Technology assumptions

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E3Modelling Energy Economy Environment

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Technology database consultation process

- **Scope:**

  energy (industry, buildings incl. renovation, power and heat, new fuels and storage), transport, technical mitigation potentials for non-CO_2 and LULUCF

- **Type:**
  - for energy: costs (investment costs, fixed costs), efficiencies, technical lifetime for power plants, learning potential
  - for transport: cost-efficiency curves for multiple technologies for all transport modes

- **How:**
  - Draft technology assumptions sent to stakeholders, asking for written feedback
  - Dedicated workshop (last time November 2019)
  - Revised technology assumptions agreed between E3M, EC (incl. technical support through JRC)

- **Publication:**
  - Currently public: https://ec.europa.eu/energy/sites/ener/files/documents/2018_06_27_technology_pathways_-_finalreportmain2.pdf (version July 2018)
  - About to be published: update for EU Reference (expected July 14th 2021)

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
- CO_2 Emissions from energy combustion and industrial processes
- Emissions of atmospheric pollutants
- Policy Assessment Indicators (e.g. imports, RES shares, etc.)

How is technology progress derived?

Techno-economic characteristics improve due to:

- Learning-by-research (LBR): R&D investments leading to autonomous progress in the costs and efficiencies of technologies
- Learning-by-doing (LBD): Economies of scale leading to e.g. decreased costs because of accumulated experience in the production, or the possibility to produce bulk amounts of a certain product.

The "ultimate" status for a technology, as provided in the tables, incorporates optimistic assumptions both for autonomous progress, but also a market large enough to provide costs reductions via economies of scale effects: it resembles a technical potential and a floor cost

Learning in scenarios can be considered differently based on expected market shares and enabling conditions

Technology description – energy (PRIMES)

- Technologies in PRIMES are classified in three categories according to their maturity:
  - Mature technologies w. limited or no further learning potential - e.g. steam/gas turbines, non-condensing boilers
  - Mature technologies w. still unexploited learning potential - e.g. solar PV, wind onshore
  - Technologies at low TRL (demonstration or early commercial applications) – e.g. electrolysers
- Cost for the last category may change due to the context of the scenario e.g. presence of enabling conditions of decarbonisation

- Technologies can also be classified in three classes according to their sector:
  - Demand-side technologies that include:
    - Energy equipment and appliances (i.e. motors, lighting bulbs, heat pumps, ICE engines), with a number of different equipment classes available at each time step (different costs and efficiency combinations that improve over time).
    - Energy renovation interventions
  - Supply side technologies, including new fuel production facilities and storage
  - Infrastructure technologies cost for network infrastructure etc. (whose investment is exogenous to the modelling).

Power and heat supply technologies

Conventional thermal	CCS plants	Renewables	Heat and steam	Storage
Open cycle steam turbine	Coal CCS post combustion	Hydro with reservoir	Boilers	Pumping
various fuels	Lignite CCS post combustion	Hydro run-of-river	various fuels	pure
various sizes	Coal CCS oxyfuel	Wind onshore	various sizes	mixed
Supercritical steam turbine	Lignite CCS oxyfuel	wind intensity categories	Electric boilers	Batteries
coal	Fuel Oil CCS post combustion	Wind offshore	Heat pumps HT	behind the meter
lignite	IG Fuel Oil CCS pre combustion	wind intensity categories	Geothermal	grid-based
oil	IG Coal CCS post combustion	Very small wind	CHP	cars
Gas turbines open cycle	IG Coal CCS pre combustion	Solar PV large-scale	various technologies	CAES
various fuels	IG Coal CCS oxyfuel	solar intensity categories	various fuels	P2H2
various sizes	IG Lignite CCS post combustion	Solar rooftop commercial	various sizes	P2G
CCGT conventional	IG Lignite CCS pre combustion	solar intensity categories		
CCGT advanced	IG Lignite CCS oxyfuel	Solar rooftop residential		
Integrated gasification	CCGT CCS post combustion	solar intensity categories		
Coal	CCGT CCS pre combustion	solar thermal		
Lignite	CCGT CCS oxyfuel	Tidal-waves		
Biomass	CCGT CCS oxyfuel	Geothermal		
HT Biomass plants	BECCS (various types)	3 enthalpy categories		
Biogas plants				
ICE power plants				
Fuel cells (various types)				
Organic Rankine Cycle				

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Buildings segmentation scheme

