NPTEL ONLINE CERTIFICATION COURSES

Introduction to Environmental Engineering and Science – Fundamentals and Sustainability Concepts

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Present Issues and Few Case Studies

CONCEPTS COVERED

Case Studies

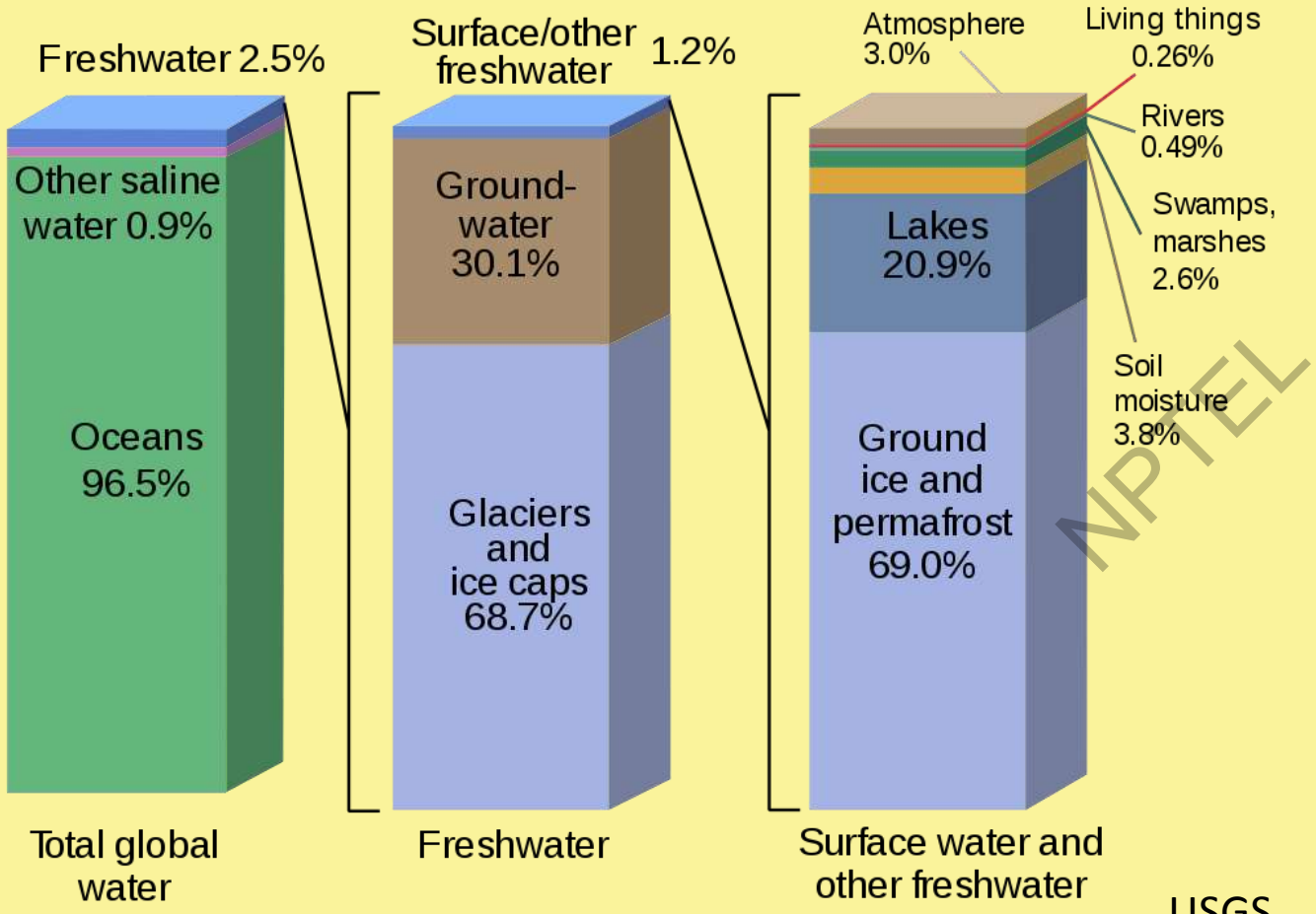
- Water
- Air Pollution
- Solid Waste Management
- Industrial Pollution and Man made Disasters

Experiences and lessons in managing water from Cape Town

(https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/briefing-papers/Experiences-and-lessons-in-managing-water.pdf)

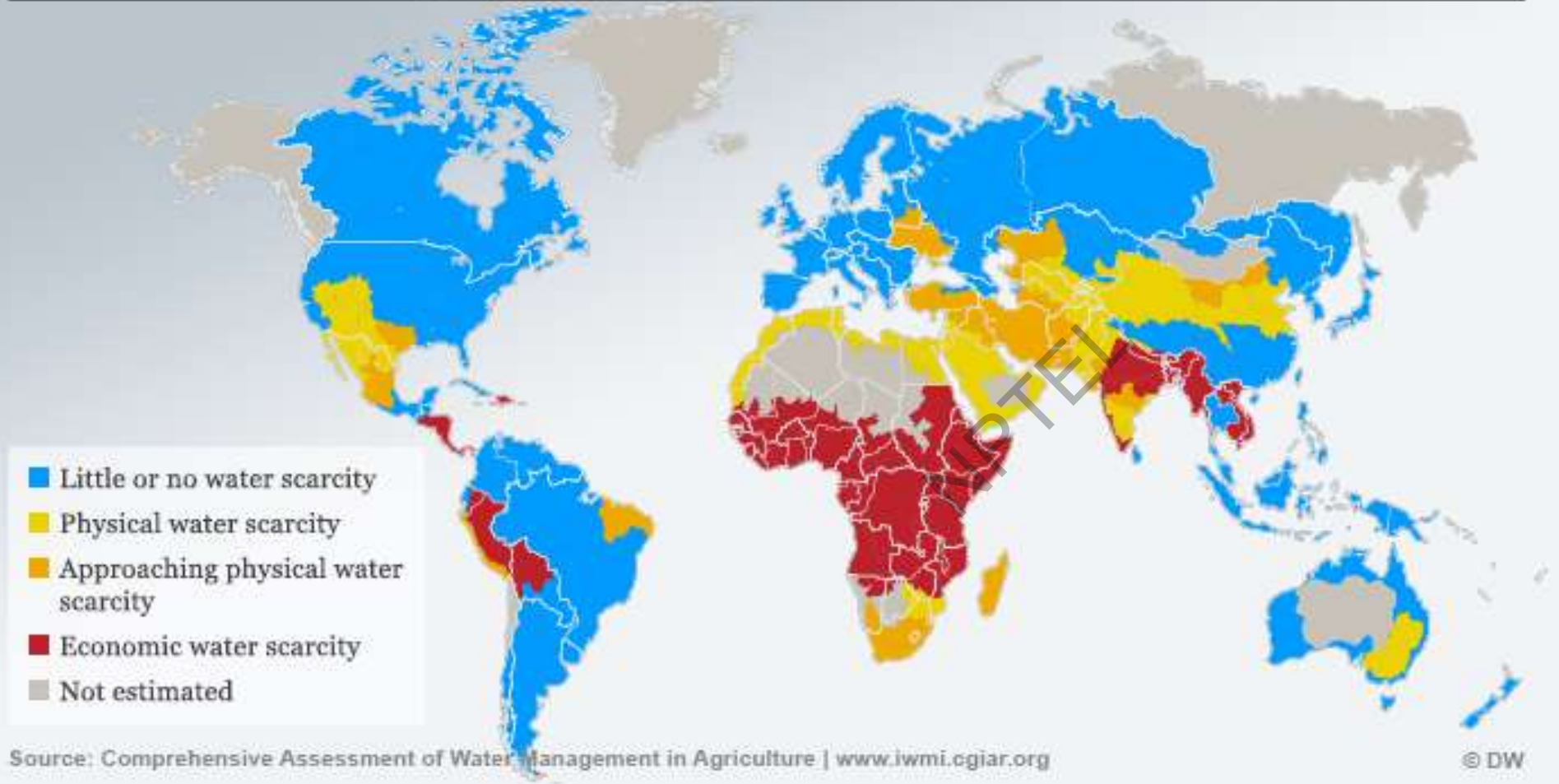
https://www.lenntech.com/Cape-Town-Day-Zero-Water-Crisis.htm

Where is Earth's Water?

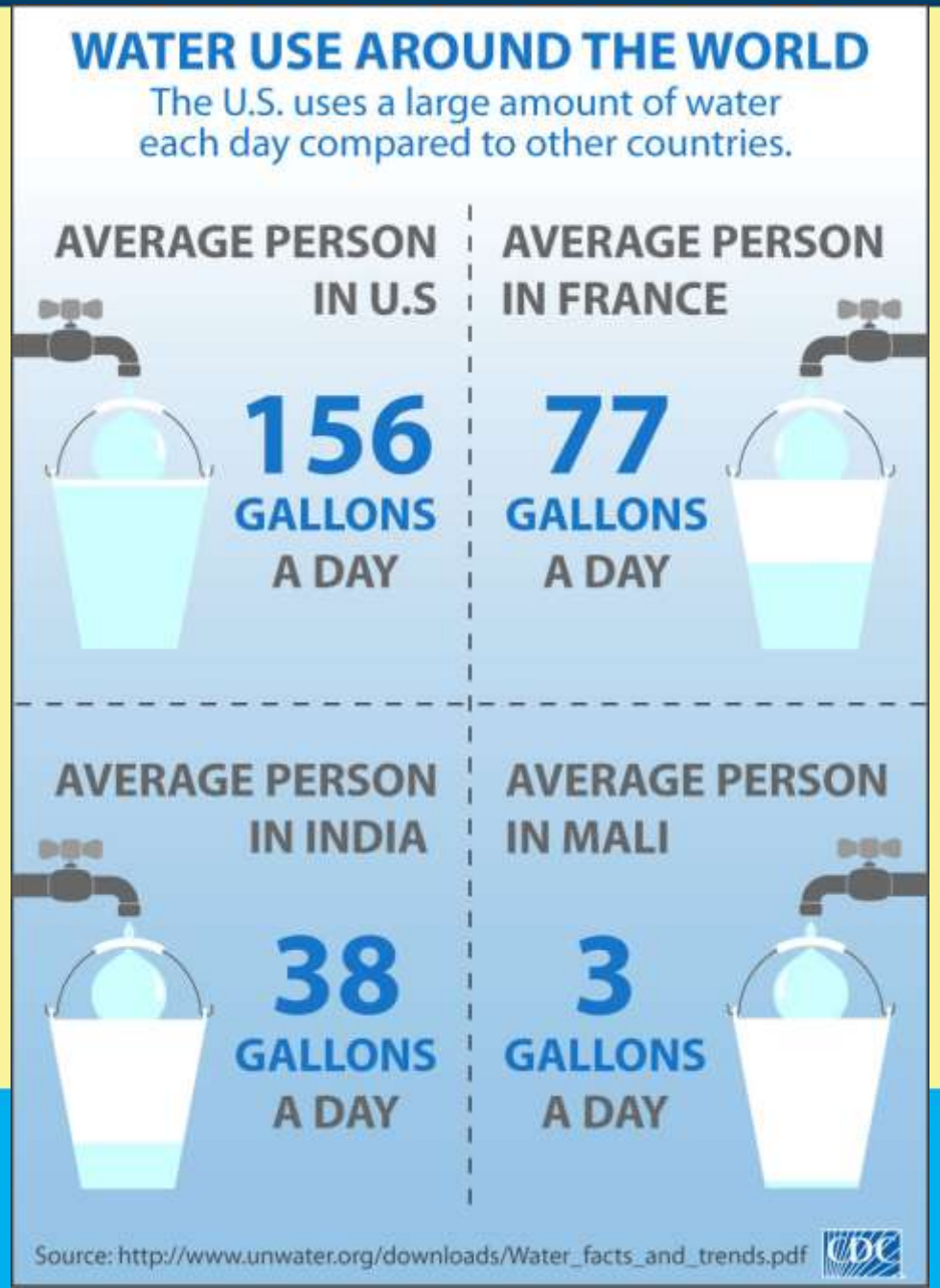


USGS

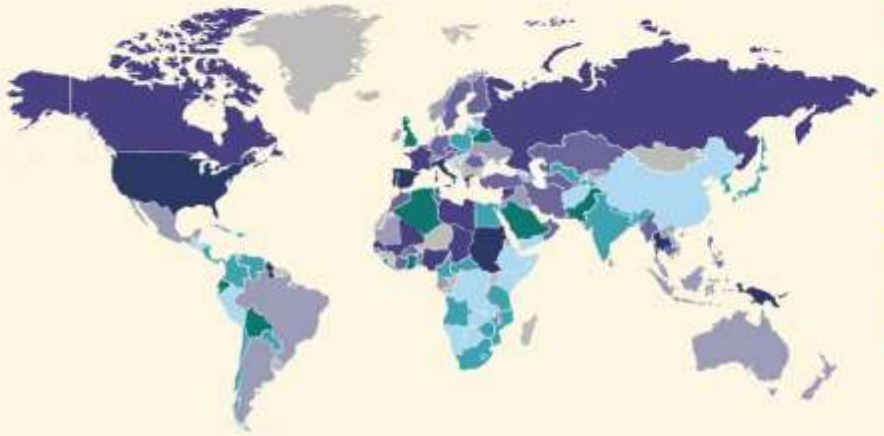
Global water scarcity by 2025



Source: Comprehensive Assessment of Water Management in Agriculture | www.iwmi.cgiar.org


WATER USE AROUND THE WORLD
The U.S. uses a large amount of water each day compared to other countries.
AVERAGE PERSON IN U.S
156
GALLONS A DAY
AVERAGE PERSON IN FRANCE
77
GALLONS A DAY
AVERAGE PERSON IN INDIA
38
GALLONS A DAY
AVERAGE PERSON IN MALI
3
GALLONS A DAY
Source: http://www.unwater.org/downloads/Water_facts_and_trends.pdf

World Water Use



Water footprint per capita (m^3)

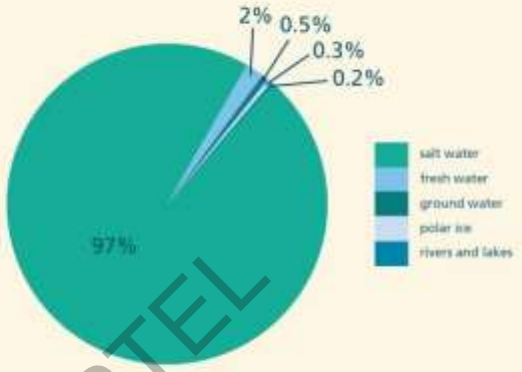
- 600 – 1000
- 1000 – 1200
- 1200 – 1300
- 1300 – 1500
- 1500 – 1800
- 1800 – 2100
- 2100 – 2500

global average water footprint is around

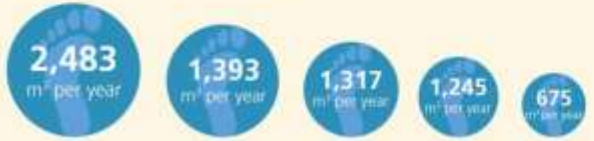
1,240

m^3 per person

Breakdown of the world's water types



Highest water footprint per capita



Countries most dependent on water imports

Water footprint of different foods

Museum2you

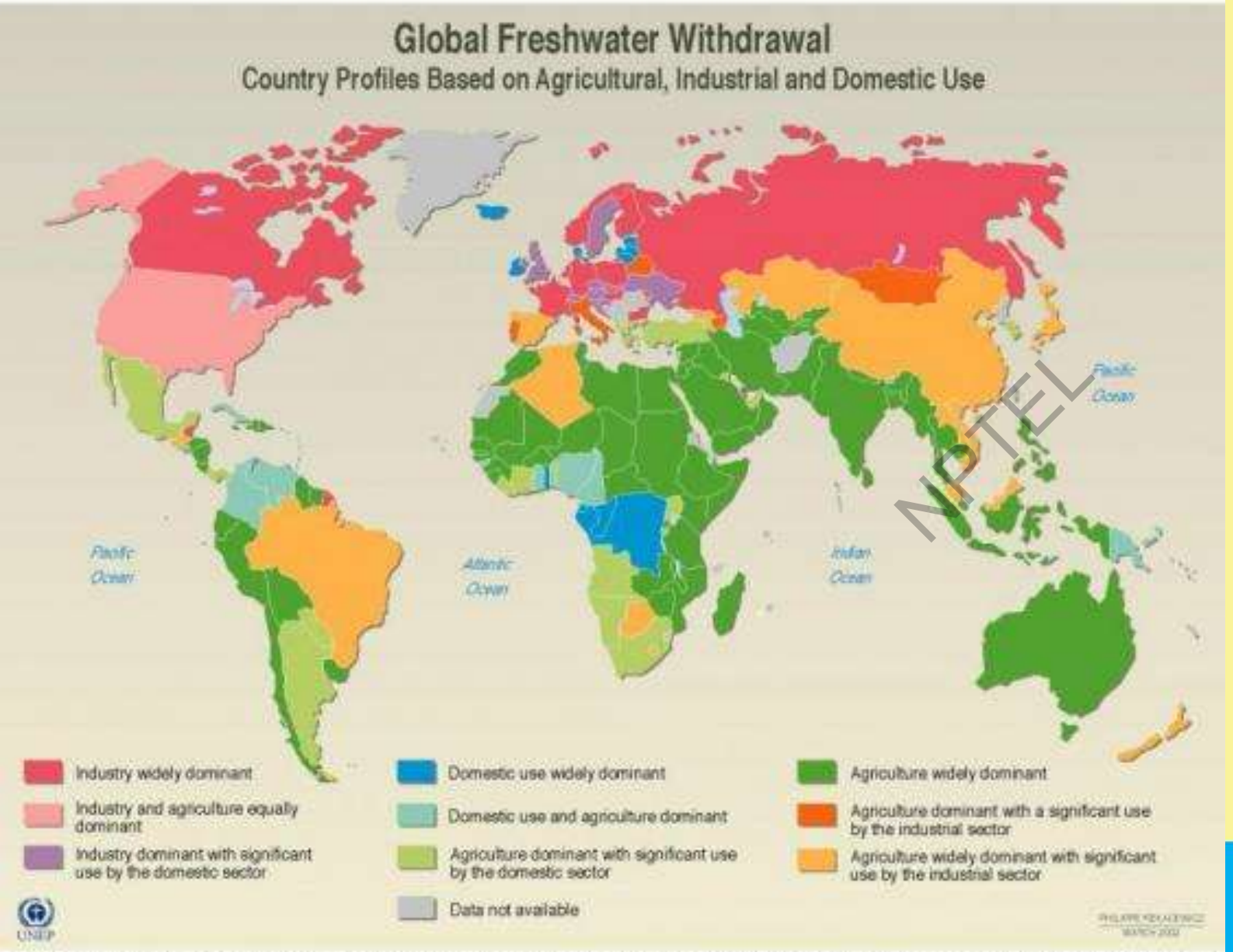
NSW

Australian museum

10 b

Global Freshwater Withdrawal

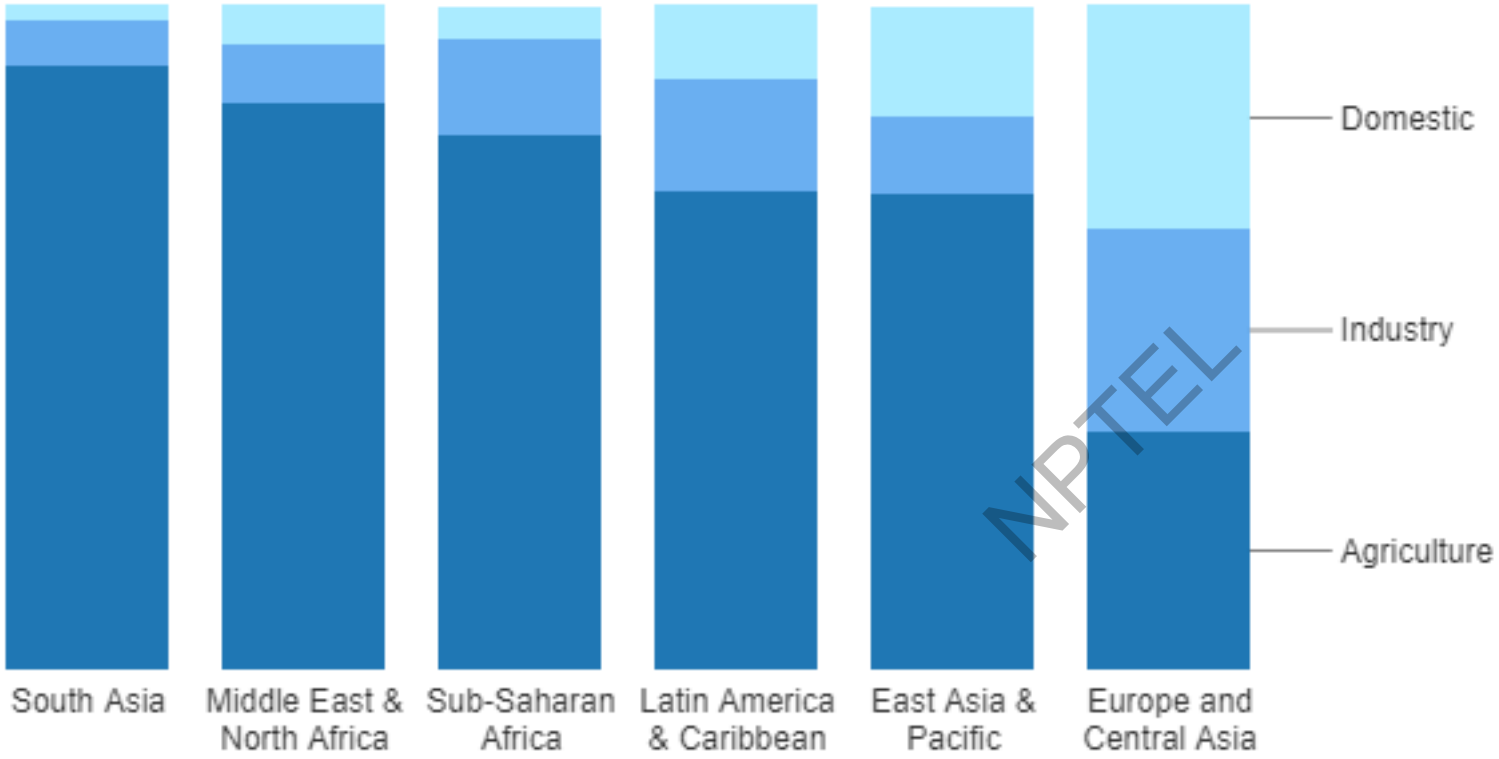
Country Profiles Based on Agricultural, Industrial and Domestic Use



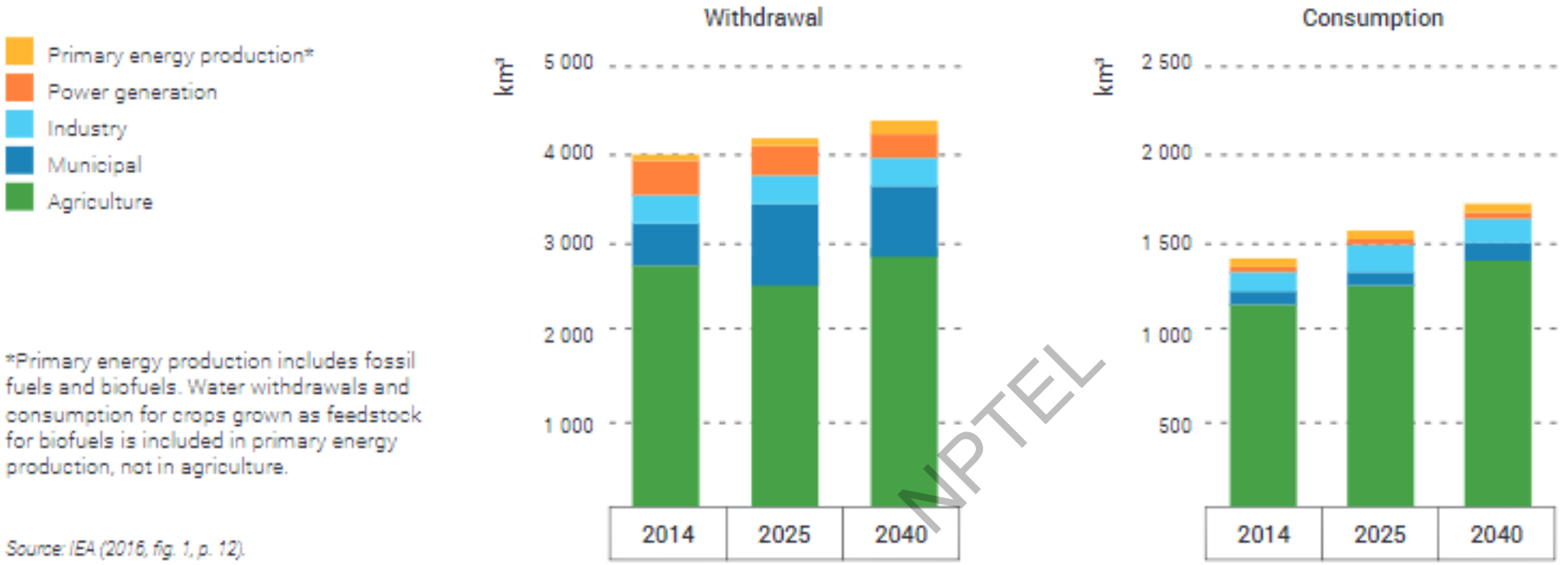
Source: Based on data from Table FW1 in *World Resources 2000-2001, People and Ecosystems: The Fraying Web of Life*. World Resources Institute (WRI), Washington DC, 2000.

Globally, 70% of Freshwater is Used for Agriculture

Share of freshwater withdrawals by sector (%) in 2014



Source: World Development Indicators



*Primary energy production includes fossil fuels and biofuels. Water withdrawals and consumption for crops grown as feedstock for biofuels is included in primary energy production, not in agriculture.

Source: IEA (2016, fig. 1, p. 12).

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Will Cape Town be the first city to run out of water?

By Gabriella Mulligan
Technology of Business reporter

12 January 2018 Share

Climate change

BBC Sign in News Sport Reel Worklife Travel Future

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Cape Town water crisis: Residents urged to turn off toilet taps

26 January 2018 Share

Cape Town faces Day Zero: what happens when the city turns off the taps?

In 10 weeks engineers will turn off water for a million homes as this South African city reacts to a one-in-384-year drought. The rich are digging boreholes, more are panic-buying bottled water, and the army is on standby

Interactive explainer: how Cape Town is running dry

by Jonathan Watts in Cape Town

TIME

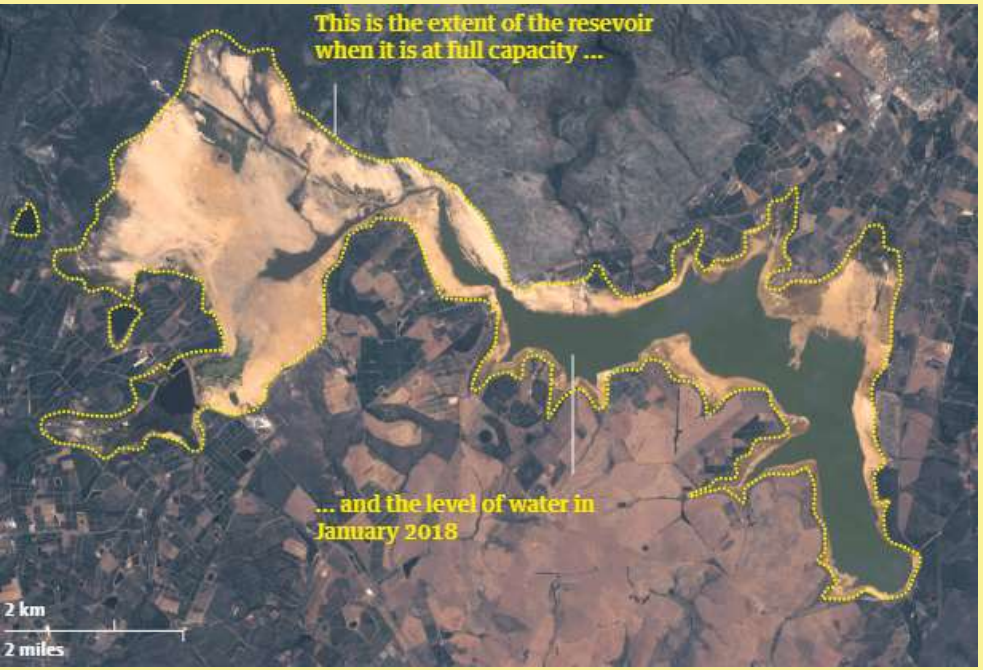
What It's Like To Live Through Cape Town's Massive Water Crisis

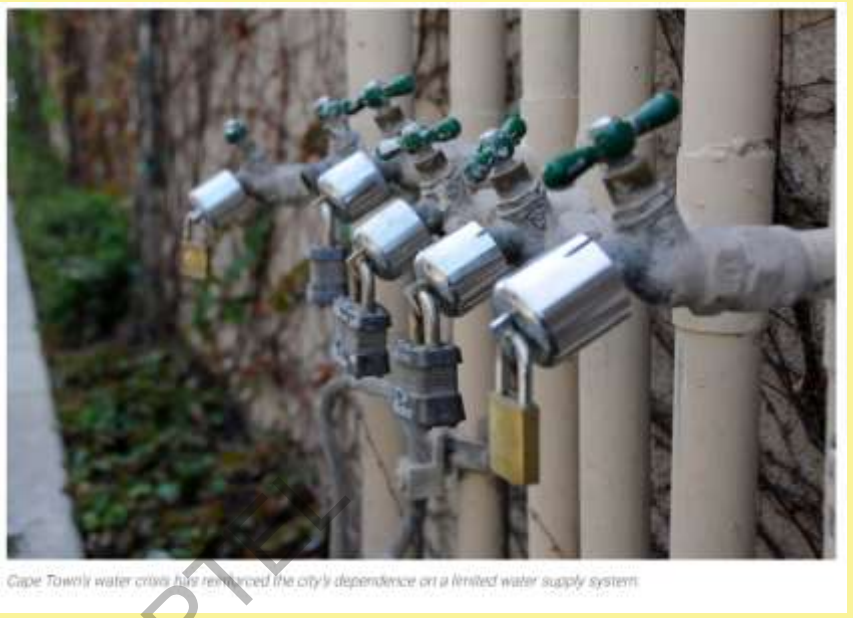
By ARYN BAKER
Photographs by MIKHAEL SUBOTZKY and JOHNNY MILLER for TIME

NATIONAL GEOGRAPHIC

Why Cape Town Is Running Out of Water, and Who's Next

The South African city plans to shut off the taps to 4 million people. But it's just one of many cities around the world facing a future with too little water.





