Shell Scenarios

The Energy Security Scenarios

Entering a world of competitive transition

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Warning: Uncertainties ahead

The Energy Security Scenarios

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Scenarios - What are they?

- Scenarios explore how the world could possibly evolve under different sets of assumptions.
  - Informed by data.
  - Constructed using models.
- Scenarios contain insights from leading experts in the relevant fields.
- Scenarios consider different versions of possible futures. Some may seem unlikely or even surprising.
- The value to Shell is to help senior management think about the long-term challenges Shell could face.
- Scenarios are not expressions of Shell's strategy, they are not Shell's business plan and they do not necessarily reflect the thinking or behaviour of the business.
- Shell also publishes some of its scenario thinking to help governments, academia and business to think about the long-term challenges that they, and the world at large, could face.
- Scenarios are possible worlds built from incomplete and uncertain information.
- Scenarios are intended as an aid to making better decisions. They stretch minds and broaden horizons.

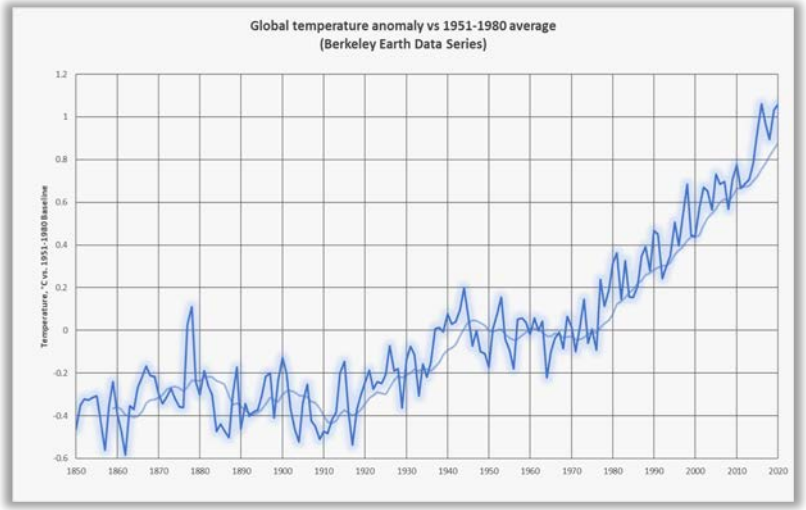
A security mindset is rapidly emerging throughout the world...

...but a deeper exploration reveals the foundation for an accelerated energy transition

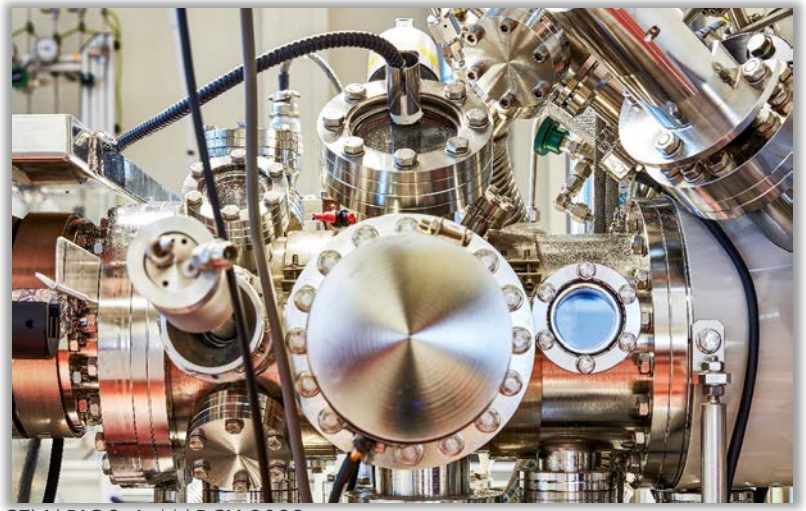
In a troubled world, four key drivers of change

