ER2FOOD

Strategic support for facilitating the adoption of Energy and Resources efficiency as drivers for the technical and business development of Egyptian SMEs and start-ups of the FOOD sector

Process Components

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Agenda

- **Introduction to the module: scope and goals**
- Examples of typical bakery lines
- The current R&D scenario in the industrial bakery sector
  - Industrial research
  - Key global players
  - Case studies
- Key areas of innovation and sustainability
- Conclusions

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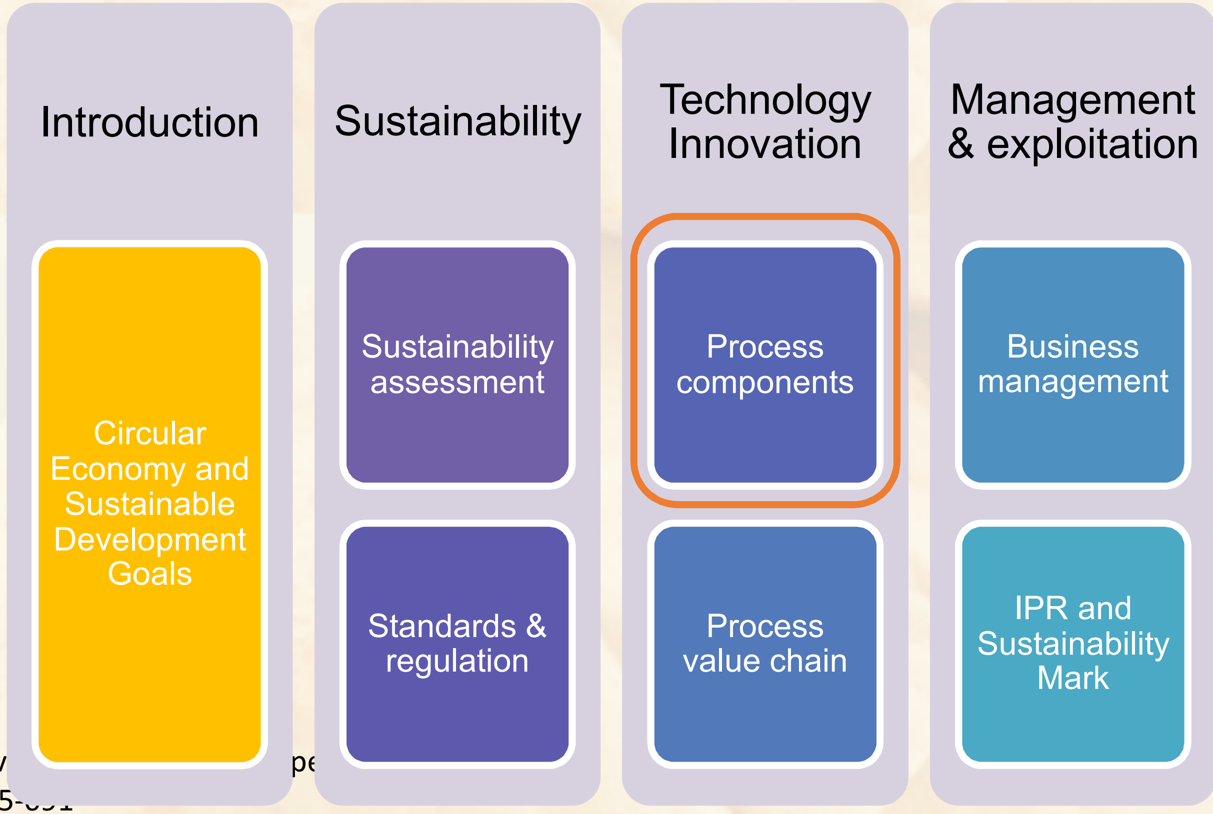
Introduction to the module: scope and goals

This is one of the training modules defined for the group: “Technology Innovation”



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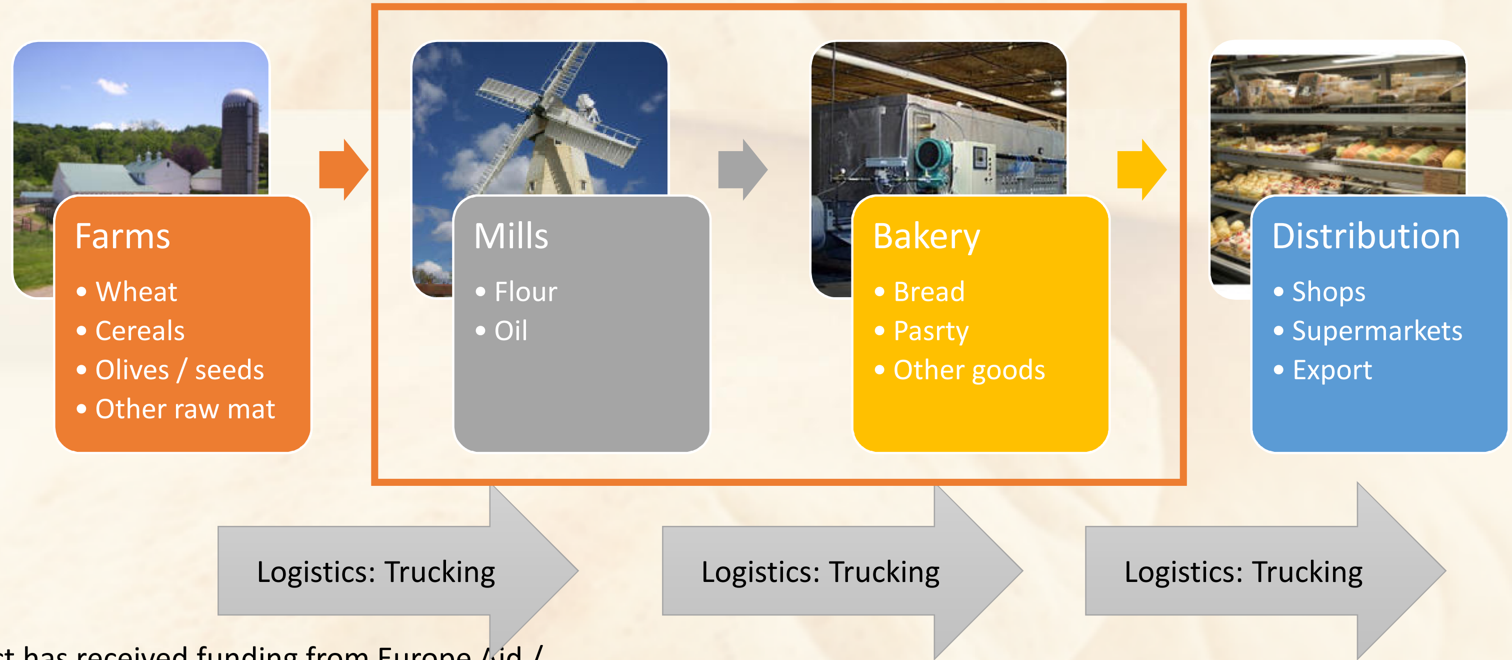
SCOPE and GOALS

The scope of the present training course and of the module itself is part of the wider perimeter of industrial bakery value chain.

This includes:



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SCOPE and GOALS

The goal of the project:

- ER2FOOD project aims at providing strategic support and expert consultancy services to Egyptian MSMEs and start-ups from the value chain of industrial bakery, for facilitating the adoption of Energy and Resources efficiency as drivers of their technical and business development

The goals of the module:

- To describe the scenario of R&D in the field of energy and resources efficiency
- To identify the best available technologies for a typical industrial bakery line
- To identify who are the key players (machinery suppliers) in the sector
- To identify the success cases that could be taken as reference by the Egyptian community

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Why this module?

This module is aimed to better clarify how the typical bakery processes affect the energy consumption and, in general, it wants to stimulate the evaluation of the different possible alternatives a bakery has to achieve a higher level of sustainability and competitiveness

- For each of the key typical steps / component of the bakery processes, the module provides a list of actions that can be done, to achieve a higher efficiency and reduce the energy bill
- The module also provides figures about the typical return on investment for the suggested actions, leveraging on past experiences and recent publications and use cases
- The use cases here provided give not only a benchmark but also a further evidence of the possible results and improvements that a bakery can achieve

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Industrial lines

Industrial bakery lines are 100% customized on the product, with special features and with specific precautions according to the type of bread that is being produced, its ingredients and the volumes to be managed.

