A Review of Global Net Zero Electricity and Energy Systems Studies

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Worldwide Studies

1. Near Zero electricity systems study

   BERKELEY LAB

   USA, Japan, South Korea, China, India,…

2. Net Zero and clean electricity system studies

   NREL ofgem IEA

3. Net Zero energy system studies

   PRINCETON UNIVERSITY

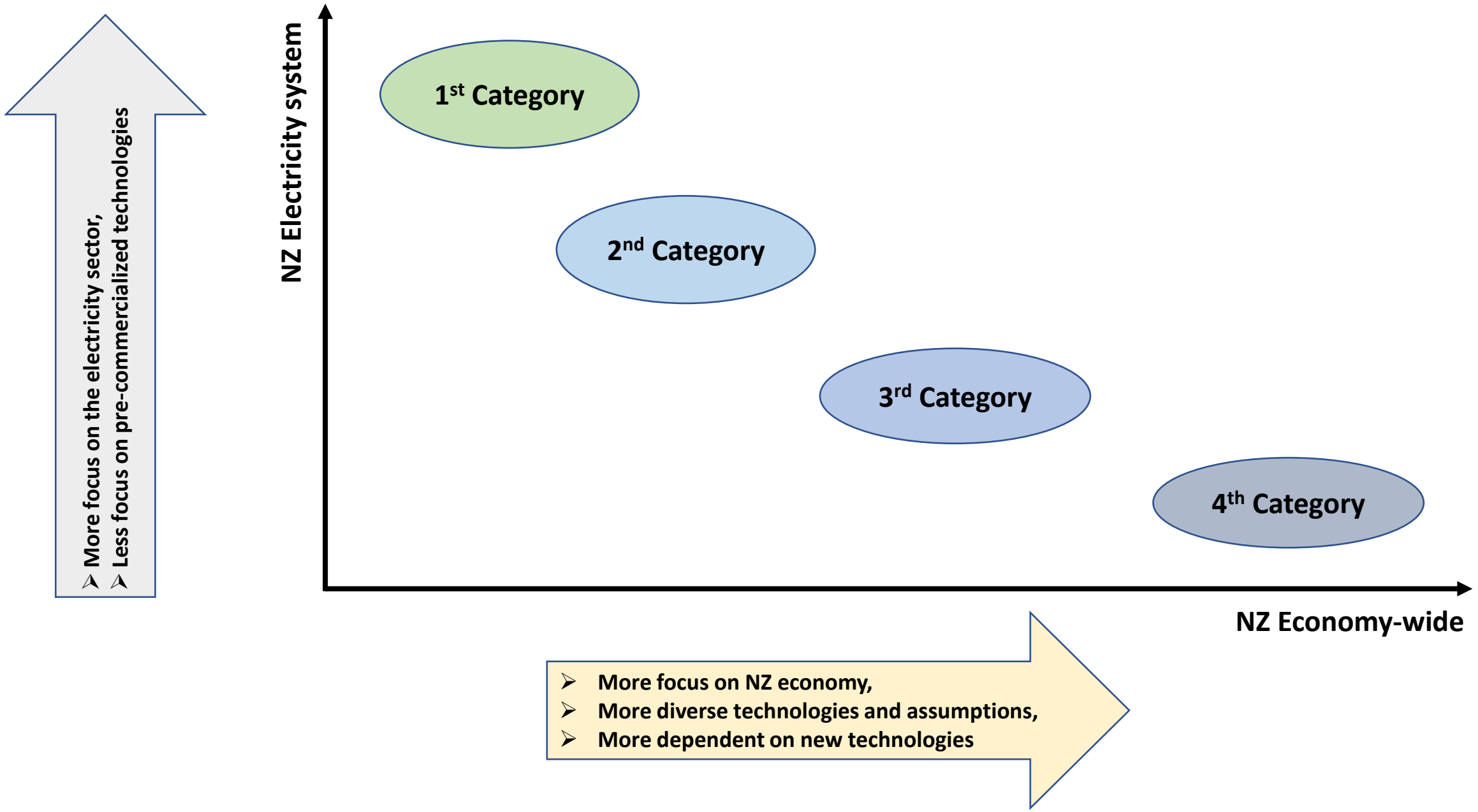
   The University of Melbourne · The University Of Queensland · PRINCETON UNIVERSITY · nous

