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Energy Efficiency and Renewable Energy Technology Characterizations

Working Definitions, Guidelines, and Forms

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Preface

The technology characterization effort for which these working definitions, guidelines, and forms were developed was sponsored by the Office of Planning and Analysis of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy Technologies (EE). The Analytic Studies Division (ASD) of the National Renewable Energy Laboratory provided overall management continuity and facilitated the processes that led to the production of the report.

The characterization of EE technologies in a uniform, self-contained, and transparent fashion is an indispensable prerequisite for establishing the credibility of assertions about the current status of and future expectations from a given technology as well as for applications to all analytical studies, such as strategic and program planning, budgeting, and modeling activities.

The effort reported here represents the culmination of approximately 1 year's effort by the author working with representatives of EE in a Technology Characterization Working Group. The group met periodically to develop, review, and agree on the material contained herein. This material is used by EE in an ongoing technology characterization effort. It was reviewed extensively by both internal and external peer reviewers.

Even though many in EE and ASD contributed to the material contained in this report, particularly the participants in the Technology Characterization Working Group, the author bears the responsibility for this report, and hereby invites your constructive comments.

Approved for the
NATIONAL RENEWABLE ENERGY LABORATORY

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Analytic Studies Division

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Energy Efficiency and Renewable Energy Technology Characterizations

Working Definitions, Guidelines, and Forms

Background and Objective

Contained herein are working definitions, guidelines, and forms for doing technology characterizations in the U.S. Department of Energy Office of Conservation and Renewable Energy (EE). This document was developed over 1 year of intensive work involving the author and representatives of each of the EE sectors. Most of the interaction occurred in the context of the Technology Characterization Working Group, which met periodically to discuss different aspects of the substance contained in this material. The final draft was essentially completed by January 1993. Since then this document has been used in final draft form.

The objective of doing technology characterization (TC) is to provide a solid foundation of consistent and credible information on the current status of and future prospects for the technical performance, cost, and environmental characteristics of all significant EE technologies. Technology characterizations can contribute to a wide variety of activities, including policy analysis, modeling, program planning, and technology transfer. TCs can be used within DOE and in industry, state governments, and other agencies. The need for TCs has been met in the past by individual efforts, typically targeted to meet specific needs. The current approach aims at providing the guidelines for a consistent characterization methodology applicable across all of EE.

Approach

To meet this objective, TCs have to be clear and the information traceable to credible studies or sources. The quality, completeness, and traceability of the information provided, including data, assumptions, and methods, is, therefore, the cornerstone of credibility. Traceability is typically accomplished in one of two ways. One can give a direct reference linking a statement or a number appearing on the TC to a document or other source. The reference should appear in Line 8 of the TC and should meet the formal quality for references in scientific publications. A second way is to attach the assumptions and any calculations necessary to duplicate the number or derive the statement appearing in the TC. These should be attached to the TC and referred to in the body of the TC where the number or statement appears.

Technologies being characterized are "systems." Working definition: A "technology" will be considered to be a "system" when it provides an energy service (such as supply or end use), can be enclosed by a system boundary with flows of inputs and outputs, and can be compared by similar indicators to a conventional or advanced competitive counterpart that provides the same energy service.

To characterize other crosscutting or enabling technologies that may be used in a variety of systems, i.e., ceramics, tribology, refrigerants, and many other such technologies, one could characterize a system in which this crosscutting technology can be applied (e.g., for ceramics, an advanced, high-temperature gas turbine) and characterize that system.

TCs should be done using the attached forms. The attached forms contain a limited set of indicator categories and assigned space. Much more could be said about a system being characterized. However, please summarize the information requested in the spaces provided. Additional information can be appended to the attached seven-page forms. Where there is uncertainty, please indicate. Particularly in the spaces labeled "Description, Rationale, and Assumptions," state the basis for, including caveats regarding, the information you provide so the degree of confidence or uncertainty about the information is clear.

The TC forms have been designed for characterization of a single system, except in the case of conservation technologies, when comparisons to alternative systems are desirable. When a comparison between two systems is presented, caution has to be exercised:

- The benefits from the two systems have to be comparable (this is usually satisfied when both systems provide the same service).