However, for an easier understanding, we can cluster industrial bakery lines in a few groups (and their combinations / adaptations):

Cookies and pastry line:	Bread line	Special lines
Soft cookies	Bread and loaf	Puff pastry
Biscuits-crackers	Flat bread	shortcrust pastry
Stuffed cookies	Pizza bread	….
Snacks and pastry		

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Example of Bread line and its components

Forming line:
- mixer, bowl, overhopper divider, volumetric divider, long loaf moulder

Pre-proofer:
- intermediate leavening cell

Forming table:
- Moulders, extruders

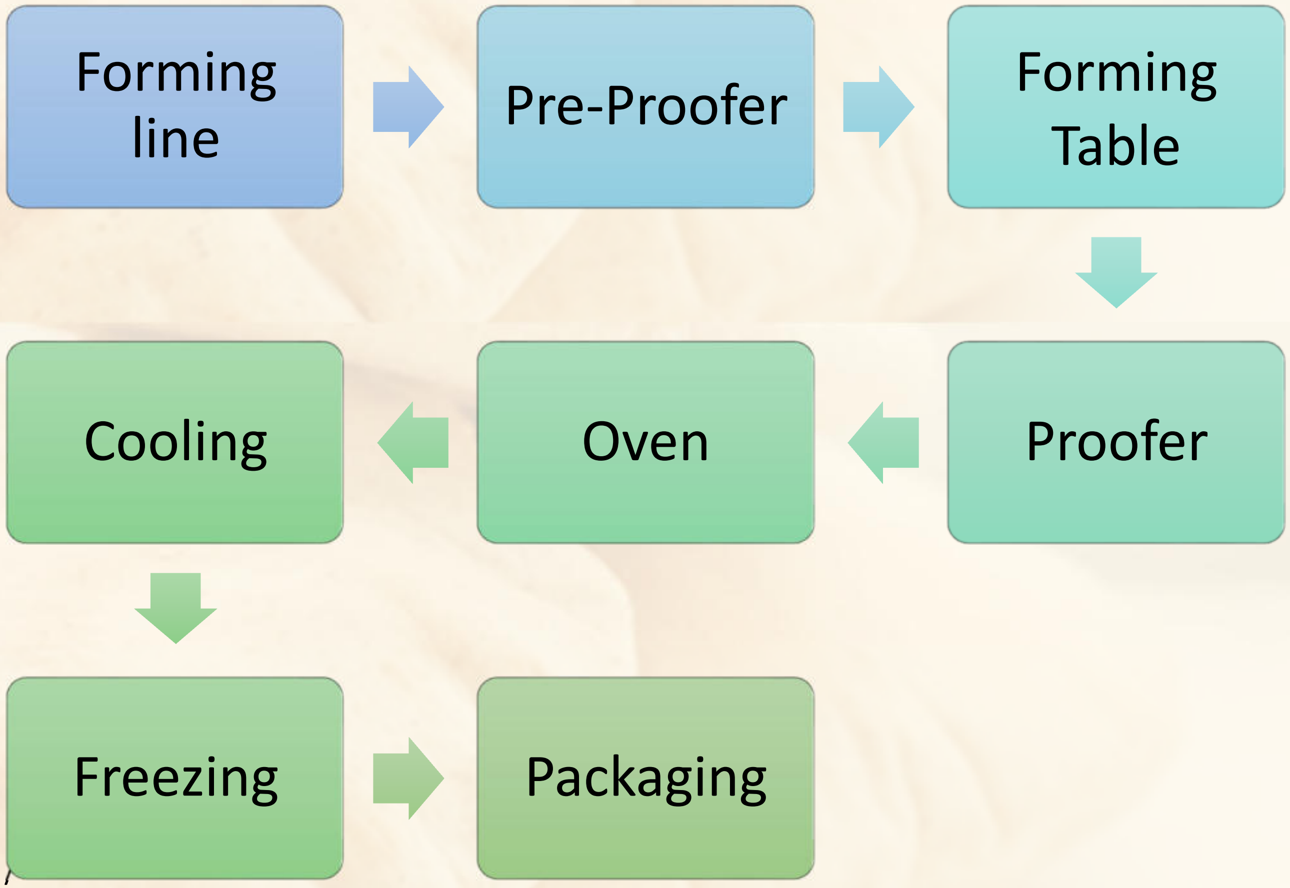
Proofer:
- leavening cell

Oven:
- Cycle-thermal, controlled oven

Cooling:
- spiral cooling, conveyor belt

Freezing:
- spiral freezing, evaporators

Packaging:
- Automated packaging



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Bread line: resources involved

1. **Forming line** — Flour; Water, other ingredients; Electricity
2. **Pre-Proofer** — Electricity, water, steam
3. **Forming Table** — Electricity, flour, water
4. **Proofer** — Electricity, steam
5. **Oven** — Electricity, gas, steam
6. **Cooling** — Electricity
7. **Freezing** — Electricity
8. **Packaging** — Electricity, paper, plastics

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Example of biscuits line and its components

Mixer:
- Horizontal mixer

Feeding unit:
- Cutter, hopper, conveyor

Lamination line:
- cylinders

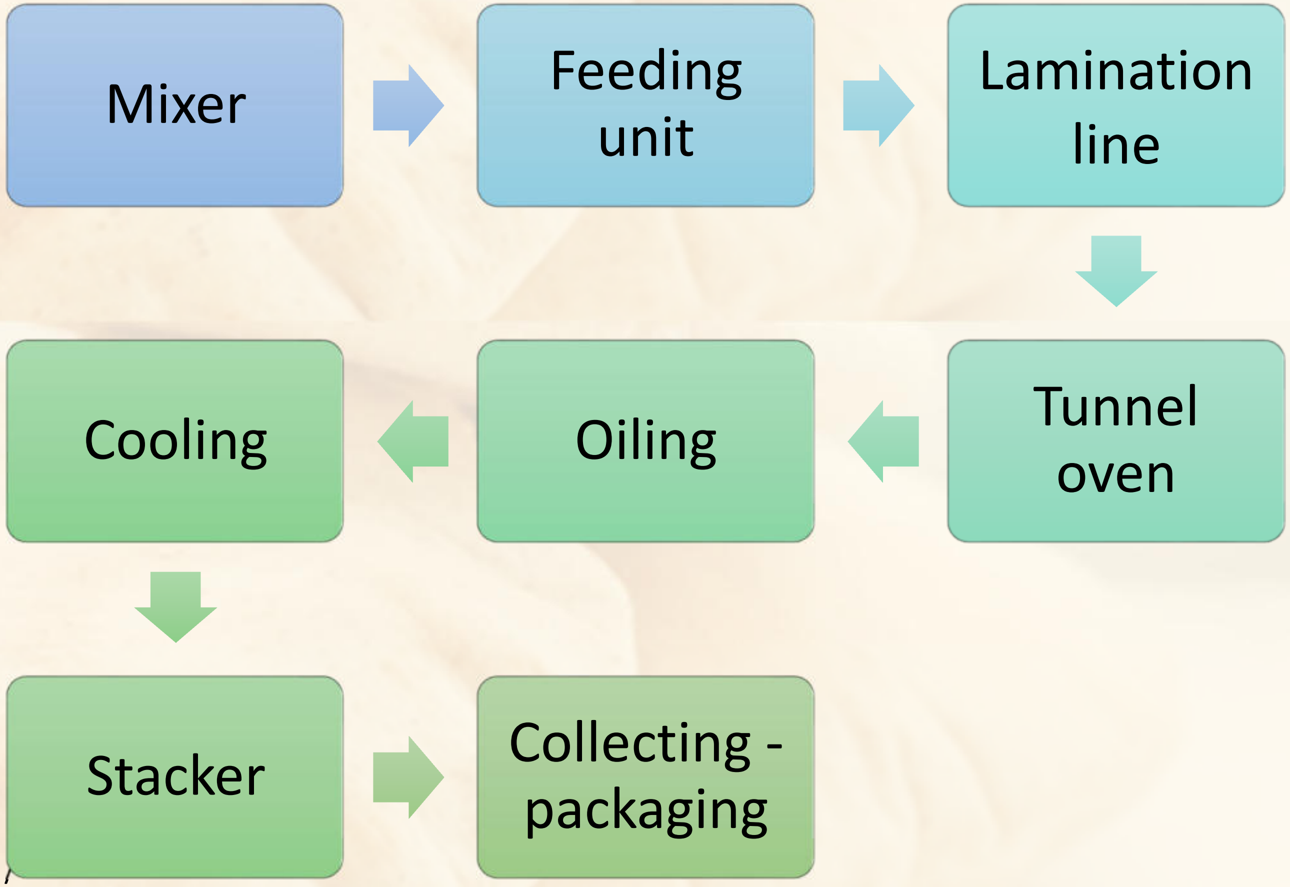
Tunnel oven:
- long, controlled oven

Oiling:
- spraying

Cooling:
- conveyor belt

Stacker:
- Automatic stacking machine

Collecting - Packaging:
- Automatic packaging



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Biscuits line: resources involved

1. **Mixer** — Flour; Water, other ingredients; Electricity
2. **Feeding unit** — Flour; Water, other ingredients; Electricity
3. **Lamination line** — Electricity
4. **Tunnel oven** — Electricity, gas, steam
5. **Oiling** — Electricity, oil
6. **Cooling** — Electricity
7. **Stacker** — Electricity
8. **Collecting - packaging** — Electricity

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Patent Analysis

- Usually, a patent analysis is used for:

✓ **Clearance & state-of-the-art search:** the analysis confirms if you have the freedom to operate in a particular technology area and avoid potential risk of infringement.

