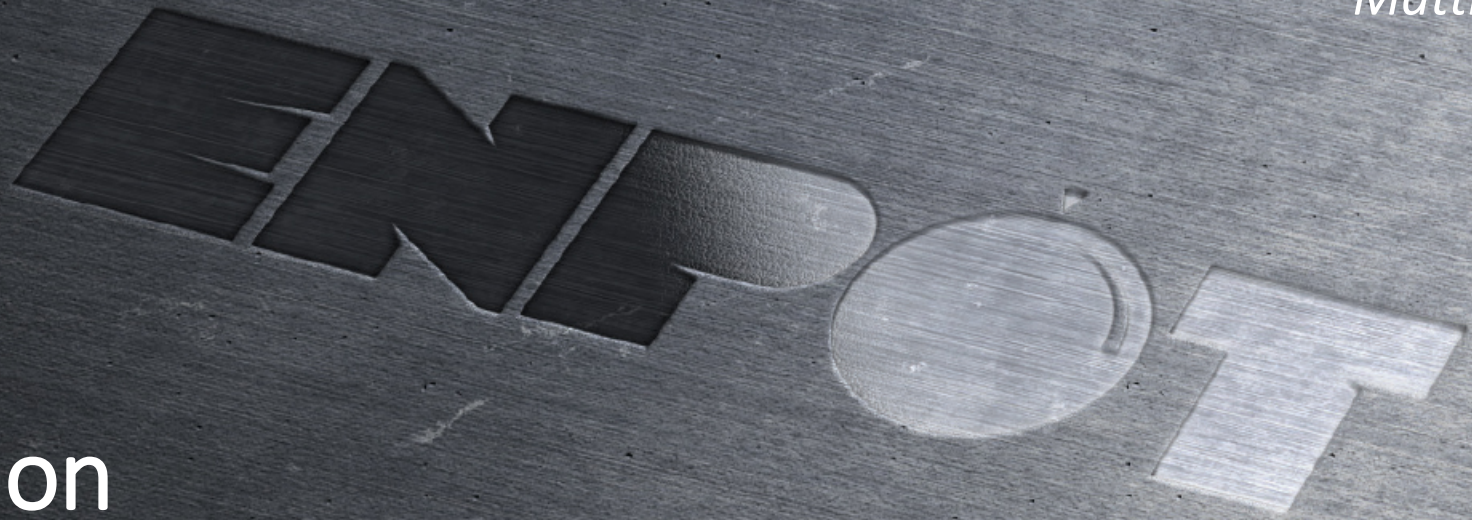
Presenter: Geoff Matthews
Authors: Dr. Mark Dorreen, Dr. Nick Depree, Geoff Matthews.



Aluminium Production Pathway to Zero Carbon 2050

- *What does the Pathway look like?*
- *Is it achievable?*

Note: This presentation has been updated from the original following feedback from the IAI

ENERGIA POTIOR

- *More Effort Needed (IEA)*

IEA Tracking Report June 2020

Getting on track with Sustainable Development Scenario (SDS) will require efforts on multiple fronts:

1. Greater secondary production (recycling)
2. Reduced emissions from primary production and combustion processes
3. Decarbonising power supply.

Source: https://www.iea.org/reports/aluminium

This presentation concentrates on primary and secondary production (excludes alumina refining)

Pathway requires all parts of the aluminium production chain to help with the heavy lifting

Photo by Dansnguyen.

For example, it could be argued that if aluminium production was 100% renewable then energy intensity doesn't matter. We have taken the approach that in the end all efforts will be required. There are no free rides.

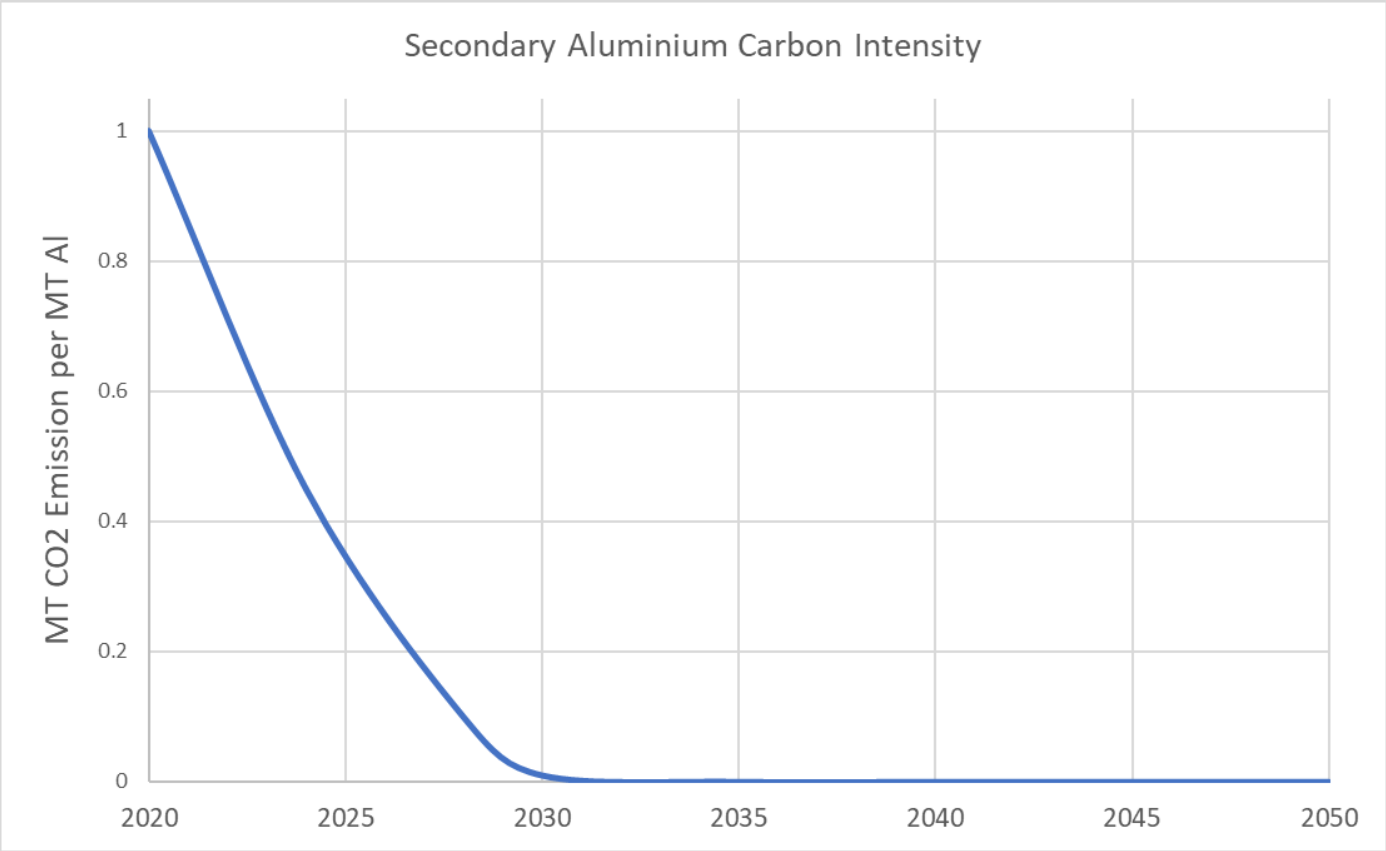
Compared to primary aluminium there are no step changes needed to the process, just conversion of process fuel sources to renewables, as well as contracting renewable power supply

Pathway to zero carbon emissions for aluminium recycling relies on four things:

1. Sourcing electricity from renewable sources to eliminate scope 2 emissions
2. Increased collection (although with long-life span products new production will always be necessary)
3. Conversion to green hydrogen reduces combustion carbon emissions effectively to zero
4. And if you want to take it one step further - decarbonisation of the transport sector to reduce scope three emissions (one of the five hard-to-abate sectors).

