Energy efficiency management in industrial enterprises

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Introduction. Overview of energy World and EU (1)

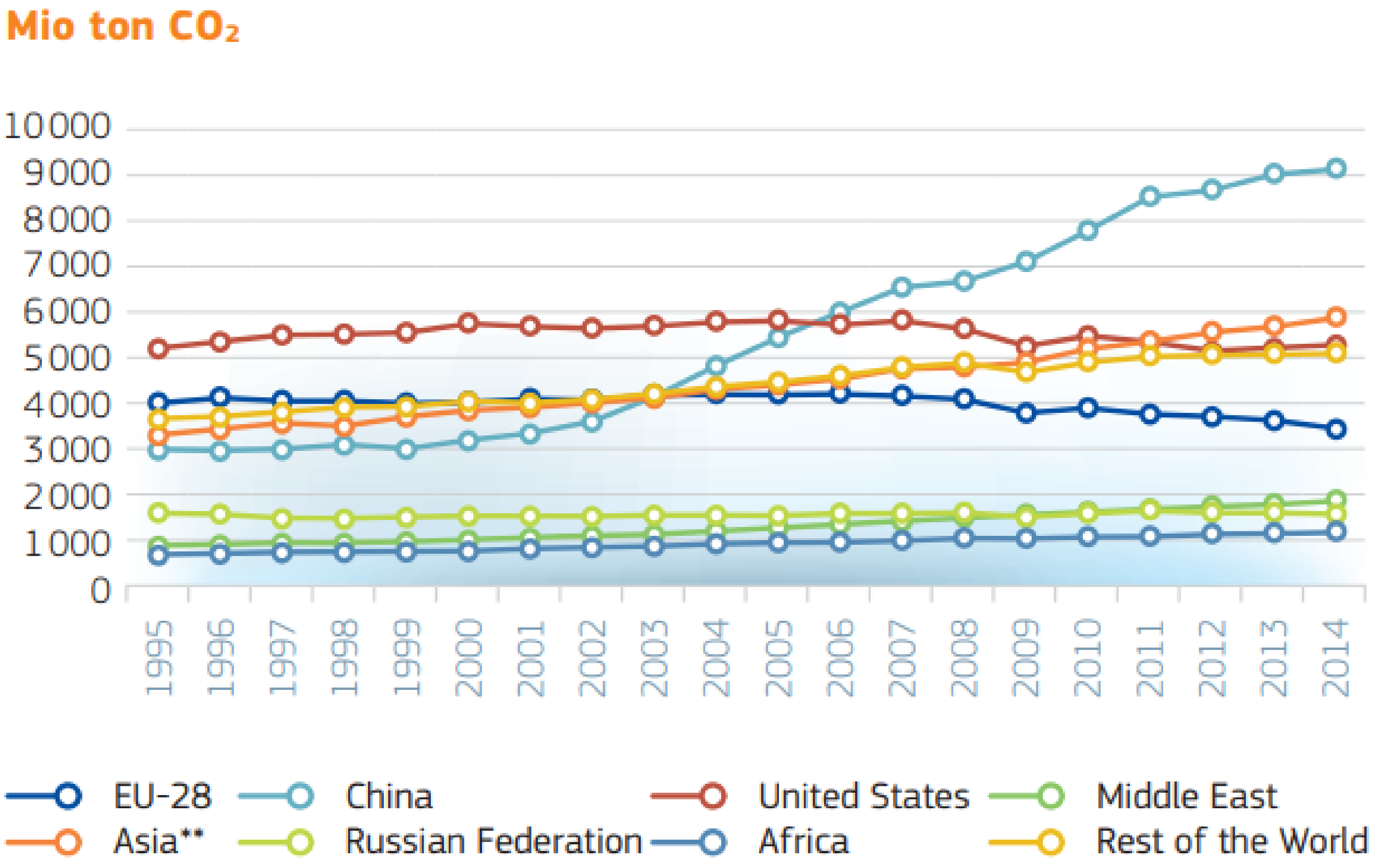
EU ENERGY IN FIGURES 2017

1.1.4 World Gross Inland Consumption by Fuel

(Mtoe) (1 Mtoe = 11630000 MWh)

	1995	2000	2005	2010	2015	2015 (%)
Petroleum and Products	3376	3660	4005	4142	4334	31.8%
Solid Fuels	2208	2311	2993	3654	3836	28.1%
Gas	1807	2071	2360	2736	2944	21.6%
Renewables	1212	1288	1398	1591	1823	13.4%
Hydro*	213	225	252	296	334	2.5%
Geothermal*	39	52	54	63	74	0.5%
Solar/Wind/Other*	4	8	17	48	126	0.9%
Biofuels and Waste*	972	1023	1096	1213	1323	9.7%
Nuclear	608	676	722	719	671	4.9%
Other	16	21	21	31	40	0.3%
Total	9228	10028	11499	12873	13647	100.0%

Introduction



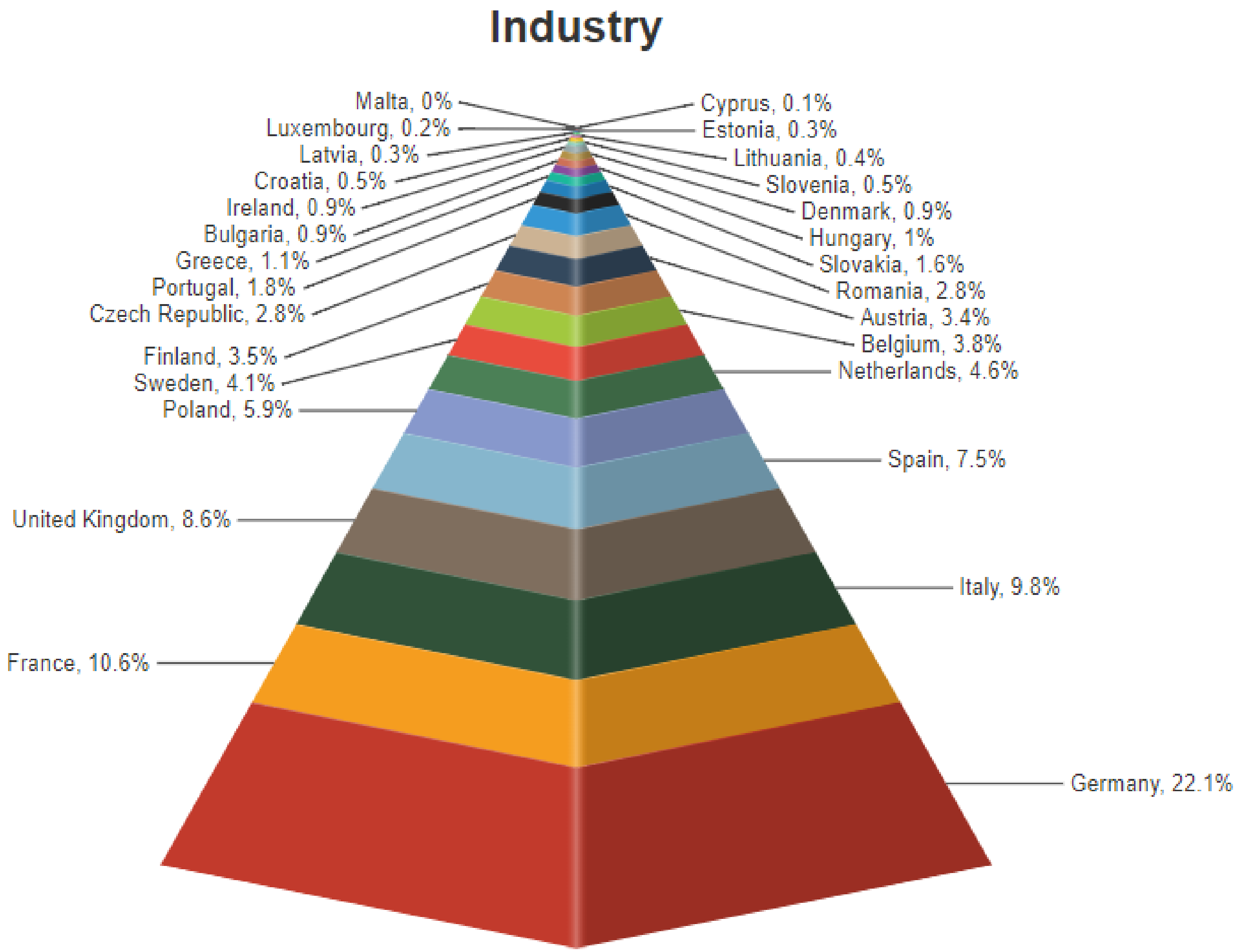
1.1.9 World CO_2 Emissions* by Region

(Mio ton CO_2)

	1995	2000	2005	2010	2014	2014 (%)
EU-28	4012	4036	4205	3898	3425	10.2%
China	2951	3159	5459	7848	9222	27.5%
United States	5211	5790	5854	5496	5290	15.8%
Asia**	3275	3836	4412	5221	5925	17.7%
Middle East	816	951	1229	1595	1846	5.5%
Russian Federation	1562	1488	1497	1552	1532	4.6%
Africa	614	700	899	1041	1148	3.4%
Rest of the World	3639	4038	4480	4926	5124	15.3%
World	22080	23997	28034	31576	33511	100.0%

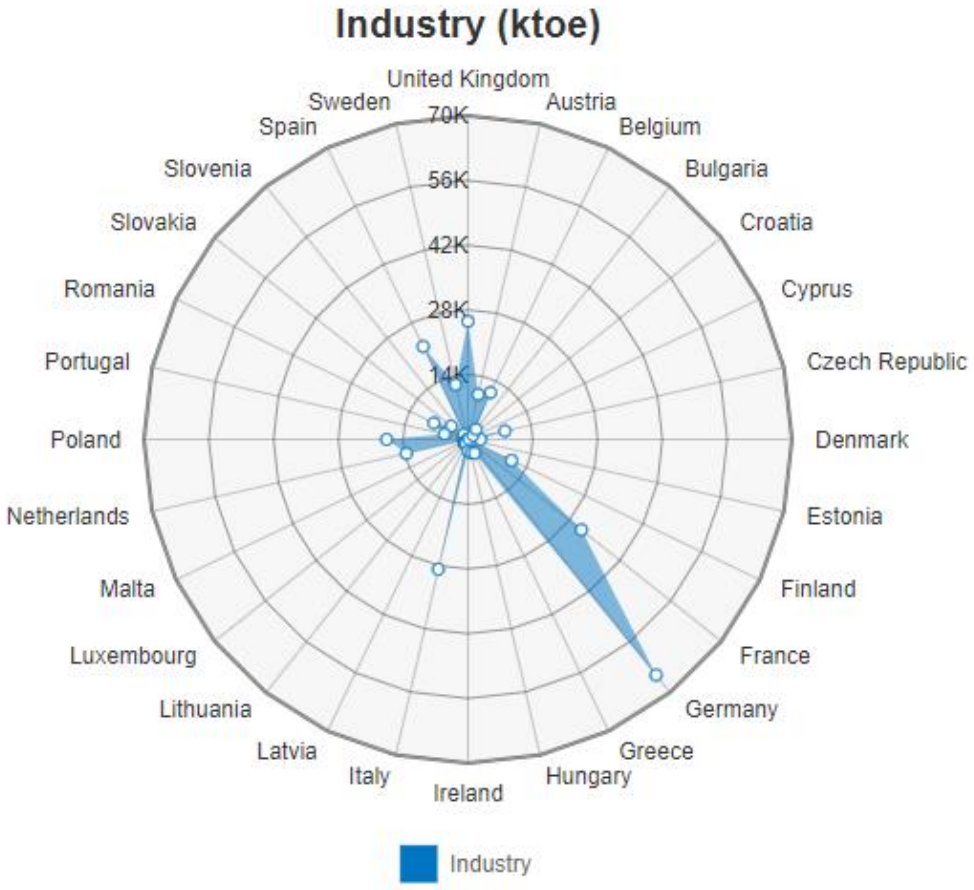
Introduction. Overview of energy demand in the EU (3)