- But the patent scenario is also a valuable source of information for:

✓ **Competitive, technical & market intelligence searching:** The analysis helps in performing strategic, technical, and competitive intelligence, with the support of an artificial intelligence.

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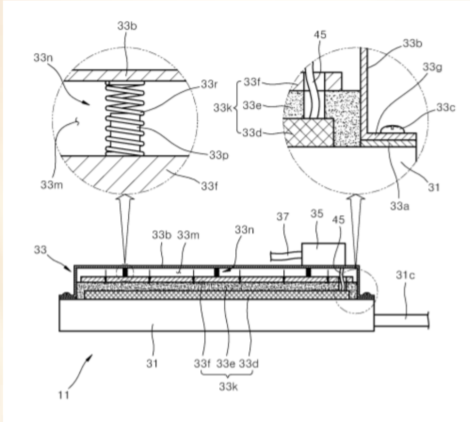
Informations stored in a patent (example)



- Title: ELECTRIC HEATING DEVICE FOR BAKING BREAD
- Assignee: Park
- Inventor: Park
- Patent legal status: Alive
- Publication date: 2016-09-08
- Publication number: KR1655252B1
- International Patent Classification code (IPC): A21B 5/02
- Abstract: The invention relates to the electrical type bakery mold heater for the bread baking. This includes the presser portion in which it pressurizes the pressing plate to the gasket, sealing the internal space of the airtightness cover by the state inserted between the airtightness cover, and flange portion and bakery mold and the state supported in the airtightness…….
- Drawings

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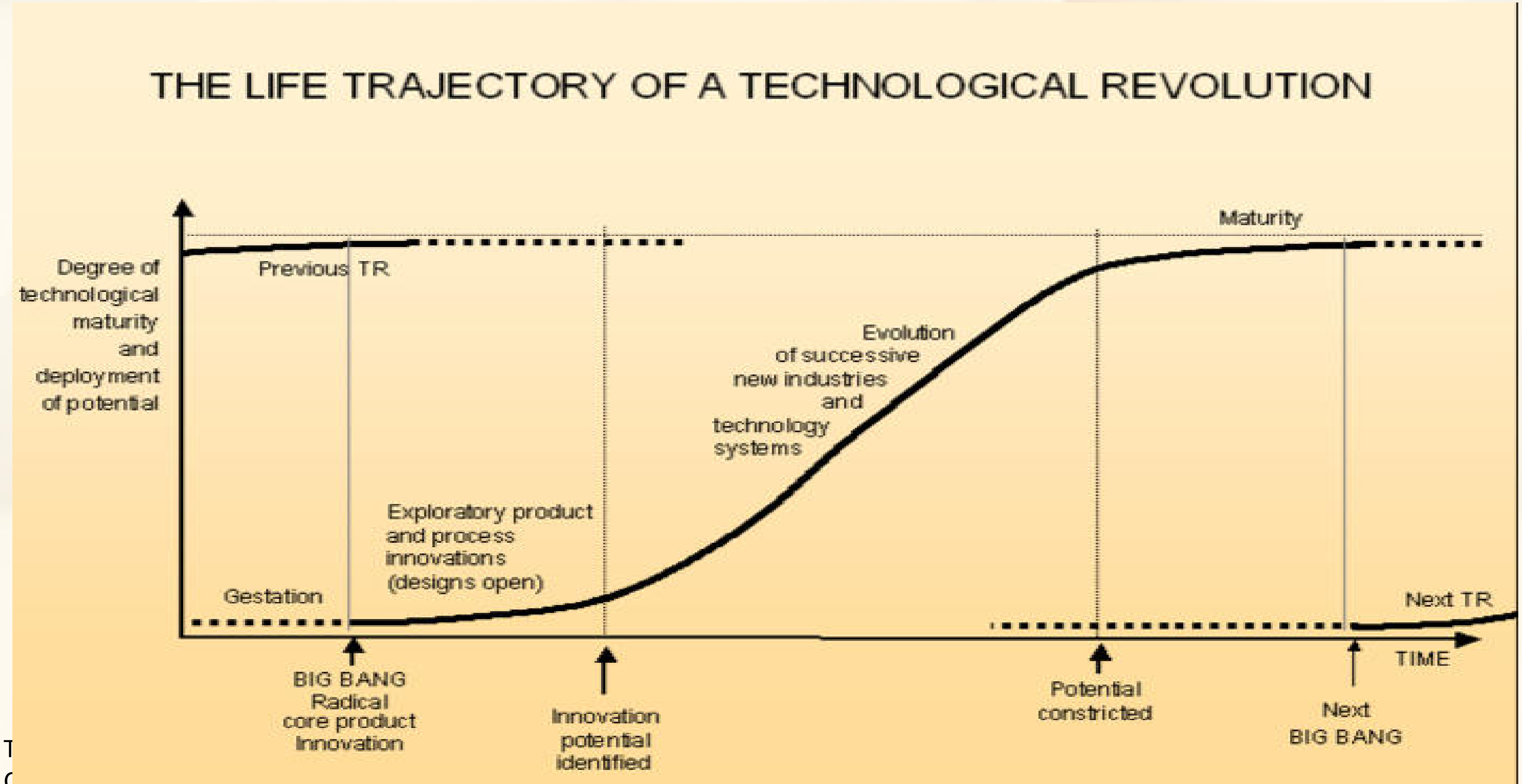
Evolution of systems



International Patent Classification code

A	HUMAN NECESSITIES
B	PERFORMING OPERATIONS; TRANSPORTING
C	CHEMISTRY; METALLURGY
D	TEXTILES; PAPER
E	FIXED CONSTRUCTIONS
F	
G	
H	

ENGINEERING IN GENERAL

F15	FLUID-PRESSURE ACTUATORS; HYDRAULICS OR PNEUMATICS IN GENERAL
F16	ENGINEERING ELEMENTS OR UNITS; GENERAL MEASURES FOR PRODUCING AND MAINTAINING EFFECTIVE FUNCTIONING OF MACHINES OR INSTALLATIONS; THERMAL INSULATION IN GENERAL
F17	STORING OR

LIGHTING; HE

F21	LIGHTING
F22	STEAM GENE
F23	COMBUSTIO
F24	HEATING; RA
F25	REFRIGERAT SYSTEMS; M
F26	DRYING
F27	FURNACES;
F28	HEAT EXCHA

F24B	DOMESTIC STOVES OR RANGES FOR SOLID FUELS; IMPLEMENTS FOR USE IN CONNECTION WITH STOVES OR RANGES [6]
F24C	OTHER DOMESTIC STOVES OR RANGES; DETAILS OF DOMESTIC STOVES OR RANGES, OF GENERAL APPLICATION (radiator stoves of the fluid-circulating type F24H)
F24D	DOMESTIC- OR SPACE-HEATING SYSTEMS, e.g. CENTRAL HEATING SYSTEMS; DOMESTIC HOT-WATER SUPPLY SYSTEMS; ELEMENTS OR COMPONENTS THEREFOR (using steam or condensate extracted or exhausted from steam engine plants for heating purposes F01K 17/02)
F24F	AIR-CONDITIONING; AIR-HUMIDIFICATION; VENTILATION; USE OF AIR CURRENTS FOR SCREENING (removing dirt or fumes from areas where they are produced B08B 15/00; vertical ducts for carrying away waste gases from buildings E04F 17/02; tops for chimneys or ventilating shafts, terminals for flues F23L 17/02)
F24H	FLUID HEATERS, e.g. WATER OR AIR HEATERS, HAVING HEAT-GENERATING MEANS, IN GENERAL (heat-transfer, heat-exchange or heat-storage materials C09K 5/00; tube furnaces for thermal non-catalytic cracking C10G 9/20; devices, e.g. valves, for venting and aerating enclosures F16K 24/00; steam traps or like apparatus F16T; steam generation F22; combustion apparatus F23; domestic stoves or ranges F24B, F24C; domestic- or space-heating systems F24D; furnaces, kilns, ovens, retorts F27; heat-exchangers F28; electric heating elements or arrangements H05B)

