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Pacific Northwest NATIONAL LABORATORY

ENERGY

Modeling of Pathways to Sustainable Energy for Belarus-Moldova-Ukraine (BMU)

Energy Ministerial and 9th International Forum on Energy for Sustainable Development

12-15 November 2018, Kyiv, Ukraine

Behnam Zakeri, Holger Rogner

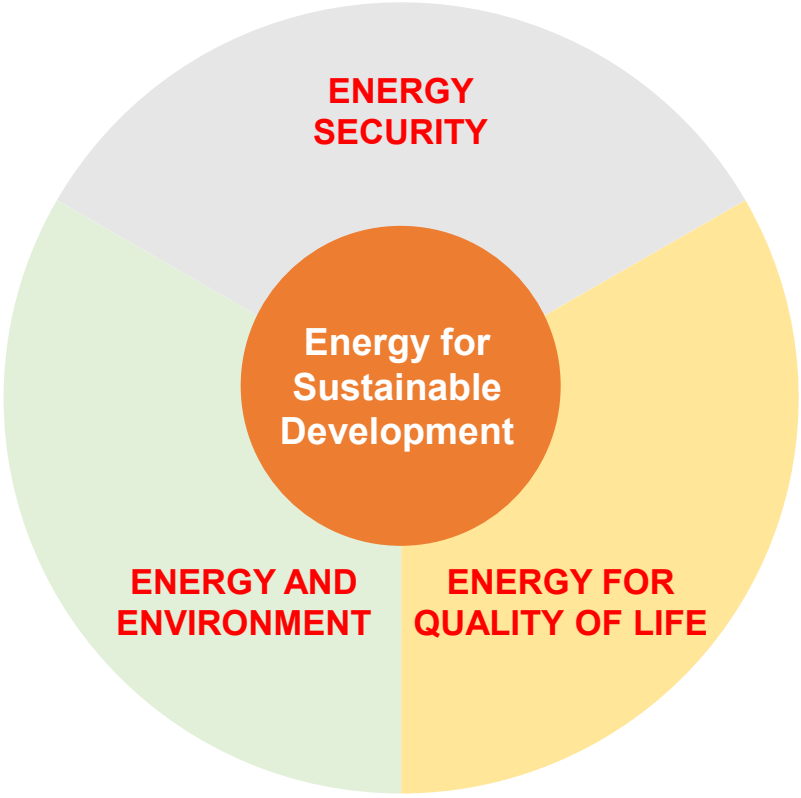
UNECE Pathways Project

Three Pillars of Sustainable Energy

ENERGY

"Secure the energy needed for economic development"

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



"Provide affordable energy that is available for all at all times"

Methodology

Modelling of Energy Scenarios

- **An integrated assessment modelling approach**
  - ***MESSAGE*** - ***M***odel for ***E***nergy ***S***upply ***S***ystem ***A***lternatives and their ***G***eneral ***E***nvironmental Impacts

- **MESSAGE Model in a Nutshell**
  - **Optimization model:** Supply must meet demand at minimum system costs
  - Developed and maintained by IIASA since 1970s
  - Has been used for consulting:

    IPCC reports, Global Energy Assessment, UNIDO, IAEA member countries, Global Energy Interconnection Development and Cooperation Org. (GEIDCO), and UNECE Pathways Project, etc.

Open access and version controlled:
https://messageix.iiasa.ac.at/

Mathematical formulation:
https://messageix.iiasa.ac.at/model/MESSAGE/model_core.html

Methodology

Why an integrated modelling approach?

ENERGY

Energy Access

Energy Security

Land & Food

Climate Change

Water Scarcity

Local Air Pollution

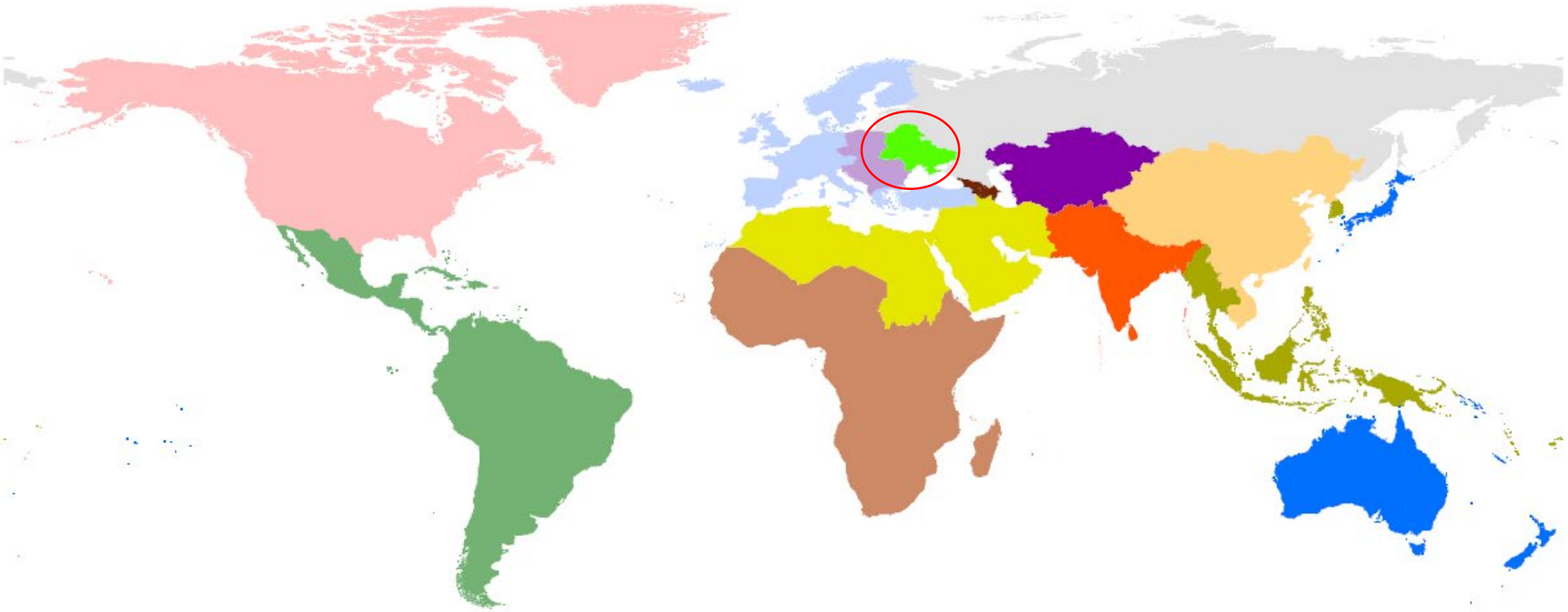
Image sources: NASA, http://www.powernewsnetwork.com/white-house-releases-plan-to-cut-oil-imports-by-13-by-2025/1798/, http://wheresmyamerica.wordpress.com/2007/08/26/i-cant-see-my-america/, http://www.americanprogress.org/issues/green/report/2009/05/14/6142/energy-poverty-101/, http://today.uconn.edu/blog/2010/12/reclaiming-water-a-green-leap-forward/, http://te.wikipedia.org/wiki/%E0%B0%A6%E0%B0%B8%E0%B1%8D%E0%B0%A4%E0%B1%8D%E0%B0%B0%E0%B0%82:Forest_Osaka_Japan.jpg

MESSAGEix

14 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		



Scenario development

Illustration of scenario design

ENERGY

INPUT	Examples	MODEL	OUTPUT	Metric examples	Targets/Goals
Demographic	• Population by region	**Integrated Model** • Resource extraction, exports-imports, energy transformation and use • Markets • Capital • Labor • Agriculture • Land use • Carbon cycle • Atmosphere • Hydrology • Oceans	Energy Security	• Price of energy • Energy imports/exports • Electricity access • Energy/GDP	LPG/KPI
Productivity	• GDP per capita by region				
Technology	•Power plant conversion efficiency •Transport fuel economy, etc. •Crop yields, etc.		Quality of Life	• GDP per capita • Energy services per capita • Share calories from non-staples • Water stress	LPG/KPI
Resources	•Fossil fuel, uranium, solar, wind, geothermal, land, water and other				
Policies	•Pollution control •NDCs •Water use		Environmental Sustainability	• SO_2 NO_x O_3 concentrations • Deforestation/afforestation • Avg. Earth surface temp • Water withdrawals/recharge	LPG/KPI

Scenario Assumptions

Shared Socio-Economic Pathways (SSPs)

ENERGY

Challenge to mitigation

SSP5: Fossil fueled development

- Rapid economic growth, free trade fueled by carbon-intensive fuels
- High technology development
- Low regard for gobal environment and SDGs
- Technology fixes Low population and high mobility

Markets first

Clash of civilisations

SSP3: Regional rivalry

- Competition among regions
- Low technology development
- Environment and social goals not a priority
  Focus on domestic resources
- High population growth
- Slow economic growth dev. countries

SSP2: Middle of the Road

SSP1: Sustainability

- Global cooperation
- Rapid technology dev.
- Strong env. policy
- Low population growth
- Declining inequity
- Focus on renewables & efficiency
- Dietary shifts
- Forest protection

UN world

Have's and have not's

SSP4: Inequality

- Inequality across and within regions
- Social cohesion degrades
- Low technology development
- Environment priority for the few affluent
  Limited trade

Challenge to adaptation

Scenario Assumptions: "Middle of the road"

Reference Scenario

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Shared Socio-Economic Pathways (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)

UNECE Sub-region case study:

Belarus-Moldova-Ukraine (BMU)

BMU Region in a Nutshell

ENERGY

- Higher primary energy intensity vs. UNECE
- Lower carbon emission intensity vs. UNECE
- A relatively large potential for renewable energy

Reference year (2015)	unit	BMU	UNECE
Population	million	55.5	986.4
GDP PPP per capita	US$	13,400	37,600
Primary energy intensity	MJ/US$ GDP PPP	5.89	5.77
Final energy intensity	MJ/US$ GDP PPP	3.97	4.20
Carbon emission intensity	kgCO2/US$ GDP PPP	0.154	0.331
Carbon emission per capita	tCO2	2.07	12.47

Map 1: The Ukrainian and Yamal-Europe pipelines

Source: Oxford Institute for Energy Studies

Technology Assumptions

Portfolio: Overview of technology options

ENERGY

- Comparison of **annualized cost** to show internal rankings
- Capital cost of coal power plant in BMU (sub-critical): 1240 $/kW

(solar PV 1120 and wind onshore 980 $/kW)

- Long lifetime of conventional technologies

In BMU with relatively low capacity factor

cost estimations from the region will help us!