- The system boundaries of the two systems must be comparable. That is, the system being characterized can substitute for the one it is being compared with. This requirement does not apply to flows across the boundary, which are likely to be different.

- The comparison should be between the system being characterized and an alternative "benchmark" system. For comparisons in future years, advances in the "benchmark" technology have to be considered.

When one or more of these requirements is not met, discussion and clarification are necessary.

The forms do not require the statement of aggregate impacts such as market penetration. In all cases, the characterization is of a system (one unit), although specific provisions have been made for its comparison with an alternative system, as discussed above, when so desired.

Beginning with performance indicators, the forms require you to estimate the value of a number of indicators in the base year, 1990, and in future years, up to 2030. As a basis for these estimates, use the assumptions and data (such as macroeconomic variables, sectoral fuel prices, and other data) in the *National Energy Strategy* (National Energy Strategy Scenario) as they appear in Technical Annex 2 DOE/5-0086P, 1991/1992. (Should there be a more current version by the time the TC effort actually starts, there will be an addendum to these guidelines.)

The TC forms have been specifically designed to be used with WordPerfect 5.1.

The rest of this document contains working definitions and guidelines for filling out the attached forms. Line numbers correspond to those on the forms.

Line 1. System Overview

(a) System schematic, system boundary, inputs, and outputs:

This space should be used to provide a schematic representation of the system being characterized. The schematic may be typically a "single line diagram" showing material and energy flows in the system, its major subsystems and other significant features. The system boundary defines the scope of the rest of the indicators used in the characterization (e.g., system performance, costs included). The schematic may also be used to indicate, when desired, energy and material flow rates, conversion variable states, and energy or material balances. Lines crossing the system boundary should include resource inputs (feedstocks, energy) and outputs, particularly products (e.g., energy, and effluents). The diagram often provides the reader both with a quick idea of what is being characterized and a reference for understanding the scope of the indicators used in the rest of the TC. A good selection of the system boundary facilitates the comparative evaluation of alternative systems generally available to meet similar energy services.

(b) System description:

This augments the system schematic with descriptive material. Typically this section should include statements explaining the major features of the system, its major subsystems, and its operation. A historical review of significant milestones in the evolution of the system is helpful particularly when it is accompanied with technical performance and cost improvements data over time.

(c) Use the term that best approximates the system you are characterizing, check the box following it, and use the space provided to clarify your choice. When there are a number of systems similar to the one you chose to characterize, and your characterization is for one of a "family" of such systems, choose a "representative" system to characterize. A "composite" characterization is one in which characteristics of more than one specific system have been used. Composites are often useful when either there are a number of similar systems being studied or a variety of systems have the same application or end use. An "average" characterization is one such specific composite. It purports to provide the reader an average characterization of a family of systems. Check "average" and use the space below to explain to the reader in what sense you have used the term (e.g., present and future technology systems mix). The benefits of using a "representative" system is that it is technology-specific. The benefit of using a national "average" characterization is that it provides a generic system characterization, ready for use in national-level models. Ideally, one would have all major systems characterized as representative systems from which different composite characterizations, including an average characterization, can be readily aggregated to meet specific needs.

(d) A "representative" region may be a significant region in some sense (e.g., near "average" resource intensity level, expected typical deployment issues), but not the "best" region. Resource and market considerations should be used to select between these two terms. A "national average" region provides the TC user with readily available information for inclusion in national-level modeling and analysis. Consider the possibility of using a national average characterization, but providing region-specific data required for more specific analyses (as appendixes to the TC form).

(e) Enter here the most appropriate "alternative system" that provides identical or nearly identical energy or energy services (i.e., the market competition). The "Alternative System" should be carefully selected by the staff performing the TC. It should serve, particularly in the case of end-use technologies, to form the basis for calculating energy savings and other benefits. A "benchmark" alternative system should be one representing the most likely current and, separately, the most likely future competition to the system characterized in the TC. When more than one system is characterized (on separate TCs), but providing the same energy service, the same benchmark technology should be used for comparisons. Ideally, one should be able to substitute the system being characterized by "removing" the alternative system along its system boundary and "plugging in" the system being characterized in its stead. Because this correspondence rarely exists, space is provided to clarify the exceptions to this ideal substitution (see also discussion of this point in Line 1a, above, regarding the choice of system boundary).