Cape Town's water crisis has reinforced the city's dependence on a limited water supply system

https://www.news.uct.ac.za/article/-2018-08-27-water-outlook-what-next-for-cape-town

- Water shortages will become more common in cities around the world during the 21st century due to climate change.
- Cape Town, South Africa experienced an especially severe drought in 2017-2018 after several years of low rainfall. This drought prompted an estimate of Day Zero, when freshwater reservoir levels supplying the city would fall below 13.5% of capacity and the majority of the municipal water network would be shut down.
- In response to this crisis, the City of Cape Town municipal government significantly extended an existing set of rules and regulations, and introduced additional measures, to limit water demand. These actions included restricting available water; new tariffs to penalise excess water usage; water management devices installed in domestic properties; and novel communication strategies.
- The water crisis has had widespread economic and social impacts, with damage to the tourist and agriculture industries; and tensions between sections of society and government.
- Any city under water stress, like Cape Town, needs a long-term strategy for water supply and demand. Such a strategy should include diversity of water sources, equity of service provisions, thoughtful but forceful messaging, early warning systems and co-operation between local, regional and national levels of government. https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/briefing-papers/Experiences-and-lessons-in-managing-water.pdf

Why has Cape Town experienced water shortages?

•The Western Cape region of South Africa has a Mediterranean climate, with wet, cool winters and warm, dry summers.

• Most rain in Cape Town falls during winter (May-August), with average annual precipitation of 749mm.

•Cape Town's surface water supplies are stored in six major reservoirs, supplied by rainfall, as well as a small portion from groundwater sources .

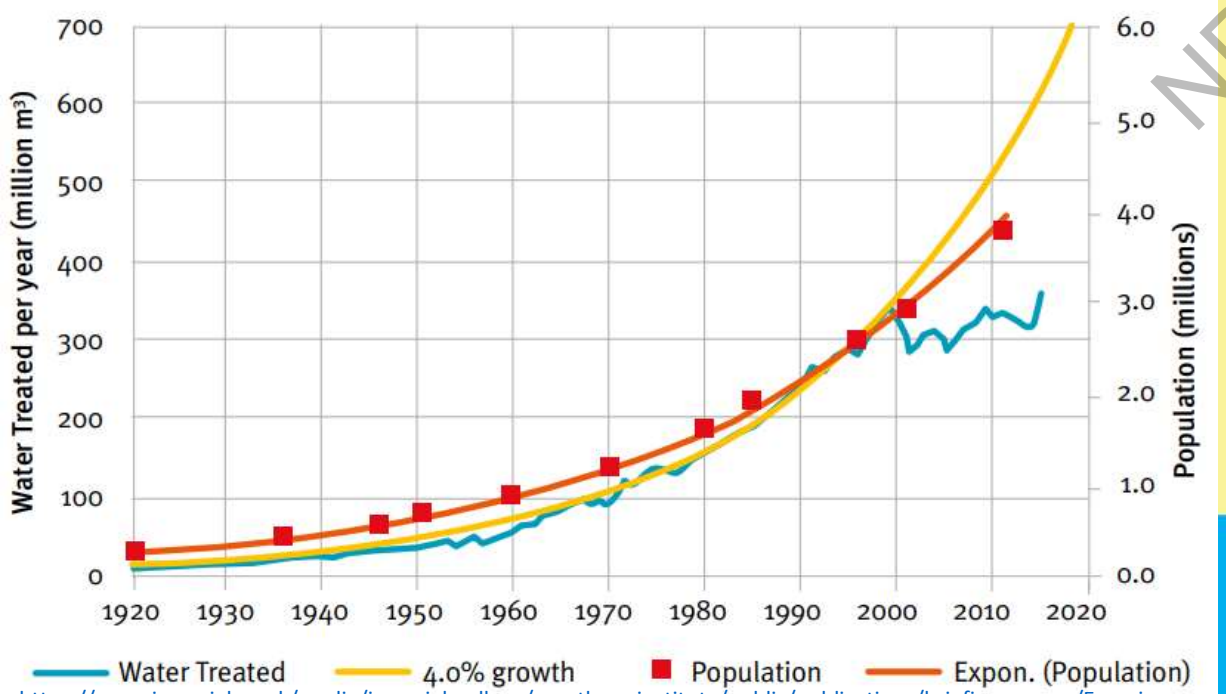
• The Western Cape Water Supply System (WCWSS) supplies water from these reservoirs via its distribution networks.

•When water restrictions have not applied, around 70% of the water supplied by WCWSS is

• allocated to urban and industrial users, with 30% for agricultural use.

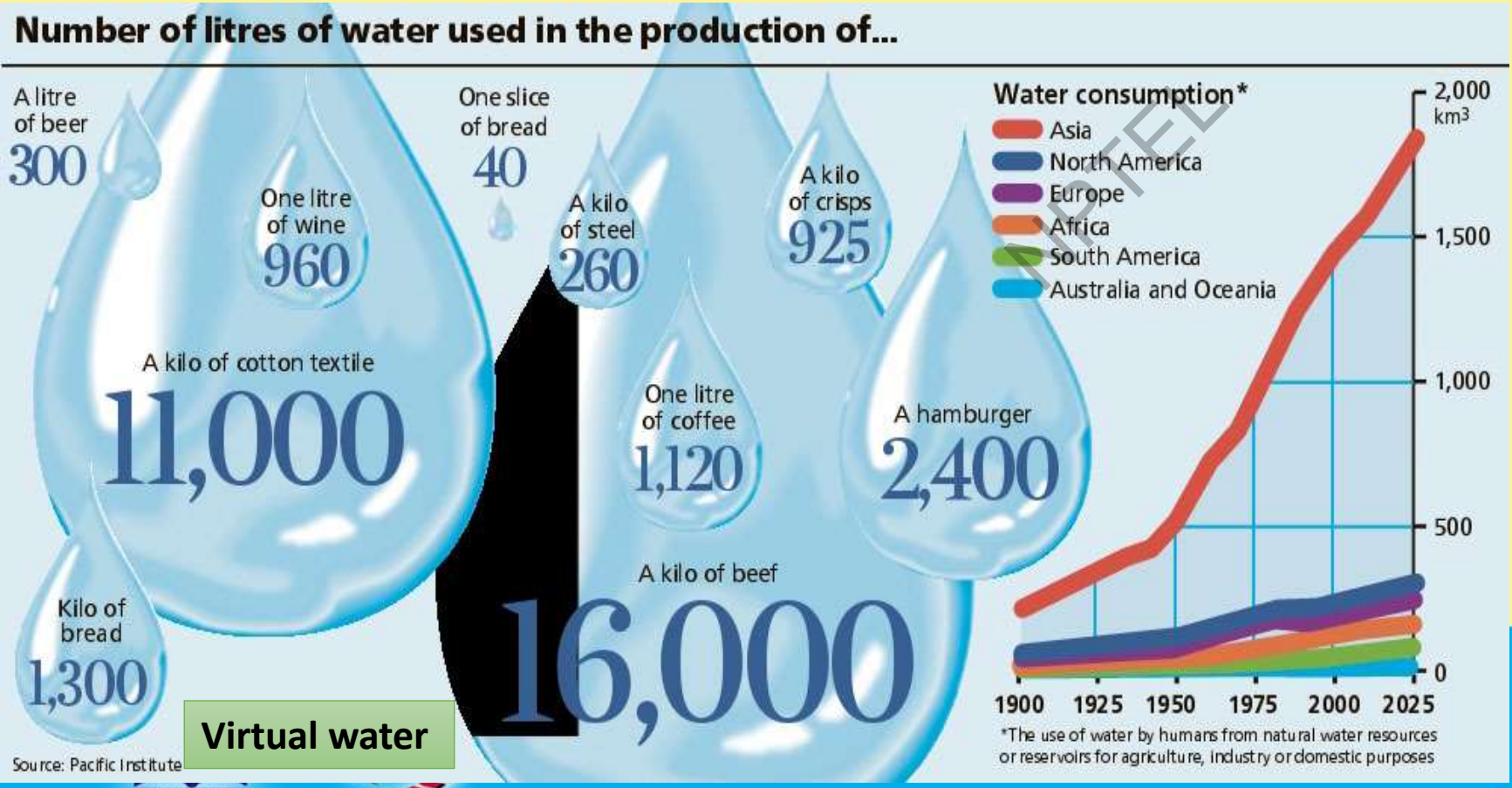
- The recent water shortages have been mainly caused by a lack of rainfall, and exacerbated by other factors, such as high consumption and lack of investment in water supply capacity.
- Freshwater supply (rainfall and groundwater combined) to the Western Cape region is sensitive to small changes in rainfall. Since 2015, the rainfall has been abnormally low.

- As the population of Cape Town has grown (from 1.6 million in 1980 to over 4 million in 2018), the water available per person each year has dramatically decreased, from a high of over 500,000 litres (100,000 gallons) per person in the early 1980s, to around 200,000 litres (50,000 gallons) per person in 2016.
- In the early 1990s, the city of cap town put in place extensive water demand management, decoupling water demand from growth in population. However, this has not diminished Cape Town's vulnerability to water shortages due to lack of diversity in the water supply system.



https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/briefing-papers/Experiences-and-lessons-in-managing-water.pdf

- Water usage by urban, industrial, and agricultural users is also changing, putting more pressure on the water supplies.
- ‘Virtual water’, water used in the production of a commodity that is then exported out of South Africa, has emerged as a key factor – South Africa is a net exporter of virtual water.



•Increases in agricultural water use has also contributed to recent shortages. The formalisation of previously informal settlements of indigent black communities, moving away from drawing water from communal taps, has made a relatively small impact on the water usage

Managing water demand

•The cape town prioritized reducing demand for water to manage the drought, and then rationed the remaining reservoir water stored within the supply system.

•Projects targeting water demand typically yield faster results with low investment cost when compared with increasing water supply.

•The cape town focused on promoting water-saving behaviour in households, while simultaneously implementing projects that would forcibly curb excessive water use.

•Aside from cape town -led initiatives, citizens, regional Western Cape Government (WCG), private industry and Cape Town's academic community all played a

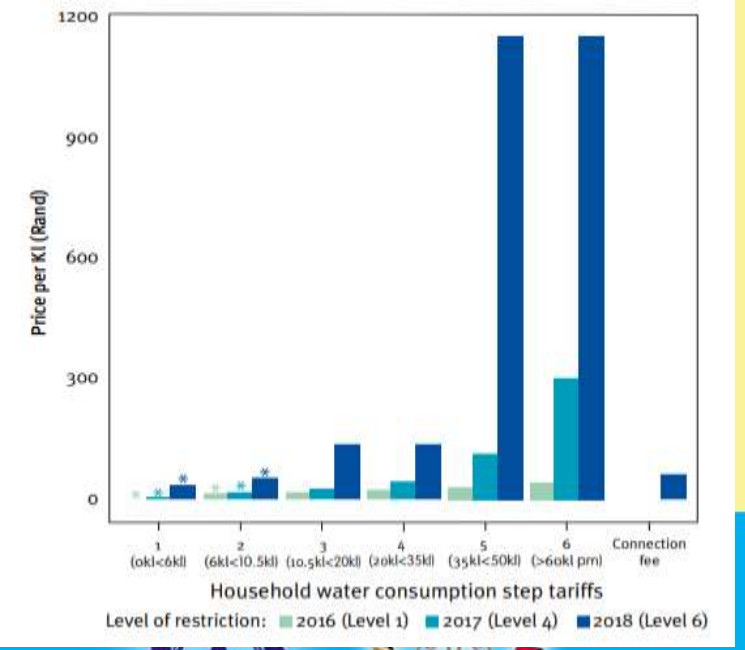
• Role in reducing water demand in the city, as outlined below.

1. Water restrictions

•The city introduced increasingly strict water restrictions over the period of the crisis, which evolved and developed over time as the water shortage became progressively more acute .

•Fines of between R1,000 ($70) and R10,000 ($700) were used as punishment for transgressive behavior and high consumption households.

•Water restrictions defined limits on how water could be used, in what quantities and for which purposes. At the most extreme level of restriction implemented, Level 6B, residents were restricted to a maximum of 50 litres (13.2 gallons) of water per person per day.



•Restrictions were revised on an ad-hoc basis by the city, with some revisions taking place within a month of the previous restriction. Under normal circumstances, further restrictions would have to be sanctioned by the Council of the city.

2. Tariffs

•The city operates on a step tariff payment system for water, in existence before the current water crisis.

•In the system, each additional unit of water becomes more expensive as greater volumes are used.

• Different rates are applied based on the level of water restrictions currently active, and households are also subject to a sanitation charge, calculated as a percentage of their water consumption for the month.

•Under normal circumstances, the city is limited to a single adjustment of tariffs per year as part of their budget review, which comes into effect annually in July.

• In response to the water crisis, tariffs were increased significantly from 2016 until late 2018 in order to reduce water demand.

Tariffs were not downgraded again until 1 October 2018.

•Prior to the drought crisis, all households in Cape Town received 6,000 litres (1,320 gallons) of free water per month, while indigent households received an additional 4,500 litres (1,189 gallons) free.

•In the 2017/2018 budget, the free allocation of water was removed for non-indigent households, while the 2018/2019 budget introduced a new fixed monthly connection charge, unconnected to the consumption volumes and based on the diameter of the supply pipe entering the property.

•This new tariff structure was required to cover the fixed costs incurred in the delivery of water, and attempted to mitigate the loss of income resulting from reduced consumption in the higher tariff blocks (which had previously been used as a buffer for these expenses).

•The potential conflict of interest here hints at a challenge in retaining commercial viability of water utility companies, public or private, when encouraging reductions in water usage while still wanting to maximise profitability.

• The challenge of maintaining commercial viability is further laid bare by the Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) report from 2017, which found that, in more than half the countries surveyed, water tariffs are already insufficient to recover operations and basic maintenance costs.

3. Water Management Devices

•A Water Management Device (WMD) is equipment that can be installed to a water supply pipe to enforce a set daily limit of water for a property. After the maximum withdrawal is reached for the day, the water is reduced to a trickle until the following day when service is resumed.

•Originally used to manage debt and unfixed leaks from indigent houses over many years, the City rolled out WMDs throughout 2017 as part of a voluntary program whereby indigent households could choose to have a WMD installed without charge, combined with a one-off house leakage fix and an agreement to write off historic water debt.

- In a shift of strategy away from targeting only indigent households, as part of Level 4 restrictions , the city targeted high-consumption households who refused to voluntarily reduce water use despite having received written warnings.
- Within the new water restrictions, households with consumption above 10,500 litres (2,773.8 gallons) per month were penalised by having a WMD fitted at their expense.
- The devices were designed to restrict households to 350 litres (92.5 gallons) per day, or 10,500 litres (2,773.8 gallons) per month. Households could apply for increased amounts of water based on the number of people living at the residence

4. City-wide water pressure reductions

•From 2017, the city steadily reduced the water pressure in municipal pipes, controlled through localized pump stations.

• Water pressure management provided various overarching benefits – the reduction of water pressure through the city, compared with pre-crisis levels, reduced overall consumption, decreased water loss through leaks, and resulted in a reduced frequency of pipe bursts and further leaks

5. Communication strategies, behavioural nudges and the Cape Town Water Map

•In 2016-2017, the city embarked upon an extensive public relations campaign to encourage water saving. Websites were set up to display current dam and consumption levels, and to help households understand their water use.

•Messages providing tips on how to save household water were published across various channels, from radio adverts, to flyers in water bills, to billboards around Cape Town .

•These communication campaigns were successful in contributing to changing the social norms around water use in the city, as many of the recommendations were widely adopted by residents

- The city's press release announcing the city's 'Critical Water Shortages Disaster Plan and Day Zero' outlined the drastic measures that would be required if water savings targets were not met .
- High-consumption households received strongly worded personalized letters from the mayor, instructing them to reduce their consumption or face severe consequences.
- The city encouraged citizens to monitor and report any transgressors to toll-free hotlines set up by the city.
- Citizens who were not adhering to water restrictions were shamed for their behavior and blamed for bringing about Day Zero, and the road names where the top 100 'water guzzlers' lived were published in local media by the city

Ways to reduce water usage from “Water Saving Checklist to Avoid Day Zero” issued for cape town

Body washing and personal hygiene

Take short, stop-start showers. Wet your body. Turn off the tap. Soap. Rinse quickly.

Don’t let taps run for too long or at full flow. Use a cup for shaving, brushing teeth, etc.

No shower? **Take a sponge bath.** Use minimal water in a basin, bowl or washtub (‘waskom’).

Use waterless hand sanitiser instead of washing your hands.

Don’t let water run while you wait for it to heat. If possible, use cold water or heat your water for a sponge bath, in a kettle or on the stove.

Collect as much washing water as possible and re-use for flushing toilets as a priority. Excess greywater can be used for plants or washing vehicles.

Ways to reduce water usage from “Water Saving Checklist to Avoid Day Zero” issued for cape town

Toilet flushing and sanitation

Only flush the toilet when necessary.
Let the ‘yellow mellow’ at home, work, school, gym, shops, etc. Don't use it as a dustbin.

Place a full glass bottle in your cistern to reduce each flush to a maximum of 6 litres (if you have no choice but to use municipal drinking water).

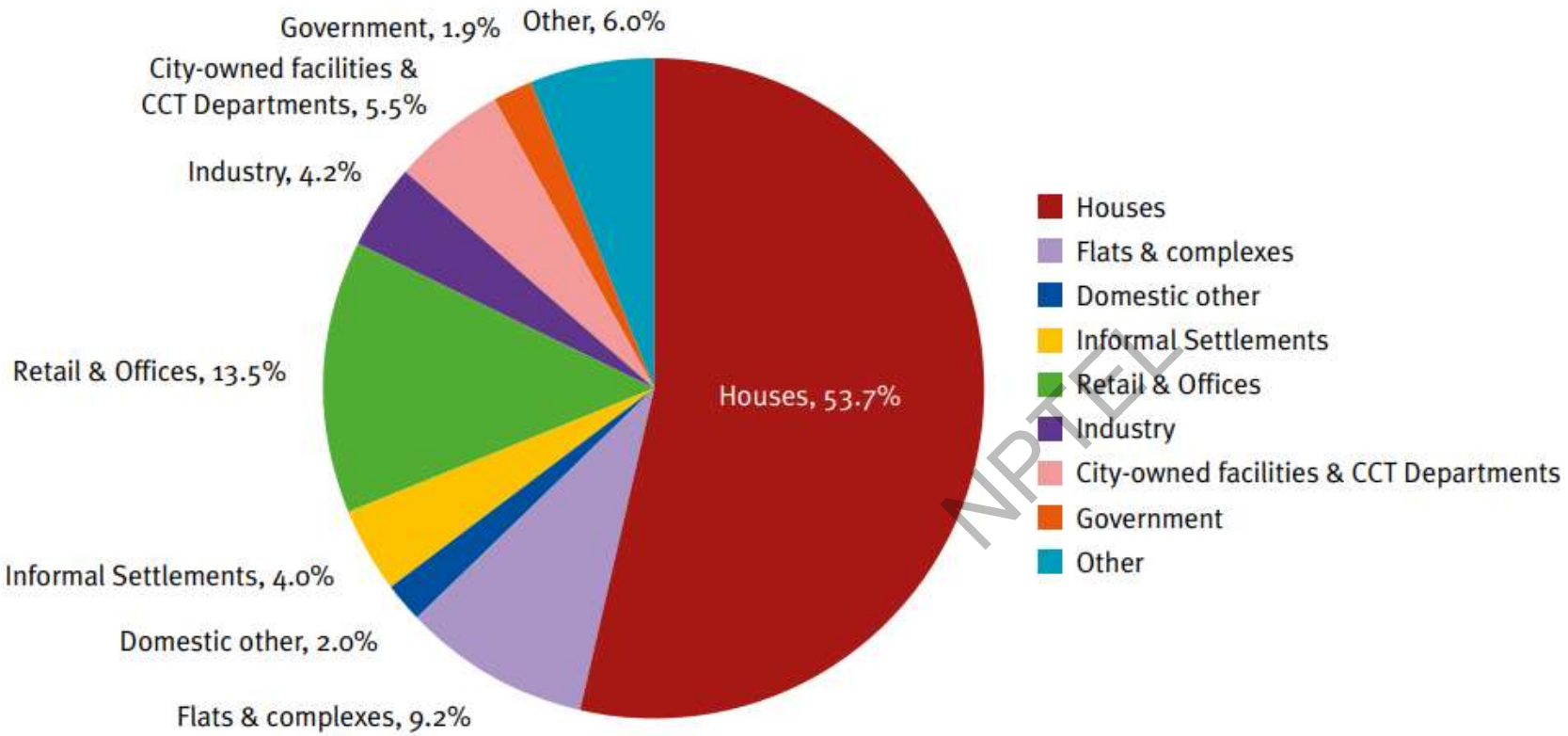
Flush with greywater only (laundry, bath and shower water) or with rain, borehole or well-point water.

Use less toilet paper to minimise the risk of sewer blockages and do not use your toilet as a dustbin.

Close toilet stopcock (angle valve).
You will save municipal drinking water.

Use bleach or disinfectant to regularly **sanitise toilets and surrounding areas** and keep hands sanitised to prevent health risks.

Potable water consumption by use category (01.01.2017 – 31.12.2017)



6. Smart Water Meters

•Smart Water Meters (SWMs) have been installed in over 350 schools across the city, alongside an educational campaign to save water.

• The project was run as a partnership between the provincial government of the Western Cape who provided access to schools, private companies that contributed funding, and local universities who monitored the impact.

7. Mobile applications

•A variety of mobile applications were produced during the drought and preceding years to address different aspects of water management, including Tap Off and Drop Drop.

•Tap Off focused on gamifying the experience of water saving, by presenting users with leader boards to display low-consumption behaviour.

•Drop Drop was developed as a research prototype by the University of Cape Town to test the impact of information on a household's water consumption behaviour, and provide them with tools to track and visualise their water use.

• Research on the original prototype of Drop Drop demonstrated that the application aided water savings amongst users.

8. Reducing water use in the agricultural, commercial and industrial sectors

- City initially focused on reducing Cape Town's domestic usage, as this made up the largest portion of water use (69% in 2017). From September 2017, at Level 5 water restrictions, non-domestic water restrictions were introduced, aiming for a 20% saving compared to the same month in the previous year.
- This was increased under Level 6 (January 2018) to target a 45% saving for commercial and industrial properties compared to 2015.
- The City hosted business forums to encourage voluntary water savings and sharing of best practices47. There were hard limits on agricultural quotas for water.

Overall impact of water demand initiatives

•The net impact of the water saving interventions was highly effective, with daily average water consumption for the city reduced from 1,200 million litres (317 million gallons) in February 2015, to 500 million litres (132 million gallons) in February 2018.

•From December 2017 to March 2018, the percentage of single-family homes using less than 10,500 litres (2,773.8 gallons) of water per month increased from 64% to 81%, with those using less than 6,000 litres (1,585 gallons) increasing from 31% to 49%.

Desalination:

•Temporary installations and barges The City originally planned to install nine temporary desalination plants around the coastal periphery of the city, contributing some 50 million liters (13.2 million gallons) per day to the water supply system, as well as a further 50 million liters (13.2 million gallons) per day through a desalination barge.

• However, upon consultation and further analysis of the technologies, the City determined that containerized desalination plants, though quick to roll out, were neither cost-effective or reliable, nor would they produce sufficient volumes of water to have a measurable impact on the immediate drought.

• Based on this feedback, the projects were scaled down to three temporary
•plants, yielding a total of 16 million liters (4.2 million gallons) per day.

City water supply augmentation planning

	Water augmentation projects as per Water Resilience Plan (August 2017)		Water augmentation projects as per Water Outlook Report (May 2018)	
Technology	**Total Ml (multiples of 1,000,000 l) per day (Short term)**	**Total Ml per day (Medium-long term)**	**Total Ml per day (Short term)**	**Total Ml per day (Medium-long term)**
Groundwater extraction	100		57	100
Desalination: temporary (land-based containers and barge)	**100**		**16**	0
Water reuse		50	**10**	70
Desalination: permanent (land based/marine based)		250		120
Surface water (dams)				60
Springs and rivers	7.5		7.5	
Total	207.5	300	90.5	350

Residential spring water collection

•Cape Town has a large network of publicly accessible spring water collection points of varying degrees of formality.

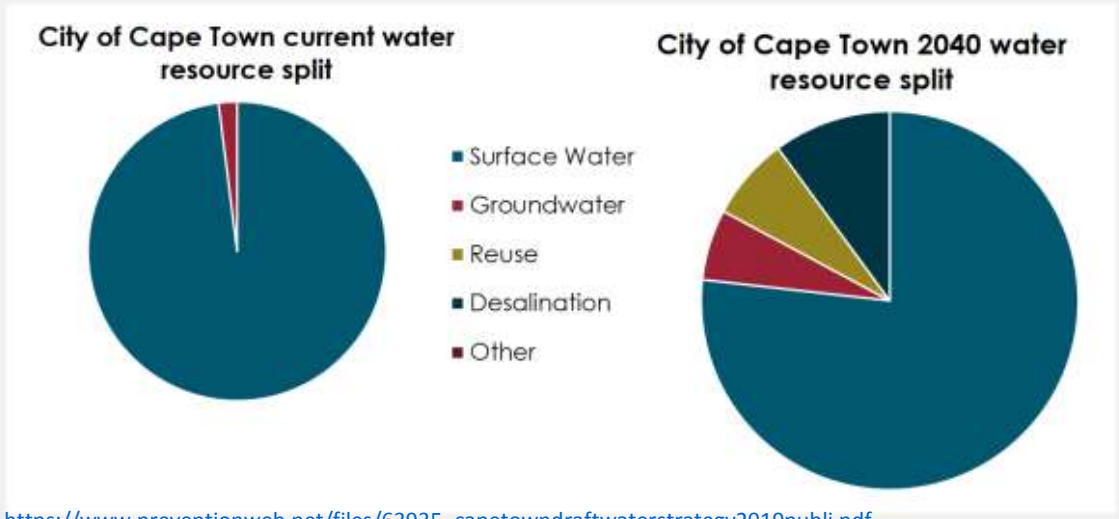
•During the water crisis, the number of households supplementing their municipal supply with spring water increased dramatically.

•For example, the number visitors to one small spring increased from 100 to 7,000 per month, while another received over 2,000 visitors per day.

https://www.pri.org/stories/2018-04-02/drought-stricken-cape-town-parched-residents-gather-watering-hole

Water recycling

•Prior to the drought, around 8% of the city's wastewater was made available to be processed into water suitable for irrigation and industrial purposes, but not of drinking quality. The Water Resilience Plan originally intended to introduce 50 million litres (13.2 million gallons) per day (later upgraded to 70 million litres) of recycled drinkable water to the city's municipal supply. These two different types of wastewater recycling will help to reduce pressure on existing drinking water supplies.



https://www.preventionweb.net/files/63935_capetowndraftwaterstrategy2019publi.pdf

LET'S BEAT DAY ZERO
WITH 50ℓ OR LESS PER DAY

This is a guide for 50ℓ per person per day. Your actual usage will depend on your appliances and personal preferences.

FOR MORE VISIT **CAPETOWN.GOV.ZA/THINKWATER**

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Policy recommendations

- Long-term supply side augmentation and diversification
- Permanent changes in water usage
- Positive, but forceful, messaging and communication
- Actionable early warning system development
- Co-operation between levels of government
- Sensitivity to different sections of society
- Incentivise water reduction while maintaining financial solvency of water utility providers
- Climate change mitigation policy

Solid waste Management

Sustainable Source Separation in Panaji, India (What a Waste 2.0)

•Panaji is the capital of the state of Goa in southwest India, with a metropolitan area population of 114,759 according to the Census of India in 2011.

• Panaji is known for its strong cultural heritage and as a popular tourist destination, with colorful villas, hillside developments, and Portuguese influence.

•After the city's only landfill was closed in 2005, and faced with a vulnerable natural ecosystem and strong tourism economy, the city turned to sustainable practices.

•Source separation was the first step toward the vision of a landfill-free city, and today Panaji serves as a role model in solid waste management.

Source Separation Overview

Panaji generated 50 tonnes of waste daily in 2017. Residential waste is source separated into five streams through a system of colored bins:

- Green bins: Wet waste
- Black or grey bins: Glass and metals
- Pink bins: Paper and cartons
- Orange bins: Plastics
- White bins: Non recyclables

•The City Corporation of Panaji provides door-to-door collection of waste.

•Wet waste is collected from households every day, and dry waste is collected twice a week.

•Household wet waste is composted at one of 96 decentralized compost units, whereas wet waste from commercial establishments is treated using windrow composting at two bulk processing units, and it is used for urban horticulture projects.

• In some cases, wet waste from hotels is digested onsite to produce biogas. In total, the city processes about 24 tonnes of wet waste daily.

•After collection, the city's dry waste is stored and aggregated at one of 12 sorting units.

•From there, the dry waste is further segregated into 20 different streams at one of two Material Recycling Facilities.

• Each day, about 4 tonnes of dry waste is sent to a cement processing plant in Wadi, Karnataka, and 3 tonnes of recyclables are auctioned to vendors.

•In 2016, about US$22,000 in revenue was generated from the sale of recyclables.

•Hazardous waste, such as batteries and tube lights, is also separated and processed at a specialized treatment facility.

Success Factors

- The success of Panaji's source separation program can be attributed to strong public engagement, financial management, and institutional commitment.
- Public engagement:
- The city promoted sustainable waste practices through a public campaign called "Bin Free in 2003." The city engaged local students, celebrities, business leaders, and neighborhood civic bodies to promote source segregation.
- As part of the campaign, the city spearheaded cultural programs ranging from music festivals to carnivals to encourage citizens to take responsibility for city cleanliness.

•Finally, the city launched a program called “Waste Wise” in all schools to promote waste segregation and to provide incentives for environmentally friendly behavior.

Photo : Sorting Center at Residential Colony in Panaji, India

(What a Waste 2.0)

Photo : Decentralized Composting Units in Panaji, India

(What a Waste 2.0)

Pilot design:

The city's source separation program was first launched at a pilot scale covering only 70 households and two waste streams, one for dry waste and one for wet waste.

