Over the past decade, San Francisco International Airport (SFO) has been constantly striving to improve the sustainable performance of its operations. Initially focused on improving energy efficiency and then expanding into areas of greenhouse gas reductions, water conservation, transportation optimization and passenger comfort and engagement, SFO recognizes the importance of responsible stewardship of its operations. This stewardship is premised on the importance of achieving triple bottom line benefits: being economically productive, environmentally responsible and socially equitable.

More recently, with the implementation of the City & County of San Francisco’s Green Building Requirements and Climate Action Goals and reflecting the environmental passion of the people of the San Francisco Bay Area, SFO has embarked on a global leadership challenge to become one of the most sustainable airports in the world. As articulated in our 2011-2016 Strategic Plan, SFO has established numerous leadership performance goals across the categories of Customers/Passengers, Airline/Aircraft/Routes, Non-Airline Revenue, Employees and Organization, Environmental Sustainability, Safety and Security, Infrastructure and External Relations.

The purpose of this document is to translate SFO’s various sustainability goals into specific, actionable planning, design and construction guidance. These guidelines are not intended to be a substitute for investigation and thought-provoking discussion of environmental responsibility, sustainability and sustainable features by the professional teams on any given project. They are, however, intended to clarify SFO’s expectations regarding the life cycle based, sustainable performance of the projects delivered by planning, design and construction teams.

Please note that while references and linkages are made to applicable codes and standards, such as the San Francisco Environment Code, these guidelines are not intended to summarize or replace the requirements of the subject codes. Rather, the intent is to highlight SFO’s objectives and priorities as we advance our goal of becoming one of the most sustainable airports in the world. We will continue to rely on our planning, design and construction teams to develop solutions that will help us achieve this goal, while at the same time, deliver projects that comply with all applicable regulatory requirements.

John L. Martin
Airport Director
# SFO Sustainable Planning, Design & Construction Guidelines

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      D. Existing Buildings
      E. Terminal 2 Final LEED Scorecard
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INTRODUCTION

1.1 OVERVIEW

1.2 HOW TO USE THESE GUIDELINES
Overview

These Guidelines were created to assist planning, design and construction teams with integrating sustainability into the project process and outcome.

The State of California, the City and County of San Francisco, and SFO are all known for their emphasis on sustainability. The bar is, therefore, set at a high level. SFO is governed by one of the most rigorous sets of mandatory environmental codes in the nation, from CALGreen at the state level (the first mandatory statewide green building code adopted in the USA) to the San Francisco Municipal Code that includes cutting edge requirements such as adherence to the precautionary principle and no use of tropical hardwoods.

History

SFO has established itself as an international industry leader in sustainability. SFO takes its role as environmental steward seriously, which has resulted in the implementation of proactive and innovative initiatives to reduce the Airport’s carbon footprint and achieve environmental gains in all areas. In late 2011, SFO launched a project to develop a comprehensive Sustainability Plan comprised of an ambitious set of elements that will further propel the Airport into the sustainability spotlight.

Summary

These Guidelines summarize the mandatory requirements and outline SFO’s additional voluntary sustainability goals, as described in the 2011-2016 Strategic Plan and as established by SFO management. The document also summarizes technical tools that could be used to establish and implement SFO’s project-specific sustainability goals.

Please note that while references and linkages are made to some of the codes and standards projects may be subject to, such as the San Francisco Environment Code, these guidelines are not intended to summarize or replace the applicable requirements. Rather the intent is to highlight the goals and priorities of SFO. Planning, design and construction teams still have the responsibility to develop project specific solutions that achieve SFO’s sustainability goals while at the same time delivering projects that comply with all applicable regulatory requirements.

Mandatory and Expanded Actions

SFO is regulated by a number of jurisdictions including federal, state, and local agencies. Most of these jurisdictions have specific sustainability or sustainability-related requirements. Planning, design and construction (PD&C) projects at SFO must comply with all applicable requirements in these regulations. These Guidelines take the broad view of sustainability – discussing environment, economy and equity principles.

Mandatory requirements ranging from greenhouse gas emission reduction levels to fair labor practice hiring are referenced in Section 2.2. SFO has established additional sustainability measures, broadly outlined in the SFO 2011 - 2016 Strategic Plan. These measures are not mandated by law, but provide a framework for selecting project-specific sustainability elements to comply with mandatory requirements as well as the Strategic Plan’s goals and objectives. Additionally, the State has established voluntary sustainability requirements under the CALGreen Building Code. SFO has endorsed these voluntary sustainability measures and PD&C project teams are required to evaluate and consider for potential implementation as many of the applicable CALGreen voluntary sustainability measures as possible, subject to feasibility constraints. These measures are referred to under “SFO Expanded Requirements”.

The implementation of these voluntary measures would also enable acquiring additional credit points for LEED certification.
How to Use These Guidelines

These Guidelines provide a framework for determining mandated sustainability requirements for planning, design and construction projects and for selecting project-specific voluntary sustainability actions to support SFO’s overall sustainability goals. The first step in any project is to define the scope of the subject project, identify project type (infrastructure, architecture, interiors etc.), establish overall goals; describe operation and maintenance requirements; identify stakeholders, and determine the budget and schedule. Once the project nature and type is established, these Guidelines can be used as described in the sections highlighted below.

Section 2.2
Use to determine which codes apply to the project

Section 2.3
Use to identify SFO expanded sustainability measures, determine the mandatory sustainability requirements, and select specific measures to support SFO goals

Section 3
Use to reference SFO specific project processes and to incorporate project sustainability actions therein

Section 4
Use applicable Measurement Tools to perform analysis of project

Section 5
Use Building Science section to explore different sustainable design concepts that meet project goals

Section 6
Reference Case Studies for inspiration and information

Section 7
Use the References section for sample checklists and documents

These guidelines are not intended to be an exhaustive list of governing codes and regulations. Governing codes and regulations are frequently updated. It is incumbent upon project teams to check the latest versions of all governing regulations in order to confirm latest requirements.
2.1 SUSTAINABILITY AT SFO
   A. SFO SUSTAINABILITY GOALS
   B. SFO GUIDING PRINCIPLE OF SUSTAINABILITY
   C. SUSTAINABILITY AT SFO: SUSTAINABILITY CRITERIA & TARGETS

2.2 KEY MANDATORY CODES
   A. CODES & TARGETS OVERVIEW
   B. SUMMARY MATRIX

2.3 SUMMARY OF REQUIREMENTS
   A. GUIDE TO MATRICES CONTENT
   B. ENERGY & ATMOSPHERE
   C. COMFORT & HEALTH
   D. WATER & WASTEWATER
   E. SITE & HABITAT
   F. MATERIALS & RESOURCES
   G. EQUITY & AESTHETICS
SFO Sustainability Goals: Reaching for #1

SFO’s primary goal is ‘Reaching for #1.’ This is articulated as follows:

- #1 ranking by customers
- One of the best Bay Area employers
- One of the world’s most sustainable airports

SFO strives to exceed the current stringent sustainability requirements that are mandated by law in the State of California and in the City and County of San Francisco. SFO’s sustainability goals are articulated in the SFO Strategic Plan which is updated every five years. The specific goals articulated in the 2011-2016 Strategic Plan are listed below:

Positive Occupant Experience
- Achieve LEED gold certification for all new buildings - SFO’s LEED target credits include not only reduced energy and water consumption, but increased daylight and use of materials low in toxicity

Climate Neutrality
- By 2017 reduce GHG emissions from Commission controlled operations by 40% below 1990 baseline emission level
- Continue to mitigate over 100% of annual GHG emissions

Zero Waste
- Achieve 80% solid waste recycling by 2015

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SFO Guiding Principles of Sustainability


In this document, SFO has identified guiding principles that provide positive environmental, social and financial benefits through the commitment to sustainable design, construction and operation of buildings at SFO. These guiding principles are listed below:

- Build for the Future
- Implement an Inclusive Planning, Design and Construction Process
- Recognize Global and Human Health Impacts at the Building Scale
- Ground Work in Evidence
- Focus on regenerative and resilient Building strategies
- Design Excellence
- Triple Bottom Line Analysis

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Sustainability at SFO: Sustainability Criteria & Targets
This section covers sustainability measures and goals for planning, design and construction projects at SFO. These mandatory requirements and expanded measures are enumerated into broad sustainability categories as noted below.

In order to further SFO’s sustainability performance above and beyond mandated requirements, a series of required evaluations are included to support the SFO Strategic Plan goals. These SFO Expanded Requirements are shown in the right hand column of the Sustainability Category matrices. All project teams are required to evaluate and consider the expanded measures for potential implementation where feasible.

These guidelines are not intended to be an exhaustive list of governing codes and regulations. Governing codes and regulations are frequently updated. It is incumbent upon project teams to check the latest versions of all governing regulations in order to confirm latest requirements.
Key Mandatory Codes: Codes & Targets Overview

A number of Federal and State laws and Regional and Local codes and ordinances have established mandatory sustainability requirements for planning, design and construction projects. These Guidelines, while citing the applicable sustainability requirements, do not re-state the text of these mandates. This section provides an overview of these mandatory requirements in matrix format. Hot links to current editions of the documents are also embedded at the top of each matrix column to enable project staff easy access to up-to-date information. Codes and regulations change frequently - it is essential for project teams to refer to the most current editions of the codes and extract the details of applicable sustainability requirements for individual projects.

<table>
<thead>
<tr>
<th>NATIONAL</th>
<th>STATE OF CALIFORNIA</th>
<th>SAN FRANCISCO BAY AREA REGIONAL</th>
<th>CITY AND COUNTY OF SAN FRANCISCO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leadership in Energy and Environmental Design (LEED) Environmental Rating System developed by the US Green Building Council; elements are mandated by State and local law</td>
<td>California Fair Employment &amp; Housing Act Prohibits discrimination in employment</td>
<td>Bay Area Air Quality Management District (BAAQMD) Regulates air pollution sources in the nine Bay Area counties</td>
<td>SF Environment Code Consolates the City's Ordinances governing protection of the environment, natural resources, and sustainability</td>
</tr>
<tr>
<td>Americans with Disabilities Act (ADA) Guarantees equal opportunity for individuals with disabilities in public accommodations, employment, transportation, government services, and telecommunications</td>
<td>CALGreen Establishes minimum 'green' building standards for construction projects</td>
<td>San Francisco Regional Water Quality Control Board Regulates water quality management activities in the nine Bay Area counties</td>
<td>SF Planning Code Regulates property development, building and infrastructure location, access, light, and privacy for properties located within SF. SFO projects incorporate Planning Code measures which enhance sustainability metrics</td>
</tr>
<tr>
<td></td>
<td>California Energy Code Establishes minimum energy efficiency standards for buildings</td>
<td>San Francisco Bay Conservation and Development Commission (BCDC) Regulates and permits development within 100’ of high tide line</td>
<td>SF Public Works Code Regulates design, construction and maintenance of city infrastructure, rights-of-way and facilities</td>
</tr>
</tbody>
</table>

The Federal Aviation Administration (FAA) governs all US airports including SFO. FAA aims to make sustainability a core objective in airport planning. FAA's interest in sustainability began in 2010, when it funded the first Sustainable Master Plan at Ithaca-Tompkins Regional Airport in Ithaca, New York, and the first Sustainable Management Plan at Northeast Florida Regional Airport in St. Augustine, Florida. FAA then initiated a “Sustainable Master Plan Pilot Program,” through which it funded either a Sustainability Master Plan or a Sustainability Management Plan at 10 airports across the USA. Due to the success of these 10 projects, FAA decided to fund another phase of sustainability pilot projects, this time at 13 airports across the country. FAA will continue to build on lessons learned from these 23 FAA-funded airport sustainability planning projects in order to develop guidance on airport sustainability planning. The guidance document is expected to be published in 2013. At the writing of this guideline, the FAA has no mandated sustainability requirements.
# MAJOR MANDATORY CODES AND REGULATIONS SUMMARY MATRIX

<table>
<thead>
<tr>
<th>Category</th>
<th>FEDERAL AND NATIONAL</th>
<th>STATE</th>
<th>REGIONAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEED NC, CI, CS, EBOM</td>
<td>California Fair Employment and Housing Act</td>
<td>CALGreen</td>
<td>California Energy Code</td>
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<tr>
<td>ADA</td>
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</tbody>
</table>

### Key Sustainability Points
- All SFO building projects over 5,000 square feet are required by San Francisco law to achieve LEED Gold certification / conformance
- Minimum facility accessibility
- Minimum non-discrimination service and employment
- Federal law
- Energy efficiency
- Water use efficiency
- Indoor environmental air quality
- Acoustical and thermal comfort
- Storm water management
- Mandatory energy efficiency
- Air quality standards and compliance regulations.
- Water quality standards and compliance regulations.
- Regulates allowable work within 100’ of high tide line, including dredging, filling and shoreline development
- Establishes shoreline development guidelines and standards
- Makes exceptions for specific development types such as critical infrastructure
- Generates various documents including the San Francisco Bay Plan

### Renewal Cycle
- Varies; target three year cycle
- Current version: v4
- Varies
- Current edition
- Varies
- Current version: 2013
- Varies by section
- Varies by section
- Varies by section
- Updates more frequent as climate change accelerates

### Regulatory Authority
- US Green Building Council
- US Congress
- State of California Court
- California Building Standards Commission
- California Energy Commission
- Bay Area Air Quality Management District
- San Francisco Regional Water Quality Control Board
- Bay Conservation and Development Commission

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### MAJOR MANDATORY CODES AND REGULATIONS SUMMARY MATRIX (CONTINUED)

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>SAN FRANCISCO CITY AND COUNTY</th>
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<tbody>
<tr>
<td><strong>Key Sustainability Points</strong></td>
<td><strong>SF Environment Code</strong></td>
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<tr>
<td>Environmental requirements</td>
<td>Environmental requirements for San Francisco municipal projects</td>
</tr>
<tr>
<td>Use precautionary principle in</td>
<td>Use precautionary principle in decision making</td>
</tr>
<tr>
<td>decision making</td>
<td>Incorporates specific criteria re: Energy and water use efficiency, Indoor environmental air quality, Acoustical and thermal comfort, Storm water management, Environmentally preferable purchasing, Recycling, and Construction &amp; demolition debris management</td>
</tr>
<tr>
<td>Incorporates specific criteria re:</td>
<td></td>
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<tr>
<td>Energy and water use efficiency,</td>
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<tr>
<td>Indoor environmental air quality,</td>
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<tr>
<td>Acoustical and thermal comfort,</td>
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<tr>
<td>Storm water management,</td>
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<td>Environmentally preferable</td>
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<tr>
<td>purchasing, Recycling, and</td>
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<td>Construction &amp; demolition debris</td>
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<td>management</td>
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<td>Targets Fossil-fuel free energy</td>
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<td>by 2030</td>
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<tr>
<td>Requires LEED Gold conformance</td>
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<tr>
<td><strong>Renewal Cycle</strong></td>
<td><strong>Varies</strong></td>
</tr>
<tr>
<td><strong>Regulatory Authority</strong></td>
<td><strong>San Francisco Department of the Environment</strong></td>
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<tr>
<td>San Francisco Department of the Environment</td>
<td>San Francisco Planning Department</td>
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</table>

These guidelines are not intended to be an exhaustive list of governing codes and regulations. Governing codes and regulations are frequently updated. It is incumbent upon project teams to check the latest versions of all governing regulations in order to confirm the latest requirements. SF Planning, Public Works, and Administrative Code Measures are incorporated into SFO projects where applicable.
### Summary of Requirements: Guide to Content of Sustainability Matrices

#### COMFORT & HEALTH: Summary of Existing Requirements and Recommended Measures

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>SF Environment Code</th>
<th>CALGreen</th>
<th>California Energy Code (CEC)</th>
<th>LEED</th>
<th>SF Public Works Code</th>
</tr>
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#### SFO Expanded Requirements (Including CALGreen Voluntary Measures Codes)

- **Air Quality**
  - Sec. 706.a (construction work plan per LEED 10.1.4.3.5; occupancy VOC registration per LEED 60.1.3.3.4)
  - Sec. 5.714.6 (additions & alterations: ventilation must meet/exceed CBC to control moisture)
  - Sec. 302 (pesticide use prohibited)
  - Sec. 1303, 1305 (arsenic use prohibited)
  - Sec. 101 (follow precautionary principle in decision making)

- **Ventilation**
  - Sec. 711.6 (Department of Public Health annual survey: humidity problems in City-owned buildings)
  - Sec. 711.7 (nurse call system required in all City-owned buildings)
  - Sec. 711.8 (healthcare, medical, and educational facilities)

- **Access**
  - Sec. 300 (all facilities shall be accessible to persons with disabilities)
  - Sec. 301 (all facilities shall be accessible to persons with disabilities)
  - Sec. 302 (all facilities shall be accessible to persons with disabilities)

- **Chemicals of Concern**
  - Sec. 101 (follow precautionary principle in decision making)
  - Sec. 102 (pesticide use prohibited)
  - Sec. 103 (listed hazardous waste characterized by project disturbing 50+ cy of soil)

- **Thermal Comfort**
  - Sec. 711.3 (Department of Public Health annual survey: thermal comfort problems in City-owned buildings)

- **Acoustic Comfort**
  - Sec. 711.4 (Department of Public Health annual survey: acoustic comfort problems in City-owned buildings)

- **Green Cleaning**
  - Chap. 2 (environmentally preferable purchasing)

#### Required Actions

- Each year, address and mitigate top problems identified in survey from prior year.

