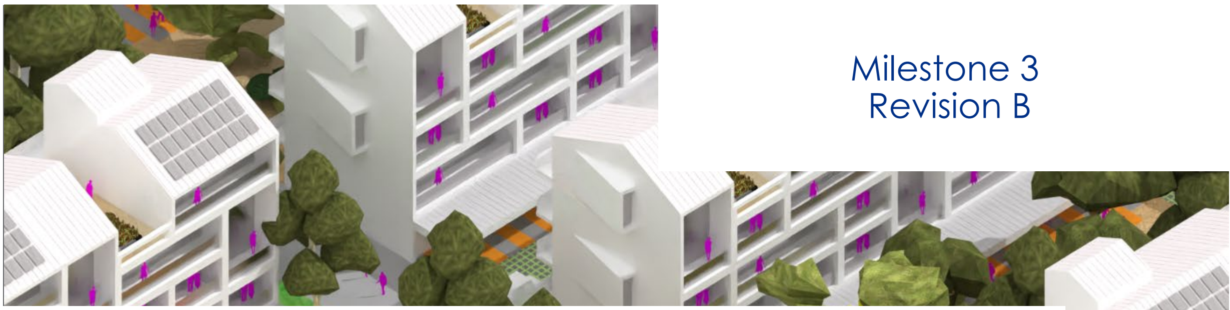
Milestone 3
Revision B



Accounting for carbon in the planning for residential neighbourhoods

Final report: Summary and recommendations

THE UNIVERSITY OF WESTERN AUSTRALIA

Cover page

Project number: 6-020

Project title: Accounting for carbon in the planning for residential neighbourhoods

Milestone number: 3

Deliverable name: Final Report: Summary and recommendations

Funding acknowledgment: This research is funded by iMOVE CRC and supported by the Cooperative Research Centres program, an Australian Government initiative.

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Date: 26.03.25

Version: B

Contents

1. Executive summary

The overarching scope of the research is to:

- Examine how the design of new greenfield and existing densifying neighbourhoods can reduce carbon emissions and contribute to the creation of low or zero-carbon neighbourhoods.
- Identify the primary contributors to greenhouse gas emissions in neighbourhoods and how emissions can be reduced through urban planning and design interventions related to subdivision patterns, street networks, open space systems, residential densities, building types, and environmental conditions.
- Determine how the modelling and reporting of emissions would occur at the district and local structure plan stages and how these could be followed through to implementation.
- Establish key indicators and assessment methodologies applicable at the district and local structure planning stages for residential areas.

1.1 Findings from the Phase 1 report

The purpose of the Phase 1 report was to analyse the emissions associated with land clearing, subdivision works, built-form (embodied and operational), transport and water in five case study precincts, three urban-edge greenfield (Jindalee, Southern River and Ellenbrook) and two urban infill (Nollamara and Subi Centro) as nominated by the Department of Planning Lands and Heritage Working Group. The case studies were selected to represent contemporary development patterns, so our findings are 'generalisable' to structure plan areas in the future.

Analysis of cumulative 50-year precinct emissions per dwelling reveals that the infill case studies Nollamara and Subiaco have the lowest emissions, and the greenfield case studies Ellenbrook and Southern River have the highest emissions, followed by Jindalee.

The differences between the precinct emissions per dwelling can be summarised as follows.

Subdivision works:

- The emissions from subdivision works in greenfield developments (Southern River and Ellenbrook) are a significant proportion of life-cycle emissions.
- Development in lower-lying areas (e.g., Southern River and Ellenbrook) leads to significantly higher emissions than the other greenfield precinct (Jindalee) due to the requirements for fill (and, in many cases, sub-soil drainage).
- Avoiding subdivision works in background infill precincts (e.g., Nollamara) essentially eliminates this source of emissions.

Built-form:

- The precincts with smaller built-form Gross Floor Areas (GFAs) have lower embodied energy in the built-form (e.g., Nollamara or Subiaco).
- The background infill and Transit Oriented Development precincts (Nollamara and Subiaco, respectively) have lower built-form embodied emissions than the greenfield compact suburbs (e.g., Southern River and Ellenbrook).
- Higher-density areas (Subiaco) can still have comparatively high operational emissions compared to lower-density background infill and even some examples of compact suburbs (e.g., Jindalee or Southern River).

Transport emissions (private cars):

- The private car emissions are roughly correlated with increasing distance to the Perth CBD for the precincts. Subiaco has the dual advantage of being close to the CBD and having local jobs and services, resulting in the lowest transport emissions.

Vegetation related emissions

- The relative impact of land clearing and landscaping on emissions, while important, is minor compared to other categories across the precincts.

Water and wastewater-related emissions

The indirect emissions associated with water and wastewater are minor compared to other emissions sources. Nonetheless, the suburban precinct with larger lots (Ellenbrook) had higher water use than the compact suburb and infill precincts (e.g., Jindalee or Nollamara).

1.2 Findings from the phase 2 report

The purpose of the phase 2 report was to evaluate interventions that can avoid future emissions. These interventions were identified through a literature review, demographic analysis and a workshop with the Department of Planning Lands and Heritage staff and the Accounting for Carbon working group. Subsequently, the impacts of the interventions were quantified and incorporated into a system dynamics model to calculate per-dwelling life-cycle emissions across our five precinct case studies. The interventions in each case study were modelled from a baseline year when the corresponding Structure Plan was approved (e.g., for Subi Centro, this was 1994).

Planning and design interventions that can reduce emissions include:

- the avoidance of development in shallow groundwater sites.
- a reduction in fill for such sites that are developed.
- the re-configuration of dwelling types and sizes to better reflect the population's existing and likely future demographics.
- significantly higher gross dwelling densities within both greenfield and urban infill areas to reduce the need to travel and more private open space to facilitate trees and gardens, and
- optimised solar access for rooftop solar PV, summer thermal comfort and winter passive heating.

These planning and design interventions would result in:

- lower levels of embodied carbon in both the subdivision works and the built-form, and
- lower operational energy demand.

These measures can reduce lifecycle per dwelling energy supply and transport emissions by 30-50%.

Home electrification interventions that can reduce emissions include:

- Replacing the use of gas in homes, e.g. with heat-pump water heaters and electric stovetops.
- The take-up of electric vehicles; both in tandem with
- increasing penetration of rooftop solar PV and home batteries.

Together with planning and design measures, these measures will potentially reduce lifecycle per dwelling energy supply and transport emissions by a further 30-35%.

Embodied emissions can be reduced by using alternative forms of construction, including:

- the incorporation of cement replacement materials in concrete; and
- sustainably produced timber products for framing and wall cladding.

These measures lead to significant reductions in embodied emissions of around 50% per m^2 of GFA. 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- nonetheless, the reductions are still significant.

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.

Our modelling shows that re-configuring dwelling types and sizes to reflect better the existing and likely future demographics is critical to reducing emissions and offering other benefits. From a developer perspective, this would lead to a larger number and greater diversity of lots per hectare of development. From a builder's perspective, this would lead to more dwelling completions per m^2 of constructed built-form. From a resident's perspective, it would improve liveability affordability and lower operational costs.

1.3 Findings from the phase 3 report

The purpose of the Phase 3 report is to identify changes within the planning and design system that contribute to low- or zero-carbon neighbourhoods. It is recommended that the State Planning Strategy and SPPs be reviewed and revised to reflect the importance of climate change to the various regions of Western Australia and align the planning system with the government's climate change legislation regarding Net Zero emissions and adaption to climate change. This review would also include consideration of the following:

- The region scheme Amendment Reports include a section on climate change, including the influence of location on greenhouse gas emissions.
- State Planning Policy 7.1 Neighbourhood Design and 7.2 Precinct Design to explicitly reference the emission reduction objectives of revised State Planning Policies
- The intent of State Planning Policy 3 Urban Growth and Settlement (Clause 5.1) to be included in the references to State Planning Policies in State Planning Policy 7.1 Neighbourhood Design and 7.2 Precinct Design.
- State Planning Policy 7.1 Neighbourhood Design and 7.2 Precinct Design to require an Energy and Greenhouse Gas Statement as a standalone Precinct Plan Output to demonstrate how the precinct plan has avoided emissions compared to a benchmark conventional development.
- The Energy and Greenhouse Gas Statement to require an evaluation of life-cycle emissions associated with subdivision works and an explanation of the measures taken to minimise earthworks and drainage infrastructure and emissions associated with transport and construction vehicles.
- State Planning Policy 7.1 Neighbourhood Design to require climatic and microclimate analysis of the site, including likely future conditions under climate change, with an appendix included to provide guidance.
- Future reviews of State Planning Policy 7.1 Neighbourhood Design and the Residential Design Codes to address a more integrated land and built-form planning approach to deliver

climate-responsive urban design to contribute to Net Zero emissions and climate resilience in Western Australia.

- The 'WA Planning Manual – Guidance for Structure Plans' be revised to ensure adequate information is provided to planning authorities for those recommendations that are adopted for State Planning Policy 7.1 Neighbourhood Design and 7.2 Precinct Design.
- The Residential Design Codes reference the proposed changes to State Planning Policies and modify the relevant text in these documents to more explicitly link the policy requirements to the mitigation of emissions (and where appropriate to adaptation).
- The Department of Energy, Mines, Industry Regulation and Safety review the NSW BASIX scheme's application of a Materials Index to require a similar calculation of embodied energy to be submitted with Building Permit applications.
- The Department of Energy, Mines, Industry Regulation and Safety review the progress of the Victorian scheme to introduce a similar ban on gas connections in new premises through the Building Permit process.
- A future review of 'Perth & Peel @ 3.5 million' to analyse alternative development scenarios for Greater Perth that fully account for climate change. This review could also reconsider Perth's infill target of 47%.

2. Introduction

2.1 Project description

The research considers the physical and social geography factors of new, predominantly residential neighbourhoods in metropolitan Perth and Peel and how planning and design impact the behaviour of residents and their associated greenhouse gas emissions, including factors affecting housing operation, choice of transport and access to places of work, services and entertainment. The research will also inform planning and design in regional areas of Western Australia. The overarching scope of the research is to:

- Identify the primary contributors to greenhouse gas emissions in neighbourhoods and how emissions can be reduced through urban planning and design interventions related to subdivision patterns, street networks, open space systems, residential densities, building types, and environmental conditions.
- Determine how the modelling and reporting of emissions would occur at the district and local structure plan stages and how these could be followed through to implementation.
- Establish key indicators and assessment methodologies applicable at the district and local structure planning stages for residential areas.
- Examine how the design of new greenfield and existing densifying neighbourhoods can reduce carbon emissions and contribute to the creation of low or zero-carbon neighbourhoods.

This report is the final of three research reports delivered:

- Phase 1 report: Case study emissions analysis;
- Phase 2 report: An urban energy and emissions model for evaluation of interventions
- Final report: A final project report summarising the research results and recommendations.

2.2 Project governance

The project steering committee comprises senior officers from the Departments of Transport (DoT), Planning Lands and Heritage (DPLH) and the iMOVE Cooperative Research Centre. DPLH has established a working group to guide the project.

2.3 Related research

In conjunction with this research, AUDRC also has a parallel climate adaptation project entitled Future Climate, Future Home: Adaptive Urban Design Strategies for WA, in which DPLH, the Department of Communities and DevelopmentWA are partner organisations. This project aims to assess the impact of climate change on the performance of housing and open space in all of Western Australia's climate regions. The project's outcome will be recommendations for adapting existing houses and open spaces and guidelines for new development.

2.4 Acknowledgements

The research team acknowledges the cooperation of several parties in providing information and support for the analysis presented here:

- The members of the project Steering Committee;
- Members of the DPLH Working Group;

- Officers of DPLH, DoT and DWER; and
- For the provision of data: Western Power, ATCO, Water Corporation and the local governments of Wanneroo, Gosnells, Stirling and Swan.

Funding acknowledgment:

This research is funded by iMOVE CRC and supported by the Cooperative Research Centres program, an Australian Government initiative.

3. Phase 1 Case study area emissions analysis - report summary

3.1 Scope

The first phase of the research involved the assessment of life-cycle emissions in characteristic Perth metropolitan precincts, representing conventional contemporary greenfield and infill developments, including those associated with:

- land subdivision and the clearing of vegetation;
- the construction of residential built-form;
- the operational energy (electricity and gas) used in residential dwellings;
- private vehicle transport associated with each precinct;
- emissions sequestered by vegetation and
- the supply of water and wastewater services.

3.2 Case study sites

The study involves five case study precincts, three urban-edge greenfield (Jindalee, Southern River and Ellenbrook) and two urban infill (Nollamara and Subiaco) as nominated by the DPLH Working Group (see Table 1 and Figure 1, Figure 2).

Table 1 Description of case study sites

Case study	Related planning document	Baseline year	Urban morphology	Contemporary policy relevance
Jindalee	Jindalee North- Local Structure Plan 88 (2014)	2014	Compact suburb	Liveable Neighbourhoods/ Neighbourhood Design
Southern River	Southern River Precinct 3A Outline Development Plan (2009)	2009	Compact suburb	Liveable Neighbourhoods/ Neighbourhood Design
Ellenbrook	Village 5- Ellenbrook City of Swan Development Plan (2001)	2001	Suburb	Liveable Neighbourhoods/ Neighbourhood Design
Nollamara	-	1995	Background infill	Residential Design Codes (State Planning Policy 7.3)
Subi Centro	Subiaco Redevelopment Act 1994	1994	Transit Oriented Development	Activity Centre policy (State Planning Policy 4.2) Precinct Design (State Planning Policy 7.2)

The analysis of development/ redevelopment within each precinct relates to a baseline year when the corresponding Structure Plan was approved.

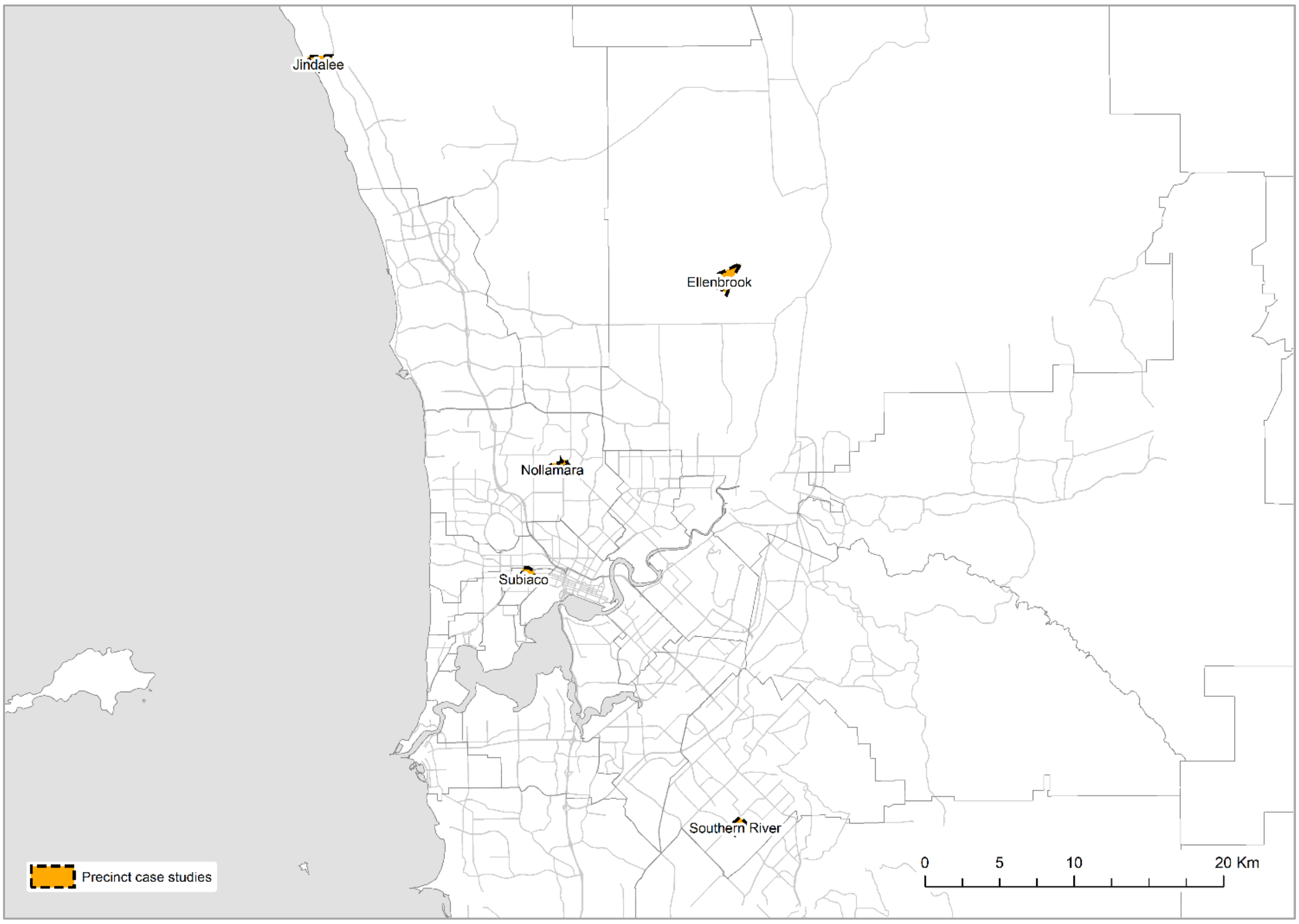
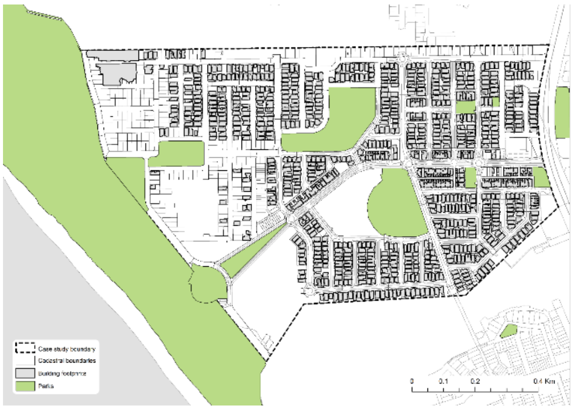


Figure 1 The case study precinct locations.

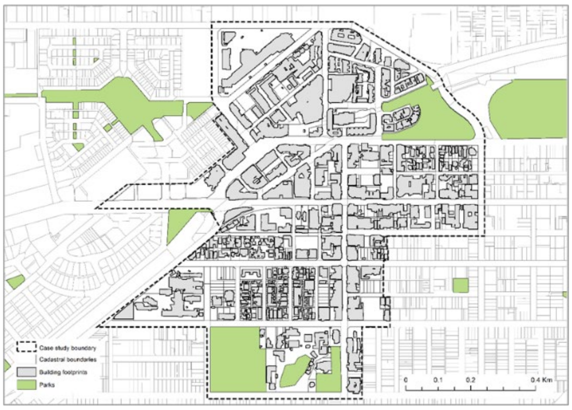


Jindalee

Southern River

Ellenbrook

Nollamara



Subi Centro

Figure 2: Case study precincts

3.3 Methods

A summary of the methods used to measure emissions across different categories is set out below. Note that in all cases, the intensity of emissions was based on current values.

3.3.1 Subdivision works

Greenfield case study sites

The emissions associated with subdivision works in greenfield precincts were evaluated using life cycle assessment (LCA) methods. The evaluation reported here is based on a previous LCA study carried out by Cerclos for the UDIA[1] for the following projects:

- 115 Hamilton Hill (DevelopmentWA) – a residential estate;
- Bushmead (Cedar Woods) - a residential estate; and
- Orion (DevelopmentWA) – an industrial estate

Accordingly, the results are not an accurate representation of subdivision works for the specific precincts studied in the research reported here but are believed to be sufficiently indicative to support the general findings of this study.

Land clearing operations are included in the subdivision calculations, while the loss of carbon in the vegetation itself is included in the vegetation analysis.

Infill sites

Subdivision works have not been included in the Subiaco case study site and this is a gap in the research. This study defines sub-division works as those external to private lots, i.e., site formation, road reserves, and infrastructure works (but exclude vegetation changes, which are calculated separately).

Regarding Nollamara, there was little or no modification to the road layout, and it was assumed there were negligible sub-division works. Again, vegetation changes were calculated separately.

Emissions associated with demolishing premises in Subiaco and Nollamara have also been neglected. For residential premises, these would involve emissions from equipment and would not be significant (although not negligible). Emissions from demolition in the old industrial part of Subiaco would have been more significant, but no information is available to quantify these.

3.3.2 Utility upgrades

Both greenfield and infill development have implications for the capacity of utility services, i.e. electricity, gas, water and wastewater. The service providers conduct studies to evaluate whether capacity upgrades beyond the development area are required. We have not sought any information to determine the necessary upgrades for the case study precincts, noting that they would generally be characterised as capital works servicing the area and may have occurred in stages. It is not straightforward to determine the need for capacity upgrades without a detailed network analysis, which is beyond the scope of this work. Accordingly, this source of emissions has not been included in the assessment reported here.

3.3.3 Built-form

Cadastral information for each precinct was sourced from Landgate and complemented by aerial imagery (Google Street View and Nearmap). Each dwelling was categorised according to the variables set out in Section 3.2 above.

[1] Land Development Infrastructure Life Cycle Assessment Study (July 2023)

Embodied emissions

LCA techniques were used to evaluate the embodied carbon in the main envelope elements of the buildings (construction phases), as these are the phases that can be influenced by planning and building codes. Cerclos's eTool software was used for this analysis[2].

Operational energy - dwellings

The National Construction Code (NCC) requirements facilitate an assessment of operational energy use for a dwelling to comply with the current seven-star standard. This assessment was conducted for each of the identified typologies, noting that the results are essentially related to the habitable dwelling area in all cases. This assessment has enabled the creation of a benchmark against which actual energy use can be compared.

