DECARBONISATION FUTURES

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DECARBONISATION FUTURES

Solutions, actions and benchmarks for a net zero emissions Australia

Overview of report findings

01 // Key findings

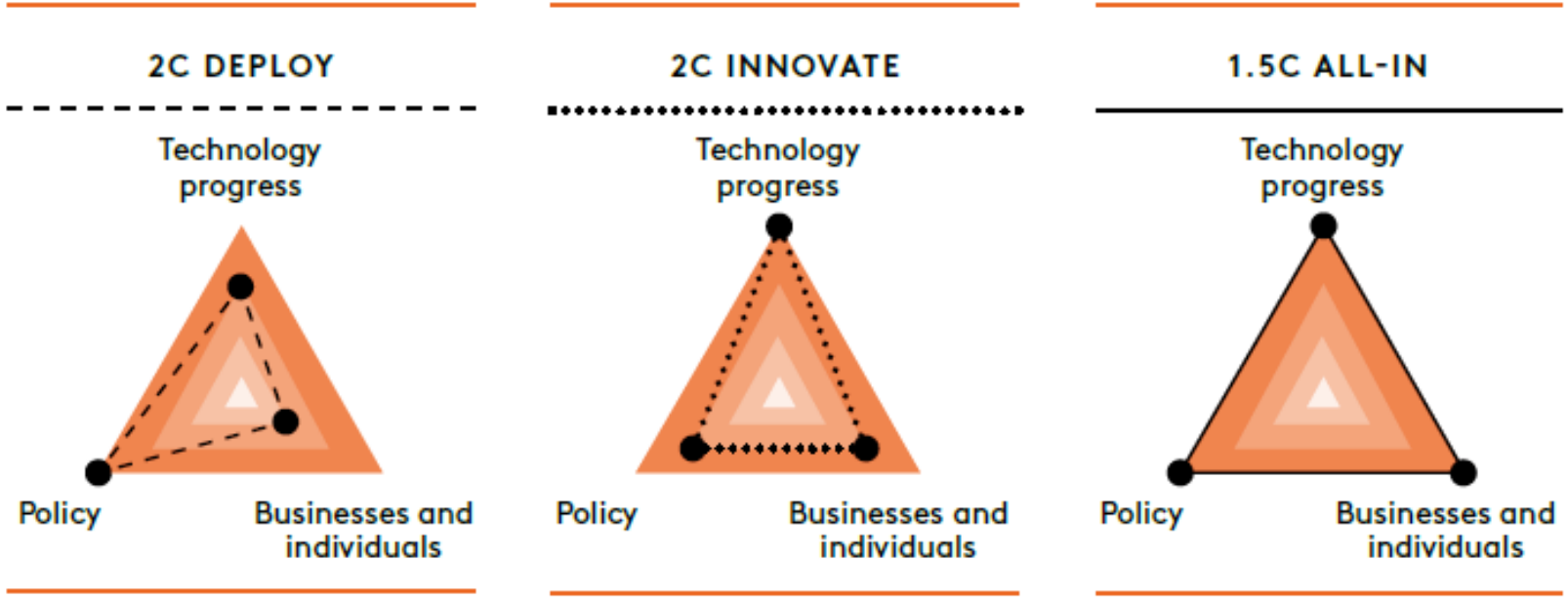
02 // Sectoral findings

03 // Our scenarios

KEY FINDINGS

Decarbonisation Futures shows how the gap between Australia's climate commitment and implementation can be bridged

+ Reviews technologies available to reduce emissions, their progress and maturity
+ Identifies actions that government, businesses and individuals can take to support them
+ Provides benchmarks for the scale of uptake of the technologies to align with the Paris goals
+ Via modelling three scenarios to illustrate possible pathways, with differing mix of levers



Net zero emissions by 2050 or earlier is fast becoming the norm in support of the Paris climate goals to limit global temperature rise to well below 2 degrees

All 8 Australian states and territories have net zero targets in place

* Aspiration

+ 121 countries, covering 25% global emissions
+ Asset owners alliance worth US$4 trillion
+ Some of Australia's largest companies

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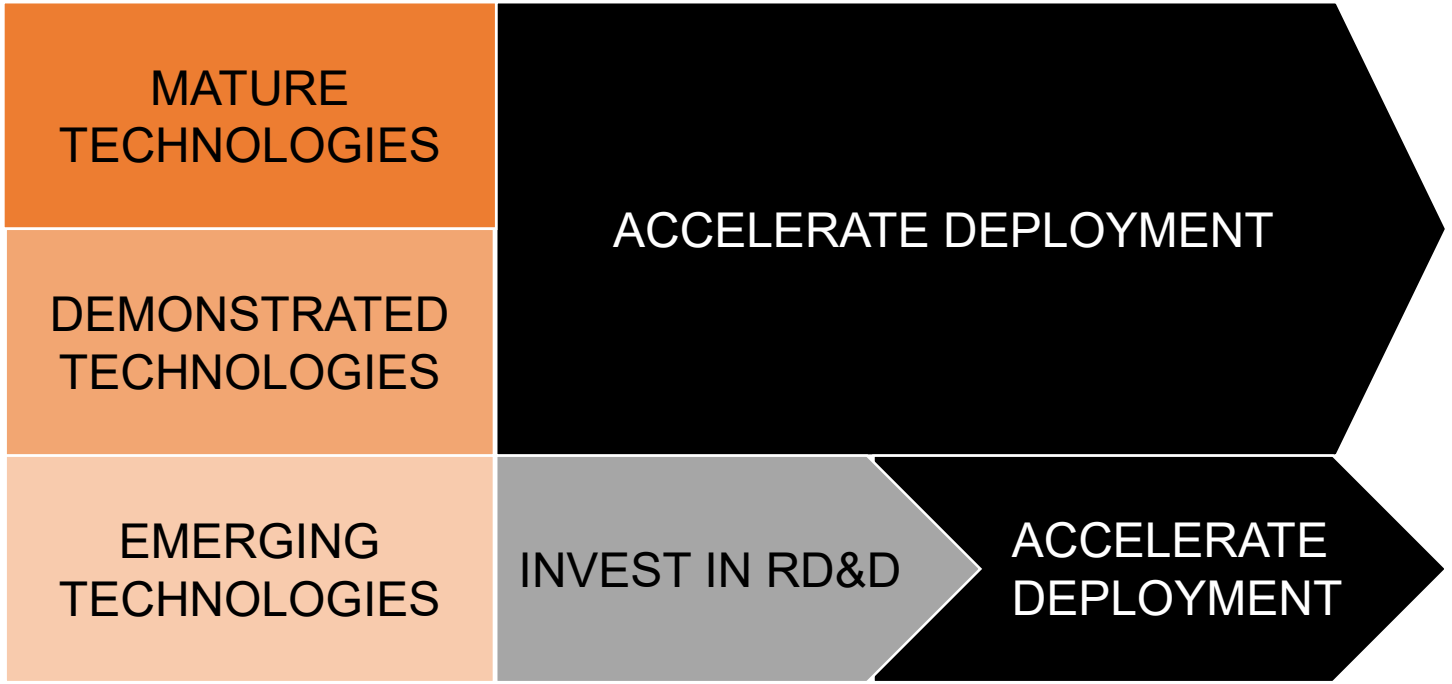
To get there, Decarbonisation Futures shows Australia must immediately accelerate deployment of mature solutions, and invest in the rapid development and commercialisation of emerging solutions in harder-to-abate sectors



Critically, these actions can support efforts to rebuild from the shock of the Covid-19 pandemic.

+ Accelerate deployment of ready solutions
+ Create jobs in sustainable industries
+ Increase Australia's resilience
+ Set up for future economic growth
+ Decrease energy costs
+ Improve health outcomes

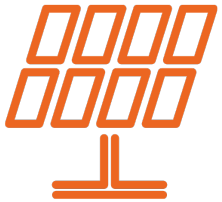
Example of readily deployable solutions include:

+ Upgrades to existing residential and commercial buildings (energy efficiency, electrification, solar PV)
+ Accelerated deployment of large scale renewables and storage
+ Construction of charging stations to support electric vehicles roll-out
+ Nature based solutions including carbon forestry (silvopasture and dedicated)
+ Circular economy – increased recycling and localised supply chains

Progress in the past five years has closed the technical gap making achieving zero emissions possible in all sectors

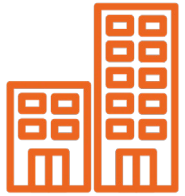
	DEMONSTRATED + MATURE SOLUTIONS	EMERGING SOLUTIONS
 ELECTRICITY	100% renewables, storage (including batteries), demand management	*There are sufficient demonstrated and mature solutions to decarbonise these sectors. However, emerging solutions could decrease costs and aid deployment at scale.*
 BUILDINGS	Deep energy efficiency, electrification	
 TRANSPORT	Electric and fuel-cell vehicles for light road transport	Biofuels, synfuels, electrification, ammonia or hydrogen for other transport
 INDUSTRY	Energy efficiency, circular economy, proven electrification, bioenergy and bio-feedstocks, industrial CCS	Material substitution, high grade heat electrification, solar thermal, hydrogen
 AGRICULTURE + LAND	Sustainable agriculture practices, plant-based substitutes, fertiliser management, carbon forestry	Lab food, enteric fermentation treatments (such as livestock vaccines)

We have found that technology has achieved significant progress since 2014, often faster than was expected then



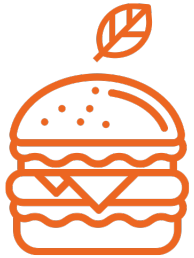
New renewables now **cheaper** than new fossil fuel generation

Battery costs per kilowatt-hour **80% cheaper** than in 2010



10-storey office tower built in timber in Brisbane

3 million EVs driven in the world

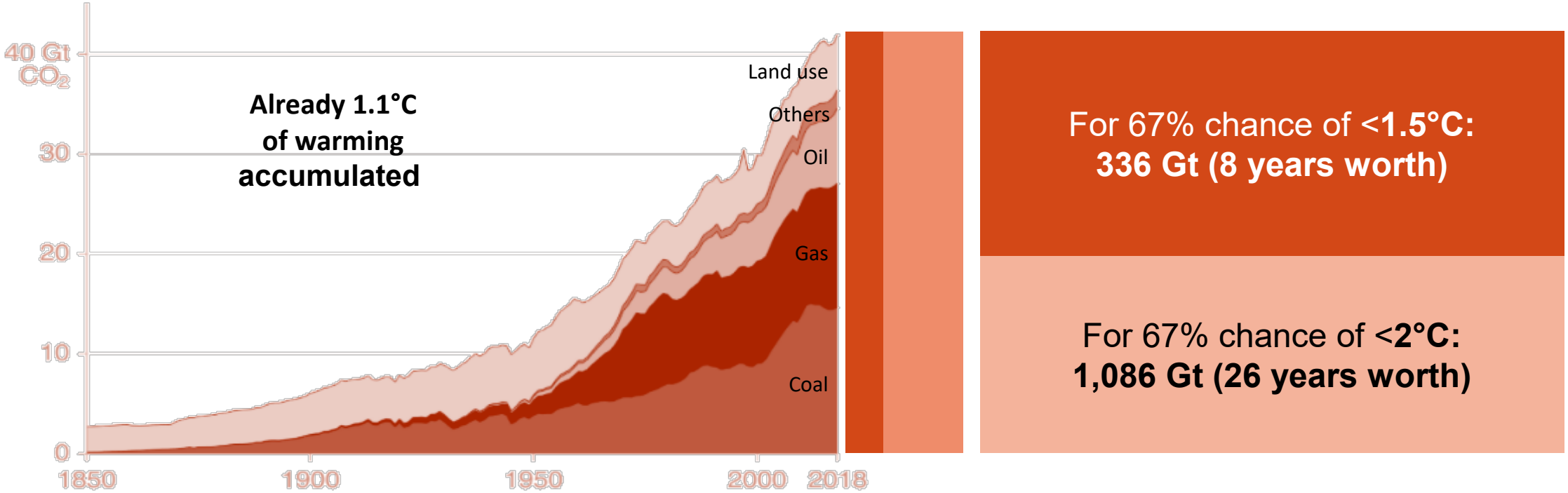


The **share price** of Beyond Meat grew more than 700% in the 3 months following its release

1- and 2-person **electric planes** are beginning to enter the market

Australia and the world have limited time to stay within the Paris Climate Agreement goals, but we are now well placed to leapfrog to zero emissions technologies in all sectors

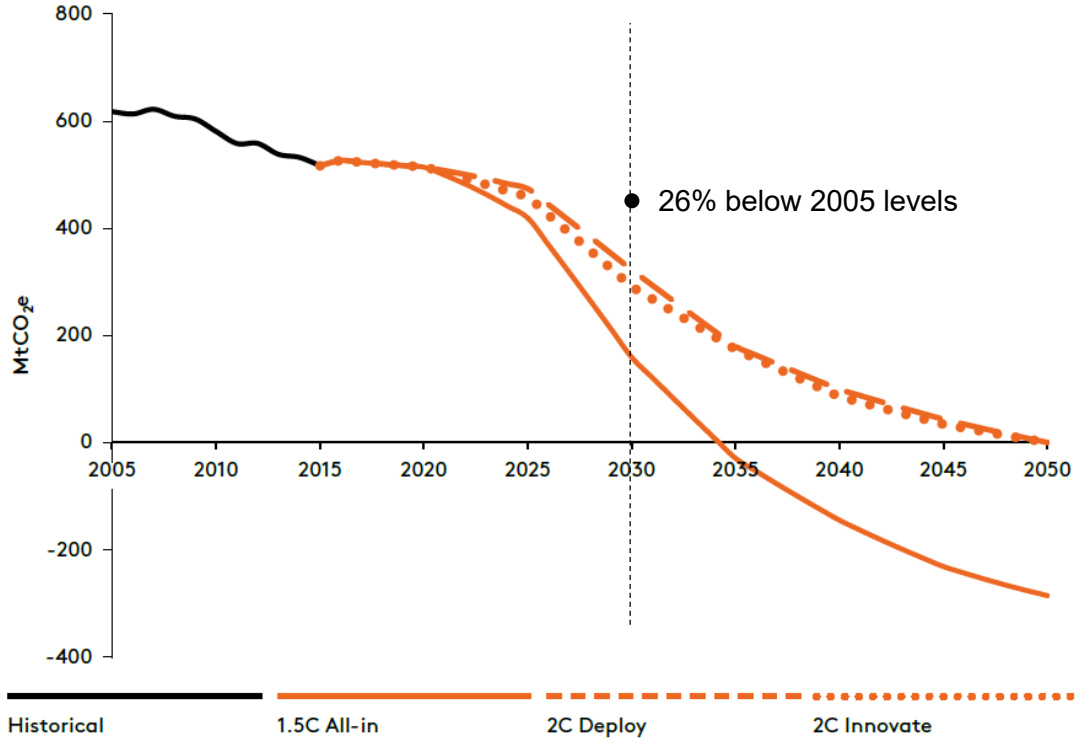
Global total CO_2 emissions and remaining carbon budget at 01/01/2020



SOURCE: IPCC, Global Warming of 1.5°C; Global Carbon Project (http://folk.uio.no/roberan/img/GCB2019/PNG/s85_2019_Total_Emissions_by_source.png)

Our scenario analysis shows that increased support to technology deployment and development can support a trajectory compatible with the global 2°C climate goal

Australia's total emissions by scenario, MtCO2e



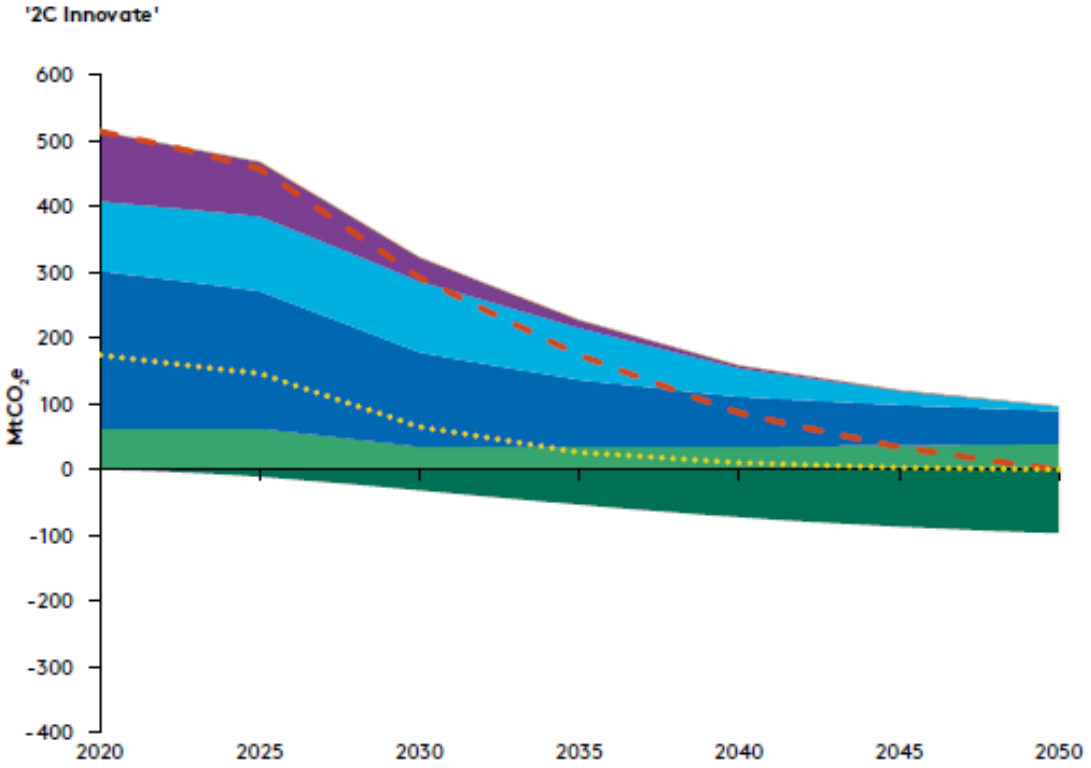
2030 EMISSIONS VS 2005

Historical	
2C Deploy	-48%
2C Innovate	-54%
1.5C All-in	-74%

Note: All three scenarios assume typical economic conditions and so do not include possible structural changes to the Australian economy

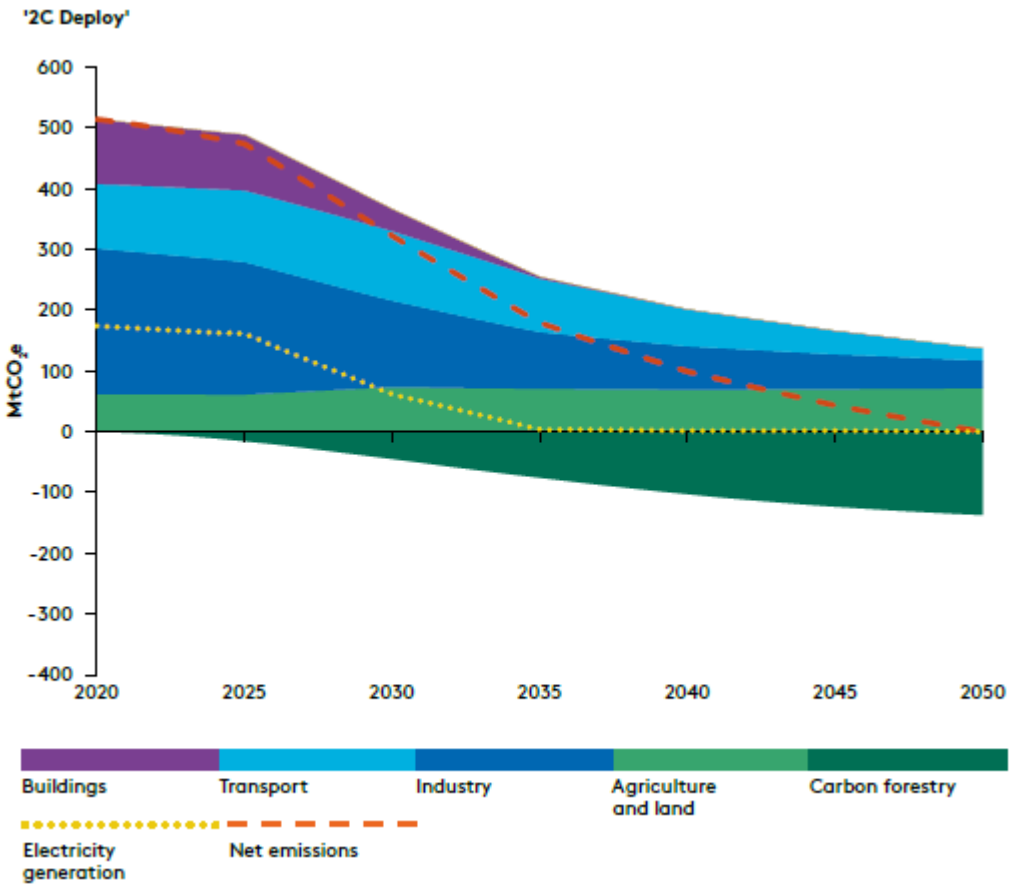
All sectors can achieve very significant emissions reduction; the pace of reduction is aligned with technology maturity

