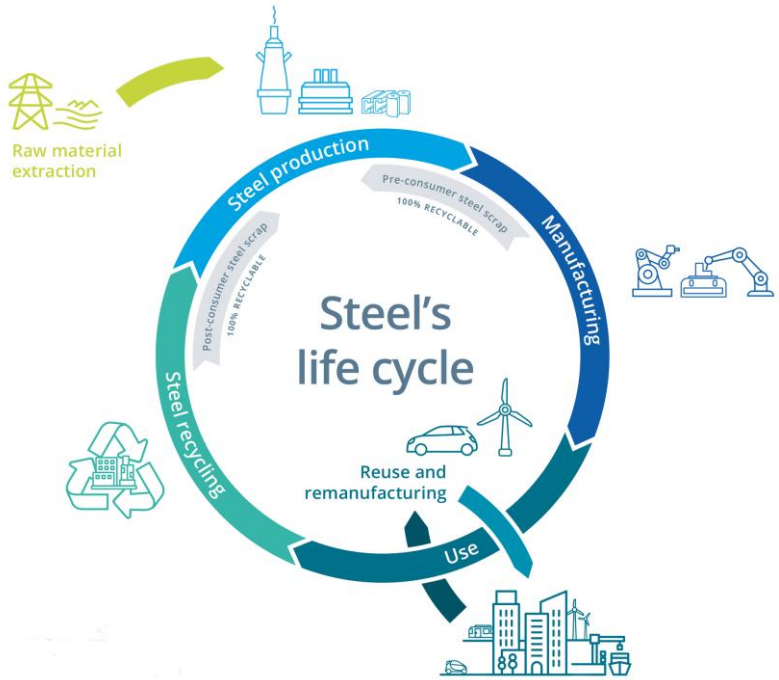
Considering Material Cycles for a Transition to Low-Carbon Energy Systems in Aotearoa – New Zealand: a Systematic Review



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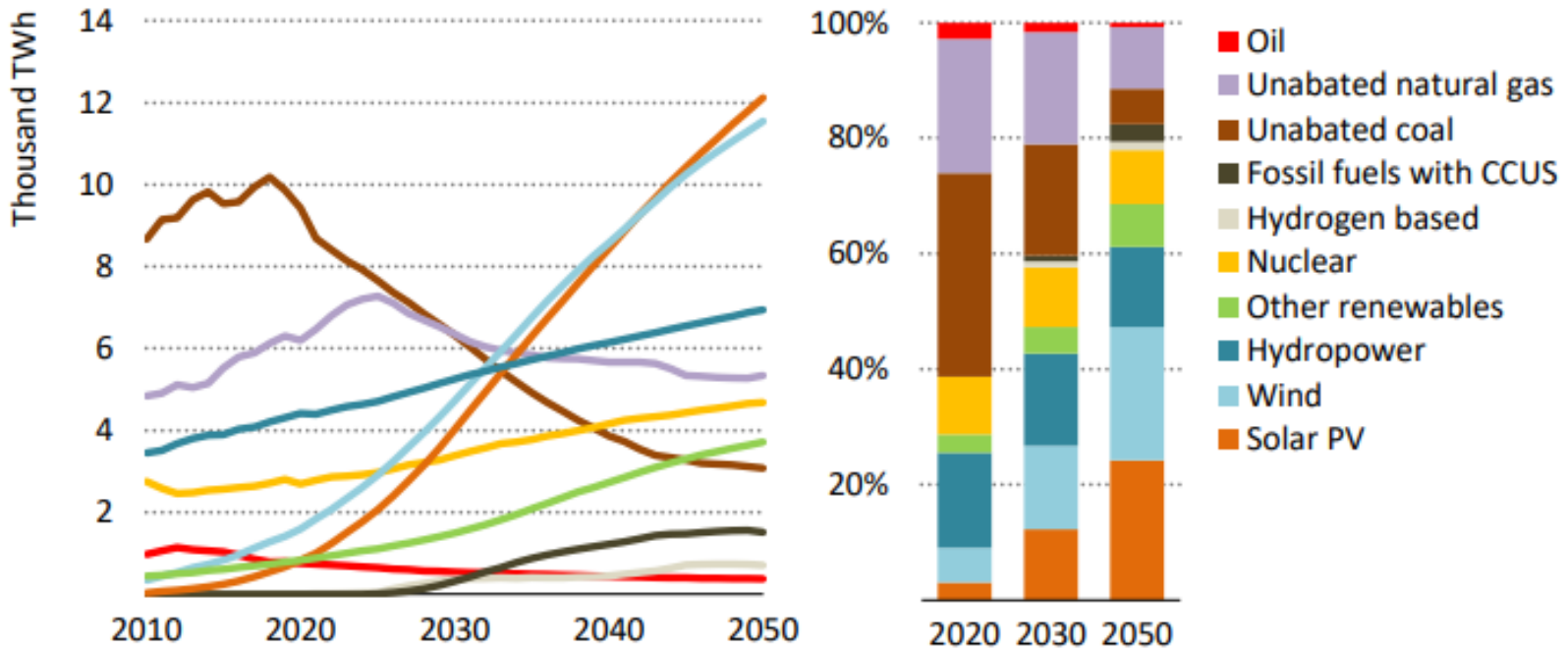
Low-carbon energy transition

