DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

13 JAN 2011

FROM: HQ AFCESA/CEO
139 Barnes Drive, Suite 1
Tyndall AFB FL 32403-5319

SUBJECT**: Engineering Technical Letter (ETL) 11-8: Decision Criteria for Installing Vegetative Green Roofs at CONUS Installations**

1. Purpose. This ETL provides guidance for determining if installing a vegetative roof on a CONUS Air Force facility is suitable. The intent is to give the base a simple tool to justify selection or non-selection of a green roof based entirely on return on investment (ROI). Selection of a vegetative green roof for environmental or social reasons can certainly be valid but is not part of this ETL's selection criteria. Vital to the ROI are the facility characteristics, occupancy type, and the local climate. This ETL lists benefits of a vegetative roof, provides initial cost and ROI prediction, and provides general maintenance requirements associated with the waterproofing and green components of this roofing system. For more details on the different types of green roofs—and the advantages and disadvantages of each—consult the Peterson AFB study referenced in paragraph 3.1.

2. Application: Bases considering installing vegetative green roofs as an energy-saving roofing system.

2.1. Authority: Air Force instruction (AFI) 32-1051, *Roof Systems Management*

2.2. Effective Date: Immediately

2.3. Intended Users:
- Major command (MAJCOM) engineers at CONUS installations
- CONUS base civil engineers (BCE)

2.4. Coordination:
- MAJCOM civil engineers
- Air Force Center for Engineering and the Environment (HQ AFCEE)
- Air Force Civil Engineer Support Agency, Facility Energy Center, Conservation Branch (AFCESA/CENE)

3. References.

3.1. Air Force:
- AFI 32-1051, *Roof Systems Management*, http://www.e-publishing.af.mil/
- *Peterson AFB Green Roof Study Findings and Recommendations*, TETRA TECH Engineering and Architecture Services, https://www.my.af.mil/afknprod/community/views/home.aspx?Filter=24764

4. Acronyms:

AFI	- Air Force instruction
BASH	- bird/wildlife aircraft strike hazard
CONUS	- continental United States
ETL	- engineering technical letter
HQ AFCESA/CENE	- Air Force Civil Engineer Support Agency, Facility Energy Center, Conservation Branch
HQ AFCESA/CEOA	- Air Force Civil Engineer Support Agency, Operations and Programs Support Division, Engineer Support Branch
MAJCOM	- major command
ROI	- return on investment

5. Requirements. Green roofs are building roof systems planted with vegetation to achieve a variety of benefits. They are categorized as “intensive,” “semi-intensive,” or “extensive,” depending on the depth of planting medium and the amount of maintenance required. Intensive green roofs have the greatest depth, support a variety of plants (including trees), and have significant structural and maintenance requirements. Extensive green roofs have a shallow planting medium and a low-growing, easily maintained vegetative installation. Semi-intensive roofs have characteristics in between the other two. This ETL will focus on extensive systems since they are the most likely type of green roof to be constructed at Air Force installations. They are the most economical, are easily maintained, and somewhat lightweight.