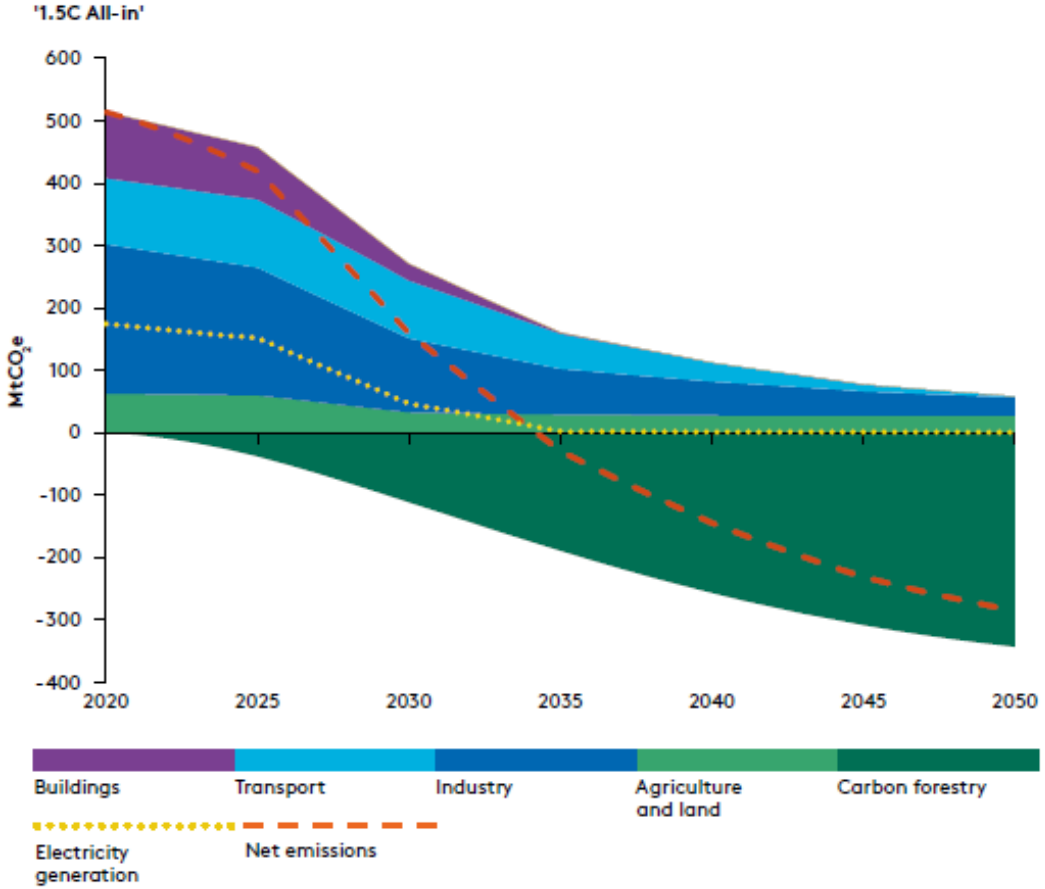
Sector emissions, MtCO2e, ‘2C Innovate Scenario’



	EMISSIONS REDUCTIONS 2030 vs 2005	2050 vs 2005
Electricity	-65%	-100%
Buildings	-67%	-100%
Transport	+1%	-93%
Industry	-41%	-79%
Land	-44%	-37%
Carbon forestry		
Net emissions		

Across all scenarios, residual emissions in 2050 are 2-4 times lower than in our 2014 decarbonisation pathways





Some key similarities and differences exist between scenarios

Similarities

+ Electricity moves to 100% renewables by 2050 and helps decarbonise other sectors
+ Much lower residual emissions than for 2014 scenario
+ Electricity, buildings and transport get to zero or near zero emissions
+ Industry and Agriculture have significant residual emissions

Differences

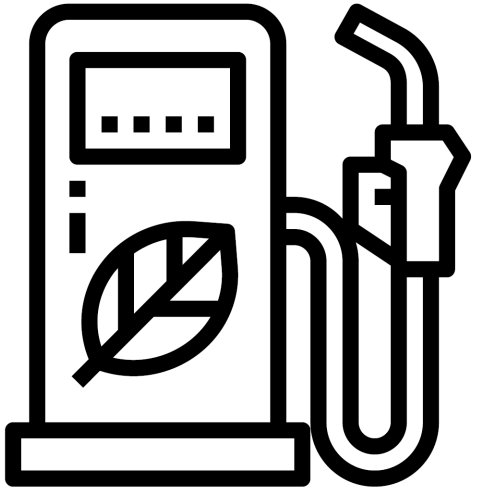
+ Net zero achieved by 2035 for ‘1.5C All-in’
+ Amount of residual emissions in 2050 (lowest for ‘1.5C All-in’)
+ Level of carbon forestry (balancing residual emissions, dependent on carbon budget)
+ Rate of retirement of coal-powered electricity generation, slowest in ‘2C Innovate’
+ Uptake in industrial CCS, dependent on policy
+ Agriculture emissions reductions, dependent on success of enteric fermentation treatments
+ Shift to lower emissions construction materials (highest in ‘1.5C All-in’)

Widespread, rapid deployment of mature technologies can achieve much of what is needed this decade and can accelerate immediately

2030 scenario results

	2°C	1.5°C	Government projections
EVs in new car sales	1 in 2	~3 in 4	~1 in 5
% renewables in electricity generation	70-74%	79%	~48%

While substantial investment in research, development and commercialisation can close the gap to zero emissions across sectors.

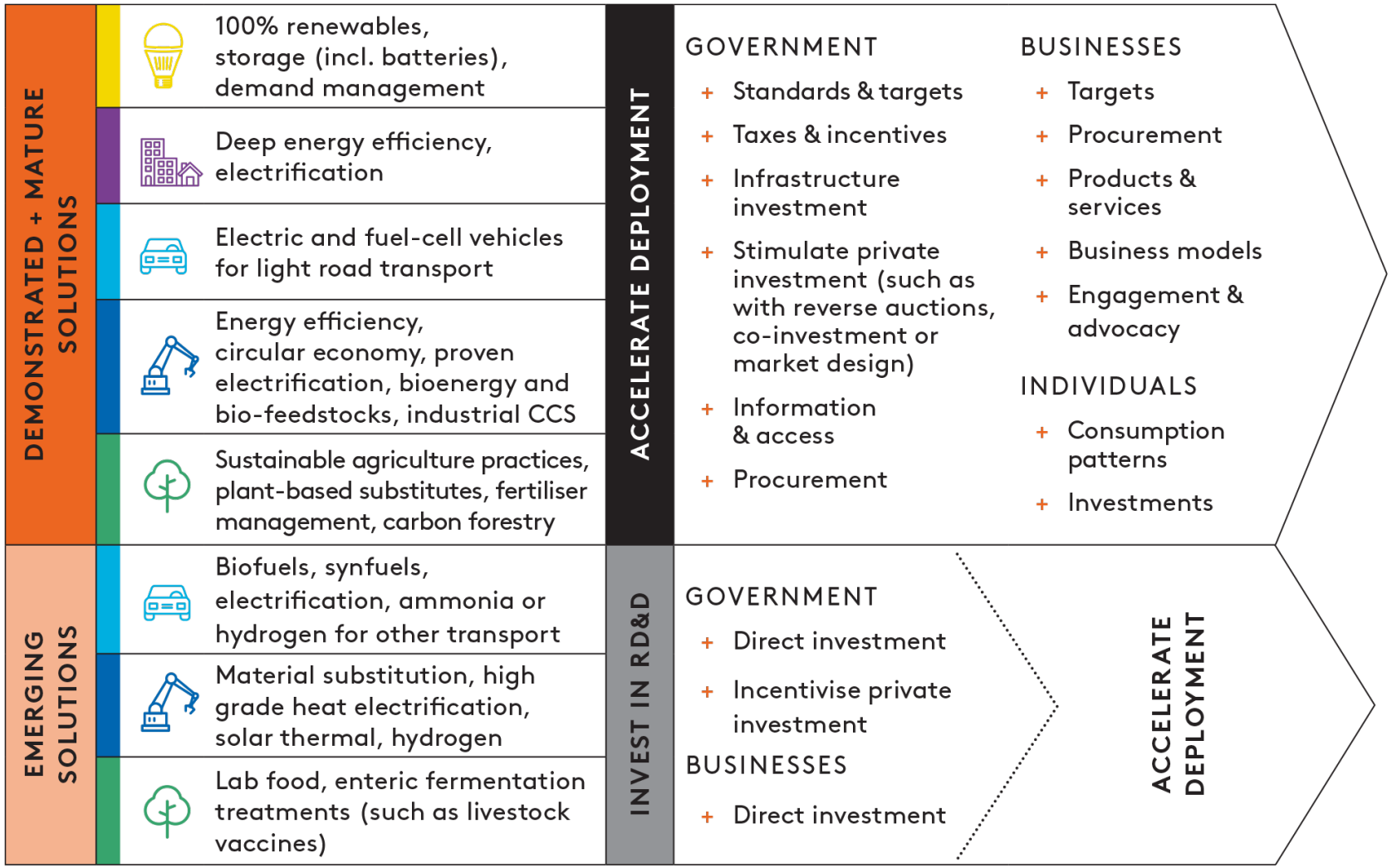


The transition will not happen in time without strong action by government, business and individuals to support technology development, demonstration and deployment

SOLUTION STATUS		ACTIONS		
		GOVERNMENT	BUSINESSES	INDIVIDUALS
MATURE	Accelerate deployment	• Standards and targets • Taxes • Financial support and/or market structure amendments • Supporting infrastructure • Information and accessibility	• Targets on scope 1-3 • Forward asset replacement • Shift products and services • New business models • Policy advocacy • Investors engagement	• Shift in consumption • Shift in behaviour • Home upgrades • Shift in investments • Advocacy
DEMONSTRATION	Accelerate deployment	• Incentives • Procurement • Supporting infrastructure • Stimulate private investment	• Pay price premium • Targeted procurement • Accept higher risk	• Pay price premium • Community investment
EMERGING	Invest in RD&D	• Investment in RD&D • Incentives for private investment	• Investment in RD&D • Consortium for risk sharing	

This is the transformational decade

Research shows that the years before 2030 offer a window for action that will not stay open.

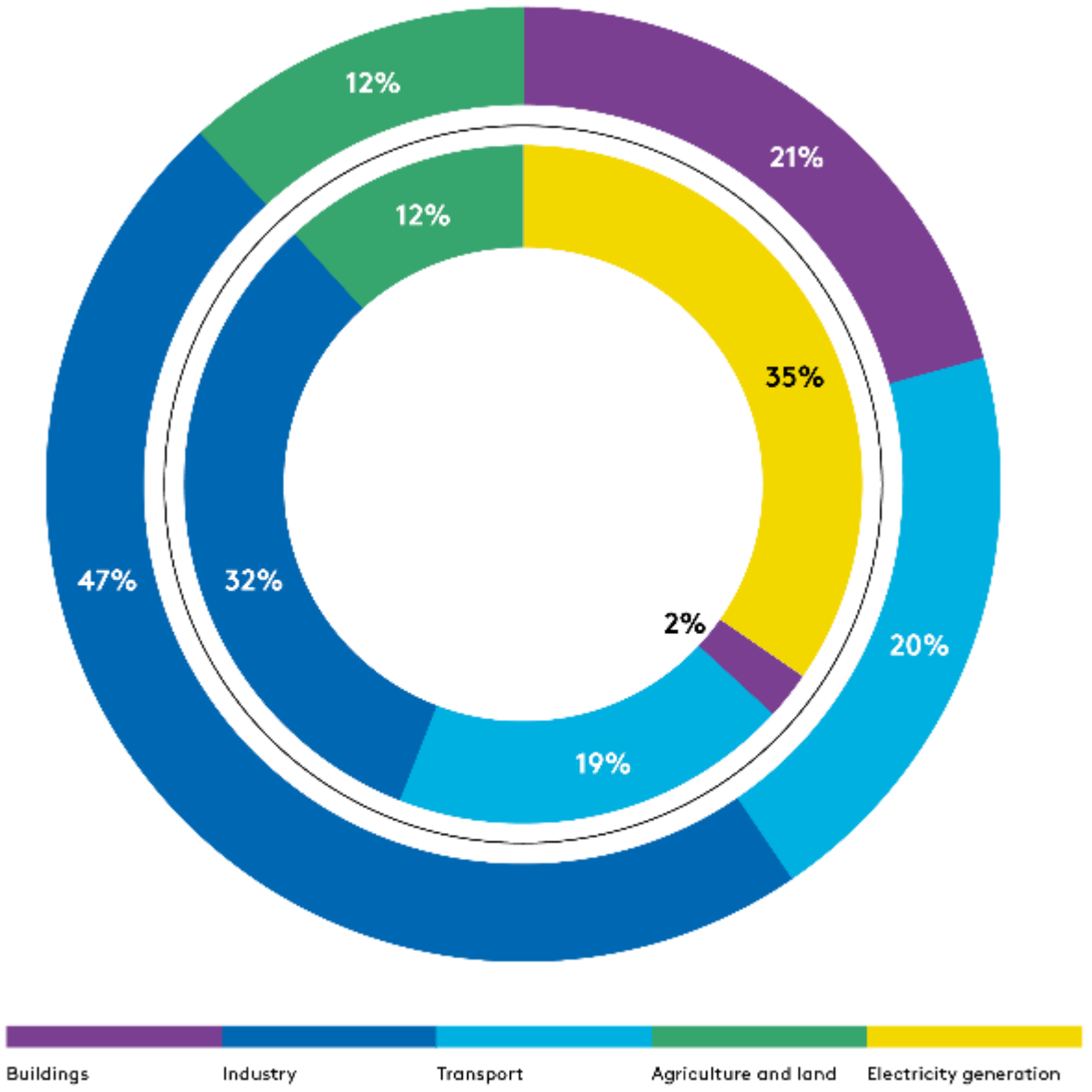


SECTORAL FINDINGS

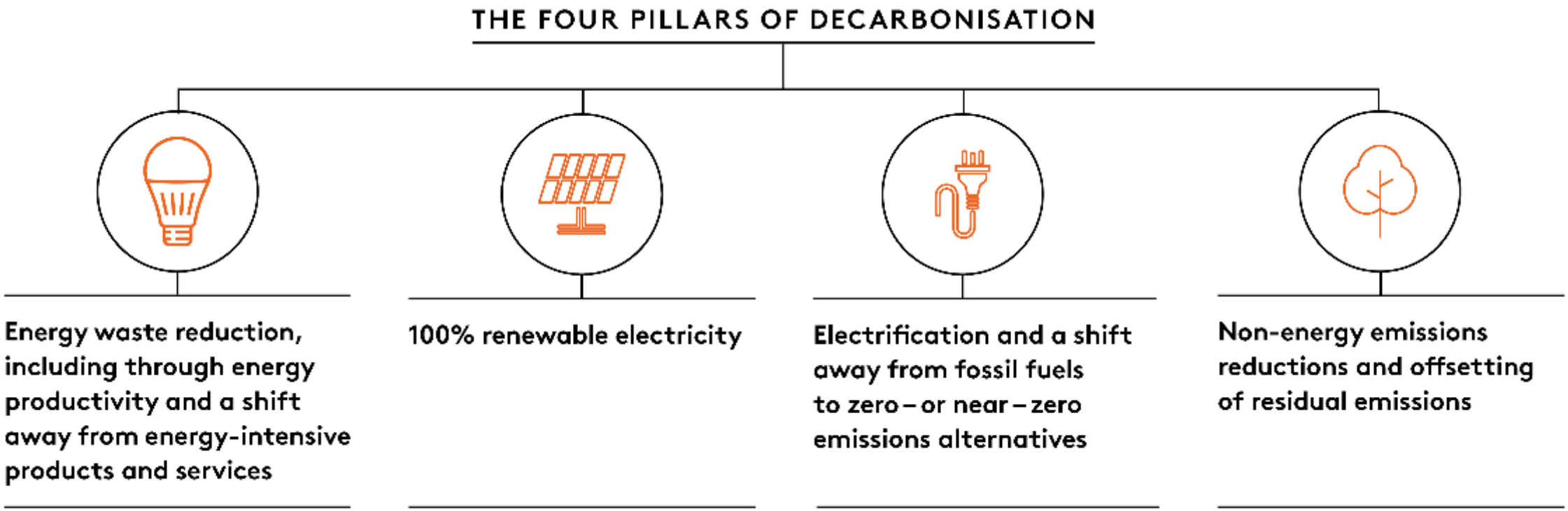
Australia's emissions are produced primarily by the electricity generation, industry and transport sectors

Australia's overall emissions by sector (2018).

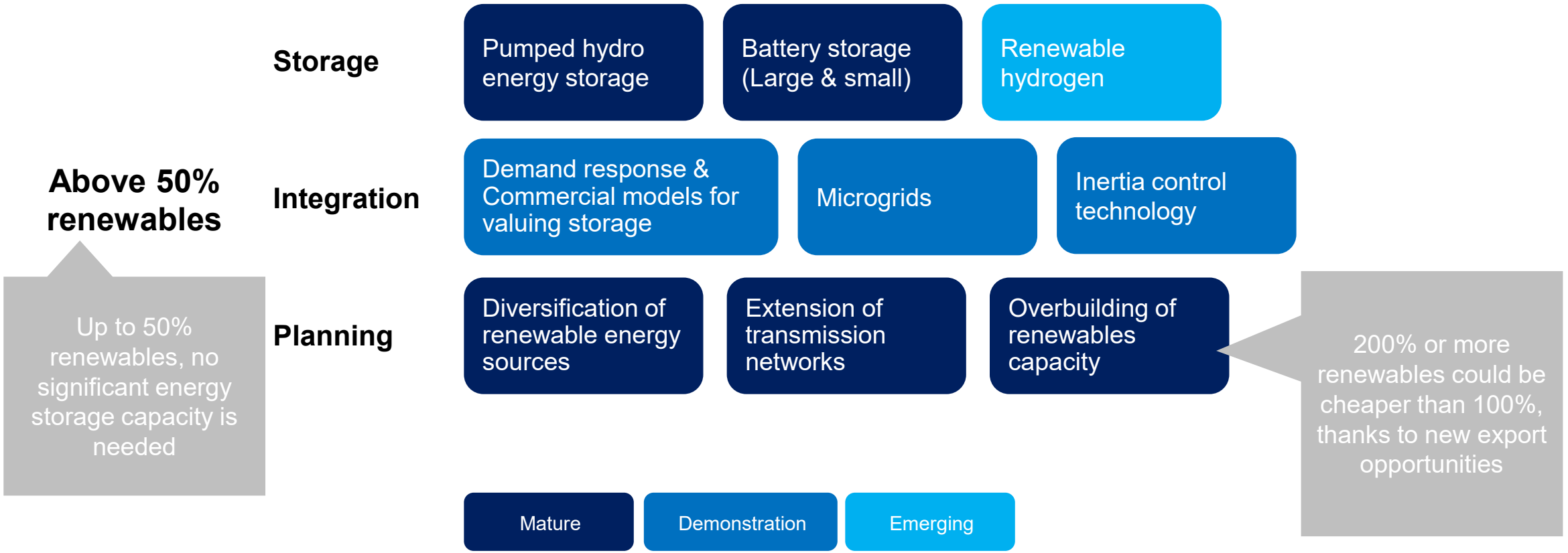
Inside circle: excluding end use electricity, outside circle: including end use electricity



The achievement of net zero emissions relies on a shift from fossil fuel based energy to renewable energy across all sectors of the economy

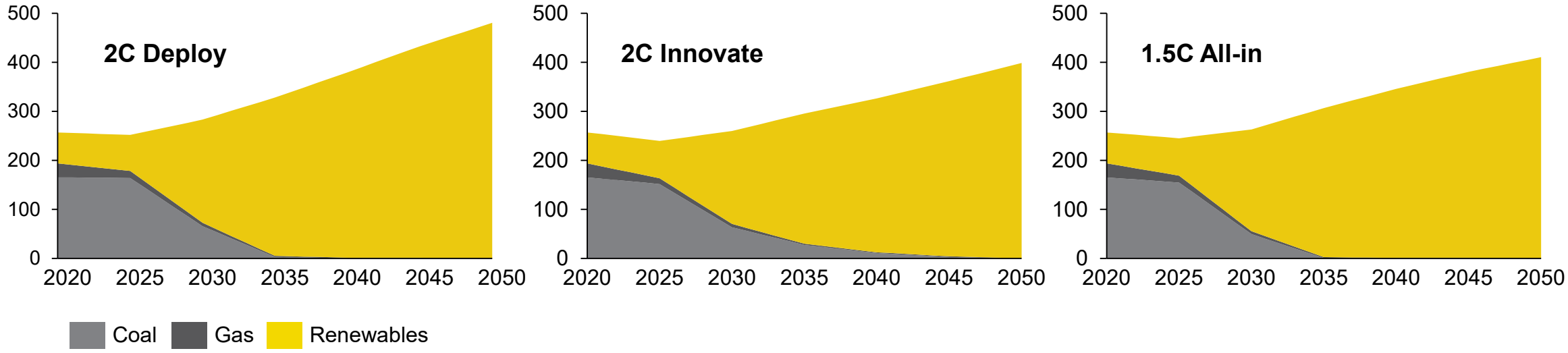


Electricity: Technologies already exist which can support moving to 100% renewables



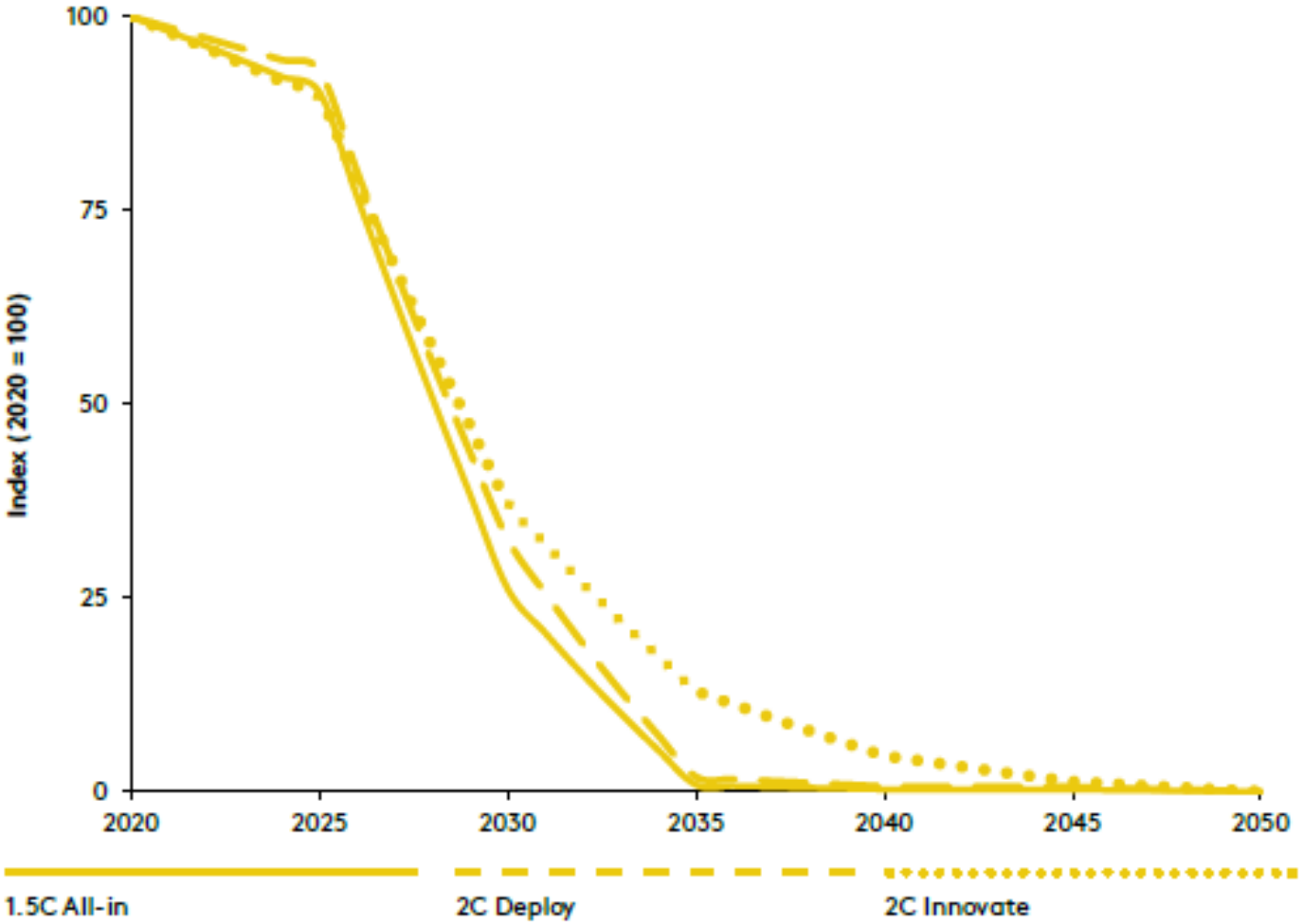
Electricity: All scenarios reach about 75% renewable electricity generation by 2030, and 100% by 2050. The key factor influencing the speed of the transition to renewable electricity is the rate at which coal generation (and then gas) exits the system.

