Columbia Global Center of Santiago

The role of Waste-to-energy in a circular economy society

August 24, 2017

Dr. Thanos Bourtsalas

COLUMBIA UNIVERSITY

EARTH ENGINEERING CENTER

WTERT-US and the Global WTERT Council (GWC)

- WTERT-U.S. was founded by the Earth Engineering Center of Columbia University with the aid of the U.S. WTE industry in 2002

- At the end of 2011, GWC was incorporated as a non-profit organization under the laws of the state of New York and the U.S.A.

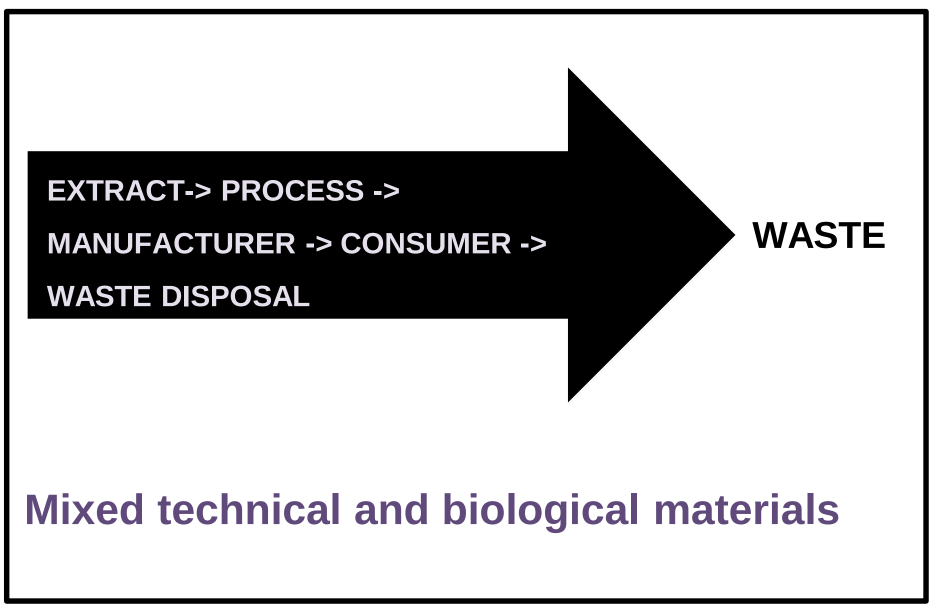
The mission of the Global WTERT Council (GWC):

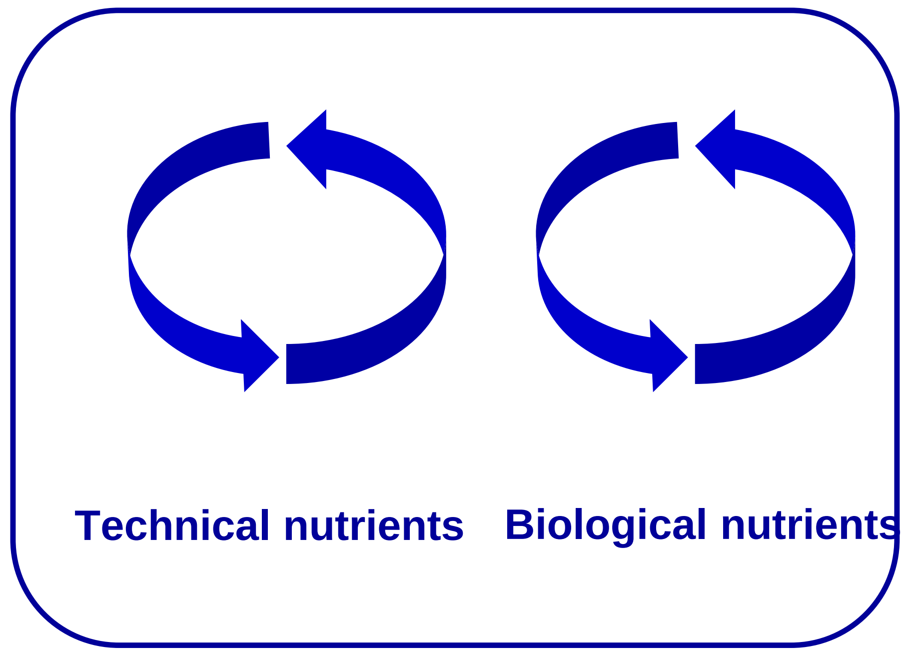
- Identify the **best available technologies** for the **recovery** of **materials** and **energy** from all types of **"wastes"**

- **Disseminate** this **information** by means of publications, the multilingual WTERT web pages, and periodic meetings and national and international conferences.

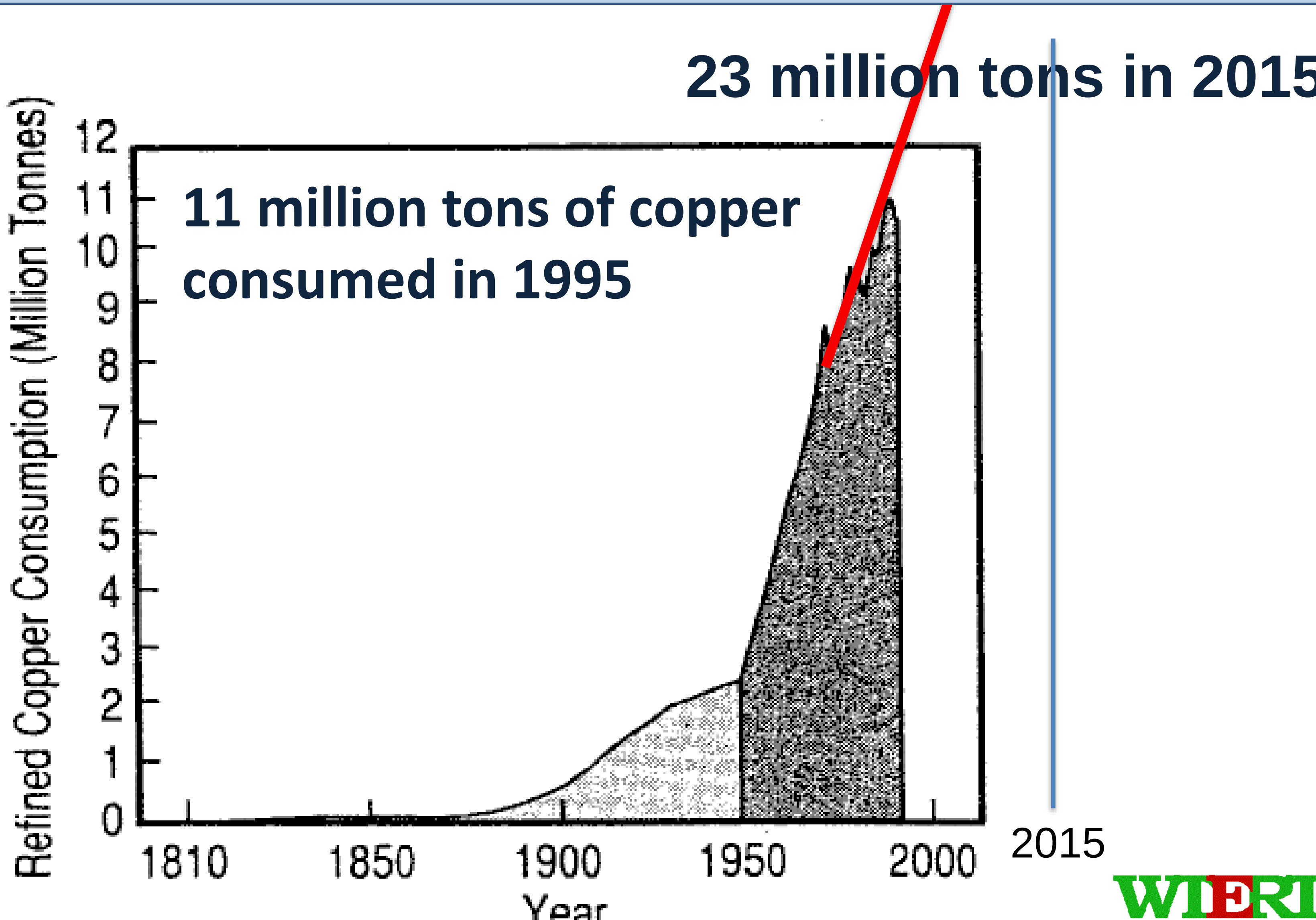
Circular economy: The concept

Linear economy → **Circular economy**





Importance of resource recovery for the sustainability of the planet:



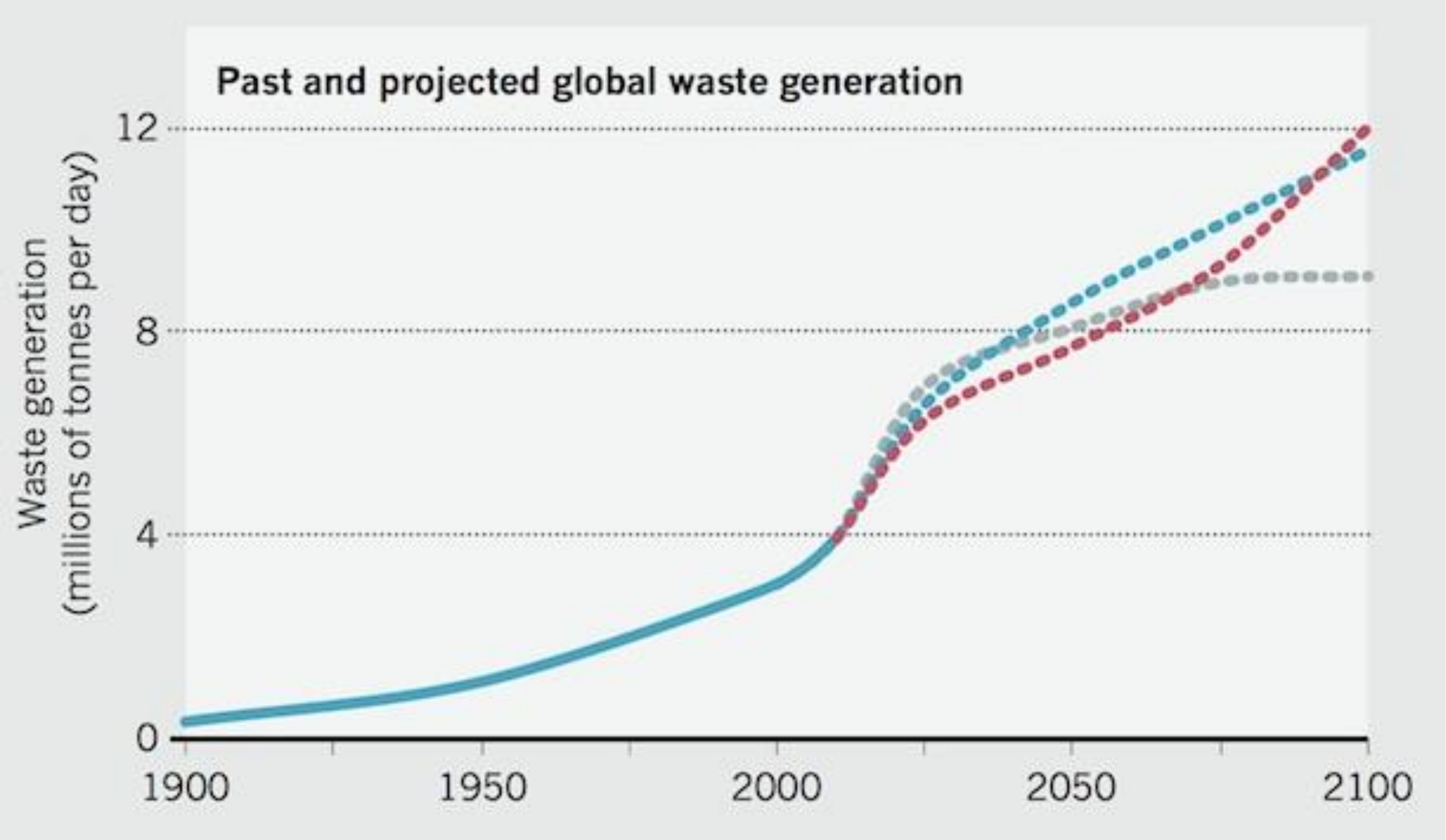
Themelis' lecture to Metallurgical Society of Finland (1996)

