

# Waste heat recovery in European Industry

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# Presentation outline

- Previous work
- New work:
  - Introduction
  - Methodology
  - Aggregated waste heat potentials detailed by member state
  - Detailed waste heat potentials for each industrial sector
  - Identification of the processes having waste heat potential in each industrial sector
- Current and Future Publications



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## Previous Work:

### Preliminary waste heat potential calculations

The data used for the estimation of the waste heat potential were taken from Forman *et al.* (2016).

A qualitative analysis was performed on the raw data based on the respective temperature range and their applicability to produce useful work. The relevant efficiency was estimated using the theoretical formula:

$$\eta_{max} = \eta_C = 1 - \frac{T_{low}}{T_{high}}$$



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## Previous Work:

# Preliminary waste heat potential calculations

Waste heat potential and Carnot potential according to Forman *et al.* (2016)

Potential	LT <100°C	MT 100–299° C	HT >300°C
Waste Heat	12.60%	6.00%	11.40%
Carnot	1.73%	2.00%	6.40%

Using a table with the temperature ranges of each process and in each industrial sector, an approximation of the potentials was estimated as shown in Table

370.41 TWh (Waste heat) and 173.99 TWH (Carnot's) per year



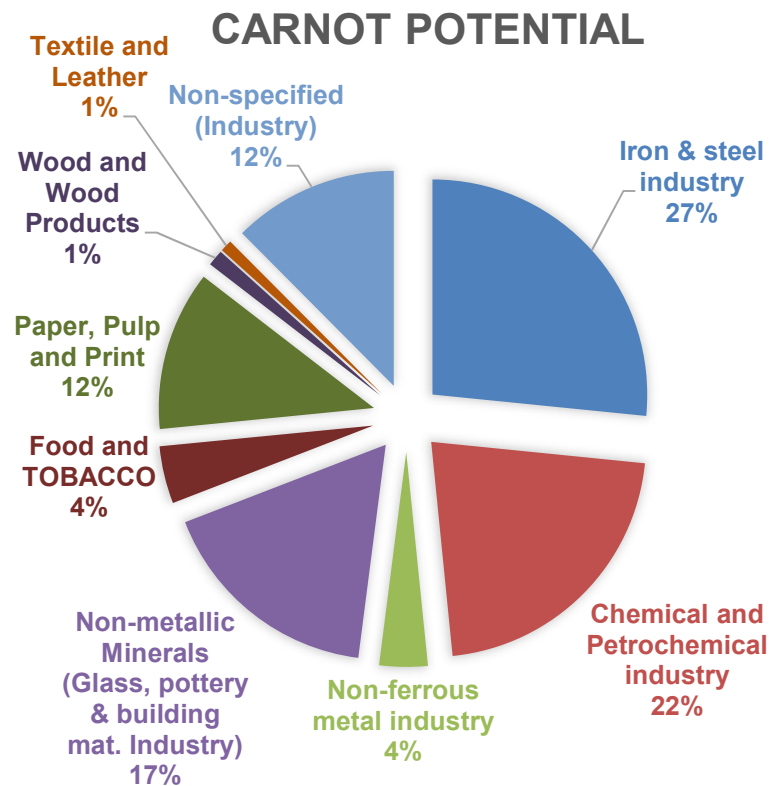
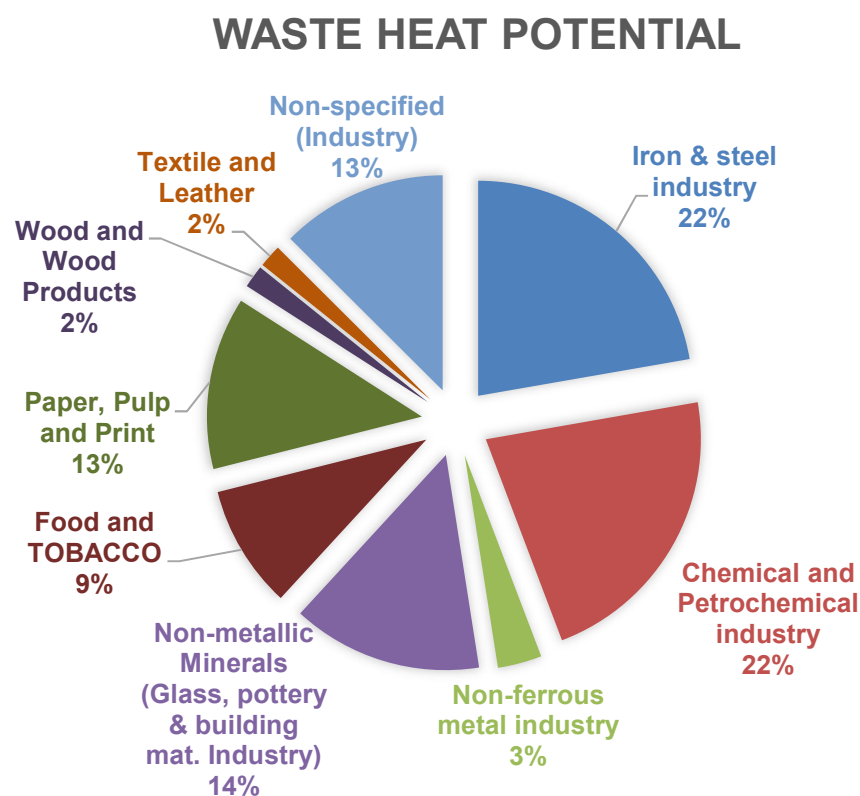
	Type of Industry	Waste heat potential	Carnot potential
1	Iron & Steel Industry	11.40%	6.40%
2	Chemical and Petrochemical Industry	11.00%	5.13%
3	Non-ferrous metal industry	9.59%	4.93%
4	Non-metallic minerals (glass, pottery & building materials industry)	11.40%	6.40%
5	Food and Tobacco	8.64%	1.89%
6	Paper, Pulp and Print	10.56%	4.59%
7	Wood and Wood Products	6.00%	2.00%
8	Textile and Leather	11.04%	2.72%
9	Non-Specified industry	10.38%	4.84%



