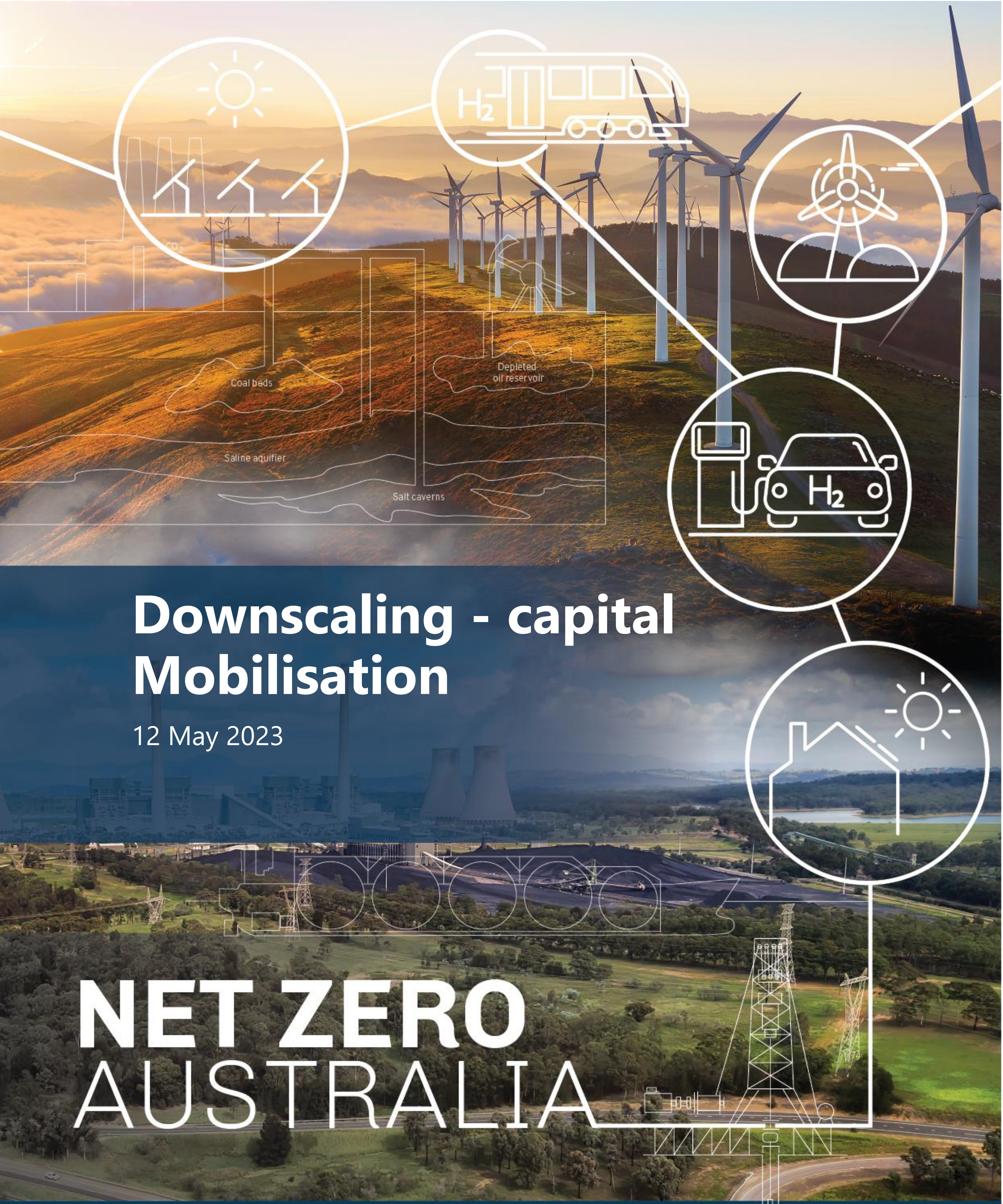

Downscaling - capital Mobilisation

12 May 2023

NET ZERO
AUSTRALIA

THE UNIVERSITY OF MELBOURNE
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CREATE CHANGE
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nous

The Net Zero Australia (NZAu) project is a collaborative partnership between the University of Melbourne, The University of Queensland, Princeton University and management consultancy Nous Group. The study identifies plausible pathways and detailed infrastructure requirements by which Australia can transition to net zero emissions, and be a major exporter of low emission energy and products, by 2050.

Net Zero Australia

Downscaling – capital mobilisation

12 May 2023

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[1] The Andlinger Center for Energy and the Environment, Princeton University

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Contents

1 Capital Mobilisation

1.1 Introduction

Pathways to achieve net-zero emissions in energy and industrial systems rely on a shift away from fossil fuels to essentially zero-emissions renewable resources, along with various combinations of increased energy efficiency, clean fuels production, bioenergy production, nuclear power, CO_2 capture and storage, and CO_2 removal through natural and engineered solutions.[1] The Net-Zero Australia study (NZAu), proposes 5 least-cost pathways to take the domestic economy to net-zero emissions by 2050, in line with federal policy, and which also transition Australia's fossil fuel exports to net-zero by 2060. The latter is not subject to any policy commitment but is frequently cited as a national aspiration.[2]

All NZAu scenarios all involve ambitious renewable energy (especially solar PV) deployment along with variations in end-use electrification, onshore and offshore wind deployment, CCUS, and clean export strategies (clean energy versus onshoring clean metal processing).

Net-zero energy supply systems that rely heavily on weather-dependent renewable energy sources have a greater capital intensity (the relative contribution that capital servicing costs make to overall energy systems cost) than conventional energy systems that rely mostly on fossil fuels and/or nuclear energy. For Net-Zero America, the increase was 2 to 4 times the reference case.[2] However, renewable resources benefit from much lower operating costs. Steep reductions in the capital costs of wind and solar over the last 20 years, and more recently in the cost of battery technology, mean that these systems can now have similar or lower through-life average unit costs. [4]

For policies that require net-zero emissions targets to be met by mid-century, the significant increase in capital intensity requires that capital be allocated to develop and build net-zero energy sector assets at much faster rates that has been previously observed in the energy sector. Furthermore, the affordability of net-zero transition scenarios hinges on capital being available at low cost. This is especially relevant because the recent rapid escalation in inflation and benchmark interest rates, and the increased uncertainty around mid- to longer-term costs of capital, present another potential headwind to rapid deployment of renewables.[5]

It is commonly asserted that an abundance of financial capital will be committed to a global net-zero economy.[7] However, most such capital is seeking opportunities to invest in fully permitted clean energy assets that are supported by well-defined and predictable economics and the stability of developed markets, rather than being allocated to the massive greenfield capital development needed. This section projects the sequencing and levels of supply-side capital that would need to be mobilised in the NZAu scenarios relative to a business as usual reference scenario.

1.2 The challenge to speed up capital allocation[5]

Macroscale energy systems models like the one used for NZAu simulate capital being allocated and assets materialising overnight to ensure supply matches, to meet both demands and the assumed emissions trajectory.

A deeper examination of how real-world projects are developed and financed reveals the nuance of mobilising that capital and hence the need to consider capital formation in the NZAu Mobilization workstream.

Project developers manage the amount of capital at risk by cautiously advancing each proposition in stages. As shown in the stylised representation of the typical sequence in Figure 1, the stages are typically *decision-gated*, meaning decisions to advance from one stage to the next are subjected to rigorous reassessment of project risks and the value proposition. The most consequential decision gate is the "final investment decision” (FID) at which third party equity and debt providers join the developer in committing sufficient capital to build and commission the project.

Figure 1 Stylised project investment decision sequence indicating typical ranges for duration and cost (as percentage of Total Investment Capital).

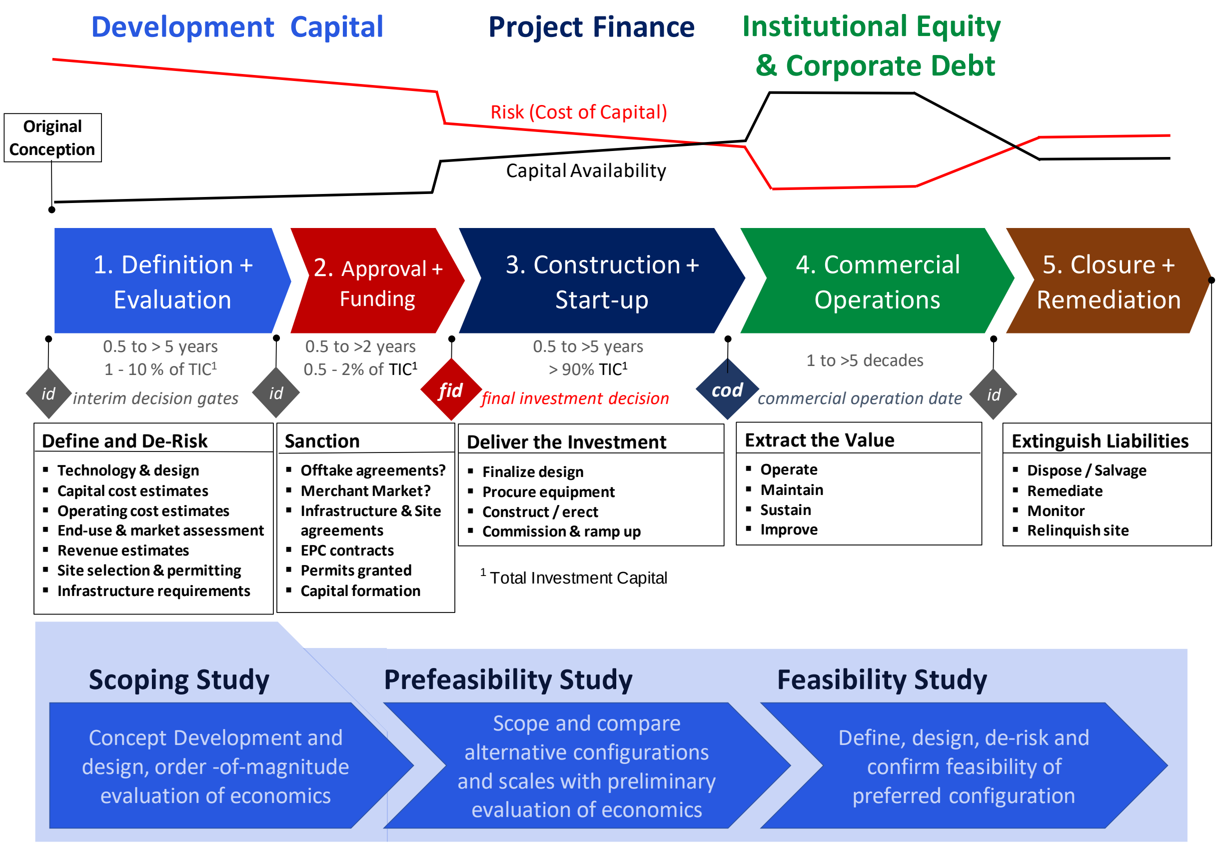


Figure 1: Stylised project investment decision sequence indicating typical ranges for duration and cost (as percentage of Total Investment Capital). Within each of the five phases of the sequence, there will often be a series of sub-phases and decisions - e.g., phase 1 will typically include an initial concept or scoping study, followed by a prefeasibility study and then a feasibility study – generally comprising activities and deliverables described in the boxes below each phase. As successful projects advance from left to right in the sequence, the level of project definition, confidence in the business case, and availability of capital increase, while the investment risk profile and cost of capital decrease.[5]