Figure 1.14 ▷ Global electricity generation by source in the APC

Announced Pledges Case (APC)

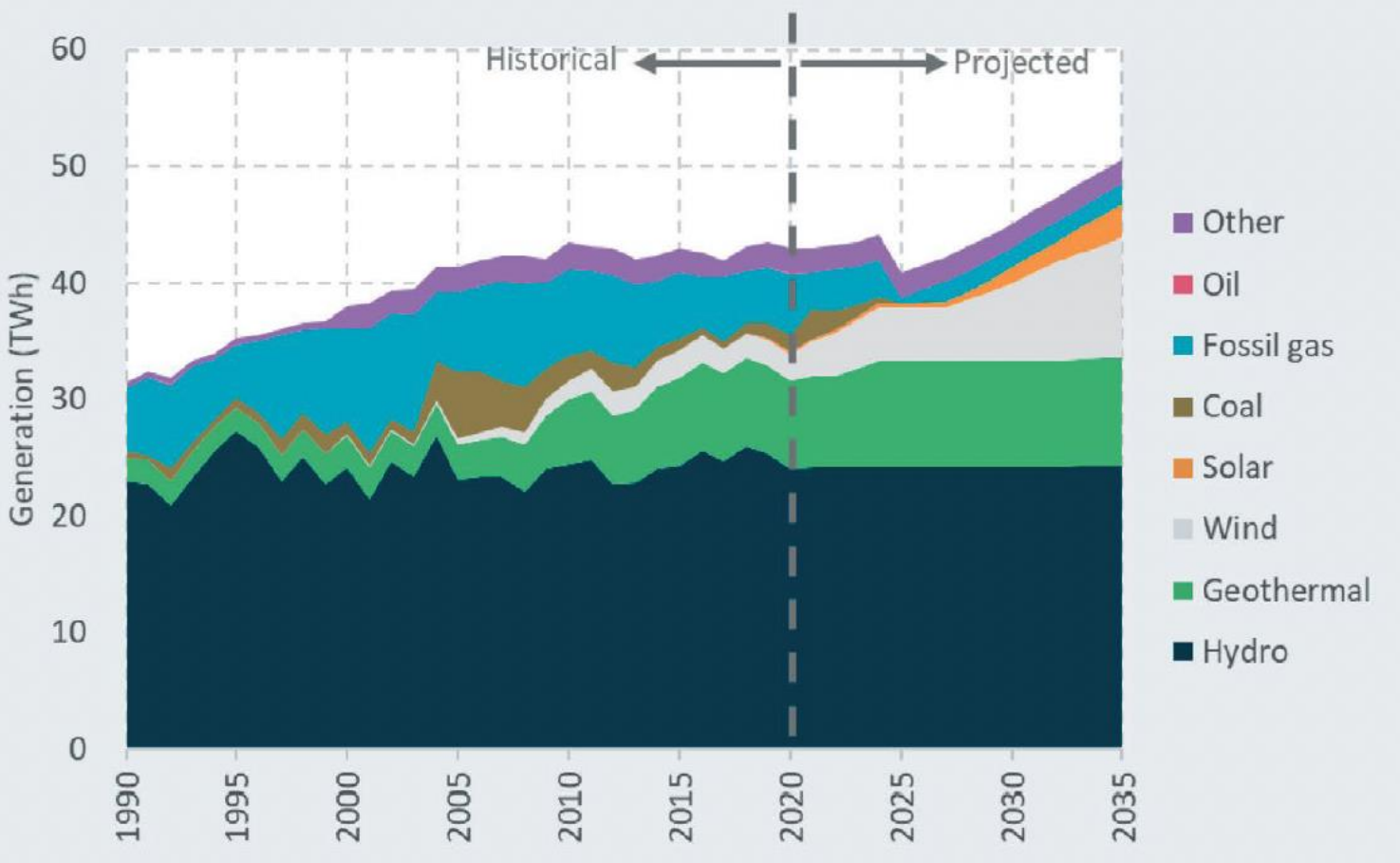


Renewables reach new heights in the APC, rising from just under 30% of electricity supply in 2020 to nearly 70% in 2050, while coal-fired generation steadily declines

(IEA, 2021a)

