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The 3Rs as the Basis for Sustainable Waste Management: Moving Towards Zero Waste

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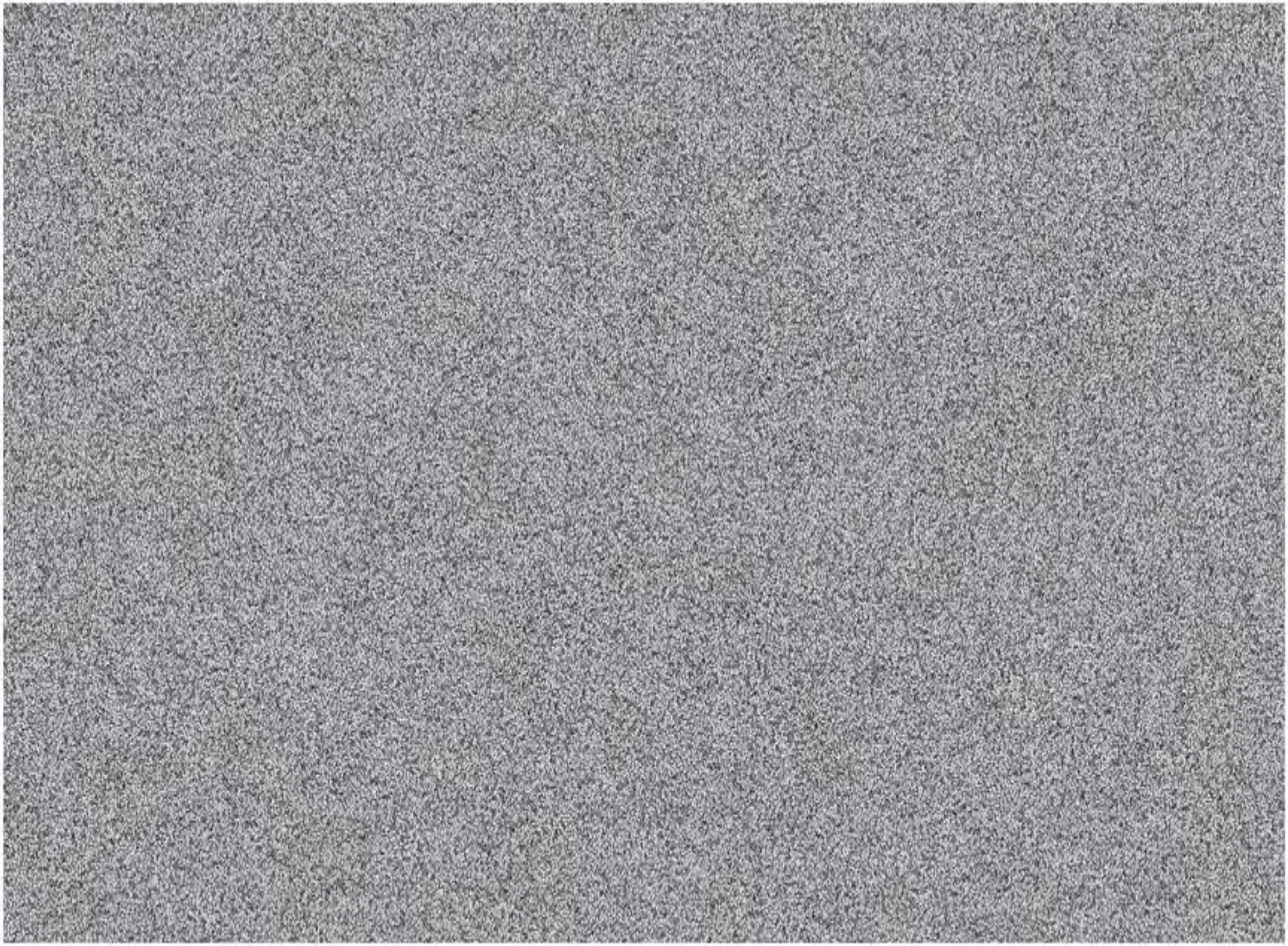

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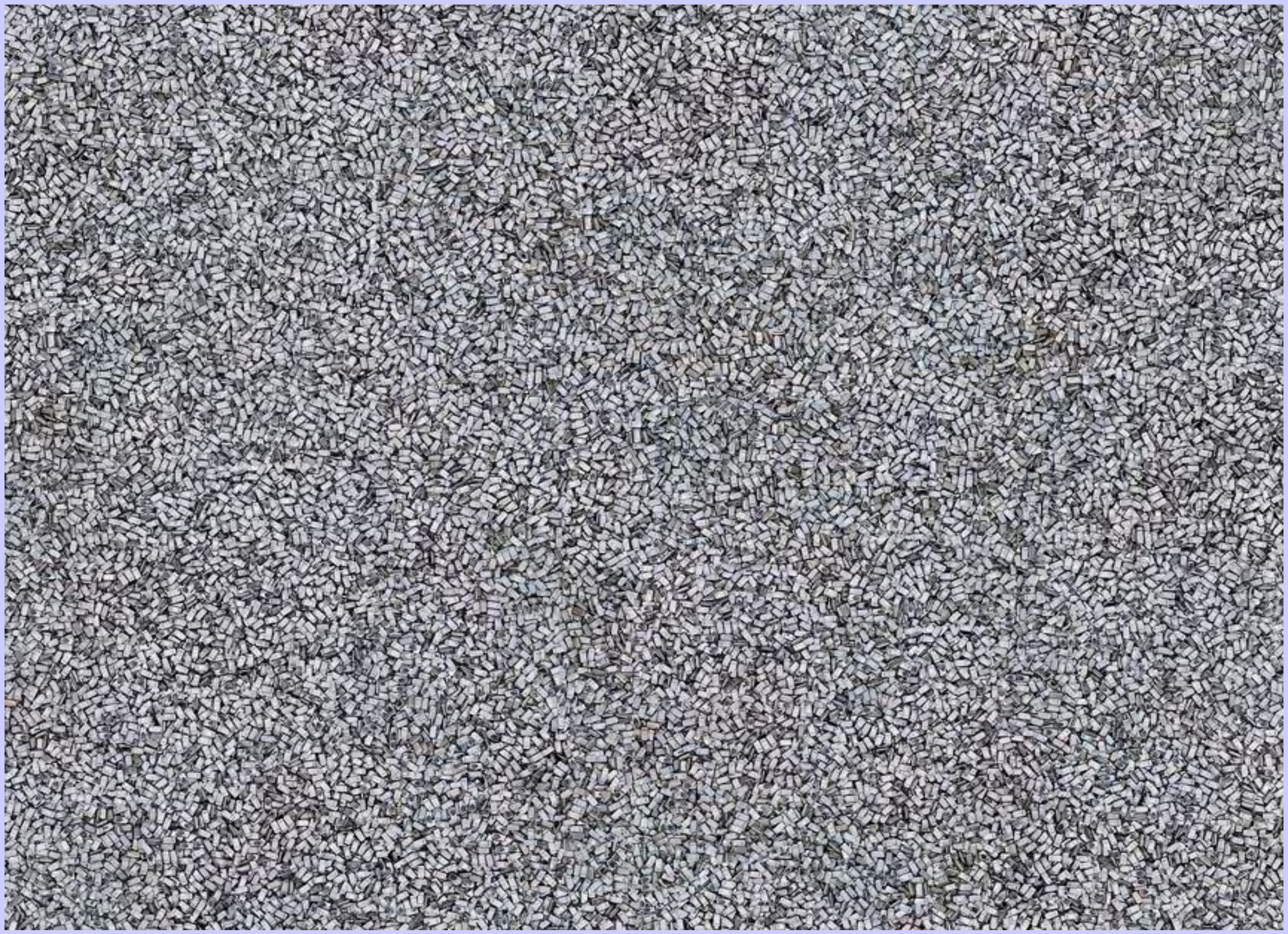

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426,000 Cell Phones are Retired in the US Every Day

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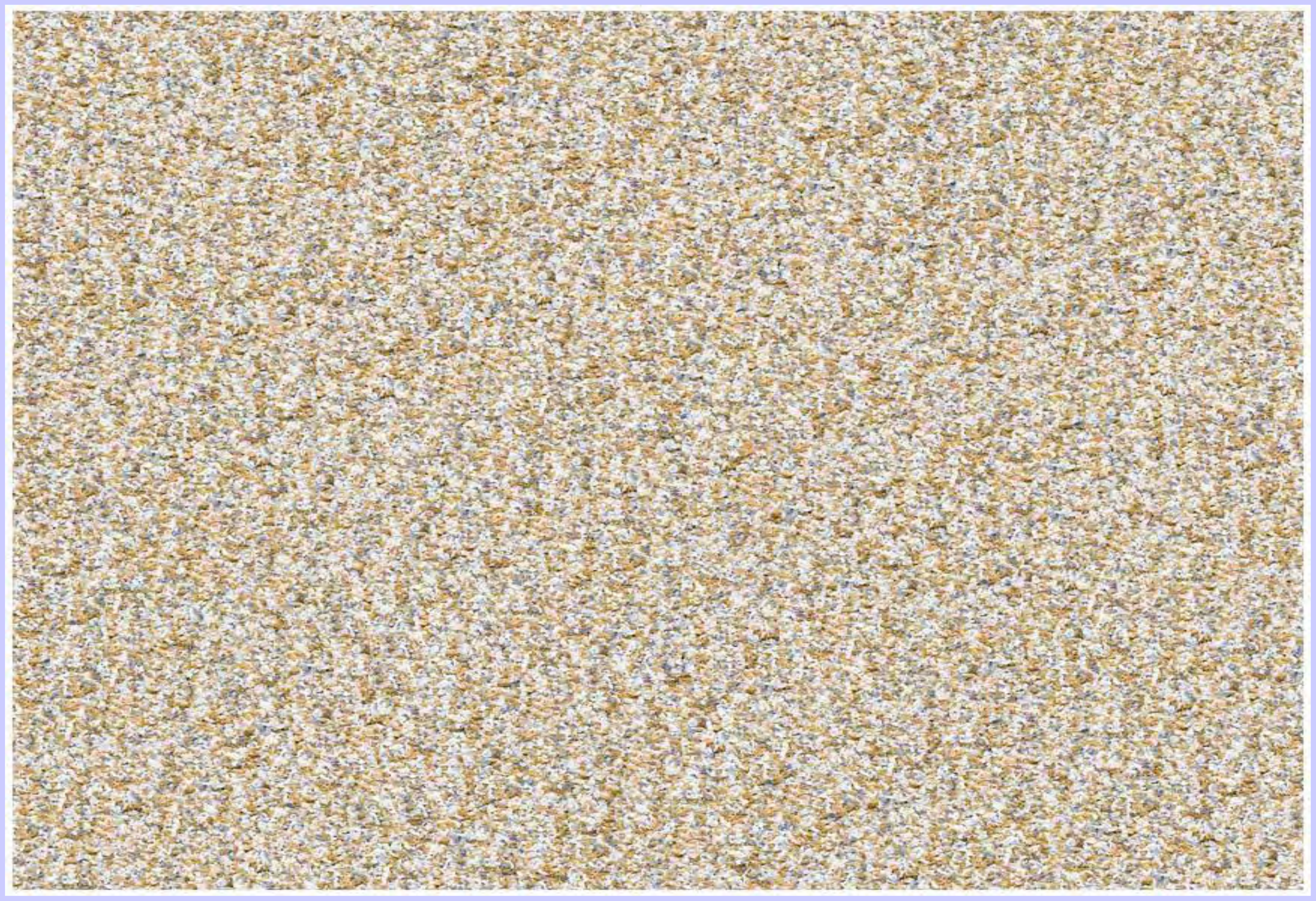

