

Climate Change The New Age of Renewables

Think Global, Act Local

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There is now a clear global consensus that climate change is real. What practical global solutions will be available to remediate climate change over the next 20-80 years?

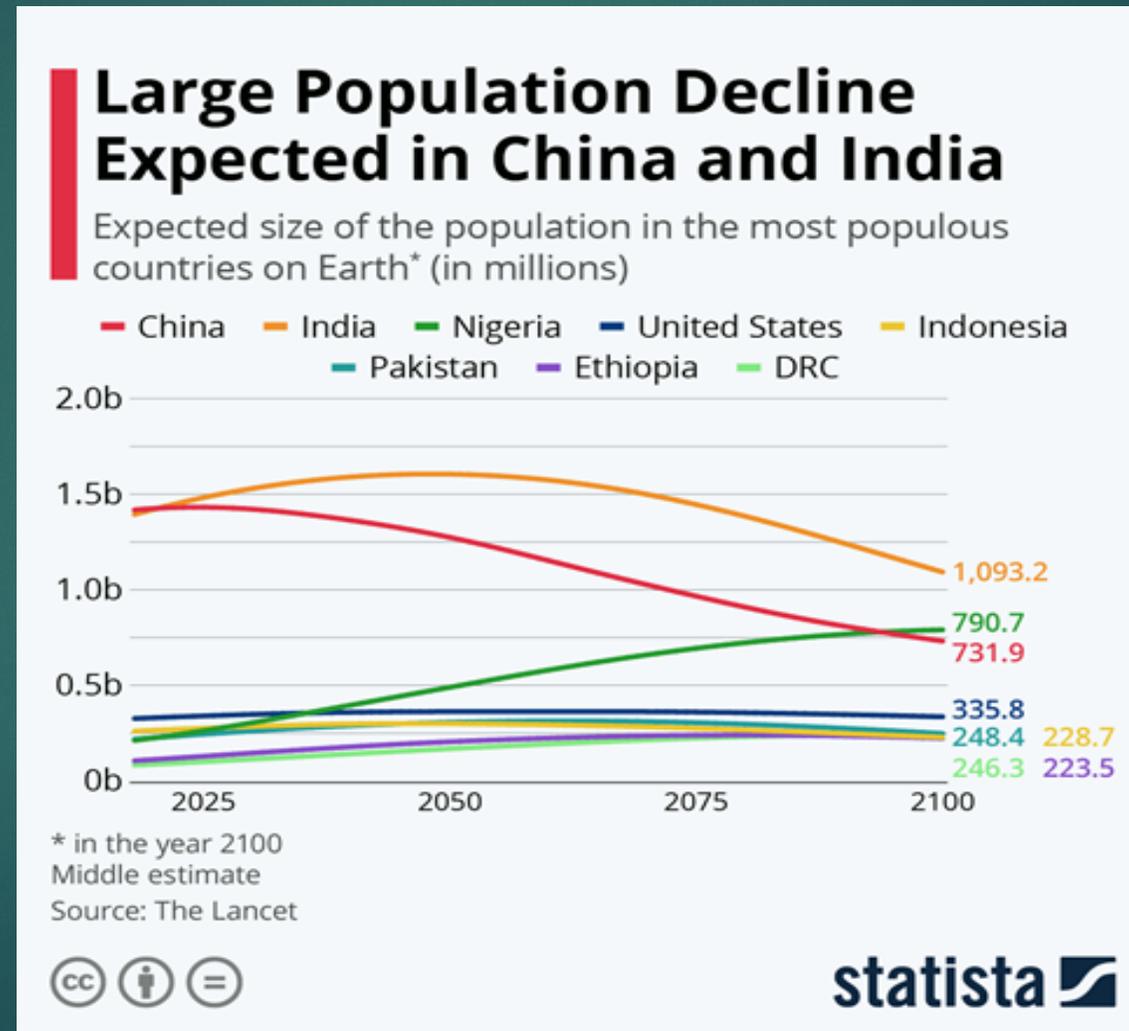
*Climate rankings: Australia, 59; **NZ, 35**; UK, 7; Scandinavia, 4-7*



THE UNIVERSITY OF
AUCKLAND
NEW ZEALAND

World Population Projections

Global Population will plateau at 11 billion by 2100
(Pew)



The First Major Global Climate Event: Where?

