

Research efforts to advance sustainable waste management

Marco J. Castaldi

Director, Earth Engineering Center|CCNY

Assoc. Professor Chemical Engineering Department

City College (CCNY), City University of New York (CUNY)

*October 6th, 2016
New York, New York*



What do the percentages say?

18% Without electricity

Source: EIA

11% Without Clean water

Source: UNwater.org

0.0% Without waste

11% Without food

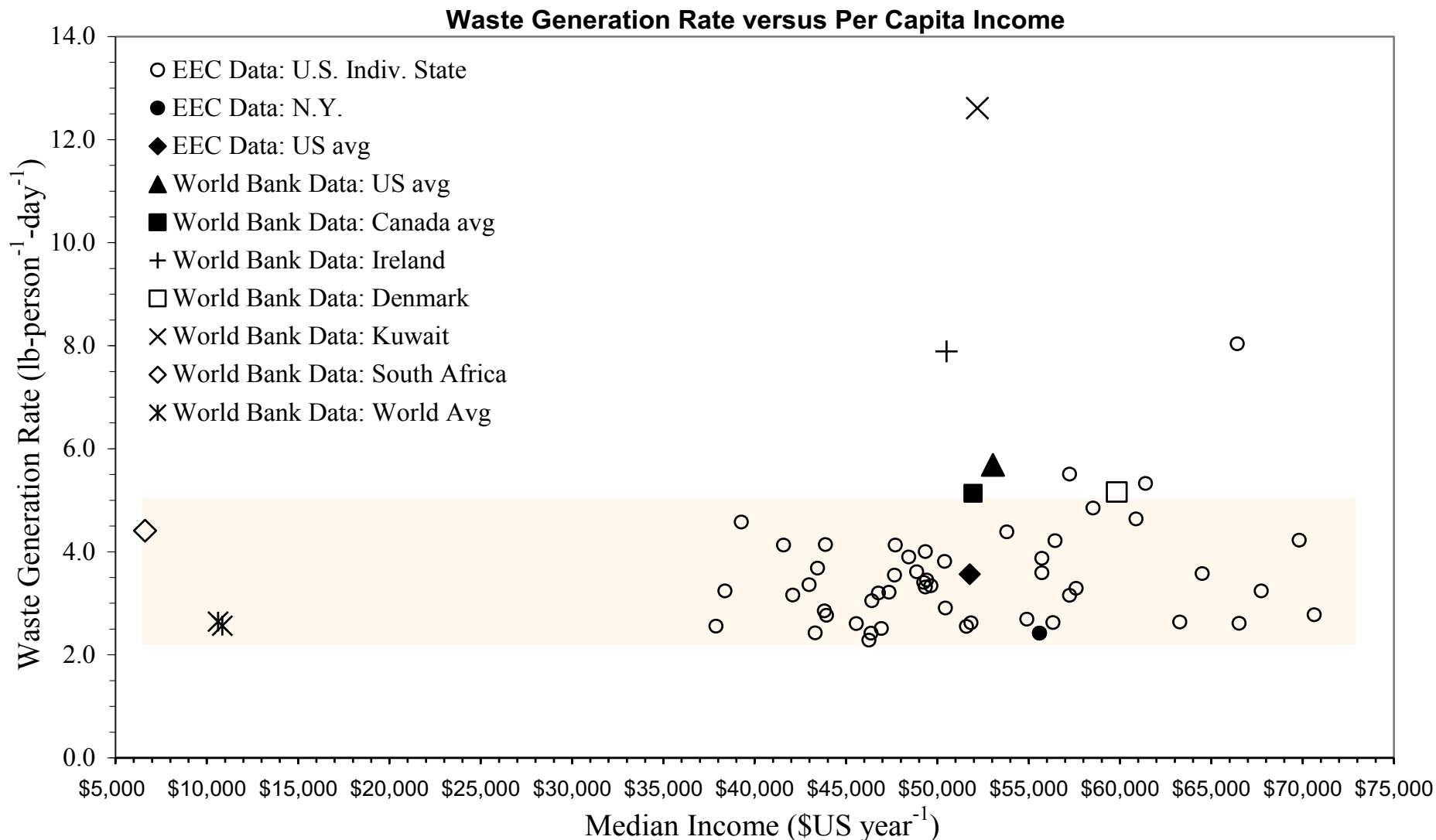
Source: worldhunger.org

Everyone in the world has access to waste

- MSW
- agricultural/biomass
- human excrement



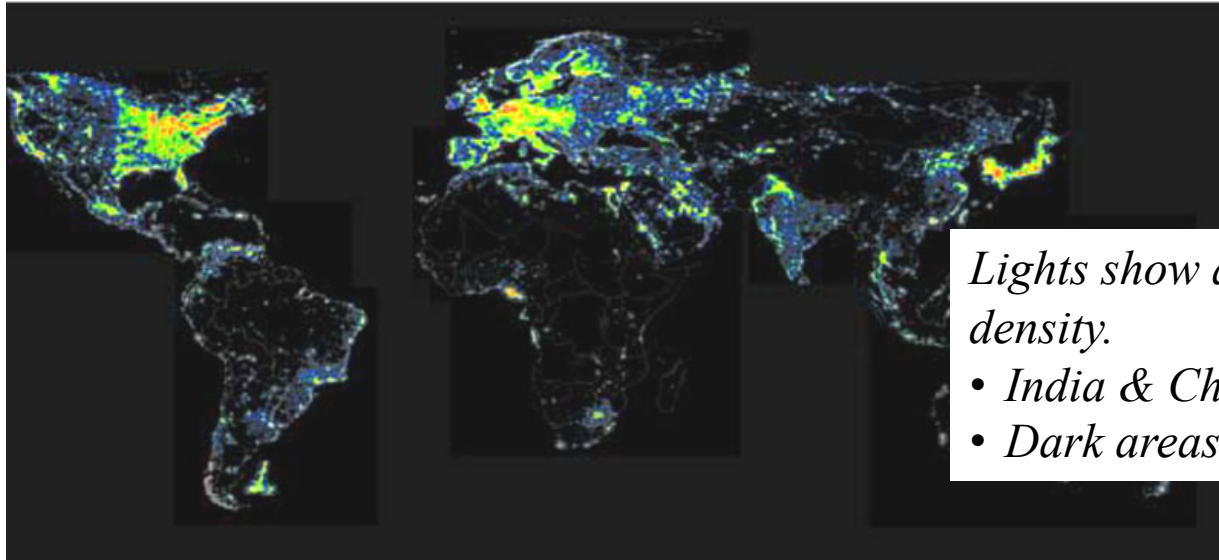
Waste Generation



- *No clear correlation with income level*
- *Narrow Band: ~2.5 and 4.0 lb/person/day*
- *Indicates a base level of waste must be generated to live?*



Some Perspective: Waste as a resource



Lights show areas of nominal population density.

- *India & China more dense than Europe*
- *Dark areas still contain people*

Total energy use/person/year (or per capita consumption) world = **70 MMBtu**
 ~2.0 lb/person/day MSW generation = **3.3 MMBtu** – **developing world**

To move ~300,000 gallons H₂O (i.e. one-acre-foot) = 1.02 kW
equivalent of ~ 45 acre-foot per day for 2.0 lb/person/day

Developed world: small but real contribution (~1.5%)

Total energy use/person/year (or per capita consumption) U.S. = **313 MMBtu**

