Plant & Food Research
Rangahau Ahumāra Kai

EECA
TE TARI TIAKI PŪNGAO
ENERGY EFFICIENCY & CONSERVATION AUTHORITY

REPORT

Baking Global Technology Scan

November 2024

Prepared by Plant & Food Research

Executive summary

EECA (Energy Efficiency and Conservation Authority) aims to mobilise New Zealanders to be world leaders in clean and clever energy use.

EECA's sector decarbonisation programme provides tailored tools and resources to help commercial bakeries be more energy efficient and lower their carbon emissions.

EECA engaged Plant & Food Research to undertake this technology scan looking at emerging technologies and innovation within the baking sector both locally and globally, and defining how these could be applied within the New Zealand context.

The top technologies and practices recommended from the findings of this report, include:

Process Technology

Electric Ovens: Studies suggest potential future viability with integrated heat recovery. However, at present electric ovens are costly due to the lower cost of natural gas and existing infrastructure gaps.

Improved tunnel oven: Combine hybrid convection and radiant heat, allowing for more precise temperature control and energy-efficient baking.

Heat Recovery

High Temperature Heat Pumps to recover and reuse low temperature heat: A robust decarbonisation solution by utilising waste heat from the production process.

Heat Recovery from Exhaust Gas: This technology provides higher greenhouse gas (GHG) savings compared to insulation upgrades, while remaining low-cost with a high Technology Readiness Level (TRL).

Fuel Switching

Dual Fuel Burners: This flexible option utilises natural gas now, with the capability to switch to electricity in the future.

Hydrogen Burners for Ovens: Future potential exists as infrastructure develops. Currently associated with high operational costs due to limited hydrogen production.

Efficiency and Monitoring

Oven Insulation Upgrades: An affordable and easy to implement solution but with minimal impact on greenhouse gas (GHG) emissions.

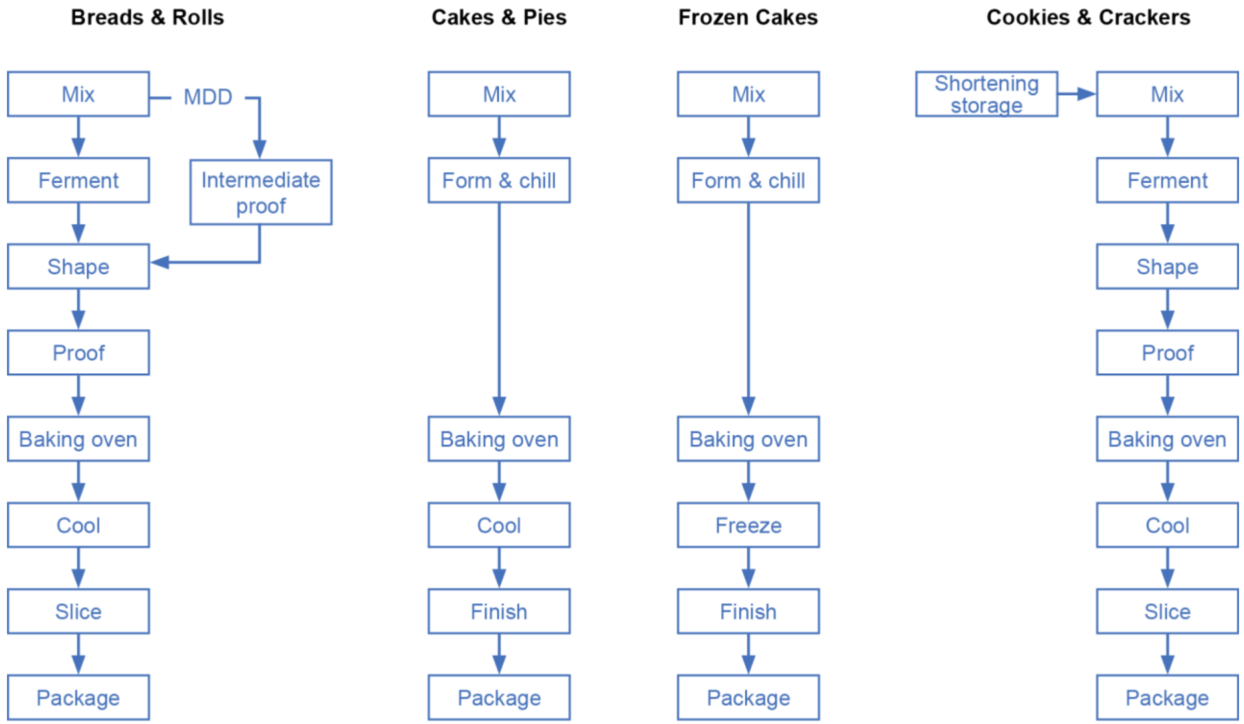
Exhaust fans with variable dampers: By optimising exhaust systems with variable dampers and adjusting fan drives, bakeries can reduce energy consumption and improve oven efficiency.

Process Scanning & Optimisation: A low-cost, high Technology Readiness Level (TRL) option, although it offers limited greenhouse gas (GHG) emission savings.

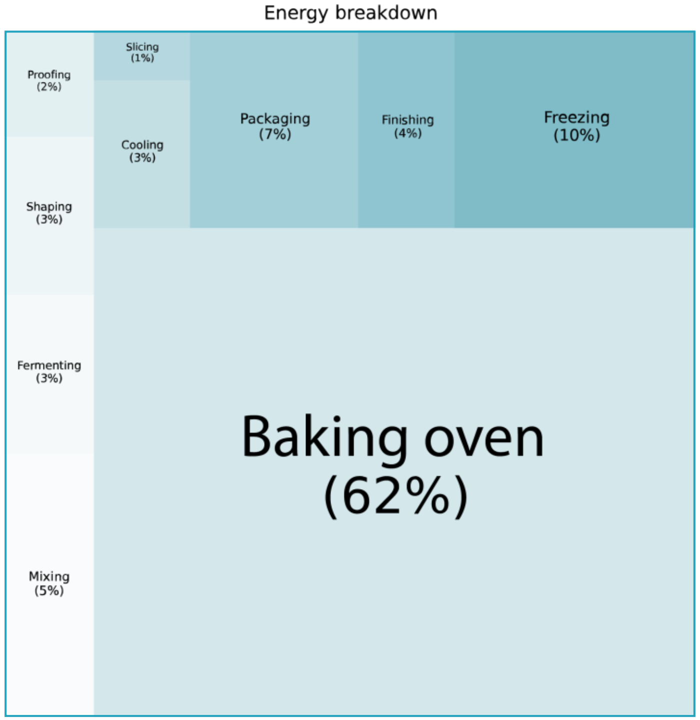
Bakery & processes overview

General energy requirements for the basic production processes in commercial bakeries has been adapted from the US [1] to reflect baking processes used in New Zealand. For example, Mechanical Dough Development (MDD) used in New Zealand, which is an adaptation of the Chorleywood Bread Process. It is important to note that this adaption may lead to slight variations in energy consumption percentages and greenhouse gas (GHG) emissions presented for the New Zealand baking sector. Figures are an average across all processes and provide a general guide to energy use. Overall, the majority of greenhouse gas (GHG) emissions are from the baking oven processes (>60%).

Basic production processes in commercial bakeries [1].



The energy breakdown shows that the baking is the processing step with the largest potential for greenhouse gas (GHG) emission reduction.



For further details on the definition of each process and the applicable products, refer to Appendix A.

