
ROLE OF CCS IN REACHING NET ZERO: JAPAN, SOUTH-EAST ASIA, AND AUSTRALIA

OPTIMIZATION VS SIMULATION MODELS

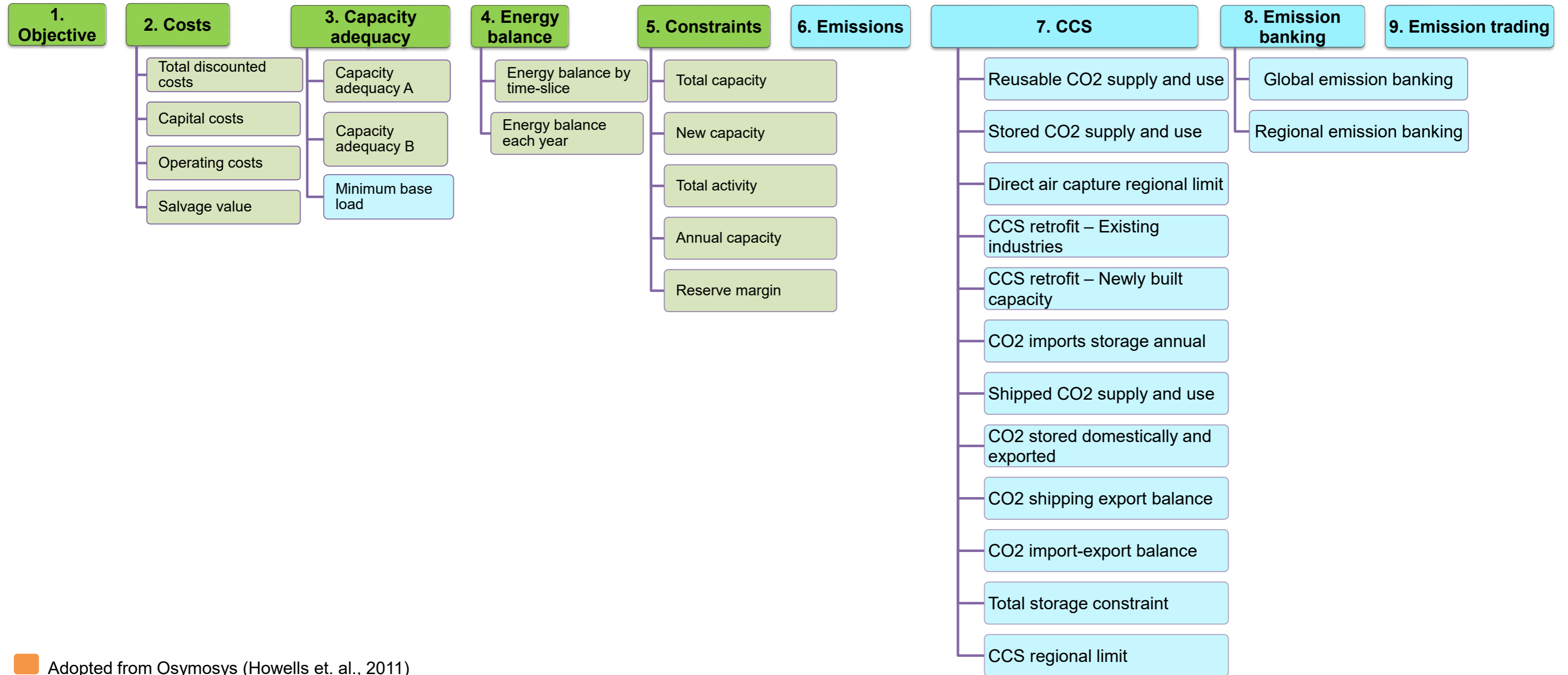
“All models are wrong, but some are useful” – George Box

| Model family | Examples | Primary focus | Objectives | Scope of Analysis | Complexity and detail |
|-----------------------------------|-----------------------------------------|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Energy system optimization models | MARKAL, TIMES, MESSAGE, OSeMOSYS, GENZO | Normative scenarios | These models are primarily designed for long-term strategic planning and policy analysis. They aim to identify the least-cost or most optimal energy system configurations and investment strategies that meet specific policy goals or targets , such as minimizing costs, reducing emissions, or maximizing energy security. | They provide a comprehensive analysis of the entire energy system , including supply-side technologies (e.g., power plants, renewable energy sources), demand-side sectors (e.g., transportation, industry, residential), energy carriers (e.g., electricity, fuels), and infrastructure (e.g., transmission lines, pipelines). | They tend to be more complex and require detailed data inputs on technology costs, performance characteristics, policy constraints, and system requirements. They can analyze a wide range of technology options and policy scenarios in detail. |
| Energy system simulation models | LEAP, NEMS, PRIMES | Forecasts, predictions | These models are used for forecasting and predictions over shorter time horizons . They simulate the behavior of energy systems under various scenarios to project future trends in energy consumption, production, prices, and emissions. They are often used for short- to medium-term policy analysis and decision-making. | They can vary in scope but often focus on specific sectors or aspects of the energy system, such as electricity generation, transportation, or specific policy interventions. They may provide detailed insights into sector-specific dynamics but may not capture the holistic interactions within the entire energy system. | They can vary in complexity, with some models offering simpler representations of the energy system. They may rely on aggregated data and assumptions to simulate the behavior of key sectors or components of the energy system. |

GLOBAL ECONOMIC NET ZERO OPTIMIZATION (GENZO) MODEL

- Based on OSeMOSYS modelling framework
- Solves for lowest total cost whilst meeting emission trajectories and other constraints
- Technologically rich
- Sectors:
 - 5 heavy industries + other industry
 - 4 modes of passenger travel
 - 7 modes of freight transport
 - Buildings, agriculture
- Trade in oil, LNG, coal, ammonia, Bio-LNG, synfuel, steel, physical CO₂ for storage, and CO₂ credits (optional)
- Future final energy service and commodity demands are exogenous
- Everything else is endogenous
- GENZO invests in and operates technologies over the entire energy system from energy resources to energy transformations to end-use technologies to satisfy final demands and constraints like net zero pathways

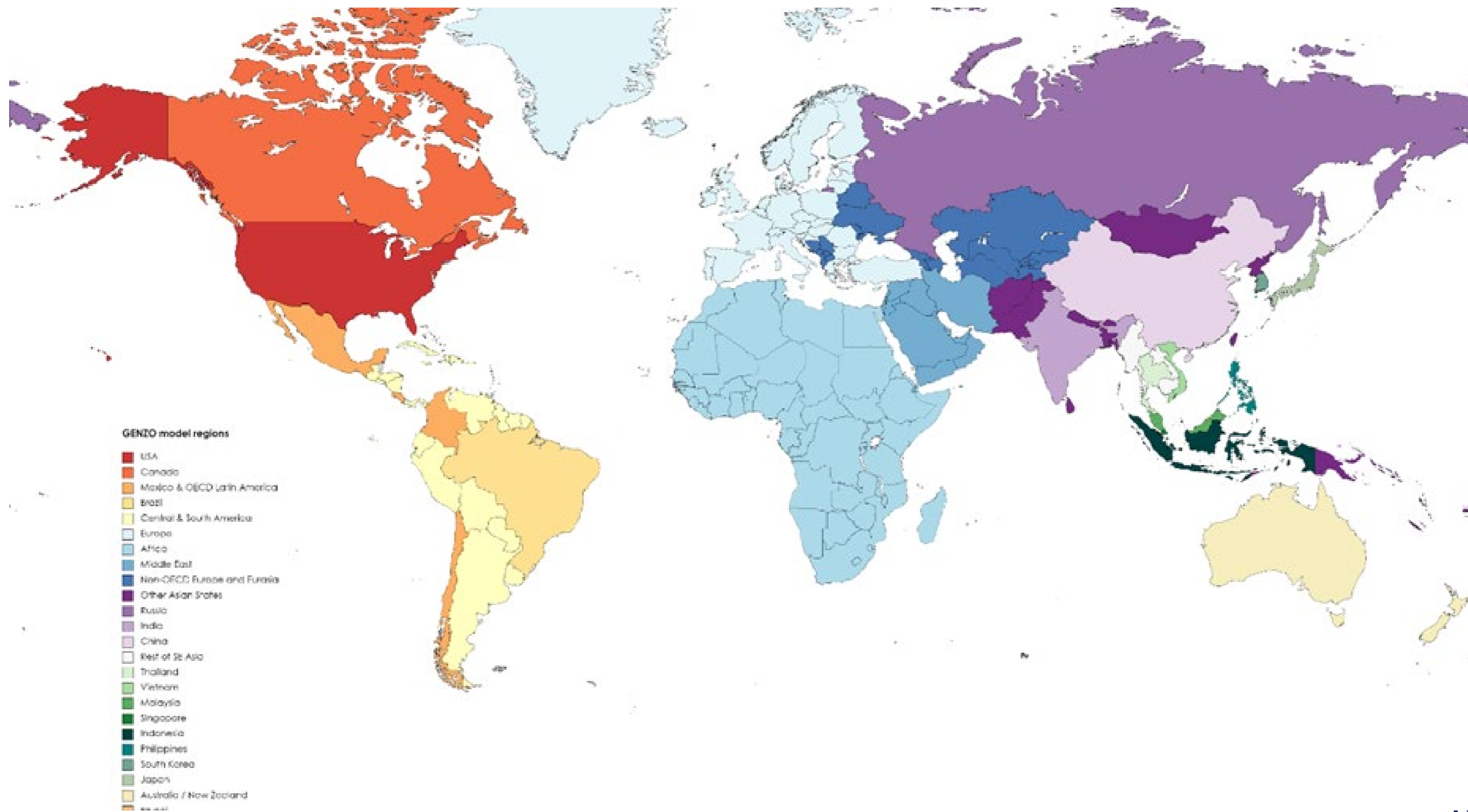
MODEL'S STRUCTURE



Adopted from Osymosys (Howells et. al., 2011)

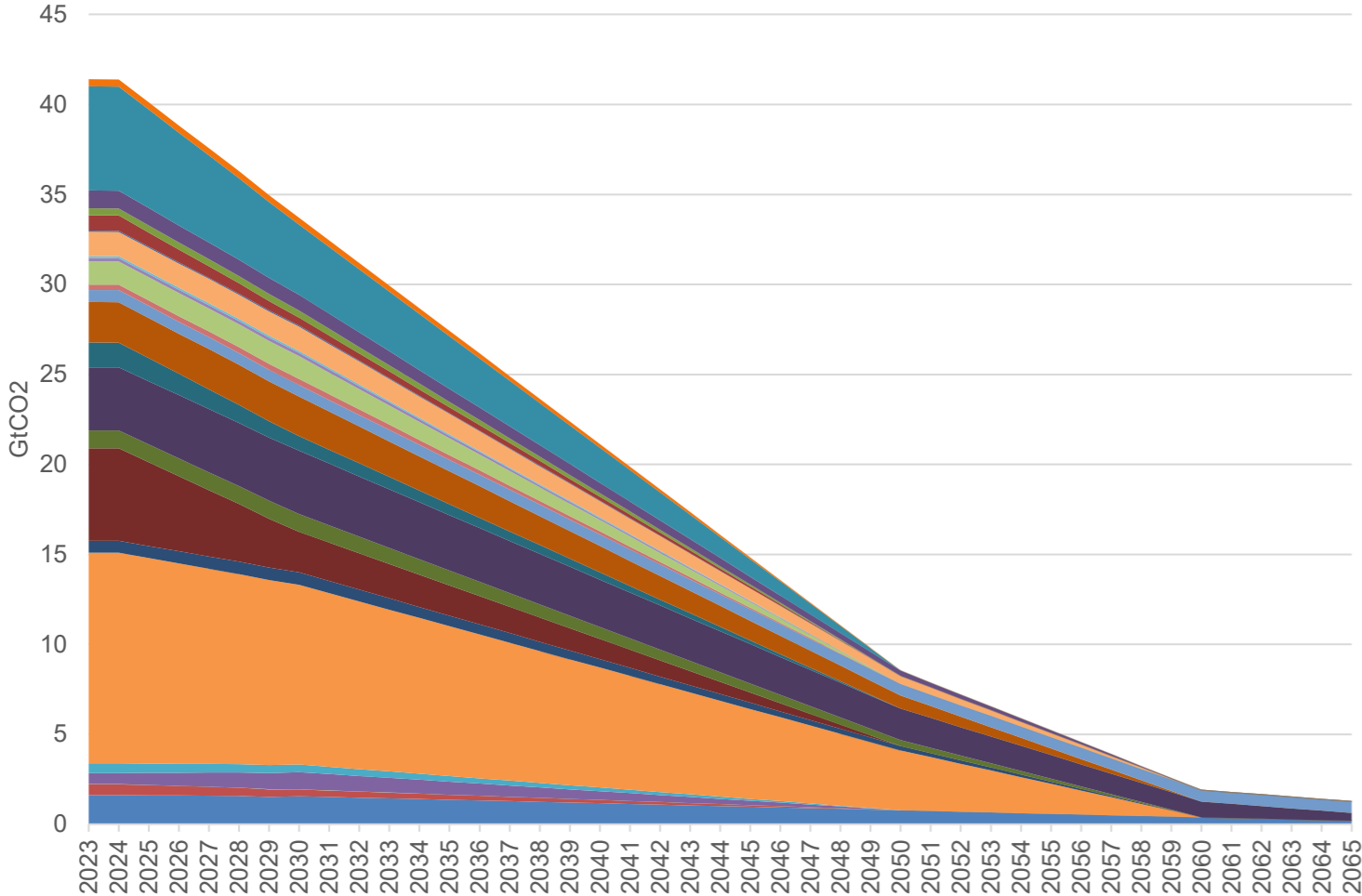
GENZO development

GENZO: 24 REGIONS



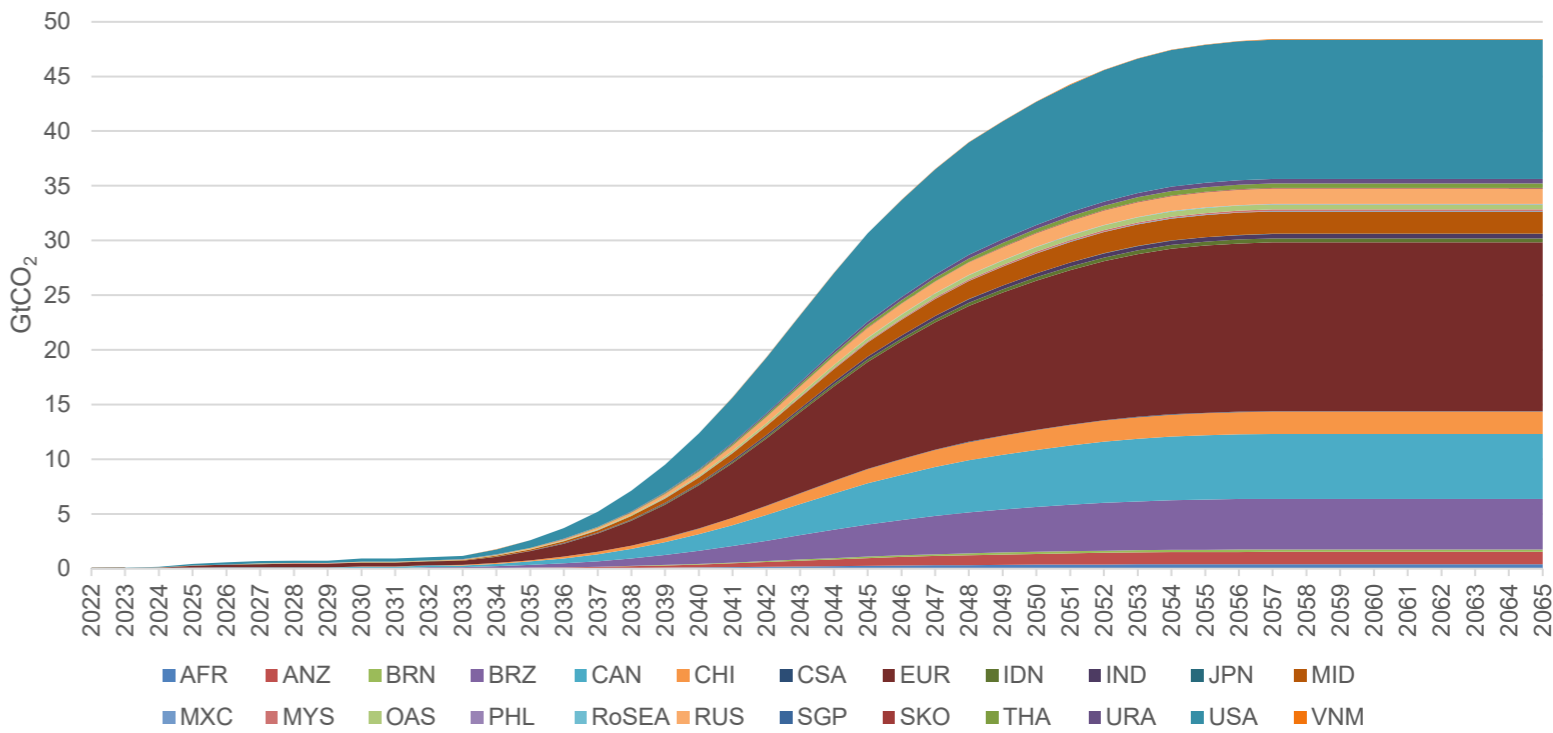
SCENARIOS

Net zero targets for all regions



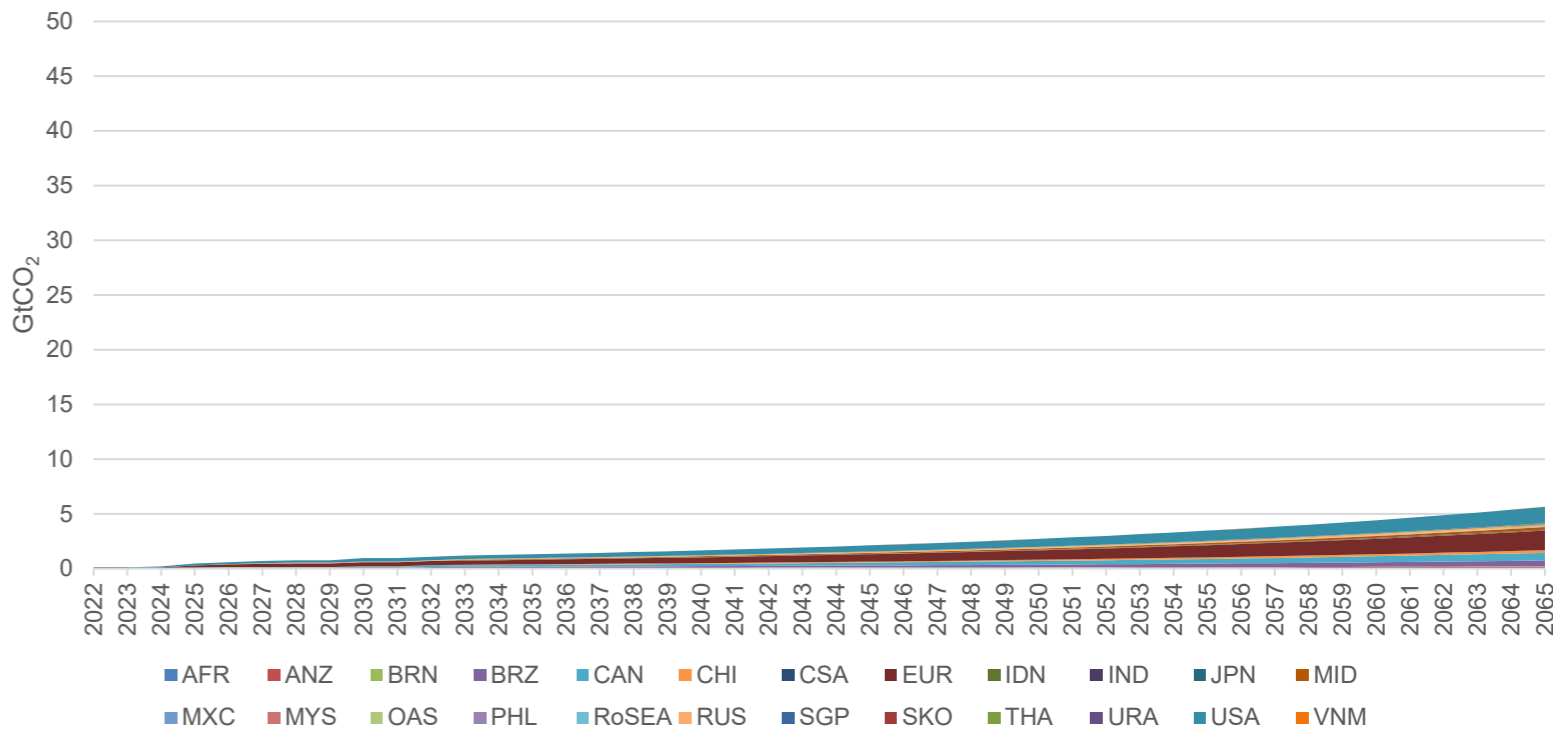
- AFR: Africa
- ANZ: Australia and New Zealand
- BRN: Brunei Darussalam
- BRZ: Brazil
- CAN: Canada
- CHI: China
- CSA: Central and South America
- EUR: Europe
- IDN: Indonesia
- IND: India
- JPN: Japan
- MID: Middle East
- MXC: Mexico and OECD Latin America
- MYS: Malaysia
- OAS: Other Asian States
- PHL: Philippines
- RoSEA: Rest of South-East Asia
- RUS: Russia
- SGP: Singapore
- SKO: South Korea
- THA: Thailand
- URA: Other non-OECD Europe and Asia
- USA: United States of America
- VNM: Vietnam

Accelerated storage scenario storage development limits



- AFR
- ANZ
- BRN
- BRZ
- CAN
- CHI
- CSA
- EUR
- IDN
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- JPN
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Low storage growth scenario storage development limits



- AFR
- ANZ
- BRN
- BRZ
- CAN
- CHI
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- EUR
- IDN
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RESULTS