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## Previous Work:

## Preliminary waste heat potential results



370.41 TWh (Waste heat) and 173.99 TWH (Carnot's) per year



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## New Work:

### Introduction

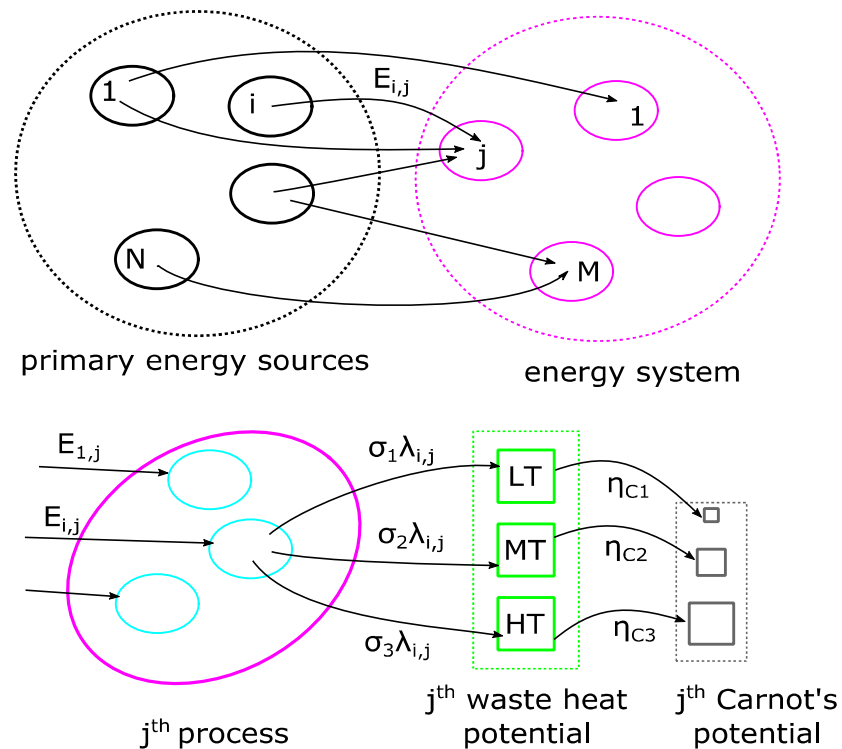
- In the current study, the theoretical waste heat recovery potential was estimated, based on the latest energy statistics of the European Union (reference year 2014), using the methodology proposed by Forman et al. (2016)
- According to other researchers, Forman's methodology concerning the usage of literature data, coefficients and estimation, is a medium accuracy approach. This is due to the following factors:
  - More than one primary energy type is used in a system. The energy may result from solid, liquid and gaseous fuels, as well as from electricity and heat.
  - Each type of energy input presents some loss terms that depend on the type of process.
  - The energy losses accounted for the estimation are those related to exhausts (flue gas, vapor) and effluents (cooling water or air). Other losses, such as radiation, electrical transmission, friction, etc., are not been taken into account.



