Extension of the EU energy and climate modelling capacity to include the Energy Community and its nine Contracting Parties

INTRODUCTION TO THE MODELLING SUITE AND THE PROJECT

PROJECT REFERENCE: ENER/2020/OP/0005

E3Modelling Energy Economy Environment

in cooperation with:

IIASA International Institute for Applied Systems Analysis www.iiasa.ac.at

EuroCARE

TU WIEN TECHNISCHE UNIVERSITÄT WIEN

REKK

Agenda and content

- EC presentation of the project and introduction
- Presentation of the project team
- Presentation of the modelling suite
- Policy support using modelling and scenario construction
- Tasks
- Timeline
- Discussion/AOB

Main objectives of the project

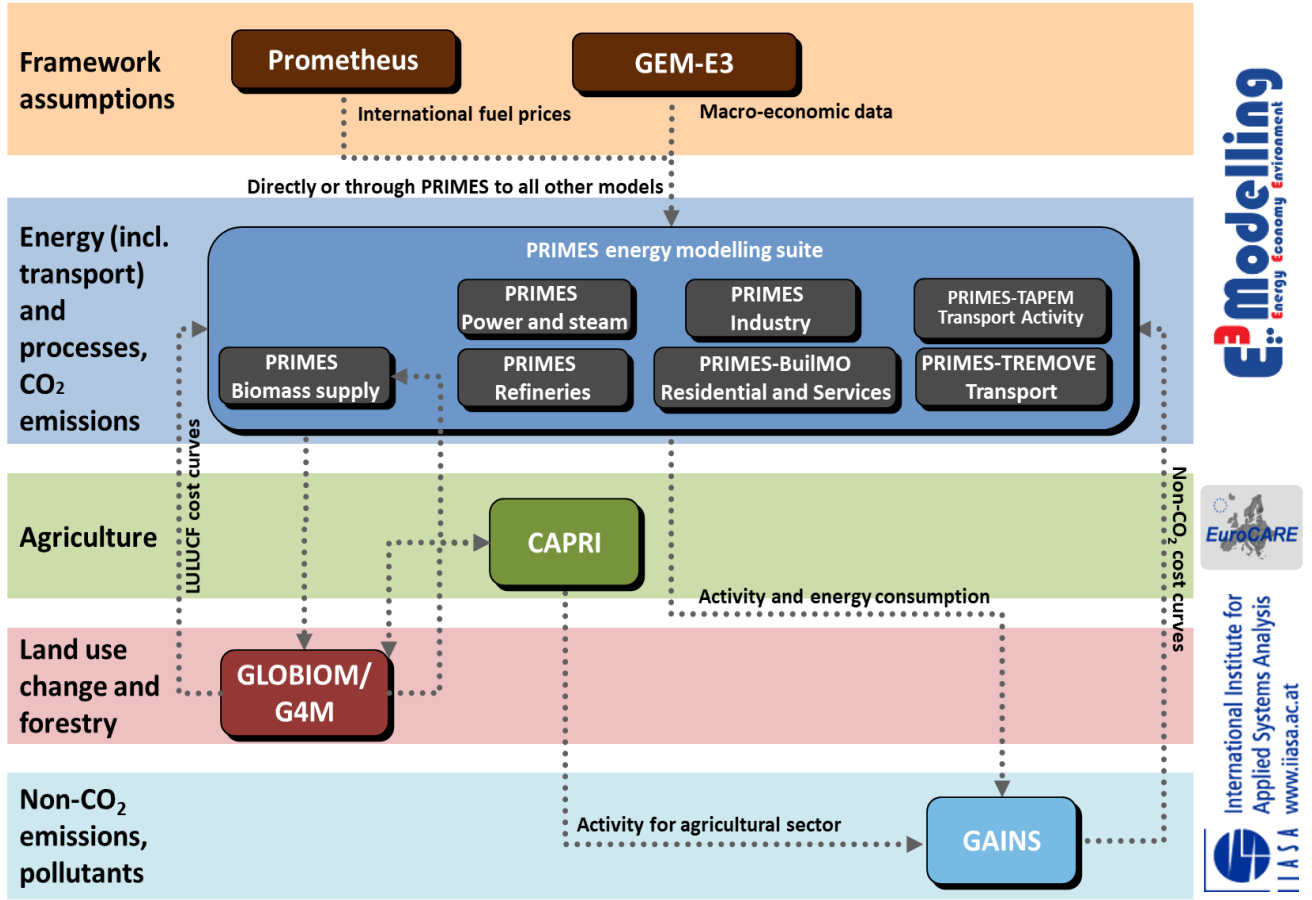
- **Extension** of the EU established **modelling suite** to the Contracting Parties (CPs) of the Energy Community.
- Use of the existing modelling capacity to **develop a baseline and a series of alternative scenarios** in order to examine ***different methodologies and set-ups for energy efficiency, renewables and GHG emissions reduction targets*** for the contracting parties individually and as a group.
- Time horizon: (1990) 2010 – 2070 in 5 year steps. Past years 2010 – 2015 (2020) will match historical statistics
- Interactions with Contracting Party experts to
  - Improve and agree on input data
  - Present preliminary and final results

