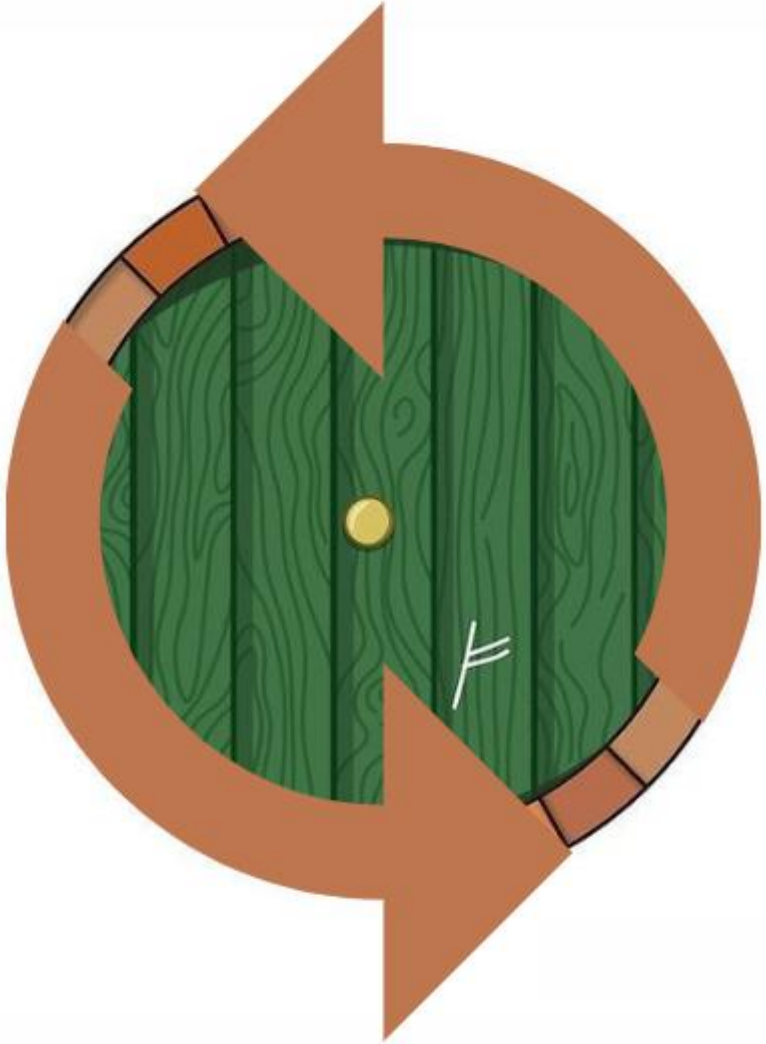
Deloitte.
Access Economics



There and Back Again: A Circular Tale in a CGE Framework
Developing DAE-CGEM

GTAP 29th Annual Conference on Global Economic Analysis, 2026

Presenter: Rhiain Powell
Team includes Hom Pant, Djauhari Pambudi & Cedric Hodges

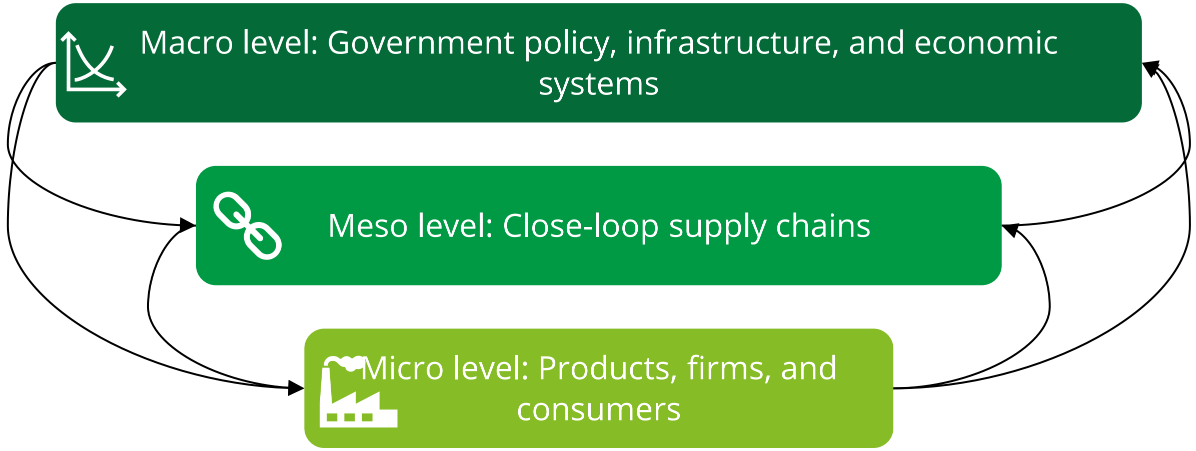
Concerning Circularity

A circular transition necessitates co-ordination and transition across the entire economic ecosystem.

Increasing calls for a transition to a Circular Economy

- Rising material use globally is raising the importance of understanding the impacts of a circular economy transition
- A circular economy is a system that is designed to minimise waste by keeping resources in use for as long as possible.
- Circularity requires co-ordination across the entire economic ecosystem.

Figure 1: Stylised representation of the co-ordination between different levels of a functional circular economy



Current challenges with modelling circularity in CGE models

- Waste is not typically recorded as a by-product of economic activity (i.e., this externality is not accounted for in traditional CGE models)
- As waste is not recorded, there are no explicit records of the producers and consumers of waste
- Underlying Input-Output tables do not traditionally account for recycling materials
- Underlying GTAP database and I-O tables often have recycling and waste sectors sitting across multiple, broader parent sectors. And these sectors seldom have the levels of granularity needed to identify key actors in the waste system.

Accounting for waste with our standard DAE-RGEM

Waste and secondary manufacturing sectors can be disaggregated in DAE-RGEM.

Table 1: Standard industry disaggregation in DAE-RGEM.