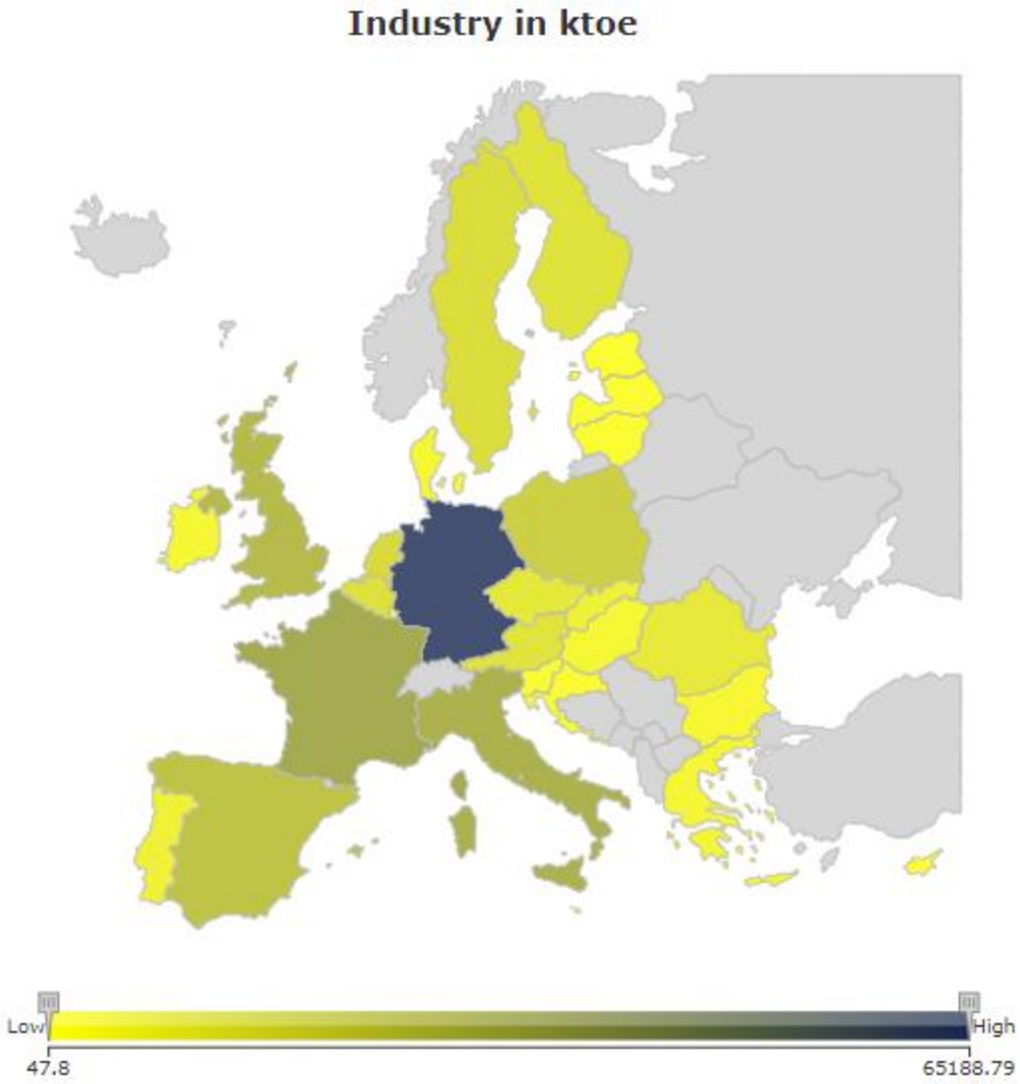
2020



Energy modelling - interactive graphs
https://ec.europa.eu/energy

2020





Energy demand (toe-tonnes of oil equivalent, 1 Mtoe = 11630000 MWh)

Introduction. Overview of energy demand in EU (5)

Energy efficiency targets for 2020 and 2030

The EU has set itself a 20% energy savings target by 2020 (when compared to the projected use of energy in 2020) – this is roughly equivalent to turning off 400 power stations.

On 30 November 2016 the Commission proposed an update to the Energy Efficiency Directive including a new 30% energy efficiency target for 2030.

The European Commission's priorities:
Energy Efficiency

Energy Efficiency Directive
The Energy Efficiency Directive sets rules and obligations to help the EU reach its 2020 energy efficiency target.

Buildings
Making old and new buildings more energy efficient helps the EU achieve its energy and climate goals.

Cogeneration of heat and power
The EU promotes cogeneration in order to improve energy efficiency in Europe.

Energy efficient products
EU energy efficiency measures for products will save money and energy

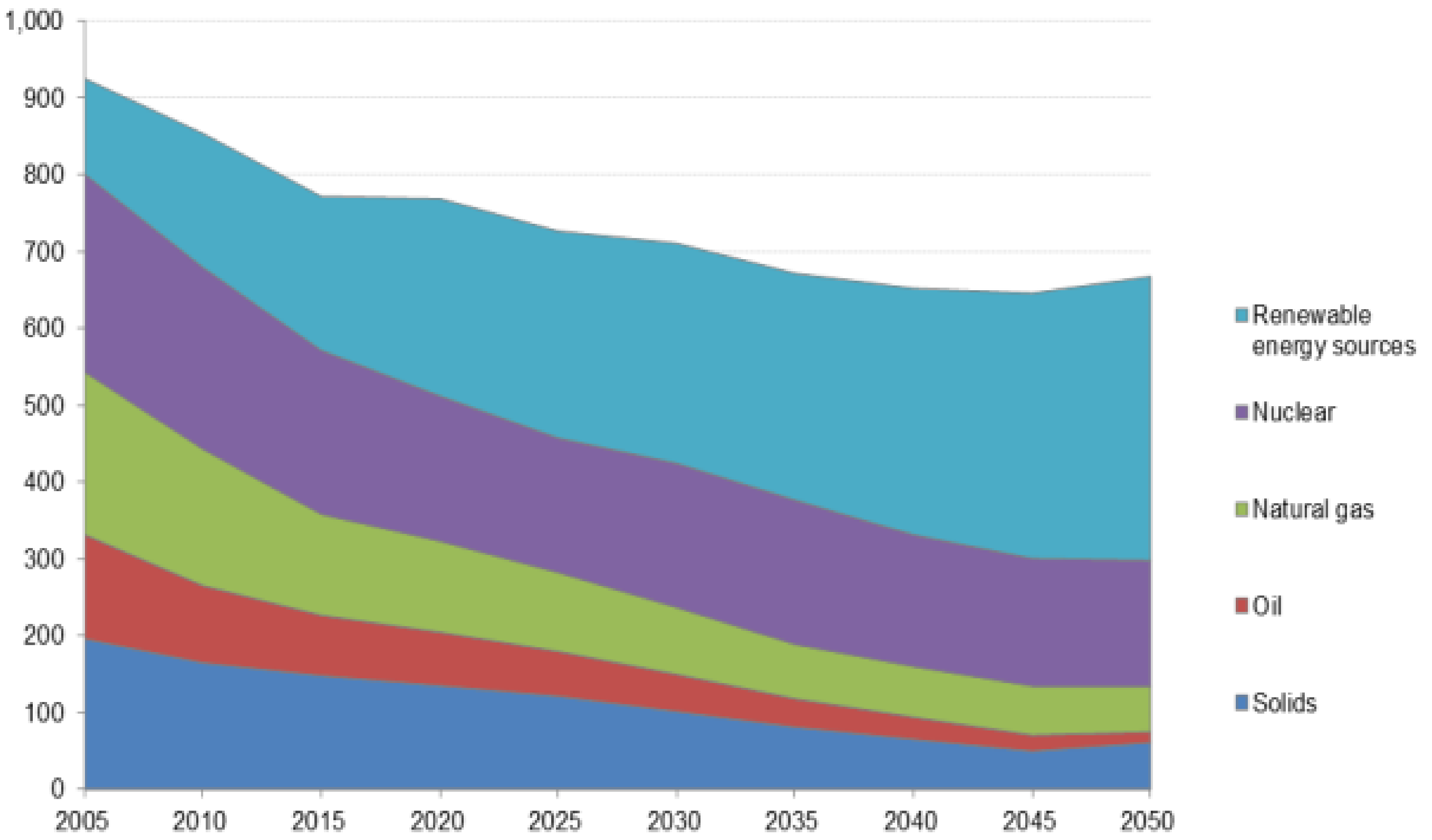
Financing energy efficiency
Mobilizing private financing for energy efficiency investments.

Heating and cooling
The EU has launched a heating and cooling strategy as a first step in tackling the large amount of energy used by the sector.

Source: https://ec.europa.eu

Energy efficient products

- In the European Union, many everyday products such as washing machines, refrigerators and cooking appliances carry energy labels and have been designed to meet minimum energy efficiency standards.
- The result of these labels and standards will be an energy saving of around 175 Mtoe (million tonnes of oil equivalent) by 2020, roughly equivalent to the annual primary energy consumption of Italy.
-