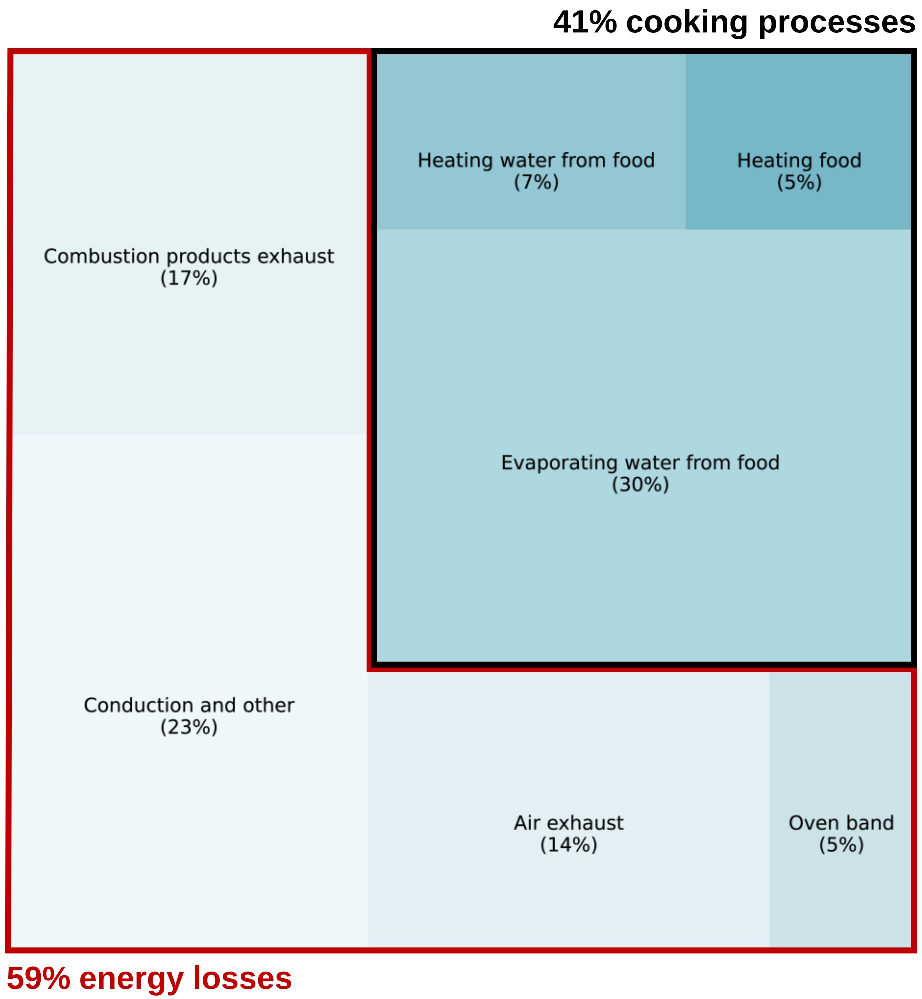
Bakery & processes overview

Case study for production of rich tea biscuits[2]

In general, the oven is the most energy-intensive stage, accounting for over 60% of total energy use. Gas-fired ovens are the main emitter of greenhouse gas (GHG) in New Zealand bakeries.

However, only 41% of the energy is used for the core cooking process, while 59% is lost through factors such as combustion products, air exhaust, and conduction to the conveyor belt.

Given the significant energy consumption of the baking process, much of the global focus on decarbonisation technologies is centred around improving oven efficiency.



Case study: Oven energy usage for the production of rich tea biscuit for Burton Foods UK[2].

Baking decarbonisation technology adoption

Baking decarbonisation technologies are prominent in regions like Europe and the US.

These include heat recovery systems that capture exhaust gas, transitioning to fully electric ovens, utilising hydrogen and dual-fuel burners, and implementing high temperature heat pumps.

In northern Europe, there is growing interest in electrical systems due to the availability of affordable electricity[3] despite 95% of bakery customers still using gas as their primary heating medium.

USA

- Hydrogen-fuelled ovens
- Dual-fuelled ovens (natural gas & electric)
- Hybrid ovens (direct gas-fired & air convection ovens)
- Insulation on oven walls
- Exhaust fans with dampers
- Emithermic ovens
- Oven scheduling
- Oven with sensors, programmable energy saving features
- Heat recovery
- Electric boilers

EUROPE & UK

- Heat recovery from flue gas
- Thermal oil ovens
- Electricity powered ovens
- Insulation of conveyor systems
- Hydrogen powered ovens
- Using infrared in the last stage of cooking process
- Using ultrasonic technology to control humidity in the proofing stage

Methodology

1

Problem definition

An extensive literature review was conducted, identifying over 75 technologies and practices related to decarbonisation in the baking industry.

Review process

2

Initial evaluation

Questionnaires were sent to various bakeries across New Zealand to understand their decarbonisation needs and awareness. The questions covered topics such as the types of decarbonisation technologies currently in use, the most energy-intensive parts of their operations, and the range of bakery products they produce.

3

Multi-criteria analysis

Consultation with experts narrowed the focus to 14 key technologies and a preliminary evaluation was conducted using a multi-criteria analysis.

4

Revaluation and expert consultation

Ratings were assigned to each option. Findings were reassessed, and experts were again consulted to ensure the selected options were appropriate, relevant, and comprehensive.

5

Supporting information

Throughout the guide, we reference supporting information from leading global experts, case studies, and potential suppliers to provide a robust and well-rounded perspective.

6

Final shortlisting

The top 14 technologies and processes were shortlisted to 10 options based on their rankings in the multi-criteria analysis and industry expert consultation.

Outcomes

7

Technology options list

Provide recommendations detailing 10 technology options and applicability to the New Zealand baking industry.

8

Future watchlist

Provide a list of emerging decarbonisation technology options that could reshape energy use and emissions reduction in the future.

Scoring for cost, effectiveness and New Zealand context

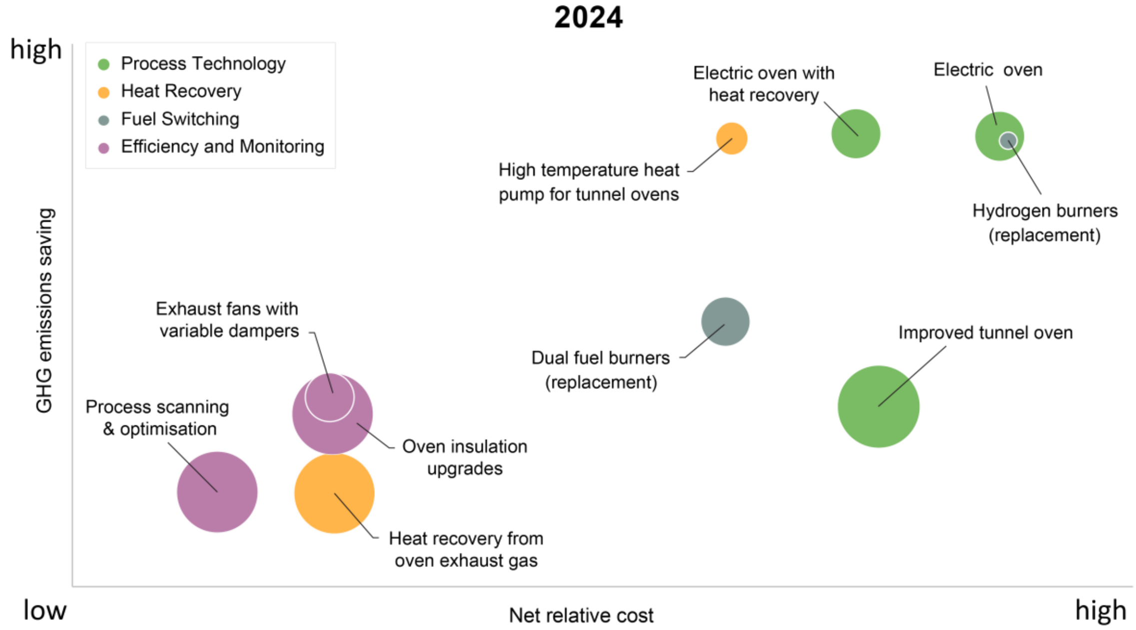
	CAPEX	OPEX	GHG Emission Savings	NZ TRL
Score	1–5	1–5	1–5	1–5

