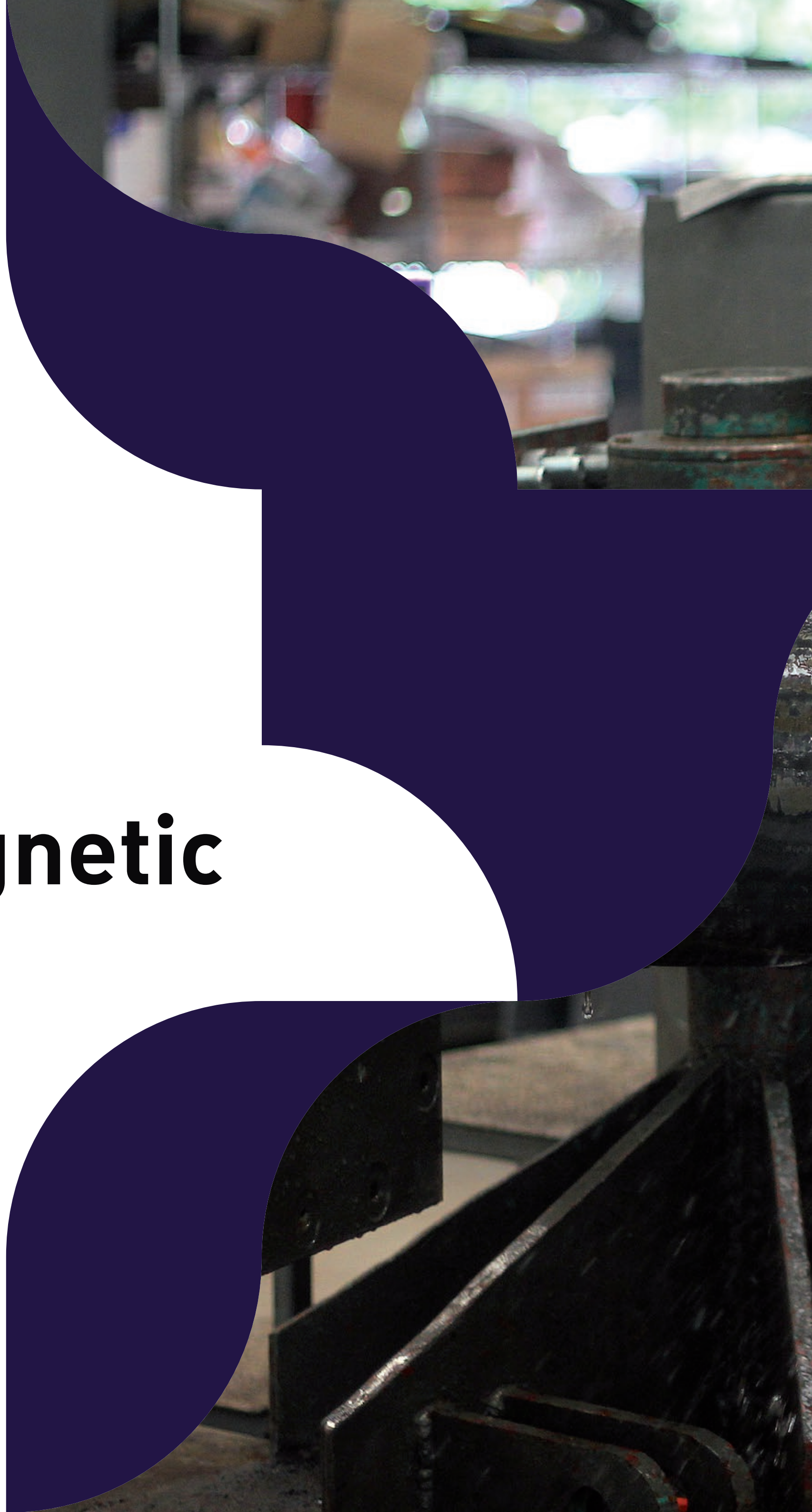
# Electromagnetic Processing



Induction pipe bending at Barnshaw Section Benders, UK.
Source: Barnshaws Metal Bending Ltd

Electromagnetic processing technologies typically heat or melt materials that are used in everyday life. Process heating is central for the manufacturing of a vast array of consumer and industrial products. The conventional method is to heat the air in a furnace by combusting a fossil-fuel and transfer the heat to the work piece by convection. This convection method has major drawbacks such as lower thermal efficiency or heat transfer to the product, it requires larger space, is noisy and produces several combustion by-products such as CO, $CO_2$ and other particulate matters. Electromagnetic processing technologies use wavelengths in the electromagnetic spectrum that correspond to microwave, radio waves, infrared, and ultra violet to heat materials. Direct heating methods generate heat within a work piece, by either passing an electrical current through the material, or inducing an electrical current (eddy current) into the material. These technologies offer significant benefits compared to the fossil fuel alternatives and contribute to decarbonization by not producing on-site emissions. Depending on the way electricity is generated, these technologies will lead to an improvement in overall air quality. Other common advantages of electro-heat technologies, apart from the lower environmental impact, are:

> Electromagnetic processing can potentially halve the final energy demand for EU process heat which is 20% of Europe's final energy demand.