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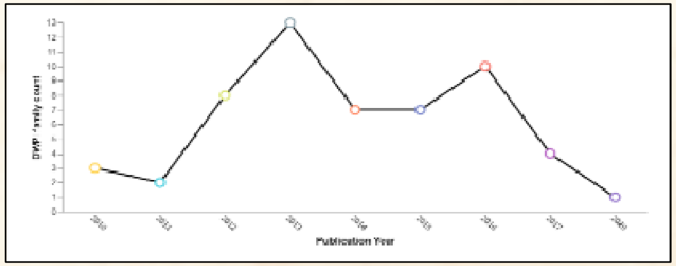
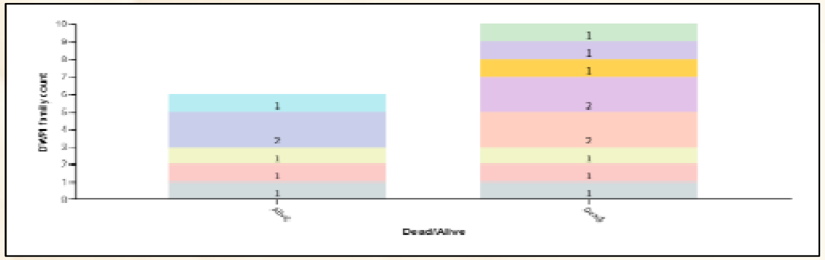
Patent Analysis

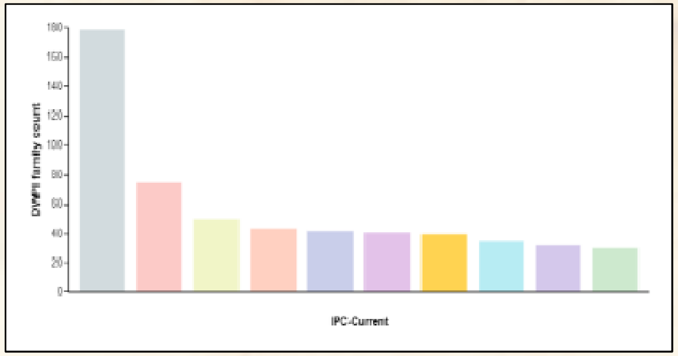
Patent publishing trend



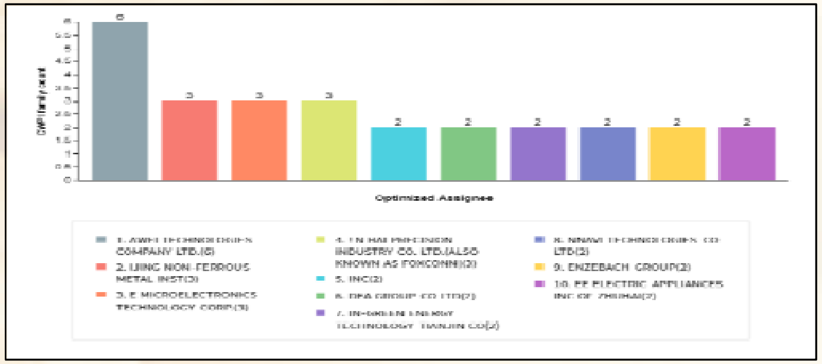
Dead vs Alive patents



Top IPC – International Patent Classification

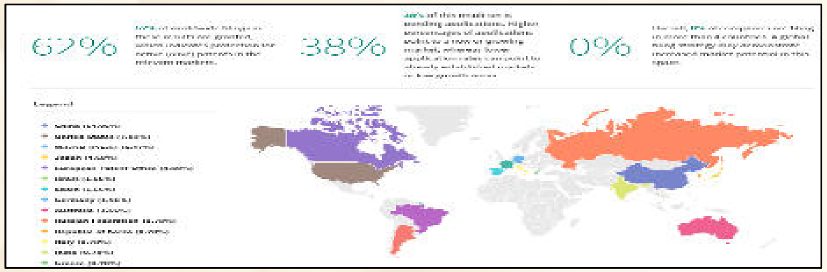


Top applicants



Technology Areas and A.I. Insights

Alive international market



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Energy Efficiency in bakery – patent analysis

Data and tools

- Derwent Innovation (www.derwentinnovation.com)
- Espacenet (www.espacenet.com)
- Time interval: from 2010 to 2020

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Energy Efficiency in bakery – patent analysis

Results

- **~11.000** records
- **~ 9300** INPADOC families. A **patent family** is a collection of **patent** documents covering a technology. The technical content covered by the applications is similar, but not necessarily the same

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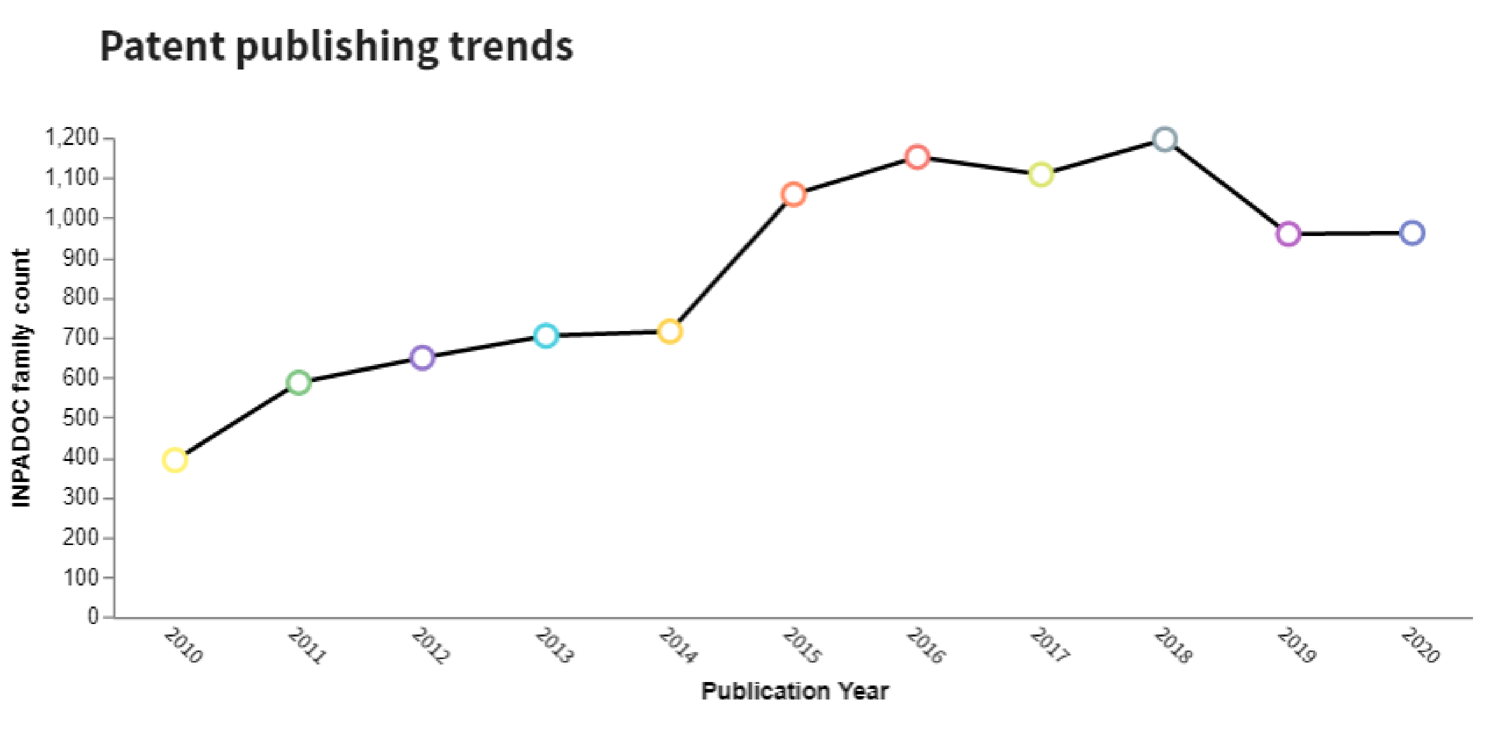
Energy Efficiency in bakery - trend

The analysis of publishing trend in the period 2010-2020 shows a constant growth in the beginning of the decade, with a strong acceleration after 2014.

In the last years, the level of patenting is stabilizing, at a very important quote of >1000 patents/year.

In general we can say that industrial products have reached a very high maturity level.