Some conclusions from the previous slide:

- 1996: Humanity used much more copper in the period of 1950-1995, than it had been used in 6,000 years before that
- 2016: Consumption of copper has nearly doubled from 1995 to 2015
- 2016: If it had not been for recycling of copper, the world would have run out of copper and copper would have become very expensive

WIERT

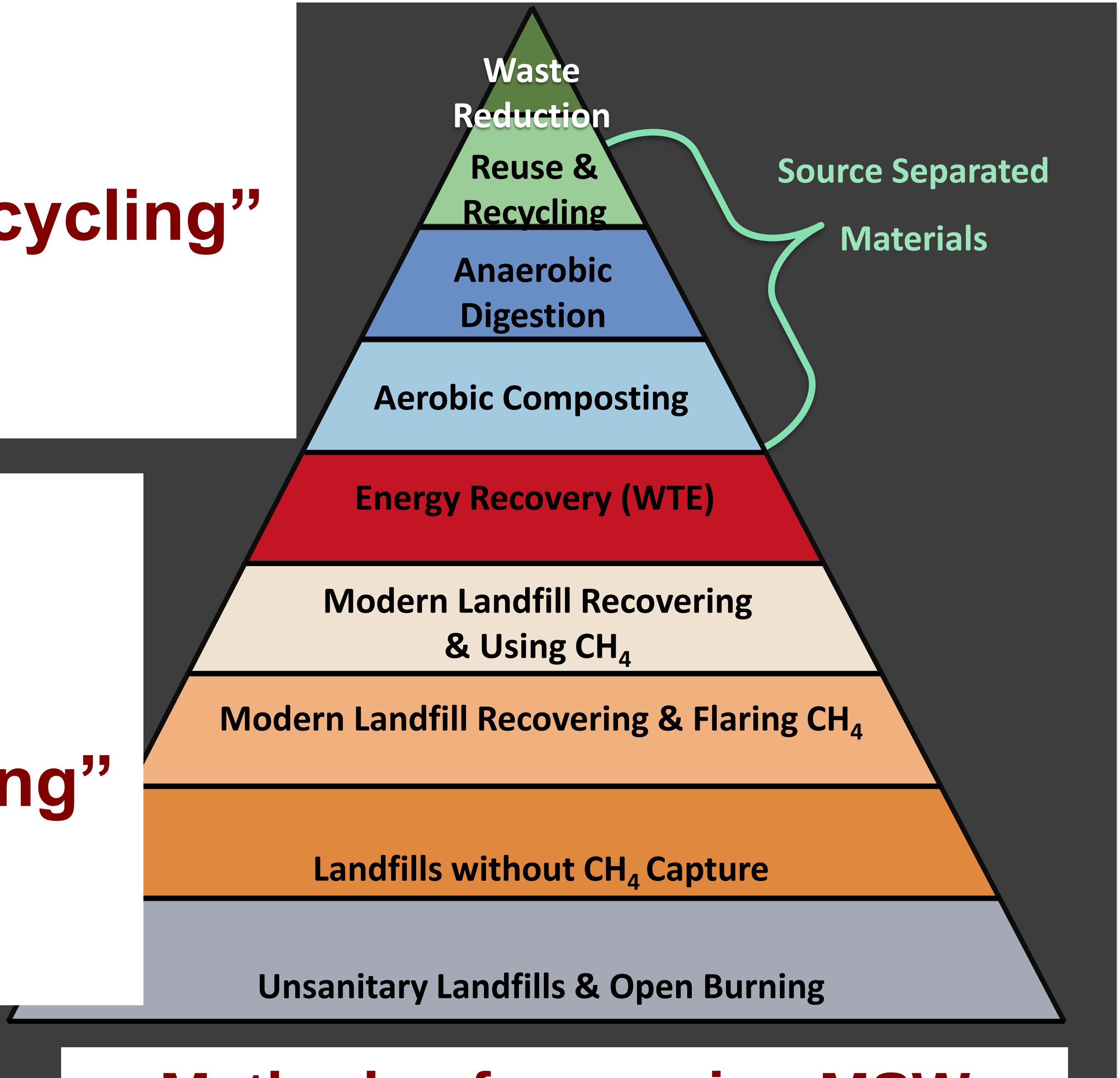
Global Waste Generation



Global waste generation predictions (Hoornweg, Bhada-Tata and Kennedy, 2013)

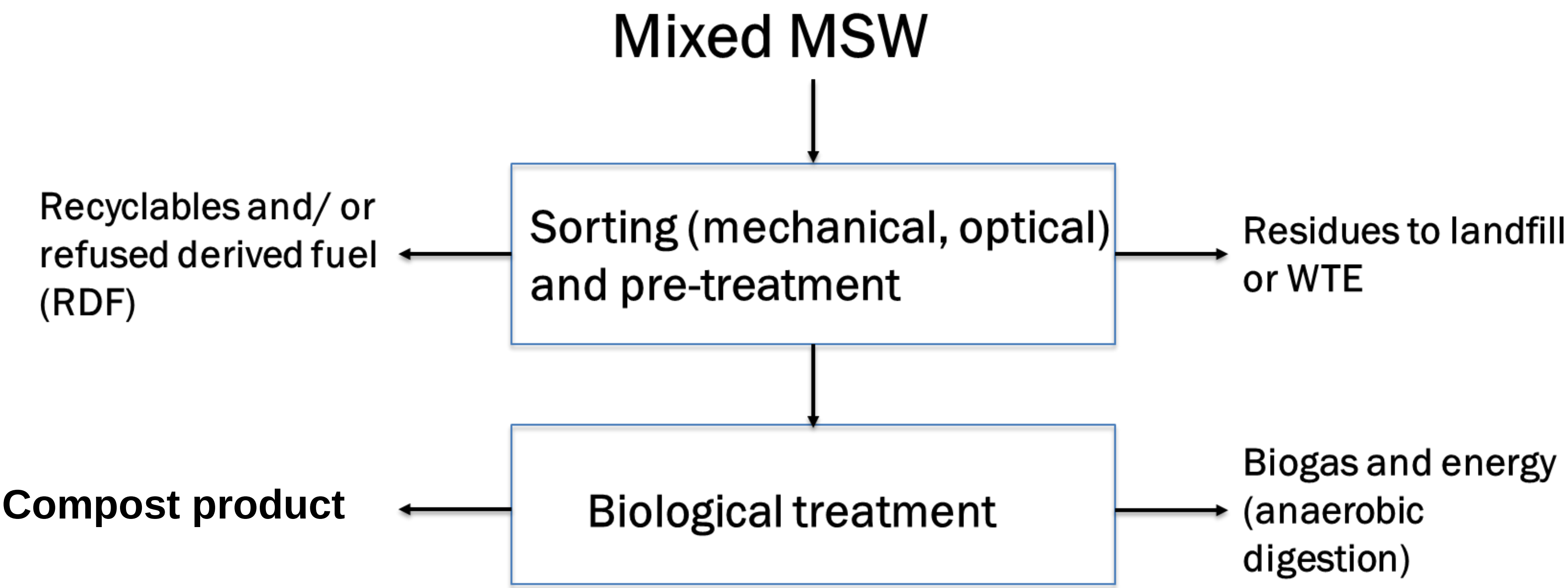
“Recycling”

“Post-recycling”



Methods of managing MSW

Mechanical Biological Treatment (MBT)



Necessary ingredients for successful recycling

- **Communities** with **separate collection** of recyclable materials (principally metals, paper/ cardboard, green wastes)

- **Citizens** who **separate** recyclables at the source

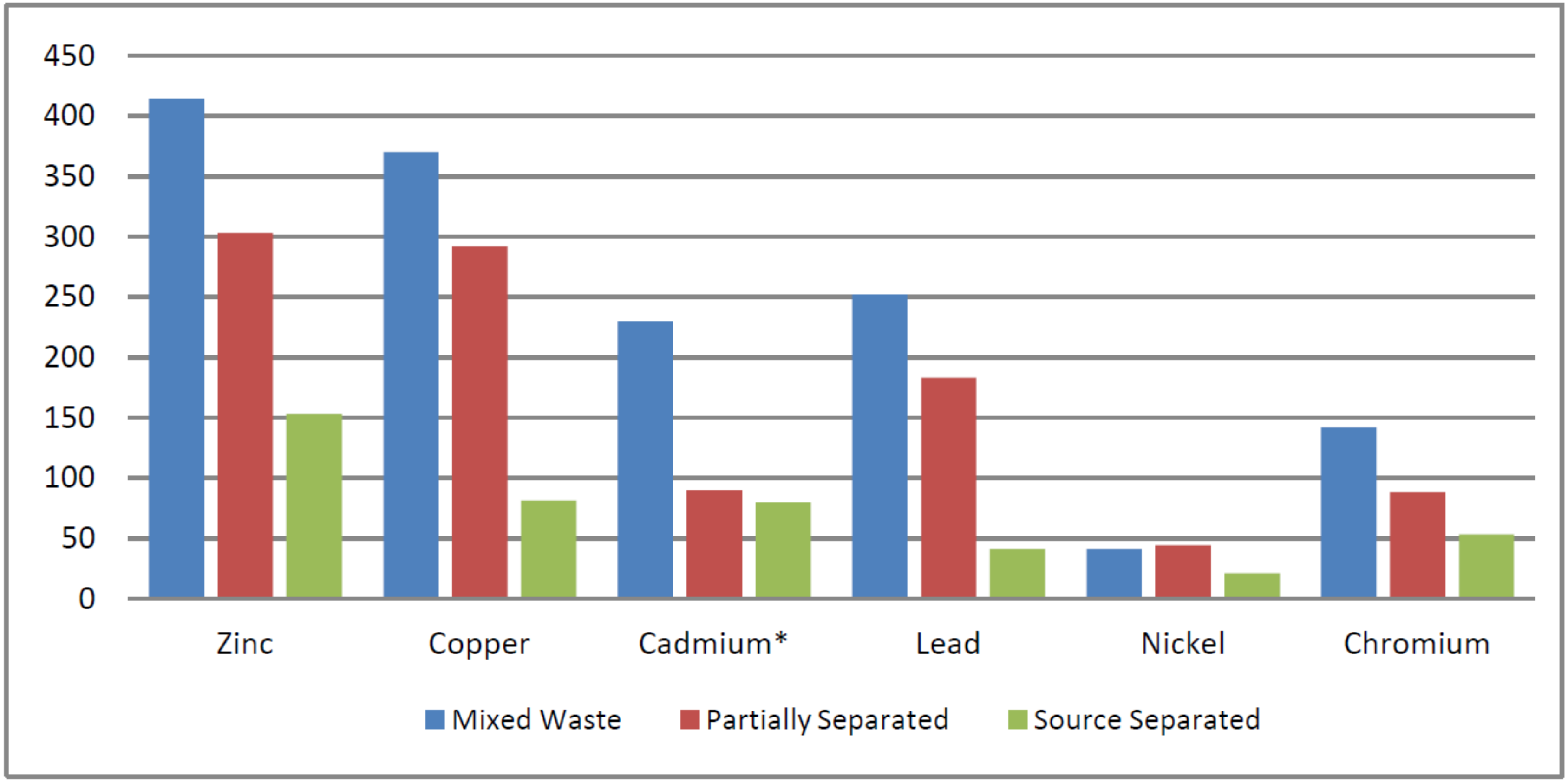
- **Markets** that can use/make profit from the recyclable materials (e.g. metal smelters, secondary paper mills)

Increasing composting

- **Least costly** way for municipal government to increase composting: Provide **a windrow composting center** where municipality and citizens transport their park/ yard wastes and get compost product to be used as soil conditioner

- Next and **more costly** means: **Anaerobic Digestion** facility where source-separated food wastes from large generators (institutions, food processors) are treated to produce methane and a compost product.