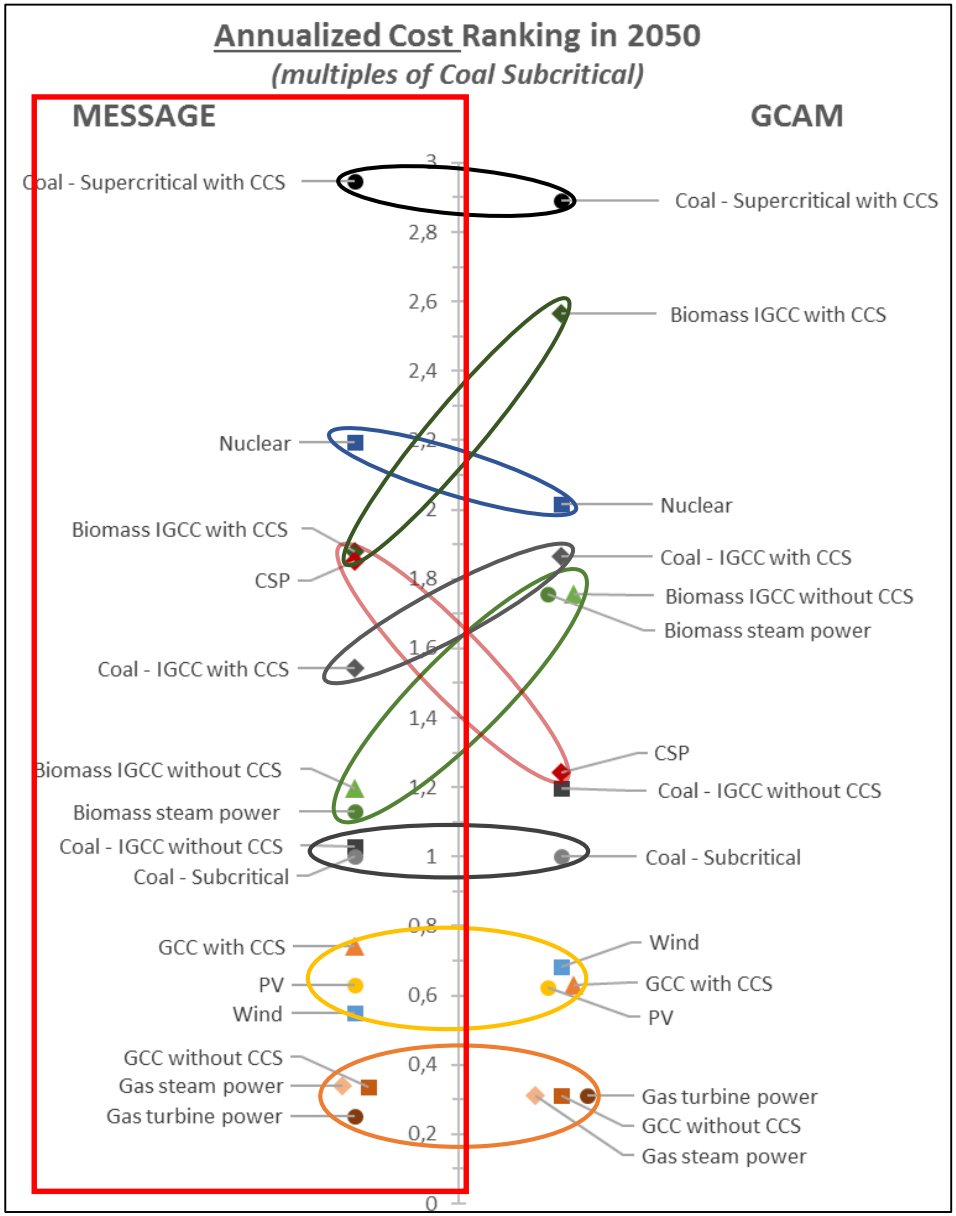

image: courtesy of Fraunhofer

BMU Progress towards NDCs

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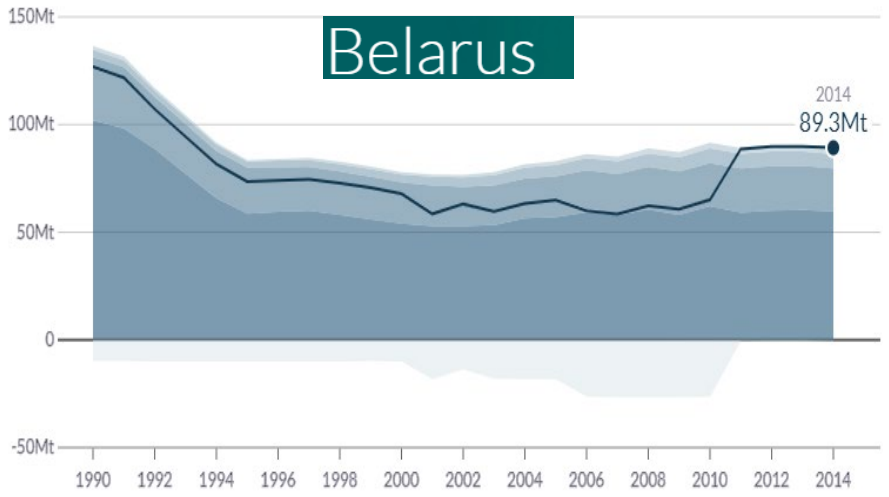
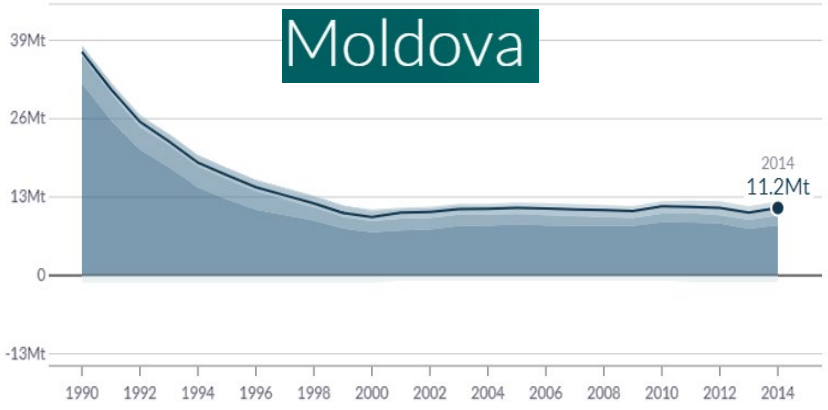
- Emission targets relative to 1990
- BMU is on track in meeting the NDCs
- Targets already met today (2016)
- Not so ambition targets relative to BAU





source: www.climatewatchdata.org

Scenario Development

To date: Three sequential steps

ENERGY

I. Reference Scenario

Based on SSP2 as point of departure, i.e., without dedicated sustainable energy or climate policies

II. NDC scenario

A scenario that implements by 2030 the current policies and NDCs under the Paris Agreement but maintains the NDCs beyond 2030 – *kind of NDCs forever*.

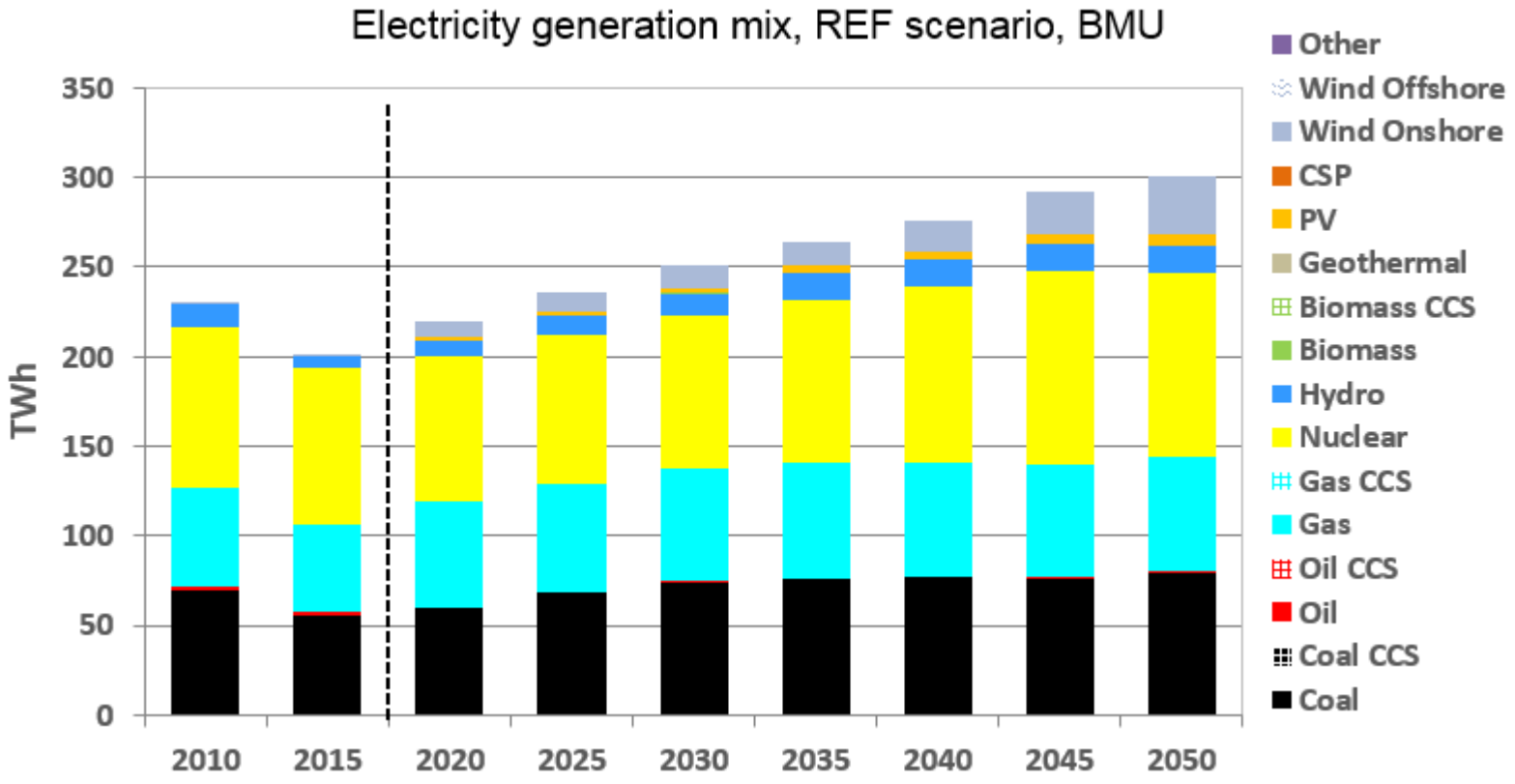
III. Designing pathways towards sustainable energy - Paris to 2°C -

