# Resource Potential of California Landfill Stream

## (and some options to pursue)

California Integrated Waste Management Board

## Emerging Technologies Forum

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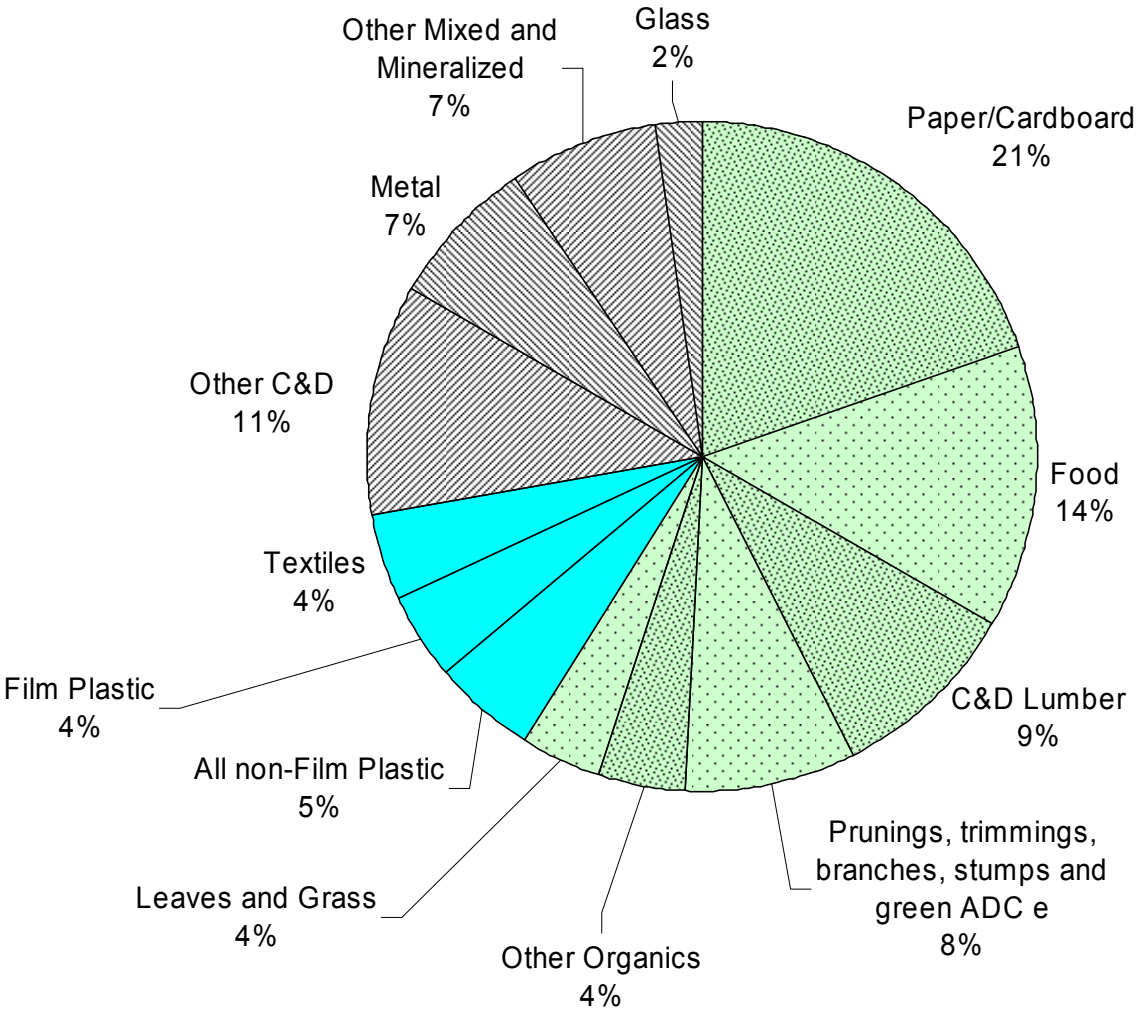
Integrated Waste Management Board

| CIWMB 2004 Waste Characterization and Disposal Amounts * | Landfilled (million tons) | % of Total |
|---|---|---|
| Paper/Cardboard | 8.6 | 19.7 |
| Food | 6.0 | 13.7 |
| C&D Lumber | 3.9 | 9.0 |
| Prunings, trimmings, branches, stumps and green ADC * | 3.7 | 8.4 |
| Other Organics | 1.8 | 4.1 |
| Leaves and Grass | 1.7 | 3.9 |
| **Biomass Components of MSW Total *** | **25.7** | **59.0** |
| All non-Film Plastic | 2.1 | 4.8 |
| Film Plastic | 1.8 | 4.1 |
| Textiles | 1.8 | 4.2 |
| **Non-Renewable Carbon Compounds Total** | **5.7** | **13.2** |
| Other C&D | 4.9 | 11.3 |
| Metal | 3.1 | 7.2 |
| Other Mixed and Mineralized | 3.1 | 7.1 |
| Glass | 0.9 | 2.2 |
| **Mineral Total** | **12.1** | **27.8** |
| **Totals *** | **43.5** | **100** |