Impact of source separation on Heavy metals concentration in MSW compost



Ref: Ranjith Annepu MS-Thesis, EEC-Columbia, Sustainable Solid Waste Management in India

Limitations to recycling and composting

- It is **not possible** to collect all recyclables or to process all wastes (E.g. disposable diapers) to marketable materials
- For example, after many efforts to increase recycling in California, less than 10% of the plastic wastes are being recycled
- Therefore, it has been necessary, universally, to develop means for disposing properly the **post-recycling wastes**

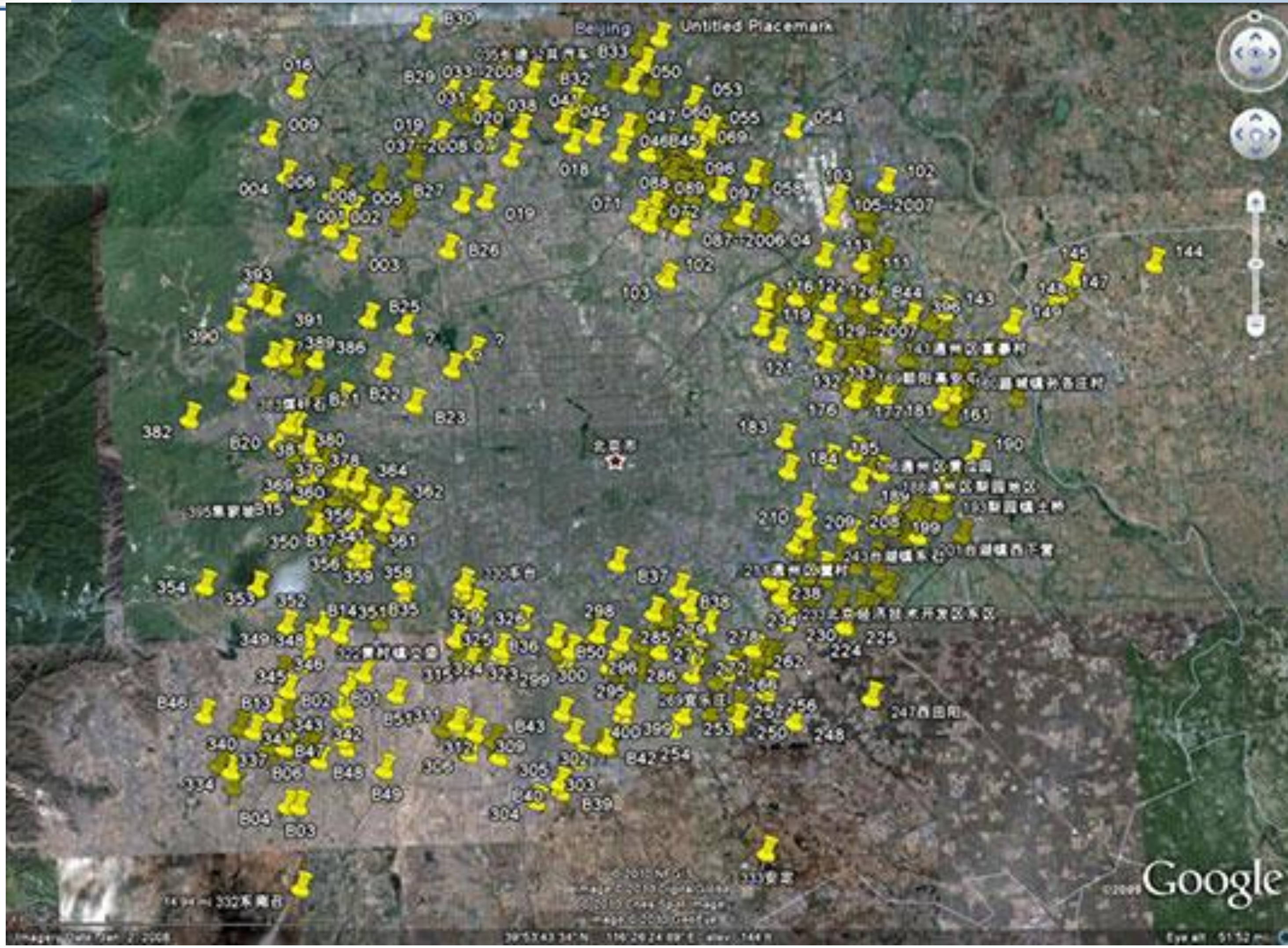
What to do with post-recycling wastes?

1) Sanitary landfilling

- protects ground and surface waters
- cuts down GHG emissions by about 0.5 ton GHG/ton MSW.
- costs $100-200 per annual ton of capacity
- uses 1 m^2 of land for every 10 tons of MSW landfilled

Photo of sanitary landfill (Stevens County, WA)

Landfilling consumes land: For example Beijing is literally surrounded by hundreds of landfills



Source: Extraordinary film by Wang Juliang, shown at CU by EEC

The Global Landfilling picture (EEC, 2015)

- MSW to global landfills: **1 billion tons/y**
- Landfill Gas (LFG) generation: **50 million tonnes CH_4**
- LFG collected and used or flared*: **6 million tonnes CH_4**
- LFG emitted globally: **44 million tonnes CH_4** *

***Equivalent to 920 million tons of CO2**

(over 3% of global Greenhouse Gases (GHG)

The US captures over 50% of the LFG captured globally

Global use of land for landfilling in one year

Estimated average ultimate use of land for proper (sanitary) landfilling of MSW: One square meter gone for ever, for every 10 tons of MSW landfilled

- Current global landfilling converts an estimated 100 square kilometers of greenfields to landfills
- If it were done at one landfill it would use up a land surface equal to that of metropolitan Paris
- At present rate of MSW generation, continued landfilling would use up 10,000 square kilometers in this century

Colonizing Mars vs. doing away with landfilling

- **Some nations are spending billions in missions in the hope of developing living space in Mars, etc.**

- **How much would it cost to create 100 square kilometers of earth-like land on Mars?**

WIERT

What to do with post-recycling wastes? (Continued)

MSW Combustion

Waste to Energy

Electricity and district heating/cooling

Bottom Ash
150-250 kg/ tonne MSW

Air Pollution Control Residues
25-35kg/ tonne MSW

Resources from Waste

Pyrolysis, Gasification or Combustion

Pyrolysis

- Normally no air
- Only heat (external or internal)
- Want liquid, Gases not desired
- Pollutants in reduced form (H_2S, COS)
- High Char
- **Scale: ~ 10 tons/day**

No additional Oxygen (only heat)
Unconverted solid will remain!

Gasification

- Sub stoichiometric air
- Lower total volumetric flow
- Lower fly ash carry over
- Pollutants in reduced form (H_2S, COS)
- Char @ Low T
- Vitrified Slag @ high T
- **Scale: ~ 100 tons/day**

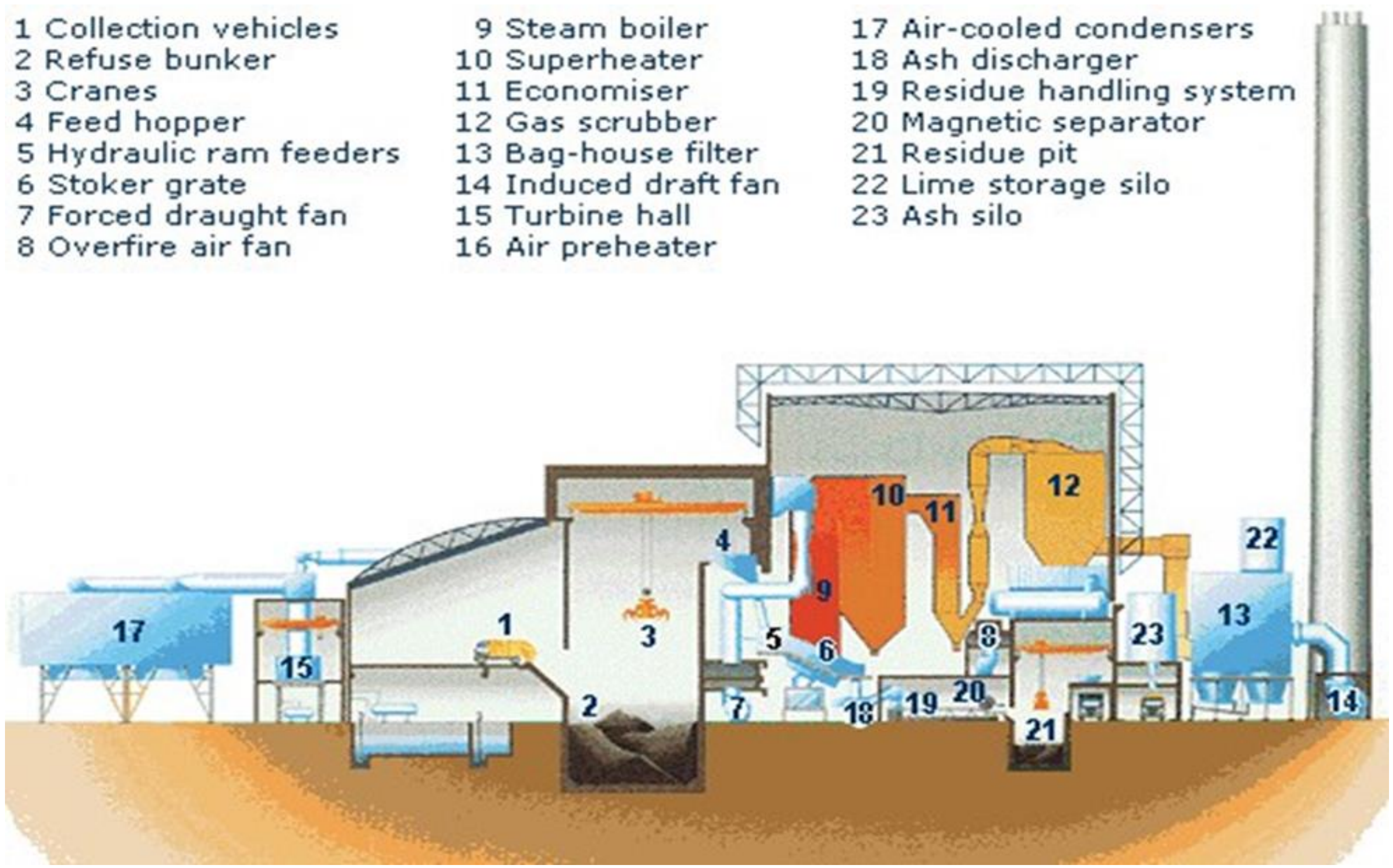
Some additional Oxygen (or air)
Heat added or comes from reactions

Full combustion

- Excess air
- Higher volumetric flowrate
- Fly ash carry over
- Pollutants in oxidized form (SO_x, NO_x, etc)
- Bottom ash
- **Scale: ~ 1500 tons/day**

Much additional Oxygen (or air)
Heat comes from reactions

Typical WTE plant



The most efficient EfW facilities are co-generators of electricity (> 0.6 MWh per tonne of MSW) and district heating (> 0.5 MWh per tonne of MSW).

