SOLAR/0004-80/18

# USER'S GUIDE
# TO
# MONTHLY PERFORMANCE REPORTS
# FOR SITES IN THE
# NATIONAL SOLAR DATA NETWORK

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## 1. INTRODUCTION

The National Solar Data Network (NSDN) is part of the National Solar Data Program of the Department of Energy. The NSDN supports the Data Program by evaluating the performance of a large variety of solar systems which are installed in residential, commercial and institutional buildings. These buildings are dispersed throughout the continental United States, Hawaii and Puerto Rico. The systems employ "active" mechanical equipment or "passive" design features, or both, to supply solar energy to typical building thermal loads such as space heating, space cooling, and domestic hot water. Solar systems on some sites are used to supply industrial process heat.

The buildings in the NSDN are instrumented to monitor thermal energy flows to the space conditioning, hot water or process loads, from both the solar systems and the auxiliary or backup systems. Data collection from each site, transmission to a central computer, and processing are automated. The performance of each of the sites in collection, storage and distribution of solar energy is monitored daily and evaluated monthly on the basis of the processed data obtained. To disseminate the results of the performance analysis, a Monthly Performance Report (MPR) is prepared for each site.

The MPR's share a common organization and format and are written in terms of performance parameters whose definitions are essentially standardized. For the sake of conciseness of presentation, neither discussions explaining the significance of report sections nor lists of definitions of vocabulary used are provided in the MPR's. The purpose of this User's Guide is to help the reader fully understand the individual sections and terminology contained in MPR's.

This User's Guide reviews the individual sections of the MPR, explains the intent of each section, and defines the parameters used in the report to characterize site solar energy system performance. Appendix A of this guide provides significant background information on the subsystems and design features affecting solar energy collection, storage, and distribution to building thermal load requirements in active and passive solar sites. Appendix B provides an overview of how data are collected on site and transmitted to Vitro Laboratories for processing and analysis. It also explains how data integrity is maintained during this process. Appendix C is a useful glossary of acronyms and drafting symbols found in the MPR.

## 2. MONTHLY PERFORMANCE REPORT SECTIONS

The standard format of the monthly performance reports for sites in the National Solar Data Network comprises six sections: (1) Summary, including Energy Flow Diagram; (2) Performance Evaluation, including Observations; (3) Action Status; (4) System Description, including System Schematic; (5) Performance Tables; and (6) Other Data Reports on the Site. Explanations of the sections and definitions of the performance evaluation parameters typically reported in each section are presented below.

### 2.1 SUMMARY

The Summary highlights the most noteworthy aspects of site solar energy system performance for the month. It provides a frame of reference for understanding the performance by presenting a brief description of the system. The Energy Flow Diagram included with the Summary illustrates the energy flows measured and inferred for the system for the month.

2.1.1 Energy Flow Diagram - This feature has been incorporated in the reports since December 1979. The Energy Flow Diagram illustrates the energy flow relationships among the site solar energy system components and subsystems. It presents the energy flows through the system for the month, from solar energy collection and storage through distribution of solar and auxiliary energy to building thermal energy load requirements, including losses. Figures 1, 2, and 3 show typical flow diagrams found in an MPR. The flow diagram contains information on:

- Collector Performance - Total solar energy incident on the gross upper surface of the modules comprising the collector array is illustrated, as well as energy "loss" from the array due to reflection and back-radiation and resultant energy available from the array for supply either to storage or directly to building thermal energy load subsystems. Operating energy of pumps or blowers for circulation of liquid or air for heat transfer from the collector array to storage is contributed either to the block for the collector array or to the energy flow between the two components. The "line loss" of energy from the heat transfer piping or duct work is likewise subtracted from the energy flow from the collector array to storage.

- Storage Performance - Energy to and from storage is shown as well as energy losses through the surface of the storage vessel. If there is a change in stored energy from the prior month it is also indicated in this block.

- Load Subsystems - Energy flows in and out of building thermal energy load subsystems (hot water supply, space heating, space cooling, etc.) are shown in the same manner as these for the storage. Usually, these subsystems have auxiliary energy sources (electric power, fossil fuels), and the amounts of thermal energy supplied from these sources are shown as contributions to the blocks for the subsystems. The arrows from the subsystems show the total energy, from both solar and auxiliary sources, which they contribute to their respective loads. Especially in the case of active solar energy systems, however, these

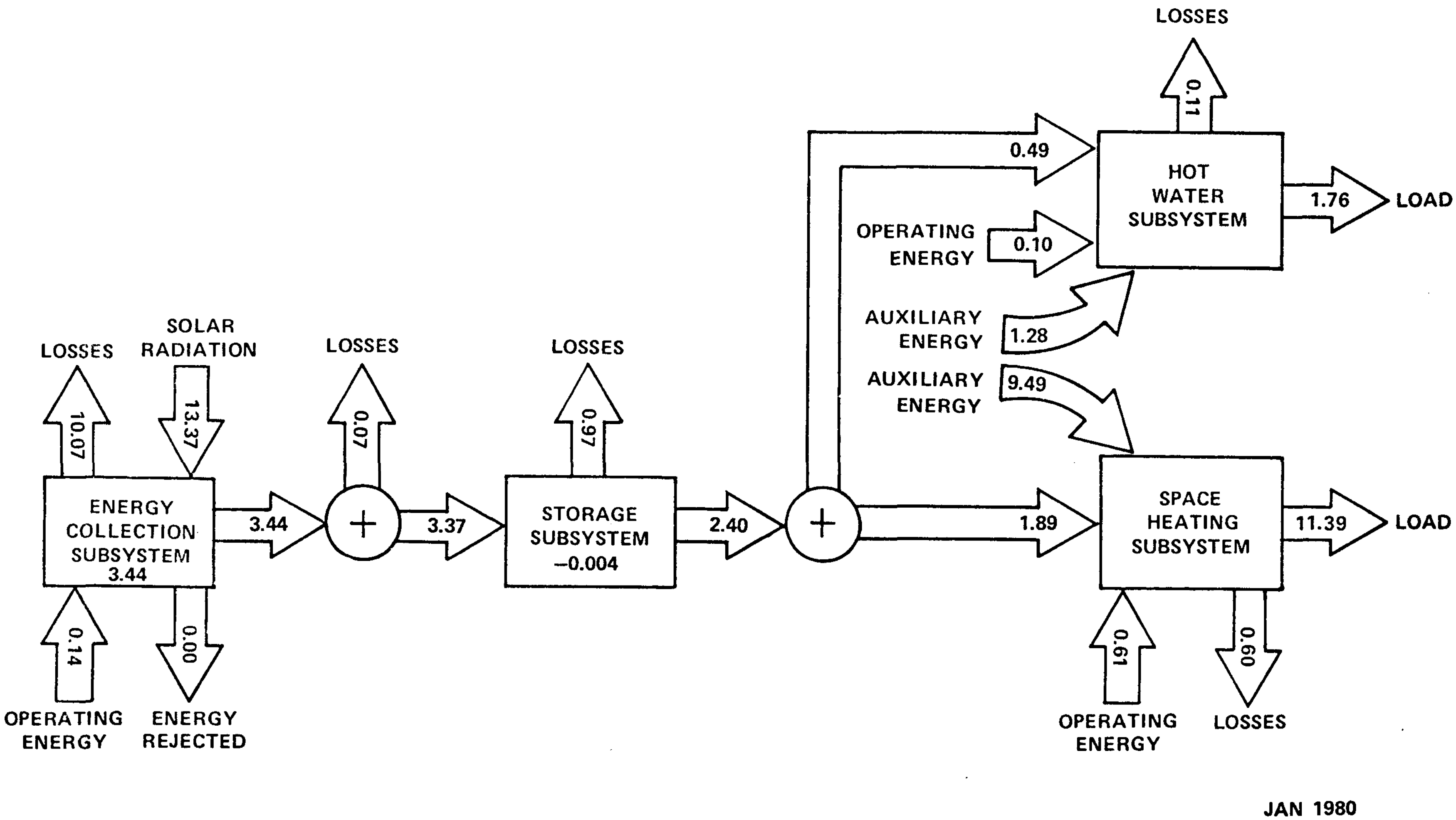


Figure 1. Sample Energy Flow Diagram of an Active Liquid Medium Solar Site
(Figures in million BTU)

