Topographic Mapping of the CU Campus for Sustainability

February 1, 2010

Abstract

The purpose of this proposal is to supplement the future decision making capabilities of the Environmental Center, the Energy and Climate Revolving Fund, and similar environmental funding sources in conducting cost-benefit analysis for funding of environmental projects on campus by purchasing and creating an accurate three dimensional data set of campus. This will be useful and effective in evaluating solar projects[1] both in terms of repayment time, and in evaluating aesthetic impact on campus. This proposal has the added benefit of being able to integrate existing georeferenced data-sets for other environmental or outreach applications, and could be further processed for additional planning purposes. These other applications could include outreach and education though cartograms[2] and dynamic maps, hydrology modeling, and architectural modeling for new and remodeled buildings.

Light Detection and Ranging (LiDAR) is an aerial remote sensing technique that produces a high number of georeferenced points in three-dimensional space.[3] Processed LiDAR data would provide topographical information showing the footprints and heights of buildings and trees. By gathering a data-set for the entire campus, the need for individual on-site and per project solar evaluation is eliminated—this is because rooftop footprints are extracted to vector form and combined with slope and aspect attribute data to provide solar radiance estimates campus wide year round. By incorporating the data set in to a Geographic Information System (GIS), multiple criteria, such as energy output and visibility impact, can be weighted and analyzed concurrently when planning projects. In addition, data gathered from East Campus and South Campus will have substantial value in planning new building and future expansion.

[1] Photovoltaic (KW/hour) and heated water (W/m^2).

[2] Cartograms are maps where objects are scaled according to some attribute; examples include states that show their populations determining the area of the state, or buildings with their size scaled according to total energy usage or efficiency.

[3] Accuracies for urban applications are around 10cm absolute and 3-5cm relative, which enables the equivalent of half-foot contours.

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1 Project Description

The aim of this project is to conduct topographic modeling for the purpose of urban planning with an emphasis on sustainability. There are many environmental planning applications that can be analyzed with topographic data, the specific focus of this study is to evaluate solar potential on campus. The reason for this focus is motivated by the large cost that is associated with the production of energy. These costs are economic, social and environmental, and for these reasons, the primary aim of this assessment is on the supply and production side of campus energy usage. This approach is necessitated by the broad success of the Blueprint for Change in addressing much of the demand issues associated with energy efficiency and conservation.[4]

CU Boulder is comprised of three campuses totaling over 1000 acres with almost 200 buildings. The majority of the buildings, and 600 acres of land, reside

[4]http://ecenter.colorado.edu/blueprint06/

on the Main Campus along with all of the student administered cost centers. While students are concerned first and foremost with the sustainability of the buildings directly under their control, any plan for sustainable development must take into account the whole of campus. When considering the addition of the capital construction fee and the corresponding financial stake students now have in capital construction projects, students currently lack a robust method for ensuring that new buildings meet, from the initial planning phase onward, the sustainable criteria imposed by that fee.

There are highly practical reasons to evaluate the campus as a whole. The marginal cost of data collection falls with increased scope, and a complete data set is easier to maintain and update then one patched together piecemeal. Project planning and feasibility studies costs thousands to evaluate a single project, and unless other studies are conducted or already exist, there is often no metric for comparing project cost once the studies are complete. By implementing a campus wide analysis, individual feasibility studies may be unnecessary in many cases, and when they are needed will have an associated context, resulting in cost savings for CU as a whole.

This focus on a campus wide analysis precludes acquiring data with ground based measurements. The remaining alternatives are aerial and satellite data. Satellite data is significantly cheaper then aerial data in acquisition, but suffers from two difficulties; much higher cost of processing and comparatively low resolution. Aerial data, specifically LiDAR, has a lower processing cost and a higher resolution, allowing for bare earth assessments and the extraction of planar geometry from roof structures. Given the primary application of this project, LiDAR data best meets the requirements of this proposal in terms of cost, feasibility and applicability. It should be noted that while the focus of this project is specifically roof modeling and view-shed analysis, any data acquired from this project could be reprocessed concurrent with other needs to be used in a wide variety of environmental initiatives.[5]

2 Project Phases

This project is composed of three distinct phases; data acquisition, data analysis and community outreach.