83 million deaths from climate warming by 2100 (*Nature*)

1. The Planetary Atmosphere

- ▶ Arctic Permafrost thaw (1.6 trillion tonnes of methane) releasing massive quantities
- ▶ Methane (CH₄) increasing in the atmosphere at 10% per decade (most potent GHG)

2. Asian mega-deltas (ASEAN)

- ▶ Himalayan and Hindu Kush thaw
- ▶ 1.7 billion people at risk in river valleys: Yangtse, Mekong, Indus and Ganges
- ▶ The valleys and deltas will flood with massive human impacts (see Pakistan floods)

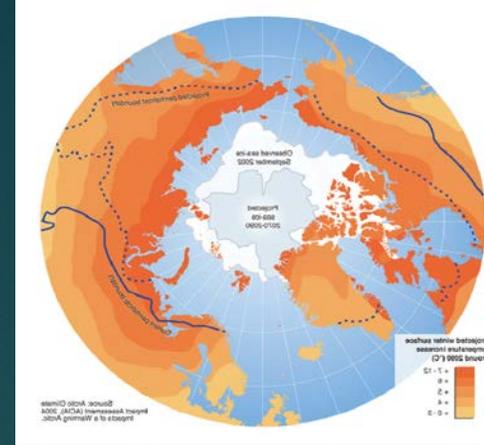
3. Sub-Saharan Africa (UNDP reports)

- ▶ Climate refugees: 86 million, vulnerable food resources (World Bank)
- ▶ Migration driven by famine and poverty

4. 90 Coastal Cities: risk of inundation (WEF/Bloomberg)

- ▶ Sea level rise mainly from Greenland (20%) and Antarctica (70%) ice thaw
- ▶ *SeaRise maps (2022)* showing rising sea levels and sinking land levels in Auckland

Others: Small and large Pacific atolls and The Middle East, India and North Africa

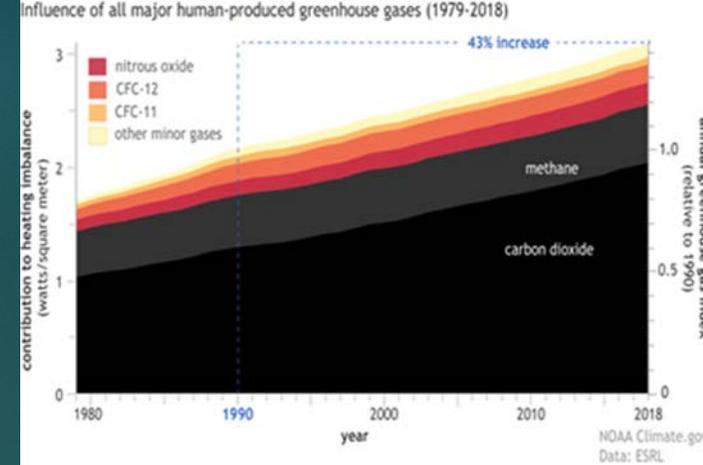


Global Emissions: The Big Problem

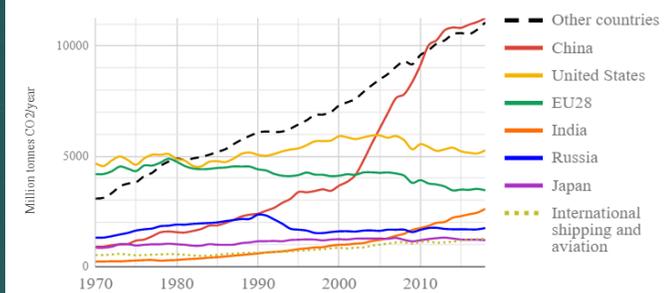
Biggest emitters: China, India, USA, EU

See Worldometer.info

- ▶ Global fossil fuel emissions have increased by 50% since 1990
 - ▶ **China, USA and India** emissions produce 50% of total gross global emissions
 - ▶ Per capita (tonnes): UAE 23 > Australia 17 > USA 16 > NZ 7 > **China 7** > **India 2**
- ▶ **China and India** have the fastest growing greenhouse emissions
 - ▶ Both China and India need energy for economic development
 - ▶ China target by 2030: replace coal by large nuclear (no GHGs)
 - ▶ >100 nuclear power stations by 2030
 - ▶ India set extrapolated ZC target at 2070!!
 - ▶ India will exhibit long-term growth into a high-tech economy (*Economist*)
 - ▶ Thorium reactors a possible silver bullet for India (see later)



