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We acknowledge and pay respect to the Tradition Owners of the Murray–Darling Basin and their Nations. We pay respect to the Traditional Owners of the lands and the waters upon and around which our organisations are situated. We acknowledge their deep cultural, social, spiritual, environmental and economic connection to their lands and waters. We pay respect to their Elders – past, present and future.

Authors

Arezoo Boroomandnia
Research Fellow
University of Sydney

Andrew Merchant
Deputy Project Leader
University of Sydney

Behzad Rismanchi
Project Leader
University of Melbourne

James John
Project Industry Leader
Renmark Irrigation Trust

Nick Waters
Managing Partner
Riparian Capital Partners

Julian Merchant
ESG Program Manager Wine Australia

Reihaneh Bandari
Research Fellow
University of Melbourne

Sam
Manager - Innovations and Strategic Partnerships
Murrumbidgee Irrigation

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Executive summary

Decarbonising the irrigation industry represents a significant opportunity to reduce emissions in Australian agriculture, particularly in the Murray–Darling Basin (MDB), which accounts for approximately 62% of national irrigation water use. Irrigation relies heavily on stationary energy for pumping and water delivery, exposing farm businesses to volatile electricity and diesel prices while contributing materially to regional and national greenhouse gas emissions.

Using a transparent, top-down approach based entirely on publicly available data, this report estimates that irrigation across the MDB generates between **4.5 and 9.01 Mt CO_2-e annually**. This corresponds to **0.53-1.06 t CO_2 per ML** of irrigation water, depending on assumptions regarding irrigation's share of agricultural energy use, and represents approximately **1–2% of Australia's total territorial greenhouse gas emissions**. Electricity dominates irrigation energy demand, with diesel accounting for a smaller but more emissions-intensive share in some regions. Emissions vary significantly across states, influenced by irrigation scale, grid-electrification levels, and differences in electricity emissions intensity.

Benchmarking these results against irrigation energy and emissions estimates from the United States and global studies, indicates that **the lower end of this range is more likely to reflect typical irrigation conditions**. Converting the emission intensities to implied energy use suggests irrigation energy requirements of approximately 0.7‑1.4 kWh/m^3, with the lower bound aligning closely with open-data estimates reported for the United States, while higher values represent more energy-intensive or conservatively allocated scenarios. Accordingly, the low-use scenario is considered the most plausible representation of current Basin-wide irrigation emissions, with the medium- and high-use scenarios serving as stress tests under uncertainty.

Evidence from regional site visits shows that investments in on-farm renewables, electrification, storage, microgrids, and small-scale hydro can significantly reduce operating costs, improve energy security and reliability, and deliver measurable emissions reductions while maintaining reliable irrigation supply. These interventions align strongly with ESG, net-zero, and sustainable finance objectives, and are supported by existing government incentives and green finance mechanisms.

The findings establish a robust Basin-wide baseline for irrigation emissions and confirm that decarbonising irrigation activities and systems represents a high-integrity, investable pathway that delivers emissions reduction, financial resilience, and long-term benefits for both the agricultural sector and the Basin as a whole.

1 Introduction

Australia has committed to deep emissions reductions under its 2030 and 2050 climate targets, aiming for a 43% reduction below 2005 levels by 2030 and net-zero emissions by 2050 (DCCEEW, 2025a). Achieving these targets requires meaningful progress across all sectors. The transition is already underway, driven by rapid expansion of renewable energy, national initiatives to electrify stationary equipment, and an increasing focus on resilience in regional and rural economies. However, meeting the 2030 milestone and staying on track for 2050 will require accelerated action in sectors traditionally considered hard to abate.

Agriculture is one of these sectors. It contributes 18% of Australia's total national emissions (DCCEEW, 2025a), largely from methane and nitrous oxide, but it also relies heavily on stationary energy, including diesel and electricity used for irrigation pumping, and other farm operations. Stationary fuels across agriculture represent a substantial share of operating costs and emissions, with exposure to fuel price volatility and grid constraints. The commonly cited figure of up to 16% is based on 2018 data (Heath, 2018), and with the recent surge in energy prices this proportion is likely to be considerably higher, although no comprehensive, up-to-date study is available to quantify the increase. Yet, compared with other sectors, agriculture—and irrigation in particular—has significant, unrealised potential for decarbonisation. Irrigated regions have abundant land, strong solar resources, and predictable seasonal energy loads that align well with on-farm generation, storage, microgrids, and deeper electrification of irrigation operations–extending beyond existing grid supply to include diesel displacement, load management, and improved energy resilience. Because irrigation requires energy for every unit of water abstracted, conveyed, and pressurised, water management decisions directly determine energy use and emissions. Given that the Murray–Darling Basin (MDB) represents approximately 62% of Australia's total irrigation water use (ABS, 2022), these characteristics make it a uniquely impactful region for targeted emissions reductions, enhanced energy self-sufficiency, reduced operational costs, and improved long-term climate resilience.

2 Methodology

Understanding the energy and emissions footprint of irrigation across the MDB requires a framework that operates across multiple spatial scales—from the national energy system down to farm-level irrigation practices. This report draws on the approach demonstrated by (Sowby & Dicataldo, 2022), who showed that robust irrigation-emissions estimates can be produced entirely from publicly available datasets, enabling transparency, repeatability, and future updates by researchers, industry groups, and the broader community. Following this principle, two complementary analytical pathways—a Top-Down method and a Bottom-Up method—were assessed. Each relies on a different combination of open-source energy, water, and emissions datasets and is summarised in Figure 1, which illustrates the hierarchical structure of inputs across the country, basin, state, and farm levels.