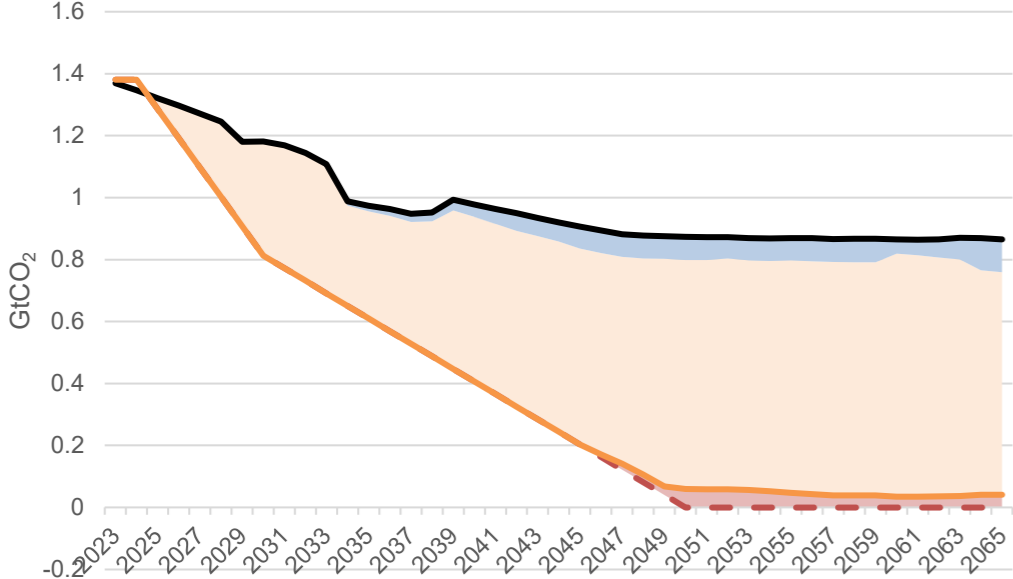
KEY FINDINGS

- **Cost savings:** Accelerated CO₂ storage leads to significant cost savings compared to low CO₂ storage while achieving the **same net zero target:**
 - Japan: USD 3 trillion
 - South-East Asia: USD 18 trillion
 - Australia: USD 4 trillion
- **CO₂ prices:** Limited CO₂ storage leads to CO₂ prices that are 3x to 4x higher after 2040
- **Carbon capture:** Accelerated CO₂ storage growth enables carbon capture opportunities across sectors and regions, but low CO₂ storage growth limits cost-effective capture opportunities to only the most critical applications, foregoing opportunities to save cost
- **Hydrogen:**
 - Limited CO₂ storage requires more hydrogen in transportation because limited storage availability limits carbon removals
 - Limited CO₂ storage also requires hydrogen-fueled electricity generation for electricity baseload because of insufficient storage for CCS in electricity generation
 - Both drive up hydrogen and electricity prices well above levels with accelerated CO₂ storage

HOW NET ZERO IS ACHIEVED

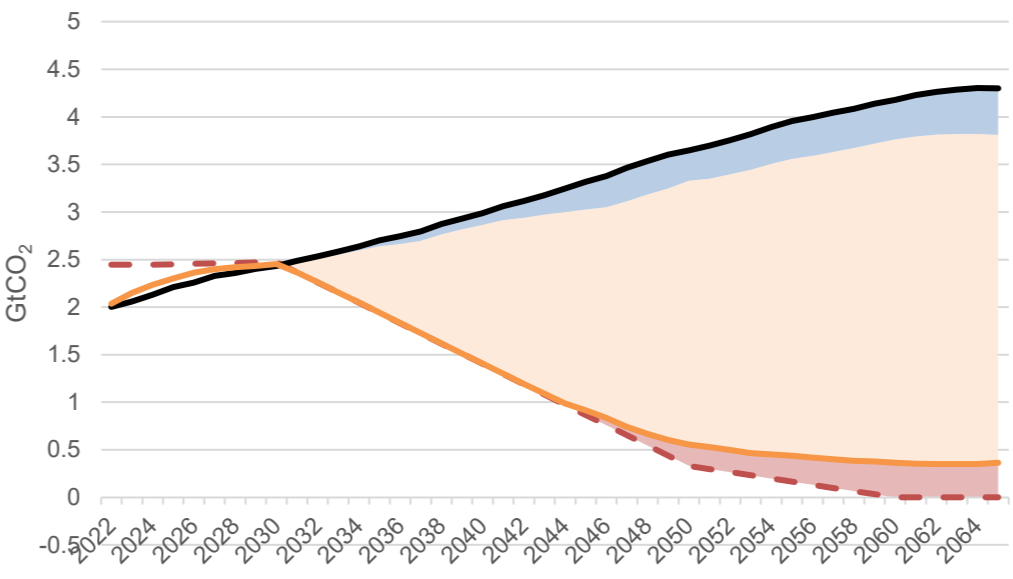
Low storage growth

Japan Net Zero pathway



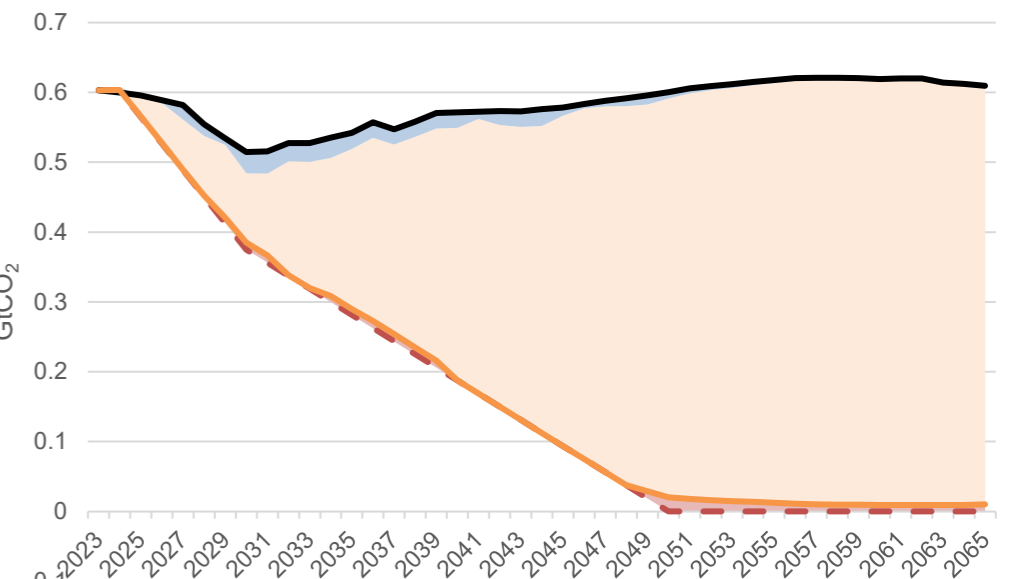
- BECCS/DACCS removals
- Renewables, H2, efficiency, etc.
- CCS
- Net zero target
- Reference emissions
- Direct CO2 emissions

South-East Asia Net Zero pathway



- BECCS/DACCS removals
- Renewables, H2, efficiency, etc.
- CCS
- Net zero target
- Reference emissions
- Direct CO2 emissions
- BECC/DACC utilization

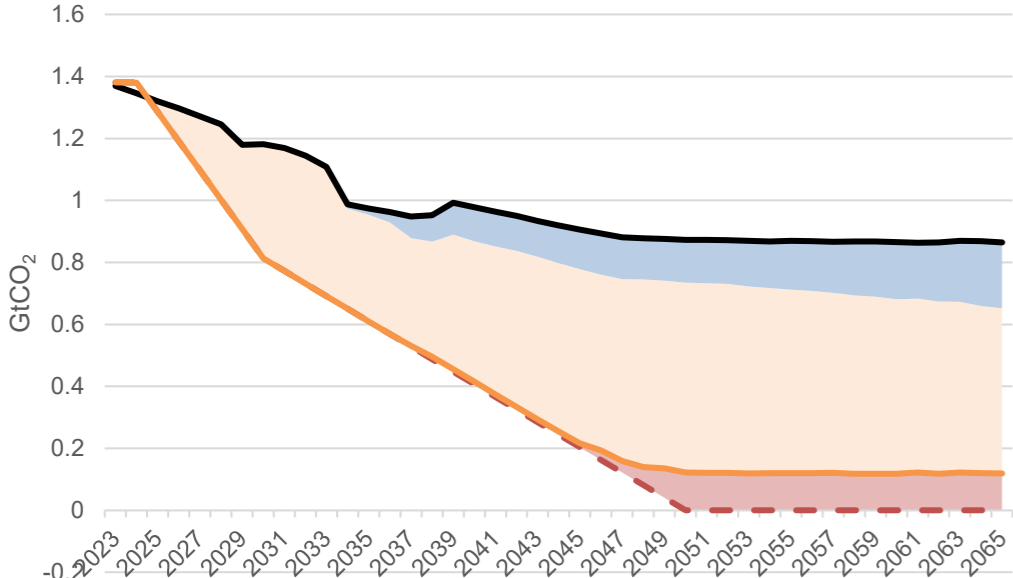
Australia and New Zealand Net Zero pathway



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- Reference emissions
- Direct CO2 emissions

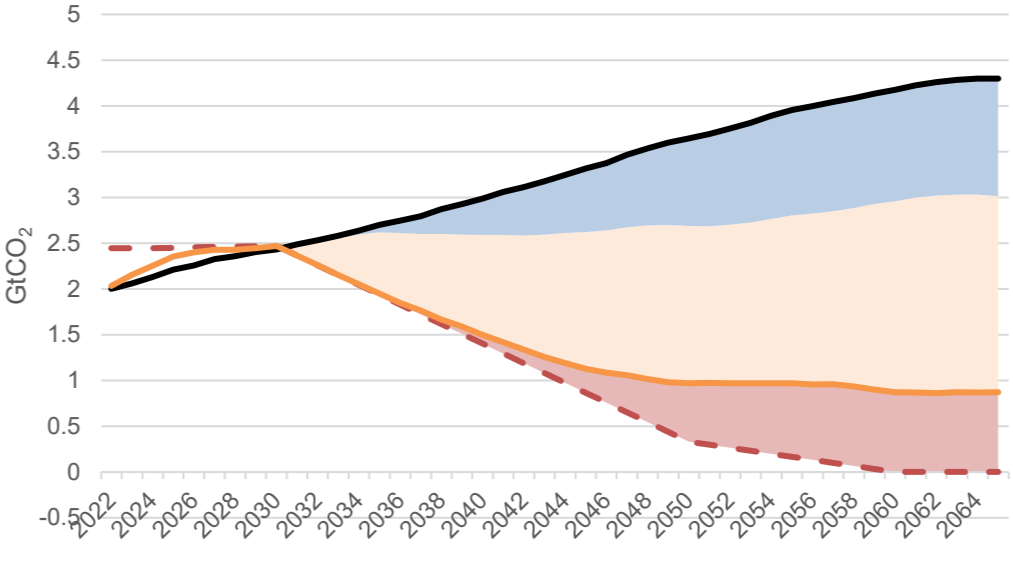
Accelerated storage growth

Japan Net Zero pathway



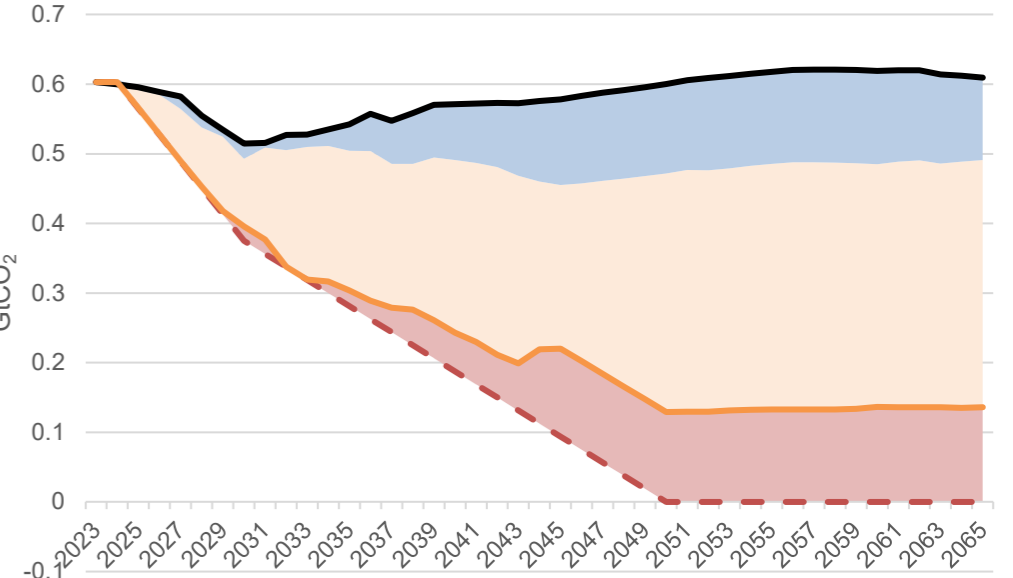
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South-East Asia Net Zero pathway



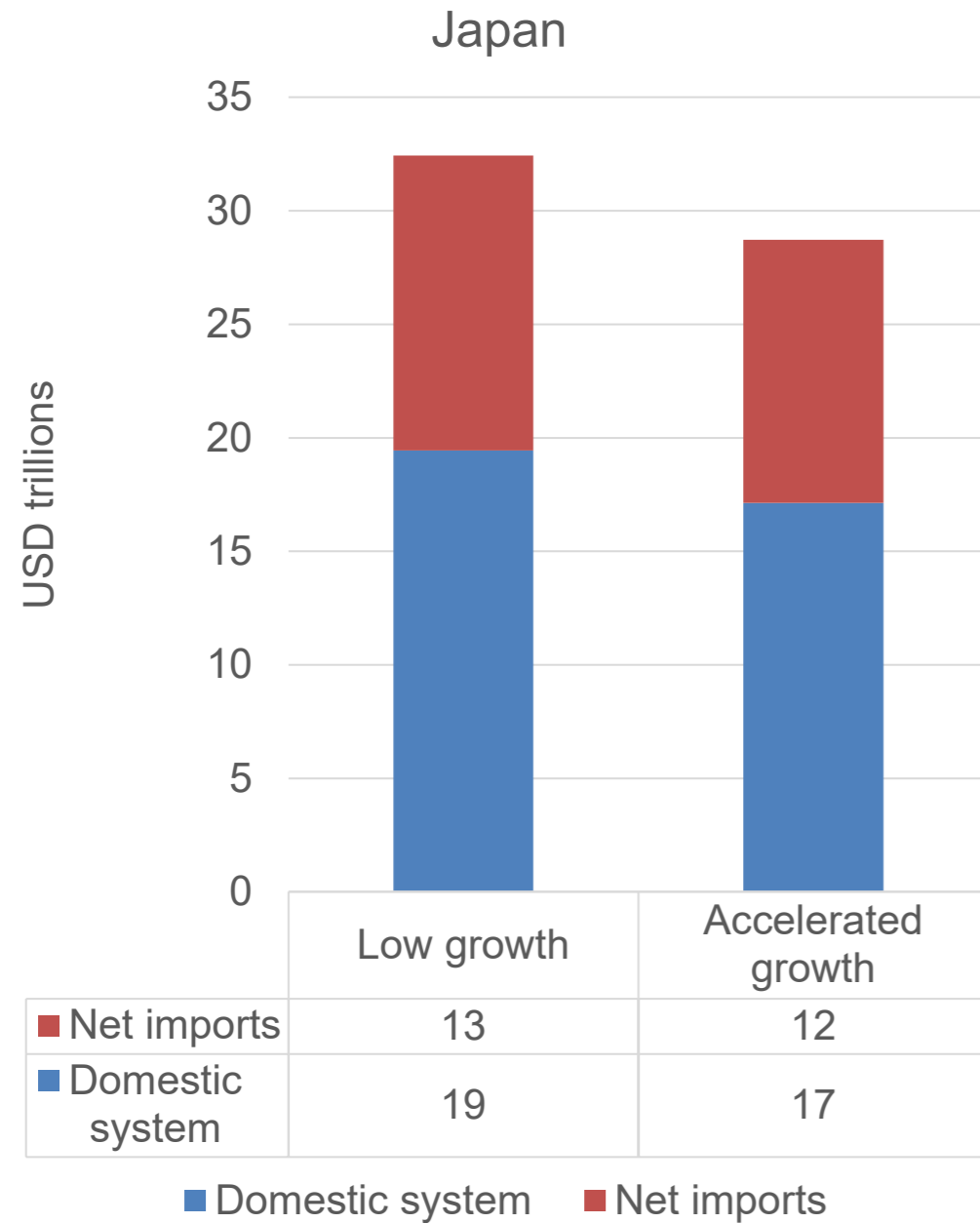
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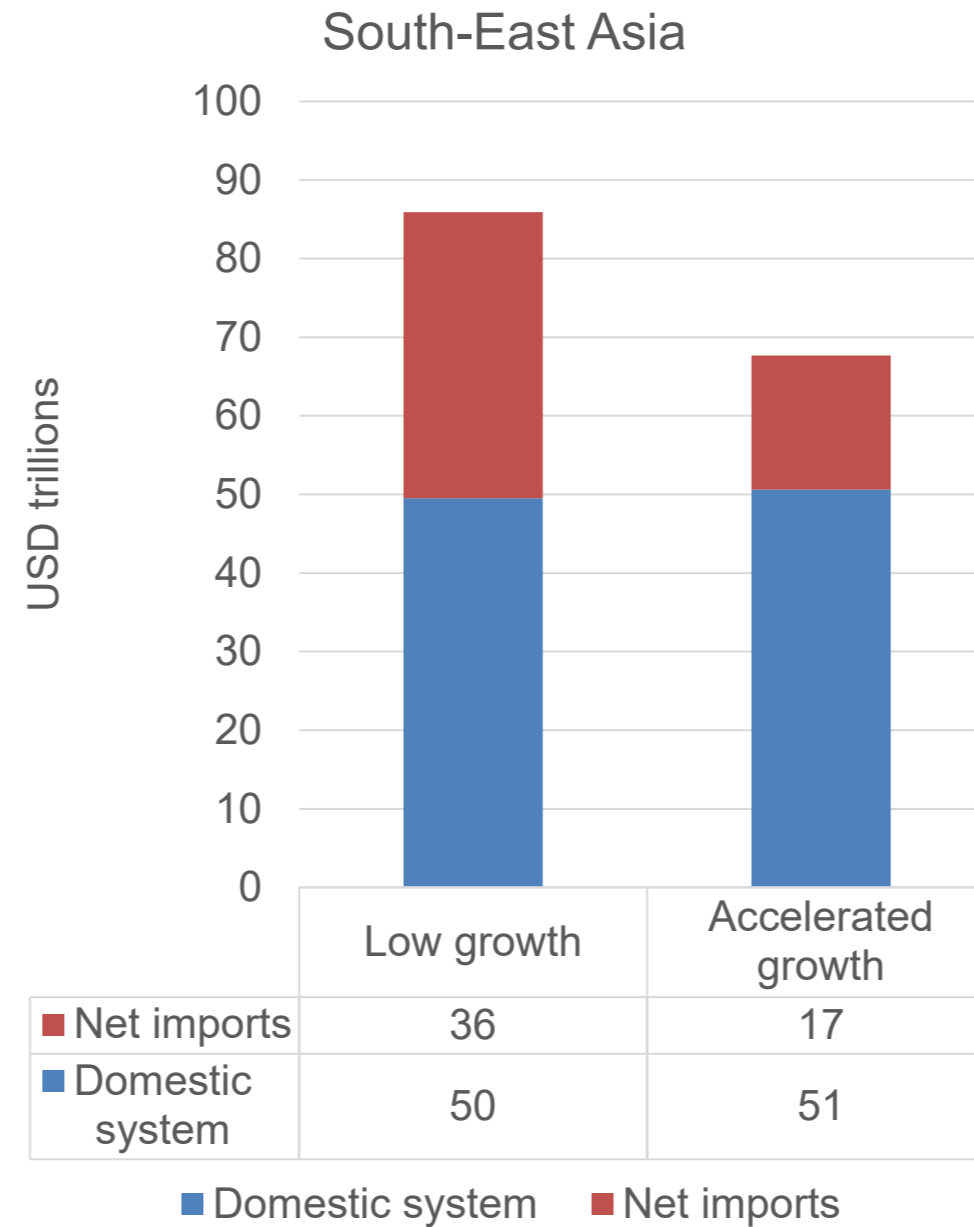


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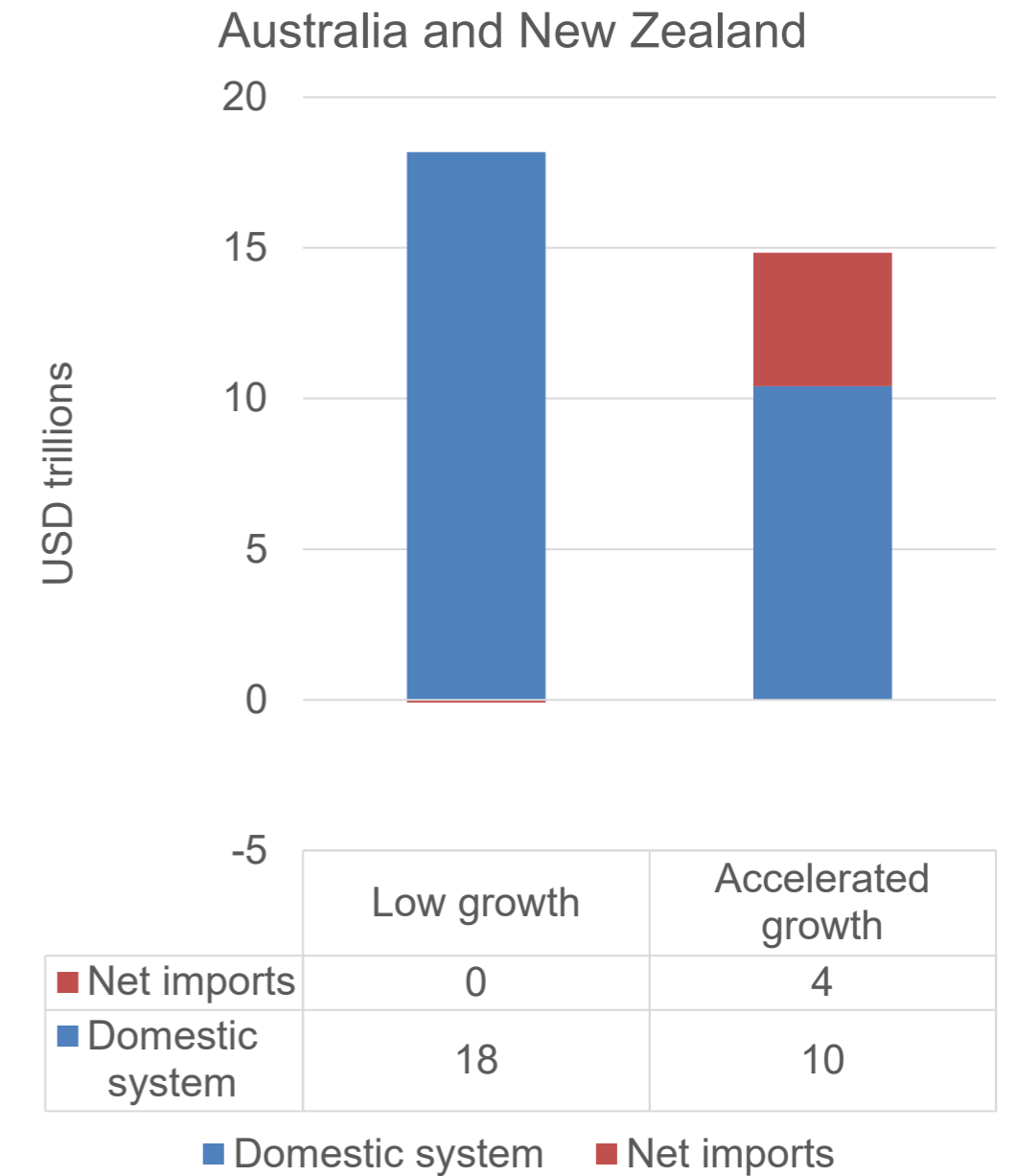
SYSTEM COSTS



