Fundamentals of Sustainable Waste Management Part 2

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Fundamentals of Sustainable Waste Management

Course Objective:

To equip you with understanding, strategies and decision making tools for advancing toward sustainable waste management.

Fundamentals of Sustainable Waste Management

Outline:

Part 1

I. Sustainability Principles

II. Waste Management Hierarchy

Application: Framework for Change

Part 2

III. Evaluation Tools

IV. Case Studies

Application: Elements of Successful Projects

III. Evaluation Tools

Section Objective

To present a brief introduction to tools that are available to assist with planning integrated solid waste management systems.

“If you want to teach people a new way of thinking, don't bother trying to teach them. Instead, give them a tool, the use of which will lead to new ways of thinking.” Richard Buckminster Fuller

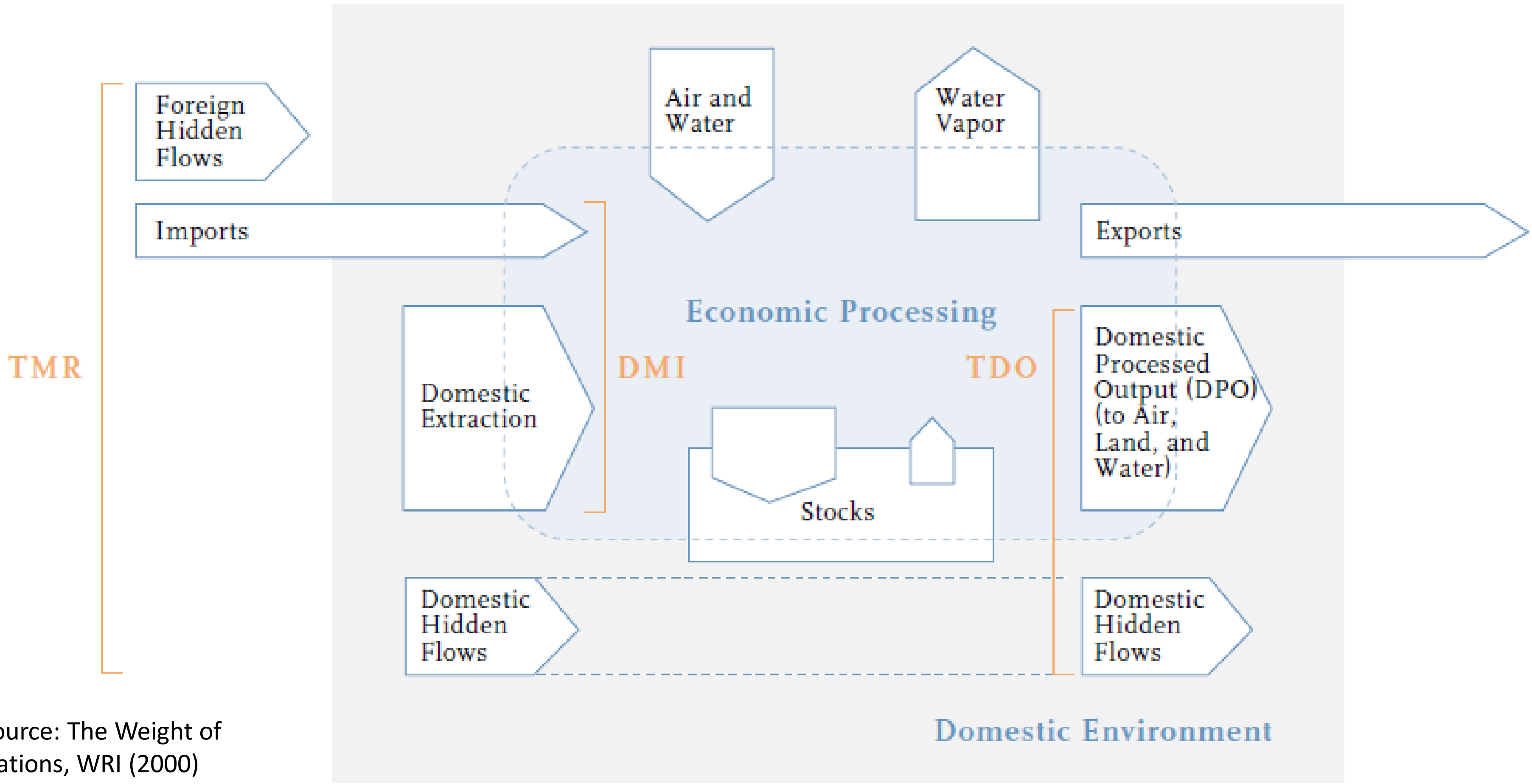
III. Evaluation Tools

Overview

- Material Flow Analysis
- Greenhouse Gas Accounting
- Life-Cycle Assessment Models
  - EASEWASTE (DTU)
  - WARM (USEPA)
  - SWOLF (NCSU)

III. Evaluation Tools
Material Flow Analysis

FIGURE 1 | THE MATERIAL CYCLE



Source: The Weight of Nations, WRI (2000)

III. Evaluation Tools
Greenhouse Gas Accounting

- International Standards (not source specific)
  - ISO 14064 Stds for Greenhouse Gas Accounting & Verification
  - “GHG Protocol” Accounting Framework (WRI/WBCSD)
- Standards Specific to Waste Management
  - EpE Protocol for the Quantification of GHG Emissions from Waste Management Activities (fully compatible with the international standards listed above)
  - USEPA’s GHG Reporting Program, Subpart HH for Municipal Solid Waste Landfills (40 CFR 98.340)

III. Evaluation Tools

LCA Models - Overview

Life-Cycle Assessment Process:

- Define the system boundary
- Inventory inputs and outputs
- Evaluate environmental impacts
- Interpret results

III. Evaluation Tools

LCA – Los Angeles County Example

Evaluation of Green Waste Management Impacts on GHG Emissions Alternative Daily Cover Compared with Composting

By Dung Kong, Ray Huitric, Mario Iacoboni and Grace Chan

This study supports the reported benefits of composting but also shows that green waste ADC can actually be more beneficial in reducing GHG emissions when compared to the composting of green waste. This result indicates the importance of site-specific environmental analysis when considering organics management options.

III. Evaluation Tools

LCA Models - EASEWASTE

- Environmental Assessment of Solid Waste Systems and Technologies (EASEWASTE) developed at the Technical University of Denmark (DTU)
- "Global Warming Factors Modelled for 40 Generic Municipal Waste Management Scenarios," Christensen, Simion, Tonini and Moller, Waste Management & Research, 2009.

III. Evaluation Tools

LCA Models - EASEWASTE

Global warming factors modelled for 40 generic municipal waste management scenarios

Table 6: Disaggregated GHG emissions (kg CO_2-equivalents/1000 kg of waste) for landfill- based scenarios.

Scenario	Total	Collection	Transport	Recycling of paper	Recycling of glass	Recycling of plastic	Composting plant (total)	Use of compost	Digester (total)	Use of digestate	Landfill: operation	Landfill: gas emissions	Landfill: energy recovery	Landfill: C-binding
LAN1-0	18	9	16	–	–	–	–	–	–	–	22	233	–	–261
LAN2-0	–112	9	16	–	–	–	–	–	–	–	22	232	–129	–261
LAN3-0	–275	9	16	–	–	–	–	–	–	–	21	102	–202	–221
LAN1-1	–207	10	19	–255	–8	–	–	–	–	–	18	183	–	–172
LAN2-1	–309	10	19	–255	–8	–	–	–	–	–	18	183	–102	–172
LAN3-1	–437	10	19	–255	–8	–	–	–	–	–	17	80	–158	–141
LAN1-2	–216	10	19	–255	–8	–10	–	–	–	–	18	183	–	–172
LAN2-2	–318	10	19	–255	–8	–10	–	–	–	–	18	183	–102	–172
LAN3-2	–446	10	19	–255	–8	–10	–	–	–	–	17	80	–158	–141
LAN1-3	–277	12	18	–255	–8	–10	23	–3	–	–	13	106	–	–172
LAN2-3	–335	12	18	–255	–8	–10	23	–3	–	–	12	106	–59	–172
LAN3-3	–396	12	18	–255	–8	–10	23	–3	–	–	12	46	–92	–141
LAN1-4	–318	12	21	–255	–8	–10	–	–	–34	–6	14	120	–	–172
LAN2-4	–385	12	21	–255	–8	–10	–	–	–34	–6	14	120	–67	–172
LAN3-4	–458	12	21	–255	–8	–10	–	–	–34	–6	13	53	–104	–141

Source: Christensen, Simion, Tonini, Moller (2009)

III. Evaluation Tools
LCA Models - EASEWASTE

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III. Evaluation Tools

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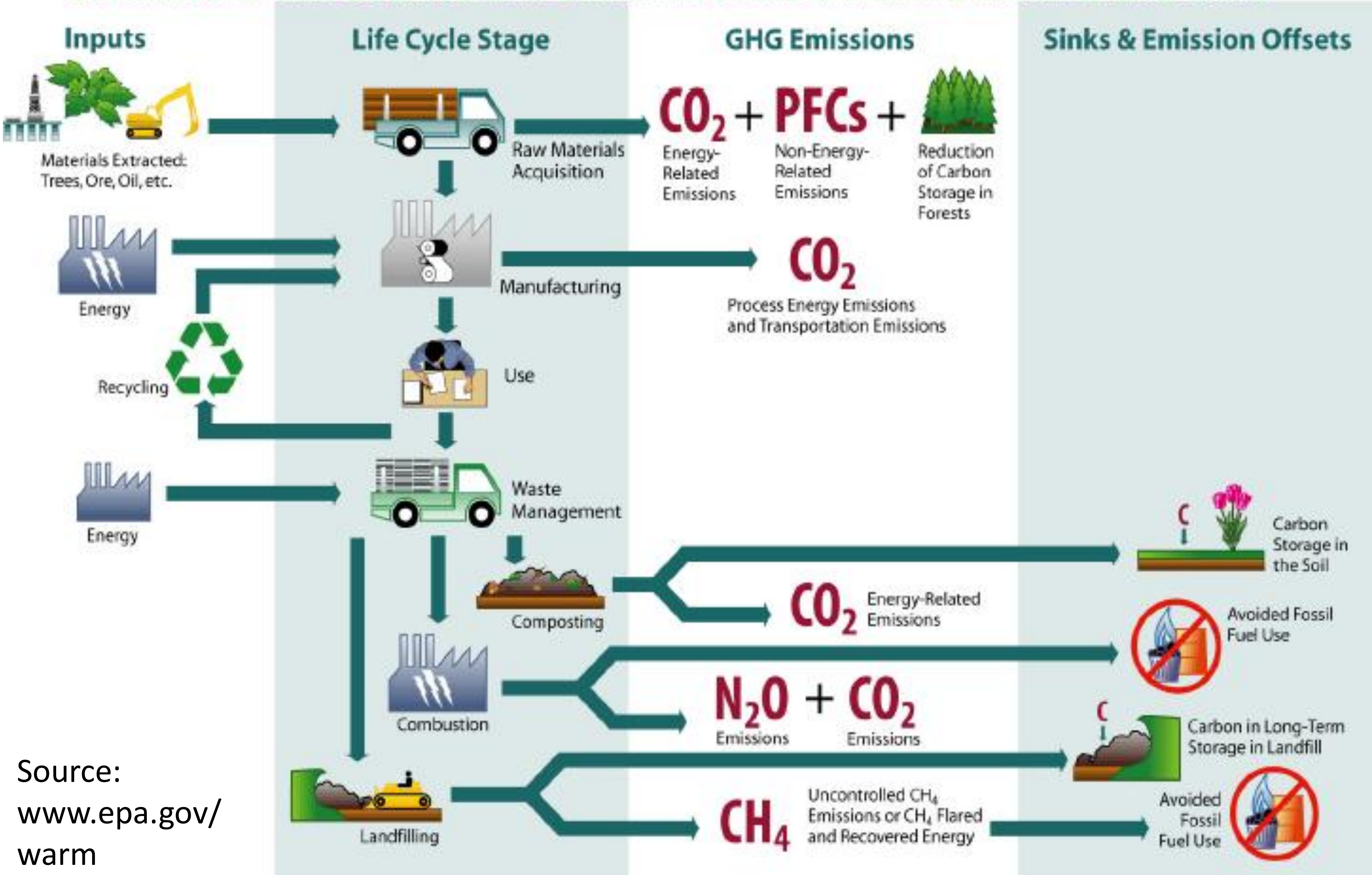
Source: Christensen, Simion, Tonini, Moller (2009)

