Final Urban Forest Carbon Protocol Outline

Urban Forestry GHG Protocols Drafting Team

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This document contains outlines for three sets of protocols:

1) Urban forest sector protocol is to be used by entities that own, control, or manage large numbers of urban trees (.e.g., cities, utilities, universities) and provides an overview of the tree population's carbon stocks and GHG emissions. This protocol focuses on carbon storage in trees, how the urban forest's carbon stocks will change over time. Indirect GHG emission reductions associated with energy savings from tree shade or bioenergy are reported by the entity in the General Reporting Protocol. This protocol is relevant to entities desiring to quantify entity-wide carbon stocks, and to entities engaging in urban forestry activities. In the later case, sector reporting makes it possible to determine if specific project activities could result in leakage. Leakage is defined as the displacement or substitution of activities from the project to non-project activities as a direct result of project activity. The purpose of the sector protocol is to provide standards and guidance for reporting GHG emissions and reductions for ALL trees owned, controlled or managed by the reporting entity.
2) Urban forest project protocol is to be used to quantify and report GHG reductions from specific project activities. Project activities should represent a change from the business-as-usual scenario, identified as a baseline scenario. Guidelines are presented for quantifying GHG reductions that are additional to the baseline, and would not have occurred without the project activity.
3) Urban forest certification protocol offers guidance on how to solicit and conduct third-party verification of reported GHG reductions.

We have attempted where possible to use the previously developed Forest Protocols (FP) as a template for the Urban Forest Protocols (UFP). The Forest Protocols are an appendix to the California Climate Action Registry's (CCAR's) General Reporting Protocol (GRP). Also, we refer to the Power/Utility Reporting Protocol. You can view and download these protocols from the CCAR web-site at: http://www.climateregistry.org/PROTOCOLS/.

Urban Forest Sector Protocol Outline

I. Key Terms

II. Intro

A. **About urban forests, carbon, climate change:** Role of trees in sequestering and emitting GHG. Special role of urban trees in reducing energy use from shading effects. Use of urban woody green waste (pruning refuse and removed trees) for products and bioenergy.

B. **Biological and nonbiological emissions and changes in stocks**
   1. Biological emissions are released directly from live or dead biomass; biological emission reductions relate to greenhouse gases captured in live or dead biomass.
      a. Carbon storage and wood products
   2. Nonbiological emissions are those not released directly from biomass and are covered in the GRP (e.g., fuel use for vehicles, chippers, chainsaws, etc. during tree maintenance). Nonbiological emission reductions relate to reductions in emissions from nonbiological sources, such as power production.
      a. Tree shade and bioenergy

C. **Direct and indirect emissions**
   1. Direct emissions are GHG emissions from sources that are owned or controlled by the reporting entity. For example, emissions associated with decomposition of wood from removed trees are direct emissions.
   2. Indirect emissions are a consequence of the actions of a reporting entity, but are produced by sources owned or controlled by another entity. An example is emissions associated with tree care activities performed by a private contractor working on city street trees, where the city is the reporting entity. Distinguishing between direct and indirect emission reductions is necessary to avoid double counting and in delineating possible ownership claims on emissions reductions. Reporting both types of emissions allows for a more comprehensive emissions profile.

D. **GHG reporting scope**

E. **Sector vs. project reporting:**
   1. Sector or entity reporting provides an overview of all of an organization’s emissions, both biological and nonbiological.
   2. Entities will use GRP for corporate-wide reporting
   3. Entities will use Urban Forest Sector Protocol for reporting GHG emissions and reductions for ALL trees they own, control or manage.
      a. Sector reporting quantifies carbon stocks from ALL trees for a base year and provides a baseline projection of reductions into the future assuming a business-as-usual scenario.
      b. Sector reporting provides a basis for assessing if leakage is occurring due to project-specific activity.
   4. Project reporting accounts for a planned set of activities to remove, reduce, or prevent CO_2 emissions in the atmosphere by conserving and/or increasing on-site urban forest carbon stocks within a defined geographic area. Urban forest projects may also

account for reduced GHG emissions from shading effects, reduced/delayed emissions from conversion to wood products, and displaced power emissions from bioenergy.

5. Reporters may opt out of entity level reporting if they can meet the following criterion:
   a. Prove that leakage will not take place for a project-specific activity.

F. Selecting urban forest vs. forest protocols

1. In Urbanized Areas (UA; min. 50,000 pop.) or Urban Clusters (UC; 2,500-50,000 pop.), as defined and mapped by the US Census Bureau (maps of Urbanized Areas are available here: http://www.census.gov/geo/www/maps/ua2kmaps.htm, and for Urban Clusters, here: http://www.census.gov/geo/www/maps/uc2kmaps.htm), with the exception of forested areas that are subject to the California Forest Practice Act: use UFP.

G. Certification of carbon stocks, biological and nonbiological emissions

1. Certification scope
2. Certifier criteria

H. Overview of the urban forest entity reporting process

I. Reporting deadlines

J. Protocol questions and comments

III. Geographic Boundaries

A. California-only or nationwide reporting

IV. Organizational Boundaries

A. Management control vs ownership (who reports/owns credits)

B. Examples

1. Municipal tree planting
2. University tree plan
3. Utility shade tree program

V. Operational Boundaries

A. Identify urban forest carbon pools

1. Direct emissions
   a. Storage
   b. Wood products
2. Required carbon pools
   a. Tree biomass (live)
   b. Wood products
3. Optional carbon pools
   a. Herbaceous understory and shrubs
   b. Dead tree biomass (standing or lying)
   c. Soil
   d. Litter and duff
   e. Carbon emissions associated with tree care activities

B. Examples

1. Municipal tree planting
2. University tree plan
3. Utility shade tree program

VI. Characterizing and Establishing an Entity-wide Baseline

Purpose – Entities may be responsible for thousands of urban trees in a variety of locations and maintenance regimes. The entity-wide baseline captures the magnitude of these carbon stocks for a selected base year and projects how these carbon stocks will change over the next 30-50 years, assuming business-as-usual (BAU) management practices.

A. Qualitative characterization of management practices

1. Written description of long-term objectives (30-50 years)
    a. Written description of management practices (e.g., levels of service by urban forest program area). Purpose here is not only to inform forecasting of the baseline, but provide a basis for assessing leakage from project activities. Information that describes levels of service for each program area, as well as productivity (trees planted/yr or pruning cycle) and investment ($/yr) can help determine if project activity results in redirection of resources. An example, is a new tree planting activity that results from a shift of existing resources from pruning to planting, rather than additional resources for tree planting.
    b. Planting rates (metrics = trees/yr, stocking level, $/yr from annual budget)
    c. Removal rates (metrics = trees/yr, removal rate, $/yr)
    d. Small tree care (metrics = trees/yr, pruning cycle, $/yr)
    e. Large tree care (metrics = trees/yr, pruning cycle, $/yr)
    f. Conflicts (metrics = trees/yr, conflict rate, $/yr)
    g. Wood utilization (metrics= trees/yr, reuse rate, $/yr)
    h. Program admin (metrics = $/yr/tree, $/yr)

B. Updating your baseline

C. Examples

1. Municipal tree planting
2. University tree plan
3. Utility shade tree program

VII. Quantifying Your Urban Forest Entity's Carbon Stocks, Emissions, and Baseline

A. Intro – Quantification requires an inventory of the reporting entity's tree population and carbon stock beginning at the base year and a long-term projection of future changes to the tree population and carbon stocks based on BAU management practices (i.e., anticipated tree growth, mortality, and planting). Annual changes in carbon stocks are projected from concomitant changes in the tree population.