   Canada Energy Regulator

4. International Net Zero economy

   IEA

   EVOLVED ENERGY RESEARCH


More focus on the electricity sector,
Less focus on pre-commercialized technologies
NZ Electricity system
1st Category
2nd Category
3rd Category
4th Category
NZ Economy-wide
More focus on NZ economy,
More diverse technologies and assumptions,
More dependent on new technologies

Overall Modelling Approach

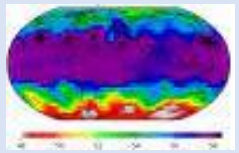
Input data

Transportation

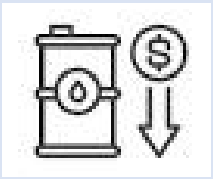
Buildings

Industry

Legislations and policies

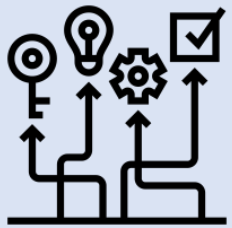


Spatiotemporal weather forecast



Fuel price

Capital and O&M costs



Feasibility studies

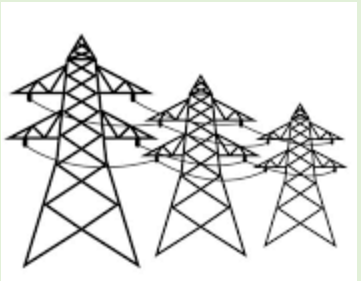
Capacity under construction

- **Multi-year and long-term optimisation model**
- **NZ scenarios**

Output results

Optimal energy resource mix

Electricity supply cost



Optimal grid expansion plan

Energy security

NZ Electricity/Energy System Studies

STEP 1

Future electricity/energy demand and VRE forecast

How will the electricity/energy demand change?

- ✓ Spatial and temporal projections,
- ✓ New demand profiles,
- ✓ Anticipated demand flexibility,
- ✓ Energy import/export targets,
- ✓ Electrification of other sectors,
- ✓ VRE time-series,

STEP 2

Scenario (pathway) analysis

What will be built (when, where, how much)?

- ✓ Renewables
- ✓ Energy storage
- ✓ Thermal power
- ✓ Grid infrastructure
- ✓ Hydrogen
- ✓ CCUS
- ✓ Interconnections

STEP 3

Cost-benefit analysis

What will be the impacts of NZ on electricity/energy costs and societal benefits?

- ✓ End-user electricity/energy costs,
- ✓ Health damage
- ✓ Broad economy-wide impacts
- ✓ Policy/legislations intervention

Developing high-resolution spatiotemporal dataset for demand and VREs

Detailed decision-making model
(grid expansion & operation/technology modelling)

