Climate Considerations in the International Energy Outlook 2023 (IEO2023)

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Executive Summary

When developing our *International Energy Outlook* (IEO) cases, we include only existing climate laws and regulations that can be reasonably quantified using our World Energy Projection System (WEPS). Our IEO cases can serve as a basis to assess future energy policy.

Background

EIA's *International Energy Outlook 2023* (IEO2023) presents our long-term analysis of global energy markets across various fuels, technologies, and end-use sectors through 2050. We develop the IEO using WEPS, an integrated economic model, which captures long-term relationships among energy supply, demand, and prices across regional markets. Inputs to WEPS include various assumptions addressing the future uncertainty of technological developments, demographic changes, economic trends, and resource availability, such as oil prices and rates of GDP growth.

Climate laws are an important economic consideration because they play an increasing role in shaping long-term energy consumption and production patterns. A number of net-zero and fossil-fuel-reduction goals and policies have been announced since IEO2021, which was published on October 6, 2021. These goals and policies are especially prevalent in OECD countries and in the electricity and industrial sectors. These policies have a number of energy market impacts:

- Some laws directly limit fuel consumption or production. For example, a carbon emissions cap means that the total amount of fuel used in a market cannot exceed the cap via emissions produced by that fuel's end use. A vehicle tailpipe emission (fuel consumption) standard would similarly require fuel consumption limits.
- Some laws affect behavior, such as a price penalty (tax) for higher-carbon behaviors or an economic incentive for implementing lower-carbon technologies.

The IEO2023 cases include both policy types—policies that directly or indirectly target energy-related carbon dioxide emissions—as they relate to energy markets and where modeling allows. The energy sector components of a country's Nationally Determined Contributions (NDCs) are included where they're codified in laws and regulations.

The WEPS model only represents emissions released from fossil fuel combustion related to energy use. Policies aimed at creating emissions sinks (such as forestry policies) and greenhouse gases (such as methane) aren't accounted for in our projections.

As countries enact climate-related policies, our model projects an increased prevalence of higher-efficiency technologies, which offsets the growth rate of overall energy consumption. In addition, during the projection period (2022–2050) it becomes more economically favorable to use less carbon-intensive sources of energy to meet demand. In summary, active climate policies are meaningful, relevant, and timely inputs to our IEO.

We include existing international climate laws and regulations in our IEO2023 cases. Because our climate policy assumptions reflect current laws and regulations, they remain the same across all modeled cases in IEO2023. In some regions, the distinction between policy statements and law is not

clear. In these cases, our analysts use their best judgment, based on their expertise in those areas. Analyst judgement may incorporate many considerations, including:

- A country's previous history in achieving policy statement requirements
- A country's financial ability to achieve policy statement requirements
- A country's economic incentives related to policy statement requirements
- Existing contracts (for example, liquefied natural gas)
- Regional trade flows

How Does WEPS Include Climate Policy in IEO2023?

WEPS is the series of macroeconomic, consumption, transformation (including electricity and district heat), supply, and emissions modules we use to produce the IEO. The WEPS Greenhouse Gases Module calculates energy-related carbon dioxide emissions based on projected fuel combustion.

For IEO2023, we divided the world into 16 regions generally based on geographic proximity. A region can contain one or more countries.

Because individual countries set their respective climate policies, in the multi-country regions, the climate policies of individual countries are more challenging to represent. In these cases, the effects of one country's climate policies may be lessened or obscured by the energy consumption trends in other countries in that multi-country region.

The climate policies implemented in WEPS are specific to each module. A list of the modules and their respective treatments of climate-related policies is outlined below. In IEO2023, economy-wide policies are captured in a piecewise manner with each sectoral module capturing its components of the policy based on offline decisions. WEPS2023 does not include a cross-module carbon broker or optimization.

Macroeconomic activity

The WEPS Global Activity Module (GLAM) projects economic driver variables for the supply, demand, and conversion modules of WEPS. GLAM's baseline economic projection contains the economic assumptions used in WEPS to help determine energy demand and supply.

