



Water Efficiency and Resource Recovery - Tools, Technologies & Approaches

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National Exposure Research Laboratory

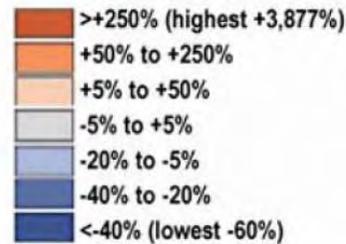
Outline of Talk

- Challenges to a Sustainable Water Future
- Shifting the Paradigm
- EPA ORD's Research Approach with SSWR
 - Sustainability Planning/Assessment Tools (Project 5.1)
 - Resource Recovery R&D (Project 5.4)

Our top 10 problems for next 50 years (Richard Smalley, Nobel Laureate)

1. Energy
2. **Water**
3. Food
4. Environment
5. Poverty
6. War/terrorism
7. Disease
8. Education
9. Democracy
10. Population

Projected change in county population (percent), 1970 to 2030

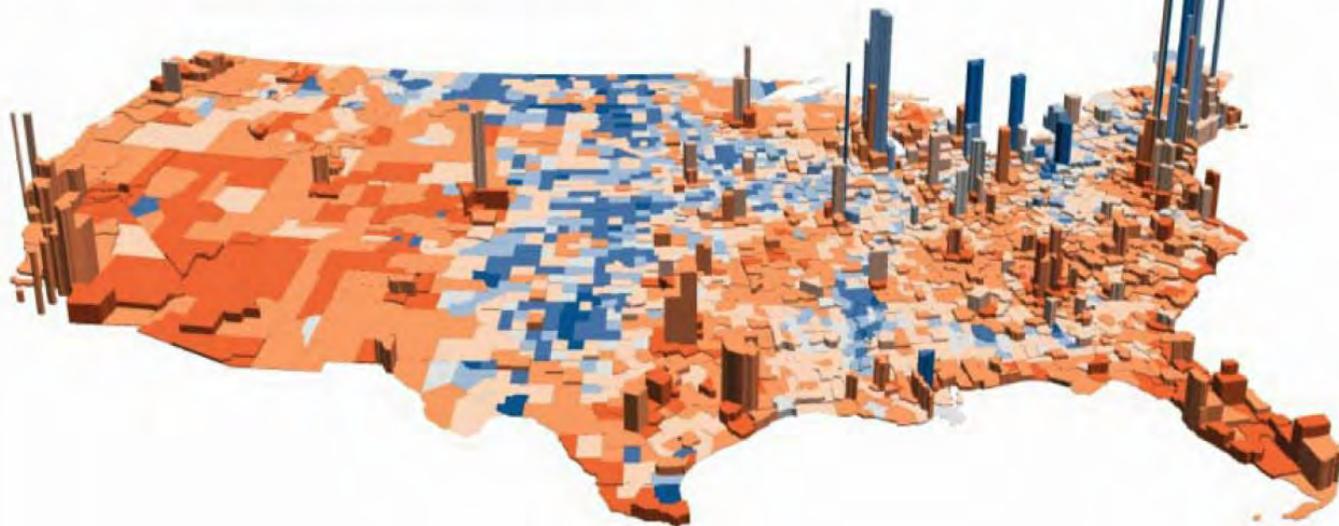


US Population & Growth trends

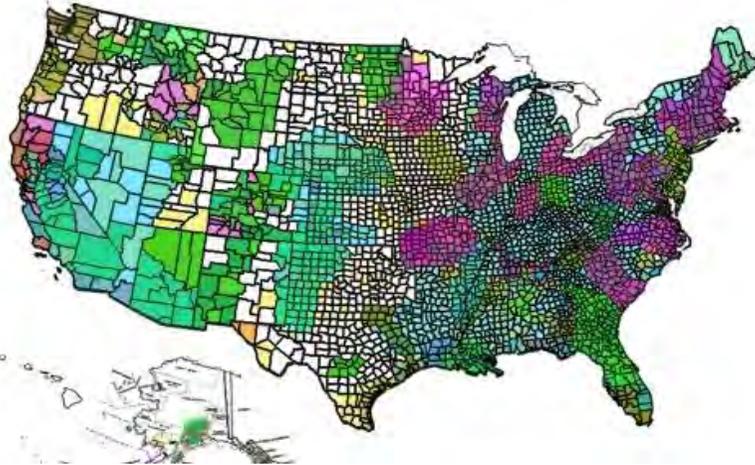
[Change in Co. population, 1970 to 2030]

- One block for each Co. in U.S.
- Height of Block = Population density
- Color = Δ Pop between 1970 & 2030

Growth along Coasts, in South, in West

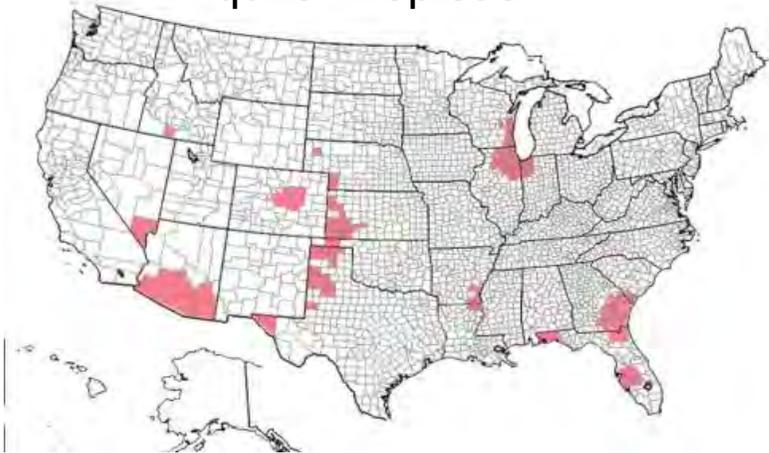


Integrated Water Problem Map



U. of Illinois WaterCampws (The Center for Advanced Materials for the Purification of Water with Systems)

Aquifer Depletion



Saltwater Intrusion into Aquifer

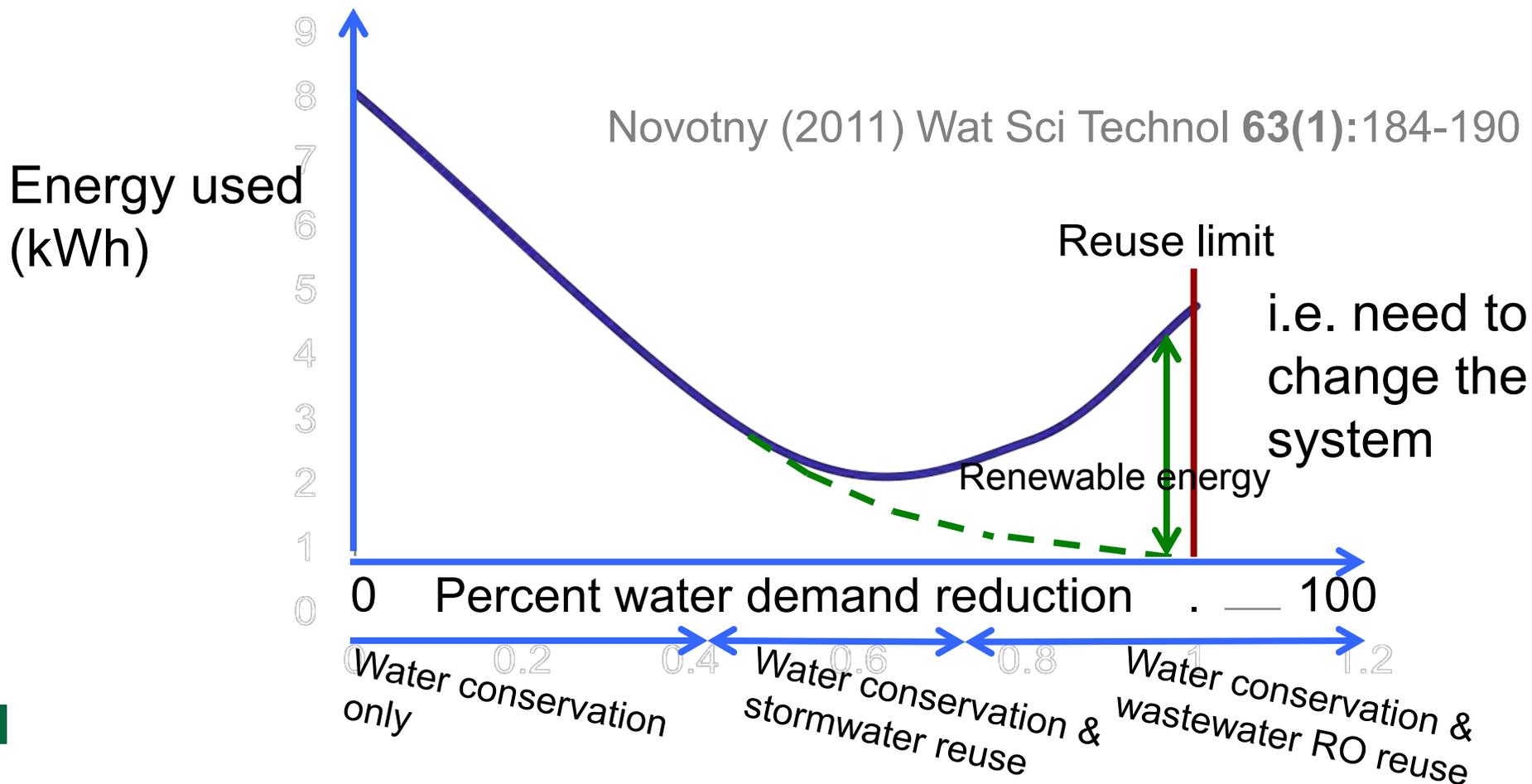


\$20 billion/y annual short-fall in water system maintenance
(EPA GAP report, 2005)