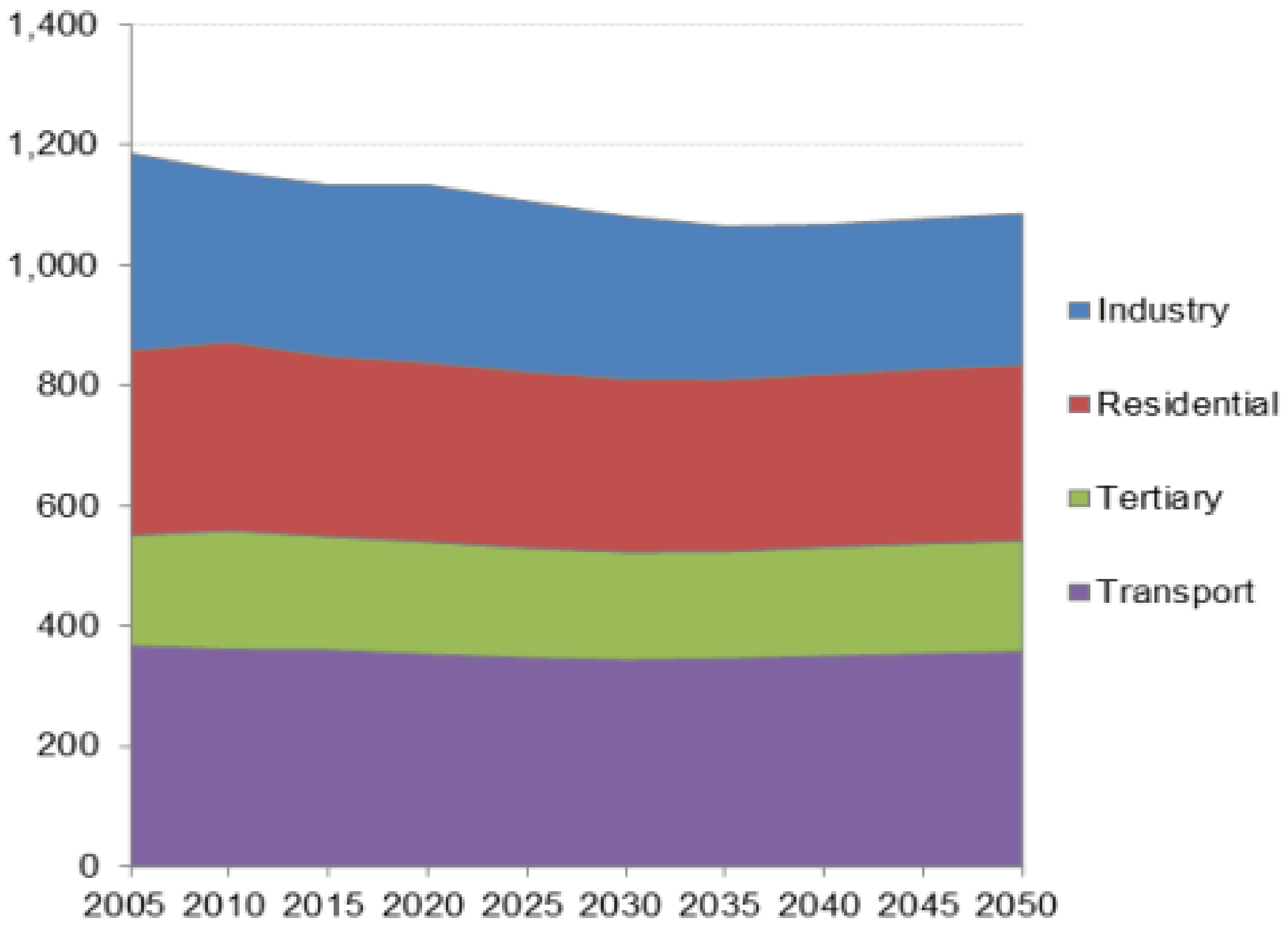


Declining resource to production ratios drive increases in oil and gas prices after 2020

Source: PRIMES modelling, NTUA, E3M-Lab

Industry consumes about 28% of global energy;

The energy consumption of industrial enterprises is always related to
electrical equipment,
technological processes (heating, ventilation, refrigeration, hydraulic, compressed air systems, etc.) and equipment necessary for them.



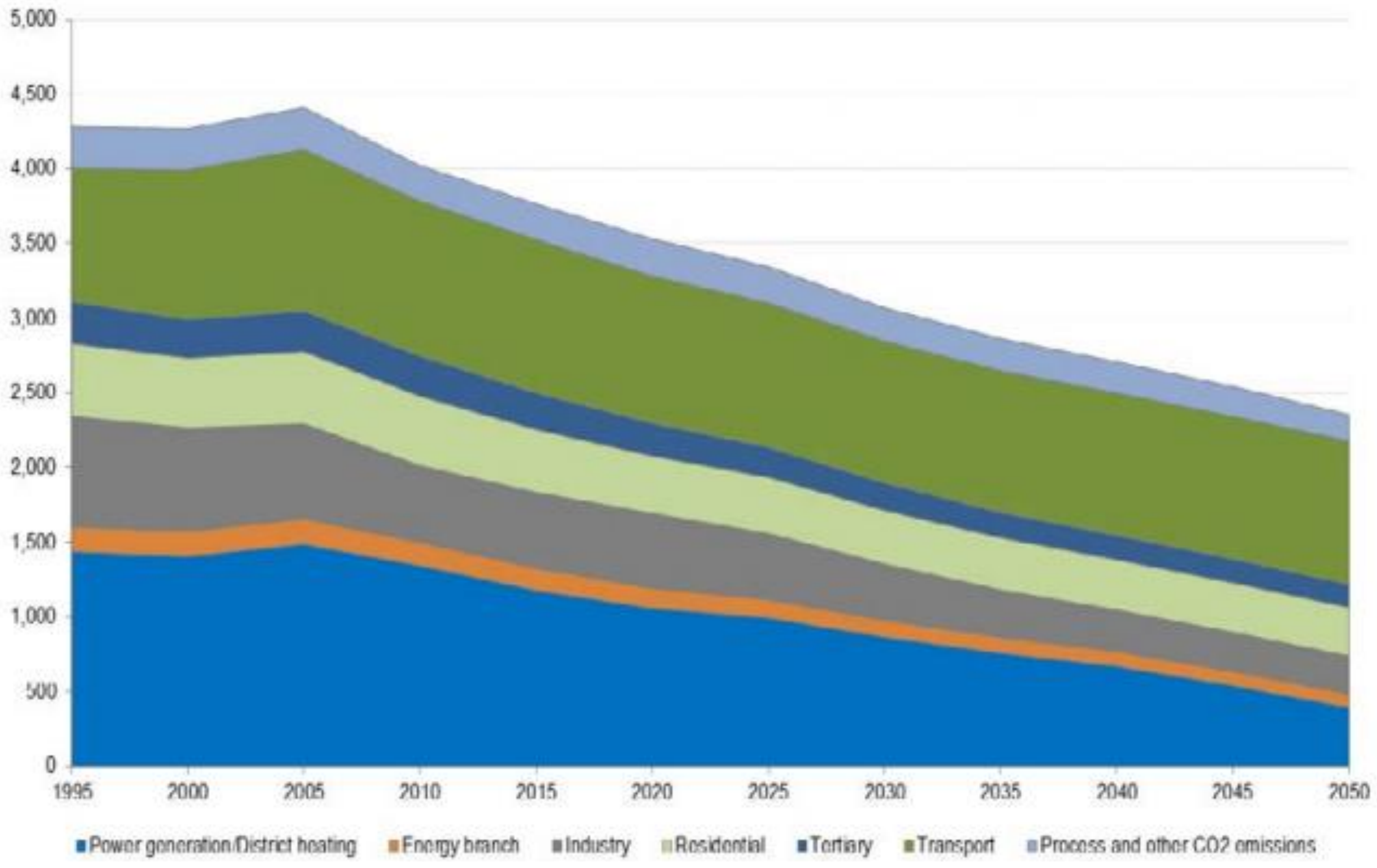
The energy consumption, its efficiency and CO_2 emissions are interconnected.

Reduction of CO_2 emissions occurs mainly in the power and heat production sectors.

In industry, reductions take place in energy related emissions, while process emissions remain stable.

Energy efficiency is the main driver of emission reductions in end-uses of energy.

CO2 emissions (Mt) by sector



Source: Modelling suite for EU Reference Scenario 2016

bn	billion
boe	barrel of oil equivalent
Gpkm	giga passenger-kilometre, or 109 passenger-kilometre
Gtkm	giga tonne-kilometre, or 109 tonne-kilometre
GWh	gigawatt-hour or 109 watt-hours
km	kilometre
ktoe	1000 toe
Mt	million metric tonnes

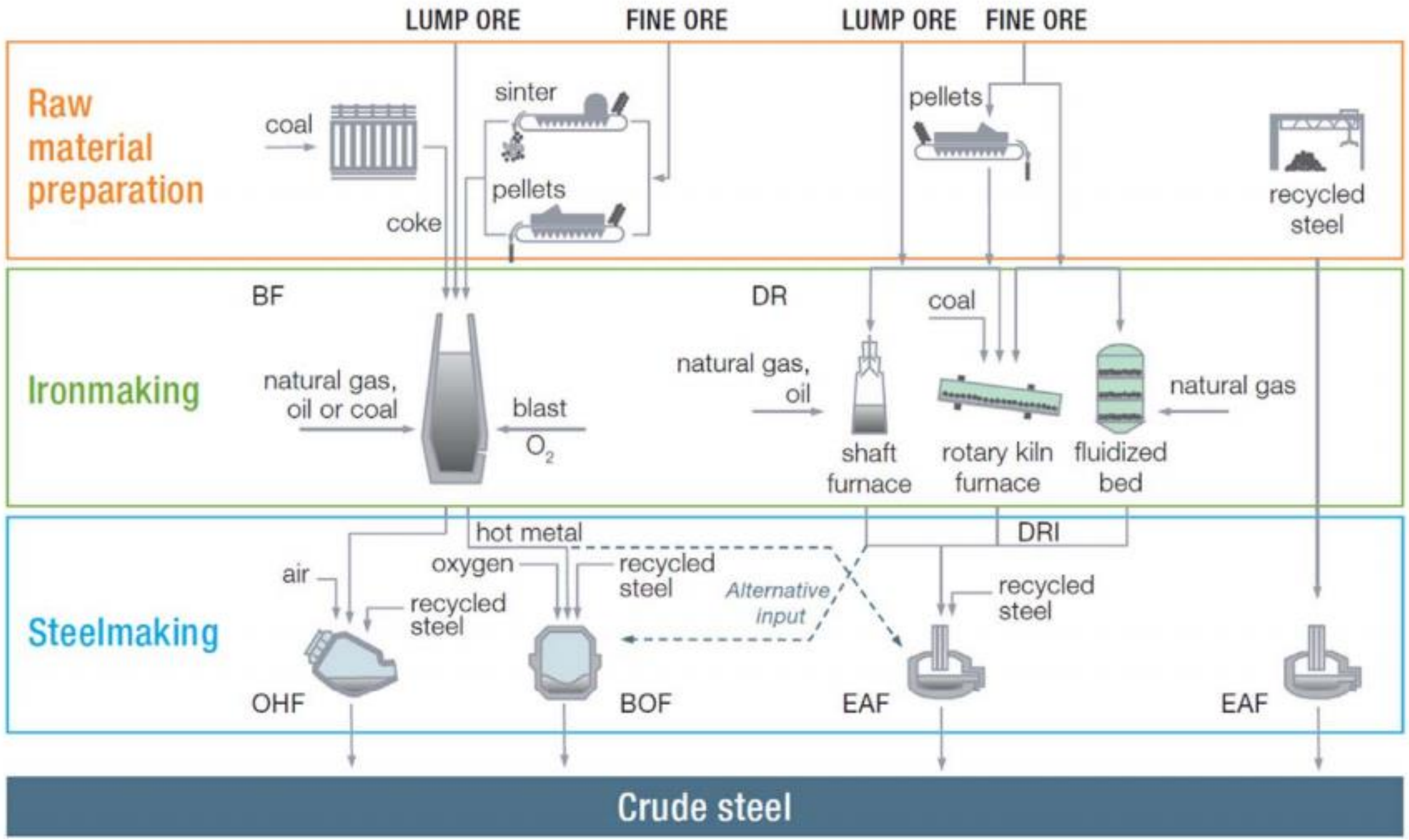
Mtoe	million toe or 106 toe
MW	megawatt or 106 watt
MWh	megawatt-hour or 106 watt-hours
p.a.	per annum
Pkm	passenger-kilometre (one passenger transported a distance of one kilometre)
T	metric tonne
toe	tonnes of oil equivalent
tkm	tonne-kilometre (one tonne transported a distance of one kilometre)

Example of most energy consuming industry

- The iron and steel industry has some of the highest levels of carbon emissions and energy consumption in Europe.
- The production process for manufacturing steel is energy-intensive and requires a large amount of resources.
- In 2013, the iron and steel sector accounted for 18% of the world's total industry final energy consumption.
- The energy efficiency of steel industry has a direct effect on overall energy consumption.
- As such, improving energy efficiency should be a primary concern for iron and steel plants.