Waste-to-Energy (WTE) Facility

Reducing the Volume of Waste & Generating Energy

IN

90% volume reduction

OUT

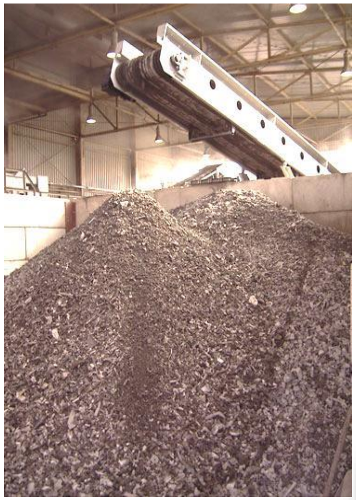
100 cubic yards
of waste

10 cubic yards
of (inert) ash

$E = M \times C^2$

*Energy **is** mass times a constant*

Waste to Energy bottom ash recycling plant



MAGNETS, ECS

SCREEN

Coarse fraction, 10- 15%

Medium fraction, 40-70 %

Fine fraction, 15- 45 %

Managing post-recycling wastes

Only two options to manage post-recycling wastes:

- **Waste to Energy (WTE)**
- **Sanitary landfills**

WTE advantages over sanitary landfilling:

- **Destruction of pathogens**
- **Conservation of land near cities (LF=1 m^2/10 tons MSW)**
- **Electricity production: >0.5 MW over sanitary LF**
- **GHG emission reduction: 0.5 -1 ton per ton MSW to WTE**
- **Metal recovery**

Public acceptance of WTE: Need to inform the public

- **In some countries, there is continuing opposition to WTE based on the early history of incineration.**

- **For example, any new proposal for WTE is opposed by people who claim that a new WTE plant will emit dioxins harmful to public health.**

Columbia detailed studies of four nations annual WTE dioxin emissions

Country	Year of study	MSW processed (million tons)	Average Dioxin Emissions (ng TEQ/Nm3)	Total Dioxins Emitted (g TEQ/year)
USA	2012	25.9	0.027	2.90
France	2010	13.8	0.013	0.79
South Korea	2010	3.9	0.007	0.11
China	2015	61.8	0.1*	24.7

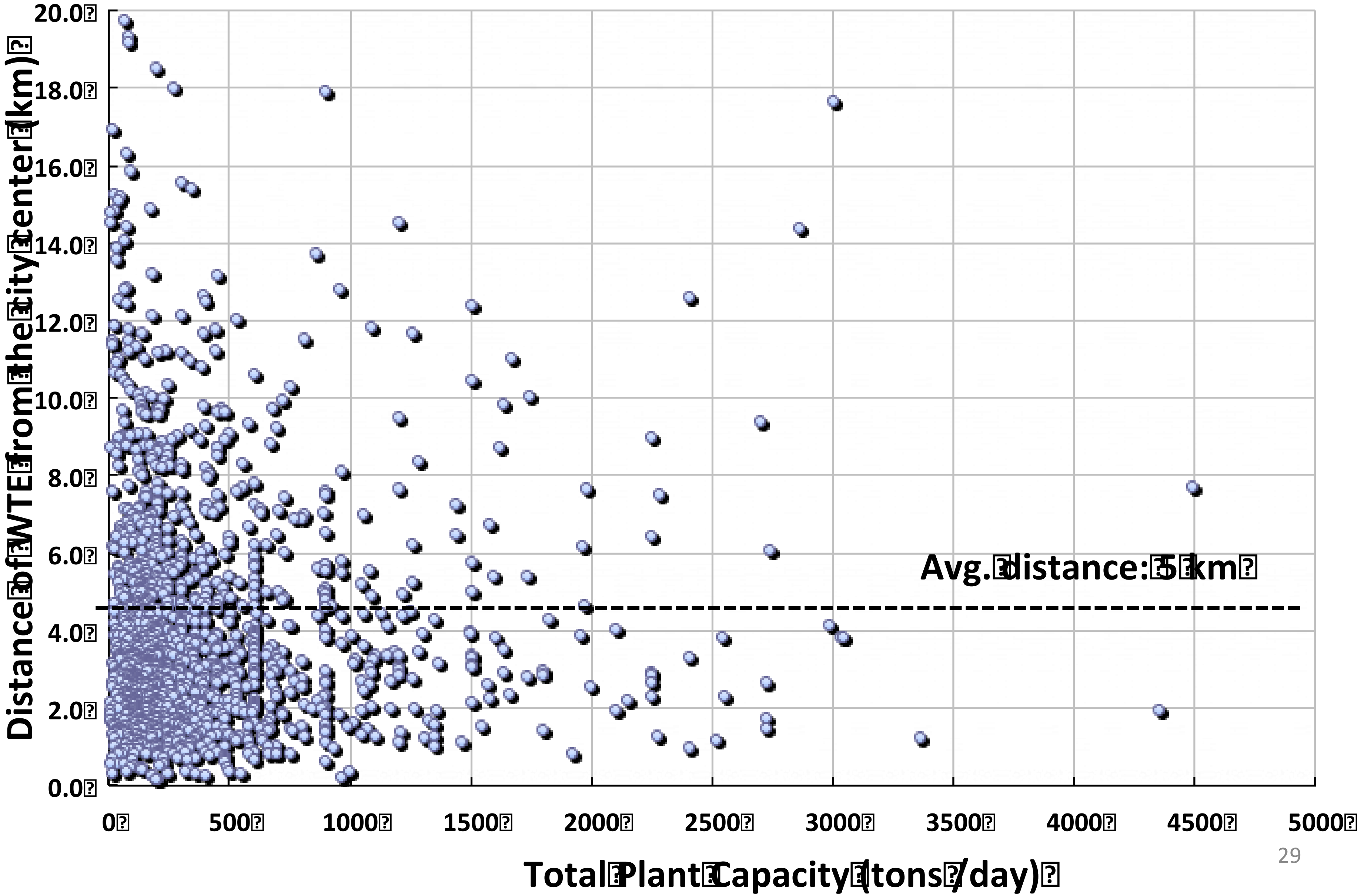
*Assumed average; Everbright average: 0.04 ng TEQ/Nm3

U.S. dioxin emissions from all industrial sources, forest and landfill fires, flaring of LFG, etc., in grams TEQ

	1987	1995	2000	2012
Total industrial sources	13,833	2,634	998	511
Total industrial plus area sources	16,125	4,925	3,827	3,808
WTE dioxins as % of total U.S. dioxins	58.9%	24.4%	2.0%	**0.08%**

Dioxins from unintended landfill fires in the U.S. in 2012: 1,300 grams TEQ vs. 3.0 grams TEQ from WTE

Current GWC-Columbia study: Distance of global WTEs from center of city



Role of universities in disseminating credible information on major environmental problems

- People generally resist change, even when change is for the good.
- The first central systems for potable water, for wastewater treatment, for management of solid wastes were resisted for lack of adequate information.
- Some people acquire “fame” by leading movements against beneficial change
- It is therefore necessary for universities to lead the effort for sustainable development

WIERT

How universities can fulfill their role:

- **Through educational programs**
- **Through academic research**
- **Through the dissemination of credible information (publications, the web, public meetings)**

Universities need industry and government support!