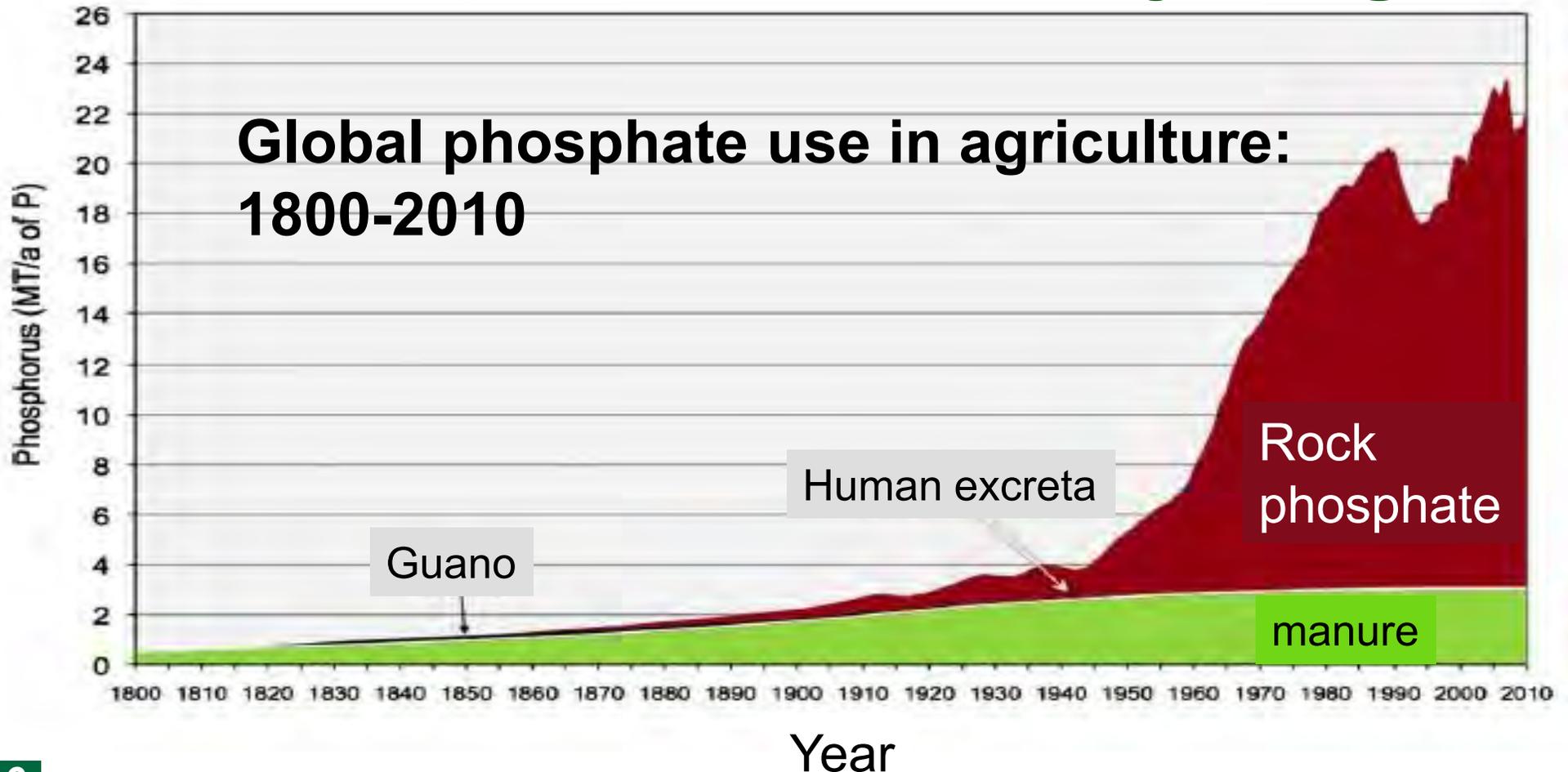
Waste of energy in the water sector

- Water services utilize about 3-7% of electricity produced
 - i.e. some 100 billion kWh/y = 16 avg coal power plants
 - Similar for drinking & waste water (500-1500 kWh/MG)
- Yet similar amount of embedded energy in food/fecal residuals & more if heat and flow captured from sewage
- However household energy use – 14% for hot water
 - i.e. heating water more important energy issue
 - 3rd highest use after heating (29%) & cooling (17%) of homes

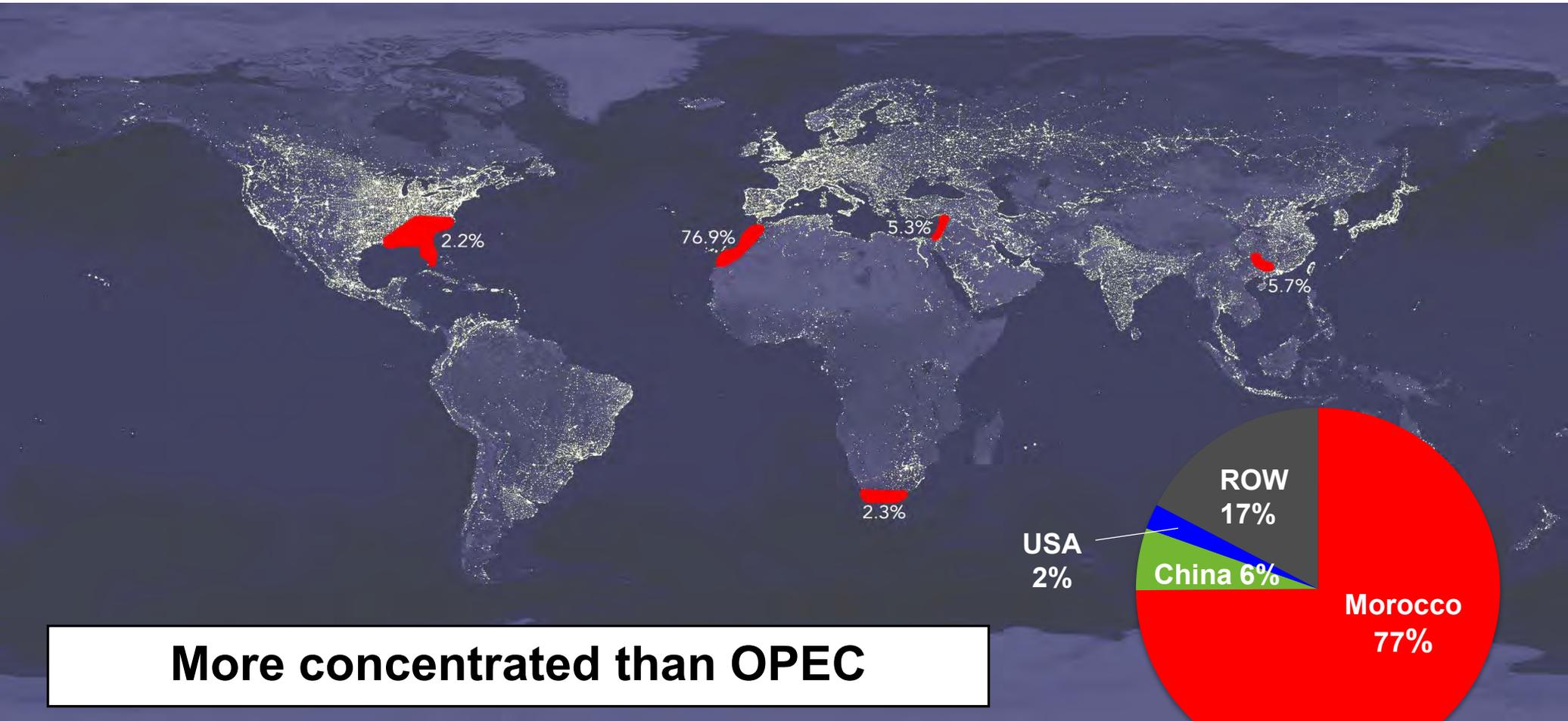
Water futures – energy issues



Need for phosphorus recycling



World Phosphate Reserves – Geopolitically Sensitive



7 Image courtesy Ostara (who have a commercial struvite process, $\text{MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}$, www.crystalgreen.com/)

e.g. EcoSan toilet: in India with unique pay-the-user

- Located in Musiri, Trichy, Tamilnadu, India, the Ecosan Community Compost Toilet
- Operating since Jan, 2008
- Users paid 10 paise per visit – about 1/4 of one US cent as human urine and feces are a valuable source of nutrients used in agriculture



(Text and image courtesy of **SCOPE**)

Society for Community Organisation and Peoples Education

<http://www.scopetrichy.org/>



Top 8 categories of impairment requiring Clean Water Act action

NB: only 26% freshwaters assessed & 50% impaired!