Sources: https://www.dnvgl.com/news/dnv-gl-launches-hydrogen-industry-consortium-to-reduce-carbon-emissions-from-manufacturing-181919
www.nzhydrogen.org

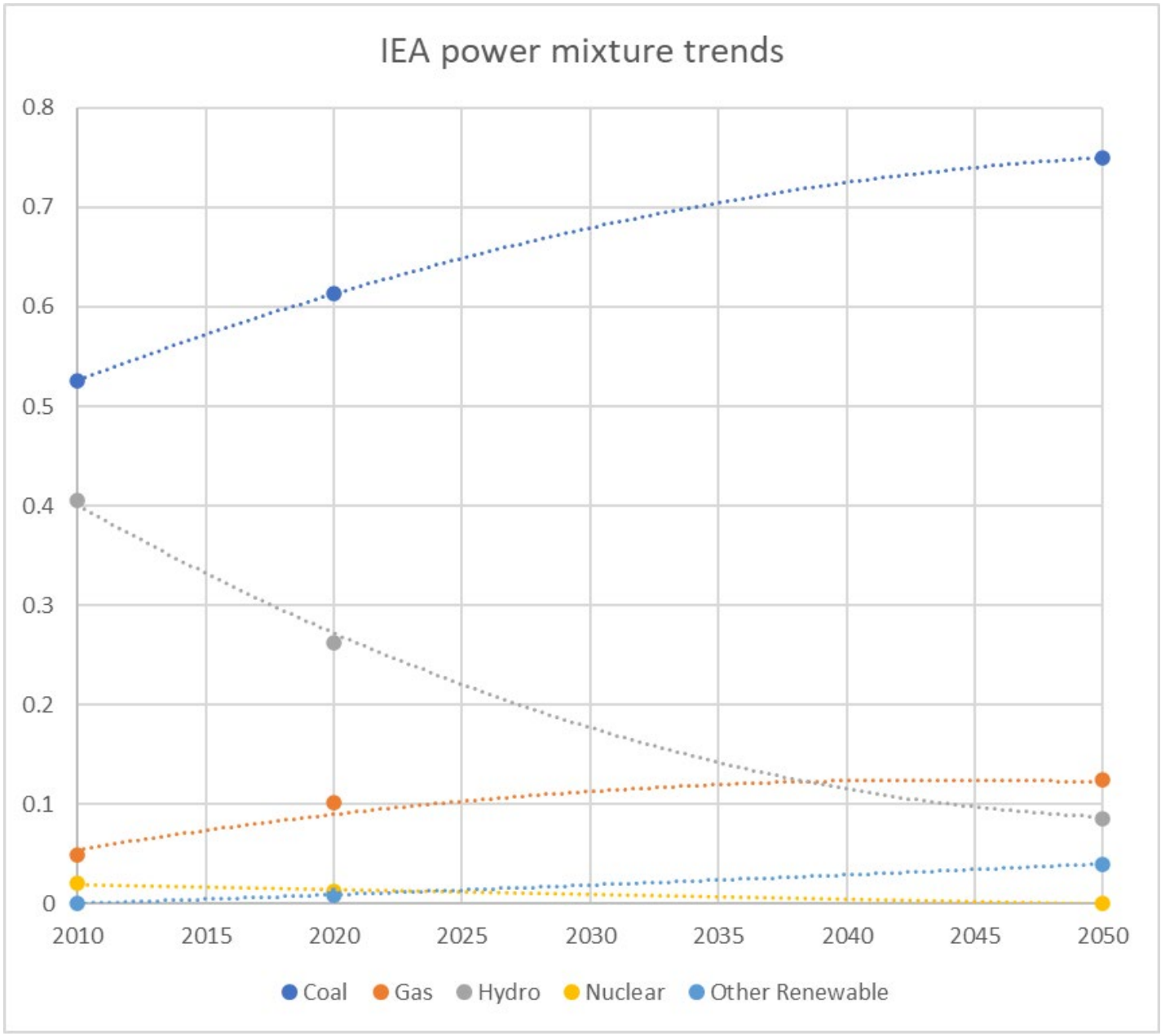
Zero net carbon from scope 1 and scope 2 emissions should be possible by 2030



- Renewable energy generation is becoming increasingly available to purchase in most markets, although increased ‘freedom-of-renewables’ is still required in some markets.
- Investment in hydrogen R&D is starting to ramp up to the level required to deliver material advancements in hydrogen’s industrial process heat potential.

Primary Aluminium Production

The current energy mix trajectory shows a continued increase in coal and diminishing percentage of ‘green’ aluminium



Sources: https://www.iea.org/reports/aluminium

Our current trajectory - high growth scenario (3.8%)

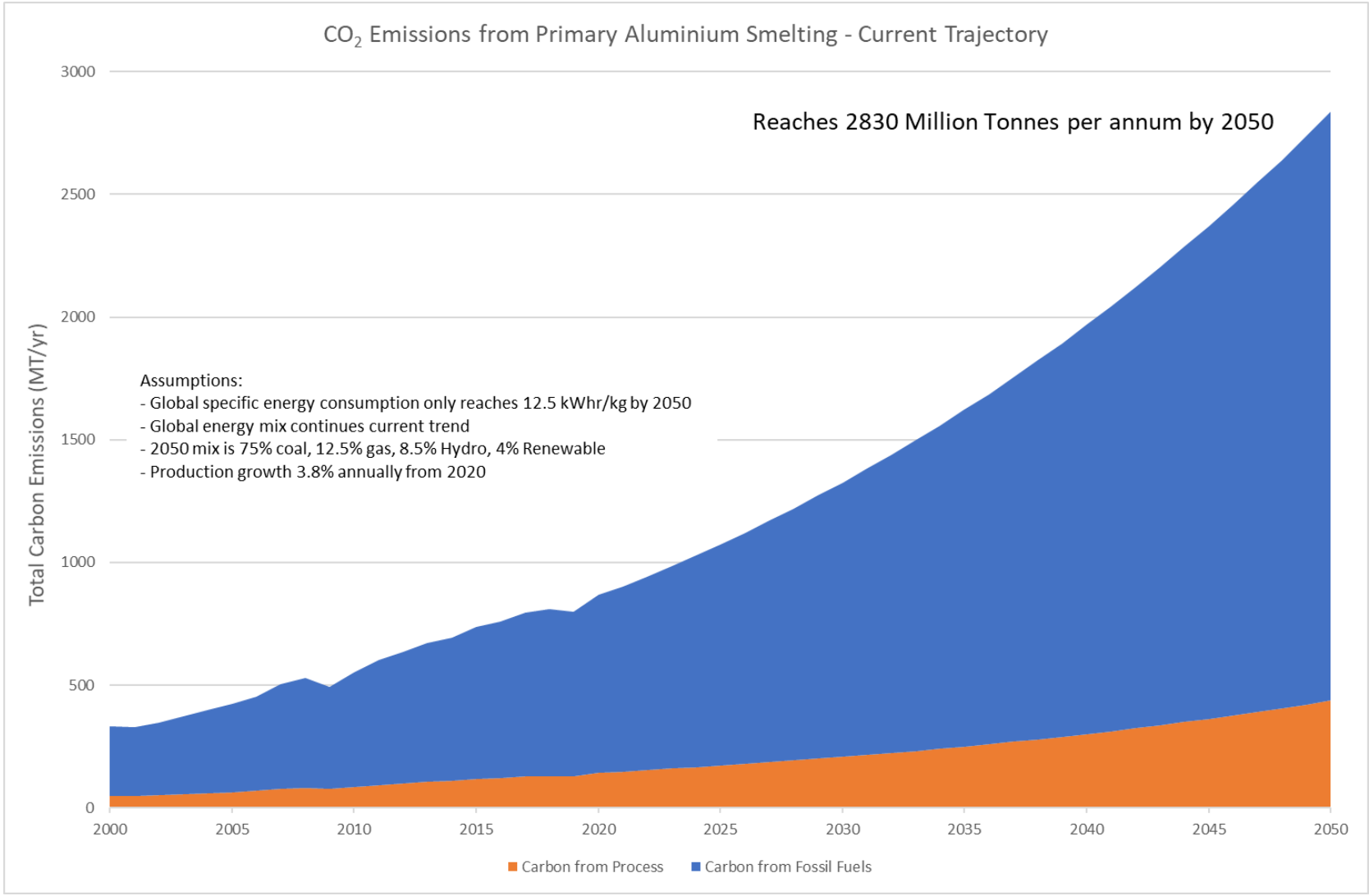
Contributes 52.7 billion tonnes of CO_2 into the atmosphere from 2020 – 2050.

By 2050 Al smelting will be the consumer responsible for 100% of the CO_2 from fossil fuel power generation globally.

