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Modelling urban emissions – a Perth case study

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Abstract: The Australian government, like many others, has committed to achieving "net zero emissions" by 2050 with an interim target of 43% below 2005 levels by 2030. A significant fraction of emissions is demand driven by government land planning and household purchasing decisions. This paper reports on the development of a system dynamics model to evaluate the performance of various intervention measures designed to avoid lifecycle greenhouse gas emissions in typical residential precincts in the city of Perth. The assessment phase identified that in new "greenfield" development precincts lifecycle emissions per dwelling were 500-700 tCO2e including emissions embodied in the construction of precincts and homes. Lifecycle emissions per dwelling in re-developed "infill" precincts were much lower at around 300 tCO2e. The modelled interventions related to land use planning (in particular smaller dwellings), revised subdivision designs, lightweight construction materials, electric vehicle penetration, home electrification, increased electricity self-supply and decarbonisation of the electricity network illustrated that up to 70% of lifecycle emissions could be avoided.

1. INTRODUCTION

According to the 6th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), urban settlements produce 70% of global emissions (IPCC, 2023). A significant proportion of these emissions are associated with households (directly and indirectly) using electricity and natural gas for home operations and (to date largely) fossil fuel energised private vehicle transport. Additionally, emissions are embodied in the construction and materials in homes themselves and the land developed for housing, including the clearing of vegetation.

Greater Perth has expanded geographically in recent decades, leading to text-book urban sprawl. Projections indicate that Perth's current population of 2.1 million could surge to 3.5 million by 2050 (Department of Planning Lands and Heritage, 2018). In the context of these dynamics, the aim of this government funded research is to quantify the lifecycle GHG emissions in existing residential precincts in Perth and model the impact of various interventions that could be implemented in the effort to achieve net zero emissions by 2050 when the population is projected to be 3.5 million by (Department of Planning Lands and Heritage, 2018).

2. METHODS

In consultation with the Western Australian Department of Planning, Lands & Heritage (DPLH), five case study precincts that typify contemporary Perth development were selected for data collection and analysis. Three of these represent greenfield developments in the outer regions of Greater Perth (i.e. some distance from the central business district (CBD)) and two represent different forms of infill development, i.e. in existing suburbs.

2.1. Phase 1 – emissions benchmarking

The methods used to measure emissions from various housing typologies in these existing case studies involved a combination of direct collection of relevant operational energy data from utilities, Life Cycle Assessment (LCA) methods and modelling to determine emissions from Subdivision works, Built-form materials, Operational energy, Transport from private vehicles, Vegetation loss and Water and wastewater.

2.2. Phase 2 - Modelling interventions to avoid emissions

Interventions were devised and incorporated into a system dynamics model using the Vensim software[1]. The structure of the model facilitates exploration of any combinations of intervention and comparisons with the Phase 1 results, referred to as the "Baseline". The model is constructed in modules that calculate emissions on a per-dwelling basis for several urban typologies, containing the dwelling mix per ha (of lots), i.e. the type and size (i.e. floor area) of each dwelling type, together with the lot area for each type.

[1] https://vensim.com/

3. RESULTS

The model allows for any combination of interventions to be simulated for all the selected case studies. An example of the model output for a selection of cascading interventions (**Error! Reference source not found.**) that evolve over time for a typical greenfield precinct in a shallow groundwater site is set out in Figure 1.

Table 1 Interventions

Embodied	Operational	Cases	0	1	2	3	4	5
✓	✓	Planning and other initiatives	✓	✓	✓	✓	✓	✓
✓	✓	Reduced fill		✓	✓	✓	✓	✓
✓	✓	Lightweight materials			✓	✓	✓	✓
	✓	EV penetration & home electrification				✓	✓	✓
	✓	Increased self-supply					✓	✓
	✓	SWIS decarbonisation						✓
		Resulting reductions in lifecycle emissions	**~35%**	**+5%**	**+5%**	**+7%**	**+15%**	**+7%**

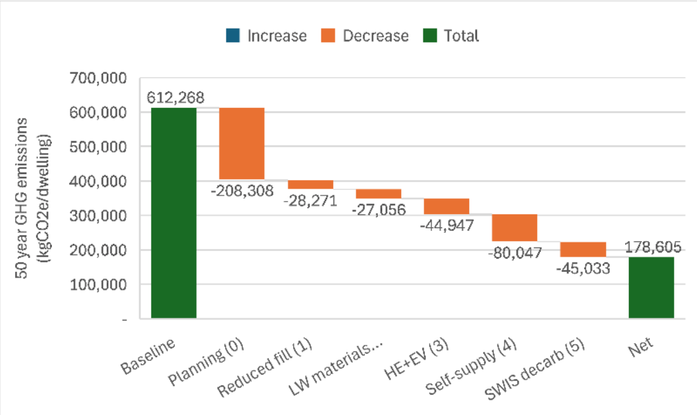

Figure 1 Potential lifecycle GHG emissions for a typical new Perth development

The cumulative impact of interventions has the potential to reduce lifecycle emissions per dwelling by around 70%.

4. CONCLUSIONS

Of the intervention categories, those that relate to planning and design (e.g., urban density and layout) and home electrification (e.g., purchasing household batteries) typically have the most significant impact on emissions. Across the interventions, the potential reduction in emissions per dwelling is lower in the infill development sites as dwelling sizes are already smaller and densities are already higher than in the greenfield sites.

The planning and design interventions for greenfield development sites revolve around the re-configuration of dwelling types and sizes to better reflect the existing and likely future demographics of the population in the Perth metropolitan area. Right-size (and less expensive) housing would result in significantly higher gross dwelling densities, delivering more private open space to facilitate trees and gardens and optimising solar access for rooftop solar PV and winter passive heating. Compared to existing forms of development, on a per-dwelling basis, these measures result in lower levels of embodied carbon in both the subdivision works and the built-form and lower operational energy demand.

The large influence of increasing electricity self-supply through solar PV and batteries reduces the additional benefit of simultaneously decarbonising the SWIS, which reduces emissions a further 5-10% per dwelling. Without the self-supply measures, decarbonisation of the SWIS would reduce lifecycle emissions by around 35%.

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