PLANNING INFRASTRUCTURE TO SUSTAIN AMERICA

NEXT GENERATION CONCEPTS TO GUIDE THE COMMUNITY, DESIGN AND INFRASTRUCTURE PROFESSIONS

Task Committee on Planning for Sustainable Infrastructure

Practice, Education and Research for Sustainable Infrastructure (PERSI) Initiative of the Infrastructure Community

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EXECUTIVE SUMMARY

This report is the result of a year-long effort to identify the place of infrastructure systems in the planning of sustainable communities at local and regional scales in the United States.

It is based, in part, on a workshop of the Task Committee on Planning for Sustainable Infrastructure held on June 25, 2009 at the Headquarters of the American Society of Civil Engineers in Reston, Virginia. This report was prepared by the Practice, Education and Research for Sustainable Infrastructure (PERSI) Task Committee on Planning for Sustainable Infrastructure. The PERSI[1] initiative was created to assist organizations within the infrastructure community in addressing sustainability consistently in their infrastructure practices.

This work is prompted by alarming indicators in peer-reviewed scientific studies, such as the Nobel Prize winning report prepared by the Intergovernmental Panel on Climate Change (IPCC),[2] indicating that many of earth's ecological systems are significantly compromised. The IPCC report links the degradation of these ecological resources to a 95% probable association with human induced activities. At the same time, there is a worldwide urgent call to address international indicators such as carbon emissions and diminishing fresh water supplies. Global health indicators similarly point to increasing social inequities and decreasing public health (including rising obesity levels) that are corroborated by the U.S. Center for Disease Control. These disturbing trends are being linked to our practice of ignoring public and environmental health in the design of communities and their infrastructures.

There is a growing consensus that the prevalent and inappropriate use of indicators such as the GDP[3] are partially responsible for directing national policies and programs towards a consumption-driven approach to development that does not account for development's negative impacts on the environment and society.

In response, a burgeoning movement is emerging. Champions of alternative communities, generally referred to as Sustainable (or Green) Community Advocates, are embracing a "triple bottom line" ethic for sustainable development addressing economic growth, environmental stewardship and social progress. However, this report could not identify any institutionalized or practical working application of the concept that fully embraces a comprehensive view of progress.

This report recommends that while other professions explore the implications of the call for sustainable communities, that the infrastructure community develops a clear working definition of the role of *infrastructure* in creating sustainable communities. The infrastructure community needs to develop goals that elaborate on the definition and ensure consistent application of its principles by establishing clear performance measures.

This report shows that numerous advancements already are being made in the planning of a sustainable future for infrastructure development. While these advances perhaps are not yet directly linked to sustainable community goals, they appear to share common values. In reviewing as many of these systems as possible within the parameters of this work, five important strategies surfaced that generally describe these emerging practices in infrastructure planning:

System Preservation There is a growing emphasis on balancing investments in new infrastructure and technologies with deliberate strategies for the maintenance of existing infrastructure systems in order to defer the expense of premature rehabilitation or replacement[4] Much of this is occurring within local and regional capital improvement programs, though also influenced by funding priorities established at the federal and state levels. With new technologies, such as sensors, it is becoming easier to determine when risks are rising and when maintenance is needed[5] in order to postpone completely rebuilding systems.

Demand Management - System preservation is complemented by efforts to manage, rather than cater to, projected demand for new infrastructure as a way to delay capital investment into new or expanded facilities. Many strategies, including consumer education, information technology, integrated land use and transportation planning, increased system efficiencies, and new technologies (such as communications, or the SMART Grid) are maximizing the use of existing systems while deferring the need for new facilities.

Preserve and Use Natural Infrastructure - There is a growing recognition that natural systems can provide many of the infrastructure needs of communities, such as storing fresh water, absorbing storm water, controlling flooding, leveling daily temperature cycles, refreshing air and storing carbon dioxide, providing food and energy and more. These systems, which include wildlife, marine life and native plants, are collectively referred to as "*Natural Infrastructure*." Scientific research and data is emerging about the important role played by natural infrastructure in maintaining human habitat. This information needs to be consistently integrated into the training and education programs as well as the handbooks and other manuals that inform the planning and design of manmade infrastructure. There is also emerging interest in new man-made systems to replenish (recharge aquifers with well-treated waste water) and restore (wetlands and forests) degraded natural infrastructure.

Advanced and Integrated Systems, Technologies and Practices - New technologies are emerging in the market at an accelerating rate. Performance measures can assess the contributions of new technologies to sustainable communities. More efforts are also being made to integrate traditionally disparate technologies and specialties for additional benefits. Transportation planning increasingly is relying on communications and information technology to manage congestion; energy planning is venturing to integrate wastewater treatment and traditional power generation with the delivery of thermal heating and cooling; and waste management programs are generating energy. Another instance is in the use of model-based, simulation-based design tools for sustainable design and constructability analysis in building information modeling (BIM) processes supported by Integrated Project Delivery (IPD) and Project Alliancing approaches. These are reducing risk, liability and project costs while improving project delivery timelines.

Multiple Financing Sources and Mechanisms - Innovations in financing are emerging, but they are leading to challenges that will need to be addressed. The federal government finances facilities of national interest, such as interstate highways, passenger rail, and major dams. At the local and regional levels, states vary in their policies for recouping costs for infrastructure financing. Strategies range from financing infrastructure capital and operations entirely through community based user fees to a beneficiary-based system that is paid for by the direct users of the system. Green building technologies are adding new challenges to these financing methodologies. While property owners appreciate that new technologies allow them to be fairly self-sufficient, recouping costs for community wide infrastructure operations, upgrades and expansion is becoming a challenge. This is compounded when these properties still connect to community utilities, though only for backup power and water for emergency fire fighting, for instance, thereby not paying their fair share of the utilities' capital costs through routine user fees.

This report concludes that while new ways of thinking will be necessary in infrastructure planning for the 21st Century, much work is already underway that can be built upon to facilitate this transition. It will be necessary for the infrastructure community to converge and lead this discussion.

Chapter 1. Introduction

Growth in human population and economic development strain the world's finite resources such as land, water, materials, food, and energy. To maintain, and in some cases, improve our quality of life, we need to develop sustainably – such that our development meets our needs for natural resources, industrial products, energy, food, transportation, shelter, and waste management; conserves environmental quality (indoor and outdoor); and reduces growing social and economic inequities. By developing sustainably, we can be assured that we will preserve essential natural, economic and social resources for the sustenance of future generations.

Community planning is now embracing the concepts of sustainable development. In March 2010, at Rio De Janeiro, the American Planning Association (APA)[6] announced its Sustaining Places Initiative. A key element is the newly formed Sustaining Places Task Force, which will focus on the role of the comprehensive plan as the leading policy document and tool to help communities of all sizes achieve sustainability.

However, also intrinsic to sustainable development is the planning, design, construction, operation, maintenance and disposal of its infrastructure. This presents an opportunity for the infrastructure community to not only better understand how it can support sustainable communities, but to also look into its own practices and technologies for greater sustainable performance and outcomes.

This study presumes that "*infrastructure*" refers to constructed facilities that shelter and support human activities. However, while this report does not delve into the subject in detail, it also acknowledges the value of natural infrastructure - features and ecologies that are integral to the sustenance of human beings and their habitat. In recognition of natural infrastructure, a new category of infrastructure is emerging, called *green infrastructure that* is being designed to minimize the facility's impact on the environment.

Sustainable infrastructure builds on this philosophy in acknowledgement of infrastructure's role in the economy. For the United States, estimates are that it will take about $2.2 trillion to upgrade the current infrastructure to satisfactory levels[7]. Access to quality infrastructure and affordability are important determinants of a community's long-term well-being.

Therefore, sustainable infrastructure is not only a reflection of a community's long-term resilience, but also a testament to its values across the sectors of social, economic and environmental well-being.

The importance of infrastructure that embodies the principles of sustainability is recognized at all levels of governance, research and investment. From the Asian Development Bank, the National Research Council, and the National Science Foundation to the City of Portland, there are committees on Sustainable Infrastructure.

This report focuses on planning for sustainable infrastructure systems at the community and regional scales. It is a review of prevalent and emerging practices in infrastructure planning and sets forth a set of recommendations for integrating sustainability principles more consistently into infrastructure planning. The infrastructure systems addressed in the report include transportation, energy, communications, waste, sewage and water. Chapter 2 develops the conceptual framework of the report. Chapter 3 considers needs for improved practices, research and education for the infrastructure systems and Chapter 4 presents the report's recommendations.

Prepared by PERSI's Task Committee on Planning for Sustainable Infrastructure, this report is based, in part, on a workshop held in June 2009, at the Headquarters of the American Society of Civil Engineers in Reston, Virginia. The Practice, Education and Research for Sustainable Infrastructure (PERSI[8]) initiative was created to assist organizations within the infrastructure community in addressing sustainability consistently in their practices.

CHAPTER 2. CONCEPTUAL FRAMEWORK

This chapter explores the concept of sustainable communities and the integration of infrastructure that helps sustain these communities. Lastly, it briefly discusses roles and tools that the infrastructure community could employ to promote the concept of sustainable infrastructure within their professions.

DEFINING SUSTAINABLE DEVELOPMENT

In 1987, the Brundtland Commission called for sustainable development,[9] i.e. development that "meets the needs of the present without compromising the ability of future generations to meet their own needs." Since then, there have been many attempts to lend further definition and clarity to this call for action. In *"The Sustainability Revolution,"* author Andres R. Edwards refers to the major 39 initiatives, including the CERES Principles, Ecological Footprint, Natural Step, The Earth Charter and so on, that were intended to define sustainability. He finds that common to most of these efforts are the principles of stewardship of biological integrity, respect for natural limits, nature as a model for the built environment, interdependence of all systems, economic restructuring, social justice and equity and maintaining an intergenerational perspective.

However, the most oft-used definition of sustainability is that it considers economic, environmental and societal needs – the triple bottom line. While this guiding principle provides little direction in terms of an authentic use of this form of measure, it establishes that sustainability promotes the integration of values across professions and disciplines.

Sustainable development, referring primarily to the built environment, is evidently measurable, and in response to growing concerns about extreme climate situations, must be resilient and regenerative. In an effort to further clarify its definition, there is a growing interest in establishing measurable thresholds for performance, called sustainable development indicators. In recent years, traditional measures of merely physical parameters have been expanded to include the emotional health and fortitude of residents. The World Happiness Index is one such measure.[10]

ROLE OF COMMUNITY PLANNING

Planning is the fundamental "best practice" for achieving sustainability;[11] planning is the methodology society uses to look into the future collectively and mold it to society's will.[12]

The core concept behind planning is "comprehensiveness." It is an integrative concept and a holistic view of project planning. Planning defines the community desired, and then determines what infrastructure systems it will need to support desired settlement patterns. The "Comprehensive Plan" (or General Plan) coordinates the infrastructure systems with land use to maximize the combined benefits of all systems. It is generally well accepted that each community should have the roads, transit services, water and wastewater systems, parks and recreation facilities, schools and other public buildings, and electric, gas, and telecommunications services it needs to thrive economically, environmentally and socially.[13]

The planning process was laid out in its modern form early in the 20th Century. It links an up-front public policy making process to a wide variety of follow-on implementation processes. However, the underlying premise of planning has evolved from a focus on community building to a complicated exercise of balancing many interests and often-competing priorities. Real estate and infrastructure are viewed more as critical components of the economic system. However, this fundamental motivation for community building led to aggressive economic development that heavily compromised social factors and environmental interests. In the 21st Century, there is growing recognition of the negative impacts this mode of planning has had on social equity and the environment.[14]

Changes in planning practice tend to come in large portions. In the 1930s, the concepts of land use zoning, building setbacks, and public housing were established to reduce the rapid spread of diseases that were rampant in urban tenement housing. These initiatives were followed by urban renewal programs in the 1950s. During the late 1960s, major new programs were enacted for water pollution control, air quality improvement, wetlands protection, and broad-scale environmental impact analysis of a wide range of federal and federally assisted physical development projects (as well as major initiatives in some of the leading states).[15] One of the most significant steps forward came in 1991 when the new federal surface transportation bill (ISTEA) passed with provisions to effectively link highway and transit planning to the Air Quality Act of 1990. The main innovation was that air quality standards became a strong driving force for designing and approving federally assisted transportation improvements in metropolitan areas where federal air quality standards were not being met — areas labeled as "non-attainment." In those areas, land-use/transportation plans, encompassing both highway and transit systems, had to pass tests for their ability to move the area toward "attainment" of air quality standards. This requirement essentially merged the comprehensive metropolitan transportation/land-use planning process with the regional air quality planning process and moderated the "highway-only" thinking in these plans. Metropolitan transportation plans are much more multi-modal today as a result.