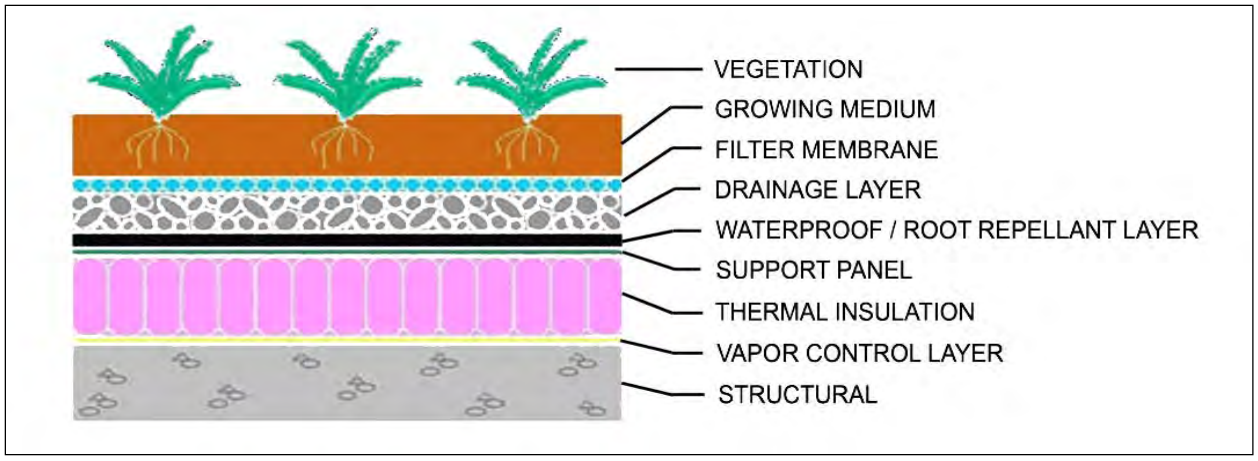

Figure 1. Typical Green Roof Components

5.1. The use of vegetative green roofs is beneficial in many ways. It reduces storm water runoff, improves the quality of storm water runoff, improves air quality, can extend roof membrane service life, and saves energy. The cost to install this type of roof is typically about 75% higher than a conventional low-sloped roof. Service life expectancy is 40 years, but this is a projection without historical data to support it and assumes diligent inspection and maintenance of the roof’s waterproofing and

drainage components. If this service life is achieved, an ROI of 145% to 204% is realized. Attachment 1 shows which CONUS installations have the greatest potential to benefit, while Attachment 2 shows which types of facilities are most appropriate.

5.2. There is a requirement to irrigate the roof during the establishment period so the plants will not perish. It is important to note that any irrigation beyond this is not acceptable. If the local climate conditions will not support a healthy vegetative cover without irrigation, do not install a green roof. In addition, knowledgeable inspection and maintenance of the vegetative cover is required. Since locating and repairing leaks in the membrane is difficult, leak-detection sensors should be installed under the roof membrane. These requirements and the associated maintenance burden should be considered prior to choosing a green roof. Maintenance requirements will depend on the selection of vegetative cover, rooftop equipment and penetrations, foot traffic, and even BASH considerations.

5.3. Suitability of a green roof to provide a positive ROI is determined by regional climate, building dimensions, structural capacity, and building occupancy.

5.4. Hot locations see the greatest benefits from lowering the roof temperature, but dry climates require more irrigation. Attachment 1 provides climate-related information for every CONUS Air Force base. OCONUS installations were not included in the study. Hawaii and Guam are worth investigating, but, due to joint basing, the Air Force no longer owns many suitable facility types there. Each CONUS base is given a total score that corresponds to a poor, fair, or good potential to benefit from a green roof.

5.5. High roof-to-wall ratios are desirable, and the structure should be able to support the additional weight without extensive upgrades. The building should be fully conditioned and occupied for long hours. Attachment 2 shows suitability by facility type.

5.6. The green roof installation decision tree in Attachment 3 will help guide the selection of vegetative green roofs.

5.7. Maintenance costs for green roof systems vary depending on roof size and the entity selected to provide this service. Typically, the larger the roof, the more labor hours are required to maintain its healthy upkeep. Regularly scheduled maintenance is intended to keep major repairs at a minimum. Proper performance of maintenance tasks should catch significant cost issues before they happen. Other items that may drive up costs are difficult roof access and equipment accessibility to the roof. Maintenance staff members who are not trained for green roof upkeep may drive up costs by inflicting damage on the green roof system, drainage system, or roofing membrane. For more information regarding maintenance requirements, see *Green Roof Study Findings and Recommendations*, Chapter 5.

5.8. The ROI over the 40-year projected service life of the green roof ranges from 145% to 204%, depending on the local climate. The most significant factor affecting the ROI is not energy savings but the savings derived from the extended service life of the roof membrane system. Successfully achieving this service life demands a sustained commitment to maintenance. A green roof may be considered for reasons other than energy savings. They improve storm water runoff, improve air quality, and have other social benefits. If a green roof is installed for these reasons, this ETL serves to indicate and highlight the maintenance requirements for the green roof to perform as expected.

5.9. The use of green roofs will continue to expand in North America as their environmental, economic, and social benefits are recognized and as green design is embraced by the public and private sectors. Relationships between conventional roof manufacturers and green roof manufacturers and installers are now well established. It is anticipated that as the green roof market expands and the industry matures in North America, green roof systems will become more commonplace, more competitive, and more standardized. Green roofs can save energy at Air Force facilities. They can also make financial sense if they are properly designed, properly installed, and a long-term commitment is made to ensure appropriate maintenance throughout their potentially long service lives. Without this commitment, consider a cool (highly reflective) roof, which will provide similar energy savings and maintenance requirements at a cost comparable to traditional low-slope roof construction.

6. Point of Contact. Questions or comments about this ETL are encouraged and should be directed to the Roofing Engineer Subject Matter Expert, HQ AFCESA/CEOA, DSN 523-6031, commercial 283-6031, AFCESAReachBackCenter@tyndall.af.mil.