The Top-Down approach begins at the national scale and allocates Australia's agricultural energy use to irrigation activities within the MDB using proportional relationships between water use, land use, and state-level activity. It relies on a structured flow of information from the national scale to the Basin and then subsequently to the state level, drawing on consistent, annually reported datasets. This method is well suited to large-scale assessments because it integrates broad indicators of energy use, irrigation activity, and grid emissions intensity without requiring detailed farm-level measurements which often is rarely available. Its strengths lie in its transparency, repeatability, and alignment with national reporting frameworks, making it highly appropriate for Basin-wide emissions estimation. These characteristics mirror the open-data approach demonstrated by Sowby and Price (2025), who showed that publicly accessible, standardised datasets can generate reliable irrigation emissions estimates and can be continually improved as new public data are released.

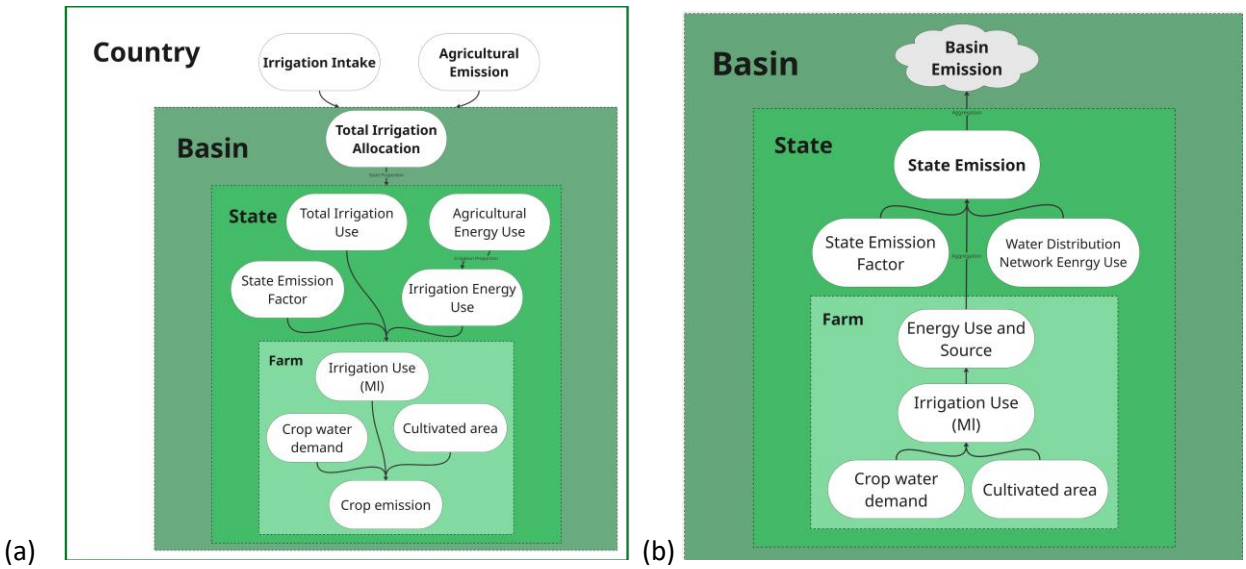

Figure 1. Overview of the two analytical pathways: (a) the Top-Down method; and (b) the Bottom-Up method.

The Bottom-Up approach builds estimates from the farm level by combining information on crop water demand, irrigated area, pump type, energy source, and water-distribution network operations. While it has the potential to provide greater detail and support analysis of specific interventions, it requires granular datasets that are not consistently available across the basin. In particular, trust-level pumping energy use, district water-delivery energy consumption, and detailed pump characteristics are either unavailable, inconsistently reported, or not publicly accessible. Compared with the Top-Down method, the Bottom-Up approach is more complex, difficult to scale, and less suited to consistent year-to-year Basin-wide estimation.

Given these constraints, the Top-Down method was selected as the primary approach for this report. It best matches the system boundaries of this study—spanning national agriculture, Basin-level irrigation activity, and state-specific energy and emissions profiles—and relies exclusively on publicly available datasets from sources such as the Australian Farm Institute, Sustainable Winegrowing Australia (SWA), Australian Bureau of Statistics (ABS), Murray–Darling Basin Authority (MDBA), Department of Climate Change, Energy, the Environment and Water (DCCEEW), ABARES, AEMO and Wine Australia. Using open data ensures transparency, repeatability, and the ability for future researchers and stakeholders to update results as new information becomes available.

Using the top-down method, the process begins with the national agricultural energy benchmark in 2023–24 published by DCCEEW. This value is represented as $E_{\text{agriculture}}$ in Equation 1. Available studies consistently show that irrigation accounts for a substantial but highly variable share of agricultural energy use in Australia. Reported values span from approximately 40% in sugar and other broadacre systems to 50–60% in dairy and cotton, and up to 80% in more intensive irrigation operations (Heath, 2018). Sector-specific data further illustrate this variability: horticulture is almost entirely irrigated and highly electricity-dependent; wine grapes derive nearly half of their emissions from purchased electricity for irrigation; and irrigation audits regularly find that pumping alone can represent 50–80% of a farm's total energy bill, requiring between 200 and 500 kWh/ML. Collectively, these findings confirm that irrigation is a major energy consumer across agricultural commodities, though its magnitude varies widely by crop type, water demand, and pumping configuration.

