

## **EU-MERCI**

**EU** coordinated **ME**thods and procedures based on **Re**al **C**ases for the effective implementation of policies and measures supporting energy efficiency in the **I**ndustry

HORIZON 2020 Project Nr. 693845

# ***Technical analysis –Machinery sector (NACE C25-28)***

WP4: Picture of efficiency projects implemented by the  
Industry sector-by-sector and process-by-process



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# 1 Introduction

The machinery sector is made up of 4 NACE divisions and their sub-categories:

- C25 Manufacture of fabricated metal products, except machinery and equipment
  - 25.1 Man. of structural metal products
  - 25.2 Man. of tanks, reservoirs and containers of metal
  - 25.3 Man. of steam generators, except central heating hot water boilers
  - 25.4 Man. of weapons and ammunition
  - 25.5 Forging, pressing, stamping and roll-forming of metal; powder metallurgy
  - 25.6 Treatment and coating of metals; machining
  - 25.7 Man. of cutlery, tools and general hardware
  - 25.9 Man. of other fabricated metal products
  
- C26 Manufacture of computer, electronic and optical products
  - 26.1 Man. of electronic components and boards
  - 26.2 Man. of computers and peripheral equipment
  - 26.3 Man. of communication equipment
  - 26.4 Man. of consumer electronics
  - 26.5 Man. of instruments and appliances for measuring, testing and navigation; watches and clocks
  - 26.6 Man. of irradiation, electromedical and electrotherapeutic equipment
  - 26.7 Man. of optical instruments and photographic equipment
  - 26.8 Man. of magnetic and optical media
  
- C27 Manufacture of electrical equipment
  - 27.1 Man. of electric motors, generators, transformers and electricity distribution and control apparatus
  - 27.2 Man. of batteries and accumulators
  - 27.3 Man. of wiring and wiring devices
  - 27.4 Man. of electric lighting equipment
  - 27.5 Man. of domestic appliances
  - 27.9 Man. of other electrical equipment
  
- C28 Manufacture of machinery and equipment not elsewhere classified
  - 28.1 Man. of general-purpose machinery
  - 28.2 Man. of other general-purpose machinery
  - 28.3 Man. of agricultural and forestry machinery
  - 28.4 Man. of metal forming machinery and machine tools
  - 28.9 Man. of other special-purpose machinery

## 2 Subsector share of energy consumption

The following table provides an estimated overview of the share of energy consumption between subsectors in the Manufacture of machinery (NACE C25-28) in Spain in accordance to the ICF Report.

Due to the diversity of products and the processes, as well as the lack of reliable statistical sources, is extremely difficult to estimate the exact share of subsector energy consumption. The National Statistics Institute of Spain provided the statistics on energy cost based on the subgroups and since Spanish data falls in range with average EU energy intensity, these figures will give a good overview about an approximate distribution of the energy consumption.

The subsector of fabricated metal products, except machinery and equipment, accounts for 56% of the energy use in the machinery sector and reflect the rather high energy requirements to produce the primary feedstock for the downstream subsectors (manufacture of computer and electronic products, as well as other machinery and equipment).

**Table 1: Energy use in machinery sector.**

Sector	NACE	Energy Cost [mil. €]	Percentage of total energy cost [%]
<b>Manufacture of fabricated metal products, except machinery and equipment</b>	<b>C25</b>	<b>431</b>	<b>56</b>
Manufacture of structural metal products	C25.1	73.1	10
Manufacture of tanks, reservoirs and containers of metal	C25.2	19	2
Manufacture of steam generators, except central heating hot water boilers	C25.3	2	0
Manufacture of weapons and ammunition	C25.4	5	1
Forging, pressing, stamping and roll-forming of metal; powder metallurgy	C25.5	86	11
Treatment and coating of metals; machining	C25.6	108.4	14
Manufacture of cutlery, tools and general	C25.7	26.3	3

<b>hardware</b>			
<b>Manufacture of other fabricated metal products</b>	C25.9	110.9	15
<b>Manufacture of computer, electronic and optical products</b>	<b>C26</b>	<b>32</b>	<b>4</b>
<b>Manufacture of electronic components and boards</b>	C26.1	9.6	1
<b>Manufacture of computers and peripheral equipment</b>	C26.2	1.8	0
<b>Manufacture of communication equipment</b>	C26.3	6.2	1
<b>Manufacture of consumer electronics</b>	C26.4	0.9	0
<b>Manufacture of instruments and appliances for measuring, testing and navigation; watches and clocks</b>	C26.5	9.9	1
<b>Manufacture of irradiation, electro medical and electrotherapeutic equipment, optical instruments and photographic equipment, magnetic and optical media</b>	C26.6 C26.7 C26.8	3.6	0
<b>Manufacture of electrical equipment</b>	<b>C27</b>	<b>155.4</b>	<b>20</b>
<b>Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus</b>	C27.1	39.9	5
<b>Manufacture of wiring and wiring devices</b>	C27.3	34.7	5
<b>Manufacture of electric lighting equipment</b>	C27.4	14.2	2
<b>Manufacture of domestic</b>	C27.5	26.9	4