One key component of SE is the 2°C target of the Paris Agreement by 2100 (Environment pillar).

MESSAGE: Preliminary Modeling Results

Electricity Generation

Electricity generation by technology, BMU Reference



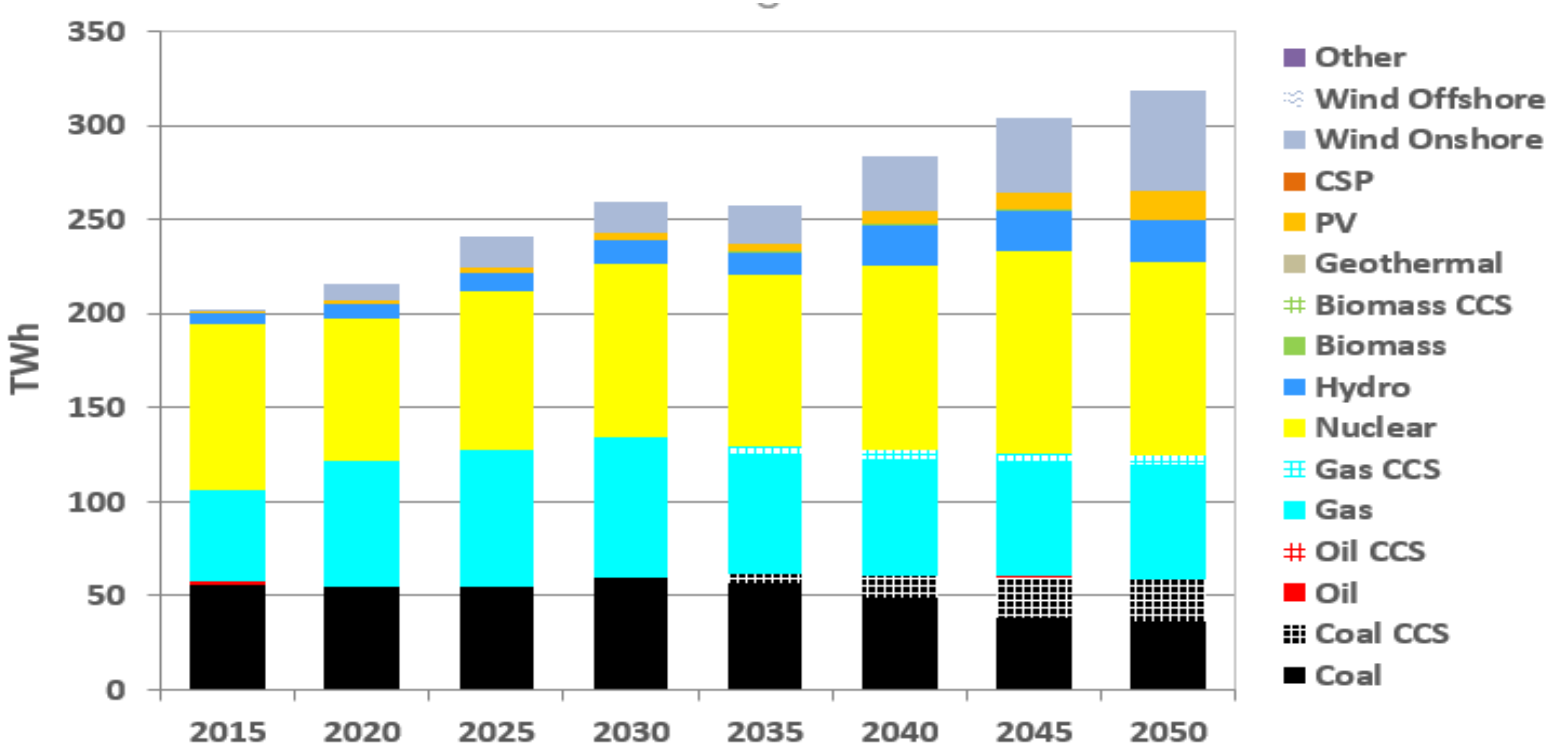
- *Slow addition of renewables*
- *Slow addition of nuclear (planned capacities)*
- *Slow increase in coal*

MESSAGE: Preliminary Modeling Results

Electricity Generation

ENERGY

Electricity generation by technology, BMU P2C



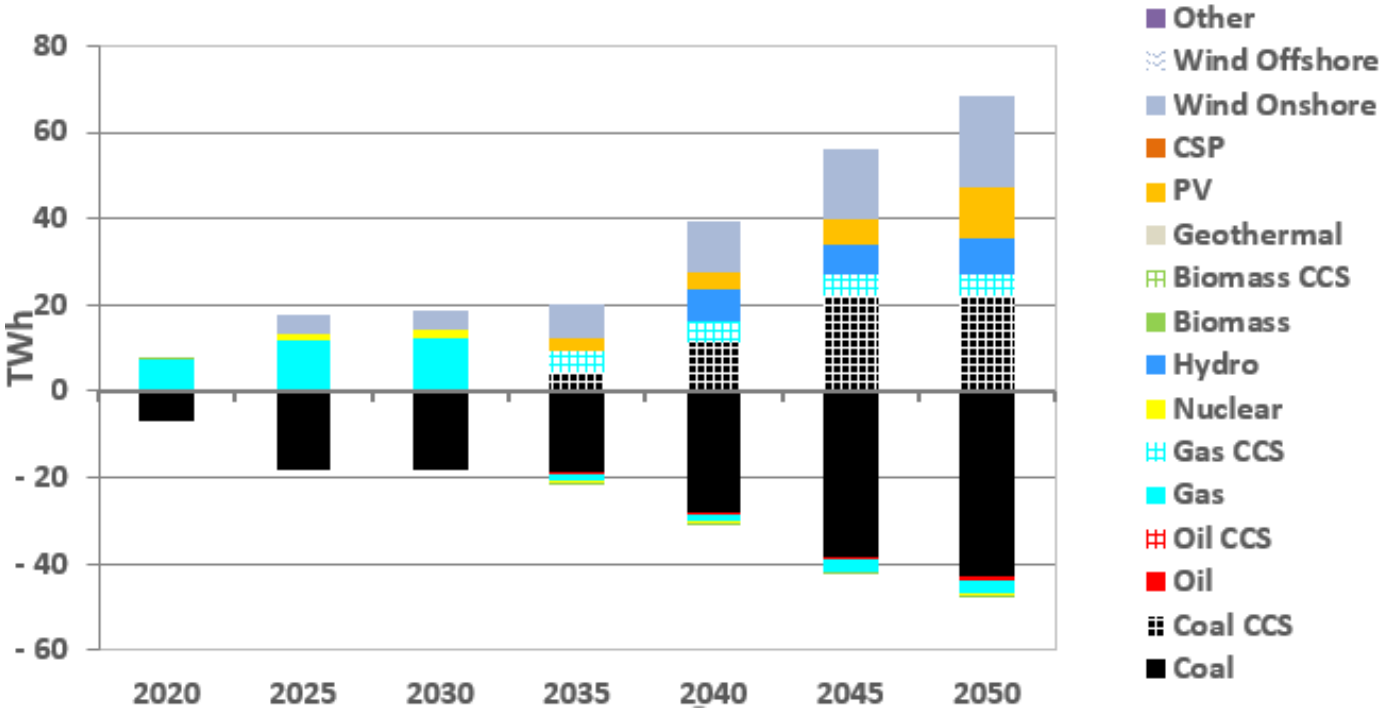
- *Slightly higher total electricity generation due to increased demand*
- *Large penetration of renewables*
- *Take-up of CCS technologies*
- *Temporary increase of nuclear power followed by decline*