B. A general physical description of the urban forest's structure

C. Summary of biological carbon pools to quantify in your entity urban forest area

D. Guidance on selecting a base year

1. 1990, corporate base year, date of most recent tree inventory

E. Determining carbon storage (biological or Scope 1 emissions)

1. About urban forest inventories and step-by-step approach

a. Complete inventory - records all of the volume or biomass
    i. Most appropriate when trees are not contiguous, such as street trees.
b. Sample inventory - requires measuring only a portion of the volume or biomass on the site. The data are used to estimate volume or biomass for the tree population
    i. Most appropriate when trees are contiguous, such as forested area within city or park trees.
    ii. Sampling methods (iTree)
c. Remote sensing and tree inventories
    i. Identify broadleaf, conifer, and palm tree types and measure each tree's crown projection area.
    ii. Estimate volume and biomass using general equations for each tree type.

2. Estimating carbon in trees from inventories and sample plots
3. Calculating the biomass density of dead wood
4. Estimating carbon in standing and lying dead-tree biomass (optional)
5. Biomass forecasting tables
6. Methods for calculating and forecasting amount of carbon in carbon pools

VIII. Certification

A. Intro
B. Rationale
C. References
D. Transparency
E. Overview of certification in project-level reporting
F. Certification cycle and direct sampling
G. Urban forest entity certification responsibilities

IX. Completing the Reporting Process

X. Annexes

A. Urban forest protocol entity process
B. Urban forest entity summary
C. Urban forest entity annual monitoring report
D. Comparison of entity and project reporting
E. References

Urban Forest Project Protocol Outline

I. Key Terms

II. Intro

- **A. About urban forests, carbon, climate change:** Role of trees in sequestering and emitting GHG. Special role of urban trees in reducing energy use from shading effects. Use of urban woody green waste (pruning refuse and removed trees) for products and bioenergy.
- **B. Project vs. entity reporting:**
  1. Sector or entity reporting provides overview of all of an organization's emissions, both biological and nonbiological.
  2. Entities will use GRP for corporate-wide reporting
  3. Entities will use Urban Forest Sector Protocol for reporting GHG emissions and reductions for ALL trees they own, control or manage.
     a. Sector reporting quantifies GHG reductions from ALL trees for a base year and provides a baseline projection of reductions into the future assuming a business-as –usual scenario
     b. Sector reporting provides a basis for assessing if leakage is occurring due to project-specific activity
  4. Project reporting accounts for a planned set of activities to remove, reduce, or prevent CO_2 emissions in the atmosphere by conserving and/or increasing on-site urban forest carbon stocks within a defined geographic area. Urban forest projects may also account for reduced GHG emissions from shading effects, reduced/delayed emissions from conversion to wood products, and displaced power emissions from bioenergy.
  5. Reporters may opt out of entity-level reporting if they can provide appropriate assurances that leakage will not take place for a project-specific activity.
- **C. Selecting urban forest vs. forest protocols.**
  1. In Urbanized Areas (UA; min. 50,000 pop.) or Urban Clusters (UC; 2,500-50,000 pop.), as defined and mapped by the US Census Bureau (maps of Urbanized Areas are available here: http://www.census.gov/geo/www/maps/ua2kmaps.htm, and for Urban Clusters, here: http://www.census.gov/geo/www/maps/uc2kmaps.htm), with the exception of forested areas that are subject to the California Forest Practice Act: use UFP
- **D. Certification of carbon stocks, biological and nonbiological emission reductions**
  1. Certification scope
  2. Certifier criteria
- **E. Overview of the urban forest project reporting process**
- **F. Reporting deadlines**
- **G. Protocol questions and comments**
- **H. Direct and indirect emissions**
  1. Direct emissions are GHG emissions from sources that are owned or controlled by the reporting entity. For example, emissions associated with tree care activities, such as pruning and removing/chipping trees, are direct emissions.

2. Indirect emissions are a consequence of the actions of a reporting entity, but are produced by sources owned or controlled by another entity. A shade tree project that influences building energy use and associated GHG emissions from a power plant owned by another entity effects indirect emissions.
3. Distinguishing between direct and indirect emission reductions is necessary to avoid double counting and in delineating possible ownership claims on emissions reductions. Reporting both allows for a more comprehensive emissions profile for a project.

I. Biological and nonbiological emissions

1. Biological emissions are released directly from live or dead biomass
2. Nonbiological emissions are those not released directly from biomass and are covered in the GRP (e.g., fuel use for vehicles, chippers, chainsaws, etc. during tree maintenance)

J. Reporting urban forest projects

1. Ownership, control, management and reporting
    a. If you are reporting an urban forestry project, your organization should own, control, or manage project trees. We recognize that issues of ownership, control and management of project trees are complex in urban areas. In this section it is important to clearly define the roles of each project participant for all aspects of the project:
        i. Project planning – who is primarily responsible
        ii. Project implementation – who is responsible for each task
        iii. Financing – who are investors and what is their contribution
        iv. Reporting – who will be reporting project activity
2. Reporting deadlines
    a. Reporting year. Jan 1 – Dec 31
    b. Reporting deadline. Aug 31 of year following reporting year
    c. Certification deadline. Dec 31 of year following reporting year
3. Overview of the reporting process
    a. Design project
    b. Optional project pre-screening process: to insure that projects meet accounting criteria
    c. Implement project
    d. Report project activity by end of first year
    e. Certify project activity after first year
    f. The following steps must be completed on an on-going basis
        i. Maintain project activity
        ii. Submit annual project monitoring reports
        iii. Perform certification at specified intervals
4. On-line reporting and transparency (CARROT: the Climate Action Registry Reporting Online Tool)

K. General information about the CCAR

L. Questions and comments

III. Urban Forest Projects Eligibility Criteria

A. Urban forest project types

1. **Carbon storage:** tree planting and maintenance to increase and prolong carbon storage in urban forest carbon pools. Tree planting increases stocking levels and associated biological storage of carbon. Appropriate tree care activities are critical to survival and growth that underpin long-term carbon storage in tree biomass. Conversion of urban woody green waste to saw timber, furniture and other products prolongs carbon storage.
2. **Tree shade:** tree planting and maintenance activities to reduce building energy use for cooling and heating, and thus reduce GHG emissions associated with power production. An example is strategic tree planting and maintenance for building shade.
3. **Bioenergy:** use of urban woody green waste (pruning refuse and removed trees) as feedstock for energy generation that displaces direct emissions from sources that emit GHGs and are owned by the reporting entity and not reported using the power/utility sector reporting protocol. Examples include small (<5MW) bioenergy plants owned and operated by universities or other entities that do not sell the power, but rather provide power for on-site users.

B. Location of projects: Currently California projects only

C. Ownership summary: Required to determine who is eligible to report the project and to enable any future external uses of the project (e.g., sale of credits, etc.)

