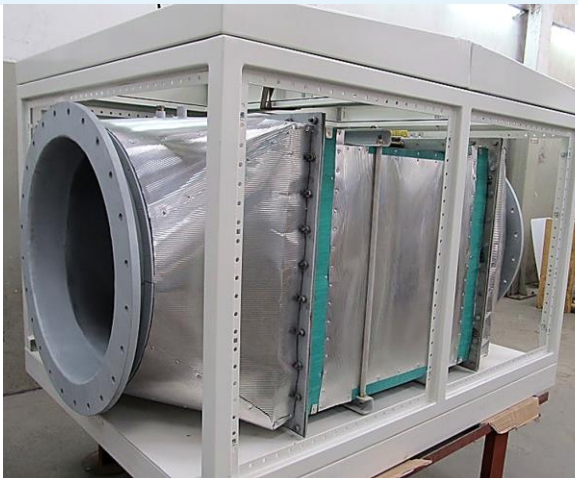
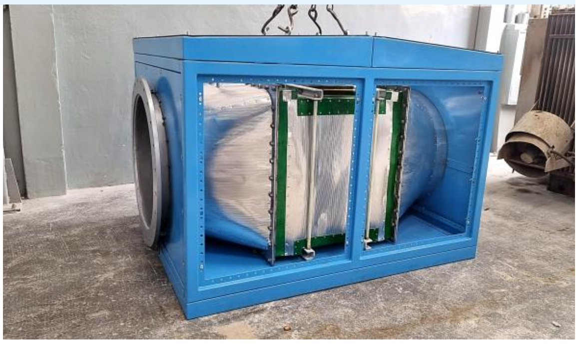
DIRECT AIR HEATING
BY ELECTROMAGNETIC INDUCTION

Thermal-Field Engineering and Technology Comparison
DIFHEMI Induction Heating vs. Direct-Fired Gas Hot-Air Systems

Real Industrial Equipment • 3D Reduced-Order Thermal Analysis • Process-Control Advantages

THE CENTRAL IDEA
DIFHEMI replaces flame-based hot-air generation with electromagnetic induction. Heat is generated in the metallic heating assembly and transferred directly to the air stream - without burner flame, combustion chamber or combustion gases in the heating mechanism. The result is a compact, controllable and highly efficient industrial hot-air source.





Real DIFHEMI/BRASCOELMA industrial heaters supplied for ANDRITZ projects - KLABIN and SUZANO.

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1. Executive Summary

Industrial hot air is traditionally generated by direct-fired gas burners, indirect gas-fired heat exchangers, steam coils or electrical resistance systems. DIFHEMI introduces a different heating architecture: electromagnetic induction generates heat in the metallic heater assembly, and the flowing air receives this heat by forced convection. The air-heating duty is therefore produced without a burner flame and without the combustion process that characterizes gas-fired equipment.

The supplied industrial references demonstrate this principle in full-size equipment. The KLABIN / ANDRITZ and SUZANO / ANDRITZ units are rated at 61 kW electrical input and 51,410 kcal/h thermal output, with a stated efficiency of 98%, 690 VAC three-phase supply and power factor 0.94. Air-flow values on the project nameplates are approximately 14.6-14.8 t/h. These units provide the physical reference for the thermal-field comparison developed in this paper.

The decisive technical difference between induction and direct-fired gas heating is where and how the heat is created. A gas burner first creates a very high-temperature combustion zone; useful process-air temperature is then obtained through dilution, mixing and/or heat exchange. DIFHEMI distributes electrical heat generation through the metallic heating structure itself. This allows the thermal field to rise progressively along the heater, with no flame core and no combustion-gas generation at the heater.

- High electrical-to-thermal conversion at the heater: 98% on the supplied nameplates.
- Distributed heat generation through the metallic heating assembly rather than a concentrated flame zone.
- Rapid power modulation and precise outlet-air temperature control.
- No burner, ignition system, flame detector, gas valve train or combustion chamber.
- No combustion products generated by the DIFHEMI heater.
- Clean hot-air generation suitable for processes where air quality, repeatability and temperature control are important.
- Compact point-of-use architecture with low thermal inertia and fast start/stop response.
- Reduced maintenance associated with the elimination of burner and combustion components.

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2. Real Industrial Reference Equipment

Figure 1. Real DIFHEMI/BRASCOELMA hot-air heater assemblies supplied for KLABIN / ANDRITZ and SUZANO / ANDRITZ.

3. Reference Heater Data:

Parameter	KLABIN / ANDRITZ	SUZANO / ANDRITZ
Heating technology	Electrothermal induction	Electrothermal induction
Process fluid	Hot dilution air	Hot dilution air
Air flow	14,759 kg/h	14,631 kg/h
Electrical power	61 kW	61 kW
Thermal power	51,410 kcal/h	51,410 kcal/h
Power supply	690 VAC - 3 phase - 60 Hz	690 VAC - 3 phase - 60 Hz
Power factor	0.94	0.94
Efficiency	98%	98%
Pressure drop	12 mbar	12 mbar
Empty weight	1,250 kg	1,250 kg

Table 1. Principal data transcribed from the supplied industrial heater nameplates.

