Optimizing Energy Choices (decisions)

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Introduction

We need energy to live and we need a lot of it to maintain our current lifestyle. But how much, and where doesl it come from?

A reliable supply of energy is essential to our omfort and well-being. Energy supply discussions usually focus on its cost, availability, and reliability. In the last few years these discussions have also included the limitations of fossil fuels, climate change and sustainability. Renewable energy seeks to reduce our carbon footprints, improve the triple bottom line, and provide more local, sustainable sources of energy. But even within these green energy discussions we continually focus on short term strategies such as solar PV collectors on roofs or big solar farms, whether to insulate or weatherize our homes, or whether to change our light bulbs. Of course we need to do all of these, and much more – on a local level.

We need a basic change to our energy infrastructure. We need to make better decisions on our energy needs and supply. This paper proposes a concept for locally driven energy infrastructures: that of energy commons. The 'commons' part of energy commons refers to resources that are collectively owned.[1] In the USA that would be akin to a HOA (home owner association), or Native American Indian tribe that has their own governing bodies and regulations, along with control of their energy sources.

We are not individual energy users, we are part of an energy community. Each community influences and is influenced by its members needs, its local geographic region, resources and infrastructure. In other words, each community is unique. Each community's energy infrastructure is also unique and needs to be uniquely designed and balanced between energy availability and its members' needs. One-size-fits-all energy infrastructure is inappropriate and unsustainable.

Most communities' current energy infrastructure, policies and supply chains are dictated by far away regulators and decision makers who have minimal knowledge of local communities' needs. These utilities and regulators focus on quarterly profits and providing a power mix based on global energy supply chains that are inherently inefficient, fossil fuel based, and are about to get very expensive as global capacity is maximized. Useful electrical power output within this supply chain is at best 20%. That means 80% of our

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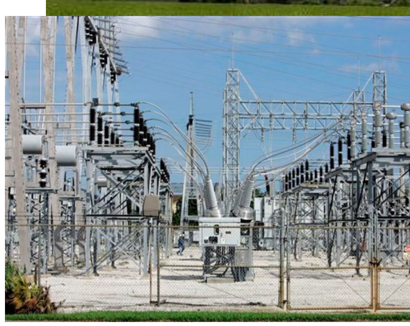
[1] Reclaiming the Commons, David Bollier, Boston Review, 2003

current energy is spent in just getting it to where we can use it! Local community energy commons would reverse these ratios.

Our current energy system is the most capital intensive sector of the global economy. To transition to energy commons we need to first focus on fossil fuel plants: Most centralized large-scale power plants convert fuel (mostly coal) into electricity with an average efficiency of 34% resulting in 66% wasted heat. They then convert, transmit and distribute this power through thousands of miles of ugly power lines ending up with a net efficiency of less than 20% at the consumer power plug. Contrast that to small local on-site co-generation or biomass plants that recover waste heat at 61% efficiency; or even smaller, off-the shelf turbines that can attain 91% efficiencies (trigen cogens, etc.); and distribute their energy close-by. Smart industrial plants are already doing this – it is proven technology.

The questions we need to ask are:

> *Would we purposely design an energy extraction, distribution and supply system the way it exists now?*
>
> *Would we design a system that supplies energy from hundreds of horizontal and vertical miles away from where it is needed? ...and shipped half-way around the world, processed and distributed by corporate behemoths that are accountable only to their shareholders?*



> *Would we voluntarily convert faraway energy sources into less than 20% usable energy and dump these inefficiencies into the atmosphere and waterways as waste heat + toxic chemical by-products?*

or

Would we prefer a reliable, locally controlled energy system, free from brown-outs + shutdowns, with enhanced diversity and security of supply?

Do we tap into current, available,' free' energy close to where we live and work; shared with our close-by neighbors, at 60%+ conversion efficiency?

In order to tap into this current, local, 'free' energy we need to have technologies and social/political systems that enable local energy commons. '…A recent synthesis (power study) found approximately 75 uncounted effects of scale on economics typically make decentralized power sources about tenfold more valuable than traditionally proposed' power sources. [2]

Our new energy technologies are now providing us with better infrastructure solutions. Science and renewable technologies are well on their way with scalable solar PV, solar lo-temp thermal, adsorption refrigeration, small geothermal, and wind energies. In the next few years, scalable energy generators and fuel technologies will become available even to individual residential homes. This is great news for local communities wanting to create an energy commons. Now! is the time to embrace energy commons.

