An Introduction to Greenroads

a sustainability performance metric for roadways

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A joint effort of:

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INTRODUCTION

Greenroads is a sustainability performance metric for roadways that awards points for more sustainable practices. A concise listing of Greenroads credits can be found at the end of this document. Fundamentally, Greenroads is a metric that helps quantify the sustainable attributes of a roadway project. This quantification can be used to:

- Define what project attributes contribute to roadway sustainability.
- Provide a sustainability accounting tool for roadway projects.
- Communicate sustainable project attributes to stakeholders.
- Manage and improve roadway sustainability.
- Grant "certification" based on achieving a minimum number of points.

Greenroads is a publically available system that can be used by anyone. However, the Greenroads logo and name remain the property of Greenroads and may only be used with permission. Any use of the Greenroads system requires proper citation of Greenroads as the origin of these ideas.

WHAT IS A GREENROAD?

A Greenroad is defined as roadway project that has been designed and constructed to a level of sustainability that is substantially higher than current common practice.

OVERVIEW

Greenroads is a collection of sustainability best practices that apply to roadway design and construction. These best practices are divided into two types: required and voluntary. Required best practices are those that must be done as a minimum in order for a roadway to be considered a Greenroad. These are called "Project Requirements," of which there are 11. Voluntary best practices are those that may optionally be included in a roadway project. These are called "Voluntary Credits". Each Voluntary Credit is assigned a point value (1-5 points) depending upon its impact on sustainability. Currently, there are 37 Voluntary Credits totaling 108 points. Greenroads also allows a project or organization to create and use its own Voluntary Credits (called "Custom Credits"), subject to approval of Greenroads, for a total of 10 more points, which brings the total available points to 118.

Project teams apply for points by submitting specific documentation in support of the Project Requirement or Voluntary Credit they are pursuing. These documents, which can range from project specifications to field documentation, are verified by an independent review team. Once a project is complete the Greenroads team verifies the application and assigns a Greenroads score based on achieving all the Project Requirements and the number of points earned from the Voluntary Credits. This score may then be used at the owner's discretion and may also be translated to a standard achievement level or "certification" if so desired: the more points earned, the higher the recognition. If a project reaches an achievement level it will be able to display the Greenroads logo and appropriate certification graphic. The Greenroads achievement levels are detailed in a subsequent section of this document.

Owner agencies, developers, design consultants and contractors may wish to pursue official certification or use Greenroads in other ways that are either voluntary or prescriptive. For instance, developers and designers may wish to use Greenroads as a list of potential ideas for improving the sustainability of a roadway project. Or, owners may wish to use Greenroads point values or certification levels as goals or

benchmarks for new roadway projects or metrics by which they can measure and manage their roadway sustainability efforts.

STAKEHOLDERS

There are a number of stakeholders who may have interest in a roadway sustainability rating system. Each stakeholder is likely to have opinions on how Greenroads should work; however it should be noted that not all points of view can be fully accommodated. Stakeholders include:

- Road owners: federal, state, county and city agencies as well as the general public.
- Funding agencies: federal, state, county, city and other regional authorities
- Design consultants: those involved with corridor, road or even parking lot design
- Contractors: heavy construction, road and paving contractors
- Regulatory agencies: U.S. Environmental Protection Agency
- Sustainability organizations: U.S. Green Building Council (USGBC), Green Highways Partnership, Sierra Club, etc.
- Research organizations: universities and other research organizations that participate in investigating related sustainable technologies.

GREENROADS DEVELOPERS

Greenroads is a research project that is working towards general implementation and use. It is being developed jointly by the University of Washington (UW) and CH2M HILL. Research at the University of Washington is headed by Steve Muench, an Assistant Professor in the Department of Civil and Environmental Engineering, while work at CH2M HILL is being led by Tim Bevan, Mountain West Region Technology and Quality Manager, Transportation Business Group. Importantly, although UW and CH2M HILL are developing this system the brand associated with any rated project will only be the Greenroads brand. You may choose to include UW or CH2M HILL if so inclined.

GREENROADS WEBSITE

All Greenroads work is documented on the official website: www.greenroads.us. Please visit this website to see the latest news, copies of presentations given, rated projects and other Greenroads related information.

GREENROADS ESSENTIALS

This section describes the essentials of the Greenroads rating system. These are items a project may want to know about when deciding whether or not to pursue Greenroads certification.

PROJECT REQUIREMENTS

Project Requirements are the items that must be done as a minimum to be considered a Greenroad. They can be thought of as characteristics common to all Greenroads. In order to achieve certification they must all be met and an additional number of Voluntary Credit points must also be earned. In other words, regardless of how many Voluntary Credit points are achieved, if a project does not meet all of the Project Requirements, a Greenroads certification level will NOT be awarded. Project Requirements are listed in their own category and consist of items related to the five main credit categories (not including the Custom Credits category). Depending on special project circumstances, a few of the Project Requirements may b e eligible for exclusion based on the scope of the project.