III. Evaluation Tools

LCA Models - WARM

- USEPA Waste Reduction Model (WARM)
  - Available at www.epa.gov/warm

Figure 1
Greenhouse Gas Sources and Sinks Associated with the Material Life Cycle



Source: www.epa.gov/warm

Table 1
Materials in WARM

Aluminum Cans	Medium Density Fiberboard
Branches	Mixed Metals
Carpet	Mixed MSW
Clay Bricks	Mixed Organics
Coal Fly Ash	Mixed Paper (3 mixes)
Concrete	Mixed Plastics
Copper Wire	Mixed Recyclables
Corrugated Cardboard	Newspaper
Dimensional Lumber	Office Paper
Food Scraps	Personal Computers
Glass	PET
Grass	Phonebooks
HDPE	Steel Cans
LDPE	Textbooks
Leaves	Tires
Magazines/third-class mail	Yard Trimmings

Source: www.epa.gov/warm

1. **Describe the baseline generation and management for the MSW materials listed below. If the material is not generated in your community or you do not want to analyze it, leave it blank or enter 0. Make sure that the total quantity generated equals the total quantity managed.**

Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum Cans				NA
Aluminum Ingot				NA
Steel Cans				NA
Copper Wire				NA
Glass				NA
HDPE				NA
LDPE	NA			NA
PET				NA
LLDPE	NA			NA
PP	NA			NA
PS	NA			NA
PVC	NA			NA

Source:
WARM.xls
screenshot

2. Describe the alternative management scenario for the MSW materials generated in the baseline.
Any decrease in generation should be entered in the Source Reduction column.
Any increase in generation should be entered in the Source Reduction column as a negative value.
(Make sure that the total quantity generated equals the total quantity managed.)

Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
				NA
				NA
				NA
				NA
				NA
				NA
	NA			NA
				NA

Source:
WARM.xls
screenshot

Total Change in GHG Emissions ($MTCO_2E$): (1)

This is equivalent to...

Removing annual emissions from	**0**	Passenger Vehicles
Conserving	**58**	Gallons of Gasoline
Conserving	**21**	Cylinders of Propane Used for Home Barbeques
Conserving	**0**	Railway Cars of Coal
	0.00000%	Annual CO_2 emissions from the U.S. transportation sector
	0.00000%	Annual CO_2 emissions from the U.S. electricity sector

Source:
WARM.xls
screenshot

III. Evaluation Tools
LCA Models - WARM

Example presentation of WARM results:

- Recycling, instead of landfilling, 600 tons of corrugated cardboard, avoids GHG emissions equivalent to those generated annually by 378 passenger vehicles.
- This activity is also equivalent to avoiding the CO_2 emissions from burning 10.8 railcars worth of coal.

Source: WARM.xls screenshot

III. Evaluation Tools

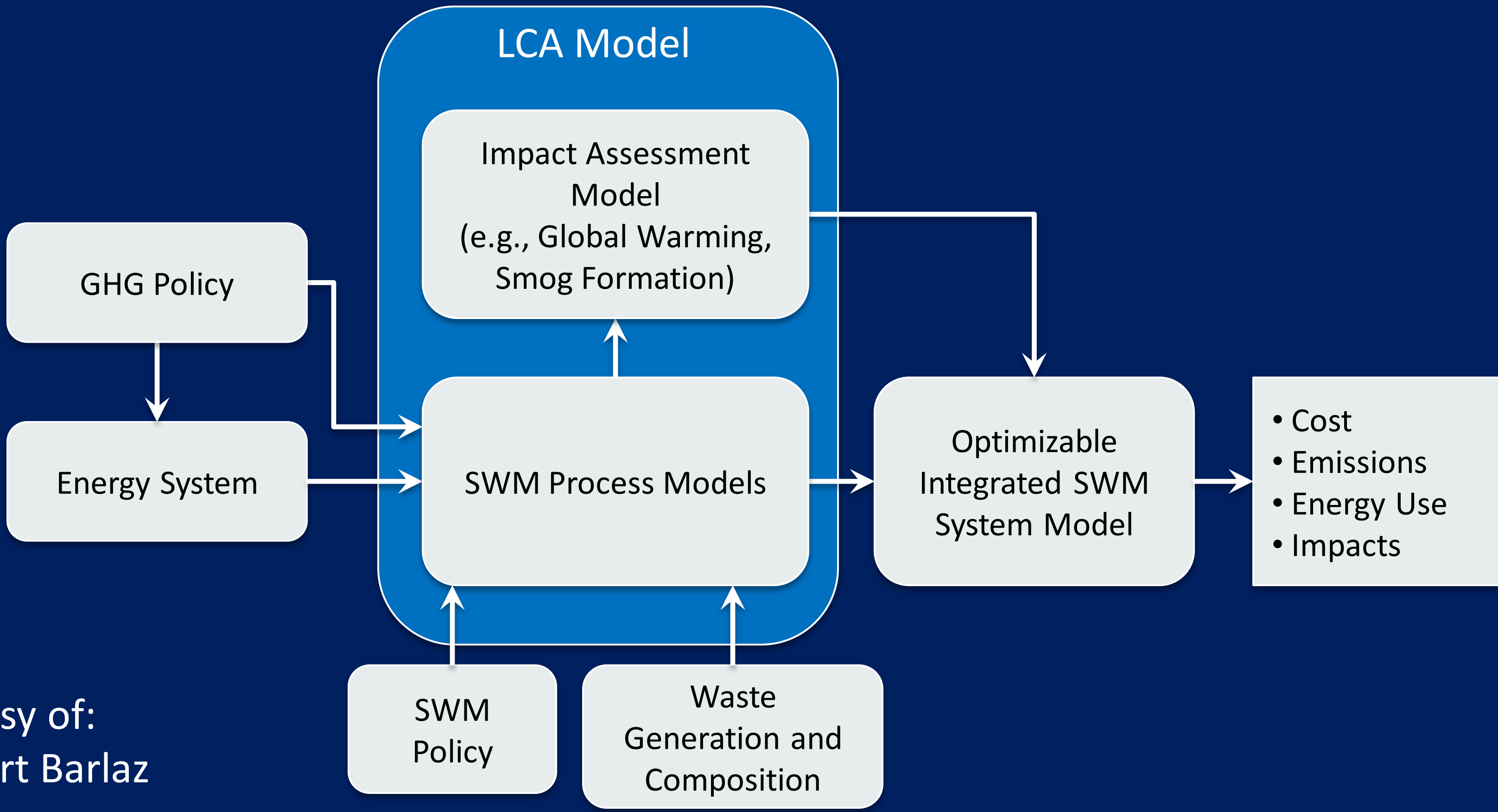
LCA Models - SWOLF

North Carolina State University's Solid Waste Optimization Life-Cycle Framework (SWOLF)

Research objective

- Evaluate system performance (i.e., economical, environmental) while accounting for changes to waste composition and generation, SWM policy, the U.S. energy system, and potential future GHG mitigation policies

Solid Waste Optimization Life-cycle Framework (SWOLF)



Courtesy of:
Dr. Mort Barlaz

NC STATE UNIVERSITY

Optimization model to explore solid waste management alternatives using life-cycle analysis

- How can net present cost be minimized over time?
  - While meeting diversion or greenhouse gas constraints
  - Considering existing infrastructure
- How can environmental benefits be maximized?
  - Minimize greenhouse gas emissions
  - Minimize fossil energy use
  - Maximize landfill diversion
  - Impose a budget constraints