Building shell renovation interventions

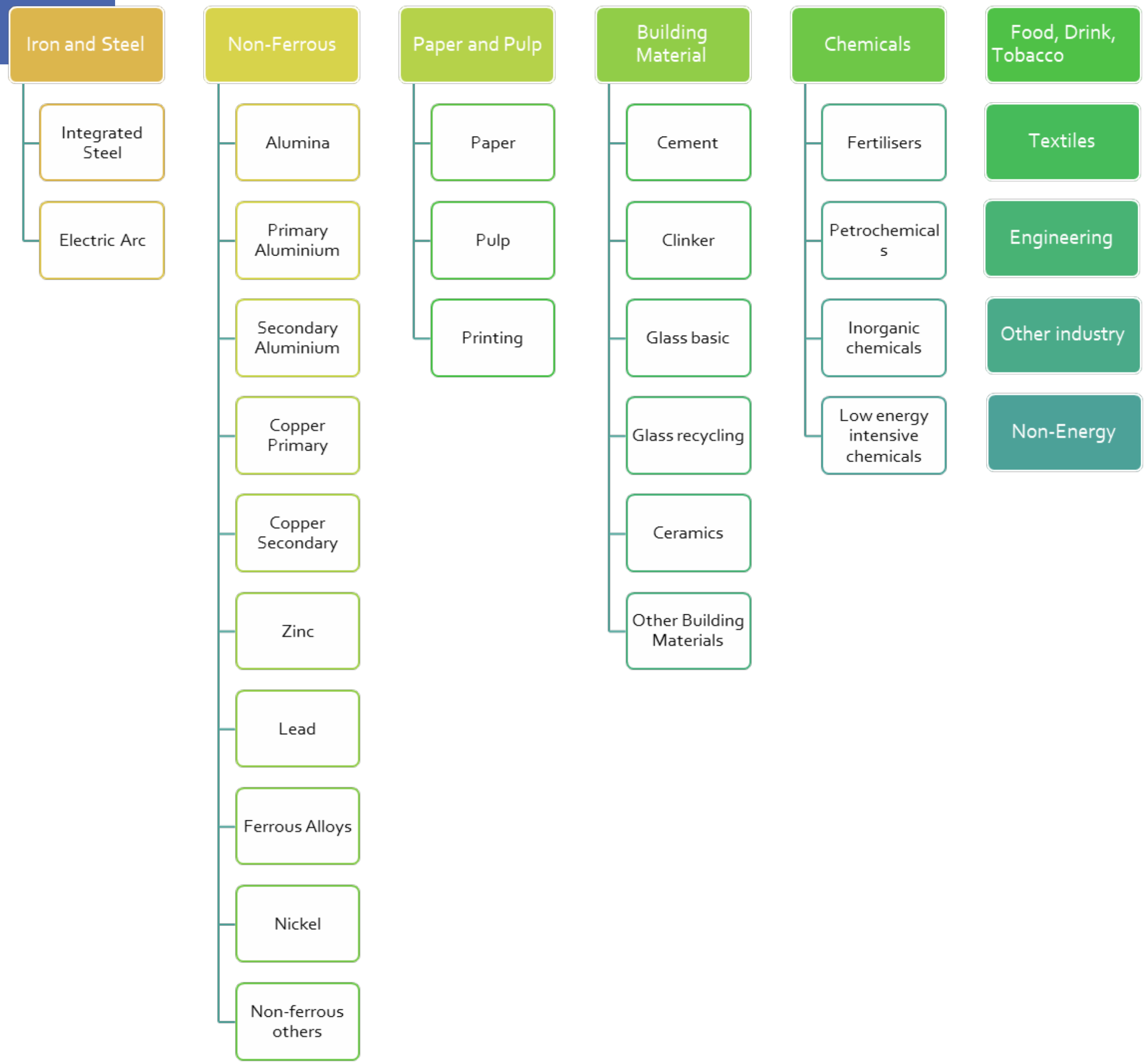
Levels	Definition
R_0	No Renovation
R_1	"Light" Renovation (Windows Replacement -U value 2.7 W/m2K)-
R_2	"Light" Renovation (Windows Replacement -U value 1.7 W/m2K-)
R_3	"Medium" Renovation (Windows Replacement -U value 2.7 W/m2K-, a 5 cm layer of insulation and achievement of air permeability of 27 m3/m2h)
R_4	"Medium" Renovation (Windows Replacement -U value 1.7 W/m2K- , a 5 cm layer of insulation and achievement of air permeability of 27 m3/m2h)
R_5	"Medium" Renovation (Windows Replacement -U value 1.7 W/m2K- , a 10 cm layer of insulation and achievement of air permeability rate of 27 m3/m2h)
R_6	"Medium" Renovation (Windows Replacement -U value 1.5 W/m2K- , a 10 cm layer of insulation and achievement of air permeability rate of to 9 m3/m2h)
R_7	"Deep" Renovation (Windows Replacement -U value 1.5 W/m2K-, a 20 cm layer of insulation and achievement of air permeability rate of to 9 m3/m2h)
R_8	"Deep" Renovation (Windows Replacement -U value 1.0 W/m2K-, a 20 cm layer of insulation and achievement of air permeability rate of to 5 m3/m2h)

