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Solar Technology Commercial Readiness Assessment Methodology

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SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT METHODOLOGY

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INTRODUCTION

1.1 OBJECTIVES

This report describes the Solar Commercial Readiness Assessment (CRA) methodology designed, developed, and implemented by SERI's Planning Applications and Impacts Division (PAID) for the U.S. Department of Energy.

The objective of the methodology is to assess numerically and qualitatively the relative degree of commercial readiness of solar technologies in specific applications.

The quantitative measure of solar commercial readiness resulting from applying the methodology is the Commercial Readiness Index (CRI). CRI is a relative measure, on an interval scale 0-100, of the progress being made in commercializing a solar technology in a specific application in competition with one or more conventional alternatives. For example:

- Solar technology: central wind systems
- Application: generation of electricity by large utilities
- Conventional competition: gas turbine generators.

CRI, somewhat analogous to the Consumer Price Index (CPI) produced monthly by the U.S. Bureau of Labor Statistics, has the following characteristics:

- Provides an overall numerical measure of the status of the commercial readiness of a solar technology/application
- Numerically shows the status of each of the individual factors contributing to the overall rating, thereby identifying problem areas
- Provides periodic (i.e., annual) assessments/snapshots of the progress being made toward commercialization.

CRI is designed to be a useful tool for program planners in:

- DOE
- SERI
- The four regional solar energy centers
  - Northeast Solar Energy Center
  - Southeast Solar Energy Center
  - Mid-America Solar Energy Center
  - Western SUN
- Energy planning offices in state governments
- United States Congress and its energy-cognizant committees.

Since this report is designed to be a User's Guide, an example is provided--application of the methodology to central wind systems/large utilities.

A complementary report, SERI technical report TR-431-368 [1], provides a summary description of the methodology and a comprehensive description of its application to four wind technology markets.

1.2 BACKGROUND

The commercialization of a solar technology to the point where it achieves market acceptance is typically protracted. During this process, products wanted by end users evolve and initial market uncertainties about such products (e.g., economics and performance) are resolved. On the basis of studies by Mansfield [2], Blackman [3], Fisher-Pry [4], and others regarding the process whereby a new technology competes with and gradually replaces an old one, solar market penetration is expected to exhibit an S-shaped pattern. Such classical market penetration studies have focused almostly exclusively on economics, showing penetration as a function of economics and time.

Before the market penetration curve can progress from the "product introduction" phase to the "growth" phase, the complex array of factors and issues--economic and noneconomic--that determine or facilitate market acceptance either has to be:

- In place; or
- In the process of being resolved.

That is, the product must progress through a commercial readiness process.

For SERI purposes, solar commercial readiness process is:

- That process--that proceeds concurrently with the commercialization process--in which all of the factors, issues, and requirements that figure in commercialization of a solar technology/application evolve to the point at which the market catches on and begins to grow at an increasing rate.

This process addresses all of the major issues and players relating to translation of a solar technology into marketable products. Specifically, commercial readiness is a function of:

- Technical, cost, and performance characteristics of the solar system
- Technical, cost, and economic performance characteristics of the competing conventional system(s)
- End user requirements--economic and noneconomic
- Producer requirements and activities
- Government programs, policies, and actions
- Market issues
- Market infrastructure development
- Institutional, legal, and environmental issues.

Figure 1-1 shows the time and scale relationships between the market penetration (the ultimate measure of commercialization) and commercial readiness:

- Commercial readiness begins prior to introduction of the product into the marketplace.
- The commercial readiness process begins to unfold significantly in the "development" phase of commercialization.
- During the "introduction" phase, rapid progress is made in attaining commercial readiness. Commercial readiness is expected to increase at an increasing rate.
- When the market penetration curve begins to increase at an increasing rate, all factors determining or facilitating market acceptance are in place or close to being in place. Hence, the commercial readiness curve continues to increase, but at a decreasing rate.

Due to the problems of data availability and interpretation, the possibility exists that CRI ratings will have some degree of imprecision in them. One means for dealing with imprecision is to stratify the CRI scale 0-100 into classes and focus on classes instead of specific numeric values. As Figure 1-1 shows the CRI scale has been structured into five stages

(1) Stage I ($0 < CRI \leq 15$): Little or no progress towards commercial readiness