DAE-RGEM	Description	DAE-RGEM	Description
AGRI_F	Agriculture, forestry and fishing	ELYDIRTY	Dirty electricity
Coal	Coal	GDT	Gas distribution and transmission
OilGas	Oil and Gas	**Water**	**Water treatment and waste sectors**
OMIN	Other mining activities	CONS	Construction
OTHMAN	Manufacturing, excluding metals	TRADE	Trade
P_C	Petroleum, coal products	SERV	Services
I_S	**Ferrous metals**	GovSERV	Government services,
METMAN	Metals nec and metal products	DWEL	Dwellings
ELYTND	Electricity transmission and distribution	CGDS	Capital goods formation
ELYCLEAN	Clean electricity		

Table 2: Alterations to DAE-RGEM database to isolate circular sectors.

Parent sector	Disaggregation	Description
I_S	I_SP	Primary steel manufacturing (using extracted resources)
	I_SS	Secondary steel manufacturing (using recovered steel)
Water	CLCT	Collection of disposable waste
	DISPOSE	Waste treatment (i.e., landfills and incineration)
	RECOV	Recoverable materials collection and sorting
	ROWATER	Rest of water

Regional disaggregation is currently:
Australia, China, APAC, and Rest of the World.

Testing the ‘Circular’ database in our standard model

Subsidising materials recovery and secondary manufacturing in. These applied a uniform subsidy to I_SS and RECOV in Australia only.

Chart 1: Deviation in output of steel manufacturing, DAE-RGEM ($ millions)

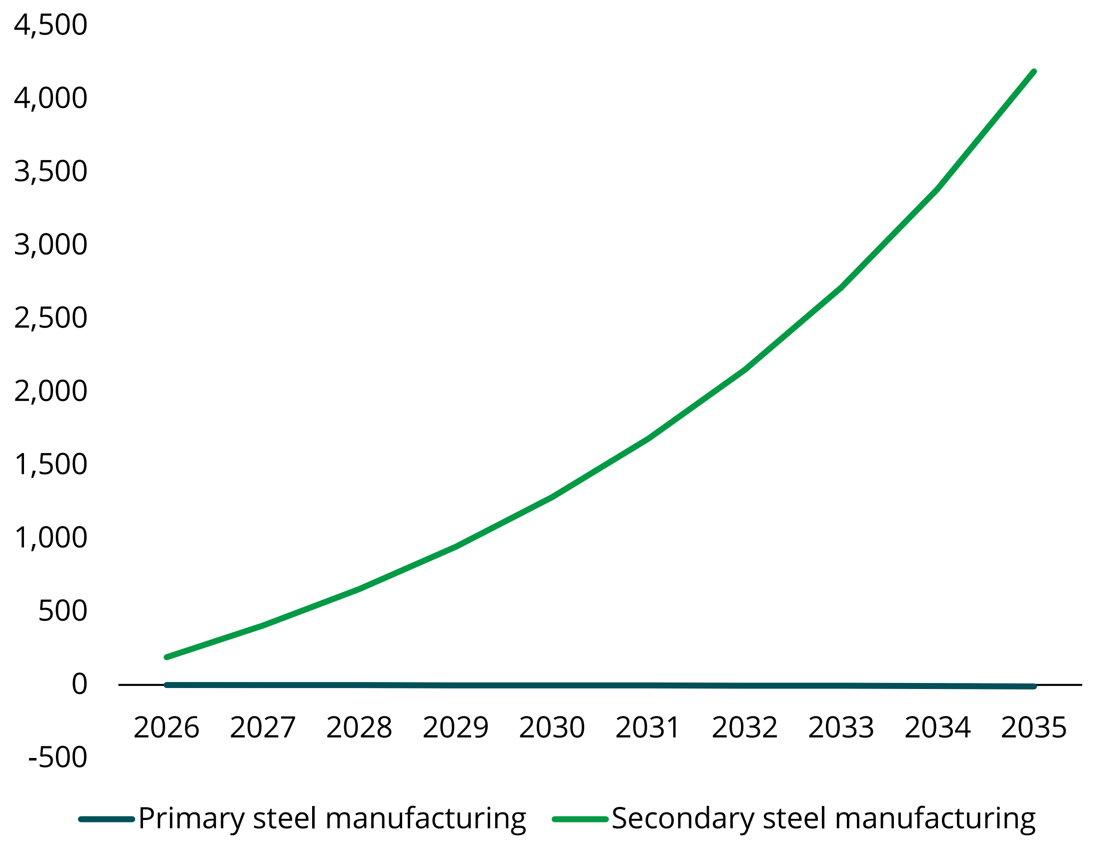
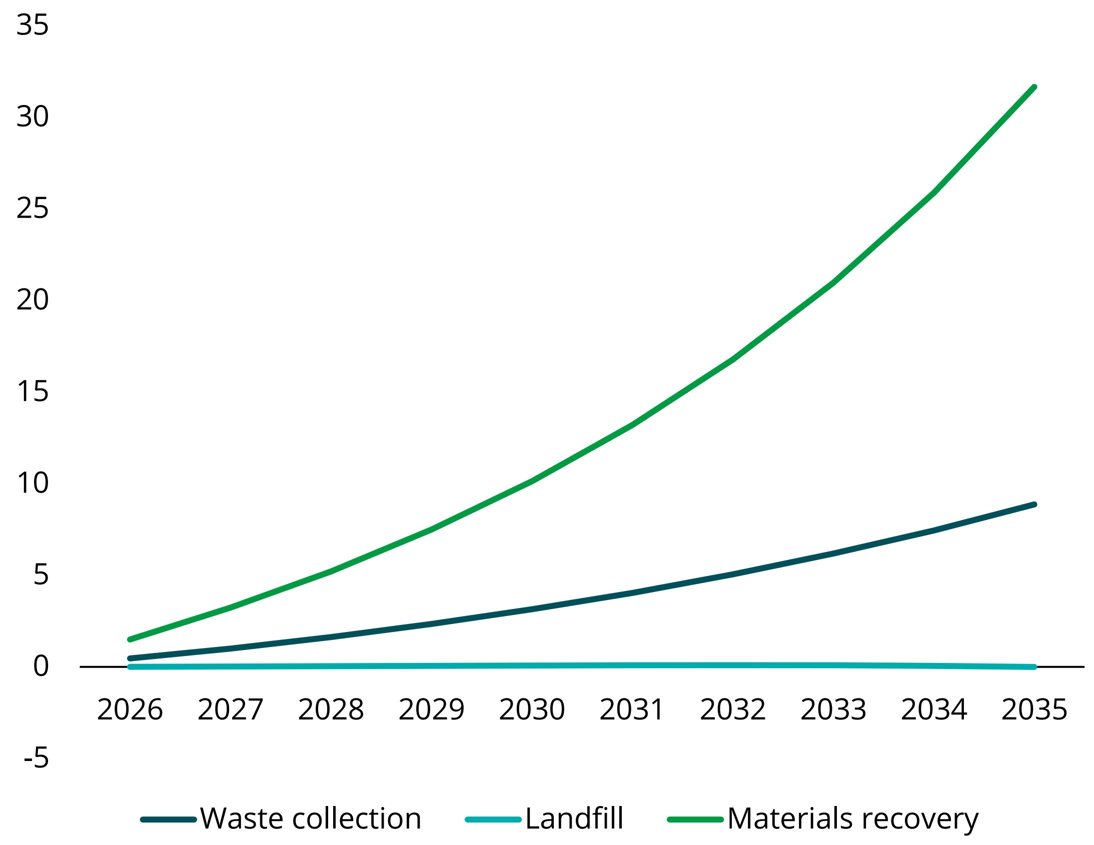