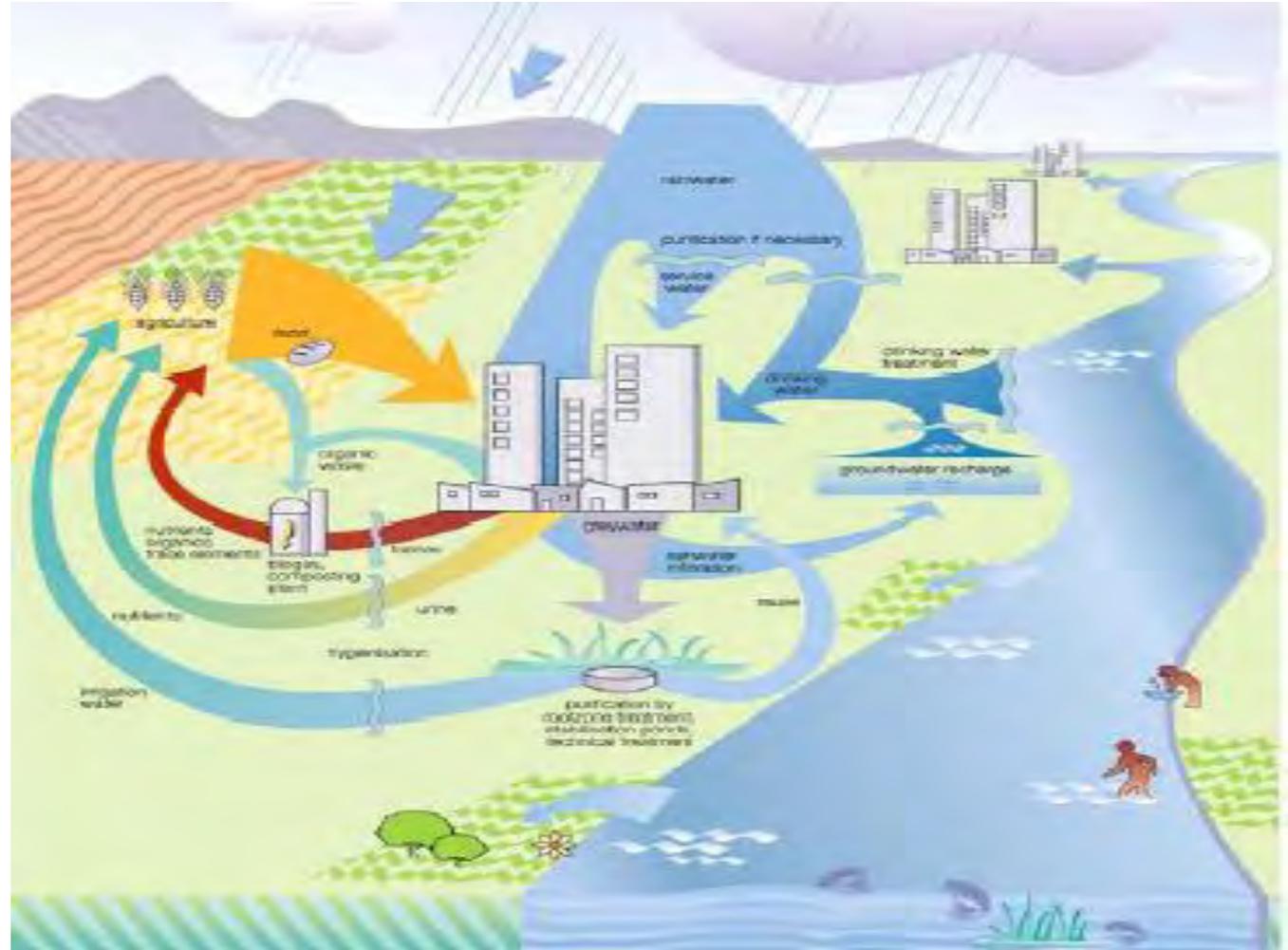
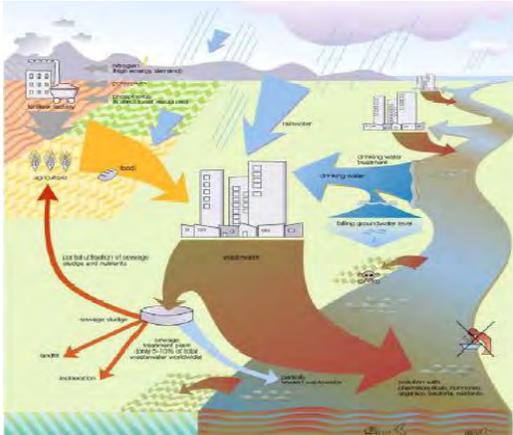
Cause of impairment	Number of TMDLs	# of causes assessed
Pathogens	9,059	
Metals (other than Hg)	7,776	7,937
Mercury (Hg)	6,933	6,965
Nutrients		5,674
Sediments	Eutrophication	4,097
Oxygen depletion by OM	1,910	2,013
Temperature	1,833	1,841
pH	1,754	1,796

Minimize emissions to waterways/aquifers

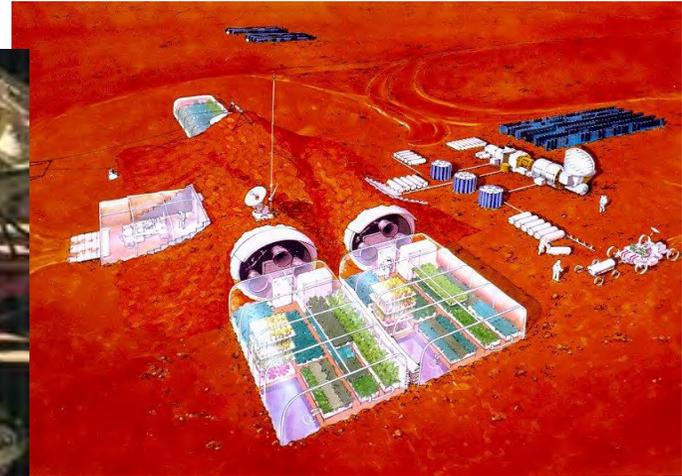
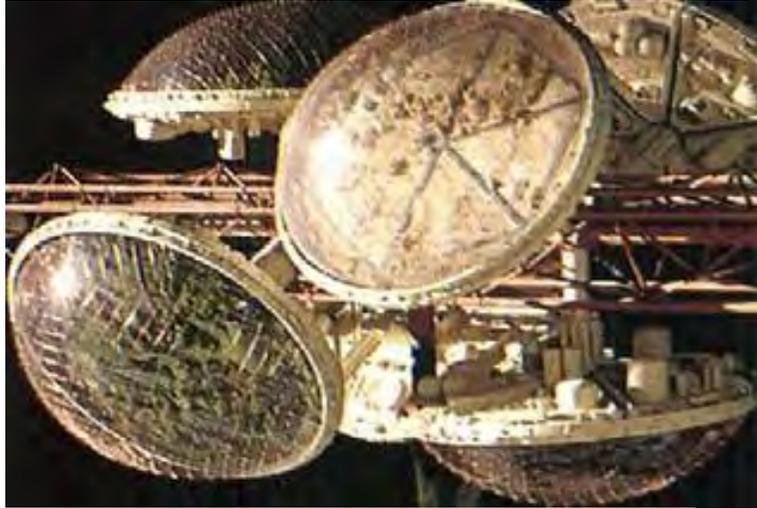
EPA, National Section 303(d): accessed 3/28/2011
 (http://iaspub.epa.gov/waters10/attains_nation_cy.control)

We need a paradigm shift

Current single use



Resource recycle instead of disposal



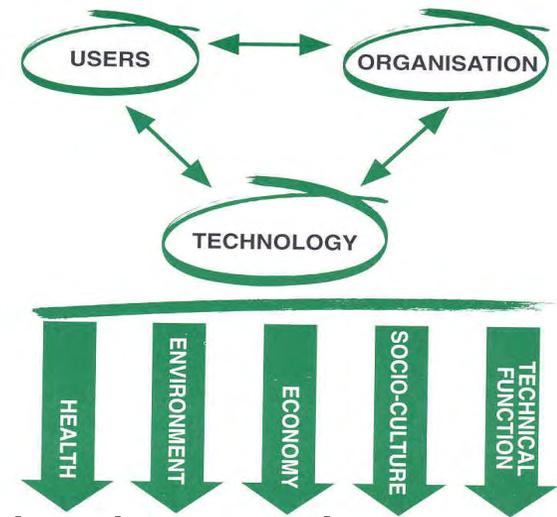
“If we knew how to live on Mars, we'd know how to reduce our footprint on Earth. Space colonization is the Rosetta stone for earthly sustainability because it's entirely about living in the absence of ecosystem services. The Moon, Mars and the asteroids are a great experimental laboratory that we're ignoring at our own peril.”