Enforcement mechanisms:

To encourage citizen engagement, the city removed all community waste bins, which required households to manage their waste privately. Simultaneously, the city introduced a door-to-door collection program through which households must personally hand their waste to collectors. Paid sanitation workers inspect waste, and a combination of the personal exchange with households and formal daily monitoring motivates compliance.

Financial management:

The City Corporation of Panaji has achieved financial sustainability for the solid waste program through fees and recycling revenues. The city established a new sanitation fee for households as well as a higher commercial fee for institutions. Households are charged a flat fee of INR 500 (US$7.3) for door-to-door collection in combination with the property tax, and commercial entities are charged between INR 600 (US$8.7) and INR 11,000 (US$16). User fees are strongly enforced with penalties. Some remaining costs are subsidized by city funds.

Institutional commitment and responsiveness:

The city government formed a new Solid Waste Management department that is overseen by a Waste Management Officer. The program also created a centralized complaint redress system, which includes a 24- hour helpline for unattended garbage and a dedicated vehicle to quickly respond to urgent waste situations. Finally, the city ensured that workers were provided with healthy and safe working conditions.

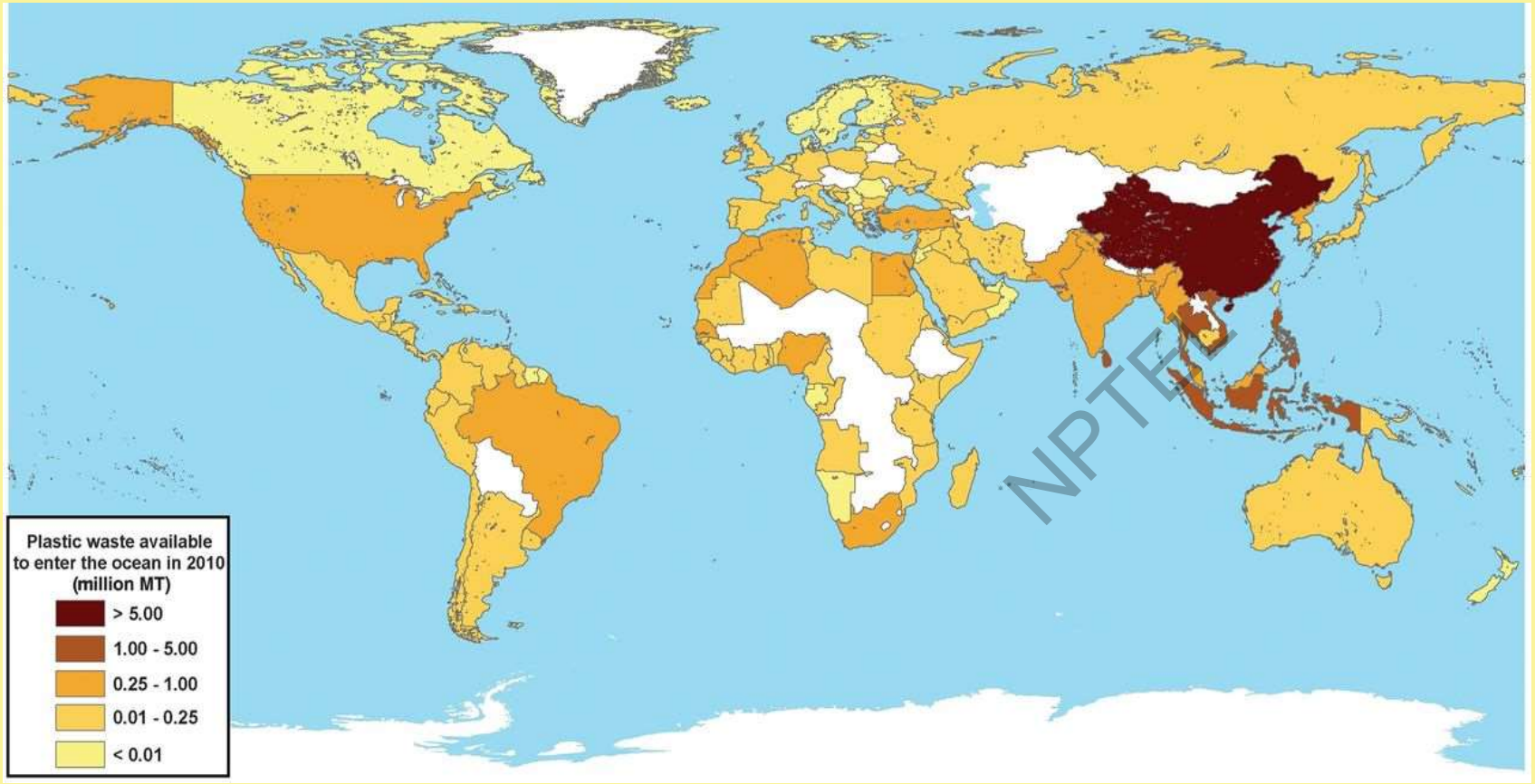
The Global Tragedy of Marine Litter

Across the world, beaches and waterways scattered with litter are an increasingly common sight and this marine litter has serious impacts on the environment, public health, and the economy.

https://openknowledge.worldbank.org/handle/10986/30317

- Marine litter comes in all shapes and sizes and, depending on the material, could be damaging to human health.
- Some 90 percent of floating marine debris is plastic, of which nearly 62 percent is food and beverage packaging. Although plastics have been mass-produced for only about 60 years, they persist in open waters for decades and even centuries.
- Even plastics designed to be biodegradable may not fully decompose since they depend on factors such as exposure to light, oxygen, and temperature which are scarce in ocean depths.
- Smaller particles of plastic from manufacturing processes could also be difficult to account for and nearly impossible to extract.

Global map with each country shaded according to the estimated mass of mismanaged plastic waste [millions of metric tons (MT)] generated in 2010 by populations living within 50 km of the coast.
192 countries considered



Jenna R. Jambeck et al. Science 2015;347:768-771

- Marine litter can be land- or sea-based and often results from poor solid waste management practices. An estimated 80 percent of marine litter originates from land-based sources such as mismanaged dumps and landfills, storm water discharge, sewage, industrial facilities, and coastal tourism

Collected and uncollected plastic waste enters the ocean from five physical locations.

- Low-waste-density rural areas that do not have collection services.

- Medium-waste-density urban areas that lack proper waste-management infrastructure.

- High-waste-density urban areas whose services are overstretched or where the cost to citizens of waste management discourages use of the services.

- Illegal dumping by trash haulers. When waste-transport systems are poorly regulated, there is little incentive to follow the rules

- Dump sites on waterways. Collection systems in the focus countries still make heavy use of informal or “open” dump sites—large piles of waste that have little or no infrastructure in place to control ocean leakage or any other adverse effects that come from the presence of waste.

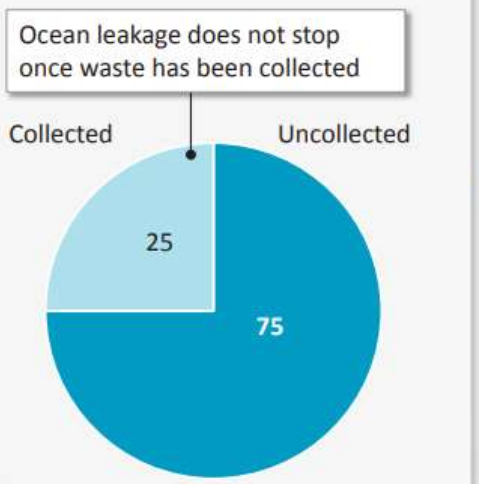
Waste may also be transported to the ocean from inland rivers. In 2010, an estimated 32 million tonnes of plastic waste were mismanaged in coastal areas, allowing between 4.8 and 12.7 million tonnes of plastic waste to escape into oceans

There are two drivers of plastic leakage: waste that remains uncollected, and low residual value of some plastic waste.

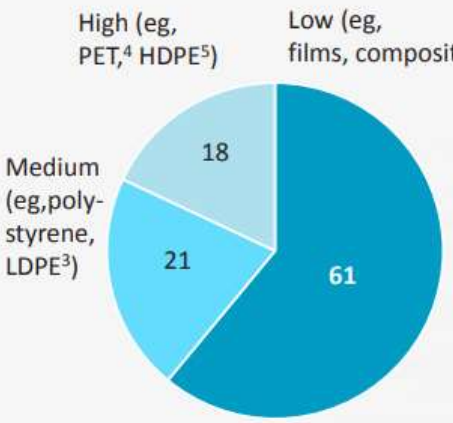
% contribution to ocean plastic, by driver[1]

Collection levels

Ocean leakage does not stop once waste has been collected



Value[2] of plastic waste



1 Average, 5 focus countries: China, Indonesia, Philippines, Thailand, Vietnam; 2 "Value" is a quantitative function of price at secondary dealers and time taken to collect, combined with a qualitative function of homogeneity and likelihood of rejection by secondary dealers; 3 Low-density polyethylene; 4 Polyethylene terephthalate; 5 High-density polyethylene.

Source: McKinsey analysis

FROM THE LAND TO THE SEA

https://wasteaid.org/wp-content/uploads/2018/03/From-the-Land-to-the-Sea.pdf

Low-residual-value plastic waste is more likely to leak than high-value plastic.

Waste pickers are less likely to collect low-value, high-bulk plastic waste.

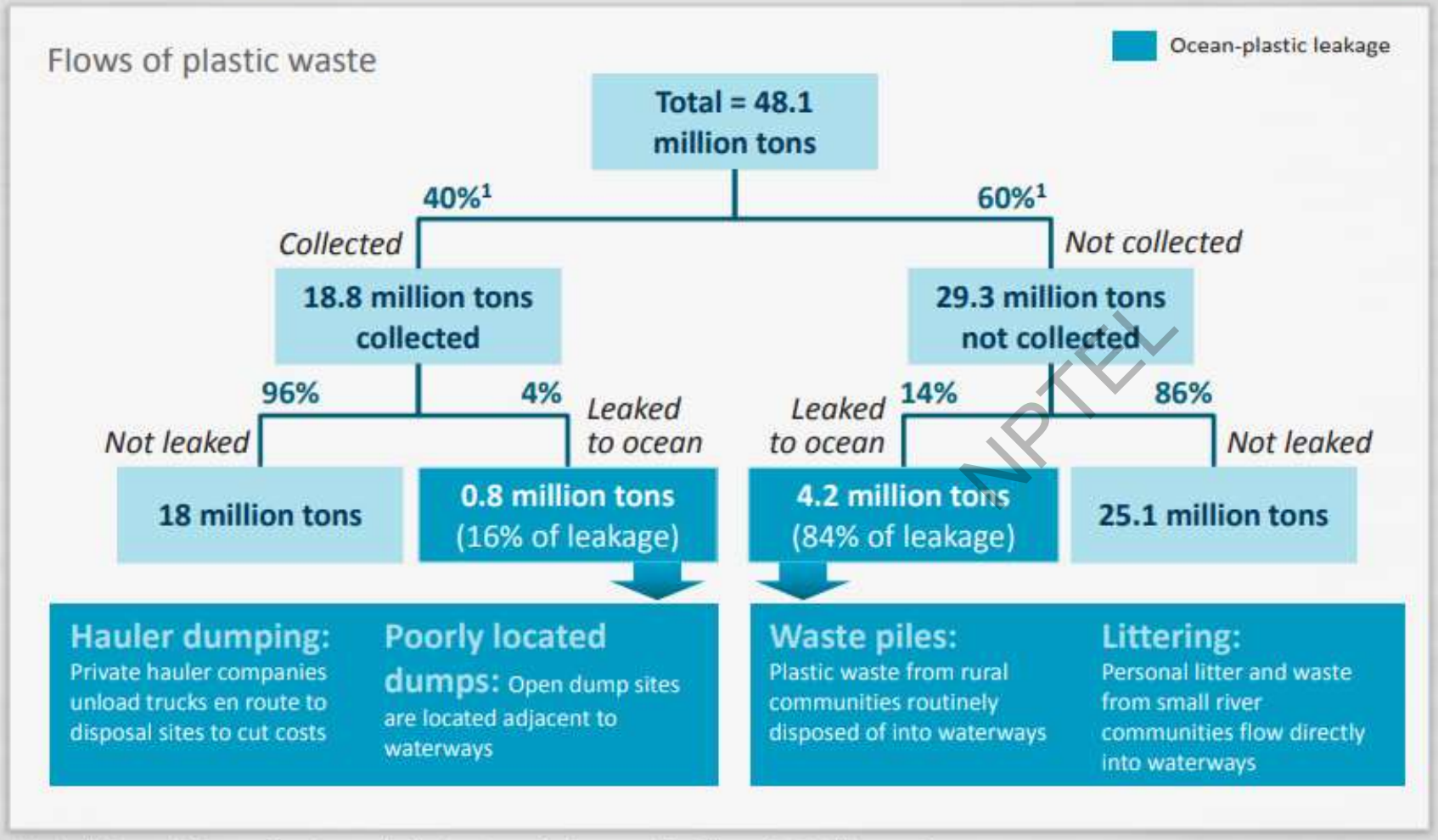
1 Assuming 10-hour collection day of waste type specified; 2 Polypropylene; 3 Polyethylene terephthalate; 4 Not all high-density-polyethylene products will fetch the same price at a junk shop or be easily recognizable by waste pickers.

Source: Expert interviews; field visits; National Solid Waste Management Commission (Philippines); McKinsey analysis

In the Philippines, 74 percent of plastic leakage comes from waste that has been collected.

Source: Expert interviews; field visits; Roland Geyer et al., "Plastic waste inputs from land into the ocean," *Science*, February 13, 2015, sciencemag.org; National Solid Waste Management Commission (Philippines); World Bank Group; McKinsey analysis

In China, 84 percent of plastic leakage comes from waste that has not been collected.



1 Not including residual waste from imported plastic, estimated at between 1.0 million and 1.5 million metric tons per year.
2 Based on aggregate of urban and rural waste.

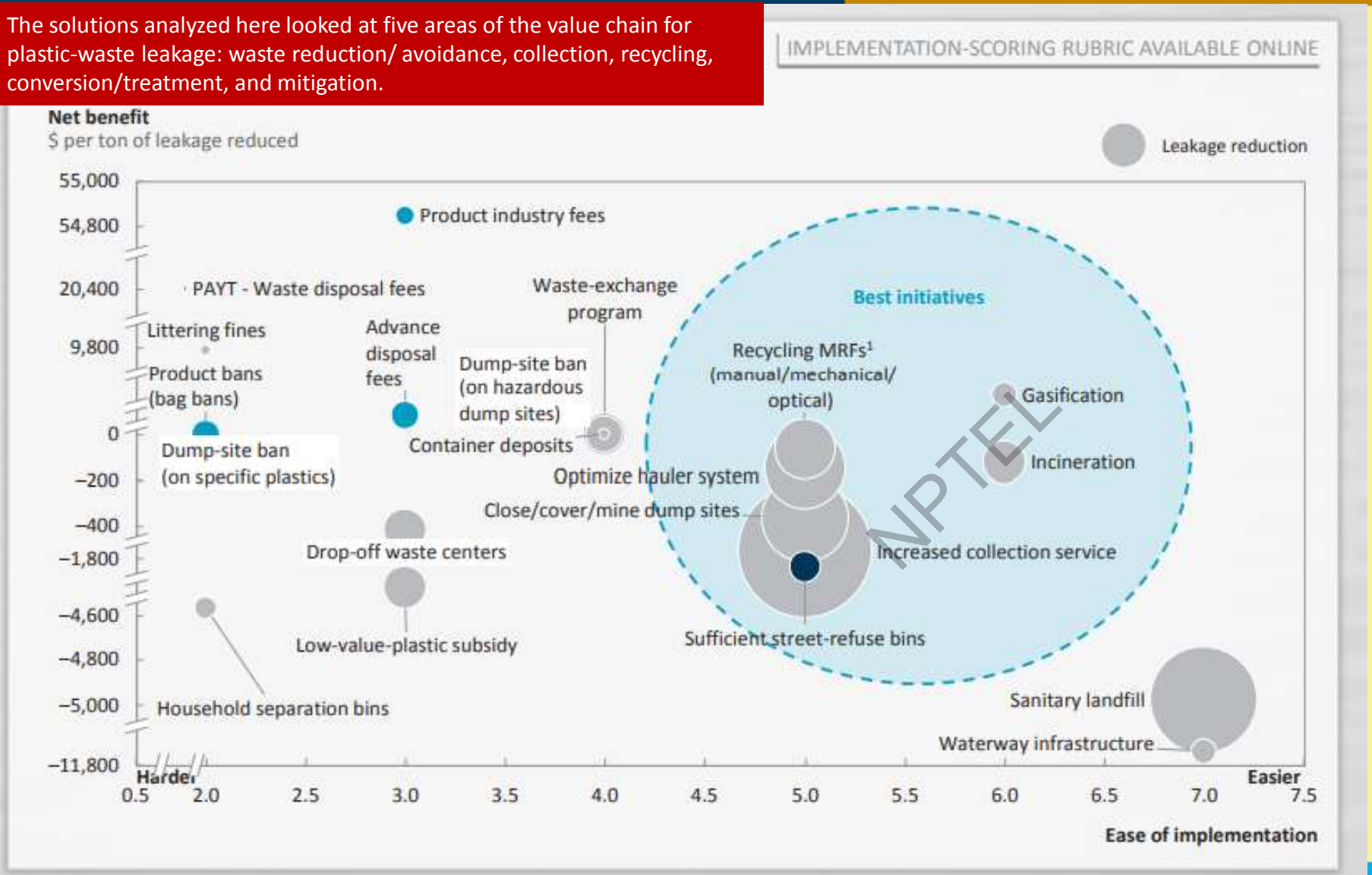
Source: *China Statistical Yearbook*, 2014; expert interviews; Roland Geyer et al., "Plastic waste inputs from land into the ocean," *Science*, February 13, 2015, sciencemag.org; World Bank Group; McKinsey analysis,

What leakage-reduction solutions are available, and what are their relevant economics? *(Based on the study by McKinsey Center for Business and Environment)*

Maximum impact can be achieved from six solutions:

1. Expand collection service and ultimately increase waste-collection rates (plastic waste is more than twice as likely to leak if it remains uncollected).
2. Close leakage points within the collection system (7 percent of collected waste currently leaks into the ocean).
3. Keep leakage points in the system closed by using commercial treatment that increases the value of plastic waste.
4. Convert waste to fuel or electricity in areas that have high waste density.
5. Manually sort waste in areas with low waste density to extract for recycling the 20 percent of plastic waste that has a high residual value.
6. Convert the 80 percent that is of low residual value to refuse-derived fuel (RDF) for industrial application.

The solutions analyzed here looked at five areas of the value chain for plastic-waste leakage: waste reduction/ avoidance, collection, recycling, conversion/treatment, and mitigation.

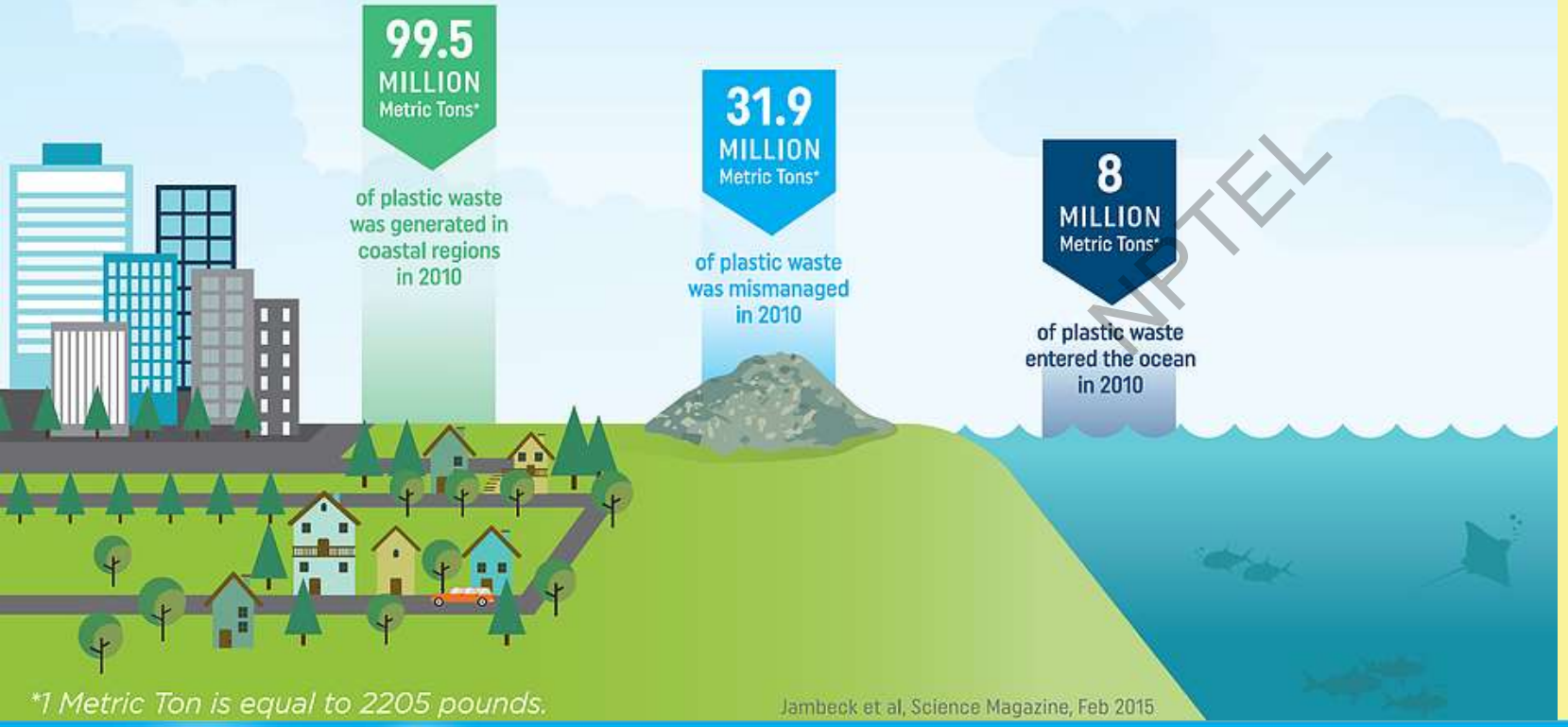


1 Materials-recycling facilities.

Source: McKinsey analysis

PLASTIC WASTE, BOUND FOR THE OCEAN FROM COASTAL AREAS, CAN BE KEPT OUT OF THE OCEAN

Mitigation Options: Reduce plastic in waste stream | Improve solid waste Management infrastructure | Increase capture, recycle and reuse



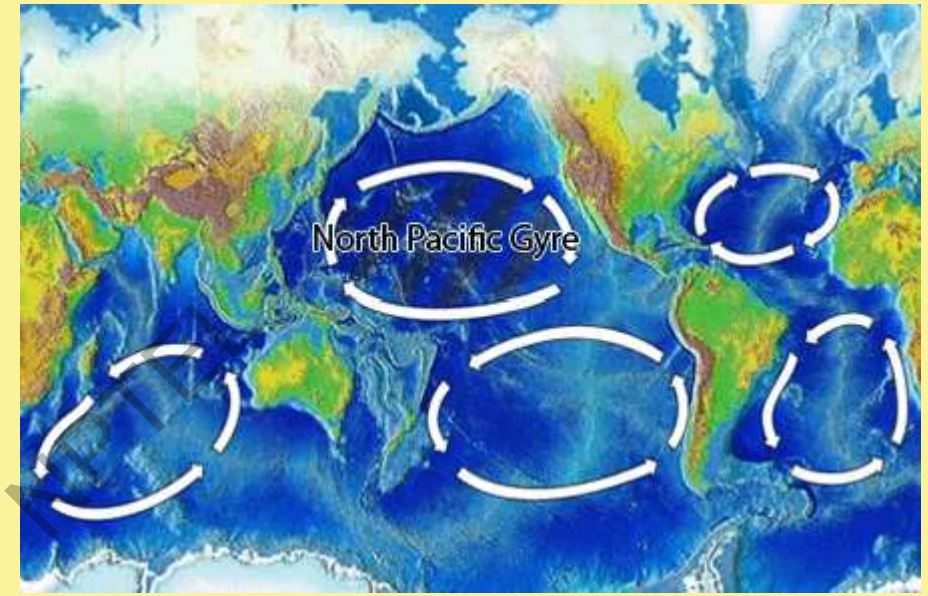
*1 Metric Ton is equal to 2205 pounds.

Jambeck et al, Science Magazine, Feb 2015

Great Pacific garbage patch

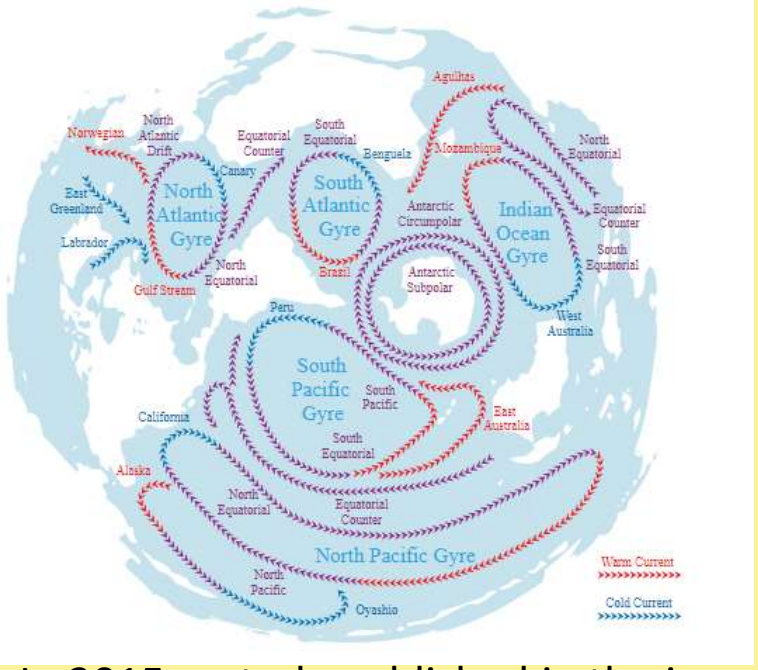
The Great Pacific garbage patch, also described as the Pacific trash vortex, is a gyre of marine debris particles in the north central Pacific Ocean.

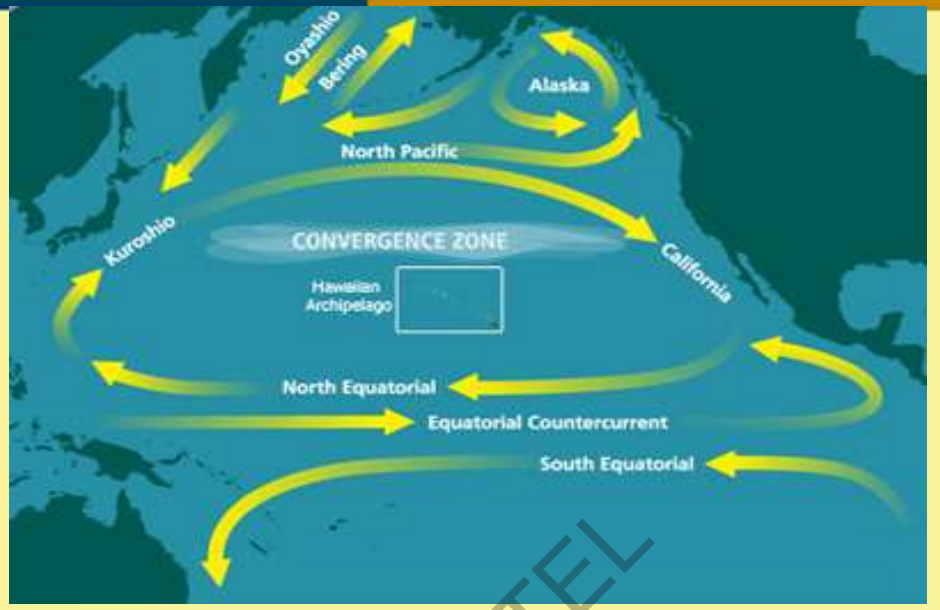
https://twitter.com/ajzfern/status/1119309287984193536



https://en.wikipedia.org/wiki/Great_Pacific_garbage_patch

The patch was described in a 1988 paper published by the National Oceanic and Atmospheric Administration (NOAA). The description was based on research by several Alaska-based researchers in 1988 who measured neustonic plastic in the North Pacific Ocean. Researchers found relatively high concentrations of marine debris accumulating in regions governed by ocean currents.