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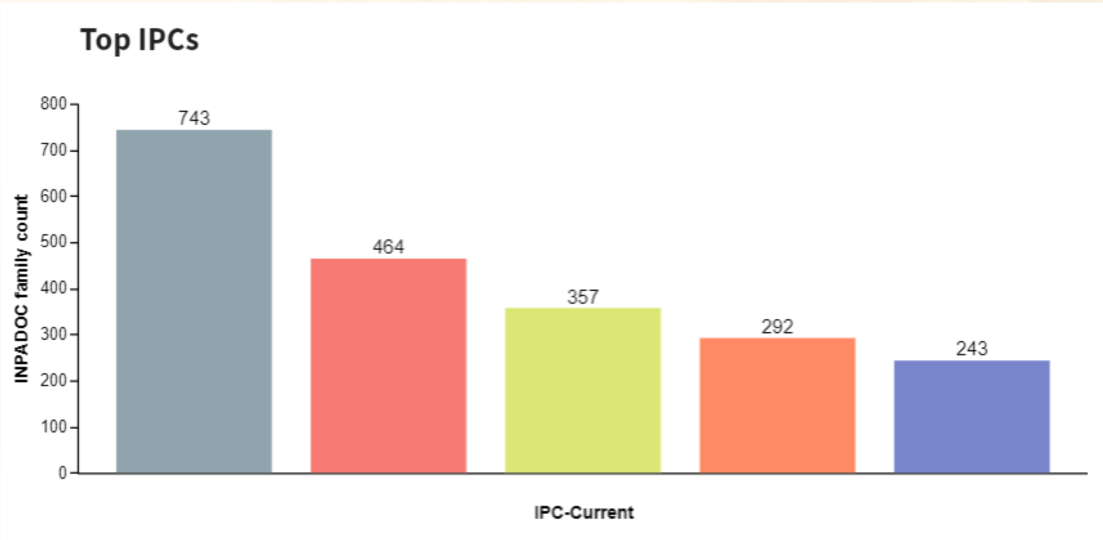
Energy Efficiency in bakery – top IPC



IPC	Description	Record
A47J 37/06	Baking; Roasting; Grilling; Frying (bakers' ovens, non-domestic baking equipment	743
F26B 21/00	Arrangements for supplying or controlling air or gases for drying solid materials	464
F26B 25/00	loading, conveying, or unloading	357
F26B 9/06	Machines or apparatus for drying solid materials or objects at rest or with only local agitation in stationary drums or chambers	292
F27D 17/00	Arrangements for using waste heat	243

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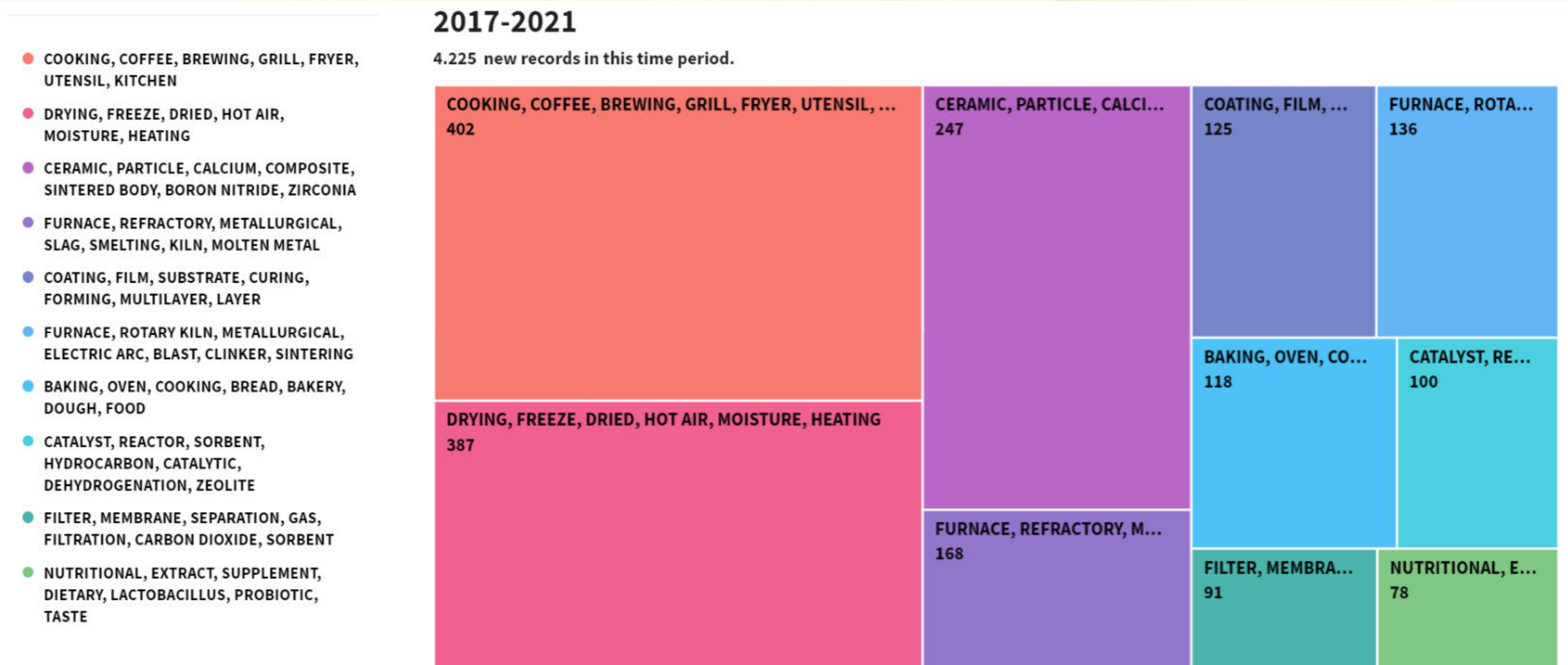
Energy Efficiency in bakery – keywords



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Energy Efficiency in bakery – top markets

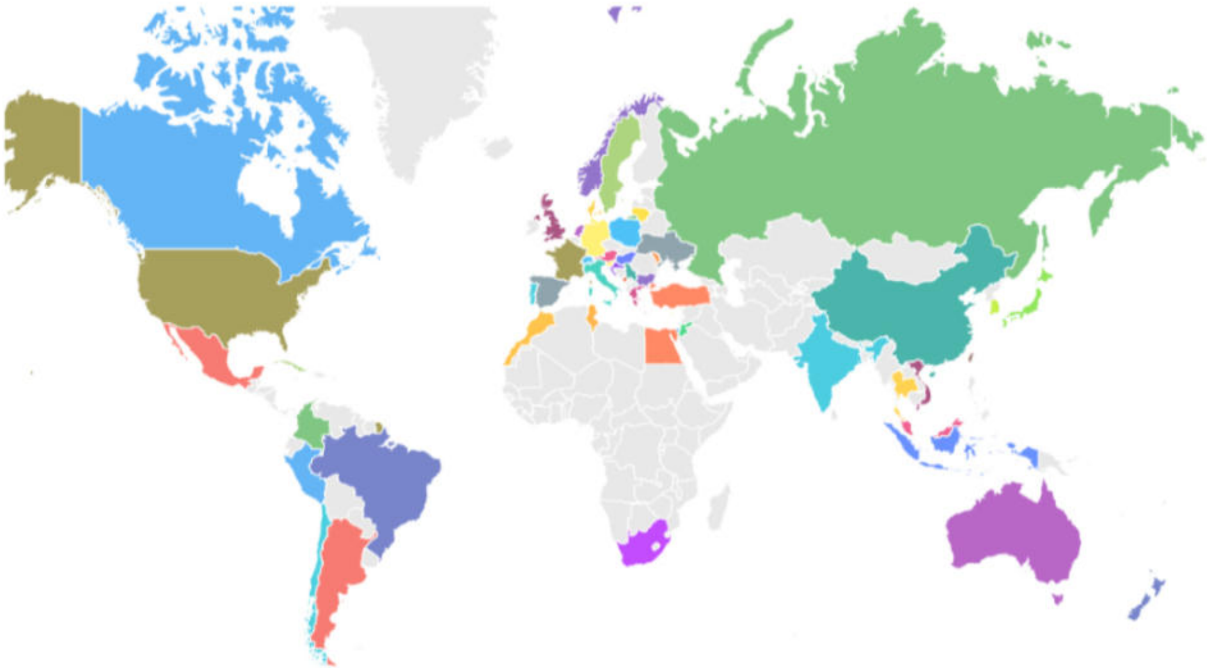
64% — 64% of worldwide filings in these results are granted, which indicates protection for active (Alive) patents in the relevant markets.

36% — 36% of this result set is pending applications. Higher percentages of applications point to a new or growing market, whereas lower application rates can point to already established markets or low growth areas.

0% — Overall, 0% of companies are filing in more than 4 countries. A global filing strategy may demonstrate increased market potential in this space.