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<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>SF Environment Code</th>
<th>CALGreen</th>
<th>California Energy Code</th>
<th>LEED (NC, CI, CS, EBOM)</th>
<th>SF Ordinance 81-08</th>
</tr>
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<tbody>
<tr>
<td>Greenhouse Gas Reduction</td>
<td>□ Sec. 201.2 (environmentally preferable purchasing)</td>
<td></td>
<td></td>
<td></td>
<td>□ Sec. 902 (mandated GHG reductions below 1990 levels – 25% by 2017, 40% by 2025 and 80% by 2050) natural gas consumption by migrating to geothermal HVAC and solar hot water</td>
</tr>
<tr>
<td>Energy Optimization</td>
<td>□ Sec. 705 (LEED Gold all projects over 5,000 sf)</td>
<td>□ Sec. 5.201</td>
<td>□ Sec. 110.1 – 110.2 (mandatory appliance efficiency)</td>
<td></td>
<td>□ EA prereq 2 (minimum 5% energy reduction over baseline for new buildings; 3% for renovations)</td>
</tr>
<tr>
<td>Energy and Enclosure Systems Commissioning</td>
<td>□ Sec. 706.a.5 (enhanced commissioning per LEED-NC + LEED-CI EAc1)</td>
<td>□ Sec. 5.410.2 (mandatory commissioning in new buildings over 10,000 sf)</td>
<td></td>
<td></td>
<td>□ EA prereq 1 (fundamental commissioning and verification)</td>
</tr>
<tr>
<td>On Site Renewable and Alternative Energy</td>
<td>□ Sec. 706.a.4 (Min. 1% of energy by renewables per LEED NC EAc5 + LEED CI EAc4)</td>
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<tr>
<td>Refrigerant Management and Ozone Protection</td>
<td>□ Sec. 706.a.6 (enhanced refrigerant management per LEED NC EAc6n + LEED CI EAc5d)</td>
<td>□ Sec. 5.508 (no CFCs or halon)</td>
<td></td>
<td></td>
<td>□ NC EA prereq. 4 (no CFCs) □ CI EA prereq. 3</td>
</tr>
<tr>
<td>Criteria Pollutants and Air Toxics</td>
<td></td>
<td>□ Sec. 5.504.7 (no smoking indoors or within 25' of entry or intake)</td>
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<tr>
<td></td>
<td></td>
<td>□ Sec. 5.506.2 (CO2 monitors required for demand control ventilation systems, including additions &amp; alternations)</td>
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</tbody>
</table>

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## ENERGY & ATMOSPHERE: Summary of Existing Requirements and Recommended Measures (Continued)

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>SFO Expanded Requirements* (Including <strong>CALGreen</strong>)</th>
</tr>
</thead>
</table>
| **Greenhouse Gas Reduction** | - Calculate GHG emissions from construction activities & take specific measures to reduce these emissions  
- Reduce GHG emissions from natural gas consumption by automating building HVAC systems, migrating to geothermal HVAC and solar hot water or by other feasible methods |
| **Energy Optimization** | - Aim for LEED Platinum in all new buildings  
- Design and install Building Automation Systems for controlling lighting and HVAC in all new buildings  
- **CALGreen Sec. A5.106.7** Provide exterior wall shading for energy use reduction  
- **CALGreen Sec. A5.212** Design energy efficient elevators, escalators, and other systems |
| **Energy and Enclosure Systems Commissioning** | - Design and implement on-going recording of all systems for continuous information that can inform continuous improvement |
| **On Site Renewable and Alternative Energy** | - **CALGreen Sec. A5.211** Prepare for on-site renewable energy. Provide infrastructure for future installation of roof top photovoltaic systems  
- Design and install solar and geothermal renewable energy systems for new buildings to the maximum extent feasible. For projects where photovoltaic system is not economically feasible, provide infrastructure for future PV installation |
| **Refrigerant Management and Ozone Protection** | - Eliminate or minimize refrigerant gas leakage, identify additional gases & chemicals used in the project that contribute to ozone depletion & create phase-out plan  
- **CALGreen Sec. A5.508** Avoid HCFCs in HVAC equipment and refrigeration equipment |
| **Criteria Pollutants and Air Toxics** | - Achieve incremental reduction in criteria and air toxics emissions over BAAQMD permit requirements, as feasible |

These guidelines are not intended to be an exhaustive list of the governing codes and regulations. Governing codes and regulations are frequently updated. It is incumbent upon project teams to check the latest versions of all governing regulations in order to confirm the latest requirements.

*SFO expanded requirements identify measures that must be evaluated and considered for potential implementation, as feasible, in SFO construction projects.
<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>REFERENCE CODE (MANDATORY ELEMENTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day light Access</strong></td>
<td></td>
</tr>
</tbody>
</table>
| **Air Quality**                      | Sec. 706.a (LEED NC+CI: EQc1 Enhanced indoor air quality strategies, EQ c3 Construction indoor air quality management plan)  <br> Sec. 706.a.10 (low emitting materials per LEED NC+CI EQc2)  <br> Sec. 706.a.11 (control pollutant entry per LEED EQc1 Enhanced indoor air quality strategies)  <br> Sec. 711.b (Dept of Public Health annual survey of IEQ problems in City-owned bldgs)  <br> Sec. 10 (cover aggregates during transport) | Sec. 5.504.3 (mandatory covering of air ducts during construction)  <br> Sec. 5.504.4 (VOC limits for adhesives, coatings, sealants, floor coverings)  <br> Sec. 5.504.3 (additions & alterations - mandatory covering of air ducts during construction)  <br> Sec. 5.504.4 (additions & alterations - VOC limits for adhesives, coatings, sealants, floor coverings) | LEED NC+CI: IEQ prereq 1 Enhanced indoor air quality strategies  <br> LEED NC+CI: IEQ prereq 2 (prohibit smoking) | SF Public Works Code |}
| **Ventilation**                      | Sec. 711.b (Department of Public Health annual survey humidity problems in City-owned buildings)  <br> Sec. 711.g.1 (moisture & mold management) | Sec. 5.505 (ventilation must meet/exceed CBC to control moisture)  <br> Sec. 5.506 (minimum ventilation per CEC)  <br> Sec. 5.505.1 (additions & alterations - ventilation must meet/exceed CBC to control moisture)  <br> Sec. 5.506 (additions & alterations - minimum ventilation per CEC) | Sec. 120.1 (natural ventilation OR minimum 15 cfm / person OR minimum 0.15 cfm per sf of conditioned area) | SF Public Works Code |}
| **Chemicals of Concern**             | Sec. 101 (follow precautionary principle in decision making )  <br> Sec. 302 (pesticide use prohibited)  <br> Sec. 711.g.2 (lead ban)  <br> Sec. 1303, 1305 (arsenic-treated wood ban)  <br> Sec. 509 (PVC ban) |  |  | Sec. 1001 (soil analysis for hazardous waste required for any project disturbing 50+ cy of soil) |}
| **Thermal Comfort**                  | Sec. 711.b (Department of Public Health annual survey thermal comfort problems in City-owned buildings) |  |  | Sec. 120 (minimum space conditioning requirements) |}
| **Acoustic Comfort**                 | Sec. 711.b (Department of Public Health annual survey acoustic comfort problems in City-owned buildings) | Sec. 5.507.4.1 (building envelope STC min. 50 STC, windows min. 30 STC)  <br> Sec. 5.507.4.2 (walls/ceilings between tenant and public spaces min. 40 STC)  <br> Sec. 5.507.4 (additions & alterations - building envelope STC min. 50 STC, windows min. 30 STC)  <br> Sec. 5.507.4.3 (additions & alterations - walls/ceilings between tenant and public spaces min. 40 STC) |  | LEED EB only: IEQ prereq 3 (green cleaning policy) |}
| **Green Cleaning**                   | Chapter 2 (environmentally preferable purchasing) |  |  |  |}

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### COMFORT & HEALTH: Summary of Existing Requirements and Recommended Measures (Continued)

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>REFERENCE CODE (MANDATORY ELEMENTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day light Access</td>
<td>- Provide daylighting for a minimum of 75% of SFO staff / tenants / passenger areas wherever possible (same as LEED IEQ 8.1 requirement plus LEED NC+CI EQc7 Daylight Requirement – (55, 75 or 90%)</td>
</tr>
<tr>
<td>Air Quality</td>
<td>- Use zero/very low VOC containing adhesives, sealants, paints, coatings and for all cleaning materials/solvents for all installation and maintenance purposes</td>
</tr>
<tr>
<td>Ventilation</td>
<td>- Provide displacement ventilation / under floor air distribution for all new projects</td>
</tr>
</tbody>
</table>
| Chemicals of Concern      | - Identify current Chemicals of Concern, described below, and exclude from building materials, products and systems used in construction and maintenance.  
                             - Chemicals of Concern: Adopt CARB formaldehyde limits for all formaldehyde-containing materials, including fabric treatments, glues, fiberglass insulation, paints and other coatings, as well as all wood-based materials not previously addressed by CARB.  
                             - Incorporate pest habitat denial measures in new buildings |
| Thermal Comfort           |                                                                                                                                 |
| Acoustic Comfort          |                                                                                                                                 |

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### WATER & WASTEWATER: Summary of Existing Requirements and Recommended Measures

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>SF Environment Code</th>
<th>CALGreen</th>
<th>LEED (NC, CI, CS, EBOM)</th>
<th>SF Public Works Code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Storm water Management</strong></td>
<td>❑ Sec. 706.a.1 (storm water control per LEED-NC SSC4 Rainwater management; construction activity pollution prevention per LEED-NC prereq SSp.1 or equal under SFPUC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Water Efficiency &amp; Conservation</strong></td>
<td>❑ Sec 706.a.2 (minimum 30% reduction indoor water use per LEED WE 3.2) ❑ Sec. 709 (water conservation requirements for retrofits -1.28 gpf toilets, 0.5 gpf urinals, shower heads 1.5 gpm max flow rate, faucets 0.5 gpm max flow rate)</td>
<td>❑ Sec. 5.303.1 (mandatory metering for any space projected to consume 100+ gpd) ❑ 5.303.2 (max flow rates - showerheads 2 gpm @ 80 psi, lavatory faucets 0.4 gpm @ 60 psi, WCs 1.28 gpf, urinals 0.5 gpf) ❑ Sec. 5.304 (mandatory irrigation controls for landscape) ❑ Sec. 5.303.1 (additions &amp; alterations - mandatory metering for any space projected to consume 100+ gpd); ❑ Sec. 5.303.2 (additions &amp; alterations – Reduce potable water use within building by 30%) ❑ Sec. 5.304 (additions &amp; alterations - mandatory irrigation controls for landscape)</td>
<td>❑ LEED – NC: WE prereq 1 (Outdoor water use reduction) ❑ LEED – CI: WEp 1 Indoor water use reduction (20% reduction over baseline)</td>
<td>❑ Sec. 1101 (no use of potable water for soil compaction or dust control); Sec. 1205 (reclaimed water use to comply with regulations of this section)</td>
</tr>
<tr>
<td><strong>Water Quality Management</strong></td>
<td>❑ Sec. 140.3 (disposal of food waste, fats, oils into wastewater prohibited)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## WATER & WASTEWATER: Summary of Existing Requirements and Recommended Measures (Continued)

### REFERENCE CODE (MANDATORY ELEMENTS)

<table>
<thead>
<tr>
<th>SFO Expanded Requirements* (Including CALGreen)</th>
</tr>
</thead>
</table>

- Require porous pavement for all surface parking lots wherever subsurface conditions are amenable to rainwater infiltration into the ground
- Track lifecycle water usage & cost
- Require the use of non-potable water for construction activities, vehicle wash, landscape irrigation
- Comply with CALGreen Sec. A5.303.5 requiring dual plumbing piping for potable and recycled water systems in all new and renovated buildings. Use the recycled water for toilet & urinal flushing, vehicle washing and landscape irrigation
- Comply with CALGreen Sec. A5.303.2.3.2 requiring 35% indoor water savings over baseline
- Comply with CALGreen Sec. A5.304.2.1 requiring Installation of separate meters or sub-meters for indoor and outdoor potable water use for landscape areas 500 – 1,000 sf
- Comply with CALGreen Sec. A5.304.4 requiring potable water use reduction for landscape irrigation
- Exceed RWQCB permit requirements by progressively decreasing the discharge of nitrogen / ammonia / chlorination by-products into the Bay, as feasible

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### SITE & HABITAT: Summary of Existing Requirements and Recommended Measures

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>REFERENCE CODE (MANDATORY ELEMENTS)</th>
<th>SF Planning Code</th>
<th>SFO Expanded Requirements* (Including CALGreen)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat &amp; Open Space</td>
<td>§ Sec. 5.106.8 Incorporate light pollution reduction measures, where feasible</td>
<td>§ Sec. 155.1 - Provide sheltered and open space bicycle parking facilities required at buildings, based on building occupancy</td>
<td>§ Install green roofs where wildlife control issues are not paramount</td>
</tr>
<tr>
<td></td>
<td>§ Sec. 5.106.4 (New Construction) Provide designated bicycle parking for employees and visitors in new and renovated buildings</td>
<td>§ Sec. 5.106.2 Provide required bicycle parking in garages</td>
<td>§ Plant tree landscaping where feasible</td>
</tr>
<tr>
<td></td>
<td>§ Sec. 5.106.5 (New Construction) Provide specified designated parking for low-emitting, fuel-efficient and carpool/vanpool vehicles</td>
<td>§ Sec. 5.106.3 Provide required number of showers and lockers based on building occupancy</td>
<td>§ Comply with San Francisco Bird Safe Building Standards</td>
</tr>
<tr>
<td></td>
<td>§ Sec. 5.106.4 (additions &amp; alternations) Provide designated minimum bicycle parking for employees and visitors</td>
<td>§ Provide Electric Vehicle Park and charge service</td>
<td></td>
</tr>
<tr>
<td></td>
<td>§ Sec. 5.106.6 (additions &amp; alternations) provide specified designated parking for low-emitting, fuel-efficient and carpool/vanpool vehicles</td>
<td>§ Use Porous pavement for surface lots wherever subsurface conditions allow rainwater infiltration into the ground</td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>§ Provide Photo Voltaic (PV) shading canopies on garage roof decks and surface parking areas; PV or Building Integrated PV on administrative, maintenance and infrastructure facilities</td>
<td>§ Provide operable windows or other means for natural ventilation in new buildings, if feasible</td>
<td></td>
</tr>
<tr>
<td></td>
<td>§ CALGreen Sec. A5.106.11 Reduce non-roof heat islands through 50% minimum hardscape alternatives (plantings, high albedo pavements, open grid pavements) and cool roofs, as feasible</td>
<td>§ Replace existing heating / cooling systems with geothermal systems, if feasible</td>
<td></td>
</tr>
<tr>
<td>Heat Islands</td>
<td>§ Sec. 907 (become fossil-fuel free by 2030)</td>
<td>§ Identify high seismic hazard areas &amp; harden structures at risk</td>
<td></td>
</tr>
<tr>
<td>Climate Change Adaptation</td>
<td>§ Provide operable windows or other means for natural ventilation in new buildings, if feasible</td>
<td>§ Restore areas disturbed by construction</td>
<td></td>
</tr>
<tr>
<td>Site &amp; Building Orientation</td>
<td>§ Provide operable windows or other means for natural ventilation in new buildings, if feasible</td>
<td>§ Identify high seismic hazard areas &amp; harden structures at risk</td>
<td></td>
</tr>
</tbody>
</table>

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<th>CALGreen</th>
<th>LEED (NC, CI, CS, EBOM)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material &amp; Resource Conservation</strong></td>
<td></td>
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</tr>
<tr>
<td>Sec. 204 (environmentally preferable purchasing, only from products on the Approved Alternates List); Sec. 504 (maximize purchase of recycled products, maximize waste diversion, develop departmental Resource Conservation Plan, consolidate recyclables by source separation, printing/writing paper should contain min 30% post-consumer recycled content, eliminate the use of PVC plastics)</td>
<td>Sec. 5.407 (requires mandatory water resistant exterior envelope construction, mandatory moisture management)</td>
<td>MRp 1:Materials &amp; Resources - prerequisite 1 (requires dedicated area for placing recyclable waste containers)</td>
<td></td>
</tr>
<tr>
<td>Sec. 707.a (provide space for, collection of recyclables &amp; compostable waste)</td>
<td></td>
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<tr>
<td>Sec. 800 (tropical hardwood and virgin redwood ban)</td>
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<tr>
<td>Sec. 1402 (achieve min 65% diversion of C&amp;D debris from landfill)</td>
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<tr>
<td>Sec. 1703 (mandatory use of recyclable or compostable checkout bags)</td>
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<td></td>
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<tr>
<td>Sec. 1902-1905 (establish recycling and refuse source separation)</td>
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<tr>
<td><strong>Regional Sourcing</strong></td>
<td></td>
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</tr>
<tr>
<td>Sec. 707.b (city employees must use Virtual Warehouse for furniture, equipment, computers and supplies before purchasing new supplies)</td>
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<td></td>
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<tr>
<td><strong>Life Cycle Based Analysis &amp; Selection</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Zero Waste</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Sec. 706.a.7 (achieve minimum 75% construction debris diversion per LEED MR2.2)</td>
<td>Sec. 5.408 (requires minimum 50% C&amp;D recycling or diversion; mandatory 100% re-use or recycling of soils, trees, rocks, stumps &amp; vegetation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sec. 708 (requires C&amp;D 75% debris diversion, source separation, C&amp;D management plan)</td>
<td>Sec. 5.410.1 (requires mandatory minimum occupant recycling of paper, cardboard, glass, plastics &amp; metals)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sec. 1903-1907 (requires waste recycling and composting including source separation)</td>
<td></td>
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<tr>
<td>Sec. 1603 (prohibits the use of disposable food service ware that contains polystyrene foam)</td>
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<tr>
<td>Sec. 1604 (requires the use of biodegradable / compostable / recyclable for disposable food service ware)</td>
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<td></td>
</tr>
</tbody>
</table>