MESSAGE: Preliminary Modeling Results

Electricity Generation

ENERGY

Difference in electricity generation, BMU P2C versus Reference



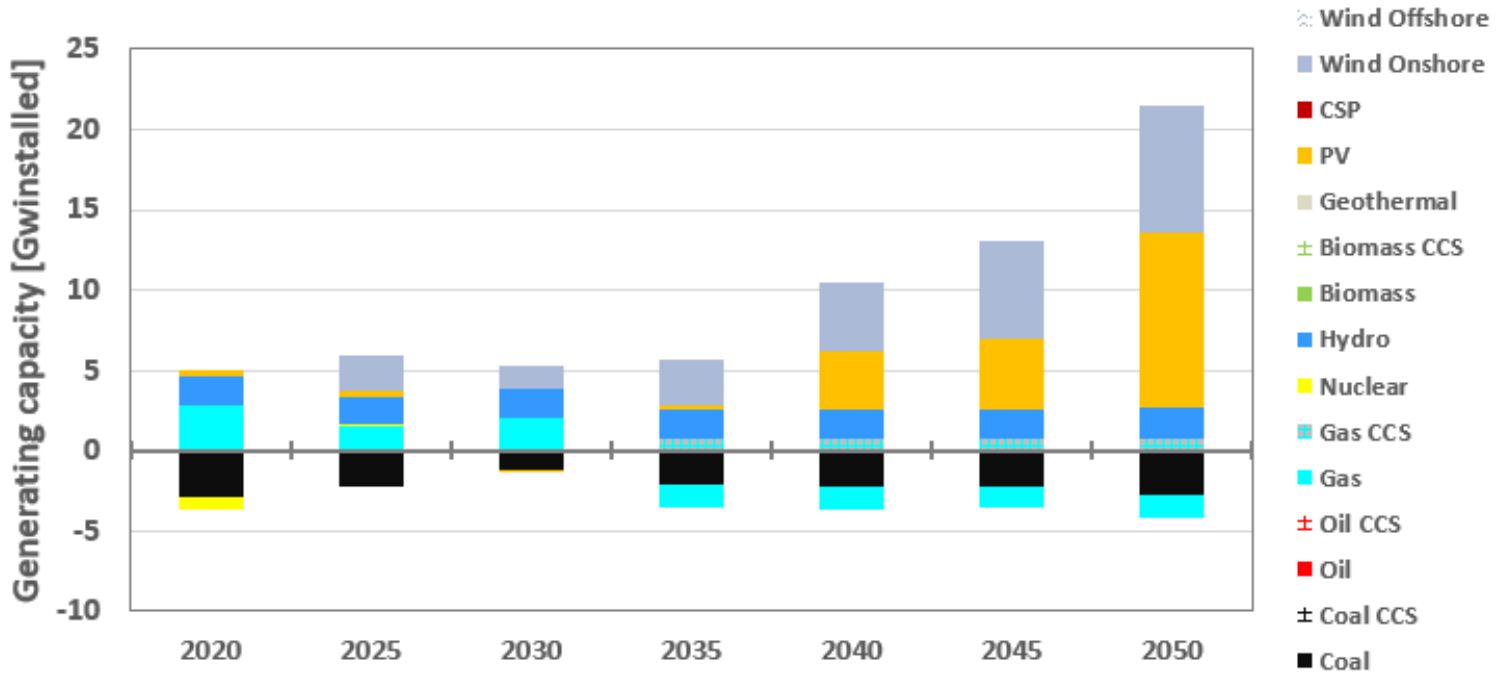
- *Coal with CCS after NDC period*
- *Renewable options increasingly displace coal*

MESSAGE: Preliminary Modeling Results

ENERGY

Electricity Generation Capacity

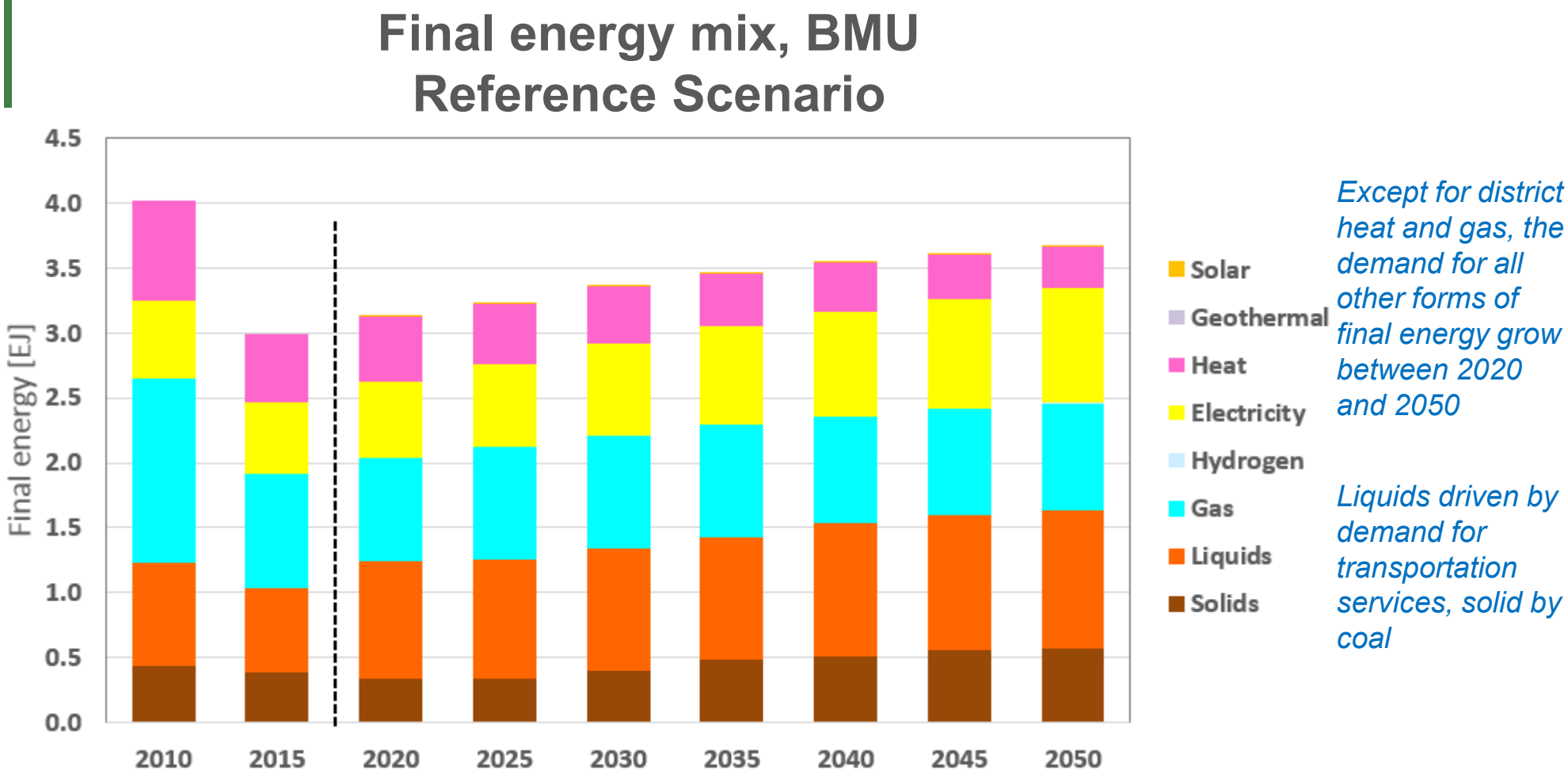
Electricity Generating Capacity (GW) by technology
BMU, Difference P2C vs. REF



MESSAGE: Preliminary Modeling Results

ENERGY

Final Energy Mix



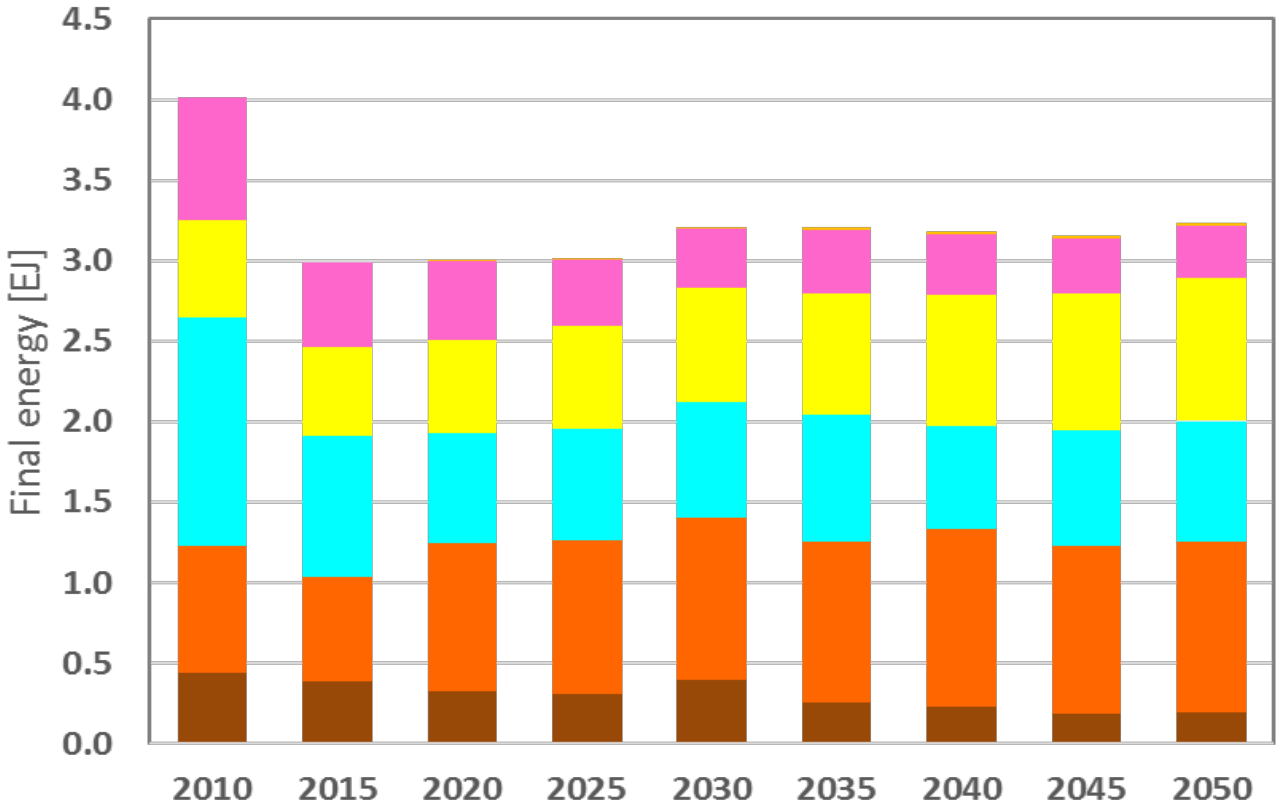
Except for district heat and gas, the demand for all other forms of final energy grow between 2020 and 2050