~4.0 lb/person/day MSW generation = **6.6 MMBtu** (@ 10.5 MJ/kg; 4515 Btu/lb) – **U.S.**



Earth Engineering Center at City College of New York (EEC|CCNY)

- We are a center that conducts research on extracting value from waste via material and energy recovery processes
- **Our research spans all types of waste and conversion technologies**
 - Expertise in thermal conversion of municipal solid waste (MSW)
- We are a not-for-profit organization housed in the **Grove Engineering School of City College of New York**
- **Our worldwide network of EEC|CCNY Research Associates include:**
 - Students
 - Academic faculty
 - Engineering professionals



The EEC|CCNY team

- **EEC|CCNY Director, Marco J. Castaldi**
 - PhD, Chemical Engineering
 - Associate Professor, Chemical Engineering, City College of New York
 - National Academy of Engineering Education Fellow
 - Fulbright Fellow

▶ **EEC|CCNY Associate Director, Demetra A. Tsiamis**

- ▶ MS, Chemical Engineering
- ▶ Previous experience in environmental consulting

▶ **Students**

- ▶ CCNY Ugrad (Chemical Engineering & Environmental Engineering)
- ▶ Visiting Students (International & Domestic)



In close collaboration with:

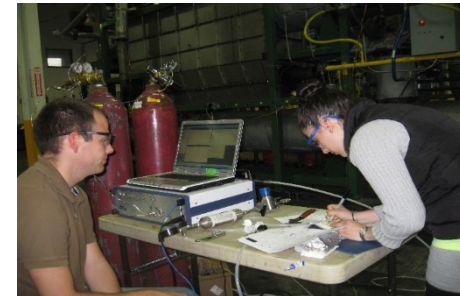
- ▶ **Nickolas J. Themelis, Director of EEC-Columbia University**
 - ▶ Professor Emeritus, Earth & Environmental Engineering
 - ▶ National Academy of Engineering Fellow