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# MATERIALS & RESOURCES: Summary of Existing Requirements and Recommended Actions (Continued)

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<thead>
<tr>
<th>CATEGORY</th>
<th>REFERENCE CODE (MANDATORY ELEMENTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material &amp; Resource Conservation</strong></td>
<td></td>
</tr>
<tr>
<td>❑ Develop a list of prioritized / preferred high durability materials &amp; include in standard specifications</td>
<td></td>
</tr>
<tr>
<td>❑ Design for re-use of existing materials, products &amp; equipment</td>
<td></td>
</tr>
<tr>
<td>❑ Design for deconstruction, re-use &amp; recycling</td>
<td></td>
</tr>
<tr>
<td>❑ Salvage materials &amp; resources</td>
<td></td>
</tr>
<tr>
<td>❑ Use min 18% recycled content asphalt</td>
<td></td>
</tr>
<tr>
<td>❑ Maximize use of re-usable concrete formwork, poplar OSB, agriboards, bamboo, cork, wool carpet and fabrics, cotton batt insulation, linoleum, bio-based plastics, wheatgrass or strawboard</td>
<td></td>
</tr>
<tr>
<td>❑ CALGreen Sec. A5.213.1 Use energy efficient steel framing</td>
<td></td>
</tr>
<tr>
<td>❑ CALGreen Sec. A5.404.1 Utilize advanced wood framing techniques to minimize wood use</td>
<td></td>
</tr>
<tr>
<td>❑ CALGreen Sec. A5.405.4 Target 10% (by total material cost) with high postconsumer or pre-consumer recycled content</td>
<td></td>
</tr>
<tr>
<td><strong>Regional Sourcing</strong></td>
<td></td>
</tr>
<tr>
<td>❑ Integrate local/regional sourcing with Local Hire - contractors (can get credit towards local hire if material suppliers use local labor)</td>
<td></td>
</tr>
<tr>
<td>❑ CALGreen Sec. A5.405.1 Use regional materials (harvested or manufactured within 500 miles of SFO)</td>
<td></td>
</tr>
<tr>
<td><strong>Life Cycle Based Analysis &amp; Selection</strong></td>
<td></td>
</tr>
<tr>
<td>❑ Develop life-cycle goals in accounting &amp; budgeting practices.</td>
<td></td>
</tr>
<tr>
<td>❑ Assign a life-cycle cost for carbon emissions</td>
<td></td>
</tr>
<tr>
<td>❑ Perform Life Cycle Analysis for material selection and evaluation of alternative design configuration</td>
<td></td>
</tr>
<tr>
<td>❑ CALGreen Sec. A5.406 Select materials with enhanced service life and reduced maintenance requirements</td>
<td></td>
</tr>
<tr>
<td>❑ CALGreen Sec. A5.409 Select materials based on life cycle assessment of their embodied energy and / or greenhouse gas emission potential</td>
<td></td>
</tr>
<tr>
<td>❑ Perform whole building Life Cycle Assessment showing minimum 10% improvement for three impacts including climate change compared to a reference building meeting 2010 CEC requirements</td>
<td></td>
</tr>
<tr>
<td><strong>Zero Waste</strong></td>
<td></td>
</tr>
<tr>
<td>❑ Pursue Extended Producer Responsibility for key materials such as carpet, furniture, ceiling tiles, etc.; coordinate with Department of Environment efforts</td>
<td></td>
</tr>
<tr>
<td>❑ Work with all tenants to reduce waste. Ensure tenants understand the City’s Zero Waste goals, and ensure all spaces are equipped with recycling and composting bins</td>
<td></td>
</tr>
<tr>
<td>❑ Design tenant spaces with adequate access to recycling and composting collection facilities</td>
<td></td>
</tr>
<tr>
<td>❑ Provide recycling facilities for deplaned waste</td>
<td></td>
</tr>
</tbody>
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## EQUITY & AESTHETICS: Summary of Existing Requirements and Recommended Measures

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<th>CATEGORY</th>
<th>REFERENCE CODE (MANDATORY ELEMENTS)</th>
<th>SFO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ADA</strong></td>
<td><strong>California Fair Employment and Housing Act</strong></td>
<td><strong>SFO Expanded Requirements</strong></td>
</tr>
<tr>
<td><strong>Fair Labor Practices</strong></td>
<td>Sec. 12990 (nondiscrimination in employment)</td>
<td>Sec. 12D &amp; 14B (Women/Minority/Local Business Utilization)</td>
</tr>
<tr>
<td></td>
<td>Sec. 12E (Employee Sexual Privacy)</td>
<td>Sec. 12P &amp; 12R (Minimum Compensation)</td>
</tr>
<tr>
<td></td>
<td>Sec. 12Q &amp; 14 (Health Care Accountability &amp; Security)</td>
<td>Sec. 12U (Sweat shop –free Contracting)</td>
</tr>
<tr>
<td></td>
<td>Sec. 14A (Disadvantaged Business Enterprise)</td>
<td>Operators &amp; designers shall submit their Code of Conduct or ethics policy statement</td>
</tr>
<tr>
<td><strong>Universal Design</strong></td>
<td>Ch. 810 (accessible routes for people with disabilities shall adjoin the general public routes,</td>
<td>All projects should include the following basic principle of Universal design: Equitable Use, Simple Intuitive Use, Perceptible Information, Low Physical Effort, Size and Approach</td>
</tr>
<tr>
<td></td>
<td>terminal information must be accessible to deaf/blind, clocks must have contrasting numbers, all</td>
<td></td>
</tr>
<tr>
<td></td>
<td>publicly accessible facilities must be fully accessible)</td>
<td></td>
</tr>
<tr>
<td><strong>Aesthetics</strong></td>
<td>Sec. 1303 (graffiti removal mandated)</td>
<td>Establish overall aesthetics criteria and incorporate in Tenant / Concession Guidelines and all new SFO project guidelines</td>
</tr>
<tr>
<td><strong>Community Engagement</strong></td>
<td></td>
<td>Establish Meeter - greeter stations</td>
</tr>
</tbody>
</table>

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3.1 PROJECT PROCESS

3.2 ASSESSMENT PROCEDURE

3.3 STAKEHOLDER ENGAGEMENT PROCESS (SEP)

3.4 LEED CONSIDERATIONS
   A. PROJECT DOCUMENTATION
   B. OWNER PROJECT REQUIREMENTS
Project Process: Overall Objectives

The objectives of sustainable planning, design, and construction (PD&C) are to minimize the environmental impacts; energy and materials consumption; and water use and waste generation associated with building construction, operation and maintenance while creating a healthy and aesthetic indoor environment for employees and the general public using such buildings.

Applicable standards and criteria to be met are found in numerous codes and supporting rating systems. Analysis and implementation of these standards and criteria occur during the different phases of a project’s life cycle, as shown below.

1. **Sustainable Planning**
   - Sustainable planning should encompass the following basic steps for developing the required facility:
     1. Defining the needs that must be met by the new facility
     2. Optimizing the scale of the facility to meet the projected needs within a reasonable time frame
     3. Identifying the stakeholders and securing their input for relevant elements of the project
     4. Siting the facility so as to minimize or avoid environmental impacts
     5. Identifying the applicable sustainability elements for the given project
     6. Defining the codes, procedures, and the tools for assessing and evaluating the applicable sustainability elements and incorporating these elements in the design process
     7. Defining the procedures and the tools for incorporating the identified sustainability elements in the construction process.

2. **Sustainable Design**
   - Sustainable design procedure should, at a minimum, meet the following requirements:
     1. Sustainability goals and objectives established during the planning phase should be further refined and incorporated in the design of the building.
     2. The building or structure should create the lowest life cycle environmental impact resulting from the use of materials and equipment incorporated in the building as well as the construction procedures associated with the building or structure.
     3. The life cycle cost of the building should be optimized without sacrificing environmental sustainability.
     4. Energy consumption of the building should be minimized with the aim of approaching a zero net energy building to the maximum extent feasible.
     5. Resource uses for operation and maintenance of the building should be minimized to the maximum extent practicable.
     6. The building should provide a healthy and aesthetic indoor environment for the intended occupants and users.
     7. Direct pollutant emissions, including greenhouse gases, from the HVAC system and other building equipment should be eliminated or minimized.
     8. The most desirable result is water balance with minimized use of municipal potable water, maximized use of reclaimed water and minimized wastewater entering the San Francisco Bay.

3. **Sustainable Construction Practices**
   - Sustainable construction practices should, at a minimum, meet the following criteria:
     1. Sustainability goals and objectives established during the planning and design phases should be further refined and incorporated in the construction contract documents.
     2. Specific environmental impact of construction equipment and activities should be addressed and any required impact mitigation measures should be included in the contract documents and enforced during construction.
     3. Potential health and safety impact of construction equipment and activities should be addressed and any required impact mitigation measures should be included in the contract documents and enforced during construction.
     4. Construction methods should not deviate from sustainability objectives for the project.
     5. Construction operations should be carried out efficiently and cost effectively.

4. **Sustainable O&M Practices**
   - The goals and objectives for sustainable operation and maintenance practices should be established during the planning and design phases and the required equipment and systems enabling the implementation of sustainable O&M practices should be incorporated in the building during the construction phase.
   - Examples of sustainable O&M practices are as follows:
     1. The HVAC system should be operated to achieve maximum energy efficiency by minimizing the use of natural gas and electricity and eliminating the unwanted loss or gain of heat in the HVAC pipeline network.
     2. The HVAC system should be operated automatically by using sensor data and computer controlled boilers, chillers, pumps, fans, etc. to minimize the need for manual operation of the system components.
     3. The lighting system should also be operated automatically commensurate with the level of daylighting in various parts of the building.
     4. Bathroom fixtures, hand dryers, etc. should be maintained to ensure maximum efficiency.
     5. A regular maintenance schedule should be maintained for building systems and electronic records of maintenance work and performance improvements should be created and stored.
     6. All meters and sub-meters for electricity, natural gas, water, outside air intake, etc. should be maintained and the consumption rates shall be recorded on servers and stored permanently. Data should be reviewed annually and a process should be developed for taking corrective action as needed.
SFO Recommended Sustainability Assessment Procedure

All SFO building construction projects should implement the following Sustainability assessment process subject to budget and schedule constraints.

1. Develop at minimum two conceptual layouts of facilities, equipment and operational procedures, prior to start of design, for use in simulation steps 2 through 5.

2. Calculate Whole Building life cycle impact (LCA) of each conceptual model for all building components, including equipment, operation & maintenance and end of life disposition using NIST’s BIRDS model or a similar approach.

3. Quantify climate Impact of the two conceptual models by assessing life cycle carbon footprint of building, equipment, and operation & maintenance activities.

4. Evaluate up to 5 alternates for various building materials which have been characterized for NIST’s BEES software LCA application or in other sources and select the optimal material for use in the building.

5. Document the impact of building deconstruction procedures for the alternative conceptual models.

6. Select the final design based on the conceptual model outcomes.

7. Repeat the assessment steps for the final as-built design.

8. Prepare a report comparing planned versus actual outcomes after completion of construction and after 5 years of operation.
### Project Initiation Phase

The following items should be addressed in this phase:

- Develop Owners Project Requirements & Basis of Design
- Determine if a building is actually needed
- Determine building orientation to optimize energy efficiency
- Develop flexibility to accommodate long term objectives of the project

### Planning & Design Phase

The following items should be addressed in this phase to ensure compliance with all relevant codes, including CALGreen and San Francisco Municipal Code:

- Storm water pollution prevention
- Bicycle parking
- Designated parking for low emission and other qualified vehicles
- Light pollution reduction
- Bird safe buildings

### Design of Building Envelope

The annual heat gain or loss in a building is, to a major extent, dependent on the material composition of the building envelope. Minimizing unwanted heat gain or loss is, therefore, an important step in the design of energy efficient buildings. Some of the parameters that could be optimized in this step are as follows:

- Shading
- Glazing Area
- Insulation of window panes, skylights, etc.
- Use of programmable tinted glass
- Insulation of walls, floors, and roofs
- Minimizing air leakage through exterior doors

Energy Modeling should be used starting in schematic design and throughout the design phase to assess the relative effectiveness of the proposed envelope to assess the relative effectiveness of the proposed envelope. The SEP should create dialogue between the design team and SFO staff on the best life-cycle options for the building envelope.

### Materials Procurement & Life Cycle Assessment

A listing of all major materials to be procured for the subject building or construction project should be developed and alternative choices should be identified. The choices should then be ranked on the basis of lifecycle environmental impacts and economic cost. Recommendations should be developed for the optimum material selection to meet technical, environmental, and economic requirements for the project. Examples of such materials include concrete mixes, exterior cladding and roofing, floor coverings, indoor furniture.

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**Stakeholder Engagement Process (SEP)**

SFO uses the SEP to strategize, establish goals, and define procedures for carrying out major construction or renovation projects. The SEP covers all aspects of SFO operations from Architecture to Baggage Handling. In general, all mandatory and SFO target requirements (see Section 2) should be evaluated by the SEP teams for any construction project.

The SEP should also serve as a platform for establishing sustainability goals for the project. These goals could be defined more systematically by major categories or elements involved in each construction project as described below. The sustainability goal-setting agenda should include all relevant elements from this set. The SFO SEP Team Structure is included in Section 7 References.

### Stakeholder Engagement Process (SEP), continued

#### Heating, Ventilation, and Air Conditioning Systems

HVAC systems are a major consumer of energy in buildings and contribute a significant portion of the buildings footprint at SFO. Improved design of these systems with emphasis on outside air circulation for cooling purposes and for controlling the temperature of heating air should be thoroughly evaluated at the design stage. Key issues include coordination of the HVAC design with the building envelope, insulation and glazing properties, connection to the Central Plant or alternative sources of heating and cooling, and energy management systems. The use of natural ventilation for HVAC purposes is a major element of Zero Net Energy buildings. Research by DOE and the California Air Resources Board indicated that natural air or hybrid ventilation systems could be used effectively in the San Francisco Bay Area to meet most of the HVAC requirements of small to mid-sized buildings. Further considerations for natural ventilation at airports are included in Section 4. Incorporation of building automation control network in the design of HVAC and lighting systems shall be given a high priority to ensure efficient operation of these systems in all new buildings.

#### Energy Efficiency

When considering the energy supply issues at SFO both electrical energy and natural gas demand must be addressed. Because SFO's electricity is supplied by the zero-carbon footprint Hetch Hetchy hydroelectric system, an emphasis should be placed on minimizing natural gas consumption in order to reduce the overall carbon footprint of the airport. The SEP should engage electrical maintenance staff to review options for integrating electric lighting with daylighting and other energy saving technologies. The use of renewable sources of energy such as solar and wind power should be considered for minimizing the demand on the utility grid.

#### Indoor Air Quality

For mechanically or naturally ventilated spaces in buildings, meet the minimum requirements of Section 121 (Requirements For Ventilation) of the 2010 California Energy Code, or the City Building code, whichever is more stringent. Environmental tobacco smoke, outdoor air purification procedures, indoor air moisture, and CO2 monitoring should also be addressed in accordance with CALGreen and/or City's Building Code, whichever is more stringent. SFO has invested in very good ventilation systems on recent projects; this trend should be encouraged. The SEP should review the performance of air filtration systems in recent projects to aid in system selection.

#### Water Supply and Wastewater Reduction

The use of efficient appliances in bathrooms is routinely practiced at SFO to reduce water use and wastewater generation. The SEP should engage plumbing and landscape maintenance staff in review of standard plumbing fixture choices and options for further improvements in fixture flow rates. All new buildings should also be equipped with dual plumbing systems to enable the reuse of treated wastewater for toilet and urinal flushing, thereby further reducing the demand for fresh water supplies. Treated wastewater or captured rainwater could be used for landscape irrigation depending on the mineral composition of such waters. The SEP should review the options for water re-use at the building scale and between buildings at SFO.

#### Construction Waste Management, Disposal, and Recycling

SFO has become a leader in waste management. The SEP process should review past successes and lessons learned to move each project closer the goal of zero waste.

#### Sustainability Commissioning

Sustainability Commissioning (including building and building enclosure commissioning) at SFO is closely linked to future monitoring of building performance. The commissioning agent should be selected early in the SEP and should ensure that SFO standards for building operation are part of the design. The mechanical and electrical maintenance staff should work closely with the commissioning agent in the SEP.
LEED Considerations: Project Documentation

All new SFO construction projects over 5,000 square feet must be built to LEED Gold standards, and SFO is now targeting LEED Platinum. In addition to the mandatory criteria described in Section 2, a number of other criteria must be met to achieve the requisite number of credits required for certification. Actual credits pursued for any given project will vary depending upon project type, size and function. LEED documentation is prepared through the project and is a shared responsibility. An example documentation responsibility matrix is shown. This matrix should be customized for each project.

<table>
<thead>
<tr>
<th>Responsibility</th>
<th>Owner</th>
<th>Contractor</th>
<th>Commissioning Agent</th>
<th>Other Systems Consultants</th>
<th>Engineer</th>
<th>LEED Consultant</th>
<th>Architect</th>
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</thead>
<tbody>
<tr>
<td>Register project &amp; manage online system</td>
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<td>Provide credit interpretation requests (as needed)</td>
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<td>LEED documentation review</td>
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<td>Review submissions for sustainability compliance</td>
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<td>Complete BOC documentation near final finish material delivery</td>
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<td>Participate in pre-construction meetings</td>
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<td>Coordinate contractor and subcontractor documents</td>
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<td>Submit certificates of occupancy</td>
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<td>Manage issue resolution with USGBC</td>
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<td>Preparing responses to review comments</td>
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<td>Manage issue resolution with USGBC</td>
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<td>Certification target follow-up</td>
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<td>Implement thermal comfort survey (if required)</td>
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LEED Considerations: Owner’s Project Requirements (OPR) and Basis of Design (BOD)

Most projects at SFO are required by governing codes to have fundamental, enhanced and building enclosure commissioning. Commissioning is the process for ensuring that designing, installing, testing, operating and maintaining the project systems are carried out according to the pre-established Basis of Design (BOD) and Owner’s Project Requirements (OPR). Fundamental, enhanced and building enclosure commissioning procedures are fully described in the LEED reference manuals and CALGreen Code. The San Francisco Environment Code references LEED for the relevant commissioning requirements.