Presentation of the modelling suite

in cooperation with:

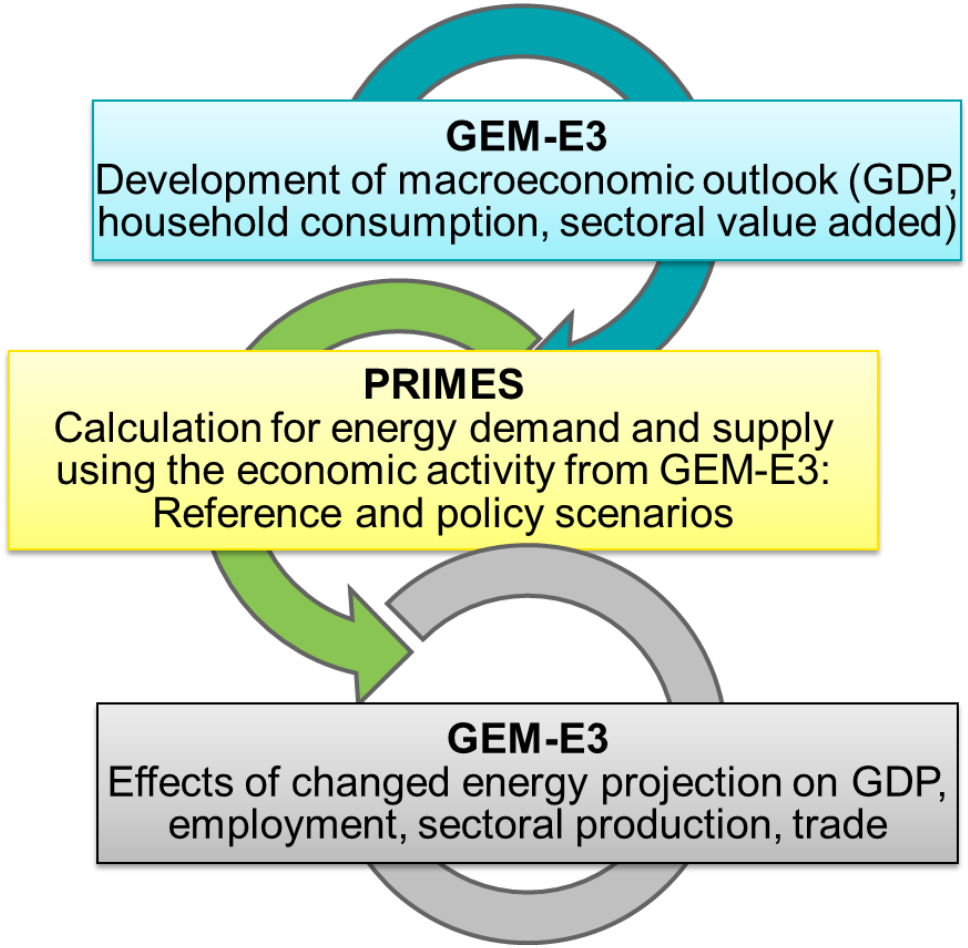
EUCLIMIT modelling suite

- A suite includes many models each focusing on a specific sector: each model follows an approach that is adequate for the sector
- Each model has a very detailed representation of the sectors covered with many fuels/subsectors/etc.
- The modelling suite uses the prices of multiple market equilibrium as explicit drivers of the linkage of the sub-models;
- Models are soft linked with each other
- Inclusion of a large set of policy instruments, covering market and non-market interventions, technology standards, infrastructure development and measures that aim at influencing behaviours
