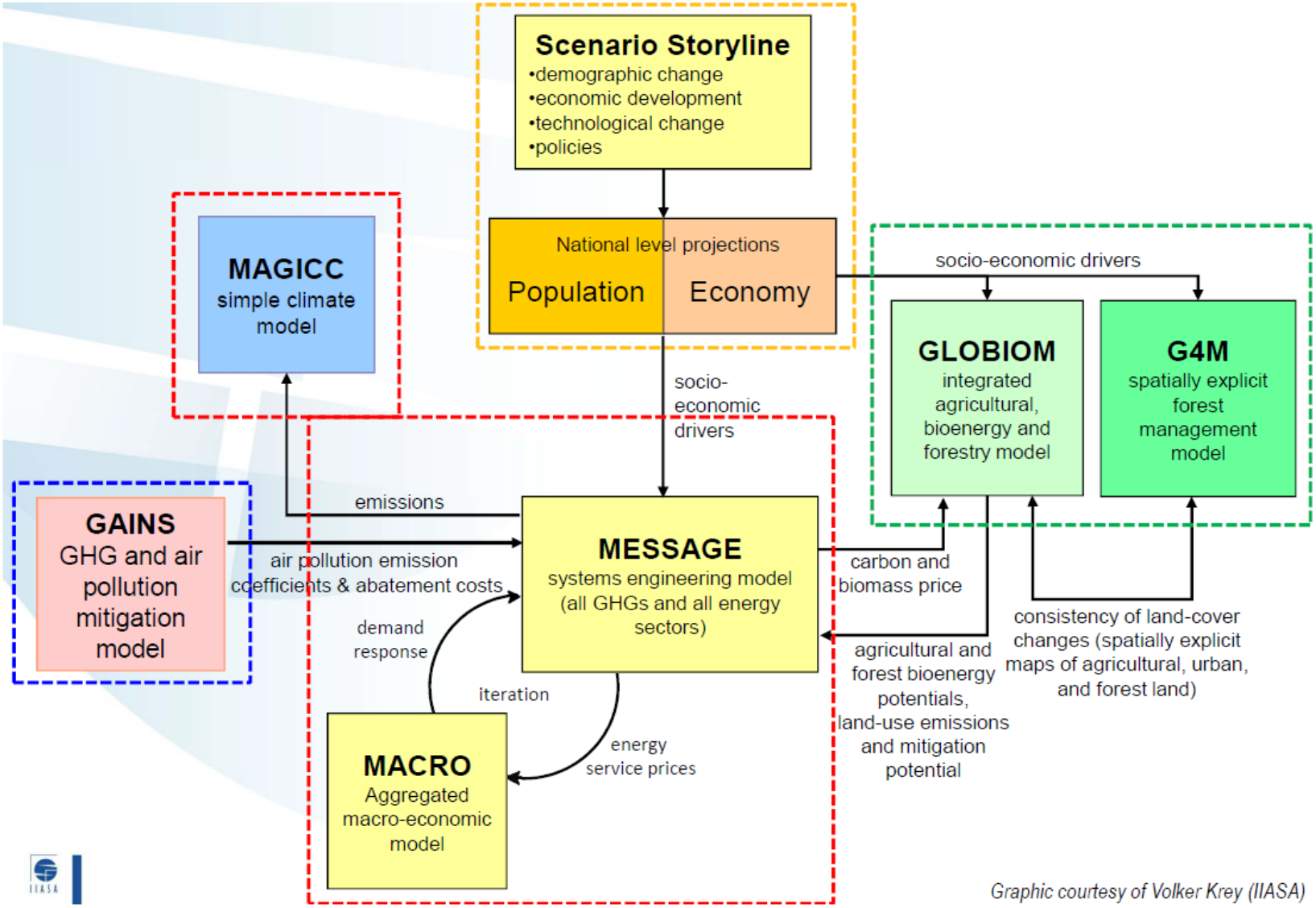
ENERGY



IIASA Integrated Assessment Framework

Overview

