Green and transition technologies (Upstream)

Ref	Sector	Fuel type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
I.01	Upstream	Ammonia production	Chemical reaction	Harber-Bosch process	The Haber-Bosch process for ammonia synthesis uses high temperature (400-650° C) and pressure (100-400 bar) with a catalyst. Energy mainly comes from the exothermic reaction, with some electricity needed for control. Methods include using hydrogen from electrolysis or biomass gasification to produce syngas, an alternative to steam methane reforming.	8～11	Enabling sector 3 (Carbon capture, storage & utilisation)	IEA Clean Energy Technology Guide
I.02	Upstream	Bioenergy production	Biocoal	Torrefaction (for high temperature heating/ low-to-medium temperature heating)	Biomass undergoes torrefaction, heated sans oxygen at 200-400° C, transforming into 'bio-coal' with coal-like traits suitable for industries. This process aids in lowering emissions from industrial heat demands. Yet, sustainable biomass scarcity and competition from other sectors constrain its potential impact.	9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.03	Upstream	Bioenergy production	Biofuel	Alcohol-to-jet biodiesel (SAF)	This process combines steps such as dehydration, oligomerisation, hydrogenation, and distillation to transform alcohols (methanol, ethanol, butanol) into renewable diesel or jet fuel. Alcohol-to-jet (ATJ) is ASTM-certified for sustainable aviation fuel (SAF), blendable up to 50%. SAF demand is high in a net-zero world due to costly or impractical alternatives like electrifying long-haul flights.	7	Focus sector 4 (Transportation and storage)	IEA Clean Energy Technology Guide
I.04	Upstream	Bioenergy production	Biofuel	FAME (SAF)	FAME biodiesel is made from vegetable or waste oils and methanol using a catalyst. It produces biodiesel and glycerine, which undergo purification. Biodiesel blends with fossil diesel (5-7%) for road use or 100% for marine engines. Limitations include blending capacity, feedstock sustainability, and waste oil availability.	9～10	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide

Green and transition technologies (Upstream)

Ref	Sector	Fuel type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
I.05	Upstream	Bioenergy production	Biofuel	Gasification and Fischer-Tropsch biodiesel (SAF)	The biomass-based Fischer Tropsch pathway, known as bio-FT or BTL, converts biomass into liquid fuel. Biomass like wood or agricultural residues is gasified into syngas, then converted into hydrocarbon liquids via Fischer-Tropsch. This process avoids food crop competition and produces "drop-in" fuels compatible with existing infrastructure, but faces challenges with tar buildup.	7〜8	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.06	Upstream	Bioenergy production	Biofuel	HEFA/HVO (SAF)	Hydroprocessed esters and fatty acids (HEFA) or hydrogenated vegetable oil (HVO), is a renewable diesel and drop-in biokerosene. Produced by hydrotreatment, it uses hydrogen to break down oils into hydrocarbons. Compared to FAME biodiesel, HVO/HEFA offers better stability and properties. It is ASTM-certified for aviation fuel, blended up to 50%.	4~10	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.07	Upstream	Bioenergy production	Biofuel	Hydrothermal liquefaction and upgrading (SAF)	Hydrothermal liquefaction (HTL) and catalytic hydrothermolysis (CHJ) use high-pressure water and temperature to convert wet biomass into gases and bio-oil, often with an alkali catalyst. This bio-oil, lower in oxygen, can produce high-quality fuels like diesel and sustainable aviation fuel, with HTL certified by ASTM.	4	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.08	Upstream	Bioenergy production	Biofuel	Pyrolysis (biodiesel)	Pyrolysis involves heating biomass without oxygen, yielding bio-oil and biochar. Fast pyrolysis, lasting seconds, of dry biomass produces mostly bio-oil, refined into fuels like diesel. It can be co-fed into refineries with crude oil. Higher Technology Readiness Level (TRL) alternative biofuels exist.	7	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide

Green and transition technologies (Upstream)

Ref	Sector	Fuel type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
I.09	Upstream	Bioenergy production	Biofuel	Synthetic Iso-Paraffins (biodiesel)	The "sugars to hydrocarbons" pathway converts biomass sugars directly into diesel and jet fuel-like hydrocarbons. It employs biological or catalytic methods. Synthetic Iso-Paraffins, an ASTM-certified sustainable aviation fuel (SAF), can blend up to 10%. In a net-zero world, the demand for SAFs is high, as alternatives are costly or technically impractical.	7	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.10	Upstream	Bioenergy production	Biofuel	Fermentation	Fermentation refers to technologies that generate bioenergy, particularly bioethanol, from fermentation process. It consists of enzymatic fermentation technology to produce lignocellulosic bioethanol, sugar and starch bioethanol, as well as syngas fermemtation.	8~10	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	
I.11	Upstream	CCS business	Direct Air Capture	Direct Air Capture	Direct Air Capture (DAC) extracts CO2 from the air using an air contactor, where a fan draws air through potassium hydroxide-treated surfaces to capture CO2 as carbonate salt. The CO2 is then purified, compressed, and prepared for storage or use, with chemical reactions sustaining the process.	4〜9	Enabling sector 3 (Carbon capture, storage & utilisation)	From the internet search
I.12	Upstream	Fossil fuel based	CCUS	CCUS in fossil fuel production	This is an umbrella term for CCUS technologies in fossil fuel-based production. These include CCUS in gas production, CCUS in heating process and refinery, and CCUS in fluid catalytic cracking (FCC).	3~7	Enabling sector 3 (Carbon capture, storage & utilisation)	IEA Clean Energy Technology Guide
I.13	Upstream	Fossil fuel based	Electrification	Process electrification in gas production	Gas production electrification methods include offshore power sources with microgrid systems and grid integration via subsea cables. LNG plants, relying on direct drive compressors and gas turbines, emit CO2. Electrification with renewable-powered electric compressors can cut emissions by up to 80%, contingent on implementation and local grid emissions intensity.	9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	1st TLP

Green and transition technologies (Upstream)

Ref	Sector	Fuel type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
I.14	Upstream	Fossil fuel based	Fugitive emissions abatement	Leak detection and repair	Methane emissions, the second largest contributor to global warming, totaled 70 Mt in 2020, with 25% from fugitive emissions. Leak Detection and Repair (LDAR) is a cost-effective method to tackle this issue, targeting leaks throughout the oil and gas value chain. LDAR systems can reduce emissions by up to 95%.	11	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	1st TLP
I.15	Upstream	Hydrogen production	Biological reaction	Biological splitting	Biotechnologies for green H2 from biomass include: 1) Dark fermentation (DF), which uses organic matter to produce H2 and biobased molecules without light, offering low costs but affected by microbial interactions. 2) Water-splitting photosynthesis by algae and cyanobacteria generates H2, though oxygen inhibition limits it. 3) Bioelectrochemical systems use microbial electrolysis cells for H2 production.	4	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.16	Upstream	Hydrogen production	Chemical reaction	Aluminum oxidation	Hydrogen can be produced via water/steam aluminum oxidation under pressure (up to 40 bar) and low temperatures (up to 300° C), using catalysts. This method requires alkaline compounds to prevent oxide layer formation. Although it offers low-emission hydrogen potential, methods like CCS and electrolysis are currently more cost-effective.	4	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.17	Upstream	Hydrogen production	Chemical reaction	Ammonia cracking	Ammonia cracking decomposes ammonia into nitrogen and hydrogen at high temperatures (600-900° C) using iron, consuming 30% of ammonia's energy content. Lower temperature cracking (~450° C) uses precious metals like ruthenium, needing further innovation for efficiency and cost. Hydrogen can be transported as ammonia but requires energy-intensive cracking for pure hydrogen.	4	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide

Green and transition technologies (Upstream)

Ref	Sector	Fuel type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
I.18	Upstream	Hydrogen production	Chemical reaction	Decomposition from methane	Methane splitting/pyrolysis/cracking decomposes methane into CO2-free hydrogen and solid carbon at high temperatures. This process includes catalytic, thermal, plasma thermal, and plasma non-thermal decomposition methods, allowing the separated solid carbon to be used in various applications.	3~8	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.19	Upstream	Hydrogen production	Chemical reaction	Partial oxidation of natural gas	In partial oxidation, natural gas reacts with limited oxygen, yielding hydrogen and CO instead of CO2 and water due to insufficient oxygen. A subsequent water gas shift process generates more H2 and CO2. This exothermic process, coupled with carbon capture, reduces CO2 emissions from hydrogen production, vital for net zero strategies.	5～6	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.20	Upstream	Hydrogen production	Chemical reaction	Reforming from methane (CCU)	Hydrogen is produced through steam-reforming, where methane reacts with high-temperature steam to produce H2 and CO (syngas). Technologies include single reformers, gas-heated reformers, electric-powered steam reforming, sorption-enhanced steam reforming, catalytic steam methane reforming, and underground reforming with CCUS.	4~9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.21	Upstream	Hydrogen production	Electrolyser	Electrolyser	Electrolysis uses electricity to split water into its basic components (H2 and O2). Under this umbrella term, there are specific technologies including alkaline electrolyser, anion exchange membrane electrolyser, polymer electrolyte membrane electrolyser, solid oxide electrolyser cell, among others.	6~9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.22	Upstream	Hydrogen production	Gasification	Biomass-waste gasification/pyrolosis	This is an umbrella term for H2 production technologies from solid feedsstock through thermochemical process. They include biomass-waste gasification technology and pyrolysis technology.	6	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide

Green and transition technologies (Upstream)