Courtesy of:
Dr. Mort Barlaz

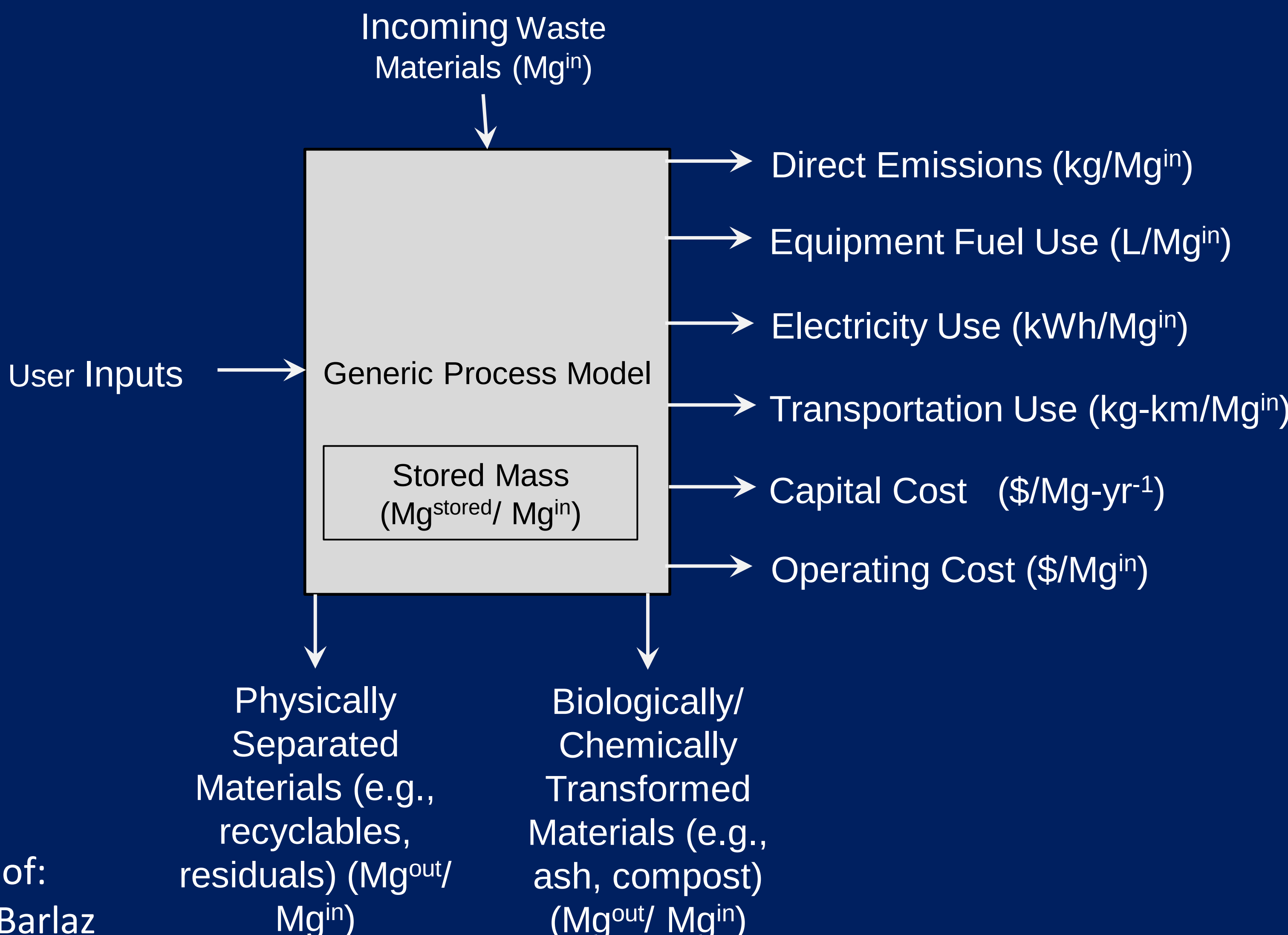
Process modeling

- Process level life-cycle assessment models form the foundation of this work
- Process models are developed “bottom-up” to determine the costs, emissions, and environmental impacts associated with each process in consideration of waste quantities and composition
- Process models are then linked using mass balance equations to develop full system models
- Included Processes
  - Collection
  - Transfer Stations
  - Material recovery facilities
  - Anaerobic Digestion
  - Composting
  - Landfills
  - Remanufacturing
  - Waste-to-energy

Courtesy of: Dr. Mort Barlaz

NC STATE UNIVERSITY

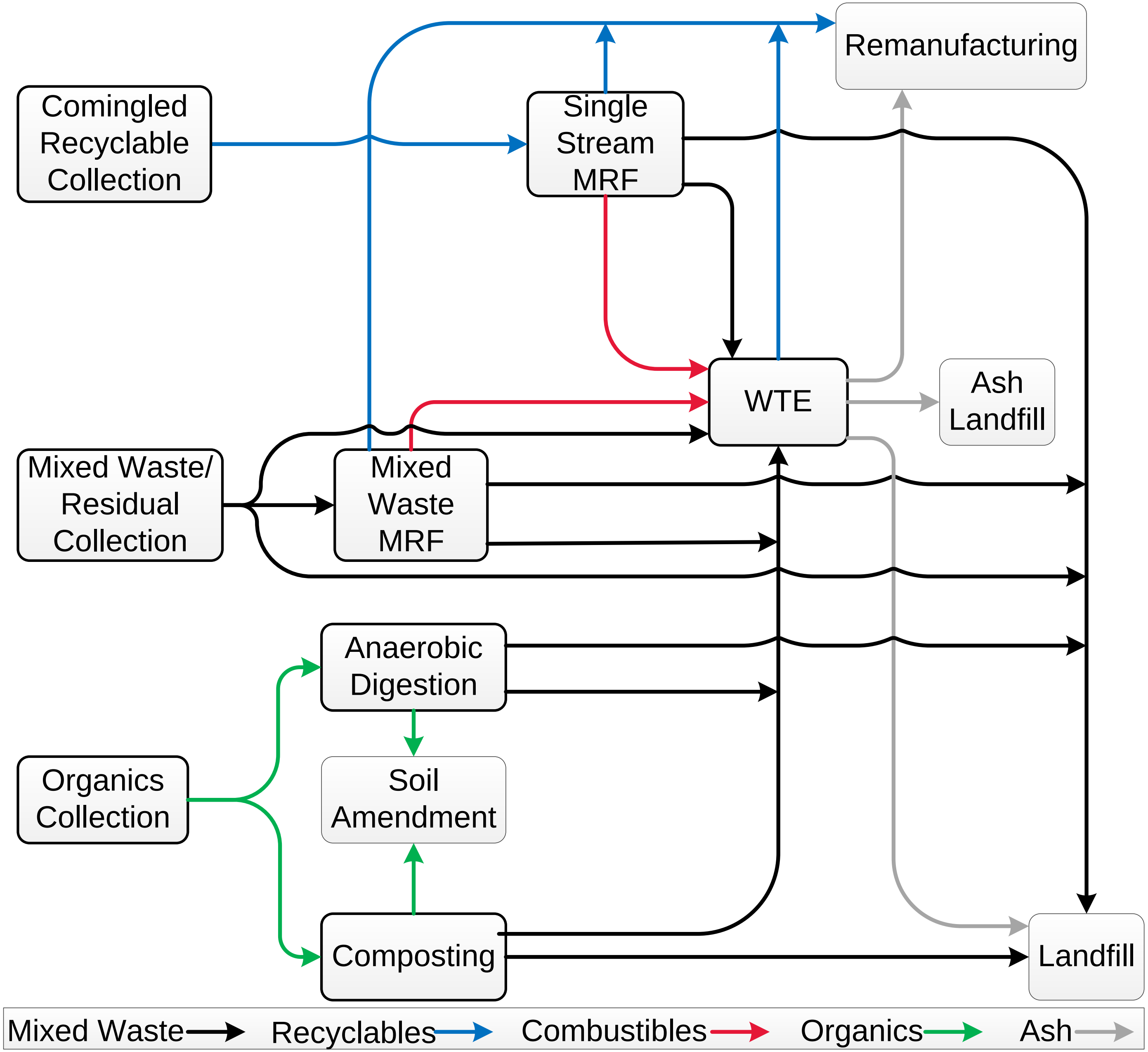
Generic process model for cost and life-cycle emissions estimation



Courtesy of:
Dr. Mort Barlaz

Illustrative system - potential mass flows

NC STATE UNIVERSITY



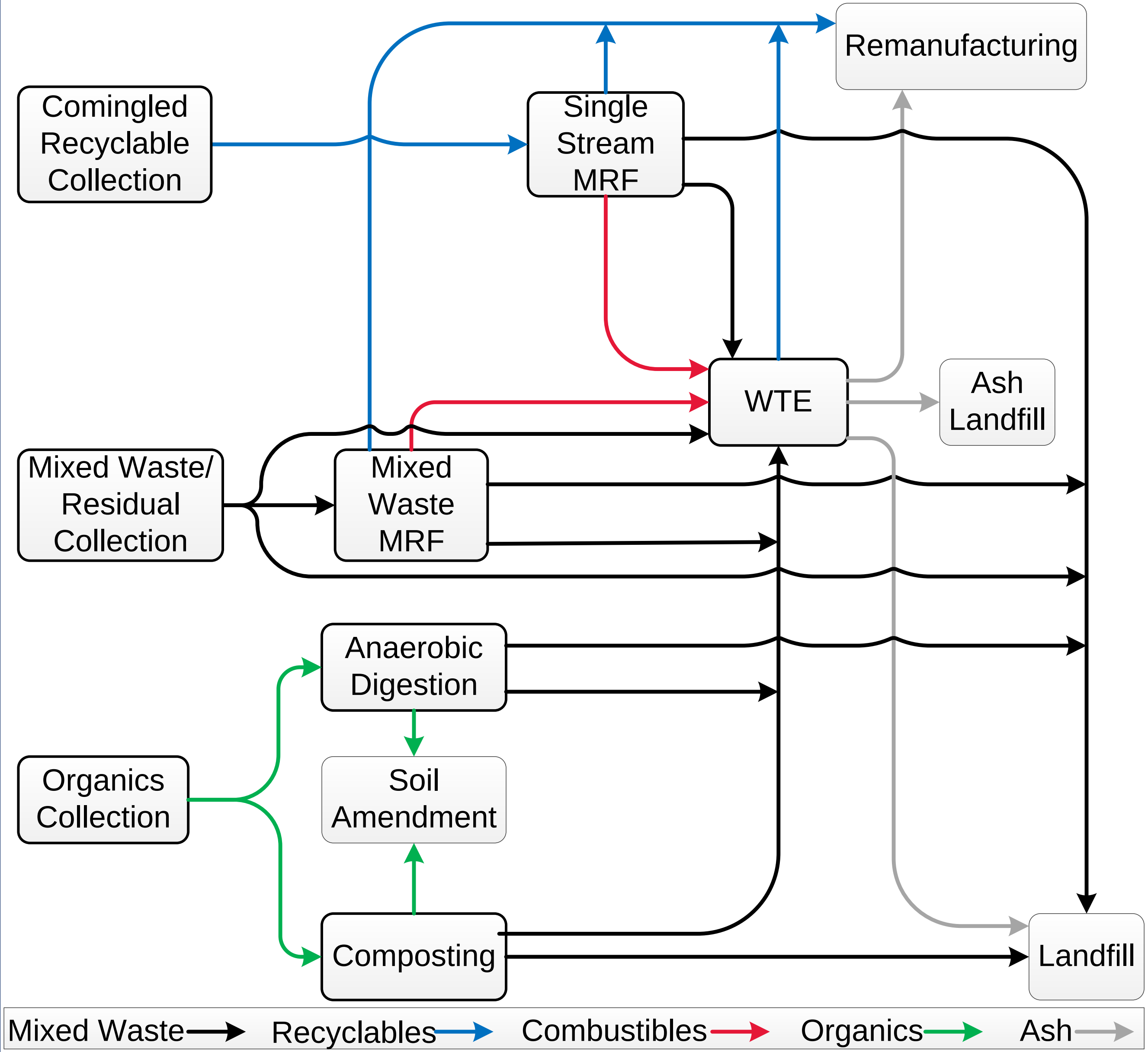
WTE-Waste-to-Energy MRF-Material Recovery Facility

Courtesy of: Dr. Mort Barlaz

Representative SWM system

Existing system

- Single stream MRF with 12,000 Mg/yr capacity and 20 years of remaining life
- Composting with 6000 Mg/yr capacity and 20 years of remaining life
- Existing landfill has enough capacity to accept all generated waste over the decision horizon



