SIXTH FRAMEWORK PROGRAMME

Neptune FP6 Project

Environmental Technology Evolution:
Water Research Prioritization

David J. Kinnear, Ph.D., P.E.
HDR Engineering, Charlotte, NC
dkinnear@hdrinc.com

HDR

Inclusion of ecotoxicity in life cycle assessment
Henrik Fred Larson

Ozonation to Remove μCONs

1. Lina and I discussed whether any μ constituents in environment are acceptable.
2. I thought – why not figure out how to target drugs in organisms so they don't end up in wastewater?
3. Maureen commented that ASA would approach this first as an IPP problem: Environmental Management Plan.
4. Hans Siegrist commented that ozonation is a reasonable cost. Policy makers still need complex cost/benefit analysis.

Engineer = Scientist + Economist

Is Water Treatment a Mature Technology?

Research funding is scarce, so duplication of effort needs to be avoided.

Hugh Monteith

LCA – A Decision Support Tool

Henrik Fred Larson

- A Question
- An Observation
- A Discussion
- References
- The Problem
- A Potential Solution

The Question…

Q: Why are wastewater treatment research funds so limited?

A: Compared to other research needs, wastewater treatment many not be a priority.

Idealist question – practical (sacrilegious) answer: data and analysis.

Wastewater research may not be a priority at the margin?

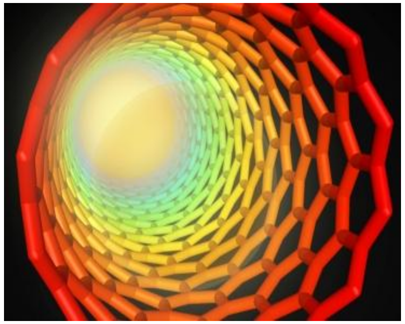
We study wastewater, but we don’t have to.

Yesterday’s began to formulate a plan that understanding wastewater N2O emissions can help solve soil N2O emissions. A much larger part of the problem.

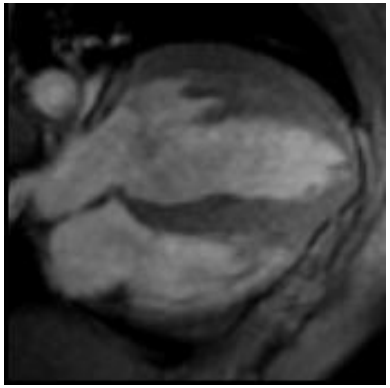
Opportunity Cost of Research Alternatives

taking a step back from our wastewater perspective…

- Scavenging energy waste to turn water into hydrogen fuel (crystal ultrasounics).
- Carbon nanotube electricity production.
- Pandemic Avian Influenza.
- Arctic seabed methane destabilization
- Medical Imaging (NIBIB). Visualizing heart attacks.
- Incorporating biofunctionality in nanomaterials.
- Cracking the plant cell-membrane code.
- Evolution of fairness and punishment.
- Primitive massive black holes.
- Large Hadron Collider.



nsf.gov



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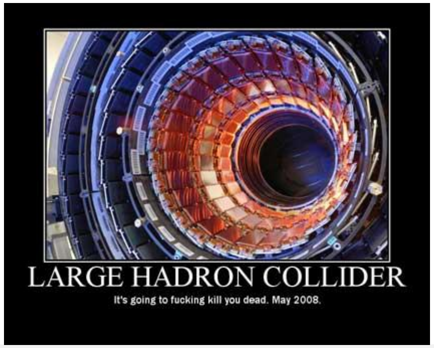