- Used since over 10 years for Impact Assessments in the EU for DG CLIMA (ENER, MOVE, ENV, etc.)
- Partial/Total representation of the Contracting Parties already included in the modelling suite.
  - In the current contract the full expansion will take place
  - Update and new collection of data for the entire modelling suite



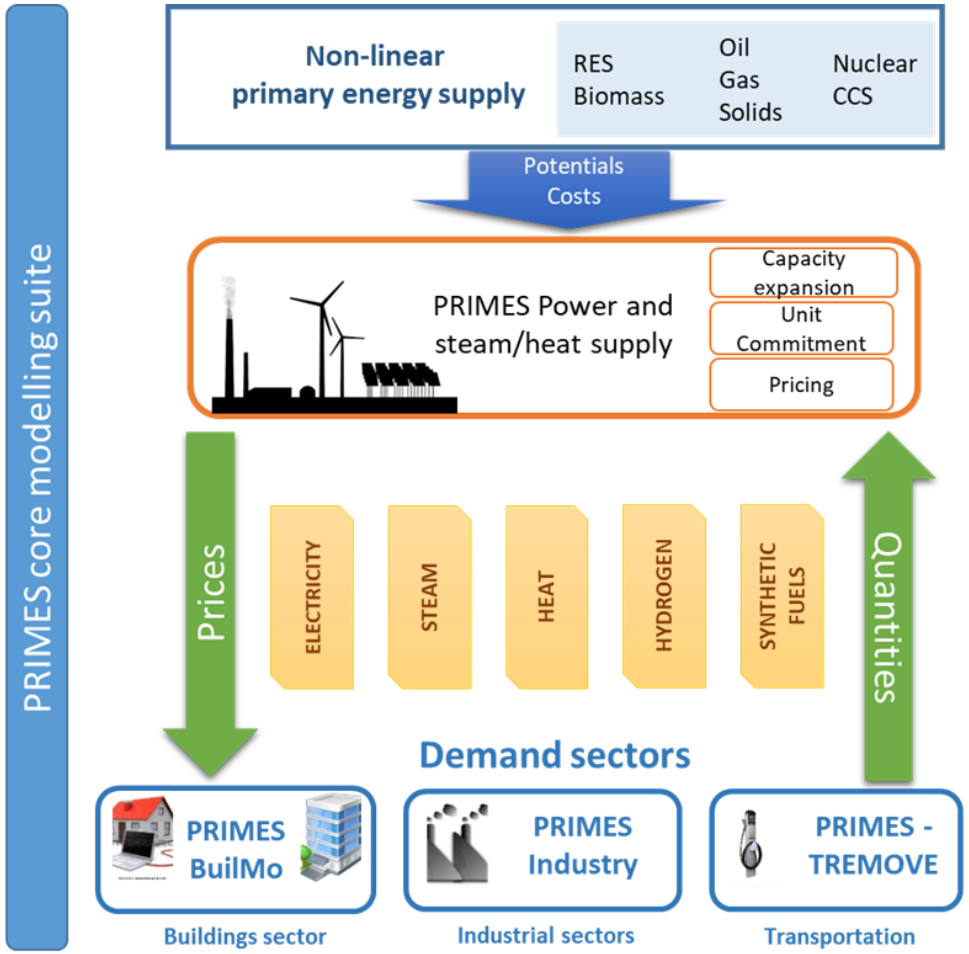
Impact analysis: socio-economic impacts

- Energy system projections and scenario analyses with GEM-E3 to quantify the socio-economic impacts of changed policies (e.g. introduction/change of GHG, RES, EE targets)
  - Reference scenario projections
  - Mid- to long-term Roadmaps
  - Quantification of:
    - Changed GDP
    - Sectoral production/Trade
    - Employment
    - Skill requirements