(f) A system is technologically "mature" when it has been commercially manufactured or constructed by a number of private enterprises, and when its performance, cost, and the record of other indicators have been established and are available in the general literature. It is "commercially available" when it can be purchased on the open market with clear engineering and fabrication/construction specifications of the system, or its costs and performance are guaranteed from at least one manufacturer. It is "near commercial" when it has been demonstrated to operate at a near-commercial, prototype scale. It is in "engineering development" when engineering or process developments or both are currently under way, and design parameters are being optimized. It is in "R&D" when it has been demonstrated to be technically feasible and work is proceeding on the study of alternative system configurations, including materials, components, and other process aspects. It is "conceptual" when it shows theoretical merit but has not yet been demonstrated to be technically feasible.

Choose the word most descriptive of the system you are characterizing, mark the box to its right, and use the space provided to explain more specifically the status of technological maturity of the system you are characterizing.

(g) Select the box that is applicable and mark it up. Use the space provided to describe the expect evolution of the technology from the present to the time when the system is expected to become commercially available. Include a "verbal timeline" with significant technical future milestones, such as R&D goals, cost, and performance targets.

Line 2. System Application, Energy Services, and Expected Benefits

Describe in some detail the applications for which the system characterized is designed. This is the place where the motivation for the effort to develop the system is given, a description of the energy service provided by the system is provided, and the potential benefits are delineated. Categories of benefits could include energy conservation and efficiency improvements; energy savings, including peak-demand reduction; energy supply from renewable resources; liquid fuels substitution, including displaced oil or oil products; productivity improvement (including a reduction in the cost of energy); environmental impacts; potential for longer term impacts of systems in the conceptual or R&D stages of development; systems that have limited "niche market" potential; and any other benefits.

When a comparison is made between two systems—the system that is being characterized and the one it displaces—it is vital that a discussion of the benefits of each system be presented. The easiest case is when the benefits are identical. When they are not, the comparative evaluation is valid only when the difference in benefits has been accounted for in some way.

Line 3. Technical Performance Indicators

(a) Scenario:

The scenario is used to document technical performance indicators in the base year and their evolution, if any, in future years. In the column called "indicator name," enter the indicators that are necessary to characterize the technical performance of the system being characterized. While "unit size" and "annual energy delivery" may be applicable to many EE systems, many other systems will have their own indicators. It is important that you enter into this column all the significant technical performance indicators necessary for the characterization of the system you are characterizing and the comparison between this system and other benchmark systems providing energy or energy services with which the systems may compete. The rest of the table contains information on the base year value of each technical performance indicator and on the expected changes of these values in future years. The future year values are not program goals (those were described generally in line 1g, above), but rather the expected values of these indicators.

In all cases, the table should be filled with quantities pertaining to the system being characterized and should be indicative of the expected technical performance improvements over time (perhaps until the system has become technically "mature," when further improvement will likely be slow or cease). Annual energy delivery and any similar indicators, therefore, are for the system only and are not national (market penetration) totals. The same rule applies for annual energy savings when an energy-efficient system is compared with an alternative system. The "units" can be for the system unit size (e.g., kWh/yr/unit), or specific (kWh/yr/installed kW), or both.

(b) Description, rationale, and assumptions:

Use this space to establish, as best you can, the credibility of the assertions made in the table by first describing the basis (in analysis, experimental results, or field measurements whenever they are available) of the values for the "base year," and the assumptions, methodology, and rationale used to derive the values entered for future years, including a Business as Usual (BAU) level of production. Include the basis for calculating annual energy savings, including peak savings and annual energy supply, as applicable.

Line 4. Cost Indicators

(a) Enter the number of years for which the system has been designed to be economical, e.g., before the cost of replacement becomes lower than the costs of ongoing maintenance.

(b) Enter the number of years required to construct the system (if applicable, otherwise, enter N/A).

