7th International Workshop of Waste to Energy
Oct. 25 to Nov. 8, 2023, Online

A brief history of Sustainability of the Waste-to-Energy (WTE) technology.

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COLUMBIA UNIVERSITY
EARTH ENGINEERING CENTER

The use of controlled fire by humans

- The use of fire to heat and feed humans is a million years old.
- At about 3300 BC, the use of **controlled fire** brought about the Bronze Age and, at about 1300 BC, the Iron Age.
- The Industrial Revolution of the 18th century was made possible by **controlled fire** and the steam engine.
- At present, much of the electricity, cement, and metals used by humanity are produced by **controlled fire** (combustion).

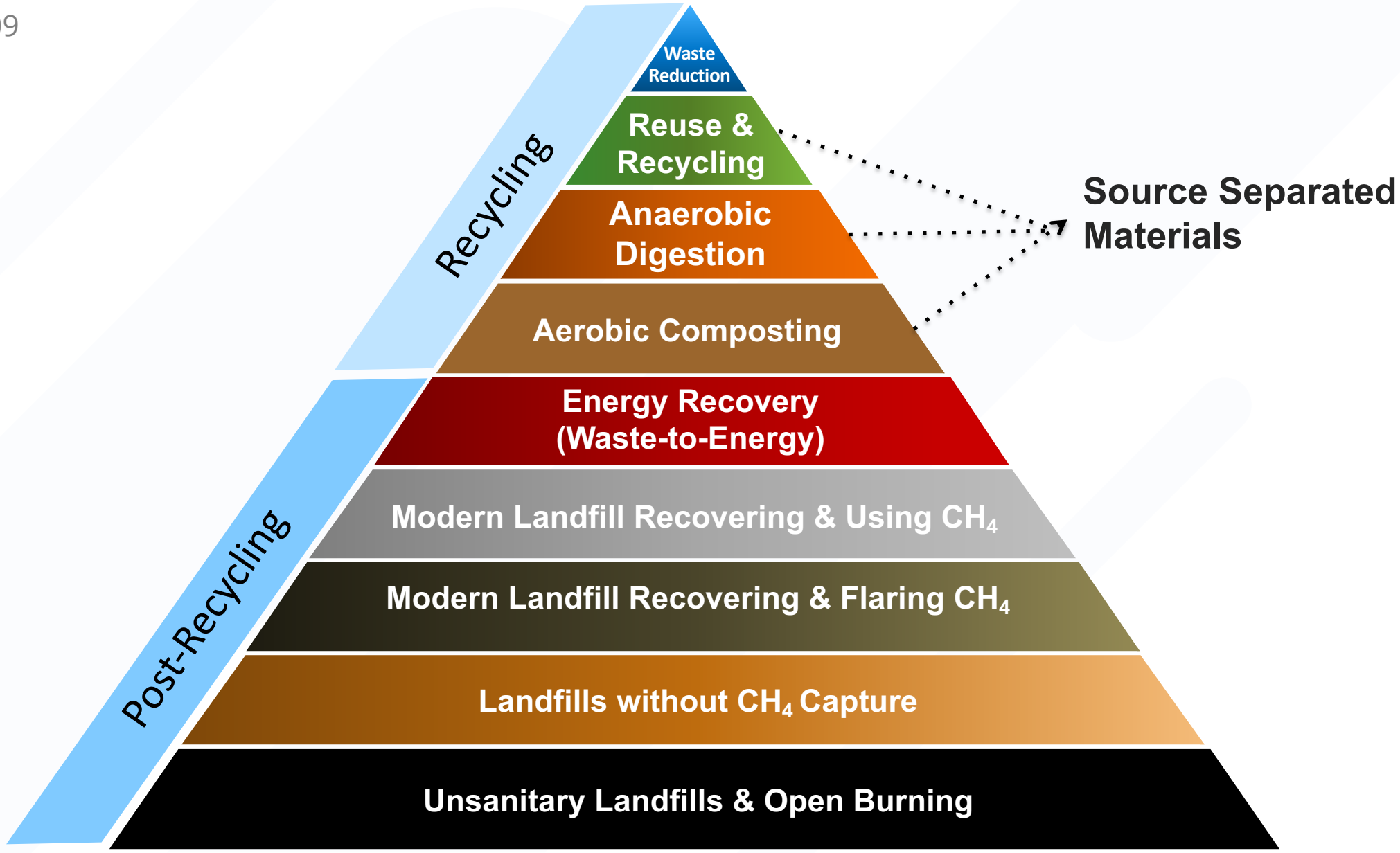
Modern use of controlled fire for waste disposal

- Industrial incineration of municipal solid wastes (MSW) started
  - in Nottingham, England, in 1874,
  - in New York City, in 1885,
  - in Hamburg, after the outbreak of cholera, in 1896.

