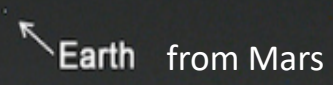
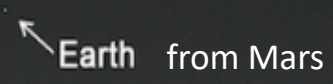
Biophysical limits to growth; the future of food and energy



from Mars

Dr Mike Joy - Institute for Governance and Policy studies (IGPS)
Victoria University

Biophysical limits to growth; the future of food and energy



from Mars

Rather than trying to comfort politicians in their utopias, scientists should instead help them to get out of the denial of reality

Gérard Bonhomme, Professor emeritus, University of Lorraine Chairman Energy/Environment commission of the French Physical Society

Limits to growth (1972) Donella H. Meadows, Dennis L. Meadows, Jørgen Randers, and William W. Behrens - updated 2014 Graham Turner

DOI: 10.1111/jiec.13084

JOURNAL OF INDUSTRIAL ECOLOGY WILEY

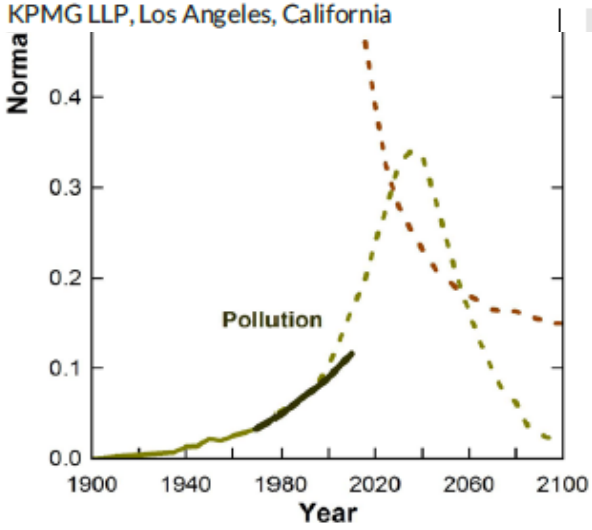
RESEARCH AND ANALYSIS

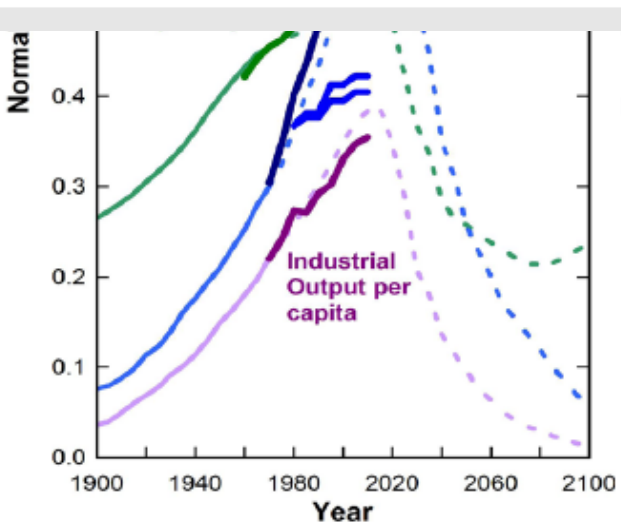
Update to limits to growth

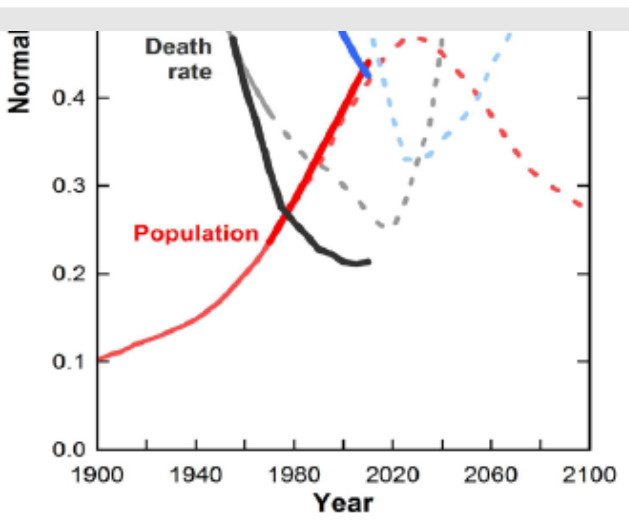
Comparing the World3 model with empirical data

Gaya Herrington

KPMG LLP, Los Angeles, California







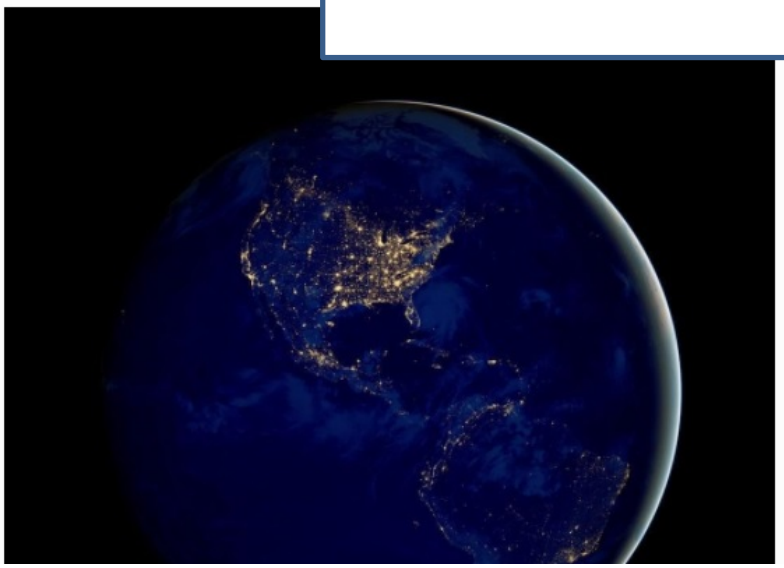
- New Zealand and global examples of biophysical realities - overshoot of planetary boundaries and warnings in relation to food production
- The reality of the switch to net negative energy food
- Energy density and its consequences
- The energy transition away from fossil carbon - the fairytale of a renewable energy future where we all live happily ever after with changing how we live.
- How we produce food in the future

Manifestation of “Limits to growth” the living world

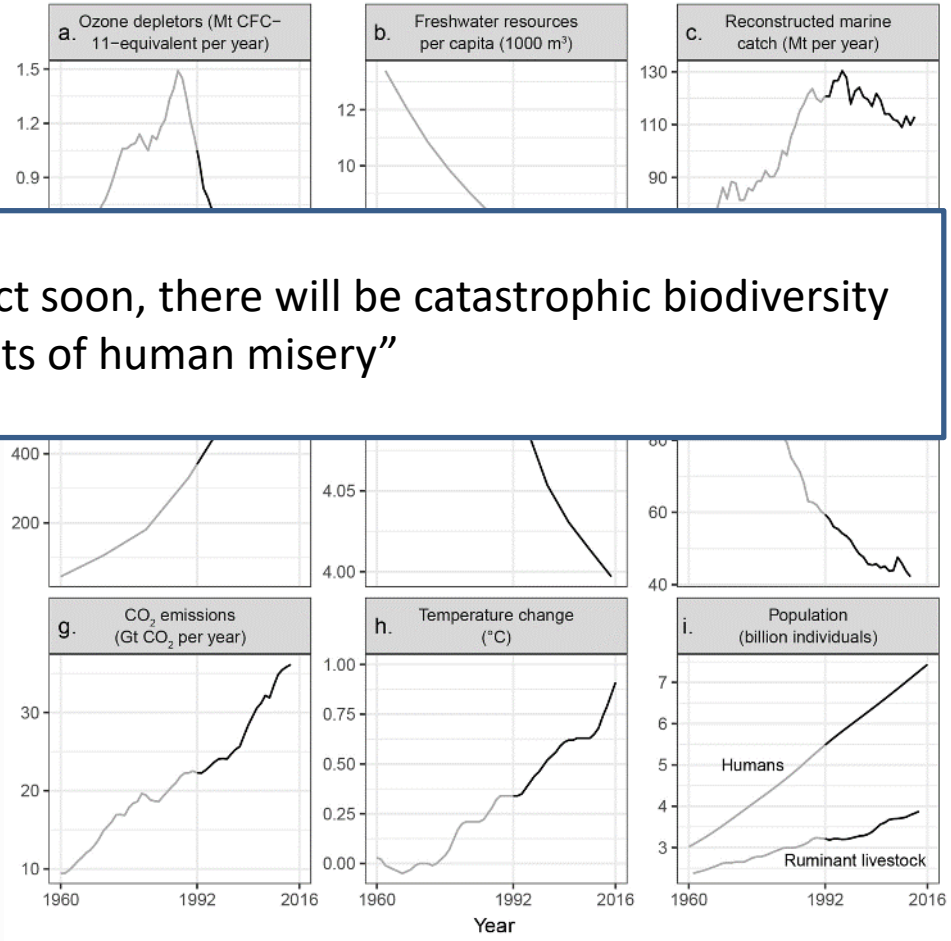
20,000 scientists give dire warning about the future in 'letter to humanity' – and the world is listening

The paper is now one of the most discussed scient
experts

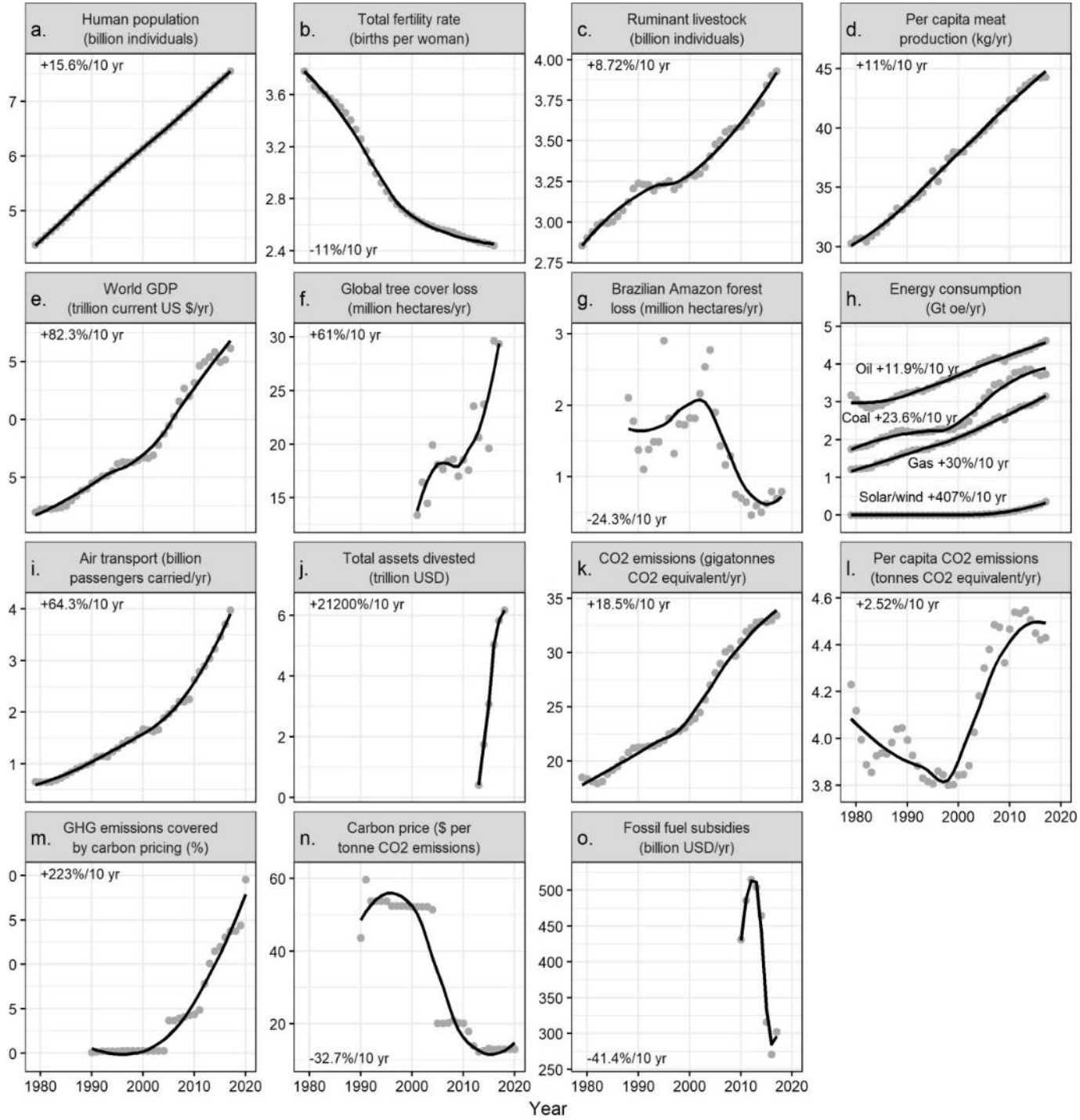
Trevor Nace Contribut
Science



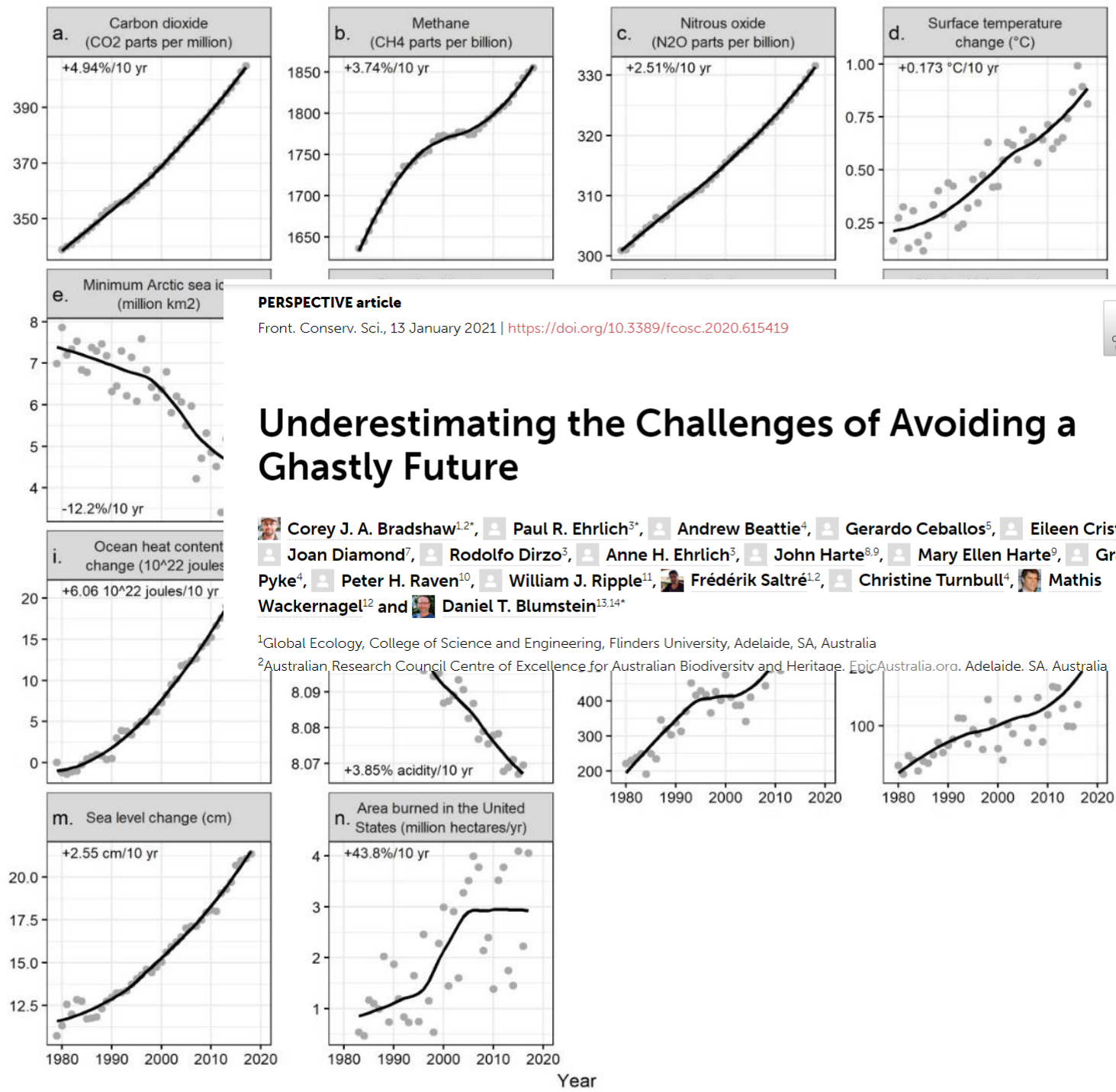
“If the world doesn't act soon, there will be catastrophic biodiversity loss and untold amounts of human misery”



