Using The Natural Step As A Framework Toward The Construction and Operation of Fully Sustainable Buildings

PART ONE: Creating a Vision of Sustainability

By the Oregon Natural Step Construction Industry Group[1]

Introduction

Interest in green building practices has existed for many years. These are ecologically oriented practices that focus on conserving energy and natural resources, protecting human health, preserving biodiversity and environmental quality while preserving or increasing a building's and site's long term value.

However, as the overall environment continues to deteriorate there is a growing awareness that "green" or environmental practices need to reach a level of environmental sustainability, a place where nature's ability to provide for the needs of both the current and future generations is not compromised.

A useful tool for determining sustainability is The Natural Step, a set of four, scientifically-based, system conditions developed by Swedish oncologist, Dr. Karl Henrik Robèrt. A construction industry task force, organized by the Oregon Natural Step Network, has been studying how to apply the Natural Step system conditions in the design, construction and operation of commercial buildings. Using a "backcasting" process delineated by Dr. Robèrt and his colleague, Professor John Holmberg (Holmberg 1998), the task force has focused on defining the attributes of a fully sustainable commercial building and then determining how to proceed from today's unsustainable building designs and practices toward creating buildings that fully meet the four Natural Step system conditions.

The process has involved the following major steps:

1. Creating a systems flow chart, or life cycle, of the major activities involved in the creation and operation of a commercial building;
2. Focusing on the construction and building-in-use portions of the flow chart and analyzing those segments for current violations of the four system conditions;
3. Next, visualizing how those two portions could be modified so that they are fully aligned with the four system conditions; and
4. Lastly, outlining the key steps that can be taken to move from today's unsustainable building practices toward ones that meet the four system conditions.

Development of all four steps will be explored in two stages. The scope of this paper is to complete the first three steps of the process outlined above. The fourth step will be

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developed in a subsequent paper. When completed, the two papers will provide a platform for members of the construction industry to use in moving toward the creation and operation of fully sustainable buildings that meet all four Natural Step system conditions. It is important to note that this effort is not intended to be prescriptive of how a building should be built and operated but instead enhance other approaches, such as the L.E.E.D. program from the U.S. Green Building Council or the Minnesota Sustainable Design Guide developed by Hennepin County, by defining a goal of full sustainability.

A major difference between this backcasting approach and other green building systems is that this effort is attempting to define a goal or end point of green design. Most other approaches to green building point the user in a direction that is environmentally better without providing a clear sense of how good things need to be. Sustainability requires that built environments must reach a certain level of “greenness” if the services of nature are to remain sufficiently viable to serve both present and future generations.

This paper is intended to provide insights for designers, builders and developers of commercial property. We chose to use the development of a commercial property because it provides a typical model with which to illustrate the concepts of sustainability. However, the issues raised and the principles suggested in this paper are applicable to all scales of development activity, from the renovation or construction of a single-family house to neighborhood and commercial district development and on to urban and regional planning.

It is not intended to be academically rigorous but to be practical and useful in its concepts. It is an attempt to define a fully sustainable state without knowing how long it might take society to achieve that state.

Lastly the task force recognized that a key implicit assumption in this process is that a property owner or developer has already decided he or she wanted to build or renovate their property. This assumption avoids answering an important question: should the property be developed or modified in the first place? An important issue in developing strategies toward sustainability is to examine the *service* that is being offered to see if there are better ways of satisfying it in non-material ways. This is an important issue that the task force decided was beyond the present scope of its work and should be addressed in more depth at a later time.

System Flow Chart

The first part of this backcasting process started with a systems analysis of the design and operation of a commercial building. This analysis examined the typical life cycle of building materials beginning with the initial extraction of natural resources onward through each stage or process where the materials are modified and transported to be used in the construction, operation and final demolition of the building. A representative flow chart is given below in Figure 1.