This is equivalent to over 90% of the CO_2 emissions from all of the passenger vehicles in the world today.

It makes the decarbonization-effect from light-weighting an urban myth.

This scenario is not only unsustainable, but it is unacceptable.



Sources: An initial assessment of the impact of the covid-19 pandemic on global aluminium demand, 18 May 2020, CM Group.
http://www.world-aluminium.org/statistics/primary-aluminium-smelting-power-consumption/
https://www.eia.gov/tools/faqs/faq.php?id=74&t=11
https://www.europarl.europa.eu/news/en/headlines/society/20190313STO31218/co2-emissions-from-cars-facts-and-figures-infographics
https://www.carbonbrief.org/mapped-worlds-coal-power-plants

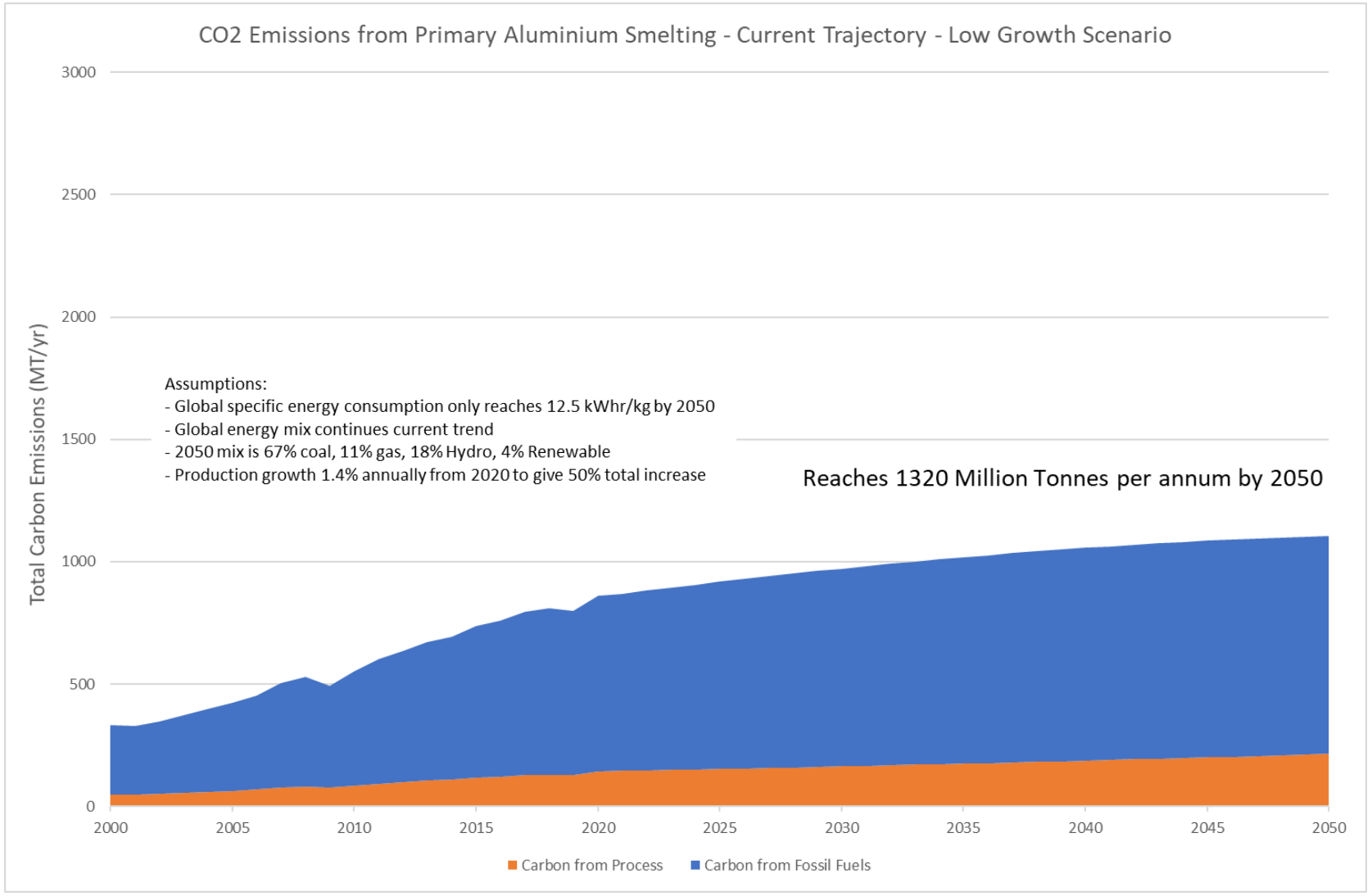
On this trajectory, aluminium production will become socially unacceptable and won't remain a relevant material

Low growth scenario @ 1.4% halves the problem, but still amounts to 34.3 billion tonnes cumulatively from 2020-2050.

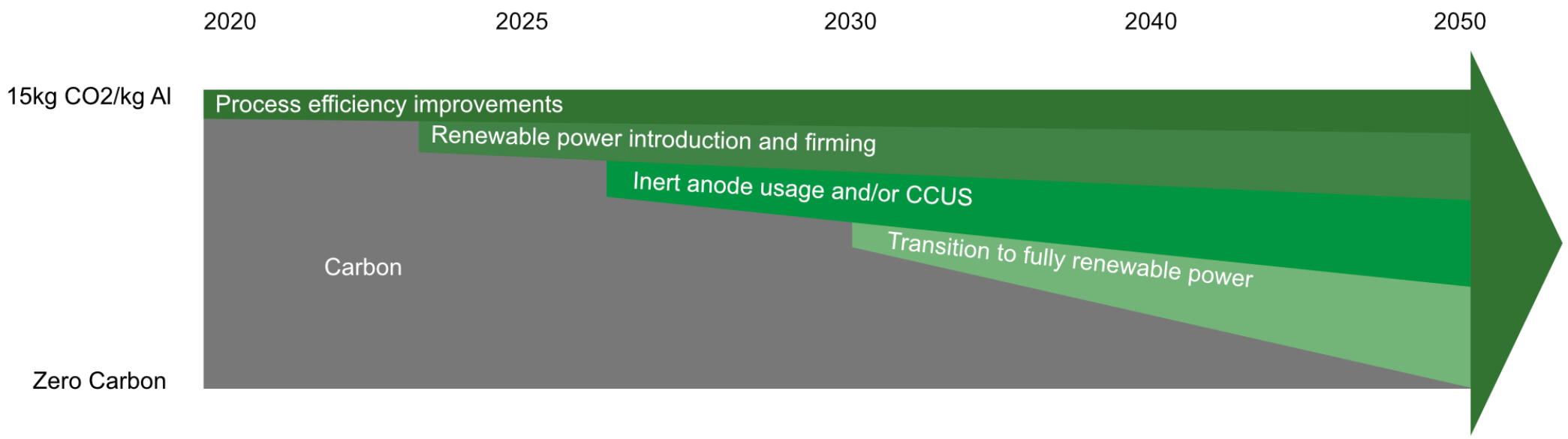
Reaching 1320 million tonnes per annum by 2050.

The equivalent of 43% of all the passenger vehicles in the world today.

…and will still be unacceptable on a global scale.