In order to have better, more local energy choices and establish energy commons; we need a framework within which to make good decisions. Luckily, this framework has already been established through the time proven principles of:

1. Permaculture
2. Biomimicry
3. Cradle-to-Cradle™
4. Industrial Ecology
5. System dynamics
6. Quality principles
7. TBL: People, planet, profit

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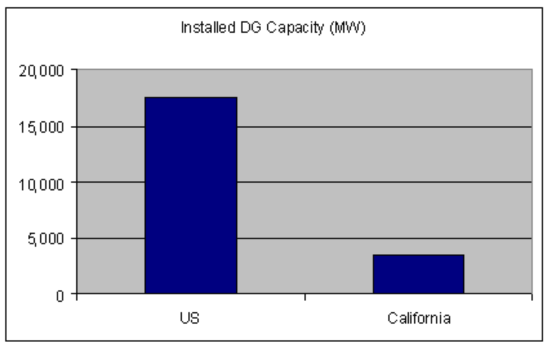
[2] Pg 130-1 'Natural Capitalism' Paul Hawken, Amory Lovins, Hunter Lovins, Earthscan Ltd (November 1, 2000) ISBN-10: 1853837636 ISBN-13: 978-1853837630

Micropower and DER / DG

One term that is commonly applied to local energy generation is: micropower. This label is incorrect. Energy commons is about power on a community level, not at an individual/building level which is the common reference for micropower.

In the USA, and especially in California there is widespread acceptance of the term DER (Distributed Energy Resources) or DG (Distributed Generation). DER are small-scale power generation technologies (typically in the range of 3 to 10,000 kW) located close to where electricity is used (e.g., a home or business) to provide an alternative to or an enhancement of the traditional electric power system.[3] Across the US, over 17,500 megawatts of distributed generation (DG) has been installed and interconnected with the electric grid.



California has approximately 3,500 MW (20%) of this installed DG capacity as shown in the above Figure.[4]

These market numbers reflect only distributed generation devices that are interconnected to the electrical grid and do not include emergency or other non-interconnected DG. EPRI reports the total US DG capacity is as high as 147 GW, including non-interconnected DG sizes up to 10 MW. If the same ratio holds for California, total DG could be as high as approximately 30 GW.[5]

No matter what scale a de-centralized energy commons power system is, the more relevant questions become:

- Which energy source to use?
- Which would be most reliable, lowest cost, longest-lasting, etc for each given commons community?

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[3] http://www.energy.ca.gov/distgen/index.html

[4] Sources: California Energy Commission (Scott Tomashevski), DG Monitor March/April 2004

[5] http://www.energy.ca.gov/distgen/markets/markets.html

- How can various social, political and logistical aspects of these energy sources and their equitable distribution be assessed and provide the best fit for each community and commons area?
- What is the right size for a task, for a given need?

EF Schumacher's 'Small is Beautiful'[6] first questioned the concept of 'bigger is better'. The correct size is not always the largest or smallest size. Two extremes on the appropriate use of energy would be:

(1) Would we heat our homes with a nuclear power plant?

(2) Can we power large factories solely with windmills or PV?

The answer lies between these two extremes and depends on the energy systems' attributes and end users' needs. System dynamics explores and can provide solutions for this. (see later section in this paper)

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[6] Small is Beautiful, EF Schumacker, Harper Perennial (September 27, 1989)
ISBN-10: 0060916303 ☐ ISBN-13: 978-0060916305

Energy Commons Tools

There are six steps in establishing an energy commons community:

1. Energy needs
2. Energy criteria
3. Energy sources
4. Balancing needs + availability
5. Distribution
6. Sharing within / without

To guide a community through each of these energy commons steps, a system of guiding principles is needed. There's no need to re-invent these. We already have a rich and diverse set of scientific and business principles to draw on in helping frame energy commons criteria. Among these are:

1. Permaculture
2. Biomimicry
3. Cradle-to-Cradle™
4. Industrial Ecology
5. System dynamics
6. Quality principles
7. TBL: People, planet, profit

These guiding principles have a rich and diverse background. Permaculture sets the criteria for how we can learn and become a permanent culture and prosper for the 'long now'. Biomimicry helps unfold some of nature's secrets which has already done a lot of homework: 1.9 billion and 10^{43} experiments! Cradle-to-Cradle™ can help us close-the-loop, use intelligent materials and adopt a natural capitalism way of modern life. Industrial ecology process has shown us how to adopt these (1-3) processes in making the products and services (along with the toys) needed by our modern society in a sustainable way. System dynamics gives us insights into complex feedback loops, desired attributes, and unintended consequences of various systems and processes. Quality and TBL (social, eco, $) principles can help us design, measure and adjust our processes within ranges of stability and assure sustainability.