Economic growth in the IEO is based on Oxford Economics' market assessments, including its assessment of how climate-related policies affect macroeconomic trends. The IEO2023 uses the February 1, 2023, Global Economic Model and the March 1, 2023, Global Industry Model baselines.

Features specific to climate policy in GLAM include:

- This module calculates fixed economic impacts to productivity per capita based on temperature changes calculated from Oxford Economics' emission assumptions (factors developed externally to WEPS).
- This module also reflects codified carbon taxes (for example, the European Union's Emissions Trading System) and accounts for tax revenues from such policies in government budgets that could affect incomes and investment.

Transportation

The WEPS Transportation Module projects the amount of energy that is consumed to provide passenger and freight transportation services. Underlying the energy consumption projections are projections of energy service demand and energy efficiency by travel mode. The transportation module projection reflects the overall assumption that the total amount of energy consumed by transportation services is determined by the total amount of service provided (passenger-miles or ton-miles) along with the average efficiency of the service.

Features specific to climate policy in the transportation module include:

- Carbon tax policy is reflected in this module through fuel price.
- Other assumptions in this module include:
  - Light-duty electric vehicle sales requirements, sales targets, tax credits, and rebates
  - Fuel economy standards for light-duty vehicles
  - Fuel economy standards for freight trucks
  - Efficiency improvements for aircraft
  - Efficiency improvements for maritime vessels

Industrial

The WEPS Industrial Demand Module projects the amount of energy that is directly consumed as a fuel or as a feedstock by industrial processes and activities. The following factors determine industry energy consumption changes over time:

- Changes in industrial gross output, defined as the total dollar value of services provided by a given industrial sector, adjusted to reflect purchasing power parity
- Changes in energy intensity, defined in thousand British thermal units (Btu) of energy consumed per U.S. dollar of gross output
- Sustained changes in industrial energy prices

Increased industrial gross output generally leads to higher consumption, and sustained fuel price increases will encourage some fuel switching and efficiency improvements.

Features specific to climate policy in the industrial module include:

- Carbon tax policies are represented by fuel price.
- Fuel demand will change based on changing fuel prices.

Buildings (residential and commercial)

The WEPS Residential Demand Module projects energy consumption in households, excluding motor vehicle fuel consumption, which is covered in the Transportation Demand Module. To project household energy consumption, we assume that four factors determine consumption changes over time:

- Changes in household income
- Changes in retail residential energy prices
- The sensitivity of energy consumption to changes in income and prices
- A linear trend

Increased income generally leads to higher consumption, and price increases generally lead to consumption declines.

In the Residential Demand Module, energy consumption's sensitivity to changes in income and prices varies by region, fuel, and time period and is represented by an elasticity parameter. The linear trend accounts for other factors, such as increases in the availability of electricified household goods in developing countries, as well as conservation efforts, policy effects, and energy efficiency improvements.

To project commercial energy consumption, we assume that four factors determine consumption changes over time:

- Changes in services gross output, defined as the total dollar value of services provided by commercial establishments, adjusted to reflect purchasing power parity
- Changes in commercial energy prices
- The sensitivity of energy consumption to changes in services gross output and prices
- A linear trend

In the Commercial Demand Module, the sensitivity of energy consumption to changes in services gross output and prices varies by region, fuel, and time period and is represented by an elasticity parameter. The linear trend accounts for other factors such as energy efficiency improvements, energy conservation efforts, and policy effects.

Features specific to climate policy in the buildings modules include:

- Building and appliance efficiency standards are implicitly incorporated.
- Demand elasticities are included for each fuel.
- Carbon tax policies are reflected in these modules by fuel price.

Electricity

The International Electricity Market Module (IEMM) projects:

- Electricity-generating capacity, including additions and retirements
- Electricity generation
- Electricity added and removed from storage
- Electricity sold and purchased
- Electricity delivered to consumers
- Fuel consumed in electricity generation
- Carbon dioxide emissions
- Electricity prices

This module projects these quantities by minimizing an objective function, subject to several constraints. The objective function represents the total cost for electricity suppliers to meet all electricity demands, by year and time slice, as projected by the WEPS demand modules.