- Prof. Themelis considers the modern age of waste-to-energy (WTE) power plants to start the last decade of the 20th century when advanced pollution control systems were implemented.

The hierarchy of waste management (EEC, Columbia U.)

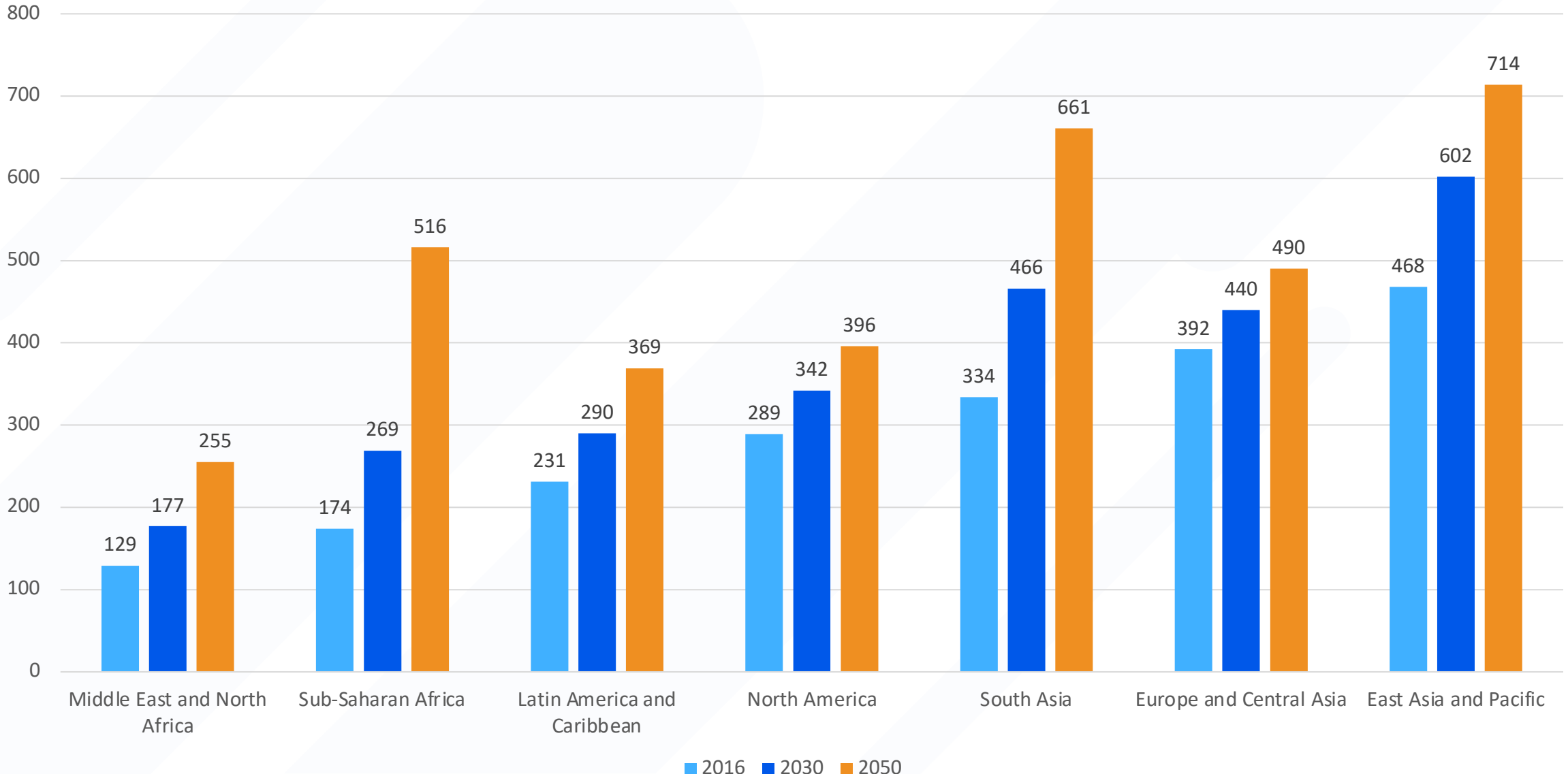
EEC 2009



Managing of the “after-recycling of urban waste is a major global problem (in millions of tons)