Equipment types

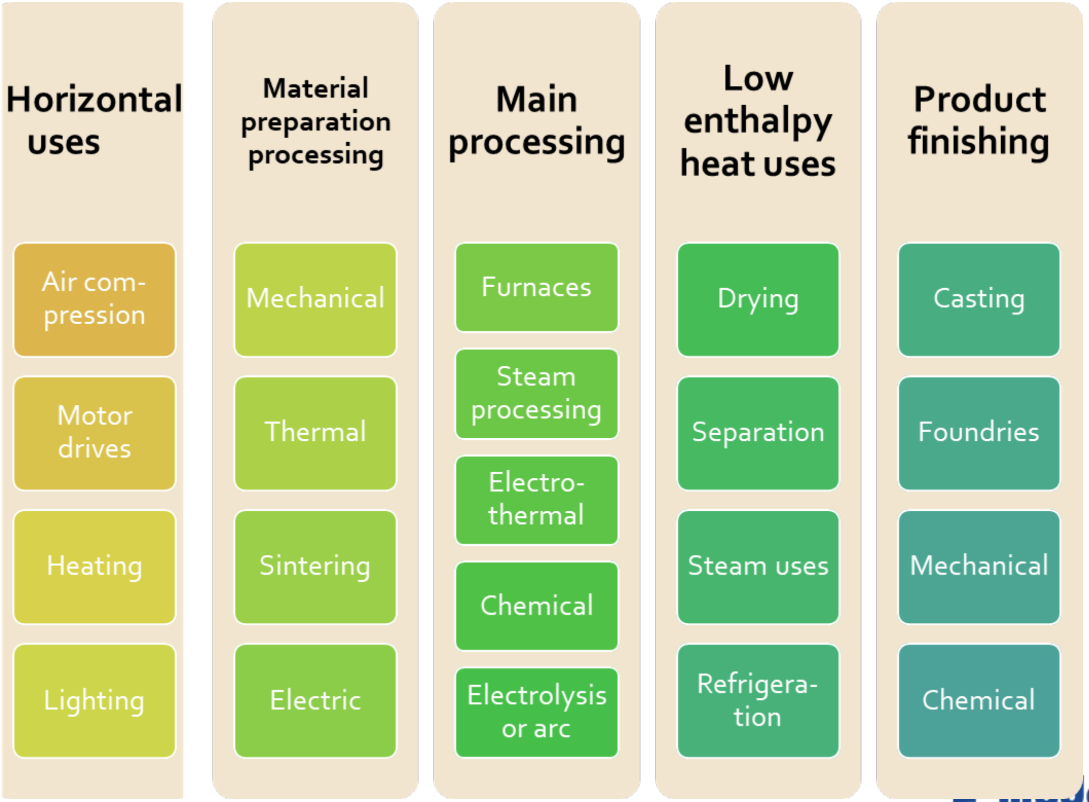
Space Heating	Water Heating	Cooling
Conventional oil boiler	Conventional oil boiler	Air-source heat pump
Condensing oil boiler	Condensing oil oiler	Water-source heat pump
Conventional gas boiler	Conventional gas boiler	Ground-source heat pump
Condensing gas boiler	Condensing gas boiler	Split system air condition
Micro-CHP ICE	Micro-CHP ICE	Centralized cooling systems
Micro-CHP fuel cell	Micro-CHP fuel cell	Gas heat pump (air)
Gas heat pump	Gas heat pump	Absorption chiller
Autonomous gas heater	Autonomous gas heater	Adsorption chiller
Wood pellets boiler	Wood pellets boiler	District cooling
Air-source heat pump	Air-source heat pump	
Water-source heat pump	Water-source heat pump	
Ground-source heat pump	Ground-source heat pump	
Electrical space heater	Heat pump water heater	
Thermal solar	Simple electric water heater	
Distributed heat	Thermal solar	
Geothermal pond	Distributed heat	
Stove for solid fuels	Geothermal pond	
Autonomous LPG heater	Stove for solid fuels	
Stove for liquid fuels	Autonomous LPG heater	