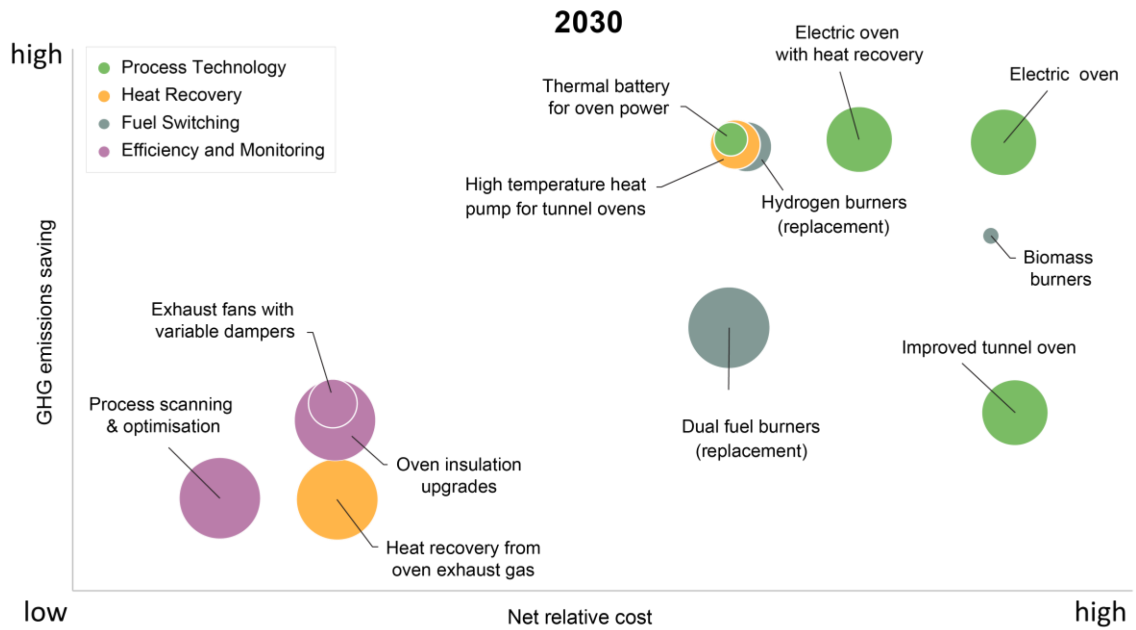
Selection of technology options

- Each technology option was given a rank score from 2–50 based on energy savings/greenhouse gas (GHG) emissions against relative cost of investment.
- These scores were used to rate and compare the technology options.
- The technologies were also evaluated for future potential, with ratings projected for 2030 to provide a dynamic outlook. The year 2030 was chosen as a reference point, aligning with New Zealand's target to reduce greenhouse gas (GHG) emissions by 50% from 2005 levels[4].

Scoring is not an exact science and affected by many factors. An estimate was made for the current state (2024) and expected future state (2030). For further details on evaluation criteria, refer to page 8.

The bubble maps on this page compare decarbonisation technologies based on greenhouse gas (**GHG) emissions** (Y-axis) and **net relative cost** (X-axis), with T**echnology Readiness Level** (TRL) indicated by bubble size. Larger bubbles represent higher technology readiness, while positioning reflects cost and emissions savings.





Evaluation criteria

Score	CAPEX (1–5 very expensive to inexpensive)	OPEX (1–5 very expensive to inexpensive)	Greenhouse gas (GHG) emissions savings (1 low savings – 5 high savings)	NZ's technical readiness level (TRL) (1 low NZ readiness – 5 high NZ readiness)
1	>$405,000 (New ovens)	0.86 $/kwh (Hydrogen)	**Very Low Savings**: Minimal reduction in GHG emissions (less than 10% savings).	Early-stage concept with limited scalability, poor compatibility with existing bakery infrastructure, no regulatory support, and low public awareness in New Zealand.
2	$150,000–$405,000	>0.18$/kwh <0.86 $/kwh	**Low Savings**: Slight reduction in GHG emissions (10-20% savings).	Technology in development, with small-scale pilots, but significant challenges in scaling across New Zealand bakeries, integrating with current systems, and gaining regulatory approval and public support.
3	$100,000–$150,000 (Installation of new burners)	0.18 $/kwh (Electricity)	**Moderate Savings**: Average reduction in GHG emissions (20-40% savings).	Proven in pilot projects, showing potential for moderate scalability in New Zealand bakeries, requiring some infrastructure adjustments, with partial regulatory backing and growing public awareness.
4	$50,000–$60,000 (Insulation upgrades, Heat Exchangers)	0.04 $/kwh (Natural gas)	**High Savings**: Significant reduction in GHG emissions (40-60% savings).	Emerging commercial technology with strong scalability potential for both small and large bakeries in New Zealand, largely compatible with existing infrastructure, supported by local policies, and gaining wider public and industry support.
5	$5000 (Oven scan)	<0.04 $/kwh	**Very High Savings**: Substantial reduction in GHG emissions (more than 60% savings).	Fully commercialised, scalable across bakery industries in New Zealand, seamlessly integrating with current infrastructure, strongly backed by NZ regulations, and widely accepted by the public and bakery sector.

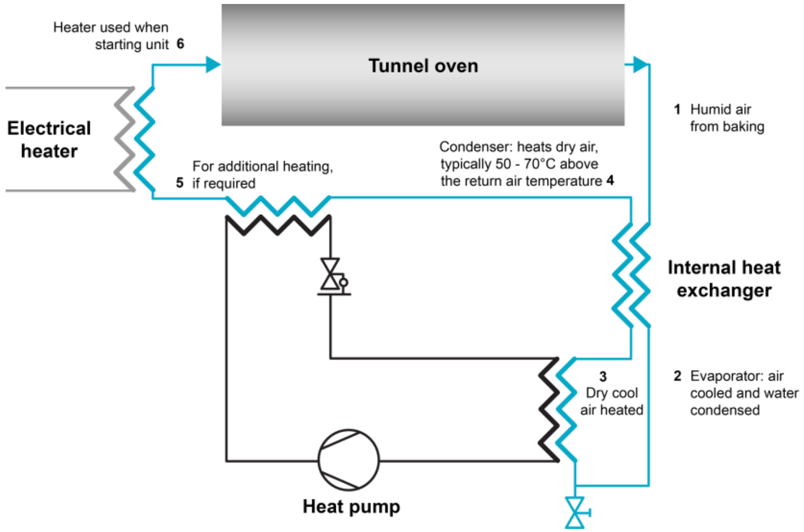
The values presented in this table are intended to provide a preliminary comparison of various decarbonisation technologies based on their capital expenditure (CAPEX), operational expenditure (OPEX), greenhouse gas emissions, and New Zealand readiness levels as of 2024. CAPEX figures are estimates derived from available literature and should be treated as indicative, as obtaining precise quotations from suppliers can be challenging. OPEX is calculated based on energy consumption in $/kWh, excluding additional costs such as maintenance, labour, or other operational expenses. Gas emissions are estimated based on the bakery process itself, without considering upstream factors such as how the energy is produced. For instance, an electric-powered oven may be rated as having high potential savings in this assessment, regardless of the carbon intensity of the electricity generation. The relative ratings assigned to each technology reflect a comparison among the options presented. For detailed and accurate pricing, it is recommended to contact the respective suppliers directly.

Shortlisted technology options

	Technology	Type	Ranking score
1	High temperature heat pumps to recover and reuse low temperature heat	Heat Recovery	30
2	Electric ovens with heat recovery	Process Technology	25
3	Electric ovens	Process Technology	20
4	Hydrogen-fuelled tunnel oven technology	Fuel switching	20
5	Hybrid burner technology	Fuel switching	18
6	Oven insulation upgrades	Efficiency & Monitoring	18
7	Exhaust gas with variable dampers	Efficiency & Monitoring	18
8	Improved oven technology	Process Technology	10
9	Process scanning and optimisation	Efficiency & Monitoring	10
10	Latent heat recovery from oven’s exhaust gases	Heat Recovery	9

1

High temperature heat pumps to recover and reuse low temperature heat



Industrial electricity driven heat pumps are highly energy efficient and enable the generation of heat in a circular and sustainable manner.

Industrial heat pump technology can upgrade the temperature of a waste heat source (i.e., either by condensing the humid air from baking or by cooling the product and conveyor after baking), such that it can be reused within a process, increasing the overall efficiency of the process. The process heat generated by the heat pump is the sum of the electrical input and the heat input from the waste heat source.

heat recovery **retrofit option**

Implementing industrial high temperature heat pumps in bakeries as a low-emission alternative to gas-fired heating offers a robust decarbonisation solution by utilising waste heat from the production process, such as humid return air or cooling of products and conveyor belts. Heat pumps can achieve Coefficients of Performance (COPs) of 2 to 3, generating two to three times more heat energy than the electrical energy they consume[8] (i.e., they are more cost effective).