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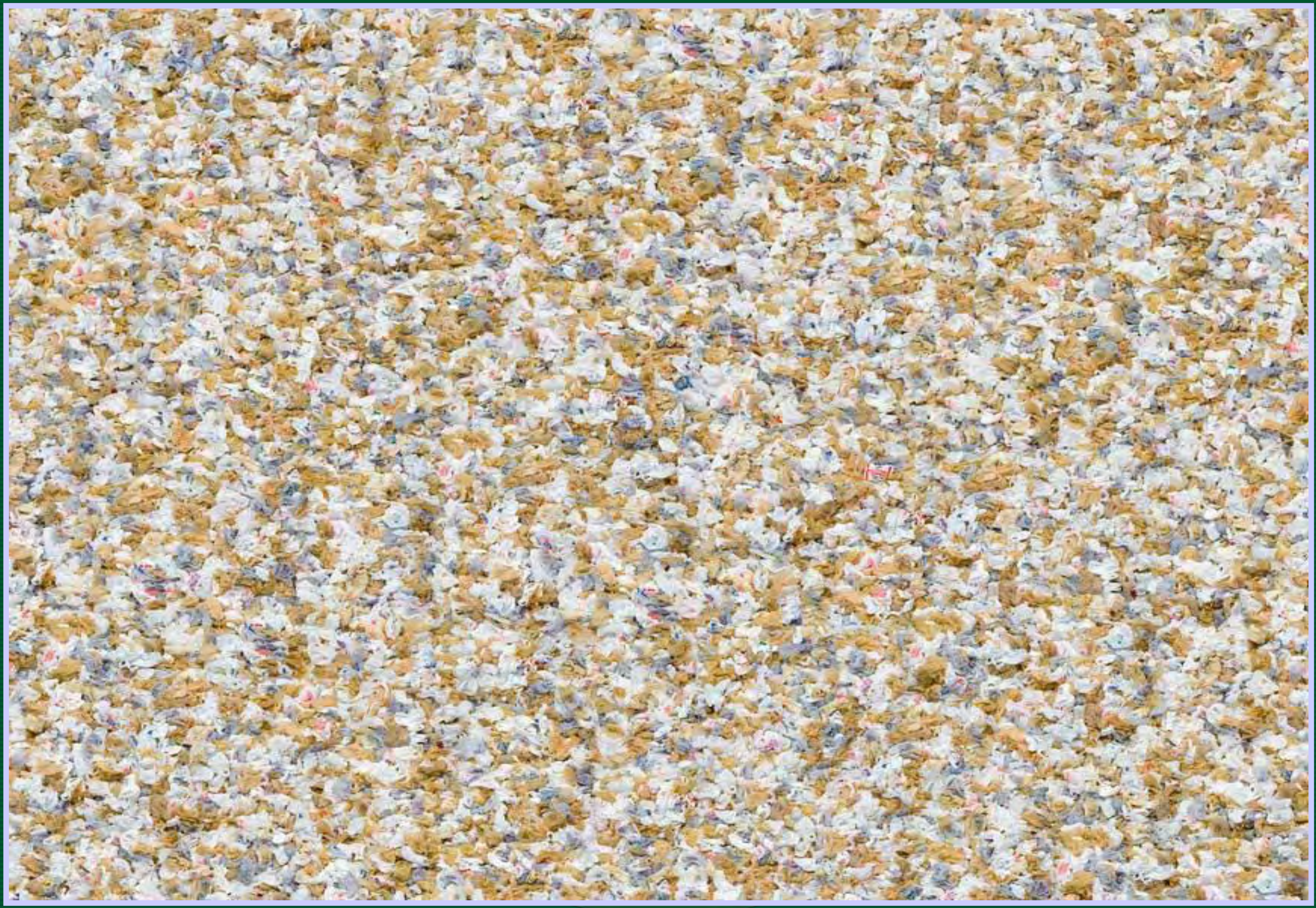

Source: www.chrisjordan.com.

60,000 Plastic Bags are Used in the US Every 5 Seconds

Source: www.chrisjordan.com.

Outline

- Introduction
- Waste management
- Asia - Pacific
- Global trends
- Summary

Introduction

- It is very possible that the 20th century will probably be remembered as the age of:
  - Unrestrained consumption of resources and
  - Large contamination of our environment
- 1960s and 1970s:
  - Attention to side effects of industrial and economic growth:
    - *Silent Spring* by Rachel Carson
    - *The Closing Circle* by Barry Commoner
- 1990s
  - Green Chemistry and Sustainable Development

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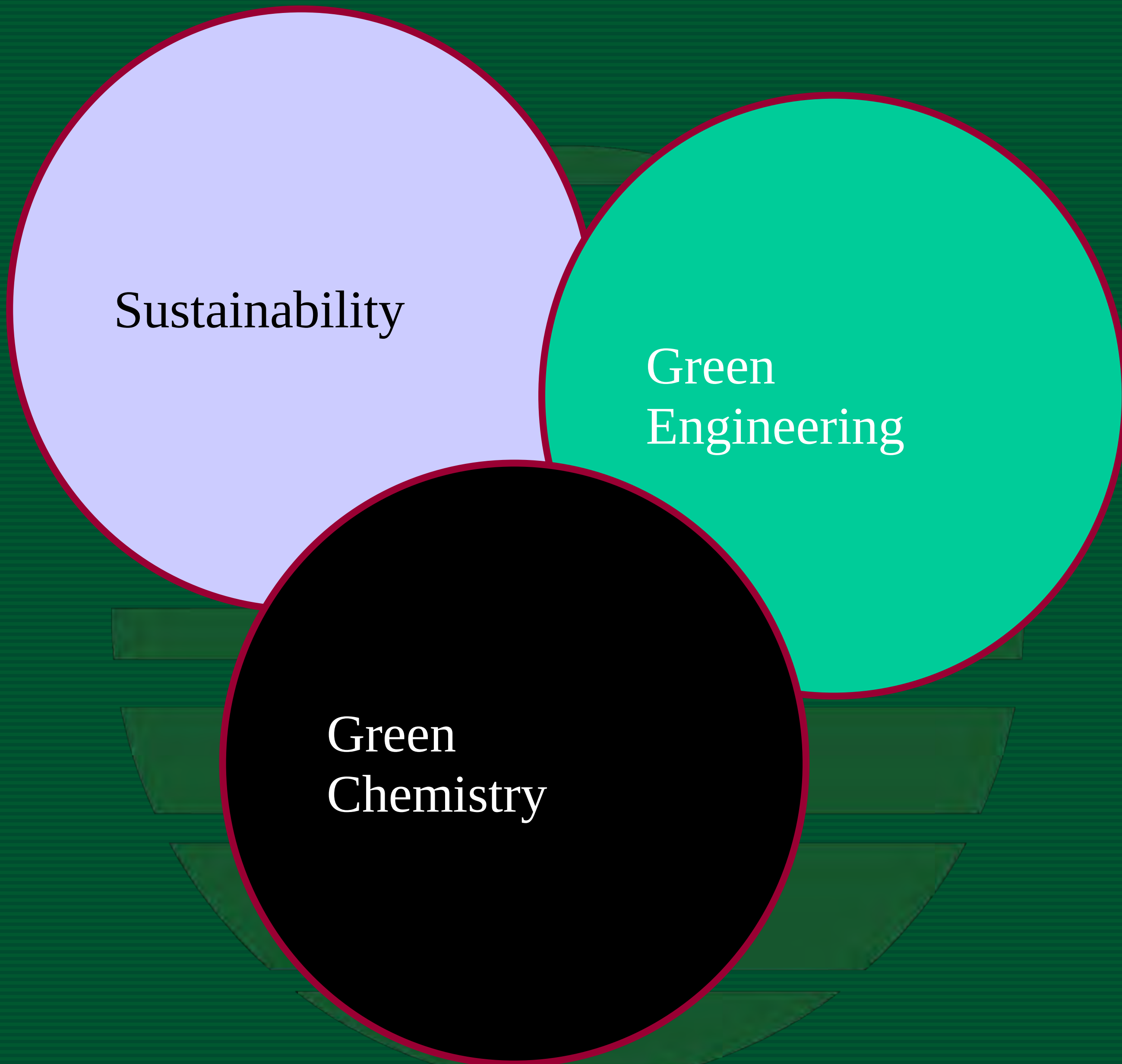
Sustainability
Green Engineering
Green Chemistry

Introduction

- United Nations Commission on Environment and Development (*Our Common Future*):
  - "*sustainable development is that which meets the needs of the present without compromising the ability of future generations to meet their own needs*" (1987)

Introduction (cont')

- Since 1987, many areas around the world have adopted the concept of sustainable development (as well as 3Rs)
- Different interpretations
- Different stages of implementation
- In the EU, since Gothenburg (2001) to recently, in the application of sustainability in production processes – three pillars: social, economic, and environmental

Introduction (cont')

- Diversion of solid waste from landfill disposal is being emphasized in many areas around the world
- Motivations are similar in most of the areas:
  - Protection of public health
  - Environmental protection (water, soil, etc.)
  - Resource conservation

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Sustainability in SWM

- Sustainability an important selection criteria in technology related to MSW
- We are now making a transition from essentially disposal in land to minimization, recycling, and other technologies
- However, we still are trying to determine if pillars of sustainability are properly applied

Management of MSW

- Industrialized: reduction at source, reuse, material recovery, energy recovery and sanitary landfilling (mostly 3Rs)
- Industrializing
  - Middle income: limited "formal" material and energy recovery and some sanitary landfilling
  - Low income: relatively high informal material recovery and mostly open dumps

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Sustainability in SWM (cont')

- With regard to economic aspects:
  - landfilling is the simplest, least expensive, and most cost-effective method
  - flushing bioreactor offers a good return for the investment and scores well as part of the economic pillar

Sustainability in SWM (cont')

- With respect to social acceptability:
  - waste treatment regarded as a continuous burden
  - economically developing countries focus on recycling and reuse (informal sector) and dump sites (at zero or very low cost)
  - in industrialized countries, we face the NIMBY syndrome (not in my back yard)

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Sustainability in SWM (cont’)

- Motivation for shifting to higher (more complex) solutions based on mostly the environmental pillar
- Intention is to set technologies as global standards
- In the EU the landfill directive stipulates a reduction in the amount of biodegradable waste to be landfilled

Development of the Management of MSW

1930s to Mid 1940s

- Onsite incineration by private individuals and businesses
- Some scavenging conducted during collection and disposal
- Residues disposed indiscriminately on land and burned or into bodies of water
- First "modern" sanitary landfill opened in Fresno, California in 1937

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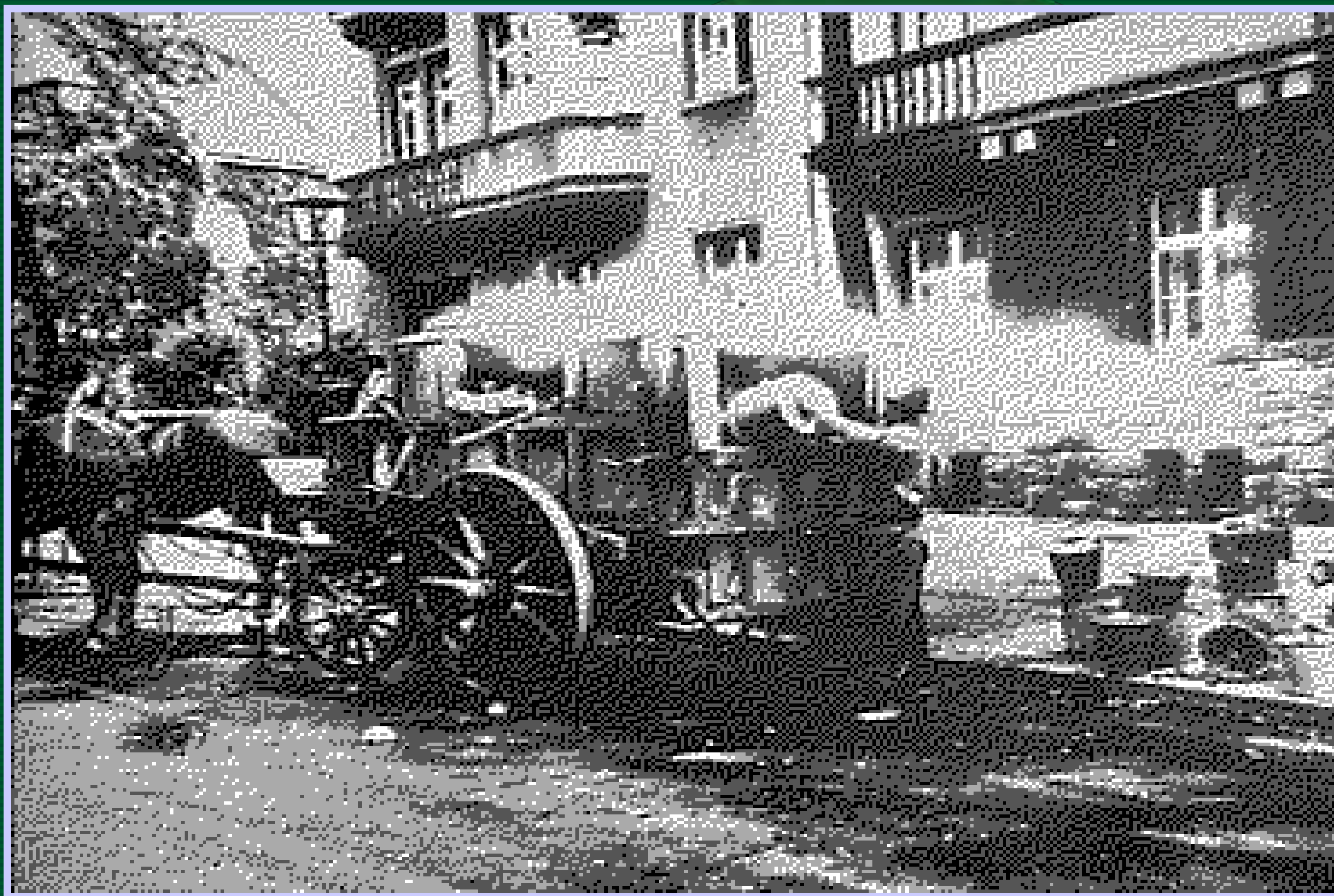
Collection Primarily Conducted Manually using Wagons Drawn by Animals