Electricity generation by fuel type, TWh



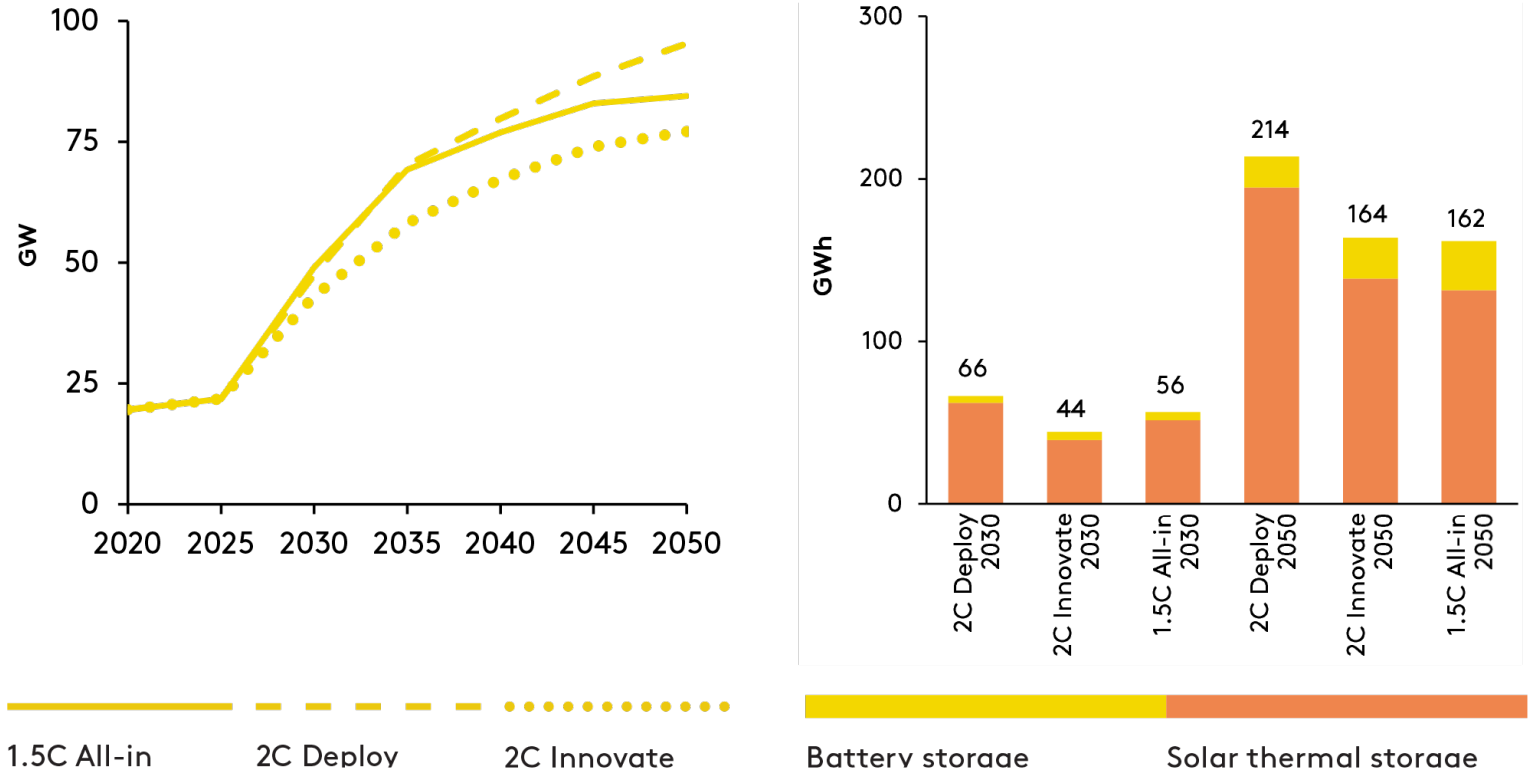
Electricity: In the two scenarios with strong policy action, electricity reaches near zero emissions by 2035

Electricity emissions intensity in the modelled scenarios (2020-2050)



Electricity: Strong increases in storage capacity (battery, solar thermal and hydro) support the high volumes of renewables

Cumulative renewable electricity build, 2020-2050 (left), Storage capacity by type (right) in the modelled scenarios, 2030 & 2050



Electricity: CSIRO models the both the east- and west-coast electricity grids at a high degree of granularity

- Includes: NEM (16 transmission zones), NWIS, SWIS, DKIS
- For each zone: existing generation capacity, maximum renewable resources and renewable generation profile, access to CCS sites (when available)
- Unit-level data for existing thermal and hydro generation fleet
- Supply aggregated to meet a pool of demand for each state
- NEM trade through 6 interconnectors links between: NSW & QLD; NSW & VIC; VIC & SA; VIC & TAS
- 16 time slices per year: seasonal, time of day

Many recent analyses have found that Australia's electricity system can be supported by 100%+ renewables

The Energy Transition Hub recently published a comprehensive analysis of possible futures for Australia's electricity system. They used 4 numerical energy-economic models from 5 partner institutes. They modelled 6 scenarios. They did an analysis of each hour of the Australian power system in 2050 for 2 scenarios.

They found that:

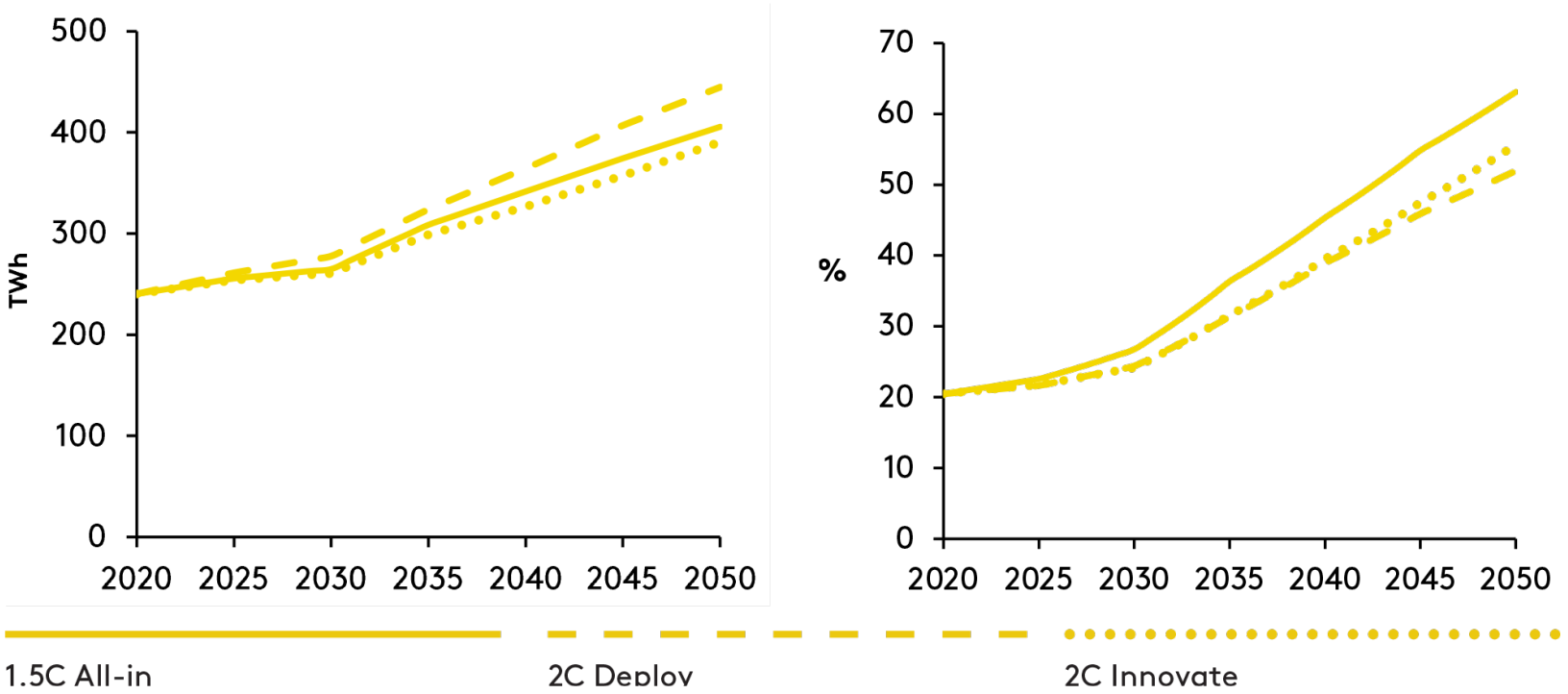
+ Costs in a renewable-based system are similar or lower than today.
+ Multiple options secure reliable supply from 100 percent renewables.
+ Going beyond 200 percent renewables by producing more hydrogen further decreases the average system cost element

Recent work:

+ Energy Transition Hub , Australia's power advantage - Energy transition and hydrogen export scenarios' https://www.energy-transition-hub.org/files/resource/attachment/australia_power_advantage_0.pdf
+ Pumped hydro storage and 100% renewable electricity. Andrew Blakers, Bin Lu, Matt Stocks Australian National University https://arena.gov.au/assets/2017/08/AndrewBlakers_Presentation.pdf
+ Electricity Network Transformation Roadmap, CSIRO and ENA https://www.energynetworks.com.au/projects/electricity-network-transformation-roadmap/

Electricity: Increased reliance on electricity across other sectors forms a major component of Australia's transition towards net zero emissions

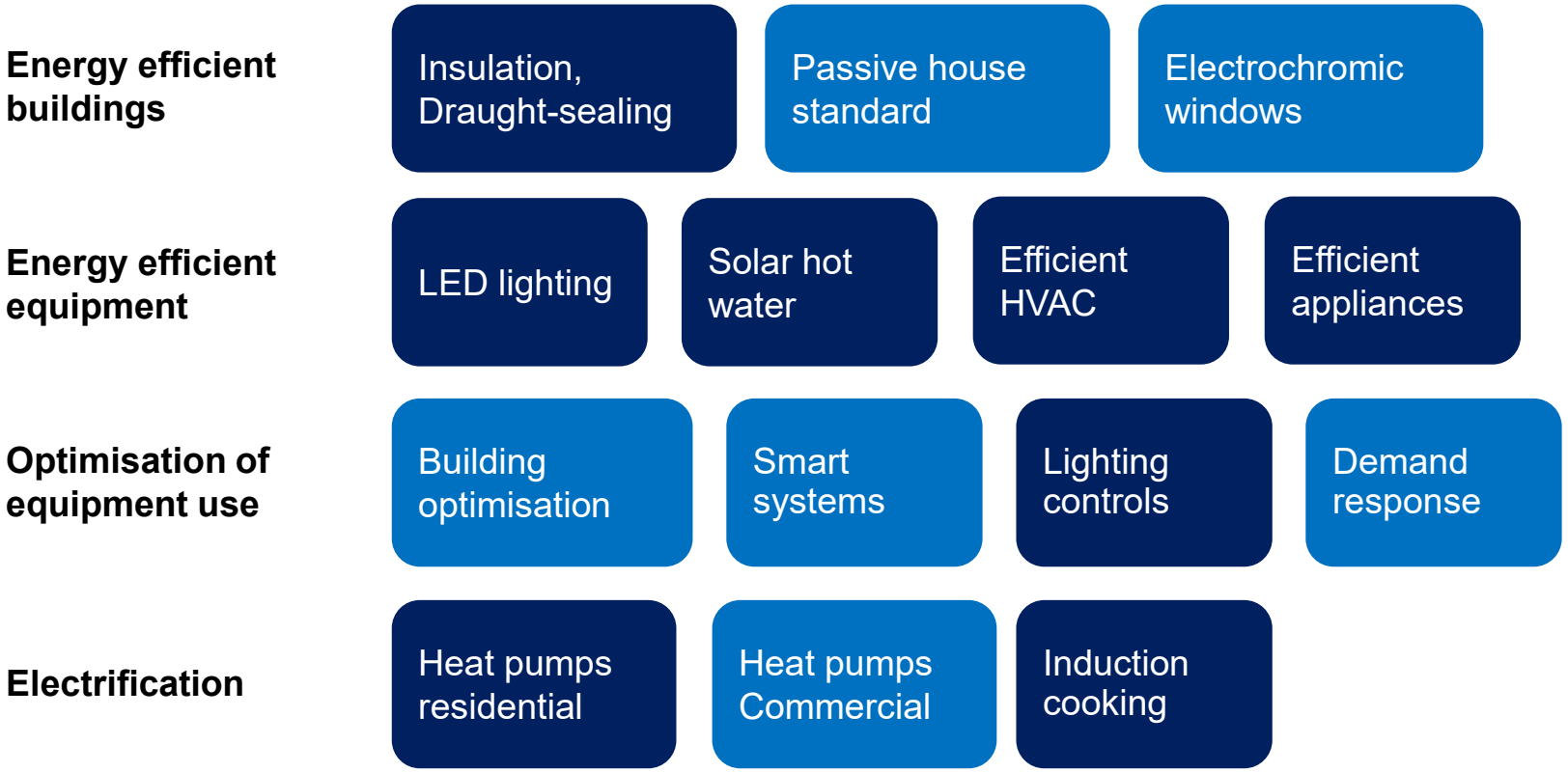
Overall electricity demand (left) and as a proportion of final energy use (right) in the modelled scenarios (2020-2050)



Benchmarks of progress towards net zero emissions by 2050

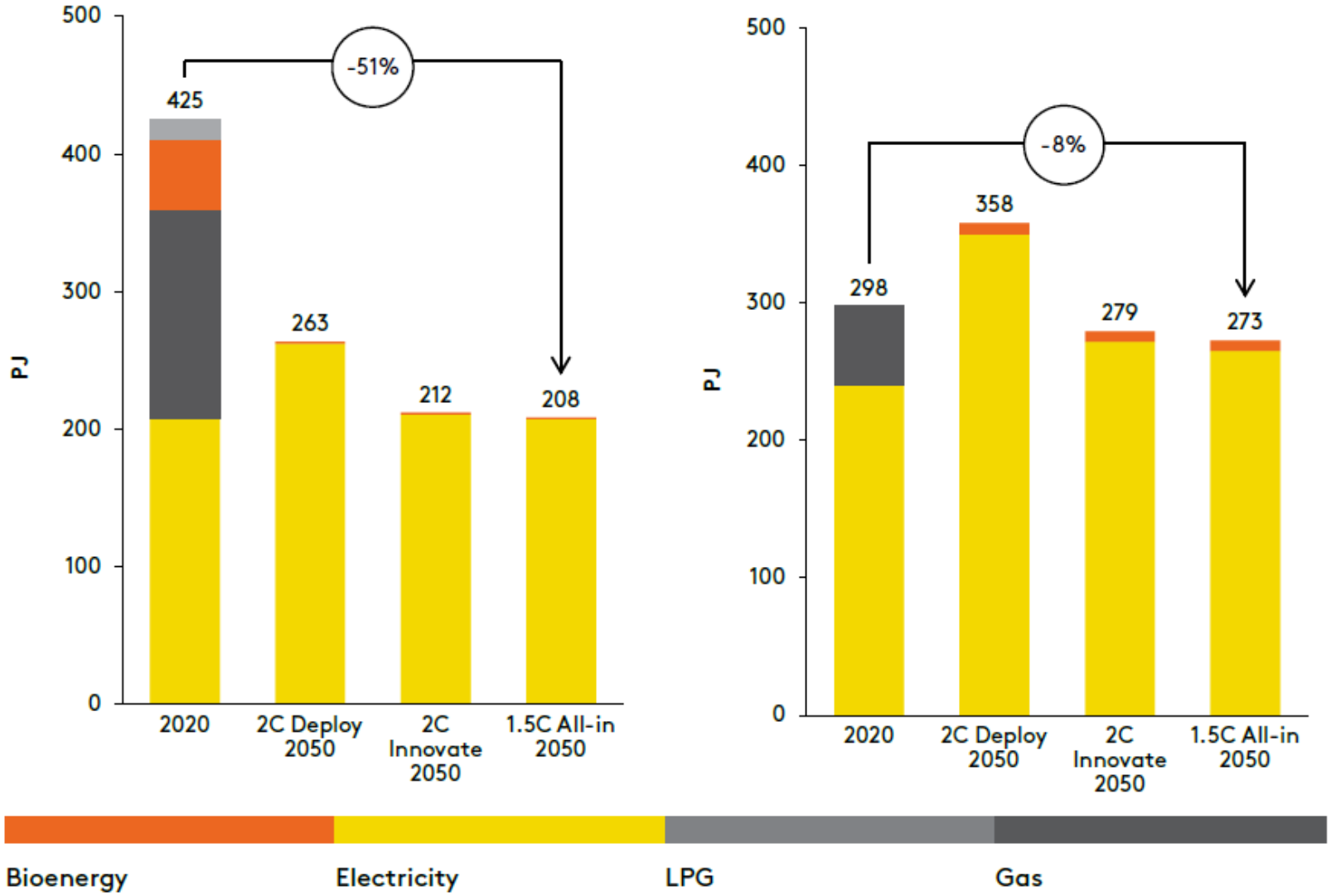
BENCHMARK	2C PATHWAYS		1.5C PATHWAY	
	2030	CHANGE versus 2020	2030	CHANGE versus 2020
TECHNOLOGY BENCHMARKS				
Share of renewable electricity generation	70-74%	2020 = 25%	79%	2020 = 25%
Additional renewable capacity between 2020 and 2030		24-28 GW added		29 GW added
Additional storage capacity between 2020 and 2030		44-66 GWh added		56 GWh added
ENERGY BENCHMARKS				
Share of electricity in total energy	24%	2020 = 20%	27%	2020 = 20%
EMISSIONS BENCHMARKS				
Annual emissions	62-65 $MtCO_2e$	63-64% decrease	46 $MtCO_2e$	73% decrease
Emissions intensity	220-252 tCO_2e/GWh	63-67% decrease	177 tCO_2e/GWh	74% decrease

Buildings: The technology required for a zero-emissions building sector – deep energy efficiency and electrification powered by renewables – is already available to be deployed