VOLUNTARY CREDITS

In addition to Project Requirements there are a number of Voluntary Credits that a project can earn. Each Voluntary Credit is associated with a number of points (from 1 to 5) depending upon the impact the credit has on sustainability (as defined later in this document). A project chooses to pursue Voluntary Credits on a voluntary basis; none are required. Once those pursued Voluntary Credits are verified by the Greenroads team, the number of points achieved is tallied up and a certification level (see next section), if desired, is awarded.

Voluntary Credits span a wide spectrum of project actions from art and multimodal access to safety to pavement materials. Therefore, it is likely that no project will be able to achieve all the Voluntary Credits. However, the goal of Greenroads is to have enough choice in Voluntary Credits that any significant roadway project could find enough relevant credits to achieve at least a minimum certification level. This means that Greenroads should work for all roadway projects from basic preservation overlays to large, multi-billion dollar corridor projects.

ACHIEVEMENT/CERTIFICATION LEVELS

Greenroads may be used to "certify" a project based on total points achieved. Depending upon the appetite of the project, these levels can be called "achievement" or "certification" levels. Obtaining these levels is an official acknowledgement by Greenroads that a project has met all Project Requirements and achieved enough of the 118 possible Voluntary Credit points to surpass a predetermined certification level. There are four certification levels:

- Certified: All Project Requirements + 32-42 Voluntary Credit points (30-40% of total)
- Silver: All Project Requirements + 43-53 Voluntary Credit points (40-50% of total)
- Gold: All Project Requirements + 54-63 Voluntary Credit points (50-60% of total)
- Evergreen: All Project Requirements + 64+ Voluntary Credit points (>60% of total)

These levels are subject to revision with new versions of Greenroads and may change in the future as the system is updated. A certified roadway can be considered a Greenroad.

Certification Review Process[1]

Greenroads certification is an online process at www.greenroads.us. Projects register at the Greenroads website (www.greenroads.us) and submit documentation and questions via an online interface. Greenroads project liaisons work with a project by answering questions online and verifying documentation to ensure credit requirements are met. Ultimately, a project is certified by a Greenroads project liaison based on documentation and narrative submitted by the project. The certification workflow works like this:

1. A project chooses to pursue Greenroads certification and signs up online.
2. The project team communicates online which credits will be pursued and, for those pursued, enters a short narrative describing the project portion that will achieve the credit.
3. The project uploads supporting documentation (or enters a link that points to such documentation that is housed elsewhere on the Internet) for each credit that is being pursued.
4. The Greenroads Project Liaison may comment informally on attempted credits to provide clarification or answer any questions the project team has.
5. Once documentation for all pursued credits is entered the Greenroads Project Liaison reviews these credits and provides a preliminary ruling on whether each credit is achieved; and, if a credit was not achieved, they will provide an explanation of what additional items must be accomplished or submitted to achieve the credit.
6. The project addresses any comments from the Greenroads project liaison and then enters a final submission for certification. At this point, the submission should be made with enough communication with the Greenroads project liaison that it the final rating should not be in serious question.
7. The Greenroads Project Liaison makes a final certification determination and officially certifies the project.
8. Greenroads sends an official letter to the project notifying it of the level of Greenroads certification.

PILOT PROJECTS

Greenroads is a new system. With version 1.0 being schedule for completion in 2009, we are looking for projects with which to partner in order to determine the following:

- **What changes should be made to Greenroads to better accommodate stakeholders?** Should we change credit wording? Add new credits? Change point values? Delete credits?
- **How much time and money are involved in pursuing Greenroads certification?** We can speculate on this but we will not know for sure without actual project input. This includes key questions like: How many person-hours (and related cost) go into pursuing Greenroads certification? Does it cost more (and if so how much) to add elements to the project in pursuit of certification? Keep in mind that “cost more” has meaning in terms of initial cost and life cycle cost. Often a higher initial investment may result in lower life-cycle costs.
- **What does a Greenroads assessment mean for a project?** In essence, why is your project choosing to pursue Greenroads certification?
- **Are the certification levels proper?** Is certification too easy or too hard? Does it accurately represent your project values?

[1] Note: as of 1 July 2009, this online system is not fully operational. Please see the “Pilot Projects” section after this one to find out how to get a project rated in the interim.

- **Are your organization's sustainability goals and objectives included in Greenroads?** Often organizations may choose to pursue Greenroads because they have an existing set of strategies that they seek to measure and manage. Does Greenroads help in doing this? Are there things that need to be changed in order for this to work better?

Above all, Pilot Projects are a partnership between the project and Greenroads to answer questions like these. As such, they will likely involve expenditure of resources by the project. This expenditure could be limited to time spent talking with Greenroads and supplying documentation but could also extend to expenses involved with changing or adding to project scope in order to achieve certification. Ideally, a project would pursue items that it felt best represented the interests of the stakeholders and then used Greenroads to quantify those items. Thus, Greenroads would not drive design or construction but rather assist as a means for quantifying sustainability measures.

FIT, BOUNDARIES AND PHILOSOPHY

This section describes the underlying ideas, scope and limits of Greenroads. It is expected that the basic system will grow and change as sustainability thought, technologies and regulations change. However, the fundamental concepts addressed here are expected to remain relatively constant.