Low-carbon energy transition

Energy transition in New Zealand



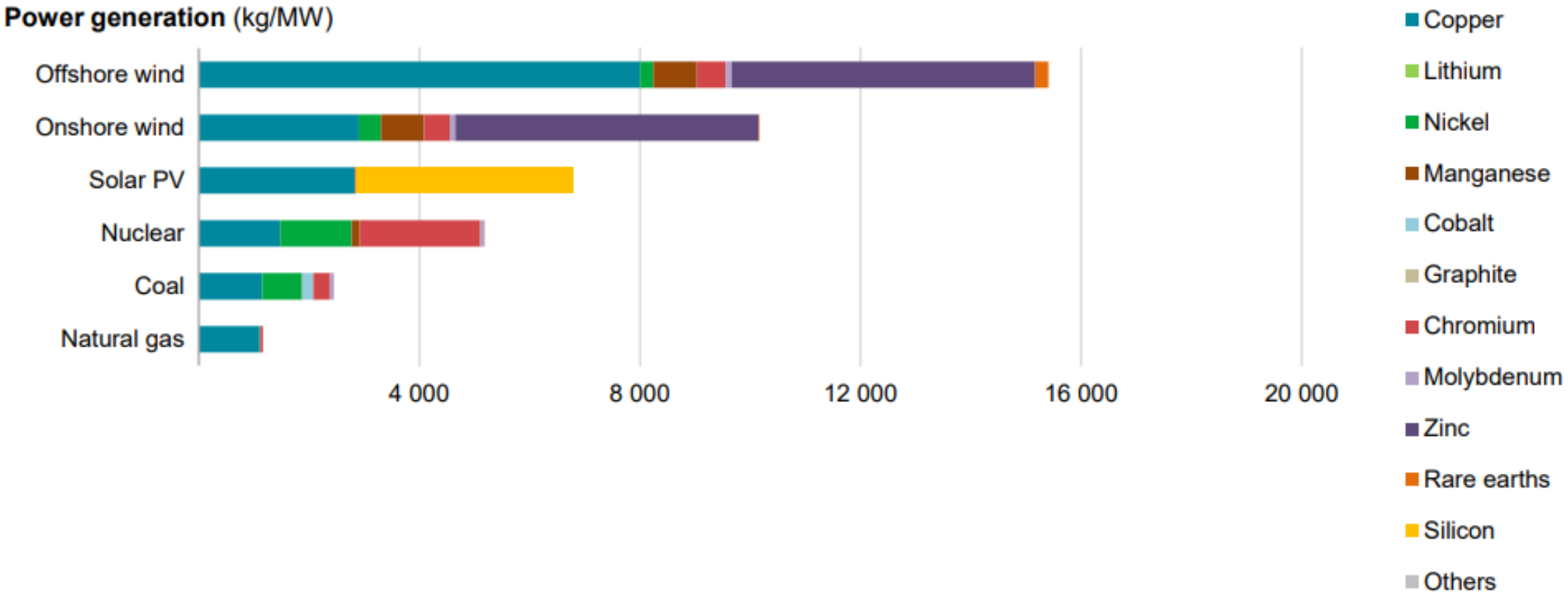
(Climate Change Commission, 2021)

Pathways for low-carbon energy systems

- Energy System Models, Integrated Assessment Models
  - System-wide models
    - Technological, economic, social, and environmental
  - **Overlook material cycles**
    (Huang & Eckelman, 2020; Kullmann et al., 2021)
  - **Incompletely represent lifecycle emissions**
    (Pauliuk et al., 2017; Lopion et al., 2018)

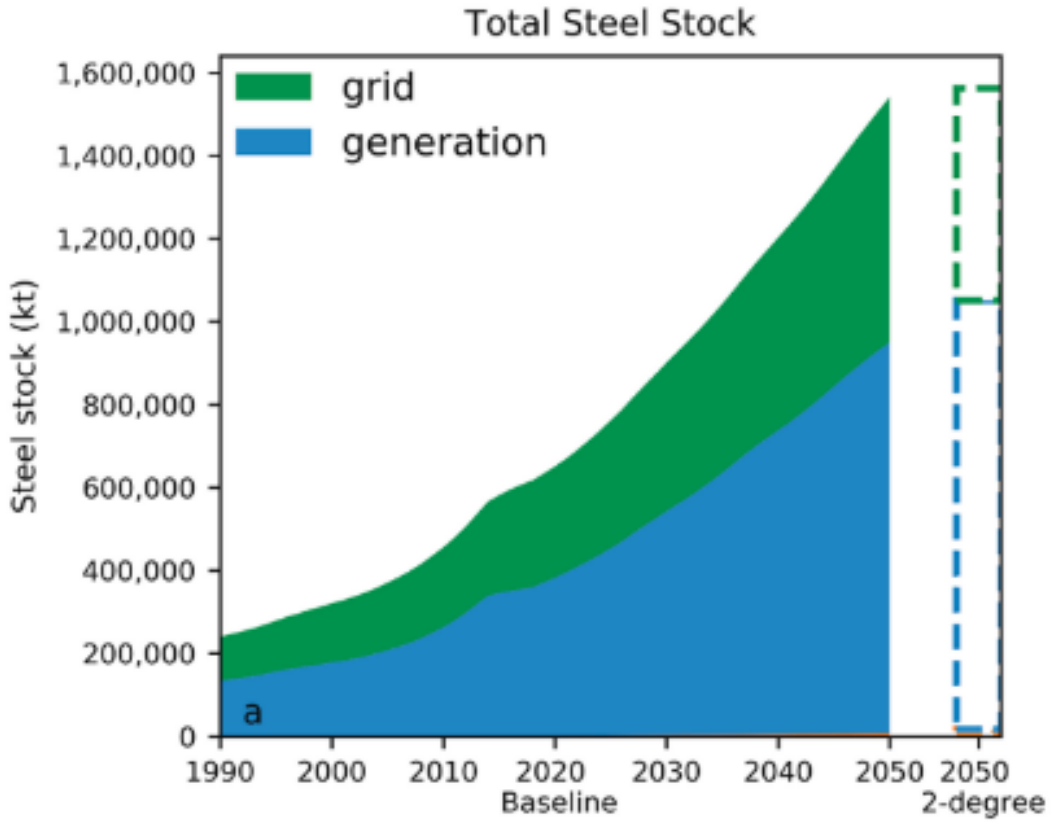
What are the implications of low-carbon energy transitions for the material cycles?