Chart 2: Deviation in output of waste sectors, DAE-RGEM ($ millions)



Testing the ‘Circular’ database in our standard model

Subsidising materials recovery and secondary manufacturing in DAE-RGEM. These applied a uniform subsidy to I_SS and RECOV in Australia only.

Chart 3: Deviation in GDP (% deviation from baseline)

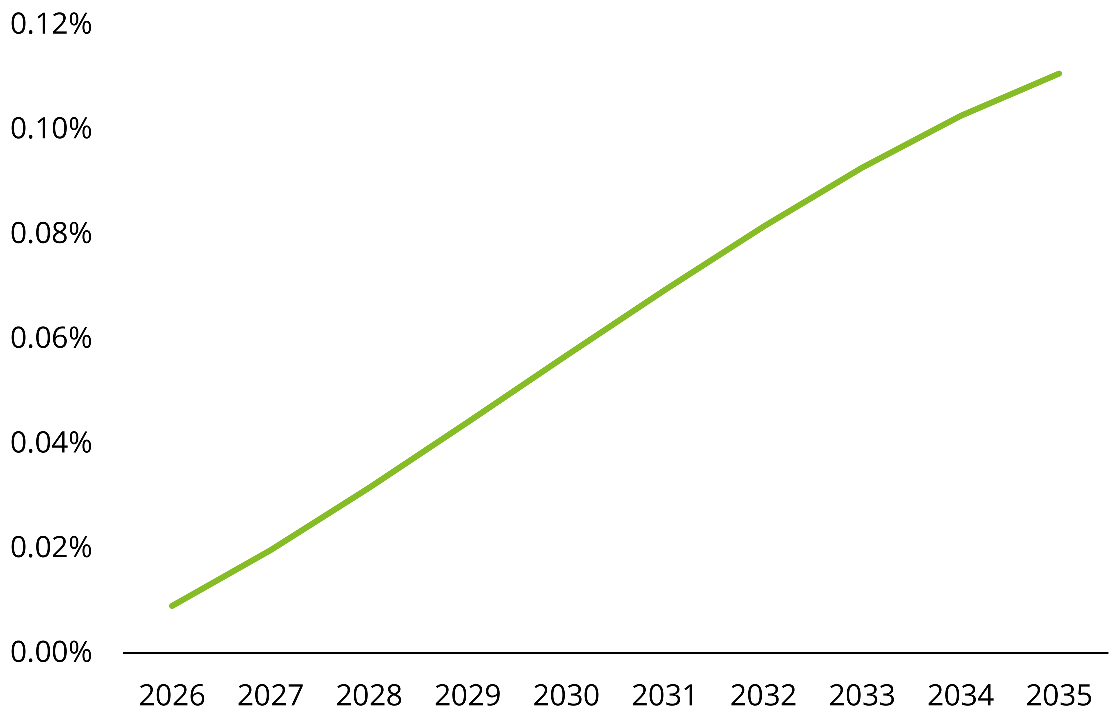
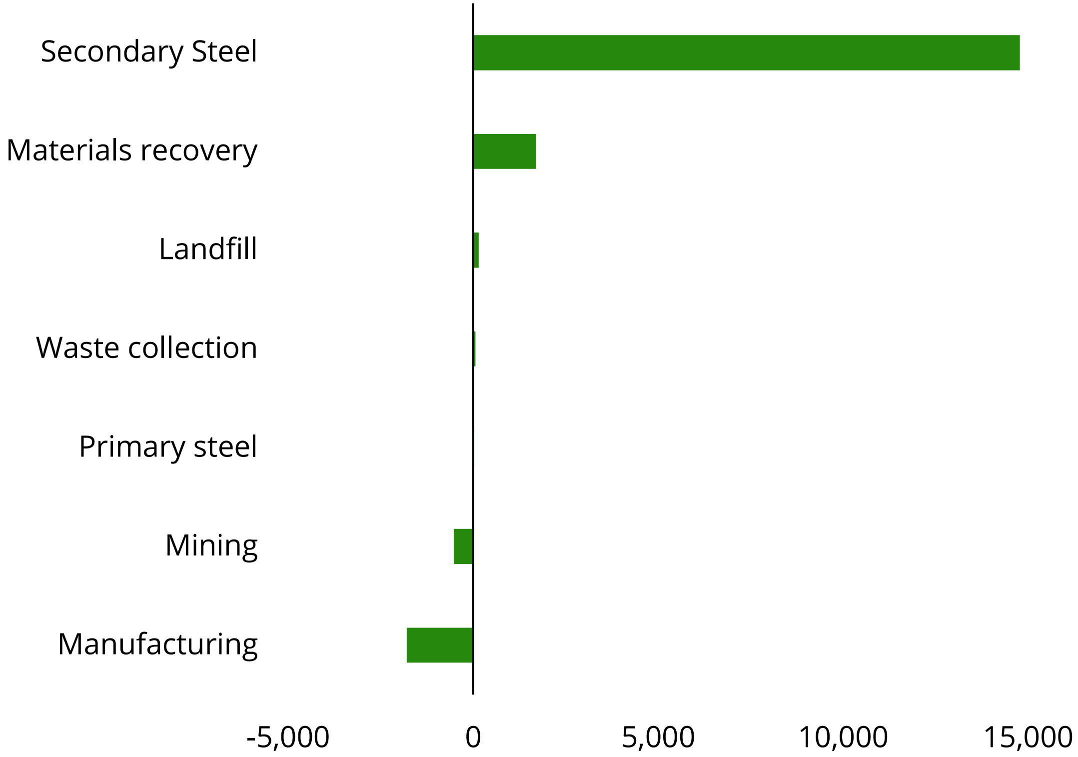


