Consulting, Solutions and Services Division
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Workshop de Fontes Energéticas no Âmbito do Planejamento de Longo Prazo

WASTE-TO-ENERGY DEVELOPMENT:
Perspective and Lesson learned

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CESI
Shaping a Better Energy Future

Waste-to-Energy
Summary

SECTION 1

- CESI overview

SECTION 2: WASTE-TO-ENERGY

- Background
- World Overview – thermal WtE plants
- Values of thermal WtE plants around the globe
- Thermal WtE plants capacity in Europe
- Thermal WtE plants capacity in Italy
- Values of waste in Brazil
- Values of waste to energy production in Brazil

SECTION 3: Lesson Learned

Waste-to-Energy
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- Values of waste to energy production in Brazil

SECTION 3: CASE STUDY

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Waste-to-Energy
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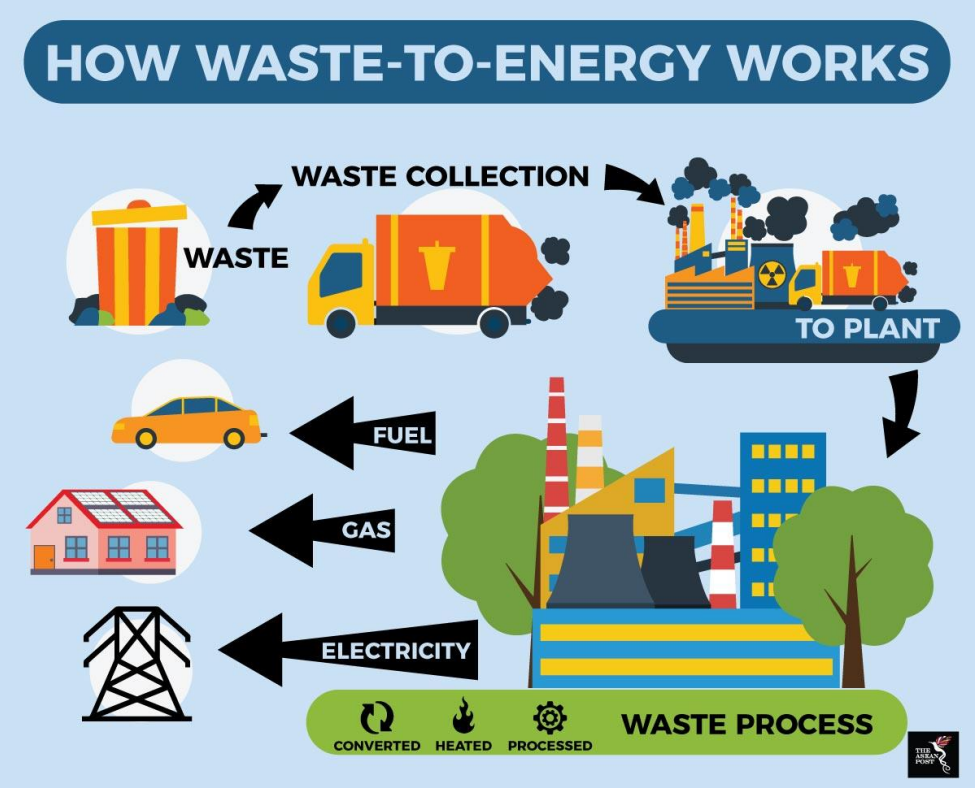
Waste-to-Energy
Background

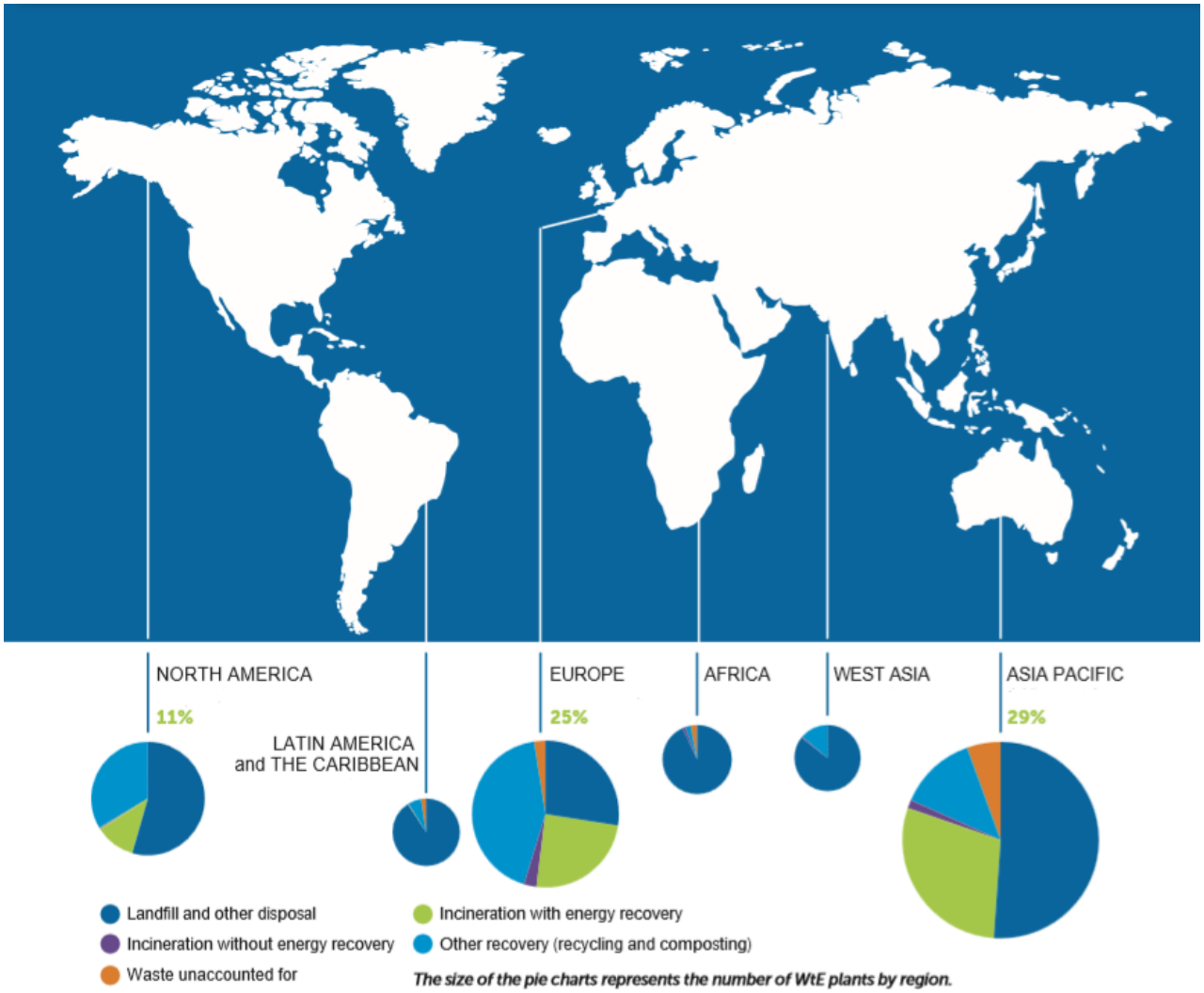
Waste-to-energy (WtE) refers to a variety of treatment technologies that **convert waste to electricity**, **heat, fuel**, or other usable materials, as well as a range of residues including fly ash, sludge, slag, boiler ash, wastewater and emissions, including greenhouse gases. Based on its energy conversion processes, WtE is classified into four categories: **thermal, mechanical and thermal, thermo-chemical and biochemical.** In the waste management hierarchy, it can also be classified into disposal, other recovery or recycling operations, according to the energy products produced and recovery level.