The work of stage 1 in the pre-FID phase relies on ‘development’ capital that today is almost exclusively provided by a project developer’s own balance sheet equity. It is the scarcest capital and hence demands the highest risk premium. This stage involves scoping and designing the project; securing a site and access to enabling infrastructure; estimating all costs and negotiating execution contracts; identifying customers and negotiating offtake deals; permitting; and qualifying for all necessary approvals. If, after stage 1, the developer has achieved a sufficient level of confidence that the project will generate sustainable levels of net income after all costs and taxes to generate an acceptable return on capital, it may elect to move into stage 2. Still in the pre-FID phase, stage 2 involves negotiating with additional investors and lenders to secure the full amount of capital needed to complete the project, i.e., finalise design, procure all equipment, and complete all construction, installation and commissioning, and start-up activities to achieve commercial operations. Once this capital is secured, the project has achieved FID. The development capital to complete stages and 1 and 2 is fully-at risk, until FID is achieved, meaning that any project has the potential to be abandoned prior to FID.

1.3 Methodology

The RIO optimization model minimises the net present value of the energy transition required to meet a linearly declining trajectory of emissions from energy and industrial systems to achieve economy wide net-zero emissions by the target date. In this scope of work, we disaggregate RIO's supply side cost outputs to extract the fixed capital that 'materialises' each year from 2021 to 2060. We then allocate estimates, based on experience and discussions with project developers, of the pre-FID costs for each technology (see Appendix 1). Note that for electricity distribution systems, RIO provides an estimate of the annual revenue needed to service national distribution networks rather that specific fixed capital estimates. To estimate the fixed capital invested per year we first deduct approximate allowances for operating and maintenance costs (4% of revenue), depreciation (2.4% of revenue), and tax and other non-capital related expenses (3% of revenue); and then divide the remaining revenue by the assumed WACC. These deductions were estimated by reference to a variety of past Australian regulatory reviews. (e.g., 8)

Finally, we allocate all extracted and estimated fixed capital costs against the typical sequence and durations of pre-FID, construction, and commissioning activities (see Appendix 1) for each of the supply side technologies, storage, connecting infrastructure (electricity transmission and distribution, hydrogen and CO_2 pipelines), significant industrial transformations (cement, iron and steel, ammonia production for export) and associated water infrastructure (desalination).

1.4 Results

The committed capital sequences for each scenario is summarized for all scenarios in Figure 2 are presented graphically by sector for each scenario, in Figure 3 through Figure 7. In appendix 2 these are broken out by technology for each of the scenarios. The results highlight the very large capital mobilisation requirements of the NZAu net-zero scenarios, each being between 7 and 9 trillion AUD, approximately 4.8 to 7 times larger than the Reference scenario. The Onshoring scenario is the least capital intensive of the net-zero scenarios and the 100% Renewables scenario is the most capital intensive. Much of these capital demands are associated with the export transitions. Note that CO_2 transport and storage is excluded from the capital needs, however these are typically small relative to capital for CO_2 capture, which in turn is small relative to electricity infrastructure and other clean fuels.

Figure 2 Total capital committed for all scenarios.

