Modern Alchemy

Turning Waste into Gold

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The nature of waste

Swedish sewaginuity

Research underway

Opportunities for Canada

Premise

Clearly raw sewage and landfills cause pollution.

In addition to the benefit of preventing pollution, resource recovery is compelling economically.

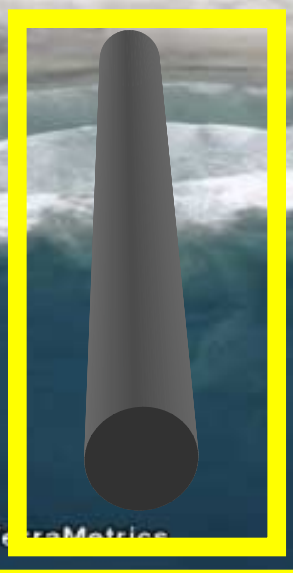
What's our "system boundary"?

If we look at waste as a "disposal problem", then our focus is limited to outfalls and landfills. What if we literally turned the problem around, and asked what waste can do for our community?

Narrow questions sub-optimize

3. Community?
(value of opportunities)

2. Treatment plant?
(visible cost of solution)

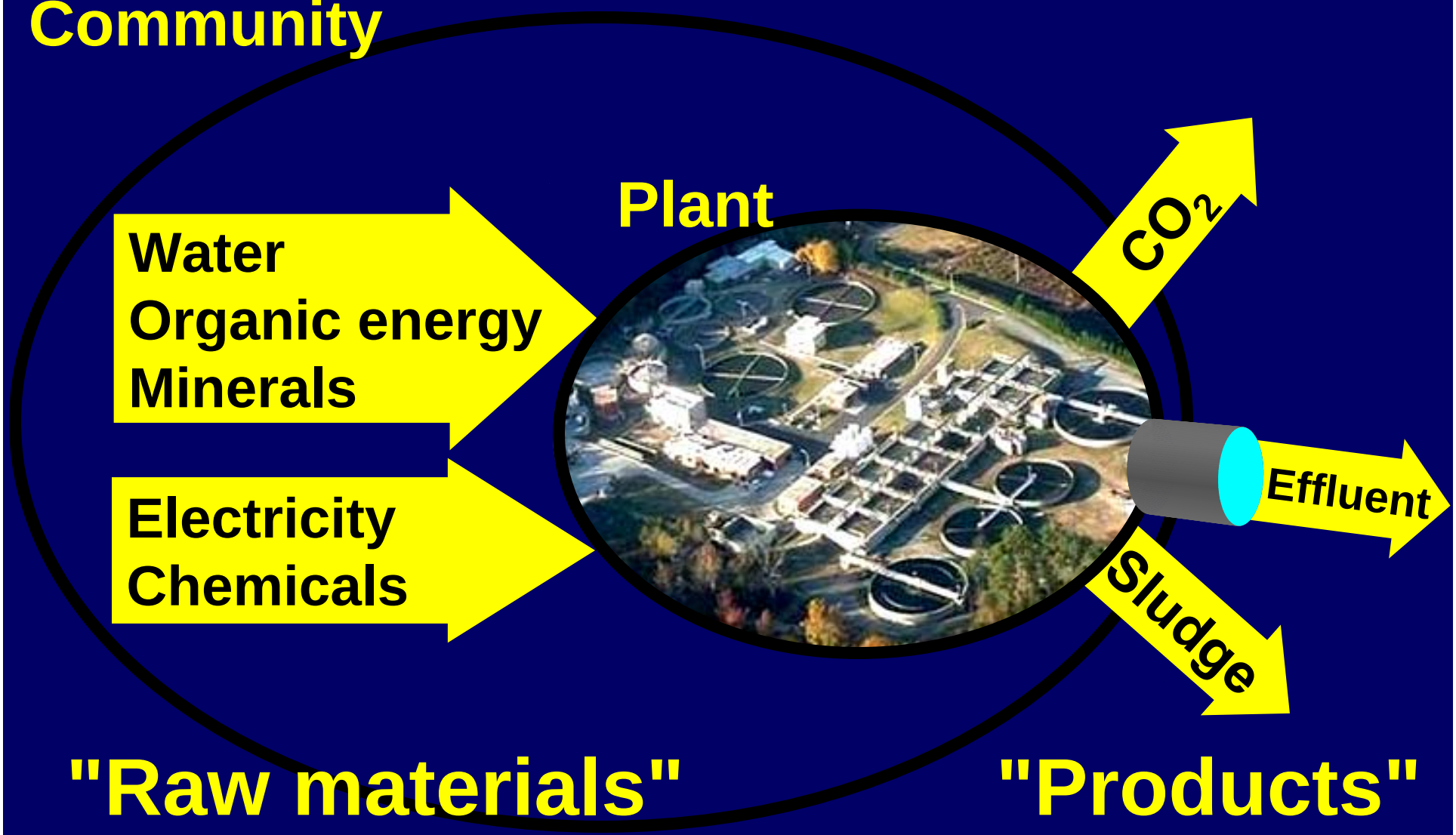


1. The outfall alone?
(visible cost of status-quo)

If our planning includes the needs of the community for energy and water, we can optimize the overall results.