Data on the actual energy use of each typology within each precinct was sought from Western Power and ATCO. Both have provided energy use data at the suburb level. This data was used to assess the operational energy use of dwellings compared to the theoretical and NCC calculations.

The Western Power data identifies the energy exported to their network from rooftop solar PV arrays and the energy imported to premises from the network. Using an in-house developed solar PV model, the capacity of solar PV (at the suburb level) was assessed to identify the energy that is self-supplied and, therefore, the total electricity demand of households on average.

The greenhouse gas intensity of electricity and gas was taken from the Australian National Greenhouse Accounts Factors (2023)[3] published by the Department of Climate Change, Energy, the Environment and Water.

3.3.4 Operational energy – transport

This study has relied on results from the Strategic Transport Evaluation Model (STEM) of Metropolitan Perth and Peel held within the DoT. DoT has provided the research team with model results that identify transport zones (TZ) associated with the selected precincts:

- vehicle kilometres travelled (VKT) related to travel to and from the transport zones for private vehicles, light commercial vehicles and heavy commercial vehicles; and
- the number and purpose of trips to and from those transport zones.

DoT has recently commissioned a consultancy report to create a framework for evaluating road transport emissions and provided excerpts from this report to the research team that provide emissions intensity values for various vehicle types. Those values have been applied to the 2021 VKT reported from the stem model to assess vehicle emissions associated with each precinct.

The analysis does not include emissions from public transport, i.e. from bus and train use of occupants of the precincts.

3.3.5 Vegetation

Each case study was individually analysed based on its characteristics and available information. A baseline year was established for each case study before significant change or development activity. For the baseline year, the amount of vegetation – including grass (lawns, verges, reserves

[2] https://etool.app/

[3] Australian Government Department of Climate Change, Energy the Environment and Water 2023 'National Greenhouse Accounts Factors:2023'. https://www.dcceew.gov.au/climate-change/publications/national-greenhouse-accounts-factors-2023.

and ovals), shrubs and trees – in place was estimated and compared with the amount of vegetation now (2023/2024) using a range of tools, including Nearmap, Google Earth Pro and Google Street View.

An estimate of carbon dioxide emissions and removals was then developed over a 50-year period based on each case study's quantified vegetation changes and applying a range of carbon dioxide removal values determined through a combination of research and a carbon accounting tool called FullCAM[4] managed by the Department of Climate Change, Environment and Water (see Volume 2).

3.3.6 Water and wastewater emissions

Operational emissions arise from treating raw water sources (e.g. groundwater and seawater for desalination) and transport through the Integrated Water Supply Scheme (IWSS) to its place of use. Emissions from the wastewater system arise from transporting wastewater from its origin to the Water Corporation's wastewater treatment plants and its treatment and disposal (including the component of wastewater that supplies the Groundwater Replenishment Scheme).

The Water Corporation has provided data on water use from 2022 to the present for all meters within each precinct. Average water usage was calculated from this data. Wastewater volumes have been estimated based on the quantity of water used and the type of lot. Larger lots, which typically have more external water uses, such as irrigation swimming pools/spas, return a lower proportion of water to the wastewater system than smaller lots.

The Water Corporation's Annual Report[5] includes data on the energy use per kilolitre of water and wastewater and the overall greenhouse gas emissions per unit of energy consumed. This information was used to translate water and wastewater flows to annual greenhouse gas emissions.

3.4 Results

The calculated 50-year emissions (per typical dwelling) for each case study site are below in Table 2 and Figure 3.

Table 2 Phase 1 results

	JINDALEE	**SOUTHERN RIVER**	**ELLENBROOK**	**NOLLAMARA**	**SUBIACO**
Area (ha)	120	62.9	207	79.81	79.01
Dwellings	1327	672	1508	1704	2927
Gross density	11.1	10.7	7.3	21.4	37.0
50-year emissions per dwelling (kgCO2e)					
Clearing	11,512	13,784	15,130	572	-
Subdivision works	37,793	162,559	182,743	-	-
Planting	- 1,201	- 526	- 2,286	0	- 157
Built-form embodied	89,514	97,717	95,536	63,159	50,915
Built-form operational	126,293	143,578	168,982	118,939	161,534
Transport	227,480	254,445	236,771	123,266	102,884
Water	19,628	19,727	28,265	15,691	12,266
Total	**511,019**	**691,286**	**725,141**	**321,626**	**327,442**

[4] https://www.dcceew.gov.au/climate-change/publications/full-carbon-accounting-model-fullcam
[5] https://www.watercorporation.com.au/About-us/Our-performance/Annual-report

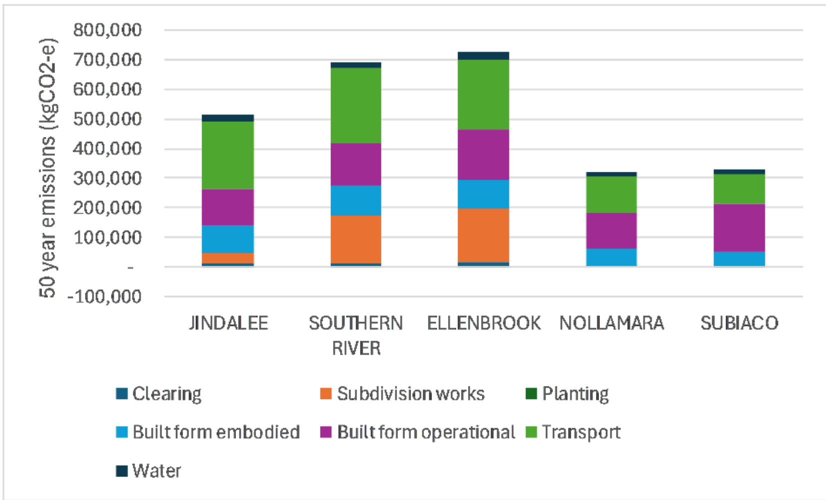


Figure 3 Cumulative 50-year precinct emissions per dwelling.

Western Australia's total emissions from all sources in 2020-21 were around 80,000 GgCO2e pa[6], equating to approximately 80,000 kgCO2e per dwelling or 4,000,000 kgCO2e per dwelling over 50 years.

Some key factors that give rise to the results are set out below.

3.4.1 Location

Vehicle emissions

The location of the precincts and the local availability of jobs and services determine the level of emissions from private vehicle transport.

Subdivision emissions

Location is also a factor in the emissions associated with greenfield subdivision construction. As new development has moved east in the Perth metropolitan area into locations with lower depth to groundwater and associated soil types, fill (and, in some cases, sub-soil drainage) is required.

Urban infill creates no additional emissions associated with subdivision works. However, it is noted that the redevelopment of Subiaco in some areas (e.g., the Australian Fine China site) would have required significant removal of contaminated soils, and there was also some provision of new/ upgraded service infrastructure, which is not captured in this analysis.

Operational emissions

Development nearer the coast will also lead to lower average summer air temperatures (see Figure 4). This will impact air conditioning energy/emissions, but it is impossible to disaggregate from the results reported here. The influence of stronger summer coastal sea breezes on the natural ventilation of houses can also not be identified.

[6] https://greenhouseaccounts.climatechange.gov.au/

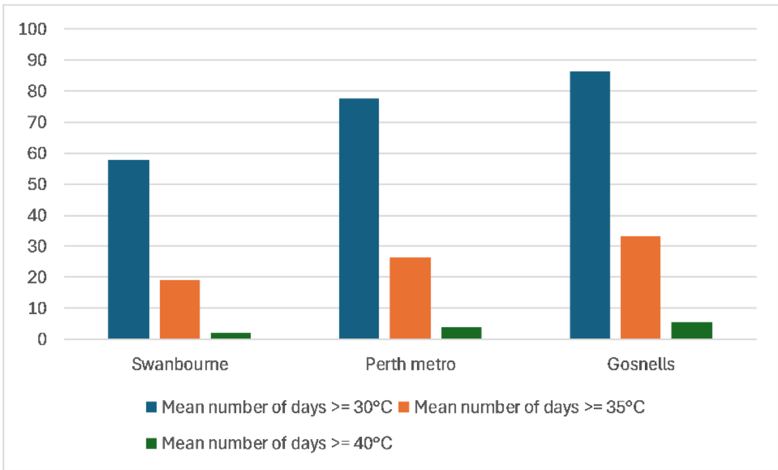


Figure 4 Locational summer temperature variations.

3.4.2 Urban and built-form

Dwelling size

The main effects of urban form identifiable from this analysis on emissions relate to the size of lots/dwellings. Irrespective of the built-form construction materials, the GFA has the most dominant impact on embodied and operational emissions.

Urban Heat Island

The analysis described in this report cannot account quantitatively for the impact of Urban Heat Island (UHI). However, it is noted that the similar urban form in Jindalee and Southern River, which have high site coverage (i.e. hard surfaces as a fraction of lot size) and low levels of tree canopy, will raise local temperatures and increase air-conditioning load/emissions.

Rooftop solar PV

All the precincts studied have a high penetration of rooftop solar, providing between 29 and 37% of the average dwelling's electricity. This has significantly reduced the average electricity consumption/emissions (see Figure 5).

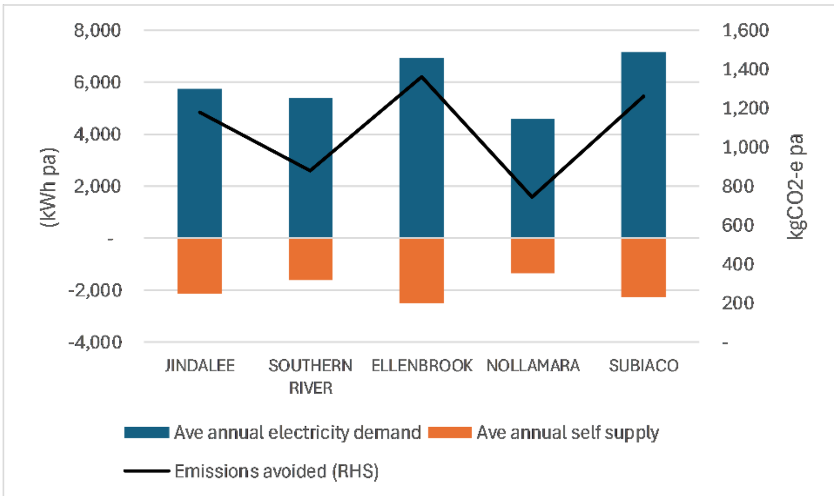


Figure 5 Impact of rooftop solar.

Form of construction

Nearly all houses sampled in each precinct were constructed with the same materials: concrete for floor slabs, cavity brick walls and steel or tile roofs. The apartment buildings in Subiaco are also concrete frame buildings[7]. Concrete, steel and brick are all high embodied energy materials that contribute significantly to the emissions in each precinct.

3.5 Key findings

The differences between the precinct emissions per dwelling can be summarised as follows.

3.5.1 Subdivision works

- The emissions from subdivision works in greenfield developments are a significant fraction of life-cycle emissions.
- Development in lower-lying areas (Southern River and Ellenbrook) leads to significantly higher emissions than the other greenfield precinct (Jindalee) due to the requirements for fill (and, in many cases, sub-soil drainage).
- The lack of subdivision works in background infill precincts such as Nollamara largely eliminates emissions associated with subdivision works.

3.5.2 Built-form embodied emissions

- The precincts with smaller built-form GFAs have lower embodied energy in the built-form.
- The background infill and Transit Oriented Development precincts have lower built-form embodied emissions than greenfield case study precincts.

3.5.3 Built-form operational emissions

- Higher-density areas, such as the Sub-Centro, can still have comparatively high operational emissions compared to the background infill (e.g., Nollamara) and greenfield precincts (e.g., Jindalee or Southern River).

3.5.4 Transport emissions (private cars)

- The private car emissions are roughly correlated with increasing distance to the Perth CBD for the precincts. Subiaco has the dual advantage of being close to the CBD and having access to public transport and local jobs and services, resulting in the lowest transport emissions.

3.5.5 Vegetation related emissions

- The relative impact of land clearing and landscaping on emissions, while important, is minor compared to other categories across the precincts.

3.5.6 Water and wastewater-related emissions

- The indirect emissions associated with water and wastewater are minor compared to other emissions sources. Nonetheless, the suburban precinct with larger lots (Ellenbrook) had higher water use than the compact suburb and infill precincts.

[7] Assumed, noting that the building permit samples for these buildings are yet to be obtained.

4. Phase 2 An urban energy and emissions model for evaluation of interventions – report summary

4.1 Scope

The purpose of the Phase 2 report was to evaluate the potential reductions in emissions from a range of interventions in predominately residential neighbourhoods. These interventions were identified through a literature review, demographic analysis and a workshop with the Department of Planning Lands and Heritage staff and the Accounting for Carbon working group. Subsequently, the impacts of the interventions were quantified and incorporated into a system dynamics model to calculate per-dwelling life-cycle emissions across our five precinct case studies. The greenfield case studies were retained from Phase 1 and included Jindalee, Southern River and Ellenbrook, and our infill case studies included Nollamara and Subiaco.

4.2 Identification of interventions

In this project phase, various interventions were devised in conjunction with the DPLH Working Group and applied to each case study site. The selected interventions reflect the significant emissions sources identified in Phase 1. The interventions were categorised as follows.

Table 3 Intervention categories[8]

Planning and design	*Interventions under the control of planning and design through the planning system and built-form controls*
Resident choice	*Decisions that consumers make about housing construction materials, home appliances, energy self-supply, transport modes and vehicles*
Other government policies and market forces	*Government policy and/or market evolution related to:* • *the energy efficiency of built-form and appliances;* • *decarbonisation of the South West Interconnected System (SWIS);* • *supply of natural gas to residential premises;* • *the embodied emissions in construction materials.*

The emissions associated with the interventions were calculated and reported for each 're-imagined' case study site.

The identification of interventions was derived from numerous sources, including those proposed in:

- policy literature;
- planning literature, and
- a workshop with Department of Planning Lands and Heritage staff and project working group members.

Table 4 illustrates the intersection of the interventions with each emission source.

[8] The authors note the overlap between these categories, for instance, some resident choices may be influenced by policy.

Table 4 Identification of interventions

	Sub-division works	*Built-form emissions*		*Transport emissions*			*Water supply*		*Vegetation*	
Intervention	*Construction works and materials*	*Embodied*	*Operational*	*Private vehicles*	*Public transport*	*Construction vehicle*	*Water-related emissions*	*Wastewater*	*Land clearing*	*Plantings*
Location of greenfield development	*P*			*P*	*P*	*P*			*P*	
Urban layout for greenfield precincts		*P*	*P*	*P*	*P*		*P*		*P*	*P*
Urban layout for infill precincts		*P*	*P*						*P*	*P*
Built-form – operational emissions		*P*	*P*							*P*
Built-form – embodied emissions		*P*								

The potential interventions are set out by category in Figure 6.

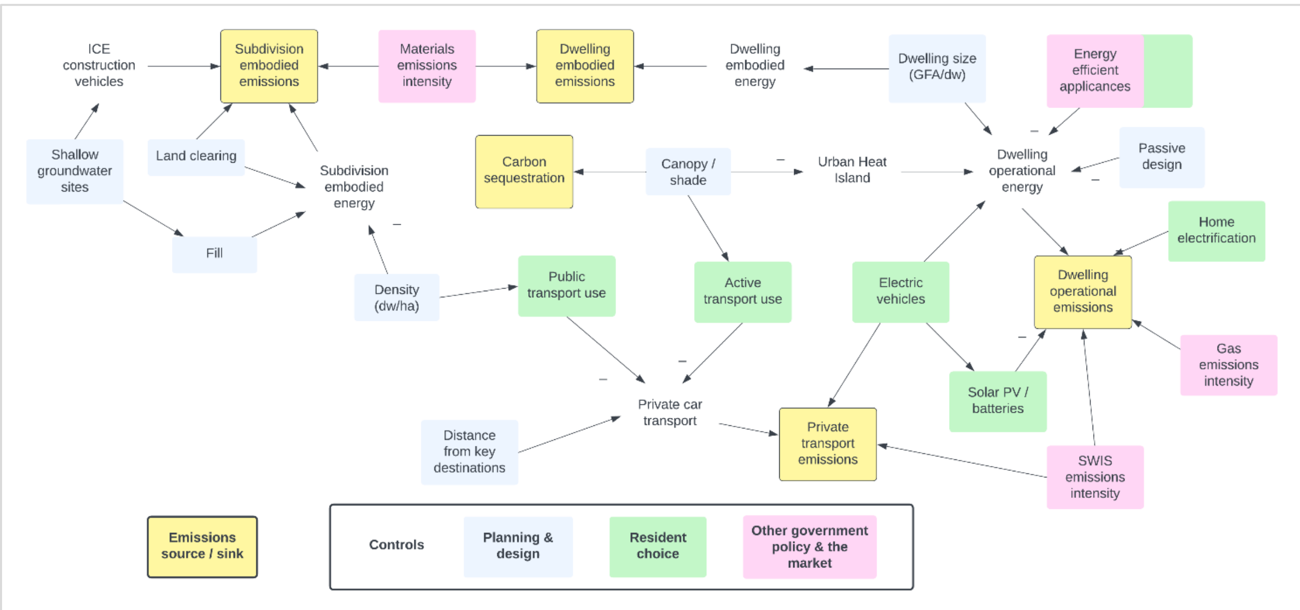


Figure 6 Intervention categories

4.2.1 Design intervention workshop

A design intervention workshop was conducted on 25.05.24 with 13 Department of Planning Lands and Heritage staff members and the Accounting for Carbon working group members. Five groups were allocated one of the Phase 1 precinct case studies and asked to rate different precinct configurations, street layouts, building types and open space structures for their potential to reduce energy use/ carbon emissions (Table 5). Blank cells mean the spatial attribute was irrelevant to the group's allocated case study. Low scores indicate likely reduced emissions. The authors note that the poor ranking of particular building types likely reflects also how and where they are generally built – both of which could be addressed through planning and design strategies.

There was consensus across the groups that a Transit Oriented Corridor Development (e.g. density along a corridor) precinct configuration would result in the lowest energy/ carbon emissions followed by Transit Oriented Node Development (e.g. density around a node).

There was a relative consensus that a Grid (150-250m street interval) street layout would result in the lowest energy/ carbon emissions followed by a Tight grid (150m street interval) or Super blocks (250m+ street interval).

There was general agreement that Perimeter block (2-6 storeys) building types would result in the lowest energy/ carbon emissions, followed by Slab (5-8 storeys, single loaded), Row house/ terrace (2-3 storey) and Semidetached (1-2 storey). Both Detached (1 storey) and Tower (> 10 storeys, double-loaded) rated very poorly, reflecting general support of medium-density building types.

In summary, the workshop participants favoured neighbourhood designs that delivered medium density 2-8 storey building forms, with density focussed along public transport routes, on a grid with a ~200m interval and serviced by linear parks or a single large park.

Table 5 shows the results of the design intervention workshop.

Spatial attribute	**Group 1 rating**	**Group 2 rating**	**Group 3 rating**	**Group 4 rating**	**Group 5 rating**	**Total rating**
Allocated case study	Jindalee	Ellenbrook	Nollamara	Subiaco	Gosnells	All
Precinct configuration						
Transit Oriented Development (e.g. density around a node)	1		2	1	3	7
Transit Oriented Development (e.g. density along a corridor)	3	1	1			5
Greenspace Oriented Development (e.g. density around a park)	4	1	4	2	1	12
Distributed density (e.g. apartments distributed in a low-density setting)	5		5	3	2	15
Background infill (e.g. Battle-axe subdivision)	6		3	4		13
Street layout						
Super blocks (250m+ street interval)	3			3		6
Grid (150-250m street interval)	2				1	3
Tight grid (150m street interval)	4			1		5
Elongated grid (varies)	5	1		2	3	11
Organic (varies)	6	2			2	10
Building types						
Detached (1 storey)	8		3	7	7	25
Semidetached (1-2 storey)	7		4		6	17
Courtyard house (1 storey)	3		5	6	5	19
Row house/ terrace (2-3 storey)	2	2	2	5	3	14
Perimeter block (2-6 storeys)	1		1	3	2	7
Slab (5-8 storeys, single loaded)	4		6	2	1	13
Slab (5-10 storeys, double loaded)	5	2	7	4	4	22
Tower (>10 storeys, double loaded)	6	2	8	1	8	25
Open space structure						
Single large park (e.g. Hyde Park)	3	1	2	1	2	9
Distributed small parks (e.g. Butler)	2	3	1	3	3	12
Linear park (e.g. Wungong)	1	1	3	2	1	8

4.2.2 Literature review

The review comprised studies of relevant literature related to a range of topics, namely:

- Urban design and planning for low-carbon neighbourhoods (e.g. New Urbanism, Green Urbanism and Climate Sensitive Urban Design);
- Development site works;
- Housing form and construction;
- Residential energy self-supply (i.e. solar PV and batteries) and
- Transition to electric vehicles (EV) and fuel efficiency in internal combustion engine vehicles (ICEV).

4.2.3 Data analysis

Data was collected from available sources, including via the literature review. Western Power provided additional data on residential electricity demand for the case study sites. The likely trajectory of emissions intensity for each of the emission sources was determined through this analysis.

4.2.4 Systems modelling

A system dynamics model of energy and emissions for each of the case study sites was developed to facilitate the evaluation of the impact of various interventions and their combination on lifecycle emissions.

4.3 The literature on low-carbon neighbourhoods

To confirm the results of the design intervention workshop, we subsequently conducted a literature review to understand which design interventions would potentially reduce energy use and emissions. The literature review related to prevailing theories such as Green Urbanism (Lehmann, 2010), New Urbanism (Congress of New Urbanism, 2016) and Climate Sensitive Urban Design (Lenzholzer, 2015) and relevant policy literature such as the WA Precinct Design Guide (Department of Planning Lands and Heritage, 2019).