What we do at EEC|CCNY:

- We conduct industry sponsored applied research projects to advance and innovate the field of sustainable waste conversion
- Our research spans **laboratory experimental analysis to pilot scale testing of commercial technologies**
- **Our research is internationally recognized:**
 - Published in technical journals i.e. WM&R, WBV, ES&T
 - Provide expert testimony to state legislatures
 - Technical consultation at US Federal and international levels





Fuel Production from Pyrolysis of Non-Recyclable Plastics

- **Golden Renewable Energy (GRE)** has a continuous process that pyrolyzes non-recyclable plastics (NRP) and produces a fuel product to be sold on the wholesale market
- EEC|CCNY conducted due diligence testing at a GRE's pilot facility in Yonkers, New York



Pyrolysis





Fuel Production from Pyrolysis of Non-Recyclable Plastics

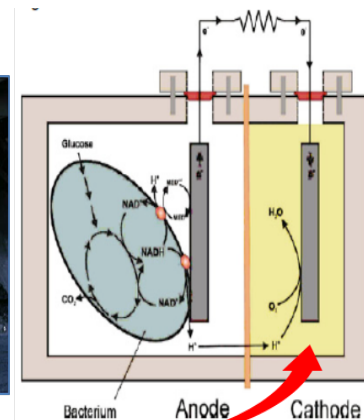


- *NRP has a high energy density*
 - *Higher heating value (HHV): ~36 MJ/kg*
 - *Higher than that of coal and natural gas*
- *HHV of final oil product from pyrolysis process: ~38 MJ/kg*
 - *Similar properties to that of traditional petroleum based fuels*
- *Air emissions of process met regulatory agency standards*
- *Typical yields of plastics pyrolysis processes are in the range of 4-6 barrels of oil/ton*



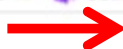
Livolt: Waste-to-Energy Ash for Electricity Generation

- *Microbes in wastewater have potential applications in fuel cells*
- *Livolt design uses ash by-product from waste incinerators as substrate material in fuel cell:*
 - *Cheaper*
 - *Utilizes waste by-product*



Livolt

Metal oxidation
state change
Oxide to base
metal





Limits to Recycling

*Some areas have great **real** recovery rates*

	Generated (Tons)	waste (Tons)		recycled
Lombardia, Italy (2009)	4403066	538730	12.2	85
Lee county, Florida, USA (2012)	1098301	145400	13.2	59
Orange county, Florida, USA (2012)	1881650	306582	16.3	58
Sarasota, USA (2012)	719643	107303	14.9	44



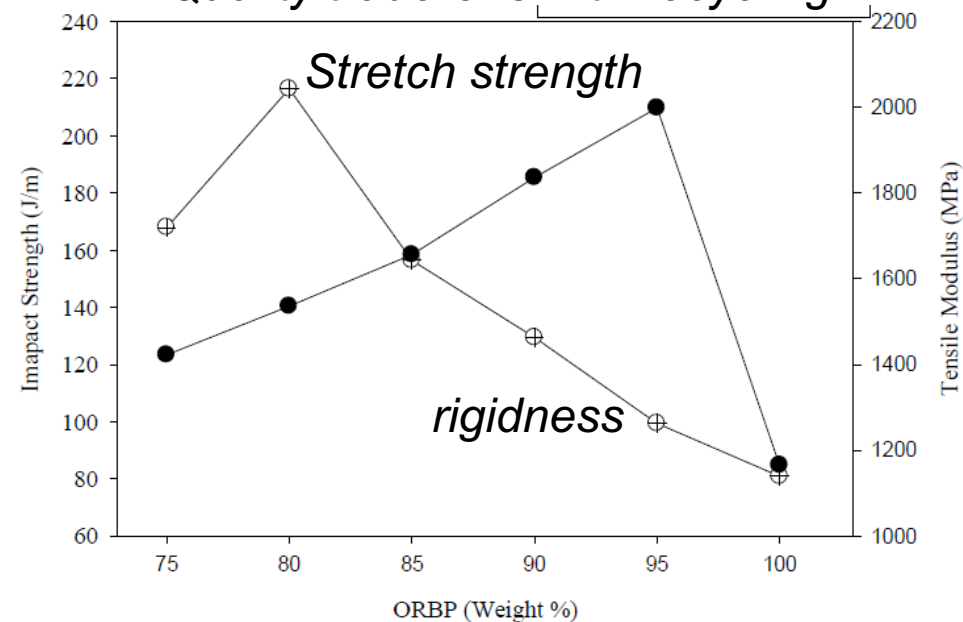
Deepak Sharma et al.