Rising energy costs, food prices, inflation

Global surface temperature continues to rise

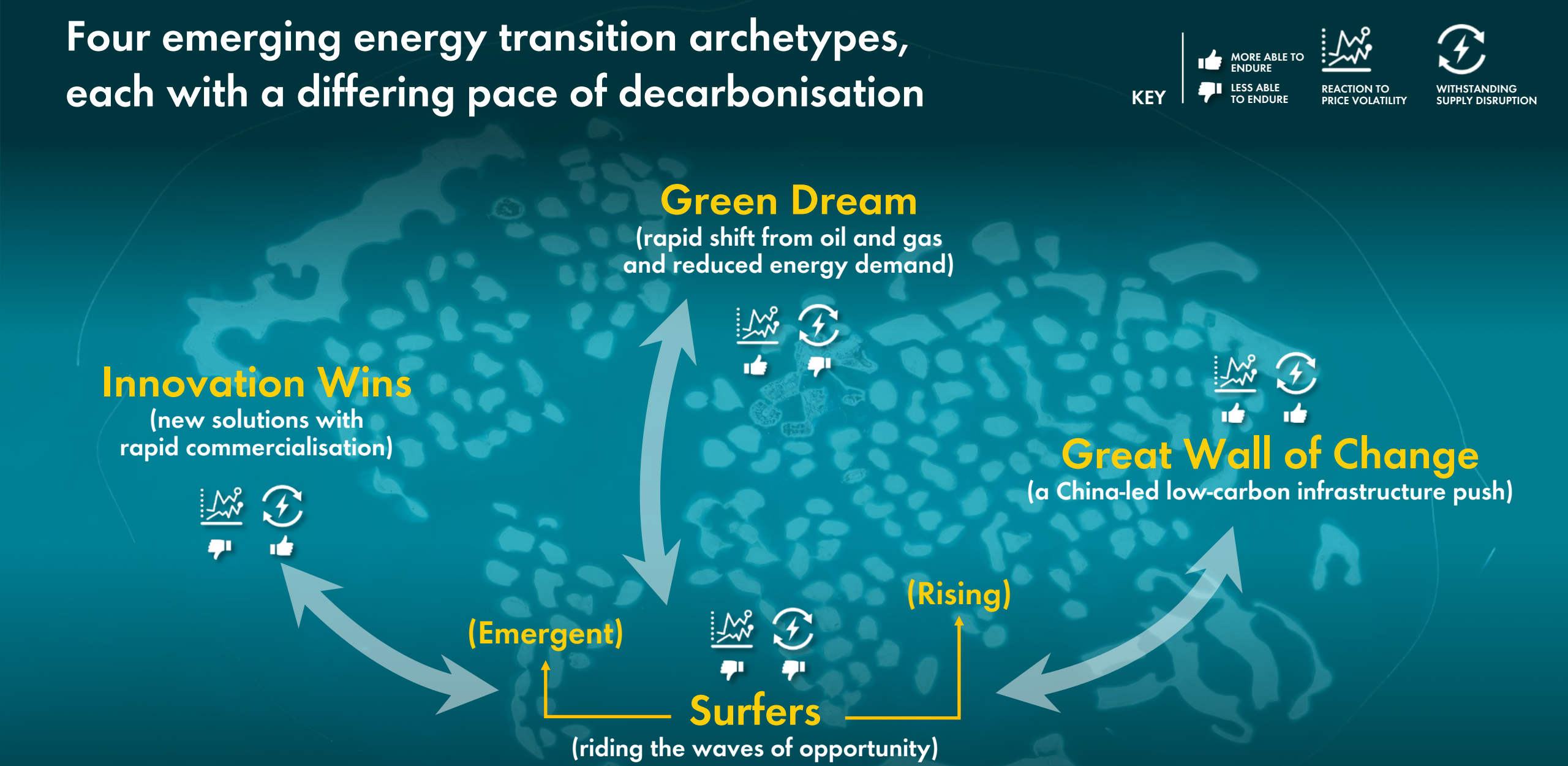


Accelerated technological change



Least developed economies need energy

Four emerging energy transition archetypes, each with a differing pace of decarbonisation



Two scenarios emerge, Sky 2050 and Archipelagos

As the security mindset takes hold and national interests take precedence a tension emerges between national climate pledges and what countries must do to address immediate energy concerns.

We are collectively entering a world of competitive transition.

Archipelagos
Security through self interest

The security mindset becomes entrenched worldwide. Sentiment shifts away from managing emissions and towards energy security.

- **Green Dream** – the energy shock speeds up transition. Supply fear is heightened.
- **Innovation Wins** – disruption in the old energy system offers new opportunities.
- **Great Wall of Change** – de-globalization supports internal energy transformation and strengthening.
- **Surfers** – shifting alliances offer immediate advantages and opportunities are taken.

Sky 2050
Security through mutual interest

Long-term climate security is the primary anchor, with specific targets to reach net zero by 2050 and limit temperature rise to 1.5°C in 2100.

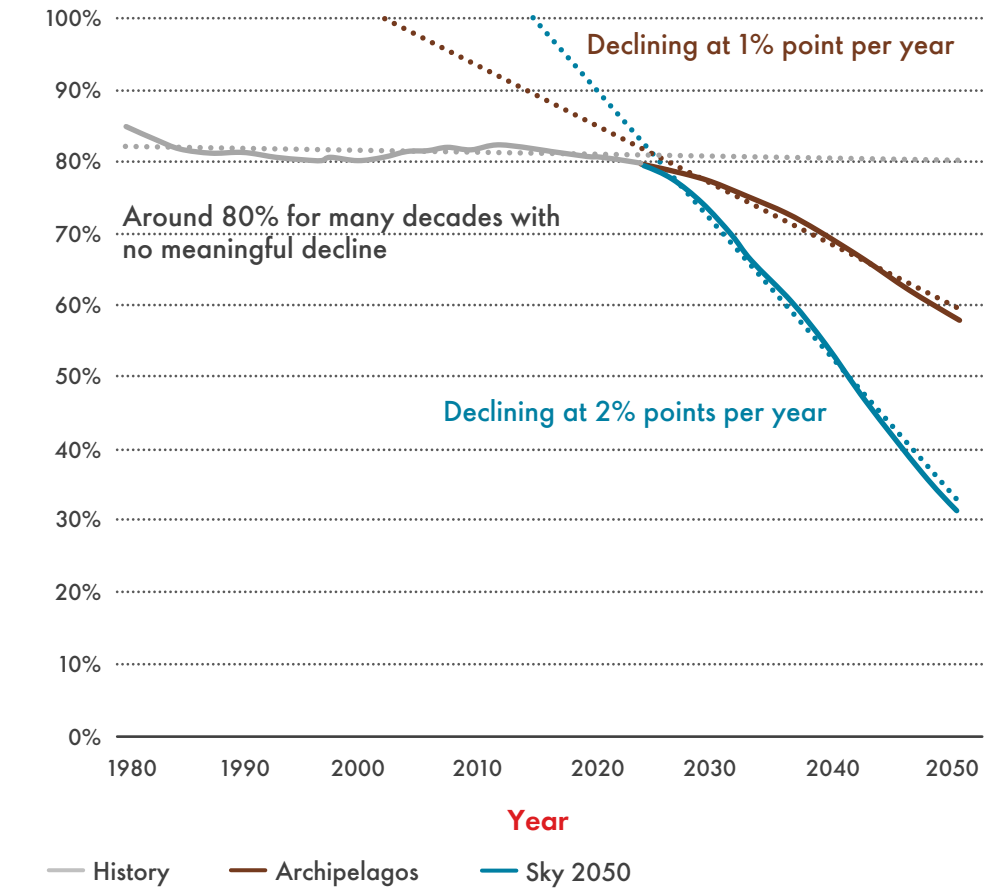
- **Green Dream**– applies global carbon pricing via border adjustment mechanisms.
- **Innovation Wins**– accelerated technology development through government funding.
- **Great Wall of Change** – enviable market position drives faster change in other regions.
- **Surfers** – intense global pressure to end deforestation, but finance becomes more available.