* Includes 2.6 million tons of green ADC

# Composition of California Landfilled Waste Stream *

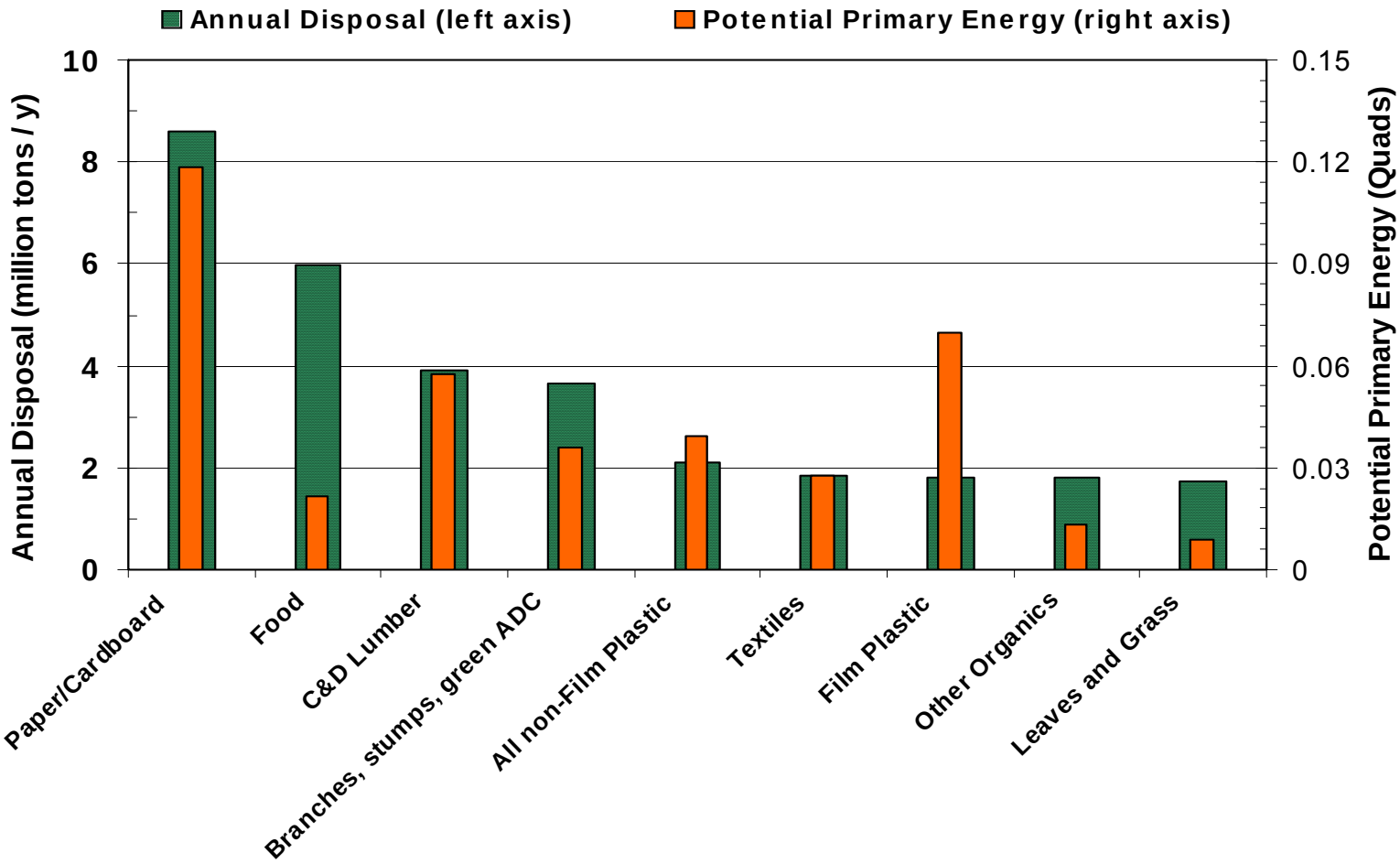



| | Fraction of waste stream (%) |
|---|---|
| **Biomass** | **59** |
| **Plastics/ textiles** | **13** |
| **Inorganic** | **28** |
| **Total** | **100** |