- Prevention
- Minimization
- Reuse
- Recycling
- Other Recovery
- Landfill
- Controlled Disposal



Waste-to-Energy

World Overview – thermal WtE plants



More than 50 per cent in all but one world region, landfill and open dumping remain major waste treatment methods.

Fonte: UNEP (2019). Waste-to-Energy: Considerations for Informed Decision-Making

*Solid Waste incinerated with energy recovery

Waste-to-Energy

World Overview – thermal WtE plants

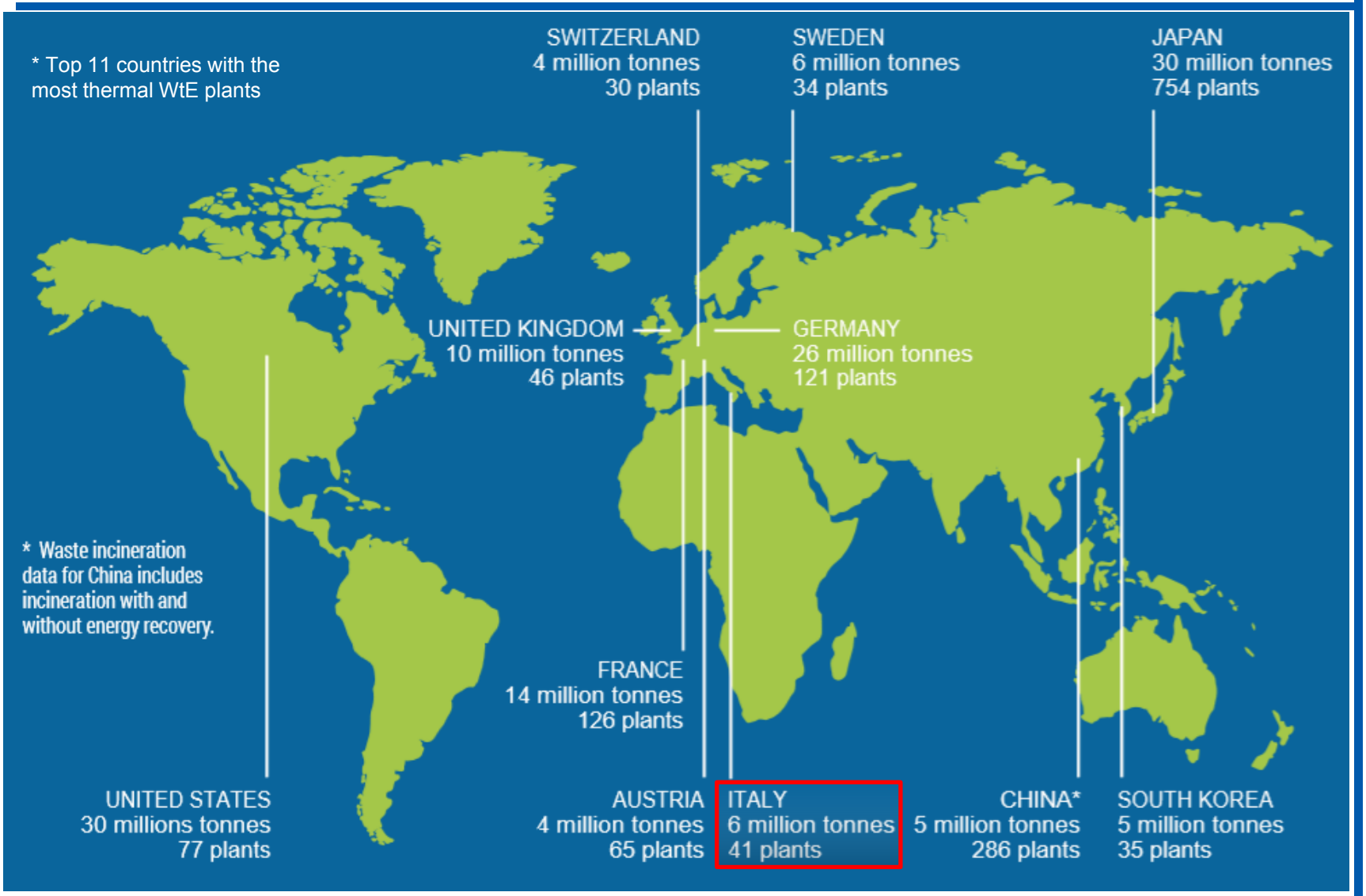
Over 80 per cent of thermal WtE plants are located in developed countries, led by Japan, France, Germany and the United States. The global WtE market was valued at 9.1 billion USD in 2016, and is expected to increase to over 25 billion USD by 2025, maintaining a steady compound annual growth rate of over 5.5 per cent according to conservative estimates.