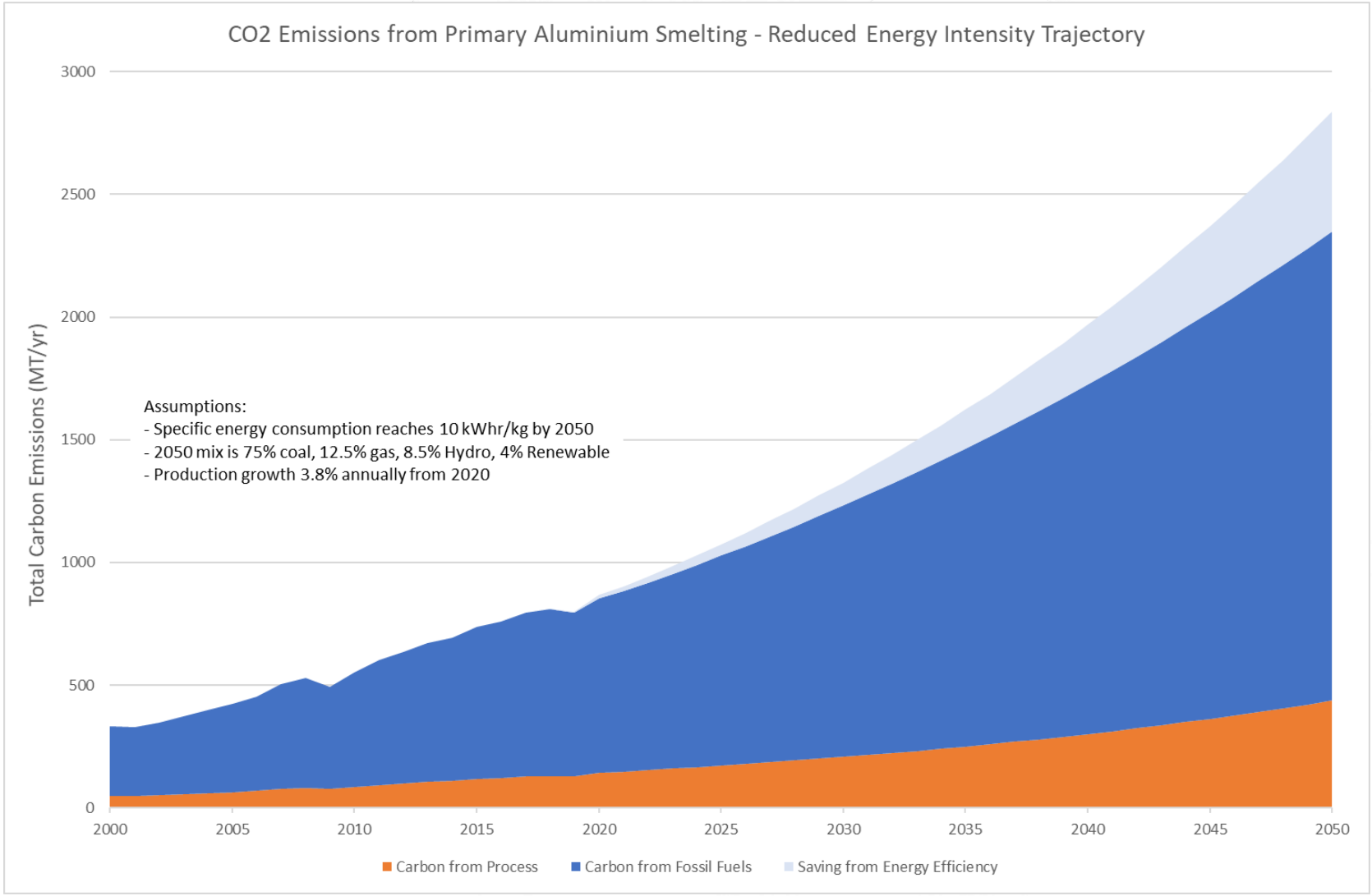


So, what are the options to achieve zero carbon by 2050?



Reducing Energy Intensity

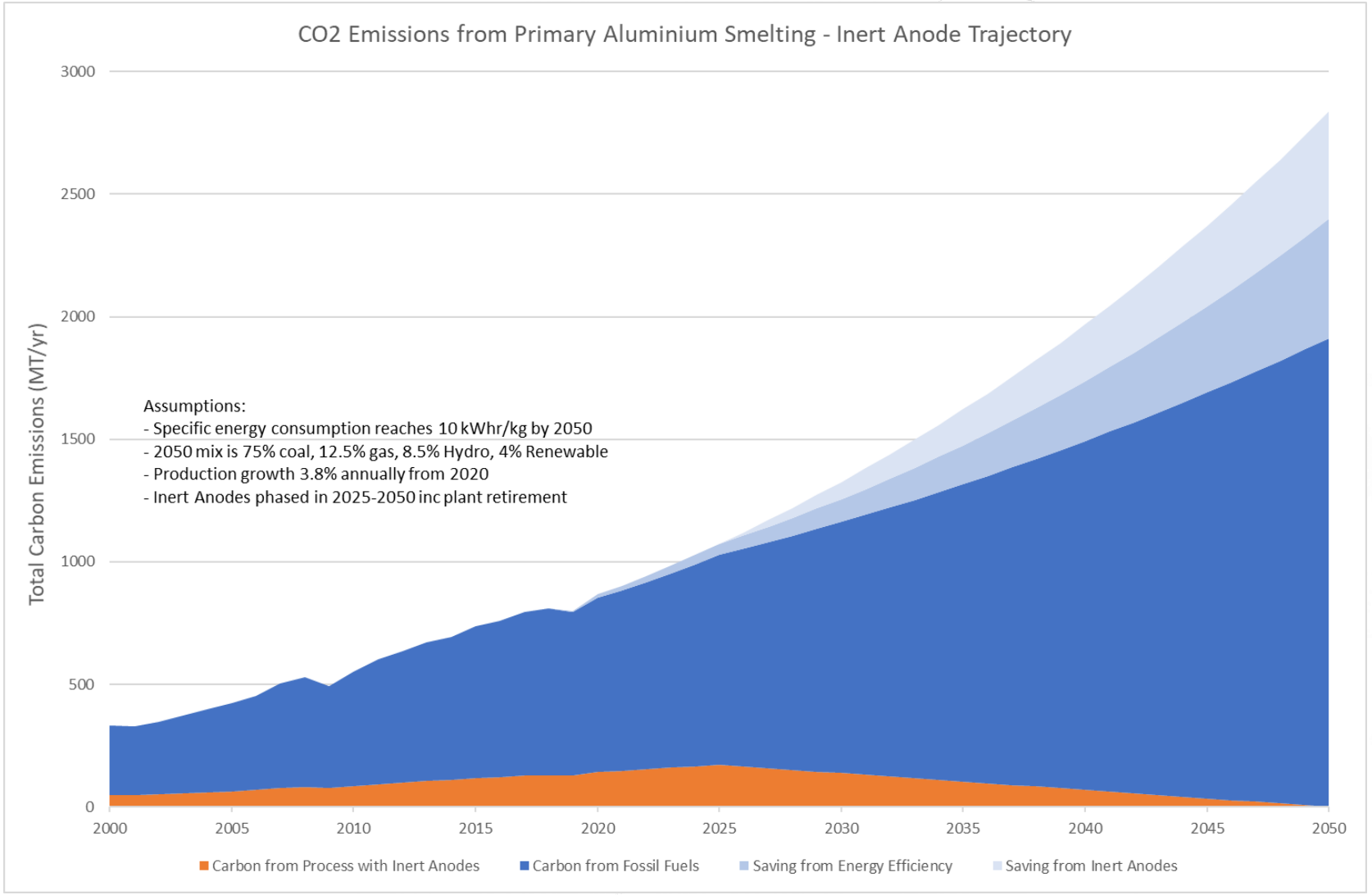
Reducing energy intensity of primary aluminium to a *present-day vision target* of 10kWh/kg without renewable energy doesn't meaningfully change the trajectory.



Sources: http://www.world-aluminium.org/statistics/primary-aluminium-smelting-energy-intensity/
https://www.lightmetalage.com/news/industry-news/smelting/karmoy-technology-pilot-world-leader-primary-aluminum-energy-efficiency/