7 TeV – March 30

www.cern.ch

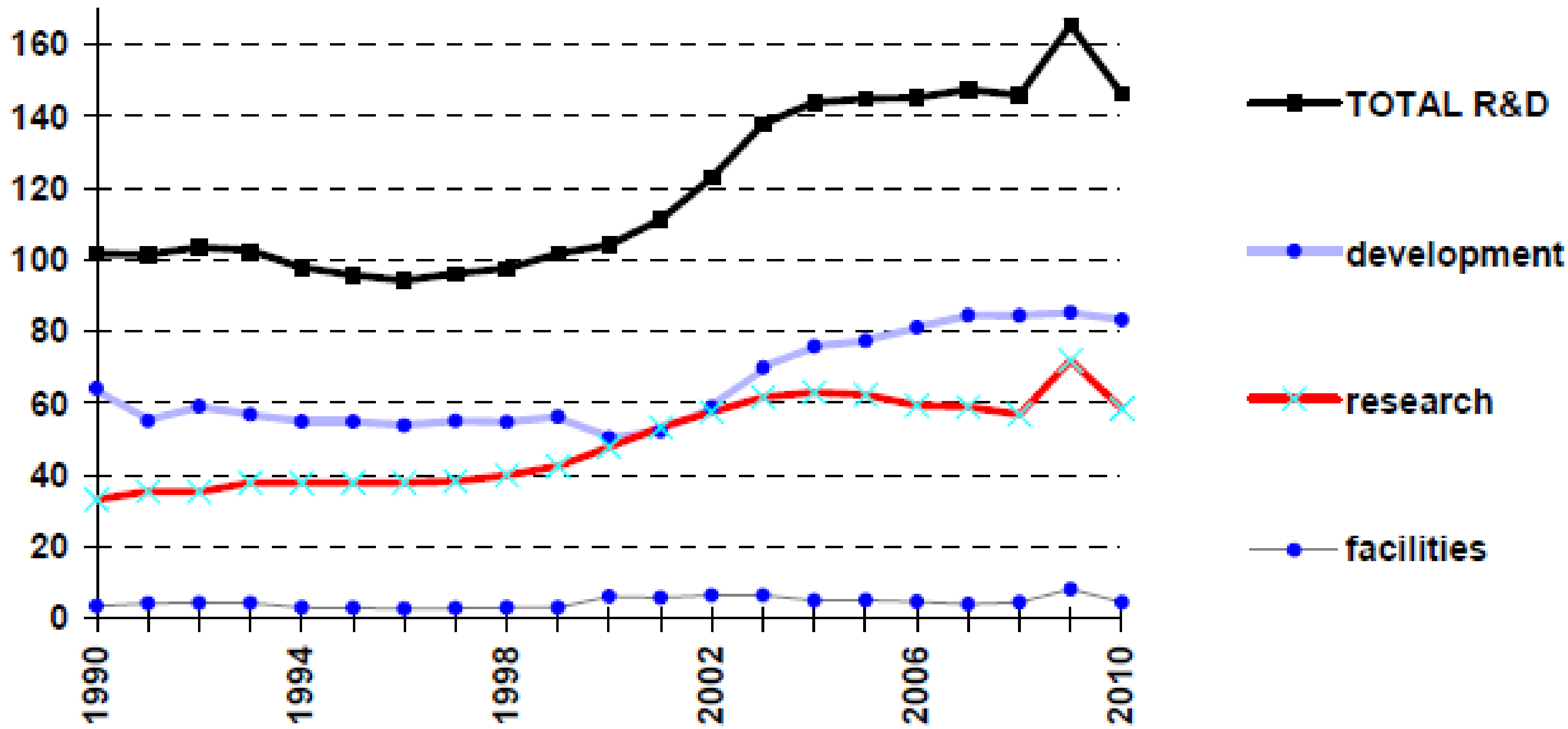
Engineering = Prioritization

NSF Accounts (FY2010: $7.045B)

- Biological Sciences (BIO)
- Computer & Information Science & Engineering (CISE)
- Cyberinfrastructure (OCI)
- Education and Human Resources (EHR)
- Engineering (ENG)
- Environmental Research & Education (ERE)
  - Climate change education (P)
  - Water Sustainability and Climate (Proposal due April 15) (Crosscutting and NSF-wide)
  - Oceanic nitrogen cycle
- Geosciences (GEO)
- Integrative Activities (OIA)
- International Science & Engineering (OISE)
- Mathematics and Physical Sciences (MPS)
- Polar Programs (OPP)
- Social, Behavioral & Economic Science (SBE)