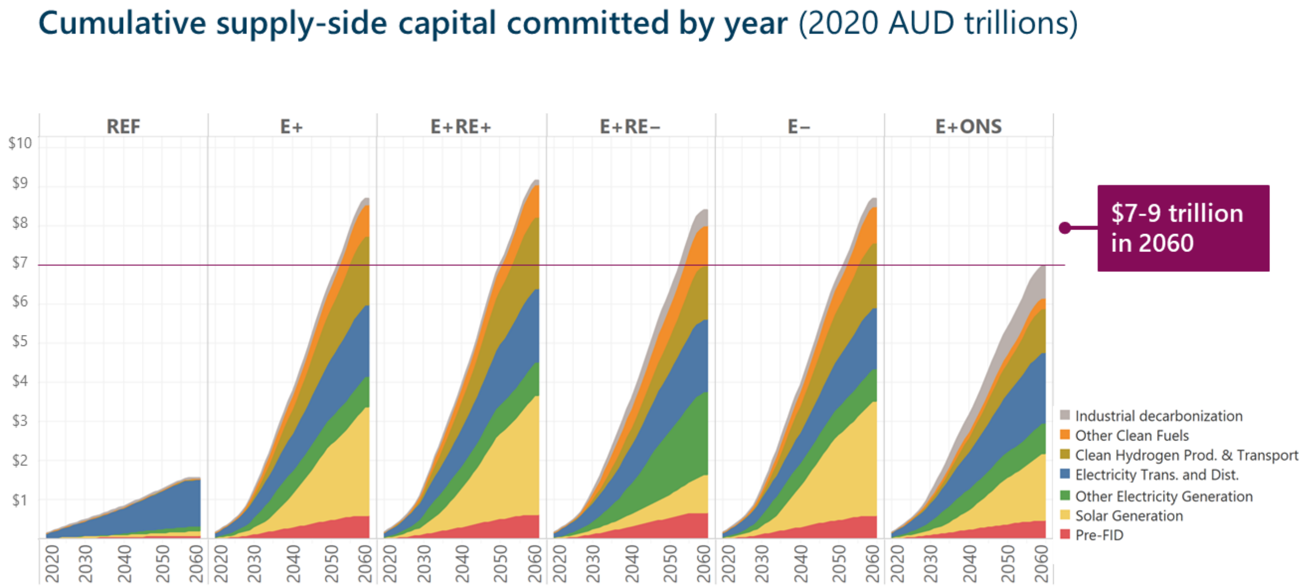


Figure 3 Total capital committed Reference Scenario

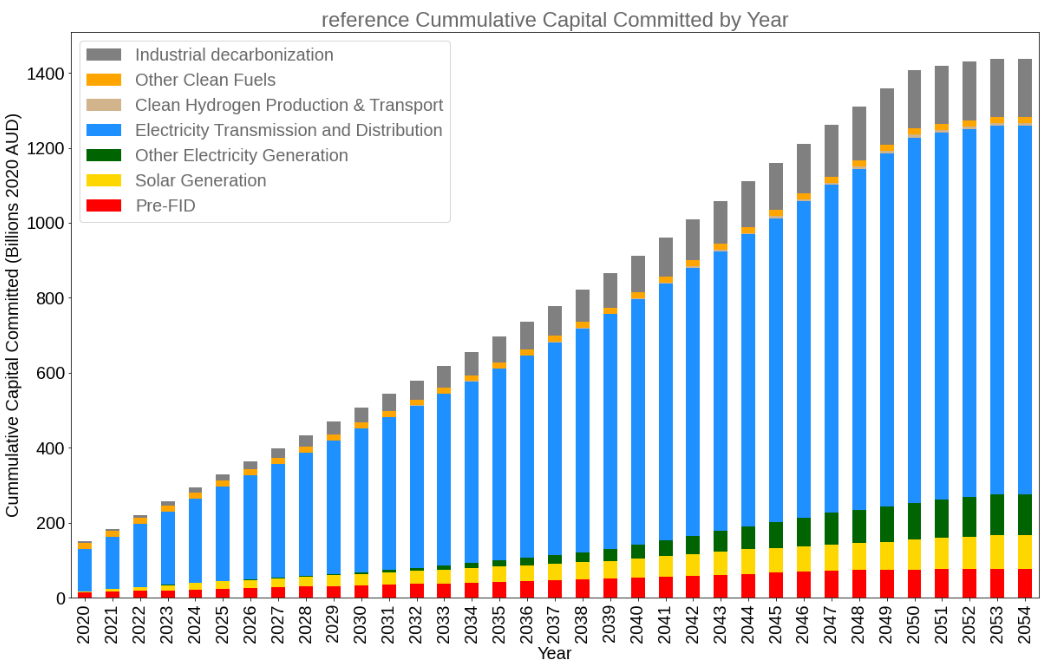


Figure 4 Total capital committed E+ Scenario

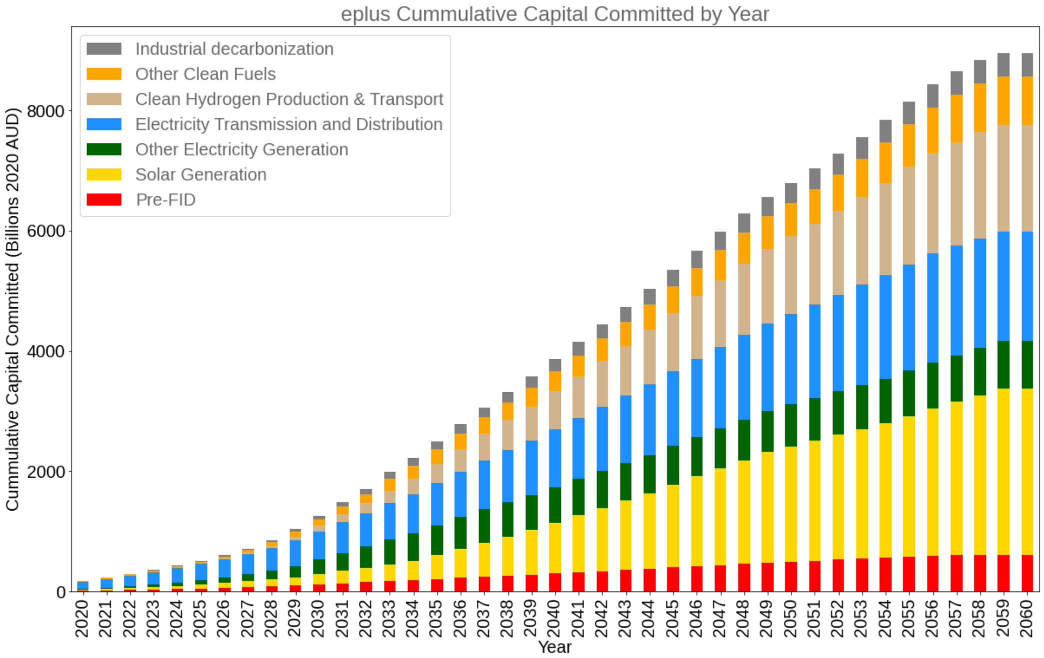


Figure 5 Total capital committed E- Scenario

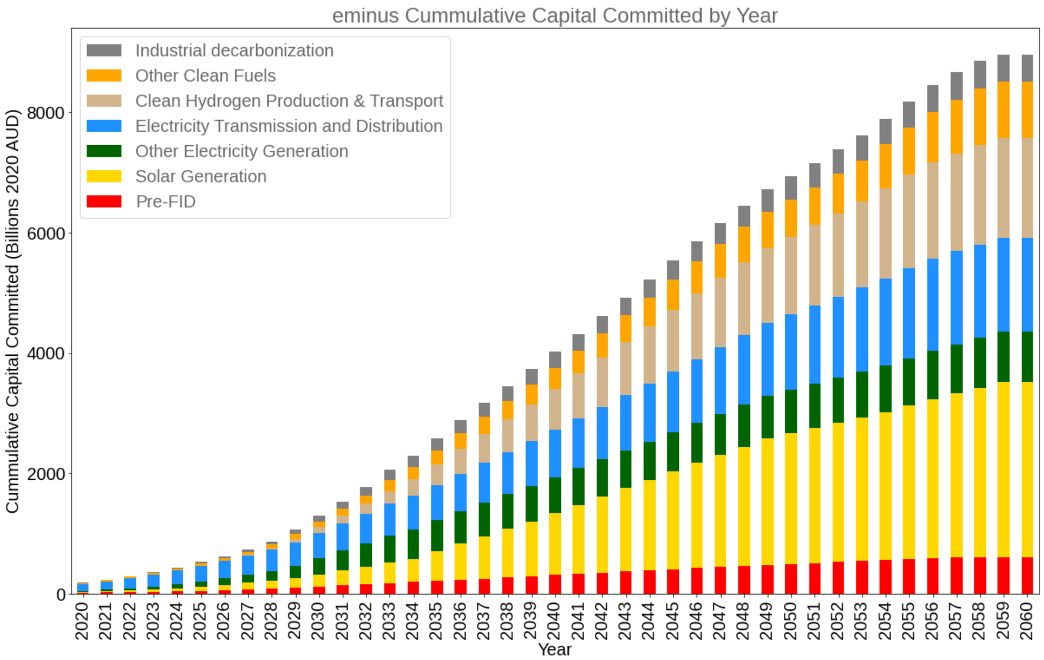


Figure 6 Total capital committed RE- Scenario

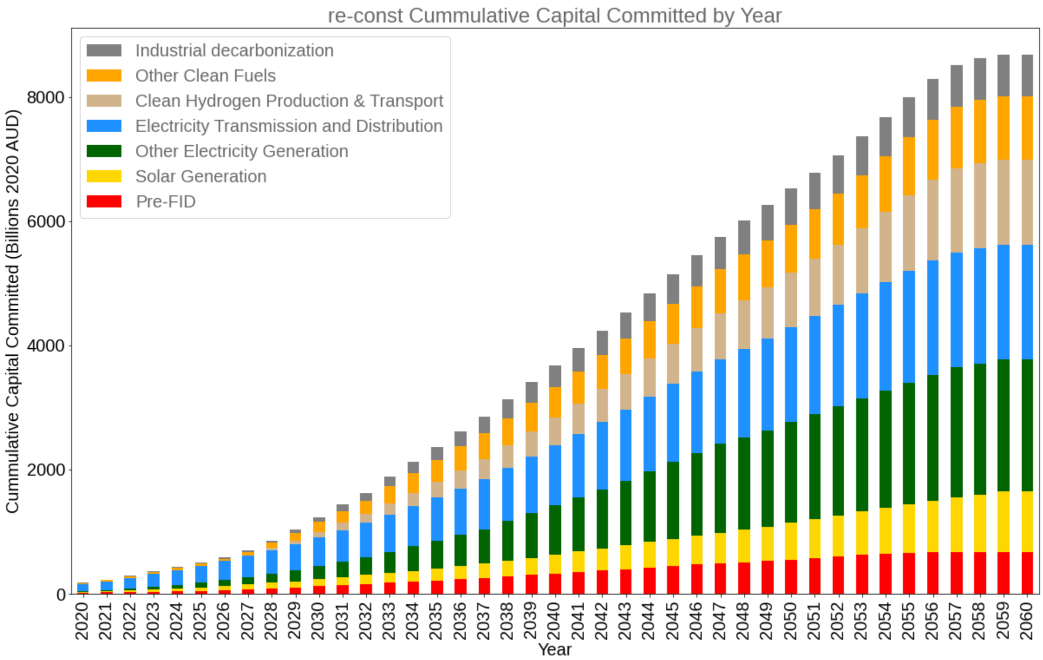


Figure 7 Total capital committed RE+ Scenario

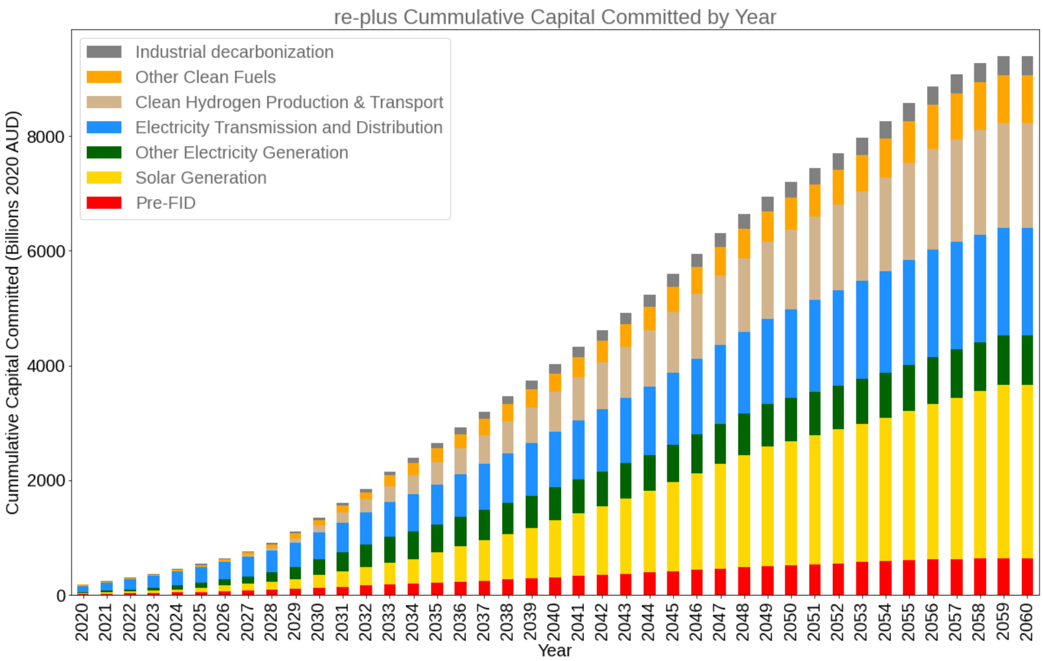
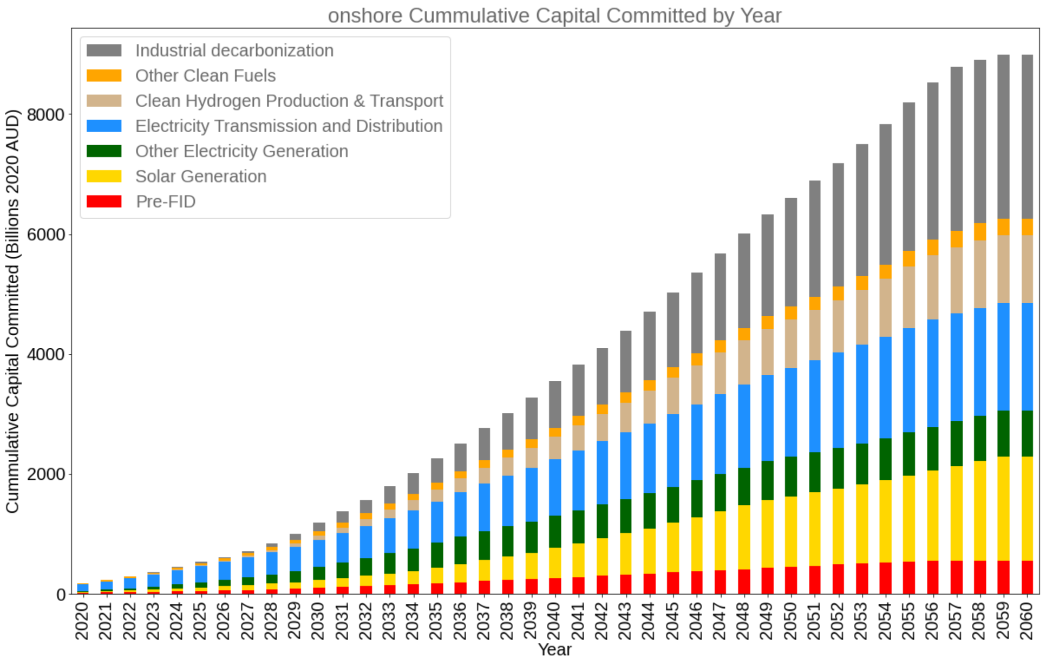


Figure 8 Total capital committed ONS Scenario



1.5 Conclusion

The results clearly indicate the capital intensity of the NZAu scenarios which variously require between 4.8 to 7 times the capital allocated through the REF scenario. As shown in Figure 8, the most capital intensive or the net-zero scenarios is the RE+ scenario and the least is E+ONS scenario.