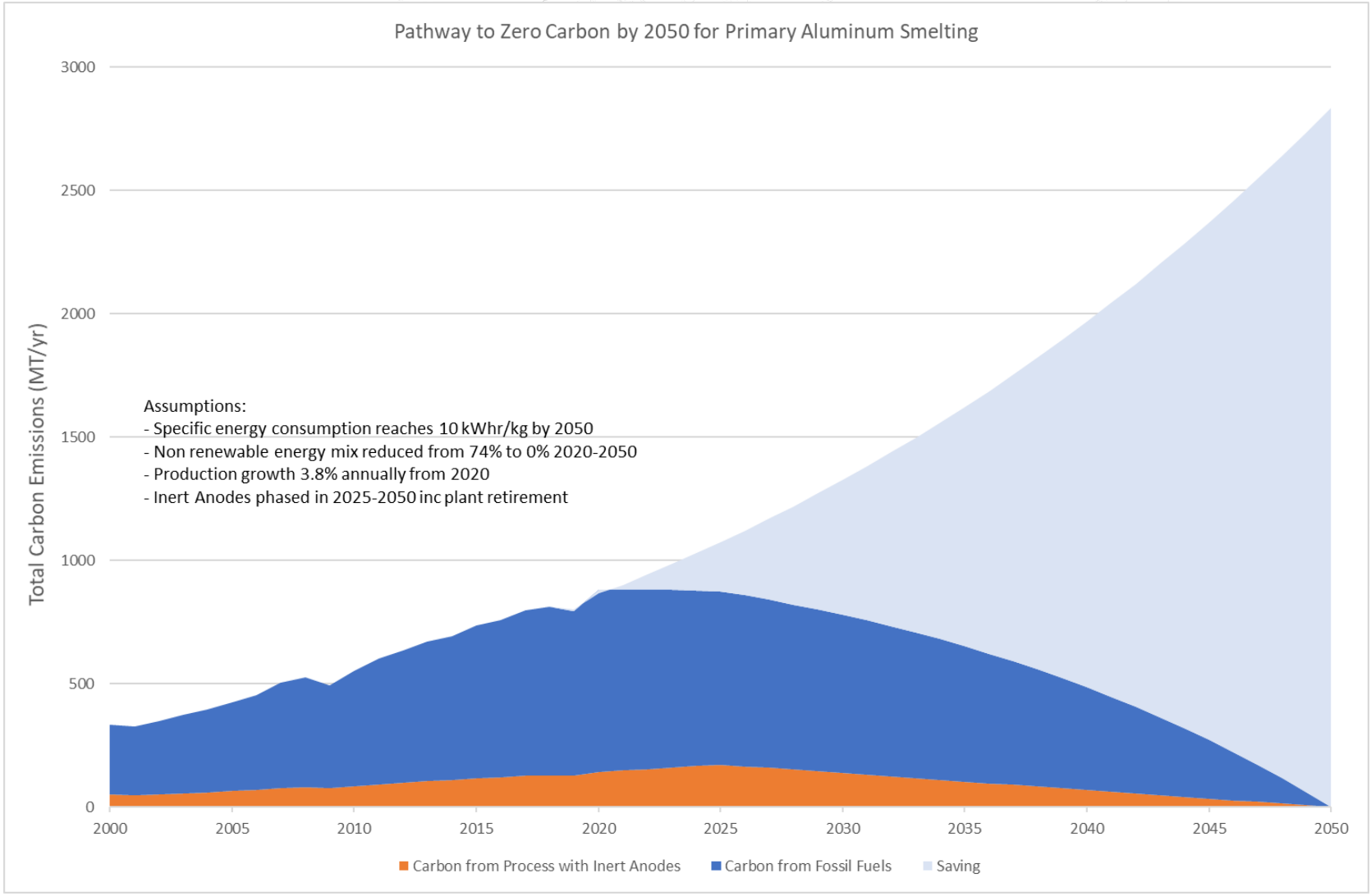
Inert Anodes

Relative to the emissions from power source, inert anodes don't really change the trajectory much either.



A credible pathway must include 100% adoption of renewable electricity generation

The only credible pathway to zero carbon by 2050 includes:
Inert Anodes,
Reduced Energy Intensity,
and
using 100% Renewably Generated Power.



The elephant in the room is firming of Variable Renewable Energy (VRE)

The cost of electricity in a decarbonised power system will be dictated by the cost of firming

Firming is how you can purchase (or trade) electricity to ensure constant supply and includes:

1. Short duration storage (batteries et al)
2. Long-term storage (pump hydro et al)
3. Demand side response (energy modulation et al)
4. Over-generation (installed capacity greater than peak use)
5. All of the above.

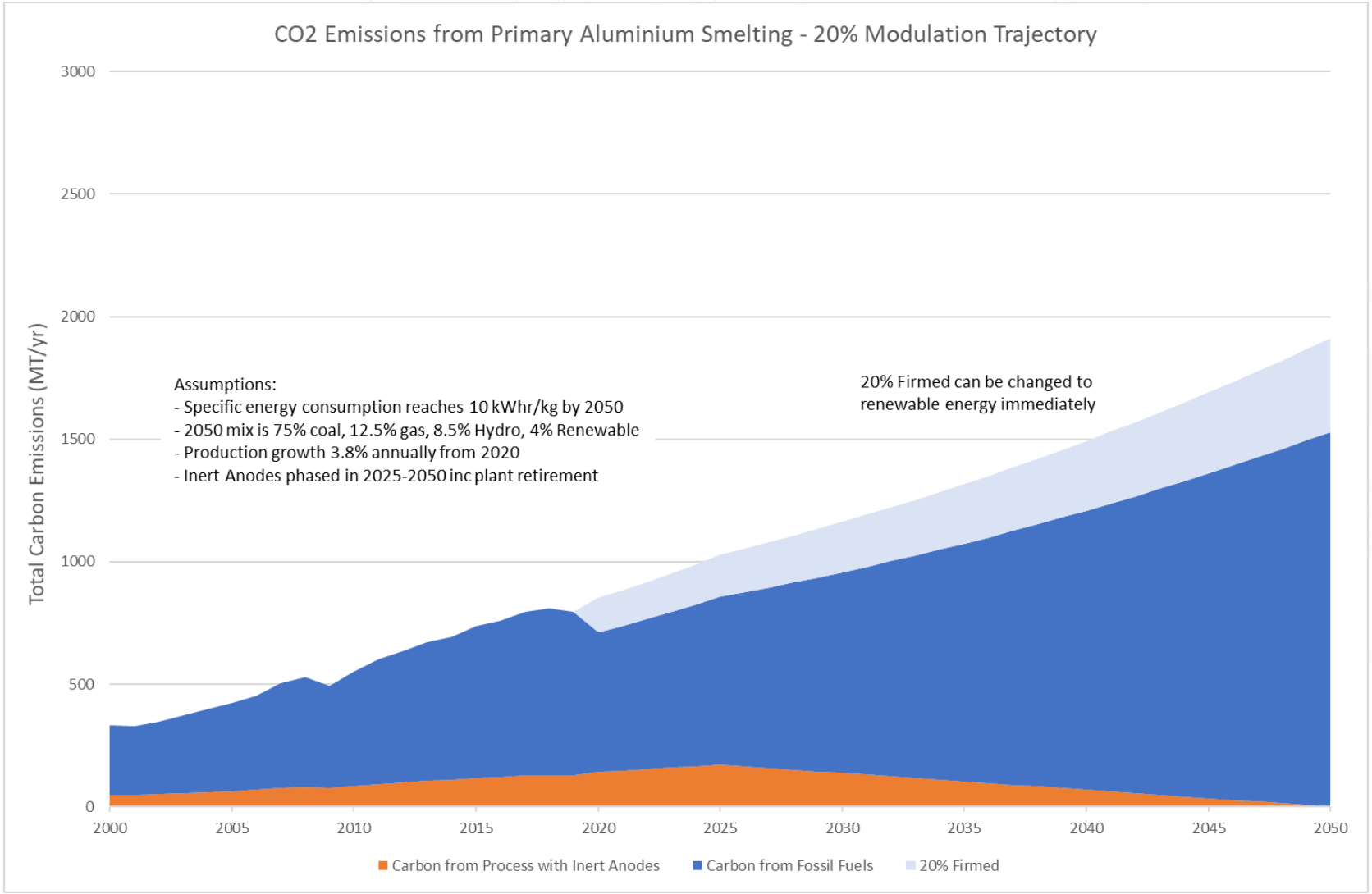
Aluminium Smelters are huge Virtual Power Plants (VPPs)

Another area of innovation is adapting aluminum production to provide flexibility to the power grid - IEA

Inherently capable of self-firming up to 40% of their electricity usage.

The first 20% of smelter self-firming is relatively straight forward with cost-effective retro-fitting of modulation technology for instantaneous downwards modulation of 20% below nominal set-point operations.

Cumulatively a reduction of 7.7 billion tonnes of CO_2 from 2020-2050.