<b>appliances</b>			
<b>Manufacture of batteries and accumulators</b>	C27.2	39.7	5
<b>Manufacture of other electrical equipment</b>	C27.9		
<b>Manufacture of machinery and equipment (not elsewhere classified)</b>	<b>C28</b>	<b>145.1</b>	<b>19</b>
<b>Manufacture of general-purpose machinery</b>	C28.1	40.3	5
<b>Manufacture of other general-purpose machinery</b>	C28.2	48.2	6
<b>Manufacture of agricultural and forestry machinery</b>	C28.3	14.7	2
<b>Manufacture of metal forming machinery and machine tools</b>	C28.4	8.3	1
<b>Manufacture of other special-purpose machinery</b>	C28.9	33.6	4

## 3 Key products

The following table shows the main products of the machinery sectors:

**Table 2: Key products of the machinery sector.**

Chemical sector	Main products	Main processes (energy intensive processes)
<b>Structural metal products (NACE C25.1)</b>	Metal structure for buildings, towers, mast, bridges, cranes, lifting equipment, metal doors, window frames	manufacture of metal frameworks or skeletonnes
<b>Treatment, coating and machining of metals (NACE C25.6)</b>	Treated metal parts for further use.	Plating, anodizing, heat treatment, deburring, sandblasting, tumbling, cleaning, colouring, engraving and non-metallic coating, hardening and polishing metals.
<b>Forging, pressing, stamping, roll-forming of metal and powder metallurgy (NACE C25.5)</b>	Treated and formed metal parts for further use, pressed parts, forged parts	Forging, pressing, roll-forming, powder metallurgy
Description	<p>Forging are high strength metal material produced as a result of a high pressure compression process by a locally applied force. Forging is applied in response to stringent engineering performance or safety requirements, which includes production of automotive parts, jet engine blades and fasteners (nuts and bolts). Forging process could be carried out cold or at hot working temperature.</p> <p>Pressing is the process of metal work piece shaping through an application of high pressure. Roll forming is also a shaping process through the constant feeding of metal work strips through consecutive series of rolls or stands, each playing an incremental part in the final shape of the metal product.</p> <p>Products: Treated and formed metal parts for further use.</p>	
<b>Manufacture of electronic components and boards (NACE C26.1)</b>	semi-conductors and other components for electronic application	Assembling parts to semi-final product
Description	Product: capacitors, resistors, electronic connectors, diodes, transistors, inductors and LEDs, microprocessors, electron tubes, printed circuit boards, integrated circuit boards, switches, transducers and display components	
<b>Manufacture of communication equipment (NACE C26.3)</b>	telephones, central office switching equipment, modems, routers, bridges, gateways, cable television equipment, antennas, cellular phones,	Assembling parts to final product

	mobile communication equipment, radio and television broadcasting/transmitting equipment and communication devices using infrared	
Description	Process: Assembling parts to final product Product: telephone and data communications equipment used to move signals electronically over wires or through air	
<b>Manufacture of instruments and appliances for measuring, testing and navigation (NACE C26.5)</b>	automatic controls and regulators	Assembling parts to final product
Description	Products: devices for measuring, displaying, indicating, recording, transmitting and controlling, instruments for search, detection, navigation, guidance, aeronautical and nautical system.  Process: Assembling parts to final product	
<b>Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus (NACE C27.1)</b>	transformers, electric motors, generators and motor generator sets	Assembling parts to final product
Description	Product: distribution transformers, substation power transformers, distribution and voltage regulators, arc welding transformers and fluorescent ballast, power generator and motor generators sets.	
<b>Manufacture of wiring and wiring device (NACE C27.3)</b>	current-carrying wiring devices and non-current carrying devices for wiring electrical circuits regardless of material	Assembling parts to final product
Description	Product: bus-bars, electrical conductors, Ground Fault Circuit Interrupters, lamp holders, lightning arrestors, switches for electrical wiring, electrical sockets and boxes for electrical wiring, non-current carrying devices the manufacture of electrical conduits, transmission poles, plastic junction boxes, wire insulation and fibre optic cables	
<b>Manufacture of domestic appliances (NACE C27.5)</b>	refrigerators, freezers, dishwashers, washing and drying machines, vacuum cleaners, floor polishers, other small kitchen appliances	Assembling parts to final product
Description	Products: electric personal care devices, Electro-thermic devices include electric water heaters, electric blankets, electric dryers, electric iron, space heaters, household type fans, electric/ microwave ovens, cookers and hotplates, toasters, coffee or tea makers and electric heating resistors	
<b>Manufacture of general-purpose machinery (NACE</b>	engines and turbines	Assembling parts to final product



<b>C28.1)</b>		
Description	Product: fluid power equipment, pumps and compressors, sanitary taps, valves, bearings, gears, mechanical power transmission equipment, internal combustion engines, mechanical parts of an internal combustion engine, gas turbines, steam turbines, wind turbines, hydraulic turbines, boiler-turbine sets, turbine generator sets and engines for industrial application	
<b>Manufacture of other general-purpose machinery (NACE C28.2)</b>	electric and non-electric domestic appliances	Assembling parts to final product
Description	Product: ovens, furnaces, burners, lifts, escalators, moving walkways, mechanical conveyor system, office machinery	