### Owner’s Project Requirements (OPR)

The Owner’s Project Requirements describe the functional requirements of a project and expectations for how the project systems should operate during use. These requirements should be developed early in the project process, and are generally the result of a collaborative effort between the owner (who states basic requirements) and the project team. Updates to the OPR during design and construction phases are carried out at the owner’s discretion.

The OPR should cover the following basic categories plus any additional project specific requirements:

- Purpose (intent of the project)
- Program (use, including number of occupants, area, activities, adjacencies)
- Expectations for flexibility, growth, durability
- Construction costs
- Sustainability goals (environmental, equity, economic)
- Indoor environmental quality expectations (light, ventilation, thermal comfort, acoustical comfort)
- Energy efficiency targets
- Operations and maintenance expectations and costs (describe expected maintenance program, level of training required for operation, etc.)
- Systems and equipment goals (quality, maintenance, specific technologies to incorporate if relevant, level of automation, required manufacturers if any, required coordination with existing systems, minimum warranties)

### Basis of Design (BOD)

The Basis of Design is prepared by the design team before commissioning, and ideally at project beginning. It describes which systems are to be commissioned and includes any design assumptions not documented elsewhere. It is updated by the design team with more specificity at each design submission if needed.

The BOD should cover the following basic categories:

- Design assumptions (project use, occupancy, heat / cooling / ventilation / lighting expectations, zoning, back up or redundancies, climatic conditions in the project area)
- Standards (codes, regulations, and project specific requirements)
- Descriptive narratives (criteria for all systems that will be commissioned i.e. enclosure, HVAC, lighting, water, water heating, on site power etc.)
4.1 LIFE CYCLE ASSESSMENT (LCA)
A. OVERVIEW
B. REGULATORY & RATING SYSTEM CONSIDERATIONS FOR SFO
C. ATHENA IMPACT ESTIMATOR
D. BUILDING FOR ENVIRONMENTAL AND ECONOMIC SUSTAINABILITY (BEES)

4.2 ENERGY MODELING
A. OVERVIEW
B. RAPID PROTOTYPING, CONCEPT DEVELOPMENT & SCHEMATIC DESIGN
C. LOAD CALCULATION, EQUIPMENT SIZING & CODE COMPLIANCE

4.3 HEALTH BASED DESIGN
A. CHEMICAL LISTS & DECLARATIONS
Life Cycle Assessment (LCA) Overview

Life Cycle Assessment (LCA) encompasses the evaluation of the potential environmental impacts of a given product, process or service over the course of its lifetime. Also known as life cycle analysis, ecobalance, cradle-to-grave and cradle-to-cradle analysis, LCA is a technique used to quantify the impacts from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling and reuse. LCA can be applied at the component, process, product and system scale, including buildings.

SFO recognizes that construction projects create life cycle impacts on the environment through the use of materials, equipment, energy and other resources. Therefore, SFO encourages Project Delivery Teams to incorporate LCA into the planning, design and construction process with the objective of identifying and then minimizing or eliminating such impacts. This process can assist teams in making informed choices on the selection of a design element, a piece of equipment or construction practice.

As defined in ISO standards, Life Cycle Assessment (LCA) is a systematic, phased approach designed to quantify the environmental impacts and benefits resulting from human interventions. The five key ISO LCA standards are:

- **Goal Definition and Scoping (ISO 14040)** - Define and describe the product, process or activity. Establish the context in which the assessment is to be made and identify the boundaries and environmental effects to be reviewed for the assessment.

- **Inventory Analysis (ISO 14041)** - Identify and quantify energy, water and materials usage and environmental releases (e.g., air emissions, solid waste disposal, wastewater discharge).

- **Impact Assessment and Reporting (ISO 14042)** - Assess the human and ecological effects of energy, water, and material usage and the environmental releases identified in the inventory analysis by applying common characterization factors to facilitate normalization and aggregation across disparate LCI data.

- **Interpretation (ISO 14043)** - Evaluate the results of the inventory analysis and impact assessment to select the preferred product, process or service with a clear understanding of the uncertainty and the assumptions used to generate the results.

- **Requirements and Guidelines (ISO 14044)** - Specify the requirements and provide guidelines for the LCA including: definition of the goal and scope, the LCI phase, the LCIA phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, relationship between the LCA phases, and conditions for use of value choices and optional elements.

**KEY ENVIRONMENTAL LIFE CYCLE IMPACT CONSIDERATIONS FOR SFO**

<table>
<thead>
<tr>
<th>Material Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>The life cycle impacts of material components of a building are generated at each of the following stages:</td>
</tr>
<tr>
<td>• Procurement of the required raw materials,</td>
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<tr>
<td>• Processing of raw materials into finished products,</td>
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<tr>
<td>• Transportation of the products to the project site,</td>
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<tr>
<td>• Incorporation of the material into the building,</td>
</tr>
<tr>
<td>• Upkeep of the materials during the life of the building, and</td>
</tr>
<tr>
<td>• Final recycling or disposal of the discarded materials upon demolition of the building.</td>
</tr>
</tbody>
</table>

**Energy Consumption Impacts**

Energy is consumed in buildings for lighting and electronic displays, providing HVAC, and for operating other equipment. The LCA under this element must focus on minimizing the overall energy consumption in the building including electric energy, natural gas, and other fuel types. The combined operational carbon footprint of the building could be used as a suitable parameter for this optimization analysis.

**Equipment Impacts**

Various equipment such as elevators, escalators, moving walkways; heating, ventilation, and air conditioning equipment, lighting and display equipment, electronic and security equipment, etc. could be incorporated into a building at the design stage. The life cycle environmental impact of such equipment should be evaluated at each of the following levels:

- Manufacturing operations producing the relevant equipment
- Transportation of equipment to the building site
- Operational efficiency of various equipment including energy consumption, expected useful life, maintenance requirements, etc.

**Other Consumption Impacts**

Water supply, cleaning products, paints and finishing products, bathroom paper products, etc. are examples of other resources that are used routinely in buildings and which could be impacted by the design or O&M of the building. Specific measures incorporated in the building such as water efficient fixtures, long lasting surface finishes, and dual plumbing systems, etc. could minimize the impact of resource consumption in the building.

**Life Cycle Assessment Tools**

- Athena Impact Estimator (IE) for Buildings
- Building for Environmental and Economic Sustainability (BEES)
- Climate Earth Hybrid Life Cycle Assessment
- Economic Input-Output Life Cycle Assessment (EIO-LCA)
- GaBi Building LCA
- SimaPro

**Other LCA Resources:**

- American Center for Life Cycle Assessment
- UNEP Life Cycle Initiative
SF Ordinance 81-08
This ordinance establishes the following greenhouse gas emission limits for San Francisco:
• By 2017, reduce greenhouse gas emissions by 25% below 1990 levels;
• By 2025, reduce greenhouse gas emissions by 40% below 1990 levels; and
• By 2050, reduce greenhouse gas emissions to 80% below 1990 levels.

The ordinance also requires that all City departments (including SFO) consider the effect of all decisions and activities within their jurisdiction on greenhouse gas emissions and undertake their responsibilities to the end that the City achieves the greenhouse gas emissions limits set forth in the Ordinance.

No later than ninety days after the close of each fiscal year all City departments (including SFO) are required to submit an update of their GHG action plans and the direct GHG emission reductions from actions taken.

In addition, while not directly an obligation of SFO, the ordinance also requests that the SFPUC, another city department, develop and implement an energy action plan that includes, among other items:
• A plan to achieve the goal of San Francisco becoming fossil fuel free by 2030; and
• Setting annual goals for generating electricity locally through renewable generation.

Applicable Tools: Athena Impact Estimator, GaBi, SimaPro, EIO-LCA, Hybrid EIO-LCA and BEES.

CALGreen A5.409 Life Cycle Assessment
Option 1: Whole building life cycle assessment.
Conduct a whole building life cycle assessment, including operating energy, showing that the building project achieves at least a 10 percent improvement for at least three of the impacts listed, one of which shall be climate change, compared to a reference building of similar size, function, complexity and operating energy performance, and meeting the requirements of the 2010 California Energy Code at a minimum. The building envelope, structural elements, including footings and foundations, interior ceilings, walls, floors and exterior finishes shall be considered in the assessment. Plumbing, mechanical and electrical systems and controls; fire and smoke detection and alarm systems and controls; conveyance systems and interior finishes are not required to be included.

Option 2: Materials and system assemblies.
If whole building analysis of the project is not elected, select a minimum of 50 percent of materials or assemblies based on life cycle assessment of at least three of the impacts listed, one of which shall be climate change.

Listed Impacts:
1. Climate change (greenhouse gases)
2. Fossil fuel depletion
3. Stratospheric ozone depletion
4. Acidification of land and water sources
5. Eutrophication
6. Photochemical oxidants (smog)

Referenced Tools: Athena Impact Estimator, GaBi, and SimaPro. Interior finishes, if included, may be assessed using the NIST BEES tool.

LEED Pilot Credit PC63 – Whole Building Life Cycle Assessment
LEED v4 MRc1 - Building Life Cycle Impact Reduction, Option 4 – Whole Building Life Cycle Assessment
For new construction buildings or additions, demonstrate a minimum 10% reduction in at least 3 of the 6 impact categories listed in comparison to a reference building. (Note: the assessment is limited to structure and envelope materials.). Any impact category not reduced must be maintained at the same level as the reference building (or not more than 5% below the reference building standard under LEED v4) in order to achieve the specified credit.

The reference and final design buildings must be of comparable size and function; as well as the same orientation and operating energy performance as defined in Energy and Atmosphere Prerequisite Minimum Energy Performance. The service life of the reference and final design buildings must be the same and at least 60 years to fully account for maintenance and replacement. Operational impacts such as energy use must be the same in both the reference case and design case, however, so they can’t be used to contribute to the 10% improvements.

Listed Impacts:
1. Climate change (greenhouse gases), kg CO2
2. Ozone layer depletion, kg CFC-11
3. Acidification, moles H+ or kg SO2
4. Eutrophication, kg N or kg Phosphate
5. Formation of ground level ozone, kg NOx or kg Ethene
6. Depletion of non-renewable energy resources, MJ

According to its developer, the Athena Impact Estimator is capable of modeling 95% of the building stock in North America, using the best available data. Pre-set dialogue boxes prompt users to describe the different assemblies — by requesting the width, span and live load of a floor assembly, for example — that together form a conceptual building design. The Impact Estimator then instantly provides cradle-to-grave implications in terms of:

- Global Warming Potential - CO2 equivalent
- Acidification Potential - moles of H+ ions equivalent
- Human Health Respiratory Effects Potential - PM10 equivalent
- Ozone Depletion Potential - CFC 11 equivalent
- Photochemical Smog Potential - O3 equivalent
- Eutrophication Potential - N equivalent
- Fossil Fuel Consumption - Total fossil fuel energy

Note that the first six impact measures listed above are based on mid-point impact estimation methods developed by the US EPA and reported in their Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI, 2007 version.)

The Impact Estimator takes into account the environmental impacts of:

- Material manufacturing, including resource extraction and recycled content
- Related transportation
- On-site construction
- Regional variation in energy use, transportation and other factors
- Building type and assumed lifespan
- Maintenance and replacement effects
- Demolition and disposal

Although the Impact Estimator does not include operating energy simulation capability, it does allow users to enter the results of a simulation in order to compute the fuel cycle burdens, including pre-combustion effects, and factors them into the overall results.
Building for Environmental and Economic Sustainability (BEES)

BEES Online implements a systematic technique for selecting environmentally-preferred, cost-effective building products. Developed by the NIST (National Institute of Standards and Technology) Engineering Laboratory’s Applied Economics Office, the tool is based on consensus standards and designed to be practical, flexible, and transparent. The BEES web based tool, aimed at designers, builders, and product manufacturers, includes actual environmental and economic performance data for 230 building products across a range of functional applications. All stages in the life of a product are analyzed: raw material acquisition, manufacture, transportation, installation, use, and waste management.

System Requirements
BEES Online is a web application. Firefox or Internet Explorer 7.0 are the recommended browsers.
Building energy performance calculations are made for two primary reasons. They are made to predict the annual energy consumption of a structure or size and select mechanical equipment. While these two tasks are not mutually exclusive, and some programs can handle both tasks, they do tend to be conducted in isolation from each other.

Energy programs are primarily designed to predict the annual energy consumed by a structure in terms of BTUs, dollars, or pollution avoidance. In the past, few buildings had energy analysis performed. Today energy analysis tools are becoming more common and are being applied earlier in the design process to help identify the best low energy strategies. Building energy modeling is required as part of Title 24 Part 11 California Code of Regulations and as a LEED certification requirement.

Sizing programs are primarily designed to calculate peak hourly loads during the heating and cooling seasons. Almost all buildings of any complexity have a sizing analysis of some kind run by an architect, engineer, or mechanical contractor. Most sizing programs are based on consensus procedures and algorithms established by ASHRAE, but many are proprietary products distributed or sold by equipment manufacturers.

Match the Tool to the Task
Not only do energy analysis software programs have varying levels of accuracy; they are also intended to be used at different phases of the design process; and require very different levels of effort and cost.

For example, some tools have been designed to provide immediate feedback to the designer or project manager during the earliest phases of a project such as Green Building Studio or Design Advisor, while others such as DOE-2 or BLAST, require more input time and detail. Consequently, they are generally reserved for later in the design process when many architectural decisions have already been finalized.

EnergyPlus and eQuest are newer building energy simulation programs for modeling building heating, cooling, lighting, ventilating, and other energy flows—building on the most popular features and capabilities of BLAST and DOE-2.

The Limits and Benefits of Energy Modeling Tools
Users of energy analysis and modeling tools should be aware that energy calculations, regardless of their sophistication, cannot precisely predict actual energy consumption. Factors such as construction quality, occupancy schedules, and maintenance procedures may vary markedly from assumptions contained in the analysis and skew results. However, this does not mean that energy analyses are not important tools.

It is also important for users of energy analysis tools to understand the interrelationships among all aspects of building design. Employing an integrated 'whole building' design approach to site selection, orientation, building envelope and high-performance HVAC system choices, while considering life cycle cost analysis, is critical to achieving a truly successful building design.

Conducting an energy study of a new building or a major retrofit project is an excellent means by which to evaluate the relative energy performance of alternative designs. In particular, the effect of low-energy strategies such as moving windows from one façade to another for passive solar heating or improved daylighting, optimizing glazing selection or installing dimmable ballasts can be carefully evaluated on a comparative basis.

Directory of Energy Modeling Tools
The US Department of Energy Building Energy Software Tools Directory provides information on 393 building software tools for evaluating energy efficiency, renewable energy, and sustainability in buildings.

The energy tools listed in this directory include databases, spreadsheets, component and systems analyses, and whole-building energy performance simulation programs. A short description is provided for each tool along with other information including expertise required, users, audience, input, output, computer platforms, programming language, strengths, weaknesses, technical contact, and availability.


Energy Simulation
Load Calculation
Renewable Energy
Retrofit Analyses
Sustainability/Green Buildings

Modeling Tools Profiled for SFO
Rapid Prototyping and Design Tools
Autodesk Green Building Studio
MIT Building Advisor
Detailed Analysis and Code Compliance Tools
EnergyPlus
eQuest

67%
The amount of all electricity generated by U.S. power plants that goes to supply the building sector.

Source: architecture2030.org
## SUSTAINABLE PLANNING, DESIGN & CONSTRUCTION GUIDELINES

### 4.2.B

#### Energy Modeling – Rapid Prototyping, Concept Development and Schematic Design

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**AUTODESK GREEN BUILDING STUDIO**

**DESCRIPTION:** Autodesk Green Building Studio enables architects to quickly calculate the operational and energy implications of early design decisions, perform whole building analysis, optimize energy efficiency, and work toward carbon neutrality. Green Building Studio uses the DOE-2.2 simulation engine to calculate energy performance and also creates geometrically accurate input files for EnergyPlus.

**EXPERTISE REQUIRED:** 3D-CAD/BIM only, users need no special training in energy analysis.

**AUDIENCE:** Practicing architects, designers, engineers, construction managers.

**OUTPUT:** Whole building energy use and carbon footprint, design alternatives analyses, carbon emission reporting, daylighting potential, water usage and costs, EnergyStar scoring, renewable energy potential (PV and wind) and natural ventilation potential. Output files for Trane TRACE 700, eQuest and EnergyPlus.

**AVAILABILITY:** Freely available as a real-time simulator on the web.

**MORE INFORMATION:**
http://usa.autodesk.com/green-building-studio/

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**MIT DESIGN ADVISOR**

**DESCRIPTION:** Web suite of building energy simulators that model energy, comfort, and daylighting performance, and give estimates of the long-term cost of utilities. The simulations restrict flexibility in order to offer users greater ease-of-use and speed. The tool can be quickly mastered by non-technical designers, and runs fast enough to allow them the scope to experiment with many different versions of a design during a single sitting. The emphasis of the energy model is on the envelope system of the building, and includes simulations of high-technology windows such as double-skin facades. Energy-load estimates are based on a library of climate data for 30 different cities around the world.