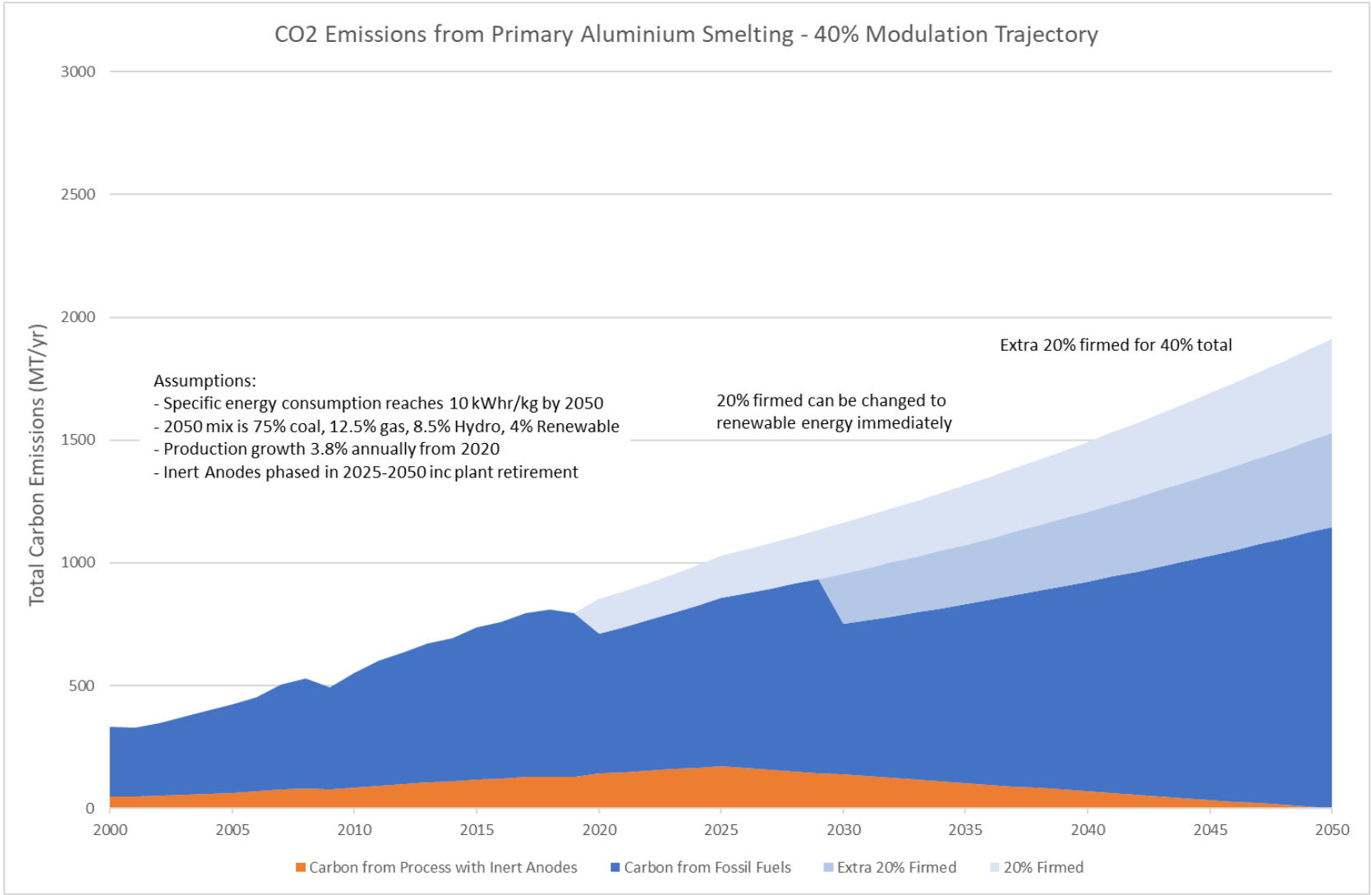
There will be significant over-generation in a decarbonised power system

For full modulation of 40%, a further 20% above nominal set-point operations is gained through upwards modulation.

Most likely to require smelter infrastructure upgrades.

Providing a further 6 billion tonne reduction in CO_2 from 2020-2050.

*The bonus is that much of this upwards modulation will be at times of low-cost or even zero cost electricity.