Technologies, costs and efficiency

The total energy needed for production of one ton crude steel using the BF/BOF route consists of 3.6 GJ for the coke oven, 1.6 GJ for the sintering, 13.8 GJ for the blast furnace process plant .



The released CO_2-emissions (incl. emissions from primary fuel inputs, process related and indirect fuels related) per ton crude steel are divided as follows:
coke production 0.25 tons CO_2,
sintering, 0.25 tons CO_2,
blast furnace 0.36 tons CO_2 (Griffin et al., 2014).

List of energy-efficiency measures and technologies

Energy-efficiency technologies and measures in coke making progress	Fuel saving	Electricity savings	Capital cost (US$)
Coal moisture control	0.3 GJ/tonne		79.6
Programmed heating	0.17 GJ/tonne		0.37/tonne
Variable speed drive compressor	6–8 MJ/tonne		0.47/tonne
Coke dry quenching		300 kW h/tonne	28.85 million/system
Improved Process Control	0.05 GJ/ tonne		
District Heating Using Waste Heat	800 TJ/ /year using sinter cooler waste heat heating 5000 houses		
Continuous Temperature Monitoring and Control	An improvement in energy efficiency of up to 5%		

- Florens Flues et all. A review of energy use and energy-efficient technologies for the iron and steel industry. Renewable and Sustainable Energy Reviews, Volume 70, April 2017, Pages 1022-1039
- Florens Flues, Dirk Rübbelke, Stefan Vogele. An analysis of the economic determinants of energy efficiency in the European iron and steel industry. Journal of Cleaner Production 104 (2015) p. 250-263
- Elisa Duran, Claudi Aravena, Renato Aguilar. Analysis and decomposition of energy consumption in the Chilean industry. Energy Policy 86 (2015) p. 552–561
- Lihong Peng, Xiaoling Zeng, Yejun Wang, Gui-Bing Hong. Analysis of energy efficiency and carbon dioxide reduction in the Chinese pulp and paper industry. Energy Policy 80 (2015) p. 65–75
- Muh. Hisjama, Adi Djoko Guritnoc, Nunuk Supriyatnoc, Shalihuddin Djalal Tandjungc. A Sustainable Partnership Model among Supply Chain Players in Wooden Furniture Industry Using Goal Programming. Agriculture and Agricultural Science Procedia 3 (2015) p. 154 – 158

- The technologies that can be implemented at a plant depend on the specifications of the installed facilities, as well as its energy management and integration with upstream activities.
- Actual payback periods and energy savings for the measures may vary, depending on plant configuration and size, plant location, plant operating characteristics, and local supply of raw materials and energy, and several other factors.


ISO 50001
Energy use
Energy consumption
Energy Performance

ISO 50001- Standard for energy management systems

ISO 50001 has considerable advantages for organizations who consume energy and must control this significant operating cost.

ISO 50001 is designed so that any company can use it, regardless of their activity, size or geographical location.

Goals:

- Increase energy efficiency;
- Optimize resources;
- Minimize environmental influences.

The ISO 50001 standard was published on the 11th June 2011 under the title

"Energy Management Systems- requirements with guidance for use".

It is not a 'law', it is a methodology.

The majority of the certified companies are concentrated in Europe.

Half of the certified companies on a global scale are concentrated in Germany, where ISO 50001 has been driven forward thanks to the restrictive energy legislation.

By offering a systematic methodology for any sizes of organization, including small and medium enterprises (SMEs), to establish own energy management system, ISO 50001 can provide organizations with a number of business benefits.

These include:

• Helping to achieve energy use reduction and carbon emissions in a systematic way;

• Creating a clear picture of current energy use status, based on which new goals and targets can be set;

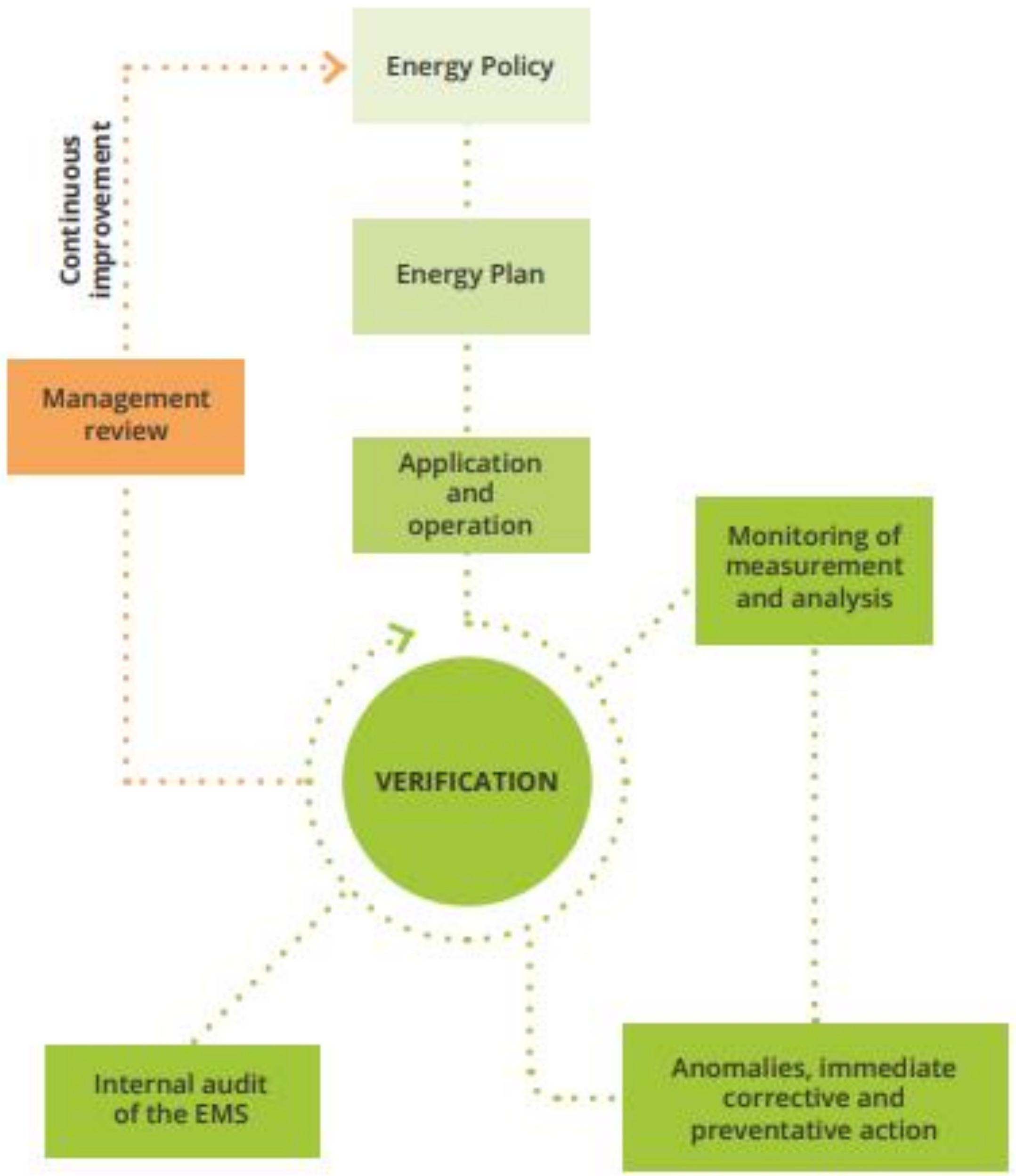
• Evaluating and prioritizing the implementation of new energy-efficient technologies and measures;

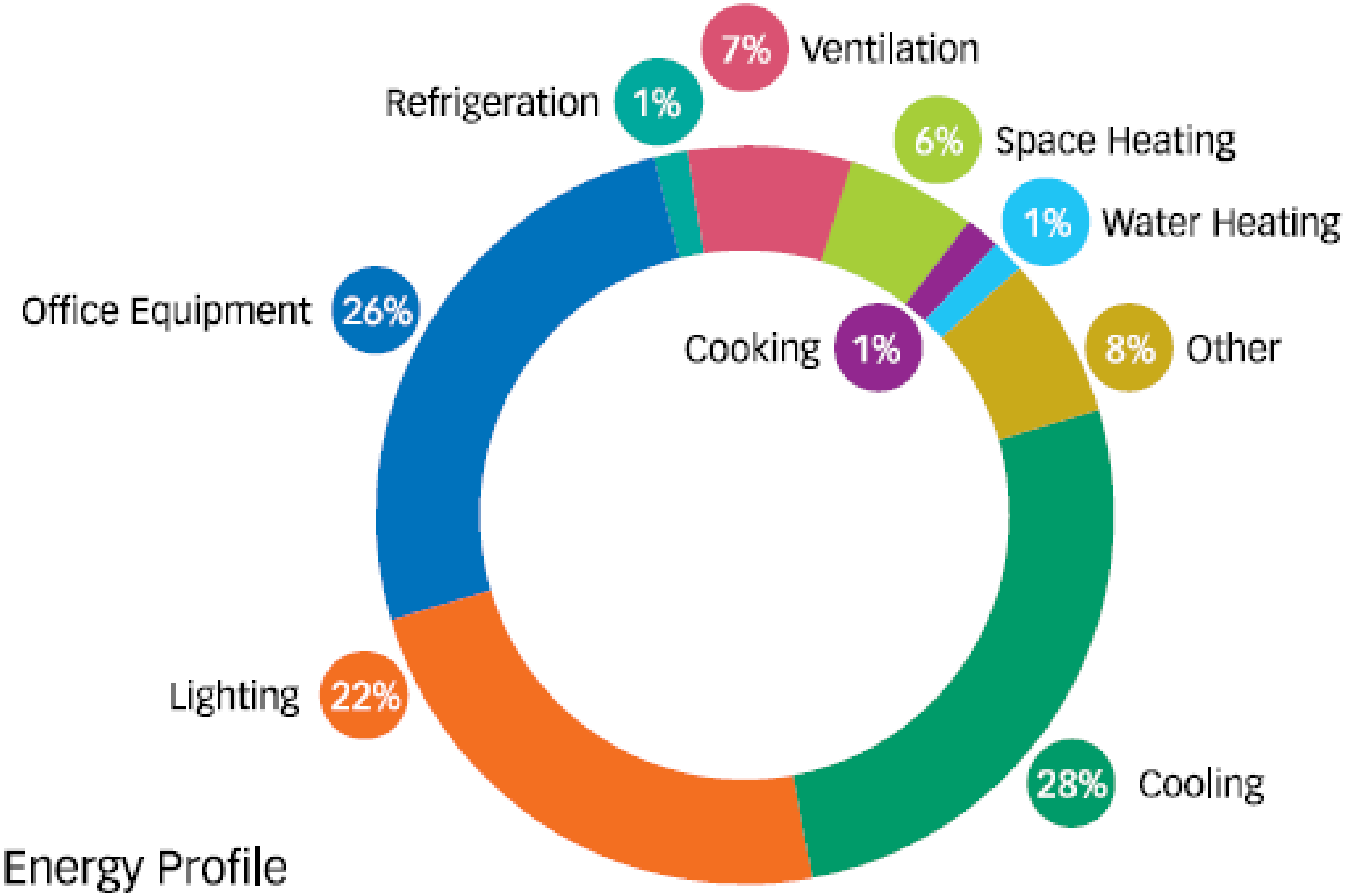
- Providing guidance on how to benchmark, measure, document and report corporate energy use;
- Making better use of energy consuming assets, thus identifying potentials to reduce maintenance costs or expand capacity;
- Demonstrating to the stakeholders that corporate commitment to comply with their best practice to protect the environment; and
- Fulfilling the associated regulatory requirements and responding with confidence to green trade barriers in global market.

