Appendix C: A Sustainable Design Cost Study for the Johnson City Customer Service Center, Tennessee Valley Authority (TVA)[1]

This appendix describes an exercise undertaken by David Zimmerman of TVA to estimate the costs of adding sustainable design features to a building in the design phase.

C.1 Project Description

The proposed TVA Johnson City Customer Service Center (CSC) is a 24,171-ft^2 district office (see Figure C-1). The building design contains offices for employees, a large meeting room for TVA and community use (13,054 ft^2), support spaces (restrooms, showers, break room, storage, instrument room, and power crew room – 6,187 ft^2) and an enclosed heated vehicle bay (4,930 ft^2).

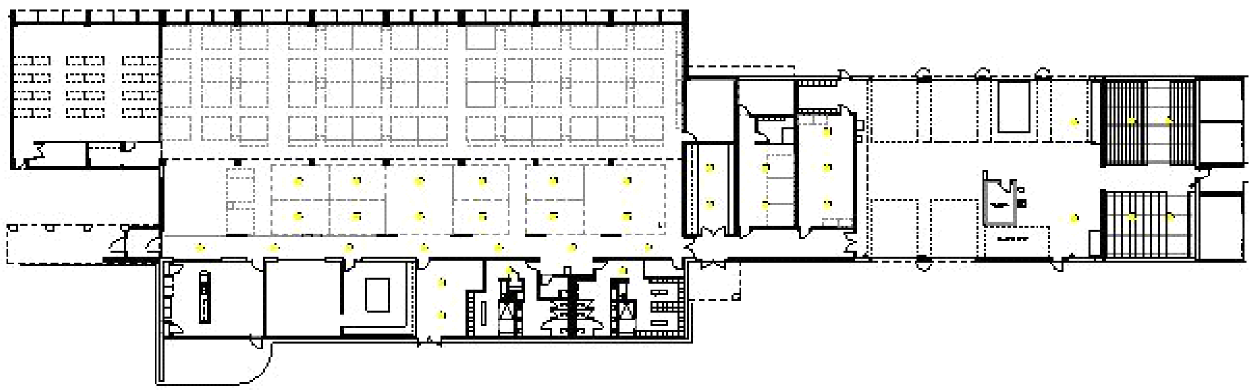

Figure C-1. Floor Plan of Johnson City CSC

C.2 Approach to Sustainable Design

The goal of the building design is to incorporate a wide range of cost-effective sustainable/energy technologies to demonstrate to TVA's customers its environmental commitment and to save energy and operations and maintenance (O&M) costs. The analysis described below is part of the initial design process. The process is similar to the approach described in Section 2.2 of this document for the prototypical building. The standard approach to efficient building design is to establish a base-case computer model of the building. The base case represents the building design without special attention to energy efficiency or sustainability. Then, various energy and sustainable technologies are added one at a time to see their impact on the base design. The cost and savings are determined, and those features found to have acceptable performance can be combined into final computer simulations to determine overall impact on the building design.

The Johnson City CSC project, like past TVA projects, underwent extensive planning and design prior to construction. Typically, every major new construction project undergoes an analysis similar to the one described below for Johnson City CSC.

[1] This appendix was written by D. Zimmerman, TVA.

C.3 Sustainable Features

The following technologies were examined for the sustainable version of the Johnson City CSC:

- **Decentralized geothermal heat pump HVAC system.** The building is heated and cooled using water to air heat pumps connected to a closed loop geothermal well system. To further reduce energy use, individual heat pumps units that use smaller pumps were connected to individual earth-coupled wells (instead of using one large well field and pump). This geothermal system cost more than a typical air-to-air heat pump, but the estimates show it pays for itself in 6.9 years as a result of energy and maintenance savings.
- **Light tube daylighting.** The building central circulation corridor, private offices, and meeting rooms are located in the interior of the building, far from exterior windows. To provide natural light to these spaces, 30 circular skylights that are 13 in. in diameter were connected to circular tubes lined with reflective material. These tubes "pipe" light to these interior areas. The light tubes, along with the switched control system to turn off electric lights when enough daylight was present, have an 8.3-year payback.
- **North clerestory daylighting to provide 50 footcandles.** The building design has a large open office area. Windows located on the south wall of this area provide daylight to a 15'-6" depth but cannot daylight the remaining 26'-6". Therefore, the roof was sloped upward and a six-foot-high continuous north facing clerestory was installed to daylight the rest of this area (see Figure C-2). Carefully sized overhangs and fins prevent direct-beam sunlight from entering the space. Continuous-dimming direct/indirect electric lighting systems were installed to maintain 50 footcandles over the whole space. The extra windows (those needed beyond what would have been installed in a conventional building), dimmable electronic light ballasts, a control system and light shelves were extra cost items attributed to the daylighting system and included in the incremental cost estimate. The analysis showed a payback of 6.5 years.
- **North clerestory daylighting to provide 15 footcandles of ambient light, with additional task lights.** This energy-saving option is the same as the option above, except fewer electric lights were installed and the control system was set to maintain a minimum light level of 15 footcandles. Task lights were added to each of the workstations. This energy-saving option has an even faster payback – 1.4 years.
- **Garage daylighting.** This energy-saving option involved adding north- and south-facing glazing to the vehicle bay to provide daylighting. The south-facing glazing also provides some passive solar heating. The cost of fiberglass glazing in place of metal panels and a control system to switch off the electric lights were included in the cost analysis. The payback was 5.5 years.
- **Light-colored roof (changing the absorptance 0.91 [dark] to 0.3 [white]).** Changing the metal roof from dark blue to white produced minimum savings. The base-case building uses a standard metal building roof system that calls for R-30 batts of insulation attached to the underside of the metal roof. This high level of insulation minimized the savings from this option, so the roof color has been left to the discretion of the architect.