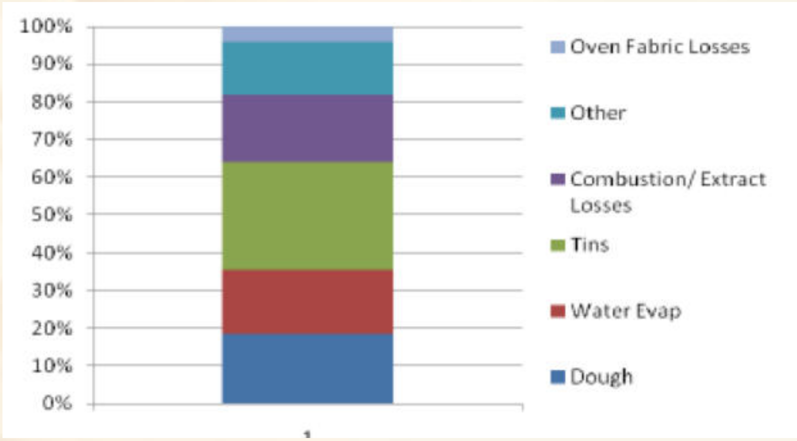
Legend

- China, Mainland (76.4%)
- United States (4.4%)
- W.I.P.O (P.C.T.) (3.15%)
- Japan (3.03%)
- European Patent Office (2.21%)
- Russian Federation (1.65%)
- Republic of Korea (1.48%)
- Germany (1.17%)
- Taiwan (0.8%)
- Canada (0.65%)
- Australia (0.56%)
- Brazil (0.47%)
- Spain (0.45%)
- Hong Kong (0.34%)
- Poland (0.28%)
- Mexico (0.24%)
- United Kingdom (0.24%)



Case studies - Improving the efficiency of bakery ovens in the UK

- Bread production in the UK is dominated by high volume plant bakeries, which are responsible for about 80% of breadconsumed in the UK.
- Energy savings available within bakeries can be significant due to the high energy consumption of baking itself, which costs an average bakery £335k per year.



- This case study, sponsored in 2016 by the UK Government's Regional Growth Fund, investigated gas production from bakery products during the baking process, how gas flow rates in flues affects oven efficiency and whether there is potential to improve oven efficiency by controlling flue gas flow rates with variable speed drives (VSDs).

The figure shows the breakdown of oven energy use for a typical direct-fired gas oven, where hot air exiting the flues is responsible for around 20% of gas use. This makes no contribution to heating bread dough and it can be considered as a direct loss.

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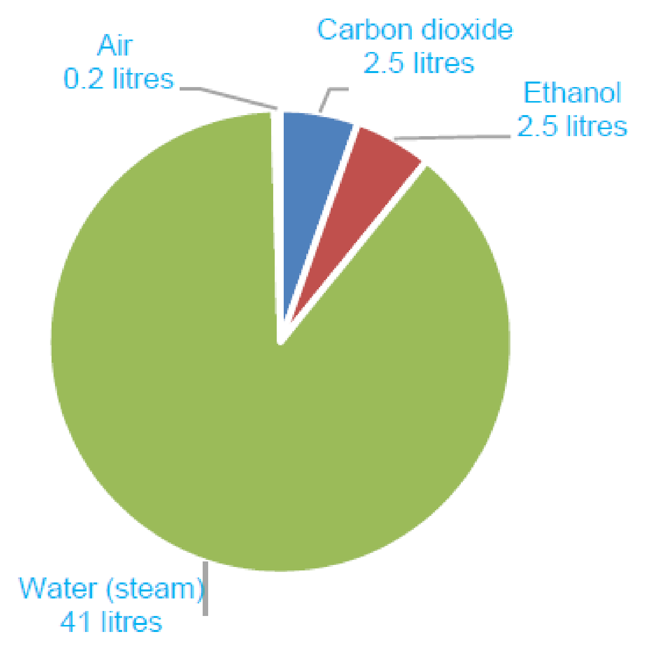
"Improving the efficiency of bakery ovens - Case study" UK Government's Regional Growth Fund (RGF), Carbon Trust's Industrial Energy Efficiency Accelerator, 2016

Case studies - Improving the efficiency of bakery ovens in the UK

- Estimates from existing research shows that a 400g loaf of bread produces 46.2 litres of gas during baking: water vapour, air, ethanol and carbon dioxide
- The case study understands the benefit that could be achieved by improving the oven balance – reducing the amount of exhaust air to match the burner air - using sensors, a ratio controller and variable speed fan



The trial simulated simulate a modern commercial bakery oven with gas flows optimised to improve efficiency.
The test was run at three different baking temperatures: 250°C, 200°C and 150°C
using different oven configuration.
The results, shown in next slide, show the relative energy consumption at each temperature in different oven configuration, normalised to the 'fixed speed' system.

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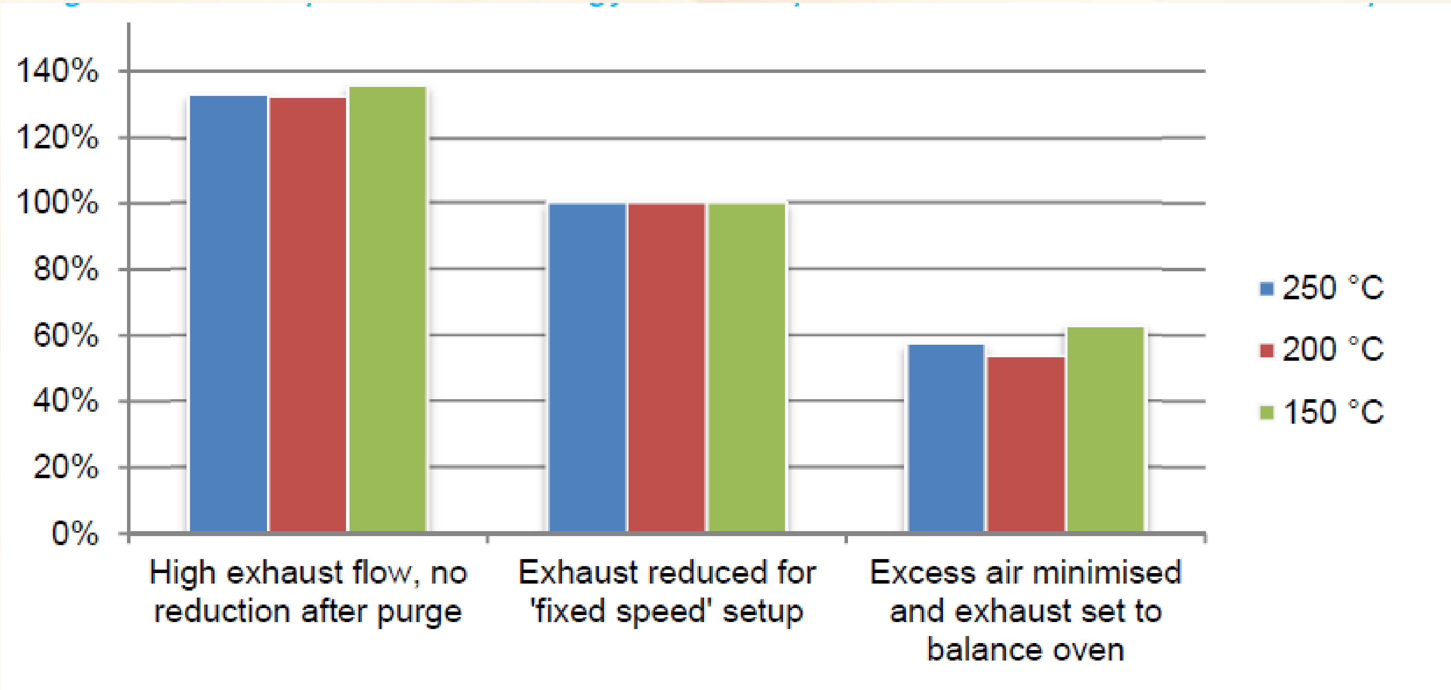
Case studies - Improving the efficiency of bakery ovens in the UK

The first test with high exhaust flow and no damper (not considered representative of a commercial bakery oven) consumed approximately 30% more energy than the fixed speed system.



The third case, with excess air minimized and with exhaust set to balance oven gases, showed a 42% energy saving over the fixed speed setup on the single chamber test oven, indicating that significant savings could be achieved by balancing oven gases.

Additional gas savings may be available by adding heat recovery technology. Estimated total cost savings of around 7.2% are possible.