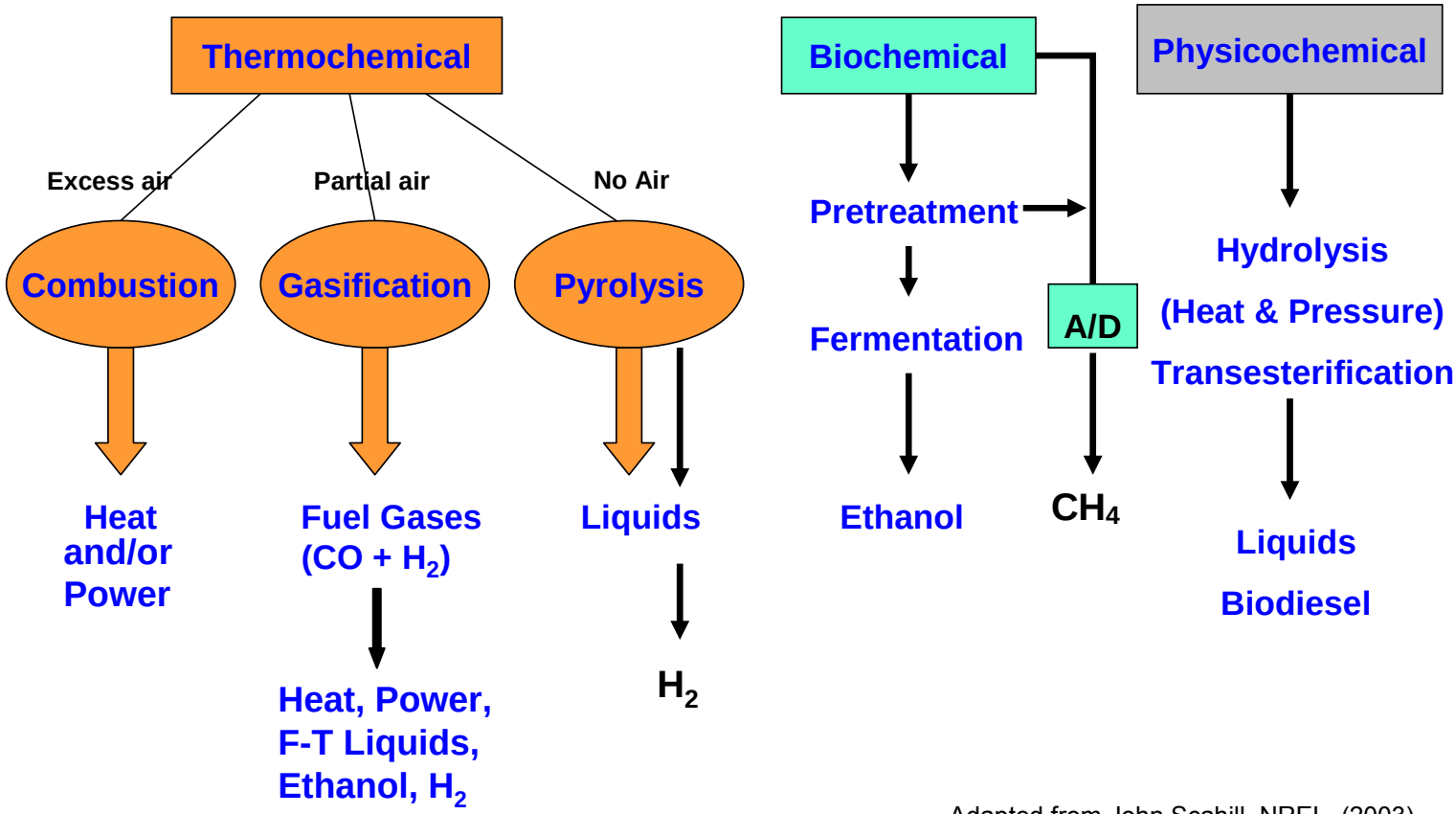
*2004 CIWMB Waste Characterization

# Waste stream component disposal amounts and potential primary energy

| | Energy Potential | |
|---|---|---|
| | Primary (million barrels of Oil) | Electrical Capacity (MW) |
| Biomass | 44 | 1750 |
| Plastics/ textiles | 23 | 914 |
| Inorganic | 0 | 0 |
| Total | 67 | 2664 |



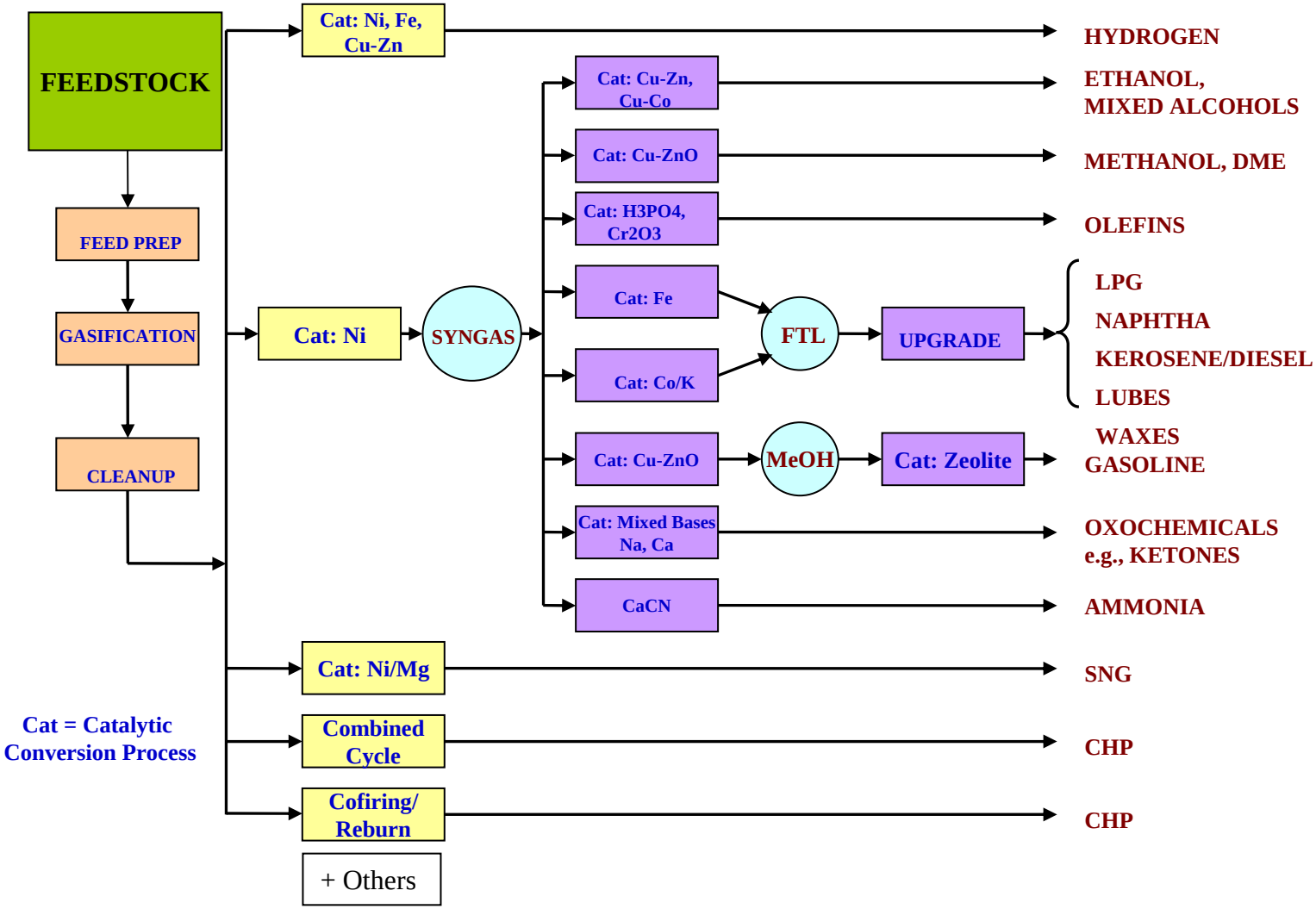
# Biomass Conversion Pathways
## (and primary products)




