Energy – CO_2

- short talk to follow James Renwick's talk on climate change science

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Energy – CO_2 the global picture: fossil fuels reign supreme

Energy is the key sector for global greenhouse gas emissions (Ritchie and Roser, 2020):

Sector	Global CO2 (equiv.) %
Energy (electricity, heat and transport)	73.2
Direct Industrial processes	5.2
Waste	3.2
Agriculture, Forestry and Land Use	18.4

Fossil fuels provided approximately 84% of world energy consumption in 2019 (BP, 2020).

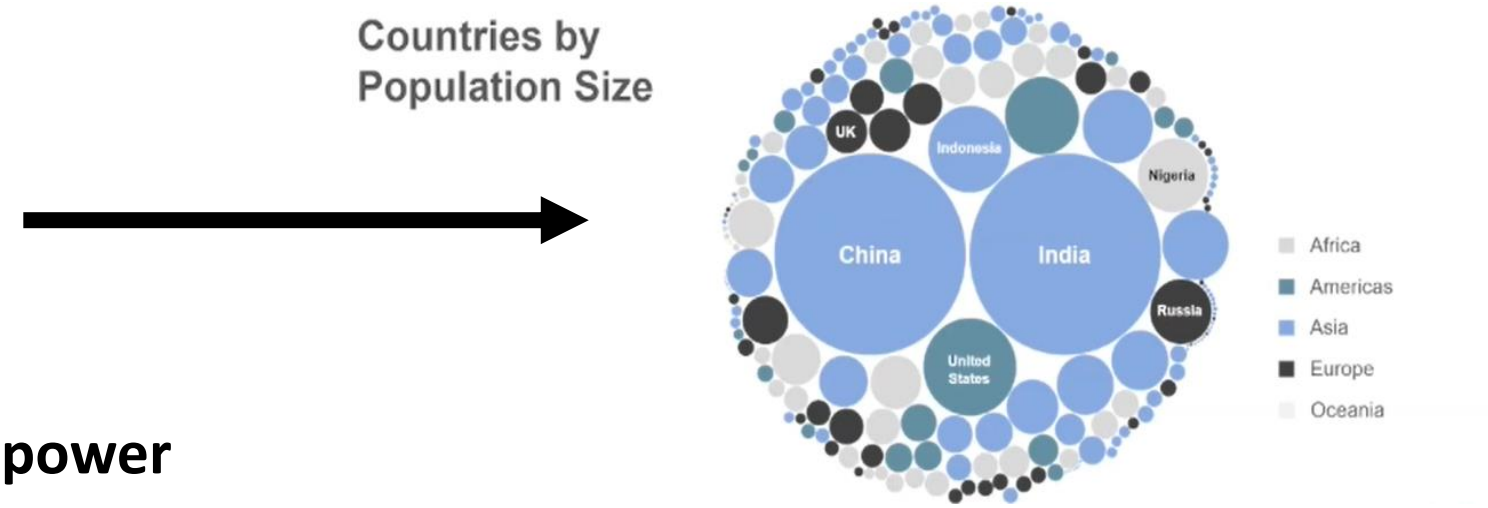
Source	World (%)
Oil	33.1
Coal	27.0
Gas	24.2
Hydro	6.4
Nuclear	4.3
Renewables (other)	5.0

Growth in fossil fuel use is calculated to result in a near-doubling world CO_2 emissions from fossil fuels between 1971 and 2100 (after Worldometer, 2021).

Year	Fossil CO_2 emissions (Billion tons)[1]	World Population (Billions)	Specific CO_2 emission (tons/capita)
1971	15.7	3.8	4.2
1980	19.8	4.5	4.4
1990	22.5	5.3	4.2
2000	25.6	6.1	4.2
2010	33.6	7	4.8
2015	35.6	7.4	4.8

CO2 generation: a tale of two data sets: population and wealth

Large countries have a tremendous influence on attaining CO_2 targets



Wealth, CO_2 generation, power

Country	GDP/capita 2020 ($US)	CO2 emissions 2020 (tonnes/capita)	Fossil fuels 2019 (kWh/capita)
United States	$59,920	15	66525
Australia	$48,679	15	64592
New Zealand	$42,775	7	34376
United Kingdom	$42,676	5	25528
China	$16,316	8	23373
India	$6,166	2	6303