Emerging Practices for Planning Sustainable Communities

Current efforts follow the examples of the public health crisis of the early 1900s and the environmental protection concerns of the 1970s through 1990s. The areas for greatest innovation presently are environmental sustainability and public health. This might be characterized as the "green and healthy revolution" in planning human settlements. Elements include green buildings both new and retrofit,[16] and green sites through Sustainable Sites[17] initiatives, green infrastructure, the Healthy Kids Healthy Communities Initiative and emerging greenhouse gas reduction efforts. Professionals and policy makers are working on all of these initiatives.

While the field of sustainable community indicators is steadily gaining traction, it is largely occurring outside the planning profession.[18] However, there are more instances where improved criteria for measuring and comparing sustainability considerations are being incorporated into current planning practices.[19] New standards and design criteria are emerging and are expected to be embedded within comprehensive planning approaches for communities and infrastructure, and within plan-implementation tools.

For example, the next generation of model planning and zoning legislation for the United States was developed with federal assistance,[20] and further developed into a comprehensive land development code that ties many different planning implementation tools together into a more effectively coordinated and flexible tool.[21] A variety of "smart growth" studies and codes also have been produced to assist those states that are taking that approach to achieving more compact and environmentally friendly development.[22]

Now, the sustainability movement is taking the next step to merge "light-on-the-land" planning considerations into the 1990s land-use/transportation/pollution control mix. The definition of "comprehensive" planning is broadening once again.[23] Limitations on greenhouse gas emissions will affect transportation and land-use plans and building construction and retrofit. There are new and evolving standards for green buildings (which minimize demands on external water and power supplies, and reduce polluted urban runoff):[24] green sites (which help to retain and treat water pollution on site and reduce urban temperatures);[25] designing streets to include walking and biking standards (embodied in the Complete Streets philosophy); districts that are not reliant on cars (included in Transit Oriented Development principles); and reducing the pollution in our cities' air, land and water. These all contribute to neighborhoods less susceptible to chronic and vector diseases.

As early as 2000, the APA adopted a Policy Guide for Sustainable Development. The Guide points to US indicators of un-sustainability, such as suburban sprawl, loss of agricultural land and open space, depletion and degradation of water resources, loss of wetlands, traffic congestion and air pollution, disproportionate exposure to environmental hazards and segregation/unequal opportunity. Along with its other Policy Guides on Smart Growth, Climate Change, Energy and Transportation, APA is recognizing and leading its membership towards developing less sprawl and low-density communities, and more walk-able, energy efficient, low carbon and sustainable communities. Other organizations, including the US Green Building Council, the International Council for Local Environmental Initiatives (ICLEI), and the Green Highways Partnership also are promoting and supporting sustainable development.

That sustainable development is emerging at the forefront of APA's agenda is indicated by its Sustaining Places Initiative, which was announced in March 2010. A key element is the newly formed Sustaining Places Task Force, which will focus on the role of the comprehensive plan as the leading policy document and tool to help communities of all sizes achieve sustainability.

Planning communities deliberately for sustainability sets the stage for sustainable infrastructure. In that regard, density, non-motorized travel, and district level utility generation are among the many factors that influence the sustainability of the community's infrastructure. Tied to this are approaches such as transit orientated development and context sensitive design for areas that require transportation solutions but in a much less environmentally impactful way than in the past, and with a more holistic sustainable view of the community.

Each infrastructure system discussed in Chapter 4 has inadvertently contributed in some way to our compromised air, water and land resources. Encouragingly, champions are conscientiously exploring new technologies or attempting to improve existing technologies for lower environmental and social impacts, and greater affordability.

Planning Infrastructure for Sustainable Communities

In the creation of sustainable communities, the obvious way to think about sustainable infrastructure is that which considers providing and maintaining the physical infrastructure (public works and utilities) to enable the community to function properly and reliably for the foreseeable future. This view focuses on the infrastructure systems themselves, and it involves the adequacy of these systems to: (1) serve a growing population (2) meet identified public service needs, (3) remain in satisfactory working order, and (4) be supported by continuing and reliable financial resources.

However, emerging views consider a broader, outlook on infrastructure systems and their role in supporting communities that lie lightly on the land—so that the land (and related air, materials and water resources) retains the capability to accommodate human habitation, support natural habitats and ecosystems, and mitigate and adapt to changing climate conditions. This is more frequently being referred to as *Green Infrastructure*.

Just as planning programs and practices have not kept up with changing economic, environmental or societal demands, or with rapidly advancing technical capabilities, and need to be revisited, the nation's infrastructure systems are not being maintained and advanced to meet needs for economic, societal and environmental sustainability.

Supporting the Economy

Infrastructure is an economic development activity. It provides jobs and supports manufacturing, retail and service industries. In itself, the planning, design, construction, operation and maintenance of infrastructure (including buildings) normally is about 1/8 of the GDP.[26]

One of the best-known examples of using infrastructure investments to stimulate the U.S. economy is President Franklin Roosevelt's New Deal program in the 1930s.[27]

In 1988, the National Council on Public Works Improvement established a national report card on the adequacy of U.S. infrastructure systems.[28] ASCE has since issued updated report cards[29] and the average grade has gone down from a C to a D. Needed and recommended increases in infrastructure investments routinely have lost out to higher spending priorities, especially at the national level, in recent years. The federal Highway Trust Fund, for example, is now widely acknowledged to be inadequate to support the nation's federal-aid highway and transit programs.[30]

Years of underestimating and inadequately planning for the costs of new or upgraded infrastructure has created situations like the following:

- Transportation congestion is rising.
- The number of bridges, dams, and levies that are at risk of collapse or functionally deficient is increasing.
- Ensuring just-in-time delivery of freight is getting harder.
- Many water and sewer pipes fail or leak, which is coupled with areas lacking adequate clean water volumes.
- Many streams, rivers, lakes and beaches are polluted and the official list of "impaired waters" is getting longer.
- The national electric power grid is not keeping pace with growing demands and fragility is increasing.

Social Equity and Health

Even prosperous communities now find their quality of life degraded by inadequate infrastructure. But less wealthy communities have fared even worse.

Until the latter part of the 20th century, U.S. community building and economic development tended to focus on suburban development and amplified the social and economic inequities in U.S. communities. Infrastructure planning practices contributed to this situation through siting decisions[31] that disproportionately affected the poor. The poor typically live in areas that have low land values and are most vulnerable to natural disasters and infrastructure failures,[32] such as on floodplains, close to power plants and near landfills. Many infrastructure siting decisions disproportionately dislocated lower-income homes and de-stabilized lower-income communities, which often did not recover from these impacts. Based primarily on a least-cost imperative, where a limited measure of cost was used that focused only on direct project expenses, developers paid only for the cost of land, neglecting the costs of social and physical rehabilitation. The poor were unable to participate in and benefit from community and infrastructure investments since they typically lacked the access and training needed to compete for the jobs that were being relocated into their communities.

There are innumerable examples where infrastructure planning's focus on a least cost imperative unfairly affected the poor. Many lower income communities also are deprived of access to alternative transport systems, such as transit and bicycle paths/trails, and their comparatively inexpensive access to jobs and housing.[33]

Infrastructure financing also often disproportionately affects the lower income population. The use of infrastructure by those economically disadvantaged, whether it is roads, electricity, etc., is comparatively at a much lower per capita rate than that of more affluent neighborhoods of a community.[34] For instance if a region is taxed for the construction of a light rail system, but the poorer neighborhoods do not have access to the system, then they are disproportionately affected since they are expending a larger portion of their income to pay taxes for a system that they may never use.

Living closer to some infrastructure systems such as highways, power plants and landfills also affects the poor. Being proximate to these facilities exposes them to pollutants in contaminated water and air, as well as noise and odors. Infrastructure in good condition and equitably located provides social benefits to all.

Environmental Sustainability

The Earth's land, water, material and air resources are being polluted by human habitation faster than their natural abilities to regenerate.[35] The result is a massive loss of benefits that natural landscape provides:

- Fish and wildlife habitats as abundant sources of food.
- Clean water bodies that offer abundant municipal, industrial, and agricultural water supplies, as well as healthy habitats for fish, wildlife and recreational benefits.
- Raw materials that offer fuel, paper/lumber products, and construction aggregate materials.
- Clean air that people can breathe without endangering their health.

Among the contributing factors are (1) urbanization that produces pollution from sewage and rapid, unfiltered runoff of pollutants from impervious surfaces, (2) agriculture, animal husbandry and unmanaged or unregulated forest harvesting that clears too much land, creates runoff polluted with excessive nutrients and sediments, and emits noxious vapors that foul the air, and (3) inefficient combustion of fuels to supply power and run vehicles at the expense of dangerously polluting and warming the earth. These "heavy" human footprints on nature are affecting the planet, with potentially tragic consequences. The sustainability of both human habitats and natural habitats are directly linked. One cannot survive without the other. Planning for sustainable infrastructure must contribute to the sustainable balance between human and natural habitats.

The green infrastructure movement is attempting to do just that. While the current focus is primarily on stormwater management and quality of run-off, there are opportunities in every aspect of infrastructure planning to limit the impact of development on the natural environment.

Natural Infrastructure

A still more recent formulation of these themes is Mark A. Benedict and Edward T. McMahon, *Green Infrastructure: Linking Landscapes and Communities*, prepared under the auspices of The Conservation Fund (Washington, DC: Island Press, 2006). The authors emphasize the need to consider the many environmental benefits provided by nature itself, benefits that could be but often are not protected. Not to be confused with Green Infrastructure described earlier, this natural infrastructure controls urban runoff without building sewers, protects against storm surges, retains clean water, recharges natural aquifers and controls flood damage, among many other beneficial functions.[36]

As they are lost through insensitive human development projects, people must construct man-made replacements for them at great cost—just to reclaim carelessly lost benefits. So, the literature returns to the classic principle — "design with nature" rather than against it.

Implementation of Plans

Planning for sustainable communities and their infrastructure must consider implementation. It is usually easier to prepare plans than to implement them. While implementation tools, including….. are available, they are difficult to use. Although plans are developed within our system of government to ensure public health, safety and the common welfare, they cost money to implement, often create winners and losers, and tend to limit individual freedoms in order to secure benefits for the many. A delicate balance must be achieved when implementing plans to ensure fairness and sensitivity to the diverse interests embodied within society and the differential impacts that may be experienced by different stakeholders. These compromises are reached through political processes in which many stakeholders vie with each other for relative advantages.

Because of these complexities, implementation practices are the stage of governance where the greatest deficiencies could occur in achieving both sustainable infrastructure systems and sustainable human settlements. Sound plans often are not fully implemented because adequate funding is not available, the regulatory powers authorized are inadequate, and/or policymakers are not willing to use their powers when needed in particular circumstances.

The three basic legislative powers of government—regulating, spending, and eminent domain—have been crafted into specific tools designed to implement comprehensive community plans. Implementation is generally carried out by the executive branch of government, which is charged with "execution of the laws." If the laws do not adequately authorize the powers needed to implement adopted plans, implementation will be incomplete.

- **Regulatory powers** have taken such forms as zoning, subdivision control, building codes, erosion control ordinances, wetland protection permits, air and water pollution control regulations, and required buffers between land and water.
- **Spending power** (which includes raising revenue through taxes, charging fees, and borrowing) pays for necessary and desirable land acquisition, construction, operation, and maintenance of infrastructure systems and services.
- **Eminent domain power** gives governmental bodies authority to purchase needed land for infrastructure even when the owner does not wish to sell. The public must pay a fair, market-based price — as determined either by free-market negotiations or in a judicial proceeding.

Additional implementation tools are being developed continually under each of these powers as public policies create new goals and new program objectives. For example, the greenhouse gas emission controls being developed now may be regulatory, perhaps combined with a spending-power cap-and-trade market mechanism. This might make multiple means of compliance available, potentially involving transportation infrastructure, green buildings, electric utilities, and more.

No single type of infrastructure is likely to be tasked with the whole compliance responsibility. Multiple means of compliance will become the norm for reaching sustainability performance goals—particularly when a broad array of problems contributes to the condition the plan is designed to address. Compliance has already followed that pattern for air quality control, and is becoming like that in non-point source water pollution control.

Conversely, each type of infrastructure may be tasked with portions of the compliance responsibility for several sustainability goals. For example, transportation will have responsibilities for helping to meet goals for air quality, greenhouse gas, water pollution, wetlands preservation and replacement, and wildlife protection.

Therefore, creating sustainable communities may be difficult using traditional form of governance. Delivery of public utilities, services and land use planning may have to be transformed to allow for shared goals across departments, political boundaries and levels of administration.