The high capital intensity of the net-zero scenarios was also a characteristic or the Net-Zero America study and is the subject of ongoing research and engagement with the private sector. These levels of capital mobilization clearly demand serious consideration in the planned NZAu mobilization work stream and ongoing research and engagement with the financial sector globally.

1.6 References

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Appendices

Appendix 1: Estimated costs and durations

Appendix 1: Estimated costs and durations (see Table 1) of pre-FID, construction, and commissioning activities for each of the supply side technologies, storage, connecting infrastructure significant industrial transformations.

POWER SECTOR

Generation

Technology	Pre-FID Time (years)	PreFID Cost[1] (% of TIC)	Financing Cost[2] (% of TIC)	Total Pre-FID Cost (% of TIC)	Financial Close (years)	Construction Time (years) FID to COD	Overall Dev Time (years) Concept to COD
biomass w cc	2.5	9.0%	1.5%	10.5%	0.5	4	7
CCGT	1	4.5%	1.0%	5.5%	0.5	2	3.5
CCGT w CC	2.5	9.0%	1.5%	10.5%	0.5	4	7
CT	1	4.5%	1.0%	5.5%	0.5	1	2.5
geothermal	2	9.0%	1.0%	10.0%	0.5	2	4.5
nuclear	5	24.1%	3.0%	27.1%	1	5	11
offshore wind	2.5	10.0%	1.5%	11.5%	0.5	3	6
onshore wind	1.5	5.5%	1.0%	6.5%	0.5	2	4
solar pv	1	5.5%	1.0%	6.5%	0.5	1	2.5
pumped hydro	2	9.0%	1.0%	10.0%	0.5	2	4.5
storage li-ion	1	4.5%	1.0%	5.5%	0.5	1	2.5

[2] Upfront project finance fee charged by lead bank

[1] Calculated as follows

Technology	Cost per study (% of TIC)			Success Rate			
	Scoping Study	Prefeasibility	Feasibility	Scoping Study	Prefeasibility	Feasibility	Cost per Project
biomass w cc	0.20%	1.00%	2%	10%	33%	50%	9.0%
CCGT	0.10%	0.50%	1%	10%	33%	50%	4.5%
CCGT w CC	0.20%	1.00%	2%	10%	33%	50%	9.0%
CT	0.10%	0.50%	1%	10%	33%	50%	4.5%
geothermal	0.20%	1.00%	2%	10%	33%	50%	9.0%
nuclear	1.00%	2.00%	4%	10%	33%	50%	24.1%
offshore wind	0.30%	1.00%	2%	10%	33%	50%	10.0%
onshore wind	0.20%	0.50%	1%	10%	33%	50%	5.5%
solar pv	0.20%	0.50%	1%	10%	33%	50%	5.5%
pumped hydro	0.20%	1.00%	2%	10%	33%	50%	9.0%
storage li-ion	0.10%	0.50%	1%	10%	33%	50%	4.5%

Transmission

Technology	Pre-FID Time (years)	PreFID Cost[1] (% of TIC)	Financing Cost[2] (% of TIC)	Total Pre-FID Cost (% of TIC)	Financial Close (years)	Construction Time (years) FID to COD	Overall Dev Time (years) Concept to COD
Long Distance Interregional Transmission	5	16.1%	1.0%	17.1%	1	4	10
Transmission Assets (average)	2.5	5.7%	1.0%	6.7%	0.5	4	7
Spur Lines (Onshore)	1.5	2.8%	1.0%	3.8%	0.5	4	6
Spur Lines (Offshore)	2.5	5.7%	1.0%	6.7%	0.5	4	7
Sustaining Capital	0.5	1.0%	0.0%	1.0%	0.5	1	2

[2] Upfront project finance fee charged by lead bank

[1] Calculated as follows

Technology	Cost per study (% of TIC)			Success Rate			
	Scoping Study	Prefeasibility	Feasibility	Scoping Study	Prefeasibility	Feasibility	Cost per Project
Long Distance Interregional Transmission	0.20%	2.00%	4%	10%	33%	50%	16.1%
Transmission Assets (average)	0.20%	1.00%	2%	20%	50%	75%	5.7%
Spur Lines (Onshore)	0.10%	0.50%	1%	20%	50%	75%	2.8%
Spur Lines (Offshore)	0.20%	1.00%	2%	20%	50%	75%	5.7%
Sustaining Capital			1%	100%	100%	100%	1.0%

Distribution Networks

Technology	Pre-FID Time (years)	PreFID Cost[1] (% of TIC)	Financing Cost[2] (% of TIC)	Total Pre-FID Cost (% of TIC)	Financial Close (years)	Construction Time (years) FID to COD	Overall Dev Time (years) Concept to COD
Distribution Assets	1	2.5%	0.5%	3.0%	0.5	1	2.5
Sustaining Capital	1	1.0%	0.5%	1.5%	0.5	1	2.5

[2] Upfront project finance fee charged by lead bank

[1] Calculated as follows

Technology	Cost per study (% of TIC)			Success Rate			
	Scoping Study	Prefeasibility	Feasibility	Scoping Study	Prefeasibility	Feasibility	Cost per Project
Distribution Assets	0.10%	0.50%	1%	20%	50%	100%	2.5%
Sustaining Capital			1%	100%	100%	100%	1.0%

Fuels Conversion

Technology	Pre-FID Time (years)	PreFID Cost[1] (% of TIC)	Financing Cost[2] (% of TIC)	Total Pre-FID Cost (% of TIC)	Financial Close (years)	Construction Time (years) FID to COD	Overall Dev Time (years) Concept to COD
Autothermal CH4 reforming	2	4.5%	1.0%	5.5%	1	2	5
Autothermal CH4 reforming with CCU	2	9.0%	1.5%	10.5%	2	3	7
BECCS Hydrogen	2	9.0%	1.0%	10.0%	2	4	8
Biomass to Syngas	2	9.0%	1.5%	10.5%	2	3	7
Biomass to Syngas with CCU	2	9.0%	1.0%	10.0%	2	4	8
Biomass FT to Diesel	2	9.0%	1.0%	10.0%	2	3	7
Biomass FT to Diesel with CCU	2	9.0%	3.0%	12.0%	2	4	8
Biomass Pyrolysis	2	4.5%	1.5%	6.0%	2	3	7
Biomass Pyrolysis with CCU	2	9.0%	1.0%	10.0%	2	3	7
Electrolyis	2	4.5%	1.0%	5.5%	1	2	5
Haber Bosch	2	9.0%	1.5%	10.5%	1	3	6
Direct Air Capture of CO2	2	9.0%	1.0%	10.0%	1	2	5
Electric Boiler	2	9.0%	1.0%	10.0%	2	1	5
Hydrogen Blend	1	4.5%	1.0%	5.5%	1	1	3
Industrial Hydrogen Boiler	2	4.5%	1.0%	5.5%	1	2	5
Industrial Pipeline Gas Boiler	2	4.5%	1.0%	5.5%	1	1	4
Liquids synthesis from H2 & CO2	2	9.0%	1.0%	10.0%	1.5	3	6.5
Methane synthesis form H2 & CO2	2	9.0%	1.0%	10.0%	1.5	3	6.5

[2] Upfront project finance fee charged by lead bank

[1]Calculated as follows

Technology	Cost per study (% of TIC)			Success Rate			
	Scoping Study	Prefeasibility	Feasibility	Scoping Study	Prefeasibility	Feasibility	Cost per Project
Autothermal CH4 reforming	0.10%	0.50%	1%	10%	33%	50%	5%
Autothermal CH4 reforming with CCU	0.20%	1.00%	2%	10%	33%	50%	9%
BECCS Hydrogen	0.20%	1.00%	2%	10%	33%	50%	9%
Biomass to Syngas	0.20%	1.00%	2%	10%	33%	50%	9%
Biomass to Syngas with CCU	0.20%	1.00%	2%	10%	33%	50%	9%
Biomass FT to Diesel	0.20%	1.00%	2%	10%	33%	50%	9%
Biomass FT to Diesel with CCU	0.20%	1.00%	2%	10%	33%	50%	9%
Biomass Pyrolysis	0.10%	0.50%	1%	10%	33%	50%	5%
Biomass Pyrolysis with CCU	0.20%	1.00%	2%	10%	33%	50%	9%
Electrolyis	0.10%	0.50%	1%	10%	33%	50%	5%
Haber Bosch	0.20%	1.00%	2%	10%	33%	50%	9%
Direct Air Capture of CO2	0.20%	1.00%	2%	10%	33%	50%	9%
Electric Boiler	0.20%	1.00%	2%	10%	33%	50%	9%
Hydrogen Blend	0.10%	0.50%	1%	10%	33%	50%	5%
Industrial Hydrogen Boiler	0.10%	0.50%	1%	10%	33%	50%	5%
Industrial Pipeline Gas Boiler	0.10%	0.50%	1%	10%	33%	50%	5%
Liquids synthesis from H2 & CO2	0.20%	1.00%	2%	10%	33%	50%	9%
Methane synthesis form H2 & CO2	0.20%	1.00%	2%	10%	33%	50%	9%

CO2 Pipeline Network

Technology	Pre-FID Time (years)	PreFID Cost[1] (% of TIC)	Financing Cost[2] (% of TIC)	Total Pre-FID Cost (% of TIC)	Financial Close (years)	Construction Time (years) FID to COD	Overall Dev Time (years) Concept to COD
Inter-Regional Trunk Lines	5	13.0%	1.5%	14.5%	1	5	11
Spur Lines	2.5	4.2%	1.0%	5.2%	0.5	3	6
E&A, Wells & Facilities	1	5.0%	0.0%	5.0%	0	1	2