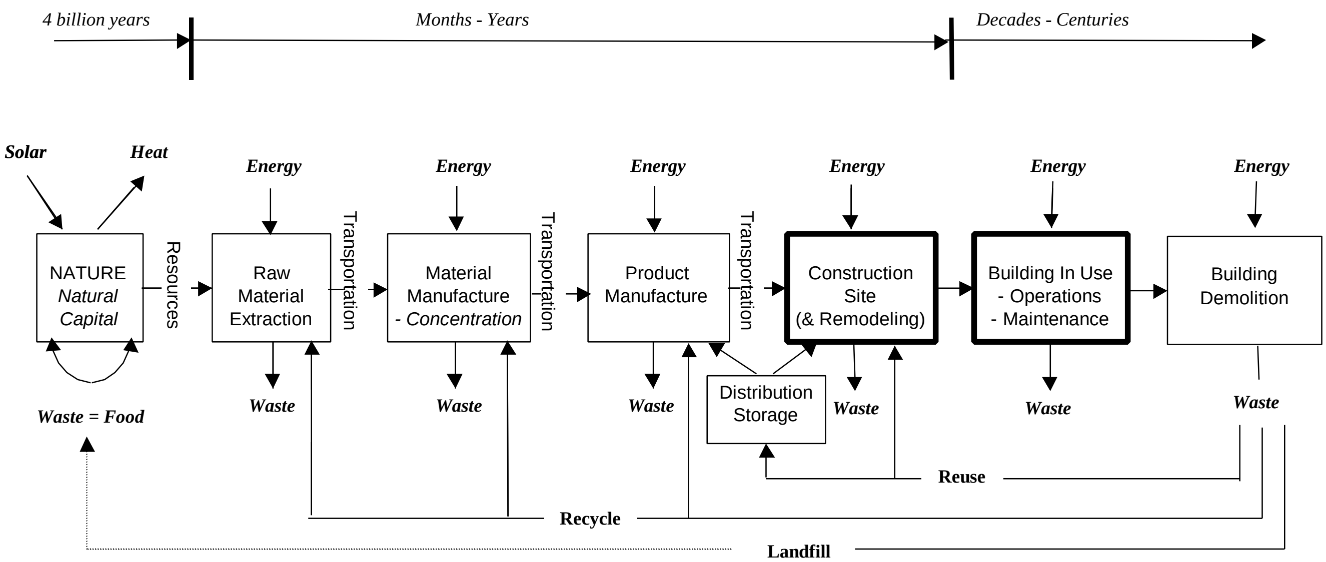

Figure 1 - Building "Life Cycle" Flow Chart

Figure 1 illustrates the flow of material and the processing required to support each stage in the life of a building. The process begins with the extraction of natural resources that feed the manufacture of raw building materials. Examples of these resources include such items as iron ore, minerals, rock, petroleum, trees and other vegetation, soil, water, etc. – anything that is used in the construction and maintenance of a building.

These materials are then processed into a form that makes them suitable for the manufacturing of a finished building component. Examples include the processing of iron ore into steel, petroleum into nylon, and trees into lumber. This refined material is next utilized to make final products such as steel into beams, nylon into carpets, lumber into molding, floors or furniture.

Finally, these products are used in the construction and operation of the completed building.

Each stage requires energy to create a higher order of product “quality,” and each stage generates waste. It is only at the first stage, the natural capital stage, that the energy input is entirely solar and the waste output is totally recycled. All other stages are human driven where the energy sources can be both solar and non-solar and the waste is either reused, recycled or sent into the air, water or ground. Although reuse and recycling can occur at every phase, this is only illustrated for the last phase in order to keep the diagram simple. The time line shown at the top of Figure 1 is to illustrate the relative length of these phases.

Natural Step System Conditions

With the growing awareness that the industrial processes illustrated in Figure 1 are causing serious degradation to the environment, there has been an attempt to redefine or redesign these processes so that they are in harmony with the environment. There have been many attempts to define what leads to sustainability. For the purposes of this project, the task force chose to use the model developed by Swedish oncologist, Karl Henrik Robèrt known as the Natural Step. The Natural Step uses basic science to define four first-order system conditions that society, or any part of it, must follow to insure a sustainable future.