Roles of Government Agencies

Sustainability goals are regional, national, and global. They cannot be compartmentalized to just one or a few communities or organizations. Sustainability results accumulating from coordinated actions that add up to large, resilient, high impact systems. A small component may be essential to the overall result, but the goals cannot be achieved by outstanding efforts of a few. Only cumulative results produced by many different organizations can provide progress at the scale needed to make a significant difference in sustaining large regions, nations, and the planet.[37]

The implementation agents for sustainable community plans and sustainable infrastructure will be multiple governments, multiple agencies within each government, multiple private sector organizations, and multiple sectors of the population—all of whom will need to take appropriate actions to achieve the broad-based "outcome" results specified in public policy plans.

Federal Government

Many elements of the nation's infrastructure are funded by the federal government. These include portions of the electrical grid, the national highway system, AMTRAK, and large-scale Army Corps of Engineers and Department of the Interior projects related to national dams, waterways, and levees.

There are many instances in which federal policies have encouraged sustainable development. Some of these policies and legislation include:

- ISTEA/SAFTEA
- 2009 Energy Development Block Grants
- National Parks
- Clean Water Act
- Air Quality Act

However, a systematic and deliberate effort to create sustainable communities at the federal level is difficult since funding is often provided in silos lacking flexibility to fit regional, state and local needs. To counter this, in 2010, the US Department of Transportation, Housing and Urban Development and the Environmental Protection Agency announced a new collaborative partnership to jointly administer grants in order to promote the development of sustainable communities.

Regional and Local Governance

Federal initiatives notwithstanding, most infrastructure planning occurs at the regional, state or local levels. These governmental levels also produce legislation and regulations that supplement federal regulations for water and air quality. They also interface with and approve the planning of private utilities that provide infrastructure systems and services. This planning generally follows the comprehensive planning process discussed above. To achieve integration of infrastructure, it is important to hold land use planning/community visioning exercises at an early stage of the process.

Implementation programs can be expected to become a highly dispersed and networked activity held together by commonly accepted performance measures. Network governance and network management are becoming best practices themselves, and a considerable body of literature is developing around both topics.[38] One of the most important forums for successful networking, when it is based on performance metrics, is high-speed information technology. While it is a relatively new form of public infrastructure that is receiving increased attention and public support, if efforts continue to improve it and make it universally available, it can reliably provide real-time data accumulated from many diverse sources to support real-time public policy making and real-time management decision making.[39]

Performance Measures

With modern technologies making real time data available, it can be collected and monitored to provide important feedback on the use and condition of an infrastructure system. The desire for sustainable infrastructure can most likely be achieved only if measured, monitored, and acted upon.

In 1995, the National Research Council, along with other institutions such as the Academy of Sciences, sponsored research on "*Measuring and Improving Infrastructure Performance*."[40] The final report states that infrastructure performance cannot be managed if not measured and that there is a need for continuous data collection. The authors clarify that for them, "Performance is not the same as engineering 'need' or the economist's concept of 'demand', but rather represents an intersection of demand and supply, need, and capability, that can be established only within the context of community interests and priorities." The report discusses how performance measures can be included in the project assessment process: project objectives are defined, specific measures listed, and conflicts reconciled.

The report acknowledges that while it is important to include project stakeholders to develop a system of performance measures for each project, the objective of the report was to develop common measures for comparability across projects and geographic locations.

The authors observe that while performance measurement is important, prevalent practices are inadequate. The measures are grouped into three broad categories: effectiveness, reliability and cost. But the report falls short of fully embracing sustainability since aspects of environmental stewardship and sensitivity to long-term project impacts are not included. It also acknowledges another oversight by recommending that quantitative measures need to be developed for the qualitative aspects of performance.

New and practical performance measures are needed to demonstrate the extent to which sustainability objectives would be achieved by proposed or adopted plans. Performance measures provide the common language that allows many different organizations to contribute to achievement of the common goals. Continuing research is needed to develop these performance measures. Appendix 2 presents quantitative environmental indicators and qualitative performance objectives that could be used to develop the needed performance measures for sustainable infrastructure.

Financing Infrastructure Systems

To sustain infrastructure systems, stronger, more reliably financed "asset management" programs will be needed to prevent the deterioration and risks of failure now being seen in many places. Such programs are accepted best practices,[41] but frequently are not used effectively to prioritize and target limited funds. Resources should be used to minimize the risk of failures with the most serious consequences, and should support the most cost-effective improvements (which often are routine maintenance to preclude needs for more costly rehabilitation or replacement).

Transitioning existing and new infrastructure systems to support greener communities will require different policies and financing arrangements. For example, incentives will be required for denser, more transit-oriented development patterns over typical suburban sprawl patterns.[42] Greener drainage and pollution treatment facilities may need to be used instead of traditional piped systems. Larger expanses of wetlands may be used in place of rivers for wastewater treatment plant effluents. Alternative energy sources may become more common compared to coal-fired and gas-fed generators, and new transmission lines may link new types of environmentally friendly generators into the grid. The list of needed transitions is long and it will affect every type of infrastructure. Key to success will be incentives that favor new ways of thinking and approaches that are more in line with forward thinking approaches organized around sustainable infrastructure planning. These transitions will be neither quick nor smooth.

Without doubt, new technologies most often entail greater upfront costs. However, sustainability takes a long term and broader view of "costs." New tools such as lifecycle analysis offer a more holistic view of project costs. This new measurement tool provides the data needed to make infrastructure planning more sustainable, socially responsible, resource prudent and economically viable long-term.

For example, buried utilities generally are beneficial environmentally and less vulnerable to natural, accidental and willful hazards. Higher initial costs are mitigated by reduced maintenance costs. Common rights-of-way and utility chases or tunnels ease maintenance and expansions, and reduce disruptions such as digging up new pavements to maintain or enlarge communications, energy or water systems.

Chapter 3. Infrastructure Systems

This section discusses current practice, gaps in current practice, approaches for implementing best practices, research, and education for planning the integration of the principal infrastructure systems: communications, energy, transportation, water (including potable, waste and storm waters), and waste. Planning may be at community, urban or regional scales.

Land Uses

At the fundamental level, land use planning sets the stage for the amount of natural environment to be preserved, protected, impacted or permanently changed. The types of uses and the densities at which communities are laid out are important determinants of the type and cost of infrastructure that will be required. While extremely low densities are an imperative for the productivity of resource and agricultural land; modestly higher densities (to about four dwelling units per acre) are costly since they often entail high costs of infrastructure and community services per capita.

Presently, despite stringent programs (such as Environmental Impact Assessments) and federal regulations, noxious land use activities continue to pollute US and the world's waters (sea, fresh and underground) and air. The time is ripe for communities to explore development patterns that, like the Living Building Challenge,[43] survive mostly off of regional resources, and treat their effluents and waste regionally, before releasing them into natural bodies. These communities must continue to strive to establish healthy, equitable and integrated communities.

Distributed systems for physical infrastructure (wireless communications, energy, water, waste, and transportation); and social infrastructures (employment, commerce, education, recreation and housing) can reduce environmental and economic costs of access to services and vulnerabilities to natural, accidental and willful damage. Smart growth reallocates distributed physical and social infrastructure to provide benefits that reach the maximum number of people.

Transportation

Transportation systems seek to deliver several different outcomes, using several different modes of movement that are integrated so that the modes work together to mutually support common outcomes. It is helpful to begin with a few words of definition about these three interrelated concepts.

Transportation systems are responsible for moving both people and goods — effectively, efficiently, and sustainably. Here is what these three characteristics of movement mean:

- Effectively means that (1) personal mobility and safety are well served, (2) goods are moved in a timely and reliable way sufficient to meet just-in-time delivery requirements, (3) economic development needs are met sufficiently to provide for needed growth in the economy, and (4) the needs of the people for social, cultural, and recreational interactions are satisfied.
- Efficiently means that transportation infrastructure and services to serve the needs for personal mobility and goods movement are affordable to the service providers and the users, and the life-cycle costs are optimized to keep them as low as possible over the long term.
- Sustainably means that air quality, water quality, and wetlands footprints of the transportation facilities and services are as small as possible, the put-in-place infrastructure of these systems is resiliently designed for long term use, the financing arrangements are reliable over

the long term, and the services provided are socially equitable — that is, they provide needed levels of service to persons of limited means and persons with special needs as well as to the majority of users.[44]

The infrastructure and services required — and those best suited to moving people and goods in varying circumstances — are provided by the following modes:

- Highways, streets, roads, and bridges
- Cycling and pedestrian facilities
- Scheduled transit, demand-responsive transit, taxis, shuttles, water taxis, and ferries
- Passenger railroads: commuter rail, regular long-distance rail, high-speed rail
- Freight rail
- Trucking
- Waterways: inland, inter-coastal, and marine highways
- Water ports
- Airports: scheduled passenger services, charters, air taxis, private aviation, air freight, rapid delivery services
- Pipelines
- Inter-modal terminals

The purpose of integrating these transportation modes is to "optimize" the transportation services and benefits that each mode is best suited to provide. Optimizing means to balance the roles of each mode within the transportation system to take best advantage of what each has to offer. Some modes have cost advantages in certain situations. Other modes use less fuel and have smaller environmental footprints.

This integration takes place distinctively at each level of government. For example:

- Local planning agencies do the planning for transit-oriented development (TOD), which integrates transit, jobs and housing with walking and cycling to reduce automobile travel.[45] These agencies also may build into the local master plan smart-growth principles,[46] the "complete streets" concept,[47] and systems of cycling and walking trails.[48]
- Metropolitan Planning Organizations (MPOs) work at a larger intergovernmental scale that crosses municipal, county, and other local boundaries to link up freeway, major transit, and railroad systems, and to connect them to the area's ports, airports, and intermodal terminals. They also perform air-quality conformity planning to meet federal regulatory requirements on a whole-airshed basis.[49] In approximately 40 cases, MPOs also cross state lines.
- State DOTs link metropolitan areas to each other and make connections to adjoining states.
- Multi-state Transportation Corridor Coalitions work with groups of states, truckers, airlines, intercity buses, Amtrak, and private railroads to provide long-distance travel to the corridor's citizens and long-distance goods movement services to the corridor's businesses.[50]

Prevalent Practices

The U.S. transportation system is the responsibility of a large number of governments and private companies, which often act independently. The mechanisms provided to coordinate them are fairly weak. Brief descriptions of these players' responsibilities and practices follow.

- **Local government planning authorities** generally are the only organizations that hold the power to zone land for various uses and densities, approve land subdivisions for development (including reserving rights-of-way for streets, highways, and utilities), issue permits to regulate sediment control and the use of septic tanks, and to require hook-ups to public water and sewer utilities. These and similar local functions are absolutely essential to developing serviceable and sustainable transportation systems. These organizations are also at the front-line of environmental protection efforts when transportation systems are being built and operated. They generally have close relationships with impacted or potentially impacted neighborhoods, and can provide local citizen input to the planning process more effectively than larger, further-distanced governments.

- **Local public works agencies**—including departments of local government, separate transit agencies and other special districts and authorities, and local government social services agencies that provide special-needs transportation services to needy and other disadvantaged or aged persons—build transportation infrastructure and provide transportation services. These agencies are direct service providers.
- **Regional organizations that span multiple local government** jurisdictions also play very important roles in developing, maintaining, and improving transportation systems. They include the federally required MPO's whose responsibilities include planning and integrating (primarily) federally assisted highway and transit systems and projects, programming the federal funds for new projects, certifying compliance with federal air quality regulations, and more. Metropolitan air quality boards often work closely with the MPOs on transportation conformity plans. Outside the metropolitan areas, Regional Planning Organizations (RPOs) are being used for similar transportation planning purposes in a growing number of states. Area wide Agencies on the Aging (AAAs) provide social services transportation to the elderly using federal funding from DHHS. In a significant number of cases, the MPOs, RPOs, and AAAs are part of the general purpose regional councils or councils of governments in the area. These general purpose councils have advantages in coordinating transportation programs with a wider range of public works and other public services than a separate transportation-only MPO would. For example, a general purpose regional council may have ties with watershed associations and others having responsibilities for wetlands and other natural resources areas that MPOs may need to coordinate with to avoid damaging water and related land resources and important wildlife habitats.
- **State agencies** having transportation and related environmental responsibilities are extremely important to planning and providing transportation facilities and services. Leading the way are the state DOTs and any specialized state transportation agencies such as a turnpike, bridge, port, or airport authority, or a commuter rail authority. Some states have several such agencies. In addition, several states have state planning or state smart growth agencies, and they all have environmental protection and natural resources or conservation agencies. All of these state agencies have important roles in sustaining sound transportation systems. At a different level of activity, the state legislature is also very important in providing the local governments with adequate planning, zoning, smart growth, and environmental protection powers of the types mentioned above. Without strong authority of these types, local governments cannot do their part to provide sustainable transportation facilities and services.
- **Multi-state transportation corridor coalitions** are relatively new organizations that began to spring up—for the most part—in the 1990s in response to new federal transportation legislation and the NAFTA free trade treaties with Mexico and Canada. Freight and trade issues

(linked to economic development) dominate the attention of most of them, but some focus on high-speed rail. Many of these coalitions are now evolving into multi-modal organizations. New federal legislative acts in 2008 and 2009 have focused urgent attention on high-speed rail. Furthermore, the corridor approach has been reinforced by release of the "mega-regions" report; more officially titled *America 2050* by the New York based Regional Plan Association. It identified 11 major groups of metropolitan areas across the nation where most of the nation's economic and population growth is occurring and is expected to continue occurring. Most of the 20 or so transportation corridor coalitions are within these mega-regions. Coordinated infrastructure systems within these mega-regions obviously would be a major plus, but these regions do not yet have institutions capable of facilitating such systems.

