

## **Developing a Regional Circular Value Ecosystem Based on Residues and Wastes: The Case of Higuera Village, Mexico**

### **Eduardo Aguiñaga**

PhD Student, Tecnológico de Monterrey, Monterrey, N.L., México  
Av. Eugenio Garza Lagüera and Rufino Tamayo n/n, Valle Oriente, Garza García, N.L.,  
66269 México, Ph: +(52)(81) 8625-6000  
E-mail: A00790980@itesm.mx

### **Carlos Scheel**

Professor Emeritus, Tecnológico de Monterrey, Monterrey, N.L., México  
Av. Eugenio Garza Lagüera and Rufino Tamayo n/n, Valle Oriente, Garza García, N.L.,  
66269 México, Ph: +(52)(81) 8280-7679  
E-mail: cscheel@itesm.mx

### **Abstract**

*Regions must be redesigned in order to be sustainable economically competitive and socially inclusive. The achievement of sustainable wealth is a complex phenomenon that includes multiple players, conditions and uncertain links among stakeholders. In this paper, we present how to assemble a “circular connected value ecosystem” and its behavior, implemented to create sustainable wealth among synergies of different stakeholders in a region. The Regional Circular Value Ecosystems (RCVE) is a synergic space where products, residues and waste (R/W) are interconnected and transformed into valuable products. To be able to observe the dynamics of all synergies within a region is a complex problem that must be modeled before decisions are taken. A case study of the village of Higuera, Mexico is selected to support this new approach to achieve sustainable wealth creation that can be replicated for developing countries. The case includes the system dynamics modeling of the main economic activities within the region. Simulation results supports our hypothesis, that the proper systemic seizing of the potential of R/W through the use of innovation with a systemic approach, new disruptive business models and appropriate technology and processes, is an effective way to transform a region into a self-sustainable community.*

**Keywords:** *systems dynamics, circular economy, sustainable wealth creation, residues, wastes*

## Developing a Circular Value Ecosystem based on Residues and Wastes: The case of Higuera Village, Mexico

The recent escalating production of wastes, pollution of water, eroded soils as well as the CO<sub>2</sub> emissions derived by the excess of consumption and by the intense industrialization are clear signs of a need to create new way of prosperity. This non-sustainable growth has caused the earth to be unfeasible to recover most its resources through natural means. A considerable contributor of this problematic is solid waste. Therefore there is an increasing need to cope with this problematic through an effective, innovative, and sustainable mechanism (Yay, in press). This situation requires a new economic paradigm based on the principle of loop-closing where all residues and wastes (R/W) can be further utilized for creating high value (economic, social and environmental). We must transform R/W from urban consumption and linear product cycles into environmentally reversible and recoverable products, economically viable and competitive, as well as socially equitable and responsible through sustainable cycles (Donald, 1999; Scheel, 2014).

### Literature Review

Solid waste management has been addressed from optimization perspectives over one linear production chain as well as industrial ecosystems capable of reducing the consumption of virgin materials and creating symbiotic linkages of R/W sharing (see Chertow, 2000). Recently, there is an increasing need to innovative, and create value adding technologies for the achievement of a zero emission goals where no residue is left unexploited and valorized. Therefore, we must change from end-of the pipe approaches to waste, to a more systemic and value generating one as suggested by Dong et al. (2014). Zero emission's goal requires radical breakthroughs to shift from individual technologies to a system's level (Schnitzer & Ulgiati, 2007).

The switch from one company or process in complete isolation, towards a more systemic, regional and interconnected level requires more attention towards integrating the diversity of stakeholders within a region and their potential synergies. Additionally, the dynamics of it, in order to unearth the behavior of the system, is needed when multiple actors and their processes are involved. Consequently, numerous researchers have integrated systems thinking and SD modelling tools into their research agendas.