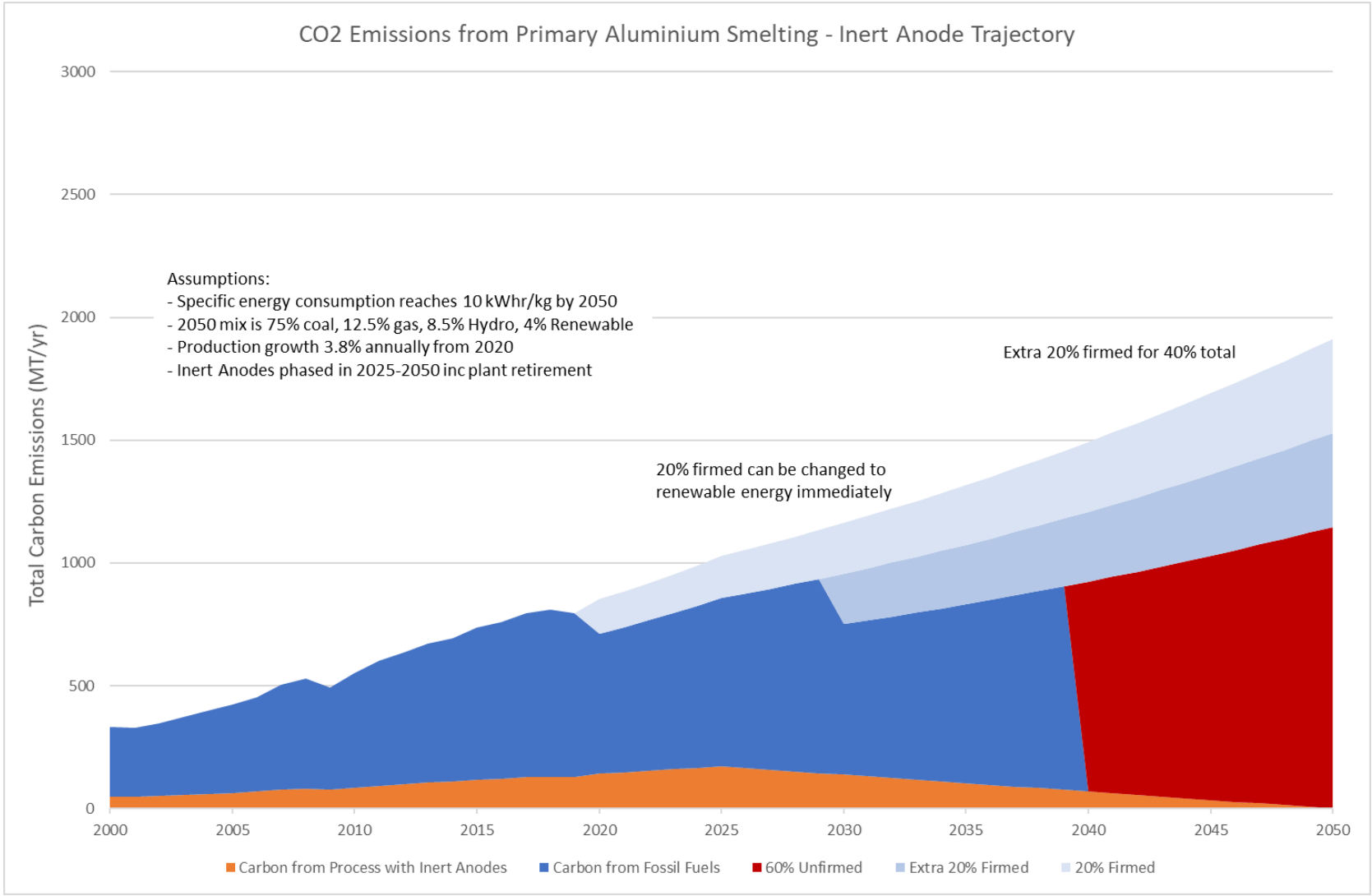


The last 1000 million tonnes is more difficult

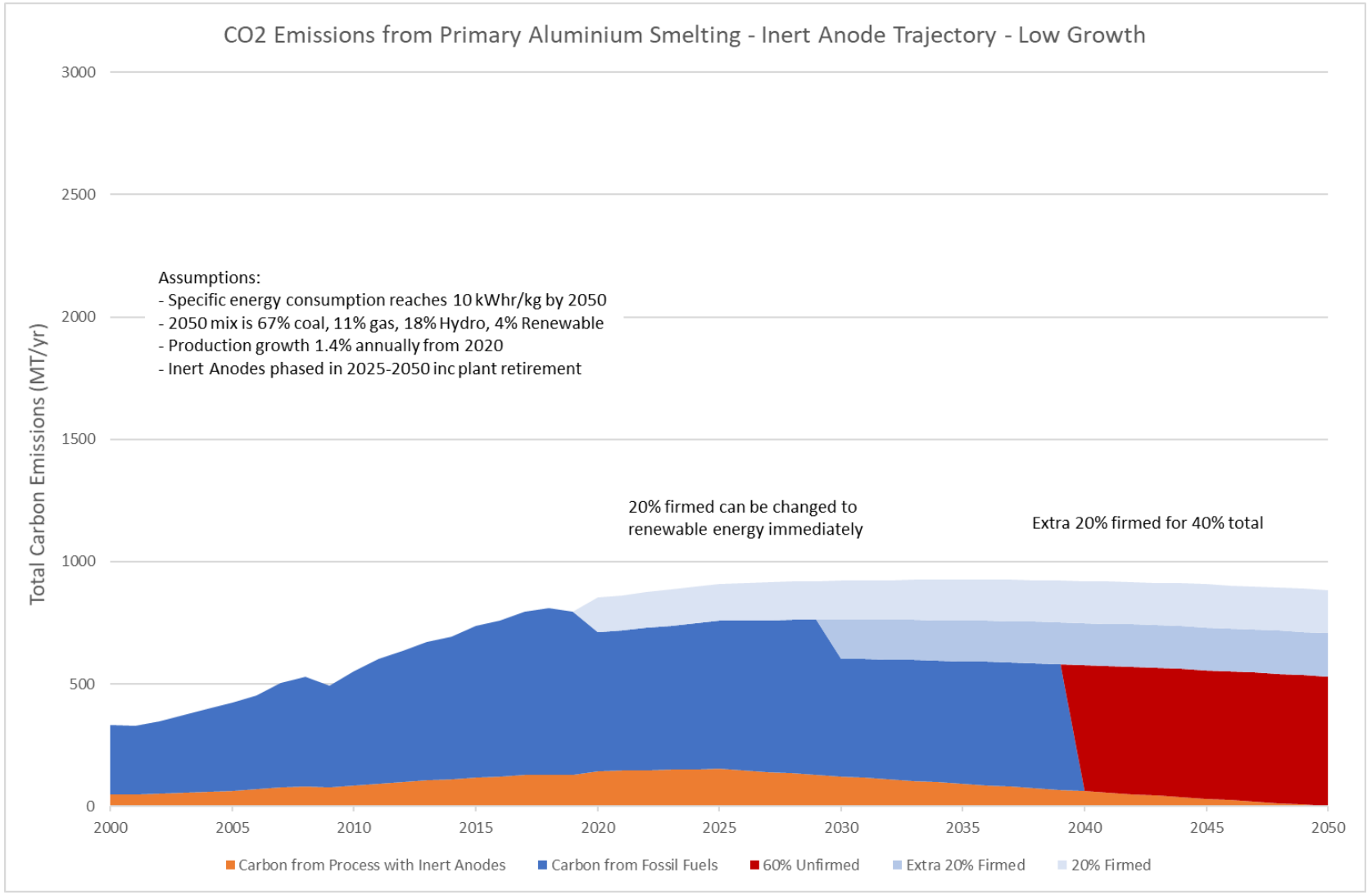
Will require collaboration with other users in the electricity grid, new purchasing arrangements, and technological innovation in the power system.

New technologies will be required to bridge the gap in supply and demand.

Including: less variable renewable generation, new energy storage options, and increased participation in demand side response services.



Low growth scenario is still over 500 million tonnes of CO2 annually by 2050

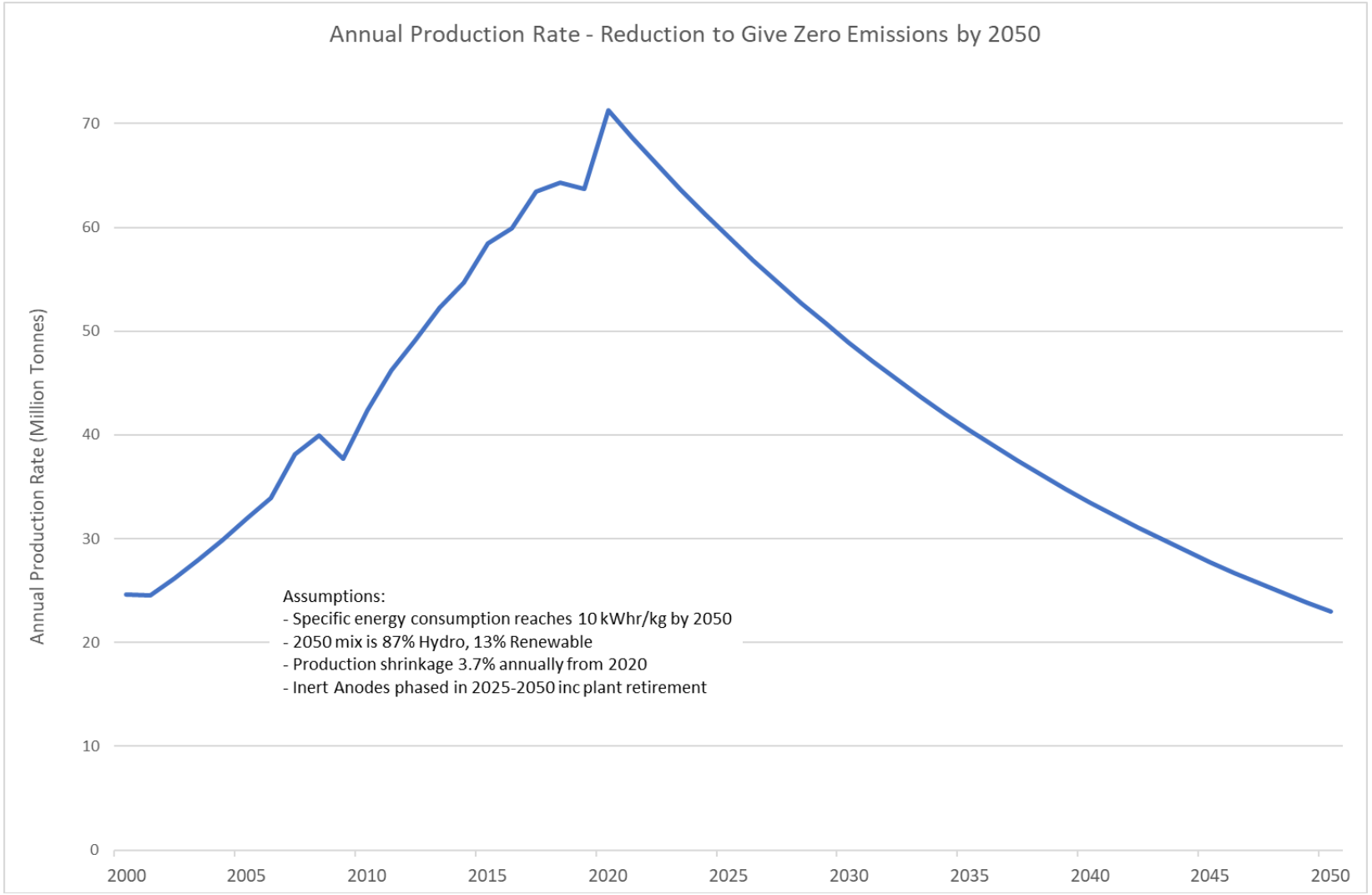


What if we don’t adapt to 100% renewable energy?

Annual production must decline by 3.7% per annum, reducing total annual production to only use existing hydro and geothermal plus current trend renewables.

Production decreases from 71 million tonnes today to 23 million tonnes in 2050, rolling back the last 20 years of growth.

Most likely stimulating replacement of aluminium as a relevant material.



At what estimated cost?