From: World Scientists’ Warning to Humanity: A Second Notice
BioScience. 2017;67(12):1026-1028. doi:10.1093/biosci/bix125



X axis is 1980 - 2020



PERSPECTIVE article

Front. Conserv. Sci., 13 January 2021 | https://doi.org/10.3389/fcosc.2020.615419

Check for updates

Underestimating the Challenges of Avoiding a Ghastly Future

Corey J. A. Bradshaw[1,2*], Paul R. Ehrlich[3*], Andrew Beattie[4], Gerardo Ceballos[5], Eileen Crist[6], Joan Diamond[7], Rodolfo Dirzo[3], Anne H. Ehrlich[3], John Harte[8,9], Mary Ellen Harte[9], Graham Pyke[4], Peter H. Raven[10], William J. Ripple[11], Frédérik Saltré[1,2], Christine Turnbull[4], Mathis Wackernagel[12] and Daniel T. Blumstein[13,14*]

[1]Global Ecology, College of Science and Engineering, Flinders University, Adelaide, SA, Australia
[2]Australian Research Council Centre of Excellence for Australian Biodiversity and Heritage, EpicAustralia.org, Adelaide, SA, Australia

phic
ery"

X axis is 1980 - 2020

The real issues – almost never in the news or consciousness of most of humanity

How do we feed a burgeoning population and maintain the life supporting capacity of the planet given all this on the horizon?:

- All these things are declining amount and quality of land, fossil fuels and EROI, water quality, biodiversity and wild fisheries.

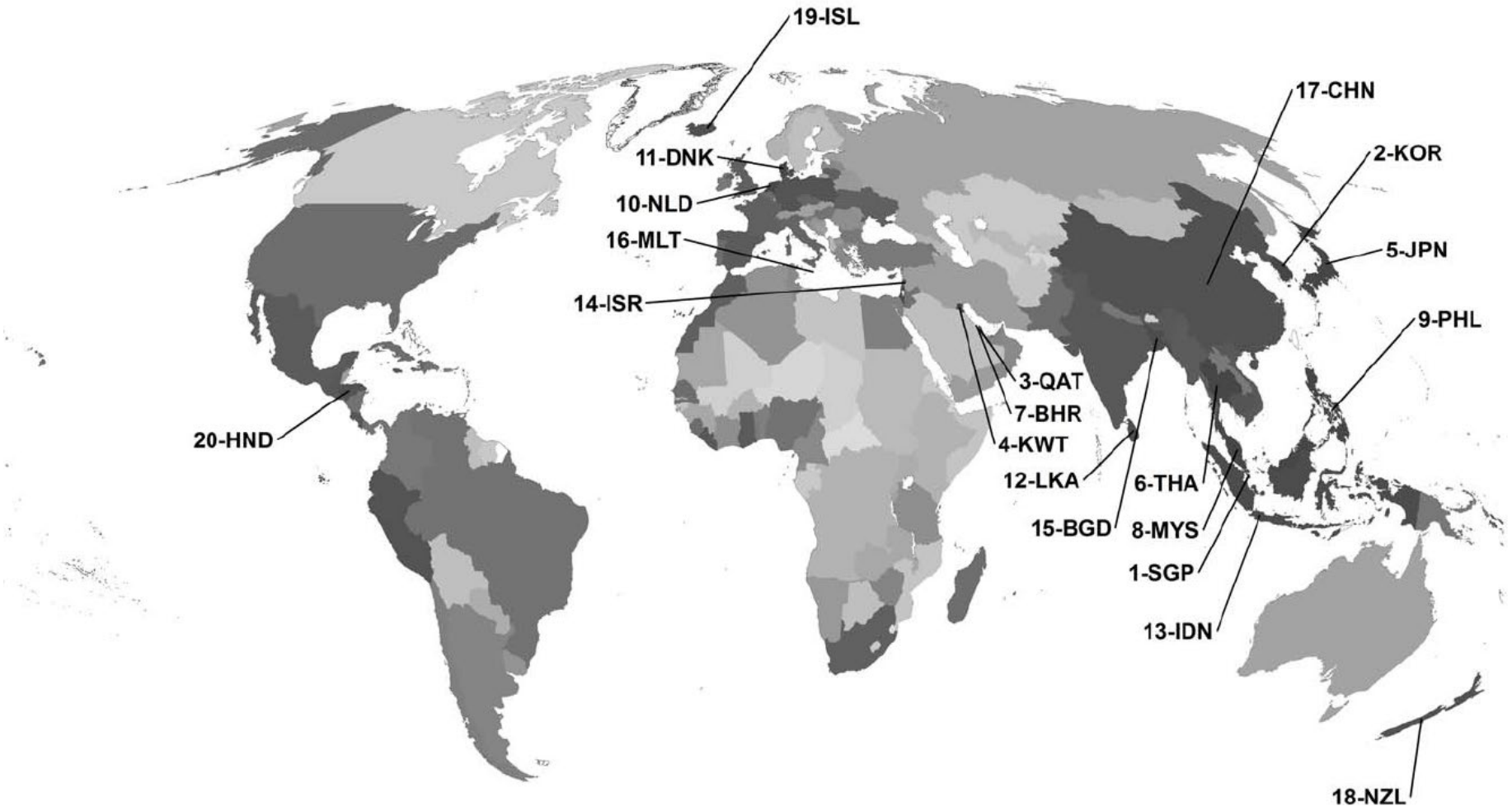
- Increasing impacts of climate change, antibiotic resistance, and much more.

- >80 million extra mouths to feed every year, increasing animal products and fossil fuels derived food in diets and increasing food wastage

- We have a perfect storm imminent as predicted by LTG

- New Zealand examples first:

Manifestation of an utter failure of environmental management NZ



Twenty worst-ranked countries by proportional composite environmental (pENV) rank

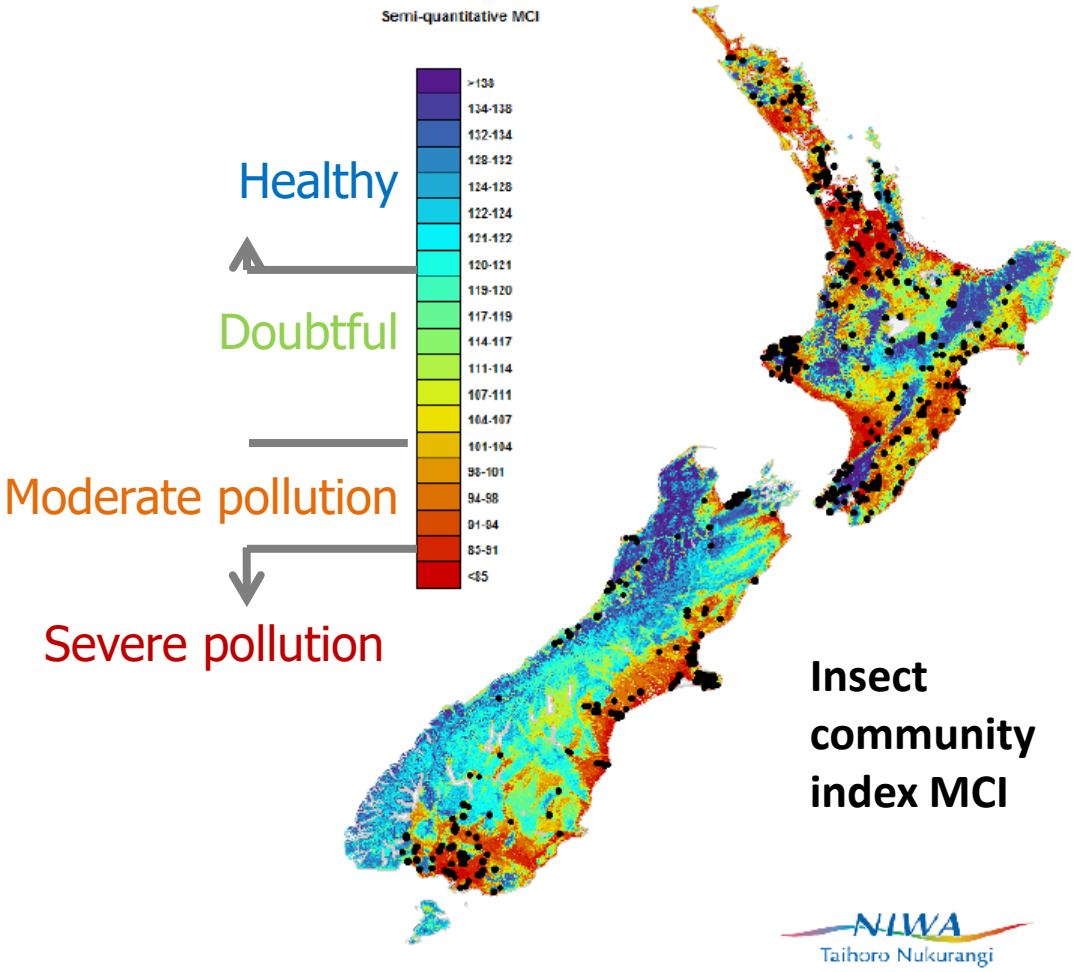
OPEN ACCESS Freely available online

PLoS one

Evaluating the Relative Environmental Impact of Countries

Capi

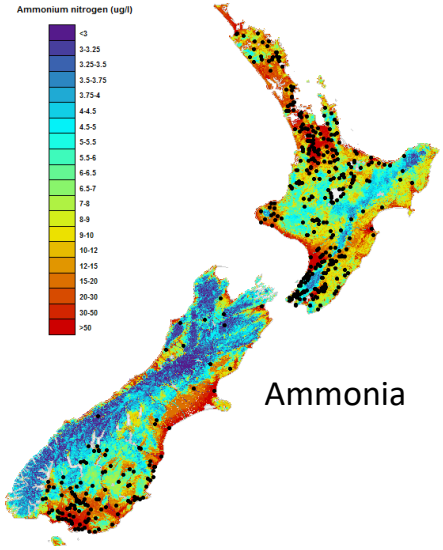
NZ example food production freshwater and GHG emissions



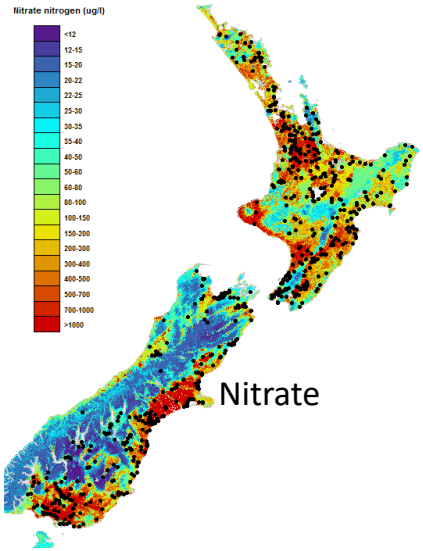
Insect community index MCI

- 74% of freshwater fish threatened
  - + crayfish and kakahi
- 44% of lakes polluted (nearly all lowland lakes)
- 85% of waterways in pasture catchments exceed nitrate guideline limits
- 62% of rivers unsafe for swimming (pathogens)

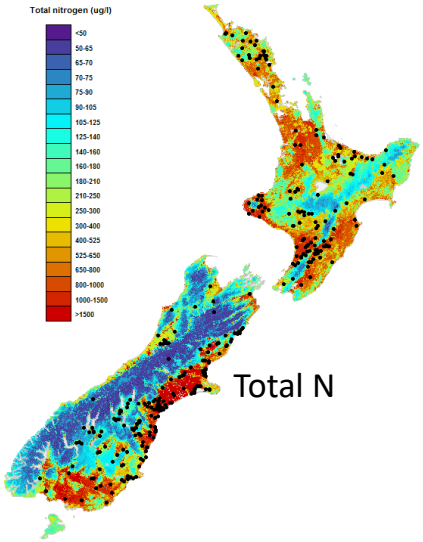
The drivers of the harm done to freshwater