World fossil carbon dioxide emission 1970-2018



Natural Climate Solutions (NCS)

WEF/McKinsey

- ▶ NCS: Mitigation pathways across forests, grasslands, wetlands
- ▶ Reforestation is the simplest natural method for removing CO₂
- ▶ Forests cover 30% of earth's surface, 30MHa deforestation annually
 - ▶ Russia, Brazil and Canada leaders in deforestation
- ▶ Largest Reforestation: **Great Green Wall** (African Union) across Sahara fringe
- ▶ NCS can provide **<37% of the emission reduction** required by 2030 (PNAS)
- ▶ NCS can restore biodiversity and habitat loss and can boost jobs
- ▶ Internationally funding for NCS is a problem (only 5% in 2018)
- ▶ Corporate funding for NCS is increasing



Aotearoa ETS: Pines or Natives?

RPC: Chair of Scion Research Ltd International Advisory Committee

- ▶ Pinus radiata is a **monoculture** in NZ : a climate change risk?
- ▶ Other countries have second contingency species (eg UK and Finland)
- ▶ CO₂ is taken up by foliage and stored in the timber: foliage is a key factor!
- ▶ Pinus radiata genetically selected for linearity and timber not foliage
- ▶ Young Pines soak up lots of CO₂ but have shorter lifetimes
- ▶ Native trees have better foliage balance, but become carbon neutral
- ▶ **Long term: A mix of fast-growing pines and bushier NZ natives?**
- ▶ <https://www.newsroom.co.nz/nobody-loves-radiata>



Scaling-up Renewables: Solar, Wind, Tidal

Wind Energy

- ▶ Gansu Wind Farm (China) is the largest in the world (7000 turbines, 20GW)
- ▶ Statoil (Norway) has built a large off-shore wind farm in Scotland
- ▶ California believes it can achieve ZC using large off-shore wind farms

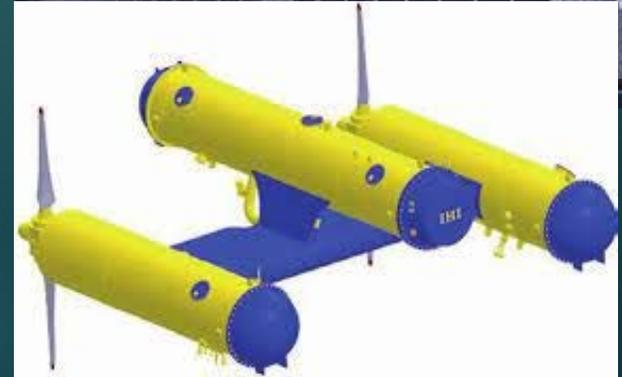
Solar energy (WEF)

- ▶ Floatovoltaics: Thai farm 145,000 solar panels (day) & 3 hydro turbines (night)
- ▶ Building-integrated photovoltaics (BIPV): solar films covering the building envelope

Tidal energy (NEDO, Japan)

- ▶ Kairyu (current) Project 200GW (60% of Japan's demand)
- ▶ A series of submerged current generators
- ▶ Resembles an airline operating in reverse mode: 330 tonne prototype unit
- ▶ Suspended at 50 meters in Kiroshio Current - one of the worlds strongest

Renewables Investments: \$2 trillion during next decade by USA & China! Jobs & Careers



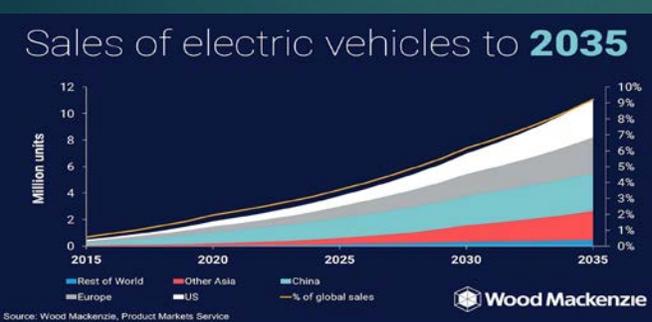
Electric Vehicles (EVs) and Green Hydrogen