Projected waste by region

Source : World Bank report “What a waste 2.0”



What to do with “after-recycling” urban wastes

- Wastes remaining after all possible recycling and composting can be called “**post-recycling wastes**”
- There are ONLY two ways for dealing with **post- recycling wastes:**
  - Sanitary landfilling, or
  - Controlled combustion with energy and materials recovery **(Waste to energy or WTE)**

The WTE technology, as of 1990

- In the 20th century, the WTE technology was developed as an alternative to sanitary landfilling.

- WTE is controlled combustion of urban wastes (MSW) to produce electricity/heat and recover metals and minerals.

- **The use of post-recycling MSW as fuel in specially designed power plants is one of the most misunderstood technologies, in parts of the developed world.**

Where the global post-recycling wastes go:

At this time:

- About 75% of the collected post-recycling wastes (900 million tons) go to landfills and waste dumps.

- About 25% go to WTE facilities (350 million tons) (Europe: 100, Japan: 50, US: 27, China: 150 Mt; others).

A lot of opportunity for this class!!!

Pros and cons of sanitary landfills

- Much lower initial capital investment than a WTE plant.

- Less costly to build and operate than WTE power plants. In the U.S., a municipality has to pay $30-50 per ton MSW landfilled; vs WTE gate fee of $60 - 90/ton.

- Landfilling uses up, **forever**, one square meter of land for every 10-20 tons of MSW landfilled.

- Landfilling generates two to three times of greenhouse gases (GHG) of methane per ton of MSW, than WTE (details in next two slides).

- The potential for energy recovery from landfill biogas is 1/5 of the WTE recovery

How much methane is generated per ton MSW landfilled? References to recent studies:

- **Columbia University study, 2021:**

"Methane Generation and Capture of U.S. Landfills"
Journal of Environmental Science and Engineering A 10 (2021), p.199-206

- **U.S.EPA, GHG Inventory, 2023:**

www.epa.gov/system/files/documents/2023-04/US-GHG-Inventory-2023-Chapter-7- Waste.pdf (Section 7: Waste)

How much methane is generated per ton MSW landfilled? Close agreement between Columbia and US EPA studies:

Columbia University study of all US landfills (Themelis and Bourtsalas, 2021):

0.05 ton CH4/ton MSW landfilled (U.S., average)

U.S. EPA, GHG Inventory estimate (2023):

- U.S. MSW landfilled in 2021: 216 MMt MSW
- CH4 generated, 2021: 335 MMt CO2, equivalent
  - 335/25 (IPCC, 100-year horizon) = 11.96 MMt CH4
  - 11.96/216 = **0.055 ton CH4/ton MSW landfilled**