WTE-Waste-to-Energy MRF-Material Recovery Facility

Courtesy of:
Dr. Mort Barlaz

Illustrative SWM analysis

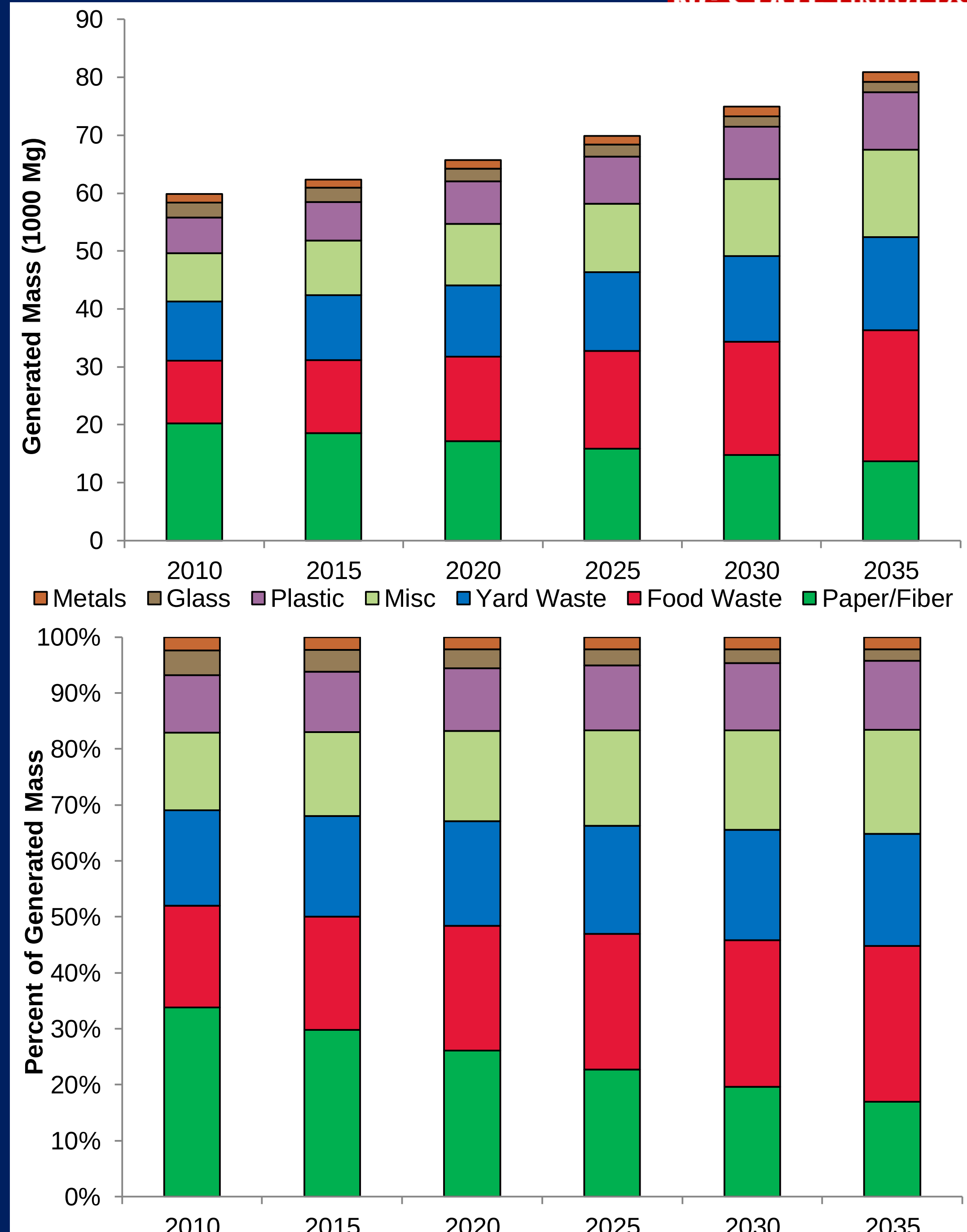
- Analyze how SWM strategies are affected by future changes to waste generation, composition, and the energy system

Cases	Description
Business-as-usual (BAU):	No new facilities
Min Cost	Minimize net present cost
Max Diversion	Minimize landfilled waste
Min GHG	Minimize 30-year cumulative GHG emissions

Courtesy of: Dr. Mort Barlaz (modified)

Representative SWM system

- Mass based on city of 100,000 with annual population growth of 4%
- Model considers 30 waste materials
- Waste composition and trends developed from EPA 2012 MSW Facts and Figures[1]
- System changes and decisions made in 5 year increments
  - Population
  - Waste generation and composition
  - SWM policy
  - Energy system
  - Greenhouse gas policy

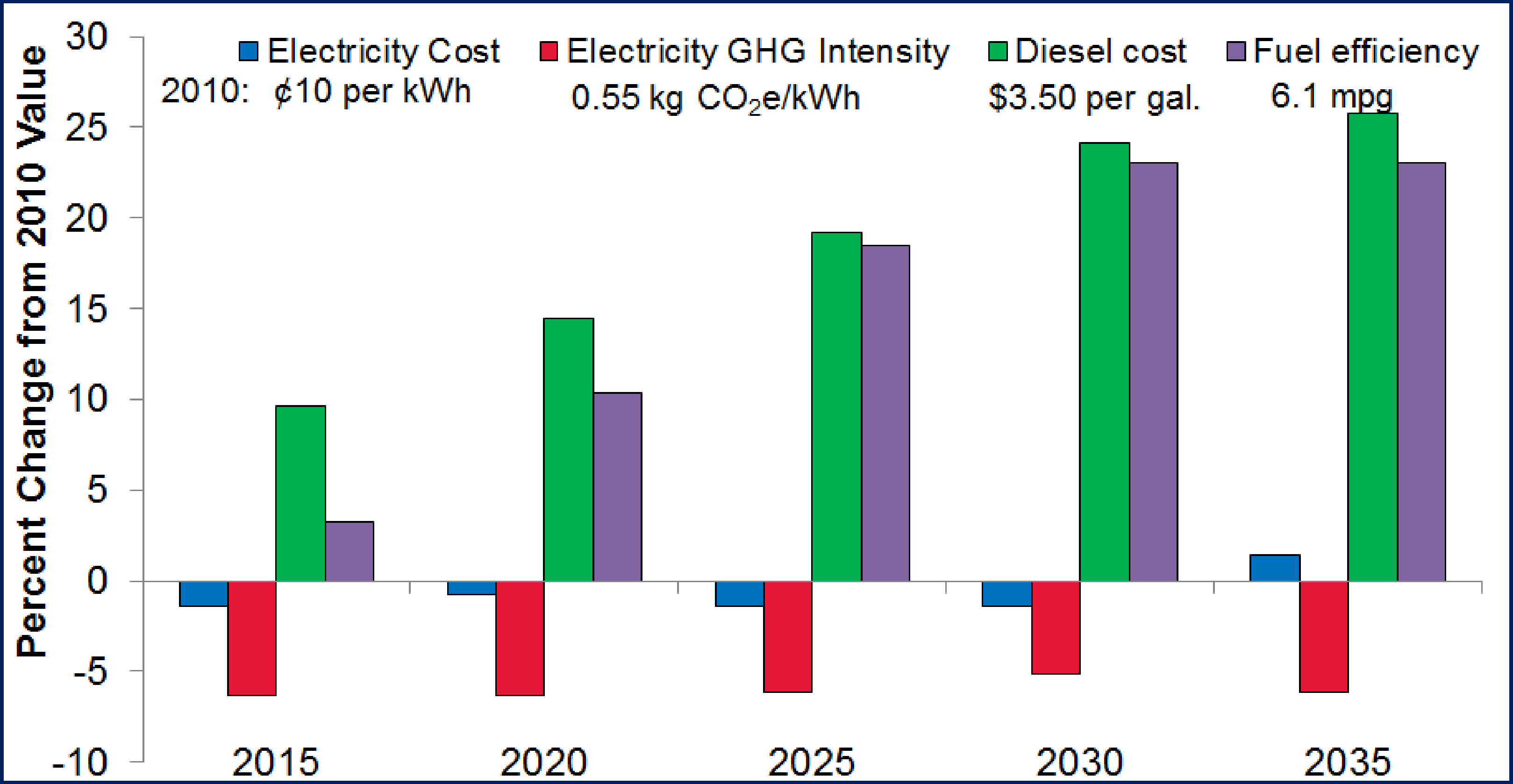


Courtesy of: Dr. Mort Barlaz

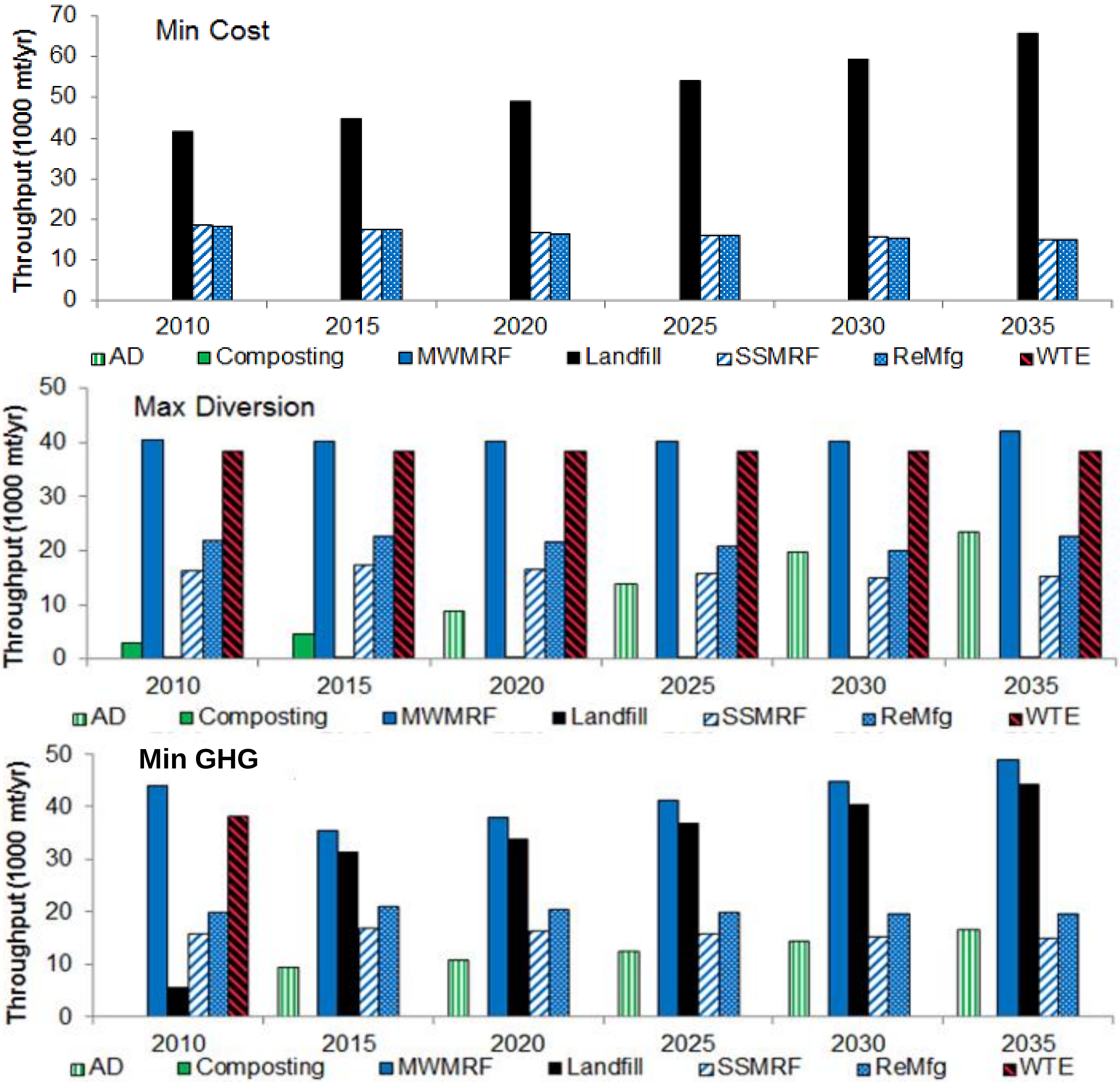
[1]*Municipal solid waste generation, recycling, and disposal in the United States: Tables and figures 2010;* United State Environmental Protection Agency: Washington, DC, 2011.