ENERGY



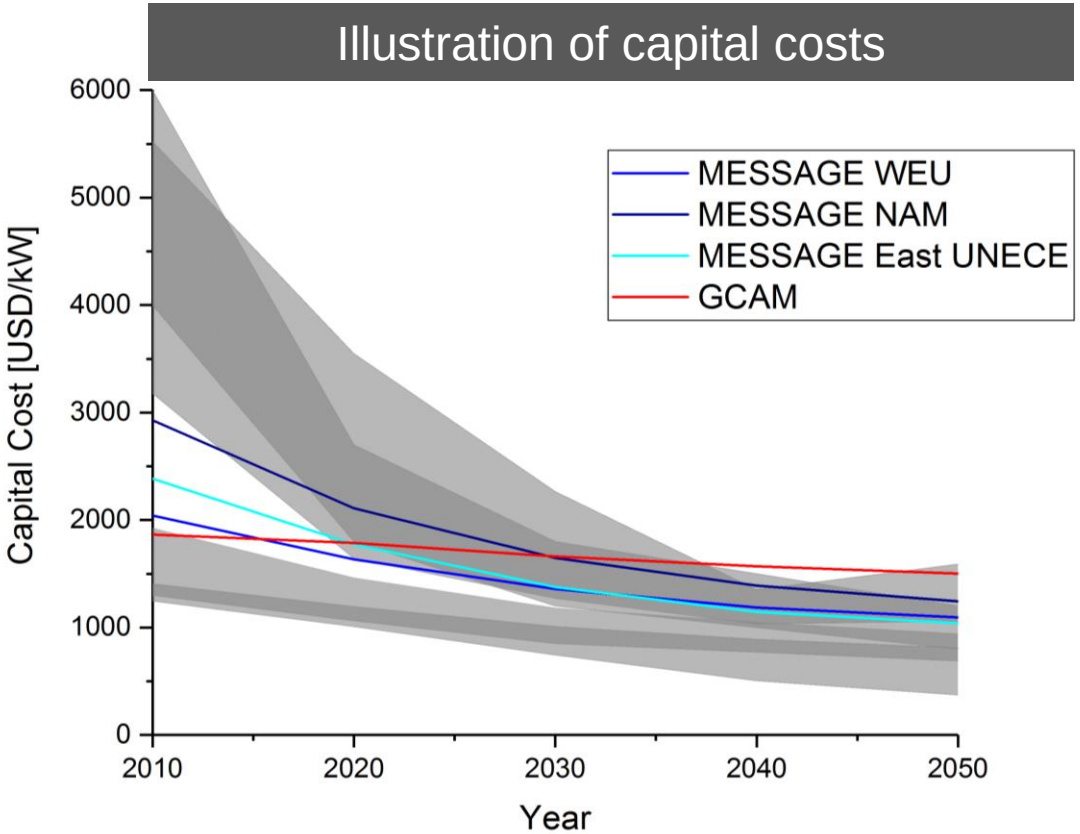
Graphic courtesy of Volker Krey (IIASA)

