



**SYNERGIA
WTERT**
Ελλάς - Greece

Συμβούλιο Ενεργειακής Αξιοποίησης Αποβλήτων
Waste-to-Energy Research & Technology Council

Advancing the goals of sustainable waste management

Global Waste-to-Energy Research & Technology Council

“STATUS OF WTE WORLDWIDE”

Dr. Efstratios Kalogirou

President WTERT Greece – SYNERGIA

Vice Chair Global WTERT Council

3rd International Brainstorming Workshop on
“Sustainable Municipal Solid Waste Management in India,
29-30 January 2015, HYDERABAD, INDIA

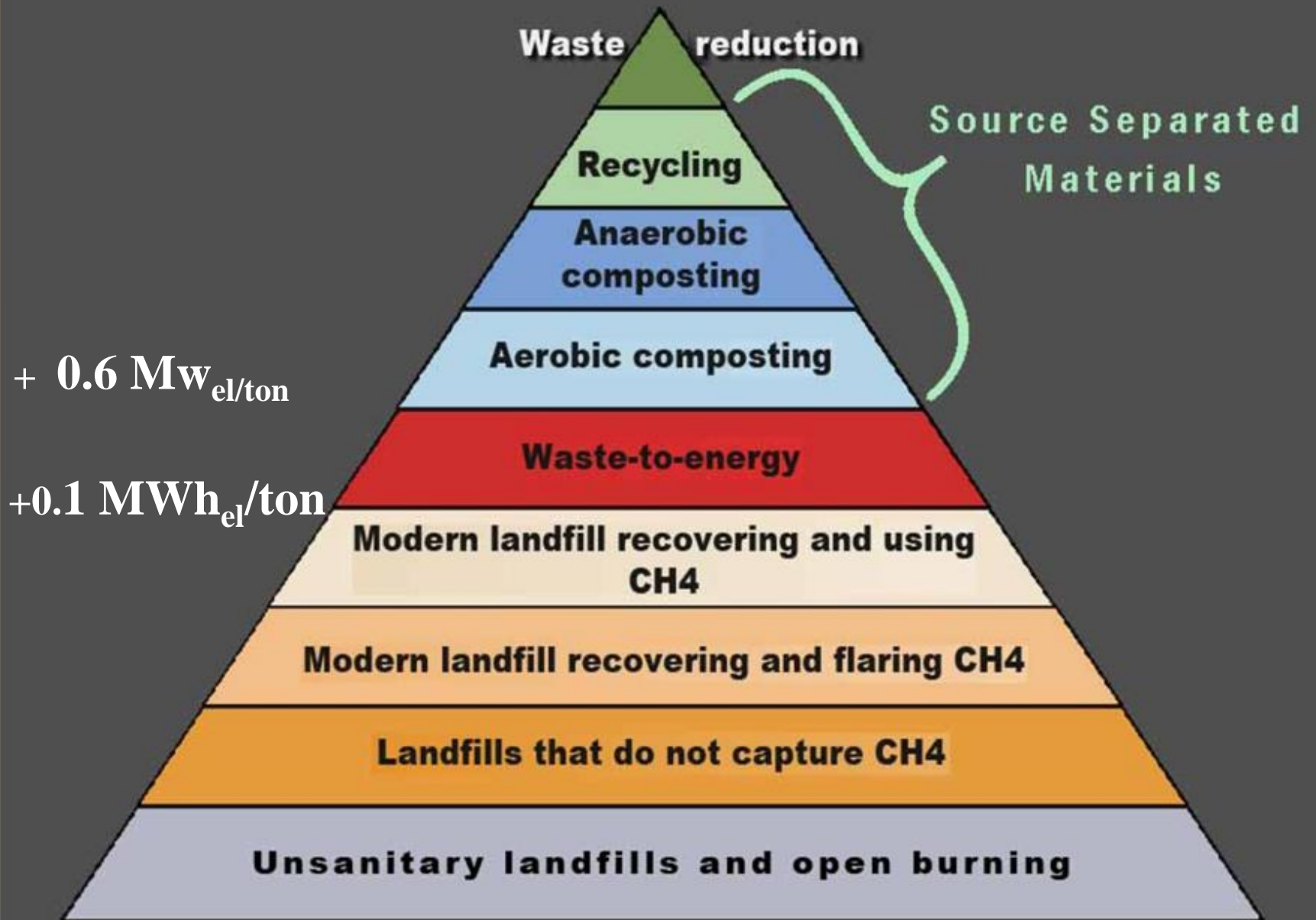


Mission of the Waste to Energy Research and Technology Council (WTERT)

WTERT was formed in 2002 EEC/CU, to promote all means of sustainable waste management by maximizing the recovery of materials and energy and minimizing the environmental impacts, on the basis of the scientific knowledge of the effects of various waste treatment technologies worldwide.

The accepted hierarchy of waste management dictates materials recovery followed by energy recovery (waste-to-energy) by means of thermal treatment, as used in more than **1000 WTE plants worldwide** (*460 in Europe, 90 in USA, and the rest in Asia and other parts of the world*).

The WERT Hierarchy of Sustainable Waste Management



The Global W'TERT Council (GWC)

The **Global W'TERT Council** has recently been formed. It will assist in the creation of new W'TERT national organizations and coordinate the activities of existing ones in achieving the common goal:

- to identify the best available technologies for the treatment of various waste materials
- to conduct additional academic research as required
- to disseminate this information by means of publications, the multilingual W'TERT web pages, and periodic meetings and conferences, at the national and international levels.

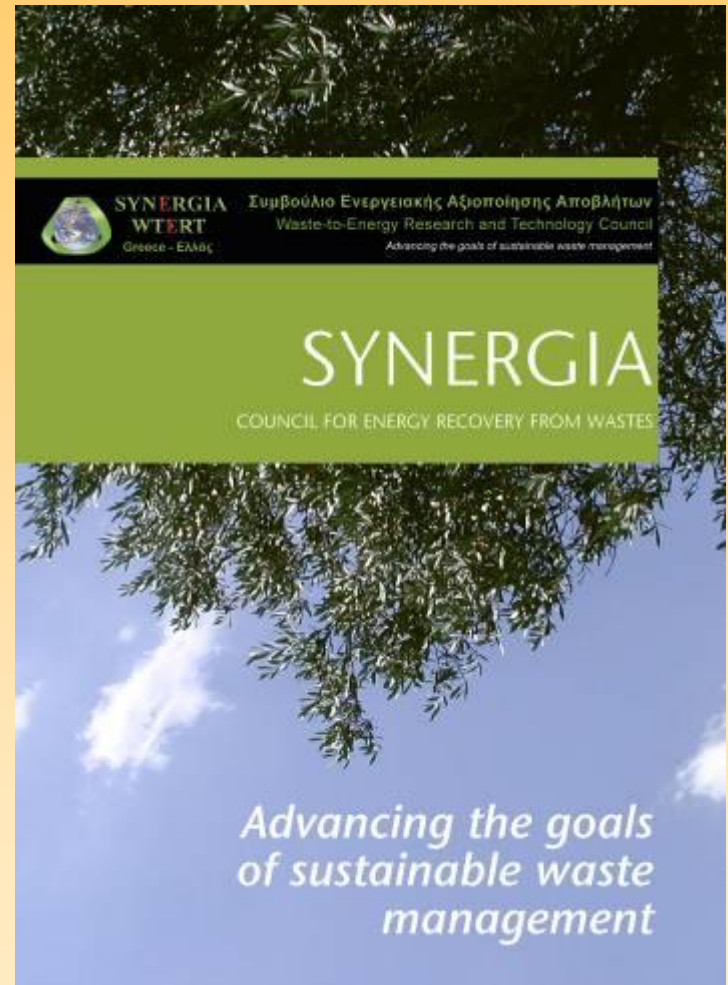
GWC will consist of the heads of the national W'TERT organizations. Its second meeting was held in conjunction with the next W'TERT-U.S. bi-annual meeting at **Columbia University (October 18-19, 2014)**.

WTERT Greece

WTERT Greece – SYNERGIA

The Waste-to-Energy Research and Technology Council (SYNERGIA, www.wtert.gr) was founded on July 2008 by the following founding members:

- The Earth Engineering Center of Columbia University, New York
- Members of the Thermodynamics and Transport Phenomena Laboratory, School of Chemical Engineering, National Technical University of Athens (N.T.U.A)
- Members of the Laboratory of Heat Transfer and Environmental Engineering, Department of Mechanical Engineering of the Aristotle University of Thessaloniki (A.U.TH.)