(2) Stage II ($15 < CRI \leq 35$): Initial slow, steady progress

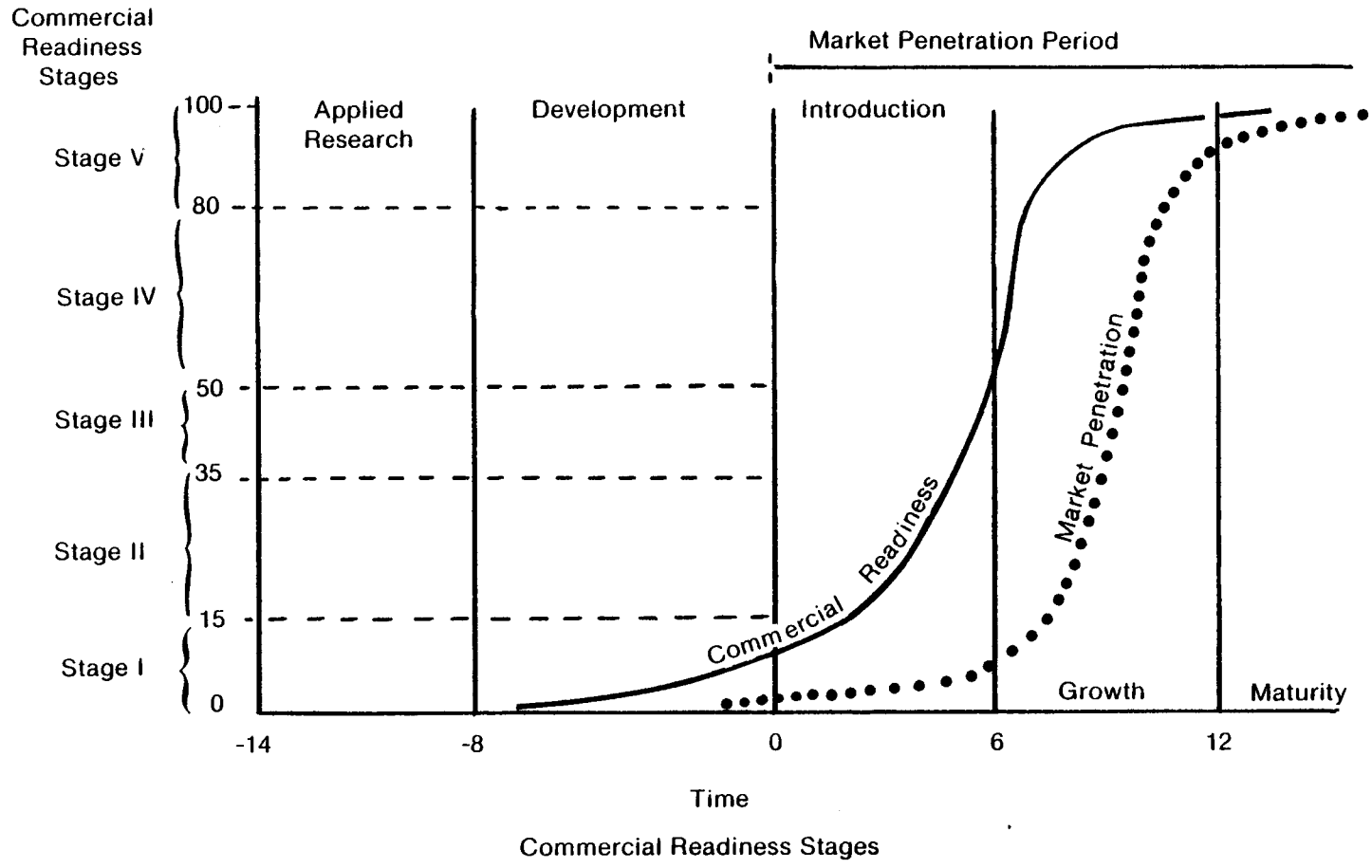
(3) Stage III ($35 < CRI \leq 50$): Initial accelerated progress

(4) Stage IV ($50 < CRI \leq 80$): Adv ced accelerated program

(5) Stage V ($80 < CRI \leq 100$): Commercially ready

Consequently, it is possible to state, for example, either of the following:

- CRI rating, as of the end of FY80, for central wind/large utilities was 43; or
- CRI rating for this application as of the end of FY80 fell in Stage III of the CRI scale: "Initial Accelerated Progression toward Commercial Readiness."



Stage I: Little or No Progress

State II: Initial Slow, Steady Progress

State III: Initial Accelerated Progress

State IV: Advanced Accelerated Progress

State V: Commercially Ready

Figure 1-1. Commercial Readiness Index (CRI)

SECTION 2.0

SOLAR COMMERCIAL READINESS ASSESSMENT METHODOLOGY

2.1 METHODOLOGY RATIONALE

One objective of the nation's evolving National Energy Policy is to lessen dependence on foreign-produced oil by stimulating usage of solar energy--especially for:

- Water heating and space conditioning in buildings
- Generating electricity
- Industrial processes
- Agriculture.

