

APPENDIX C.6: Poultry Sector Technology Assessment

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Technology assessments

Methane capture and utilisation (anaerobic digestions (AD))

Summary:

Anaerobic digestion (AD) is a biological process where microorganisms break down organic matter (e.g., poultry manure) in the absence of oxygen (AgriFutures Australia, 2023; Arriagada et al., 2019). This produces biogas (mainly methane and CO₂), which can be used for electricity, heat, or upgraded to renewable natural gas (Huang & Shih, 1981). It also produces digestate, a nutrient-rich byproduct usable as fertiliser, replacing synthetic inputs (Pierie et al., 2017). In Australian poultry systems, baseline methane emissions from dry litter are low; therefore, AD does not primarily reduce methane emissions but instead converts manure into an anaerobic system where methane is generated and captured in a controlled manner, displacing uncontrolled emissions pathways and fossil energy use. The applicability of anaerobic digestion in Australian poultry systems is fundamentally constrained by the dominance of dry litter systems; wet manure systems are limited, and co-digestion is typically required for viable operation.

Annual Abatement Potential (Technical):

AD has potential to reduce methane emissions where wet organic streams are available; however, in dry litter systems typical of Australian poultry production, the abatement potential is limited without significant system modification or co-digestion. AD can technically process poultry manure, but only a limited proportion is practically abatable due to a) high total solids, b) high ammonia content, which inhibits microbial activity. Dry anaerobic digestion (DAD) is being explored to address these issues, but no commercial-scale DAD plants for poultry manure currently exist (Shapovalov et al., 2020). Estimated abatable proportion is 10-30% with co-digestion (e.g., with food waste or dairy effluent) and advanced ammonia control technologies. Technical abatement potential is moderate due to the dry nature of poultry litter. Dry litter

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systems are less conducive to methane generation, limiting AD potential unless co-digested with wetter substrates (Arriagada et al., 2019).

Abatement Potential – Economic/Feasible:

Justification: Combining the methane pool with realistic technical extent (10%–30%) and 10-year adoption of 5%–20%, feasible abatement is $\sim 0.28\text{--}5.07 \text{ kt CO}_2\text{-e yr}^{-1}$. Barriers include dry-litter handling, capital and digestate markets noted in Australian assessments.

Breadth of application:

Ranking: Low

AD is technically feasible for poultry but not broadly applied in Australia. Most poultry farms use dry litter systems, which are less suitable for standalone AD.

Co-benefit potential

Ranking: High

Renewable energy generation. Odour reduction and improved air quality. Nutrient recovery via digestate. Waste diversion from landfill.

Barriers and Knowledge Gaps

Ranking: High

Lack of wet manure systems in poultry. High capital costs and long payback periods. Digestate regulation varies by state. Limited co-digestion infrastructure. Limited technical expertise and data (Kaparaju et al., 2023). Generally, not suitable for spent litter from meat chicken production (low moisture content). Layer manure has a high ash content which can also cause issues.

Stacking Potential

Ranking: High

Low-protein diets. Covered manure stockpiles.

Technology Readiness Level (TRL)

Ranking: 7

For poultry-specific AD, the TRL is lower than for other sectors, due to limited application and technical challenges with dry litter (Arriagada et al., 2019; Kaparaju et al., 2023).

Commercial Readiness Level (CRL)

Ranking: 4

Less wet manure than in piggeries and wastewater treatment (Gaudutis et al., 2023).

Enabling Potential

Ranking: Moderate

In the poultry sector, AD is currently more of a complementary technology since poultry predominantly use dry litter systems, which are not ideal for conventional wet AD. Poultry manure has high nitrogen content, leading to ammonia inhibition in digesters. These factors reduce the biogas yield and make mono-digestion (using poultry manure alone) technically and economically challenging. The manure type is more suitable for co-digestion.

Capital Costs: \$500,000–\$2 million depending on scale and complexity, likely more (Florin et al., 2009). Operating Costs: Moderate; offset by energy savings and fertiliser value. Based on this rough depiction we estimate 5-year costs of installation and implementation at ~\$8 million.