(c) Scenario:

In the column called "indicator name" have been entered the most commonly used indicators:

The "system capital cost" is defined as the total cost of the system at the time it is first ready for operation (also known as the "turnkey" cost) or the cost to a consumer. (The "turnkey" cost has some advantages over the "overnight" or "instant" capital cost. However, if you choose to use one of the latter, describe in 4d, below, the construction profile giving the capital expenditure at each year prior to start-up). The "system O&M cost" includes all major costs required for the operation and maintenance of the system, including labor, feedstocks, input energy, replacement parts, other supplies, and environmental abatement costs, as applicable.

The "levelized cost" of energy or energy service produced by the system is a significant cost indicator enabling an easy comparison among systems providing identical benefits (identically valued energy services).

In the column labeled "units," enter the unit cost in base year dollars; the levelized cost of energy (LCOE) is usually per unit of output (e.g., ¢/kWh, $\$/10^6$ Btu, \$/VMT).

Add other significant cost indicators commonly used or necessary to properly characterize your system.

In "base year" and "future" scenarios, give the expected costs. This is not the programmatic cost goal but rather the best estimate available to you of the future costs. A column is provided for entering a +x% and –y% next to the expected value entry. Use this column to estimate the range of values the cost numbers may take.

Use constant, or real, base year U.S. dollars throughout.

(d) Description, rationale, and assumptions:

Describe in detail the basis of the base year costs by stating the degree of specificity to which the system was defined as the basis for the cost estimate (e.g., "base year costs are based on engineering specifications and construction drawings" or "base year costs are based on single line process diagrams, including materials and energy balances, and sizing of major system components"). State what has been included and what has been excluded in both capital and O&M costs. Use the assumptions and methodology in *A Manual for the Economic Evaluation of EE Technologies* (NREL Draft dated August 1992) for the LCOE. Describe the basis for the range of cost values you selected (e.g., "A Delphi analysis was done to estimate the range. . ." or "the range of values is based on analogy with similar systems").

For estimating the cost in future years, a BAU level of commercial production should be specified. As in all other cases, be clear about the substance of and state the basis for this assumption.

Line 5. Market Indicators

(a) Scenario:

In the column called "indicator name," appears only one indicator, namely the maximum technical market potential. This indicator is defined as the lower of two numbers: one is the maximum number of units of the system being characterized (or an equivalent energy or other units, as appropriate) that could, from a technical feasibility standpoint, be sustained by the resource base. Use the resource base accessible to the application of the system as if economic competition was not an issue. The other is the demand base: the maximum number of units (or other measure, as described above) that could supply future markets from a technical feasibility standpoint, if competition was not an issue.

(The number sought here is the largest in the hierarchy of "market indicators," others typically being the "economic market potential" and actual "market penetration." Estimating either one of these is fraught with even more difficulties than the difficulties inherent in estimating the maximum technical market potential sought here. For this reason, they are deemed beyond the scope of the current TC effort. However, you are free to perform analyses of economic market potential and market penetration and attach them to the TC forms, particularly as reference material needed to substantiate future performance, cost, or other indicators.)

(b) Description, rationale, and assumptions:

Describe the method you used to arrive at the values entered in the table, whether the value is based on resource or market constraints. Describe the approach used to estimate the total potential and the methods and assumptions used to reduce that value to the one entered in the table. Include the approach you used to deal with the existing stock of technologies, i.e., replacement versus new demand. If a mathematical model was used, briefly describe its methodology and data base.

(c) Market analysis and deployment issues:

Describe the market for the system being characterized. Include its size, the sector of the economy of which it is a part, current and future conventional or alternative competing technologies, major structural characteristics of the market, stakeholders, current stocks and stock turnover, competition (or the lack thereof) in the market, market barriers, and the significance of federal and state regulatory trends. Identify deployment issues likely to influence the market penetration of the system characterized.

Line 6. Effluents

(a) Scenario:

In the column called "indicator name," list the known effluents—gaseous, liquid, and solid—from the system being characterized. Typical units are units of weight per year (for the unit size characterized) or units of weight per year per unit of energy or product produced. If you wish, include, for the gaseous effluents, a CO_2 equivalent, but only in addition to flow rates of the individual effluents.

(b) Description, rationale, and assumptions:

Describe the methodology and data base used in estimating the numbers used in the scenario (e.g., "based on material balances performed at the conceptual design level").