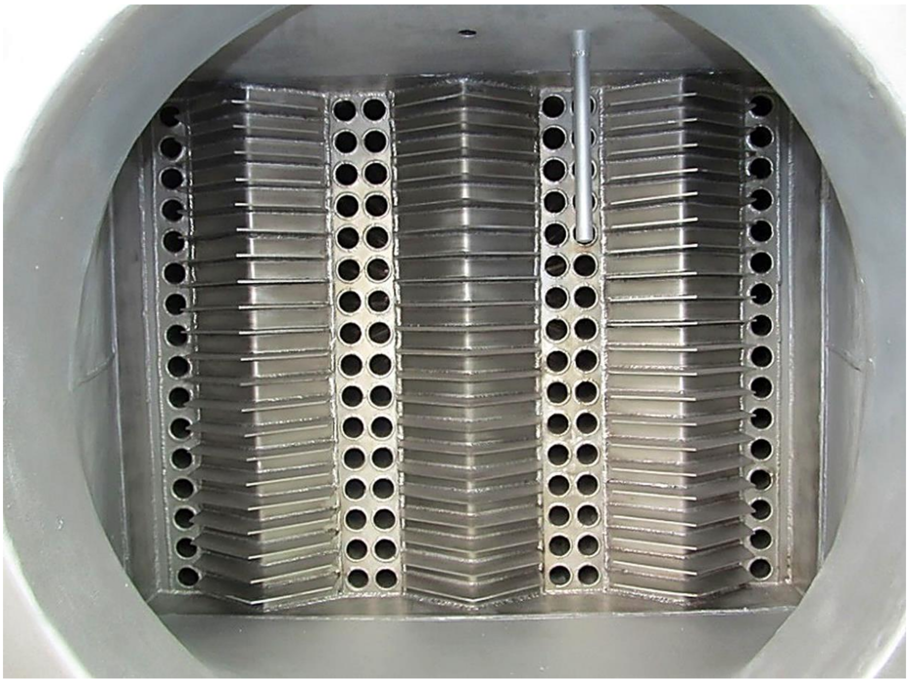

Figure 2. Internal metallic heating structure of the real KLABIN / ANDRITZ unit.

4. Heating Mechanism: Induction vs. Direct-Fired Gas

In a direct-fired gas system, chemical energy is released in a flame. The combustion zone is necessarily much hotter than the required process air, after which the energy is transferred and the gas/air stream is mixed or exchanged until the target outlet temperature is obtained. This

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creates an intrinsically concentrated high-temperature source followed by a thermal-mixing section.

In DIFHEMI, the electromagnetic field induces electrical currents directly in the metallic heating assembly. The metal becomes the heat source and transfers energy continuously to the passing air. Because heat generation is distributed over the engineered metallic surface, the air temperature can rise progressively along the heater length rather than being derived from a flame-temperature peak.

Engineering characteristic	DIFHEMI induction	Direct-fired gas
Primary heat source	Induced heat in metallic assembly	Combustion flame
Combustion at heater	None	Required
Flue/combustion gases generated	None	Yes
Thermal field	Distributed along heating surface	Concentrated near flame, followed by mixing
Power response	Immediate electrical modulation	Burner firing-rate modulation
Low-load operation	Wide electrical controllability	Depends on burner turndown
Process-air architecture	Clean electrically heated air	Combustion/mixing or heat-exchanger architecture

5. Quantitative Comparison with Direct-Fired Gas Heating

To compare technologies on an equal useful-heat basis, the DIFHEMI nameplate output of 59.78 kW is used. Gas-fired efficiency is not a universal number; three screening cases (80%, 85% and 90%) are therefore shown. These represent heater-level efficiency only and do not include site-specific distribution losses.

Case	Useful heat	Input energy	Extra input vs DIFHEMI	On-site combustion
DIFHEMI, 98%	59.78 kW	61.0 kW	Reference	None at heater
Gas-fired, 90%	59.78 kW	66.42 kW	+5.42 kW / +8.9%	Yes
Gas-fired, 85%	59.78 kW	70.33 kW	+9.33 kW / +15.3%	Yes
Gas-fired, 80%	59.78 kW	74.73 kW	+13.73 kW / +22.5%	Yes

Figure 4 — Input energy required to deliver the same 59.78 kW useful heat.