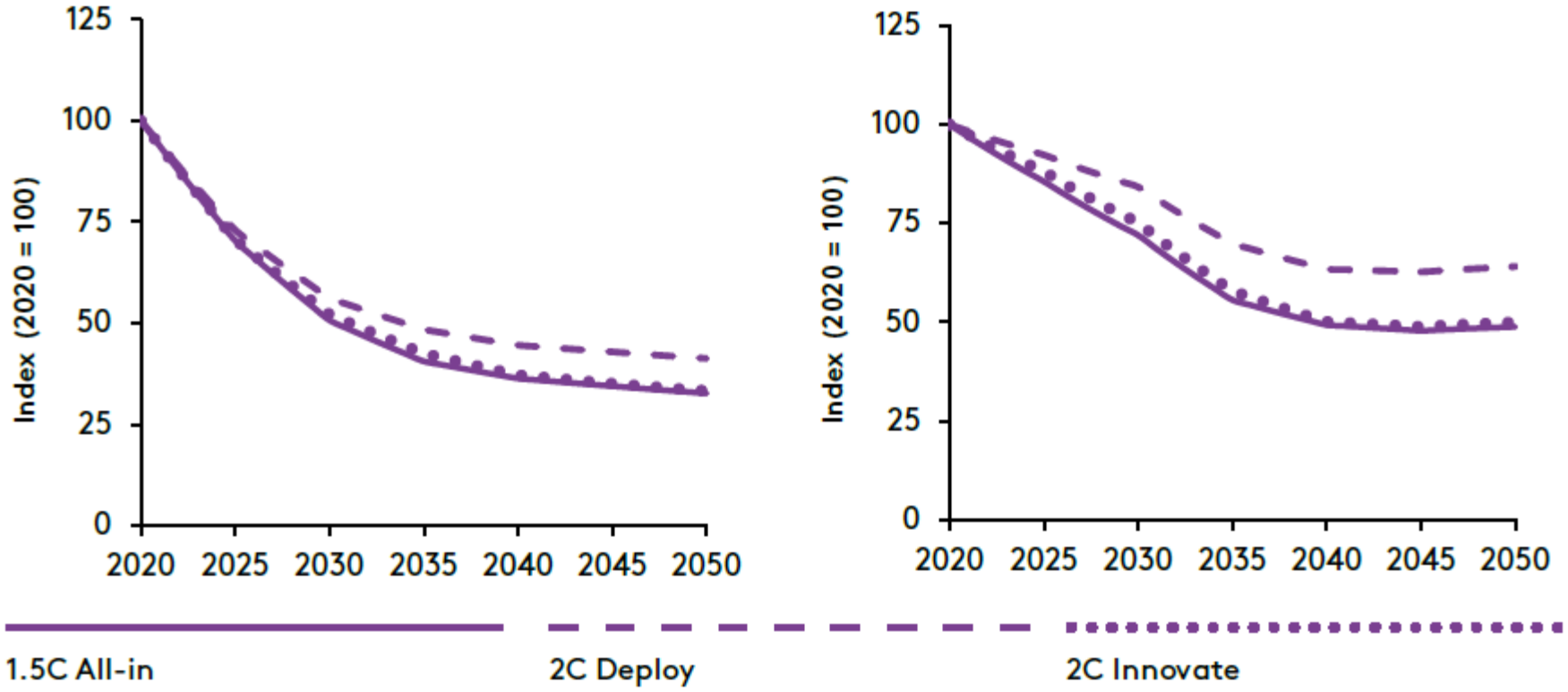
Buildings: Zero-emissions buildings combine energy efficiency with electrification

Residential (left) and commercial (right) buildings energy use in the modelled scenarios, by fuel type (2020-2050)



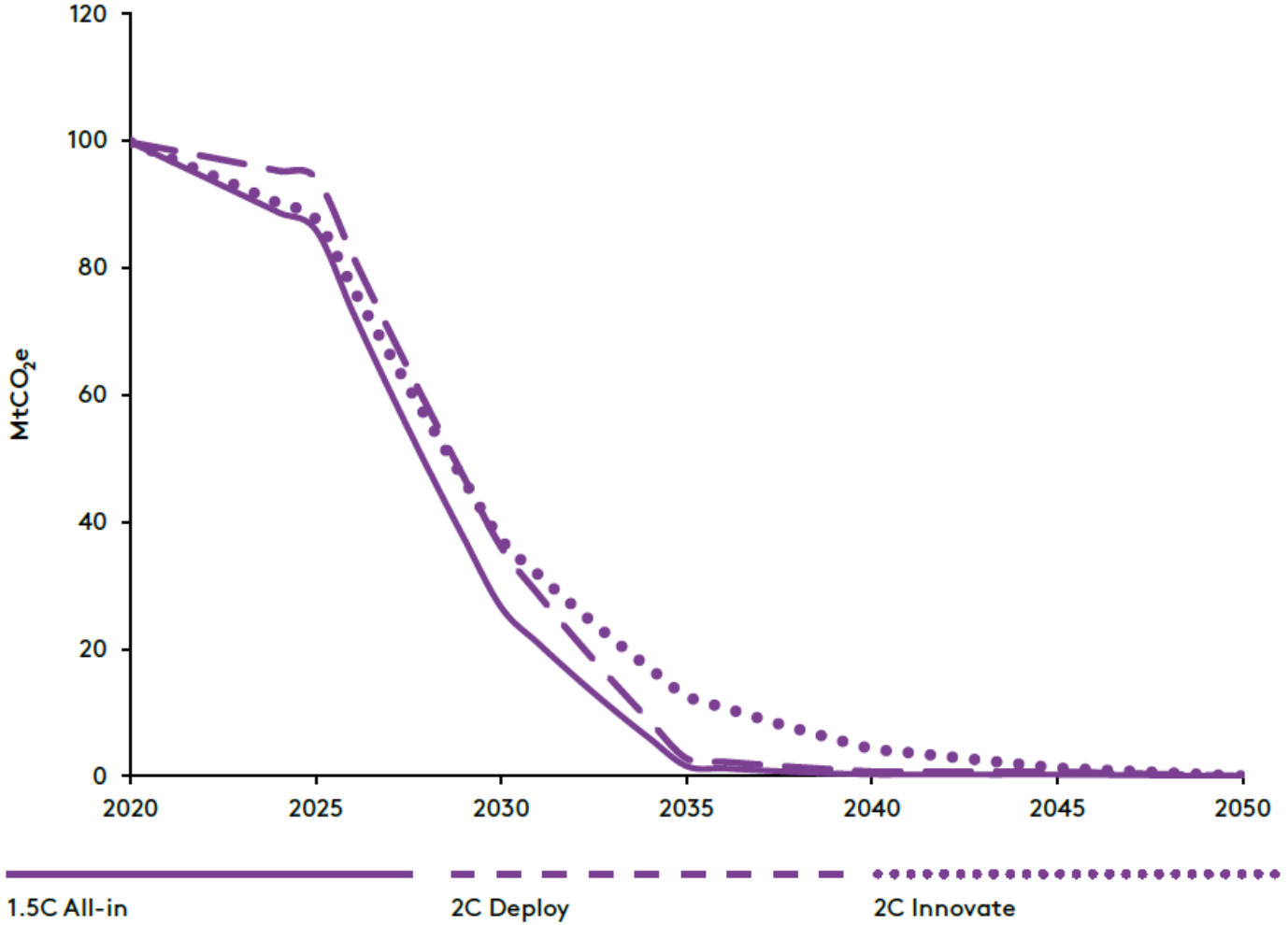
Buildings: Energy efficiency improvements and electrification drive lower energy intensity in all scenarios

Residential (left) and commercial (right) buildings energy intensity in the modelled scenarios (2020-2050)



Buildings: The emissions trajectory of the building sector is strongly linked to the transition to renewable electricity generation

Overall buildings emissions in the modelled scenarios (2020-2050)

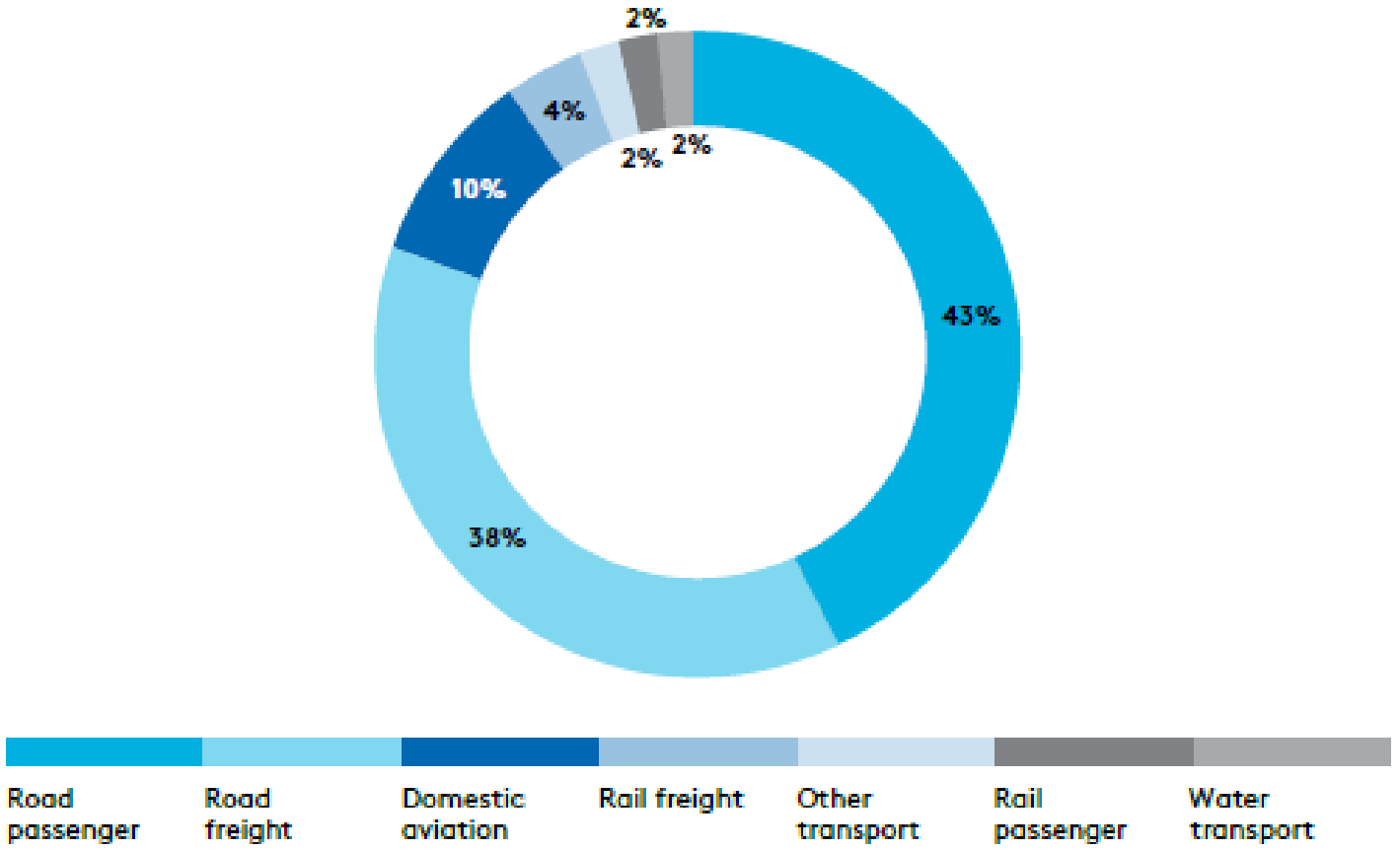


Benchmarks of progress towards net zero emissions by 2050

BENCHMARK	2C PATHWAYS		1.5C PATHWAY	
	2030	CHANGE versus 2020	2030	CHANGE versus 2020
TECHNOLOGY BENCHMARKS				
Rooftop solar electricity generation	22-26 TWh	85-116% increase	26 TWh	116% increase
ENERGY BENCHMARKS				
Residential building energy intensity		44-48% decrease (improvement)		49% decrease (improvement)
Commercial building energy intensity		16-25% decrease (improvement)		28% decrease (improvement)
Share of electricity in residential buildings	76-78%	2020 = 49%	75%[1]	2020 = 49%
EMISSIONS BENCHMARKS				
Annual emissions	36-37 $MtCO_2e$	63-64% decrease	27 $MtCO_2e$	73% decrease

Transport: The majority of Australia's transport emissions come from road transport

Australia's transport emissions shares by subsector (2018)

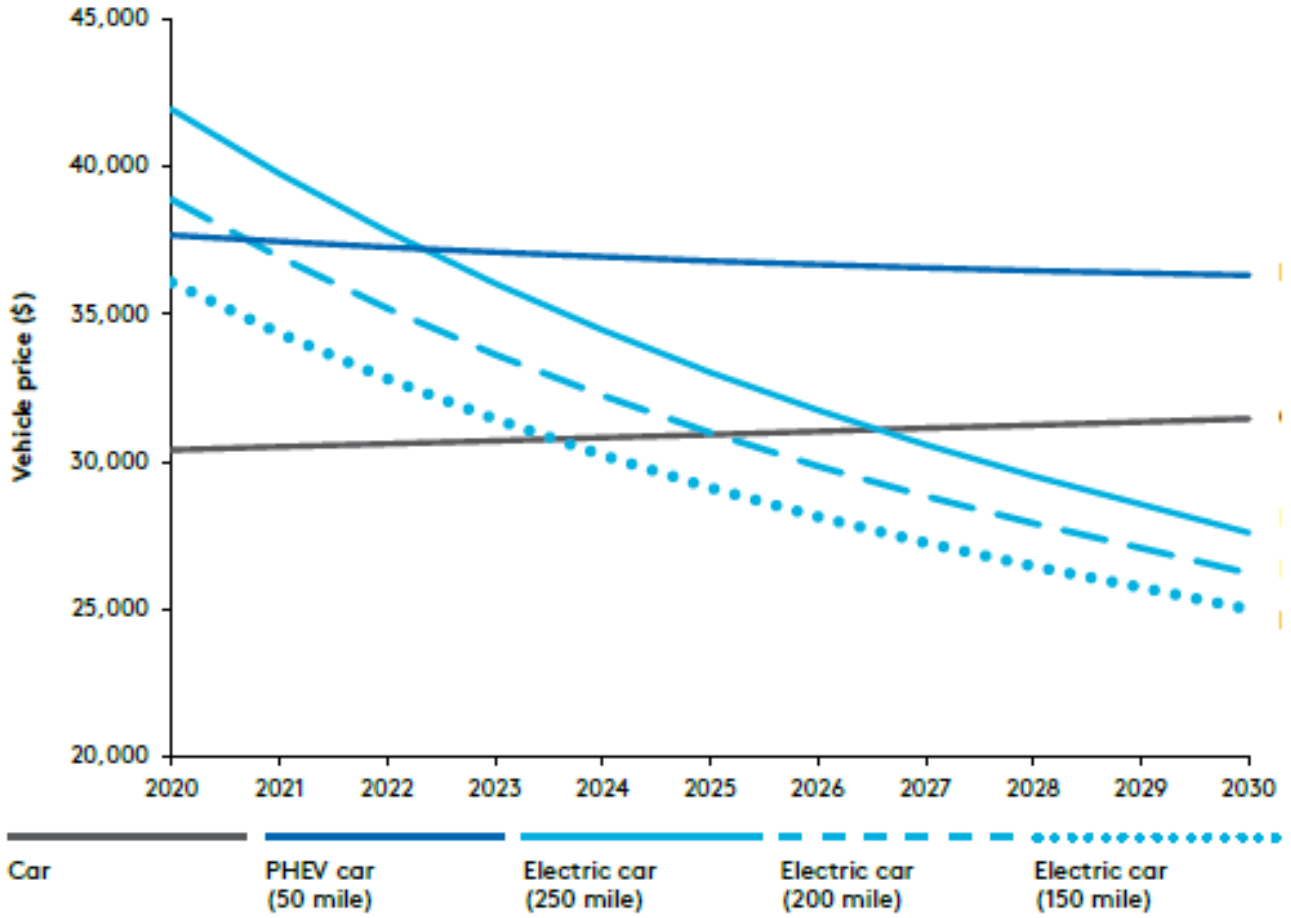


Transport: Short-term efforts can focus on improving travel and energy efficiency, and increasing the use of biofuels, while technology progresses for zero-emissions solutions

Optimise travel needs	Mode shift (active, rail, lighter vehicles)	Video-conferencing	Logistics, warehouse location	Autonomous vehicles	
Improve efficiency	Vehicle design improvement	Route optimisation	Improved fleet maintenance	Eco-driving	
Electrify (battery or fuel cell)	Cars & buses	Road freight	Rail freight	Short-haul shipping	Short-haul aviation
Use alternative fuels	Biofuels (1st generation) – limited scale	Biofuels (2nd and 3rd generation)	Renewable hydrogen	Renewable ammonia	

Light road transport: Within the next decade, electric vehicles are expected to become cost-competitive with, or cheaper than, conventional vehicles

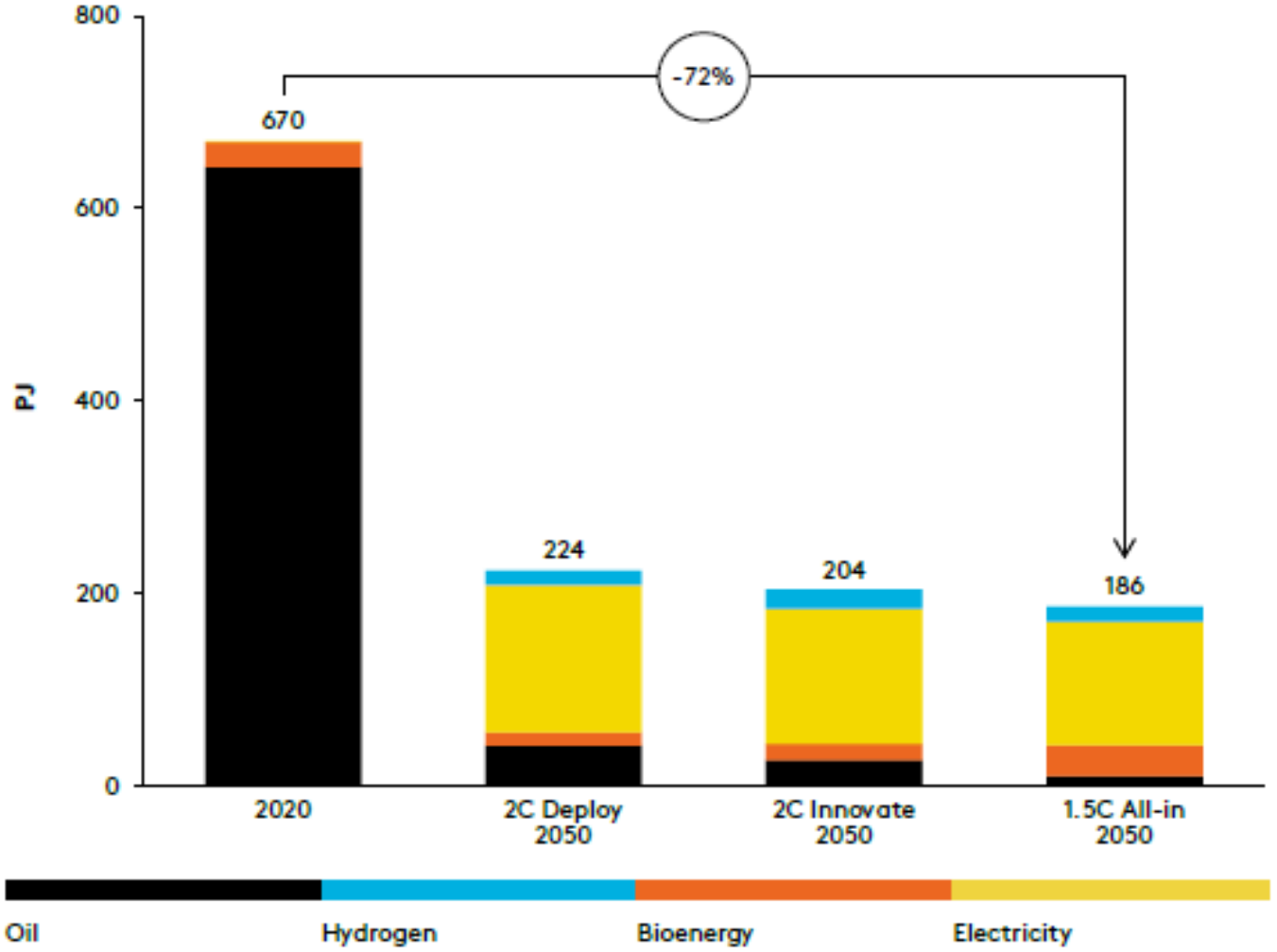
Initial purchase price of conventional vehicles and electric vehicles for cars showing the crossover point in comparative vehicle purchase price (2020-2030)



Source: ICCT (2019)