Adapted from John Scahill, NREL. (2003)

# Thermochemical Processing/Conversion

## SELECTED SYNTHESIS GAS OPTIONS




Source: NREL

# Feedstocks for Conversion Technologies

- Thermochemical processes can accept nearly all organic material (biomass and plastics)
- Biochemical processes convert only biodegradable materials
  - Food wastes
  - Leaves, grass, trimmings
  - Paper/cardboard
  - Wood waste
  - Some 'high solids' reactors can accept more inhomogeneous waste with the non biodegradable components exiting as digestate
- Biodegradation varies in rate and degree and lignin fraction does not degrade anaerobically

# Products from Thermochemical Conversion

- **Fuel gases**
  - Internal/external combustion engines/boilers
  - Fuel cells
  - Other prime movers
- **Liquid Fuels**
  - Methanol
  - Fischer-Tropsch (FT) liquids
  - Hydrogen
  - Ethanol
- **Chemicals**
  - Ethylene (recycling of plastics)
  - Ammonia based fertilizers
  - Substitute petroleum products
  - Adhesives and resins
  - Food flavorings
  - Pharmaceuticals
  - Fragrances

# Biochemical Process Feedstocks

- Biodegradable components of the landfill stream include:
  - Food wastes
  - Leaves, grass, trimmings
  - Paper/cardboard
  - Wood waste
- Biodegradation varies in rate and degree
- Biodegradation is not complete
  - Lignin fraction will not degrade anaerobically

    Lignin amounts:
    - Wood (20-30%)
    - Food wastes (5-20%)
    - Paper (1 – 25%)
- Practical systems can not completely degrade the non-lignin components, due to time, volume, energy, and expense limitations

# Biochemical Process Feedstocks

- Anaerobic decomposition
  - Biodegradable material only (lignin does not degrade anaerobically)
  - Polymer carbohydrate needs to be broken up into simpler molecules (sugars). Hydrolysis accomplishes this
  - Facultative and Fermentive bacteria/yeasts produce
    - Biogas (~ 50-65% methane, balance $CO_2$, + small amounts of impurities): Anaerobic Digestion - AD
    - Ethanol (and/or other chemicals): Fermentation

# Fermentation

- Hydrolysis Methods (up front pretreatment)
  - Hydrothermal
    - Hot water, maybe high pressure
    - Steam or Ammonia explosion
  - Enzymatic
    - Cellulase enzymes to de-polymerize the cellulose
    - Currently expensive but believed to be most economical route in future
    - Intensive research and engineering of microbes ongoing in public and private institutions world wide
  - Acid
    - Dilute or Concentrated – Technologically mature
    - Currently more economical than enzymatic

# Fermentation

After Hydrolysis

Carbohydrate + Cell mass → Ethanol + $CO_2$ +
More cell mass

Under best circumstances, mass yield of Ethanol is 51% of mass of input carbohydrate

Accounting for microbe cell growth, best yield in practical systems is ~ 46% (mass basis)

Recall, the lignin component does not participate

# Anaerobic Digestion Feedstocks

## Biomethane Potential (BMP) of some feedstocks

### Energy in Biogas per wet pound of feedstock

| | $CH_4$ Generated (BTU/lb input) |
|---|---|
| Vegetable oil | 16024 |
| Office paper | 5609 |
| Corrugated paper | 4389 |
| MSW C | 2586 |
| MSW B | 2466 |
| MSW D | 2387 |
| Food waste | 1969 |
| MSW A | 1918 |
| Newspaper | 1534 |
| Branches | 1519 |
| Grass | 1161 |
| Blend of grass, leaves | 1130 |
| Leaves | 1123 |