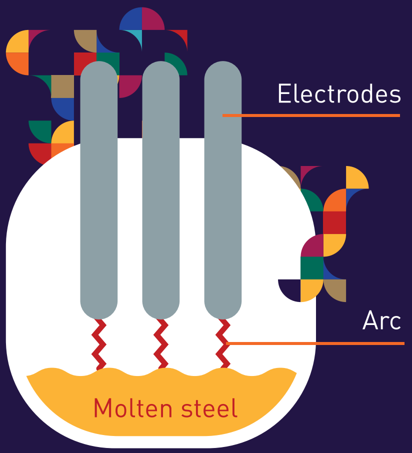
- A lower investment cost
- A compact installation relative to the production capacity
- No fuel transport and storage is required

The inherent power of most electro-heat technologies lies in the fact that they generate heat within the target material, leading to advantages in terms of process control and end-use energy efficiency. Typically, a factor two improvement in end-use efficiency can be observed, depending on the process. This means that electromagnetic processing can potentially halve the final energy demand for EU process heat which is 20% of final energy demand in the EU.

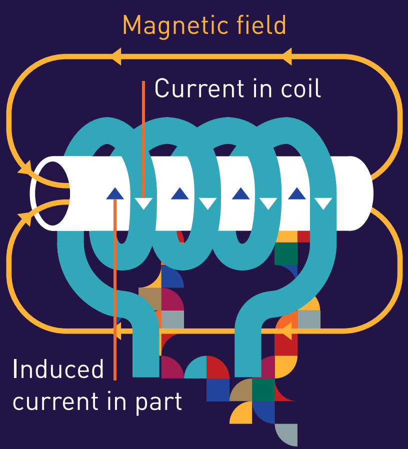
Another important difference in electrical versus fossil energy furnaces is in the oxidation losses of the materials processes. Typically, oxidation losses are 2-4% in fossil burners and 1% or lower with electromagnetic processing. While a few percentage losses of material through the chimney may not seem a lot, this difference is significant since it occurs every time a material is recycled, and the lifecycle environmental impact of the material lost has to be attributed to the process where the material is lost. Europe needs these technologies to meet its energy and climate objectives, and to achieve circular economy ambitions.