REGULATORY FIT

Greenroads is designed to promote sustainability best practices within and beyond existing federal, state and local regulations. Specifically, Greenroads credits are designed to influence decisions regarding sustainability options where they are not precluded by regulation or where regulation allows a choice between options that could have sustainability impacts. An important corollary to this is that Greenroads is not an absolute measure of sustainability because it does not include sustainability items that are covered by current U.S. regulation (e.g., Clean Water Act, Clean Air Act, National Historical Preservation Act, Americans with Disabilities Act, etc.). However, given that all U.S. agencies are governed by the same set of federal regulations, Greenroads can be considered a sustainability metric built on U.S. standard practice. Greenroads is also meant to encourage organizations to include sustainable practices in their company-wide strategy and daily work practices. Importantly, Greenroads is not meant to dictate design or trade-off decisions. Rather it provides a tool to help with such decisions.

SYSTEM BOUNDARIES

Greenroads is a project-based system. It is applicable to the design and construction of new or rehabilitated roadways including expansion or redesign. Specifically, it applies to (1) the design process and (2) construction activities within the workzone as well as material hauling activities, production of portland cement concrete (PCC) and hot mix asphalt (HMA). This means that some typical items associated with roadways are considered in specific ways that merit explanation:

- **Roadway planning**. Decisions regarding the location, type, timing, feasibility or other planning level ideas are excluded. While planning is fundamental to roadway and community sustainability, these decisions are often too complex or political to be adequately defined by a point system.
- **Materials manufacturing or refining**. Items such as cement and asphalt manufacturing/refining are only considered in life cycle inventories (LCI) or analyses (LCA). This means that specific

improvements in these processes may not be captured by Greenroads depending upon the data source(s) used for the required pavement LCI or voluntary roadway LCA.

- **Structures**. Bridges, tunnels, walls and other structures are considered only as a collection of materials. Points can be awarded for materials used; however the structural design, aesthetics and other non-material qualities are excluded. A future system focused on structures could be incorporated into Greenroads but none currently exist.
- **Paths and trails**. If directly associated with the roadway (e.g., adjoining foot/bicycle path or sidewalk), they are considered. Independent paths and trails (e.g., a conversion of a rail right-of-way to a bicycle path) are excluded but could be addressed within something like the Sustainable Sites Initiative (www.sustainablesites.org).
- **Maintenance and preservation**. Although maintenance and preservation actions have a large impact on overall roadway sustainability and are considered in LCA, they occur after certification. Because a Greenroads score is calculated at substantial project completion, they are judged as promises to perform rather than as observable actions.

GENERAL PHILOSOPHY

The fundamental tenets that guide the development and writing of Greenroads are:

- **Straightforward and understandable**. Non-experts should be able to understand the system. Simplicity is valued over excessive detail because it is more understandable. Credits are often simplistic interpretations of complex ideas; they are bound to contain some controversy however the interpretation should hold true to the fundamental idea.
- **Empirical evidence and existing evaluative techniques**. Credits are based on a preponderance of empirical evidence and, to the extent possible, should be evaluated using existing tools and techniques.
- **Credit commensurate with impact**. Items that have high economic, environmental or social impact are given more credit than low impact items.
- **Flexible**. Greenroads should be able to accommodate a broad range of both urban and rural roadway projects from preservation overlays to major new corridor development. Credits should be applicable anywhere in the U.S. International versions may need further development in the future.
- **Continual evolution**. Over time, better ideas, more complete knowledge and technology advances will require Greenroads to be updated and changed.
- **Minimal bureaucracy**. Obtaining credits and certification requires documentation but documents should either come from existing documents (e.g. plans and specifications) or be simple and inexpensive to produce from existing documents.
- **Beyond minimum requirements**. Greenroads should spur innovation and encourage design and construction decisions based on sustainability considerations that go beyond regulatory requirements. While regulatory requirements and design standards contribute to sustainability, a rating system that awards credit for these items alone essentially becomes a marketing tool that is technically redundant and administratively burdensome.

HOW GREENROADS WAS BUILT

This section describes some of the inner thoughts, definitions and ideas that helped shape Greenroads. An understanding of these ideas can help the user understand how Greenroads came to be in its current form.

SUSTAINABILITY DEFINED

Greenroads defines "sustainability" as *a system characteristic that reflects the system's capacity to support natural laws and human values*. By "natural laws" we specifically mean three basic principles that must be upheld to maintain the ecosystem[2]:

1. Substances must not be extracted at a faster pace than their slow redeposit and reintegration into the Earth's crust.
2. Substances must not be produced at a faster pace than they can be broken down and integrated into nature near its current equilibrium.
3. Do not harvest or manipulate ecosystems in such a way that productive capacity and diversity systematically diminish because our health and prosperity depend on the capacity of nature to reconcentrate and restructure wastes into new resources.

Human values" refers to equity and economy. Equity is interpreted as a primarily human concept of seeking quality of life for all involved. This is a vague concept that changes along with human values; however it is fundamental to many basic human institutions, including humanitarian law and organizations like the United Nations and the U.S. government, to name a few. Economy is broadly interpreted as management of human, manufactured, natural and financial capital[3]. Thus, by this definition economy can refer to project finance but it can also refer to forest resources management and carbon cap-and-trade schemes.