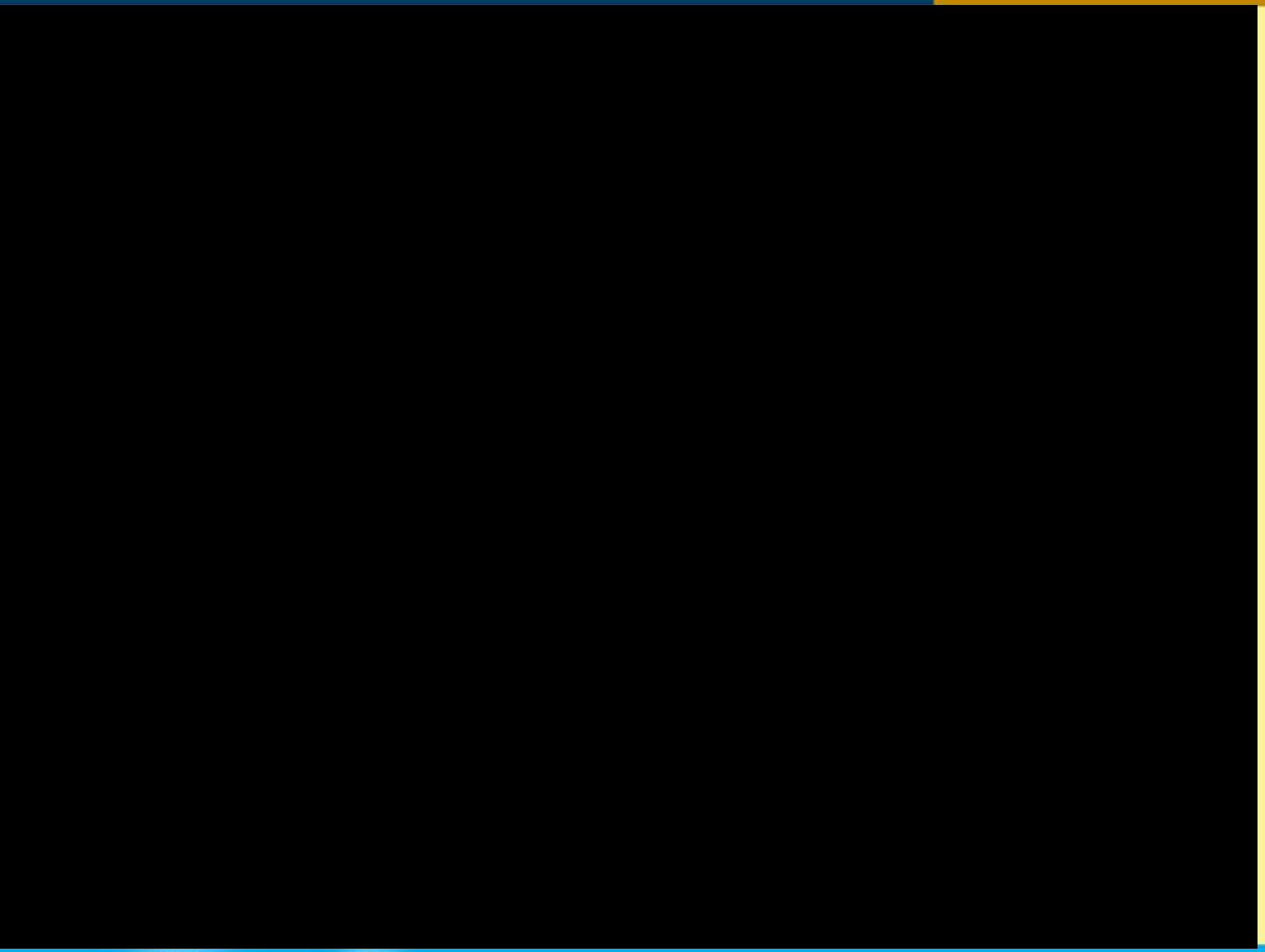




https://en.wikipedia.org/wiki/Great_Pacific_garbage_patch

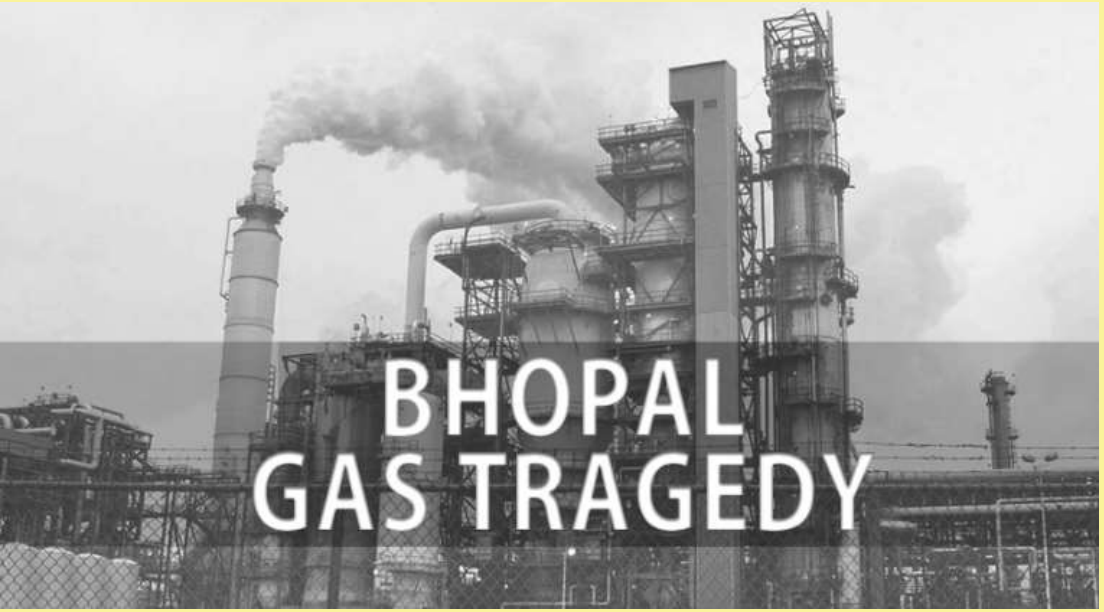
In 2015, a study published in the journal *Science* sought to discover where exactly all of this garbage is coming from. According to the researchers, the discarded plastics and other debris floats eastward out of countries in Asia from six primary sources: China, Indonesia, the Philippines, Vietnam, Sri Lanka and Thailand. In fact, the Ocean Conservancy reported that China, Indonesia, Philippines, Thailand, and Vietnam dump more plastic in the sea than all other countries combined. China alone is responsible for 30% of worldwide plastic ocean pollution.[Efforts to slow land generated debris and consequent marine debris accumulations have been undertaken by the Coastal Conservancy, Earth Day, and World Cleanup Day.

NASA's Garbage Patch Visualization Experiment



Video Credit: NASA's Scientific Visualization Studio

Industrial Pollution and Disasters



https://barandbench.com/bhopal-gas-tragedy-supreme-court-hear-additional-compensation-april/

The Bhopal Gas tragedy is the worst air pollution episode ever witnessed in India.

https://economictimes.indiatimes.com/magazines/panache/my-film-on-bhopal-gas-tragedy-a-cautionary-tale-ravi-kumar/articleshow/45334646.cms

It happened in Bhopal on December 3, 1984.

A leak of methyl isocyanate (MIC) gas and other chemicals from the plant resulted in the exposure of hundreds of thousands of people.

https://www.bhopal.net/what-happened/setting-the-stage-for-tragedy-1969-1984/1969-1979-union-carbide-enters-bhopal/

Background

- In 1934 the American company Union Carbide Corporation (UCC) created an Indian subsidiary – Union Carbide India Limited (UCIL).
- UCC owned the majority of UCIL, thereby effectively controlling all actions undertaken by UCIL.

Just a few decades late, starting in the 1950s, an international agricultural boom began: the development of new seeds were yielding huge harvests, greatly expanding the amount of food production around the world. It was dubbed the “green revolution.”

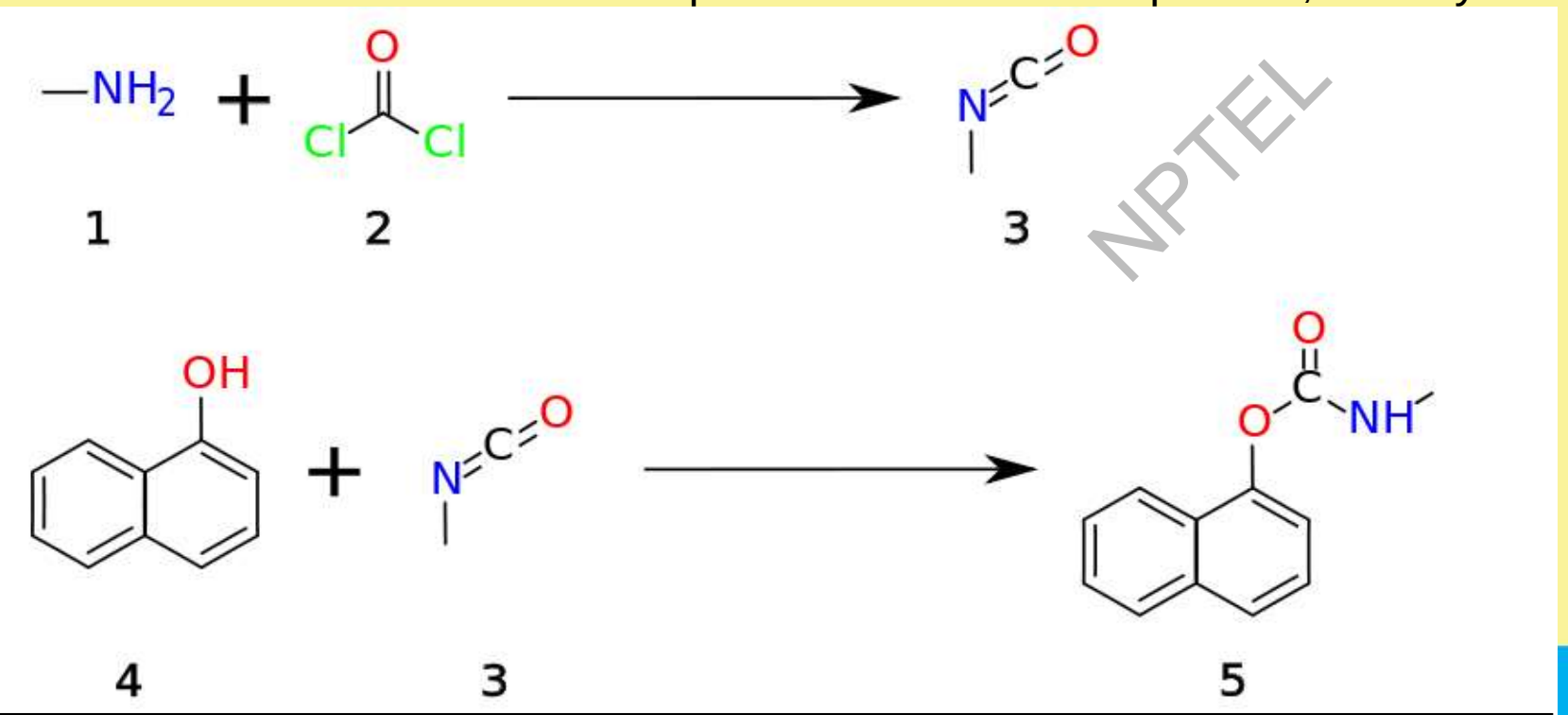
UCC was eager to join the fray and reap its own financial boom through the increased sale of pesticides. It decided to build a new pesticides formulation factory in India, which would be able to manufacture large quantities of the UCC product **Sevin**.

The UCIL factory was built to produce the pesticide Sevin (UCC's brand name for carbaryl) using methyl isocyanate (MIC) as an intermediate.

In 1969, through its subsidiary UCIL, UCC leased land from the Indian state of Madhya Pradesh and got to work creating a new factory in the city of Bhopal.

The company built the plant in Bhopal because of its central location and access to transport infrastructure. The plant was initially approved only for formulation of pesticides from component chemicals, such as MIC(methyl iso- cyanide).

The chemical process employed in the Bhopal plant had methylamine reacting with phosgene to form MIC, which was then reacted with 1-naphthol to form the final product, carbaryl.



Methylamine (**1**) reacts with phosgene (**2**) producing methyl isocyanate (**3**) which reacts with 1-naphthol (**4**) to yield carbaryl (**5**)

Disaster

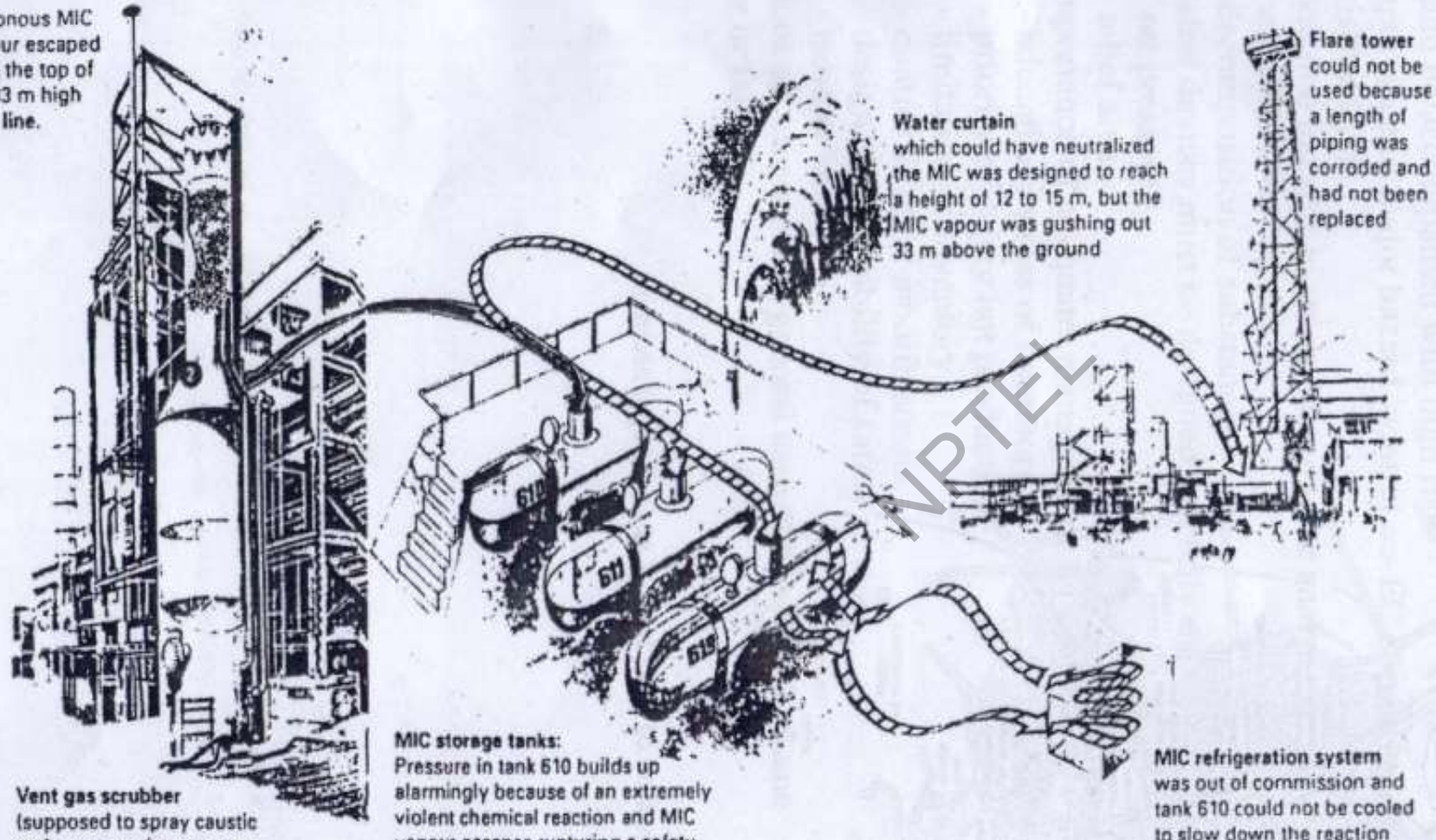
•The Bhopal UCIL facility housed three underground 68,000-liter liquid MIC storage tanks: E610, E611, and E619. In the months leading up to the December leak, liquid MIC production was in progress and being used to fill these tanks.

•UCC safety regulations specified that no one tank should be filled more than 50% (here, 30 tons) with liquid MIC. Each tank was pressurized with inert nitrogen gas.

•This pressurization allowed liquid MIC to be pumped out of each tank as needed, and also kept impurities out of the tanks.

Tank 610 in 2010. During decontamination of the plant, tank 610 was removed from its foundation and left aside.

https://en.wikipedia.org/wiki/File:Bhopal_Plant_7.JPG



State of safety features of MIC plant at Bhopal at time of disaster

•In late October 1984, tank E610 lost the ability to effectively contain most of its nitrogen gas pressure, which meant that the liquid MIC contained within could not be pumped out. At the time of this failure, tank E610 contained 42 tons of liquid MIC.

• Shortly after this failure, MIC production was halted at the Bhopal facility, and parts of the plant were shut down for maintenance. Maintenance included the shutdown of the plant's flare tower so that a corroded pipe could be repaired.

• With the flare tower still out of service, production of carbaryl was resumed in late November, using MIC stored in the two tanks still in service. An attempt to re-establish pressure in tank E610 on 1 December failed, so the 42 tons of liquid MIC contained within still could not be pumped out of it.

- During the night of 2–3 December 1984, water entered Tank E610 containing 42 tons of MIC.
- The resulting exothermic reaction increased the temperature inside the tank to over 200°C (392 °F) and raised the pressure.
- About 30 metric tons of methyl isocyanate (MIC) escaped from the tank into the atmosphere of Bhopal in 45 to 60 minutes.

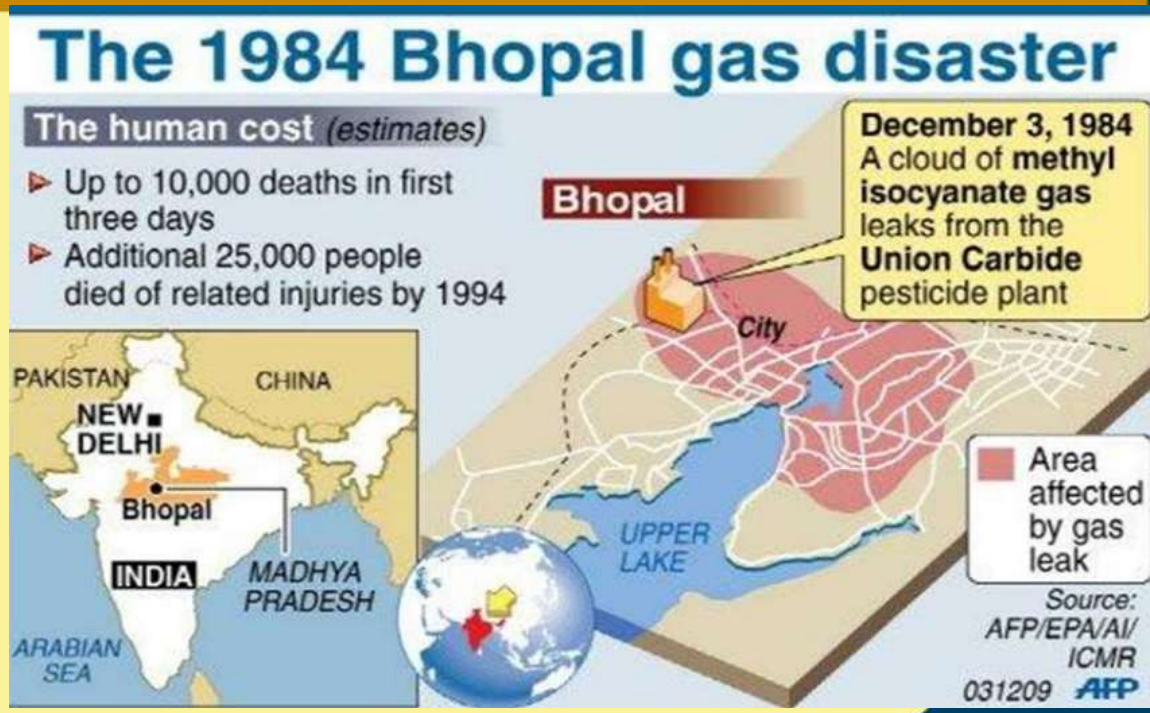
•A refrigeration system meant to cool tanks containing liquid MIC, shut down in January 1982, and whose freon had been removed in June 1984.
•Since the MIC storage system assumed refrigeration, its high temperature alarm, set to sound at 11 °C (52 °F) had long since been disconnected, and tank storage temperatures ranged between 15 °C (59 °F) and 40 °C (104 °F)
•A flare tower, to burn the MIC gas as it escaped, which had had a connecting pipe removed for maintenance, and was improperly sized to neutralise a leak of the size produced by tank E610
•A vent gas scrubber, which had been deactivated at the time and was in 'standby' mode, and similarly had insufficient caustic soda and power to safely stop a leak of the magnitude produced.
•About 30 tonnes of MIC escaped from the tank into the atmosphere in 45 to 60 minutes.
•This would increase to 40 tonnes within two hours time. The gases were blown in a southeasterly direction over Bhopal.

•A UCIL employee triggered the plant's alarm system at 12:50 a.m. as the concentration of gas in and around the plant became difficult to tolerate.

•Activation of the system triggered two siren alarms: one that sounded inside the UCIL plant, and a second directed outward to the public and the city of Bhopal.

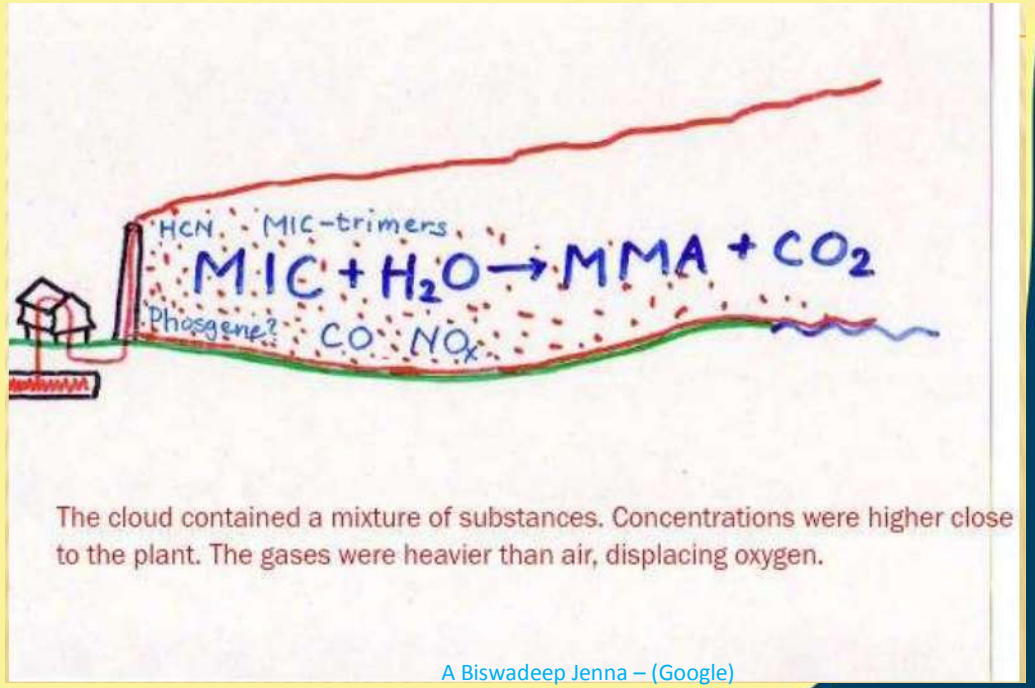
•The two siren systems had been decoupled from one another in 1982, so that it was possible to leave the factory warning siren on while turning off the public one, and this is exactly what was done: the public siren briefly sounded at 12:50 a.m. and was quickly turned off, as per company procedure meant to avoid alarming the public around the factory over tiny leaks.

• Workers, meanwhile, evacuated the UCIL plant, travelling upwind.



•The gas cloud, composed mainly of materials denser than air, stayed close to the ground and spread in the southeasterly direction affecting the nearby communities. The chemical reactions may have produced a liquid or solid aerosol.

•Apart from MIC, based on laboratory simulation conditions, the gas cloud most likely also contained chloroform, dichloromethane, hydrogen chloride, methylamine, dimethylamine, trimethylamine and carbon dioxide, that was either present in the tank or was produced in the storage tank when MIC, chloroform and water reacted.



The cloud contained a mixture of substances. Concentrations were higher close to the plant. The gases were heavier than air, displacing oxygen.

A Biswadeep Jenna – (Google)

- Most city residents who were exposed to the MIC gas were first made aware of the leak by exposure to the gas itself, or by opening their doors to investigate commotion, rather than having been instructed to shelter in place, or to evacuate before the arrival of the gas in the first place.

https://www.downtoearth.org.in/coverage/environment/30-years-of-bhopal-gas-tragedy-a-continuing-disaster-47634

CONSEQUENCES

Health Issues

•The initial effects- coughing, severe eye irritation, suffocation, burning in the respiratory tract, breathlessness, stomach pain and vomiting.

• The immediate death toll was 2,259; the government confirmed a total of 3,787 deaths related to the gas release.

•The leak caused 558,125 injuries including 38,478 temporary partial injuries and approximately 3,900 severely and permanently disabling injuries.

• Others estimates 8,000 died within two weeks and another 8,000 or more have since died from gas-related diseases.

- The causes of deaths were choking, reflexogenic circulatory collapse and pulmonary oedema.
- Findings during autopsies revealed changes not only in the lungs but also cerebral oedema, tubular necrosis of the kidneys, fatty degeneration of the liver and necrotising enteritis.
- The stillbirth rate increased by up to 300% and neonatal mortality rate by 200%

Studied and reported long term health effects are:

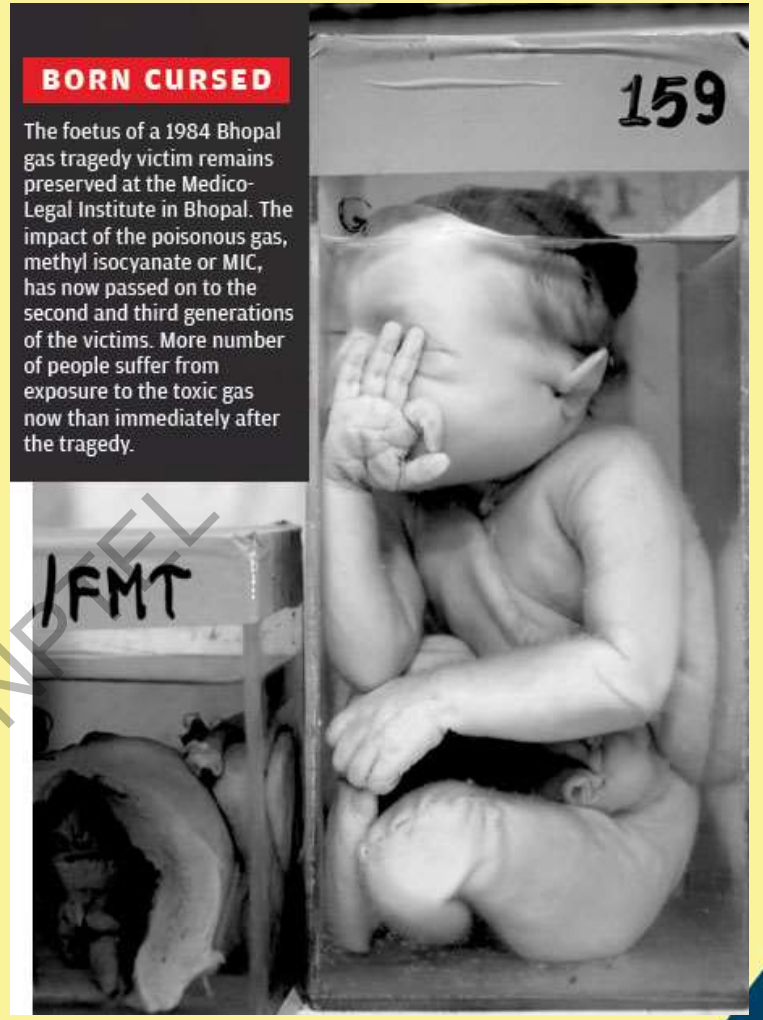
•Eyes: Chronic conjunctivitis, scars on cornea, corneal opacities, early cataracts.

• Respiratory tracts: Obstructive and/or restrictive disease, pulmonary fibrosis, aggravation of TB and chronic bronchitis.

•Neurological system: Impairment of memory, finer motor skills, numbness etc.

• Psychological problems: Post traumatic stress disorder (PTSD)

Google search with key word: health effects Bhopal gas tragedy



Down to Earth

- Children’s health: Perinatal and neonatal death rates increased, failure to grow, intellectual impairment etc.
- Missing or insufficient fields for research are reproduction, chromosomal aberrations, cancer, immune deficiency, neurological problems, post traumatic stress disorder (PTSD) and children born after the disaster.
- Late cases that might never be highlighted are respiratory insufficiency, cardiac insufficiency, cancer and tuberculosis.

- The official immediate **death toll** was 2,259, and in 1991, 3,928 **deaths** had been officially certified. Ingrid Eckerman estimated 8,000 **died** within two weeks. The government of Madhya Pradesh confirmed a total of 3,787 **deaths** related to the **gas** release.

NEWS 18

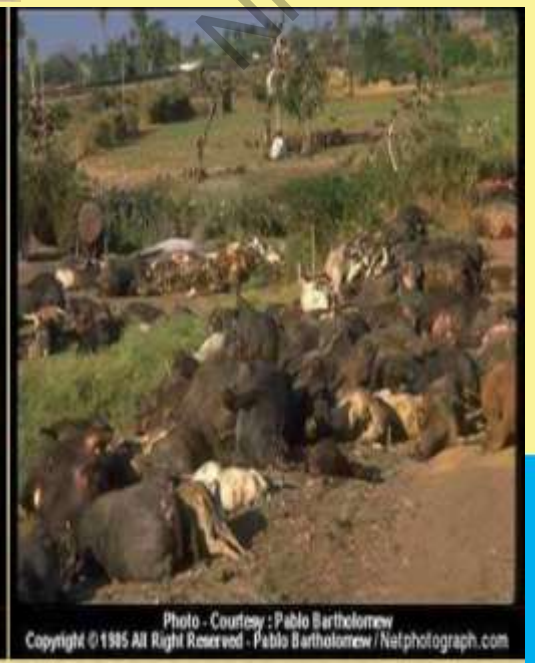
NEWS18 » INDIA

1-MIN READ

Bhopal Gas Tragedy Survivors Stage Protest, Urge State Govt To Quote Correct Figures Before SC

Jointly led by four local organisations, the survivors urged the state government to correct the figures of deaths and extent of health damage caused by the disaster in the Curative Petition that is expected to be heard by the apex court soon.

Vivek Trivedi | News18.com | Updated:July 25, 2019, 8:13 PM IST



https://www.indiatoday.in/india/photo/bhopal-gas-tragedy-in-pics-363786-2010-06-08/3

A file photo taken December 4, 1984, shows victims who lost their sight in the Bhopal poison gas tragedy.

Health Effects

New Generations

The leak of Methyl Isocyanate killed thousands of people and left thousands more with lasting health issues. Generations later, the people of Bhopal are still being affected. Women who conceived after the gas leak have given birth to babies with a wide variety of birth defects, such as webbed fingers and toes, cleft palates, extra or missing limbs, artificial aging or youth, and dysfunctional reproductive systems. Some women have even lost the ability to menstruate.

In addition to birth defects, children born in Bhopal have a high chance of being born with Down's Syndrome, a chromosome disorder. Many children have also been diagnosed with mental disorders including bipolar disorder, depression, and anxiety. Children may experience a variety of disabilities and disorders if they live longer than infancy. Many babies are stillborn and 8% of all babies die as infants in Bhopal.

child born after the leak

effect of the leak

Bhopal child

https://bhopalgasdisaster.weebly.com/health-effects.html

LEGAL ISSUES

Till then, governments had handled floods, cyclones and even earthquakes. They had no clue how to respond in this case. The US-based multinational company, Union Carbide Corporation (UCC), which owned the plant through its subsidiary UCIL, did little to help deal with the human tragedy. Thirty years later, there is no closure. Not because of what happened that fateful night, but because our response has been incompetent and callous (https://www.downtoearth.org).