Accelerated storage savings: \$3 trillion



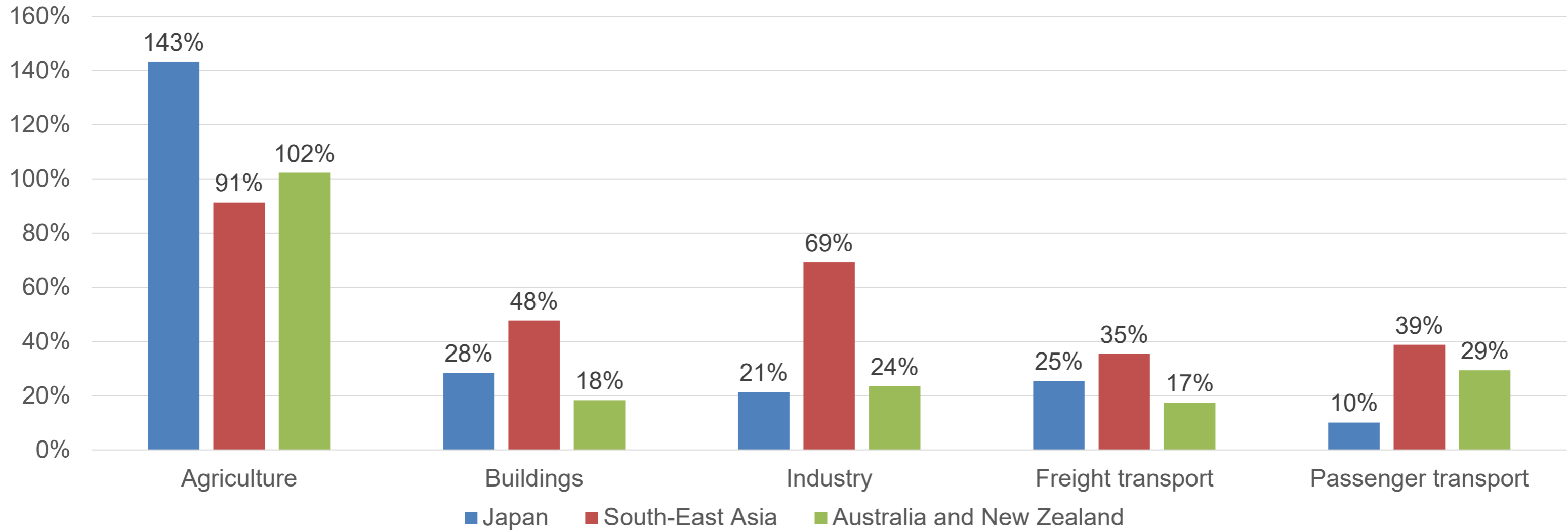
Accelerated storage savings: \$18 trillion



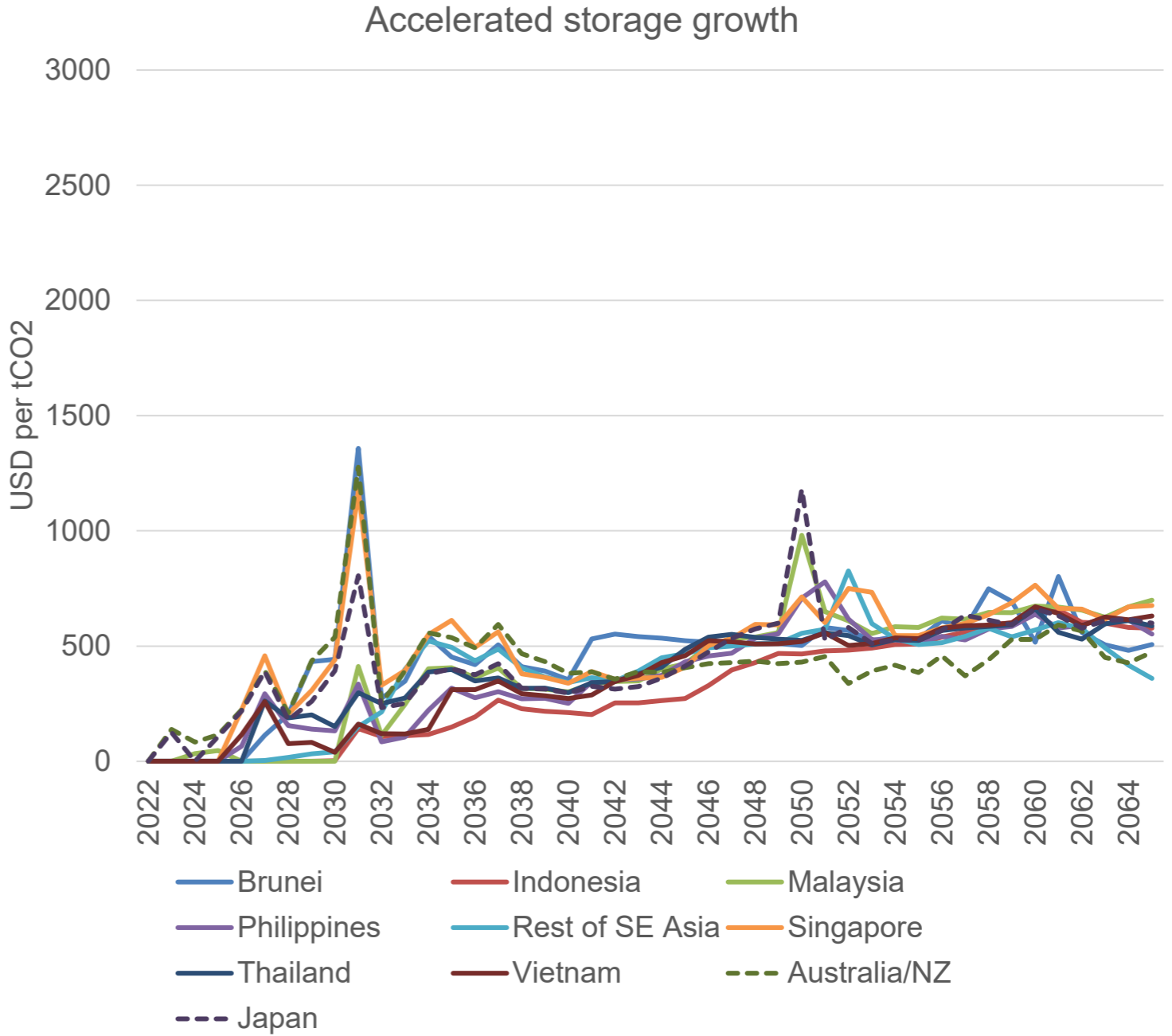
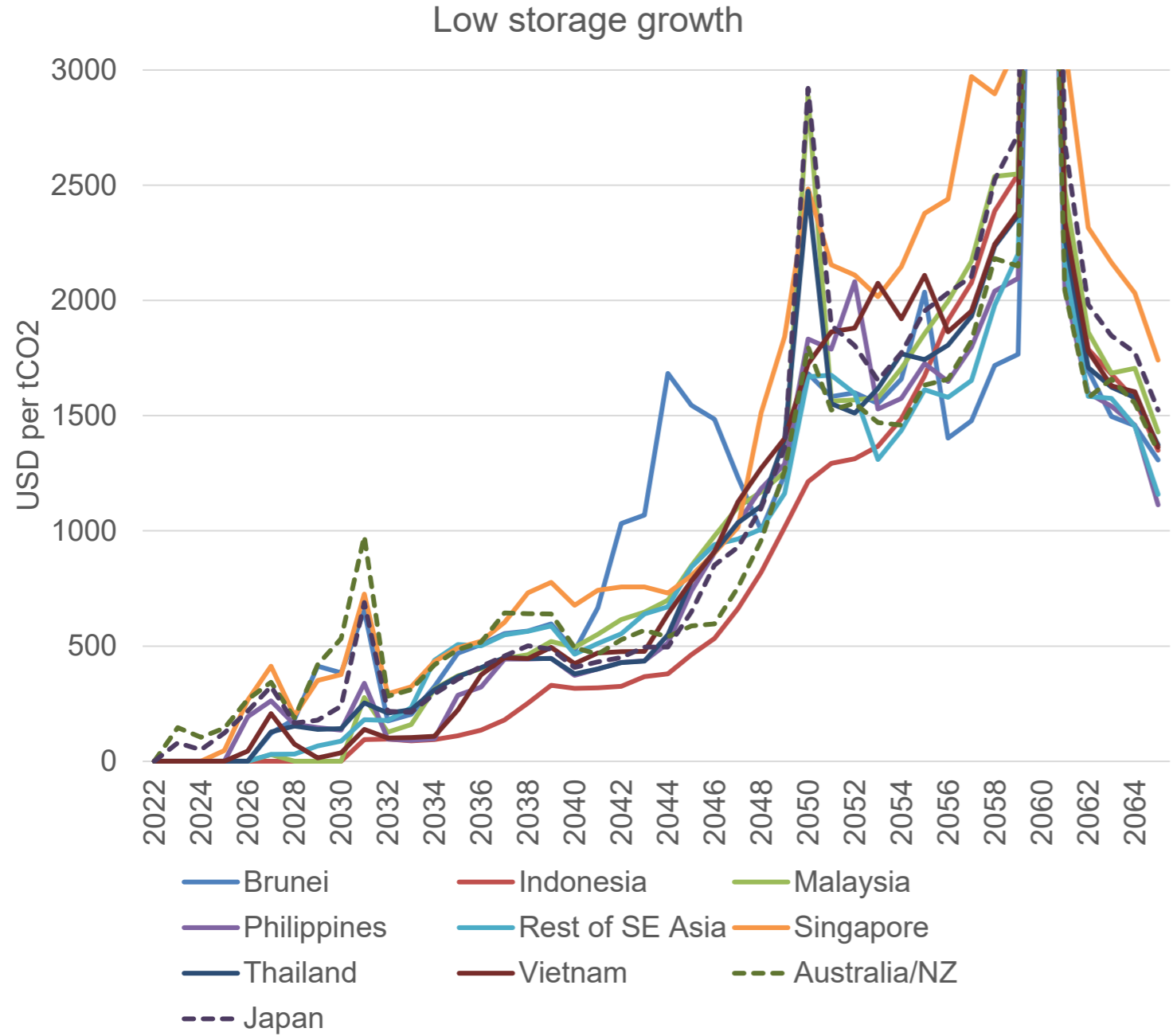
Accelerated storage savings: \$4 trillion