Wealthy countries: more fossil fuels (per capita)

Poor countries: less fossil fuels (per capita)

Bricker (2021)

Our World in Data (2023)

Worldometer (2021)

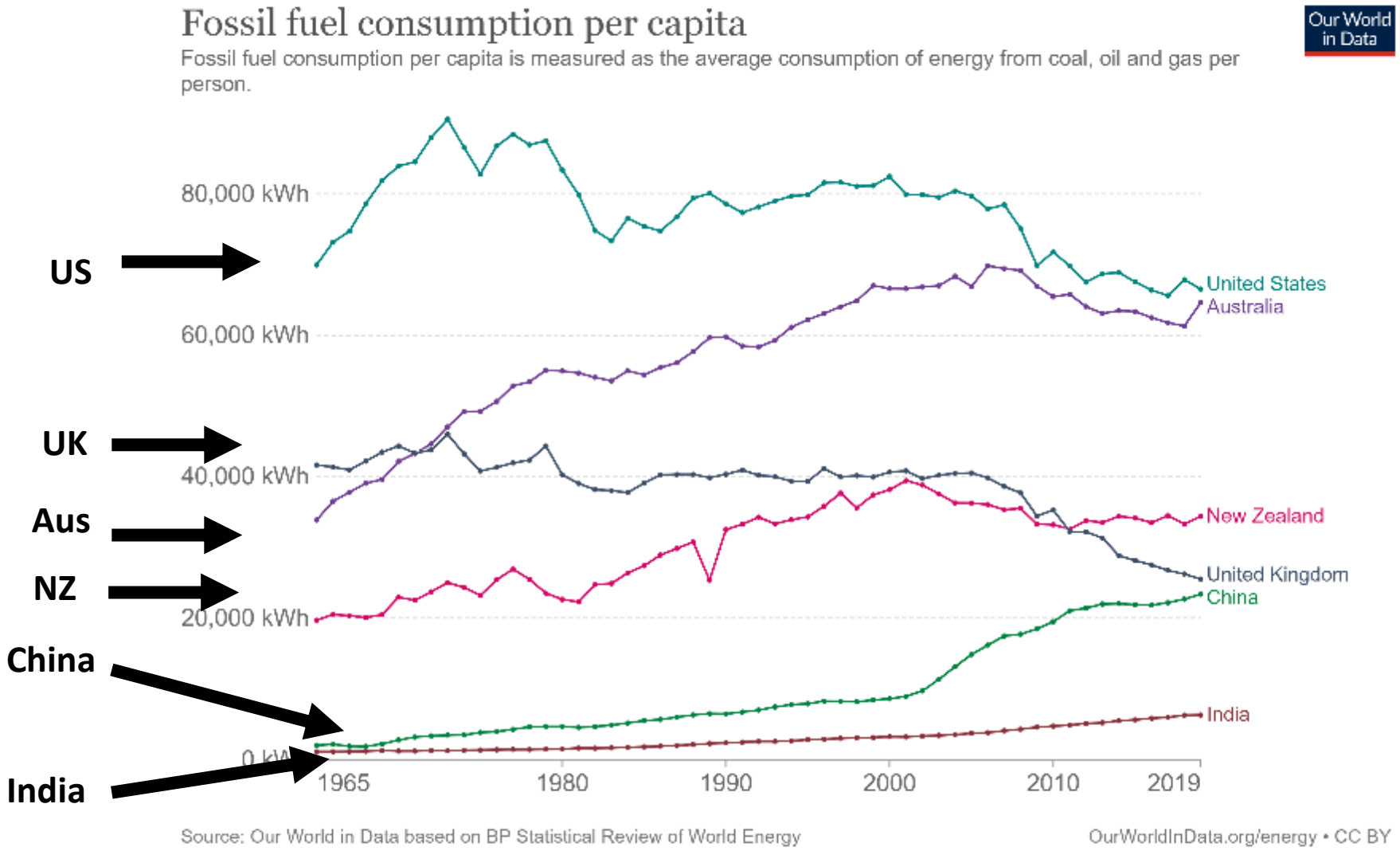
CO2 generation: a tale of two data sets: population and wealth

Wealthy countries:

- some up, some down

Poor countries:

increases in fossil fuel usage (per-person and per-country).