4.3.1 Precinct configurations

There is a consensus in the New Urbanism and Green Urbanism literature that higher building densities and a diversity of land uses should be within walking distance of transit stops, referred to as Transit Oriented Development (TOD). Indeed, many activities of daily living should occur within walking distance, allowing independence to those who do not drive, especially the elderly and the young (Congress of New Urbanism, 2016). The literature on TOD proposes that:

- Increasing the density of the neighbourhood population around transit nodes will support improved public transit services, make transit a viable alternative to automobiles, and reduce transport emissions (Congress of New Urbanism, 2016).
- The denser a city, the less its residents drive, and the more they will walk and bike, a critical component to lessening oil dependence and reducing transport-related emissions (Newman, Beatley, & Boyer, 2009) which was found to be one of the largest precinct related emissions sources.
- Dense mixed-use urban development (e.g., including housing, retail or office space) can support district energy systems (central plants producing hot water, steam, and/or chilled water which flows through to dwellings), reducing carbon generation by 30% and energy consumption by as much as 50% (Farr, 2008).

Emerging alternatives to TOD include Greenspace-Oriented Development (GOD). While TOD correlates urban densification with mass transit hubs, GOD correlates urban densification with significant, upgraded parks within a 5-minute cycle or 15-minute walk of public transport in middle-ring suburbs.

4.3.2 Street layouts

There is a consensus in the New Urbanism and Green Urbanism literature that interconnected networks of streets should be designed to encourage walking, reduce the number and length of car trips, and conserve energy (Congress of New Urbanism, 2016). Related policy literature also suggests that street and block layouts should support an active transport network (Department of Planning Lands and Heritage, 2019).

Climate Sensitive Urban Design (CSUD) theory proposes that streets should:

- Frame East-West running lots to enable east-west oriented rectangular-shaped buildings to minimize direct solar radiation (the bulk of solar radiation is intercepted by the east and west walls and roof of a building) (Oke, Mills, Christen, & Voogt, 2017).
- Enable buildings parallel or up to 30 degrees to the prevailing wind direction to maximise the penetration of prevailing wind through a district (Kusumastuty, Poerbo, & Koerniawan, 2018). CSUD theory also ventures that widening streets along the prevailing wind direction is highly effective in increasing ventilation (Kusumastuty et al., 2018). T

4.3.3 Built-form

A consensus exists that sustainable urbanism is not achievable at low densities (Farr, 2008). As such, New Urbanism theory proposes that a broad range of housing types should be provided within neighbourhoods (Congress of New Urbanism, 2016).

Green Urbanism and Climate Sensitive Urban Design theories affirm the importance of passive design (solar architecture) in producing low-energy, zero-emission designs and dramatically reducing reliance on mechanical cooling and subsequent building operation energy use (Lehmann, 2010).

Green Urbanism theory suggests that built-form should be constructed using regional materials and lightweight prefabricated systems, e.g., regional timber, to achieve shorter supply chains and reduce embodied emissions (Lehmann, 2010).

4.3.4 Open space structures

The different theories tend to prioritise different open-space structures. New Urbanism prioritises smaller yet accessible neighbourhood parks (Bolleter, 2017), while Climate Sensitive Urban Design approaches favour the creation of larger parks, which can generate substantial park cool island effects (Lenzholzer, 2015). Finally, Water Sensitive Urban Design approaches prioritise linear parkland along drainage networks.

4.3.5 Literature summary

A high degree of alignment exists between the findings from the interventions workshop and the academic and policy literature about the type of urban form that should deliver energy and emissions reductions. This form constitutes compact urban development (comprising a wide diversity of building types and land uses) arranged around transit (in a nodal or corridor form), structured by a fine interconnecting street grid. The built-form should be responsive to climate, appropriately oriented and ventilated, and allow enough site area to sustain mature trees. While there was consensus on the importance of green infrastructure, there was less consensus on the appropriateness of different open-space structures, as these differed by theory.

4.4 The size and type of dwellings

Demographic analysis should also underpin planning for low-carbon neighbourhoods. Australia has the world's largest housing sizes per occupant Figure 7, and new dwellings have become much larger over recent decades. The average size of new dwellings in Australia is 214m² (Figure 8), while separate houses nearing 250m² on average have come to dominate the Western Australia new dwellings market. At the same time, the average number of occupants in Australian households has been dropping steadily for many years. From 1990 to 2001, the number dropped from 2.8 to 2.6 people across Australia; the figures are similar for Perth, according to the 2021 ABS Census. The 2021 census reports some 560,000 empty bedrooms in Western Australia.

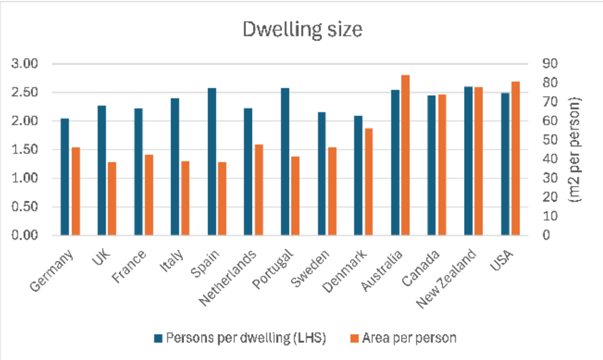


Figure 7 Dwelling size - various countries

(Source: https://worldpopulationreview.com/country-rankings/house-size-by-country)

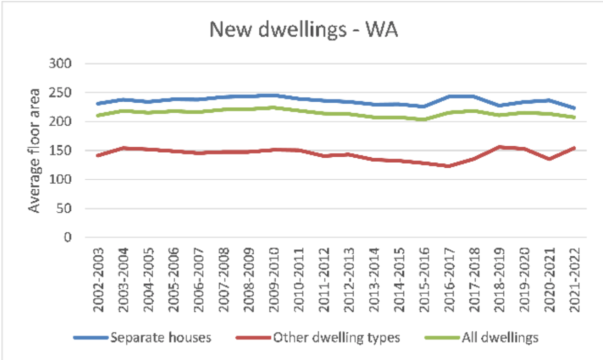


Figure 8 New dwellings – WA

(Source: Australian Bureau of Statistics, Average Floor Area of New Residential Dwellings 12/04/2023)

The 2021 Census for Greater Perth reveals that most dwellings (over 70%) are separate houses, and 40% of those separate houses have only one or two occupants (Figure 9 and Figure 10).

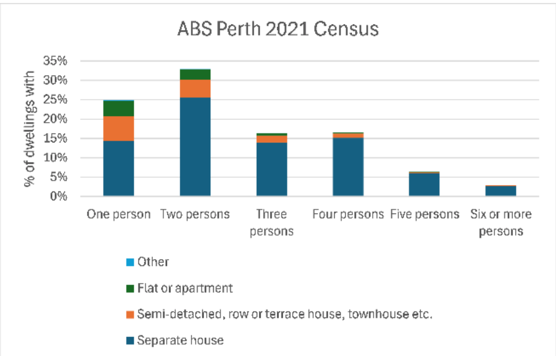


Figure 9 Perth housing mix by occupancy

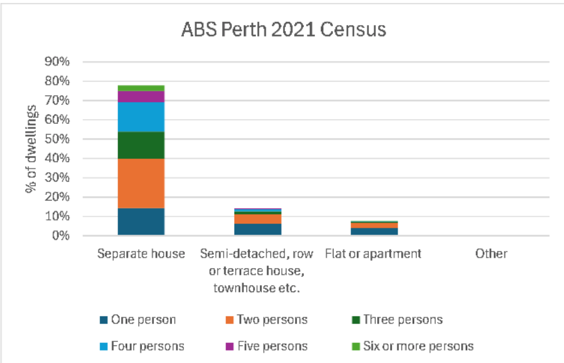


Figure 10 Perth housing mix by dwelling type

As expected, the number of persons per dwelling is slightly higher in the newer greenfield suburbs than elsewhere, but even in those suburbs, 80% of dwellings have four or fewer occupants (see Figure 11).

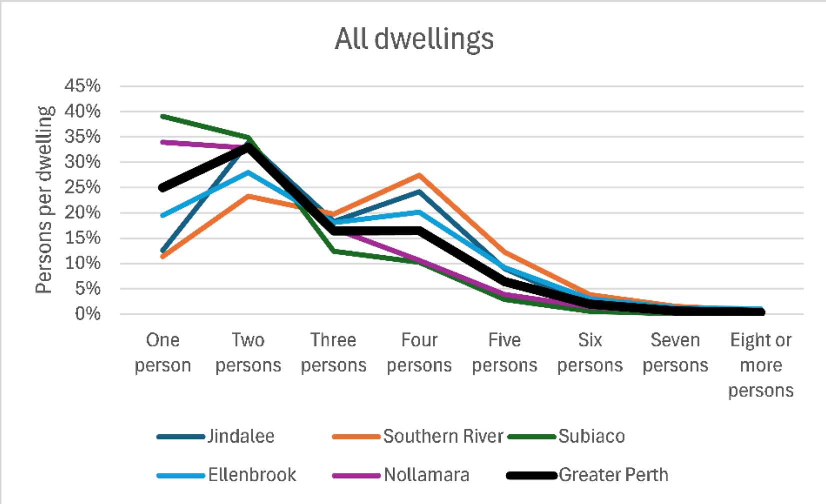


Figure 11 Dwelling occupancy in the case study sites

Dwelling size is by far the largest leverage point concerning reducing greenhouse gas emissions in residential neighbourhoods, and there are many other potential benefits to reducing the size of dwellings. Not only do smaller dwellings (on average) lead directly to:

- Lower embodied emissions, lower operational emissions, more private open space (and more canopy);
- More dwellings per ha of developed land; lower land development costs per dwelling; lower pressure on greenfield sprawl; lower costs per dwelling (benefitting affordability); more dwelling completions per year (benefitting supply); and other density benefits such as improved public transport services.

Irrespective of the form of housing, reducing the size of dwellings to match the actual demographics of the population better will assist in yielding these benefits.

The prevalence of separate (and large) houses on individual green title lots is a major contributor to the urban sprawl in Perth. As noted in the Phase 1 report, the energy associated with sub-division works significantly contributes to life cycle emissions per dwelling basis. Europe has a much more balanced mix of dwelling types (Appolloni & D'alessandro, 2021) (see Figure 12). While there is undoubtedly an underlying market preference for separate houses, considering realities such as current housing costs, many people will happily consider more compact typologies (e.g. row housing) (Kelly, Weldmann, & Walsh, 2011, p. 2). Moreover, a larger proportion of alternative housing forms would substantially reduce the size of lots per person. It is often assumed that this means apartments. However, alternative building types like semi-detached and row housing and townhouses offer density benefits.

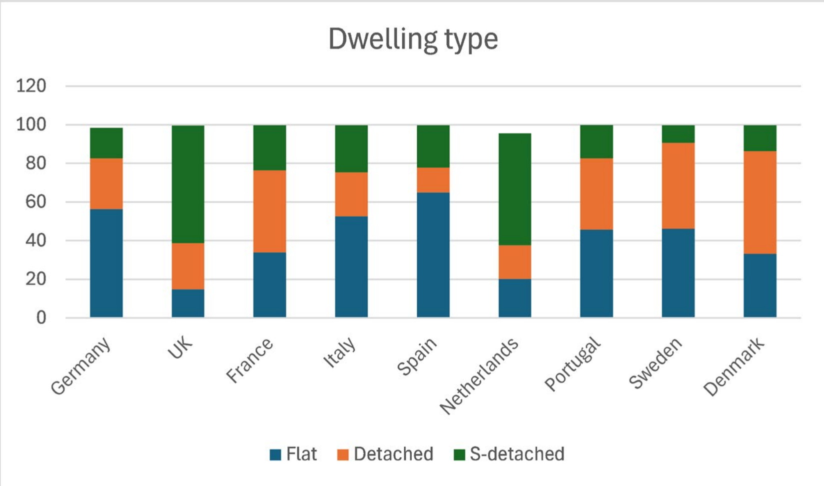


Figure 12 Dwelling mix in European countries.

Table 6 and Figure 13 set out the size and type of dwellings that reflect Perth's demographics and achieve higher density, and they are the basis for the case study interventions considered in the following section.

Table 6 Revised dwelling types and sizes

	One person	*Two persons*	*Three persons*	*Four persons*	*Five persons*	*Six persons*
Persons/dwelling	*25%*	*33%*	*16%*	*16%*	*6%*	*3%*
Separate houses	*5%*	*10%*	*30%*	*50%*	*80%*	*100%*
Semi-detached	*10%*	*10%*	*20%*	*30%*	*20%*	
Row	*15%*	*20%*	*15%*	*20%*		
Town	*20%*	*20%*	*10%*			
Three storey apt	*30%*	*20%*	*15%*			
Four storey apt	*20%*	*20%*	*10%*			
	100%	*100%*	*100%*	*100%*	*100%*	*100%*
Net floor area (m2)	*105*	*120*	*150*	*170*	*190*	*200*
NFA / person	*105*	*60*	*50*	*43*	*38*	*33*

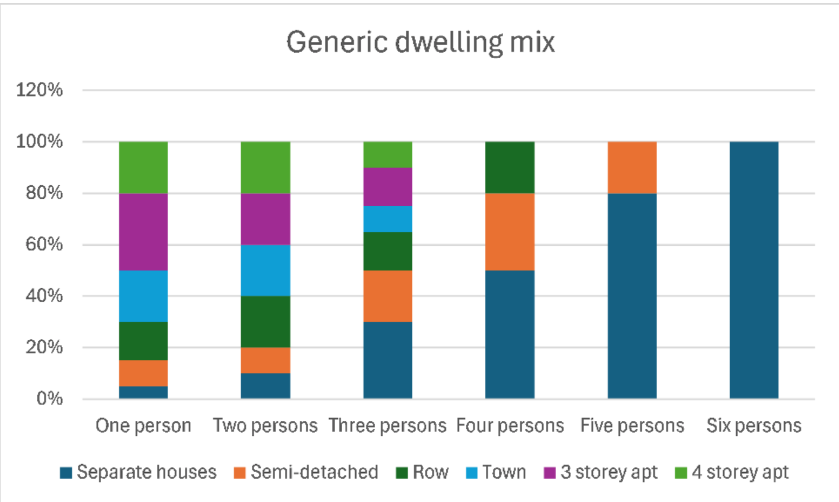


Figure 13 Revised generic dwelling mix

4.5 Description of interventions

4.5.1 Urban form and structure

A summary of the interventions applied to each case study site is included in Table 7 and Figure 14 - Figure 23.

Table 7 Summary of case study site interventions

Subdivision works	• *Increased urban density reduces the area of required land clearing and site works (embodied emissions). [Jindalee, Southern River & Ellenbrook]* • *Site graded so that stormwater collects in Living Streams or subsoil drains behind dwellings to reduce fill requirements on private lots (embodied emissions). [Southern River & Ellenbrook]*
Precinct configuration	• *Urban density increases adjacent to transit to encourage patronage (transport emissions). [Jindalee, Nollamara,]* • *High urban density adjacent to transit to encourage patronage (transport emissions) [SubiCentro]* • *Urban density increases adjacent to significant parks and related cooling effects (operational emissions). [Ellenbrook]*
Streets	• *Pedestrianised road environments encourage active transport (transport emissions)* • *Swales collect stormwater off roads and increase evapotranspiration cooling (operational emissions).* • *Reinforced turf paving in shared zones provides evaporative cooling (operational emissions);* • *Light emulsions on road surfaces reduce UHI (operational emissions) and* • *N-S-oriented tree lines reduce the heat load on E-W house faces (operational emissions).*
Built-form	• *A modest GFA results in emission reductions associated with construction (embodied emissions);* • *Light-coloured roofs and walls reflect heat and reduce heat load (operational emissions);* • *Living areas facing north reduces mechanical cooling/ heating requirements (operational emissions);* • *Upstairs bedrooms purge heat at night (operational emissions);* • *A diversity of housing (detached, duplex, row housing and apartments) provides efficient living options for small households (embodied emissions) and* • *Lightweight construction materials result in emission reductions (embodied emissions).*
Open space system	• *Linear open spaces allow the enhancing of natural water courses (embodied emissions) [Southern River]* • *N-S running linear open space system and accompanying tree lines reduce the heat load on E-W house faces (operational emissions) [Jindalee and Southern River]* • *Urban density arranged around parks and related cooling effects to reduce reliance on mechanical (operational emissions). [Ellenbrook]* • *Deep soil zones in linear open spaces allow for substantial trees and related urban cooling (operational emissions). [SubiCentro]*

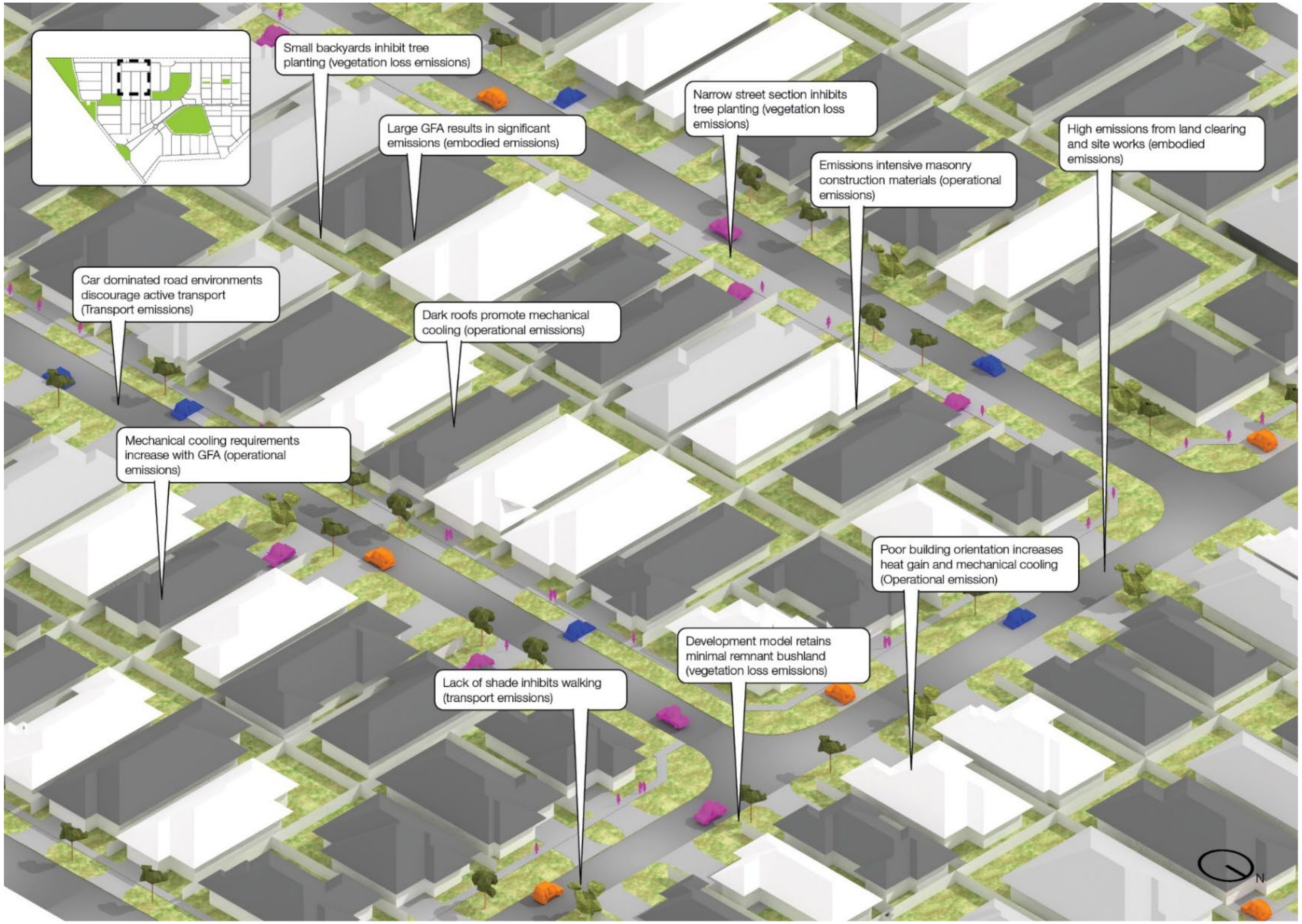


Figure 14: Jindalee study site 1- existing.

The Jindalee study site 1 is characterised by largely undifferentiated compact suburban fabric with large houses on medium-sized lots and minimal tree canopy coverage.