WTERT-Greece, SYNERGIA

www.wtert.gr

GLOBAL WTERT COUNCIL



www.wtert.org



<http://www.wtert.in>



www.mater.polimi.it/mater/



www.wtert.co.uk



www.wtert.ca



www.wtert.eu



www.wtert.cn



www.wtert.com.br



www.wtertuane.com.mx/



www.wtert.jp



New Entries: France, Singapore

Recent Participations of GWC in Congresses worldwide



10 June 2010: 2nd SYNERGIA FORUM in Athens

2014년 추계 총회 및 기술 WORKSHOP

폐기물과 바이오매스 에너지화의 최신 기술 및 상업화 적용

»일시 : 2014. 10. 22(수) 09:30 ~ 17:30

»장소 : 공주대학교

너지기술협의회, 공주대학교 에너지인력양성사업단, 연세대학교 폐자원 및 바이오매스에너지화특성화대학원사업단, 충남대학교 가연성폐자원에너지화특성화대학원



Recent participations of GWC in Congresses worldwide



18-22 June 2012: 1st International Sustainable Waste Management Workshop in Athens, co-organised by EEC Columbia University, SYNERGIA and AIT



Waste to Energy as an Integral Part of Sustainable Waste Management.

The case of Baku city, Azerbaijan

June 17-21, 2013 - Baku, Azerbaijan

Organizers:

"Tamiz Shahar" JSC

Earth Engineering Center (EEC) of Columbia University

WTERT-Greece/SYNERGIA

Duration:

5 days/28 Total Course hours

Key topics: Technical aspects, environmental benefits, and economic viability of Waste-to-Energy, Anaerobic Digestion, Mechanical-Biological Treatment, and Sanitary Landfilling.

Target Audience: Professionals in related industries, working in the environment field throughout the region, for government agencies, companies planning and executing waste projects and researchers, university students, as well as anyone wishing to take advantage of their understanding in this field

Advantages: The opportunity to widen knowledge on waste-to-energy technologies, to share experiences, to learn best practices and latest novelties in this field, a visit to Baku Waste-to-Energy Plant, Certificate of continuing education by the Earth Engineering Center of Columbia University, Certificate of completing course requirements satisfactorily by "Tamiz Shahar" JSC



BAKU WTE PLANT AZERBAIJAN

AVROPADA ƏN BÖYÜK TULLANTIDAN ENERJİYƏ ZAVODLARINDAN BİRİ

ONE OF THE BIGGEST WASTE-TO-ENERGY PLANTS IN EUROPE

İllik yandırma gücü

Bərk məqal tullantılar: 500 000 ton/illik
Təbii tullantılar: 10 000 ton/illik

Yandırma dərəcəsi: 850-1100 C
Azalacaq tullantı həcmi: 10 dəfə
Azalacaq tullantı çəkisi: 3 dəfə
Zavodun ümumi sahəsi: 20 ha

Annual incineration capacity

Municipal solid waste: 500 000 tonnes
Medical waste: 10 000 tonnes

Degree of combustion: 850-1100 C
Volume of reduced waste: tenfold
Weight of reduced waste: threefold
Total area of the plant: 20 ha



İllik istehsal olunan enerji
50 000 evin istehlak ehtiyacına bərabərdir

Energy produced annually: equals the
consumption of 50 000 households

4G texnologiyaları əsasında qurulan zavod Avropa Birliyinin
ətraf mühit sahəsində ən sərt normativlərinə cavab verir

The plant constructed using 4G technologies is completely compliant with the
most stringent European standards of environmental protection.



təmiz
şəhər

ENIM



Technical Visits of GWC in WTE Plants



Presentation of GWC at Panama City



BAKU, SWM seminar 2013



Meeting at sister organization Mater/Italy

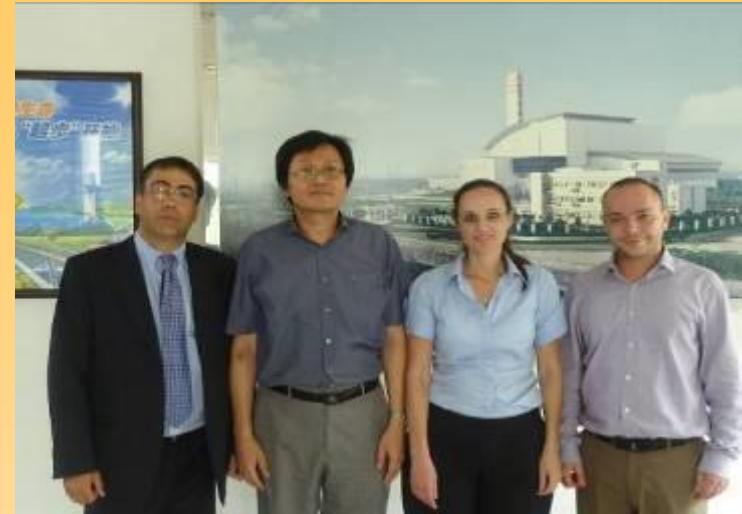


WTE Seminar in Tsinghua University

International WTE Technical Visits



Barcelona, Tersa WTE Plant



Pudong (SHANGHAI, WTE Plant)



WTE Seminar at Yonsei Univ. Korea



Flue Gas Cleaning in Suzhou WTE Plant

Technical Visits of GWC in WTE Plants



25 – 26 February
2010: Acerra/Naples
WTE Plant in Italy
covering
electricity needs for
230,000 families

Naples WTE Plant

Estimated global disposition of urban post-recycling municipal solid wastes (total: 1.2 billion tons; 2012)

- **Thermal treatment (WTE): 200 mill. tons**
- **Sanitary landfill, partial CH₄ recovery: 200 mill. tons**
- **Landfilled without CH₄ recovery: >800 mill. tons**

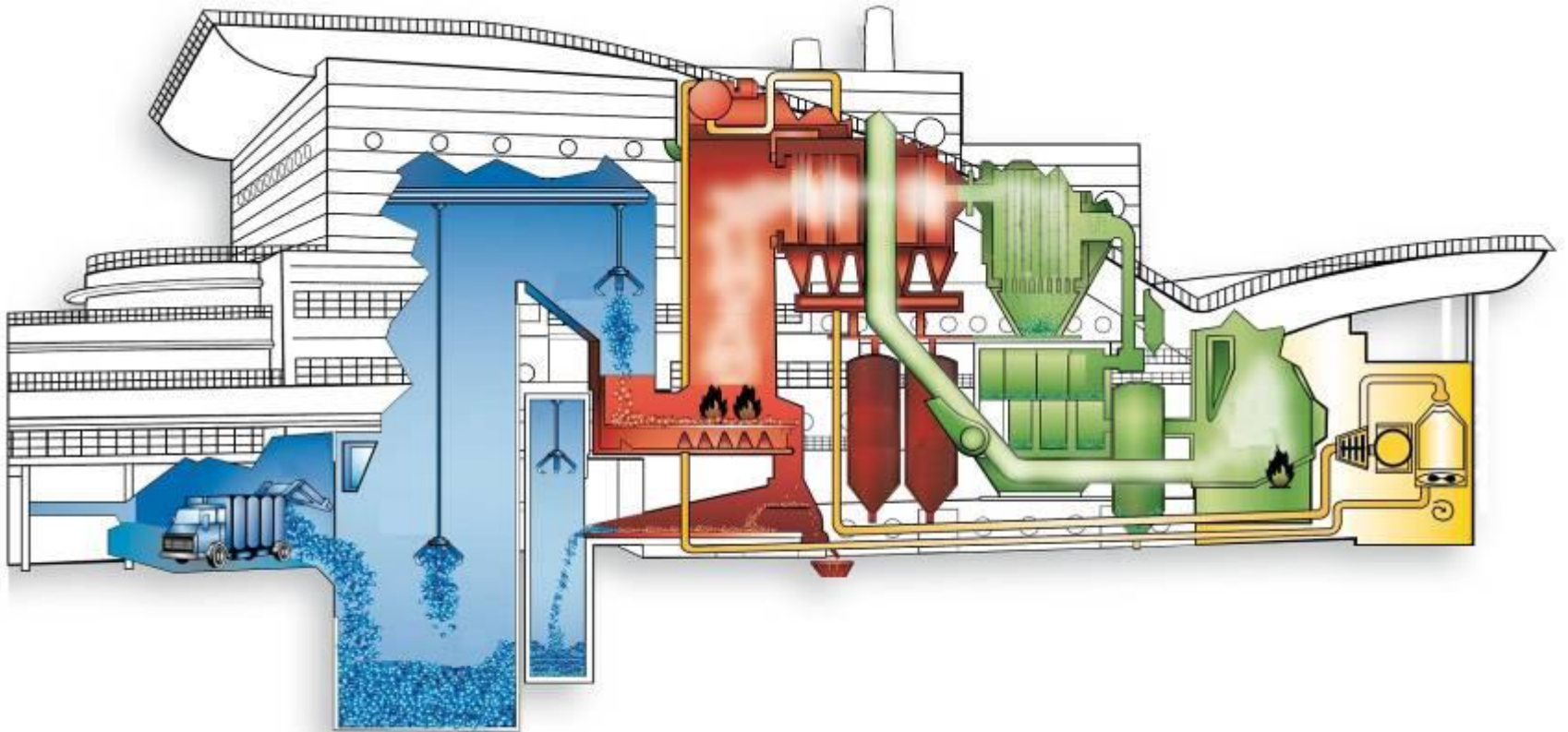
Estimated land use for sanitary landfilling: 10 tons MSW/m²