**EXPERTISE REQUIRED:** None

**AUDIENCE:** Architects, Planners, Contractors

**OUTPUT:** Architects, Planners, Contractors

**AVAILABILITY:** Freely available as a real-time simulator on the web.

**MORE INFORMATION:**
http://designadvisor.mit.edu
Energy Modeling – Load Calculation, Equipment Sizing and Code Compliance

**ENERGYPLUS**

DESCRIPTION: Next generation building energy simulation program that builds on the most popular features and capabilities of BLAST and DOE-2. EnergyPlus models heating, cooling, lighting, ventilation, other energy flows, and water use. EnergyPlus includes many innovative simulation capabilities: time-steps less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multizone air flow, thermal comfort, water use, natural ventilation, and photovoltaic systems. Recent additions include multizone airflow, electric power simulation including fuel cells and other distributed energy systems, and water manager that controls and report water use throughout the building systems, rainfall, groundwater, and zone water use.

EXPERTISE REQUIRED: High level of computer literacy not required; engineering background helpful for analysis portions

AUDIENCE: Mechanical, energy, and architectural engineers working for architect/engineer firms, consulting firms, utilities, federal agencies, research universities, and research laboratories.

OUTPUT: ASCII output files, readily adapted into spreadsheet form for further analysis

AVAILABILITY: Free download from web site. Available for Windows XP/Vista, Mac OS or Linux. There are many free add-ons and other 3rd party software products available for use with EnergyPlus that serve to streamline data inputs and improve visualization of the output.

MORE INFORMATION: [http://www.energyplus.gov](http://www.energyplus.gov)

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**eQUEST**

DESCRIPTION: eQUEST® is a widely used whole building energy performance design tool. Its wizards, dynamic defaults, interactive graphics, parametric analysis, and rapid execution make eQUEST uniquely able to conduct whole-building performance simulation analysis throughout the entire design process, from the earliest conceptual stages to the final stages of design. eQUEST’s simulation engine, DOE 2.2, is also time-proven, well known, and widely used

EXPERTISE REQUIRED: For wizard-based use, virtually no experience with energy analysis is necessary. To use eQUEST's Detailed Interface, however, knowledge of building technology is required. Experience with other energy analysis simulation tools, especially DOE-2 based tools, is helpful.

AUDIENCE: Building designers, operators, owners, and energy/LEED consultants. eQUEST is also widely used by regulatory professionals, universities, and researchers.

OUTPUT: Graphical summary reports provide single-run results summary, comparative results summary, and parametric tabular reports. Additional output includes input/output summary reports, non-hourly simulation results, hourly simulation, and California Title 24 compliance analysis reports.


MORE INFORMATION: [http://www.doe2.com](http://www.doe2.com), [http://www.energydesignresources.com](http://www.energydesignresources.com)
Health-Based Design: Chemical Lists and Declarations

Research in the multi-disciplinary field of evidence-based design shows that a person's physical environment can affect health, productivity, safety, well-being and stress level. Building elements such as mainstream manufactured carpet, fabric, ceiling tile, epoxies, woodwork, paint, insulation and plastic components can contribute to a range of health impacts.

It is important to understand that chronic human health impacts are not well addressed by typical chemical disclosures such as MSDS reports, or emerging LCA studies. Therefore, designers should research and assess building materials, products and systems for chemical content and emissions using a variety of resources such as chemical databases, emissions certifications, health product declarations and environmental product declarations. In order to achieve building product transparency contractors shall supply both an Environmental Product Declaration (EPD) and a Health Product Declaration (HPD) for major building materials for review and approval by SFO.

Prime Suspects
As can be determined from the diagram below, there are numerous classes of chemical compounds present in interior finishes, furnishings and their accessory installation components. Primary among these are formaldehydes, heavy metals, chlorinated flame retardant chemicals, plasticizers and petroleum by-products. The classifications can be confusing and overlapping because there are abundant chemical lists, including groupings that have been banned from use and production in EU countries and by international accords.

Chemicals of Concern

There are over 85,000 chemicals currently registered and in production in the US. 2,000 new chemicals are added every year. Of these, 2,500 are considered high-volume pollutants and only 45% have been adequately studied for human health impacts (California Toxic Substances Control). Chemical types include:

- Heavy metals such as lead, mercury, cadmium and chromium
- VOCs, which represent the overarching category of many of the chemicals listed below, many of which are persistent organic pollutants or bio-accumulative toxins (POPs / PBTs)
- Fluorocarbons contained in refrigerants, solvents and oil/water-repellent coatings
- Chlorinated and brominated chemicals in flame retardants and plastics
- Aldehydes and ketones
- Nanoparticles

More Information:
- California Standard Method
- California Office of Environmental Health Hazard Assessment (OEHH)
- EPA Priority Chemicals
  [http://www.epa.gov/epawaste/hazard/wastemin/priority.htm](http://www.epa.gov/epawaste/hazard/wastemin/priority.htm)
- European Chemicals Agency (ECHA) Chemicals of Concern:
- Green Screen for Safer Chemicals:
- Healthy Building Network (HBN) “Chemicals of High Concern–List of Lists”
  [www.healthybuilding.net/pvc/alternatives.html](http://www.healthybuilding.net/pvc/alternatives.html)
- Perkins + Will Red List

Transparency

Manufacturers are beginning to disclose the ingredients in their products to varying degrees. Previously, the claim of proprietary ingredients and trade secrets had been prevented the release of this data. Widespread demand for transparency has caused a shift toward greater disclosure. Databases are in development so that designers can access and search by chemical and by specific product.

Databases and Declarations:
- ASTM EPD Program:
- EPD: The Green Yardstick:
  [http://www.environdec.com](http://www.environdec.com)
- Healthy Building Network PVC-free alternatives:
  [http://www.healthybuilding.net/pvc/alternatives.html](http://www.healthybuilding.net/pvc/alternatives.html)
- Health Product Declaration (HPD) Library:
  [http://hpdp.pharosproject.net/library](http://hpdp.pharosproject.net/library)
- NSF EPD Program:
- Perkins + Will Transparency database:
  [http://transparency.perkinswill.com](http://transparency.perkinswill.com)
- The Pharos Project:
  [http://www.pharosproject.net](http://www.pharosproject.net)
- UL Environment EPD Program:
Overview: Designing & Constructing Zero Net Energy High Performance Buildings

SFO defines a Zero Net Energy (ZNE) Building as one with sufficient on-site renewable energy (solar, wind) to meet the energy demand of the building. ZNE buildings are typically also High Performance Buildings, incorporating a number of measures for minimizing energy consumption. A Zero Net Capable (ZNC) Building is a high performance building that does not have sufficient on-site energy production. This element of the Sustainability Guidelines includes information for project teams to use in determining which aspects of occupant comfort, building features and on-site renewable energy generation are applicable to a specific project, as outlined below.

Section 5.2
Assess the project site / proposed site conditions for opportunities to maximize occupant comfort

Section 5.3
Review and select building features to enhance energy performance (siting, skin systems, insulation etc.)

- Single
- Double
- Punched Openings
- Hybrid Systems

Section 5.4
Investigate options for including on site renewable power generation

- Wind Turbines
- Solar Panels
- Geothermal Pump

Section 5.5
Research and select building materials, products, and systems for least impact to indoor occupant health.

Rendering: Inchon International Airport, Gensler

DMC Landmark Tower, Seoul Korea, Gensler

Wind Turbine Photo: Logan International Boston, Courtesy of AeroVironment, Inc.; Solar Panel Photo: Port of Long Beach, Gensler; Geothermal Pump Photo: Portland Jetport Geothermal Pump Construction, Gensler

Photo courtesy of freedigitalphotos.net
Building Physics and the Dynamics of Comfort: Overview

The primary driver for building performance is human comfort. The concept of comfort varies based on human cultural and climatic influences. The design drivers are internal and external loads and parameters.

- **Ventilation**
  - Natural ventilation
  - Mechanical ventilation

- **Sun Protection**
  - Shading
  - Glare protection

- **Lighting**
  - Daylight
  - Artificial light

- **Insulation**
  - Thermal break
  - Thermal mass

- **Noise**
  - Sound mitigation

- **Water Management**
  - Conservation

- **Pressure**
  - Building seals
  - Weather stripping

**Ventilation**

**Natural Ventilation**
Natural ventilation in the appropriate environment greatly increases occupant comfort. Careful study of the environment is required for airport spaces. Natural ventilation should be used when the program allows, and in environments with good air quality and comfortable outside air temperatures. Openings in the facade, such as windows, are the most common form of natural ventilation and are most successful when they can be individually operated. Automated operation of openings has a protective and climatic function that allows for better control of the interior environment at passenger facing areas.

**Mechanical Ventilation**
Mechanical ventilation should be used when heating, cooling, or humidity control is required. Ventilation systems should be designed to guarantee optimum air quality with the minimal use of energy.

**Sun Protection**

**Shading and Glare control**
Shading systems control interior heat gain and undesired direct solar radiation. Excessive contrast due to incoming light in a space can cause glare and occupant discomfort.

**Heat gain**
Incident solar radiation can be included in the passive heating strategy of the building.

**Lighting**

**Daylight**
Daylight harvesting contributes greatly to reducing energy usage in buildings as well as improving overall human comfort. Daylighting provides the best quality light for the general illumination of a space. Its inclusion contributes to a higher level of occupant comfort.

**Automated light controls linked to solar controls and daylight levels can improve comfort and energy efficiency.**

**Insulation & Pressure**

**Thermal & Fire Insulation**
The choice of material and detailing of the insulation directly affects its performance as a temperature and fire barrier.

**Bridging**
Careful detailing is necessary to minimize thermal bridging between exterior and interior environments through the envelope and achieve optimum performance.

**Pressure**
Internal and external pressure differentials must be accounted for in the design of openings.

**Noise**

**Outside Noise**
Building envelopes can mitigate sound infiltration through careful detailing of material and skin systems.

**Internal Noise**
Appropriate control of ambient noise levels inside the building should be appropriate for the comfort level of its occupants.
Comfort: Impact
The Importance of Occupant Comfort
The primary function of a building is to provide shelter to its occupants. This shelter is defined by an improvement in comfort over the ambient environment for an unsheltered individual. Buildings improve comfort through a variety of passive and active mechanisms, dependent upon the quality of design.

Comfort Requirements
The various comfort requirements that an envelope must address are thermal, acoustical, air quality and visual. Occupants should enjoy a sense of well being attributable to good daylighting, high-efficiency lighting, good indoor air quality, and the appropriate temperature and humidity.

Comfort Requirement | Boundary Condition | Passive/Active Measures | Energy
--- | --- | --- | ---
Thermal | External temperature (-4°F – 104°F) | Heating and Cooling | Heating
Visual | Brightness (0-929 fc) | Lighting | Lighting
Hygienic | Air consumption | Ventilation (inlets/outlets) | Ventilation
Acoustic Comfort | Sound level (0-140dB) | Insulation | Insulation

D.H. Parks
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Sanitary
Air changer rate
Air quality

Heating and Cooling
Humidification/Dehumidification
Lighting
Ventilation

Dried air when necessary
Thermal mass and ventilation.
Reduce heat transfer
Reduce incoming solar radiation
Thermal insulation of opaque components
Passive use of solar radiation
Minimize ventilation heat/cool loss
Active solar thermal energy gains

Air temperature
Direct radiation
Indirect radiation
External temperature
Humidity
Air movements

Compliment air temperature
Humidity
Air movements

Fresh air supply temperature
Humidity
Air movements

Boundary Condition
External temperature (-4°F – 104°F)
Humidity (0-100%)
Brightness (0-929 fc)

ACOUSTIC COMFORT
Block airborne noise and vibrations

THERMAL COMFORT
Reduce heat transfer
Reduce incoming solar radiation
Thermal insulation and ventilation.

COMFORT
Thermal
Air temperature
Direct radiation
Indirect radiation
External temperature
Humidity
Air movements

Acoustic
Block airborne sound and vibrations

Visual
Viewout
Illuminance and luminance distribution
Contrast, glare
Daylight factor
Ambient lighting

Sanitary
Air changer rate
Air quality

MAINTAINING AND GAINING HEAT/COOL
Surface optimization and re-orientation strategies
Thermal conversion of opaque components
Passive use of solar radiation
Minimize ventilation heat/cool loss
Active solar thermal energy gains

Content courtesy of ‘High Performance Building Envelopes’, Gensler, September 2010
Comfort: Thermal

Thermal comfort is directly related to solar gain. High light penetration can increase surface temperature and warm the air thus affecting thermal comfort.

The degree of activity, amount of clothing, direct solar radiation and the possible heat exchange by radiation and evaporation all influence individual judgment. In addition, thermal comfort depends on corporeality, body mass, age and sex. Therefore, a certain thermal situation is always judged differently by various persons: an ideal climate with 100% satisfaction does not exist.

Perception

Prediction of Human Comfort

Individual thermal perception is specified in terms of PMV (Predicted Mean Vote) value. This value predicts the percentage of dissatisfied individuals. PMV establishes a thermal strain based on steady-state heat transfer between the body and the environment and assigns a comfort vote to that amount of strain. PPD is the predicted percent of dissatisfied people at each PMV. As PMV changes away from zero in either the positive or negative direction, PPD increases. Even with a PMV value of 0 (ideal) the number of dissatisfied persons will still be 5%. Comfort varies by age, gender, culture, activity, time, and occupancy.

Physical Perception

Physical perception of comfort is perceived in multiple ways from conduction, convection, air movement, humidity, visual, acoustic, and hygienic. A thermally comfortable interior environment relates to the average temperature of the internal air in relation to the external air. In addition to the relationship between the exterior and interior air, surface temperature, direct solar radiation, movement of air (speed and direction), humidity of the air, and quality of the air, change ones perception of the temperature. Comfortable interior air temperature is 68-72°F (in summer up to 79°C if humidity is low).

Temperature

The average infra red radiation from surrounding enclosures (walls, ceiling, floor, windows) and air temperature is called operative temperature. In winter the air temperatures can be lowered when higher surface temperatures are provided (e.g. by radiant panels) yielding a reduction of transmission and ventilation heat losses. Also, in summer the air temperatures can be increased when lower surface temperatures are provided allowing a considerable reduction of cooling energy (e.g. chilled ceiling).

Mean Radiant Temperature (MRT)

The mean radiant temperature has a considerable influence on a person’s heat loss and thus the state of comfort. MRT is dependent on geometry and will generally be different at each point in the occupied zone. MRT is dependant on occupant position and occupant orientation relative to the surfaces of the space.

Air Movement

Higher air velocity can help in attaining a pleasant environment by dissipating body heat. ASHRAE Standard 55 includes elevated air speed for the first time as a component of human comfort, which allows local air movement rather than air-conditioning to help occupants stay comfortable in warmer conditions.

Humidity

With ambient temperatures of 68-72°F, the recommended value for interior air relative humidity is 40-60%.

Air movement, drafts, and quality of the air exchange can create a thermally comfortable environment in a warmer temperature.
Comfort: Visual & Acoustic

The highest comfort possible should be achieved with the least possible energy consumption. Each requirement responds to an exterior boundary condition, shown below. A less comfortable exterior environment usually results in more energy being used to achieve a comfortable interior environment. Passive measures should be considered prior to active measures when choosing strategies for meeting comfort requirements.

Visual Comfort
Visual comfort can be achieved through a combination of daylight and artificial light sources. Natural daylight creates a more comfortable condition as it includes every color in the spectrum. Sunlight, illuminance (the entire light output emitted by a light source), glare, and angle of light/contrast all contribute to perception of comfort. Relative glare is caused by excessive contrast and must be limited to maintain agreeable conditions. Bright wall and ceiling surfaces increase the reflections from the surroundings and reduce the risk of relative glare by creating a more consistent distribution of the luminance.

Acoustic Comfort
Acoustic comfort is essential to a positive customer experience and to productivity in the work environment. Acoustic requirements depend on the use of a space; for instance, the acoustic requirements of an office space are more stringent than for a café. The acoustic comfort of a room is dependent on the level of external noise, the sound reduction index of the building envelope, noises from the building services, the shape and/or size of the room, and the surface characteristics of the enclosing surfaces. Noise pollution can even occur at low sound pressure levels, decreasing comfort. The reverberation time describes the acoustic properties of a room. A minimal reverberation time helps ensure legibility of speech. Materials with a high Sound Transmission Class (STC) rating will help mitigate sound where needed.
Indoor Air Quality (IAQ)

The majority of passengers and employees at SFO spend 90% or more of their time at the airport indoors. In the past decade, scientific research has lead us to understand that indoor air is often more unhealthy than outdoor air. These facts demonstrate the importance of designing and maintaining airport interiors in a way that enables the best possible indoor air quality.

IAQ and Health

Good Indoor Air Quality (IAQ) is key to the health of passengers and all airport personnel. In 2000, the World Health Organization stated that healthy IAQ is an important impact of the human environment and that should be analyzed as deeply as energy strategies. It noted that it is a human right to breath healthy indoor air.

IAQ and Productivity

Research has shown that superior IAQ increases productivity, reduces absenteeism and enhances learning in school settings. Recent studies on cost impacts show that healthcare cost, compensation claims, lost productivity, lower real estate values and potential lawsuits demonstrate that the quality of indoor air can have significant cost impacts.

IAQ Design Strategies

Good IAQ is achieved through four key strategies:

a. Source control of building materials, products and systems (See Page 39)
b. Superior ventilation and filtration,
c. Enclosure and systems commissioning efforts, and
d. Operation and maintenance procedures.