Trends in Federal R&D, FY 1990-2010

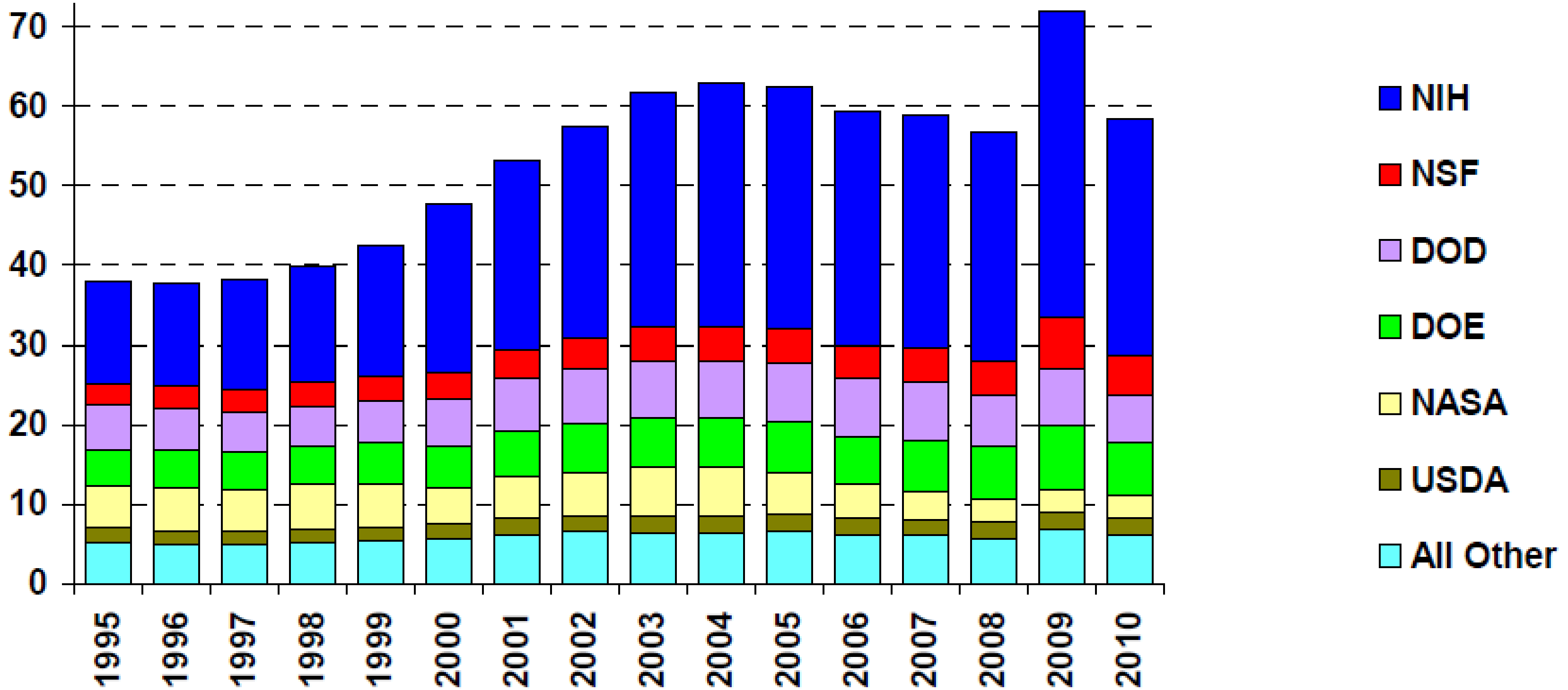
in billions of constant FY 2009 dollars



FY 2009 figures include Recovery Act appropriations.
Research includes basic research and applied research.
MAY '09 OSTP

Trends in Research by Agency, FY 1995-2010

in billions of constant FY 2009 dollars



Presently, this is all determined politically.