Literature on industrial ecology has integrated SD modeling into their methodologies (e.g. Bollinger et al. 2012; Verhoef, Dijkema & Reuter, 2004) acknowledging the importance of dynamic simulation on the cyclic usage of materials. Research over sustainable systemic activities within a region that take into account not only efficiency on financial grounds, but focus also in the increase of social and environmental wealth are also present in the literature. Ometto et al. (2007) research focused on an agro-industrial network, concluding that the integration of multiple industrial activities through symbiosis i.e. waste sharing and reprocessing, represents the main factor for succeeding at the ecological, sociological and economical arenas.

It is clear that recent research suggested broadening both the unit of analysis and the time scope. There is an increasing focus over analyzing regions from a systemic perspective above isolated processes and products, and dynamics of systems on longer time spans.

Therefore we propose a new approach is needed to cope with this new reality where all the regional economic operations are circularized in order to create what we have termed a Regional Circular Value Ecosystem (RCVES).

We define the RCVES as regions composed of a network of new start-ups and already established economic activities linked through non-usual business opportunities of residues and wastes revalorization enabled through concepts such as: (a) cascading business models and multiple cash flows from Blue Economy (Pauli, 2010); (b) waste and residue sharing from industrial ecology (Frosch and Gallopoulos, 1989); (c) circularity principles from circular economy (Ellen MacArthur Foundation, 2012) and (d) systems dynamic modelling (Richmond & Peterson, 1997; Sterman, 2000). Through these concepts and frameworks we have developed a mechanism called Zero Residues Industrial Ecology System (ZRIES). In the ZRIES mechanism, we contend that each economic activity and residue generator in the region is able to achieve sustainable wealth through an effective and efficient clean production, waste revalorization creator of sustainable wealth while increasing the natural resilience of the region. Therefore, ZRIES enables the circularization and interweaving of all activities within a region, allowing it to become self-sustainable.

## **Methodology**

### **System dynamics and waste management**

We opted to use SD as the methodology of the present research as it can cope with the complexity of systems such as waste management and since it is capable of dealing with both the structure and the resulting effects derived from changes in subsystems and their relationships (Chaerul, Tanaka & Shekdar, 2008). Also, SD provides a useful methodology to create different scenarios based on specific assumptions and values of the variables, therefore foreseeing through the simulation results how the system reacts to changes, thus making it valuable tools for communicate the possible impacts of different decisions and changes in the system. Moreover, according to Rochas et al. (2015) one of the methods for resilience assessment is SD modelling.

For the above, we opted for using SD as the best suited methodology for our investigation as it provides a systemic approach that takes into account the social, environmental and economic aspects that need to be analyzed in a time scale reference (Pubule et al., 2015).

### **Higueras Village, Nuevo Leon, Mexico**

Higueras is located 58 km north of Monterrey, capital city of the state of Nuevo Leon, Mexico. It is a small village of 1,594 inhabitants (INEGI, 2010) with an increasing food, energy, economic and health dependence over the capital compromising their long-term supply. Therefore, the challenge is to develop a Regional Circular Value Ecosystems by focusing on strengthens the following parameters: (a) capacity to achieve food security (through the cultivation of most of their own food), (b) creation of rich topsoil in order to regenerate the natural environment (resilience), (c) improved health through correct use and exploitation of regional natural resources and (d) improve regional water usage.

Figure 1 depicts the synergies among all the stakeholders of the community. The most important players based on their systemic wealth creating potential entail the following: (a) a goat cheese factory, (b) an oregano plantation, (c) the village lake and (d)

urban gardens. Moreover, also depicted are their connections with a key decomposer (red worm farm) and enabler (technologies) systems that are capable to transform and revalorize R/W into a system of capital for the entire region.