Having ideal recovery of rates of 85% and 73% for paper and plastic waste streams.

Leaves **83,846** tons of waste left in this ideal community (~15 %)

This is only plastic and paper

Quality trade-offs with recycling



Sponsors & Collaborators

➤ ***All points of the waste managements spectrum.***



= *Reduction via education & Awareness*



= *Reuse Sector*

➤ **Waste Generators:**



= *ACC represents plastics manufacturers – they have an interest in end of life alternatives for non-recyclable plastics*



Public

= *Need for clear direction and further education & awareness*

➤ **Waste Converters**, both established and start-up companies:



Waste to energy



Start-up: wet waste gasification



Livolt



Start-up: wastewater microbial fuel cells

➤ **End Users of Waste Conversion Processes:**



Interest in use of waste syngas for turbines



Interest in use of waste to power cement kilns



Publications

Total of 5 publications to date in 2016

*J LeBlanc, M Uchimiya, G Ramakrishnan, MJ Castaldi, A Orlov
Energy & Fuels 30 (8), 6537-6546*

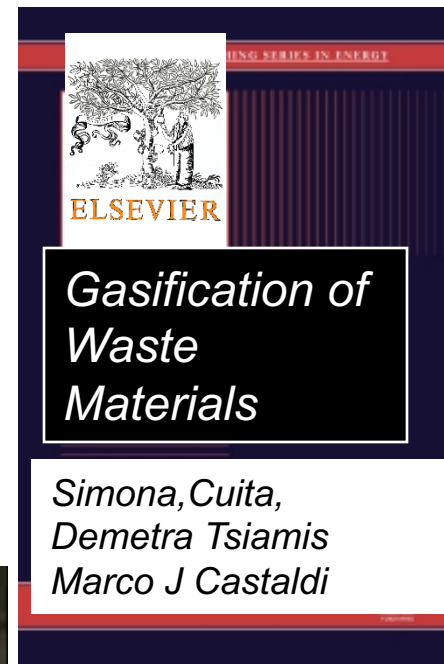
*MJ Castaldi, Thermochemical Waste Treatment: Combustion, Gasification, and
Other Methodologies, CRC Press*

*K Jones, G Ramakrishnan, M Uchimiya, A Orlov, MJ Castaldi, J LeBlanc,
Energy & Fuels 29 (12), 8095-8101*

*Sharobem, T; PhD Thesis: Mitigation of High Temperature Corrosion in
Waste-to-Energy Power Plants*

*Sharma, D., Rice, E., Brandes, R, Castaldi MJ., TECHNICAL FEASIBILITY OF
ZERO WASTE FOR PAPER AND PLASTIC WASTES, Waste Management
Research – in revision*

Next Book – release in 2017





Recent Event:

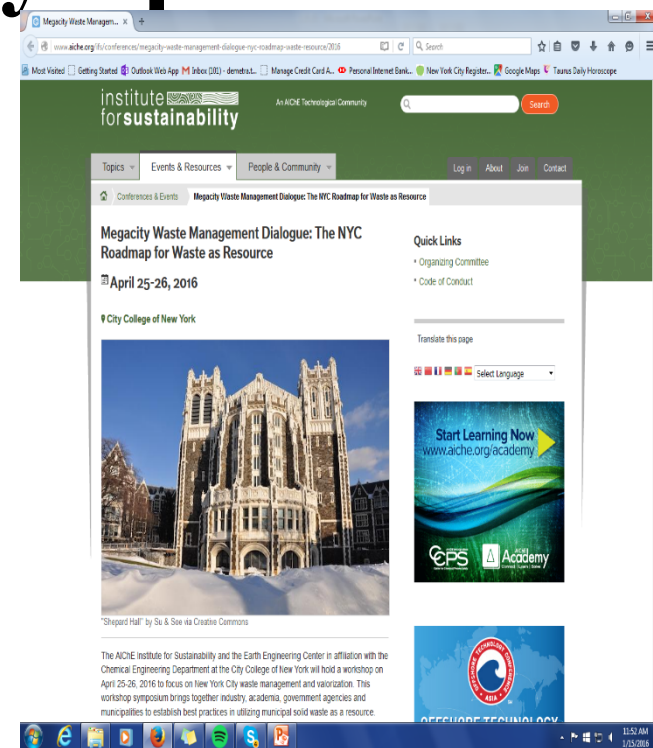
2016 EEC|CCNY Symposium

- **Megacity Waste Management Dialogue: The NYC Roadmap for Waste as a Resource** Apr. 25-26th, 2016 at CCNY
- Outcome will be **a roadmap for NYC waste sustainability** spanning technical, social, and economic aspects
- ~100 Participants (Industry, Govn't, Academia, Public)
- **Participation from all facets of waste:**
 - DSNY – Handling, Collection, etc
 - EPA – Regulatory
 - DEP – Water Impacts
 - Reduction
 - Recycling
 - Composting
 - Ash Handling