Equation 1

$$E_{Basin} = E_{agriculture,AUS} \times f_{MDB} \times f_{\text{Scenario}}$$

Given this spread and the absence of a unified national dataset, three irrigation-energy scenarios—40% (low-use), 60% (medium-use), and 80% (high-use)—were defined to provide a transparent, evidence-based structure for Basin-wide estimation. This proportional range is expressed as f_{scenario} in Equation 1. To determine the Basin share of national irrigation energy, a factor $f_{\text{MDB}}$is applied using irrigation-water statistics published by ABS, which indicate that 62% of national irrigation water use occurs within the MDB. The resulting Basin-level irrigation energy is then distributed across the four Basin states according to MDBA irrigation water-take proportions, as presented in Table 1. This distribution is represented by f_{state}in Equation 2. Based on the available time-series data, the proportion of irrigation water intake across states remains relatively stable, with only small variations (±3%) observed for NSW & ACT and QLD.

Within each state, irrigation energy was disaggregated into electricity and diesel components. Sustainable Winegrowing Australia indicated an average diesel share of approximately 12% of irrigation pumping energy in the 2020–21 financial year. But applying a uniform diesel share across all Basin regions is insufficient to reflect variations in grid accessibility and local infrastructure conditions. Information on electricity network coverage, including distribution and transmission infrastructure from the DCCEEW, further highlights the spatial variability in grid access across irrigation regions (Adriana Robaina, 2024). To address this limitation, a spatially explicit approach was developed to estimate diesel dependence based on proximity to electricity infrastructure. Using geospatial datasets of irrigated land and electricity transmission lines and substations, the distance from each irrigated polygon to the nearest grid connection point was calculated. Irrigated areas were then classified into three categories: (i) *Good access* (<10 km), (ii) *Moderate access* (10–30 km), and (iii) *Fringe or off-grid* (>30 km). Areas located beyond 30 km from transmission infrastructure were assumed to have limited or no access to grid electricity and therefore to rely predominantly on diesel-powered pumping (Mahapatra & Dasappa, 2012; Szabó et al., 2011). The proportion of these areas shown in Figure 2, expressed as a share of total irrigated land within each state, was used as a proxy for the diesel energy share ($f_{diesel,i}$), enabling a spatially differentiated estimation of energy sources across the Basin. Emissions are then calculated by applying state-specific grid-emission factors from AEMO and the diesel-oil emission factor from the *National Greenhouse Accounts Factors 2024*. Standard energy-unit conversions (PJ to MWh for electricity and PJ to GJ for diesel) ensure consistency throughout. Equation 1 and Equation 2 summarise the full allocation and emission-calculation process.

Equation 2

$$Emission_{Basin} = \sum_{i} \left(E_{Basin} \times f_{State} \times f_{diesel,i} \times C_{diesel,i}\right) + \sum_{i} \left(E_{Basin} \times f_{State} \times (1 - f_{diesel,i}) \times C_{grid,i}\right)$$

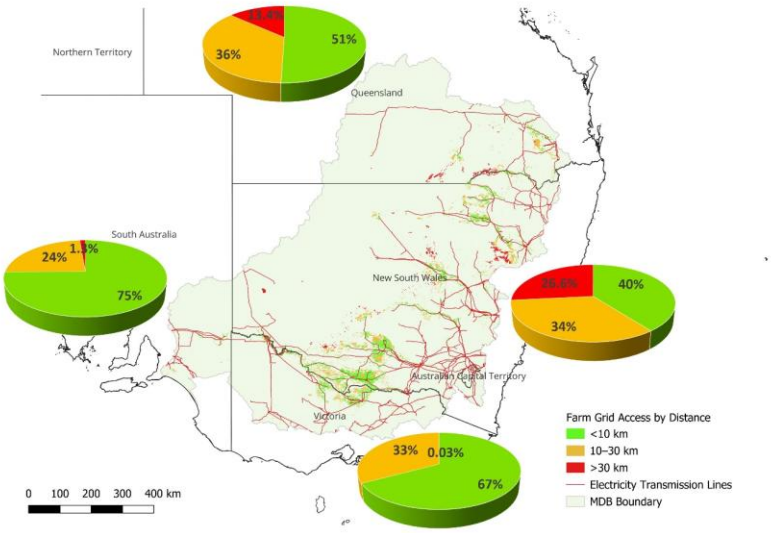

Figure 2. Grid accessibility of irrigated lands across the MDB, shown by distance to electricity transmission infrastructure (<10 km, 10‑30 km, >30 km)

The estimates presented here are subject to uncertainties arising from data gaps and the need for simplifying assumptions. National and Basin-scale datasets vary in temporal coverage, limiting their ability to reflect recent changes in irrigation technologies, electrification, or energy-supply configurations. While spatial overlays suggest widespread grid coverage across irrigated regions, publicly available data do not provide pump-level or farm-level information on grid connectivity, diesel reliance, or hybrid energy systems. The absence of targeted survey data, combined with the decentralised and heterogeneous nature of irrigation infrastructure, constrains the precision of state-level fuel allocations. Consequently, the results should be interpreted as indicative Basin-scale estimates rather than precise measurements; nevertheless, they provide a robust basis for strategic planning and clearly identify priorities for improved data collection and future refinement.

Table 1: Input data and statistics

Parameter		Value	Unit	Reference
Agriculture energy consumption in 2023-24		110.9	PJ	(DCCEEW, 2025b)
Irrigation energy use from total agricultural energy		40-80	%	(Heath, 2018)
energy for pumping water		200-500	kWh/ML	(David Eyre, 2014; Heath, 2018)
MDB irrigation volume proportion from total Australian farms 2021		62	%	(ABS, 2022)
Annual water take 2023-24	NSW & ACT	60.7	%	(MDBA, 2023, 2024)
	QLD	12.5	%	
	SA	6.1	%	
	VIC	20.7	%	
Conversion factor PJ to KWh		277.78×10^{6}	-	-
Grid emission factor 2023-24	NSW & ACT	0.66 (0.63)*	kg CO_2-e/KWh	(AEMO, 2025; DCCEEW, 2025c)
	QLD	0.71 (0.67)*	kg CO_2-e/KWh	
	SA	0.23 (0.15)*	kg CO_2-e/KWh	
	VIC	0.77 (0.77)*	kg CO_2-e/KWh	
Diesel pump share	NSW & ACT	26.6	%	Figure 2
	QLD	13.4	%	
	SA	1.3	%	
	VIC	0.03	%	
Emission factor for diesel oil		70.2	kg CO_2-e/GJ	(DCCEEW, 2025c)
Total Irrigation Volume across MDB		4,843,788	ML	(ABS, 2021-22)
Total Irrigation Volume across MDB		8,488,480	ML	(Meteorology, 2024)