INCREASE IN COST TO END-USE SECTORS WITH A LOW GROWTH SCENARIO COMPARED TO ACCELERATED

Low vs accelerated storage growth



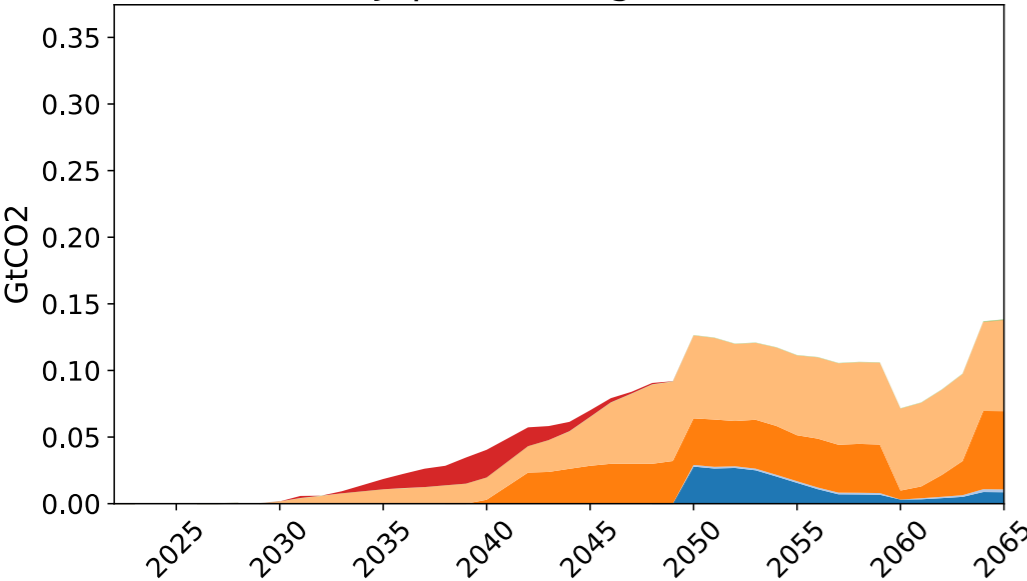
MARGINAL COST OF CO₂ TO REACH NET ZERO



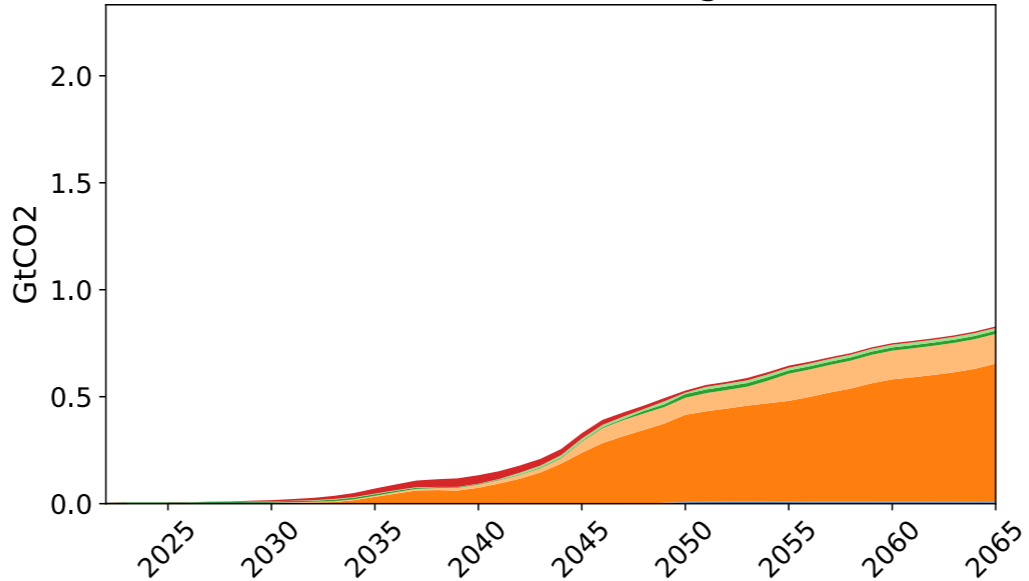
CCS RESULTS

CO₂ CAPTURE BY SECTOR

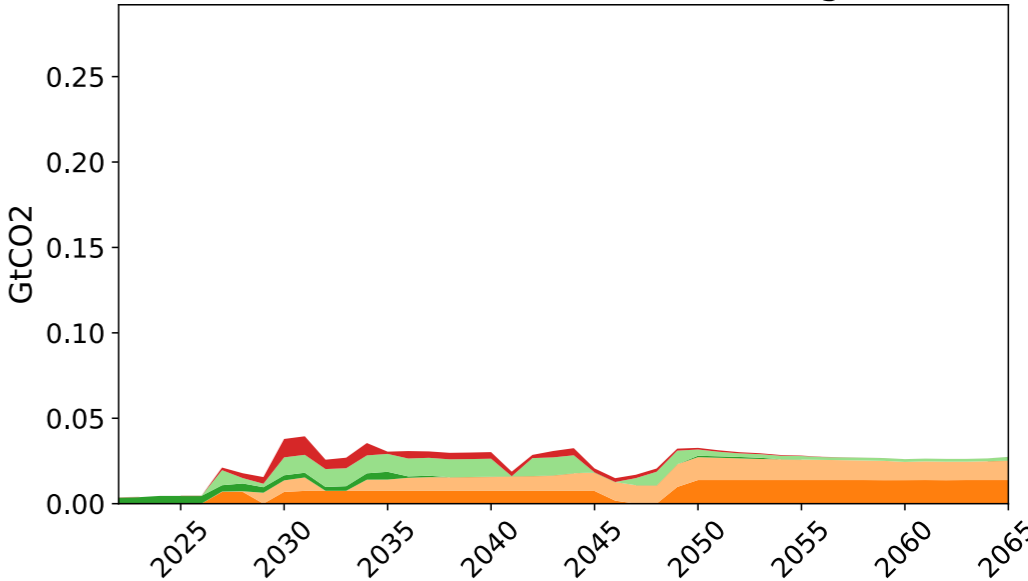
Japan - Low growth



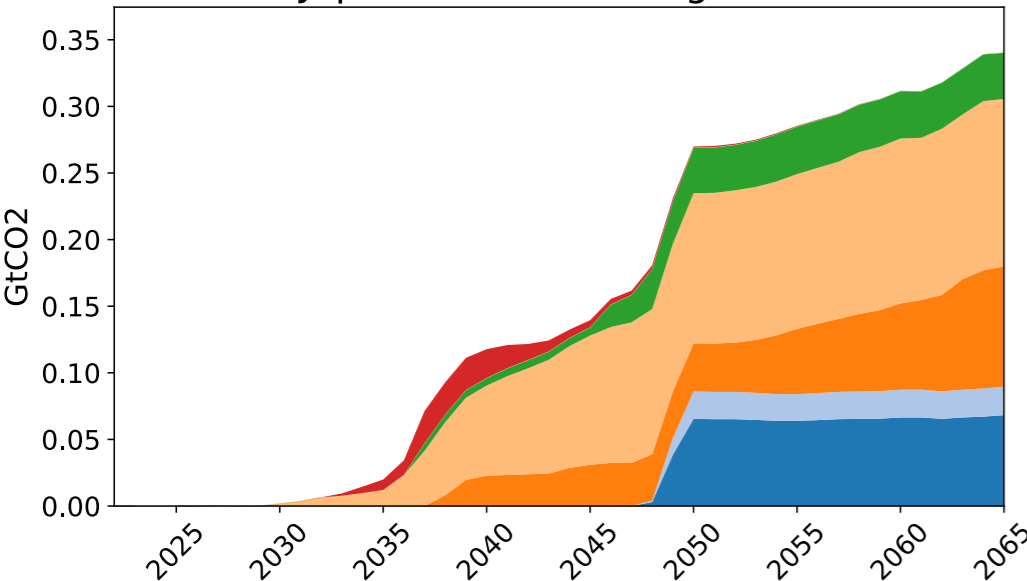
South-East Asia - Low growth



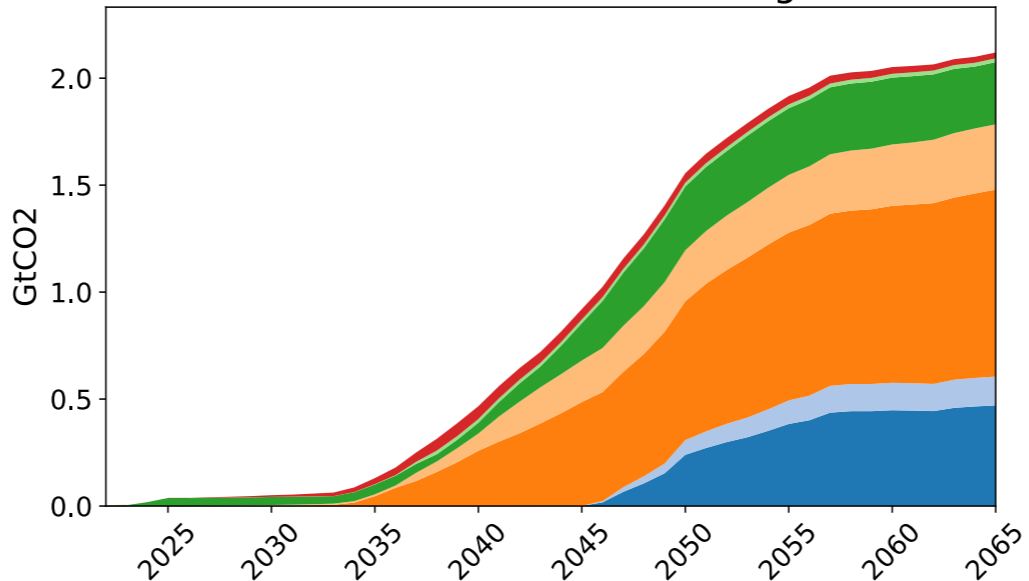
Australia and New Zealand - Low growth



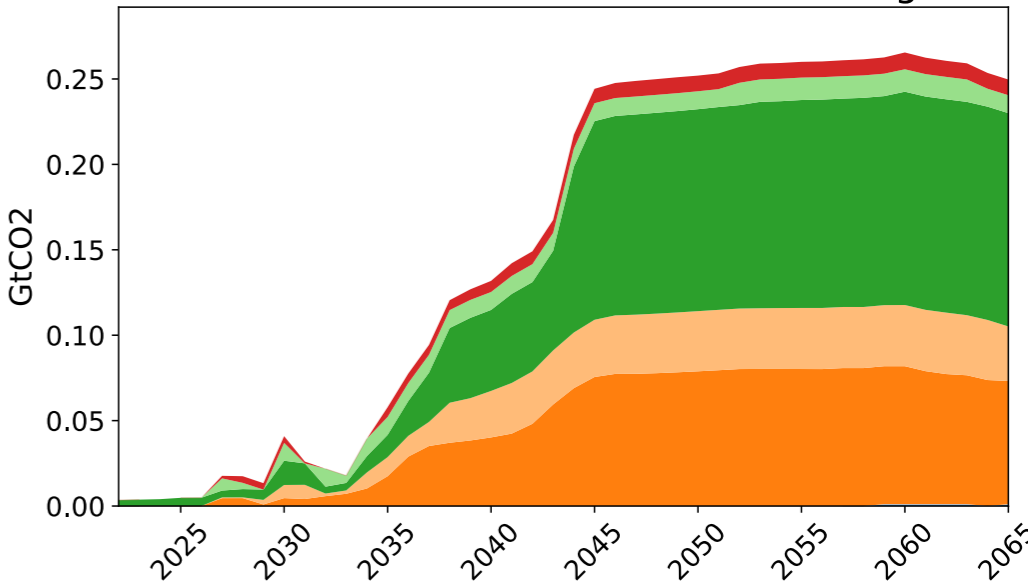
Japan - Accelerated growth



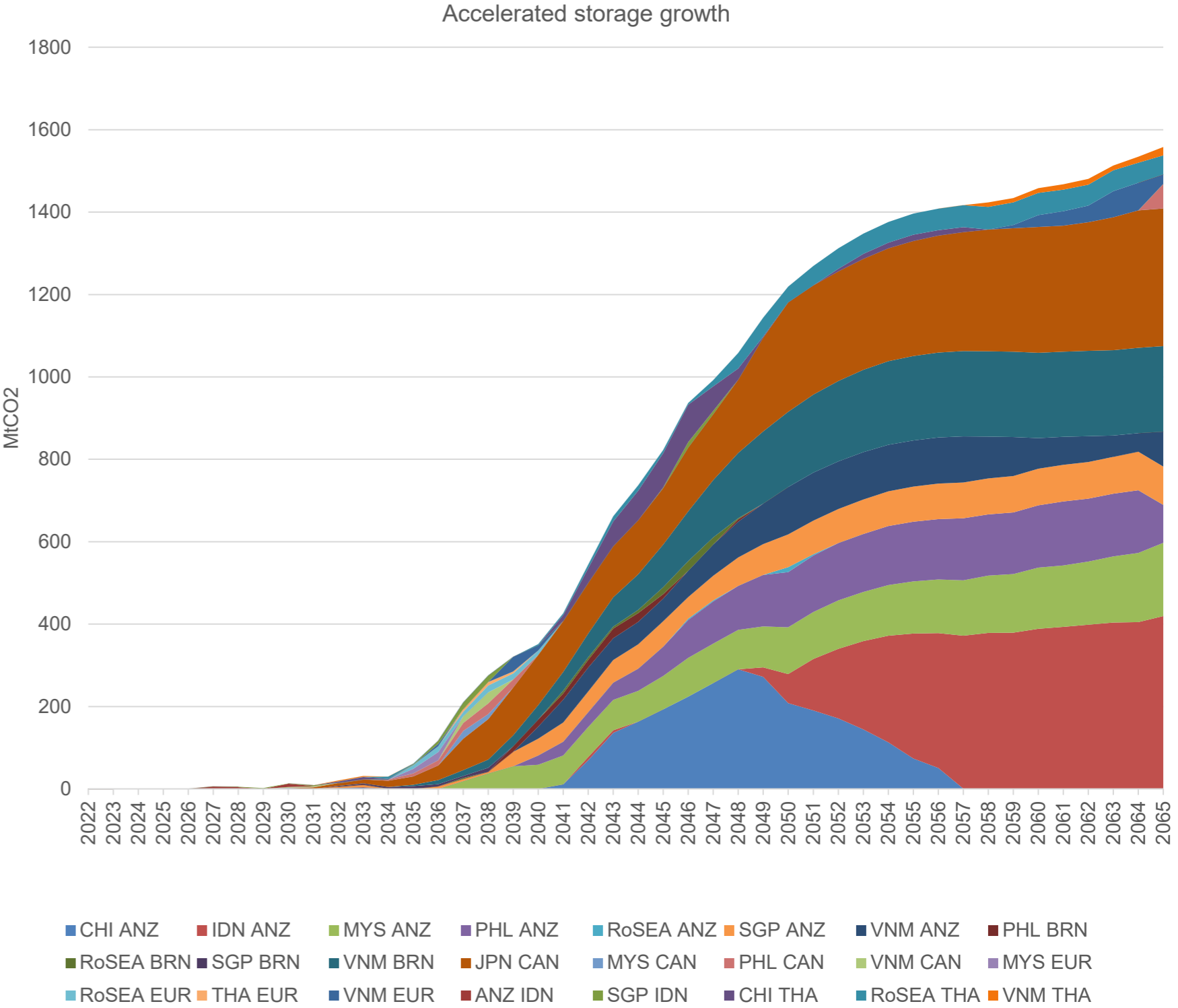
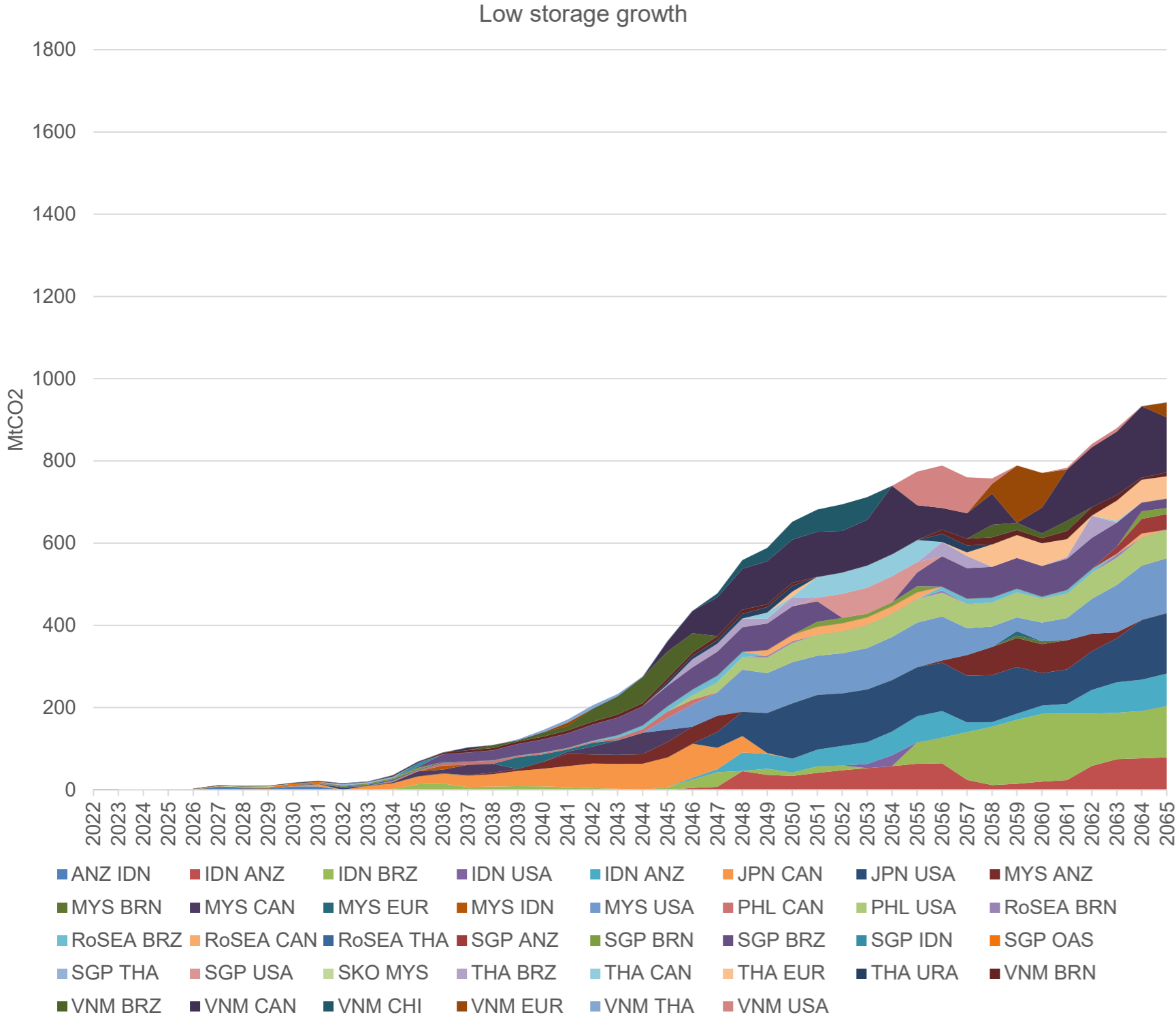
South-East Asia - Accelerated growth



Australia and New Zealand - Accelerated growth

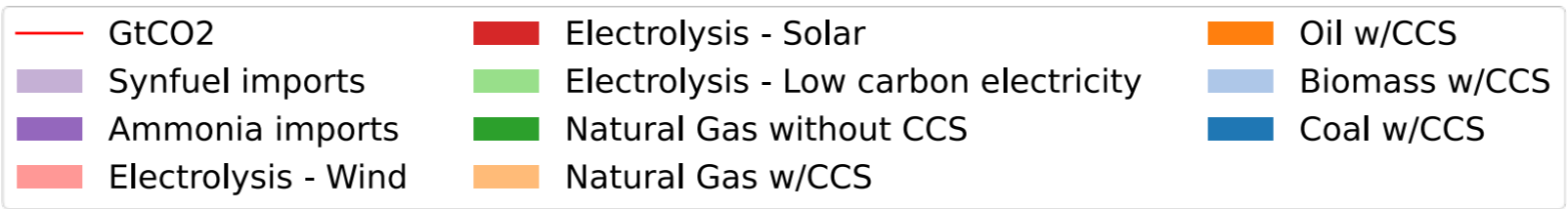
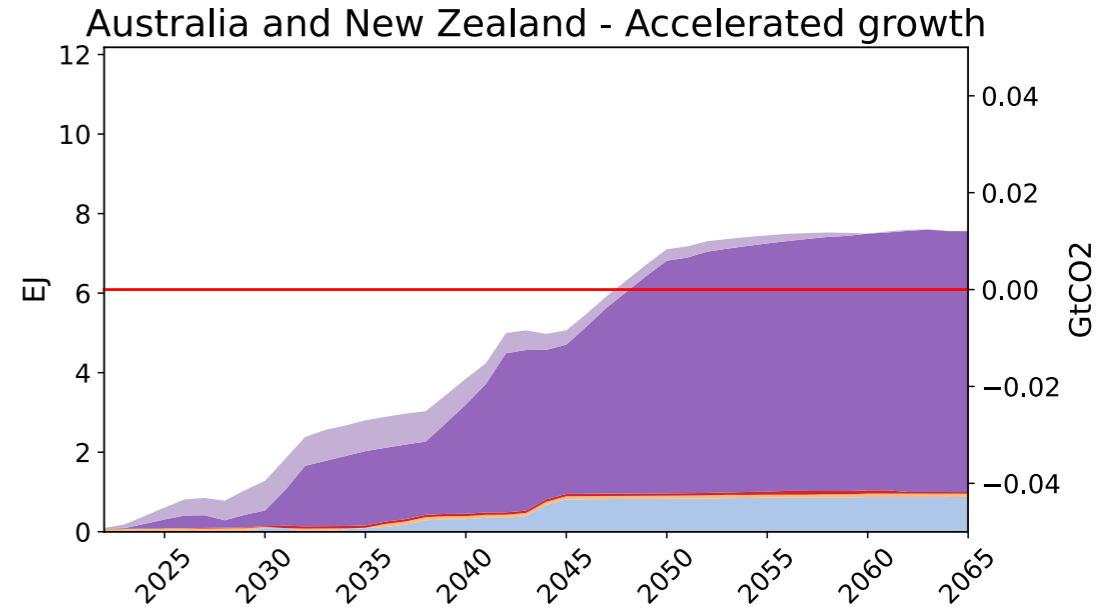
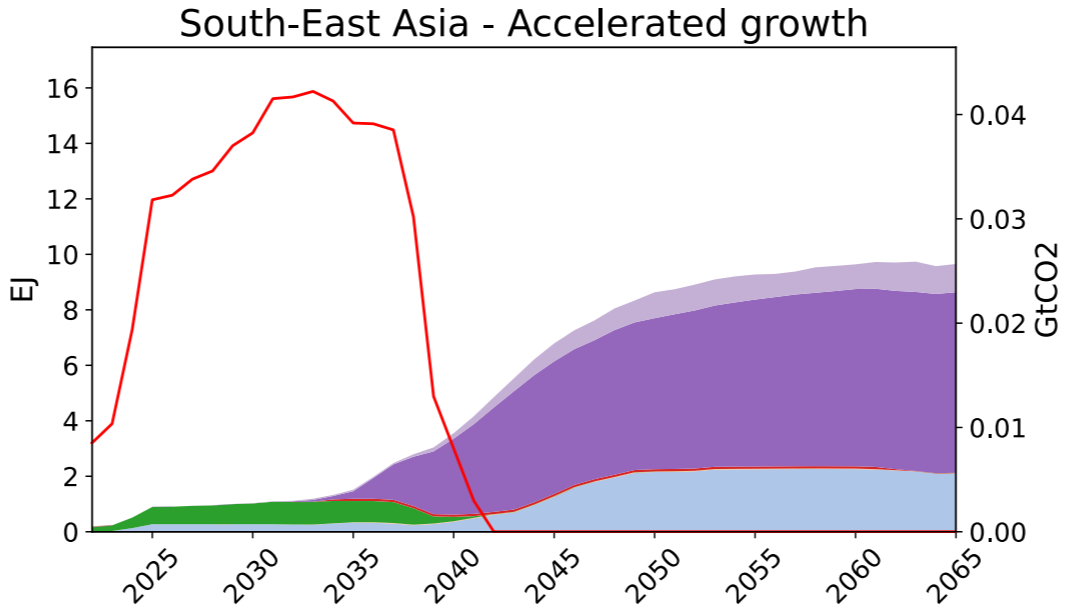
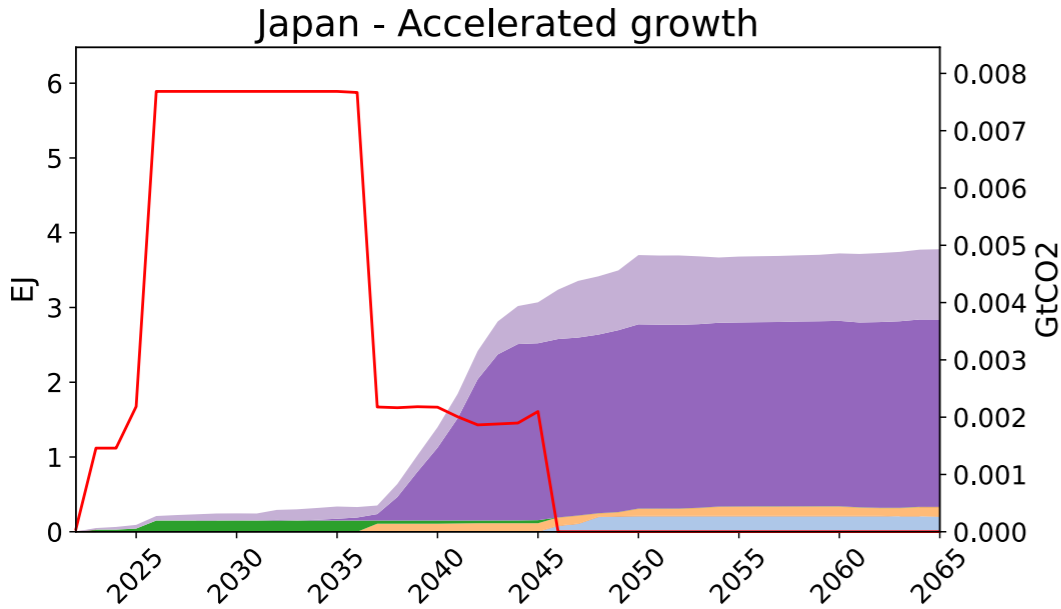
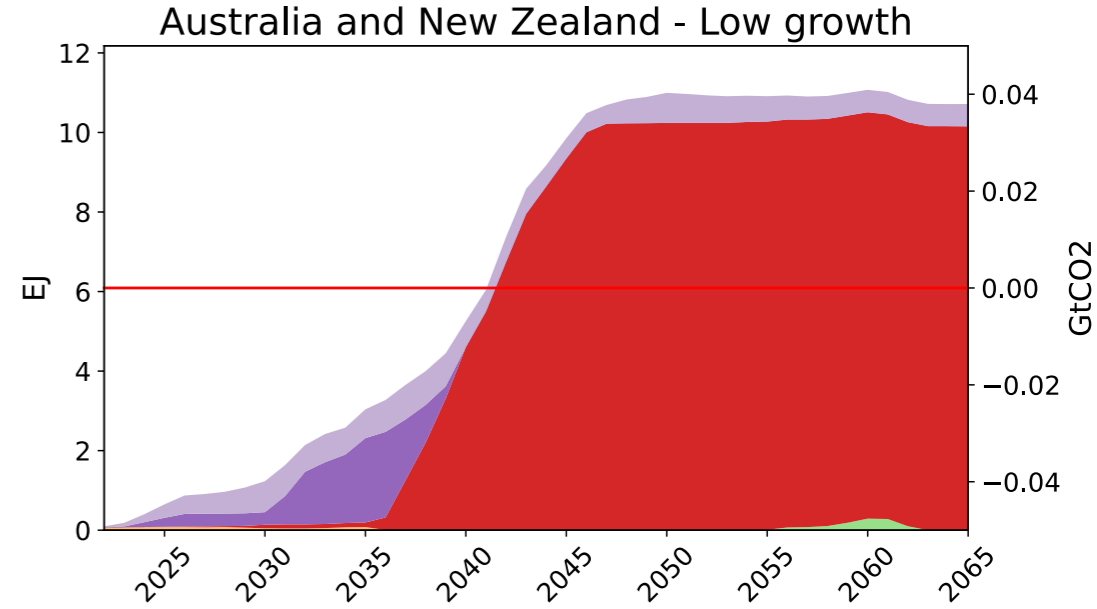
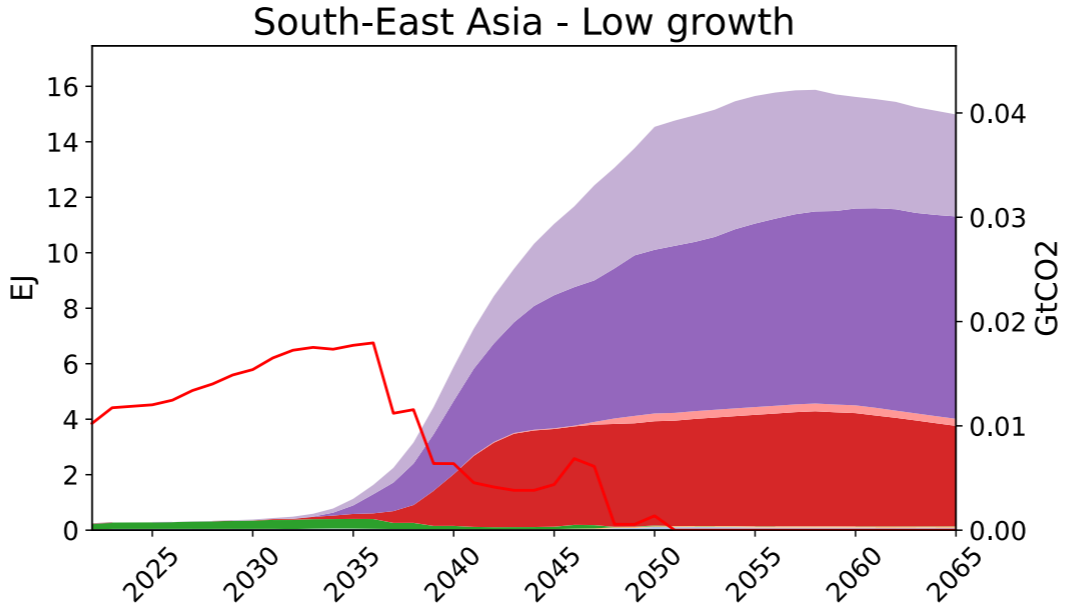
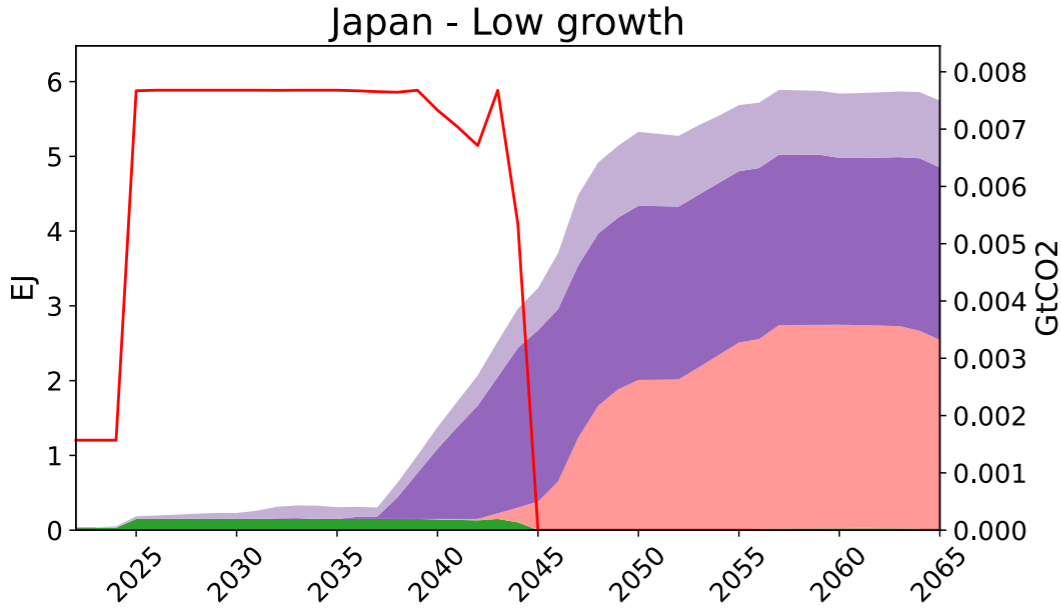