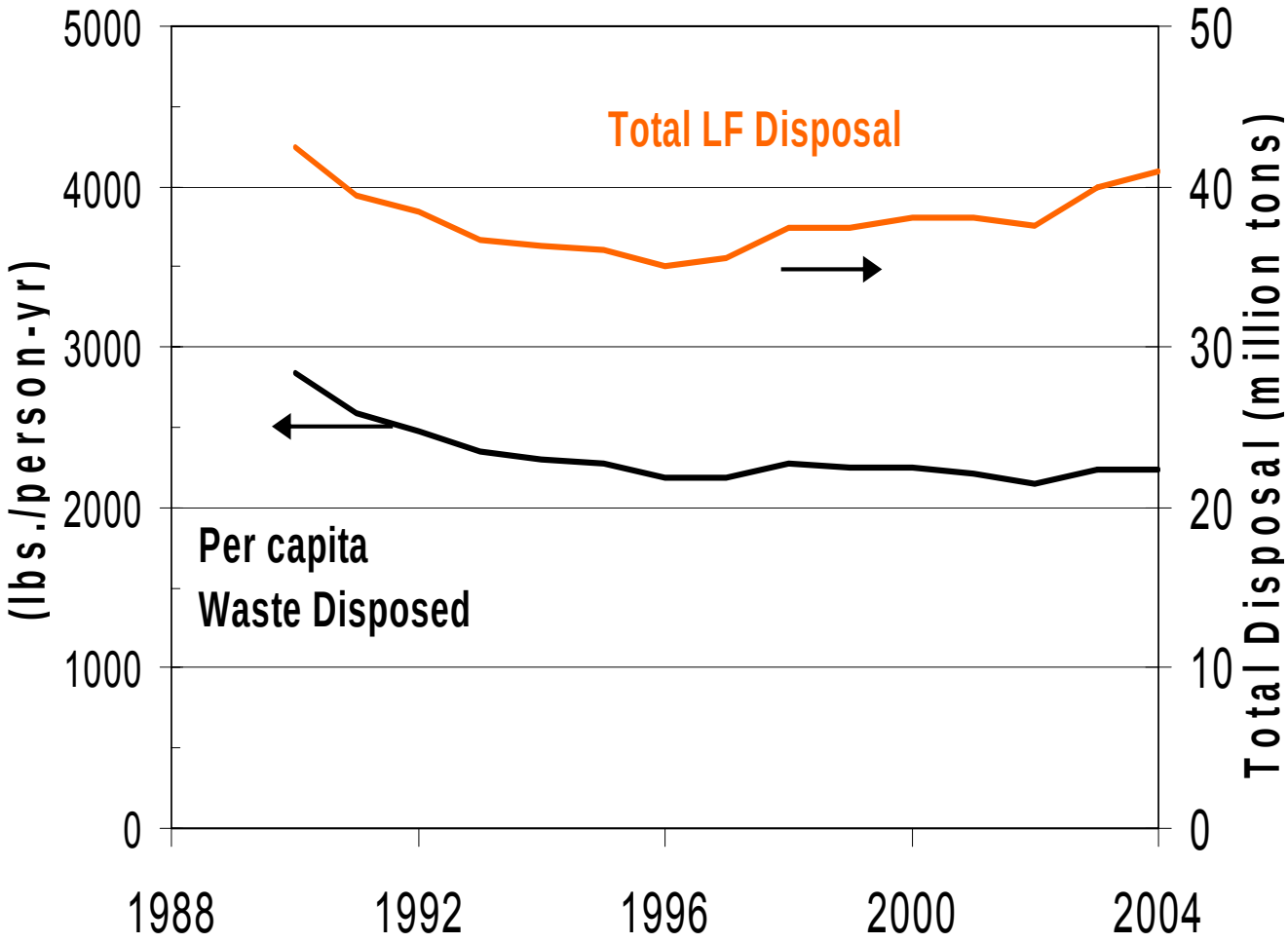
Sources:
Chynoweth, et.al., (1993)
Owens and Chynoweth (1993)
Eleaser, et.al., (1997)
Tchobanoglous, et.al.., (1993)