2.1 Data Acquisition

The first phase, data acquisition, will compose the bulk of the funding request, and will require the least amount of time. Three sources of LiDAR data were considered for this project: Merrick and Company, Sanborn, and NCALM.[6]

[5] View-shed analysis determines every point or area that can be seen by line of sight from a given point or area. This enables quantification of aesthetics by knowing what is visible from where, and to what proportion of campus.

[6] See section 5 for contact information.

Sanborn and Merrick and Company are both for profit geospatial companies while NCALM is an NSF supported research group.

2.1.1 Scope

Given the high initial cost and the low marginal cost, the spatial extent of data collection would include all of Main Campus, East Campus, South Campus, as well as the whole of family housing, including the Bear Creek Apartments. Most firms offer additional data analysis for the data that they collect, with the primary advantage of a fast analysis turnaround. The disadvantage of company bid data analysis is that cost for specialized analysis is comparable to that of data collection, and the capacity for future analysis is greatly restricted. Given the additional cost and decreased flexibility, the scope of the hired geospatial company will be limited to that of a data provider, not that of an analyst.

2.1.2 Timeline

Data acquisition with LiDAR is very fast. The whole spatial extent described above would be captured in a half day. There would be some additional time needed to do basic preprocessing,[7] but the data needed for analysis would be available within a week of the acquisition. Availability of flight dates range from March to May, depending on the company. At the earliest, LiDAR data would be available within the first two weeks of March, but at the latest flights would occur during the second week May. A firm deliverable date of a three dimensional georeferenced point cloud would be prior to June.

2.1.3 Feasibility and Cost

Data collection costs are determined by setup and correction costs, transport cost, and time to capture cost. Per hour rates of planes cost in excess of $800-$1,200 an hour, but given the rate of data collection, the speed of the planes and the size of the area to be surveyed, we can expect less then four hours of flight time. Initial setup cost will range from $7,000 to $8,000. The remainder of the cost consist of correction costs for the gathered data, and any associated transport cost. Sanborn was able to give the most complete bid, an estimate of $12,000 - $15,000 with a guaranteed price cap to not exceed $18,000. Merrick and Company supplied a similar bid, an estimate of $15,000 - $18,000, but was unable to commit to a price cap prior to preparing a flight plan. NCALM would potentially be $3,000 to $5,000 cheaper then Sanborn, as they have already been booked for a project at the CU Mountain Research Center on Niwot ridge. However, they accept funding from NSF for their projects, and their ability to accept funding from alternate grant sources is still under review.

Costs can be modified at the margins by changing the requested point density and flight lines, which will change the required number of hours for the flights. The above costs are the result of bids for georeferenced X, Y and Z coordinates,

[7] In this case, correction for the pitch, yaw and roll of the airplane.

with associated information on return number[8] and intensity at a density of 10 points per meter. This would be sufficient to do roof top extraction modeling and slope calculations, as well as view-shed, hydrology and other terrain modeling. If necessary, the density of points could be reduced to 5 - 7 points per meter and still accomplish most terrain modeling objectives. This reduction in density would reduce the flight time by 45 minutes to an hour, resulting in a savings equivalent to the corresponding hourly rate. This proposal is requesting $18,000 for the acquisition of the data set, based off of the lowest guaranteed project quote. This estimate, and the bids on which it is based, are consistent with previous aerial data collection costs for campus.[9] While actual acquisition costs may be significantly lower according to final flight plans and the availability of NCALM, the requested amount guarantees the feasibility of this project phase. Return of underutilized funds concurrent with lower flight costs in discussed specifically in section 4.5, Return of Funds.

2.2 Data Analysis

While the data acquired from the LiDAR flyover will be able to be analyzed in many different ways for years to come, the analysis that this project will conduct are defined below.