GWC – Achievements

- New Renewable Energy Sources Law **3851/2010** regarding the electricity price from WtE **87,85€/MWh**, for the biodegradable fraction of MSW. This way a very competitive gate fee is achieved, which will make WtE attractive for international investors
- Advising local decision makers in Brazil to apply law number 12.305/2010, which will establish WtE as a Renewable Energy Source.
- **SYNERGIA**, in cooperation with **WTERT/US** and **WTERT/China** advised the policy makers to change the dioxin/furan emissions limit to **0.1 ng/Nm³** (EU standards), helping the country develop state of the art WtE plants.

Waste-to-Energy in Europe

Typical WTE Plant



WTERT-Greece, SYNERGIA

www.wtert.gr

GUIDEBOOK

FOR THE APPLICATION OF WASTE TO ENERGY TECHNOLOGIES IN LATIN AMERICA AND THE CARIBBEAN

**NICKOLAS J. THEMELIS, MARIA ELENA DIAZ BARRIGA,
PAULA ESTEVEZ, AND MARIA GAVIOTA VELASCO**

EARTH ENGINEERING CENTER, COLUMBIA UNIVERSITY



JULY, 2013

*EXECUTIVE SUMMARY PRINTED ON THE OCCASION OF THE
COLUMBIA GLOBAL CENTERS WORKSHOPS IN RIO DE JANEIRO
(AUGUST 29, 2014), AND SANTIAGO DE CHILE (SEPTEMBER 1,
2014)*

*The full Guidebook (228 pp.) can be downloaded from:
<http://www.seas.columbia.edu/earth/wtert/wpublication.html>
(titled: "WTE Guidebook for Latin America and the Caribbean")*

Reasons for dominance of grate combustion

- **Simplicity of operation**
 - **Very high plant availability**
 - **Low personnel requirement (<70 for a one-million tons/year plant) and ease of training of people in existing operating plants**
-

BAT issues coverage:

Waste input, storage, handling, pretreatment

Combustion + operating conditions

Flue Gas Treatment: design and operation

Emission levels

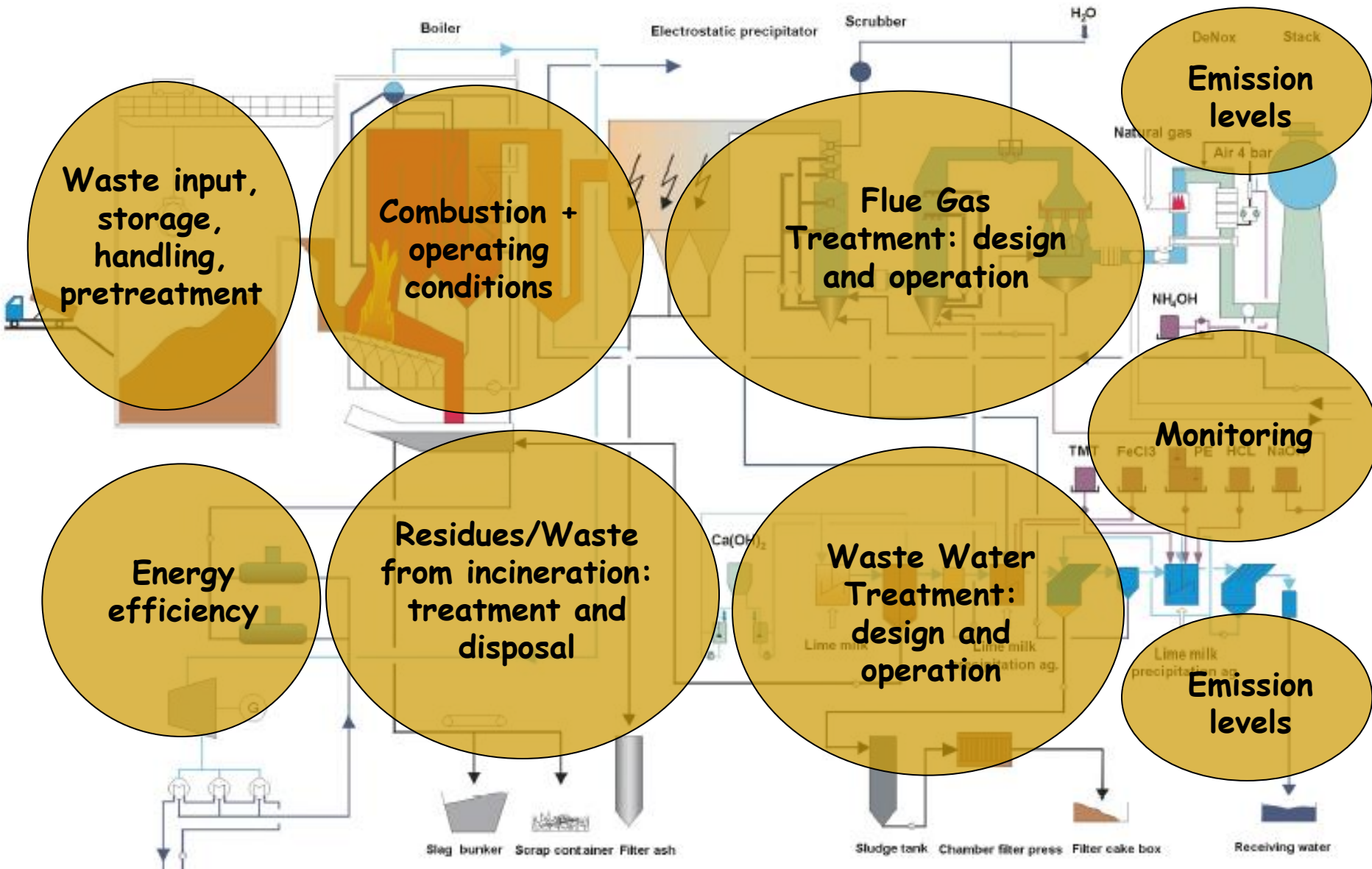
Energy efficiency

Residues/Waste from incineration: treatment and disposal

Waste Water Treatment: design and operation

Monitoring

Emission levels



Methods of Thermal Treatment

- **Gasification:** Very energy intensive, not available yet on a large commercial scale, untested in mixed municipal solid waste. Very few units of low capacities operational (more in Japan). Plasma gasification shows much more promise but lacks big references.
- **Pyrolysis:** Hasn't been used efficiently in municipal solid waste (reference in tyres, etc.)
- **Incineration:** Proven, dominant, tested on a large scale (over 1000 units worldwide), efficient, waste management process



Europe

Waste-to-Energy in Europe Legislation

- According to the **European Union legislation** for sanitary landfills **1999/31** only residues of waste management can be disposed to landfills, **whereas by 2020** there will be a gradual reduction of the biodegradable fraction that is landfilled
- According to the European Union directive **2000/76** (the emission limits of Waste to Energy plants are set). New Directive **2010/75**
- On the 19th of November 2008 according to the EU **directive 2008/98**, WTE is upgraded in the hierarchy of Solid Waste Treatment in Europe.