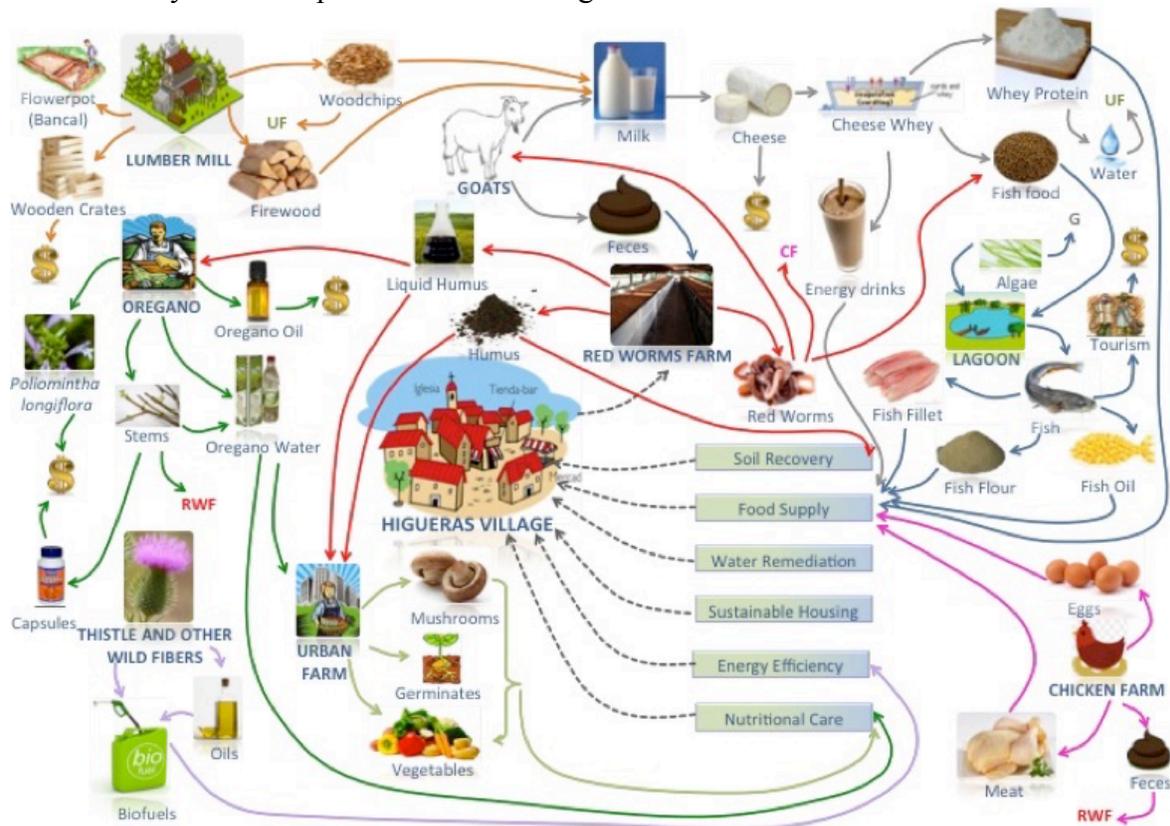


Fig. 1. Synergy Map of Higueras Village’s main stakeholders and economic players

All the stakeholders and participants in linear production chains can be circularized, creating networks of knowledge and residue sharing beyond that of industrial symbiosis through upcycling (McDonough & Braungart, 2013) processes and technologies.

### Systems Dynamic Modeling

#### Model Construction

We constructed the model by integrating data from experts’ interviews, as well as secondary sources and field observation using Vensim® software. We identified two main economic activities, and waste and residue producers as well as one decomposer firm (Vazquez, 2014). These were the following: (a) goat cheese factory, (b) an oregano plantation and (c) a red worm farm respectively.

After all the residues were analyzed and the best and most appropriate technologies and processes for upcycling residues and sharing across the systems were found, we proceeded to model all the Regional Circular Value Ecosystem in order to foresee its impact on Higueras village. Figure 2 depicts the causal loop diagram of the Higueras Village’s model structure.