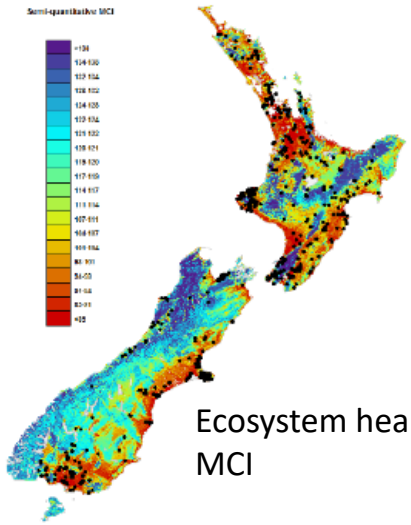
Ammonia



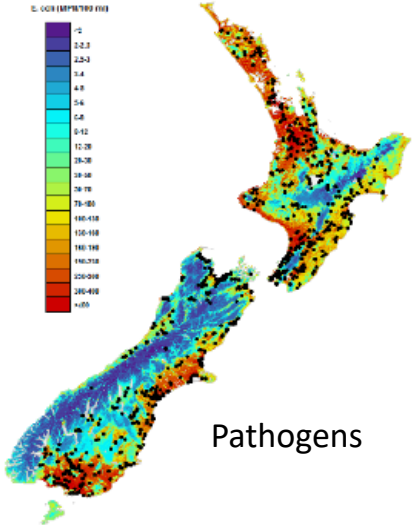
Nitrate



Total N



Ecosystem health
MCI

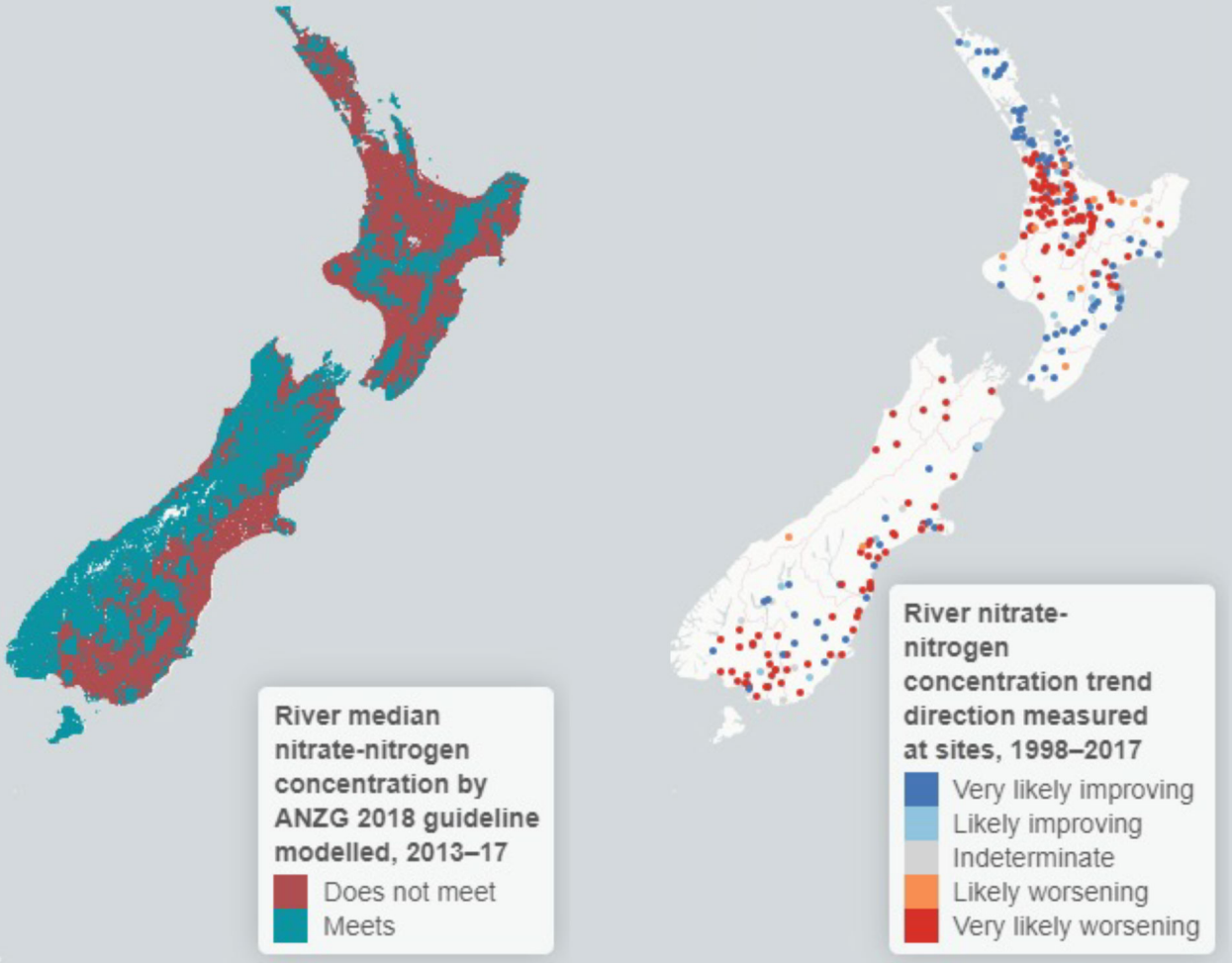


Pathogens

Red is bad, blue is good – the pattern is consistent

Data by NIWA Taihoro Nukurangi

The scale of the harm done



https://www.stats.govt.nz/indicators/river-water-quality-nitrogen

159%

increase in NO_{3}-N loads in rivers nationally and getting worse

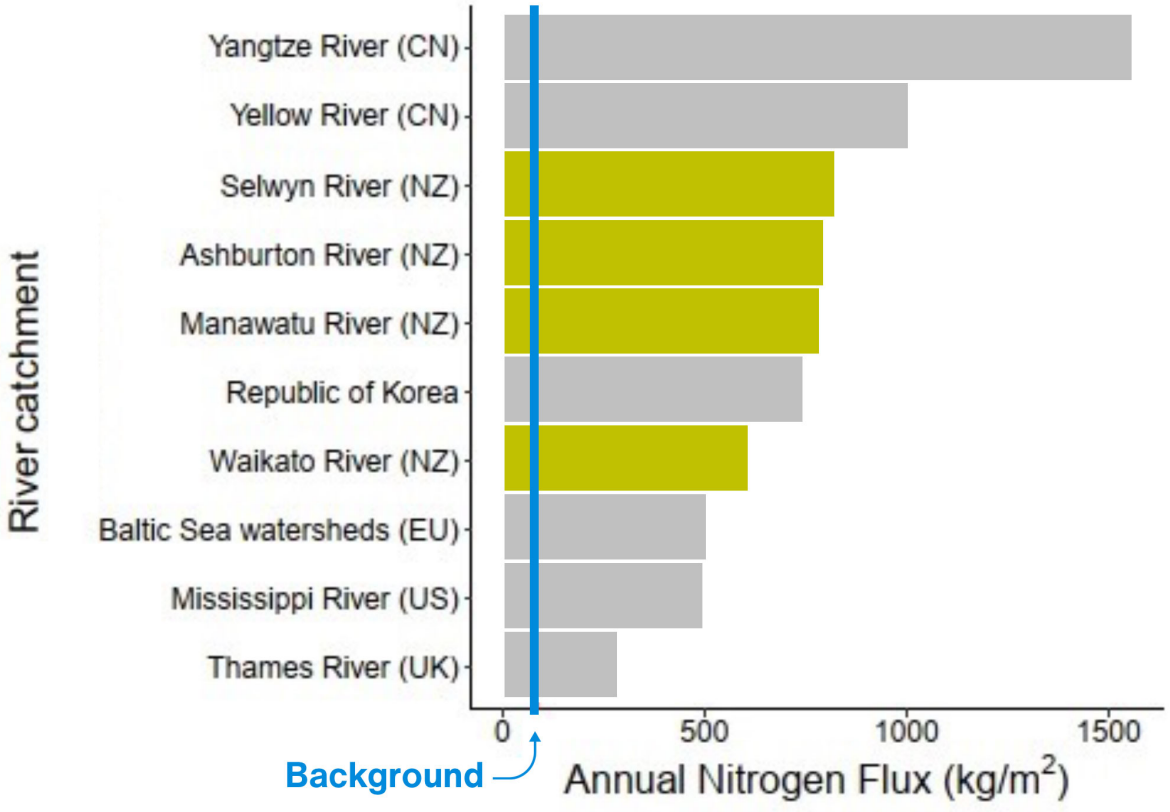
257%

NO_{3}-N load Increase in Canterbury

Ton H. Snelder, Scott T. Larned & Rich W. McDowell (2018) Anthropogenic increases of catchment nitrogen and phosphorus loads in New Zealand, New Zealand Journal of Marine and Freshwater Research, 52:3, 336-361

The scale of the harm done

Global comparison nitrogen flux in rivers



1361%

increase in emissions from Urea application since 1990.

662% increase in synthetic nitrogen fert use in NZ since 1990 (24,586 tonnes in 1990 to 358,000 tonnes in 2019)

The volatilisation from combination of urine, dung, N fert amounts to about 80% of emissions from agricultural soils.

Joy, M. K., and A. D. Canning. Shifting baselines and political expediency in New Zealand's freshwater management. Marine and Freshwater Research.
https://environment.govt.nz/assets/Publications/New-Zealands-Greenhouse-Gas-Inventory-1990-2019-Volume-1-Chapters-1-15.pdf
662% increase in synthetic nitrogen fert use in NZ since 1990 (24,586 tonnes in 1990 to 358,000 tonnes in 2019 (page 216). Emissions from Urea application increased 1,356.1 per cent between 1990 and 2019 (pg. 244)

The drivers of the crisis

Hydrology and Earth System Sciences — Open Access — EGU

"The greatest negative impact on river water quality in NZ in recent decades has been high-producing pastures that require large amounts of fertiliser to support high densities of livestock"

Julian, J.P., de Beurs, K.M., Owsley, B., Davies-Colley, R.J., and Ausseil, A.G.E. (2017) River water quality changes in New Zealand over 26 years: response to land use intensity. Hydrology and Earth System Sciences 21(2), 1149-1171.

The human health consequences of intensive dairy – nitrate contamination of drinking water

Emerging international evidence revealing nitrate contamination in drinking water potentially responsible for adverse health outcomes including birth defects,[1] preterm births,[2] or birth weight[2,3] and cancers of the colon or rectum,[4-11] thyroid,[12] kidney[13] and bladder.[14]

NZ research estimated that as many as 800,000 New Zealanders may be exposed to nitrate levels above >1mg/L which could have implications for both chronic and acute conditions

1. Huber JC, Brender JD, Zheng Q, Sharkey JR, Vuong AM, Shinde MU *et al.* Maternal dietary intake of nitrates, nitrites and nitrosamines and selected birth defects in offspring: a case-control study. *Nutrition Journal*. 2013;12(1):1-10. http://www.nutritionj.com/content/12/1/34.
2. Stayner LT, Almberg K, Jones R, Graber J, Pedersen M, Turyk M. Atrazine and nitrate in drinking water and the risk of preterm delivery and low birth weight in four Midwestern states. *Environmental Research*. 2017;152:294-303. https://doi.org/10.1016/j.envres.2016.10.022
3. Coffman VR, Jensen AS, Trabjerg BB, Pedersen CB, Hansen B, Sigsgaard T *et al.* Prenatal exposure to nitrate from drinking water and markers of fetal growth restriction: A population-based study of nearly one million Danish-born children. *Environmental Health Perspectives*. 2021;129(2):027002. https://doi.org/10.1289/EHP7331
4. Weyer PJ, Cerhan JR, Kross BC, Hallberg GR, Kantamneni J, Breuer G *et al.* Municipal drinking water nitrate level and cancer risk in older women: the Iowa Women's Health Study. *Epidemiology*. 2001;12(3):327-338. https://www.jstor.org/stable/3703710.
5. Schullehner J, Hansen B, Thygesen M, Pedersen CB, Sigsgaard T. Nitrate in drinking water and colorectal cancer risk: A nationwide population-based cohort study. *Int J Cancer*. 2018;143(1):73-79. https://doi.org/10.1002/ijc.31306
6. Espejo-Herrera N, Gràcia-Lavedan E, Boldo E, Aragonés N, Pérez-Gómez B, Pollán M *et al.* Colorectal cancer risk and nitrate exposure through drinking water and diet. *Int J Cancer*. 2016;139(2):334-346. https://doi.org/10.1002/ijc.30083
7. De Roos AJ, Ward MH, Lynch CF, Cantor KP. Nitrate in public water supplies and the risk of colon and rectum cancers. *Epidemiology*. 2003;14(6):640-649. https://www.jstor.org/stable/3703422.
8. McElroy JA, Trentham-Dietz A, Gangnon RE, Hampton JM, Bersch AJ, Kanarek MS *et al.* Nitrogen-nitrate exposure from drinking water and colorectal cancer risk for rural women in Wisconsin, USA. *Journal of Water and Health*. 2008;6(3):399-409. https://doi.org/10.2166/wh.2008.048
9. Fathmawati, Fachiroh J, Gravitiani E, Sarto, Husodo AH. Nitrate in drinking water and risk of colorectal cancer in Yogyakarta, Indonesia. *Journal of Toxicology and Environmental Health, Part A*. 2017;80(2):120-128. https://doi.org/10.1080/15287394.2016.1260508
10. Jones RR, DellaValle CT, Weyer PJ, Robien K, Cantor KP, Krasner S *et al.* Ingested nitrate, disinfection by-products, and risk of colon and rectal cancers in the Iowa Women's Health Study cohort. *Environment International*. 2019;126:242-251. https://doi.org/10.1016/j.envint.2019.02.010
11. Taneja P, Labhasetwar P, Nagarnaik P, Ensink JHJ. The risk of cancer as a result of elevated levels of nitrate in drinking water and vegetables in Central India. *Journal of Water and Health*. 2017;15(4):602-614. https://doi.org/10.2166/wh.2017.283
12. Ward MH, Kilfoy BA, Weyer PJ, Anderson KE, Folsom AR, Cerhan JR. Nitrate intake and the risk of thyroid cancer and thyroid disease. *Epidemiology (Cambridge, Mass)*. 2010;21(3):389-395. https://doi.org/10.1097/EDE.0b013e3181d6201d
13. Jones RR, Weyer PJ, DellaValle CT, Robien K, Cantor KP, Krasner S *et al.* Ingested Nitrate, Disinfection By-products, and Kidney Cancer Risk in Older Women. *Epidemiology (Cambridge, Mass)*. 2017;28(5):703-711. https://doi.org/10.1097/EDE.0000000000000647

The scale of change required - Canterbury example

- How much zero nitrate water would be required to dilute the nitrate released by the dairy sector in Canterbury?

- Rainfall alone is barely sufficient to dilute the nitrate from dairy farming to meet the New Zealand drinking water standard 11.3mg/L but would provide only less than a twentieth of the water required to meet the ANZG ecosystem health guideline 0.44mg/L, and a twelfth of the limit where there is a significant risk of cancer in drinking water and the EU and STAG limit surface water of 1mg/L

- **This means a minimum 12 to 20 fold reduction in farming intensity**

The amount of water required to dilute in order to meet the ANZG and current New Zealand drinking water standard NO3-N limits of 0.44 and 11.3 mg NO3-N, respectively the amount of water required would be 5.544×10^{13} and 2.161×10^{12} L/year, equivalent to volumetric flows of 1,758 and 68.5 m3/s for a full year, respectively. The area of dairy farmland in Canterbury is ~360,000 ha the mean rainfall over that area is 700 mm/year, the quantity of rainwater for that farmland is 2.52×10^{12} L/year this would just meet the 11.3mg/l drinking water standard

We (taxpayers) subsidise the harm done by intensive farming

Identifying Complementarities for the Dairy and Forestry Industries in the Central North Island

		Forest		Dairy	
	Hectares	28,000		26,600	grazable
LAND	Land value	10,000	$/ha	36,100	$/ha
	Yield/unit	678	m^3/	950	kg milk solids/ha
	Price range	89 to 102	$/m	5 to 9	$/kg milk solids
PROFIT	Surplus range	22 to 32	million $/yr	-6 to 96	million $/yr
	Probabilities of loss	0	%	13	%
	Manufactured Product	67,550	t p	38	million kg whole milk
		275,268	gre mber m^3		
	10-year avg. export price	737	$/t	7	$/kg milk solids
		404	$/m nber	5	$/kg whole milk
	Manufactured exports	161	mil $/yr	179	million $/yr
	Employment: Upstream	84	em rest/yr	415	emp/farm/yr
	Downstream	280	em ill/yr	175	emp/plant/yr
	Phosphorus	0.05	kg/ r	1	kg/ha/yr
	Nitrogen discharge	3	kg/ r	54	kg/ha/yr
	Nitrogen price	400	$/kg	400	$/kg
	Carbon emitted/stored	11	t CO ha/yr seq	10	t CO_2e/ha/yr emitted
	Carbon price	7	$/t CO_2e	- 7	$/t CO_2e
EXTERN	Externality	31	million $/yr	- 18	million $/yr

Identifying Complementarities for the Dairy and Forestry Industries in the Central North Island
November 2015
DOI: 10.13140/RG.2.2.26093.18403
Report number: 978-0-478-11044-8 Scion (New Zealand Forest Research Institute)
Juan J. Monge, Sandra J Velarde, Richard Tolentino-Yao, Warren Parker

We (taxpayers) are paying/paid dairy farmers ~ $130 million not to farm, in an attempt to reduce nitrogen entering lake Taupo and Rotorua …

---

what about all the other lakes and rivers?