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Case studies - Improving the efficiency of bakery ovens in the UK

Intervention	Requirements	Payback (years)	Savings (est.%)
Suitable burner with existing ratio controller	• Survey • Instruments • Gas meter • Commissioning	1	4.7
Suitable burner without ratio controller	All above, plus: • Ratio controller • Gas train • Valves, • Installation	2.5	4.7
Burner redundant or not suitable for upgrade	All above, plus: • New burners	5	4.7
Heat recovery installation	• Space available • Suitable burner	<4	7.2

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Energy Efficiency Measures in Bakeries toward Competitiveness and Sustainability - QUITO

The Case study is taken from the recent article “Energy Efficiency Measures in Bakeries toward Competitiveness and Sustainability – Case Studies in Quito, Ecuador”, published in 2021. This study evaluates the energy efficiency in the bakery industry toward competitiveness and sustainability through energy audits that were carried out on six bakeries located in Quito, Ecuador

1. Thanks to the energy surveys, the information of the energy consumption of the facilities was collected, including the electricity bills, power data, equipment usage time, habits, and monthly consumption
2. With the energy balances, the critical points were identified in the baking process and the production activity, as those with the highest energy consumption within each establishment.
3. Subsequently, with the indicator of electrical energy consumed per unit produced, the energy consumption by production processes and the bakery’s total energy consumption were determined.
4. Several improvement proposals were generated for the bakery industry based on the results
5. Finally, a comparison the consumption of electrical energy has been done, considering a benchmark sample of bakeries

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Energy Efficiency Measures in Bakeries toward Competitiveness and Sustainability - QUITO

Energy Consumption in each studied bakery

	Electricity Bill Total Electricity Consumption (kWh/month)	Electricity Bill ($)	Estimated Electricity Consumption (kWh/month)	Error (%)
Bakery 1	1043	137.18	1049.82	0.653
Bakery 2	1492	171.43	1472.31	1.320
Bakery 3	1303	165.69	1295.00	0.614
Bakery 4	1101	138.52	1063.22	3.431
Bakery 5	1324	168.57	1316.69	0.552
Bakery 6	1176	148.26	1154.85	1.798

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Energy Efficiency Measures in Bakeries toward Competitiveness and Sustainability - QUITO

- Using the electricity consumption value and the total amount of flour used every month, the value of the energy consumption indicator of each bakery was determined.
- The best energy indicator corresponds to bakery 2, which has a value of 0.124 kWh/kg. This means that it is the most efficient bakery, since it requires less energy and produces good quantities.
- On the contrary, bakery 4 has the worst indicator, with a value of 0.315 kWh/kg

	Energy Use (kWh/month)	Mass of Flour Processed (kg/month)	Energy Indicator (kWh/kg)
Bakery 1	1043.00	3628	0.287
Bakery 2	1491.22	12,000	0.124
Bakery 3	1303.00	9000	0.145
Bakery 4	1101.00	3500	0.315
Bakery 5	1325.00	10,000	0.133
Bakery 6	1173.00	5000	0.235

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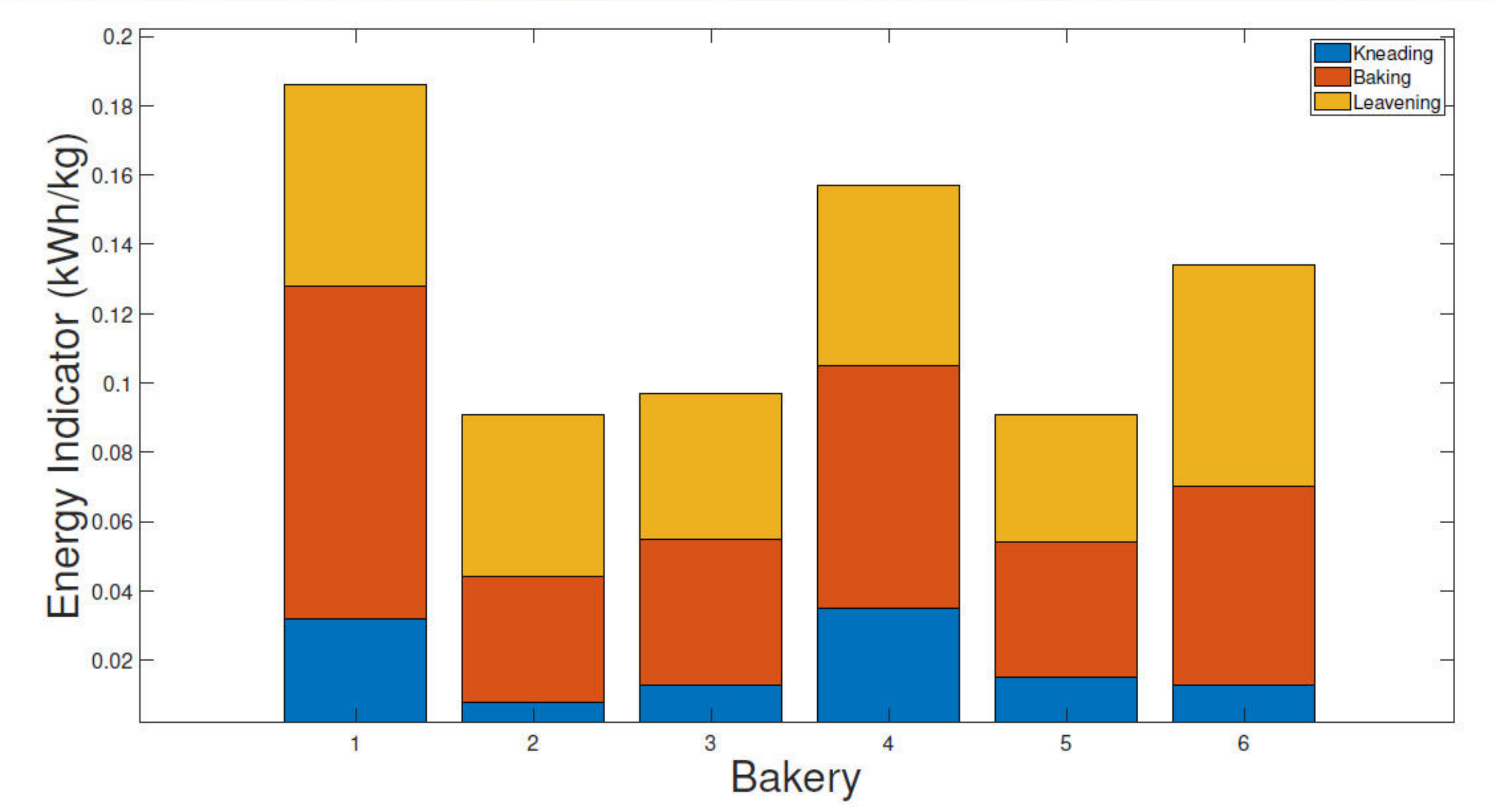
Energy Indicator for bread production by bakery



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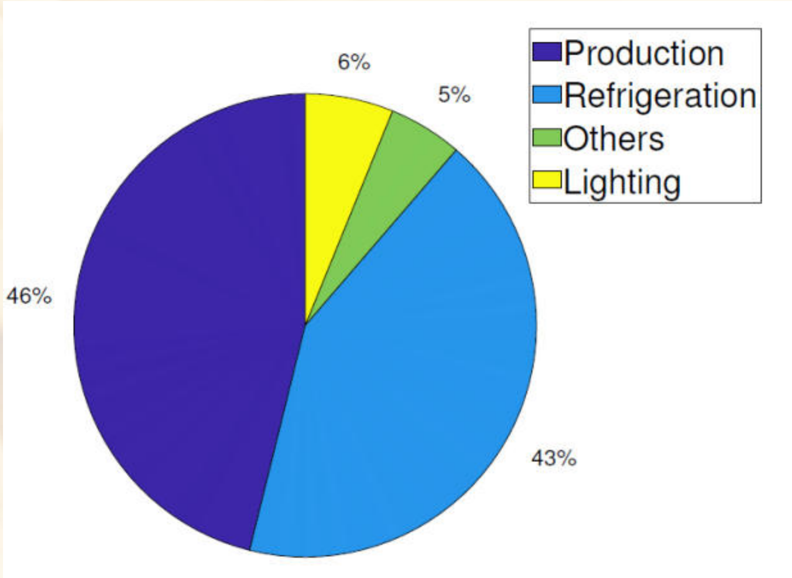
Energy Efficiency Measures in Bakeries toward Competitiveness and Sustainability - QUITO

For each bakery, the energy consumption was split into production, refrigeration, lighting, and other activities

The figure illustrates the share of each consumption activity in bakery 2:

- production activity is the highest value of electrical energy used, representing 46% of the entire bakery with 679 kWh.
- refrigeration activity consumes 626 kWh of the total To be noticed that at least one refrigeration equipment is on 24/7
- Lighting consumes 91 kWh
- the other activities 76 kWh, representing a small share of the total energy consumption



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Energy Efficiency Measures in Bakeries toward Competitiveness and Sustainability - QUITO

Proposal for the improvement of energy efficiency in Bakery 1

- A change of equipment was proposed for the kneading process
- The proposed equipment has a higher capacity for dough processing, with 10 kg per cycle, which will reduce the processing time from 120 h in a month to 36 h
- Moreover, the proposed equipment has less power with 750 W, and the energy-saving will be 105 kWh/month

Kneaders	Power W	Capacity kg/cycle	Cost $
Old	1100	3	121.03
New Option	750	10	636.96

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Energy Efficiency Measures in Bakeries toward Competitiveness and Sustainability - QUITO

- For the fermentation chamber, better process management was proposed since the fermentation chamber was partially used due to the limitations of the kneading process. This action reduced the time of use from 300 h in a month to 96 h, with an energy saving of 102 kWh/month.
- The oven was also partially used due to constraints in the kneading process, and better process management will reduce the time of use with savings of 200 kWh/month.
- The refrigeration activity has a poor performance since the heat emission from ovens is quickly gained by refrigerators. It was recommended to improve thermal isolation
- Lighting and minor equipment were not analyzed in detail, since they represent 11% of the whole energy consumption. However, the time of use of this equipment could be reduced with staff training.

