



Sphera Energy LCI Modelling – 2024

February, 2024



Dr. Oliver Schuller
Director Consulting
Team Lead Energy & Mobility

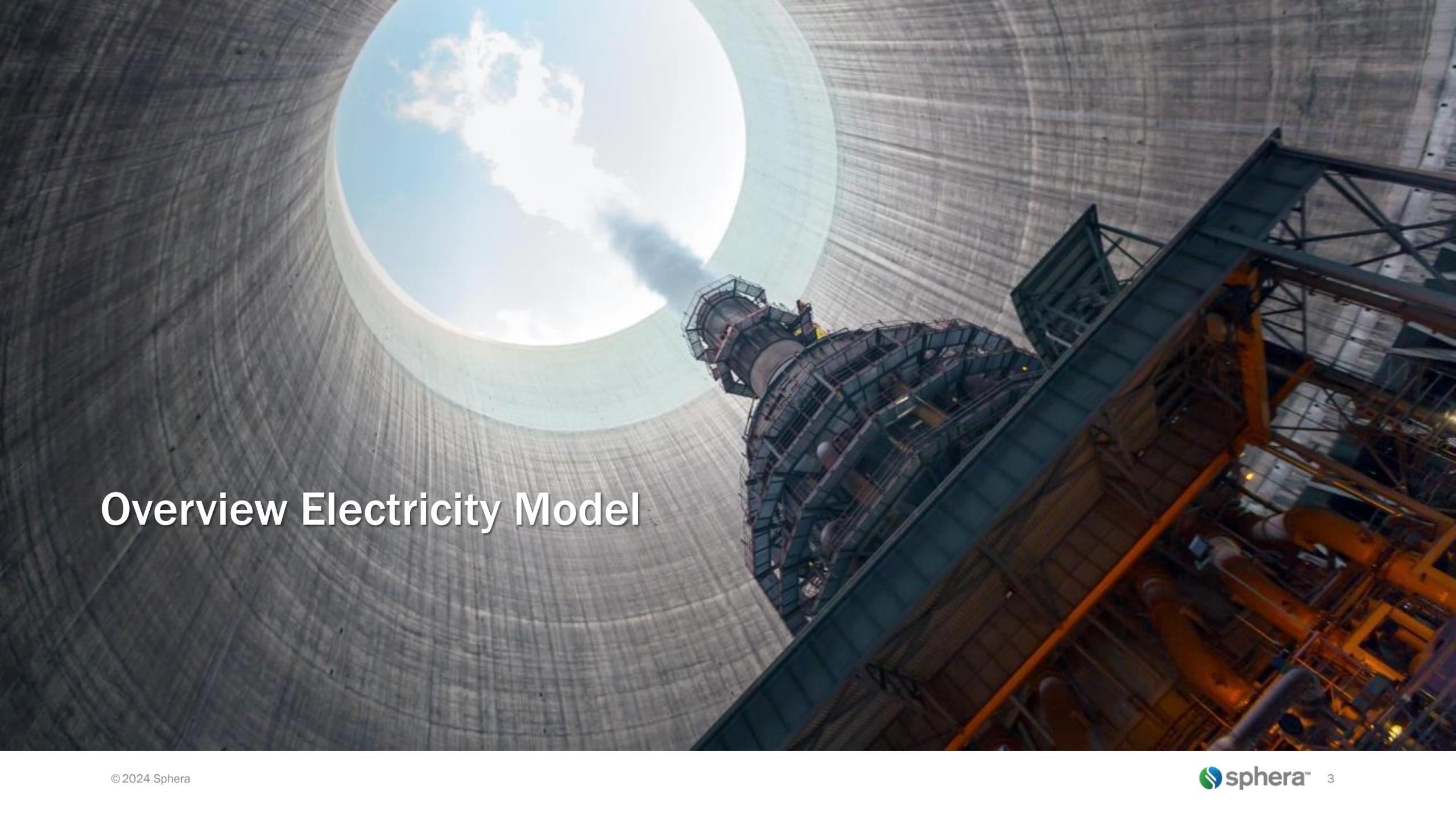


Jasmin Hengstler
Senior Consultant
Energy & Mobility

Agenda

- Overview Electricity Model
- Individual Modules – Energy Carriers
- Individual Modules – Energy Conversion
- Electricity Mixes

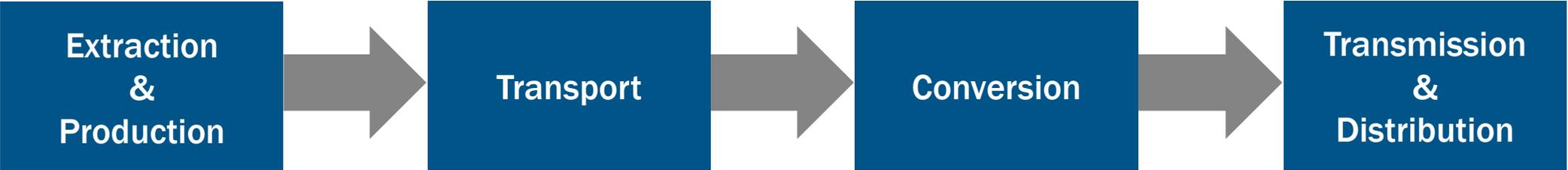


A low-angle, upward-looking photograph of the interior of a massive industrial cooling tower. The structure is composed of a dense grid of concrete or metal panels, creating a series of concentric, curved lines that lead the eye towards a large, circular opening at the top. Through this opening, a bright blue sky with scattered white clouds is visible. In the center of the tower, a tall, dark metal stack rises, emitting a plume of white steam or smoke that drifts towards the top. To the right, a complex network of dark metal beams, pipes, and structural supports is visible, illuminated by warm, orange-toned lights. The overall atmosphere is industrial and imposing.

Overview Electricity Model

Overview Electricity Model

Life Cycle Assessment of Energy Supply Chains



Overview Electricity Model

Energy Systems/Generic Modeling

To provide a comprehensive range of LCI data sets, a large amount of data has to be handled

How do we handle large amounts of data and generate consistent datasets?

Challenge Development of a model which allows the adaptation to various country-specific and technology-specific boundary conditions

Approach Generic, parameterized, adaptable models

Overview Electricity Model

Energy Generation (Power Plants) – Example

Conversion parameter

Energy conversion unit:

- Plant type (direct, CHP, etc.)
- Combustion technology
- Combustion efficiency
- Type of cooling system
- Flue gas cleaning technology
- Allocation method

Fuel parameter

- Calorific value
- Carbon content
- Sulphur content
- etc.