Primary energy in Sky 2050 and Archipelagos

The energy transition accelerates

- It becomes increasingly competitive as nations seek security of supply.
- Sky 2050 takes a wider view of security, with positive reinforcement leading to rapid change.
- Fossil fuels lose market share within the primary energy mix.
- Multiple energy transition tipping points emerge worldwide throughout the 2020s.

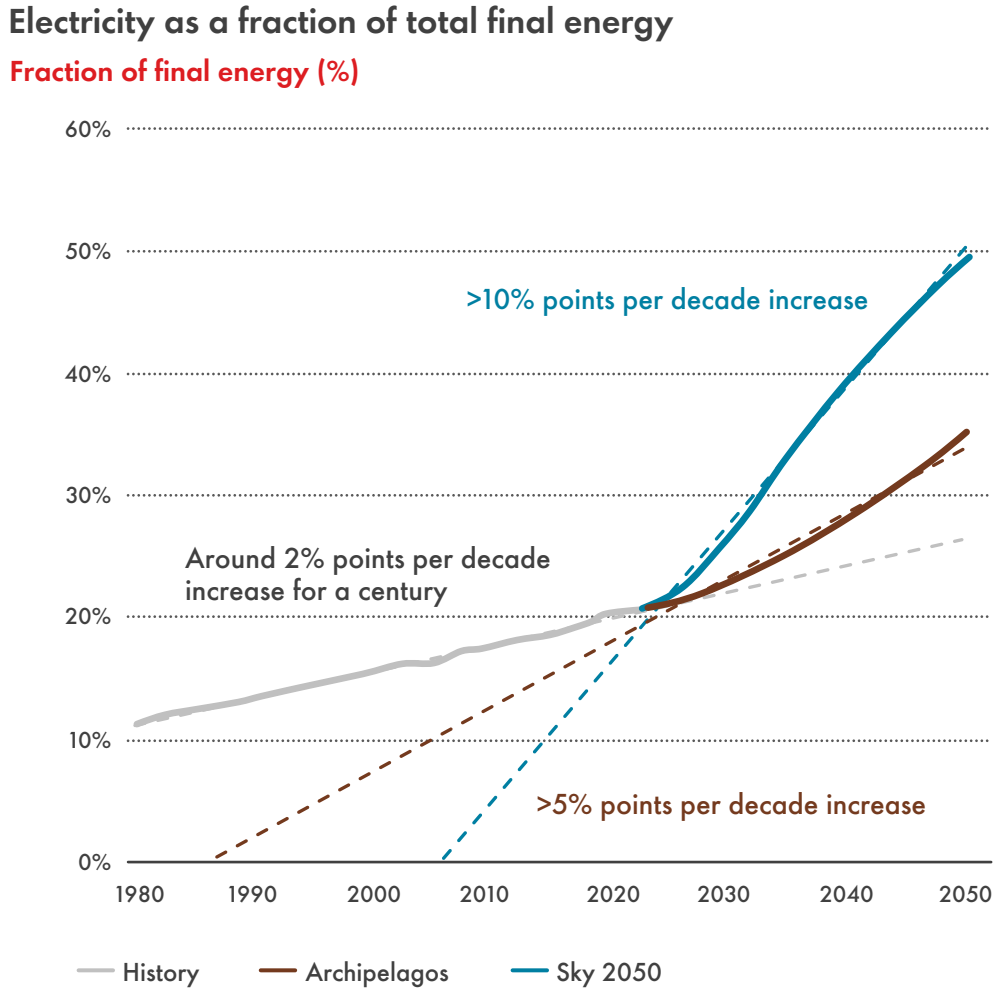
Oil, coal and gas as a fraction of total primary energy



In any scenario, the long-term electrification trend accelerates

The final energy system trends rapidly towards electricity

- A century long trend shifts gear in the 2020s.
- Electrification of transport leads the way:
  - Passenger vehicles.
  - Light road freight.
- Residential energy use trends towards full electrification, even for heating.
- Industrial energy use shifts more slowly, but still electrifies over time.