ADVANTAGES

Energy Efficiency: Captures and reuses waste heat, significantly improving energy efficiency.

CO_2 Reduction: Lowers carbon dioxide (CO_2) emissions by replacing gas-fired heating with more efficient, electric-based heating.

Cost-Effective in NZ: With New Zealand's increasing reliance on renewable electricity, heat pumps offer a cost-efficient solution that aligns with decarbonisation goals.

Retrofitting Potential: Can be retrofitted onto existing gas-fired ovens, facilitating a smoother transition for bakeries.

DISADVANTAGES

Low NZ TRL: Technology is still under development, contributing to a low Technology Readiness Level (TRL) in New Zealand.

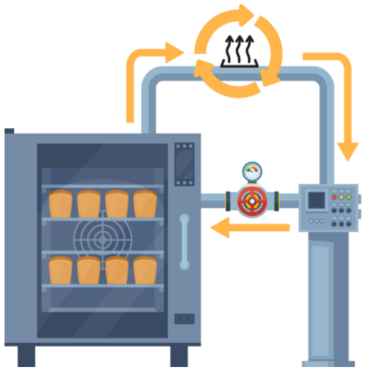
Global Expert Info:

Project - High-temperature heat pump for tunnel oven - Danish Technological Institute (dti.dk)

2024	
CAPEX	2
OPEX	4
CO_2 emissions rating	5
NZ TRL	2

2030	
CAPEX	2
OPEX	4
CO_2 emissions rating	5
NZ TRL	3

2
Electric ovens with heat recovery



Electric ovens paired with heat recovery systems offer a promising pathway toward energy-efficient baking solutions. However, they require optimisation to achieve commercial viability.

While current electric ovens can deliver acceptable product quality, their energy efficiency and operational cost performance remain insufficient under prevailing energy prices. Integrating heat recovery systems, such as direct contact economisers for process heat or plate heat exchangers for electricity generation, could significantly enhance energy efficiency.

These systems would need to address challenges like fouling, maintenance, and contamination, potentially employing advanced coatings like PTFE and modular designs for ease of cleaning. Such advancements could make electric ovens more suitable for widespread fuel-switching initiatives while supporting sustainable energy practices.

Process technology | **Greenfield option**

Electric ovens, when paired with heat recovery systems, offer a more energy-efficient alternative to gas-fired ovens in commercial baking. The integration of heat recovery addresses the challenges of high energy consumption and operating costs.

ADVANTAGES

Enhanced Energy Efficiency: Heat recovery systems capture waste heat, reducing the overall energy consumption and improving the efficiency of electric ovens.

Proven Feasibility: Successful projects like **Project Zap**[9] and **Project NEO**[10] demonstrate the practicality of integrating heat recovery systems to make electric ovens competitive in commercial baking.

DISADVANTAGES

Initial Cost: The integration of heat recovery systems increases the upfront cost of electric ovens, potentially posing financial challenges for bakeries without available capital.

Electricity Costs: Despite the benefits of heat recovery, the current higher cost of electricity in New Zealand compared to natural gas remains a challenge, particularly in the short term.

Global Expert Info:

assets.publishing.service.gov.uk/media/649aa9ae83131100132963ff/Burtons_Foods_-_Zap_-_IFS_Feasibility_Report.pdf

www.gov.uk/government/publications/industrial-fuel-switching-programme-successful-projects/industrial-fuel-switching-programme-phase-1-summaries-of-successful-projects

www.gov.uk/government/publications/industrial-fuel-switching-programme-successful-projects/industrial-fuel-switching-programme-phase-2-summaries-of-successful-projects

Industrial oven technology (camsensin.com)

2024 (with heat recovery)	
CAPEX	1
OPEX	4
CO_2 emissions rating	5
NZ TRL	3

2030 (with heat recovery)	
CAPEX	1
OPEX	4
CO_2 emissions rating	5
NZ TRL	4

3

Electric ovens

Electric Tunnel Ovens

(Image credit: Sveba Dahlen)

Sveba Dahlen's electric tunnel ovens are energy-efficient, designed for continuous use over decades. Built with advanced insulation materials to minimise heat loss, the ovens maintain a cool exterior and are suitable for baking a wide range of products, including bread, pastries, and cakes. They feature customisable temperature ranges up to 500°C.

The ovens use efficient heating elements placed above and below the chamber, with options for turbo zones to optimise baking time, temperature, and uniformity. Additional features include robust belt driving systems for exact baking times and optional steam systems for enhanced baking flexibility and control.

Process technology | Greenfield option

Electric ovens are emerging as alternatives to gas-fired ovens in commercial baking, though efficiency and energy consumption remain challenging.

ADVANTAGES

Decarbonisation Potential: Electric ovens align with New Zealand's renewable energy transition, offering significant opportunities for reducing carbon emissions.

Future Cost Competitiveness: As gas becomes less available, and emissions trading systems (ETS) costs increase, together with an overbuild of intermittent electricity generation (targeting 90% by 2025), electricity may become more cost-effective, potentially reducing operating costs for electric ovens.

Renewable Electricity: With over 80% of electricity currently generated from renewable sources[6], electric ovens could contribute to further sustainability in baking.

DISADVANTAGES

High Electricity Costs: The current higher cost of electricity compared to natural gas in New Zealand makes electric ovens less economically viable without heat recovery systems.

Suppliers: SVEBA DAHLEN, Royal Kaak

2024	
CAPEX	1
OPEX	3
CO_2 emissions rating	5
NZ TRL	3

2030	
CAPEX	1
OPEX	3
CO_2 emissions rating	5
NZ TRL	4

4
Hydrogen-fuelled tunnel oven technology

AMF Den Boer Multibake® Vita
(Image credit: AMF)

AMF Den Boer's hydrogen ovens, part of the Multibake® VITA series, represent a breakthrough in zero-emission baking technology. The hydrogen ribbon burners, developed and patented by AMF, are designed for both new installations and retrofitting existing natural gas ovens. These burners, available in lengths up to 4 meters with plans for further extension, offer sustainable baking solutions with zero carbon emissions.

AMF provides comprehensive support, including hydrogen production, certification, and installation guidance. Demonstrations of the technology are available at AMF's test bakery in the Netherlands, showcasing its potential for sustainable baking practices.

fuel switching

retrofit option

AMF Bakery Systems' Multibake® VITA Tunnel Oven is the world's first emission-free tunnel oven powered by hydrogen fuel.

ADVANTAGES

Zero Emissions: Powered by green hydrogen, this oven is completely emission-free, offering a highly sustainable solution for baking.

Retrofitting Option: Can be integrated into existing setups, reducing the need for completely new investments in infrastructure.

Future Cost Competitiveness: Hydrogen fuel costs in New Zealand are expected to decrease by early 2030 [5], driven by advancements in hydrogen production and efficiency improvements.

DISADVANTAGES

Current Hydrogen Cost: Hydrogen is currently more expensive than traditional fuels, which could limit short-term adoption in New Zealand until costs fall.

Infrastructure Requirements: Hydrogen storage and supply infrastructure need to be developed further, which could present initial logistical challenges.

Global Expert Info:

amfbakery.com/5-routes-to-a-more-sustainable-industrial-oven/

bakingbiscuit.com/bbi-2022-01-on-the-way-to-co2-neutral-bread/

Suppliers:

AMF BAKERY SYSTEMS

2024	
CAPEX	3
OPEX	1
CO_2 emissions rating	5
NZ TRL	1

2030	
CAPEX	3
OPEX	3
CO_2 emissions rating	5
NZ TRL	3

5 Hybrid burner technology

Hybrid burner technology integrates both electric and gas heating sources, allowing bakeries to optimise energy use by switching between electricity and natural gas based on cost and availability.

ADVANTAGES

Energy Flexibility: Allows for the use of electricity when it is more cost-effective, reducing reliance on natural gas and offering operational flexibility.

Cost Reduction: By optimising energy use based on price fluctuations between gas and electricity, bakeries can lower operational costs over time.