D. Entity-wide inventory reporting:

1. Must report at entity level, using the GRP and Urban Forest Sector Protocol, for each year reports at Project level.

E. Long-term carbon security and environmental integrity. Carbon reductions and other co-benefits from urban forestry projects can be lost either temporarily or permanently if trees are disturbed or removed. Project design and management will influence the permanence of carbon benefits (e.g., initial selection of a diverse assemblage of well-adapted species, timely and professional tree care). To maximize future benefits and minimize the risk of loss, urban forestry projects must report the type of mechanisms instituted to promote long-term carbon security. Examples include:

1. Perpetual easement (permanently dedicates project area to urban forest use)
2. Other Agreements (written agreement, license agreement – both are revocable and not binding on future owners/managers, they can stipulate conditions of management)
3. Ordinances, codes/covenants/restrictions and enforcement (cities, counties, homeowner associations and other statutory authorities legally require and ensure that a project's existing and additional carbon stocks and reductions remain protected.

F. Co-benefits. Urban forest activities can have beneficial and adverse effects on environmental quality, human health, and social welfare. Activities that provide co-benefits in addition to atmospheric carbon reductions are encouraged. Examples include plantings that filter and reduce stormwater runoff, intercept air pollutants, and increase wildlife habitat. Activities that can have harmful effects are discouraged. Examples include tree plantings with species known to be invasive, tall-growing trees under powerlines, and species known to increase the threat of fire and air pollution.

IV. **Baseline and project forecast qualitative characterization**: The baseline forecast is a long-term projection of the carbon stocks and emission reductions that would have occurred (or the absence thereof) within a project's physical boundaries in the absence of the project. It serves as a basis for quantifying and forecasting additional carbon stocks and emission reductions due to project activities. The qualitative characterization of the baseline scenario will rely on performance standards that reflect regional best management practices.

A second forecast, called the Project Activity forecast, will quantify and forecast changes in carbon stocks and emission reductions due to project activities. Reductions are initially calculated as the difference between the Baseline and the Project Activity forecasts. In all cases, project activities must meet or exceed the applicable performance standards.

Urban forestry protocols require identification of Baselines and Project Activity forecasts for different types of projects. Different procedures are required to establish Baselines and quantify Project Activity for each type of urban forest project. For instance, a tree planting activity could require one set of Baseline and Project Activity forecasts for carbon storage, a second set that forecast reduced power plant emissions from tree shade effects on electricity used for air conditioning buildings, and a third set that forecast displaced power plant emissions from dead tree wood used as bioenergy.

A. **Temporal context**: choosing initiation date and duration; also need to identify the geographic context in which baseline characterization is assessed/developed, e.g., neighborhood, park, street, city, county; and need to give an indication of how long to expect the baseline projection to be, and how long projects will be valid, typically 30-50 years.
    1. Projects must be "current", that is two years prior to certification.
B. **Carbon storage projects:**
    1. Account for regulatory requirements for tree planting, care, and removal: for example, local ordinance may require planting one tree per lot in development.
    2. Identify the performance standards that best apply to this project activity in terms of:
        a. Type of project (i.e., carbon storage, tree shade, bioenergy)
        b. Type of entity responsible for reporting (i.e., city, utility, university, etc.)
        c. Scale and scope of the project activity (number of trees, partners involved)
        d. Describe relevant performance standards for items such as:
            i. Average annual planting rates
            ii. Establishment mortality rates
            iii. Post-establishment mortality rates
            iv. Replacement planting rates
            v. Tree wood utilization

Example A: A University of California campus wants to register a carbon storage project as part of their new 100 Year Tree Plan. The project will increase carbon stocks by planting 500 trees annually throughout developed parts of the campus and improving the level of tree care. The university has no regulatory requirement for tree planting or care. To develop the Baseline they must identify the performance standards that best apply to this type of project activity. After consulting with urban foresters at other universities they found that the appropriate performance standards are based on the following practices :

- Tree planting: 100 trees/year average
- Tree removals: 100 trees/year average
- Average annual establishment mortality rate: 5% for 5 years
- Average annual post-establishment mortality rate: 1%
- Tree wood utilization: 70% disposed of as mulch, 30% to landfill

2006 is selected as the base year. These performance standards will help them establish a reasonable Baseline forecast of urban forest population dynamics (tree numbers by species and dbh size classes over a 30-yr planning horizon) and associated carbon stocks for 2006 to 2035.

C. Tree shade projects:

1. The goal here is to project future emissions associated with building energy use for space heating and cooling. The baseline is a residential building with a typical amount of shade from surrounding buildings and trees. Buildings with more than one tree greater than 12 m tall (40 ft) located within 15 m (50 ft) of the east-, south-, or west-facing walls are considered "shaded" and ineligible for including in calculations of emission reductions from new tree planting.

   Account for regulatory requirements and regional best management practices that may influence energy savings and reduce GHG emissions. For example, local ordinance may require planting one tree per lot in new development.

   Example B: The same University of California campus wants to register another project as part of its 100 Year Tree Plan. This project will strategically locate approximately 300 trees annually for 10 years to shade residential buildings in a new development for faculty and staff. The university has no regulatory requirement for tree planting or care. To develop a baseline they must determine space heating and cooling energy use and associated GHG emissions for the buildings. They review their residential development plans to determine:

   - The types of buildings (vintages) and their base case energy use
   - Presence of existing trees greater than 12 m tall (40 ft) located within 15 m (50 ft) of the east-, south-, or west-facing walls
   - If emission reductions are on-site and direct or indirect (achieved in off-site power plants owned by another entity)
   - Emission factors for facilities and fuels that will be used to heat and cool the houses

Based on these analyses, they determine the building vintages are post-1980 construction, none will be shaded by existing trees and therefore are eligible for inclusion in this project. They assume a static Baseline using data for the base case vintage. Emission reductions will be on-site and direct because electricity for cooling is generated by the campus's own power plant. GHG emission factors are obtained for the power plant.

D. Bioenergy projects:

1. The goal here is to reflect the Baseline emissions associated with the mix of energy that the bioenergy project will displace. It is important to note that whether wood waste slowly decomposes as mulch or is rapidly burned as bioenergy, the stored carbon is released to the atmosphere. Hence, the focus here is on displaced emissions resulting from bioenergy, not reduced emissions owing to alternative disposition of the wood waste. Furthermore, only displaced direct emissions are reported in this protocol. The owner of the displaced GHG emissions source must be primarily responsible for the urban forest project activity that produces trees used as feedstock
   a. Bioenergy projects will need to account for upstream emissions and verify that greater upstream emissions were not caused by their project. Upstream emissions might include fossil fuels consumed in the harvest, handling, and transport of dead trees.
   b. Account for regulatory requirements for urban woody green waste disposal

Example C: At the same time, the University of California campus will register a bioenergy project that changes the way they manage urban woody green waste. They recognize that it is inherently more expensive to generate power from biomass than fossil fuels, but biomass use reduces ancillary waste disposal costs—a benefit that is worth considerably more than the electricity produced. They will convert tree wood waste into biomass fuel for combustion at an existing power plant. The current performance standard assumes that 70% of the pruning waste and dead trees is converted to mulch, and the remainder is put into a landfill. To establish a baseline for this project they determine:

- Emission factors for their power plant and GHGs that will be displaced by the bioenergy project

V. **Project additionality requirement**: All urban forest projects must demonstrate that the project activity is additional to, or exceeds the project baseline characterization. There are qualitative and quantitative components. Additionality is assessed when the project is first registered and should be demonstrated throughout the life of the project through annual reporting and certification. The same factors used to characterize your Baseline and Project Activity forecasts serve as a basis for demonstrating that the project activity is additional. To provide additionality, project activities must incorporate practices that meet or exceed the applicable performance standards. Examples of additional activities are given below.