Financial benefits are difficult to estimate, but associated with:

- Co-digestion with other organic wastes improves biogas yield and economic return (Pierie et al., 2017).
- Digestate can replace synthetic fertilisers, offering cost savings (Pierie et al., 2017).
- Energy generation (electricity or heat) can offset farm energy costs.
- Payback periods of 2.5–3.5 years are possible in mixed-waste systems with poultry manure as a partial feedstock.

We estimate overall 5-year returns at a minimum of \$500,000.

Range: N/A

Focus on scaling, cost reduction, and digestate valorisation.

Summary:

Gasification is the partial oxidation of spent poultry litter at high temperatures (500–1,800°C). It produces syngas (CO , H_2 , CH_4) for energy generation (Jeswani et al., 2019; Santos Dalólio et al., 2017). Converts waste into ash or slag with reduced volume and emissions. Pyrolysis is the thermal decomposition in the absence of oxygen (250–900°C) (Hussein et al., 2017). It produces biochar, bio-oil, and syngas. Biochar can be used for carbon sequestration and soil improvement. Both are considered waste-to-energy technologies (AgriFutures Australia, 2023; ARENA, 2023; EFA., 2023; Hussein et al., 2017). These processes are slightly different compared to combustion of spent litter (see below dddddd dddddd dddddd dddddd dddddd dddddd dddddd).

Output: Pyrolysis and gasification can reduce emissions from manure by up to 70–95% depending on system design and energy recovery efficiency (Preuss & You, 2023). Biochar can sequester up to 50% of the carbon in the original manure, offering long-term carbon storage. Research confirm these estimates (Preuss & You, 2023).

Assuming technical extent 10%–25% of the industry over 10 years and adoption of 5%–15%, feasible abatement is $\sim 0.79\text{--}8.02 \text{ kt CO}_2\text{-e yr}^{-1}$.

Ranking: Low

Some pilot and demonstration projects (e.g., Renergi in Western Australia and Chandala Poultry) (ARENA, 2023; EFA., 2023).

Ranking: High

Co-benefit potential through:

- Biochar production: Enhances soil fertility, water retention, and carbon sequestration.

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- Renewable energy: Syngas and bio-oil can displace fossil fuels.
- Waste reduction: Diverts poultry litter from landfills or open-field application.
- Odour and pathogen control: High-temperature processing destroys pathogens and reduces odour.
- Circular economy: Converts waste into valuable products (biochar, energy, fertiliser).

Barriers and Knowledge Gaps

Ranking: Moderate-High

High capital investment. Moisture content of litter affects efficiency (Santos Dalólio et al., 2017). Regulatory complexity (air emissions, ash use).

Stacking Potential

Ranking: High

Can effectively be stacked with:

- Precision feeding (reduces nitrogen in manure).
- Covered manure storage (prevents methane loss before processing).
- Biochar application (as a soil amendment or carbon credit strategy).

Technology Readiness Level (TRL)

Ranking: 6

Demonstrated in pilot and pre-commercial settings in Australia and globally (Santos Dalólio et al., 2017). TRL is lower in poultry than for other livestock sectors due feedstock challenges and limited trials.

Commercial Readiness Level (CRL)

Ranking: 3

Small-scale trial exists. Commercial scale up is limited, reliant on grants/subsidies.

Enabling Potential

Ranking: High

Gasification and pyrolysis are not just standalone waste treatment technologies—they can act as platforms for broader system transformation through:

- Infrastructure integration: These systems can be co-located with feed mills, abattoirs, or regional waste hubs.
- Carbon accounting: Biochar produced through pyrolysis can be quantified and credited under carbon farming initiatives.
- Catalyst for circular economy: They enable nutrient recovery, energy generation, and waste valorisation.
- Supports adoption of other technologies: For example, precision feeding reduces nitrogen in manure, improving the quality of feedstock for thermal conversion.

Estimated Cost Range:

Estimated high capital costs \$8 million+ for commercial systems but depending on system size and emissions controls (Florin et al., 2009). Economic feasibility improves with co-location with other waste streams, reduced feedstock variability and pre-treatment costs, integration into circular economy models, and support to manage regulatory hurdles and emissions controls. We estimate 5-year costs at \$10 million, but given the stage of development, these are uncertain.

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Estimated Financial Benefits:

Financial returns are unclear, but are associated with:

- Energy savings: Syngas can offset electricity or heating costs.
- Biochar sales at approximately \$300–\$1,000/tonne depending on quality and market.
- Carbon credits: Potential revenue from biochar sequestration.
- Waste disposal savings: Reduced landfill or composting costs.