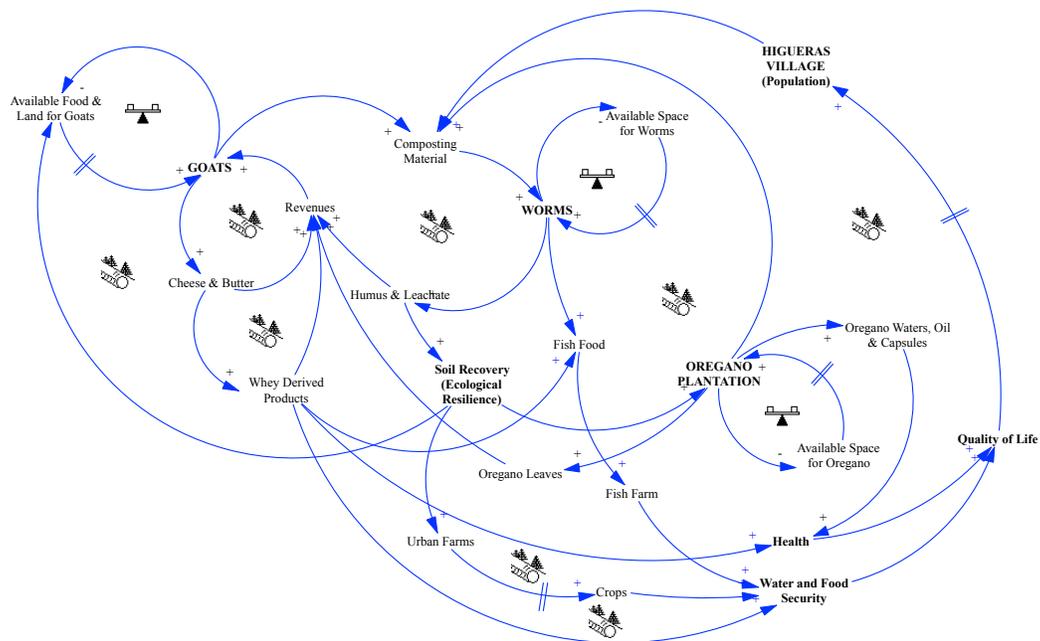


Fig. 2. Causal loop diagram of the model's structure.

### Oregano plantation

The oregano system comprises a plantation of oregano (*Poliomintha longiflora*) with a continuous production of leaves as condiment. Although the main product is the oregano leaf, residues in form of stems are subject to two revalorization processes found to be the most suitable: (a) Hydrodistillation for obtaining essential oils and (b) encapsulation for nutraceutical purposes.

Hydrodistillation process yield two main revalorized products, essential oils and oregano waters, both powerful natural antiseptics, fungicide and disinfectant (Gündüz, Gönül & Karapınar, 2010; Karabagias, Badeka & Kontominas, 2011). Residual stems from hydrodistillation, containing no chemical value, are used as feedstock in the red worm farm composting process. Oregano capsules provide another product derived from a residue. These capsules represent a natural nutraceutical that fight fungus and microbes.

### Goat Cheese Factory

The goat cheese factory (houses 130 goats. Along the cheese production chain, it generates wastes in form of wastewaters that contain large amounts of dissolved whey that has a high chemical oxygen demand (Lebrato et al., 1990), that when released to nearby body of waters can be highly pollutant. Three products that can be obtained from the cheese whey namely: (a) isotonic protein beverages, (b) whey protein powder and (c) fish food. Moreover, given the local presence of a lake, the fish food derived from dried cheese whey is devoted for feeding the local fish and turtle population.

Finally, two other residues are generated. First, derived from the drying processes, residual water is obtained which serves for local irrigation of urban gardens. The second residue is goat manure, which enters the red worm composting process as a prime feedstock.

### **Higueras' Lake**

Higueras' lake houses fishes and turtles, which represents a potential tourist attractor as well as food source. Moreover, the lake has the space and the conditions to generate two star-ups, a fish farm where catfish filet is produced and a microalgae farm, feedstock for animal feed given its high protein content. Therefore, the lake receives fish food and provides food availability for both the village and the cattle.