The cost (the externalities) of dairy or a subsidy

Identifying Complementarities for the Dairy and Forestry Industries in the Central North Island

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30 million kg N leached in Canterbury annually multiply that by $400/kg = $12 billion

---

So by allowing them to pollute that much is equivalent to a **$12 billion subsidy in Canterbury $52 billion nationally**

Subsidising harm NZ

Animal type	Nitrate-N leached kg/yr	Nitrate-N leached kg/yr * $400/kg/yr
Beef cattle	37,244,652	$14,897,860,859
Dairy cattle	129,806,132	$51,922,452,800
Deer	1,644,536	$657,814,491
Sheep	30,493,616	$12,197,446,477
Total	199,188,937	$79,675,574,627

Sector	Emissions ($kt CO_2$-e)	@ $74/tonne
Agriculture	39,617.71	$199,356,316,000
Land Use, Land-Use Change and Forestry (LULUCF)	-27,425.09	$138,003,052,000
Agriculture minus LULUCF (Net)	12,192.62	$902,253,000

Industry	2017-18 ($ million)	2018-19 ($ million)	2019-20 ($ million)
Total tax revenue	72,100	77,900	77,700
Agriculture tax paid as a % of total tax revenue	1.7%	1.6%	1.8%

(Dairying contributed 0.7% to total tax revenue over the 2019-20 year)

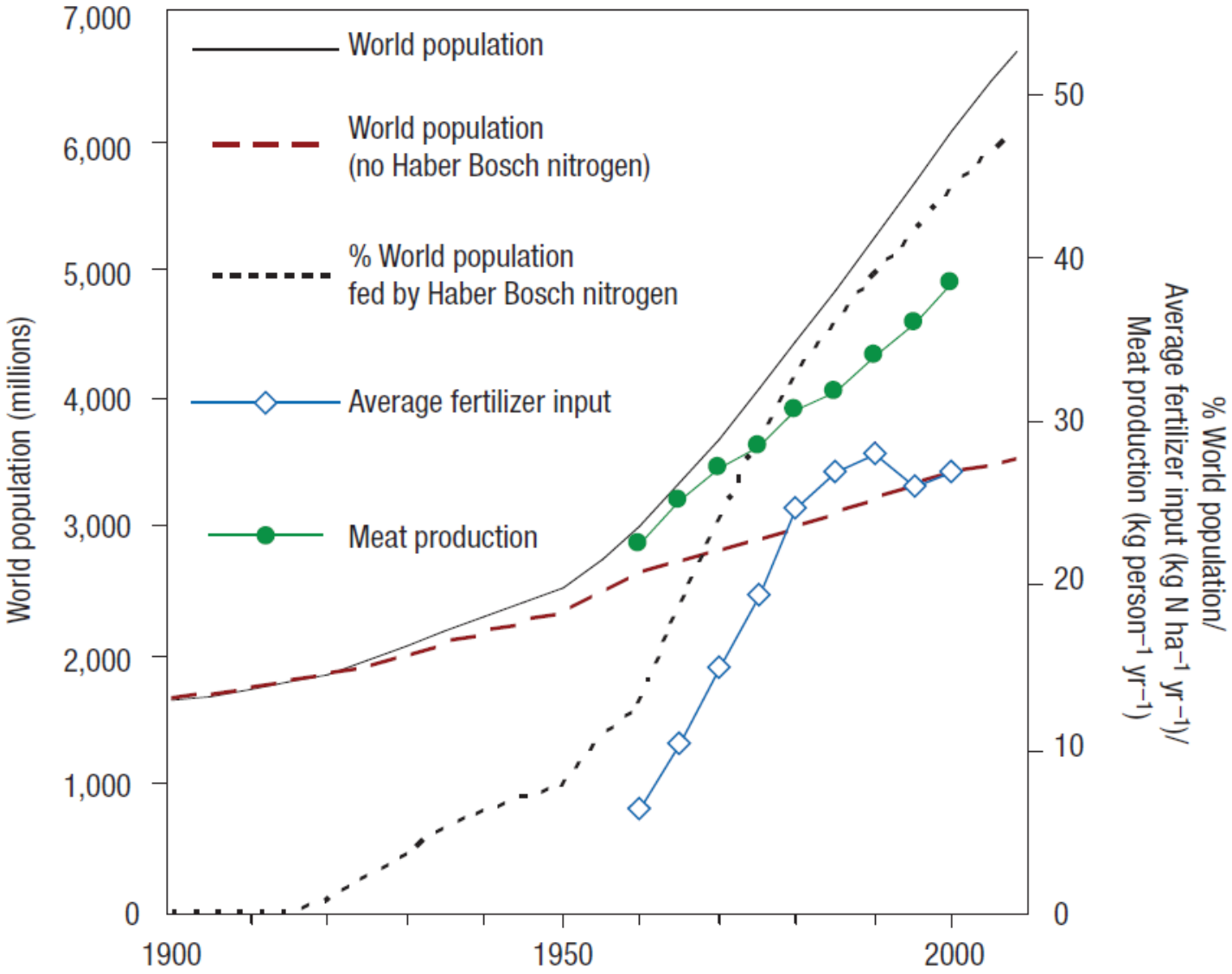
Subsidising harm NZ

- Dairy in NZ an example of the stupidity of current “food” production. Huge amounts of irrigation water to make it and then dried out of the product using coal.
- Dependent on fossil energy derived urea (1/3 Kapuni 2/3 Middle East - was clover) and Palm Kernel from Indonesia
- Dependent on transporting across the world,
- Dependent on desperate workers from overseas
- But we are feeding the world aren’t we? NO product mostly ends up either as human breast milk replacement and junk food filler – is that feeding the world?
- All the harm for an industry that only exists because we subsidise it by exempting the harm. And worse that that it means we are effectively stopping better options

Eating the past

- More and more people dependent on fossil fuels but they are running out - EROI down from ~70 to ~ 15 globally – the easy stuff is gone
- Once we started eating oil we initiated the massive population increase of humans and the animals we eat (the ‘green’ revolution)
- As indicator of human dominance of the planet - the ratio of humans and our food animals and pets to wild animals?

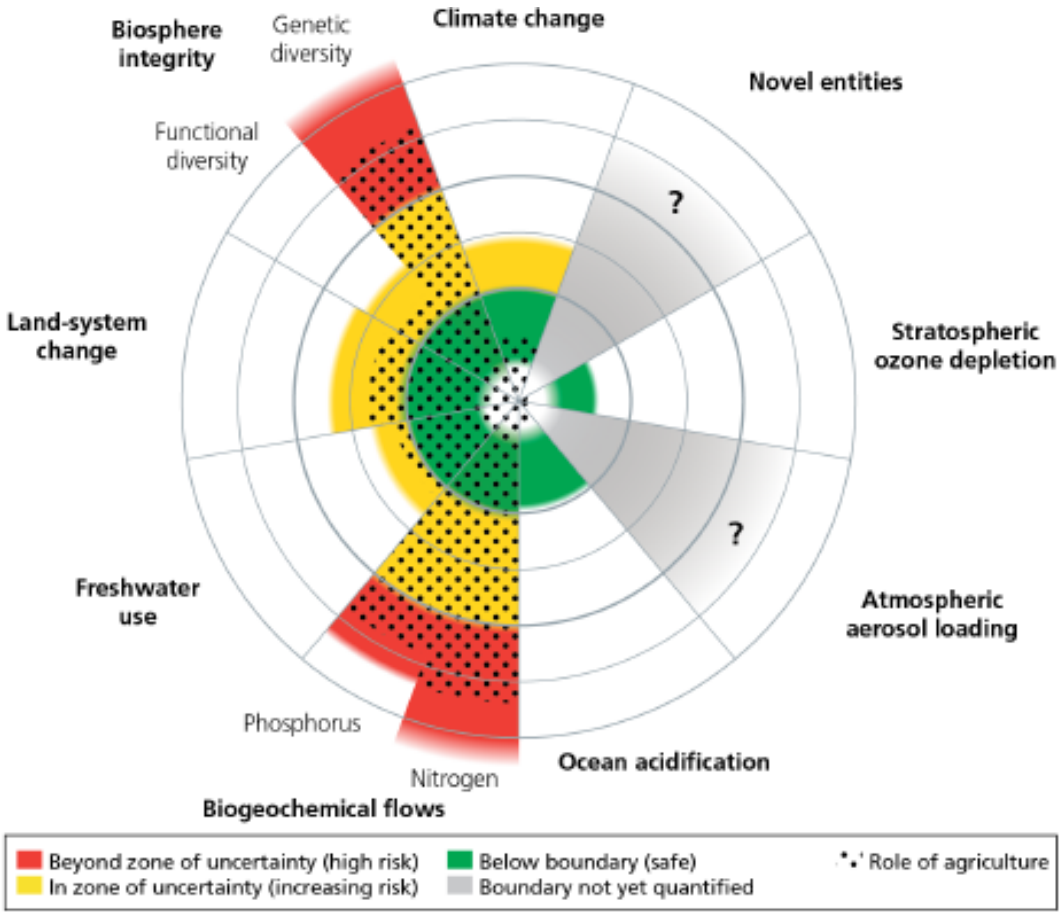
The green (or fossil fuel) revolution? The industrialisation of food production

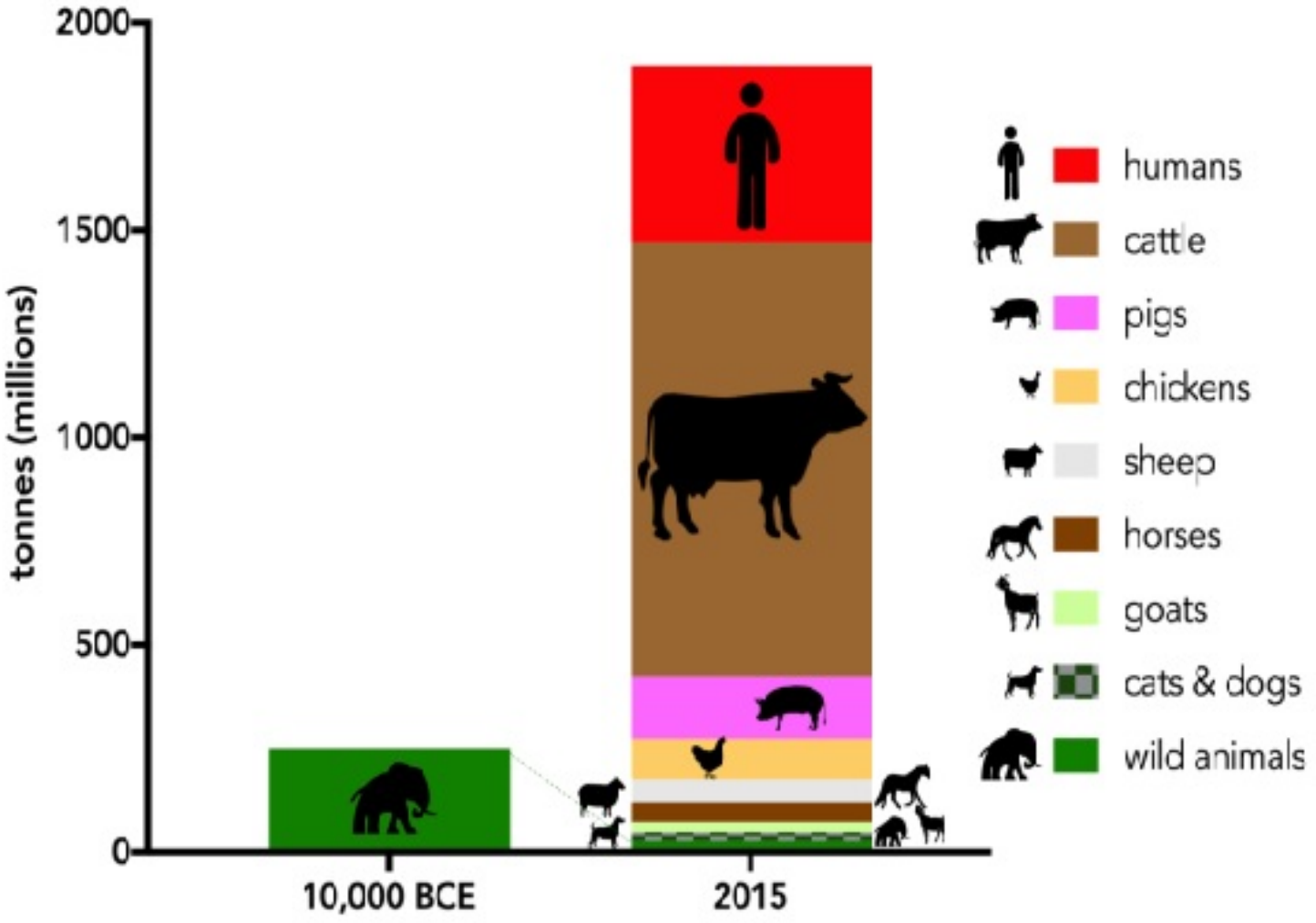


How a century of ammonia synthesis changed the world

Manifestation of “Limits to growth” the living world

- Planetary boundaries exceeded
- Food production ever more dependent on fossil fuels, Agriculture, aquaculture, fishing and forestry (AAFF) 43% fossil fuels in 1970 - 62% now
- AAFF currently 68% of earths terrestrial surface
- 22% of GHG emissions (2010)
- https://link.springer.com/article/10.1007/s41247-020-00074-3



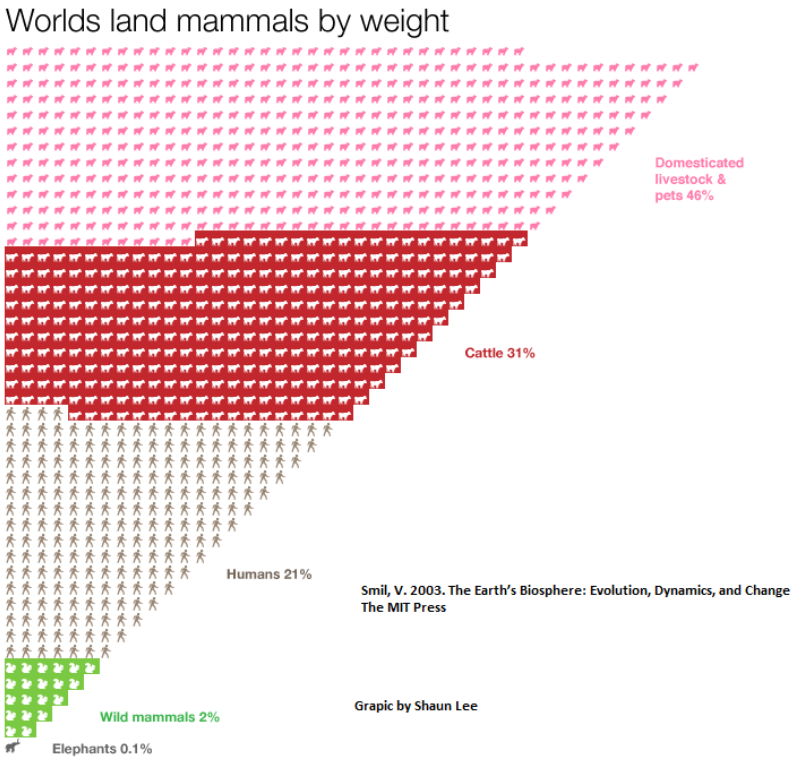

2000
1500
1000
500
0
tonnes (millions)
10,000 BCE
2015
humans
cattle
pigs
chickens
sheep
horses
goats
cats & dogs
wild animals
Paul Chefurka 2015

Manifestation of “Limits to growth” the living world

- Vertebrate animal communities shrunk on average 68 percent between 1970 and 2016 now 3% of global vertebrate biomass (the rest us and what we eat)
- Tropical Americas animal populations declined 94 percent
- Animal communities in or near freshwater globally have fallen by 84 percent

Humans too

- 6.4 billion ppl live on countries exposed to medium or high ecological threats (worst are in Sub-Saharan Africa)
- More than 2.6 billion ppl live in the 46 countries with high or extreme water stress. (don’t receive enough water to meet needs)
- Even if we stay below 2°C, up to three billion people may suffer “chronic” water scarcity - IPCC.