We provide a low 5-year estimate of \$500,000.

Investment in R&D and Commercialisation (expanded)

Range: limited investment in individual pilots apparent.

Combustion of litter*Summary:*

Direct burning or combustion of spent poultry litter converts organic matter into heat energy and ash, reducing methane and nitrous oxide emissions from manure decomposition (AgriFutures Australia, 2023; Florin et al., 2009; Watson & Wiedemann, 2018). It can be used for on-farm space heating (e.g., broiler sheds), electricity generation and ash recovery for fertiliser use. While combustion, gasification, and pyrolysis all involve the thermal treatment of biomass (like poultry litter), they are distinct technologies with different processes, outputs, and environmental implications (see Table 2 below).

Table 2: Difference in combustion, gasification, and pyrolysis technologies.

Feature	Combustion	Gasification	Pyrolysis
Oxygen presence	Excess oxygen (complete oxidation)	Limited oxygen (partial oxidation)	No oxygen (anaerobic)
Temperature range	800–1,200°C	800–1,500°C	300–700°C
Main outputs	Heat, CO ₂ , water vapor	Syngas (CO, H ₂ , CH ₄), biochar products, tar	Biochar, bio-oil, syngas
Energy use	Direct heat generation	Syngas can be used for electricity, heat, or fuels	Bio-oil and syngas for energy; biochar for soil
GHG mitigation	Displaces fossil fuels but emits CO ₂	Displaces fossil fuels; can reduce methane and N ₂ O	Sequesters carbon in biochar; displaces fossil fuels
Residue	Ash	Biochar and ash	Biochar (carbon-rich solid)

Source: Florin et al. (2009)

Annual Abatement Potential (Technical):

Based on 60–90% of manure-related emissions can be avoided if combustion is efficiently implemented (Costello, 2007). This equates to about 30,000–60,000 tonnes CO₂-e/year under current conditions. Combustion converts volatile solids into energy and ash, avoiding methane and nitrous oxide emissions.

Abatement Potential – Economic/Feasible:

We assume a relatively low technical extent of application 15%–35% and 10-year adoption 10%–30%. Based on these assumptions, the feasible abatement is ~03–21.26 kt CO₂-e yr⁻¹. Practical constraints are emissions controls, labour and ash logistics; heat use on farm strengthens deployment cases.

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Breadth of application:

Ranking: Low

Adoption in Australia is currently limited, with most litter used for land application or composting. There are technical, economic, and regulatory challenges.

Co-benefit potential

Ranking: High

Renewable energy generation. Reduction in pathogen load through high-temperature treatment. Ash as fertiliser, e.g., concentrated nutrients, especially phosphorus.

Barriers and Knowledge Gaps

Ranking: High

Very high capital costs for combustion systems and emissions control. Technical complexity and emissions control. Ash handling and disposal challenges due to high alkali and chlorine content. Air quality regulations (e.g., nitrogen oxides and sulfur oxides emissions). Feedstock variability (e.g., moisture, ash content) affects combustion efficiency.

Stacking Potential

Ranking: High

Can be stacked with litter drying systems (to improve combustion efficiency), covered manure stockpiles, biochar production (via pyrolysis) and precision feeding (to reduce nitrogen and ash content in litter).

Technology Readiness Level (TRL)

Ranking: 8

Systems like fluidised bed combustors and direct-fired furnaces are commercially available and proven.

Commercial Readiness Level (CRL)

Ranking: 4

While technically mature, commercial deployment in poultry farms is limited in Australia. Adoption is growing in the USA and Europe (e.g., Fibrowatt plants), but Australia lacks large-scale examples.

Enabling Potential

Ranking: Medium

Combustion of litter is primarily a complementary technology, but it can enable energy self-sufficiency on farms, support nutrient recycling via ash, and reduce reliance on land application of manure.

Estimated Cost Range:

Capital 5-year costs are estimated at ~\$10 million. There is a lot of variation depending on system size and emissions controls, and regulatory/compliance costs. Operating costs: Include fuel handling, ash disposal, and maintenance. Pre-treatment: Litter may need drying or densification (e.g., pelletising).