If our focus is disposal

our plants become wasteful



If our focus is the community

we'll make waste pay

Theoretical limit is 9.3

Gain

Loss

Break even

Microbial cell

Stockholm

Gothenburg

Annacis

Worst plants

In cities, waste pollutes twice

once-through model

Food

Water

Energy

Greenhouse Gas

Solids

landfill

Liquids

treatment

Heavy eco-footprint

Upstream Impacts

Downstream Impacts

In nature, waste = food

In nature, nothing is wasted. As we remodel our cities to mimic nature's cycles, we reduce our overall eco-footprint.

Closing the loop is natural

eco-cycle model

Food

Water

Energy

GHG

Solids

Liquids

Resource recovery

Light eco-footprint

Biofuels

Power

Minerals

Water

Heat

Why bio is better

CO_2

Broken cycle

Fossil fuels

CO_2

Closed cycle

Biofuels

More sustainable

What about solid waste?

Hartland landfill

CO_2, CH_4

Organics
80,000t/yr

CO_2

Cogen

Energy
12 GWh/yr

Leachate

Cost = $20 million/year for 160,000t/yr

CO_2e capture = 25%

Net CO_2e output = 165,000 t/yr

Another source of fuel
Kristianstad biogas plant

Organics
100,000t/yr

CO_2

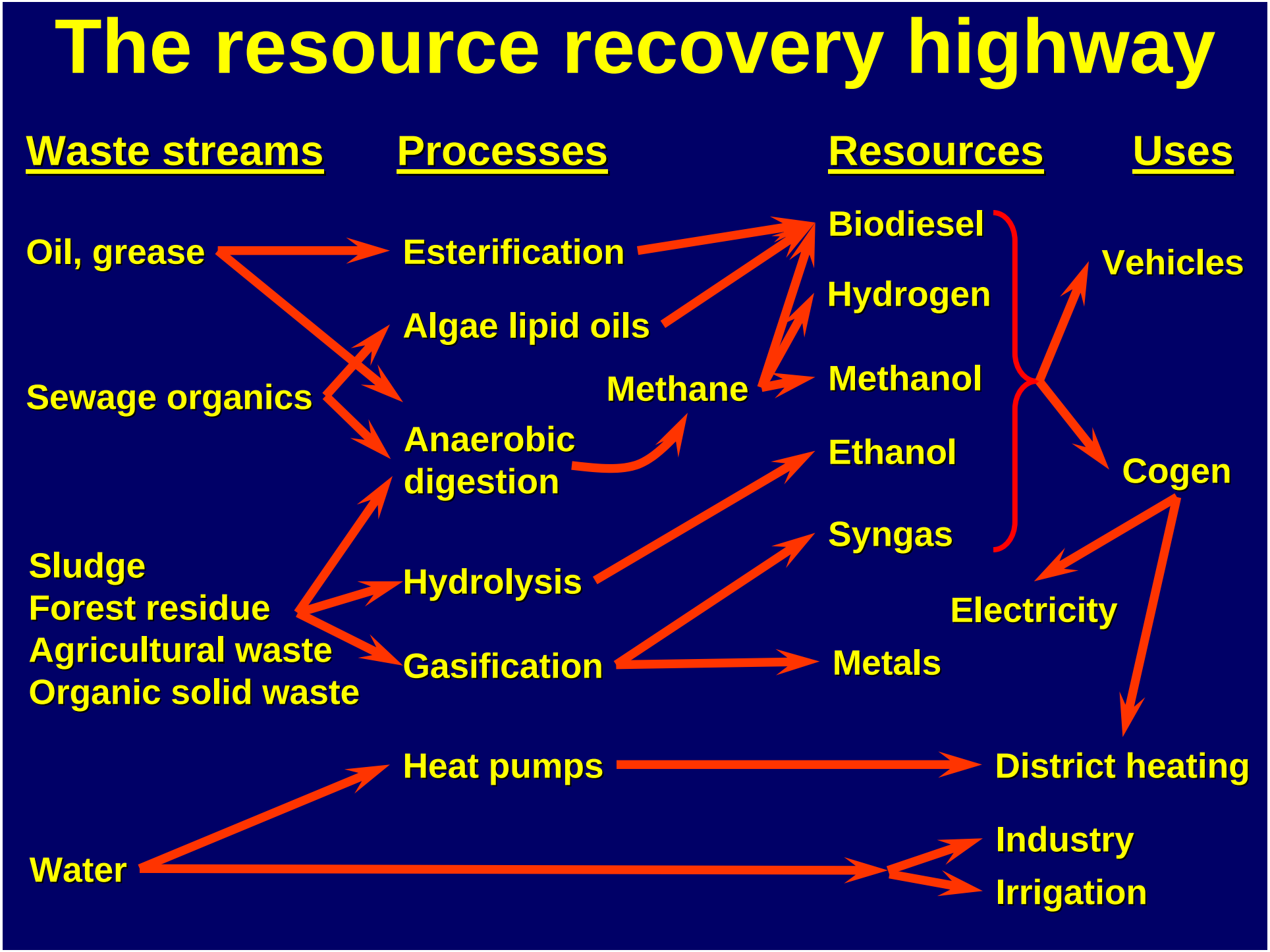
Cogen Vehicles

Energy
44 GWh/yr

Cost = $2 million/year
Benefit = GHG-neutral fuel

The bottom line is that it's not only better for the environment to turn waste into fuel, it's financially responsible as well.