Following is a detailed look at three of these: Permaculture, Industrial Ecology and Cradle-to-Cradle™.

Permaculture

Many applicable principles for energy commons can be found in the practice of permaculture. It encompasses the principles of cradle-to-cradle™ redesign and industrial ecology.

Permaculture is a design system based on ethics and principles which can be used to establish, design, manage and improve all efforts made by individuals, households and communities towards a sustainable future.
It is an approach to designing human settlements and perennial agricultural systems that mimics the relationships found in natural ecologies. It was first developed by Australians Bill Mollison and David Holmgren and their associates during the 1970s in a series of publications. The word *permaculture* is a portmanteau of *permanent agriculture*, as well as *permanent culture*.[7]

12 Permaculture Principles

1. observe and interact
2. catch and store energy
3. obtain a yield
4. apply self-regulation and accept feedback
5. use and value renewable resources and services
6. produce no waste
7. design from patterns to details
8. integrate rather than segregate
9. use small and slow solutions
10. use and value diversity
11. use edges and value the marginal
12. creatively use and respond to change

These 12 permaculture design principles are thinking tools, that when used together, allow us to creatively re-design our environment and our behavior in a world of less energy and resources. These principles are seen as universal, although the methods used to express them will vary greatly according to the place and situation. They are applicable to our personal, economic, social and political reorganization as illustrated in the *permaculture flower*.[8]

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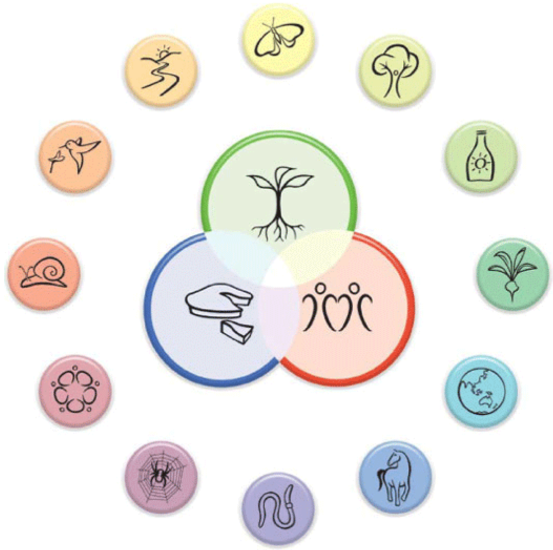
[7] http://en.wikipedia.org/wiki/Permaculture
[8] http://permacultureprinciples.com/principles.php



Permaculture principles also set up geographical zones within which each of the 12 principles are followed – albeit in different ways. Energy commons can provide the best solution for Principle#2 when combined with the Cradle-to-Cradle principle of using only current solar income.

Energy commons needs to set appropriate boundaries and establishing appropriate, local energy solutions for each zone:

Six Permaculture Zones

0 = where we live, home
1 = our garden, property
2 = the surrounding forest, community
3 = the larger support area, farms
4 = harvest forests
5 = natural conservation forests
6 = office, shop, factory

Industrial Ecology

The developers of eco-industrial parks (EIP) are applying previously tested concepts and practices (of Industrial Ecology) in an innovative whole system. You can find the separate components of the EIP vision working effectively in industry today. In some cases (i.e., energy efficiency in new process, equipment, and plant design) their obvious contribution to competitive advantage is defining these "new" approaches as best business practices. Many of these tested ideas are simply applied common sense: *"Why pay money to produce a product you can't sell, call it a waste, and pay someone to dispose of it?" "Why not use the energy of the sun and wind when you locate a building and design its heating and cooling systems?"*
The real innovation in creating eco-industrial parks is bringing such ideas together in a whole system. If you integrate as many of these well-tested individual strategies as possible into your initial EIP vision, your team may

achieve results beyond the “reasonable” expectations of a piecemeal approach. For instance, including renewable energy sources in your site’s infrastructure can guarantee reliable and clean power for industries that experience large losses when outages occur. This becomes a valuable recruitment incentive. One such source, biogas energy, may provide a market for a food processing company’s discards.
With this integrative approach, each addition to the system adds to the value of the other elements in the design. Potential investors will see that standard feasibility studies show the project passes their conventional tests.