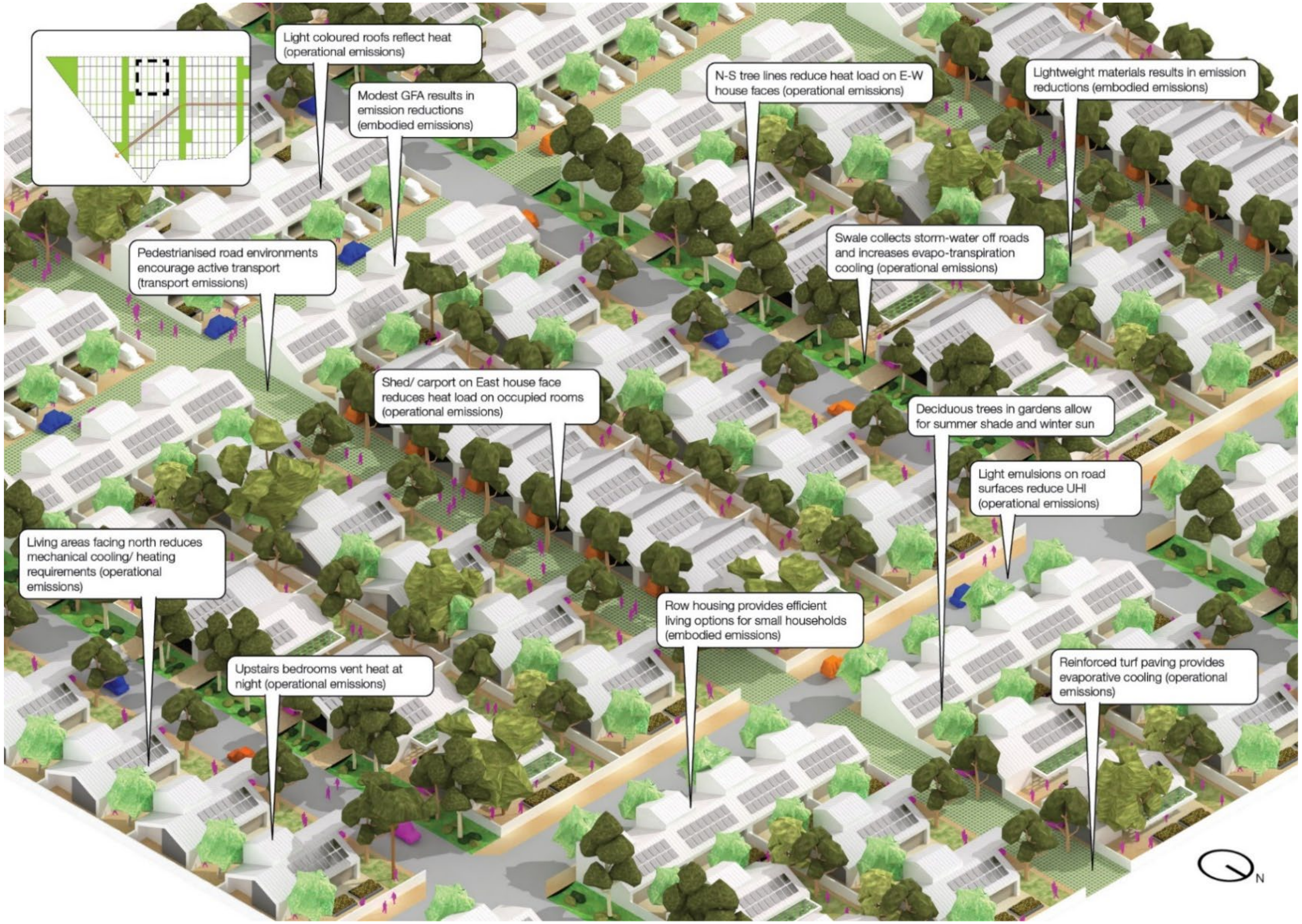


Figure 15: Jindalee study site 1- proposed.

The vision is for a more compact, climate-responsive, well-forested suburban fabric. The predominant built-form in the Jindalee study site 1 comprises detached housing, row housing and duplex housing.

Figure 16: Jindalee study site 2- existing.

While laneway-serviced small lots have been allocated along Reflection Boulevarde (pictured), there has been little increase in density or land use diversity per Transit Oriented development models.

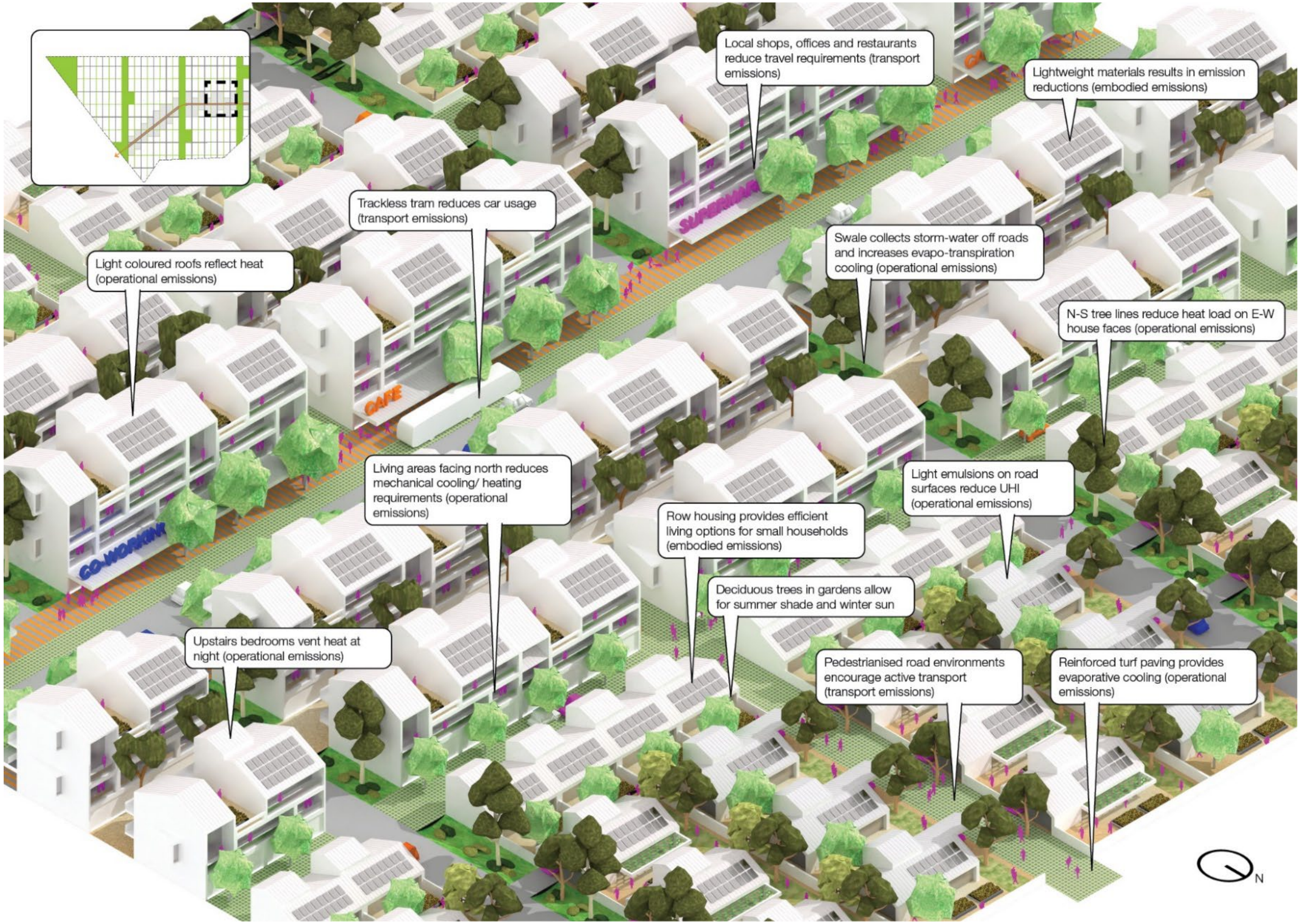


Figure 17: Jindalee study site 2- proposed.

The vision is for a generally more compact, climate-responsive and well-forested suburban fabric, which increases density along Reflection Boulevarde's central spine. The predominant built-form in the Jindalee study site 2 comprises detached housing, row housing and 3-4 storey apartment buildings.

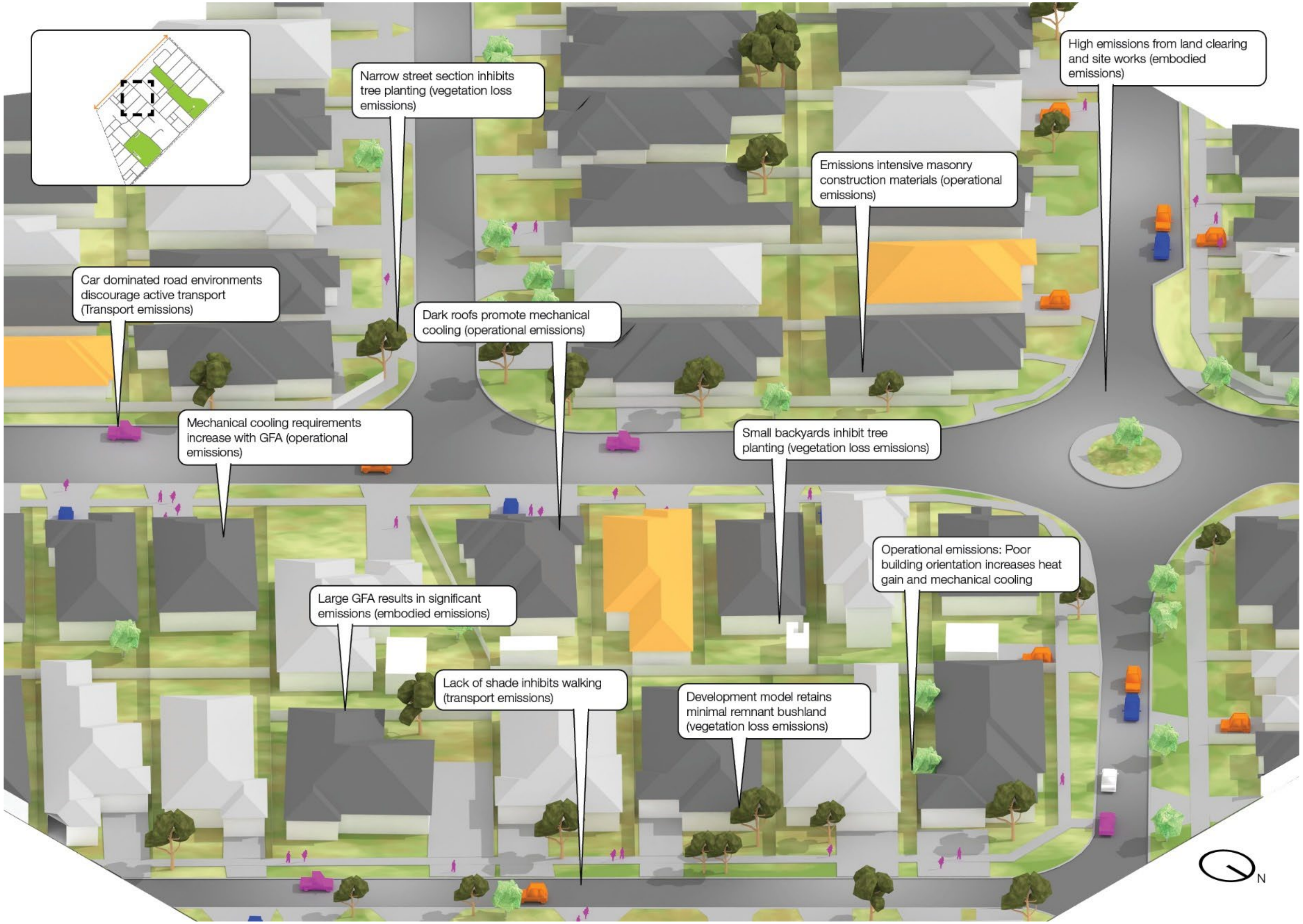


Figure 18: Southern River study site 1.

The site is characterised by largely undifferentiated suburban fabric with large houses on small-sized lots and minimal tree canopy coverage.

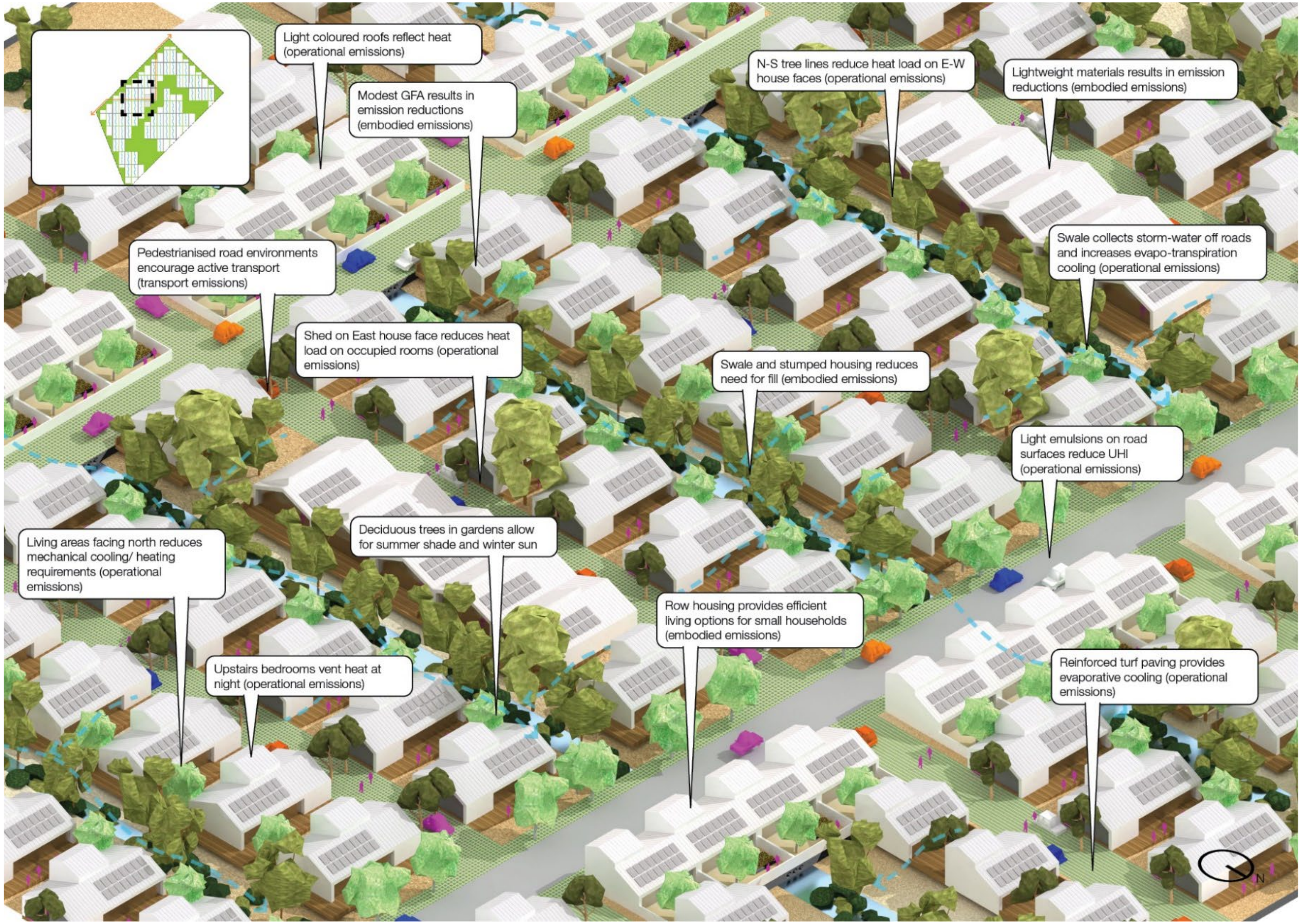


Figure 19: Southern River study site 1- proposed.

The vision is for a generally more compact, climate-responsive, well-forested suburban fabric that requires less fill by draining towards Living Streams (or subsoil drains) at the back of lots. The predominant built-form in the Southern River study site 1 comprises detached and row housing.

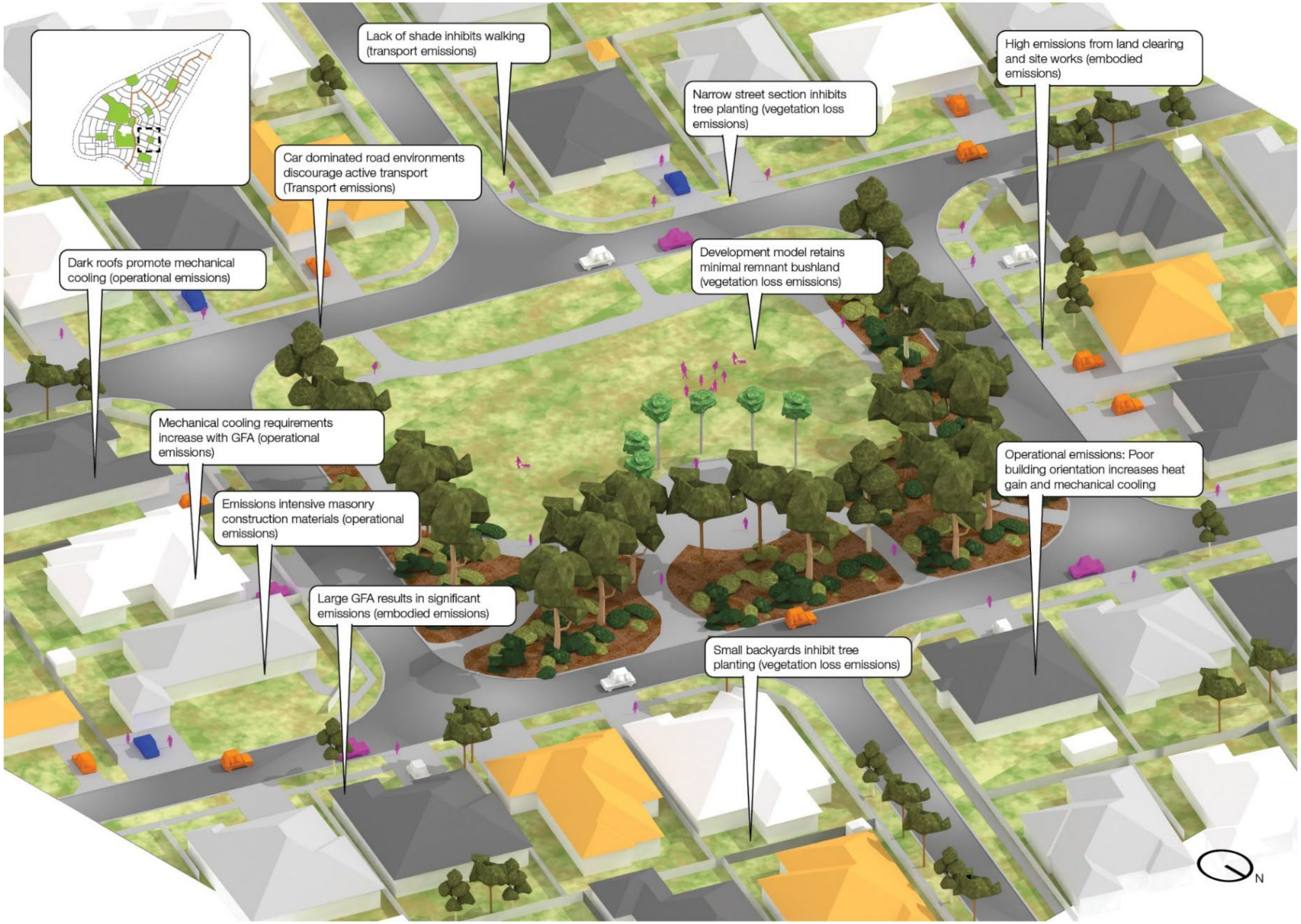


Figure 20: Ellenbrook study site 1- existing.

The Ellenbrook study area 1 is characterised by largely undifferentiated suburban fabric with large houses on medium to large size lots and no urban density increase around park amenity.

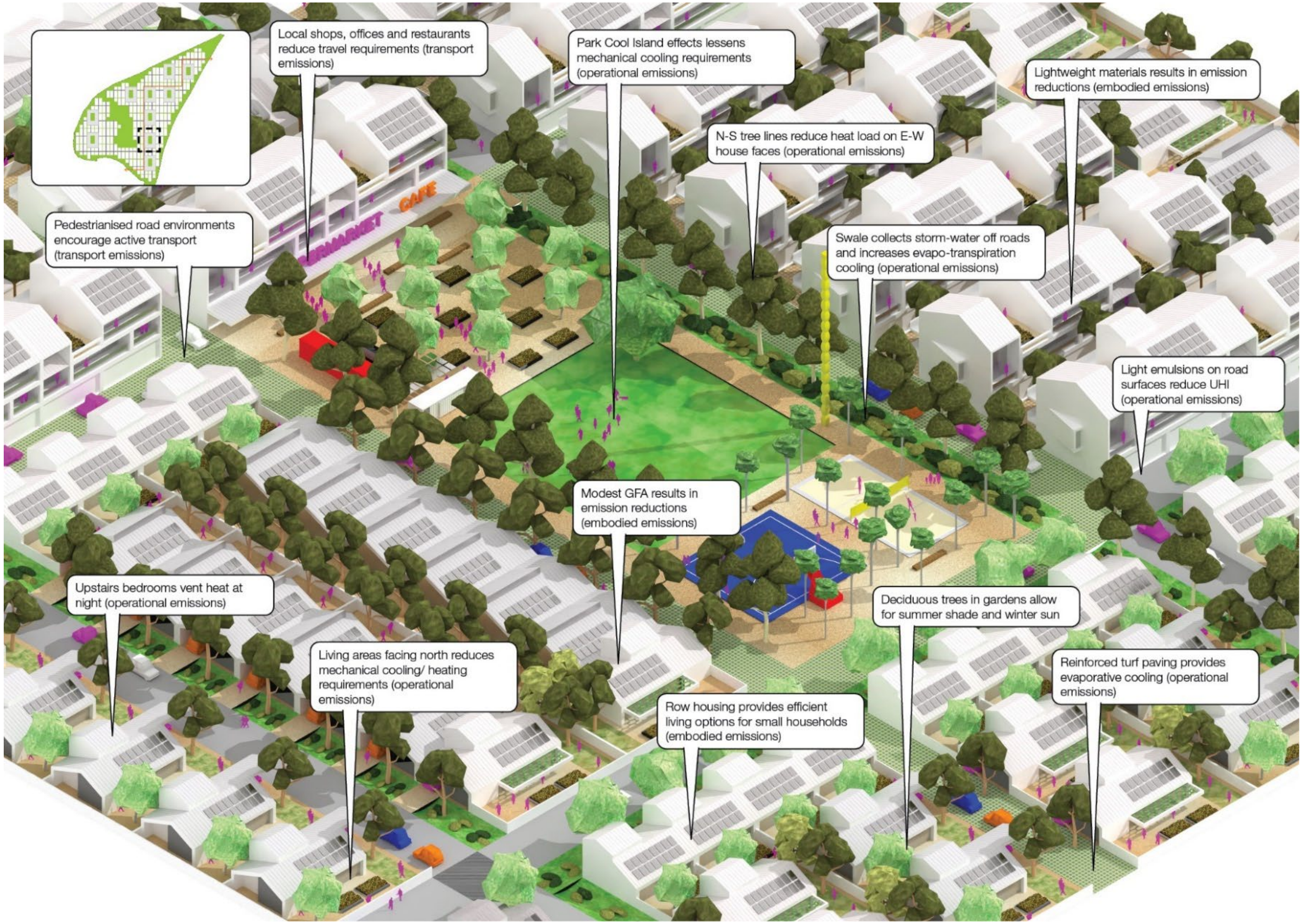


Figure 21: Ellenbrook study site 1- proposed.