'China approved equivalent of two new coal plants a week in 2022, report finds'

- This is 106 GW of coal-fired production capacity in the year

- Huntly 1 GW of capacity!

Our World (2021)

Bricker (2021)

Poor countries want to develop - CO2 emissions will increase

Social indicators

Country	GDP/capita 2020 ($US)	CO2 emissions 2020 (tonnes/capita)	Fossil fuels 2019 (kWh/capita)	Global hunger index (2020)	Expected schooling 2020 (years)
United States	$59,920	15	66525	NA	16.3
Australia	$48,679	15	64592	NA	21.1
New Zealand	$42,775	7	34376	NA	20.3
United Kingdom	$42,676	5	25528	NA	17.3
China	$16,316	8	23373	2.5	14.2
India	$6,166	2	6303	27.5	11.9

Social indicators: everyone wants to go this way

Our World in Data (2023)

CO2 reduction: good news - wealthy countries can reduce CO2 production for energy supply

The UK reduced electricity generation from fossil fuels by reducing coal use, e.g. the UK (Carbon Brief, 2019).

For example, note:

- the large decrease in coal*
- the large increase in renewables

*coal produces CO_2 at twice the rate of gas for electricity production

Source	Electricity generation (TerraWatt-hours)		Change in period (%)
	2000	2017	
Oil	6.5	2.2	-66
Coal	120	23	-81
Gas	148	133	-10
Nuclear	85	70	-18
Renewables*	9.9	99	900

Energy the big picture: how hard will it be to meet the Paris Accord?

To meet the Paris Accord (Figueres and Rivett-Carnac, 2021):

- world CO2 emissions cut by 50% to 2030
- then, world CO2 emissions cut by a further 50% to 2040
- then, world CO2 emissions need to be nett 0 by 2050

This is going to be really tough:

world CO_2 production from fossil fuels is calculated to rise significantly 2020 – 2100 (White, 2021). →

Year	Fossil CO_2 emissions (Billion tons)[1]	Population (Billions)[2]	Specific CO_2 emission (tons/capita)[3]
2020	34.3	7.8	4.4
2030	37.4	8.5	4.4
2040	40.5	9.2	4.4
2050	42.7	9.7	4.4
2075	46.6	10.6	4.4
2100	48	10.9	4.4

[1] Calculated as population*specific CO_2 emission.

[2] World population estimate (United Nations, 2021).

[3] Average (historic).

NZ Electricity System and CO_2

Energy in NZ: fossil fuels provide the majority of energy

NZ's primary energy sources (Energy in New Zealand, 2020).

Source	PetaJoules/yr	Class	Fraction (%)
Oil	296	Fossil fuel	60
Coal	64[2]	Fossil fuel	
Gas	185	Fossil fuel	
Hydro	92	Renewable	40[1]
Wind	7	Renewable	
Wood	61	Renewable	
Geothermal	196	Renewable	
Solar	0.7	Renewable	
Sum	901.7		

[1] Third-highest fraction in the OECD.

[2] = 18 GWh/yr = approx. 3.5 *Huntly Power Station annual output

NZ electrical power production: sources (2022)

NZ's electrical power sources

Source:

MBIE Quarterly Electricity report:

Generation and Consumption

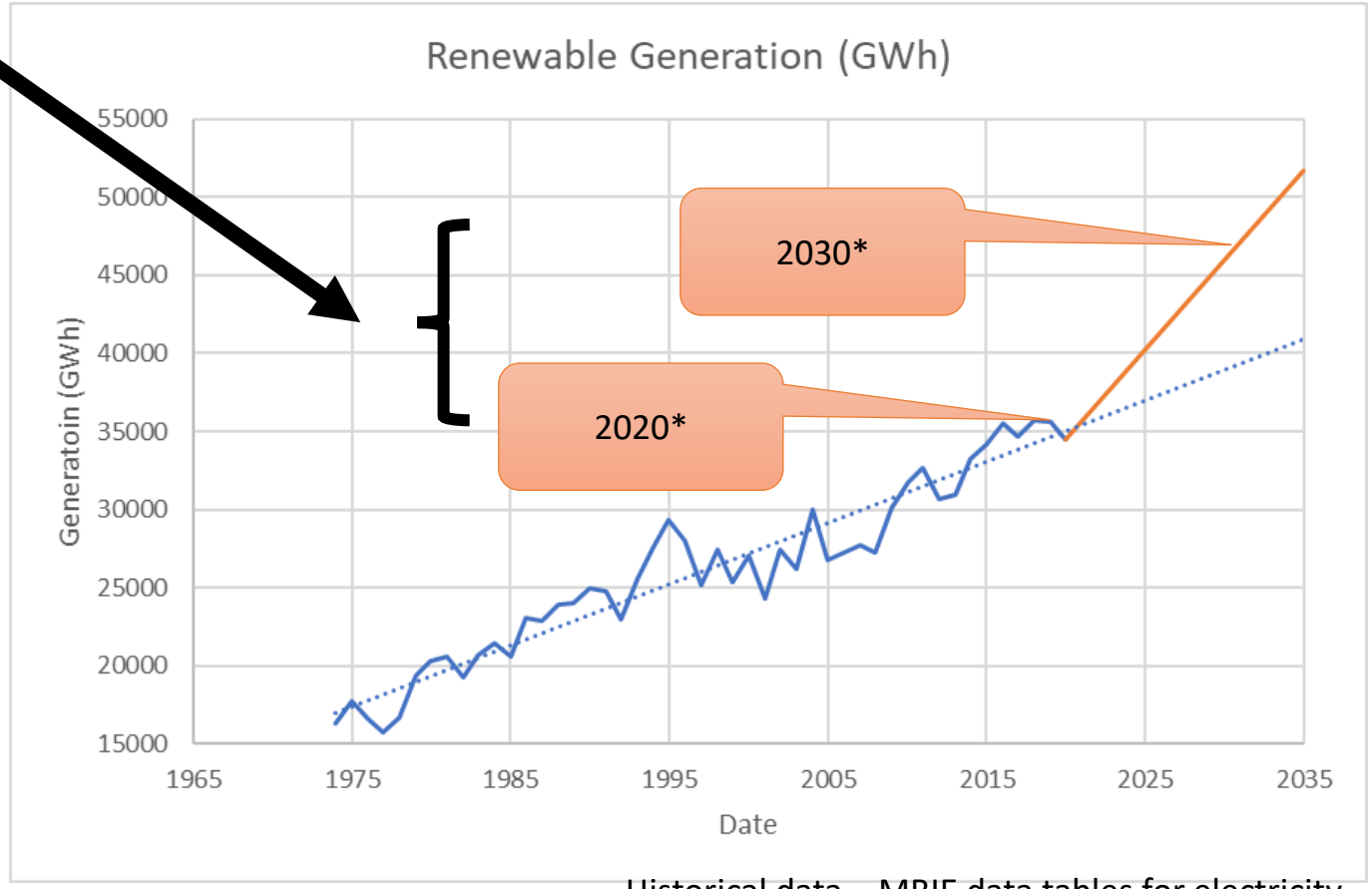
Fossil fuels (13%)

Renewables (87%)

Source	2022	
	GWh	%
Oil	5	0
Coal	1254	3
Gas	4310	10
Hydro	26,001	60
Geothermal	8,060	19
Wind	2,837	6
Biogas	257	1
Wood	458	1
Solar	276	1
Waste Heat	45	0
Total	43,503	101

Generation: what NZ needs to achieve by 2030: demand for renewables and growth

- current NZ targets require approx. 30% increase in renewable energy to 2030
- this energy increase equivalent to approx.
  - 12000 GWh
  - 2.4 Huntly Power Stations – that is a lot of power!
- this is a big challenge!
- big developments have been done
  - Huntly
  - Manapouri
- but, what large* developments are in construction now?



