



# Smart Water Grid

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# Sustainable and Resilient Water Systems

## n Sustainability

- Maintaining water supply over the long-term
- Managing multiple environmental, economic and social aspects of water systems.

## n Resilience

- Building in adaptability to external shocks such as water shortages



# Information and Communication Technology (ICT) revolution





Can increased adoption of ICTs improve sustainability and resilience of water systems?



# Smart Grid Comparison: electricity versus water

| <b>Components of Smart Electrical Grid</b>       | <b>Analogous Components of Smart Water Grid</b> |
|--|---|
| Smart electrical meters                          | Smart water meters                              |
| Decentralized renewables:<br>wind and solar      | Decentralized water<br>treatment/distribution/  |
| Efficient home/business<br>electrical management | Efficient home/business<br>water management     |
| Detection and improvement<br>of power quality    | Detection and improvement<br>of water quality   |

- n Treatment plants
- n Distribution system
- n Users:
  - Industry
  - Agriculture
  - Residential

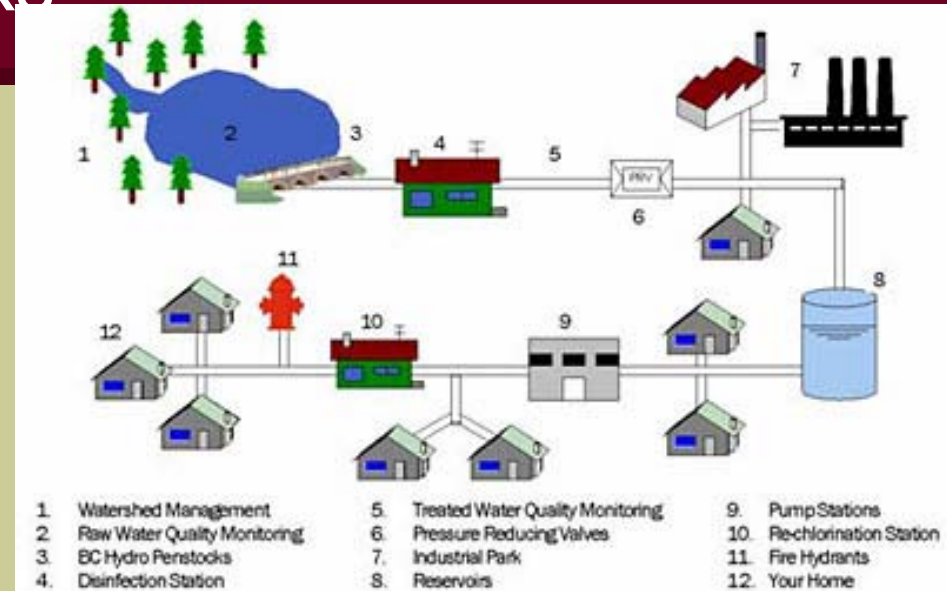




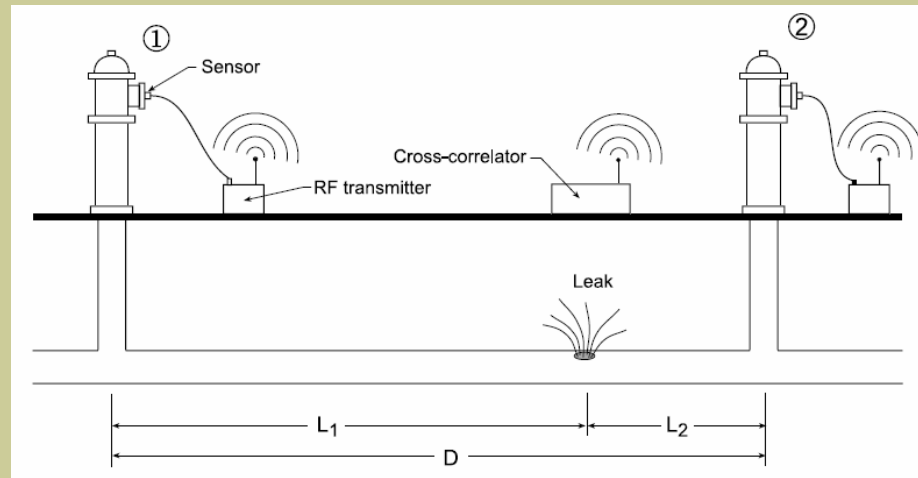
# What to address with smart water grid?

- n Water demand – users often use more water than needed to realize “service” delivered
- n Water leaks – 10-20% of water lost in distribution, difficult to detect underground leaks
- n Automate meter reading/data collection
- n Checking water quality from treatment plant to tap

- Current system: monitored after treatment, then at end users (monthly or greater aggregates)
- ~10-20% losses in leaks
- The big question: do new technologies enable a different paradigm in detection?