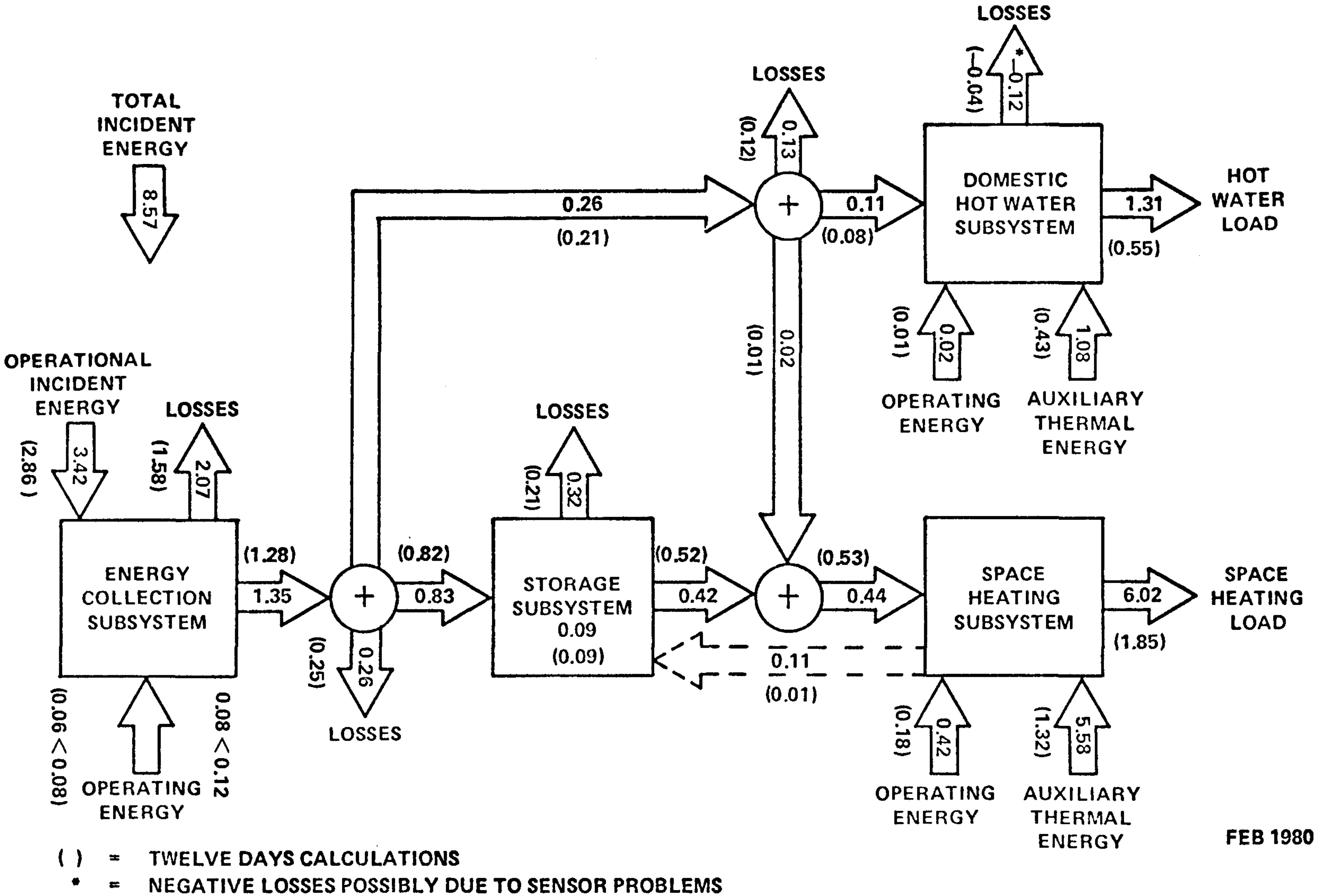


Figure 2. Sample Energy Flow Diagram of an Active Air Medium Solar Site
(Figures in million BTU)

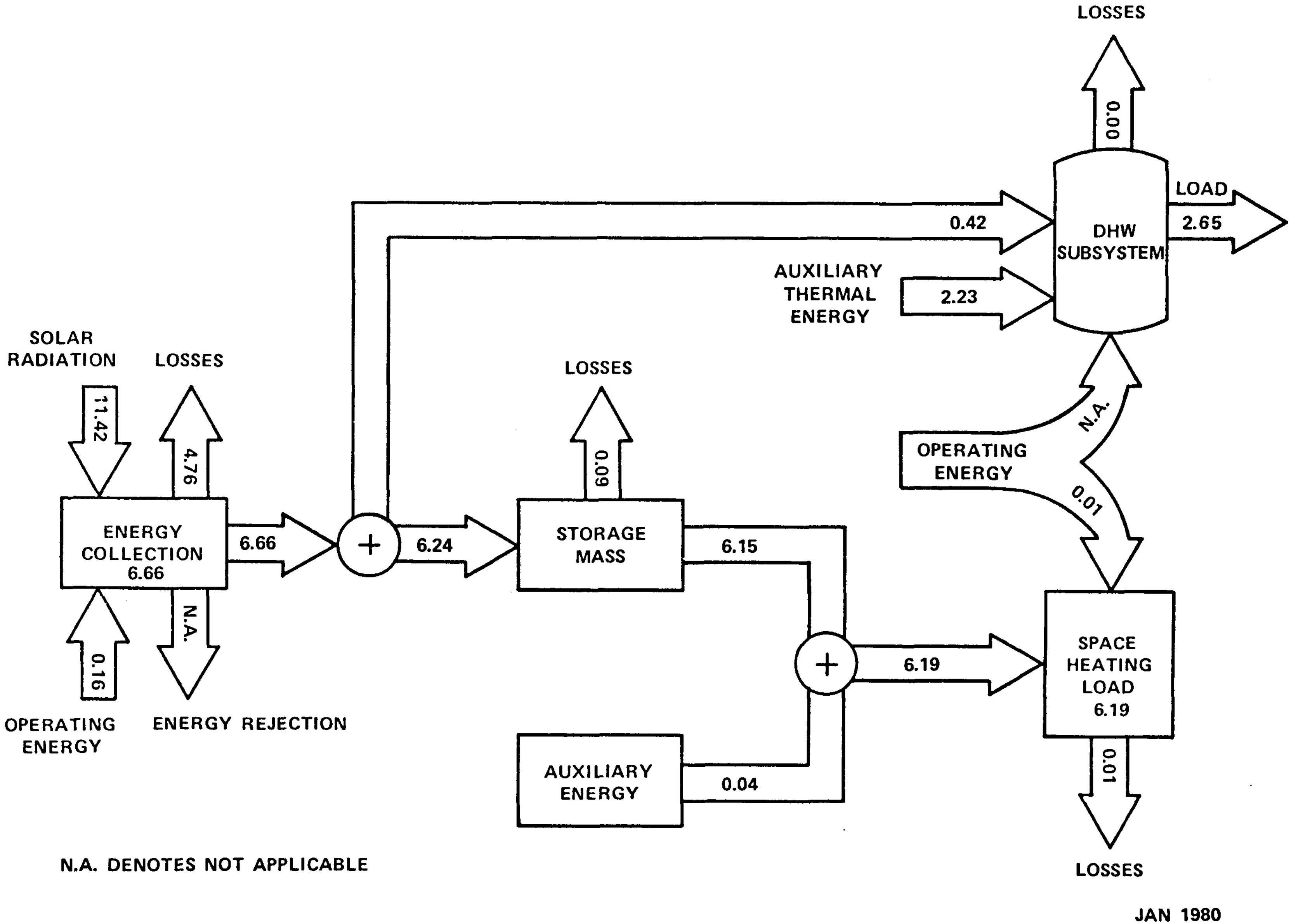


Figure 3. Sample Energy Flow Diagram of a Passive Solar Site
(Figures in million BTU)

contributions from load subsystems to their loads may not represent the total loads, as fireplaces and portable heaters, which may be used for supplemental energy supply to space heating or hot water, are not accounted for in the contributions from the load subsystems to the loads for active sites. The foregoing caveat is not generally applicable in the case of sites with passive solar design. Passive sites are analyzed by considering the building structure as a thermal energy storage subsystem, and all contributions of energy to the building thermal energy loads, including fireplaces and, of course, passive solar heating of the structure, are generally accounted for in the analysis process for these sites.

- Losses - Energy losses are shown for subsystems, heat exchangers, and piping runs. Losses are inferred from energy flow balances computed for system components. Thus, for example, the reflection and back-radiation loss from the collector array is calculated as the difference of the solar energy incident on the array and the collected solar energy.

## 2.2 PERFORMANCE EVALUATION

The Performance Evaluation section describes the effectiveness of the system in collection and storage of solar energy, in provision of solar energy to building thermal energy load requirements, and in reduction of the level of electrical or fossil fuel energy consumption needed to supply the load requirements. Moreover, the section reports the weather conditions, the site occupancy or usage, and any condition or malfunction observed in the site solar energy system or its controls which may have significantly affected system performance during the month. The Observations portion of the section in particular discusses the possible significance of apparent system performance anomalies.

The Performance Evaluation section contains five subsections: (1) Introduction, (2) Thermal Performance, (3) Energy Savings, (4) Weather Conditions, and (5) Observations. Specific contents of each of these sections are listed below.

2.2.1 Introduction - The Introduction to the Performance Evaluation section summarizes the overall solar energy system performance for the month and identifies the conditions under which the performance evaluation for the monthly performance report is made. The Introduction identifies the condition of the site with regard to its occupancy or usage and the condition of the solar energy system of the site with regard to the functioning of its mechanical equipment and controls for the month. In addition, it reports the number of days during the month for which site instrumentation or data collection problems prevented data collection from the site. Particular parameters reported in the Introduction to the Performance Evaluation section are:

- Occupancy Status - Whether the site was occupied or unoccupied during the month; or, in the case of a commercial site, whether the facility was utilized or not utilized for all or part of the month.

- System Operation Status - Number of days for which the solar system was in operation.

- Collected Solar Energy - The net thermal energy removed from the collector array by the heat transfer medium.

- Total Solar Energy Used - Total amount of solar energy supplied to all building thermal energy load subsystems.

- ECSS Solar Conversion Efficiency - Percentage delivered to the load subsystems of the solar energy incident on the gross upper surface area of the modules comprising the collector array.

- Solar Fraction of System Load - Percentage supplied by solar of the total system thermal energy demand from all solar-assisted space conditioning or process load subsystems for the month.

- Total Fossil/Electrical Savings - Difference between the fossil/electrical energy requirements of an assumed conventional system carrying the full measured load and the fossil/electrical energy requirements of the actual solar-supplemented system used.

- Data Communication Problems Chronology - Listing of days for which data communication problems prevented data collection.

2.2.2 Thermal Performance - The Thermal Performance subsection of the Performance Evaluation section comprises the core of the report. In this subsection, the energy flows through the site solar energy system and its subsystems for the month are documented, and the performance parameter values describing the effectiveness of the system in solar energy collection, storage, and distribution for the month are reported. The subsection comprises an introductory paragraph and additional paragraphs for individual subsystems and components: System, Collector, Storage, Domestic Hot Water, Space Heating, and Space Cooling. Parameters reported in the Thermal Performance subsection are the following:

2.2.2.1 System

- Collected Solar Energy - Net thermal energy removed from the collector array by the heat transfer medium.