Energy modeling

- The energy model considered changes to electricity cost ($/kWh), electricity GHG intensity ($/kg CO2e), diesel cost ($/L) and heavy duty vehicle fuel efficiency (L/km)



Courtesy of: Dr. Mort Barlaz (modified)



- Min Cost: Landfilling dominates.
- Max Diversion: MWMRF and WTE dominate.
- Min GHG: MWMRF and landfilling dominate.

Courtesy of: Dr. Mort Barlaz (modified)

Courtesy of:
Dr. Mort Barlaz

Base results

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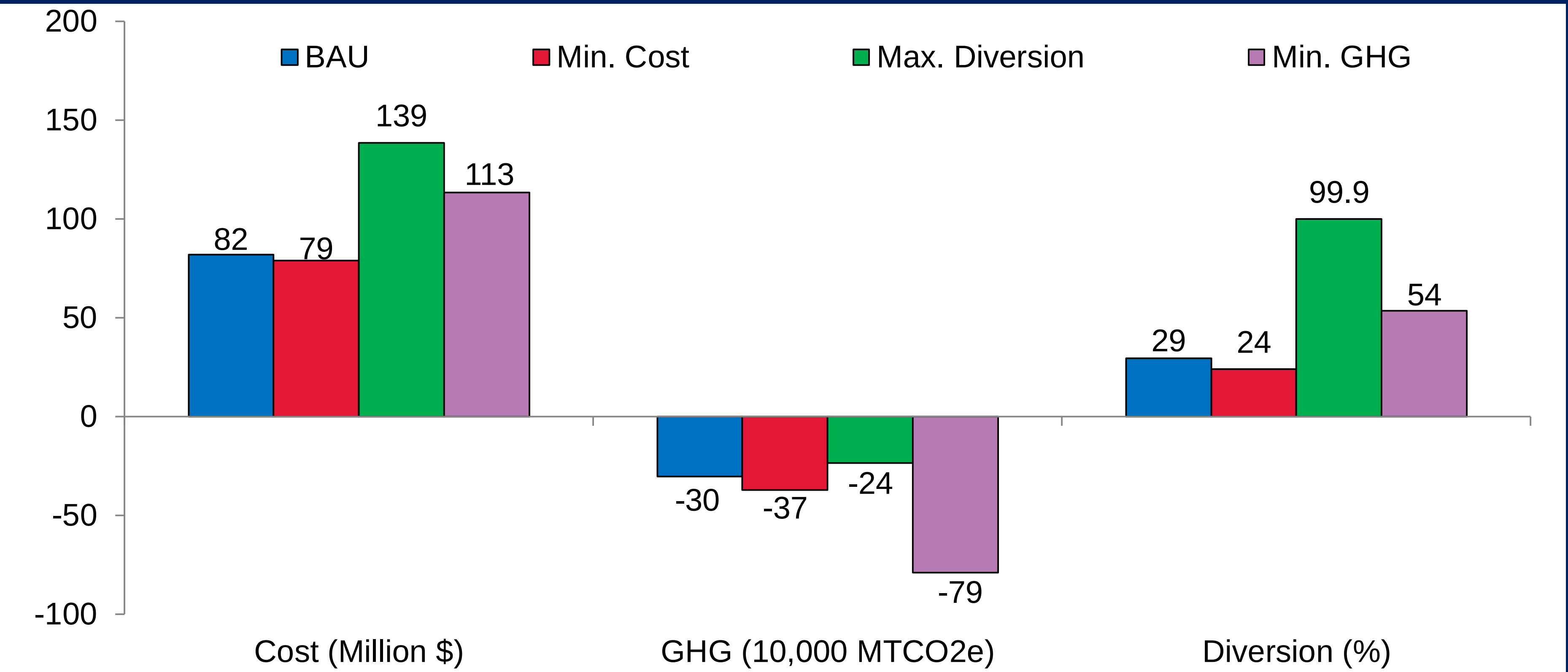
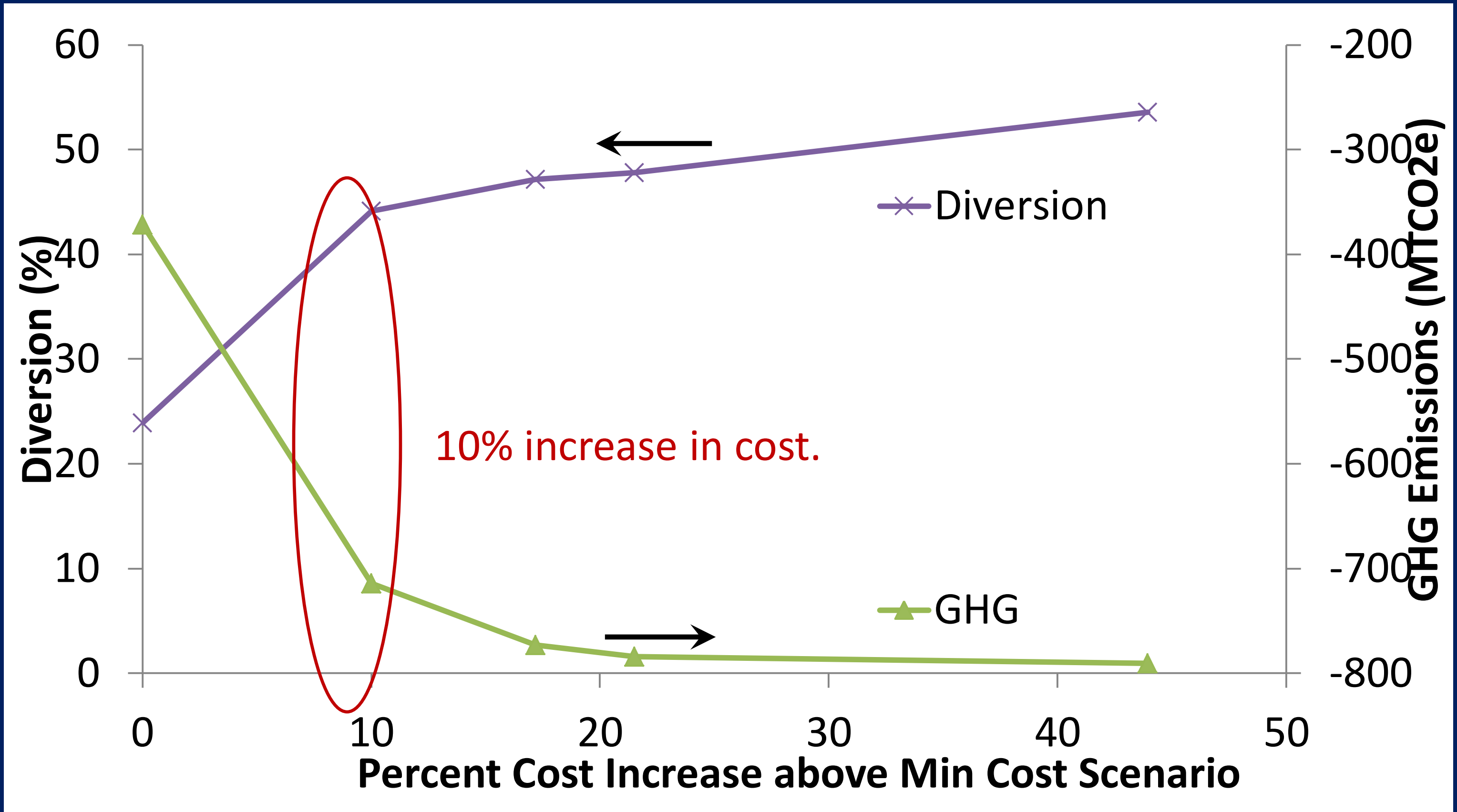


- Negative GHG emissions are due to electricity generation offsets (AD, landfill, WTE), material recovery offsets, and carbon storage (AD, composting, landfill)
- Min Cost reduces cost and GHG emission compared to the BAU case by eliminating yard waste composting
- Min GHG case reduces cost and GHG emissions compared to the Max Diversion case by eliminating WTE combustion and more selective recycling and landfilling

Cost-GHG trade-off



Courtesy of: Dr. Mort Barlaz (modified)

Illustrative case study - Discussion

- A single stream MRF was selected in every scenario .
  - earns net revenue
  - reduces GHG emissions
  - increases diversion
- The materials recovered vary based on the objective.
- In the Max Diversion and Min GHG cases, AD, composting, recycling, and landfill throughputs change in stages as waste composition and generation change.
- Min Cost case also adjusted recycling/landfilling based on composition and generation.

Courtesy of: Dr. Mort Barlaz (modified)

Illustrative case study - Discussion

- The Min Cost case was able to reduce GHG emissions while saving money over the Business as Usual scenario by eliminating yard waste composting

- Changing composition and changes to the energy system can affect technology choice
- Combustion minimized cost early with higher paper and lower plastic in waste, but was discontinued in later stages.

- Results show that GHG emissions may increase with increased diversion (e.g., composting branches, recycling office paper or magazines)

Courtesy of: Dr. Mort Barlaz

IV. Case Studies

Objective:

To present case studies linked to the levels of the material management hierarchy that illustrate the successful application of sustainability principles.