Source: <http://www.campbellriver.ca/Business/CityServices/WaterSupplyandDistribution/Pages/SupplyandDistribution.aspx>



Leak detection through sound timing differences  
Source: Hunaidi (2000)

- n Smart water meters can:
  - Be networked
  - Record real time data
  - Do sophisticated information processing



<http://www.outpostcentral.com/english/ProductLiveWaterMeter.aspx>





# Resiliency application: drought response

- n If detailed metering of water use for different applications were available, provides tool for reducing consumption in times of drought.



# Where is the water smart grid?

- n Very little integration of ICTs into water grids.
- n Challenges:
  - Are the products and systems developed enough to realize economic payoffs?
  - Water is generally cheap in the U.S.
  - Utilities generally have little incentive to innovate
  - Water conservation low priority for consumers and businesses

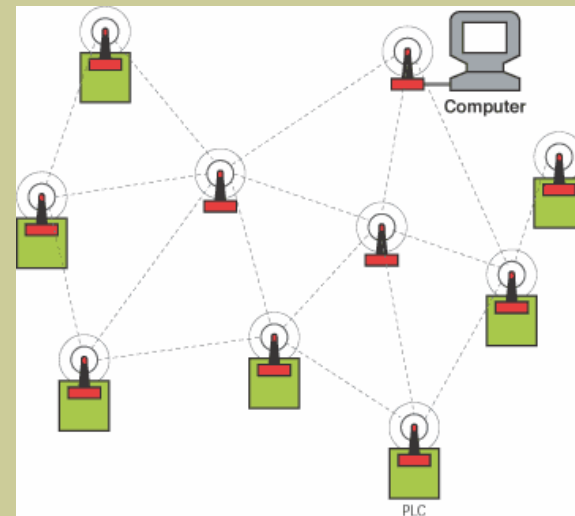


# Challenge: powering the water smart grid

- n Sensors need power, can be expensive to run electrical line to every meter
- n Options: solar, water powered dynamo, battery
- n Low power network achievable with mesh-network concept: signal need only reach nearest nodes, e.g. Zigbee protocol



Solar-powered smart water meter  
Source: Hauber-Davidson and Idris (2006)