Source separated waste input to DRANCO , Brecht, Belgium

Dewatered digestate is composted.
DRANCO facility, Brecht, Belgium

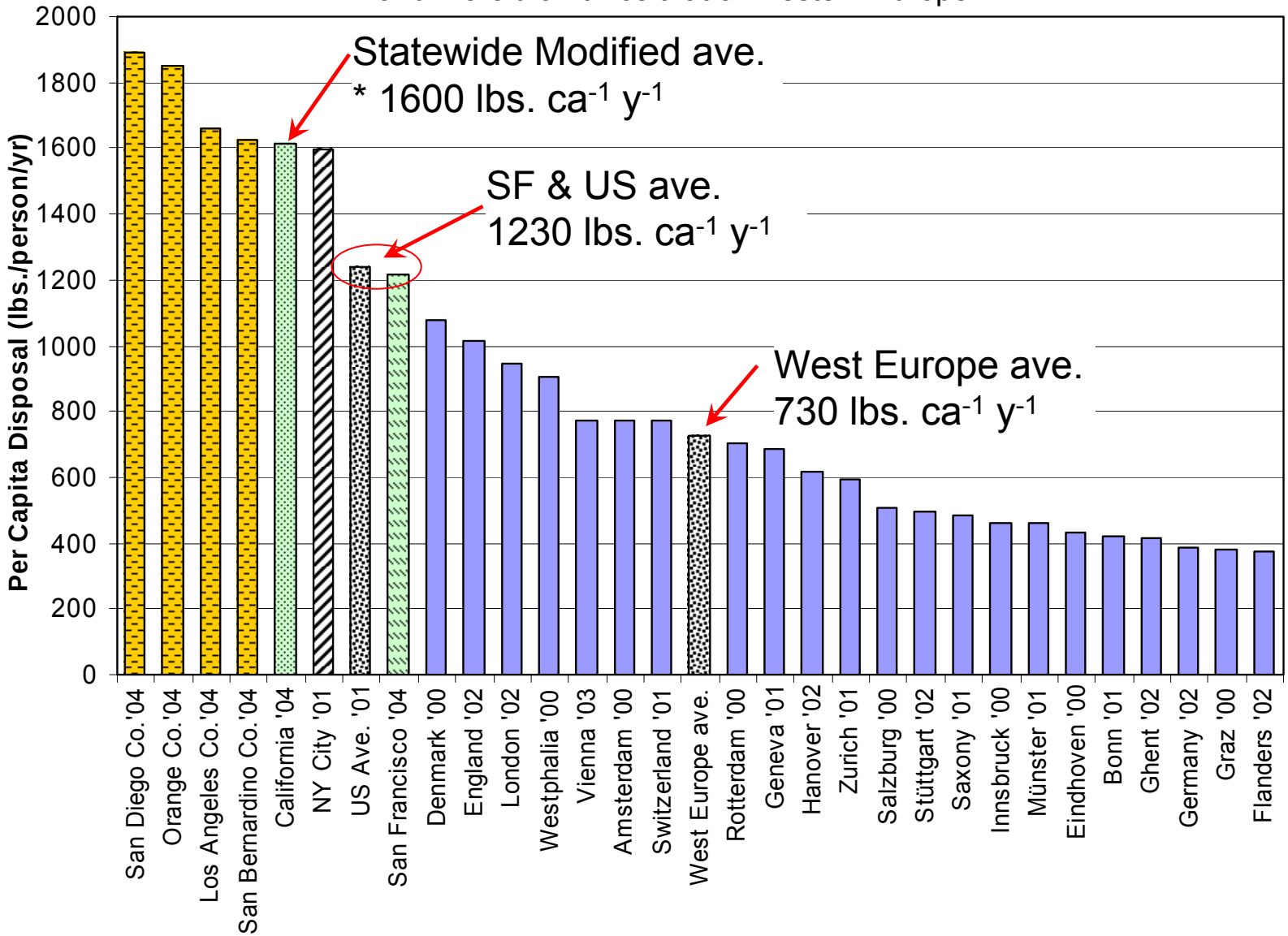
DRANCO facility, Brecht, Belgium

# Per-capita and total MSW disposal in California since implementing AB 939



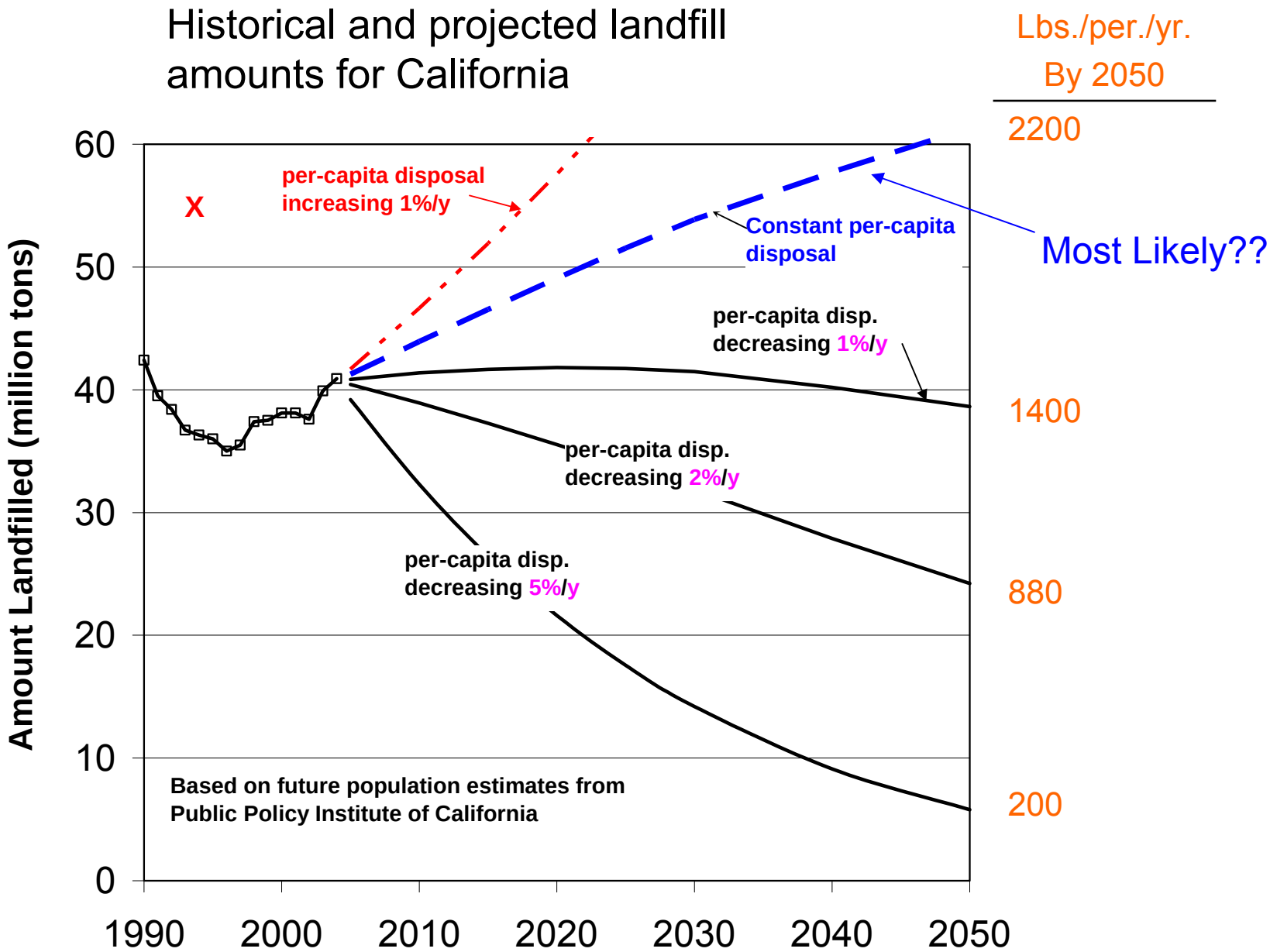
# Per-capita landfill disposal for US and Western Europe

California per capita disposal is a third more than the US average and more than twice that of Western Europe.

