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Editorial

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A Systems View towards More Sustainable Irrigation Design

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There are exceedingly few human activities that are sustainable. Our societies today are based on the utilization of resources, where the overwhelming majority of these resources are either nonrenewable or at least very slow to be replenished. There may be water everywhere, but not every drop is easily accessible for our use. There is an abundance of untapped energy, with over 1.57 PW-hr/yr solar energy striking the upper atmosphere; approximately 74% is transmitted within the atmosphere [1-3]. Currently there is about 12.4 PW-hr/yr of solar radiation induced renewable resource consumption capacity (or less than 0.0008% of the total available); and the total energy consumption (from all sources), 159 PW-hr/yr, is only around 0.01% of what is available solely from solar energy within the atmosphere [4]. With cheap and abundant energy, there would be no water quality or quantity problems. To date, accessible energy is neither cheap nor abundant enough to limit water borne problems in either the developed or developing world. This requires engineers, designers and managers to take a more deliberate view of the system to be developed. Right now, as a society in whole we are failing to do much more than implementing a patchwork of temporary solutions to our growing problems [5]. Sustainability requires designers to consider the effective and affective parameters which govern long term system efficiency; oversight of sociological aspects (e.g., employment, awareness, stakeholder acceptance) often leads to system failure [6].

Ultimately, irrigation systems need to be selected and designed on a new paradigm, a total system cost approach. The true costs associated with new systems are often boiled down to the tangible fixed and variable system outlays. In many cases, alternative decision metrics are employed, but there are times this fails to adequately account for ostensibly intangible costs that are necessary to be both competitive and responsible. This problem is compounded when water is undervalued, or the true costs associated with the withdrawal are obscured, deferred, or even subsidized.

Sustainable water/energy technologies which can reliably supplement existing infrastructure should be developed based on *systems level thinking*, and should be easily integrated into existing systems without creating new challenges. The National Aeronautics and Space Administration (NASA) uses a tool, the Equivalent System Mass (ESM), to evaluate seemingly divergent complex systems on a side by side basis [7,8]. While this method could be used to directly evaluate different irrigation system proposals, an Equivalent System Cost (ESC) metric would be more appropriate. This simple tool provides a framework for considering the functional, economic, social, and ecological aspects of a given technology. On the face, it simply could be defined by

$$ESC = C_{Capital} + C_{Operational} + C_{Societal} + C_{Affectual} - S_{Effectual}, \qquad (1)$$

Where *ESC* is the equivalent system cost, the *C* terms represent the costs, and *S* is the savings. However, the complexity lies in how each term itself is defined (see Savings example to follow). The ESC metric would contain the standard fare of capital costs (including cost for infrastructure, equipment, water rights/permits, interest on borrowed capital, insurance, taxation, depreciation, etc.) and operational costs (including costs for energy costs, labor, chemicals, scheduling/management services, transportation, maintenance, etc.), but would also include societal and other system impact costs as well as effectual savings.

Societal costs are those indirect costs associated with the level of society strife that can be inherent with the application of technology. These costs can include but are not limited to workforce transport costs, although this may also include the regional industrial/economic impact of workforce, resource allocation, and/or added social unrest associated with training and education.

Effectual costs would be those indirect costs due environmental impacts a given system can have on the local ecosystem. These costs can include the devaluation of land over time due to soil salinization, the influence of perched water tables, the added costs which contaminate runoff mitigation, the increase in water exportation, and the like.

Effectual savings are the indirect perceived benefits of a system. Such savings can come from decrease in exportation costs, increasing regional sustainability and transportation cost reduction. An example might be the use of micro irrigation in a water-limited environment, where the savings could be determined by

$$S_{Effectual} = \Delta WUE \cdot \eta \cdot \frac{V}{A} \cdot P \quad (2)$$

where the effectual savings can be determined from the product of the increase in water use efficiency, ΔWUE, the commodity price, *P*, the volume of water saved, *V*, the application efficiency η, divided over the additional land water could be applied over, *A*. Complexity is introduced from nonlinear functions, like in this case the water use efficiency

$$WUE = \phi\left(\eta \cdot \frac{V_{saved}}{A}\right) (3)$$

which is a function of the additional applied depth, but also from the definition of parameters like the commodity price. The commodity price could be simply the market price, a function of the energy stored in the crop, or could also incorporate reduced transportation costs for the commodity.

The societal, effectual and effectual components are by their nature somewhat nebulous and therefore guidance or frameworks should be established for use by the design team. A suggested framework is provided in Figure 1, where the design team first determines the needs and design criteria. Next the designers examine which costs should be integrated; then how those costs should be determined. An iterative cost evaluation process should be implemented to test the efficacy of the assumed cost structure, ideally against a known similar example.

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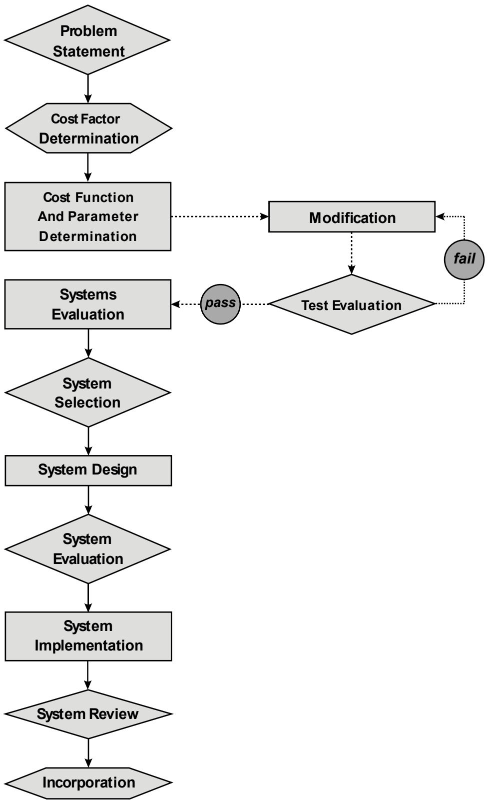

Figure 1: Suggested framework for implementing the ESC.

Upon completion of the testing phase, each system alternative should be analyzed form which a selection could be made. A full system cost evaluation follows the full system design, as does a final system cost review after implementation of the designed system. This allows for data reporting and incorporation of learned outcomes in future designs.

Bare in mind that not all systems will have drastically different cost components beyond traditional ones of capital and operational, but then this would tend to bolster the system selection process regardless. Also, each component will vary, as does water availability and quality, on a regional basis. In many instances the global systems view is no different than what has been taught for many years, the difference lies in codifying a structure that helps students and future professional to use those tools. Ultimately the incorporation of the intangibles into the selection analysis may neither be fully substantiated or very rigorous, from its very nature, but the incorporation will move engineers and designers down the path of learning to be more innovative and sustainable.

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