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# New Work:

## Calculation Methodology



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## New Work:

### Calculation Methodology

$$WHP = \sum_{i=1}^N \sum_{j=1}^M \lambda_{i,j} E_{i,j}$$



A further breakdown of the waste heat recovery potential can be performed with reference to the temperature levels that are commonly categorized into:

- Low Temperatures (LT): < 100 °C
- Medium Temperatures (MT): 100-299 °C
- High Temperatures (HT): ≥ 300 °C



$$WHP = \sum_{i=1}^N \sum_{j=1}^M \sum_{k=1}^3 \lambda_{i,j} E_{i,j} \sigma_{i,j,k}$$



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## New Work: Identification of the processes having waste heat potential in each industrial sector

Type of Industry	Processes used	Temperature range (°C)	Temperature range (LT, MT, HT)
Iron and Steel Production	Sinter Process	1300 – 1480	HT
	Pelletisation Plants - Induration process	straight grate process: 1300 – 1350 grate kiln process: 1250	HT
	Coke oven plants – Jewell - Thompson oven	1150 – 1350	HT
	Blast furnace – Hot Stoves	900 – 1500	HT
	Basic Oxygen Steelmaking	1200	HT
Large Combustion Plants	Combustion process – Gasification / Liquifaction process	430 – 630	HT
	Steam process - Boiler	Coal and Lignite fuels: 540-570 Liquid fuels: 120 – 140	HT
	Co-generation/combined heat and power	100	LT
	Combined cycle plants	430 – 630	HT
Large Volume Inorganic Chemicals- Ammonia, Acids and Fertilizers	Conventional steam reforming - Desulphurization process	350-400	HT
	Conventional steam reforming - Primary and Secondary reforming	Primary: 400-600 Secondary: 400-600 Exhaust gas: 1000	HT
	Sulphuric Acid	400-1500	HT
Large Volume Inorganic Chemicals - Solids and Others industry	Sulphur burning process	145	MT
	Tank furnace process	430-650	HT
	Sodium silicate plant (revolving hearth furnace) process	600	HT

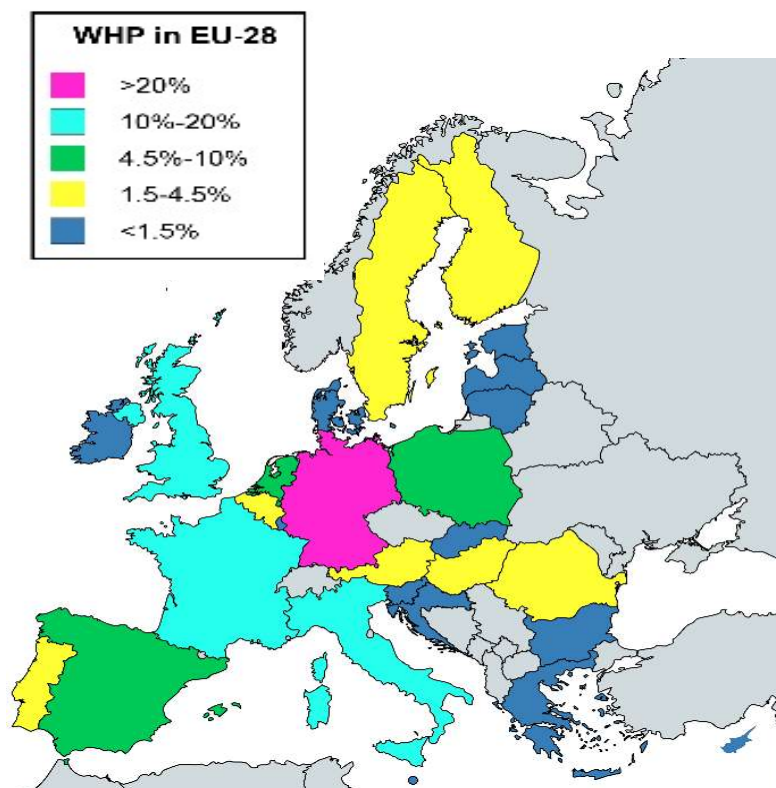
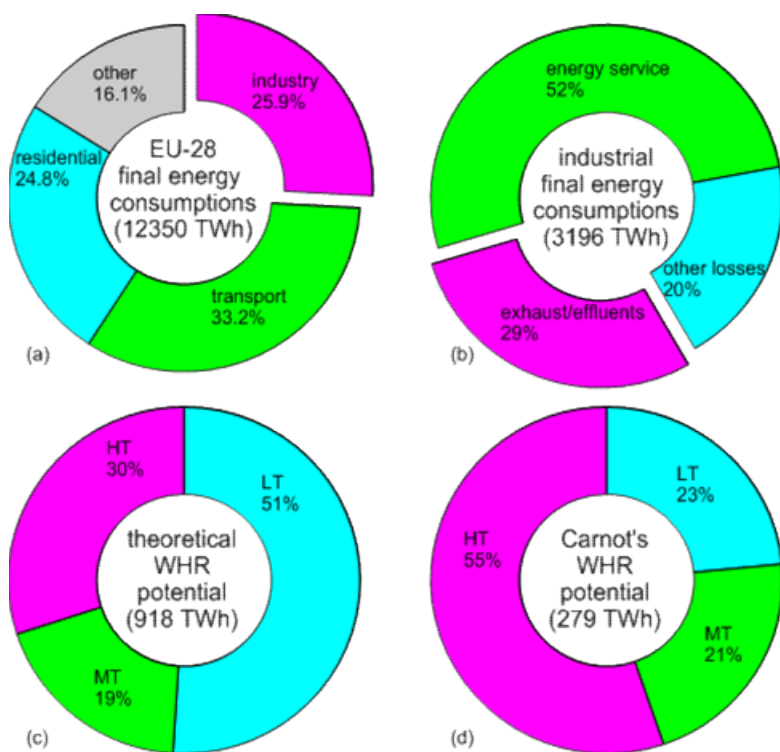
## New Work: Identification of the processes having waste heat potential in each industrial sector