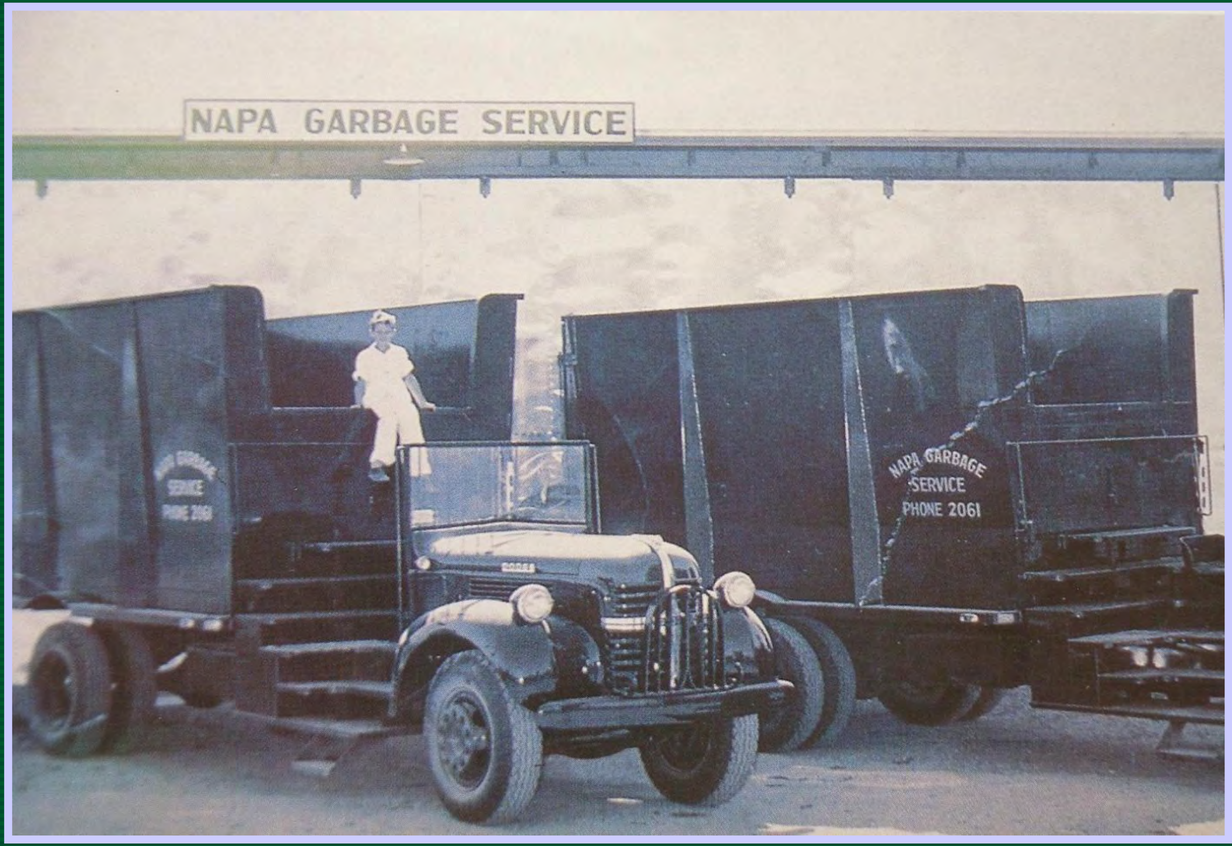


Source: California Refuse Removal Council – Northern District.

Mid 1940s to Late 1940s

- USPHS begins to work in solid waste, partners with American Public Works Association (APWA)
- USPHS was the precursor to the US EPA

Introduction of Some Motorized Vehicles for Collection, but Still Not Specialized



Source: California Refuse Removal Council – Northern District.

1950s to 1960s

- A few composting plants established to treat mixed MSW
- Comprehensive studies conducted on composting at University of California at Berkeley
- USPHS and APWA publish recommended guidelines for collection and disposal of MSW
- New, specialized equipment developed for landfilling

Open Dump Still Prevalent Method of Solid Waste Disposal

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Development of the Compactor Vehicle

1960s to 1970s

- Passage of the Clean Air Act (1963)
- Passage of the Solid Waste Disposal Act (SWDA) in 1965
- Steps taken to eradicate the open dumps
- Establishment of several government institutions (at the state level to improve treatment and disposal of solid waste)
- States begin to adopt the concept of sanitary landfill

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1960s to 1970s (cont.)

- Emissions and odors from incinerators persist; several facilities closed
- Identification of migration of landfill gas as a problem in sanitary landfills
- Increased levels of funding led to beginning of demonstration programs

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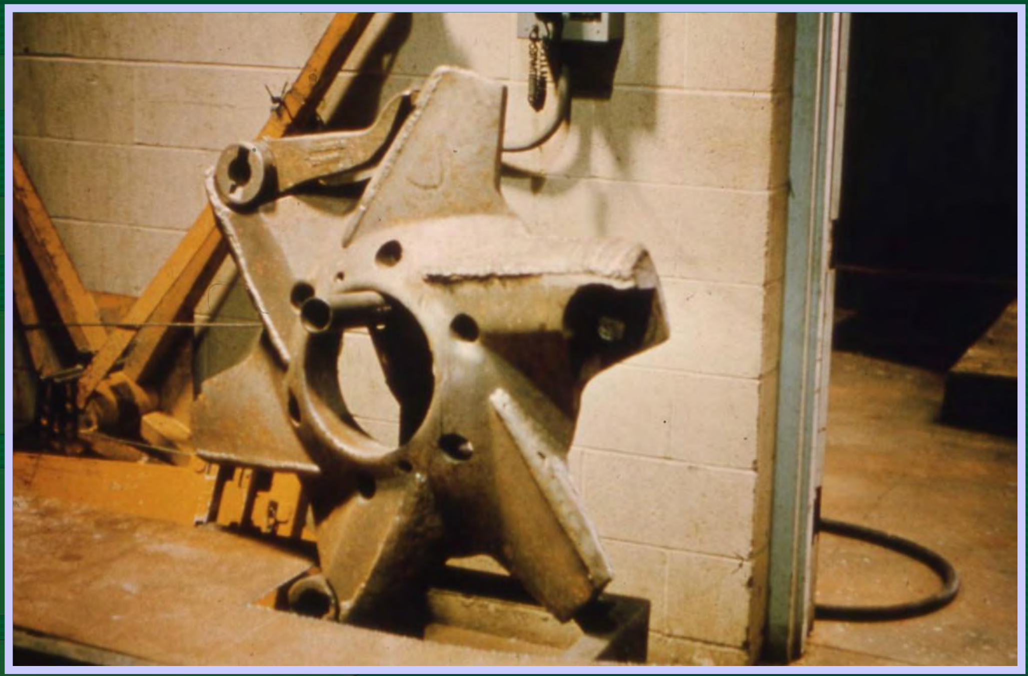
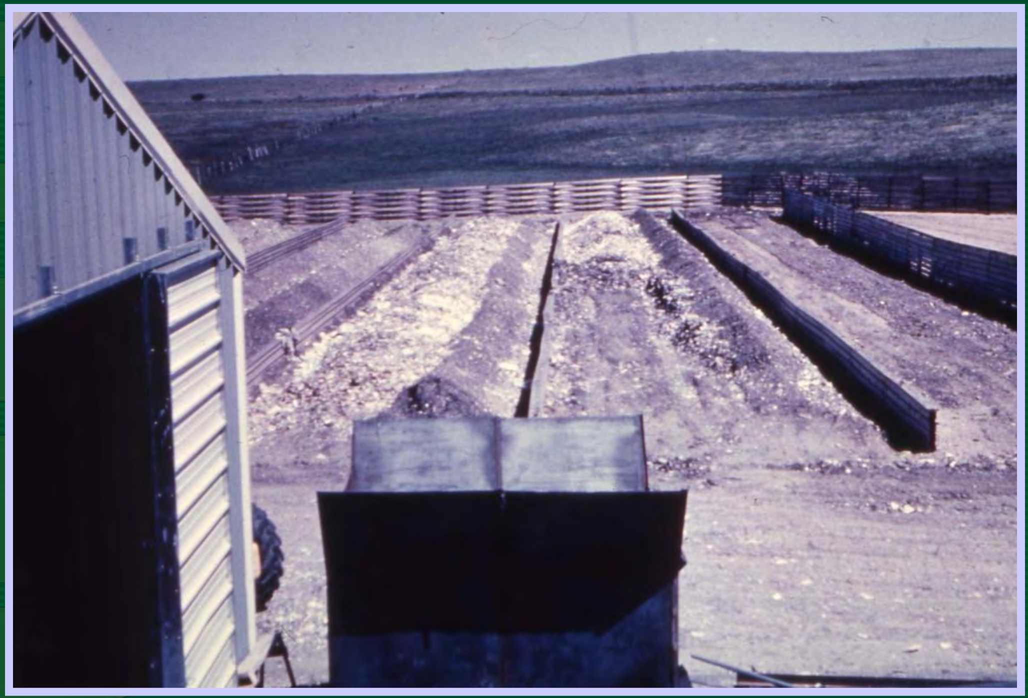
Black – Clawson Demonstration in Franklin



Monsanto Pyrolysis Plant in Baltimore

MSW Composting in Johnson City



Try to Reduce Number of Personnel per Collection Vehicle

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Birth of Recycling Programs Recovering Source-Separated Materials (and 3Rs)

El Cerrito, California

Work at University of California -- RFS

UC Berkeley -- RFS Composting

UC Berkeley -- RFS
Paper Pulp Recovery

Beginning of Formal Curbside Recycling Collection Programs

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1980s to 2000s

- EPA promulgates new criteria for SLF to be put into practice by the States (1991)
- New Source Performance and Emission Guidelines requiring that LFG be collected (1996)
- First LFG to energy plants built
- Energy tax credit legislation passed and encouraged the development of LFG projects

Growth of Interest in Thermal Conversion, Application of Several European Designs

Introduction of Large-Scale Materials Recovery Facilities (processing mixed MSW)

Establishment of Yard Waste Composting Facilities

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Asia – Pacific Region

- The population has been estimated at about 3.75 billion people
- Experiencing a rapid rate of urbanization
- The generation of solid waste has also increased
- The majority of countries in the region still depend on the disposal of their solid wastes in the land

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Composition of MSW Disposed in Some Cities in Asia

Component (% wt.)	China (Shanghai) 1998	Sri Lanka 2003	Thailand 2003	South Korea 2001	Philippines (Manila) [a] 2003	Japan 2000
Organic Matter	67.3	64.7	56.2	32.8	50.1	34
Paper & cardboard	8.8	12.3	7.7	23.8	12.5	33
Plastics	13.5	6.8	13.7	--	24.7	13
Glass	5.2	3	4.3	2.8 [b]	3.1	5
Metals	0.7	3.7	3.1	--	5.0	3
Textiles & others	4.5	10.2 [c]	14.3	40.6 [d]	4.6	12

Components may not add up to 100

[a] Average of five local government units

[b] Include metals and cerámics

[c] Wood

[d] Includes ash

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Asia (cont') -- Philippines

- Manila in the 1980s

Dump Site After Closure

Asia (cont') -- Philippines

Payatas -- Manila, before slide

Asia (cont') -- Philippines

Payatas -- Manila, after slide

Asia (cont') -- Philippines

Asia (cont') - Mongolia

Asia (cont') - Mongolia

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Asia (cont') - Cambodia

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Asia (cont') - Cambodia

- Phnom Penh

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Asia (cont')

- Japan serves as an excellent example to give an interesting perspective on Asia
- It is a country "island" with an estimated population on the order of 127 million