When the system boundary is drawn in such a way that the system characterized requires effluents to be generated outside of the system boundary, such as in the process of making a feedstock or other material necessary for the fabrication or operation of the system characterized, describe these circumstances in this section and refer the reader to a more complete treatment, if such a one is available.

Line 7. Direct Resource Requirements

(a) Scenario:

In the column called "indicator name" land, water, energy, feedstocks, and labor are listed. Quantify the inputs required for the construction of the system (or its fabrication, as appropriate) and operation of the system being characterized using appropriate units. Add or delete indicators to this list (or enter zero [0] values) as appropriate. Include any strategic or otherwise scarce or rare inputs required for the construction and operation of the system.

(b) Description, rationale, and assumptions:

Similarly to the manner of treating effluents, describe the basis for the estimates of resource requirements. Also similarly, include a discussion of resource requirement of special interest used in the process of fabricating the system being characterized, even when those requirements are outside the boundaries of the system.

Line 8. References

Include here the list of references used throughout the text.

Forms

for

EE Technology Characterization

Last update ________

Name of system characterized ______________________________

Line 1. System Overview

(a) System schematic, system boundary, inputs, and outputs

(b) System description

Prepared by: ______________________ Phone: __________

DOE contact: ______________________ Phone: __________

Name of system characterized ______________________________

Line 1. System Overview (cont'd)

(c) The system characterized is: representative ☐, best present ☐, best future ☐, a composite ☐, an average ☐

(d) The system characterized is located in a: representative region ☐, best region ☐, national average location ☐

(e) Alternative system : ______________________________
____

(f) State of technological maturity of the system: conceptual ☐, R&D ☐, engineering development ☐, near commercial ☐, commercially available ☐, mature ☐

(g) Expected time to commercial availability (years): currently available ☐, 1–5 ☐, 6–10 ☐, 11–15 ☐, 16–20 ☐

Name of system characterized ______________________________

Line 2. System Application and Expected Benefits

Line 3. Technical Performance Indicators

(a) Scenario:

INDICATOR		BASE YEAR	FUTURE					
NAME	UNITS	1990	1995	2000	2005	2010	2020	2030
Unit Size Annual Energy Delivery Annual Energy Savings Other Indicators • • • • • •								

(b) Description, rationale, and assumptions:

Name of system characterized ____________________________________

Line 4. Cost Indicators

(a) Expected economic life (years): ______________

(b) Construction period (years): ______________

(c) Scenario:

INDICATOR NAME	UNITS	BASE YEAR		FUTURE											
		1990	+% −%	1995	+% −%	2000	+% −%	2005	+% −%	2010	+% −%	2020	+% −%	2030	+% −%
System Capital Cost															
System O&M Cost															
Levelized Cost															
(Other Indicators) • • • • • •															

(d) Description, rationale, and assumptions:

Last update ________

Name of system characterized ______________________________

Line 5. Market Indicators

(a) Scenario:

INDICATOR		**BASE YEAR**	**FUTURE**					
NAME	**UNITS**	**1990**	**1995**	**2000**	**2005**	**2010**	**2020**	**2030**
Maximum Technical Market Potential								

(b) Description, rationale, and assumptions:

(c) Market analysis and deployment issues:

Name of system characterized ________________________________

Line 6. Effluents

(a) Scenario:

INDICATOR NAME	UNITS	BASE YEAR 1990	FUTURE 1995	2000	2005	2010	2020	2030
– Gaseous • • • – Liquid • • • – Solid • • •								

(b) Description, rationale, and assumptions:

Line 7. Direct Resource Requirements

(a) Scenario:

INDICATOR NAME	UNITS CONST/OP	BASE YEAR 1990	FUTURE 1995	2000	2005	2010	2020	2030
Land Water Energy (specify) Feedstocks (specify) Special materials (specify) Labor								

(b) Description, rationale, and assumptions:

Name of system characterized ______________________________________

Line 8. References

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This publication contains working definitions, guidelines, and forms for characterizing technologies at the U.S. Department of Energy, Office of Conservation and Renewable Energy (EE). It was produced to provide a consistent characterization methodology applicable across all of EE.

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