FY 2009 figures include Recovery Act appropriations. Research includes basic research and applied research.
MAY '09 OSTP

The Observation…

Wastewater plant system evaluations frequently result in a dead heat. Why?

Wastewater process development = slowly-moving evolutionary process and we only evaluate a snapshot in time…

Sewage Treatment in America
L.R. Howson (1933)

- Institution of Chemical Engineers (UK)
- *Paper read at a meeting of the Institution held in the Rooms of the Chemical Society, Burlington House, London W.1, on Wednesday, January 25, 1933, Mr. W. A.S. Calder, Past-President, occupying the Chair.*
- …activated sludge is being adopted almost universally where secondary treatment is necessary.
- The larger activated sludge installations are of the diffused air type…
- …sludge is digested in separate, heated tanks arranged for the collection of the gas generated… Several plants are considering power generation through gas engines.
- Within recent years, plants for the treatment of sewage have been placed under the guidance of a qualified engineer or chemist.
- Along with the prevention of Odours, American designers are now recognizing the psychological advantages of attractively designed and laid out buildings and grounds, thus reducing the popular objective to sewage treatment plants.

Evolution of Wastewater Technologies

<u>Successful</u>

- Conventional Activated Sludge
- Clarification
- Filtration
- Selector technology
- Chemical/EBPR
- Biological nitrogen removal
- Denitrification filters
- High-rate clarification
- Centrifuge /BFP

<u>Emerging</u>

- IFAS
- Struvite Precipitation
- ASM
- Certain sensors/controls
- Biosolids minimization
- Membrane bioreactor
- Nitritation/Annamox
- Thermal biosolids oxidation
- Cannibal®

<u>Marginal/Failed/Distrupted</u>

- High-Purity Oxygen?
- Zimpro (high-temperature, high-pressure processs)
- RBC?
- SBR?
- Spiral-roll coarse-bubble diffusion?
- Vacuum filtration

1. Must be technically feasible, economically competitive, and provide proven benefits to stakeholders (highly adopted).
2. What other examples can this group think of?

Digital Game-Based Learning Workshop

Table 1. Project Capitalization

Team	Capital Cost, M$	Bond Rate, %
Team 1	69.5	4.25
Team 2	59.1	4.25

Table 2. Life-Cycle Cost Assessment Cash Flow, M$

Category	Team 1		Team 2	
	2010	2015	2010	2015
Debt Service	5.25	5.64	4.45	5.35
Nutrient Market	(0.44)	(0.42)	(0.40)	(0.08)
Labor	0.80	0.96	0.56	0.80
Operations	0.55	0.66	0.45	0.99
Sludge Disposal	0.15	0.21	0.15	0.21
Power	0.72	0.92	0.49	0.70
GHG Emissions	0.12	0.16	0.08	0.12
Chemicals	0.22	0.25	0.00	0.59
Total Annual	**7.37**	**8.38**	**5.78**	**8.68**
Present Value		**$72.89**		**$72.67**

Digital Game-Based Learning Volunteers

- WEF Membrane Applications 2010
  Hilton Anaheim
  6 – 9 June 2010: Anaheim, California

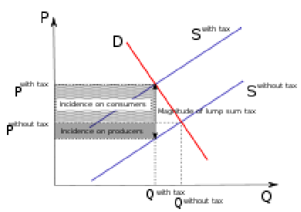
- IWA World Water Congress and Exhibition - Nitrogen
  19–24 September 2010: Montréal, Canada

- WEFTEC.10 – Nitrogen Upgrade
  2-6 October 2010: New Orleans, Louisiana U.S.A.

The Discussion…

Wastewater utilities do not fund enough research.

Utilities Opportunity Cost of Research…



- Employee Salaries
- Capital Improvements
- Debt Service
- Power
- Chemicals
- Consultants
- Research
- Equipment Replacement
- Biosolids Disposal

Wastewater R&D Funding Benefits

- Publicly-Funded
  - Reduce waterborne illness.
  - Reduce human impact on water ecosystems.
  - Improve efficiency.
- Privately-Funded
  - Marketplace advantage – not necessarily in the public interest.