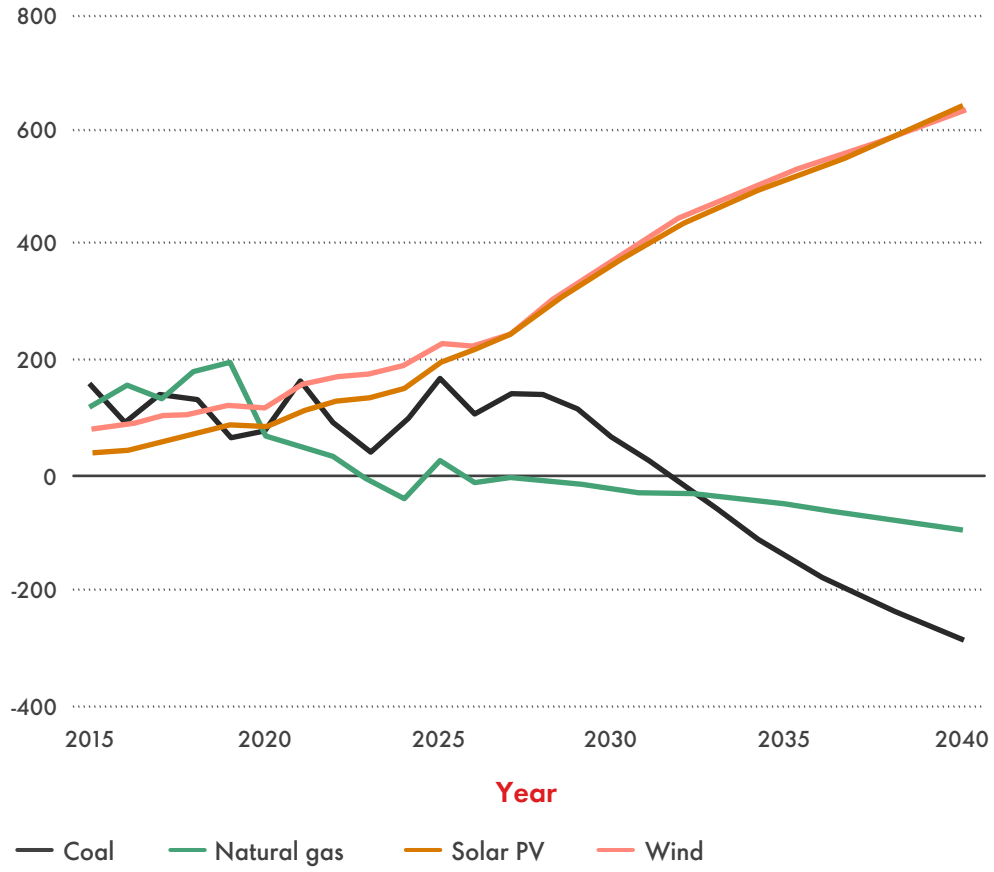
A renewable energy tipping point

Electricity generation is driven by the availability of renewables

- Solar PV capacity of over 200 GW is being added on an annual basis, delivering some 250-300 Terawatt hours (TWh) of electricity.
- In **Archipelagos** this grows to around 400 TWh in the early 2030s, greater than the early 2020s additions from coal and natural gas combined.
- Both coal and natural gas stop growing as sources of electricity into the 2030s, then decline sets in.

Annual change in global electricity generation **Archipelagos**

TWh per year (5-year moving average)



Molecular fuels remain important in some applications

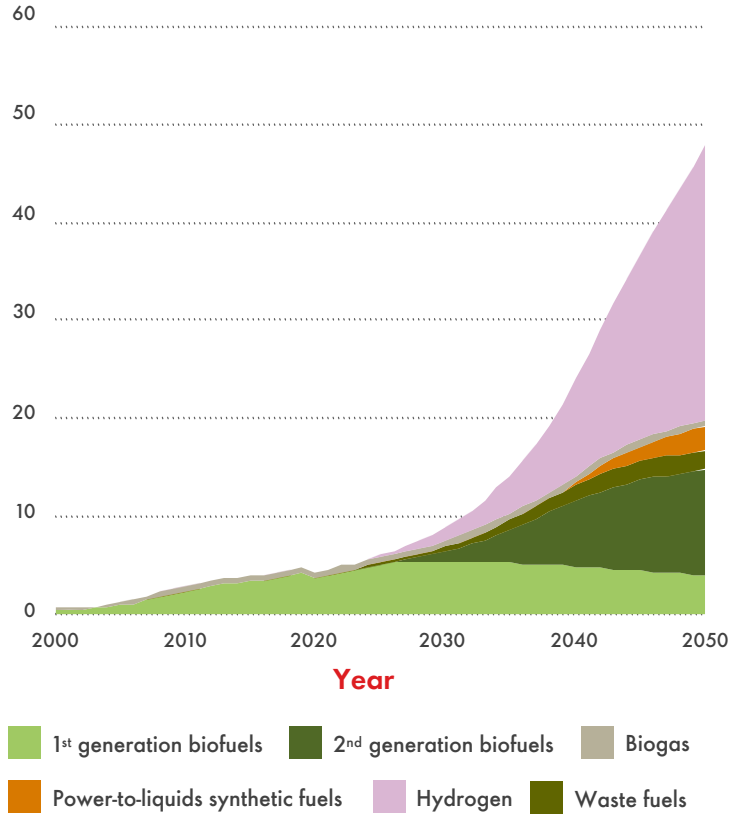
Biofuels, synthetic fuels and hydrogen all have increasing roles

- Liquid biofuels increase, but 1st generation ethanol peaks before 2035. 2nd generation fuels grow from 2025.
- Hydrogen emerges in the 2020s and is quick to ramp up in **Sky 2050**.
- In 2050, oil and gas derived final energy fuels still total 107 EJ in **Sky 2050** (vs. 230 EJ in 2019), over four times that of low carbon fuels.