Columbia study of CH4 captured at U.S. landfills

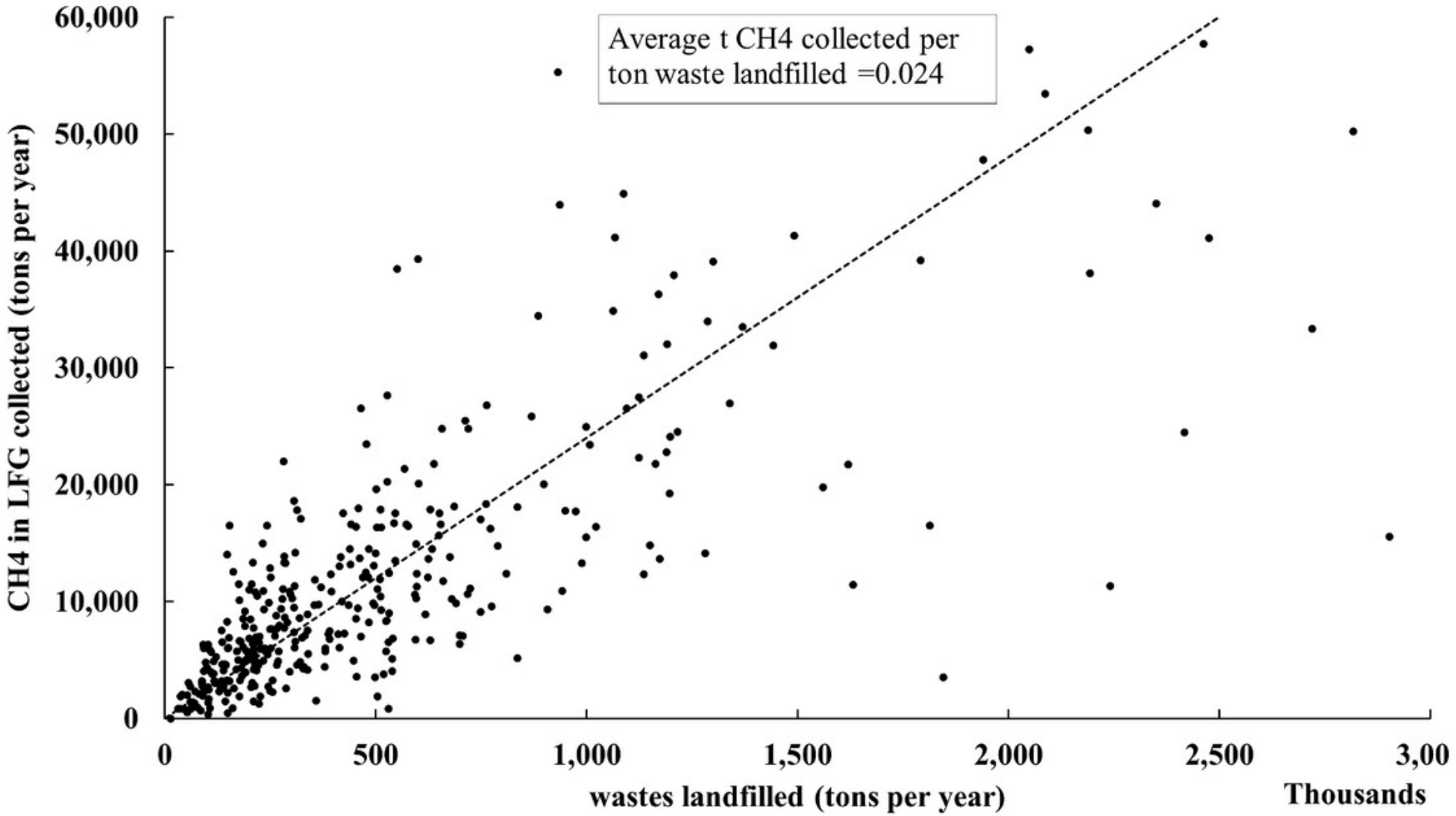
Source: Themelis and Bourtsalas, 2021; see data on next slide

- 396 U.S. landfills report biogas capture to Landfill Methane Outreach Program (LMOP).

- Daily methane capture rates of all CH4-capturing landfills were assumed to apply to 365 days/year.

- Reported production of electrical power (MW) by LMOP landfills was assumed to be at 45% thermal efficiency and applying to 365 days/year.

Calculated CH4 tons captured vs tons MSW/year



CO2 contribution of landfilling and WTE in the U.S.

CO2 emissions of landfills (90% of post-recycling MSW):

- 216 million metric tons of MSW landfilled x 0.05 ton CH4/ton MSW = 10.8 MMt CH4 generated
- Minus CH4 captured at U.S. CH4 capturing landfills (Themelis and Bourtsalas, 2021): 4.6 MMt CH4

CH4 loss to atmosphere: 6.2 MMt CH4

- **CO2,equ from landfills at 20-year horizon (IPCCC), 6.2 x 80 = 496 MMt CO2**
- **CO2 emissions of WTE (10% of post-recycling MSW): 33 MMt CO2***

**2/3 is biogenic CO2*

Land conservation by use of WTE

- The SEMASS WTE, that serves my town of Sandwich, (MA, USA) has already processed 30 million tons of MSW and occupies about **10 hectares (nearly one half is park area).**

- For this tonnage, the forty landfills that SEMASS replaced in Massachusetts would have used 150-300 hectares of land.