[2] Upfront project finance fee charged by lead bank

[1]Calculated as follows

Technology	Cost per study (% of TIC)			Success Rate			
	Scoping Study	Prefeasibility	Feasibility	Scoping Study	Prefeasibility	Feasibility	Cost per Project
Inter-Regional Trunk Lines	0.20%	1.00%	4%	10%	33%	50%	13%
Spur Lines	0.10%	0.50%	2%	20%	50%	75%	4%

INDUSTRY

Technology	Pre-FID Time (years)	PreFID Cost[1] (% of TIC)	Financing Cost[2] (% of TIC)	Total Pre-FID Cost (% of TIC)	Financial Close (years)	Construction Time (years) FID to COD	Overall Dev Time (years) Concept to COD
Cement	2.5	4.2%	1.0%	5.2%	0.5	4	7
Steel	2.5	4.2%	1.0%	5.2%	0.5	3	6

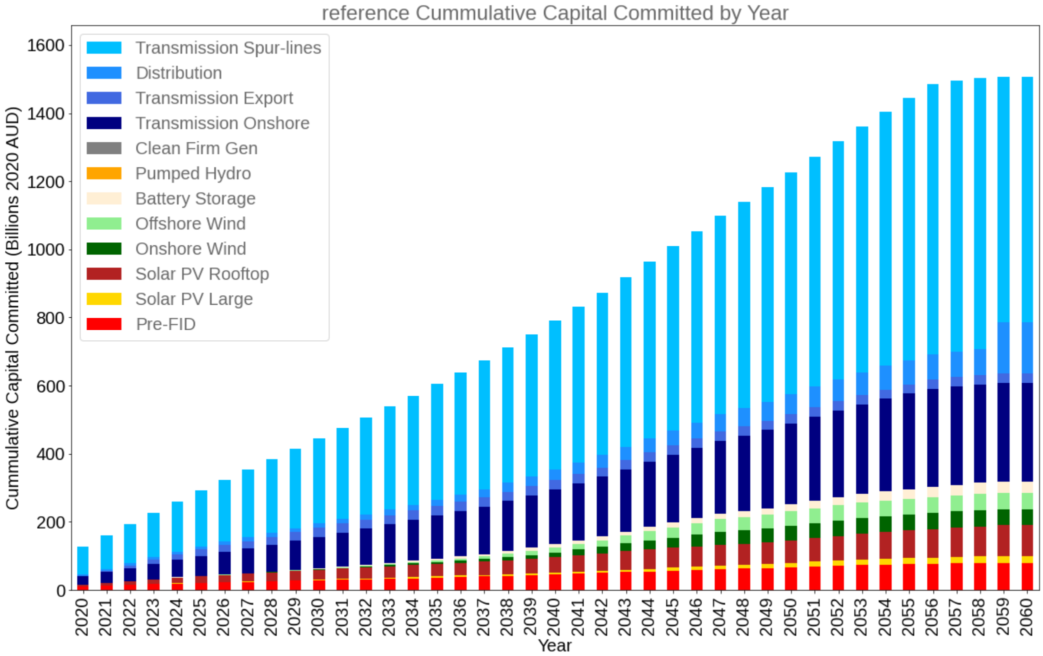
[2] Upfront project finance fee charged by lead bank

[1]Calculated as follows

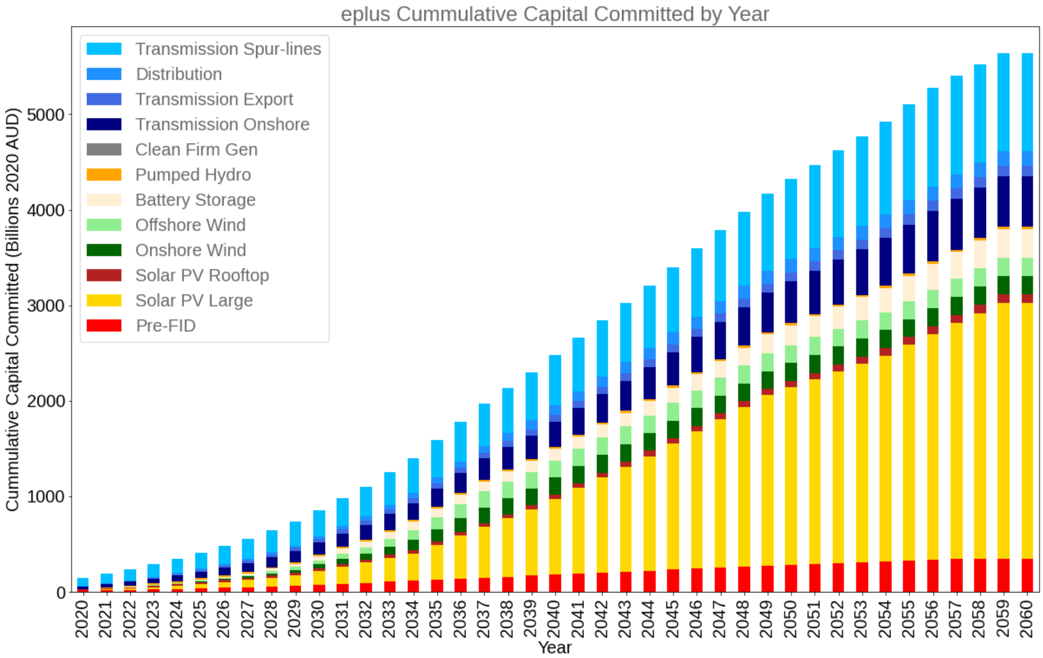
Technology	Cost per study (% of TIC)			Success Rate			
	Scoping Study	Prefeasibility	Feasibility	Scoping Study	Prefeasibility	Feasibility	Cost per Project
Cement	0.10%	0.50%	2%	20%	50%	75%	4%
Steel	0.10%	0.50%	2%	20%	50%	75%	4%