WIERT

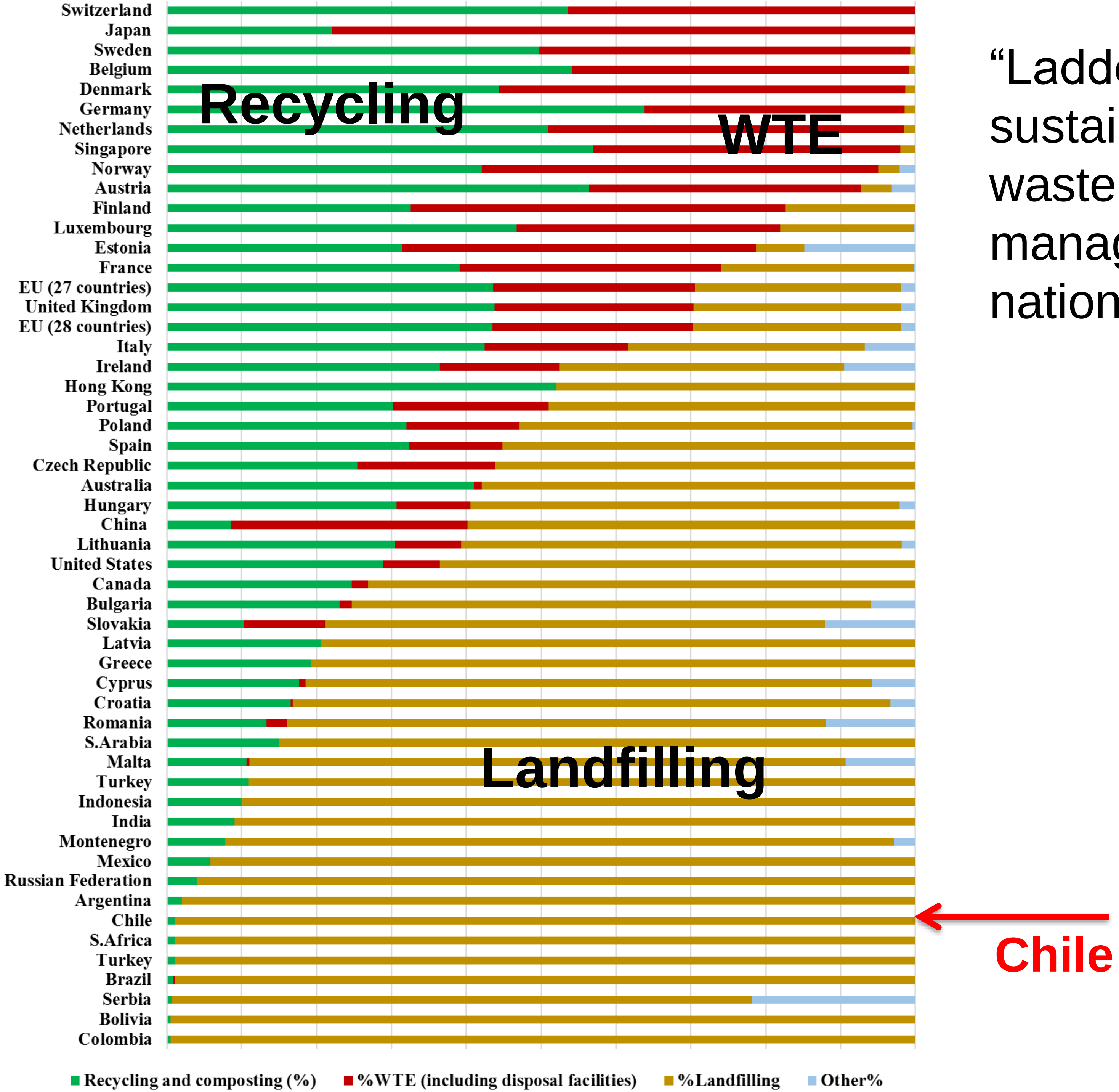
The Global picture

Global generation and disposition of MSW

Estimated global disposition of <u>urban</u> <u>post-recycling MSW</u>

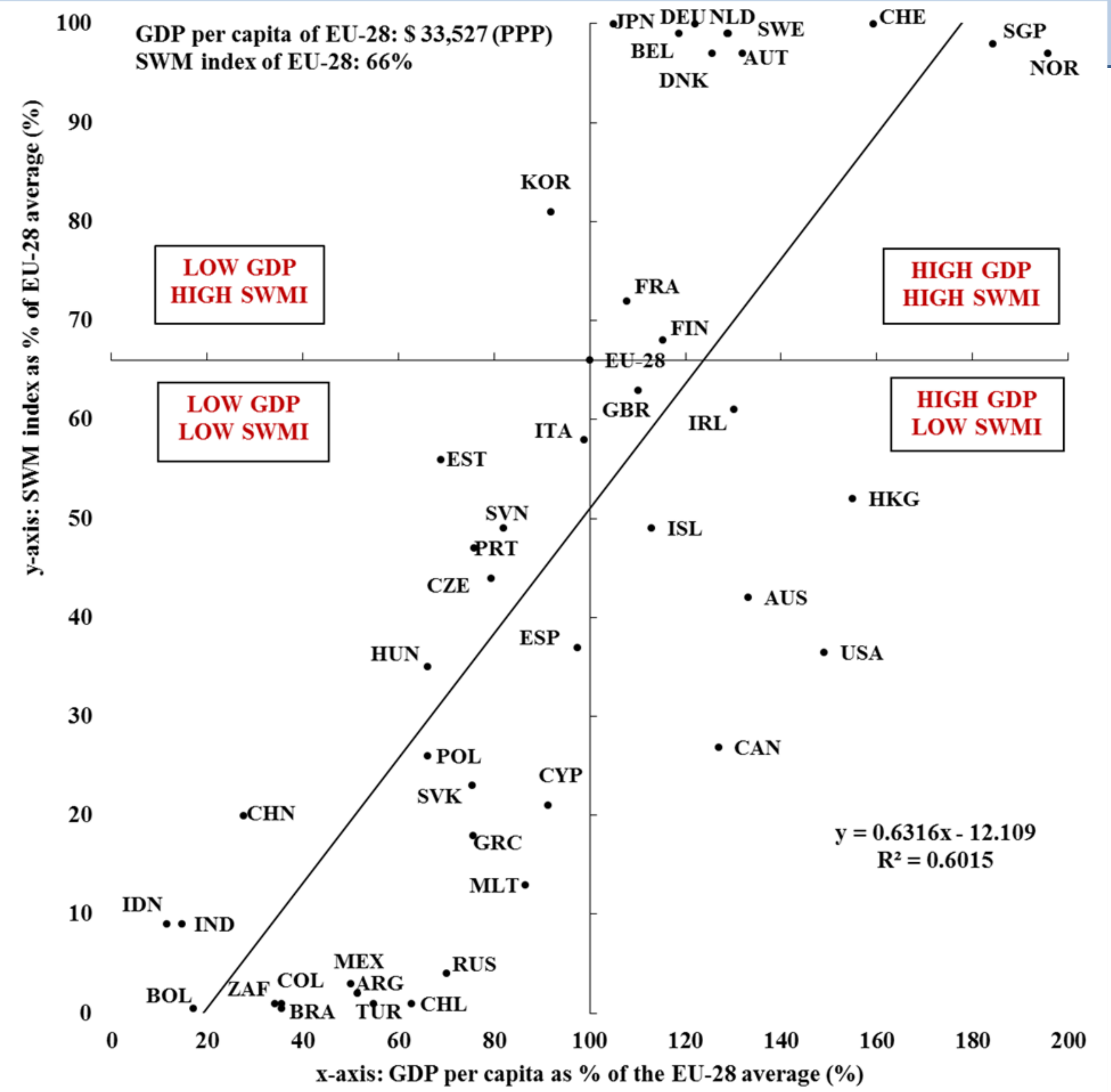
- **Thermal treatment (WTE): 230 mill. tons**
- **Sanitary landfill, partial CH4 recovery: 250 mill. tons**
- **Landfilled without CH4 recovery: >800 mill. tons**

- **MSW generation has tripled since 1950 and is expected to be six times greater by 2030**



“Ladder” of sustainable waste management of nations

Sustainable waste management (SWM) index vs per capita GDP

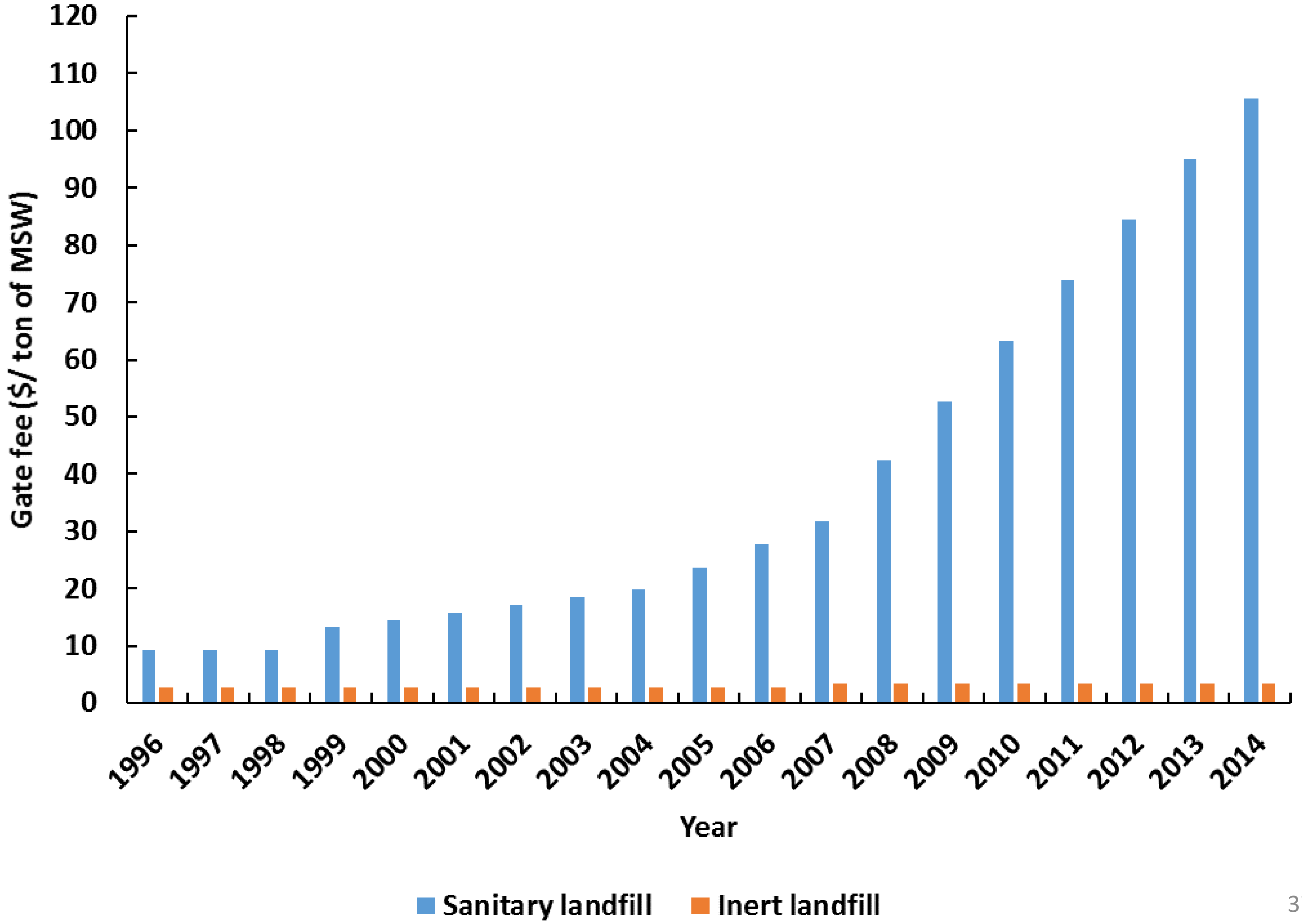


How S. Korea has done it?

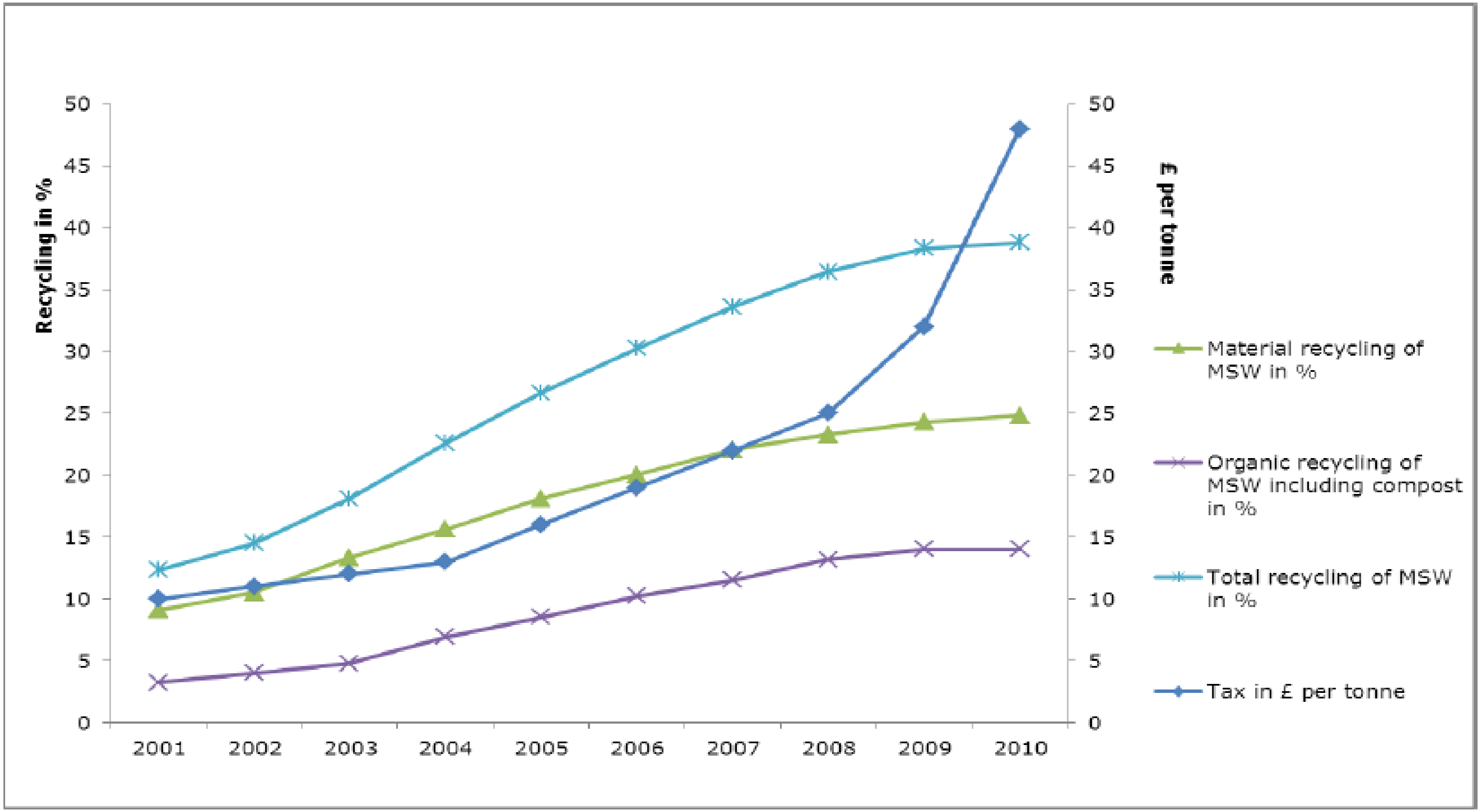
Very high levels of recycling, composting and WTE, achieved in less than 20 years, by means of:

- Planning, policy, regulations, and public education at national level
- Implementation at municipal level
- Assistance by national/regional agencies to municipalities in implementing regulations
- Citizen compliance and participation

Successful case in recycling and composting: UK through increase in landfill tax



Successful case in recycling and composting: UK through increase in landfill tax

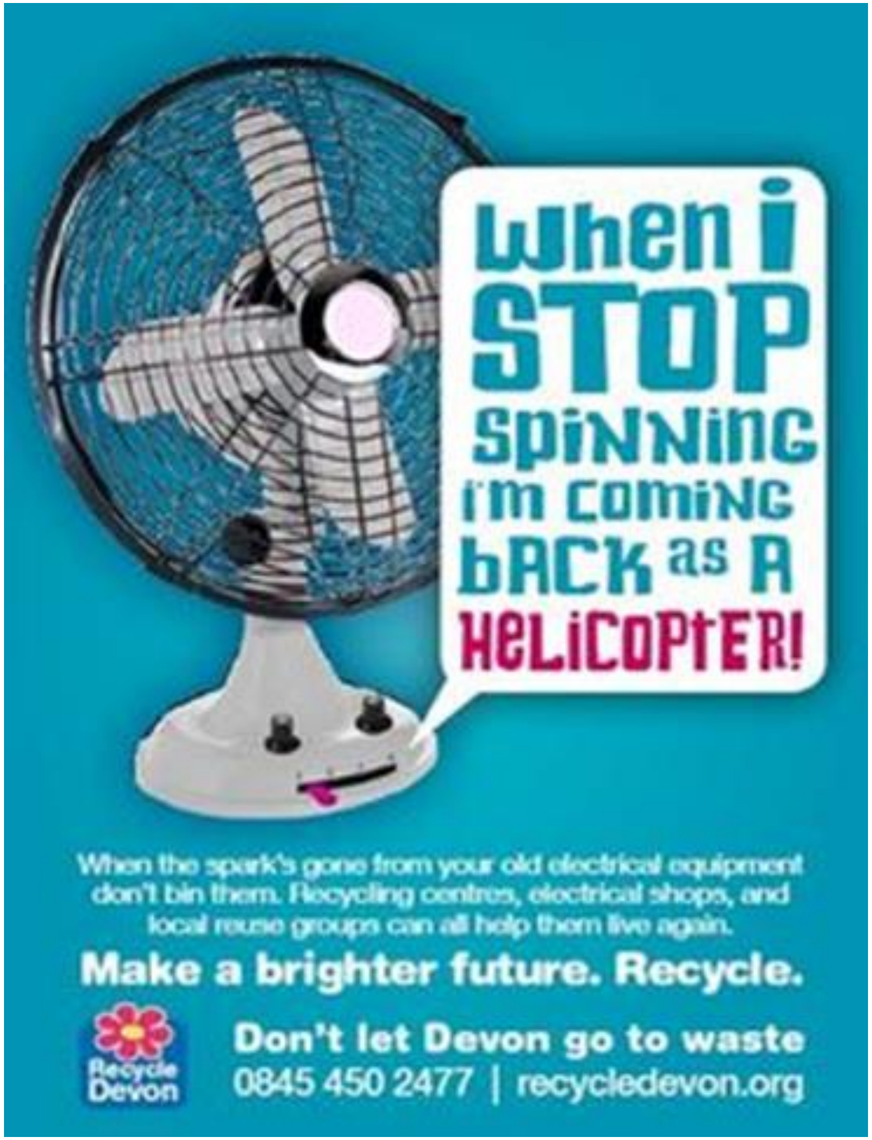


Source: ETC/SCP, 2012 and Eurostat, 2012. Note : landfill tax is shown for active waste – for inactive waste it lies at GBP 2.50/tonne

UK campaign


I R£CYCLE
FOR MY EDUCATION.
Ershad, north London resident
R£CYCLE.
CAN YOU
AFFORD NOT TO?
I R£CYCLE
FOR THE TEAM.
Waleed Matta, Team AP, north London
R£CYCLE.
CAN YOU
AFFORD NOT TO?
wiseuptowaste.org.uk
nlwa
recycle

UK campaign

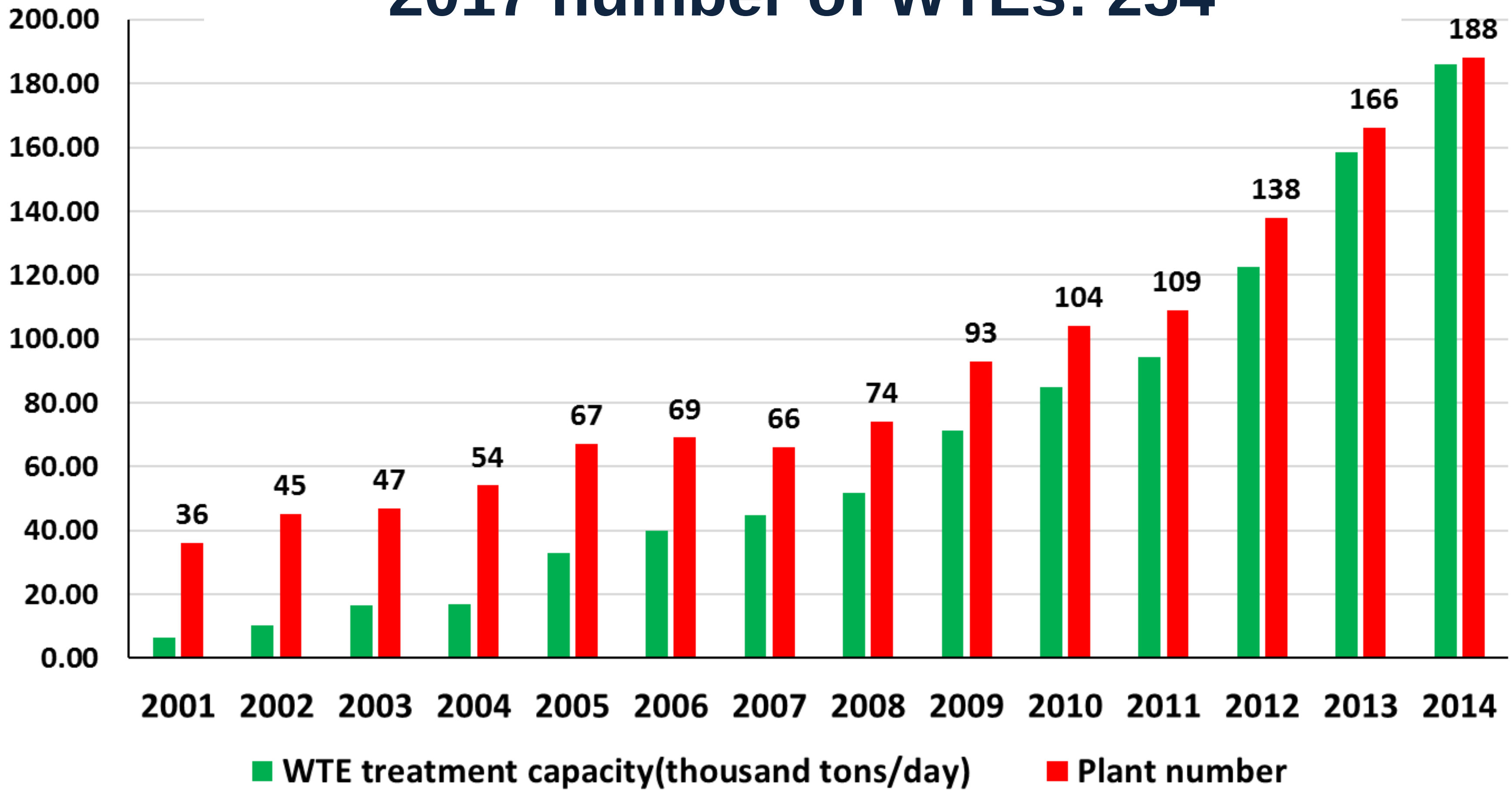


When i STOP SpiNNiNG i'm COmiNG bACK as A HELiCOPtER!
When the spark's gone from your old electrical equipment don't bin them. Recycling centres, electrical shops, and local reuse groups can all help them live again.
Make a brighter future. Recycle.
Recycle Devon
Don't let Devon go to waste
0845 450 2477 | recycledevon.org

Your RECYCLED PLASTIC BOTTLES can come back as
FOOTY SHIRTS
good to know
Lots of plastics from around your home can be recycled again and again into amazing things.
recycle for London
www.recycleforlondon.com