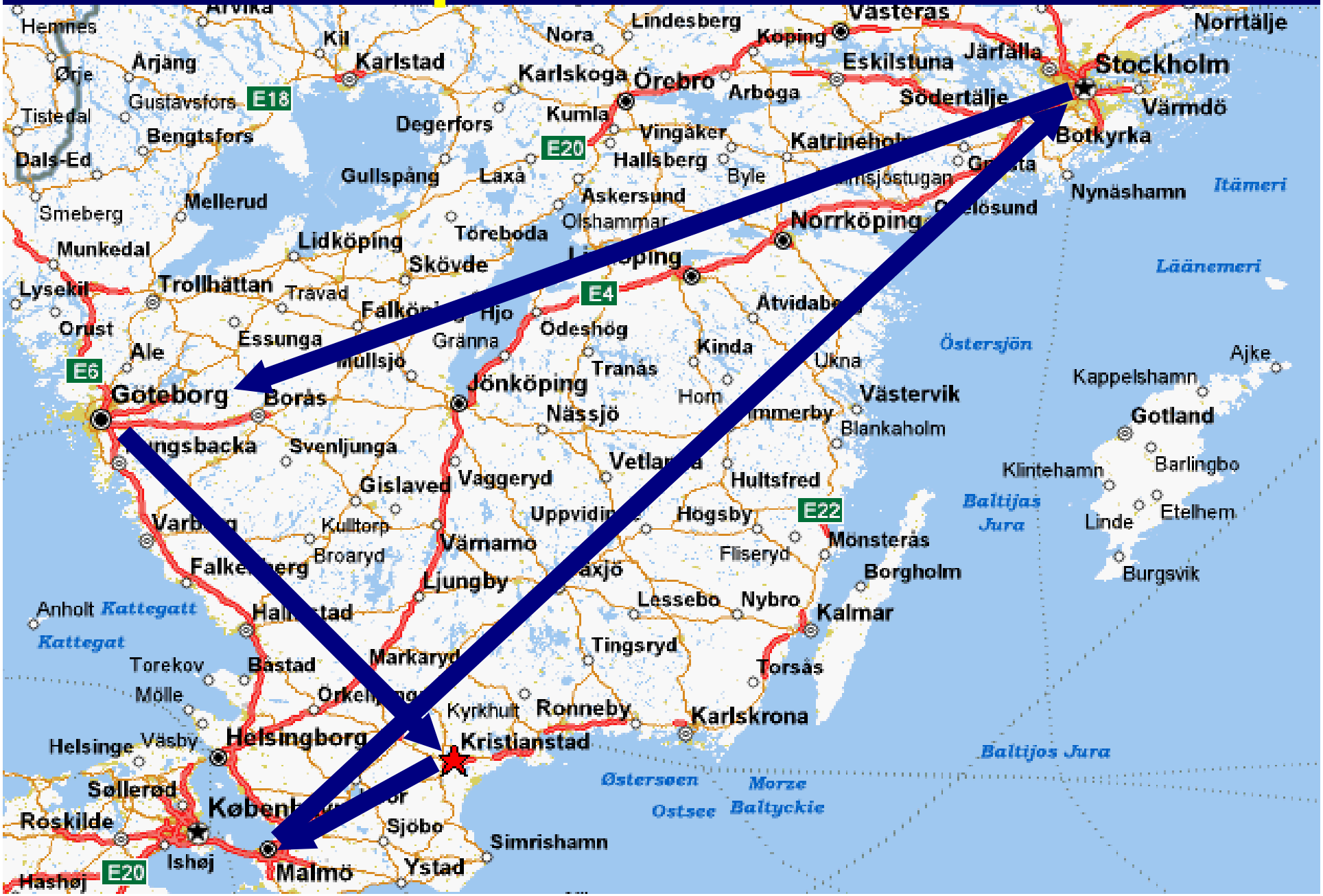
The resource recovery highway



The technology's not new

	Who	When
Integrated planning	Europeans	1980
Fuel cell	William Groves	1839
Heat pump	Jacob Perkins	1834
Biogas digester	Humphry Davy	1808
Gasification	Dean Clayton	1699
District heating	Romans	300

Principles from Sweden



1. Waste planning is community planning

Stockholm's Henriksdals tertiary treatment plant is buried in the hill, and a large apartment block is located directly above the plant.