Waste-to-Energy in Europe

Waste-to-Energy Cycle

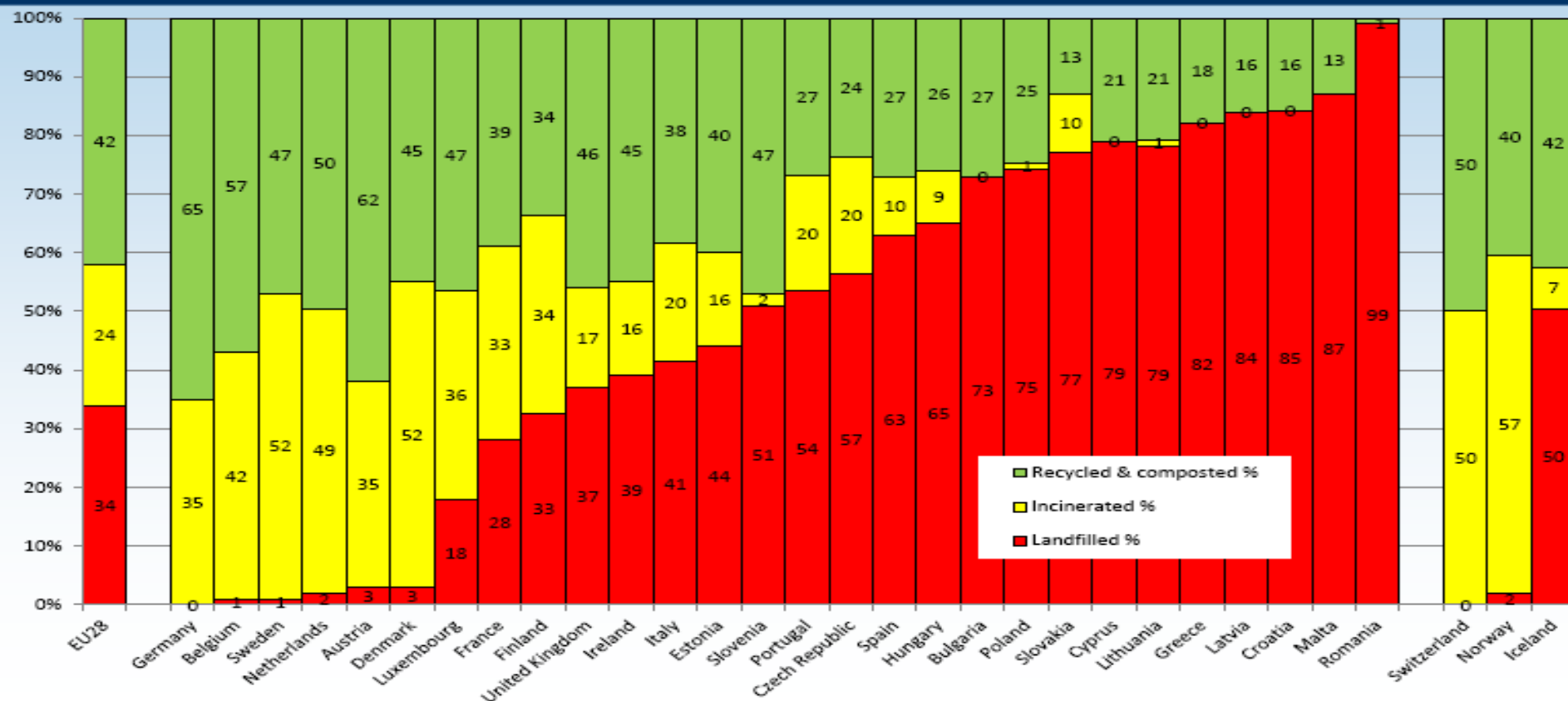


Municipal waste treatment in 2012

EU 28 + Switzerland, Norway and Iceland



Graph by CEWEP, Source: EUROSTAT 2012



In the E.U., recycling is excellently combined with waste to energy, whereas in countries where landfill is dominant, recycling and waste to energy are lagging behind

WTE Plants in Europe

Waste-to-Energy in Europe in 2012

- Waste-to-Energy Plants operating in Europe (not including hazardous waste incineration plants)
- Waste thermally treated in Waste-to-Energy plants in million tonnes



Data supplied by CEWEP members unless specified otherwise

* From EUROSTAT

** Includes plant in Andorra



International WTE PLANT, The case of BARCELONA



*Barcelona, Tersa WTE Plant
with district heating & district cooling*

Energy recovery from “wastes” (waste-to energy or WTE) is equivalent to recycling (E.U.)

- Today, several countries such as Japan, Austria, Switzerland, Germany, the Netherlands, Korea and Singapore use WTE as the main process for treating **post-recycling** municipal solid wastes (MSW).
-

There are only two options for managing post-recycling wastes: Sanitary landfill or thermal treatment (WTE)

WTE advantages:

- **Conservation of land near cities**
- **Energy recovery: 0.5 MWh/ton, over LFG recovery**
- **Reduction of Greenhouse Gas (GHG) emissions: 0.5-1 ton CO₂ per ton MSW (vs landfilling)**
- **Esthetically more acceptable to communities; in fact only acceptable option in most developing countries.**

Waste-to-Energy as Renewable Energy Source

- Waste-to-Energy will contribute in achieving the goals set by the European Union regarding the **production of energy from Renewable Energy Sources**, as the biodegradable part of the MSW is considered biomass (Directive 2009/28), thus R.E.S.
- According to international practice Waste-to-Energy plants are considered R.E.S., according to the percentage of biomass contained in the incoming waste, i.e. its biodegradable fraction. The examples of several countries are shown in the following table (Data from CEWEP)

Waste-to-Energy Plants as R.E.S.

Austria	50%	Ireland	72%
Belgium	47,78%	Italy	51%
Denmark	80%	Netherlands	51%
France	50%	Switzerland	50%
Germany	50%	Portugal	Calculated from empirical equation