EVs Growth

- ▶ EVs have 20 moving parts vs 2000 for ICVs: last longer, low maintenance, cheaper energy, cheaper cost
- ▶ 50 countries have fossil-fuel vehicle end-dates: 2025 Norway; 2030 UK; 2035 Canada; 2040 NZ
- ▶ Sodium ion batteries (lower power density) in production, lithium-ion batteries are now being recycled

The "Green" Hydrogen Economy: Tipping point at US\$2/kg for replacing fossil fuels

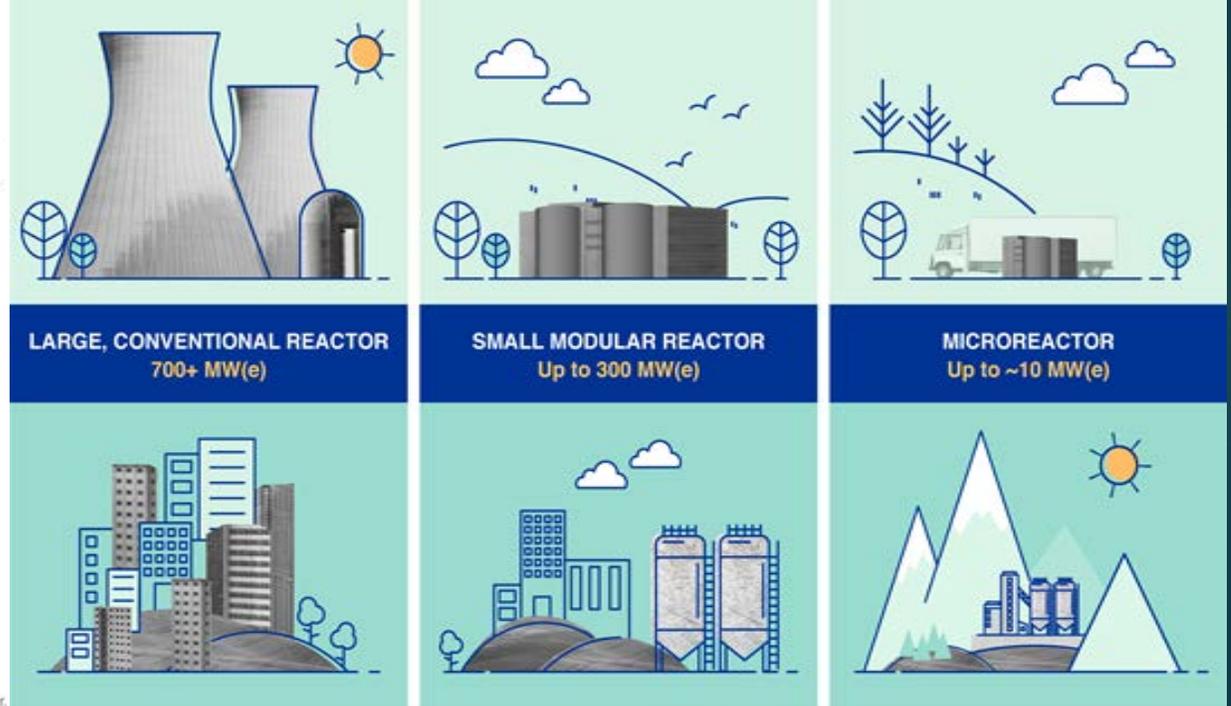
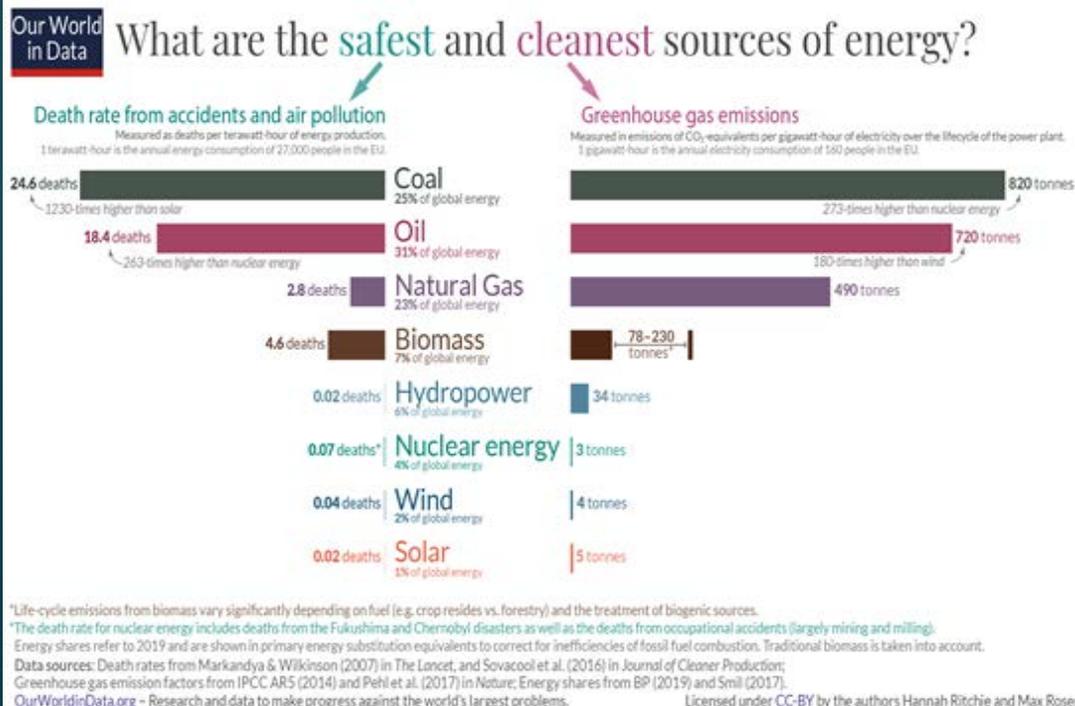
- ▶ **Green Hydrogen Catapult Initiative (Saudi, Australia, EU, China & Norway)** increase x50 in 6 years
- ▶ **Asian Renewable Energy Hub - largest green hydrogen hub:** BP acquired 40% of US\$30B Pilbara project
- ▶ **Production:** Electrolysis or photolysis of water using wind or solar energy (Siemens, Toshiba, Fronius etc)
- ▶ **Hydrogen combustion engine:** Aquarius Engine (Israel) – small and powerful
- ▶ **Hydrogen Fuel Cell:** Zero emissions, useful where more power required (Hyundai trucks, ocean vessels etc)
- ▶ Current price \$3.70/kg projected to reach **\$1/kg by 2035** (Downtoearth.org.in)