PRIMES: energy system model

- Model structure:
  - **Modular system:** one module per sector
  - **Microeconomic foundation with engineering representations**
- Aim:
  - Simulate structural changes and long-term transitions
- Focus:
  - **Market-related mechanisms**
  - Representation of **policy instruments for market, energy and emissions**, for policy impact assessment
- Technology database:
  - Energy technology database has a standard format and is open access
  - Latest publicly available: https://ec.europa.eu/energy/sites/ener/files/documents/2018_06_27_technology_pathways_-_finalreportmain2.pdf



Temporal resolution: to 2070, in 5-year time steps
Geographic resolution: 27 EU MS +UK+ *10 European non-EU countries*
Mathematically: concatenation of mixed-complementarity problems with equilibrium conditions and overall constraints (e.g. carbon constraint with associated shadow carbon value) - EPEC

Model coverage

PRIMES power and heat

- Capacity expansion, Unit Commitment, Pricing module
- Power, heat and steam production
  - CHP, boilers, industrial plants, etc
- Database (Europe) includes over **13000** power plants
- Detailed representation of RES including classes for wind and solar
- Represents policies in detail including different types of RES support, facilitation policies,
- Different market design and cross border options can be studied with the model

PRIMES-BuiMo

- Very detailed segmentation of households and dwelling types (270 building types);
- RES, fossil and P2X fuels
- 28 heating and cooling technologies
- Dynamic programming modelling of renovation strategies
- Representation of several non-market barriers, hidden costs and idiosyncratic behaviors
- Detailed portrayal of policies specific comprising economic policies and measures (i.e. taxes-subsidies, white certificates), regulatory instruments (i.e. efficiency standards, eco-design standards) as well as research and development measures
- 5 income classes

PRIMES Industry

- 10 industrial sectors
  - further split in 31 sub-sectors and in total 234 energy uses
  - distinct sectors for primary and secondary (recycling) production
- 22 different fuels, including "new" fuel carriers (hydrogen, biofuels)
- process emissions included
- CCS option is included for all process emissions
- Detailed portrayal of policies specific comprising economic policies and measures (i.e. taxes-subsidies, white certificates), regulatory instruments (i.e. efficiency standards, BAT) as well as research and development measures

PRIMES-TREMOVE

- All transport modes: passenger, freight (also maritime and aviation)
- All fuel types: fossil, biofuels, P2X
- Re-fueling and recharging infrastructure is represented in a stylized manner and its influence on choices
- Transport-related choices with consideration of heterogeneity of agents
- Large number of policies portrayed: CO_2 standards, blending rates and/or mandates by mode and fuel
- *PRIMES biomass: verifies the sustainability criteria and computes prices for biofuels*

Overview of PRIMES modelling approach

What PRIMES can do

- The distinctive feature of PRIMES is the combination of micro-economic foundations with engineering at a fairly high level of detail, compatible with a long-term time scale and sectorial detail of available statistics for Europe
- Designed to provide long term energy system projections and system restructuring up to 2070, both in the demand and the supply sides. Projections include detailed energy balances, structure of demand by sector, structure of power system and other fuel supplies, investment and technology uptake, costs per sector, overall costs, consumer prices and certificate prices (incl. ETS) where applicable, emissions, overall system costs and investment.
- Impact assessment of specific energy and environment policies, applied at Member State or EU level, including
  - Price signals, such as taxation, subsidies, ETS
  - Technology promoting policies
  - Standards
  - Infrastructure
  - RES supporting policies
  - Efficiency promoting policies
  - Environmental policies
- The linked model system PRIMES and CAPRI (EuroCARE), GAINS (IIASA) and GLOBIOM (IIASA) (for non-CO2 gases, air quality, biomass resources and land use) cover all GHGs.