Karl Schroeder

Water management: a Wicked Problem

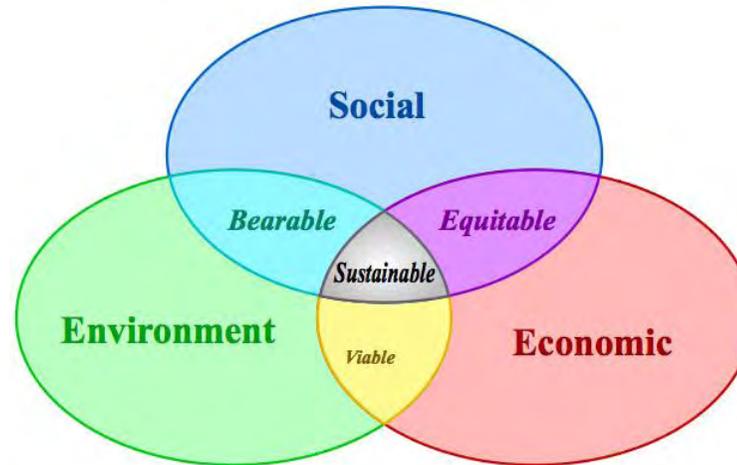
- As described by Rittel & Webber (1969 AAAS, 1973*), social problems are ‘wicked’ & beyond reach of science because they are complex, indefinable & lack an objective ‘good’ to aim for;
i.e. problem interconnected with the process of its solution
 - To ask all the relevant questions you must already know all the conceivable alternative solutions
 - You can not tell when the problem is „solved’
 - The adequacy of the solutions depends on stakeholders
 - „One-shot’ operation, no room for trial & error; every attempt counts and no way to ID all solutions to consider

*Dilemmas in a General Theory of Planning, pp. 155–169, Policy Sciences, Vol. 4, Elsevier Scientific Publishing Company, Inc., Amsterdam, 1973



Need for System Thinking

- Given the „locked-in’ situation from the complex interaction of institutional frameworks, technologies, & societal expectations within the socio-technical water system
- Looking at the system as a whole provides an approach
 - i.e. understanding relationships between parts, rather than the properties of the parts themselves, or
 - Problem solving which views „problems’ as parts of an overall system rather than reacting to present outcomes or events and potentially contributing to undesired issues
 - e.g. Disinfection by products



Such solutions always involve a definition of the problem that is either false or so narrow as to be virtually false.. The whole problem must be solved, not just some handily identifiable and simplifiable aspect of it. A bad solution is bad, then, because it acts destructively upon the larger patterns in which it is contained... A bad solution solves for a single purpose or goal, such as increased production. And it is typical of such solutions that they achieve stupendous increases in production at exorbitant biological and social costs.

Solving For Pattern, Wendell Berry

Quit producing “more efficient engines...that sustain a fundamentally flawed system” . Don’t feel good about doing less bad

Cradle to Cradle, McDonough and Braungart

Complex systems demand an interdisciplinary approach

- Hence the need for a „toolbox’ of relevant concepts and theories and a pragmatic approach to choices of methodology – to address water’s „wicked problem’
 - That has resulted from a „locked-in’ management pattern due to the **co-evolutionary triangle of institutional inertia, infrastructure legacy & societal expectations about water use**

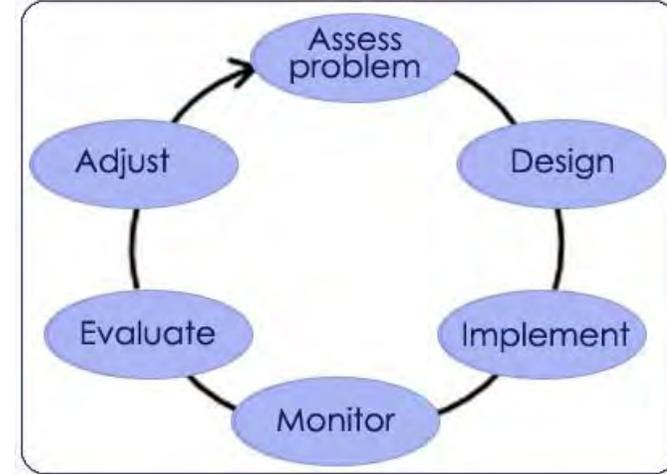
SSWR Project 5.1

- Use of specific process-oriented tools to aid in sustainability assessments, and
- Product-oriented decision support systems to aid stakeholder involvement in the process



Problem framing & narrative

- Framing reflects the lens with which various stakeholders perceive a situation, represent an issue & debate policy
- Analysis of framing helps explain policy controversies through illuminating multiple realities of conflicting frames
 - So participants disagree with both one another and also the nature of their disagreements
 - Technical experts tend to view from their specific area, which tends to eliminate ambiguities in complex situations by assuming a predetermined definition of the problem; supported by norms/rules of their discipline

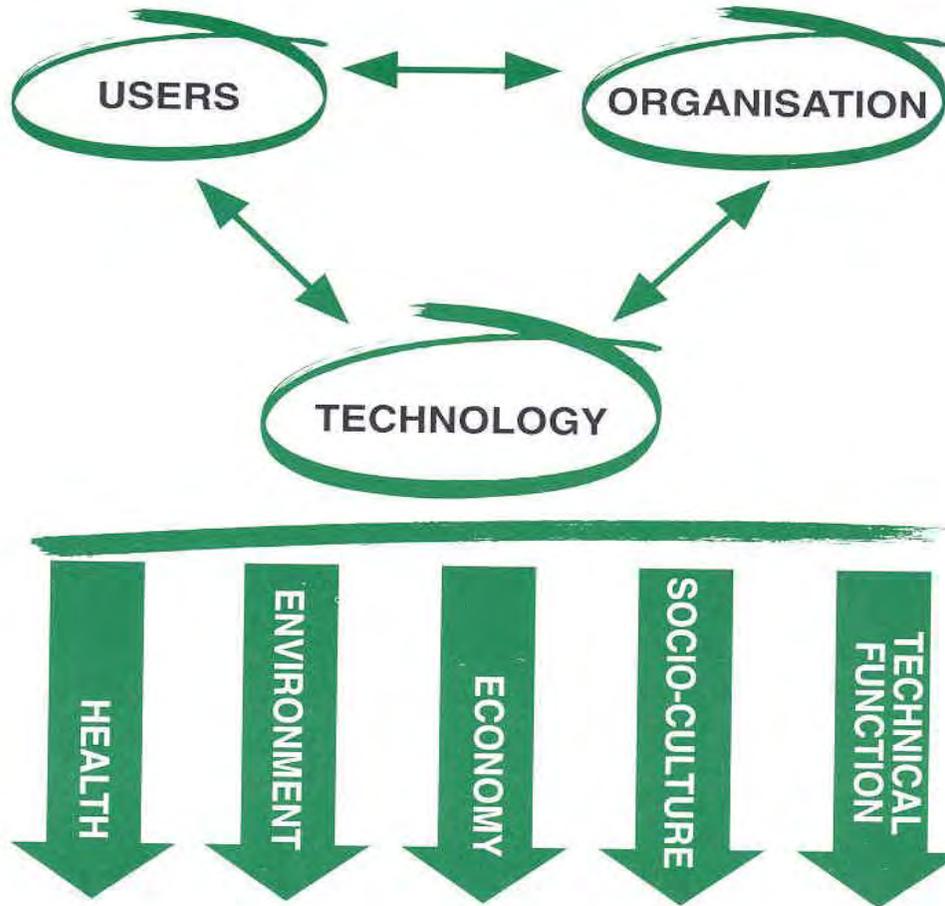


Therefore....

- **Institutions** need to reform along with **technologies**, and **adaptive management** and **social learning** are necessary elements of a successful transition
- An idealized institutional framework would take an explicitly adaptive approach to address the uncertainties of climate change and ensure that urban water systems improve socio-ecological resilience

**However, in providing reliable and safe water, organizations have little opportunity for policy experimentation
So causing a 'locked-in' reinforcement of inst. barriers**

Swedish-Australian Urban water sustainability framework



Multi-Criteria Decision Aiding (MCDA), using process tools & being stakeholder-driven:

- Health Impact Assessment
- Life-Cycle Assessment, EF
- BCA, Life-Cycle Costing
- Reliability/ robustness

Lundie, S., Ashbolt, N., Peters, G., Livingston, D., Lai, E., Kärman, E., Blaikie, J. and Anderson, J. (2008) Sustainability Framework. WSAA Occasional Paper No.17. Water Services Association of Australia, Melbourne.