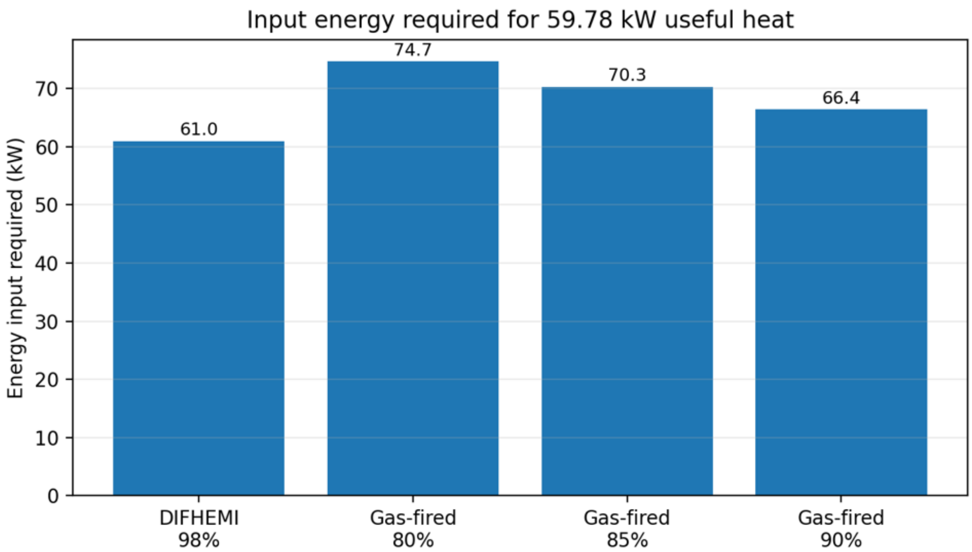
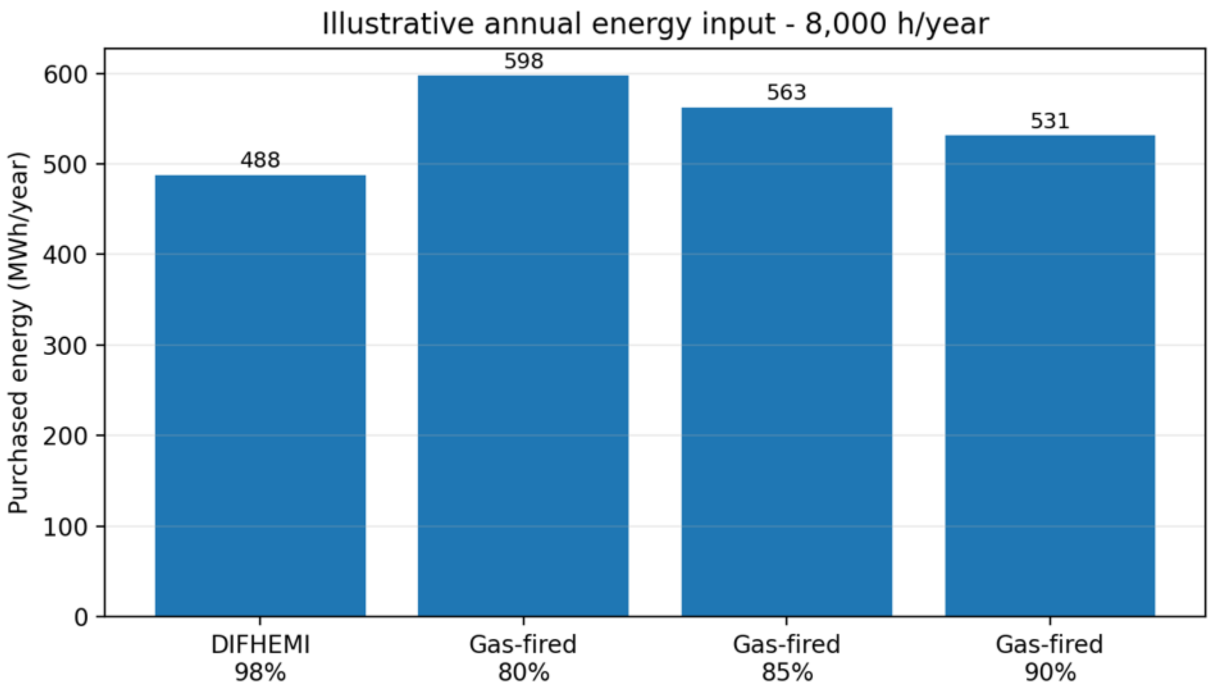


Figure 5 — Illustrative purchased energy at 8,000 h/year. Electricity and gas prices are intentionally not assumed; site tariffs should be inserted for an economic study.



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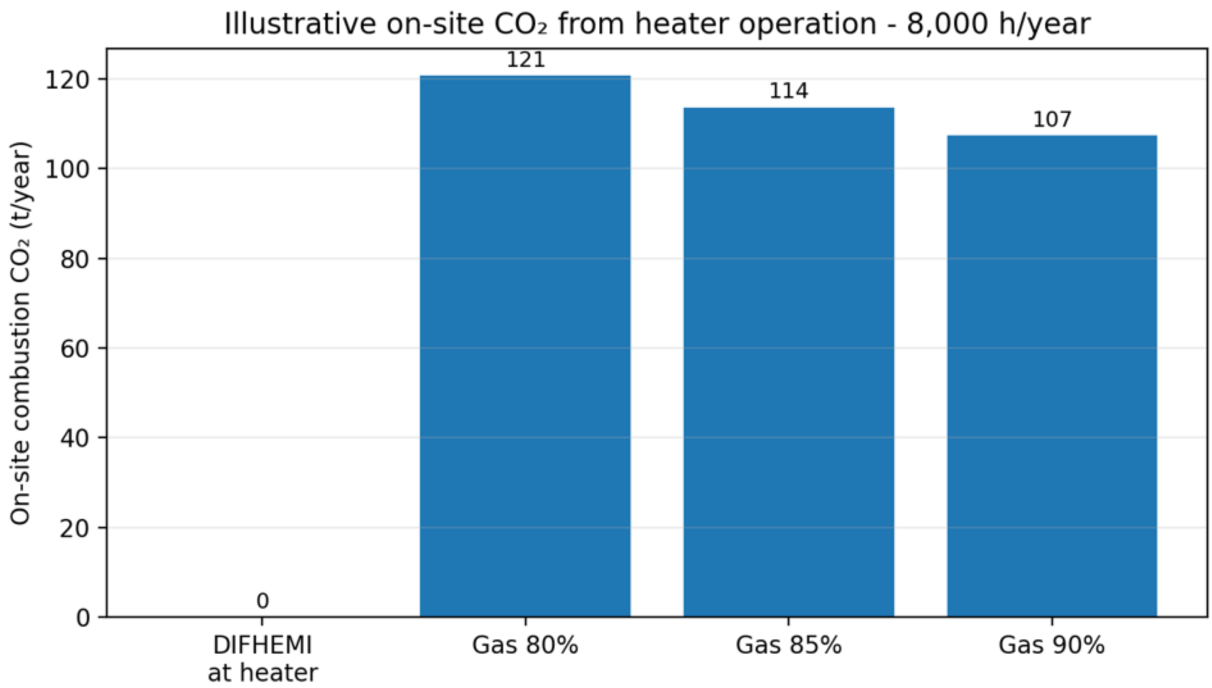
5.1 Natural-gas and on-site CO_2 screening

For illustration only, natural gas is taken at 10.0 kWh/Nm³ LHV and 2.02 kg CO_2/Nm³. Under these assumptions, a gas-fired heater providing 59.78 kW useful heat consumes approximately 6.64 Nm³/h at 90% efficiency, 7.03 Nm³/h at 85%, or 7.47 Nm³/h at 80%.