Chart 4: Annual average deviation in employment of select industries, 2026 - 2036 (FTEs)



Close, but not quite. These results are missing one important element of the circular economy.

Where is all the garbage?!

Building DAE-CGEM

Creating a Waste Satellite Account

Australia's National Waste and Resource Recovery Database

- Provided by Department of Climate Change, Energy, the Environment and Water, this gives:
  - Tonnes of waste generated in each State/Territory by source stream (Table 3)
  - Broken down by material type (e.g., metals, plastics, paper & cardboard, timber, organics)
  - And the fate of waste (Figure 2).

This data helps us build in a waste coefficient to DAE-CGEM

- This follows the form of

$$WASTE = waste\ type, industry, region$$

- Where waste type is currently 'Disposed' or 'Recovered'
- This reflects the amount of waste generated by each industry in Australia, as well as households and government.

Table 3: NWRR concordance to DAE-CGEM Waste Satellite Database

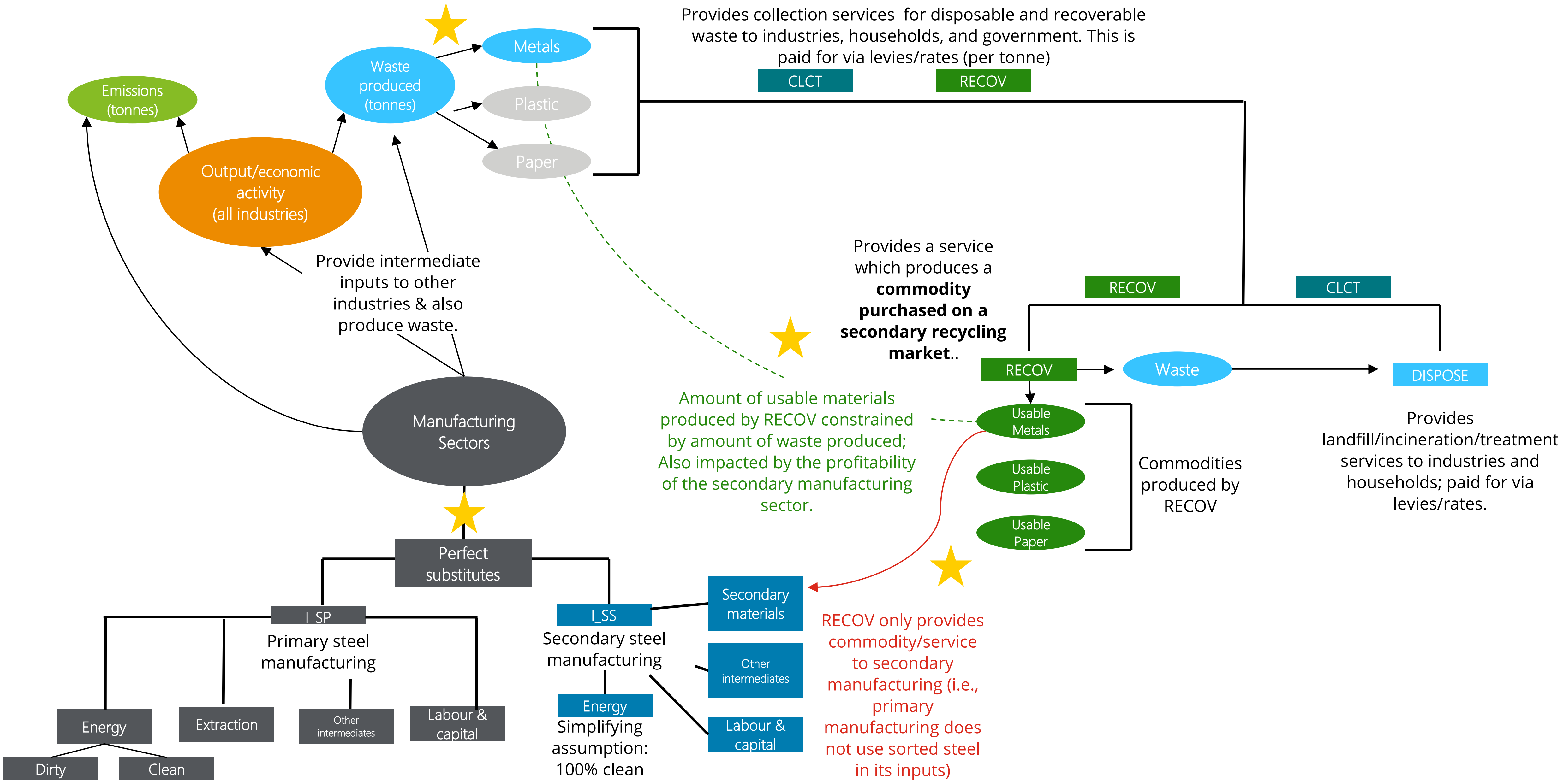
Material Source Stream	DAE-CGEM Industry	Description
Construction and Demolition (C&D)	CONS	Primary steel manufacturing (using extracted resources)
Commercial and Industrial (C&I)	All other industries in the DAE-CGEM database	Proportion of waste generated was assumed to be proportional to each industry's use of waste industries following the commodity-split process
Municipal Solid Waste (MSW)	Households Government	Assumed 50/50 split between households and government