CLIFFORD C. FETTER, P.E., GS-15, DAF
Acting Chief, Operations and Programs Support

4 Atchs
1. Appropriateness Table – Green Roof Benefits by Location
2. Green Roof Suitability Based on Facility Type
3. Decision Tree
4. Distribution List

APPROPRIATENESS TABLE
GREEN ROOF BENEFITS BY LOCATION

Base	Energy Benefits[a]	Irrigation Demands[b]	**Total score[c]**
Air Force Region 1			
Beale AFB, California	8	2	**10**
Edwards AFB, California	9	2	**11**
Los Angeles AFB, California	9	2	**11**
Travis AFB, California	8	2	**10**
Vandenberg AFB, California	10	3	**13**
Air Force Region 2			
Creech AFB / Nellis AFB, Nevada	8	1	**9**
Davis-Monthan AFB, Arizona	9	1	**10**
Fairchild AFB, Washington	4	2	**6**
Hill AFB, Utah	6	2	**8**
Luke AFB, Arizona	9	1	**10**
McChord AFB, Washington	5	3	**8**
Mountain Home AFB, Idaho	6	2	**8**
Air Force Region 3			
Buckley AFB, Colorado	7	2	**9**
Ellsworth AFB, South Dakota	5	2	**7**
F.E. Warren AFB, Wyoming	6	2	**8**
Grand Forks AFB, North Dakota	4	3	**7**
Malmstrom AFB, Montana	4	2	**6**
Minot AFB, North Dakota	4	3	**7**
Offutt AFB, Nebraska	6	2	**8**
Peterson AFB / Schriever AFB, Colorado	7	2	**9**
Air Force Region 4			
Altus AFB, Oklahoma	8	2	**10**
Cannon AFB, New Mexico	8	2	**10**
Dyess AFB, Texas	9	2	**11**
Goodfellow AFB, Texas	10	1	**11**
Holloman AFB, New Mexico	9	1	**10**
Kirtland AFB, New Mexico	8	2	**10**
Lackland AFB, Texas	10	2	**12**
Laughlin AFB, Texas	10	1	**11**
McConnell AFB, Kansas	7	2	**9**
Randolph AFB, Texas	10	2	**12**
Sheppard AFB, Texas	9	2	**11**
Tinker AFB, Oklahoma	8	2	**10**
Vance AFB, Oklahoma	8	2	**10**

a. Energy benefits scoring: 4 (minimum) to 10 (maximum)
b. Irrigation demand scoring: 1 (high), 2 (medium), 3 (low)
c. Total Score <7 is poor; 7 ≤ total score <11 is fair; total score ≥ 11 is good

APPROPRIATENESS TABLE (CONTINUED)
GREEN ROOF BENEFITS BY LOCATION

Base	Energy Benefits[a]	Irrigation Demands[b]	**Total score[c]**
Air Force Region 5			
Barksdale AFB, Louisiana	9	2	**11**
Little Rock AFB, Arkansas	9	2	**11**
Scott AFB, Illinois	7	2	**9**
Whiteman AFB, Missouri	7	2	**9**
Air Force Region 6			
Columbus AFB, Mississippi	8	2	**10**
Eglin AFB, Florida	10	2	**12**
Keesler AFB, Mississippi	10	2	**12**
MacDill AFB, Florida	10	2	**12**
Maxwell AFB, Alabama	9	2	**11**
Patrick AFB, Florida	10	2	**12**
Tyndall AFB, Florida	10	2	**12**
Air Force Region 7			
Arnold AFB, Tennessee	8	2	**10**
Charleston AFB, South Carolina	8	2	**10**
Moody AFB, Georgia	9	2	**11**
Pope AFB, North Carolina	7	2	**9**
Robins AFB, Georgia	8	2	**10**
Seymour Johnson AFB, North Carolina	7	2	**9**
Shaw AFB, South Carolina	8	2	**10**
Air Force Region 8			
Joint Base Andrews, Maryland	6	2	**8**
Bolling AFB, Washington D.C.	6	2	**8**
Dover AFB, Delaware	6	2	**8**
Langley AFB, Virginia	6	2	**8**
Wright-Patterson AFB, Ohio	7	2	**9**
Air Force Region 9			
McGuire AFB, New Jersey	6	2	**8**
Hanscom AFB, Massachusetts	5	2	**7**

a. Energy benefits scoring: 4 (minimum) to 10 (maximum)
b. Irrigation demand scoring: 1 (high), 2 (medium), 3 (low)
c. Total Score <7 is poor; 7 ≤ total score <11 is fair; total score ≥ 11 is good