"You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete." Richard Buckminster Fuller

IV. Case Studies

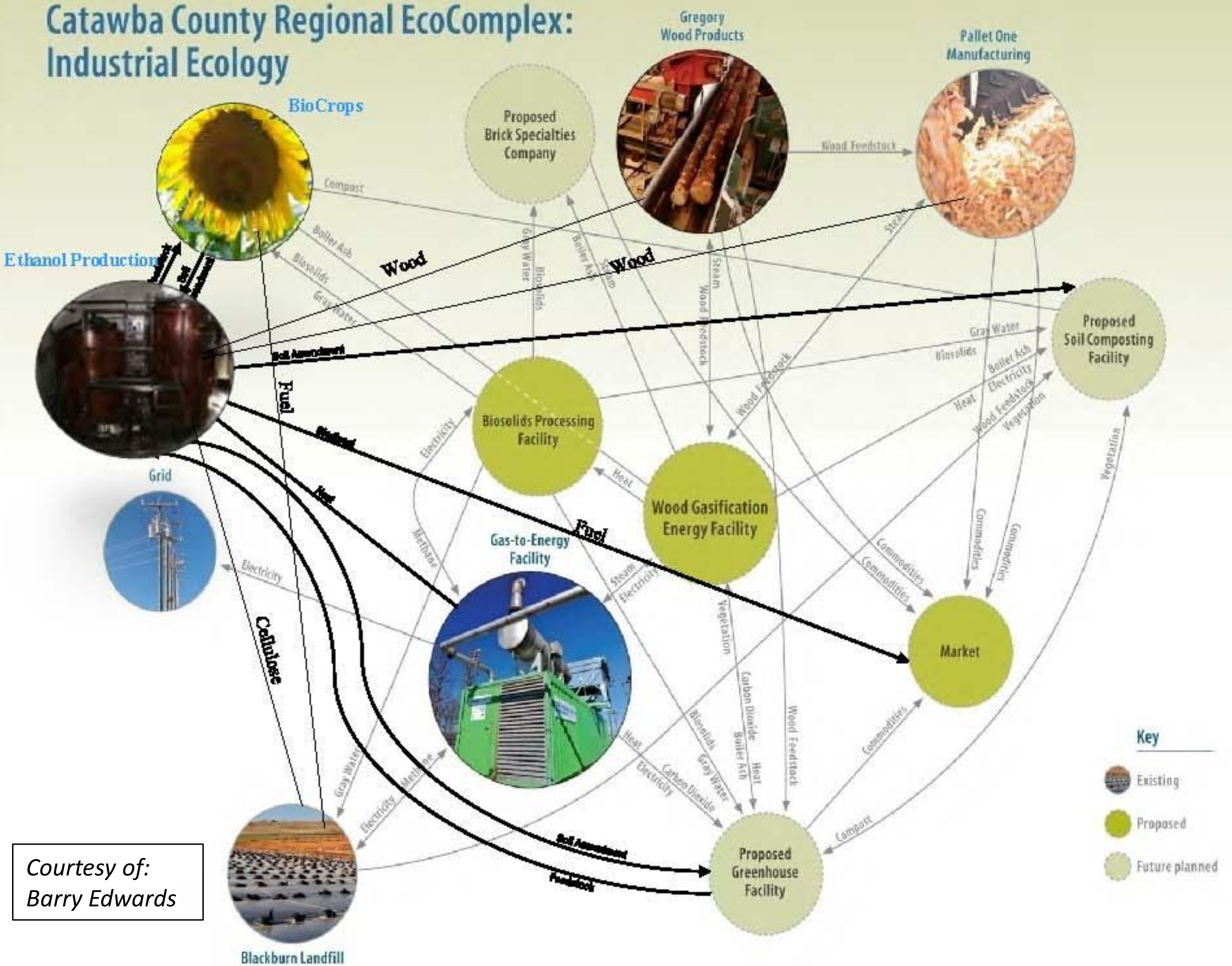
Catawba County EcoComplex

- Hierarchy Level: 1.Source Reduction/Reuse, 2.Recycling & Composting, 3. Energy Recovery and 4.Landfilling (with Energy Recovery)
- Key Concept: Industrial Ecology
- Key Leader: Barry Edwards, P.E.
- Key Driver: Finding value in “waste” by seeing relationships.
- Tools Used: Custom analyses

CATAWBA COUNTY
EcoComplex

Industrial Ecology Applications in Improving Solid Waste Management

Courtesy of:
Barry Edwards



Courtesy of:
Barry Edwards

Blackburn Resource Recovery Facility

Courtesy of:
Barry Edwards

Catawba County-Appalachian State University
Biodiesel Research, Development and Production Facility

Cultivating Crops for Biodiesel Research

Courtesy of:
Barry Edwards

Courtesy of:
Barry Edwards

65,000 board ft/hr

Byproducts to future
Wood Gasification Energy & Ethanol
Facilities

Dimensional Lumber Production Facility

Courtesy of: Barry Edwards

Byproducts to future
Wood Gasification Energy & Ethanol
Facilities

Courtesy of:
Barry Edwards

Pallet Recycling Facility

Impending Component

Wood Gasification Energy Facility

First combined heat and power facility of its kind in the United States

Courtesy of:
Barry Edwards

- Appalachian State University
- University of North Carolina – Charlotte
- North Carolina Agricultural and Technical State University
- North Carolina State University

Courtesy of:
Barry Edwards

EcoComplex University Partners

IV. Case Studies

Society of St Vincent de Paul of Lane County

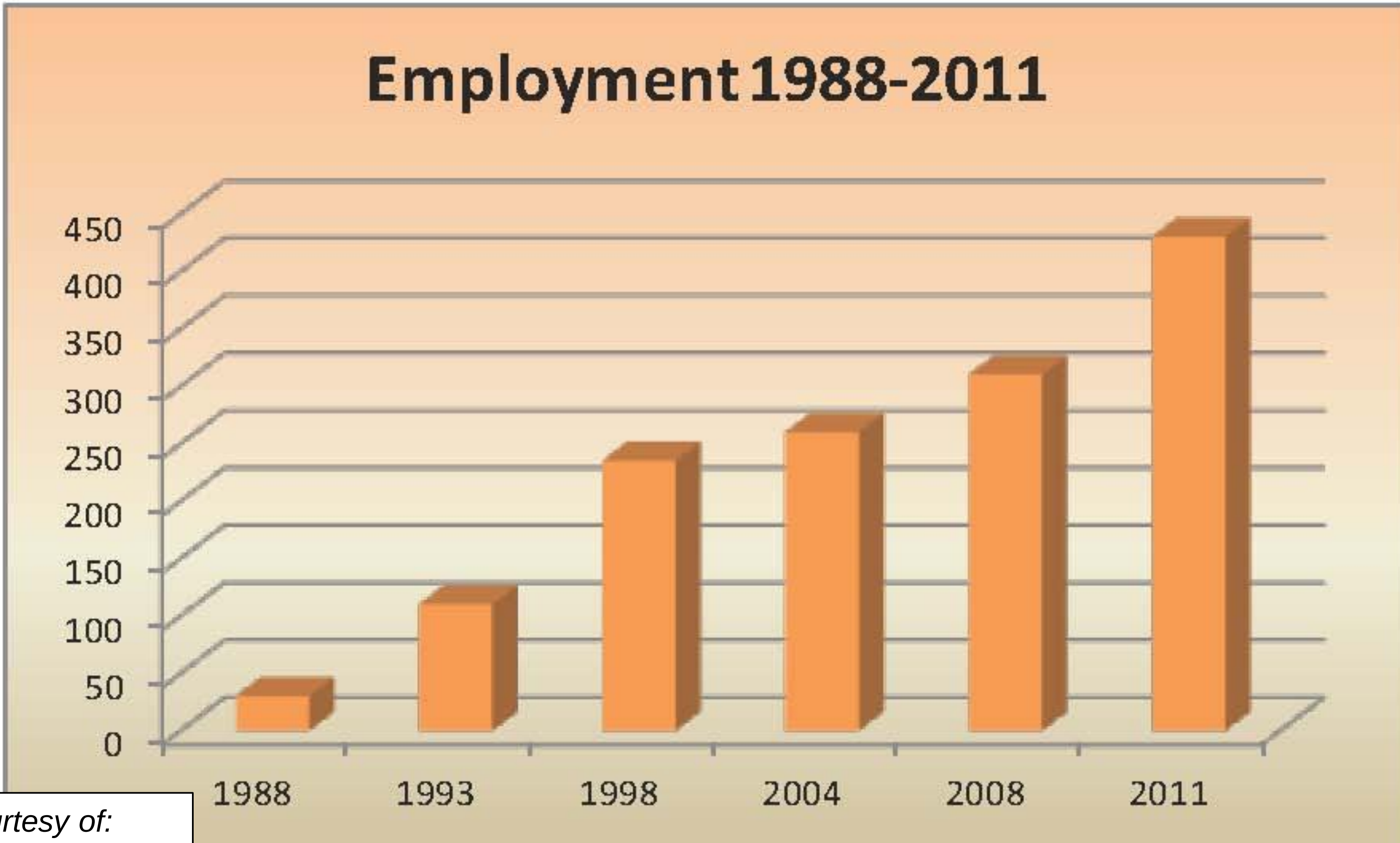
- Hierarchy Level: 1. Source Reduction/Reuse and 2. Recycling
- Key Concepts: Waste and Recycling Based Business
- Key Leader: Terry McDonald
- Key Drivers: Finding value in "waste" to create jobs and affordable housing.
- Tools Used: Basic economic analyses; no technical.

IV. Case Studies

Society of St Vincent de Paul of Lane County

“I’m in this for the money and I want your trash.”

It creates Jobs....



Courtesy of:
Terry McDonald

Courtesy of:
Terry McDonald

Thinking of Waste as an Asset

- Clothing and other textiles
- Belts, purses and accessories
- Wood
- Steel, copper, aluminum, brass
- Foam
- Window glass
- Household goods
- Books and magazines
- DVDs, CDs and videos
- Propane tanks
- Fire extinguishers
- Motors and compressors
- Cardboard
- Microwaves
- Styrofoam
- CFCs
- Candles
- Furniture
- Appliances
- Mixed plastics
- Stuffed toys
- Electric cords
- Motor oil
- Cars and other vehicles
- Bicycles