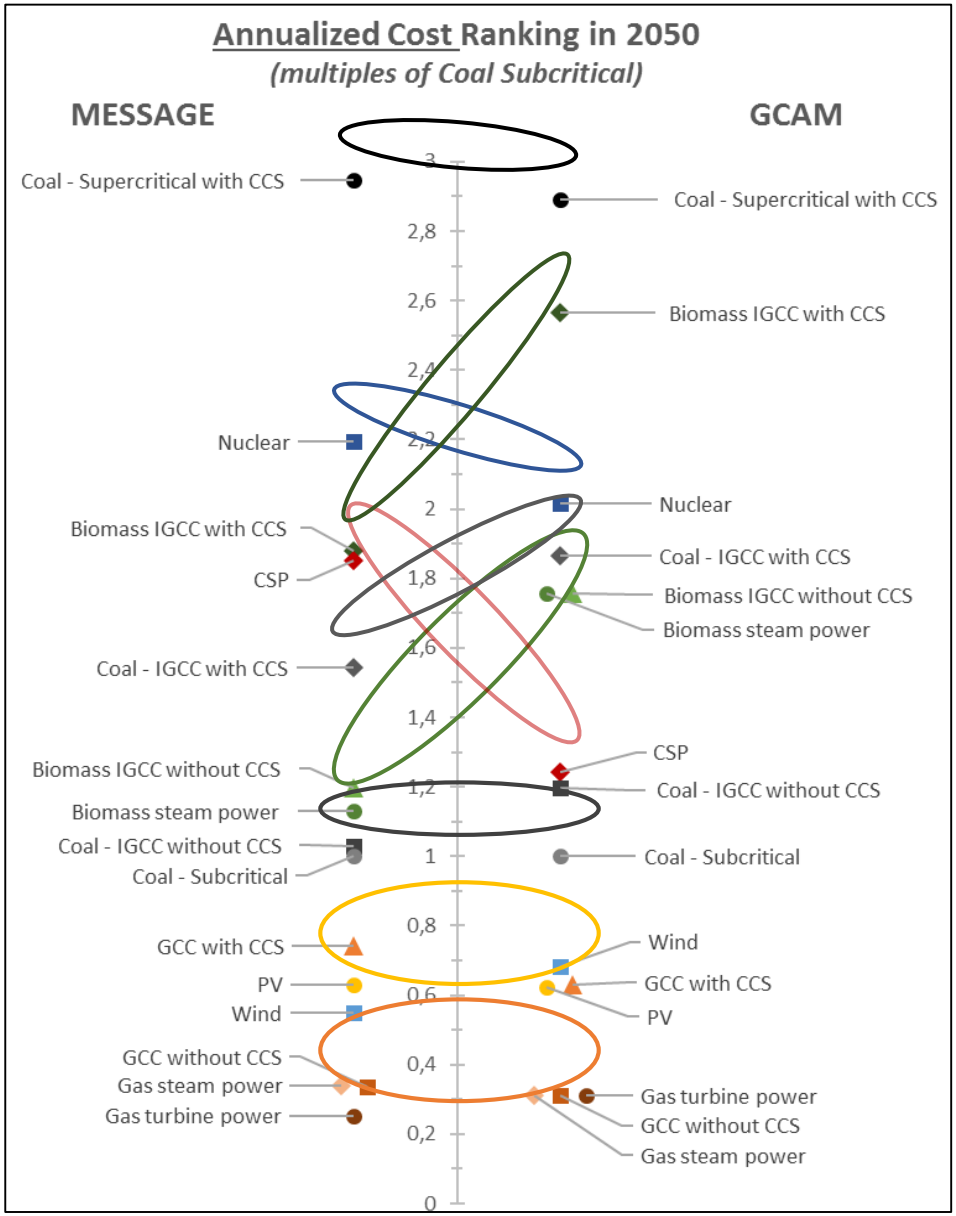
Technology Research

Portfolio: Overview of future technology options

ENERGY

- 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

ENERGY

Why the SSPs?

- **SSPs[1] 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

[1]Adapted from B. van Ruijven (2015); K. Riahi (2017); and O'Neil (2017)