Bhopal was struck by two tragedies: the one that happened immediately, and the other that unfolded in the years that followed.

- Civil and criminal cases were filed in the district court of Bhopal involving UCC and Warren Anderson, CEO at the time.
- Legal Issues: One of the main issues which the Bhopal Gas tragedy raises is the issue of absolute liability.
- The Principle of Absolute Liability states that when an enterprise is engaged in hazardous or inherently dangerous industry and if any harm results in account of such activity then the enterprise is absolutely liable to compensate for such harm and that it should be no answer to the enterprise to say that it had taken all reasonable care and that the harm occurred without any negligence on its part.

•When the case began, the government said there were some 3,000 deaths and 30,000 cases of injury. Later, it was realised that many more were suffering from exposure to the poisonous gas. So, when the case was decided, compensation was doled out to virtually the entire city. Some 573,588 people got money as “affected” by the gas leakage—many times above the number of claims filed, and representing some 70 per cent of the city population in 1980. Of them, 5,295 were death cases, in which families of the victims got a paltry Rs 2-3 lakh as compensation. The rest—568,293—were classified as injured. As the government deducted what was paid over six years as interim relief, the final settlement was less than Rs 15,000 per victim.

https://www.downtoearth.org

- Photo series by Sri Raghu Rai

INDIA. Bhopal disaster. 1984.

For Greenpeace, Sri Raghu Rai has completed an in-depth documentary project on the chemical disaster at Bhopal in 1984, and on its ongoing effects on the lives of gas victims. This work resulted in a book and three exhibitions that have been touring Europe, America, India and southeast Asia since 2004, the 20th anniversary of the disaster.

INDIA. Bhopal disaster. 1984.

This victim was identified as Leela who lived in the Chola colony near the Union Carbide factory.

INDIA. Bhopal disaster. 1984.

Burial of unknown children, victims of the Bhopal disaster.
More than 8.000 people died during the first days, cemeteries were overcrowded with no space for individual burials.

INDIA. Bhopal disaster. 1984.

A family suffering from serious eye and lung damage.

INDIA. Bhopal disaster. 1984.

This elderly woman was badly injured when exposed to the poisonous gas. Everyone else in her family died.

INDIA. Bhopal disaster. 1984.

A man carries the body of his dead wife past the deserted Union Carbide Factory, the source of the toxic gas that killed her the night before.

INDIA. Bhopal disaster. 1984.

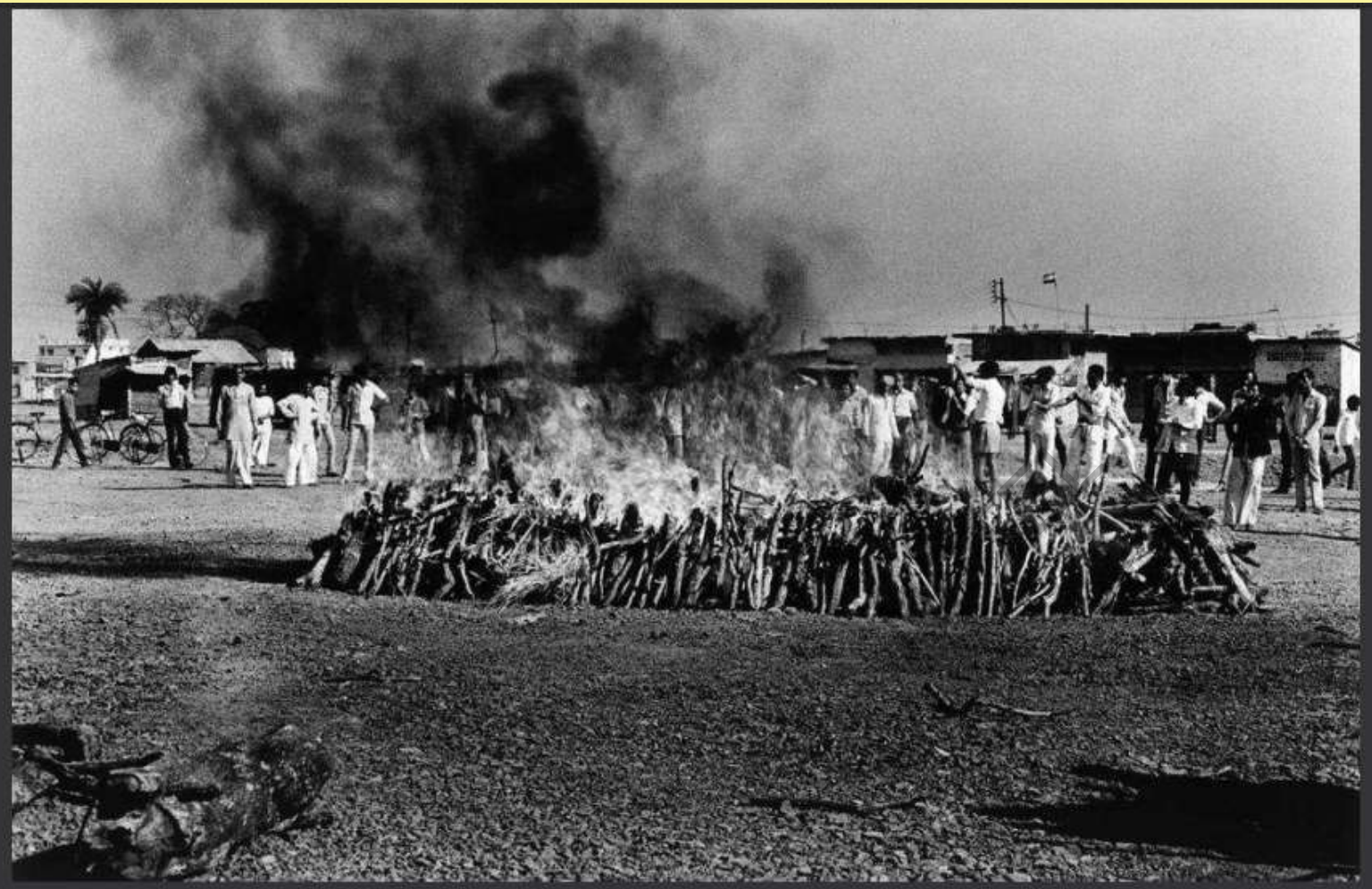
Poster of the dead and missing displayed all over Bhopal within days of the disaster. Many bodies were never identified.

INDIA. Bhopal disaster. 1984.

In the immediate aftermath of the disaster, thousands of sick children were brought to the state government-run Hamida Hospital, their parents too ill to take care of them properly.

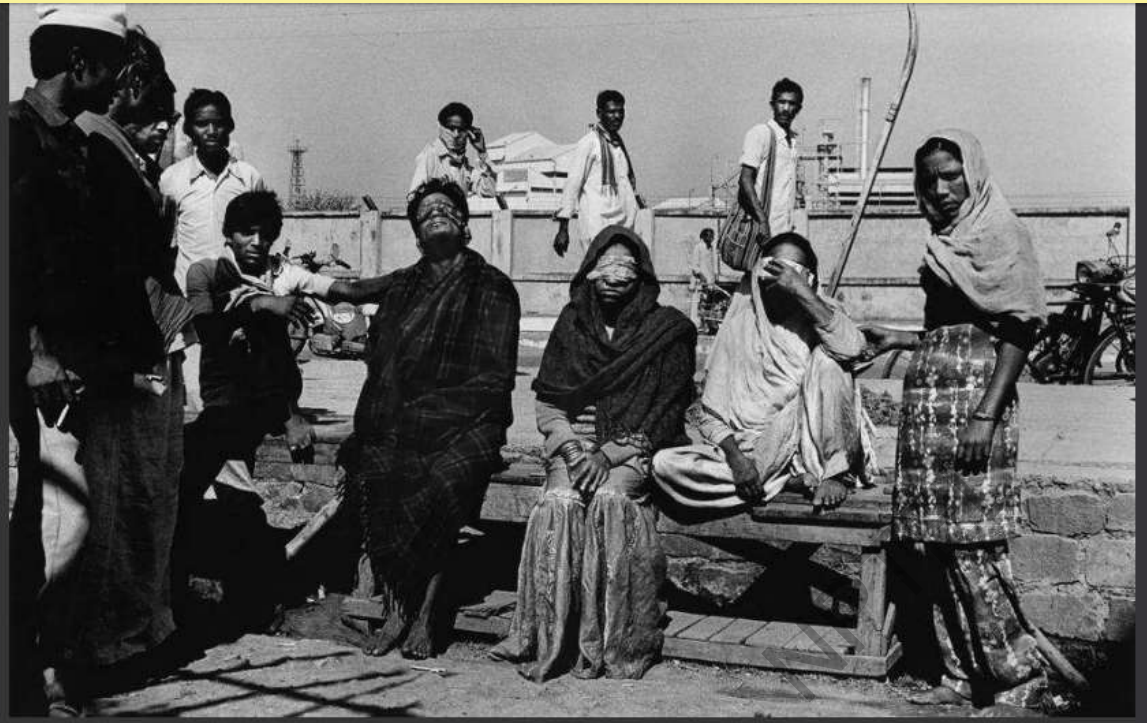
INDIA. Bhopal disaster. 1984.

A man pastes identification labels onto dead children's foreheads before their cremation..



INDIA. Bhopal disaster. 1984.

Mass cremation of victims held alongside the communal graves.



INDIA. Bhopal disaster. 1984.

Survivors of the Bhopal disaster from the nearby Jayaprakash Nagar colony, stand in front of the Union Carbide factory the day after it leaked 40 tonnes of toxic gas on the city. Their eyes and lungs have been badly damaged.

INDIA. Bhopal disaster. 1984.

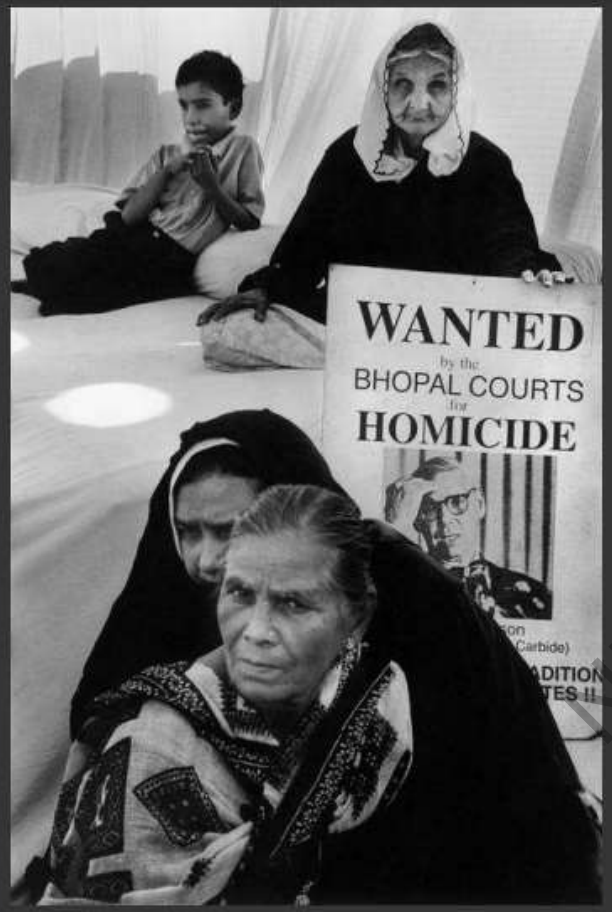
Foetuses which were aborted by pregnant women while escaping from the gas, were preserved by Dr. Satpathy, a forensic expert at the State Government's Hamida Hospital, to establish the exact cause of death. 2001.

INDIA. Bhopal disaster. 1984.

Nanko, now 76 years old, was independent and able to provide for his family. Since the disaster he has become a beggar. 2001.

INDIA. Bhopal disaster. 1984.

Skulls discarded after research at the Hamida Hospital. Medical experts believe that the toxic gas inhaled by the people of Bhopal may have affected the brain.

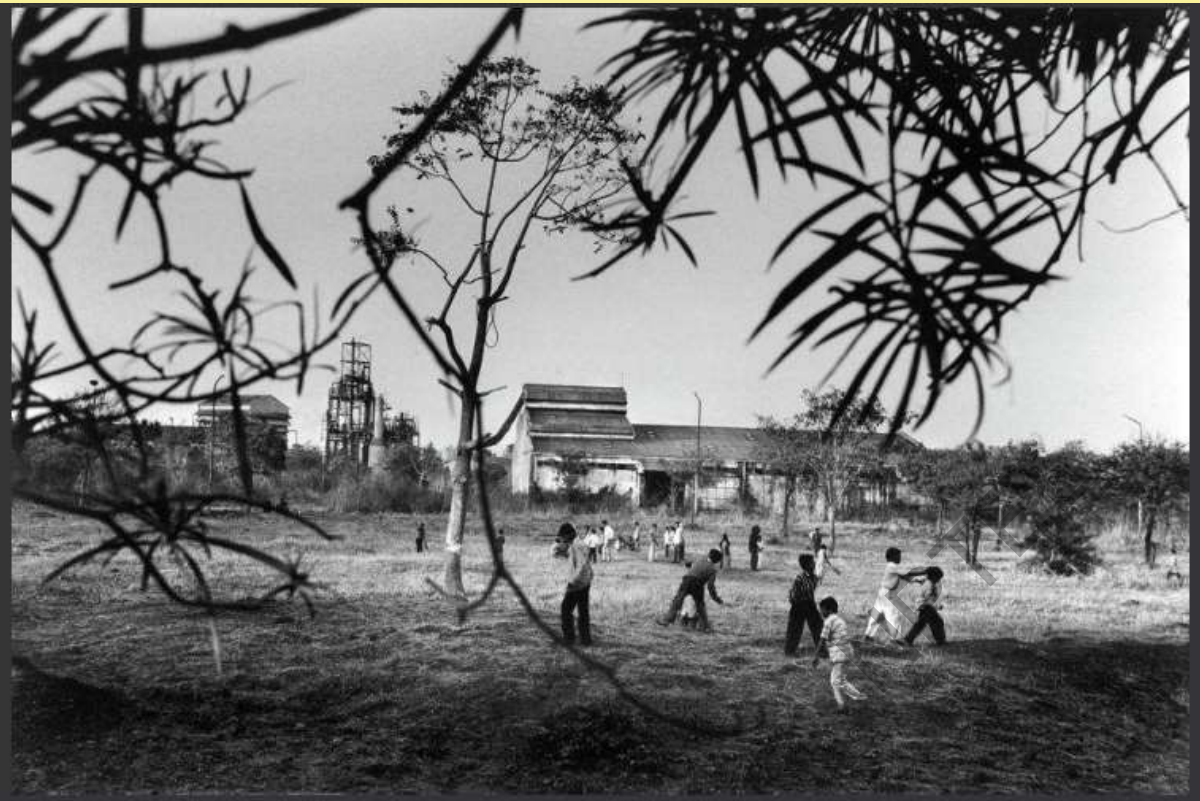


INDIA. Bhopal disaster. 1984.

Bhopal survivors protest in New Delhi, to extradite Warren Anderson, former chief executive of Union Carbide. Anderson is evading justice in the United States and is wanted by Interpol for crimes in Bhopal. 2001.

INDIA. Bhopal disaster. 1984.

Gangaram had come to Bhopal to get treatment for leprosy at the Hamida Hospital. He was cured when the toxic gas hit the city. He is now, again, dependent on others for survival. 2001.

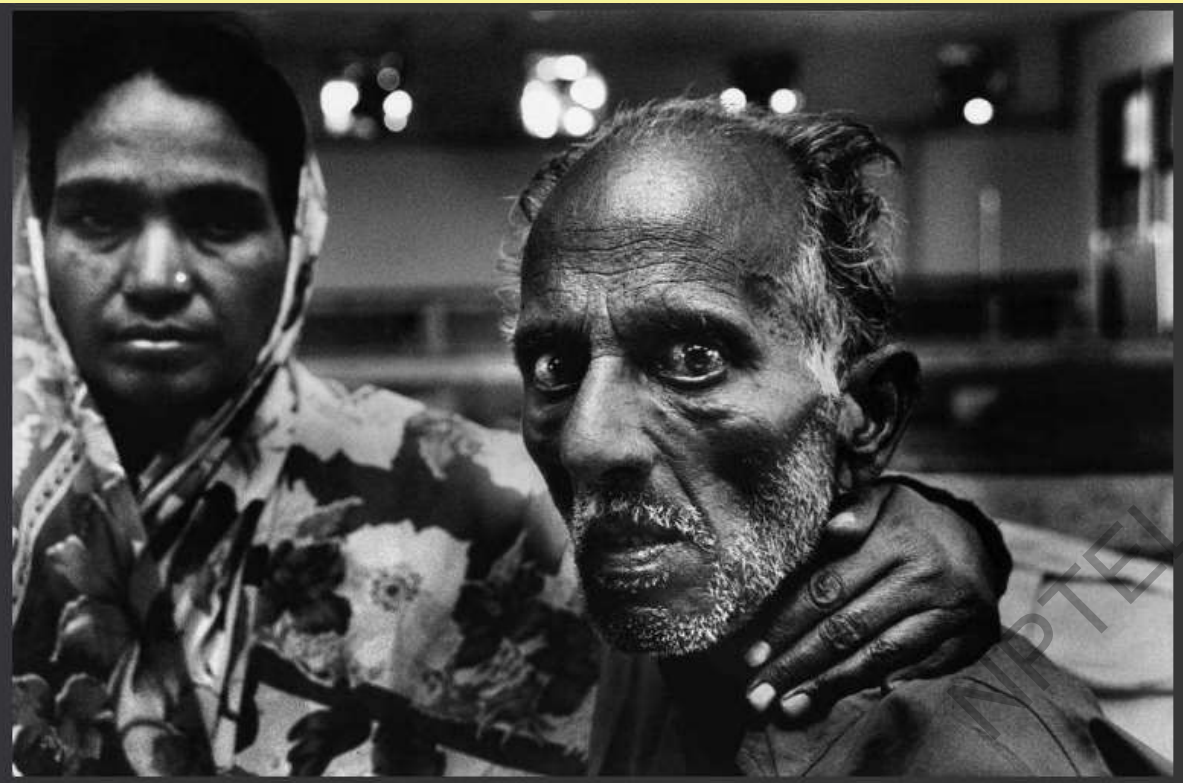


INDIA. Bhopal disaster. 1984.

Union Carbide abandonned its factory after the disaster, leaving hundreds of tonnes of toxic waste on the site. Until mid 2001 the factory ground was inaccessible. Now local children play in the area which remains dangerously contaminated. 2002.

INDIA. Bhopal disaster. 1984.

Bhopal. 2002. These women have all lost their husbands in the Bhopal tragedy. They now live in one-room tenements in a seperate widows' colony in the outskirts of the city, built by the state government.



INDIA. Bhopal disaster. 1984.

Mohammed ARIF has pulmonary fibrosis due to the toxic gas, a condition that can only be cured by replacing the lungs.

For all the photos of the slides 85- 103

Photo Courtesy

Magnum Photos

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Still a no-brainer for most people

Firstpost.
Friday, September 27, 2019

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POLLUTION

A new generation inherits poisoned genes of Bhopal gas tragedy, and the broken promises of govts too

Even 35 years after the Bhopal gas tragedy, the city is still feeling its after-effects. Those born to the survivors have been afflicted with birth defects, while the survivors themselves suffer from a myriad of ailments.

By Manish Chandra Mishra
Mar 12, 2019 15:45:28

THE ECONOMIC TIMES | Politics and Nation

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34 years after Bhopal gas leak, survivors continue to fight for proper care

Various organisations fighting for gas leak survivors have been seeking proper medical care, adequate compensation and cleaning of the groundwater.

PTI | Updated: Dec 03, 2018, 09.45 AM IST

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"Finding gainful employment in accordance with the reduced capacity to work, and to lead a dignified life has been a serious challenge for survivors"

Thirty-four years after the Bhopal gas tragedy, survivors continue to demand proper rehabilitation and adequate compensation besides proper medical treatment for ailments caused by the toxic leak.

In what is termed as the world's worst industrial disaster, over 15,000 people were killed after methyl isocyanate leaked on the intervening night of December 2-3, 1984 from the pesticide plant of Union Carbide India Limited (UCIL) in the city.

Such report in the media raises the question of accountability and liability

hindustantimes

Friday, Sep 27, 2019 |

Bhopal gas tragedy site has 336 tonnes of hazardous waste, says govt

A deadly gas leak at the Union Carbide plant in Bhopal in 1984 killed over 3,000 people and maimed thousands of others. Around 336 tonnes of hazardous waste is lying in the premises of Union Carbide India Limited.

INDIA Updated: Mar 28, 2017 19:23 IST

Bhopal-like disasters in the making

Hazardous waste contaminated sites identified by the Central Pollution Control Board

https://www.downtoearth.org.in/coverage/environment/30-years-of-bhopal-gas-tragedy-a-continuing-disaster-47634

1. **Eloor-Edyar area, Cochin, Kerala:** Sits over 200,000 tonnes of highly hazardous chemicals, pesticides waste
2. **Ranipet chromium contaminated area, Tamil Nadu:** About 220,000 tonnes of chromium waste piles, of 2-4 metres high, cover 3 hectares
3. **Ratlam Industrial area, Ratlam, Madhya Pradesh:** Contaminated with effluents from pharma industry, manufacturing H-Acid
4. **Chromium contaminated area, Sundargarh, Odisha:** 50,000 tonnes of chromium waste dumped in open land
5. **Talcher chromium contaminated area, Talcher, Odisha:**
6. 60,000 tonnes of waste from closed chrome salt manufacturing unit dumped in the open

https://www.downtoearth.org.in/coverage/environment/30-years-of-bhopal-gas-tragedy-a-continuing-disaster-47634

6. **Ganjam mercury contaminated area, Ganjam, Odisha:** Over 50,000 tonnes of mercury waste from closed caustic soda plants at different locations
7. **Juhi-Baburaiya-Rakhi-Mandi, Kanpur, Uttar Pradesh:** about 2 hectares of soil contaminated with roughly 10,000 tonnes of hexavalent chromium within densely populated settlement; owners not known
8. **Rania, Kanpur Dehat, Uttar Pradesh:** About 45,000 tonnes of hexavalent chromium waste pile up on 200 hectares of private land
9. **Nibra Village, West Bengal:** 4,440 tonnes of chromium waste dumped; owners not known
10. **Persistent Organic Pollutants contaminated area, Lucknow:** Indian Pesticide Ltd generated 36,432 tonnes of hexachlorocyclohexane (HCH) waste

Global Food Waste Initiative

REDUCING FOOD LOSS AND WASTE Setting a Global Action Agenda

https://en.wikipedia.org

Based on the report by

WORLD RESOURCES INSTITUTE

- “Food loss and waste” refers to the edible parts of plants and animals that are produced or harvested for human consumption but that are not ultimately consumed by people.
- “Food loss” refers to food that spills, spoils, incurs an abnormal reduction in quality such as bruising or wilting, or otherwise gets lost before it reaches the consumer.
- Food loss is the unintended result of an agricultural process or technical limitation in storage, infrastructure, packaging, or marketing.
- “Food waste” refers to food that is of good quality and fit for human consumption but that does not get consumed because it is discarded—either before or after it spoils. Food waste is the result of negligence or a conscious decision to throw food away.

- During production or harvest in the form of grain left behind by poor harvesting equipment, discarded fish, and fruit not harvested or discarded because they fail to meet quality standards or are uneconomical to harvest.
- During handling and storage in the form of food degraded by pests, fungus, and disease.
- During processing and packaging in the form of spilled milk, damaged fish, and fruit unsuitable for processing. Processed foods may be lost or wasted because of poor order forecasting and inefficient factory processes.
- During distribution and marketing in the form of edible food discarded because it is non-compliant with aesthetic quality standards or is not sold before “best before” and “use-by” dates.
- During consumption in the form of food purchased by consumers, restaurants, and caterers but not eaten.

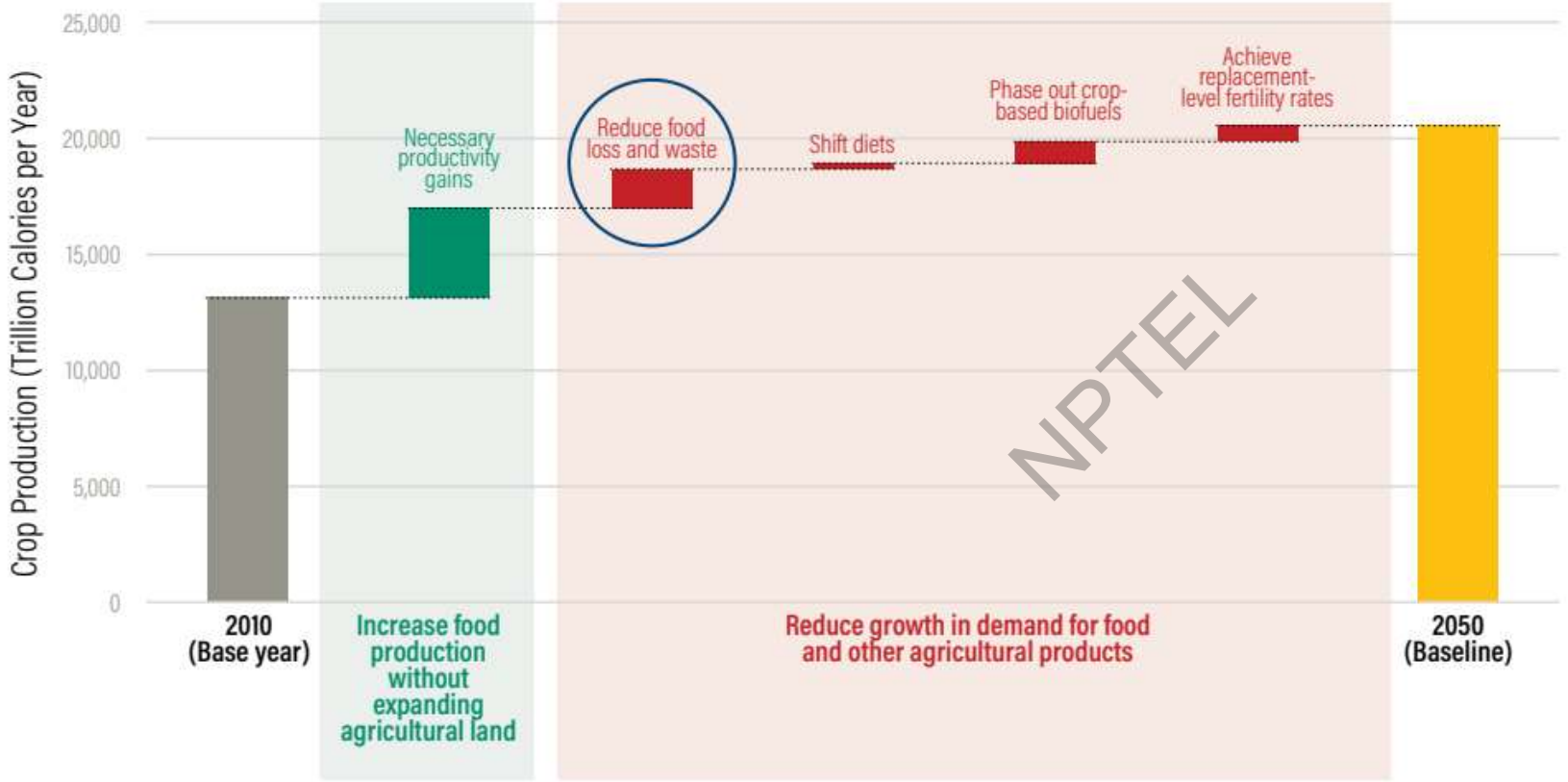
https://iasscore.in/free-downloads/report-reducing-food-loss-and-waste-report-by-unep

- A new report by the World Resources Institute (WRI) with the support of the Rockefeller Foundation has quantified global food wastage nearly one-third of the food that is produced each year goes uneaten, costing the global economy over $940 billion.
- The Food and Agriculture Organization of the United Nations (FAO) estimates that 32 percent of all food produced in the world was lost or wasted in 2009.
- This estimate is based on weight. When converted into calories, global food loss and waste amounts to approximately 24 percent of all food produced. Essentially, one out of every four food calories intended for people is not ultimately consumed by them.

- Food loss and waste have many negative economic and environmental impacts. Economically, they represent a wasted investment that can reduce farmers' incomes and increase consumers' expenses. Environmentally, food loss and waste inflict a host of impacts, including unnecessary greenhouse gas emissions and inefficiently used water and land, which in turn can lead to diminished natural ecosystems and the services they provide.
- It is estimated that saving one-fourth of the food currently lost or wasted globally would be enough to feed 870 million hungry people in the world, of which the highest number are in India.