- Expected Collected Solar Energy - Thermal energy which would be expected to be removed from the collector array by the heat transfer medium for the given insolation and collector orientation on the basis of manufacturer-supplied collector performance parameters.

- Total Solar Energy Used - Total amount of solar energy supplied to all building thermal energy load subsystems.

- Expected Total Solar Energy Used - Total amount of solar energy which would be expected to be supplied to the load subsystems on the basis of a modified f-chart analysis (predictive model used for active system).

- Solar Fraction of System Load - Percentage supplied by solar of the total system thermal energy demand from all solar-assisted space conditioning or process load subsystems for the month.

- Expected Solar Fraction of System Load - Percentage of the total energy demand from all solar-assisted building thermal energy load subsystems which would be expected to be supplied by solar on the basis of f-chart analysis.

- Total Fossil/Electrical Energy Savings - Difference between the fossil/electrical energy requirements of an assumed similar conventional system carrying full load and the fossil/electrical energy requirements of the actual solar-supplemented system used.

2.2.2.2 Collector

- Incident Solar Energy - Total solar energy incident on the gross upper surface area of the modules comprising the collector array. The collector area used in the calculation is based on the area within the perimeter of a single solar module frame, multiplied by the number of collector modules in the array.

- Collected Solar Energy - Thermal energy removed from the collector array by the heat transfer medium.

- ECSS Operating Energy - Electrical energy required to support operation of the ECSS (e.g., fans, pumps, etc.), which is not intended to affect directly the thermal state of the subsystem.

- ECSS Rejected Energy - Energy intentionally rejected or dissipated from the ECSS.

- Collector Array Efficiency - Percentage collected of the incident solar energy on the collector array.

- Energy to Storage - The measured amount of energy delivered to the ECSS storage, including solar energy and thermal energy from an auxiliary heater directly incorporated into storage, but not including other auxiliary thermal energy indirectly delivered to storage.

- Solar Energy Directly to Load - Solar energy delivered to the load subsystems directly from the collection subsystem, without prior storage. This term is only applicable to systems which include components for direct heat transfer from the collector array to the load subsystems.

- Solar Energy Lost in Transfer to Storage - Collected solar energy less the solar energy delivered to the ECSS storage (and also, where applicable, less any portion of the collected solar energy supplied directly to load subsystems).

2.2.2.3 Storage

- Energy to Storage - Amount of energy delivered to the ECSS storage, including solar energy and thermal energy from an auxiliary heater directly incorporated into storage, but not including other auxiliary thermal energy indirectly delivered to storage.

- Energy from Storage - Total amount of energy removed by all load subsystems from the ECSS storage medium.

- Change in Stored Energy - Difference of the amount of energy in storage at the end of the specified time period (day or month) from that at the beginning of the same time period, as indicated by the relative temperatures of the storage medium at these two times.

- Energy Loss from Storage - Difference between the amount of energy delivered to the ECSS storage and the sum of the amount of energy removed by the load subsystems from the storage and the change in stored energy.

- Storage Efficiency - The ratio of the sum of the energy removed from storage and the change in stored energy to the energy delivered to storage.

- Storage Average Temperature - The average temperature of the ECSS storage medium.

2.2.2.4 Domestic Hot Water (DHW)

- Hot Water Load - Amount of energy required to heat the hot water demanded at the site, based on the temperature difference between the supply water (cold water) temperature and the outlet hot water temperature. This does not include standby losses and usually does not include recirculation losses. If these losses are combined or if hot water demand is separated from tank heating loads, it will be so noted in the MPR.

- Solar Energy Used for DHW - Amount of energy from the solar ECSS supplied to the DHW subsystem.

- Auxiliary Thermal Energy Used for DHW - The measured amount of thermal energy added to the DHW supply water from an auxiliary source (e.g., gas or electrical resistance heating), either directly or by means of a heat transfer fluid. This term does not include auxiliary thermal energy input to the ECSS storage and thus only indirectly affecting the DHW subsystem.

- Solar Fraction of Load for DHW - Percentage supplied from the solar ECSS of the total thermal energy demand from the DHW subsystem.

- Operating Energy for DHW - Amount of electrical energy required to support the DHW subsystem (e.g., fans, pumps, etc.) which is not intended to affect the thermal state of the subsystem.

- Energy Lost from DHW Subsystem - Difference between the sum of the solar and auxiliary thermal energies used to heat the DHW supply water and the amount of energy comprising the hot water load.

- Hot Water Used - Volume of heated water delivered from the hot water subsystem.

- Average Hot Water Temperature - Average temperature of the outlet water supplied from the DHW subsystem.

- Fossil/Electrical Energy Savings for DHW - Difference between the fossil/electrical energy requirements of an assumed conventional DHW system carrying the full measured load and the fossil/electrical energy requirements of the actual solar-supplemented system used.

2.2.2.5 Space Heating Subsystem (SHS)

- Space Heating Load - The measured amount of thermal energy supplied to the heated space of the building by the solar ECSS and by the central SHS auxiliary equipment. Solar thermal energy gain incurred directly by the structure or through windows is accounted to the space heating load only for passive systems, as is auxiliary thermal energy supplied by fireplaces. Thermal energy gain due to operating energy of fans and pumps is never accounted to the space heating load. Both the solar and auxiliary contributions to the load may be measured in several ways, depending on the system configuration and instrumentation of a specific site.

  (1) Space heating load may be measured on either the supply or delivery side of load heat exchangers.

  (2) In some systems, load is inferred by calculating the auxiliary heating contribution based on auxiliary fuel consumption. For fossil fuels, the fuel usage is multiplied by the nominal heating value of the fuel and a nominal 0.6 thermal conversion efficiency. For electric heating, a thermal conversion efficiency of 1.0 is used.

  In light of these qualifications of the space heating load definition, the user is advised to be cautious in comparing space heating load data from different NSDN sites. In addition, caution is advised in comparison of these data with design space heating loads calculated by standard methods on the basis of conduction and infiltration heat losses[1].

- SHS Solar Energy Used - The measured amount of thermal energy supplied to the heated space of the building by the solar ECSS (cf. qualifications specified under "Space Heating Load" above).

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[1] ASHRAE Handbook & Product Directory: 1977 Fundamentals (New York: American Society of Heating, Refrigerating & Air-Conditioning Engineers, 1978).

- SHS Auxiliary Thermal Used - The measured amount of thermal energy supplied to the heated space of the building by the central space heating system auxiliary equipment. For heat pump systems, this term includes only that portion of the thermal energy supplied to the load from the heat pumps which is derived from mechanical compression. It does not include the portion of the thermal energy supplied by the heat pumps which is derived from their low temperature thermal energy supply.

- SHS Solar Fraction of Load - Percentage of space heating load supplied by SHS solar energy.

- SHS Operating Energy - Amount of electrical energy required to support the SHS (e.g., fans, pumps, etc.) which is not intended to affect the thermal state of the subsystem.

- Building Temperature - Average temperature in the heated space of the building which the subsystem serves.

- Energy Lost from SHS - Difference between energy supplied to SHS and energy delivered to heated space in building. (For certain system and instrumentation configurations it is only possible to estimate this parameter.)

- Fossil/Electrical Energy Savings for SHS - Difference between the fossil/electrical energy requirements of an assumed similar conventional SHS carrying full load and the fossil/electrical energy requirements of the actual solar-supplemented system used.

2.2.2.6 Space Cooling Subsystem (SCS)

- Space Cooling Load - Amount of thermal energy removed from the air-conditioned space of the building by all central SCS solar- and auxiliary-powered equipment. Thermal energy removed by unassisted ventilation is accounted to the space cooling load only for passive systems. Auxiliary space cooling supplied by room window air conditioners is never included. The space cooling load is measured in terms of total thermal energy transferred from the air-conditioned space, inferred from heat transfer fluid mass flow and temperature gain across load heat exchangers.

- SCS Solar Energy Used - Amount of thermal energy supplied to the SCS by the solar ECSS, calculated from the heat transfer fluid temperature drop across the SCS thermal driving energy loop supplied by the ECSS (e.g., the heat input loop driving the refrigerant vapor generator in an absorption chiller).

- SCS Auxiliary Thermal Used - Amount of thermal energy supplied to the SCS by the central SCS auxiliary equipment. The thermal energy supplied may be inferred from either the heat transfer fluid mass flow and temperature gain across the auxiliary heater in the SCS thermal driving energy loop or from the fuel consumption of the heater. In the case of a central SCS auxiliary electric chiller, the thermal energy supplied is inferred from the electrical fuel consumption of the chiller (i.e., the compressor) and its coefficient of performance (COP). Auxiliary space cooling supplied by room window air conditioners is not accounted to the SCS auxiliary thermal used.

- SCS Solar Fraction of Load - Percentage supplied by SCS solar energy of the total thermal energy supplied to the SCS (neither including SCS operating energy nor debiting SCS waste heat rejected).

- SCS Operating Energy - Amount of electrical energy required to support the SCS (e.g., fans, pumps, etc.) which is not intended to affect the thermal state of the subsystem. Electrical fuel consumption of a central SCS auxiliary electric chiller (i.e., to drive the compressor) is accounted to SCS auxiliary thermal rather than operating energy (cf. above). Operating energy of room window air conditioners is not included.

- Building Temperature - Average air-conditioned space dry bulb temperature.

- Energy Lost from SCS - Difference between the sum of solar and auxiliary thermal energy supplied to the SCS and the amount of thermal energy used by the SCS equipment in its energy transfer process. (It is only rarely possible to estimate this parameter from the available sensor data.)

- Fossil/Electrical Energy Savings for SCS - Difference between the fossil/electrical energy requirements of an assumed conventional SCS carrying the full measured load and the fossil/electrical energy requirements of the actual solar-supplemented system used.