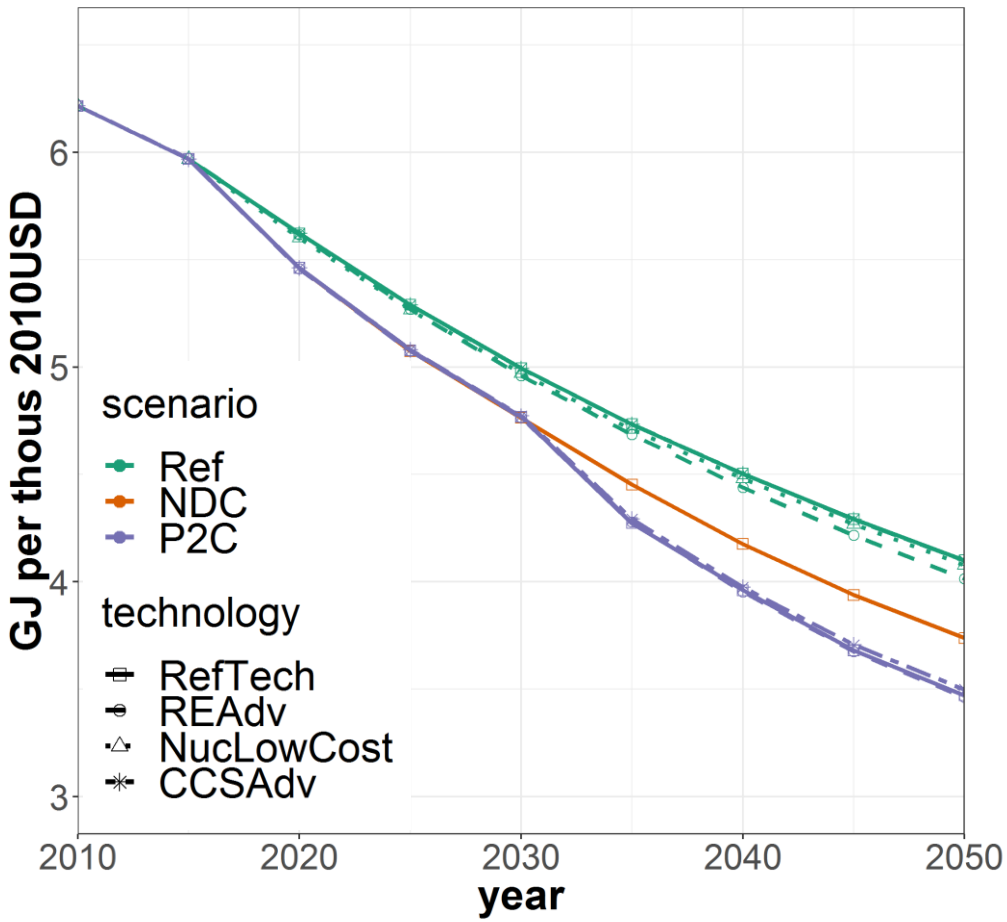
Preliminary Modeling Results

GCAM

ENERGY

Energy Security - Metric: Decrease energy intensity of economy

Global energy intensity (GJ per thous 2010USD)



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

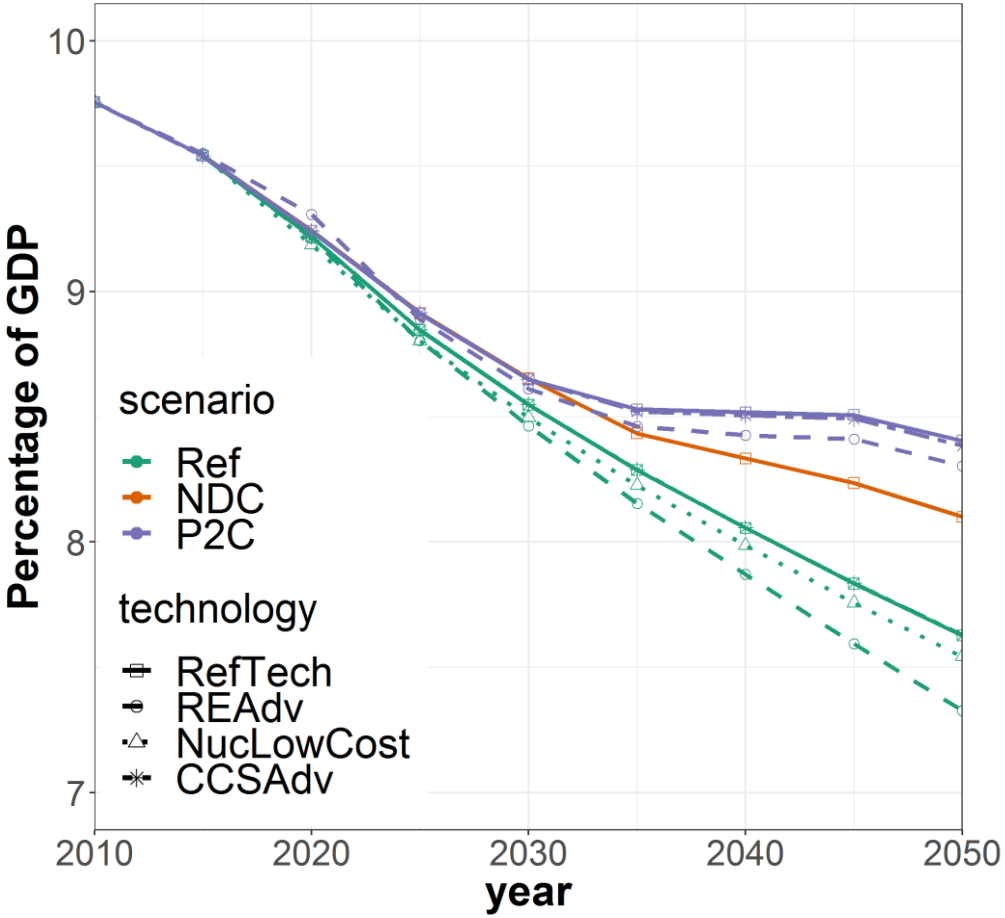
Preliminary Modeling Results

GCAM

ENERGY

Energy for Quality and Life - Metric: 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.