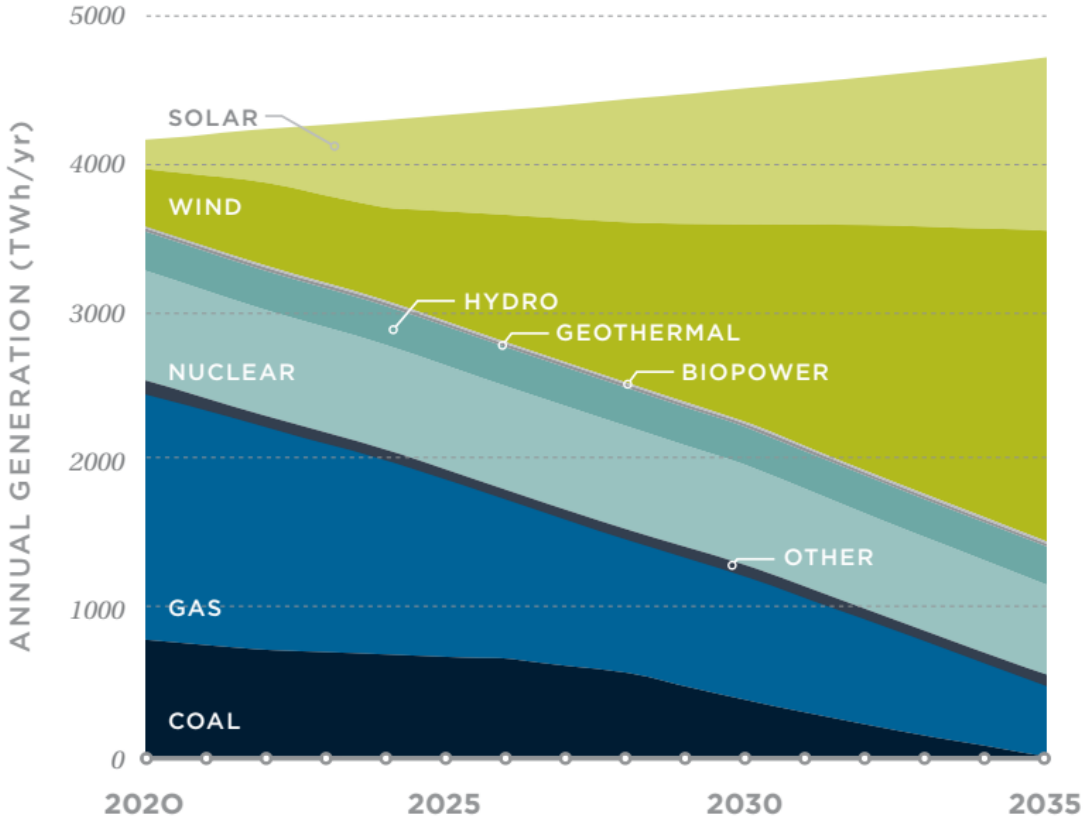
Technology adoption for NZ

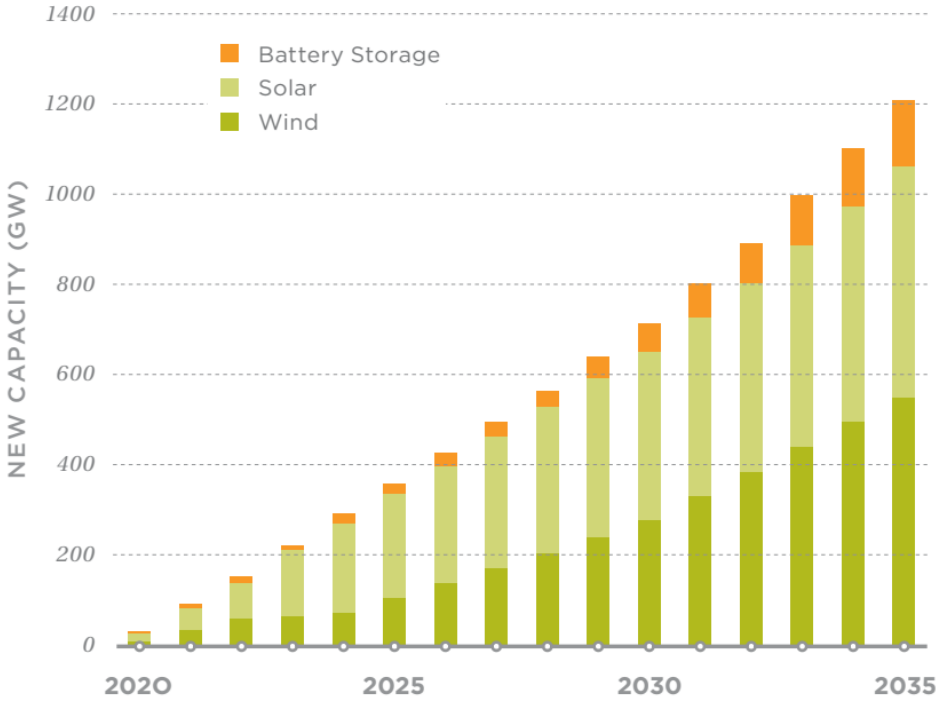
Country:		USA			UK	Canada	Australia	Japan	South Korea	China	Ireland	International
Target year/(%NZ)		2035/100% (NREL)	2035/90% (LBNL)	2050/100% (PU)	2035	2035	2050	2035	2035	2035	2050	2050
Variable RE:												
wind	Onshore	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Offshore (fixed+floating)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Solar	Rooftop PV	Y	Y	Y	Y	Y	Y	Y	Y	Y	-	Y
	Utility/Commercial PV	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Solar concentration	Y	-	-	-	-	-	-	-	-	-	Y
Non-Variable RE:												
Hydro		Y	Y	Y	-	Y	Y	Y	Y	Y	Y	Y
Geothermal		Y	Y	Y	-	Y	N	Y	-	-	Y	Y
Biomass		Y	Y	Y	-	Y	Y	Y	Y	-	Y	Y
Nuclear:												
Life extension		Y	-	Y	Y	Y	N	Y	Y	-	N	Y
New capacity (SMR, etc.)		Y	Y	Y	Y	Y	N	Y	Y	Y	N	Y
Fossil fuel-based Generations:												
Gas	With CCUS	Y	-	Y	Y	Y	Y	-	-	-	-	Y
	Without CCUS	Y	Y	Y	-	N	Y	Y	Y	Y	Y	Y
coal	With CCUS	Y	-	N	-		Y				-	Y
	Without CCUS	Y	N	N	-	N	Y	N	N	Y	-	Y
CCUS	BECCS	Y	-	Y	Y	Y	Y	-	-	-	-	Y
	DAC	Y	-	Y	Y	Y	Y	-	-	-	-	Y
	LULUCF	-	-	Y	-	Y	Y	-	-	-	-	Y
Energy storage:												
Hydrogen		Y	-	Y	Y	Y	Y	Y	-	-	-	Y
Battery ES		Y	Y	Y	Y	Y	Y	Y	Y	Y	-	Y
Thermal ES		Y	-	-	Y	-	-	-	-	-	-	Y
Pump Hydro ES		Y	Y	Y	Y	-	Y	Y	Y	Y	-	Y
Interconnections:												
Electricity (imp/exp)		Y	-	-	Y	Y	Y	-	-	-	Y	Y
Hydrogen (imp/exp)		-	-	-		-	Y	-	-	-	-	Y