These four system conditions are:

1. *In order for a society to be sustainable, nature's functions and diversity are not systematically subject to increasing concentrations of substances extracted from the earth's crust*

   In a sustainable society, human activities such as the burning of fossil fuels and the mining of metals and minerals will not occur at a rate that causes them to systematically increase in the ecosphere. There are thresholds beyond which living organisms and ecosystems are adversely affected by increases in substances from the earth's crust. Problems may include an increase in greenhouse gases leading to global climate change, contamination of surface and ground water, and metal toxicity which can cause functional disturbances in animals. In practical terms, the first condition requires society to implement comprehensive metal and mineral recycling programs and decrease economic dependence on fossil fuels.

2. *In order for a society to be sustainable, nature's functions and diversity are not systematically subject to increasing concentrations of substances produced by society*

   In a sustainable society, humans will avoid generating systematic increases in persistent substances such as DDT, PCBs, and freon. Synthetic organic compounds such as DDT and PCBs can remain in the environment for many years, bioaccumulating in the tissue of organisms, causing profound deleterious effects on predators in the upper levels of the food chain. Freon, and other ozone depleting compounds, may increase risk of cancer due to added ultraviolet radiation in the troposphere. Society needs to find ways to reduce economic dependence on persistent human-made substances.

3. *In order for a society to be sustainable, nature's functions and diversity are not systematically impoverished by over-harvesting or other forms of ecosystem manipulation*

   In a sustainable society, humans will avoid taking more from the biosphere than can be replenished by natural systems. In addition, people will avoid systematically encroaching upon nature by destroying the habitat of other species. Biodiversity, which includes the great variety of animals and plants found in nature, provides the foundation for ecosystem services which are necessary to sustain life on this planet. Society's health and prosperity depends on the enduring capacity of nature to renew itself and rebuild waste into resources.

4. *In a sustainable society resources are used fairly and efficiently in order to meet basic human needs globally.*

   Meeting the fourth system condition is a way to avoid violating the first three system conditions for sustainability. Considering the human enterprise as a whole, we need to be efficient with regard to resource use and waste generation in order to be sustainable. If one billion people lack adequate nutrition while another billion have more than they need, there is a lack of fairness with regard to meeting basic human needs. Achieving greater fairness is essential for social stability and the cooperation needed for making large-scale changes within the framework laid out by the first three conditions.

   To achieve this fourth condition, humanity must strive to improve technical and organizational efficiency around the world, and to live using fewer resources, especially in affluent areas. System condition number four implies an improved means of addressing human population growth. If the total resource throughput of the global human population continues to increase, it will be increasingly difficult to meet basic human needs as human-driven processes intended to fulfill human needs and wants are systematically degrading the collective capacity of the earth's ecosystems to meet these demands.

The above explanation comes from the Natural Step – U.S. website (www.naturalstep.org). For a greater understanding of the science behind these system conditions and the implications of following them, the reader is encouraged to read additional material. (See *References* at the end of this paper.)

Creating a sustainable set of construction and building practices as measured against the four system conditions of the Natural Step requires analyzing each stage of the process outlined in Figure 1 for system violations and then finding alternative methods that are aligned with the system conditions. Such an analysis for the whole system would be daunting to say the least. To make the task more manageable, the task force concentrated on just the Construction and Building-In-Use portions of the system diagram, analyzed their violations and then created a vision of sustainability within the limits of those two portions of the system diagram. Achieving sustainability for the complete system diagramed in Figure 1 requires that the other phases also receive a similar analysis.

System Condition Violations

Current Construction Practices

The construction of a new building involves choosing a piece of land, modifying it to accommodate a structure and then assembling various materials to form the building itself.