What PRIMES cannot do

- Cannot produce short-term forecasts as it is not an econometric model (so projections are not statistically based on past observations, which in PRIMES are only used for parameter calibration).
- It is a partial equilibrium model, not performing closed-loop energy-economy equilibrium analysis, unless linked with a macroeconomic model such as GEM-E3.
- PRIMES lacks spatial information at a subnational level and so lacks details about distribution and transport infrastructure and flows that depend on spatial information (except electricity and gas flows over a country-to-country based grid infrastructure, which is represented in PRIMES).
- PRIMES considers infrastructure exogenously in all sectors. Also PRIMES considers learning by doing exogenously (except for the Biomass module), but varies assumptions across scenarios to represent “enabling conditions”.
- PRIMES is an empirical numerical model with emphasis on sectoral and country specific detail; it has a very large size and so some compromises were necessary to limit computer time at reasonable levels. In this sense, although rich in technology representation, the modules of PRIMES are far more aggregated than pure engineering models.

PRIMES typical inputs and outputs

Input

- GDP and economic growth per sector (many sectors) –GEM-E3
- World energy supply outlook – world prices of fossil fuels – PROMETHEUS (or POLES)
- Taxes and subsidies
- Interest rates, risk premiums, etc.
- Environmental policies and constraints
- Technical and economic characteristics of future energy technologies
- Energy consumption habits, parameters about comfort, rational use of energy and savings, energy efficiency potential
- Parameters of supply curves for primary energy, potential of sites for new plants especially regarding power generation sites, renewables potential per source type, etc.

Process

PRIMES model

(PRice-Induced Market Equilibrium System)

Performs iterations of demand and supply through explicitly calculated prices

Output

- Detailed energy balances (EUROSTAT format)
- Detailed demand projections by sector including end-use services, equipment and energy savings
- Detailed balance for electricity and steam/heat, including generation by power plants, storage and system operation
- Production of fuels (conventional and new, including biomass feedstock)
- Investment in all sectors, demand and supply, technology developments, vintages
- Transport activity, modes/means and vehicles
- Association of energy use and activities
- Energy costs, prices and investment expenses per sector and overall
- CO2 Emissions from energy combustion and industrial processes
- Emissions of atmospheric pollutants
- Policy Assessment Indicators (e.g. imports, RES shares, etc.)

GEM-E3

- GEM-E3 is a multi-country computable general equilibrium model built to evaluate the economic impacts of structural policies and mainly the interactions between the economy, the energy system and the environment (including technological progress)
- GEM-E3 is a modelling framework simultaneously representing European countries (including all MS), linked through endogenous bilateral trade and environmental flows; a World version of the model is also available
- The model will be extended to cover the contracting parties individually and requires:
  - Input-output tables
  - Bilateral trade data:

GAINS

- GAINS provides a bottom-up assessment framework for simulation/optimization of strategies to reduce emissions of multiple air pollutants (SO_2, NO_X, $PM_{2.5}$, BC/OC, VOC, CO, NH_3) and greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6) at least costs, and minimize their negative effects on human health, ecosystems and climate change.
- Within the EUCLIMIT consortium, GAINS has provided projections and marginal abatement cost curves for non-CO_2 gases CH_4, N_2O and F-gases, and impact assessments for air pollutants SO_2, NO_X, $PM_{2.5}$, BC/OC.
- GAINS is operated at the country-level, identifying several hundred emission source sectors and about 2000 emission control technologies, and produce annual estimates of emissions, abatement potentials and marginal abatement cost curves in five-year intervals from 1990 to 2050 (to 2070 for Europe).
- GAINS relies on input of externally produced scenario projections for the energy and agricultural sectors. Within the consortium GAINS imports this from PRIMES (energy) and CAPRI (agriculture)
- GAINS is open source and can be accessed here: http://gains.iiasa.ac.at/models/index.html

E3Modelling Energy Economy Environment

GAINS –Examples of data requirement

- Data availability for historical years, preferably 1990-2020 (1970-2020 for solid waste)