Adaptability: Can be implemented without completely replacing existing gas infrastructure, making it a viable option for gradual transitions toward decarbonisation.

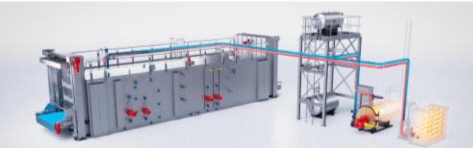
DISADVANTAGES

Upfront Costs: Initial investment in hybrid burner technology can be higher due to the need for systems that support dual energy sources.

Dependent on Electricity Costs: While renewable energy is growing[6], the technology's effectiveness depends on the continued reduction in electricity costs relative to gas.

Hybrid Thermal Oil Ovens

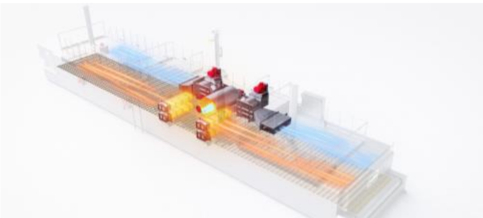
Developed by Royal Kaak, these ovens combine electric and gas heating sources. When electricity is more affordable or abundant, an electric boiler is used. Gas serves as a back-up, ensuring flexibility in energy sourcing.



(Image credit: Royal Kaak)

Gas-Electric Hybrid Cyclotherm Oven

Developed by Royal Kaak, this oven design incorporates electric heating elements in the main airshaft, supplemented by additional fans to compensate for reduced burner propulsion. During electric mode, the gas exhaust chimney is closed, minimising heat losses and achieving 10-15% energy savings. This set-up maintains consistent baking performance while reducing energy consumption.



(Image credit: Royal Kaak)

fuel switching | **retrofit option**

Global Expert Info:

https://kaak.com/food-without-footprint/

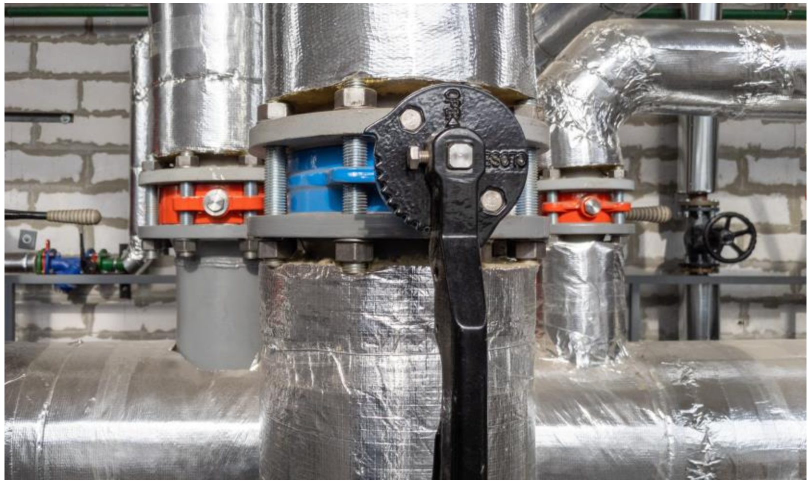
https://kaak.com/sustainable-oven-solutions/

Suppliers: Royal Kaak

2024	
CAPEX	3
OPEX	3
CO_2 emissions rating	3
NZ TRL	3

2030	
CAPEX	3
OPEX	3
CO_2 emissions rating	3
NZ TRL	5

6 Oven insulation upgrades



Heavy-duty ovens operate at very high temperatures, which leads to significant energy consumption. Without proper insulation, they can be a major source of heat loss and can be costly to operate.

For example, stone wool has a high thermal performance which helps retain hot air inside the oven, reducing the energy needed to maintain heat.

efficiency and monitoring

retrofit option

Insulating ovens prevents heat from escaping through the walls, reducing energy consumption needed to maintain consistent temperatures during baking. Thicker insulation layers significantly minimise energy losses, leading to substantial cost savings.

ADVANTAGES

Energy Efficiency: Prevents heat loss, requiring less energy to maintain stable internal temperatures, thus lowering energy bills.

Cost Savings: Immediate financial benefits from reduced energy consumption make insulation a practical investment.

Enhanced Performance: Helps ensure uniform heat distribution within the oven, improving baking quality and consistency.

DISADVANTAGES

Limited Impact on CO_2 Savings: While insulation improves energy efficiency, its contribution to overall carbon dioxide (CO_2) savings may be relatively low compared to other technologies aimed at direct emissions reduction.

Limited Impact on New Equipment: The benefits are more pronounced in older models; newer ovens may already have sufficient insulation.

Global Expert Info:

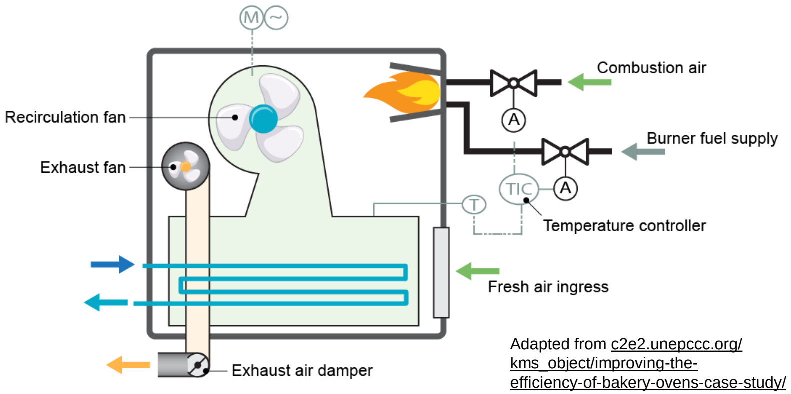
7 Ways to Reduce Energy Costs of Industrial Ovens – Despatch

Rockwool industrial oven insulation

2024	
CAPEX	4
OPEX	5
CO_2 emissions rating	2
NZ TRL	5

2030	
CAPEX	4
OPEX	5
CO_2 emissions rating	2
NZ TRL	5

7 Exhaust gas with variable dampers



Adapted from c2e2.unepccc.org/kms_object/improving-the-efficiency-of-bakery-ovens-case-study/

By optimising exhaust systems with variable dampers and adjusting fan drives, bakeries can reduce energy consumption and improve oven efficiency.

These dampers adjust the airflow in the exhaust system based on real-time requirements, reducing the excess air used and improving efficiency. By adjusting the dampers, bakeries can optimise the removal of gases while maintaining the necessary safety ventilation. Setting fans to the minimum necessary drive while maintaining safe ventilation helps reduce unnecessary energy consumption. This adjustment ensures that only the required amount of air is removed from the oven, preventing over-ventilation. Minimising excess air and balancing the oven gases (i.e., ensuring what comes into the oven matches what is expelled) has been shown to result in up to 42% energy savings[7].

efficiency and monitoring | retrofit option

Exhaust fans are crucial in industrial ovens for removing moisture, solvents, and combustion by-products. Optimising exhaust systems with variable dampers and fan drive adjustments can enhance energy efficiency and reduce energy consumption.

ADVANTAGES

Energy Savings: Adjusting dampers to optimise airflow can result in energy savings of up to 42% by minimising excess air and balancing oven gases in a laboratory oven[7].

Cost-Effective Implementation: Many commercial ovens are already equipped with compatible burner systems and ratio controllers, making the installation of variable dampers relatively inexpensive compared to other decarbonisation technologies.

DISADVANTAGES

Limited Impact on CO_2 Savings: While optimising exhaust fans improves energy efficiency, the overall contribution to carbon dioxide (CO_2) savings may be limited compared to other decarbonisation technologies that directly replace fossil fuel use.