2. Use each resource for its highest value

Raw biogas is about 70% methane and 30% CO_2. The Henriksdals plant upgrades this raw gas to 98% methane for sale to Stockholm's bus company, and as cooking fuel to the Hammarby Sjöstad development.

...provides biogas for inner-city buses,

Biogas runs 51 buses in Stockholm as of December, 2006, and the number will increase to 200 by 2010 as the Henriksdals plant produces more biogas from organic waste. Each biogas bus added in the inner city displaces an ethanol-powered bus to the suburbs, where a diesel-powered bus retires.

... and for the Hammarby Sjöstad development,

Stockholm's energy company (Fortum Energi) uses heat pumps to extract heat from treated sewage effluent to provide hot water and heating to 80,000 apartments, including the Hammarby Sjöstad development. After the heat has been extracted, effluent is just above freezing. This "coolth" flows through a separate network of district cooling pipes for refrigeration and air conditioning. The sewage plant is paid for this energy as well as for biogas, which helps offset the cost of treatment.

...where kitchen waste is collected for treatment.

Kitchen waste in Hammarby Sjöstad is collected via underground vacuum tubes, and increasingly is sent to the sewage treatment plant to produce biogas; an ecologically closed loop.

3. Solve several problems together

The Karpalund biogas plant accepts kitchen, agricultural, and food factory waste. Since the raw material is clean, residue from digestion does not contain the contaminants found in sewage sludge and is returned to farm land.

Sweden's treatment plants handle liquid and municipal waste, and counter climate change by providing clean fuel.

Biogas is also produced from Kristiansad's sewage plant. Residue from this plant is not applied to farmland, but is applied to industrial sites such as mines and gravel quarries.

Biogas as fuel

Biogas provides fuel for Kristianstad's transit & school buses...

... plus most taxis, and a cogen plant for electricity & district heating...

Biogas as fuel

Kristianstad
Capacity for 1,500 cars

Capital Region
Potential for 10,000 cars
Value: $13 million/year

District heating

Energy companies pay to insulate their clients' buildings, which allows more clients to be added to the district heating network. In this way, the interests of the energy company and the environment are aligned.

<u>Capital Region</u>
38,000 homes could be heated from sewage
Value: $30 million/year

Biogas at the pump

Välkommen
E.ON Förs.Sverige AB

KVITTO FÖR TANKNING

DATUM OCH TID	2006-10-06 12.00
PUMP	1, BIOGAS
VOLYM	15,84 M3
PRIS	9,13 KR/M3
TOTALT BELOPP	144,61 KR
VARAV MOMS	28,93 KR

KORTBETALNING
Transaktionstyp: Köp
(Personlig kod)
Kortnr:
Belastat: Konto
Belopp: SEK 144,61
Kontrollnr: 636046
Refnr: 713

Biogas in Kristianstad is about 25% cheaper than gasoline, due in part to the Swedish carbon tax on fossil fuels, and to the fact that biogas is produced from waste. The city subsidizes the cost of converting a car to biogas, and provides owners of biogas cars with free parking.