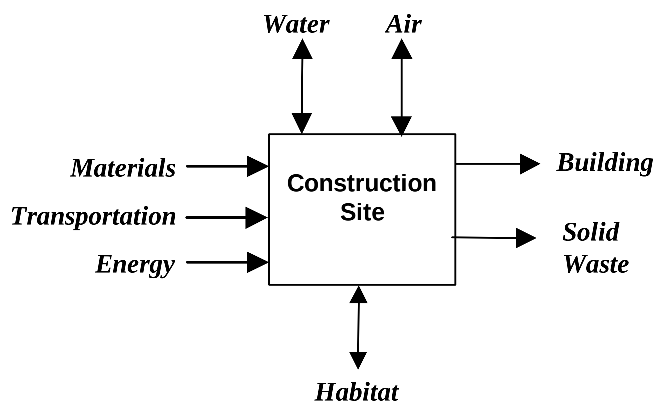

Figure 2 - Construction Flow Chart

The diagram in Figure 2 is a more detailed view of the construction portion of Figure 1. It goes beyond the material flows to show all of the major system flows in and out of the construction process.

Materials refers to the items that are brought on-site either permanently or temporarily in the construction of the building. *Transportation* refers to any form of transportation and energy used to bring people and materials to the site. It also refers to the infrastructure such as roads, rail, etc. to support those services. *Energy* refers to any energy expended on-site in the construction of the building. It does not include embodied energy that occurred off-site in the manufacture of building materials. *Water* and *Air* refer to how each of these elements is impacted by the construction process. *Habitat* refers to the impact on the land community, meaning the soils, microorganisms, plants, and animals. For example, paving over a plot of land results in a loss of nature's services such water absorption, decomposition of organic material, and photosynthesis as well as a loss of homes for plants and animals

The "backcasting" procedure involves identifying the system condition violations in this flow chart and then suggesting how to modify the construction process to eliminate all of the violations. Table 1 below examines each flow in and out of Figure 2 and identifies representative system condition violations. Although the list of violations may not be exhaustive, it is felt to be sufficiently thorough that any solutions required to eliminate them will also eliminate any other System Condition violations that might occur.

Table 1 - Construction System Condition Violations

Area	Item	Violation examples	System Condition 1	2	3	4
Materials	*Durables*	Use of less abundant, virgin mined metals & minerals (copper, chromium, titanium)	X		X	
		Use of heavy metals (mercury, lead, cadmium)	X			
		Use of persistent, synthetic materials (PVC, HCFC, formaldehyde particleboard)		X		
		Wood from rainforests and old growth timber that is harvested unsustainably.			X	
	Consumables	Use of petroleum based products (solvents, oils, plastic film)	X	X	X	X
		Excessive packaging and other disposables		X	X	X
	Solid Waste	Landfill disposal of demolition, remodel or construction scrap and packaging including toxins such as lead, asbestos	X	X	X	X
Energy	*Fossil fuels*	Oil, natural gas, propane, diesel	X			
	Electricity	Non renewable sources (Coal, gas, nuclear, diesel)	X			
		Large scale hydro			X	
Water	*Sourced from wells, rivers*	Sufficient depletion to cause habitat degradation			X	X
		Ground water disruption			X	X
		Contaminated surface water run off	X	X	X	
	Waste	Soil erosion			X	
Transportation	*Energy sources*	Fossil fuels including synthetic additives (MTBE)	X	X	X	X
	Materials	Extensive transport of non-local building material				X
	Infrastructure	Permanent habitat degradation			X	
Air	*Waste*	Use as a pollution sink for dispersion of gases & particulates including VOCs	X	X	X	
Habitat	*Site selection*	Site location & manipulation degrade the local habitat through soil erosion, wet lands destruction or species disruption.			X	X
	Non-native species	The introduction of non-native vegetation that damages native vegetation and other species.			X	

Acronym Glossary

HCFC – hydrochlorofluorocarbons
MTBE – methyl tertiary butyl ether
PVC – polyvinyl chloride
VOC – volatile organic compound

Current Building-In-Use Practices

The building-in-use phase looks at the building after it is completed and prior to its demolition. This phase is shown in Figure 3 below. It includes operation and maintenance of the building.