## 4 Main processes

Given the Figures above it shows that even though “Manufacture of fabricated metal products, except machinery and equipment”, NACE C25 has a 28% share in turnover it causes 56% of the machinery sectors energy costs. Therefore the analysis of the related key products showed the following categorization of the main production processes and/or sub-processes:

### Surface preparation

- abrasive blasting process
- pickling process
- cleaning

### Mechanical processing

- casting (molding, sinter)
- reshaping (rolling, forging)
- separating (flame cutting, milling)
- joining (screwing, welding)

### Surface finishing

- Anodizing
- Coating
- Hardening

The following section shows a further description of the production processes. Considering the wide variety of processes in this sector, only some of them were chosen for detailed explanation, based on the related energy intensity: abrasive blasting process, anodizing, pressing and roll forming.

### 4.1 Abrasive Blasting

Abrasive blasting is the operation of forcibly propelling a stream of abrasive material against a surface under high pressure to smooth a rough surface, roughen a smooth surface, shape a surface, or remove surface contaminants. A pressurized fluid, typically compressed air, or a centrifugal wheel is used to propel the blasting material (media).

The most abrasive are shot blasting (with metal shot) and sandblasting (with sand). Moderately abrasive variants include glass bead blasting (with glass beads) and media blasting with ground-up plastic stock.

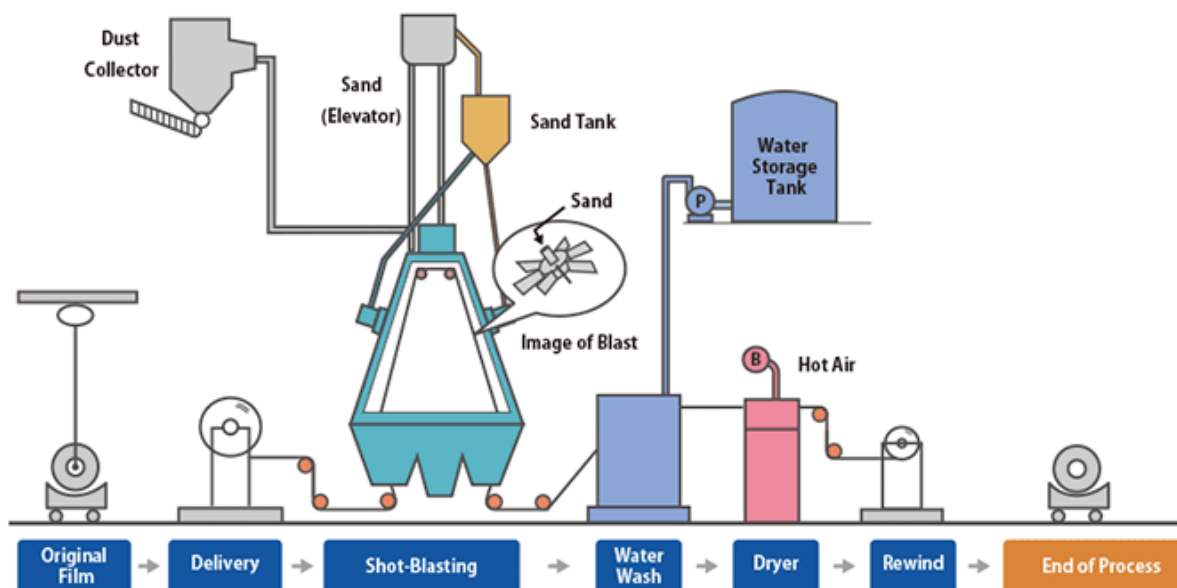


Figure 1: example of abrasive blasting.

## 4.2 Casting

Casting is the manufacturing of a solid object out of shapeless material by creating cohesion. Since casting is one of the main parts of NACE C24, it will not be further treated within in this paper.

## 4.3 Reshaping

Reshaping describes changing the plastic form of a solid object; it includes forming under pressure (rolling, extrusion), tensile compression (deep drawing, wire drawing), stretching, bending (bottom bending, roll bending), twisting and relocating.

## 4.4 Roll forming

Roll forming is a type of rolling involving the continuous bending of a long strip of sheet metal (typically coiled steel) into a desired cross-section. The strip passed through sets of rolls mounted on consecutive stands, each set performing only an incremental part of the bend, until the desired cross-section (profile) is obtained. Roll forming is ideal for producing constant-profile parts with long lengths and in large quantities.

Roll forming is, among the manufacturing processes, one of the simplest. It typically begins with a large coil of sheet metal, between 1 inch (2.5 cm) and 20 inches (51 cm) in width and 0.004 inches (0.10 mm) and 0.125 inches (3.2 mm) thick, supported on an uncoiler. The strip is fed through an

entry guide to properly align the material as it passes through the rolls of the mill, each set of rolls forming a bend until the material reaches its desired shape. Roll sets are typically mounted one over the other on a pair of horizontal parallel shafts supported by a stand(s). Side rolls and cluster rolls may also be used to provide greater precision and flexibility and to limit stresses on the material. The shaped strips can be cut to length ahead of a roll forming mill, between mills, or at the end of the roll forming line.