Growing away wastewater*

Constructed wetlands

Solar Aquatic Systems, Living Machines

Carol Steinfeld, www.carol-steinfeld.com

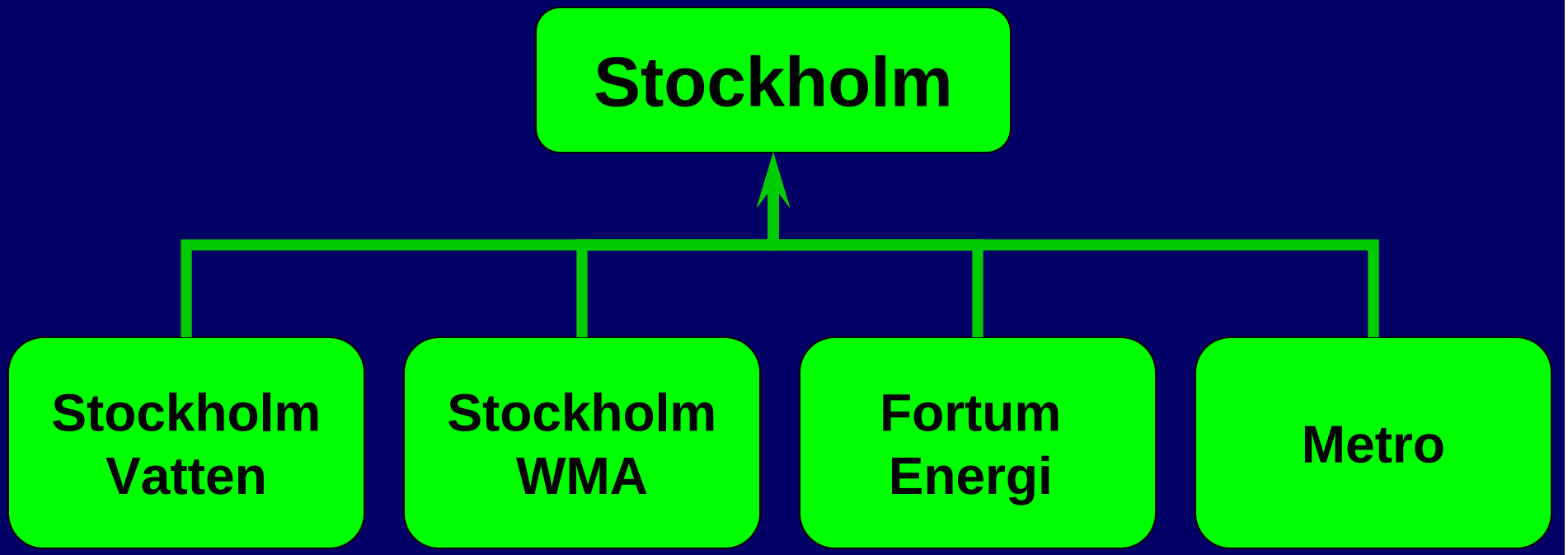
Reclaiming water

Water reclamation in San Diego

Water reuse in Dockside Green

4. Integrate the community planning

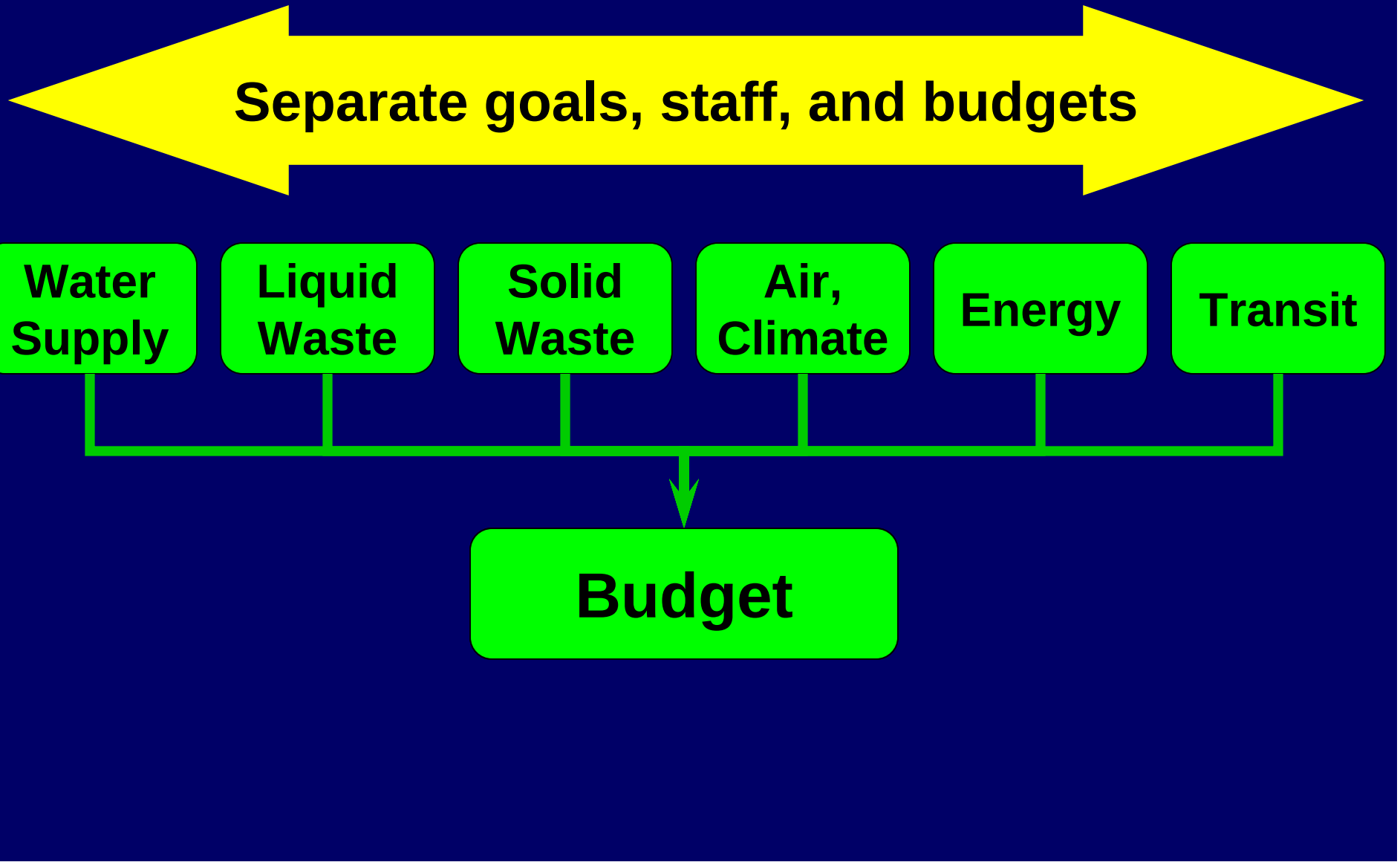
Swedish for common sense



Each Swedish city owns separate companies for managing sewage, solid waste, energy, and transportation. These companies take their direction from the municipal council, and integrated planning ensures the best results for the community as a whole.