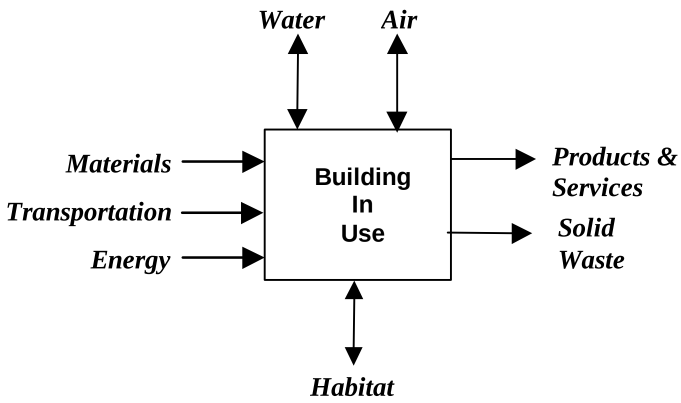

Figure 3 - Building-in-Use Flow Chart

The diagram in Figure 3 is an expanded view of the building-in-use portion of Figure 1. It shows all of the major system flows in and out of the building after it is completed and is in use. The flows in and out are virtually identical to the flows shown in Figure 2 except now the output are products and services instead of a completed building.

Again, the task force analyzed the flows in Figure 3 for system condition violations. The resulting list is provided below in Table 2. There is significant duplication between Tables 1 and 2. Those areas of Table 2 that are different are highlighted in bold.

Table 2 - Building-In-Use System Condition Violations

			System Condition			
Area	**Item**	**Violation examples**	**1**	**2**	**3**	**4**
Materials	*Durables*	**Components using less abundant, virgin mined metals and minerals (, copper, chromium, titanium)**	X		X	
		Components that use heavy metals (mercury, lead, cadmium)	X			
		Components that use persistent, synthetic materials (PVC, formaldehyde particleboard)		X		
		Furniture and appliances that use wood from rainforests or old growth timber that are harvested unsustainably			X	
	Consumables	Use of petroleum based products (solvents, oils, plastic film)	X	X	X	X
		Use of persistent, synthetic materials for cleaning and building maintenance		X		

		Excessive packaging and other disposables		X	X	X
	Solid Waste	Landfill disposal of non-biodegradable and toxic material	x	X	X	X
Energy	*Fossil fuels*	Oil, natural gas, propane, diesel	X			
	Electricity	Non renewable sources (Coal, gas, nuclear, diesel)	X			
		Large scale hydro			X	
Water	*Sourced from wells, rivers*	Sufficient depletion to cause habitat degradation			X	X
	Waste	**Off-site storm and waste water disposal**			X	X
		Use as a pollution sink for dispersion of metals, minerals and persistent, synthetic materials	X	X	X	
Transportation	*Energy sources*	Fossil fuels including synthetic additives (MTBE)	X	X	X	X
	Materials	Extensive transport of non-local operating supplies				X
	Construction Site selection	**Use of remote sites for development**			X	X
	Infrastructure	Permanent habitat degradation			X	
Air	*Waste*	Use as a pollution sink for dispersion of gases & particulates including VOCs	X	X	X	
Habitat	*Site maintenance*	**Use of toxins and persistent, synthetic materials for landscaping.**		X	X	
	Non-native species	The introduction of non-native vegetation that damages native vegetation and species.			X	

"Full Alignment" State

Designing, building and operating a structure that is sustainable as defined by The Natural Step principles means that none of the four system conditions are violated. This phase of the study is intended to look at the various system condition violations in Tables 1 and 2 and imagine what a building could be if none of these violations occurred. The group labeled this fully sustainable outcome as the "Full Alignment" state.

Although it may seem impossible to conceive of how such a Full Alignment state could be achieved, this phase is intended to only describe the end state of sustainable building practices not *how* they are achieved. When the task force was faced with choices between construction practices that might technically meet the four system conditions but were too complex to implement versus practices that were simpler to implement but went beyond the four system conditions, the group usually chose the latter. The group's feeling was that it was better to go beyond sustainability toward restoration if the approach was easier to understand and simpler to implement.

Because there is so much overlap in system condition violations in both the construction phase and building-in-use phase, the task force analyzed the same flow element for each phase at the same time. Any significant differences between the Construction Flows (Fig. 2) and Building-in-Use Flows (Fig. 3), if they occurred, are noted below.