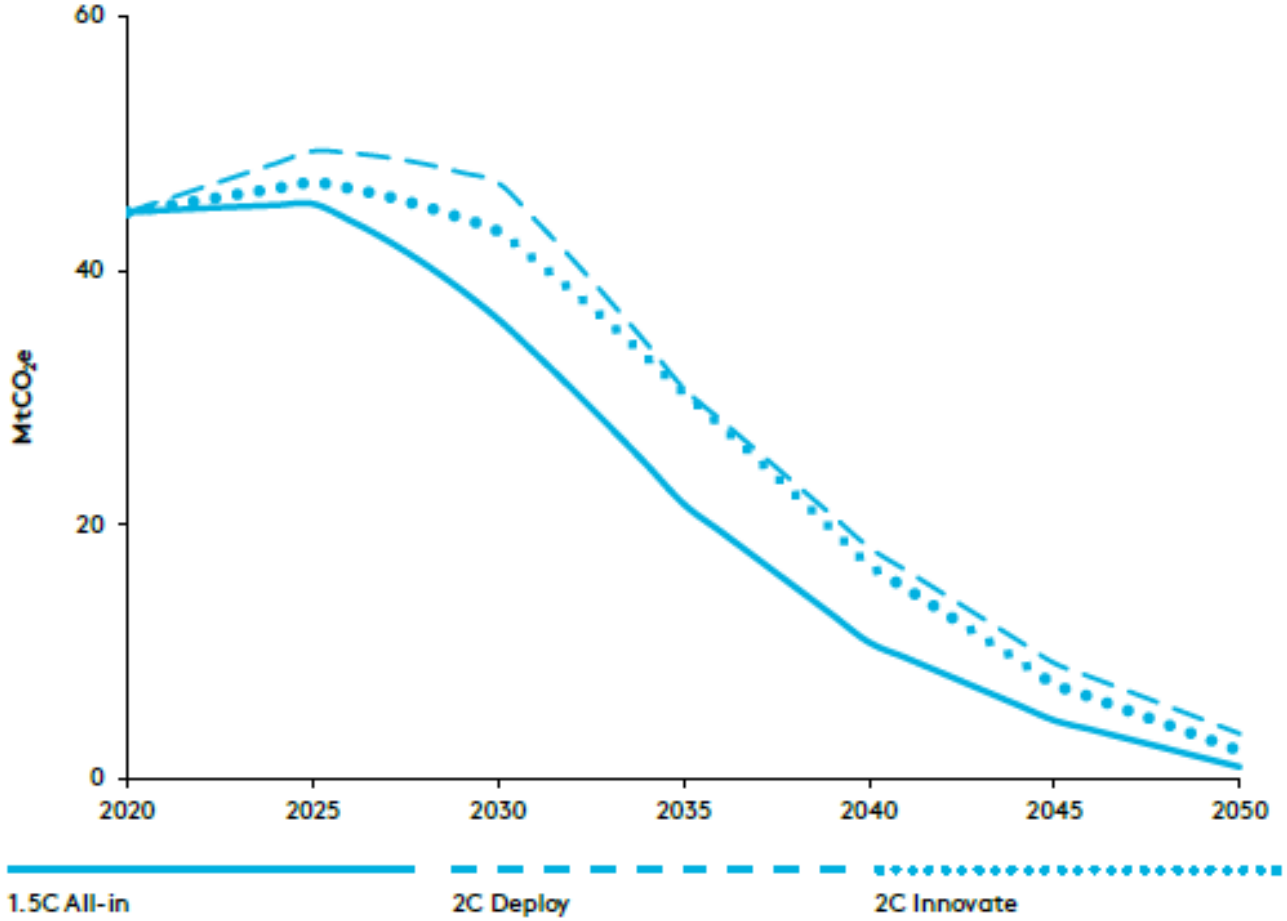
Light road transport: The high uptake of electric vehicles charged with renewable electricity has the potential to drive road passenger transport close to zero emissions

Road passenger transport energy use in the modelled scenarios, by fuel type (2020 & 2050)



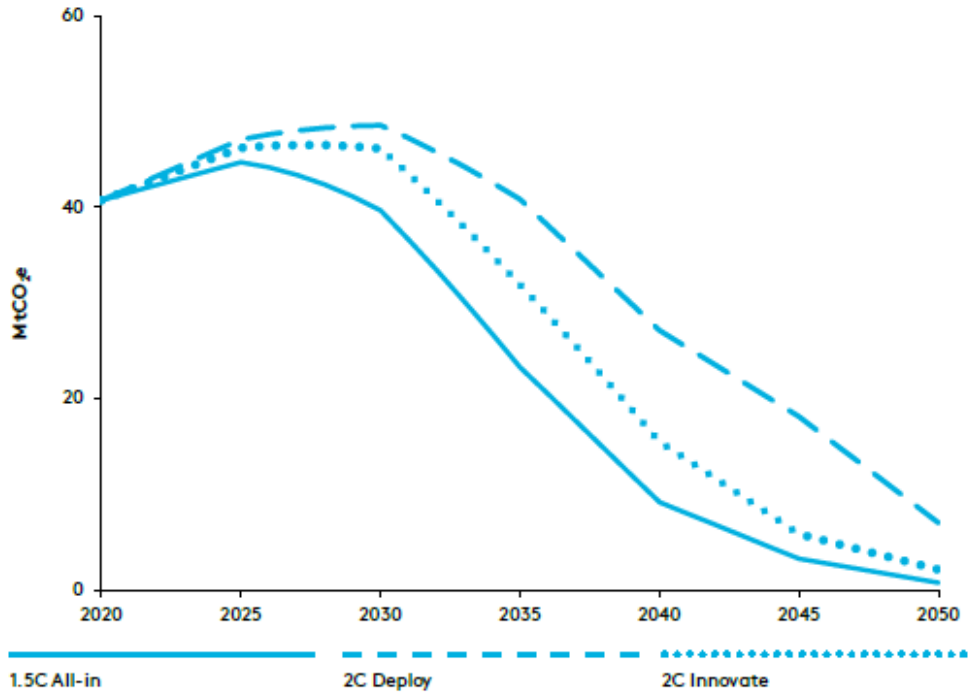
Light road transport: Emissions decrease accelerates after 2030. This reflects the delay between electric vehicles becoming cost-competitive (around 2025) and uptake in new vehicle sales

Road passenger transport emissions in the modelled scenarios (2020-2050)

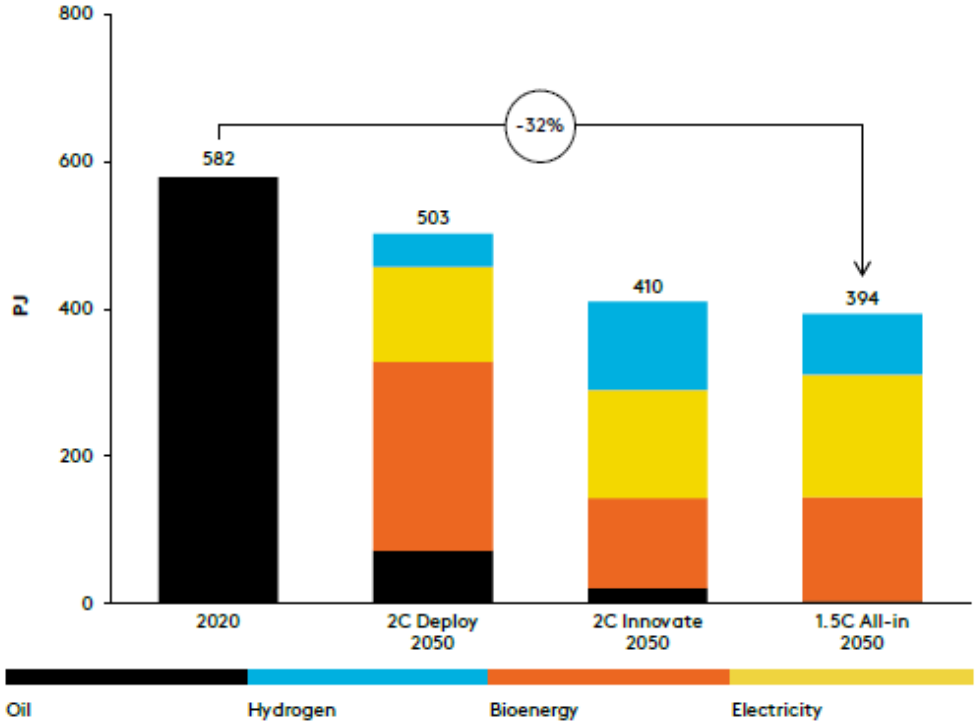


Heavy road transport: Technological developments and policy support could help reach near zero emissions in 2050 through shifts to renewable electricity, bioenergy and hydrogen

Road freight transport emissions in the modelled scenarios (2020-2050)

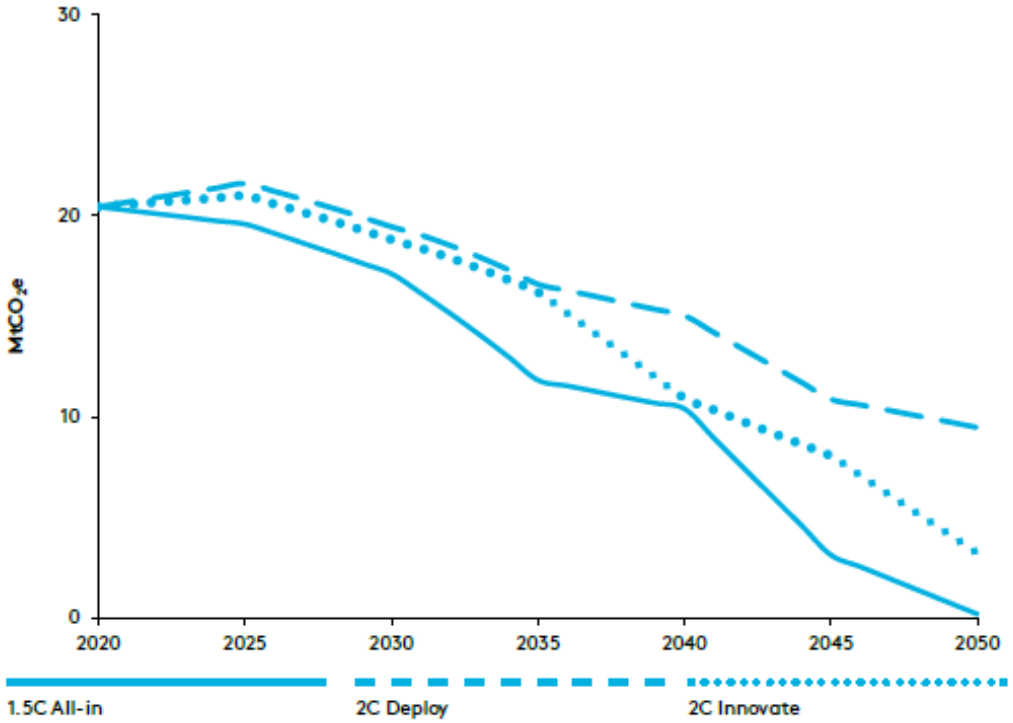


Road freight transport energy use in the modelled scenarios, by fuel type (2020 & 2050)

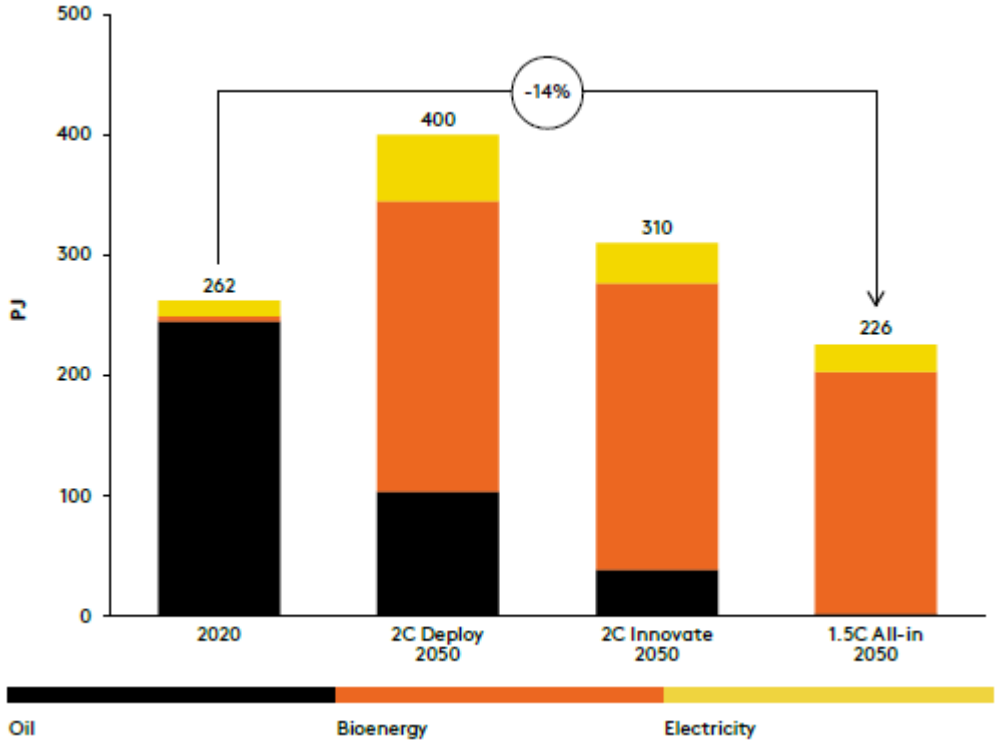


Non-road transport: Energy-efficiency improvements, renewable fuel cost reductions and demand shift can help significantly reduce emissions in aviation and shipping

Non-road transport emissions in the modelled scenarios (2020-2050)

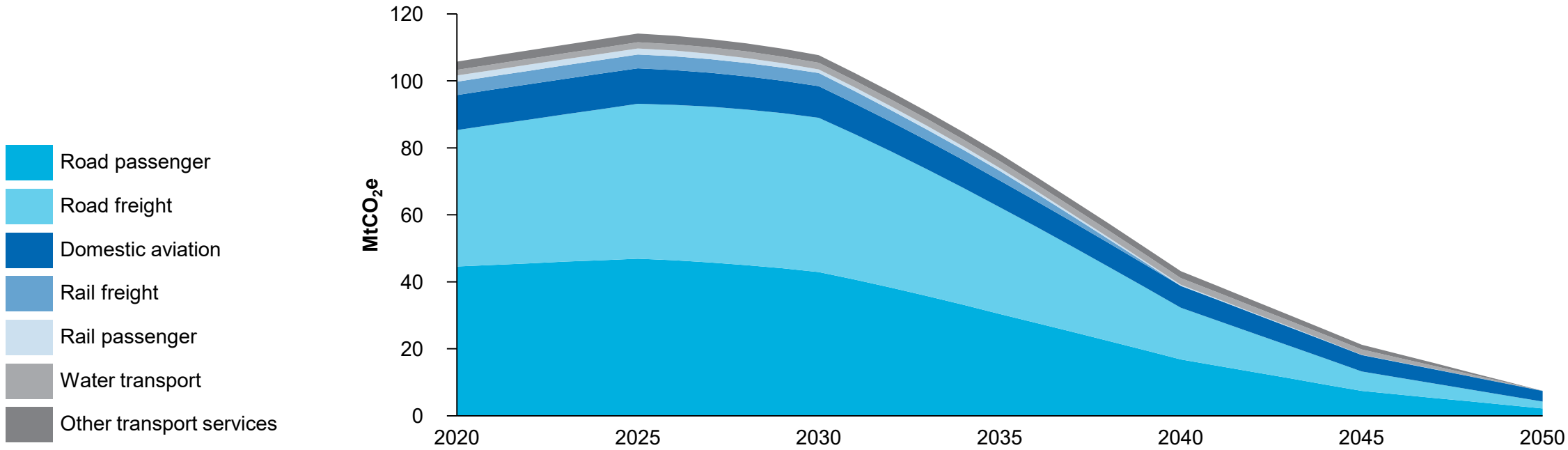


Non-road transport energy use in the modelled scenarios, by fuel type (2020 & 2050)



Transport: It is possible to achieve near zero emissions by 2050

Transport emissions by subsector, MtCO2e, ‘2C Innovate’ scenario

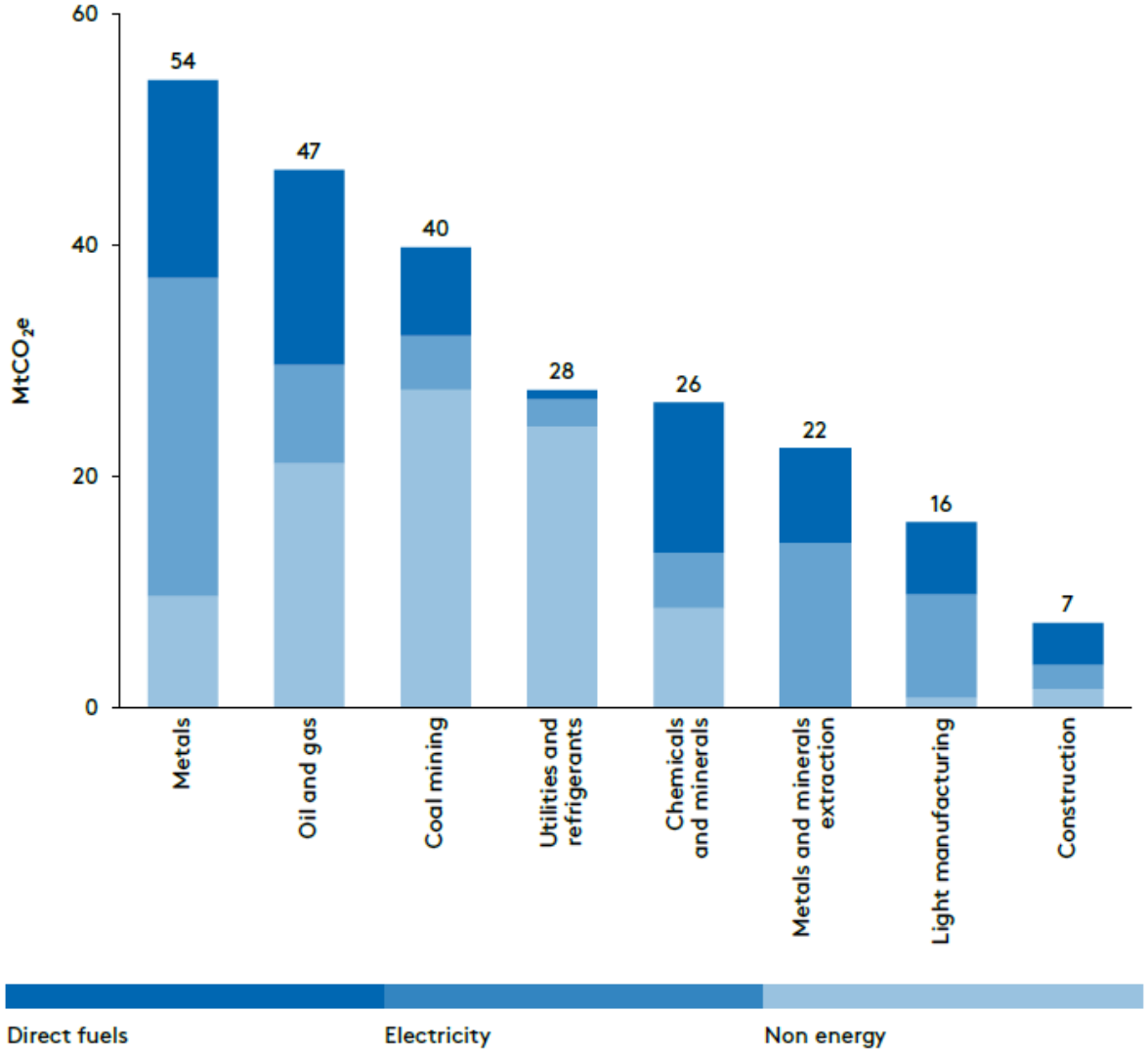


Benchmarks of progress towards net zero emissions by 2050

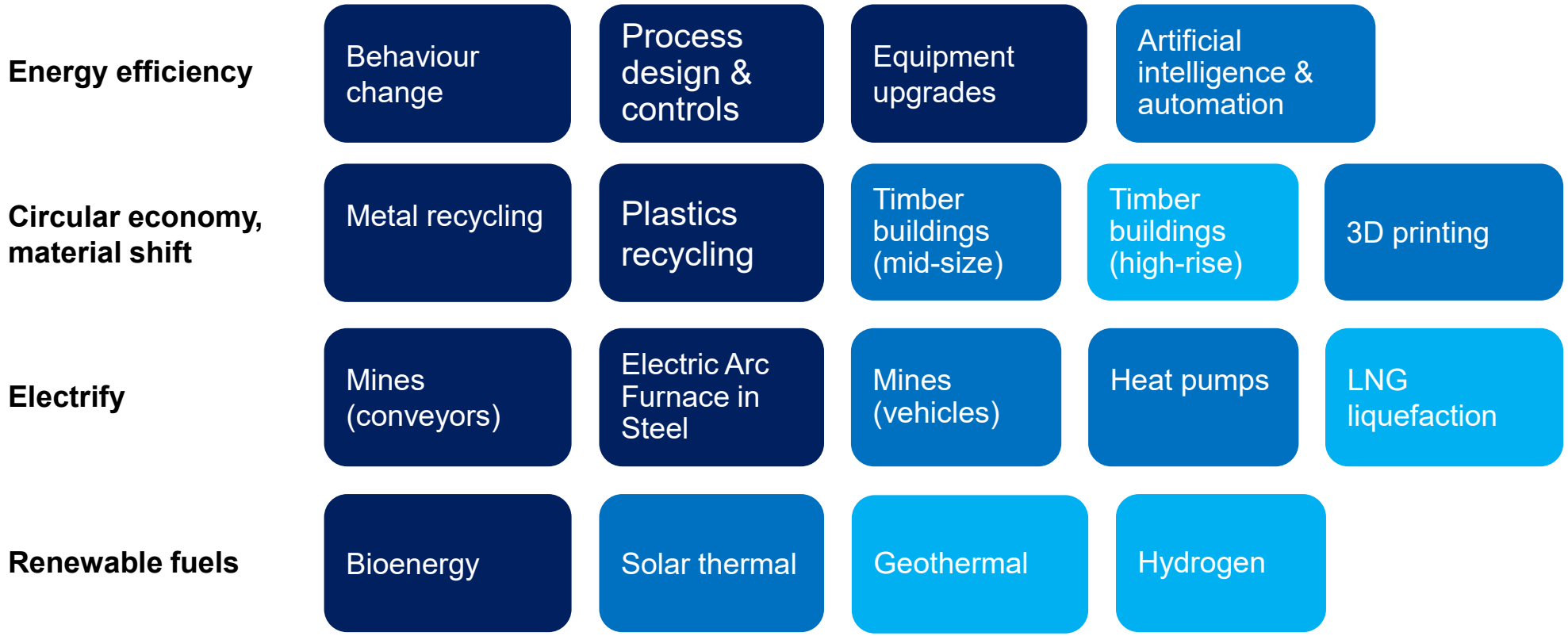
BENCHMARK	2C PATHWAYS		1.5C PATHWAY	
	2030	CHANGE versus 2020	2030	CHANGE versus 2020
TECHNOLOGY BENCHMARKS				
Electric cars (battery electric vehicles and fuel cell electric vehicles)	50% of new-car sales, 15% of total fleet	2020 = <1% of sales and total fleet	76% of new-car sales, 28% of total fleet	2020 = <1% of sales and total fleet
Electric trucks (battery electric vehicles and fuel cell electric vehicles)	25-39% of new-truck sales, 8-13% of total fleet	2020 = <1% of sales and total fleet	59% of new-truck sales, 24% of total fleet	2020 = <1% of sales and total fleet
Volume of zero-emissions fuels (bioenergy and hydrogen)	83-111 PJ	171-265% increase	134 PJ	338% increase
ENERGY BENCHMARKS				
Share of electricity and zero-emissions fuels in total transport energy use	9-11%	2020 = 3%	16%	2020 = 3%
Share of electricity and zero-emissions fuels in road passenger and freight energy use	5-9%	2020 = 2%	17%	2020 = 2%
Fossil fuel use in non-road transport	226-233 PJ	5-8% decrease	203 PJ	17% decrease
EMISSIONS BENCHMARKS				
Total transport emissions	108-115 $MtCO_2e$	2-9% increase[1]	93 $MtCO_2e$	12% decrease
+ Road transport emissions	89-95 $MtCO_2e$	5-12% increase[2]	76 $MtCO_2e$	11% decrease
+ Other transport emissions	18.8-19.5 $MtCO_2e$	5-8% decrease	17 $MtCO_2e$	16% decrease