As part of this policy, the Federal Government is attempting to accelerate the commmercialization of the solar technologies.

However, national (and regional) planning to effect the accelerated commercialization of the various solar technologies in specific applications must address four major issues:

- Specification of the multidimensional array of things to be done and/or conditions that must hold in order to attain market acceptance--things to be done by
  - The Federal Government
  - State and local governments
  - Industry
  - Others (e.g., R&D performers, financial community, etc.).

  Examples of things to be done include:
  - Problem resolution - technical
  - Problem resolution - economic
  - Barrier removal
  - Enactment of incentives programs by the Federal Government
  - Getting strategic players involved (e.g., financiers, producers, etc.).
- Specification of "good" solutions for each thing to be done:

  For each thing to be done, an objective/goal must be established which, if attained, facilitates commercialization.
- Ranking and sequencing of the things to be done given the set of things to be done, effective commercialization planning requires an understanding of:
  - The relative importance of each thing to be done
  - Order in which they should be addressed.

- Assessment of progress being made in attaining the goal/objective established for each indicator.

  For each thing to be done, given its goal/objective, the final issue is to determine progress towards the goal.

Clearly, the four issues are interrelated. The SERI Commercial Readiness Assessment (CRA) Methodology is a system procedure for addressing all four issues, but focusing on the last--assessment of the relative degree of progress being made in preparing the solar technology/application for the marketplace. More specifically, it is a strategy for:

(a) Obtaining a "consensus" regarding what needs to be done to commercialize a solar technology/application

(b) Obtaining a "consensus" regarding the relative importance of the things to be done

(c) Establishing a goal/objective for each thing to be done

(d) Qualitatively and numerically assessing progress towards commercial readiness.

Items (a), (b) and (c) above are achieved via the following:

- Field surveys of representative actual (or potential) end users and their associations
- Field surveys of representative actual (or potential) producers and their associations
- Analysis of the literature
- Discussions with the cognizant DOE program office(s)
- Discussions with the regional solar energy centers
- Discussions with the cognizant SERI elements.

Numerical commercial readiness assessments are generated using the Commercial Readiness Assessment algorithm.

Figure 2-1 graphically depicts the structure of the methodology.

2.2 METHODOLOGY LOGIC: MACRO DESCRIPTION

The SERI CRA methodology is a generalized structured procedure for measuring and assessing the progress being made in commercializing a solar technology in a specific application. Like many other operations research tools--linear programming, for example--the SERI methodology consists of a structured framework and a computational algorithm. An analyst adapts the methodology to the general and unique features--with respect to commercialization--of the technology/application under investigation.