Estimated Financial Benefits:

Energy savings: Offsets propane/natural gas for heating. Ash value: Fertiliser-grade ash can be sold or reused. Waste disposal savings: Reduces transport and spreading costs. Payback period

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is estimated at 3–6 years depending on energy prices and system efficiency but probably does not include ongoing costs and regulatory/compliance costs. Hence, we estimate 5-year returns at \$5 million.

Investment in R&D and Commercialisation (expanded)

Range: unknown

Current investment seems to focus on improving combustion efficiency, emissions control, ash valorisation

Shed litter management

Summary:

Shed litter management refers to the in-shed practices used to maintain aerobic conditions in litter, which have potential to reduce the formation of methane and nitrous oxide relative to poorly managed systems, inside poultry sheds (AgriFutures Australia, 2023; Cockerill et al., 2020; Dunlop & Pepper, 2023).

Key practices include:

- Litter tilling: Mechanically disturbing litter to maintain friability and reduce caking.
- Ventilation and humidity control: To keep litter dry and reduce ammonia emissions.
- Litter amendments: Additives to reduce ammonia volatilisation and pathogen load.
- Moisture monitoring: Ensuring litter remains in the optimal 20–25% moisture range (Dunlop & Pepper, 2023).

Annual Abatement Potential (Technical):

Well-managed litter has potential to reduce GHG emissions by 10–40% compared to poorly managed systems. Ammonia emissions may be reduced by up to 60–80% with proper ventilation and litter conditioning. Methane and N₂O emissions are also potentially reduced by maintaining aerobic conditions in the litter.

Abatement Potential – Economic/Feasible:

With an applicable extent assumed to be 80%–100% and 10-year adoption estimated relatively low (10%) due to high existing adoption rates, feasible abatement is ~ 2–7 kt CO₂-e yr⁻¹. Costs per square metre are modest; consistent moisture control and ventilation discipline determine realised benefits.

Breadth of application:

Ranking: High

Shed litter management is applicable across conventional and free-range systems. All major growing regions in Australia. Litter turning is used by 89% of surveyed growers. Litter reuse is less common, with 32% adoption. Indicates high adoption of basic litter management, but moderate adoption of advanced practices like reuse and amendments.

Co-benefit potential

Ranking: High

Shed litter management offers high co-benefits for improved bird welfare (dry litter reduces footpad dermatitis), better air quality (lower ammonia and dust), reduced odour and pathogen risks, and enhanced fertiliser value of spent litter. High impact on animal welfare, environmental quality, and potential economic returns.

Barriers and Knowledge Gaps

Ranking: Medium

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Operational challenges, e.g., machinery use in sheds can be difficult, especially with high liveweight density. Health risks, e.g., litter turning may cause spikes in ammonia, dust, and odour. Biosecurity concerns, e.g., reuse of litter raises risks of disease transmission and pest management. Limited time between flocks, e.g., fast turnaround limits time for litter treatment. Supply constraints, e.g., shortages of traditional bedding materials (e.g., wood shavings, rice hulls) (Dunlop & Pepper, 2023). Evidence on the emissions impact of specific practices such as litter tilling is limited and in some cases contested.

Stacking Potential

Ranking: High

Shed litter management can be effectively stacked with:

- Precision feeding: Reduces nitrogen excretion, improving litter quality.
- Covered stockpiles: Preserves nutrient value post-removal.
- Composting or biochar: Enhances nutrient recovery from spent litter.
- Ventilation and heating upgrades: Improve litter drying and reduce emissions (Ren et al., 2023).

Technology Readiness Level (TRL)

Ranking: 9

Shed litter management is fully deployed and widely practiced across Australian poultry farms.

Commercial Readiness Level (CRL)

Ranking 9

Shed litter management is commercially mature, with widespread adoption and industry-supported best practice guidelines.

Enabling Potential

Ranking: Medium

Shed litter management is a complementary technology. It supports broader sustainability goals (e.g., nutrient cycling, animal welfare).

Estimated Cost Range:

Costs vary depending on bedding material: Wood shavings, straw, rice hulls, machinery, e.g., litter tillers or conditioners, ventilation and heating upgrades. Litter is described as one of the largest operational investments for growers, and we estimate 5-year investments at approximately \$450,000.