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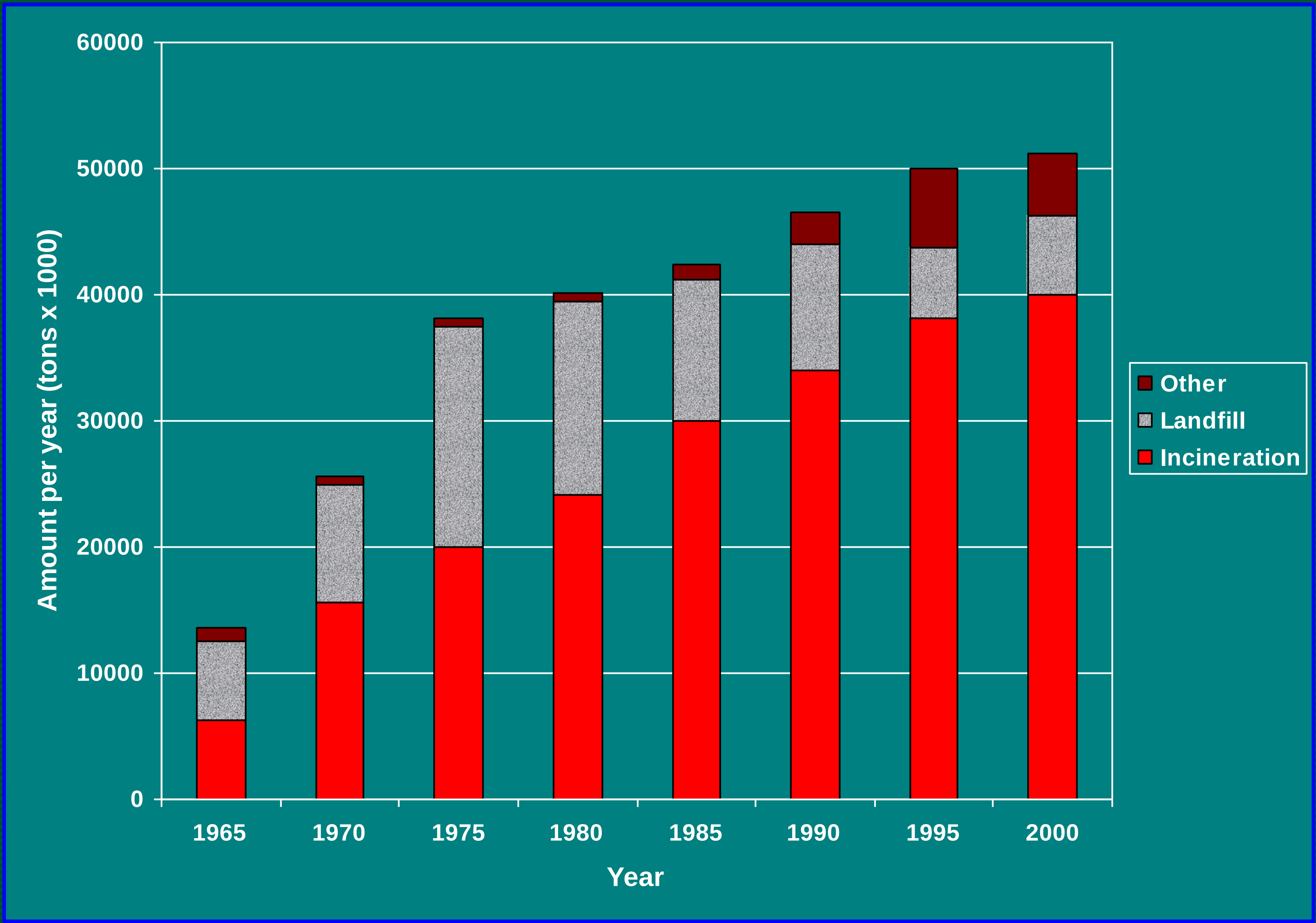
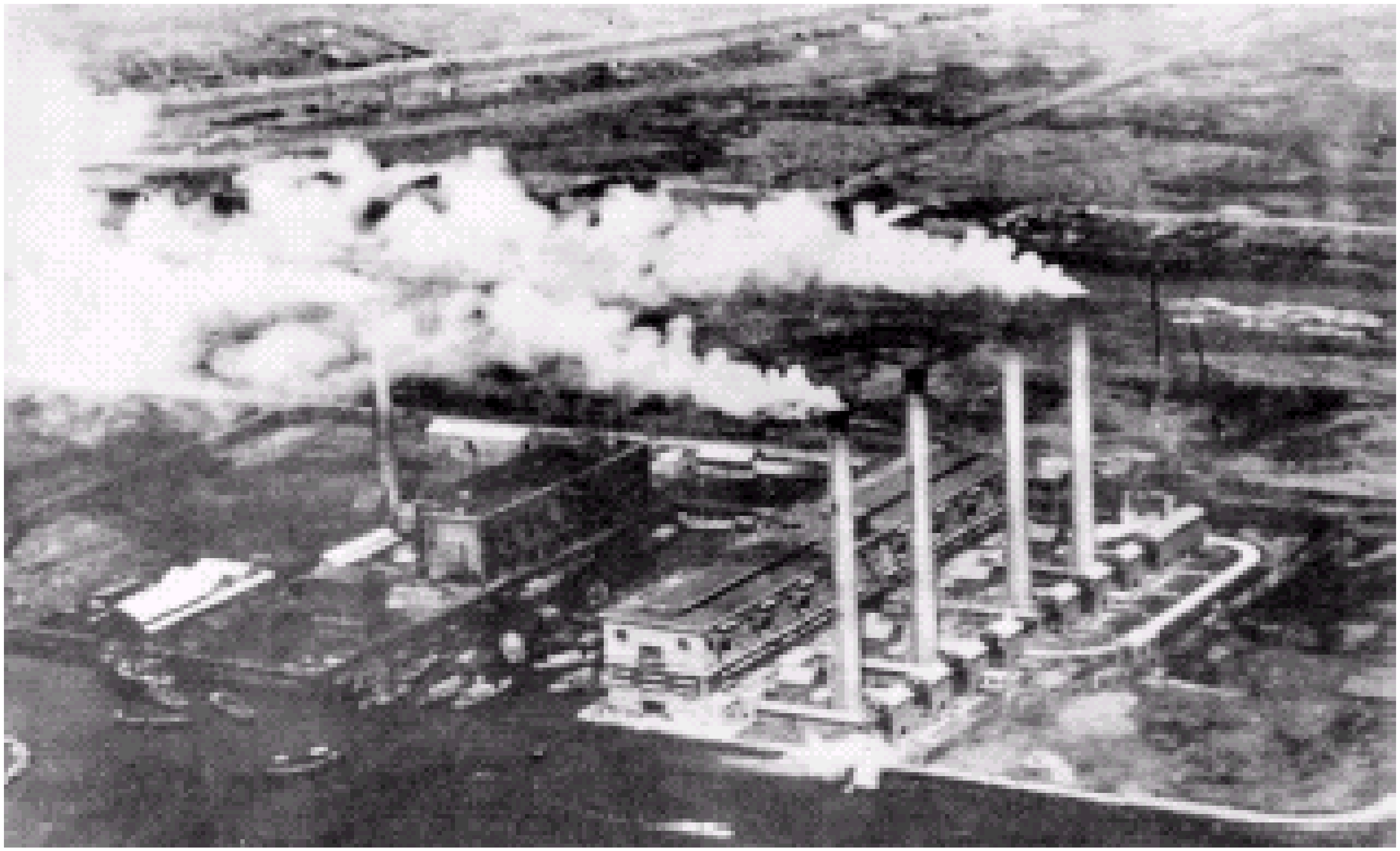
Management of MSW in Japan (1965 to 2000)



Incinerator in Tokyo ~ 1933



第 3－3　深川塵芥処理工場

左の小さい煙突が第一工場、右奥 2 本が第二工場、右手前 2 本が第三工場の煙突

Source: T. Matsuto

Why was Incineration Selected?

- Selected as national strategy in 1900 to primarily control diseases (i.e., cholera)
- Subsidy program began in 1963
- Tax revenues distributed to local governments
- Revenues facilitated construction of expensive facilities

Modern Incinerator in Sapporo (2003)

Collection of Recyclables by Local Government

- In 1975:
  - Numazu City, regular collection of cans, bottles, and waste paper
- In 1993:
  - About 40 percent of municipalities have the program
- In 1997:
  - Package and Containers Recycling Law made a major impact on SWM

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Separate Collection – 21 Categories, Minamata, Kyushu (began in 1993)

Bottles (returnable, clear, blue, brown, green, black); Plastics; Steel cans; Aluminum cans; Cooking pans; PET bottles; Newspaper; Magazines; Cardboard; Textiles; Bulky waste; Fluorescent lamps; Batteries; Combustibles; Food waste; Waste to be landfilled