Preliminary Modeling Results

GCAM

ENERGY

Energy for Quality and Life - Metric: Energy affordability

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.

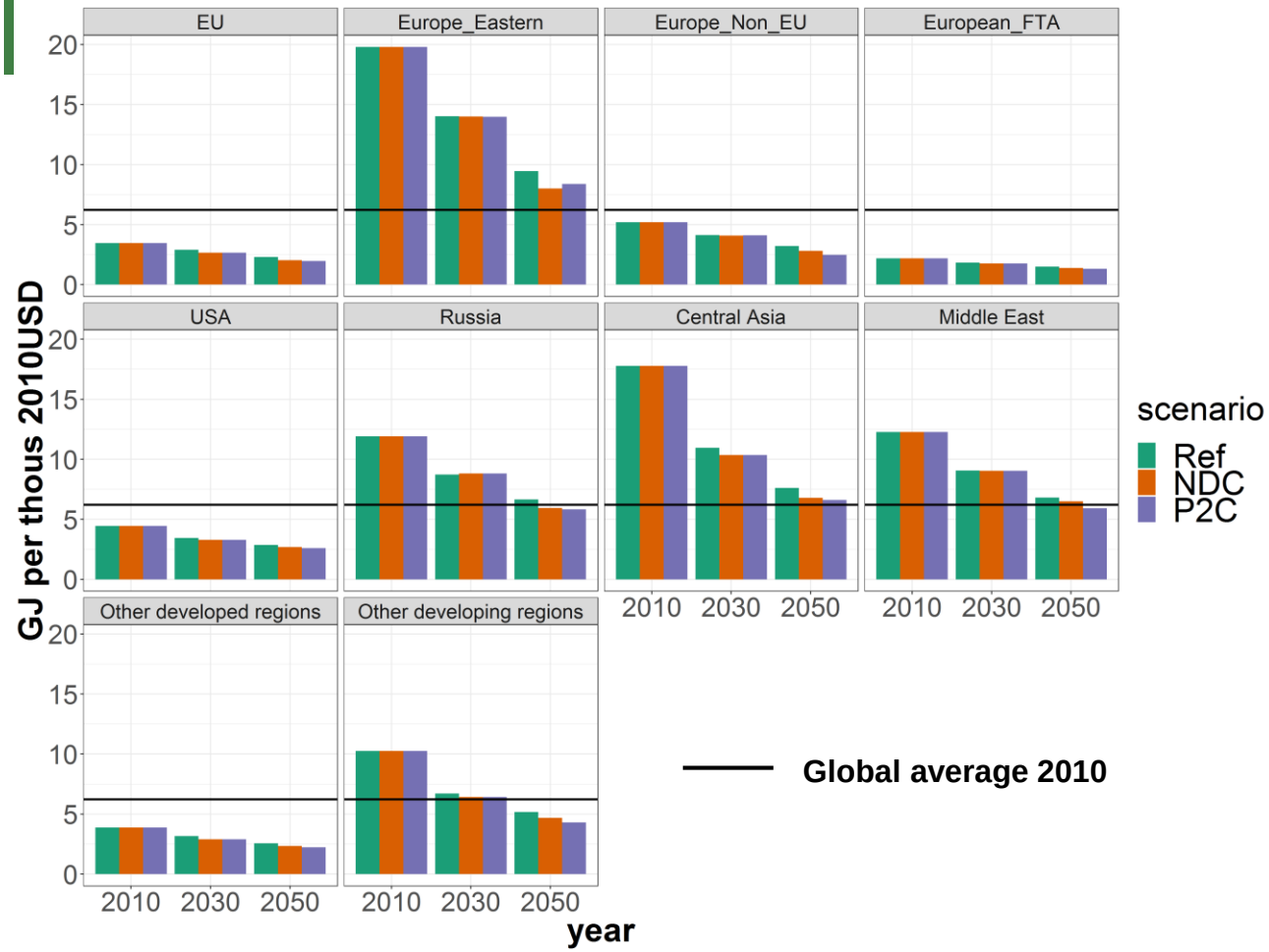
GCAM. Preliminary Modeling Results

Exemplary results: “Energy Security”