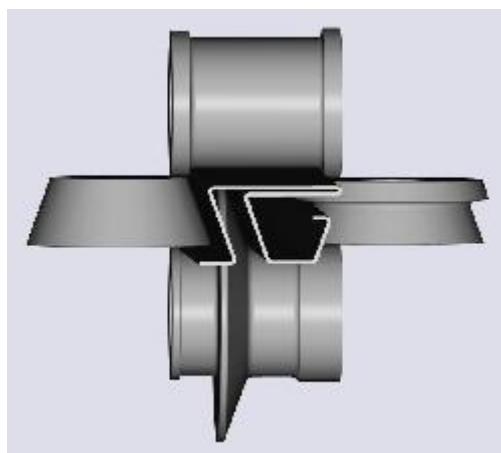


Figure 2: Roll forming equipment.

## 4.5 Pressing

A “forming press”, commonly shortened to “press”, is a machine tool that changes the shape of a workpiece by the application of pressure. Presses can be classified according to:

- their mechanism: hydraulic, mechanical, pneumatic;
- their function: forging presses, stamping presses, press brakes, punch press, etc.;
- their structure, e.g. Knuckle-joint press, screw press;
- their controllability: conventional vs. servo-presses.

During the process, a piece of sheet metal is formed along a straight axis. This may be accomplished by a "V"- shaped, "U"-shaped, or channel-shaped punch and die set.

The most common industrial press braking process is called air bending. Air bending relies upon three point bending. The angle of the bend is dictated by how far the punch tip penetrates the "V" cavity. The greater the penetration of the punch tip the greater the angle achieved.

The main benefit of air bending is that it uses much less force than other methods to achieve a 90° bend due to the leverage effect.

Characteristic of the metal brake forming process include:

- Its ability to form ductile materials,

- Its use in both low and medium production run applications,
- The need for minimal tooling,
- Its suitability to produce smaller parts,
- Its output of long workpieces using a "V", "U", channel, or other special punch and dies.

The illustrations that follow provides a two-dimensional look at a typical press brake setup. Note how the tool removes the notched part. The left side of the illustration shows the press brake in the open position and the right side shows it in a closed position, press braking the metal workpiece.

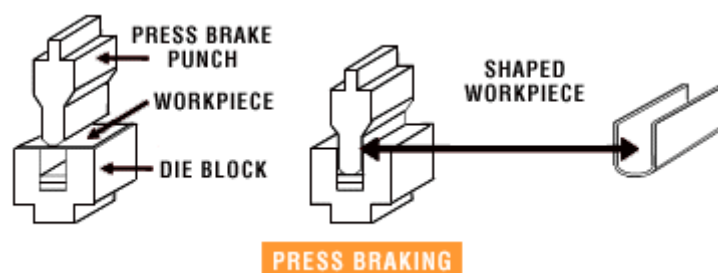


Figure 3: Press braking technology.

## 4.6 Separating

Separating is the local repeal of cohesion of a certain object. It includes division (tearing, breaking), chipping (turning, drilling), milling, grinding, ablation, electrical/electrochemical discharging, disassembling, cleaning and evacuating.

## 4.7 Joining

Joining means bringing together at least two fragments by using formless material. It includes assembling, filling, adhesion and composition (welding, brazing and soldering)

## 4.8 Coating

A coating is a covering that is applied to the surface of an object, usually referred to as the substrate. The purpose of applying the coating may be decorative, functional, or both.

## 4.9 Anodizing

Anodizing is an electrolytic passivation process used to increase the thickness of the natural oxide layer on the surface of metal parts. The process is called anodizing because the part to be treated forms the anode electrode of an electrical circuit. Anodizing increases resistance to corrosion and wear and provides better adhesion for paint primers and glues than bare metal does. It is also used to prevent galling of threaded components and to make dielectric films for electrolytic capacitors. Anodizing changes the microscopic texture of the surface and the crystal structure of the metal near the surface. Thick coatings are normally porous, so a sealing process is often needed to achieve corrosion resistance.