Metals and minerals used for low-carbon energy technologies



(IEA, 2021b)

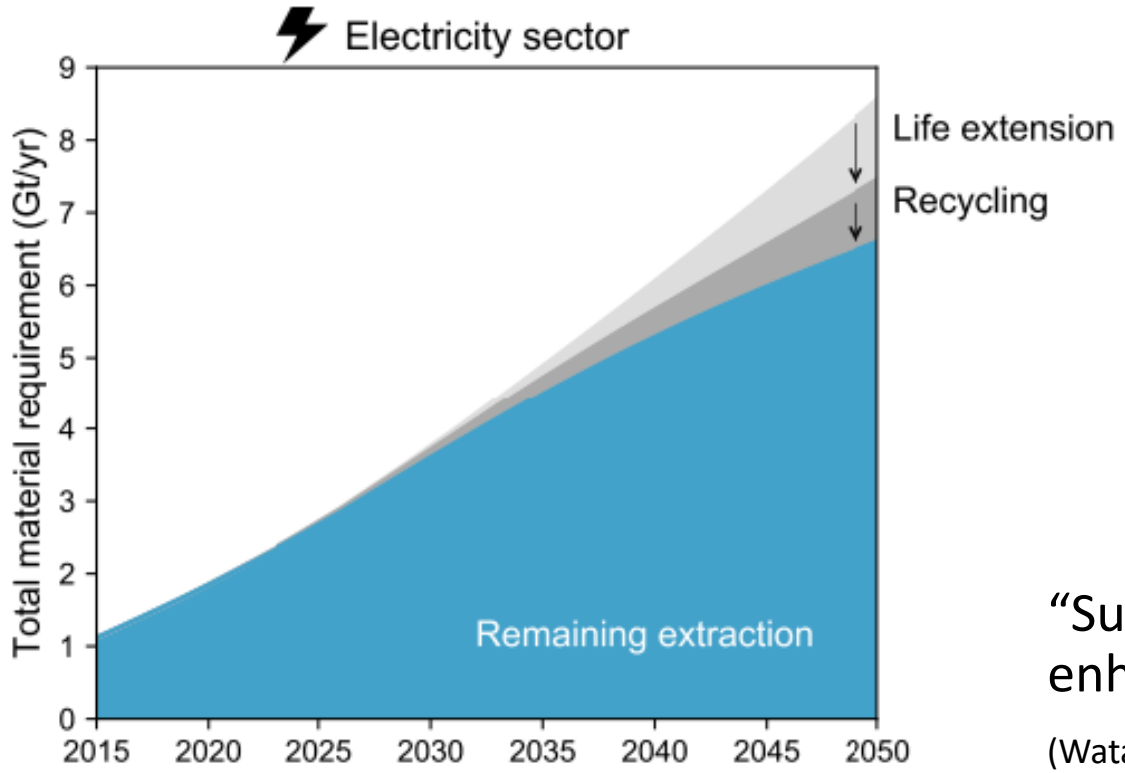
Demand for materials for the transition in the energy sector



(Deetman et al., 2021)

Supplies of material for the energy transition

- Material scarcity could be a limiting factor to the expansion of renewable energy
  (Månberger and Stenqvist, 2018; Elshkaki et al., 2018)