Ref	Sector	Fuel type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
I.23	Upstream	Hydrogen production	Hydrogen conditioning	Hydrogen post-production conditioning	This is an umbrella term for technologies to treat H2 post-production. These include hydrogen liquefaction, liquid organic hydrogen carriers, and hydrogen compression.	6~9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	-
I.24	Upstream	Hydrogen production	Mining	Natural hydrogen extraction	Natural hydrogen, produced by iron oxidation and radiolysis, is explored in iron-rich and radioactive areas using methods similar to hydrocarbon exploration. Targeted are source rocks, migration paths, and reservoirs like volcanic sills or salt layers. Despite progress, incomplete surveys and economic uncertainties limit its net-zero transition role.	5	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.25	Upstream	Hydrogen production	Water splitting	Water splitting	Water splitting consists of technologies to split water into oxygen and hydrogen using catalysts, thermal energy or thermochemical reactions. These include photocatalytic water splitting, or water splitting with solar/nuclear/very high temperature reactor (VHTR).	4~5	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.26	Upstream	Methane production	Biomethane	Anaerobic digestion for biomethane and biogas production	This term encompasses technologies using anaerobic digestion to produce bioenergy, such as biogas, biomethane via methanation with hydrogen, and biomethane with CO2 separation. Anaerobic digestors break down biomass like animal manure, MSW, and agricultural residues without oxygen, producing biogas (methane and CO2).	3~9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.27	Upstream	Methane production	Biomethane	Biomass gasification and methanation	This term encompasses technologies for producing methane from biomass gasification and methanation, including small-scale, catalytic, and combined methods. Biomass with high lignocellulosic content is gasified in an oxygen-restricted environment to produce syngas (H2, CO, CO2). The syngas is cleaned, CO2 removed, dried, and then converted to biomethane via catalytic or biological methanation.	4~9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide

Green and transition technologies (Upstream)

Ref	Sector	Fuel type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
I.28	Upstream	Methane production	Methanation	Chemical/biological methanation	This term covers technologies for producing methane from CO2 via chemical or biological methanation. These methods include chemical and biological methanation, converting CO or CO2 to methane through hydrogenation using a catalyst. Carbon sources include CO in syngas from gasification or pyrolysis, or CO2 from exhaust gases, fermentation, anaerobic digestion, or direct air capture.	7	Enabling sector 3 (Carbon capture, storage & utilisation)	IEA Clean Energy Technology Guide
I.29	Upstream	Methane production	Synthetic methane	Synthetic methane from CO and H2	Fischer Tropsch synthesis converts CO2 (via RWGS reaction) and hydrogen into synthetic liquid hydrocarbons. Key challenges include CO2 thermal stability and reaction efficiency. Products include light olefins, gasoline, kerosene, and value-added chemicals, using iron, cobalt, or ruthenium catalysts. Synthetic fuels are crucial for decarbonizing sectors like long-distance shipping and aviation.	6	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.30	Upstream	Methanol production	Biomass gasification	Biomass and waste gasification	Biomass can replace fossil fuels for methanol production by converting it into syngas. While this avoids direct fossil fuel use, sustainable biomass availability limits potential. The process is capital and energy-intensive, making it costlier than alternatives like hydrogen and CCS.	8	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
I.31	Upstream	Methanol production	Chemical reaction	CO2- and electrolytic hydrogen-based methanol production	Syngas, mainly CO2 and hydrogen, is produced from methane and used to make methanol. This process relies on hydrogen from water electrolysis and waste CO2 from industrial sources. It can avoid direct fossil fuel use if renewable electricity is used for hydrogen production and CO2 is sourced sustainably.	7	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide

Green and transition technologies (Upstream)

Ref	Sector	Fuel type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
I.32	Upstream	Methanol production	Chemical reaction	Methane pyrolysis	Methane pyrolysis generates CO2-free hydrogen and solid carbon, which can be used in various applications. It produces syngas for methanol production without CO2 emissions, with minimal changes to subsequent processes. While promising for reducing methanol production emissions, CCS is currently more advanced. Projects are also exploring hydrogen use for methanol and ammonia production.	8	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide

Green and transition technologies (Power)

Ref	Sector	Tech type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
II.01	Power	CCUS	CCS business	CO2 storage	This entry consists of different CO2 storage technologies, the most common options being depleted oil/gas reservoirs, aquifers, among others.	11	Enabling sector 3 (Carbon capture, storage & utilisation)	IEA
II.02	Power	CCUS	CCS business	CO2 transport	CO2 transport technologies include pipelines, shipping, and trucks. Pipelines transport CO2 in various forms, requiring refrigeration and compressors. Shipping handles long-distance transport, needing infrastructure for liquification, loading, and storage at both departure and receiving ports.	6~10	Enabling sector 3 (Carbon capture, storage & utilisation)	-
II.03	Power	CCUS	CCS business	Enhanced oil recovery (EOR)/Enhanced gas recovery (EGR)	CO2 injections can occur during production at oil fields or gas fields to enhance oil/gas recovery. Following EOR/EGR operations, the majority of injected CO2 may remain permanently trapped in the reservoir where it was injected. Additional activities may be required to confirm that injected CO2 remains stored underground.	11	Enabling sector 3 (Carbon capture, storage & utilisation)	IEA Clean Energy Technology Guide
II.04	Power	CCUS	CCUS in power plants	Biomass-fired power plant with CCUS	In biomass-fired power plants employing post-combustion capture with chemical absorption, CO2 from flue gas is separated using solvents like amines. The CO2 is released at high temperatures, regenerating the solvent for continued use in capturing emissions.	6～7	Enabling sector 3 (Carbon capture, storage & utilisation)	IEA Clean Energy Technology Guide

Green and transition technologies (Power)

Ref	Sector	Tech type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
II.05	Power	CCUS	CCUS in power plants	CCUS in coal/gas power plant	CCUS in coal or gas power plants captures emitted CO2, preventing its release. Chemical absorption is a common method, where CO2 reacts with a solvent like amines to form an intermediate compound. Regenerating the solvent with heat yields a concentrated CO2 stream. This process can capture around 90% of emitted CO2.	6~9	Enabling sector 3 (Carbon capture, storage & utilisation)	1st TLP
II.06	Power	CCUS	CCUS in power plants	Chemical looping with CCUS	Chemical looping combustion (CLC) utilizes metal oxides to burn fossil fuels, capturing CO2 emissions. Fluidized bed CLC employs two reactors to produce hydrogen and pure CO2: one oxidizes an oxygen carrier with steam to generate H2, while the other oxidizes fuel to produce CO2, operating in a loop. Fixed-bed CLC alternates oxidation and reduction in a single reactor for efficient hydrogen production with high purity and continuous operation.	4	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.07	Power	Fossil fuel based	Thermal	Combined cycle gas turbine	Combined cycle gas turbine (CCGT) power plants use gas and steam turbines for higher efficiency (60%) than open cycle turbines and coal plants (40%). Generating capacity ranges from 300 to 1,000+ MW. Plant availability is over 80%, with a technical life exceeding 25 years.	11	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	1st TLP
II.08	Power	Fossil fuel based	Thermal	Supercritical CO2 cycle	Supercritical CO2 (sCO2) cycles replace conventional steam with CO2 above its critical temperature and pressure, blending liquid and gaseous phases. They promise higher efficiency, lower emissions, and reduced costs, aided by high CO2 capture rates and potentially lower water use. Operational challenges like combustion dynamics remain a focus area for further study.	5～6	Enabling sector 3 (Carbon capture, storage & utilisation)	IEA Clean Energy Technology Guide

Green and transition technologies (Power)

Ref	Sector	Tech type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
II.09	Power	Fuel switching	Thermal	Low-carbon ammonia cofiring	Low carbon ammonia co-firing in coal-fired power plants involves modifying the boiler and investing in additional facilities like ammonia tanks. Ammonia is mixed with pulverized coal before entering the burner zone for combustion. Optimizing boiler design is crucial for stable flame and NOx reduction. Technological advancements may allow higher co-firing ratios, but beyond a certain threshold, replacing the steam turbine with a gas turbine may boost thermal efficiency.	3~5	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	1st TLP
II.10	Power	Fuel switching	Thermal	Biomass cofiring	Biomass co-firing power generation combines renewable biomass with fossil fuels like coal or gas in existing power plants to cut greenhouse gas emissions and fossil fuel dependence. This method works across different plant types, enabling a shift towards sustainable energy production with minimal adjustments.	10	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	NEDO Energy Saving/Non-fossil Energy Conversion Technology Strategy
II.11	Power	Fuel switching	Biomass	Integrated gasification combined-cycle biomass power plant	In integrated gasification combined-cycle biomass plants, biomass is converted to synthesis gas, containing hydrogen and carbon monoxide. The gas undergoes a water-gas-shift reaction to enhance hydrogen and convert CO to CO2. CO2 is separated using methods like adsorption, while hydrogen fuels a combined-cycle turbine for power generation, potentially enabling negative emissions if CO2 is permanently stored.	3	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.12	Power	Fuel switching	Fuel cell	Fuel cell	Fuel cell technologies include molten carbonates and solid oxide fuel cells, suitable for hybrid hydrogen fuel cell-gas turbine systems. They convert hydrogen into electricity and heat with no direct emissions, achieving over 60% electric efficiency (80% including heat output) and higher efficiency at partial loads, ideal for flexible operations.	6~9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide

Green and transition technologies (Power)

Ref	Sector	Tech type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
II.13	Power	Fuel switching	Hydrogen	Low-carbon hydrogen cofiring	Low carbon hydrogen can be used alone or mixed with natural gas in power plants, requiring adjustments to burners. Most gas turbines can handle up to 5% hydrogen without significant changes. Standard turbines might run on up to 60% hydrogen with infrastructure updates, facing risks like autoignition and combustion instability. Pure hydrogen firing is in initial pilot stages.	7~9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	1st TLP
II.14	Power	Fuel switching	Waste	Waste to Energy	Four types of Waste-to-Energy (WtE) technologies include direct combustion, thermochemical gasification, anaerobic digestion, and landfill capture. Direct combustion burns waste to generate steam for electricity; gasification converts waste carbon to syngas; anaerobic digestion produces biogas from organic waste; landfill capture extracts gas from landfills. Commercial viability relies on waste supply, economics, and alternative waste management options.	10	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	1st TLP
II.15	Power	Nuclear	Nuclear reactor	High-temperature reactor and very high temperature nuclear reactor	Very high temperature reactors (VHTR) produce high temperatures (up to 1,000° C) for hydrogen production and industrial heat applications, achieving high efficiency with Brayton cycles. Designs include 250 MW electricity or 600 MW heat, using helium coolant and graphite-moderated fuel. Key challenges include high-temperature materials and fuel design. China and Japan have prototype reactors.	7~8	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide

Green and transition technologies (Power)

Ref	Sector	Tech type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
II.16	Power	Nuclear	Nuclear reactor	Sodium-cooled fast nuclear reactor	Sodium-cooled fast reactors (SFRs) are established Generation IV technologies using fast neutron spectrum, liquid sodium coolant, and closed fuel cycles with multi-recycling of nuclear materials. Full-sized designs (up to 1,500 MW) use mixed uranium-plutonium oxide fuel. SFRs offer higher temperatures (550° C), enhancing non-electricity applications. Key challenges include reducing capital costs and increasing passive safety.	8〜9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.17	Power	Nuclear power	Nuclear reactor	Light water nuclear reactor	This umbrella term covers large-scale and small modular light water nuclear reactors (LWRs). LWRs, the most common Water Cooled Reactors, include Pressurized Water Reactors (PWRs) and Boiling Water Reactors (BWRs). PWRs use separate steam generators, while BWRs use steam from the reactor core. All require U-235 enriched fuel.	6~11	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.18	Power	Renewables	Geothermal	Binary plant	This umbrella term covers binary-cycle geothermal plant technologies, including closed-loop, hybrid closed-loop systems, Kalina process, and organic Rankine cycle. These plants transfer heat from geothermal hot water to another liquid, which turns to steam and drives a generator turbine.	5~11	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.19	Power	Renewables	Geothermal	Combined cycle and hybrid plant	Some geothermal plants use a combined cycle, adding a traditional Rankine cycle to utilize waste heat from a binary cycle, enhancing electric efficiency. Hybrid geothermal power plants combine geothermal basics with other heat sources, such as concentrating solar power (CSP), to increase the brine temperature and power output.	7	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IRENA https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Aug/IRENA_Geothermal_Power_2017.pdf

Green and transition technologies (Power)

Ref	Sector	Tech type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
II.20	Power	Renewables	Geothermal	Direct dry steam plant	Dry steam plants, which make up about a quarter of geothermal capacity today, directly utilise dry steam that is piped from production wells to the plant and then to the turbine.	11	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.21	Power	Renewables	Geothermal	Enhanced geothermal system	Enhanced geothermal systems (EGS) utilize Earth's heat where conventional sources are lacking. EGS involves engineering extensive heat exchange areas in hot rock by enhancing permeability via fracturing. Heat transfer occurs by pumping water into fractured rock, cycling it through a power plant. Despite potential, future costs remain uncertain.	6	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.22	Power	Renewables	Geothermal	Flash steam plant	Flash steam plants, comprising most of current geothermal capacity, utilize reservoirs with temperatures surpassing 180° C. Water boils into steam as pressure decreases, powering turbines for electricity. Remaining hot water may undergo multiple flashings to produce more steam. Despite mature technology, deployment hinges on local potential.	11	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.23	Power	Renewables	Hydropower	Hydropower	Hydropower harnesses falling water for electricity, constituting 16% of global power. It's categorized into run-of-river, reservoir, and pumped storage plants. Being mature and cost-competitive, it's crucial for clean energy and offers flexibility to the power grid.	11	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.24	Power	Renewables	Ocean	Ocean thermal	Ocean Thermal Energy Conversion (OTEC) utilizes temperature gradients in ocean depths for energy production, also enabling Sea-Water Air Conditioning (SWAC) and desalination. SWAC is economically viable for cooling, particularly in European commercial and data center applications, expanding its utility beyond power generation.	5	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide

Green and transition technologies (Power)

Ref	Sector	Tech type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
II.25	Power	Renewables	Ocean	Ocean wave	Wave Energy Converters (WECs) utilize wave movement for energy. They're adaptable in placement, near the shore or over 100 meters away. Unlike tidal tech, wave tech is still evolving. Various prototypes globally test different designs. Four main types exist: point absorber, attenuator, hinged flap, and Oscillating Water Column (OWC). Developers aim for higher power ratings and commercialization.	6～7	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.26	Power	Renewables	Ocean	Salinity gradient	Salinity gradient technology utilizes osmotic pressure between seawater and freshwater but requires further development for widespread deployment. The Netherlands and Mexico are actively involved in testing and advancing this technology alongside other countries globally.	4	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.27	Power	Renewables	Solar PV	Crystalline silicon PV	The majority of photovoltaic (PV) modules use wafer-based crystalline silicon (c-Si) technology. Manufacturing involves growing silicon ingots, slicing them into wafers, making cells, and assembling modules. Current single-crystalline modules offer higher efficiency (14-20%) compared to multi-crystalline ones. Efficiency improvements are anticipated, making c-Si competitive in sunny regions.	9～10	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.28	Power	Renewables	Solar PV	Perovskite	Perovskite-based thin-film PV tech, not silicon, shows promise with light absorption. Lab efficiency at 25%, but only in small cells. Scaling challenges persist; durability is short-lived. Larger cell production process not established, durability remains an issue.	4～5	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide

Green and transition technologies (Power)

Ref	Sector	Tech type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
II.29	Power	Renewables	Solar PV	Thin-film PV	Thin-film solar cells are second-generation cells made by depositing thin layers of photovoltaic material on substrates. Commercial technologies include hydrogenated amorphous silicon, cadmium telluride, and CIS-CIGS. Organic thin-film PV cells use dye or organic semiconductors. R&D has developed low-cost technologies like copper zinc tin sulphide, Perovskite, and organic solar cells, though stable products are still in development.	5~8	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.30	Power	Renewables	Solar thermal	Solar thermal energy	This term encompasses solar thermal energy technologies, including solar towers, parabolic troughs, linear Fresnel reflectors (LFRs), and solar thermal district heating. These systems concentrate sunlight to generate high temperatures for electricity production, using mirrors to focus sunlight onto a receiver, heating a fluid to produce steam that drives a turbine generator.	7~10	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.31	Power	Renewables	Ocean	Tidal energy	This entry consists of technologies related to tidal energy. These include tidal range, which generates electricity based on conventional hydropower principles, and tidal sream turbines, which work in a similar way to wind turbines.	9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.32	Power	Renewables	Wind	Airborne wind energy system	Airborne wind energy systems (AWES) convert wind energy into electricity using kites or unmanned aircraft tethered to the ground. They include lift-type and drag-type designs. AWES require less material, lower cost, faster deployment, and can harness stronger winds at higher altitudes. Applications range from small off-grid power to large-scale offshore production, though operational reliability is still developing.	4〜5	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide

Green and transition technologies (Power)

Ref	Sector	Tech type	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
II.33	Power	Renewables	Wind	Offshore wind turbine	Seabed fixed offshore wind turbines dominate current offshore wind capacity. Their energy capture and power generation are similar to onshore turbines, but they are optimized for marine conditions. Foundation types include monopiles, multi-piles, gravity foundations, and suction caissons, supported by structures like tubular towers, jackets, tripods, lattice towers, and hybrids.	9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.34	Power	Renewables	Wind	Onshore wind turbine	Wind turbines convert wind's kinetic energy into electricity via a rotor and generator. Onshore turbines are versatile, installed in diverse locations and climates, from coasts to deserts. They are an innovative, growing technology, enhancing size, performance, and services. Onshore wind is a key renewable resource.	9～10	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
II.35	Power	Waste heat utlisation	Energy efficiency	Organic Rankine Cycle Power generation	An Organic Rankine Cycle (ORC) system uses low to medium-high temperature heat sources (80 to 400° C) for power production, efficiently exploiting low-grade heat. Traditionally, ORC cycles use axial or radial inflow turbines. Exergy's Radial Outflow Turbine (ROT) innovation offers greater efficiency for customized ORC power plants.	7～ 9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	NEDO Energy Saving/Non-fossil Energy Conversion Technology Strategy

Green and transition technologies (Midstream)

Ref	Sector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
III.01	Midstream	Electricity distribution	DC microgrid	Direct Current (DC) Microgrids use DC power from photovoltaic (PV) sources and battery storage to directly power DC loads like EV charging and lighting without DC/AC conversion, enhancing efficiency. With AC/DC converters, they can connect to the grid and AC loads. 100% DC systems improve efficiency by avoiding conversion losses, assuming local electricity production and consumption.	7	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
III.02	Midstream	Electricity distribution	Demand respond systems	A hybrid network combines energy-consuming equipment and batteries to provide demand response services to the electricity grid. Using smart grid principles, it rotates energy use based on flexibility and fills gaps with batteries, ensuring reliability without on-site batteries. This enables robust flexibility services, aiding the integration of renewable energy sources into the grid.	9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
III.03	Midstream	Electricity distribution	Double (dual) smart grid	A double smart grid combines smart electricity and district energy networks, optimizing synergies among energy loads (electricity, heating, cooling) and integrating renewable (PV, solar thermal, Power-to-Heat) or waste energy resources. It enhances system efficiency, scalability, and is suitable for dense, mixed-use districts.	9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
III.04	Midstream	Electricity distribution	Smart grid	A smart grid uses digital technologies to manage electricity transport, coordinating generators, operators, and users to meet demand efficiently. It minimizes costs and environmental impacts while maximizing reliability, resilience, flexibility, and stability. Technologies include smart inverters, dynamic line rating, and virtual inertia fast frequency response (FFR), most of which have matured.	7~10	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA
III.05	Midstream	Electricity distribution	Flexible AC transmission system	Flexible Alternating Current Transmission Systems (FACTS) encompass technologies that provide reactive power support, enhance controllability, improve stability, and increase power transfer in AC systems. They support variable renewables, distributed generation, and new electric demands. Key components include series compensation, synchronous condensers, static synchronous compensators, static VAr compensators, and mechanically switched capacitor damping networks.	11	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide

Green and transition technologies (Midstream)

Ref	Sector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
III.06	Midstream	Electricity distribution	High voltage (HVDC) transmission sytem	High-voltage direct current (HVDC) systems use DC for power transmission, enabling efficient long-distance electricity transfer and offshore wind farm integration. New advancements make HVDC systems economical, offering flexible power control and network support. HVDC links operate at 320-1100 kV, with up to 12GW capacity, ideal for remote renewable resources and long-distance transmission, surpassing HVAC systems.	11	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
III.07	Midstream	Energy/fuel storage	Ammonia storage tank	Ammonia is stored as a liquid, with modern atmospheric tanks holding up to 50,000 tonnes. Low-pressure storage is preferred due to lower capital costs. New ammonia storage units may serve as fuel bunkers if ammonia is used as a fuel in shipping.	11	Not found	IEA Clean Energy Technology Guide
III.08	Midstream	Energy/fuel storage	Battery for grid use	This term covers various grid-connected batteries for storing excess electricity, including lithium-ion, sodium-ion, redox, solid-state, and metal-air batteries. A Battery Energy Storage System (BESS) charges from the grid or power plant, discharging energy later to provide electricity or other grid services when needed.	7~10	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
III.09	Midstream	Energy/fuel storage	Hydrogen storage	This term covers hydrogen and ammonia storage methods, including salt and lined hard rock caverns, liquid hydrogen tanks, and metal hydrides. Hydrogen storage can be as gas in high-pressure tanks, as liquid at cryogenic temperatures, or on/within solids through adsorption or absorption.	4~11	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide
III.10	Midstream	Energy/fuel storage	Mechanical energy storage	This term encompasses mechanical energy storage technologies, including liquid air, compressed air, gravity-based storage, and flywheels. These systems convert electrical energy into kinetic or potential energy, reconverting it to electricity as needed. They balance grid peak periods and provide services like frequency, primary, and voltage control.	6~9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide

Green and transition technologies (Midstream)

Ref	Sector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
III.11	Midstream	Energy/fuel storage	Power-to-heat	This entry consists of power-to-heat technologies i.e. energy is stored in the form of heat, and electricity can be generated when needed. These include sorption process storage, moten salts storage, solids heat storage, among others.	5~9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
III.12	Midstream	Energy/fuel storage	Thermal storage	This term covers thermal storage technologies, including geothermal networks, phase-changing materials, solid-solid thermal storage, and thermochemical storage. Thermal energy storage involves heating or cooling a medium, like water in a tank, to store energy for later use when energy supply is lower.	8~9	Not found	IEA Clean Energy Technology Guide
III.13	Midstream	Fuel distribution	Hydrogen pipeline	Pipelines for transporting hydrogen. These can be repurposed natural gas pipelines or newly built pipelines.	8~9	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
III.14	Midstream	Fuel distribution	Natural gas supply network	Natural gas is transported through pipelines from wells to customers via a mainline system, including transmission pipes and compressor stations. Investment depends on system parameters such as pipe diameter, thickness, pressure, length, and compression ratio.	9~11	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	METI Transition Roadmaps
III.15	Midstream	Fuel distribution	Ammonia truck	Truck transportation is the most expensive way to transfer ammonia, used mainly for distances under 150 km or where other transport means are unavailable. It supplies retail distribution centers or small fertilizer manufacturers. Truck capacities range from 15 to 30 tonnes of ammonia in pressurized tanks (10-28 bar), depending on regional regulations.	11	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	From the internet search
III.16	Midstream	Fuel distribution	Hydrogen truck	Hydrogen transport for small demands uses multi-element gas container trailers with steel or composite pressure vessels. Steel tubes carry 380 kg at 180-250 bar, while composite vessels carry 560-900 kg at 350-500 bar. Cryogenic trailers transport 1500-3000 kg of liquid hydrogen. Trucks are cost-effective for small-scale, short-distance transport.	11	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide

Green and transition technologies (Midstream)

Ref	Sector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
III.17	Midstream	Fuel distribution	Ammonia tanker	Ammonia is shipped in fully refrigerated, non-pressurized vessels, often designed for LPG. With a boiling point of -33° C, it can use LPG carriers if no copper or zinc parts are present. Annual shipments are about 20 million tonnes. Research explores using ammonia as fuel and carrying both LPG and ammonia. Hydrogen may be traded as ammonia, requiring tankers at ports.	11	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
III.18	Midstream	Fuel distribution	Hydrogen tanker	Ships designed to transport hydrogen. These can be liquified hydrogen tanker or liquid organic hydrogen carrier tanker.	7~11	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
III.19	Midstream	Fuel distribution	LNG tanker	Combined use of synthetic methane in existing infrastructure such as liquefaction stations, LNG carriers, receiving stations, and pipelines.	7～8	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	METI Transition Roadmaps

Green and transition technologies (Downstream)

Ref	Sector	Tech group	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
IV.01	Downstream	Electricity charging	EV charging	This term covers EV charging technologies, including smart, fast, ultra-fast, conductive, inductive charging, and battery swapping. The growing EV market drives advancements in public charging infrastructure, particularly fast and ultra-fast chargers on highways, enabling longer journeys and reducing range anxiety, a key barrier to EV adoption.	6~10	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
IV.02	Downstream	Electricity charging	Fast charging for ships	Fast charging equipment, using plugs or wireless devices, is essential for recharging electric ships' batteries. Battery-electric ferries recharge at each docking. High power (up to several MW) requires active cooling systems for cables and connectors, with solutions like water, air, fluid cooling, or superconductive cables. Electric ships, with low energy density, are suited for short-distance routes.	7	Focus sector 2 (Electricity, gas, steam and air conditioning supply)	IEA Clean Energy Technology Guide
IV.03	Downstream	Hydrogen refuelling	Hydrogen station	Hydrogen refueling stations (HRSs) are crucial infrastructures for deploying fuel cell electric vehicles. They have strong tanks (above or below ground) and can refuel up to 60 passenger cars. HRSs require high pressure and compressors to reduce the hydrogen gas volume.	9~11	Focus sector 4 (Transport and storage)	METI Transition Roadmaps
IV.04	Downstream	Lower emission fuel supply	Lower emission fuel bunkering for ships	This term covers lower-emission fuel bunkering technologies for ships, using fuels like ammonia, hydrogen, and methanol. Bunkering supplies fuel to ships onshore via barge, truck, or pipeline, or offshore by barge, necessary for long journeys where ships can't carry enough fuel. Fuel is transferred through a bunker hose.	4~9	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide

Green and transition technologies (Building)

Ref	Sector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
V.01	Building	Energy management system	Building energy management system (EMS)	Building EMS consists of a smart meter, monitoring devices, control system, communication system and other smart appliances. Smart meters record electricity consumption hourly or more frequently, reporting daily to utilities. They support two-way communication for time-based pricing and demand response. Automated demand response broadcasts signals for timely consumer response. Control systems manage heat pumps/storage as virtual power plants. Smart thermostats use advanced algorithms and controls. Batteries store/discharge energy but have limited building sector applicability.	7~10	Enabling sector 1 (Information & communication) Focus sector 6 (Construction and real estate)	IEA Clean Energy Technology Guide
V.02	Building	Energy-efficient equipment	Evaporative cooling	Evaporative technology cools by converting sensible heat to vapor enthalpy, using air or water mediation, saving energy and costs without refrigerants. Best for areas with low heating and hot water needs. Development includes permeable membrane and desiccant systems. Evaporative coolers (swamp coolers) are efficient in low-humidity areas, lowering air temperature by 15° -40° F. They cost less to install and use less energy than central AC but need more maintenance and are suitable only for low-humidity regions.	4~10	Focus sector 2 (Electricity, gas, steam, and air conditioning supply), Focus sector 6 (Construction and real estate)	IEA Clean Energy Technology Guide
V.03	Building	Energy-efficient equipment	Solid-state equipment cooling	Solid-state equipment cooling technology consists of Barocaloric cooling, Elastocaloric cooling, Electrocaloric cooling, Magnetocaloric cooling. These technologies apply an external field (pressure, mechanical force, electric or magnetic fields) under adiabatic conditions leads to temperature increase of the caloric material. All of these are in the development phase (TRL 4~5).	4~5	Focus sector 2 (Electricity, gas, steam, and air conditioning supply), Focus sector 6 (Construction and real estate)	IEA Clean Energy Technology Guide

Green and transition technologies (Building)

Ref	Sector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
V.04	Building	Energy-efficient equipment	Energy-efficient household appliances	Electric stoves use vitroceramic or hot plates with integrated electric resistance for cooking. Induction cooking relies on magnetic induction, offering high efficiency and no indoor air quality impact. Hot water tanks store household hot water, being cheap and reliable but with low energy density. Vacuum-insulated high-temperature water tanks use electric resistance and vacuum insulation, with a potential 20-year lifetime but are heavy and less efficient than heat pumps. Chilled water storage systems use air/water/ground conditioning units to charge cold water, reducing peak electricity load and costs.	8~11	Focus sector 5 (Construction and real estate)	IEA Clean Energy Technology Guide
V.05	Building	Energy-efficient equipment	Energy-efficient lighting	This entry consists of energy-efficient lighting systems, particularly LED lighting (including OLED, PLED, DC LED, etc.) and smart lighting systems (such as LEDs whose power can adjust to natural daylight and turn off when not used),	9~11	Focus sector 6 (Construction and real estate)	IEA Clean Energy Technology Guide
V.06	Building	Energy-efficient equipment	Energy-efficient ventilation system	Dual-flow ventilation: Heat exchange between incoming air and exhaust streams. Energy savings through heat and moisture recovery, controllable heat losses compared to the randomness of natural ventilation. Heat exchanger: Advanced heat exchangers for building-level substations. New plate design can reduce pressure loss by 35% and improve the heat transfer by 10%.	10~11	Focus sector 6 (Construction and real estate)	IEA Clean Energy Technology Guide
V.07	Building	Energy-efficient equipment	Heat pump	This entry covers various heat pumps: air-source, water-source, ground-source, thermally-driven, and solar. Heat pumps extract and transfer heat from sources like air, ground, or water, making them more efficient than traditional heating methods. They produce several times more heat energy than the electricity used to power them.	8~10	Focus sector 2 (Electricity, gas, steam, and air conditioning supply), Focus sector 6 (Construction and real estate)	IEA Clean Energy Technology Guide

