Waste-to-Energy (WTE) Session\
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hat to do with the global problem of plastic wastes: lastics to Energy (PTE) and Pyrolysis to Oil (PTO)

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Plastics: A boon and a problem

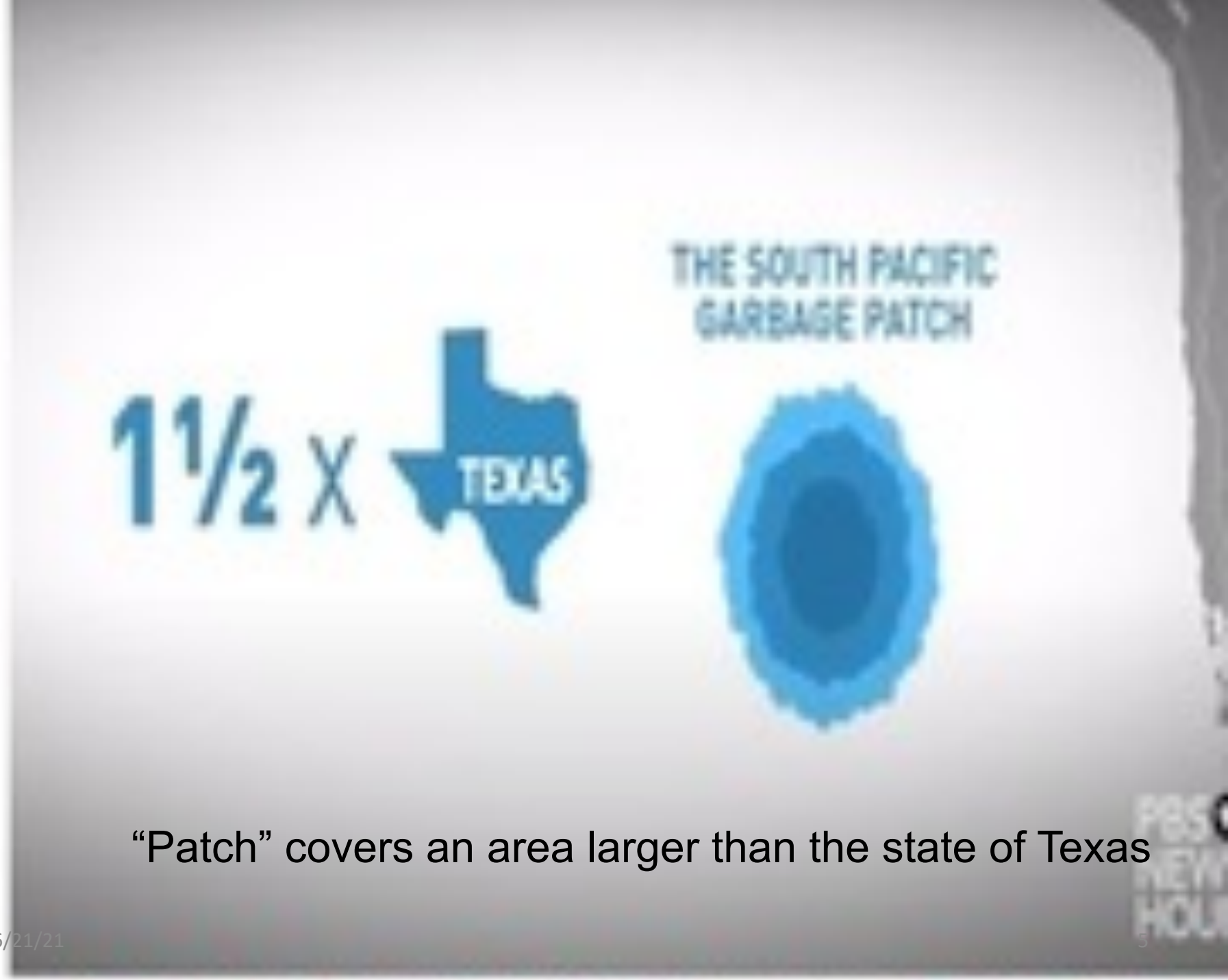
- Plastics are one of the most useful materials invented by mankind.
- The tonnage of used plastics generated globally is estimated at 350 million tons.
- For technical and economic reasons, only 10% of the plastic wastes are recycled as materials, despite an enormous effort, by governments and the petrochemical industry, to increase recycling.