http://www.minamatacity.jp/kankyouhtml/main/gomi23.htmより）

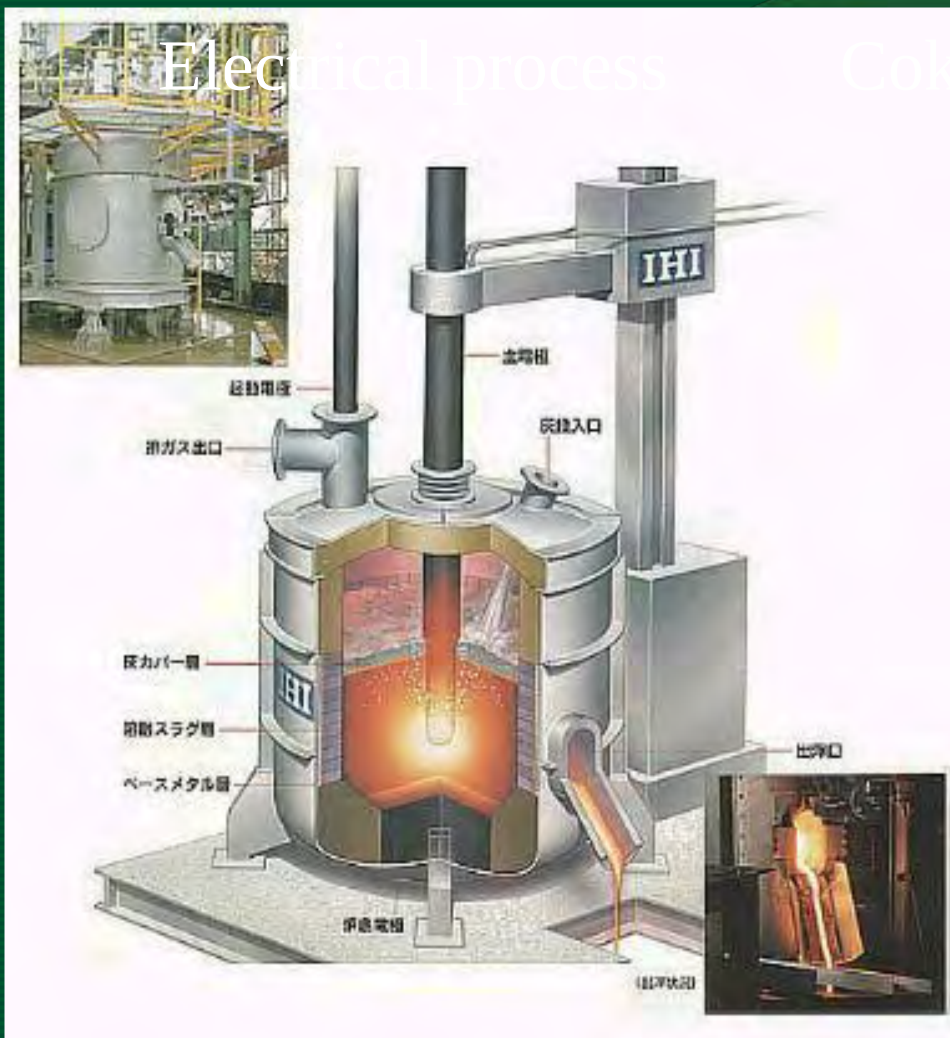
Incineration

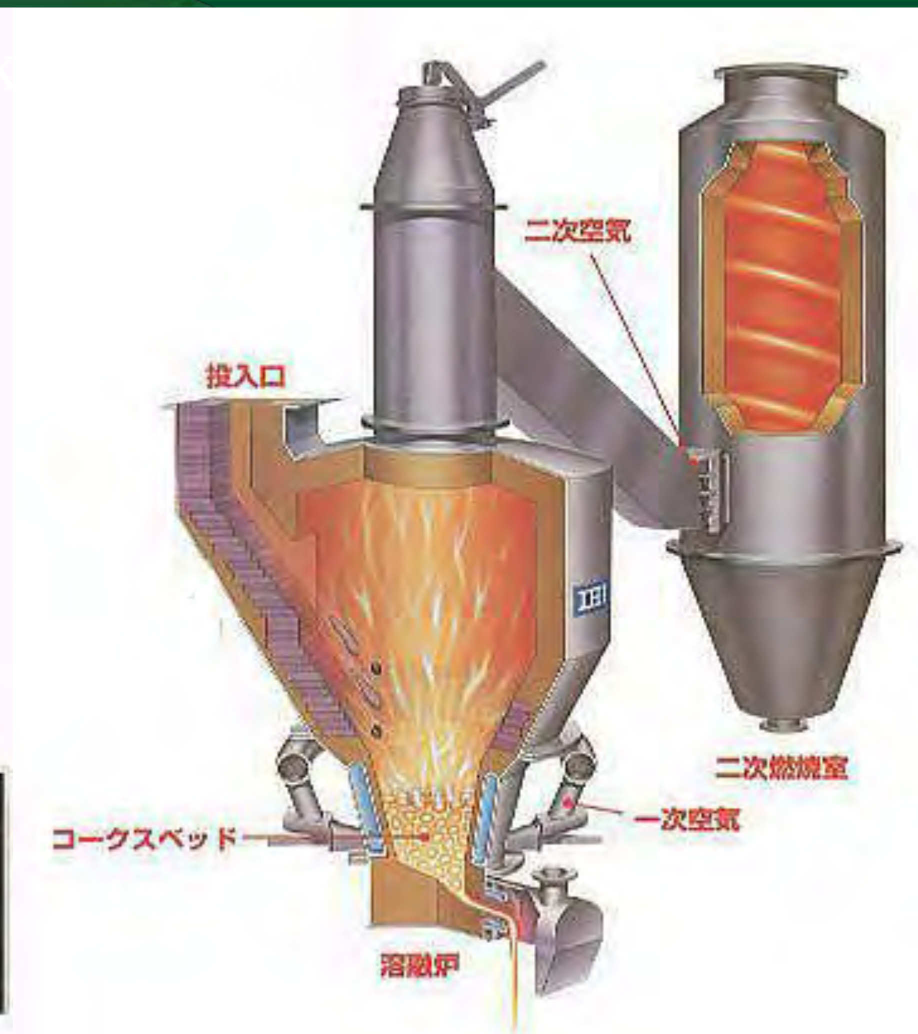
- PCDD/DF from MSW incinerators was a major concern in the late 1990s

- Implemented controls:
  - *For gas:*
    Furnace renovation, particulate control, temperature control, etc.
  - *For solid residue:*
    Melting process became common

Ash Melting

Electrical process Cok





Requirement for obtaining government subsidy

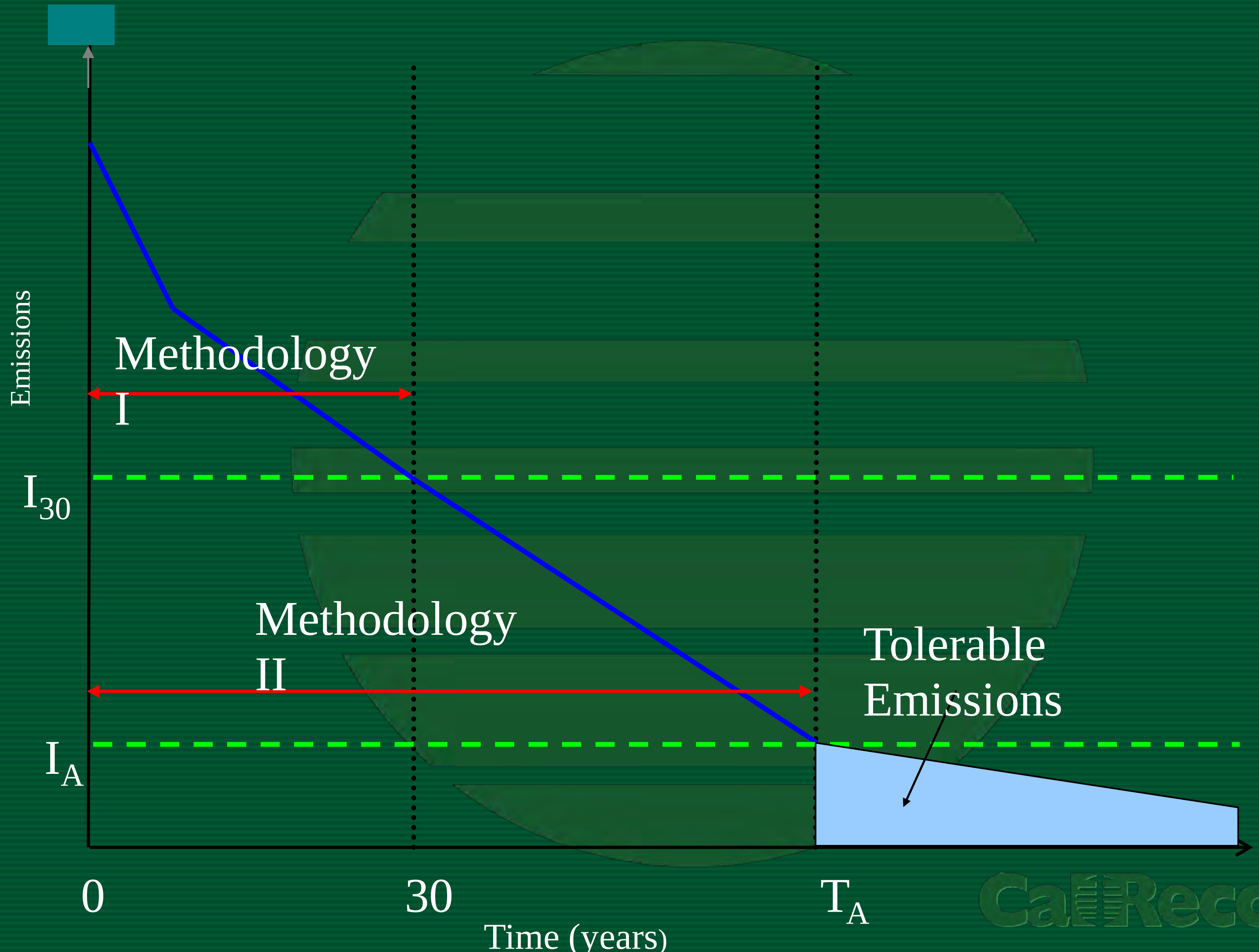
Slag and Metal

About 150 melting systems in operation in 2002

Landfills in Sustainable SWM

- Regulations in Europe have set the aftercare period for landfills as 30 years after stopping operations
- However, gaseous and liquid emissions do not meet standards of acceptable quality after 30 years
- Length of time not a good indicator if landfill is stable (biologically or chemically)

Comparison Between the Methodology Presented by European Regulations and that Obtained from the Concept of "Final Storage"



Waste Management

Generation and Characteristics of MSW

Type of Country	Avg. Generation (kg/cap-day)	Paper & Plastics (%)	Concentration of Organic Matter (%)	Moisture Content (%)
Industrialized	1.5	30 to 50	20 to 40	20 to 30
Developing				
- Middle Income	0.90	20 to 30	40 to 50	50 to 60
- Low Income	0.62	10 to 20	50 to 60	60 to 80

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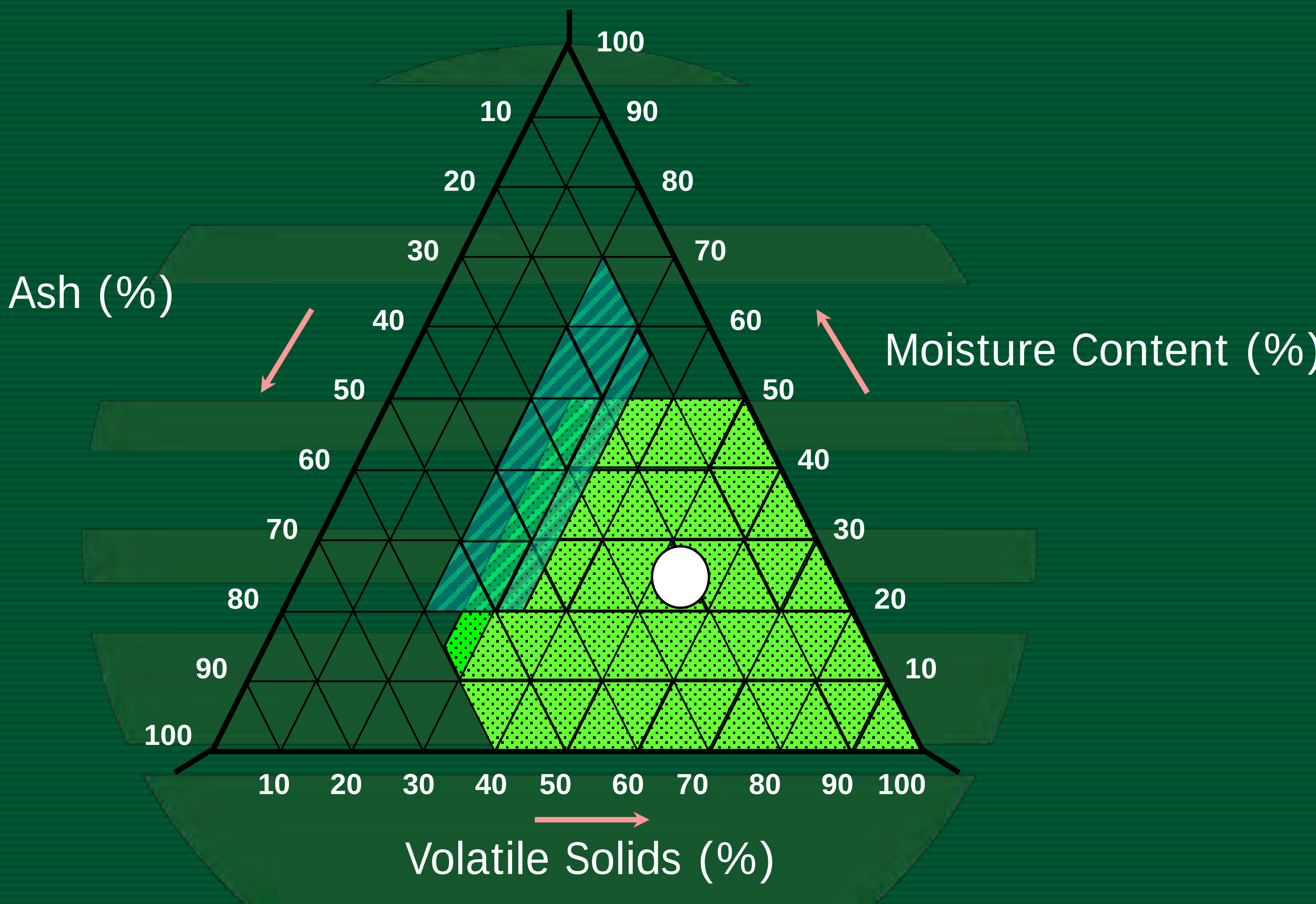
Key Characteristics of MSW in Economically Developing Countries

- High concentration of organic matter
- Relatively high volumetric density
- High moisture content

Comparison of the Thermal Characteristics of MSW with Those Required for Auto-Combustion



Area for auto-combustion

Typical values in industrialized countries

Typical values in developing countries

EU – Increasing Diversion Levels

- Importance of proper management of biodegradable residues
- Impact of biowaste in landfills
- Introduction of several legislative initiatives in European countries
- Effects of legislation on requirements for pre-treating MSW

Development of Legislation in the EU

- Limited legislation specifically dealing with the management of biowaste
- Primary legislation:
  - directive dealing with sewage sludge
  - directive covering animal waste processing and disposal
  - landfill directive – impacts biological treatment of biowaste
  - proposed animal by-products health rules

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Landfill Directive

- Became effective July 1999
- First directive to define biodegradable waste
- Sets targets for diversion from landfills
- Exceptions for countries that landfilled at least 80% of MSW in 1995