2.2.1 Scope

The scope of our analysis is limited to factors affecting the feasibility of on campus renewable energy projects. In talking with Moe Tabrizi it has become clear that energy potential is only one of several factors determining project precedence. Specifically, repayment on investment, visual impact to campus, and ability to take advantage of sustainable incentives all shape feasibility of proposed projects.[10] In addressing these factors, the data analysis will focus on visual impact assessment through view-shed analysis and on repayment on investment assessment through radiance analysis. In addressing these assessments buildings, vegetation, and pavement will be separated and classified. Buildings will further be separated into roof sections, that will then have attributes such as aspect and slope derived. This will allow for energy calculations of both whole buildings, and of individual roofs. View-shed analysis will be conducted at two scales; what can be seen within campus while close to the structure, and what can be seen from immediately off-campus, from roads, and from further vantage points. These three factors (radiance, close visual impact, far visual

[8] This allows for vegetation height to be modeled, and buildings to be differentiated by examining pulse separation.

[9] Specifically, these cost estimates match the actual cost of acquiring thermal imagery for all of campus, which Moe Tabrizi commissioned in a previous sustainability project to map heat loss.

[10] Additional information on the ability to take advantage of sustainable incentives is detailed in the Wolf Law proposal for solar energy, http://ecenter.colorado.edu/files/6d566095e2a2c1a884ea4ad5a9fd1595a9394111.doc

impact) will then be used to assess both campus at large and student administered buildings. To ensure feasibility, the data set will be divided, with Main Campus being assessed first.

2.2.2 Timeline

Data analysis will occur over May-August 2010, with analysis being finished and results submitted no later then the second week in September. Some of the algorithms needed to process the data will be written prior to the data acquisition during the second half of spring semester 2010. The view-shed analysis is programmatically and mathematically simple, however, given the size of the data set, the computing time needed to process the analysis will take weeks.[11] The classification and isolation of buildings and individual roof features, with their associated attributes, will be more difficult to program, but will be computationally easier; I estimate a month of programming followed by a day or two of time to run the model. The data analysis of Main Campus should take two and a half months to three months assuming a mean of 20 hours of work a week. Allowing for delays and assuming a late delivery of data (second week in May), 16 weeks, or roughly 340 hours, are budgeted for data analysis.

2.2.3 Feasibility and Cost

Given our scope, the project appears entirely reasonable for the given timeline. Specific deliverables from the analysis portion will include a report on the campus potential for solar power consistent with preserving aesthetic values, maps of roofs scaled to show capacity potential, maps of roofs scaled to show both close and far visibility, a composite map showing main campus recommendations, and a report specifically addressing the student administered cost centers. In addition, the data that was used for these deliverables will be available as well. The principle investigator has experience with programming, cartography, GIS, remote sensing and image interpretation, and is qualified to conduct the analysis. In an effort to reduce the cost of this proposal to the E-Center, a separate funding request for $2400 will be submitted to UROP to cover most of the data analysis portion of this project. A supplemental $1200 is requested from the E-Center to to complete the data analysis ($600) and insure data integrity through the purchase of backup disks ($600).

2.3 Community Outreach

2.3.1 Scope

The largest portion of community outreach involves making data analysis from the project available to the campus. One deliverable will be a web portal making available both the maps and the report findings to the public. The availability of all purchased and processed data to the campus as whole is fundamental to

[11] Computations will occur on campus in the Meridian Visualization and Modeling Lab.

nature of the project and the empowerment of students to plan the next round of sustainable initiatives. While all the data may not be able to be posted for direct download, it is key that the availability of this data is publicly known and advertised.[12] Toward this end, presentations will be given during the first half of the fall semester 2010 describing our findings and the availability of our data.[13] The addition of data from Facilities Management will enable cartograms and other visual aids showing energy usage and efficiency of campus at its best and worst. Thus, both potential renewable and current conventional energy will be visualized and shown in an educational and outreach application.

2.3.2 Timeline

The specific deliverable of a web portal will coincide with the date for analysis delivery (section 2.2.2). Presentations will be given during fall semester 2010 prior to Thanksgiving.