In addition to the energy-saving options above, a wide range of additional technologies was investigated for incorporation into the design. Most of these can be classified as sustainable and are as follows:

- **Membrane energy recovery heat exchanger.** This is a relatively new technology that involves transferring heat and moisture between incoming ventilation air and outgoing exhaust air using a thin membrane. The manufacturer had a prototype unit and wanted to install it and monitor performance. If successful, such a unit could pay for itself in energy savings in 3 to 4 years.

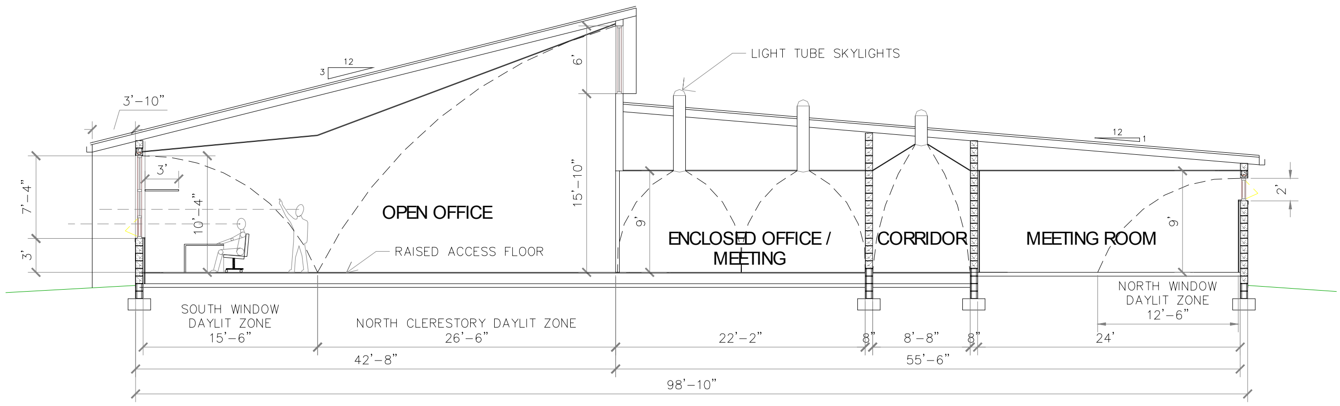

Figure C-2. Typical Section of Johnson City CSC, Showing Clerestory Windows

- **Using ultraviolet (UV) light to treat HVAC supply air.** This technology involves passing HVAC supply air through ductwork lined with UV light tubes. UV light is very effective at killing bacteria. Such a system would not have an easily quantified savings. It uses additional electricity to operate but could have a payback based on employee wellness (less absenteeism).
- **Metal roof vs. asphalt roof.** Typical roofs on small commercial buildings are either built-up asphalt or asphalt-based shingles. A heavy-gage standing-seam metal roof can have substantially longer life compared with asphalt and is easily recycled, making it a more sustainable choice. Analysis showed that the extra cost of a metal roof would pay for itself in 6.6 years, so it was included in the design.
- **Permeable pavement.** Permeable pavement allows water to drain through to the ground below. Such pavement prevents water runoff and erosion. New forms of permeable asphalt pavement were found to be almost identical in cost to standard asphalt pavement. Permeable pavement also reduces the need for storm water catchment structures and storage making permeable pavement an instant payback.
- **Rain water collection for irrigation and vehicle washing.** This sustainable option involved collecting rainwater off the roof and storing it for use in a 7500-gallon aboveground tank. The water would be used for washing vehicles and irrigating landscaping. This option was estimated to have a 9.4 –year payback.
- **Climate appropriate plants.** Research showed that climate-appropriate plants for TVA's climate in most cases cost no more than imported plants. Climate-appropriate plants were included in the design.
- **Autoclaved concrete block.** Autoclaved concrete block covered with a manufacturer-approved exterior stucco material was included in the design. This sustainable material contains recycled-content (fly ash) and has excellent insulation qualities. The cost of this block was found to be equal to standard concrete block with the addition of rigid insulation, resulting in no extra cost.
- **Waterless urinals compared with standard urinals.** Waterless urinals were found to cost less to install and maintain than standard urinals. They are fiberglass units with a vapor trap that contains a liquid that allows urine to pass through. They do not require a water supply line, flush valves, etc., resulting in substantial water and maintenance savings.
- **High-velocity electric hand dryers – Excel Xlerator® compared with paper towels.** The Excel Corporation markets a hand dryer that it claims can dry hands in 10 to 12 seconds compared with standard dryers, which can take up to 30 seconds. Two of these hand dryers were added to the design; and if fully used, they will reduce the use of paper towels. The projected payback for the dryers cost is 1.6 years compared with paper towel use and disposal.