# HEATING PROCESSES

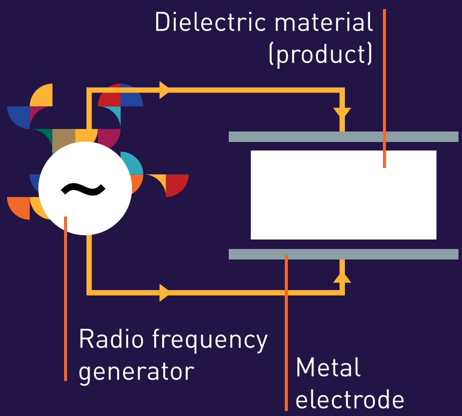
## Electric arc heating



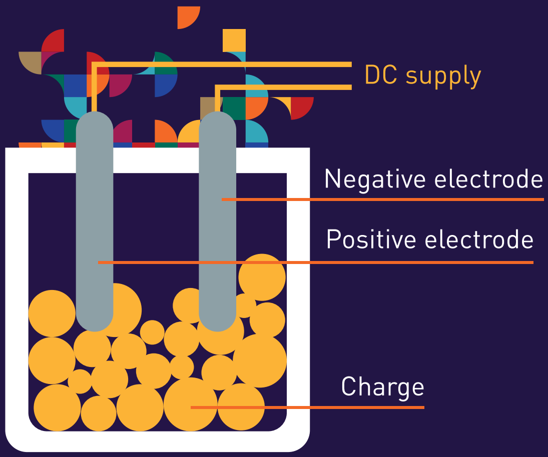

## Induction heating



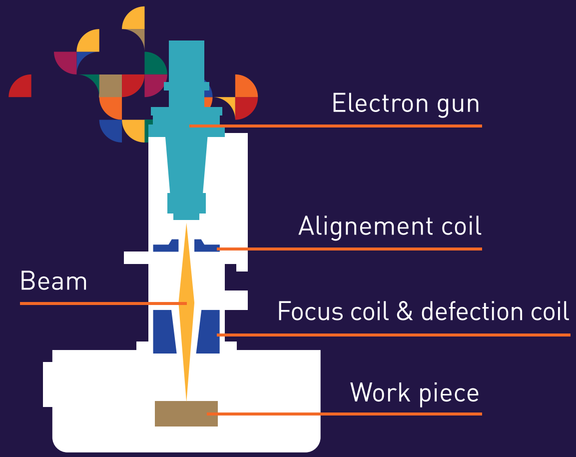

## Dielectric heating




## Direct resistance heating




## Electron beam heating



# 10 FACTS

1. An estimated **90%** of industrial thermal processes in Europe are powered by non-electrical energy carriers (gas, coal, oil).

2. Electrical heating methods **save final energy**, as the energy is used more effectively and in a more targeted manner.

6. It is possible to replace the major part of energy carriers (gas, coal, oil) currently used for process heat with electricity.

7. Electromagnetic processing technology offers the opportunity to **increase demand response** potential for industry.

Switching the most energy-intensive industries in Europe from fossil fuel to electricity would save 5 billion tons of $CO_2$ by 2050 (on average up to 150 million tons per year which is more than 3% of total EU annual emissions).

3. **Increasing renewables** in the energy mix means that the electrification of industrial heat processes becomes a cost-effective way of decarbonizing Europe.

4. From a lifecycle perspective, electromagnetic processing technologies exhibit significantly better results than local fossil fuel heating systems in terms of $CO_2$ emissions.

5. Process advantages are often the main driver for electro-heat technologies: higher productivity, high level of automation, high reliability, reproducibility, etc.

8. **Demand Side Management (DSM)** programs are of growing importance and are expected to play an important role in any electricity system of the future.

9. Electric furnaces and ovens in the EU is a growing industry with a high share of > **50%** export value.

10. Electromagnetic processing technologies facilitate the integration of electrical renewables.

Sources: Fraunhofer ISI, UIE, ECI, Institute of Electrotechnology, Leibniz University of Hannover

**1. Switch fuels to electromagnetic processing (EP) technologies.**

Switching from heating fuels to electricity produces net final energy savings as well as primary energy savings in an increasingly renewable electricity system. Such savings should be added to the list of options in Article 7(2) of the European Energy Directive (EED), provided that the 25% limit in Article 7(3) is increased accordingly.

**2. Provide a level playing field for all heating sources in the RED.**

An important bias towards combustion technologies in the heating & cooling sector can be observed in RED Article 23. The approach should be significantly broadened and equal footing needs to be provided for alternative technology options based on electricity.

**3. Increase the share of renewables in the heating and cooling sector.**

RED Article 23.3 on heating and cooling should provide an explicit focus on the case for replacing fossil fuel-based systems by electricity. The electrification of industrial heat processes can take place mainly through two routes: heat pumps and electromagnetic processing technologies.

Electromagnetic technologies use electricity to produce a useful thermal effect. They have the potential of largely displacing fossil fuels used in industry (~2,000 TWh/year). Significant efficiency gains of final energy are obtained, which requires the application of a multiplication factor to the amount of renewable electricity used.

**4. Widen the application and innovation scopes for EP technologies.**

While EP technologies are ready for market, their application to individual processes needs to be investigated and engineered on a case-by-case basis. While this is obviously a role for the market to play, a network of centers of competence could greatly facilitate technology adoption in this sector, moreover since many manufacturers of EP technologies are SMEs.

**5. Develop technology further for emerging electromagnetic processes.**

While many EP technologies have been available for decades and can be considered highly mature, many promising emerging technologies merit further development, such as plasma-arc, electron-beam and laser heating or microwave and radiofrequency heating.

# Baskar Vairamohan

## Senior Technical Leader at the Electric Power Research Institute

**How do electromagnetic processing technologies contribute to the energy transition?**

Electromagnetic processing technologies offer significant benefits compared to fossil fuel alternatives, such as not producing on-site emissions.

**Induction heating** generates heat within the workpiece, in contrast to conventional processes, and the location of the heating can be applied to a precise area on the metal component to achieve accurate and consistent results. Heat depth can be adjusted to the surface or can include the entire cross section. Temperatures can be controlled and because heat is generated internally, induction processes do not require a furnace enclosure or a large working area.

**Microwave heating** uses specific parts of the electromagnetic spectrum to heat non-conductive materials internally. The major advantages of using a microwave system for industrial processing include: rapid heat transfer, volumetric and selective heating, compactness of equipment, speed of switching on-and-off, and a pollution-free environment as there are no products of combustion.