In the administrative world,

the issues seem separate



In the physical world,
solutions are connected

Common problems, impacts, and solutions

- Water Supply
- Liquid Waste
- Solid Waste
- Air, Climate
- Energy
- Transit

Eco-footprint

When we try to pick out anything by itself, we find it attached to everything else in the universe.
John Muir, 1892

5. Make waste pay its own way

lowest cost is lifecycle cost

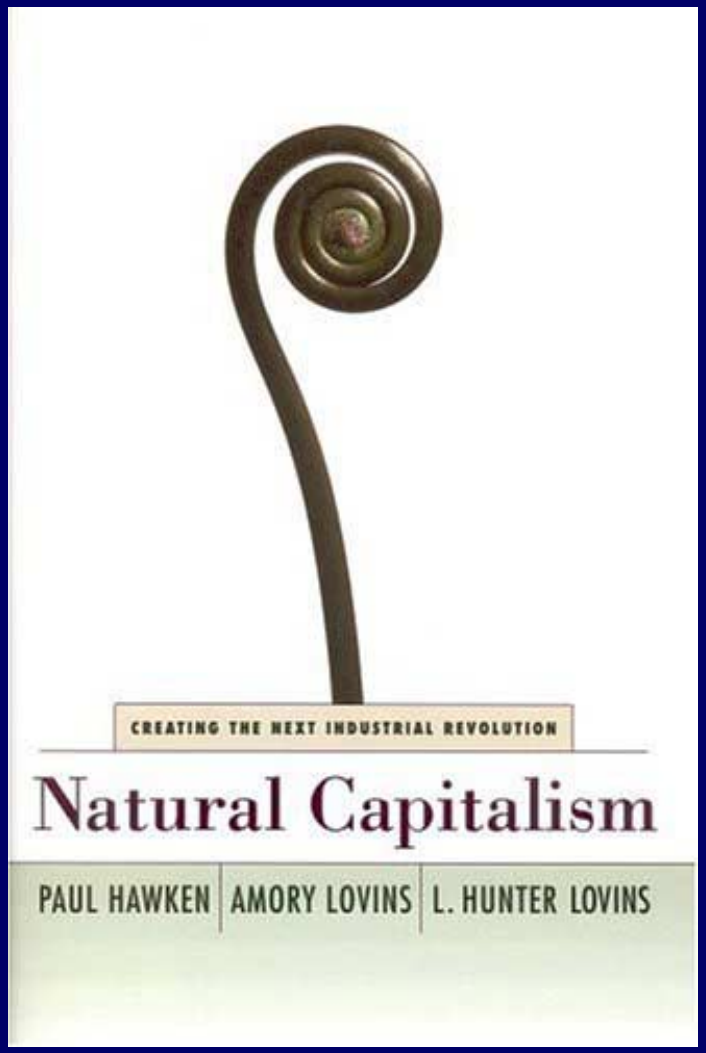
Cost of Treatment (per home per year)	City
$120.00	Canadian average
$86.11	Gothenburg
$77.84	Stockholm

Sewage treatment costs are offset by revenues from the sale of biogas and heat. Since Swedish plants are net energy providers, the cost of treatment will fall as energy prices rise. Canadian treatment costs rise with energy prices.

Natural Capitalism

Ecology at work

"Optimizing the components in isolation tends to pessimize the whole system"



"Nature does not compromise, nature optimizes"

Resource means "to rise again"