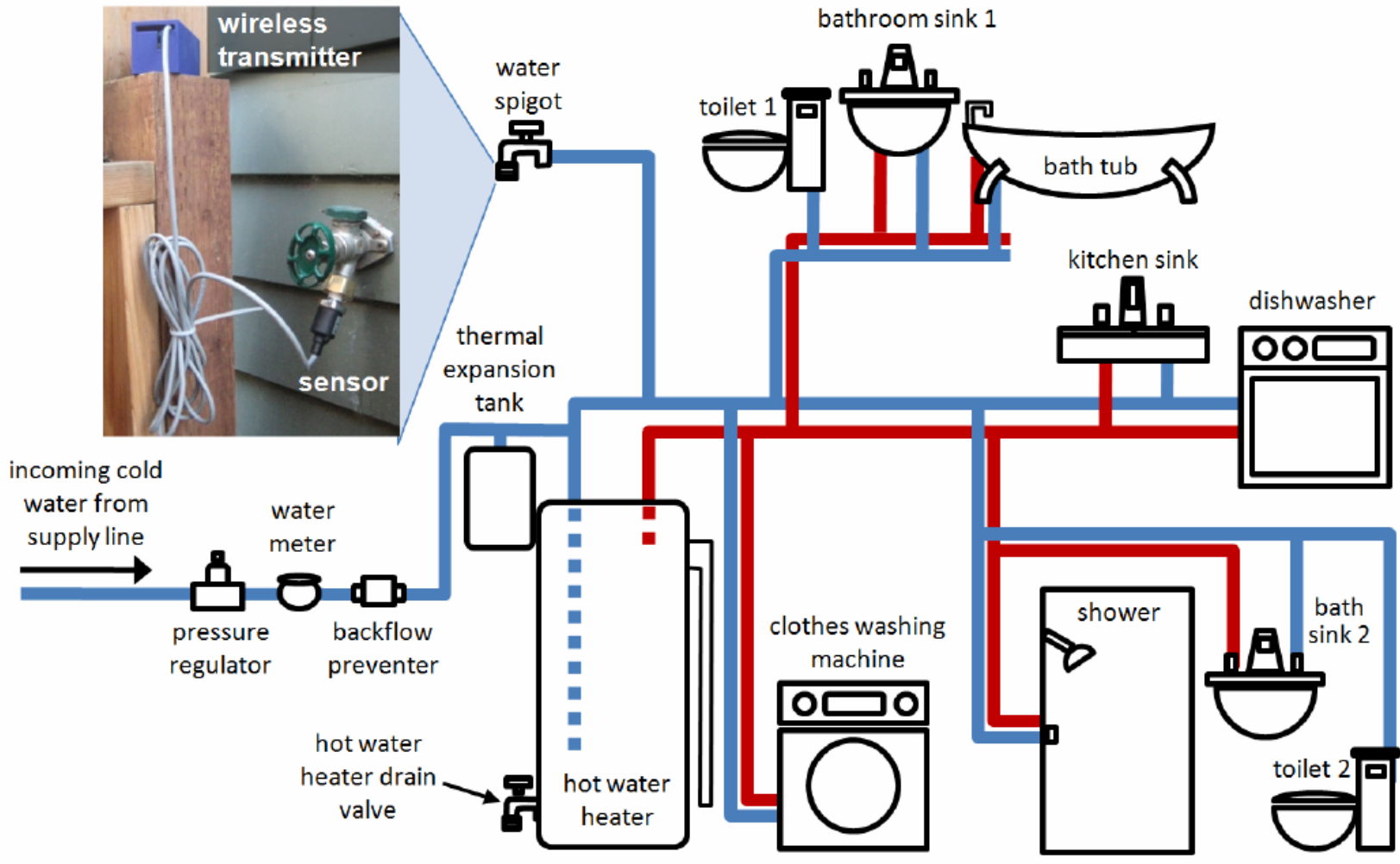
Topology of a mesh network



# Challenge: reduce expense/complexity of sensing

- n Given low cost of water sensing must also be low cost.
- n Reduce cost per sensor (learning, economies of scale)
- n Reduce number of sensors needed.