Modelling Frameworks

Country	Electricity network modeling						
	Modeling platform	Power flow model	Distribution network modeled?	Production cost model (UC)	Grid expansion model (GEP and/or TEP)	Temporal resolution	Spatial resolution
USA	ReEDS	DC	N	Y	Y	Hourly (8760 h/A)	Reduced grid model (regional grid modeling)
	PLEXOS	DC	N	Y	Y	Hourly (8760 h/A)	Reduced grid model (regional grid modeling)
	RIO+EP	Pipe flow	N	N	Y	Hourly (representative days: 24*41 h/A)	Reduced grid model (regional grid modeling)
Japan	PLEXOS	DC	N	Y	Y	Hourly (8760 h/A)	Reduced grid model (regional grid modeling)
China	PLEXOS	DC	N	Y	Y	Hourly (8760 h/A)	Reduced grid model (regional grid modeling)
South Korea	PLEXOS	DC	N	Y	Y	Hourly (8760 h/A)	Reduced grid model (regional grid modeling)
UK	DDM & DNM	AC	Y	Y	Y	Half hourly	Detailed electricity grid model (T&D)
Australia	RIO+EP	Pipe flow	N	N	Y	Hourly (representative days: 24*41 h/A)	Reduced grid model (regional grid modeling)
Ireland	TIM	-	-	Y	Y	Hourly (8760 h/A)	No electricity grid modelling
Worldwide	GEC (WPM & ETP)	-	-	Y	Y	Hourly (8760 h/A)	No electricity grid modelling

LBLN's study for the USA





- VRE Capacity 1100 GW @ 2035 (today's USA electricity sector size: 1300 GW)
- VRE deployment rate of 70 GW/Year

Is this annual VRE deployment rate possible?

- ✓ Unprecedented supply chain capacity for VREs
- ✓ Significant policy support

Conclusion

- ✓ Significant uncertainties around the economic and operational viability of potential NZ technologies
- ✓ Unprecedented supply chain capacity for VREs
- ✓ Improve technical aspects of electricity grids (reliability and PQ standards,…)
- ✓ Strengthen stakeholder engagement (technology acceptance,…)
- ✓ Reform electricity market and pricing structures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