6. Reduced-Order 3D Thermal-Field Comparison

Following the presentation method, the figures below are reduced-order engineering thermal-field visualizations. Both concepts are referenced to the same industrial hot-air duty. The objective is to visualize the fundamental difference between distributed induction heating and flame-originated gas heating.

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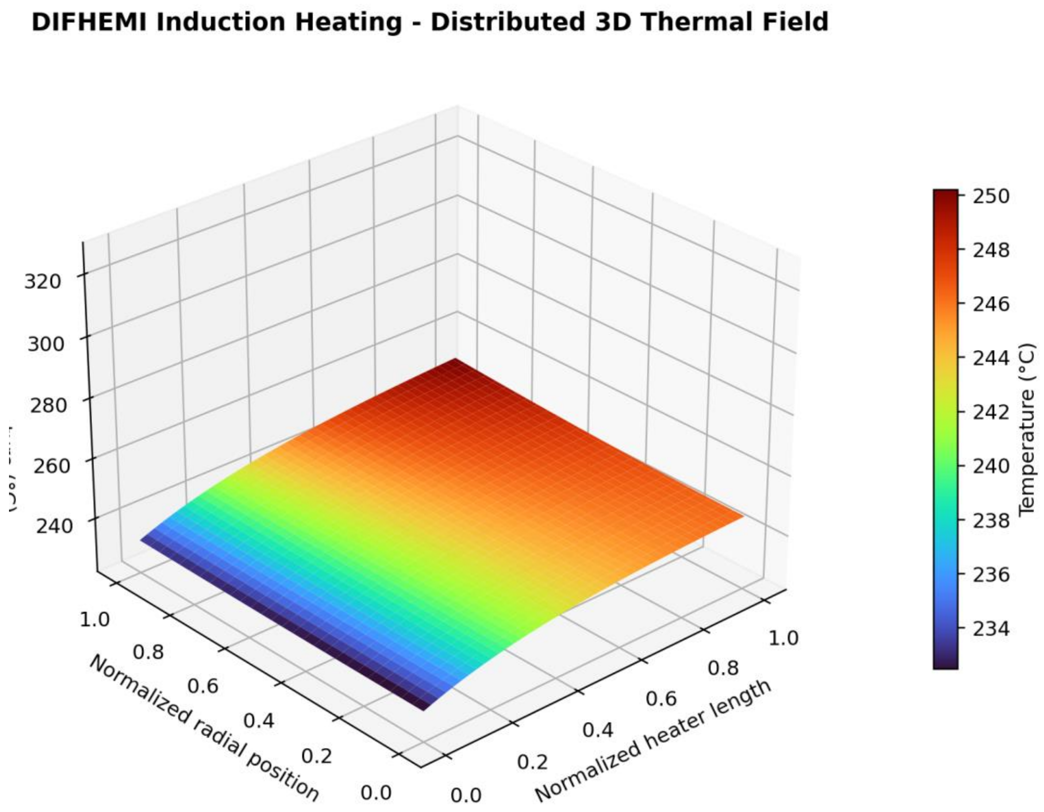

Figure 3. DIFHEMI 3D thermal field - progressive, distributed heating through the induction-heated metallic assembly.

The DIFHEMI field is characterized by a smooth axial temperature increase and comparatively small radial temperature differences. The energy source is distributed over the metallic heat-transfer structure, promoting a controlled thermal approach to the target process temperature.

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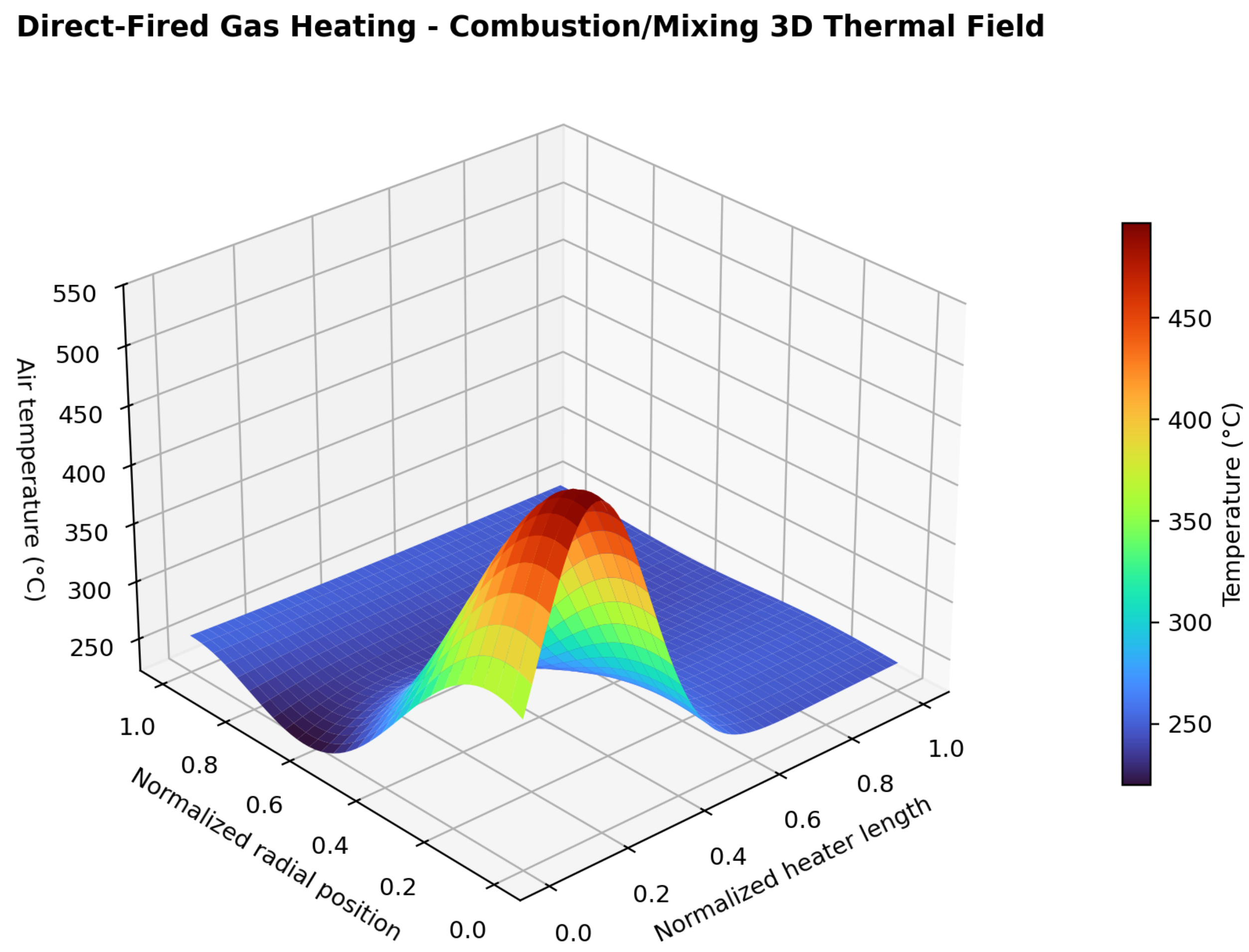