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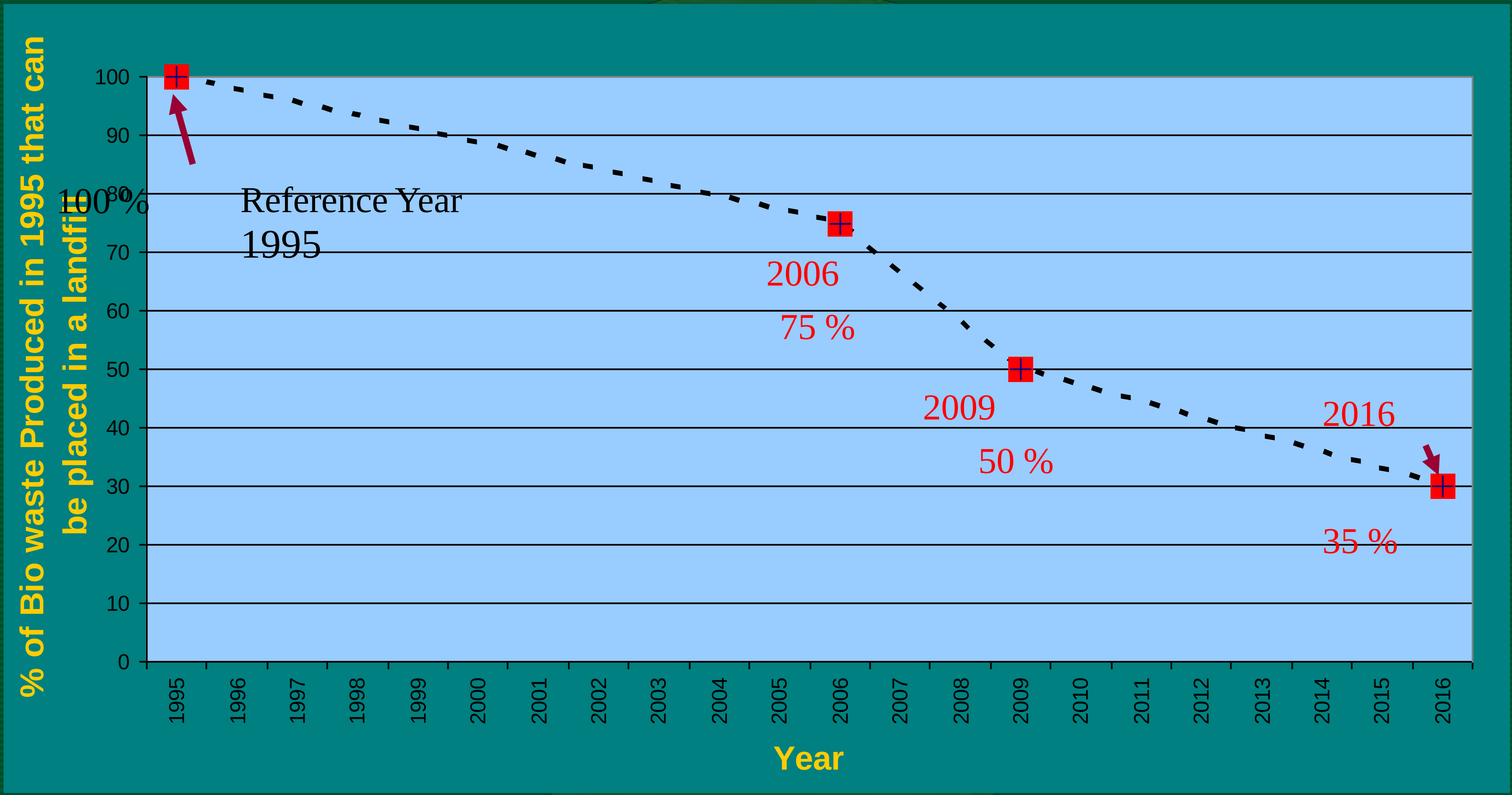
Targets of Landfill Directive



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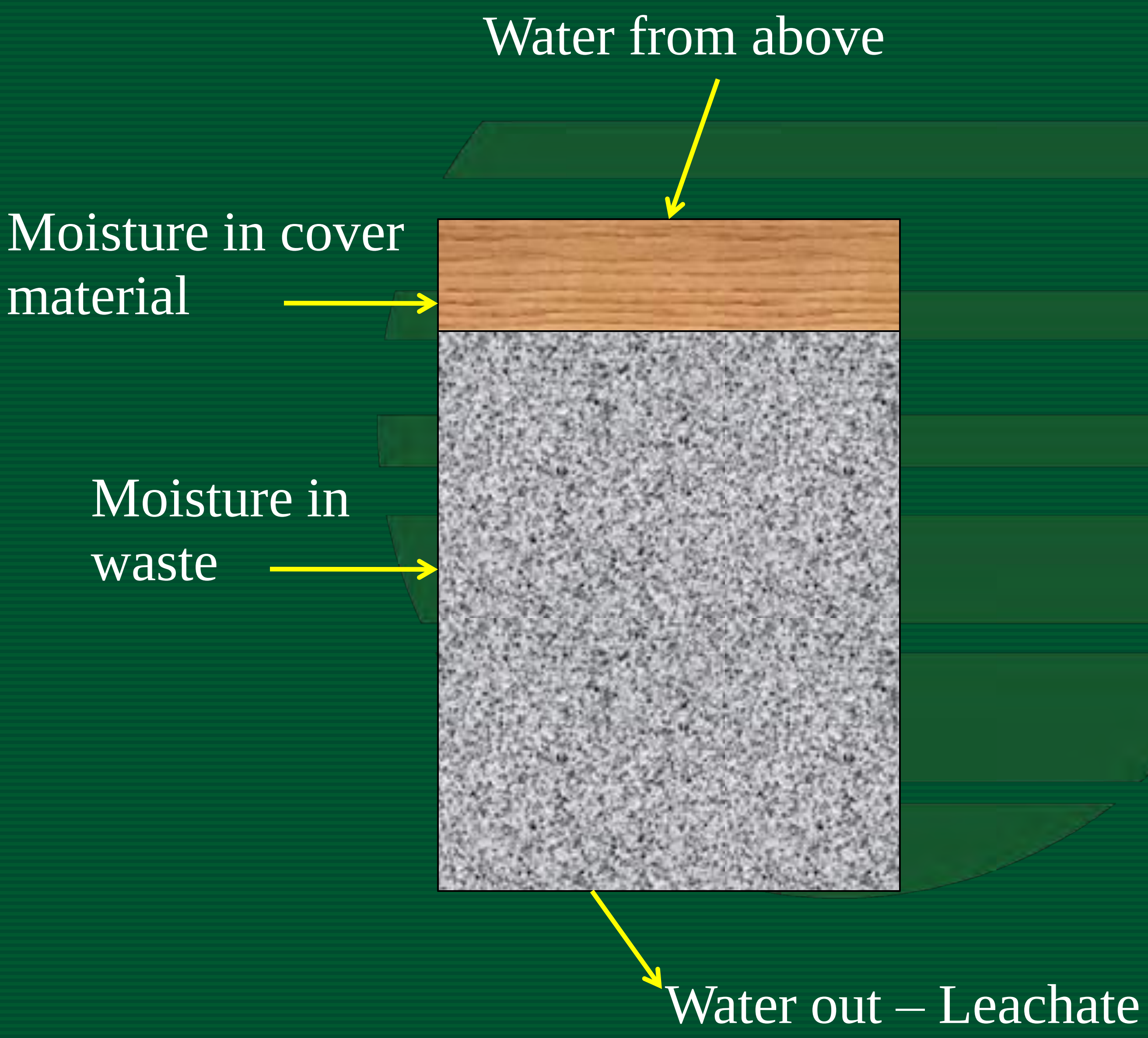
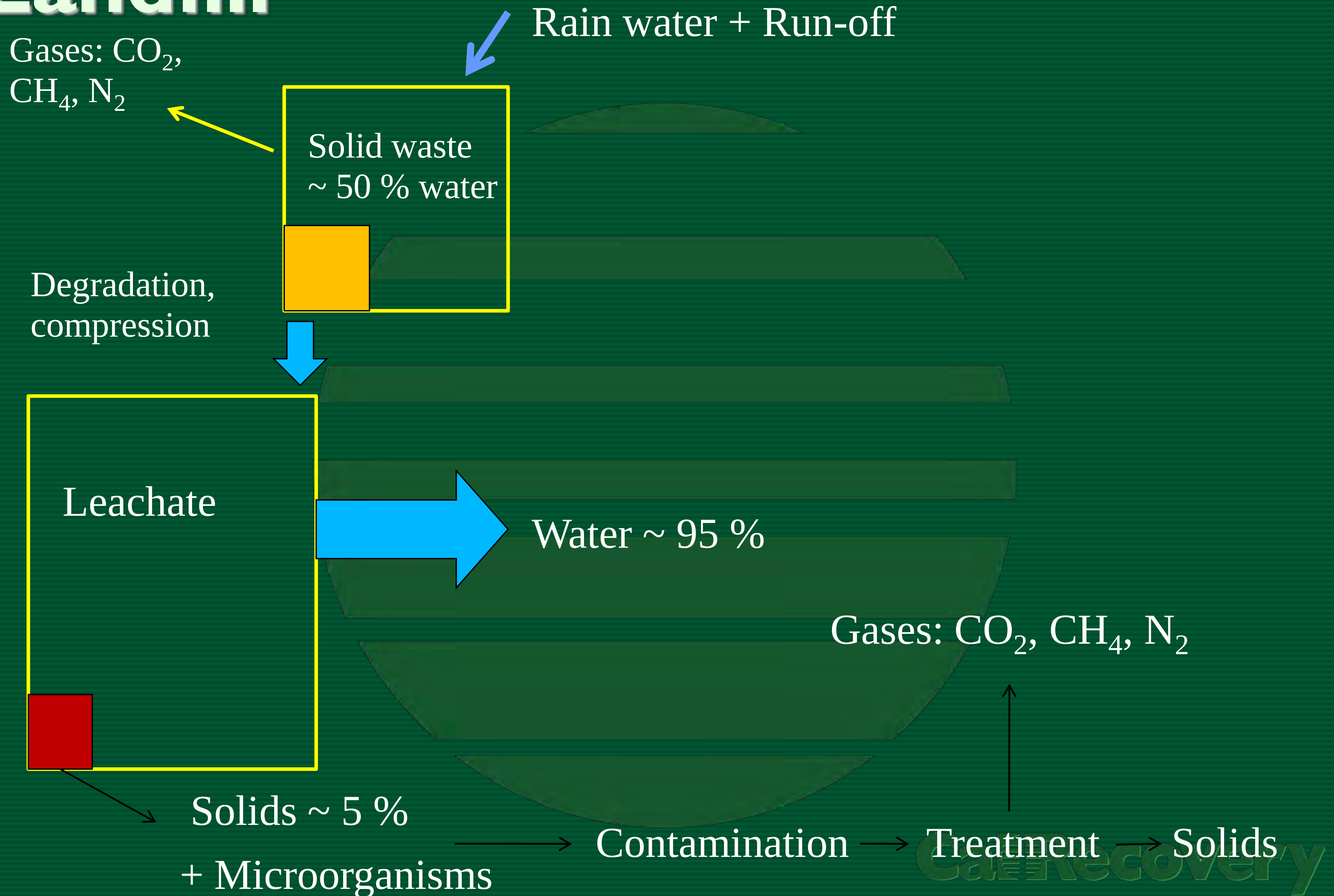
Leachate formation in Landfills



Schematic Diagram of a Sanitary Landfill



Landfill Directive (cont.)