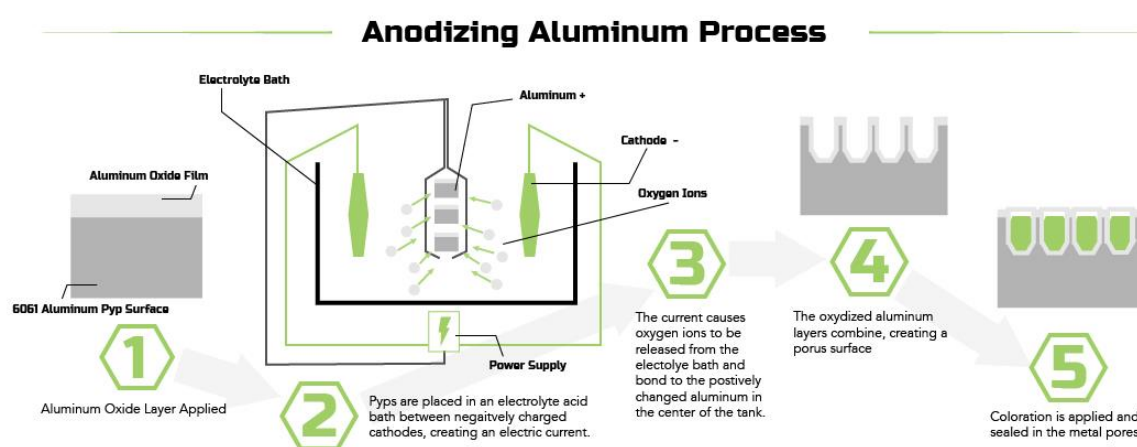


Figure 4: Anodizing aluminium process.

The anodized aluminium layer is grown by passing a direct current through an electrolytic solution, with the aluminium object serving as the anode. The current releases hydrogen at the cathode and oxygen at the surface of the aluminium anode, creating a build-up of aluminium oxide. The voltage required by various solutions may range from 1 to 300 V DC, although most fall in the range of 15 to 21 V. Higher voltages are typically required for thicker coatings formed in sulfuric and organic acid. The anodizing current varies with the area of aluminium being anodized and typically ranges from 30 to 300 A/m<sup>2</sup>.

Aluminium anodizing is usually performed in an acid solution, which slowly dissolves the aluminium oxide. The acid action is balanced with the oxidation rate to form a coating with nanopores, 10–150 nm in diameter. These pores are what allow the electrolyte solution and current to reach the aluminium substrate and continue growing the coating to greater thickness beyond what is produced by aut passivation. However, these same pores will later permit air or water to reach the substrate and initiate corrosion if not sealed. They are often filled with colored dyes and/or corrosion inhibitors before sealing. Because the dye is only superficial, the underlying oxide may continue to provide corrosion protection even if minor wear and scratches may break through the dyed layer.

Conditions such as electrolyte concentration, acidity, solution temperature and current must be controlled to allow the formation of a consistent oxide layer. Harder, thicker films tend to be produced by more dilute solutions at lower temperatures with higher voltages and currents. The film thickness can range from under 0.5 micrometers for bright decorative work up to 150 micrometers for architectural applications.

## 4.10 Modifying material properties

Hardening is a metallurgical metalworking process used to increase the hardness of a metal. The hardness of a metal is directly proportional to the uniaxial yield stress at the location of the imposed strain. A harder metal will have a higher resistance to plastic deformation than a less hard metal.

## 5 EU final energy consumption for the machinery sector

The following Figures present the average fuel mix for EU machinery plants in 2012.