Industry: Industry produces nearly half of Australia's emissions, with a significant proportion from non-energy sources

Industrial emissions by subsector and emissions type, MtCO2e, 2018 (estimated)

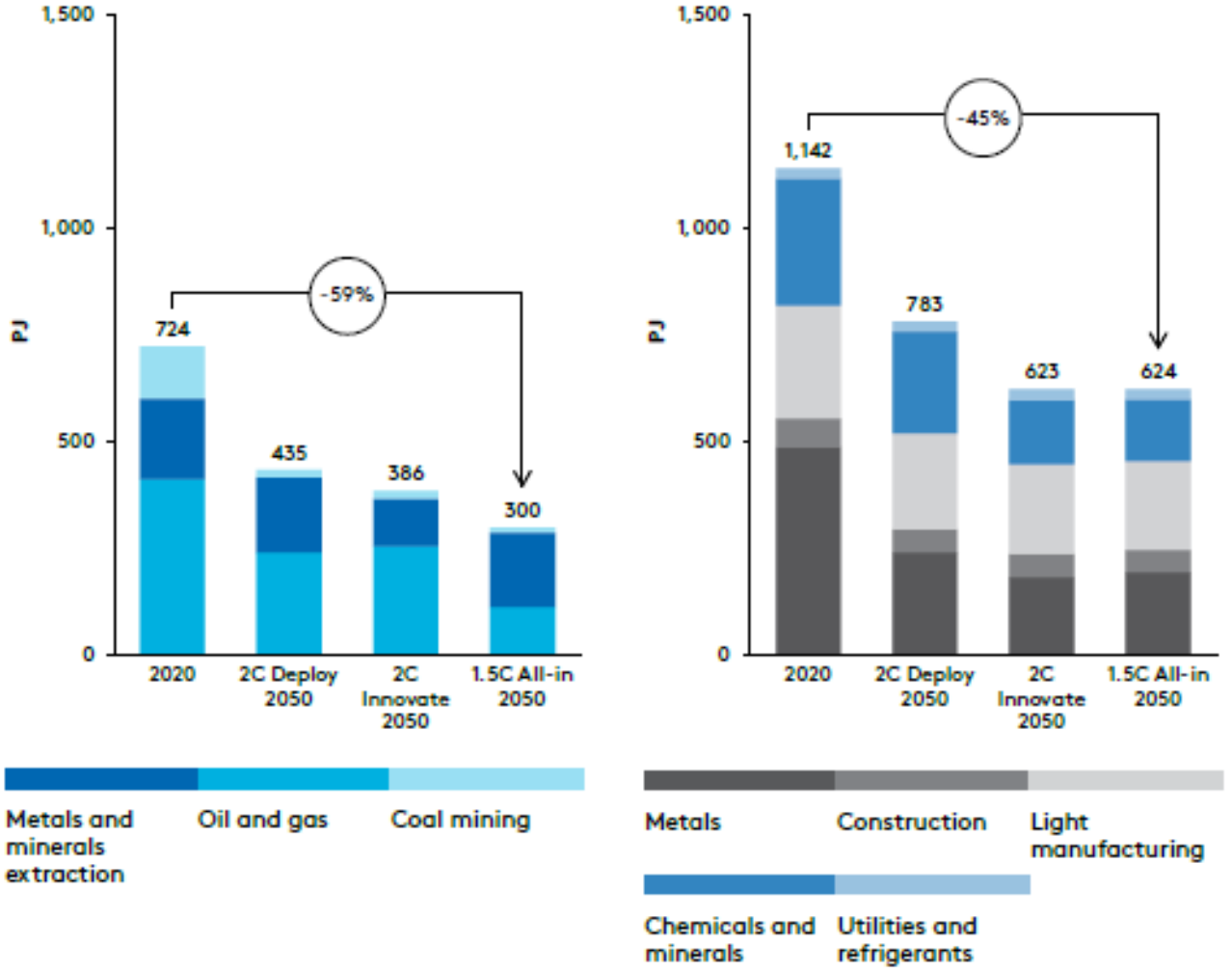


Industry: A number of technologies are ready to be deployed at scale to reduce energy emissions, in particular increased energy efficiency and recycling



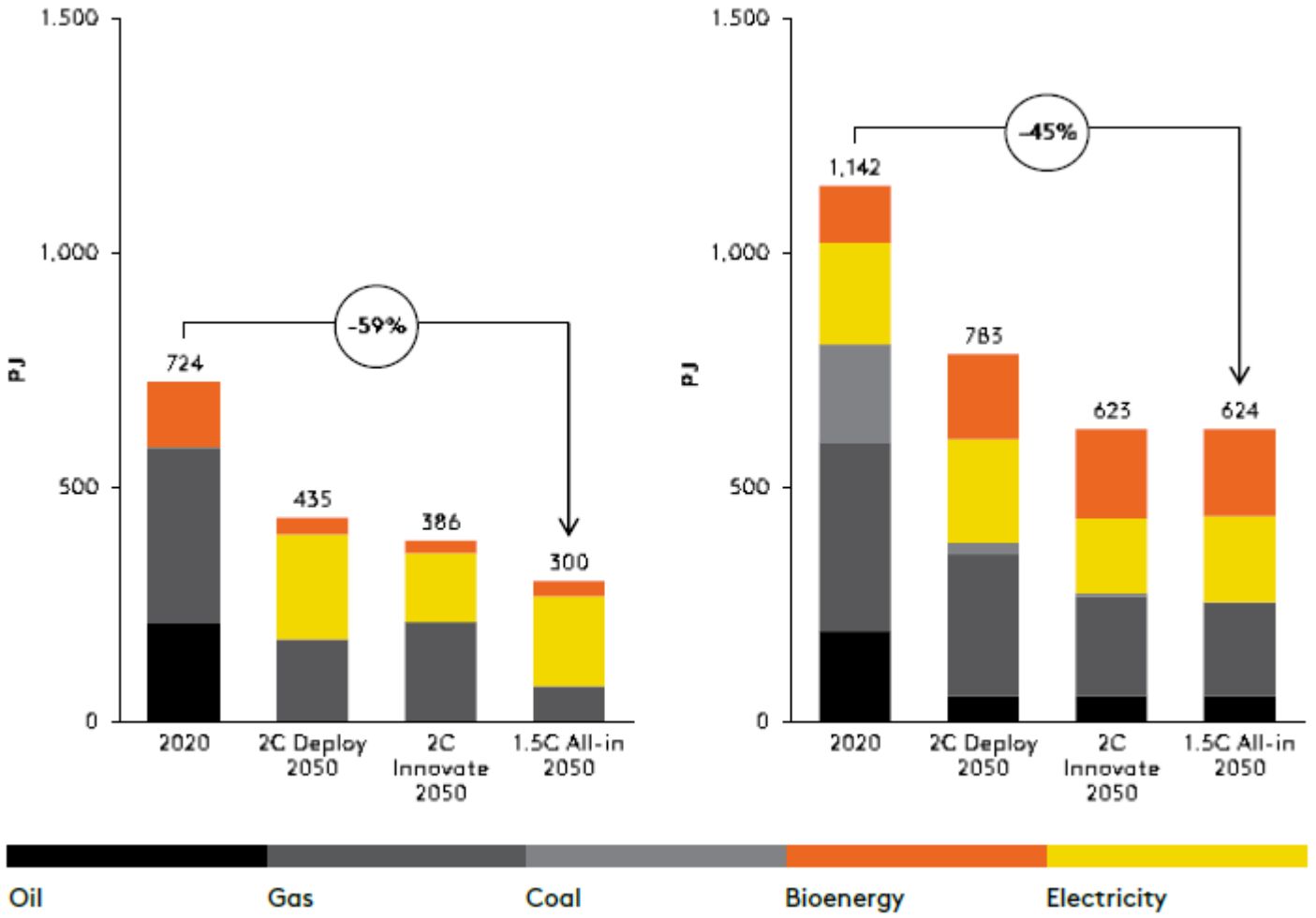
Industry: Improvements in energy and material efficiency, combined with the uptake of other circular economy principles, drives significant energy use reductions

Mining (left) and manufacturing and other industry (right) energy use in the modelled scenarios, by subsector (2020 & 2050)



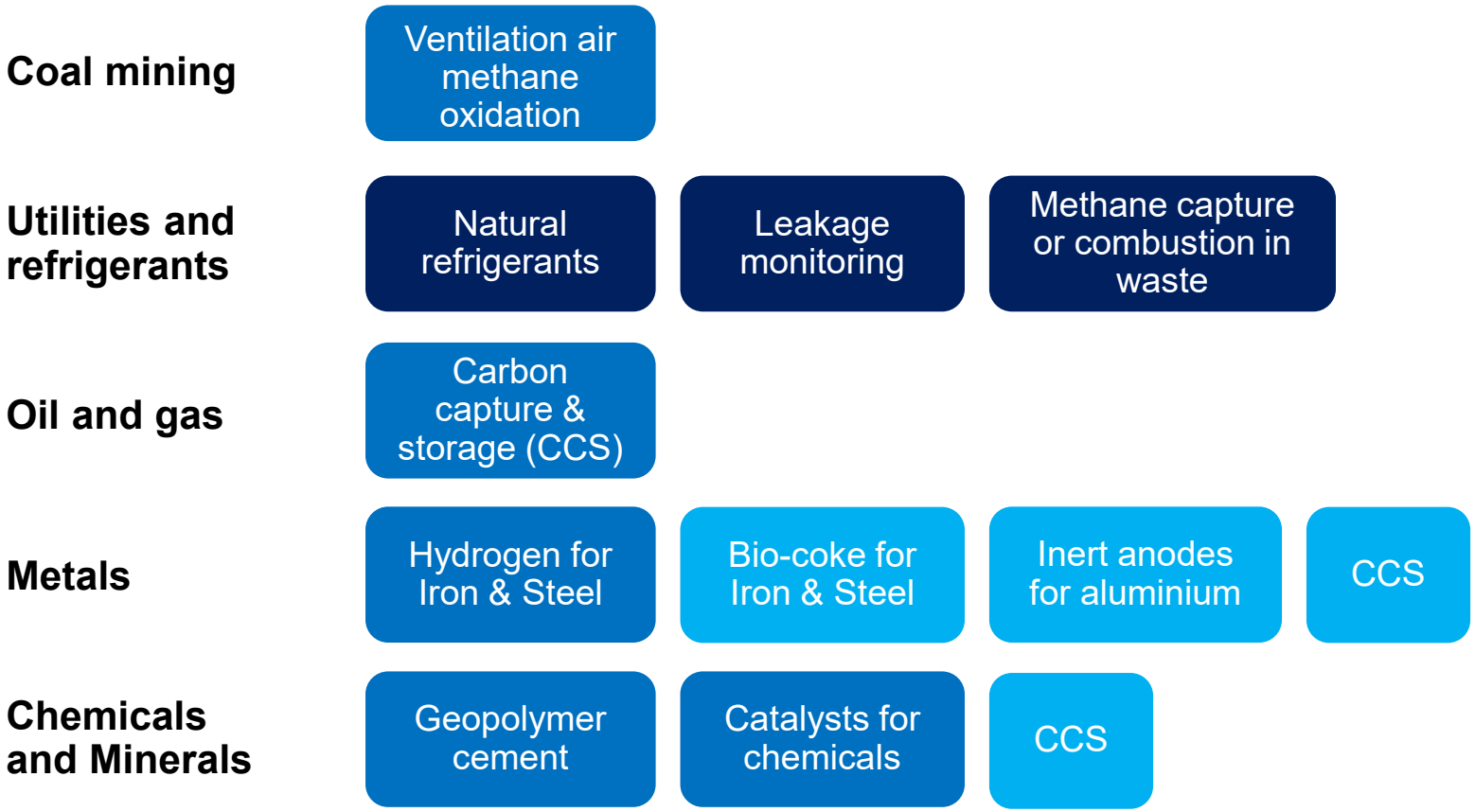
Industry: Electrification and fuel switching could help most industrial processes achieve zero emissions by 2050

Mining (left) and manufacturing and other industry (right) energy use in the modelled scenarios, by fuel type (2020 & 2050)



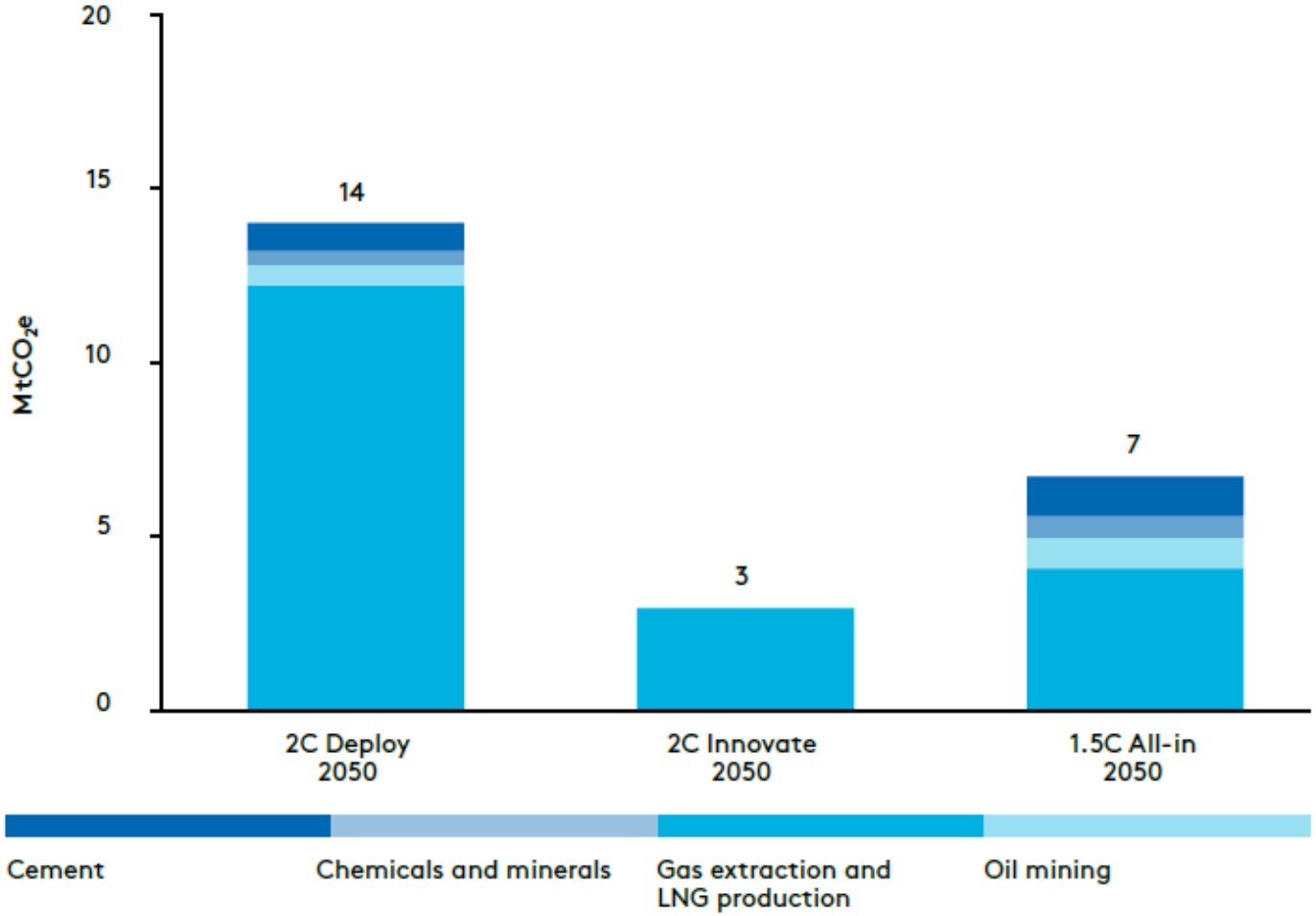
Note: hydrogen is not modelled yet in industry, but could be substituted in future as a zero emissions fuel

Industry: Further targeted solutions to reduce process and fugitive emissions can be developed and deployed



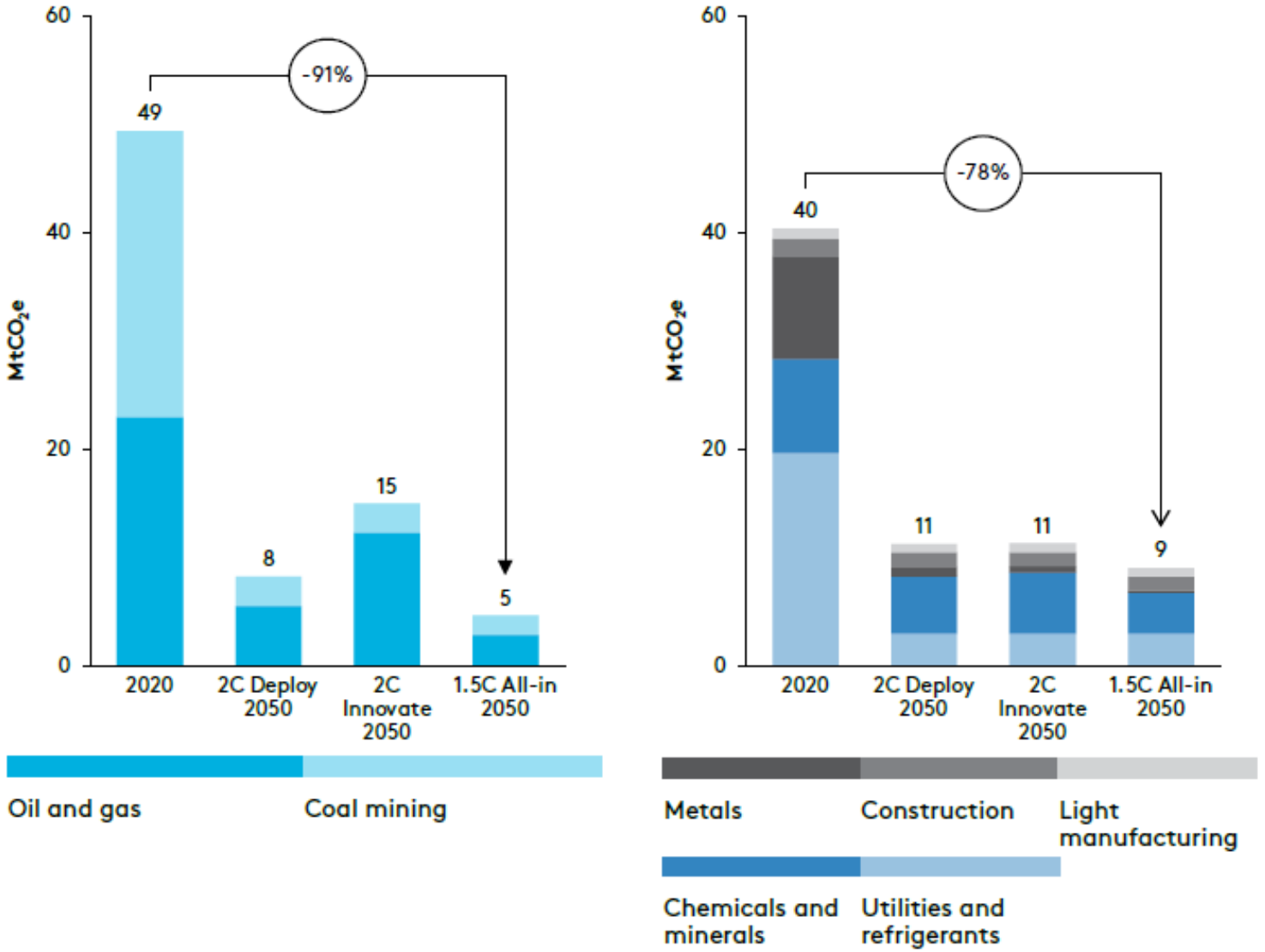
Industry: Carbon capture and storage (CCS) is likely to play a key role in oil and gas