Liquids driven by demand for transportation services, solid by coal

MESSAGE: Preliminary Modeling Results

Final Energy Mix

ENERGY



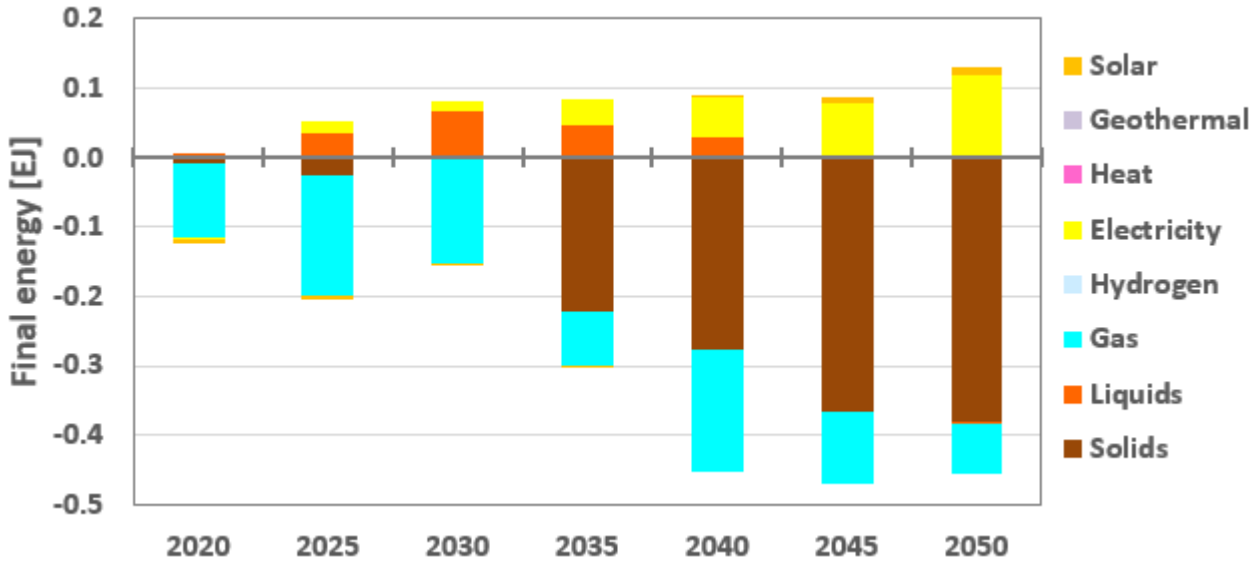
- *Demand kept constant after NDC 2030, even with economic growth*
- *Liquids driven by demand for transportation services*

MESSAGE: Preliminary Modeling Results

Final Energy Mix: Scenario differences

ENERGY

Final energy mix, BMU P2C versus Reference Scenario



- *P2C shifts to grid electricity services*
- *Solids (coal) massively replaced*
- *High efficiency and zero-emissions at the point of FE conversion to energy services*

MESSAGE: Preliminary Modeling Results

EN-M1: Global GHG emissions

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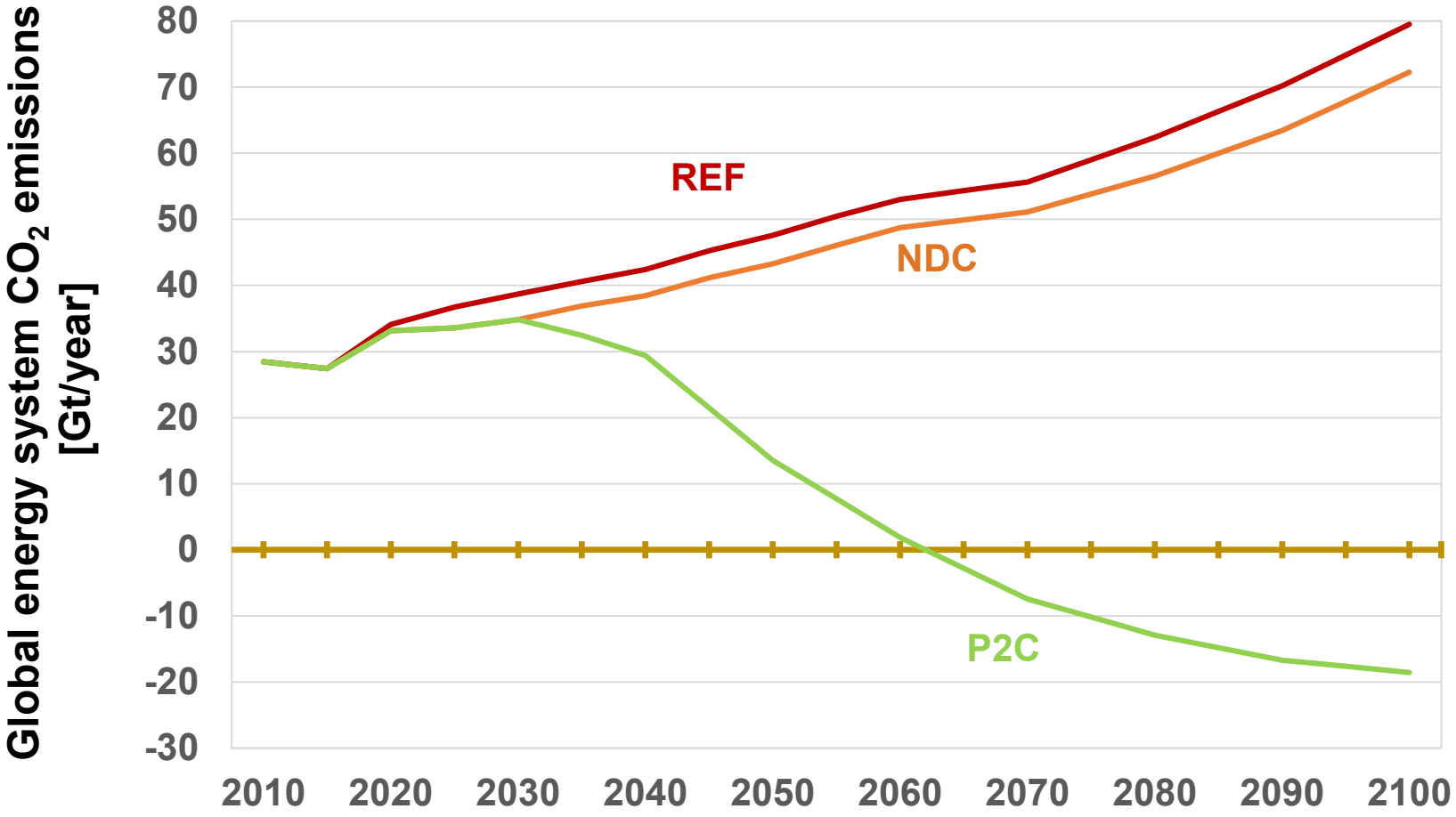
Current NDCs are a modest step on the bumpy road to a 2°C target