Appendix 2: Capital Committed for each Scenario for Clean Electricity Sector

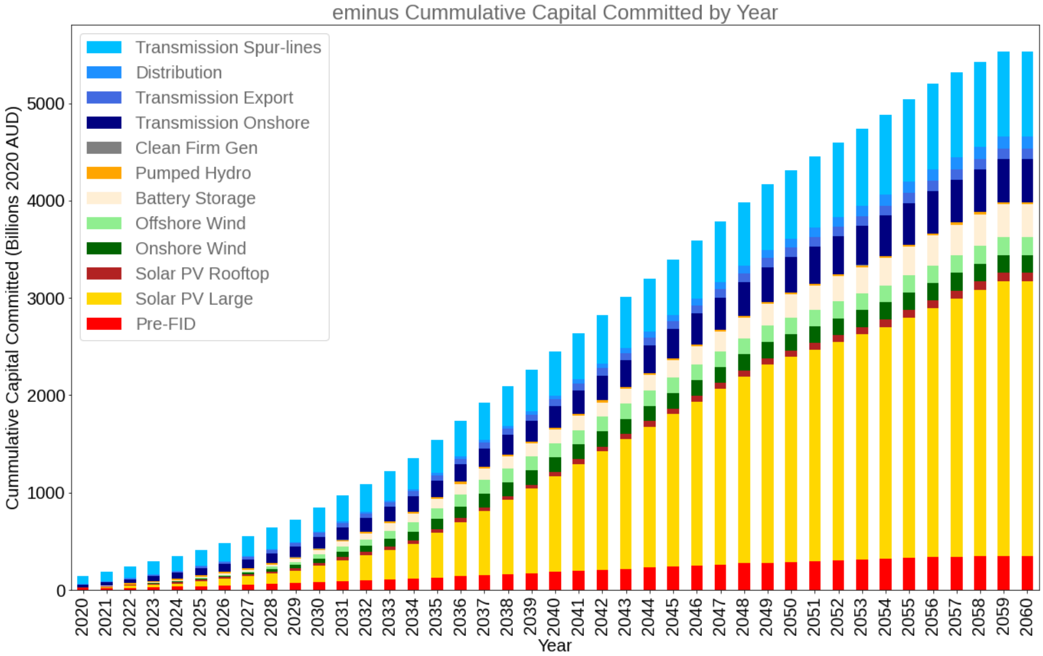
A2.1 REF Scenario



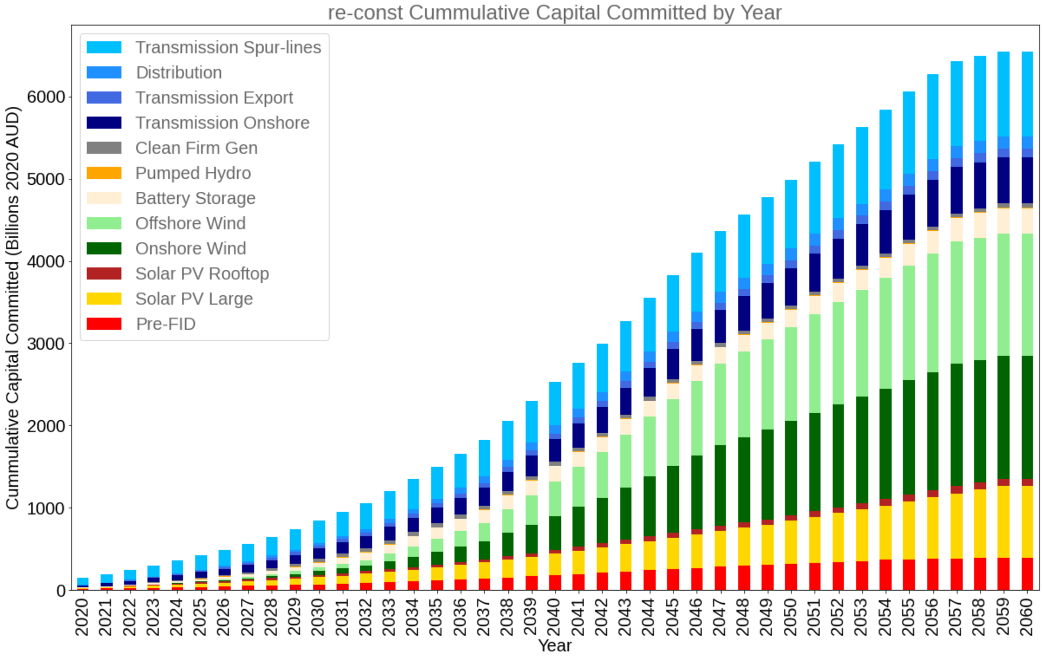
A2.2 E+ Scenario



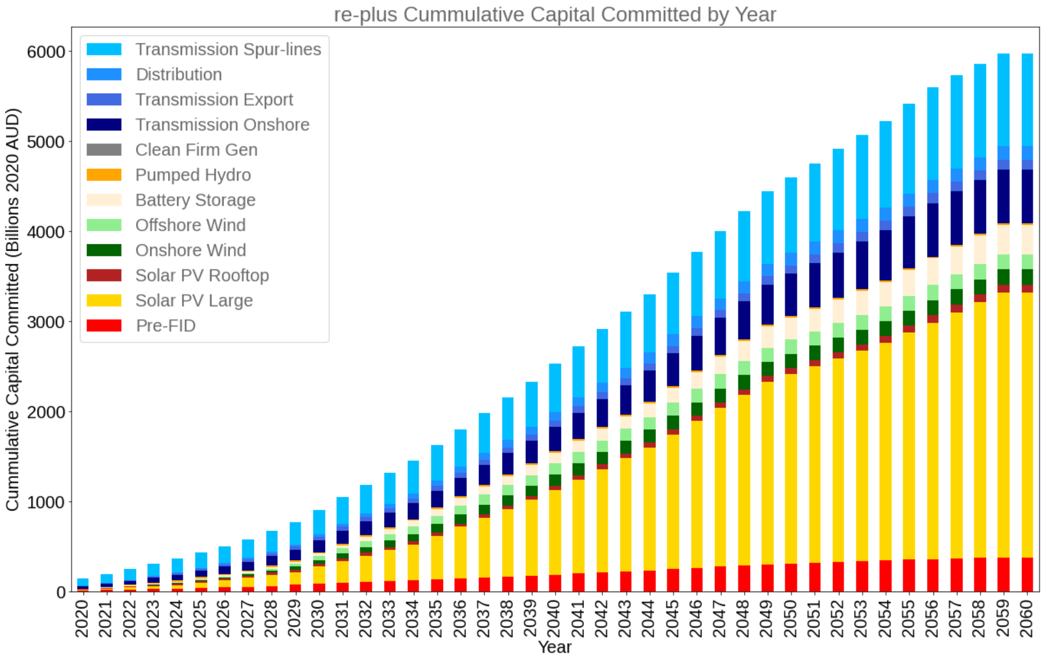
A2.3 E-Scenario



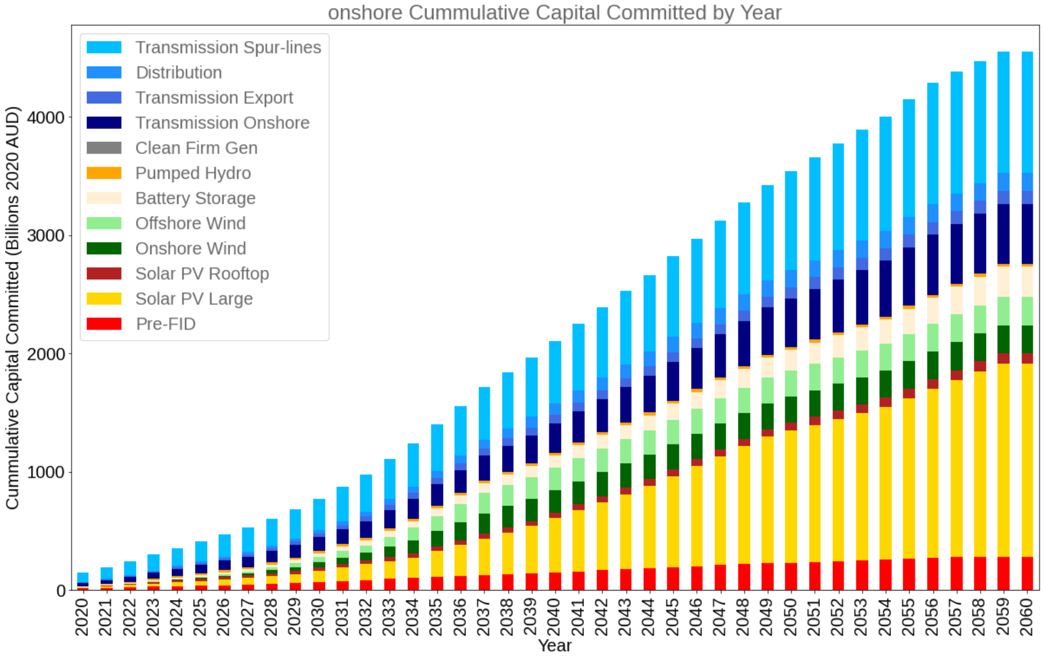
A2.4 RE- Scenario



A2.5 RE+ Scenario

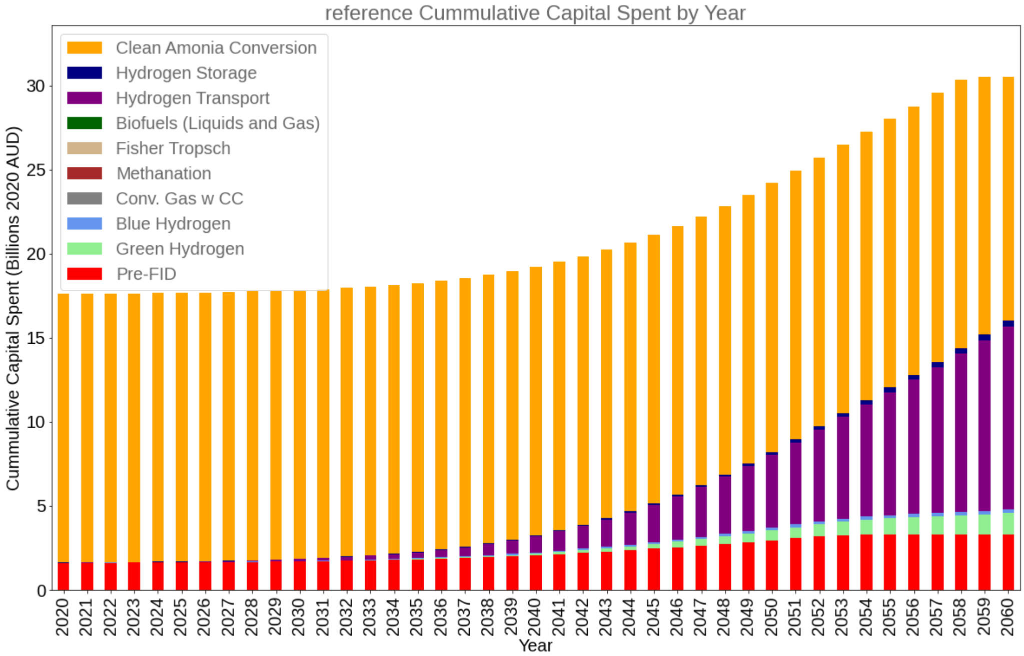


A2.6 ONS Scenario