Master Programme for Env & Sust in SRS



VISION
SRS - a World Class Environmental City District

OVERALL GOALS

Climate	Ecological sustainability	Social sustainability	Economic sustainability
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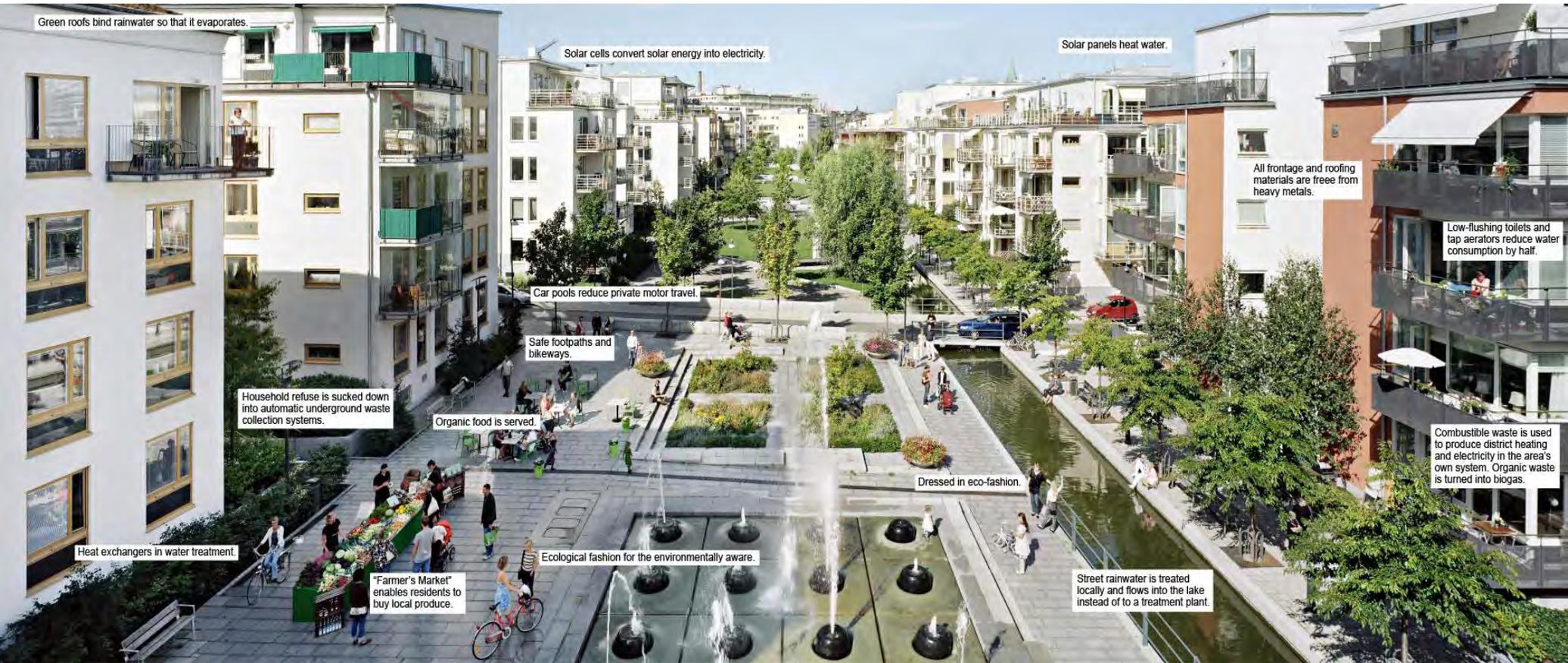
FOCUS AREAS & SECTORS

Climate Adaptation	Sustainable Energy	Ecocycles		Eco-efficient transport & buildings		Sustainable living	
Climate adapted & Greening living environment	Sust Energy System	Sust Recycling System	Sust Water & Sanitation	Sust transports	Ecodesigned buildings	Sust Lifestyles	Sust Business
Vision Goals Measures	Vision Goals Measures	Vision Goals Measures	Vision Goals Measures	Vision Goals Measures	Vision Goals Measures	Vision Goals Measures	Vision Goals Measures

ACTION PROGRAMS (phases & activities)

Infrastructure	Housing & commercial buildings	Lifestyles	Business
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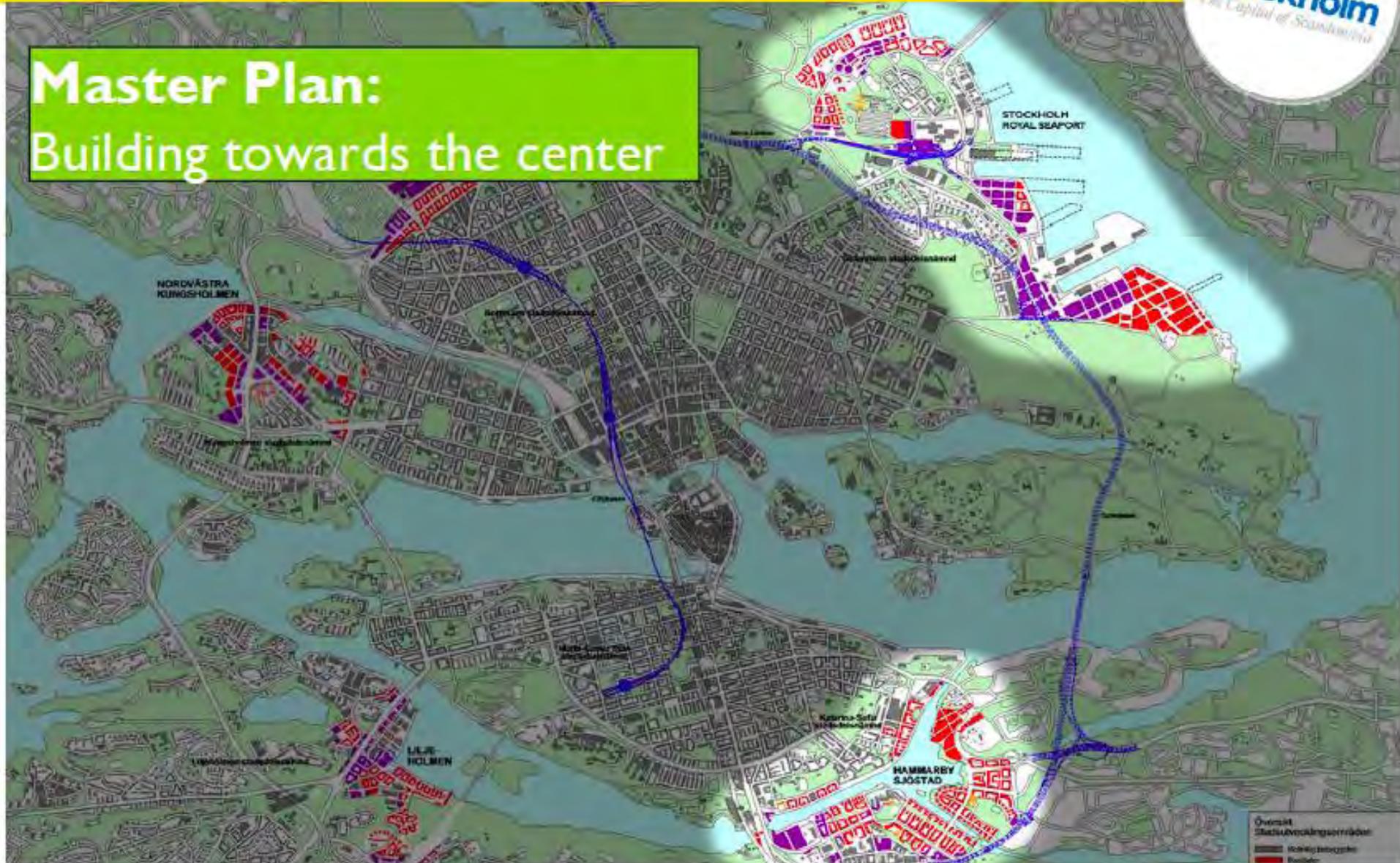
Hammarby Sjöstad, Stockholm



Stockholm Royal Seaport (SRS) (Norra Djurgårdsstaden)

- This urban development for 10,000 new residences and 30,000 new workspaces, based on Hammarby Sjöstad
- Planning work started in the early 2000s and the new city district will be fully developed around 2025
- Goals:
 - By 2020, carbon emissions <1.5 tonnes/person.year
 - By 2030, free of fossil fuels
 - Resilient to future climate changes