Food, Drink and Milk Industry	Solubilisation/alkalizing process	45-130	MT
	Utility processes -CHP	60-115	MT
	Heat recovery from cooling systems	50-60	LT
	Frying	180-200	MT
Production of Glass	Heating the furnaces and primary melting	750 – 1650	HT
Production of OFC	Energy Supply	45 – 130	LT
	Thermal oxidation of VOCs and co-incineration of liquid waste	950 – 1000 (SNCR) or SCR	HT
	Recovery and abatement of acetylene	N/A	N/A
Production of Non-ferrous metals	Primary lead and secondary lead production	200 – 400	MT
	Smelting Process	400 – 1200	HT
	Zinc sulphide (sphalerite)	900 – 1000	HT
Production of Cement, Lime & Magnesium Oxide	Kiln firing	≥2000	HT
	Clinker burning	1400 – 2000	HT
Production of Polymers	Thermal treatment of waste water	N/A	N/A
Ferrous Metals Processing	Hot rolling mill	1050 – 1300	HT
	Re-heating and heat treatment furnaces	N/A	N/A

Pulp, Paper and Board production	Kraft pulping process (chemical pulping)	155 – 175 (Cooking and delignification)	MT
		90 – 100 (Oxygen delignification)	LT
	Sulphate pulping process (chemical pulping)	800 – 1100 (calcination reaction - lime kiln)	HT
	Mechanical pulping and Chemimechanical pulping	95 – 125 (Grinding- Pressure Groundwood pulping) 70 – 170	LT-MT
		45 – 90 (Paper machine)	LT
	Papermaking and related processes	>350 (Coated wood-free printing tissue process with conventional Yankee dryer)	HT
Surface Treatment Using Organic Solvents	Printing	700-800	HT
	Drying and curing	400-700	HT
	Waste gas treatment from enamelling	500-750	HT
	Manufacturing of Abrasives	35-110 in the drier	LT
		700 for the exhaust air treatment	HT
	Coil coating	150-220	MT
Tanning and Hides and Skins	Drying	60-90	LT
Textiles industry	Dirt removal	1200	HT
	Optimisation of cotton warp-yarn	60-110	LT-MT
	Dyeing	80-100	LT
	Oxidation	750	HT
	Drying	130	MT
Waste Incineration	Drying and degassing	100-300	MT
	Pyrolysis	250-700	MT-HT
	Gasification	500-1600	HT
	Oxidation, Combustion	800-1450	HT
Waste Treatment	Thermal Treatment	Vitrification 1300-1500 Sintering 900-1200	HT
	Drying	100	LT
	Regeneration of carbon	650-1000	HT
	Incineration	850-1200	HT
	Catalytic combustion	200-600	MT-HT
	Drying of wood particles	200-370 for single/triple pass dryers	MT
		500 at rotary dryers	HT
Wood based panels production	Drying of wood fibres	60-220	MT
	Pressing	100-260	MT

