Design constraints to realize economic and carbon benefits for smart irrigation controllers in Southwestern United States

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(1) Introduction

- Smart irrigation controller (SIC) studies show overall water savings, but there is a large difference in individual results within studies and when comparing different studies.
- Further study on the cause of these differences is needed, as well a need for optimization of design and field performance.
- To inform the technology development process, we develop a Design for Environment (DfE) method that overlays economic and environmental performance goals under different operating conditions.

(2) Methodology

The purpose of this methodology is to identify performance goals robust enough to deliver benefits under different operating conditions. While not all technologies will display variability in operation that significantly affects design, this is clearly relevant for SICs and there are many other examples. We start with the following equation:

$$LCI_l\,(D_1,\ \ldots,\ D_n;\ O_{1,\ldots,\,m}) = T_l\ ,$$

where LCI is the life cycle impact, D is a design parameter, and O is an operating condition. The index, l, denotes the life cycle cost/impact of concern, n is the number of design parameters considered, m is the number of operating conditions, and T is the target life cycle impact. Each operating condition can have a number of different variables. Life cycle impact has the following meaning:

LCI_l = Resource Allocation + Manufacture + Transportation + Purchase And Installation + Maintenance And Use + End Of Life.

Graphical Example of Methodology:

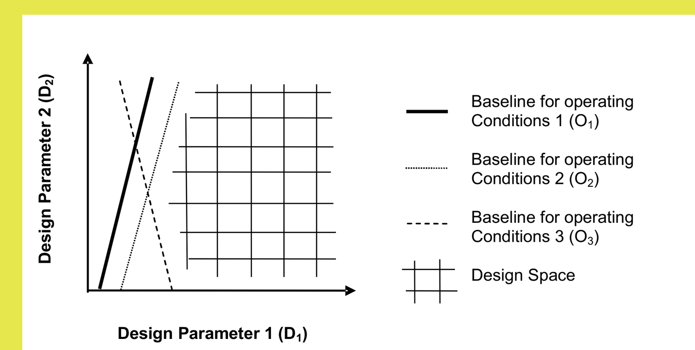

Figure 1. Hypothetical results for a two dimensional design space meeting the first target life cycle impact: $LCI_l\ (D_1,D_2;\ O_{1,2,3}) = T_l$.

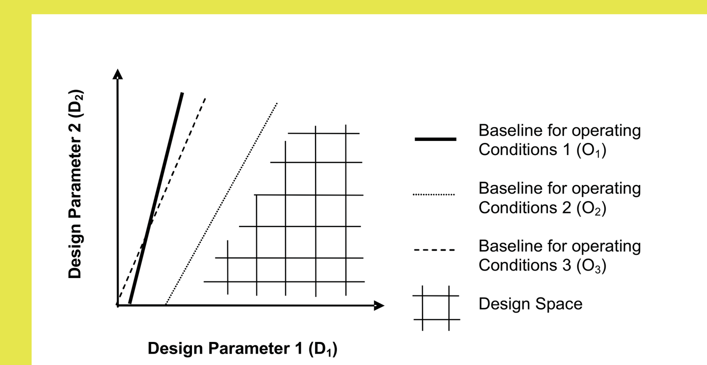

Figure 2. Hypothetical results for a two dimensional design space meeting second target life cycle impact: $LCI_2\ (D_1,D_2;\ O_{1,2,3}) = T_2$.

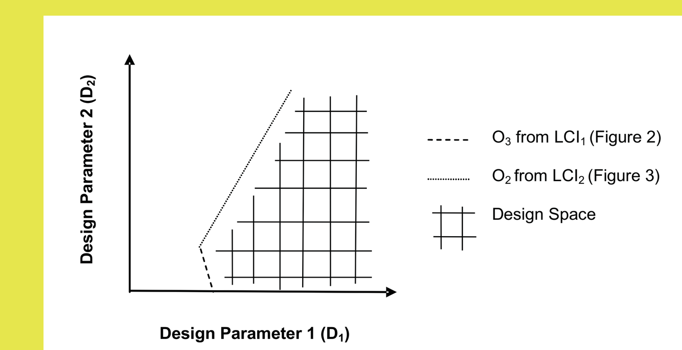

Figure 3. The hypothetical design space that meets both targets under all operating conditions.

(3) Results

Economic Analysis (consumer impact) – the price and water savings characteristics a controller must meet in order to realize net economic benefits for a resident in different Southwestern U.S. cities:

$$LCI_1\ (D_1,\ D_2;\ O_{1\text{-}6}) \le 0\ ,$$

where LCI_1 is the economic performance over the life cycle of the controller; D_1 is the percent outdoor water savings of the controller; D_2 is the annual cost of controller; O_1 is the operating conditions in Tucson, AZ; O_2 is the operating conditions in Phoenix, AZ; O_3 is the operating conditions in Las Vegas, NV; O_4 is the operating conditions in San Diego, CA; O_5 is the operating conditions in Los Angeles, CA; and O_6 is the operating conditions in Riverside, CA. LCI_1 is the following equation with the following operating conditions:

LCI_1 = (Controller Price – Water Bill Savings + Additional Electricity Cost)(Net Present Cost adjustment).