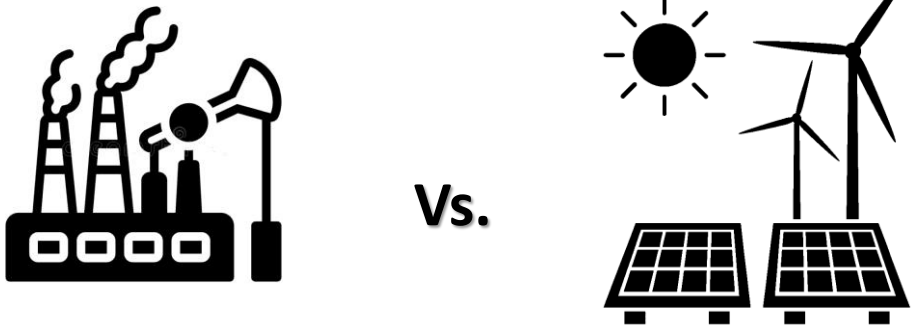


"Sustainable energy transitions require enhanced resource governance"

(Watari et al.,2021)

Lifecycle perspective of low-carbon energy transitions

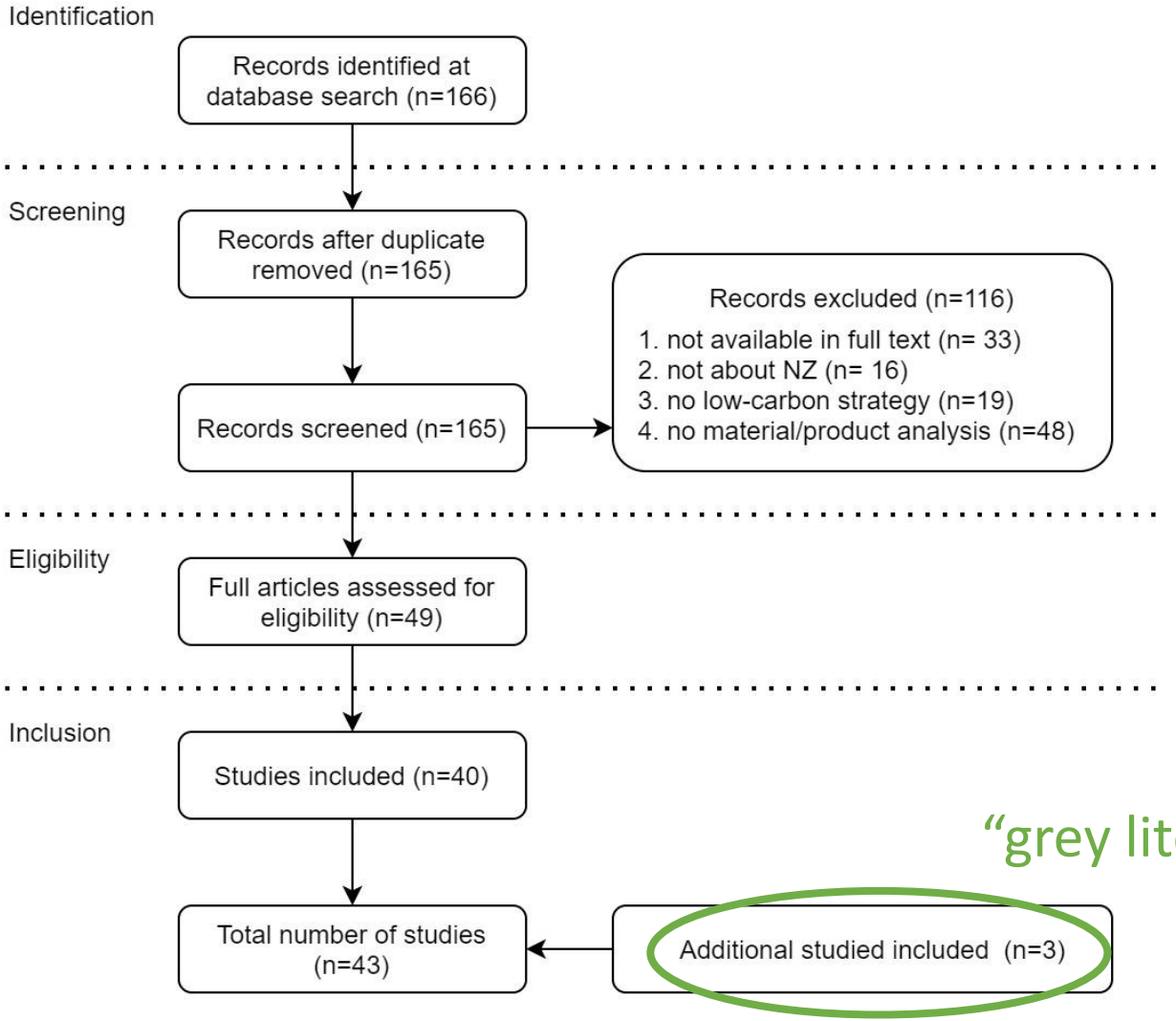
- Lifecycle emissions of renewable energy generation is modest compared to emissions from the combustion of fossil fuel.
- Indirect emissions of low-carbon energy might become relevant in a low-carbon economy (Daly et al., 2015)
- Ambitious national targets of reducing direct emissions by 2050 might still result in substantial global emissions from upstream emissions (Vandepaer et al., 2020)



How has New Zealand addressed material cycles for the low-carbon energy transition?