Coal or Nuclear? Bill Gates New Safer Nuclear Energy: No GHGs!

Bill Gates "we cannot get to ZC by solar, wind and hydro alone – nuclear must also have a role!"

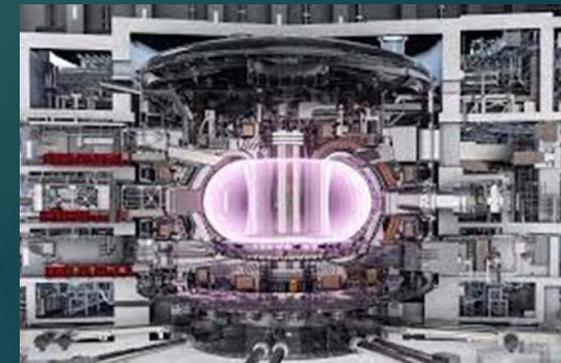
- ▶ Nuclear is important for the major carbon emitters: China, India, USA and EU
- ▶ Nuclear energy is safer than fossil fuel energy (*Data: Lancet, Nature, below*)
- ▶ Context: 450 large nuclear power plants already exist globally
- ▶ **Future:** safer small reactors in developed economies



The New Safer Nuclear Age?

Small Modular Reactors, Thorium Reactors, Fusion Reactors

- ▶ **Small Modular Reactors** (77-300 MWe): already manufactured by NuScale, Rolls Royce & Westinghouse. They will be deployed in USA, Canada, EU etc
 - ▶ **Pros and Cons:** mass produced, small, safer but waste disposal remains an issue
- ▶ **Thorium Reactors** (Thor Energy/ Cambridge U): China and India have constructed prototypes. About 35 countries are interested.
 - ▶ **Pros and Cons:** much safer than uranium reactors: can be switched off easily, much less nuclear waste, not usable in weapons
 - ▶ Thorium mineral is naturally abundant eg India and Australia, both coal-dependent economies. Is this a silver bullet for India?
- ▶ **Fusion Reactors using light atom elements (D,T):** The "holy grail" of nuclear processes promising an endless source of clean power. Perhaps in 20 years?
 - ▶ **Public Sector:** EU consortium leading the development of fusion reactors
 - ▶ **Private Sector:** 26 start-up companies accelerating fusion reactor technology
 - ▶ <https://edition.cnn.com/interactive/2022/05/world/iter-nuclear-fusion-climate-intl-cnnphotos/?position=7>



Planetary Engineering?