* Values shown in parentheses are sourced from AEMO for the 2023‑24 financial year. However, as the figures reported by DCCEEW in the Australian National Greenhouse Accounts Factors are more commonly used by individuals and organisations to estimate greenhouse gas emissions, this report adopts that approach. In practice, the two sets of values are very similar.

To strengthen transparency, Table 2 summarises the system boundaries applied in the top-down assessment of irrigation-related emissions. The analysis focuses on stationary energy used for irrigation pumping and water delivery and uses total agricultural energy only as a benchmark to allocate irrigation energy shares. Non-irrigation energy uses and on-site renewable generation are excluded from explicit modelling, with irrigation electricity emissions estimated using average state-level Scope 2 grid emission factors and standard diesel emission factors consistent with national greenhouse accounting practice.

Table 2: System boundaries for the top-down irrigation emissions assessment

Component	Included	Excluded	Notes
Irrigation pumping (on-farm)	✓		Includes electricity and diesel used to abstract and pressurise irrigation water
Irrigation water delivery (district / network)	✓		Includes pumping and pressurisation within irrigation distribution systems
Total agricultural energy consumption	✓ (as starting benchmark only)		Used to allocate irrigation energy share (40–80%)
On-site renewable generation (e.g., solar PV/wind)		✕	Not explicitly modelled in the baseline; electricity emissions are estimated using grid emission factors, so this represents “typical grid-supplied electricity” conditions.
Farm machinery and tractors		✕	Mobile fuel use excluded
On-farm transport		✕	Vehicle fuel use excluded
Processing, packing, cold storage		✕	Post-harvest activities excluded
Farm buildings, sheds, lighting		✕	Non-irrigation electricity excluded
Electricity emissions (Scope 2)	✓		State-specific grid emission factors (National Greenhouse Accounts)
Diesel emissions (Scope 1)	✓		National Greenhouse Accounts diesel emission factor
Embedded emissions in infrastructure		✕	Capital construction emissions excluded
Fertiliser, methane, nitrous oxide		✕	Non-energy agricultural emissions excluded

3 Baseline Irrigation Emissions

Using the top-down allocation method, total irrigation-related emissions across the MDB were estimated under three irrigation-energy scenarios—low-use, medium-use, and high-use—reflecting the variability in published irrigation-energy intensities. The process begins with Australia's total agricultural energy consumption (110.9 PJ in 2023–24), from which only the irrigation portion is considered. After applying the Basin's 62% share of national irrigation activity, the MDB-specific irrigation energy becomes 68.76 PJ, which forms the core energy pool from which all scenarios are derived. The three scenarios represent alternative assumptions about how much of Australia's agricultural energy is attributable to irrigation. These yield Basin-level irrigation energy estimates of 27.5 PJ (low), 41.2 PJ (medium), and 55 PJ (high). These values anchor the first tier of the diagram and feed directly into state-level allocations (Figure 3).

The MDBA irrigation water-take proportions determine how Basin energy is distributed across New South Wales & Australian Capital Territory, Queensland, South Australia, and Victoria. Because NSW&ACT has the largest irrigated area, it consistently receives the largest share of irrigation energy across all scenarios, followed by VIC, QLD, and SA. This pattern is visible in the bar charts beneath each scenario block. Within each state, irrigation energy is allocated between grid electricity and diesel fuel based on available benchmarks and access to the electricity network. Electricity accounts for the majority of irrigation energy use across the MDB, reflecting the Basin's generally high level of grid connection. Although diesel represents a relatively minor share of total energy use, it can contribute disproportionately to irrigation-related emissions once end-use efficiency is considered. Electric pump–motor systems typically operate at overall efficiencies of 50–85%, whereas diesel engine–driven pumping systems commonly achieve 20–35% efficiency, particularly under variable load conditions (CottonAustralia). As a result, diesel pumping generally requires substantially more fuel energy to deliver the same volume of water, leading to higher emissions per unit of water pumped, even in jurisdictions where grid electricity has a higher emissions intensity per kWh.

For each scenario, energy use is converted to emissions using state-specific grid-intensity factors and the diesel emission factor from the National Greenhouse Accounts. The resulting Basin-wide emissions are illustrated in Figure 3 and Table 3 and summarised below:

- Low-use scenario: 4.50 Mt CO_2-e equals 0.53 t CO_2-e/ML
- Medium-use scenario: 6.76 Mt CO_2-e equals 0.8 t CO_2-e/ML
- High-use scenario: 9.00 Mt CO_2-e equals 1.06 t CO_2-e/ML

The pie charts highlight that NSW&ACT consistently contributes the majority of total emissions, both because it receives the largest irrigation-energy allocation and because its grid is more carbon-intensive than that of South Australia. VIC also exhibits a sizeable contribution despite its assumed 100% electrical pumping, owing to its comparatively high grid-emission factor. SA's contribution remains minimal, reflecting its clean electricity mix. QLD's contribution is moderate, driven by its moderate grid intensity and smaller irrigated footprint.