Estimated Financial Benefits:

The benefits accrue in ways that are financially difficult to estimate through improved bird performance and welfare, reduced bedding costs through reuse, revenue from spent litter sold as fertilizer, compliance with accreditation and biosecurity standards, reduced environmental impact and odour complaints.

Investment in R&D and Commercialisation (expanded)

Range: Unknown

Ongoing RD&E foci include development of best practice manuals, ammonia and odour monitoring, litter amendment trials, spent litter utilisation studies. There is currently limited research to verify whether tilling, etc. achieves a benefit or whether may contribute to breaking up the topsoil layer.

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Covered stockpiles

Summary:

Covered stockpiles refer to poultry litter (manure mixed with bedding) that is temporarily stored outdoors under a protective cover (e.g., plastic sheeting or tarpaulin) to:

- Prevent nutrient leaching into soil and water.
- Reduce ammonia (NH₃) and GHG emissions (methane and nitrous oxide).
- Preserve the fertiliser value of the litter

Covers can be:

- Plastic tarps (low-cost, temporary).
- Permanent roofed structures (higher cost, more durable).

Covered stockpiles are best viewed as a nutrient-retention, environmental-protection and risk-management practice that can also reduce ammonia and greenhouse-gas emissions from litter storage. Benefits are greatest where litter is stored outside for extended periods and exposed to rainfall (Kamp & Feilberg, 2024). However, in Australian poultry systems the incremental emissions reductions achievable through covered storage are likely to vary substantially depending on existing litter-management practices and current rates of adoption of covered storage.

Annual Abatement Potential (Technical):

We estimate technical potential by targeting all manure storage and treatment emissions stemming from stockpiles, estimated at 10-30% of all of the total manure related emissions (225.0 kt CO₂-e yr⁻¹), or 22-67.5 kt CO₂-e yr⁻¹. Farm-scale measurements show large cuts in ammonia and nitrous oxide and meaningful methane reductions under coverage; we adopt 30%–65% as technical reduction where covers are applied promptly and continuously.

Abatement Potential – Economic/Feasible:

With above as technical reduction, and extent of application assumed to be 40%–60% and 10-year adoption 20%–40%, feasible abatement is ~ 1–19 kt CO₂-e yr⁻¹. Low cost and simplicity favour rapid uptake, noting the need to manage emissions when covers are removed.

Breadth of application:

Ranking: Moderate

Moderate industry potential, highly dependent on current management practice and storage duration.

Co-benefit potential

Ranking: High

Odour reduction. Improved nitrogen retention in manure for fertiliser use. Reduced runoff and leaching, compliance with water quality regulations. Improved soil health when litter is later applied as fertiliser.

Barriers and Knowledge Gaps

Ranking: Moderate

Initial setup costs for permanent structures (e.g., sheds or bunkers). Labour and time required to manage tarps or covers effectively. Lack of awareness or training on best practices. Regulatory complexity and variation across jurisdictions. Manure as a product is classed differently in different jurisdictions, e.g., as industrial waste in Victoria and New South Wales, while considered an agricultural product or soil amendment in Queensland, South Australia and

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Western Australia. Differences affect licensing, transport, and reuse requirements. Consistency in classification of manure as a product across jurisdictions is needed. Land requirements for litter storage can be a barrier. Covers can degrade quickly depending on management and climate with regular replacement costs.

Stacking Potential

Ranking: High

Can be combined with:

- Precision feeding (reduces nitrogen excretion, improving litter quality).
- Composting systems (covered piles can transition into composting).
- Biochar or combustion (covered litter retains nutrients for further processing).
- Anaerobic digestion (if co-digested with wetter waste streams).

Technology Readiness Level (TRL)

Ranking: 9

Covered stockpiles are a fully mature and widely proven technology.

Commercial Readiness Level (CRL)

Ranking: 8

Commercially available and easily implemented. Proven market applications. Established supply chains (e.g., tarp suppliers, shed builders).

Enabling Potential

Ranking: Moderate

Covered stockpiles are a complementary technology, they support nutrient management and regulatory compliance.

Estimated Cost Range:

Plastic covers: ~\$15–20/m² for heavy-duty recycled HDPE or \$300 – \$9,450 per Polytex cover (fabric size dependent). Permanent welded shed: \$100,000–300,000+ depending on size and materials. A value of \$100,000 is given as the indicative of cost of setup, and 5-year operations.