▶ Removal of atmospheric CO₂ (sequestration) - Iceland Facility

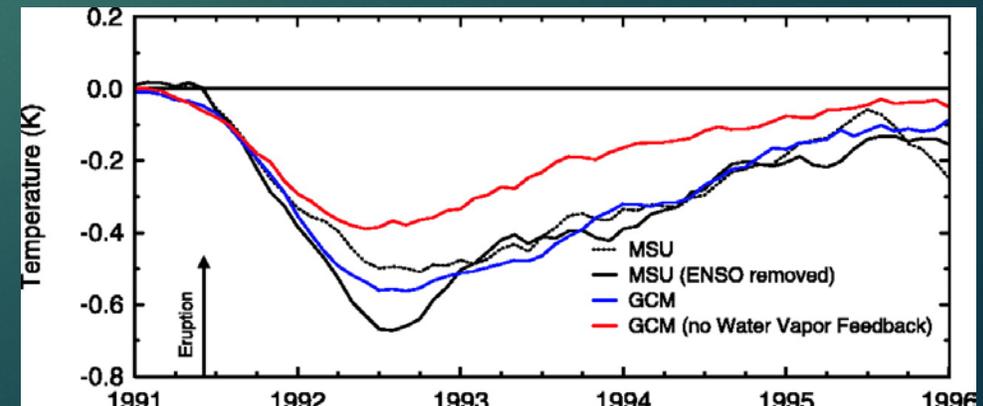
- ▶ Small prototype in Iceland: 4000 tonnes captured pa vs 32,000,000,000 emitted pa
- ▶ Scale up for total carbon capture 8 million times!
- ▶ CO₂ captured as carbonate minerals or used in green house farms for horticulture
- ▶ Expensive! Reducing current emissions is a much cheaper simpler option!
- ▶ Exxon intending to build a \$100 billion recapture hub – that will test viability!

▶ Enhancing Marine Snow in low-chlorophyll zones of the southern oceans (The “Biological Pump”)

- ▶ Addition of small quantities of iron compounds stimulates release of organic matter from phytoplankton growth
- ▶ The carbonaceous particles fall to the ocean bottom, creating capacity for more surface CO₂ uptake

▶ Reflection of solar energy back into space by injected atmospheric sulphate particles

- ▶ Quantitative study based on actual cooling observed during Pinatubo Eruption, 1991



Agri-methane (CH₄): A Global Problem

NZ Dairy Sector

- ▶ NZ produces 3% of global dairy products, exports to >130 countries
- ▶ Methane is 30-80 times more potent GHG than carbon dioxide
- ▶ 71% of NZ agricultural emissions are agri-methane

Feedstock 1: Royal DSM (\$16B company) Bovaer agent NOP-3

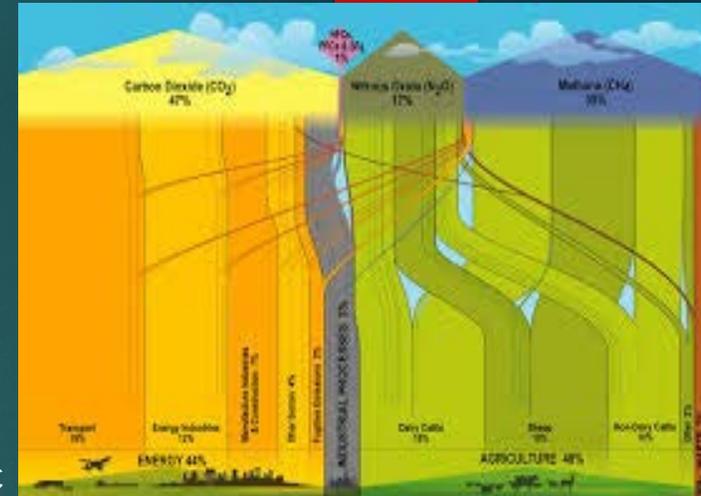
- ▶ 43 Trials completed or on-going across 13 countries: US, UK, Germany, Canada etc
- ▶ ¼ teaspoon daily gives immediate reduction: 30% Dairy Cows, 90% beef cattle
- ▶ Safe for cows and humans (DSM)