	Landfill and other disposal	Incineration with energy recovery	Incineration without energy recovery	Other recovery (recycling and composting)	Waste unaccounted for
Asia Pacific	51.2	29.2	1.3	12.9	5.3
Europe	27.5	24.7	2.7	42.9	2.4
West Asia	89.5	0.0	0.7	15.5	0.02
Africa	93.1	0.0	1.6	2.3	3.0
North America	54.8	11.2	0.5	33.6	0.0
Latin American and the Caribbean	91.2	0.1	0.1	6.4	2.4
Global Average	59.8	15.2	1.2	22.2	2.4

Note: Estimation derived from latest available data from 122 countries, and extracted from the UNSD (2019), OECD (2019) and the World Bank (2018) "What a Waste 2.0" report. Years of data range from 2000 to 2016.
Incineration with energy recovery is often reported together with incineration without energy recovery as one combined category in waste databases, including at UNSD and the World Bank. Waste data reported by the OECD is the only data accounting for incineration with and without energy recovery. The percentage for incineration with energy recovery includes countries from the OECD with reported data, and assumes countries with reported data from the UNSD and the World Bank that own thermal WtE plants incinerate MSW with energy recovery.
"Waste unaccounted for" refers to the percentage of waste without a reported waste treatment method.

Waste-to-Energy

Values of thermal WtE plants around the globe



Fonte: UNEP (2019). Waste-to-Energy: Considerations for Informed Decision-Making

Waste-to-Energy

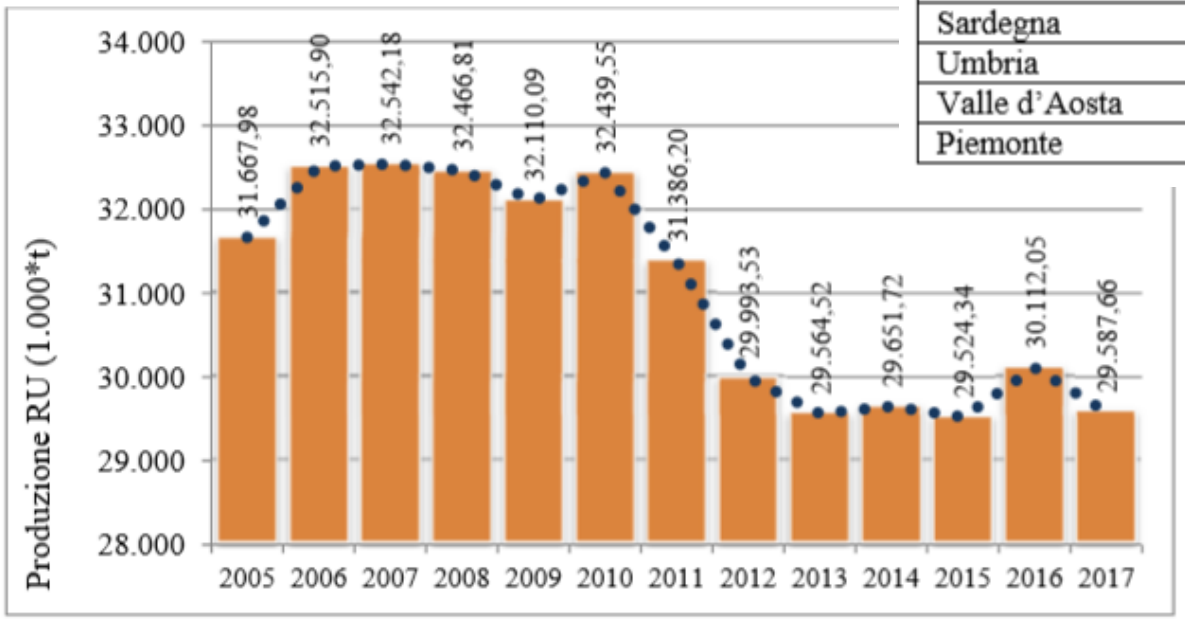
Thermal WtE plants capacity in Europe

	Total		Mining and quarrying	Manufacturing	Energy	Construction and demolition	Other economic activities	Households
	(million tonnes)	(kg per inhabitant)	(%)					
EU-28	2 502.9	4 931	28.1	10.2	3.7	34.7	14.9	8.3
Belgium	65.6	5 838	0.1	21.7	2.1	40.2	27.3	8.6
Bulgaria (1)	179.7	24 872	88.6	:	5.1	0.7	4.0	1.5
Czech Republic	23.4	2 223	1.0	18.8	4.3	40.2	21.8	13.9
Denmark	20.1	3 558	0.1	6.4	5.4	52.6	18.5	17.1
Germany	387.5	4 785	1.9	15.8	2.6	53.3	16.9	9.5
Estonia	21.8	16 587	36.3	20.2	32.6	3.1	5.6	2.2
Ireland (1)	15.2	3 285	17.8	:	2.1	12.4	57.6	10.0
Greece	69.8	6 404	67.9	7.0	15.6	0.7	2.3	6.5
Spain	110.5	2 378	16.9	13.4	4.8	18.5	28.3	18.3
France	324.5	4 913	0.7	6.7	0.5	70.2	13.1	8.8
Croatia (1)	3.7	879	0.1	:	3.2	16.6	48.9	31.2
Italy	159.1	2 617	0.6	16.7	2.0	32.5	29.5	18.6
Cyprus (2)	2.1	2 406	:	:	:	31.0	48.9	20.2
Latvia	2.6	1 315	0.2	9.4	27.8	17.3	18.3	27.1
Lithuania	6.2	2 114	0.4	42.1	1.6	7.0	30.1	18.7
Luxembourg	7.1	12 713	1.8	4.0	0.0	84.5	6.1	3.4
Hungary	16.7	1 688	0.5	16.2	13.9	20.7	31.0	17.7
Malta (1)	1.7	3 896	2.2	:	0.2	74.5	13.8	9.3
Netherlands	133.2	7 901	0.1	10.1	1.3	68.1	14.1	6.4
Austria	55.9	6 541	0.1	9.7	0.9	72.1	9.8	7.5
Poland	179.0	4 710	42.3	17.6	12.2	9.5	13.7	4.6
Portugal	14.6	1 402	1.9	17.9	1.2	10.3	36.3	32.3
Romania (1)	175.6	8 820	87.0	:	4.0	0.6	6.2	2.2
Slovenia	4.7	2 273	0.2	28.1	13.5	17.4	28.9	12.0
Slovakia (1)	8.9	1 636	3.2	:	6.1	15.6	55.4	19.6
Finland	96.0	17 572	65.4	10.7	1.5	17.0	3.7	1.7
Sweden	167.0	17 226	83.2	3.4	1.1	5.3	4.5	2.5
United Kingdom	251.0	3 885	10.5	3.2	1.3	48.0	26.0	11.0
Iceland (3)	4.5	1 651	0.0	17.6	0.3	2.1	36.1	44.0
Liechtenstein	0.6	14 919	1.7	2.0	0.1	0.0	0.4	95.9
Norway (1)	11.7	2 283	2.8	:	1.3	23.0	52.7	20.3
Montenegro	1.2	1 872	22.5	5.2	31.7	9.2	15.3	16.1
FYR of Macedonia	2.2	1 058	3.4	67.9	23.3	0.5	4.9	0.0
Serbia	49.1	6 890	84.5	1.8	9.1	0.6	0.7	3.3
Turkey (4)	73.1	947	4.2	:	32.8	:	20.2	42.8
Bosnia and Herzegovina (3)	0.5	1 161	1.6	27.2	71.1	0.0	0.0	0.0
Kosovo (UNSCR 1244)	1.0	574	19.3	7.0	0.0	0.3	26.3	47.0