Global Expert Info:

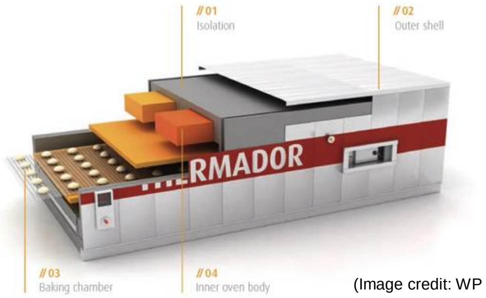
c2e2.unepccc.org/kms_object/improving-the-efficiency-of-bakery-ovens-case-study/
www.carbontrust.com/news-and-insights/news/carbon-trust-takes-the-hot-air-out-of-baking-bread
www.bakingbusiness.com/articles/51253-taking-mistakes-out-of-the-baking-process

2024	
CAPEX	4
OPEX	5
CO_2 emissions rating	2
NZ TRL	3

2030	
CAPEX	4
OPEX	5
CO_2 emissions rating	2
NZ TRL	3

8 Improved oven technology

Thermador Tunnel Oven



(Image credit: WP Bakery Group)

The THERMADOR tunnel oven offers a reliable and energy-efficient solution for continuous baking, tailored to meet individual product requirements with precise temperature, heat transfer, and moisture control.

The oven's modular design allows for flexible configurations, combining Cyclotherm, Duotherm (convection heat transfer), infrared, and Quattro zones to achieve perfect baking conditions. Indirect heating through the closed Cyclotherm system ensures heat is transferred without combustion gases affecting the product, and Spectra infrared technology speeds up baking time (by up to 30%), saves energy, retains moisture, and enhances product freshness and taste.

Low exhaust gas temperatures and heat insulation provide efficient use of energy. Designed for minimal maintenance and remote servicing, the oven system offers long-term reliability and high availability.

Process technology | **Greenfield option**

Investing in advanced oven technology presents a promising pathway for decarbonisation in the baking industry by enhancing energy efficiency and reducing greenhouse gas emissions.

ADVANTAGES

Energy Efficiency: Technologies like **Sveba Dahlen ovens**, designed with super-insulating materials and hybrid heating systems, significantly reduce heat loss, leading to lower operational costs and greenhouse gas emissions.

Consistent Quality: Innovations such as **Thermador by WP Bakery**, which incorporates Spectra infrared technology, ensure even and rapid heating, maintaining high-quality baking results.

DISADVANTAGES

High Initial Capital Investment (CAPEX): The upfront costs associated with purchasing advanced ovens may be prohibitive for some bakeries.

Long Payback Period: The return on investment may take time, making it a commitment for bakeries focused on long-term sustainability.

Global Expert Info:

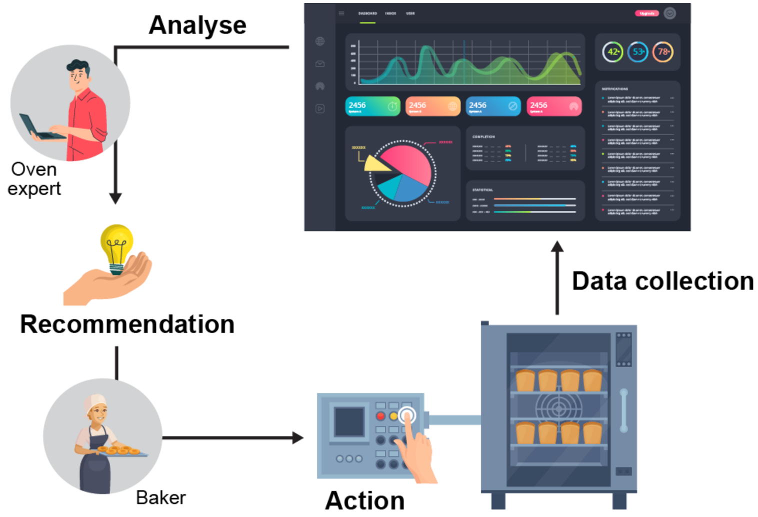
www.readingbakery.com/rbs-designs-emithermic-xe-oven-to-replace-direct-gas-fired-oven-technology.html
www.heuft-industry.com/en/heiztechnologie/
www.wpib.de/en/products/continuous-tunnel-oven-thermador.html
sveba.com/en/electric-tunnel-oven-artista-deli

Suppliers: SVEBA DAHLEN, Royal Kaak, WP BAKERYGROUP, AMF BAKERY SYSTEMS

2024	
CAPEX	1
OPEX	4
CO_2 emissions rating	2
NZ TRL	3

2030	
CAPEX	1
OPEX	3
CO_2 emissions rating	2
NZ TRL	4

9 Process scanning and optimisation



Process scanning tools allow specialists to quickly run a check and gain an informed understanding of the performance of an existing oven and where saving potential may be, in each circumstance. The tools can provide real-time insights to energy usage and long-term energy trends assisting with correct determination of potential solutions to help achieve energy savings and reach sustainability goals.

efficiency and monitoring

retrofit option

The energy consulting approach provides bakeries with a strategic framework to gain comprehensive insights into their energy consumption patterns and implement actionable changes to optimise energy use.

ADVANTAGES

Data-Driven Insights: The use of **advanced sensors** and **smart software** by companies like **Royal Kaak** allows bakeries to collect and analyse energy consumption data effectively.

Cost-Effective Solution: This approach is relatively low in cost compared to installing new technologies or equipment, enabling bakeries to optimise current operations and equipment without significant upfront investments.

DISADVANTAGES

Dependency on Existing Infrastructure: The effectiveness of the consulting approach may be limited by the existing equipment and processes in place at the bakery.

Limited Impact on CO_2 Savings: While the energy consulting approach can lead to energy savings, the overall reduction in carbon dioxide (CO_2) emissions is typically low compared to more significant technological upgrades or equipment changes.

Global Expert Info:

amfbakery.com/5-routes-to-a-more-sustainable-industrial-oven/

https://kaak.com/ovenscan/

Suppliers: AMF Bakery Systems, Royal Kaak

2024	
CAPEX	NONE
OPEX	5
CO_2 emissions rating	1
NZ TRL	5

2030	
CAPEX	NONE
OPEX	5
CO_2 emissions rating	1
NZ TRL	5

10 Latent heat recovery from oven's exhaust gases

Heat recovery systems capture excess heat from the oven's hot flue gases using a heat exchanger, repurposing it into useful energy (e.g., generating hot water or pre-heating combustion air). This technology provides significant opportunities for energy savings and emission reductions.

(Image credit: Royal Kaak)

ADVANTAGES

Energy Efficiency: By capturing and repurposing heat that would otherwise escape into the atmosphere, heat recovery systems can substantially reduce energy waste, enhancing overall operational efficiency in bakeries.

Cost-Effectiveness: With low capital and operational costs, heat recovery systems represent a financially viable solution for bakeries in New Zealand seeking to optimise energy use and decrease emissions.

Flexibility in Application: Various types of heat recovery systems, such as direct contact economisers and plate heat exchangers, can be tailored to specific applications, ensuring high efficiency and adaptability to different processes [2].

DISADVANTAGES

Maintenance Challenges: Systems can require regular maintenance to prevent fouling which can lead to decreased efficiency if not managed properly.

Limited CO_2 Savings: While heat recovery systems can significantly reduce energy consumption and operational costs, the direct reduction in carbon dioxide (CO_2) emissions varies based on the specific application and integration into existing processes.