Feedstock 2: Methane-busting Seaweed Solution: <https://www.ch4global.com/>

- ▶ US start-up aqua-farming native NZ methane-busting seaweed
- ▶ NZ Native seaweed: *Asparagopsis* can be grown in tanks or in ocean farms

Conclusion:

- ▶ *Future markets will reject NZ dairy products if they are seen to damage the climate!*



Climate Report Card: Planet Earth

Can we limit climate warming to +2C by 2050?

1. Populations in high-emitting countries (China, India, EU etc) will decrease by 2050 (certain)
2. Natural Climate Solutions (NCS) can contribute 37% of remediation (uncertain funding)
3. China: replaces coal by large nuclear within 10-20 years (almost certain)
4. India: develop and implement thorium reactors (uncertain)
5. USA and EU continue to reduce emissions (almost certain)
6. Large floating wind farms and floatovoltaics will be widely used (certain)
7. The electric transportation revolution, cars, planes, ships, will occur (certain by 2040)
8. 130 out of 198 countries have adopted ZC targets: more required (uncertain)
9. 234 out of 1177 cities have developed ZC targets and plans: many more required (uncertain)
10. Consumer pressure: 700 major companies have ZC targets and strategies: more required (certain)

Conclusion: Significant progress but ZC unlikely unless all of the above are achieved!

Climate: What can I do personally?

1. Follow **indicators of GHG** emissions: NZ 82.3 million tonnes, Global 32 billion tonnes
2. **Plant fast-growing NZ native trees**
3. Exercise your **green consumer power** in all retail purchases
4. Ensure **investments** are in non-fossil fuel areas
5. When it is practical, revert to **electric transportation** (cars, buses, planes)
6. Employ **renewable energy** in your home and business
7. Urge **all your political representatives** to be more determined in pursuing ZC
8. Urge the company you work for to join **NZ Climate Leaders Coalition** (105 Kiwi CEOs)
9. Urge young people to pursue **careers in the global renewable** revolution (next 20 years)
10. Read the **Auckland Council Climate Action Plan**: Ranked A grade by CDP (top 7%)

<https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/Pages/te-taruke-a-tawhiri-ACP.aspx>





Climate Science: Interdisciplinary Contributions

Climate Change Theme	Outcomes	Disciplines
Future Projections	Climate Modelling	Mathematics Statistics Information Technology
Measurement, Monitoring & Solutions	Carbon dioxide levels Atmospheric Warming Ice Sheet Melting Sea Level change <i>Technology Solutions</i>	Physics (Climatology) Chemistry Engineering
Environmental Impacts	Habitat Loss Species Loss <i>Natural Solutions</i>	Biology Geography

Core Climate Sources: 100 in total

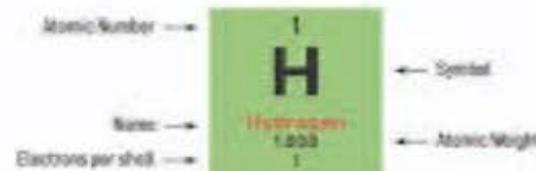
- ▶ *Nature and related publications*
- ▶ *Science (AAAS)*
- ▶ *Scientific American*
- ▶ *Chemical and Engineering News (ACS)*

- ▶ *Economist*
- ▶ *Guardian*
- ▶ *BBC*
- ▶ *The Atlantic*
- ▶ *New York Times*
- ▶ *The Conversation*
- ▶ *Stuff.co.nz*

- ▶ World Economic Forum (WEF)
- ▶ United Nations Development Programmes (UNDP)
- ▶ USA National Aeronautical and Space Administration (NASA)
- ▶ USA National Oceanic and Atmospheric Administration (NOAA)