Potential IAQ Pollutant Sources

• Volatile and semi-volatile organic compounds from building products. These include: formaldehyde, toluene, styrene, phenol, naphthalene, chlorinated flame retardants, organophosphate pesticides and synthetic fragrances.
• Microbials from moisture intrusion.
• Particulates from combustion processes
• Ozone from chemical synergies

Air Quality Comfort

The quality of the interior air is influenced by the composition of the external air, furnishings, fittings, and building materials, plus the usage related contamination due to occupants. An adequate supply of fresh air plus the extraction of CO₂, moisture, pollutants and odors guarantees a comfortable and hygienic condition.

In some cases, the quality of external air at the airport is not adequate for natural ventilation due to pollution. In this case, a filtration system is necessary to achieve a comfortable interior environment.
# Building Technology to enhance performance: Overview

Strategies developed in the project concept stages must manifest themselves through the use of various building technologies that facilitate optimum energy performance and comfort.

<table>
<thead>
<tr>
<th>Passive Systems</th>
<th>Skin Systems</th>
<th>Energy Generation</th>
<th>Materials</th>
<th>Water Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive and active heating and cooling systems must work together to achieve optimum performance.</td>
<td>Systems vary from lightweight curtain wall to load bearing, solid walls.</td>
<td>Building Integrated Photo-voltaic and solar collectors contribute to building energy needs.</td>
<td>Use of the correct material determines the energy performance and life span of an envelope.</td>
<td>Efficient use of potable and grey water is essential to both energy and water conservation.</td>
</tr>
</tbody>
</table>

## Passive Systems

### Heating and Cooling

The project team should consider using passive technology as the first option for the design. The relevant active system should be overlaid as a compliment to achieve the desired energy performance goal.

## Materials

- **Glass, Stone, Ceramics, Metals, Concrete, Synthetics, Wood, Fabric**
- Modern materials are expected to perform multiple functions above and beyond basic aesthetics, weather control and noise mitigation needs. Layers and coatings such as low-e metallic coatings on glass and fabric, PVC coatings on wood, metal and stone, and resins or thin film PV coatings, improve the performance characteristics of the base material. All these materials have appropriate uses in an airport.

## Skin Systems

### CW Systems, Rain screen systems

Skin systems perform best with the layering of various technologies that address functions such as shading, light transmission, daylight harvesting, heat gain, energy generation and sound mitigation. Multiple functions can be seamlessly integrated into a hi-tech new or replacement façade on an airport building.

## Energy Generation

### Energy Generating Systems

The third layer of technologies, above and beyond passive and active systems, are energy generation systems such as Building Integrated Photo Voltaics (BIPV), solar collectors, and wind turbines. These systems generate electricity and/or hot water, and help achieve the goal of a zero net energy building. Some of these technologies are widely applicable at SFO and others may have limited use.

## Water Management

### Waterproofing, Rainwater harvesting, Greywater recycling

In the near future water will be a critical resource that must be managed and integrated into the building systems. Water management systems in buildings are already being explored for reuse, water conservation and rainwater harvesting. Seasonal rainwater runoff can be extensive at SFO and catchment options should be explored.
Natural Ventilation: Openings

The design of natural ventilation systems calls for an accurate analysis of the climate and usage-related requirements, especially in an airport environment where noise and jet exhaust are present. Pressure differences result in a natural circulation of air. Natural ventilation can take place by way of direct exchange via the building envelope or systems that create the natural air flow.

When do I use natural ventilation?
Good air quality (this will be select locations at SFO), comfortable outside air temperature, shallow buildings, minimal acoustic issues

How do I use natural ventilation?
Windows/ Ventilation flaps
Double Leaf Facade
Glazed Atria

What causes energy loss, how can it be prevented?
Uncontrolled ventilation of space with high temperature differences causes energy loss. Automatically operated flaps and windows or occupants with operation instructions will prevent energy loss.

Openings
Occupants enjoy access to natural ventilation and the ability to open a window for immediate access to the exterior. The challenges of natural ventilation are: drafts, temperature differences, air distribution, and humidity. Natural ventilation is not a feasible option for every environment and building type. Building depth and geometry are initial factors in making natural ventilation a feasible option.

Air Movement
The movement of air and hence the air change rate is caused by the temperature and pressure differences between the internal and external environments.

Heat Loss
Extremely low exterior temperatures during the winter and extremely high exterior temperatures during the summer can cause large energy losses when natural ventilation is used. Large temperature differences between the inside and outside may require that the windows be opened for only a few minutes at a time to replace the entire air volume in a space. Natural ventilation does not allow for heat recovery whereas mechanical systems may.

Noise and Outdoor Pollution
Any opening to the outside will allow noise to penetrate to the inside. Special provisions have to be taken in areas of high noise pollution like busy streets, freeways, airports and railways. In the case of polluted outside air, it is advisable to supply air for the interior mechanically from less polluted areas and use filters.

Automatic Operation of Openings
Automatic operation of openings has a protective and climatic function. It protects from rainfall and allows better control of the interior environment. The Building Management System (BMS) regulates the fresh-air inlets to regulate interior comfort.
Natural Ventilation: Air Movement

Thermal Currents
Thermal currents are the driving force for extracting air from the interior of the building. The strength of the suction depends on the temperature difference created. Double-leaf facades, glazed atrias, and solar chimneys all take advantage of this principle.

Wind Forces
Wind patterns around a building are influenced by climatic conditions, topography, and surrounding buildings. At SFO, aircraft activities also create localized air movement patterns. Wind patterns lead to forces such as pressure and suction acting on the envelope of a building. The force is influenced by the height and geometry of the building itself. In order to compensate for fluctuations in the local temperature and wind conditions, natural ventilation systems can be supported by exhaust-air ducts and mechanical ventilation in order to guarantee continuous operation.

Driving Energy
Natural ventilation is caused by wind forces and thermal currents in a building. The air movement causing natural ventilation is a result of the environment surrounding the building and the temperature difference between the interior and exterior.

Double skin facades
Double skin facades are used to ventilate interior spaces, to insulate against high levels of street noise, high wind loads, and high temperature differentials between exterior and interior spaces. The exterior skin shields the interior from the elements. This can be particularly significant as the high wind pressures on tall buildings cause increased air leakage, particularly in unitized curtain walls, diminishing the overall performance of the façade system. The space between the two skins also tempers the variable temperature difference between the outside and inside. Double skin systems can be naturally or mechanically ventilated at each level or over multiple floors.

Glazed Atria
Removes hot exhaust air that builds up beneath the atrium. The atrium must be higher than the adjoining structure in order to reduce the thermal load on the topmost floors.

External Influences
• Topography
• Surrounding buildings (pressure and suction)
• Aircraft activity

Building Influences
• Height
• Geometry
• Orientation

Building orientation and layout with respect to sun and wind exposure
a. no ventilation, sun protection
b. cross ventilation, no sun protection
c. ventilation and sun protection

Natural Ventilation in Buildings: A Design Handbook (p.206), Francis Allard and Matheos Santamouris
Mechanical Ventilation

Ventilation Systems in High Performance buildings should be designed to guarantee optimum air quality with minimum energy use. Where the program allows it at SFO, natural ventilation should be used as a passive energy optimized solution.

What is its purpose?
Ventilation of Space
Humidifying and Dehumidifying
Heating and cooling for occupant comfort

When do I use mechanical ventilation?
When natural ventilation is not possible.
Extreme outside air temperatures
When the floor area is large/deep
Tall buildings

What can I do to optimize it?
Reduce air treatment
Minimize air volume
Optimize the driving energy
Heat recovery of exhaust heating or cooling energy

Optimization

Reduce air treatment
Humidifying/ Dehumidifying
Heating/ Cooling

Minimize air quantity
Airflow rates
The air change rate is influenced by the number of people or the usable floor area. An hourly air change rate related to the volume of the interior spaces can be specified. Programs that contain or produce hazardous substances have a need for a higher air change rate.

Duct and Shaft Sizes
As the capacity of the ventilation system increases, so does its space requirement. The duct cross-section can be calculated by the air velocity in the duct and the flow rate of air.

Optimize air management
Centralized vs Decentralized Plants
The choice of centralized or decentralized is to be carefully evaluated with the total area used and performance efficiency for ventilation systems. Decentralized air handling units may increase the area for vertical shaft space with each additional floor but depending on the climate, dehumidification of heat-recovery may be more efficient. A decentralized ventilation concept via the façade minimizes costs for air management. A centralized unit is connected with ductwork to the conditioned area.

Optimize driving energy
Wind Ventilation
High structures can take advantage of natural wind movement to optimize ventilation. Wind towers or venturi spoilers are two systems that enhance this. Wind patterns at the project’s airport location should be studied to determine if wind ventilation is possible.

Thermal Currents
With solar chimney, the density differences between cold and hot air lead to airflows that can be used specifically for the building ventilation. This is amplified as the temperature gradient and height of the building increase. Atria or double leaf facades are ideal for exploiting thermal currents.

Mechanical Ventilation
Mechanical ventilation controls supply/exhaust air. Ventilation heat losses represent a significant item in the energy balance of a building depending when weather is cool. The ventilation energy losses from heating or cooling can be almost completely recuperated with an integral heat exchanger system. Different heat exchanger designs include:
- Cross flow heat exchanger
- Counter flow heat exchanger
- Run-around coil
- Rotary heat exchanger

San Jose Airport, Gensler Los Angeles

Content courtesy of "High Performance Building Envelopes", Gensler, September 2010
Daylighting

Daylighting systems have the ability to greatly reduce the energy needs of buildings, by reducing the reliance on artificial lighting, as well as reducing heat loads emitted by light fixtures.

**Comfort and Productivity**
Natural light provides the most complete spectrum of lighting, and is the most comfortable for building occupants. Due to this occupant preference, the use of natural lighting has been shown to have beneficial impacts upon productivity.

**Building Depth and Programming**
The massing of the building and the layout will strongly impact the use of daylighting strategies. The distance into a building that natural light can penetrate from an opening is limited, and massing strategies should take this into account when considering placement of program elements requiring natural light.

**Controlling Daylight**
Excessive contrast and glare can also be an issue, particularly in an airport environment with multiple display monitors. Various light directing devices as shown in the section below can help direct light farther into the building spaces, while simultaneously helping with the reduction of glare.

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**Strategies for Daylighting**
Conventional daylighting strategies by the means of providing a glazed opening into a room or floor space are limited since direct light only penetrates to a limited depth, and is dependent upon the season and time of day. Light levels beyond that zone will drop off quickly, requiring additional light sources to maintain desired light levels. It is also important to factor in programmatic functions of the space being daylighted. For example, spaces with computer screens may have much lower lighting requirements than meeting spaces and circulation areas, and may be best suited by a different daylighting strategy.

**Glare and Controlling Natural Light**
Unaltered, direct natural light entering through the glazed opening might produce glare due to contrast levels as well as discomfort due to solar heat gain. Controlling and directing daylight can project it more evenly and deeply into the space. This can also help manage solar heat gain and glare. Reducing solar heat gain may allow for glass with lighter coatings, improving the quality of visible light entering through the glazed openings.

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**Light Directing Devices**

**Light Shelves**
Light shelves help to reflect daylight deeper into the room and control solar gain and glare for work stations close to the window. The angle of light shelves can be adjusted to maximize the depth to which light is reflected. The top surface of light shelves should be highly reflective.

**Light Directing Louvers**
Light directing louvers reduce solar gain and glare next to the window and redirect diffuse light back towards the ceiling and into the space. The shape of the louver blades enables them to redirect light from various angles. Light directing louvers can be embedded into the IG units or mounted internally. Louvers are manufactured with mirror coats on the top surface and light color reflective surface on the underside of the louver blades.

**Prismatic Louvers**
The angles of prismatic plates are adjusted to reject direct sun rays, but redirect diffuse light deep into the interior space. Prismatic plates can be embedded into IG units or used as adjustable exterior louvers.

**Laser Cut Panels**
Panels made of acrylic with small slots laser cut within them act as reflecting surfaces, which can either reject direct sunlight or project it towards the ceiling of a space, essentially acting as many tiny light shelves. Laser cut panels can be produced with vertical or horizontal slots.
Glass Energy Values

The majority of solar heat gain in a building comes from the windows, glazed doors, and skylights. However, transparency is crucial in the design of buildings. There are glazing systems available that can reduce the solar heat gain while still allowing daylight transmission.

U-Value

The U-value for framing is often times poorer than that of the glazing. A larger edge cover dimension and setting blocks with a thermal break will improve the U-value. The creation of window areas with a smaller frame proportion results in further energy-efficiency optimization potential.

Shading

Glazing with lower U-values (and/or a lower transmittance due to coatings) is often less transparent than glazing with higher U-values. The use of shading devices can help manage solar heat gain when using high transparency glass.

Key Terms

U-Factor measures heat transmission per unit time through a unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on each side (ASHRAE 90.1). It measures how well a product prevents heat through an assembly. The lower the U-Factor, the better a product is at keeping heat in.

Solar Heat Gain Coefficient (SHGC) measures how well a product blocks radiation from the sun. SHGC is expressed as a number between 0 and 1. The lower the SHGC, the better a product is at blocking solar radiation. Blocking solar heat gain is particularly important during the summer cooling season. SHGC can be determined for a shading system, glass or an entire facade system.

Visible Transmittance (VT) or Daylight Transmission (TL) measures how much light comes through a product. VT is expressed as a number between 0 and 1. The higher the VT, the higher the potential for daylighting.

Air Leakage (AL) measures how much outside air comes into a building through a product. AL rates typically fall in a range between 0.1 and 0.3. The lower the AL, the better a product is at keeping air out.

Convection

The cavity between the panes is generally 0.5 - 1.0" in order to reduce the convection processes within the gas in the space. Dividing the cavity into several layers can reduce the convection still further and improve the insulating properties of the glazing unit.

Gas-Filled Insulating Glass

An inert gas (such as Argon) of greater density than air is normally used within the sealed cavity of an insulating glass (IG) unit. This gas is more resistant to convection than air and can lead to dramatically improved performance. The use of such a gas fill is assumed in the U-values shown in the diagrams at right.
Sun Protection

Sun protection is a balance between solar heat gain, daylighting and glare. The choice of systems and approach is largely dependent upon climate, location, overall building performance and the building program. Every project at SFO should be studied to determine the appropriate system.

Greenhouse Effect
Short-wave radiation penetrates glass easily, and is absorbed by objects within the space, raising their temperature. The objects then emit long wave radiation for which glass is much less impermeable. As a result of this ‘Greenhouse Effect’, the room gradually heats up. In addition, when sun radiation reaches the glass it heats the inner pane which also causes warming of the room surfaces due to radiation and convection.

Interior Shading
To reduce the Greenhouse Effect, internal shades should present a light colored or highly reflective surface towards the glass to repel as much short-wave solar radiation as possible. However, the heat energy absorbed by the sunshade will still add to the thermal load of the interior. In addition, some of the reflected solar radiation is absorbed by the glass, heating the space. Internal sunshades do not achieve as much sun protection as exterior shades.

Exterior Shading
Exterior shading is the most efficient way to prevent direct solar radiation into the space. The geometry of the fixed exterior shades needs to be studied and optimized for every project depending on the orientation of the building/facade, location and climate.

Evaluation of Sunshades
Reducing the radiation intensity with sunshades also lowers the amount of daylight entering the space. Particular attention should be paid to the ratio of light transmittance to the total energy transmittance. If the space is too dark with lowered or fixed sunshades, and additional artificial lighting is needed, the benefit of windows for natural light should be questioned and an alternative design strategy should be considered.

Fixed vs. Automatic
Due to the daily and seasonal changes of the sun-path only some facade areas of a building are in direct sunlight at any one time. Weather and cloud coverage also vary constantly. A constant, high degree of shading can block daylight and view. Therefore automatic shading systems which are solar radiation sensitive and fully retractable are the optimal solution to manage direct sunlight when the need arises, while still optimizing views and daylighting.

Glare
Glare is the product of high contrast. The better the light is distributed in a space, the lower the risk of glare. Roller shades are excellent at preventing glare. Bright ceilings and walls combined with an adequate shading will help minimize glare problems.
Thermal Insulation

Choices of materials and detailing of thermal insulation directly impacts performance. Good thermal insulation increases the surface temperatures on the inside of the façade during winter, and decreases the surface temperatures in summer. This improves the level of comfort near the façade, reducing the maximum heating / cooling requirement.

Optimization
Thermal insulation cuts the consumption of energy and operating costs by shortening the operating time of the heating / cooling system. Optimization of façade thermal performance involves an overall optimization of frames, glazing, and opaque areas. The goal is to reduce conduction, convection, and the exchange of long-wave radiation.

Weak Points
- Transitions between different façade types and assemblies
- Joints along the hermetic edge seals of glazing and panels
- Around fasteners caused by linear or discrete thermal bridges and/or leak points.
- Corners: Horizontal, vertical, internal and external
- Parapets and bases
- Offsets in the insulation or sealing layers/leaves

Thermal bridges generally represent weak spots in terms of moisture control because of an increased risk of condensation on inner surfaces. Facade details where the developed inner surface area is smaller than the outer area, for instance, at “slender” external corners are at high risk for condensation.

Protection against condensation is crucial to the health of a building and its interior environment. Mold is dangerous and can start to grow even before condensation is visible.

Heat loss through thermal bridging is not accounted for in the u-value for the planar building elements that contain the bridge. Therefore the thermal bridge must be evaluated separately. It is usually expressed in terms of a fraction known as $y$.
Acoustic Insulation and Sound Transmission Class (STC)

Sound transmission can be caused by airborne and / or structure borne vibration. Airborne sound travels through the air and can transmit through a material, assembly or partition. Sound can also pass under doorways, through ventilation, over, under, around and through obstructions. Managing sound is crucial in the airport setting.