Global Expert Info:

assets.publishing.service.gov.uk/media/649aa9ae83131100132963ff/Burtons_Foods_-_Zap_-_IFS_Feasibility_Report.pdf

exodraft.com/heat-recovery/

exodraft heatrecovery schwarze bakery (video)

heat recovery from tunnel baking ovens (video)

www.sciencedirect.com/science/article/pii/S2214157X23010201

bakeryinfo.co.uk/promotional-features/optimise-oven-efficiency-in-a-green-and-cost-effective-way/677167.article

www.mecatherm.fr/en/news/mosaique/details/mecatherm-develops-solutions-to-optimize-energy-consumption-in-ovens.html

Suppliers: Royal Kaak, exodraft, MECATHERM

heat recovery | retrofit option

2024	
CAPEX	4
OPEX	5
CO_2 emissions rating	1
NZ TRL	5

2030	
CAPEX	4
OPEX	5
CO_2 emissions rating	1
NZ TRL	5

Watchlist –
future technologies to watch

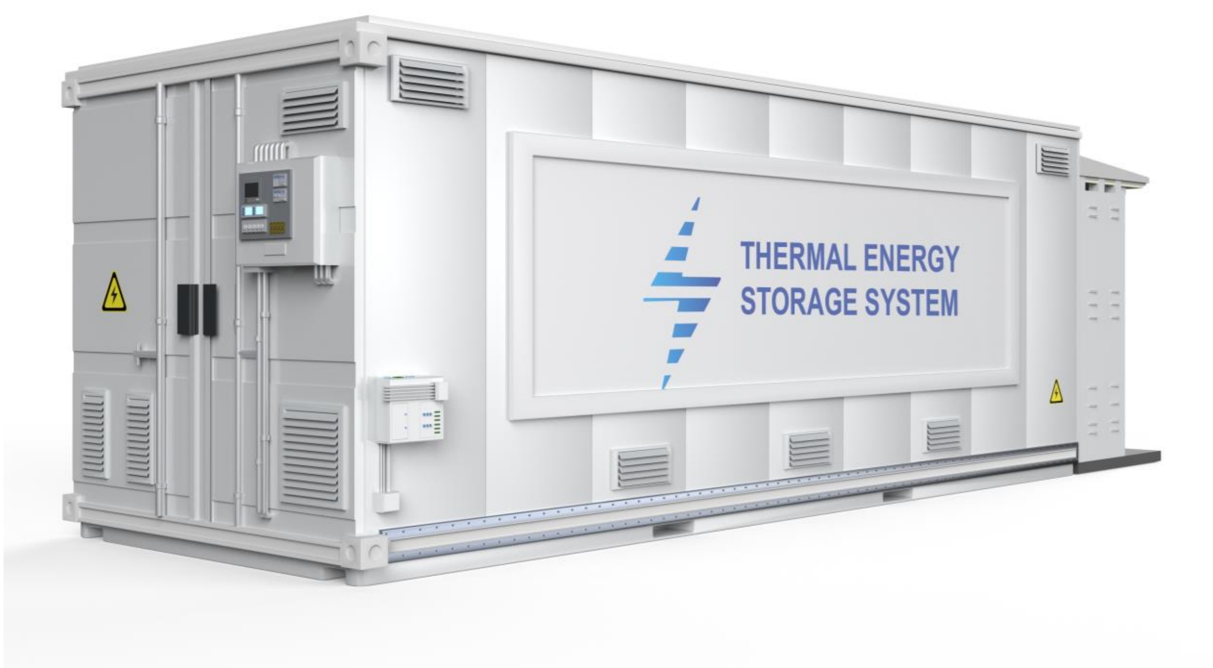
While certain decarbonisation technologies have not been shortlisted due to their low Technology Readiness Level (TRL) and ongoing development stages, they hold significant potential for the future of the baking industry. These emerging technologies could reshape energy use and emissions reduction, and it is essential to monitor their progress closely.

1 Renewable energy hybrid oven technology with thermal battery

Royal Kaak is pioneering a hybrid oven technology that integrates renewable energy sources to enhance sustainability and cost-efficiency in baking processes.

This innovative system combines solar and wind energy with a thermal battery to manage heat supply effectively. The system harnesses solar and wind energy to generate electricity and provide heat. Solar heat directly contributes to the oven's heating needs. A thermal battery, or heat buffer, stores excess heat using thermal oil, with a maximum temperature of 400°C [11].

This battery features a special concrete mix to store heat, a heating element on one side, and a heat exchanger on the other, facilitating efficient heat transfer and storage. The system optimally uses the most economical heat source available each hour, balancing costs and efficiency.



Global Expert Info:

energy-nest.com/thermal-battery/

Suppliers:

Royal Kaak   ENERGYNEST

2030	
CAPEX	4
OPEX	5
CO_2 emissions rating	1
NZ TRL	5

Process technology   retrofit option

Watchlist – future technologies to watch

While certain decarbonisation technologies have not been shortlisted due to their low Technology Readiness Level (TRL) and ongoing development stages, they hold significant potential for the future of the baking industry. These emerging technologies could reshape energy use and emissions reduction, and it is essential to monitor their progress closely.

2 Biomass burners

Biomass burners present an effective solution for improving the sustainability of bakery operations by replacing conventional fossil fuels with renewable biofuels such as wood pellets and olive pits.

These burners can significantly reduce energy consumption by 30-60%, enhance product quality through more consistent and gradual heat, and lower carbon dioxide (CO_2) emissions, with a 150 kW biomass boiler potentially cutting emissions by 103 tonnes annually [12].

The potential economic benefits claimed are notable, with the initial investment in biomass systems being amortized within 5 years due to lower fuel costs and the use of production waste materials.

QUEBINEX has successfully implemented biomass technology in bakeries across various countries, highlighting its potential for significant energy and cost savings. For New Zealand's baking industry, biomass burners align with sustainability goals and offer a practical way to reduce carbon emissions and improve energy efficiency.

QUEBINEX burners.
Image from https://www.expobiomasa.com/en/biomass-installations/Extremadura-bakeries-already-use-biomass-thanks-to-Quebinex-burners

Global Expert Info:

task32.ieabioenergy.com/wp-content/uploads/sites/24/2019/03/The-bakery-that-runs-on-heat-from-biomass.pdf

www.saatotuli.ca/2021/03/01/biomass-fired-bread-oven/

www.expobiomasa.com/en/biomass-installations/Extremadura-bakeries-already-use-biomass-thanks-to-Quebinex-burners

www.zero-emissions.at/index.php?title=Bioenergy_in_bread/biscuits/cakes_production

Suppliers:

QUEBINEX

2030	
CAPEX	1
OPEX	3
CO_2 emissions rating	4
NZ TRL	1

fuel switching

retrofit option

References

1. Masanet E, Therkelsen P, Worrell E 2012. Energy Efficiency Improvement and Cost Saving Opportunities for the Baking Industry: An ENERGY STAR® Guide for Plant and Energy Managers Lawrence Berkeley National Lab.(LBNL), Berkeley, CA (United States). https://www.energystar.gov/buildings/tools-and-resources/energy-efficiency-improvement-and-cost-saving-opportunities-baking

2. Martin Beckford KD, Dan Ahearn, Tim Hartley, Mark Williamson 2022. Industrial Fuel Switching Feasibility Study Project Zap - Electrification of Biscuit Production Burton's Foods Ltd., 42T, Cambridge Sensor Innovation https://assets.publishing.service.gov.uk/media/649aa9ae83131100132963ff/Burtons_Foods_-_Zap_-_IFS_Feasibility_Report.pdf [accessed September, 2024].

3. Electricity price statistics https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_price_statistics [accessed September, 2024].

4. New Zealand's emissions reductions targets https://genless.govt.nz/about-energy/new-zealands-emissions [accessed September 2024].

5. New Zealand Hydrogen Scenarios and the Future of Gas, Castalia Limited https://www.mbie.govt.nz/dmsdocument/27266-new-zealand-hydrogen-scenarios-and-the-future-of-gas-september-2022-pdf [accessed September, 2024].

6. Our Energy Mix https://www.energyresources.org.nz/oil-and-gas-new-zealand/our-energy-mix/. [accessed September 2024].

7. Ashcroft M 2015. Improving the efficiency of bakery ovens Case study Carbon Trust https://c2e2.unepccc.org/kms_object/improving-the-efficiency-of-bakery-ovens-case-study/ [accessed September 2024].

8. Madsboll H 2022. High-Temperature Heat Pump for Tunnel Oven Danish Technological Institute. https://www.dti.dk/_/media/86433_High-temperature%20heat%20pump%20for%20tunnel%20oven.pdf [accessed September 2024].

9. Industrial Fuel Switching Programme, Phase 1: summaries of successful projects. Department for Energy Security & Net Zero https://www.gov.uk/government/publications/industrial-fuel-switching-programme-successful-projects/industrial-fuel-switching-programme-phase-1-summaries-of-successful-projects [accessed September, 2024].

10. Industrial Fuel Switching Programme, Phase 2: summaries of successful projects. Department for Energy Security & Net Zero https://www.gov.uk/government/publications/industrial-fuel-switching-programme-successful-projects/industrial-fuel-switching-programme-phase-2-summaries-of-successful-projects [accessed September, 2024].