Waste management in USA

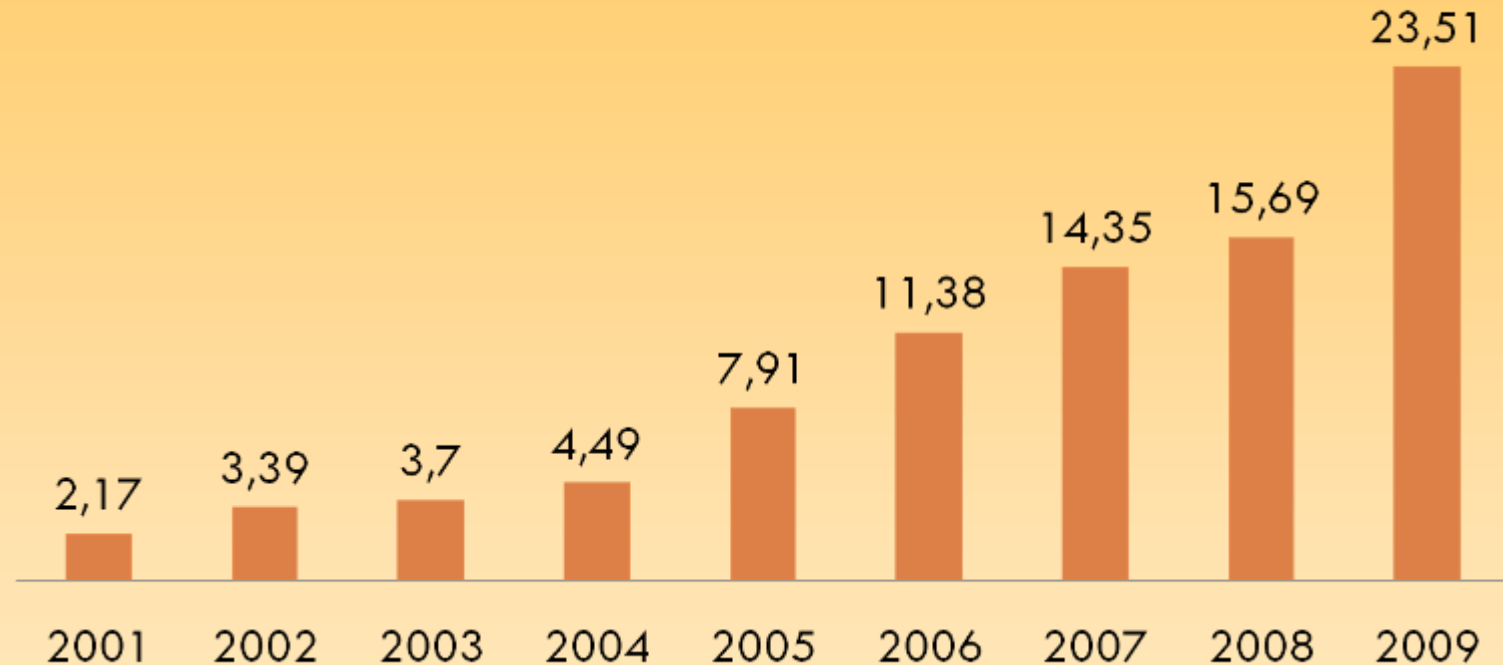




ASIA

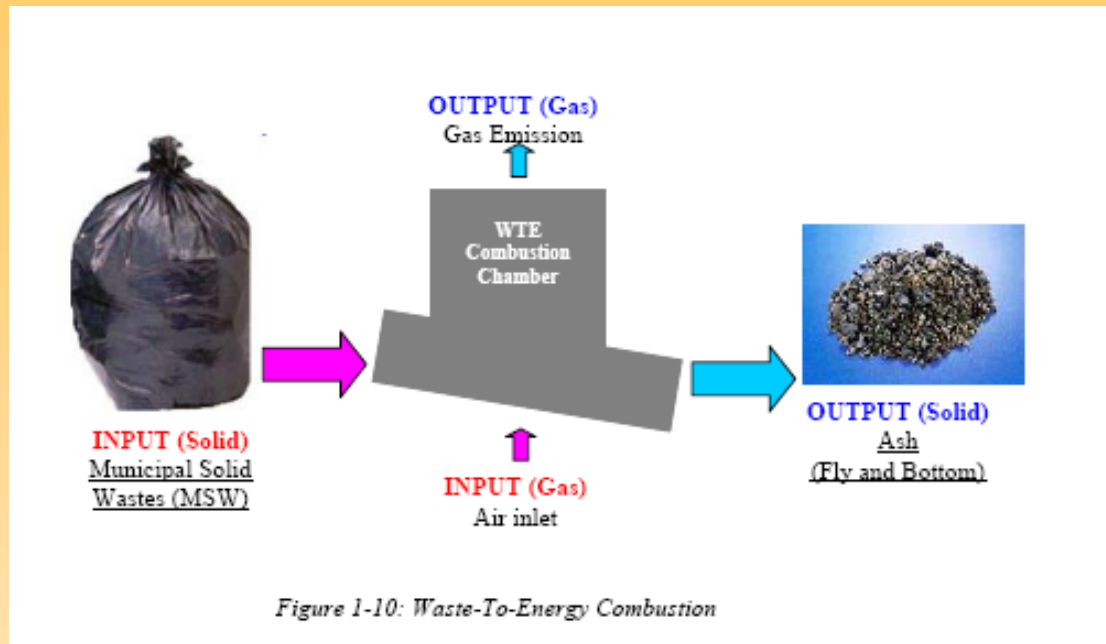
Waste-to-Energy in China

Total WTE capacity, million tons/y



China has become the fourth largest user of waste-to-energy (WTE), after E.U., Japan, and the U.S.

Technology of WTE in China



Combustion system	Number of plants	Total capacity, tons/day	Capacity distribution
Stoker grate, imported	56	47,585	50%
Stoker grate, domestic	20	12,885	17%
Circulating Fluidized Bed(CFB)	37	31,920	33%
Total	113	92,390	100%

MSW Composition

	Organic	Paper	Plastic	Glass	Metal	Textile	Wood	Ash
China (2003)	52.6	6.9	7.3	1.6	0.5	4.7	6.9	19.2
USA (2005)	25.0	34.0	12.0	5.0	8.0	-	-	-
France (2005)	32.0	20.0	9.0	10.0	3.0	-	-	-
Australia (2005)	47.0	23.0	4.0	7.0	5.0	-	-	-

