Electroheat technologies: physical principles and economics

Prof. Fabrizio Dughiero
Electromagnetic Processing of Materials
Department of Industrial Engineering
University of Padova
Italy
Fabrizio.Dughiero@unipd.it

Copyright rules

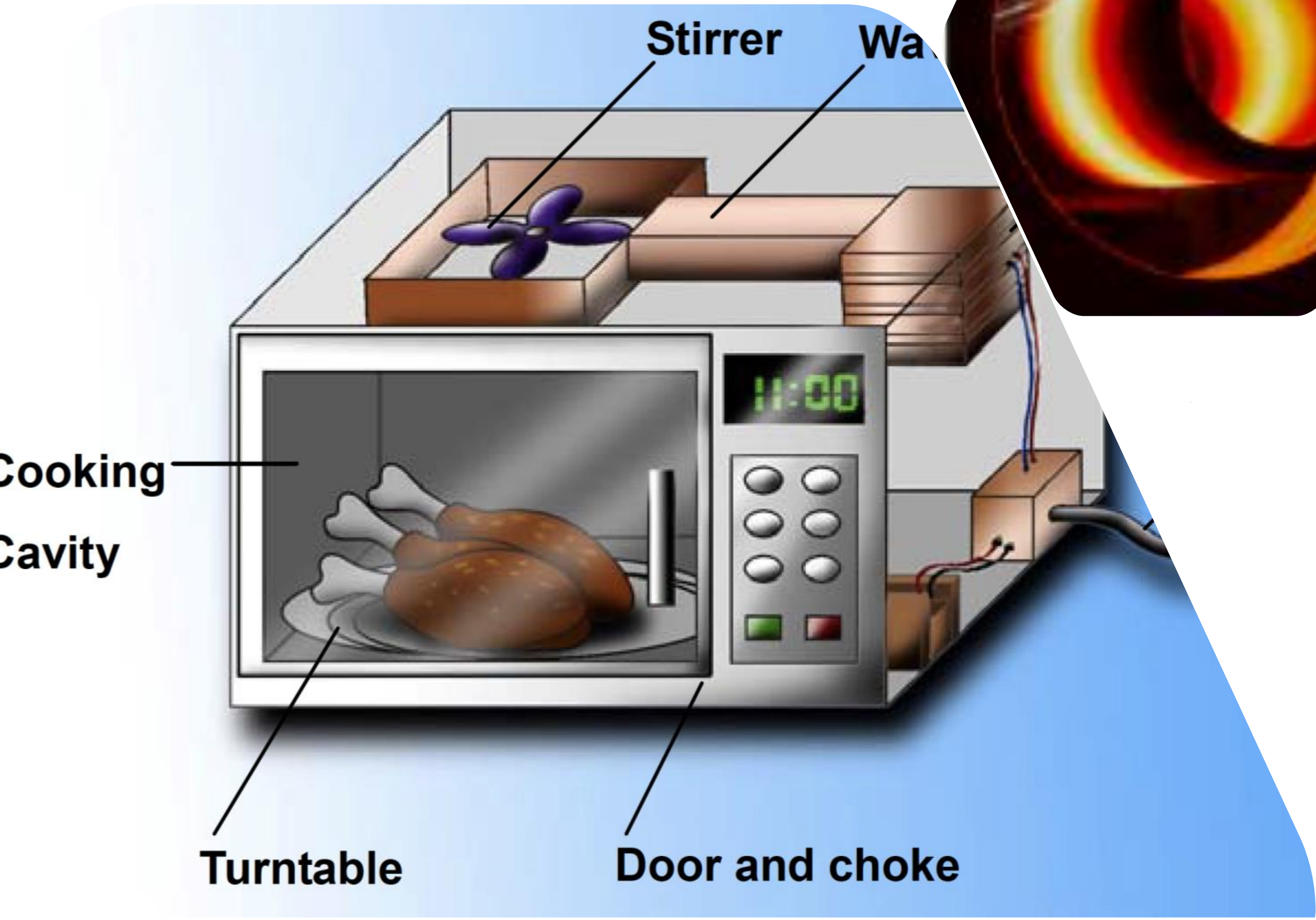
inovaLab

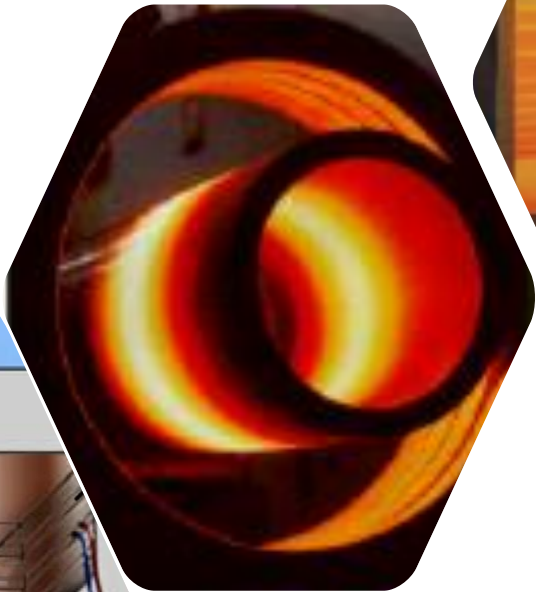
Course Contents

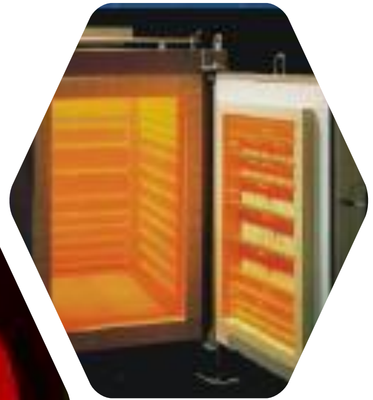
- Module I
  - Introduction to Electroheat Technologies
  - External sources technologies
  - Internal sources technologies
- Module II
  - Economics of Electroheat Technologies
  - Replacement coeffcient
  - Cost saving

Module I: Introduction to Electroheat Technologies

inovaLab







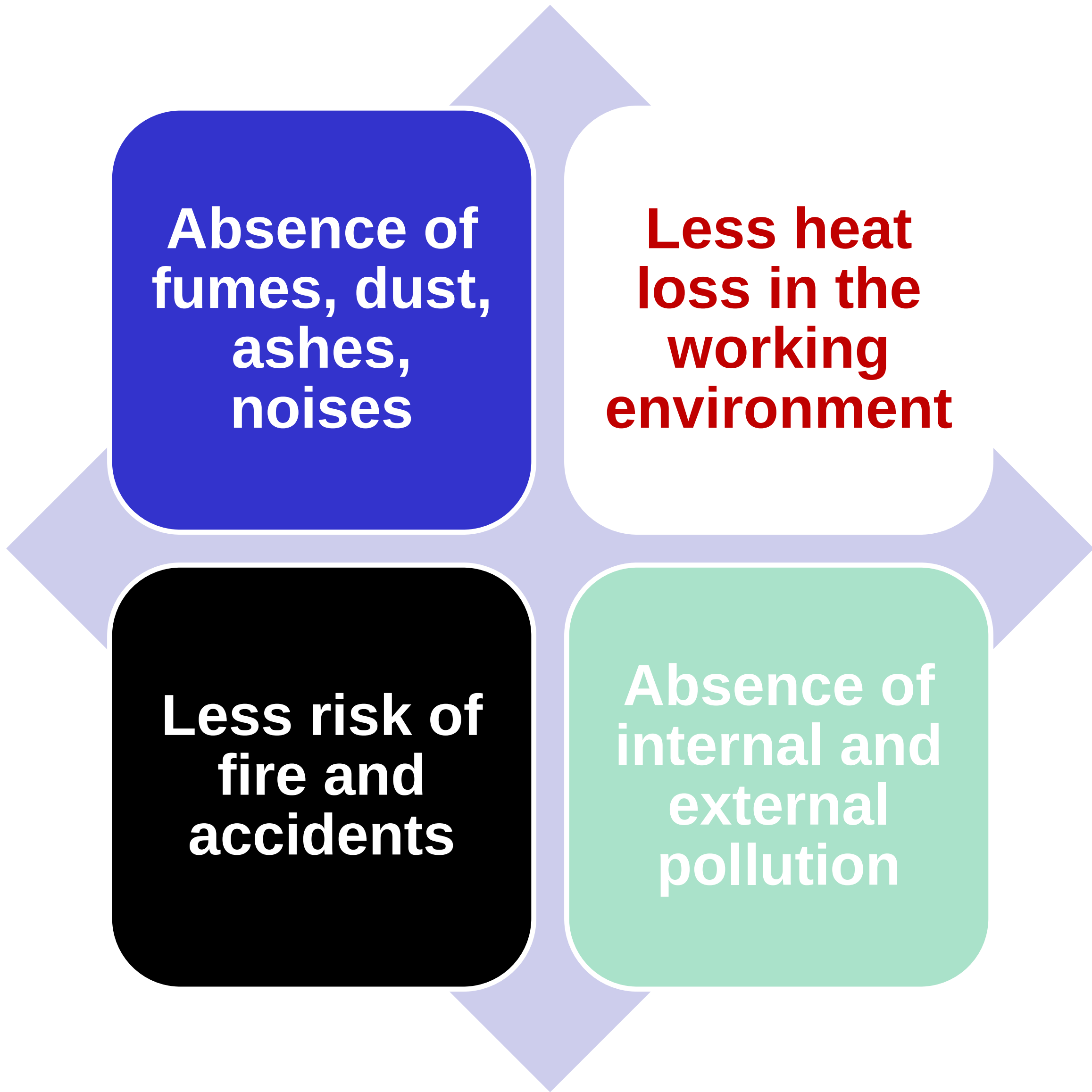
Electroheat technologies transform electricity into heat for different end uses (heat treatments, food processing, chemical reactions, biomedical applications etc.)

Main characteristics of electroheat processes

High temperatures	High power densities	Heat sources inside the workpiece
Short heating times	High frequencies	Automation
High effciency	Control of temperature distribution in the workpiece	

inovaLab

WORK ENVIRONMENT IMPROVEMENT



Electroheat technologies allow cost saving and are sustainable

Saving primary energy

Reduction of emissions of CO_2

Reduction of industrial operating costs

Improvement of product quality

inovaLab

Classification of Electroheat Technologies

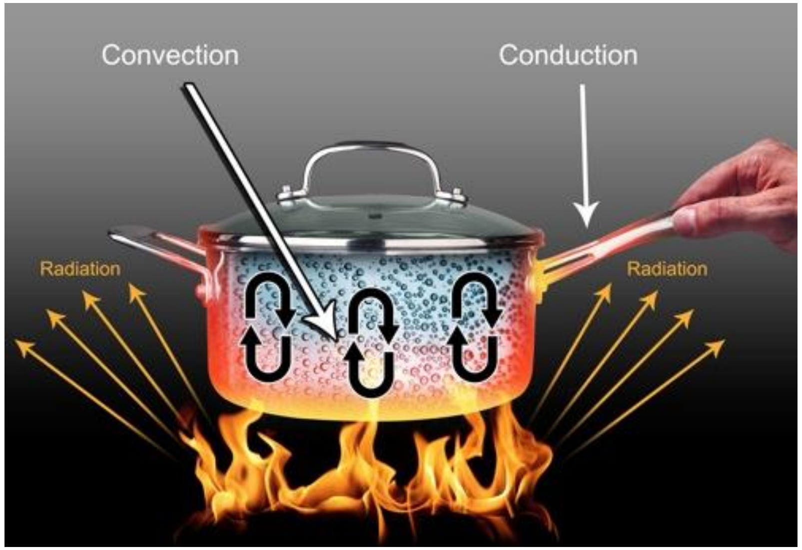
inovaLab

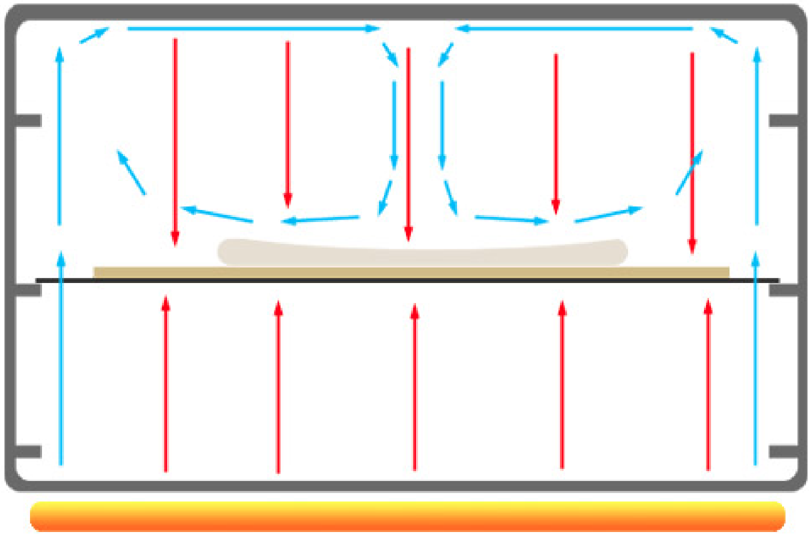
Heat transfer mechanisms

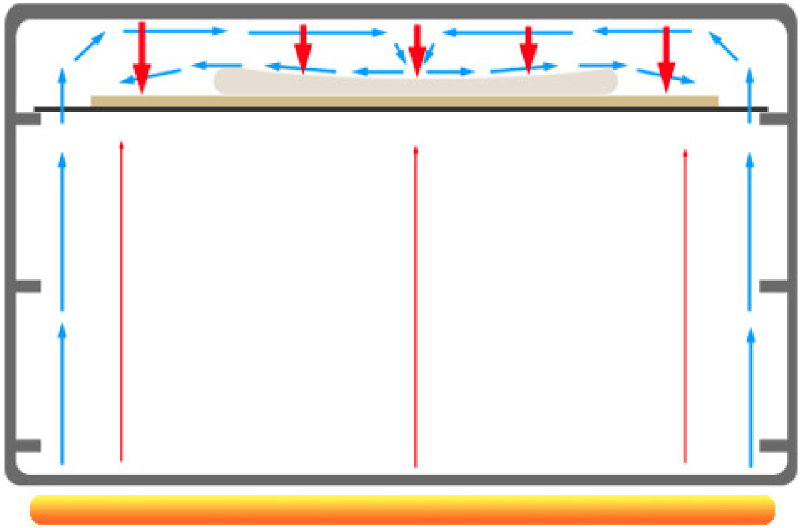
Radiation

Convection

Conduction



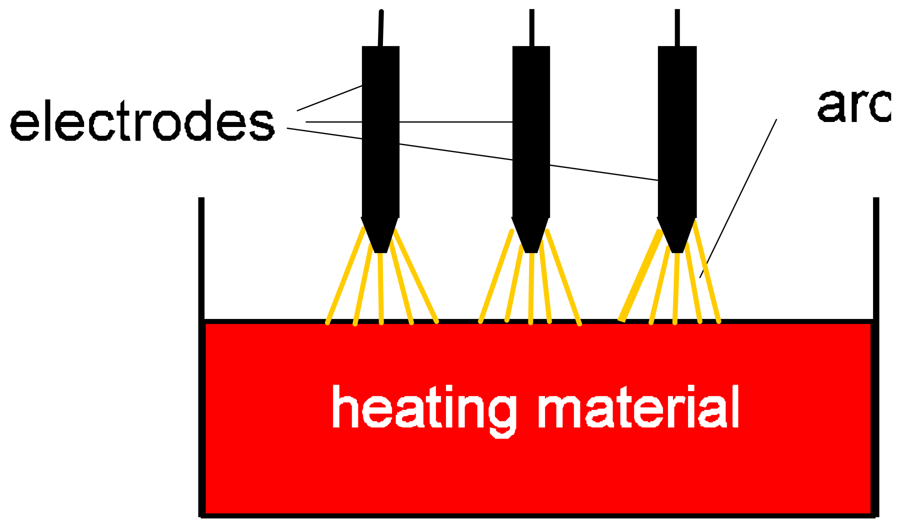




Electric Arc Furnace

Typical Applications:

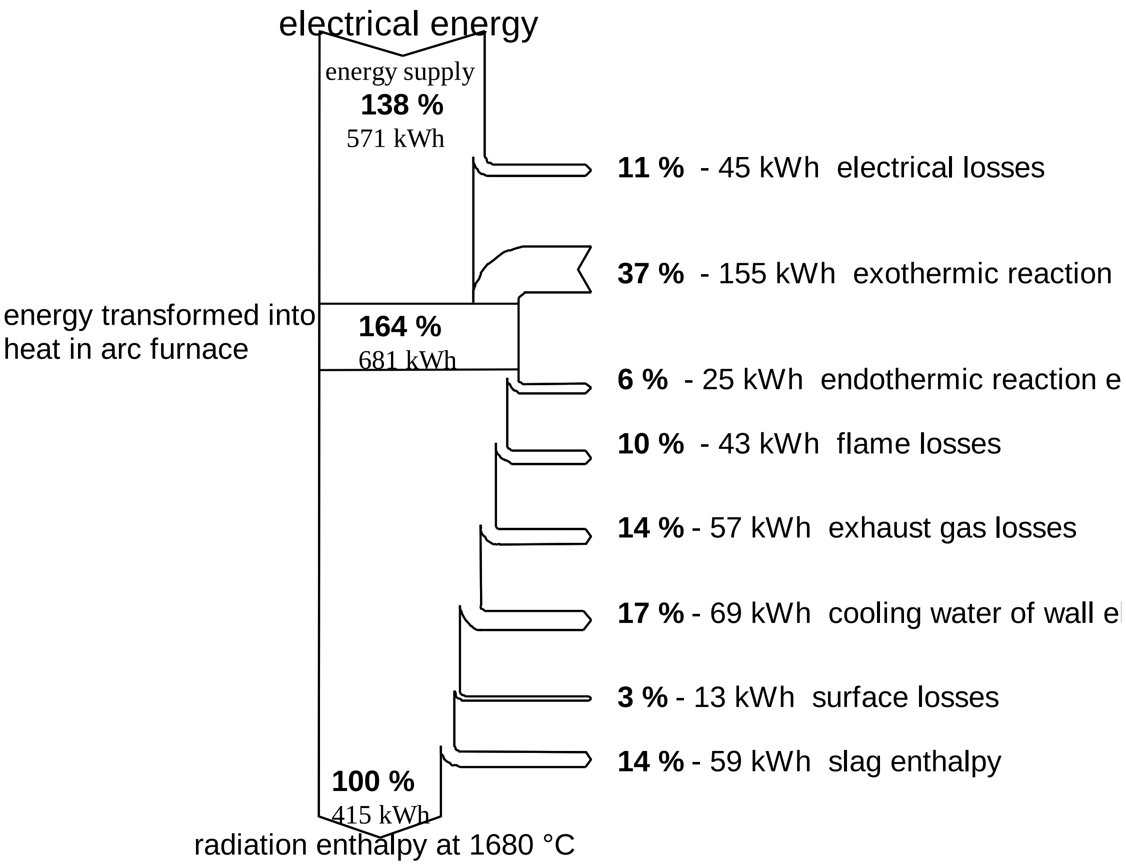
- **Melting of various metals: steel, cast iron, etc.**
- **Production of ferrous alloys (e.g. FeSi, FeCr, FeMn)**
- **Vacuum remelting of ingots of special metals**



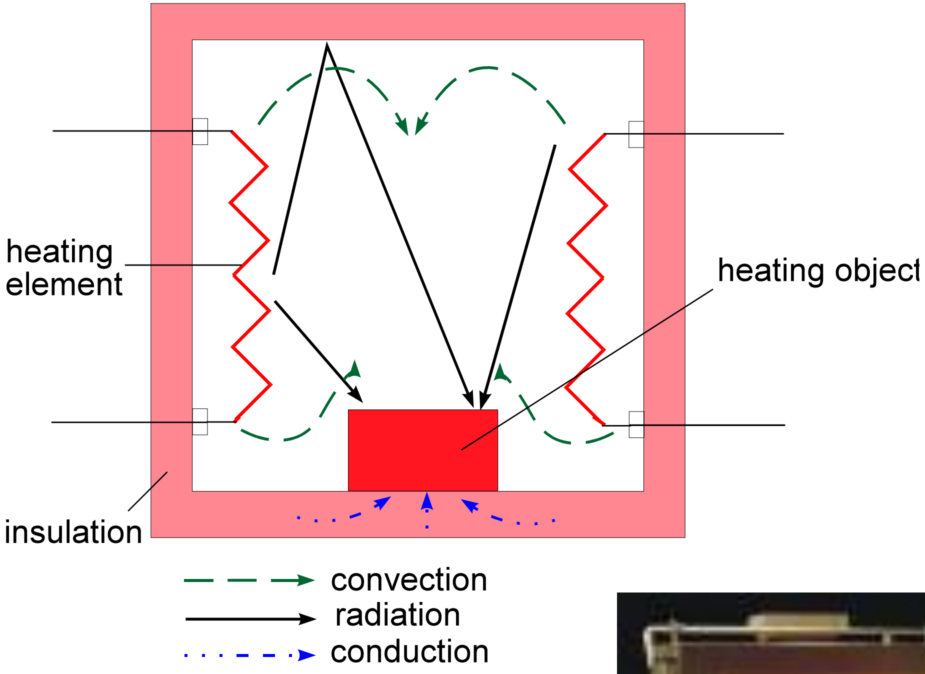
Three-phase arc furnace

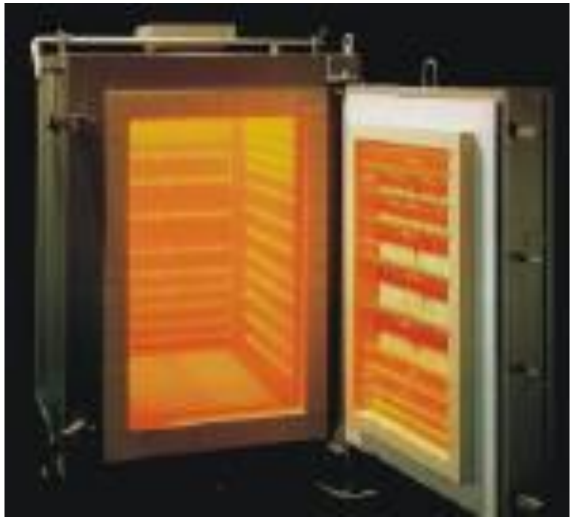
Energy Balance

(heat losses can be used for preheating scrap material)



Indirect resistance heating



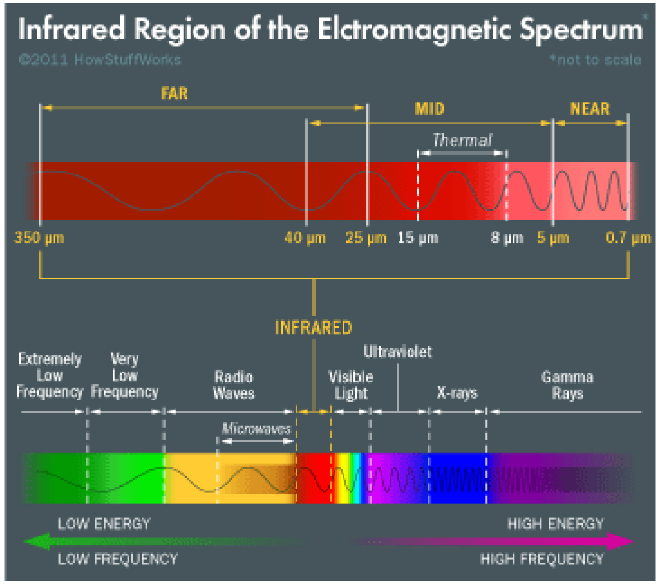


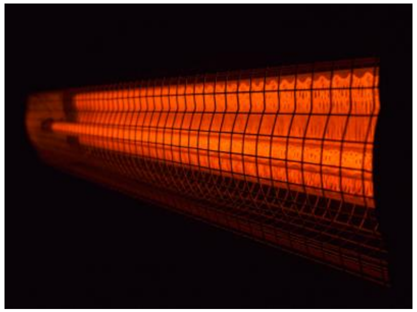
Examples of Application:

- **Melting and holding of metals**
- **Heat treatments**
- **Baking of ceramics**
- **Drying processes in textile, paper and wood industry**
- **Warming of fluids, gases and water**
- **Food Technologies**

Infrared heating

Infrared heating is the mechanism under which a source at high temperature delivers heat to a work-piece (food) at lower temperature by means of electromagnetic radiation.





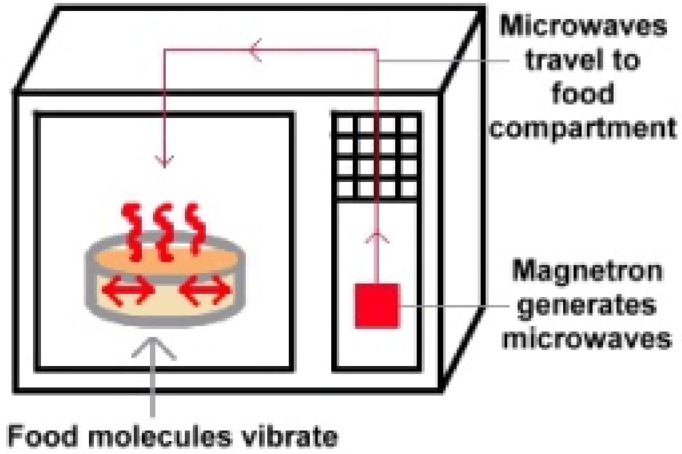
inovaLab

Infrared cooking

- Infrared cooking is mainly used for browning but it can be used also for cooking.
- Radiation can penetrate the food depending on the wavelength (short wavelength high penetration) and depending on absorbtion coefficient and emissivity of food.
- Infrared is very rapid (short wavelength lamps)
- It’s easy to control (voltage is the main control quantities)
- Life time of lamps is sometimes limited
- Pollution (steam, fats, oils) inside a oven can deteriorate the performances of lamps and the reflections of walls

Heating by Electromagnetic Sources

- Traditionally people use **external heating** methods for cooking. Only in the last years MW has been considered as an internal cooking method reliable for fast and quality cooking
- In order to be sure that the temperature inside food reaches a proper value, we need to wait for a certain time due to the conductivity of the material. Heat flux depends on temperature gradient.
- **Volumetric or "internal heating"** has a completely different heat transfer mechanism in comparison with external heating



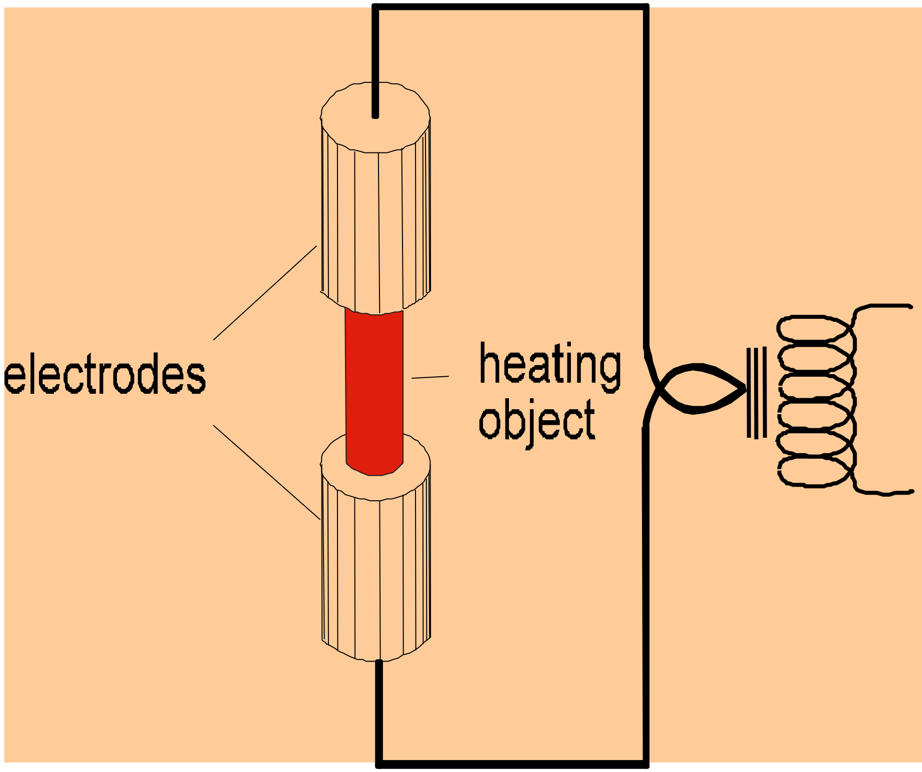
Heating by Electromagnetic Sources

- Microwave, Radio Frequency, Conduction and Induction are all «internal source heating» techniques.
- Microwave and Radiofrequency work on dielectric (non conductive) materials like most of foodstuff.
- Induction and conduction work on conductive materials like pans and pots and on special food (hot dogs).

The main advantages of these techniques are:

- **Fast (high values of power density)**
- **Precise (the electromagnetic field can be controlled in space and time)**
- **Efficient (most of these techniques deliver heat inside the workpiece – this means low heat losses)**
- **Controllable (all these techniques are supplied by electricity)**
- **Clean (no pollution for combustion process)**
- **Safe (non free flames, no high temperatures)**

Direct resistance heating

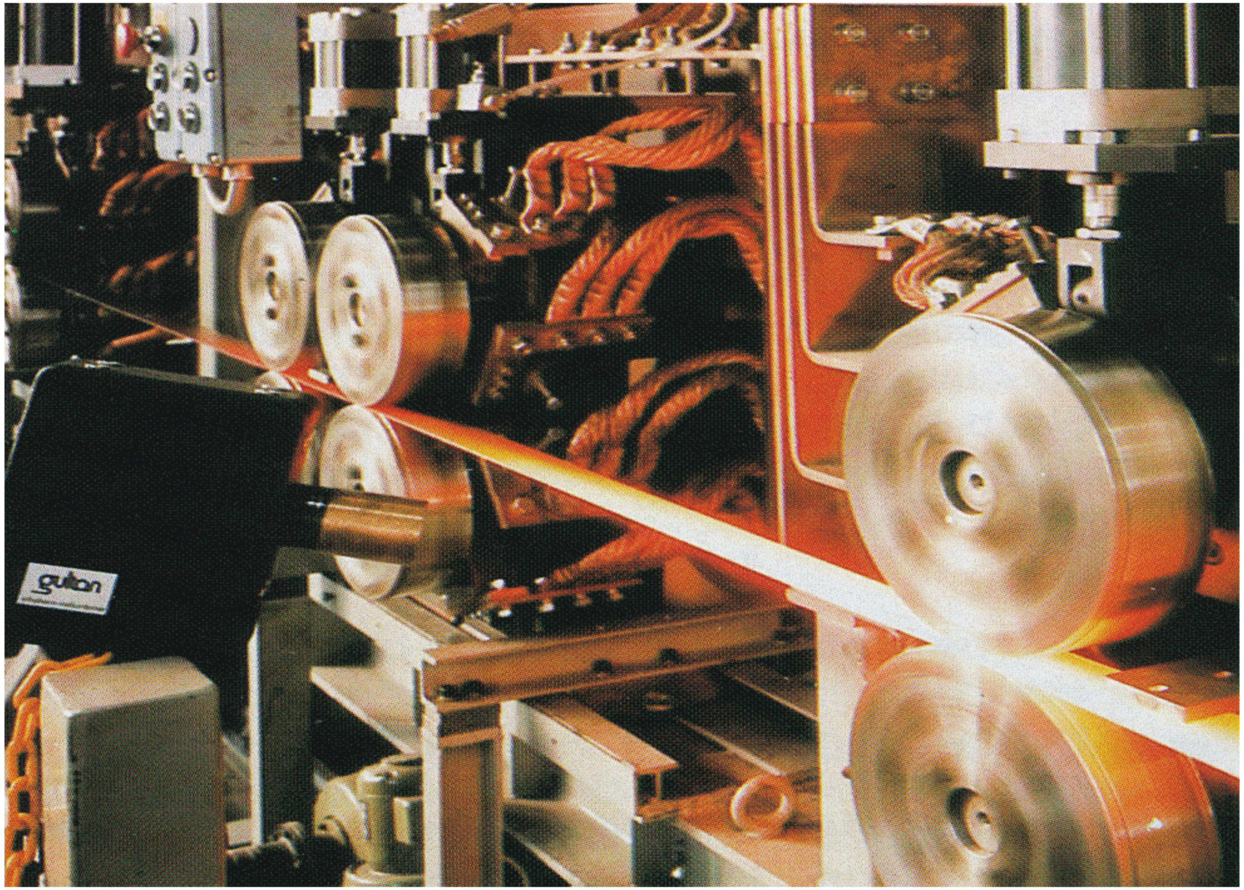


Examples of Application:

- **Melting of glass**
- **Heating of billets, wires, tubes**
- **Graphite production**
- **Electrolysis of aluminium**
- **Heating of liquids**
- **Steam production**