In total, this definition contains the key elements of ecology, equity and economy and is essentially consistent but more actionable on a project scale than the often quoted United Nations 1987 Brundtland Commission report excerpt: "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[4] It is also compatible with the Millenium Ecosystem Assessment (www.millenniumassessment.org).

Beyond *ecology*, *equity* and *economy* we believe there are four other essential components to a sustainability definition. First, sustainability is context sensitive. Hence, for a particular project, the project's *extent* in space and time (i.e., its scope and life cycle) and performance *expectations* (i.e., design life, metrics of performance, and assessment of risks and unintended consequences) must be part of the definition. Second, sustainable solutions generally involve integration of past information (e.g., lessons learned, performance of similar infrastructure) and experts from diverse fields. Thus, *experience*, both in the form of history and expertise, becomes part of the definition. Finally, if the concept of sustainability is to cause a paradigm shift in individual, community and societal behavior then it must include an education component. It is not enough to believe that the idea will self-propagate; we

[2] These principals were originally developed as part of K-H. Robèrt's *The Natural Step*. (2002).
[3] Hawken, P.; Lovins, A.B. and Lovins, L.H. *Natural Capitalism*, Little, Brown, 1999.
[4] A/RES/42/187

feel *exposure* of the engineering community and, more broadly, society to the sustainability concept and its importance is instrumental in causing this paradigm shift. In total, our sustainability definition has seven components: ecology, equity, economy, extent, expectations, experience and exposure.

RESOURCES

Any roadway project will involve the consumption or use of resources. These resources are a further breakdown of the "ecology" component in the "sustainability" definition. This list of resources can be mapped to each credit so that projects may then choose to pursue certain credits based on the resources they value most highly within the "ecology" component. For instance, a national park may value virgin space quite highly and choose to pursue related credits. Resources are broken down as follows:

- **Natural resources**. Those that are fundamental to life on earth and that can be used, polluted or conserved. While other items (e.g., sunlight) could be logically included here they are not as air, water and earth tend to be the material resources we control and regulate.
    - *Air*. The atmosphere in general but especially those components that affect human life (e.g., air pollution) and climate change (e.g., greenhouse gases).
    - *Water*. All forms of water but especially water that supports life (e.g., drinking, agriculture, aquatic life).
    - *Earth*. Includes soil, rock, minerals and other materials from these items.
- **Space**. Space on earth is finite and, at any particular point in time, fully allocated. Space is subdivided into virgin and developed to distinguish its use by humans.
    - *Virgin*. Space without significant human infrastructure. Virgin space can be conserved or protected by law.
    - *Developed*. Space with significant human infrastructure.
- **Energy**. Taking existing resources and fashioning infrastructure requires energy input. "Energy", as defined here, is created from either renewable or non-renewable sources.
    - *Renewable*. Energy derived from sources that can be replenished quickly on a human time scale. Examples are solar, wind and geothermal.
    - *Non-renewable*. Energy derived from sources that cannot be replenished quickly on a human time scale. Examples are oil, natural gas and coal.
- **Life**. Items on the earth that are considered to be living. A distinction is made between human and non-human life because the idea of sustainability is itself a human construct and, as such, extra emphasis (intended or not) is placed on human life.
    - *Non-human*. Includes plants, animals, and lesser known kingdoms such as fungi, protista and monera.
    - *Human*. Only includes human beings.

TRACING GREENROADS CREDITS TO SUSTAINABILITY AND RESOURCES

Each Greenroads Project Requirement and Voluntary Credit can be traced back to at least one relevant sustainability component and, if ecology is one of those components, at least one ecological resource; most can be traced to several. We call this "mapping", and believe it is important because it provides the basis by which a Greenroads Project Requirement or Voluntary Credit can be considered to contribute to "sustainability" as Greenroads defines the term. This mapping involves subjective judgment as to which components and which resources map to which items. While elimination of this

subjectivity would be ideal, more complex systems for mapping would likely just obfuscate rather than eliminate this subjectivity.

Further, mapping of an item back to sustainability and its seven components must, where at all practical, be done using empirical evidence with proper citations. The goal is to create a metric where each Project Requirement and Voluntary Credit is, to the extent possible, shown through existing research to have an impact on sustainability.

This mapping can assist in selecting Voluntary Credits to pursue based on user values because it is generally simpler to quantify physical and monetary resources than it is to quantify philosophical constructs. The nature of sustainability requires users to make trade-offs between different aspects of sustainability. For instance, one might have to select between using recycled material that must be trucked over a long distance or using locally provided virgin material. Both concepts (recycled material, local material) relate to sustainability (e.g., ecology and economy) however only one can be chosen. Decisions regarding these types of trade-offs are likely to be at least partly, if not wholly, based on the values held by a project, which is a conglomeration of values held by its stakeholders, owners, designers and constructors. Since these values are not likely to be identical between projects, over time or between stakeholders, one predetermined set of values included in a performance metric is probably not wise. Rather, Greenroads allows users to choose from a long list of Voluntary Credits based on their values. Mapping to sustainability components is done because users may find it more straightforward to choose between resources rather than Greenroads Voluntary Credits. For instance, it may be difficult to choose between warm mix asphalt and porous pavement unless a technical expert is consulted to fully explain each item. However, it may be easier to choose between clean water and energy conservation; concepts that are more familiar to the lay person.