Systematic review – NZ focus

- Scopus database
- Keywords
  - New Zealand
  - Energy systems
  - Material systems
  - Future planning
- From 2011 to 2021



"grey literature"

Demand for materials for the low-carbon energy transition in New Zealand

- **No** studies about the demand for **material**
  - **No** analysis of the supply of those materials
  - **No** consideration of Circular Economy strategies

- Studies analysed **some** of the **infrastructure** required
  - Renewable energy generation (Vennell et al., 2020)
  - Low-carbon micro-grids (Mohseni et al. 2021)
  - No holistic study about all the infrastructure required by NZ

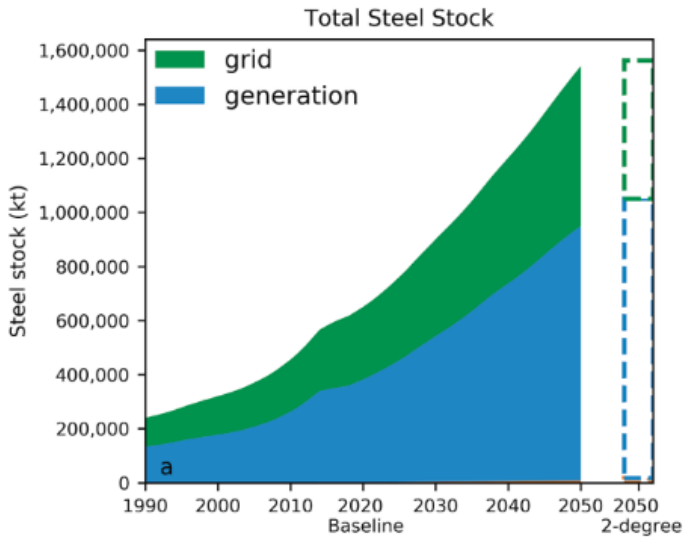
Prospective lifecycle impacts for the transition in New Zealand

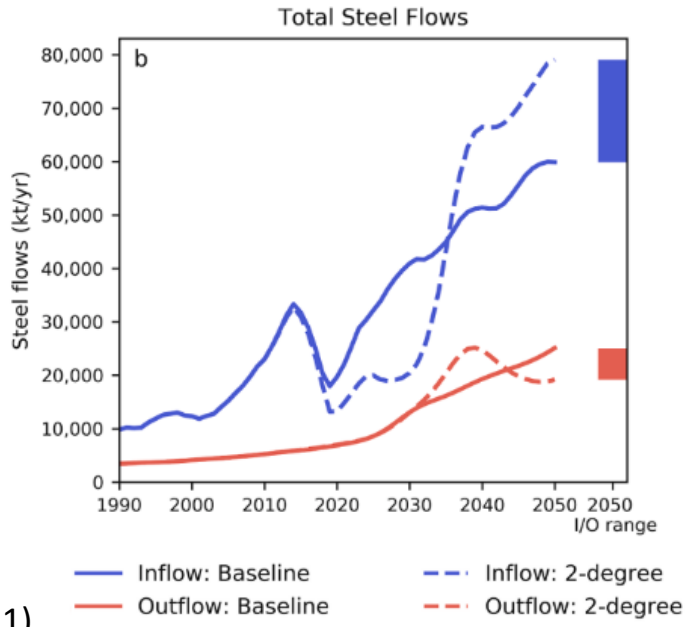
- Several studies analysed lifecycle emissions of low-carbon technologies for NZ
  - Renewable electricity generation (only)
  - Emissions were regarded as average historical factors (Walmsley et al., 2018)
  - Missing dynamic changes
    - Mining production
    - Ore grade decrease
    - Decarbonisation
    - Secondary share of material

How could material cycles be integrated with the New Zealand's low-carbon energy transition pathways?