Features



High organic content



High moisture content

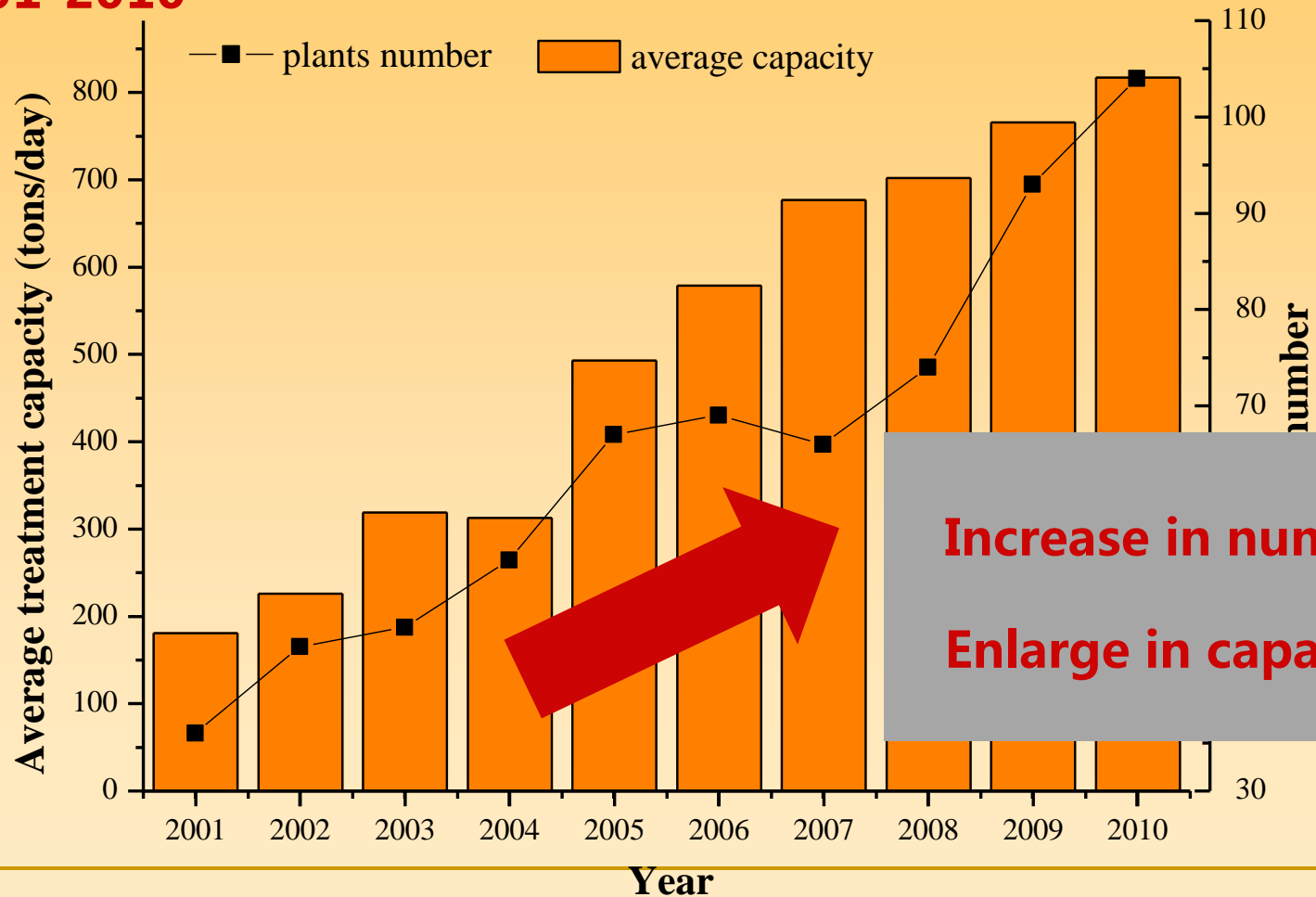


Low heating value



WTE Number & Capacity

2001-2010



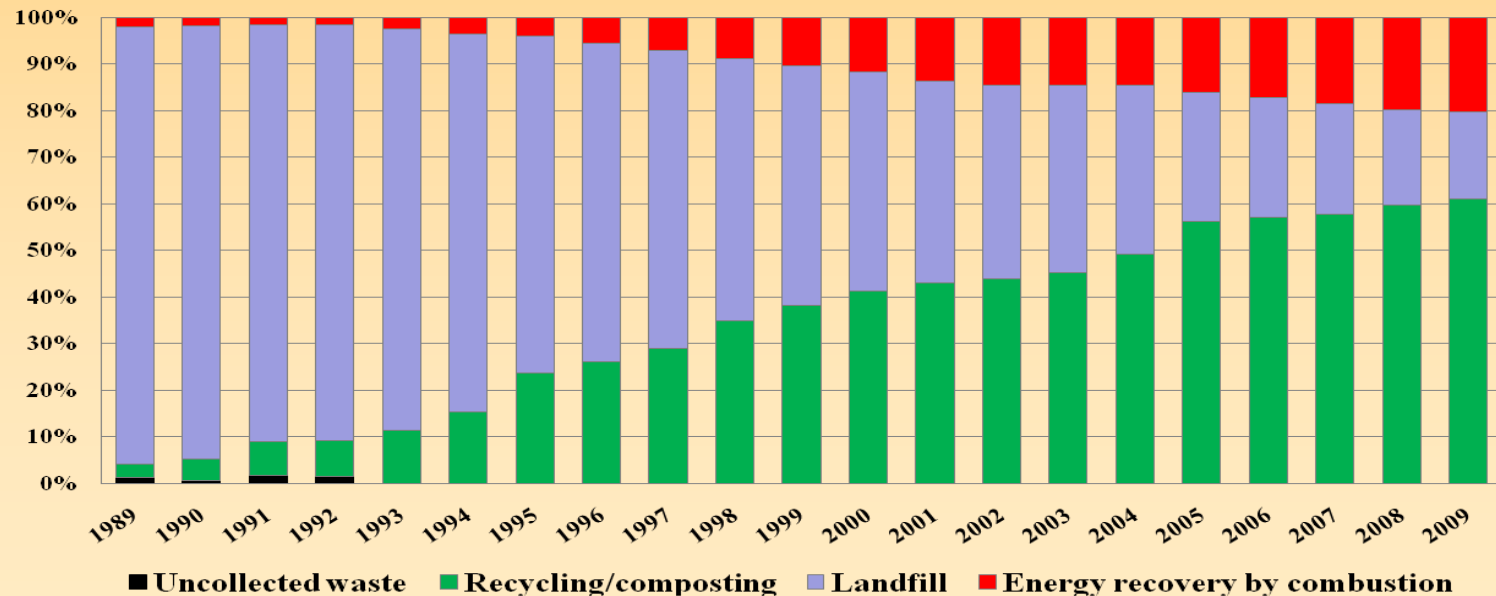
WTE Tendency

- ◆ Renewable energy law and policy promote WTE electricity selling price (2007) :
WTE = fossil fuel power plant + 0.25 ¥ RMB
- ◆ Increased MSW capacity for WTE plant: **800-1000 t/d** (under design and construction)
- ◆ Increased incineration proportion to **35%** by the end of 2016, with **48%** in eastern region



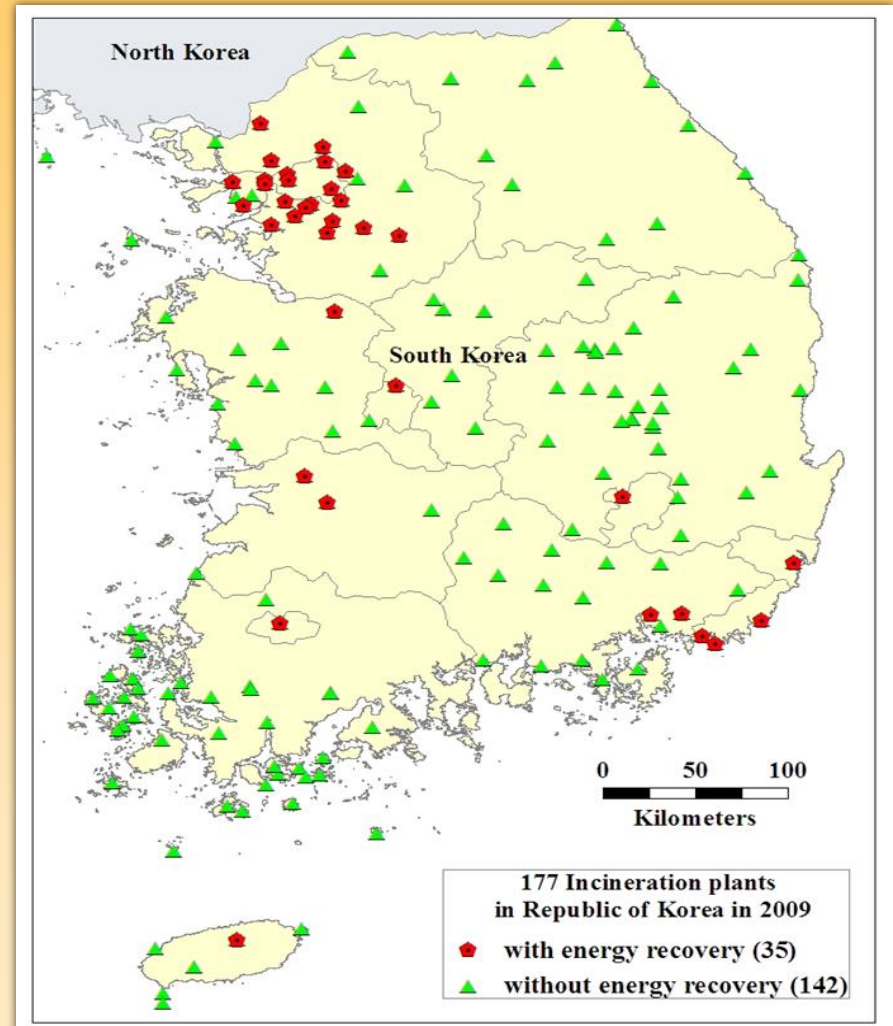
Trends in MSW treatment in the Republic of Korea (1989 – 2010)

- Energy recovery by combustion has increased from 2% (0.5 million tons) to 20% (3.8 million tons).
- Recycling/composting has also increased from 3% (0.8 million tons) to 61% (11.4 million tons)
- Landfilling has been drastically reduced from 94% (26.8 million tons) to 19% (3.5 million tons).



Waste Incineration Plants in the Republic of Korea

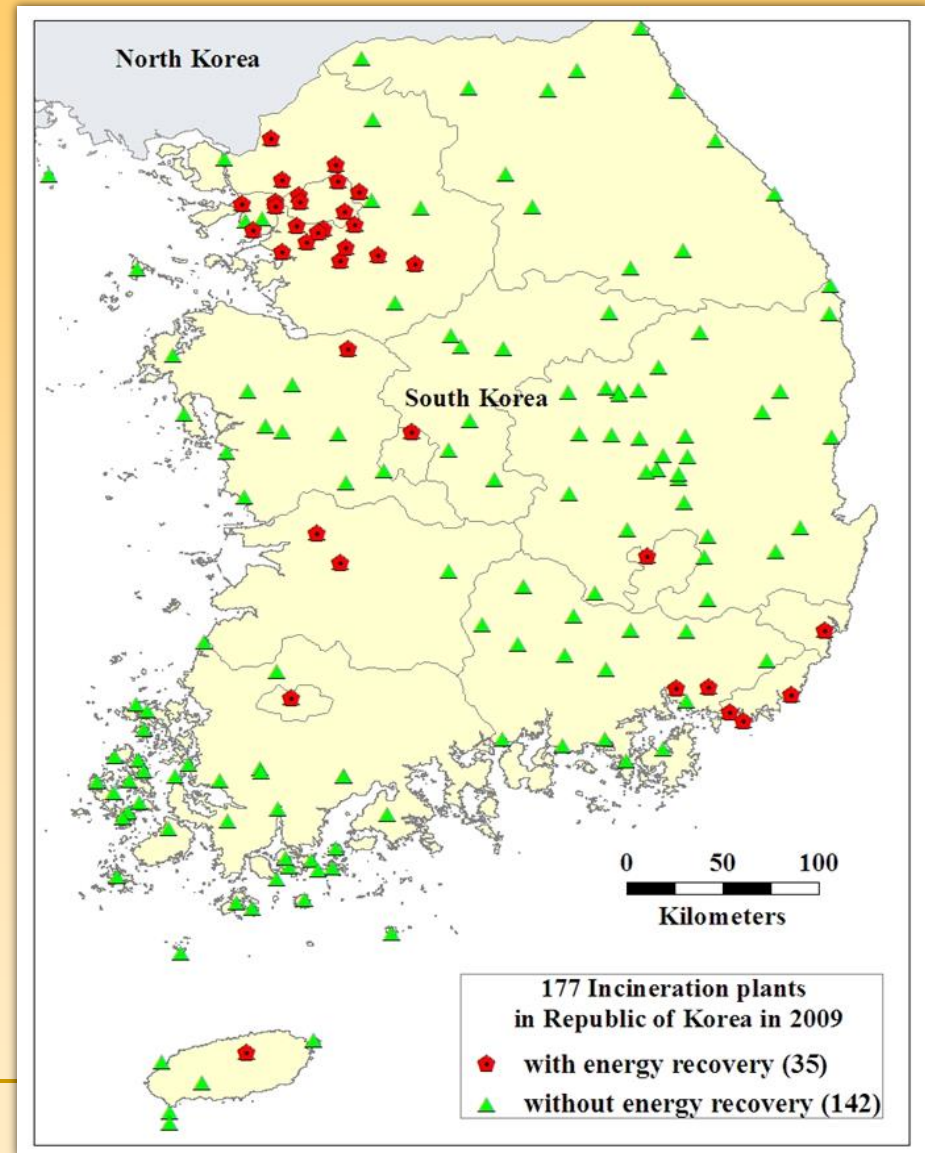
- 35 large incinerators (in red symbols), mostly using grate-type furnaces
- Heat supply 4.4 million MWh and electricity generation 0.2 million MWh