# Possible solution: single point Hydro Sense system

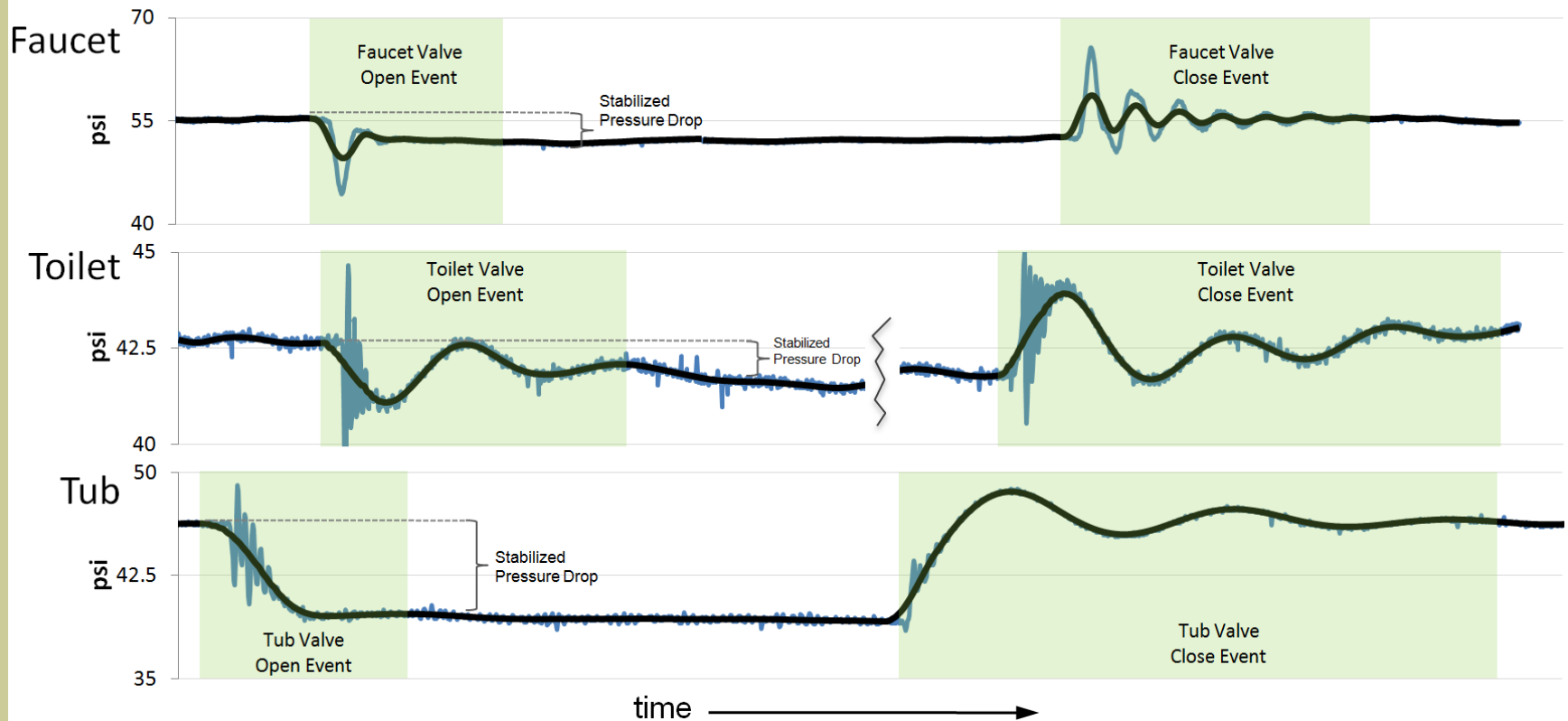


Source: Jon Froehlich et. al. U. Washington (2009)



# HydroSense Single-Point Sensing of Home Water Activity

## Open/Close Pressure Waves



Source: Jon Froehlich et. al. U. Washington (2009)



# Initial ASU Research: inform design process

- n Companies developing technology elements for water smart grid
- n Our task: inform development process to ensure economic and environmental performance.
- n Case study: Smart Irrigation Controllers for residences



# Application: advanced controllers reducing landscape water use



- n Landscape water use large share of residential water use, especially in Southwest
- n Smart Irrigation Controllers use sensors, site information, and weather data to give landscapes the proper amount of water.
- n Studies in various cities show huge variation from increase in outdoor water use to significant savings. Aggregations show net savings 6-40%