Low carbon fuels in final energy

Sky 2050

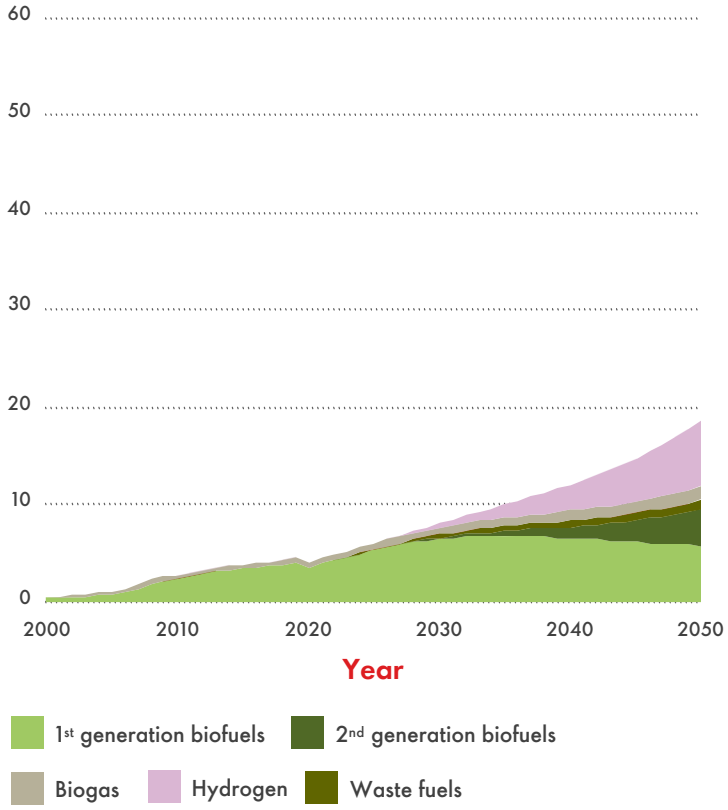
EJ per year



Low carbon fuels in final energy

Archipelagos

EJ per year

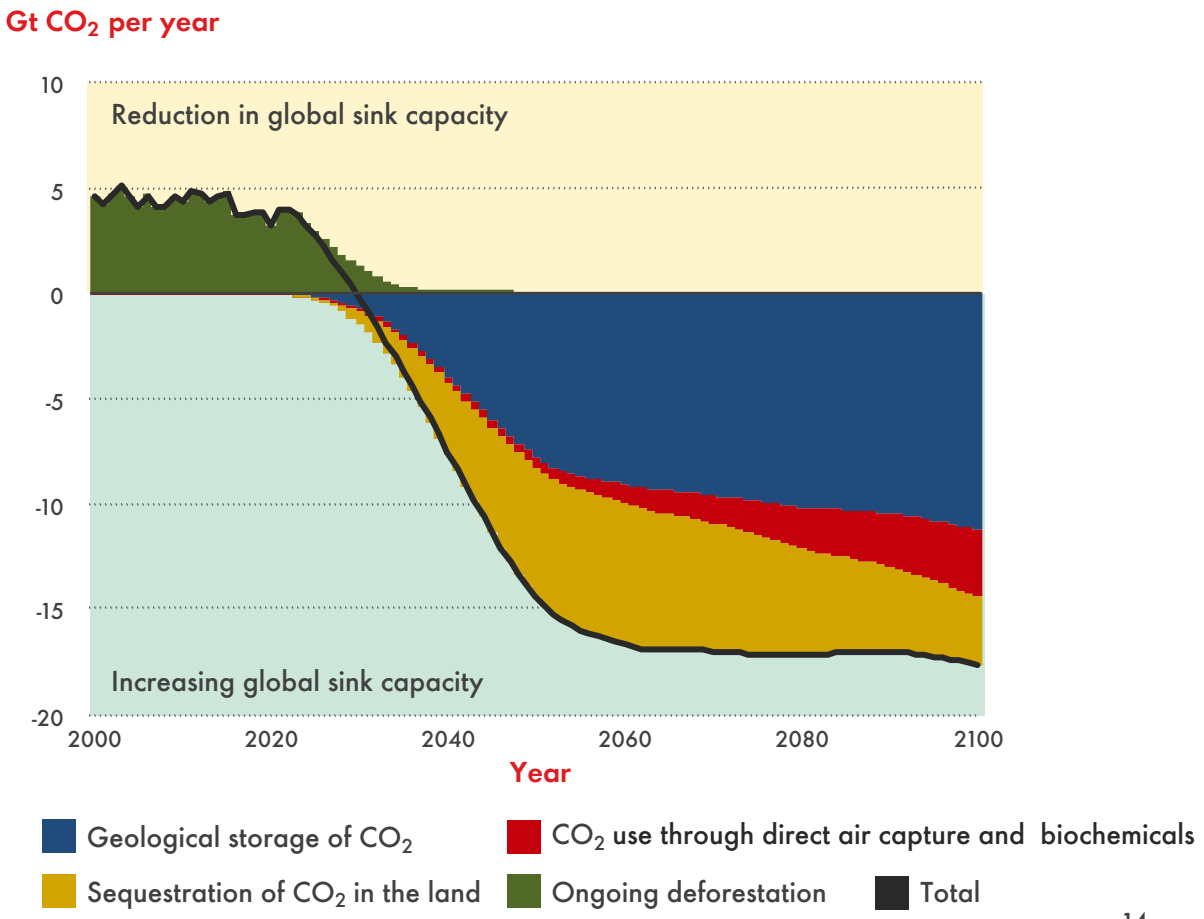


Sinks play a critical role in Sky 2050

In Sky 2050 570 Gt of CO_2 is stored geologically and land carbon is bolstered by 340 Gt (in CO_2 terms)

- Geological storage is the long-term mechanism for balancing remaining fossil-fuel use.
- Land carbon management is essential for a stable climate:
  - Stopping deforestation then restoration. An area the size of Mexico requires reforestation.
  - Managing soil carbon – most arable land comes under some form of carbon management through farming.
  - Sustainable business models need to emerge to support carbon farming.