Direct resistance heating

Direct resistance heating

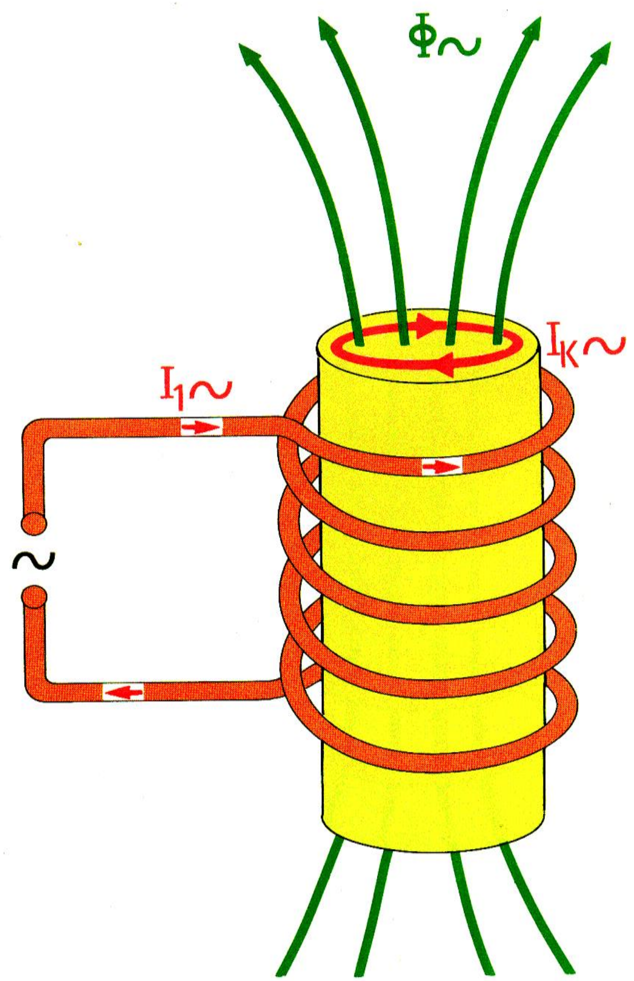


Continuous heating of sheets

Conduction heating

- Conduction heating is based on a very simple physical principle: the ohm and Joule law
- We apply a voltage between two terminals of the food and a current will flow in it.
- The current will produce heat inside the food

Induction heating

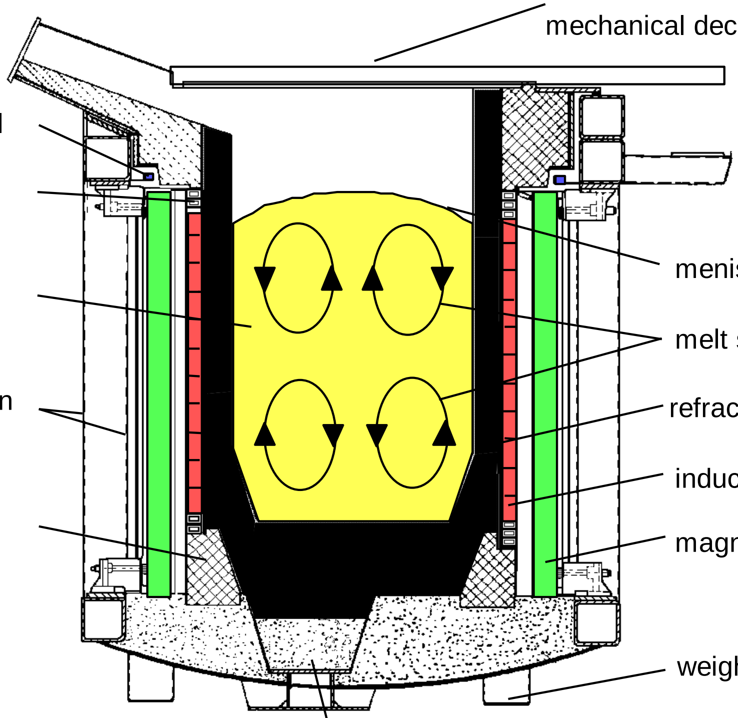


THROUGH HEATING
OF TUBES

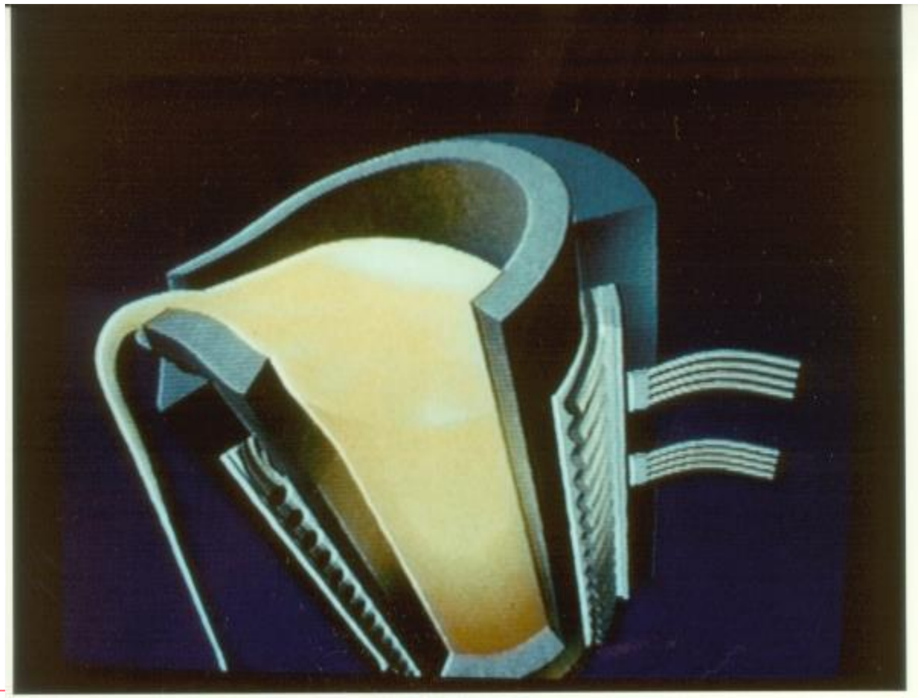
Examples of Application

- Through heating for forging or rolling
- Heat treatments of metals (hardening, annealing, tempering)
- Melting of ferrous, heavy and light metals
- Induction cooktops

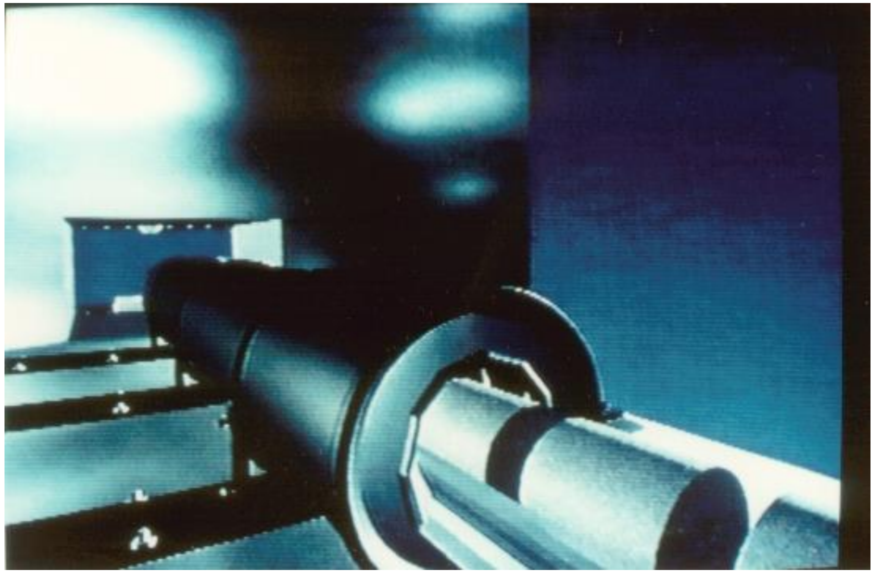
Induction melting

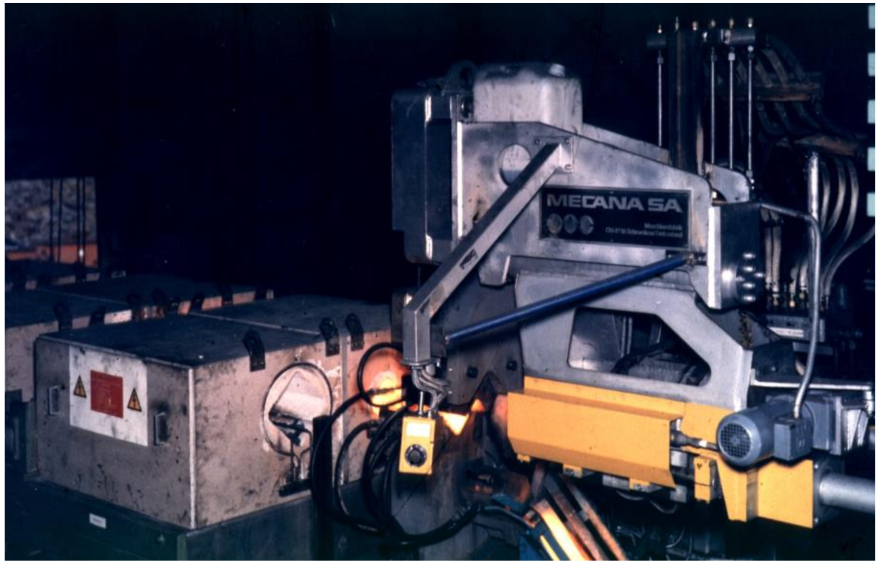


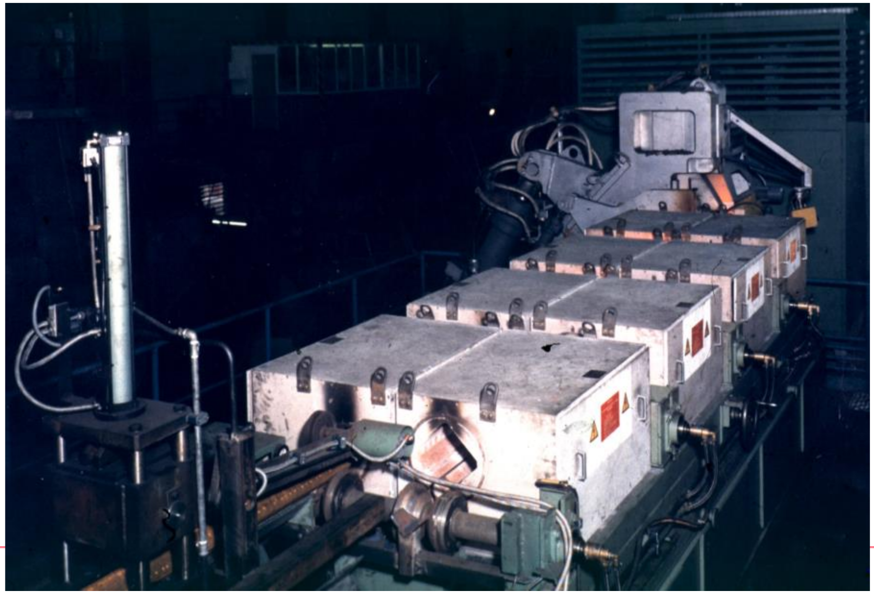
Induction Crucible Furnace (ICF)