Industry carbon capture and storage in the modelled scenarios (2050), MtCO2e



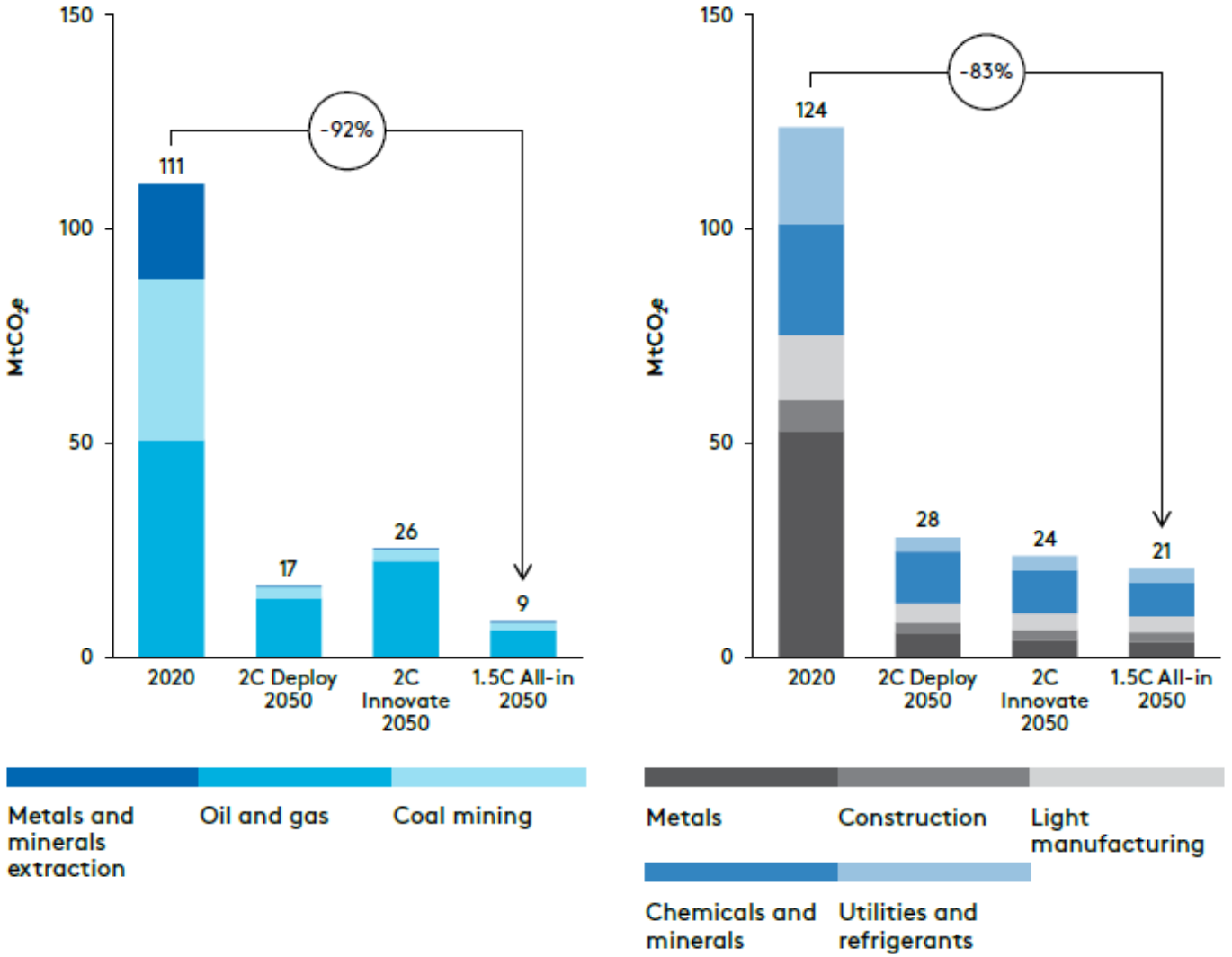
Industry: There is potential to significantly reduce non-energy emissions in key sectors

Mining (left) and manufacturing and other industry (right) non-energy emissions in the modelled scenarios, by subsector (2020 & 2050)



Industry: Significant residual emissions subsist in 2050, demonstrating the size of the technical challenge

Mining (left) and manufacturing and other industry (right) total emissions in the modelled scenarios, by subsector (2020 & 2050)



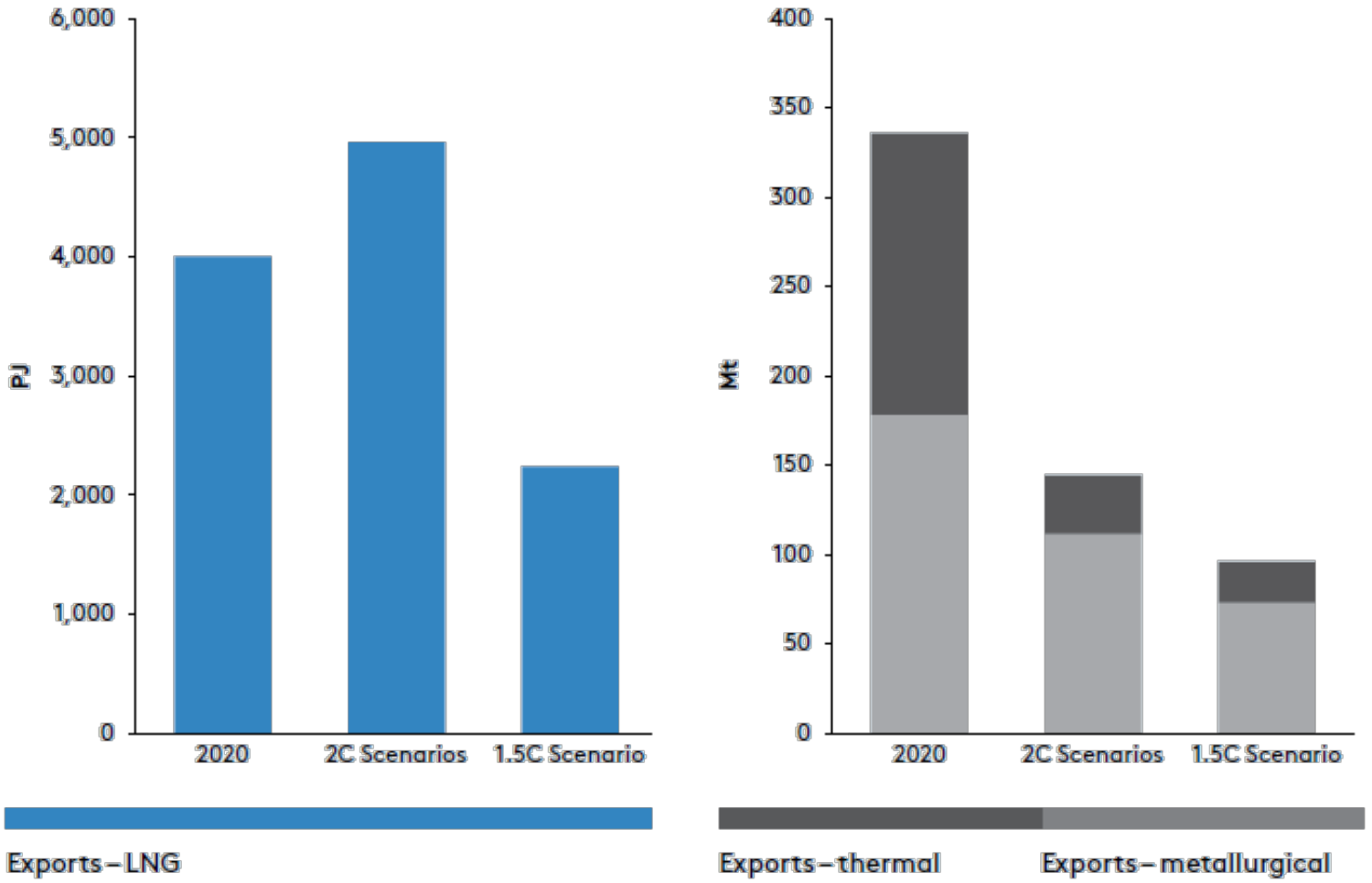
Industry: Substantial emissions reductions are achieved for industry in all scenarios, but significant challenges remain to achieve zero emissions by 2050

Challenges to achieve zero emissions by 2050 include:

+ Eliminating non-energy emissions in the **chemicals** and continued **LNG production** and export sectors
+ Eliminating residual emissions from subsectors that use **fossil fuel as a feedstock** rather than a fuel
+ Shifting away from fossil fuel-based energy exports towards **renewable energy exports**

Industry: Based on international scenarios, Australian gas and coal exports would decline significantly by 2050 under 1.5 degrees

Australian exports of gas (left) and coal (right) in the modelled scenarios (2050)

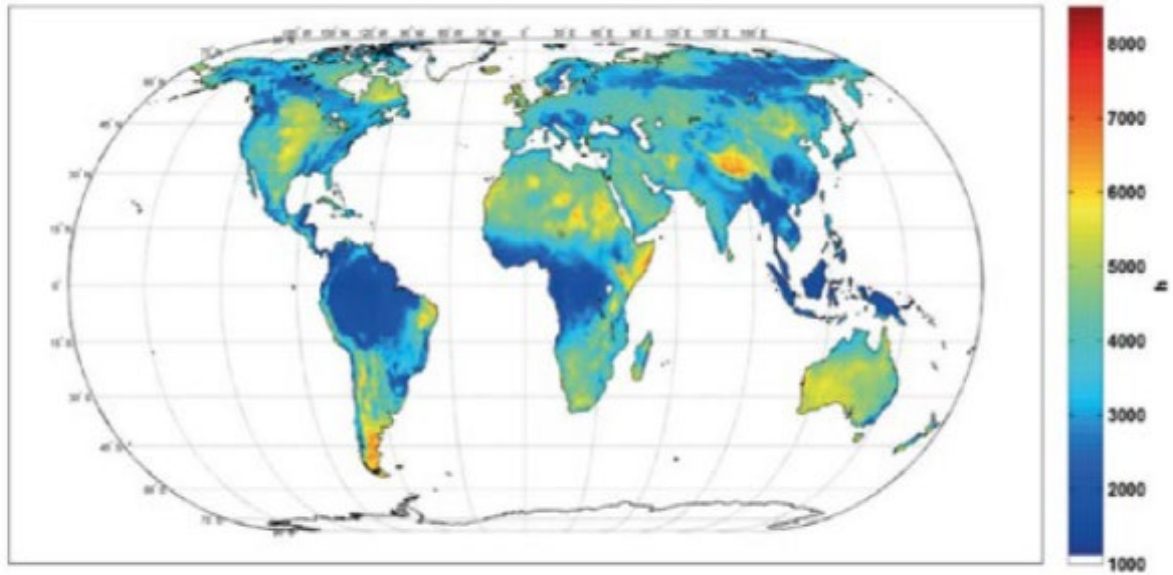


Industry: Decarbonising our supply chains comes with a unique set of opportunities

Australia is well-positioned with:

+ Abundant mineral and energy resources
+ World-class renewable energy resources (identified by the ETC)
+ Project finance capability
+ Engineering capability
+ Existing trade relationships and proximity to Asian markets

Availability of wind and solar resources differ significantly by region



Source: IEA (2017), *Renewable Energy for Industry* (Adapted and based on Fasihi, Bogdanov and Breyer (2016), *Techno-Economic Assessment of Power-to-Liquids (PtL) Fuels Production and Global Trading Based on Hybrid PV-Wind Power Plants*)

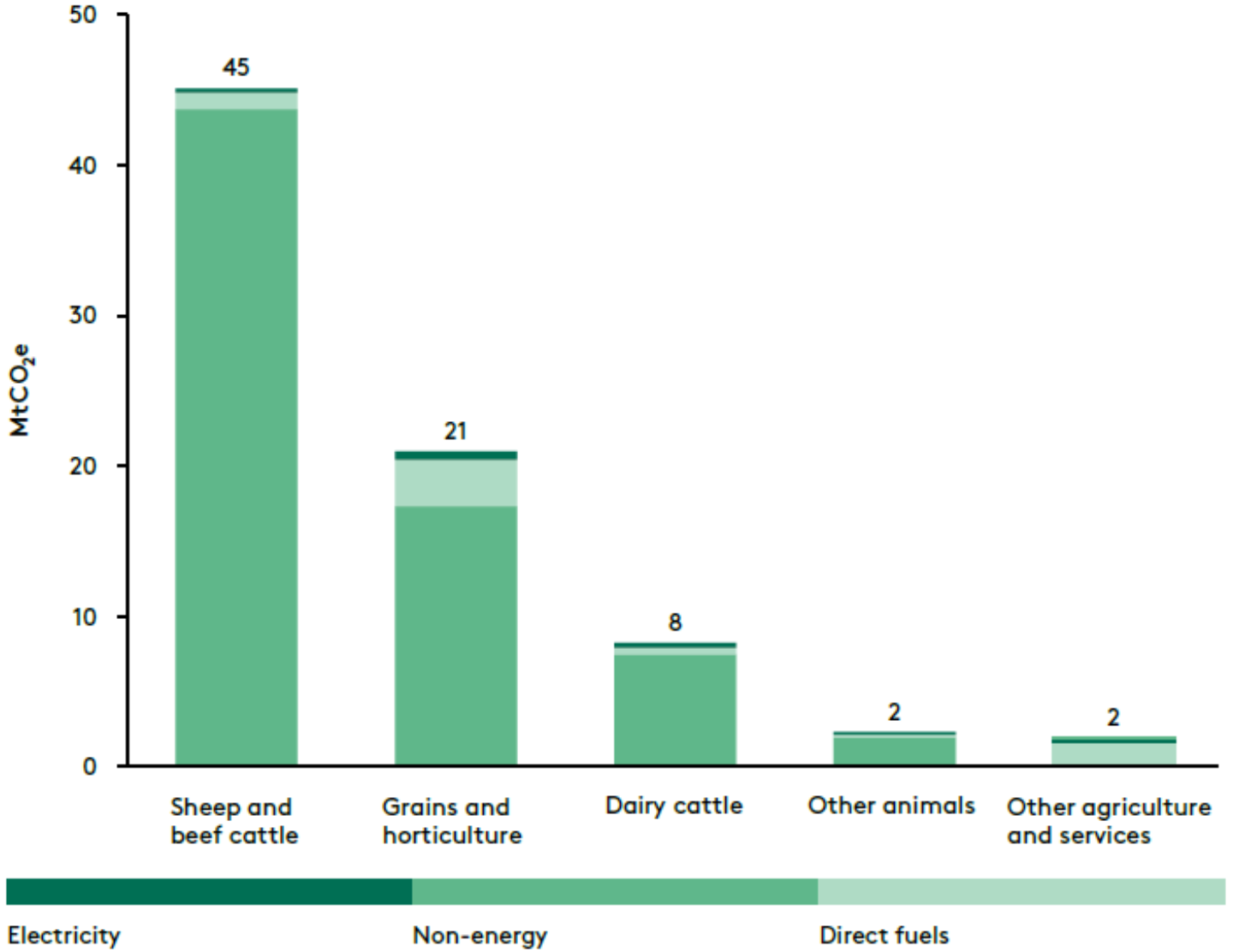
Source: Energy Transitions Commission 2019, *Mission Possible*

Benchmarks of progress towards net zero emissions by 2050

BENCHMARK	2C PATHWAYS		1.5C PATHWAY	
	2030	CHANGE versus 2020	2030	CHANGE versus 2020
TECHNOLOGY BENCHMARKS				
Share of electricity in energy used for steel production	16-20%	2020 = 11%	27%	2020 = 11%
% clinker in cement	45-75%	2020 = 75%	15%	2020 = 75%
Share of new large buildings built using timber	7-20%	2020 = negligible	20%	2020 = negligible
ENERGY BENCHMARKS				
Total energy use	1684-1785 PJ	4-10% decrease	1580 PJ	15% decrease
Share of electricity and zero-emissions fuels in total energy use	30-32%	2020 = 25%	33%	2020 = 25%
EMISSIONS BENCHMARKS				
Total industry emissions	141 $MtCO_2e$	40% decrease	120 $MtCO_2e$	49% decrease
+ Extractive sectors emissions	67-71 $MtCO_2e$	36-39% decrease	56 $MtCO_2e$	49% decrease
+ Manufacturing and other sectors emissions	70-74 $MtCO_2e$	40-43% decrease	63 $MtCO_2e$	49% decrease

Agriculture: Non-energy emissions represent the vast majority of emissions

Agriculture emissions by subsector and emissions type (2018)

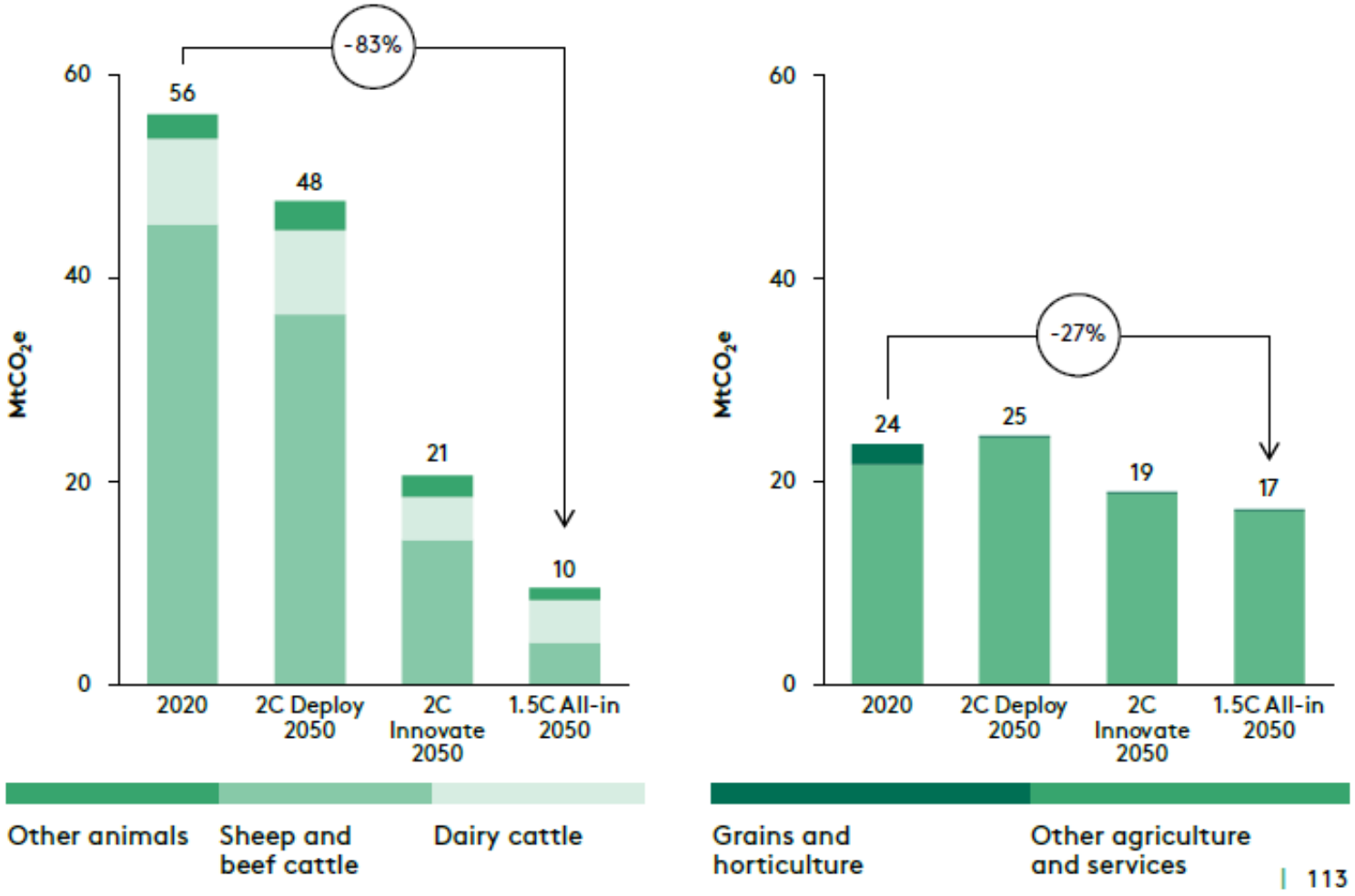


Agriculture: Sustainable agricultural practices can be implemented today to reduce emissions, while more investment in RD&D will be required to achieve zero-emissions

Energy	Sustainable agriculture practices, energy efficient equipment	Precision agriculture, automation	Onsite renewables	Electric machinery	
Non-energy - livestock	Product substitutes: plant-based	Product substitu-tes: Laboratory grown meat	Breeding, feeding & pasture practices (step change)	Manure manage-ment	Anti-methane vaccines
Non-energy - grains & horticulture	Precision agriculture, fertiliser management	Soil carbon sequestration			