Estimated Financial Benefits:

Financial benefits are difficult to estimate, but a variety of benefits can accrue with financial implications:

- Preserves nitrogen in litter, increasing its fertiliser value.
- Reduces environmental compliance risks (e.g., runoff, odour).
- Minimises nutrient loss, improving soil application efficiency.
- Potential insurance benefits for improved environmental risk management.

Because these are easily valorised in minimum 5-year return of \$0 is given.

Investment in R&D and Commercialisation (expanded)

Range: Unknown

Covered stockpiles are not a major focus of R&D investment. However, they are often included in best practice guidelines and extension programs. Investment is more likely to come through broader waste management or nutrient stewardship programs.

Feed additives*Summary:*

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Feed additives including enzymes (e.g. phytase, protease), amino acids, organic acids, probiotics, and phytogenics act through different mechanisms such as improving nutrient digestibility, balancing amino acid supply, and altering gut microbial function. These effects can reduce nitrogen excretion and subsequently lower ammonia and nitrous oxide emissions from manure (AgriFutures Australia, 2023; Bundgaard et al., 2014; Lewis et al., 2015). Effects are broadly associated with lower crude protein diets and are here assumed to include this intervention (de Rauglaudre et al., 2023).

Annual Abatement Potential (Technical):

Output: Feed additives can reduce nitrogen excretion by 15–30%, depending on additive type and diet formulation. Estimated emission reduction: Up to 10–15% of total poultry emissions when combined with low-protein diets and improved feed conversion ratios.

Based on the proportion of emissions from feed and manure, and the additive's ability to reduce nitrogen losses and improve feed efficiency.

Abatement Potential – Economic/Feasible:

Output: With technical extent 80%–100% and 10-year adoption is given a wide range (30%–80%) reflecting current industry adoption being high and uncertainty about continuous improvement. Based on these assumptions, feasible abatement is $\sim 3\text{--}26 \text{ kt CO}_2\text{-e yr}^{-1}$.

Breadth of application:

Ranking: Moderate-High

Change in low-capex and familiar with strong potential for continuous improvement. Widespread in commercial operations. Enzymes (e.g., phytase, protease) and amino acids (e.g. lysine, methionine) are standard in most broiler diets (Lewis et al., 2015). Emerging adoption of advanced additives (e.g., phytogenics, probiotics). Remaining opportunities are likely to come from incremental improvements, the integration of increasingly sophisticated nutritional strategies, and adoption of emerging additive classes where evidence and economics support their use.

Co-benefit potential

Ranking: High

Additives improve feed efficiency, growth rates, bird health and gut function. Reduced ammonia emissions, improving shed air quality. Lower feed costs and better nutrient retention. Reduced environmental impact of manure. Reduced feed costs through better nutrient utilisation.

Barriers and Knowledge Gaps

Ranking: Medium

Cost of specialised additives (e.g., nano-formulated or novel enzymes). Need for formulation expertise to balance amino acids correctly. Regulatory approval for novel additives.

Stacking Potential

Ranking: High

Compatibility with litter management (reduces nitrogen in manure), covered stockpiles (less ammonia loss), nutrient recovery (more concentrated nutrients).

Technology Readiness Level (TRL)

Ranking: 9

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Fully deployed and validated in commercial poultry systems.

Commercial Readiness Level (CRL)

Ranking: 8-9

Commercially mature with widespread industry use.

Enabling Potential

Ranking: Medium

Feed additives are a complementary technology:

They support broader sustainability goals, but do not independently drive systemic transformation.

Estimated Cost Range:

Five-year costs are assumed to be around \$500,000 but will vary widely by additive and the scale of operation. Indicative price differences sources for this study suggest the following cost estimates: enzymes (Phytase, Xylanase, Protease): \$5–\$15 per tonne of feed. Amino acids (Lysine, Methionine, Threonine): \$10–\$30 per tonne, depending on type. Organic acids (Formic, Propionic, Citric): \$5–\$10 per tonne of feed. Probiotics (Bacillus subtilis (e.g., Calsporin®): \$10–\$25 per tonne of feed. Phytogenics: \$15–\$40 per tonne of feed.