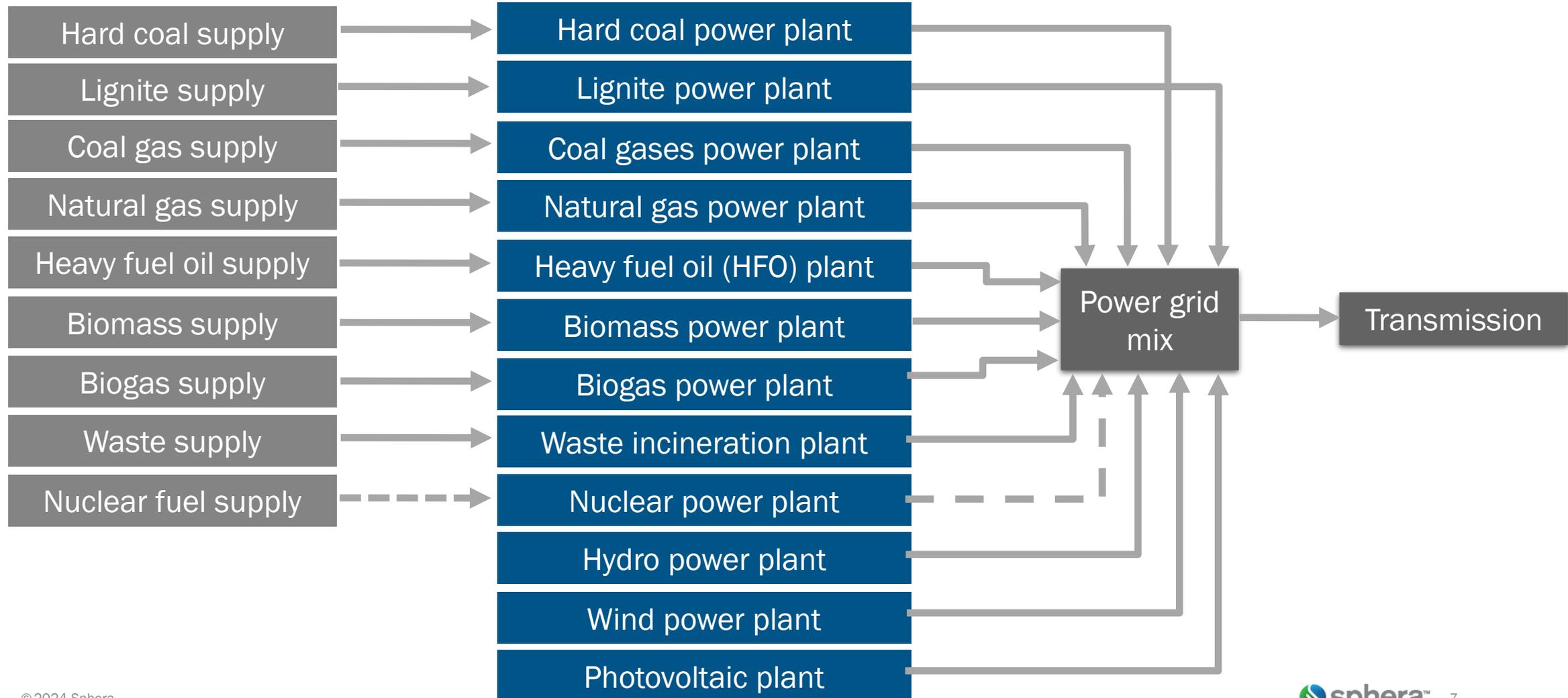


Life Cycle Inventory

- Auxiliary materials
- Emissions (CO₂, NO_x)
- Waste heat

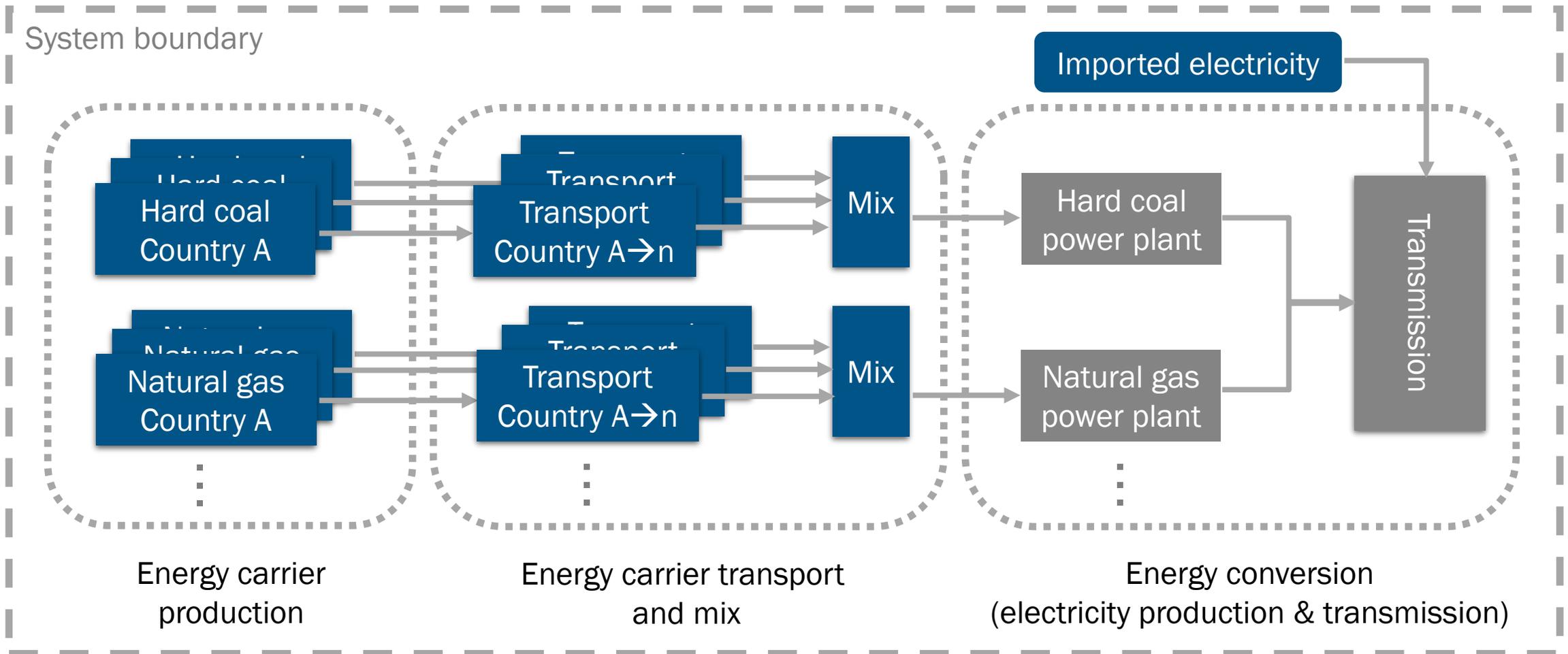
Overview Electricity Model

Parameterized Models – Electricity Grid Mix



Overview Electricity Model

Parameterized Models – Electricity Grid Mix



Overview Electricity Model

Conclusions

- Generic models offer the adaptability to various country and boundary conditions → micro, macro, and global level
- Results are comparable due to consistent approach and system boundaries
- Allows comprehensive LCI, LCIA, carbon footprint, and water footprint analysis
- Complex models with a large amount of data, but reduced number of key parameters are easy to manage and adapt
- High quality data with acceptable time effort → reduce costs
- Supports scenario modeling and outlooks
- Creating, maintaining and updating the Managed LCA Content (MLC) since 1990