Materials

A state of Full Alignment could be achieved if materials used in construction and in the operation of the building met the following conditions:

1. *All materials are non-persistent, non-toxic and procured either from reused, recycled, renewable, or abundant (in nature) sources.*
   a) *Reused means reused or remanufactured in the same form, such as remilled lumber, in a sustainable way.*
   b) *Recycled means the product is 100% recycled and can be recycled again in a closed loop in a sustainable way.*
   c) *Renewable means able to regenerate in the same form at a rate greater than the rate of consumption.*
   d) *Abundant means human flows are small compared to natural flows, i.e., aluminum, silica, iron,, etc.*
   e) *In addition, the extraction of renewable or abundant materials has been accomplished in a sustainable way, efficiently using renewable energy and protecting the productivity of nature and the diversity of species.*

2. *Design and use of materials in the building will meet the following in order of priority:*
   a) *Material selection and design favor deconstruction, reuse, and durability appropriate to the service life of the structure.*
   b) *Solid waste is eliminated by being as efficient as possible, or*
   c) *Where waste does occur, reuses are found for it on-site, or*
   d) *For what is left, reuses are found off-site.*
   e) *Any solid waste that can not be reused is recycled or composted.*

<u>Rationale</u>

Fully meeting System Conditions #1 and #2 means eliminating the use of less abundant metals, heavy metals and persistent synthetic substances. The reason for this is that these substances build up in nature, damaging living systems. Depending on them is not a long-term strategy for success. However it doesn’t mean one can’t use metals such as copper or chromium. It just means that use of these should come from what has already been extracted from the earth’s crust. This suggests that if a designer or builder wishes to use these materials, they must already exist in a form where they can be reused as is or remanufactured from recycled metals.

Where these materials are not suitable due to either cost or scarcity, renewable materials such as lumber can be used. However, the renewable materials are used only if they are harvested or extracted using sustainable harvesting practices such as those put forth by the Forest Stewardship Council for certifying sustainably harvested timber.

Meeting System Condition #4 requires using materials in the most efficient manner possible. Ultimately this means creating zero waste on a building project. This can be achieved if material selection and design are done in a way to preserve the quality of materials and if all material left over from construction and from demolition is put back into use by society or incorporated into nature's cycles. For example, design of the building would consider future remodeling and deconstruction, and the materials would be kept pure for future disassembly and reuse, recycling or composting.

Energy

Energy addresses the energy used in constructing the building and later to operate and maintain it. For the moment, "embodied" energy that has been expended in earlier phases of the construction flow shown in Figure 1 is not considered here as it is assumed that it will be addressed in a future analysis of the rest of the flow chart. Thus to meet a Full Alignment state for the usage of energy in the construction and operation of a building, the following conditions must be met:

1. *All energy sources used are 100% renewable and meet the four system conditions. Examples include:*
   - ? *"Fish friendly" hydro (fish flows are not systematically degraded)*
   - ? *"Bird friendly" wind (bird migration patterns are not systematically degraded)*
   - ? *Photovoltaic (without rare metals or persistent or toxic materials)*
   - ? *Geothermal (water table is not systematically degraded and toxic substances are not released.)*
2. *Wind, heat and light generated do not systematically degrade the surrounding habitat.*
3. *The total amount of energy available to each site is equal to or less than the solar energy falling on that site. If the energy needs exceed the site solar limits, the difference may be purchased from sites that have excess solar energy to sell.*

<u>Rationale</u>

Sustainability requires that essentially all energy come from renewable sources. This means the phasing out of petroleum, coal or nuclear sources of fuel. Even the use of renewable sources must meet the four system conditions. For example, to meet System Condition #3, hydro power must not be used in a way that systematically degrades fish flows or wind in a way that destroys birds or their migration. It also means that other effects such as the generation of excess wind, heat or light do not damage the habitat.

Second, System Condition #4 states that there must be "fair and efficient use of resources with respect to meeting human needs." This suggests that some type of energy budget should be used to insure that there is enough energy to support the needs of all people. One test of "fairness" is to ask the question, "Could every person function if they used the resource the same way I am using the resource?"