Green and transition technologies (Building)

Ref	Sector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
V.08	Building	Energy-efficient equipment	Fuel cell co-generation	Electrochemical devices operate at up to 80° C, requiring backup for peak heat demand. They offer high electrical (48-66%) and total efficiency, emitting no pollutants. High-temperature models (600-850° C) achieve 30-59% efficiency. Cogeneration reduces carbon emissions and energy costs, with combined heat and power systems achieving up to 90% efficiency, aiding decarbonization in various sectors.	9	Focus sector 2 (Electricity, gas, steam, and air conditioning supply), Focus sector 6 (Construction and real estate)	IEA Clean Energy Technology Guide
V.09	Building	Energy-efficient equipment	Fuel combustion co-generation	Co-generation systems use lower emission fuels (natural gas, biomass) for combustion, efficiently generating electrical power and hot water. They reclaim heat from engines to produce heated water, significantly increasing primary energy efficiency, reducing energy costs, and lowering CO2 emissions. Cogeneration can achieve up to 90% efficiency, aiding in decarbonizing power grids, district heating, and factories.	11	Focus sector 2 (Electricity, gas, steam, and air conditioning supply), Focus sector 6 (Construction and real estate)	From the internet search
V.10	Building	Energy-efficient equipment	Quad generation	Quadgeneration systems produce heating, cooling and electricity while simultaneously recovering CO2 from the exhaust gases. Covers a wide range of potential applications with potential low to zero carbon emissions.	3	Focus sector 2 (Electricity, gas, steam, and air conditioning supply), Focus sector 6 (Construction and real estate)	IEA Clean Energy Technology Guide
V.11	Building	Energy-efficient equipment	Trigeneration systems (heating, cooling & electricity)	Trigeneration systems produce heating, cooling, and electricity, ideal for facilities needing all three continuously, like data centers, hospitals, and universities. They are beneficial in ASEAN's constant heat, providing sustainable refrigeration solutions. District cooling can meet air conditioning needs in commercial buildings, hotels, and shopping malls by combining distributed power generation and waste heat utilization.	9	Focus sector 2 (Electricity, gas, steam, and air conditioning supply), Focus sector 6 (Construction and real estate)	IEA Clean Energy Technology Guide

Green and transition technologies (Building)

Ref	Sector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
V.12	Building	Insulation materials	Heat harvesting using building integrated materials	Building integrated heat and moisture exchange panels precondition ventilation air in heat recovery ventilators, combining energy savings and increased insulation. Phase-change materials store latent heat and improve thermal performance by reducing heat loss, integrated into various building components. Solar thermal collectors convert solar radiation into heat for heating/cooling, needing packaged solutions for cost and efficiency. Transpired solar heat collectors draw sun-heated air through perforations, reducing heating demand by converting up to 80% of solar radiation into warm air.	6~9	Focus sector 6 (Construction and real estate)	IEA Clean Energy Technology Guide
V.13	Building	Insulation materials	Reflective materials, Insulating materials for wall and façade, Insulating window	Reflective paints, sky-facing surfaces, and advanced insulation methods like double skin facades, SIPs, and VIPs reduce space cooling demand and improve energy efficiency. Trombe walls store solar heat, and double skin facades enhance insulation and ventilation. Advanced glazing technologies, including electrochromic and dynamic glazing, offer significant energy savings and improved comfort.	4~10	Focus sector 6 (Construction and real estate)	IEA Clean Energy Technology Guide
V.14	Building	On-site renewables	Building integrated photovoltaic systems	Photovoltaic systems, integrated into building skins, include thick crystal products (crystalline silicon) and thin-film products (active material on glass or metal). They offer high electricity generation potential and cost-competitiveness. By 2030, under the Net Zero Emissions by 2050 Scenario, solar PV and wind are projected to supply about 40% of building electricity use.	9	Focus sector 2 (Electricity, gas, steam, and air conditioning supply), Focus sector 6 (Construction and real estate)	IEA Clean Energy Technology Guide
V.15	Building	On-site renewables	Building integrated wind turbines	Wind energy technologies include macro wind turbines for large-scale energy generation and micro wind turbines for local use, known as 'building-integrated wind turbines'. Small turbines are vertical axis wind turbines (VAWTs), quieter and aesthetically preferred over horizontal axis (HAWTs). Wind turbines can be grid-connected or off-grid. Recent developments focus on improving efficiency, reliability, and reducing costs.	8	Focus sector 2 (Electricity, gas, steam, and air conditioning supply), Focus sector 6 (Construction and real estate)	CTCN

Green and transition technologies (Building)

Ref	Sector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
V.16	Building	Utilisation of lower emission fuels	Appliances using lower emission fuels	Bag digesters and composite material digesters for cooking use biogas from anaerobic digestion, reducing carbon emissions and improving indoor air quality compared to solid fuels. Improved biomass stoves, LPG stoves, and solar cooking stoves are fuel-efficient and health-beneficial alternatives. Hydrogen-driven ovens and nobs use hydrogen to produce heat.	9~11	Focus sector 6 (Construction and real estate)	IEA Clean Energy Technology Guide
V.17	Building	Utilisation of lower emission fuels	Biomass-fuelled heater	Biomass, particularly wood, is widely used for heating. Biomass boilers are efficient, firing wood to produce heat. 40% of Europe's sustainably produced wood is used for heating, making it carbon neutral. Central heating biomass boilers reduce greenhouse gas emissions and benefit local economies. Modern systems use pellets, wood chips, or logs, and can integrate with solar thermal systems for higher efficiency.	11	Focus sector 2 (Electricity, gas, steam, and air conditioning supply), Focus sector 6 (Construction and real estate)	From the internet search

Green and transition technologies (Transport)

Ref	Sector	Subsector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VI.01	Transport	Aviation	Efficient engine plane	Efficient plane engine	Geared turbo fans with ultra-high bypass ratios aim to cut energy use by up to 25%, with bypass ratios exceeding 15 in pre-commercial stages. Open rotor jet engines promise up to 28% efficiency gains but face challenges like noise and practicality limitations, particularly for larger aircraft classes and long-distance flights, making them less compatible with current aircraft designs compared to geared turbo fans.	4~7	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide
VI.02	Transport	Aviation	Fuel cell plane	Hydrogen fuel cell plane	Hydrogen fuel cell-powered aircraft leverage advancements from hybrid and battery electric propulsion in aviation, offering a sustainable pathway amidst shifting energy carriers. With potential for longer ranges compared to electric aircraft, they aim to enable zero-emission medium- and long-haul flights, positioning hydrogen as a key player in sustainable aviation's future.	6~7	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide
VI.03	Transport	Aviation	Hybrid plane	Hybrid electric plane	Hybrid electric plane continues to utilize liquid jet fuels, they can achieve substantial reductions in energy consumption due to their improved powertrain efficiency.	6~7	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide
VI.04	Transport	Navigation	Electrification	Battery-electric ship	Battery electric ships rely on shore-based electricity grids to charge their batteries while docked, limiting their viability to short-distance routes due to current energy density constraints. Despite low deployment projections in the overall shipping sector by 2050, they could still account for 5% of energy use in domestic shipping under NZE scenarios, especially in future zero-emissions zones on water.	8~9	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide

Green and transition technologies (Transport)

Ref	Sector	Subsector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VI.05	Transport	Navigation	Energy efficiency	Energy efficient ship engine	Rotor sails, like Flettner Rotor Sails, utilize the Magnus effect to generate lift perpendicular to wind flow, reducing ship engine power requirements by harnessing wind energy. Effective on slow-steaming vessels, they promise fuel savings of 5-8%, potentially up to 12-20%, with low maintenance needs. Kites towed by ships, operating in optimal wind conditions, provide additional propulsion, potentially reducing fuel consumption by 10-20%, but require deck space and favorable weather conditions.	8~9	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide
VI.06	Transport	Navigation	Fuel switching	Ammonia-fuelled ship	Ammonia-powered combustion engines offer a potentially carbon-free solution for long-distance ship propulsion. Ammonia's high energy density and existing infrastructure for storage and transport make it viable for large-scale adoption. Challenges include its toxicity, ignition properties, and infrastructure scaling. Adapted internal combustion engines are being explored as one approach to utilize this promising synthetic fuel.	6~7	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide
VI.07	Transport	Navigation	Fuel switching	Biofuel-fuelled ship	Ethanol/methanol engines are similar in design to gasoline engines, with moderate changes, so the use of these biofuels does not require major changes to production lines.. Ethanol is currently the cheapest biofuel available. Methanol can be produced as a biofuel or as a synthetic fuel (from electrolysis from low-carbon electricity with a carbon source). However, the availability of sustainably sourced biomass to produce methanol is limited.	8~9	Focus sector 4 (Transport and storage)	

Green and transition technologies (Transport)