Cooking
Gas cookers
Solid/Biomass cookers
Electric cookers
Liquid cookers

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



Electrification and hydrogen options in industry

Power to Heat for High enthalpy Process Heat:
Electric Arc furnace, Electric melting, Induction furnace

Power to Heat for Low enthalpy Process Heat in drying, sterilization, pasteurization: UV, Microwave heating
Plasma heating, Infrared Heating

Electrolysis for metal production
Electrolysis for chemical production, e.g. chlorine, ammonia

Power for separation
Mechanical, electrostatic, filtration, Nano-technologies, reverse osmosis

Conventional and advanced Heat pumps – low to medium temperatures

High-temperature Heat pumps

Electric boilers

Mechanical vapor recompression

Mechanical drive replacing steam drive

H_2: Direct iron ore reduction to produce steel

H_2: Ammonia, Refineries, Glass purification, metal treatment

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H_2: Green production to avoid CO_2

H_2: Direct use in high temperature applications

H_2: to syngas and use for heat and chemistry

H_2: Fuel cells CHP applications

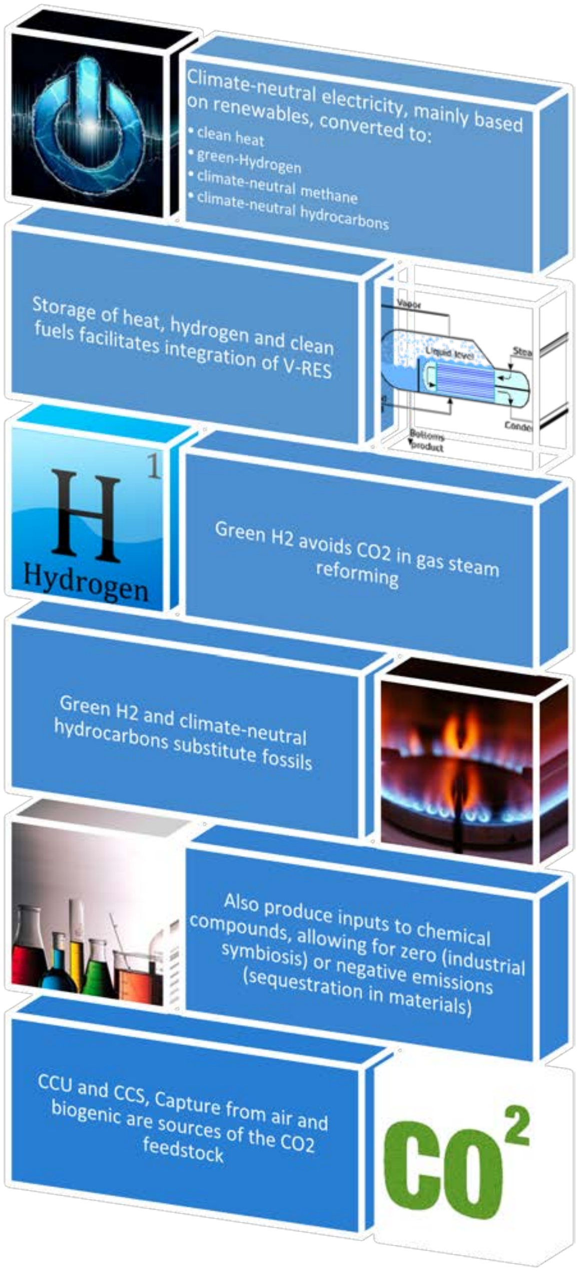
H_2: Mix in gas supply and use of gas in heat applications