## New Work:

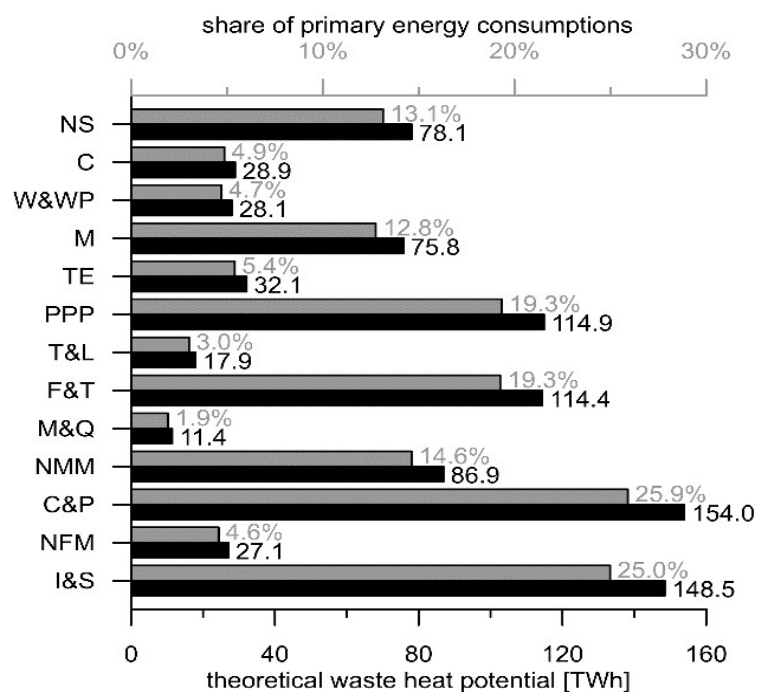
# Aggregated waste heat potentials detailed by member state



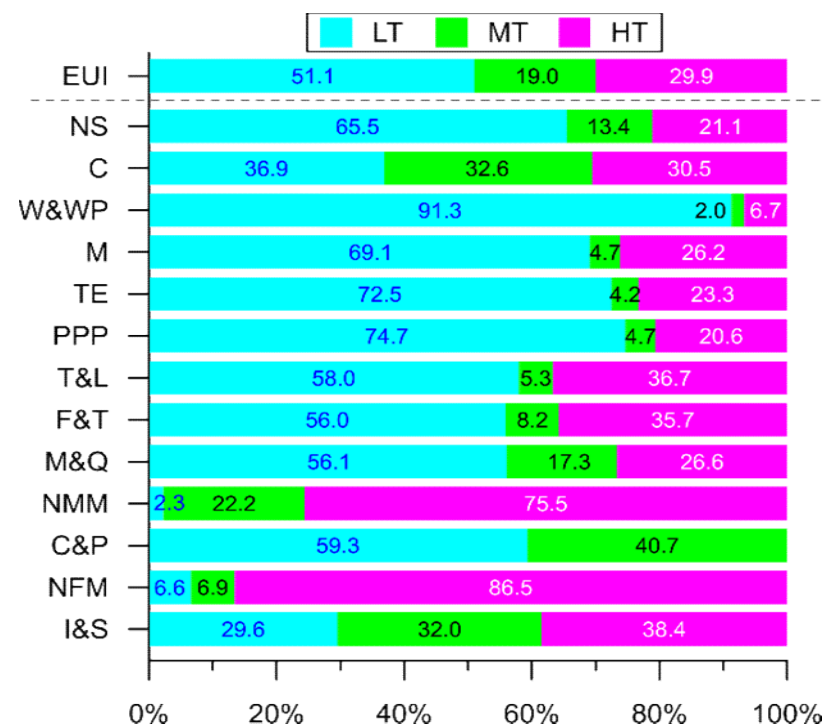
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## New Work:

### Detailed waste heat potentials for each industrial sector



Theoretical waste heat potential and relevance on primary energy consumptions for EU industry (top x-axis)