Historical data – MBIE data tables for electricity

*Electrical power plant size:
small < 1 MW
medium < 0.8 GW
large > 0.8 GW

Annual Emissions Data table (2020), MBIE

With these global and national challenges, why should NZ move from fossil fuels for electricity production?

Arguments that we do should do this:

1) Environmental
   - canvassed in James's talk
2) Psychological
   - need for conformity
   - reduce existential angst:

> "Once we start to act, hope is everywhere. So instead of looking for hope, look for action. Then, and only then, hope will come."
>
> Greta Thunburg

With these global and national challenges, why should NZ move from fossil fuels for electricity production?

Arguments that we do should do this:

3) Moral

- ‘The Earth deserves better’
- ‘Our children will never forgive us’

4) Market

- “NZ needs to show ‘green’ credentials to our markets”
- can NZ market its climate-change approaches to the world?

Future challenges: NZ's electrical power systems

- some thoughts about future challenges: generation, network, efficiency, demand and price

Challenges: electricity supply

How to build the equivalent of
2.4 Huntly Power Stations?

Huntly

1 GW (approx.) installed capacity.

5000 GWh/yr (approx.) production capacity

Issues:

- no major builds are currently under construction
- ageing infrastructure
- many, many ideas under development for future power production
  - e.g., the USA's IRA (Inflation Reduction Act) will be spending billions on green energy R+D
- generation cost decreasing over time – when do we buy?
- the rise of distributed power production at a variety of scales:
  - small - houses, cars, hydro
  - medium hydro, solar, wind - 96% of planned new builds wind/solar (Transpower)
  - large e.g. Onslow, 1.2 GW? but construction not started yet – finished 2037?
- Rural land use with joint solar and agri-business?

Challenges: electricity network

- more sources and more variability in supply
  - e.g., solar - daily variability; wind – minute-by-minute variability.
  - how does the network cope with much larger variability than now?
  - how is power quality maintained?
- Transpower’s new Clutha-Upper Waitaki lines project (2022) an excellent investment
  - increase northward transmission of Manapouri power from about 600 MW to about 1000 MW.