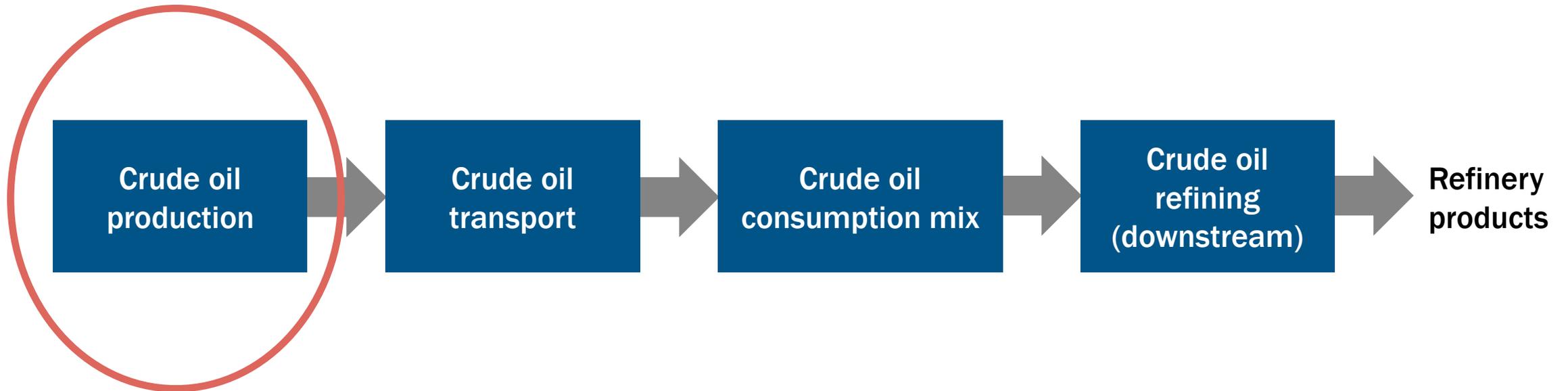




Individual Modules – Energy Carriers

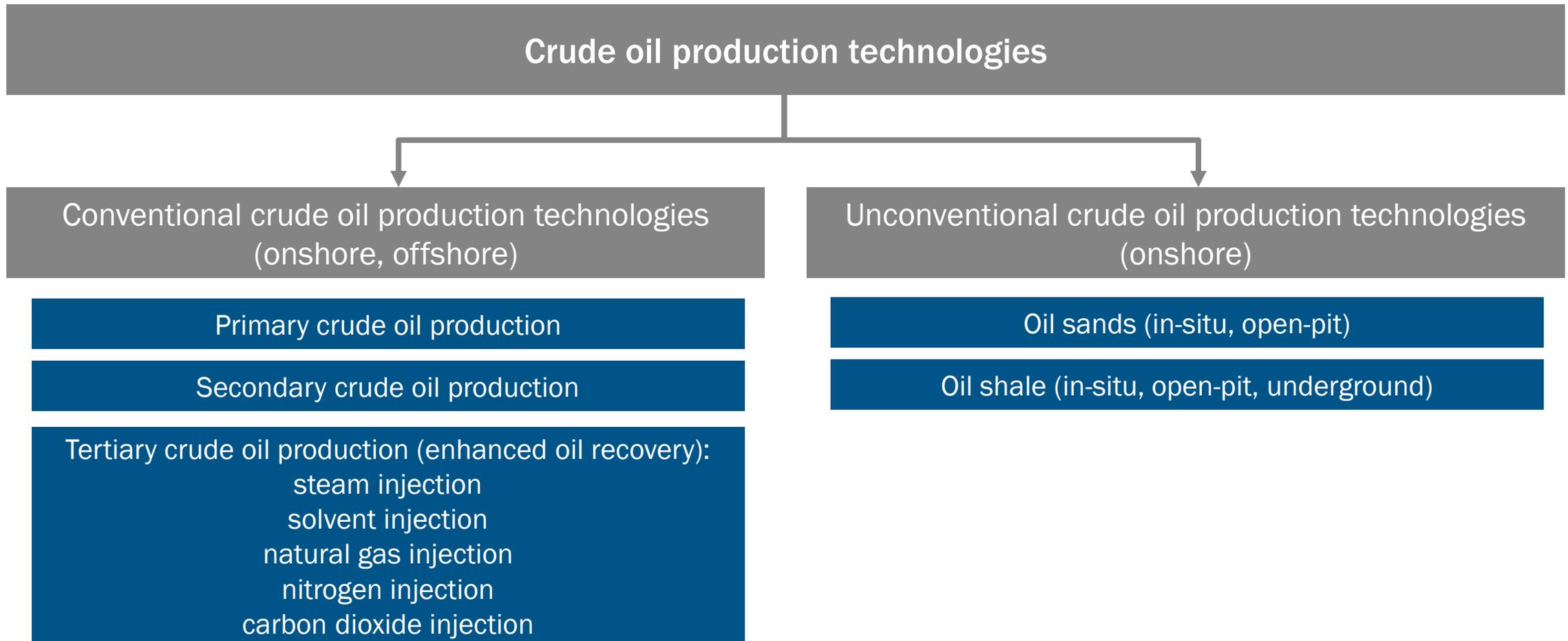
Individual Modules – Energy Carriers

Example: Refinery Products – Supply Chain



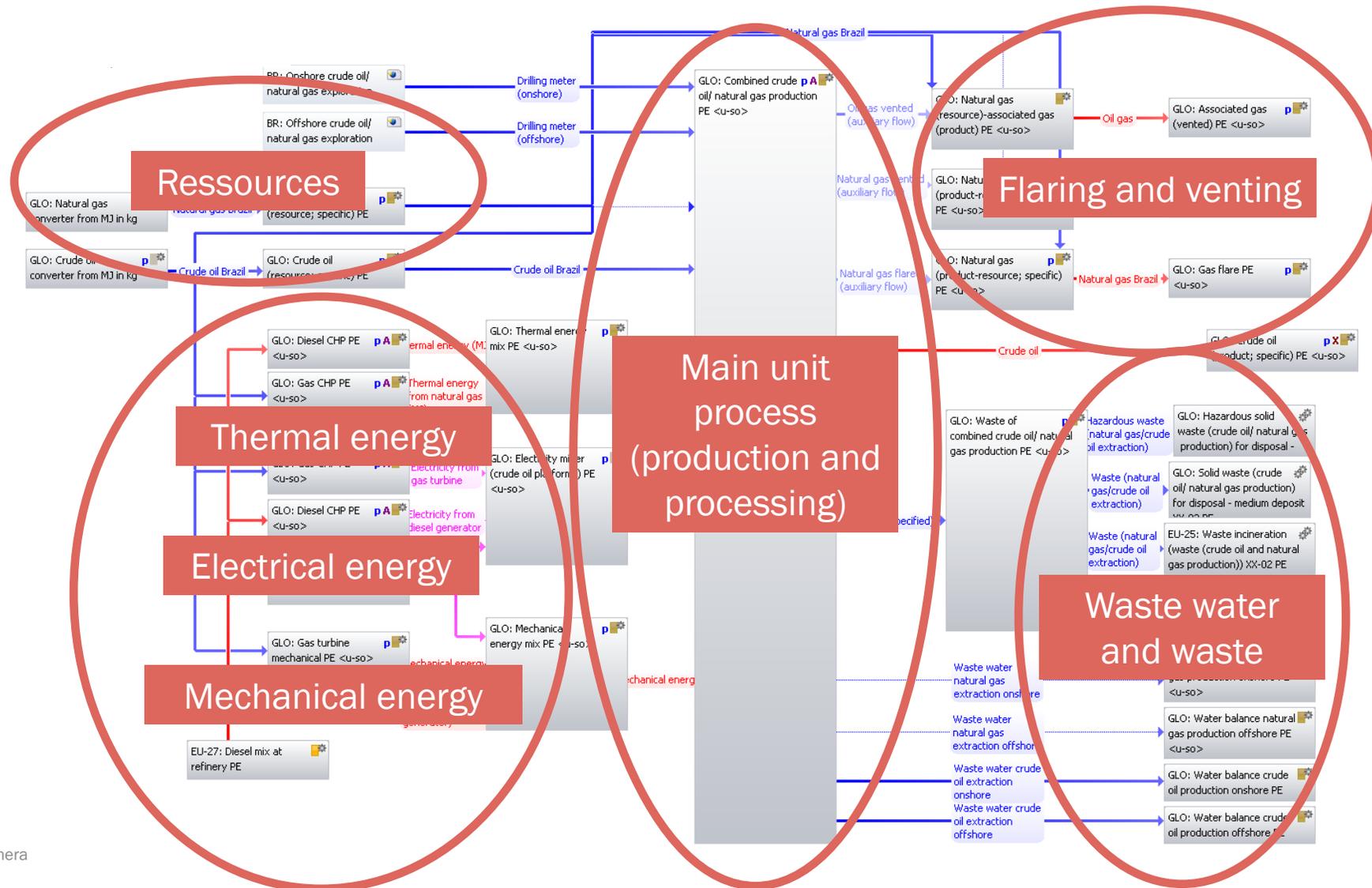
Individual Modules – Energy Carriers

Example: Refinery Products – Crude Oil Production Technologies



Individual Modules – Energy Carriers

Example: Refinery Products – Screenshot of Crude Oil Production



Individual Modules – Energy Carriers

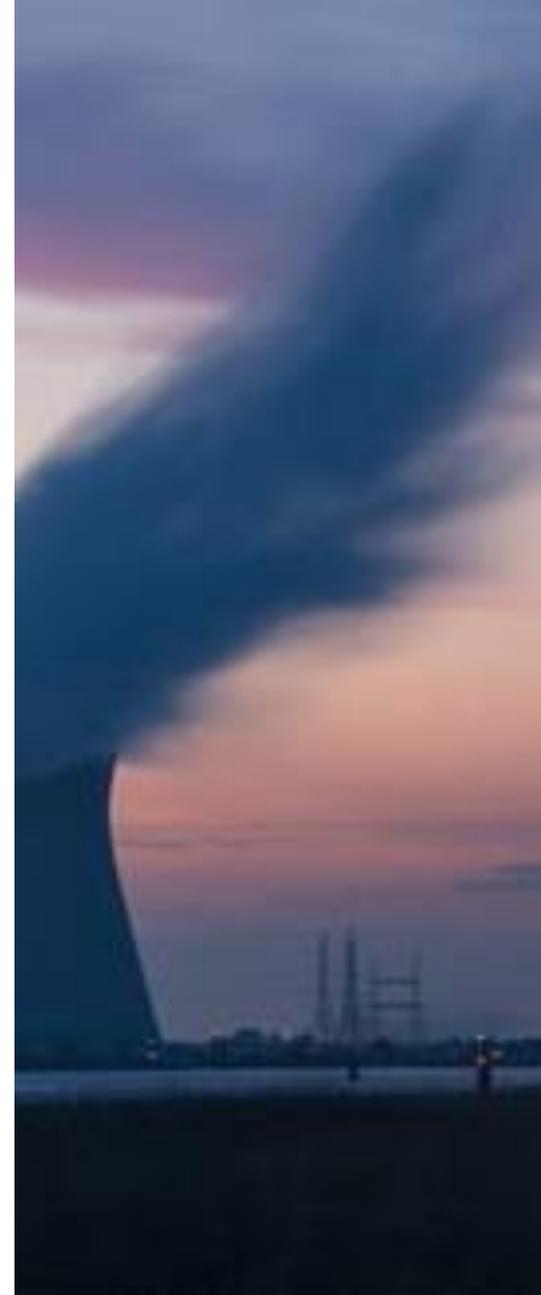
Refinery Products – Model Parameters of Crude Oil Production

Calculation of energy consumption depending on:

- Reservoir depth
- Water-oil-ratio (at well)
- Steam-oil-ratio and steam quality (if any)
- Amount of injected media (water, steam, solvent, etc.)
- Efficiency (pumps, generators etc.)
- Quality of natural gas (concentration of water, H₂S, CO₂)

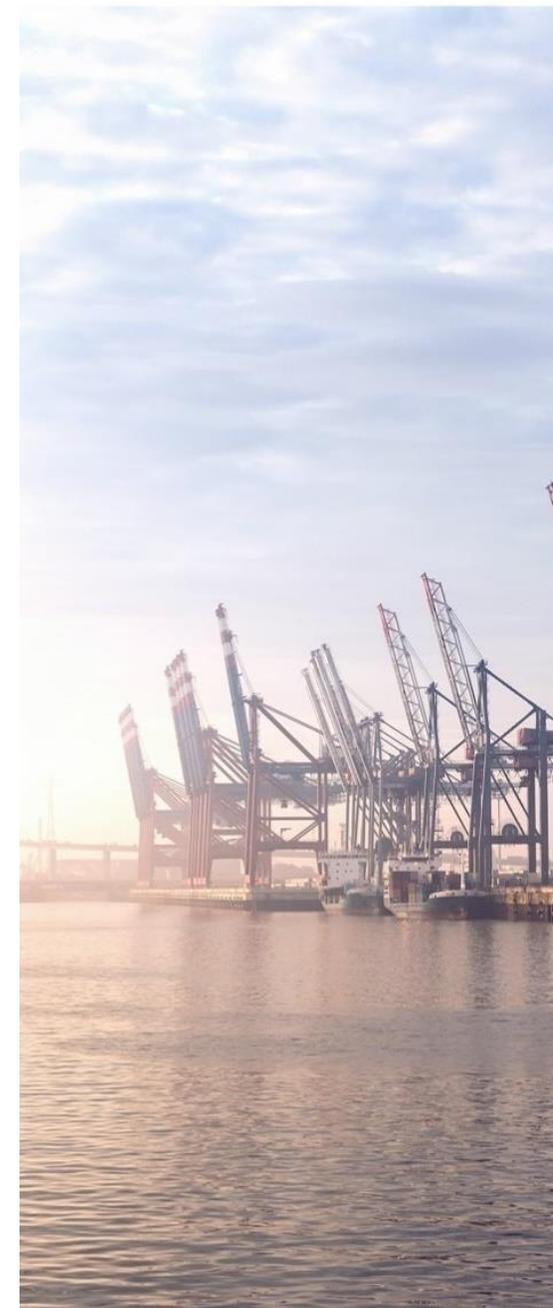
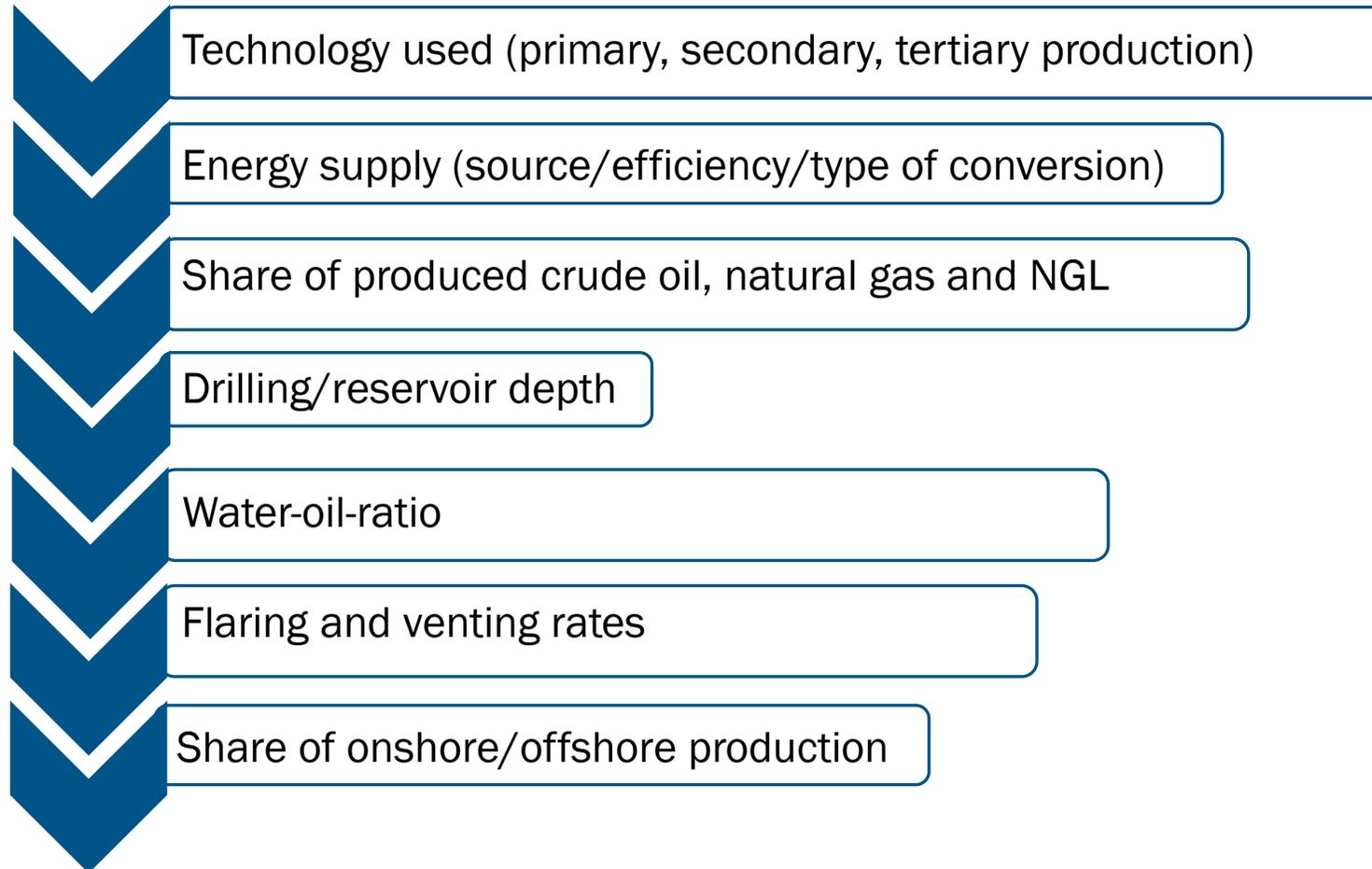
Data from measurements, literature for:

- Flaring and venting rates
- Solid waste
- Waste water
- Share of onshore/offshore production
- Produced amount of crude oil/natural gas/natural gas liquids (NGL) (allocation according to net calorific value)



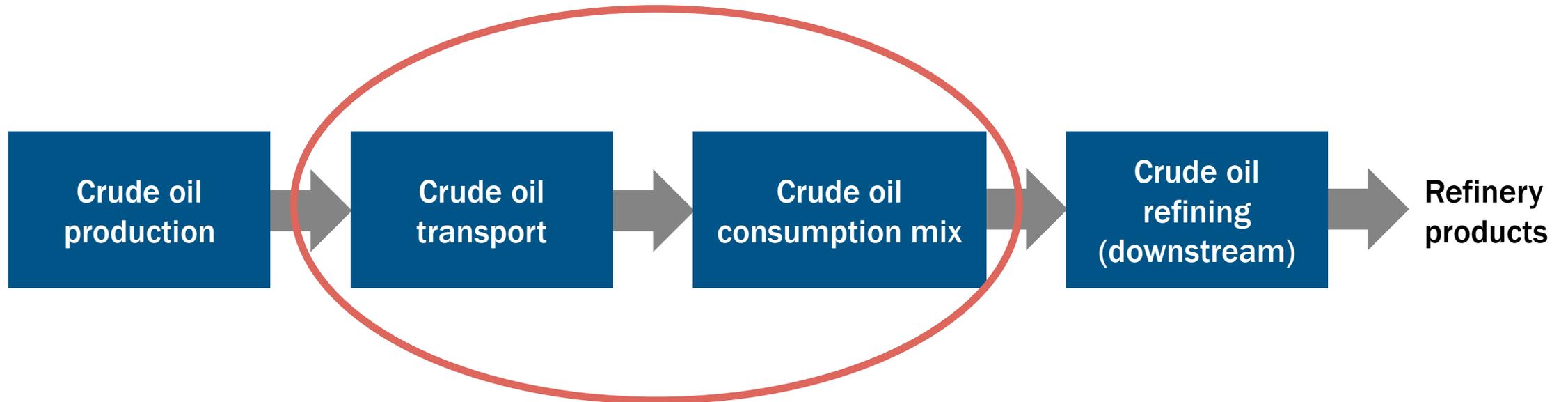
Individual Modules – Energy Carriers

Refinery Products – Key Parameters of Crude Oil Production



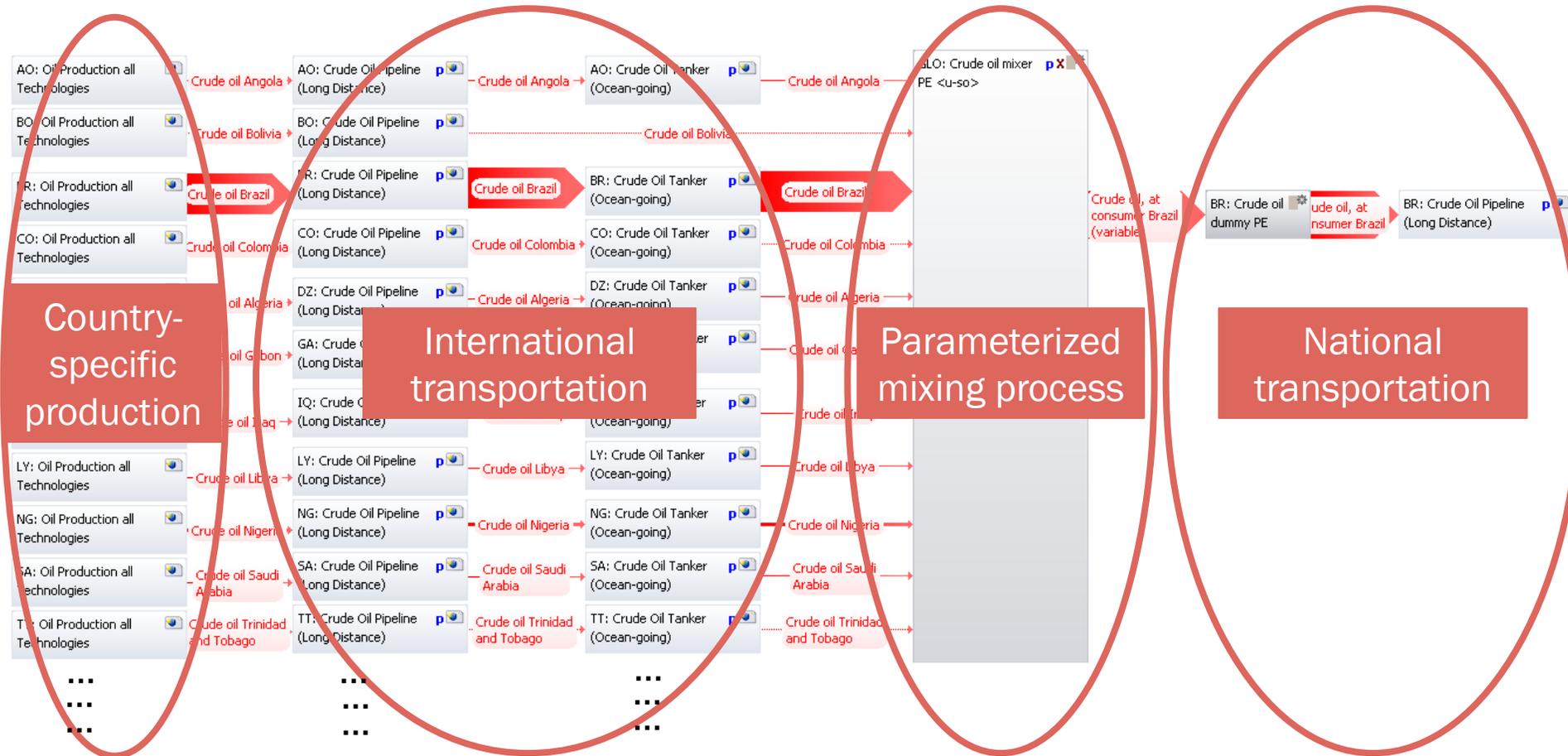
Individual Modules – Energy Carriers

Example: Refinery Products – Supply Chain



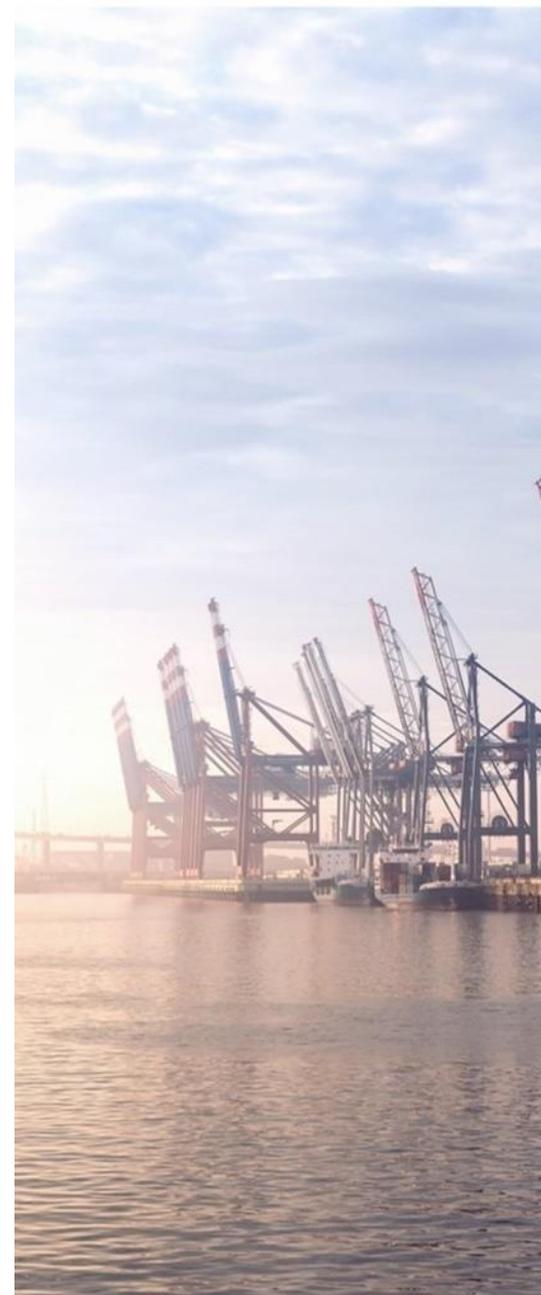
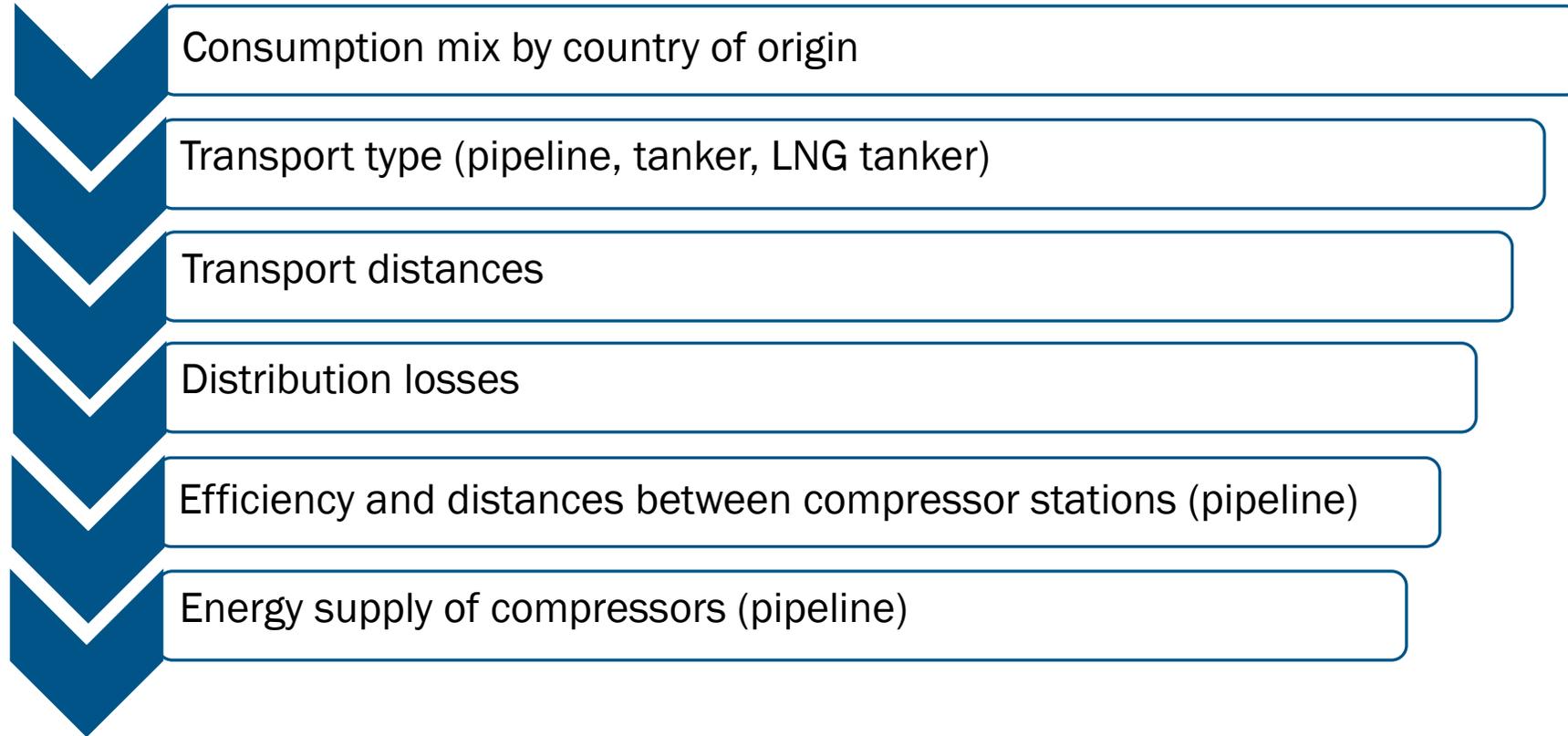
Individual Modules – Energy Carriers