- **The federal government** also provides several organizations with capabilities that could contribute to improving the nation's transportation systems beyond their current vital contributions that focus on making grants to state DOTs, MPOs, and local transit agencies. Amtrak provides nationwide passenger rail service, and has taken some steps toward providing high-speed rail—first with the Metroliner in the Northeast Corridor, and more recently with the somewhat higher speed Acela train serving the same corridor. Nevertheless, these trains attain speeds well below the high-speed trains in Japan and Europe. The rest of the nation's high-speed trains remain on the drawing boards, not yet providing a more fuel-efficient alternative to short-distance airplane trips. Until April 15, 2009, the Federal Railroad Administration had no plan for high-speed rail. The new plan issued then identified an initial set of ten high-speed passenger rail corridors eligible for new stimulus money to get this initiative started. Federal freight corridor planning and research is housed in the Federal Highway Administration. Inland and inter-coastal waterways and ports are the responsibility of the U.S. Army Corps of Engineers. Maritime programs are under the jurisdiction of the Federal Maritime Administration. DOT's environmental and energy footprints require coordination with the U.S. EPA and Department of Energy. Environmental Impact Statements, of course, are required for most projects involving federal funding, and that process is under the jurisdiction of the President's Council on Environmental Quality. And, the new Administration has ordered DOT to coordinate more closely with HUD and EPA—especially with respect to urban and metropolitan policy and the initiatives of the new White House office of urban policy. Most of these new initiatives remain to be assembled.

This partial listing of key organizations responsible for the nation's transportation system provides a general idea of now many complex relationships are involved. Digging deeper into them would reveal wide disparities among the practices and capabilities of local governments, MPOs, state DOTs, and other players. Most of the current transportation organizations are not up to the integrated sustainability tasks that have been set before them.

Sustainability Challenges

There are five key gaps between the nation's current capabilities for sustainable transportation systems and the needed capabilities:

- <u>Intermodal integration</u>. Most of the funding for transportation programs is stove-piped into single modes, with very little flexibility to shift funds back and forth according to differing local or regional needs. Additionally, the main organizations charged with integrating the separate modes — the MPOs and Corridor Coalitions — are not fully developed. Some federal support for them has been provided, but much more will be required if they are to become effective.

- Federal transportation funding. Two national commissions established by Congress have reported serious deficiencies over the consistency of funding.
- Environmental regulations. Work is beginning to cut emissions of greenhouse gases and to develop the clean energy alternatives needed to support environmentally sustainable transportation systems; these require much time to become common practices.
- Rail systems and multi-state corridors**.** Federal leadership over the past three decades has been limited. The new high-speed rail plan issued in April 2009 may provide a new beginning for federal leadership more in keeping with past traditions.
- Performance management. Although the federal government has been striving toward performance management since 1993 when Congress passed the *Government Performance and Results Act* (GPRA), and some state and local governments began such work even earlier, not enough progress has been made yet to provide a reliable set of adopted indicators, goals for future results, and intergovernmental recognized performance measures that could enable summarizing local and state results into timely annual reports on progress toward achieving sustainable transportation nationwide. Such a management process, although vitally important, remains elusive today.

Future Practices

Future practices in the transportation community should close these five gaps in capability. New and improved capabilities should be made more uniform or consistent from the local to the national levels of government, and should involve the private sector more closely. Work is proceeding on all these fronts, but at too slow a pace and with too little unifying national leadership. It should be accelerated, with an eye toward addressing:

- Service deficiencies
- Efficiency and financial deficiencies
- Environmental sustainability deficiencies
- Informational and educational deficiencies
- Design to construction workflow inefficiencies

In these domains, improved demand and capacity modeling should to be coupled with actual measurement and real-time reporting that is adequate to support fact-based management decisions designed to improve results. Better design to construction visualization and simulation workflows will help reduce inefficiency and recover some of the 15-20% of overall projects costs tied to change orders, rework and mistake mitigation. With improved planning, design and construction processes coupled with sensors and controls, highway transportation can achieve integrated vehicle-highway systems, similar to those for rail and air transportation, maximize investment dollars, optimize traffic control signals in real time, and provide automatic vehicle control for safety as well as guidance to drivers. Performance and budget integration, which has been a goal in the federal government for the past several years, should be further emphasized. A series of threshold performance measures/indicators should be adopted for use at every level of government, along the lines of those suggested below.

Threshold Performance Indicators

A wide variety of performance indicators has been evolving in the transportation and environmental sustainability fields for some time, but many have not yet been standardized or widely adopted.

Sources of such indicators include DOT, the Transportation Research Board, various federal regulations (especially in regulatory fields such as safety and environmental protection), AASHTO, the International Standards Organization (ISO), the Government Accounting Standards Board (GASB), and others. The indicators that follow are illustrative of the areas of greatest interest for developing a list of "the vital few." However, they should not be taken as definitive in any sense.

Service Measures

- Mobility/Accessibility (mode choice: the extent to which "best" choices are available to most people, and are used as intended to help reduce environmental footprints)
- Trip reliability (incident management success is part of this)
- Congestion relief (trip lengths, delays, and elapsed time)

Efficiency Measures

- Costs per trip
- Remaining service life of facilities and equipment (involves deferred maintenance measures, on the theory that it is cheaper to maintain than to rebuild or replace. Statistical models are available to help calculate this realistically.)
- Investment gaps (planned investments not made on schedule, thereby delaying the realization of benefits and probably increasing liabilities for higher future costs)

Environmental Performance

- Median Vehicle miles traveled per unit energy consumed (reducing them will help to reduce environmental footprints)
- Average fuel mileage (increasing it will help to reduce environmental footprints)
- Air quality non-attainment days per year
- Particulate pollution violations per year
- Carbon footprint
- Wetlands impacts
- Amount of land developed (total and per person)
- Average size of contiguous land areas not cut through by major transportation or infrastructure
- Amount of *impervious surface* in-place (total and per person)
- Stormwater runoff vs recycled volumes
- Wildlife habitat/ species impacts (and conditions)

Workflow Efficiencies

- Number of change orders
- Number of RFI's (requests for information)
- RFI turnaround times
- Percentage of project costs resulting from rework
- Cost overrun or under runs
- Schedule reduction

Energy

Energy infrastructure at community, urban and regional scales provides (principally) electrical and thermal energy. Sources of energy include: biomass, coal, natural gas, geothermal, hydro, nuclear, petroleum, solar, and wind. Modern civilization relies upon adequate, economical, healthy, safe and reliable energy. These, with the addition of aesthetics, are the socially sustainable requirements for energy infrastructure.

Energy is needed to power all other forms of infrastructure including buildings, communications, transportation, water and waste. Manufacturing, mining, commerce, education, health care, governance, police and fire protection, and homes all require energy to power their processes.

Energy infrastructure includes:

- Central Generators: Central electrical energy or combined heat and power generation such as: hydro-electric dams and electrical power generation through the use of fossil fuel, biomass, geothermal energy, nuclear fusion, solar thermal and photovoltaic's and wind turbines.

- Distributed Generators: Onsite combined heat and power systems, solar photovoltaic and thermal energy, and geothermal energy.
- Transmission Infrastructure: Transmission and distribution systems to transmit electrical power, fuels and thermal energy to their points of use. Pipelines for gas and liquid fuels are treated here as energy infrastructure rather than transportation infrastructure.
- Storage Facilities: Energy storage infrastructure to address differences in amounts and times of energy supplies and demands. This is becoming particularly relevant to time-varying wind and solar energy supply and electrical storage capacities for Plug-In-Hybrid and Electrical Vehicles. As natural gas is imported by sea, the siting of gas storage facilities is becoming an issue for port and river communities
- Waste Disposal Infrastructure: Sites and processes to address waste fuel from nuclear plants, fly ash from coal plants, and mercury and lead from solar panels and compact florescent lights are becoming an important consideration in the design of energy infrastructure.
- Embodied Energy: Embodied energy denotes the energy used in creating the infrastructure including the materials used, their transportation to the point of use, and their placement during construction. For instance, a tunnel may seem to use relatively little material compared to an alternative bridge, but much energy is consumed in excavating the tunnel and transporting the excavated materials. Embodied energy can be reduced by using materials more efficiently, and using renewable materials (where service lives are adequate), recycled materials, and reusing materials that otherwise would be land filled or hazardous. Standard practices are available for use of recycled materials and their improvement is an important research need.

Delivering Energy – Current Practices

Although fossil fuels have, since the 19th century, dominated US domestic energy consumption, their share has fallen since 1950, with the balance made up by increasing amounts of renewable and nuclear energy. The 1992 Energy Policy Act allowed markets to develop across state boundaries, opened the playing field to utilities across the country, and allowed customers the freedom to choose their energy sources, including green energy from non-carbon sources.

In the United States, energy can be delivered under a variety of ownership arrangements, For petroleum, most providers are privately held. For stationary energy providers, ownership includes Investor-Owned, Municipal, Public Utility District, Cooperative and Power-Marketer. Each of these ownership arrangements offers varying levels of flexibility and profit motivations. The national grid is owned by a number of different generator operators and transmission owners. Of these, the independent system operator or regional transmission organizations (ISOs and RTOs) play an important role by monitoring and operating the grid system; and preparing contingency plans in case of emergencies. A challenge to policies that facilitate a free-flow of energy throughout the national grid system is the inability of local grid owners to recover their full costs of investment and cost of repair.

Energy delivery in the United States remains largely demand-driven with the exception of a few states that require new development to pay for the extension of energy infrastructure (such as Washington State). Within a demand-supply model, utilities provide electricity wherever it is required, and the cost of the new infrastructure is shared by all customers served by the utility. This subsidizes the extension of utilities to remote locations. These utilities do not differentiate between capital and operating costs. Therefore, the hard cost of utility extension is wrapped into the fees for energy use. This financing model provides little incentive to reduce energy use since increased use covers the capital investments (reducing demand becomes imperative when capital facilities reach their projected capacities. By reducing use, utilities are able to postpone building new facilities by many years).

Since the 19th century the decentralized energy system that was once prevalent throughout the country (coal and wood-stove based) has become increasingly centralized. A centralized system results in greater losses from transmission and distribution of energy. The Energy Information Administration estimates[51] that for 2005 end use electrical energy was approximately 44% of the fuel energy consumed in its generation.

SUSTAINABILITY CHALLENGES

Energy infrastructure is planned to have these qualities:

- *Reliability*: Providing energy when and where it is required for quality of life, economic activity and safety.
- *Efficiency*: Maximizing the useful energy from a given amount of resource.
- *Economy*: Providing energy at an affordable cost.

These qualities have influenced the choice of energy sources. Since environmental concerns have not been equally prioritized, some of the major concerns regarding energy delivery is its impacts on the environment: lead and mercury contamination from coal combustion; carbon emissions from fossil fuel burning; pollution in rivers runoff from mines; toxic pollution from nuclear waste; the list goes on.

ENVIRONMENTAL MISCOUNTING

Typically, the cost of energy does not account for the cost of restoring the environment from which the fuel is extracted; nor does it include the cost of eliminating the pollution generated from burning the fuel. This has distorted the pricing and therefore the preferential selection of one technology over another.

Integrating the value of the environment into energy planning will ensure that the most sustainable energy choice will be the most economical. This will significantly change fuel choices, technology preference and the overall planning structure for communities and infrastructure.

Perhaps, at some future date, requirements for environmental and social sustainability will be reflected accurately in energy prices. For some time, however, sustainability will be addressed by a complex and inaccurate system of prices, subsidies and regulations guiding selection among planning options for energy infrastructure.

Other concerns relate to the dependence on non-renewable fuels. Concerns about safety, cost and waste disposal have stopped the growth of nuclear technology in the United States. However its freedom from green house gas emissions is bringing it new attention, while concerns about unprecedented drought and water unavailability brought about by climate change make its long term feasibility questionable. Similar concerns are being raised about hydropower.