Adding Mass
The weight or thickness of a partition is the major factor in its ability to block sound. For example, a thick concrete wall will block more sound than a thin gypsum/2x4 wall. When the mass of a barrier is doubled, the isolation quality (or STC rating) increases by approximately 5 dB, which is clearly noticeable.

Increasing or Adding Air Space
An air space within a partition can also help to increase sound isolation. This in effect creates two independent walls. However, the STC will be much less than the sum of the STC for the individual walls. The airspace can be increased or added to an existing partition. A common way to add an airspace is with a resilient channel and a layer of gypsum.

Adding Absorptive Material in the Partition
Sound absorptive material can be installed inside of a partition’s air space to further increase its STC rating. Installing insulation within a wall or floor/ceiling cavity will improve the STC rating by about 4-6 dB, which is clearly noticeable. It is important to note that specialty insulations often do not perform any better than standard batt insulation.

Ways to Improve the STC Rating of a Wall Assembly:
• Add insulation
• Staggered or double stud walls are higher rated than single stud walls
• Metal stud walls perform better than wood stud walls
• Add a resilient channel
• Add additional layers of drywall to a single stud wall
• Add additional layers of drywall to a double stud wall can dramatically increase the STC rating

Recommended ratings
An STC of 50 blocks approximately 50 dB from transmitting through the partition. Speech generally is not audible through an STC 60 wall, while an STC of 30 may lack sufficient privacy for some uses. Assemblies with a higher STC should be specified in sensitive areas where sound transmission is a concern.

STC | What can be heard
---|---
25 | Normal speech can be understood quite easily and distinctly through wall
30 | Loud speech can be understood fairly well, normal speech heard but not understood
35 | Loud speech audible but not intelligible
40 | Speech or privacy
42 | Loud speech audible as a murmur
45 | Very loud sounds such as musical instruments can be fairly heard; 99% of pop; not annoy
50 | Loud speech not audible; 99% of statistical population not annoyed
60+ | Superior soundproofing; most sounds inaudible

Key Terms

Sound Transmission Class (STC) 
STC is a single-number rating of the ability of a material or an assembly to resist airborne sound transmission at the frequencies of 125-4000 Hz. This frequency is consistent with the frequency range of speech. In general, a higher STC rating blocks more noise from transmitting through a partition. STC is highly dependant on the construction of the partition. A partition’s STC can be increased by:
  • Adding mass
  • Increasing or adding air space
  • Adding absorptive material within the partition

Decibel (dB) = measure of sound pressure level

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Solar Reflectance Index (SRI)

The Solar Reflective Index is a measure of the constructed surface’s ability to reflect solar heat, as shown by a small temperature rise. It is defined such that a standard black (reflectance 0.05, emittance 0.90) is 0 and a standard white (reflectance 0.80, emittance 0.90) is 100. SRI combines reflectance and emittance into one number.

LEED

To receive LEED Sustainable Sites Credit 7.2, at least 75% of the surface of a roof must use materials having a Solar Reflective Index (SRI) of at least 78. This criterion may also be met by installing a vegetated roof for at least 50% of the roof area, or installing a high albedo and vegetated roof that, in combination, meets this formula: (Area of SRI Roof/0.75)+(Area of vegetated roof/0.5) • Total Roof Area.

Solar Reflectance Index (SRI) Calculation

**LOCATION**

**WIND SPEED**

**SURFACE TEMPERATURE**

**CONVECTION COEFFICIENT**

**SOLAR REFLECTANCE INDEX (SRI)**

**Cool Roof**

**Codes and Standards**

ASTM E903 or C1549
ASHRAE 90.1 (Commercial Buildings)
Minimum required Solar Reflectance: 0.70
Minimum required Thermal Transmittance: 0.75

If a cool roof is used in climate zones 1, 2, or 3, the minimum requirement for insulation is reduced.

For more information contact:
Claire Ramspeck (404) 636-8400
claire.ramspeck@ashrae.org

**Key Terms**

**Solar Reflectance Index (SRI)**
Solar Reflectance (R) is the fraction of the total solar energy that is reflected away from a surface. To be considered “cool”, products must have a Solar Reflectance of at least 0.25. Thermal Emissivity (E) is the measure of a panel’s ability to release heat that it has absorbed. Solar Reflectance Index (SRI) is calculated by using the values of solar reflectance, thermal emittance, and a medium wind coefficient. The higher the SRI value, the lower its surface temperature and consequently, the heat gain into the building.

**Urban Heat Island Effect**
Building and pavement construction materials and high-density structures in urban areas can actually cause cities to become 2°F to 8°F warmer than the surrounding countryside.

**Solar Reflectance (Albedo)**
Solar reflectivity (or reflectance) is the fraction of the solar energy that is reflected by the surface (i.e., roofing membrane) back to the sky. White membranes have the highest solar reflectivity, while black have the lowest.

**Solar Emittance**
Infrared emissivity (or emittance) is a measure of the ability of a surface to radiate some of its heat (in the form of infrared radiation) away from the surface (i.e., roofing membrane). High infrared emissivity helps keep surfaces cool. Metallic surfaces have a low infrared emissivity.

**Cool Roof**
A roofing system that can deliver high solar reflectance (the ability to reflect the visible, infrared and ultraviolet wavelengths of the sun, reducing heat transfer to the building) and high thermal emittance (the ability to radiate absorbed, or non-reflective solar energy) is called a cool roof. Most cool roofs are white or other light colors. Cool roofs enhance roof durability and reduce both building cooling loads and the urban heat island effect. Benefits of Cool Roofs include:
- Energy savings and global warming mitigation
- Reduction in urban heat island effect and smog
- Improved occupant comfort
- Compliance with codes and green building programs
Green Roofs

A green roof is a vegetative layer grown on a rooftop. As with trees and vegetation elsewhere, vegetation on a green roof shades surfaces and removes heat from the air through evapotranspiration. These two mechanisms reduce the temperatures of the roof surface and the surrounding air.

Environment

A rooftop is an unusual environment for plant life; not all species will thrive in its particular conditions. The selection of appropriate plants is essential to both the aesthetic and environmental function of the green roof. Selecting plants appropriate for rooftop conditions requires consideration of micro-climatic and individual plant characteristics that may not be relevant to ground gardens. Roofs have microclimates as well: specific sun, shade, and wind patterns that affect plant growth. High walls or other irregular features can create wind tunnels or shady areas. In addition, the natural groundwater and humidity which keep plants on the ground saturated are not available on green roofs. Wet environments and coastal regions may be suitable for green roofs, because high solar gains and a lack of shading can result in desiccation and poor survival of some plant species when insufficient water is not provided.

SFO’s location, while Bay coastal, is relatively dry at present, so a green roof used at the airport must have plants suited to the microclimate.

Structure (Extensive vs. Intensive)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Extensive</th>
<th>Intensive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>8&quot; or less</td>
<td>More than 8&quot;</td>
</tr>
<tr>
<td>Accessibility</td>
<td>may be partially</td>
<td>Usually</td>
</tr>
<tr>
<td>Topsoil weight</td>
<td>less than 1&quot;</td>
<td>Heavy in depth</td>
</tr>
<tr>
<td>Plant Density</td>
<td>Low</td>
<td>Great</td>
</tr>
<tr>
<td>Cost</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Moderate</td>
<td>Usually High</td>
</tr>
</tbody>
</table>

Extensive Green Roof

An extensive Green Roof uses a select range of hardy plants, making it attractive to look at while requiring little maintenance. Extensive green roofs are not intended for recreational use, but are usually chosen for their appearance or to help reduce the “urban heat island” effect and minimize stormwater run-off. Extensive roofs only require a shallow growing media depth, generally as little as 3” - 4”, and therefore add little weight (typically 18-34 lb/sf wet weight) to the roof structure below.

Intensive Green Roof

The Intensive Garden Roof incorporates plants that require regular maintenance, such as watering, fertilizing and mowing. The potential variety of plants is numerous, including sod grass lawns, perennial and annual flowers, shrubs, and even small trees. When used in conjunction with hardscaping elements, such as architecturally finished pavers and precast items, roofs and plazas can serve as pedestrian and recreational areas.

Components and Layers

**Vegetation**

The choice of vegetation depends on the type of roof (extensive or intensive), building design, local climate, available sunlight, irrigation requirements, and anticipated roof use. Extensive green roof plants are shallow-rooting, self-generating plants that spread rapidly and require minimal nutrients. Succulents, such as sedums, are well adapted for green roofs because they are drought and fire resistant. Intensive green roofs are larger and allow deeper roots. Shrubs, bushes, and trees (preferably varieties that are indigenous to the area) can be used. Most intensive green roofs have irrigation systems.

**Growing Medium**

The growing medium is engineered to provide the best support for plants and to retain water, with the least weight possible. Typically 80% of the material is inorganic minerals.

**Filter Membrane**

The filter membrane can improve thermal insulation, conventional insulation will further conserve energy.

**DRAINAGE LAYER**

Protects the roof from water penetration.

**VAPOR BARRIER**

A plastic or foil sheet that resists passage of moisture through the ceiling.

**THERMAL INSULATION**

Although a green roof can improve thermal insulation, conventional insulation will further conserve energy.

**SUPPORT PANEL**

A structural element that supports the growing medium, which also serves as a thermal barrier and structural support.

**GROWING MEDIUM**

Includes the growing medium, which includes soil, vegetation, and a vapor barrier.

**FREQUENCY OF MAINTENANCE**

The frequency of maintenance is dependent on the type of roof (extensive or intensive), building design, local climate, available sunlight, irrigation requirements, and anticipated roof use. Extensive green roof plants are shallow-rooting, self-generating plants that spread rapidly and require minimal nutrients. Succulents, such as sedums, are well adapted for green roofs because they are drought and fire resistant. Intensive green roofs are larger and allow deeper roots. Shrubs, bushes, and trees (preferably varieties that are indigenous to the area) can be used. Most intensive green roofs have irrigation systems.
Solar Passive Systems

The sun is an enormous source of potential energy for heating and lighting buildings. Windows are the most common way of letting daylight and solar radiation into a building. The proportion of usable solar energy depends on the climatic conditions, local parameters, orientation, and size of openings.

Climatic Parameters

Solar passive systems are not appropriate for all building uses at SFO. A careful context analysis will help determine if a passive solar solution is likely to be effective for a given building type and location at the airport.

Green House Effect

When short-wave radiation penetrates through glass, objects behind the glass layer heat up by absorbing the solar radiation. Short-wave radiation is transformed into long wave radiation for which glass proves impermeable, trapping the heat. As a result, the space heats up cumulatively. Proper ventilation allows the heat to circulate into the building.

Thermal Mass and Color

Materials like concrete, ceramic tile, brick, stone and masonry have high thermal storage capacities: they are good at storing heat during the sunny hours (acting like a sponge), and at releasing it slowly later, typically during the night. On the other hand, wood and most insulation materials are good examples of materials with low thermal mass and do not absorb/release heat to a degree that is likely to affect building performance. Moderate-dark or dark colors are best suited for solar thermal storage, as they absorb more infrared radiation. White or very light colors will have the opposite impact.

Phase change materials (PCMs)

The task of temporarily storing excess heat and later releasing it into the interior calls for materials with high admittance and high energy storage capacity. With typical thermal mass strategies this requires a higher specific weight or a large surface area. PCMs provide a high energy storage capacity through their latent heat, absorbed by changing phase, allowing them to be much lighter in mass for the same effect. Some PCMs may allow passage of daylight and limited transparency.

Solid absorbers

Solid absorbers are planar, solid external wall components with internal circulation pipes acting as a heat exchanger exposed to the ambient heat. They can be used with all building components or systems in contact with the outside air. This approach is not often used because of the high power requirement of the heat pump.

Box Window

The box window is a simple method of improving the energy performance of a punched opening. A box-like assembly adds an extra layer of glazing and an air space to each window, vastly improving the insulation properties of the window opening. These simple systems share many of the benefits of a full double skin wall.

Trombe Wall

The trombe wall was one of the earliest passive solar collectors. It uses a south-facing glazed surface, a solid wall painted matte black and an air layer to create a thermal mass system. During the day, sunlight penetrates the insulated glazing and is absorbed by the thermal mass. At night, heat escapes from the thermal mass, warming interior air via conduction. To improve the degree of efficiency, the collector zone is linked to the adjoining room by means of ventilation flaps at the top and bottom of the wall. Sunshading may be necessary to avoid overheating during the summer. The efficiency of such a system can be increased significantly if the glazed areas are covered during the night, decreasing the amount of stored heat lost through the glass as outdoor temperatures drop.

Double Skin Wall

These systems include an extra layer of glazing on the exterior facade system to improve thermal, acoustic, and visual performance. The additional zone created between the interior and the exterior helps decrease heat losses and increase solar gains. This zone of intermediate temperature allows additional recovery of building heat losses and can be used to preheat incoming external air. Double skin facades can also provide a protected space to house systems that improve transparency and decrease glare, such as sunshading devices. The result is a wall that provides better performance than is possible with a single skin. Air circulation within the double skin is handled via natural stack effects, mechanical forced ventilation, or a combination of the two. Noise propagation and fire control may become challenges when creating large multi-story interior spaces, and should be considered during the design process.

Wintergarden

Winter gardens provide a buffer zone between the interior and exterior of a building, while still allowing ventilation and natural light to penetrate. Such spaces help to precondition air using heat loss from interior spaces, saving on heating costs. They also can provide additional space in a semi-conditioned environment that can be used for circulation and other program elements that do not require a high level of thermal control.

Content courtesy of ‘High Performance Building Envelopes’, Gensler, September 2010
On-Site Power Generation: Solar Active Systems

Solar power is converted into electricity, either directly through photovoltaic systems or by the solar thermal process, where steam is generated for power. Solar thermal is also used for hot water systems.

Photovoltaic systems (PV)

A photovoltaic system converts solar radiation directly into electricity. A group of solar cells are assembled to form a panel. Photovoltaic installations are generally connected to the public electricity grid, which serves as a storage medium. The degree of exposure and the inclination of the panel surface determine the annual yield of a photovoltaic system. The yield from a vertical facade panel is much lower than a horizontal system due to angle of incidence.

Rigid vs. Movable systems

An alternative to the rigidly mounted unit is the one or two-axis tracking system. The axis of rotation can be horizontal or vertical, depending on the orientation and the installation. Photovoltaic panels with two-axis tracking can exploit almost twice as much solar radiation than a rigid system over the year. One-axis systems are only marginally less efficient than the two-axis system and are significantly easier to install and more cost efficient.

Integrated façade systems

Slim assemblies and flexible cables with small cross-sections, make PV systems ideal for integrating into facades. Design, materials and the surface finishes, as well as the size, proportion and subdivision of the components determine the appropriateness of the system.

Environmental Factors
- Seasonal radiation
- Cloud cover
- Precipitation

Program Factors
- Identify program areas with high warm water use

Building geometry
- Large roof area vs. facade area
- Availability of surface for solar active systems.

Context
- Shading of other buildings
- Landscaping that may block sunlight

Orientation
- South facing for optimum orientation

Solar Thermal Systems

Solar thermal systems collect the sun’s heat either to be distributed into a building directly via liquid, or to heat exchangers producing steam to power electrical power generators.

Hot-water heating: The size of the collector system must be designed for loads based upon number of occupants, consumption levels, equipment, etc.) and the amount of coverage required.

Space Heating: Flat-plate collectors with a selective coating and Evacuated-tube solar collectors are suitable for space heating purposes.

Solar evacuated tube collectors

Solar evacuated tube collectors are used to supply a building with hot water through heat exchangers. Solar powered air conditioning systems use absorption chillers, which are powered by the solar collectors. Solar air conditioning systems are available in sizes from 5 – 100 tons. Due to the round shape of the tube, these collectors are efficient over a wide range of sun angles.

Flat plate collectors

This is the most common type of collector. The flat-plate collector is fitted with a metal absorber, usually copper, and covered with a pane of highly transparent safety glass. An absorptive coating is used to absorb a high amount of solar radiation. Can be used for heating, hot water, or cooking purposes.

Air collectors (air-preheat)

Air is used directly as the transport medium to heat a space. There is no risk of problems due to frost or corrosion and therefore the sealing requirements for these components are less stringent. However, the specific heat capacity of air is far less than that of water. Large quantities of air and large duct cross-sections are therefore required.

Parabolic trough collectors

The trough collector concentrates heat through its parabolic shape. The heat is concentrated on a linear conductor filled with media which absorbs the heat and transports it to the power generators. Single axis tracking of the sun can be included. Collectors can be grouped in large arrays to form complete power plants, or sized for building or SFO campus-wide application.
On-Site Power Generation: Wind Systems

Windmills or turbines are primarily used to generate electricity. Wind availability is fairly consistent over large time scales but highly variable on a day to day basis. Wind power is renewable, clean, relatively plentiful, and produces no greenhouse gas emissions during operation. Building-mounted and smaller turbines are already in use at a number of world airports.

Wind Power

Potential

Wind power use is expanding rapidly in the US, and California is second only to Texas in generation. The US Department of the Environment website has utility scale wind maps for use in determining site capacity.

Types

Horizontal Axis Wind Turbines (HAWT)

Traditional windmill style, with blades that rotate around a horizontal axis. They consist of a rotor shaft and have an electric generator at the top of the tower. They must point into the wind.

Vertical Axis Wind Turbines (VAWT)

Typically more suitable for building integrated applications, as the vertical axis is fixed and does not have to point into the wind. Lower power co-efficient than HAWT.

Considerations

High wind speeds can cause building mounted wind turbines to generate noise and/or high structure stresses. Wildlife safety is a concern with rapidly spinning blades on HAWTs. Large scale turbines near airports may create additional turbulence for aircraft and tall turbines are incompatible with flight paths.