A. Carbon storage projects: Demonstrate that the project will exceed performance standards resulting in carbon storage that is additional to the Baseline, and that the project exceeds any regulatory requirements.

Example A: The University of California campus will demonstrates that planting trees is 1) not required and 2) exceeds the Baseline activity. As part of their 100 Year Tree Plan, they will plant 500 trees per year in campus open space, 400 more than the baseline of 100 trees per year. Also, they will reduce their small tree pruning cycles from 4 years to 2 years, thereby reducing the annual establishment mortality from 5% to 3%, and adding carbon stock. They intend to use 20% of the dead tree woody biomass for wood products. At project initiation, the plan to undertake these activities that exceed the baseline would be deemed additional. After project initiation, the university's annual reporting and the third party certifier's monitoring of the project would confirm that the additional activities were being implemented and maintained. Additionality is activity additional to the baseline that should be reflected as overall biomass/carbon increase relative to the baseline.

B. **Tree shade projects:** Demonstrate that the project activity will lead to a reduction in GHG emissions from power generation through energy savings from tree shade on buildings. In cases where emission reductions are from grid-connected utilities there is a high level of uncertainty regarding their Baseline forecast and emission factors. Hence, the climate benefit associated with reduced emissions may not be certifiable

Example B: The same University of California campus will strategically locate approximately three trees around every new residential structure to reduce air conditioning loads without blocking solar access (300 trees per year for 10 years). Strategic tree planting is not required, and buildings shaded by existing trees will be ineligible for new trees. Therefore, emission reductions from shade cast by the new trees will be over and above the baseline (unshaded buildings). As the trees grow this additional activity should result in greater reductions in overall energy use and associated GHG emissions.

Bioenergy projects: Demonstrate that switching fuel to wood from dead trees results in GHG emissions reduction through displaced emissions for power generation or fuel. In this project there is also the potential issue of showing substitution for that alternative use of energy – i.e., demonstrating that the energy is not just additive. It is recognized that there is a high level of uncertainty regarding the Baseline forecast and emission factor for Bioenergy projects. Hence, the climate benefit associated with displaced emissions may not be certifiable and may be accounted for in a variety of units, such as carbon, kWh, or kBtu.

Example C: The University of California campus will divert 70% of their woody green waste into bioenergy feedstock for an existing power plant. Additionality is activity that displaces power plant emissions above and beyond the baseline.

VI. Assessing Activity-Shifting Leakage, Market Leakage and Other Effects

A. **Activity-shifting leakage –** This is the displacement of activities from inside the project's physical boundaries to outside of the boundaries as a direct result of project activity. An example is municipal investment in a tree planting project in one part of the city, but this causes cutbacks for tree pruning and removal in other areas outside the project's boundaries. Another example is increased emissions associated with an aggressive tree removal program undertaken to provide more tree planting sites for future tree planting project activity.

B. **Market leakage –** Causes substitution or replacement elsewhere. For example, increased tree planting by a municipality results in a reduction in the number of trees planted by homeowners.

C. **Other effects –** Nonbiological upstream and downstream effects. An upstream effect may be increased GHG emissions associated with handling/processing urban woody green waste feedstock, a downstream effect may be increased GHG emissions associated with delivery of irrigation water through selection of high water use species.

VII. Quantification of Baseline, Project Activity and GHG Reductions: The quantification approach is based on changes in GHG reductions or emissions. This section identifies what to measure and describes how to measure existing carbon stocks, emissions, and emission reductions for your project activity.

- **A. Quantifying carbon stocks and carbon dioxide emissions vs other GHGs:** Other GHGs not required at this time but are allowed for. We will need to include other GHGs with tree shade and bioenergy projects. For example there will be N_20 and CH_4 emissions associated with any combustion sources.
- **B. Provide background information** on urban forest project activity
- **C. Carbon storage projects:**
  1. Quantifying your baseline:
     - a. Use accepted urban forest inventory method (see Annex A)
     - b. Estimate carbon in trees (see Annex B)
     - c. Optionally, estimate carbon in dead woody biomass (standing and lying) (same as FPPs)
     - d. Optionally, estimate carbon in wood products (same as FPPs)
     - e. Optionally, estimate carbon in understory, litter, duff, soil (same as FPPs).
  2. Baseline projection
     - a. Estimate growth of trees (see Annex B), accounting for baseline levels of tree care and mortality
     - b. Minimum confidence in estimates
     - c. Use of models to estimate and forecast carbon stocks for baselines and annual reporting of project activity
     - d. About models and their eligibility for use in the Registry
  3. Calculating GHG reductions for carbon storage projects
     - a. Measure tree size and calculate corresponding carbon storage by project trees
     - b. Subtract last year's carbon stock from this year's to determine if you report net emissions or reductions for the year.
     - c. Account for any activity-shifting leakage
     - d. Subtract your baseline from this year's carbon stock to assess additionality. Calculate cumulative reductions, as well as annual reductions.
     - e. Translate carbon stock changes into carbon dioxide equivalents
  4. Annual monitoring and reporting for carbon storage projects
     - a. Duration or permanence of reductions
       - i. Reduction adjustment – if project has not accumulated as much carbon as projected or if carbon stocks have been reduced (unanticipated pruning, storm damage, etc.)
       - ii. Examine long-term reductions to see if reductions from previous years are being maintained
     - b. Direct sampling – all carbon pools and sample plots sampled within ten years
       - i. Disturbances – catastrophic event or natural disturbance (pest/disease/fire)
     - c. Annual monitoring report identifies changes in carbon stocks
       - i. Carbon stock estimate
       - ii. Project compliance

iii. Disturbances
iv. Leakage

D. Tree shade projects:

1. Background
   a. Effects of tree shade on building energy use (shade effect, indirect emissions)
      i. Example: strategic tree planting
   b. Effects of air temperature and wind speed reductions by trees on building energy use (climate effect, not included at this time)
   c. Effects of changes in electricity and natural gas use on GHG emissions
   d. Approach used here considers only shade effects on single-family residential structures. Climate effects are too difficult to accurately model, measure, and verify given current state of the science. This approach includes adverse effects of wintertime tree shade on emissions from natural gas used to heat homes (may increase emissions).
2. Quantifying your Baseline
   a. Identify your climate zone (see map, Central Valley, Desert, Inland Empire, Mountains, North & Central Coast, South Coast & Valley)
   b. Determine which buildings are shaded by existing trees, and therefore ineligible. Shaded buildings are those that have more than one tree greater than 12 m tall (40 ft) located within 15 m (50 ft) of the east-, south-, or west-facing walls.
   c. For unshaded buildings, determine the vintage (post-1980, 1950-80, pre-1950) then look-up annual electricity and natural gas use for space cooling/heating (base case). These values are used to create a static baseline.
   d. Sum annual cooling/heating energy use for all single-family residences in project area
   e. Select appropriate electricity emission factors that apply (see Chapter 6, GRP, use natural gas default of 0.053 kg/kBtu, check WRI grid-connected electricity guidance for appropriate electricity factor)
   f. Determine total annual GHG emissions in metric tons (see Chapter 6, GRP)
   g. Convert non-CO_2 gases to carbon dioxide equivalent (CO_2e) (see Chapter 6, GRP)
   h. Total the sum of all CO_2 and CO_2e gases (see Chapter 6, GRP)
3. Forecasting emissions due to the Project activity
   a. Estimate growth of trees and corresponding tree shade effects (see Annex C), with tree planting and maintenance activities exceeding applicable performance standards
   b. Readjust/update baseline projections to account for changing emission factor from utility, etc.
   c. Minimum confidence in estimates
   d. Use of models to estimate and forecast tree shade effects for annual reporting of project activity
4. Calculating GHG emission reductions for tree shade projects
   a. Use accepted urban forest inventory methods (see Annex A)
   b. Collect data on trees (within 15 m of residence)