DEPENDENCE ON IMPORTS

Another concern is the energy portfolio's dependence on imported fuels: crude oil, and natural gas, being the largest. This has a number of impacts such as dependence on unstable geographic locations across the world, loss of U.S. dollars to other economies, as well as environmental vulnerabilities created during the transport of these toxic resources. While some amount of trade will always occur in the energy sector, it is currently heavily dependant on imports.

WASTE

As discussed earlier, waste is clearly becoming a driver in energy policy. Whether it is heat recovery programs to utilize wasted heat or reusing fly ash from coal plants in cinder blocks, efforts are underway and should be encouraged to address waste in energy planning. Dealing with technological hazardous waste from newer technologies is a recent problem that includes the safe disposal programs of Compact Fluorescent bulbs and solar tubing. Disposal and clean up of nuclear waste remains an issue and will definitely have to be addressed should there be a renewed interest in the technology to address climate change.

System Preservation

For the energy sector, as early infrastructure items are deteriorating, efforts are underway to increase their design life. This is evident in the aging national grid, early dams, and nuclear and coal plants. As technologies age, there are greater chances that they will pollute more. Yet, the cost to completely replace these structures is prohibitive.

Passive Energy

Reducing energy during design was how traditional societies dealt with nature's vagaries. Passive energy systems employ natural features to reduce or eliminate demands for artificial generation and distribution of energy. At building, community and larger scales, uses of natural vegetation and green or reflective roofs and pavements reduce summer temperatures and needs for artificial cooling. At the scale of sites and buildings, siting orientation and building design can provide for natural ventilation, lighting, shading and useful solar heating. Pre-industrial age practices for buildings and communities often provide insights into passive design concepts effective for specific locations. Integration of these principles at the code and permit level can play a very important role in managing the increasing demand for building energy use in the United States.

Emerging Practices

There have always been pioneers in the energy industry. It is only recently however, that some of these pioneering technologies are gaining traction in the market place. The main trends are discussed below.

Energy Efficiency

Leading authorities now consider increased energy efficiency to be the largest and most economical source of energy for both the developed and developing nations. Energy efficiency programs are aimed at reducing the demand for energy through improved efficiencies at the level of the end user.

Planning practices for energy infrastructure should address energy efficiency directly in the life cycles of the energy infrastructure systems, and, to even greater effect, enable energy efficiency in other infrastructure systems and in end uses.[52] Examples of enablement through planning include making windy sites available for wind power generation, making ground water available for heat sourcing and storage, orienting buildings to exploit desired and to avoid undesired solar irradiation, and permitting reflective and green roofs among many others.

CAFÉ standards (Corporate Average Fuel Economy) for vehicular fuel efficiency have had significant effects on energy efficiency, but have been offset by increases in vehicular size and miles driven. Programs such as the Energy Star, LEED and Built Green have helped increase the energy efficiency of buildings.

Energy Conservation

Another approach to reducing the demand for energy is Energy Conservation. Energy conservation, in contrast to energy efficiency, involves changes in the behavior and life styles of energy users. Planning may enable or require energy conservation. For example, sensors and current price information enable a business or home to shift energy use to more economical hours, while automatic load shedding reduces air conditioning during peak hours of energy demand.

Alternative technologies and education can support energy conservation without perception of loss of quality of life. Examples are improved natural ventilation and lighting as alternatives to artificial heating, air-conditioning and lighting. Conservation programs and incentives can greatly reduce the demand for additional energy. For instance, by providing incentives to homeowners to improve their homes' insulation can offset the need for additional generation capacity. At the Federal level programs such as LIHEAP (Low Income Home Energy Assistance Program) provides assistance to low-income families to improve their homes' insulation. Another simple technique for changing behavior is through energy use disclosure programs. These include professional audits of buildings' energy performance and required disclosure of energy use at the time of sale of a property, or on an annual basis as now required by the City of Seattle.

Alternative Technologies

Beyond generation, there are low-carbon initiatives in other aspects of energy distribution and use. These include:

- Electrical and hybrid electric vehicles and lighting with more efficient compact fluorescent and light emitting diodes.
- Energy storage systems can operate on regional, urban, community and single building scales.
- Where topography, land use, water supply and off-peak energy costs are appropriate, water can be pumped to an elevated reservoir when energy is inexpensive, and energy regained through hydro-electric generation when needed.
- Annual cycle energy storage can be obtained where ground water is available at nearly uniform annual temperature by efficiently pumping heat from the ground water in the heating season, and efficiently transferring unwanted heat to the ground water during the air-conditioning season.
- Daily cycle energy storage is available for space conditioning and hot and chilled water for individual buildings or complexes of buildings using water and phase change materials (such as ice).
- A useful transfer without energy storage is to capture heat rejected in cooling of parts of a building or other facility and use it for hot water and space heating in other parts of the same or a neighboring facility.

Concerted public and private international efforts to provide high performance and economical batteries for electric vehicles are anticipated to provide important energy storage capabilities for buildings and communities. Electrical power systems can charge vehicles' batteries when power is available and economical, and can draw upon these same batteries for load leveling or emergency electrical power.

Smart end use systems, such as energy management and control systems for buildings, interface with smart grid systems to obtain most economical (time of use) or desired (e.g. renewable) electric power. These can load level using their own generation (solar, wind, heat cells, or diesel) or energy storage systems (batteries, flywheels, etc.). Smart systems also can control fire protection, emergency power, heating, ventilating, air conditioning, and water use.

Carbon capture and sequestration (CCS) extracts CO2 and other greenhouse gases from combustion exhaust and either provides long term storage for the gases (sequestration) or delivers them to other uses (such as carbonated beverages). Planning may provide facilities and sites for sequestration, such as safe burial deep in the earth, or green spaces for absorption of GHGs through growth of vegetation (for ultimate use as foods and renewable building materials and fuels). CCS presently is at the demonstration phase for central electrical power plants but is likely in time to become cost effective at smaller scales such as CHP systems.

Distributed Generation

A trend popular in Europe and gaining traction in the US is decentralized energy generation. The boundary between central and decentralized energy systems is hard to define. For our purposes, a decentralized energy system is one for which energy is transformed or generated and used within the planning area, while a central energy system has its sources external to the planning area.

While distributed generation is most evident in thermal electrical, photovoltaic and wind systems, there also are small generators along a river or ocean's edge. These systems include micro-dams, wave and tidal technologies. These systems are being integrated with central power systems through the smart grid system, which controls and distributes electrical power as appropriate. It provides for load leveling and load shedding in the event of excessive demands, failures of generation or distribution, or problems in the national electrical grid. Smart grids have also helped in the advancement of net metering programs that allow smaller generation units to be connected to the larger grid and for homeowners to get credit in their energy bills for their net onsite generation. Smart grids also are applicable to distribution of gas, liquid fuels and thermal energy (steam or hot water).

Combined power and heat (CPH) systems use the heat wasted in traditional power plants or waste water treatment plants for steam and hot water use in space conditioning and industrial processes. Since electrical power generation typically uses only one-third of the energy in the fuel, great increases in energy efficiency and GHG reductions are obtained with CPH systems.

Financial Incentives and Regulatory Requirements

Public policies such as financial incentives and regulatory requirements address marketplace failures to provide for sustainable communities and infrastructure. Financial incentives include subsidies and tax breaks for selecting renewable energy sources or making investments for energy efficiencies. Regulatory requirements include mandated uses of renewable energy and recycled materials. Design and implementation of such incentives and regulations is becoming an important aspect of planning for sustainable communities and infrastructure.

An important element of promoting alternative technologies has been instituting a variety of financing programs. These have ranged from community wide or individual level Green Power purchasing programs that subsidize the cost of providing alternative energy operations and construction. Net metering programs allow individual owners to get credit for the net electrical energy generated on their site.

Potential Indicators

In measuring energy use during the planning stage of an infrastructure project, it is important that the goals intended for the performance and utilization of energy are clear. While there is clearly a preference to "green" energy sources away from carbon based fuels and to lower GHG emissions, there is growing awareness of the need to lower overall energy use and reduce dependence on imported fuels. While there could be a predilection to measure outcome performance of a system, more dramatic changes can be expected if efforts focused on system performance indicators. Like other infrastructure systems, however, final energy use is largely dependant on user behavior and cannot always be fully accounted for in system design or maintenance.

Systems Indicators

- Ratio of end use energy from local generators to energy produced outside the region
- Percentage of total energy use from imported fuels or energy sources
- Tons of GHG emitted for total energy use (including generation and distribution)
- Total energy consumed (including the energy to extract, transport, store, maintain, dispose waste etc) to produce an unit of electricity for different technologies (solar, wind, coal, nuclear) for each region

Outcome Indicators

- Total energy use by sector
- Wealth accrued locally through onsite energy generation
- GHG emitted per unit energy generated
- Percentage of energy lost (from generation to end use)
- Waste generated (tons) per unit energy generated

Water

Water is an increasingly scarce and precious resource. In many areas around the globe, water tables are falling – the victim of excessive pumping and overuse, even as demand continues to double every 21 years. As more than 70 percent of all water use is for irrigation of vegetation, landscaping, and crops, attempts to limit water consumption can lead to limits on food production, particularly in countries with high poverty levels. Such limits can result in higher food prices, an increase in imports, and even political instability. The problem is a thorny one. The United Nations Intergovernmental Panel on Climate Change found that as many as 2 billion people won't have sufficient access to clean water by 2050. That figure is expected to rise to 3.2 billion by 2080. At the beginning of this decade, the World Health Organization estimated that 1.1 billion people did not have sufficient access to potable water.

Water design

Since engineers design much of the infrastructure that stores, treats and conveys water, they have an opportunity to mitigate some of these problems. By designing systems that minimize the overall use of water (and wasted water due to leakage), engineers can greatly reduce the costs and risks associated with water and wastewater. In their new, more sustainable designs, they balance costs and choices to encourage using recycled water for off-site irrigation, minimizing contaminants in wastewater and investigating the feasibility of capturing, recycling, and reusing water onsite. So while water is critical, it is part of a system and applying more sustainable approaches to sewer designs and storm water management methods will in fact reduce general water demand and contribute to more water savings than water conservation alone can accomplish. Goals and guidelines that help to establish a zero water footprint in infrastructure design, in the same way that architects focus on zero carbon footprints in buildings, will be a key concept for engineers for sustainable design approaches.

Wastewater

America's aging wastewater system is another source of tremendous opportunity for engineers.[53] Sewage, also called blackwater, is a complex mixture of contaminants containing pathogens, toxic chemicals, heavy metals, debris, nutrients, nitrates and phosphates. It is wastewater from both domestic and industrial sources –and anything else that is flushed down a toilet or gets poured down a drain in our cities and towns.

Today's urban standard of practice has existed for at least a century, most homes are connected via laterals to the sewer mains, whereby effluent travels through a system of pipes to be collected at an industrial treatment plant of varying type and size. It is then treated with chemical and mechanical processes to remove contaminants and separate sludge from liquid. The treated liquid is discharged into the nearest large body of water or reused, and the sludge is incinerated or partially used in agriculture as a controlled fertilizer. The cost of maintenance of the pipes, lift/pump stations and associated networks is expensive with most repairs and replacements done on an ad-hoc or emergency repair basis. This has resulted in most of these pipes being upwards of 30-50 to sometimes 100 yrs old, and in some cases, with design capacity exceeded well before its planned end of life cycle.

According to analysis by the Environmental Protection Agency (EPA), since 2003 hundreds of municipal sewer authorities have been fined for a wide variety of violations, including some with serious environmental consequences. To improve this situation, local governments across the USA plan to spend billions modernizing failing sewer systems over the next 10 to 20 years. While some upgrading has taken place, it has not kept up with the pace of urbanization now facing our cities nor is the planned infrastructure spending and stimulus money going to allow it to keep pace.

More emphasis must be placed on alternative disposal methods to supplement and augment traditional systems in both new developments, or in retrofitting existing infrastructure. These new methods should minimize the need for extensive piping requirements of existing systems and leverage more natural, local capture and treatment options.

WASTEWATER DESIGN

The traditional wastewater disposal system, which is still the standard of practice today, conveys sewage from urban areas to nearby natural wetlands after collection and treatment. Today, however, engineers are helping to develop systems that do much more beyond discharging treated waste into a stream, river or larger water body. By using modeling and analysis software tools, engineers are developing and establishing more efficient and higher-capacity constructed wetland systems that leverage the natural ecosystems which have the capacity and tendency to purify water and recycle nutrients. Design depends on location, climate, and population, but passing wastewater through a managed or constructed environment such as engineered wetland that contains a diversity of plant and animal organisms transforms the wastewater in very clean if not pure water.