Energy—More efficient use of energy is a major strategy for cutting costs and reducing burdens on the environment. In EIPs, companies seek greater efficiency in individual building, lighting, and equipment design. For example, flows of steam or heated water from one plant to another can be used (energy cascading) and these can also be conducted into district heating or cooling systems. (In power plants and many industrial processes, the majority of heat generated goes up the stack rather than producing value.) In many regions, the park infrastructure can use renewable energy sources such as wind and solar energy.

Materials Flows—In an EIP eco-park, companies perceive wastes as products they have not figured out how to re-use internally or market to someone else. Individually, and as a community, they work to optimize use of all materials and to minimize the use of toxic materials. The park infrastructure may include the means for moving by-products from one plant to another, warehousing by-products for shipment to external customers, and common toxic waste processing facilities. Companies in the EIP also enter into regional exchanges. [9]

Cradle to Cradle™

Energy commons needs to embrace a redesign principles as put forth by the cradle-to-cradle™ concept. C2C, as it is commonly referred to, has revolutionized the design industry when a book by the same title was released in 2002[10]. it focuses on three basic principles that evoke a passion for redesigning our entire current supply chain from the ground up, and in educating young designers away from our current ‘take-make-waste’ approach. Having spent some time working with Dr. Michael Braungart at his EPEA company in Hamburg, I can attest to the difficulty of implementing these principles into our industrial and commercial world. An open architecture is needed to assure access by everyone to all these practices and learnings. As with many things in our redesign, we need to get further upstream. The farther we go up the supply pipe, the better the efficiency, the less the risk. This must be a fundamental, guiding principle within energy commons.

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[9] Eco Industrial Park Handbook, 2001
[10] Cradle to cradle 2002

Following, are some citations from renowned experts on C2C:

> A phrase invented by Walter R. Stahel in the 1970s and popularized by William McDonough and Michael Braungart in their 2002 book of the same name. This framework seeks to create production techniques that are not just efficient but are essentially waste free. In cradle to cradle production all material inputs and outputs are seen either as technical or biological nutrients. Technical nutrients can be recycled or reused with no loss of quality and biological nutrients composted or consumed. By contrast cradle to grave refers to a company taking responsibility for the disposal of goods it has produced, but not necessarily putting products' constiuent components back into service.[11]
>
> *Cradle to Cradle Design* (sometimes abbreviated to C2C or in some circles referred to as regenerative) is a biomimetic approach to the design of systems. It models human industry on nature's processes in which materials are viewed as nutrients circulating in healthy, safe metabolisms. It suggests that industry must protect and enrich ecosystems and nature's biological metabolism while also maintaining safe, productive technical metabolism for the high-quality use and circulation of organic and synthetic materials. Put simply, it is a holistic economic, industrial and social framework that seeks to create systems that are not just efficient but essentially waste free.[1] The model in its broadest sense is not limited to industrial design and manufacturing; it can be applied to many different aspects of human civilization such as urban environments, buildings, economics and social systems.[12]

Cradle-to-Cradle identifies three key design principles in the intelligence of natural systems, which can inform human design:

1. *Waste Equals Food*
2. *Use Current Solar Income*
3. *Celebrate Diversity*

Waste Equals Food. Waste does not exist in nature because the processes of each organism contribute to the health of the whole ecosystem. A fruit tree's blossoms fall to the ground and decompose into food for other living things. Bacteria and fungi feed on the organic waste of both the trees and the animals that eat its fruit, depositing nutrients in the soil in a form ready for the tree to use for growth. One organism's waste is food for another and nutrients flow indefinitely in cradle-to-cradle cycles of birth, decay and rebirth. In other words, waste equals food.