Biodiesel

Fuel

or

Electricity

Oil & grease

Biogas

District heating
& cooling

Sewage

Garbage

Treatment

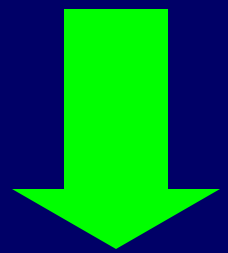
Heat
pump

Disinfection

Water for
industry,
irrigation

The real value of waste

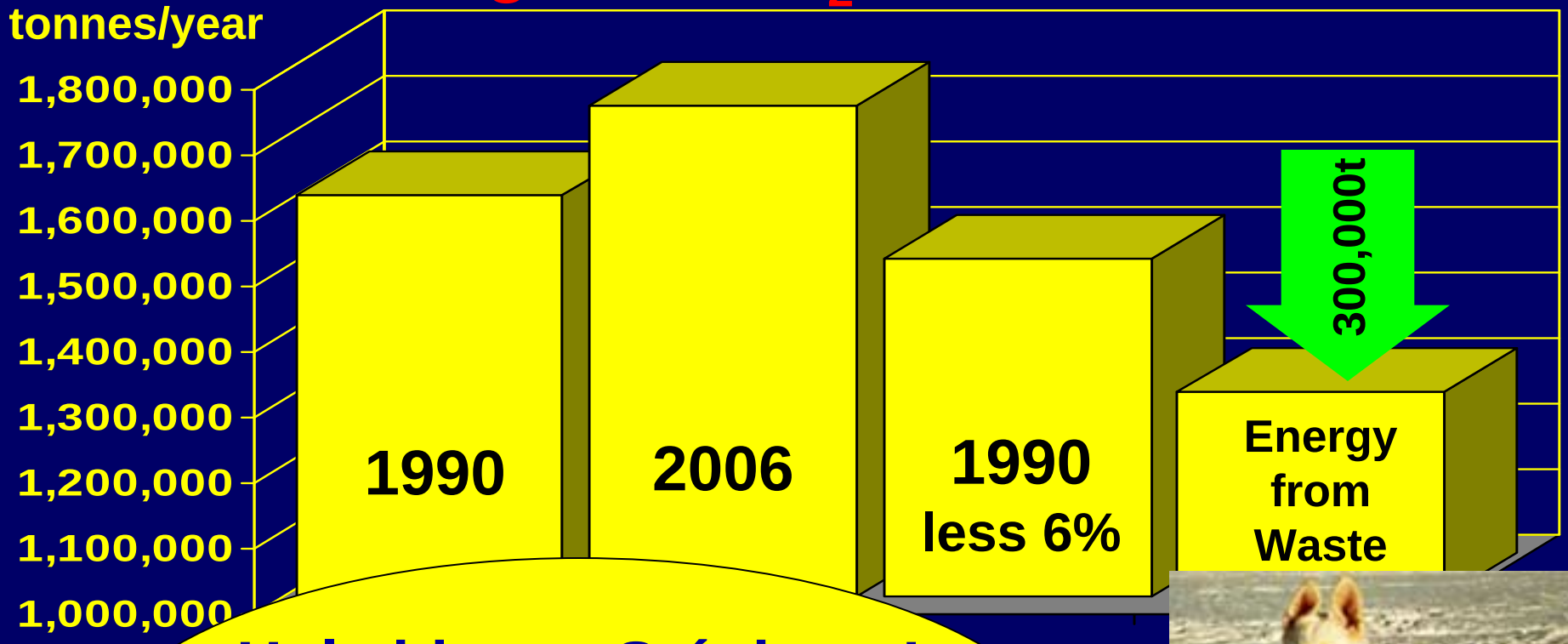
	$/yr	CO_2t/yr
Waste diverted from landfill:	$10M	165,000
Recovered biofuels:	$13M	33,000
Reclaimed water (15%):	$2M	
Recovered heat:	$30M	100,000
	$55M	300,000
Cost of standard treatment:	$16M	



Reduction of CO_2 = 60,000 cars

What about Kyoto?

Regional CO_2 emissions

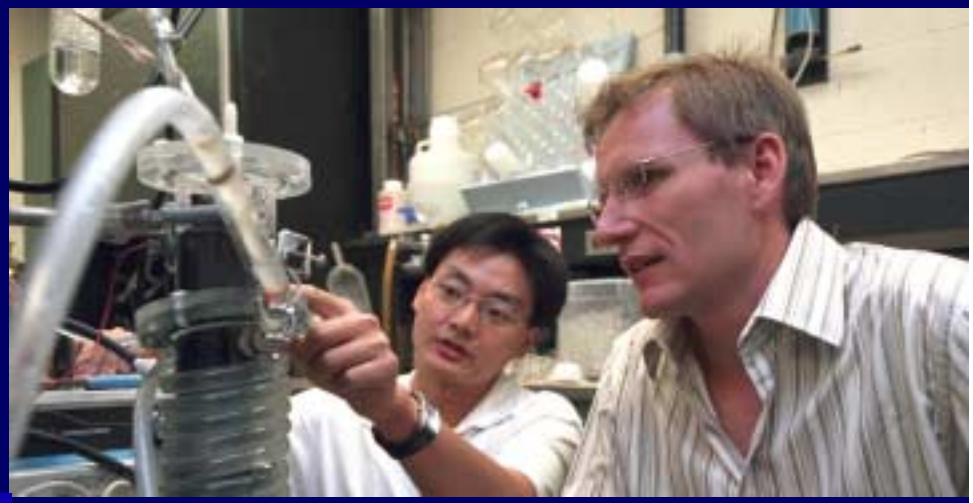


Holy biogas Stéphane!
We could meet
our Kyoto target
on waste alone!