Source Activities	Type of information	Units (examples)
Livestock	Livestock numbers (Dairy cows, non-dairy cattle, pigs, sheep etc.) Milkyield	[1000 heads] [kg/head]
Agricultural waste burning	Burning of agricultural field residues	[Mt residues burned]
Soils	Mineral fertilizer use Crop residues to fields Histosols	[kt N input] [kt N input] [M ha]
Fossil fuel production and transportation	Abandoned coal mines Long-distance gas transmission	[kt CH4] [PJ gas transmitted]
Industrial processes	Production of Nitric acid, Adipic acid, Caprolactam Primary aluminium production Magnesium production Semiconductor production HCFC-22 production	[kt produced] [kt produced] [kt produced] [PFCs in kt CO2-eq] [t HCFC-22 produced]
Municipal solid waste Industrial solid waste	Municipal solid waste, whereof waste type (food/paper/textile/wood/...) Manufacturing industry solid waste by industry (food/pulp&paper/textile&footwear/wood)	[kt waste -gross[1]] [kt waste -gross[1]]
Waste treatment streams	Share of MSW food waste to anaerobic digestion and to composting Share of MSW paper waste recycled Share of mixed MSW incinerated Share of MSW openly burned Share of MSW to landfills (managed/unmanaged) Share of food industry waste to anaerobic digestion and to composting	[% of MSW food waste] [% of MSW paper waste] [% of MSW] [% of MSW] [% of MSW] [% of food industry waste]
Domestic wastewater Industrial wastewater	Population with centralized/decentralized wastewater collection Production volumes or COD content by industry (food, pupl&paper, other organic industry)	[1000 people] [kt COD]
Refrigeration and cooling	Commercial AC, Residential AC, Mobile AC, Commercial refrigeration, Industrial regrigeration, Refrigerated transport, Domestic refrigeration)	[t refrigerant stored in equipm.]
Other F-gas sources	Aerosols, Foams, Heat pumps, Fire extinguishers, Solvents, High- and mid voltage switches, etc.	[t F-gas consumed]

GLOBIOM-G4M

GLOBIOM

- **Partial equilibrium land-use model**
  - Agriculture, forestry, and bioenergy sectors
- **Bottom-up approach**
  - Global coverage with detailed spatial resolution
  - 6 different land use types
  - Explicit description of production technologies by grid cell
  - Bilateral trade flows
  - Standard EU version has 58 regions
  - flexible re-aggregation of regions
- **Linear programming approach**
  - Maximization of consumer and producer surplus
  - Optimization constraints

G4M

- **Economic forest sector model**
- **Bottom-up approach**
  - global coverage, spatially explicit.
- Projects **changes in forest area** (afforestation, deforestation)
- Estimates the **impact of forestry activities** (afforestation, deforestation and forest management) on harvestable biomass and forest **carbon stocks**.

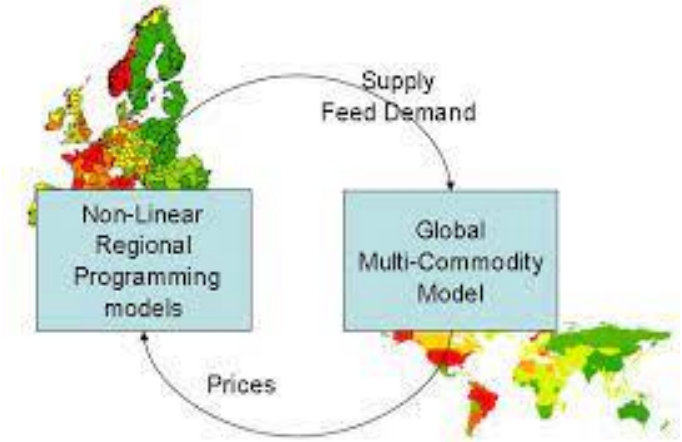
GLOBIOM-G4M – expected challenges

- Data availability at national level or spatially explicit for historical years (1990 onwards) to calibrate model & validate projections
  - Bio-physical: yields/increment, age-class structure, carbon stocks etc.
  - Economic: area developments, production & consumption, prices etc.
- Singling out of Kosovo, Montenegro, and Serbia for which usually no 2000 (model base year) data are available, will be most challenging and more data intensive. Remaining countries should be more straightforward if data is available.
- GHG reporting: LULUCF projections are usually calibrated to UNFCCC data, CRF tables are only available for Ukraine

CAPRI model

CAPRI is an agricultural sector model comprising two components that iterate during solutions