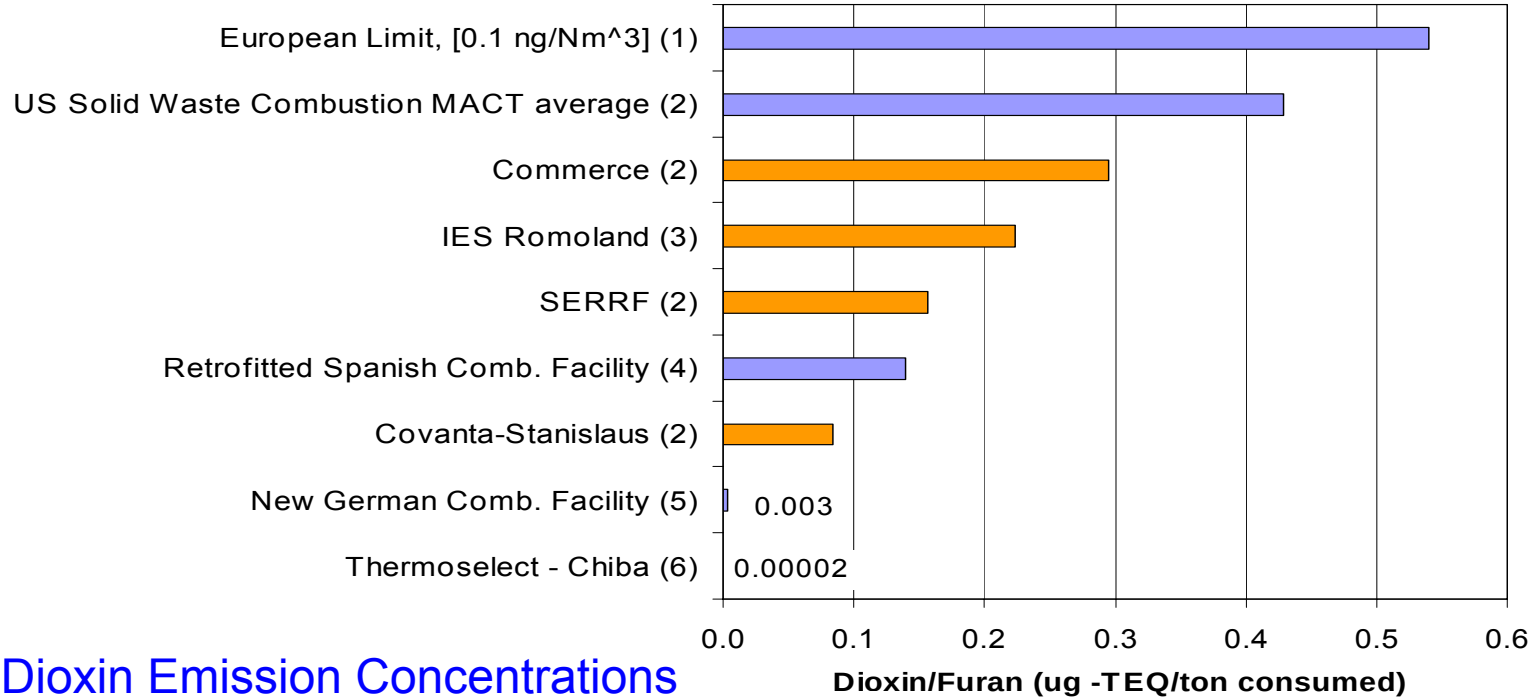



* Note: **California and US amounts reduced by 30%** to remove C&D and 'special waste' for comparison with European data

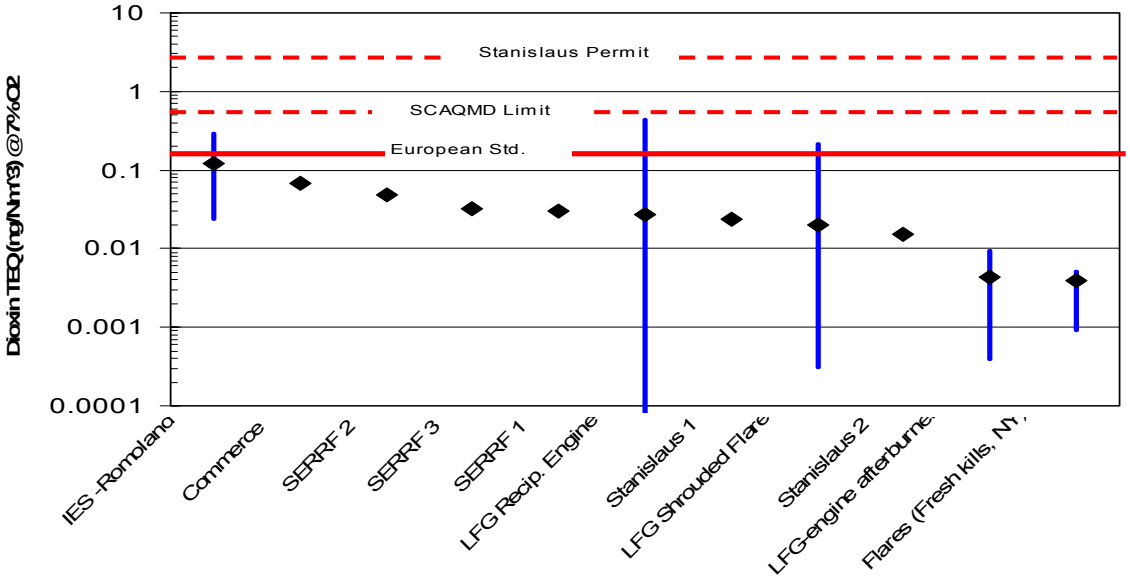
# Historical and projected landfill amounts for California