Understanding these regenerative systems allows engineers and designers to recognize that all materials can be designed as nutrients that flow through natural or designed metabolisms. While nature's nutrient cycles comprise the biological

[11] http://www.sustainabilitydictionary.com/c/cradletocradle.php

[12] http://en.wikipedia.org/wiki/Cradle_to_Cradle

metabolism, the technical metabolism is designed to mirror them; it's a closed-loop system in which valuable, high-tech synthetics and mineral resources circulate in cycles of production, use, recovery and remanufacture.

Within this cradle-to-cradle framework, designers and engineers can use scientific assessments to select safe materials and optimize products and services, creating closed-loop material flows that are inherently benign and sustaining. Materials designed as biological nutrients, such as textiles and packaging made from natural fibers, can biodegrade safely and restore soil after use. Materials designed as technical nutrients, such as carpet yarns made from synthetics that can be repeatedly depolymerized and repolymerized , are providing high quality, high-tech ingredients for generation after generation of synthetic products.

Use Current Solar Income. Living things thrive on the energy of the sun. Trees and plants manufacture food from sunlight, an elegant, effective system that uses the earth's unrivalled and continuous source of energy income. Despite recent precedent, human energy systems can be nearly as effective. Cradle-to-cradle systems-from buildings to manufacturing processes-tap into current solar income using direct solar energy collection or passive solar processes, such as daylighting, which makes effective use of natural light. Wind power-thermal flows fueled by sunlight-can also be tapped.

Celebrate Diversity. From a holistic perspective, natural systems thrive on diversity. Healthy ecosystems are complex communities of living things, each of which has developed a unique response to its surroundings that works in concert with other organisms to sustain the system. Each organism fits in its place and in each system the fittingest thrive. Needless to say, long term perspective is needed since even the introduction of an invasive species can enhance diversity for the immediate term while virtually destroying that diversity over time.

Nature's diversity provides many models for human designs. When designers celebrate diversity, they tailor designs to maximize their positive effects on the particular niche in which they will be implemented. Engineers might profit from this principle by considering the cradle-to-cradle maxim, "all sustainability is local." In other words, optimal sustainable design solutions draw information from and ultimately "fit" within local natural systems. They express an understanding of ecological relationships and enhance the local landscape where possible. They draw on local energy and material flows. They take into account both the distant effects of local actions and the local effects of distant actions. The point is this: Rather than offering the one-size-fits-all solutions of conventional engineering, designs that celebrate and support diversity and locality grow ever more effective and sustaining as they engage natural systems.[13]

With these guiding principles serving as a general framework for energy commons, it is then possible to establish measurable criteria for inclusions and exclusions of various energy sources available to each local community.

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[13] http://www.mcdonough.com/writings/c2c_design.htm

Energy Commons 10 Criteria

Here is an engineering approach to selecting appropriate local energy sources:

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1. Availability + Reliability
   Includes technology issues, local distances
   Continuity/Intermittency,
   Sustainability

2. First Cost
   Construction, investment, financing, capitalization,

3. Extraction + Delivery
   Difficulty of access to energy source, distribution and sharing

4. Conversion efficiency btu in/btu out[14]
   LCA of supply chain for energy input vs useful energy output

5. Social + Political Constraints
   Cultural regards and issues, political considerations,

6. Risk: Chemical, security
   Potential risk of toxic exposures, security risks
   External risks, risk avoidance, measurement

7. Technology
   Where on the technological innovation curve is this energy source? What are some upcoming technological innovations?

8. O+M costs
   What are the long term operations and maintenance costs?
   How often will major maintenance be required for system?

9. Carbon intensity gCO2e/MJ
   $Emission_{pollutant} = Activity * Emission\ Factor_{pollutant}$[15]

10. Power intensity
    Measure of overall energy efficiency[16]

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[14] http://en.wikipedia.org/wiki/Energy_conversion_efficiency + http://en.wikipedia.org/wiki/Energy_efficiency
[15] http://en.wikipedia.org/wiki/Emission_intensity
[16] http://en.wikipedia.org/wiki/Energy_intensity