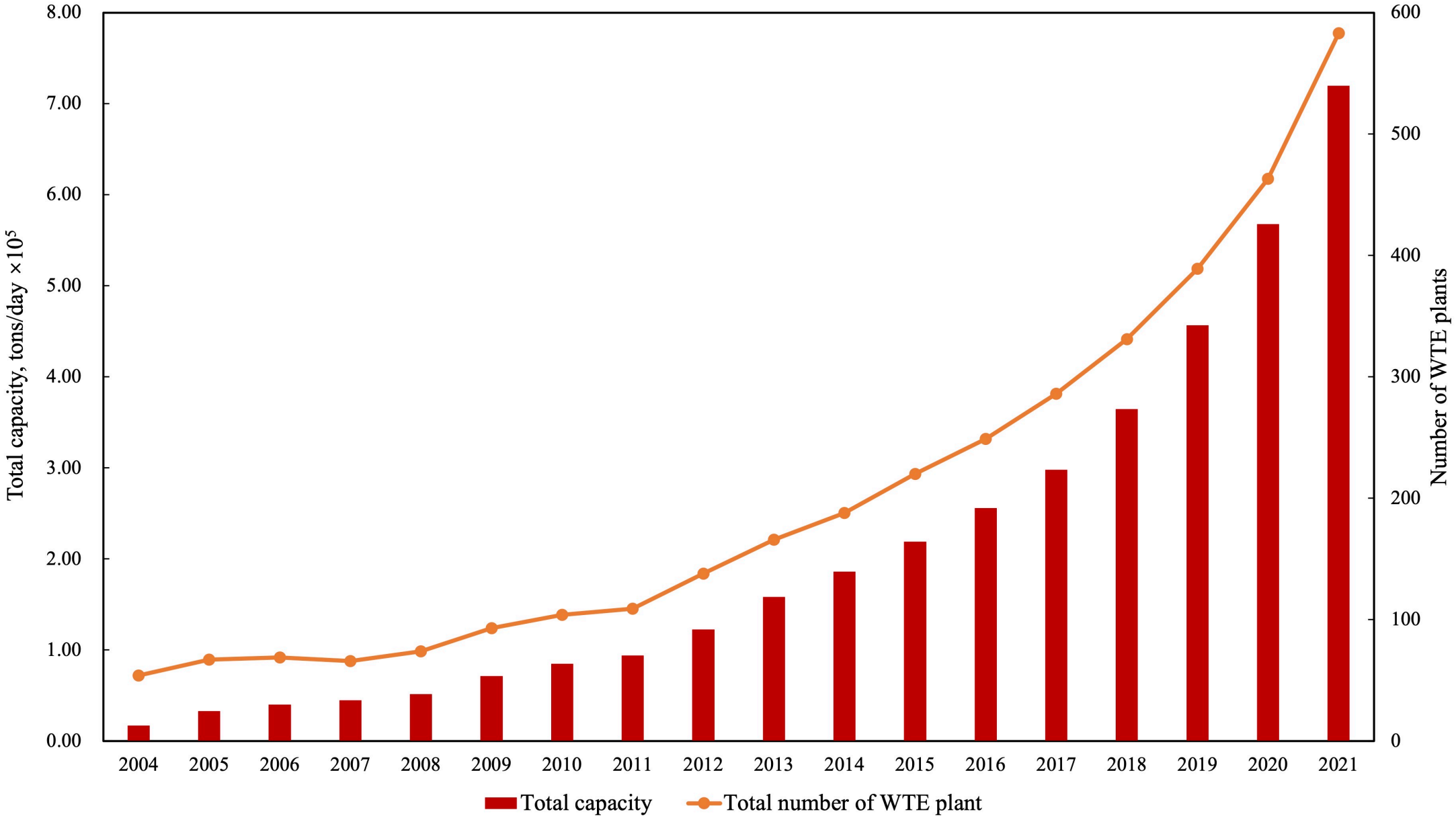
China at the forefront of WTE application: Progress made in 2000-2022

- China has grown from “developing country” to being the No.2 global economy
- Rapid rail transport in China now serves 300 cities
- Current Chinese WTE capacity is now greater than the E.U. and Japan put together
- Because of “mass production” of WTE plants, China has been able to reduce greatly the capital cost of WTE plants.

For example: Factories that produce WTE equipment (China Everbright, Changzhou, China)

Same in change from “custom-built” to “Ford mass production of cars

Exponential growth of WTE industry in China is continuing



Everbright Jiufeng WTE plant in Hangzhou, China (3,000 tons/day)

Important “fallout” from enormous growth of WTE in China: Lower CAPEX makes WTE power plants cost-competitive to sanitary landfilling

- Cities in the developing world can skip the sanitary landfill stage and move directly from landfilling to **WTE power plants** (already done in Ethiopia, Serbia, Turkey, Vietnam, etc.).