## Dioxin Emission Factors



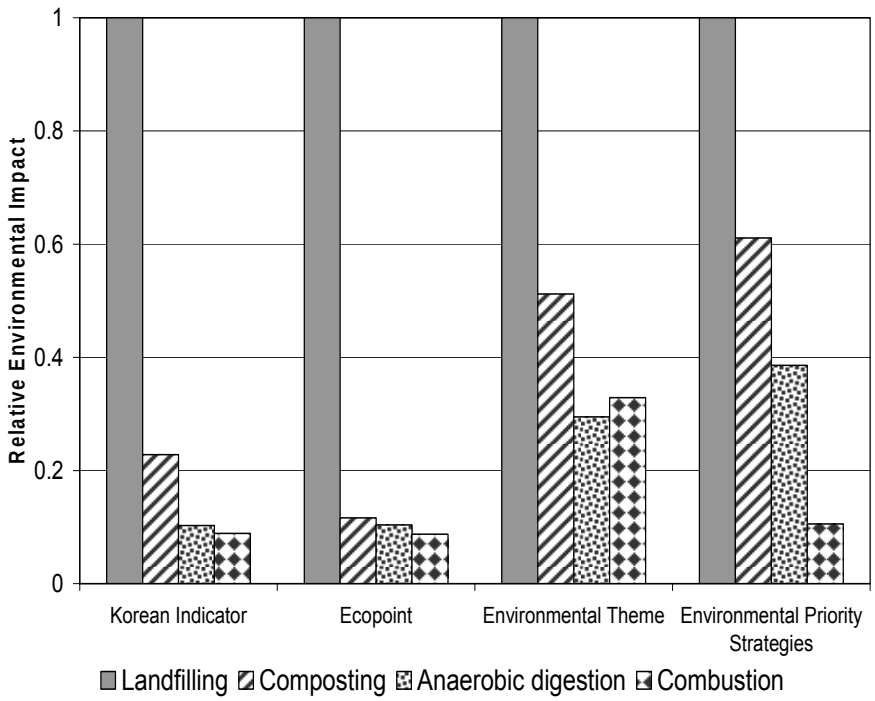

## Dioxin Emission Concentrations



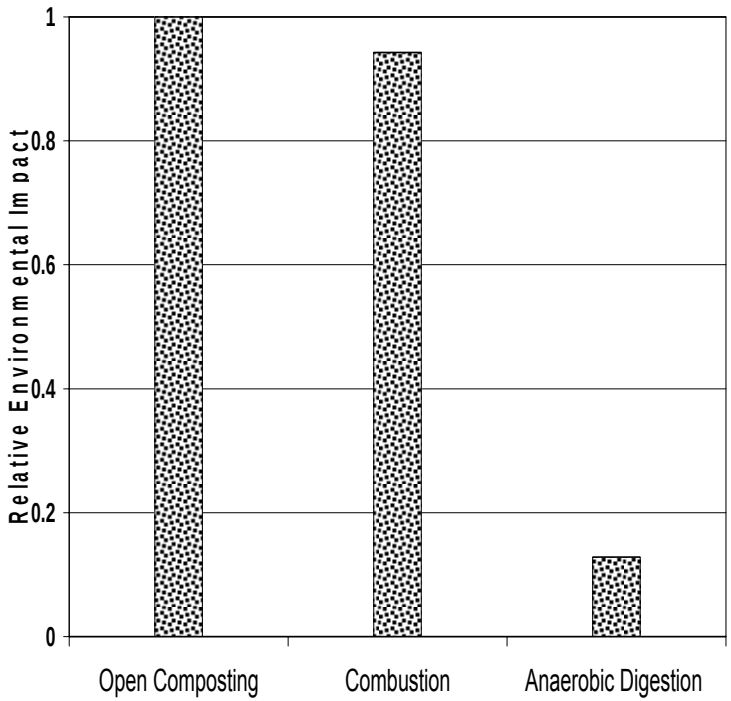

Williams, R.B. (2006)

# Relative Impacts:

## Results from four life-cycle impact assessments comparing solid waste management scenarios in Korea




adapted from Seo, et al. (2004)




adapted from Edelmann et al. (2004)

# Summary

- Despite estimated diversion of nearly 50%, California per capita landfill disposal has remained fairly constant at 2200 lbs. per person per year since 1995.
- California per capita landfill disposal (adjusted down for comparison) is a third more than the US average and more than twice that of Western Europe.
- Total annual landfill disposal is expected to increase as population grows.
- Policies and technologies that can reduce per capita waste disposal should be implemented in place of a diversion based approach.
  - Why not implement a landfill ‘cap and trade’ policy?
- Energy and solid waste policies in Europe have advanced the state of technology for waste management and conversion. There are potential opportunities to adapt these policies and advanced systems in Europe to the emerging market in California.

# Summary
## (Continued)

- Landfill material restrictions have been implemented in Europe (to reduce environmental impacts from landfills).
  - e.g., treatment is required before landfilling – ban on biodegradable wastes
- Europe classifies all thermal conversion systems as ‘incineration’ but because they have set strict environmental performance standards, rather than prescribed technologies, thermal conversion in Europe is a significant component of their strategies to reduce landfill disposal and GHGs emissions.
- England has implemented a landfill 'cap and trade' scheme in order to meet the EU landfill directive targets for biodegradable waste (began in April, 2005). Jurisdictions that exceed the limit will be fined £150 for every metric tonne they are over the limit. This is believed to be the first of its kind in the municipal waste sector.
- There is need for a comprehensive LCA of integrated waste management in California (to include the full range of waste management techniques and strategies including composting and the various conventional recycling methods [including emissions and conditions of recycling processes overseas that receive California waste]).
- Need to address and reaffirm or vacate ‘legacy decisions’ that led to material ‘highest and best use’ and the waste hierarchy. (i.e., AB 939 is nearly 20 years old)

# Database and Reports

- Initial database
  - "Solid Waste Conversion: A review and database of current and emerging technologies"

    Interactive Data Base and download available at:

    http://cbc1.engr.ucdavis.edu/conv/home.asp

- UC Conversion Technology Evaluation Report

  http://biomass.ucdavis.edu/pages/reports.html

# THANK YOU

- **Contact Information**

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