Figure 4. Direct-fired gas 3D thermal field - high-temperature combustion zone followed by dilution/mixing toward the process-air temperature.

The direct-fired gas field begins with a concentrated combustion-energy region. The useful hot-air condition is obtained downstream as the flame energy is transferred and mixed into the process stream. This difference in heat-source topology is central to the comparison: DIFHEMI generates the required heat at the engineered metallic surface instead of first producing a flame-temperature peak.

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7. 2D Temperature-Field Interpretation

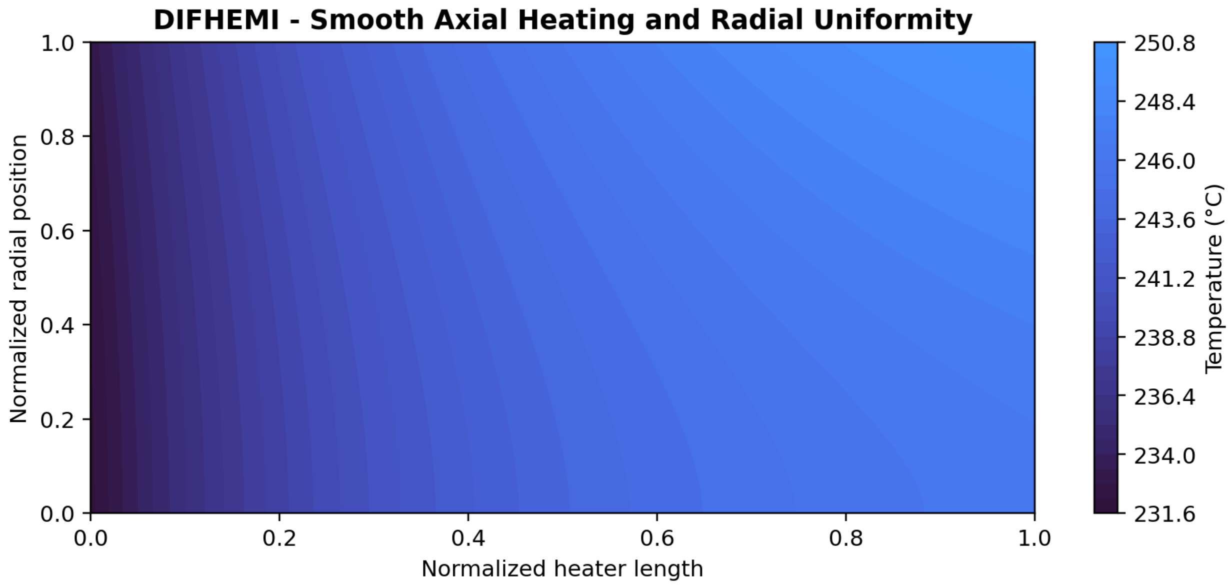

Figure 5. DIFHEMI 2D temperature contour - distributed heat input and controlled radial temperature field.