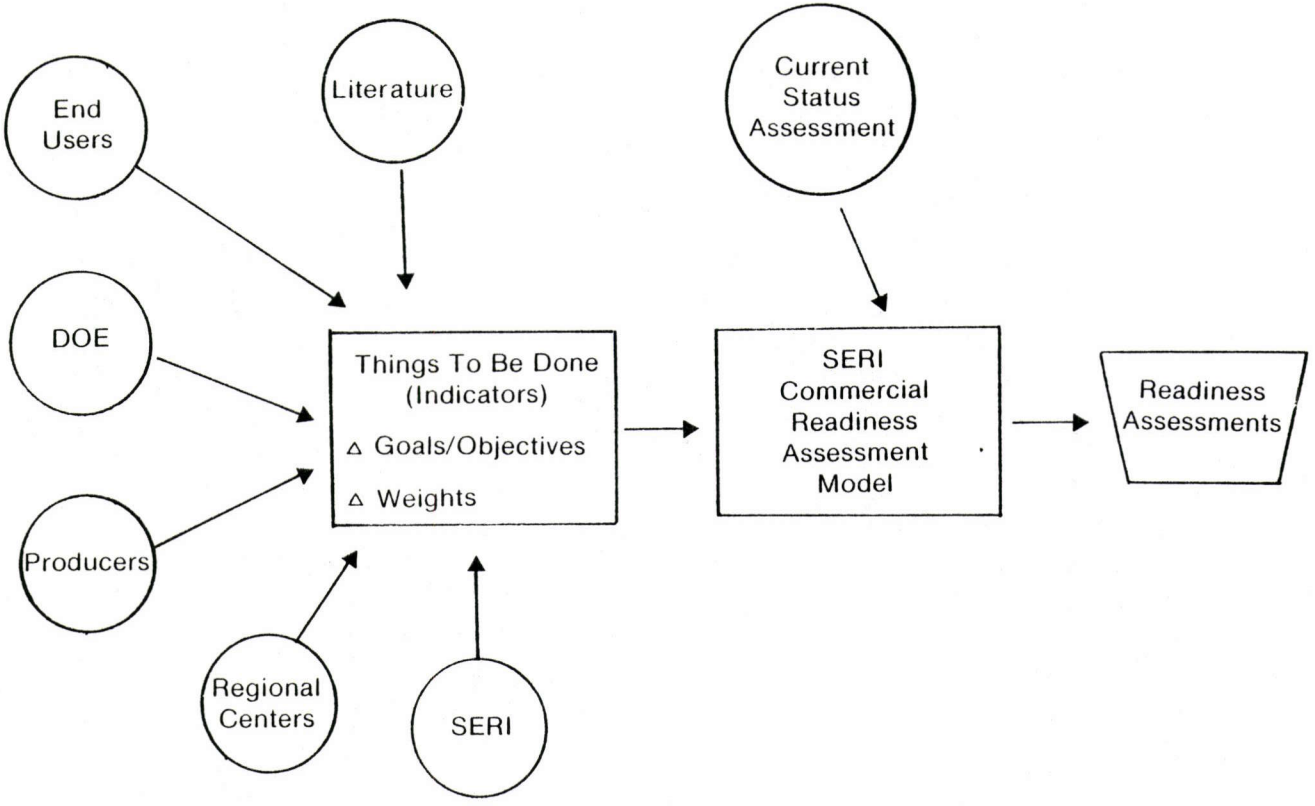


Figure 2-1. SERI Commercial Readiness Assessment Methodology

The methodology can be used to assess the commercial readiness of any solar technology/application for which the following conditions hold:

- The Federal Government is attempting to accelerate the commercialization of the technology/application: efforts are being made to speedup the process whereby a new technology competes with and replaces an existing one.
- For the subject technology/application, the Federal Government is not the principal end user.
- A proven, well-developed conventional alternative exists, as well as an industry and infrastructure.
- Potential end users are reluctant to accept the new technology; they prefer the conventional alternative. Their reluctance is due primarily to the following reasons:
  - Uncertainties regarding the mechanical performance and reliability of the solar technology
  - Uncertainties regarding economic performance
  - High initial cost of the solar technology.
- The overwhelming majority of the funds needed to develop and commercialize the new technology came from the Federal Government.
- Commercial readiness indicators (i.e., things to be done) can be specified for which
  - Goals at commercial readiness--quantitatively stated--can be specified
  - Data are available for determining the current status of each indicator relative to its goal.

The CRA methodology can be used to:

- Track and measure the progress being made towards commercialization of the subject solar technology/application from year-to-year, using a common frame of reference
- Identify information gaps
- Identify problem areas--just as the Consumer Price Index identifies problem areas (i.e., areas where prices are rising fastest)--the CRA methodology identifies commercialization problem areas
- Facilitate commercialization and RD&D program planning and determination of funding priorities
- Show the overall progress being made in commercializing a solar technology across all applications; for example:
  - Wind technology applications
    1. Central wind/large utilities
    2. Central wind/small utilities
    3. Distributive wind/residences
    4. Distributive wind/agriculture

- Overall wind technology CRI = $\sum_{\alpha=1}^{4} (MP)_\alpha (CRI)_\alpha$

  where

  α = the α^{th} application

  $(MP)_\alpha$ = relative market potential (percentage) of application α

  $(CRI)_\alpha$ = commercial readiness index for application α.

- Compare, quantitatively, the relative progress being made in commercializing different solar technologies for the same application (for example, OTEC versus central wind for generation of electricity by large utilities).

Figure 2-2 depicts, macroscopically, the steps in the methodology. Explanations are provided in following sections.

A large-scale computer is not necessary. However, if used, the optimum roles for a computer are:

- Data base storage and maintenance
- Computation of the figure of merit
- Sensitivity analyses.

2.3 COMMERCIAL READINESS INDEX EQUATION

The SERI quantitative measure of solar commercial readiness is the Commercial Readiness Index (CRI). CRI is a relative measure, on an interval scale 0-100, of progress towards commercial readiness.

In formulating the CRI equation, the following assumptions were utilized:

- For any solar technology/application, the governing market penetration curve, as a function of time, follows an S-shaped pattern
- Commercial readiness--as measured by the CRI equation--begins to unfold in the "development" stage of the commercialization process (see Fig. 1-1)
- Commercial readiness, as a process, proceeds as follows:
  - Initially, slow growth
  - After slow growth, growth at an increasing rate, especially when the technology/application becomes available commercially
  - When the governing market penetration curve enters the growth stage, commercial readiness stops increasing at an increasing rate. It continues to increase, but at a declining rate.