Example: Refinery Products – Screenshot of Crude Oil Consumption Mix



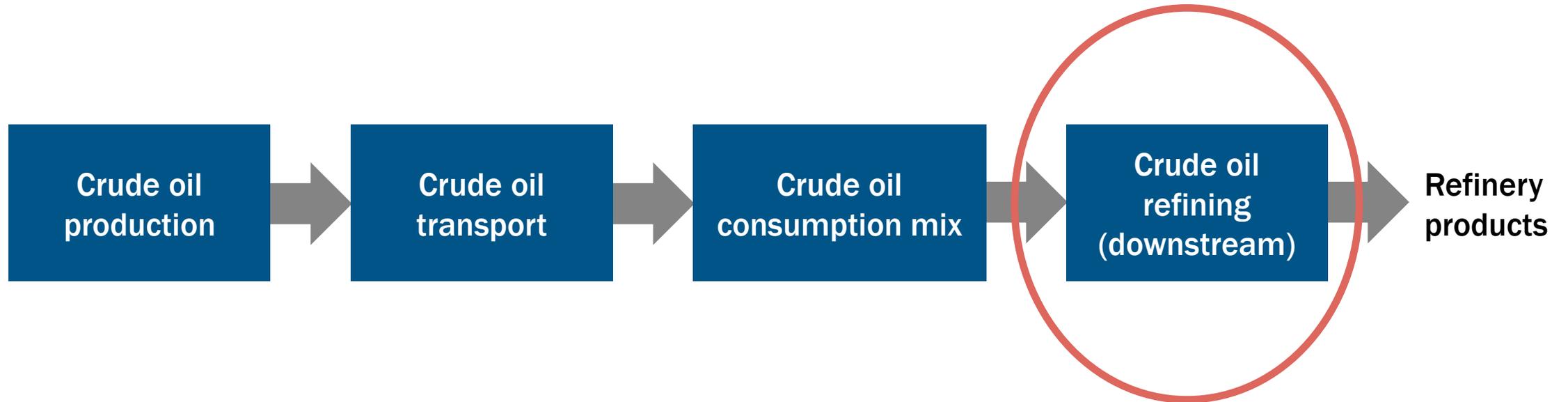
Individual Modules – Energy Carriers

Refinery Products – Key Parameters of Crude Oil Production



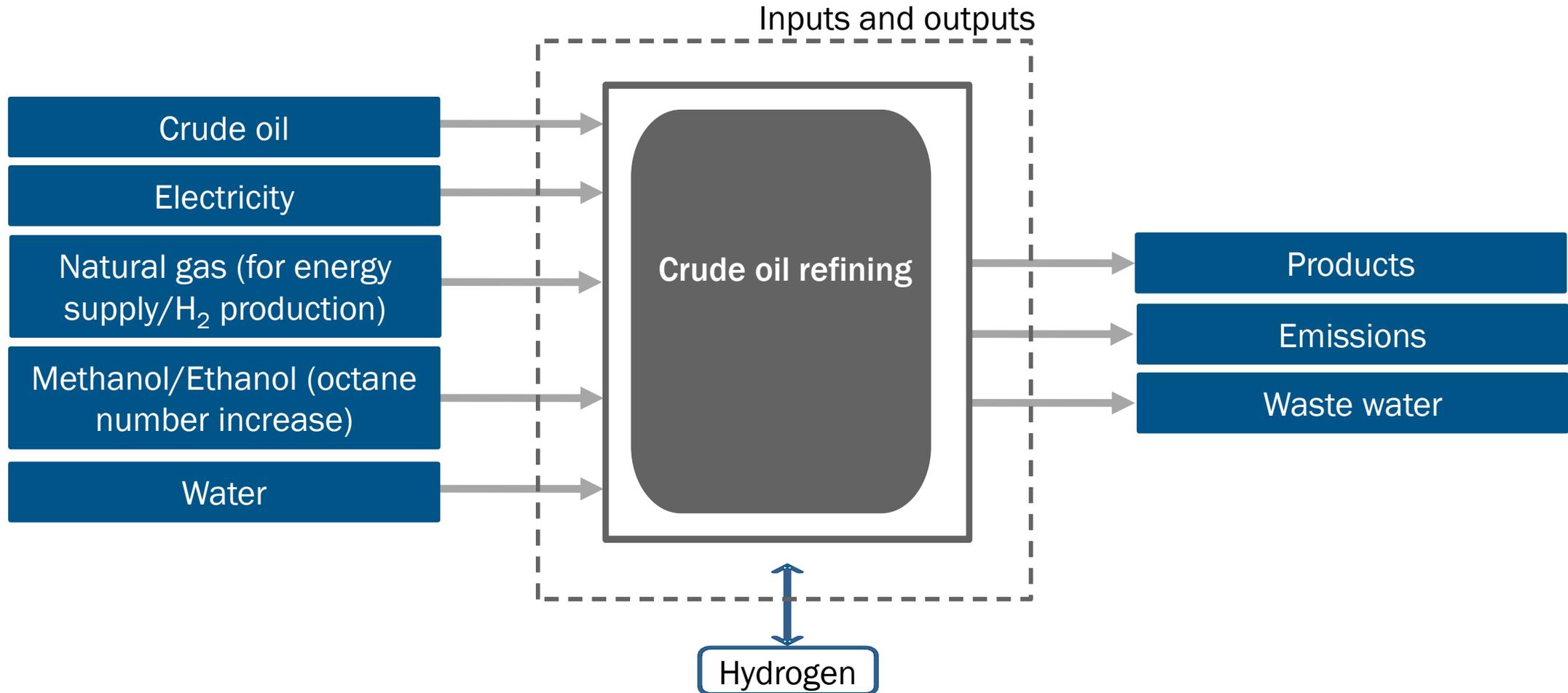
Individual Modules – Energy Carriers

Example: Refinery Products – Supply Chain



Individual Modules – Energy Carriers

Example: Refinery Products – Refinery System Boundary



Individual Modules – Energy Carriers

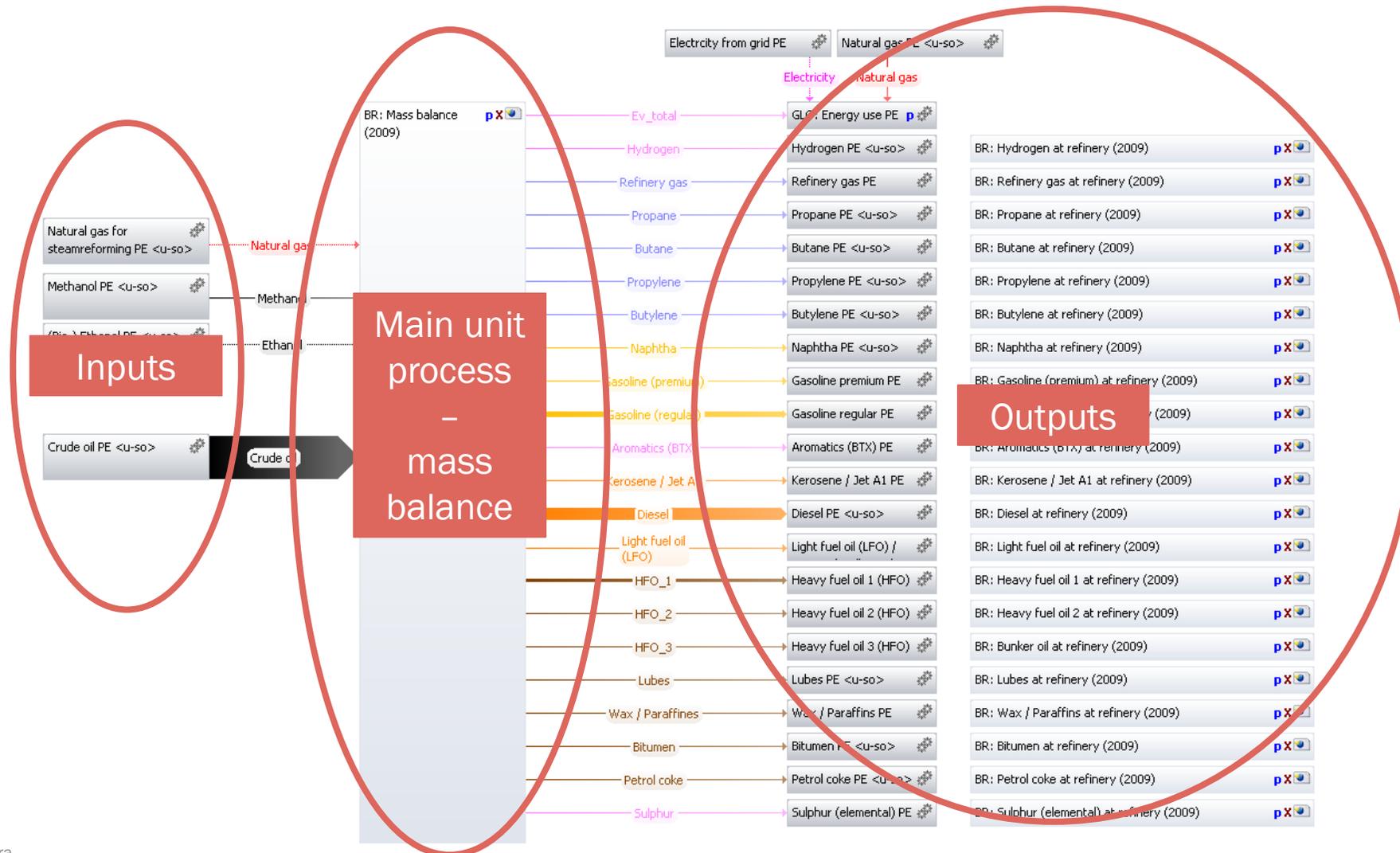
Example: Refinery Products – Refinery System Boundary