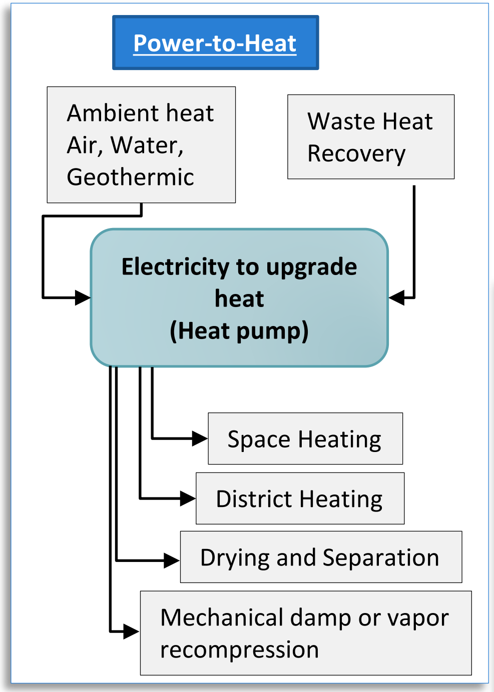
0 – 8 years | 8 – 15 years | 15 – 30 years

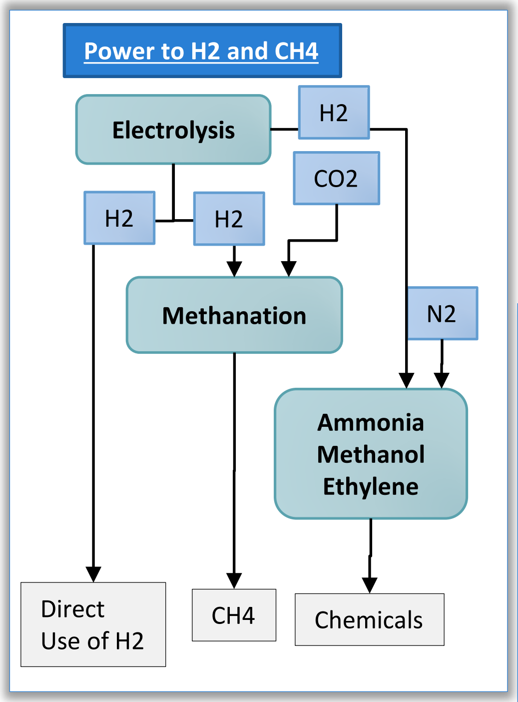
Horizon of commercial deployment

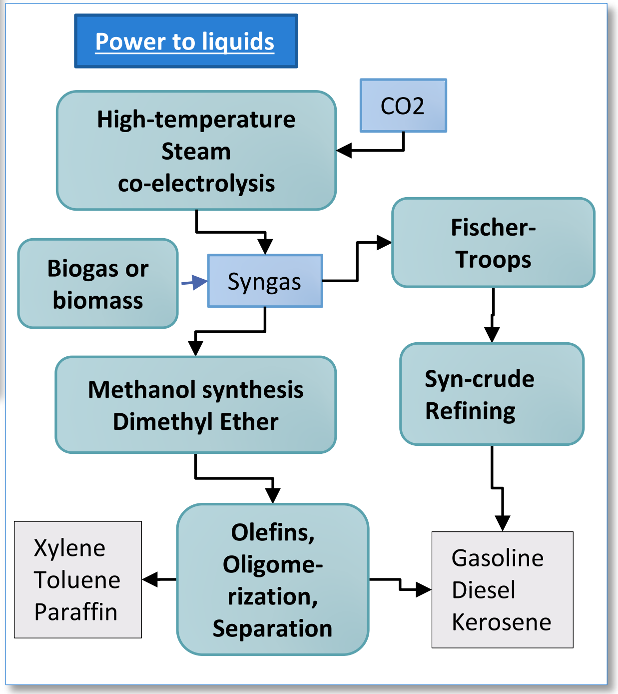
Sectoral Integration

Building blocks









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Technology description – transport (PRIMES-TREMOVE)

Transport modes segmentation

- **Private Cars**
  - Small
  - Medium
  - Large
- **Two wheelers**
  - Motorcycles
  - Mopeds
- **Light Commercial Vehicles (<3.5 ton)**
  - Passenger
  - Freight
- **Busses & Coaches**
  - Urban buses
  - Inter-urban coaches
- **Passenger Rail**
  - Metro/Tram
  - Conventional passenger rail (Railcars, Locomotives)
  - High speed Rail
- **Sea Transport**
  - Passenger inland navigation
  - National freight maritime
  - International freight maritime
    - Container
    - Dry bulk carrier
    - General cargo
    - Liquid tanker
- **Aviation**
  - <500 km distance class
  - 500-1000 km distance class
  - 1000-1500 km distance class
  - 1500-2000 km distance class
  - >2000 km distance class
- **Heavy goods vehicles**
  - 3.5-7.5t trucks
  - 7.5-16t trucks
  - 16-32t trucks
    - 4x2 Rigid Regional
    - 6x2 Rigid Regional
  - >32t trucks
    - 4x2 Tractor Regional
    - 4x2 tractor long-haul
    - 4x2 Rigid long-haul
    - 6x2 Tractor regional
    - 6x2 Tractor long-haul
- **Freight Rail**
  - Railcars
  - Locomotives