(1) Other economic activities includes also manufacturing.
(2) Other economic activities includes also mining, quarrying, manufacturing and energy.
(3) 2012.
(4) Other economic activities includes also manufacturing, construction and demolition.
Source: Eurostat (online data code: env_wasgen)

Waste-to-Energy
Thermal WtE plants capacity in Italy

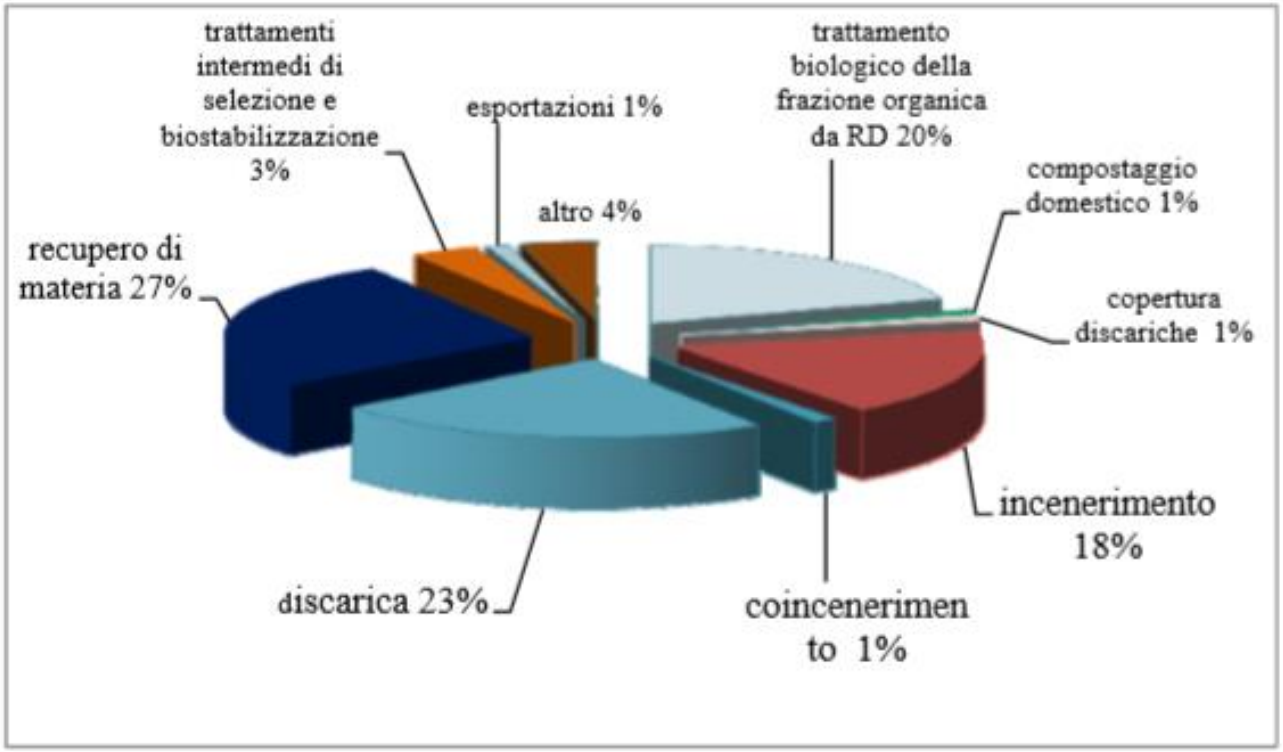
Percentuale raccolta differenziata rifiuti urbani per Regione 2017	
Veneto	73,6%
Trentino Alto Adige	72,0%
Lombardia	69,6%
Friuli Venezia Giulia	65,5%
Emilia Romagna	63,8%
Marche	63,2%
Sardegna	63,1%
Umbria	61,7%
Valle d'Aosta	61,1%
Piemonte	59,3%