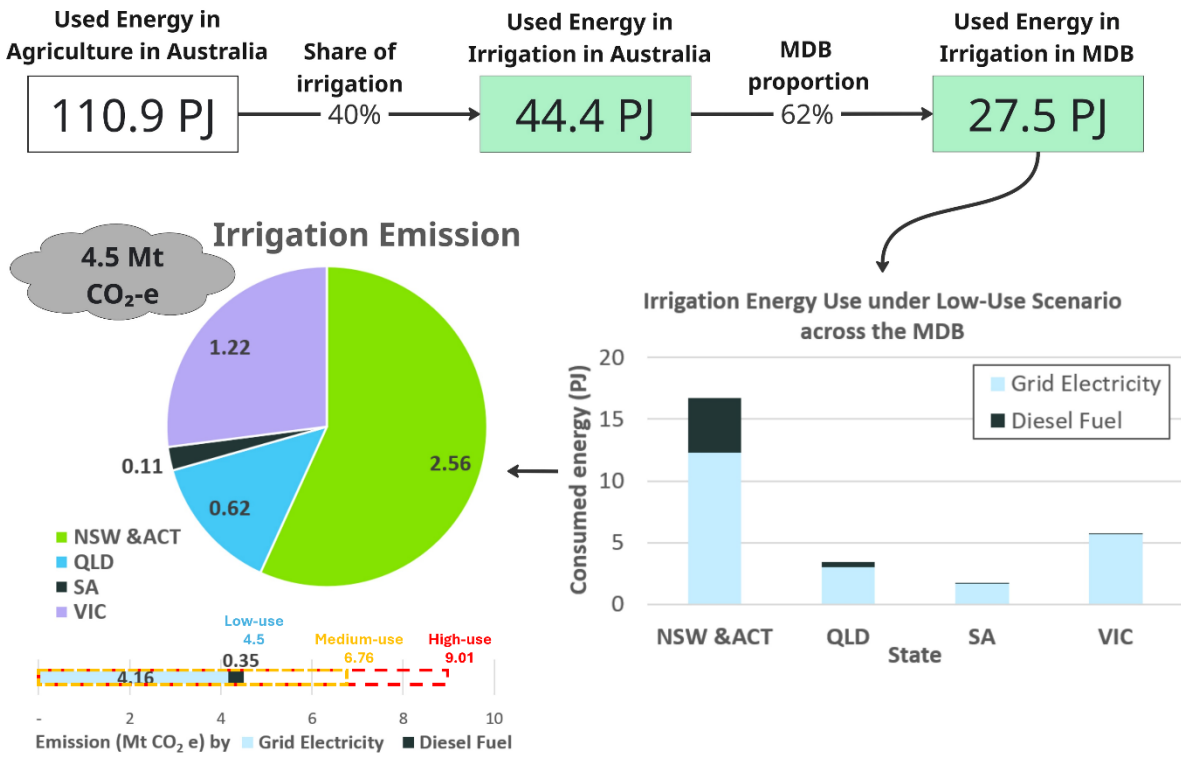

Figure 3. Breakdown of irrigation energy use and associated emissions across the MDB

Table 3: MDB emission under three scenarios

Scenario	State	Irrigation Energy share (PJ)	Grid (PJ)	Diesel (PJ)	Emission Grid (Mt CO_2-e)	Emission Diesel (Mt CO_2-e)	Total Emission (Mt CO_2-e)
High-use	NSW &ACT	33.38	24.51	8.87	4.49	0.623	**9.01**
	QLD	6.90	5.98	0.92	1.18	0.065	
	SA	3.34	3.30	0.04	0.21	0.003	
	VIC	11.38	11.38	0.00	2.43	0.000	
Medium-use	NSW &ACT	25.04	18.38	6.65	3.37	0.467	**6.76**
	QLD	5.17	4.48	0.69	0.88	0.049	
	SA	2.51	2.48	0.03	0.16	0.002	
	VIC	8.54	8.53	0.00	1.83	0.000	
Low-use	NSW &ACT	16.69	12.25	4.44	2.25	0.311	**4.50**
	QLD	3.45	2.99	0.46	0.59	0.032	
	SA	1.67	1.65	0.02	0.11	0.002	
	VIC	5.69	5.69	0.00	1.22	0.000	

Across all scenarios, MDB irrigation emissions fall within a stable range of roughly 4.5–9 Mt CO_2-e in 2024, depending on assumptions about irrigation's share of agricultural energy use. This range reflects existing

uncertainty in national irrigation-energy statistics while providing a robust Basin-wide emissions envelope. Importantly, the results confirm that:

- Electricity decarbonisation is the dominant lever for reducing irrigation emissions, particularly in NSW & ACT and Victoria, where grid electricity supplies most irrigation energy.
- Decentralised renewable energy solutions—such as on-farm solar PV, solar-powered pumping, and local microgrids—offer substantial abatement potential, especially in regions with high grid emission intensity or limited grid access, by directly displacing grid electricity and diesel use.
- Reducing diesel dependence delivers smaller but still meaningful emissions savings, particularly in NSW & ACT and Queensland, where off-grid and weak-grid irrigation systems remain common.
- Microgrids combining renewables, storage, and load management enable reliable irrigation operations while lowering emissions, supporting peak pumping demands and eliminating diesel use in remote or network-constrained areas.
- State-level grid emission intensities and geographic location strongly shape emissions outcomes, meaning similar irrigation energy use can yield very different emissions profiles across the Basin, reinforcing the need for spatially tailored decarbonisation strategies.