    Hence, commercial readiness follows an S-shaped curve.
- Most solar technologies/applications are considered to have reached "full commercial readiness" when they attain a CRI rating of 80-90. A CRI rating of 100 is probably unobtainable. The case of the automobile clarifies this assumption. It is generally agreed that private

- **For the Solar Technology under Investigation**
  - **Specify the Applications/Markets to be Assessed**
- **For Each Application/Market Assessed**

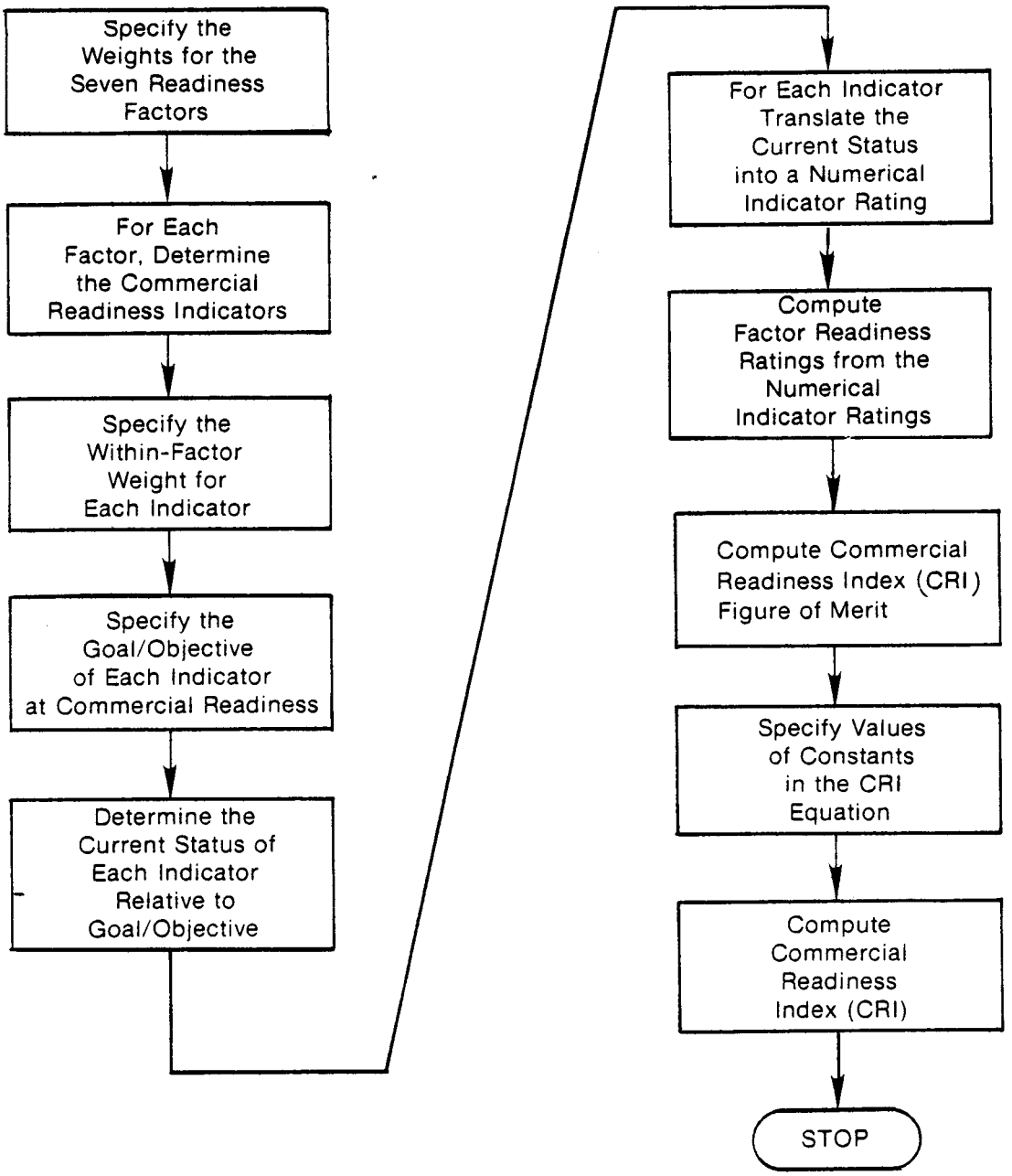


Figure 2-2. Flow Diagram: Solar Technology Commercial Readiness Assessment Methodology

automobiles attained commercial readiness/market acceptance in the mid- to late 1920s. If the SERI methodology had been available in the 1920s to track automobile commercial readiness, one of the factors going into the CRI figure of merit would have been "human safety." Although automobiles would have attained a CRI rating of 80-90 by 1929, the rating probably has not improved much as of the end of 1978, because of "human safety." The fact that Americans kill each other at the rate of 50,000 per year and injure each other at the rate of 5.575 million per year--resulting in economic losses of $47.7 billion per year [5]--keeps the CRI rating from approaching 100.