Waste Incineration Plants in the Republic of Korea

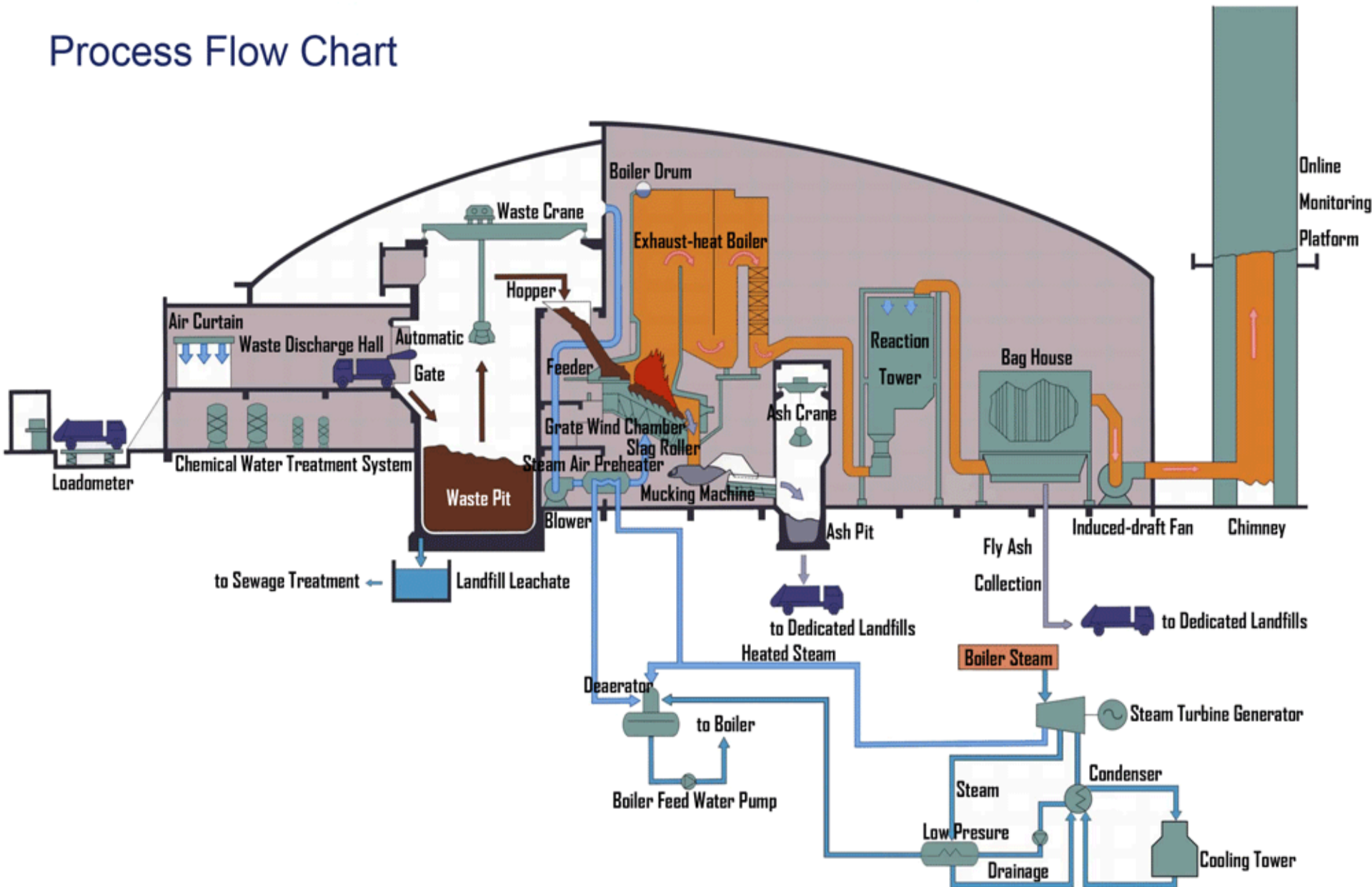
- WTERT-Korea sister organization is being developed under the leadership of Prof. Yong-Chil Seo of Yonsei University, Republic of Korea.

<http://www.wtert.kr>



700 TPD Phuket Waste Incineration Plant

Process Flow Chart



700 TPD Phuket Waste Incineration Plant

- Plant Location : Phuket City Municipality
- Capacity : 2 x 350 TPD with 14 MWe (Turbine Generator Rated)
- Technology : Stoker Incinerator + Steam Turbine-Generator + SDR + Bag Filter
- Contract : BOT for 15 yr and can re-contract for another 15 yr

Japan: Leader in use of older and newer technologies

Moving grate: 84%	No. of plants	Total tons per day	Average tons/day	% of Japan WTE capacity
Martin reverse acting grate (66 plants)	66	71,500	1083	62%
JFE Volund grate (54 plants)	54	10,100	187	9%
Martin horizontal grate (14 plants)	14	7,454	532	7%
Nippon Steel Direct melting (28 plants)	28	6,200	221	5%
JFE Hyper Grate (17 plants)	17	4,700	276	4%
Rotary kiln (15 plants)	15	2,500	167	2%
JFE Thermoselect (gasification; 7 plants)	7	1,980	283	2%
All other fluid bed (15 plants)	15	1,800	120	2%
Ebara fluid bed (8 plants)	8	1,700	213	1%
JFE Direct Melting (shaft furnace, 14 plants)	14	1,700	121	1%
Hitachi Zosen fluid bed (8 plants)	8	1,380	173	1%
JFE fluid bed (sludge & MSW; 9 plants)	9	1,300	144	1%
All other Direct Melting (9 plants)	9	900	100	1%
Fisia Babcock grate (2 forward, 1 roller)	3	710	237	1%
Babcock & Wilcox (43 plants)	43	690	16	1%
Total	310	114,614		100%
Total tons/year (330 days, 24 hour operation)		37,822,620		

Emission levels in Waste to Energy

Emissions from the Brescia plant, Italy

All units are in mg/Nm ³ The values correspond to dry air, normal conditions, 11% O ₂	Plant authorization limits 1993	Design Plant limits 1994	European Union Limits 2000	Actual Operating Data 2005
Particulate matter	10	3	10	0,4
Sulphur Dioxide	150	40	50	6,5
Nitrous Oxides (NO _x)	200	100	200	<80
Hydrochloric Acid (HCl)	30	20	10	3,5
Hydrofluoric Acid (HF)	1	1	1	0,1
Carbon Monoxide	100	40	50	15
Heavy Metals	2	0,5	0,5	0,01
Cadmium (Cd)	0,1	0,02	0,05	0,002
Mercury (Hg)	0,1	0,02	0,05	0,002
Polycyclic Aromatic Hydrocarbon (PAH)	0,05	0,01		0,00001
Dioxin (TCDD Teq)	0,1	0,1	0,1	0,002

WTERT-Greece, SYNERGIA

www.wtert.gr

Comparison of Dioxin emission

Data: Prof. Berd Bilitewski

Modern Waste incineration plant:	1	0,01 ng/m ³
Hazardous waste incineration plant:	1	0,01 ng/m ³
Household store:	100	1,00 ng/m ³
Open fire place:	1000	10,00 ng/m ³
Fire works:	10.000	100,00 ng/m ³
Burning landfill	100.000	1000,00 ng/m ³

Global warming – Climate Change

Energy recovered from thermal treatment of waste contributes to the reduction of greenhouse gases in two ways :

1. Prevents the production of methane CH₄ (21 times more potent greenhouse gas than **CO₂**) and other emissions from landfill sites

2. Emits less **CO₂** compared to fossil fuels which it replaces (i.e. lignite)

In thermal treatment processing plants it is possible to co-incinerate industrial waste with similar composition to municipal waste, sludge from biological treatment and biomass

Ash Usage – International Practice

BOTTOM ASH

- Aggregate on asphalt (France, United Kingdom, USA)
- At landfills as a covering material (partial replacement of daily coverage)

FLY ASH (after stabilization/solidification)

- Filling in salt mines and quarries (soil stabilization)
- Usage in road construction (Germany)
- Neutralization of acid wastes (i.e. Titanium Industry in Norway)
- Construction material (gravel for concrete and blocks of pulverized ash Holland)
- or disposal in sanitary landfill

Recycling and WTE in 10 Metropolitan Cities of the World

CITIES	POPULATION mill.	WASTE PRODUCTION mill. tones	RECYCLING	WTE	COMPOSTING	LANDFILLING
SINGAPORE	5,0	6,1	57%	41%	-	2%
BERLIN	3,4	0,7	50%	40%	10%	-
METRO VANCOUVER	2,3	3,4	51%	8%	7%	34%
VIENNA	1,6	1,0	23%	63%	11%	3%
MUNICH	1,4	0,6	44%	49%	6%	1%
COPENHAGEN	0,9	2,1	62%	25%	4%	9%
MALMO	0,7	2,0	20%	69%	6%	5%
LEE COUNTRY FLORIDA	0,6	1,1	46%	51%	3%	-
ZURICH	0,4	0,3	29%	62%	9%	-
MARION COUNTY OREGON	0,3	0,4	45%	34%	9%	12%