Fonte: ISPRA – Rapporto Rifiuti 2018

Waste-to-Energy

Thermal WtE plants capacity in Italy

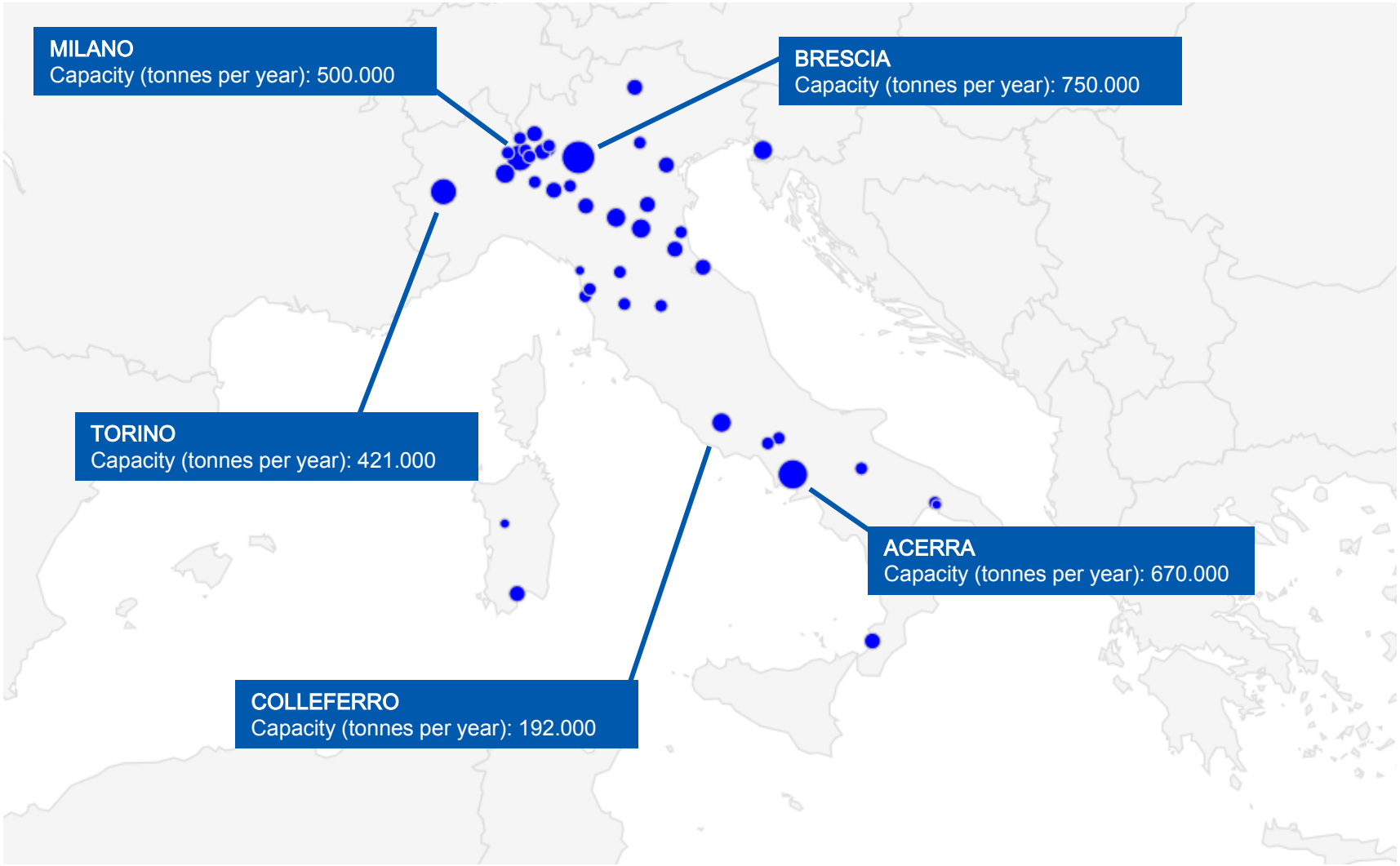


Not all regions are equipped with the necessary waste treatment facilities. The lack of facilities means that in many territorial contexts there is a transfer of waste collected to other regions or abroad. Urban waste produced in 2017 was managed in 644 facilities. Landfill disposal, amounting to 6.9 million tons, affects 23% of urban waste produced, showing a reduction of 6.8%. The operational landfills, in 2017, are 123, 11 less than the previous year.

Fonte: SPRA – Rapporto Rifiuti 2018

Waste-to-Energy

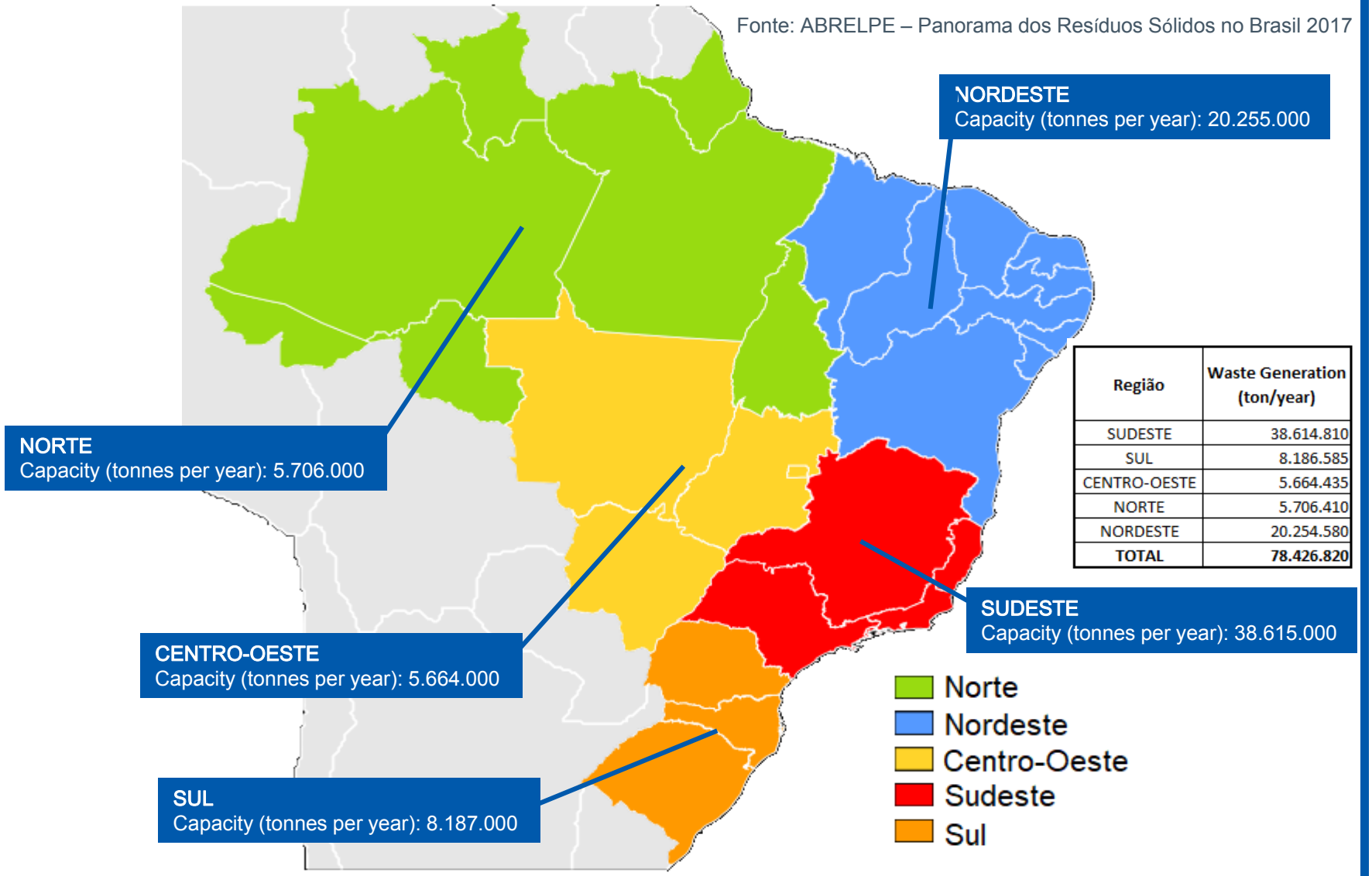
Thermal WtE plants capacity in Italy



Fonte: Confederation of European Waste-to-Energy Plants (2017)