The CRI equation is given by

$$CRI(I,J,K,t,FOM) = \left\{ \frac{(FOM) \exp\left[\left(\frac{t - t^{o}}{\beta}\right)\left(1 - \frac{1}{FOM}\right)\right]}{1 + \alpha\,(FOM) \exp\left[\left(\frac{t - t^{o}}{\beta}\right)\left(1 - \frac{1}{FOM}\right)\right]} \right\} 100$$

where

I = solar technology

J = conventional competition

K = application

t = time at which the assessment is being made (e.g., 1978)

t_o = time at which CRI equals some reference value CRI_o

α = scale factor

β = time constant

FOM = CRI figure of merit

$$FOM = \sum_{f} W_f \sum_{i} w_i \, (IR_i)$$

f = factor number ($f = 1, 2, \ldots, 7$)

i = commercial readiness indicator ($i = 1, 2, \ldots, I_f$)

W_f = relative weight attached to factor f

w_i = relative weight attached to indicator i

IR_i = current status of indicator i relative to its goal at commercial readiness

The CRI equation is characterized as follows:

- CRI (I,J,K,t,FOM) = Commercial readiness of solar technology "I" competing against conventional alternative "J" in application "K" during year "t," given that its readiness figure of merit is "FOM."
- CRI is a nondecreasing function of time.
- $CRI_{Minimum\ readiness}$ = 0 (CRI = 0 denotes no progress towards commercial readiness)
- $CRI_{Maximum}$ = 100 (CRI = 100 denotes complete commercial readiness)
- CRI stops growing at an increasing rate when market penetration reaches 5-20%, depending upon the solar technology/application.
- CRI figure of merit is a function of seven factors.

2.4 COMMERCIAL READINESS FACTORS AND INDICATORS

2.4.1 Commercial Readiness Factors

For the solar technology/application being assessed, the figure of merit in the CRI equation (see Section 2.3) is a function of seven commercial readiness factors:

- End-user requirements (noneconomic)
- Producer requirements
- Costs and economics
- Technology requirements
- Government initiatives
- Legal/institutional/environmental issues
- Market development.

Table 2-1 describes and details the types of commercialization issues covered under each factor.

Each factor is assigned a weight, W_f, reflecting its relative importance in the technology/application under investigation.

The analyst is responsible for assigning factor weights. They can be derived via the following:

- Surveys of cognizant federal solar program planners
- Analysis of the literature relating to the subject solar technology/application
- Surveys of manufacturers
- Delphi (or equivalent) conferences consisting of respected, knowledgeable individuals.

Table 2-1. COMMERCIAL READINESS FACTORS

Commercial Readiness Factors	Types of Commercialization Issues Covered
End-User Requirements (Noneconomic)	• Concerns of and issues expressed by actual or potential end users that are - Noneconomic - Not covered under other factors • EXAMPLES: - Long-term reliability of the solar system - Warranties
Producer Requirements	• Concerns of issues expressed by producers of the technology that relate directly to producers • Problems that must be resolved or conditions that must hold in order for producers to invest in the solar technology • EXAMPLES: - Return on investment - Availability and cost of capital
Cost and Economics	• Cost and economic performance criteria demanded by end users • EXAMPLES: - System payback period - System installed cost
Technology Requirements	• Technical and engineering performance criteria demanded by end users and the Federal Government • EXAMPLES: - Expected useful life requirement - System maintainability requirements
Government Initiatives	• Activities and programs of governments--Federal, State, and local • Programs and actions demanded of governments by producers and end users • EXAMPLES: - Federal procurement program - Tax credits for end users
Legal/Institutional/ Environmental Issues	• Legal issues • Institutional issues • Environmental issues • EXAMPLES: - Utility rate structures favorable to solar energy - Solar access
Market Development	• Activities in the subject solar industry and its infrastructure • End-user awareness • EXAMPLES: - Number of solar system financiers - Number of producers

2.4.2 Commercial Readiness Indicators

Each factor consists of one or more commercial readiness indicators. Indicators are (or relate to):

- Things to be done to effect commercial readiness
- Specific conditions that must hold
- Problems and issues to be resolved
- States of nature that must exist.

Collectively, the indicators embrace all issues, problems, and requirements relating to commercializing a solar technology/application.