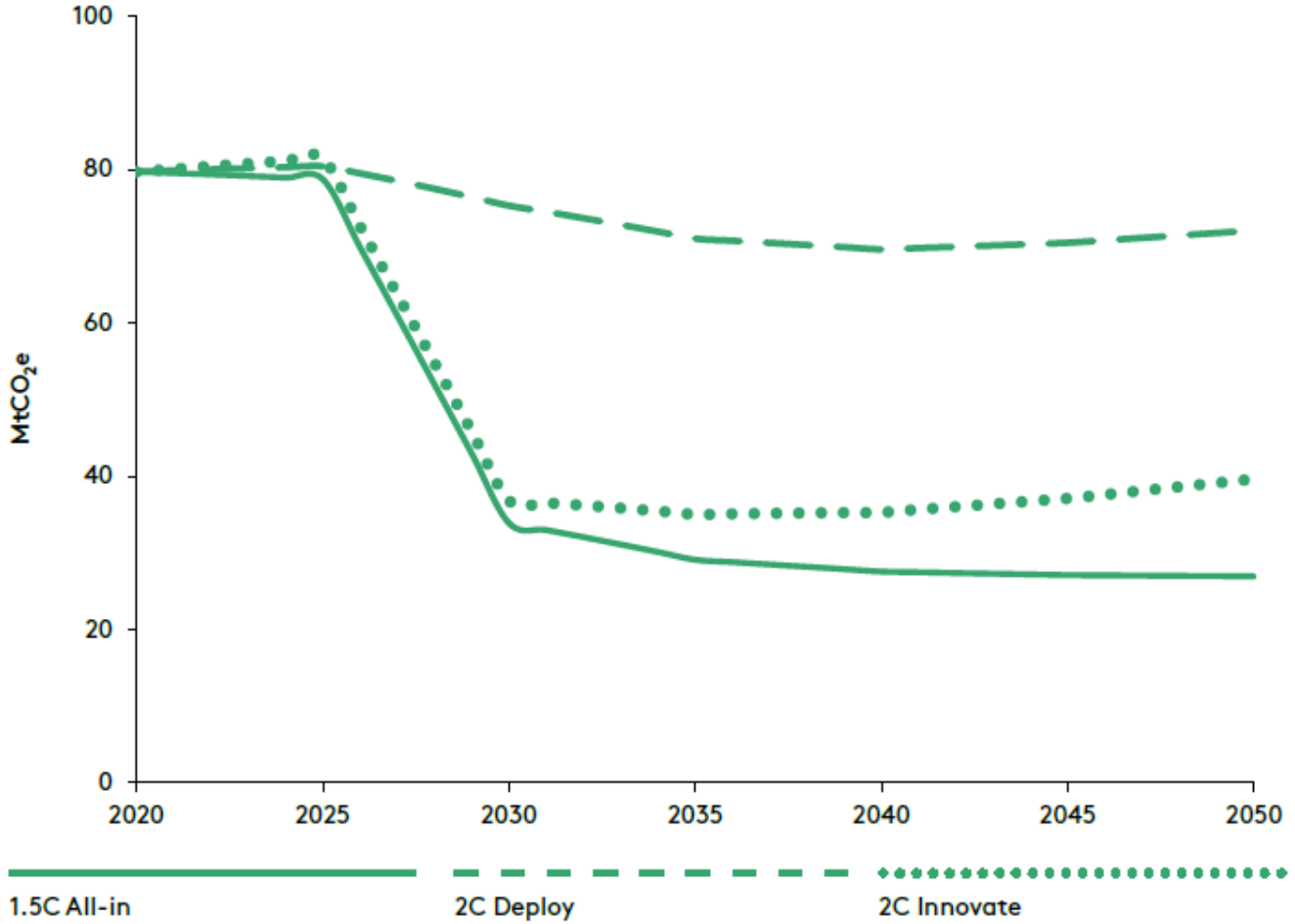
Agriculture: Technological breakthroughs and behaviour change can significantly reduce livestock emissions by 2050, but challenges such as non-energy emissions from grains and horticulture production must also be addressed

Livestock (left) and grains, horticulture and other agriculture (right) emissions in the modelled scenarios, by subsector (2020 & 2050)



Agriculture: Significant residual emissions remain by 2050 across all our scenarios

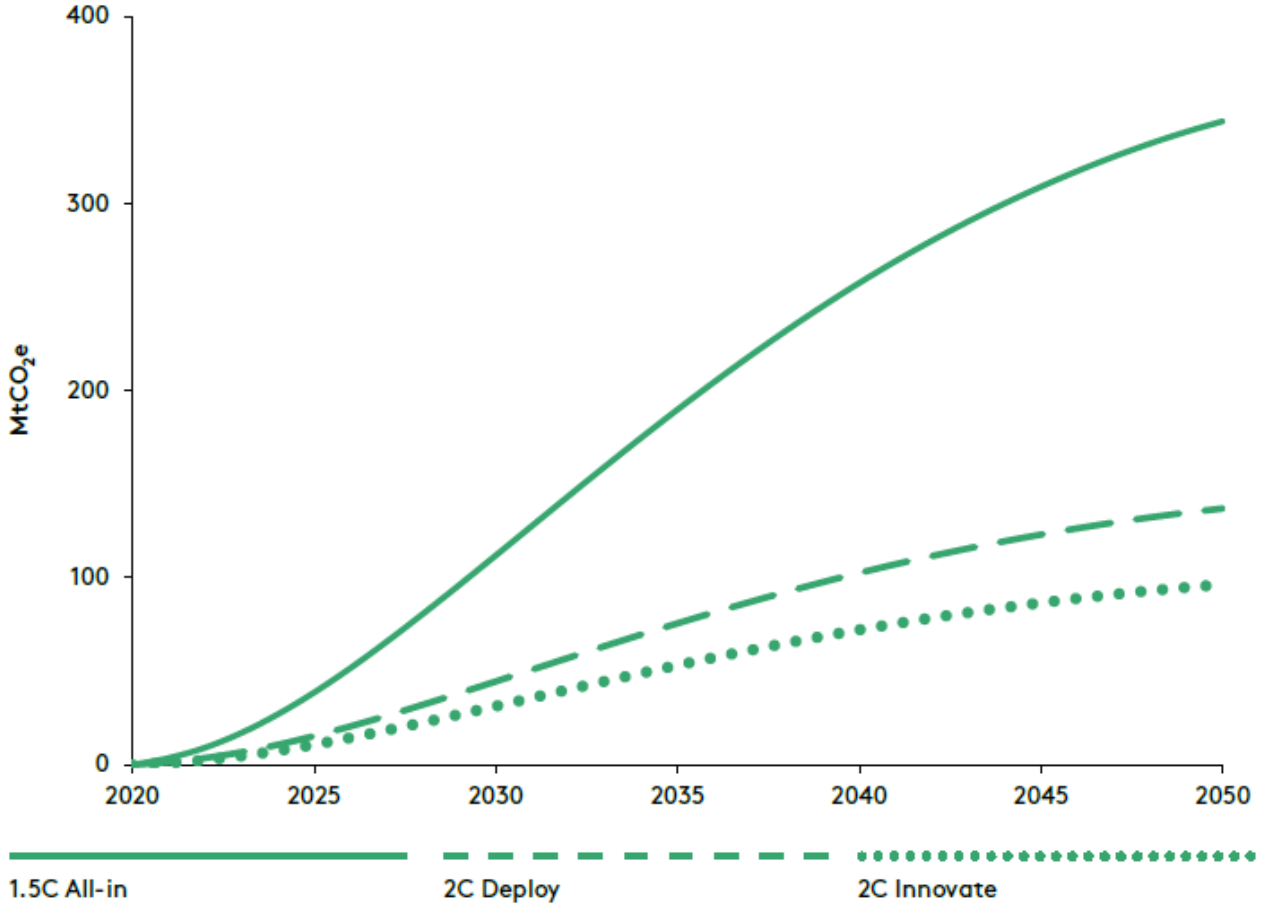
Overall agriculture emissions in the modelled scenarios (2020-2050)



Forestry: Australia's ample carbon forestry potential can help achieve net zero emissions in the medium term

- Not all emerging zero emissions solutions could be modelled
- Carbon forestry was used to fill the gap
- It represents the size of the RD&D effort required

Carbon forestry sequestration in the modelled scenarios (2020-2050)



Forestry: Nature-based solutions such as carbon forestry will continue to play a role in Australia – although they can only be a temporary solution on a pathway to zero emissions

Carbon forestry:

+ Is vulnerable to bushfires, drought and heatwaves
+ Requires long lead times
+ Requires significant areas of land
+ Competes against other land use needs
+ Increases water use
+ Poses threats on biodiversity
+ Will need new parcels of land to be reforested to offset new emissions

Benchmarks of progress towards net zero emissions by 2050

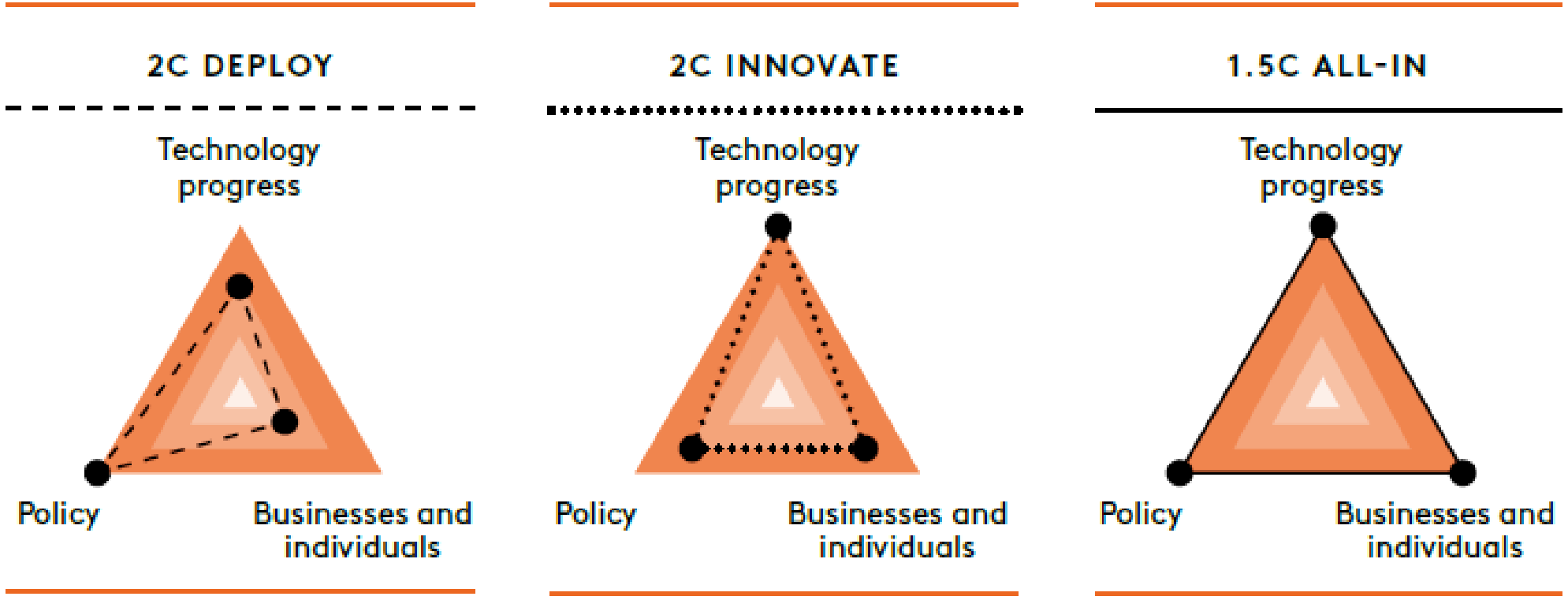
BENCHMARK	2C PATHWAYS		1.5C PATHWAY	
	2030	CHANGE versus 2020	2030	CHANGE versus 2020
TECHNOLOGY BENCHMARKS				
Carbon forestry	~ 5 Mha plantings		~ 8 Mha plantings	
EMISSIONS BENCHMARKS				
Agriculture and land emissions	37-75 $MtCO_2e$	6-54% decrease	34 $MtCO_2e$	57% decrease
+ Livestock emissions	19-53 $MtCO_2e$	5-66% decrease	18 $MtCO_2e$	69% decrease
+ Other agriculture emissions	18-22 $MtCO_2e$	7-24% decrease	16 $MtCO_2e$	31% decrease
+ Carbon forestry sequestration	31-45 $MtCO_2e$ sequestration		112 $MtCO_2e$ sequestration	

OUR SCENARIOS

We used the CCA methodology to calculate an updated Australian carbon budget for 1.5 and 2 degrees

CLIMATE GOAL	CARBON BUDGET, AS OF 01/01/2020	EQUIVALENT TO X YEARS AT CURRENT EMISSIONS LEVELS	REQUIRES NET ZERO BY
GLOBAL PERSPECTIVE			
2°C, 67% chance	1,086 $GtCO_2$	26 years	~2070
1.5°C, 50% chance	496 $GtCO_2$	12 years	~2050
1.5°C, 67% chance	336 $GtCO_2$	8 years	~2050
AUSTRALIAN PERSPECTIVE[8]			
2°C, 67% chance	11.1 $GtCO_2e$	21 years	~2050
1.5°C, 50% chance	4.1 $GtCO_2e$	7.6 years	~2035
1.5°C, 67% chance	2.1 $GtCO_2e$	4.0 years	~2035 (with overshoot)

Decarbonisation Futures uses scenarios to explore a range of possible low-emissions futures for Australia



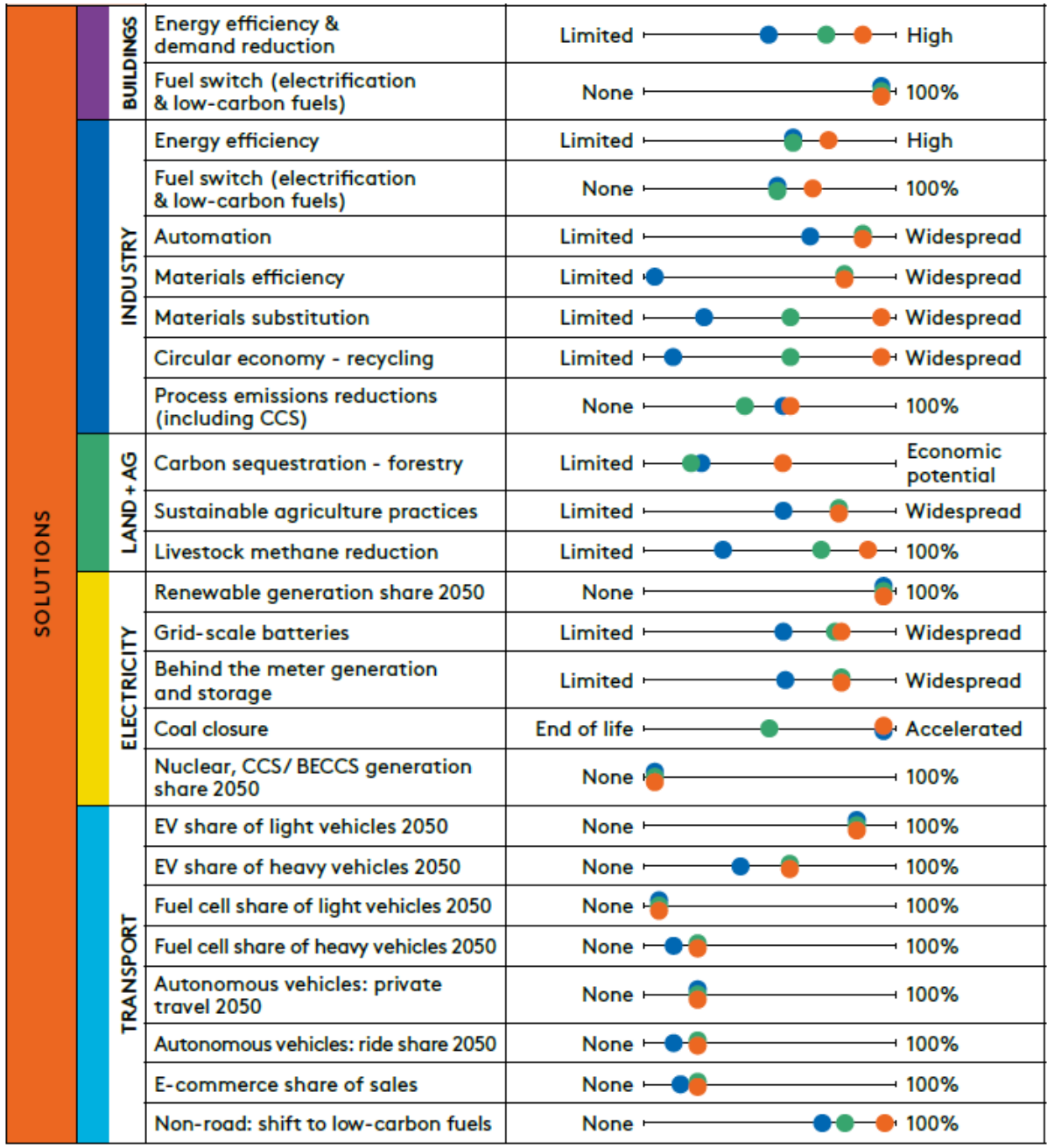
Scenario assumptions – Overall context

2C Deploy 2C Innovate 1.5C All-in

CONTEXT	Population growth	Low growth — High growth
	GDP growth	Low growth — High growth
	Climate ambition	6 degrees — 1.5 degrees
	Trajectory	Insufficient — Rapid decline
	Transition from fossil fuels	Limited — High
	Policy	Weak action — Strong action
	Business/individual actions	Weak action — Strong action
	Technology progress (technology cost reductions)	Limited — High

Scenario assumptions – Solutions

2C Deploy 2C Innovate 1.5C All-in



Our scenario analysis provides technology uptake…

TECHNOLOGY				
BENCHMARK	2°C PATHWAYS		1.5°C PATHWAY	
	2030	CHANGE versus 2020	2030	CHANGE versus 2020
Emissions intensity	220-252 tCO_2e/GWh	63-67% decrease	177 tCO_2e/GWh	74% decrease
Share of renewable electricity generation	70-74%	2020 = 25%	79%	2020 = 25%
Additional renewable capacity between 2020 and 2030		24-28 GW added		29 GW added
Additional storage capacity between 2020 and 2030		44-66 GWh added		56 GWh added
Rooftop solar electricity generation	22-26 TWh	85-116% increase	26 TWh	116% increase
Electric cars (battery electric vehicles and fuel cell electric vehicles)	50% of new car sales, 15% of total fleet	2020 = <1% of sales and total fleet	76% of new car sales, 28% of total fleet	2020 = <1% of sales and total fleet
Electric trucks (battery electric vehicles and fuel cell electric vehicles)	25-39% of new truck sales, 8-13% of total fleet	2020 = <1% of sales and total fleet	59% of new truck sales, 24% of total fleet	2020 = <1% of sales and total fleet
Volume of zero emissions fuels (bioenergy and hydrogen)	83-111 PJ	171-265% increase	134 PJ	338% increase
Share of electricity in energy used for steel production	16-20%	2020 = 11%	27%	2020 = 11%
% clinker in cement	45-75%	2020 = 75%	15%	2020 = 75%
Share of new large buildings built using timber	7%-20%	2020 = negligible	20%	2020 = negligible
Carbon forestry	~ 5 Mha plantings		~ 8 Mha plantings	

… as well as energy and emissions measures

ENERGY				
BENCHMARK	2°C PATHWAYS		1.5°C PATHWAY	
	2030	CHANGE versus 2020	2030	CHANGE versus 2020
Total final energy use		3-8% decrease		16% decrease
Share of electricity and zero-emissions fuels in final energy use	31-32%	2020 = 23%	35%	2020 = 23%
Share of electricity in total energy	24%	2020 = 20%	27%	2020 = 20%
Residential building energy intensity[5]		44-48% decrease (improvement)		49% decrease (improvement)
Commercial building energy intensity[6]		16-25% decrease (improvement)		28% decrease (improvement)
Share of electricity in residential buildings	76-78%	2020 = 49%	75%[7]	2020 = 49%
Share of electricity and zero-emissions fuels in transport energy	9-11%	2020 = 3%	16%	2020 = 3%
Share of electricity and zero-emissions fuels in road energy use	5-9%	2020 = 2%	17%	2020 = 2%
Fossil fuel use in non-road transport	226-233 PJ	5-8% decrease	203 PJ	17% decrease
Total energy use	1684-1785 PJ	4-10% decrease	1580 PJ	15% decrease
Share of electricity and zero-emissions fuels in total energy use	30-32%	2020 = 25%	33%	2020 = 25%

EMISSIONS				
BENCHMARK	2°C PATHWAYS		1.5°C PATHWAY	
	2030	CHANGE versus 2020	2030	CHANGE versus 2020
Net annual emissions	**291-322 $MtCO_2e$**	**37-43% decrease[1]**	**159 $MtCO_2e$**	**69% decrease[2]**
Electricity emissions	**62-65 $MtCO_2e$**	**63-64% decrease**	**46 $MtCO_2e$**	**73% decrease**
Buildings emissions	**36-37 $MtCO_2e$**	**63-64% decrease**	**27 $MtCO_2e$**	**73% decrease**
Total transport emissions	**108-115 $MtCO_2e$**	**2-9% increase[3]**	**93 $MtCO_2e$**	**12% decrease**
+ Road transport emissions	89-95 $MtCO_2e$	5-12% increase[4]	76 $MtCO_2e$	11% decrease
+ Other transport emissions	18.8-19.5 $MtCO_2e$	5-8% decrease	17 $MtCO_2e$	16% decrease
Total industry emissions	**141 $MtCO_2e$**	**40% decrease**	**120 $MtCO_2e$**	**49% decrease**
+ Extractive sectors emissions	67-71 $MtCO_2e$	36-39% decrease	56 $MtCO_2e$	49% decrease
+ Manufacturing and other sectors emissions	70-74 $MtCO_2e$	40-43% decrease	63 $MtCO_2e$	49% decrease
Agriculture and land emissions	**37-75 $MtCO_2e$**	**6-54% decrease**	**34 $MtCO_2e$**	**57% decrease**
+ Livestock emissions	19-53 $MtCO_2e$	5-66% decrease	18 $MtCO_2e$	69% decrease
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+ Carbon forestry sequestration	31-45 $MtCO_2e$ sequestration		112 $MtCO_2e$ sequestration	

Thank you. Please contact us for more information.

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MONASH University

MONASH SUSTAINABLE DEVELOPMENT INSTITUTE

THE MYER FOUNDATION

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