Waste-to-Energy
Values of waste in Brazil

Fonte: ABRELPE – Panorama dos Resíduos Sólidos no Brasil 2017



Região	Waste Generation (ton/year)
SUDESTE	38.614.810
SUL	8.186.585
CENTRO-OESTE	5.664.435
NORTE	5.706.410
NORDESTE	20.254.580
TOTAL	**78.426.820**

Waste-to-Energy
Values of waste in Brazil

REGIÃO	MUNICÍPIOS	Geração de Resíduos (ton/ano)	Waste-to-Energy	
			Potência (MW)	Geração (MWh/ano)
SUDESTE	228	19.667.322	1.324	7.946.393
SUL	139	4.387.894	295	1.772.887
CENTRO-OESTE	60	3.222.113	217	1.301.864
NORTE	15	1.851.864	125	748.228
NORDESTE	80	6.520.858	439	2.634.690
TOTAL	**522**	**35.650.051**	**2.401**	**14.404.061**

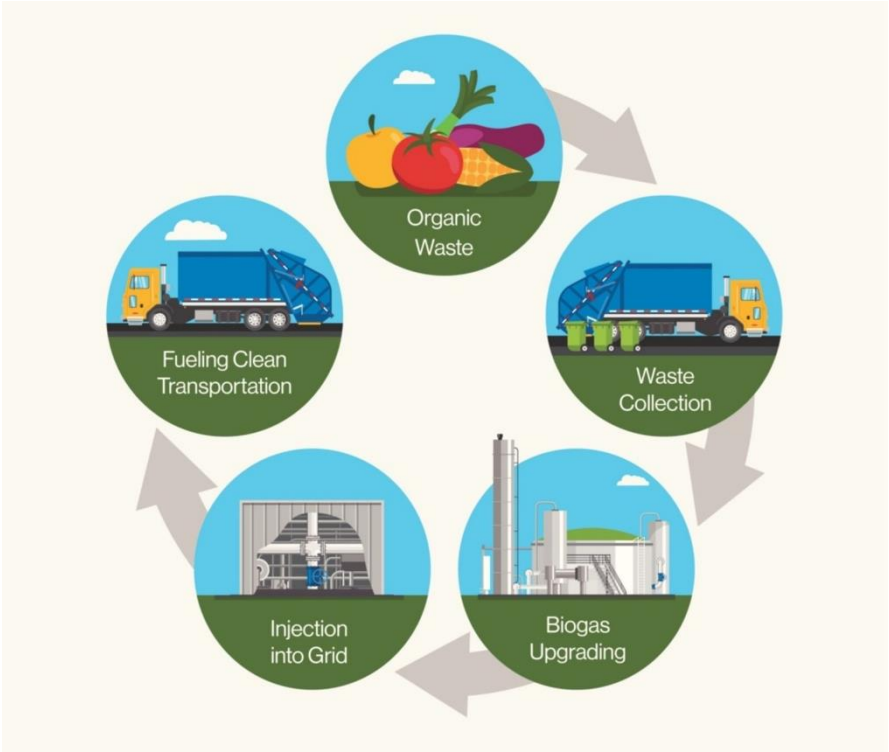
Fonte: Ecogerma 2015 – Waste to Energy: Uma alternative viável para o Brasil

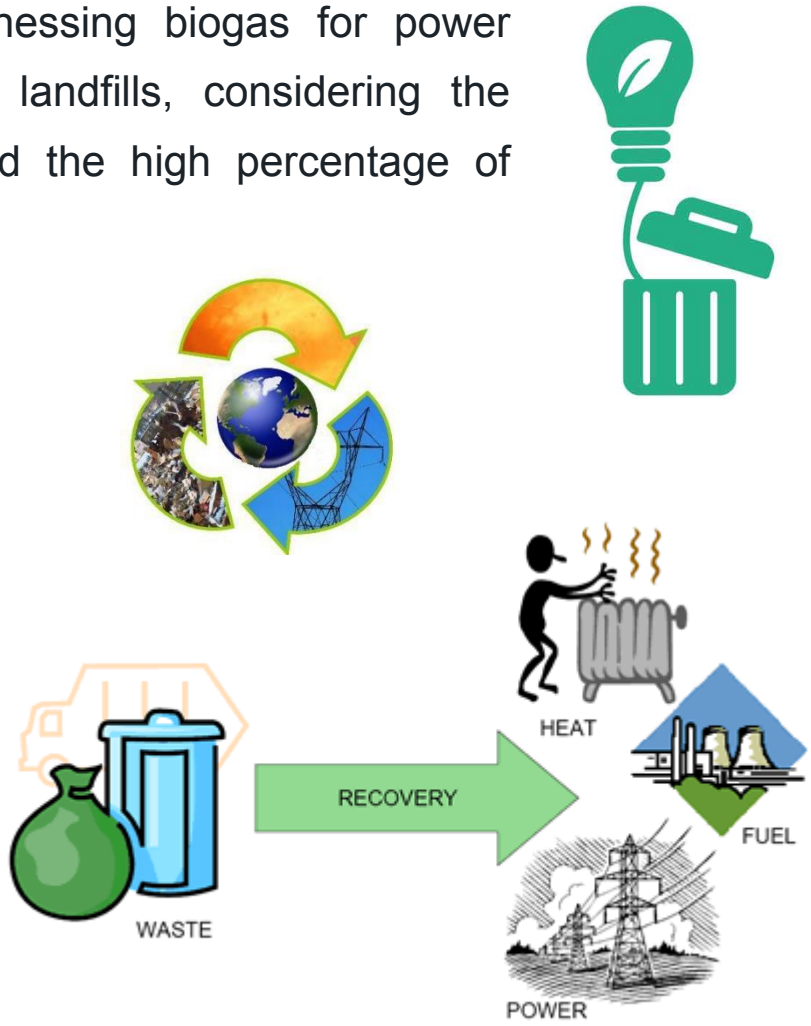
Only Brazil's metropolitan regions have sufficient scale to deploy Waste-to-Energy technology. The estimated total potential is 2.4 GW (1.85% of the national matrix), with an annual generation of 14,400 GWh (2.74% of the total generation). The availability factor for this type of energy is over 80% and its main characteristic is the distributed generation close to the consumers. The amount collected in 2017 was 71.6 million tons, recording a collection coverage rate of 91.2% for the country, which shows that 6.9 million tons of waste were not collected and, consequently, had an inappropriate destination.