The vision is for a generally more compact, climate-responsive, and well-forested suburban fabric that increases significantly in density around parks. The predominant built-form comprises detached housing, row housing, duplex housing and 2-3-storey apartment buildings.

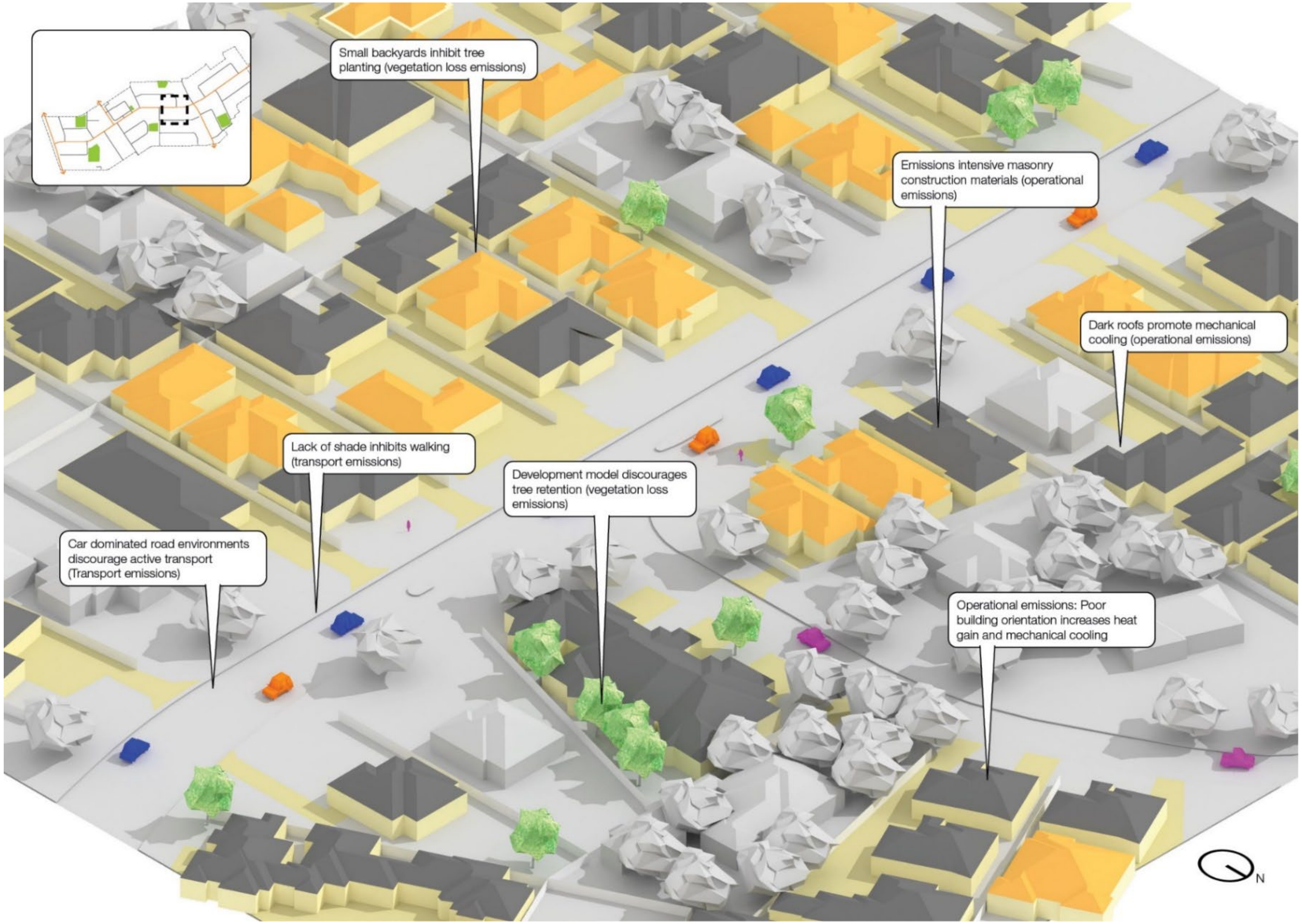


Figure 22: Nollamara study site 2- existing.

No negligible increase in urban density occurs along the central spine of the case study, Nollamara Avenue.

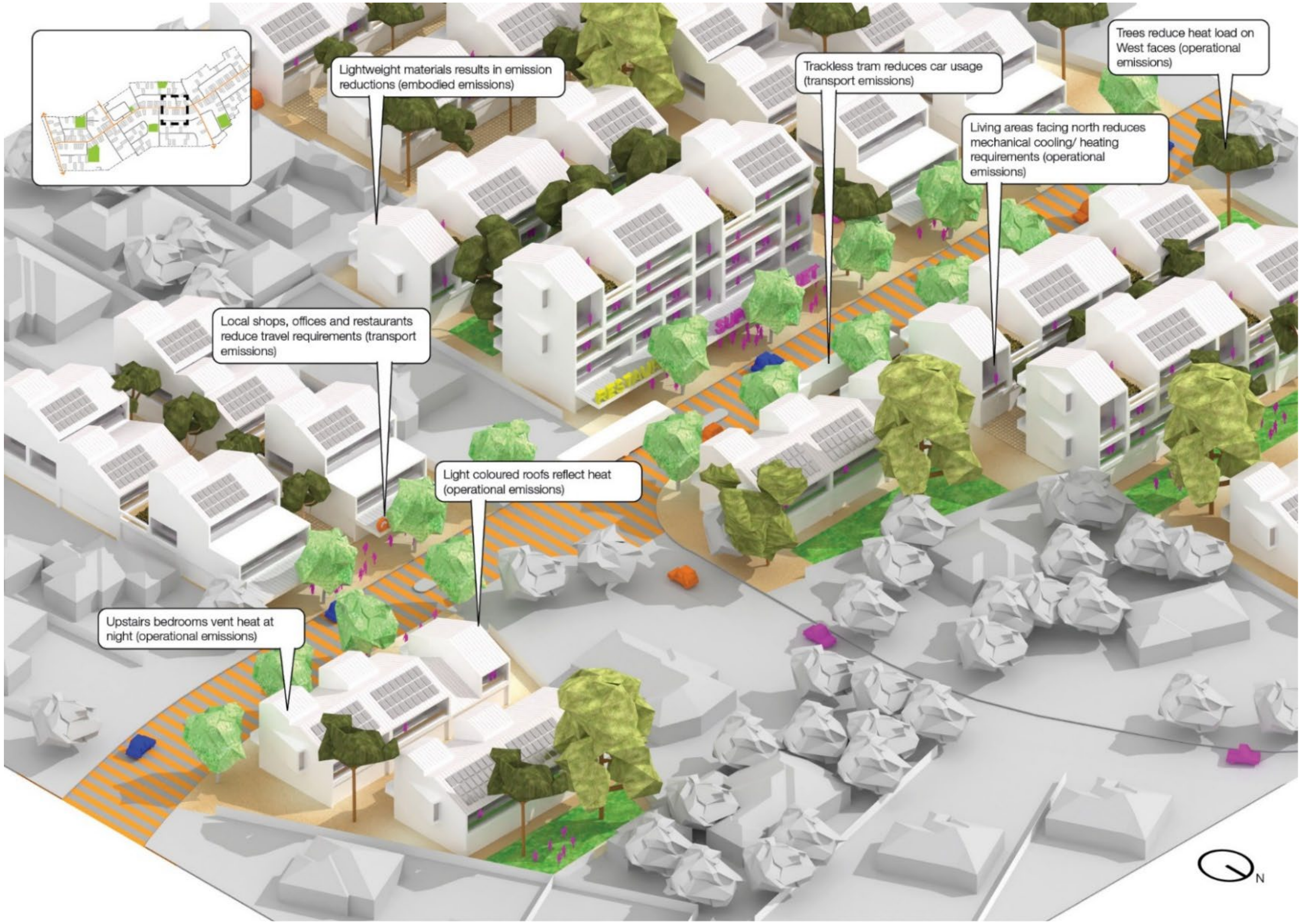


Figure 23: Nollamara study site 2- proposed.

The vision is to significantly increase density along the central spine of Nollamara Avenue. The predominant built-form along Nollamara Avenue comprises 2 -4-storey apartment buildings.

4.5.2 Subdivision works

Clearing

Clearing of the sites, while detrimental to biodiversity, was not identified as a significant contributor to emissions in the Phase 1 report, representing only around 2% of lifecycle emissions per dwelling in the greenfield sites. In this research, it was assumed that the same amount of clearing occurs per ha of development.

Planting

Similarly, the sequestration of CO_2 from landscaping planting had only a small influence on the Phase 1 results and was assumed to be the same on a per-ha of development basis. The likely real mitigation benefit of the proposed urban design measures will be to reduce the urban heat island effect and potentially reduce summer air-conditioning loads. This benefit is complex to quantify and has not been considered in this phase of work.

Site establishment

The Phase 1 report identified that subdivision works on shallow groundwater locations such as Southern River and Ellenbrook significantly contributed to emissions (25% of lifecycle). This is attributed to the conventional approach to development in these sites, which comprise large quantities of fill, which are transported by heavy haul vehicles from offsite quarries and compacted using diesel-fuelled construction equipment.

This study assumes that lots are separated by living streams or landscaped drains to avoid subsoil drains on private land. Based on further analysis of the Cerclos report used to determine subdivision emissions in Phase 1, it is estimated that emissions from the site formation component could be halved, leading to a reduction of overall emissions per ha by 36%.

For this research element, it was assumed that this is an option for the case study sites at Southern River and Ellenbrook, while the Phase 1 calculations for the other sites have been retained. For the infill sites at Nollamara and SubiCentro, the Phase 1 report assumed negligible subdivision works. In this research phase, it was assumed[9] that subdivision works would lead to 20% of the emissions arising from the Jindalee site.

The research identifies that emissions associated with larger construction vehicles are likely to reduce only marginally over the coming decades.

4.5.3 Built-form

Materials intensity

The Phase 1 report identified that most new housing construction involves concrete floor slabs, double brick external walls and either steel or tile roofing. Recent research by Curtin University (Hopkins et al., 2024) identifies concrete as the most significant category in terms of annual material inflows for building stock in Greater Perth at 5.6 Mt (53.8%).

[9] No information was available to identify subdivision related emissions in Phase 1. They would have likely been negligible for Nollamara where most work was undertaken within lots. Because, these emissions, and those for Subiaco were not represented in the Phase 1 work an arbitrary value was assumed for this report.

In this research phase, the emission intensity of alternative forms of construction was determined by analysing them using the eTool LCA software. A detailed description of the analysis is provided in the appendices.

Adopting lightweight envelope construction for housing, as described in Table 8, would significantly reduce embodied emissions (assuming existing emissions intensities), as illustrated in Figure 24.

Table 8 Built-form embodied energy - houses

	Ground floor slab	Upper floor	External walls	Roof
Baseline	*Concrete Slab, 100mm, 30MPa, 3.8% reo (m2) (AFC)*	*Poured Concrete - Upper Floors 1.5% Reinforced (AFC)*	*Masonry Wall - Double Brick*	*Roof – TimberTruss / SteelSheeting / 25°Pitch*
Australian average[10]	*Waffle Pod Slab, 30MPa, Stable Soils, 1.0% Reo*	*Poured Concrete - Upper Floors 1.5% Reinforced*	*Brick Veneer Steel Frame plbrd 150mm EPS insulation*	*Roof – TimberTruss / Steel Sheeting/ 25°Pitch*
Lightweight	*Poured Concrete - Lowest Floor, 30MPa, 40% GGBS/BFS (m3)*	*Floor, Superstructure, 140mm Elevated Timber Framed Upper Floor (m2)*	*Timber Clad Timber Frame External Wall*	*Roof - 115mm Timber Structural Insulated Panel (SIP), Timber Framed, EPS core*

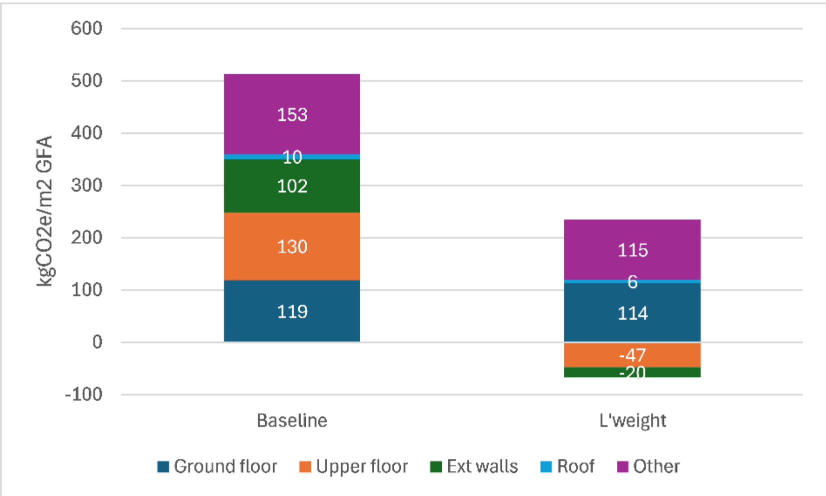


Figure 24 Embodied energy for baseline vs lightweight constructed houses.

The LCA assumes that all timber is 'sustainable', i.e., sourced from plantations that sequester carbon while growing, and that carbon is then immobilised in built-form.

Concrete and steel structural elements presently dominate the construction of apartments, while internal elements and finishes are similar to housing. For this study, we have relied on a detailed LCA of multi-storey timber residential buildings from the journal Energy & Buildings ((Lukić, Premrov, Passer, & Leskovar, 2021). This source reports that embodied emissions on a per m^2 basis could be reduced by around 40% to 342 kgCO2e/m^2. This value was assumed for lightweight apartment construction.

[10] Obtained from https://ahd.csiro.au/dashboards/construction/construction-overview/

4.5.4 Operational energy use

The Phase 1 report identified that actual operational electricity use in residential housing is much higher than would be predicted by reference to current code compliance. Analysis of additional data received from Western Power for the specific typologies studied in the Phase 1 report (which represented suburb-level data) was similar to or higher than previously reported. For this research phase, we have blended that data to produce an electricity demand based purely on a per m^2 GFA basis. The demand calculation includes an assessment of the self-supply of electricity from private rooftop solar PV (see Sect 4.5.7 below). The previously obtained data from ATCO was used to determine the demand for natural gas. The adopted assumptions for existing electricity and gas demand for electric-only and electric-plus-gas dwellings are illustrated in Figure 25 and Figure 26.

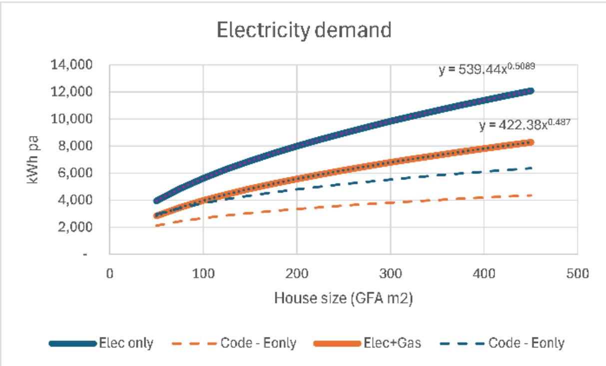


Figure 25 Electricity demand

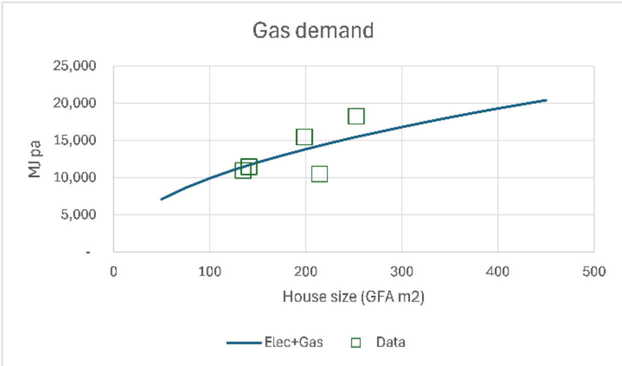


Figure 26 Natural gas demand

The data in the Phase 1 report identifies that electricity use is around 50% higher in summer than in winter, which can be attributed to cooling loads. Application of the NCC thermal load equations for Perth suggests that cooling loads overall are around 20-30% higher than heating loads.

Natural gas demand was assumed to be as identified in the Phase 1 report for houses retaining electricity and gas supplies (10-13 GJ/dwelling depending on dwelling size), consistent with the Residential Baseline Study[11] (RBS) report. The emissions intensity of natural gas was assumed to decline by around 10% by 2050 on the basis that the network will combine that quantity of hydrogen by then.

4.5.5 Energy efficiency

The RBS study includes overall energy efficiency projections, including appliances, lighting, and space conditioning, which have been adopted here. The RBS assumed reductions of 17% of appliance electricity consumption per dwelling between 2020 and 2040.

4.5.6 Electrification

The Phase 1 report identifies from Western Power and ATCO data that, on average, around 80% of dwellings have a combined electricity and natural gas supply, although the figure is lower for apartments. The Phase 2 report assumes a slower transition with 80% electrification of homes by 2050.

[11] https://www.energyrating.gov.au/industry-information/publications/report-2021-residential-baseline-study-australia-and-new-zealand-2000-2040

4.5.7 Electricity self-supply

The Phase 1 report includes an analysis of the Western Power electricity data to evaluate the amount of electricity self-supplied by households via rooftop solar PV. This was updated with the more recent Western Power data, which indicates that some 30-40% of electricity demand is currently being self-supplied.

In this phase of work, previously published research (Grace, 2023) has shown that self-supply is likely to grow significantly as the cost of solar PV and household batteries reduces. The projections from that modelling have been used here to project future self-supply in residential properties. Irrespective of the size of a solar PV array, the amount of electricity self-supplied is limited to around half of electricity demand. However, with battery storage, the amount of self-supply that offers a reasonable return to householders will likely grow, leading to 70% of dwellings having solar PV, with 50% also having batteries by 2050.

4.5.8 Water and wastewater

The results of the Phase 1 study are assumed to apply to each type of dwelling. Although the planning and design assumptions assume smaller dwellings, the amount of private open space per dwelling for housing typologies is somewhat larger. This would potentially lead to higher water demand for irrigation, but this was neglected as emissions related to water and wastewater are relatively small.

4.5.9 Transport

<u>Travel patterns</u>

The Phase 1 report concluded that emissions from private vehicles ranged from 30 – 45% of total lifecycle emissions based on modelling from the DoT's STEM simulations. The planning interventions contemplated in this phase of research could potentially influence private transport emissions in several ways:

- distribution of density better aligned with public transport routes, making access easier and, therefore, more attractive;
- reduced on-lot parking (maximum of 1 bay per dwelling);
- improved walkability (e.g. shade and improved pedestrian access to local amenities, including public transport nodes);
- enhanced micro-mobility (e.g. improved cycleways, e-bikes/scooters, electric skateboards); and
- improved local public transport (e.g. local destination-related bus transit).

However, it was determined that the densification of the case study sites and the factors outlined above could not be realistically modelled with STEM regarding trips 'produced' or 'attracted' to/from key destinations or local travel. Accordingly, the vehicle-kilometres-travelled (VKTs) were assumed to be unchanged in the Phase 2 report.

In this phase of the research, two factors have been considered:

- Fuel efficiency improvements in internal combustion engine vehicles (ICEV); and
- The take-up of electric vehicles.

The former was taken from a report by the Global Fuel Economy Initiative (GFEI) (Kodjak & Meszler, 2019), which projects that emissions per km for passenger cars could improve from the present average value of 210 gCO2e/km to 120 gCO2e/km by 2050[12].

CSIRO has produced projections for all types of electric vehicles (CSIRO, 2023a) under three scenarios 'Progressive Change,' Step Change,' and 'Green Energy Export'. The CSIRO data is provided as a projection of fleet share from 2025 to 2055. A more conservative trajectory was adopted for this study, assuming saturation is not achieved until 2075. The Australian Electric Vehicle Industry Recap Report 2023 states that 'EVs now represent approximately 1% of Australia's total light vehicle fleet (31 Mar 2024).'

4.5.10 Electricity in the SWIS

Decarbonisation of the SWIS is a major element of the Western Australia government's Sectoral Emissions Reduction Strategy (SERS)[13]. The report states:

'By 2050, 96 per cent of energy consumed is projected to come from renewable generation, compared with 34 per cent currently in the SWIS and 2 per cent in the Pilbara.'

The trajectory adopted for the Phase 2 report assumes this outcome is realised.

4.6 The model

4.6.1 Description

The interventions described in Section 4.5 were incorporated into a system dynamics model using the Vensim software[14]. Systems dynamics models simulate changes to stocks over time (e.g. take-up of private solar) by combining interdependence between variables with feedback (e.g. the penetration of EVs) to enable an understanding of how a change in one or more variables affects others. The structure of the model facilitates the exploration of many combinations of intervention and comparisons with the Phase 1 results, referred to as the 'Baseline'.