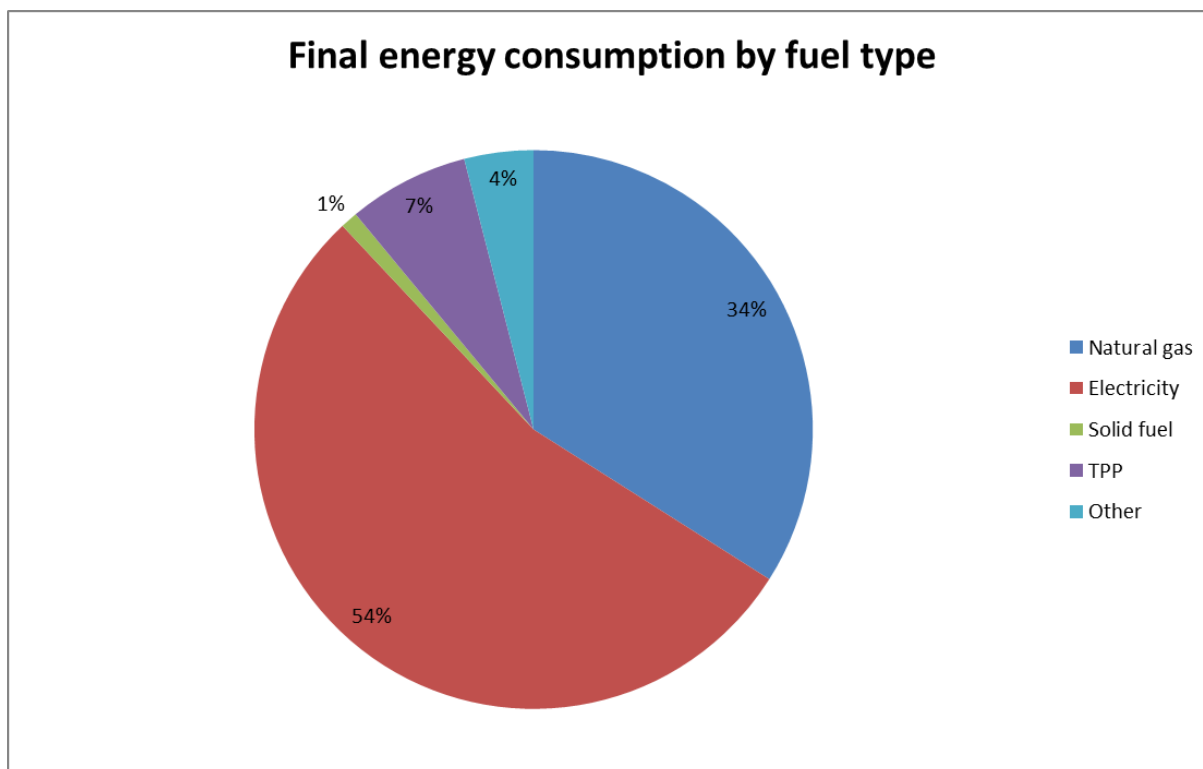


Figure 5: Final energy consumption by fuel type in machinery sector.



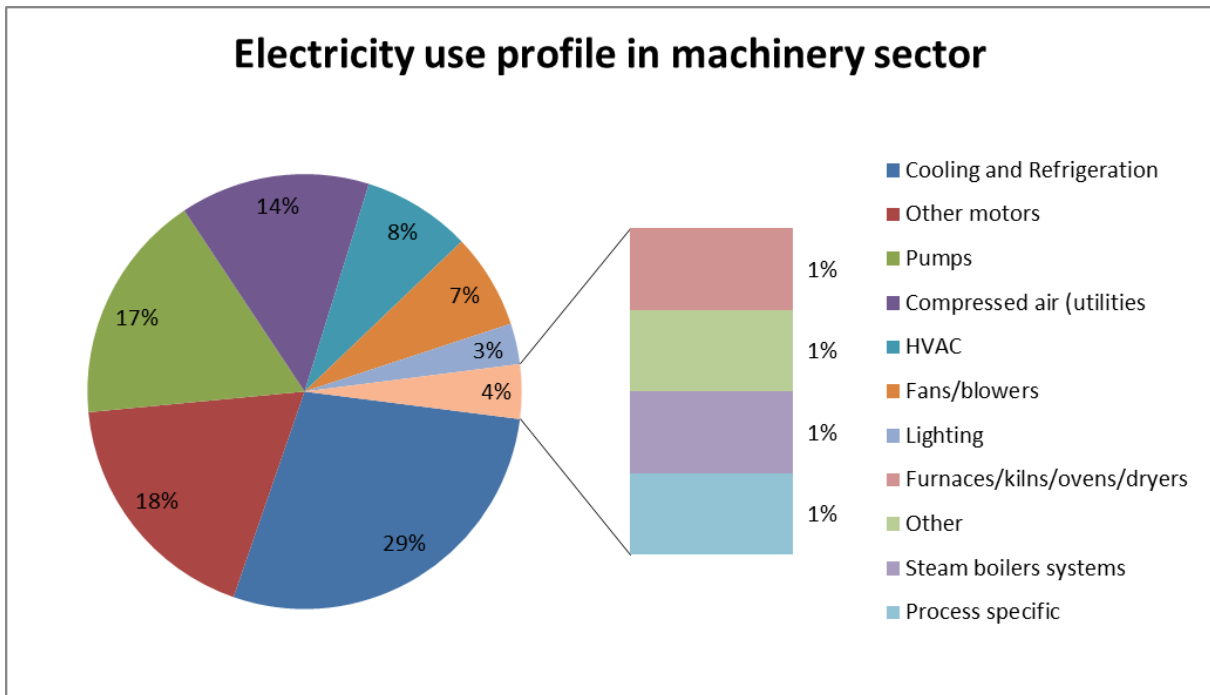


Figure 6: Electricity use profile in machinery sector.