c. Determine tree species (or assign species if not one of 20 listed for the climate zone), age (year after planting), and condition (good, fair, poor, dead/dying). If tree is in poor or dead/dying condition, do not consider its shade effect.
d. Determine tree location: distance from building, azimuthal bearing from opposite wall
e. Use Shade Effects Worksheets to determine annual change in electricity (kWh/tree) and natural gas (kBtu/tree) due to shade
f. Subtract tree shade effect from Baseline building energy use to calculate annual change in baseline cooling/heating energy use for each building
g. Sum annual changes in cooling/heating energy use for all single family residences in project area
h. Select appropriate electricity emission factors that apply (see Chapter 6, GRP, use natural gas default of 0.053 kg/kBtu, check WRI grid-connected electricity guidance for appropriate electricity factor)
i. Determine total annual change in GHG emissions in metric tons (see Chapter 6, GRP), and calculate cumulative change over the long-term.
j. Convert non-CO_2 gases to carbon dioxide equivalent (CO_2e) (see Chapter 6, GRP)
k. Total the sum of all CO_2 and CO_2e gases (see Chapter 6, GRP)
l. Account for any activity-shifting leakage
m. Subtract your Baseline from this year's emission reductions to assess additionality

5. Annual monitoring and reporting for tree shade projects
    a. Duration or permanence of reductions
        i. Reduction adjustment – if project has not accumulated as much GHG emission reduction as projected
    b. Direct sampling – all sample plots sampled within ten years
        i. Disturbances – catastrophic event or natural disturbance (pest/disease/fire)
    c. Annual monitoring report
        i. Emission reduction estimate
        ii. Project compliance
        iii. Disturbances
        iv. Leakage

E. Bioenergy projects:

1. Background
    a. Potential emission reductions based on displaced emissions from power generation
    b. Direct and indirect emission sources and double counting
    c. Use of this protocol: only for energy or gas generation that displaces direct emissions from sources that emit GHGs and are owned by the reporting entity. Users of this protocol generate power/steam/heat/gas for own use with biomass from project trees that they are principally responsible for.
    d. Bioenergy projects that produce power or gas that is sold should register and report displaced emissions using the power/utility protocol
2. Quantifying your baseline:

   a. We need a methodology for establishing Baseline and Project forecast for a fuel switching project of this nature. We'll probably need to look to CDM methodologies or to WRI
      i. Identify power plant's GHG emission factors (EF) for electricity generation (kg/MWh) (EF for marginal kWh or average for electricity pool or build/margin factor as described in WRI grid connected electricity guidance)
   b. Carbon flow accounting
      i. Count displaced emissions against stocks immediately when tree is removed
      ii. Count displaced emissions against stocks later when tree is used as bioenergy feedstock
3. Calculating GHG emission reductions for bioenergy projects
   a. Use accepted urban forest inventory method (see Annex A)
   b. Determine amount carbon harvested and transferred to bioenergy pool (bone dry tonnes, BDT)
   c. Identify type of bioenergy combustion process (direct thermal combustion, fluidized-bed combustion, close-coupled gasifier) and conversion efficiency (kWh/BDT), and calculate annual electricity generation from urban woody green waste.
   d. Use GHG emission factors associated w/ the bioenergy technology (kg/MWh) to calculate emissions in metric tons, if emissions not assumed to be zero.
   e. Calculate reduced GHG emissions from baseline (local utility's power plants) by subtracting bioenergy emissions from baseline power plant emissions
   f. Account for GHG emissions released associated with on-site handling, trucking to storage/processing site, and storage/processing
   g. Convert non-CO_2 gases to carbon dioxide equivalent (CO_2e)
   h. Total the sum of all CO_2 and CO_2e gases
   i. Subtract last year's GHG emission reductions from this year's to determine if you report net emissions or reductions for the year
   j. Account for any activity-shifting leakage
   k. Subtract your BAU baseline from this year's emission reductions to assess additionality
4. Annual monitoring and reporting for bioenergy projects
   a. Duration or permanence of reductions
      i. Reduction adjustment – if project has not accumulated as much GHG emission reduction as projected
   b. Direct sampling – all sample plots sampled within ten years
      i. Disturbances – catastrophic event or natural disturbance (pest/disease/fire)
   c. Annual monitoring report
      i. Emission reduction estimate
      ii. Project compliance
      iii. Disturbances
      iv. Leakage

F. **Co-Benefits**: Projects may produce costs and co-benefits not explicitly considered in carbon protocols. This co-benefits are not eligible as carbon reduction or emission measures. However, users of these protocols may want to identify other benefits and costs of trees. Examples of costs include use of water to irrigate trees, emissions of biogenic volatile organic compounds (ozone precursor) from certain tree species, and trees obstructing solar access to photovoltaic systems. Examples of benefits include stormwater runoff reductions, uptake of air pollutants, lower summer air temperatures and reduced ozone formation, increased property values, increased biodiversity, more commercial activity. Judicious tree species selection and location can minimize costs and conflicts between trees and infrastructure, while increasing co-benefits. Resources for calculating co-benefits are included in Annex X.

VIII. Reporting and Certifying Your Project Results and GHG Reductions

- **A.** Certification references
- **B.** Rationale for certification
- **C.** Transparency
- **D.** Overview of certification in the project-level reporting process
- **E.** Certification cycle and direct sampling
- **F.** Project developer certification responsibilities
  1. Review checklist & compile data
  2. Finalize data entered into CARROT
  3. Hire certifier
  4. Discuss and understand certification documentation
- **G.** Completing the Reporting Process
- **H.** Submit GHG data for reporting year
- **I.** Mail hard copy to CCAR

IX. Annexes

- **A.** Urban forest inventory methods
- **B.** Calculating and predicting biomass and carbon in urban trees
- **C.** Calculating tree shade effects
- **D.** Project reporting flow chart
- **E.** Project-entity reporting comparison
- **F.** Easement references and elements
- **G.** Leakage assessment
- **H.** Leakage mitigation
- **I.** Selected land use statues and regulations
- **J.** Sample public report for urban forest entities
- **K.** References