CO₂ SHIPPING INVOLVING JAPAN, SE ASIA, AND AUSTRALIA

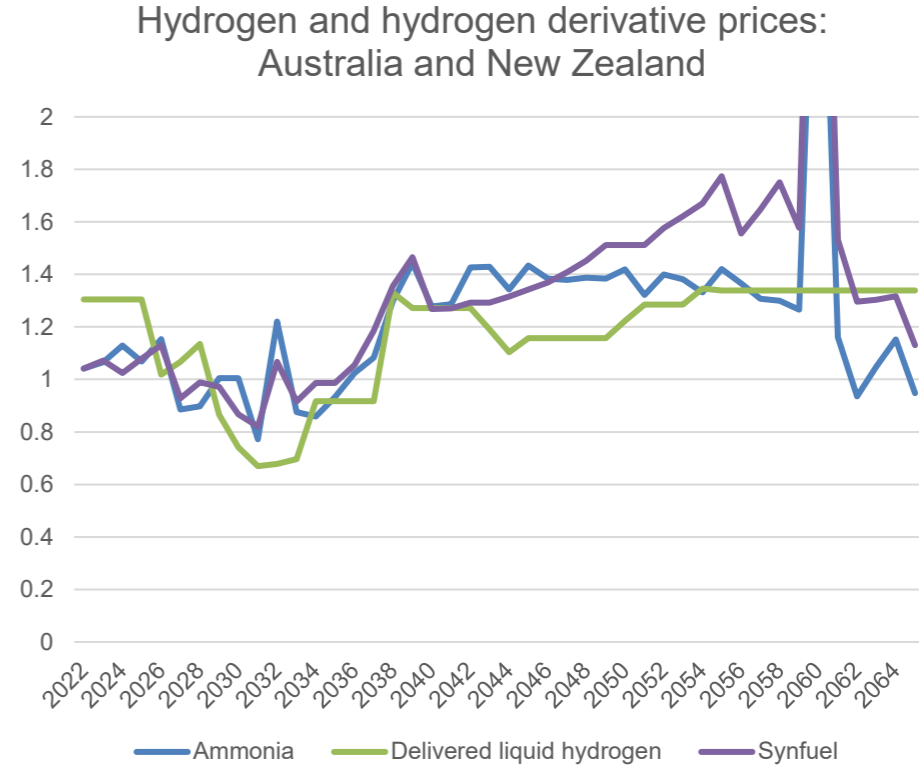
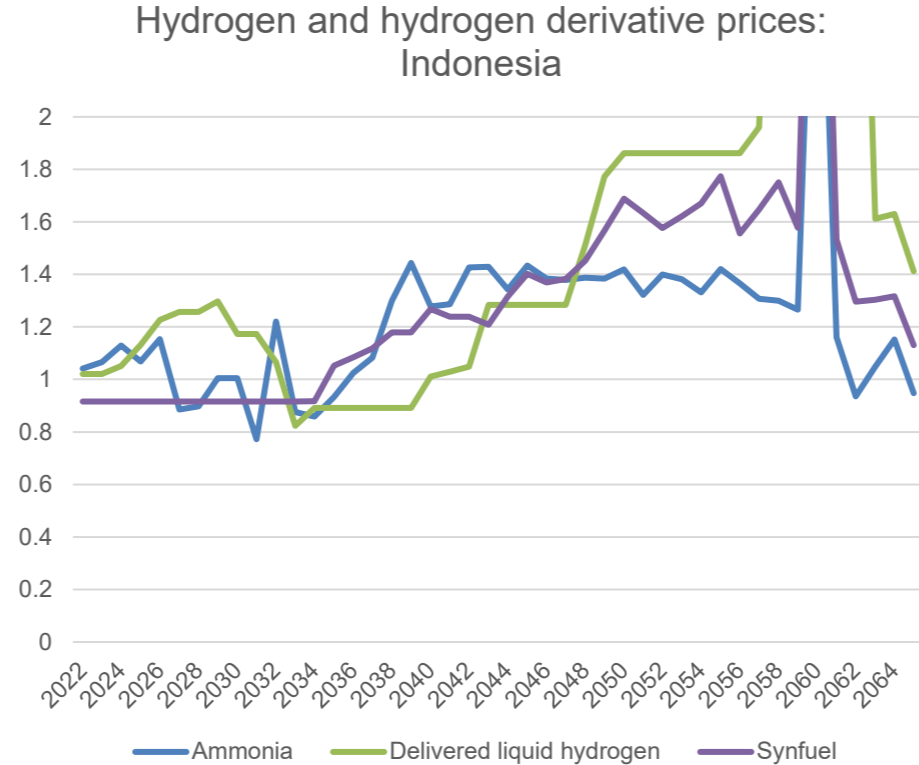
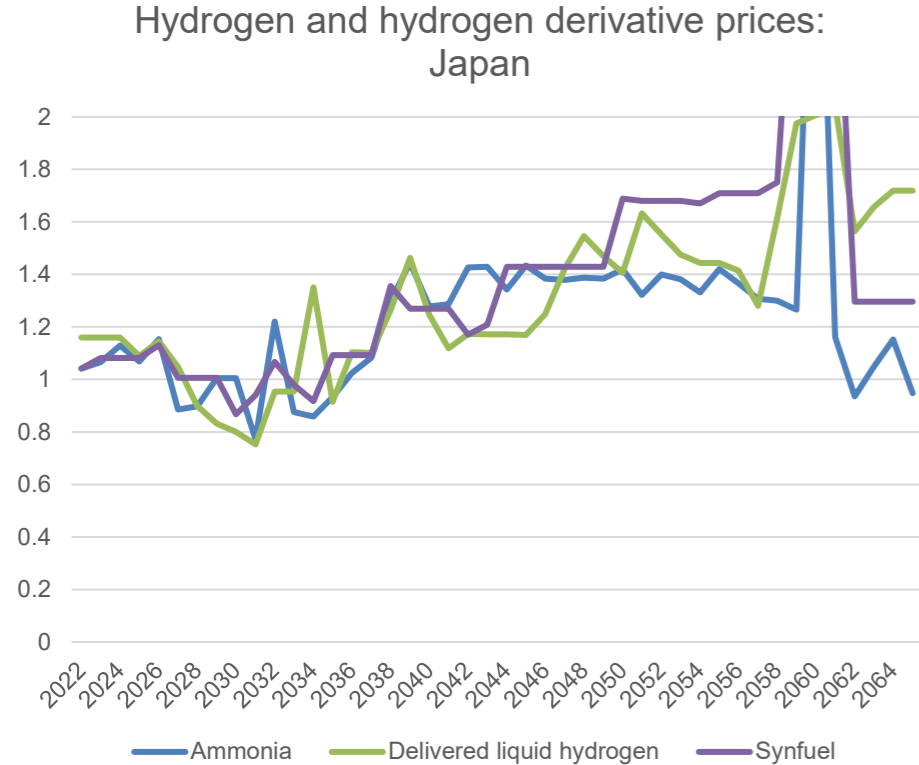


ENERGY OVERVIEW

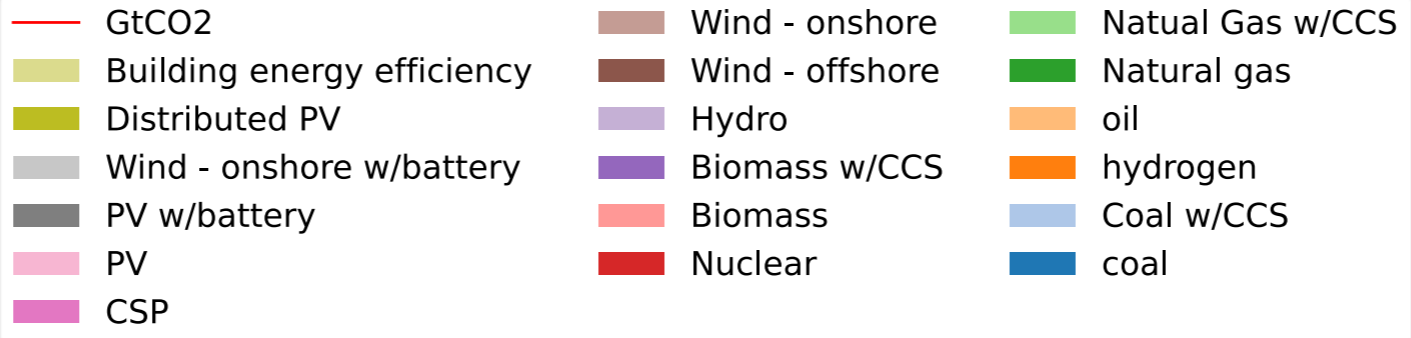
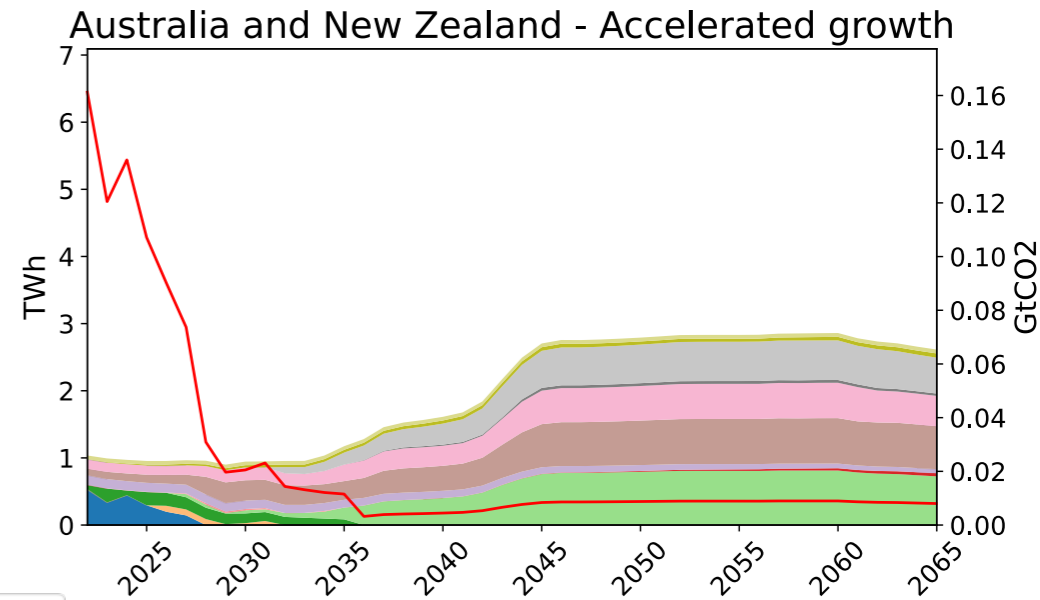
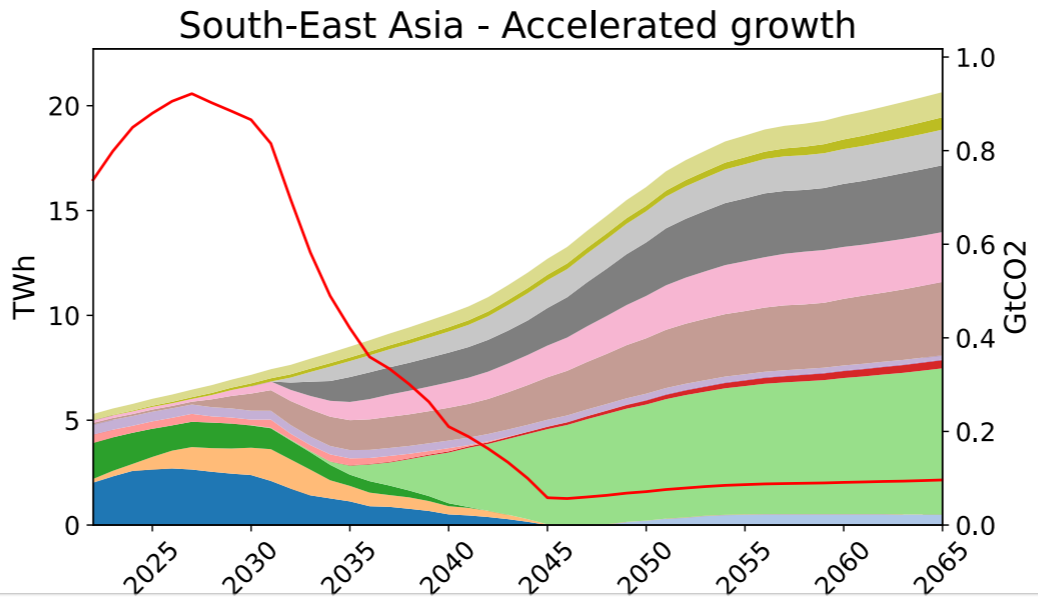
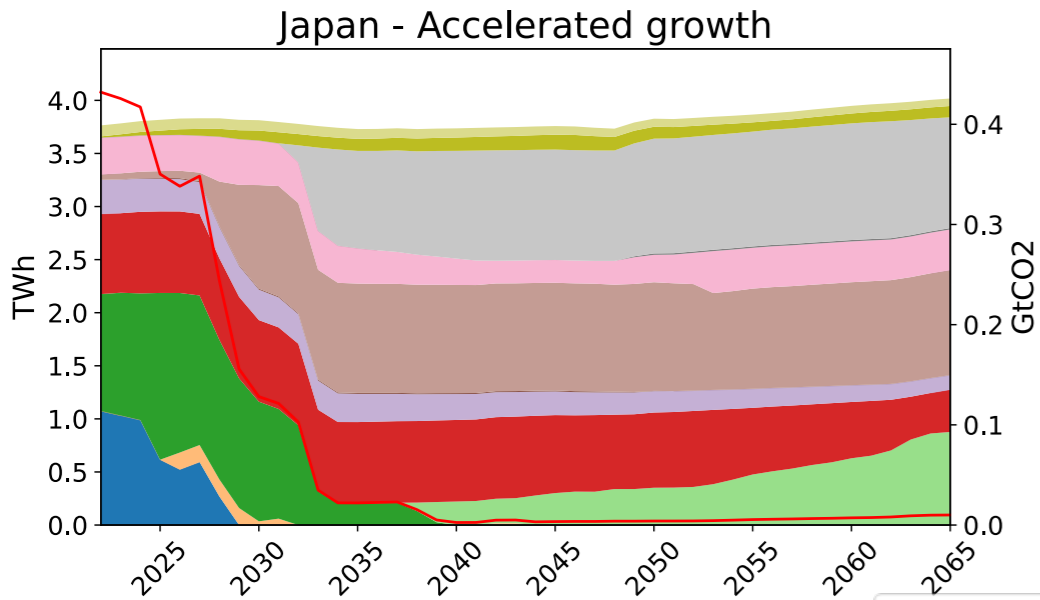
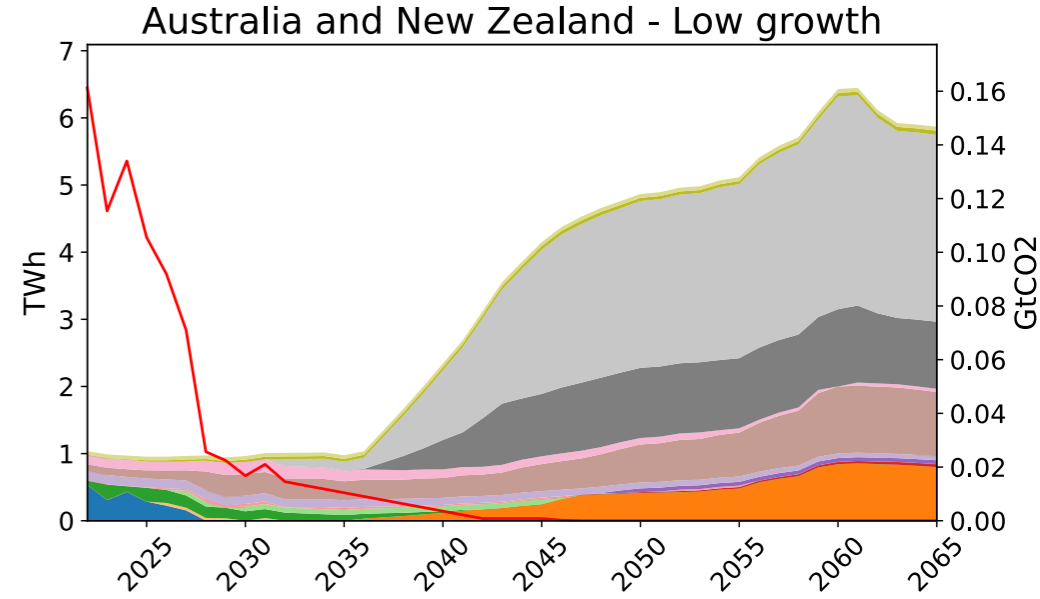
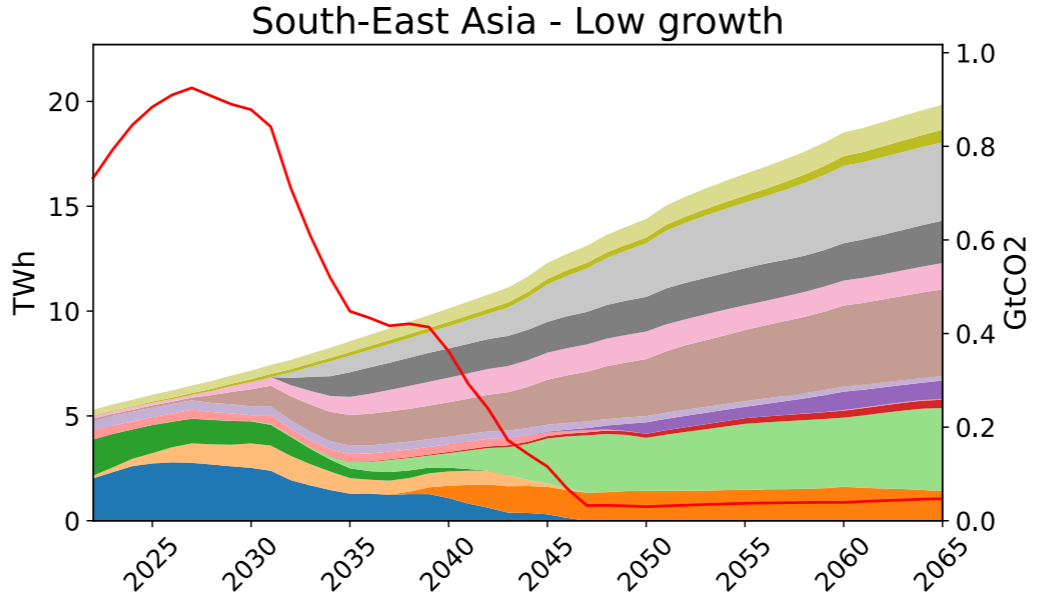
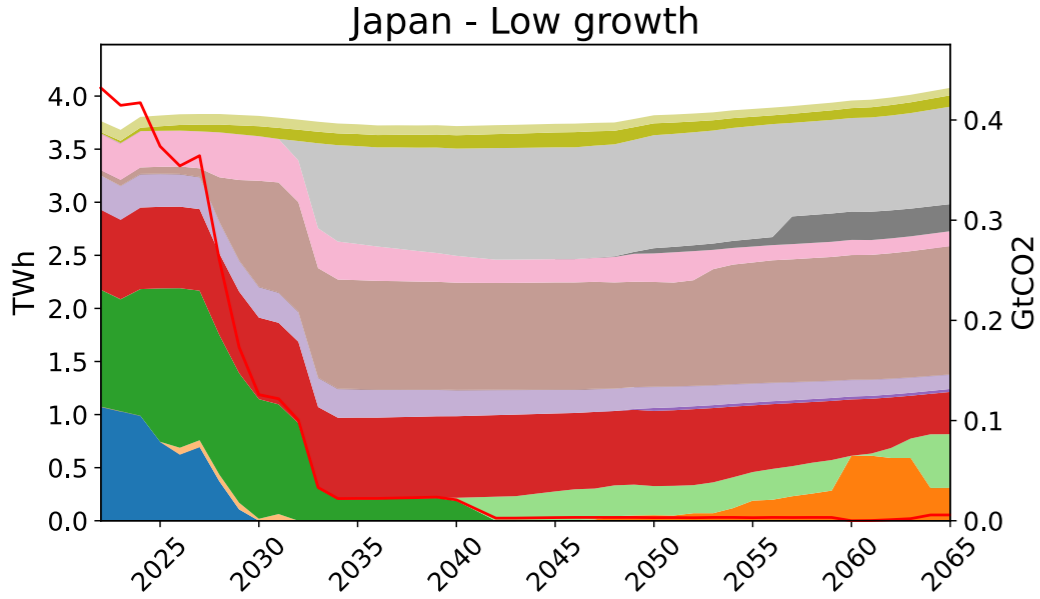
HYDROGEN PRODUCTION