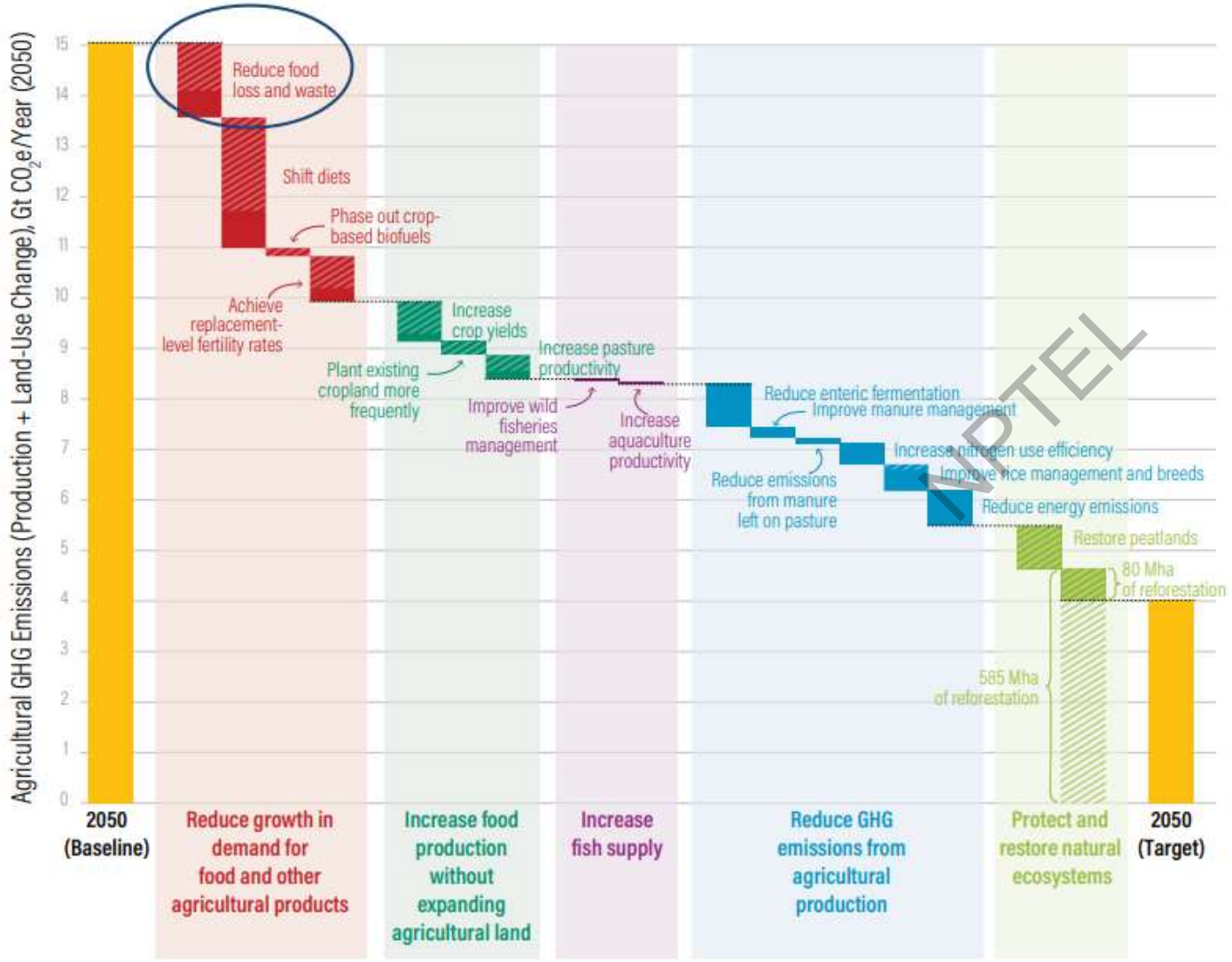
INITIATIVE OR ORGANIZATION	GEOGRAPHY	DESCRIPTION
SAVE FOOD	Global	SAVE FOOD, a global initiative on food loss and waste reduction, is led by FAO and Messe Düsseldorf, a leading trade fair organizer. Since 2011, it has worked with donors, development agencies, financial institutions and the private sector (particularly the food packaging industry) to develop and implement a program to reduce food loss and waste. The program rests on four pillars: 1) awareness raising; 2) collaboration with like-minded initiatives; 3) policy, strategy, and program development; and 4) support to food supply chain actors and organizations involved in food loss and waste reduction. For more information, visit http://www.save-food.org and http://www.fao.org/save-food.
Think.Eat.Save campaign	Global	Think.Eat.Save is a campaign of the SAVE FOOD initiative led by UNEP, FAO, and Messe Düsseldorf. The campaign seeks to galvanize widespread global, regional, and national actions to reduce food waste, and specifically targets food wasted by consumers, retailers, and the hospitality industry. The Think.Eat.Save website is a portal showcasing inspiring ideas and solutions, and a one-stop shop for news and resources on reducing food waste. For more information, visit http://www.thinkeatsave.org.
Global FoodBanking Network	Global	The Global FoodBanking Network (GFN) is a global nonprofit organization committed to creating, supplying, and strengthening food banks and food bank networks throughout the world outside the United States. GFN supports food banks and national food bank networks in more than 25 countries that are home to more than one-third of the world's undernourished people. Food banks acquire donated food, much of which would otherwise be wasted, and make it available to those in need through a network of community agencies that provide food to the hungry. For more information, visit http://www.foodbanking.org.
OECD Food Chain Analysis Network	Global	The OECD Food Chain Analysis Network provides a broad platform for dialogue building on analytical work and policy experiences on emerging issues of relevance to the food chain. It consists of government officials, international organizations, industry stakeholders, consumers, academic experts, and non-governmental organizations. The Network's 4th annual meeting (June 2013) will be dedicated to the issue of reducing food waste along the supply chain. The meeting will help improve data and policy information on food waste, allow exchange of analysis and best practices, and identify appropriate policy and industry responses to food waste. For more information, visit http://www.oecd.org/site/agrfcn.
FUSIONS	Regional	FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies) aims to reduce food waste in Europe. It is a four-year project running from 2012 to 2016, funded by the European Commission. FUSIONS has 21 project partners from 13 countries, including universities, research institutes, consumer organizations, and businesses. FUSIONS aims to support the European Commission target of a 50 percent reduction in food waste and the Roadmap toward a Resource Efficient Europe. For more information, visit http://www.eu-fusions.org.

Reducing Food Loss and Waste Can Play an Important Role in Closing the Food Gap Between 2010 and 2050 Without Expanding Cultivated Area



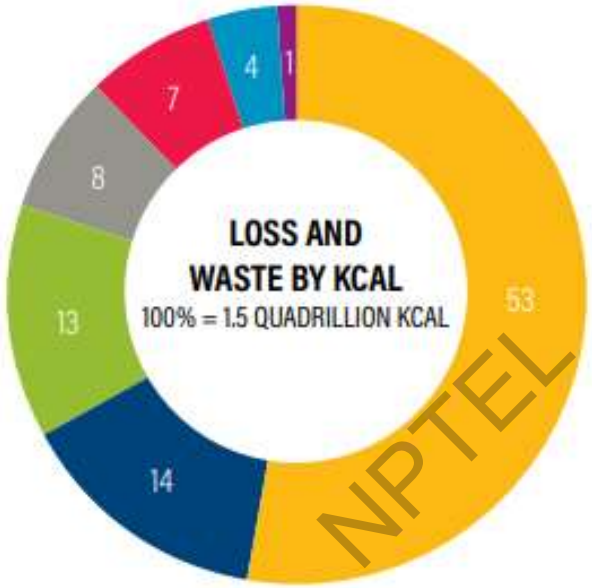
Note: Includes all crops intended for direct human consumption, animal feed, industrial uses, seeds, and biofuels.
Source: Searchinger et al. (2018).

Reducing Food Loss and Waste Can Play an Important Role in Eliminating the Projected 15 Gt of Greenhouse Gas Emissions from Agriculture and Land-Use in 2050 (CO_2 equivalent)



Note: Solid areas represent agricultural production emissions. Hatched areas represent emissions from land-use change.
Source: Searchinger et al. (2018).

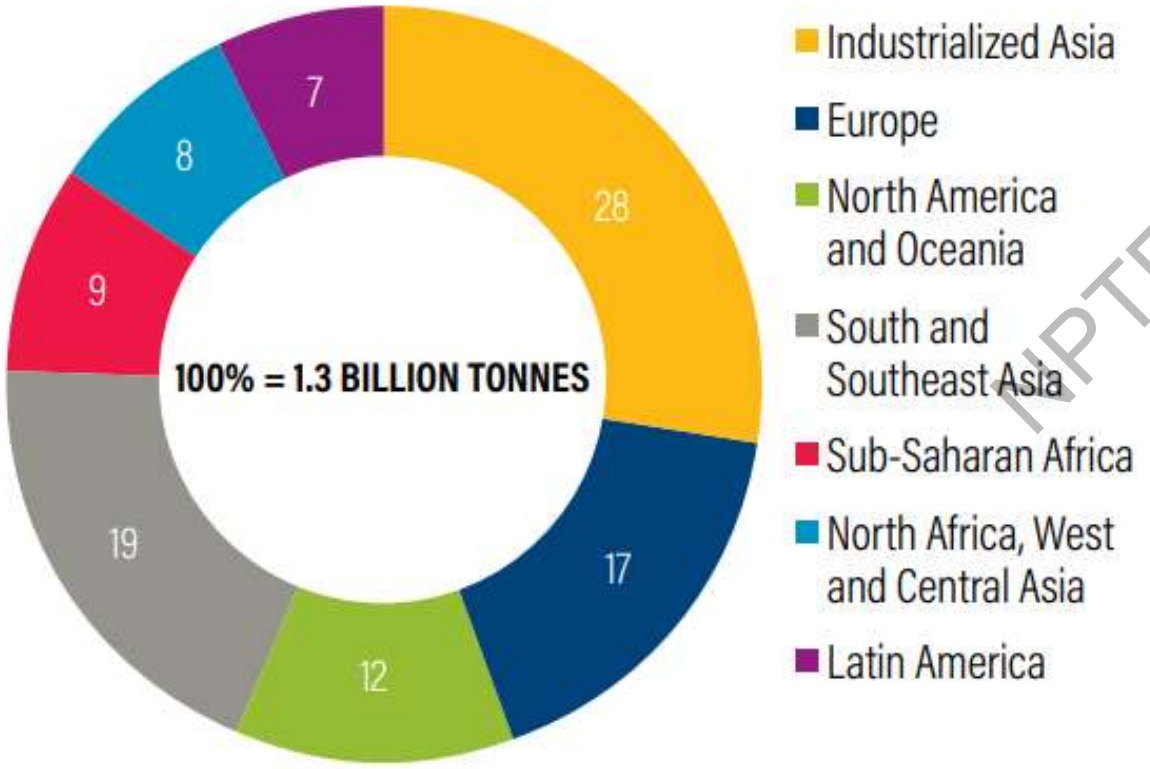
Share of Global Food Loss and Waste by Commodity (2007)



- Cereals
- Roots and Tubers
- Fruits and Vegetables
- Oilseeds and Pulses
- Meat
- Milk
- Fish and Seafood

Source: WRI analysis based on FAO (2011).

Share of Global Food Loss and Waste by Region (2007)



Source: WRI analysis based on FAO (2011).

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Examples of Food Loss and Waste along the Food Supply Chain (Not Exhaustive)

PRODUCTION	HANDLING AND STORAGE	PROCESSING AND PACKAGING	DISTRIBUTION AND MARKET	CONSUMPTION
During or immediately after harvesting on the farm	*After leaving the farm for handling, storage, and transportation*	*During industrial or domestic processing and/or packaging*	*During distribution to markets, including at wholesale and retail markets*	*In the home or business of the consumer, including restaurants and caterers*
■ Fruits discarded due to bruising during picking ■ Crops sorted out post-harvest for not meeting cosmetic standards ■ Crops left behind in fields due to poor mechanical harvesting or drops in prices ■ Fish discarded during fishing operations	■ Harvested food eaten by pests ■ Harvested food degraded by fungus or disease ■ Fish that are spilled or degraded after landing	■ Milk spilled during pasteurization and processing ■ Food sorted out as not suitable for processing ■ Livestock trimming during slaughtering and industrial processing ■ Fish spilled or damaged during canning or smoking	■ Food sorted out due to quality ■ Safe food disposed because of going past sell-by date before being purchased ■ Food spilled or damaged in market	■ Food sorted out due to quality ■ Food purchased but not eaten ■ Food cooked but not eaten

Source: WRI analysis based on FAO (2011).

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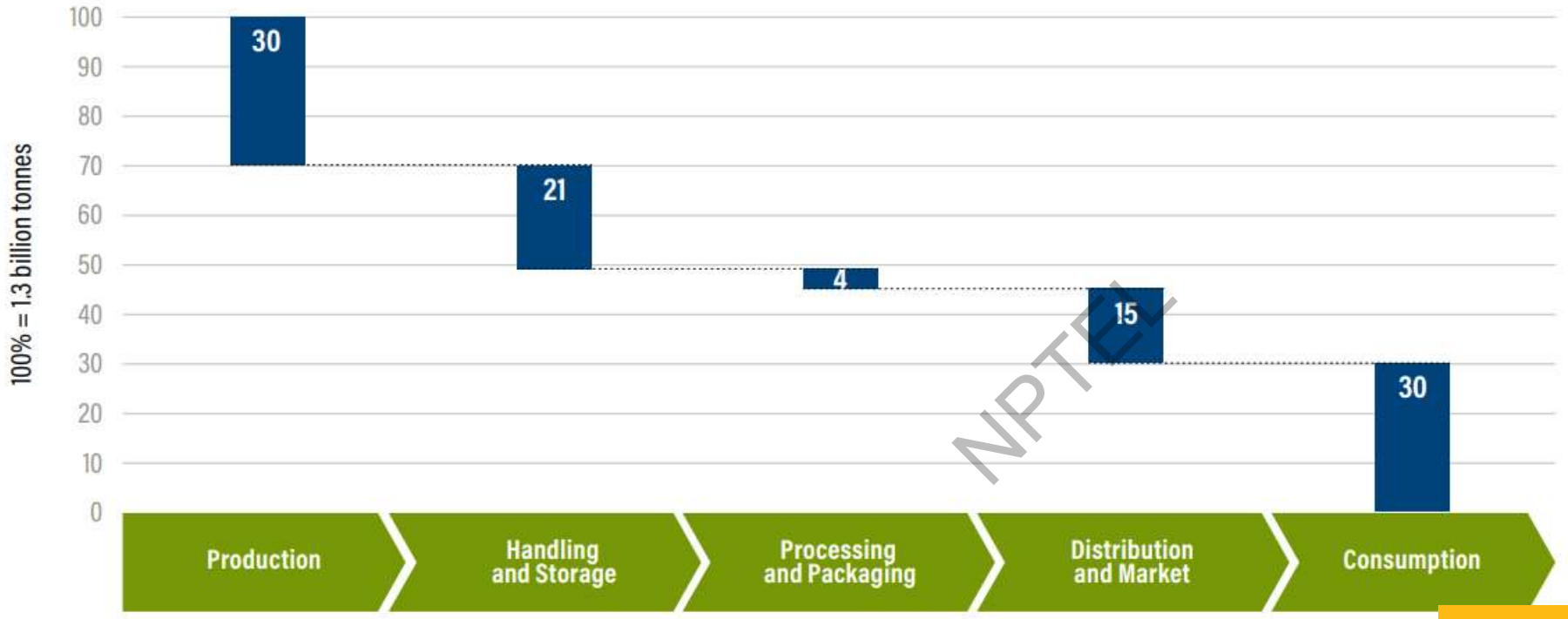
Distribution of Total Global Food Loss and Waste across the Food Supply Chain (2007)



Source: WRI analysis based on FAO (2011).

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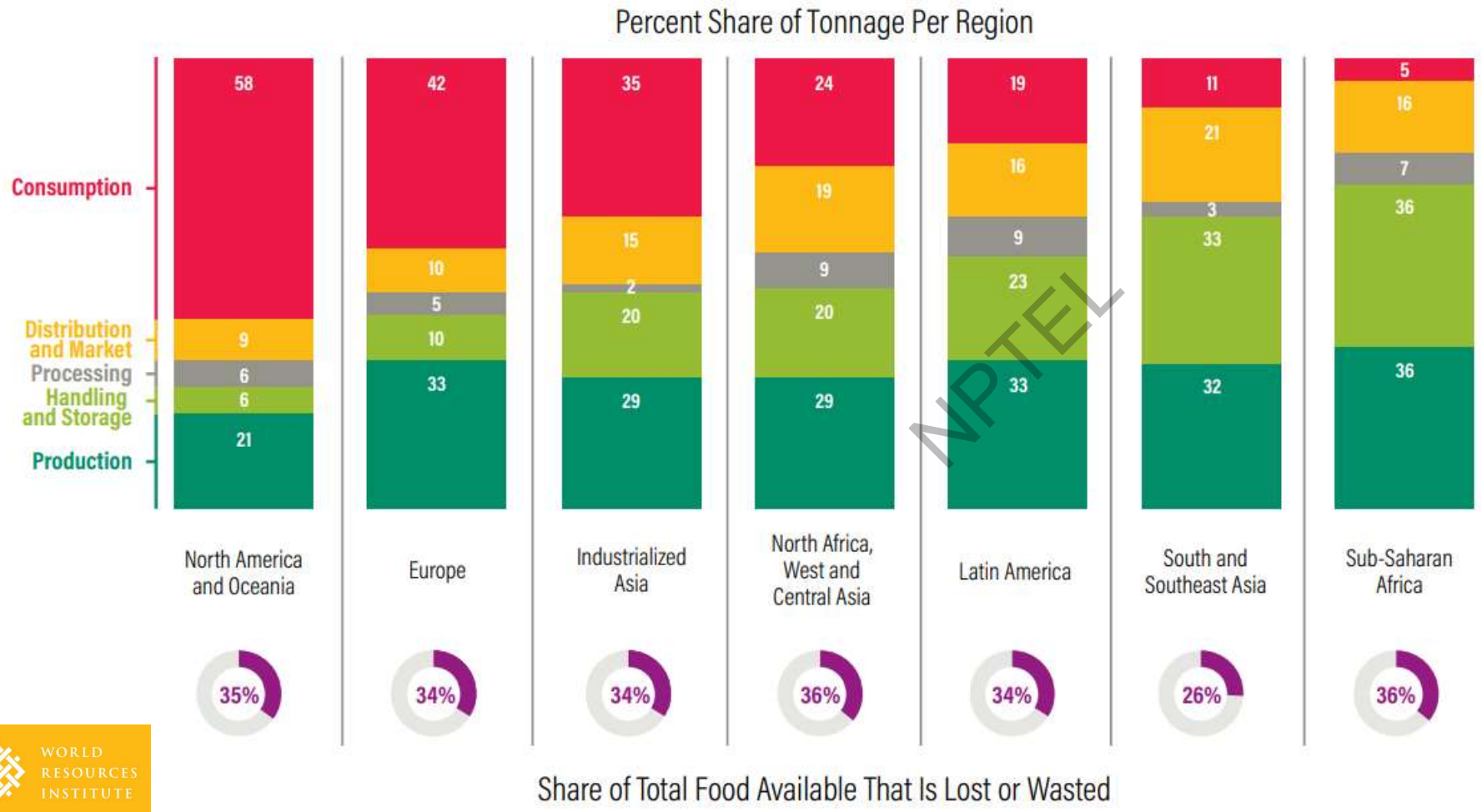
Distribution of Food Loss and Waste by Region and Stage in the Food Supply Chain, 2007



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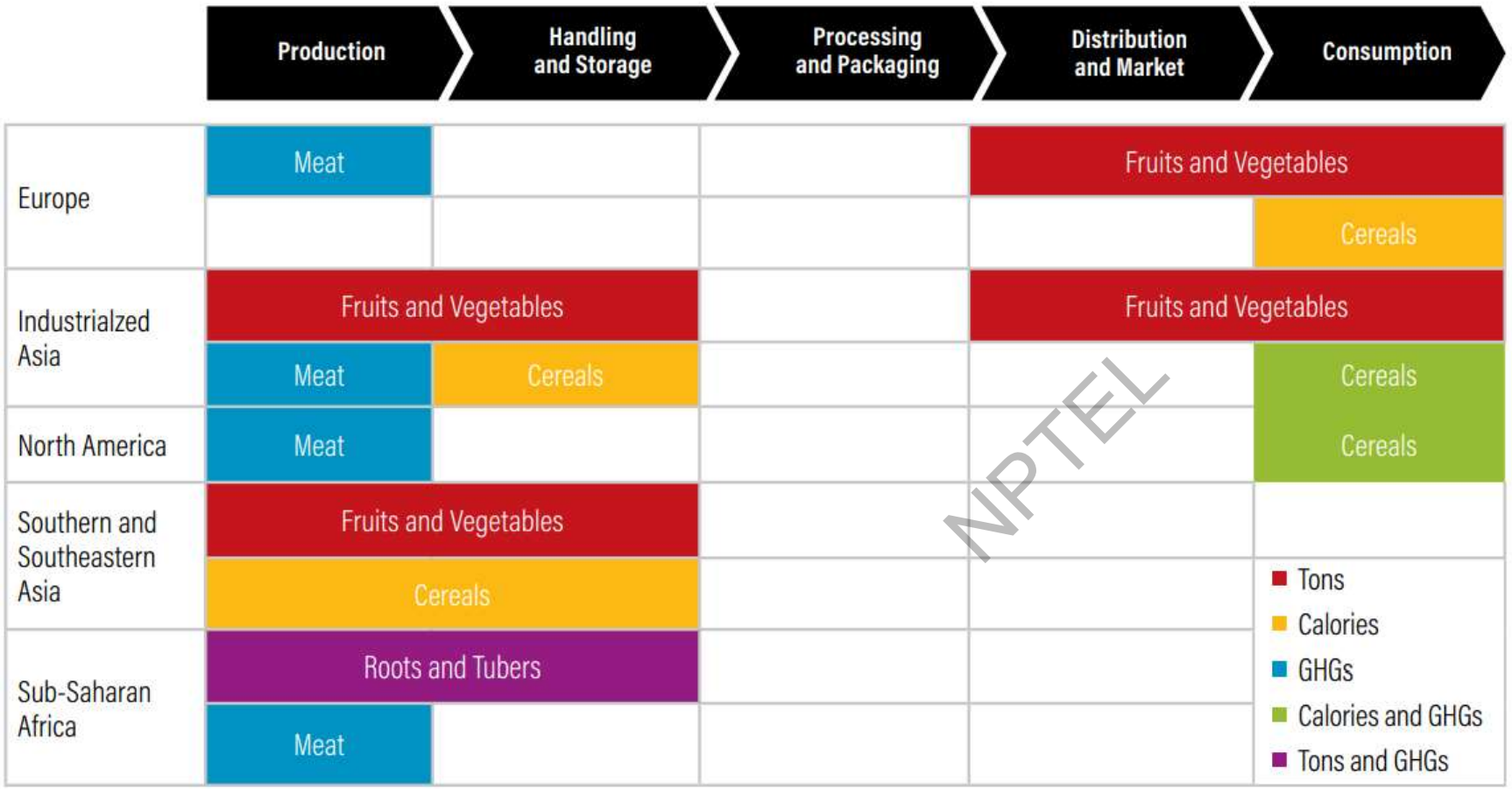
Hotspots of Food Loss and Waste per Objective



Note: Not all regions had hotspots that crossed our threshold of scale.
Source: WRI analysis based on FAO (2011).

SUMMARY POINTS

- Food loss and waste matters in terms of the environment, economy, food security, jobs, and ethics, and reducing it helps address multiple Sustainable Development Goals (SDGs).
- In terms of the **environment**, food loss and waste is responsible for an estimated 8 percent of annual greenhouse gas emissions, consumes a quarter of all water used by agriculture each year, and requires agricultural area the size of China to grow food that ultimately is not eaten by people.
- In terms of the **economy**, at a global level, the annual market value of food that is lost and wasted is estimated to be an astounding $940 billion.
- In terms of **food security**, more than 1 billion metric tons of food is lost and wasted per year in a world where one in nine people is still undernourished.
- In terms of **jobs**, reducing food loss and waste might play a modest role in job creation across the supply chain, ranging from jobs for smallholders in processing close to the farm to jobs in technology start-up companies.
- In terms of **ethics**, reducing food loss and waste is considered by many people as simply "the right thing to do."
- In terms of the **SDGs**, reducing food loss and waste can help meet various globally agreed aspirations, including SDG 1 (no poverty), SDG 2 (zero hunger), SDG 12 (sustainable consumption and production), and SDG 13 (climate action), among others.

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- The **benefits** of reducing food loss and waste can be significant. For instance, reducing the current rate of food loss and waste by 50 percent by 2050 would achieve the following goals:
  - Close the gap between food needed in 2050 and food available in 2010 by more than 20 percent.
  - Avoid the demand to convert an area of natural ecosystems roughly the size of Argentina into agricultural land between 2010 and 2050.
  - Lower greenhouse gas emissions by 1.5 gigatons of carbon dioxide equivalent (Gt CO_2e) per year by 2050, an amount more than the current energy- and industry-related emissions of Japan.

WHY DOES IT MATTER?

Reducing food loss and waste can generate a range of benefits for people and the planet. This chapter explores these benefits.

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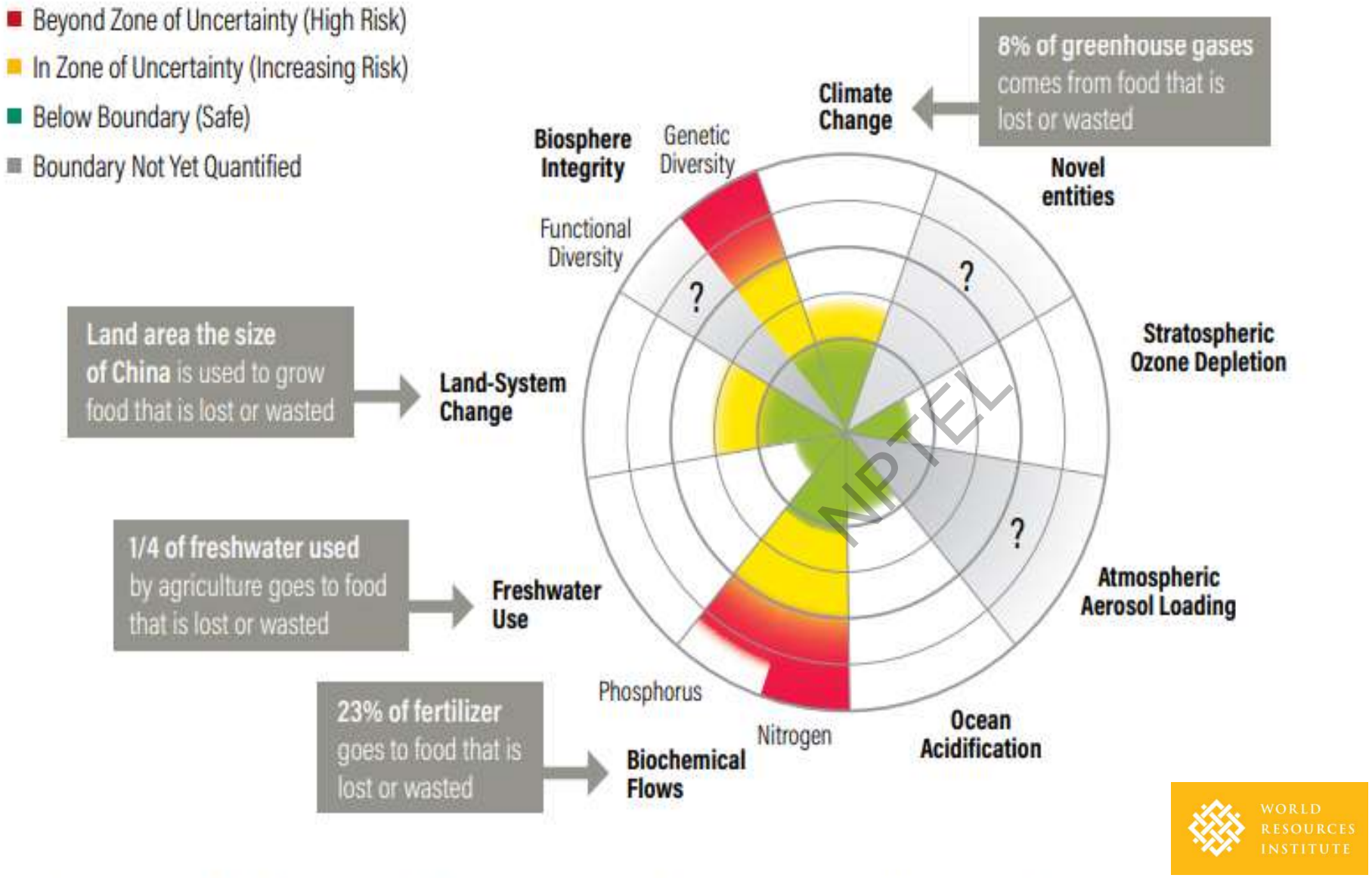
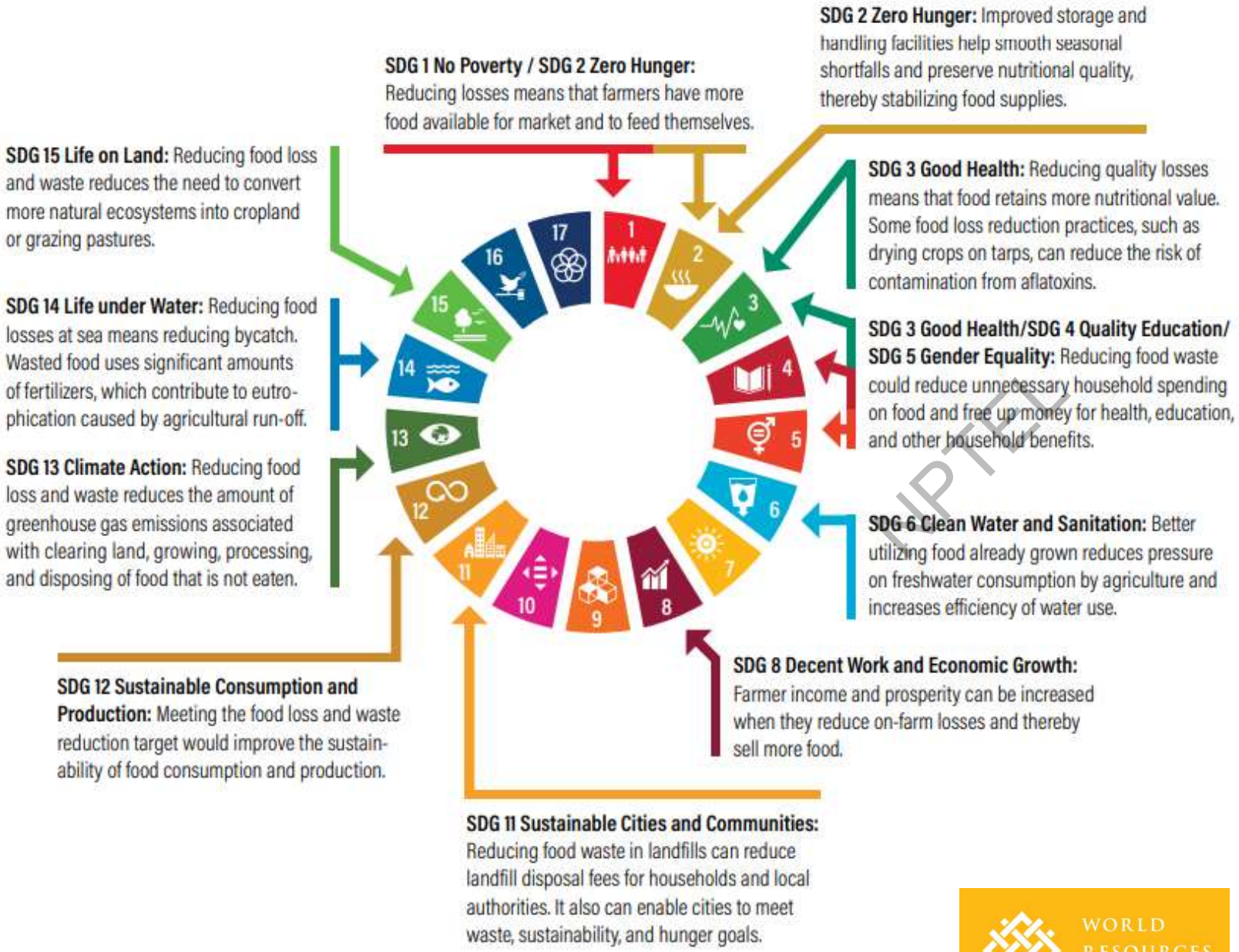
Where Food Loss and Waste Pushes against Planetary Boundaries



Note: Novel entities are defined as new substances, new forms of existing substances, and modified life forms that have the potential for unwanted geophysical and/or biologic effects. Functional and genetic diversity refers to all living species on Earth, not just those species used for food.