2.2.3 Energy Savings - The fossil fuel and electrical savings accruing to solar-supplemented subsystems for domestic hot water, space heating, and space cooling represent in each case the difference between the amount of total fuel input and operating energy required to support an assumed similar conventional system carrying the full measured load and the actual amount of total fuel input and operating energy used as measured in the solar-supplemented system, for identical loads. For most systems, the savings are calculated by the means of the equations:

$$\text{Savings} = \begin{pmatrix}\text{Energy Required with} \\ \text{Pure Conventional System} \\ \text{To Meet Measured Load}\end{pmatrix} - \begin{pmatrix}\text{Energy Actually Spent} \\ \text{with Solar-Assisted System} \\ \text{To Meet Measured Load}\end{pmatrix}$$

$$= \left(\frac{\text{Load}}{\text{COP}} + \text{Operating Energy}_c\right) - \left(\text{Auxiliary Energy} + \text{Operating Energy}_s\right)$$

where the subscripts c and s denote conventional and solar, respectively, and COP is the fuel-to-load conversion efficiency of the conventional equipment.

The reference alternative conventional system used in energy savings computations is often identical to the auxiliary portion of the solar-supplemented system, particularly if solar is a retrofit to an existing system or if the solar system is sized to carry only a small fraction of the load. However, the conventional system may also be completely different. The selection of the reference alternative conventional system (and the corresponding fuel-to-load conversion efficiency) can significantly affect the magnitude of the fuel savings estimated. The reference alternative conventional system selected and the rationale for its selection are recorded in the site documentation.

In the above equations for savings, the terms for auxiliary and operating energy for the solar-assisted system and the term for the load are determined from measurement instrumentation. The COP of the conventional source may be estimated from known characteristics of the equipment, computed from measurements in the subsystem, or assigned a plausible generic default value. The Operating $Energy_s$ term in the equation includes operating energy which is purely to support the solar subsystem (e.g., collector loop circulating pump), and operating energy that is required independent of the solar system (e.g., load distribution blower).

Separate computations of electrical and fossil fuel savings are carried out for each subsystem. The energy forms are not mixed. In the subsystem calculations, the operating energies that are used in computing savings do not include ECSS operating energy. The ECSS operating energy is debited against electrical energy savings only at the system level.

2.2.4 Weather Conditions - Parameters reported in the Weather Conditions subsection of the Performance Evaluation section are the following:

- Incident Solar Energy - Total solar energy incident on the gross upper surface area of the modules comprising the collector array.

- Average Incident Solar Energy Flux - Average measured daily incidence of solar energy per unit area in plane of collector array.

- Long-Term Average Incident Solar Energy Flux - Average daily incidence of solar energy per unit area in plane of collector array for region of given site, averaged for days of the given month over several years (obtained from, e.g., National Weather Service).

- Collector Array Orientation and Tilt - Angles between the array and, respectively, due south and the horizontal.

- Average Ambient Temperature - Average measured temperature of the outdoor environment at the site.

- Long-Term Average Ambient Temperature - Average temperature of the outdoor environment for the region of the given site, averaged for days of the given month over several years (obtained from, e.g., National Weather Service).

- Heating/Cooling Degree-Days - Sum over days of the month of the deficiency/excess of measured daily temperature relative to building reference temperature (65°F).

- Long-Term Average Heating/Cooling Degree-Days - Product of the deficiency/excess of the long-term average ambient temperature for the month relative to building reference temperature (65°F) and the number of days in the month.

2.2.5 Observations - This section of the MPR is unique for each site. Besides general comments on the performance, Observations may include energy system problems noted, explanations for unusual data, or the necessity of calculations to replace tabular printout data. Unfavorable conditions impairing system performance, such as site non-occupancy, solar energy system equipment or control malfunction, or unusual weather conditions are reported in this section. Energy losses from storage or transport to space heat, losses from storage through the collector array, and other noteworthy operating characteristics are discussed as appropriate.

## 2.3 ACTION STATUS

This section of the MPR reports actions completed or anticipated in response to the problems noted in the Observations section.

## 2.4 SYSTEM DESCRIPTION

This section of the MPR describes the solar-supplemented system type and its configuration. It includes a schematic diagram of the system configuration and makes note of any significant anomalies of the system configuration or its instrumentation.

## 2.5 PERFORMANCE TABLES

The numbers which appear in the completed report forms are presented in predefined positions and lengths. In general, energy values are given in the format-dddd.ddd, with each character representing a digit, and the value is in millions of BTU. This particular selection provides sufficient range to display very small energy values (1,000 BTU) as well as the largest values that can be reasonably anticipated from the systems in the program (up to 10 billion BTU). This standard format should not be interpreted to imply that the numbers are accurate to the full number of digits presented; the data which appear are simply the result that is automatically generated (via the data processing program) from the measured data. The accuracy of the data must be inferred from the specifications of the instruments, the data collection and processing system, and site-particular considerations such as faulty sensors or peculiar installation (which are items identified in the narrative summary).

A detailed description of each report form is given in the following subsections. In an actual report, the forms as shown would, of course, be filled in with data values. In many cases, a more thorough treatment of the performance factors listed can be found in section 2.2.2, "Thermal Performance," of this guide.

2.5.1 Site Summary - The Site Summary includes the monthly values of all significant system performance parameters. See Figure 4 for an example in Conventional Units. The Site Summary is also provided in SI Units as shown in Figure 5.

(A) MONTHLY REPORT:
SITE SUMMARY:

CONVENTIONAL UNITS

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(B) GENERAL SITE DATA:

| | |
|---|---|
| INCIDENT SOLAR ENERGY. (1) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | MILLION BTU<br>BTU/SQ.FT. |
| COLLECTED SOLAR ENERGY . (2) . . . . . . . . . . . . . . . . . . . . . . . . . . . . | MILLION BTU<br>BTU/SQ.FT. |
| AVERAGE AMBIENT TEMPERATURE. (3) . . . . . . . . . . . . . . . . . . . . . . . . . . | DEGREES F |
| AVERAGE BUILDING TEMPERATURE . (4) . . . . . . . . . . . . . . . . . . . . . . . . . | DEGREES F |
| ECSS SOLAR CONVERSION EFFICIENCY . (5) . . . . . . . . . . . . . . . . . . . . . . . | |
| ECSS OPERATING ENERGY. (6) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | MILLION BTU |
| TOTAL SYSTEM OPERATING ENERGY. (7) . . . . . . . . . . . . . . . . . . . . . . . . . | MILLION BTU |
| TOTAL ENERGY CONSUMED. (8) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | MILLION BTU |

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(C) SUBSYSTEM SUMMARY:

| | HOT WATER | HEATING | COOLING | SYSTEM TOTAL |
|---|---|---|---|---|
| LOAD | | | | MILLION BTU |
| SOLAR FRACTION | | | | PERCENT |
| SOLAR ENERGY USED | | | | MILLION BTU |
| OPERATING ENERGY | | | | MILLION BTU |
| AUX. THERMAL ENERGY | (10) | | | MILLION BTU |
| AUX. ELECTRIC FUEL | | | | MILLION BTU |
| AUX. FOSSIL FUEL | | | | MILLION BTU |
| ELECTRICAL SAVINGS | | | | MILLION BTU |
| FOSSIL SAVINGS | | | | MILLION BTU |

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(D) SYSTEM PERFORMANCE FACTOR: (9)

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(E) N.A. DENOTES NOT APPLICABLE DATA.

(F) REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT OF THE NATIONAL SOLAR DATA PROGRAM, FEBRUARY 28, 1978, SOLAR/0004-78/18. READ THIS BEFORE TURNING PAGE.

Figure 4. Monthly Site Summary Report Form (Conventional Units)

MONTHLY REPORT:
SITE SUMMARY:

SI UNITS

GENERAL SITE DATA:

| | |
|---|---|
| INCIDENT SOLAR ENERGY. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | GIGA JOULES<br>KJ/SQ.M. |
| COLLECTED SOLAR ENERGY . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | GIGA JOULES<br>KJ/SQ.M. |
| AVERAGE AMBIENT TEMPERATURE. . . . . . . . . . . . . . . . . . . . . . . . . . . . | DEGREES C |
| AVERAGE BUILDING TEMPERATURE . . . . . . . . . . . . . . . . . . . . . . . . . . . | DEGREES F |
| ECSS SOLAR CONVERSION EFFICIENCY . . . . . . . . . . . . . . . . . . . . . . . . . | |
| ECSS OPERATING ENERGY. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | GIGA JOULES |
| TOTAL SYSTEM OPERATING ENERGY. . . . . . . . . . . . . . . . . . . . . . . . . . . | GIGA JOULES |
| TOTAL ENERGY CONSUMED. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | GIGA JOULES |

SUBSYSTEM SUMMARY:

| | HOT WATER | HEATING | COOLING | SYSTEM TOTAL |
|---|---|---|---|---|
| LOAD | | | | GIGA JOULES |
| SOLAR FRACTION | | | | PERCENT |
| SOLAR ENERGY USED | | | | GIGA JOULES |
| OPERATING ENERGY | | | | GIGA JOULES |
| AUX. THERMAL ENERGY | | | | GIGA JOULES |
| AUX. ELECTRIC FUEL | | | | GIGA JOULES |
| AUX. FOSSIL FUEL | | | | GIGA JOULES |
| ELECTRICAL SAVINGS | | | | GIGA JOULES |
| FOSSIL SAVINGS | | | | GIGA JOULES |

SYSTEM PERFORMANCE FACTOR:

N.A. DENOTES NOT APPLICABLE DATA.

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT OF THE NATIONAL SOLAR DATA PROGRAM, FEBRUARY 28, 1978, SOLAR/0004-78/18. READ THIS BEFORE TURNING PAGE.

Figure 5. Monthly Site Report Summary Report Form (SI Units)

In addition, the Site Summary contains notes and comments needed to understand the significance of the data presented, anomalies, off-line analysis results, or other items which may be important in assessing the system.