Figure 2: The Fate of ~~Ophelia~~ Waste

Landfill

Recycling

Now we have to show the journey of waste through the economy



Provides collection services for disposable and recoverable waste to industries, households, and government. This is paid for via levies/rates (per tonne)
CLCT
RECOV
Metals
Plastic
Paper
Waste produced (tonnes)
Emissions (tonnes)
Output/economic activity (all industries)
Provide intermediate inputs to other industries & also produce waste.
Manufacturing Sectors
Perfect substitutes
I_SP
Primary steel manufacturing
Energy
Extraction
Other intermediates
Labour & capital
Dirty
Clean
I_SS
Secondary steel manufacturing
Energy
Simplifying assumption: 100% clean
Secondary materials
Other intermediates
Labour & capital
Amount of usable materials produced by RECOV constrained by amount of waste produced; Also impacted by the profitability of the secondary manufacturing sector.
RECOV only provides commodity/service to secondary manufacturing (i.e., primary manufacturing does not use sorted steel in its inputs)
Provides a service which produces a **commodity purchased on a secondary recycling market**..
RECOV
CLCT
RECOV
Waste
DISPOSE
Usable Metals
Usable Plastic
Usable Paper
Commodities produced by RECOV
Provides landfill/incineration/treatment services to industries and households; paid for via levies/rates.

Building DAE-CGEM

"You're getting serious now" – Hom Pant, 2025.

- Continued generation of waste as economic activity grows and summing this for each industry and region in the model (Equations 1 to 2)
- Forcing the output of the RECOV sector to be measured in total tonnes of waste generated, and constraining its total possible output by the amount of waste generated and an assumed recovery rate (currently 75%). (Equations 3 to 4)
- RECOV's total input costs being determined at the general equilibrium level of the system (Equation 5).
- The levies that RECOV and DISPOSE charge for their services, and where these appear in RECOV's zero-profit condition (Equation 6). This is what the RECOV sector must charge to break even

! Normally, the ZPC determines the scale of operation for a competitive sector. However, RECOV's output is constrained by (3).

1. $W * (k,j,r) = \alpha(k,j,r) * Q\ (k,j,r)$
2. $W(k,r) - \sum_{j=1}^{n} W * (k,j,r)$
3. $Q(t,r) = \sum_{k=1}^{2} W(k,r)$
4. $QF(i,t,r) = \beta(i,r) Q(t,r)$
5. $VFA\ (t,r) = \sum_i PF(i,t,r) * QF(i,t,r)$
6. $VFA\ (t,r) + LFEE * W(Landfill,r) = P(RWaste,r) + \sum_j \begin{matrix}[WLEVY(Landfill,r) * W(Landfille,j,r) \\ +WLEVY(RWaste,r),j,r)]\end{matrix}$

Where:
$\alpha(k,j,r)$ is the waste output coefficient
k represents the type of waste (Recovery and Disposal)
t is the RECOV sector
i ε DEMD_COMM
$\beta(i,r)$ is the output coefficient of RECOV
$VFA\ (t,r)$ is total cost of inputs for RECOV

Building DAE-CGEM

“You’re getting serious now” – Hom Pant, 2025.

- Output of secondary steel is also constrained by the amount of scrap steel that RECOV can sort and sell on. Equations 7 to 8 specify the output and input demands for this sector.
- We assume that secondary steel is sold in the same market as primary steel (they are perfect substitutes). A joint market clearing condition determines the market price that both primary and secondary steel charge (Equations 9 to 10).

  ! There may now be two prices for recycling waste, P and P*. This is resolved with the endogenous subsidy rate linking the prices in Equation 10.
- The demand for secondary steel is defined in Equations 11 through 12. We assume only production sectors buy scrap steel, and their distribution across sectors is the same as primary steel.
- A joint market-clearing condition for primary and secondary steel is defined in Equation 13.

7. $Q(k,r) = \mu(k,r) * W(Rwaste,r)$
8. $QF(i,k,r) = \varphi(i,k,r) * Q(k,r)$
9. $QF(i,t,r) = \beta(i,r)Q(t,r)$
10. $VFA\ (t,r) = \sum_i PF(i,t,r) * QF(i,t,r)$
11. $\sigma(j,r) = VDFM(kp,j,r)/SUM\big(t,j,VDFM(kp,t,r)\big)$
12. $QF(k,j,r) = \sigma(j,r) * Q(k,r)$
13. $\sum_j QF(kp,j,r) + QP(kp,r) + QG(kp,r) + \sum_s QEX(kp,r,s) + \sum_j QF(k,j,r) = Q(kp,r) + Q(k,r)$

Where:
k represents the recycling sector (e.g., I_SS)
μ is the recovery rate of Rwaste
φ is the respective I-O coefficient, *i* ε DEMAND_COMM.
j ε PROD_COMM and *kp* is for the primary sector for the recycled sector *k*.

Testing DAE-CGEM

Incentivising circularity with the same subsidy test applied in DAE-RGEM. A uniform subsidy to I_SS and RECOV.

Chart 5: Deviation in output of steel manufacturing, DAE-CGEM ($ millions)