Main Outcomes:

- *People's behavior must change / national policy*
- *Conflict between generators (reduce, reuse, recycle) and management (compost, WTE, LF)*
- *Need more accurate hierarchy*
- *Technology transfer and deployment – needs to align with local situation*

Data compiled, report to be issued Jan. 2017





EEC|CCNY Projects

- *Technical Due Diligence of Pilot Scale Pyrolysis Unit for Non-Recycled Plastics—WASTE PLASTICS*
- *Assessment of Longterm Market Opportunities in the Waste Gasification Industry*
- *Technical Due Diligence of a Pilot Scale Gasifier for Wet Waste –WET WASTE*
- *Air Emissions Testing for Pilot Scale Pyrolysis Unit for Non-Recycled Plastics*
- *Determination of Heating Value of Non-Recycled Plastics—WASTE PLASTICS*
- *Understanding technical limitations to paper and plastic recycling*
- *Impact of Non-Recycled Plastics on Syngas Quality for a Pilot Study*
- *Decoupling of Waste and GDP*
- *Material Assessment & Characterization for WTE facilities*
- *Metals & Material Recovery from Ash: Characterization and Assessment*



Ambitious Plans!

MacArthur Foundation



\$100,000,000

this equals ~2800 Graduate students

- *Global Education & Awareness about Wastes*
- *Technology Test-beds*
- *Leveraging our World-wide EEC Network*

We will lead in:

- *Technical Consultation*
- *Academic Research*
- *International Visitor Exchange*



WTER Efforts

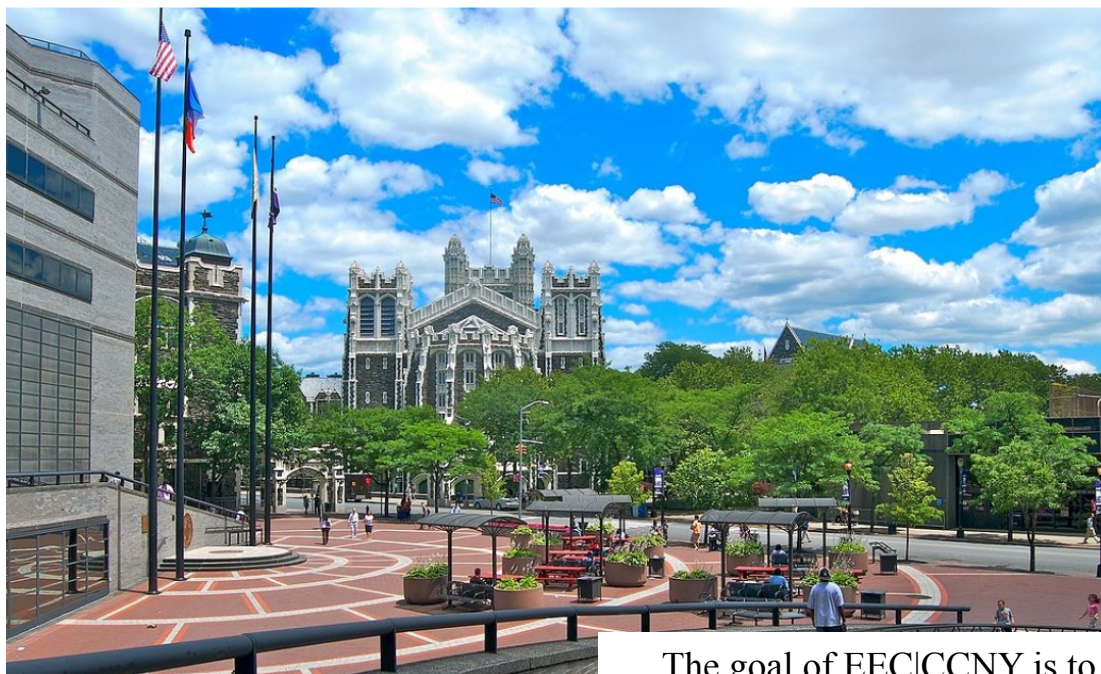
Research

People

Sponsors

Publications

Contact



Welcome to the EEC
at CCNY!