The main parts of this report form, identified on Figure 4, are as follows:

(A) Month of report and site name. Each of the performance data report printouts will contain this information.

(B) General parameters for the energy collection and storage subsystem and the entire system.

(C) Performance parameters for each load subsystem.

(D) System performance factor value.

(E) Symbols which appear on the Site Summary form.

(F) Space available for listing applicable references which may be useful if further investigation is desired.

The data entries for the system's primary performance factors, summarized for the month, are identified on this report, as shown on Figure 4, and are defined as follows:

(1) Incident Solar Energy - Total solar energy incident on the gross upper surface area of the modules comprising the collector array. The area includes both collector energy-receiving apertures and their borders, but not the spaces between modules. The incident solar energy per unit area is also listed.

(2) Collected Solar Energy - Thermal energy removed from the collector array by the heat transfer medium. The energy removed per unit of gross collector module area is also listed.

(3) Average Ambient Temperature - Average measured temperature of the outdoor environment at the site.

(4) Average Building Temperature - Average temperature in the controlled space of the building which the system serves.

(5) ECSS Solar Conversion Efficiency - Ratio of the solar energy delivered to the load subsystems to the total energy incident on the gross upper surface area of the modules comprising the collector array. In general, this will be a small number, since it includes effects of the overall collection efficiency; losses by the collectors, the transport mechanism, and the storage device; and losses imposed by the control system.

(6) ECSS Operating Energy - Electrical energy required to support the operation of the ECSS (e.g., fans, pumps, etc.) which is not intended to affect directly the thermal state of the subsystem.

(7) Total System Operating Energy - Total operating energy of all load subsystems and ECSS operating energy.

(8) Total Energy Consumed - Sum of the collected solar energy, the total system operating energy, the total auxiliary fossil fuel energy, and the total auxiliary electrical fuel energy. This performance factor represents the total energy demands of the system from all outside sources. The total auxiliary fossil fuel energy is the energy content of the fossil fuel consumed to supply auxiliary thermal energy to the load subsystems.

(9) System Performance Factor - Ratio of the total system load to the equivalent fossil fuel energy required to support the system for the month. The equivalent energy, as used in this context, is the sum of the actual fossil fuel and (1/.3) times the electrical requirements (for operating energy and fuel). This multiplication factor results from the estimation that, on the average, the efficiency of extracting fossil fuels from the ground, converting to electricity, and transmitting the electrical energy to the site is about 0.3.

(10) Subsystem Load Summaries - All factors for the load subsystem summary are totaled here for the month. The energy savings figures are computed in accordance with the comments presented above in Section 2.2.3. The following are the definitions for each subsystem load summary:

- Load - Amount of energy supplied for the month to satisfy the desired temperature control demands for each of the respective subsystems.
- Solar Fraction - Percentage of the load demand supported by solar energy during the month for each subsystem.
- Solar Energy Used - Total amount of solar energy supplied to each subsystem for the month.
- Operating Energy - Amount of electrical energy required to support the operation of each subsystem for the month (e.g., fans, pumps, etc.), which is not intended to affect directly the thermal state of the subsystem.
- Auxiliary Thermal Used - Amount of energy supplied during the month to the major components of each subsystem in the form of thermal energy in a heat transfer fluid or its equivalent. This term includes the thermal energy converted from the auxiliary electrical and fossil fuel energy supplied to the subsystem. For heat pump systems, this term includes only that portion of the thermal energy supplied to the load from the heat pumps that is derived from mechanical compression in them. It does not include the portion of the thermal energy supplied by the heat pumps that is derived from their low temperature thermal energy supply.
- Auxiliary Electrical Fuel - Total amount of electrical energy supplied to each subsystem during the month for conversion to thermal energy towards meeting the subsystem load.
- Auxiliary Fossil Fuel - Total amount of fossil fuel energy supplied to each subsystem during the month for conversion to thermal energy towards meeting the subsystem load.

- Electrical Energy Savings - Estimated difference between the electrical energy requirements of an alternative conventional system (carrying the full load) and the actual electrical energy required by each subsystem.
- Fossil Energy Savings - Estimated difference between the fossil energy requirements of the alternative conventional system (carrying the full load) and the actual fossil energy requirements of each subsystem.

2.5.2 Energy Collection And Storage Subsystem - The Energy Collection and Storage Subsystem (ECSS) is composed of the collector array, the primary storage medium, the transport loops between these, and other components in the system design which are necessary to mechanize the collector and storage equipment.

The report form for the ECSS contains the following performance factors as listed in Figure 6:

- Incident Solar Energy - Total solar energy incident on the gross upper surface area of the modules comprising the collector array. The area includes both collector energy-receiving apertures and their borders, but not the spaces between modules.

- Ambient Temperature - Average measured temperature of the outdoor environment at the site.

- Energy to Loads - Total thermal energy transported from the ECSS to all load subsystems (including any auxiliary energy supplied to the ECSS).

- Auxiliary Thermal Energy to ECSS - Total auxiliary energy supplied to the ECSS, including auxiliary energy added to the storage tank, heating devices on the collectors for freeze-protection, etc.

- ECSS Operating Energy - Electrical energy required to support operation of the ECSS (e.g., fans, pumps, etc.) which is not intended to affect directly the thermal state of the subsystem.

- ECSS Rejected Energy - Amount of energy intentionally rejected from the ECSS, including energy emitted through nocturnal radiation through the collectors for freeze-protection, excess energy released from storage for temperature control, etc.

- ECSS Solar Conversion Efficiency - Ratio of the solar energy delivered to the load subsystems to the total energy incident on the gross upper surface area of the modules comprising the collector array. In general, this will be a rather small number, since it includes effects of the overall collection efficiency; losses by the collectors, transport mechanism, and storage device; and losses imposed by the control system.

MONTHLY REPORT:
ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

| DAY OF MONTH (NBS ID) | INCIDENT SOLAR ENERGY MILLION BTU (Q0001) | AMBIENT TEMP DEG F (N113) | ENERGY TO LOADS MILLION BTU | AUX THERMAL TO ECSS MILLION BTU | ECSS OPERATING ENERGY MILLION BTU (Q102) | ECSS ENERGY REJECTED MILLION BTU | ECSS SOLAR CONVERSION EFFICIENCY (N111) |
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* DENOTES UNAVAILABLE DATA.

Figure 6. Energy Collection and Storage Subsystem Report Form

2.5.3 Collector Array Performance - The collector array performance is characterized by the amount of solar energy collected with respect to the energy available to be collected. The specific items on this report form are listed in Figure 7 and defined by the following:

- Incident Solar Energy - Total solar energy incident on the gross upper surface area of the modules comprising the collector array. The area includes both collector energy-receiving apertures and their borders, but not the spaces between modules.

- Operational Incident Energy - Amount of solar energy incident on the gross upper surface area of the modules comprising the collector array while the collector loop is active (attempting to collect energy).

- Collected Solar Energy - Thermal energy removed from the collector array by the heat transfer medium.

- Daytime Ambient Temperature - Average temperature of the environment at the site during the period from three hours prior to local solar noon to three hours past local solar noon. (This time frame is selected independently of the operation of the collectors at the site, and it is intended to serve as a historical record of the ambient temperature during normal collector operation.)

- Collector Array Efficiency - Ratio of the energy collected to the total energy incident on the collector array. It should be emphasized that this efficiency factor is for the collector array, and available energy includes the energy incident on the array when the collector loop is inactive. This efficiency must not be confused with the more common collector efficiency figures, which are determined from instantaneous data during steady-state operation of a single collector unit. These efficiency figures are often provided by collector manufacturers or presented in technical journals to characterize the functional capability of a particular collector design. In general, the collector panel maximum efficiency factor will be significantly higher than the collector array efficiency reported here.

2.5.4 Storage Performance - The storage performance is characterized by the relationships among the energy delivered to storage, removed from storage, and the subsequent change in the amount of stored energy. The particular performance factors provided in this form are listed on Figure 8 and defined as follows:

- Energy to Storage - Amount of energy delivered to the ECSS storage, including solar energy and thermal energy from an auxiliary heater directly incorporated into storage, but not including other auxiliary thermal energy indirectly delivered to storage.

- Energy from Storage - Total amount of energy removed by all load subsystems from the ECSS storage medium.

MONTHLY REPORT:
COLLECTOR ARRAY PERFORMANCE

| DAY OF MONTH (NBS ID) | INCIDENT SOLAR ENERGY MILLION BTU (Q001) | OPERATIONAL INCIDENT ENERGY MILLION BTU | COLLECTED SOLAR ENERGY MILLION BTU (Q100) | DAYTIME AMBIENT TEMP DEG F | COLLECTOR ARRAY EFFICIENCY (N100) |
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* DENOTES UNAVAILABLE DATA.

Figure 7. Collector Array Performance Report Form

MONTHLY REPORT:

STORAGE PERFORMANCE

| DAY OF MONTH (NBS ID) | ENERGY TO STORAGE MILLION BTU (Q200) | ENERGY FROM STORAGE MILLION BTU (Q201) | CHANGE IN STORED ENERGY MILLION BTU (Q202) | STORAGE AVERAGE TEMP DEG F | STORAGE EFFICIENCY (N108) |
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* DENOTES UNAVAILABLE DATA.

Figure 8. Storage Performance Report Form

- Change in Stored Energy - Difference between the amount of energy in storage at the end of the specified reporting period and that at the beginning of the period, as indicated by the relative temperatures of the storage medium at these two times.

- Storage Average Temperature - Average temperature of the ECSS storage medium.

- Storage Efficiency - Ratio of the sum of the energy removed from storage and the change in stored energy to the energy delivered to storage.