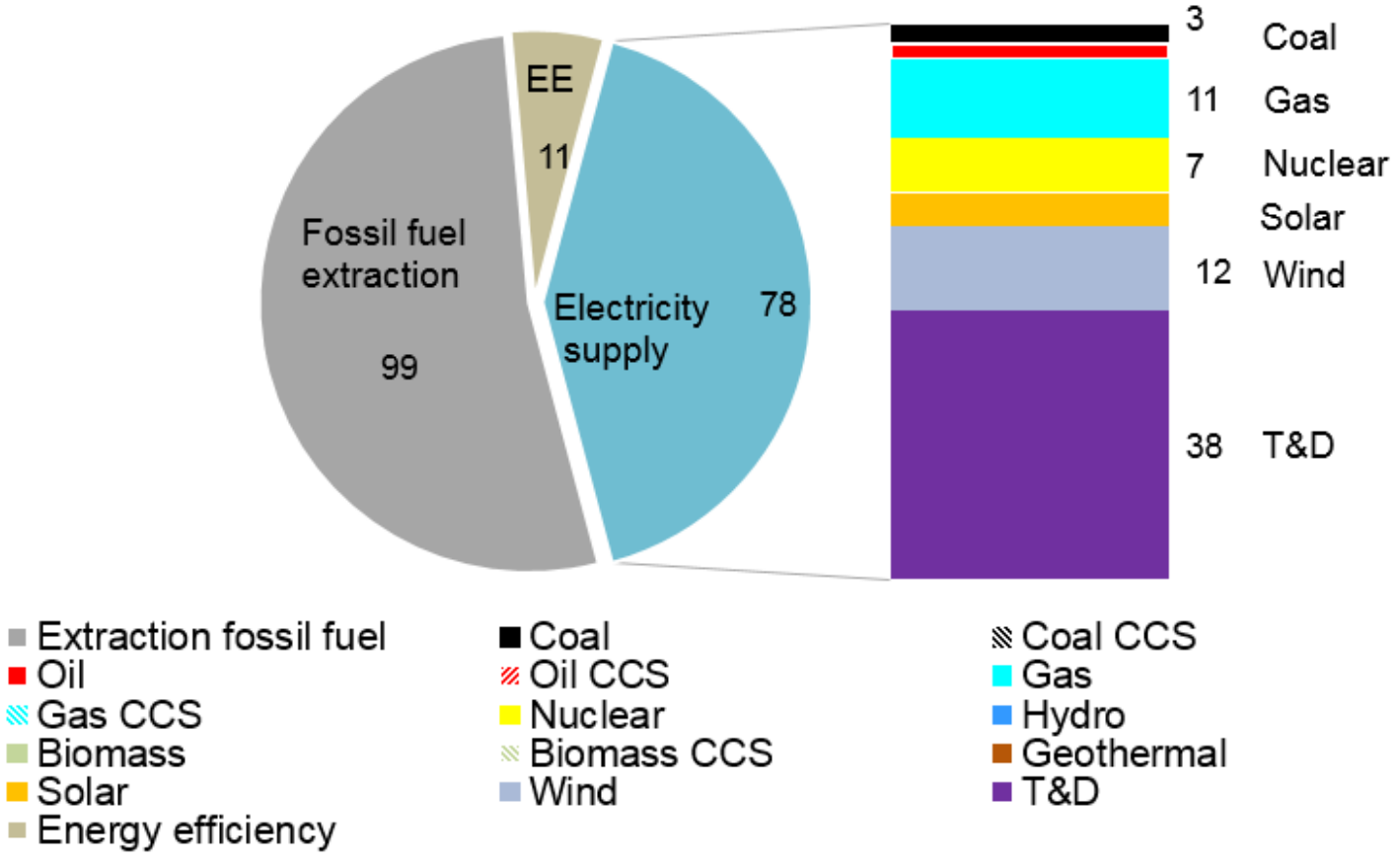


MESSAGE: Preliminary Modeling Results

ENERGY

QL-M2: Cumulative Energy Sector Investments

BMU Region - Reference Scenario
2020 – 2050 in billion US$$_{2015}$$



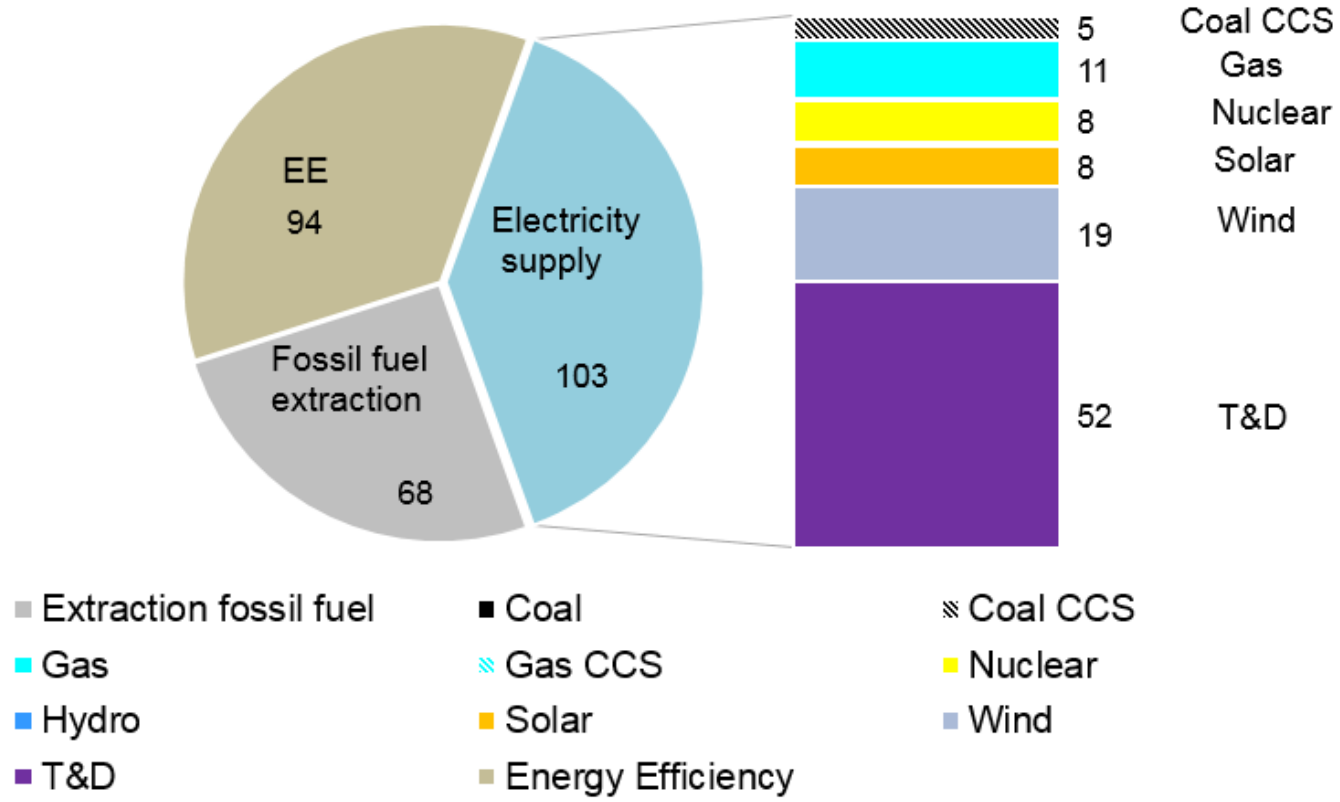
Total cumulative investment 188

MESSAGE: Preliminary Modeling Results

ENERGY

QL-M2: Cumulative Energy Sector Investments

BMU Region – P2C Scenario
2020 – 2050 in billion US$$_{2015}$$



Total cumulative investment 265

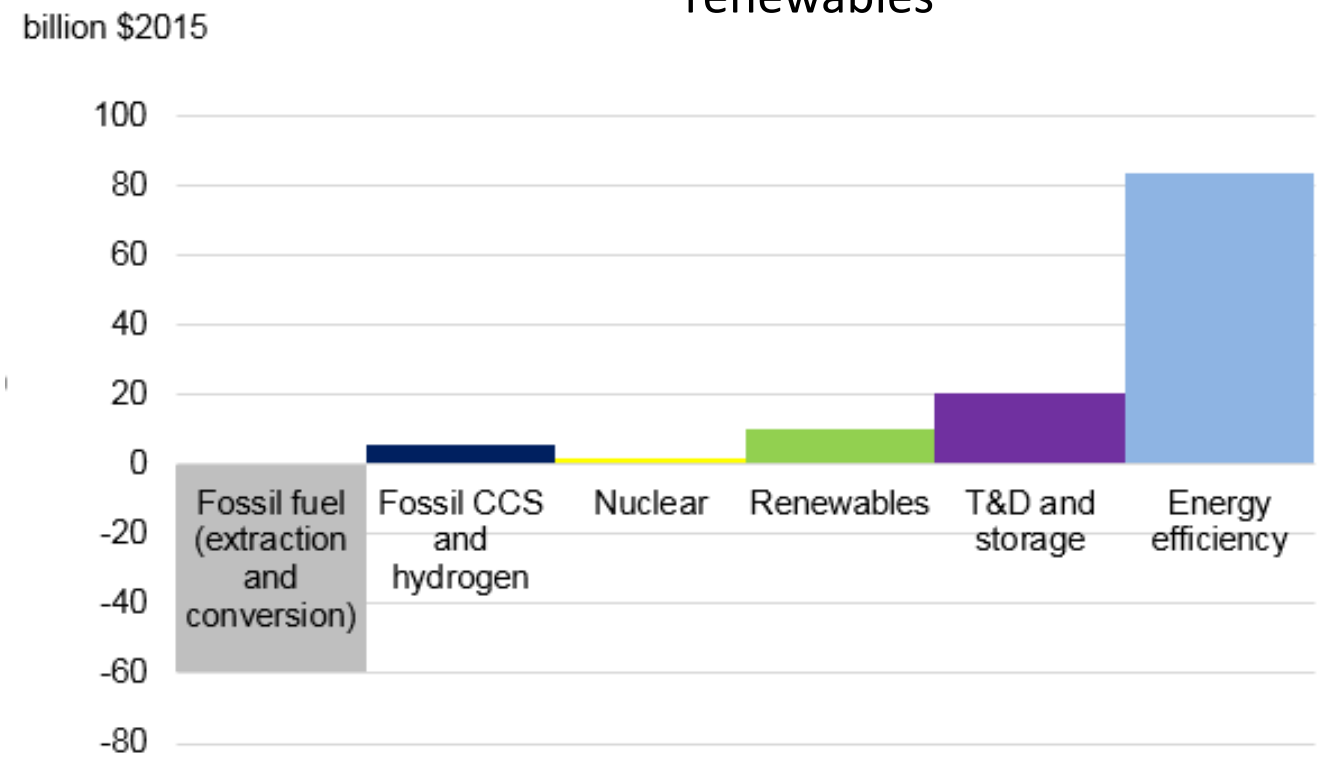
MESSAGE: Preliminary Modeling Results

ENERGY

QL-M2: Cumulative Energy Sector Investments

BMU Region – P2C Scenario vs. Reference
2020 – 2050 in billion US$$_{2015}$$

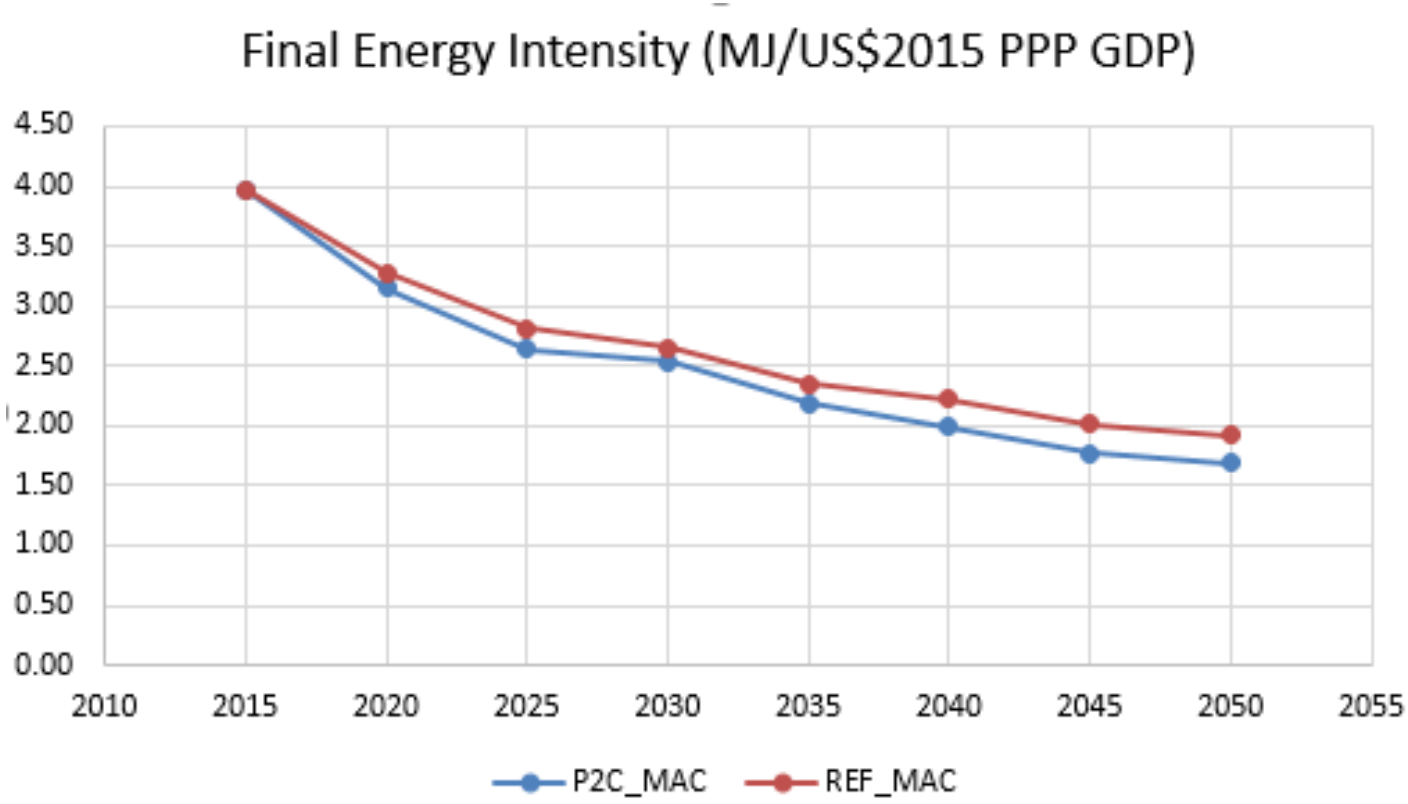