Generation of plastic wastes in the U.S.A.

- Plastics represented nearly 11% (39.3 million tons) of the U.S. MSW stream.
- Of this amount, 2.66 million tons (6.8%) were recycled; 3.9 million tons (9.9%) were converted to energy in WTE plants; 0.27 million tons (0.7%) were used as fuel in cement production
- 32.5 million tons (82.7%) were mixed in the MSW disposed in landfills.
- Rate of recycling plus energy recovery of plastics increased was 17.3% in 2011.
- An additional source of about 1.9 million tons of NRP is in the form of automotive shredder residue (ASR).

Non-recycled plastics (NRP)

- Due to their wide use and non-biodegradability, NRP pose a variety of environmental impacts.
- A very visible impact is the formation of “garbage patches” in rivers and oceans
- The next slide shows the area covered by the “garbage patch” of South Pacific.



“Patch” covers an area larger than the state of Texas

What to do with NRP?

- Non-recycled plastics (NRP) cannot be recycled to original materials
- However, the chemical energy stored in NRP (35 MJ/kg) is 83% of the energy of petroleum (42 MJ/kg)
- Therefore, NRP can be an important source of energy
- Also, since plastics will continue to be used by humanity, NRP can be considered as a "renewable" source of energy

How to recover the energy of NRP?

- There are two technologies for recovering the chemical energy of NRP.
- Both of these technologies have been developed and are available for use with NRP feedstock:

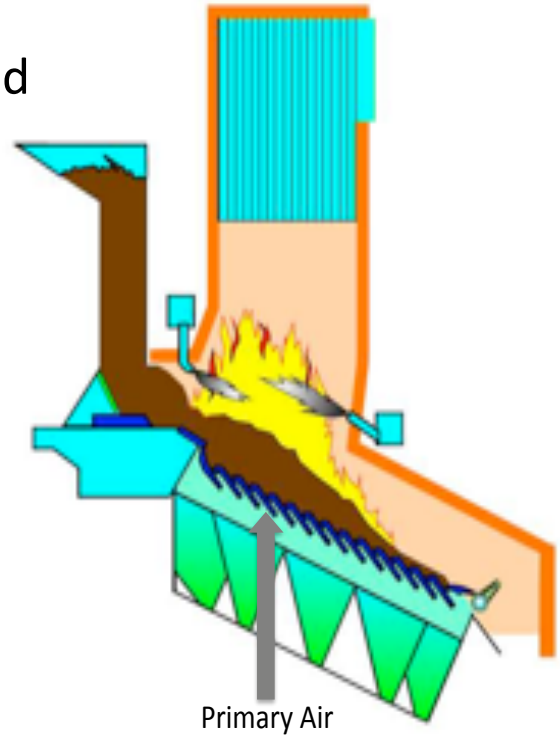
1. Combustion with electricity production (Plastics to Electricity, or **PTE**)
2. Pyrolysis to oil (**PTO**)

Combustion with electricity production (Plastics to Electricity, or **PTE**)

- This technology is similar to the waste to energy (WTE) power plants which combust mixed urban wastes to generate steam and produce electricity in a seam turbine.

The principal WTE technologies

as received
wastes



Moving Grate WTE

shredded
wastes

Circulating Fluid Bed WTE

A WTE plant similar to the first PTE plant (WTE of Lancaster County, Pennsylvania)

Differences between PTE and existing WTE technology

- The principal difference between WTE and PTE is the heating value of the fuel.
- WTE facilities combust urban wastes of heating value 6-14 MJ/kg
- The future PTE will combust plastic wastes of heating value 30-35 MJ/kg
- The moving grate WTE will require water cooled grates
- The fluid bed WTE technology appears to be more suitable for PTE plants.

Differences between PTE and existing WTE technology (cont.)

- Another big difference is that mixed wastes are collected and delivered to WTE plant by the community at a gate fee **revenue** of $50/ton (estimated average).
- In contrast, the non-recycled plastics (NRP) must be separated at the source and their collection and delivery will be a **cost** to the PTE plant of an estimated $50/ton NRP.

Differences between PTE and existing WTE technology (cont.)