REFERENCES

A Search for Science Policy

- The Science of Science Policy: A Federal Research Roadmap. National Science and Technology Council (November, 2008).
- Evaluating Research Efficiency in the US Environmental Protection Agency. National Academy Press (2008).

The NAS has published four reports since 1993 that examine how to assess the benefits and effectiveness of Federal investment in science and technology.

Neptune FP6 Project

Science of Science Policy

“To provide a scientifically rigorous, quantitative basis from which policy makers and researchers can assess the impacts of the Nation’s scientific and engineering enterprise, improve their understanding of its dynamics, and assess the likely outcomes”.

Science of Science Policy

"…science policy discussions are frequently dominated by advocates for individual fields who argue for their particular interests, but leave policy makers with little ability to objectively discriminate between investment options".

Science of Science Policy

Theme 1: Understanding Science and Innovation
- *What are behavioral foundations of innovation?*
- *What explains technology development, adaption and innovation?*
- *How and why do communities of science and innovation form and evolve?*

Theme 2: Investing in Science and Innovation
- *What is the value of the Nation’s public investment in science?*
- *Is it possible to “predict discovery”?*
- *What are the determinants of investment effectiveness?*

Theme 3: Using the Science of Science Policy to Address National Priorities
- *What impact does science have on innovation and competeveness?*
- *How competitive is the US scientific workforce?*
- *What is the relative importance of different policy instruments in science policy?*

Desire for more econometric decision models.

Evaluating EPA Research Efficiency

1. NAS provided EPA advice on:
   - 1993 Government Performance and Results Act
   - OMB Program Assessment Tool (2002)
2. R&D evaluation proves difficult for all Federal agencies.
   - *Inputs*: agency resources (funds, facilities, people)
   - *Outputs*: papers, schedules, budgets
   - *Outcomes*: benefits resulting from the research program
   - *Efficiency*: doing the right research and doing it well.

The desire to move from process efficiency (output metrics) to investment efficiency (outcome metrics) is much easier said than done.

Ultimately, this allows engineers more influent over policy

There was a lawyer, an engineer and a politician…

Why do professional paths to the top vary so much?

The Economist, April 16, 2009

Econometric Model of Water Research

- Research Resources

Research cannot be planned or known in advance, it requires constant feedback.
Converting research into outcomes often requires activates “by others” following the research.
A long complex time delay typically exists between research activities and outcome.

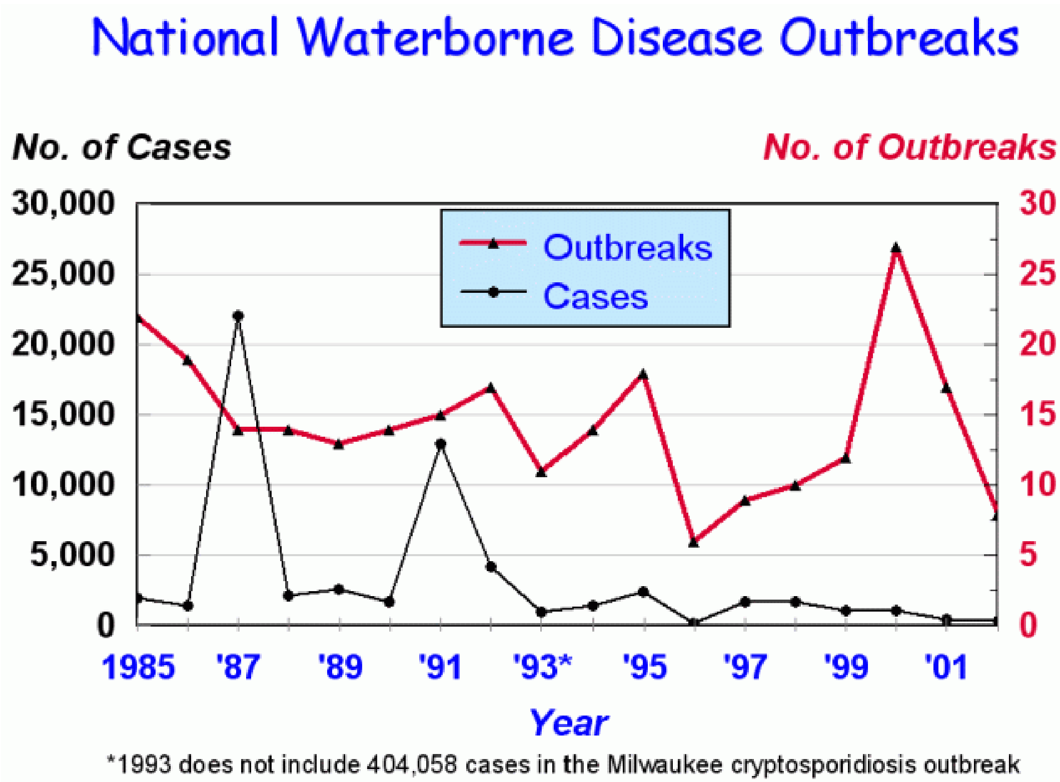
IT, data mining, and economic modeling beginning to make these relationships possible rather than counting citations and tracking schedules and budgets.