Engineering of Earth's energy and
material resources for responsible
utilization and preservation

The goal of EEC|CCNY is to bring to bear rigorous engineering solutions that enable responsible use of energy and materials for the advancement of society. Through industry collaborations and research sponsorship EEC|CCNY develops novel solutions to some of the world's most pressing problems. EEC|CCNY routinely engages students with industry professionals enabling a holistic approach to creative realistic, forward-looking applications. The reach of EEC|CCNY is international in scope with many projects connecting international students and companies with a global presence.

Acknowledgements



Yearly Activities

- ~5 Publications & 10 Presentations on MSW management per year
- Metals for Corrosion Resistance
- Ash – New uses: Catalytic / Leaching Reduction
- Energy Value of NRP
- Market Assessments of MSW as Resource
- International: China, Dominican Republic, Island Nations, Germany
- Student Internships
 - Technical due diligences on pilot scale thermal facilities
 - Analytical assessments
 - Lab scale materials characterizations and evaluations

backup



Gasification of High Moisture Waste for Electricity Production

- ***Sustainable Waste Power Systems***
gasifies high moisture content waste
(i.e. agricultural waste, brewery waste)
 - *Up to 85% moisture content*
- *Modular design of system for on-site treatment of waste*





How MSW Conversion Impacts Food/Energy/Water Nexus

- *FEW Nexus*
 - *Sufficient food, sustainably grown to feed population*
 - *Access to clean, reliable energy*
 - *Access to clean sufficient water resources*
- *Thermal Conversion Technologies Enables FEW Nexus*
- *Technologies Must be Affordable, Distributed & Versatile*
- *Small Scale Thermal Conversion of Distributed Technologies Will Impact the Food/Water/Energy Nexus*



- EEC|CCNY: intro
- List of projects
- DSNy reuse collaboration (reuse conference)
- EEC|CCNY Conference
- Textbook/publications
- ASME/Power conference
- ESE program integration
- Projects:
 - ACC:Enerkem, EIA, multilayer
 - GRE
 - SWPS
 - Dow
 - Covanta
 - Magotteaux
 - LabUSA
 - Waste Management

Collaboration between EEC|CCNY and the City of New York

- **EEC|CCNY** conducts research on sustainable waste management
 - Inform Dept. of Sanitation about EEC|CCNY
- Our expertise is in **waste conversion**
 - **EEC|CCNY** and our vision can be seen in video below:
 - Interest to learn more about OneNYC waste goals

Additional Projects at

EEC|CCNY

- Reuse of waste materials (collaboration with NCECMR at DSNY)
- Metals recovery from residual by-product of WTE facilities
- Investigation of boiler corrosion in WTE systems
- Investigation of temperature profiles in landfills
- Decoupling of MSW from economic growth
- Determining accurate heating value of non-recyclable plastics
- Use of RDF as fuel for cement kilns
- Use of syngas and landfill gas mixtures in IC engines
- Metals and energy content in multilayer plastics
- Assessment of worldwide waste gasification market for gas turbine applications



Golden Renewable Energy: Waste Plastics Pyrolysis Process



Welcome

- **Workshop Chairs**

- Marco J. Castaldi, *Director, EEC|CCNY*
- Demetra Tsiamis, *Associate Director, EEC|CCNY*

- **Steering Committee**

- Prof. Marco Castaldi, EEC|CCNY, Co-Chair
- Demetra Tsiamis, EEC|CCNY, Co-Chair
- Prof. Nickolas Themelis, Columbia University
- Dep. Commissioner, James Roberts, NYC Depart. of Environmental Protection
- Prof. Ange Nzihou, Ecole des Mines d'Albi-Carmaux, France
- Prof. Charles Vörösmarty, CUNY Advanced Science Research Center