- Inert anodes and 10kWh/kg

= US$128 billion for 11 billion T saving

assuming 50% of today's existing smelting capacity is replaced, 50% upgraded at 50% of the cost of replacement

- EnPot Modulation technology

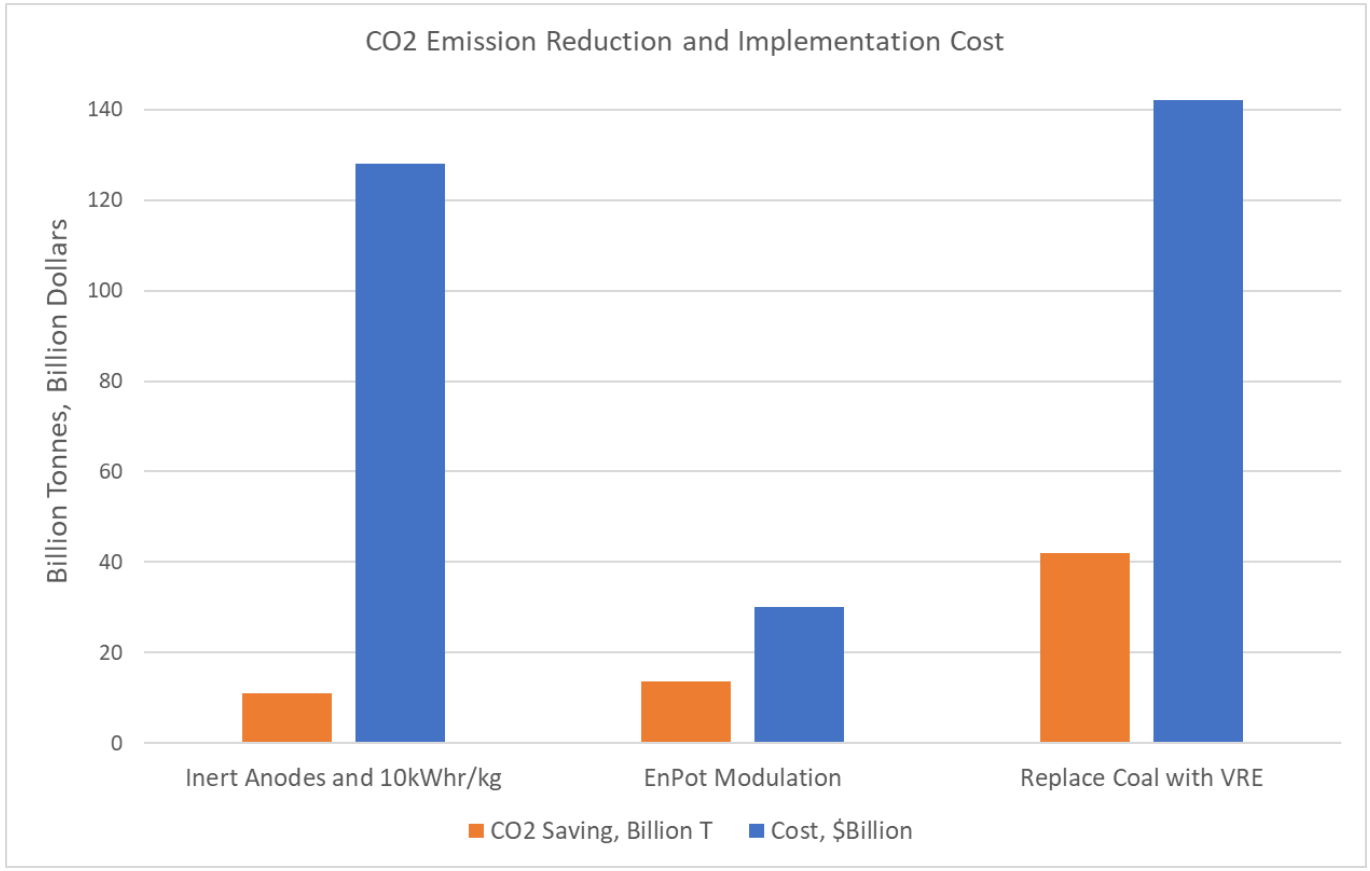
= **US$30 billion** for 13.7 billion T saving

@US$125k/MW + US$100m per smelter, and including hydro, which may become increasingly variable with climate change and be required to seasonally modulate

- Replacing all of todays coal-fired electricity used by Al smelters

= **US$142 billion** for 42 billion T saving

assuming replacing 70GW of coal with 230GW installed VRE @US$618 per KW @ 30% load factor



Sources: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Power_Generation_Costs_2019.pdf
https://www.sciencedirect.com/science/article/pii/S0140988316303528
https://www.sciencedaily.com/releases/2007/11/071114163448.htm

Perhaps the question should be…why aren't we doing it?

ROI from operational savings if they were all installed today

- Energy intensity @ 10Kwh/kg

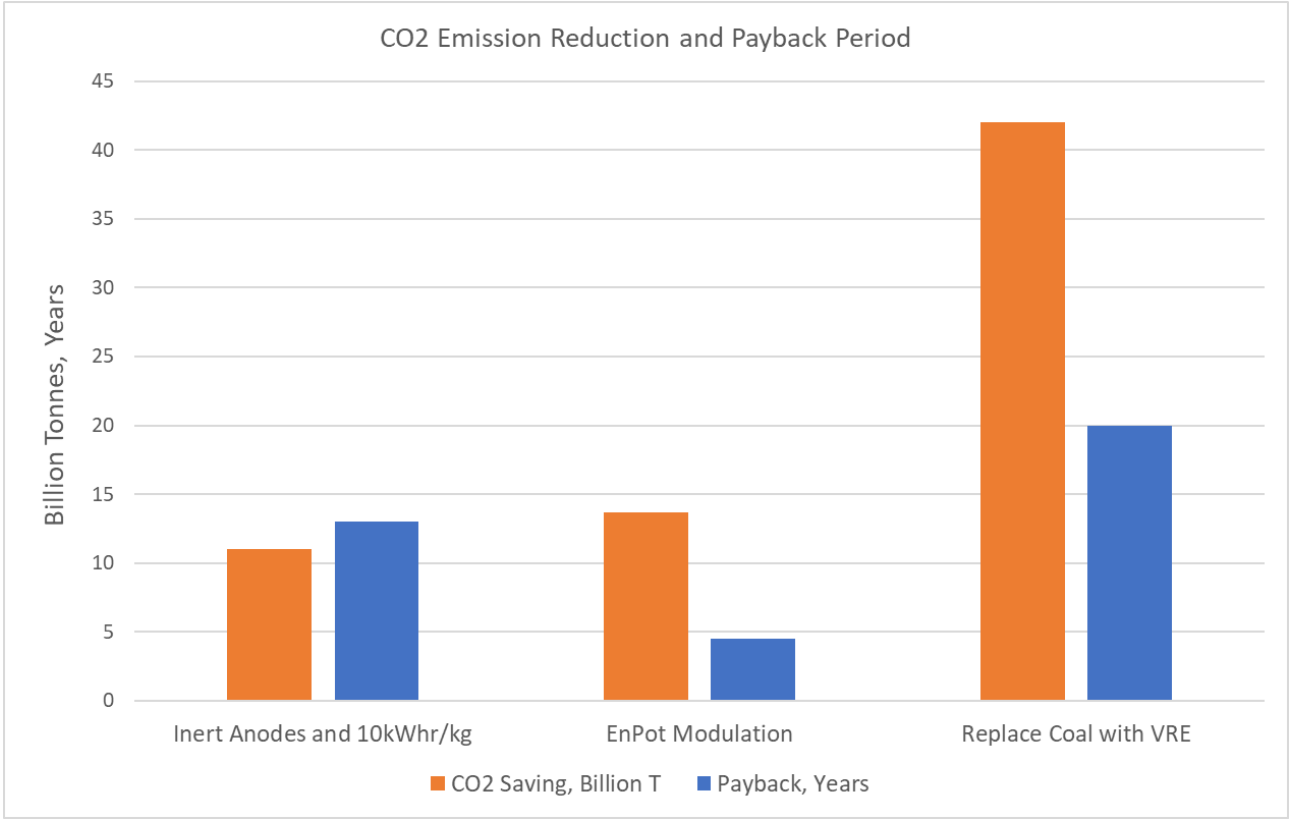
= **13 years** @ 30% reduction of electricity cost @US$35 /MWh

- EnPot Modulation Technology

= **4.5 years** @ 20% reduction of electricity cost @US$35 /MWh

- Coal replacement

= **20 years** @ US$7 billion pa from operational savings at generation.



Primary Aluminium Smelting Pathway to Zero Carbon 2050