GREEN ROOF SUITABILITY BASED ON FACILITY TYPE

General Facility Type or Use/Activity	Recommended?	Comments - Conditions
AIR TERMINALS		
Freight	No	—
Freight/passenger	Yes	Passenger only - fully conditioned
Passenger	Yes	Depending on frequency of use
BAKERIES	No	—
COMMUNICATIONS AND IT FACILITIES (ALL)	Yes	Fully conditioned
Air Force communications-computer maintenance facility	Yes	Fully conditioned
Audiovisual & TV facilities	Yes	Fully conditioned
COMMUNITY & SUPPORT FACILITIES		
Commissary	Yes	Fully conditioned
Post office	Yes	Fully conditioned
Exchange	Yes	Fully conditioned
Commercial shops	Yes	Fully conditioned
Religious facilities	No	Part-time use
Dependent school-support facilities	Yes	Fully conditioned
Dependent school	No	Unless year-round use and fully conditioned
Banks, credit unions	Yes	Fully conditioned
Day care center - preschool	Yes	Fully conditioned
Community activity center	Yes	Fully conditioned
Theater	No	—
Recreation facilities	Yes	Excludes gyms - fully conditioned
Library	Yes	Fully conditioned
DINING HALLS	Yes	Depending on make-up air requirements - fully conditioned
FITNESS FACILITIES	No	High make-up air requirements
FIRE STATION	Yes	Excludes apparatus bays - fully conditioned
GUARD AND RESERVE FACILITIES	No	Part-time use
HANGARS	No	—
HOUSING		
Housing - all types - fully conditioned	Yes	Depending on configuration
Housing - all types - heat only	No	—
LAUNDRY AND DRY-CLEANING PLANTS	No	—

NOTE: If facility type is not listed, compare with most similar type listed. Facility should be recommended if it meets the following criteria:

- Fully conditioned building with normal and not high make-up air requirements.
- Facility is occupied a minimum of 8 hours per day for 5 days a week
- Building has a high roof area to wall area ratio (tall buildings have a low roof area to wall area ratio)

GREEN ROOF SUITABILITY BASED ON FACILITY TYPE (CONTINUED)

General Facility Type or Use/Activity	Recommended	Comments - Conditions
MEDICAL/DENTAL		
Clinics - all types	Yes	Fully conditioned
Ambulatory health care center	Yes	Fully conditioned
Composite medical facility	Yes	Fully conditioned
Hospitals	Yes	Fully conditioned
Aerospace medical facility	Yes	Fully conditioned
Occupational health clinic	Yes	Fully conditioned
MUSEUM	No	If part-time use
OPERATIONS FACILITIES & OFFICES		
Offices - all types	Yes	Fully conditioned
Squadron operations facilities	Yes	Fully conditioned
Base operations facilities	Yes	Fully conditioned
Administrative facilities - all types	Yes	Fully conditioned
Legal facilities	Yes	Fully conditioned
PARKING FACILITIES	No	—
SHOPS & MAINTENANCE FACILITIES		
Shops/maintenance facilities - all types - fully conditioned	Yes	Only if standard make-up air requirements
Shops/maintenance - unconditioned or semi-conditioned	No	—
STORAGE & WAREHOUSE FACILITIES	No	—
TRAINING FACILITIES		
Education center	Yes	Fully conditioned
Classroom facilities	Yes	Fully conditioned
Automotive skills centers	No	—
Airman Leadership School	Yes	Fully conditioned

NOTE: If facility type is not listed, compare with most similar type listed above. Facility should be recommended if it meets the following criteria:

- Fully conditioned building with normal and not high make-up air requirements.
- Facility is occupied a minimum of 8 hours per day for 5 days a week
- Building has a high roof area to wall area ratio (tall buildings have a low roof area to wall area ratio)

DECISION TREE

A3.1. The decision tree in Figure A3.1 should be used with Attachments 1 and 2 to help determine whether an existing or proposed new building is an appropriate candidate for a green roof. If a green roof installation is determined to be appropriate, complete the "Green Roof System Selection" and "Green Roof Membrane Selection" decision trees in *Green Roof Study Findings and Recommendations*, located at https://www.my.af.mil/afknprod/community/views/home.aspx?Filter=24764 .

A3.2. The fourth question in the decision tree addresses the capacity of a structure to support the anticipated saturated green roof loading. **Note:** A structural engineer should provide the appropriate analysis both for existing facilities and new construction. System weights vary and this may be a determinant in the specific system selected.