Demand for material for low-carbon energy transitions

- Different approaches
  - System-wide model + Input-Output models
  - System-wide model + Life Cycle Inventories
    - **Data aggregated**
  - System-wide model + dynamic stock-flows models
    - **Model actual physical flows of materials**
- Mostly, **global** studies
- Focus on **energy generation**





(Deetman et al., 2021)

Availability of material for low-carbon energy transitions

- Supply of metals
  - Comparing the demand to reserves of metals (Deetman et al., 2021)
  - Modelling the constraints for the supply of metals (Watari et al., 2019)

- Distinct aspect of circular economy (CE) strategies have been analysed

STUDY	MATERIAL INTENSITY	SUBSTITUTION	LIFETIME EXTENSION	REUSE	RECYCLING
(Månberger & Stenqvist, 2018)	yes	yes	no	no	yes
(Watari et al., 2019)	no	no	no	no	yes
(Elshkaki & Shen, 2019)	yes	yes	partially	no	yes
(Elshkaki, 2019)	yes	no	partially	no	yes
(Tokimatsu et al., 2017)	yes	yes	no	no	yes
(Watari et al., 2021)	no	no	yes	yes	yes

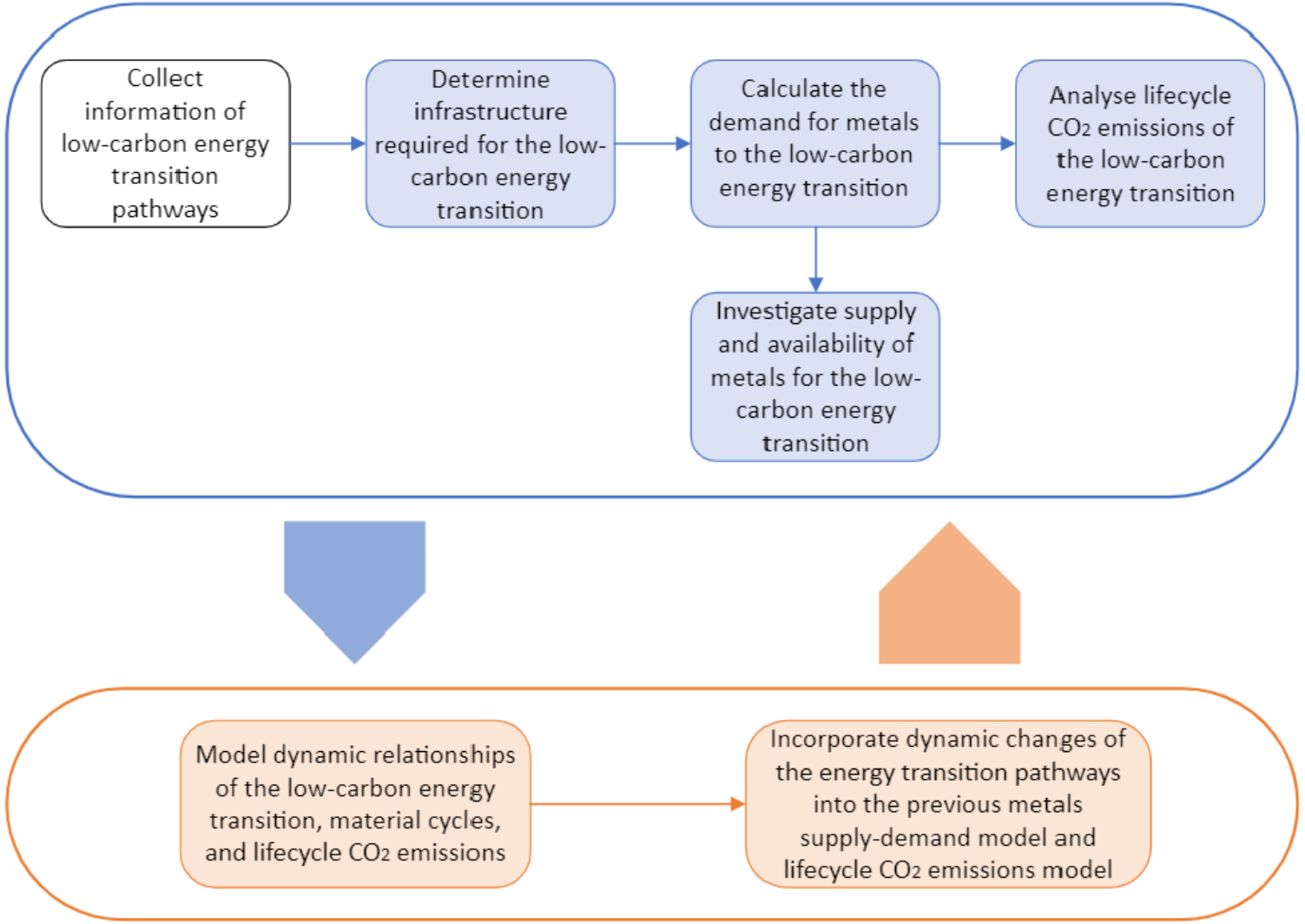
Prospective lifecycle emissions of low-carbon energy transitions

- Methodological challenges
- Prospective lifecycle assessment (LCA)
  - **Not standardised** yet (Hauschild et al., 2018)
- Considering changes in the systems
  - No consensus (Arvidsson et al., 2018; Beltran et al, 2018)
  - For example, changes in the energy mix can be very relevant (Beltran et al, 2018)

Understanding dynamic changes

- System dynamics
  - Investigate patterns of behaviour of the system
  - Analyse inter-relationship of energy and material systems, and corresponding CO_2 emissions

Recommendation



Conclusion

- A well-managed low-carbon energy transition requires the efficient use of the most sustainable and least polluting technologies available.