- Petroleum refineries are complex plants.
 - The combination and sequence of the processes is usually very specific to the characteristics of the crude oil and the products to be produced.
 - Due to the interlinkages within the refinery, all refinery products have to be considered.
 - What technologies and processes are used within the refinery?
 - Possible approaches regarding level of detail of analysis:
 - Refinery as black box model
 - Detailed refinery analysis (every single process)
 - Hybrid approach
 - Level of detail in dependency of scope, level of data availability, etc.
- Every refinery is individual



Individual Modules – Energy Carriers

Example: Refinery Products – Screenshot of Refinery



Individual Modules – Energy Carriers

Example: Refinery Products – Refinery Approach

Method:

- Detailed modeling of the refinery mass and energy balance
- Emissions of the total refinery (black box) are allocated to the products
- But allocation factors are modeled precise (due to detailed mass & energy balance)

Consequence: Clear, relatively precise, but no environmental analysis of single processes possible

Which data are required?

- Input and output flows of refinery
- Product output spectrum, i.e., 20% diesel, 10% naphtha, 30% gasoline, 2% refinery gas,...
- Amount of purchased energy from external sources (outside refinery)
- Process capacities (incl. utilization) of each process → detailed flow chart including figures to model the mass balance
- Environmental impacts, i.e. emissions of the whole refinery (black box, bubble)
- Feedstock and product properties (net calorific value, sulphur content,...)
- Energy demand of each single process



Individual Modules – Energy Conversion

Individual Modules – Energy Conversion

Example: Hard coal power plant (1 of 2)

Conversion parameter

Energy conversion unit:

- Plant type (direct, CHP, etc.)
- Combustion technology
- Combustion efficiency
- Type of cooling system
- Flue gas cleaning technology
- Allocation method

Fuel parameter

- Calorific value
- Carbon content
- Sulphur content
- etc.



Life Cycle Inventory

- Auxiliary materials
- Emissions (CO₂, NO_x)
- Waste heat

Individual Modules – Energy Conversion

Example: Hard coal power plant (2 of 2)

- Basis for all combustion models
- Efficiency, share of CHP/direct, own consumption: Data are calculated based on statistics and directly used in the power plant models
- Emissions:
 - Relevant emissions (CO_2 , CO , NO_x , SO_2 , dust, NMVOC, N_2O , CH_4 , dioxin) are derived country-specific from literature/databases. Data is used directly and partly indirectly (used to determine e.g. efficiency for desulphurization or dedusting in the model).
 - Other emissions like heavy metals, consumption of air, water in flue gas etc. are calculated based on combustion calculation and fuel properties
- Energy input: Input of energy carriers is calculated based on efficiency, allocation and net calorific value (NCV) of energy carrier
- Waste/secondary products (bottom ash, fly ash, gypsum, etc.): Calculation based on fuel properties and combustion calculation (transfer coefficients)

Individual Modules – Energy Conversion

Example: Hydro Power Plant (1 of 3)

Run-of-river plants

- Production of base load electricity from hydropower
- Efficiency $\eta \approx 93\%$
- Low-pressure plant (low head)
- Kaplan-turbines

Storage plants

- Production of average and peak load electricity from hydropower
- Efficiency $\eta \approx 85\%$
- Medium- or high-pressure plant (medium or high head)
- Two types of dams: concrete dam and earth-/rockfill dam
- Francis-turbines (medium or high head), Pelton-turbines (high head)

Pumped storage plants

- Efficiency $\eta \approx 75\%$ (storage of base load energy)
- Often combined with storage plants (pumped-storage plants with natural inflow)
- Medium- or high-pressure plant (medium or high head)
- Two types of dams: concrete dam and earth-/rockfill dam
- Francis-turbines (medium or high head), Pelton-turbines (high head), combined with pumps



Individual Modules – Energy Conversion

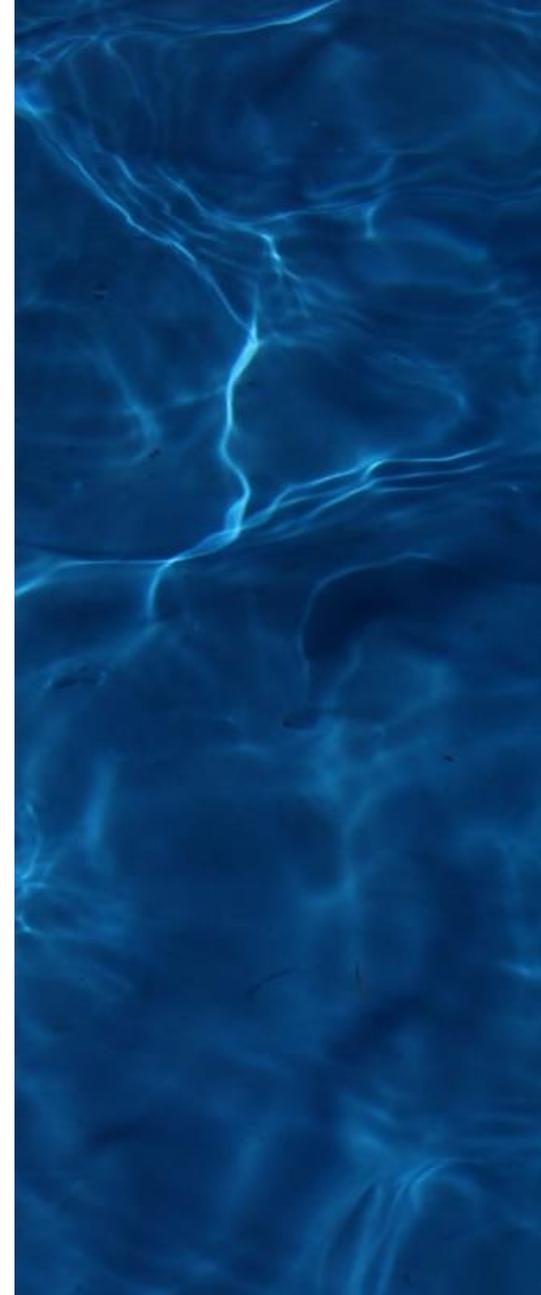
Example: Hydro Power Plant (2 of 3)

Greenhouse gas emissions during the operation of run-of-river, storage and pumped-storage plants are a result of biomass degradation in the dammed water depending on

- climatic boundary conditions:
 - climatic cold and moderate regions: Increasing CO₂ emissions from aerobic degradation of biomass in the first years of operation, then temporary decreasing within the first 10 years of operation
 - climatic tropical regions: Increasing CH₄ emissions from anaerobic degradation of biomass in the first years then slower temporary decreasing, which can be longer than the first 10 years of operation
- vegetal boundary conditions (amount of inundated biomass): Sub polar lea, cultivated land, steppe, boreal forest, rain forest

Used values of emissions are arithmetic mean values over 100 years of operation and are based on gross greenhouse gas emissions (problem of absorbed CO₂ from atmosphere), net emissions are estimated to be 30 – 50 % lower

Greenhouse gas emissions of run-of-river plants are minimal since the water is not stored for a long time



Individual Modules – Energy Conversion

Example: Hydro Power Plant (3 of 3)

Model parameters of the hydro power LCA-models:

- Country-specific distribution of electricity production by hydropower [%]
- Country-specific relation between consumed electricity and generated electricity by pumped-storage [kWh/kWh]
- Country-specific greenhouse gas emissions from operation [kg CO₂ eq./kWh]
- Plant-specific efficiency [%]
- Country-specific plant life span and life spans of components [a]
- Country-specific share of concrete dams as a part of storage and pumped storage plants [%]

Individual Modules – Energy Conversion

Example: Wind Power Plant

Construction

- considers main components (foundation, tower, nacelle rotor), and
- transports are included.

Operation and maintenance

- full load hours determined by electricity produced from wind divided by installed capacity, and
- maintenance considered.

End of life

- recycling potential for metals,
- incineration of polymers,
- inert materials to landfill, and
- foundation not recycled.



Individual Modules – Energy Conversion

Example: New Photovoltaic (PV) model (1 of 3)

Technology Mixes:

- Monocrystalline silicon (mono c-Si), Multicrystalline silicon (multi c-Si), Cadmium Telluride (CdTe), Copper Indium (Gallium) diselenide/sulphide (CI(G)S) modules
- Ground-mounted systems and Roof-top installed systems
- Regionalized electricity grid and thermal energy mixes across the supply chains of PV module manufacturing according to market shares