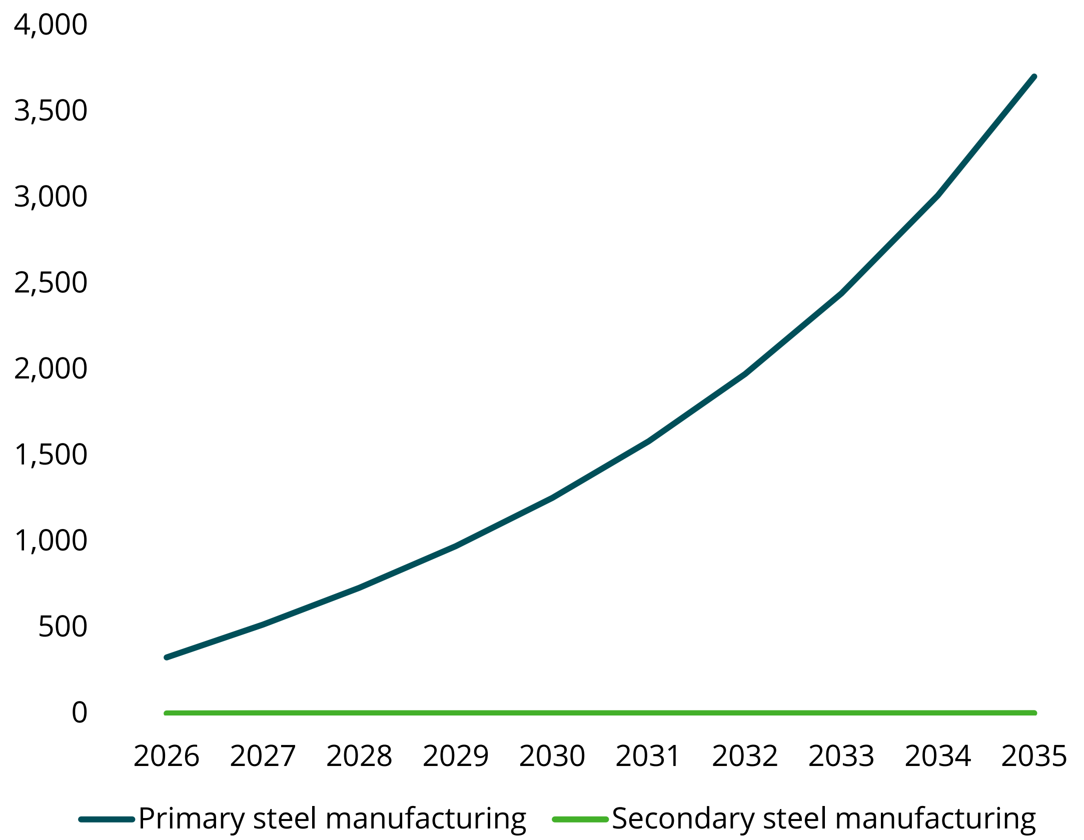
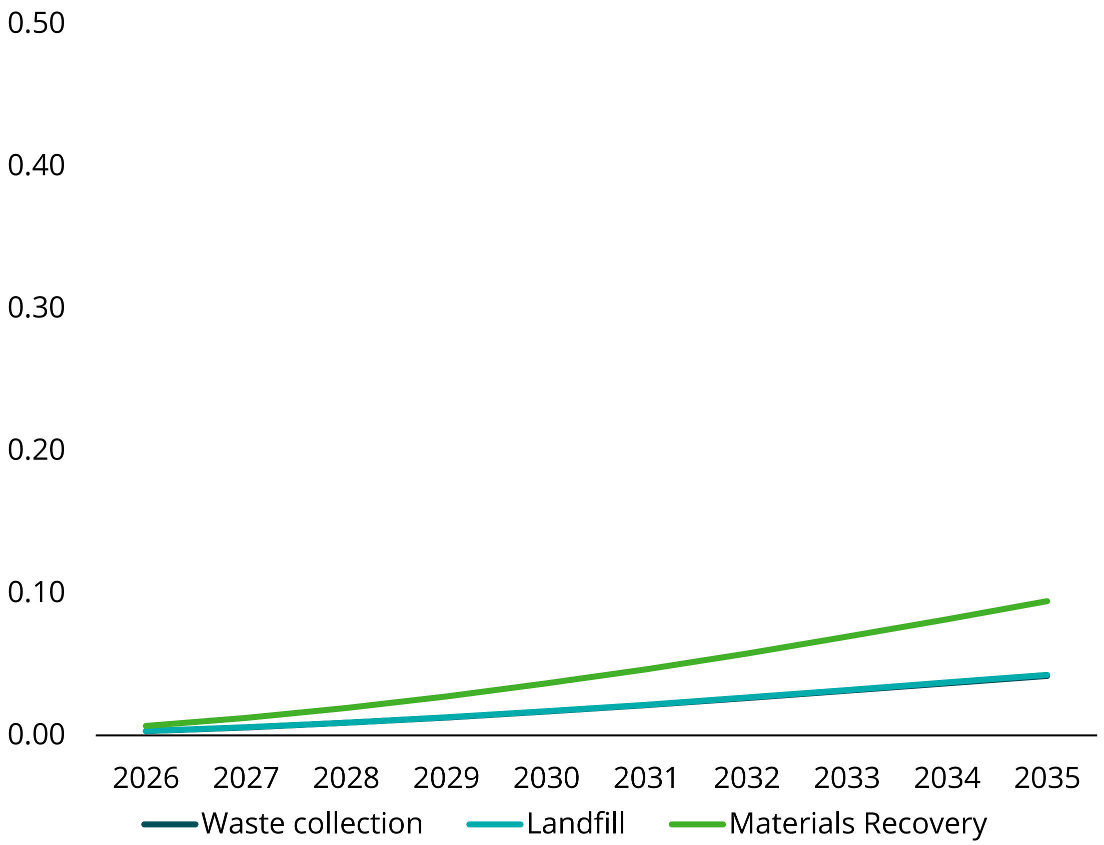


Chart 6: Deviation in output of waste sectors, DAE-CGEM ($ millions)



Testing DAE-CGEM

Changing the type of subsidy gets us closer. This test subsidised circular sectors' use of capital and applied a subsidy to Construction's use of secondary steel.