- Objective (Utility) Function [*Outcomes*]
  - Minimize waterborne illness.
  - Minimize human impact on water ecosystems.
  - Minimize cost (improve efficiency)

Waterborne Illness Under Control?

…from public perception

Soho, England, 1854



Ecosystem Conditions Improving?

…..from public (environmental group) perception

Wastewater Treatment Cos
...from the individuals perspective

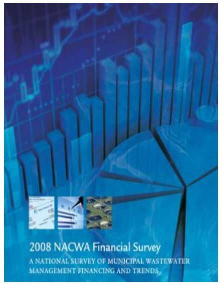
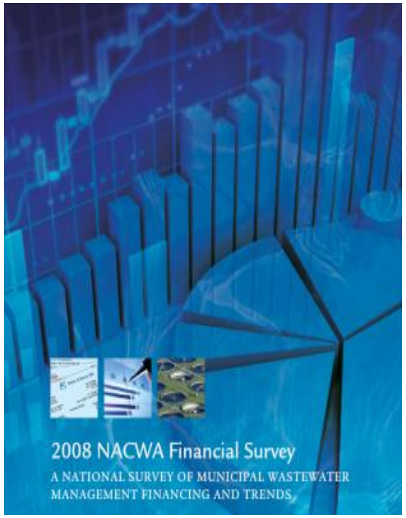


TABLE A-19 SUMMARY STATISTICS FOR COMMON BENCHMARKS (2008 ALL RESPONDENTS)

Utility Benchmarks	# of Agencies	Maximum	Average	Median	Minimum
Total Cost ($) Per Million Gallons Treated	88	18,672	4,437	3,587	968
- Agencies Providing Collection and Treatment	62	18,672	4,581	3,727	968
- Agencies Not Providing Collection Services	24	9,212	4,054	3,382	1,715
Biosolids Costs ($) Per Dry Ton Biosolids Produced	38	4,831	467	238	22
- Agencies Providing Collection and Treatment	23	4,831	583	238	22
- Agencies Not Providing Collection Services	15	1,098	288	239	62
Collection System Cost ($) Per Retail Sewer Mile	62	76,375	8,258	5,042	801
- Agencies Providing Collection and Treatment	52	16,800	5,825	4,533	801
- Agencies Not Providing Collection Services	10	76,375	20,909	18,168	2,952
Average Annual Residential Sewer Charge ($)	78	694	303	279	80
- Agencies Providing Collection and Treatment	62	694	305	282	80
- Agencies Not Providing Collection Services	16	588	296	272	171