Redistribution of investment mainly from fossil fuels to energy efficiency and renewables



MESSAGE: Preliminary Modeling Results

ES-M2: Final Energy Intensity

BMU Region
ES-M2: Final Energy Intensity



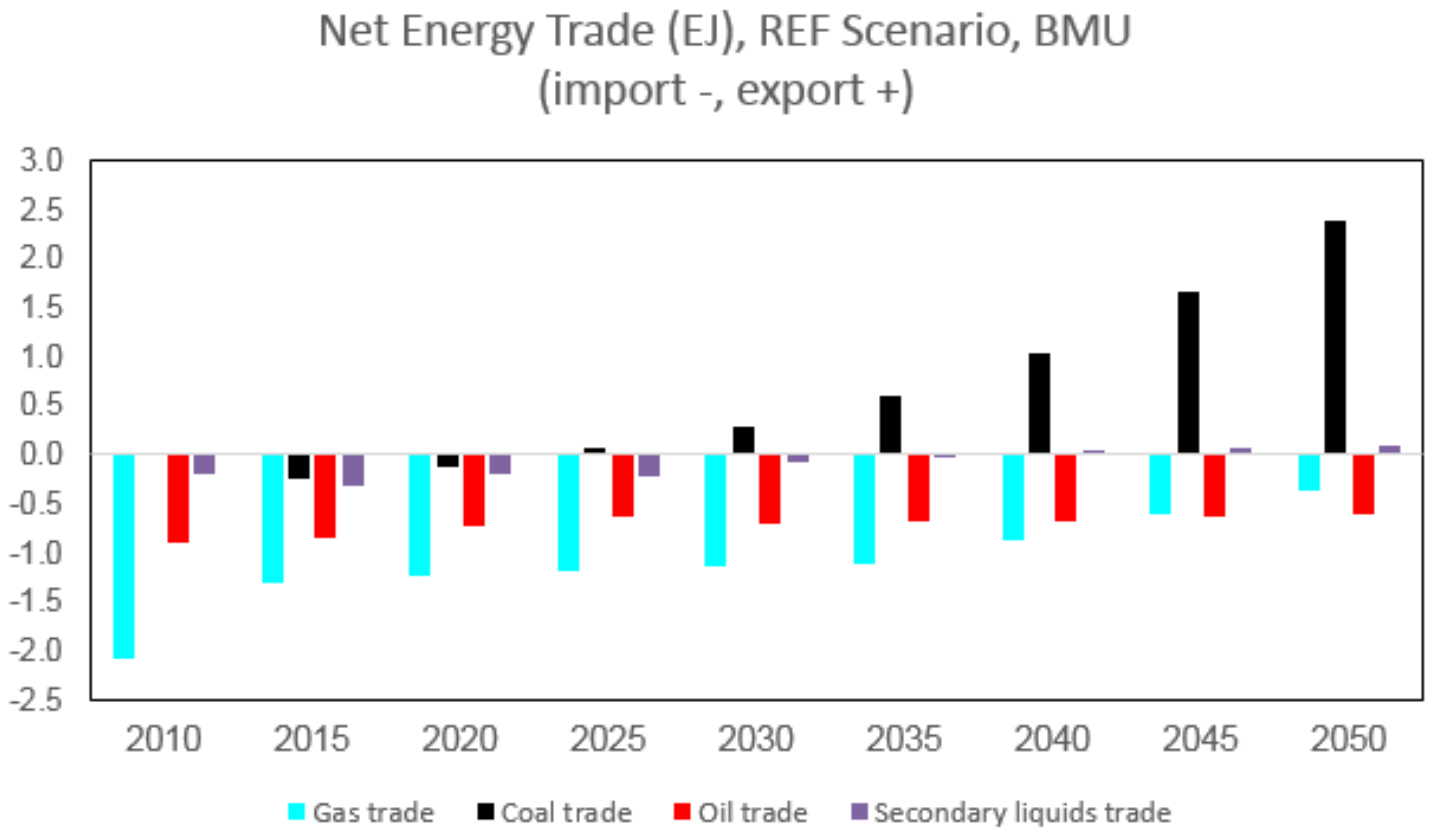
MESSAGE: Preliminary Modeling Results

Modelling of gas trade in BMU Region

- Gas interconnectors from Russia to EU modelled differently through Belarus and Ukraine
- Estimating a “cost of diversification of energy supply” for Russian gas through Ukraine (based on the loss of income in the past and possible penalties)
- Modelling of gas reverse flow from EU to Ukraine
- The decline of trade through Urengoy-Uzhgorod
- Here: we departed from a purely techno-economic analysis