The estimated emission intensities imply irrigation energy requirements of approximately 0.7 to 1.4 kWh/m^3 across the low-, medium-, and high-use scenarios. Benchmarking these values against irrigation energy estimates from the United States indicates that the lower end of this range aligns closely with the first open-data estimate reported by (Sowby & Dicataldo, 2022), which found an average irrigation energy intensity of approximately 0.59 kWh/m^3. By contrast, the higher MDB scenarios correspond to more energy-intensive conditions, which may reflect higher pumping heads, a greater prevalence of pressurised irrigation systems, or conservative assumptions regarding irrigation's share of total agricultural energy use.

Global analyses further support this interpretation. Studies such as (Qin et al., 2024) report lower average emissions intensities for irrigation at the pump or system level, driven by differences in irrigation methods, pumping depths, and electricity mixes across regions. Taken together, these comparisons suggest that while the full MDB range represents a plausible upper-bound envelope under current data constraints, the low-use scenario is likely to be more representative of typical irrigation energy intensity, with the medium- and high-use scenarios serving as stress-test cases in the absence of detailed pump-level energy data. This reinforces the value of improved, targeted data collection to refine future estimates.

An alternative approach to estimating Basin-wide irrigation emissions is to base the calculation on total agricultural water consumption and an assumed energy intensity of water pumping. Using total agricultural water use of 8,488,480 ML (Meteorology, 2024) and applying a pumping energy intensity range of 200‑500 kWh/ML, as reported by (Heath, 2018) and summarised in Table 1. However, several limitations constrain the reliability of this method. Most notably, the resulting emissions are highly sensitive to the assumed range of pumping energy intensity. While the 200‑500 kWh/ML range is supported by publicly available national studies, case studies assessed by Landscape South Australia suggest that energy intensity can exceed 700 kWh/ML in some pressurised irrigation systems such as gun. These case studies, however, were provided through project industry partners, date back to 2016, and are not representative of the Basin as a whole. As this report is deliberately grounded in publicly available data, these higher values are not incorporated, although they indicate that the true upper bound of pumping energy intensity may be higher than assumed here. Using this approach, and accounting for state-level shares and specific emission factors, the resulting Basin-wide emissions are estimated to range between 1.13 and 2.81 Mt CO_2-e. This range is lower than the estimates derived under the three scenarios of the top-down method, although the upper bound is broadly consistent with the low-use scenario, reinforcing the higher likelihood of that scenario relative to the medium- and high-use cases. The discrepancy arises primarily from two factors. First, the pumping energy-intensity range is based on dated evidence and may not fully reflect current irrigation practices or technological changes across the Basin. Second, and more importantly, this water-

volume-based approach largely overlooks emissions associated with irrigation water distribution networks. Distribution infrastructure varies significantly across the Basin: in some catchments, such as the Murrumbidgee and Mallee, systems are predominately gravity-fed open canals, whereas in others such as South Australia, pressurised, piped networks dominate and require substantially higher energy inputs. This should not be read as open channels being 'better' than pipes overall: open-channel systems can have higher conveyance losses, while pressurised piped systems can deliver major water-efficiency and operational benefits–energy outcomes depend on local topography, service standards, and how the system is operated. Capturing these differences would require direct access to energy-use data from irrigation trusts, which is not currently available in public datasets.

Presenting emissions on a per–crop type basis could provide a useful metric for decision-makers seeking to reduce emissions by adjusting cultivation patterns. The time series in Figure 4 illustrates that the volume of water applied to different crop groups fluctuates substantially from year to year. These shifts largely reflect changes in water availability under entitlement and allocation rules—except for perennial tree crops, which are less flexible—as well as movements in global and domestic demand for agricultural commodities. Periods of high water allocations and strong commodity prices are typically associated with expanded irrigated areas and increased water use for annual crops, while dry years or weaker market conditions lead to contractions and reallocation of water between crop types.

In this report, irrigation-related emissions are estimated for the 2023–24 energy year, whereas the most recent crop-specific irrigation water-use data from ABS and ABARES underpinning Figure 4 extend only to 2021–22. Because crop patterns and water-use shares can change markedly between seasons, applying 2023–24 emissions estimates to 2021–22 crop-level water data would introduce significant uncertainty and potentially misleading results. For this reason, it is not methodologically robust to calculate precise emissions per litre for individual crop types; instead, the Basin-wide emissions estimates should be interpreted as aggregate benchmarks rather than crop-specific emission factors.

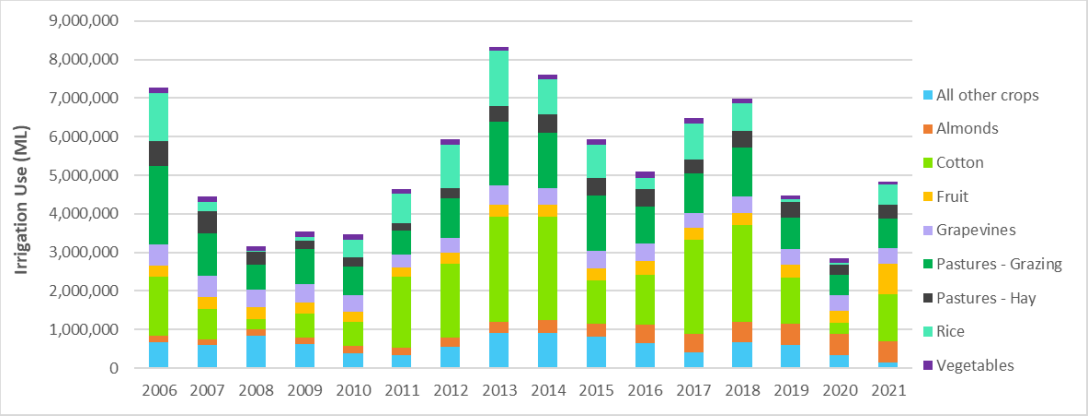

Figure 4. Irrigation intake by crop type across MDB from 2006 to 2021 (ABARES, 2025; ABS, 2021-22)

In summary, this Basin-wide result provides a defensible baseline to evaluate future interventions, compare irrigation technologies, and estimate per-ML emissions intensities for specific crop types.