Courtesy of: Terry McDonald

Appliance Repair and Reuse Program

Courtesy of:
Terry McDonald

Mattress Recycling

Courtesy of:
Terry McDonald

www.svdp.us

Courtesy of:
Terry McDonald

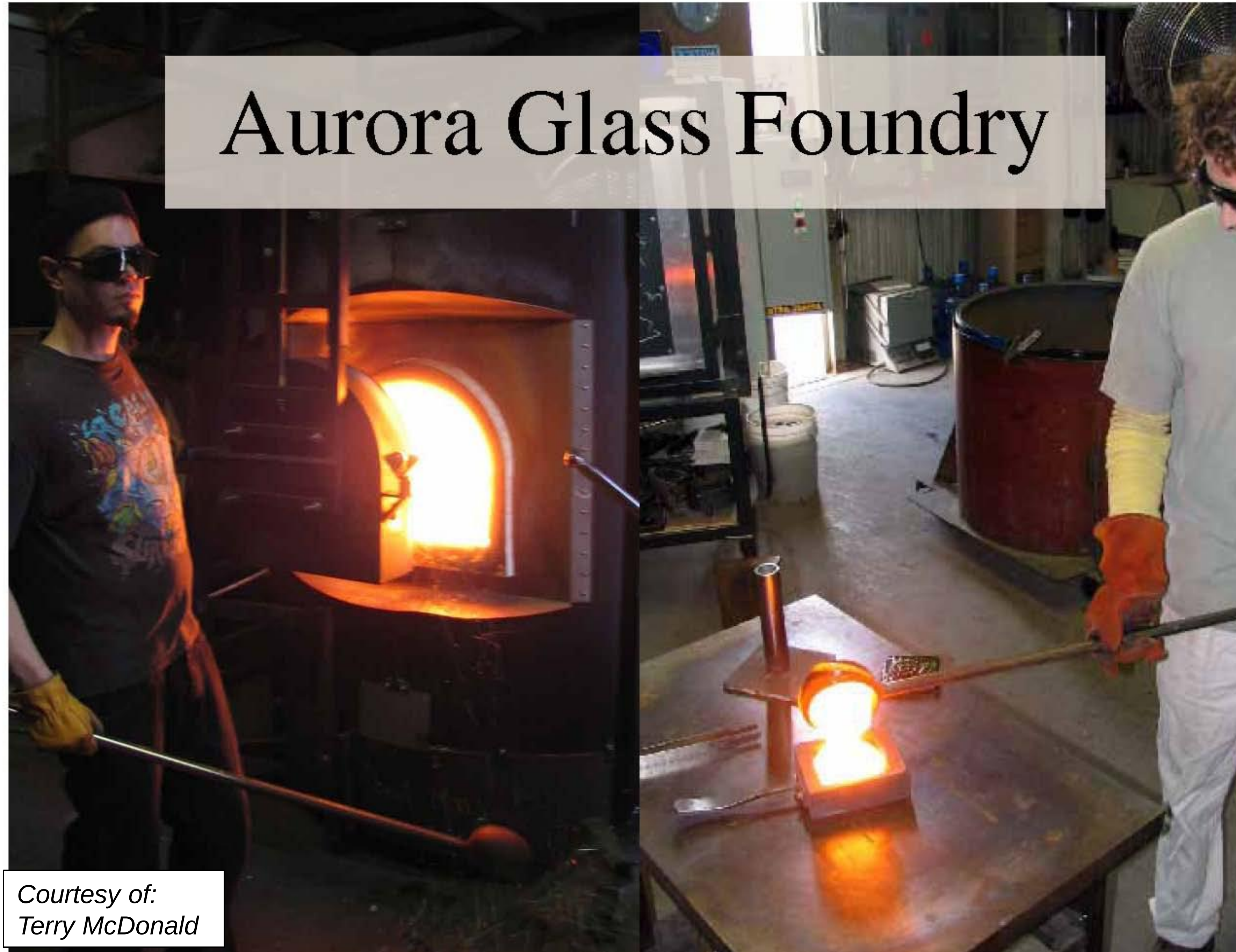
Mattress Rebuilding

Courtesy of:
Terry McDonald

Last year we recycled 60,000 pounds of parafin wax. This year, already, we have doubled that.

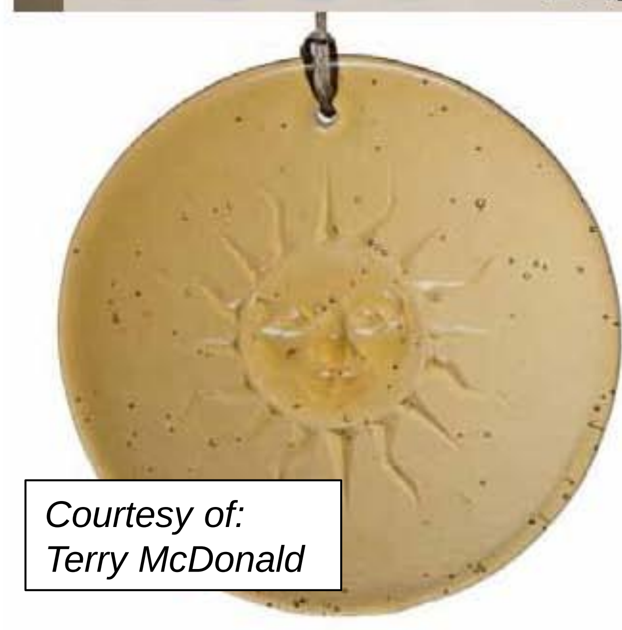
Courtesy of:
Terry McDonald

Aurora Glass Foundry



Courtesy of:
Terry McDonald

Products from recycled glass



Courtesy of:
Terry McDonald

St. Vincent de Paul

www.svdp.us

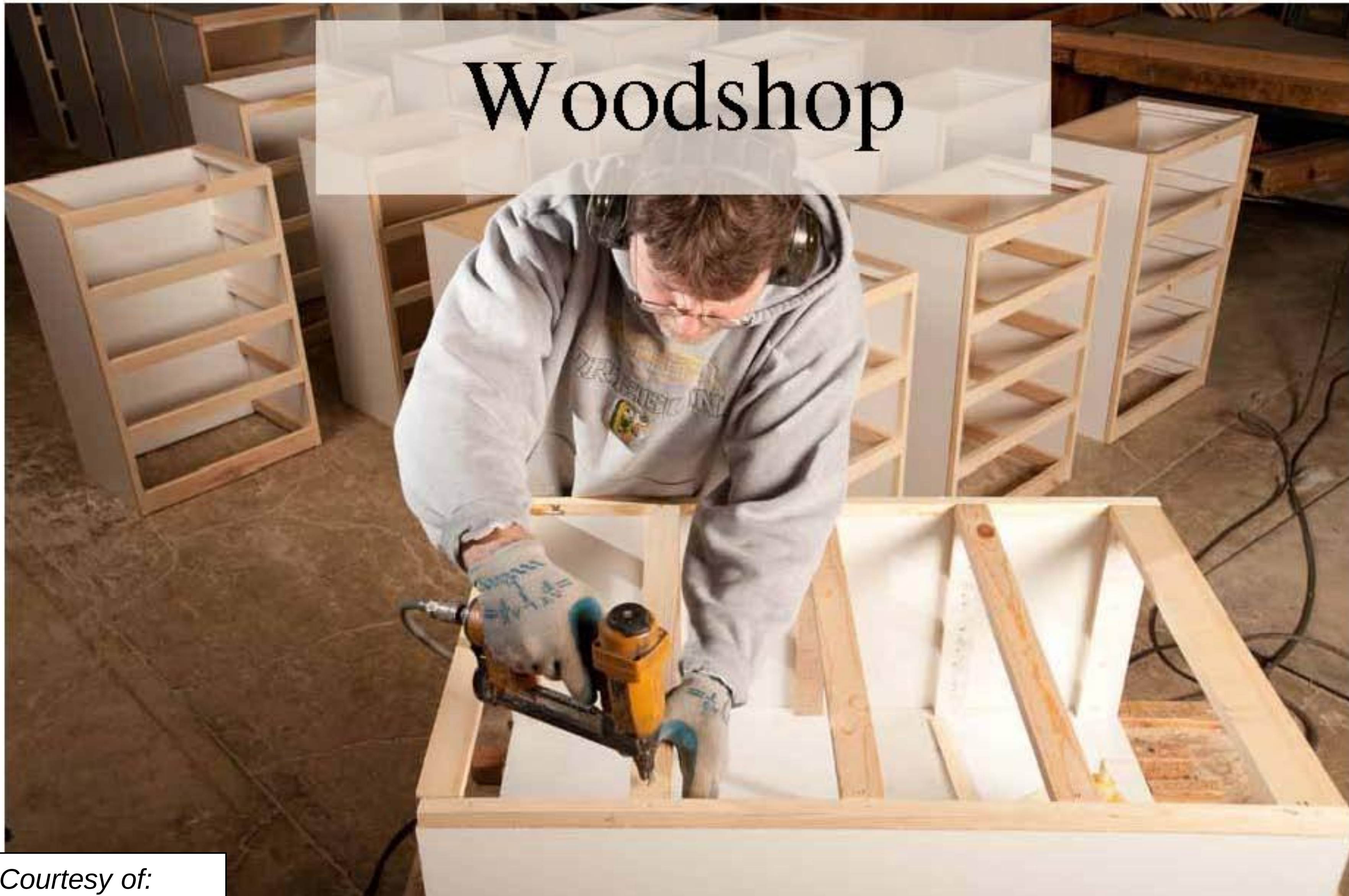
Tumbled Glass

Courtesy of:
Terry McDonald

Styrofoam Recycling

Courtesy of:
Terry McDonald

Woodshop



Courtesy of:
Terry McDonald


Recycling in 2012
In 2012, St. Vincent de Paul diverted from the landfill:
Scrap Metal 4,070,000 lbs.
Textiles 2,042,800 lbs.
Books 1,227,665 lbs.
Wood Waste 936,000 lbs.
Glass 30,000 lbs.
Ewaste 120,000 lbs.
Shoes/Belts/Purses 149,063 lbs.
Plastic 184,710 lbs.
Polyurethane Foam 1,137,016 lbs.
Paper/Cardboard/Magazines 159,496 lbs.
Media 121,260 lbs.
Paraffin Wax 60,000 lbs.
The 4-year old Styrofoam recycling program collected 31,000 pounds of material!
Art Taylor
Mattress Facility Manger
Total weight diverted in Lane County: 10,657,088 POUNDS!
142,000 mattresses were diverted from our Eugene location and DR³ recycling facility in California allowing us to divert from regional landfills: 7,810,000 POUNDS!
SVdP diverted in 2012: 18,467,088 pounds from landfills!

City of Eugene Reuse Industry Study

- The economic impact of solid waste related industries and businesses is $13.1 million in Eugene and $24.5 million in Lane County
- The used merchandise industry experienced 60% employment growth between 2005 and 2010
- Find a link to the report at www.svdp.us

Courtesy of:
Terry McDonald

IV. Case Studies

Lamar County Pyrolysis

- Hierarchy Level: 3. Energy Recovery
- Key Concept: Energy Recovery
- Key Leader: Johnny Poore
- Key Drivers: Finding value in "waste" and providing public services by making good business decisions.
- Tools Used: Custom analyses, prototyping

Lamar County Pyrolysis

Photo: Ed Jackson

WHAT IS PYROLYSIS?