Features specific to climate policy in the electricity module include:

- A country's carbon taxes and carbon caps are incorporated
- A country's electricity sector targets (for example, capacity, generation, and consumption shares originating from renewable energy sources) that are enacted legislation are incorporated

District heat

The District Heat Module estimates district heat generation and the amount of fuel consumed for district-heat generation annually by region and fuel type over the projection period. The module uses a stock-flow approach in which new heat generation is added each year as necessary, based on the heat generation requirement from the end-use demand sectors. The District Heat Module can simulate compliance with analyst-specified minimum or maximum targets for heat generation from specific fuels. For each region, if a generation target is specified, the module first determines whether the target is a single-fuel target or a combined renewable energy target.

Features specific to climate policy in the District Heat module include:

- Carbon tax policies are reflected in this module by fuel price.
- Input assumptions include:
  - Heating fuel targets and limits that are enacted legislation
  - Combined-heat-and-power targets

Coal

The WEPS International Coal Market Module (ICMM) projects coal production, imports, exports, and prices by region and coal commodity type for the WEPS. The data preprocessor submodule reaggregates data from different sources that use different regional and coal commodity subdivisions. The coal supply submodule estimates coal supply curves. The logistics submodule uses the supply curves to project coal prices. The data postprocessor submodule communicates ICMM results to the rest of WEPS.

The logistics submodule is a linear program where the objective function represents profits from coal shipments from the supply regions to the demand regions. This submodule projects the price of the different coal commodities in the demand regions, the trade quantities of each trade route, and coal

production, based on the supply curve response. Because the objective function represents profits, the submodule determines the trade routes with the lowest transportation rates and the supply regions with the lowest supply prices to provide demand with the lowest delivered cost, thereby maximizing profit.

Features specific to climate policy in ICMM include:

- Coal supply is responsive to coal demand requirements, which reflect policies in the industrial, electricity, and buildings modules, as appropriate.
- The adjusted cost of coal production and the transportation rate is based on new taxes or restrictions on coal mining output that might be imposed on a country or region.

Hydrocarbon supply

The World Hydrocarbon Activity Model (WHAM) projects:

- Production of upstream natural gas, natural gas plant liquids, and crude oil by type
- Energy used in upstream production and in natural gas transmission
- Refinery activity, which includes natural gas consumption and converting crude oil into refined products
- Petroleum product and natural gas end-use prices by WEPS region and sector
- Spot prices for crude oil and natural gas in select markets

WHAM is made up of two parts: an optimization module coded in AIMMS and an integration wrapper written in Python that connects the module to the greater World Energy Projection System (WEPS).

Features specific to climate policy in WHAM include:

- Biofuel estimates—which include biomass-based diesel and ethanol—generally reflect a country's carbon-reduction policies.
- We make assumptions concerning biofuel blending for renewable diesel, biodiesel, and ethanol, which are represented in the module's production of these fuels. We don't model production of sustainable aviation fuel.
- We do not restrict production, trade, or refining of natural gas or crude oil based on carbon policies. If an activity is economical, based on the assumptions in the model, we allow it to occur.
- Oil and natural gas supply is responsive to demand requirements, which reflects policies in the other modules as appropriate.

What Uncertainties and Future Work Remain?

We have several possible pathways for future development in subsequent IEOs. We are currently monitoring and actively improving our understanding of:

- How to reconcile a country's policy goals with inconsistent past performance
- How to model and incorporate emerging technologies, such as hydrogen

- How to model new policies and new policy mechanisms that aren't easily incorporated in the WEPS framework

Future international energy developments are subject to significant uncertainties outside of the energy realm. Political developments (for example, elections and political initiatives) can significantly influence policies that alter the outlook for new technology development and adoption. In addition, energy security and other noneconomic considerations can play significant roles in global energy projections.