4.6.2 Model structure and operation

The model was constructed in modules that calculate emissions on a per-dwelling basis for several urban typologies, namely:

Table 9 Precinct typologies

Precinct typology	*Applicable case study sites*
Greenfield housing precinct	*Jindalee, Southern River, Ellenbrook*
Greenfield apartment precinct	*Jindalee, Southern River*
Greenfield – GOD precinct	*Ellenbrook*
Infill – retained housing precinct	*Nollamara*
Infill – new housing precinct	*Nollamara*

[12] ICE vehicles include hybrid vehicles that maintain their charge solely through ICE-derived energy, but exclude plug-in hybrid and electric vehicles.
[13] https://www.wa.gov.au/service/environment/environment-information-services/sectoral-emissions-reduction-strategy
[14] https://vensim.com/

Infill – TOD precinct	*SubiCentro*

Each of these precinct typologies contains 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.

The dwelling types considered were:

- Separate houses;
- Semi-detached houses;
- Rowhouses;
- Townhouses;
- Apartments in 3-storey buildings;
- Apartments in 4-storey buildings; and
- Apartments in 5-storey buildings.

4.6.3 Subdivision emissions

Subdivision emissions are based on four ground conditions, namely:

- Shallow groundwater sites – conventional fill;
- Shallow groundwater sites – reduced fill;
- Sandy soil sites; and
- Infill sites.

4.6.4 Vegetation – clearing and planting

The results of the Phase 1 study are retained but lead to lower values per dwelling basis due to the assumed density increases.

4.6.5 Embodied energy of built-form

The embodied emissions of each dwelling type are determined by its construction materials, namely:

- Conventional; and
- Lightweight.

4.6.6 Operational energy emissions

Operational energy use for dwellings is calculated separately based on dwelling size, which varies over time based on projections for:

- The fraction of electric-only and electric + gas houses;
- Electrical efficiency of household appliances;
- The take-up of solar PV and/or batteries and
- The take-up of EVs.

Emissions intensities for electricity and natural gas are also assumed to vary over time, and these are applied to the energy calculations to provide annual emissions per dwelling.

4.6.7 Private vehicle emissions

Emissions from private vehicles are based on:

- The fraction of EVs varies over time and impacts electricity demand in homes and
- The fraction of ICEVs and their emissions intensity varies over time.

4.6.8 Emissions from Water and Wastewater

The results of the Phase 1 study are retained and calculated for each dwelling type. The Water Corporation's emissions intensity is assumed to decline in line with the SWIS.

4.6.9 Exclusions

Several emissions sources are not included in the model, including:

- embodied emissions in vehicles, household furniture, fittings and appliances;
- operational emissions associated with public transport and other electric mobility devices, and
- any changes to transport emissions that may arise from ride-sharing (via autonomous vehicles or otherwise).

4.6.10 Controls

The model is configured to report embodied, operational and 50-year lifecycle emissions for each precinct type, which are compiled to report emissions for each case study site. For this report, results have been produced that reflect emissions associated with each level of control as set out in Figure 6, i.e.:

- Planning & design;
- Resident choices;
- Other government policies and the market.

<u>Scenarios</u>

To avoid too many combinations of interventions, there are some common assumptions underlying all scenarios:

- Transport
    - Continuing improvement in the fuel efficiency of ICEVs.
- Planning & design
    - Adoption of revised urban form (types and sizes of dwellings).
- Consumer choices
    - Continuing energy efficiency measures and
    - Business as Usual private travel patterns.

The model was used to test the main uncertainties with major impact:

- Consumer choice
    - Electrification of homes and private vehicles;
    - Projected take-up of solar and batteries and
    - House construction materials.
- Other government policies and the market
    - SWIS decarbonisation.

4.7 Results

50-year lifecycle emissions for each case study site were developed and compared to the results of the Phase 1 study (noted as the Baseline[15]). For each precinct, the scenarios are compiled cumulatively as follows:

Table 10 Intervention scenarios

Tag	*Scenario*
P&D	• *Planning and design measures only.*
+ Home elect	• *Planning and design measures/ plus* • *Home electrification, solar and battery takeup, EV takeup.*
+ Materials	• *Planning and design measures, plus* • *Home electrification, solar and battery takeup, EV takeup, plus* • *Home construction with lightweight materials.*
+ SWIS	• *Planning and design measures, plus* • *Home electrification, solar and battery takeup, EV takeup, plus* • *Home construction with lightweight materials, plus* • *SWIS decarbonisation.*
P&D+SWIS only	• *Planning and design measures, plus* • *SWIS decarbonisation.*

The cumulative emissions of all the case study sites are depicted in Figure 27.

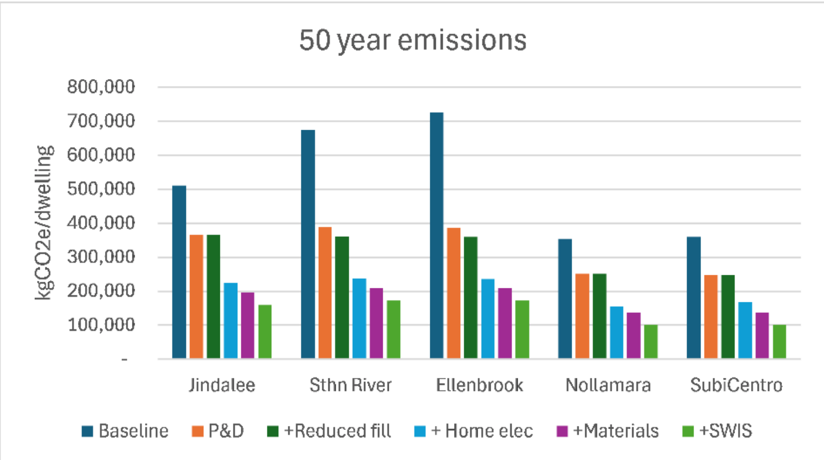


Figure 27 Summary of modelling results

In 2019, the State Government set an economy-wide target of net zero emissions by 2050 and committed to working with all sectors of the economy to achieve this goal. The State Government also set a target for reducing emissions from State Government operations by 80 per cent below 2020 levels by 2030. The Climate Change Bill[16] will enshrine the state's long-term net zero emissions target by 2050, provide statutory requirements to develop policies to reduce emissions, set interim emission reduction targets, and enhance climate resilience.

The operational emissions in this study derive from the following (in order of diminishing magnitude):

[15] There are some minor changes to the Baseline values compared to those reported in the Phase 1 report, including the addition of nominal subdivision related emissions.
[16] At the time of writing the Bill has been introduced into Parliament but not enacted.

- Household energy supply (electricity plus gas);
- Vehicle emissions from ICEVs;
- Water and wastewater; and
- Plantings.

The impact of the interventions on annual operational emissions is depicted in Figure 28.

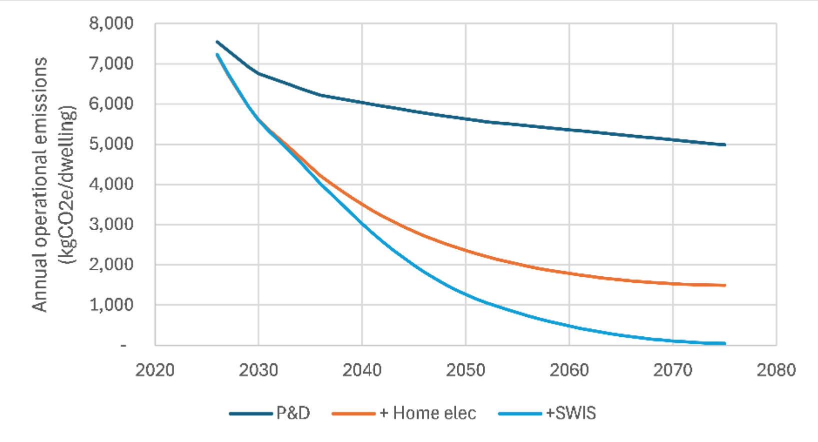


Figure 28 Annual emissions

Note that the annual improvements in P&D emissions result from the measures locked into all scenarios, i.e. improvements in energy efficiency of household appliances and ICEV fuel efficiency (see Section 4.6.10). The improvements in the other scenarios result from incremental changes, e.g. the take-up of home batteries and EVs and the decarbonisation of the SWIS.

4.8 Key Findings

4.8.1 Greenfield sites

Planning and design measures

The focus of these interventions for greenfield development sites revolves 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. From a developer perspective, this would lead to a larger number and greater diversity of lots per ha of development. From a builder's perspective, this would lead to more dwelling completions per m^2 of constructed built-form.

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 measures are particularly effective for the greenfield sites due essentially to the larger increase in gross dwellings per ha.

Subdivision emissions

The model assumes the same subdivision works emissions per ha of development land under the planning and design measures. This leads to a 50-60% reduction in lifecycle subdivision-related emissions per dwelling. For the Southern River and Ellenbrook case study sites, the opportunity to reduce fill reduces those values by a further 15%.

Relatively high emissions associated with subdivision works are influenced by the likely slow decarbonisation of construction vehicles.

Home electrification

The selected interventions include:

- increasing penetration of rooftop solar PV, together with home batteries, driven by the financial incentives of homeowners to reduce electricity costs;
- a gradual electrification of homes and
- the take-up of electric vehicles.

These measures alone have the potential of reducing lifecycle per dwelling energy supply and transport emissions by around 40%, despite the adoption of EVs increasing the demand and emissions from energy supply (see Figure 29).

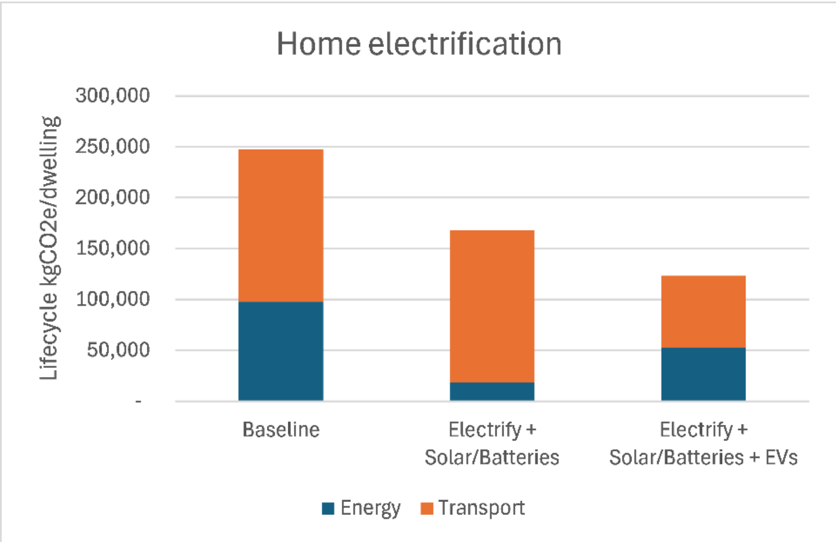


Figure 29 Lifecycle emissions per dwelling for home electrification (Southern River example)

These interventions cannot be controlled through any regulation presently contemplated, although the National Construction Code 2024 introduces stricter energy efficiency requirements and a whole-of-home energy use allowance, which incentivise the integration of rooftop solar and batteries. It is also possible that future versions of the NCC could require onsite solar.

Embodied emissions

The embodied emissions in this research phase have been assumed to be the same as in Phase 1 of the research on a per m^2 GFA basis. The reduced average size of dwellings alone leads to 30-40% reductions in the built-form lifecycle embodied emissions per average dwelling, noting that the figures are dominated by the building envelope, conventionally comprising concrete, steel and brick. Substituting these materials with a lightweight form of construction leads to major reductions in embodied emissions of around 50% per m^2 GFA. This reduction is mainly influenced by the LCA assumption that timber is sustainably sourced, producing negative emissions, which is challengeable. This is discussed further in the Appendices.

Although this report assumes that consumers choose construction materials, it is possible that regulations could follow. Indeed, reporting of embodied carbon is to be introduced in the 2025 Australian National Construction Code (NCC). A minimum standard could be adopted in NCC 2028.

4.8.2 Infill sites

The reduction in emissions per dwelling is lower in the infill sites of Nollamara and Subiaco, as densities are already much higher than the greenfield sites. However, the reductions are still significant at around 30% per dwelling due to planning and design measures alone.

The revised urban layout of Nollamara illustrates that densities could be higher than business as usual through the measures assumed here:

- retention of around 30% of existing lots and houses;
- much more modest subdivision of a further 30% of lots with a single additional dwelling and
- a dense transport-oriented corridor development.

There are challenges with the achievement of the lot amalgamation necessary to deliver such corridor development.

5. Phase 3 conclusions and recommendations

5.1 Potential interventions

The interventions set out in this report are categorised as:

- Planning and design Interventions controlled through the planning system and built-form controls
- Resident choice
- Other government policies and market forces (see Table 3)

This section of the report focuses on measures that can be taken within the planning and design system, including planning policies and controls on development required by the 'Residential Design Codes' and the NCC. Some commentary is provided on the other categories, noting that some of what is presently resident choice can potentially also be incorporated into planning and development policies.

Figure 30 describes the interdependencies between the interventions outlined in Section 4.5.

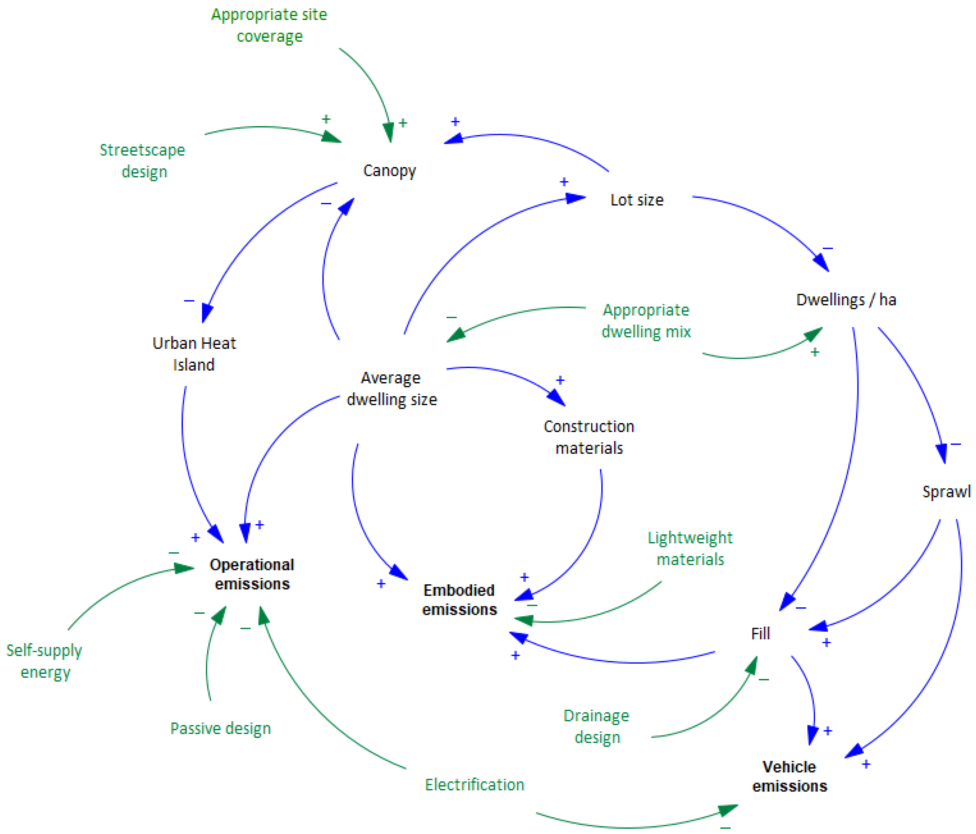


Figure 30 Emissions related interventions

The emissions intensity of built-form construction is determined significantly by the conventional use of concrete, steel and bricks. The level of canopy on private and public land influences the urban heat island effect, which affects the attractiveness of active mobility and the energy demand for housing. As noted in Section 4.5, the electrification of homes and vehicles, supported by self-supply (solar PV and batteries), significantly impacts emissions reductions.

The following section addresses how these interventions could be incorporated into the planning and design processes.

5.2 The intersection of the interventions with planning and design policies

The planning system has a hierarchy of documents that seek to guide development. Approval at each stage is intended to be reflected in subsequent stages, e.g. local planning schemes must reflect the requirements of the Metropolitan Region Scheme (MRS). Statements of Planning Policy (SPPs) are therefore relevant to all stages of development and are intended to be guided by the State Planning Strategy 2050.

Figure 31 illustrates the stages of planning control that influence the various emissions sources. We note that this graphic representation is necessarily simplified.

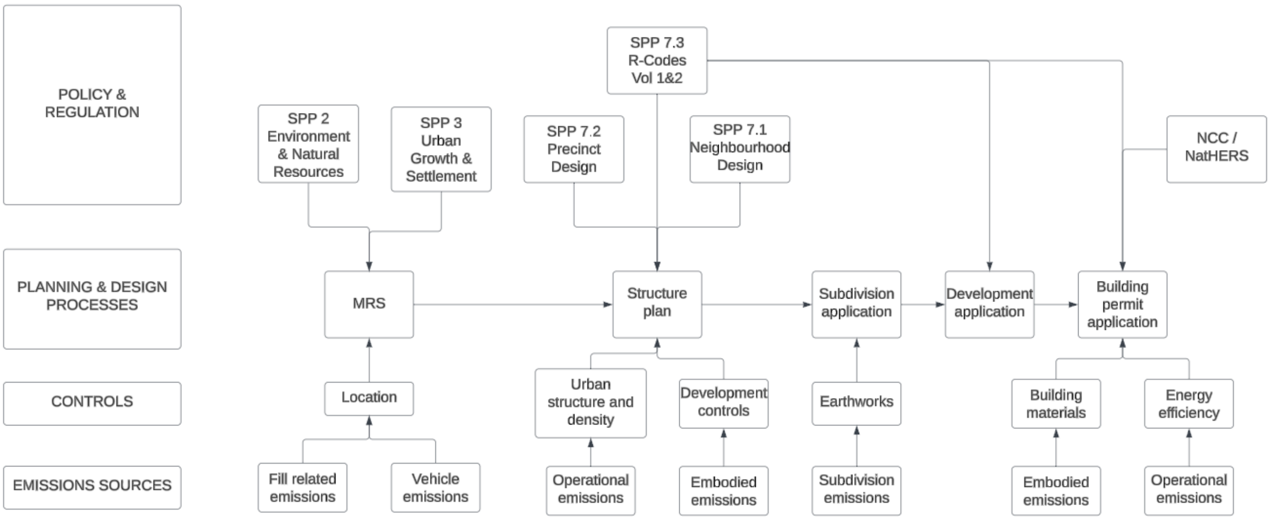


Figure 31 Emissions sources and the planning system.

Table 11 provides an overarching summary of possible revisions of relevant policies for enabling low-carbon neighbourhoods. These are subsequently discussed in detail in section 5.2.1.

Table 11 A summary of possible revisions of relevant policies for enabling low-carbon neighbourhoods

Policy	***Recommendation***	***Responsibility***
State Planning Strategy 2050	*Consider revising to reflect the importance of climate change to the various regions of Western Australia.*	*WAPC*
Perth & Peel @ 3.5 million	*Consider a review of 'Perth & Peel@3.5 million' to account for climate change mitigation and adaptation and increase the current 47% infill target.*	*WAPC*
State Planning Policies (SPPs)	*Consider aligning the planning system with the government's climate change legislation in respect of Net Zero emissions and adaption to climate change.*	*WAPC*
	Consider incorporating climate change mitigation and adaptation objectives in a single State Planning Policy, with references to the objectives included in other SPPs as appropriate.	*WAPC*
Region Scheme amendments	*Consider requiring Region scheme Amendment Reports to include a section on climate change, including the influence of location on greenhouse gas emissions.*	*WAPC*
SPP 7.1 Neighbourhood Design & SPP 7.2 Precinct Design	*Consider revising SPP 7.1 and 7.2 to explicitly reference the objectives of the proposed climate-related SPP.*	*DPLH*
	Consider revising SPP7.1 to require climatic and microclimate analysis of the site, including likely future conditions under climate change.	*DPLH*
	Consider SPP 7.1 and 7.2 requiring an Energy and Greenhouse Gas Statement as a standalone Precinct Plan Output.	*DPLH*
	Consider revising SPP 7.1 to require a more integrated land and built-form planning approach to deliver climate-responsive urban design to contribute to Net Zero.	*DPLH*
	Consider requiring an evaluation of life-cycle emissions associated with subdivision works and an explanation of the measures taken to minimise such works.	*DPLH*
	Consider revising to require a more integrated land and built-form planning approach to deliver climate-responsive urban design to contribute to Net Zero emissions.	*DPLH*
Structure Planning	*Consider revising the Planning Manual to ensure adequate emission-related information is provided to planning authorities, including in the proposed expanded Energy and Greenhouse Gas Statement.*	*DPLH*
Residential Design Codes	*Consider revising to reference the proposed climate change SPP and explicitly link the policy requirements to the mitigation of emissions.*	*DPLH*
	Consider requiring a more integrated land and built-form planning approach to deliver climate-responsive urban design to contribute to Net Zero emissions and climate resilience in Western Australia.	*DPLH*
Building permit applications	*Consider requiring a calculation of embodied energy (similar to the NSW BASIX scheme's application of a Materials Index) to be submitted with applications.*	*DEMIRS*

	Consider a ban on new gas connections (similar to the recent Victorian scheme (Amendment VC250).	*DEMIRS*
Other recommendations	*Consider an education campaign to promote individual and societal benefits of 'right-sized', low emissions dwellings.*	*WA state government*
	Consider promoting state-based schemes for home electrification and household energy upgrades.	*WA state government*
	Consider extending the Zero Emission Vehicle (ZEV) Rebate Scheme beyond May 2025.	*WA state government*
	Consider monitoring the response of developers and builders to the introduction of the mandatory climate reporting requirements.	*DPLH*
	Consider the establishment of a program for monitoring residential emissions.	*DPLH*

5.2.1 Overarching policy

While the State Planning Strategy 2050 recognises the reality of climate change, it contains no guidance on how the planning system should address either mitigation of or adaptation to climate change.