# Research context for Smart Irrigation Controllers

- n A number of systems on the market, none have achieved significant market penetration
- n Questions/challenges:
  - n What characteristics must a controller have to save consumer money over life cycle?
  - n How to ensure at least neutral effect on carbon emissions? (controllers use electricity to save water)



## Agenda for analysis

- n Build life cycle \$ cost and life cycle carbon emissions model for smart irrigation controllers
- n Develop design targets to achieve economic and carbon savings
- n Key issue: operating conditions (e.g. water price, CO<sub>2</sub>/kWh) vary substantially by location.

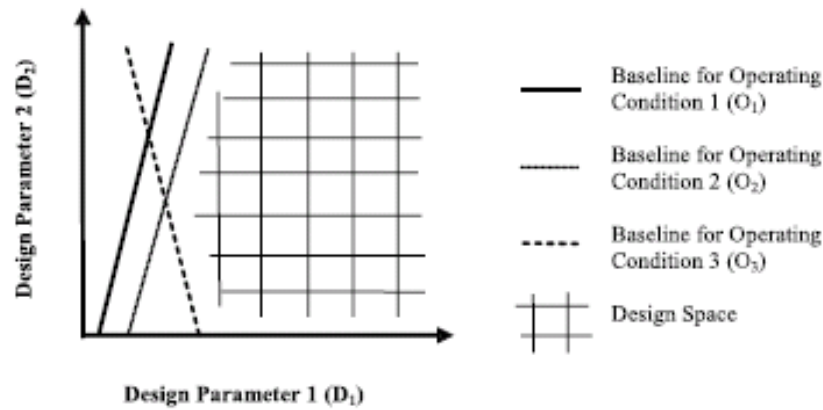


## Methodology:

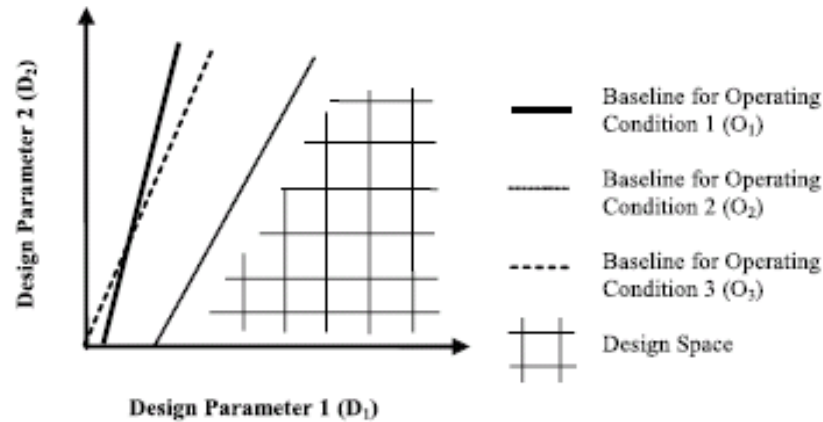
- n Let D1, D2 be design characteristics, e.g. price of controller, water savings
- n Let O1, O2, O3 be different operating conditions, e.g. water price, CO2/kWh in Phoenix, Las Vegas, Tuscon
- n Can build function LC\_Impact (D1, D2 ; O1,2,3)
- n Set minimal targets for performance (e.g. zero life cycle cost):