4 Why Investors Should Care

For investors, decarbonising irrigation activities in the MDB represents a high-integrity opportunity that combines material reductions in operating costs, improved cash-flow stability, and measurable emissions reductions, while enhancing long-term system resilience. These investments align closely with government policy priorities, renewable-energy incentives, and emerging carbon and energy markets, and are already being demonstrated through practical on-farm and irrigation-district projects across the Basin. These aspects are elaborated in this section.

4.1 Reduced operating costs, improved investment resilience

Irrigation is one of the most energy-intensive activities in Australian agriculture, exposing farm businesses to significant electricity and diesel price volatility; however, recent Basin case studies demonstrate that targeted investments in on-farm renewables—particularly solar, electrification, and emerging small-scale hydro—can deliver substantial and predictable operating cost savings, with project-specific payback periods that depend on site conditions, capital structure, and energy prices. Site visits across the Riverland (SA), Red Cliffs/Mallee (VIC), and Narromine (NSW) show that solar systems sized between 180–500 kW, when directly coupled to irrigation pumps, can reduce annual energy bills by 60–70%. For example, a large mixed almond–citrus enterprise in the Mallee has installed approximately 700 kW of on-farm solar, reducing electricity costs from AUD 400–450k per year to around AUD 120k, while significantly improving cash-flow stability even after accounting for loan repayments. Similarly, a cotton operation in NSW replaced diesel-based pumping with a 500 kW solar system, achieving annual fuel savings of around AUD 180k and an estimated five-year payback, before transitioning to full electrification as the lowest-risk long-term option.

In addition to solar, small-scale hydro presents a complementary opportunity in portions of the MDB, particularly where existing irrigation channels, head differences, or regulated water releases can support run-of-network generation. In these settings, the primary value proposition is avoided electricity costs and improved energy reliability, with eligibility under Australia's Small-scale Renewable Energy Scheme (SRES) potentially providing supplementary benefits through Small-scale Technology Certificates (STCs) that improve project economics and reduce upfront capital costs. Larger hydro installations may instead be eligible under the Renewable Energy Target to generate Large-scale Generation Certificates (LGCs), providing an alternative revenue stream for appropriately sized projects.

While site-specific feasibility assessment is essential—particularly to manage water-delivery requirements to maximise efficiency and manage ecological considerations —small-scale hydro offers firm, dispatchable renewable energy that aligns well with irrigation operating profiles. Together, these observations confirm that irrigation decarbonisation—through solar, electrification, storage, and selective small- and large-scale hydro deployment—functions not only as an emissions-reduction pathway but also as a robust cost-management and resilience strategy for capital-intensive agricultural businesses. These findings are consistent with prior analyses showing that behind-the-meter renewable energy projects in agriculture can outperform traditional infrastructure investments when high and volatile energy costs are displaced (Beca, 2015; Nagrath, 2018). While such investments do not guarantee uniform financial returns across all settings, they consistently reduce exposure to energy price volatility and operating risk—characteristics highly valued by both farm businesses and long-term infrastructure investors.

4.2 ESG performance, and carbon market alignment

The Basin-wide emissions assessment confirms that the sector is highly relevant for investors with ESG, net-zero, and climate-risk mandates. Decarbonising irrigation activities and systems offers direct, measurable and attributable emissions abatement, primarily through the displacement of grid electricity and diesel with on-farm renewables, electrification, and microgrid solutions. Evidence from site visits and stakeholder discussion indicates that solar-powered pumping and electrified irrigation systems are already delivering verifiable reductions in Scope 1 and Scope 2 emissions while maintaining operational reliability across diverse production systems, including cotton, wine grapes, almonds, citrus, and mixed horticulture. Moreover, these reductions enhance the credibility of farm-level emissions reporting and position Basin agricultural products to better meet increasingly stringent emissions requirements in global markets, where buyers, financiers, and regulators are placing greater emphasis on product-level carbon intensity and traceable decarbonisation pathways. Beyond emissions reduction, irrigation decarbonisation can support

market access and value preservation for Basin agricultural products in increasingly emissions-sensitive export markets. For example, the wine sector provides a clear illustration of this dynamic: wineries supplying the EU and North American markets are increasingly required to measure, report, and disclose product-level emissions and broader sustainability metrics as a condition of market access. Reductions in irrigation-related emissions improve the credibility of farm-level and product-level carbon accounts, helping producers and processors meet buyer, financier, and regulatory expectations related to traceable decarbonisation pathways and declining carbon intensity.

Importantly, irrigation decarbonisation aligns well with emerging green and sustainability-linked finance mechanisms, including sustainability-linked loans, green loans (Becker et al., 2025; Prasun Kumar Das, 2023), and emissions-reduction incentive programs already being offered by major Australian banks (Cameron Armour, 2023). While awareness and uptake among Basin landholders remains uneven, these mechanisms increasingly reward projects that demonstrate measurable emissions reductions, energy efficiency improvements, or renewable-energy deployment. In addition, irrigation energy projects can interact with established compliance and voluntary markets—such as LGCs, state-based energy-savings schemes, and selected ACCU methodologies—enhancing revenue certainty and improving project bankability where eligibility conditions are met.