Chart 4: Deviation in output of steel manufacturing sectors when subsidising demand & use of capital, DAE-CGEM ($ millions)

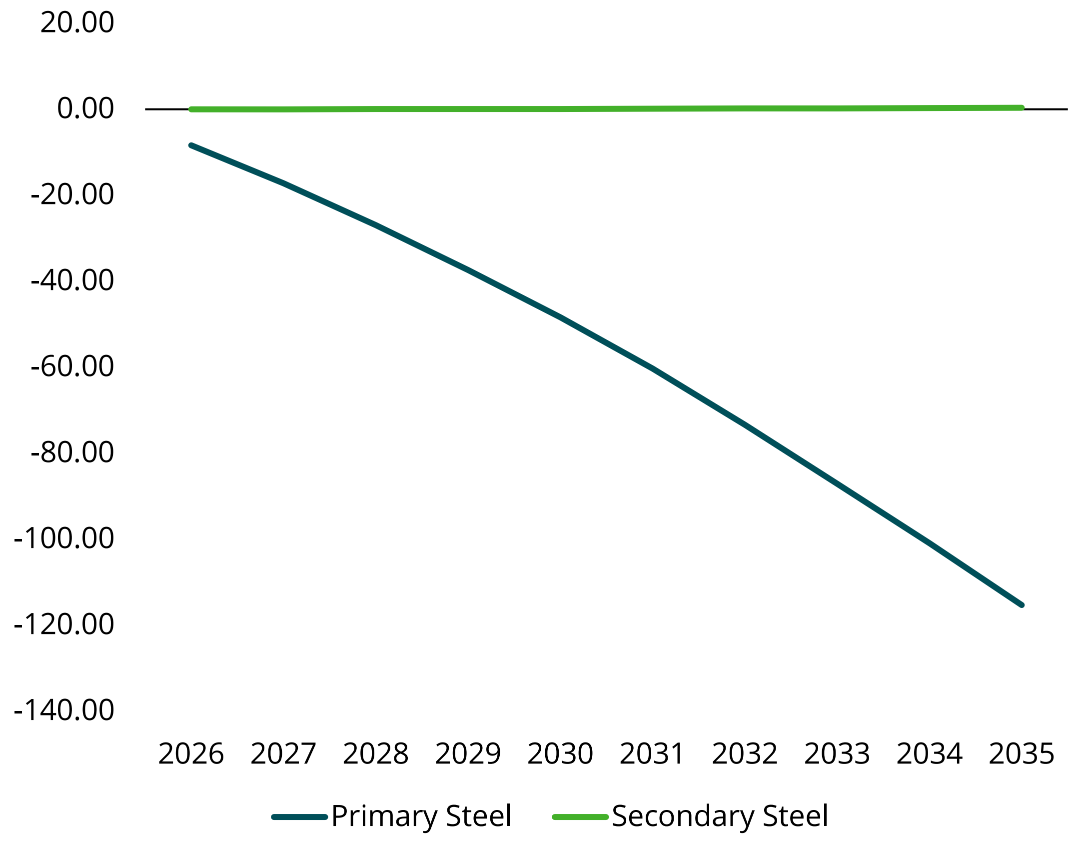
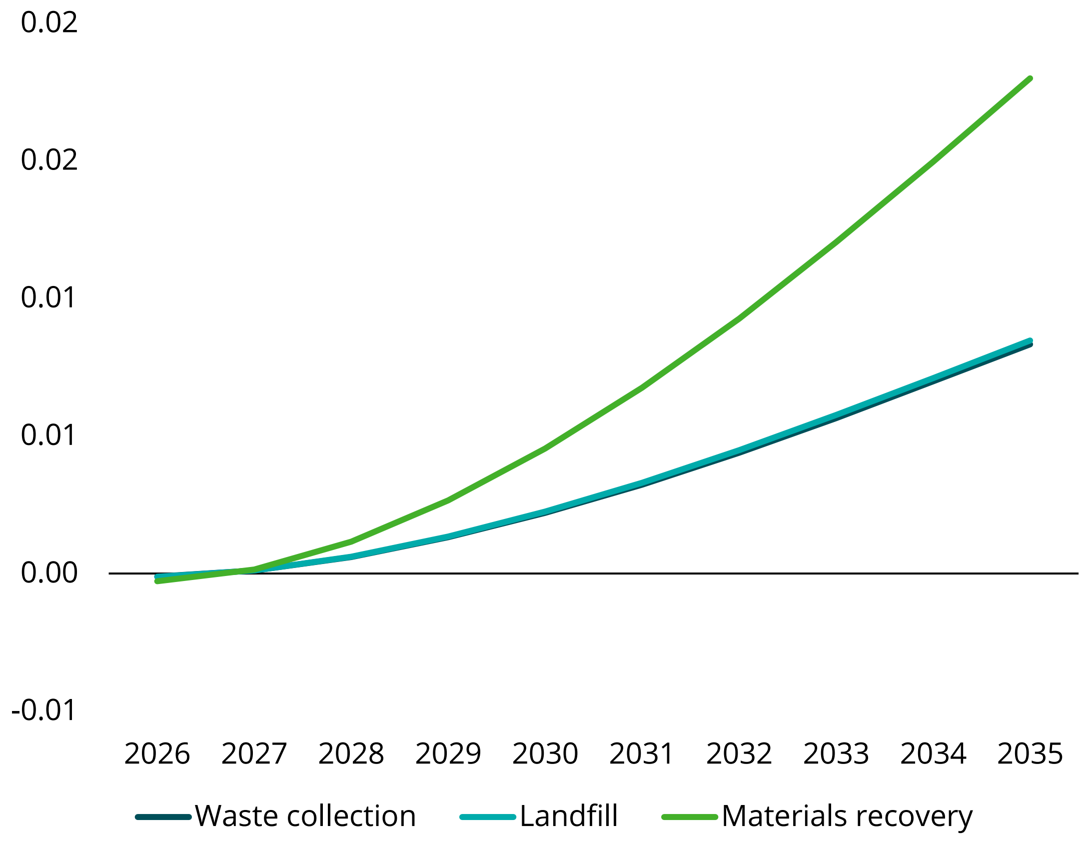


Chart 5: Deviation in output of waste sectors when subsidising demand & use of capital, DAE-CGEM, ($ millions)



Testing the ‘Circular’ database in our standard model

Changing the type of subsidy gets us closer. This test subsidised circular sectors’ use of capital and applied a subsidy to Construction’s use of secondary steel.