11. ThermalBattery The ENERGYNEST ThermalBattery https://energy-nest.com/thermal-battery/ [accessed September 2024].

12. AEE INTEC A Bioenergy in bread/biscuits/cakes production http://www.zero-emissions.at/index.php?title=Bioenergy_in_bread/biscuits/cakes_production [accessed September, 2024].

Appendix A

Baking process, definitions and products applicable

Area	Function	Products applicable
Mixing	Evenly blends ingredients while developing a gluten network, crucial for structure and texture in the final bread.	Bread & Rolls, Cakes & pies, Frozen Cakes, Cookies & Crackers
Shortening Storage	Solid shortening, often used instead of butter, adds fat to dough while maintaining crispness and extending shelf life.	Cookies & Crackers
Forming and Chilling	Chilling firms up dough fats (like butter), helping maintain shape and preventing excessive spread during baking.	Cakes & Pies, Frozen Cakes
Fermentation	Yeast breaks down sugars, producing carbon dioxide, alcohol, and gas bubbles, which cause the dough to rise while developing flavour and texture.	Breads & Rolls, Cookies & Crackers
Shaping	Kneading and folding dough stretch gluten strands, release excess gas, and ensure even gas distribution for uniform crumb structure.	Breads & Rolls, Cookies & Crackers
Proofing	The dough undergoes its final rise as carbon dioxide builds up, filling it with gas bubbles that expand before baking.	Breads & Rolls, Cookies & Crackers
Baking oven	Oven heat rapidly expands gases, sets the crumb structure, and causes Maillard reactions that brown and flavour the crust.	Bread & Rolls, Cakes & pies, Frozen Cakes, Cookies & Crackers
Cooling	Bread cools to release steam and stabilise its structure before slicing, with controlled airflow helping achieve the right texture.	Bread & Rolls, Cakes & pies, Cookies & Crackers
Freezing	Cakes are frozen to lock in freshness and extend shelf life.	Frozen Cakes
Pan Washing	Pans are cleaned thoroughly before returning to the next round of shaping and forming.	Bread & Rolls, Cakes & pies, Frozen Cakes
Finishing	Cakes and baked goods are decorated with icing, glazes, or other toppings.	Cakes & Pies, Frozen Cakes
Slicing	Bread and baked goods are sliced uniformly for packaging and consumer convenience.	Breads & Rolls, Cookies & Crackers
Packaging	The final product is packaged and labelled, ready for distribution and sale.	Bread & Rolls, Cakes & pies, Frozen Cakes, Cookies & Crackers

Appendix B

Greenhouse Gas (GHG) Emission Factors from different energy sources

Energy Source	Unit	GHG Emissions Factor ($kgCO_2e$/unit)	Calorific Value (kWh/unit)	Normalised GHG Emissions factor ($kgCO_2e$/kWh)	Relative GHG Emissions Factor to Purchased Electricity	References
Coal - Sub-bituminous	kg	2.00	6.01	0.33	4.56	environment.govt.nz/publications/measuring-emissions-a-guide-for-organisations-2024-detailed-guide/
Natural gas	kWh	0.20	1.00	0.20	2.67	environment.govt.nz/publications/measuring-emissions-a-guide-for-organisations-2024-detailed-guide/
Purchased electricity - annual average (2023)	kWh	0.07	1.00	0.07	1.00	environment.govt.nz/publications/measuring-emissions-a-guide-for-organisations-2024-detailed-guide/
Geothermal				0.06	0.86	ourworldindata.org/grapher/carbon-intensity-electricity
Biomass (wood industrial)	kg	0.01	2.47	0.01	0.07	environment.govt.nz/publications/measuring-emissions-a-guide-for-organisations-2024-detailed-guide/
Green hydrogen				0.00	0.00	hydrogeneurope.eu/wp-content/uploads/2024/06/2024_H2E_CleanH2ProductionPathwaysReport.pdf

Greenhouse Gas (GHG) Emissions Factors

- GHG emissions factors and calorific values of various energy sources
- Outcomes:
  - Coal produces 4.6 times more GHG emissions per kWh of energy than electricity supplied by the national grid as of 2024
  - Biomass produces 14 times less GHG emissions per kWh of energy than the electricity supplied by the national grid as of 2024
  - Electricity generated by geothermal energy produces 1.16 times less GHG emissions per kWh of energy than the electricity supplied by the national grid. As of 2023, most of the electricity produced by renewable sources is supplied by geothermal energy.

CAPEX & OPEX References

OPEX	Price	References
Electricity	0.18 $/kwh	www.statista.com/statistics/988214/new-zealand-industrial-electricity-costs/
Natural Gas	0.04 $/kwh	www.statista.com/statistics/987958/new-zealand-industrial-natural-gas-price
Hydrogen	0.86 $/kwh	1626295071-the-nz-hydrogen-opportunity.pdf (isk.nz)

CAPEX	Price	References
New Ovens	~ $405,000	Industrial Bakery Oven Prices: A Comprehensive Guide - Bresso (bresso-oven.com)
Hybrid Burners	~ $100,000	Flynn Burner Corporation | Bakery Burner and Flame Treating Solutions
Hydrogen Burners	~ $100,000	saacke.com/fileadmin/saacke/pdf/hydrogen-burners-industrial-decarbonization-whitepaper.pdf
Insulation Upgrades	~$ 60,000	Industrial Oven Selection, Configuration, and Operations Best Practices Guide (internationalthermalsystems.com)
Heat Exchanger	~$ 50,000	Email communication with suppliers
Oven Scan	~$ 5,000	Email communication with suppliers

Disclaimer

CAPEX and OPEX figures are estimates derived from available literature and should be treated as indicative, as obtaining precise quotations from suppliers can be challenging. For detailed and accurate pricing, we recommend contacting the respective suppliers directly.

Appendix C

Options Register

No	Option	Option type	Retrofit or Greenfield	CAPEX score	OPEX score (2024)	OPEX score (2030)	Cost score 2024 (2–10)	Cost score 2030 (2–10)	GHG emissions saving score (2024)	GHG emissions saving score (2030)	Rank score 2024 (2–50)	Rank score 2030 (2–50)	NZ TRL (2024) (1–5)	NZ TRL (2030) (1–5)
1	Hydrogen burners (replacement)	Fuel Switching	R	3	1	3	4	6	5	5	20	30	1	3
2	Dual fuel burners (replacement)	Fuel Switching	R	3	3	3	6	6	3	3	18	18	3	5
3	Heat recovery from oven exhaust gas	Heat Recovery	R	4	5	5	9	9	1	1	9	9	5	5
4	Electric oven	Process Technology	G	1	3	3	4	4	5	5	20	20	3	4
5	Improved tunnel oven	Process Technology	G	1	4	3	5	4	2	2	10	8	5	4
6	Thermal oil as heat carrier in oven	Process Technology	G	1	4	3	5	4	2	2	10	8	5	4
7	Process scanning & optimisation	Efficiency and Monitoring	R	5	5	5	10	10	1	1	10	10	5	5
8	Oven insulation upgrades	Efficiency and Monitoring	R	4	5	5	9	9	2	2	18	18	5	5
9	Exhaust fans with variable dampers	Efficiency and Monitoring	R	4	5	5	9	9	2	2	18	18	3	3
10	High temperature heat pump for tunnel ovens	Heat Recovery	R	2	4	4	6	6	5	5	30	30	2	3
11	Ultrasound proofer	Process Technology	R	3	3	3	6	6	1	2	6	12	1	2
12	Thermal Battery for oven power	Process Technology	R	1	5	5	6	6	5	5	30	30	1	2
13	Electric oven with heat recovery	Process Technology	G	1	4	4	5	5	5	5	25	25	3	4
14	Biomass burners	Fuel Switching	R	1	2	3	3	4	1	4	3	16	1	1

Each decarbonisation technology in this register is assigned scores for capital expenditure (CAPEX), operational expenditure (OPEX), greenhouse gas emissions (GHG), and its NZ Technology Readiness Level (TRL). In addition, each option is evaluated for its suitability for retrofit and categorised by the specific process step it addresses. The technologies are also classified by type, such as fuel switching, heat recovery, process technology, or efficiency and monitoring solutions.

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