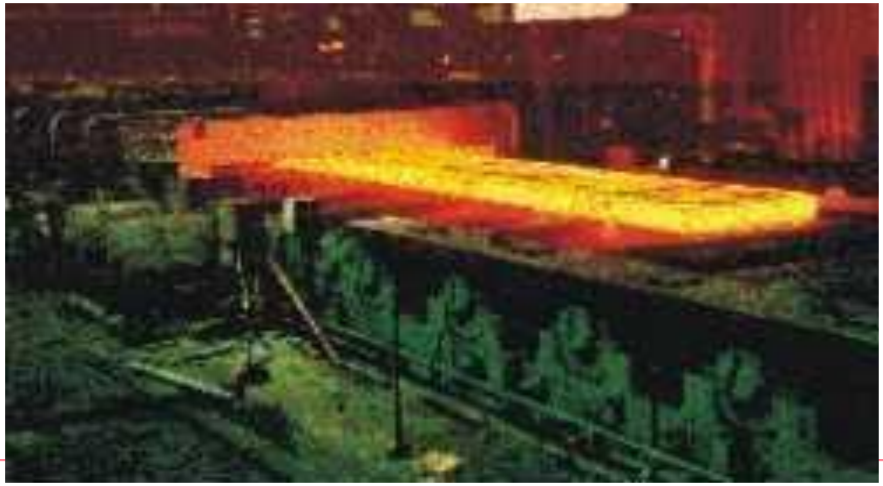


Induction through heating

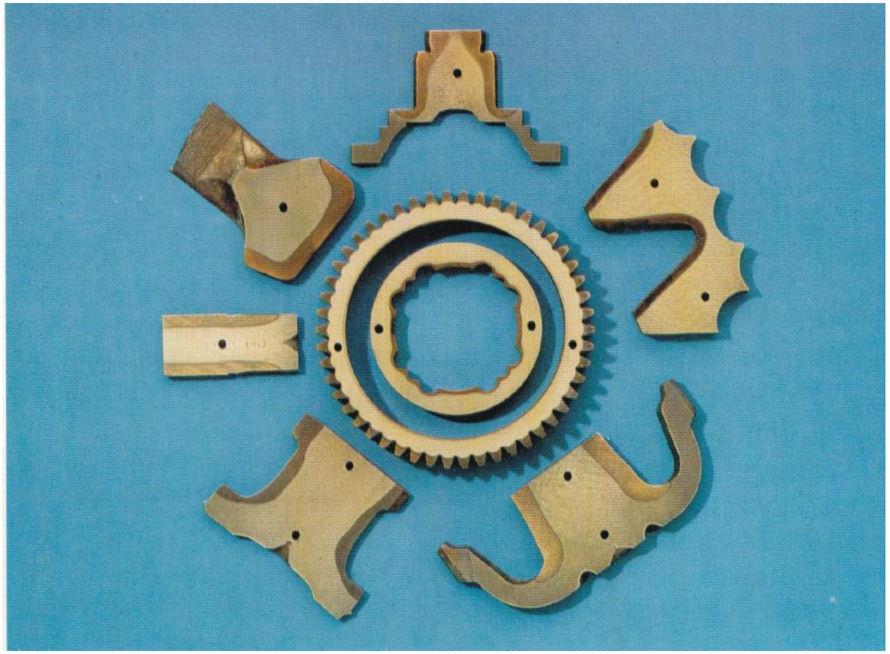






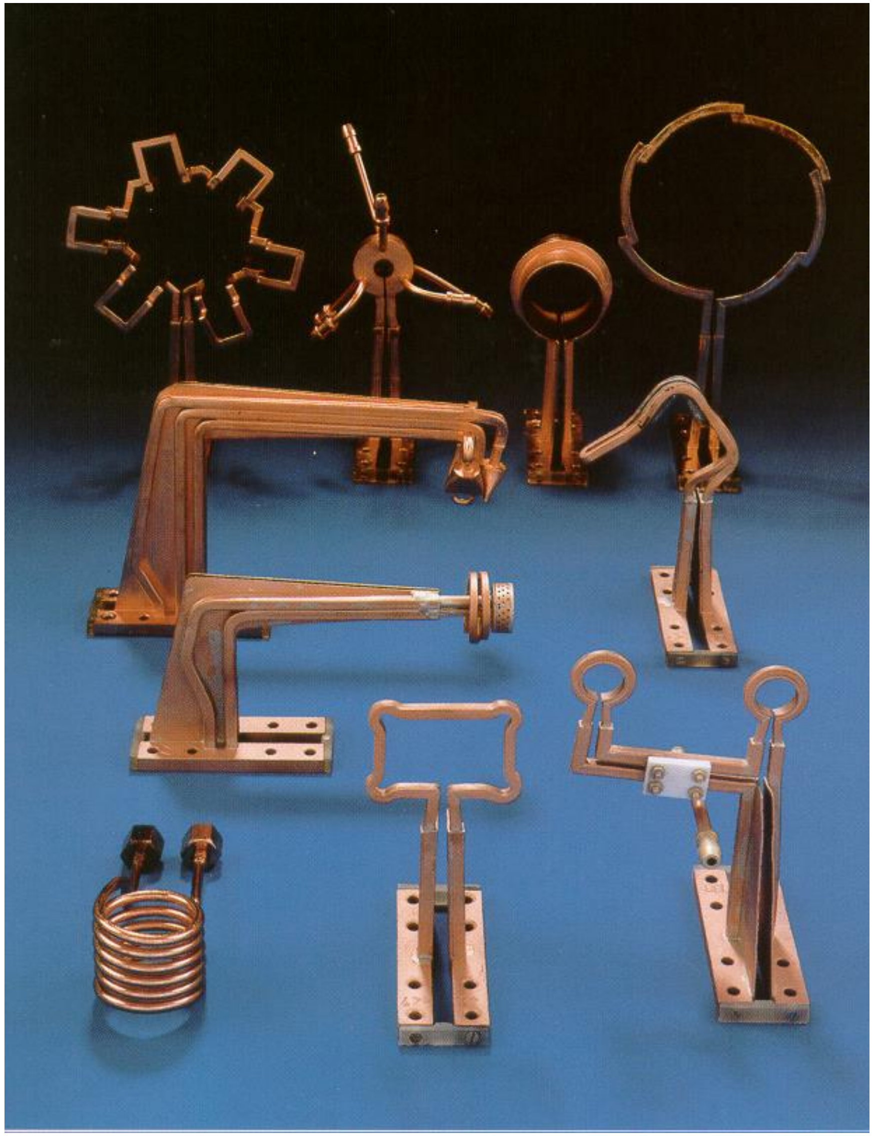


Induction Hardening

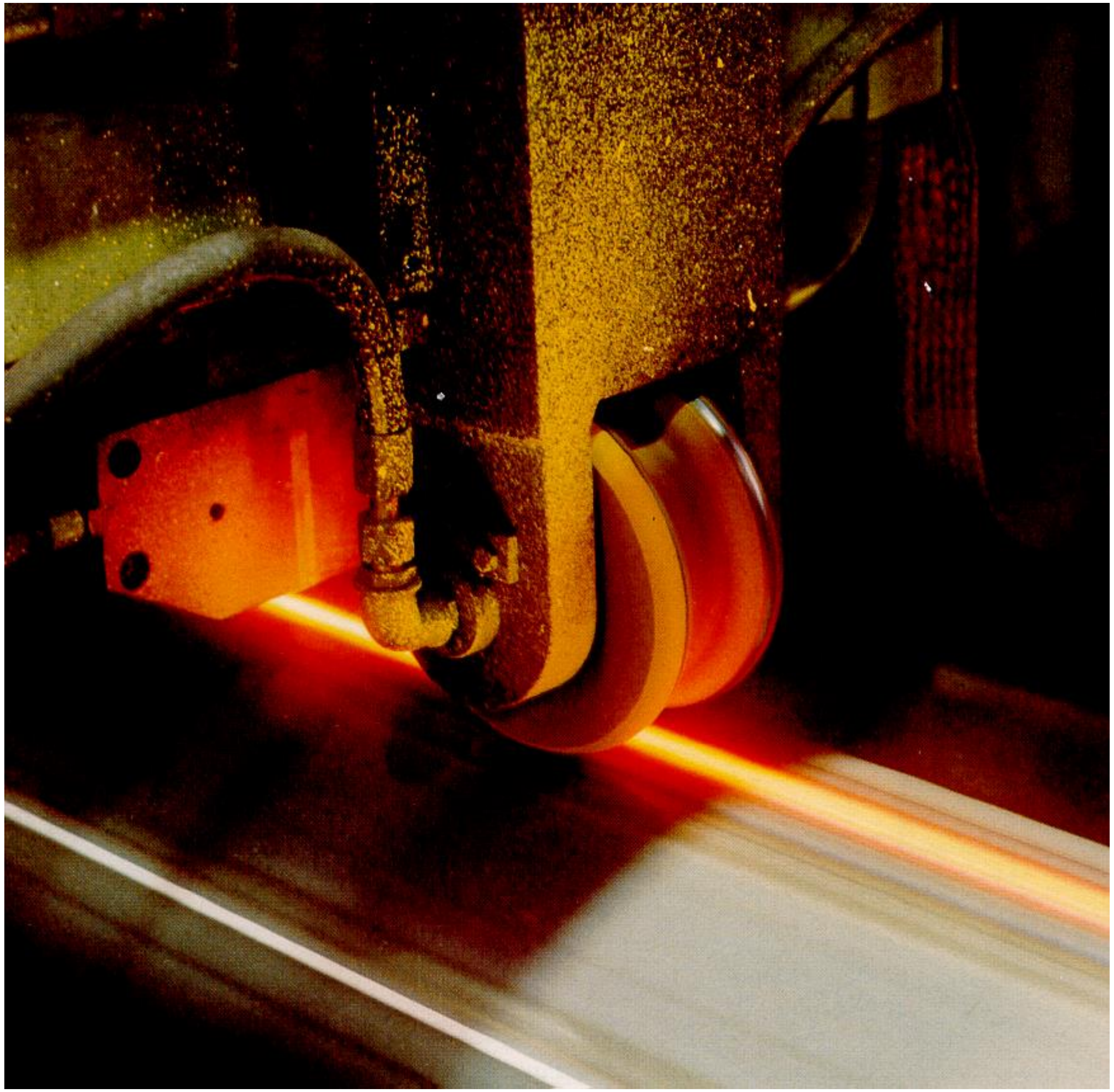


Hardened profiles

Inductors



Induction welding of tubes



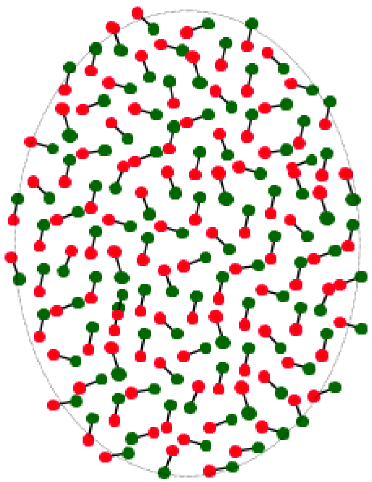
High Frequency Heating

- When we want to ***heat food*** by means of MWO or RF we apply an

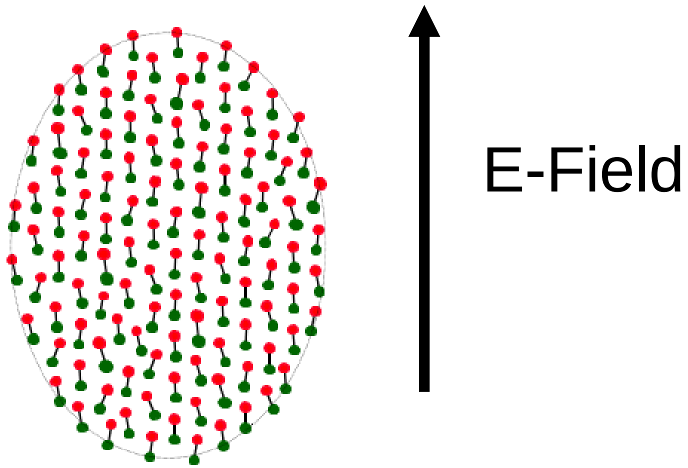
Electric Field

at high frequency in order to ***induce electrical currents*** inside it

Food molecules in normal condition



Food molecules when E-Field is appiled



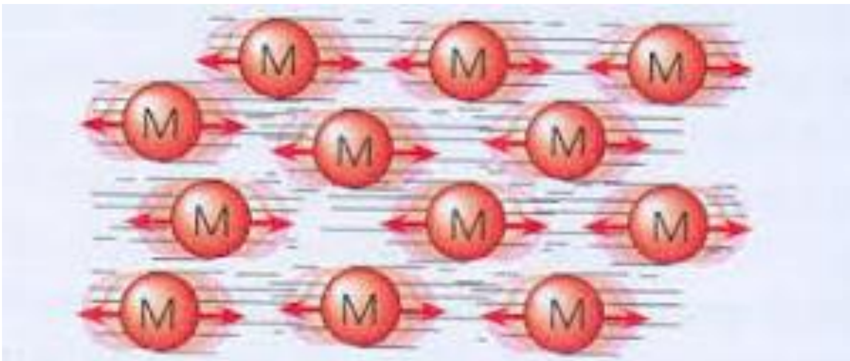
High Frequency Heating

Electric Field at high frequency makes the molecules

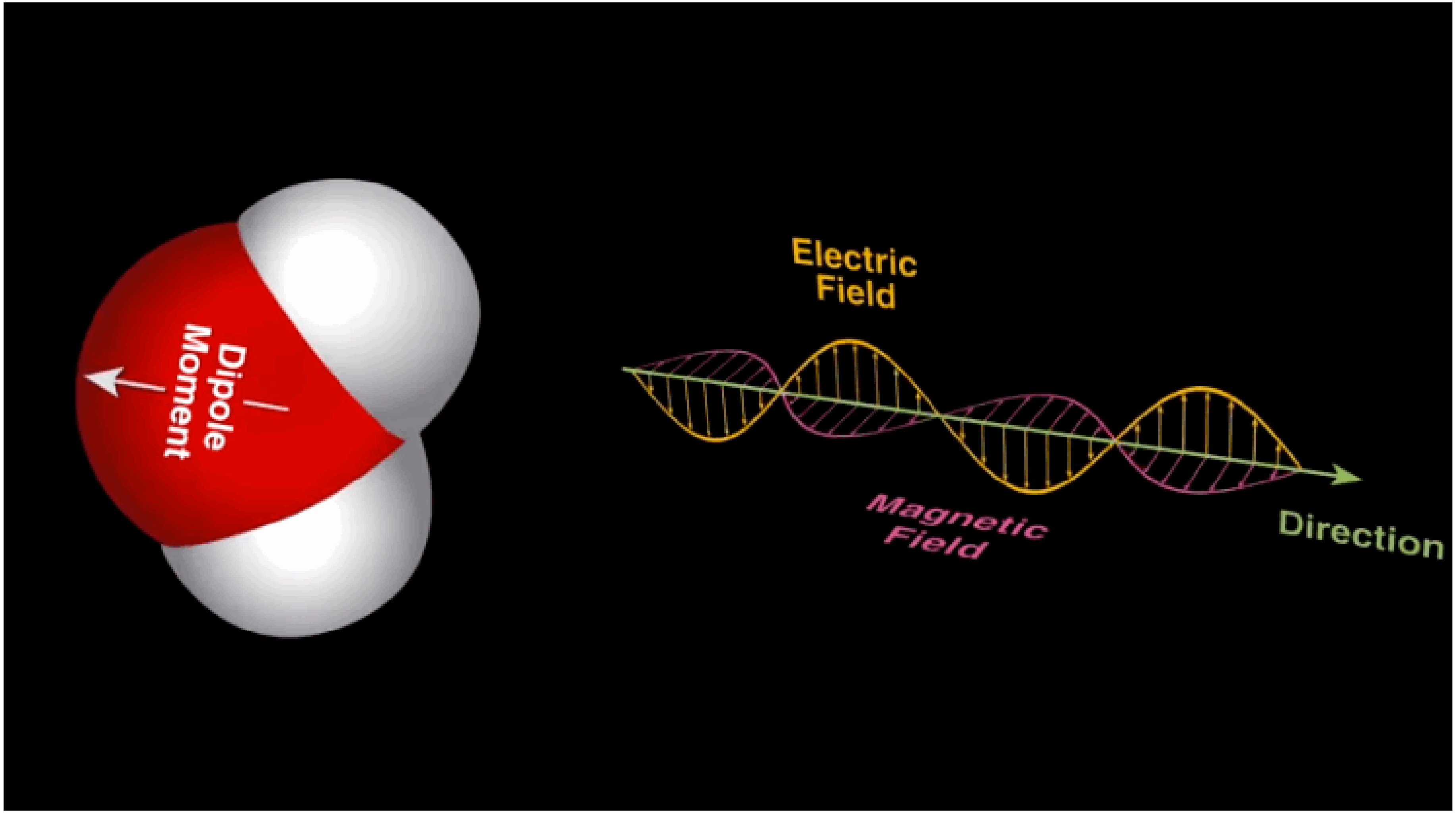
moving around their steady position

and the food can be heated by the ***Joule effect*** due to the so called

displacement current



Microwave Heating



inovaLab

MW and RF Heating

The load is positioned inside a

resonating cavity

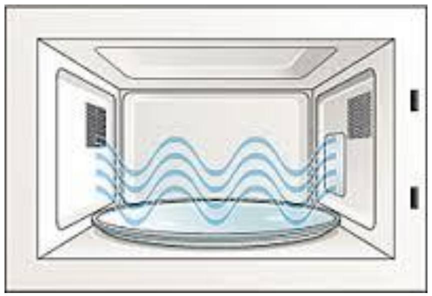
the distribution of EM energy is

not uniform

because of the

small wavelength

(12 cm for 2.45 GHz, 32 cm for 915 MHz)



The load is positioned inside a

big capacitor

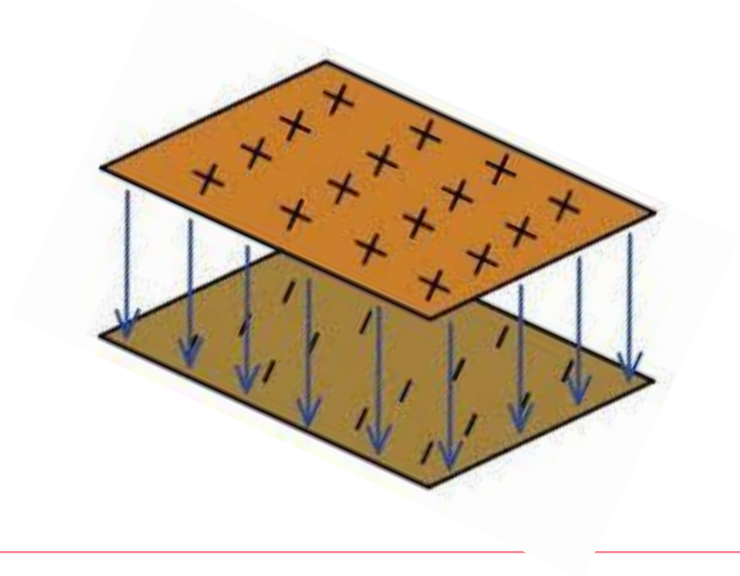
the distribution of EM energy is

quite uniform

because of the

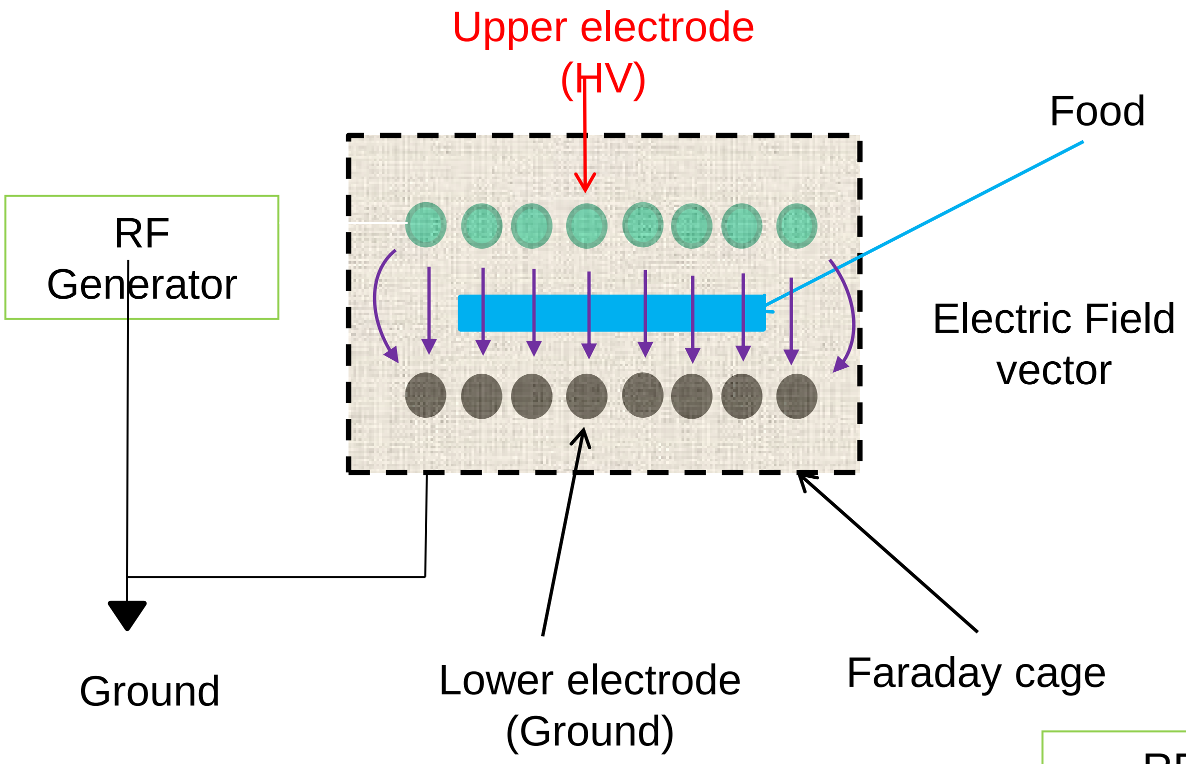
large wavelength

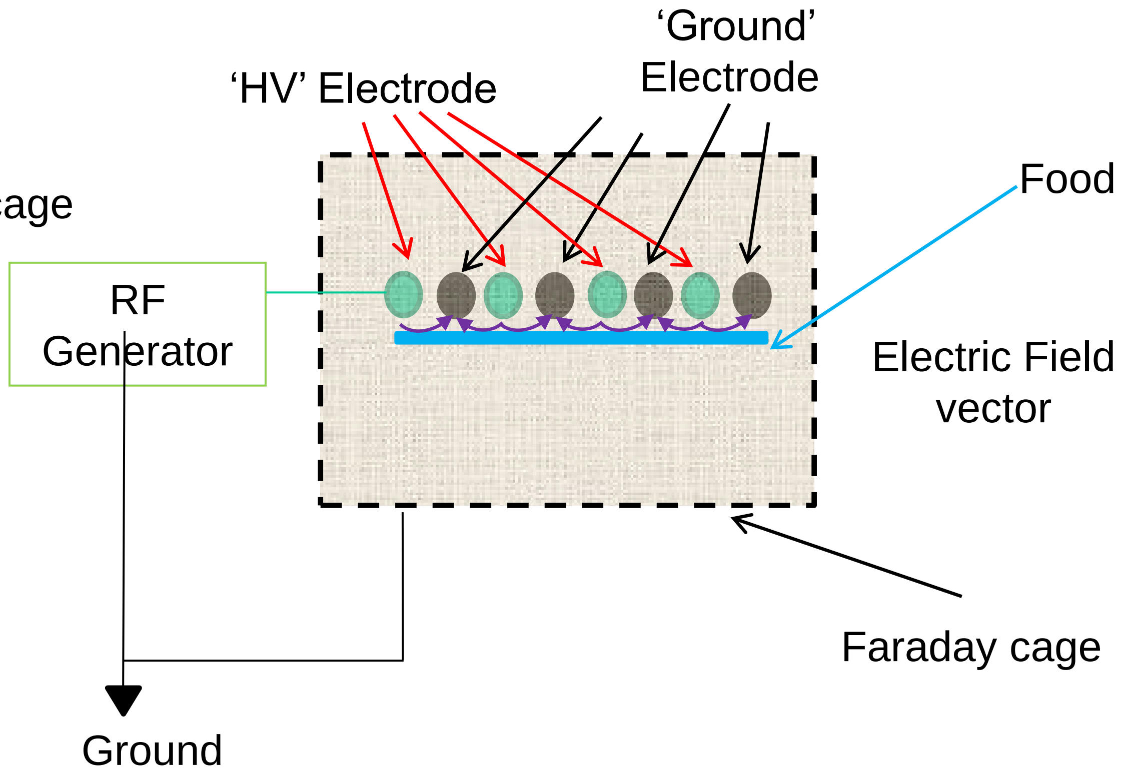
(11 m for 27.12 MHz)