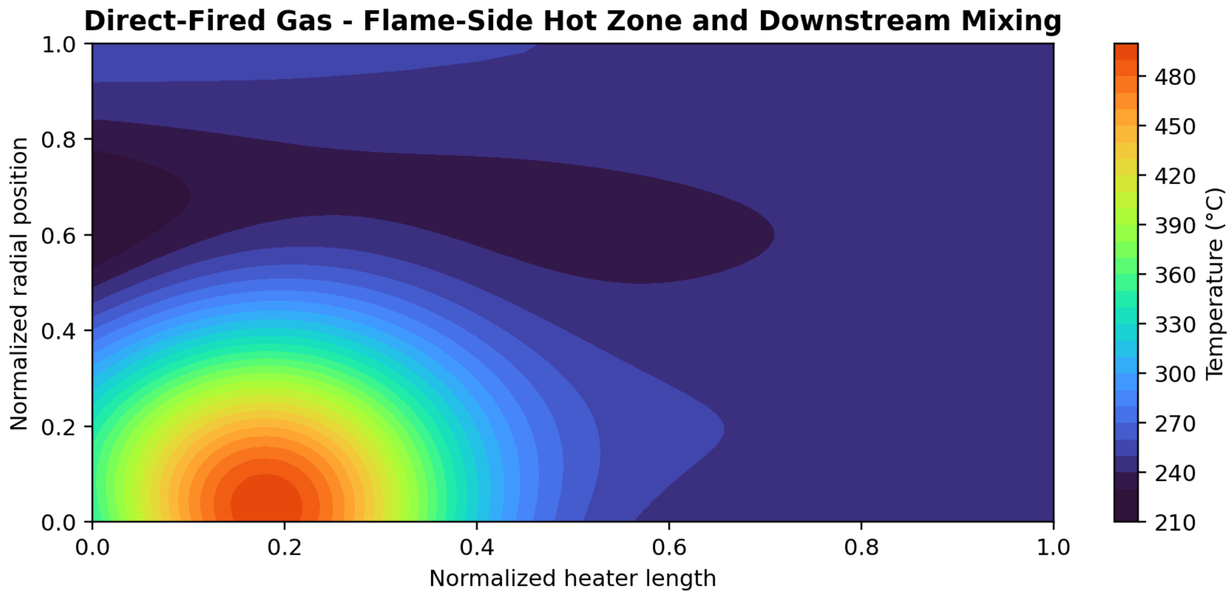

Figure 6. Direct-fired gas 2D temperature contour - localized combustion-side temperature peak and downstream mixing field.

The comparison highlights why induction is particularly attractive for applications requiring repeatable hot-air quality. The heating action is tied to electrical power delivered to the metallic

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exchanger geometry, so the process can be controlled through electrical power and measured outlet temperature without combustion chemistry, excess-air control or flame stabilization.

8. Thermal Uniformity and Process Control

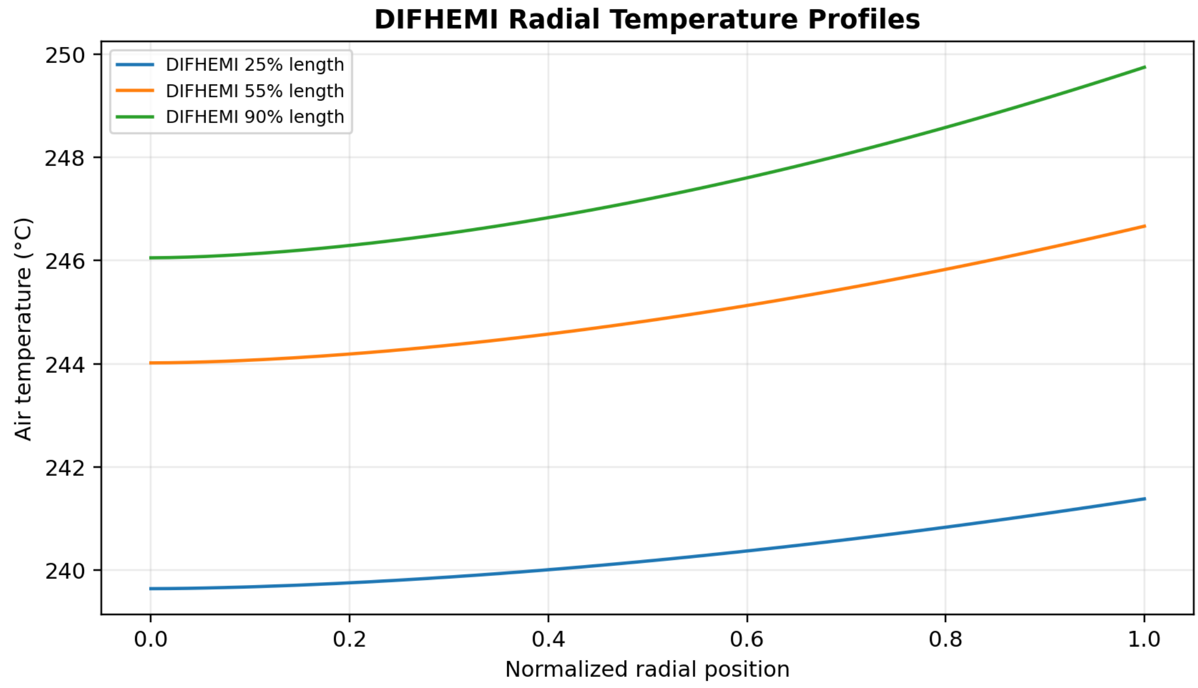

Figure 7. Representative radial profiles for the DIFHEMI reduced-order model.

Temperature uniformity is a function of heater geometry, air velocity and heat-transfer surface distribution. DIFHEMI's multi-surface metallic architecture is specifically suited to distributing heat across the moving air stream. The absence of a flame core also removes the primary combustion-origin hot zone from the heater.

- Fast electrical response: induction power changes immediately with the electrical command.
- Low stored combustion heat: when power is reduced, there is no continuing flame or burner refractory heat release.
- Precise set-point control: outlet temperature can be linked directly to closed-loop electrical power modulation.
- High repeatability: electrical power is inherently measurable and reproducible.
- Strong turndown capability: the heat source can be modulated without maintaining flame stability.
- Uniform heat-transfer architecture: multiple heated metallic surfaces distribute the thermal duty across the air flow.

9. Combustion-Free Hot-Air Generation

Gas-fired hot-air systems require a combustion chain: fuel supply, pressure control, shut-off valves, burner, ignition, flame supervision, combustion air and exhaust or combustion-product management. DIFHEMI removes this entire combustion chain from the hot-air generator. Its energy chain is electrical supply, power electronics, induction coil, metallic heating assembly and controlled air flow.