- According to the definition stipulated in ISO 50001 standard, energy can be in various forms,

such as electricity, fuels, steam, heat, compressed air and renewable, which can be purchased, stored, treated, used in equipment or in a process, or recovered.

The main purpose of adopting an Energy Management System (EnMS) is to enable an organization to improve its energy performance, which generally includes energy use, energy efficiency and energy consumption, in a systematic approach.


Energy Policy
Continuous improvement
Energy Plan
Management review
Application and operation
Monitoring of measurement and analysis
VERIFICATION
Internal audit of the EMS
Anomalies, immediate corrective and preventative action



: Sample of an Energy Profile

Type of Equipment	Brand Name and Model No.	Unique ID and / or Serial No.	Equipment Location	Type of Energy	Power Rating (kW)	Energy Consumption in 2013 (kJ)			
						Jan	Feb	Mar	Apr
Chiller A									
Chiller B									
Chiller C									
Boiler 1									
Boiler 2									
Lighting at Workshop A									
Lighting at Workshop B									
PAU 1									
PAU 2									
Oven dryer									
20HP air compressor									

Energy efficient products

Air conditioners and comfort fans
Industrial fans
Standby and off-mode
Air heating and cooling products
Lighting
Televisions
Circulators
Local space heaters
Tumble driers
Computers and servers
Power transformers
Tyres

Cooking appliances
Professional refrigerators
Vacuum cleaners
Dishwashers
Set-top boxes
Ventilation units
Electric motors
Solid fuel boilers
Washing machines
External power supplies
Space and water heaters
Water pumps
Fridges and freezers

Source: https://ec.europa.eu/energy/e

The ISO 50001 do impact upon all the processes of the company.

Three prerequisites to have ready before beginning include:

- personnel,
- documentation,
- and the necessary technology.

The Staff Needed

- It is advisable for the company to have an Environmental Manager.
- The Environmental Manager must be a capable decision maker and carry authority within the organization. In addition, you may find it necessary to appoint a technical auditor.
- This figure is external to the company and is responsible for drafting the energy audit. The audit is not mandatory, but it is a good practice before implementing the Energy Management System (EMS).
- Finally, the technological condition of the internal energy management equipment must be taken into account, alongside building maintenance or environment.

Documenting the Process

It is necessary to document the following steps of the implementation process:

- Documenting the Process
- The energy policy of the business
- The energy plan (energy review, baseline energy consumption, energy performance indicators, programme objectives)
- The results of monitoring and measurement.
- The evaluation of legal compliance
- The results of the internal audit and review carried out by the management of the organization.
- ISO 50001 advises companies to have at their disposal, as a minimum, the monthly consumption of the last 12 months from all energy sources that are representative of the global energy consumption within the organization. With this information at hand, you will be ready to begin the implementation process.

The Technology

- Implementing ISO 50001 will require you to manage your consumption data in real time.
- Only in this way will you be able to correctly measure your installation, monitor your progress and as such, guarantee the cycle of continuous improvement that is offered by ISO 50001.
- Two fundamental technologies are involved when it comes to achieving this: energy efficiency hardware and software.

- The hardware, or devices for measurement, includes all meters, concentrators, gauges, etc. that are installed in switchboards, gas meters or simply in the building itself to take measurements of energy consumption.
- There are also specific ones for monitoring other conditions that affect energy use such as humidity, temperature, etc.

- Software is the tool that collects all of this data and presents it to you so that you can analyse and understand it and thus make decisions.
- At ISO 50001 standard, it is taken as given that your software should facilitate the documentation process.
- Of course, it is very much recommended for your software to incorporate measurement and verification tools. This function helps demonstrate the savings generated by the energy plan.

Case study. Data and their analysis of energy consumption in the furniture manufacturing company

Main tasks

To identify the main components of energy consumption in the manufacturing industry

To collect energy consumption data for the last 3 years

To identify the most energy-consuming equipment, lines, components.

To perform statistical analysis of the data, determine the dependencies

In order to be able to perform energy consumption analysis, data is needed consumption of different types of energy.

The main sources of energy used in furniture manufacturing companies are:

Electricity;

Compressed air;

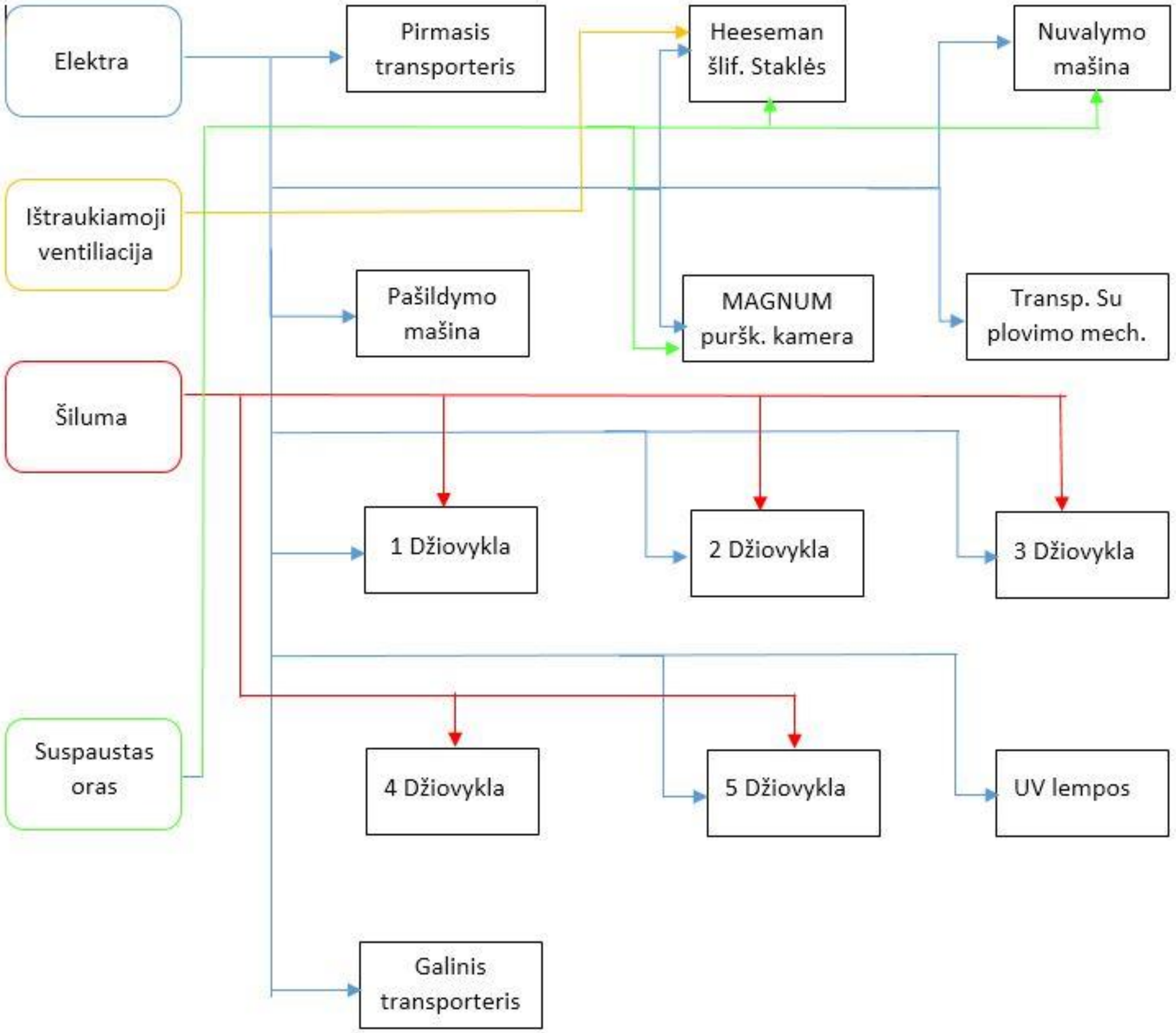
Heat.

Data of 3 production lines was fixed every 1 min

Electricity meter RAIL 350 with MODBUS connection

Time	Power	CosFi	Voltage,	Current 1	Power 1	Voltage 1	Current 2	Power 2	Voltage 3	Curernt 3	Power 3	1 Cosφ	2 Cosφ	3 Cosφ
	kW		V	A	kW	V	A	kW	V	A	kW			
16:00:00	69,5	0,88	225,5	132,4	26,3	227,5	106,7	20,4	225,6	110,5	22,8	0,882	0,842	0,915
16:01:00	59,4	0,838	226	119,1	22,7	227,4	96,1	17,2	225,9	97,9	19,5	0,843	0,788	0,882
16:02:00	56,4	0,826	225,8	115,3	21,6	227,5	91,7	16,1	226,1	94,7	18,7	0,83	0,774	0,873
16:03:00	58,1	0,835	225,8	118,1	22,4	227,5	93,6	16,5	225,8	96,5	19,2	0,842	0,778	0,884
16:04:00	60,1	0,84	226,4	120	22,9	228	97	17,4	226,1	99	19,8	0,845	0,787	0,887
16:05:00	59,2	0,842	225,4	118,2	22,5	227,2	95,6	17,2	225,4	97,8	19,5	0,845	0,792	0,886
16:06:00	60,7	0,85	226,5	121,5	23,4	227,8	94,9	17,1	226,8	98,7	20,2	0,85	0,791	0,905
16:07:00	59,1	0,841	226,5	118,7	22,6	227,8	93,3	16,7	227	97,8	19,8	0,843	0,787	0,891
16:08:00	61	0,843	227,5	122,2	23,5	228,9	95,3	17,2	227,8	99,7	20,3	0,845	0,788	0,894
16:09:00	54,7	0,809	226,2	115,6	21,2	227,6	89,6	15	226,8	93,8	18,5	0,812	0,738	0,872
16:10:00	60	0,854	226,2	118,2	22,8	227,6	93,3	17	226,7	98,8	20,2	0,853	0,801	0,905