Energy Commons Sourcing Evaluation Matrix	1. Availability + Reliability	2. First cost	3. Extraction + delivery	4. Conversion eff. btu/btu	5. Social+political constraints	6. Risk: Chemical + Security	7. Technology	8. O+M costs	9. Carbon intensity gCO2e/MJ	10. Power intensity
A. Solar PV										
B. Solar thermal=lo-temp										
C. Solar thermal=hi- temp										
D. Wind										
E. Hydro										
F. Geothermal electric gen										
G. Geothermal direct hvac										
H. Biomass										
I. Bio fuels										
J. Ocean Tides										
K. River										
L. Wood										
M. Hydrogen										
Nuclear										
Co-generation (CHP)										
Gasoline										
Diesel										
Fuel Oil #6										
Coal										
LNG										

As technological innovations and new discoveries emerge; because of the energy commons' relatively small nature and adaptability, these new technologies can be embraced quicker and cheaper than our existing global energy infrastructures.

Here is a look at the current array of emerging energy technologies.

Table 4.2 Energy R&D opportunities

Technologies	R&D	Demonstration
Transport sector		
Hybrid vehicle	yellow	
Hydrogen fuel cell vehicle	yellow	
Fuel – ethanol (cellulosic)	orange	orange
Fuel – Hydrogen	orange	orange
Industry sector		
Materials production process	orange	orange
Materials/product efficiency	yellow	orange
Feedstock substitution	orange	orange
Carbon dioxide capture and storage	orange	orange
Buildings and appliances sector		
Heating and cooling technologies	yellow	
Building energy management systems	yellow	yellow
Lighting systems	yellow	yellow
Reduce stand-by losses		yellow
Building envelope measures	yellow	yellow
Solar heating and cooling		yellow
Power generation sector		
Biomass	yellow	yellow
Geothermal	yellow	yellow
Wind (onshore and offshore)		yellow
Solar photovoltaics	orange	orange
Concentrating solar power	yellow	orange
Ocean energy	orange	orange
Advanced steam cycles (coal)		yellow
Integrated gasification combined cycle (coal)	yellow	orange
Fuel cells	orange	orange
Carbon capture and storage + Advanced steam cycle with flue-gas separation (coal)	yellow	orange
Carbon capture and storage + Advanced steam cycle with oxyfueling (coal)	orange	orange
Carbon capture and storage + Integrated gasification combined cycle (coal)	orange	orange
Carbon capture and storage + Chemical absorption flue-gas separation (natural gas)	yellow	orange
Nuclear – Generation II and III	yellow	yellow
Nuclear – Generation IV	orange	orange

(orange) indicate significant opportunities and needs.

(yellow) Indicate that the technology under scrutiny would benefit from further R&D and/or demonstration.

Source: IEA, 2006.

What will the above table look like 5, 10, 20 years from now; and how we will be able to adapt them? Which would be better at adapting these: Our current global energy infrastructure or small to medium-sized energy commons?

Energy commons analyses

Energy commons needs to explored and developed further. There are two tools that can help: System Dynamics and Energy modeling software.

System dynamics is a methodology for studying and managing complex feedback systems, such as one finds in business and other social systems. It can be very valuable to energy commons. System dynamics has been used for decades to address every sort of complex energy system.

The methodology of system dynamics is[17]:

1. identify a problem,
2. develop a dynamic hypothesis explaining the cause of the problem
3. build a computer simulation model of the system at the root of the problem,
4. test model to be certain that it reproduces behavior seen in the real world,
5. devise and test the model alternative policies that alleviate the problem, and
6. implement this solution.

Rarely is one able to proceed through these steps without reviewing and refining an earlier step. For instance, the first problem identified may be only a symptom of a still greater problem.[18]

The process of system dynamics is often heralded as yielding more value than the actual simulation model results. Process learnings always engage designers, policy makers and technologists to improve their initial designs given unintended consequences of positive and negative feedback loops. More examples of this will be provided in the presentation of this paper. Here is a typical example of the complexity and counter-intuitive nature of system dynamic analyses. [19]