Fonte: ABRELPE – Panorama dos Resíduos Sólidos 2017

Waste-to-Energy
Conclusion

Brazil has considerable potential for harnessing biogas for power generation or biomethane in its various landfills, considering the significant volume of MSW generated and the high percentage of organic matter (52%) contained in it.





Fonte: Ecogerma 2015 – Waste to Energy: Uma alternative viável para o Brasil

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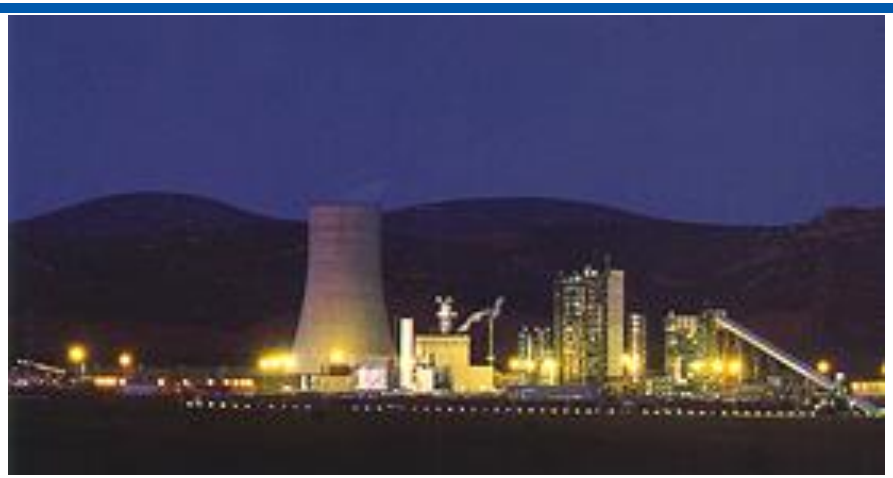
SECTION 3: CASE STUDY

Waste-to-Energy
Puertollano Project

Puertollano IGCC project has been financed EC, a pool of European Utilities and industrial technology developer (Siemens, Babcock, Krupp). Support from technologic



The project had three secondary goals:

- To use the secondary product of a oil refinery located in the area
- To revitalize a coal mine located in the area
- To develop a new gasification process – PRENFLO

Waste-to-Energy
Puertollano Project Data

The design (should) ensures:

- Use of waste refinery production
- Low generation variable cost
- Low gaseous emissions
- Very low solid and liquid waste production

Main design data

Fuel

	COAL	PET COKE	FUEL MIX (50:50)
Moisture (%w)	11.8	7.00	9.40
Ash (%w)	41.10	0.26	20.68
C (%w)	36.27	82.21	59.21
H (%w)	2.48	3.11	2.80
N (%w)	0.81	1.90	1.36
O (%w)	6.62	0.02	3.32
S (%w)	0.93	5.50	3.21
LHV (MJ/kg)	13.10	31.99	22.55

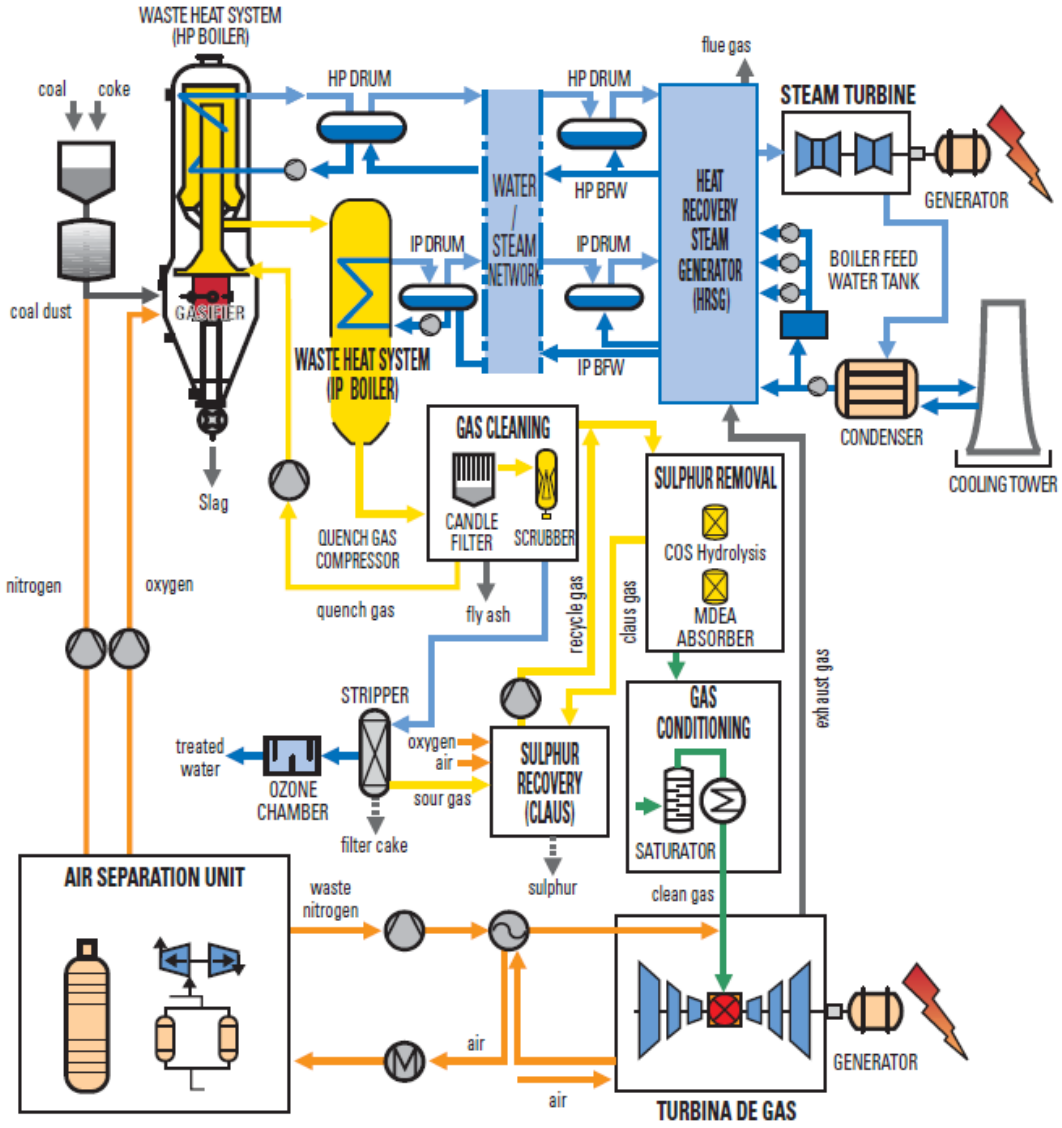
POWER OUTPUT	GAS TURBINE (MW)	STEAM TURBINE (MW)	GROSS TOTAL (MW)	NET TOTAL (MW)
	182.3	135.4	317.7	282.7