2.5.5 Hot Water Subsystem - The hot water subsystem is characterized by a complete accounting of the energy flow into and from the subsystem, as well as an accounting of internal energy. The energy into the subsystem is composed of auxiliary fossil fuel, electrical auxiliary thermal energy, and the operating energy for the subsystem. In addition, the solar energy supplied to the subsystem, along with solar fraction, is tabulated. The load of the subsystem is tabulated and used to compute the estimated electrical and fossil savings of the subsystem. The load of the subsystem is further identified by tabulating the supply water temperature, the outlet hot water temperature, and the total hot water consumption. The specific factors which are presented on this report form are shown in Figure 9 and defined as follows:

- Hot Water Load - Amount of energy required to heat the hot water demanded at the site from the supply water temperature to the outlet hot water temperature.

- Solar Fraction of Load - Percentage of the DHW load demand which is supplied from the solar ECSS.

- Solar Energy Used - Amount of energy supplied from the solar ECSS to the DHW subsystem.

- Operating Energy - Amount of electrical energy required to support the DHW subsystem, (e.g., fans, pumps, etc.) which is not intended to affect directly the thermal state of the subsystem.

- Auxiliary Thermal Used - Amount of thermal energy added to the DHW supply water from an auxiliary source (e.g., gas or electrical resistance heating), either directly or by means of a heat transfer fluid. This term does not include auxiliary thermal energy input to the ECSS storage, thus only indirectly affecting the DHW subsystem.

- Auxiliary Electrical Fuel - Amount of electrical energy supplied to the DHW subsystem for conversion to thermal energy towards meeting the subsystem load.

- Auxiliary Fossil Fuel - Amount of fossil fuel energy supplied to the DHW subsystem for conversion to thermal energy towards meeting the subsystem load.

MONTHLY REPORT:
HOT WATER SUBSYSTEM

| DAY OF MON. (NBS) | HOT WATER LOAD MILLION BTU (Q302) | SOLAR FR. OF LOAD PER. (N300) | SOLAR ENERGY USED MILLION BTU (Q300) | OPER ENERGY MILLION BTU (Q303) | AUX THERMAL USED MILLION BTU (Q301) | AUX ELECT FUEL MILLION BTU (Q305) | AUX FOSSIL FUEL MILLION BTU (Q306) | ELECT ENERGY SAVINGS MILLION BTU (Q311) | FOSSIL ENERGY SAVINGS MILLION BTU (Q313) | SUP. WAT. TEMP DEG F (N305) | HOT WAT. TEMP DEG F (N307) | HOT WAT. USED GAL (N308) |
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* DENOTES UNAVAILABLE DATA.

Figure 9. Hot Water Subsystem Report Form

- Electrical Energy Savings - Estimated difference between the electrical energy requirements of an alternative conventional DHW system (carrying the full load) and the electrical energy required by the actual solar-supplemented subsystem.

- Fossil Energy Savings - Estimated difference between the fossil energy requirements of the alternative conventional DHW system (carrying the full load) and the fossil energy requirements of the actual solar-supplemented subsystem.

- Supply Water Temperature - Average inlet temperature of the water supplied to the DHW subsystem.

- Average Hot Water Temperature - Average temperature of the outlet water as it is supplied from the DHW subsystem to the load.

- Hot Water Used - Volume of subsystem heated water delivered from the DHW subsystem.

2.5.6 Space Heating Subsystem - The space heating subsystem is characterized by performance factors similar to those of the hot water subsystem, described in Section 2.5.5. The average building temperature and the average ambient temperature are tabulated again on this form to indicate the relative performance of the subsystem in satisfying the space heating load and in controlling the temperature of the conditioned space. The performance factors provided on this report form (Figure 10) are defined as follows:

- Space Heating Load - Amount of energy supplied to satisfy the temperature control demands of the space heating subsystem.

- Solar Fraction of Load - Percentage of the SHS load demand which is supplied from the solar ECSS.

- Solar Energy Used - Amount of energy supplied from the solar ECSS to the space heating subsystem.

- Operating Energy - Amount of electrical energy required to support the space heating subsystem (e.g., fans, pumps, etc.) which is not intended to affect directly the thermal state of the subsystem.

- Auxiliary Thermal Used - Amount of thermal energy supplied to the heated space of the building by the central space heating system auxiliary equipment. For heat pump systems, this term includes only that portion of the thermal energy supplied to the load from the heat pumps which is derived from mechanical compression. It does not include the portion of the thermal energy supplied by the heat pumps which is derived from their low temperature thermal energy supply.

- Auxiliary Electrical Fuel - Amount of electrical energy supplied to the space heating subsystem for conversion to thermal energy towards meeting the subsystem load.

MONTHLY REPORT:
SPACE HEATING SUBSYSTEM

| DAY OF MON. (NBS) | SPACE HEATING LOAD MILLION BTU (Q402) | SOLAR FR. OF LOAD PCT. (N400) | SOLAR ENERGY USED MILLION BTU (Q400) | OPER ENERGY MILLION BTU (Q403) | AUX THERMAL USED MILLION BTU (Q401) | AUX ELECT FUEL MILLION BTU | AUX FOSSIL FUEL MILLION BTU (Q415) | ELECT ENERGY SAVINGS MILLION BTU (Q417) | FOSSIL ENERGY SAVINGS MILLION BTU (Q417) | BLDG TEMP DEG F (N406) | AMB TEMP DEG F (N113) |
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* DENOTES UNAVAILABLE DATA.

Figure 10. Space Heating Subsystem Report Form

- Auxiliary Fossil Fuel - Amount of fossil fuel energy supplied to the space heating subsystem for conversion to thermal energy towards meeting the subsystem load.

- Electrical Energy Savings - Estimated difference between the electrical energy requirements of an alternative conventional space heating system (carrying the full load) and the electrical energy requirements of the actual solar-supplemented system.

- Fossil Energy Savings - Estimated difference between the fossil energy requirements of an alternate conventional space heating subsystem (carrying the full load) and the fossil energy requirements of the actual solar-supplemented system.

- Building Temperatures - Average temperatures in the controlled space of the building which the system serves.

- Ambient Temperature - Average measured ambient temperature of the outdoor environment at the site.

2.5.7 Space Cooling Subsystem - The space cooling subsystem is characterized by performance factors similar to those of the hot water subsystem and space heating subsystem, described previously. The performance factors in this form (Figure 11) are defined as follows:

- Space Cooling Load - Amount of thermal energy removed from the air-conditioned space of the building by all central SCS solar- and auxiliary-powered equipment. Thermal energy removed by unassisted ventilation is accounted to the space cooling load only for passive systems. Auxiliary space cooling supplied by room window air conditioners is never included.

- Solar Fraction of Loads - Percentage of the SCS load demand which is supplied from the solar ECSS.

- Solar Energy Used - Amount of energy supplied from the solar ECSS to the space cooling subsystem.

- Operating Energy - Amount of electrical energy required to support the space cooling subsystem (e.g., fans, pumps, etc.) which is not intended to directly affect the thermal state of subsystem.

- Auxiliary Thermal Used - Amount of thermal energy supplied to the space cooling subsystem by the central subsystem auxiliary equipment. Auxiliary space cooling supplied by room window air conditioners is not accounted to the auxiliary thermal used.

- Auxiliary Electrical Fuel - Amount of electrical energy supplied to the space cooling subsystem for conversion to thermal energy towards meeting the subsystem load.

- Auxiliary Fossil Fuel - Amount of fossil fuel energy supplied to the space cooling subsystem for conversion to thermal energy towards meeting the subsystem load.

MONTHLY REPORT:
SPACE COOLING SUBSYSTEM

| DAY OF MON. (NBS) | SPACE COOLING LOAD MILLION BTU (Q502) | SOLAR FR. OF LOAD PCT. (N500) | SOLAR ENERGY USED MILLION BTU (Q500) | OPER ENERGY MILLION BTU (Q503) | AUX THERMAL USED MILLION BTU (Q501) | AUX ELECT FUEL MILLION BTU | AUX FOSSIL FUEL MILLION BTU (Q504) | ELECT ENERGY SAVINGS MILLION BTU (Q512) | FOSSIL ENERGY SAVINGS MILLION BTU (Q514) | BLDG DRY BULB DEG F (N406) | AMB TEMP DEG F (N113) |
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* DENOTES UNAVAILABLE DATA.

Figure 11. Space Cooling Subsystem Report Form

- Electrical Energy Savings - Estimated difference between the electrical energy requirements of an alternative conventional space cooling system (carrying the full load) and the electrical energy required by the actual solar-supplemented subsystem.

- Fossil Energy Savings - Estimated difference between the fossil energy requirements of an alternative conventional space cooling system (carrying the full load) and the fossil energy requirements of the actual solar-supplemented system.

- Building Dry Bulb Temperature - The average temperature of the space-cooled area.

- Ambient Temperature - Average measured ambient temperature of the outdoor environment at the site.

2.5.8 Environmental Summary - The environmental summary is a collection of the weather data for which each site in the program is generally instrumented. It is tabulated in this report for two purposes: as a measure of the conditions prevalent during the operation of the system at the site, and as a historical record of weather data for the vicinity of the site. The performance factors on the report form (Figure 12) are defined as follows:

- Total Insolation - Accumulated total incident energy per unit area measured in the plane of the collector array at the site.

- Diffuse Insolation - Accumulated diffuse solar energy per unit area measured at the site.

- Ambient Temperature - Average temperature of the environment at the site.

- Daytime Ambient Temperature - Average ambient temperature of the environment at the site during the period from three hours prior to local solar noon to three hours past local solar noon. (This time frame is selected independently of the operation of the collectors at the site, and it is intended to serve as historical data for the ambient temperatures during the normal collector operating period.)

- Relative Humidity - Average relative humidity of the environment at the site.

- Wind Direction - Average direction of the prevailing wind.

- Wind Speed - Average wind speed measured at the site.