In total, 407 kWh/month could be reduced in bakery 1, which represents 39% of the energy saving.

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Energy Efficiency in bakery

From the analysis of the current research scenario and considering the publication "Energy Efficiency Improvement and Cost Saving Opportunities for the Baking Industry" (Ernest Orlando Lawrence Berkeley, National Laboratory, funded by the U.S. Environmental Protection Agency) we can conclude that:

- Energy consumption is mostly concentrated in both the baking and cooling/ freezing processes
- For non-frozen products, baking is the largest energy consumer ranging between 26 and 78% of total energy. For instance, baking represents 78% of the energy requirement for cookies and crackers, which are products produced with no need to wash pans or provide a fermentation and proofing period
- In the case of frozen products, the freezing process consumes the most energy

In addition to the analysis of specific equipment:

- other cross cutting energy usage related to equipment such as motors, pumps, HVAC systems, lighting, and boilers
- These systems can account for more than half of the energy consumed by a bakery and can be simpler and more affordable to manage that process specific equipment

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Energy Efficiency Opportunities – Proofing

Opportunity	Payback time
Insulation/coverage of storage bins	3 months
Automatic distribution, Conveyors	6 months
T° sensors can increase energy use but it increases quality and cooling time of the prepared dough can be reduced by about 5 mins	6 months
Advanced Mixers	6 months
• with variable speed and dough control to decrease the need for cooling	
• Continuous mixing systems are able to limit dough exit temperature	
• Without the pre-blending step, energy can be reduced by as much as 20%.	
• Controllers and instrumentation allow monitoing dough temperature, coolant temperature, and energy consumed by the mixer	

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https://www.spiromatic.com/nl/?gclid=Cj0KCQjwrJOMBhCZARIsAGEd4VHZTs5ChBGfKgev6fWXRa-lbr4kngsmra-tHR4c13910GZRRC1vZPcaAjchEALw_wcB
https://amfbakery.com/equipment/proofing-baking/proofing/

Energy Efficiency in bakery

- Proofing of dough requires a conditioned space that provides a desired ambient temperature and humidity, typically around 40°C and 70 to 80% humidity
- According to bakery size, proofing can be done in small boxes or in large rooms
- Proofers are typically heated and humidity created by a boiler. Alternative sources of heat and steam can be found throughout the bakery but must be assessed (waste heat)

Opportunity	Payback time
Lower steam pressure	6 months
Direct gas-fired with water sprayer	4 years
Oven heat recovery	3-5 years

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https://sveba.com/en/news/2020-02-11/optimal-fermentation-our-revolutionary-series-proofers

Energy Efficiency in bakery – Ovens

- Ovens and dryers can consume more than 10% of a bakery's total energy and 26 to 75% of process-specific energy, often inefficiently
- Dryers often consume 2-3 times the minimum required energy to dry a product. Ovens consume up to 5 times the thermodynamic energy necessary to heat a product
- Extra energy is usually just wasted and exchange with the outdoor environment
- Gas burners are 85 to 95% efficient while steam heat systems are 70 to 80% efficient. Electricity has a lower efficiency
- The selection of oven technology depends on the type of product and the volume produced:
  - Traditional convection oven – small-medium sized companies, high flexibility, low volumes
  - Radiation tubes – allow a good variety of products and higher volumes
  - Direct gas – For short cooking time and lange volumes
  - Hybrid ovens – comnbination of the above
  - Other specific ovens (e.g. high temperature)

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Energy Efficiency in bakery – Ovens

Opportunity	Payback time
Insulation of the oven, insulation of other equipment (e.g. exhaust stacks)	6-18 months
Replacement of the oven (with a more efficient one)	5-8 years
Replacement of the burner (with a more efficient one)	18 months
Optimization of the burner operating conditions	18 months
Implementation of exchangers for waste heat recovery	2-4 years
Preventive maintenance (for air leakage)	10 months

https://www.aasted.eu/equipment/heating/convection

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Energy Efficiency Opportunities – Cooling and Freezing

- The only use of unconditioned air to cool bakery products is typically too slow for industrial productions. For this reason, energy is used to condition air for a faster cooling step
- Cooling should be carried on in a place far from heat source (e.g. ovens), in order to avoid inefficient thermal interferences. Relocation/optimization of spaces could bring savings

Opportunity	Payback time
Adoption of spiral conveyor cooling racks	1-3 years
Optimization of fans and compressed air circuit	10 months
Shift from batch to continuous freezing	12 months
Adoption of spiral freezers	1-3 years
Adoption of cryogenic technologies	2-4 years

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Energy Efficiency Opportunities – Cross-cutting

Lighting:
- Replacement of bulbs with efficient and long-lasting LEDs
- Increase use of daylight - Increasing levels of daylight within rooms can reduce electrical lighting loads by up to 70%
- Automatic control of lighting - Occupancy sensors can save 10% to 20% of a facility's lighting energy use

HVAC (heating, ventilation, and air conditioning) system:
- energy monitoring and control systems. An energy monitoring and control system supports the efficient operation of HVAC systems by monitoring, controlling, and tracking system energy consumption.
- Adjust non-production hours set-back temperatures. Setting back building temperatures during periods of non-use, such as weekends or non-production times, can significantly reduce energy consumption.
- Consider new high-efficient systems, including heat pumps
- Consider heat recovery systems, e.g. using waste heat from ovens
- Improve the building overall efficiency (e.g. insulation)

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Agenda

- Introduction to the module: scope and goals
- Examples of typical bakery lines
- The current R&D scenario in the industrial bakery sector
    - Industrial research
    - Key global players
    - Case studies
- Key areas of innovation and sustainability
- **Conclusions**

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Conclusions

- According to recent experiences and to the collected use-cases, industrial bakeries have a good potential for improvement, especially in terms of energy efficiency
- It has been highlighted how the sustainability improvements can positively affect the competitiveness of a company, opening new opportunities for its market
- All the typical processes included in bakery lines can be investigated and, possibly, made more efficient with solutions that have different costs, returns on investments and final effects
- Also solutions that require no or livery limited investments are possible. These are typical best practices to be customized by the company and shared internally to be fully adopted by staff
- In the next slides, a summary of measures that can be implemented in industrial bakeries is provided, starting from those that require the lowest investments

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Summary Table

Efficiency measures	No (or low) capital investment
Lighting	Automatic light management systems, sensors
HVAC	Adjust non-production hours temperatures, automatic control
Boilers	Visula inspection, correct sizing
Steam	Maintain insulation, check for leaks, maintain steam traps
Refrigeration	Recharge refreigerant, check for contamination, minimize heat sources in cold areas, defrost, keep condensers clean
Baking	Automatic switch off oc conveyors, proper placement of the oven, minimize oven heat up time, temperature profiling
Water efficiency	Water management programs, water use audit

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Summary Table

Efficiency measures	Short payback period
Lighting	Full automatic lighting control, replacement of bulbvs with LED
HVAC	Energy manitoring system, variable air volume and adjustable speed drives, more efficient fans, building insulation, roof coating
Boilers	Process control, improve insulation, condensate return, recover waste heat, reduce excess air
Steam	Improve insulation, monitor steam traps, recover flash steam
Refrigeration	Performance monitoring, piping insulation, reduction of building heating loads, optimized air flows, adjustable speed drives, automatic purging of condensers
Baking	Reduced ingredients exposure, handling and temperature control, adjustable speed mixers, waste heat recovery in ovens, automated conveyors, cooling line controls
Water efficiency	Start/stop controls, reduce cooling tower bleed-off

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Summary Table

Efficiency measures	Higher capital investments
Lighting	increase daylight
HVAC	Heat recovery systems, solar air heating, roof gardens
Boilers	Upgrade of boilers
Steam	Improve insulation, monitor steam traps, recover flash steam
Refrigeration	Upgrade cooling towers/spirals, compressor for defrosting
Baking	Combined heat and power systems, PV panels for self generation, solar thermal panels, continuus mixers, multi-level ovens, upgraded ovens, robotic movement and handling, robotic packaging

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