Determining exactly what the energy budget is that meets this fairness test is a difficult challenge. However, one way it can be accomplished for a construction and building project is to limit the amount of energy used to the equivalent amount of solar energy that falls on a building site. (For an example of how this might work compared to current typical energy use, see "*Comparison of Typical Energy Usage vs. Sustainable Solar Budget*" on page 13.)

If a site desired more energy, it could acquire it by purchasing excess renewable energy that isn't used by another site.

Although this suggestion for an energy limit may be overly conservative, it does seem to meet the requirements of System Condition #4 and feels prudent until a better guideline can be suggested.

Water

The guidelines for Full Alignment regarding the use of water are:

1. *The water budget does not exceed the water that falls on or flows through the site. If the needs exceed site water limits, the difference may be purchased from sites that have excess water to sell as long as this process has no damaging impact on the natural systems.*
2. *The quality, temperature and rate of flow of the water both on-site and leaving the site have no damaging impact on the natural systems of the watershed.*

Rationale

Like energy there is a limit to how much water a site can use and not violate System Condition #4. One way of meeting the "fairness" test is to limit water usage to the amount that is available to that site as determined by what falls or flows onto the site. Because some water flows are greatly concentrated, such as in a river that flows nearby, it could be possible for a number of sites to aggregate their needs and collectively limit their total usage to the amount of water that flows through their territory.

However, no matter how large the site is defined to be, the flow of water off the site needs to be of sufficient quality and quantity that the surrounding habitats are not systematically degraded. This seems assured if the quality and quantity of water leaving the site are equal to what comes on-site.

In order to meet System Condition #3, the use of water both on-site and flowing off-site should not systematically degrade the natural habitat. This suggests understanding what role water may plays in the existing habitat, such as a wetland, and ensuring that that role is not compromised.

Comparison of Typical Energy Usage vs. Sustainable Solar Budget

To meet the four Natural Step system conditions, this paper is proposing that the energy budget for a particular building be lim on that site. Table 3 below shows how a variety of structures might fare under a conservative use of this budget by considering the roof top of each structure.

Table 3 - Solar Budget Energy Analysis

				Portland, Oregon				Medf	
Building Type	**Total Bldg Area (SF)**	**# of Stories**	**Typical Energy Use (1)**	**Annual Solar Energy (2)**	**Converted Electrical Energy (3)**	**Typical % of Converted Solar**	**Typical % of Total Solar**	**Annual Solar Energy (2)**	**Conve Electı Energ**
			kWh	**kWh**	**kWh**			**kWh**	**kW**
Residential Home	2,000	2	17,580	131,660	12,556	140%	13%	164,870	15
General Office	100,000	4	2,498,389	3,291,503	313,911	796%	76%	4,121,760	39
Mid Rise Office	75,000	10	1,873,791	987,451	94,173	1990%	190%	1,236,528	11
High Rise Office	500,000	50	10,802,813	1,316,601	125,564	8603%	821%	1,648,704	15
Elementary School	20,000	1	253,267	2,633,202	251,128	101%	10%	3,297,408	31
Library	80,000	3	1,847,524	3,510,936	334,838	552%	53%	4,396,544	41
(4) Oberlin College	14,000	2	63,000	921,000	87,895	72%	7%	1,155,000	11

NOTES: (1) Based on Portland General Electric (PGE) and BPA data for buildings constructed after 1990

(2) Based on 1990 solar insolation data from National Renewable Energy Lab (NREL).