Engineers need to look for opportunities to treat and reuse wastewater in a sustainable manner that recognizes the need of the community and the restrictions of the location and climate. Constructed wetlands are one option for a more sustainable design that utilize a variety of locally occurring aquatic plants (reeds/cattails, rushes, lilies &water hyacinths, duckweed etc) to break down toxic chemicals, nitrates and phosphates etc and also allow for the bio-accumulation of the heavy metals in their stems and leaves. Two examples of such systems are constructed reed beds and solar aquatic systems. These systems employ plants that not only clean the water but also provide an oxygenated environment in which fish and aquatic invertebrates along with bacteria, fungi, snails and more can thrive and also contribute to the water purification process. With other possible sustainable developments such as using harvested algae for bio-fuel production, there are many possible synergies down the road.

These systems are good examples of sustainable design for engineers to look toward going forward. Far from the norm, they need to be discussed and included in planning for future development and urban revitalization projects. They are energy-efficient, inexpensive, effective and environmentally friendly, and can be applied at any scale, from a single home to a large city. They can contribute to certification of sustainable development.

This approach is only one path towards leveraging sewage's potential as a resource; others include looking at it for heat generation, fuel recovery or CH4. Sewage contains nutrients that can be used to improve soil fertility, or to produce natural gas. Bio-gas plants can use sewage as an energy and nutrient source. Wastewater must be viewed as a valuable resource and systems planned and designed for urban development with that in mind. This is part of the cradle to cradle view of water use.

STORM WATER

In traditional storm water management, drains capture runoff from buildings and impervious surfaces into extensive networks of pipes or open channels directing runoff away from sites and into natural water courses. This has created problems of flash flooding, erosion, and contamination of water courses. Sustainable storm water management uses detention and retention areas for removing pollutants, replenishing ground water and assuring that post-development runoff does exceed the pre-development amounts.

Urban drainage systems are vital infrastructure assets, which protect our towns and cities from flooding and the transmission of waterborne diseases. The network of buried pipelines is often unseen and neglected. Many urban systems have not kept pace with their increased demands resulting from development nor provided the maintenance and repairs needed to keep the systems fully functional and safe.

Combined systems for both wastewater and storm water runoff were developed from the middle years of the 19th century. They convey both types of water to treatment plants and then into adjacent watercourses. However during intense rainfalls, the capacity of treatment plants is exceeded and untreated waters are released into and contaminate the receiving watercourses. What was once thought a good idea for saving money, materials and effort must now be corrected to achieve clean water goals.

Stormwater Systems Design

Modern thinking in urban hydrology is to work with and leverage nature rather than fighting against it. Low-tech solutions cost less to design, construct and maintain, and provide recreational and aesthetic benefits in addition to flood control. These objectives are achieved by replacing conventional urban underground drainage pipes with grassed swale filter and infiltration strips, and wetlands and ponds for collection, storage and treatment by natural processes as opposed to traditional storm water conveyances. Work is needed to update practices and regulations for effective use of these systems.

Sustainable storm water management should be considered in the context of Low Impact Development (LID). The LID approach follows the basic principles of nature: manage rainfall as near the source as possible using micro-scale controls. LID's goal is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. Design options such as rain gardens, roof top collection and storage, and natural swales all aid in this and can provide a water source for a buildings or developments non-potable water supply from the flushing of toilets to landscape irrigation, again reducing the use of clean drinking water for sanitary or non-potable uses. Other options such as porous asphalt or concrete, grassed parking lots, or native gravel material provide a travel surface, but reduce runoff and increasing recharging of ground water.

Waste Management

Waste systems are used to collect and process solid and hazardous waste. Waste systems include the collection, transport, processing, recycling or disposal, and monitoring of waste materials. For full sustainability, waste should be eliminated. However, today's systems have not reached that level of reduction or reuse.

Thanks to the work of sustainable advocates such as William McDonough, who have redefined the concept of waste, and early environmental activists such as Rose Rowan who established the recycling movement in Woodbury, New Jersey in the 1970s, there is much better appreciation of the energy embedded in waste. While "Waste Management" continues to be an important municipal (and in some cases private sector) service, major strides have been made in redefining waste. Programs such as "waste-to-energy," "zero-waste industrial complexes" among others, and powerful concepts such as McDonough's "up-cycling[54]" are redefining the manner in which waste is viewed and handled as shown in many of this report's cited best practices. These applications include combined heat and power plants that utilize typically "wasted" heat generated for thermal energy, or new concepts that are considering tapping "wasted carbon dioxide" exhausted from power plants to grow algae as fodder for bio-fuel.

Planning for Waste Systems

Waste systems planning in the United States is a shared public/private process. In some communities, the private sector owns and operates the collection, processing, disposal and recycling elements. In other communities, all of these elements are the responsibility of the government. In some communities, certain elements are public and others are private. This makes the planning process complicated.

The waste processing system has three elements: collection, processing and disposal. However the most sustainable approach to waste management is "reducing, reusing and recycling" which varies with the scale of the community.

Communities are finding now that separating compostable materials from waste greatly reduces a municipality's expenditure for landfill fees.

Waste Collection

While waste collection remains predominantly a truck-based system, some advances in technology have made this more of an infrastructure system. Some communities now use standardized bins which allow specially designed trucks to empty the bins with a single operator. In many communities, some types of waste are deposited by residents at central collection sites. Examples are plastic bags at grocery stores, hazardous materials like used motor oil (at gas stations), dead batteries, old paint cans, and old TVs (at municipal and county solid waste dumps or transfer stations), old cars and other large items (at commercial junk yards) and yard wastes (at county dumps or composting sites).

Nevertheless, collection of solid waste from residential areas remains largely a street-by-street pick-up by truck. In areas where collection is by private haulers, a neighborhood may see three or four different companies collecting trash on different days. Some neighborhoods have required companies to collect on the same day. Other communities have contracted with a single company to provide collection for the entire community.

Waste Processing

In many communities, no waste processing occurs, with the trash transported directly to disposal sites. One step above this is the "transfer station." The planning and design of transfer stations provides an opportunity to introduce more sustainable elements.

Transfer stations may provide consolidation of material from collection trunks to larger capacity tractor-trailers or containers to be shipped by rail, barge, or ship. However, it also provides the opportunity for some sorting of materials and recycling. Finally, a few communities provide processing centers that can separate recyclable materials to a high degree and reduce the volume of material taken to disposal.

Waste Disposal

Waste disposal facilities represent the major "infrastructure" component of the solid waste management system. They are usually regulated by state or local governments but are often owned and operated by private companies. Therefore, the planning for future landfills or incinerators is a disjointed process.

The design of landfills and incinerators is an ongoing process of improvement to reduce the impacts. Most solid waste in the United States is now disposed of in "sanitary landfills." These are designed to provide long-term storage of the material in a safe manner. A properly-designed and well-managed landfill can be a hygienic and relatively inexpensive method of disposing of waste materials. Older, poorly-designed or poorly-managed landfills can create a number of adverse environmental impacts such as wind-blown litter, attraction of vermin and birds, and generation of liquid leachate. Another common byproduct of landfills is gas (mostly composed of methane and carbon dioxide), which is produced as organic waste breaks down anaerobically. This gas can create odor problems, kill surface vegetation, and is a greenhouse gas. In addition, care must be taken in siting landfills so they do not attract flocks of birds near airport runways where they create safety hazards.

Design characteristics of a modern landfill include methods to contain leachate such as clay or plastic lining material. Deposited waste is normally compacted to increase its density and stability, and covered to prevent attracting vermin (such as mice or rats). Many landfills also have landfill gas extraction systems installed to extract the landfill gas. Gas is pumped out of the landfill using perforated pipes and flared off or burnt in a gas engine to generate electricity.

Some communities use incineration for disposal of solid waste and to recover some energy from the material. Increasingly, bio-waste is providing fuel for waste-to-energy plants. This practice is especially evident in areas subject to wildfires where large quantities of yard and forest wastes are cleared routinely to reduce fire hazards. Both landfills and incinerators are regulated by state and federal agencies to protect public health, as is the burning and disposal of underbrush and other bio-waste.

Hazardous Materials Disposal

Hazardous materials have their own collection and disposal infrastructure with much more government oversight. Disposal practices usually involved some processing of the materials to reduce potential hazards.

Household hazardous wastes are usually collected through special events and/or special collection sites. Commercial and industrial hazardous wastes are handled through private sector companies and taken to processing and disposal sites operated by private or public entities. Sustainable practices include processing the materials to remove the hazard and, possibly reselling them for the purposes of creating reusable materials.

Waste Disposal Design

The design of the collection system supports waste minimization by diverting recyclables from the processing system. Communities are incorporating diversion through source separation by households. Separate containers are provided for various recyclables such as paper and plastics, versus trash. However, some communities are finding that mixed wastes can be more easily managed at processing centers.

Minimizing the volume of waste that needs ultimate disposal may be most efficient at transfer station locations. Eco-cycle of Boulder, Colorado, is an example of a community-supported processing site that can efficiently separate materials that can be recycled from the waste stream and deal with enough volume to make re-processing affordable.

The design of landfills and incinerators is also leading to more sustainable designs. Methane recovery at landfills can reduce this hazardous waste and, in fact, turn it into an energy source. Incinerator design can reduce the problems from air pollution and ash disposal while producing energy for a community.

Emerging Practices

The goal of waste disposal design focuses now on minimizing waste at all stages of the use of materials. Minimization might occur through waste reduction. This can occur in the production process by reducing the packaging materials and the more efficient use of raw materials. Households can reduce their waste volume through practices such as composting.

One suggestion for improving the practice of waste management is that the parties involved in the various elements of the process conduct some planning together. This will provide an opportunity to identify actions that will increase the sustainable practices in the system.

In Europe waste to energy programs are growing in popularity, thereby reducing the amount of land dedicated and cost of delivery to remote landfill locations. Improved filter technologies would reduce amounts of landfills or emissions from incinerators

Neighborhoods might focus on public education and social change. A community might consider recycling centers where waste is processed to remove various recyclable materials. A region might have the necessary resources to re-process waste into reusable products; for example, collecting construction waste and reusing concrete and wood materials in new local construction projects.

A number of volunteer and private sector run companies are emerging that salvage reusable construction materials and parts from buildings slated for demolition or reconstruction. This diverts tons of valuable material from landfills. The collection system should also consider ways to incorporate recycling, such as source separation prior to collection.

Performance Measures

Dealing with waste is obviously transforming from a "management" strategy to a "reduction" focus. Measuring the effectiveness of waste reduction programs should therefore focus on factors that relate to behavior and personal choices, as well as the efficiency of the waste reduction system. There are also growing concerns about industrial waste, electronic waste and household hazardous waste, including building materials as well as leftover pharmaceuticals. Some performance indicators could be:

- Percentage of waste diverted to composting, reusing and recycling
- Presence of hazardous waste in stormwater and sewage effluents
- Percentage of electronic waste recovered for reuse or recycling (at source or downstream)
- Energy expended per unit waste to transfer waste from transfer station to landfill

Communications

Communications technology plays a vital role in the creation of truly sustainable infrastructure. Resilience, survivability and security are unfortunately concepts that must be addressed in the face of a changing global climate, and communications technology provides the means to do so.

The development of smart grids -- the power and information matrix in which buildings, urban areas and larger metropolitan regions operate -- depends entirely on communications infrastructure, including broadband from both wired and wireless systems. High performance, efficient buildings will rely on communications infrastructure within the building to generate, monitor and transmit information to the building control system and to the external utility grid, creating a powerful feedback loop for efficient use of power. The widespread availability of robust broadband Internet will allow people to work where they live – not live where they work – enabling a profound demographic shift toward smaller, more sustainable communities.

This section explores the state of communications infrastructure today and its crucial role in the sustainability agenda. It also looks ahead to how communications technology can further progress toward long-term sustainability goals. Finally, the section makes recommendations for how both the design and construction communities, as well as regulatory and governmental bodies, can best prepare for, benefit from, and work with the future communications infrastructure, which will be increasingly high tech and pervasive.

Today's Evolving Communications Infrastructure

To say that communications technology is changing rapidly is to understate the revolution that is occurring. As anyone who used Netscape on a desktop computer in 1995 and an iPhone in 2009 can attest, ICT (information and communications technologies) has made its mark in everyday life.

From a communications infrastructure perspective, the world has shifted from one of single-purpose, restricted, silo-like transmission networks (traditional cable TV coaxial cable for transmission of television signals; copper wires for transmission of voice, etc.) to an environment where any one of many transmission channels can accomplish virtually anything (video via wireless to an iPhone; telephone via cable coaxial network, etc.). Thanks to the pervasive use of IP (Internet Protocol), communications networks now enable the use and development of a mind-boggling array of applications – most of which we have yet to experience.

From a demographic, economic and social perspective, the true impact has yet to be recognized. Indeed, one of the most profound potential benefits of evolving communications infrastructure – one that is only just beginning to be felt – may come from its use in sustainable building design, construction and operation and in the planning for sustainable infrastructure.