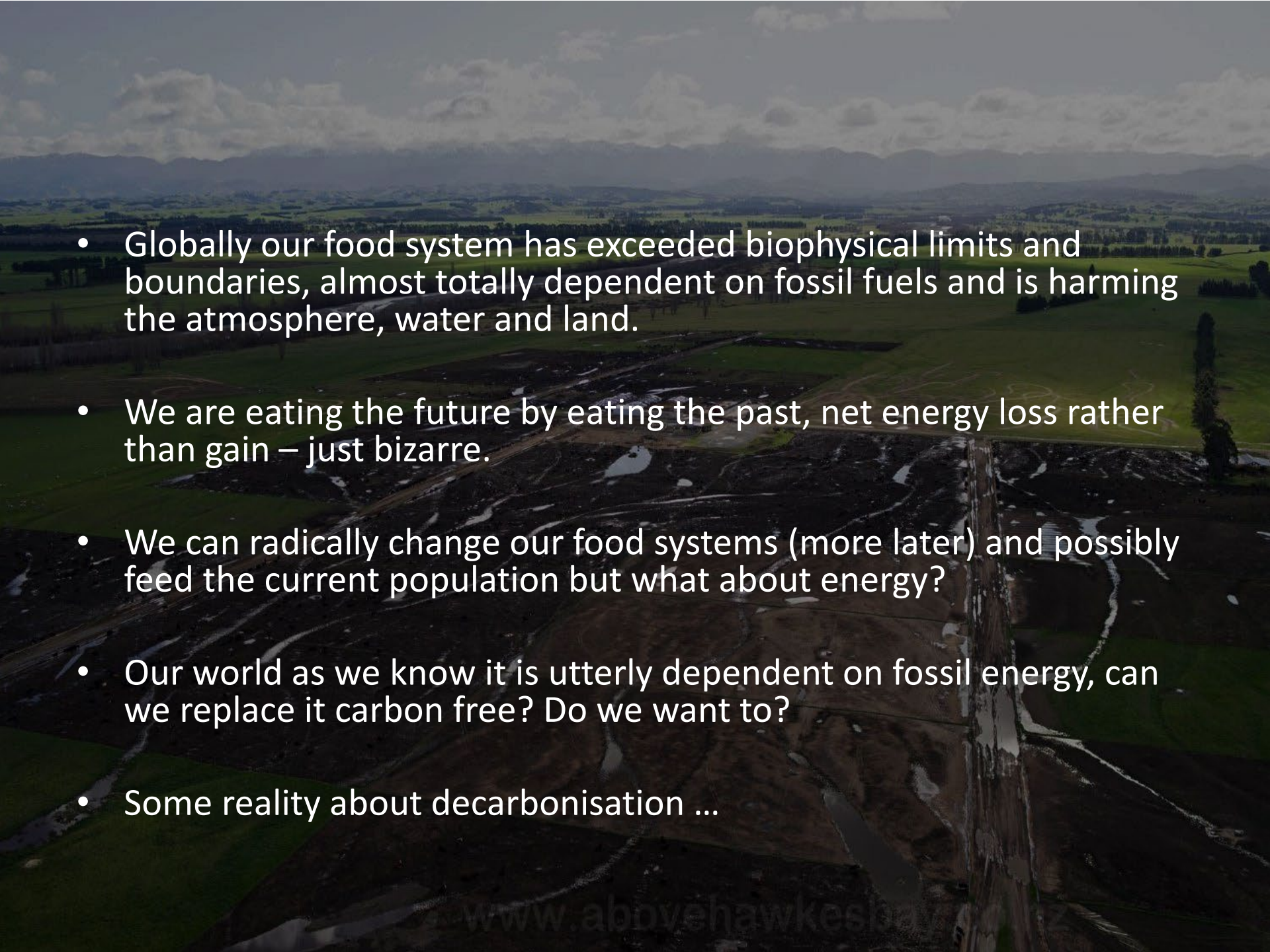


Overdose for some not enough for others and energy loss

- But ~ 1 billion people have inadequate and insecure diets, while 2.1 billion people are obese or overweight from the move to highly processed foods high in refined sugar, refined fats, oils and meats.
  - Food system dependant on fossil energy not just fertiliser - industrial food production system now uses more than 10 - 33 units of fossil energy to plough, plant, fertilise, harvest, transport, refine, package, store/refrigerate, and deliver 1 unit of food energy to be eaten by humans. Idiotic transporting of food all around the globe
  - Producing 1 calorie food in USA uses 21 calories of fossil energy

Eating the past – implications for workforce distribution

- So now the EROI of food production is tremendously negative, pre-industrial it was positive - it had to be
- Eating fossils has allowed a massive switch in workforce from primary to tertiary - food and fibre producers and processors to lawyers, property speculators and life coaches



- Globally our food system has exceeded biophysical limits and boundaries, almost totally dependent on fossil fuels and is harming the atmosphere, water and land.

- We are eating the future by eating the past, net energy loss rather than gain – just bizarre.

- We can radically change our food systems (more later) and possibly feed the current population but what about energy?

- Our world as we know it is utterly dependent on fossil energy, can we replace it carbon free? Do we want to?

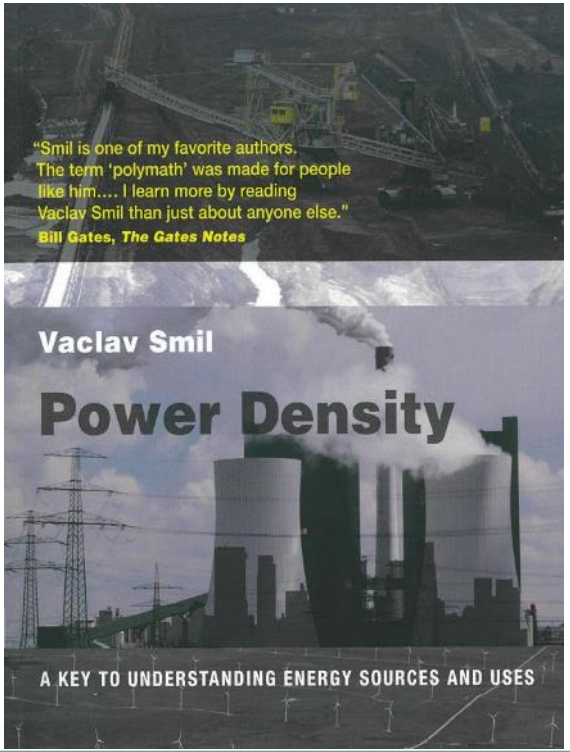
- Some reality about decarbonisation …

How do we transition to this decarbonised world?

Biomass → coal → hydrocarbons → ?

Can we move to a world without
fossil fuels that looks a lot like today?

The crucial issue to understand is power density



The transition to a decarbonised world

Energy density of different energy options

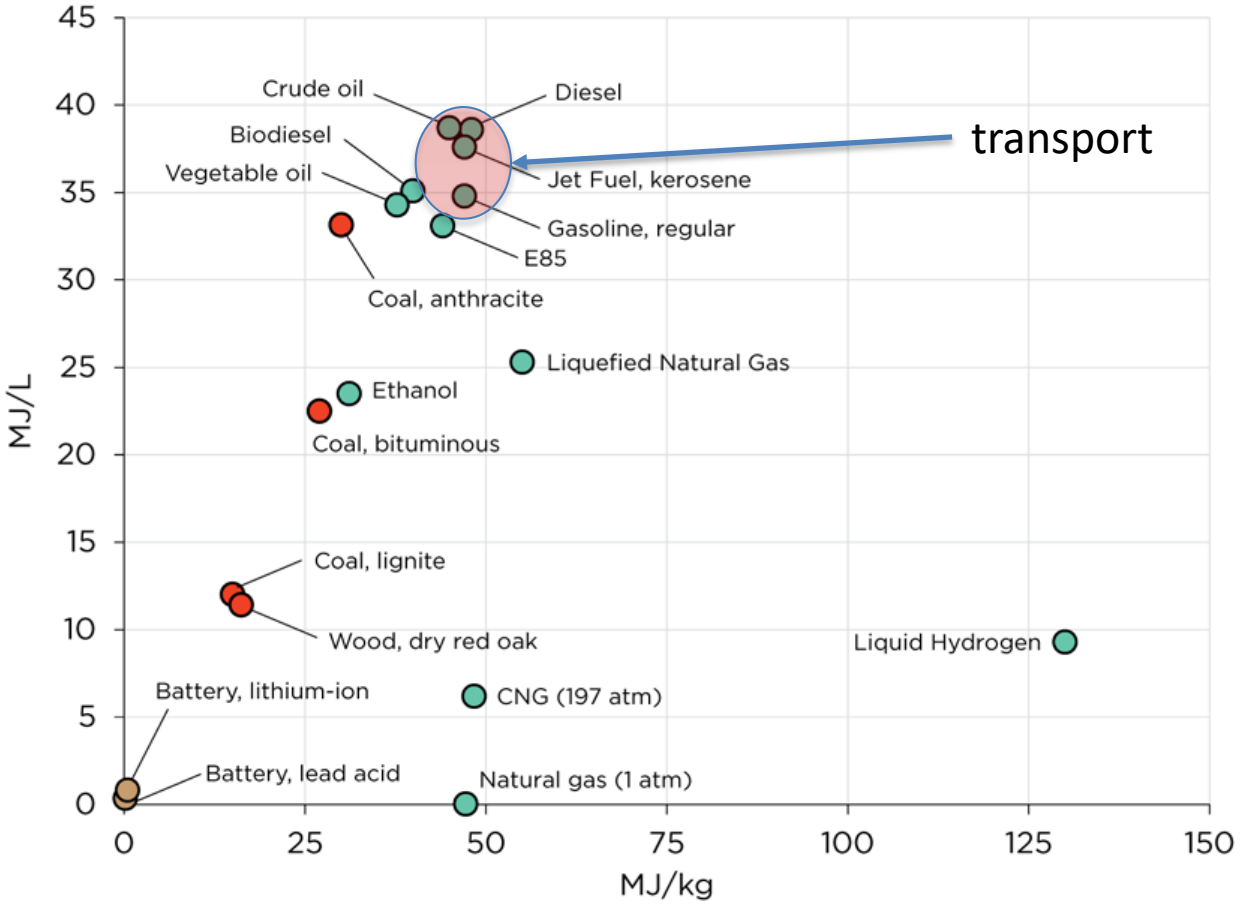


Figure 1.3. Volumetric and gravimetric density of fuels and storage media. Sources: Coal: Tadeusz Patzek and Gregory Croft, "A Global Coal Production Forecast with Multi-Hubbert Cycle Analysis," *Energy* 35 (2010): 3111. Natural gas. Crude oil and wood. Batteries and additional batteries. All others: Charles Hall and Kent Klitgaard, *Energy and the Wealth of Nations: Understanding the Biophysical Economy* (New York: Springer, 2012).

How is our transition to a decarbonised world coming along?

Where we are now

Energy use fossil vs renewable (per capita)

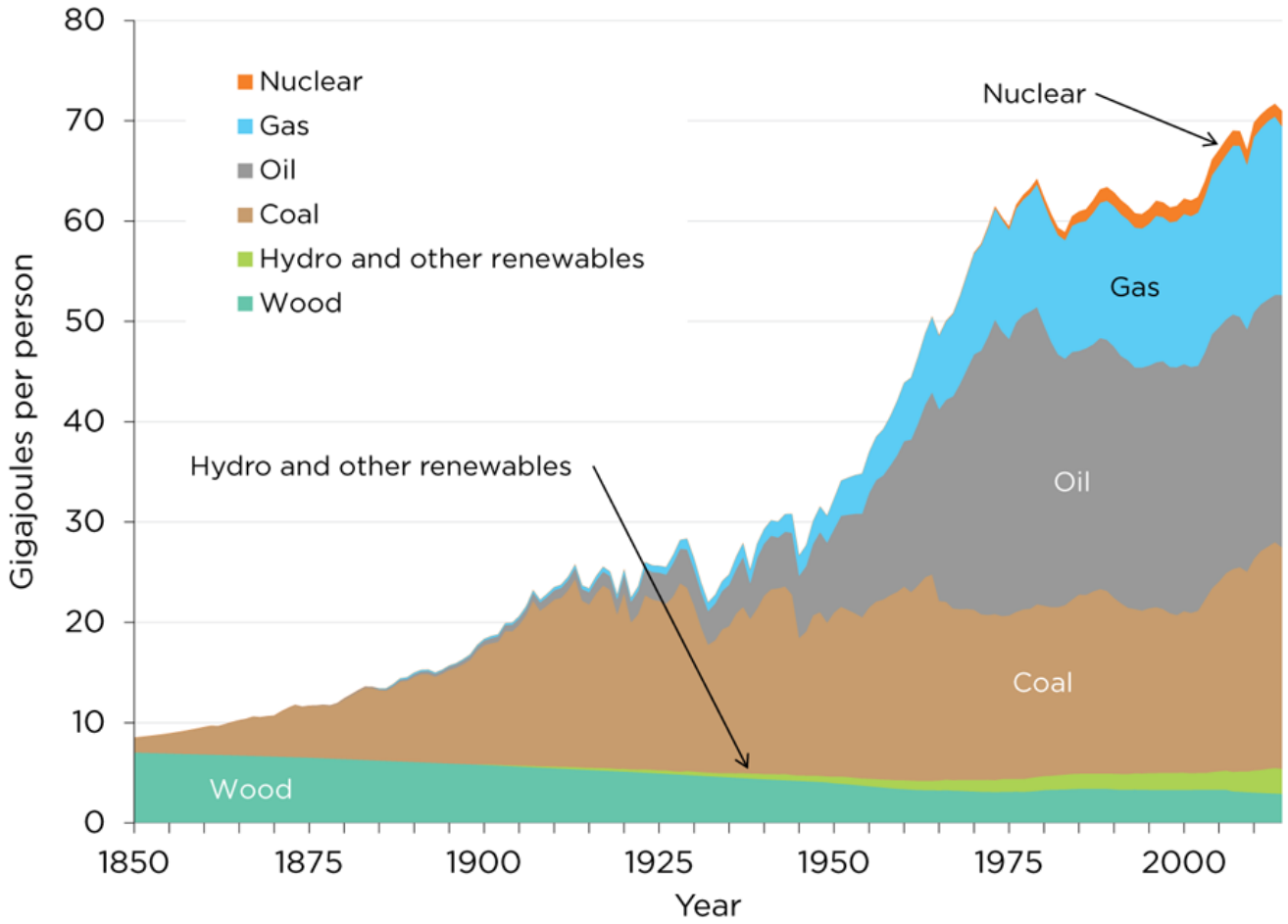


Figure 2.1. World per capita primary energy consumption per year by fuel type, 1850–2014. Primary electricity converted by direct equivalent method.
Source: Data compiled by J. David Hughes from Arnulf Grubler, "Technology and Global Change: Data Appendix," (1998), and BP, *Statistical Review of World Energy,* (annual).