Sources: Steffen et al. (2015); FAO (2015a, 2013); Kummu et al. (2012).

Reducing Food Loss and Waste Can Help Achieve Multiple SDGs (Not Exhaustive)



WHAT IS CAUSING IT?

Understanding the causes of food loss and waste is a prerequisite for identifying appropriate solutions. This chapter identifies the direct causes and underlying drivers of food loss and waste.

- Understanding why food loss and waste occurs (whether intentionally or not) is important to successfully reducing it.
- The most immediate reasons food leaves the human food supply chain (the "direct causes") tie back to concern about a food's safety or suitability for consumption, or there being no perceived use or market for it. This may be due to deterioration or suboptimal quality, or issues such as the food's appearance, excess supply, and seasonal production fluctuations.

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- Leading to these direct causes are a number of "underlying drivers." These can be categorized as technological, managerial, behavioral, or structural. The technological drivers are poor infrastructure, inadequate equipment, and suboptimal packaging. The managerial drivers are inadequate food management practices, skills, or knowledge; inflexible procurement practices; poor supply and demand forecasting and planning; and marketing strategies. The behavioral drivers are norms and attitudes, lack of awareness, and concerns about possible risks. The structural drivers are conditions in demographics, climate, policies and regulations, economics, and financing that lead to food loss and waste. These 15 underlying drivers need to be addressed for food loss and waste to be reduced.

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- The underlying drivers of food loss and waste are closely interrelated. An instance of food loss and waste often has more than one driver (e.g., rice losses may occur due to inadequate storage bags, which, in turn, may be caused by a grower's lack of access to credit to purchase better bags). Moreover, while an underlying driver may occur during one stage of the food supply chain, the generation of loss and waste might actually occur at a different stage. For instance, orders modified last-minute by food retailers at the distribution and market stage of the food supply chain can result in fruits and vegetables being left in the farm field, leading to losses during the production stage.

- Among the various drivers, some are more relevant in certain regions. For example, lack of infrastructure is typically a more significant driver in low-income countries, whereas social norms and attitudes such as the acceptability of not eating all the food on one's plate are often a driver in high-income countries. Reducing food losses close to the farm (during production as well as handling and storage) can be a result of "good economic development." But as economies develop and underlying drivers shift, food loss may give way to food waste closer to the plate.

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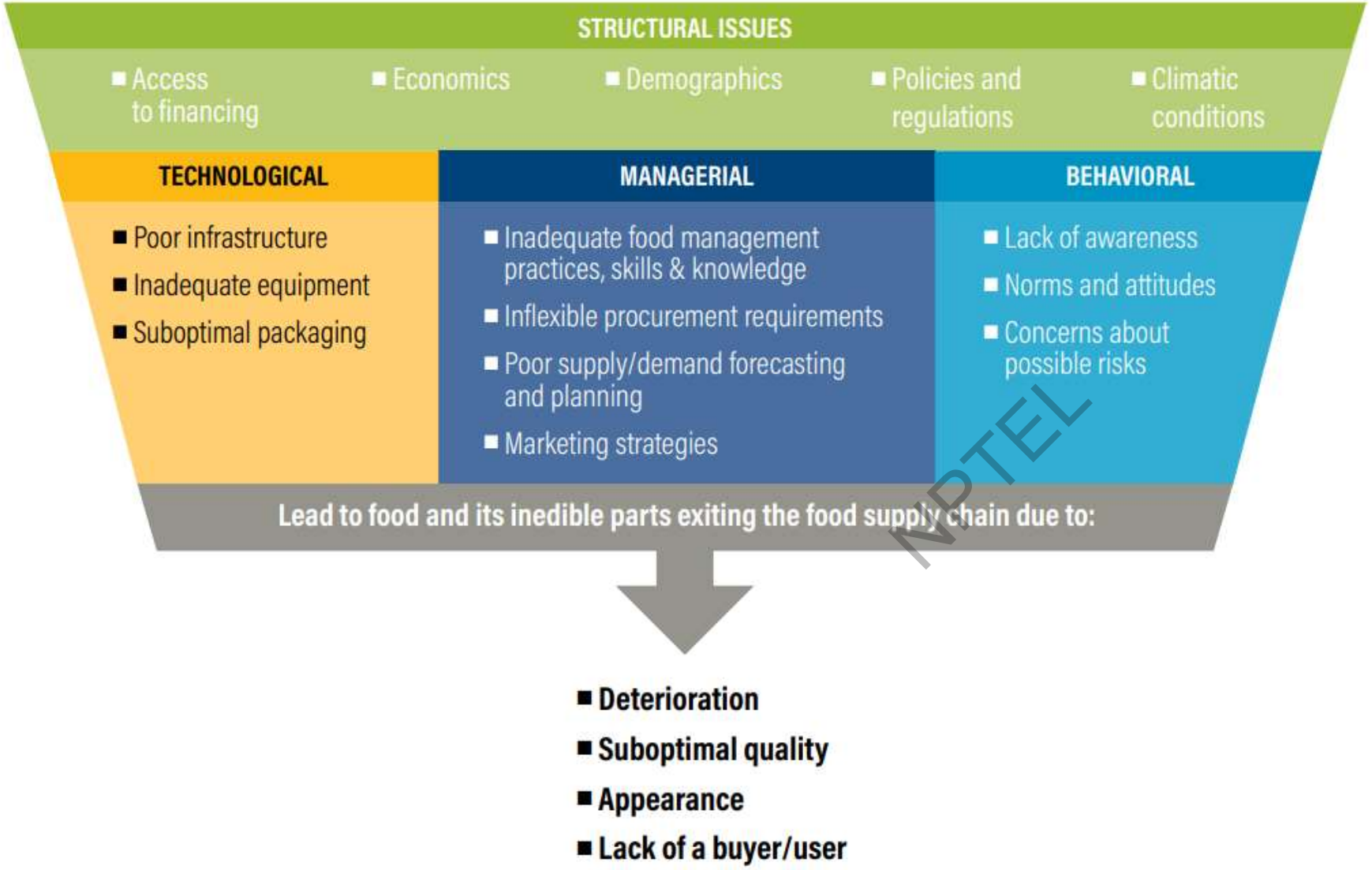
Why Food Is Lost or Wasted Is Due to Multiple Underlying Drivers



Underlying Drivers of Food Loss and Waste and Where in the Supply Chain Loss and Waste

CATEGORY	UNDERLYING DRIVER	DESCRIPTION
Technological	Poor infrastructure	Lack of or poor-quality infrastructure (public or private) along the food supply chain. Public infrastructure includes reliable power supplies, reliable communication, usable roads, and access to markets. Private infrastructure includes storage facilities, cold chains, processing facilities, and distribution- or market-related logistics (e.g., handling facilities).
	Inadequate equipment	Lack of or suboptimal equipment along the food supply chain. This includes equipment used during harvesting (e.g., combines), storage (e.g., bags), distribution (e.g., pallet jacks), merchandising (e.g., displays), and food preparation (e.g., stoves, refrigeration).
	Suboptimal packaging	Suboptimal pack sizes, and insufficient packaging to protect products after harvest from deterioration and damage.

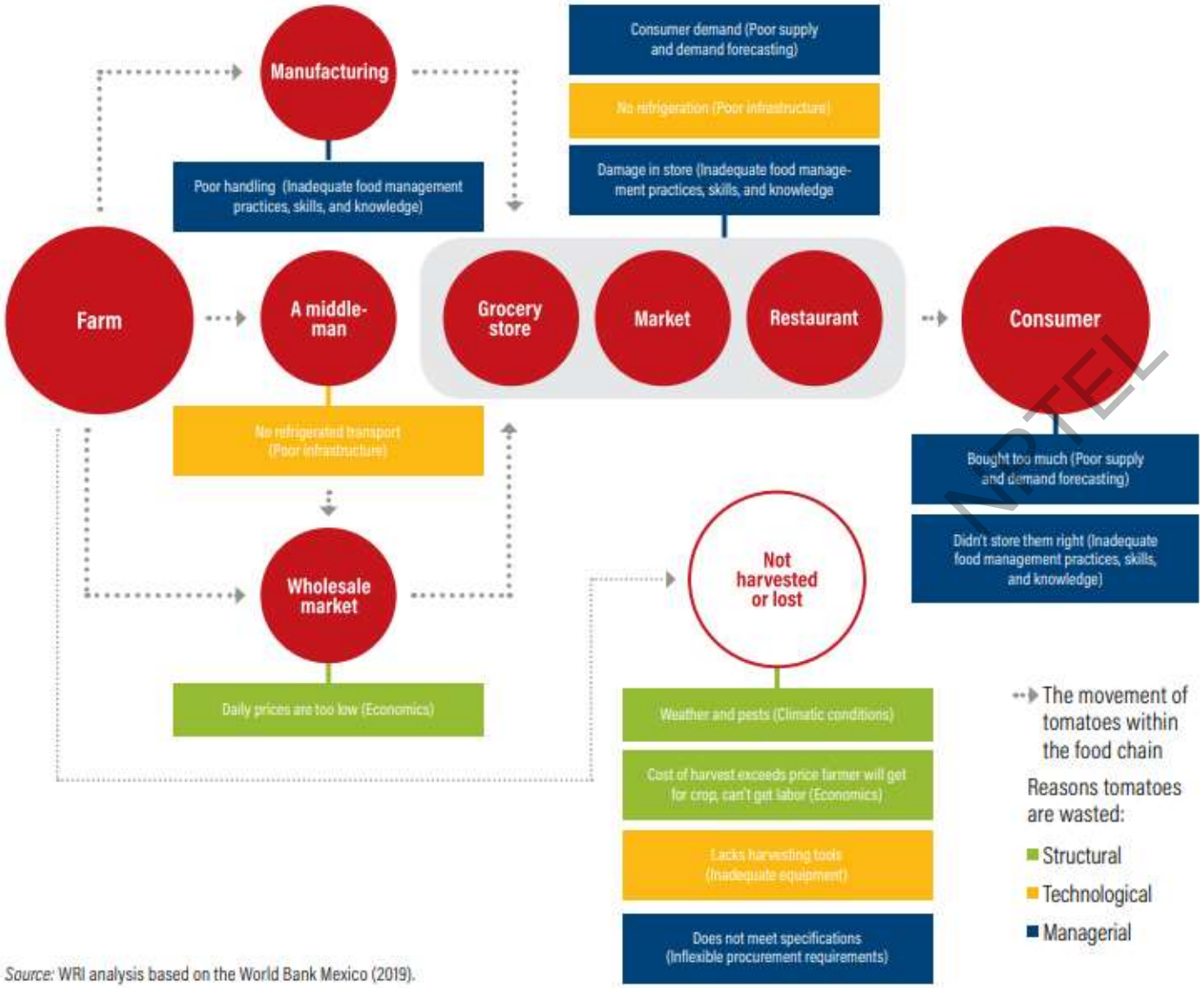
Managerial	Inadequate food management practices, skills, and knowledge	Lack of or inadequate management practices or use of equipment due to a lack of knowledge, skills, or incentives. Among producers, this could include poor use of mechanical harvesters, improper use of fishing gear, and inadequate animal care practices. Among households this includes a lack of knowledge about planning and preparing meals, as well as how to assess product freshness and interpret date labels.
	Inflexible procurement requirements	Contractual practices (e.g., last-minute order changes, take-back clauses) or quality and cosmetic standards (e.g., undesired attributes) that result in food leaving the supply chain. While some procurement requirements may reduce the amount of unusable food that is sent further down the supply chain, other requirements may result in nutritious, edible food exiting the human food supply chain.
	Poor supply and demand forecasting and planning	Poor forecasting and information flow between buyer and supplier. At the farm, this includes suboptimal crop scheduling and forecasting. In the middle of the supply chain, this includes suboptimal inventory management. At the consumption stage, this includes buying and preparing more food than will be consumed.
	Marketing strategies	Promotions, merchandising displays, or other marketing strategies that increase the likelihood of product damage, surplus, or overpurchasing by consumers.

Behavioral	Norms and attitudes	Norms and attitudes that influence food production and consumption behaviors and cause products to be removed from the food chain at any stage. These include what types of foods are considered appealing (e.g., whether certain parts of an animal are typically eaten), the preferred appearance of products (e.g., no blemishes), showing off "abundance" to indicate wealth or hospitality, attitudes about food generally (e.g., dislike of leftovers, desire for variety, preference for "fresh"), and social values that accept resource waste and its impacts.
	Lack of awareness	Lack of awareness that food loss and waste happens and has an impact, and how one contributes to the problem. Farmers, business managers, and consumers often do not think they lose or waste food, but measurement suggests otherwise. Lack of awareness also can include a limited understanding of how reducing food loss and waste can provide direct (personal or business) benefits (e.g., enhanced product freshness, reduced costs).
	Concerns about possible risks	Actual or perceived risks related to food safety (including food labeling), reputation, and liability. This includes concerns about safe food consumption, or fear about liability linked to food donation.

CATEGORY	UNDERLYING DRIVER	DESCRIPTION
Structural	Demographics	Household size, urbanization, and growth in the middle class (which is linked to higher disposable income) impact food production and consumption. This includes reduced availability of labor to harvest food in the production stage, which can increase food losses. The rise of the middle class can change how people acquire, eat, and manage food (e.g., portion sizes, shopping habits, preference for "fresh"), which can increase the likelihood of food waste.
	Climatic conditions	Weather (e.g., rain, snow, ice, wind, cold, heat) and impacts from a changing climate affect growing conditions, which can result in damage to crops or surplus product. These conditions also affect other factors such as the degree of damage by pests and diseases, and the ability to get a product to market (e.g., disruptions in transportation networks).
	Policies and regulations	Policies and regulations may be barriers, be poorly coordinated, or be absent, resulting in food leaving the food supply chain. Policy barriers may relate to food safety, food quality, labeling, packaging, trade and customs, tax incentives, agricultural extension services, and use of unsold food for animal feed or energy.
	Economics	Costs of avoiding or reducing food loss and waste are (or are perceived to be) high in comparison to the benefits that would be obtained. Growers, especially smallholders, may not invest in loss reduction practices or technologies due to poverty. Growers may harvest crops prematurely (increasing the risk of food losses) because they need cash or because market prices are currently high. Conversely, growers may not harvest crops where the cost to do so exceeds the market price, and if alternative markets for second-grade products are not profitable. A food processor may accept food loss and waste as the "cost of doing business" or because disposal costs are low. In many countries, food comprises only a small share of household expenditures, lowering the cost of waste and the perceived value of conserving food.
	Access to Financing	Inability to access sufficient financing (e.g., investment, loans, grants) to purchase, implement, or scale technologies, capacity-building programs, and/or enterprises that would reduce food loss and waste.

Sources: WRI analysis based on Canali et al. (2014); CEC (2017, 2018, 2019); Clowes et al. (2018a, 2018b, 2019); Food Loss and Waste Protocol (2016); Global Knowledge Initiative (2017); Gunders and Bloom (2017); Hegnsholt et al. (2018); HLPE (2014); ReFED (2016); Gooch et al. (2019); and WWF-US (2018).

Example of Underlying Drivers in Tomato Supply Chain (Mexico)



Source: WRI analysis based on the World Bank Mexico (2019).

Leading Underlying Drivers and Supply Chain Stage of Food Loss and Waste per Region

Production → Handling and Storage → Processing and Packaging → Distribution and Market → Consumption

Note: The map highlights by geographic region the leading underlying driver of food loss and waste for the supply chain stage that is estimated to account for the largest share of food loss and waste in that region. Countries are grouped in the same regions as given in FAO (2011). Which food supply chain stage accounts for the highest share of food loss and waste per region is based on FAO (2011). The leading driver of food loss and waste draws upon a review of HLPE (2014).
Source: WRI analysis based on FAO (2011) and HLPE (2014).

WHAT SHOULD BE DONE ABOUT IT?

A simple three-step approach can set anyone on the path toward reducing food loss and waste. This chapter explains that approach and introduces a "to do" list for the principal types of actors in the food supply chain.

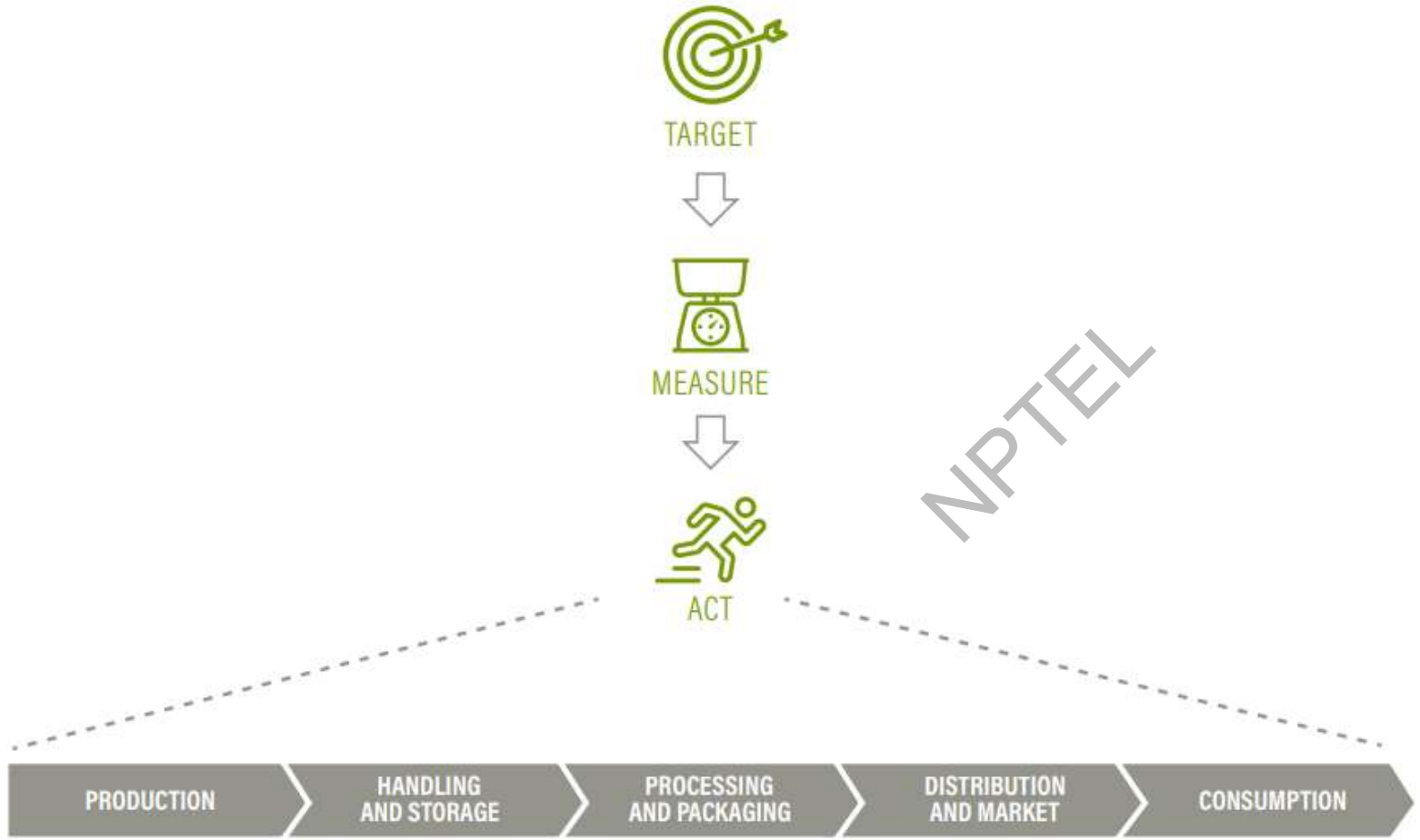
- The three-step approach Target-Measure-Act is a useful framework being used by governments and companies to guide food loss and waste reduction strategies.
  - **Target:** Setting a reduction target increases decision-maker attention to the issue of food loss and waste—and attention is a prerequisite for taking action.
  - **Measure:** Measuring and analyzing how much and where food is being lost or wasted enables identification of the largest opportunities for reduction. Measurement is important for developing the evidence base for prioritizing food loss and waste reduction interventions and for tracking progress over time.
  - **Act:** Taking action consists of identifying the specific interventions that one should implement to reduce food loss and waste, and then implementing them. These interventions include technologies, practices, programs, investments, and/or behavior changes that aim to reduce food loss and waste at one or more stages of the food supply chain.

- There is a role for everyone in the food system, from farmers all the way to consumers, in reducing food loss and waste. We propose a short list of priority "**to dos**" for each kind of actor that will help them implement the "Act" portion of the Target-Measure-Act framework.

- Experiences from reduction initiatives that are making progress provide **insights** relevant to the action agenda:

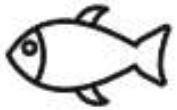
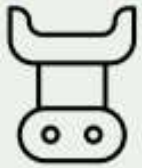
  - Awareness is a start (but only a start).
  - Make the "business case" to motivate actors (so they see reducing food loss and waste as in their self-interest).
  - Recognize that there is no silver bullet (a number of interventions are typically required).
  - Which interventions are relevant varies from country to country and within countries (especially depending on the level of economic development).
  - Beware of knock-on effects across the supply chain (reductions at one stage might merely trigger loss and waste later).
  - Collaboration among actors is crucial (especially when one is pursuing a "whole supply chain" approach).

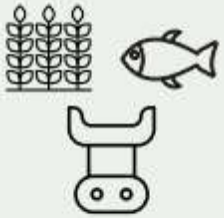
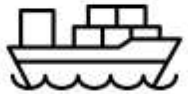
A Strategy for Tackling Food Loss and Waste

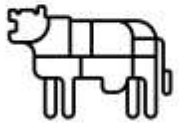


Source: WRI analysis.

Key Actors for Reducing Food Loss and Waste (Not Exhaustive)

ACTOR	KEY "TO DO"
Crop farmers 	■ Improve harvesting practices (e.g., ensure product is harvested at the right maturity and use appropriate harvesting equipment to maximize yield while minimizing crop damage). ■ Improve skills or use tools to better schedule harvesting (including accessing better data on weather). ■ Engage customers (e.g., wholesalers, retailers) to communicate implications of order changes. ■ Engage customers to explore changes in quality specifications to enable more of what is harvested to be sold. ■ Identify financially viable alternative markets or use for crops otherwise left in the field (e.g., value-added processing, donation, secondary surplus markets).
Fishers 	■ Use fishing gear designed for target species to reduce bycatch. ■ Identify (or create) markets for unavoidable bycatch (e.g., animal feed or processed products).
Ranchers and animal farmers 	■ Build capacity in practices to reduce losses (e.g., reduce milk spills, minimize contamination). ■ Implement best practices in animal welfare to avoid stress and injuries that can reduce the shelf life of meat from animals.

ACTOR	KEY "TO DO"
Primary producers 	■ **Crop farmers:** Improve training in best practices (e.g., handling to reduce damage, drying, fumigation treatments, and on-farm processing). Establish aggregation centers that provide adequate storage and preservation options, such as cooling chambers. ■ **Fishers:** Improve temperature management, handling, and preservation techniques (e.g., fenced-off landing beaches or drying racks to improve the quality of fish and to minimize losses). ■ **Ranchers and animal farmers:** Improve handling and preservation options (e.g., establish milk collection centers with cooling tanks). Improve conditions during transportation of food-producing animals from farm to markets.
Packinghouses 	■ Adopt best practices to provide the clean, cool, and/or dry conditions required to reduce postharvest losses. ■ Reexamine handling and storage practices to reduce damage (e.g., use liners in wood and basket containers, reduce the size of sacks or crates to minimize product damage). ■ Build near-farm facilities to convert unmarketable crops and by-products into value-added products.
Storage providers 	■ Use storage containers that protect against temperature variations, humidity and precipitation, and insect and rodent infestation. ■ Adopt low-cost storage and handling technologies (e.g., hermetic grain storage bags, plastic or metal silos, plastic crates) that prevent spoilage and increase shelf life. ■ Work with intended users and community experts to design and produce locally relevant storage solutions.
Transportation and logistics providers 	■ Improve handling practices during loading and unloading. ■ Use technology innovations to improve the flow of information (e.g., about road and traffic conditions, as well as timing of pickup and delivery) to optimize movement of food. ■ Introduce (or expand) energy-efficient, clean, low-carbon cold chains from farm to wholesalers. ■ Work upstream with customers to provide planning tools and handling and storage technologies that help them reduce losses. ■ Create access to alternative markets for products that cannot be marketed.

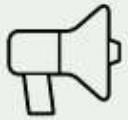
ACTOR	KEY "TO DO"
Processors and manufacturers 	**Operations-related:** ■ Improve training of staff to reduce technical malfunctions and errors during processing. ■ Reengineer production processes and product design to reduce waste during product line changeovers. ■ Introduce software and related information and communications technologies to optimize operations (e.g., to identify waste, track temperature and ensure freshness, assess ripeness, better balance demand and supply forecasts, and accelerate delivery of food). **Customer-related:** ■ Use product sizes and packaging that reduce waste by consumers (e.g., accommodate desire for smaller or customizable portions). ■ Standardize date labels (e.g., eliminate "sell by" and use only "use by" for perishable items and "best before" for others) to reduce consumer confusion. ■ Develop new food products or secondary uses (e.g., animal feed or other value-added products) from what cannot be marketed (e.g., spent grains, fruit trimmings, vegetable peels). ■ Seek donation of excess food that is still safe to consume (e.g., revise vendor agreements with retailers to allow for donation instead of mandatory destruction).
Slaughterhouses 	■ Ensure that proper temperature management conditions are maintained. ■ Follow best practices in cleaning and sanitation to reduce losses due to contamination. ■ Fully leverage potential for using animal by-products to safely manufacture other products (e.g., animal feed supplements). ■ Identify and address management practices that lead to avoidable losses (e.g., using remote video auditing to assess whether best practices are being implemented).
Packaging providers 	■ Invent, design, produce, and mainstream packaging options or coatings (e.g., resins used on pouches or on foods) that extend a product's shelf life (although consideration should be given to the impact of the packaging, and efforts should be made to create reusable and recyclable packaging, as discussed in Box 4.3). ■ Offer packaging that is resealable to allow for incremental consumption and to extend how long the remainder of a product stays suitable for consumption. ■ Provide commercial customers with a greater variety of packaging sizes to help shoppers purchase the amount appropriate for their needs. ■ Adjust packaging so it is easier for consumers to empty all the contents.

ACTOR	KEY "TO DO"
Wholesalers 	■ Build capacity for better handling and storage practices to reduce mistakes that result in food loss. ■ Expand cold storage systems during wholesale and logistics to protect products vulnerable to heat damage. ■ Find food rescue partners or establish online marketplaces that facilitate sale or donation of rejected shipments or short-life products. ■ Use backhauling (or other logistics solutions) to enable return of reusable storage containers or rescue of surplus food for people in need. ■ Invest in technologies to track temperature and ensure freshness, streamline routing, track movement of goods in and out of warehouses, and monitor food loss and waste.
Retailers (formal) 	**Operations-related:** ■ Improve training of staff in temperature management, product handling, and stock rotation. ■ Optimize inventory management systems (and increase flexibility in supplier contracts) to better match forecasting and ordering. ■ Review cosmetic specifications and accept a wider diversity of produce. **Consumer-related:** ■ Enable consumers to purchase smaller or customized portions (e.g., through bulk bins or staffed seafood and meat counters). ■ Adjust promotions to avoid excessive purchase of additional items (e.g., offer half off or mix-and-match deals rather than two-for-one offers). ■ Redesign in-store merchandising to avoid excessive handling of products by consumers (e.g., sort by stage of maturity), and to achieve the desired appearance of abundance but with less damage and excess product (e.g., through smaller bins and bowls). ■ Educate consumers about better food management (e.g., proper storage, meal planning, understanding date labels, safe food handling, cooking tips).
Retailers (informal) 	■ Participate in groups or associations of informal operators to access guidance and training in best practices in food handling and storage. ■ Take advantage of municipal support to access clean water, storage areas, equipment that improves food safety, and training in how to reduce food contamination. ■ Use practices that minimize damage such as handling produce gently, stacking properly (e.g., to avoid bruising delicate produce), marking cases to track inventory, and rotating stock following a "first-in-first-out" method. ■ Ensure that displays allow air to be circulated and temperature conditions to be appropriate for product to remain fresh (e.g., high-ethylene producers should be kept away from ethylene-sensitive commodities). ■ Avoid sprinkling unclean water on products (to minimize wilting and shriveling) as such practices result in unsafe foods shunned by buyers.

ACTOR	KEY "TO DO"
Households 	■ Buy only what you expect to eat: check refrigerator and cupboards before shopping, use a shopping list, and plan meals in advance. ■ Know the difference between "use by" (which is about food safety) and "best before" (which is about quality and still safe to eat after this date). ■ Freeze or preserve food before it spoils, and find out how to best store different foods so they stay fresh and safe longer. ■ Find creative ways to use leftover ingredients and products past their peak quality (e.g., in soups, sauces, smoothies), as well as to cook the parts you may not normally eat (e.g., stems, cores). ■ Organize the kitchen and refrigerator so that items do not get lost and spoil.
Restaurants 	■ Engage staff on food waste reduction (e.g., explain why reduction is important, give tips on waste reduction, reward staff who deliver against targets). ■ Shift away from preparation methods such as batch cooking, casserole trays, and buffets to reduce over-production and repurpose excess food (e.g., offer customers "doggy bags," safely incorporate unused items into other dishes, sell excess food at a discount, donate unsold food). ■ Revisit inventory management and purchasing practices (as well as menus) to better fit needs based on historical trends and waste data. ■ Use scales in the kitchen to weigh food and track items most commonly wasted (and estimate the financial cost of food disposed, thus creating a financial signal to waste less). ■ Consider whether portions served exceed what can be eaten, and rethink promotions that encourage over-purchasing by customers.
Hotels 	■ Engage staff on food waste reduction (e.g., explain why reduction is important, give tips on waste reduction, and reward staff who deliver against targets). ■ Rethink the buffet (e.g., shift certain items to à la carte near end of mealtimes, reduce the size of dishes used in buffets). ■ Reduce overproduction by producing smaller quantities of items consistently left on the plate. ■ Repurpose excess food (e.g., by safely incorporating unused items into other dishes, or by donating it). ■ Communicate to guests about food waste and encourage them to take only as much as they need.