WTERT-Greece, SYNERGIA

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WTE EXPERIENCE WORLDWIDE

Grate Technology

- •Proven technology
- •Approx. 1,000 plants
- •Normal size per line is 300 - 1000 tpd
- •Few worldwide recognized equipment manufacturers
- •Electricity production (per tonne of waste) for MSW 0,6-0,8 MWh/tonne
- •High availability >8,000 h/y
- •Gate fee 40 - 130 USD/t

Alternative Technologies

- Under Development - Number in commercial operation is unclear
- •Typical capacity 25-250 tpd
- •Many (>100) suppliers, many relative small
- •Electricity production around 0-0,5 MWh/tonne (difficult to get real data)
- •Lower availability – 5,500 h/y
- •Requires homogenous waste input
- •Gate fee 200-400 USD/t



Conclusions

Conclusions

- Many efforts should be made in order to inform the society and the policy makers that modern waste to energy technology is the demanded step after recycling and composting at the source, in order to be severed by the landfill sites and the illegal dumps
- Green Metropolitan Capitals (Stockholm, Copenhagen, Hamburg, Paris, London , Seoul, Shanghai, Tokyo, New York) use a combination of recycling at the source and thermal treatment with energy recovery
- Waste to energy, in harmonic cooperation with the recycling of MSW at source, is considered to be the most **efficient, dominant, integrated and proven technology** for solving the municipal solid waste management and treatment problem of metropolitan cities.

-
- For the short term (<5 years), building a **sanitary** landfill is cheaper than building a WTE (same as renting rather than buying a house).
 - In the longer term (10-50 years), WTE is a better investment and, also, better for the environment, a city, and a nation.
 - Regional and national governments should place sustainable waste management high up on their list of essential infrastructure, same as is done for wastewater treatment, electricity and water supply.
-

Photos of WTE Plants

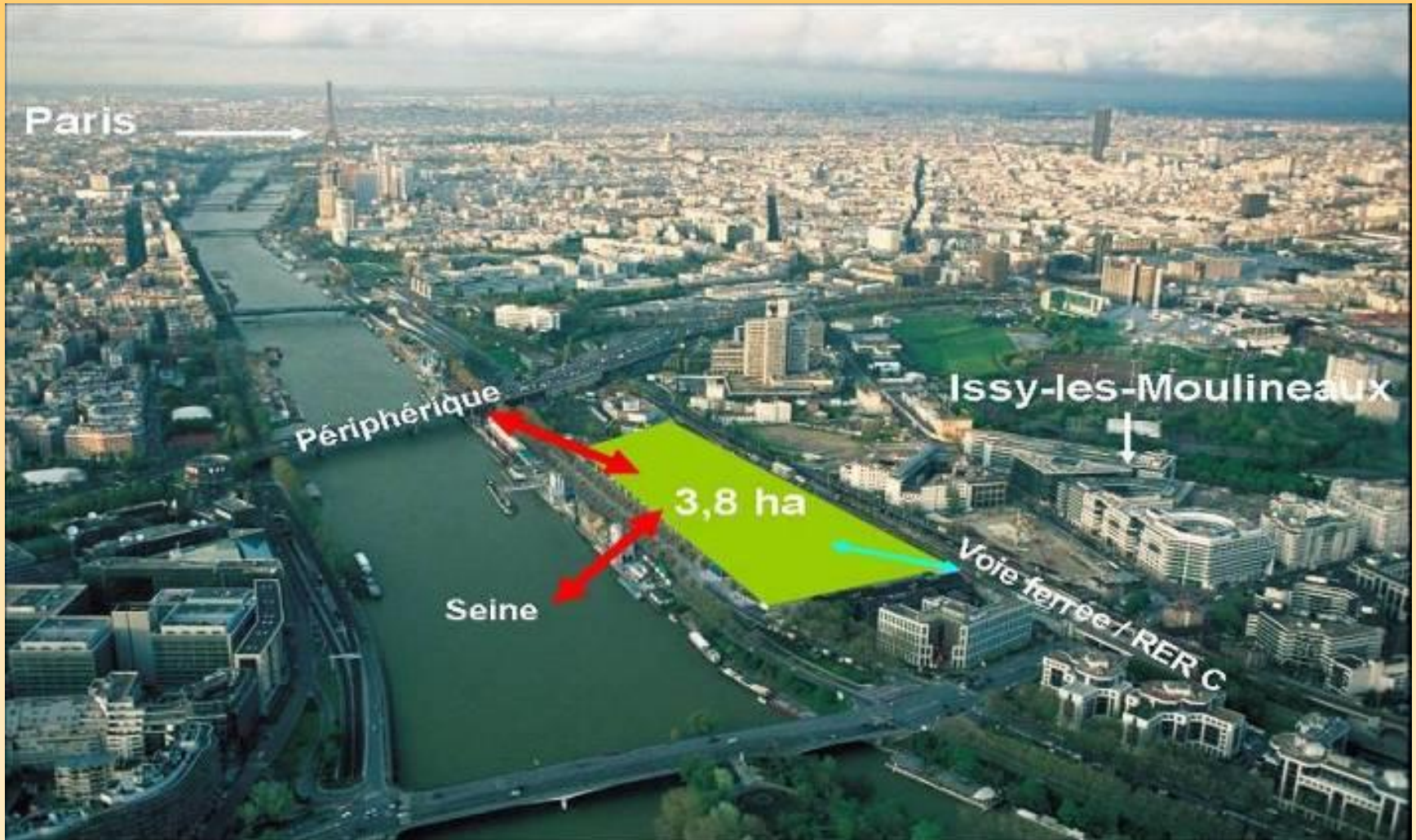


“Isséane” Plant - Paris

WTERT-Greece, SYNERGIA

www.wtert.gr

Photos of WTE Plants



WTERT-Greece, SYNERGIA

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International WTE PLANT



*Barcelona, TERSA WTE Plant
with district heating & district cooling*

Photos of WTE Plants

Uppsala, Sweden



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Photos of WTE Plants



Alkmaar WTE, Netherlands

WTERT-Greece, SYNERGIA

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Photos of WTE Plants



Budapest WTE, Hungary

WTERT-Greece, SYNERGIA

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Photos of WTE Plants



Photos of WTE Plants



Isle of Man



01/06/2011

Copenhagen, Denmark



WTERT-Greece, SYNERGIA

www.wtert.gr

Waste Atlas Partnership



- The **Waste Atlas Partnership** is a non-commercial initiative involving:
- ❑ D-Waste consultants,
 - ❑ University of Leeds,
 - ❑ International Solid Waste Association (ISWA),
 - ❑ GIZ/SWEEP-Net,
 - ❑ Waste to Energy Research Council (WTERC) and
 - ❑ Solid Waste Network of Asian and Pacific Islands.

In recognition of this effort, the Clinton Global Initiative announced its collaboration with D-Waste and international organizations to complete a global mapping system for waste management.

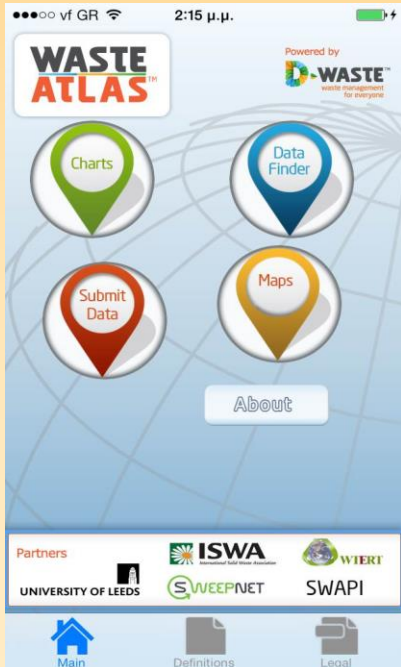


CLINTON
GLOBAL
INITIATIVE

Waste Atlas Partnership and D-Waste Colleagues...



UNIVERSITY OF LEEDS



EcoMENA



GESTÃO ECOEFICIENTE DE RESÍDUOS SÓLIDOS



environmental management centre



ASOCIACIÓN PARA EL ESTUDIO DE RESIDUOS SÓLIDOS



SYNERGIA
WTERT
Ελλάς - Greece

Συμβούλιο Ενεργειακής Αξιοποίησης Αποβλήτων
Waste-to-Energy Research & Technology Council

Advancing the goals of sustainable waste management

Thank you for your attention

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