WEIGHTING VOLUNTARY CREDITS

The overall goal of weighting is to make each Voluntary Credit's point value commensurate with its impact on sustainability. This cannot be achieved by a strictly objective or empirical approach because:

- Some sustainability components are difficult to directly compare because there is no generally accepted metric of comparison (e.g., comparing scenic views to stormwater treatment).
- Traditionally accepted quantitative methods, e.g., life cycle assessment (LCA), life cycle cost analysis (LCCA), benefit-cost analysis, do not adequately address all sustainability components.
- Greenroads is designed to function as a supplement to current U.S. regulations. Therefore, some areas that might otherwise have been heavily weighted receive less emphasis in Greenroads because current U.S. regulation already requires many mandatory actions leaving little room for supplemental voluntary actions.
- There are some actions for which the direct impact on sustainability may be difficult or impossible to measure, however their execution may provide valuable information on which to base future decisions.

Weighting follows the general framework described here. As a beginning point, we established a minimum value of one point and a maximum value of five points. This range allows weights to reflect a range of sustainability impact but limits the impact of potential missteps. Individual construction activities during initial construction have the lowest impact (see discussion later) on sustainability so we start by assigning these Voluntary Credits one point each. From here Voluntary Credit point values are

modified based on the logic presented next. Importantly, weights are based on the relationship of their associated prevailing broad concepts while the actual level of achievement necessary to qualify for a Voluntary Credit is based on an assessment of what is practically achievable given current technology and practice. The goal is to make the level of achievement beyond current practice but enticingly attainable using current technology. Using this logic, it follows that as the industry's sustainability savvy grows and technology advances VC requirements must change. The following sections discuss weighting system details.

Ecology weighting. While it is difficult to place a value on ecosystem services, some researchers have tried. One effort[5] valued them at US$16 -54 trillion/yr with a mean of US$33 trillion/yr for 17 ecosystem services (in 1994 US dollars). This compares to a world gross national product (GNP) of US$18 trillion (1994 US dollars) making ecosystem services about 1.8 times the global GNP if the mean value is assumed. This effort acknowledges that the estimate is on the low side, incomplete and flawed but reason that some estimate is better than none. Based on this, we estimate the value of ecosystems as about three times the value of human economic systems (represented by the baseline value of one point) for the purposes of weighting Voluntary Credits. This uses the high end estimate (US$54 trillion) to at least partially account for their admitted underestimation. From this, we assign EW-2, EW-3, EW-5, EW-6, EW-7, EW-8 and PT-2 three points each because they are primarily concerned with ecosystem services.

Equity weighting. Equity, as it is reflected in Greenroads can primarily be addressed by portions of what is commonly called context sensitive design (CSD) or context sensitive solutions (CSS). To our knowledge, nobody has attempted to place a monetary value on CSD/CSS however, there is substantial evidence suggesting that it has come to be viewed as an important if not the essential component in U.S. roadway design over the last decade. While CSD/CSS also includes ecological elements, its strength lies in its approach to identifying and involving stakeholders and reflecting community values in a project (the equity component of sustainability). It does not contain significant guidance on ecological specifics but rather a framework in which to consider them. While CSD/CSS provides evidence of equity's importance it does not provide any insight regarding its level of importance in relation to other sustainability components. In fact, it argues that such value is context sensitive. We believe that the U.S. move towards CSD/CSS and its emphasis on a collaborative community-based approach to design (versus a strictly low-cost standards-based approach) shows that equity issues ought to be valued more than the minimum of one point. As a first-order approximation, we assign equity Voluntary Credits two points. Based on this we assign AE-1, AE-5, AE-6, AE-8, AE-9 two points each because they are primarily concerned with equity issues. We assign AE-4 the maximum of five points because it actually gives credit for a CSD/CSS approach, while the other AE Voluntary Credits address outcomes of a CSD/CSS approach.

Incentive-based weighting. Some Voluntary Credits are assigned additional points to provide incentive to collect data, undertake organization-wide efforts and obtain high achievement levels. The following Voluntary Credits use incentive-based weighting: EW-1, CA-1, CA-4, CA-5, CA-7, CA-8, MR-1, MR-4 and MR-5.

[5] Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. *Nat.*, 387, 253-260.