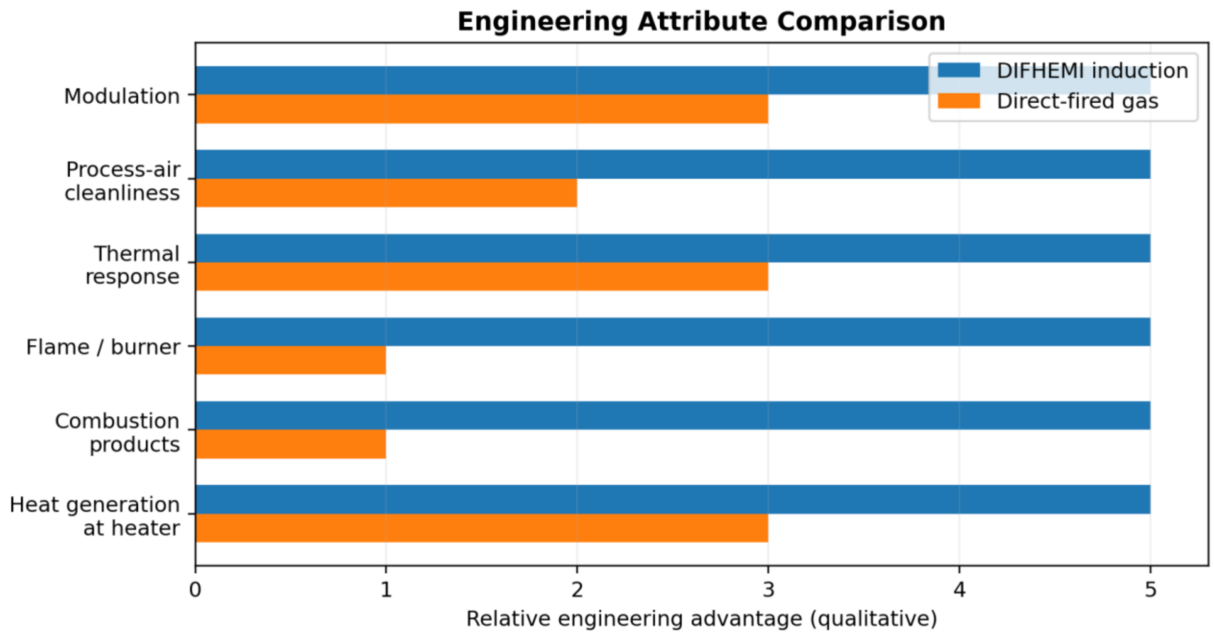

Figure 8. Qualitative engineering comparison of the two hot-air generation architectures.

This simplification has direct technical consequences. There is no flame to stabilize, no burner to tune, no combustion ratio to maintain and no combustion products generated by the heater. The result is a clean electrothermal system particularly well suited to modern automated production lines.

10. Air Quality and Industrial Process Advantages

For drying, coating, laminating, paper, pulp, converting, plastics and flexible-packaging processes, hot-air quality is often as important as temperature. DIFHEMI produces hot air without generating combustion gases in the heater. This separates the process-air heating function from fuel chemistry and burner operation.

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- No CO2, CO, NOx or water vapor is generated by combustion inside the DIFHEMI heater.
- No fuel-derived combustion odor or combustion particulate source at the heater.
- No oxygen consumption by the heating mechanism.
- Suitable for recirculating-air concepts where clean electrical reheating is advantageous.
- Temperature control is independent of air/fuel ratio.
- Electrification makes the heater immediately compatible with renewable or low-carbon electrical supply.

11. Compactness, Start-Up and Maintenance

The real equipment photographs show a compact packaged construction with large process-air connections and an internal metallic heat-transfer assembly. Unlike a gas-fired heater, the DIFHEMI package does not require a combustion chamber sized to contain and stabilize a flame. This supports compact installation close to the point of use.

Maintenance is concentrated on the electrical power system, induction components, instrumentation and air-side heat-transfer surfaces. Burner-specific items - igniters, flame scanners, burner nozzles, gas valves, combustion tuning and flue-gas components - are absent.

1. Engineering Interpretation of the 61 kW Industrial Reference

The supplied 61 kW reference units provide a useful industrial scale point. At 98% stated efficiency, the useful thermal power is approximately 59.8 kW, corresponding to the 51,410 kcal/h nameplate rating. With air flow around 14.7 t/h, the heater is handling approximately 4.1 kg/s of air. This combination demonstrates high-flow, controlled process-air heating with a compact electrothermal package.

61 kW electrical input → electromagnetic induction → heated metallic assembly → 51,410 kcal/h useful hot-air duty

The significance of the 98% figure is technological: almost all electrical input at the heater is converted into useful thermal duty. In a combustion system, by contrast, the heat source is created at flame temperature and the useful process-air condition is reached only after combustion and thermal transfer/mixing.

12. Principal Advantages of DIFHEMI over Direct-Fired Gas Heating

DIFHEMI advantage	Engineering significance

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Distributed electromagnetic heat generation	Heat is created in the metallic heating assembly rather than in a flame, producing a fundamentally different and more controllable thermal field.
98% stated heater efficiency	The supplied industrial units document very high electrical-to-thermal conversion at the heater.
No combustion	No burner flame, combustion chamber or fuel-burning process is required.
Clean hot air	The heater itself introduces no combustion products into the air-heating process.
Fast response	Electrical power can be increased, reduced or stopped immediately.
Precise temperature control	Power modulation can follow the outlet-air temperature directly.
Wide operating flexibility	No minimum firing rate is needed to sustain flame stability.
Compact architecture	No flame volume or combustion chamber is required.
Reduced burner maintenance	Igniters, flame scanners, burner nozzles and gas-train maintenance are eliminated.
Automation-ready	Electrical heating integrates naturally with PLC, PID, process recipes and digital control.