Periodic Table of the Elements

1 IA H Hydrogen 1.008	2 IIA He Helium 4.003											13 IIIA B Boron 10.81	14 IVA C Carbon 12.01	15 VA N Nitrogen 14.01	16 VIA O Oxygen 16.00	17 VIIA F Fluorine 18.99	18 VIIIA Ne Neon 20.18
3 Li Lithium 6.94	4 Be Beryllium 9.01											19 Al Aluminum 26.98	20 Si Silicon 28.09	31 P Phosphorus 30.97	32 S Sulfur 32.06	35 Cl Chlorine 35.45	36 Ar Argon 39.95
11 Na Sodium 22.99	12 Mg Magnesium 24.31	3 IIIB Sc Scandium 44.96	4 IVB Ti Titanium 47.88	5 VB V Vanadium 50.94	6 VIB Cr Chromium 52.00	7 VIIB Mn Manganese 54.94	8 VIIIB Fe Iron 55.85	9 VIIIB Co Cobalt 58.93	10 VIIIB Ni Nickel 58.69	11 IB Cu Copper 63.55	12 IIB Zn Zinc 65.38	31 Ga Gallium 69.72	32 Ge Germanium 72.64	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.79
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.88	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.38	31 Ga Gallium 69.72	32 Ge Germanium 72.64	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.79
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium 98.91	44 Ru Ruthenium 101.07	45 Rh Rhodium 101.07	46 Pd Palladium 106.38	47 Ag Silver 107.87	48 Cd Cadmium 112.41	47 In Indium 114.82	48 Sn Tin 118.71	49 Sb Antimony 121.76	50 Te Tellurium 127.60	51 I Iodine 126.91	54 Xe Xenon 131.29
55 Cs Cesium 132.91	56 Ba Barium 137.33	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium [209]	85 At Astatine [210]	86 Rn Radon [222]
87 Fr Francium [223]	88 Ra Radium [226]	89-103 Actinides	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [263]	107 Bh Bohrium [264]	108 Hs Hassium [265]	109 Mt Meitnerium [266]	110 Ds Darmstadtium [267]	111 Rg Roentgenium [268]	112 Cn Copernicium [269]	113 Nh Nihonium [270]	114 Fl Flerovium [271]	115 Mc Moscovium [272]	116 Lv Livermorium [273]	117 Ts Tennessine [274]	118 Og Oganesson [274]



State of matter (color of some): GAS LIQUID SOLID UNKNOWN

Subcategory in the metal-metalloid-nonmetal triad (color of background):
 ■ Alkali metals ■ Lanthanides ■ Metalloids
 ■ Alkaline earth metals ■ Actinides ■ Reactive nonmetals
 ■ Transition metals ■ Post-transition metals ■ Noble gases
 ■ Unknown chemical properties

57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium [145]	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.05	71 Lu Lutetium 174.97
89 Ac Actinium [227]	90 Th Thorium 232.04	91 Pa Protactinium [231]	92 U Uranium 238.03	93 Np Neptunium [237]	94 Pu Plutonium [244]	95 Am Americium [243]	96 Cm Curium [247]	97 Bk Berkelium [247]	98 Cf Californium [251]	99 Es Einsteinium [252]	100 Fm Fermium [257]	101 Md Mendelevium [258]	102 No Nobelium [259]	103 Lr Lawrencium [260]

Climate Change consensus: *What solutions are possible?*

UNDP Oxford U Peoples Climate Poll (2021): **Consensus**

- 64% across 52 countries accept climate change is real
- 59% demand more urgent action

- 81% in the UK
- 80% in New Zealand (RNZ poll)
- 72% in Australia

We must now urgently identify and evaluate **solutions**:

- ▶ Natural Climate Solutions
- ▶ Solar and Wind Developments
- ▶ New smaller nuclear reactors
- ▶ Carbon dioxide sequestration
- ▶ Solar Reflection from atmospheric particles



Electric Vehicles (EVs) and Green Hydrogen

EVs Growth

- ▶ EVs have 20 moving parts vs 2000 for ICVs: last longer, low maintenance, cheaper energy, cheaper cost
- ▶ 50 countries have fossil-fuel vehicle end-dates: 2025 Norway; 2030 UK; 2035 Canada; 2040 NZ
- ▶ Sodium ion batteries (lower power density) in production, lithium ion batteries are now being recycled
- ▶ Critical elements for batteries and devices: long term solutions are undeveloped mineral reserves
 - ▶ Lithium (Chile > Australia), cobalt (DRC > Australia), rare earths (China > Vietnam > Brazil)

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