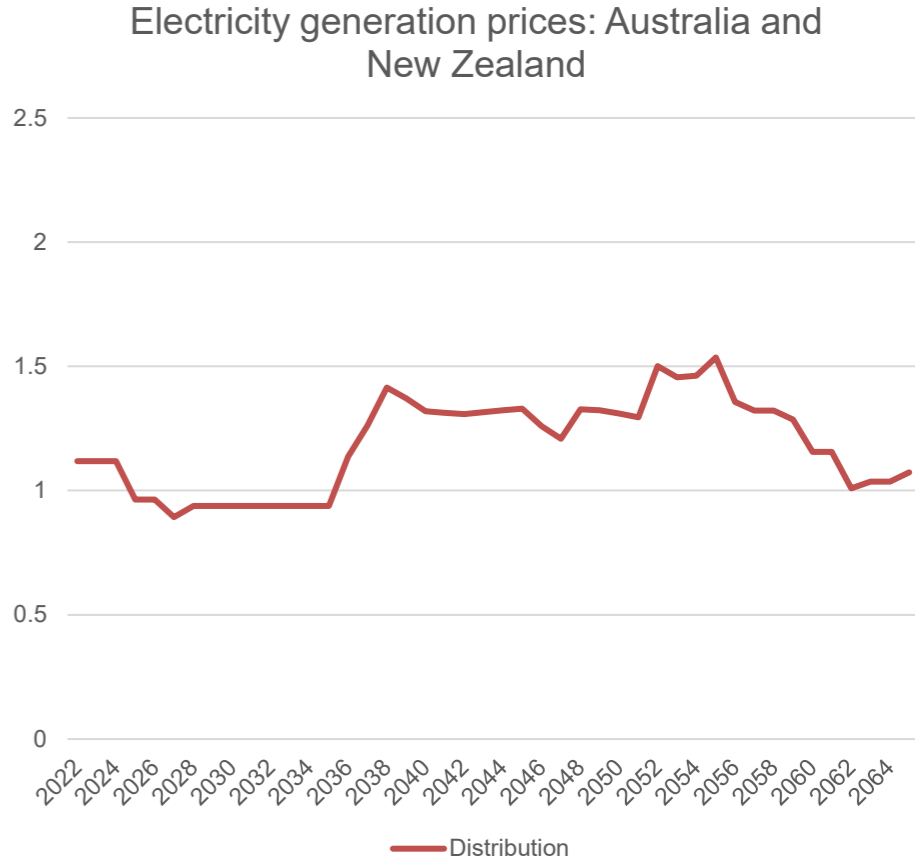
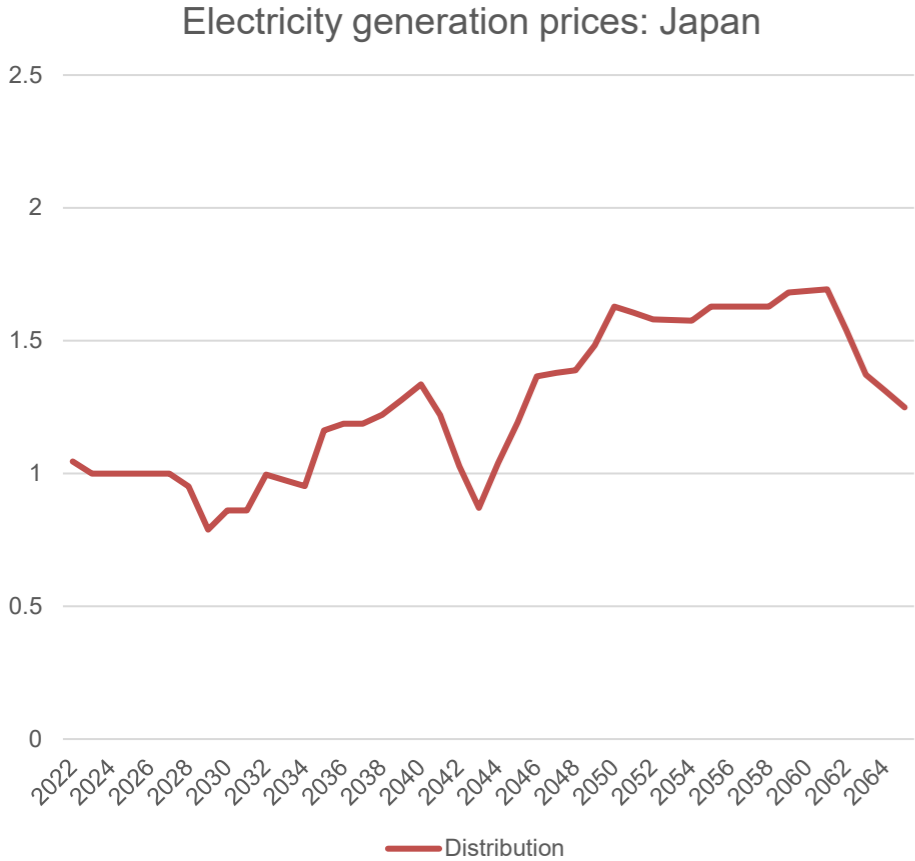
HYDROGEN PRICES: RATIO OF LOW TO ACCELERATED STORAGE



ELECTRICITY GENERATION



ELECTRICITY PRICES: RATIO OF LOW TO ACCELERATED STORAGE

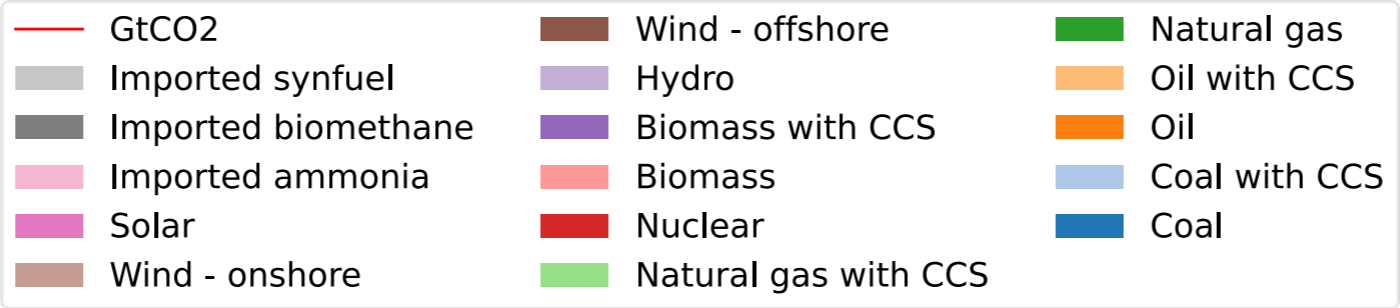
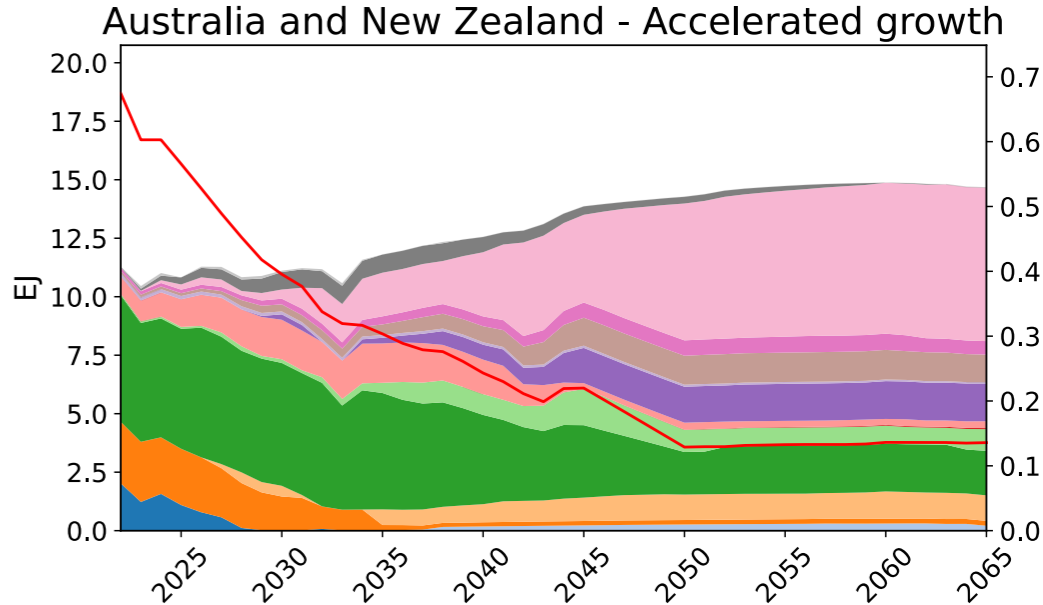
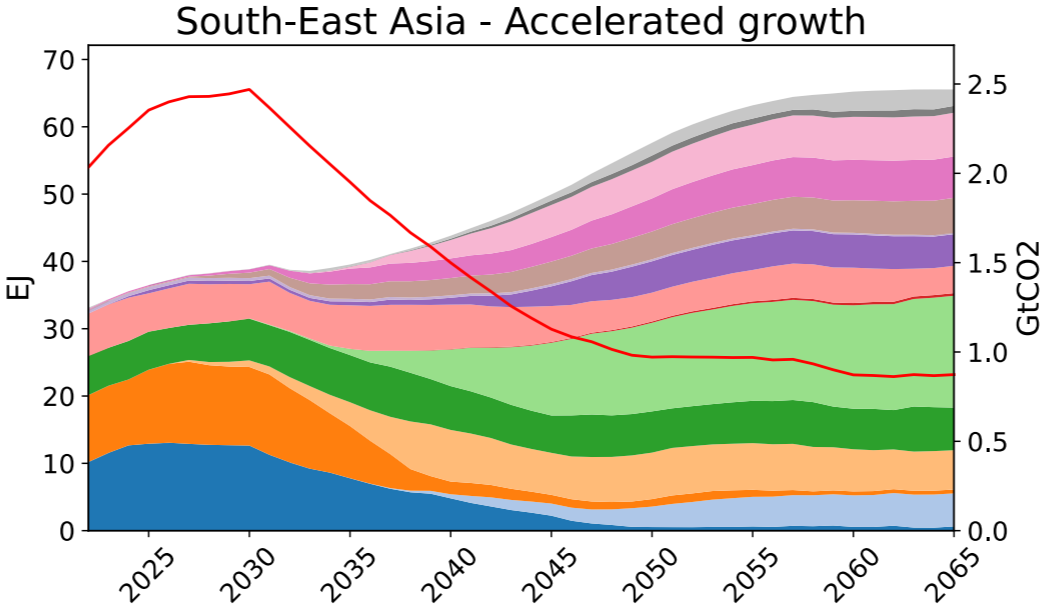
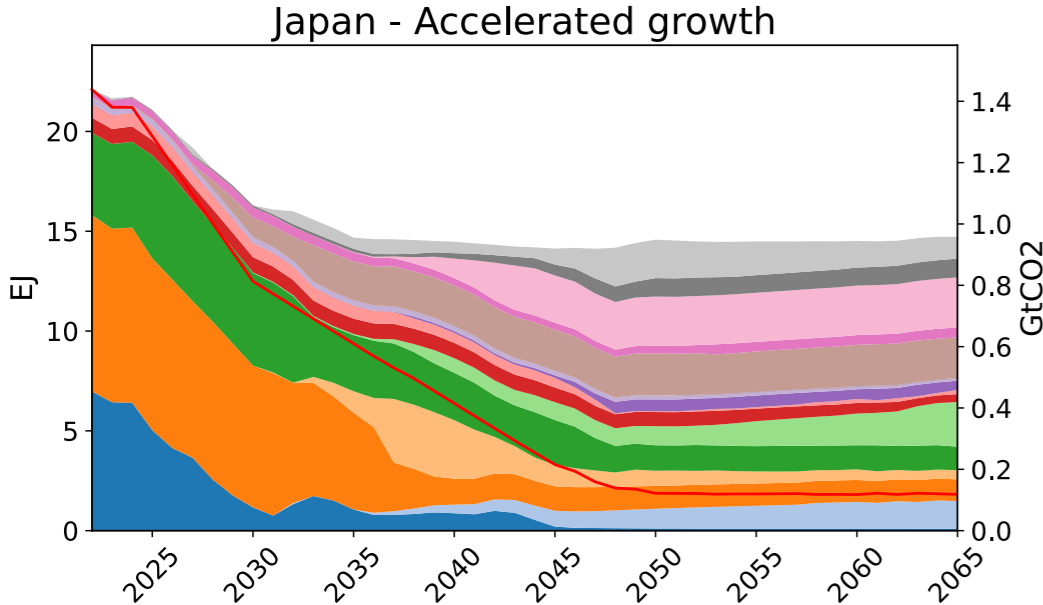
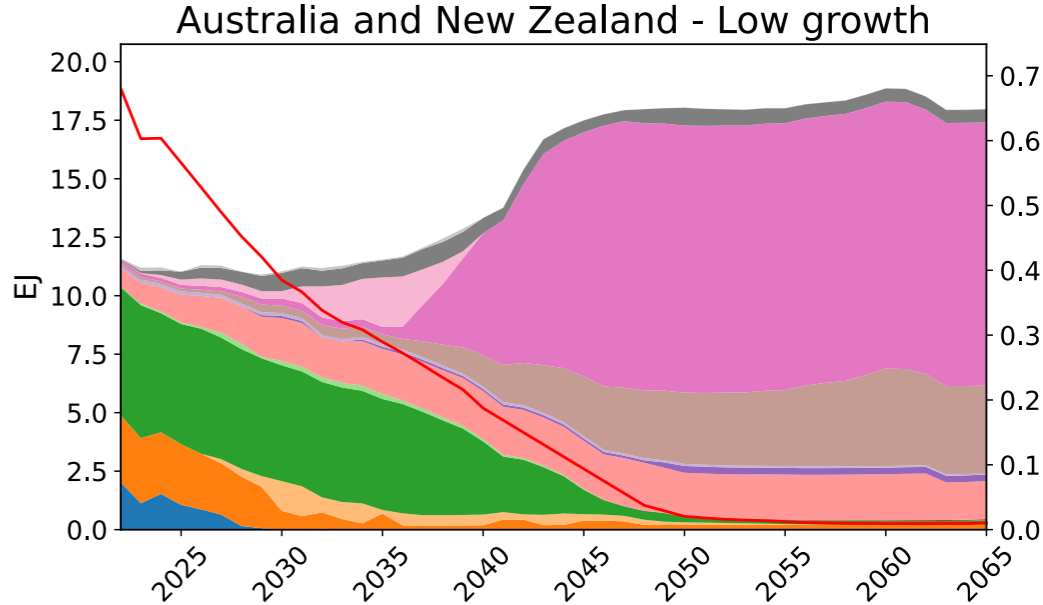
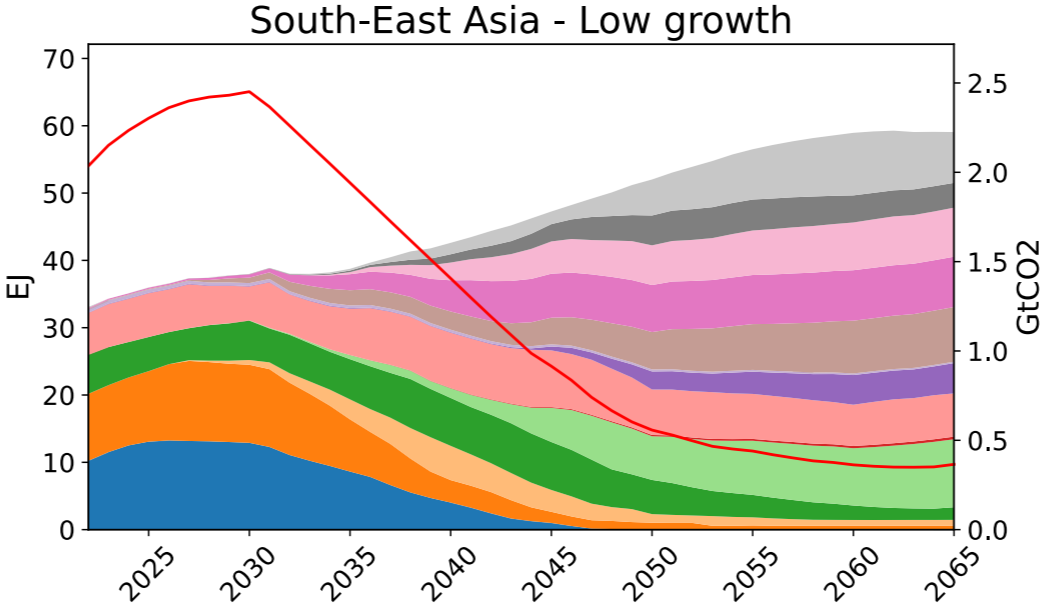
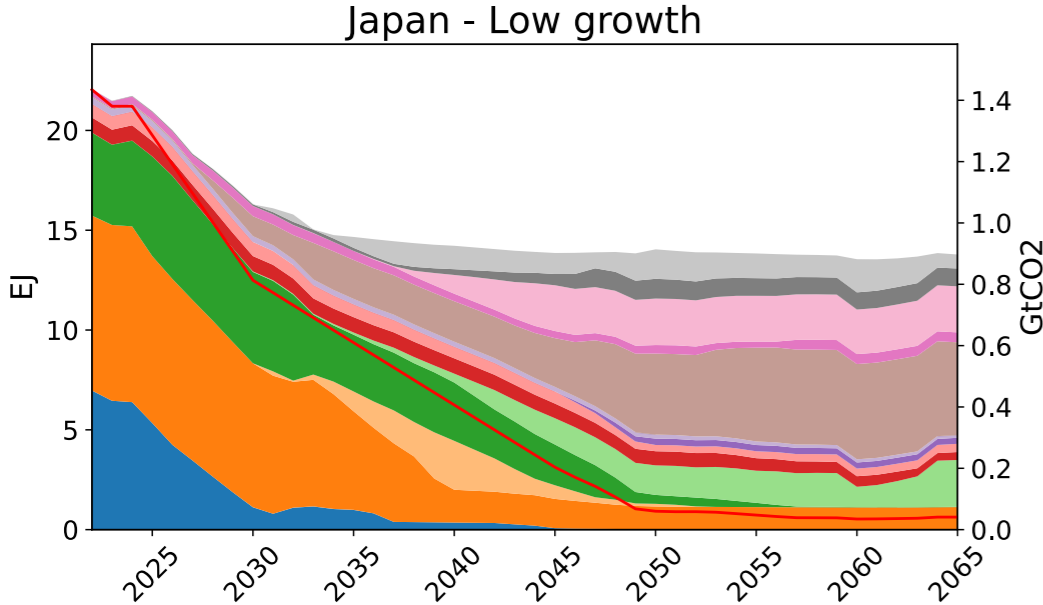


THANK YOU!