Life cycle assessment (LCA)-based weighting. For Voluntary Credits dealing with materials production, construction, transportation associated with the construction process and traffic use, weighting is based on LCA results to the greatest possible extent. Since Greenroads is meant to apply to any roadway project, LCA results specific to a particular project cannot be used alone because they are project-specific and not entirely transferrable. However, examining a range of specific LCAs may provide insight into some general trends that could be used to weight Voluntary Credits. We identified 12 roadway LCA peer-reviewed journal papers consisting of 43 assessments of either actual or hypothetical roadways (we are publishing paper on these findings so the details are not available here). Five papers addressed PCC pavements (10 assessments), while all 12 address HMA pavements (34 assessments). Some general trends observed were:

- Energy use and emissions for construction followed the same basic trends in most studies. Roughly, these were:
  - Materials production has 20 times the impact of construction.
  - Transportation has 9 times the impact of construction.
  - Maintenance has 1/3 the impact of initial construction.
- For the one study that quantified them, roadway operations (e.g., lighting, signals, etc.) over 40 years had about the same energy use as all construction activities (initial construction plus maintenance).
- For the two studies that related them, the energy expended in initial construction of a new roadway is roughly equivalent to the energy used by traffic on the facility over 1-2 years.

Based on these ideas, the following weighting is used:

- Operations vs. construction: MR-6 is assigned 5 points.
- Traffic use vs. initial construction: AE-2, AE-3, and AE-7 as assigned 5 points each.
- Transportation associated with construction: MR-5 is assigned 5 points.
- Materials production: MR-2 and MR-4 are assigned 5 points each. MR-3 is assigned 1 point and PT-3 is assigned 3 points.

Noise-based weighting. One study[6] investigated different monetization approaches for the health impacts from road noise. From their work we assign noise one-third the impact of traffic-related emissions. Since tire-pavement noise is the predominant source or road noise above about 50 km/hr (for automobiles) a change in tire-pavement noise resulting from so-called "quieter pavement" use is about one-third as impactful as actions resulting in traffic-related emissions reduction. Noise reduction characteristics of quieter pavements tend to diminish over time. PT-5 is assigned 2 points.

Urban heat island (UHI) effects. The UHI effect is "…a measurable increase in ambient urban air temperatures resulting primarily from the replacement of vegetation with buildings, roads, and other heat-absorbing infrastructure."[7].UHI can impact sustainability by increasing energy consumption, and related emissions and affecting human health and water quality. Based on research from the Lawrence

[6] Hofstetter, P., Müller-Wenk, R., 2005. Monetization of health damages from road noise with implications for monetizing health impacts in life cycle assessment. *J. of Clean. Production* 13, 1235-1245.
[7] U.S. Environmental Protection Agency (EPA). *Heat Island Effect* website. [http://www.epa.gov/hiri] Accessed 9 June 2009.

Berkeley National Laboratory[8] a gross approximation is that road pavements constitute about one-quarter the total surface area contributing to the UHI. From this PT-4 is assigned 5 points.

Long-life pavement weighting. Long life pavement generally results in lower life cycle costs, less material and fewer traffic interruptions over the life cycle of a pavement. While more work needs to be done in quantifying these reductions, a value for PT-1 can be attempted by drawing the link between less material and fewer traffic interruptions to less energy and lower emissions. PT-1 is assigned 5 points.

Why Pavements Seem to be Emphasized

According to the Bureau of Transportation Statistics (BTS), "Highways and streets are the largest component of public transportation infrastructure spending. Pavement is by far the largest part of that spending, accounting for about 70 percent of state and local roadway expenditures."[9] Because pavements and their supporting structure make up a majority of roadway infrastructure cost and materials quantities, they should be given commensurate attention. Also, while items such as highway runoff, safety and the environment are closely regulated (and thus, there are comparatively fewer opportunities for Voluntary Credit points), items like materials use are less regulated (and tend to be governed more by specification) and thus have comparatively more opportunities for Voluntary Credit points. Thus, there is a category devoted to pavement technologies in addition to the Materials and Resources category.

FUTURE CHANGES

Greenroads will change in the future as more information is gathered and new industry standard practices/rules are developed. This means that new credits could be added, old ones removed, point values changed, certification levels adjusted and more. No matter what the current Greenroads version is, we are already working on the next. Therefore, user comments are welcomed and might very well be incorporated into the next version.