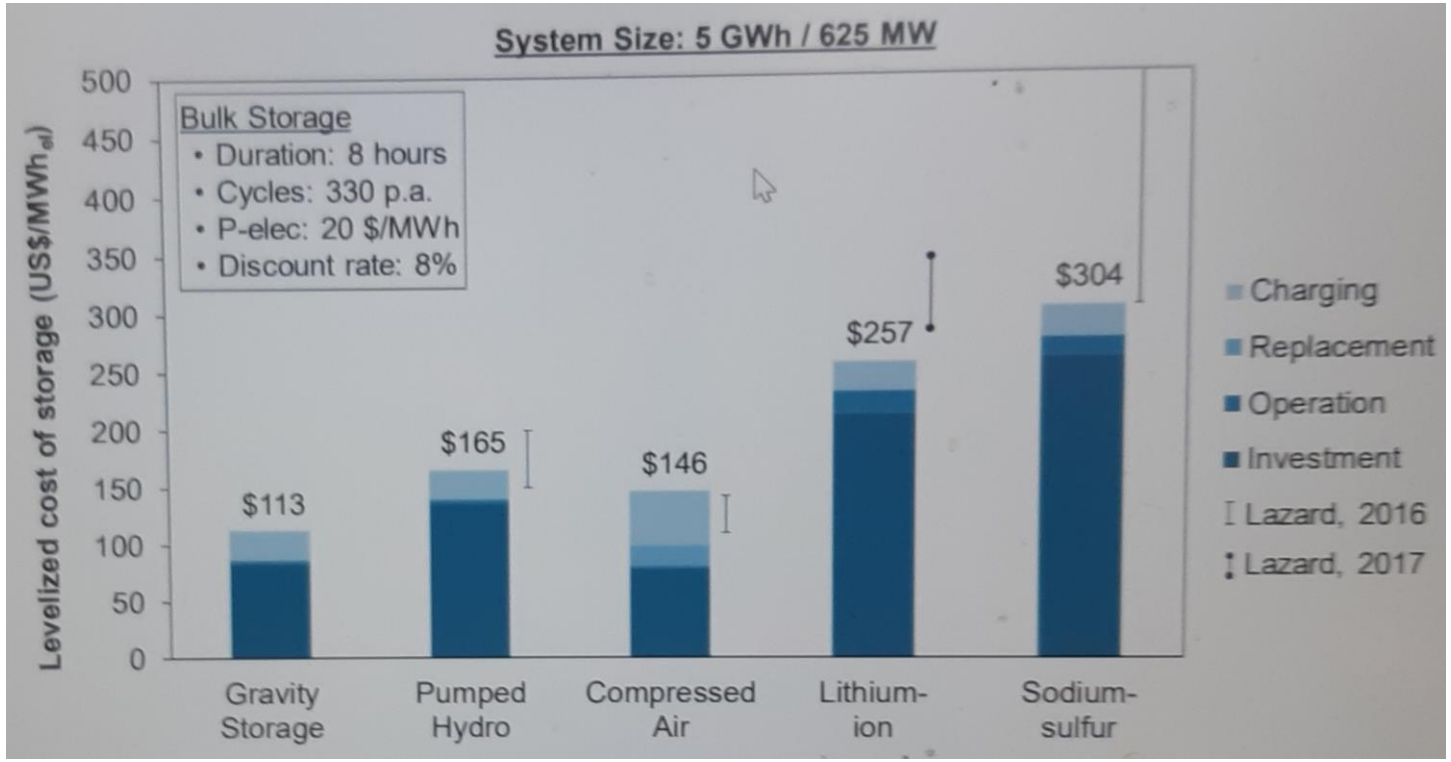
Challenges: storage

- storage is a potential solution to future network challenges
- naturally, solar and wind systems lack power storage.
  - should power storage be compulsory for small systems?
    - household storage = four days of demand?
  - should power storage be compulsory for medium systems?
    - system storage = four days of production?
- Meridian's 'Ruakaka Battery Energy Storage System' (2023), near Whangarei, an excellent investment
  - peak 100 MW; in the future, an adjacent 130 MW solar farm

Challenges: storage

- the price of storage is hugely variable
  - portable devices (solar cell+storage) to charge cell phones $1,600,000/MWh!
  - household solar power storage approx. $1,000,000/MWh!

- Medium-scale storage systems



- should we subsidise storage?

Challenges: electricity demand, efficiency and price

- can we expect power to be available 100% of the time?
- should medium-scale solar and wind development be regulated?
- what about engineered and economic efficiency measures?
  - e.g., moving supply closer to source
  - e.g., price
- are we heading towards zero-priced midday-power with a surfeit of solar power?
- the unit cost of generation - will it increase to 2030 with solar and wind?
- EECA (Energy Efficiency Authority): use of ‘smart’ appliances will increase in the future – these devices can be used to control power demand (i.e., the modern approach to ripple control of hot water systems)

Future research challenges: NZ's electrical power systems

My organisation (GNS Science) is thinking about future research needs for the electrical power system and the environment

- I would appreciate your feedback on a short survey that aims to gauge community opinion on power-system associated with climate change.
- could you please fill out the survey – responses are anonymous.

Thank you very much

This talk is aligned with the Geoscience for Future Energy Special Interest Group

Geoscience Society of New Zealand

Aims to bring together members with interests that relate to the production of energy, providing a forum to discuss how geoscience expertise should be involved in addressing the opportunities and challenges involved in making NZ's energy system highly renewable, sustainable and efficient.

Contact the group's convenor Jess Hillman here: energy@gsnz.org.nz

Learn more about the Geoscience Society of New Zealand and become a member here: www.gsnz.org.nz

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BP. 2020. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/year-in-review.html.