X. Project Contributors

XI. Bibliography

Urban Forest <u>Certification</u> Protocol Outline for Entities & Projects

I. Introduction & Key Certification Concepts
   A. Urban Forest Certification Protocol vs Forest and General Certification Protocols
   B. Key Certification Concepts
II. Approved Urban Forest Certifiers
   A. Becoming an Approved Urban Forest Certifier
III. The Certification Process
   A. Overview
   B. Urban Forest Certification Cycle
   C. Annual Monitoring Reports
   D. Optional Reporting
IV. Core Certification Activities: Urban Forest Projects
   A. Review and confirm project eligibility
   B. Identify potential emission sources/reductions//carbon pools
   C. Review and assess urban forest project baseline
   D. Review & assess urban forest project activities & management systems
   E. Confirm project emission & reduction calculations
V. Core Certification Activities: Specific Urban Forest Projects
   A. Certifying Carbon Storage Projects
   B. Certifying Tree Shade Projects
   C. Certifying Bioenergy Projects
VI. Completing the Certification Process
VII. Annexes
   A. Overview of the CCAR Certification Process
   B. Biological entity inventory certification activities log
   C. Certification activities log: Carbon storage projects
   D. Certification activities log: Tree shade projects
   E. Certification activities log: Bioenergy projects
   F. Certification opinion for urban forest projects

Annex A: Urban Forest Inventory Methods

I. About urban forest inventories and step-by-step approach

A. **Complete inventory** - Records all of the volume or biomass within the boundaries of the project

B. **Sample inventory** - Requires measuring only a portion of the volume or biomass on the site and use the data to estimate volume or biomass for the tree population

1. Sampling methods - Enable you to quantify the carbon pools within your established boundaries and employ statistically accepted methods for extrapolating the urban forest biomass based on sample plots. Four examples:

   a. Rolling sample - A percentage of the complete inventory is sampled annually with results used to infer biomass or volume for the complete inventory for the annual report. Example: a non-profit tree group plants 3,000 new trees along a greenway. Each year, 10% of the trees are sampled, until, at the end of 10 years, 100% of the inventory has been sampled. The annual 10% samples are fixed samples proportional to species representation. Thus, the complete inventory is divided into 10 samples at the outset of the project. On an annual basis, the urban forest biomass is extrapolated to the entire population from the 10% sample for yearly biomass reporting.

   b. Periodic sampling - All trees are re-inventoried but not annually. A sampling period is determined at the outset. For example, all trees are re-inventoried every 3 years. The annual biomass reports are calculated using the DBH and height tables developed for the region (see Biomass Estimation and Forecasting Tables section below).

   c. Fixed plot sampling - All trees in a geographical area are never completely inventoried. A set of plots of fixed size and number is established and used to extrapolate volume or biomass on an area basis. Example: the city of San Francisco establishes a new 30-mile long multi-use greenway along a former railroad corridor. They employ the UFORE plot sampling method (Annex ___) and establish thirty 10-m radius permanent plots based on land use stratification. The plots are sampled annually. Biomass or volume for the greenway is extrapolated based on sample plots to area relationship.

   d. Variable plot – Similar to fixed plot except the area sampled varies to coincide w/ logistical requirements, such as property boundaries where permission to access private property is required. Area of the plot is measured and used to infer to the total area based on plot area to total area ratio.

   e. Note that there are many additional methods for sampling. Annex ___ contains recommended references and resource guidelines for developing sampling methodologies and finding statistical support for sampling and extrapolation. Inventory documentation and software includes public domain (e.g., FIA, i-Tree) and proprietary products (e.g., CITYGreen, TreeKeeper, TreeWorks).

f. Sample stratification. Because biomass density is often related to land use and amount of canopy cover, sample plot establishment may be based on land use or canopy cover stratification so that a larger number of plots are randomly placed in areas more densely forested and, conversely, fewer plots established where urban hardscape or buildings predominate. This increases sampling efficiency.

C. **Remote sensing** as an inventory and monitoring tool.

D. Accounting for **confidence of estimates**

Annex B: Calculating and Predicting Biomass and Carbon in Urban Trees

I. **Estimating carbon in trees from inventories and sample plots.** Equations for calculating tree volume are available for about 30 open-grown urban tree species. Additional biomass equations have been adapted from the literature on natural and native forest biomass for use in urban settings. Complete listings of all equations are available in Annex ____ with examples for applying the biomass equations each type.

A. Estimating biomass using volumetric equations is a two-step process that entails 1) calculating volume and 2) converting volume to biomass and carbon.

1. **Calculating biomass density of live trees:** Tables 1 and 2 provide examples of volumetric equations and biomass conversion factors for three common urban species (Pillsbury et al. 1998; McHale et al. 2000; Alden 1995, 1997). These equations estimate volume (ft^3/tree) from diameter (DBH) and height (HT) measurements.

Table 1. Volume equations (ft^3) for 3 urban tree species.

		Limitations	
Species	Volume (ft^3)	DBH range (in)	Height range (ft)
Blue Gum	$0.00309*(DBH)^{2.15182} * (HT)^{0.83573}$	6.1 - 51.2	46.3 - 144.0
Camphor	$0.00982*(DBH)^{2.1348} * (HT)^{0.63404}$	5.2 - 27.1	17.0 - 56.0
Monterey Pine	$0.00533*(DBH)^{2.22681} * (HT)^{0.66899}$	6.6 - 41.5	18.0 - 105.8

Table 2. Lists factors for converting tree volume (ft^3) to carbon (lbs)

Species	Above ground Fresh Weight Conversion (lbs)	Above ground Dry Weight Conversion (lbs)	Add Roots	Carbon factor
Blue Gum	70	0.62	1.28	0.5
Camphor	60	0.51		
Monterey Pine	46	0.43		

Example:

Volume (V) for a 40-ft tall blue gum tree with a 16.1-in DBH is calculated as:

$V = 0.00309\ (16.1)^{2.15182}\ (40)^{0.83573}$

$= 26.65\ ft^3$

To determine biomass and carbon for this tree, biomass conversion factors in Table 2 must be applied, below ground biomass accounted for and carbon calculated.

Carbon (C) for the blue gum tree above would be calculated as follows:

$C = 26.65 * 70 * 0.62 * 1.28 * 0.5$

$= 578.3$ lbs

Carbon mass is to be reported in metric carbon tons. Therefore, any product resulting in pounds (English units) must be multiplied by 0.00454 to convert to pounds to metric tons.

a. Biomass calculated using equations derived from native or natural forest trees (will be listed in Annex ____) must be adjusted by a factor of 0.80 when applied to open-grown, urban trees (Nowak 1994, McHale 2007) because of differences in biomass allocation between the tree populations.

2. **Calculating the biomass density of dead wood** (Note: literature search to be conducted on soundness and density estimates for urban tree species to determine best method for estimating dead wood density).
   a. Estimating carbon in standing dead tree biomass. Follow the protocols outlined by Brown and others (2004) in "Methods for Measuring and Monitoring Forestry Carbon Projects in California," for measuring standing dead wood as outlined here. Relative classes for standing dead trees are defined as follows:
      i. Class 1 - tree with branches and twigs and resembles a live tree (except for leaves): biomass is estimated from DBH using the same function as for live trees, but subtracting out the biomass of leaves (determine percentages from literature). Where only a bole is remaining (Class 4), volume is estimated using dbh and height measurements and an estimate of the top diameter. Volume is then estimated as the volume of a truncated cone, and converted to dry biomass using an appropriate dead wood density class (sound or intermediate).
      ii. Class 2 - tree with no twigs but with persistent small and large branches
      iii. Class 3 - tree with large branches only: estimates of the proportion of the tree that is missing need to be made. The principle of conservatism should be applied (Note: literature search necessary to ascertain state of knowledge re: proportions of biomass in tree vegetation for urban trees before this section can be completed).
      iv. Class 4 - bole only, no branches
   b. Estimating carbon in lying tree biomass. It is assumed that in nearly all urban applications that lying dead trees are removed almost immediately and that this pool will rarely, if ever exist. It is most likely to exist in natural settings within cities like riparian or nature areas. In this case, sampling, measurement and carbon estimation procedures should follow the forest protocols rather than the urban forest protocols.