The transition to a decarbonised world
a reality check

Example: Britain consumes energy at a rate of about 5000 watts per person, popn. density

= 250 people km^2 1.25 watts m^2

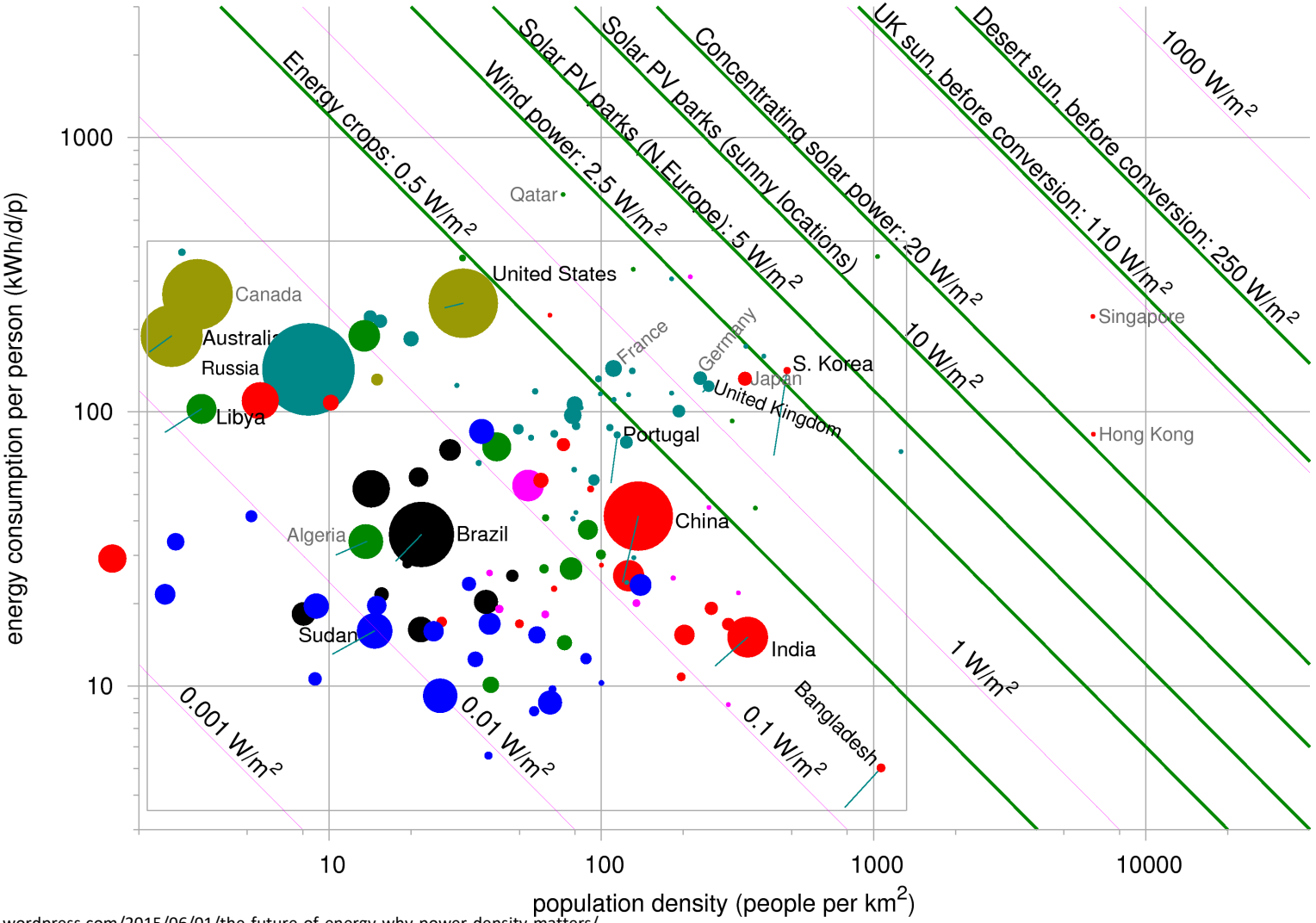
The options:

- Hydro; the gravitational potential energy of rainfall in the Scottish highlands has a raw power per unit area of roughly 0.24 watts/M^2
- Biofuel; energy crops in Europe deliver about 0.5 watts/M^2
- Wind; wind farms deliver roughly 2.5 watts/M^2
- Solar; solar photovoltaic farms in Bavaria, Germany, and Vermont, USA, deliver 4 watts/M^2

Average for a mixture of renewables ~ 1.25 watts/M^2 ----- see the problem?

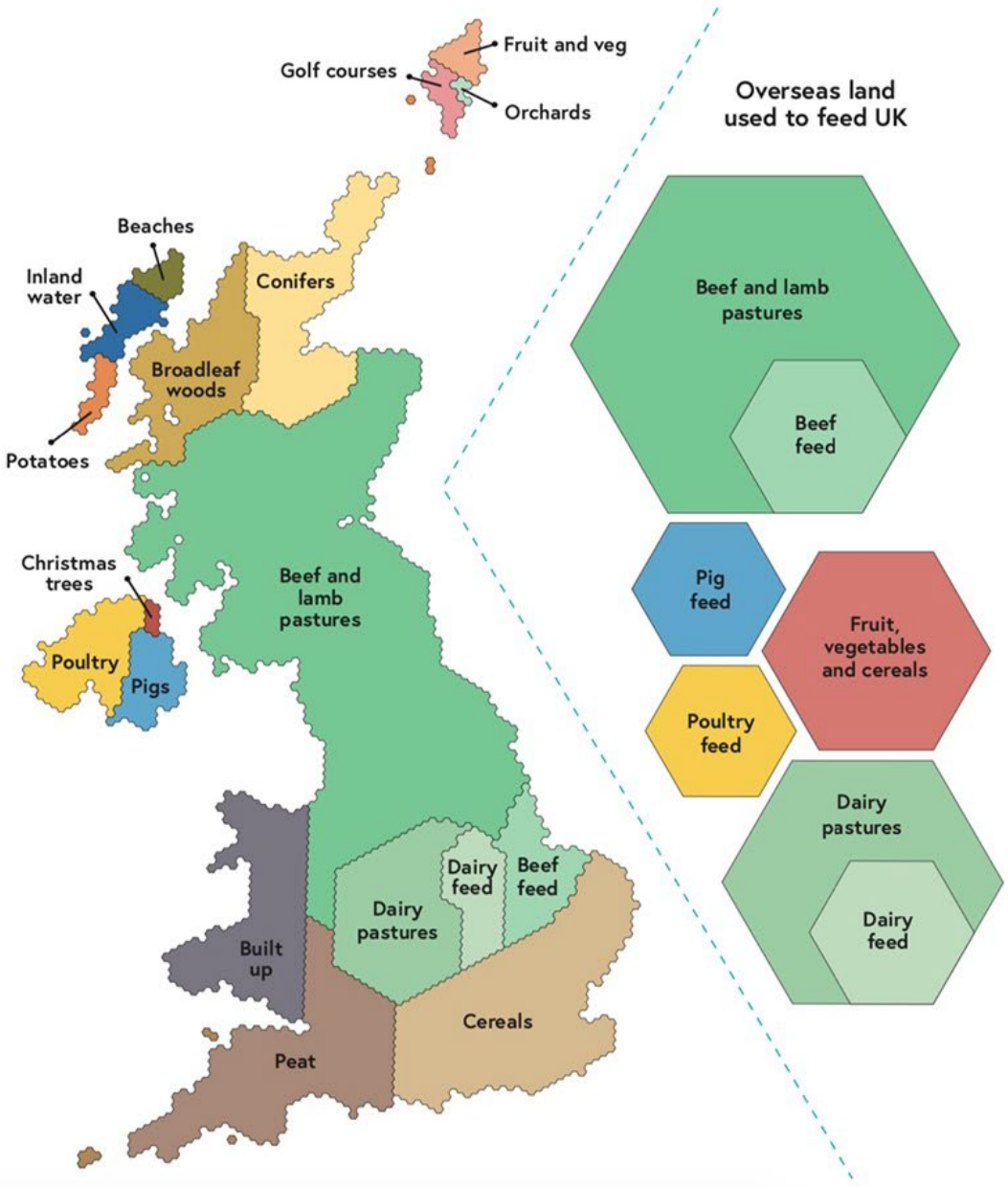
MacKay, D. J. C. (2013). "Solar energy in the context of energy use, energy transportation and energy storage." Philosophical Transactions of the Royal Society a-Mathematical Physical and Engineering Sciences **371.**

The transition to a decarbonised world



https://carboncounter.wordpress.com/2015/06/01/the-future-of-energy-why-power-density-matters/

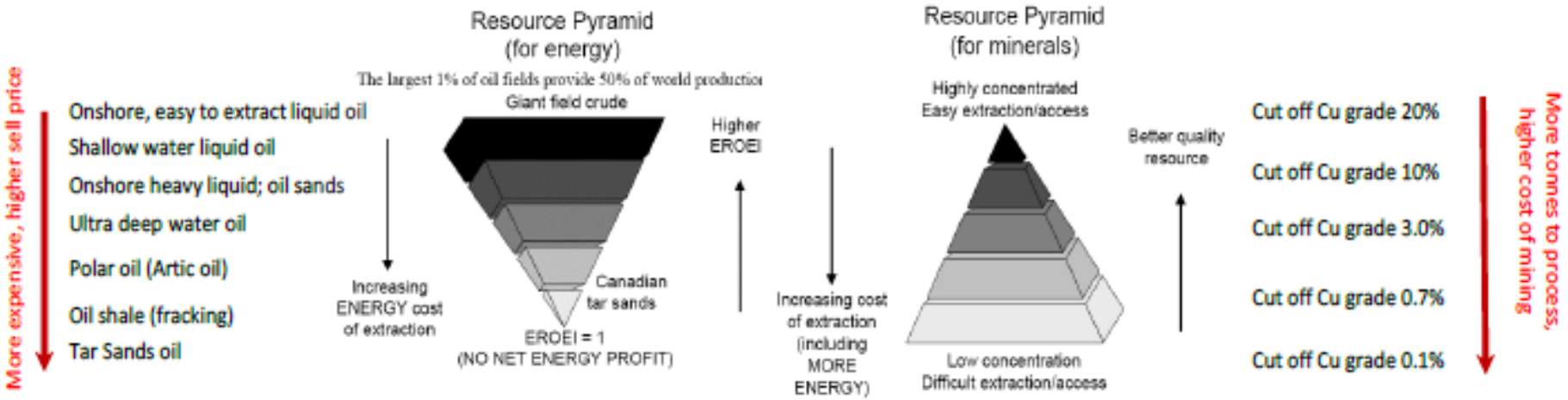
Not just energy land area as well

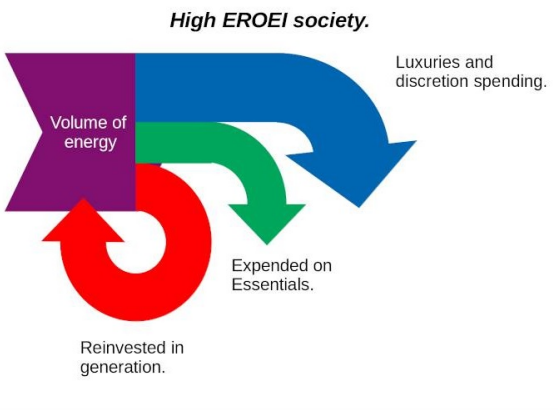


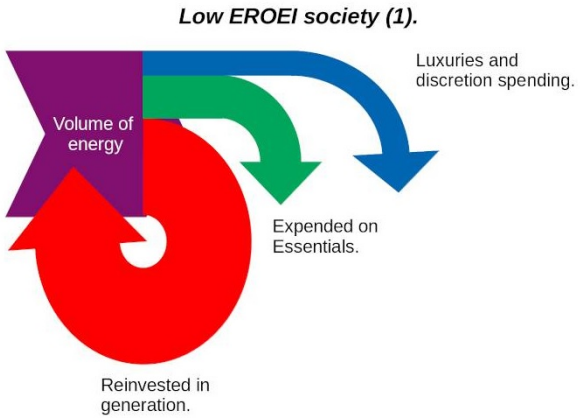
Land area required under current food system UK example

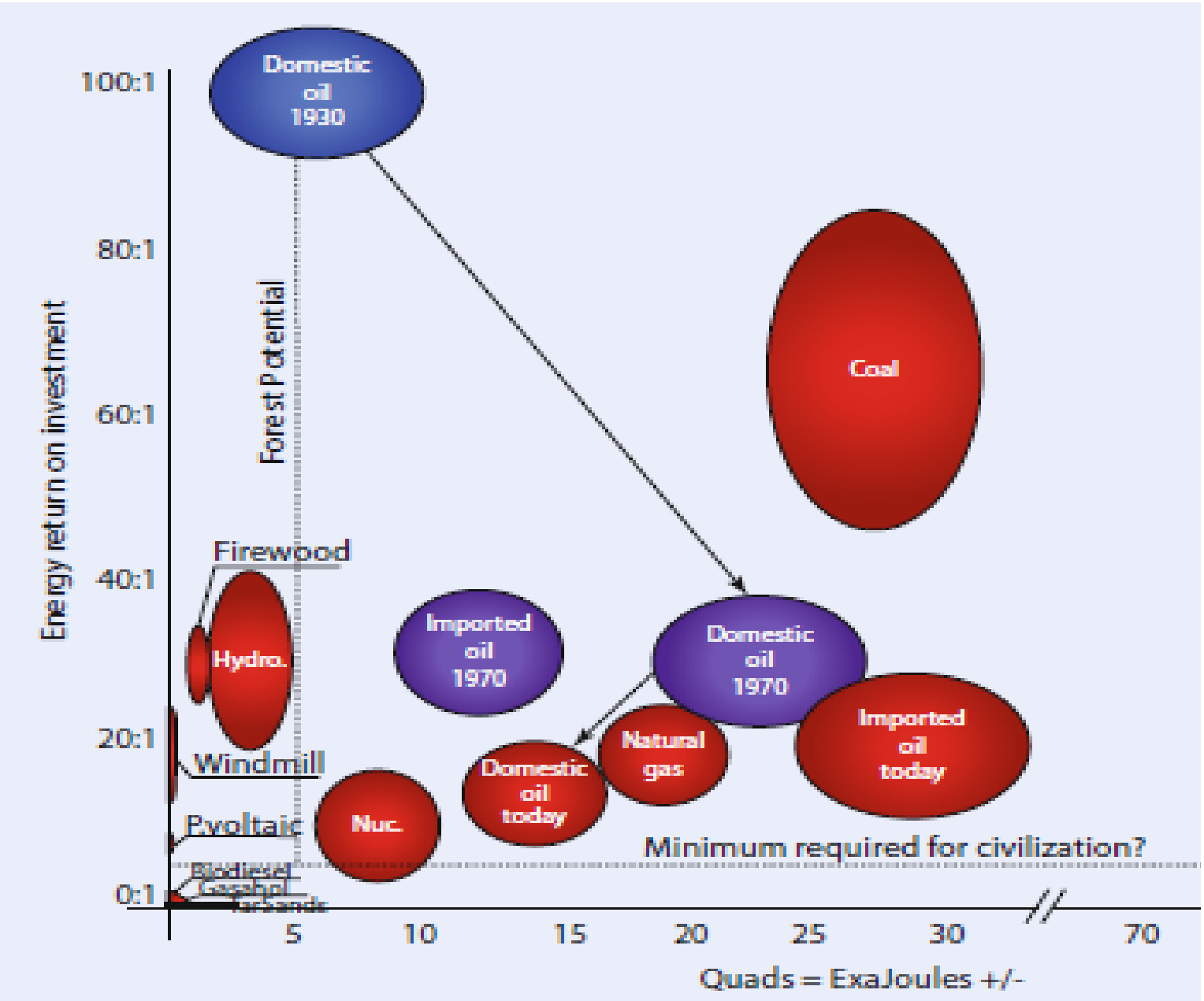
UK land area divided up by purpose. About 70% is devoted to agriculture, mainly livestock and livestock feed and pasture. The right-hand side of the chart, using the same scale, shows how much land is used overseas to produce food for the UK. About half of the total land use takes place overseas. The combined land area for rearing beef and lamb for UK consumption is larger than the UK itself. Source The National Food Strategy, Part II