- **Organizations**



Special Thanks

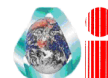


Combustion & Catalysis Laboratory



Earth Engineering Center
CITY COLLEGE of NEW YORK

WTERT



Waste-To-Energy Research
and Technology Council

*Students & Research Associates
Research Sponsors
Colleagues*



CUNY
ADVANCED
SCIENCE
RESEARCH
CENTER

Environmental CrossRoads Initiative

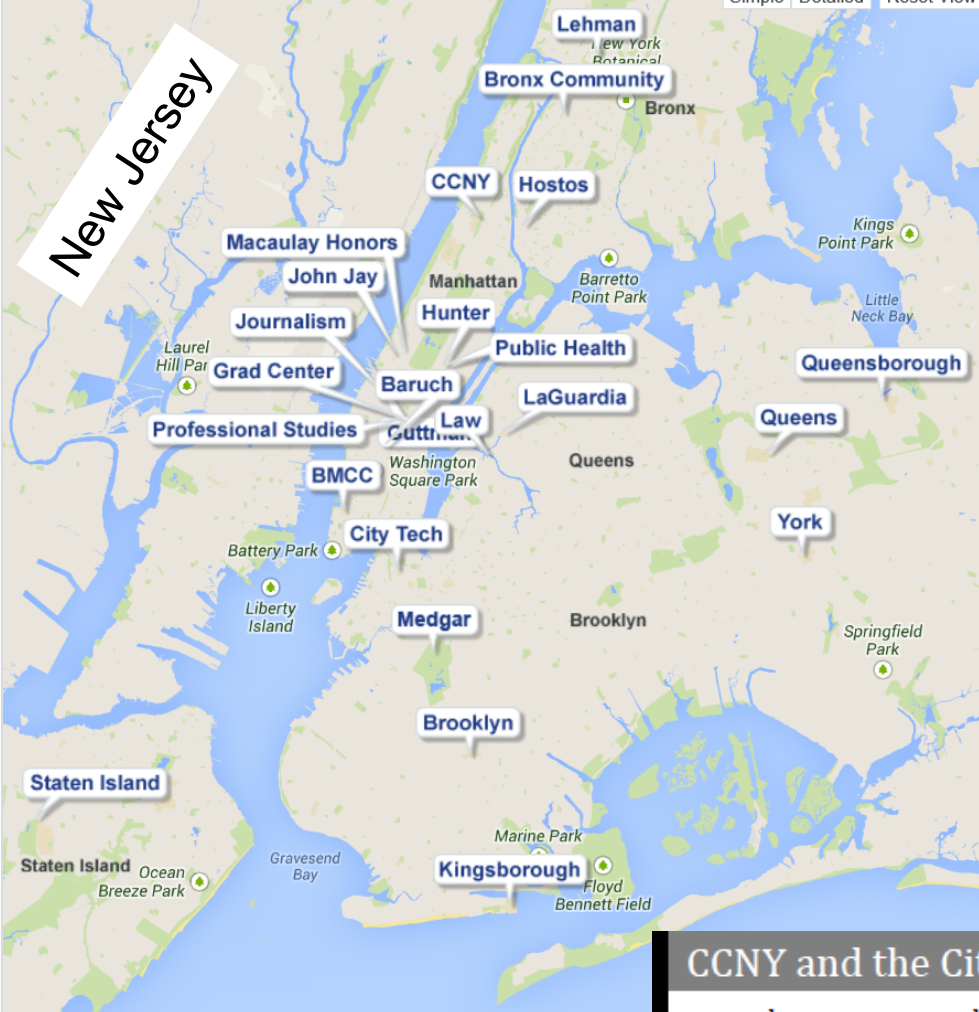
The City College
of New York

institute 
for **sustainability**
An AIChE Technological Community

Website, Coffee Break, Lunch, Reception

Hosting, Facilities & Workshop Contributions

City University of New York



CCNY and the City University of New York

3 rd	Ranked 17 th	6	11	7	\$3.0 Billion
Largest University in the US	Regional Public Universities	CCNY Degree Awarding Schools	Senior Colleges	Community Colleges	Annual Budget



13
Nobel
Laureates

6700
Full Time Faculty

540,000
Total Students

Total Population:*



- 0.1% Native American
- 25.0% Asian
- 20.7% Black
- 31.3% Hispanic
- 22.8% White

*CCNY Fast Facts Fall 2013, Office of Institutional Research

New York, NY





City College of New York



*Flagship campus of the City University of New
York*



Founded 1847 by Townsend Harris (1st U.S. Consul General to Japan) as the
“Free Academy of the City of New York”

Nine Nobel Laureates graduated from CCNY

-Hofstadter (1961) Penzias (1978) Lederman (1988)

-Most of any public institution

First U.S. Lecture by Albert Einstein, 1921

Prominent Graduates:

Jonas Salk – First Polio Vaccine (Salk Institute)