13. Why Induction Can Be Advantageous for Industrial Hot Air

Engineering aspect	DIFHEMI implication
Thermal efficiency	The documented units state 98% heater efficiency. A fired heater loses part of the fuel energy through flue gas, excess air, casing radiation and incomplete heat recovery.
Clean process-air architecture	DIFHEMI can heat air without introducing combustion products into the process-air stream. This is valuable where product quality, odor, contamination or controlled atmosphere matter.
No flame and no local fuel combustion	Removing the burner eliminates flame-related ignition, burner tuning and combustion-control functions at the heater. Electrical and process safety requirements remain essential.
Fast control	Electrical induction power can be modulated rapidly. This can reduce overshoot and support tighter outlet-air temperature control when paired with suitable sensors and controls.
Reduced auxiliary systems	A direct-fired system commonly requires burner, gas train, combustion-air fan, ignition, flame safeguard and exhaust/stack provisions. DIFHEMI replaces these combustion auxiliaries with electrical power electronics and controls.
Maintenance profile	There is no burner nozzle, igniter or combustion chamber to inspect. Maintenance shifts toward coils, power electronics, instrumentation, insulation, airflow surfaces and electrical protection.
Point-of-use installation	The absence of a flue-gas train can facilitate compact placement close to the process, subject to electrical clearances, airflow and plant-layout requirements.
Decarbonization pathway	DIFHEMI electrifies process heat. As electricity becomes lower-carbon or is supplied from renewable generation, operational carbon intensity can fall without replacing the process heater.

14. Direct-Fired Combustion: What DIFHEMI Avoids

A direct-fired hot-air system can be technically effective and may be economically attractive where fuel is inexpensive. Its engineering chain, however, is longer: fuel supply → pressure

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regulation → safety shut-off valves → burner → combustion air → ignition/flame supervision → combustion chamber → heat transfer/mixing → exhaust or process discharge. Every additional subsystem introduces pressure losses, maintenance points and safety functions.

- Stack/flue losses: sensible heat leaves with combustion products unless recovered.
- Excess-air penalty: practical burners normally operate with excess combustion air, increasing the mass of hot exhaust that must be heated.
- Combustion controls: safe start-up, purge, ignition, flame proving and shutdown sequences are mandatory.
- NOx formation: high-temperature combustion can create nitrogen oxides; actual emissions depend on burner design, flame temperature and local regulation.
- Indoor heat and ventilation burden: burner and exhaust equipment can add heat, noise and ventilation requirements.
- Fuel infrastructure: gas piping, isolation, pressure regulation and hazardous-area considerations may be required.

15. Typical Industrial Applications

- Drying air for coating and laminating lines.
- Flexible-packaging printing and solvent/water evaporation stages.
- Paper, pulp and converting-process hot air.
- Hot dilution air and process-air conditioning.
- Industrial ovens and dryers.
- Polymer-film production and auxiliary drying duties.
- Recirculating hot-air systems requiring accurate temperature control.
- Replacement of burner-based hot-air generators in electrification projects.

16. Design Data Required for a New DIFHEMI Air Heater

- Air mass flow (kg/h) and minimum/normal/maximum flow.
- Inlet and required outlet temperatures.
- Operating and design pressure; allowable pressure drop.
- Air composition, humidity, solvent content, dust loading and corrosive constituents.
- Required thermal duty and turndown ratio.
- Available voltage, frequency, short-circuit level and electrical power capacity.
- Control philosophy, temperature sensors, interlocks and required SIL/ATEX/PED/CE scope where applicable.
- Materials of construction and contamination requirements.
- Installation environment, IP rating, ambient temperature and maintenance access.
- Operating hours, redundancy philosophy and required availability.

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17. Final Engineering Perspective

DIFHEMI changes the architecture of industrial hot-air generation. Instead of creating a flame and then converting flame energy into usable process air, the system converts electrical energy directly into heat within the metallic heating assembly. The process air is heated as it passes through this engineered surface network.

The real KLABIN / ANDRITZ and SUZANO / ANDRITZ units demonstrate the industrial implementation of this concept: 61 kW electrical rating, 51,410 kcal/h thermal duty, approximately 14.6-14.8 t/h air flow and 98% stated efficiency. These are not laboratory concepts but packaged industrial heaters designed for high-flow process-air service.

The 3D thermal-field comparison illustrates the key physical advantage. Direct-fired gas heating originates in a concentrated high-temperature combustion region and relies on downstream transfer and mixing. DIFHEMI distributes heat generation through the metallic exchanger structure, enabling a progressive temperature rise, high controllability and clean combustion-free hot-air production.

DIFHEMI: ELECTROMAGNETIC ENERGY → DISTRIBUTED METALLIC HEATING → CONTROLLED HOT AIR

For industrial users seeking precision, repeatability, fast response, clean process air, compact equipment and the elimination of burner technology, DIFHEMI provides a high-performance electrothermal alternative to conventional direct-fired gas hot-air systems.

18. Technical Basis

The equipment data and photographs in this paper are taken from the supplied DIFHEMI/BRASCOELMA industrial reference documentation. The thermal-field figures follow the reduced-order CFD-style visualization approach and are intended to illustrate the heat-source topology and temperature-field differences between induction and direct-fired gas heating.

Independent technical literature also identifies fast response, precise temperature control, cleanliness, compactness and absence of combustion by-products as characteristic advantages of induction-based fluid heating. Recent industrial-electrification research likewise describes induction as a route for efficient hot-gas generation and substitution of gas-intensive process heating.

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