2.5.9 Thermodynamic Conversion Equipment - Thermodymanic cycle, or heat pump, equipment is used to transform thermal energy from a lower to a higher temperature for space heating. The performance of such equipment is reported in the MPR for a site only if the equipment is "solar-assisted" in the sense that its lower temperature thermal energy source is preheated from the solar ECSS (e.g., is the ECSS storage medium).

MONTHLY REPORT:
ENVIRONMENTAL SUMMARY

| DAY OF MONTH (NBS ID) | TOTAL INSOLATION BTU/SQ. FT (0001) | DIFFUSE INSOLATION BTU/SQ.FT | AMBIENT TEMPERATURE DEG F (N113) | DAYTIME AMBIENT TEMP DEG F | RELATIVE HUMIDITY PERCENT | WIND DIRECTION DEGREES (N115) | WIND SPEED M.P.H. (N114) |
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| 29 | | | | | | | |
| 30 | | | | | | | |
| 31 | | | | | | | |
| SUM | | | | | | | |
| AVG | | | | | | | |

* DENOTES UNAVAILABLE DATA.

Figure 12. Environmental Summary Report Form

Thermodynamic cycle equipment for space heating which is not solar-assisted in the manner just described is analyzed for the MPR only in terms of the auxiliary heating performance criteria already discussed.

Absorption chillers for air-conditioning are solar-assisted in the sense that solar energy is used to provide these systems with thermal driving energy for generation of pressurized refrigerant vapor. This is comparable to the mechanical driving energy used in compression refrigeration. Solar-supplemented absorption chiller systems are analyzed for the MPR in terms of the space cooling criteria already discussed.

The performance of a solar-assisted heat pump system is characterized by the energies flowing to and from the equipment and the coefficient of performance of the equipment. Due to the many methods used to calculate coefficients of performance, the method used is noted in the MPR Performance Evaluation on the page that the coefficient of performance is presented.

The performance factors on this report form (Figure 13) are defined as follows:

- Equipment Load - Thermal energy added by thermodynamic conversion equipment to the air being heated (cf. qualifications regarding thermal energy determination, under "Space Heating Load").
- Thermal Energy Input - Equivalent thermal energy supplied as a fuel source to thermodynamic conversion equipment (e.g., thermal equivalent of electrical energy driving heat pump compressor).
- Operating Energy - Amount of electrical energy supplied to support the operation of thermodynamic conversion equipment (e.g., pumps, fans, etc., but not including the heat pump compressor) which is not intended to affect directly the thermal state of the air being heated.
- Energy Rejected - Amount of energy intentionally rejected or dumped from thermodynamic conversion equipment as a by-product or consequence of its principal operation. (This parameter is principally of interest when the equipment is being used for space cooling. At such time, the equipment is not operated in a solar-assisted mode.)
- Coefficient of Performance (COP) - Typically, the ratio of equipment load to thermal energy input, as these terms are defined above.

2.5.10 Additional Forms - Certain solar energy systems in the National Solar Data Program may have features which cannot be accurately described and evaluated by the data report forms described herein. Additional tables may be included in the report for these features as appropriate.

## 2.6 OTHER DATA REPORTS ON THE SITE

This section of the MPR lists previously published MPR's for the site in chronological order. It should be noted that there will usually be additional MPR's for a given site which have not been published. Other types of reports generated for the specific site are also listed.

MONTHLY REPORT:
THERMODYNAMIC CONVERSION EQUIPMENT

| DAY OF MONTH | EQUIPMENT LOAD MILLION BTU | THERMAL ENERGY INPUT MILLION BTU | OPERATING ENERGY MILLION BTU | ENERGY REJECTED MILLION BTU | COEFFICIENT OF PERFORMANCE |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
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| 30 | | | | | |
| 31 | | | | | |
| SUM | | | | | |
| AVG | | | | | |

* DENOTES UNAVAILABLE DATA.

Figure 13. Thermodynamic Conversion Equipment Report Form

# APPENDIX A - SOLAR ENERGY SYSTEM CHARACTERISTICS FOR ACTIVE AND PASSIVE SITES

Although most solar energy sites have a number of things in common, each site has its own operational characteristics based on the configuration of the solar energy subsystems, the architectural design and building materials used, and the lifestyle of the occupants.

Generally a major division is made between sites by application, i.e., residential or commercial. Further classifications are made by the type of solar system employed, i.e., active or passive solar energy system.

The Monthly Performance Report contains a description of the site, and identifies significant characteristics of the solar energy system components and the system operational modes available. The various subsystems are illustrated in the solar energy system schematic in each MPR. In reviewing MPR's, obvious differences are noted between active and passive site components and the depth of analysis provided for each type of site. Basic characteristics of active and passive solar energy systems are given below.

Active Solar Energy Systems - Active systems contain active mechanical equipment components to collect, transfer, store, and distribute solar energy. Pumps or fans move liquids or air throughout the system where the collected energy is used directly or via heat exchangers to provide space heating, cooling, hot water, or heat for some industrial process. Active systems are identified by a collector array, thermal storage tank, a hot water preheat tank, and an interface with an auxiliary fossil fuel or electric system, i.e., heat pump, space heater, or domestic hot water tank.

Analysis of an active solar energy system provides the amount of energy (in BTU) contributed to space heating, heating of hot water, space cooling, etc. The MPR for active sites does not identify the total load demands. That is, solar energy and auxiliary energy contributed to the various loads are quantified, but other forms of energy that make up the total loads, such as passive heating gain through windows, portable space heaters, heat from cooking, etc., are not accounted for in the analysis of energy to loads.

Fireplaces are another heat source that are usually not accounted for in the computation of loads, but there are exceptions, as some fireplaces are instrumented and others are accounted for in the program software used in the analysis of active sites.

Therefore the term "loads" in reference to an active site usually means the energy (solar or auxiliary) contributed to the load, and not necessarily the total load required or provided at the site.

Another important consideration at active sites is the definition of "losses." Losses are defined as the difference between the energy measured at one point and that measured at a point further in the transfer loop of the system, e.g., the energy measured at the input to a storage tank and that measured at the output of the storage tank. This energy escaping from the transfer loop may, however, not be lost as usable energy, as it may contribute to heating the site and, as such, not be a loss but an unintentional distribution of energy.

The MPR defines losses from the collector as energy that is not collected, i.e., the difference between the energy available (insolation) and the energy absorbed or captured by the transfer medium (liquid or air). This "loss" term is actually a summation of collector design factors that prevent the accumulation or retention of the insolation available.

Other losses, such as losses through windows, walls, etc., are not measured or defined in an MPR for an active site.

Passive Solar Energy Systems - Passive sites do not have an external collector array, although there are hybrid passive systems that use a roof collector array for the domestic hot water supply. Energy is received through south-facing windows, and captured in mass storage structures such as Trombe walls (masonry walls), stone floors, water-filled barrels, etc. Passive sites usually have a greenhouse or similar structure to capture and retain incoming solar energy. Some passive sites use fans to circulate the energy (heat) from room to room through mass storage areas such as rock beds, and to remove energy in the case of overheating. Other sites employ no active devices in the solar system but may use fans from auxiliary systems to distribute energy as required. Thermosiphoning systems, which are hybrid systems, operate a form of free convection to distribute solar energy.

Analysis of passive systems must necessarily consider the effects of infiltration and building losses, and passive sites are instrumented with more sensors than active sites for this purpose. Contributions to the total load are considered, as the entire structure is both a part of the solar system and a load. The definition of load is therefore more descriptive for a passive site than an active site.

Losses are also more carefully defined in a passive house, as solar energy is usually the major source of energy (as opposed to a large auxiliary or backup system in an active site) and the sources of losses and effects on solar energy performance are carefully evaluated.

The MPR for passive sites (or hybrid sites) will define energy contributions from all sources, including Drumwalls, Trombe walls, greenhouses, storage areas, etc. Since most passive sites employ a fireplace or a wood- or coal-burning stove, this energy input must also be calculated in the total load. Often these values must be estimated to complete the load calculations.

Commercial sites present a variety of individual characteristics too numerous to discuss in detail in this text. Some notable differences are in the collector area, where concentrating collectors, evacuated tube collectors, and other special types of collectors are found, as well as conventional flat-plate type collectors. The analysis of these types of collectors is somewhat different and should be explained in the MPR System Description or in the Performance Evaluation section.

Flow rates and temperatures also vary significantly from residential sites. It is not always possible to measure subsystem performance accurately because small instrumentation errors are magnified by the larger flows incurred. For this reason, the MPR may contain estimated values based on alternate measurement techniques or good engineering judgment, supported by the site operator, designer, or site maintenance personnel.

# APPENDIX B - DATA COLLECTION AND TRANSMISSION IN THE NSDN

Data collection and transmission from residential and commercial sites in the National Solar Data Network are illustrated in Figure B-1. As shown, the major elements are:

1. On-site instrumentation, including temperature and flow sensors, power sensors, valve and damper position indicators, an electrical junction box, and a Site Data Acquisition Subsystem (SDAS) (electronic scanner and signal conditioning device).

2. A telephone link between the instrumented site and a Communicating Processor at Vitro Laboratories.

3. Data processing systems at Vitro Laboratories that convert the data from the site into engineering units, in suitable format for daily printout of performance information and monthly compilation of energy performance factors suitable for analysis and preparation of Monthly Performance Reports.

The solar energy system at each site is instrumented to provide sufficient measurements to support the thermal performance analysis of each subsystem. Instrumentation generally includes sensors to monitor the following:

- Total Insolation (sunlight in the plane of the collector array)
- Outdoor ambient temperature (and sometimes wind speed and direction)
- Internal building temperature
- Collector loop temperatures and flow rates
- Storage inlet and outlet temperatures and flow rates
- Internal storage tank temperatures
- Load subsystem temperatures and flow rates
- Auxiliary fuel flows and values.