$$\text{LC\_Impact (D1, D2 ; O1,3)} = T$$

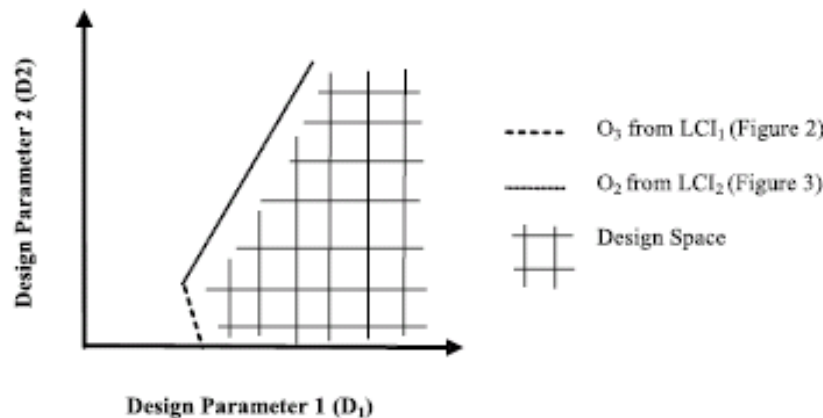
overlapping  
 design space  
 ensuring  
 targets under  
 different  
 operation  
 conditions



**Figure 3** Hypothetical results for a two-dimensional design space meeting first target life cycle impact:  $LC\_impact_1(D_1, D_2; O_{1,2,3}) = T_1$ .



**Figure 4** Hypothetical results for a two-dimensional design space meeting second target life cycle impact:  $LC\_impact_2(D_1, D_2; O_{1,2,3}) = T_2$ .



**Figure 5** The design space that meets both target life cycle impacts under all operating conditions.

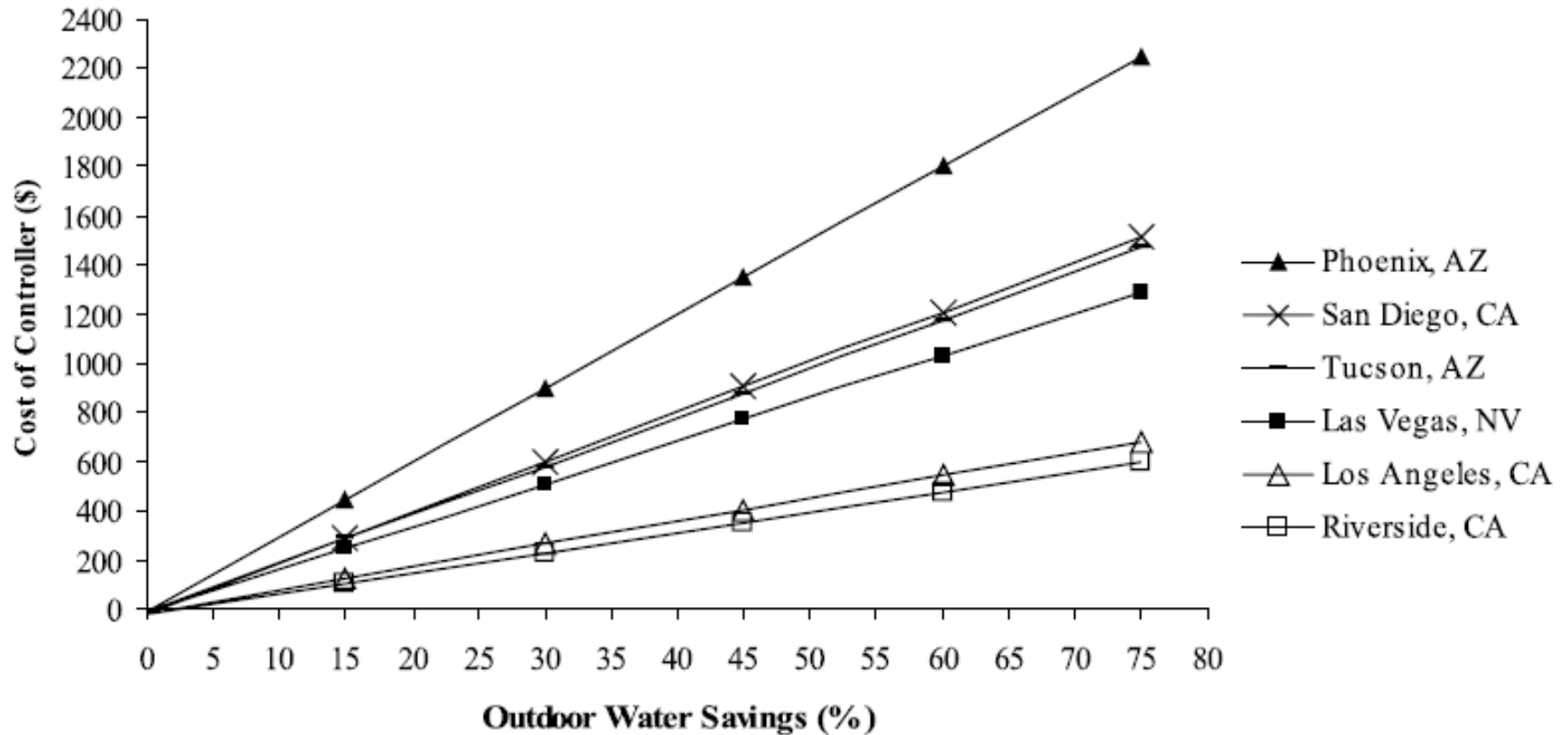
$$\begin{aligned}
 LC\_impact_1 &= SIC\ Price - Water\ Bill\ Savings \\
 &\quad + Additional\ Electricity\ Cost \\
 &\quad (adjusted\ for\ net\ present\ cost) \\
 &= D_1 + \sum_{t=1}^N \frac{(-K_1 K_2 K_3 D_2) + (K_4 - K_5) (K_6)}{(1 + r)^t} \\
 &= 0,
 \end{aligned} \tag{5}$$