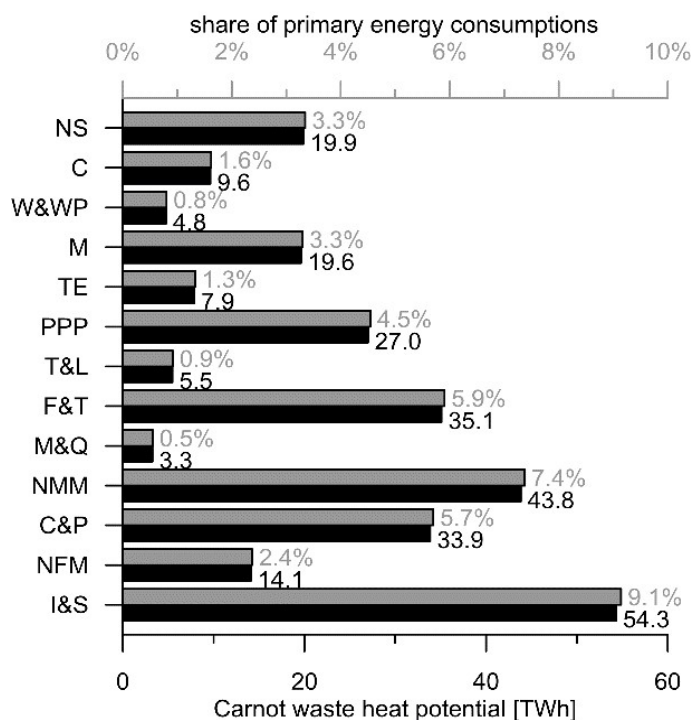
Breakdown of the theoretical waste heat potential in EU industry with respect to temperature levels



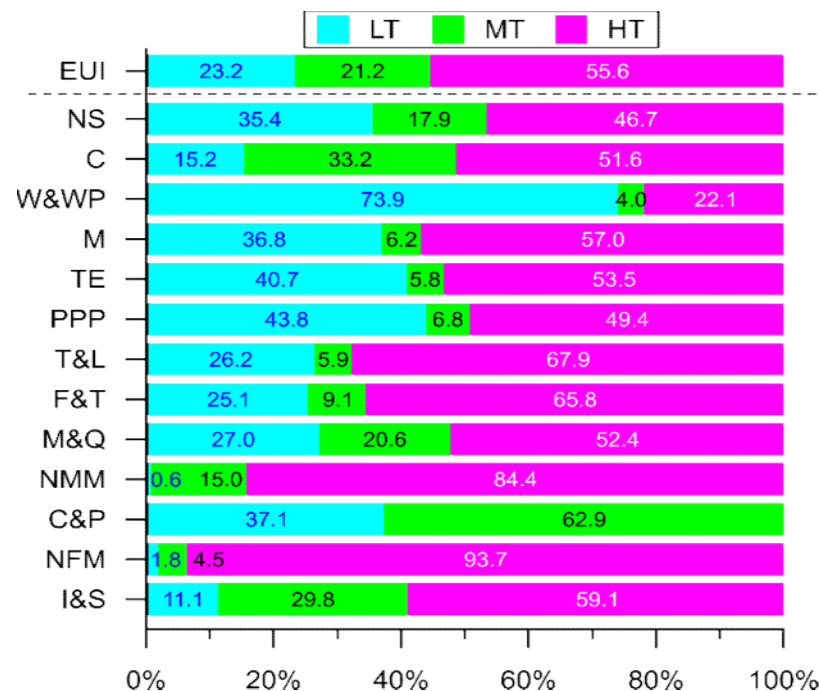
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## New Work:

### Detailed Carnot waste heat potentials for each industrial sector



Carnot waste heat potential and relevance on primary energy consumptions for EU industry (top x-axis)



Breakdown of the Carnot waste heat potential in EU industry with respect to temperature levels



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# Current and Future Publications

## Previous work (preliminary results):

- Panayiotou, G. P., Bianchi, G., Georgiou, G., Aresti, L., Argyrou, M., Agathokleous, R., Tsamos, K.M., Tassou, S.A., Florides, G., Kalogirou, S.A., & Christodoulides, P. (2017). **Preliminary assessment of waste heat potential in major European industries.** *Energy Procedia*, 123, 335-345.

## Future work:

- A paper is in preparation for a possible Journal Publication
- The type of heat exchanger and the use of the heat backed up should be mentioned. For example exhaust gas to air or exhaust gas to water or steam, condensing economiser, steam generator, etc.
- Not only heat to power applications should be considered but other applications too. Classifications based on factors other than temperature level should be examined.



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# Thank you for your attention!



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