- Cities that have sanitary landfills can move to the WTE technology.

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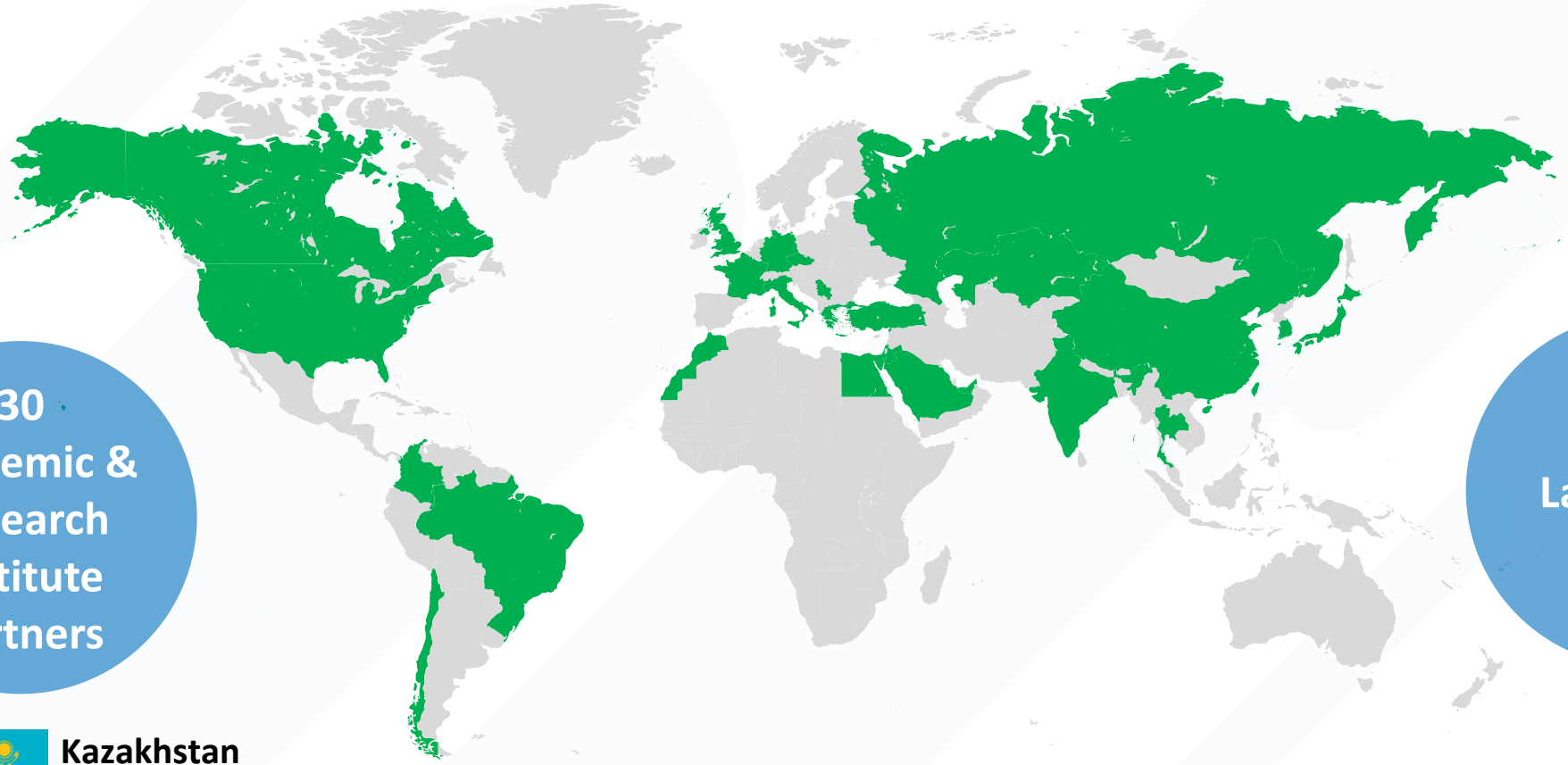

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Good luck to the 2023 WTE Class in advancing the WTE technology worldwide

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