2.3.3 Feasibility and Funding

A simple portal serving static files from data analysis, as well as printing charges for presentations is considered in the base request for community outreach. The base funding request for is $800, which is to be combined with the remaining balance of this grant after the LiDAR is acquired, capped at $3,200.[14] The total that is available will fundamentally decide the involvement and scope of the portal. If no funding remains after the LiDAR is collected, then the portal will consist of a static page with links to reports and map images. If the LiDAR comes in at $12,800 and there is $3,200 left for community outreach following a $2,000 return of funds, the scope of the portal increases. Things such as daily displays of the amount of energy hitting buildings on campus, or total energy use at a given time for a given building, are all possible to show in a dynamic portal. How much a user can interact instead of observe will be decided by the allotment left for a web portal.

3 Impact and Involvement

3.1 Environmental Impact & Social Equity

By approaching the Blue Print for Change from the supply side of energy, change is effected not only fiscally, but environmentally and morally. Almost all of the energy produced on campus comes from coal and natural gas. The most obvious and direct effect of these energy sources is in terms of the immediate pollution

[12] While not all data will be available directly from the web due to technical limitations of bandwidth and data set size, contact information and instructions for receiving data will be made explicit.

[13] Examples of presentations audiences include the E-Center, Legislative Council, the Environmental Studies Club, and any other student or administrative groups that are interested.

[14] Section 4.5, 'Return of Funds', will be instructive to the budgeting discussed here.

from burning. Pollution in general disproportionately effects minorities and economically disadvantaged people, with the production sites of energy often located in industrial low valued urban areas. In evaluating the cost of energy production, the costs associated with resource extraction and purification must be taken into account as well; the harmful practices of mining affects not only the environment from which they are extracted, but also has transportation costs and social consequences.

3.2 Student Impact & Involvement

The number of students which stand to benefit from this proposal is quite high. Projects that use information generated from this project will affect students in different ways for decades to come. Students living in dorms and housing projects will have lower carbon footprints. Student administered sites that utilize this information will directly lower their operating budgets, leading to reduced student fees or increased services. The access to information found from this study will affect student awareness about both energy usage in general and about energy usage on campus and alternative ways to address said usage. Students studying disciplines that focus on planning, GIS, remote sensing, or environmental studies, will have access to an excellent and familiar data set on which to hone their skills and advance their own projects. Student administrators involved in governance will have a set of evaluative tools by which to gauge projects, both for planning and for ensuring that the Blue Print for Change is being followed.

3.3 Innovation

Meeting carbon neutrality goals starts first and foremost with energy conservation, but to transition to a zero or less then zero carbon footprint, a shift is needed in energy production. As mentioned in section 2.2.1 (Data Analysis Scope), the factors that confront expanded on campus production of solar energy are not simply related to the amount of energy that can be produced. The factors also include the look of campus and the ability for CU to take advantage of incentives. Currently, the ability of CU to take advantage of incentives is low. This is due to both the cut in subsidies from XCEL and the status of the University as a nonprofit entity that cannot directly take advantage from any tax breaks that sustainable practices may be eligible for. One solution to this problem is to start thinking of solar energy beyond simple PV cells. Heated water systems are much cheaper to install and most of CU already has the pipe infrastructure to support building heating and hot water delivery. Buildings which provide domestic utilities such as dishwashers, showers and on-site food production may have more of their energy needs being filled by gas boilers than electricity. When evaluating solar renewable energy solutions for these buildings, it is valuable to have an estimate of the total heating energy that can potentially be shifted off of current heating systems. By knowing the total radiance and area of project site, we can evaluate the site in terms of solar heating systems in addition to PV cells. Then we can balance and weigh competing factors in evaluating solar projects, including factors such as visibility and aesthetic impact.

3.4 Project Longevity

While our goal for this project is urban modeling, it is important to realize that many other types of modeling are available. Topographic, biomass, hydrology, architectural planning, and many other applications would be able to process the data obtained for useful analysis of other sustainability projects. In addition, South Campus would be well modeled for future planning projects.