Estimated Financial Benefits:

Financial returns will vary widely, but there is general acceptance that feed additives can improve performance and create co-benefits that produce returns that are comparable or in excess of costs, underpinning their high adoption rates in the industry, especially through reducing overall feed costs (less protein required), improving growth rates and feed conversion ratios, and reduced environmental compliance costs (e.g., ammonia control).

Investment in R&D and Commercialisation (expanded)

Investment in related R&D could not be identified.

Precision feeding

Summary:

Precision feeding involves daily adjustment of feed composition to match the changing nutrient requirements of broilers (Moss et al., 2021) and puts feed additives (above) into a larger strategic intervention through models, programs and systems that enable variable degrees of precision of feeding. It reduces nitrogen excretion, lowering ammonia and nitrous oxide emissions and overfeeding of protein, which leads to inefficient nutrient use and environmental pollution. Reducing crude protein by <2% can lower litter nitrogen by 18%. Emissions reductions are driven by improved feed efficiency and reduced nitrogen excretion.

Annual Abatement Potential (Technical):

We estimate technical potential by targeting manure nitrous oxide (direct and indirect) (131.2 kt CO₂-e yr⁻¹). Frequent or daily adjustments to energy and amino acids reduce surplus nitrogen; Australian trials report efficiency gains consistent with a 10%–25% technical reduction where blending hardware and analytics are in place (Moss et al., 2021).

Abatement Potential – Economic/Feasible:

With potential abatement as above and technical applicability estimated as 50%–80% and a wide 10-year adoption range as per 30%–80%, feasible abatement is ~ 2–21 kt CO₂-e yr⁻¹.

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Adoption is moderated by software, data workflows and training according to by Australian stakeholders.

Breadth of application:

Ranking: Low – Medium

Phase feeding is already an established practice. Adoption of precision feeding is increasing in integrated broiler operations that have access to feed blending systems. Social and market demand for larger eggs is driving the need to improve feed conversion ratios to support production of larger eggs efficiently.

Co-benefit potential

Ranking: High

Improved bird health and welfare through tailored nutrient delivery. Reduced ammonia emissions, improving air quality in sheds. Enhanced feed conversion ratio and carcass uniformity. Lower nitrogen excretion, improving litter quality and reducing environmental impact. Reduced reliance on imported soybean meal, supporting local feed industries (Olejnik et al., 2022).

Barriers and Knowledge Gaps

Ranking: Medium

Implementation cost is a barrier; positive net benefits if feed savings exceed high capital and training expenses. Limited software tools for max-profit and stochastic feed formulation. Insufficient training for nutritionists and producers. Data gaps in non-integrated farms (e.g., lack of real-time nutrient analysis). Cost of equipment and integration with existing infrastructure (Olejnik et al., 2022). Performance indicators focused on least-cost diets, discouraging innovation.

Stacking Potential

Ranking: High

Nutrient recovery: Precision feeding can reduce nitrogen excretion, enhancing nutrient recovery efficiency. Anaerobic digestion: Lower nitrogen improves digestate quality. Carbon accounting systems: Precision feeding provides granular data for emissions tracking. Breeding programs: Supports genetic selection for feed efficiency.

Technology Readiness Level (TRL)

Ranking: 8

Demonstrated in operational environments. Qualified through test and demonstration in final form.

Commercial Readiness Level (CRL)

Ranking: 4

Early commercial deployment in integrated operations. Growing market confidence and pilot-scale commercialisation (Moss, 2022).

Enabling Potential

Ranking: High

Precision feeding is best classified as an enabling technology. It supports system transformation in feed formulation, nutrient recovery, and carbon accounting. It catalyses adoption of

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complementary technologies like smart sensors, automated feeders, and microbial management (Moss, 2022).

Estimated Cost Range:

The major capital expenditure inputs into the setup of precision feeding include: feed blending systems (~\$50,000–100,000 per shed), and software and sensors (~\$10,000–30,000 depending on scale). Ongoing operational costs include training and integration into systems and workflows: Additional costs for staff and system upgrades. Overall, 5-year costs are estimated at \$700,000, which will vary widely, but include high upfront investment.

Estimated Financial Benefits:

Benefits in financial terms were not obtainable, but include:

- Feed cost savings: Up to 4.13% per kg live weight.
- Improved FCR: ~4.6% increase in feed efficiency.
- Reduced feed waste and associated savings in inputs.
- Improved carcass uniformity: Enhances marketability and processing efficiency.