Ref	Sector	Subsector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VI.08	Transport	Navigation	Fuel switching	Fuel cell electric ship	Hydrogen or methanol, when utilized in fuel cells,can generate electricity through chemical reactions with only water as a byproduct, if sourced from renewables. Limited maritime applications currently exist with up to 100 kW output. Projects like the Norwegian hydrogen ferry and H2Ports aim to advance fuel cell technology in ports, enhancing efficiency and safety while reducing carbon emissions.	6	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide
VI.09	Transport	Navigation	Fuel switching	Hydrogen-fuelled ship	This vessel type uses an internal combustion engine fueled by hydrogen, with current engines employing a diesel-H2 blend, while pure hydrogen engines are in development. Compared to fuel cells, hydrogen engines offer higher power density crucial for ocean-going vessels, potentially suitable for long-distance, carbon-neutral propulsion, despite challenges in bunkering infrastructure and hydrogen's low energy density.	4〜5	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide
VI.10	Transport	Navigation	Fuel switching	LNG-fuelled ship	LNG bunkering infrastructure is expanding, available in major shipping hubs. Switching to LNG offers regulatory compliance, competitiveness, and environmental benefits: reducing EEDI rating and Carbon Intensity Indicator by 20%, ensuring compliance longer than conventional vessels, cutting NOx by 80%, virtually eliminating SOx and PM, and potentially lowering GHG emissions by 23% with modern engines.	10~11	Focus sector 4 (Transport and storage)	From the internet search
VI.11	Transport	Navigation	Fuel switching	Nuclear powered ship	Nuclear-powered ships use pressurised-water reactors with highly enriched uranium for high power and long operational spans. Future marine applications may employ Small Modular Reactors (SMRs) like VHTRs or MSRs, potentially eliminating refuelling needs. Despite benefits, high costs and safety concerns hinder broader adoption.	4~5	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide

Green and transition technologies (Transport)

Ref	Sector	Subsector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VI.12	Transport	Rail	Electric train	Battery electric train	Pure battery electric trains on non-electrified tracks provide zero-pollution and low CO2 emission solutions, depending on electricity's carbon intensity. Suited for suburban and short intercity routes due to limited range, they cater to non-electrified lines lacking low-CO2 fuel infrastructure, emphasizing shorter-distance applications.	8	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide
VI.13	Transport	Rail	Electric train	Magnetic levitation	Maglev trains float above rails using electromagnetic forces between onboard superconducting magnets and ground coils. This eliminates wheel-rail friction, enabling higher speeds and reducing operating costs due to fewer moving parts and lower rolling friction.	9	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide
VI.14	Transport	Rail	Fuel cell train	Hydrogen fuel cell electric train	Hydrogen fuel cell systems power electric motors for trains on non-electrified tracks, offering an alternative to diesel. This solution depends on future cost-effective, abundant low-carbon hydrogen production. It targets regions with significant non-electrified rail lines, such as interregional lines in the Americas, a majority of conventional lines in Africa, and substantial portions in India and Europe.	8	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide
VI.15	Transport	Rail	Hybrid train	Gas hybrid train (internal combustion engine and battery)	When catenary lines are absent, trains draw energy stored in high-capacity batteries or from gas engines. Braking energy is also recovered and stored. Future viability hinges on cost-effective, abundant synthetic methane production from low-carbon electricity. This solution targets partially or non-electrified rail lines, prevalent in interregional and conventional routes across continents like North and South America, Africa, India, and Europe.	8	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide

Green and transition technologies (Transport)

Ref	Sector	Subsector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VI.16	Transport	Road	Electrification	Battery-electric vehicle	A battery electric vehicle (BEV) uses batteries (today almost exclusively Li-ion batteries) arranged in a battery pack. The battery pack is combined with inverters and an electric motor to convert electrical energy provided by the batteries into mechanical energy. Heavy duty vehicles (such as urban transit buses or trucks) may require larger battery capacity than light duty vehicles (such as passenger cars).	9~10	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide
VI.17	Transport	Road	Electrification	Battery driven freezer/ refrigerater truck	Electrification of road transport vehicles, together with increasing penetration of renewables and zero-carbon electricity generation, is the most promising technology opportunity for decarbonising light-duty transport in the mid- to long-term.	9~10	Focus sector 4 (Transport and storage)	From the internet search
VI.18	Transport	Road	Electrification	Electric motor bike	Electric motorcycles are evolving with each new generation, enhancing range, performance, and reducing charge times and weight. Their global adoption is driven by their crucial role in last-mile Mobility-as-a-Service (MaaS), allowing efficient planning, booking, and delivery of diverse services	9~10	Focus sector 4 (Transport and storage)	From the internet search
VI.19	Transport	Road	Electrification	Hybrid electric vehicle (HEV)	Hybrid electric vehicles (HEVs) combine an internal combustion engine with electric motors powered by batteries charged through regenerative braking and the engine itself. HEVs enhance fuel efficiency by utilizing electric power for auxiliary functions and reducing engine idling, potentially enabling smaller engines while maintaining performance standards.	10~11	Focus sector 4 (Transport and storage)	METI Transition roadmaps

Green and transition technologies (Transport)

Ref	Sector	Subsector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VI.20	Transport	Road	Electrification	Plug-in hybrid (PHEV)	Plug-in hybrid electric vehicles (PHEVs) utilize batteries to drive an electric motor and an internal combustion engine (ICE) powered by gasoline. They can be charged via outlet, ICE, or regenerative braking. PHEVs operate electrically until battery depletion, then seamlessly switch to ICE. By 2030, PHEVs aim to cut fossil fuel energy consumption per kilometer by 30% compared to traditional ICE vehicles.	10~11	Focus sector 4 (Transport and storage)	METI Transition roadmaps
VI.21	Transport	Road	Energy management system	Automated and connected vehicles	Automated, connected, and electrified vehicles promise greater energy efficiency through features like eco-driving and platooning. Shared use further enhances efficiency. Key advancements in AI, sensors, and computing are essential for adoption. However, if limited to private cars, these technologies could reduce mobility costs, increasing vehicle use and potentially harming public transit.	6~7	Focus sector 4 (Transport and storage) Enabling sector 3 (Information & communication)	IEA Clean Energy Technology Guide
VI.22	Transport	Road	Fuel switching	Flex fuel vehicle	Flexible fuel vehicles (FFVs) are equipped with internal combustion engines that can run on gasoline or blends containing up to 83% ethanol, like E85. In the US, over 20.9 million FFVs exist as of 2022. While often unrecognized by owners, FFVs offer flexibility in fuel choice and slightly altered performance characteristics compared to gasoline-only vehicles.	10~11	Focus sector 4 (Transport and storage)	From the internet search
VI.23	Transport	Road	Fuel switching	Hydrogen fuel cell electric vehicle (FCEV)	Hydrogen fuel cell systems in FCEVs generate electricity from hydrogen, allowing smaller batteries compared to BEVs. Challenges include safety, storage efficiency, and high fuel cell costs, though economies of scale may help. Competitive deployment relies on affordable, low-carbon hydrogen production and distribution technologies.	9	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide

Green and transition technologies (Transport)

Ref	Sector	Subsector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VI.24	Transport	Road	Fuel switching	Hydrogen-fuelled vehicle	Hydrogen engines, an alternative to fuel cells, combust hydrogen directly with 40-50% efficiency, lower than fuel cells' 50-60%, but avoid rare materials like platinum. They offer better transient behavior and cold-weather performance but face issues with safety, power density, and NOx emissions. Ongoing R&D aims to improve these aspects.	7	Focus sector 4 (Transport and storage)	IEA Clean Energy Technology Guide
VI.25	Transport	Road	Fuel switching	Natural gas-fuelled vehicle	Vehicles using compressed natural gas (CNG) or liquefied natural gas (LNG) have spark-ignited internal combustion engines, similar to gasoline vehicles but with lower GHG emissions. CNG and LNG are used for heavy-duty vehicles like buses and trucks, emitting significantly less CO2, NOx, and SOx compared to gasoline and diesel.	10~11	Focus sector 4 (Transport and storage)	DoE, USA

Green and transition technologies (Specific industries)

Ref	Sector	Industry	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VII.01	Industry (specific)	Agriculture	Genetic engineering	Genetic engineering to produce crop with enhanced carbon sequestration	This biological approach uses traditional breeding and biotechnological methods to develop crop varieties with higher carbon sequestration capacity, aiding climate change mitigation. GM crops enhance productivity, disease resistance, and reduce GHG emissions by increasing yield, enabling no-till farming, and lowering fossil fuel use. However, implementation requires years, significant research, and adaptation to changing conditions.	5	Focus sector 1 (Agriculture, forestry & fishing)	From the internet search
VII.02	Industry (specific)	Agriculture	Genetic engineering	Genetically modified rumen bacteria that produce less methane	Modern molecular biotechnology aims to reduce methane synthesis in ruminants by genetically modifying microorganisms. These modified microbes are introduced into the rumen to establish stable microbiota, competing with methanogens that convert CO2 and hydrogen into methane. This approach leverages symbiotic microbial relationships but is currently in the basic research stage, far from practical application.	4	Focus sector 1 (Agriculture, forestry & fishing)	From the internet search
VII.03	Industry (specific)	Agriculture	Modification to fertiliser	Nitrification inhibitors	Nitrification inhibitors reduce nitrous oxide emissions by suppressing soil microbes that convert nitrogen into nitrate, decreasing nitrogen loss and increasing plant uptake. They lower greenhouse gas emissions, reduce water pollution, and increase crop yields. Compounds like SBT butanoate and SBT fluroate cut N2O emissions by 4-5% and reduce global warming potential by 8.9-19.5%.	10	Focus sector 1 (Agriculture, forestry & fishing)	World Research Institute

Green and transition technologies (Specific industries)