ERIC.WILLIAMS@GLOBALCCSINSTITUTE.COM

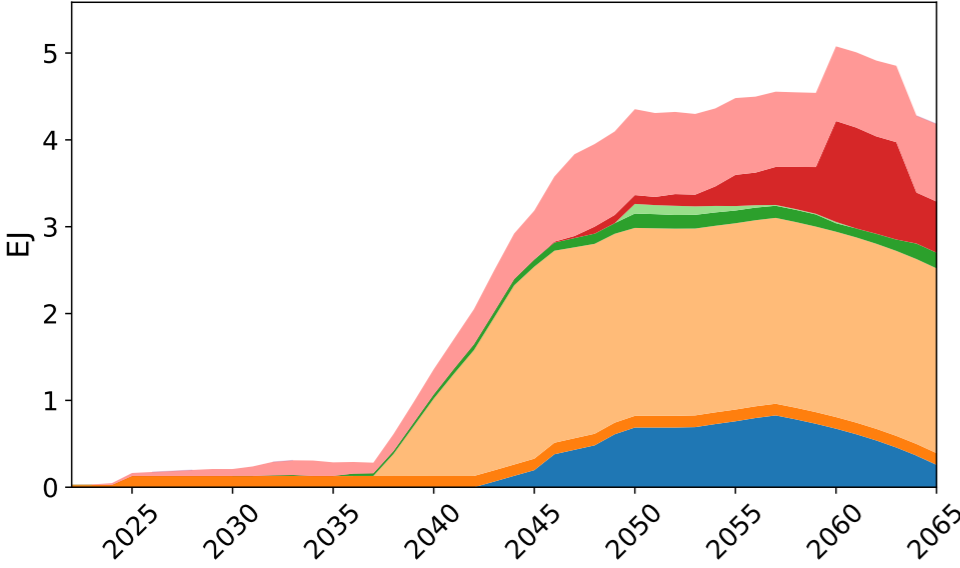
ADDITIONAL SLIDES

PRIMARY ENERGY USE AND DIRECT CO₂ EMISSIONS

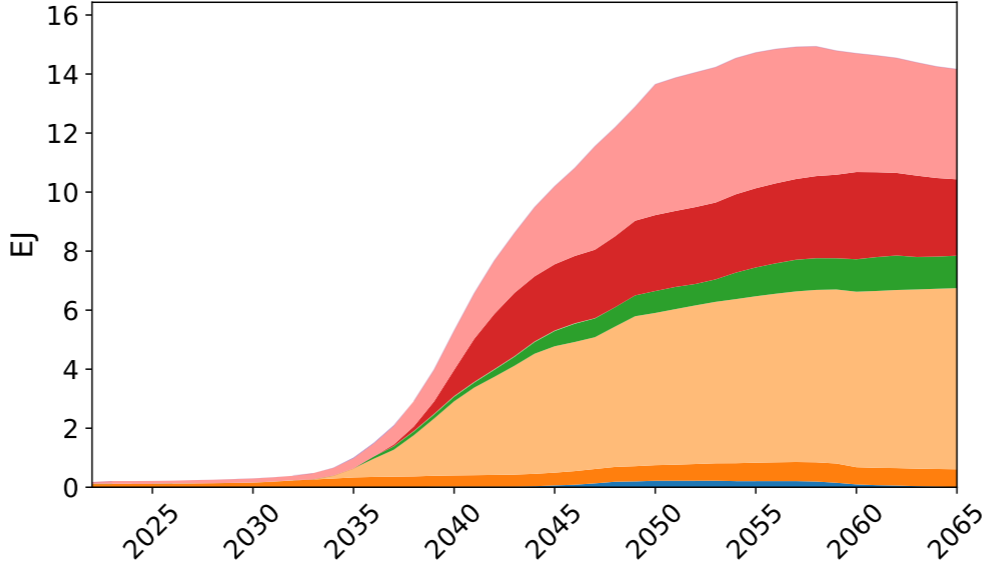


HYDROGEN USE

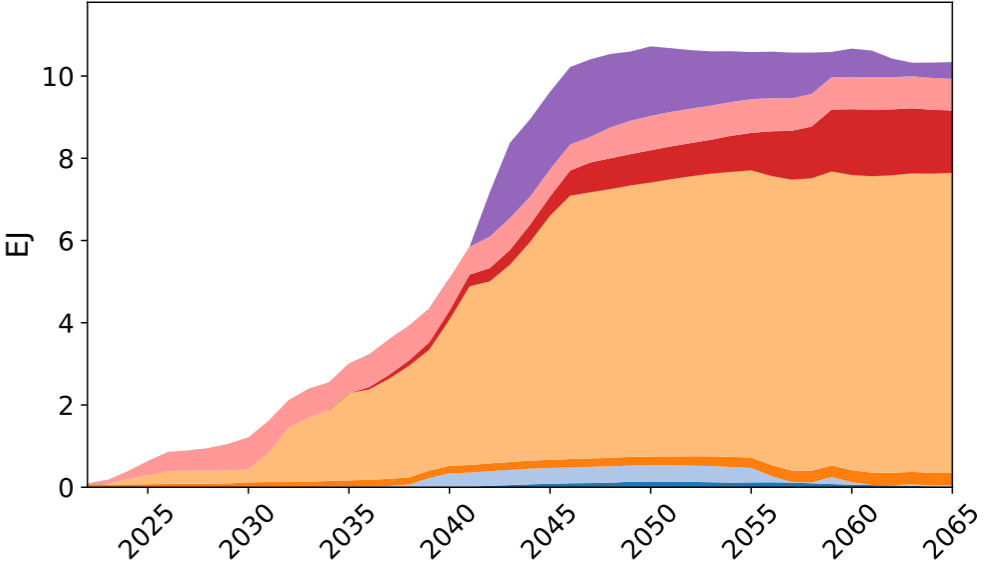
Japan - Low growth



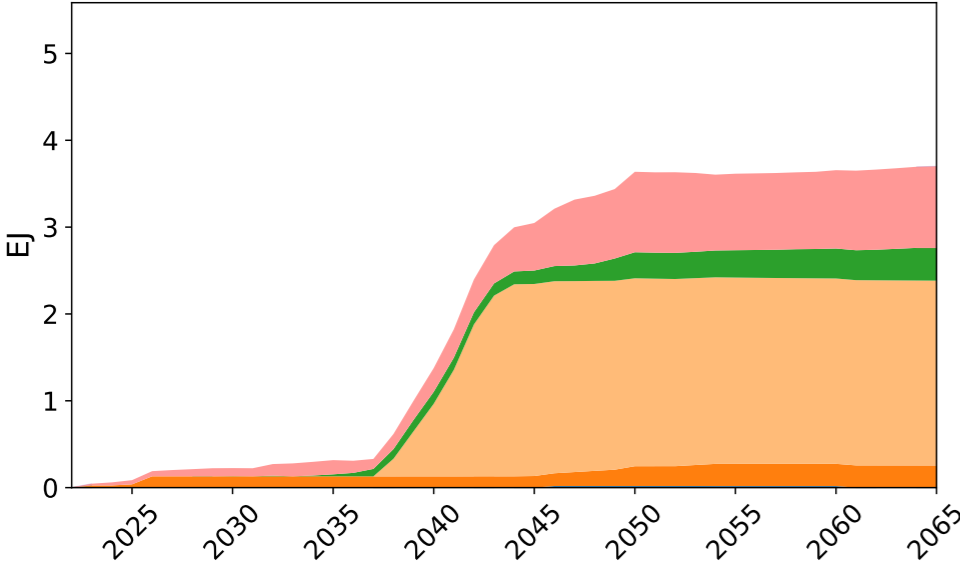
South-East Asia - Low growth



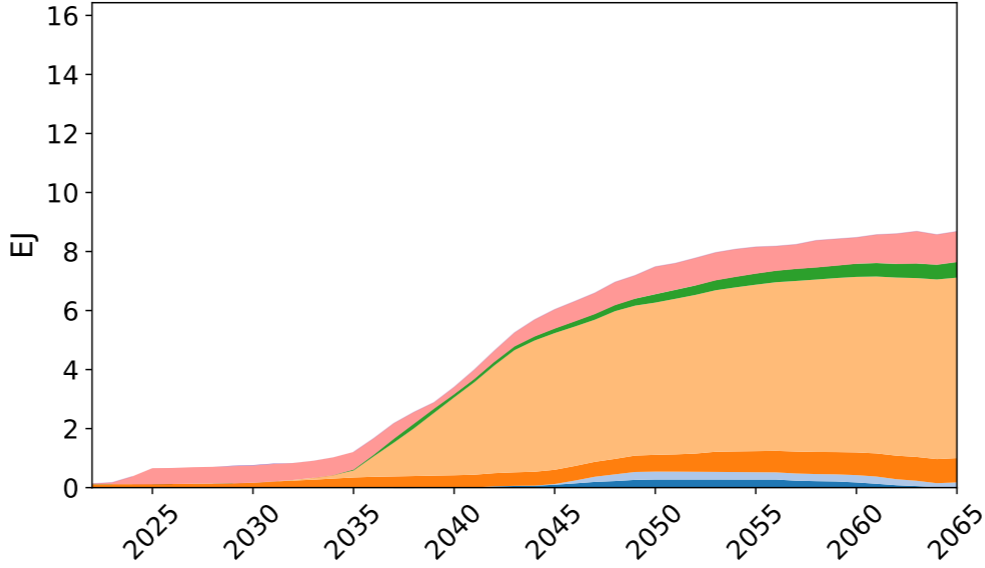
Australia and New Zealand - Low growth



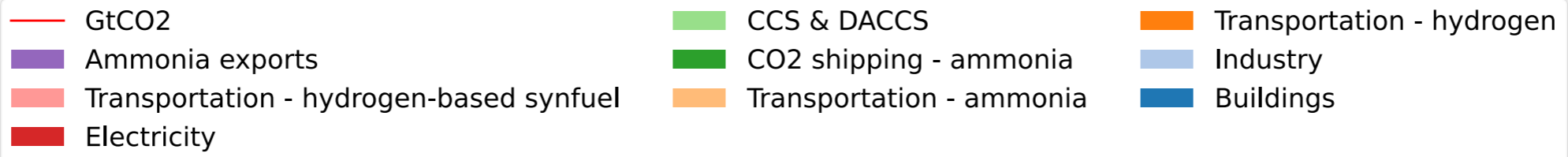
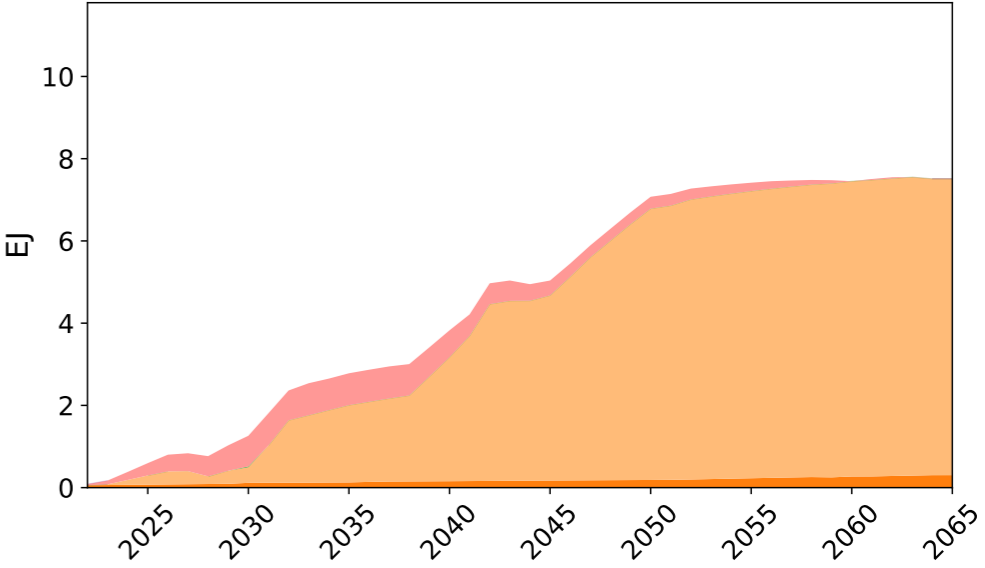
Japan - Accelerated growth



South-East Asia - Accelerated growth

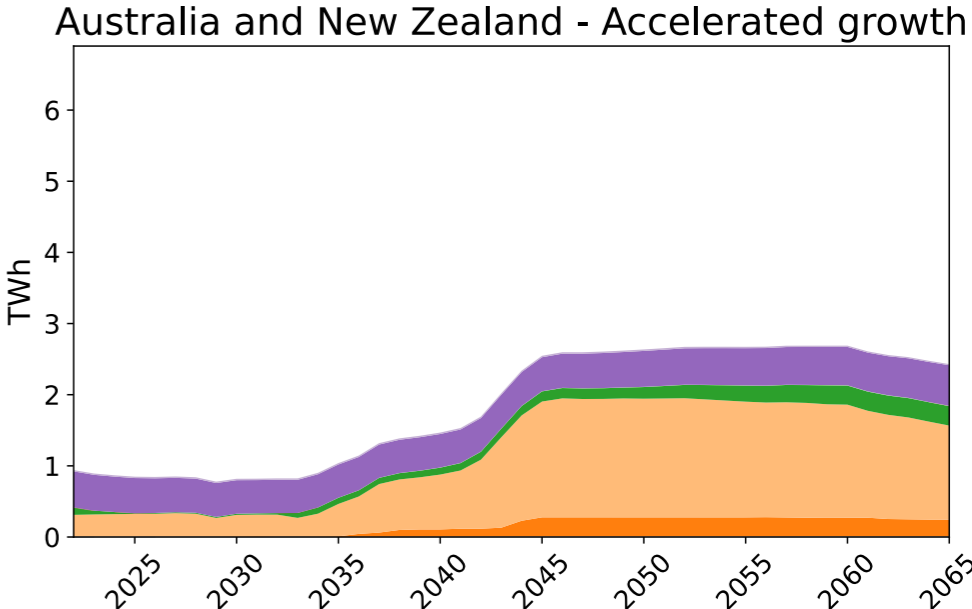
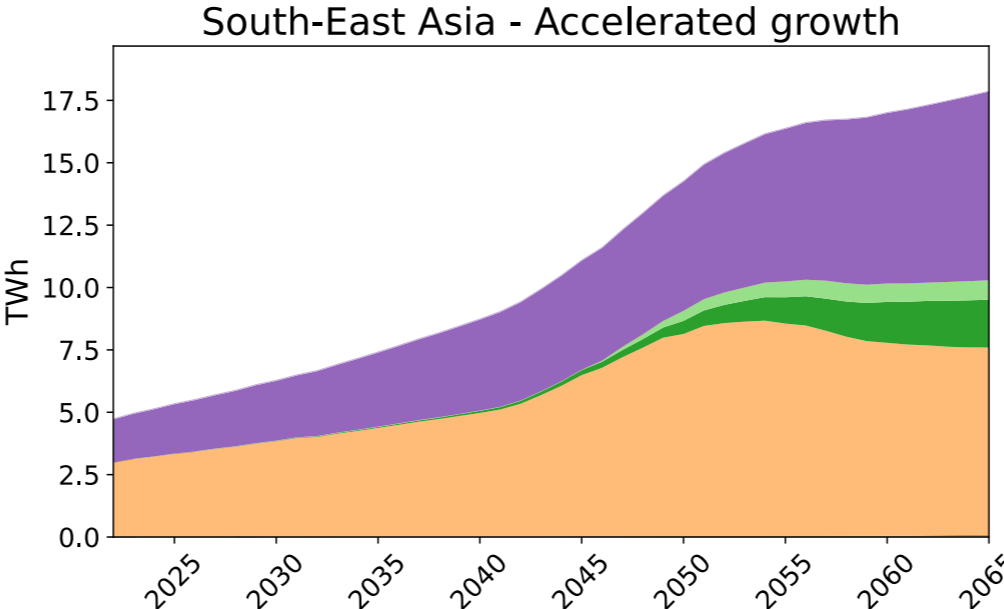
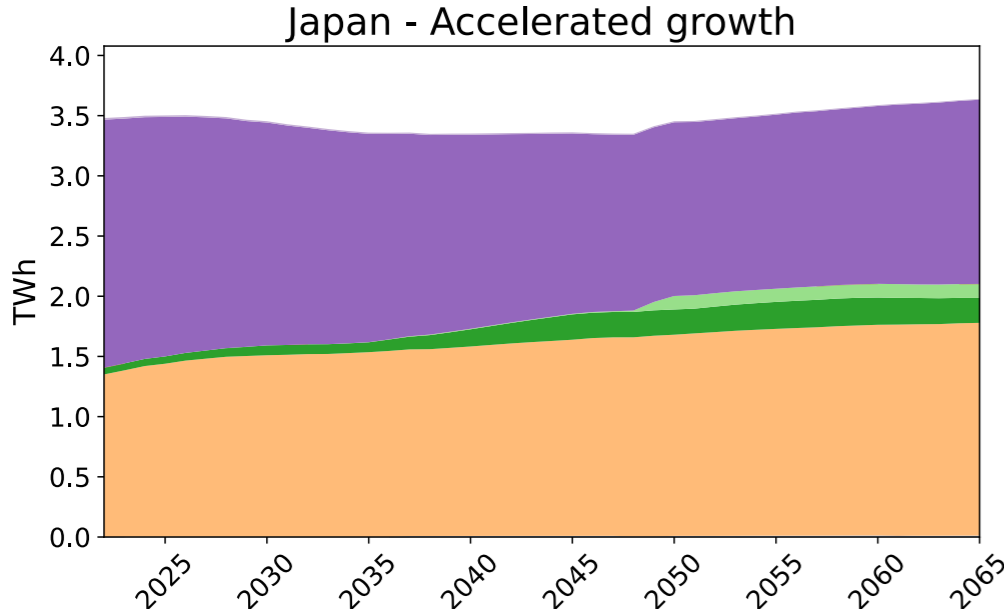
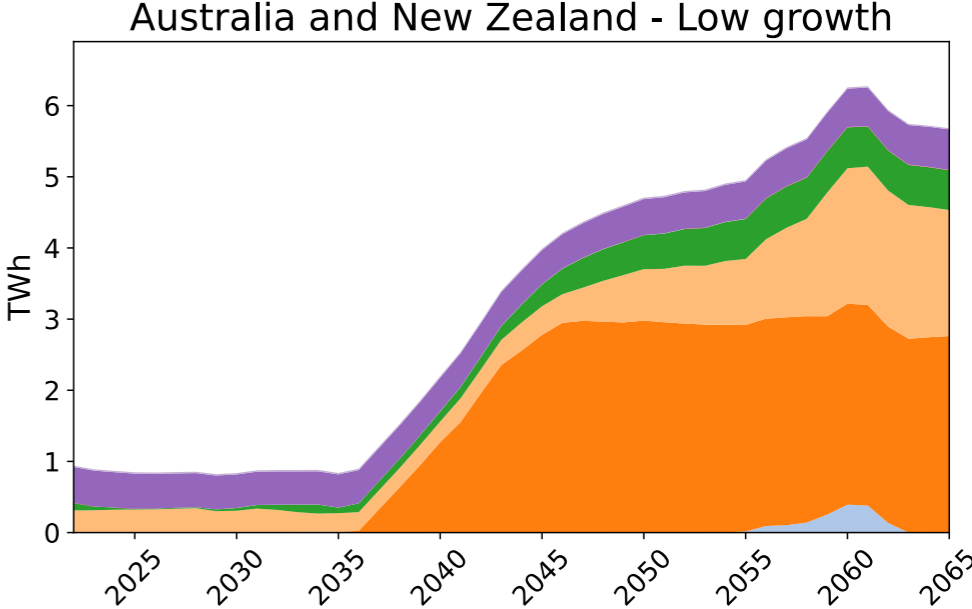
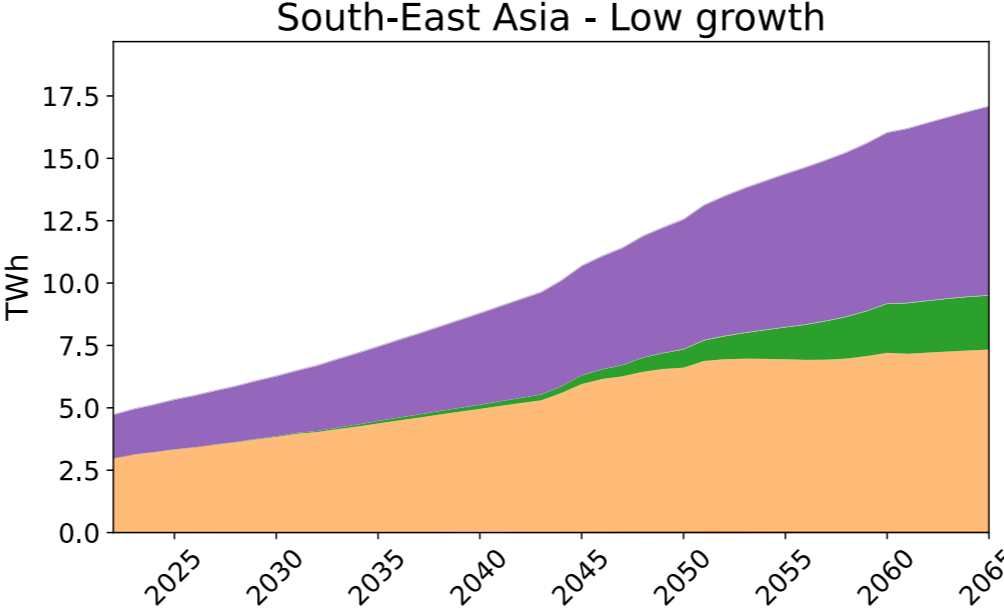
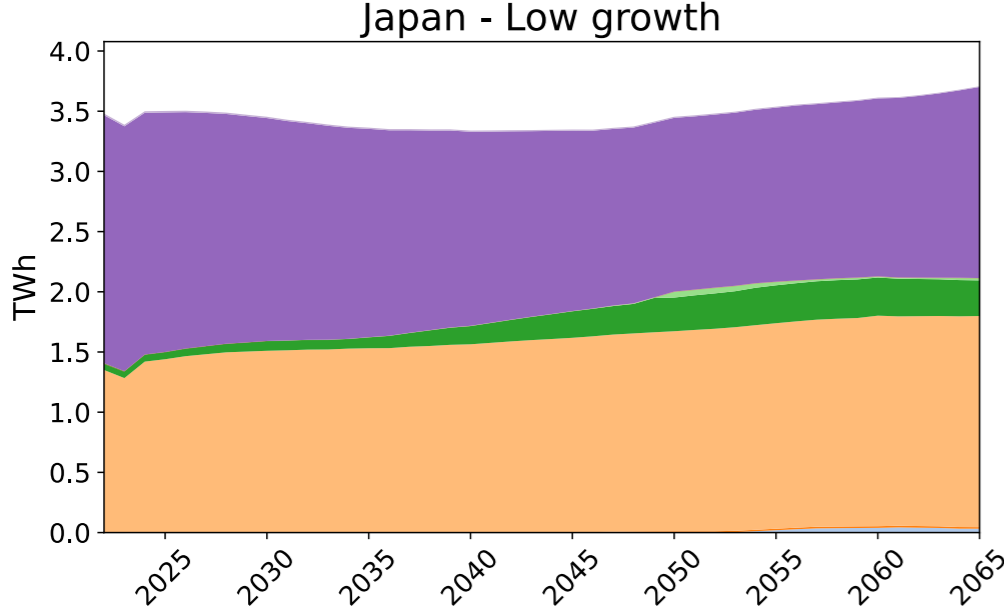