Emerging Practices

More and more new buildings are likely to be fiber-enabled, due to owner demand for high speed communications capability, and advancements in baseline building technologies being adopted, especially in the commercial market. There is a pervasive cloud of secure, predictable, building-wide "industrial wireless" building environments on which operational support applications can be hung. Smart devices are just coming online in a major way, with applications for building operations and maintenance, and expanded use in emergency management. Smart buildings are not a new concept, but one that can now reach its potential with improvements in building systems technology such as mechanical and electrical systems, lighting and communications equipment. Smart devices are an essential part of smart buildings, which are an essential part of attaining a truly smart grid.

Early attempts to improve efficiency and reduce demand through the use of communications technologies have depended on changing consumer behavior. Residents may be able to use a website periodically to tweak household use of electricity, or may receive messages encouraging them to undertake high-demand activities during periods of low system-wide demand. History shows, however, that simply giving consumers tools to effect change does not mean it will necessarily occur on a large scale, even if various incentives are established to encourage such change. Accordingly, it is crucial that automated systems be put in place that harness the power of communications technology in imaginative ways -- without relying on direct intervention by consumers. Though we cannot predict what future generations of communications technology will look like, the important thing is to create an ecosystem developers can count on. To continue to grow demand for intelligent systems, good ideas must be cultivated and investment will follow.

Communications technology can also play a very crucial role in the planning for sustainable communities and their infrastructures. It provides a critical tool for communicating on a real-time basis with the community to inform and solicit information and feedback regarding an infrastructure project. This technology is becoming more important in planning for minimal disruptions during construction.

As mentioned earlier, it is also providing a way to get real time updates on the status of infrastructure projects, allowing for greater systems preservation. Communications technology is also useful for demand management strategies. By providing instantaneous information, it can encourage behavior change and choices, enough to avert major system overload or damages. Common applications are in the use of traffic flow information, integrating individual appliances and generators into the Smart Grid and providing up to date information regarding weather events that might threaten a community's infrastructure. The world was witness to this during recent floods in South Dakota and the hurricanes in New Orleans.

An interesting use of communications technology in a 2-way format is the CitiStat tool in operation within the city of Baltimore. Upon logging into the system, residents can report infrastructure issues directly to the appropriate city staff from the comfort of their homes. This has proved to be a very effective infrastructure maintenance tool.

With advances in cell phone technology, now this information can be made available through mobile devices, allowing for greater opportunities to use this technology in the planning for infrastructure systems. For instance, it could potentially reroute traffic by interacting with a car's or phone's GPS system.

Recommendations for the Design and Construction Community

Setting goals for a high performance project that creates smart buildings for a smart grid require changes in the traditional way buildings are designed and constructed. Early involvement of players in the design process, including research and communication with utilities and all members of the design team is one such change in the traditional design and construction process.

Progress toward these innovations is being facilitated in the communications arena by development of the first green model code, the International Green Construction Code (ICC). Additional sustainability-related regulatory changes in the construction industry can be expected.

CHAPTER 4. RECOMMENDATIONS

It is obvious that there is still much work ahead in getting a general consensus on the definition and goals of sustainable infrastructure. As shown by the efforts of numerous architectural, landscaping, and engineering organizations, performance measures play an important role in setting standards and providing further clarity by distinguishing sustainable infrastructure from traditional solutions. Global trends such as resource depletion, global warming, intense climate events, population explosion, and erosion of the natural environment, among others, suggest that the 21st Century will demand new ways of approaching society's need for infrastructure.

This work has identified key infrastructure providers, identified sustainability challenges for these providers, identified emerging innovations and examined potential performance measures. It has also identified a key set of recommendations on which future work will depend. This section lays out the most important of these recommendations and calls for infrastructure professionals to consider them collectively so that, in the future, infrastructure planning can be an integral partner in the development and support of sustainable communities.

DEFINE SUSTAINABLE INFRASTRUCTURE

While we have reviewed a number of infrastructure systems at the broader scale, this work struggled without a clear definition and parameters for sustainable infrastructure. PERSI is supporting an interdisciplinary dialogue to more clearly define sustainable infrastructure by identifying shared goals, performance measures and emerging best practices. As a part of this effort, PERSI has the opportunity to invite infrastructure organizations to develop a coherent and practical definition that can help every stakeholder involved in infrastructure planning steer the work of providers toward greater sustainability. Some of the emerging practices being undertaken today provide clues for where system improvements can occur and how desired results can be achieved. Additionally, this definition should involve the input of ecologists, environmental scientists, and biologists, among others; to help the design professions understand the many complex functions of natural infrastructure. This understanding can then be integrated into the definition of sustainable infrastructure and guide the development of future engineering manuals and standards.

ESTABLISH A PROCESS FOR INTEGRATED AND CROSS DISCIPLINARY SOLUTIONS

New ways of planning, such as demand management, are best reviewed through a multidisciplinary platform. Comprehensive plans provide a means to mitigate deferred infrastructure maintenance. and can be integrated into a city's capital improvement program. Presently, the non-infrastructure and societal goals of demand management lack a professional stronghold or credibility. This study confirmed that, in general, infrastructure is planned for in a linear, uni-sectoral manner. While the intention of comprehensive planning is to set up the platform for the cross-sectoral holistic review of issues and development of solutions, it is rarely done in that manner. Typically, with funding being available over a period of many years, in most cases, each element of a comprehensive plan is done sequentially and siloed. Expensive engineering analyses for water, stormwater, sewage, and, ever more frequently, energy, usually are contracted separately. This limits opportunities for innovative solutions with new ways of approaching infrastructure planning and design solutions that can be leveraged by multiple systems.

Develop a Research Agenda

Information about best practices and measured outcomes will encourage others to apply these practices. Research into promising technologies and practices, along with effective financial packages/incentives and regulations, will support these new technologies. These transitions can be accelerated if the appropriate legislation (with benchmarks or targets) is enforced, particularly at the national and state levels. However, it is clear to the authors of this report that much will be needed before sustainable infrastructure will be the norm. Much of the innovations discussed in this report do not necessarily challenge current engineering practice. There is a strong possibility that new technologies will demand new manuals and approaches to infrastructure planning. However, most of the recommendations in this report are simply logical solutions that are making infrastructure systems more efficient, practical, affordable and reliable. Researching and sharing best practices will help not only spread their applicability far, but will also help modify current manuals to make them more sustainability oriented.

Goals and Performance Measures

Despite the large amount of valuable work already accomplished, much still remains to be done to develop performance measures for sustainable infrastructure. One course of action could be as follows:

- Establish a set of broadly accepted sustainable development goals having global reach.
- Establish intuitive, relatively easy to understand, and practical-to-collect performance metrics for each goal.
- Mainstream both the goals and performance metrics into planning practice for both comprehensive planning and infrastructure system planning, and into plan implementation tools .

For sustainable communities, infrastructure planning professionals should revisit and extend the three categories offered in the NRC study to i include sustainability principles. Several concepts that could extend the sustainability reach of the earlier report are as follows:

Reliability

Service Life – The understanding of reliable infrastructure needs to include the concept of service life. Service life is a matter of how long a system will be adequately functional. This determination is based on expected changes in demand as well as anticipated investments in maintenance, rehabilitation and alternative systems. For an infrastructure system to be sustainable and resilient, its designed life-span must be extended through maintenance and rehabilitation planned to maximize the embedded energy in the structure. The "asset management" programs discussed earlier are integral to this practice. Demand management programs can help extend the service life of infrastructure, and their effectiveness could be assessed as a measure of infrastructure sustainability.

Effectiveness

Efficiency - The notion of effectiveness of a solution must engage the original concepts of efficiency of an infrastructure system. Efficiency is generally defined as a ratio of inputs to outputs. Efficiency *thresholds* for sustainability need to be defined for each infrastructure project since there are no 100% efficient infrastructure systems. For instance, centralized power operates at 30-45% efficiency (not including any other externalities other than heat input-output). The concept of efficiency must be re-integrated into engineering such that research and innovation keeps leading us to 100% efficient solutions.

At the same time, the measurement of efficiency needs to broaden from measurement of economic investments to benefits to measurement in units of energy. As mentioned by the NRC report, since there are not many ways to fully account for social and environmental impacts (or benefits), traditionally, efficiency has been measured somewhat uni-dimensionally. While the science behind social and environmental accounts is emerging, project assessment methods must go beyond typical efficiency measurement.

Cost

As most project managers will assert, at the end of the day, a bottom line concern about projects eventually dictates solutions. Unfortunately, the concept of cost that is used in this decision making is outdated. It might refer to only project costs, without including the benefits or cost to the local economy or to the community networks/functions.

- Strengthen local context/economy – Infrastructure is typically viewed as a cost to communities for providing a service of value (clean water, access and so on). As discussed earlier in the report, if it sets out to, infrastructure in and of itself can provide much value to a community through jobs, purchase of regional resources and services, safeguarding vulnerable and less resilient neighborhoods and jobs, and so on.
- Lifecycle analysis or environmental accounting – As discussed in Chapter 2, traditional infrastructure systems have been unable to mimic the regenerative properties of natural systems. This approach has been shown to solve one problem (stormwater run-off or pollution treatment and effluent discharge, for instance) at the risk of other valuable services that natural infrastructure provides (such as the river providing fish habitat and nutrition). An important performance measure for sustainable infrastructure system would appear to be the system's long-term impacts on the environment. Infrastructure systems that are built to support the natural functions of the environment include highway designs that incorporate animal migration corridor over-bridges or wastewater treatment plants that use natural wetlands to clean the sewage effluents prior to it being discharged into a natural water body. Cost-benefit analysis that considers the economic benefits of natural infrastructure will begin to impact how a particular solution is viewed. For instance, considerations such as impacts on fisheries and impacts on flooded communities are being considered in the assessment and reflected in the decisions to not build new large dams or to tear down exciting dams.[55]
- Zero Waste - Major strides have been made in redefining waste. Programs such as "waste-to-energy," "zero-waste industrial complexes" among others, and concepts such as McDonough's "up-cycling"[56] are redefining the manner in which waste is viewed and handled as shown in many of this report's cited emerging practices. These applications also include combined heat and power plants that utilize typically "wasted" heat generated for thermal energy, or new concepts that consider tapping "wasted carbon dioxide" exhausted from power plants to grow algae as fodder for bio-fuel. Sustainable infrastructure performance measures for waste should include these new concepts.

Planning Approaches for Sustainable Infrastructure

From the work to date in this study, the following five strategies are recommended for planning infrastructure.

1. System Preservation

Infrastructure generally is built to last, but requires maintenance to reduce costs of premature rehabilitation or replacement. The rapid levels of urbanization in the last century caused a focus on new infrastructure rather than on maintenance and repair of existing infrastructure. This has led to poor condition of much infrastructure[57]. Carefully balancing 10 to 20-year capital budgets to include both deferred maintenance projects as well as new projects will help reduce the instances of deteriorating infrastructure. Fitting new structures with sensors designed to measure when maintenance is needed, and when risks are rising, promises to ease this burden in new and rehabilitated structures and systems.[58]

2. Demand Management

Community and infrastructure systems planning and public education can make communities and their infrastructures more sustainable through managing demand for infrastructure systems. Co-locating residential, employment and shopping areas, and providing pedestrian and bicycle lanes, can reduce demands for transportation. Distributed electricity generation, water supply, and waste and storm water treatment can reduce needs for transmission and distribution lines and reduce concomitant resource losses.

Modeling tools for infrastructure planning and design includes analysis, simulation and visualization capabilities to assist in outcome based understanding of options by predicting the capacity of the various options. Growth modeling is an important practice for anticipating demand. Growth models should account for changes in externalities (such as future cost of energy, regional impacts of climate change, and social considerations) and take a long-term view of local impacts of the various infrastructure alternatives. Modeling also provides a tool to include the benefits of reducing demand through programmatic and education strategies. Programs such as the federal Energy Star program have had substantial impact on reducing the demand for new energy. Called Non-Energy Benefits, the value of these programs are best assessed and highlighted through modeling programs.

3. Preserve and Use Natural Infrastructure

Natural systems serve many of the infrastructure needs of our communities: storing fresh water, absorbing storm water, controlling flooding, leveling daily temperature cycles, refreshing air and storing carbon dioxide, providing food and energy, etc. Planning should preserve natural infrastructure, including wildlife and native plants, and use it to complement manmade infrastructure. Infrastructure planning disciplines should include earth and life scientists as well as planners, engineers and architects.

4. Advance and Integrate Systems, Technologies and Practices

Benefits and process efficiencies can be achieved through integration of infrastructures facilitated by advancements of technologies.