Land use changes and the development of sinks Sky 2050



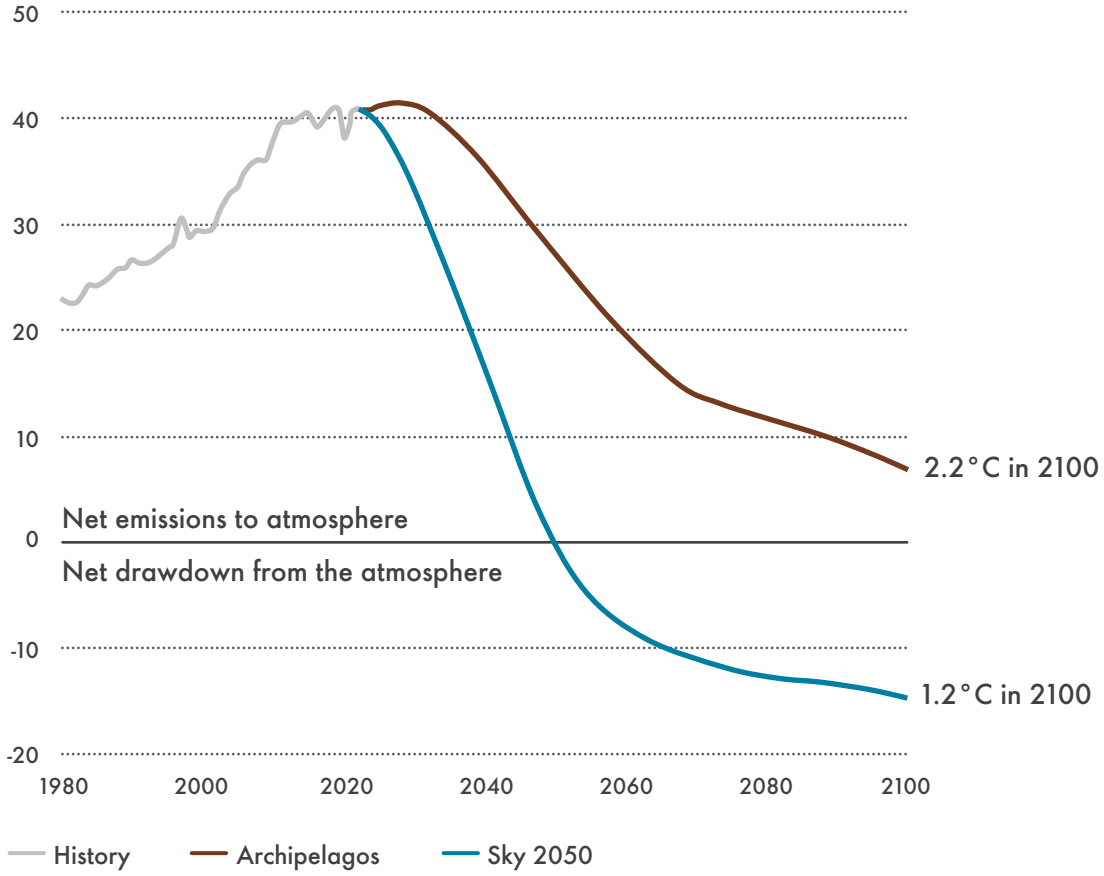
Features of Sky 2050 and Archipelagos

Net zero emissions (NZE) is an almost inevitable outcome

- Sky 2050 reaches NZE in 2050 (by design), combining energy and land use changes.
- By 2100, warming is less than 1.5°C in Sky 2050.
- Archipelagos reaches NZE early in the 22nd century but warming exceeds 2°C.
- Scenarios above 2.5°C no longer appear plausible given the anticipated pace of the energy transition.

Global anthropogenic CO_2 emissions

Energy, Industrial processes and land use, CO_2 emissions (Gt per year)

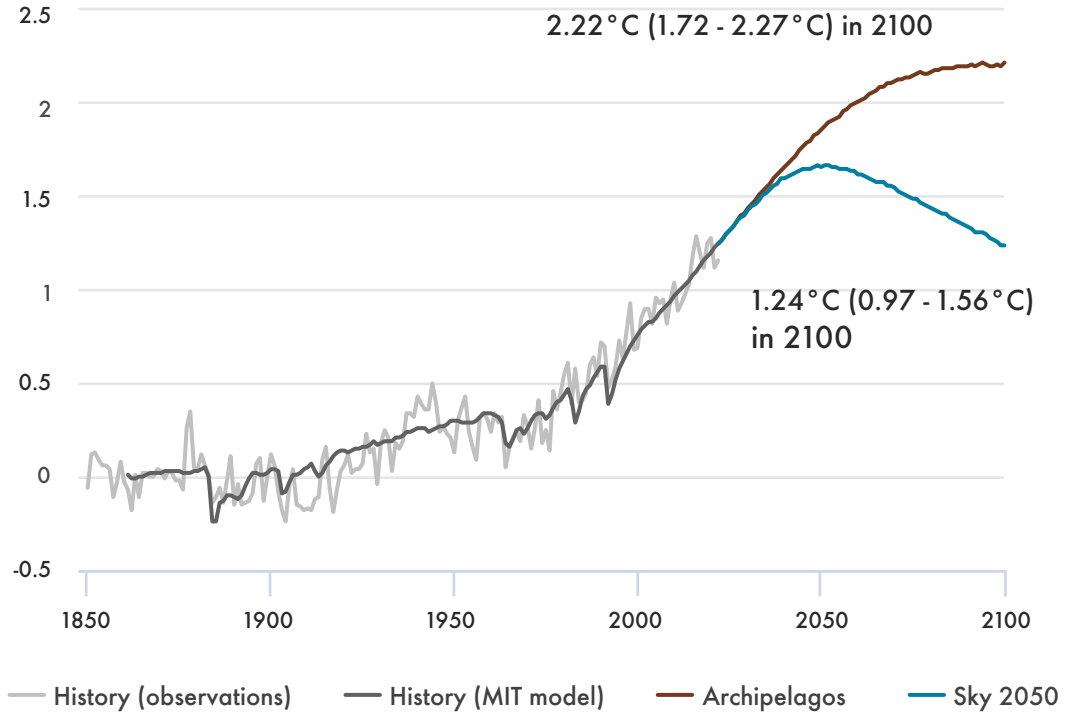


Temperature outcomes in Sky 2050 and Archipelagos

Sky 2050 is consistent with the Paris Agreement

- Sky 2050 is an overshoot 1.5°C scenario, peaking at 1.67°C in 2049, falling to 1.24°C by 2100.
- It meets the IPCC AR6 definition for a 1.5°C scenario with high overshoot.
- According to MIT's model, in 2023, the global mean surface temperature is 1.27°C above 1850-1900.
- Both scenarios pass 1.5°C by 2034.
- In Sky 2050, the temperature in 2100 is almost the same as the world experiences in 2023.

Global mean surface temperature above 1850-1900 baseline: Sky 2050 and Archipelagos



Historical temperature data are taken from HadCRUT5 (November 2022). In these scenarios, we use global mean surface temperatures (ensemble medians) as modelled by the MIT Joint Program (December 2022). The figures in brackets refer to the 'very likely' range, defined as the 90% interval.