- n D1 = controller price
- n D2 = % outdoor water saved
- n K1 = water price
- n K2 = water consumption
- n K3 = outdoor share

- n K4 = elec. Use SIC
- n K5 = elec. Use conv.
- n K6 = elec. price
- n r = discount rate



# Results for life cycle cost

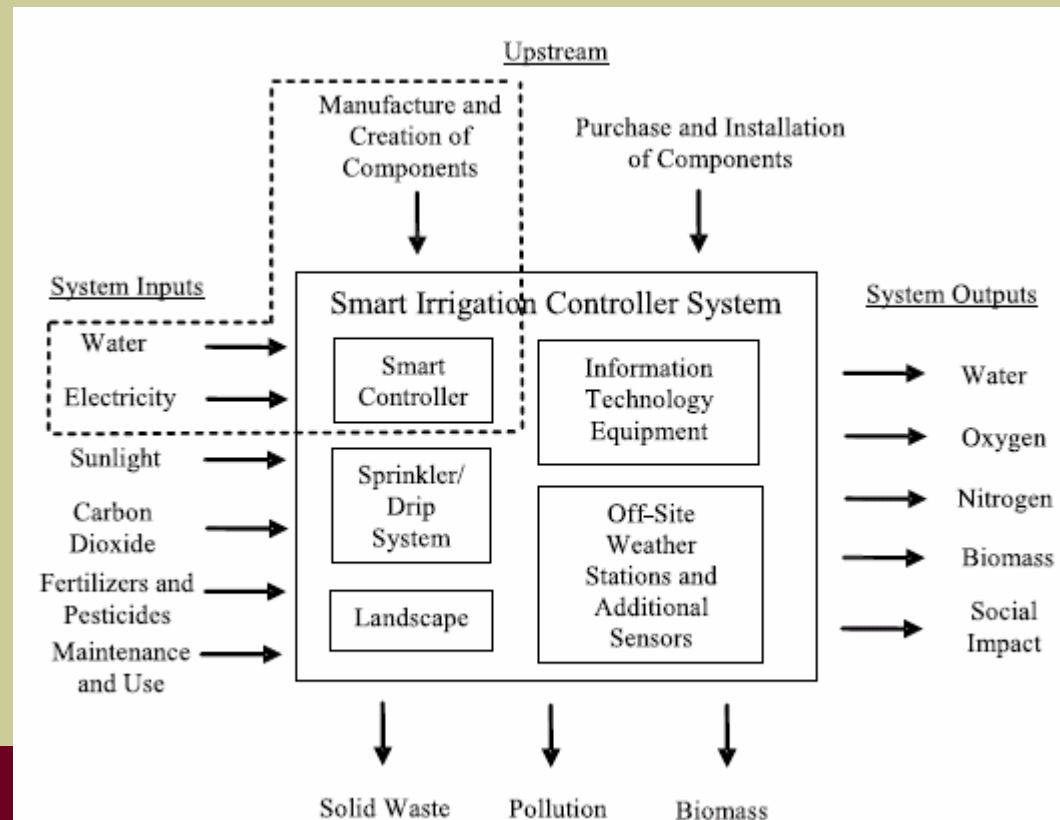


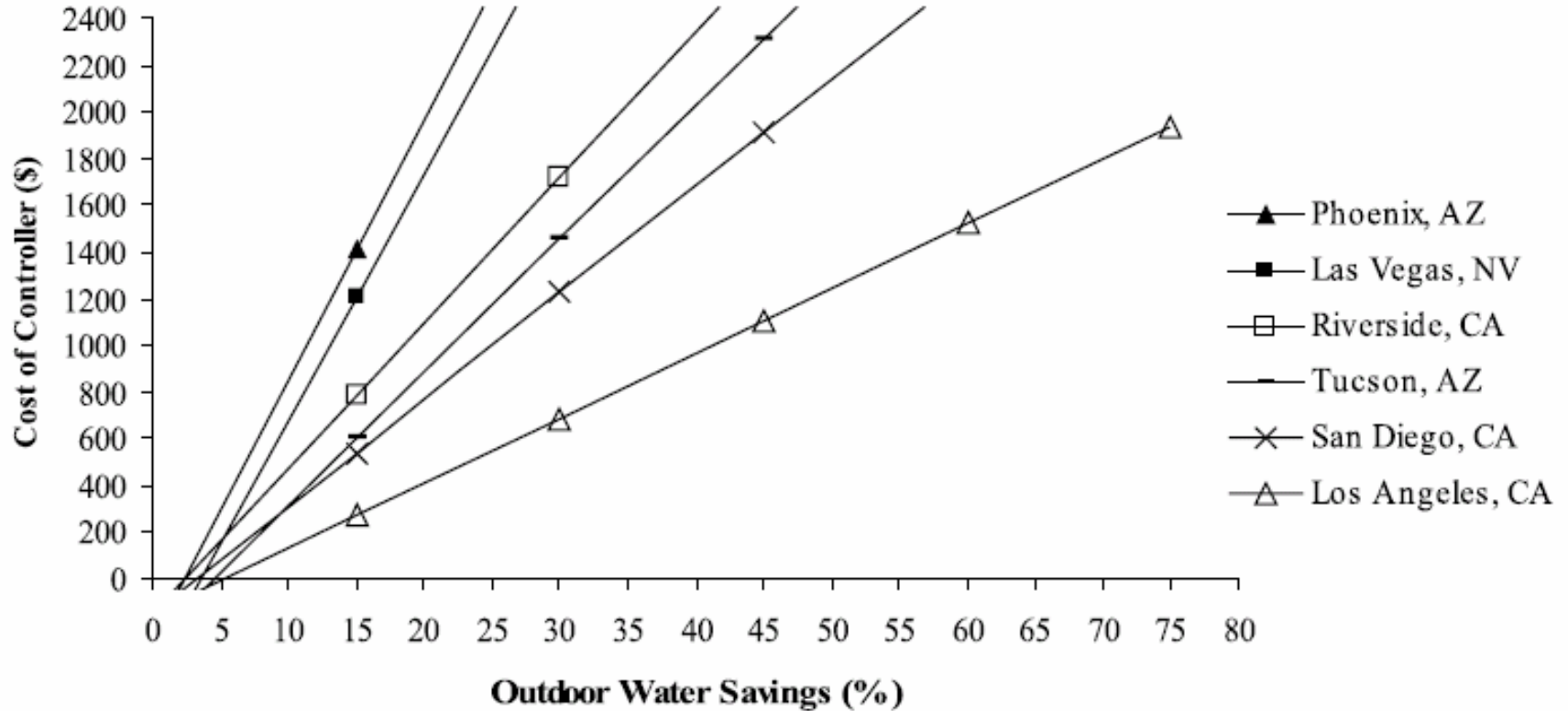
**Figure 6** Baselines representing a life cycle cost of zero for residential smart irrigation controllers in different cities in the Southwest. The cost of the controller is the retail cost, plus ten years of service fees for brands that charge annual service fees.