4 Budget

4.1 Cost

The requested funds from sustainable CU for this project are $20,000. These funds will be used to acquire a data set for environmental modeling, specifically urban modeling with a focus on planning solar projects. The bids submitted for data acquisition range from $12,000 to $18,000 and are consistent with previous flyovers of campus. Any funds which are not utilized in the purchase and maintenance of a data set will be allocated to increase the community outreach budget consistent with the Return of Funds policy, leading to a more interactive and dynamic view of energy use on campus. Matching funding for data analysis, as described below, will be sought from UROP.

4.2 Matching Funds

The $20,000 requested from Sustainable CU will be supplemented by a request for funds from UROP for data analysis in the amount of $2,400. As UROP applications are due March 1st, funding has not yet been committed. A sponsor has been found for the UROP proposal, Professor of Geography Barbara P. Buttenfield. It should be noted that while UROP funding cannot be guaranteed, having a data set makes funding extremely likely.

4.3 In Kind Matching

In kind matching of data has been committed by Chris Anderson-Tarver. Chris is a Doctoral student at the University in the Meridian Visualization and Modeling Lab, and has a two dimensional data set of building footprints, bike paths, walkways, and bike racks for Main Campus from 2004. This information will be of great use in checking and registering our analysis as well as conducting our community outreach. In addition, in kind matching is currently being explored with Facilities Management. Phil Martin is the CAD Manger at the CAD/GIS and Document Management Office, and has expressed interest in collaborating. Creating a Geographic Information System (GIS) for Facilities Management is the newest effort of the Document Management Office, and they are currently in the process of gathering field data and information for utilization in campus graphics and databases.[15] In addition to CAD data, thermal infrared imagery of heat loss and data on campus energy usage is managed by Facilities Management. The addition of energy usage data from them would add a great deal of value to sustainability analysis. Another potential source of in kind funding is Geoeye, a company that provides high resolution satellite imagery. The Geoeye Foundation has an interest in funding initiatives relating to climate change and the environment through data grants.[16] The addition of satellite imagery would ease the analysis by providing a descriptive reference, and would allow for much greater outreach and education through the web portal.

4.4 Budget Spreadsheet

	Unit Cost	# of Units	Total Cost	% Sustainable CU	% Project
Sustainable CU Grant	$20,000	-	$20,000	100%	89%
LiDAR Acquisition	$12,000 - $18,000	-	$18,000	90%	80%
Data Backup	$600	-	$600	3%	2.5%
Data Analysis	$9/hr	67 hours	$600	3%	2.5%
Community Outreach	$9/hr	89 hours	$800	4%	4%
UROP Data Analysis	$9/hr	266 hours	$2400	12% Equivalent	11%

4.5 Return of Funds

A substantial variance exists between the expected and guaranteed cost of data acquisition. In order to avoid having a project that is mostly funded but unable to proceed, funds are being requested that match the lowest guaranteed bid. In the probable event that data acquisition occurs significantly below the guaranteed bid, the following policy for return of funds is proposed. Unused funds from data acquisition are to be added to the community outreach budget in order to enhance the core mission of this proposal. This reallocation is capped at $3200, for a maximum community outreach budget of $4000. Should the unused funds exceed $3200, then 90% of the remaining balance will be immediately returned to the environmental center, with the remaining 10% returned on September 17th 2010. The held portion will be used only as contingency fund, with the express approval of the Chair of the UCSU Environmental Board. All funds which have not been used, regardless of original budget allocation, will be returned on September 17th 2010.

[15] See http://www.colorado.edu/facilitiesmanagement/pdc/cad/index.html
[16] http://www.geoeye.com/CorpSite/corporate/foundation/

5 Contacts

Primary Proposal Contact Person: Shane P. Grigsby, Geography Student. Staff Member of the Meridian Lab, Member of the Energy and Climate Revolving Fund Board.

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UROP Faculty Sponsor: Barbara P. Buttenfield, Professor Geography. Meridian Lab Director.

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