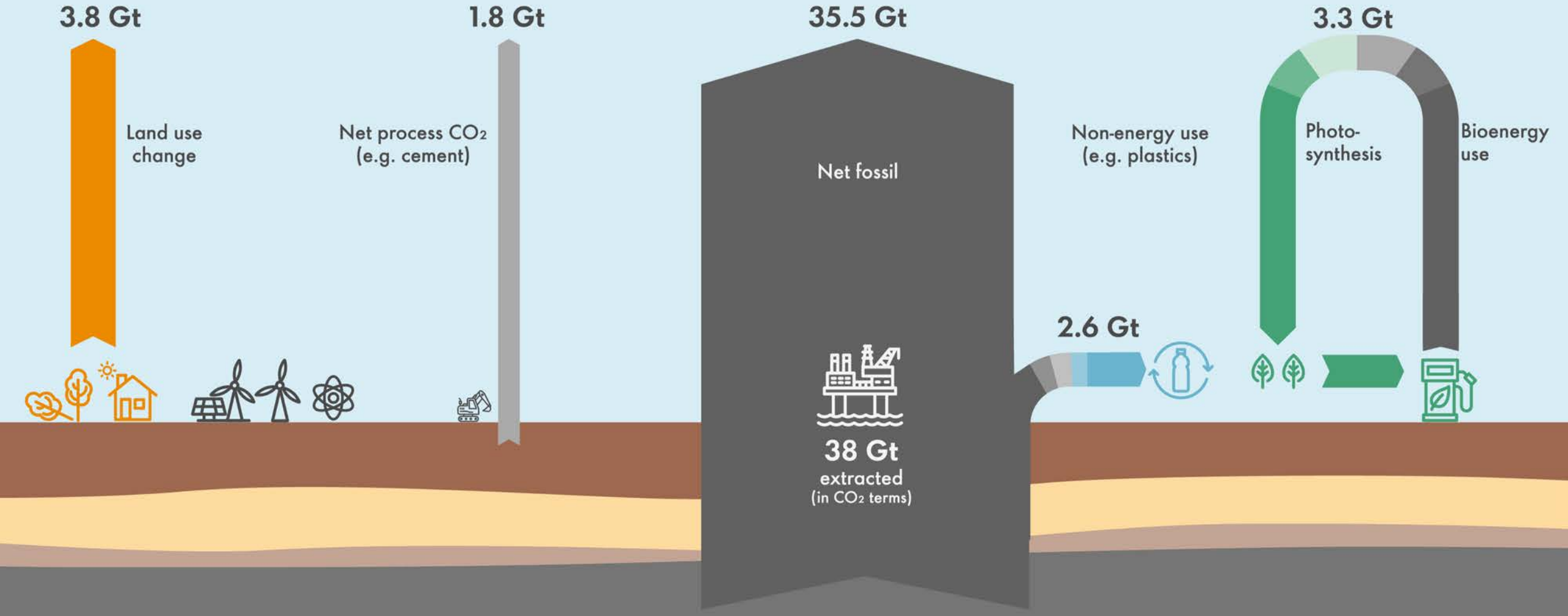
The Energy Security Scenarios
The world in 2050 and 2100

Sources and sinks of anthropogenic carbon (as CO_2) in 2019

Positive emissions of 41 Gt CO_2 per year

		Flow (Gt/year)		Stock
Sources	Coal, oil, gas extraction	38	+39.8	Atmosphere build of 41 Gt CO_2 in 2019
	Limestone for cement	1.8		
Sinks	Land use and agriculture	3.8	+1.2	
	CCS + DACCS	~0		
	Bioenergy + CCS (BECCS)	~0		
	Products in society	- 2.6		