4.3 Long-term resilience

Beyond short-term cost savings and emissions reductions, investments in irrigation decarbonisation significantly enhance long-term operational and climate resilience across the MDB. This aligns with regional drought resilience plans, which consistently identify rainfall- and water-independent income sources, along with cost reductions, as critical to maintaining the financial viability of farm enterprises during prolonged dry periods. Field evidence from Riverland, Red Cliffs, and inland NSW demonstrates that energy infrastructure investments are increasingly integrated with water-security strategies, including co-located solar with pumping assets, batteries to manage irrigation load profiles, and decentralised microgrids that reduce reliance on fragile grid connections. In several cases, renewable electricity is effectively “stored” through pumped or diverted water, allowing production to continue during peak-price periods, heatwaves, or grid disruptions.

Importantly, irrigation decarbonisation also plays a growing role in maintaining access to international agricultural markets that are becoming increasingly stringent on carbon performance, particularly in Europe. Export-oriented sectors reliant on irrigated production–such as wine, horticulture, almonds, and cotton–are increasingly exposed to carbon disclosure requirements, sustainability standards, and emerging carbon border and supply-chain transparency mechanisms. By reducing the emissions intensity of irrigation, producers can strengthen the carbon credentials of irrigated commodities, reduce future trade and compliance risks, and protect long-term market access and price competitiveness in carbon-constrained markets. In this context, irrigation decarbonisation is not only an emissions-reduction strategy but also a strategic investment in export resilience and market positioning.

These approaches directly address risks identified by Basin landholders and investors, including exposure to electricity price volatility, fuel supply constraints, and climate extremes. At a policy level, irrigation decarbonisation is strongly aligned with Australian Government priorities around regional energy transition, emissions reduction, climate-smart agriculture, and sustainable water management. Public co-funding pathways through ARENA, CEFC, and CRC programs are already supporting feasibility studies and deployments, lowering development risk and enabling private capital to scale proven solutions. At the Basin scale, this supports business models that are more resilient to drought and climate shocks by stabilising cost structures and reducing dependence on variable natural inputs. This creates a pathway for

investors to participate in long-life, infrastructure-like assets that deliver stable returns, diversified income streams, and durable alignment with national emissions targets to 2030 and 2050.

5 Conclusions

This report provides the first Basin-wide estimate of irrigation-related emissions for the Murray–Darling Basin using a fully transparent, open-data methodology aligned with national energy and emissions reporting frameworks. This analysis is subject to several important sources of uncertainty. Most notably, Basin-wide irrigation emissions are inferred from publicly available national and state-level datasets rather than direct pump-level or irrigation-district energy measurements, requiring proportional allocation assumptions for irrigation's share of total agricultural energy use. Additional uncertainty arises from limited, dated, or sector-specific information on diesel versus electricity use for irrigation, spatial variability in grid access and emission intensities, and the absence of consistent data on irrigation distribution networks and on-farm renewable generation. Temporal mismatches between energy, water-use, and crop data further constrain precision. As a result, the estimates presented should be interpreted as indicative Basin-scale benchmarks rather than precise measurements, with the scenario range explicitly designed to bracket uncertainty and provide a robust envelope for strategic planning and investment assessment.

Based on a transparent, top-down analysis using publicly available data, this report estimates that irrigation across the MDB produces 4.5 to 9 Mt CO_2-e per year, equivalent to around 1–2% of Australia's total territorial greenhouse gas emissions. On a unit basis, this equates to 0.53–1.06 t CO_2 per ML of irrigation water, depending on assumptions regarding irrigation's share of agricultural energy use. Benchmarking against irrigation energy and emissions estimates from the United States and global studies suggests that the lower end of this range is more likely to reflect prevailing irrigation conditions across the Basin, with higher values representing more energy-intensive or conservatively allocated scenarios. As such, the low-use scenario is considered the most plausible representation of current Basin-wide irrigation emissions, while the medium- and high-use scenarios provide useful stress tests under uncertainty. The results show that irrigation emissions are material at both regional and national scales, and that decarbonising irrigation activities and systems has the potential to make a meaningful contribution to Australia's 2030 and 2050 climate targets. While the precise magnitude of emissions depends on assumptions about irrigation energy use, the scenario range presented establishes a defensible baseline for policy, investment, and further research.

The findings underscore that electricity decarbonisation is the primary lever for emissions reduction in irrigation, particularly in jurisdictions where grid electricity supplies most pumping energy. Reducing diesel reliance remains important in off-grid and weak-grid regions, where targeted electrification and renewable microgrids can deliver outsized emissions and cost benefits. The strong influence of state grid emission intensities on results reinforces the need for spatially tailored decarbonisation strategies rather than one-size-fits-all solutions across the Basin. Improving water-use efficiency represents an important complementary pathway, as reducing the volume of water applied directly lowers pumping energy requirements and associated emissions. Measures such as improved irrigation scheduling, system optimisation, and crop-appropriate irrigation technologies therefore offer dual benefits–reducing both water demand and energy use–while also improving farm productivity and resilience.

From an investment perspective, irrigation decarbonisation offers more than emissions reduction alone. Case studies across the MDB demonstrate strong financial performance, improved cash-flow stability, and enhanced resilience to climate and energy-market shocks. When combined with emerging green finance instruments, renewable-energy incentives, and government co-funding programs, these characteristics position irrigation decarbonisation as an infrastructure-like opportunity with long asset lives and diversified value streams.

Looking ahead, future work should focus on improving data availability—particularly around irrigation-district energy use, diesel pumping, and distribution-network operations—to enable more detailed bottom-up analysis and crop-specific emissions intensities. Integration of these results into the forthcoming S2H Decarbonisation Roadmap will support prioritisation of interventions, targeting of demonstration projects, and mobilisation of private capital. Overall, the analysis confirms that the "size of the prize" for decarbonising irrigation activities and systems in the Murray–Darling Basin is both large and actionable, offering tangible benefits for emissions reduction, farm profitability, and long-term Basin resilience.

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