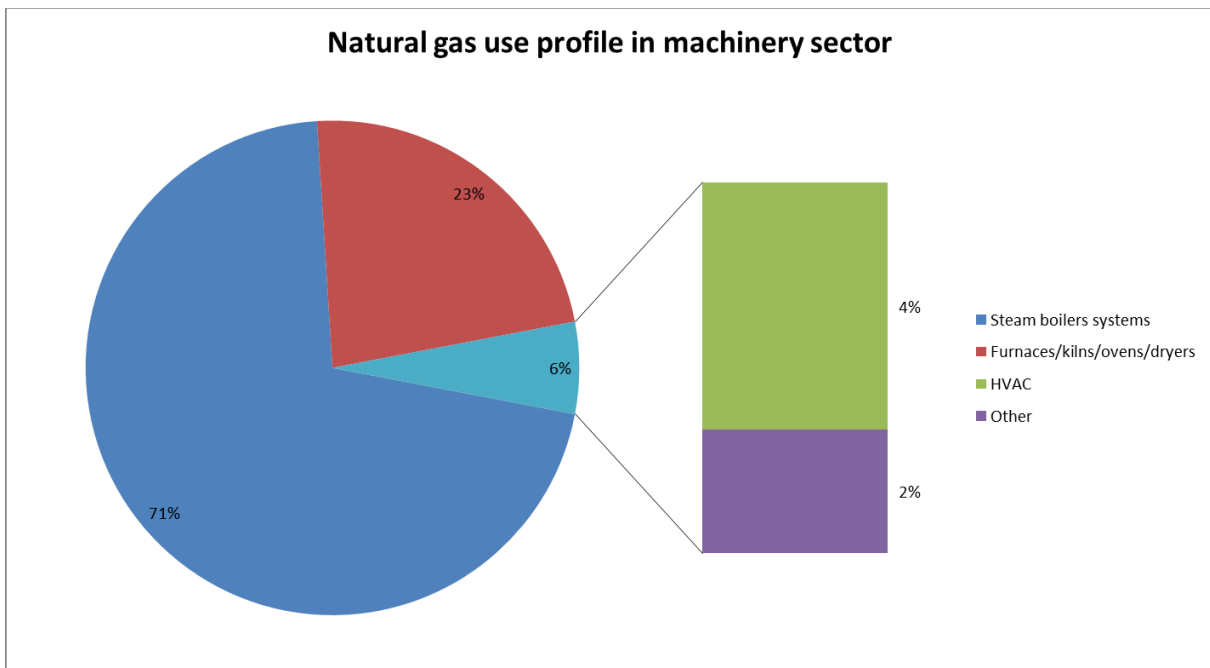


Figure 7: Natural gas use profile in machinery sector.

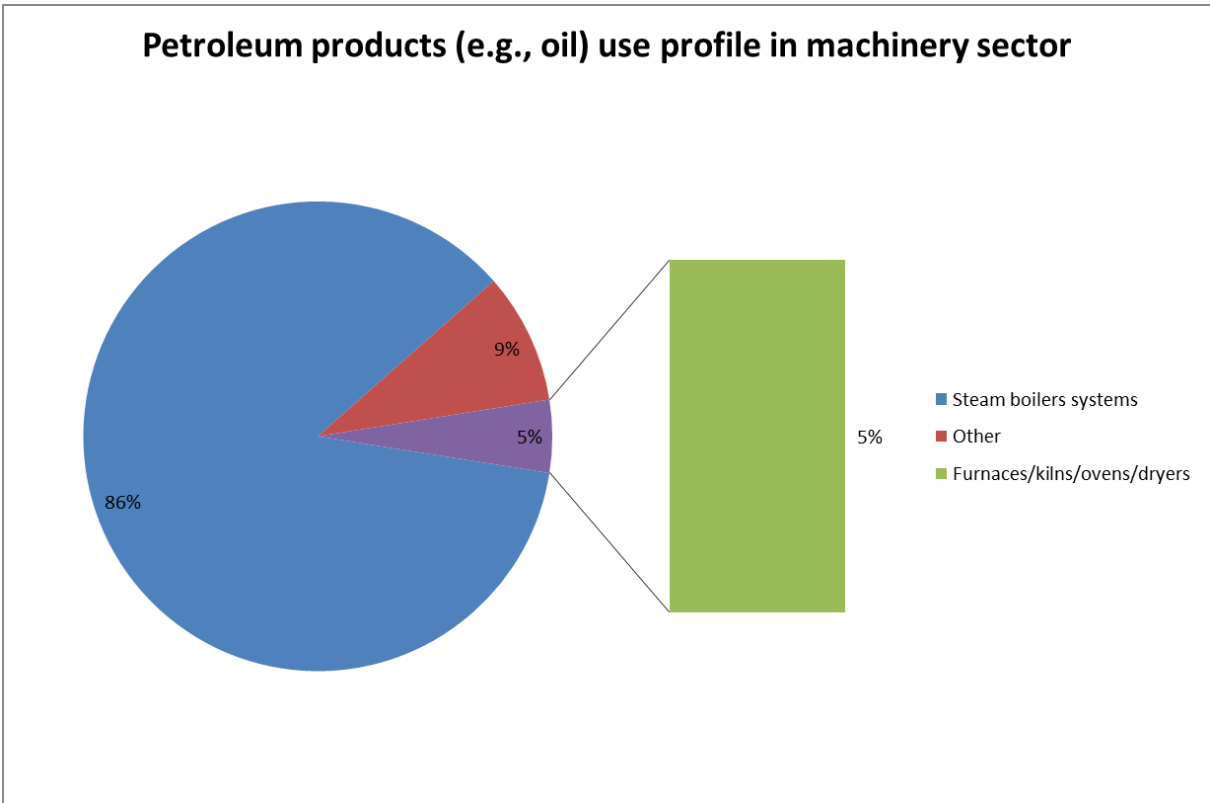


Figure 8: Petroleum products (e.g., oil) use profile in machinery sector.