II. **Biomass forecasting**. These DBH and height tables are based on mean regional tree growth data and will assist users in forecasting the increase in baseline biomass and carbon for up to 80 years (Tables 3 and 4). These may also be used to interpolate change in biomass for a year or more within the 5-year intervals (e.g., for interpolating change in growth for periodic sampling inventories). Tables will be developed using measured data for approximately 20 species of street trees in six cities that represent six California climate zones (Figure 1)

Table 3. Showing the diameter at breast height at given age for each species listed from the Inland Empire Region

		Tree DBH for each species at a given age															
Species	Common name	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
Brachychiton populneum	Kurrajong	3.6	6.1	8.2	10.4	12.1	13.7	14.9	16.0	16.7	17.4	17.4	17.4	17.4	17.4	17.4	17.4
Cinnamomum camphora	Camphor tree	4.2	7.3	10.1	12.9	15.4	17.9	20.1	22.3	24.2	26.1	27.7	29.4	30.7	32.0	33.1	34.1
Eucalyptus sideroxylon	Red ironbark	5.4	8.5	11.4	14.2	16.7	19.2	21.4	23.5	25.4	27.2	28.6	30.1	31.2	32.3	33.0	33.8

Table 4. Showing the tree height at given age for each species.

		Tree Height for each species at given age															
Species	Common name	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
Brachychiton populneum	Kurrajong	12.5	17.0	20.6	23.5	25.6	27.3	28.5	29.4	30.0	30.4	30.6	30.6	30.6	30.6	30.6	30.6
Cinnamomum camphora	Camphor tree	17.6	22.7	27.4	31.6	35.5	38.9	42.1	44.8	47.3	49.5	51.5	53.2	54.7	56.0	57.1	58.1
Eucalyptus sideroxylon	Red ironbark	23.3	29.1	34.6	39.7	44.6	49.2	53.4	57.3	60.9	64.2	67.1	69.8	72.1	74.0	75.6	76.9

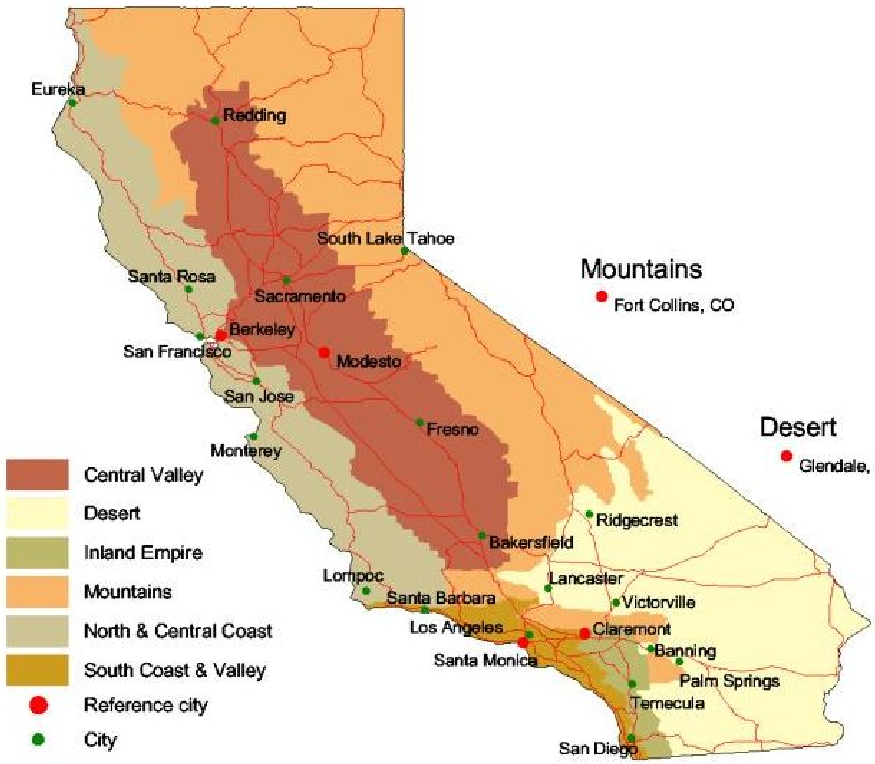

Figure 1. Six climate zones and reference cities for each zone, where data were collected on tree growth for predominant species.

Example: A shopping mall owner is interested in estimating potential carbon stored in 20 years by the 400 camphor saplings she is planting around the perimeter of mall parking lots. She looks up the estimated DBH and height for camphor trees in the tables above, uses the equations and factors in Tables 1 and 2 to estimate that the 400 trees will store 2,633.3 metric tons of carbon in 20 years:

$$C = (0.0092 * (31.6)^{2.1348} * (12.9)^{0.63404})(60)(0.51)(1.28)(0.5)(400)(0.00454)$$
$$= 2633.3 \text{ metric tons}$$

Annex C: Calculating Tree Shade Effects Example

In this example we assume that two Jacaranda trees were planted 10 years ago to shade a residence. No other trees were present or planted, so the baseline remains constant, the unshaded home's annual emissions associated with space cooling and heating. The residence would have been ineligible for a tree shade effect emission reduction if more than one tree greater than 12 m tall (40 ft) was located within 15 m (50 ft) of the east-, south-, or west-facing walls.

I. Quantifying your baseline (single family residences only)

A. Identify your climate zone (see map, Central Valley, Desert, Inland Empire, Mountains, North & Central Coast, South Coast & Valley)
   1. **South Coast & Valley**

B. Determine which buildings are shaded by existing trees, and therefore ineligible. Shaded buildings have more than one tree greater than 12 m tall (40 ft) located within 15 m (50 ft) of the east-, south-, or west-facing walls.
   1. Our baseline building energy use model assumes shade from adjacent buildings and several existing trees, including one tree (greater than 12 m tall and within 15 m of residential building w/ AC). If other large trees are present, the marginal contribution of additional tree shade is negligible.

C. Determine each unshaded buildings' vintage (post-1980, 1950-80, pre-1950) then look-up annual electricity and natural gas use for space cooling/heating (base case). These values are used to create a static baseline.
   1. Number of buildings: **1**
   2. Vintage: **Post-1980**
   3. Electricity base case: **3,081 kWh**
   4. Natural gas base case: **6,098 kBtu**

D. Sum base case annual electricity and natural gas energy use for all single family residences in project area
   1. Total electricity base case: **3,081 kWh = 3.081 MWh**
   2. Total natural gas base case: **6,098 kBtu**

E. Select appropriate electricity emission factors that apply (see Chapter 6, GRP, use natural gas default of **0.053** kg CO_2 /kBtu)
   1. Electricity: CO_2 = **629** kg/MWh

F. Determine total annual GHG emissions in metric tons (see Chapter 6, GRP)
   1. Electricity: CO_2 = 629 kg/MWh x 3.081 MWh = 1,938 kg = **1.938 metric tons**
   2. Natural gas: CO_2 = 0.053 kg/kBtu x 6,098 kBtu = 323 kg = **0.323 metric tons**
   3. Total CO_2 = 1.938 + 0.323 = **2.261 metric tons**