Australia and New Zealand - Accelerated growth

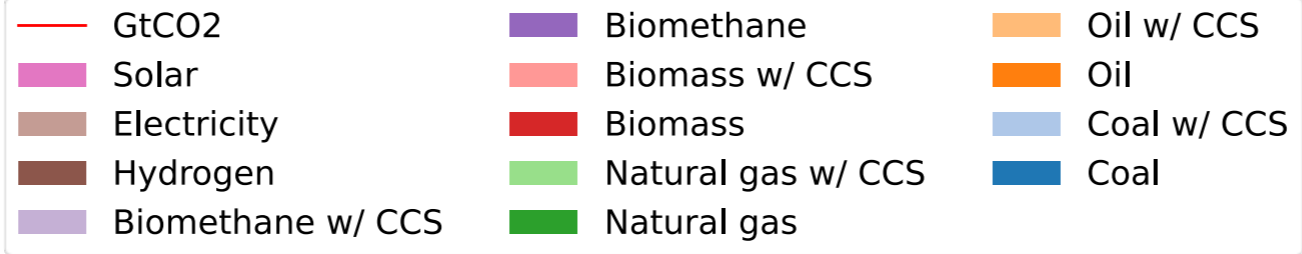
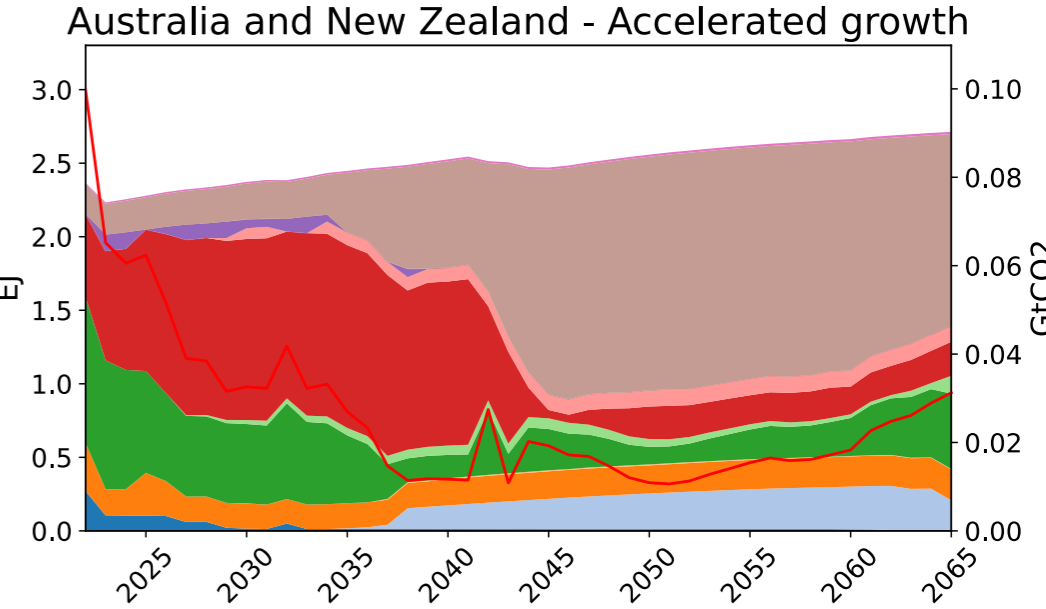
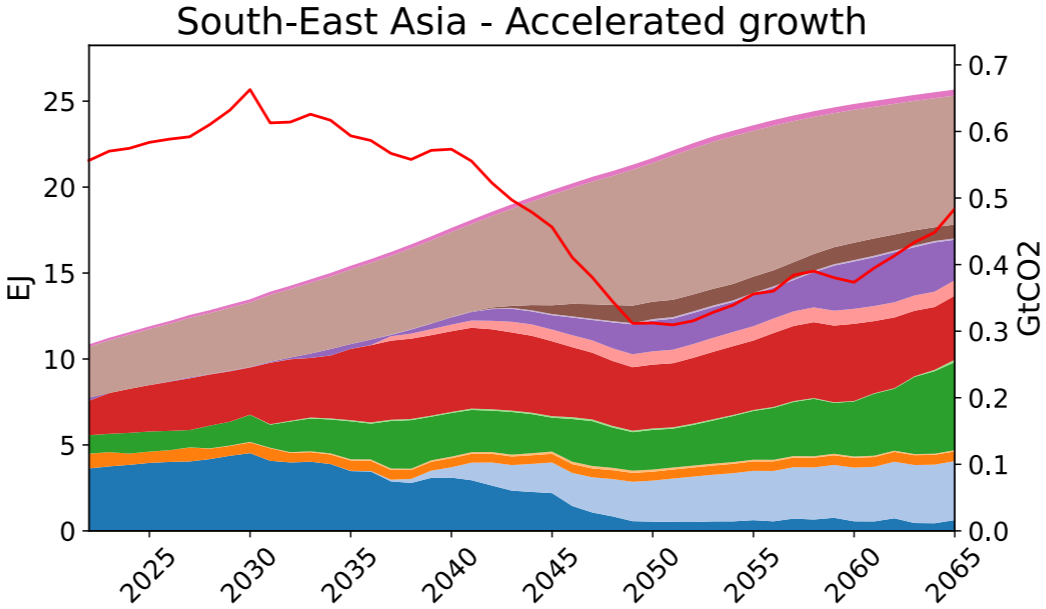
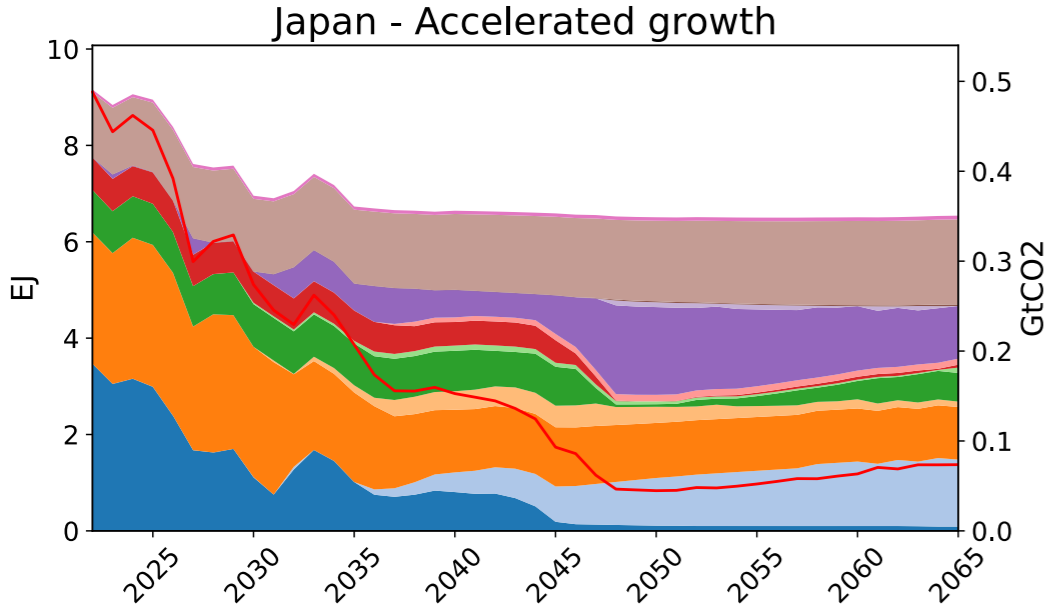
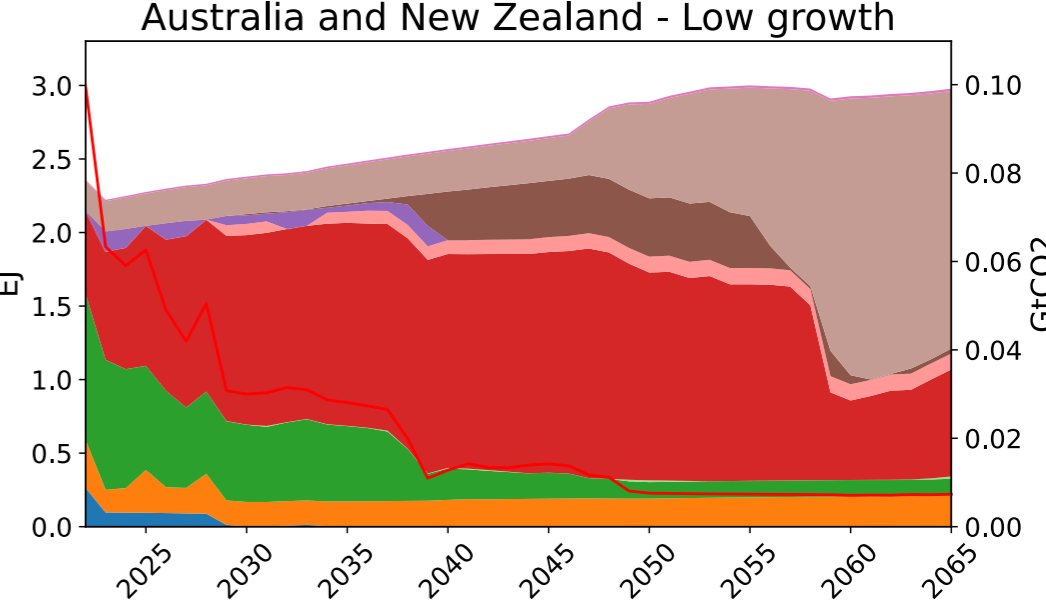
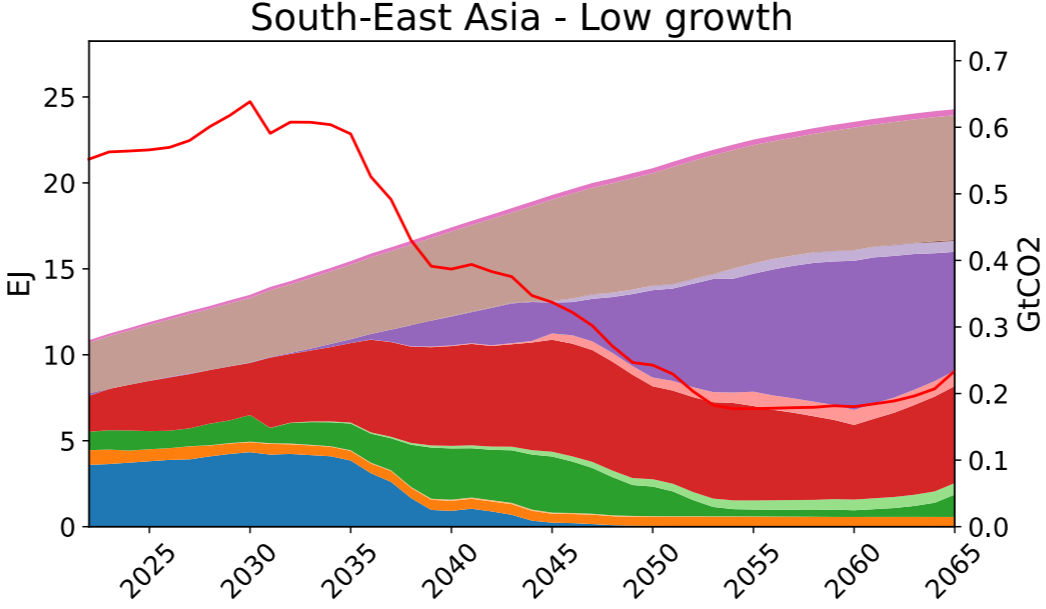
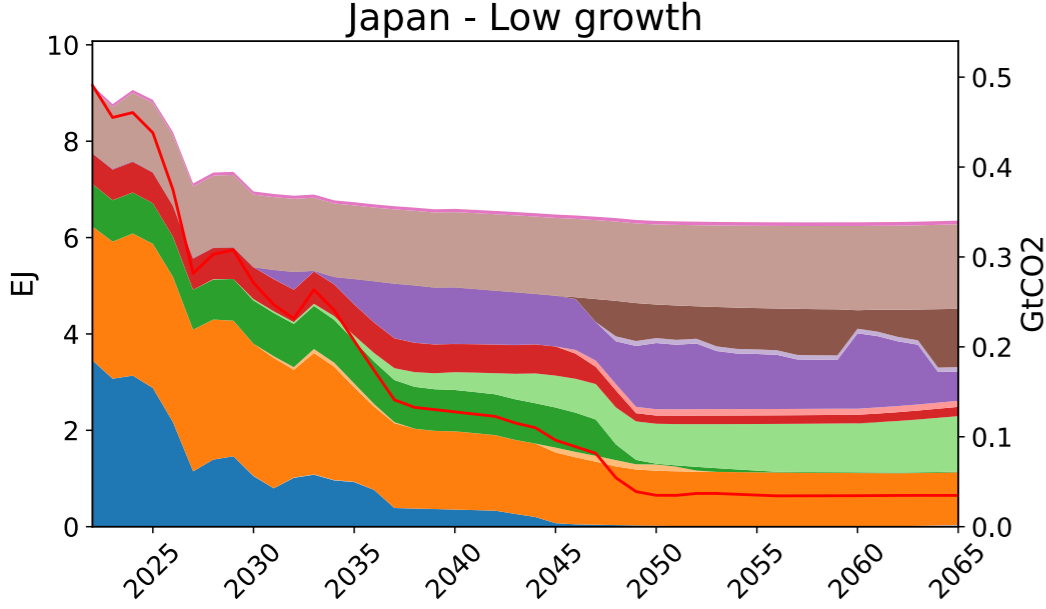


ELECTRICITY USE

NOTE: electricity use excludes dedicated solar and wind hydrogen electrolysis

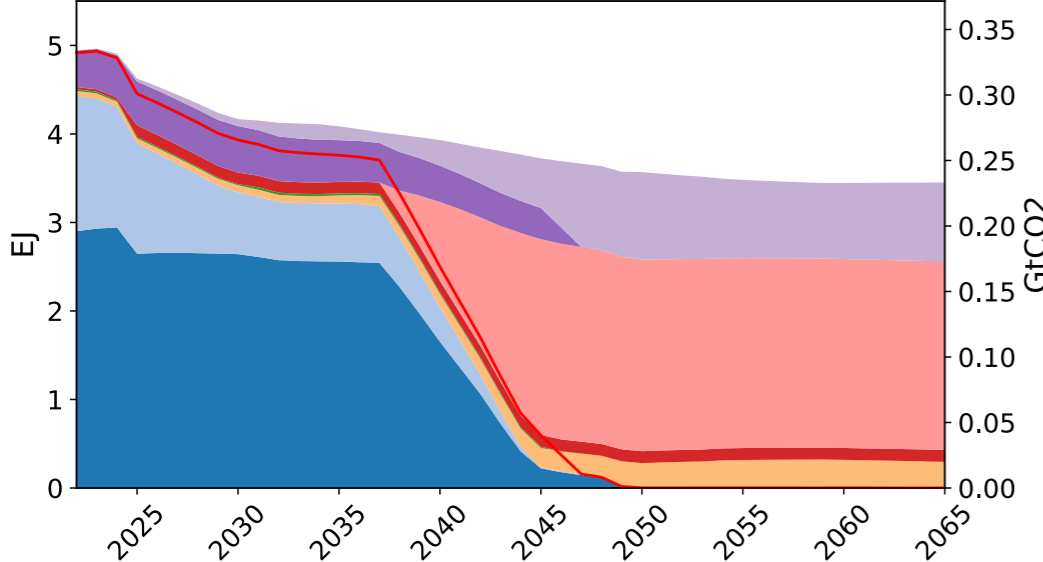


INDUSTRY ENERGY USE

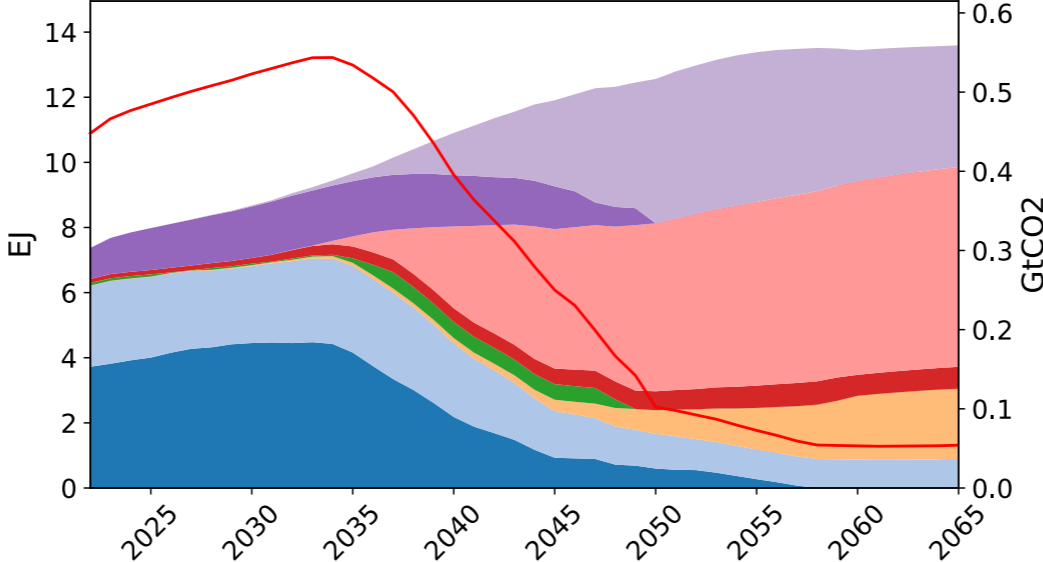


TRANSPORTATION ENERGY USE

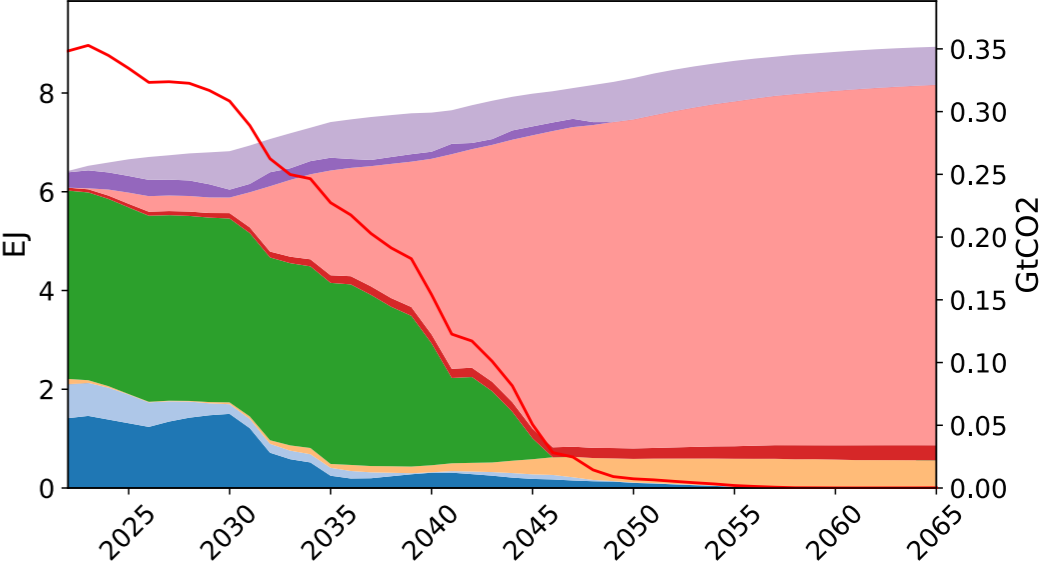
Japan - Low growth



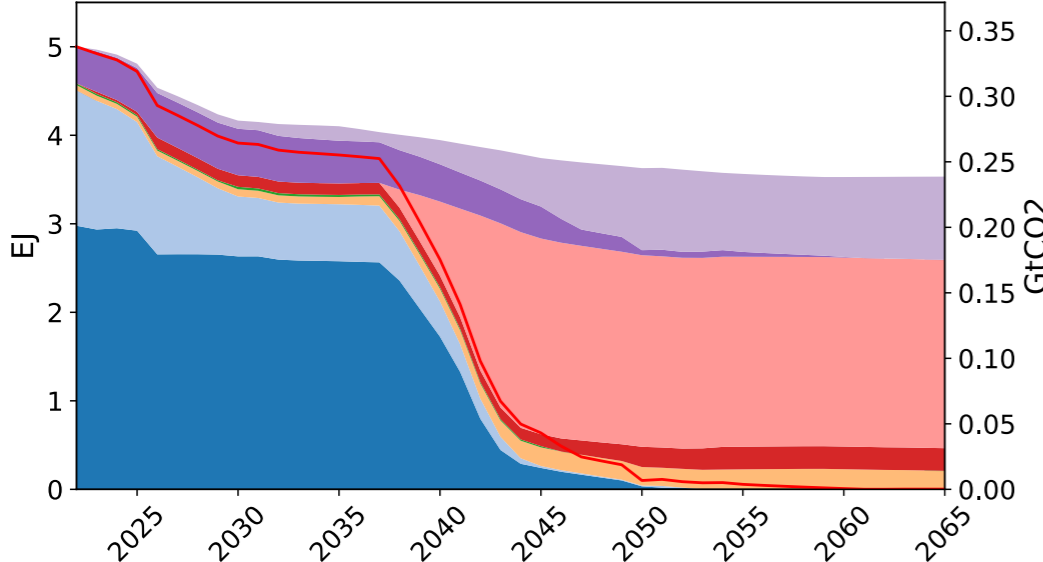
South-East Asia - Low growth



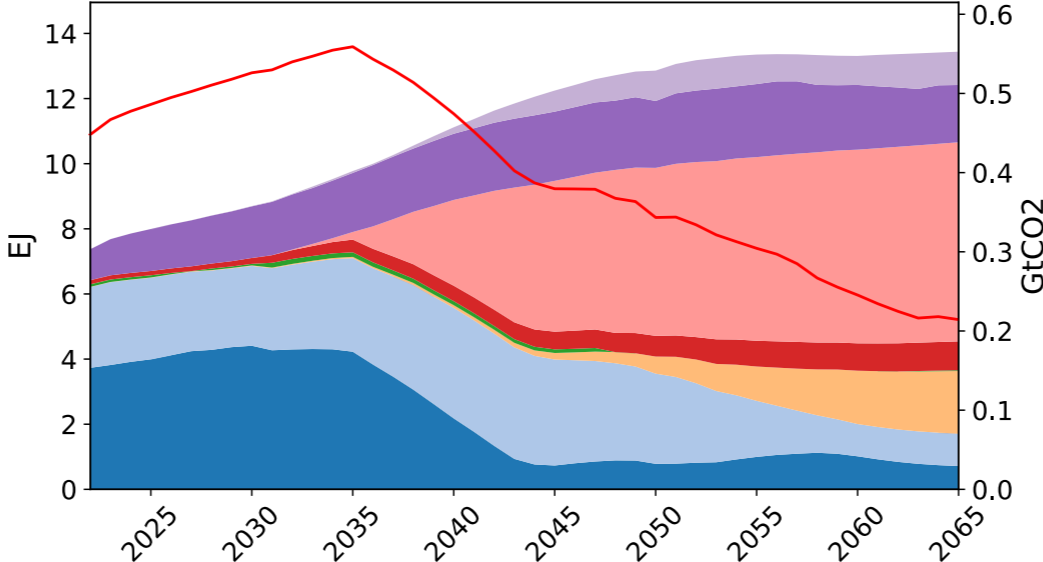
Australia and New Zealand - Low growth



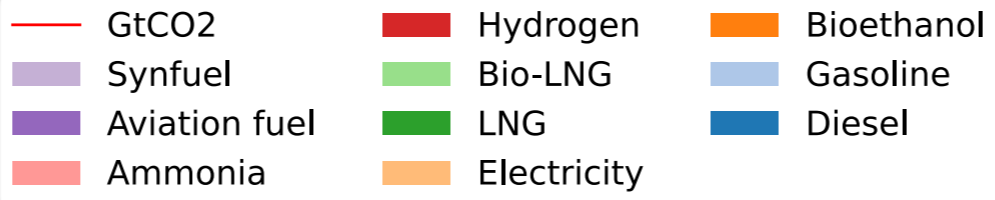
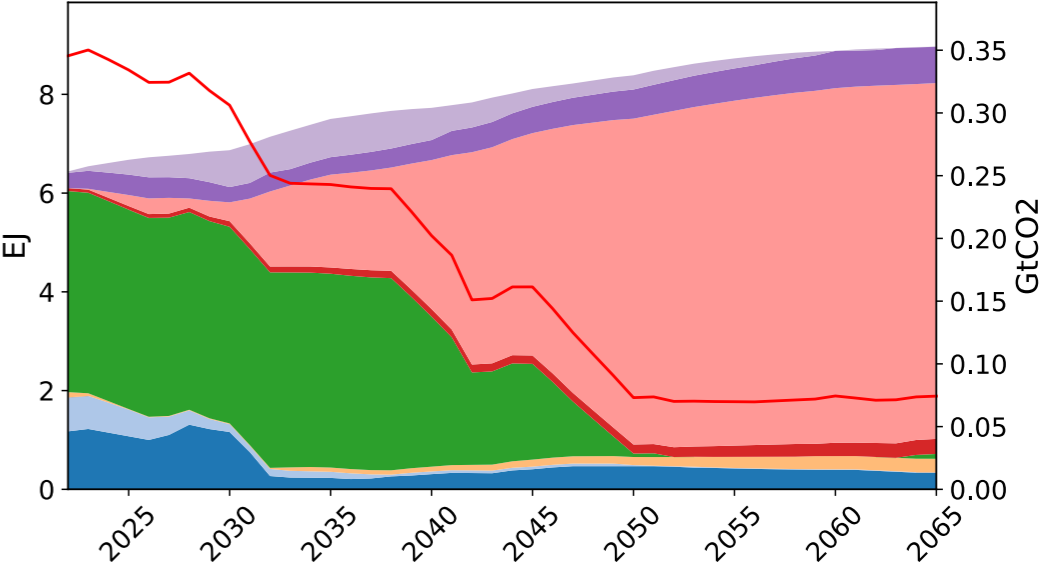
Japan - Accelerated growth



South-East Asia - Accelerated growth



Australia and New Zealand - Accelerated growth



BUILDINGS ENERGY USE