- Requires treatment of any waste with potential negative impacts to health, environment
- Residual waste (MSW minus recyclables and biowaste) has potential of negative impact
- Requires full cost accounting for landfilling, including closure and aftercare for at least 30 years

Technology

- Most commonly used processes to treat biowaste and meet EU requirements:
  - combinations of biological processes
  - anaerobic digestion and composting
- Increases in plant capacity in EU from 1990 to 2000:
  - compost: from 2 million to about 16 million tons
  - A/D: from 0.1 million to about 1.0 million

Composting in Germany

- Potential:
  - 10 – 12 million tons
- Biological waste treatment:
  - 1999: 594 plants; 8.4 million tons throughput
  - 2001: 700 to 900 installations

Three-bin system in Germany

Organics	Recyclables	Residual waste
20.6 – 38.2 %	31.9 – 49.5 %	22.3 – 36.9 %
3.95 – 5.21 kg/cap-week	1.03 – 1.85 kg/cap-week	0.97 – 1.29 kg/cap-week

Impurities: Average 8%

Composting Systems

- Types of systems used:
  - aerated static pile
  - aerated pile with mechanical turning
  - container systems
- Approximately 70% of the organic fraction of MSW in Germany is composted in reactor systems

Anaerobic Digestion Systems

- Systems used:
  - high-solids (20% to 40% TS)
  - low-solids (3% to 15% TS)
- Systems operating at high-solids have reported fewer problems than systems operating at low-solids

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Rennerod, Germany

Rennerod – Loading of Treatment Unit

Rennerod – Biotreatment Process

Rennerod – Water Purification

Rennerod – Emission Control

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Poessneck - Interior of Composting Unit

USA – Increasing Diversion Levels

- Approaches vary from state-to-state
- California legislation:
  - AB 2020 (1986) – redemption values on beverage containers
  - AB 939 (1989) – mandated diversion goals
  - SB 1322 (1989) – programs to improve markets for recyclable materials
  - AB 2076 (1991) - used oil recycling program

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California – Diversion Goals/Levels

- AB 939 mandated 50% diversion by 2000 for every jurisdiction – some cities have established higher diversion goals
- Diversion in California has increased steadily:
  - 1990 – 17%
  - 1995 – 28%
  - 2000 – 42%
  - 2002 – 48%
- In 2000, almost one-half of the jurisdictions had met the 50% goal
- Currently some jurisdictions have reached 70% diversion of MSW from land disposal

California – Reaching 50% Diversion

- Multi-faceted programs:
  - Generator types
  - Materials
  - Approaches
- Involving private recyclers
- Public education
- Economic motivation

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Example:
Residential Curbside Collection

California – Going Beyond 50% Diversion

- Improving/expanding existing programs
  - Residential and commercial
- Introducing new programs, e.g.:
  - C&D
  - Food waste
- Providing proper incentives to the collection service provider and processor
- Trying to apply new conversion technologies

Food Waste

- Characteristics of food waste:
  - Can represent 5% to 20% of residential waste
  - Highly putrescible, high moisture content
- Storage/collection presents challenges:
  - Potential for foul odors
  - Requires watertight containment
  - Difficulty in segregating (esp. commercial)

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Example:
Food Waste Composting Operation

Global Trends that Drive Use of Resources

- Rapid population growth
- High level of resource and energy use in industrialized countries
- Very large industrialization in large emerging economies (BRIC)
- Increasing affluence, high levels of consumption, and
- Relative ease of global trade

Consequences of Global Trends

- Climate change due to combustion of fossil fuels
- Loss of biodiversity and ecosystems
- Loss of fertile land
- Growing quantities of waste generation

Use of material resources

- In EU-27
  - average use of material resources is about 16 tons/person-year. Most end up as material accumulated in economy, the rest converted into emissions or waste
  - average total waste generation about 6 tons/person –year (16 kg/person-day). MSW is about 1.4 kg/person-day)

Trade Balance between EU-27 and Rest of World

- From EU to Rest of World
  - 1999: 397 million tons
  - 2008: 536 million tons
- From Rest of World to EU
  - 1999: 1,340 million tons
  - 2008: 1,798 million tons (1,384 million tons fuels and mining products)

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Decoupling

- Use of resources decoupled from economic growth
  - May be due to increased imports substituting domestic production
  - Not using less material resources but relying on those extracted and processed in other countries (1 ton of platinum leaves 400,000 tons of residue behind)

Motivating Service Providers

- Requires a shift from “collect and dispose” ethic to “collect and divert” ethic
- Basic approaches:
  - Required performance - defined in scope of work
  - Incentivize performance – rewarded based on performance
- Motivation works well when compensation is very attractive to service providers when high levels of diversion are achieved

Motivating Service Providers

- Incentives (examples):
  - Revenue from sale of recyclables
  - Operating ratio/profit margin based on performance:
    - Diversion rate
    - Recovery rate
    - Contamination levels
- Important considerations:
  - Balancing risk and reward
  - Provide incentives only in those activities in contractor's control
  - Ability to fund incentives

Incineration in the EU

Spittelau – Vienna, Austria

Installation sited in the middle of urban area

Modern Incineration Plant in Sapporo, Japan

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Summary

- European Union
  - Relatively sophisticated policies, resources/waste
  - Landfill directive bans organic materials from being disposed in landfills
  - Imposition of landfill taxes
  - Generally enclosed, relatively high technology processing operations for organic materials and residual

Summary

- US / California
  - AB 939 mandates diversion from landfill
  - Several other pertinent bills have been passed (AB 32, SB 375, etc.)
  - Generally open, low-to-medium technology processing operations for treatment of organic materials
- Industrializing countries
  - Very few have national policies related to MSW, few sanitary landfills, many open dumps, relatively strong informal recycling

Background and Sustainable, Integrated Community Support Systems

Zero Waste Definition

- There are several literal means of interpretation
- **Zero Waste** is <u>NOT</u> a way to manage our wastes so that we will not produce any discharges
- **Zero Waste** is a philosophy that provides guidance to our society
- Guidance to change most present habits to improve our methods of using resources; thus, approaching as close to **Zero Waste** as possible

Approaches to Achieving Zero Waste

- Keep to minimum the use of raw materials and energy at manufacturing level
- Minimize use of toxic materials in product manufacturing
- Rely on the use of outputs from processes so that some of them can become inputs to other processes -- an example of this is Energy-Agro-Waste system that will be described later in this presentation

Zero Waste -- System Design

- Design of every process must take into consideration not only the raw materials and energy inputs, but also:
  - ✓quantity
  - ✓type
  - ✓quality of outputs (including residues)
- All outputs should be in such a form that they can easily be reused, recycled, or processed into other materials

Composting as Key Component

The Place of Composting in a Community System

Community as a whole:

- community support systems
- waste management
- composting of organic materials and compost production

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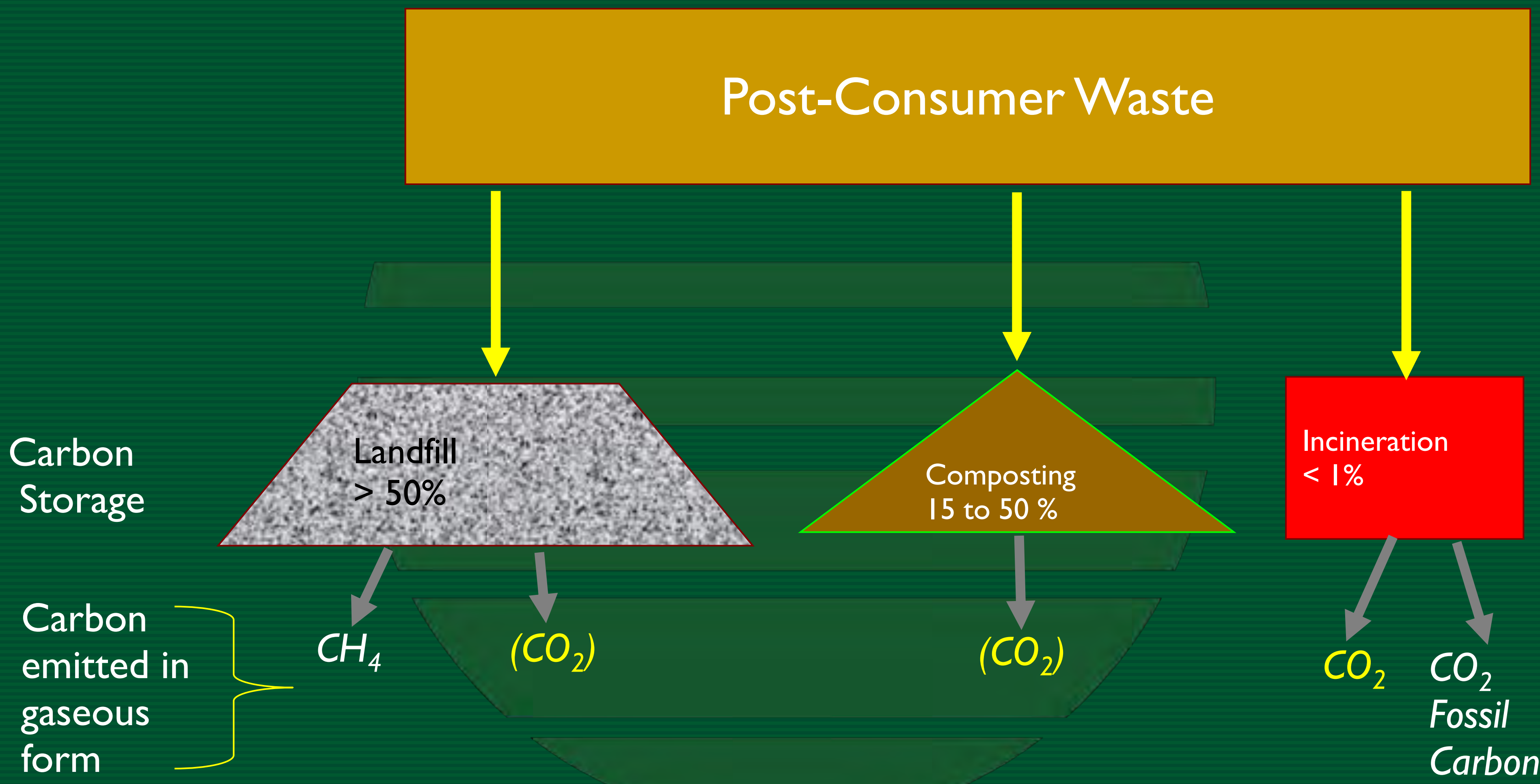
Carbon Flows for Post-Consumer Waste



(CO_2) from biomass is not included in GHG inventories of waste

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Full Scale Composting

Objective: Reliable, cost-efficient production of quality compost

- Pre-processing/feedstock preparation
- Composting
- Refinement of finished product (post-processing)
- Compost application

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Potential Options to Increase Organics Diversion

- System options relevant to this presentation include:
  - composting
  - anaerobic digestion and composting

Potential Options to Increase Organics Diversion (cont.)

- Sources of organics/increased diversion:
  - residential (e.g., food waste and yard waste, 5% to 35% of sector)
  - commercial/institutional (e.g., restaurant and market wastes, landscaping waste, 5% to 20% of sector)
  - industrial/C&D (e.g., wood waste)

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Potential Solutions: Energy-Agro-Waste Systems for Maximum Efficiency

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Introduction

- Communities are not planned from the outset for optimal utilization of materials and energy
- Community systems are composed of a number of individual subsystems, e.g.:
  - food production
  - wastewater treatment
  - electricity supply
  - Solid waste processing

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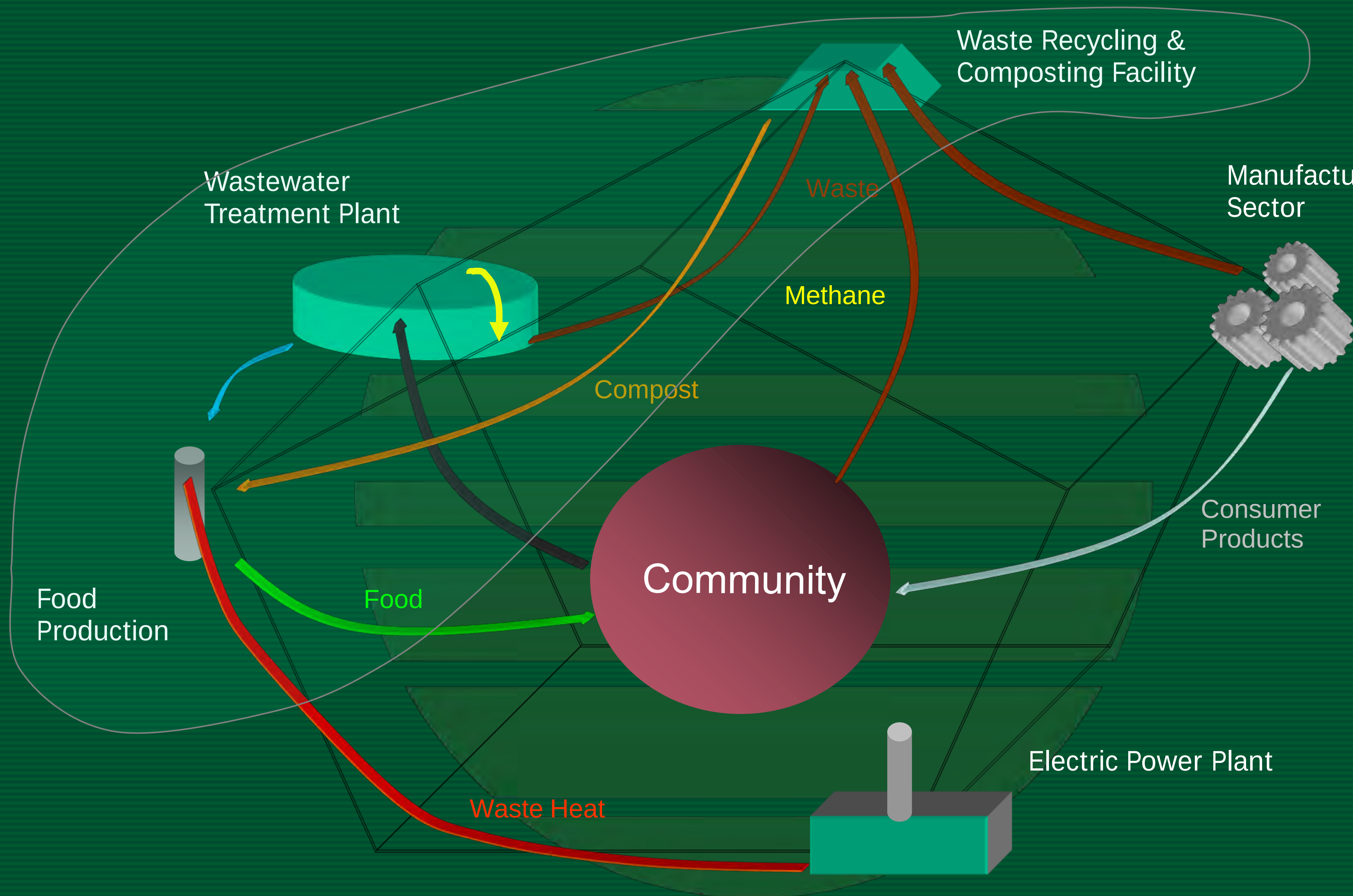
Community Support Subsystems



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Community Support Subsystems

- Design of any one subsystem does not take into account impact on all of the other subsystems
- Planned development of community systems needs to account for mass and energy balances among subsystems -- result:
  - high overall system efficiency
  - reduced net waste production
  - conservation of energy
  - overall optimum use of resources

Models of Unit Processes

- Requirements for modeling unit processes:
  - identification of fundamental variables
  - governing relations among variables (inputs and outputs)
  - reliable scientific data
  - foresight to identify common inputs and outputs among different types of unit processes

INTEGRATION

Models of Unit Processes (cont.)