For example, in assessing the commercial readiness of central wind systems/large utilities, the following indicators are included under "End-User Requirements (Noneconomic)":

- Availability and cost of capital
- Availability of insurance
- Wind system mechanical reliability
- Dispatch techniques
- Availability of wind resource data
- Availability of responsive and reliable design, installation, and maintenance services.

These are important issues and concerns of potential end users that affect their propensity to buy.

In applying the methodology to various solar technologies/applications, the same seven factors are always used. However, the indicators included under each factor vary, depending upon the specific features of the technology/application.

Just as a weight is assigned to each factor, a relative weight, w_{fi}, is assigned to each indicator within that factor--providing a measure of the importance of the indicator relative to the others. Hence, the methodology involves a dual weighting scheme:

- Factor weights W_f: where $W_f = 1.0$
- Indicator weights w_{fi}--within each factor the indicator weights sum to 100: $\sum w_{fi} = 100$ for factor f.

The analyst assigns indicator weights. Resources to be used in formulating the weights include:

- Representative producers
- Representative end users
- Persons of recognized standing in
  - Universities

  - Regional solar energy centers
  - DOE RD&D contractors
  - SERI
- Current literature relating to the subject solar technology/application
- DOE program planners.

The CRA methodology centers around the indicators. The two most crucial tasks in using it are:

- Specification of the indicators associated with each of the seven factors. The CRI figure of merit and, ultimately, the CRI rating, is a function of the set of indicators.
- Specification of the goal/objective--preferably, quantitatively--of each indicator at commercial readiness.

In the CRA methodology, the subject solar technology/application is deemed to have attained full commercial readiness at that point in time when each indicator meets or exceeds its defined goal/objective. For example, if 50 indicators are utilized, full commercial readiness is not attained until the goal-objective specified for each is met or exceeded.

Since the methodology centers around the indicators, it is imperative that analysts using it:

- Select one or more indicators for each factor that figures heavily in getting the subject solar technology/application commercialized
- Select indicators for which well-defined quantitative (or qualitative) goals/objectives can be established and measured
- Specify a goal/objective for each indicator for which data are available (or can be obtained) to assess the current status of the indicator relative to its goal.

As an example of the care that must be exercised in selecting indicators and specifying their goals/objectives, consider a problem encountered by SERI in assessing the commercial readiness of solar water heating for new single family homes (tract construction). "Number of solar system producers" was included as an indicator for the factor "Market Development." Lists of "solar manufacturers" are available from many sources. However, no data were available which carefully delineated manufacturers that had production facilities and marketable solar systems from manufacturers that:

- Had plans, but no marketable products
- Had patents, but no production facilities or products
- Had products, but no sales since inception
- Manufactured solar components, but did not produce solar systems
- Existed solely because of government RD&D programs.

Hence, the following goal/objective was established for the indicator:

- Entry of at least 50% of the 10 largest producers of conventional gas and electric residential water heaters into the production and marketing of solar water heaters.

Data were readily available for assessing the current status of this indicator relative to the goal.

As was mentioned earlier, the methodology is market-oriented and focuses on three key participants: end users, producers, and the Federal Government. Therefore, in selecting indicators and establishing their goals/objectives at commercial readiness, the user should:

- Ensure that he or she understands how the application under investigation functions:
  - Who are the equipment decision makers
  - Their decision-making criteria
  - Who influences the decision makers
- Query representative end-user associations (Electric Power Research Institute, in the case of electric utilities, for example) regarding commercialization issues
- Query representative end users that are perceived as trendsetters by the wider end-user community regarding end-user needs
- Query representative producers regarding their needs and the functioning of the market.

Table 2-2 lists the complete set of factors and indicators used in the central wind systems/large utilities assessment. For the factor "End-User Requirements (Noneconomic)," Table 2-3 shows the associated indicators and their goals.

Given the indicators and their goals, the quantitative assessment is performed by:

- Determining the current status of each indicator
- Comparing the current status of each indicator with the goal/objective
- Quantifying the difference between the current status and the goal-objective.

Figure 2-3 summarizes this discussion of factors and indicators.

2.5 COMPUTATION OF INDICATOR READINESS RATINGS AND FACTOR READINESS RATINGS

Once the best set of indicators associated with each of the seven factors is selected and their goals/objectives established, the next major tasks in applying the CRA methodology are to:

- Compute the indicator readiness ratings
- Compute the factor readiness ratings.