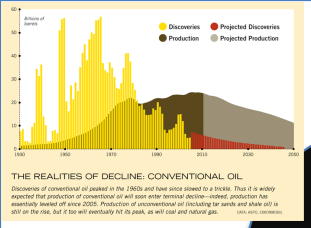
The non-living limits to growth
The resource pyramid conundrum





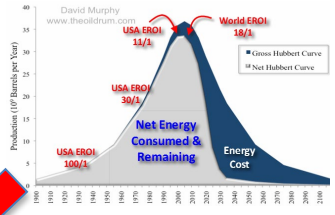


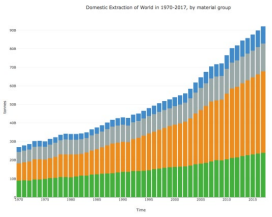

100:1
80:1
60:1
40:1
20:1
0:1
Energy return on investment
Domestic oil 1930
Forest Potential
Coal
Firewood
Hydro.
Imported oil 1970
Domestic oil 1970
Windmill
Natural gas
Imported oil today
Domestic oil today
Nuc.
Pvoltaic
Minimum required for civilization?
Biodiesel
Gasahol
5
10
15
20
25
30
70
Quads = ExaJoules +/-

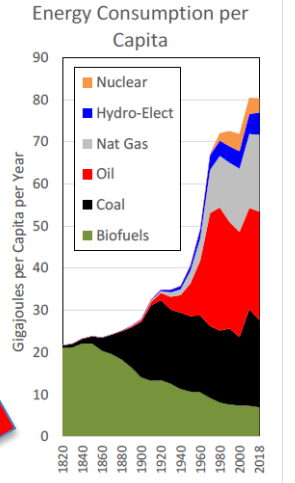


Peak oil

Net fossil energy decline





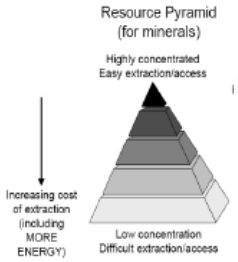


More gadgets = per capita energy and mineral use increase

Biodiversity impacts

More effort required to get minerals

More energy required



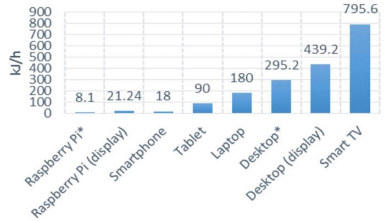


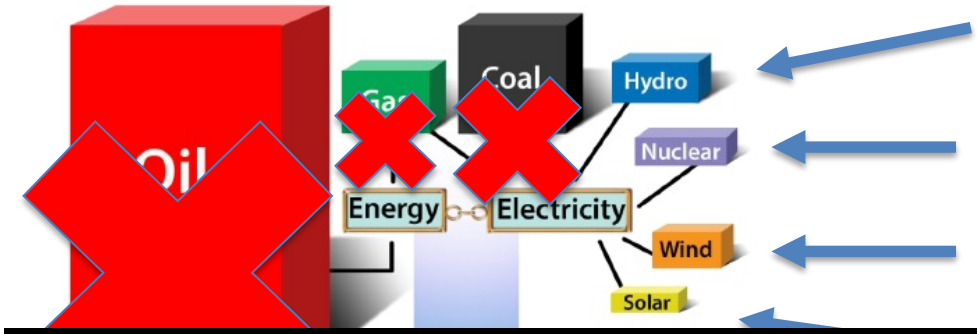
Figure 2: Energy consumption comparison of Raspberry Pi in kilo joules per hour.

Carbon zero for liveable planet

transition to renewables

Carbon sequestration

Food production uses more fossil fuels 43% 1970, 62% now



Most rivers that could be dammed are and very extensive biological and physical impacts

Expensive, slow and unsolved waste issues

Big installation environmental and material footprint. Intermittent

What if we discovered a free non harming energy source tomorrow would we be better off?

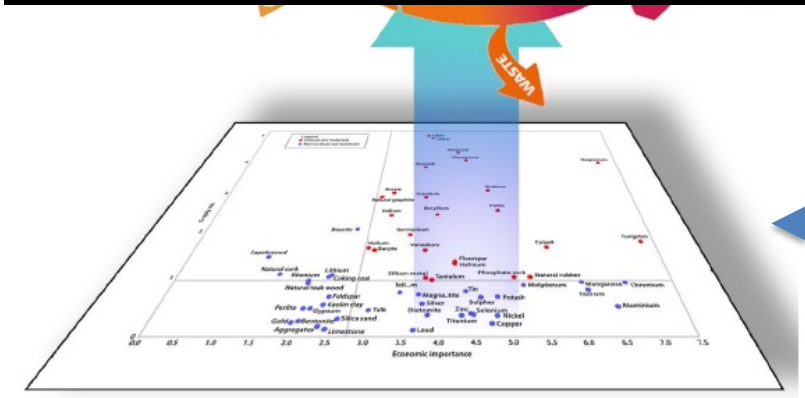
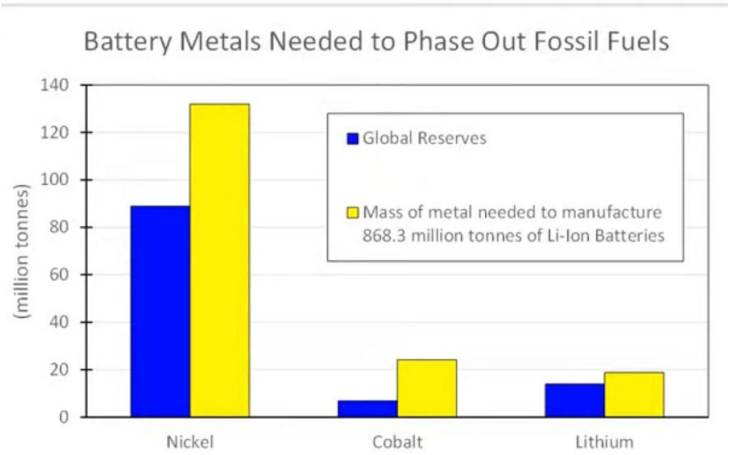


Figure 301. Proposed paradigm for the next generation of the Circular Economy (Image: by Tania Michaux, EIT Raw Materials, and European Commission)

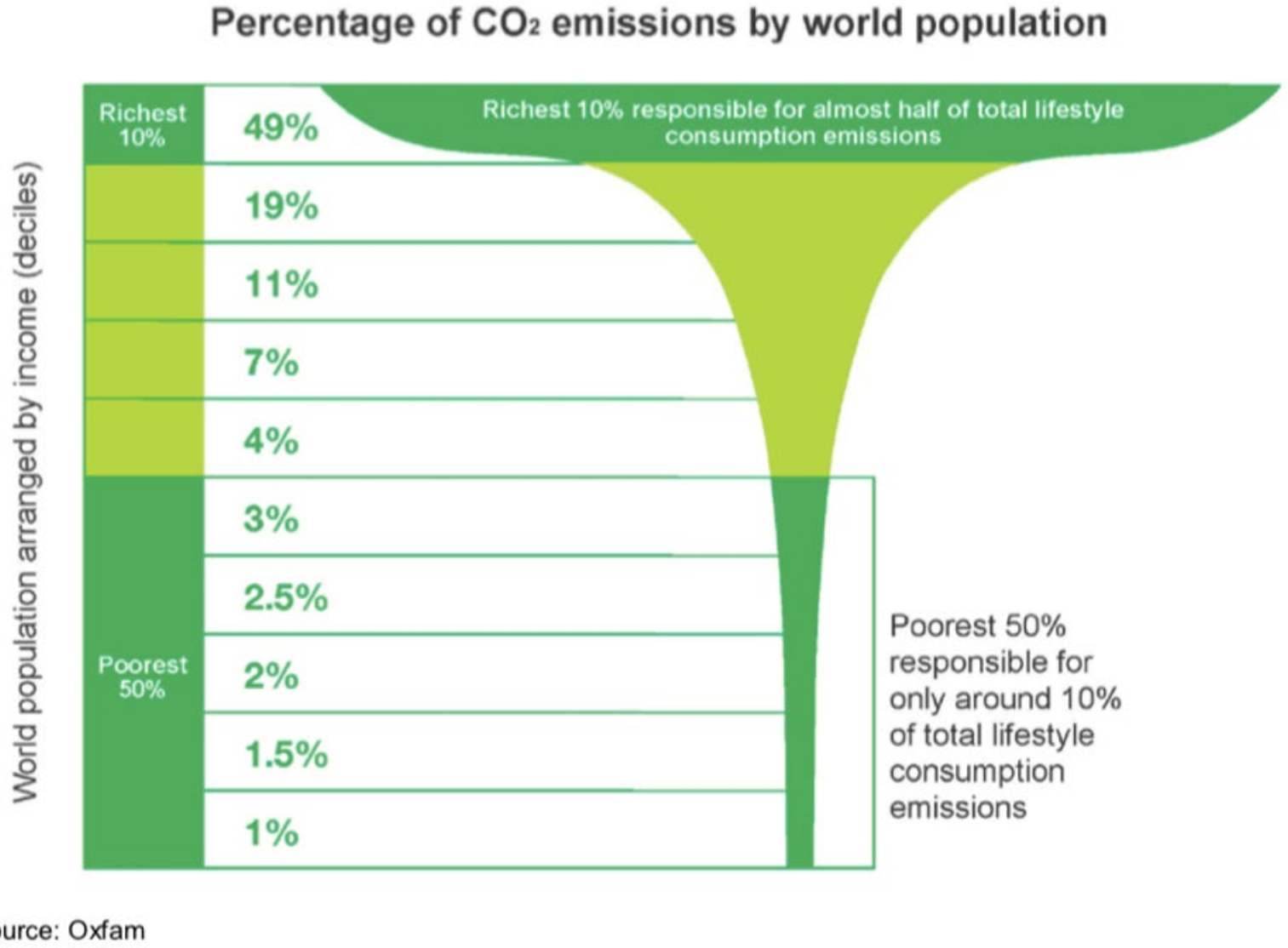


discover another 7.13 DRC Congo cobalt deposits

discover another 6.97 Australian lithium deposits

discover another 6.28 Indonesian nickel deposits

A JUST TRANSITION?



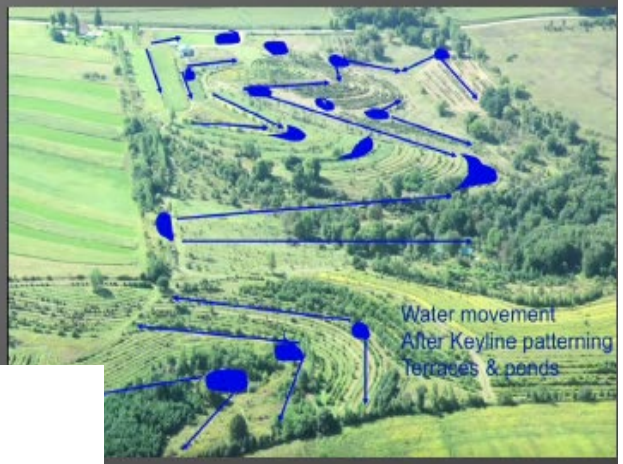
Source: Oxfam

What do we need to do?

Food and agriculture in NZ

- Establish full emissions profile (atmosphere and water) of industrial agriculture and horticulture then apply the full costs to the industry
- This would level the playing field and sustainable food production would be the obvious economic choice.
- Investigate the true value of food systems in terms of nutrition and human health. The current system does not differentiate the crucial difference between junk food and real food (milk powder)
- New food systems, local, no external inputs, no emissions, no monocultures, must be EROI positive.

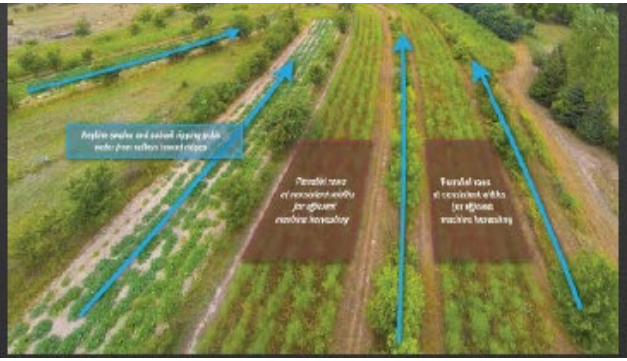
Example: New Forest Farm, WI (USA)