21st century growth of WTE industry in China

2017 Capacity: 230,000 tons/day
2017 number of WTEs: 254



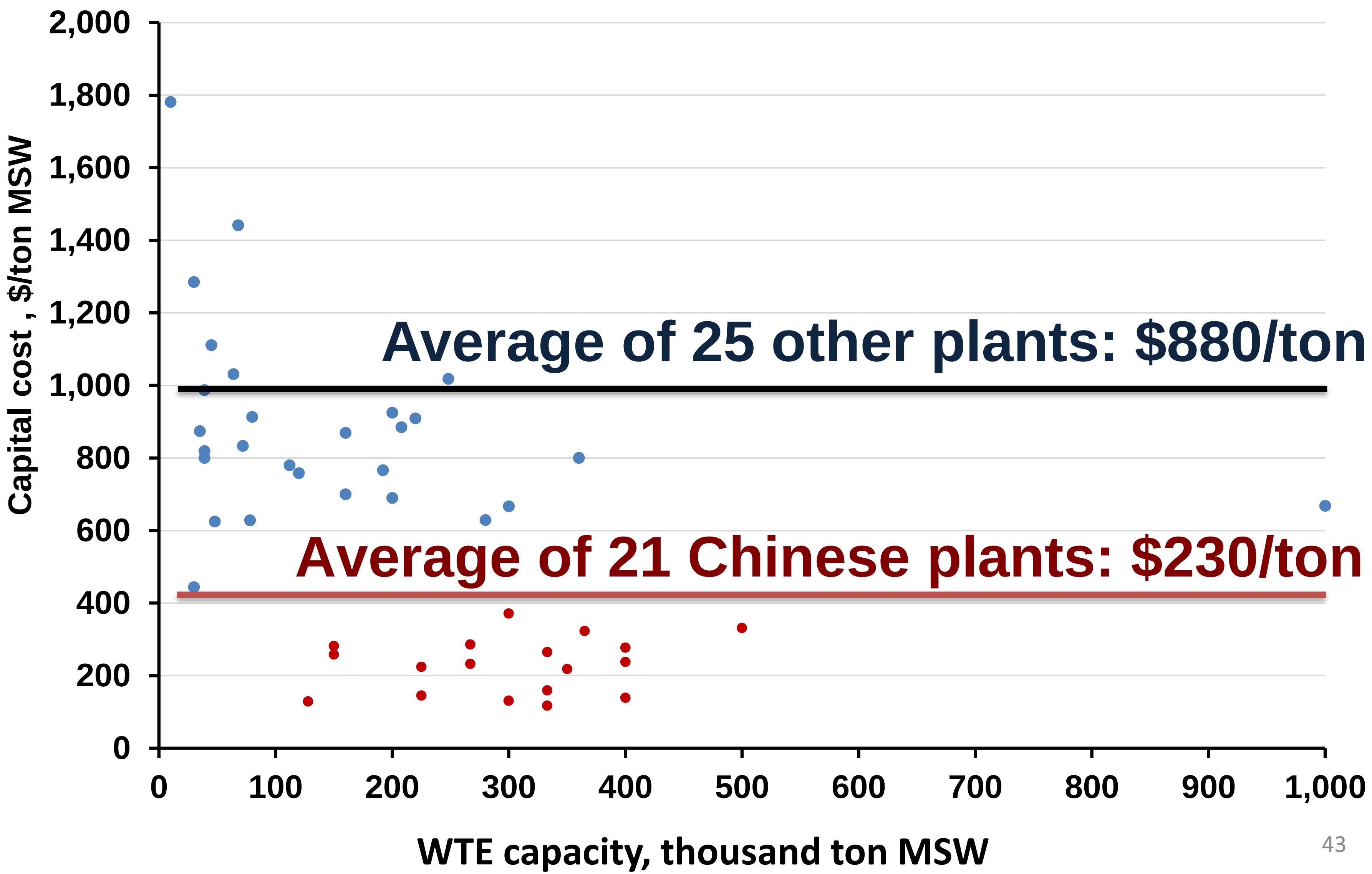
Yating Yu, EEC/Columbia 2016

Reducing the initial capital investment in WTE plants has made them cost-competitive with sanitary landfills

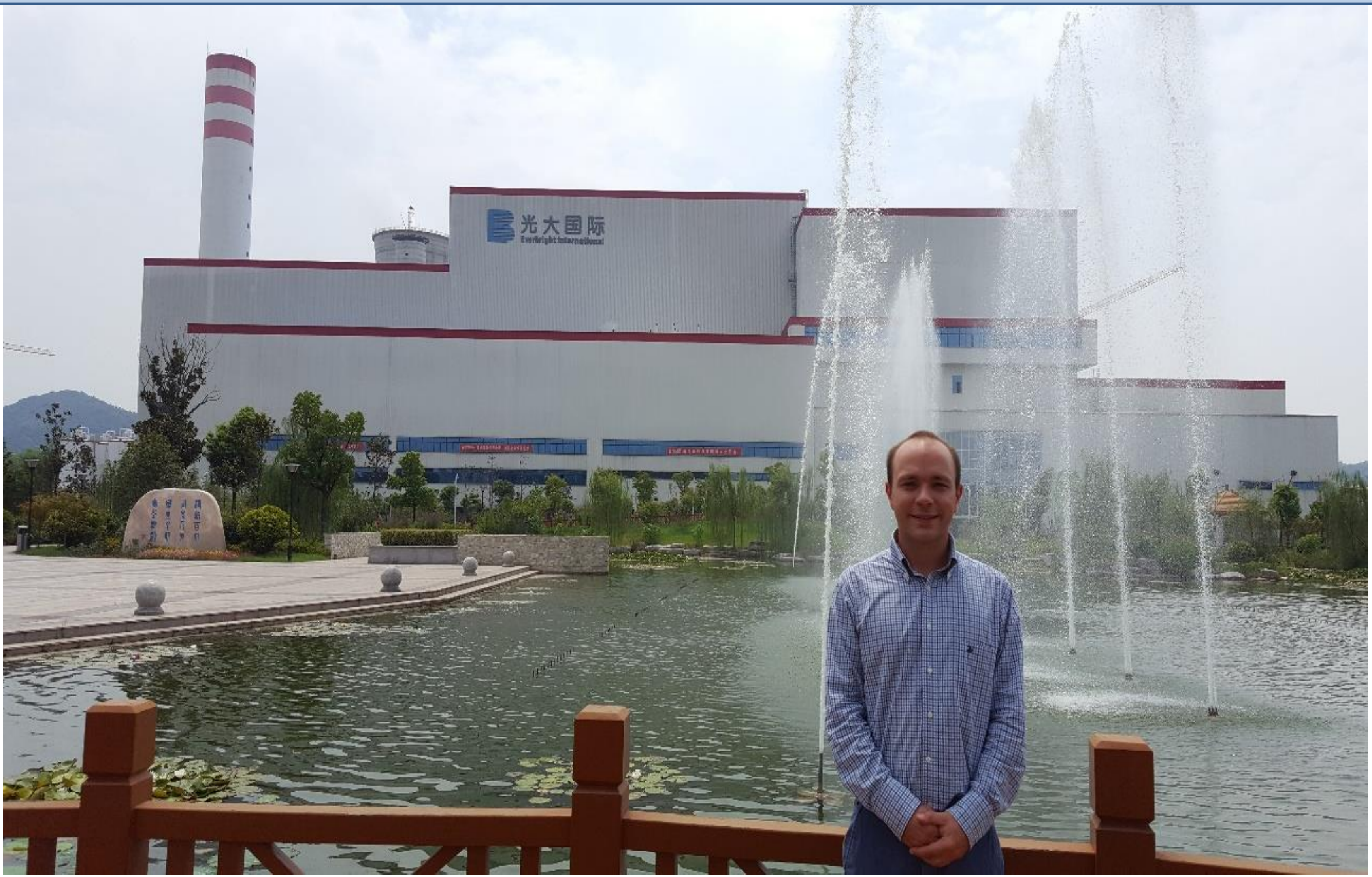
- China has demonstrated that it is possible to reduce the capital cost of WTE plants by means of
  - Industrial and academic R&D
  - Mass production, Instead of one plant at the time
- Incentives to WTE: Credit for renewable energy production ($30/MWh of electricity produced by WTE vs coal-fired power plants)

WTERT

All types of WTE are much less costly in China



The Everbright Nanjing WTE
(4,000 tons/day; total investment: $270 million

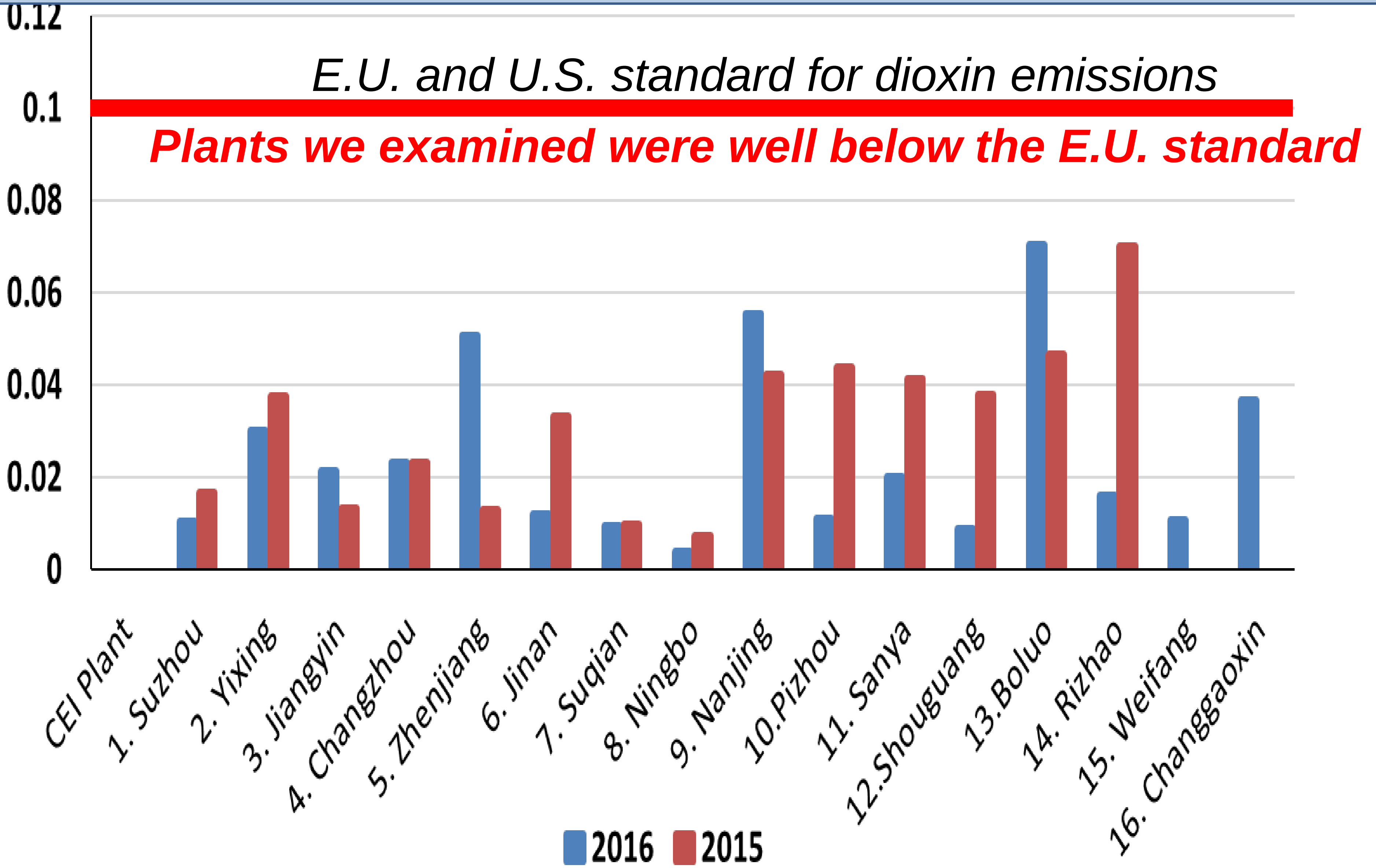


Everbright manufacturing plant of WTE equipment (Changzhou, China)

Control room of Nanjing WTE plant

Continuous public display of WTE plant emissions

2015 and 2016 dioxin emissions of Everbright plants (Columbia Univ. 2017 study, ng TEQ/Nm3 stack gas)



Why all this talk about China becoming a world leader in WTE in about ten years?