inovaLab

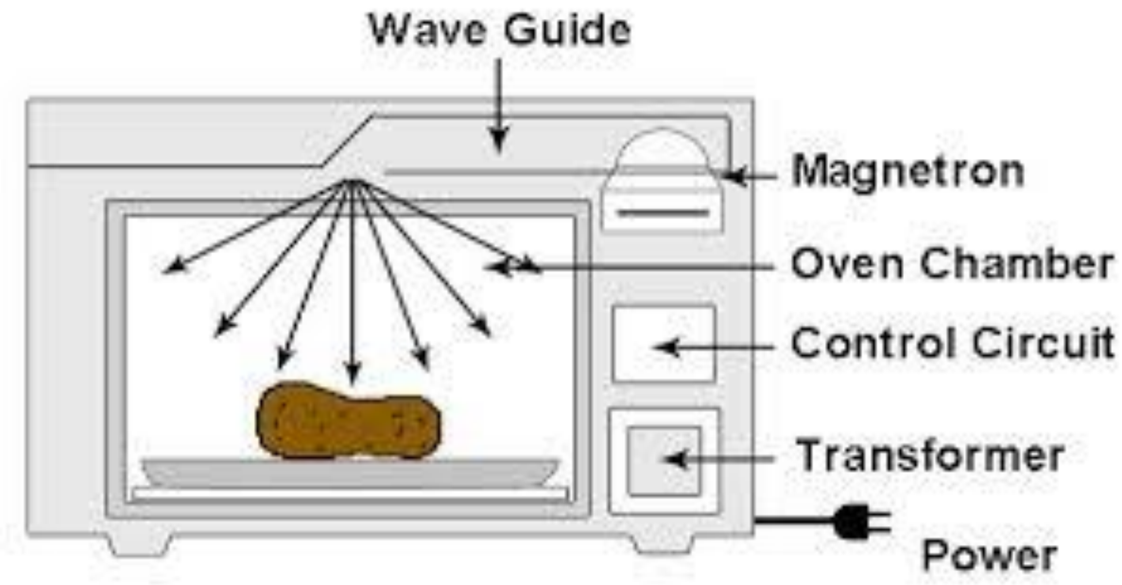
RF Heating: how it works

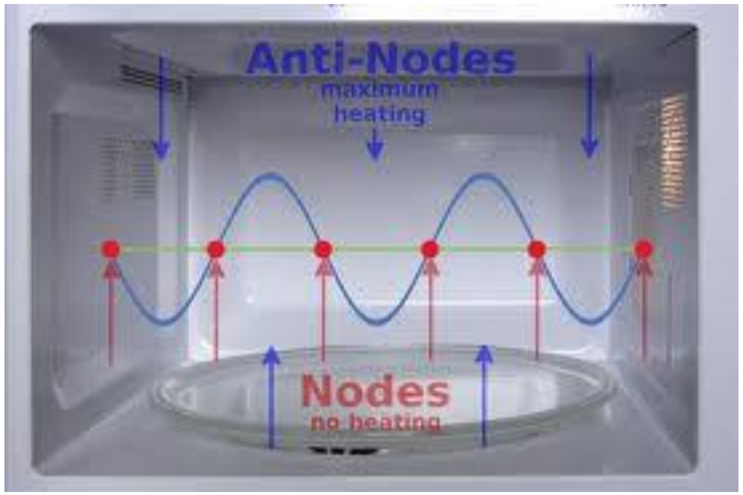


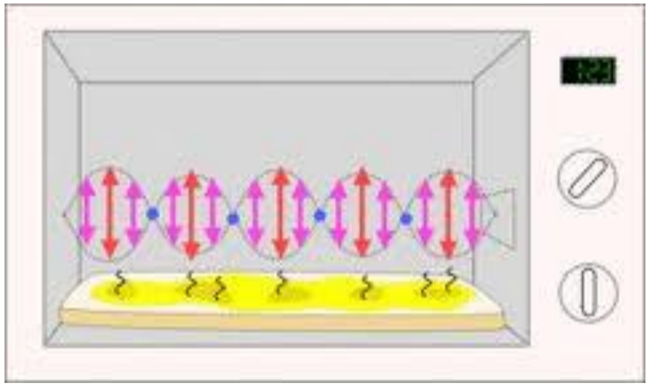


inovaLab

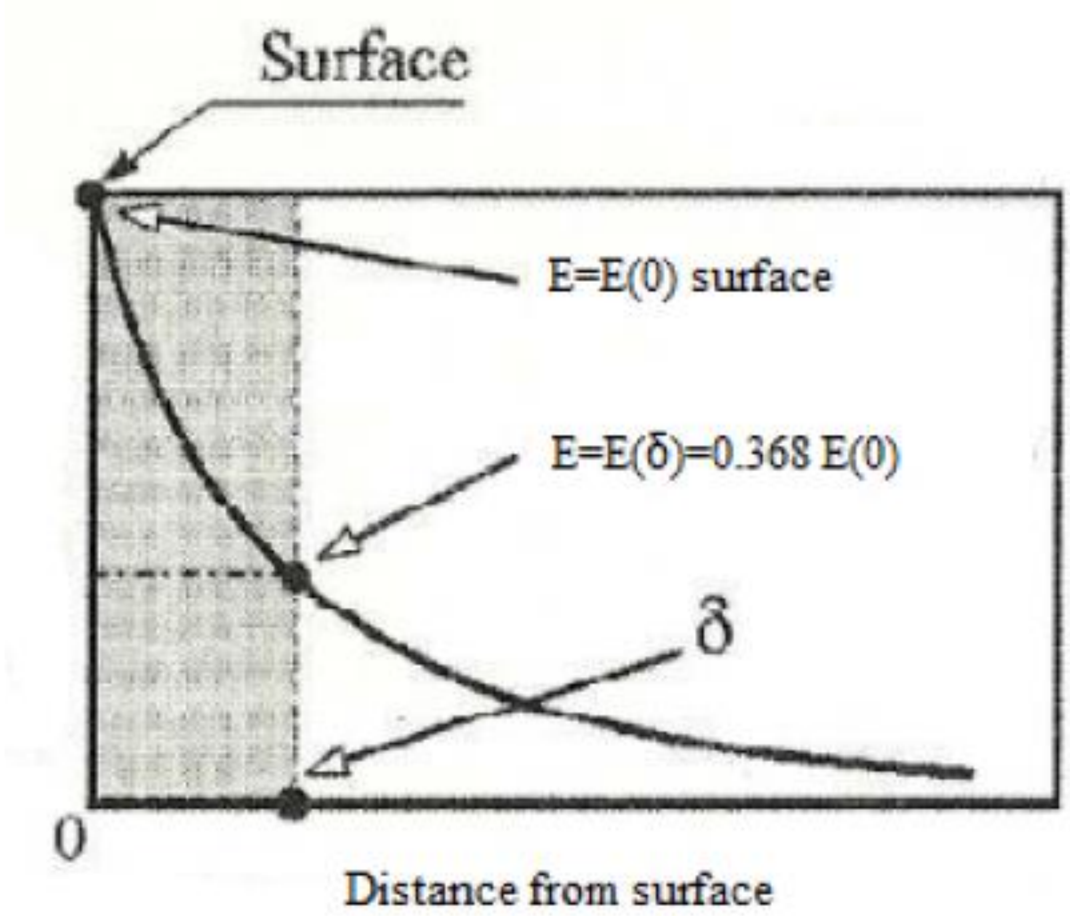
Microwave oven: how it works





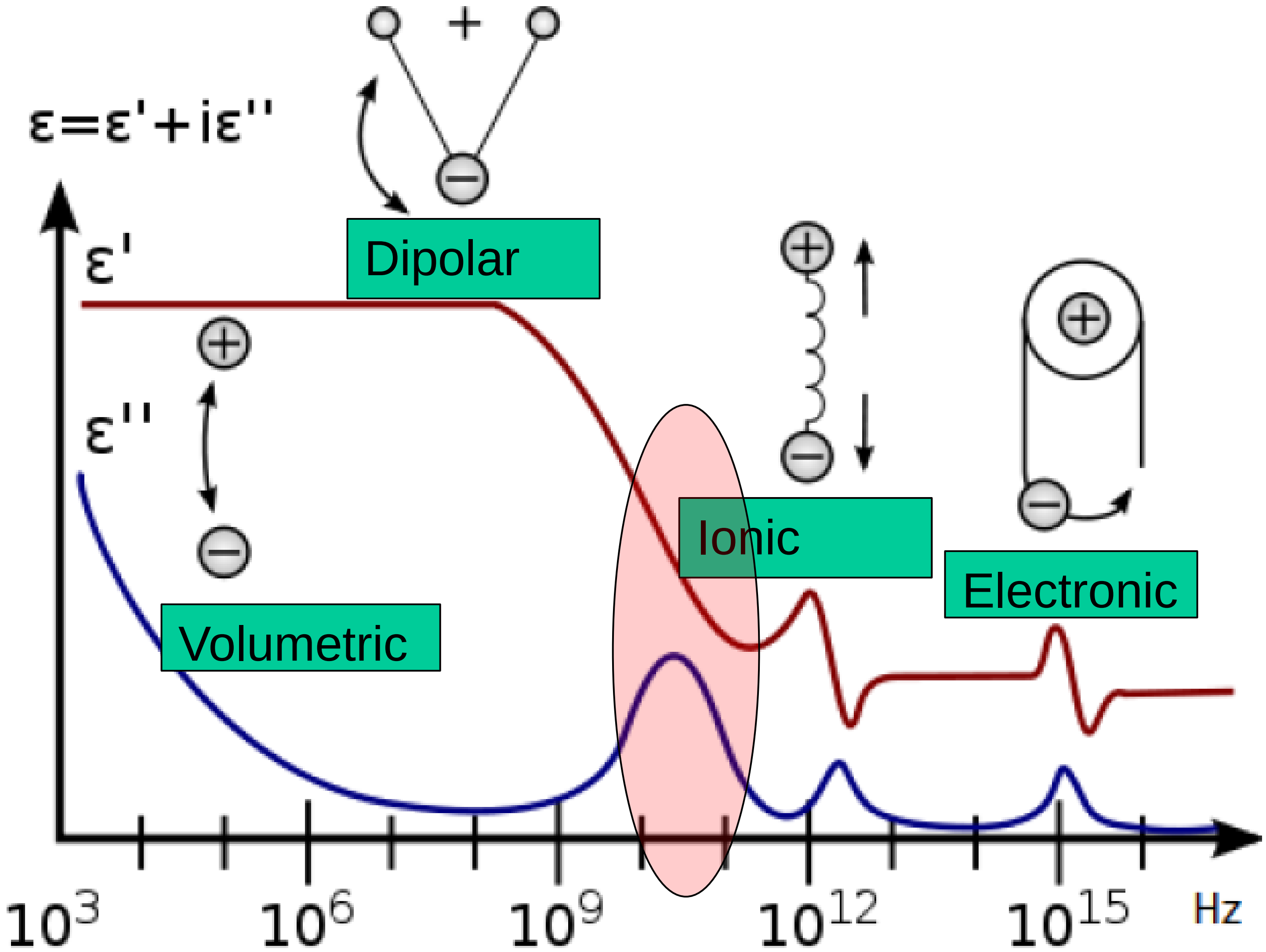


Penetration Depth in foods



$$d_p = \frac{1}{\alpha} = \frac{1}{\pi f \sqrt{2\mu\varepsilon\left[\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2}-1\right]}}$$

Food characteristics for MW



inovaLab

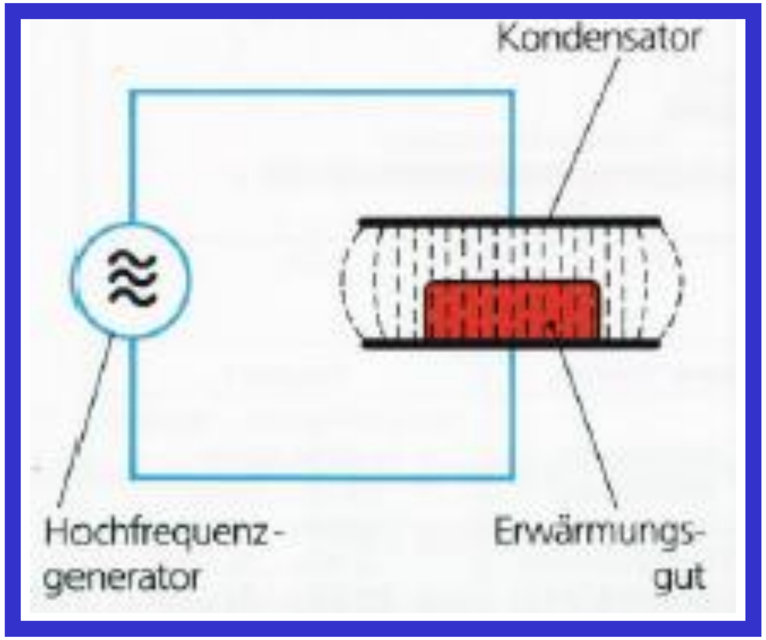
How the food influences the heating process

Behaviour of MW heating @2450 MHz

Material	Dielectric constant ($F\,m^{-1}$)	Loss factor	Penetration depth (cm)
Banana (raw)	62	17	0.93
Beef (raw)	51	16	0.87
Bread	4	0.005	1170
Brine (5%)	67	71	0.25
Butter	3	0.1	30.5
Carrot (cooked)	71	18	0.93
Cooking oil	2.6	0.2	19.5
Distilled water	77	9.2	1.7
Fish (cooked)	46.5	12	1.1
Glass	6	0.1	40
Ham	85	67	0.3
Ice	3.2	0.003	1162
Paper	4	0.1	50
Polyester tray	4	0.02	195
Potato (raw)	62	16.7	0.93

inovaLab

Dielectric Heating



- Frequencies: 13,56 MHz

  27,12 Mhz

  40,68 MHz

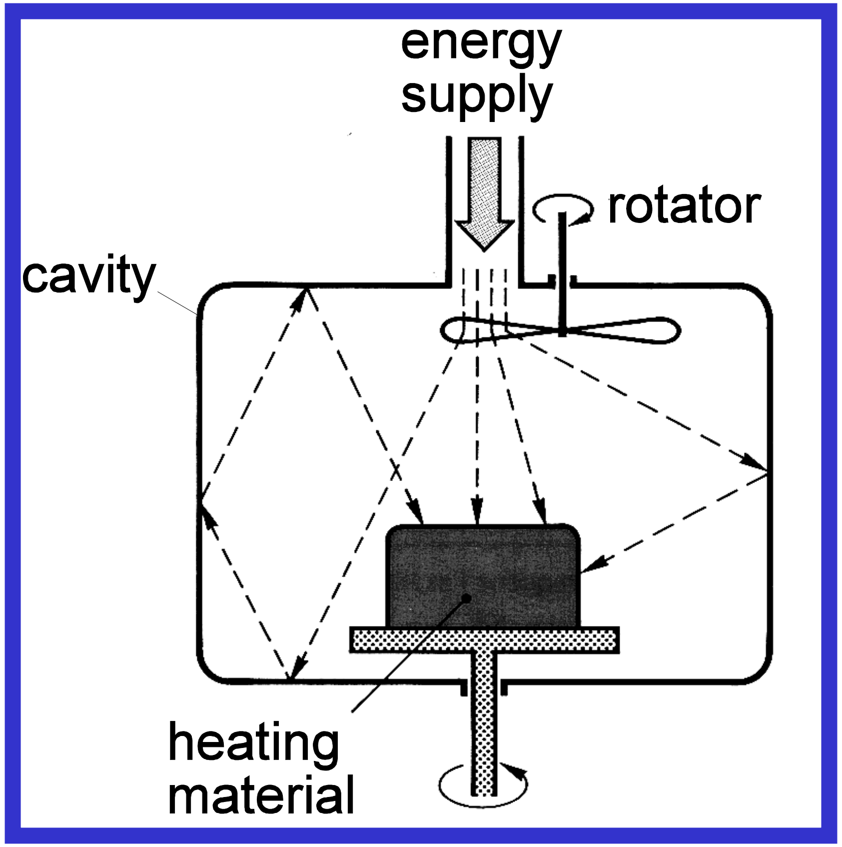
- Amplifier: oscillator on C class

Examples of Application:

- **Drying of textiles, leather, paper and board**
- **Food and drugs processing**
- **Plastics preheating and welding**
- **Rubber processing**
- **Wood glueing and drying**
- **Ceramics drying and heating**

RF Drying

Microwave Heating



Examples of Application:

- **Drying of textiles, leather, paper and board**
- **Food and drugs processing**
- **Rubber processing**
- **Wood drying**
- **Ceramics drying and heating**

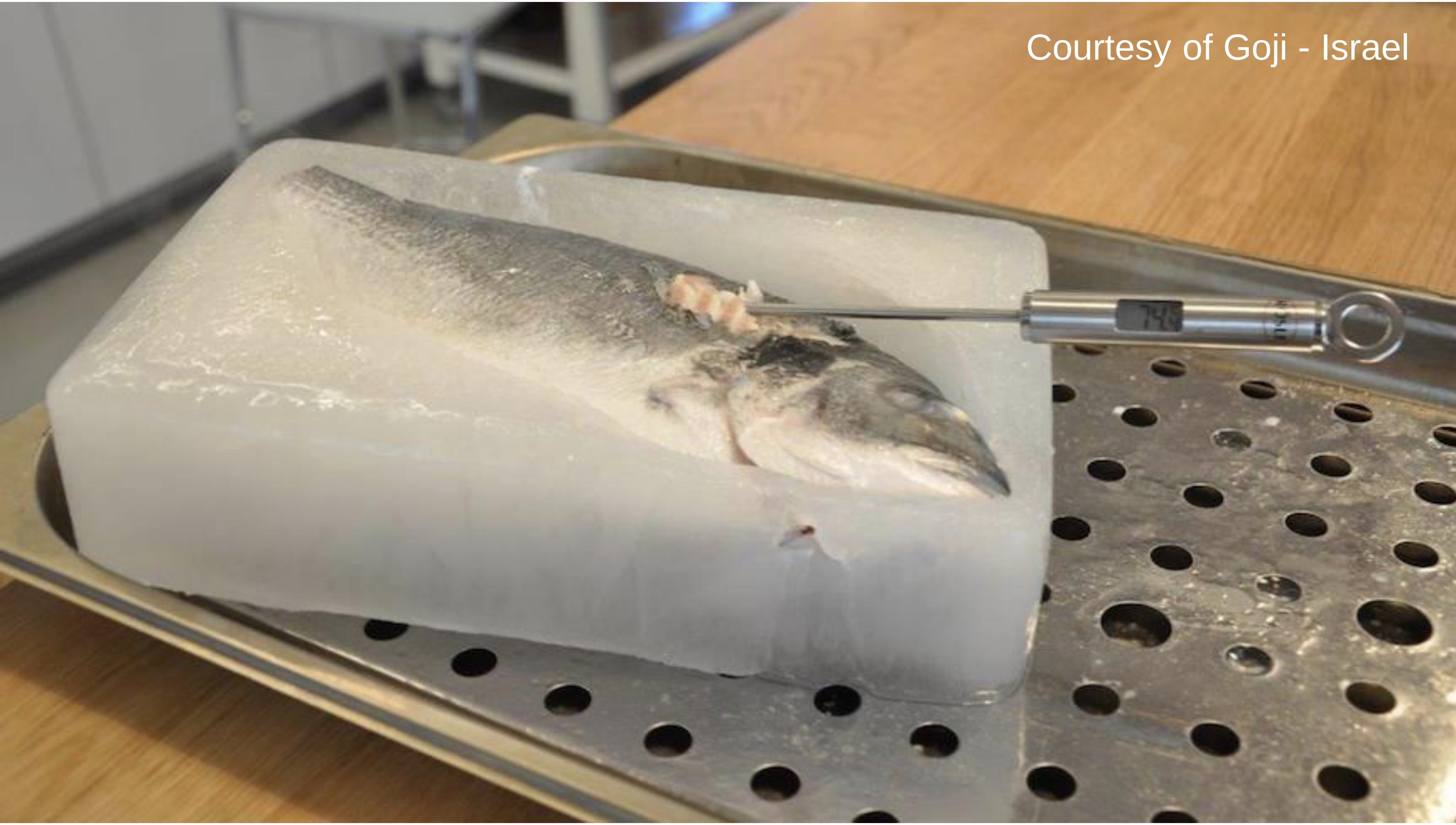
- Frequencies: 915 MHz

  2450 MHz

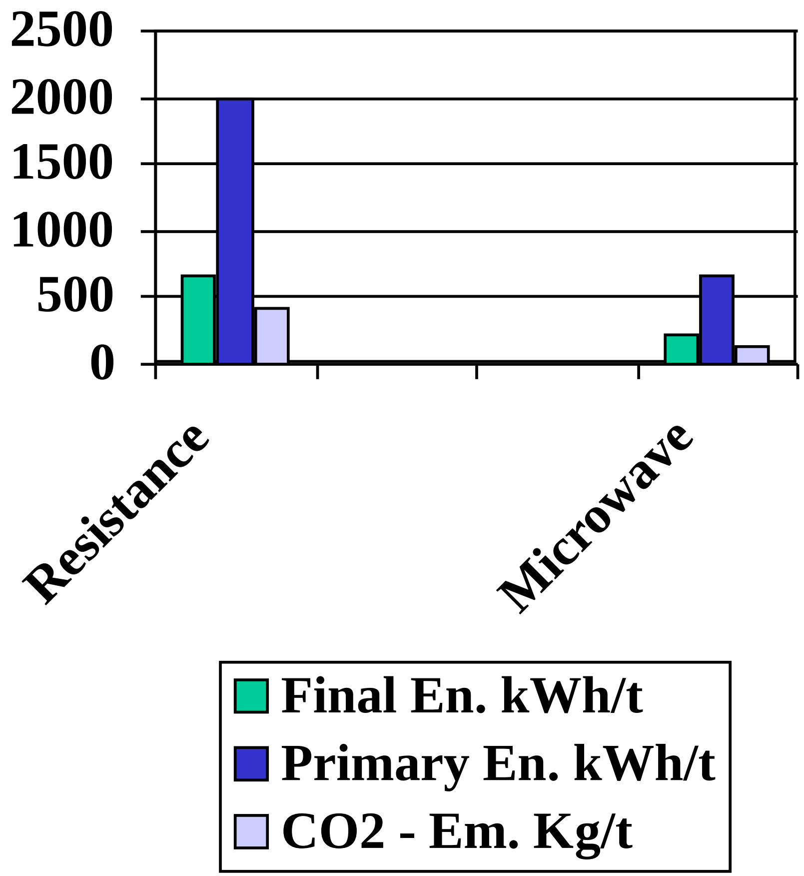
- Generator:
  - Magnetron
  - Solid state amplifiers

inovaLab


12:49


Courtesy of Goji - Israel

MW heating in Food Processing

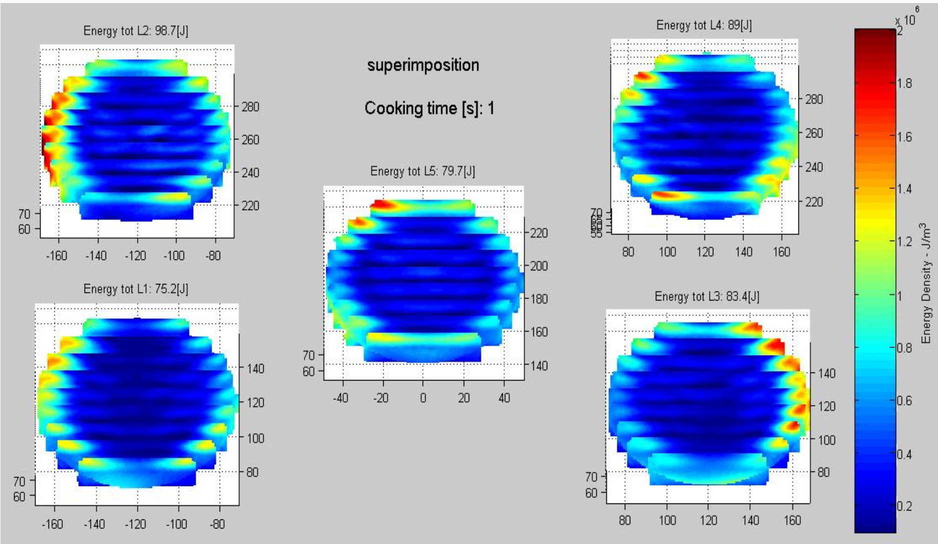


Re-heating food in a canteen (550 meals per day)

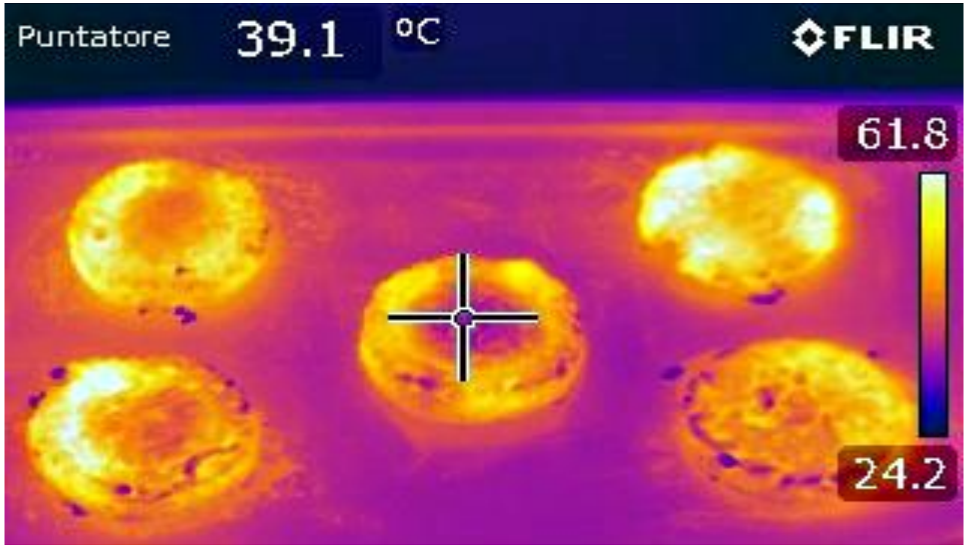
MW cooking

MW heating allows you to significantly reduce the cooking process times by creating heat sources directly inside the food, but it is an uneven process.

The new technology of the solid state generators allows to control the distribution of the EM field and increase the uniformity of the heating.



Energy density distribution [J/m³];



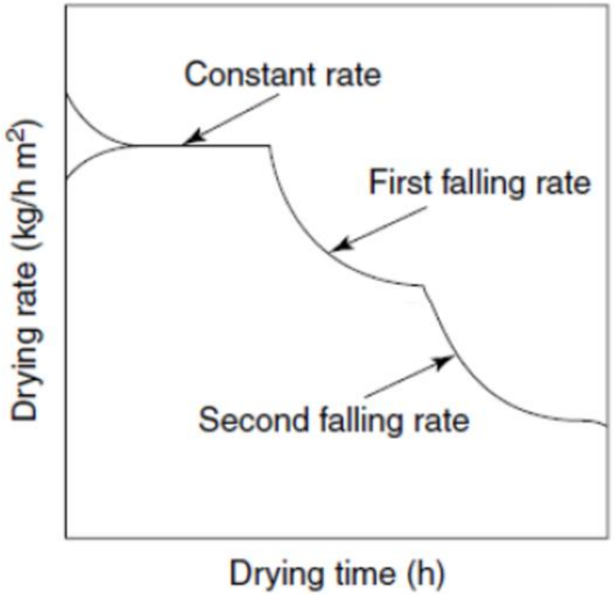
Temperature distribution [°C];
Initial temperature 12 °C; each sequence for 45 s

Drying

It is an energy-consuming and long-lasting process that reduces the moisture content.

The traditional air process can be divided into 3 phases:

- **period with constant drying rate:** the surface is kept wet by the constant flow of capillary water guided from inside the particle. The factors that determine and limit the drying rate are related to air.
- **first period of decrease in the drying constant:** the drying rate drops sharply.
- **second period of decrease in the drying constant:** the drying rate drops more slowly.



The MW process has 2 advantages over the traditional process:

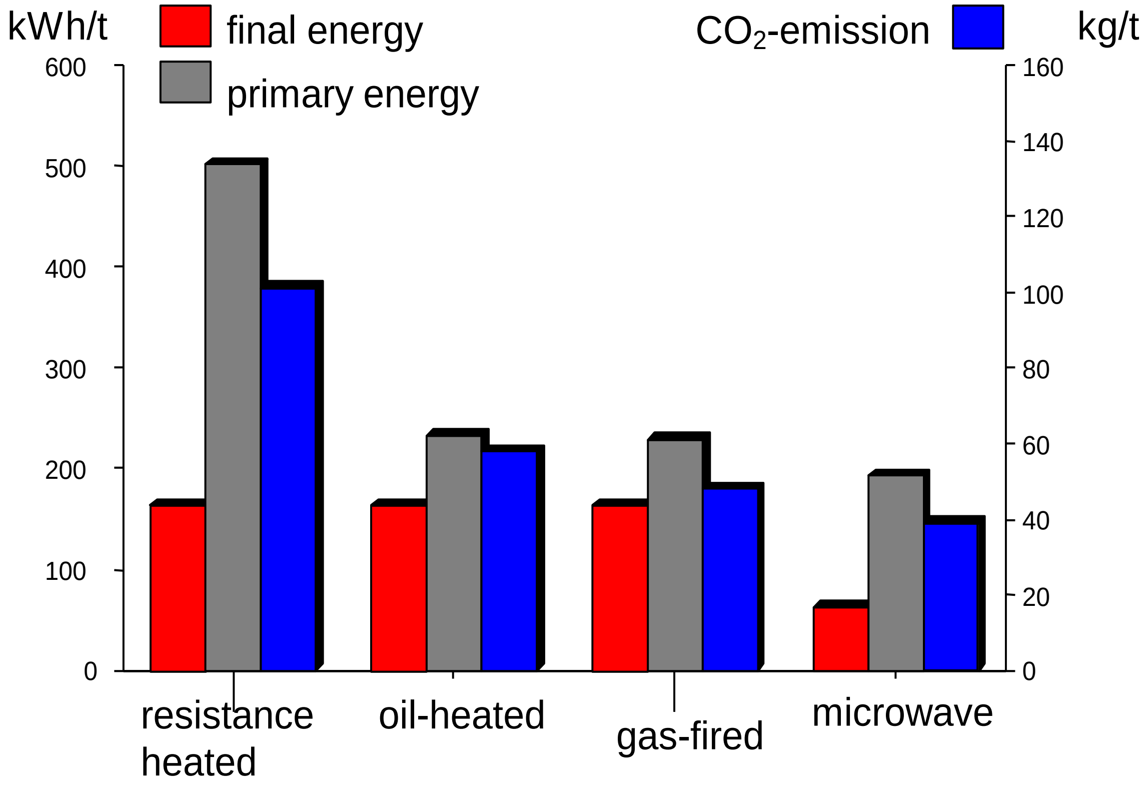
- temperature and humidity gradient are directed in the same direction;
- the MW act on the residual moisture component in the load.

The main advantage of MW therefore consists in speeding up the process, especially in products with a low humidity content (where the air is struggling to act).

Combined MW + convection drying systems are often used, in series or in parallel.

inovaLab

Final, primary and CO_2 energy in the different drying technologies



Advantages of MW heating:

- **Heating rate**
- **Energy saving**
- **Production rate increasing**
- **Reduction of CO2 emissions**

inovaLab

Module II

Energy equivalences and primary energy saving

inovaLab

Theretical Energy equivalences

1 kcal	=	4184 J	=	1.16 Wh	=	4184 Nm	=	427 kgm
1 Wh	=	3600 J	=	0.86 kcal	=	3600 Nm	=	368 kgm

Example N.1

Energy needed to heat one kilogram / liter of water from 0 to 20 ºC

427 Kgm • 20 = 42,7 q • 2 m

Example N.2

From a tube with a diameter of 10 mm, heated water from 10 to 60 ºC comes out at the speed v = 2 m / s; How many 40 W lamps can light up with the same power?