This suggests that financial benefits of precision feeding will exceed costs within ~5-year timeframe. We assume break-even within this timeframe, in the absence of usable data.

Investment in R&D and Commercialisation (expanded)

Range: N/A

Poultry breeding programs

Summary:

Poultry breeding programs involve genetic selection to improve traits such as:

- Feed conversion ratio.
- Growth rate.
- Meat yield.
- Disease resistance.
- Reproductive efficiency.

In the context of emission reduction, breeding programs aim to produce birds that:

- Require less feed (reducing emissions from feed production).
- Excrete less nitrogen (lowering nitrous oxide and ammonia emissions).
- Grow faster and more efficiently, reducing resource use per unit of meat or egg produced (de Verdal et al., 2013; Leinonen & Kyriazakis, 2016).

Annual Abatement Potential (Technical):

We estimate technical potential by targeting manure nitrous oxide (direct and indirect) (131.2 kt CO₂-e yr⁻¹). Ongoing improvements in feed conversion ratio (FCR) and nutrient utilisation—driven in part by genetic selection—reduce feed demand, manure output, and nitrogen excretion per unit of production. These improvements are typically incremental, with evidence indicating ~1% per year reductions in emissions intensity, accumulating to ~5–15% over a decade, depending on the rate of realised genetic gain and system-level constraints (Leinonen & Kyriazakis, 2016).

Abatement Potential – Economic/Feasible:

With industry-wide technical suitability and high 10-year adoption of 80%–100% as new genetics diffuse through commercial strains with relatively low friction, feasible abatement is ~5–20 kt CO₂-e yr⁻¹. Gains are incremental but broad-based and stack with nutritional strategies.

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Breadth of application:

Ranking: High

Most birds in Australia are sourced from global breeding companies (e.g., Aviagen). Advanced breeding technologies (genomics, AI) are increasingly used.

Co-benefit potential

Ranking: High

Improved feed conversion ratio and potentially reduces feed costs and emissions. Enhanced bird health and welfare, including reduced skeletal deformities and mortality. Lower nitrogen excretion, improving litter quality and reducing ammonia emissions. Greater adaptability to free-range and organic systems, supporting market diversification. Genomic selection improves disease resistance and productivity.

Barriers and Knowledge Gaps

Ranking: Moderate

Regulatory constraints and standards can limit innovation. Reliance on international breeding pipelines means the rate of improvement is influenced by global breeding company priorities, breeding objectives and access to new strains suitable for Australian production systems. High upfront investment in breeding infrastructure and data systems. Knowledge gaps in genetic selection and performance monitoring.

Stacking Potential

Ranking: High

Precision feeding: Breeding for nutrient efficiency enhances feed strategies. Low crude protein diets: Genetically efficient birds require less protein. Nutrient recovery: Lower nitrogen excretion improves manure processing. Carbon accounting: Genomic data supports emissions tracking.

Technology Readiness Level (TRL)

Ranking: 9

Commercial breeding programs are mature and market driven.

Commercial Readiness Level (CRL)

Ranking: 9

Global breeding companies (e.g., Aviagen) supply most Australian poultry genetics.

Enabling Potential

Ranking: High

Drives system-wide transformation in feed efficiency, welfare, and emissions. Poultry breeding programs can influence technologies like:

- Precision feeding.
- Low crude protein diets.
- Manure management.
- Energy efficiency upgrades.

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Estimated Cost Range:

Most commercial poultry farms in Australia do not run independent breeding programs. Instead, they source genetically improved birds from specialist breeding companies or hatcheries. This means adoption of new strains happens relatively smoothly and is low cost, effectively zero.

Estimated Financial Benefits:

A variety of benefits relate to financial performance, contributing to our rough, 5-year estimate of \$225,000 for an average operation in value creation driven by breeding improvement. Benefits include:

- Feed cost savings: Up to 15% reduction in feed use per kg of meat.
- Improved productivity: Faster growth and higher meat yield.
- Lower mortality and better welfare: Reduces losses and improves marketability.
- Estimated return on investment: High, especially in integrated systems.

Investment in R&D and Commercialisation (expanded)

No data available

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