MESSAGE: Preliminary Modeling Results

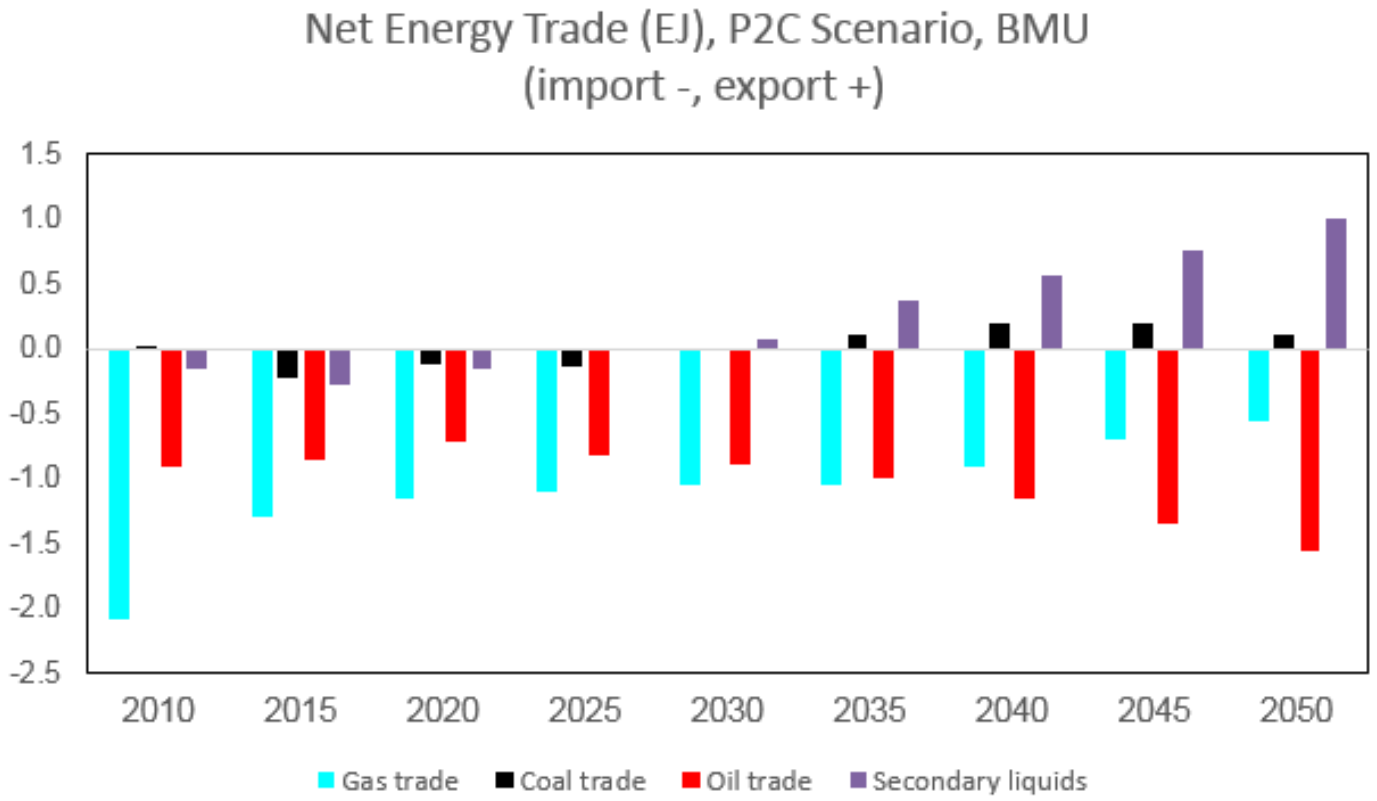
Energy trade in BMU Region



MESSAGE: Preliminary Modeling Results

Energy trade in BMU Region under P2C

- **The 2-degree world shows lower demand for coal and shale gas**



BMU efforts insufficient towards 2C

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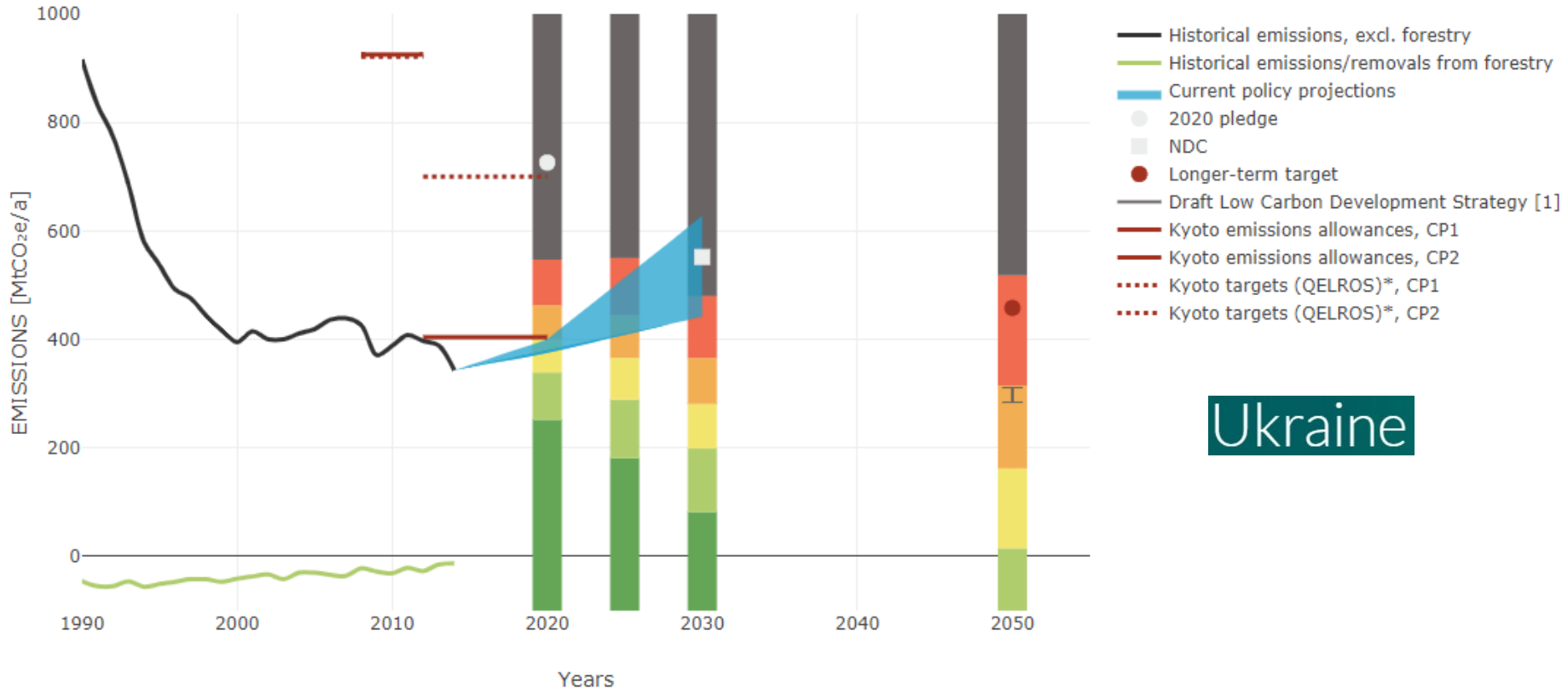
4°C+ WORLD	< 4°C WORLD	< 3°C WORLD	< 2°C WORLD	< 1.5°C WORLD	<< 1.5°C WORLD
CRITICALLY INSUFFICIENT	HIGHLY INSUFFICIENT	INSUFFICIENT	2°C COMPATIBLE	1.5°C PARIS AGREEMENT COMPATIBLE	ROLE MODEL

Commitments with this rating fall well outside the fair share range and are not at all consistent with holding warming to below 2°C let alone with the Paris Agreement's stronger 1.5°C limit. If all government targets were in this range, warming would exceed 4°C.

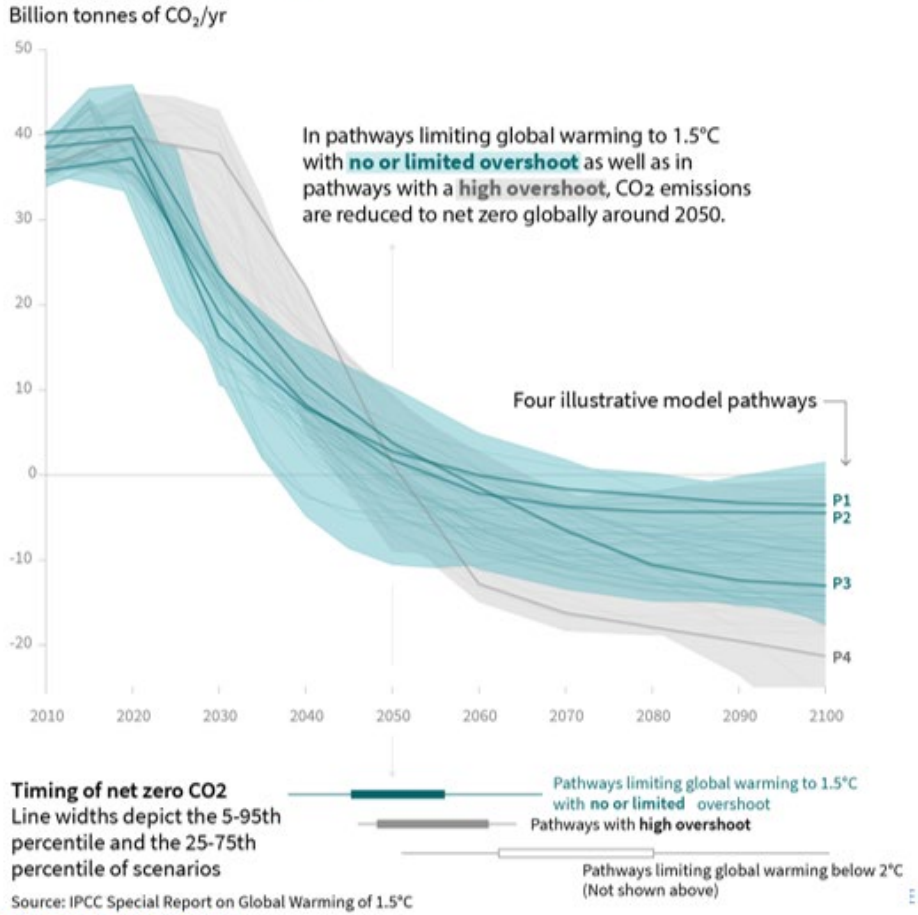


source: https://climateactiontracker.org

Difference between 1.5C and 2C

ENERGY

SPM3a | Global CO_2 emissions pathway characteristics



Source: IPCC Special Report on Global Warming of 1.5°C

ipcc ENTAL PANEL ON climate change

WMO UNEP

Keywan Riahi – LA, Chapter 5 – IPCC SR1.5

Final Notes

ENERGY

- The BMU region is on track towards NDCs but it shouldn't compromise the efforts beyond 2030
- A relatively high energy intensity and the structure of the energy system in in the region favours investments in the improvement of energy efficiency
- The need for flexibility in a future high-renewable scenario in the region can be more optimally met if the countries were in a common power market/system (as we assumed in this study)
- The demand for gas in the rest of the world (mainly in EU) will influence the development of shale gas in the region ➔ under a 2-degree target the region may become more energy-import dependence

Discussion

ENERGY

I. How fast technologies can be taken up or phased out

- What are the implications of the fast phase-out of one old technology?
- Region specific
- Scenario assumptions

II. Integration of variable renewable energy

- What are regional regulations for integration of VRE?
- Capacity value of wind and solar (contribution to peak demand and reserves) in the region
- Flexibility and balancing requirements
- Treatment of curtailment
- The future of the regional power market

III. Regional approaches

- The future of the regional power market

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Pacific Northwest NATIONAL LABORATORY

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Thank you!

Behnam Zakeri on behalf of the Pathways Project Team
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Date 15 I 11 I 2018, Kyiv

BACK-UP SLIDES

List of technologies

Energy Economics 64 (2017) 583–599

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

System integration of wind and solar power in integrated assessment models: A cross-model evaluation of new approaches

Robert C. Pietzcker [a,*], Falko Ueckerdt [a], Samuel Carrara [b], Harmen Sytze de Boer [c], Jacques Després [d], Shinichiro Fujimori [e], Nils Johnson [f], Alban Kitous [i,1], Yvonne Scholz [g], Patrick Sullivan [h], Gunnar Luderer [a]

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[d] Univ. Grenoble Alpes, Grenoble, France
[e] National Institute for Environmental Studies, Tsukuba, Japan
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[g] German Aerospace Center — DLR, Stuttgart, Germany
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[i] European Commission Joint Research Centre

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

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

Consultation and Information Workshop Geneva, 25 Sep 2018

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