Carbon Dioxide Analysis (global impact) – the SIC must at the very least be carbon neutral, i.e., the additional electricity used to manufacture and use the controller must at least be balanced by the carbon reductions from reduced water use:

$$LCI_2\ (D_1,\ D_2;\ O_{1\text{-}6}) \le 0\ ,$$

where LCI_2 is the carbon dioxide emissions over the life cycle of the controller, and the variables are the same as in the economic analysis above. LCI_2 is as follows:

LCI_2 = SIC Manufacturing Emissions + Differential Electricity Use Emissions (compared to conventional controller) - Emissions from avoided water use.

(3.1) Graphical Example of our SIC Case Study

– The area below each baseline represents an economic or carbon dioxide savings. The cost of the controller is the retail cost, plus 10 years of service fees for brands that charge service fees.

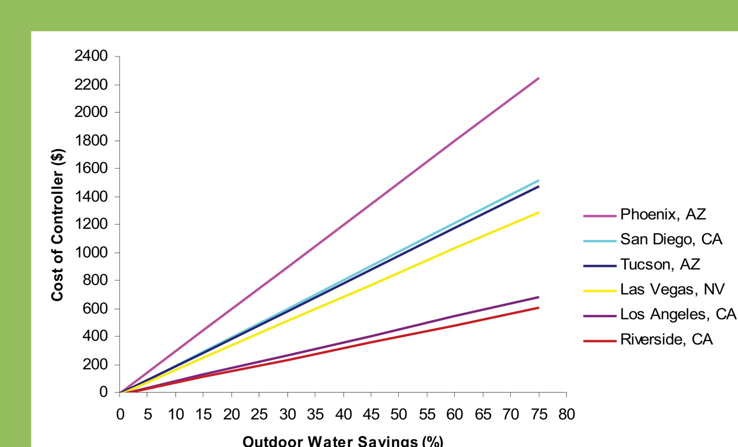

Figure 4. Economic baselines – Economic life cycle cost equals zero for residential SICs in six Southwestern U.S. cities.

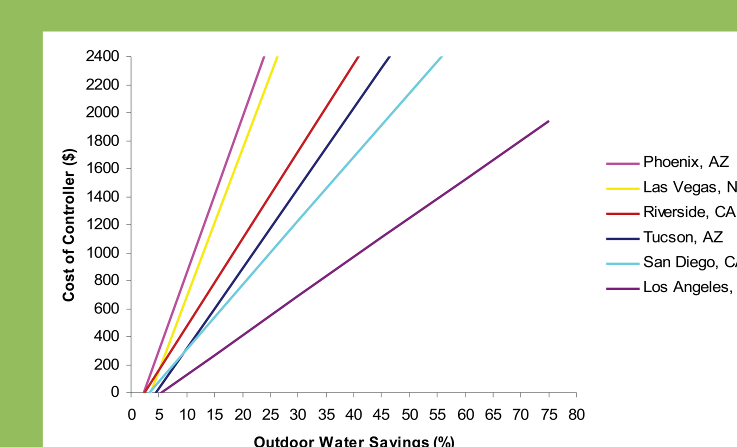

Figure 5. Carbon dioxide baselines – Carbon dioxide emissions equals zero for residential SICs in six Southwestern U.S. cities.

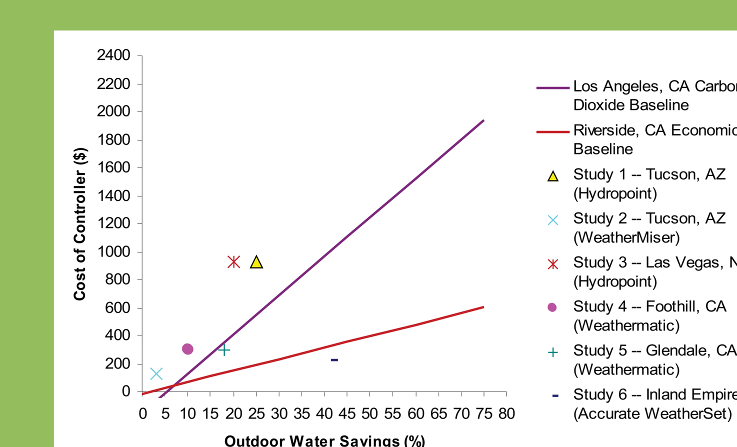

Figure 6. The least conducive baselines from Figures 4 and 5 compared to six individual studies on SICs. For practical matters, the design space is below the Riverside Economic Baseline. Only study 6 falls inside this design space.

(4) Conclusions

There is a need to lower prices and increase water savings to make SICs broadly attractive to residential consumers in the Southwest. We suggest the following steps:

1. Target the use of SICs in cities like Phoenix in the early phase of product development, because economic and carbon dioxide conditions are more favorable.
2. Understand better the interfaces between controller design, landscape type, climate, user behavior, and other such variables that affect SIC performance.
3. Determine the most broadly effective evapotranspiration or soil moisture tracking strategy and standardize the technology to reduce cost and increase water savings, and/or target the appropriate technology to the appropriate environmental conditions.

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for further information

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