- On the plus side for the PTE technology:
- The WTE plants produce an average of 0.5 MWh of electricity per ton of urban wastes.
- As shown in the following Table, because of the higher heating value of NRP, the PTE power plant will produce four times the electricity of the WTE per ton of feedstock

Electricity production of PTE = **four times that of the WTE**

Power plant	Heat ipnut loss, MJ/kg	Process heat loss MJ/kg	Heat to steam turbine MJ/kg	Heat to electricity, at 30% thermal efficiency, MJ/kg	Equivalent electricity, MWh/ton
WTE	8	2	6	1.8	**0.5**
PTE	30	2	28	8.4	**2.3**

Big problem for investors in PTE plants

- Variable and low price of wholesale electricity .
- In 2020, worldwide price of electricity ranged from $50-$180/MWh. At $70/MWh, the electricity revenue of the PTE plant would be $140 minus $50 for cost of feedstock = $90/ton.
- Assuming that CAPEX and OPEX of PTE will be the same as for same capacity WTE plant, the revenue of $90/ton NRP would be marginally sufficient for economic viability of PTE plant.
- Economics will improve by using the turbine exhaust for heating or desalination.

PYROLYSIS of plastic wastes to a synthetic oil (PTO)

- Has been developed and tested on the scale of <25 tons/day in Japan, South Korea, China, India.
- Products: Synoil, carbon residue, syngas (used for external heating of pyrolysis reactor)
- Principal technology: Horizontal, cylindrical reactor heated externally to 400-600oC.
- Promising new technology (S. Korea): Microwave heating of pyrolysis reactor.

Yield of syncrude oil from pyrolysis of non-recycled plastics

- The chemical energy stored in one ton of NRP is equivalent to about 5 barrels of oil.
- Therefore, a pyrolysis process operating at 80% thermal efficiency is expected to produce, on average, four barrels of oil per ton of plastic wastes processed.
- The rest of the chemical energy goes to carbon residue and syngas which is usually combusted to provide the heat for pyrolysis.

Economics of PTE plant (at current $70/ton syncrude)

- One ton of NRP is expected to produce 4 barrels of syncrude oil. At current prices of US$70/barrel, the PTO revenue would be $280/ton NRP.
- From this amount, we subtract $50/ton for the collection and delivery of NRP to the pyrolysis plant.
- Therefore, the net revenue will be $280-50 = $230/to NRP.
- Since the CAPEX of a pyrolysis plant is expected to be the same or lower than current WTE plants (about $500/ton feedstock), the PTO technology is economically more attractive that for PTE.

"*Pyrocrat*" 10 t/day pyrolysis plant (WTERT visit, Mumbai, Jan.2019)

City Oil Field Korea, Pyrolysis of plastic residues

1st Equipment

5 ton / day

Molecule ring cracking of waste plastic and vinyl

2nd Equipment

20 ton / day

Production of industrial light liquid

Where we will see the first large scale pyrolysis plant?

Prediction: CHINA

China has become the world leader in the application of Waste to Energy (WTE)

Province or nation	WTE capacity, million tons of urban wastes
Guangdong, China	28.3
Jiangsu, China	22.3
Zhejiang, China	20.1
Shandong, China	19.2
CHINA, total	**191**
E.U.	**90**
Japan	**40**
U.S.A.	**27**

The China Everbright WTE, Nanjing (4,000 tons/day, Capex total: 270 mill USD)

China Everbright factory of WTE equipment (Changzhou, China)

Control room of China Everbright (Nanjing City)

Continuous monitoring of emissions of WTE plant at entrance of Chinese WTE plant

项目	国家标准		欧盟2000	单位	1#炉	2#炉
	小时均值	日均值	日均值		小时均值	
颗粒物	30	20	10	mg/Nm3	2.0031	1.5375
HCL	60	50	10	mg/Nm3	4.3937	3.3750
SO2	100	80	50	mg/Nm3	2.0437	0.9750
NOX	300	250	200	mg/Nm3	114.8125	125.1562
CO	100	80	50	mg/Nm3	1.5125	1.1249
HF	100	80	1	mg/Nm3	0.2887	0.1350
炉膛断面烟气温度均值（850度/2秒）				℃	1039.5000	1002.1499

ASM BRESCIA, ITALY

Winner of WTERT/Columbia 2006 Industry Award

3 units, 760,000 tons/year