G. Convert non-CO_2 gases to carbon dioxide equivalent (CO_2e) (see Chapter 6, GRP)

H. Total the sum of all CO_2 and CO_2e gases (see Chapter 6, GRP)

I. Baseline projection **(Not applicable because unshaded building baseline is static)**

J. Minimum confidence in estimates (std error w/in 20% of estimate of mean)

K. Use of models to estimate and forecast tree shade effects for baselines and annual reporting

II. Calculating GHG emission reductions for tree shade projects
   A. Use accepted urban forest inventory methods (**One building only in example**)
   B. Collect data on program trees (within 18 m of residence with AC)
      1. Determine tree species (or assign species if not one of 20 listed for the climate zone), age (year after planting), and condition (good, fair, poor, dead/dying). If tree is in poor or dead/dying condition, do not consider its shade effect.
         a. Tree #1: **Jacaranda**
            i. Age: **10 years**
            ii. Condition: **Good**
         b. Tree #2: **Jacaranda**
            i. Age: **10 years**
            ii. Condition: **Fair**
      2. Determine tree location: distance from building, azimuthal bearing from opposite wall
         a. Tree #1: Jacaranda
            i. Distance from building: **Adjacent (3-6 m)**
            ii. Azimuth: **West**
         b. Tree #2: Jacaranda
            i. Distance from building: Near **(6-12 m)**
            ii. Azimuth: **South**
   C. Use Shade Effects Worksheets to determine annual change in electricity (kWh/tree) and natural gas (kBtu/tree) due to shade
      1. Tree #1: Jacaranda
         a. Change in electricity (from Shade Effects Worksheet): **63 kWh**
         b. Change in natural gas (from Shade Effects Worksheet): **72 kBtu**
      2. Tree #2: Jacaranda
         a. Change in electricity (from Shade Effects Worksheet): **25 kWh**
         b. Change in natural gas (from Shade Effects Worksheet): **29 kBtu**
      3. Total for Building #1
         a. Total change in electricity (from Shade Effects Worksheet): 63+25 = **88 kWh**
         b. Total change in natural gas(from Shade Effects Worksheet): 72+29 = **101 kBtu**
   D. Subtract tree shade effect from baseline energy use to calculate annual change for baseline cooling/heating energy use
      1. Change from the baseline (electricity): 3,081 **–** 88 = **2,993 kWh**
      2. Change from the baseline (natural gas): 6,098 **–** 101 = **5,997 kBtu**
   E. Sum annual changes in cooling/heating energy use for all single family residences in project area
      1. **88 kWh and 101 kBtu**
   F. Select appropriate electricity emission factors that apply (see Chapter 6, GRP, use natural gas default of **0.053** kg CO_2 /kBtu)
      1. Electricity: CO_2 = **629** kg/MWh
   G. Determine total annual change in GHG emissions in metric tons (see Chapter 6, GRP)
      1. Electricity: CO_2 = 629 kg/MWh x 0.088 MWh = 55 kg = **0.055 metric tons**
      2. Natural gas: CO_2 = 0.053 kg/kBtu x 101 kBtu = 5 kg = **0.005 metric tons**
      3. Total CO_2 = 0.055 + 0.005 = **0.06 metric tons**

H. Convert non-CO_2 gases to carbon dioxide equivalent (CO_2e) (see Chapter 6, GRP)
I. Total the sum of all CO_2 and CO_2e gases (see Chapter 6, GRP)
J. Subtract last year's GHG emission reductions from this year's to determine if you report net emissions or reductions for the year (No data for this example)
K. Account for any activity-shifting leakage (None)
L. Subtract your baseline from this year's emission reductions to assess additionality
    1. **Additionality is 0.06 metric tons, the unshaded baseline minus tree shade effect**

Table 1 --Change in electrical energy use (kWh/tree) for JAMI, post-1980 construction

		Tree age									
Distance	Azimuth	5	10	15	20	25	30	35	40	45	50
Adjacent	N	1	3	4	6	7	8	10	11	13	14
	NE	6	11	17	23	28	34	40	45	51	57
	E	15	30	46	61	76	91	106	122	137	152
	SE	13	27	40	54	67	80	94	107	120	134
	S	19	38	57	76	95	114	133	152	171	190
	SW	16	33	49	65	82	98	114	131	147	164
	W	31	63	94	126	157	188	220	251	282	314
	NW	11	23	34	46	57	69	80	92	103	115
Near	N	1	2	3	4	5	6	7	8	8	9
	NE	4	8	11	15	19	23	26	30	34	38
	E	10	20	30	41	51	61	71	81	91	101
	SE	9	18	27	36	45	54	62	71	80	89
	S	13	25	38	51	63	76	88	101	114	126
	SW	11	22	33	44	55	65	76	87	98	109
	W	21	42	63	84	105	126	146	167	188	209
	NW	8	15	23	31	38	46	54	61	69	77
Far	N	0	1	1	2	2	3	3	4	4	5
	NE	2	4	6	8	9	11	13	15	17	19
	E	5	10	15	20	25	30	35	41	46	51
	SE	4	9	13	18	22	27	31	36	40	45
	S	6	13	19	25	32	38	44	51	57	63
	SW	5	11	16	22	27	33	38	44	49	55
	W	10	21	31	42	52	63	73	84	94	105
	NW	4	8	11	15	19	23	27	31	34	38

Table 2 --Change in natural gas energy use (kBtu/tree) for JAMI, post-1980 construction

		Tree age									
Distance	Azimuth	5	10	15	20	25	30	35	40	45	50
Adjacent	N	2	4	5	7	9	11	13	15	16	18
	NE	6	12	19	25	31	37	43	50	56	62
	E	15	30	45	60	75	90	105	120	135	150
	SE	14	28	42	56	70	84	97	111	125	139
	S	22	44	66	88	111	133	155	177	199	221
	SW	20	40	60	80	101	121	141	161	181	201
	W	36	72	107	143	179	215	251	286	322	358
	NW	14	28	42	56	70	84	98	113	127	141
Near	N	1	2	4	5	6	7	9	10	11	12
	NE	4	8	12	17	21	25	29	33	37	41
	E	10	20	30	40	50	60	70	80	90	100
	SE	9	19	28	37	46	56	65	74	84	93
	S	15	29	44	59	74	88	103	118	133	147
	SW	13	27	40	54	67	80	94	107	121	134
	W	24	48	72	95	119	143	167	191	215	239
	NW	9	19	28	38	47	56	66	75	84	94
Far	N	1	1	2	2	3	4	4	5	5	6
	NE	2	4	6	8	10	12	14	17	19	21
	E	5	10	15	20	25	30	35	40	45	50
	SE	5	9	14	19	23	28	32	37	42	46
	S	7	15	22	29	37	44	52	59	66	74
	SW	7	13	20	27	34	40	47	54	60	67
	W	12	24	36	48	60	72	84	95	107	119
	NW	5	9	14	19	23	28	33	38	42	47

Tables 1 & 2. Shade Effects Worksheets show annual changes to base case building electricity and natural gas use for a specific tree species and building vintage, in this case Jacaranda and post-1980 construction. Distances of the tree from residence are shown in three classes: Adjacent (3-6 m), Near (6-12 m), and Far (12-18 m). Directions are shown in eight azimuthal classes. Linear interpolation is used to calculate tree shade effects for ages not shown.