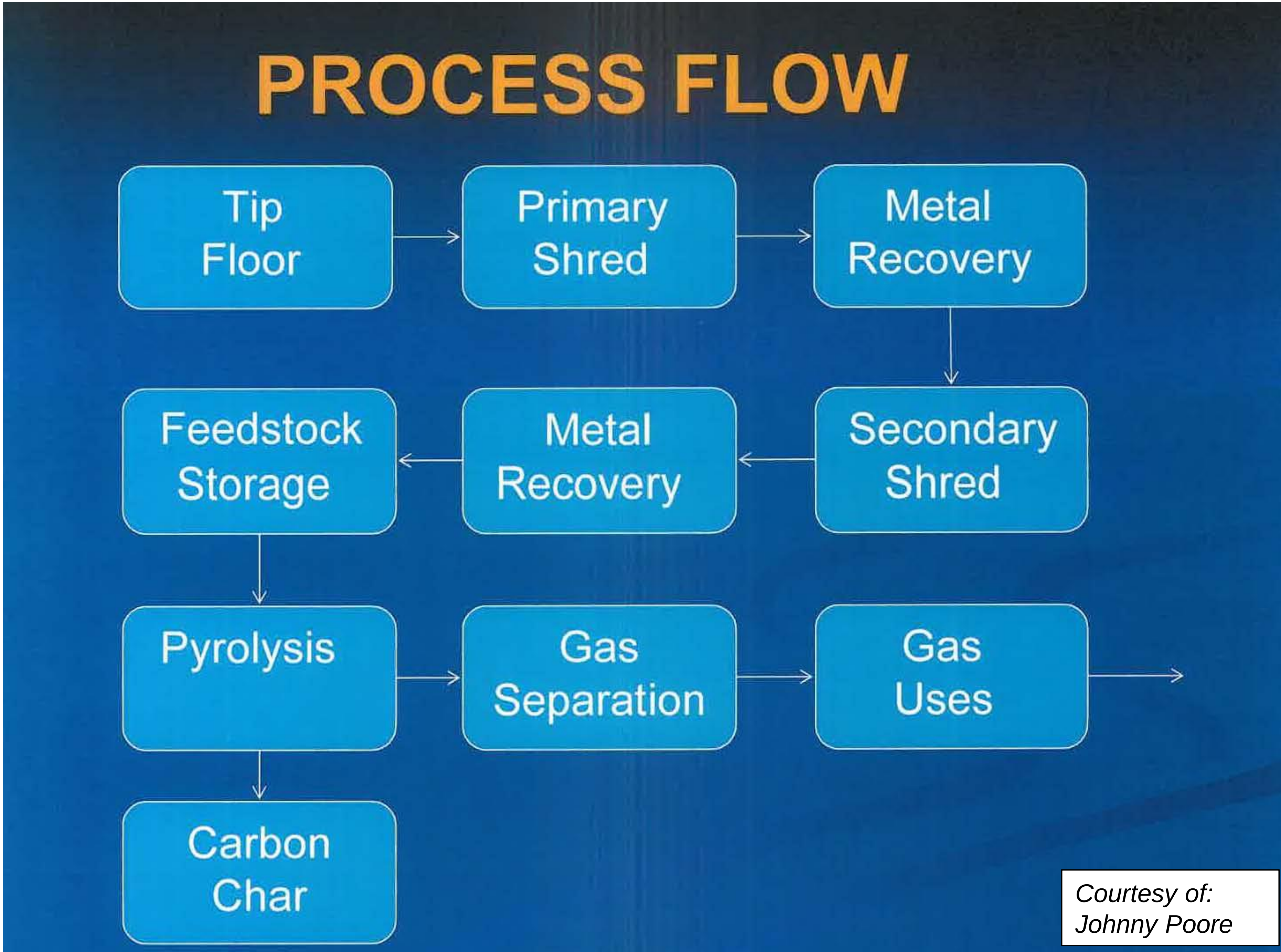
- PYROLYSIS IS A THERMOCHEMICAL DECOMPOSITION OF MATERIAL AT ELEVATED TEMPERATURES WITHOUT THE PARTICIPATION OF OXYGEN.

Courtesy of:
Johnny Poore

WHERE ARE WE NOW

- VALIDATED PYROLYSIS WASTE REDUCTION MODELS THROUGH PROTOTYPE UP TO 1,800 ° F
- VALIDATED MECHANICAL AND THRU PUT CAPABILITIES OF PROTOTYPE.
- SELECTED TECHNOLOGY – PARADIGM MANUFACTURING ELECTRICAL PYROLYSIS SYSTEM
- TECHNOLOGY ON SITE (SINGLE UNIT). EACH UNIT CAN PROCESS UP TO 50 TONS PER DAY OF INCOMING WASTE
- EPD PERMITTING FOR BENCH TEST
  - AIR QUALITY PERMIT (APPROVED)
  - LAND PROTECTION PERMIT (APPROVED)
- FULL ARRAY OF TESTING

Courtesy of:
Johnny Poore



Courtesy of: Johnny Poore

WASTE FEEDSTOCK

Courtesy of:
Johnny Poore

PYROLYSIS UNIT

Courtesy of:
Johnny Poore

CARBON CHAR

90% REDUCTION OF WASTE BY VOLUME

Courtesy of:
Johnny Poore

GAS SEPARATION

Courtesy of:
Johnny Poore

GAS USES

- Electricity – Internal and/or Grid
- Propane – Heating Fuel
- Butane – Heating Fuel
- NGL – Transportation Additive
- CNG – Transportation Fuel
- LNG – Transportation Fuel
- Pipeline – Natural Gas

Courtesy of:
Johnny Poore

FUELS BREAKDOWN

Sample ID	1100.01*	Flow CFM	Volume C5+	Volume Butane	Volume Propane	Volume Gas (cfm)	BTU by Gas	BTU by Volume
Methane	18	216.00				216.00	909.40	198.90
Ethylene	0	0.00				0.00	1,514.00	0.00
Ethane	5.9	70.80				70.80	1,618.70	116.04
Acteylene	5.9	70.80				70.80	1,438.00	103.09
Hydrogen	7.5	90.00				90.00	273.93	24.96
CO2	18	216.00				216.00	0.00	0.00
Nitrogen	15	180.00				180.00	0.00	0.00
CO	12	144.00				144.00	320.50	46.73
Propane	8.9	106.80			2.85 gal/min	987.60		490
Isobutane	0.1	1.20		0.0392	4,104 gpd	1,094.40		668
n-Butane	3.5	42.00		1.3708	1,497,960 gpy			
Neopentane	0.38	4.56	0.1648	1.41 gal/min				
Isopentane	0.038	0.46	0.0167	2,030 gpd				
n-Pentane	0.28	3.36	0.1214	740,950 gpy				
n-Hexane	1.8	21.60	0.8860					
n-Heptane	1.7	20.40	0.9390					
Octane	1.2	14.40	0.7356					
% of sample	100.20	1202.38	2.86 gal/min					
BTU (net)	951		4,118 gpd					
BTU (gross)	1030		1,503,070 gpy					

Courtesy of:
Johnny Poore

IV. Case Studies

Seneca Meadows Landfill

- Hierarchy Level: 4. Landfilling (with Energy Recovery)
- Key Concepts: Ecology, Community Engagement
- Key Leader: Steve Apfelbaum
- Key Driver: Finding value in land and how we relate to it.
- Tools Used: Custom Analyses

IV. Case Studies

Seneca Meadows Landfill

What If, your landfill was not merely a disposal facility?

1. Improve neighboring property values
2. Improve community esteem
3. Create outdoor educational opportunities
4. Create recreational opportunities
5. Work with rather than duel with anti-groups
6. Enhance regulator relationships

APPLIED ECOLOGICAL SERVICES

Solid waste professionals are proficient managing previously wasted resources …

But, what about the land resources they control and its connection to your community?

APPLIED ECOLOGICAL SERVICES

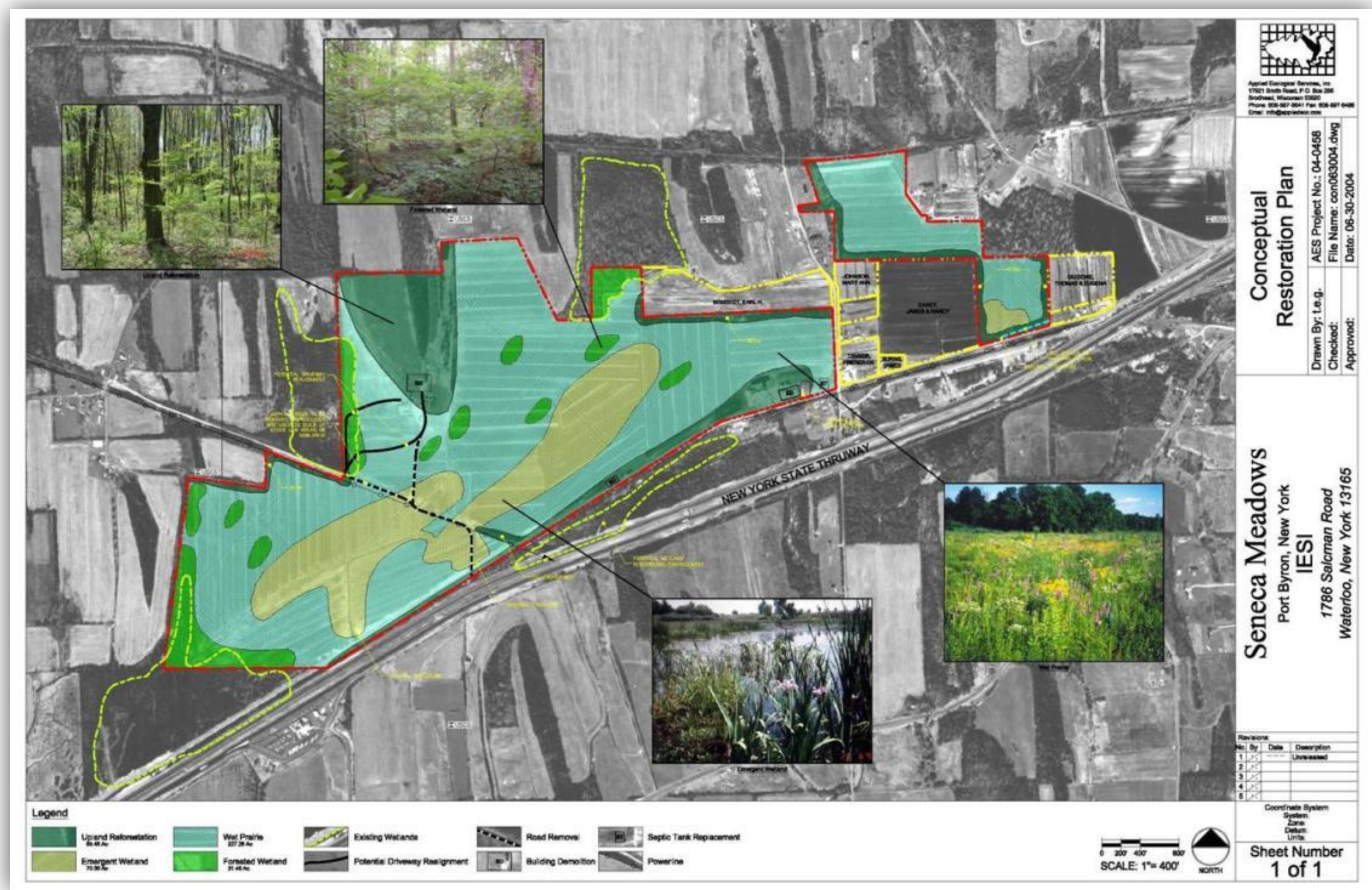
Seneca Meadows Wetland, Landfill

Waterloo, NY

APPLIED ECOLOGICAL SERVICES

Seneca Meadows

Waterloo, NY



APPLIED ECOLOGICAL SERVICES

Courtesy of:
Steve Apfelbaum,
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Elements of Successful Sustainability Projects

- A leader who communicates the vision.
- A long-term vision coupled with short-term successes.
- Viewing components as part of a larger system.
- Regular measurement and evaluation.
- Effective business management.
- Interventions at multiple levels of the hierarchy and beyond.

Reference List – Part 2

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