ENERGY

Decrease energy intensity of economy

Energy intensity by region (GJ per thous 2010USD)



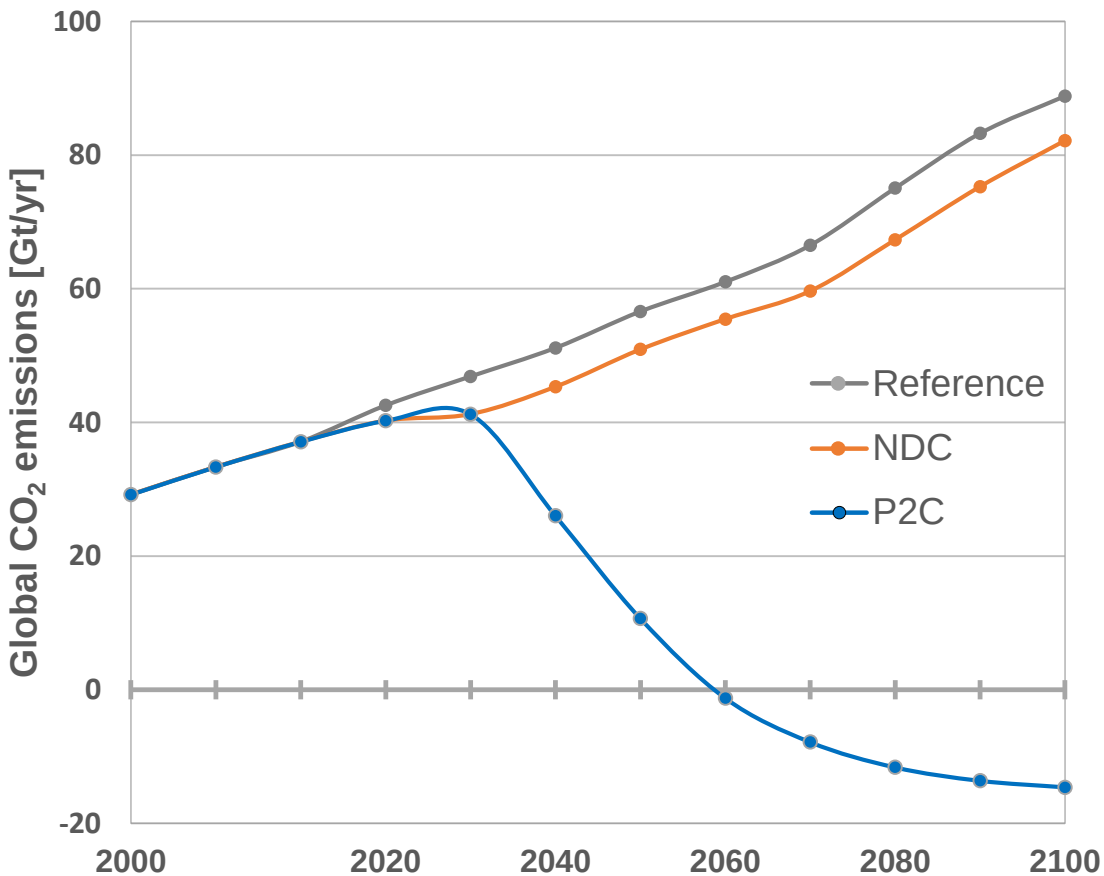
- Energy use per unit of GDP **decreases**, with **higher rates under policy scenarios**
- Several regions (e.g., Eastern Europe, Russia, Central Asia) may still be **above the 2010 global average** level by 2050

MESSAGE: Preliminary Modeling Results

Global GHG emissions in different Scenarios

ENERGY

Current NDCs are a modest step on the bumpy road to a 2ºC target



Stakeholder Community: Pathways to Sustainable Energy