Research underway

Microbial fuel cell

Washington University in St. Louis



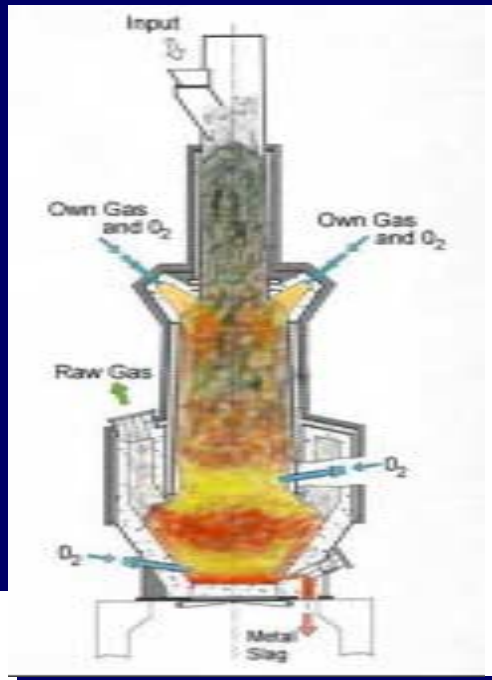
Waste to hydrogen

Indian Institute of Technology

Research underway

Low-temperature gasification

University of Tsukuba



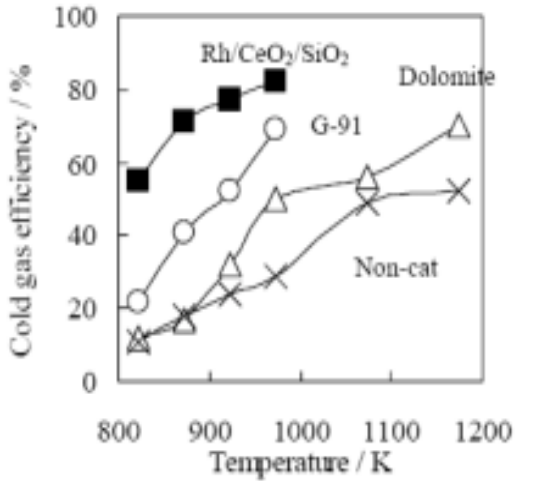
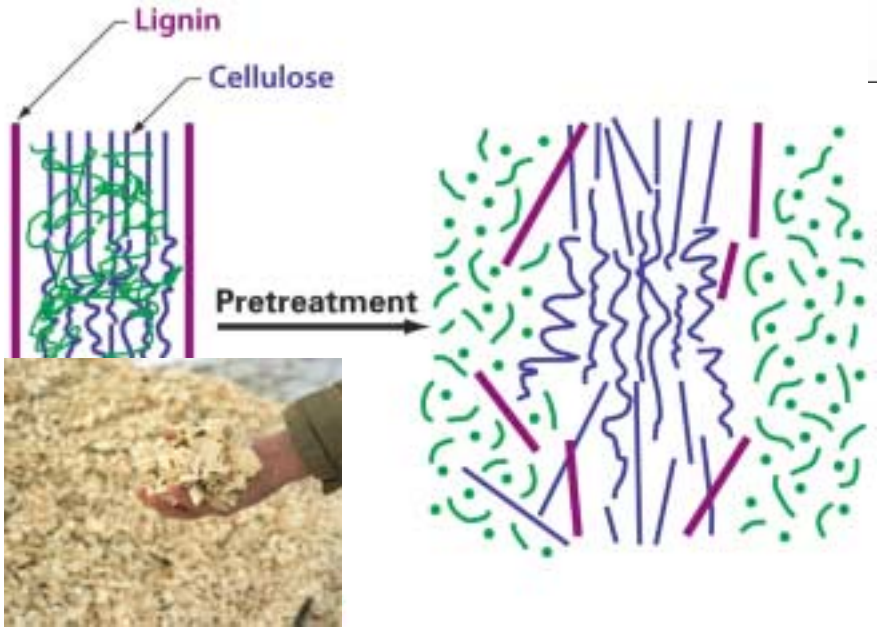


Figure 2. Dependence of cold gas efficiency on reaction temperature using various methods in the gasification of cedar wood. Reaction conditions are the same as those in Table 1.



Cellulosic ethanol

Lund Institute of Technology

Research underway

Algae on flue gas

Greenfuel Technologies
Cambridge, Massachusetts

Biodiesel from algae

Aquaflow Bionomic
Marlborough, New Zealand

Research needed
Canadian opportunities

- **Policies and planning:**
  - **Integrated community planning practices**
  - **Tax steering & economic policies**

- **Technologies:**
  - **Siloxane removal**
  - **Efficient biogas upgrading**
  - **Conversion processes (e.g. cellulose to biofuels)**
  - **Separation processes (e.g. ethanol distillation)**

Funding is available

Federal Infrastructure Fund

(Public Transit, Capacity Building, Community Energy Systems, Water and Wastewater, Solid Waste Management)

http://www.infrastructure.gc.ca/ip-pi/index_e.shtml

Green Municipal Fund

http://www.sustainablecommunities.fcm.ca/GMF/

Sustainable Development Technology Canada

http://www.sdtc.ca/en/contact.htm

More information

Georgia Strait Alliance
www.georgiastrait.org/

TBuck Suzuki Environmental Foundation
www.bucksuzuki.org/foundation.htm

BC Sustainable Energy Association
www.bcsea.org/

Dockside Green
www.docksidegreen.ca/

Natural Capitalism
www.natcap.org/