Additionally, passive sites have sensors in walls, along windows, and in thermal mass storage areas to better define building infiltration losses and passive heat gains.

Sensors at the site are scanned (approximately every five minutes) and the data are recorded on magnetic tape in the Site Data Acquisition Subsystem. The communication processor at Vitro Laboratories calls each site once a day and extracts the data (via the telephone link). Data compiled on the processor are then operated on by the Central Data Processing Computer, which uses program routines to provide daily tab data and compile data for monthly printouts.

Programming requires the development of equations specifically designed for the site to be evaluated. A Site Equation Document is prepared for each site and specifies the routines for development of hourly performance factors, daily performance factors, and summation of monthly performance values used in the analysis of solar energy system performance and energy savings achieved.

An important factor in the above process is the assurance of valid data. Data integrity is maintained by checking data received from various sites to insure that the transmission quality is acceptable. Incoming data are examined, and data with apparent errors are tagged by the data processing software and recognized thereafter as invalid.

Similarly, there are data which may be transmitted properly but may appear questionable because of the values obtained after conversion to engineering units. These apparent anomalies may be caused by a sensor failure at the site, incorrect sensor installation, a transmission problem (otherwise undetected), a software problem not previously detected, or a malfunction of the solar energy system. Data of this character are also tagged as invalid.

No data which have been identified as invalid are used by the Central Data Processing System for the computation of performance factors. The existence of such invalid data, however, implies that suitable procedures must be incorporated into the software to assure viable data in the Monthly Performance Report, and to identify the existence of any unacceptable data. Such procedures are implemented in the software by enforcing a requirement for a minimum amount of data necessary to provide reasonable validity. These minimum limits are selected (from the results of data analysis studies) to insure that the performance factors computed from the data fall within 10% of the true value even in the case of missing data.

There may be a maximum of 12 measurement scans recorded within any particular clock hour. When there is a missing measurement, the next good measurement is assumed to replace the missing measurement for the purpose of computing the hourly performance factors. (The missing measurement is assumed only for the purpose of computing the appropriate performance factors; it is not actually replaced in the data.) Therefore, all performance factors which are computed are supported by a reasonable amount of good data. All other performance factors are tagged as invalid.

Similarly, there must be a representative number of good, hourly samples within any one calendar day to initiate the calculation of daily performance factors. When there are sufficient data, any invalid data are replaced (for computational purposes) by the average of the good samples.

The monthly performace factors are computed only if there is a minimum number of good daily samples. Invalid data are replaced (for computation) by the average of all of the good daily samples. These techniques provide performance factors which are supported by sufficient data, thereby producing a high confidence level in the information.

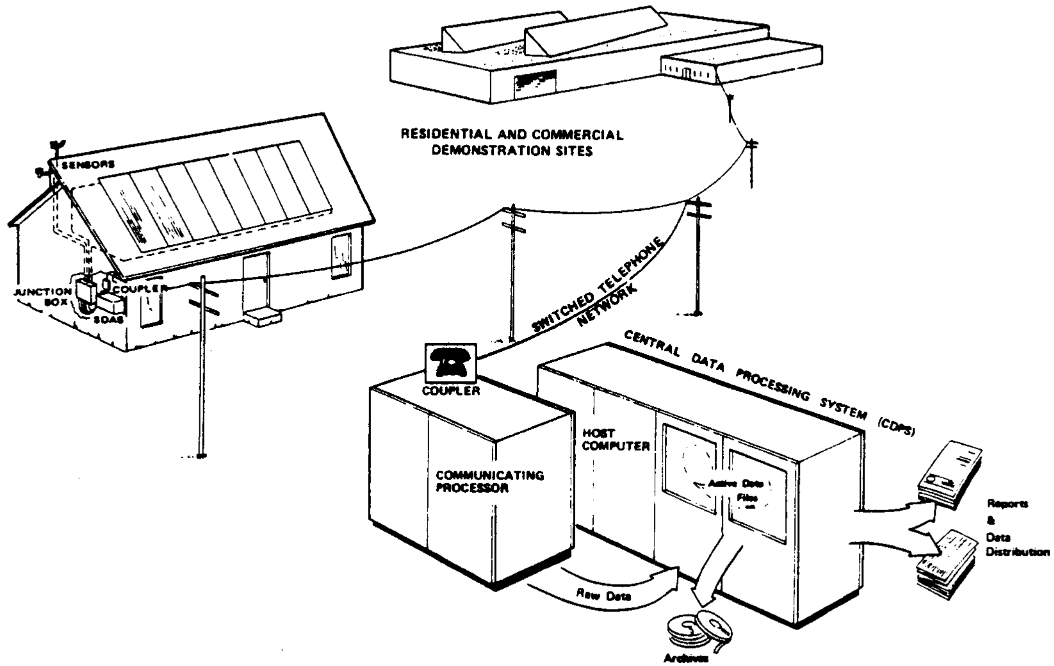


Figure B-1. Data Collection and Transmission in the NSDN

## APPENDIX C - GLOSSARY OF ACRONYMS AND SYMBOLS

AUX - Auxiliary fossil fuel, electric fuel, or thermal energy

AMB - Ambient temperature

AVG - Average daily values

BTU - British Thermal Unit(s)

COP - Coefficient of Performance

DD - Degree-Days

DHW - Domestic Hot Water

ECSS - Energy Collection and Storage Subsystem

EFF - Conversion Efficiency or Subsystem Efficiency

EST - (E) Estimated Value (an alternate method of computation or engineering judgment)

f-Chart - An analysis method used to predict monthly performance for active solar energy systems with characteristics typically found in residential applications, on the basis of (1) monthly insolation and ambient temperature data, (2) building heating load characteristics, (3) experimentally determined performance characteristics of the solar collectors employed, and (4) other basic design specifications of the building's solar energy system.

NSDN - National Solar Data Network

MPR - Monthly Performance Report

SCS - Space Cooling Subsystem

SHS - Space Heating Subsystem

SUM - Summation of Daily Values

TCE - Thermodynamic Conversion Equipment

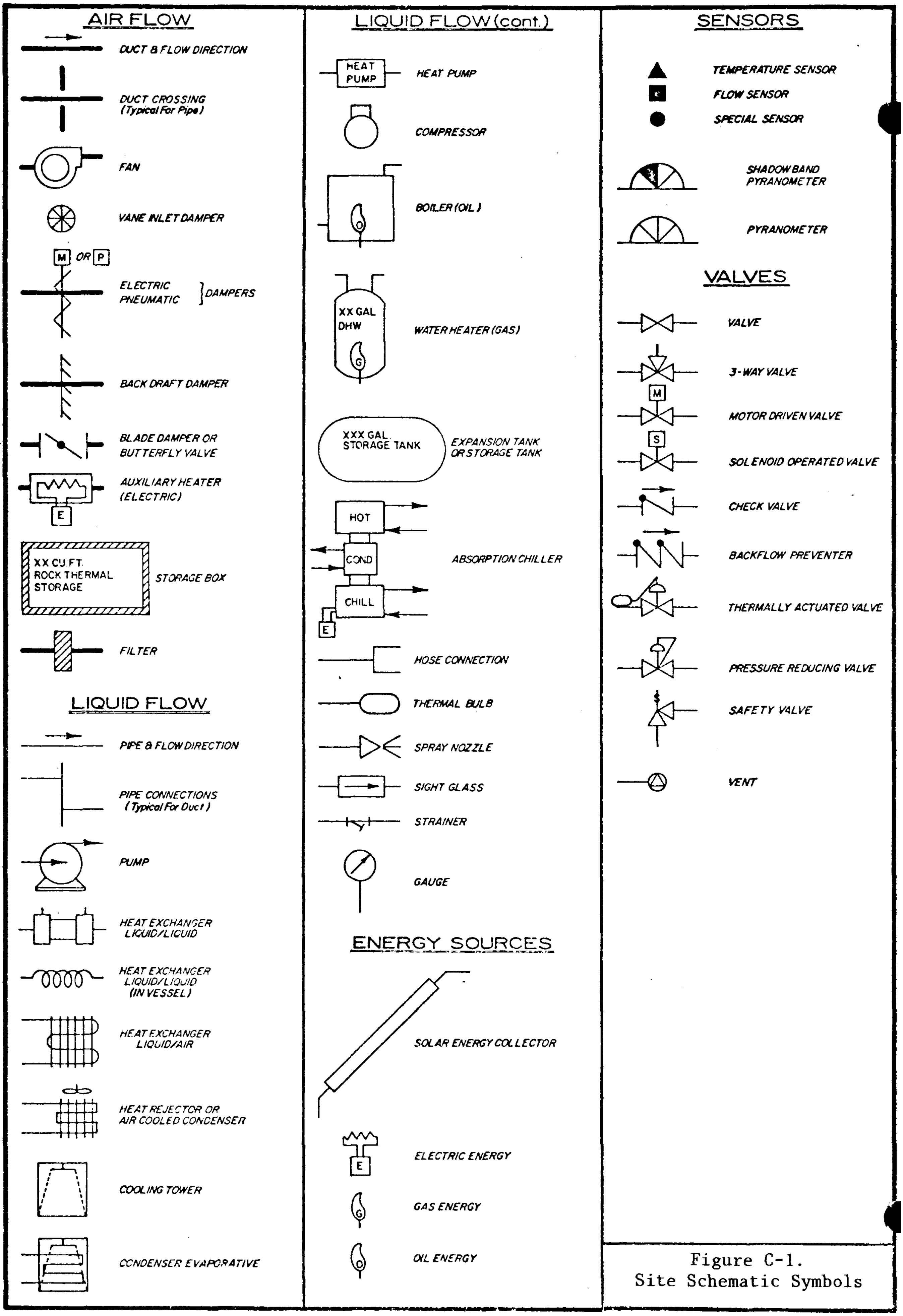


Figure C-1.
Site Schematic Symbols