**How is electromagnetic processing a cost-effective solution to decarbonize industries?**

Using induction heating as an example, the most notable advantages are:

**Rapid heating of parts:** induction heating of the workpiece provides much higher heating rates than the convection and radiation processes that occur in furnaces.

**Fast start-up time:** furnaces contain large amounts of refractory materials that must be heated during start-up, resulting in large thermal inertia. The internal heating of the induction process eliminates this problem and allows much quicker start-up.

**Lower energy costs:** when not in use, the induction power supply can be turned off because restarting is so quick. With furnaces, energy must be supplied continuously to maintain temperature during delays in processing and to avoid long start-ups.

**Ease of automation:** many manufacturers have completely automated their induction heating equipment. Automatic transfer devices, such as walking-beam conveyors pick and place mechanisms, and robots are used in conjunction with programmable controllers and computers. Parts can be washed, induction hardened, washed again, and tempered automatically.

**Easier process control and monitoring:** new and more precise methods of controlling the process variables are constantly being introduced. Because parts are heated individually, rather than in batches, it is much easier to control repeatability and monitor the process on a part-by-part basis. Some of the newer developments allow for real-time process monitoring.

**Compact footprint:** induction heating installations are generally much smaller than conventional gas-fired heating furnaces, and induction processes typically require no insulated enclosures, yielding a much smaller floor space requirement. Manufacturers can thus make more productive use of their floor space.

### What are the challenges to adopting more electromagnetic processing technologies?

**Short production runs:** induction heating is the most cost-effective method for high-volume production of identical parts; induction coils are designed for a single part shape and powered to achieve a hardened depth. For short production runs on differing parts, the cost of induction heating may prove prohibitive because each part may require a different coil design.

**Complex part geometry:** induction coils must be near the metal to be effective, some complex parts are not suited for induction heating.

**Diffusion processes:** induction heating usually occurs in an ambient atmosphere and temperature whereby diffusion processes for altering surface metallurgy cannot be used. However, new methods that combine induction with direct heat such as vacuum furnaces promise to overcome this limitation.

**Up-front cost:** expensive material handling systems may be required before the advantages of higher throughput promised by inductive heating can be realized. Acquiring an inventory of induction coils may also be expensive.

**Trained operators:** while fewer person-hours may be required per part when compared to direct heat methods, induction heating operators need knowledge that requires specific training.

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# INDUCTION HEATING
## Spain

At Porcelanosa in Spain, a GH induction ECOMOULD furnace improves the replacement and recycling process of so-called punches used in the press moulds for ceramic tile production. Punches—rubber or elastomer coatings on the steel plate—deteriorate and need to be replaced every certain number of tile cycles. With the innovative furnace, the ceramics manufacturer saved 75% on energy and tripled its production output. Where a traditional resistance furnace needed up to four hours to heat up 500 kg of steel moulds, the GH induction ECOMOULD technology achieves the same in just one hour. It is an environmentally friendly technology that improves labour conditions by avoiding contamination of burned elastomers.

# ELECTRICAL FURNACE
## France

With a new annealing and coating line, ArcelorMittal St-Chély d'Apcher is increasing its production capacity of high-grade non-grain oriented (NGO) electrical steel strips. In the line, the internal microstructure of the electrical steel strip is adjusted during the annealing process. The material is then coated with an insulating layer. The strip is heated up to 1,100°C by means of inductors and electrical heating elements in the horizontal annealing furnace of Drever International. The furnace can be operated with hydrogen up to 100%, helping to achieve a particularly oxide-free and clean strip surface, which is important for a high-quality material grade.

# INFRARED
## United Kingdom

A carbon infrared oven from Heraeus Noblelight is helping a UK company to achieve significant energy savings at its beverages plant. It has also saved factory space by allowing a single cold rinse line to be used both for juices and carbonated drinks. Since installation, the new medium wave infrared system has proved very successful, providing energy savings at the rate of £10,000 per year. As the manufacturing engineer comments:

"Heraeus explained that medium wave infrared was ideally suited for heating glass and then proved this in practice. Apart from helping us to save on energy costs, the new system also allows us to cold rinse bottles before heating. This is important as it means that the rinse line can now be shared with the carbonated drinks line without major modifications, and cost, as it is impossible to fill carbonated drinks in heated bottles."

**(Left)** Innovative ECOMOULD furnace. Source: GH Induction
**(Middle)** New annealing and coating line in St-Chély d'Apcher. Source: Drever International
**(Right)** Pre-heating of glass bottles prior to filling. Source: Heraeus Noblelight GmbH, Infrared Process Technology