2019

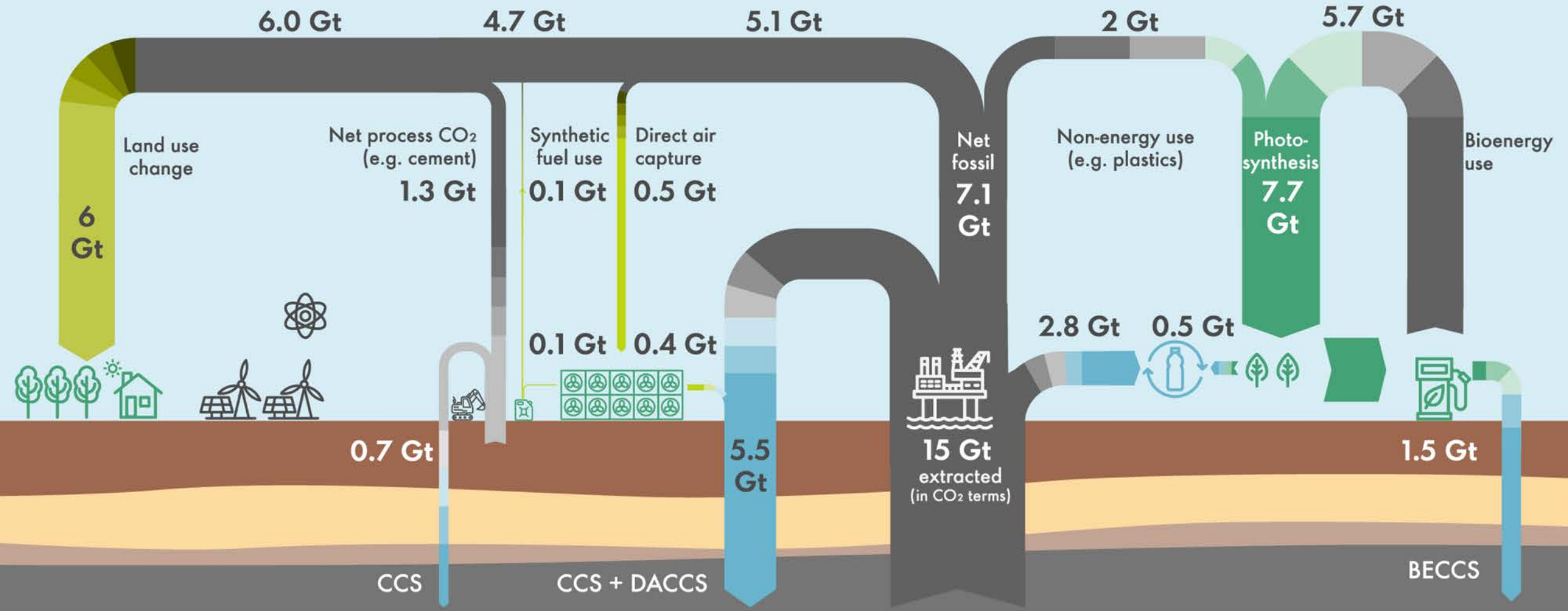


Sources and sinks of anthropogenic carbon (as CO_2) in Sky 2050

Net zero emissions in 2050

		Flow (Gt/year)		Stock
Sources	Coal, oil, gas extraction	15	+17	Net zero emissions in 2050
	Limestone for cement	2		
Sinks	Land use and agriculture	- 6	- 17	
	CCS + DACCS	- 6.2		
	Bioenergy + CCS (BECCS)	- 1.5		
	Products in society	- 3.3		

2050

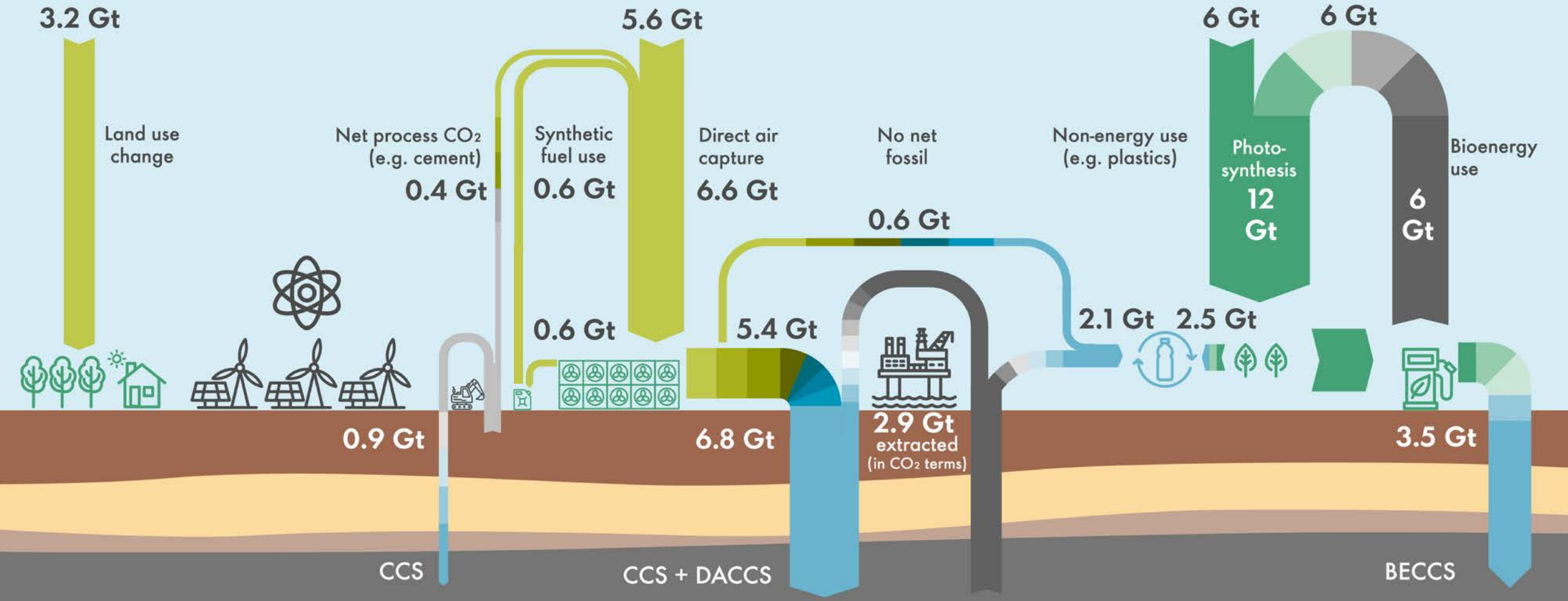


Sources and sinks of anthropogenic carbon (as CO_2) in Sky 2050

Net negative emissions of 14.8 Gt CO_2 per year in 2100

		Flow (Gt/year)		Stock
Sources	Coal, oil, gas extraction	2.9	+4.2	Atmosphere drawdown of 14.8 Gt CO_2 In 2100
	Limestone for cement	1.3		
Sinks	Land use and agriculture	- 3.2	- 19	
	CCS + DACCS	- 7.7		
	Bioenergy + CCS (BECCS)	- 3.5		
	Products in society	- 4.6		

2100



Concluding remarks

1. Countries with similar energy vulnerabilities behave in similar ways.
2. **Rising Surfers** and the energy pathway they take are key to limiting warming.
3. The world switches to electricity at an accelerated pace, but hydrogen and bioenergy have important roles to play.
4. Fossil fuels inevitably lose market share.
5. Emissions do not initially fall quickly, with a 12% reduction in CO_2 emissions by 2030 achieved in **Sky 2050** (vs. 2010).
6. Overshoot of 1.5°C appears almost inevitable, but recovery is possible in the second half of the century. The world must remove carbon dioxide from the atmosphere at large scale.
7. There is a significant emissions gap between the scenarios, but society is nevertheless heading towards net-zero emissions.
8. The timing of net-zero emissions is dictated by policy efforts and the business, consumer relationship.