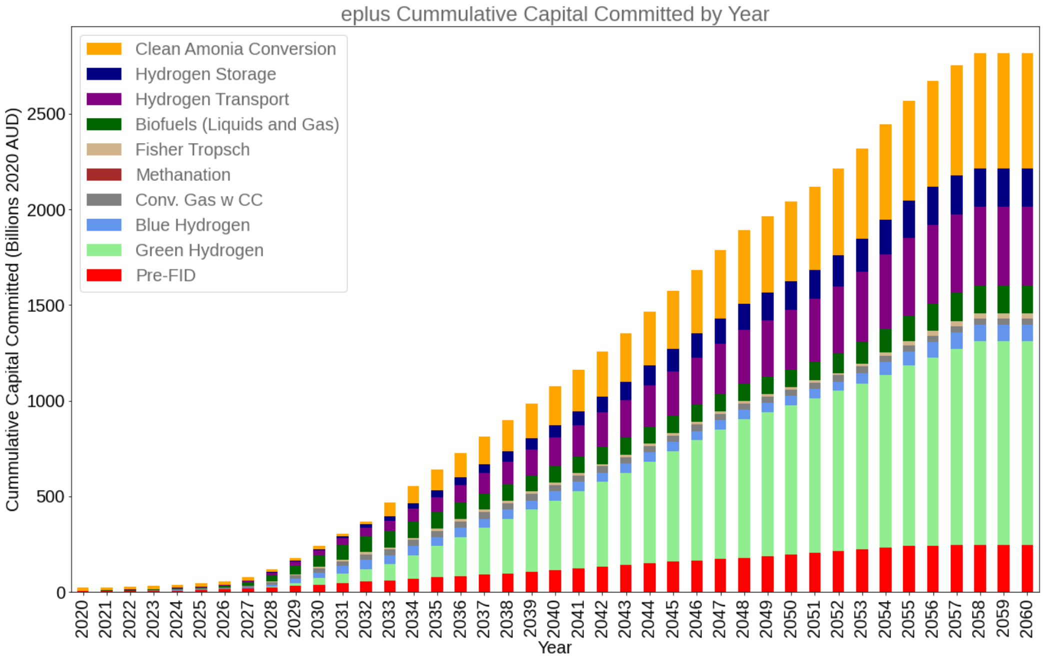


Appendix 3: Capital Committed for each Scenario for Clean Fuels Sector

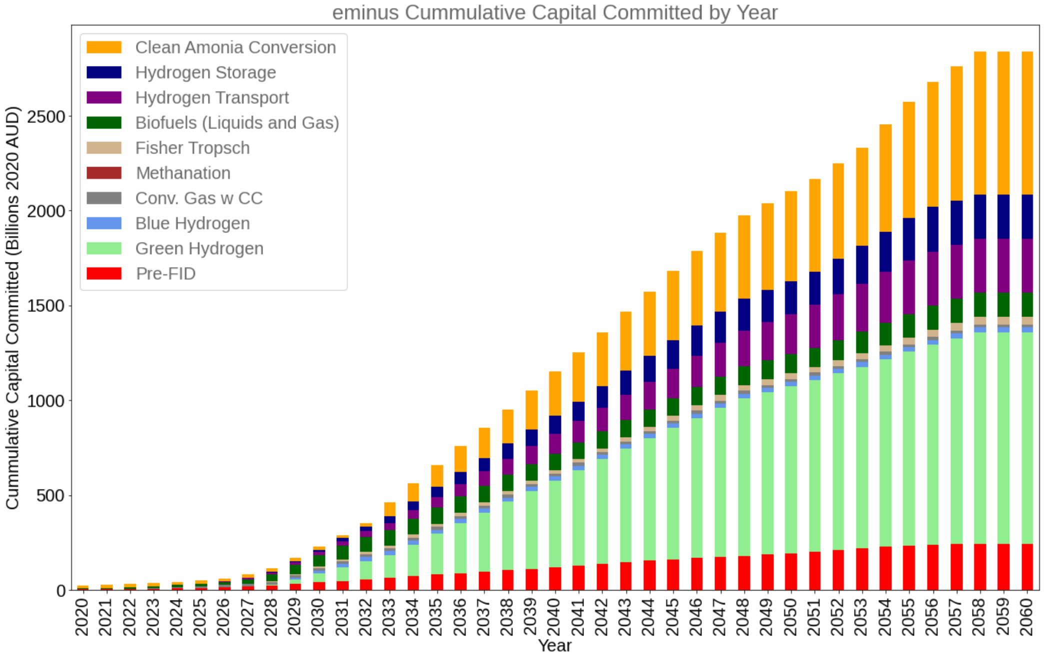
A3.1 REF Scenario



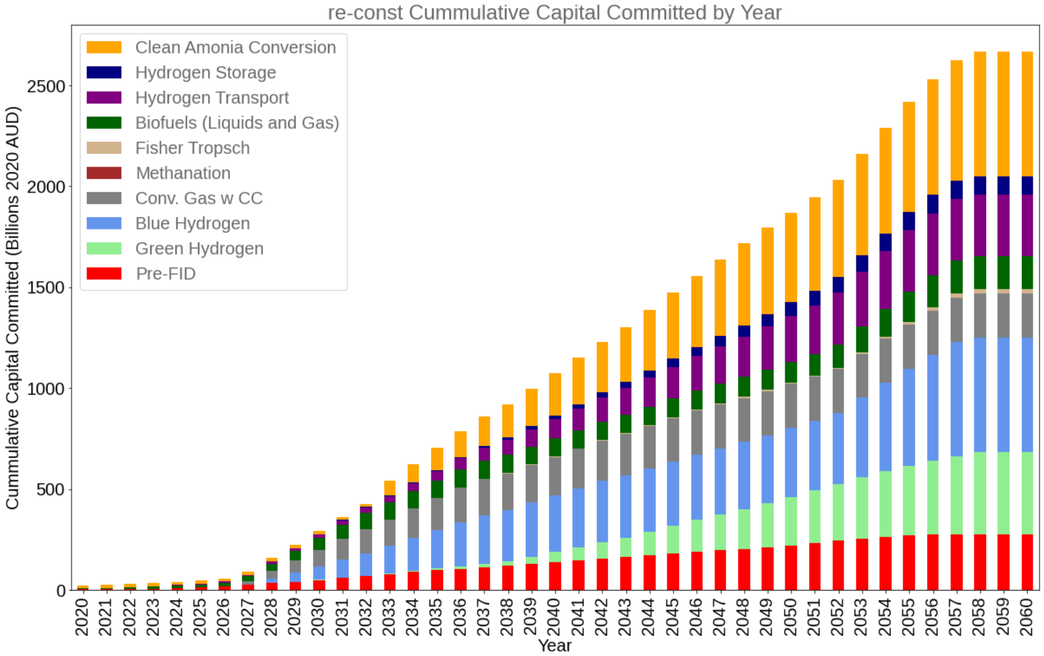
A3.2 E+ Scenario



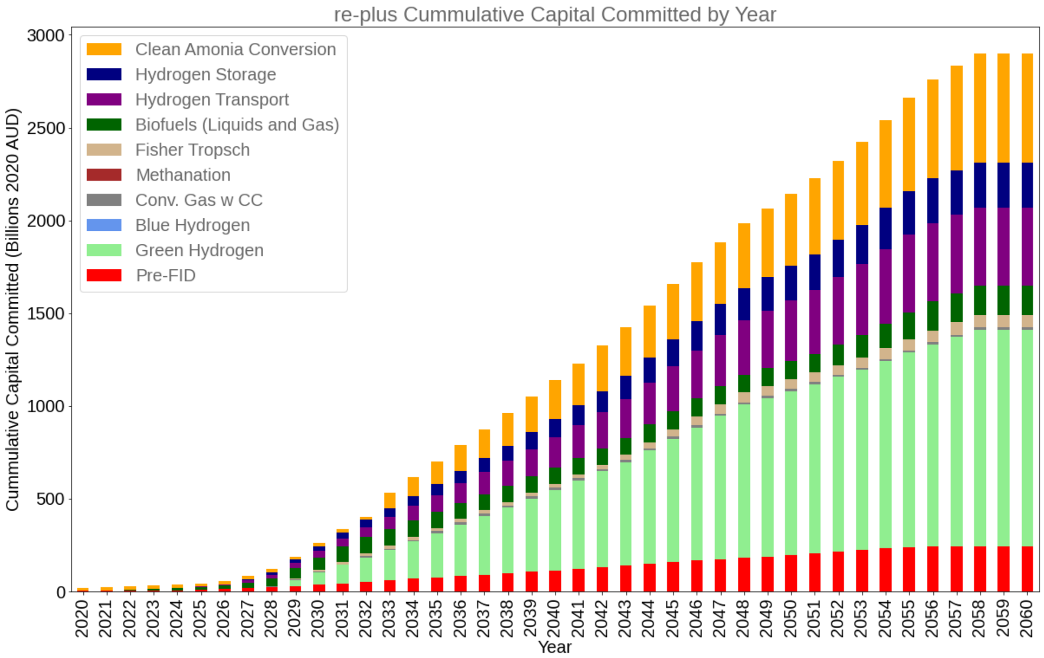
A3.3 E-Scenario



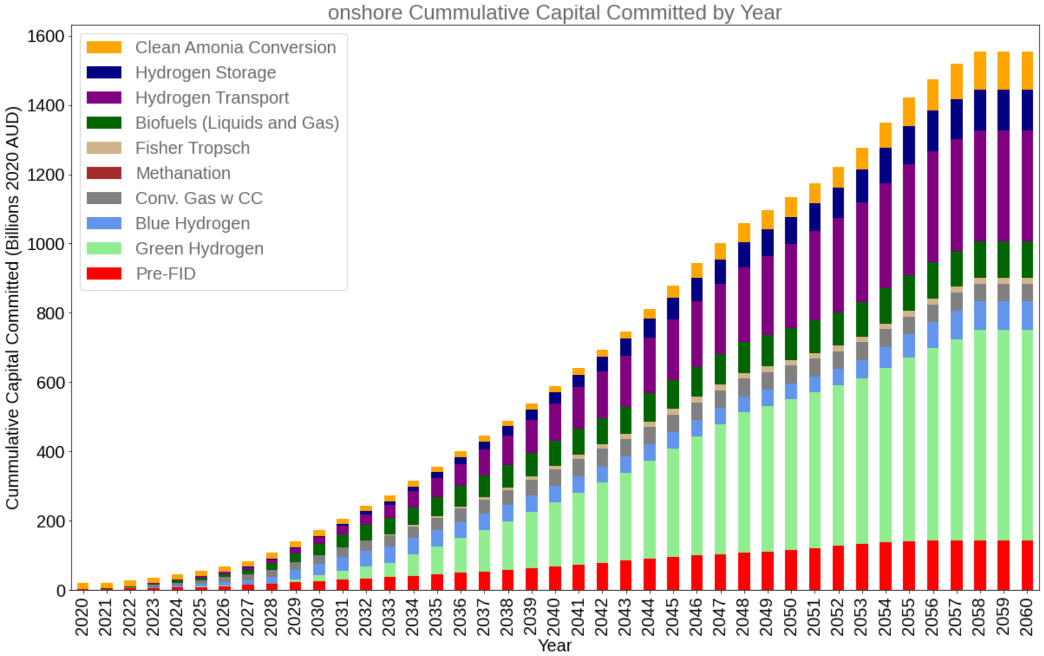
A3.4 RE- Scenario



A3.5 RE+ Scenario

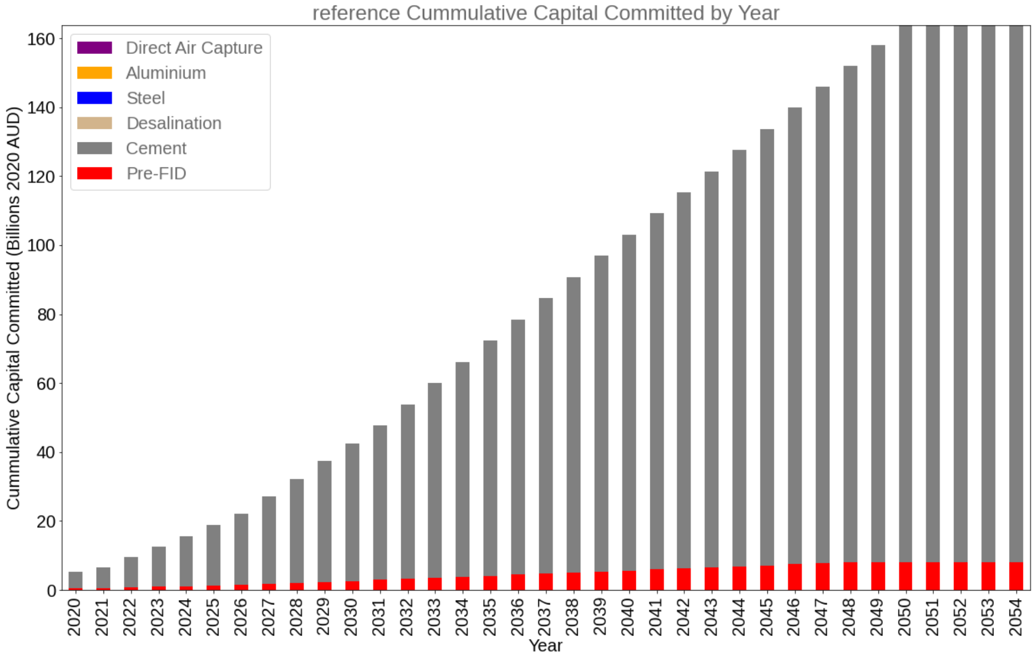