- supply module covering supply of EU regions
- market module covering supply of non-EU regions and demand for all regions



supply module

- independent non-linear regional agricultural programming models
- depicts agriculture on activity level in detail with nutrient balances for crops and livestock
- ex-ante impact assessment of agricultural, environmental (incl GHG) and trade policies
- covers EU-27, UK, Norway, Turkey at NUTS2 level and 6 Western Balkan countries (only country level)

market module

- simulates supply, demand, and price changes in globally in about 40 “trade regions” disaggregated into 80 “market regions
- Bilateral trade and trade policies between “trade regions”
- about 60 agricultural raw and processed products (e.g. beef, pork) but no activities (no cattle, pigs etc)
- Georgia and Modova belong to „FSU“ trade region; Ukraine is single trade region

CAPRI challenges

Task 1 / Task 5: Collection of quality data for all nine CPs

- Different coverage in databases and international sources
  - Western Balkan countries are covered based on past projects
    => Only update and validation
  - Ukraine is an important single market region in CAPRI and it is an Annex 1 country in UNFCCC
    => updates, validation, estimations for activity data, hopefully straightforward
  - Georgia and Moldova are smaller countries (weak FAO data?) and not Annex 1 countries in UNFCCC
    => more intensive data work probably needed

Task 2 / Task 5: Modelling of Baseline scenario for all nine CPs

- Also collecting, assessing, incorporating national projections / expectations on agriculture
- Linking CAPRI model variables to agricultural activity data to obtain suitable input for GAINS

Task 4 / Task 5: Policy scenarios

- Presumably only minor role for CAPRI, as mitigation modelling will occur in GAINS

Policy support using modelling and scenario construction

in cooperation with:

Energy Systems Analysis

- It is a multi-disciplinary applied scientific field based on: economics, operations research and engineering
- Its' distinguishing feature is considering the energy sector as a whole – as a system, as opposed to sub-sector approaches, like power economics, petroleum economics, etc.
- The goal is to aid decision making: energy policy analysis, impact assessments, cost-benefit evaluation, pricing and investment planning
- Often the analysis considers the interactions with other systems: Energy-Economy-Environment Systems Analysis
- Usually it aims at providing quantitative results and is data intensive
- Usually it uses mathematical models as a way of approaching complex problems, emphasizing comprehensive rather than partial analysis

Main Objectives

- Understanding inter-fuel substitution
- Closed-loop energy demand and supply through market competition
- Trade-offs between demand-side and supply-side energy investment
- Understanding behaviour of agents and the influence of policy instruments
- Energy system chains (e.g. hydrogen economy versus electricity economy)
- Close the loop energy and economy

Problem Solving

- **Systems Simulation**: understanding, training
- **What if questions, impact assessment**: policy analysis, investment evaluation
- **Normative analysis, optimization**: policy and investment recommendation
- **Forecasting – projections** of demand, prices, technology penetration, etc.
- **Scenario construction and comparison of scenarios**: exploration of uncertain futures and policy analysis

Policy support using PRIMES

Basic approach

- PRIMES include a rich representation of policy instruments and measures.
- A scenario is a projection into the future which includes explicit assumptions regarding policies
- Causalities in the model depend on policies and desired outcomes cannot be imposed but only induced by appropriate policies
- Usually, a scenario includes groups-collections of policies
- Impact assessment of policies draws on comparisons of scenario projections, which differ regarding policy options
- Normative support using the model also relies on scenario comparisons

Price or market-based policies

- Taxation is specific to fuels, sectors and countries. The data draw on the EU taxation directives.
- Exogenous subsidies may apply on all levels of costing
- Cap and trade mechanisms: Emission Trading Scheme, green and white certificates; grandfathering and auctioning with different provisions by sector covered.
- Feed-in tariffs and other renewable support schemes
- Net metering for self-generation
- Cogeneration support schemes
- Price caps, grid tariffs and social prices
- Contract for differences

Targets and Policy Indicators

- Targets: they can be directly included in the model at various level, by sector, by country, and EU-wide
- The targets concern emissions, renewables, energy efficiency, security of supply, fossil fuel independence, and others.
- Performance against targets derives from scenario projections
- Achievement of targets usually requires several model runs
- A target usually conveys shadow values to the decision-making problems of agents.
- The PRIMES output reports include a large number of policy indicators, and specifically those provided for in the legislation