Chart 6: Annual average deviation in employment when subsidising demand & circular industry’s use of capital, 2026 - 2035, DAE-CGEM,

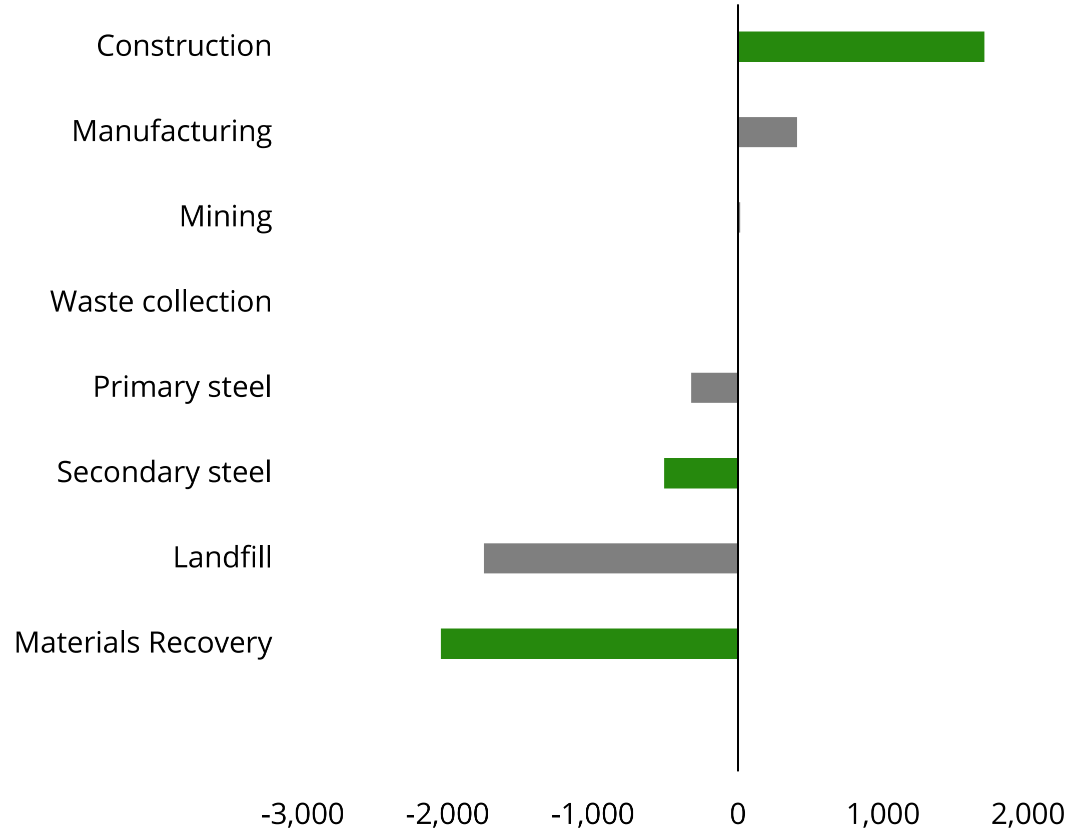
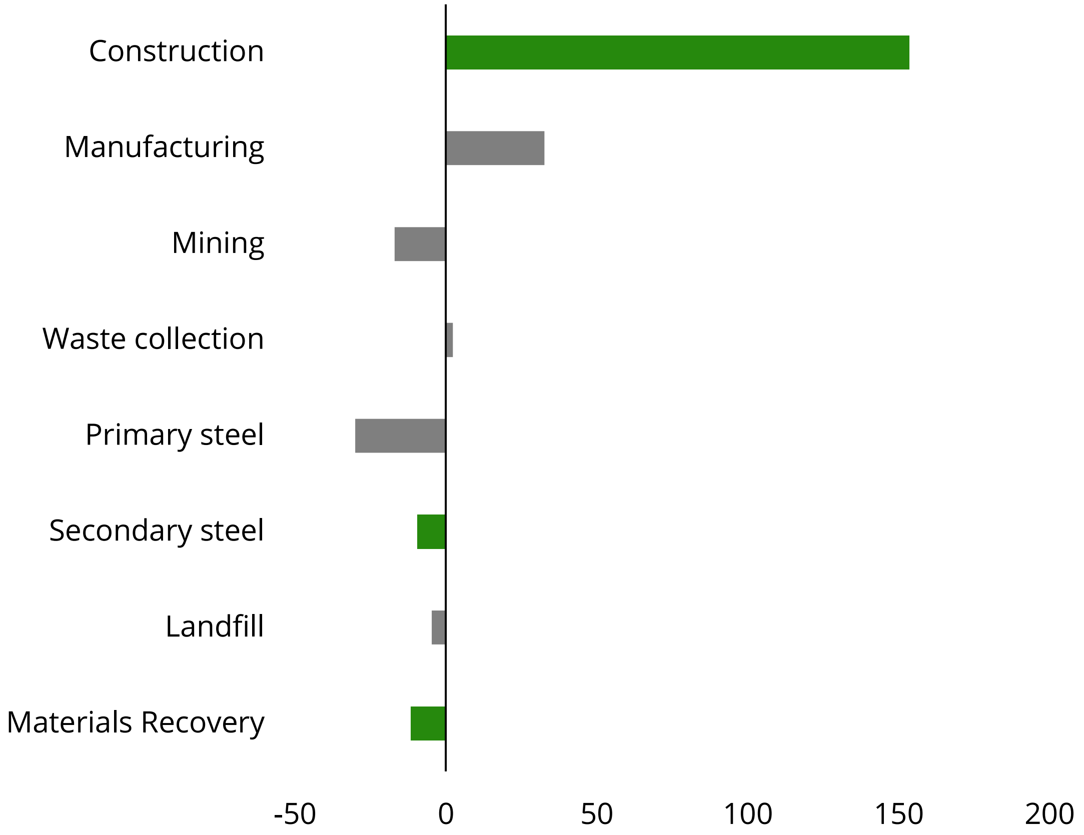


Chart 7: Annual average deviation in industry GVA when subsidising demand & circular industry’s use of capital, 2026 – 2036, DAE-CGEM



Next steps

- Test the impact of Australia's trade partners increasing their domestic secondary steel manufacturing.
- Test policies on Australia's supply-chain resilience if we increase domestic production of secondary steel.
- Test different tax instruments to incentivise switching away from landfill and towards recycling. This would likely require further adjustments to the model code.
- Refine underlying waste data & database. Currently, the implied levies charged for collection and recovery services are different for all industries. Ideally this would be the same fee applied to all industries per tonne.
- Work towards building in individual commodities.

Would love your feedback and questions!