A3.6 ONS Scenario

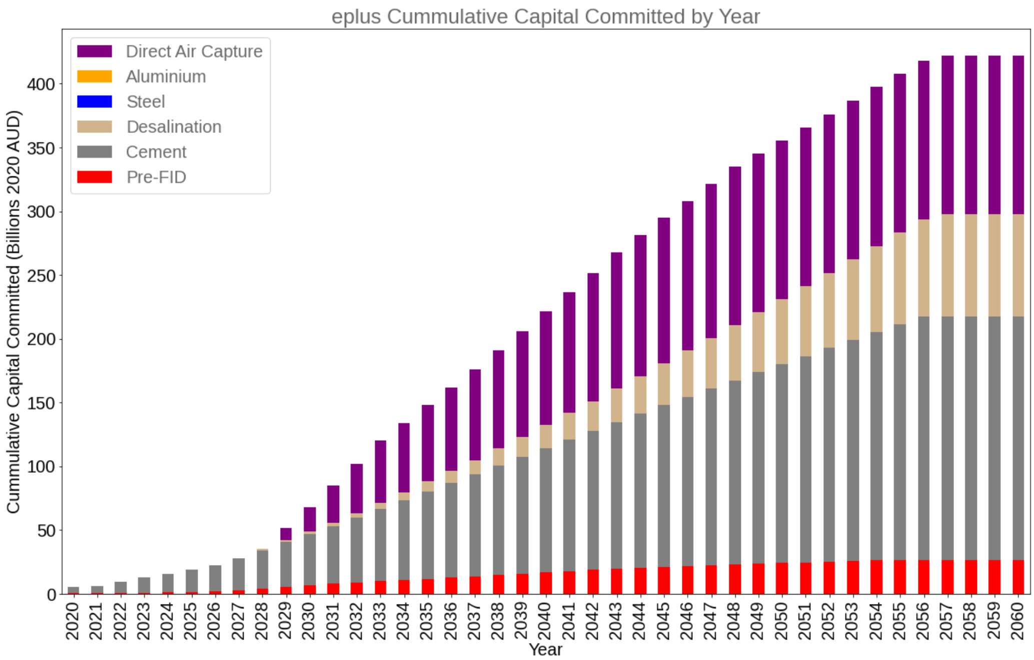


Appendix 4: Capital Committed for each Scenario for Industrial Sector (incl. DAC)

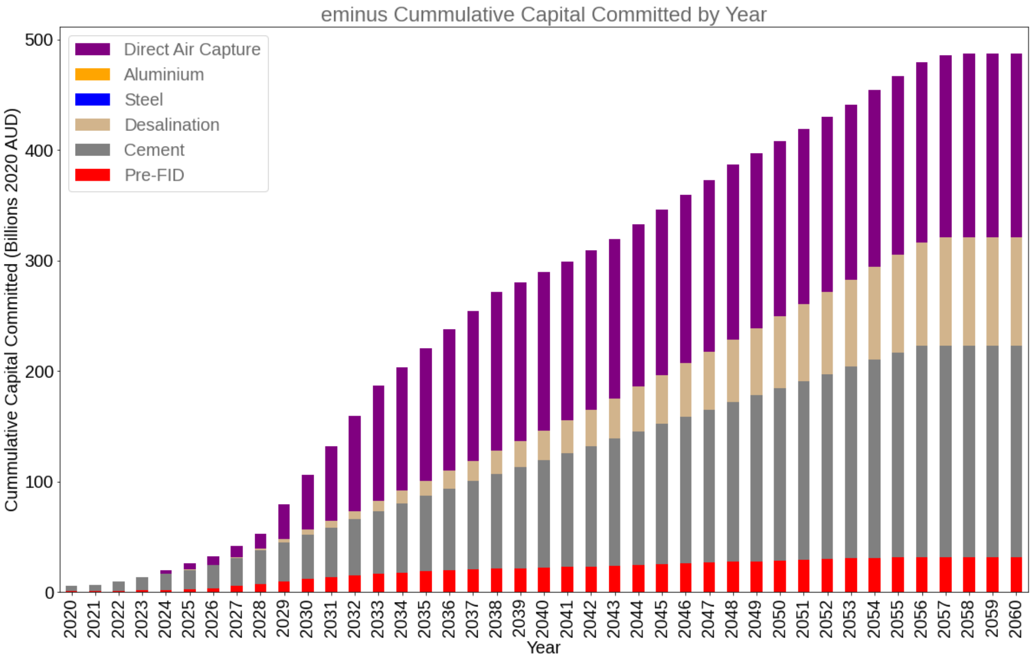
41 REF Scenario



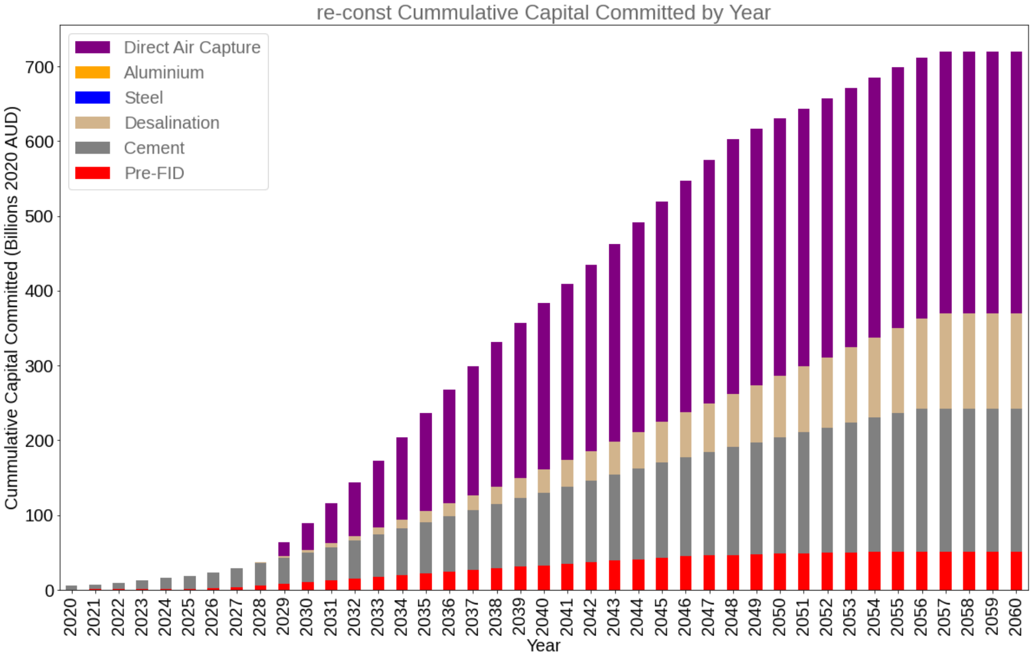
A4.2 E+ Scenario



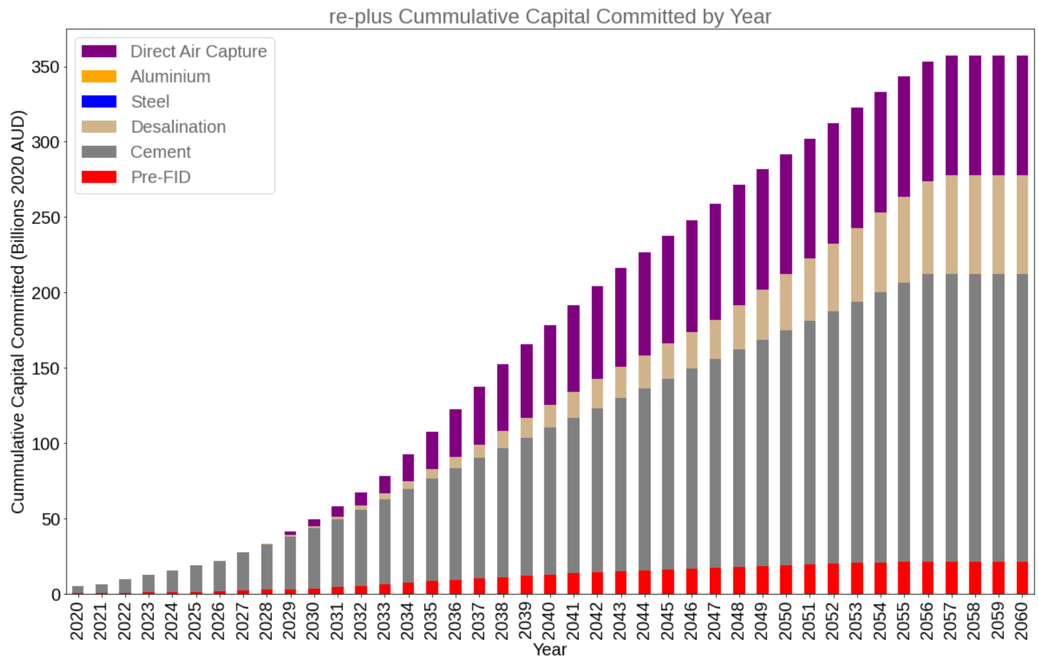
A4.3 E-Scenario



A4.4 RE- Scenario



A4.5 RE+ Scenario



A4.6 ONS Scenario