Non-market based and behavior-oriented policies

- Institutional mechanisms and regulations that may induce lower interest rates and lower perception of risks by individual investors; largely applied for modelling energy efficiency policies and other policies that concern decisions by individuals.
- Regulations and policies that address market failures and/or enable tapping on positive externalities (e.g. technology progress) which induce reduction of cost elements (technology costs) and improve perception by consumers leading to lower subjective cost components.
- Policies facilitating or restricting potential of fuels, sites etc.

Policy support using PRIMES

Technology standards (efficiency or emission performance)

- Standards that promote or eliminate certain technologies or options in various sectors
  - Eco-design standards in detail
  - Best Available Techniques
  - Emission standards or efficiency standards in all demand sectors (overall or by type of equipment)
  - Large combustion plant directives
  - Fuel quality regulations
  - Blending mandates
  - Reliability and reserve standards (power and gas sectors)

Enabling conditions

- A general policy context and specific measures (e.g. infrastructure, standards, R&D) inducing reduction in technology costs, removal of non-market barriers, decrease in perceived costs and uncertainty, and thus enabling faster uptake of advanced technologies and structural changes.
- An ambitious decarbonisation scenario usually includes enabling conditions
- Other more specific examples are:
  - Ambitious renovation program for buildings
  - Recharging infrastructure and electrification in transport
  - Blanding mandates and infrastructure for alternative fuels
  - Agriculture policies enabling feedstock development for advanced biofuels

Infrastructure

- Policies regarding permission or restriction of power and other technologies, for example for nuclear, CCS etc.
- Policies regulating extension of lifetime of power plants
- Infrastructure policies for distribution of fuels
- Interconnection infrastructure (electricity and gas) influencing the possibilities of trade in the EU internal market

<u>Coverage of infrastructure:</u>

- Power interconnectors, including expansion to remote areas for RES (e.g. wind offshore), and options for allocation of capacities
- Power grids and smart systems within countries, which are not spatially represented but only through reduced-form cost-possibility curves, considered as facilitators of RES, self-generation and demand-response
- Gas transport, LNG, storage and liquefaction infrastructure
- Refueling and recharging infrastructure in all transport modes
- CO2 transport and storage infrastructure
- Transport infrastructure parameters influence mobility and modal shifts but modelling does not include spatial information (limited to urban, semi-urban and inter-urban)
- Hydrogen transport and distribution infrastructure (various types of carrying H2 without spatial modelling)
- Heat-steam district heating infrastructure (no spatial modelling)

Timeline

Project Timeline

	January-21	February-21	March-21	April-21	May-21	June-21	July-21	August-21	September-21	October-21	November-21	December-21
Task 1: Collection of quality data for all nine CPs												
Economic data												
Energy data												
Agriculture												
Non-CO2												
LULUCF												
Task 2: Modelling of Baseline scenario for all nine CPs												
Model preparation												
Economic outlook												
Energy outlook												
Agricultural outlook												
Non-CO2 outlook												
LULUCF outlook												
Rerun												
Final baseline delivery						x						
Task 3: Development of methodology for target setting												
Establishment of a methodology for setting of targets												
Review of the methodology with client (and stakeholders)												
Finalisation of the methodology												
Task 4: Development of policy scenarios/variants for all CPs												
Task 5: Interactions with CPs' experts and the EnC Secretariat												

Deliverables

Deliverables	January-21	February-21	March-21	April-21	May-21	June-21	July-21	August-21	September-21	October-21	November-21	December-21
Inception report	X											
Progress report							X					
Draft final report									X			
Final report											X	

Other Information

in cooperation with:

Data sets and information requirements

- Contracting parties will receive data templates for all information required by the models:
  - Initially partly empty to familiarise with data structured
  - Pre-filled by country before the meeting on 23rd February
- A questionnaire to inform modellers about the policies/measures in place in countries
- Based on the information requested any additional data will be very helpful to the modellers

THANK YOU in advance for your collaboration!