Wastewater Treatment Cost



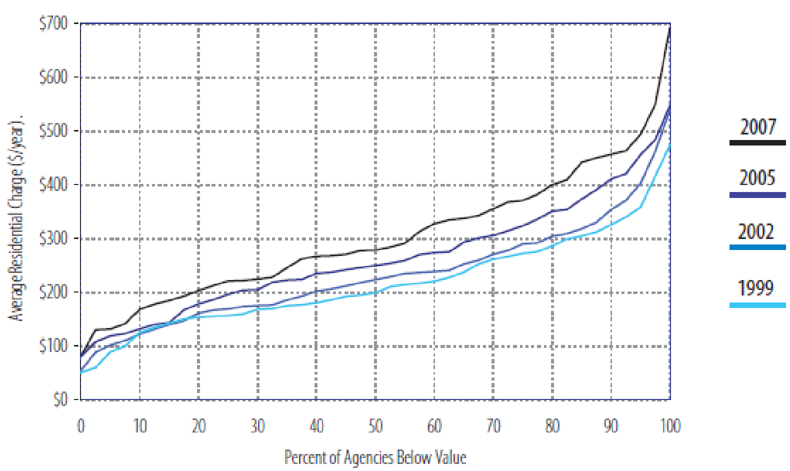
$303/$50,233 = 0.60 %

Much lower for many in decision making roles.

Two Perspectives:

1. Low enough there is no price driver to influent behavior (induce research).
2. Low enough that people would invest more.

FIGURE C.9 AVERAGE RESIDENTIAL CHARGE DISTRIBUTION (ALL RESPONDENTS)