Heesemann
MFA 10
magnum

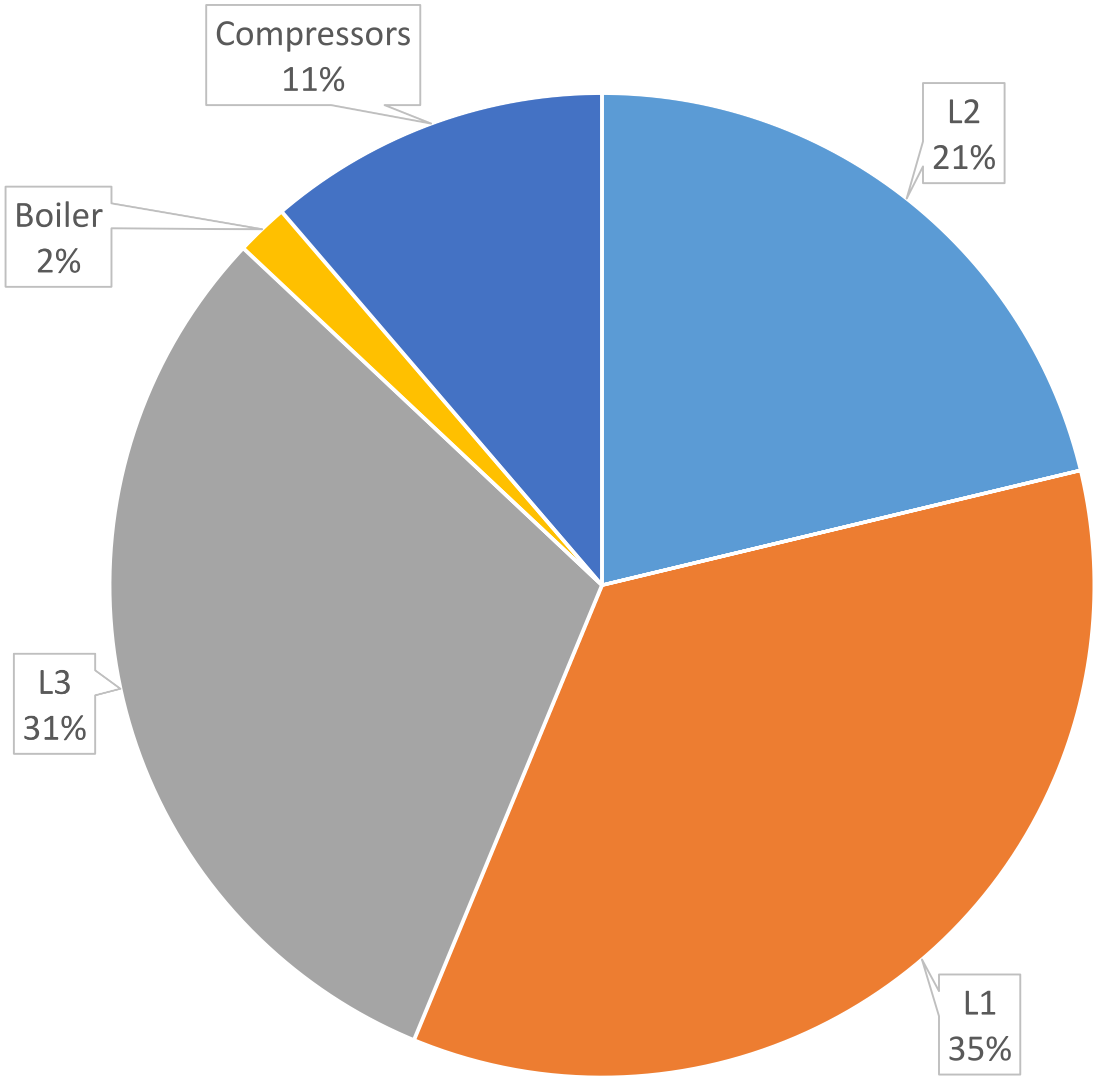

Elektra
Pirmasis transporteris
Heeseman šlif. Staklės
Nuvalymo mašina
Ištraukiamoji ventiliacija
Pašildymo mašina
MAGNUM puršk. kamera
Transp. Su plovimo mech.
Šiluma
1 Džiovykla
2 Džiovykla
3 Džiovykla
Suspaustas oras
4 Džiovykla
5 Džiovykla
UV lempos
Galinis transporteris

	1	2	3	4	5	6	7	8	9	10	11	12	Total
Total	957284	894433	951623	857468	916231	852622	882134	943436	999834	1096759	1050713	1000868	11403405
L-1	242650	203960	213000	209340	233750	212270	220690	217729	259071	261372	250874	235661	2760367
L-2	366442	351663	379383	331948	393077	335612	362809	424263	423195	504402	455283	424878	4752955
L-3	328479	321445	338968	302643	280500	289800	281700	285900	308100	312900	324300	318600	3693335
Boiler	19713	17365	20272	13537	8904	14940	16935	15544	9468	18085	20256	21729	196748
Compressors	117780	104000	119600	117640	132080	116000	101840	97210	123590	129949	125958	114008	1399655

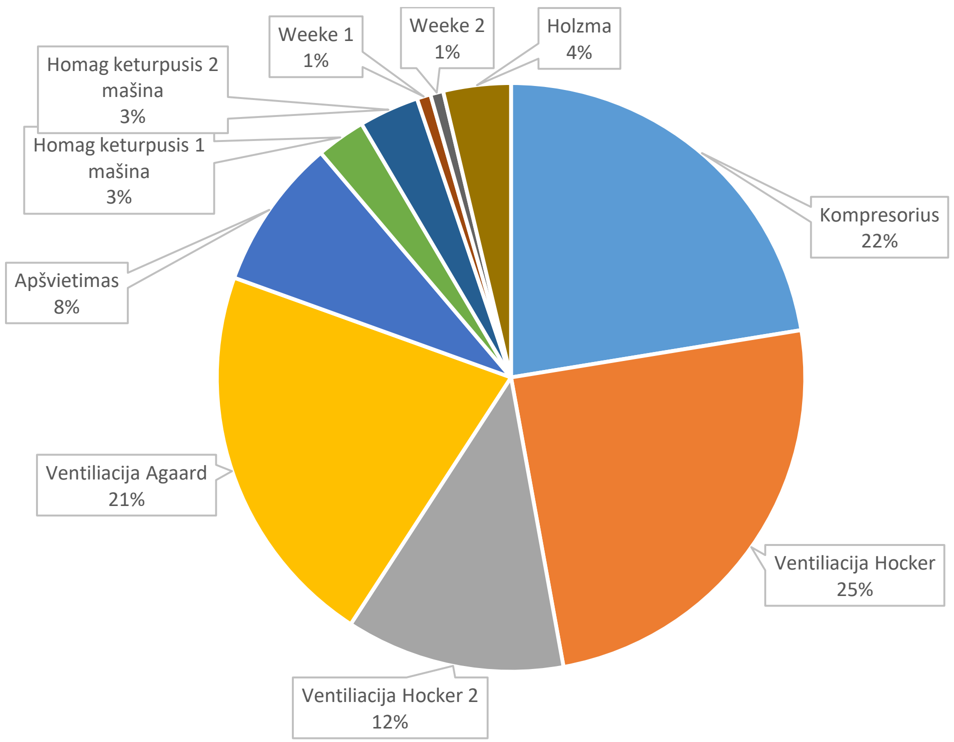
Electricity consumption (1 year)

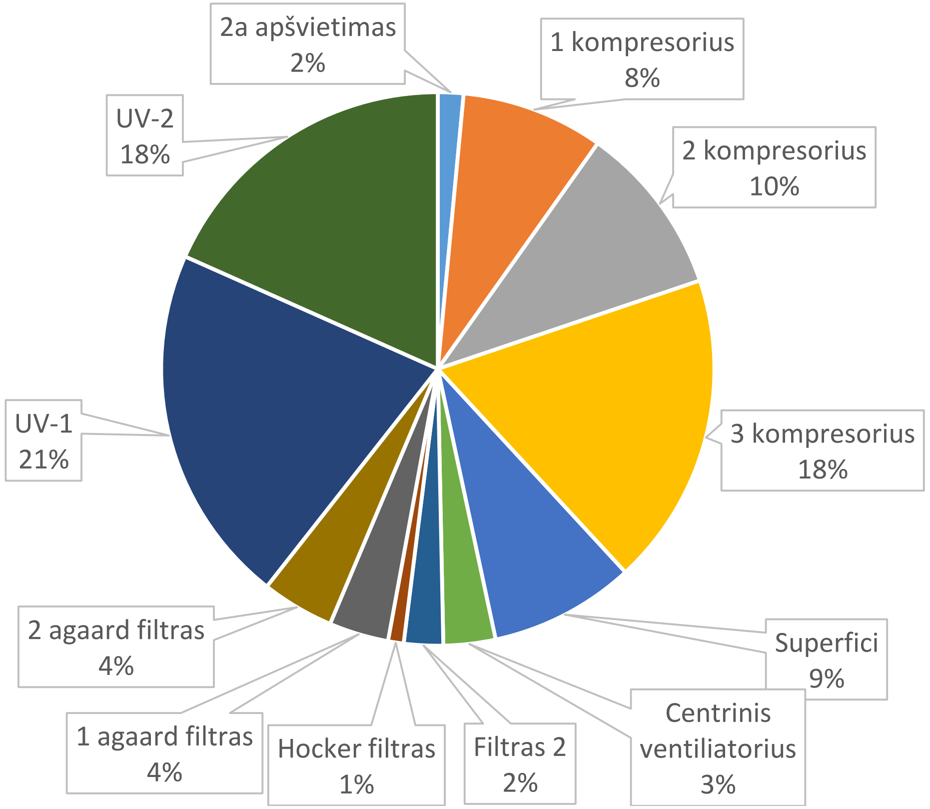
ciuoti eksperimentiniai duomenys

	average	dispersion	Standard deviation	Coefficient of variance
Power L1	24,52	1,79	1,34	22,50
Power L2	18,82	1,98	1,41	16,70
Power L3	21,71	1,93	1,39	19,50
Total	65,03	16,75	4,09	59,10