Andrew Grove – Intel

George Goethals – Panama Canal Engineer

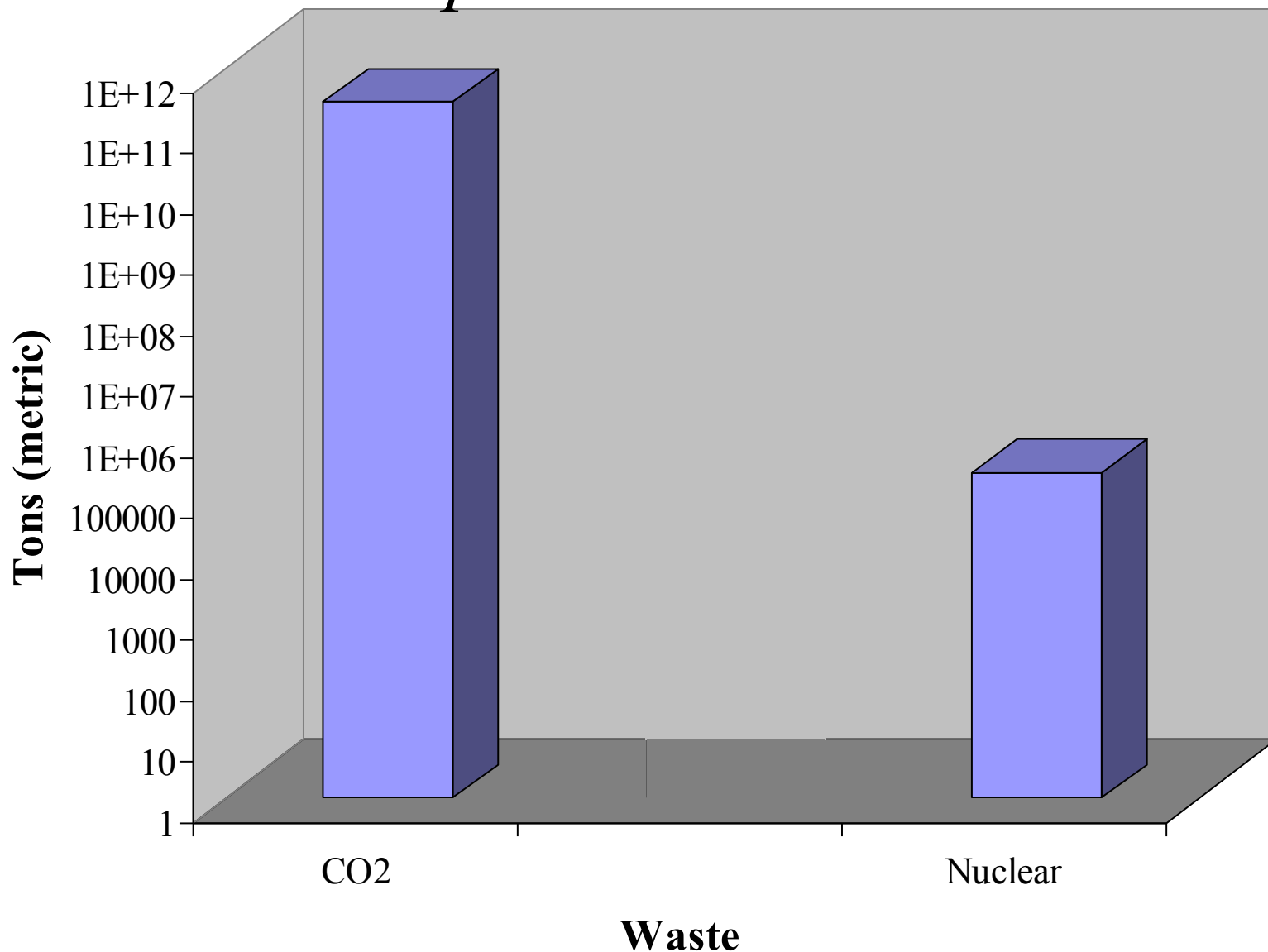
*Neuroscientist Dr. John
O’Keefe (’63) is CCNY’s 10th
Nobel Laureate*



- 48 PhD students
- 14 faculty
- Support Staff: 3 administrators, 2 technicians, and 2 RAs
- Facilities: Multi-million dollar, cutting-edge, shared characterization facility (SEM, IR, Clean Room, Confocal microscope, AFM, pendent-drop set up, evaporators, etc...)
- 3 National Academy Members (Acrivos, Denn, and Shinnar)
- \$2.4M/per year in research funding



Perspective on Wastes



Not Just Energy but also waste and by-products impact the Environment

The Workshop

Full representation of all aspects of MSW Management

Reuse, Recycle, Compost, WTE, Landfill

Policy, Health, Public Perception

Break Sessions

Important that attendees participate

Engage in respectful exchange of ideas based on FACTS

Network, Learn and Have Fun

Thank you for Attending!