- In New Zealand, low carbon transition studies have not considered material cycles.

- We now have a good opportunity to develop a model to integrate material cycles into the low-carbon energy transitions in New Zealand.

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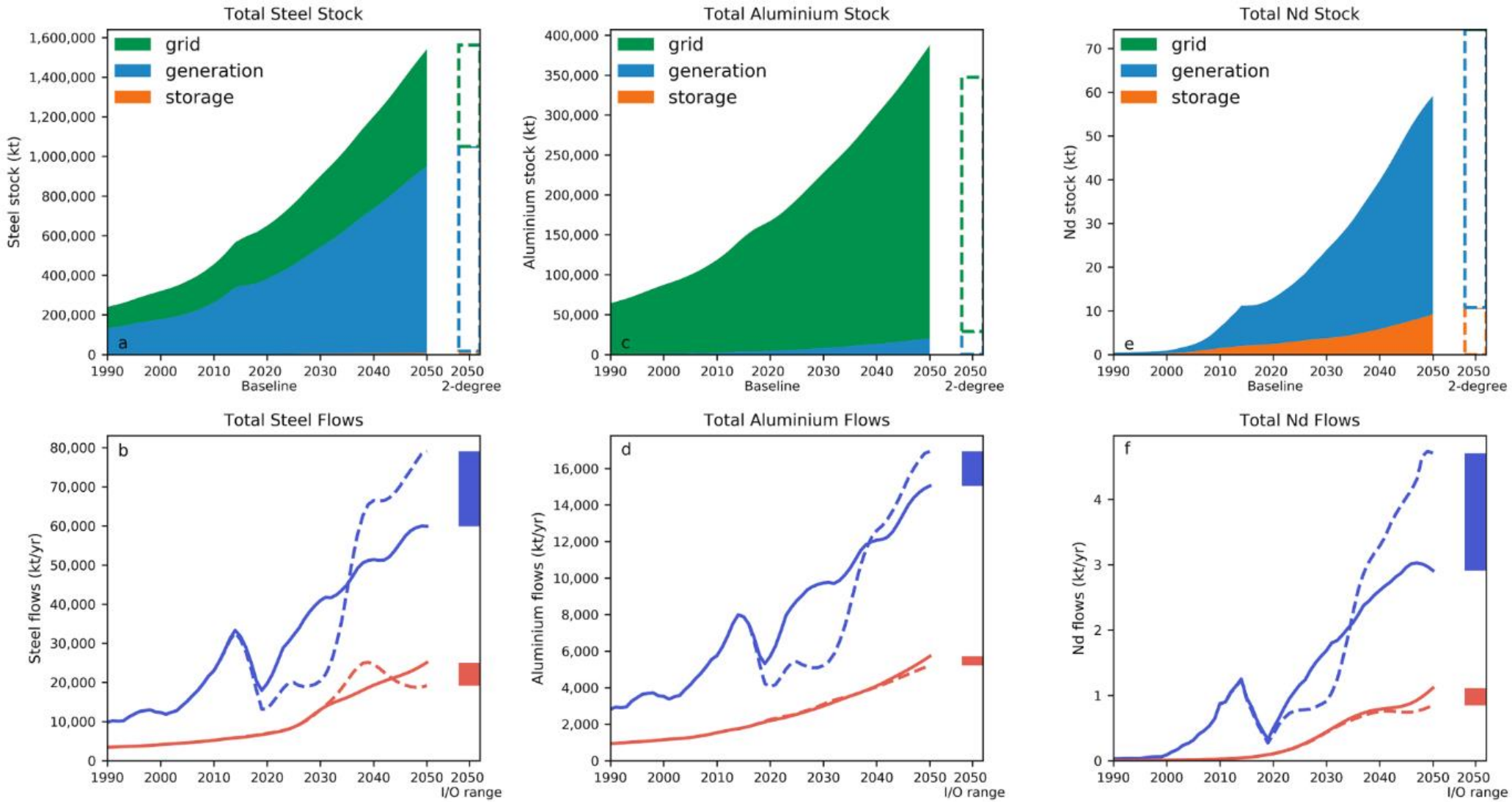
Total Steel Stock
grid
generation
storage
Steel stock (kt)
a
Baseline
2-degree
Total Aluminium Stock
Aluminium stock (kt)
c
Total Nd Stock
Nd stock (kt)
e
Total Steel Flows
Steel flows (kt/yr)
b
Total Aluminium Flows
Aluminium flows (kt/yr)
d
Total Nd Flows
Nd flows (kt/yr)
f
I/O range
Inflow: Baseline
Outflow: Baseline
Inflow: 2-degree
Outflow: 2-degree