During planning, design and construction - model based design tools and building information modeling (BIM) processes supported by Integrated Project Delivery (IPD) or Project Alliancing (PA). These approaches are reducing risk and liability in infrastructure projects around the world by leveraging advanced 3D visualization, simulation and analysis of designs, aimed at reducing the 15-20% of overall project costs due to rework and allowing for shorter timelines. The intersecting process innovation between BIM, sustainability and IPD is about shifting the focus of rebuilding infrastructure from fixed, non-coordinated scopes and budgets to holistic coordinated views of projects with outcome-based processes as indicated above in Chapter 3. In this era of rapid innovation in sustainable thinking, tools and processes, the recommendation for owners is to stipulate the desired outcomes of a BIM-based approach, rather than worrying about the specific characteristics of data, files, or outputs, and free the Engineers planning creativity to approaches that address the sustainable infrastructure problem.

Federal and local governments should revise the procurement system to ensure improved sustainability of infrastructure as a key performance metric by which to award a contract, changing their procurement model from today's typical system of outlining what they want at an estimated price and awarding a contract to the lowest bidder.

During operations and maintenance, advanced sensors, communications and controls can improve traffic capacity instead of providing additional traffic lanes. Distributed electrical generation, with either renewable energy or fossil fuels, can be linked efficiently to central power systems for both supply and demand, and also can provide local space heating and cooling. Centralized and distributed water supply as well as wastewater and storm water treatment systems can increase water supplies through recycling and expand energy supplies through waste to energy systems.

5. Multiple Financing Sources and Mechanisms

There is a need to identify, review and educate state and local governments about financing tools that are equitable, fair and reflect the principles for sustainable infrastructure. There is a preference for beneficiary based (repaid by beneficiaries) infrastructure financing tools, dedicated to assure long term payoff of bonds and effective operations and maintenance over the service life, and scaled to fit the scale of the infrastructure system, but it may not be appropriate in all instances. Property taxes, user fees, fares, etc. are appropriate to local infrastructure services, but interstate highways, passenger rail, major dams and other large scale facilities need financing at a larger scale. Another critical step in infrastructure financing is to charge users for both the capital investments they require in infrastructure and the actual services they use. For instance, a property that usually lives off the grid with its own electrical power source and/or water source, should be charged for the utilities' or community's capital costs for providing backup power and fire fighting services.

Complementary Actions and Programs

Beyond the emerging practices discussed in Chapter 3, "greening" the nation's infrastructure might include complementary innovations such as:

- Creating per capita and net income thresholds for greenhouse gas emissions to drive local and state policies.
- Modifying building codes and infrastructure design codes to favor sustainable options.
- Updating site-plan review standards.
- Emphasizing investments for transit-oriented development and sustainable community approaches.
- Making sediment control ordinances more widespread.
- Increasing the use of Low Impact Development approaches.
- Extending the reach of "critical areas" regulations to a much larger proportion of stream banks and shorelines.
- Expanding the number of states that have active "growth management" programs capable of guiding development into suitable locations and away from environmentally sensitive areas.
- Restoring the reach of federal wetlands permitting authority to all waters of the United States.
- Increasing the reach of wetlands restoration and remediation, habitat restoration, and farmland conservation programs.
- Reenacting reforestation programs on marginal lands to expand state and national forests.
- Funding urban forestry programs.
- Systematically regulating concentrated feeding lots.
- Replicating Maryland's septic tank restoration trust fund program in other states.
- Establishing a robust national infrastructure bank to help finance large-scale projects of regional and national interest.
- Creating a new national multimodal transportation trust fund to replace the current failing Highway Trust Fund.

- Recommending new technologies (BIM) and best practices (IPD) to ensure reduced design and construction costs, and to deliver greater schedule and project predictability for complex sustainable urban infrastructure revitalization projects

On the positive side, work on these innovations has begun and will continue.

Transitioning to new infrastructure technologies will create winners and losers, which has both financial and political consequences. Yet it is apparent that given the challenges that the planet faces, infrastructure, as it is defined, designed and constructed, needs to evolve from the practices of the earlier century. There is an unquestionable need for the nation's infrastructure to be prudent, cautious, inter-disciplinary and innovative over the next 100 years. With the vast portfolio of deteriorating infrastructure, it appears that the focus of the 21st Century needs to be on rehabilitation and regeneration of our infrastructure. At the same time, it is apparent that many practices are evolving as new technologies emerge and older yet improved technologies are being reconsidered. The new communications, transit, and renewable energy sectors are some examples of these trends. These, among other emerging practices are making possible new solutions that were perhaps not feasible in the previous 100 years. While these new technologies will require some amount of new or re-engineering of old approaches, mostly the possibilities they present include a broadening of scope, changing the focus of solutions, and will demand cross-sectoral funding. It is hoped that the 21st Century will offer new models of city planning, infrastructure planning and design for removing the pollution we created in the last century, eliminating the emissions that are accumulating in our troposphere and repairing the harm that we have collectively done to our living habitat in only 150 years.

Appendix 1 Workshop Participants

Listed below are the participants in the PERSI Workshop on Planning for Sustainable Infrastructure on June 25, 2009, at ASCE Headquarters in Reston, VA.

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Appendix 2. Metrics of Sustainable Infrastructure

As described in Chapter 2, performance measures are needed to inform and guide decisions for sustainable infrastructure. Their development will require research. This appendix shows foundations for quantitative environmental indicators and qualitative performance requirements for development of performance measures.

Performance indicators (goals, standards and targets) are qualitative statements of performance characteristics (such as greenhouse gas emissions); performance measures quantify performance with respect to the indicators.

Indicators address three dimensions of sustainability: environmental, economic and social. A great challenge to planning for sustainability is that the indicators generally are incommensurate. That is, there is no known and rational quantitative method to sum the impacts for a particular situation to arrive at an overall impact measure. However, this situation is not unique to sustainability. For instance, for structural safety, in commensurate impacts of potential life loss, injuries, property damages and costs of safety measures, are weighed by experts and stakeholders in setting structural standards and codes. Similar deliberations can be used to develop standard practices for planning sustainable infrastructure.

The National Institute of Standards and Technology, in cooperation with manufacturers of building products, has developed BEES 59a rational and systematic method to apply individual or group judgment to evaluation of the environmental and economic performance of building products. Conceptually, the method is extensible to communities and to the inclusion of social performance, but much research will be required to supply valid quantitative measures for the performance indicators important to planning. Care is required to evaluate performance over a consistent time period – perhaps about 50 years for a community, urbanization or region and the infrastructure systems that serve it.

Another source of indicators and measures relevant to infrastructure systems and planning is the Civil Engineering Environmental Quality and Assessment Scheme (CEEQUAL)60 which was developed in the United Kingdom by a team led by the Institution of Civil Engineers. Much information is available from its website, www.ceequal.com. Environmental, economic and social performance indicators also are available in the *Project Sustainability Management Guidelines* of the International Federation of Consulting Engineers, 200461.

Example Performance Indicators

The list below from BEES summarizes the most popular indicators used for measures of environmental impact.

Acidification damages trees, soil, buildings, animals, and humans. Commonly referred to as "acid rain," its principal human source is fossil fuel and biomass combustion.

Criteria Air Pollutants arise from many activities including combustion, vehicle operation, power generation, materials handling, and crushing and grinding operations. They include coarse particles known to aggravate respiratory conditions such as asthma, and fine particles that can lead to more serious respiratory symptoms and disease.

Ecological Toxicity measures the potential of pollutants from various sources to harm land- and water-based ecosystems. Toxic substances do not have equal damage per unit or to different media. Thus weighting methods (e.g., Human Toxicity Potential) are often used to help normalize these flows.

Energy Use tracks uses of fuels and electricity needed to manufacture, construct, transport, maintain, use, and dispose of products and processes.

Eutrophication is the addition of mineral nutrients to the soil or water, which in large quantities results in generally undesirable shifts in the number of species in ecosystems and a reduction in ecological diversity.

Fossil Fuel Depletion occurs when these resources are consumed at rates faster than nature renews them.

Global Warming is due to emissions generated by humankind that keep the earth's surface warmer than it would be otherwise.

Habitat Alteration measures the potential for land use by humans to lead to undesirable changes in habitats for animals and plants.

Hazardous Waste is generated, managed, or shipped as a result of construction and manufacturing processes. Such waste is specifically defined by agencies such as the US EPA.

Human Health effects can arise from exposure to industrial and natural substances, and range from transient irritation to permanent disability and even death.

Indoor Air Quality suffers when products release pollutants indoors during their use.

Ozone Depletion, or a thinning of the stratospheric ozone layer, allows more harmful short wave radiation to reach the Earth's surface, potentially causing undesirable changes in ecosystems, agricultural productivity, skin cancer rates, and eye cataracts, among other issues.

Smog forms under certain climatic conditions when air emissions from industry and transportation are trapped at ground level where they react with sunlight. Smog leads to harmful impacts on human health and vegetation.

Water Intake can be problematic in areas where water is scarce, such as the Western United States.

Assessing economic performance is more straightforward than assessing environmental performance. Published economic performance data are readily available and there are well established ASTM standard methods62 for conducting life cycle cost evaluations.

First cost is explicit in life cycle cost analyses (and is likely to be excessively weighted in decision making). Costs accrue directly in the installation, operation and maintenance of infrastructure systems, but economic indicators should extend to the costs and benefits of the infrastructure systems to the community served (since community is a flexible term, we can apply the term at scales ranging from a housing development to region of the country). Thus, in addition to the direct life cycle costs of the infrastructure systems, we can include indicators for costs and benefits accruing from both the siting and provision of infrastructure services. These would include factors such as property values and tax revenues. A key issue in economic analysis is selection of the discount rate for establishing present worth for costs and benefits over the selected lifetime.

Social indicators relate to costs and benefits that are difficult to express in economic terms. Possible social indicators are cited by CEEQUAL and FIDIC's Sustainability Guidelines.

- Proportion of local workers and firms employed.
- Effects on local populations and communities
- Effects on local culture, historic buildings, archeological sites and landscapes.
- Safety performance during construction.
- Potential losses due to natural hazards (wind, earthquake, landslides, wildfires, etc.)
- Potential losses due to accidental and willful hazards (fires, sabotage, etc.)

CEEQUAL deals with a civil project and is independent of the type of infrastructure system. It provides insights on performance measures for community planning as well as for infrastructure projects and systems for which it was developed. CEEQUAL's Weighting Factors are shown below with the performance measures they imply as lettered subheadings.

Project Environmental Management – covering the need for environmental risk assessments and active environmental management, training, the influence of contracting and procurement processes, delivering environmental performance, minimizing emissions and human environmental considerations.

- Life cycle costs
- Integrated life cycle pollution prevention and control
- Life cycle health and safety implications

Land Use – design for minimum land-take, legal requirements, flood risk, previous use of the site, contamination and remediation measures.

- Land take and costs/benefits for adjacent land uses
- Natural, accidental and willful hazards risk assessments
- Contaminated land exposure assessment

Landscape – covering consideration of landscape issues in design, amenity features, local character, loss and compensation or mitigation of landscape features, implementation and aftercare.

- Definition of landscape character areas
- Preservation/enhancement of areas of outstanding natural beauty

Ecology and Biodiversity – covering impacts on sites of high ecological value, protected species, conservation and enhancement, habitat creation measures, monitoring and maintenance.

- Designation for nature conservation value
- Preservation/enhancement of wildlife (animals and plants)

Archeological and Cultural Heritage – covering surveys and measures to be taken if features are found and information to the public and public access.

- Preservation/enhancement of archeological and cultural heritage

Water Issues – covering control of a project's impacts on, and protection of, the water environment, legal requirements, minimizing water usage, and enhancement of the water environment.

- Protection/enhancement of wetlands, lakes, streams, etc.
- Water conservation
- Pollution control
- Storm water management

Energy – covering life-cycle energy analysis, energy in use, and energy performance on site, but not embodied energy, which is located in Section 8.

- Life cycle energy analysis for materials and components

Use of Materials – covering minimizing environmental impact of materials used, minimizing material use and waste, selection of timber, using re-used and/or recycled material, minimizing use and impacts of hazardous materials, durability and maintenance, and future demolition.

- Life cycle assessment of materials uses.

Waste – covering design for waste minimization, legal requirements, waste from site preparation, and on-site waste management.

- Life cycle assessment of waste minimization and recycling

Transport – covering location of a project in relation to transport infrastructure, minimizing traffic impacts of a project, construction transport, and minimizing workforce travel.

- Life cycle assessment of transportation impacts

Nuisance to Neighbors – covering, minimizing, operation and construction-related nuisances, legal requirements, nuisance from construction noise and vibration, and from air and light pollution, and visual impact, including site tidiness.

- Life cycle assessment of nuisance to neighbors

Community Relations – covering community consultation, community relations programs and their effectiveness, engagement with relevant local groups, and "joy in use."

- Effectiveness of community relations throughout life cycle (planning, design, construction, operation, maintenance and replacement).

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