Energy consumption 2015-2017 year



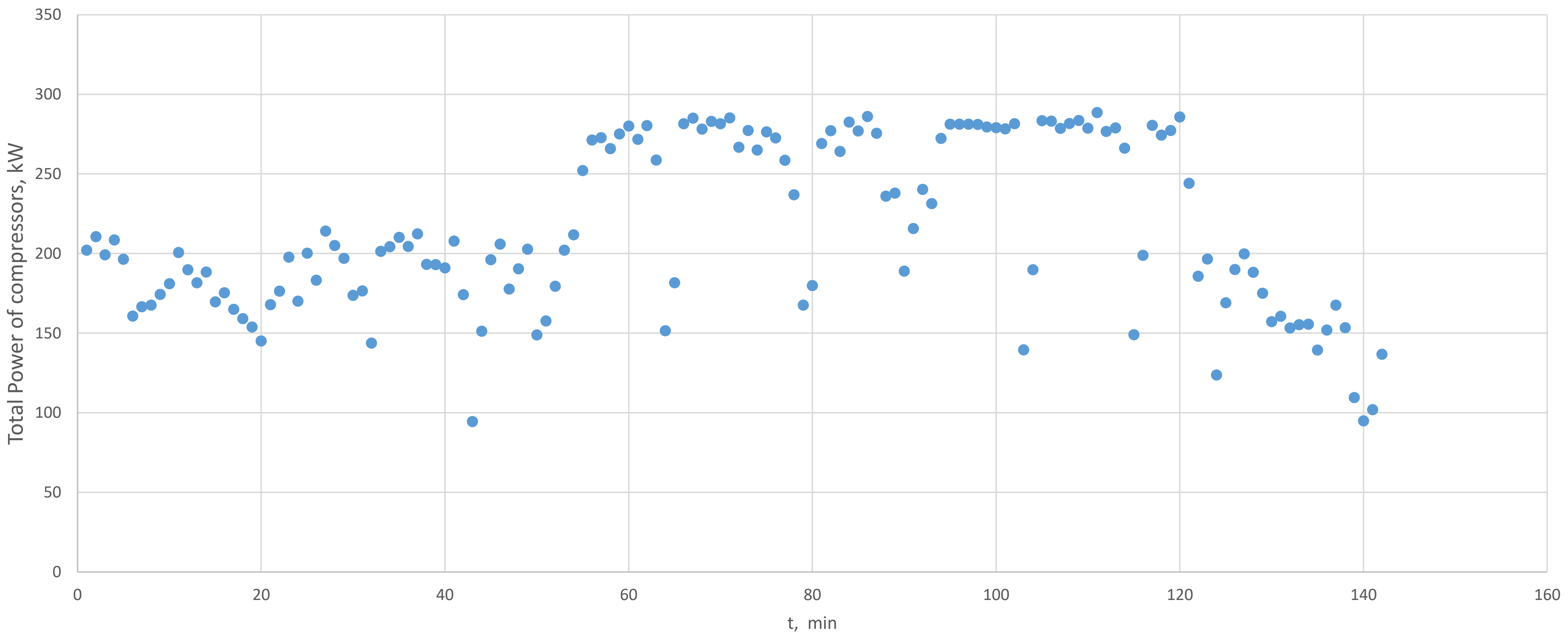


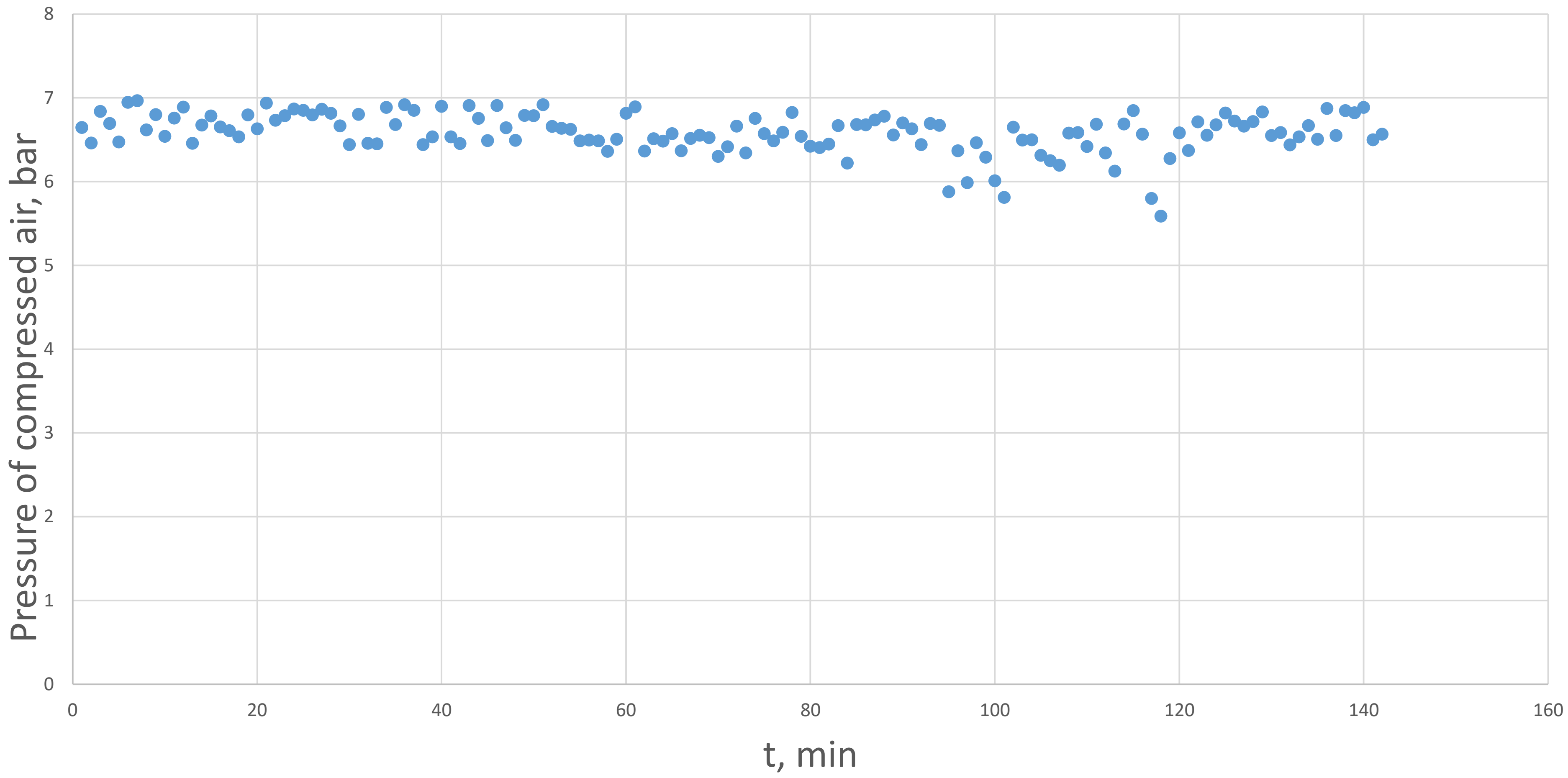
According to the ISO 50001 guidelines, it is necessary to further analyze those units that have a significant impact on energy consumption, i.e. exceeds 10% of total energy consumption.

- It is not possible to determine whether it is used efficiently if analyzing only energy consumption.
- It is necessary to compare energy with the production (the amount of energy that is consumed per unit of product)

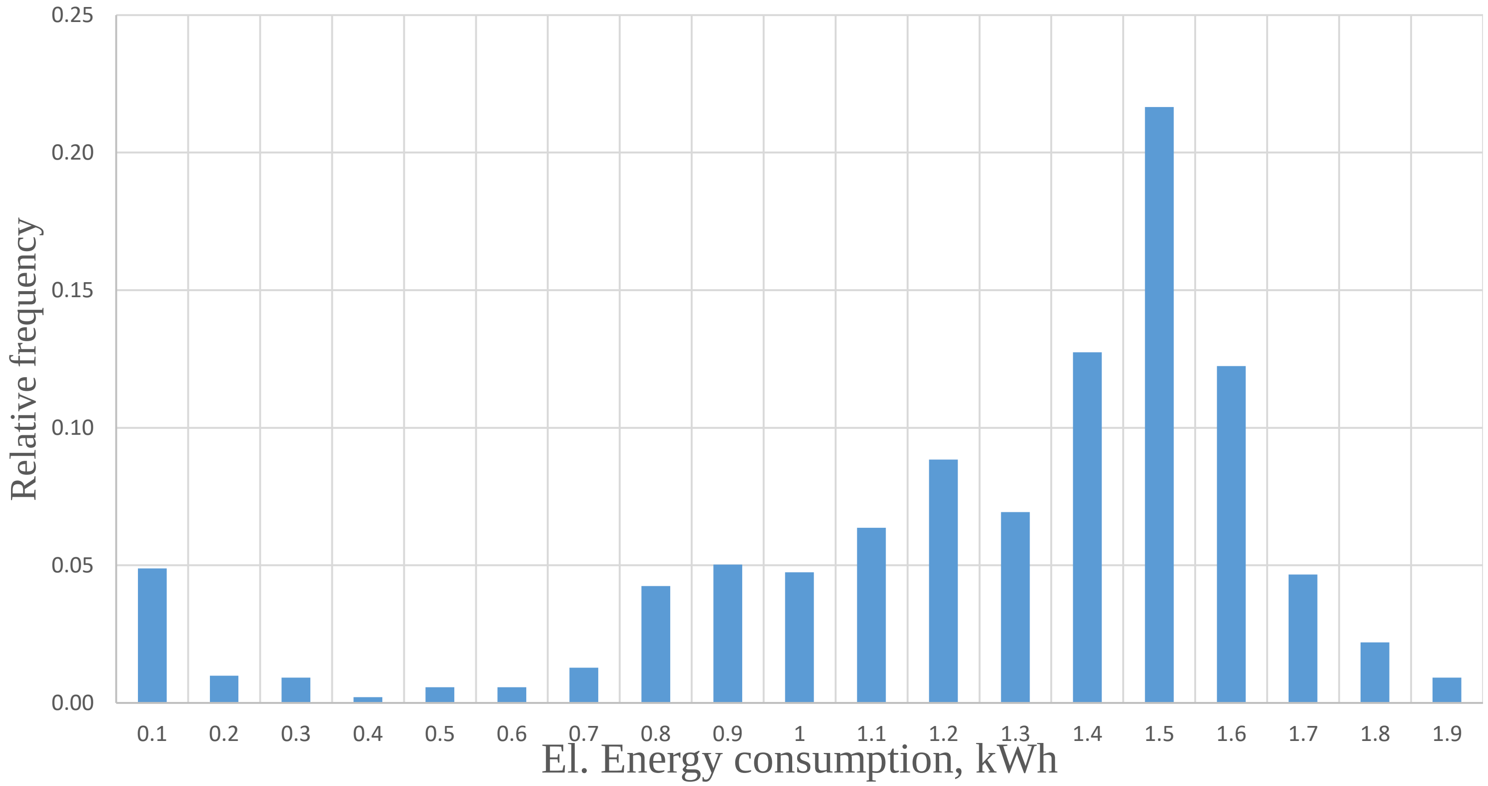
- In the research papers authors recommend following steps in order to properly monitor and analyze the process's efficiency:
- to analyze technological processes and collect information on production amount,
- to properly measure energy consumption,
- compare energy consumption with the amount of production (produced, consumed, processed, etc.).