Ref	Sector	Industry	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VII.04	Industry (specific)	Agriculture	Treatment of micro-organisms	Addition of electron acceptors to paddy fields	Methane emissions from paddy fields can be reduced by adding electron acceptors (e.g., Fe(III), sulfate) to promote microbial competition with methanogens. Ferrihydrite and gypsum effectively suppress methanogenesis by utilizing more favorable electron acceptors. This method is still experimental, showing incomplete inhibition and requiring further research for practical application.	4	Focus sector 1 (Agriculture, forestry & fishing)	From the internet search
VII.05	Industry (specific)	Cement, concrete and glass	Carbon capture and utilisation (CCU)	Calcium looping (carbon capture and utilisation)	Calcium looping captures CO2 from high-temperature gas streams using lime (CaO) as a sorbent to form calcium carbonate (CaCO3) in one reactor, and regenerates lime and pure CO2 in another. It utilizes oxyfuel combustion for heat, potentially lowering energy consumption compared to other capture methods. Suited for cement kiln flue gases, it addresses challenging process emissions in cement production.	7	Focus sector 3 (Manufacturing) Enabling sector 3 (Carbon capture, storage & utilisation)	IEA Clean Energy Technology Guide
VII.06	Industry (specific)	Cement, concrete and glass	Carbon capture and utilisation (CCU)	Carbon mineralisation (carbon utilisation)	CO2 from industries can transform into building materials through CO2 curing in concrete and reacting with waste like slag and fly ash for aggregates, storing CO2 permanently. CO2-cured concrete offers cost advantages, while materials from waste can compete by sidestepping disposal costs, yet their production remains energy-intensive and requires extensive testing for structural applications.	9	Focus sector 3 (Manufacturing) Enabling sector 3 (Carbon capture, storage & utilisation)	IEA Clean Energy Technology Guide
VII.07	Industry (specific)	Cement, concrete and glass	Carbon capture and utilisation (CCU)	Direct separation from limestone (carbon capture)	Direct separation captures CO2 from limestone during clinker production by heating it in a special steel vessel. This method isolates process emissions, allowing for pure CO2 capture without contamination from fuel combustion emissions. It's a promising technology for reducing cement production emissions if developed further and made cost-effective, potentially complementing other CCS methods.	6~7	Focus sector 3 (Manufacturing) Enabling sector 3 (Carbon capture, storage & utilisation)	IEA Clean Energy Technology Guide

Green and transition technologies (Specific industries)

Ref	Sector	Industry	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VII.08	Industry (specific)	Cement, concrete and glass	Carbon capture and utilisation (CCU)	Oxy-fuelling in cement kilns (carbon capture)	Oxyfuel CO2 capture involves burning fuel with pure oxygen to produce a CO2-rich flue gas, which is dehydrated to obtain high-purity CO2. This method, using oxygen from air separation units, is less developed in cement production but shows potential with oxyfuel gas turbines and pressurized systems. It aims to cut process emissions, complementing other advanced capture technologies like chemical absorption and calcium looping.	6	Focus sector 3 (Manufacturing) Enabling sector 3 (Carbon capture, storage & utilisation)	IEA Clean Energy Technology Guide
VII.09	Industry (specific)	Cement, concrete and glass	Carbon capture and utilisation (CCU)	Synthetic methane production for power generation (carbon utilisation)	Producing synthetic methane for power in cement manufacturing reduces CO2 emissions by capturing CO2 from exhaust gases and converting it into synthetic methane for use.	5~6	Focus sector 3 (Manufacturing) Enabling sector 3 (Carbon capture, storage & utilisation)	METI Transition Road Maps
VII.10	Industry (specific)	Cement, concrete and glass	Electrification	Electric kiln	Efforts to electrify cement kilns, crucial for clinker production, are progressing with technologies like plasma arc or resistance-based heating. This approach, at an early development stage, necessitates renewable electricity to achieve substantial emission cuts. Advancement to commercial viability is needed to compete effectively, though it primarily targets energy emissions rather than process emissions in cement production.	5	Focus sector 3 (Manufacturing)	IEA Clean Energy Technology Guide

Green and transition technologies (Specific industries)

Ref	Sector	Industry	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VII.11	Industry (specific)	Cement, concrete and glass	Electrification	Electrolyser for decarbonating calcium carbonate	A novel process aims to electrochemically convert calcium carbonate ($CaCO_3$) into calcium hydroxide ($Ca(OH)_2$) using an electrolyser, generating a concentrated CO_2/O_2 stream suitable for capture, along with hydrogen for subsequent production stages. This technology, at early development stages, requires renewable energy for significant emissions reductions and commercial viability, potentially enabling easier CO_2 capture in cement production.	3	Focus sector 3 (Manufacturing)	IEA Clean Energy Technology Guide
VII.12	Industry (specific)	Cement, concrete and glass	Energy-efficient equipment	Advanced grinding technologies	Various advanced technologies for grinding raw materials and fuel in cement production are being researched, including contact-free systems, ultrasonic-comminution, high voltage power pulse fragmentation, and low temperature comminution. These innovations aim to reduce electricity intensity significantly, potentially cutting power consumption by 10% to 20% with roll press systems and enhancing grid-related CO_2 reductions as electricity grids transition to lower emissions in the NZE Scenario.	6~7	Focus sector 3 (Manufacturing)	IEA Clean Energy Technology Guide
VII.13	Industry (specific)	Cement, concrete and glass	Energy-efficient equipment	All-electric forehearth	In glass production, molten glass from the furnace flows into the forehearth where it's cut into gobs for forming. Maintaining precise and uniform heating in the forehearth is crucial to ensure consistent glass viscosity. Even small temperature variations affect viscosity, impacting production rates and scrap rates due to glass breakage, while efficient temperature control also enhances fuel efficiency.	10	Focus sector 3 (Manufacturing)	From the internet search

Green and transition technologies (Specific industries)

Ref	Sector	Industry	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VII.14	Industry (specific)	Cement, concrete and glass	Energy-efficient equipment	NSP kiln	The NSP kiln, an advanced cement firing technology, enhances thermal efficiency with a preheater system including cyclones and a calcine furnace. Compared to older methods, NSP and SP kilns reduce clinker production energy by approximately 40% and increase kiln capacities significantly, making them pivotal in modern cement manufacturing for efficiency gains.	9~11	Focus sector 3 (Manufacturing)	METI Transition Road Maps
VII.15	Industry (specific)	Cement, concrete and glass	Energy-efficient equipment	Vertical mills	Vertical coal mills and blast furnace slag mills, or verticalisation, have been introduced to enhance energy efficiency in cement production. Reports indicate that vertical roller mills for raw material grinding can achieve energy efficiency rates of 60% to 80% higher than ball mills, while vertical mills for cement grinding reduce electric power consumption by 30% compared to tube mills.	9~11	Focus sector 3 (Manufacturing)	METI Transition Road Maps
VII.16	Industry (specific)	Cement, concrete and glass	Raw material switching	Reduction of clinker ratio (using tricalcium aluminate, blast furnace slags, etc.)	To reduce cement emissions, lower clinker use by increasing tricalcium aluminate and adding more blast furnace slag to Portland blast furnace slag cement type B. Calcined clay is also a viable alternative to clinker in blended cements.	9	Focus sector 3 (Manufacturing)	IEA Clean Energy Technology Guide
VII.17	Industry (specific)	Chemicals	Carbon capture and utilisation (CCU)	Chemical production from CO2	Chemical production from CO2 includes: Producing methanol using hydrogen and CO2. Producing hydrocarbons through electrolysis and CO2 synthesis. Producing polycarbonate, polyurethane raw materials, and DMC from CO2.	7~8	Focus sector 3 (Manufacturing) Enabling sector 3 (Carbon capture, storage & utilisation)	METI Transition Roadmaps

Green and transition technologies (Specific industries)

Ref	Sector	Industry	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VII.18	Industry (specific)	Chemicals	Production process improvement	Production of functional chemicals using flow method	Continuous flow methods, rather than conventional batch methods, are used for producing functional chemicals. This approach is expected to reduce emissions by 4.91 million tons/year by 2030 and 11.7 million tons/year by 2050.	9	Focus sector 3 (Manufacturing)	METI Transition Roadmaps
VII.19	Industry (specific)	Chemicals	Production process improvement	Utilisation of naptha in fluid catalytic cracking (FCC)	Fluid catalytic cracking (FCC) is the second largest source of propylene, a by-product of refinery gasoline production. Using naphtha as feedstock improves yield and control of olefins. FCC enhances chemical production efficiency but does not achieve near-zero emissions.	9	Focus sector 3 (Manufacturing)	IEA Clean Energy Technology Guide
VII.20	Industry (specific)	Chemicals	Raw material switching	Production of chemicals from bio-derived materials	Olefins like ethylene and propylene can be produced from methanol (MTO) or ethanol (ETO) instead of petroleum, avoiding the energy-intensive steam cracking process. MTO operates at lower temperatures (300-450° C). BTX aromatics can be derived from lignin through various methods, though sustainable biomass availability may limit these processes.	6	Focus sector 3 (Manufacturing)	METI Transition Roadmaps
VII.21	Industry (specific)	Iron and steel	Carbon capture and utilisation (CCU)	Oxygen-rich smelting reduction (carbon capture)	A new oxygen-rich smelting reduction technology is in development for steel production, using a reactor where iron ore and powdered coal react to produce liquid iron for high-quality steel. This process emits concentrated CO2 in a single stack, suitable for integrating CCUS. It promises 80% emission reductions compared to conventional methods and is cost-effective compared to alternatives.	7	Focus sector 3 (Manufacturing) Enabling sector 3 (Carbon capture, storage & utilisation)	IEA Clean Energy Technology Guide

Green and transition technologies (Specific industries)