Recommendation:

The State Planning Strategy 2050 and State Planning Policies be reviewed and revised to reflect the importance of climate change to the various regions of Western Australia and align the planning system with the government's climate change legislation in respect of Net Zero emissions and adaption to climate change.

5.2.2 Reducing emissions associated with the location of development

The location of development principally controls subdivision-related embodied emissions associated with earthworks (fill), the design of subdivision works (e.g. groundwater management and drainage design) and construction methods (e.g. use of diesel-fuelled machinery). The study's findings identify that the emissions associated with development in shallow groundwater sites are a significant component of life-cycle emissions.

The development location also strongly influences private vehicle emissions relative to key destinations (employment, education, services).

The location of urban land is controlled by the Metropolitan Region Scheme (MRS), Peel Region Scheme, Greater Bunbury Region Scheme and other local schemes. Currently, there is no consideration of the emissions associated with land development in the consideration of amendments to the MRS. The MRS Amendment Report prepared by DPLH includes a section entitled 'Sustainability appraisal'. However, this does not explicitly address emissions. A commonly found paragraph in this section reads:

'The proposed amendment will allow further detailed planning to facilitate the development of the [……] locality, consistent with the goals and objectives of the WAPC's [structure plan or planning framework], which addresses the sustainability of proposed urban development in general.'

This essentially demotes consideration of climate change and other sustainability issues to district structure planning and associated processes (e.g. regional planning frameworks). These, in turn, require reference to SPP 7.2 Precinct Design and Liveable Neighbourhoods (in future SPP 7.1 Neighbourhood Design), which principally deal with the nature of development at a particular location rather than the suitability of the location itself. Accordingly, guidance for consideration of MRS amendments, which give rise to new urban land, is guided mainly by 'Perth & Peel at 3.5 million' and its associated sub-regional frameworks. These documents are essentially silent on the mitigation of climate change.

However, the WAPC already has a policy on greenhouse gas emissions, which is intended to be reflected in all planning-related decisions.

SPP No.2 Environment and Natural Resources*:*

> *5.10 Greenhouse Gas Emissions and Energy Efficiency*
>
> *The primary objective is to reduce greenhouse gas emissions by means including (but not limited to) increasing energy efficiency, decreasing reliance on non-renewable fuels, and increasing usage of renewable energy sources.*

Planning strategies, schemes, and decision-making should:

(i) Promote energy-efficient development and urban design incorporating such issues as energy-efficient building design, walkable neighbourhoods, higher densities in areas accessible to high-quality public transport, local access to employment, retail and community facilities, and orientation of building lots for solar efficiency.
(ii) Support the retention of existing vegetation and revegetation in subdivision and development proposals.
(iii) Support the use of alternative energy generation, including renewable energy, where appropriate.
(iv) Support the adoption of adaptation measures that may be required to respond to climate change.

SPP 2.0 could be re-titled and expanded to become the overarching policy instrument for climate change while retaining environment and natural resources. Alternatively, climate-related objectives could be incorporated into a new SPP dedicated to climate change, and SPP 2.0 could be revised accordingly.

Recommendation:

The planning framework be revised to include climate change mitigation and adaptation objectives in a single State Planning Policy, with references to the objectives included in other SPPs as appropriate.

Recommendation:

Region scheme Amendment Reports include a section on climate change, including the influence of location on greenhouse gas emissions.

A focus on climate change (including this research) questions the appropriateness of 'Perth & Peel at 3.5 million' from both an adaptation (sea level rise, heat stress, bushfires and declining rainfall) and mitigation perspective (location and form of development).

Recommendation:

Any future review of 'Perth & Peel at 3.5 million' consider alternative development scenarios for Greater Perth that fully consider climate change mitigation and adaptation. This review should also consider Perth's modest infill target of 47%, the lowest across Australia's major cities.

5.2.3 Reducing emissions associated with residential land use

The design, size and diversity of dwelling types directly influence embodied and operational built-form emissions and indirectly influence the amount of land developed per dwelling. The urban structure directly influences the operational energy/emissions of housing due to the urban heat island effect, canopy cover and air movements.

Existing SPPs such as SPP2.0 Environment and Natural Resources (noted above), SPP3.0 Urban Growth and Settlements, and SPP 7.2 Precinct Design already address these issues. The text that influences emissions is noted below in **bold**.

SPP 3.0 Urban Growth and Settlements

5.1 Creating sustainable communities

The key requirements for sustainable communities are—

• variety and choice in the size, type and affordability of housing to support a range of household sizes, ages and incomes and which is responsive to housing demand and preferences;

• affordable land for housing and affordable housing products in both greenfield and brownfield locations to ensure the housing needs of all the community can be met, including those with special needs;

• the cost-effective use of urban land and buildings, schools and community services, infrastructure systems and established neighbourhoods; and promoting and encouraging urban development that is consistent with the efficient use of energy;

• directing urban expansion into designated growth areas which are, or will be, well serviced by employment and public transport;

• proper consideration of the environment, recognising the need to restore and enhance as well as protect biodiversity and to minimise development impacts on land, water, energy, minerals, basic raw materials, agriculture and other natural resources that help sustain urban economies and society;

As for SPP2.0, this policy is intended to be reflected in all planning decisions.

Several emissions-relevant clauses exist in the SPP 7 suite (noted in **bold**).

SPP 7.2 Precinct Design

Policy Outcomes

Development within precincts integrates landscape design that enhances sustainability outcomes and contributes to community wellbeing. The local environment is enhanced through the following:

• protection of water and soil resources
• retention and/or enhancement of the green network
• protection and/or restoration of fauna habitat, where appropriate
***• consideration of microclimate and urban heat island impacts**.*

SPP 7.2 Precinct Design Guidelines

Design Element 1 Urban Ecology

C1.3.1 Identify opportunities to retain existing trees and enhance the tree canopy through new planting.

C1.3.2 Consider the influence of the precinct design on energy demand and review the potential for precinct-scale energy generation, distribution and storage.

Precinct Plan Outputs - Energy and greenhouse gas emissions statement: to demonstrate how the precinct has reduced emissions and incorporated renewable energy sources.

Design Element 2 Urban Structure

C2.3.3 Design lot layouts to respond to local climate, topography and existing natural features while supporting the intended built-form.

Design Element 3 Public Realm

*C3.3.2 Ensure the public realm contributes to **creating and/or improving the urban tree canopy** within the precinct and its surrounds.*
*C3.3.5 Provide opportunities for urban greening, such as **community gardens and rooftop gardens**.*

Design Element 6 Built-form

*C6.1.3 Promote a **diversity of built-form types** appropriate to the precinct.*
*C6.3.1 Locate and arrange buildings to **optimise solar access** to buildings and the public realm.*
*C6.3.2 Consider the placement and layout of buildings to **optimise natural ventilation** and minimise wind impact at street level and on adjoining properties and public spaces and streets.*

Liveable Neighbourhoods (2015 Draft) (LN)

<u>Element 1 Community Design</u>

Site and context analysis

- *Objective 1: To achieve a sustainable urban structure that balances the provision of urban development through **site-responsive design**.*

  Req 1.5 Facilitate climate-responsive design where topography and other site conditions allow and avoid the need for major earthworks, which increase demand for basic raw materials and reduce loss of remnant vegetation.

Housing choice and residential densities

- *Objective 7: Facilitate **housing diversity, responsive built-form**, local employment and amenity within a legible and efficient urban structure of compact, walkable neighbourhoods*

<u>Element 2 Movement Network</u>

Design principle 3:

- *Ensure all streets provide space for utility services, stormwater drainage, **street trees** and lighting*

  Street trees are an integral component of urban streetscapes, encouraging pedestrian and cyclist use, community interaction and fewer vehicle trips. The provision of street trees provides shade to buildings, outdoor living areas, street pavements, and parking areas; lowers ambient temperatures; and assists in reducing adverse effects of urban heat islands and electricity use.

<u>Element 4 Lot Design</u>

Site Responsive Design Requirements

5.1 Street and lot design is to:

*• **facilitate climate-responsive design**;*
*• accommodate natural topography and **minimise earthworks, fill/excavation and retaining walls** on sloping sites;*
*• provide for appropriate **planting for microclimate management** and energy conservation;*
*• maximise opportunities for **retention of mature trees**.*

*5.2 **Lots to be of a size, width and shape** (generally rectangular or square) to provide for:*

• solar orientation;

• usable private outdoor space;

*5.3 **Lot shape, size and orientation to facilitate climate-responsive and energy-efficient buildings** by maximising solar access in winter and minimise in summer*

Design principle 6:

- *Provide **housing density and diversity to meet the changing community needs***

Design principle 7: [in respect of reticulated natural gas supply]

- *Provide sustainable utility services to each new lot in a timely, cost-effective, coordinated and visually acceptable manner.*

Energy

In all cases, the provision of alternate renewable electricity generation systems (for example, solar and wind) from local (lot-specific) to district (multiple lots) scales is encouraged.

Recommendation:

SPP 7.1 Neighbourhood Design and 7.2 Precinct Design be revised to explicitly reference the objectives of the proposed climate-related SPP, and the text noted above revised to specifically link their requirements (inter alia) to that SPP.

It is recommended that SPP 3.0 Urban Growth and Settlements (Clause 5.1) be included in the references to SPPs in SPP 7.1 and SPP 7.2.

This research identifies several shortcomings concerning new greenfield development that influence lifecycle emissions:

- Large dwellings that do not reflect the existing and future demography of Perth.
- Site coverage that limits the private open space available for trees and restricts natural ventilation.
- Dwelling designs that do not reflect best practice passive solar design, particularly with respect to summer cooling and natural ventilation and
- Streetscapes that provide inadequate shade for both dwellings and pedestrians/cyclists, disincentivising active mobility and incentivising car use for local travel.

Planning that reflects the policy intentions requires a holistic approach to urban design that integrates:

- The overarching settlement objectives derived from (inter alia) overall density (i.e. dwellings/ha development) and the consideration of SPP3 Urban Growth and Settlements (5.1) objectives, with
- The conception of the settlement as an integrated configuration of buildings (rather than lots) and other land uses within the local landscape and microclimate as intended by LN Elements 1 and 4.

The former gives rise to a mix of dwelling sizes and types that reflect existing and future demographics. The latter requires a precinct-scale microclimate analysis (solar gain and breezeways) to guide the urban structure of lots, streetscapes, and open spaces, as well as the appropriate canopy cover in private and public open spaces.

In LN, the overarching policies associated with urban design are included in Element 1 Community Design. However, Element 4 (as noted above) also includes site requirements, including site responsive design and density/diversity.

Recommendation:
Element 1'Community Design' consolidate all site and urban design requirements (Site Design), and Element 4 'Lot Design' retains specific lot level requirements. Element 1 'Community Design' be revised to require climatic and microclimate analysis of the site, including likely future conditions under climate change, and an appendix included to provide guidance.

It is assumed that SPP7.1 Neighbourhood Design will have similar requirements as SPP7.2 Precinct Design for providing an Energy and Greenhouse Gas Statement. While the objective is appropriate, emissions are associated with (almost) all the Design Elements (as noted above), so their inclusion in this Design Element is inappropriate.

Recommendation:
SPP 7.1 Neighbourhood Design and 7.2 Precinct Design require an Energy and Greenhouse Gas Statement as a standalone Precinct Plan Output to demonstrate how the precinct plan has avoided emissions in comparison to a benchmark conventional development. This requirement will require a guideline to be prepared to describe how emissions are to be calculated and the supporting information to be provided.

The urban design approach to Structure Planning proposed here requires including building envelopes as an integral part of the urban fabric. Under the current LN requirements, only block-level R-Code designations are defined, and:

- Individual lots are defined via the subdivision process, and
- The built form is controlled by the R-Codes (and any Design Guidelines) at the lot development stage.

This approach disconnects built-form from broader urban design, which is not conducive to climate response design.

The R-Codes (Vol.1) specify a maximum site cover of 60-70% for R30-R80 lots, so for an average contemporary lot of 350-400m^2 that delivers large dwellings with extremely small side and rear separations between single lot dwellings and little room for gardens, let alone trees (see Figure 32).

Figure 32 Built-form example (Jindalee)

Such high levels of site coverage greatly restrict the opportunity for natural ventilation and winter solar gain, which are likely to be a factor in the very high electricity demand identified in the Phase 1 report for such precincts.

The revised dwelling size/typology mix proposed in the Phase 2 research has much lower site coverage for separate houses (30-40%) to facilitate passive design and space for trees, but with land savings for smaller (on average) houses and additional typologies such as semi-detached and row houses that can retain these features.

This disconnect between urban and built-form is one reason why the sensible provisions of the current planning policies regarding climate-responsive design are not translating to outcomes on the ground. It is difficult to see how this can be overcome without SPP 7.1 Neighbourhood Design requiring Structure Plans to specify dwelling sizes, types and site coverage beyond street block R-Code identification. Only a complete picture of the fully constructed precinct would facilitate a proper evaluation by planning authorities of climate-responsive urban design performance against policy and facilitate a whole of development emissions inventory.

It is recognised that such a major departure from current practices is not practical to consider for the current review of LN and, in any case, would require complementary changes to the R-Codes.

Recommendation:

Future reviews of SPP 7.1 Neighbourhood Design and 7.3 Residential Design Codes require a more integrated land and built-form planning approach to deliver climate-responsive urban design to contribute to Net Zero emissions and climate resilience in Western Australia.

5.2.4 Reducing emissions for subdivision works

Although minimising earthworks is a policy requirement, Structure Plans do not require any information on the nature and extent of earthworks, although information is usually provided in an engineering report annexed to the Structure Plan. The emissions are significant and difficult to avoid because diesel-fuelled heavy vehicles are predominantly used for subdivision works.

The Urban Development Institute of Australia (UDIA) has recently completed a study of emissions associated with subdivision works using Life Cycle Assessment techniques. This analysis can be conducted based on civil engineering design quantities and works specifications required to prepare Structure Plans and Subdivision applications.

Because of the diversity of site soil types, typography and groundwater conditions and the dearth of data available on emissions, it is not presently practical to set a target (e.g. 50-year emissions per ha of development). However, this should follow when sufficient data becomes available.

Recommendation:

SPP 7.1 Neighbourhood Design and 7.2 Precinct Design require an evaluation of life-cycle emissions associated with subdivision works, together with an explanation of the measures taken to minimise earthworks and drainage infrastructure and emissions associated with transport and construction vehicles—this evaluation to be included in the Energy and Greenhouse Gas Statement.

Adopting this recommendation will require further work to specify the required analysis.

5.3 Structure Plans

As noted above, the SPPs already include many important climate-related issues but are not reflected in the approval of Structure Plans. The requirements for structure plans documents are set out in the *WA Planning Manual – Guidance for Structure Plans (2023)*. The manual specifically references the following policy documents:

- State Planning Policy 3.6 Infrastructure Contributions
- State Planning Policy 4.2 Activity Centres
- State Planning Policy 7.0 Design of the Built Environment
- Liveable Neighbourhoods (LN)
- State Planning Policy 7.2 Precinct Design
- State Planning Policy 7.3 Residential Design Codes - Volumes 1 and 2

Although it refers to 'Other relevant State Planning Policies, Operational Policies, Position Statements and Guidelines', the required information for standard residential/mixed-use development is limited to:

- Zoning/land uses; Street blocks/ movement network; Open space (reserves); R-Codes; Staging; Utility servicing and Transport infrastructure.

Precinct structure plans under SPP 7.2 Precinct Design require additional information on the following:

- Lot layout; Building exclusion zones; Development controls & design concepts

Given that most new urban developments will be subject to the new SPP 7.1 Neighbourhood Design, consideration should be given to expanding the submission requirements in the Planning Manual.

Recommendation:

The Planning Manual be revised to ensure adequate information is provided to planning authorities for those recommendations adopted for SPP 7.1 Neighbourhood Design and 7.2 Precinct Design, including in the proposed expanded Energy and Greenhouse Gas Statement.

5.4 Development approvals

The approval of development is controlled by the planning processes and the granting of a building permit under the Building Act 2011, sections 14, 16 and Building Regulations 2012, regulations 4, 16. The local government grants permits.

5.4.1 Residential Design Codes (Volume 1)

Although the R-codes are principally used to control development within lots, they also contain provisions that relate to urban form in so far as addressing the influence of adjoining properties. The text that influences emissions is noted below in **bold**.

PART B

5.1 Context

> *C To ensure **adequate provision of sunlight and natural ventilation** for buildings and to limit the impacts of building bulk, overlooking, and overshadowing on adjoining properties.*

5.1.3 Lot boundary setbacks

> *P3.1 Buildings set back from lot boundaries or adjacent buildings on the same lot so as to:*
>
> *• **provide adequate sunlight and ventilation to the building** and open spaces on the site and adjoining properties;*

5.1.4 Open space

> *P4 Development incorporates suitable open space for its context to:*
>
> *• **provide access to sunlight for the dwelling**;*

5.3 Site Planning and Design

5.3.1 Outdoor living areas

> *P1.1 A consolidated outdoor living area is provided to each single house and grouped dwelling, which provides space for entertaining, leisure and connection to the outdoors that is:*
>
> *• of sufficient size and dimension to be functional and usable;*
> *• capable of use in conjunction with a primary living space of the dwelling;*
> *• sufficient in uncovered area to **allow for winter solar gain and natural ventilation** into the dwelling;*
> *• sufficient in uncovered area to provide for landscaping, including the planting of a tree(s); and*
> *• **optimises use of the northern aspect** of the site.*

5.3.2 Landscaping

> *P2 Landscaping of open spaces that:*
>
> *• contribute to **positive local microclimates**, including provision of shade and solar access as appropriate; and*
> *• **retains existing trees and/or provides new trees** to maintain and enhance the tree canopy and local sense of place.*

5.4 Building Design

> *B To optimise comfortable living, **access to sunlight and solar energy** to facilitate sustainable housing development with particular regard for place and local conditions.*

*5.4.2 **Solar access for adjoining sites***

> *P2.1 Effective solar access for the proposed development and protection of the solar access.*

P2.2 Development designed to protect solar access for neighbouring properties taking account the potential to overshadow existing:

• outdoor living areas;
• north facing major openings to habitable rooms, within 15 degrees of north in each direction; or
• roof mounted solar collectors.

<u>PART C</u>

1.0 THE GARDEN

1A To ensure dwellings are provided with functional outdoor amenity and outlook.

*1B To support **tree retention and reestablishment of the urban tree canopy** with the aim of reducing the impact of heat island effect.*

*1C To enable **solar access and natural ventilation** to the dwelling through the provision of open space.*

1.1 Private Open Space

P1.1.1 Dwellings are designed to have direct access to private open space which provides for entertaining, leisure and connection to the outdoors that is:

i. of sufficient size and dimension to be
functional and usable for the intended number of dwelling occupants;
*ii. is sited, oriented and designed for occupant amenity, including consideration of **solar access and natural ventilation** appropriate to the climatic region; and*
iii. capable of use in conjunction with a primary living space of the dwelling.

P1.1.2 Private open space allows for sufficient uncovered area to:

*i. **permit winter sun and natural ventilation** into the dwelling; and*
*ii. provide for soft landscaping, including the **planting of a tree(s) and deep soil area**.*

1.2 Trees and Landscaping

P1.2.1 Site planning allows for:

i. site responsive and sustainable landscape design; and
*ii. the **retention of existing trees** on the subject site and adjoining properties.*

P1.2.2 Provision of trees and high-quality landscaping:

i. enhances the built-form, streetscape and pedestrian amenity, as viewed from the street;
*ii. provides **shade and amenity for communal streets** and parking areas; and*
iii. contributes to the visual appeal, comfort and amenity of the development, in particular private open space and communal open space and outlook from habitable rooms.

*P1.2.3 Development provides **sufficient deep soil area to sustain healthy tree and plant growth**, providing for an increase in urban tree canopy over time, and assist in managing the quantity and quality of stormwater.*

1.3 Communal open space

P1.3.1 Communal open space provides:

*i. good quality landscaping, **trees and deep soil areas**;*

2.0 THE BUILDING

*2A To promote the development of a **range of housing options** to suit the needs of the community.*

*2B To optimise comfortable living, **natural ventilation and winter solar gain** to facilitate sustainable housing with particular regard for place and local climatic conditions.*

2.1 Size and layout of dwellings

P2.1.1 Dwellings have a primary living space that:

*iii. incorporates **environmental design principles, including passive solar design and appropriate daylighting and shading**, appropriate for the climate.*

*P2.1.2 Ceiling heights and room dimensions provide for well-proportioned spaces that facilitate **good natural ventilation and daylighting**.*

*P2.1.3 The **size and layout** of dwellings:*

i. is functional with the ability to flexibly accommodate furniture;
*ii. is **appropriate to the intended number of occupants**; and*
iii. ensures functional, high amenity spaces.

*P2.1.4 Development provides **a mix of dwelling types, sizes and configurations** that cater for diverse household types and changing community demographics, appropriate to the existing and/or future context of the locality.*

*2.2 **Solar access and natural ventilation***

P2.2.1 In climate zones 4, 5 and 6 the development is sited, oriented and designed to optimise winter solar gain whilst limiting summer sunlight into:

i. the primary living space and habitable rooms; and

ii. private open spaces, including the primary garden area; while balancing site constraints, outlook and views of significance.