- *Water flow rate:* **$q = v (\pi \cdot d^2/4) = 0.157$ l/s**
- *Power:* **$P = q \cdot c \cdot (\theta_2 - \theta_1) = 0.157 \cdot 4184 \cdot 50 = 32{,}87$ kW**
- *Lamps number:* **n = 32870 / 40 = 822 !!!**

inovaLab

Energy equivalences and use of primary energy [Coal]

Theoretical

•1000 [kcal] = 4,184 • 10^6 [J] =

1,16 [kWh]

• Coal = 7.000[kcal/kg]

• 1000 [kcal] = 0,143 [kg]

• 1 [kWh] = 0,143 / 1,16 =

0,123 [kg]

Practical

• Average efficiency of a typical power plants system:

$\eta \approx 0{,}37$

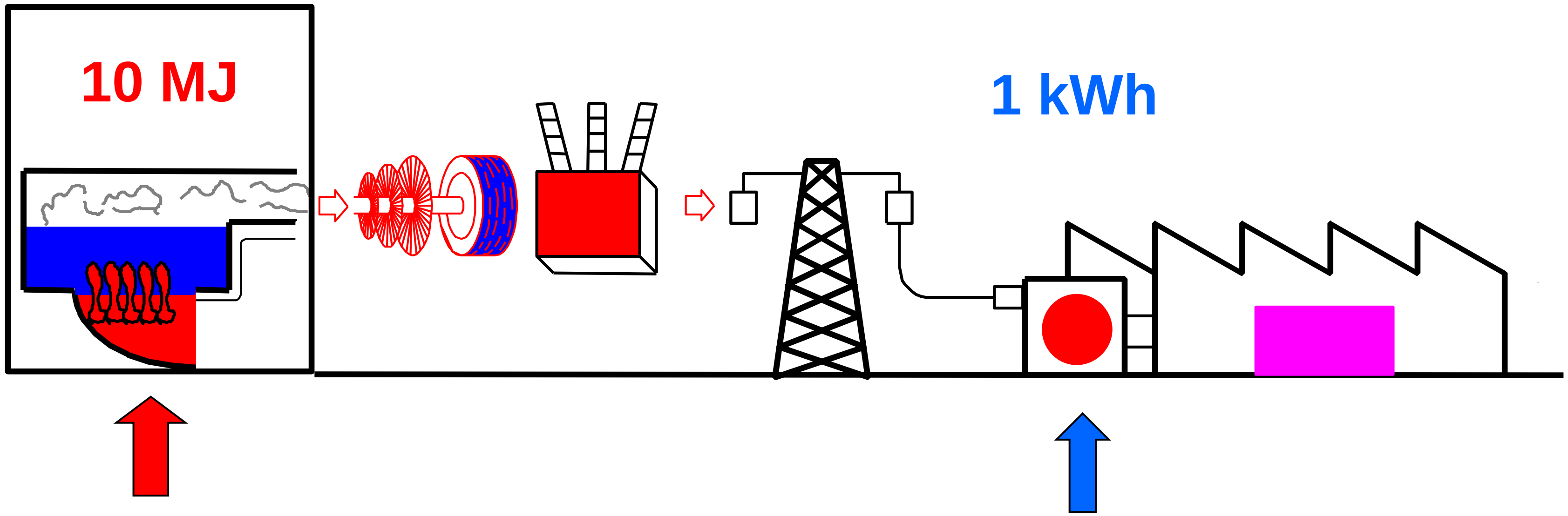
• Energy equivalence:

1 [kWh] = 0,123 / 0,37 = 0,332 [kg] =

2310 [kcal] = 9,7 [MJ]

inovaLab

Primary Energy-Electricity equivalence (Assumption only thermal power plants with η=37%)



Practical equivalence commonly adopted considering transformation and transmission losses

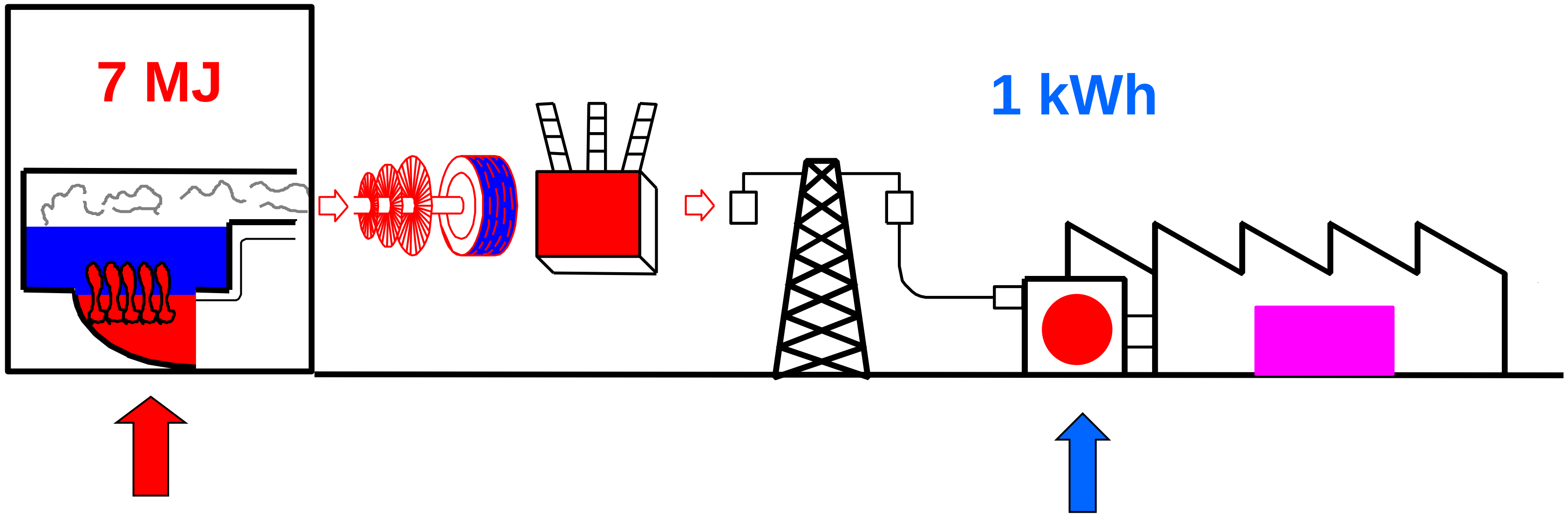
1 kWh of electricity at end user side

=

10 MJ of primary energy

inovaLab

Primary Energy-Electricity equivalence
(Current assumption with renewable energy η=55%)



Practical equivalence commonly adopted considering transformation and transmission losses

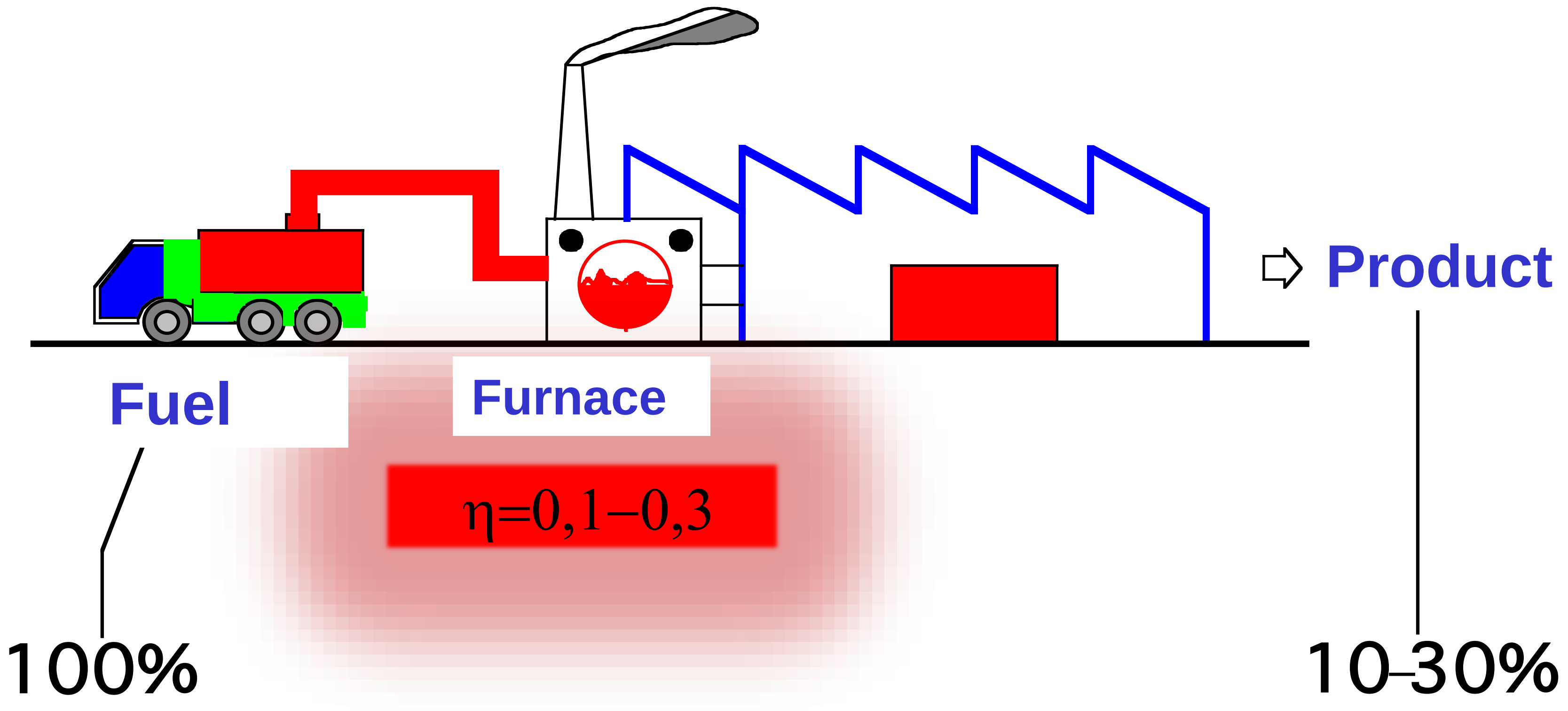
1 kWh of electricity at end user side

=

7 MJ of primary energy

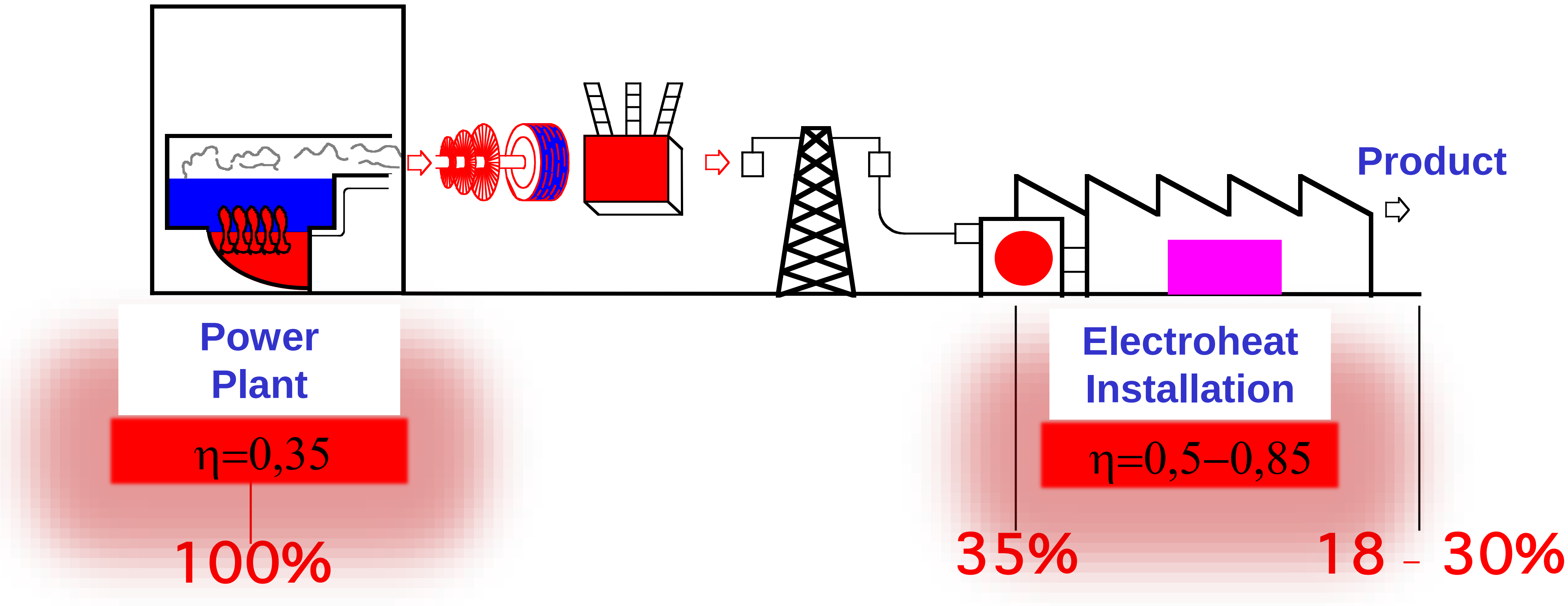
inovaLab

Energy balance of a thermal process with direct use of fuel



inovaLab

Energy balance of an electroheat process or with the use of electricity



inovaLab

Processes with use of fossil fuel and use of electricity

FUEL

(MJ)

C_1

ELECTRICITY

E_1

(kWh)

1

PRODUCT

FUEL

(MJ)

ELECTRICITY

C_2

E_2

(kWh)

2

PRODUCT

$C_1 > C_2$ → **Decrease in fuel consumption**

$E_1 < E_2$ → **Increase of use of electricity**

Saving of primary energy and coefficient "γ"

$$\gamma = \frac{C_1 - C_2}{E_1 - E_2} \quad \left[\frac{MJ}{kWh} \right]$$

When C1> C2 and E1 <E2, by replacing process 1 with process 2, the "γ" MJ of fuel is replaced with 1 kWh of electricity.

A primary energy saving occurs when it turns out :

γ>10 (Thermal power plants)

γ >7 (Current power plants with renewable energy)

inovaLab

Typical values of "γ" [MJ/kWh]

• Drying of food at High Frequency:	9.6
• Induction boiling of H_2O:	10.5
• Electric heating of water:	18.8
• Drying by heat pump:	19.2
• Concentration of dairy products:	54.4

inovaLab

Economic convenience for the end user

$$\beta = \frac{K_E}{K_C}$$

- K_E – **Cost of Electricity [€/kWh]**
- K_C – **Cost of fuel [€/MJ]**

It is necessary to evaluate the performance of individual processes and quantify the amount of the cost of energy spent in MJ of gas / petrol / fuel oil compared to the cost of electricity. This also depends on the country by country base within Europe.

inovaLab

Example: H_2O Induction and gas

1 kcal	**=**	**4184 J**	**=**	**1.16 Wh**	**=**	**4184 Nm**	**=**	**427 kgm**
1 Wh	**=**	**3600 J**	**=**	**0.86 kcal**	**=**	**3600 Nm**	**=**	**368 kgm**

Useful energy to heat a liter of water from 0 to 100 ºC

4184 J • 100 = 418400 J= 0,116 kWh

- *Efficiency of a gas heating approx* η*=30%*
- *Efficiency of an induction heating approx* η*=90%*
- *Energy required for gas heating* E_{gas}*=0,116/0,30=0,387 kWh=1,392 MJ*
- *Energy required for Induction heating* E_{el}*=0,116/0,90=0,129 kWh*

γ*=1,392/0,129=10,79 [MJ/kWh]*

PRIMARY ENERGY SAVING

Gas and electricity prices for some European countries

Electricity and gas prices in Europe (non domestic users)					
Country	Electricity EE [€/kWh]	Natural Gas NG [€/kWh]	Ratio EE/NN	Natural Gas [€/MJ]	Beta [€/kWh/€/MJ]
Italy	0,166	0,034	4,857	0,010	17,484
Germany	0,156	0,032	4,896	0,009	17,626
Spain	0,115	0,031	3,727	0,009	13,418
France	0,102	0,038	2,709	0,011	9,752
Poland	0,100	0,035	2,890	0,010	10,406
Romania	0,097	0,032	3,066	0,009	11,038
Serbia	0,083	0,039	2,136	0,011	7,689
Denmark	0,071	0,034	2,098	0,009	7,553

Electricity and gas prices in Europe (domestic users)					
Country	Electricity EE [€/kWh]	Natural Gas NG [€/kWh]	Ratio EE/NN	Natural Gas [€/MJ]	Beta [€/kWh/€/MJ]
Italy	0,230	0,077	2,992	0,021	10,772
Germany	0,309	0,063	4,886	0,018	17,590
Spain	0,240	0,074	3,265	0,020	11,754
France	0,177	0,074	2,398	0,020	8,633
Poland	0,134	0,047	2,839	0,013	10,222
Romania	0,136	0,035	3,914	0,010	14,089
Serbia	0,071	0,034	2,113	0,009	7,608
Denmark	0,298	0,086	3,490	0,024	12,564

Example: H_2O Induction and gas

γ=10,79

Italy

- *Electricity cost in Italy for domestic user: 0.230 € / kWh*
- *Cost of gas in Italy per domestic user: € 0.077 / kWh*
- β_{Italy}=10,772
- *Cost for gas heating = 0.387 * 0.077 = 0.0298 €*
- *Cost for Induction heating = 0.129 * 0.230 = 0.0297 €*