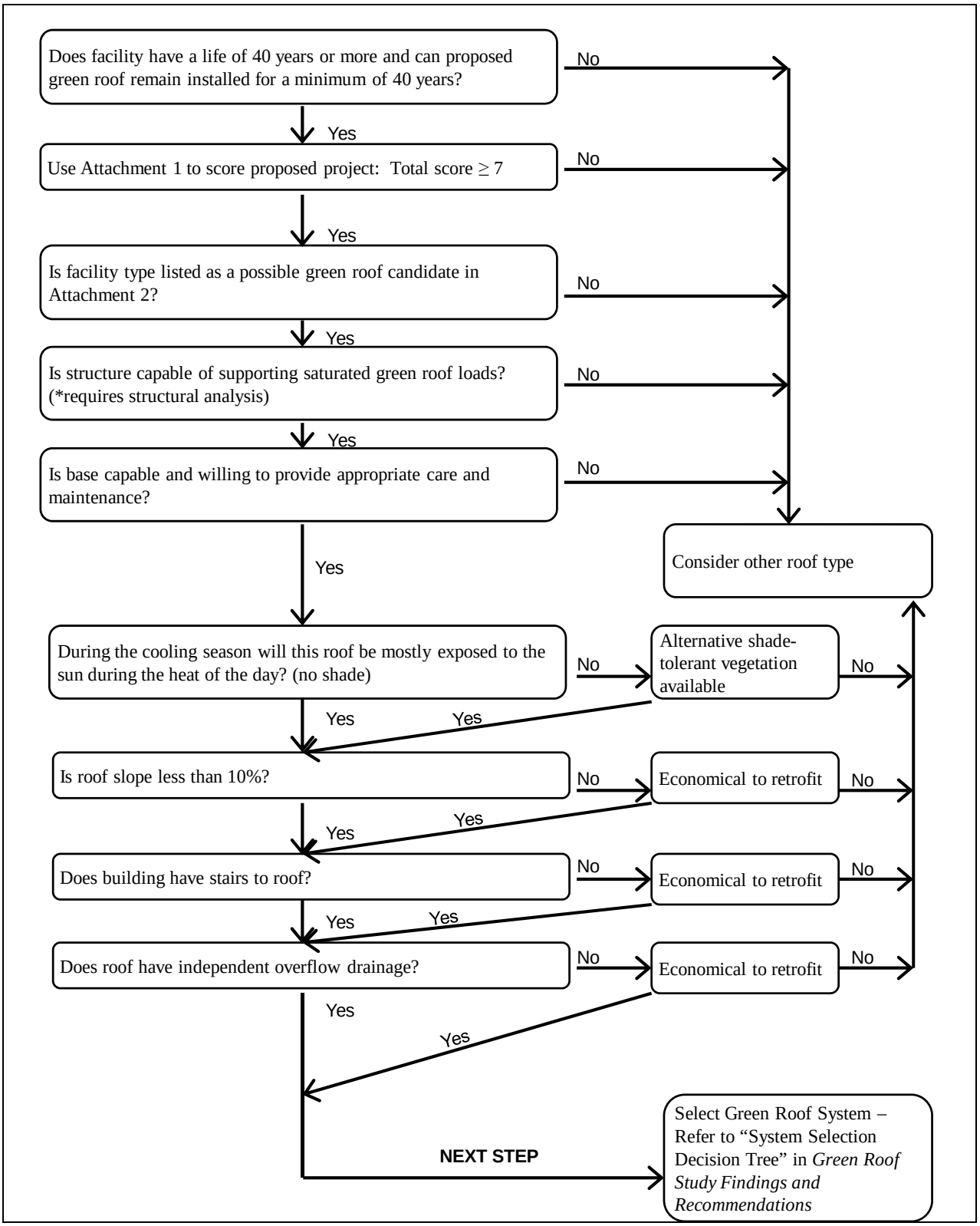

Figure A3.1. Green Roof Installation Decision Tree

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

Defense Commissary Agency (1)
Design and Construction Division
2250 Foulois St., Suite 2
Lackland AFB, TX 78236

AAFES (1)
ATTN: RE-C
PO Box 660202
Dallas, TX 75266-0202

SPECIAL INTEREST ORGANIZATIONS

Information Handling Services (1)
15 Inverness Way East
Englewood, CO 80150

Construction Criteria Base (1)
National Institute of Bldg Sciences
Washington, DC 20005