Statistical analysis of data

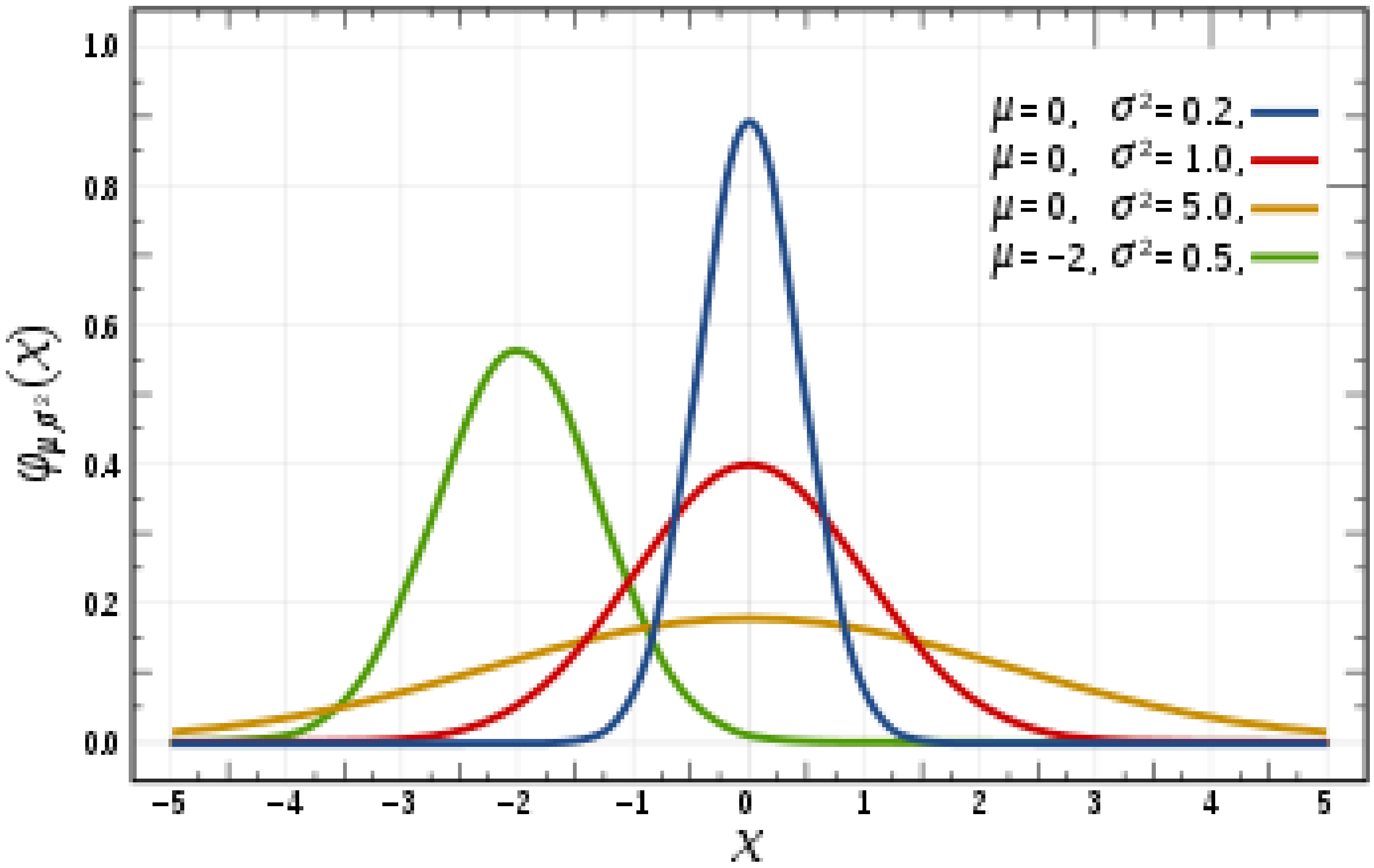




Compressed air pressure changes in the system



$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-m)^2}{2\sigma^2}}$$



1.0
0.8
0.6
0.4
0.2
0.0
$\varphi_{\mu,\sigma^2}(X)$
$\mu = 0, \quad \sigma^2 = 0.2,$
$\mu = 0, \quad \sigma^2 = 1.0,$
$\mu = 0, \quad \sigma^2 = 5.0,$
$\mu = -2, \sigma^2 = 0.5,$
−5
−4
−3
−2
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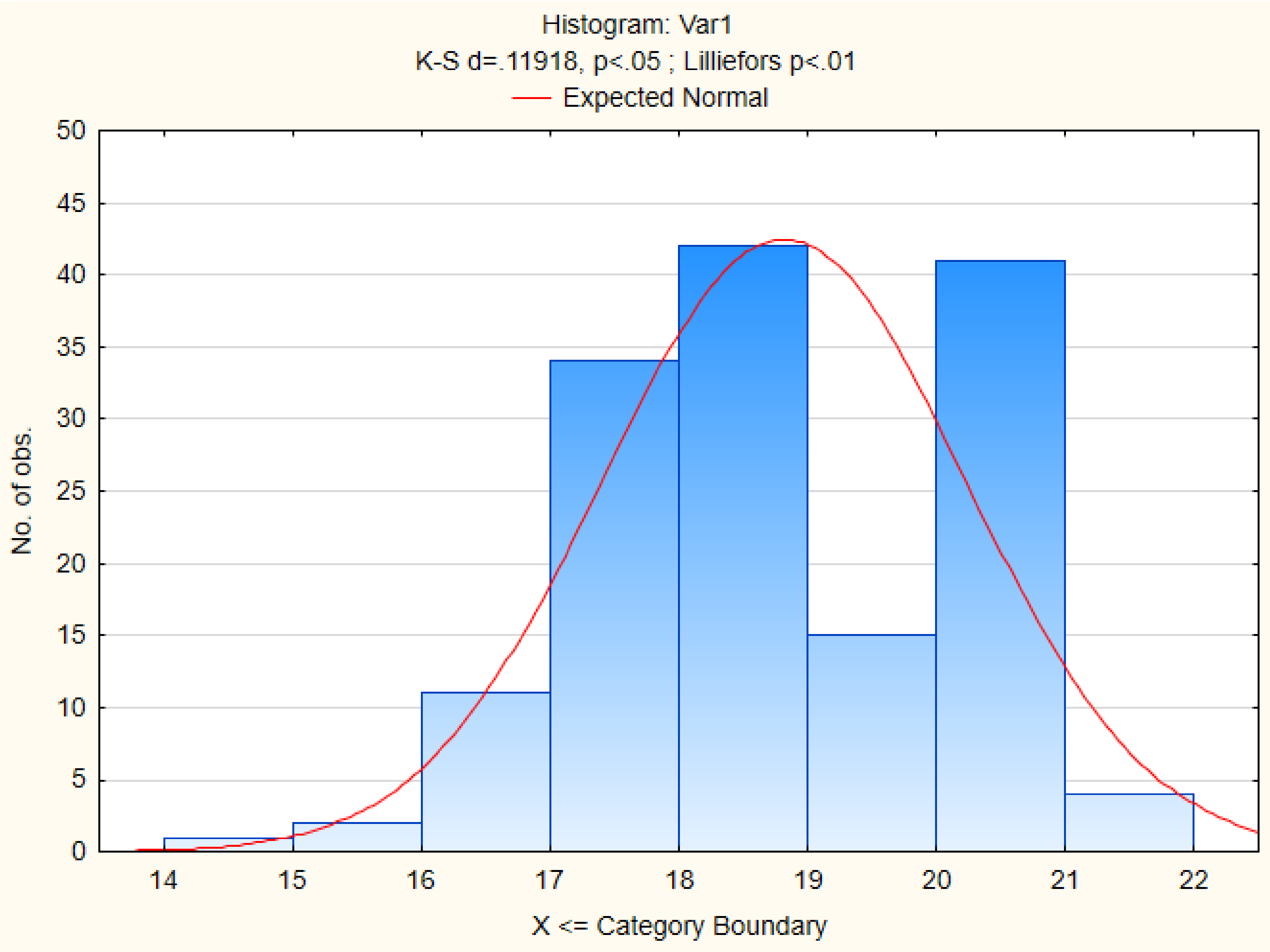
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Expected Normal
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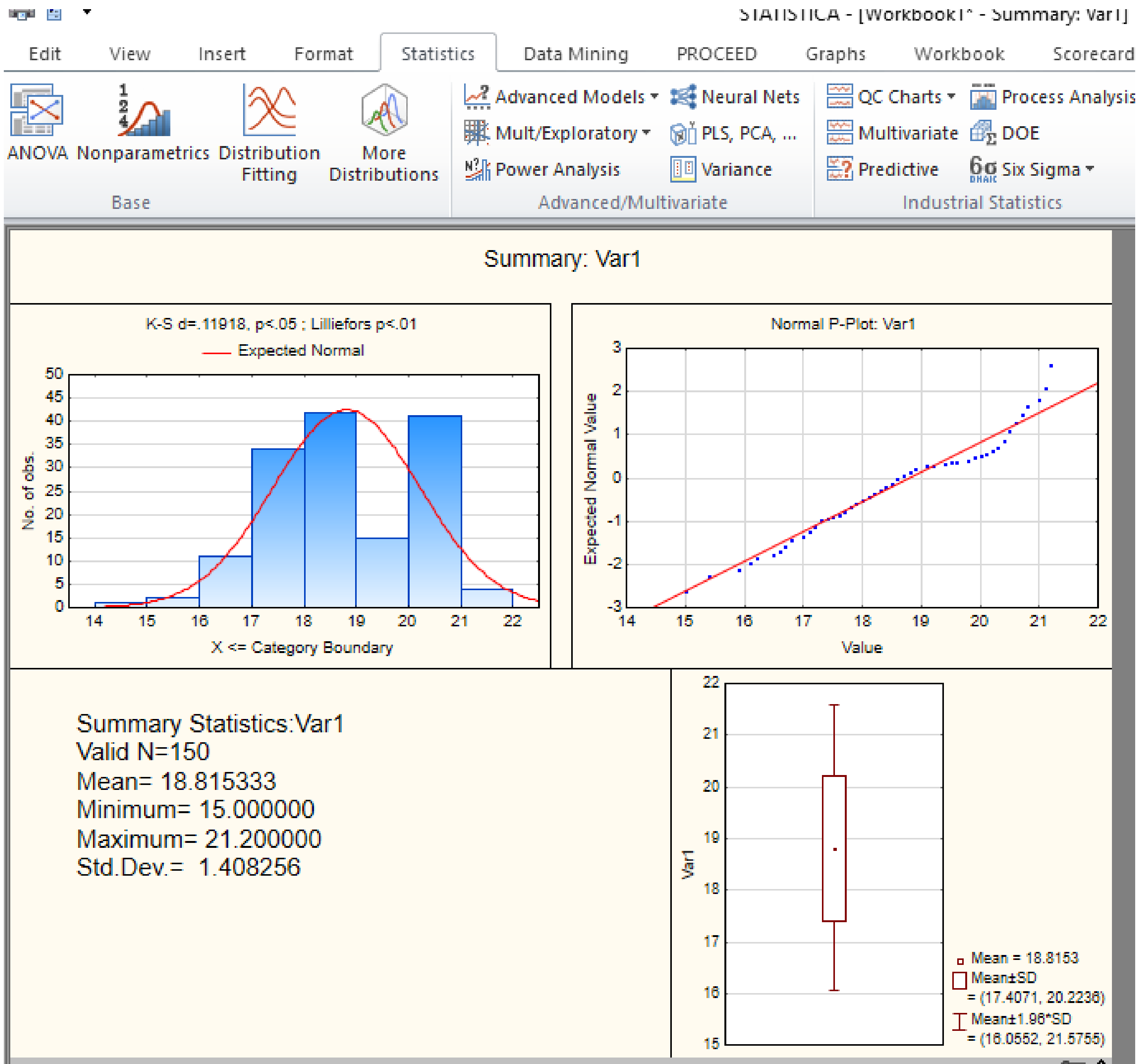
STATISTICA - [Workbook1* - Summary: Var1]
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Scorecard
ANOVA
Nonparametrics
Distribution Fitting
More Distributions
Base
Advanced Models
Mult/Exploratory
Power Analysis
Neural Nets
PLS, PCA, ...
Variance
Advanced/Multivariate
QC Charts
Multivariate
Predictive
Process Analysis
DOE
Six Sigma
Industrial Statistics
Summary: Var1
K-S d=.11918, p<.05 ; Lilliefors p<.01
Expected Normal
No. of obs.
X <= Category Boundary
Normal P-Plot: Var1
Expected Normal Value
Value
Summary Statistics:Var1
Valid N=150
Mean= 18.815333
Minimum= 15.000000
Maximum= 21.200000
Std.Dev.= 1.408256
Var1
Mean = 18.8153
Mean±SD
= (17.4071, 20.2236)
Mean±1.96*SD
= (16.0552, 21.5755)

conclusion

The main purpose of adopting an Energy Management System (EnMS) is to enable an organization to improve its energy performance, which generally includes energy use, energy efficiency and energy consumption, in a systematic approach.