Master Plan: Building towards the center



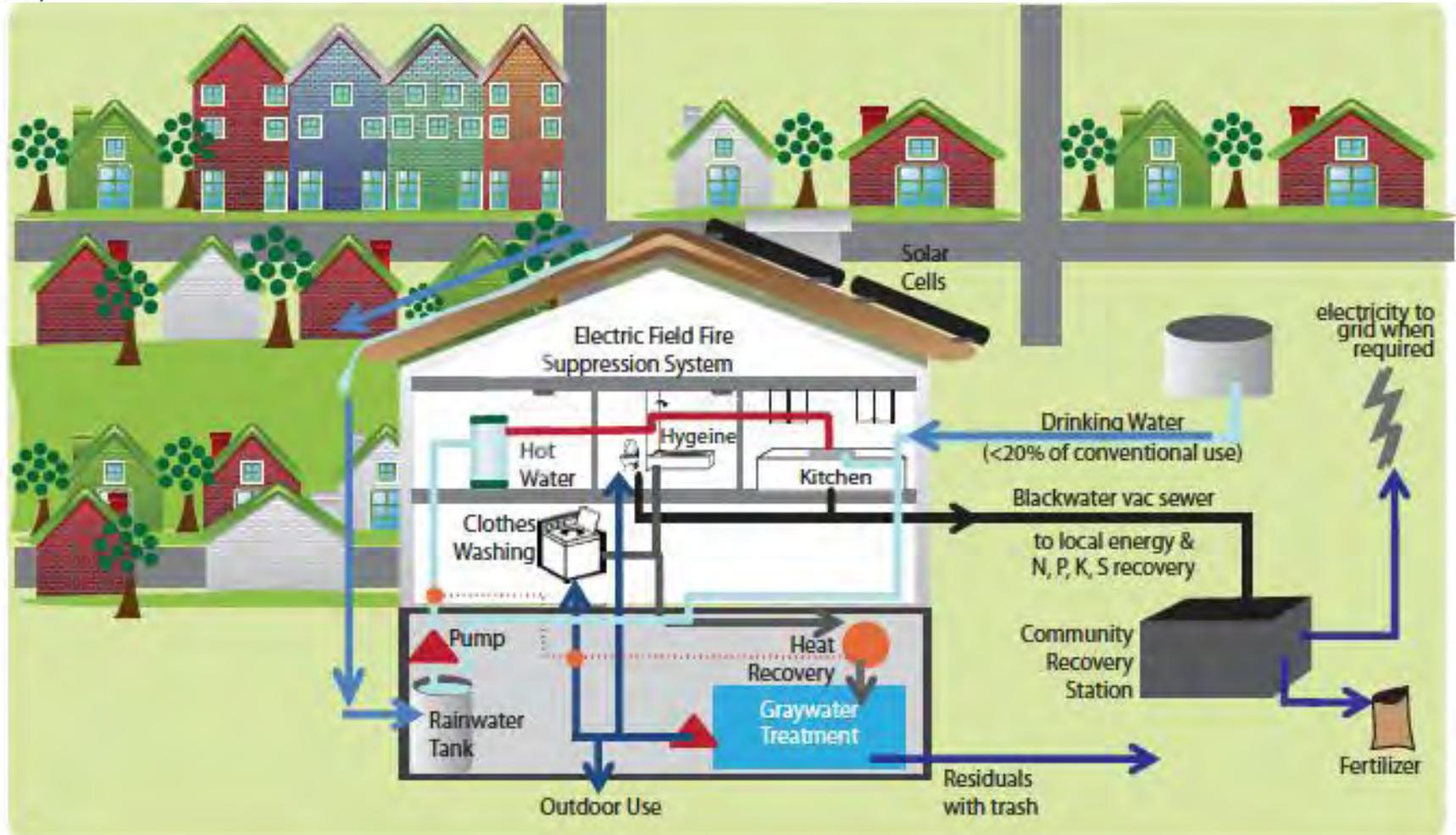
Likely trends / Implications

- **Climate change / climate resilient infrastructure:**
 - More intense storms, sewer overflows, outages
 - Pressure sewers, off grid systems more resilient
 - Aging population, more prone to diseases
 - e.g. legionellosis via water aerosols (etc.)
- **Need to reduce greenhouse gases:**
 - Move less water over long distances, i.e. recycle, especially reuse within homes/buildings
- **Renewable energy & nutrient recovery:**
 - Utilize energy within ‘wastes’ energy/heat recovery
 - Urban agriculture / recycle of local nutrients



United States
Environmental Protection
Agency

Future municipal water services



Ashbolt, N.J. (2011). *In: Energy and Water 2011*. Water Environment Foundation, July 31-August 3, 2011, Hyatt Regency McCormick Place, Chicago, Illinois, pp. 1233-1241

Resource Recovery Based R&D

SSWR Project 5.4

- Integrated assessments of new (and existing, but not widely adopted) technologies for wastewater treatment based on resource recovery
- Demonstration projects
 - Social and engineering acceptance
 - Risk Assessments under real world situations
- Identify priority research areas (some built in flexibility)
 - partner and stakeholder input
 - work within “opportunity space”

Available Technologies

Sewage treatment (Biolytix NZ system)



Graywater treatment



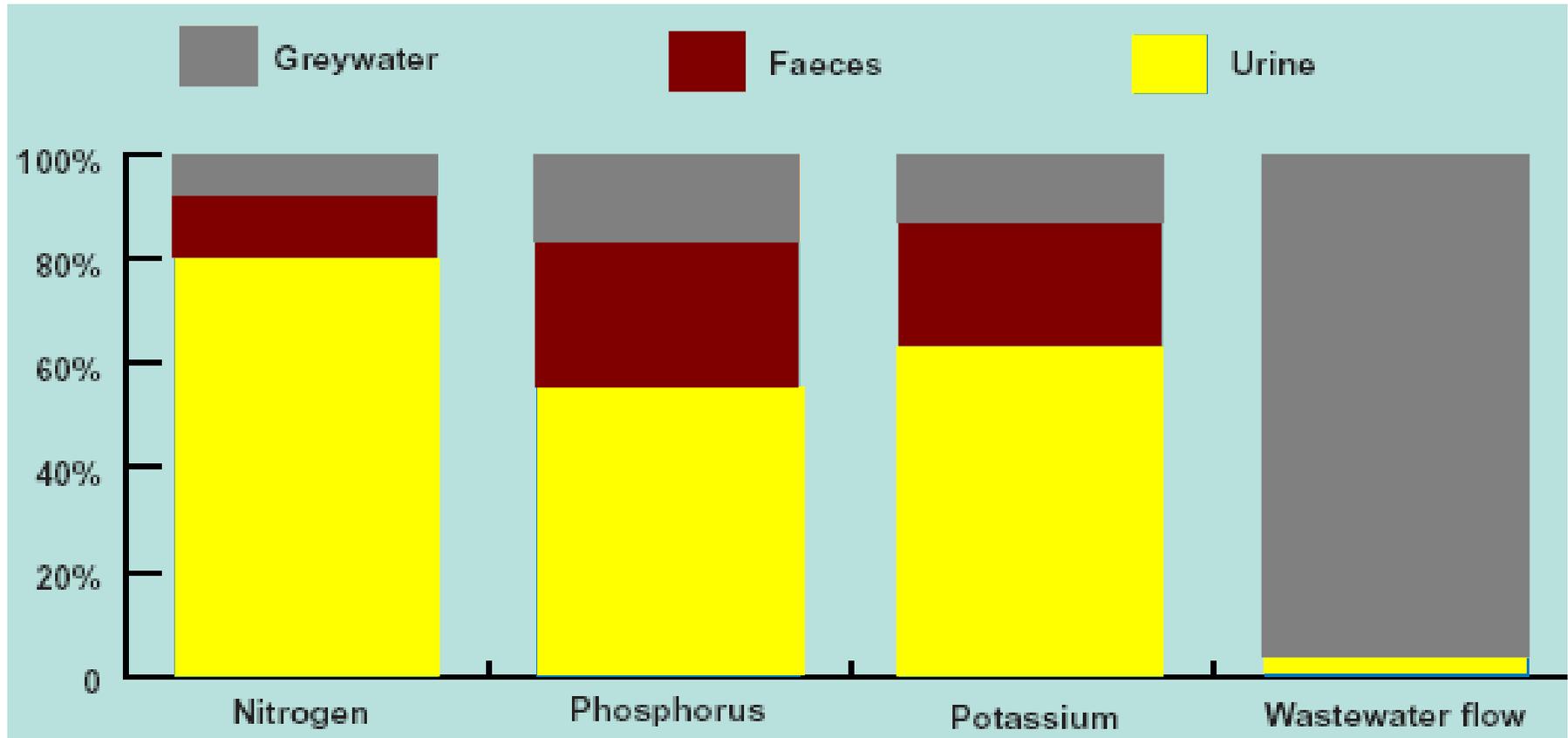
Vacuum toilet



Urine-diversion dual-flush toilet



Why divert the urine?



- Use as a plant fertilizer
 - Normal nitrogen application (80-100 kg/ha)
≡ 10-40 tonnes of urine/ha is needed