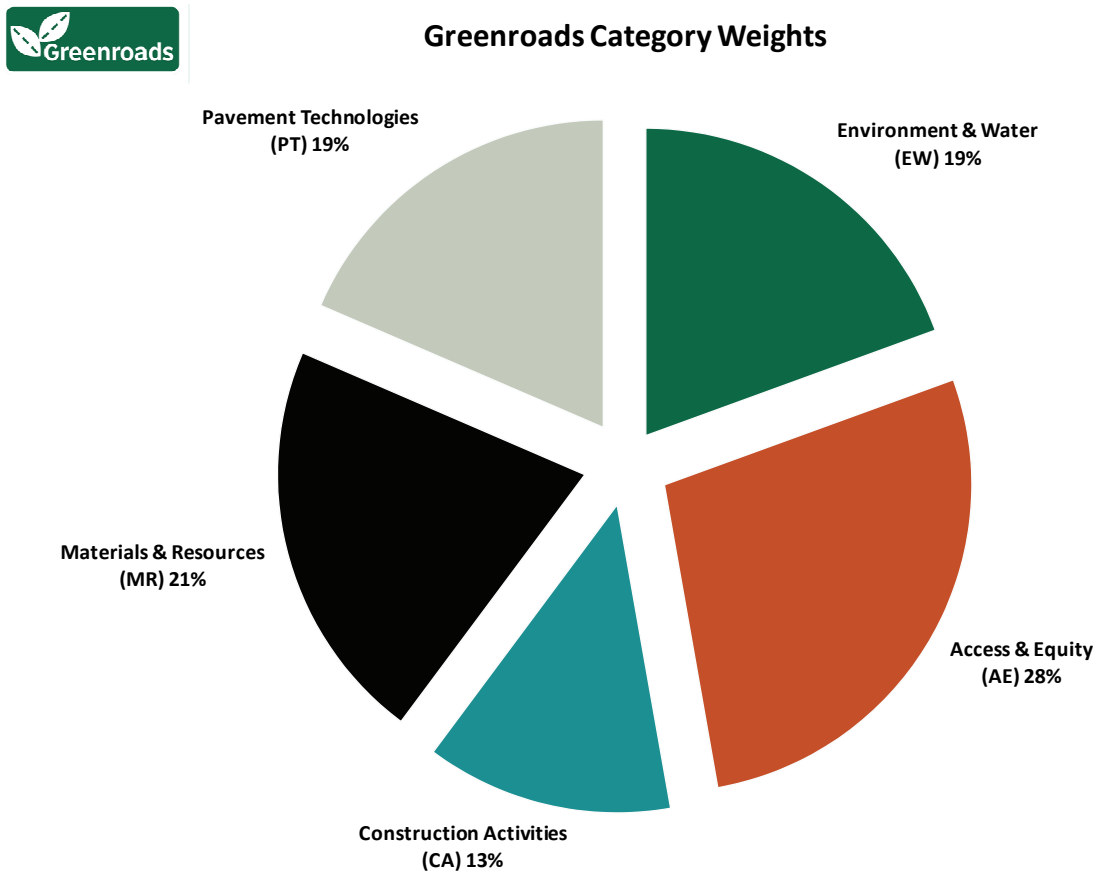
[8] Rose, L.S., H. Akbari, and H. Taha. 2003. Characterizing the Fabric of the Urban Environment: A Case Study of Greater Houston, Texas. Paper LBNL-51448. Lawrence Berkeley National Laboratory, Berkeley, CA.

[9] Bureau of Transportation Statistics, Transportation Statistics Annual Report 2007.Table G-8: Public Expenditures on Construction of Highways and Streets: January 2006-May 2007. http://www.bts.gov/publications/transportation_statistics_annual_report/2007/html/chapter_02/table_g_08.html. Accessed 2 February 2009.