ACTOR	KEY "TO DO"
Catering/food service 	■ Engage staff on food waste reduction (e.g., explain why reduction is important, give tips on waste reduction, and reward staff who deliver against targets). ■ Reduce the amount overproduced (e.g., by producing smaller quantities of items that are consistently underconsumed). ■ Repurpose excess food (e.g., by safely incorporating unused items into other dishes, or by donating it). ■ Use scales in the kitchen to weigh food and track items most commonly wasted (and estimate the financial cost of food disposed, thus creating a financial signal to waste less). ■ Evaluate contractual obligations between clients and suppliers that generate waste and overproduction (e.g., contracts that stipulate that all hot dishes must be available for the full-service period).
Public and private institutions (e.g., schools, hospitals, government canteens) 	■ Engage staff on food waste reduction (e.g., explain why reduction is important, give tips on waste reduction, and reward staff who deliver against targets). ■ Reduce the amount overproduced (e.g., by producing smaller quantities of items that are consistently under-consumed), and repurpose excess food (e.g., by safely incorporating unused items into other dishes, or by donating it). ■ Introduce techniques to minimize people taking overly large portions (e.g., trayless dining, flexible portion sizes, pay-by-weight pricing system, smaller plates). ■ Revisit inventory management and procurement practices (as well as menus) to better fit needs based on historical trends and waste data. ■ Use scales in the kitchen to weigh food and track items most commonly wasted (and estimate the financial cost of food disposed, thus creating a financial signal to waste less).

ACTOR	KEY "TO DO"
Policymakers 	■ Embed into agricultural extension services (and in farmer subsidy programs) food loss reduction awareness, technical assistance, and financial aid. ■ Develop, facilitate, promote, and/or improve climate-smart infrastructure (e.g., roads, electricity, irrigation, community storage) and access to it, especially for smallholder farmers who live far from markets. ■ Increase investment in agricultural research related to postharvest loss and provide incentives for the adoption of postharvest technologies (e.g., zero-rates tax on imported postharvest technologies, incentives for local manufacturers of postharvest technologies, subsidies for postharvest technologies). ■ Implement policies to prevent unfair trading practices (e.g., last-minute order cancellations and unilateral or retroactive changes to contracts). ■ Remove barriers to food redistribution via policies (e.g., liability limitations, tax breaks) that make it easier for food suppliers to donate safe (but unsold) food to charities or to those in need. ■ Support policies to standardize food date labeling practices to reduce confusion about product safety and quality, and improve consumer understanding of the meaning of date labels. ■ Include food waste reduction lessons in school curricula and include food waste reduction training in public procurement programs. ■ Provide municipal support for informal retailers to access clean water, storage areas, equipment that improves food safety, and training in how to reduce food contamination. ■ Make measurement and reporting of food loss and waste by large companies mandatory.
Financiers 	■ Increase the number of philanthropic institutions funding food loss and waste prevention activities. ■ Create financing instruments and product lines (e.g., funds, bonds, loans) dedicated to reducing food loss and waste. ■ Increase start-up financing for new technologies and business models that would reduce food loss and waste, as well as financing to scale up proven technologies and models. ■ Increase development cooperation between high-income and low-income countries targeting food loss and waste. ■ Introduce "pay-as-you-go" programs to make technologies affordable for smaller operations (e.g., for solar-powered refrigeration units and mobile processing).

ACTOR	KEY "TO DO"
Innovators and intermediaries (e.g., brokers, consolidators, digital solution developers) 	■ Develop and improve availability of processing and preservation facilities (including aggregation centers and mobile low-carbon options). ■ Develop alternative outlets during peak season through organizing export opportunities to markets with other seasonalities. ■ For unmarketable crops, improve flow of information to find alternative buyers, promote financially viable alternative markets, or develop new outlets (e.g., as processed foods, industrial products, animal feed). ■ Apply innovations to reduce delays for imported products during the point of exit and entry, which extends the shelf life of perishable products. ■ Leverage technology and digital solutions to rethink and better coordinate key processes between suppliers and customers in a more organized and informed way.
Researchers 	■ Research new and innovative technologies to preserve food quality and extend shelf life. ■ Develop innovative products from perishable food commodities, such as fruits and vegetables, to promote whole food utilization. ■ Undertake research to fill data gaps and standardize reporting of food loss and waste data in order to better compare results, create benchmarks, and provide clearer direction for stakeholders. ■ Assess impact of interventions to improve evidence base of what works and the return on investment. ■ Develop sector-specific guidance that provides the motivation and technical information for businesses to take action (e.g., promote industry roadmaps for food loss and waste reduction).
Civil society 	■ Raise awareness and shift social norms so that food loss and waste is considered "unacceptable" for all, including higher-income consumers. ■ Encourage public and private sector leaders to pursue the Target-Measure-Act strategy. ■ Act as a channel for the sharing and reporting of food waste data and progress.

Source: Canali et al. (2014); CEC (2017, 2018, 2019); Clowes et al. (2018a, 2018b, 2019); Food Loss and Waste Protocol (2016); Global Knowledge Initiative (2017); Gunders and Bloom (2017); Hegnsholt et al. (2018); HLPE (2014); ReFED (2016); Gooch et al. (2019); WWF-US (2018).

The Role of Women in Reducing Food Loss and Waste

- Women in both developing and developed countries have an important role to play in reducing food loss and waste, since women interact with food at each stage of the value chain from farm to fork.
- Close to the farm, women comprise 41 percent of the agricultural workforce worldwide and make up the majority of agricultural workers in South Asia and Sub-Saharan Africa.
- Close to the fork, surveys in a wide range of countries show that women are responsible for 85-90 percent of the time spent on household food preparation. Therefore, targeting women in food loss and food waste reduction campaigns could result in greater reductions than pursuing an unfocused campaign.
- One such gender-targeted initiative in Tanzania focused on providing female farmers with greater access to markets and supplied participants with access to solar drying technology that allowed for surplus fruits that might other be lost to be dried and preserved.
- Another campaign in Australia called "1 Million Women" encourages women to take action on a number of environmental issues, including reducing food waste. The campaign has hosted events with a celebrity chef to raise awareness of food waste, and its official website provides tips on how to reduce waste and recipes for how to efficiently use food.

Case Study: Second Bite (Australia)

- In Australia, the nonprofit organization SecondBite facilitates food donation by linking farmers and retailers with community groups and food banks.
- SecondBite effectively functions as a broker, first collecting food from donors and then distributing it among community groups that are already aware of where hunger and malnutrition are most prevalent.
- In this way, SecondBite draws upon existing knowledge and expertise of other organizations to further its mission.
- SecondBite also works with state governments in Australia to introduce Good Samaritan Acts to promote food donation.
- In 2012, SecondBite rescued and redirected 3,000 metric tons of fresh food that otherwise would have been lost or wasted.

Hydrothermal carbonization of the Organic Waste stream - Waste to Fuel

HTC of the organic fraction of MSW

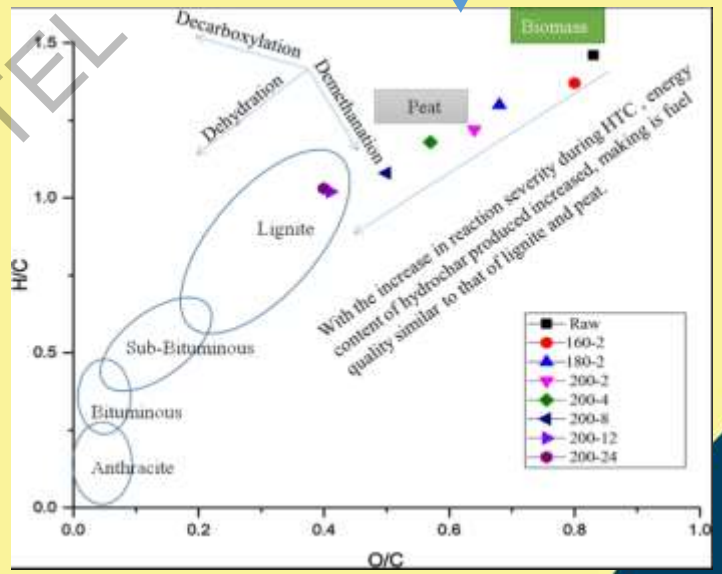
Yard Waste

Food Waste

Reactor

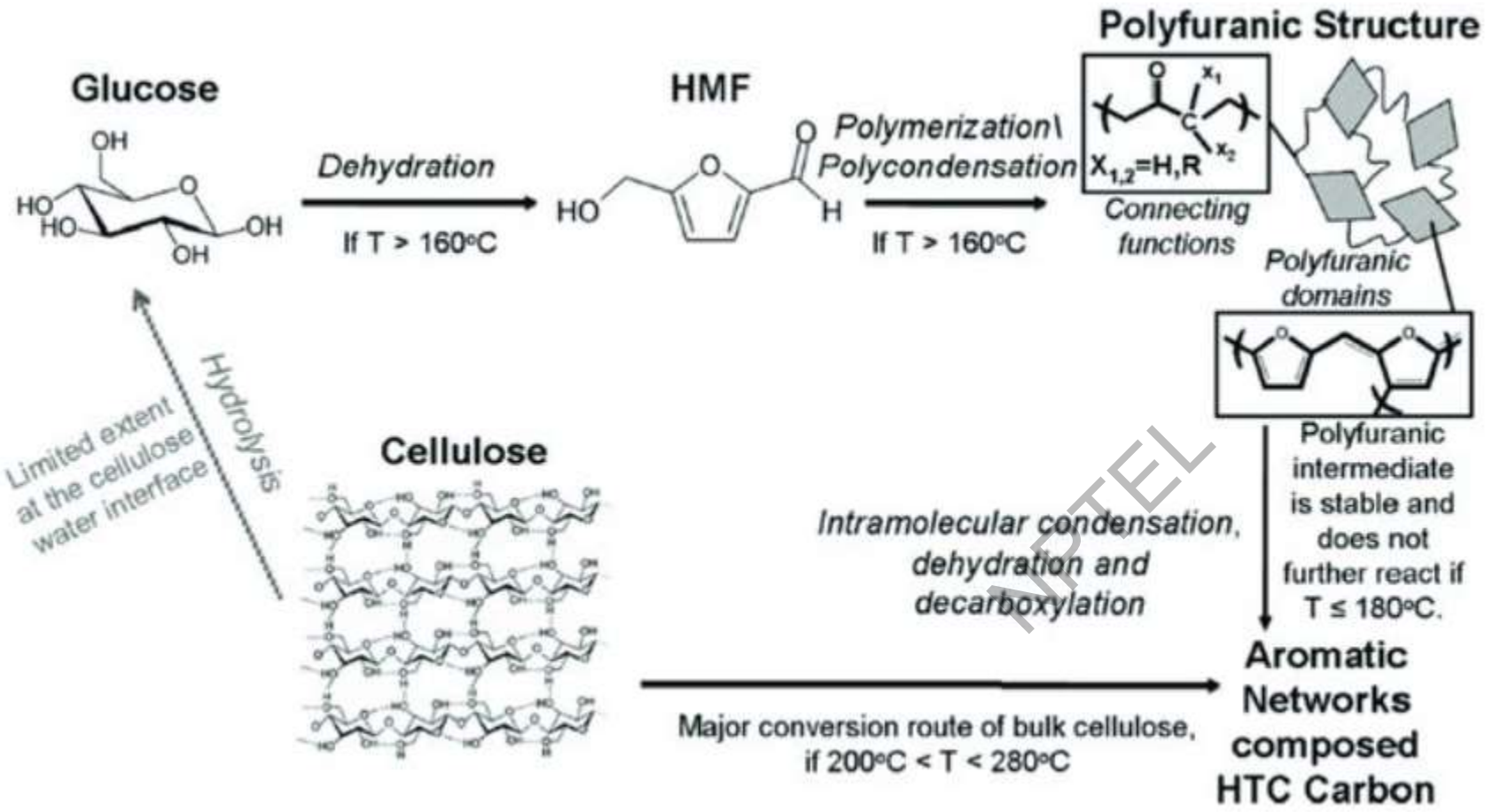
Hydrochar

Fuel Pellets



Van Krevelen diagram

Mechanism



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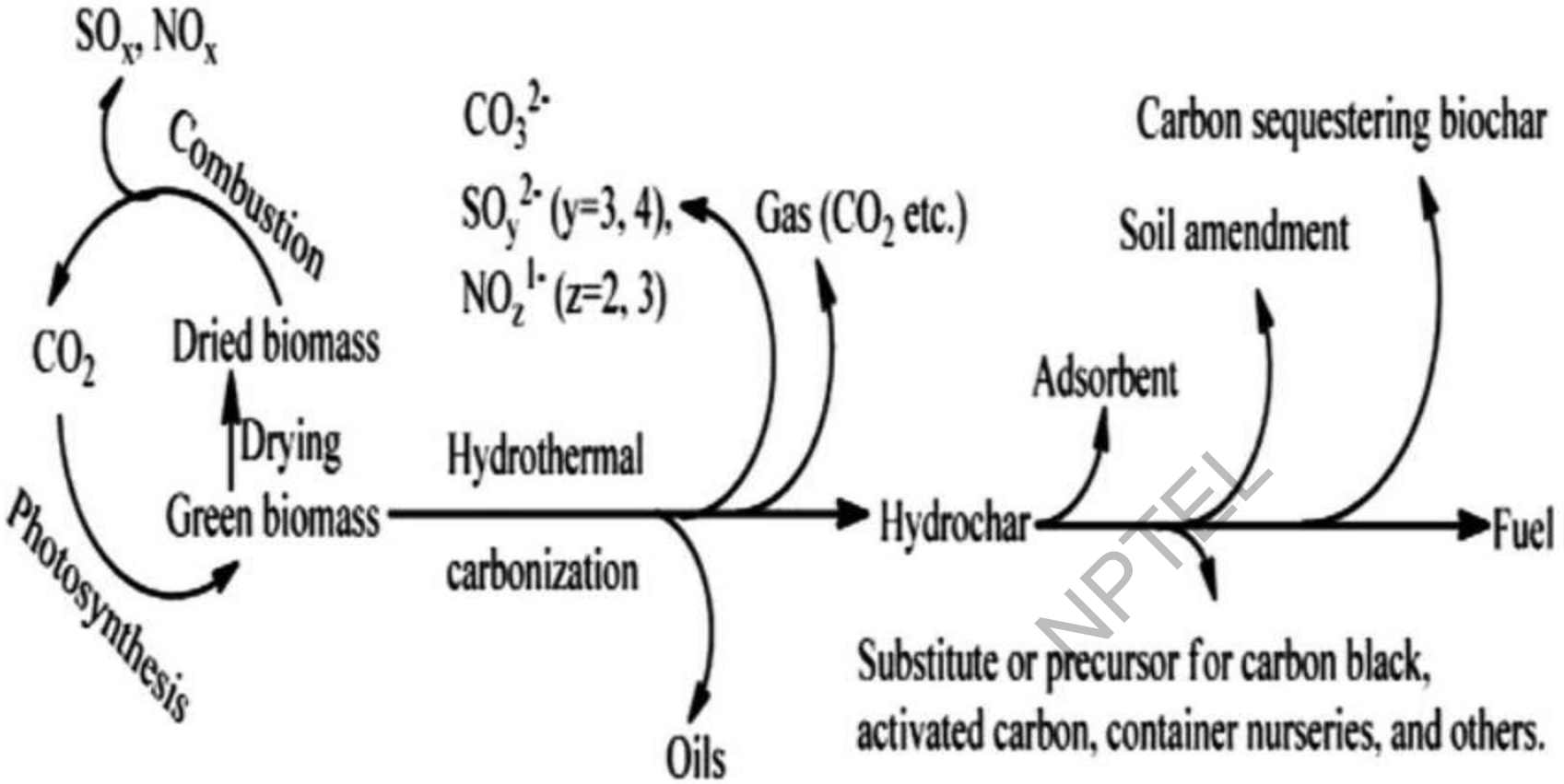

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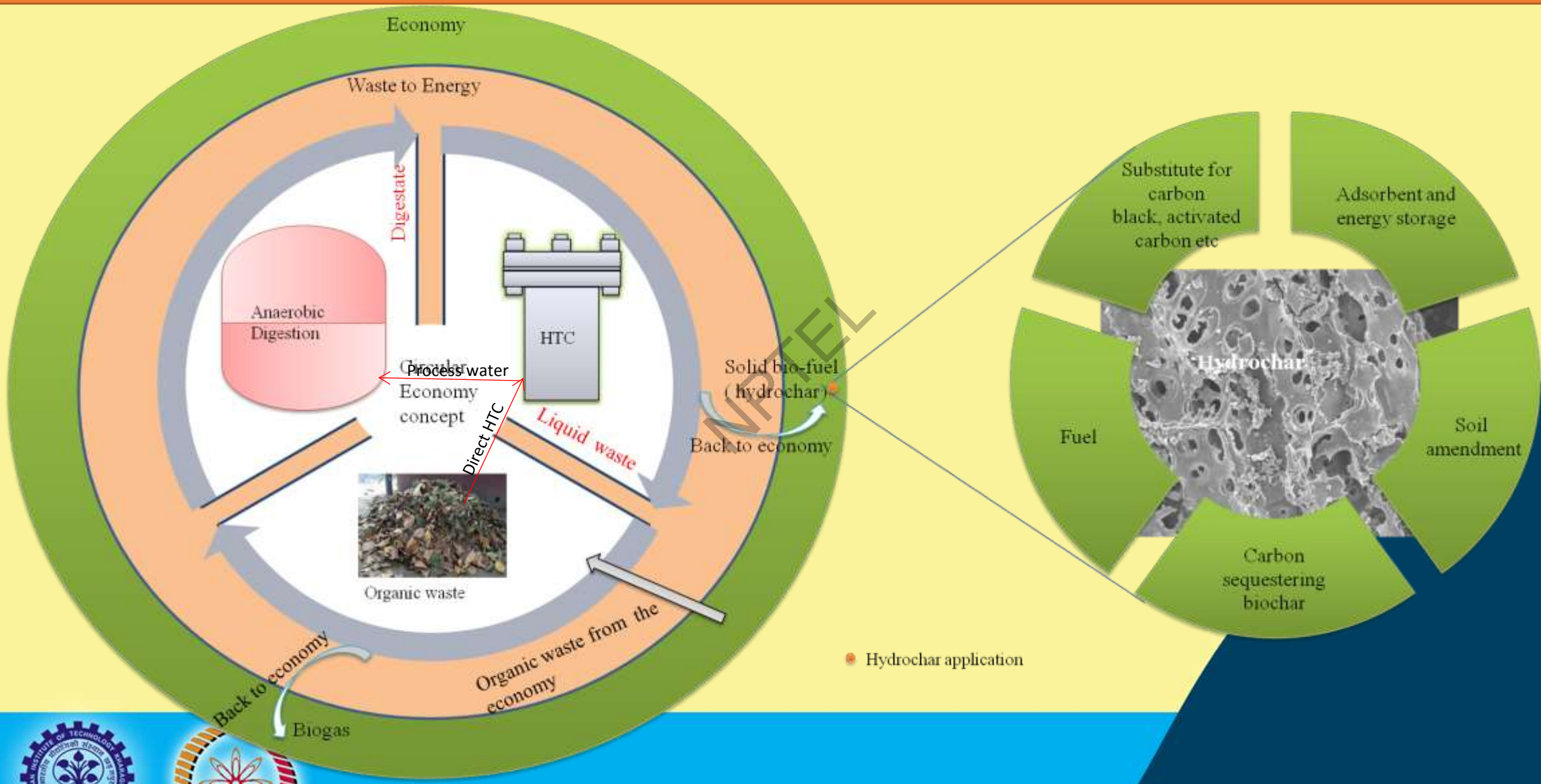
Zero loss process to treat organic fraction of MSW in a line of circular economy concept



Press Information Bureau
Government of India

Ministry of Human Resource Development

IIT Kharagpur Researchers Develop 'Zero Loss' Process for Wet Municipal Solid Waste Management

Posted On: 31 JUL 2019 5:45PM by PIB Kolkata

Kolkata, July 31, 2019

A research team from IIT Kharagpur has adapted a process called Hydro Thermal Carbonization (HTC) for the Indian conditions which can effectively manage mixed Municipal Solid Waste (MSW) with high moisture content. Through the process most of the mixed MSW can be converted into biofuel, soil amendmentand absorbents.

This particular technology converts organic fraction of MSW intohydrochar by using a batch reactor. The moisture in the waste is used to the advantage of the process which uses water for the reaction. The process has increased the resource recovery yield to 50-65% of urban organic waste. The key to the success of the technology lies in designing proper industrial scale HTC reactor with improved heat integration system.

Recent Publication addressing Hydrothermal carbonization of organic waste

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Hydrothermal carbonization of yard waste for solid bio-fuel production: Study on combustion kinetic, energy properties, grindability and flowability of hydrochar

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Hydrochar
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Combustion behavior

ABSTRACT

Yard waste is either dumped or is being openly burned to get rid of it, instead of using it as a valuable renewable energy source. In this study, hydrothermal carbonization of yard waste was conducted to valorize it as a solid bio fuel, using a batch reactor. The effect of process parameter on yield, energy and physicochemical properties of the valorized solid bio fuel (hydrochar) was examined in this study by varying reaction temperature (160–200 °C for 2 h) and reaction time (2–24 h at 200 °C). The calorific value of hydrochar was within a range of 17.72–24.59 MJ/kg as compared to 15.37 MJ/kg for untreated yard waste. Hydrochar mass yield decreased from 78.6% at operating temperature – time of 160 °C – 2 h to 45.6% at 200 °C -24 h. The plot of atomic ratios (H/C and O/C) demonstrates improvement in the coalification process which was mainly governed by decarboxylation and dehydration reactions. The grindability of the prepared hydrochar was comparable to that of coal. Hydrochar produced at lower reaction condition (160–200 °C at 2 h) have better flowability as compared to that produced at higher reaction condition (4–24 h at 200 °C). The reaction time longer than 12 h has a minimal effect on the yield, energy and physicochemical properties of hydrochar. Increasing reaction time and temperature improved the ignition and burnt temperature of hydrochar. All reaction condition has an energy ratio (energy output to energy input) of more than one making HTC process a net energy producer.

Science of the Total Environment 690 (2019) 261–276

Contents lists available at ScienceDirect

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Review

Valorisation of food waste via hydrothermal carbonisation and techno-economic feasibility assessment

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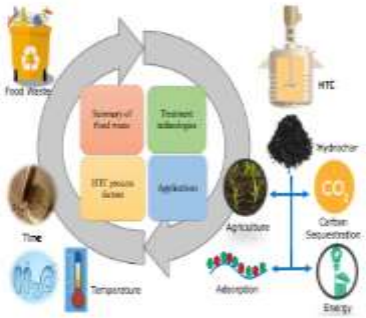
HIGHLIGHTS

- Thermal treatments like incineration and pyrolysis are not favourable for food waste.
- Hydrothermal carbonisation (HTC) is an effective treatment for conversion of food waste into energy.
- HTC is highly dependent on process parameters (i.e. temperature, time and pressure).
- HTC is highly dependent on fluctuating cost of equipment, labour, and transportation.

GRAPHICAL ABSTRACT



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Last Updated at August 1, 2019 09:40 IST

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The new technology - Hydro Thermal Carbonization (HTC) - can convert municipal solid waste to biofuel, soil amendment and absorbents, the premier institute

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IIT-KGP researchers develop tech for solid waste management

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IIT Kharagpur Develops Technology For Solid Waste Management

The new technology reaches the zero waste scale with this process. It can effectively manage mixed Municipal Solid Waste (MSW) with high moisture content. Read further to know more.

Story Covered by media

IIT Kharagpur researchers develop process to manage wet municipal solid waste

The process novelty lies in the use of water for the reaction thus the moisture in the MSW gets used during the recycling process.

By *Rica Bhattacharyya*, ET Bureau | Jul 31, 2019, 04.19 PM IST

BCCL

Another novelty of this technology is the zero waste scale is reached through this process. (Representative image)

MUMBAI: A research team from IIT Kharagpur has adapted a process called Hydro Thermal Carbonization (HTC) for the Indian conditions which can effectively manage mixed Municipal Solid Waste (MSW) with high moisture content. Through the process most of the mixed MSW can be converted into biofuel, soil amendment and absorbents, the premier institute said in a press statement.

The current waste burning processes adopted from the developed nations are primarily focused on treating drier waste

IIT Kharagpur researchers develop 'zero loss' process for wet municipal solid waste management

With this technology, waste management can be reached to zero waste level.

India Today Web Desk
New Delhi
July 31, 2019 UPDATED: July 31, 2019 16:39 IST

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NOVATION: IIT-Kharagpur researchers develop ro-loss process for solid waste management

urrent waste incineration processes adopted from the developed nations are primarily focused on treating drier content

gyWorld | July 31, 2019, 13:58 IST

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New Delhi: A research team from Indian Institute of Technology (IIT)-Kharagpur has adapted a process called Hydro Thermal Carbonization (HTC) for Indian conditions, which can effectively manage mixed Municipal Solid Waste (MSW) with high moisture content. Through the process most of the mixed MSW can be converted into biofuel, soil

lment and absorbents

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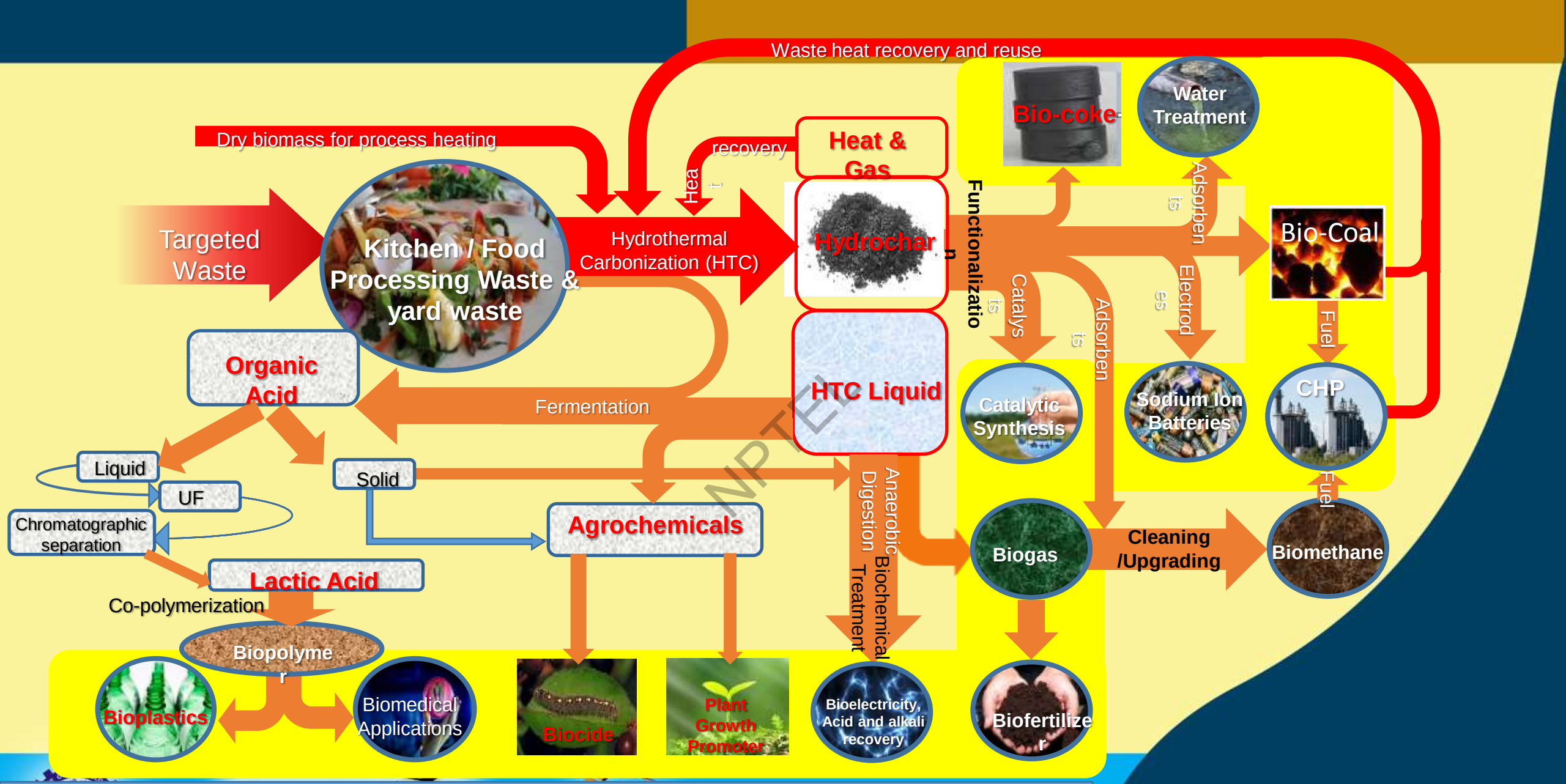
Converting wet organic municipal waste to biofuel & biogas without pre-drying

Posted by: Clean India Journal - Editor September 10, 2019 in News

India's humongous waste problem has a very specific issue: a greater portion of urban waste generated is organic. This part is very high in moisture content, which, during the monsoons, can rise up to 60-65%. Indian cuisine is dominated by gravies and daals, which keeps the water content of organic waste high even during the dry season.

If such wet organic waste is traditionally incinerated, the water component brings down the calorific value of the waste. Municipal corporations have to devote time, money and space to dry waste before incineration, or set up a separate bunker for the same.

Hydrothermal carbonization (HTC) is another looming WTE technology specially designed for conversion of wet biomass feedstock with no dependency on energy input, which otherwise is needed for drying of the feedstock in other techniques.



Application that we are researching currently and is planned for near future

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