Urine storage tank (264 gal) & Aquatron solids separator composter



Risks via food:
Chemicals
Microbials
Soil/plant treatment efficacy

What's in the 'pipeline' to reduce demand: 40 to 13 gal/p.d

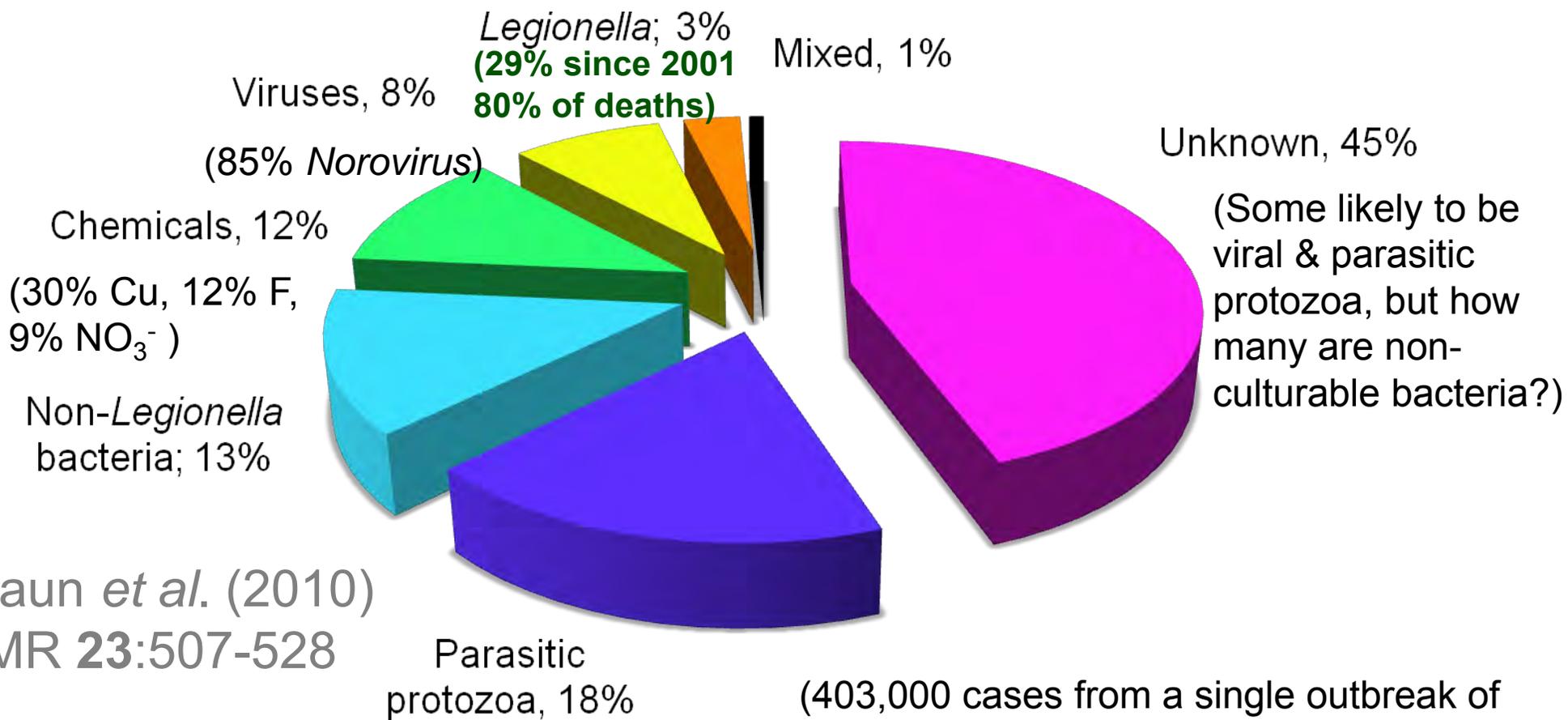
- Slone *FLUSHMATE*[®] Pressure-Assist toilet (1 gal)
- **The Propellair[™] toilet (0.4 gal flush)**
 - The 'Propel air' flushing system reduces water consumption to 0.4 gal per flush, using 84% less water & 80% less energy than avg 2.4 gal WC
- **The Quench[™] recirculating shower system**
 - The commercially available Quench conservation shower uses up to 67% (25 vs 43 L) less water than a low flow shower head & use up to 87% less energy
- **The Xeros[™] cloths washer**
 - uses 90% less water & 2% energy since clothes nearly dry, no dryer required

Water Reuse: Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater (NRC Report 2012)

- Improved risk assessment requires better understanding of the performance of reuse systems
 - Including variability and failure (not such average performance)
 - Need for simple surrogates of performance for intensive monitoring

Dominant microbiological concern may be non-fecal

Etiologic agents (%) for 780 drinking water outbreaks, 1971-2006 USA



Craun *et al.* (2010)
CMR 23:507-528

Virus Occurrence Methods -Research Efforts

Collection and Concentration



Viability



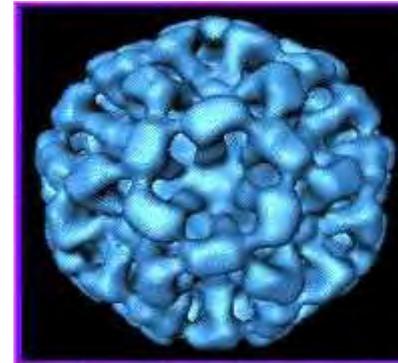
Detection and Speciation

Methods in Development

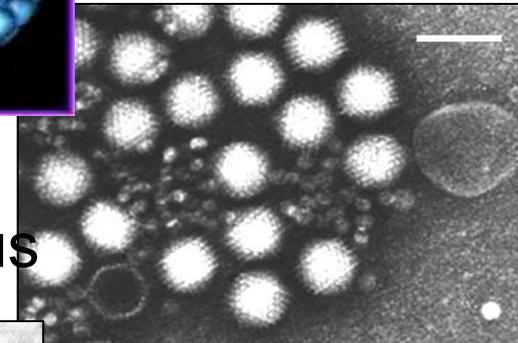
Adenovirus

Enterovirus

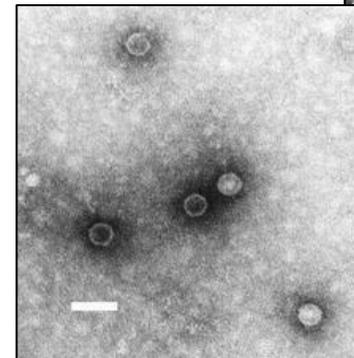
Norovirus (qPCR)



Norovirus

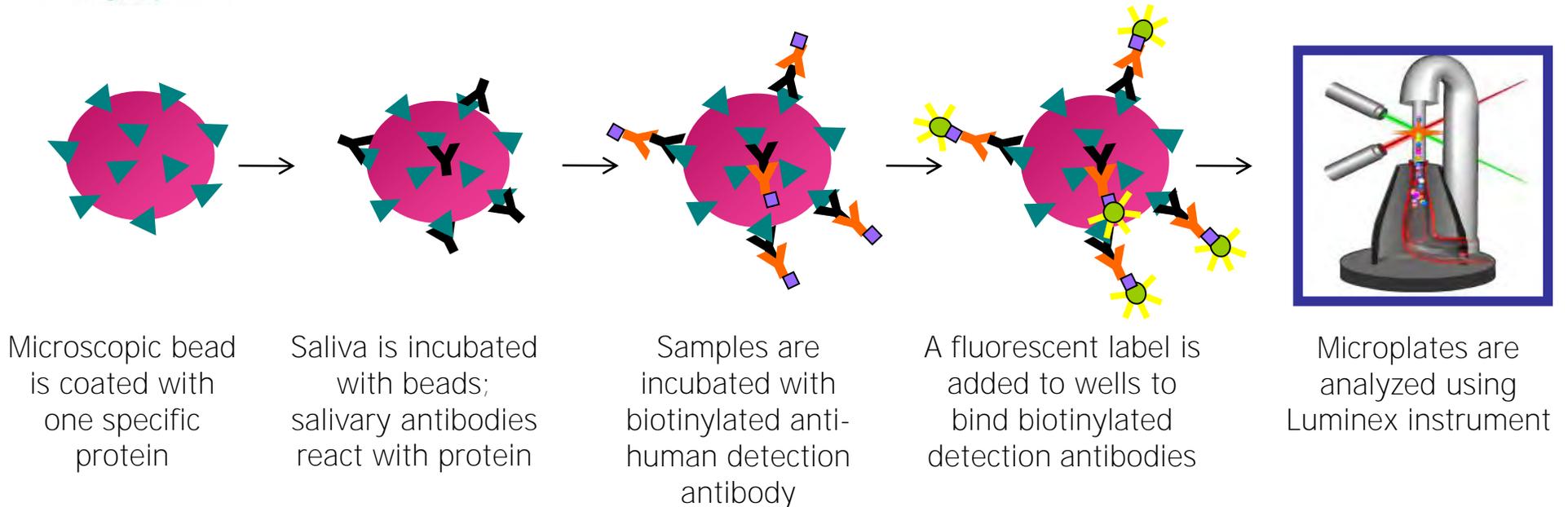


Adenovirus



Enterovirus

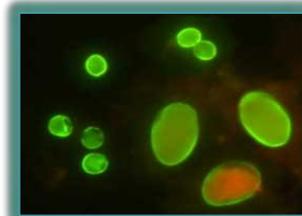
Microbial Exposure Methods



Luminex xMAP® microsphere suspension microplate immunoassay

- Epidemiological evidence of endemic waterborne infections is needed to support theoretical risk assessment estimates.
- New methods of detecting exposure are needed to help better understand how pathogen occurrence relates to human exposure and illness. A novel saliva-based assay was developed that detected antibodies to specific pathogens. These assays are less invasive than traditional sera-based methods and allowed testing of both adults and children.

QMRA within Sustainability Asses't



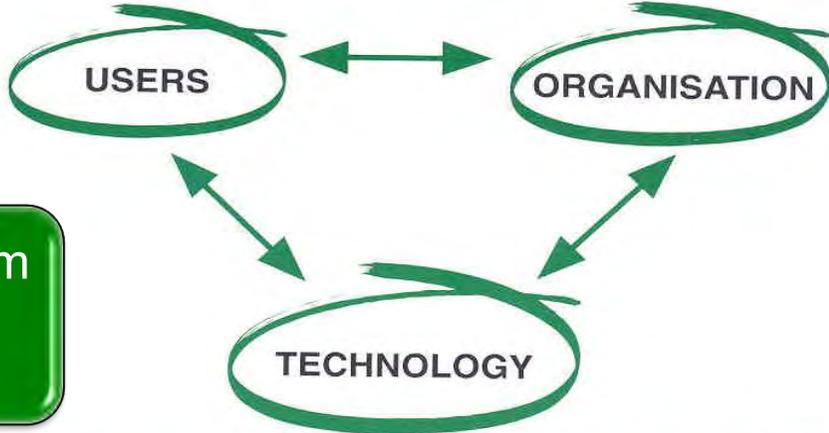
System life-time
risks (QMRA)

Prioritize system
risks
(harmonize)