Energy carriers

Fossil liquids
- Gasoline, diesel, fuel oil, kerosene

Fossil gases
- LPG, CNG/LNG

Bioenergy (blended or drop in)
- Ethanol, biogasoline, biodiesel, biokerosene, bioheavy, biogas, biomethane

Synthetic fuels (drop-in)
- E-gas, e-diesel, e-kerosene, e-gasoline

Electricity

Hydrogen

Powertrains

Private Cars
- Gasoline
- Hybrid gasoline
- PHEV gasoline
- Diesel
- FFV (E85, E100)
- Hybrid diesel
- LPG
- CNG
- PHEV diesel
- BEV
- Fuel cell

Two wheelers
- Conventional engine
- Electric

Light Commercial Vehicles
- Gasoline ICE
- Hybrid Gasoline ICE
- PHEV gasoline
- Diesel
- Hybrid Diesel
- LPG
- CNG
- PHEV diesel
- BEV
- Fuel cell

Heavy Goods Vehicles, Buses and Coaches
- Conventional diesel ICE
- Gaseous ICE
- Hybrid
- Electric
- Fuel cell
- Pantograph trucks

Passenger and Freight Rail
- Diesel ICE
- Electric
- Fuel cell

Sea Transport
- Conventional FO ICE
- Conventional diesel ICE
- Gaseous ICE
- Electric
- Fuel cell

Aviation
- Jet engine
- Hybrid
- Electric
- Fuel cell

GAINS model: technical non-CO_2 mitigation potentials 2050 (example EU-28)

Emission source sector	Non-CO_2 mitigation measure	% of full mitigation potential adopted in Baseline	Additional technical mitigation potential 2050 (incl. technological development) MAC ≤ 20 €/t CO_2eq Mt CO_2eq	MAC > 20 €/t CO_2eq Mt CO_2eq
Livestock -enteric fermentation	Breeding for productivity, animal health & fertility; animal feed changes			
Livestock -manure management	Anaerobic digestion of manure with biogas recovery, on farms > 100 LSU			
Agricultural soils	VRT; nitrification inhib.; precision farming; abandon histosol cultivation			
Other agriculture	Intermittent aeration of rice fields; enforced ban on agr waste burning			
Coal mining	Ventilation Air Methane Oxidation			
Oil production	Extended recovery of associated gas & leakage control			
Gas production, transmission & distribution	Leak Detection & Repair programs e.g., using infrared cameras			
Stationary combustion	Modification in fluidized bed combustion			
Industrial processes (Caprolactam prod., Primary Al prod., Solvents use etc.) -BAT				
Refrigeration	Replace HFCs			
Stationary air conditioning	Replace HFCs			
Mobile air conditioning	Replace HFCs			
Other N_2O and F-gas use	Mixed options			
Industry solid waste	Food industry: Anaerobic digestion with biogas recovery	n.a.		
Industry wastewater	2-stage treatment: anaerobic w biogas recovery then aerobic	n.a.		
Municipal solid waste	Ban on landfill of organic waste	n.a.		
Domestic wastewater	Optimize process towards low N2O; Anaerobic digestion w biogas recovery	n.a.		
Total technical mitigation potential for non-CO2 GHGs in 2050: 277 Mt CO_2eq			**184**	**92**

Technology description – GLOBIOM

- LULUCF options agriculture:
  - Change in tillage practice: conventional, reduced & minimum
  - Change in crop rotations: various NUTS2 specific crop rotations
  - Perennial grasses and bioenergy crops: miscanthus, switchgrass, other green fodder, set-aside
  - Short rotation tree coppice – poplar, willow
  - Reallocation of production across pixels, crops or countries with different CO2 intensities
  - Abandonment of CO2 intensive production areas
  - Demand side options – behavioral changes, diets & food waste, harvested wood products etc.

- LULUCF options forestry:
  - Reduction of deforestation area
  - Increase of afforestation area;
  - Change of rotation length of existing managed forests in different locations
  - Change of the ratio of thinning versus final fellings
  - Change of harvest intensity
  - Change harvest locations
  - Change in forest residue harvest intensity