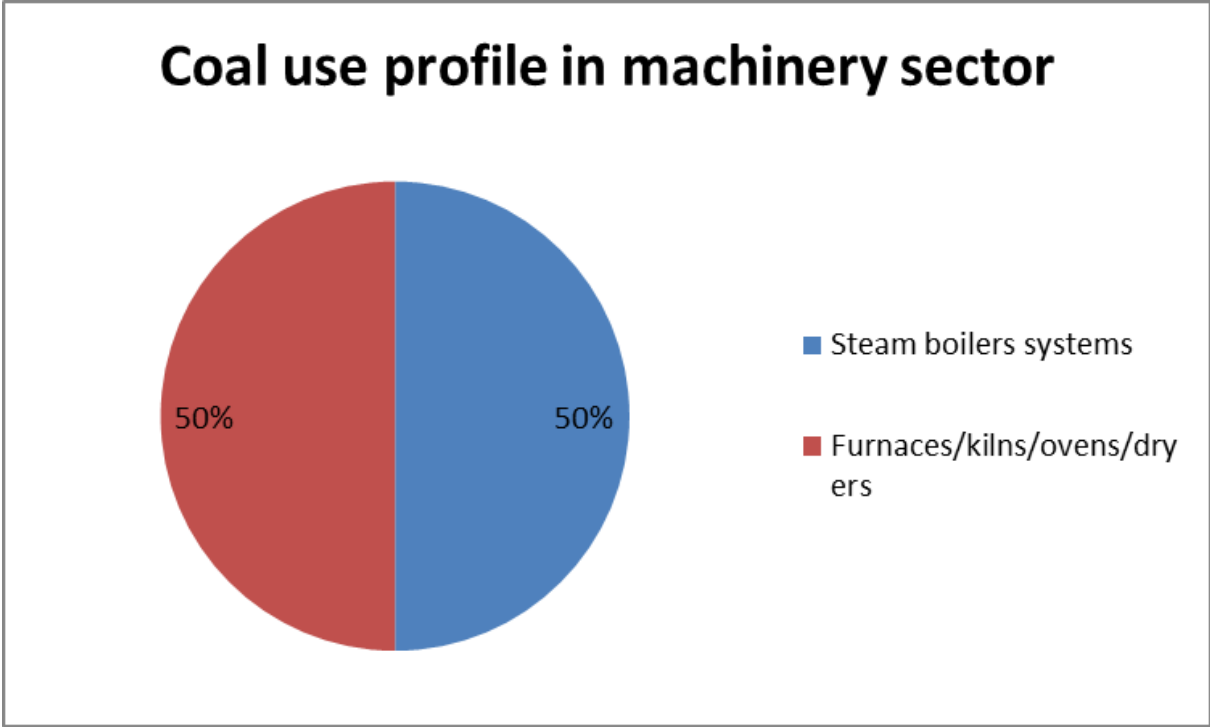


Figure 9: Coal use profile in machinery sector.

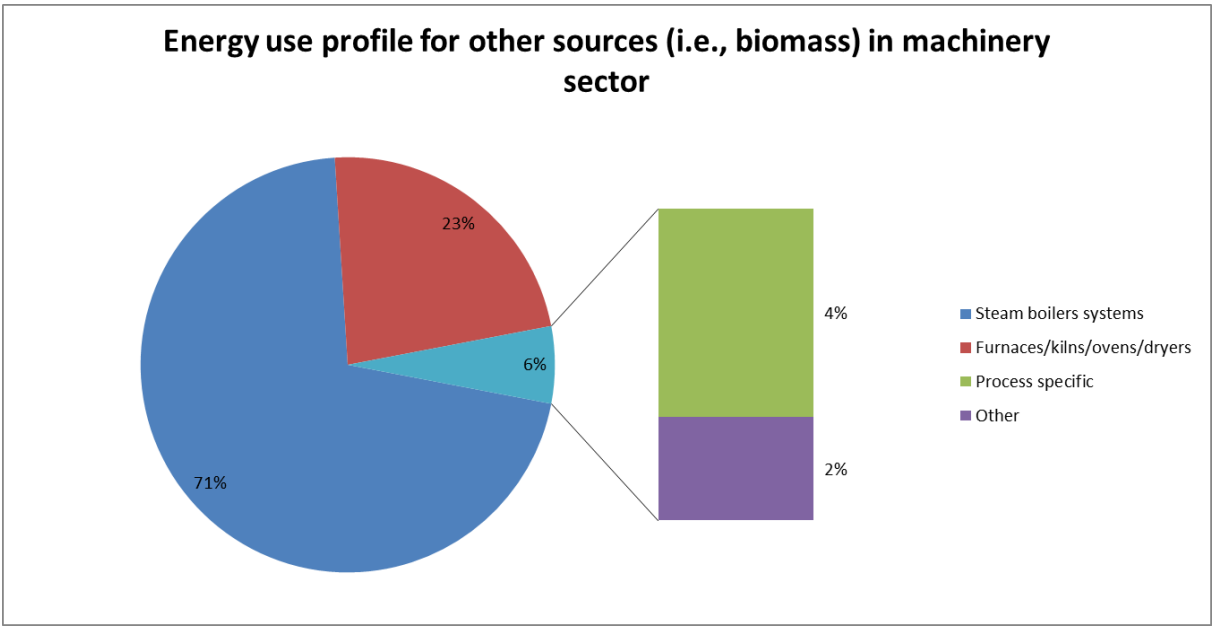


Figure 10: Energy use profile for other sources (i.e. biomass) in machinery sector.