(3) Based on 16.5% efficient solar cells and 15% inverter losses. Solar panels cover 80% of roof area and solar cells cover 85% of

(4) High Efficiency building located outside the Portland/Medford area but is included for comparison

The columns labeled "Typical % of Converted Solar" show how the typical energy usage in each of these buildings compares on the roof of that site based on the conversion levels of current technology. Under conventional practices, the typical energy u school in Medford, would fall within the proposed budget level. However, the Oberlin College example demonstrates that des can substantially improve the ability of a building to fall within the energy budget guideline

The column labeled "Typical % of Total Solar" shows the ability of each building's current typical energy usage to fall within energy available to the roof of that site. In theory, at least, all the buildings in both locations would meet the limit except for th

The overall results of this analysis are encouraging. Other than the 10 and 50 story high rise offices, the energy needs of all stru probably be met with improved efficiencies, energy conservation and use of solar panels on other portions of the building site. meet this solar energy budget if solar panels were put on the side surfaces of the structure. It is also important to note that even not meet the energy budget guideline, it doesn't mean they should not be built. What it does mean is that they will need to purc structures that have surplus energy to sell.

Air

The requirements for achieving Full Alignment regarding the use of air are as follows:

1. *The purity of air surrounding and flowing off-site is as pure or purer than the air flowing on to the site. This means that air is not a waste sink for harmful particulates or gasses that may contain heavy metals, fossil fuel by-products, hazardous or persistent compounds.*
2. *Changes to airflow or air temperature do not systematically degrade natural systems.*

Rationale

Typically air is used as a vehicle to disperse waste gases and particulates. This can violate System Conditions #1, 2 and 3. To avoid these violations any gaseous emissions should be in harmony with the surrounding gaseous environment in terms of composition, temperature and air flow. The implication is that gaseous emissions should either have the same purity and chemical balance (O_2, CO_2, N, H_2O, etc.) as clean air, or the emissions should be eliminated all together.

Transportation

1. *Energy sources are renewable.*
2. *Existing infrastructure is used wherever possible by selecting building sites that fit within the current transportation infrastructure. If changes to the infrastructure occur, any degradation of natural systems resulting from paving land and increased driving is repaired or restored.*

Rationale

The use of non-renewable energy such as fossil fuels for transporting people and goods violates all four System Conditions and is one of the greatest sources of environmental degradation. Thus all energy used for transportation should be renewable.

Meeting System Condition #4 suggests that buildings be located to minimize transportation and, where it is needed, make use of current transportation systems. Where transportation infrastructure must be changed, any damage to the habitat needs to be compensated for. As an example, habitat destruction or disruption to accommodate a temporary road needs to be restored once the road is no longer needed. Destruction due to permanent new roads needs to be compensated for by the restoration of an equivalent natural habitat.

Habitat

Habitat refers to the living space and systems required by any species to support its existence. Since buildings always impact habitat, the goal is to not systematically degrade the services provided by nature that are necessary to sustain life. These guidelines are intended to address the siting of a building and how to compensate for the disruption in the services nature is providing:

1. *The philosophy regarding habitat is the same as that used with water and energy*

budgets, namely that the <u>net</u> degradation on the natural systems is zero. This can be accomplished by restoring enough of the same habitat within the local area to replace the natural systems that have been disrupted by the construction of the building and its site.

2. *Whatever disruption that does occur does not extend beyond the boundary of the construction-site development. This means that wetlands, soil or stream habitat downstream of the site are not disturbed.*
3. *Any vegetation used is compatible with the local natural systems.*

<u>Rationale</u>
It is virtually impossible to create a building and not change the local habitat. However, it should be possible to restore sufficient local habitat either on-site or near the site to compensate for the effects of introducing a new structure. Whatever habitat changes occur, they should not cause permanent disruption or damage to the natural services provided by that habitat beyond the building and construction site.

Conclusion

The intention of this paper is to stimulate a discussion of what a truly sustainable building would look like, both in its construction and operation phase, based on the four system conditions of The Natural Step. One conclusion that the participants drew from this exercise is that true sustainability may be more feasible than originally believed. Although it may take decades for the technology and practices to be fully developed, the task of achieving Full Alignment with The Natural Step system conditions as defined above is possible. In some cases, as demonstrated by the solar energy example, the goal may be achieved more quickly than first imagined.

The next phase of this project is to develop an implementation strategy that members of the construction industry can use to move forward from the current state of Natural Step system condition violations toward one of Full Alignment with these system conditions.

In the meantime, this project is viewed as a work in progress. Feedback, comments, or suggestions for improvement are welcome and should be sent to the paper's author:

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