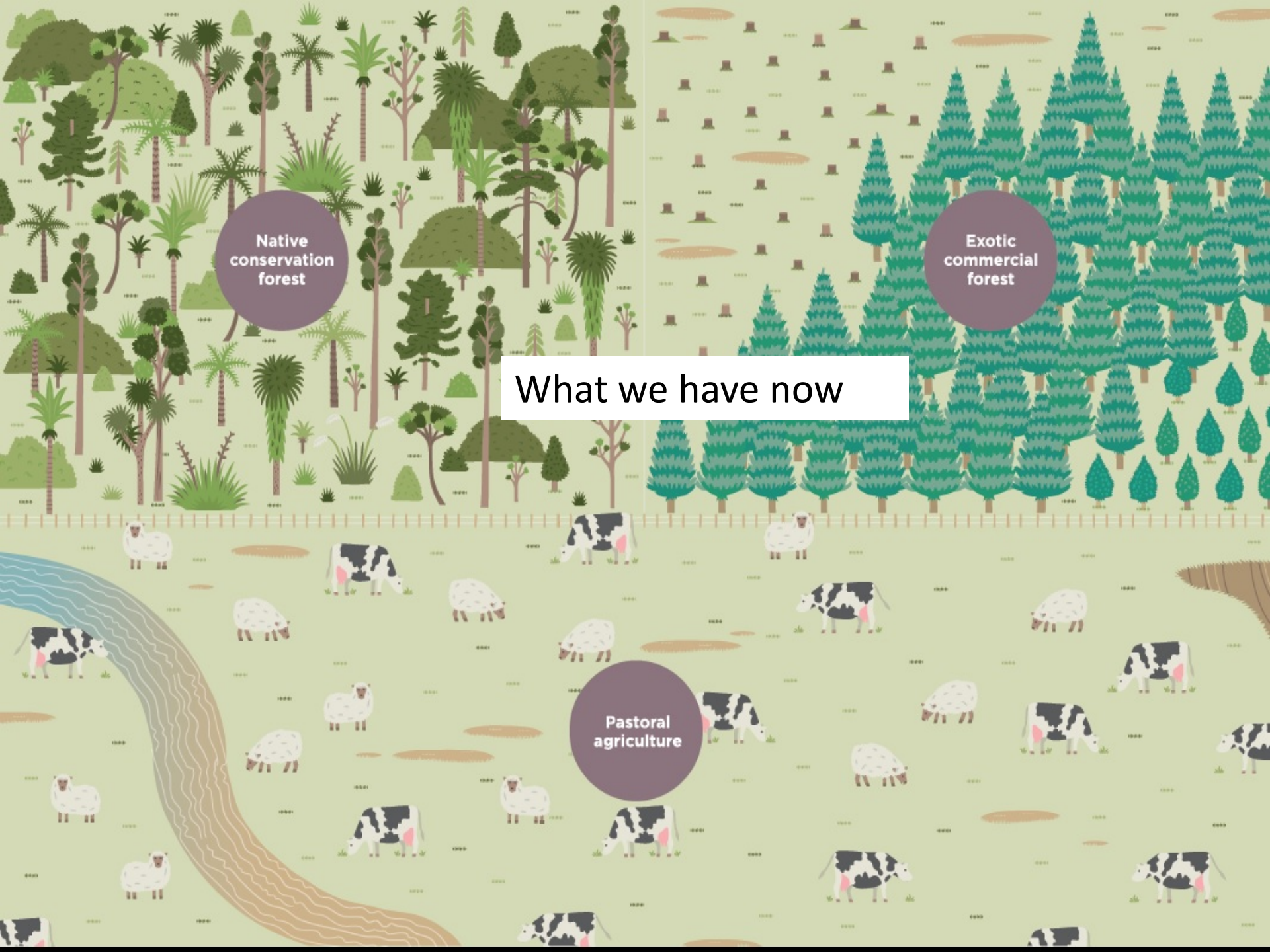


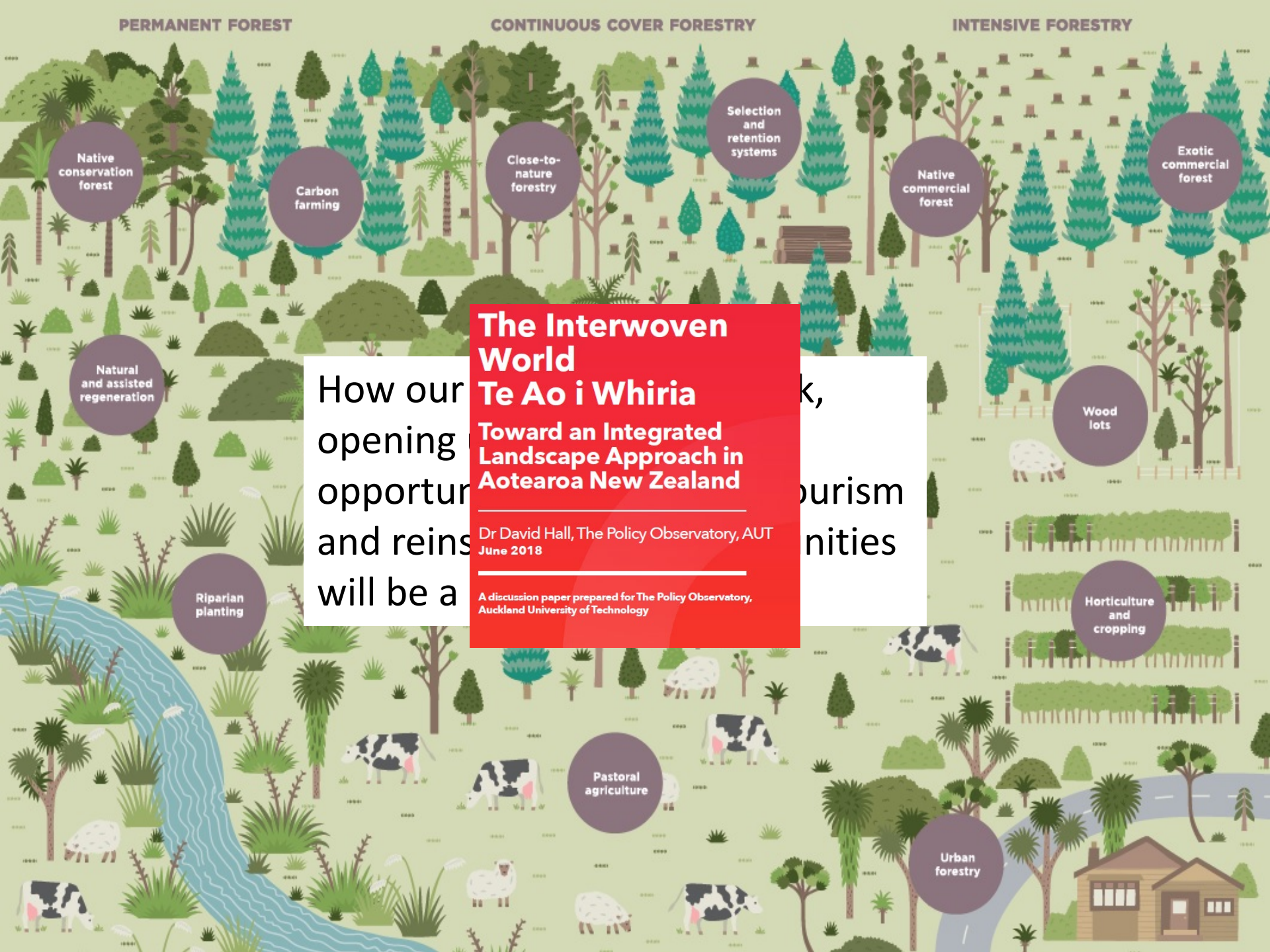
110ac Former maize farm converted to high
Eastern woodlands as the ecological mode
animals), fuel, fibre & medicine. Hazelnuts,
crops - where they provide weed control an
wind powered and farm equipment is powe

using oak savanna, successional brushland and
e another to produce food (for humans and
anaged in an integrated manner with the tree
r the livestock. The farm is entirely solar and

How our landscapes will look, opening up many other opportunities like on farm tourism and reinstating rural communities will be a necessity




Native conservation forest
Exotic commercial forest
What we have now
Pastoral agriculture



How our k,
opening
opportur ourism
and reins nities
will be a

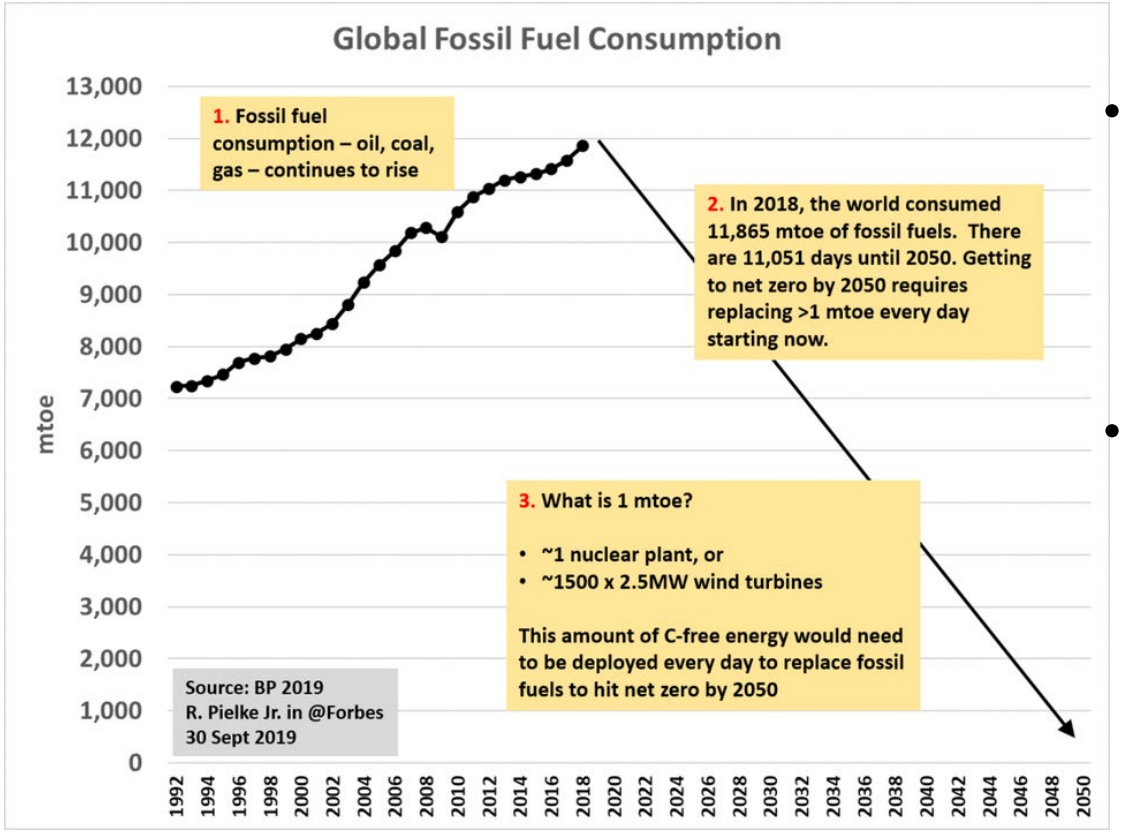
The Interwoven World
Te Ao i Whiria

Toward an Integrated Landscape Approach in Aotearoa New Zealand

Dr David Hall, The Policy Observatory, AUT
June 2018

A discussion paper prepared for The Policy Observatory, Auckland University of Technology

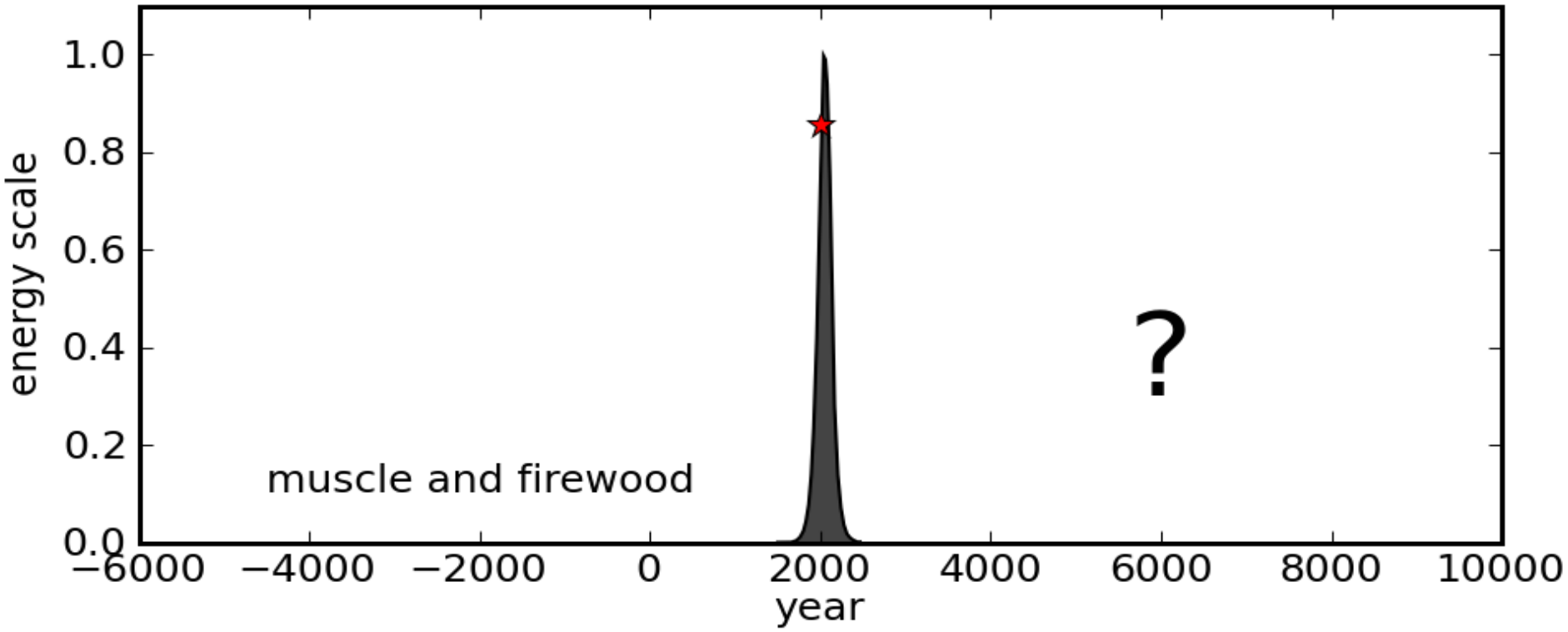
Reality check on decarbonisation – why we have to act now



- In 2018 the world consumed 11,743 mega-tonnes of oil equivalent (mtoe) fossil fuel
- So to reach net-zero carbon by 2050 (~11,000 days) we need to replace about 1 mtoe every day from now until 2050
- Thus, we would need to build 1500 2.5 mw wind turbines (covering 777 km^2) every day from now until 2050, or 1 large nuclear power plant per day!

https://www.forbes.com/sites/rogerpielke/2019/09/30/net-zero-carbon-dioxide-emissions-by-2050-requires-a-new-nuclear-power-plant-every-day/?fbclid=IwAR0arZXkUCKU_QndkmlTYvQ04clCJyG_axZ70_6EswVcgu6xsCR_0X8_lml#1c3eb84135f7

- We are dependent for everything that makes our modern existence including food either directly of indirectly on fossil fuels but that is almost over, 10% reduction p/a or catastrophe



The future:

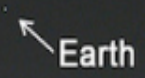
1. end the self delusion

- Net zero, carbon zero tree planting
- CCS
- Decoupling emission from GDP
- Military emissions

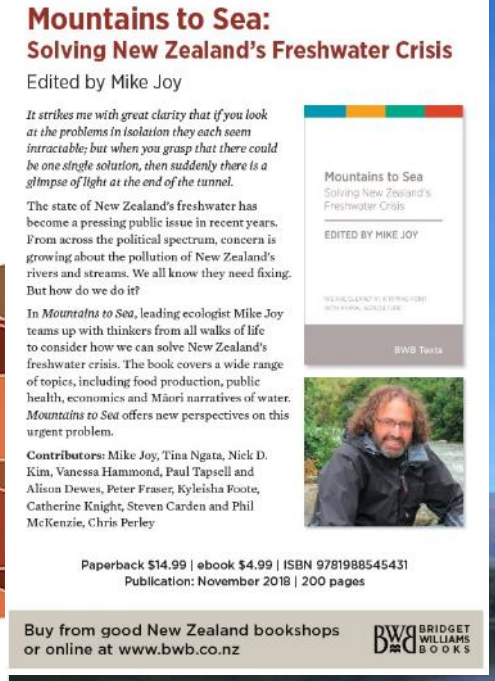
2. Bring in some reality

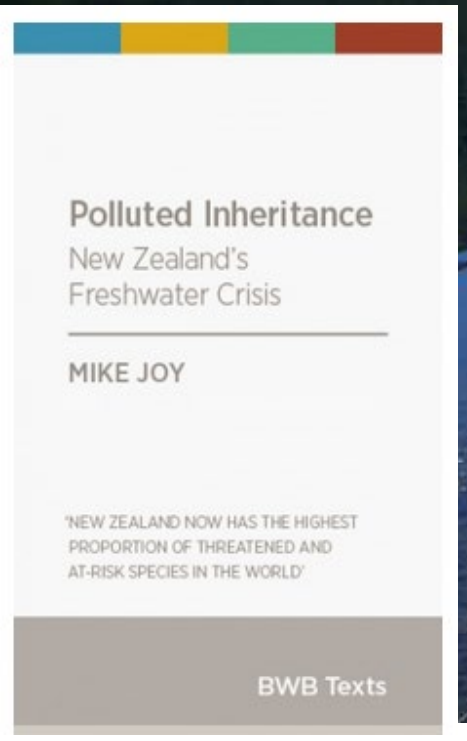
- Begin consumption based accounting of GHG emissions
- Use the remaining carbon budget (<10 yrs) on preparation only
- TEQs f embodied carbon or embodied emissions" and degrowth

- “The real problem of humanity: we have Palaeolithic emotions; medieval institutions; and god like technology” – E.O. Wilson



- “not everything that is faced can be changed, but nothing can be changed until its faced” – James Baldwin





Activism is my rent for living on this planet
(Alice Walker)

http://futurelivingskills.org.nz/

Doing nothing will not make you immune to the consequences

www.waterqualitynz.info

Thanks to:

Victoria University
IGPS,
Freshwater activist friends
students &
colleagues all over New Zealand