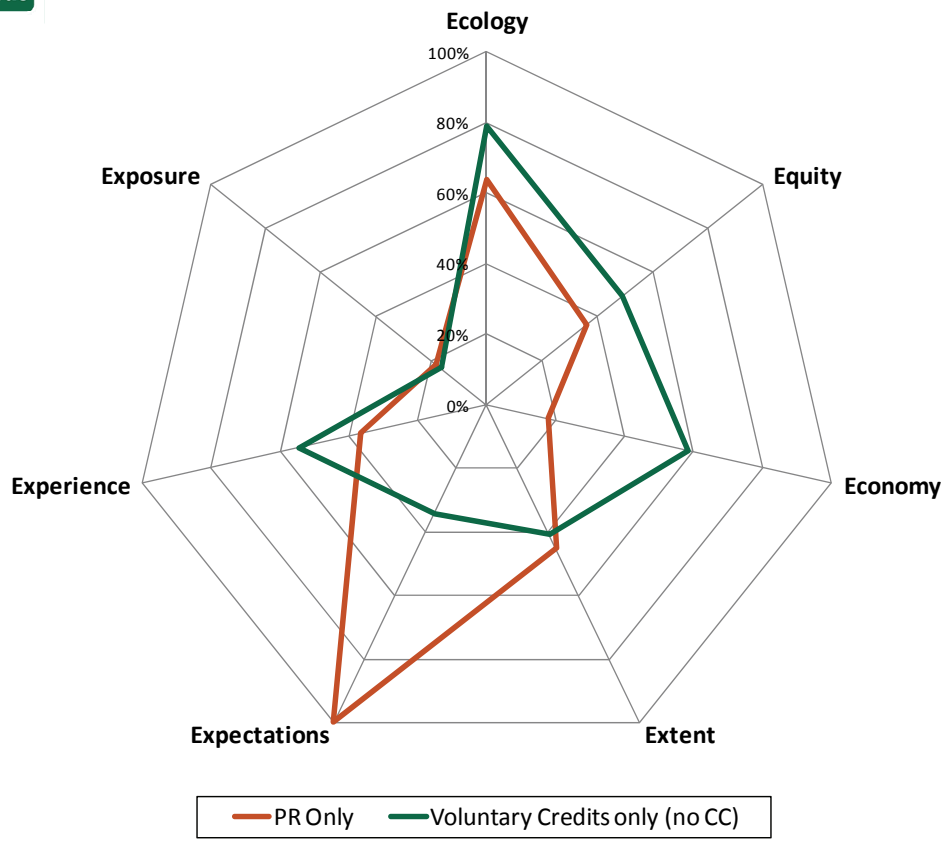
LISTING OF VERSION 1.0 CREDITS

No.	Title	Points	Brief Description
Project Requirements (PR)			
PR-1	NEPA Compliance	Req	Conform to NEPA or equivalent
PR-2	Life Cycle Cost Analysis (LCCA)	Req	Perform LCCA for pavement section
PR-3	Life Cycle Inventory (LCI)	Req	Perform LCI of pavement section with computer tool
PR-4	Quality Control Plan	Req	Have a formal contractor quality control plan
PR-5	Noise Mitigation Plan	Req	Have a construction noise mitigation plan
PR-6	Waste Management Plan	Req	Have a formal plan to divert C&D waste from landfill
PR-7	Pollution Prevention Plan	Req	Have a TESC/SWPPP
PR-8	Low-Impact Development (LID)	Req	Use LID stormwater management where applicable
PR-9	Pavement Maintenance	Req	Have a pavement preservation system
PR-10	Site Maintenance	Req	Have a plan for maintaining the site (e.g., landscape, etc.)
PR-11	Educational Outreach	Req	Publicize sustainability information for project
Environment & Water (EW)			
EW-1	Environmental Management System	2	Obtain ISO 14001 certification for general contractor
EW-2	Runoff Quantity	3	Capture stormwater or otherwise reduce runoff quantity
EW-3	Runoff Quality	3	Treat stormwater to a higher level of quality
EW-4	LID/BMP Cost Analysis	1	Conduct an LCCA for stormwater BMP/LID selection
EW-5	Native Revegetation	3	Use native low/no water vegetation
EW-6	Habitat Restoration	3	Create new habitat beyond what is required
EW-7	Ecological Connectivity	3	Connect habitat across roadways (fish/wildlife passage)
EW-8	Light Pollution	3	Discourage light pollution
	EW Subtotal:	**21**	
Access & Equity (AE)			
AE-1	Safety Audit	2	Perform roadway safety audit
AE-2	Intelligent Transportation Systems (ITS)	5	Implement ITS solutions
AE-3	Single-Occupant Vehicle (SOV) Reduction	5	Reduce SOV travelers through quantifiable methods
AE-4	Context Sensitive Planning	5	Plan for context sensitive solutions (Req'd for AE-5 to AE-9)
AE-5	Pedestrian Access	2	Provide/improve pedestrian accessibility
AE-6	Bicycle Access	2	Provide/improve bicycle accessibility
AE-7	Transit Access	5	Provide/improve transit accessibility
AE-8	Scenic Views	2	Provide views of scenery or vistas
AE-9	Cultural Outreach	2	Promote art/culture/community values along roadway
	AE Subtotal:	**30**	
Construction Activities (CA)			
CA-1	Quality Process Management	2	Obtain ISO 9001 certification for general contractor
CA-2	Environmental Awareness Training	1	Provide environmental training
CA-3	On-Site Recycling Plan	1	Provide plan for on-site recycling and trash collection
CA-4	Fossil Fuel Use Reduction	2	Use alternative fuels in construction equipment
CA-5	Equipment Emission Reduction	2	Meet EPA Tier 4 standards for non-road equipment
CA-6	Paving Emission Reduction	1	Use pavers that meet NIOSH requirements
CA-7	Water Use Monitoring	2	Develop data on water use in construction
CA-8	Performance-Based Warranty	3	Warranty on the constructed pavement
	CA Subtotal:	**14**	
Materials & Resources (MR)			
MR-1	Full Life Cycle Assessment (LCA)	2	Conduct a detailed LCA of the entire project
MR-2	Pavement Reuse	5	Reuse existing pavement sections
MR-3	Soil Rehabilitation	1	Use native soil rather than import fill
MR-4	Recycled Materials	5	Use recycled materials for new pavement
MR-5	Regional Materials	5	Use regional materials to reduce effects of transportation
MR-6	Energy Efficiency	5	Improve energy efficiency of operational systems
	MR Subtotal:	**23**	
Pavement Technologies (PT)			
PT-1	Long-Life Pavement	5	Design pavements for long-life
PT-2	Permeable Pavement	3	Use permeable pavement as a LID technique
PT-3	Warm Mix Asphalt (WMA)	3	Use WMA in place of HMA
PT-4	Cool Pavement	5	Contribute less to urban heat island effect (UHI)
PT-5	Quiet Pavement	3	Use a quiet pavement to reduce tire-pavement noise
PT-6	Pavement Performance Monitoring	1	Relate construction to performance data
	PT Subtotal:	**20**	
Custom Credits (CC)			
CC-1	Custom Credits	10	Design your own credit
	CC Subtotal:	**10**	
	Greenroads Total:	**118**	

GRAPHS AND CHARTS



Graph showing the distribution of Voluntary Credit points (by percentage of the total) in each of the 5 categories.



Spider graph showing the percentage of Project Requirements and Voluntary Credit points (not including any Custom Credits) that can be traced to each of the seven components of sustainability as defined by Greenroads. Note that most Project Requirements and Voluntary Credits can be traced to more than one component.

An example of how to read this graph: The sustainability component “ecology” shows that 80% of the Voluntary Credit points and 63% of the Project Requirements can be traced back to it.