Controllers use electricity but save water, which has embodied energy

Life cycle model includes CO2 to

- n Produce controller
- n Run controller
- n Produce water

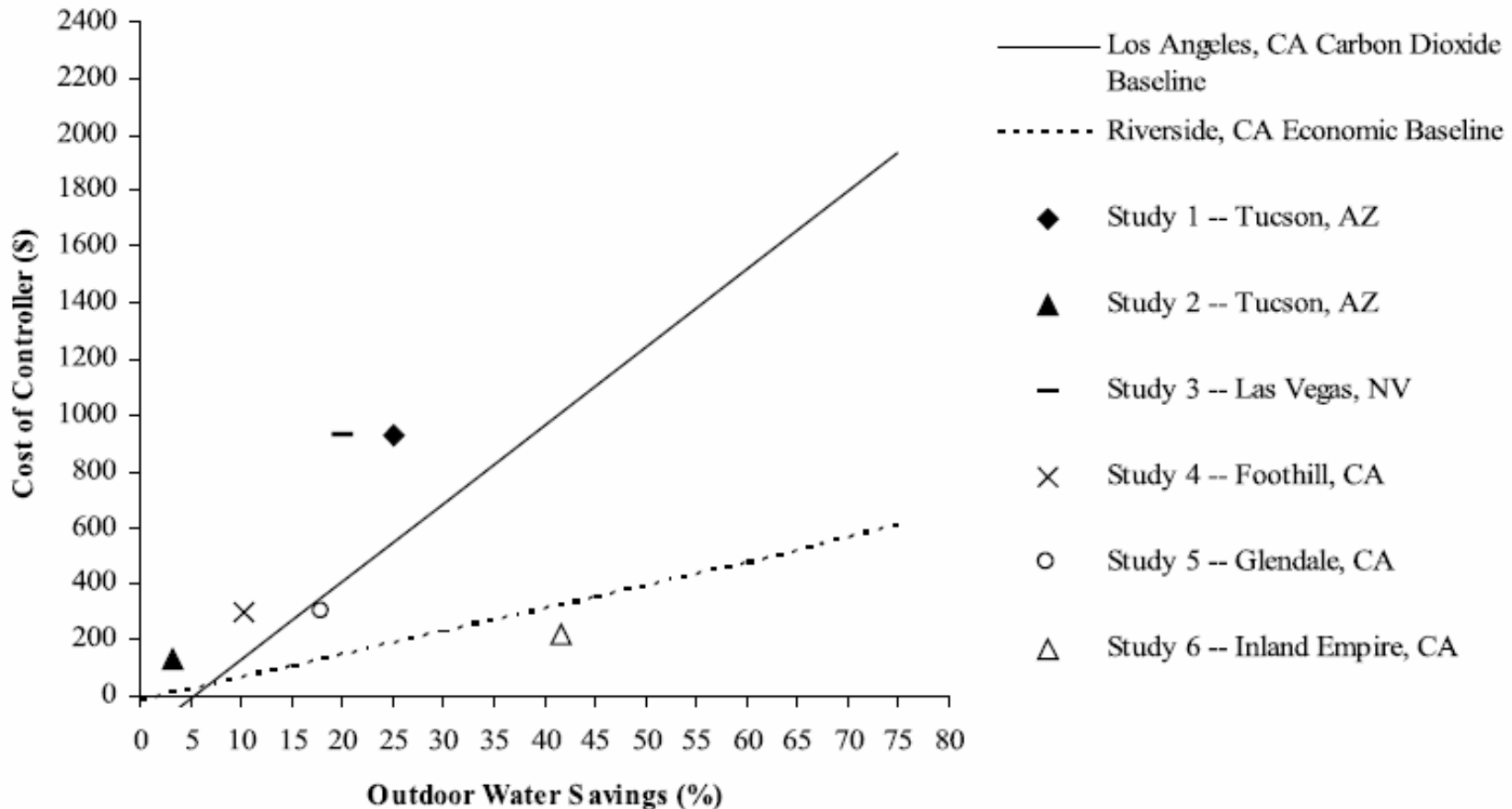




**Figure 7** Baselines representing a carbon dioxide life cycle emissions of zero for residential smart irrigation controller in different cities in the Southwest. The cost of the controller is the retail cost, plus ten years of service fees for brands that charge annual service fees.



# Constraints for controller to yield \$ and carbon benefits in all areas



**Figure 8** The results of six smart irrigation controller studies compared with the least favorable economic and carbon dioxide conditions from figures 6 and 7. The cost of the controller is the retail cost, plus ten years of service fees for brands that charge annual service fees.



## Conclusions from case study

- n Smart irrigation controller design still has a way to go before achieving both \$ and carbon savings in general
- n Key parameters to improve:
  - n Cost
  - n Electricity consumption
  - n Water savings (in practice given consumer use)



# Future Directions for water smart grid

- n Cost benefit analysis of different applications
- n Technology work to develop new systems and improve performance
- n Interface between user behavior/attitudes and design/performance is important.



Questions/  
comments?

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