- **Sustainable (healthy) interior finishes.** Low volatile organic compound (VOC) paints and finishes along with materials with recycled content and the ability to be recycled have been gradually introduced into TVA renovation and new construction work and were included in the CSC design.

Some options were considered but not included in the design:

- **Operable windows for ventilation.** This option was briefly considered and rejected because of the high humidity levels and very hot summers. The installation of a very efficient HVAC system (geothermal heat pump) further reduces the potential of this option to save money and provide comfortable indoor conditions.
- **Wind electric generation.** This energy option was not included because the current building site does not have the necessary wind levels.
- **Photovoltaic roof canopy.** Replacing the covered parking canopy with a canopy made up of photovoltaic cells was found to be very costly and to have a very long payback period.

In addition to the above sustainable technologies, a decision had already been made to incorporate the following sustainable technologies, so they were included in the base-case cost:

- Raised access floor to provide flexibility in changing the spaces and to provide underfloor HVAC with individual work station air controls
- Movable walls to construct interior private offices and meeting rooms to minimize the use of drywall and provide easy changes to the space in the future.

C.4 Financial Considerations

Figure C-3 (at the end of the appendix) shows the calculated incremental first costs and annual cost savings (with payback periods). In addition to the individual technologies described above, the analysis included a number of combinations of technologies:

- **Total building daylighting (north clerestory – 50 footcandles).** This is a combination of light tube daylighting, garage daylighting, and open office north clerestory daylighting to 50 footcandles. This combination yielded a payback of 7.5 years.
- **Total building daylighting (north clerestory – 15 footcandles).** This is the same as the option above, except the open office area is lit to only 15 footcandles, and task lights are installed in each of the workstations. This combination yielded a payback of 5.0 years.
- **Total building daylighting (50 footcandles) plus geothermal heat pump.** This is a combination of total building daylighting (north clerestory – 50 footcandles) and the geothermal heat pump HVAC system. This combination yielded a payback of 6.9 years.
- **Total building daylighting (15 footcandles) plus geothermal heat pump.** This is the same as the option above (daylighting combined with geothermal heat pump), except the open office area is being lit to only 15 footcandles, and task lights are installed in each of the workstations. This combination yielded a payback of 5.7 years. The significance of this combination is that overall energy use of the building design was reduced by almost 50%.

The energy cost savings of the energy-saving options (daylighting and geothermal heat pump system) were determined by creating an energy model of the building using the PowerDOE building energy analysis program (Version 1.18g by James J. Hirsch & Associates), which uses DOE-2.1 as the principal underlying model (see Section 3.1 and Appendix B for description of how DOE -2.1 was applied in this study). This program takes into account all the heat loss/gain through the various building surfaces and the amount of internal energy use and heat gain from lights, people, and equipment and models the HVAC system to maintain set indoor conditions. The program performs an hour-by-hour simulation of the building design and outputs a wide range of reports, including yearly energy cost based on utility rate structure.

The costs of the various energy-saving options were determined using several approaches. The geothermal heat pump system size and cost were determined by a TVA engineer experienced in designing such systems for TVA customers. The cost of daylighting components were determined from "RS Mean Building Construction Cost Data – 2002" (RS Means 2002) along with some actual numbers from specific manufacturers.

C.5 Key Conclusions for the Business Case

Many cost-effective sustainable design options exist. Energy reduction of 50% from the base case design, with a payback period of 5.7 years, was projected for this building by adding many daylighting features, very low light levels, and a geothermal heat pump. Lighting options can be very cost-effective because they tend to lower first costs.