- For systems using biological processes, e.g., humans, animals, microorganisms (composting operations), two fundamental governing conditions are required to support life:
  - source of energy
  - macro-nutrients (nitrogen, phosphorus, potassium)

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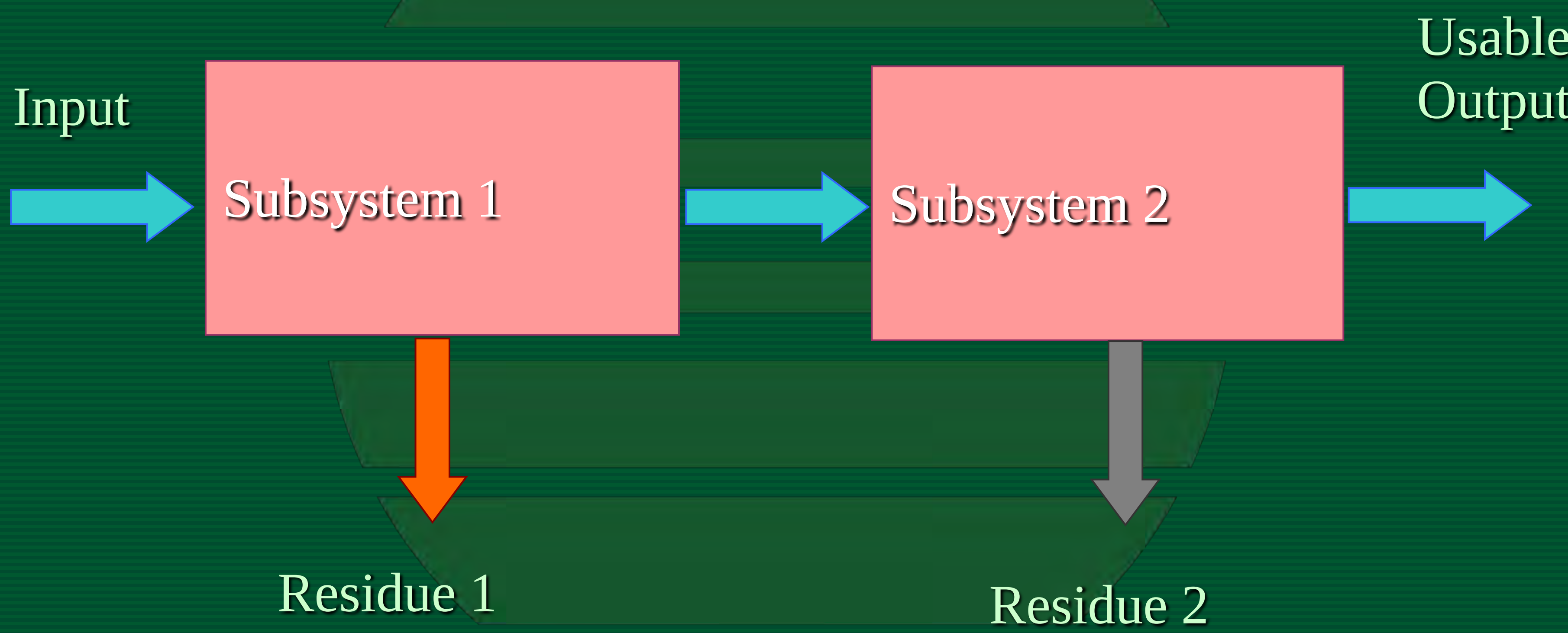
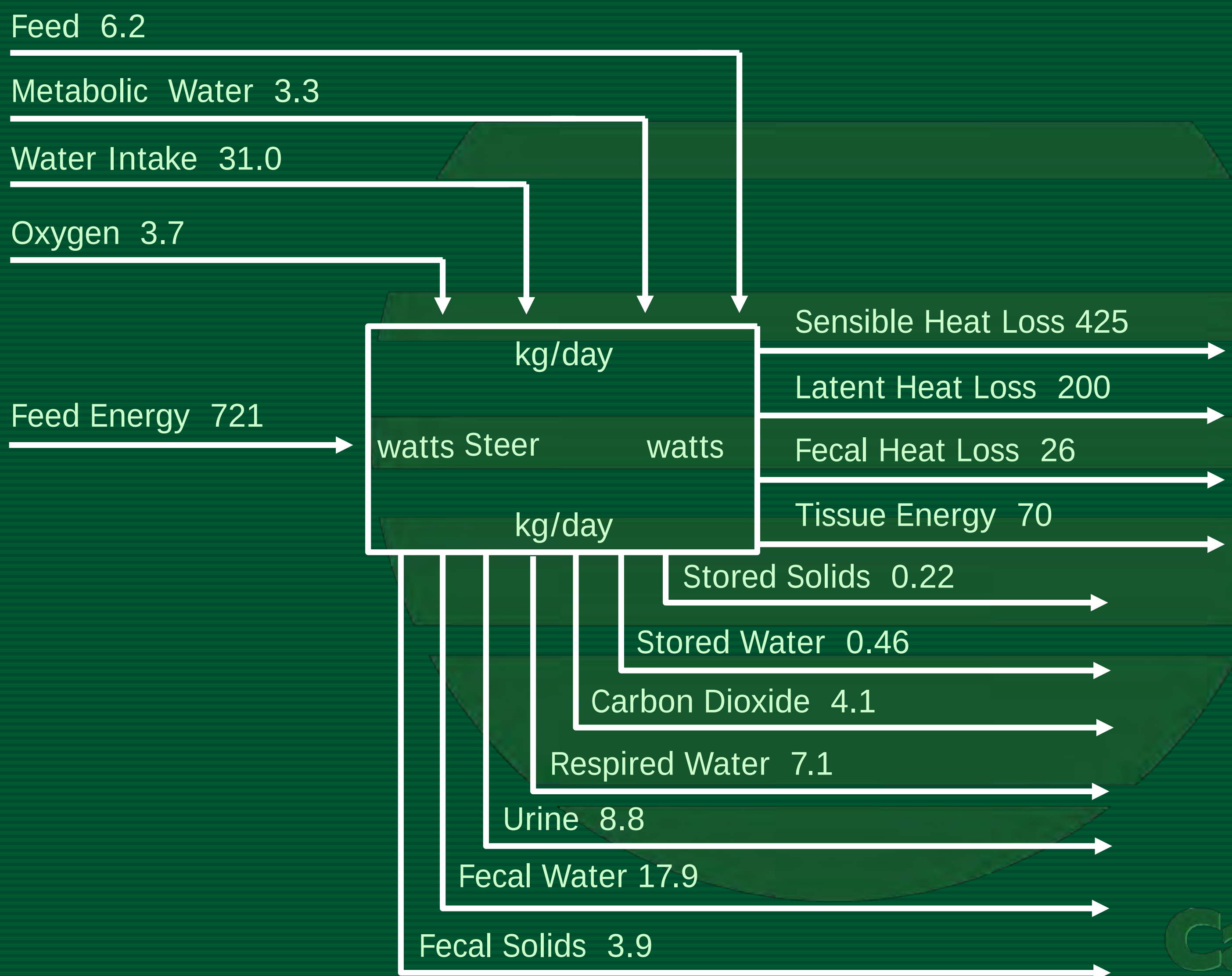
Models of Unit Processes (cont.)



Potential Roles of Some Unit Processes in Integrated Complexes

Unit Process	Primary Role in System	Use of Waste Heat	Possible Recycled Inputs	Possible Recycled Outputs
Cattle	Meat production	Housing	Chicken manure and bedding, water hyacinths, crop residues, algae	Manure, slaughter wastes
Swine	Meat production	Housing	Cattle manure and bedding, water hyacinths, crop residues, algae	Manure, slaughter wastes
Catfish	Fish production	Water warming	Feedlot manure, algae	Slaughter wastes, fish wastes
Green-houses	Plant production (vegetables, flowers)	Maintenance of optimum temperature	CH_4 for heating, CO_2 enrichment, composted sludge, and crop residues	Crop residues
Anaerobic digestion	Water treatment, methane production	Maintenance of optimum temperature	All types of organic wastes	CH_4, CO_2, supernatant, sludge

Mass and Energy Balance Diagram for Beef Production



Results for 100-Steer Rearing Operation

- Masses are balanced if integrated complex is designed with:
  - 4-ha greenhouse facility
  - 140-m^3 digester
  - 8.3-ha alfalfa and 13-ha corn fields
- Total area of complex is 26 ha (excluding electric power plant)

Summary

- Community support services that can be integrated into sustainable overall systems include wastewater treatment, food production, energy generation, and solid waste treatment

- The development of mass and energy balances requires:
  - knowledge of fundamental governing principles and parameters of processes
  - application of forethought and analysis to select appropriate common parameters among a potential group of processes being considered for integration into a total system

Summary (cont.)

- Mathematical modeling of mass and energy balances of processes that support communities can be used to optimally integrate processes

- Modeling of community support systems is not without problems

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Summary (cont.)

- Concept of process integration can be extended beyond waste management to include integration of other types of community support services, of which waste management itself could be one key component
- Concept of overall community subsystem integration is considered essential in developing sustainable communities that conserve natural resources, maintain quality of human life, and protect environment

Concluding Remarks

Status of our Industry

Many changes have taken place in waste management practices during the last 70 years

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Status of our Industry (cont.)

- However, still consuming large quantities of items each day
- As an example, in the EU each person produced:
  - 460 kg of solid waste per year in 1995
  - 520 kg of solid waste per year in 2004
  - 680 kg of solid waste per year (projected in 2020)

Critical Interventions Toward Improvement

- Standardize collection system:
  - storage containers
  - type and frequency of service
- Provide reliable collection service to entire population
- Establish transport and transfer systems
- Identify and set up a sound final disposal system

Final Disposal System

- Should include:
  - closure of dumpsites
  - improvement of controlled sites
- Design and operate modern sanitary landfills
- Modern does not necessarily mean to immediately adopt other countries' stringent regulations (e.g., Germany, USA)

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Other Important Interventions

- Establish comprehensive recycling programs
- Identify uses/markets for the recyclables materials
- Develop programs to manage the organic fraction of the waste
- Establish cost recovery mechanisms
- Determine role of recycling in economy

Conclusions/Recommendations

- Limited or conflicting information to make important management decisions
  - Need reliable, scientifically based information
- Veracity in reporting results of programs
- Strategies used by most industrialized countries:
  - Waste minimization
  - Recycling (including bio treatment)
  - Waste diversion from landfill

Conclusions/Recommendations

- Strategies used by most economically developing countries:
  - Informal recycling
  - Final disposal in the land
- Following are some specific suggestions for economically developing countries

Keys to Success

- Political will to solve the problem of waste management
- Development of realistic plans:
  - appropriate technology (site selection, facility design)
  - available resources (financial and human) for sustainable operations
  - availability of uses/markets (product quality)
- Establishment of sound final disposal sites

Keys to Success

- Education
- Education
- Education

- AND

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Lifestyle Germany

example food (source: Menzel, So isst der Mensch, 2005)

Food for one week

"Lifestyle" Rural Area - Ecuador

example food (source: Menzel, So isst der Mensch, 2005)

Food for one week