France

- *Electricity cost in France for domestic user: 0.177 € / kWh*
- *Cost of gas in France per domestic user: 0.074 € / kWh*
- β_{France}=8,633
- *Cost for gas heating = 0.387 * 0.074 = 0.0286 €*
- *Cost for Induction heating = 0.129 * 0.177 = 0.0228 €*

inovaLab

Electricity prices, first semester of 2017-2019

(EUR per kWh)

	Households (¹)			Non-households (²)		
	2017S1	2018S1	2019S1	2017S1	2018S1	2019S1
EU-28	0.2043	0.2066	0.2159	0.1146	0.1152	0.1251
Euro area	0.2210	0.2214	0.2294	0.1224	0.1215	0.1306
Belgium	0.2857	0.2733	0.2839	0.1104	0.1085	0.1147
Bulgaria	0.0955	0.0979	0.0997	0.0763	0.0810	0.0887
Czechia	0.1438	0.1573	0.1748	0.0688	0.0733	0.0768
Denmark	0.3049	0.3126	0.2984	0.0845	0.0807	0.0707
Germany	0.3048	0.2987	0.3088	0.1519	0.1499	0.1557
Estonia	0.1207	0.1348	0.1357	0.0870	0.0865	0.0917
Ireland	0.2305	0.2369	0.2423	0.1237	0.1321	0.1400
Greece	0.1711	0.1672	0.1650	0.1073	0.1038	0.1059
Spain	0.2296	0.2383	0.2403	0.1061	0.1059	0.1148
France	0.1704	0.1748	0.1765	0.0978	0.0982	0.1024
Croatia	0.1196	0.1311	0.1321	0.0874	0.0994	0.1034
Italy	0.2132	0.2067	0.2301	0.1477	0.1423	0.1661
Cyprus	0.1863	0.1893	0.2203	0.1414	0.1405	0.1619
Latvia	0.1586	0.1531	0.1629	0.1179	0.1039	0.1052
Lithuania	0.1116	0.1097	0.1255	0.0837	0.0838	0.0926
Luxembourg	0.1615	0.1671	0.1798	0.0780	0.0833	0.0897
Hungary	0.1125	0.1123	0.1120	0.0772e	0.0840	0.0970
Malta	0.1328	0.1285	0.1305	0.1351	0.1346	0.1392
Netherlands	0.1562	0.1706	0.2052	0.0822	0.0863	0.0941
Austria	0.1950	0.1966	0.2034	0.0930	0.0997	0.1076
Poland	0.1446	0.1410	0.1343	0.0866	0.0876	0.1003
Portugal	0.2284	0.2246	0.2154	0.1145	0.1123	0.1186
Romania	0.1198	0.1333	0.1358	0.0769	0.0831	0.0972
Slovenia	0.1609	0.1613	0.1634	0.0784	0.0860	0.0959
Slovakia	0.1435	0.1566	0.1577	0.1118	0.1166	0.1286
Finland	0.1581	0.1612	0.1734	0.0667	0.0681	0.0709
Sweden	0.1936	0.1891	0.2015	0.0648	0.0684	0.0738
United Kingdom	0.1766	0.1887	0.2122	0.1264	0.1337	0.1517
Iceland	0.1598	0.1545	0.1406	0.0795p	0.0769e	0.0579
Liechtenstein	0.1724	:	:	0.1296	:	:
Norway	0.1642	0.1751	0.1867	0.0711	0.0778	0.0829
Montenegro	0.0983	0.1024	0.1032	0.0775	0.0810	0.0868
North Macedonia	0.0820	0.0781	0.0783	0.0524	0.0624	0.0687
Albania	0.0844	:	:	:	:	:
Serbia	0.0664	0.0705	0.0706	0.0639	0.0704	0.0833
Turkey	0.1048	0.0904	0.0847	0.0634	0.0589	0.0706
Bosnia and Herzegovina	0.0859	0.0864	0.0873	0.0594	0.0661	0.0667
Kosovo (³)	0.0662	0.0633	0.0600	0.0798	0.0746	0.0660
Moldova	0.0977	0.1020	0.0936	0.0828	0.0880	0.0771
Georgia	:	0.0685	0.0809	:	0.0489	0.0595
Ukraine	0.0393	0.0410	0.0442	:	0.0595	0.0656

(:) not available

(p) Provisionnal

(¹) Annual consumption: 2 500 kWh < consumption < 5 000 kWh.

(²) Annual consumption: 500 MWh < consumption < 2 000 MWh.

(³) This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo Declaration of Independence.

Source: Eurostat (online data codes: nrg_pc_204 and nrg_pc_205)

eurostat

inovaLab

Natural gas prices, first semester of 2017-2019

(EUR per kWh)

	Households (¹)			Non-households (²)		
	2017S1	2018S1	2019S1	2017S1	2018S1	2019S1
EU-28	0.0583	0.0591	0.0632	0.0295	0.0306	0.0327
Euro area	0.0650	0.0662	0.0711	0.0307	0.0316	0.0335
Belgium	0.0522	0.0536	0.0554	0.0235	0.0231	0.0239
Bulgaria	0.0330	0.0379	0.0449	0.0218	0.0256	0.0308
Czechia	0.0550	0.0575	0.0586	0.0238	0.0256	0.0293
Denmark	0.0888	0.0872	0.0855	0.0333	0.0373	0.0337
Germany	0.0611	0.0608	0.0632	0.0317	0.0317	0.0318
Estonia	0.0418	0.0401	0.0458	0.0276	0.0306	0.0343
Ireland	0.0632	0.0632	0.0683	0.0332	0.0342	0.0342
Greece	0.0560p	0.0532e	0.0555	0.0283p	0.0291e	0.0299
Spain	0.0667	0.0665	0.0736	0.0273	0.0290	0.0308
France	0.0639	0.0665	0.0736	0.0332	0.0352	0.0378
Croatia	0.0359	0.0368	0.0375	0.0246	0.0256	0.0299
Italy	0.0704	0.0714	0.0769	0.0271p	0.0286	0.0342
Latvia	0.0378	0.0385	0.0446	0.0270	0.0300	0.0318
Lithuania	0.0365	0.0399	0.0450	0.0246	0.0326	0.0327
Luxembourg	0.0418	0.0411	0.0448	0.0323	0.0319	0.0334
Hungary	0.0352	0.0358	0.0346	0.0261	0.0243	0.0287
Netherlands	0.0763	0.0815	0.0921	0.0365	0.0384	0.0387
Austria	0.0674	0.0669	0.0660	0.0336	0.0324	0.0326
Poland	0.0417	0.0423	0.0473	0.0273	0.0304	0.0347
Portugal	0.0773	0.0759	0.0760	0.0279	0.0273	0.0325
Romania	0.0303e	0.0321e	0.0347e	0.0256e	0.0259e	0.0317e
Slovenia	0.0553	0.0547	0.0572	0.0309	0.0318	0.0339
Slovakia	0.0421	0.0427	0.0449	0.0282	0.0289	0.0342
Finland	:	:	:	0.0463	0.0561	0.0627
Sweden	0.1212	0.1153	0.1183	0.0413	0.0481	0.0397
United Kingdom	0.0469	0.0465	0.0493	0.0251	0.0262	0.0282
Liechtenstein	0.0826	:	:	0.0509	:	:
North Macedonia	0.0482	0.0407	0.0598	0.0260	0.0270	0.0323
Serbia	0.0321	0.0335	0.0335	0.0310	0.0321	0.0390
Turkey	0.0258	0.0216	0.0199	0.0187	0.0176	0.0211
Bosnia and Herzegovina	0.0307	0.0326	0.0335	0.0343	0.0356	0.0367
Moldova	0.0308	0.0254	0.0297	0.0263	0.0242	0.0265
Georgia	:	0.0151	0.0151	:	0.0213	0.0230
Ukraine	0.0231	0.0209	0.0267	0.0262	0.0246	0.0258

(:) not available
(p) Provisionnal
(e) Estimate
(c) Confidential

(¹) Annual consumption: 5 555 kWh < consumption < 55 555 kWh (20 - 200 GJ).
(²) Annual consumption: 2 778 MWh < consumption < 27 778 MWh (10 000 - 100 000 GJ).

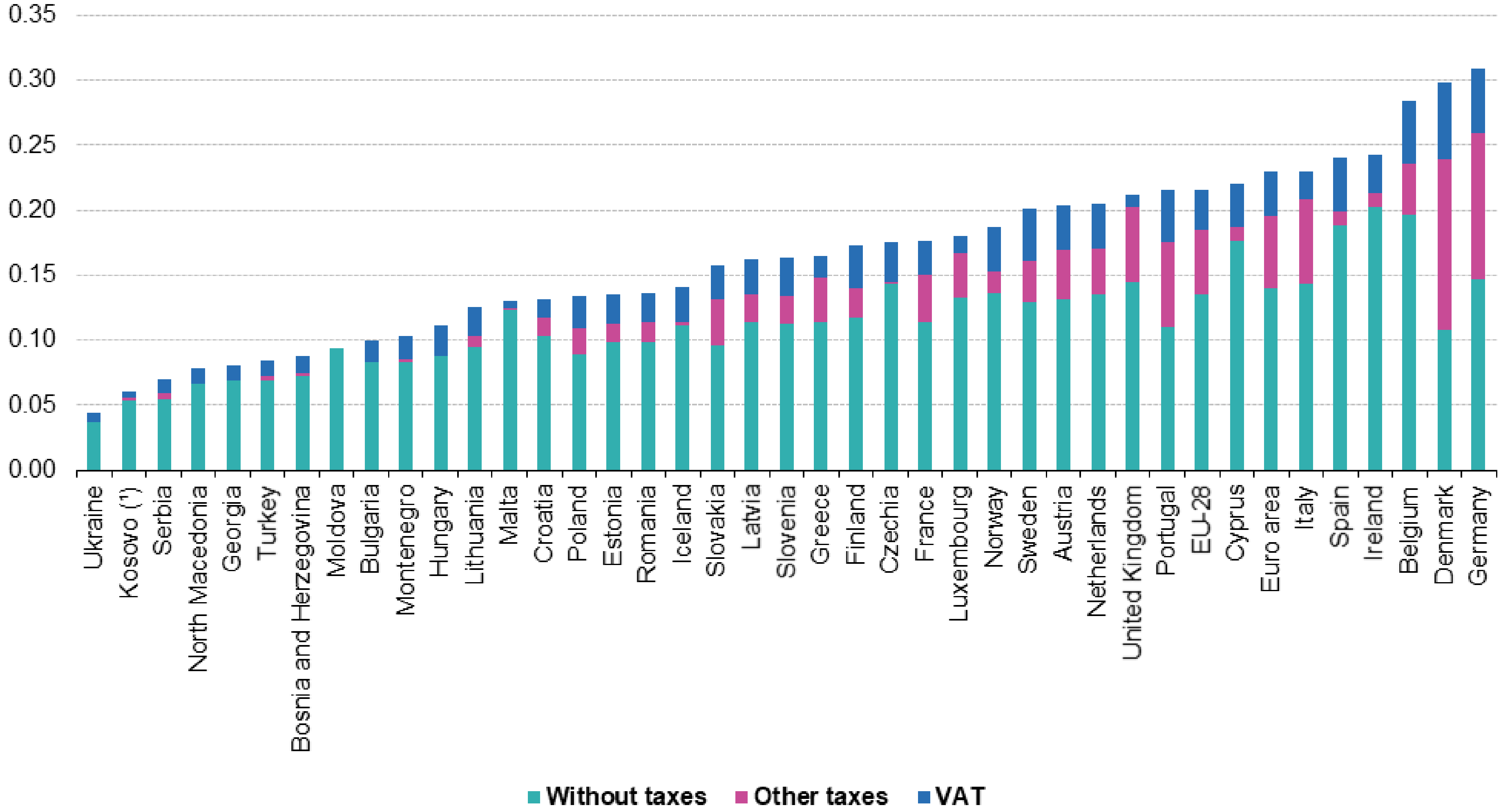
Source: Eurostat (online data codes: nrg_pc_202 and nrg_pc_203)

eurostat

inovaLab

Electricity prices for household consumers, first half 2019

(EUR per kWh)



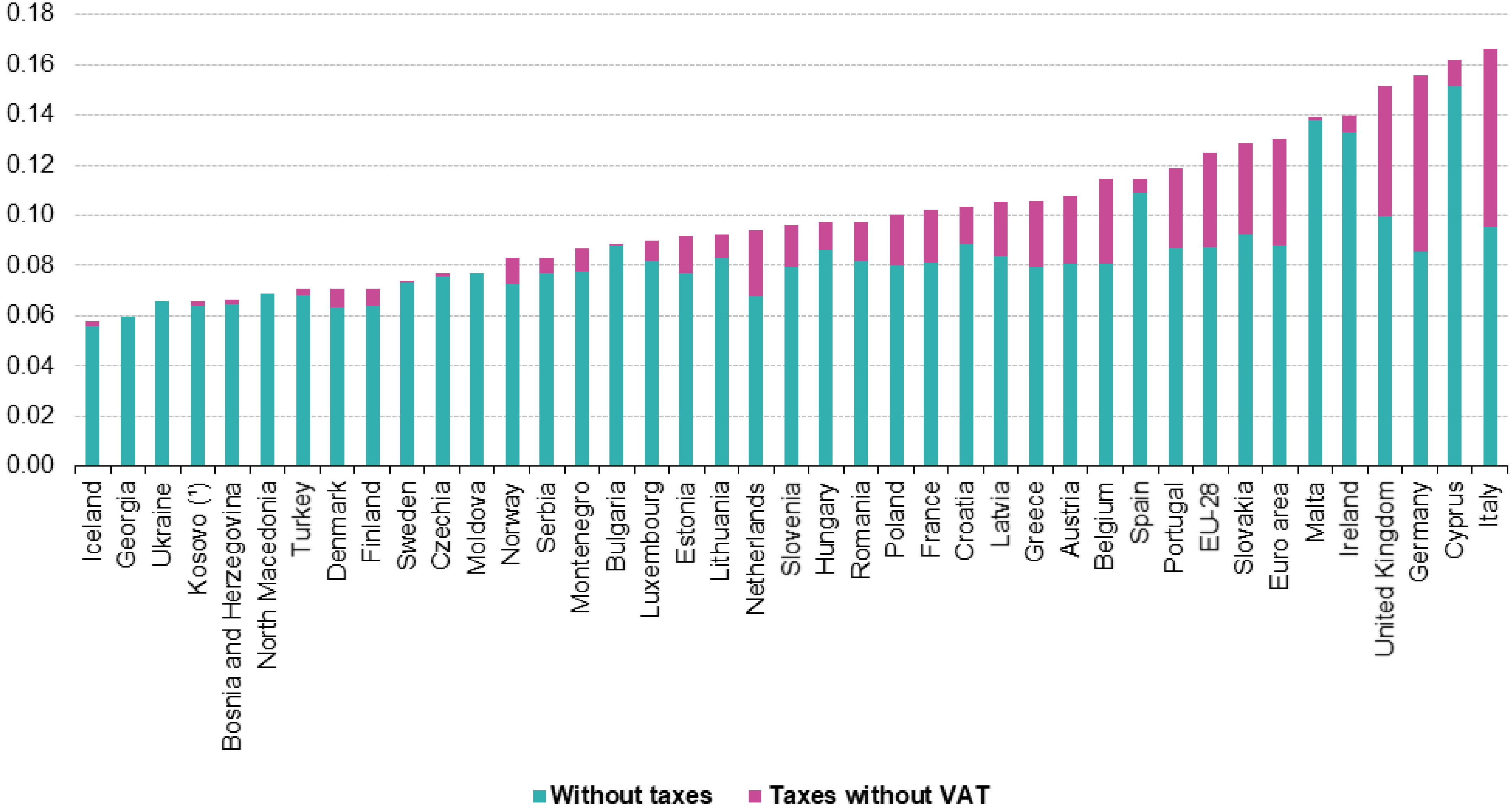
(¹) This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo Declaration of Independence.

Source: Eurostat (online data codes: nrg_pc_204)

eurostat

inovaLab

Electricity prices for non-household consumers, first half 2019
(EUR per kWh)



(¹) This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo Declaration of Independence.

Source: Eurostat (online data codes: nrg_pc_205)

eurostat

inovaLab

Additional factors to be considered

Factors that determine the choice of an electrothermal process

ENERGY COST	**40%**
PRODUCT QUALITY	**30%**
SIMPLICITY'	**10%**
PROCESS AUTOMATION	**8%**
MATERIAL SAVING	**7%**
FLEXIBILITY	**5%**

inovaLab

Outlook and further considerations

Energy efficiency and sustainability pass through an increasing use of electricity in all industrial processes, «food processing» too.

In this sense, electroheat technologies lend themselves to bringing innovation to the various production processes in all sectors including agrifood, increasing production rate and the quality of final products and decreasing process energy costs.

It is necessary to start from an analysis of the state-of-art and then perform a feasibility study to arrive at defining the true competitive advantages that derive from the use of electroheat technologies in terms of economic and environmental sustainability and quality of the final products.

inovaLab