Airports with Ground Mounted Wind Turbines

East Midlands, UK
Detroit Metro
Burlington International
Denver International

Airports with Building Mounted Wind Turbines

Boston Logan (Administration Building)
Honolulu International (Administration Building)
Minneapolis – St Paul (ARFF)
**On-Site Power Generation: Geothermal Heat Pump (GHP)**

These systems use earth or water as a medium of exchange instead of air. Ground temperature a few feet beneath the surface remains fairly constant, unlike air temperature, so these systems are extremely efficient. GHPs use a system of sunken pipes for heat exchange. These systems are also quiet, clean, durable, and can significantly reduce greenhouse gas emissions associated with building heating and cooling. However initial costs are high.

**Summer Cooling**

Earth (or water) acts as a heat sink in the warmer months. Cooler earth temperatures chill refrigerant in the subsurface piping system and circulate it back to the building, where it is distributed through the floor slabs, chilled beams, or through a conventional ducted air system. The refrigerant draws heat from the building and circulates it back to the ground to dissipate below grade.

**Winter Heating**

Ground temperatures are warmer than winter air. Liquid medium in the piping loop warms below grade and circulates back to the building to distribute heat through floor, beams or ducted air.

**Closed vs. open loop system**

Open loop systems use natural groundwater to exchange heat while closed loops use a mixture of anti-freeze and water. Open loop systems exchange heat directly using a ground water source while closed loop systems need a heat exchanger between the refrigerant and water loop. This makes closed loop systems a little less efficient than open loop. They also need longer and larger pipes along with pumps. However, closed loop systems have greater reliability and require less maintenance.

**Potential Savings**

Portland Jetport Airport installed a geothermal closed loop system when they expanded the airport by 145,000 square feet in 2010-2011. The system is estimated to save the airport $195,000 per year paying for itself in 15 years. The system also reduced the number and usage of heating and cooling equipment required for the terminal. Finally, it is estimated to reduce CO2 emissions by 1,000 tons which is equivalent to removing 181 cars from the road each year.
Health-Based Design and Occupant Well-Being: Material and Product Selection

Health-Based Design employs critical thinking during the design and specification process using the lens of human health impacts. Critically assessing materials for content and emissions of Chemicals of Concern is key to avoiding a body burden of synthetic and naturally occurring chemicals in the indoor environment. (see also pages 39 and 46)

Health Based Design
Research in the multi-disciplinary field of evidence-based design shows that a person’s physical environment can affect health, productivity, safety, well-being and stress level. Building elements such as mainstream manufactured carpet, fabric, ceiling tile, epoxies, woodwork, paint, insulation and plastic components can contribute to a range of health impacts.

Chemicals in the Environment
Historically, the presence of synthetic (anthropogenic as opposed to biological) chemicals in the environment is tied to the by-products of human activity, among them: petroleum processing, plastics development and chemical weapons development. These innovations gave rise to chlorinated chemicals and pesticides, for examples. Another source is the waste stream formed by industries such as construction, mining, manufacturing as well as landfill, pharmaceutical and hazardous waste disposal streams.

Chemical Migration Pathways
Chemicals end up in the environment through trans-boundary pollutant migration: emissions (release), transmission (travel) and deposition (settlement) into air, water, soil and food.

Human Health effects
Synthetic chemicals can act on the human system in a variety of ways, as carcinogens, mutagens, neurotoxins, endocrine disruptors, immune system, developmental and reproductive toxicants, among others.

Health Based Design Process
Designers should research and assess building materials, products and systems for chemical content and emissions using a variety of resources such as chemical databases, emissions certifications, health product declarations and environmental product declarations.

Cleaning and maintenance considerations
Specify products that require little, infrequent or no maintenance. Require manufacturers to provide recommendations for green cleaning alternatives for floor strippers and cleaners, protective coatings, anti-bacterial soaps and cleaners, odor control systems, wood and stone care products, environmental surface disinfectants and specialty cleaners.

Routes of Exposure
The human body absorbs chemicals (through inhalation, ingestion, contact with mucous membranes or skin, or exposure through various pathways as caused by accidental releases such as radiation.

Building Products to Focus On

Non-finish materials: Insulation, framing, glazing waterproofing membranes

Interior Finishes: Carpet, paints, protective coatings / sealers, sealants, caulks, adhesives / bonding agents, upholstery fabrics, furniture, ceiling tile, composite woods, PVC in resilient flooring wall-coverings and other plastic components.
6.1 CASE STUDY OVERVIEWS
6.2 SFO TERMINAL 2
6.3 PORTLAND INTERNATIONAL JETPORT
6.4 SFPUC HEADQUARTERS
Case Study Overviews
1. San Francisco International Airport Terminal 2
2. Portland Jetport Airport
3. San Francisco Public Utilities Commission

Daylighting at SFO Terminal 2
Daylight is a key factor for pleasant interior conditions. It is critical for our visual perception and has a positive impact upon productivity. In fact, natural daylighting has a great effect on passengers and it is a goal to incorporate it into the design of all spaces where passengers and employees spend time.

Radiant Heating Systems at Portland Jetport
According to the International Energy Agency, 75% of a building’s total energy demand goes towards space heating and domestic water heating. Using more energy efficient systems for heating can greatly reduce a building’s overall energy usage.

Accounting for Carbon at SFPUC
By using a low-cement concrete mix and an innovative structural design, SFPUC was able to achieve large CO2 savings as well as meet the immediate-reoccupancy performance mandate.
Case Study: SFO Terminal 2
Understanding the effects of sunlight and sun radiation in different seasons in San Francisco was crucial for creating a holistic environmental building concept for Terminal 2. The effect of sunlight influences envelope performance, daylighting, and shading strategies.

Daylighting
Daylight is a key factor for pleasant interior conditions. It is critical for our visual perception and has a positive impact upon productivity. In fact, natural daylighting has a great effect on passengers and it is a goal to incorporate it into the design of all spaces where passengers and employees spend time. Where possible, the use of side lighting or clerestory lighting is preferred over direct skylights. Daylighting strategies require a site and sun study to ensure the quality of the light brought into the space at all times of the day and the year. Anti-glare strategies must be incorporated to help ensure passenger and employee comfort.

Direct vs. diffuse radiation
Daylight can be transmitted, absorbed, reflected and refracted. Diffuse radiation results in a better illumination of interiors, but direct radiation can reach farther into a building using different light directing strategies.

Seasonality
Solar energy input is limited by the sun trajectory and cloud-coverage, and there is often a conflict between energy needs and energy availability through the seasons.

Glare, Contrast and other aspects of light
The amount and density of daylight should be studied to determine the presence of glare, an often neglected factor in modern work environments. By introducing more daylight, heat enters the building, therefore heat gain and daylighting needed to be balanced in Terminal 2 of San Francisco International Airport.
Case Study: Portland International Jetport

The Jetport expansion is firmly rooted in its context through the use of honest natural materials and an ambitious sustainable design program that reinforces Maine’s connection to the natural environment. The Voluntary Airport Low Emissions (VALE) grant provided the funds for the geothermal heating and cooling system which is estimated to save 100,000 gallons of fuel oil and 2 million pounds of CO2 annually.

Project Details
16,000 sq. ft. expansion
Remodel
Cost $75 million

Low-temp/ Low energy radiant floor
Applying heat directly to the floor, radiant heating systems rely on both heat transfer and convection. The heated floor warms the objects and people above. The heated floor also warms the air above the floor causing it to rise. Radiant floor systems are more efficient than other systems because they eliminate duct losses. It provides energy savings with lower-temperature boiler settings, lower thermostat settings, and reduced infiltration.

Recognition
Certified LEED Gold
ACI’s 2012 Environmental Achievement Award
ACEC’s 2011 Engineering Honor Award

Portland Jetport Radiant Floor
Instead of a standard ducted hot air system, radiant floors were installed in the Portland Jetport. The floor is not only a LEED-friendly system, but it also takes advantage of the thermal mass of the terminal’s concrete slab.
Case Study: SFPUC Headquarters
Slated to achieve LEED Platinum, the SFPUC building located at 525 Golden Gate Avenue will consume 55% less energy than mandated. The building is predicted to save $3.7 billion in ratepayer costs over the building’s 100-year lifespan.

Tipping Mar’s Innovative Structural Design and Concrete Mix
SFPUC headquarters is designed by KMD Architects and constructed by Webcor Builders. In 2008, Webcor Builders asked Tipping Mar to step in to redesign the building’s structure. They wanted the building to be redesigned in concrete while still fulfilling the immediate-reoccupancy performance mandate.

Tipping Mar redesigned the SFPUC headquarters using a vertically post-tensioned concrete shear-wall system with composite link-beams. The redesign reduced indirect and direct building costs while still providing a seismically resistant building.

Tipping Mar also worked with Central Concrete Supply Co. to reduce carbon emissions by designing low-cement concrete mixes. This cement-replacement strategy accounts for 7 million pounds in CO2 emissions savings. This cut SFPUC headquarters’ carbon footprint to about half the size of a similarly sized building.

Energy Savings
$118 million in energy cost savings over 25 years
32% less energy due to hybrid solar panel and wind turbine system
60% less water due to 100% wastewater onsite treatment and rainwater harvesting system.

Impact of Changed Core
49% less carbon from concrete
40% less carbon from rebar
63% less carbon from framing and drywall
7.1 SF GREEN BUILDING REQUIREMENTS SAMPLE CHECKLIST

7.2 LEED SCORECARDS
A. NEW CONSTRUCTION
B. COMMERCIAL INTERIORS
C. CORE & SHELL
D. EXISTING BUILDINGS
E. TERMINAL 2 FINAL LEED SCORECARD

7.3 SFO STAKEHOLDER ENGAGEMENT PROCESS (SEP) STRUCTURE
San Francisco Green Building Requirements Sample Checklist

**Green Building Submittal for San Francisco Municipal Government LEED Projects**

<table>
<thead>
<tr>
<th>LEED v4 Scorecard</th>
<th>REQUIREMENTS</th>
<th>VERIFICATION</th>
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<tr>
<td><strong>Introduction</strong>: This form is used for LEED projects that are not submitted to the City and County of San Francisco's Planning Department. Select the section that corresponds to your project type. If the checklist does not apply, write &quot;N/A&quot; in the box and cross out the checklist item. Failure to submit a signed and dated checklist must be noted in the LEED application.</td>
<td><strong>San Francisco Green Building Requirements Summary</strong></td>
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<td><strong>Mock-up</strong></td>
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**Insert Project Name / Titleblock here**
LEED v4 for BD+C: New Construction and Major Renovation
Project Checklist

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**Location and Transportation**

Possible Points: 16

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**Sustainable Sites**

Possible Points: 10

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**Water Efficiency**

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**Materials and Resources**

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**Indoor Environmental Quality**

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**Innovation**

Possible Points: 6

| Credit 1 | Innovation | 5 |
| Credit 2 | LEED Accredited Professional | 1 |

**Regional Priority**

Possible Points: 4

| Credit 1 | Regional Priority: Specific Credit | 1 |
| Credit 2 | Regional Priority: Specific Credit | 1 |
| Credit 3 | Regional Priority: Specific Credit | 1 |
| Credit 4 | Regional Priority: Specific Credit | 1 |

**Total**

Possible Points: 102

Certified 40 to 49 points  Silver 50 to 59 points  Gold 60 to 79 points  Platinum 80 to 110
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**Location and Transportation** Possible Points: 20

| Credit 1 LEED for Neighborhood Development Location | 20 |
| Credit 2 Sensitive Land Protection | 2 |
| Credit 3 High Priority Site | 3 |
| Credit 4 Surrounding Density and Diverse Uses | 6 |
| Credit 5 Access to Quality Transit | 6 |
| Credit 6 Bicycle Facilities | 1 |
| Credit 7 Reduced Parking Footprint | 1 |
| Credit 8 Green Vehicles | 1 |

**Sustainable Sites** Possible Points: 11

| Credit 1 Site Assessment | 1 | Credit 1 Construction Activity Pollution Prevention | Required |
| Credit 2 Site Development--Protect or Restore Habitat | 2 | Credit 2 Construction Activity Pollution Prevention | Required |
| Credit 3 Open Space | 1 | Credit 3 Construction Activity Pollution Prevention | Required |
| Credit 4 Rainwater Management | 3 | Credit 4 Construction Activity Pollution Prevention | Required |
| Credit 5 Heat Island Reduction | 2 | Credit 5 Construction Activity Pollution Prevention | Required |
| Credit 6 Light Pollution Reduction | 1 | Credit 6 Construction Activity Pollution Prevention | Required |
| Credit 7 Tenant Design and Construction Guidelines | 1 | Credit 7 Construction Activity Pollution Prevention | Required |
| **Credit 1 Integrative Process** | 1 | **Credit 1 LEED for Neighborhood Development Location** | 20 |
| **Credit 2 Sensitive Land Protection** | 2 | **Credit 3 High Priority Site** | 3 |
| **Credit 4 Surrounding Density and Diverse Uses** | 6 | **Credit 5 Access to Quality Transit** | 6 |
| **Credit 6 Bicycle Facilities** | 1 | **Credit 7 Reduced Parking Footprint** | 1 |
| **Credit 8 Green Vehicles** | 1 | **Credit 2 LEED for Neighborhood Development Location** | 20 |

**Materials and Resources** Possible Points: 14

| Credit 1 Storage and Collection of Recyclables | 2 |
| Credit 2 Construction and Demolition Waste Management Planning | 2 |
| Credit 2 Green Power and Carbon Offsets | 2 |
| Credit 3 Renewable Energy Production | 3 |
| Credit 4 Enhanced Refrigerant Management | 1 |
| Credit 5 Green Power and Carbon Offsets | 2 |

**Indoor Environmental Quality** Possible Points: 10

| Credit 1 Minimum Indoor Air Quality Performance | Required |
| Credit 2 Environmental Tobacco Smoke Control | Required |
| Credit 3 Enhanced Indoor Air Quality Strategies | 2 |
| Credit 4 Low-Emitting Materials | 3 |
| Credit 5 Daylight | 1 |
| Credit 6 Quality Views | 1 |
| **Credit 1 Minimum Indoor Air Quality Performance** | Required |
| **Credit 2 Environmental Tobacco Smoke Control** | Required |
| **Credit 3 Enhanced Indoor Air Quality Strategies** | 2 |
| **Credit 4 Low-Emitting Materials** | 3 |
| **Credit 5 Daylight** | 1 |
| **Credit 6 Quality Views** | 1 |

**Innovation** Possible Points: 6

| Credit 1 Innovation | 5 |
| Credit 2 LEED Accredited Professional | 1 |
| **Credit 1 Innovation** | 5 |
| **Credit 2 LEED Accredited Professional** | 1 |

**Regional Priority** Possible Points: 4

| Credit 1 Regional Priority: Specific Credit | 1 |
| Credit 2 Regional Priority: Specific Credit | 1 |
| Credit 3 Regional Priority: Specific Credit | 1 |
| Credit 4 Regional Priority: Specific Credit | 1 |

**Total Possible Points: 110**

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110
### LEED v4 for Operations & Maintenance: Existing Buildings

#### Project Checklist

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<td>Credit 10 Green Cleaning - Products and Materials</td>
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<td>Credit 11 Green Cleaning - Equipment</td>
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<td>Credit 12 Integrated Pest Management</td>
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<td>Credit 13 Occupant Comfort Surveys</td>
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<td>Innovation</td>
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<td>Credit 2 LEED Accredited Professional</td>
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<td>Regional Priority</td>
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<td>Credit 1 Regional Priority: Specific Credit</td>
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<td>Credit 2 Regional Priority: Specific Credit</td>
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<td>Credit 3 Regional Priority: Specific Credit</td>
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<td>Credit 4 Regional Priority: Specific Credit</td>
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#### Site Management Policy

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<th>Certification Level</th>
<th>Points</th>
<th>Silver</th>
<th>50 to 59 points</th>
<th>Gold</th>
<th>60 to 79 points</th>
<th>Platinum</th>
<th>80 to 110 points</th>
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<td>Certified 40 to 49 points</td>
<td>40</td>
<td>Silver</td>
<td>50 to 59 points</td>
<td>Gold</td>
<td>60 to 79 points</td>
<td>Platinum</td>
<td>80 to 110 points</td>
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</table>

Total Possible Points: 106
Final LEED Scorecard for Terminal 2

SFO Terminal 2
Green Building (LEED-NC v2.2) Scorecard

Final Score: October 2011

7.2.E

SFO SUSTAINABLE PLANNING, DESIGN & CONSTRUCTION GUIDELINES

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**SFO Terminal 2**

Final Score: October 2011

7.2.E

SFO SUSTAINABLE PLANNING, DESIGN & CONSTRUCTION GUIDELINES

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**SFO Terminal 2**

Final Score: October 2011

7.2.E

SFO SUSTAINABLE PLANNING, DESIGN & CONSTRUCTION GUIDELINES

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**SFO Terminal 2**

Final Score: October 2011

7.2.E

SFO SUSTAINABLE PLANNING, DESIGN & CONSTRUCTION GUIDELINES

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SFO Stakeholder Engagement Process (SEP) Structure

The diagram below reflects the typical structure of the SEP Team. Stakeholder Engagement Groups are called for all aspects of a project. They should be leveraged at project kick-off to help establish project-specific sustainability goals and assist in follow through. Please refer to the SFO’s Delivering Exceptional Projects – Our Guiding Principles document for more information available at [http://www.sfoconstruction.com](http://www.sfoconstruction.com).
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UPDATED BY T1 PARTNERS (PARSONS, THE ALLEN GROUP, EPC)
Anthony Bernheim
Nivya Sannareedy