### **Urban Gardens**

Urban gardens are being developed throughout Higueras in order to develop the three axis of sustainability. On the economic side, urban gardens are productive poles where food production for self-consumption increases their food independence, and any surplus could eventually translate into marketable organic products. Socially speaking, urban gardens help to restore and strengthen the social fabric as the people gather to perform joint agricultural activities. Finally, the environment is also benefited with the increase of food independence, as carbon footprint is lessened, and more importantly given that the construction of urban gardens promotes re-vegetation and soil recovery through the use of solid humus and leachate from the red worm system. The urban gardens also serve as nursery for the recovery of endangered endemic species.

### **Red Worm Farm**

The red worm farm (*Eisenia Foetida*) produces three main products: (a) solid humus, (b) leachate (liquid humus) and (c) worm meat. Three physical inputs are required for the production of these products: (a) water (a) manure and (c) organic matter, all of which can be obtained locally from the lake, goats and the Higueras village respectively.

Solid humus and leachate are produced concomitantly. These are the best known natural fertilizers as they contain all the micro and macronutrients needed for agriculture. Therefore, these two products have the potential to enrich substrate and re-vegetate, consequently remediating the eroded soil (Piippo et al., 2014). Finally the worm meat produced by the excess of worm population serves as fish food for the lake.

### **Higueras as Regional Circular Value Ecosystem: A 10<sup>th</sup> Anniversary Scenario**

After the 10<sup>th</sup> year of Higueras implementing the regional synergies, the simulation suggests the following regarding four parameters:

**Water usage.** The efficient usage of water and its proper recovery have saved the village of the equivalent of 665,000 liters, therefore improving the water availability. Moreover, the daily production of isotonic beverages provides a free nutritional supplement to all the approximately 225 children (15% of the total population) of Higueras.

**Health.** Cases of gastrointestinal diseases have never been lower given the usage of the oregano waters as antiseptic for disinfecting the locally grown vegetables. Coupled with the intake of oregano stems at no cost, which strengthens the immune system, less common illnesses have been present at Higueras.

**Topsoil recovery (resilience).** By the 10<sup>th</sup> year, more than 660 hectares have been fertilized using just worm leachate, helping re-vegetating and recovering previously poor soils. Solid humus used on the construction of urban gardens, have provided nearly an

additional 1.5 hectares of recovered soil suitable for growing vegetables.

**Food Security.** With the topsoil recovery, urban gardens provide all the vegetable requirements (383 vegetables a day) for completely satisfying the vegetable requirements of 75 families, consequently reinforcing their self-sustainability.

Although successful, new challenges arise as more people come to populate therefore it has to be constantly reinventing itself and evolve in order to maintain its homeostasis.

### **Discussion and Conclusions**

Higueras has proven that regions can become self-sustainable communities through the feasible and harmonic connection between the systems. Moreover, the village has proven its capacity to overcome the production of waste by systematically interlinking stakeholders, proper technologies, innovative processes and their R/W to create valuable nutrients for other processes as well as products for the region. The simulation results show a clear improvement of four parameters namely, capacity to achieve food security, creation of rich topsoil, improved health and water usage. Additionally the regional synergies produced, as collateral impact, an increase in demand for human capital, which translates into job security and opportunities, lessening the migration trend of the working force.

In sum, simulation results suggest a clear synergy among these systems and its stakeholders. The environmental, social and economical impacts are clear.

The present model, beyond providing a tool for simulating each and the overall village system, it enables a proper mechanism to answer several strategic decisions regarding the future of Higueras as a potential self-sustainable village. It enables a support decision system through scenario development where the impact of the variables to the whole system is measured and most importantly, it shows how regional redesign affects the parameters of interest.

We conclude that the proper systemic seizing of the potential of R/W through innovation, new business models and appropriate technology and processes, is an effective way to redesign and transform a region in order to be self-sustainable and at the same time economically competitive and socially inclusive into a self-sustainable community.

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