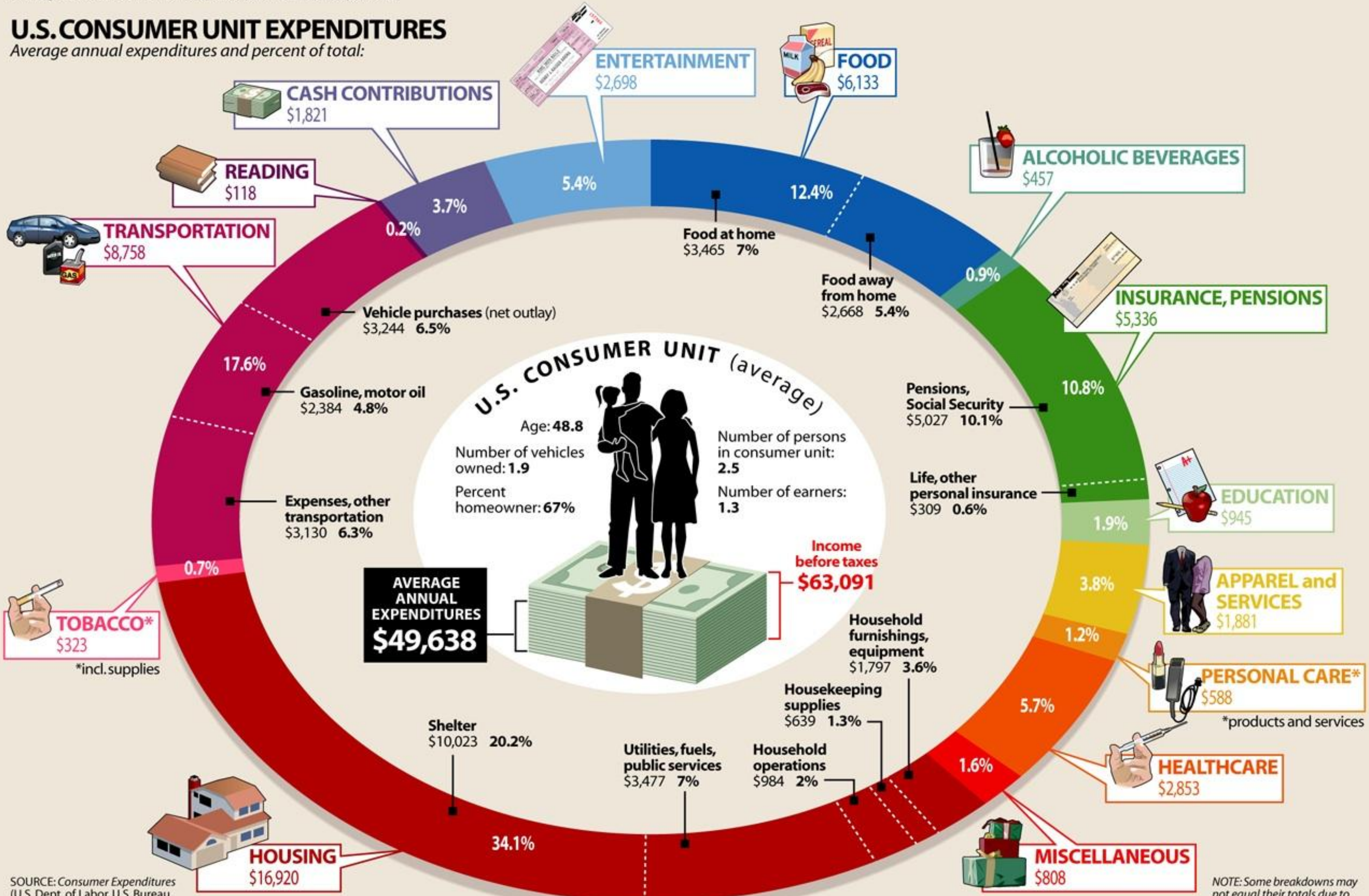


Where Does the Money Go?

The Department of Labor's latest survey provides a detailed look into how the average U.S. consumer unit spends their annual paycheck.

U.S. CONSUMER UNIT EXPENDITURES

Average annual expenditures and percent of total:



SOURCE: *Consumer Expenditures* (U.S. Dept. of Labor, U.S. Bureau of Labor Statistics, April 2009)

NOTE: Some breakdowns may not equal their totals due to rounding.

Conclusions

- Not advocating "No Need for Environmental Research", just including improved prioritization metrics warranted.
- If water researchers have "worked themselves out of a job" – there are lot of other jobs to do.
- Engineers, as economists, need to step back from personal interests and develop data to demonstrate research effectiveness.
- US federal funds beginning to consider decision making with econometric models. The water sector should consider getting involved.

NAS has not suggested "backtesting" (*posterior analysis?)* strategies to determine more appropriate research metrics.

Is Modeling a Mature Technology?

This contribution is meant to start a discussion

Willi Gujer

1. Financial industry uses it.
2. NAS did not think of it.
3. W. Gujer and X. Flores-Alsina thinking along these lines.

Table 1. Evolution of the Zurich-Werdhölzli wastewater treatment plant over a period of approx. 20 yrs. (See also Dominguez and Gujer, 2006)

1975	Pilot experiments are performed in order to develop design information for the new WWTP.
1978	The design is based on design loads which exceed observed loads by approx. 15% An existing activated sludge plant is converted into a two step nitrifying activated sludge process which includes phosphorus removal by simultaneous precipitation.
1979	In a public vote the people of Zurich support the new works with a margin of 19:1. This opens over four years the biggest construction site in the city.
1985	The new plant starts operation in two-step mode.
1986	Phosphorus is banned in washing powders which results in massive reduction of Fe^{3+} addition and thus less sludge production and thus the possibility to increase SRT.
1989	The old activated sludge plant is abandoned. Only single step mode remains.
1993-1998	Gradual introduction of pre-denitrification up to 28% anoxic volume in existing aeration tanks.
1996	Reduction of max. hydraulic load from 9 to 6 $m^3\ s^{-1}$ allows to increase MLTSS from 3 to 4.5 kg m^{-3}
1978-2003	The infiltration of unpolluted water into the sewer system is reduced from 0.9 to 0.6 $m^3\ s^{-1}$. The overall water consumption is reduced from 190'000 to 125'000 $m^3\ d^{-1}$, the connected population shrinks from 400'000 to 350'000, a large slaughter house, a national brewery and a national dairy company leave town.
2001	A second wwtp of the city is closed down and 100'000 pe. are connected to the plant.
2002	The treatment plant treats deicing fluids from an international airport

Dave Kinnear

HDR Engineering

dkinnear@hdrinc.com