Reassess
system

Research
knowledge gaps

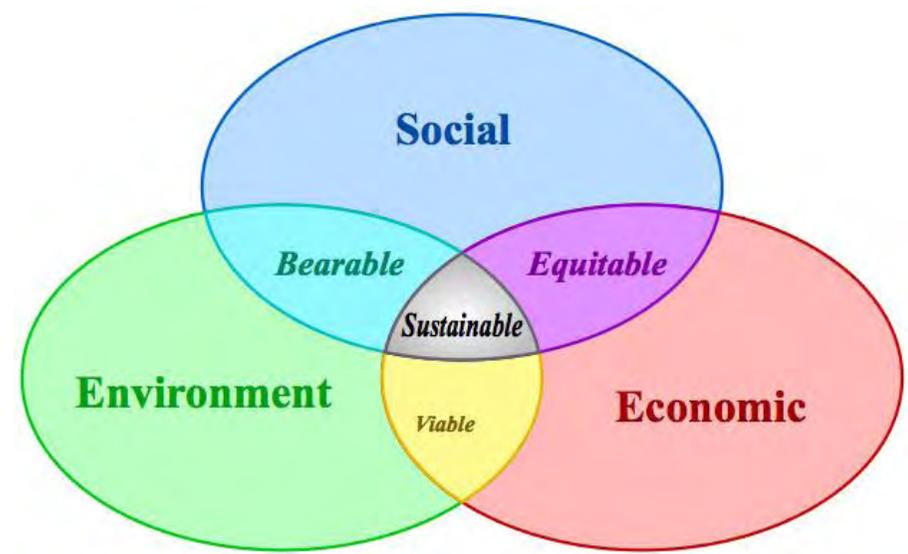
Identify control
surrogates &
control levels



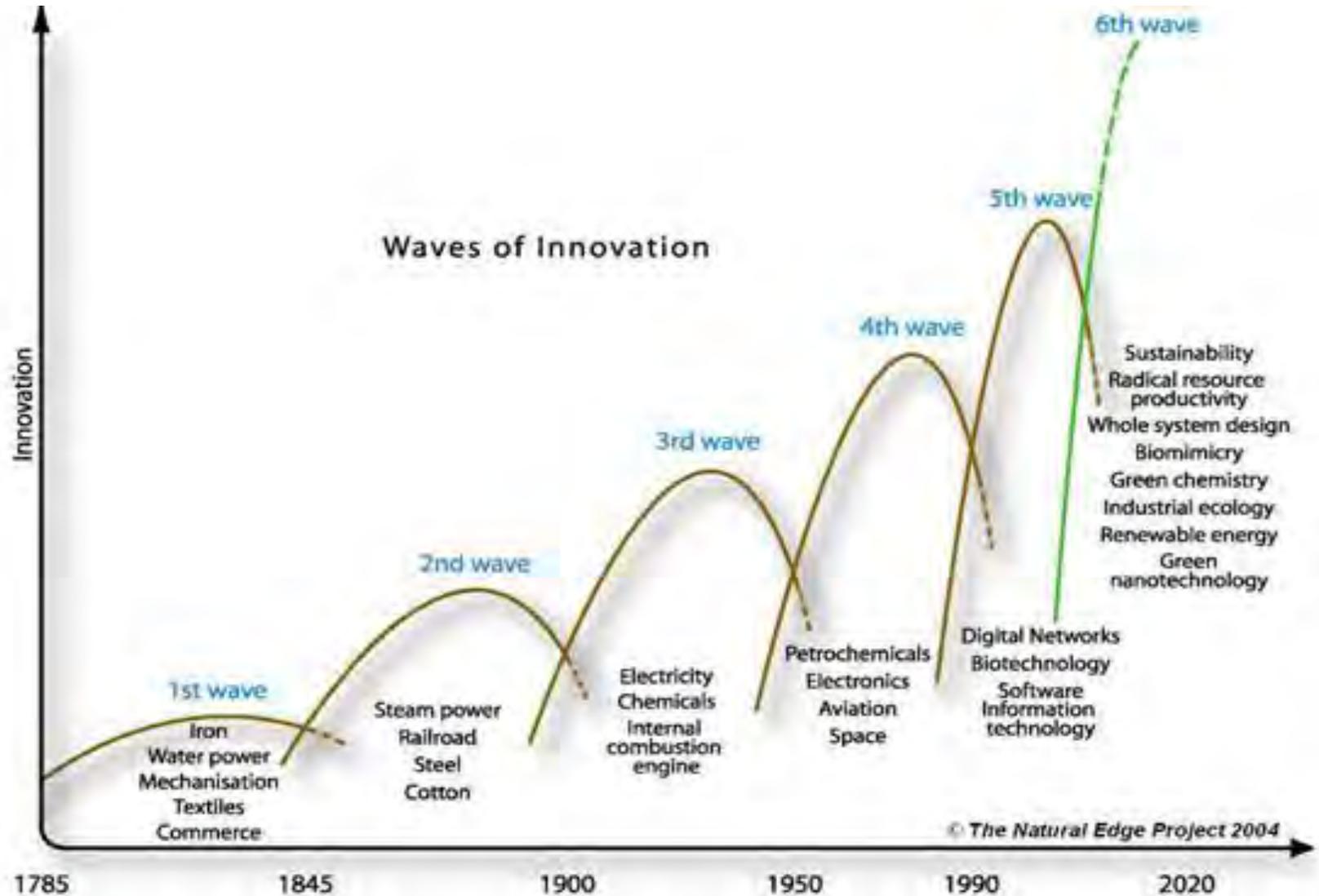
And a wider variety of tools are availability with EPA-ORD

- Human health effects
- Ecological effects (especially with respect to potential water reuse scenarios)

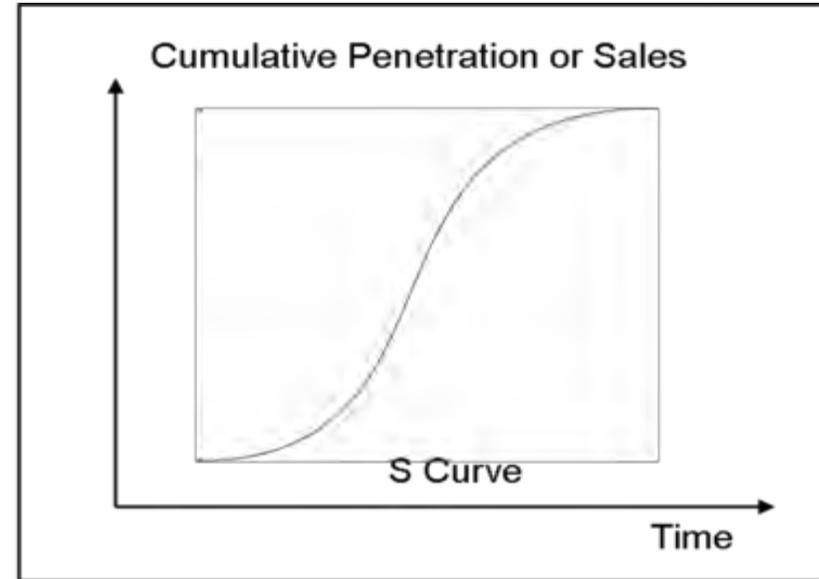
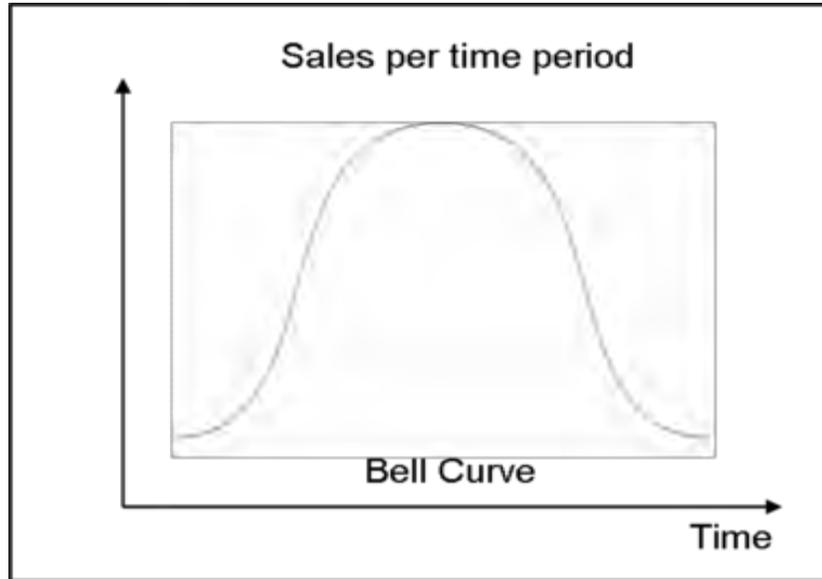
Conclusions



- Our new research efforts are poised for collaboration on:
 - Development and application of process-oriented tools and decision support systems to aid stakeholder involvement in the planning process
 - Integrated assessments of innovative water infrastructure systems based on resource recovery



Diffusion of Technology (*Everett Rodgers*)



Innovators (2.5%) - venturesome, educated, multiple info sources, greater propensity to take risk

Early adopters (13.5%) - social leaders, popular, educated

Early majority (34%) - deliberate, many informal social contacts

Late majority (34%) - skeptical, traditional, lower socio-economic status

Laggards (16%) - neighbours and friends are main info sources, fear of debt