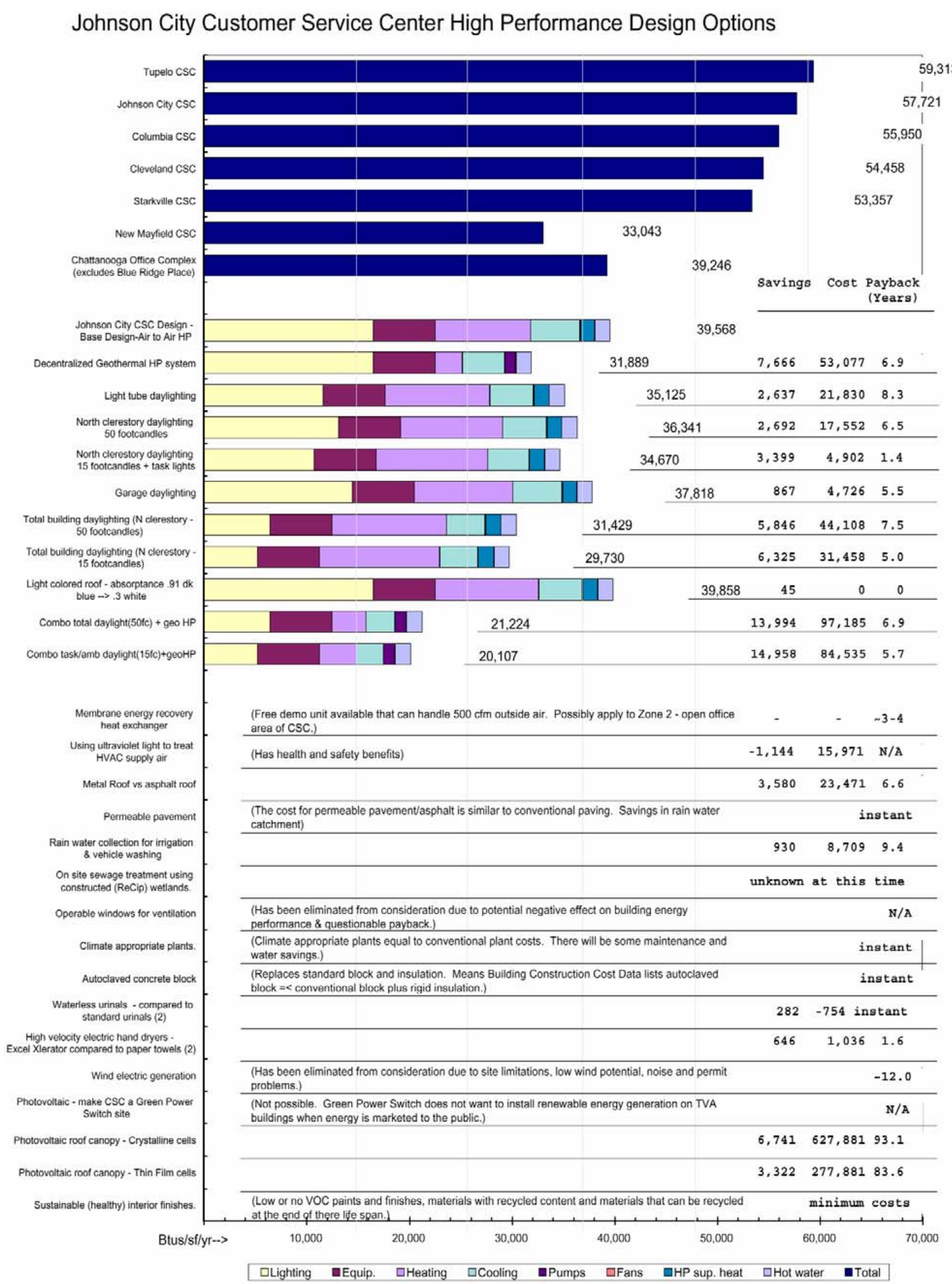

Figure C-3. Analysis of Sustainable Features for Johnson City CSC

How to Read Figure C-3

The "Johnson City Customer Service Center High Performance Design Options" bar chart is divided into three sections. ***The solid bars*** at the top show actual energy performance of existing customer service center buildings along with the Chattanooga Office Complex, which is one of TVA's most energy-efficient office buildings. These solid bars provide a reference to which to compare the Johnson City CSC design. (The units are Btu/ft^2/yr.)

The multicolored bars show the performance of the "base" Johnson City CSC design, as well as the individual technologies considered and the combinations of energy-saving options. Each color shows the amount of energy going to the various component energy uses within the building such has lighting, equipment, heating, etc. (shown at the bottom of the chart). All the energy-use bars are in units of Btu/ft^2/year, which makes it easy to not only compare to the solid reference bars but to other non-TVA buildings.

Data for ***technologies listed below the bars*** are primarily sustainable technologies that don't have energy savings but have other types of cost savings (or in some cases have no additional costs compared with standard technologies) Those showing less than a 10-year payback, an instant payback, or low costs have been recommended for incorporation into the design.