Ref	Sector	Industry	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VII.22	Industry (specific)	Iron and steel	Carbon capture and utilisation (CCU)	Recycling of CO2 from steel production process (carbon utilisation)	Technologies to recycle CO2 from steel plants, such as thermochemical coupling and converting off-gas to chemicals or synthetic fuels, aim to close the carbon loop and reduce emissions. They can lower the lifecycle CO2 footprint of products, though total savings vary based on the displaced inputs.	3~8	Focus sector 3 (Manufacturing) Enabling sector 3 (Carbon capture, storage & utilisation)	IEA Clean Energy Technology Guide
VII.23	Industry (specific)	Iron and steel	Energy-efficient equipment	High productivity electric arc furnace (EAF)	High productivity EAFs are highlighted for their efficiency across multiple metrics like yield, energy, environmental impact, cost, and safety. The American Steel Manufacturers' Association reports EAFs can double steel production while emitting 75% less greenhouse gases compared to blast furnaces. This underscores their significant environmental and operational advantages.	9~11	Focus sector 3 (Manufacturing)	METI Transition Roadmaps
VII.24	Industry (specific)	Iron and steel	Energy-efficient equipment	Plasma torch	Plasma torches provide high-temperature heat for industrial applications, including iron ore pelletisation furnaces. Nippon Steel's tundish plasma heater uses a plasma arc with argon to heat molten steel to over 10,000° C, optimizing temperature control and preventing oxidation, nitriding, and carburizing more effectively than gas combustion heating.	5~10	Focus sector 3 (Manufacturing)	Website of Nippon Steel
VII.25	Industry (specific)	Iron and steel	Energy-efficient equipment	Utilisation of submerged arc furnace (SAF)	The direct reduced iron (DRI) process uses low-emission hydrogen for steelmaking and relies on high-quality iron ore (67% iron). Due to declining ore quality, solutions include using a submerged arc furnace (SAF), producing DRI with lower quality ore, and hydrogen-based fluidised bed reduction, which does not require pelletisation.	5~6	Focus sector 3 (Manufacturing)	IEA Clean Energy Technology Guide

Green and transition technologies (Specific industries)

Ref	Sector	Industry	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VII.26	Industry (specific)	Iron and steel	Raw material switching	Direct reduced iron (DRI)	Direct reduced iron plants use natural gas or coal to reduce iron ore. Emissions decrease by substituting some of these fuels with hydrogen from water electrolysis using fossil-free electricity. Current technology handles up to 30% hydrogen replacement, potentially reducing CO2 emissions by 10-82% compared to blast furnaces. Novel biogenic reducing agents are also being explored.	6~9	Focus sector 3 (Manufacturing)	IEA Clean Energy Technology Guide
VII.27	Industry (specific)	Iron and steel	Raw material switching	Electrolyser-based reduction	Molten oxide electrolysis (MOE) produces liquid metal from oxide feedstocks using electrons, yielding pure metal and oxygen. Using renewable electricity for electrolytic steelmaking can achieve CO2-free production, reducing energy use by 30%. It can also integrate with variable renewables for power generation but is in early development stages.	4~5	Focus sector 3 (Manufacturing)	IEA Clean Energy Technology Guide
VII.28	Industry (specific)	Iron and steel	Raw material switching	Reduction via alkali metal looping	A novel process reduces iron ore using alkali metals to separate oxygen and iron. The alkali metals are recycled in a closed loop, requiring thermal energy at 300-900° C, depending on the loop part. This method efficiently reuses materials and maintains continuous operation.	4	Focus sector 3 (Manufacturing)	IEA Clean Energy Technology Guide
VII.29	Industry (specific)	Iron and steel	Raw material switching	Smelting reduction based on hydrogen plasma	Hydrogen plasma smelting reduction (HPSR) uses hydrogen in a plasma state to reduce iron oxides, creating a CO2-free steel production route with renewable electricity. The process involves a hydrogen plasma arc between a graphite electrode and liquid iron oxide. It is in early development stages compared to other low-emission steel technologies.	4	Focus sector 3 (Manufacturing)	IEA Clean Energy Technology Guide

Green and transition technologies (Specific industries)

Ref	Sector	Industry	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VII.30	Industry (specific)	Iron and steel	Raw material switching	Utilisation of ferro-coke	Ferro-coke, made from low-grade iron ore and coal, accelerates the blast furnace reduction reaction due to its ultra-fine metallic iron content. This catalytic effect significantly reduces the amount of coke required in ironmaking, improving efficiency and utilizing otherwise unusable materials.	7~8	Focus sector 3 (Manufacturing)	METI Transition Roadmaps
VII.31	Industry (specific)	Iron and steel	Raw material switching	Utilisation of plastic waste for coke production	Waste plastics, agglomerated to 20-30 mm, are blended with coal (1 mass%) and decomposed in coke ovens into 20% coke, 40% hydrocarbon oil, and 40% coke oven gas. These are used in blast furnaces, chemical industry, and power plants. Chlorine is converted to ammonium chloride, making the process efficient and environmentally friendly.	9~11	Focus sector 3 (Manufacturing)	METI Transition Roadmaps
VII.32	Industry (specific)	Waste	Methane collection	Anaerobic digestion	Anaerobic digestion occurs in closed digesters, ranging from simple to automated designs, classified by solids content, feeding mode, temperature, and stages. It produces biogas (55-60% CH4, 35-40% CO2, impurities) and nutrient-rich digestate. Biogas, with 21-24 MJ/m³ energy value, is used for fuel, lamps, or electricity, while digestate is used as fertilizer.	10	Focus sector 5 (Water supply, sewage & waste management)	From the internet search
VII.33	Industry (specific)	Waste	Methane collection	Landfill with a methane collection system	Installing a landfill methane collection system captures methane for generating electricity or biogas, reducing odors and hazards, and preventing atmospheric emissions. This system can also generate revenue from selling electricity or biogas, offering both environmental and economic benefits.	9	Focus sector 5 (Water supply, sewage & waste management)	CTCN

Green and transition technologies (Specific industries)

Ref	Sector	Industry	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VII.34	Industry (specific)	Waste	Wastewater energy generation	Energy generation from sewage sludge	The wastewater sludge gasification power generation system converts sludge into useful gas (H2 and CO) for high-efficiency power generation, drastically reducing greenhouse gas emissions (N2O, CO2). Partial combustion modifies organic components into clean fuel gas. High-temperature reactions prevent N2O emissions and decrease fossil fuel usage.	9	Focus sector 5 (Water supply, sewage & waste management)	From the internet search

Green and transition technologies (Industry cross-cutting)

Ref	Sector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VIII.01	Industry (cross-cutting)	Carbon capture and utilisation (CCU)	Carbon capture	This umbrella technology consists of different technologies to capture and separate CO2 from exhaust gas or syngas during the industrial processes. These include chemical/physical absorption, adsorption, membrane separation, cryogenic separation.	7~8	Focus sector 3 (Manufacturing) Enabling sector 3 (Carbon capture, storage & utilisation)	IEA Clean Energy Technology Guide
VIII.02	Industry (cross-cutting)	Electrification	Electric heating	This umbrella consists of different technologies for electrification of the industrial heating process. These include radiation heating (by UV light, infrared, etc.), dieletric heating (by microwave, radiowave, etc.), rotary compression heater, among others.	6~9	Focus sector 3 (Manufacturing)	IEA
VIII.03	Industry (cross-cutting)	Electrification	Large-scale industrial heat pump	Large industrial heat pumps, using renewable or waste energy, provide heating and cooling for industrial processes. They are considered large if over 100 kW. Critical for electrifying industry and decarbonizing heating/cooling networks, a project in Thailand demonstrated 74% energy cost and 70% CO2 reductions at a food processing factory.	9	Focus sector 3 (Manufacturing)	IEA Clean Energy Technology Guide
VIII.04	Industry (cross-cutting)	Energy management system (EMS)	Batteries for industrial use	Lithium batteries are ideal for industrial applications due to higher energy density, longer lifespan, faster charging, high efficiency, and scalability. They store more energy in a smaller form, endure more charge cycles, recharge quickly, have low self-discharge rates, and allow easy system expansion as power needs grow.	9~10	Focus sector 3 (Manufacturing)	From the internet search
VIII.05	Industry (cross-cutting)	Energy management system (EMS)	Introduction of advanced EMS (AI, IoT, Automated driving, etc.)	Utilizing IT advances for energy management can optimize energy use in production processes. In cement production, best practice technologies combined with energy-efficient equipment can reduce energy intensity by approximately 5.7%.	9~11	Focus sector 3 (Manufacturing) Enabling sector 1 (Information & communication)	METI Transition Roadmaps

Green and transition technologies (Industry cross-cutting)

Ref	Sector	Tech group (1)	Tech name	Description	TRL	Relevant activity in ASEAN taxonomy*	Source
VIII.06	Industry (cross-cutting)	Energy-efficient heating system	Small-scale energy efficient heating equipment	Small-scale boilers are more efficient than conventional industrial boilers and can switch to lower emission fuels. For instance, MIURA's small-scale hydrogen boiler achieves 105% efficiency.	10	Focus sector 3 (Manufacturing)	Website of Miura Co. Ltd.
VIII.07	Industry (cross-cutting)	Fuel switching	Lower emission fuel equipment	This is an umbrella term for industrial equipment (primarily heating equipment such as boiler) that can utilise lower emission fuels, including natural gas, hydrogen, ammonia, among others. These can contribute to the reduction in energy-derived CO2 by reducing the amount of fossil fuel used during combustion.	6~11	Focus sector 3 (Manufacturing)	
VIII.08	Industry (cross-cutting)	Waste/renewable heat utilisation	Direct heat from renewables	Concentrated solar power (CSP) plants use mirrors to focus solar radiation into high temperature heat, suitable for industrial processes like treating non-metallic particles and producing clinker. While promising for replacing fossil fuels, it's early in development, needing cost reductions and facing limitations in areas with optimal solar conditions. Fully replacing process heat with solar thermal remains challenging.	6	Focus sector 3 (Manufacturing)	IEA
VIII.09	Industry (cross-cutting)	Waste/renewable heat utilisation	Use of wastes for thermal energy	Using waste plastics, sludge, and wood waste for thermal energy involves direct combustion or converting waste into syngas for steam production. Upgrading syngas to methane for gas grid injection is more efficient. The most efficient method (90%) is burning waste in cement kilns. The main challenge is securing long-term customers for infrastructure support.	9~11	Focus sector 3 (Manufacturing)	METI Transition Roadmaps
VIII.10	Industry (cross-cutting)	Waste/renewable heat utilisation	Waste heat recovery	Waste heat from industrial systems can be recycled for power or heat generation, potentially saving energy costs. However, industries may hesitate to adopt waste heat recovery (WHR) technologies due to concerns about negative impacts on production.	9~11	Focus sector 3 (Manufacturing)	METI Transition Roadmaps