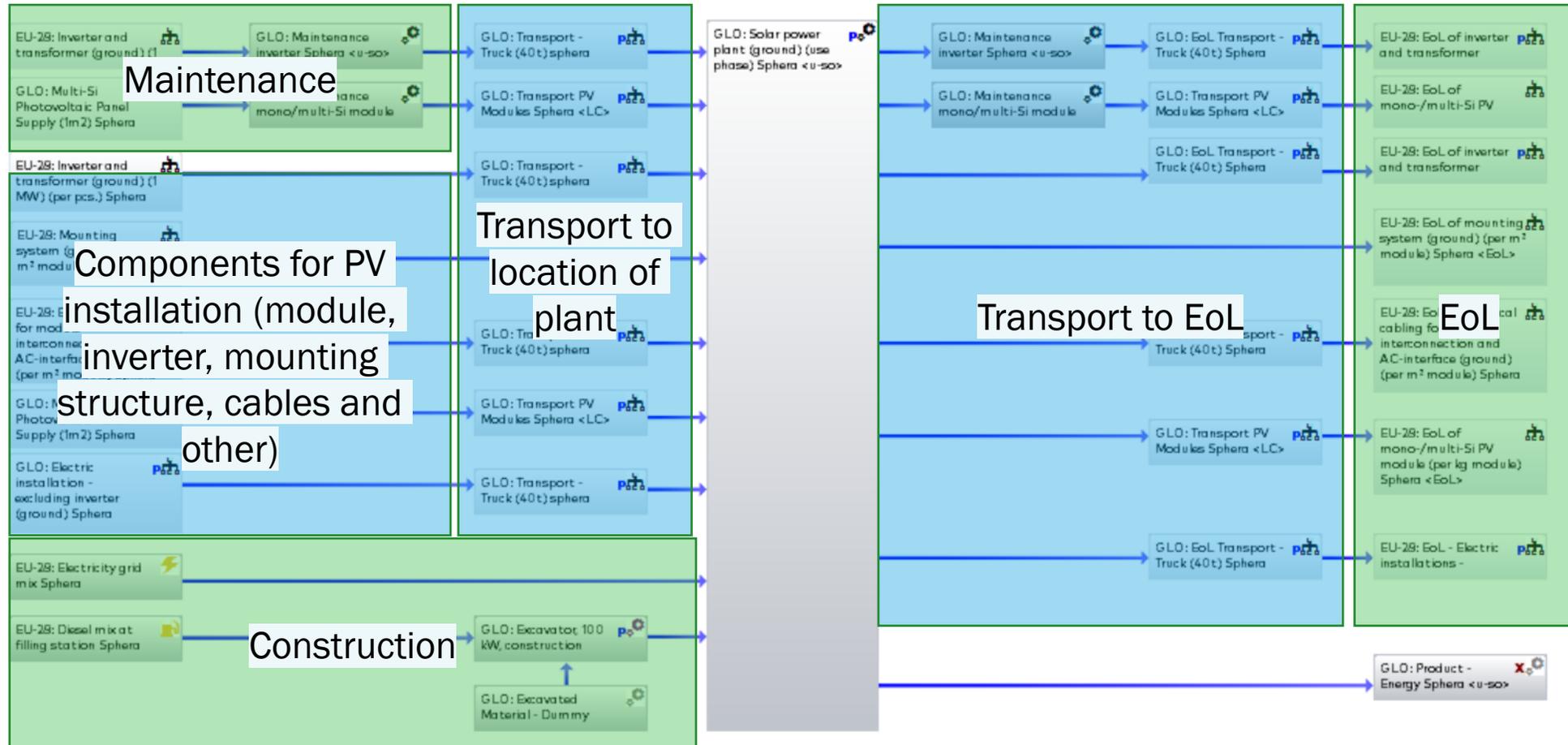
Further parameters:

- Technology specific efficiencies
- Country specific average Solar irradiations, GTI (Global Titled Irradiation)
- Lifetimes and dynamic module degradation rates
- Installation depending performance ratios

Individual Modules – Energy Conversion

Example: New Photovoltaic (PV) model (2 of 3)

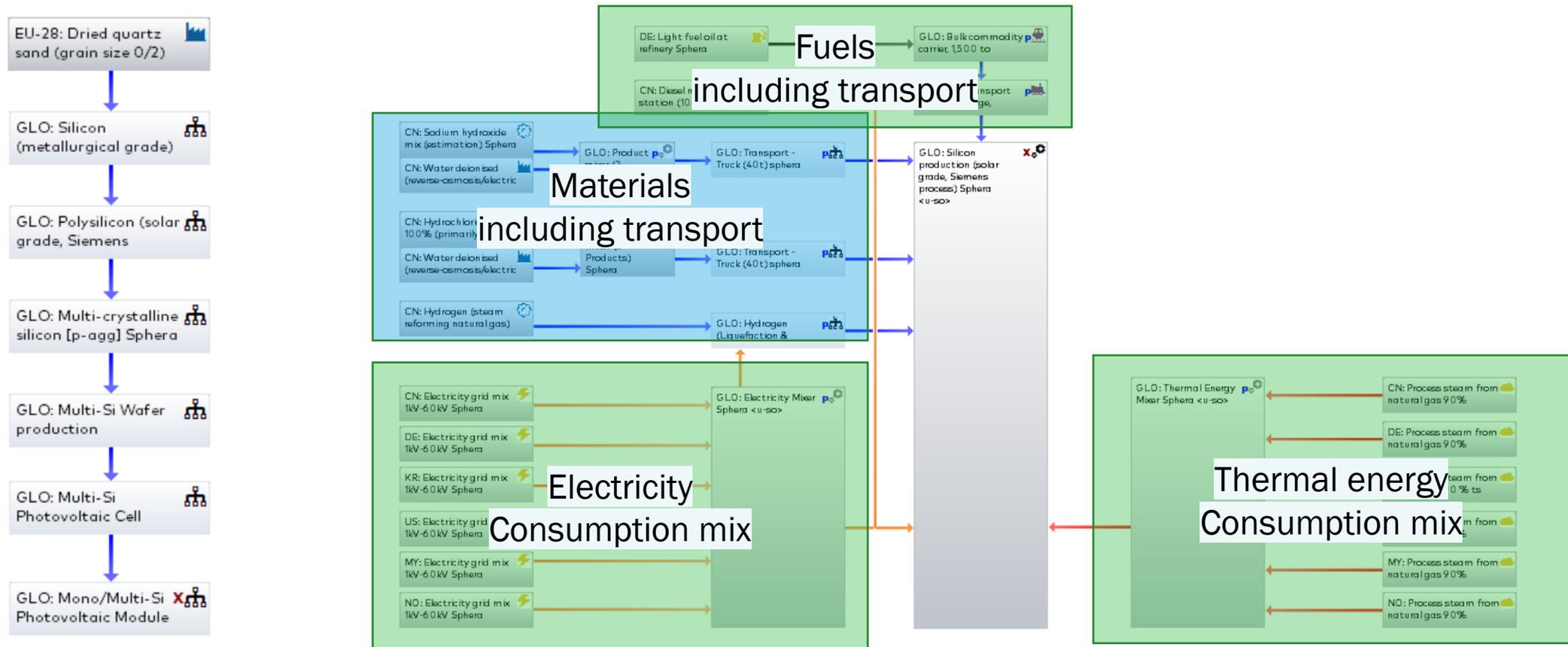
Example: Multi c-Si PV ground mounted system (image 1 of 2):



Individual Modules – Energy Conversion

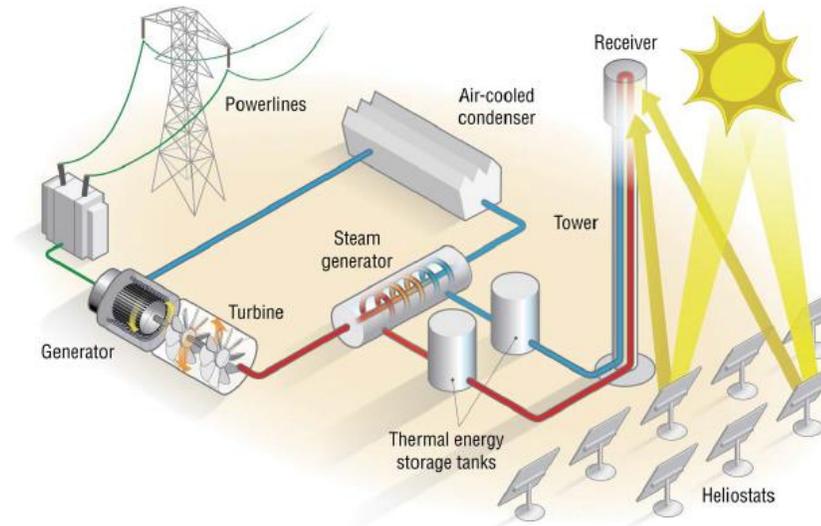
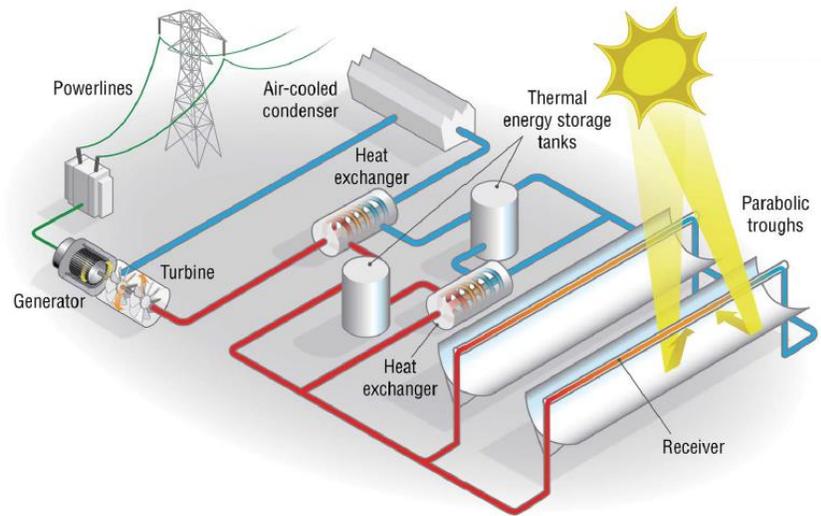
Example: New Photovoltaic (PV) model (3 of 3)

- Manufacturing of cells and modules (on the left) (image 2 of 2):
- Polysilicon production (Siemens process) (on the right)



Individual Modules – Energy Conversion

Example: Concentrated Solar Power (CSP) model (1 of 2)