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https://edition.cnn.com/2023/02/27/energy/china-new-coal-plants-climate-report-intl-hnk/index.html

Youtube videos etc re the electrical power system (new developments).
Checked 10th May 2023

Power supply

Micro-nuclear

https://www.youtube.com/watch?v=60q_l_VPhtU

https://www.youtube.com/watch?v=xxXlD4e-wTE

Trompe: https://www.youtube.com/watch?v=uvf0lD5xzH0

Solar

https://www.youtube.com/watch?v=sUvaYycoWqI

https://en.wikipedia.org/wiki/Ivanpah_Solar_Power_Facility

https://www.youtube.com/watch?v=oiPSy2bKZkE

Agri solar: https://www.youtube.com/watch?v=lgZBlD-TCFE

Rooftop wind: https://www.youtube.com/watch?v=XPZei_UONX0

China coal: https://edition.cnn.com/2023/02/27/energy/china-new-coal-plants-climate-report-intl-hnk/index.html

Small hydro Otago: https://www.odt.co.nz/lifestyle/travel/lake%E2%80%99s-power-scheme-small-meaningful

LNG: https://www.youtube.com/watch?v=vOZS--1gMnI

Youtube videos etc re the electrical power system (new developments).
Checked 10th May 2023

Storage

Storage: various systems, economics etc: https://www.youtube.com/watch?v=zfCZKwEjR5Y

Storage: pumped hydro etc: https://www.youtube.com/watch?v=qBW3KpXp1FM

Pneumatic storage: https://www.youtube.com/watch?v=TRdn_C2WKqc

Zinc-bromide batteries: https://www.youtube.com/watch?v=2wsSRq-bEm0

Redox flow battery: https://www.youtube.com/watch?v=vm2hNNA4lvM

Aluminium ion batteries: https://www.youtube.com/watch?v=5B6icvUBNzE

Sodium ion batteries:

https://www.youtube.com/watch?v=U40rHy9TeTU

https://www.youtube.com/watch?v=-rD8UHxzk_s

https://www.youtube.com/watch?v=ts2vRBhj658

Youtube videos etc re the electrical power system (new developments).
Checked 10th May 2023

Storage

Solar Kowhai: https://www.christchurchairport.co.nz/about-us/sustainability/kowhai-park/

Ruakaka battery

https://www.meridianenergy.co.nz/power-stations/ruakaka-energy-park

https://www.meridianenergy.co.nz/assets/Investors/RUAKAKA-BATTERY-ENERGY-STORAGE-SYSTEM.pdf

Solar storage home

https://www.youtube.com/watch?v=0PQmgSyarNk

https://www.youtube.com/watch?v=Dr1VTc-io1k

Gravity storage: https://www.youtube.com/watch?v=lz6ZB23tfg0

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Checked 10th May 2023

Storage

- **Compressed air energy storage etc**
- https://www.youtube.com/watch?v=GCOnAmGzT5M
- https://www.youtube.com/watch?v=sVDh_4ymcyY
- https://www.youtube.com/watch?v=ErporgO9UaA
- https://www.youtube.com/watch?v=UhNgG3QDS-g
- **Storage:** https://www.youtube.com/watch?v=EoTVtB-cSps
- **Super capacitors and graphine:** https://www.youtube.com/watch?v=swdyGHvmXw0

Youtube videos etc re the electrical power system (new developments).
Checked 10th May 2023

Network etc

USA spend on green industries

https://www.youtube.com/watch?v=7OBFMCAQrTo

Power grid

https://www.youtube.com/watch?v=qjY31x0m3d8

https://www.youtube.com/watch?v=v1BMWczn7JM

Clean energy milestone

https://www.bbc.com/future/article/20230414-climate-change-why-2023-is-a-clean-energy-milestone

Electrical power futures: Blenheim MRC talk 8/5/2023

Survey results; average of responses; n= 38

Please respond to the following statements on a scale of 1 to 5:
1 = totally disagree with the statement
5 = totally agree with the statement

Power reliability: my property needs 100% reliable national power network.	3.9
Climate-change response is the main challenge for the future power network.	4.2
NZ's renewable energy generation will increase by 30% to 2030.	3.2
Distributed storage is a key strategic issue for the national power network.	4.2
Medium-scale power storage is worth subsidising.	4.3
Higher power prices are acceptable if they accelerate renewable development.	3.5

In addition, MBIE is seeking your input on the future of electrical power in NZ:

https://www.mbie.govt.nz/about/news/have-your-say-on-the-future-of-the-electricity-sector/