*P2.2.2 Windows to habitable rooms are designed and positioned to **optimize daylight, natural ventilation** and outlook, while maintaining a reasonable level of visual privacy.*

*P2.2.3 Dwellings **optimize natural ventilation** to habitable rooms (and bathrooms where possible) that is responsive to site and local climatic conditions.*

3.1 Site cover

*P3.1.1 The **site cover** of the development is suitable for its context to:*

i. achieve appropriate building bulk on the site, consistent with the intent of the applicable density code and/or as outlined in the local planning framework;
*ii. ensure **sufficient outdoor space for landscaping including trees** and deep soil areas;*
*iii. ensure **adequate solar access and natural ventilation** into the dwelling;*

PART D

1.0 LAND

OBJECTIVES

*1C **To promote a range of lot sizes to support housing diversity and a variety of built-form typologies**.*

5.4.2 Residential Design Codes (Volume 2)

4 Designing the building

*4.1 **Solar and daylight access***

Good, climate sensitive design can contribute to significant reductions in energy consumption through good daylighting, maximising beneficial solar gain in winter and reducing solar gain in summer. Regular daylight exposure also improves people's sense of well-being.

*4.2 **Natural ventilation***

Good indoor air-quality is essential for healthy and comfortable living environments, with poor indoor air quality being a significant contributor to poor respiratory health. In most situations, optimising natural ventilation is the most affordable and effective way to manage indoor air quality.

*4.3 **Size and layout of dwellings***

Good design ensures that despite having a smaller size, apartments have adequate space and efficiency to meet the needs of occupants and their family and friends, and are flexible enough to respond to changing circumstances

4.8 Apartment mix

*Apartments are becoming a more common housing option for a wide variety of households. As demand grows, there is an increasing need for **greater choice in the size, layout and design** of individual apartments to meet the diverse needs of occupants and ensure that West Australians view apartments as an attractive and practical housing option.*

4.11 Roof design

*Roof space can also be used to enhance building amenity and sustainability through use as open space, increasing the total area of landscape on the site or **accommodating photovoltaic panels** and other sustainability infrastructure.*

4.12 Landscape design

*Good landscape design integrates apartment development with the existing ecology, enhances natural systems and **contributes to tree canopy** and biodiversity in the locality. It should improve the street presence of the development and the amenity of pedestrians and building occupants, through the creation of attractive open space, connection to nature, opportunities for food production, provision of shade and micro-climate benefits. The inclusion of landscape elements is therefore an important aspect of apartment design even in highly-urbanised environments*

4.15 ***Energy efficiency***

As energy demand and costs rise, so does the imperative to reduce the energy consumption of all dwellings, with benefits for residents, the community and the environment. Good design can deliver energy-efficient dwellings that are attractive, healthy, and comfortable. Air-conditioning, water heating and lighting account for the majority of energy use in a typical apartment. Early *design decisions to improve thermal performance and select energy-efficient fixtures can, therefore, have a significant impact on energy use.*

Recommendation:
The Residential Design Codes volumes reference the proposed climate change SPP and modify the relevant text in these documents to more explicitly link the policy requirements to emissions mitigation (and, where appropriate, to adaptation).

5.4.3 Application of the R-codes

Despite the policy intent of the provisions set out above, the R-Codes' prescriptive 'Deemed-to-Comply' provisions are used to grant development approval in most cases. These provisions are responsible for delivering the quality and climate performance of new housing in Western Australia, together with the National Construction Code (NCC). The following Volume 1 items have the most influence on climate-responsive performance:

- Table B – Primary controls for all single house(s) in areas coded R40 and below, grouped dwellings in R25 and below, and multiple dwellings in R10 to R25.
- Table 2a & 2b - Boundary setbacks

Beyond maximum site coverage, there is no control over the size of dwellings (nor is it practical to require one), so this is left to the market to determine, which is dominated by the offerings of the major house builders. As very large houses on increasingly smaller lots have become common, the 'Deemed-to-Comply' minimum/maximum style provisions (site cover, open space, setbacks) have increasingly reduced the ability of dwellings to facilitate passive heating in winter and natural ventilation / passive cooling in summer.

A detailed review of the R-codes is beyond the scope of this research, although it is noted that some elements of the R-codes (setbacks and size and layout of dwellings) can be overridden by local government policies and schemes.

5.4.4 NCC 2022 Volume Two - Building Code of Australia Class 1 and 10 buildings

The new residential energy efficiency provisions apply to houses and other high-rise multiple-dwelling projects (Class 1 buildings) and apartment buildings (Class 2 sole-occupancy units and Class 4 parts of buildings).

There are 2 key elements to the changes.

- The minimum level of thermal performance of new homes is raised to the equivalent of 7 stars under the Nationwide House Energy Rating Scheme (known as NatHERS).
- A new whole-of-home, annual energy use budget now needs to be met by new homes.

This budget applies to the energy use of a home's heating and cooling equipment, hot water systems, lighting, swimming pool, and spa pumps. Renewable energy systems, such as rooftop solar panels, are not mandatory but can also be installed to help keep a home's energy use under the required budget.

Part H6 Energy efficiency

H6P1 Thermal performance

(1) The total heating load of the habitable rooms and conditioned spaces in a building must not exceed the heating load limit in Specification 44.

(2) The total cooling load of the habitable rooms and conditioned spaces in a building must not exceed the cooling load limit in Specification 44.

(3) The total thermal energy load of the habitable rooms and conditioned spaces in a building must not exceed the thermal energy load limit in Specification 44.

H6P2 Energy usage

(1) The energy value of a building's domestic services must not exceed 70% of the energy value with—

- *a 3-star ducted heat pump, rated under the 2019 GEMS determination*[17]*, heating all spaces that are provided with heating; and*
- *a 3-star ducted heat pump, rated under the 2019 GEMS determination, cooling all spaces that are provided with cooling; and*
- *a 5-star instantaneous gas water heater, rated under the 2017 GEMS determination, providing all domestic hot water; and*
- *a lighting power density of 4 W/m2 serving all internal spaces that are provided with artificial lighting.*

In Phase 1 of this research, we calculated the whole-of-home energy demand for the various typologies identified in the case study sites as a benchmark (noting that most of the housing was approved under previous editions of the NCC). This analysis incorporates the NatHERS assessment of space conditioning energy demand (i.e., heating and cooling) and lighting and appliance loads. We found that actual energy consumption is significantly higher than the benchmark, even for the more recently completed dwellings. Further research is underway to determine the reasons for this discrepancy.

5.4.5 Construction materials

The Phase 1 study identified that the embodied energy of conventional housing is a significant contributor to lifecycle emissions and is dominated by high emissions-intensity materials such as concrete, steel and brick in the building envelope. The embodied energy of housing is not presently subject to any planning, building policy, or regulation in Western Australia. However, there is increasing interest in addressing this element of climate mitigation in Australia more generally.

The Australian Sustainable Built Environment Council (ASBEC) has produced an issue paper on embodied carbon[18]. ASBEC aims to create a national standard for measuring upfront embodied carbon emissions in Australia through a 'joint initiative between NABERS and the Green Building Council of Australia (GBCA), called the NABERS Embodied Carbon project'.

NABERS is now developing an Embodied Carbon rating tool[19] that will enable 'new buildings and partial rebuilds to measure, verify, and compare their upfront embodied carbon with similar buildings. The tool will provide a certified measure of carbon intensity, incorporating material, transport and construction emissions.'

Buildings eligible for a NABERS Embodied Carbon rating include residential dwellings.

[17] Greenhouse and Energy Minimum Standards (GEMS) determination

[18] https://www.asbec.asn.au/research-items/issues-paper-embodied-carbon-emissions-in-australias-built-environment/

[19] https://www.nabers.gov.au/ratings/our-ratings/nabers-embodied-carbon

The tool is founded on a national emission factors database[20] , which is a new standard for building product emission factors in Australia that was developed with industry collaboration.

The Building Sustainability Index (BASIX) is a sustainability assessment tool for residential buildings in NSW. BASIX requirements apply to all residential dwelling types in NSW and form part of the development application process, requiring new homes to meet certain minimum standards (for water and energy efficiency and thermal performance) and to report on construction materials being used so their embodied energy can be calculated as part of a Material Index. The Materials Index is expected to be a requirement in the future.

The BASIX Materials Index utilises the Environmental Performance in Construction (EPiC) database developed by the University of Melbourne[21], which 'is a comprehensive and consistent open-access Life Cycle Inventory of environmental flow coefficients for construction materials, containing over 1 000 embodied emissions, energy and water coefficients'.

Using the EPIC and NABERS databases is an alternative to conducting full LCA studies for the materials used in built-form construction.

Recommendation:

The Department of Energy, Mines, Industry Regulation and Safety (DEMIRS) review the NSW BASIX scheme's application of a Materials Index to require a similar calculation of embodied energy to be submitted with Building Permit applications.

5.4.6 Natural gas supply

The Phase 2 modelling illustrates the benefits of electrifying homes and transitioning away from natural gas supplies for household uses such as hot water, space heating and cooking. The Victorian government has introduced a ban on new gas connections. The policy utilises the development approval process (Amendment VC250):

Amendment VC250 was gazetted on 1 January 2024 and introduces new requirements for the construction of new dwellings, apartments and residential subdivisions that require a planning permit through a new particular provision at clause 53.03.

Clause 53.03 prevents a permit being granted to connect to reticulated natural gas when constructing a new dwelling, apartment development or subdividing land for residential purposes.

Recommendation:

The Department of Energy, Mines, Industry Regulation and Safety (DEMIRS) should review the progress of the Victorian scheme to introduce a similar ban on gas connections in new premises through the Building Permit process.

5.5 Resident choice and market demand

Although the interventions identified under this category cannot be directly controlled by the planning and design system (at present), awareness and information resources can be provided through the various methods of community engagement that occur during those processes.

[20] https://www.nabers.gov.au/publications/national-emission-factors-database

[21] https://msd.unimelb.edu.au/research/projects/current/environmental-performance-in-construction

5.5.1 Affordability

Reducing the average size of homes would lead to avoided emissions and improve affordability.

A selection of land prices from new developments across the metropolitan area is shown in Figure 33 ($ total) and Figure 34 ($/m²)[22]. Most of these are in the range of $350-$550k, with only a small reduction in price for smaller lots.

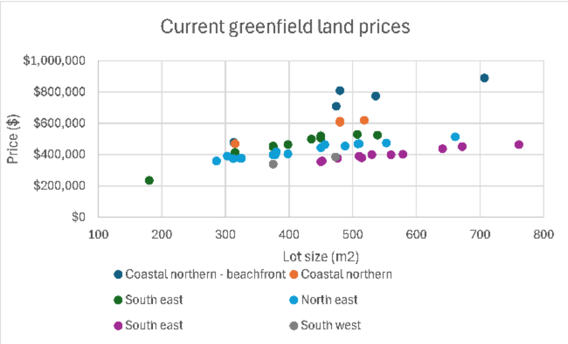


Figure 33 Greenfield land prices ($)

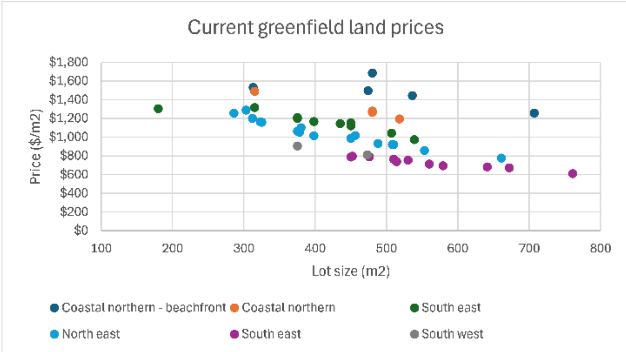


Figure 34 Greenfield land prices ($/m2)

The price of new project homes in various locations across the metropolitan area is set out in Figure 35[23] and represents a conventional single-storey house with double brick external walls and Colourbond or tile roof.

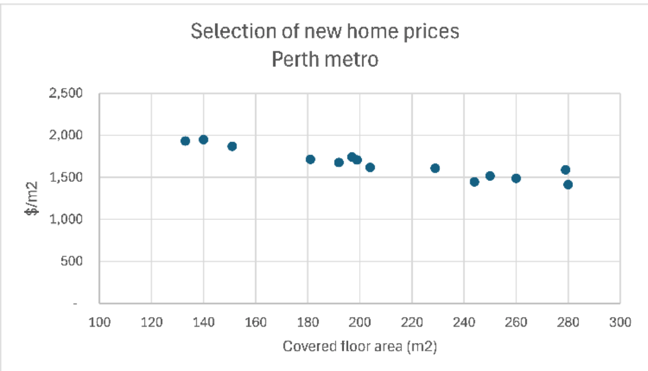


Figure 35 Project house prices ($/m²)

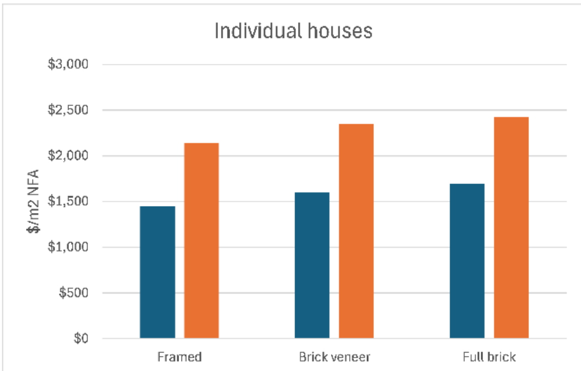


Figure 36 Project house prices for various constructions

Table 12 provides a comparison of 30-year costs and emissions between:

- a 3-4 bedroom house with a (presently average) net floor area of 225m² constructed of conventional materials on a 435m² lot; and
- a 3-4 bedroom house with a net floor area of 170m² constructed of lightweight materials on a slightly smaller 385m² lot.

The cost comparison assumes an 80% mortgage over 30 years at 5% pa interest. Emissions are calculated assuming grid electricity and gas supply are at current emission intensities.

Table 12 Housing costs and emissions

	Current average	Alternative	Saving

[22] Sourced from land developer websites
[23] Sourced from https://www.ibuildnew.com.au/house-and-land-packages-in-wa

House		$402,158	$300,570	$101,587	25%
Lot		$444,705	$421,333	$23,371	5%
		$846,862	$721,903	$124,959	15%
Deposit	20%	$169,372	$144,381	$24,992	15%
Loan	80%	$677,490	$577,523	$99,967	15%
Annual repayments @ 5% interest		$44,072	$37,569	$6,503	15%
Annual energy costs		$4,635	$4,029	$607	13%
Total costs over 30 years		$1,630,584	$1,392,297	$238,287	15%
Net present cost @ 7% discount rate		$723,159	$617,348	$105,811	15%
Emissions (kgCO2e)	Embodied	101,250	36,125	65,125	64%
	Operational	125,249	109,134	16,115	13%
		226,499	145,259	81,240	36%

The alternative lightweight, smaller dwelling would reduce the necessary deposit for homeowners by some $25,000, reduce annual repayments by around $6,500 and save around $240,000 over the life of the mortgage ($105,000 in net present costs). 30-year emissions are 36% lower for the alternative house and land[24].

It is often suggested that homeowners select large dwellings for resale value. However, the occupancy per dwelling has been falling for decades, so it is unlikely that there will be greater demand for large houses in the future. Indeed, there is a growing demand for downsizing as the population ages and a '... lack of appealing alternatives'[25] for those who wish to remain in houses rather than apartments.

The market is locked into 'path dependency', i.e. both homeowners and developers/builders continue to purchase/provide houses based on historical preference, even if more suitable alternatives are available.

Recommendation:

Given the urgency to reduce emissions, the cost-of-living pressures and the housing supply-demand deficit, a concerted effort by the government to improve awareness of the individual and societal benefits of 'right-sized', low emissions dwellings would be beneficial.

5.5.2 Electrification of homes

The electrification of homes is an essential element of an emissions reduction strategy and has been shown to reduce costs to homeowners[26]. There are various government incentive schemes involving energy upgrades more generally, including but not limited to electrification. A range of programs are available nationally and in other states, although not yet in Western Australia.

The federal government's Household Energy Upgrades Fund[27], the Clean Energy Finance Corporation (CEFC), will work with lenders (banks and green loan providers) to provide discounted finance products to help households upgrade their homes with:

[24] Subdivision related embodied emissions are neglected in this calculation.
[25] https://www.templeandwebster.com.au/rightsizing
[26] https://www.monash.edu/__data/assets/pdf_file/0005/3433550/Switching-On_Benefits-of-household-electrification-in-Australia_report.pdf
[27] https://www.energy.gov.au/rebates/household-energy-upgrades-fund

- Energy generation and storage: Solar PV systems and batteries, Solar hot water systems
- Heating and cooling: Double-glazed windows, insulation, air-conditioners, ceiling fans and heat pumps
- Miscellaneous: EV chargers, energy monitoring systems, pool pumps and induction cooktops.

A summary of the state-based schemes offering rebates for various products is set out here.

5.5.3 Private energy self-supply

The take-up of rooftop solar PV in Western Australia has grown exponentially in recent years (Grace, 2023). Although the rebates provided under the federal government's Small-scale Renewable Energy Scheme (SRES) are declining to the scheme's end in 2030, this is offset by the reduced capital cost of solar PV and home batteries. Accordingly, self-supply is likely to continue to grow strongly.

The Household Energy Upgrades Fund noted above includes solar and battery funding.

Recommendation:
Information on the state-based schemes offering rebates for the electrification of homes and the Household Energy Upgrades Fund be promoted through an awareness campaign.

5.5.4 Electric vehicles

The Western Australian government has a Zero Emission Vehicle (ZEV) Rebate Scheme[28] , which provides a financial incentive to encourage the purchase of zero-emission vehicles (excluding hybrid vehicles).

The ZEV rebate scheme provides owners a $3,500 rebate after purchasing an eligible vehicle and submitting an application form to the Department of Transport (DoT). At present, the scheme is due to end in May 2025.

Recommendation:
Extend the Zero Emission Vehicle (ZEV) Rebate Scheme beyond May 2025.

5.6 Mandatory climate reporting

The Australian Government's Treasury Laws Amendment (Financial Market Infrastructure and Other Measures) Bill 2024 (Cth) was enacted on 1st January 2025. This requires mandatory climate reporting for large businesses and financial institutions in Australia through amendments to the Corporations Act 2001 (Cth) and the Australian Securities and Investments Commission Act 2001 (Cth).

These requirements will require affected organisations to measure and disclose Scope 1, 2 and 3 emissions in accordance with the Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (2004)[29]. Developers and builders captured under the scheme will, therefore, be required to report not only on the Scope 1 and 2 emissions from their operations but also Scope 3 emissions (defined as emissions that '.. are a consequence of the activities of the company, but occur from sources not owned or controlled by the company'. Scope 3 downstream emissions include the so-called Category 11 'Emissions from end use of goods and services sold' by the

[28] https://www.transport.wa.gov.au/projects/zero-emission-vehicle-zev-rebate.asp
[29] https://ghgprotocol.org/corporate-standard

reporting company in the reporting year, including 'emissions that can be influenced by engagement with the end users of products created'.

It is not yet completely clear where the boundary will be for land developers selling only lots, but it could arguably include the construction and operation of houses, which is the 'end use' of the sold product and could be influenced through sales contracts. For builders, the construction of houses results in direct Scope 1 and 2 emissions and the operation of houses by owners, at least some of which would logically be considered the builder's downstream Scope 3 emissions (e.g. those arising from heating, cooling and lighting energy).

When the legislation matures in 2027, it will capture firms that meet 2 of the three criteria:

- Consolidated revenue: $50 million or more.
- Consolidated gross assets: $25 million or more.
- 100 or more employees.

The legislation does not capture all developers and builders in Western Australia, so the reporting will not comprehensively cover all relevant emissions. However, the larger developers and builders will be required to report emissions and 'the entity's material climate-related financial risks and opportunities' and 'governance, strategy, or risk management' regarding projected climate change.

Recommendation

Monitor the introduction of the mandatory climate reporting requirements for developers and builders to gauge their responses to obligations to reduce emissions, particularly concerning the 'end use' of the sold product.

5.7 Monitoring urban emissions

In order to evaluate progress in reducing emissions across the built environment, a greater focus could be placed on measurement and reporting. In addition to monitoring the mandatory disclosure reporting, several data sources are available for compilation in an annual report on residential-related emissions.

The National Greenhouse Accounts[30] include an inventory by economic sector for each state, including residential Scope 1 and 2 emissions. Annual changes can be matched with housing data to evaluate changes to per-dwelling emissions.

Subdivision works (DPLH)

The recommended requirement for land developers to report subdivision-related emissions will provide data over time that can be converted to per-dwelling embodied emissions.

Building permits (DPLH/LGA)

The recommended requirement for building permit applications is to include an assessment of embodied emissions, which can be collated and analysed to identify per-dwelling embodied emissions.

Energy data & rooftop solar / batteries (DMIRS)

[30] https://www.greenhouseaccounts.climatechange.gov.au/

Western Power collects data on electricity imported to and exported from residential premises. ATCO collects similar data on natural gas usage. This information can be analysed (as in this research) to evaluate residential emissions from network energy and avoided emissions from private solar / battery systems.

Emissions from transport (DoT/PTA)

The National Greenhouse Accounts includes vehicle emissions that can be disaggregated to provide information on private vehicles. Data on energy use in the public transport system can be obtained from PTA data sets.

EV take-up will be reflected in the vehicle emissions data but can also be tracked by the Australian Automobile Association.[31]

Urban greening (DPLH/LGA)

The present focus on urban greening could include assessments of carbon lost in clearing and sequestered in urban environments due to development/redevelopment.

Recommendation
Government agencies collaborate to establish a program for monitoring residential emissions.

[31] https://www.aaa.asn.au/research-data/electric-vehicle/

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