Parabolic trough, no storage

- No storage capacity

Parabolic trough, indirect storage

- 18 h molten salt storage

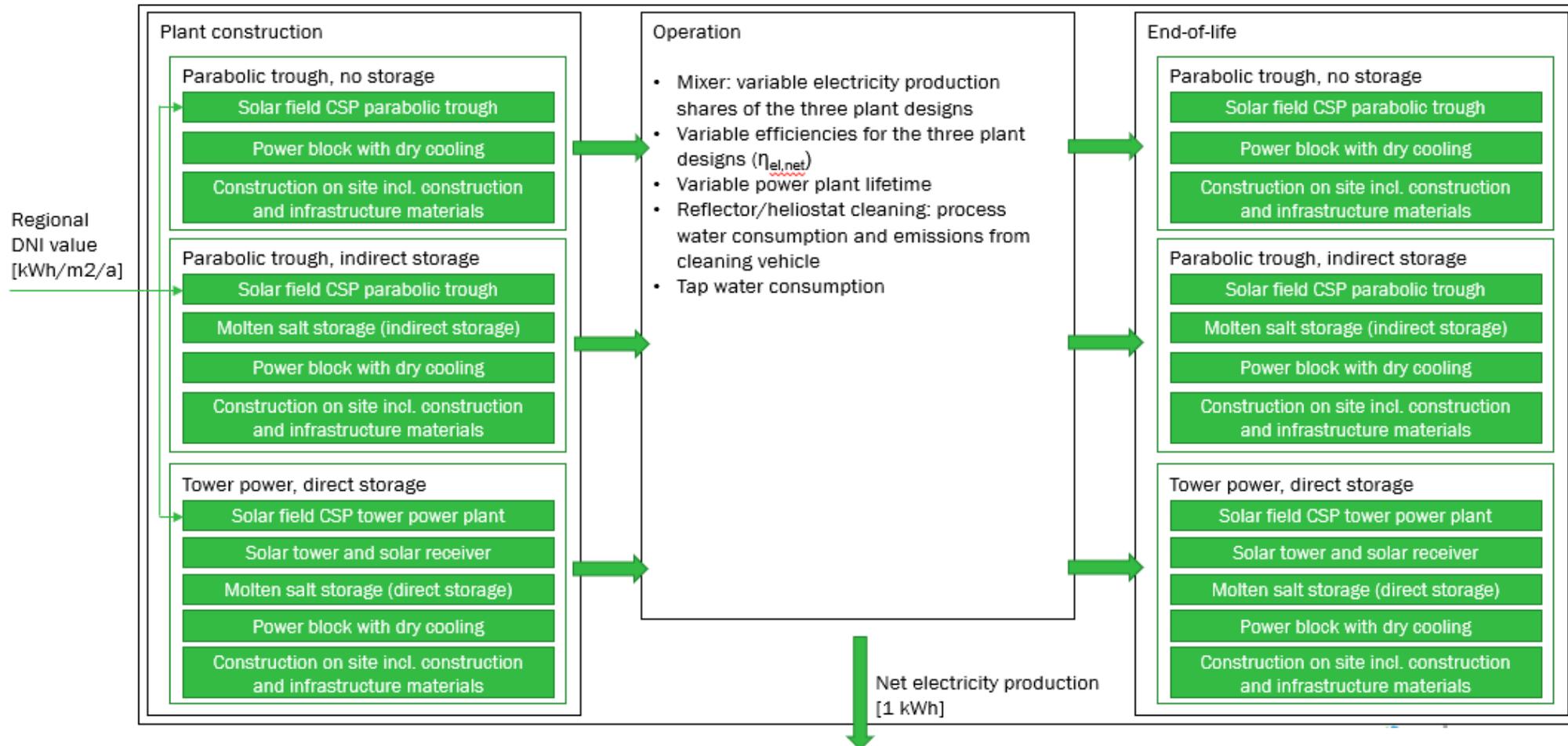
Tower power, direct storage

- 18 h molten salt storage

Source: Kutscher C., Concentrating Solar Power (CSP), NREL

Individual Modules – Energy Conversion

Example: Concentrated Solar Power (CSP) model (2 of 2)

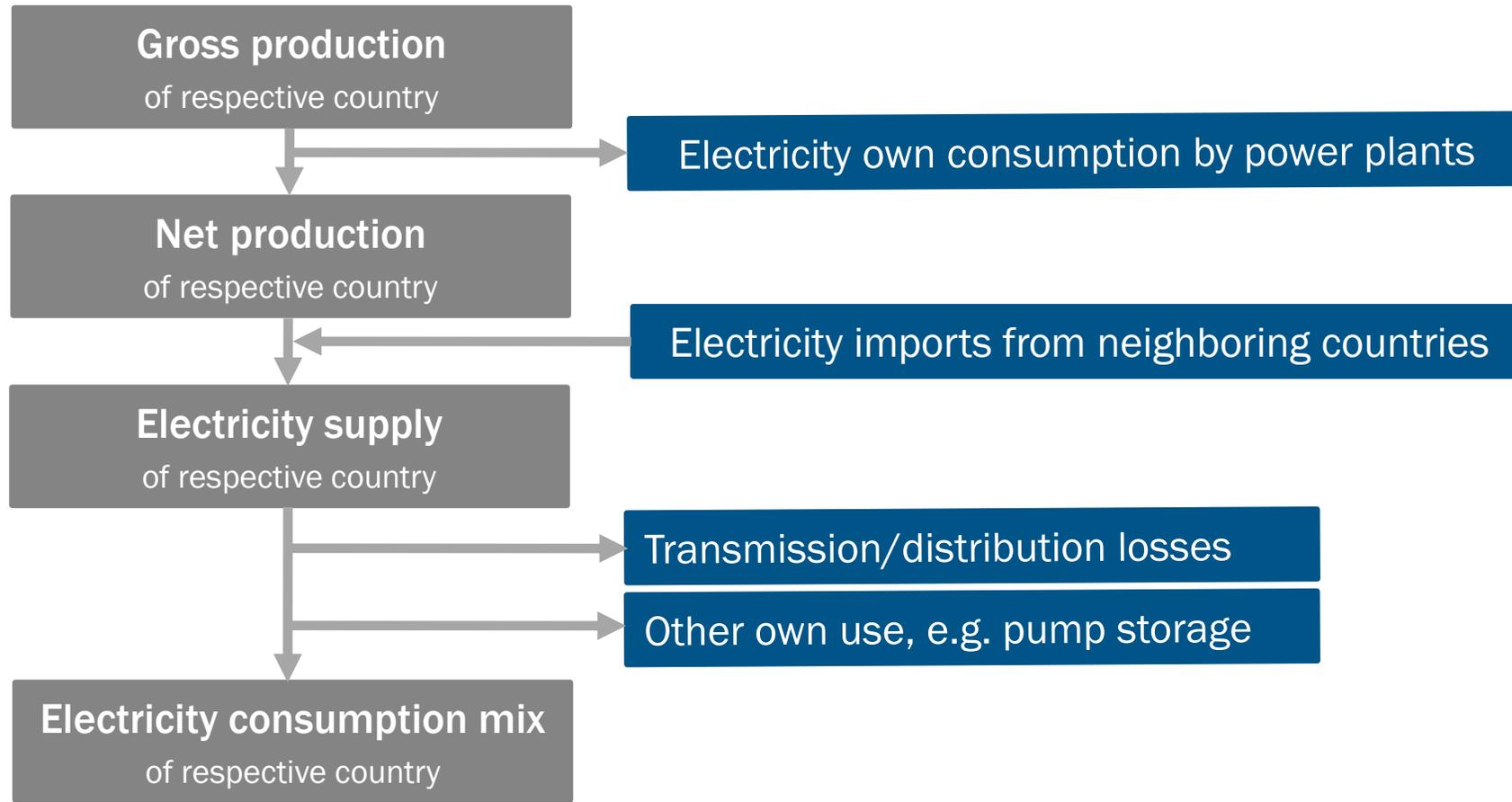


Electricity Mixes



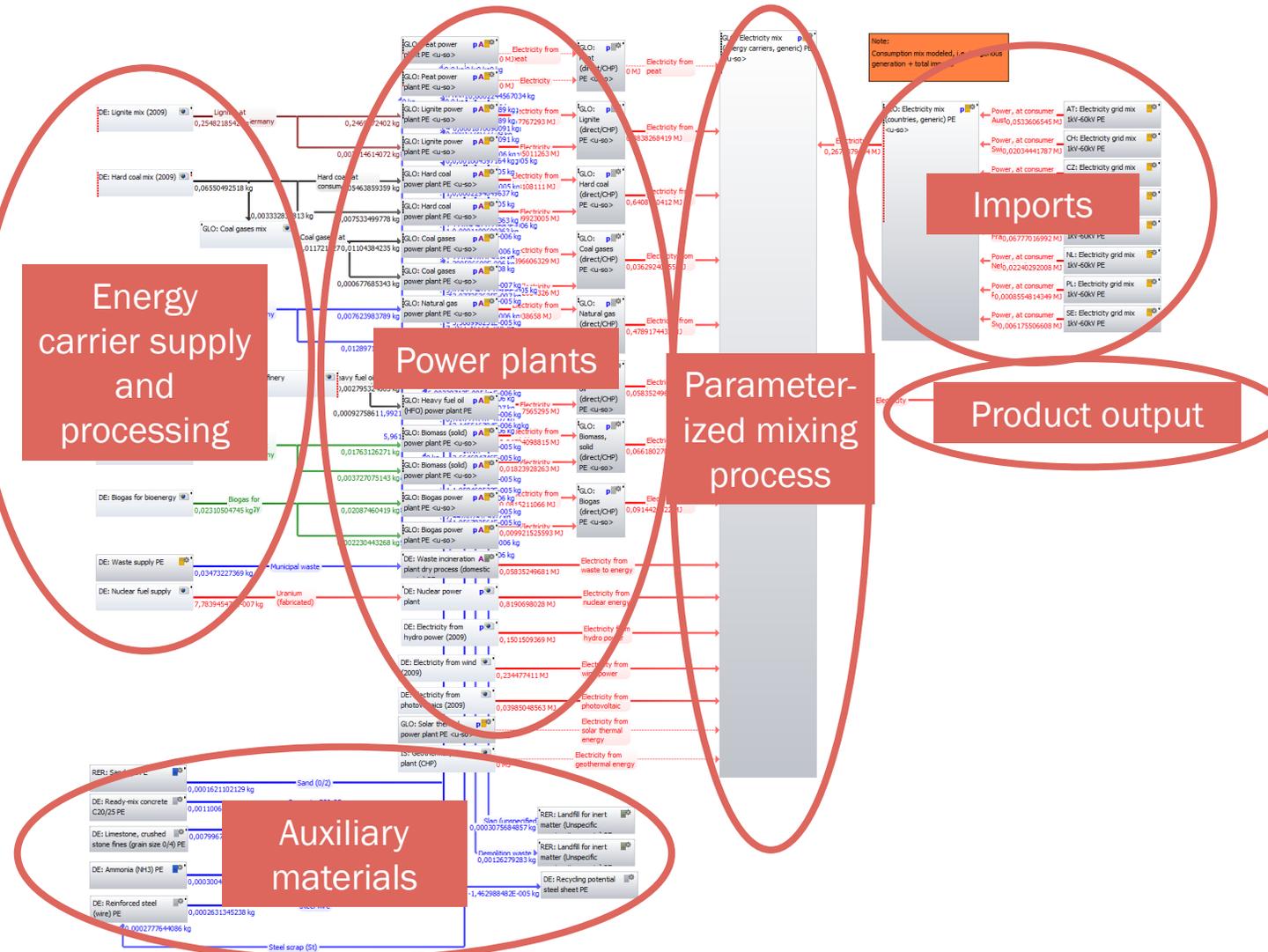
Electricity Mixes

Modeling of Electricity Consumption Mixes



Electricity Mixes

Screenshot of Electricity Consumption Mix



Managed LCA Content - Available Documents

MLC documents:

- Sphera LCA Databases Modelling Principles
- Sphera Water LCI Modelling & Assessment
- Sphera Duty Vehicles LCI Modelling
- Sphera Passenger Vehicles LCI Modelling
- Sphera Land Use Change LCI Modelling & Assessment
- Sphera Land Use LCI Modelling & Assessment
- Sphera Agricultural LCI Model
- Sphera Energy LCI Modelling
- Sphera Refinery LCI Model
- Upgrades and Improvements (compared to preceding version)

Contact customercare@sphera.com for more information.