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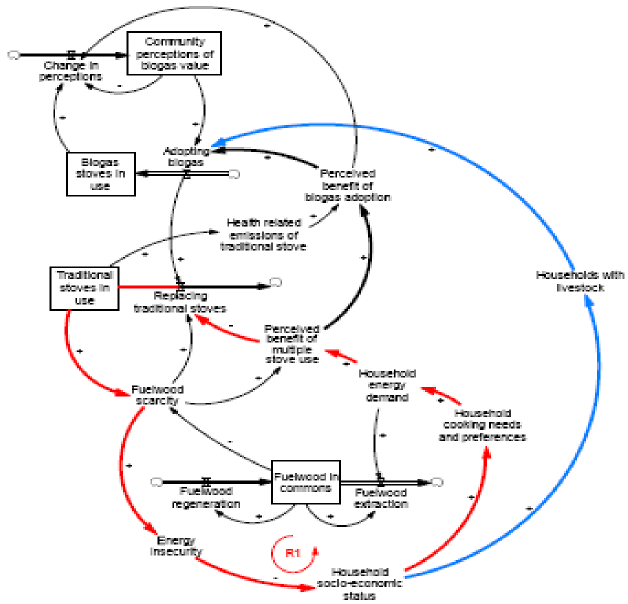
[17] ccccccccccccccccccc

[18] http://www.systemdynamics.org/what_is_system_dynamics.html

[19] http://www.systemdynamics.org/conferences/2009/proceed/papers/P1198.pdf

Figure 2: Household Biogas Adoption and Traditional Technology Replacement



Energy Modeling Software

One energy systems modeling software that is already proven in the marketplace is Polysun from VelaSolaris.[20] This software allows the designer to pre-configure and customize systems and components for any renewable energy system BEFORE installation and assess its performance at any global location.

Such simulation modeling will enable energy commons to review system options, costs and performance to better serve their residents and provide insights into various technical issues.

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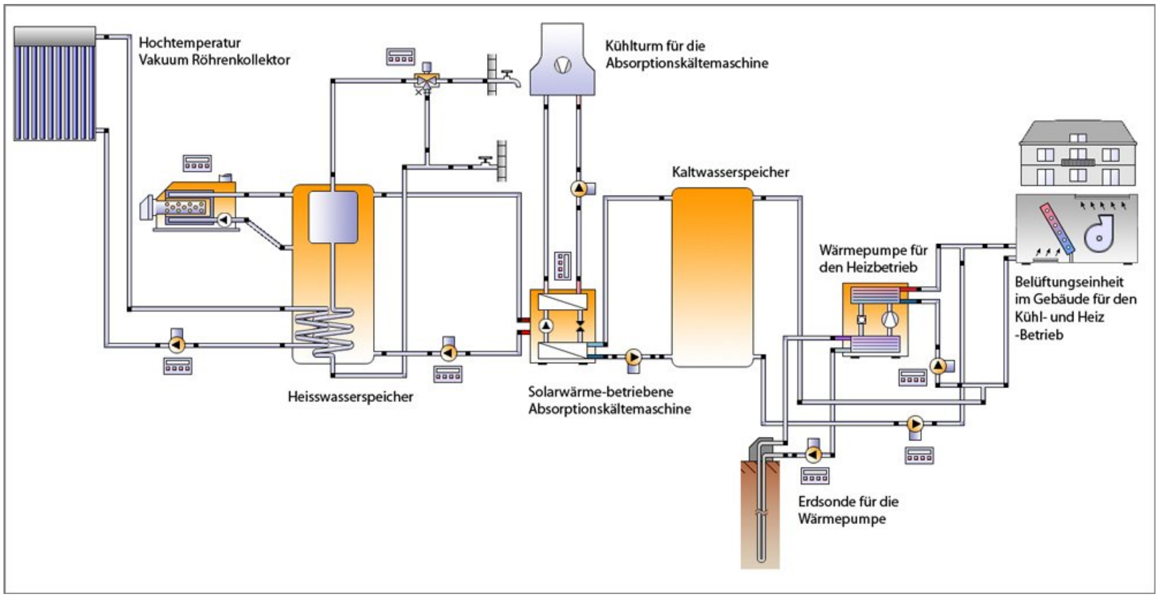
[20] http://www.polysunsoftware.com/vs2/index.php


Hochtemperatur
Vakuum Röhrenkollektor
Kühlturm für die
Absorptionskältemaschine
Kaltwasserspeicher
Wärmepumpe für
den Heizbetrieb
Belüftungseinheit
im Gebäude für den
Kühl- und Heiz
-Betrieb
Heisswasserspeicher
Solarwärme-betriebene
Absorptionskältemaschine
Erdsonde für die
Wärmepumpe