EFFICIENCY (LHV)	GROSS	NET
	47.12%	42.2%

EMISSIONS	g/kWh	mg/Nm^3 (6% Oxygen)
SO_2	0.07	25
NO_x	0.40	150
Particulate	0.02	7.5

Power output and emissions

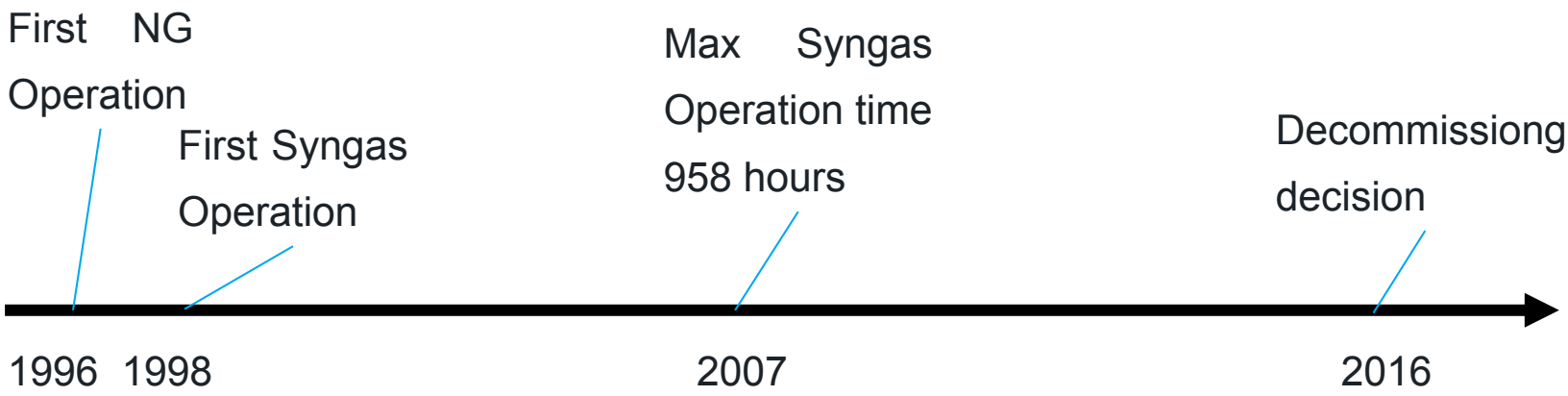
Waste-to-Energy
Puertollano Project Data



Very complex plant design has been necessary in order to:

- Manage the (very low) quality of the fuels
- Implement a full integrated process
- Comply with the target limit for air, liquid and solid emissions

Waste-to-Energy
Puertollano Project History



During all the plant life serious availability issues affected the operation, with consequent economic losses (start-up cost are very high) and operation limitation (minimum technical load quite high). Although its advantages in relation to plant efficiency have been demonstrated, the total integration between the ASU and Combined Cycle involves, besides a greater level of complexity and a long and costly start-up sequence.

Even if these problems are quite “physiological” for a pilot project, the cut of production incentivization made impossible to continue the production.

Waste-to-Energy
Puertollano Project Lesson Learned

The story of this project provide the following, general, indication:

Use of the refinery waste/sub-product can be efficiently used for power generation. If correctly considered the environmental cost, this solution is cost-effective and provide positive contribution to emission (in Syngas operation variable cost at 18.01 €/MWh vs 59,97 €/MWh in Natural Gas operation in 2006).

This goal of the project have to be extremely focused. The use of the local coal required increased coast and complexity of the plant, main cause of the poor performance of the plant

Public administration should plan, address and support projects having positive returns for all the aspect of their community life (environment, occupation, economic growth), establishing clear and long term regulatory framework. Public-private partnerships can be the better solution to develop big project.

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Waste-to-Energy

Values of waste to energy production in Brazil

Production of waste-derived fuel (CDR) would require 86.5% of plastics and paper, resulting in 48.99 million tons of CDR in the base year.

Produção de CDR e disponibilidade de materiais - (Mt)

Disponibilidade de Material para CDR		*Material Restante após Produção de CDR*	
Matéria Orgânica	37,09	*Matéria Orgânica*	0,00
Papel	10,06	*Papel*	1,57
Plástico	6,71	*Plástico*	1,05
Vidro	-	*Vidro*	1,94
Metal	-	*Metal*	1,32
Outros	-	*Outros*	3,14
CDR	53,86		9,02

The electrical conversion efficiency considered was 20% and there is a specific production of 0.398 MWh/t of MSW, without accounting for the recycling of the remaining materials.

Potencial de Geração Elétrica

	Eletricidade (GWh)	*Capacidade (MW)*	*Unidades*
GDL	-	311	-
Incineração	236.520	3.176	106
Digestão Anaeróbica Acelerada	6.701	868	1.021

Fonte: EPE – Nota Técnica DEA 18/14 – Inventário Energético dos Resíduos Sólidos Urbanos

Waste-to-Energy
References

Confederation of European Waste-to-Energy Plants (CEWEP) - http://www.cewep.eu/

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Fonte: ABRELPE – Panorama dos Resíduos Sólidos no Brasil 2017