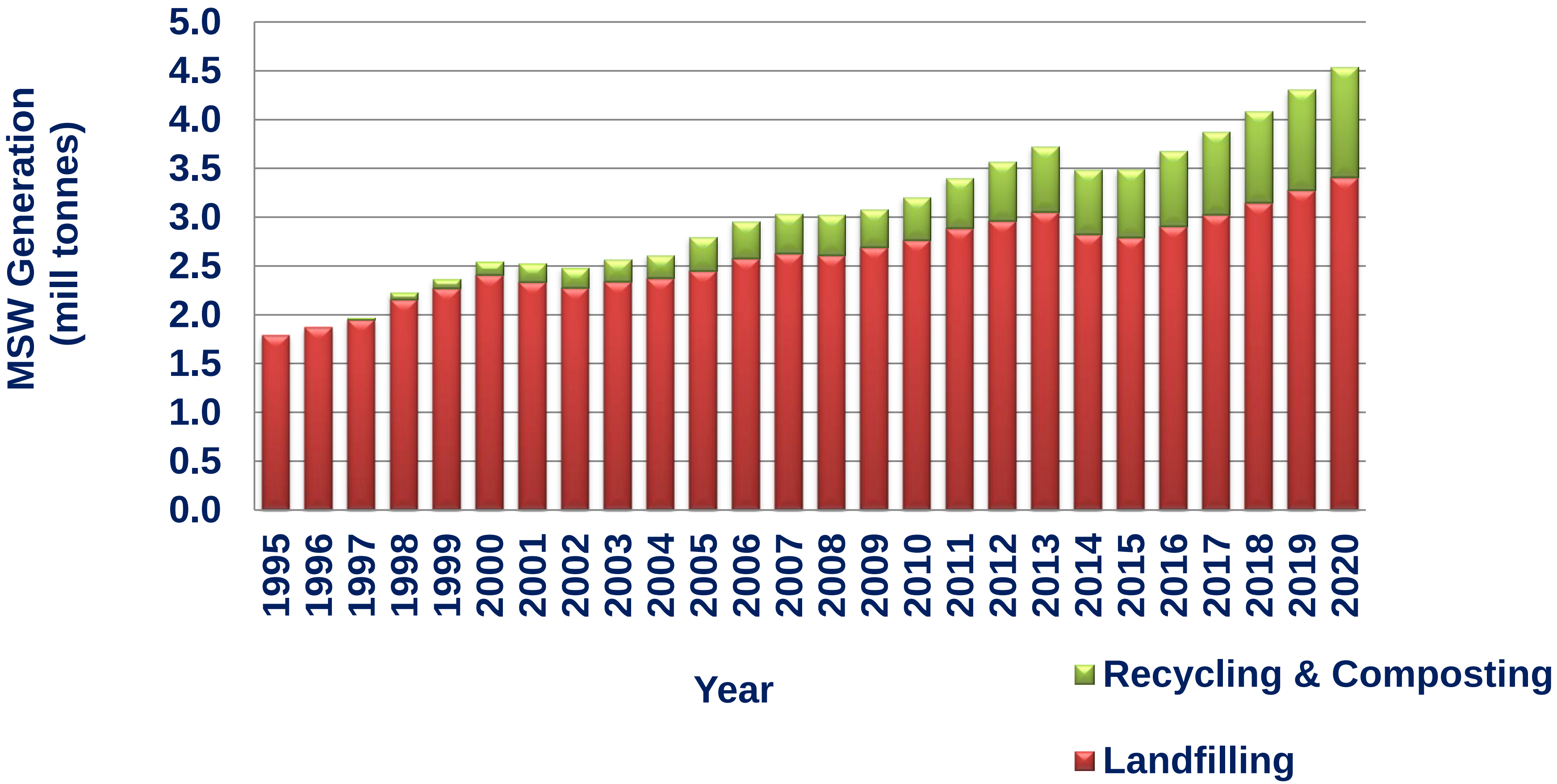
- **China should be a good example to other countries**

- **Developed nations took several decades to reach their present state of development and achievement in sustainable waste management**

- **Developing nations can use Chinese knowhow and capital to accelerate the application of WTE technology and the phasing out of landfilling**

WTERT

MSW generation, recycling and landfilling in Chile



Fernanda Cabanas, EEC/Columbia 2017

Comparison of three scenarios for 2020

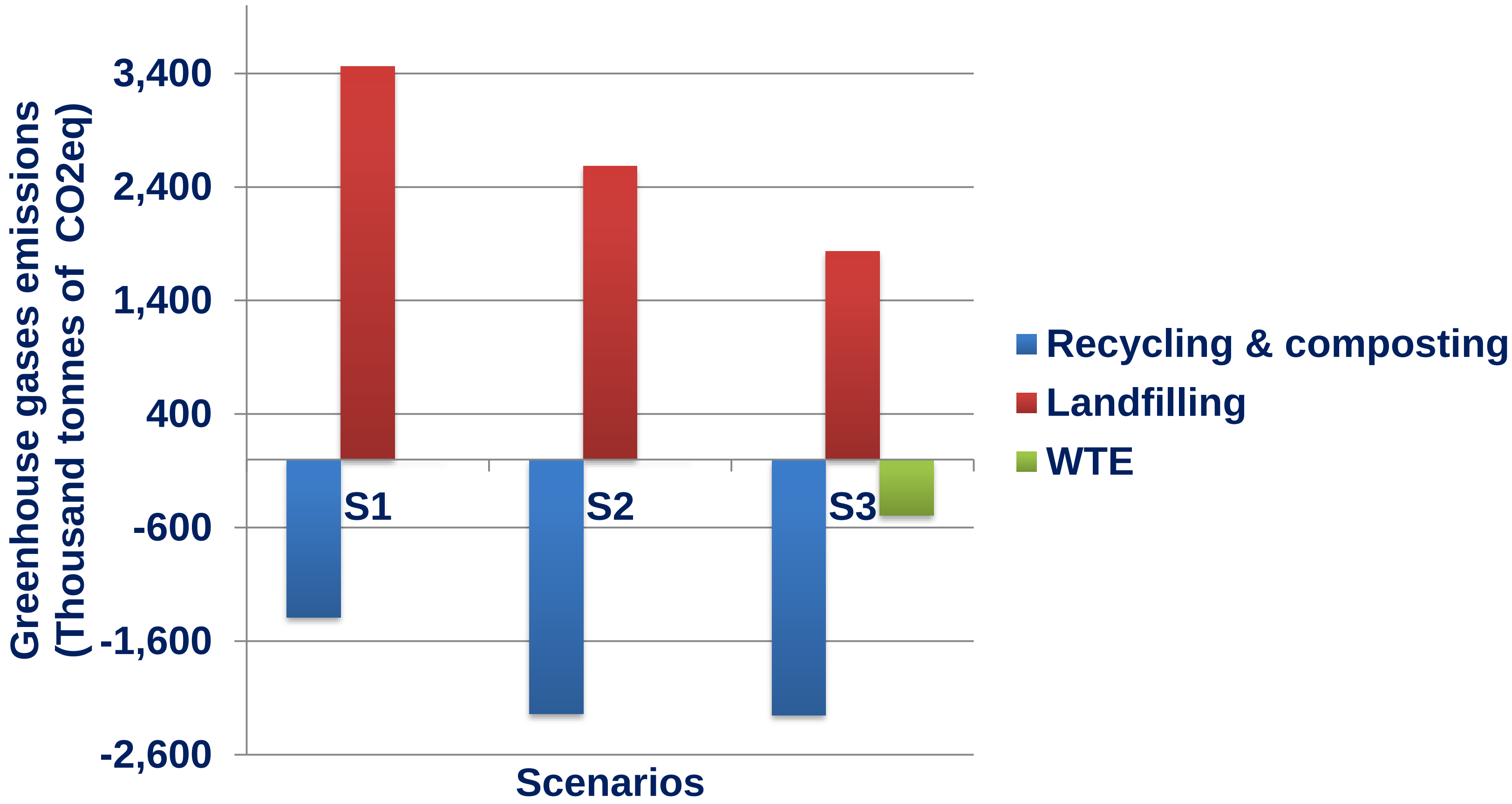
Management technique	S1: BAU	S2: ISWM + LF	S3: ISWM + WTE
Recycling	14%	25%	25%[b]
Landfilling	86%[a]	75%	55%[c]
WTE	0%	0%	20%

[a] It is assumed that 91% go to authorized landfills and 9% to illegal dumping.

[b] It does include metal recovery from bottom ash.

[c] It does include ashes from WTE

Comparison of three scenarios for 2020



Fernanda Cabanas, EEC/Columbia 2017

Why it is the Perfect Time for Chile to join the modern age?

- A perfect opportunity for a PPP project
  - A nation blessed with world famous climate and land should not continue converting it to landfills
  - Technology is now available at an affordable capital cost
  - Outside investment is available and return on investment will be very high
- Required partner: Major Chilean company in construction and infrastructure
- The first and largest WTE in Santiago will lead to future smaller projects.

Taiwan WTE: Not your usual stack

Taiwan WTE Observation Deck on Stack

Leeds, UK (214,000 tons/year)

Worldwide examples: Copenhagen, Denmark

Worldwide examples: Spittelau, Vienna, Austria

To be built in Shenzen, China.
The world's largest(1.6 million tons)

Sponsored by:

IDB Inter-American Development Bank

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

MARCH 2012

WTERT "wte guidebook"

- **Already available In English, Portuguese, Spanish.**
- **Chinese edition underway by WTERT-Asia**

…for those of you interested in Sustainable Waste Management "google" **WTERT** or look up

www.sofos.org

Earth Engineering Center

Columbia University

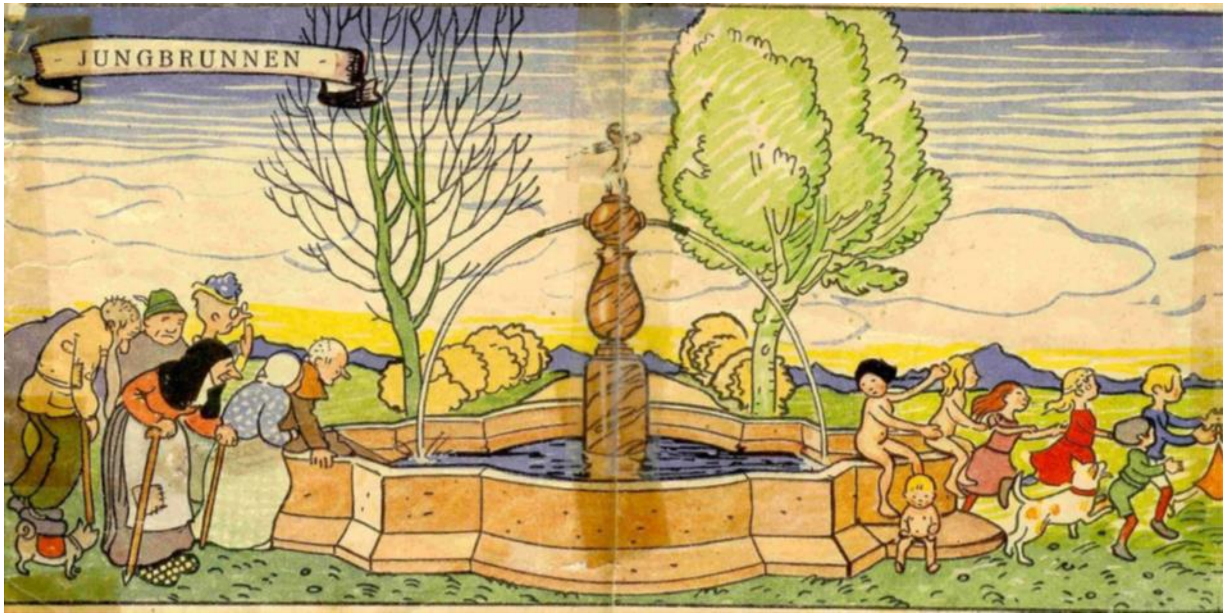
Or look up Google for WTE Guidebook

Waste to Energy providing new material resources

Waste → Resource opportunity

Research

The best opportunities need research to make them happen……..



Thank you very much for your attention!

Thanos C. Bourtsalas: ab3129@columbia.edu