Since the commercial readiness of the solar technology/application is assessed as of a specific time (for example, as of the end of calendar year 1978), it

Table 2-2. COMMERCIAL READINESS FACTORS AND INDICATORS

Solar Technology/Application: Central Wind Systems/Large Utilities

Commercial Readiness Factors Associated Indicators	Factor Weight (Scale: 0-1)	Indicator Weight (Scale: 0-100)
End-User Requirements (Noneconomic):	0.10	
• Availability of Financing		15
• Availability of Insurance		10
• WECS Mechanical Reliability		40
• Dispatch Techniques		10
• Availability of Wind Resource Data		10
• Availability of Responsive and Reliable WECS-Specific Design, Installation, Spares, and Maintenance Services		15
		100
Producer Requirements:	0.08	
• Availability and Cost of Capital		15
• Return on Investment		50
• Availability of Product Liability Insurance		10
• Utility Rate Structures		25
		100
Cost and Economics:	0.24	
• System Installed Cost		100
		100
Technology Requirements	0.20	
• Rotor Assembly		20
• Drive Train		12
• Yaw		10
• Tower Assembly		10
• Other WECS Subsystems and Installation		12
• Operation and Maintenance		6
• System Performance		20
• Transients		10
		100

Table 2-2. COMMERCIAL READINESS FACTORS AND INDICATORS (concluded)

Solar Technology/Application: Central Wind Systems/Large Utilities

Commercial Readiness Factors Associated Indicators	Factor Weight (Scale: 0-1)	Indicator Weight (Scale: 0-100)
Government Initiatives	0.14	
• Federal Procurement Program		35
• Federal Wind Program RD&D Funding Distribution (Annual)		20
• Federal Funding Plans		15
• Federal Special Financial Incentives for Producers		7
• State Special Financial Incentives for Producers		3
• Federal Special Financial Incentives for Utilities		12
• State Special Financial Incentives for Utilities		8
		100
Legal/Institutional/Environmental Issues	0.10	
• Television Signal Interference		15
• Aesthetics		5
• Noise/Infrasound		5
• Wind Rights		30
• Safety/Liability Issues		10
• Land Use		10
• Utility Interconnection Issues		25
		100
Market Development	0.14	
• Extent of Cumulative Market Penetration		50
• Extent and Quality of Published Market Development/Marketing Research Information		5
• Number of Central WECS Manufacturers		15
• Consensus Standards		5
• Industry, Professional, and Trade Journals		5
• Strong, Respected, and Active Trade Association		5
• End-User Awareness		15
		100

Table 2-3. EXAMPLES OF COMMERCIAL READINESS INDICATORS AND GOALS/OBJECTIVES

Factor: End-User Requirements (Noneconomic)

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales
WECS Mechanical Reliability	40	• WECS mechanical reliability at least equal to those for a conventional coal or oil-fired plant. • WECS availability of at least 90%.	• Utilities demand reliability in all of their generating equipment. • According to EPRI, annual availability of oil-fired equipment averages 80.2%. • NASA-Lewis/DOE goal for the MOD-OA wind machine is 90% availability.
Availability of Financing	15	• Capital availability to utilities from traditional sources (or mechanisms) and at rates approximately equal to those for acquiring conventional generating equipment.	• Expensive capital or capital available only under restrictive terms - Constitutes barriers to market acceptance - Serves to increase the cost of producing energy.
Availability of Property and Liability Insurance	10	• WECS property and liability insurance available to utilities from traditional insurers and at rates comparable to those for conventional generating equipment.	• Recommendation of DOE Large Wind Systems Commercialization Task Force. • Expensive insurance or unavailability of insurance barriers to market acceptance.

Table 2-3. EXAMPLES OF COMMERCIAL READINESS INDICATORS AND GOALS/OBJECTIVES (concluded)

Factor: End-User Requirements (Noneconomic)

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales
Availability of Responsive, Reliable, and Experienced WECS-Specific Design, Installation, Parts, and Maintenance Services	15	• Entry of 50% of the largest manufacturers of conventional generating equipment into central WECS production. • Entry of 50% of the 10 largest utility A&E firms into central WECS design.	• Manufacturers of conventional equipment entering WECS have their own presently existing power systems service network. This can be used for providing services for WECS. • A&E's are a major factor in providing design installation services. Their entry is essential for development of the industry infrastructure.
Dispatch Techniques	10	• Utility planning models which permit analysis of wind systems in the utility's mix of generating equipment. • Validated techniques and algorithms form the dispatch of WECS-produced electricity.	• Existing dispatching techniques are not capable of addressing wind generators.
Availability of Wind Resource Data	10	• Systematic collection and cataloging of wind resource data at the sub-county level--data suitable for central WECS site indentification--for the 10 states having the greatest central-WECS market potential.	• Major need as determined by two-year GE/EPRI study. • Utilities mention need for wind resource data for appropriate siting.

- **For Each Application of the Solar Technology under Assessment:**

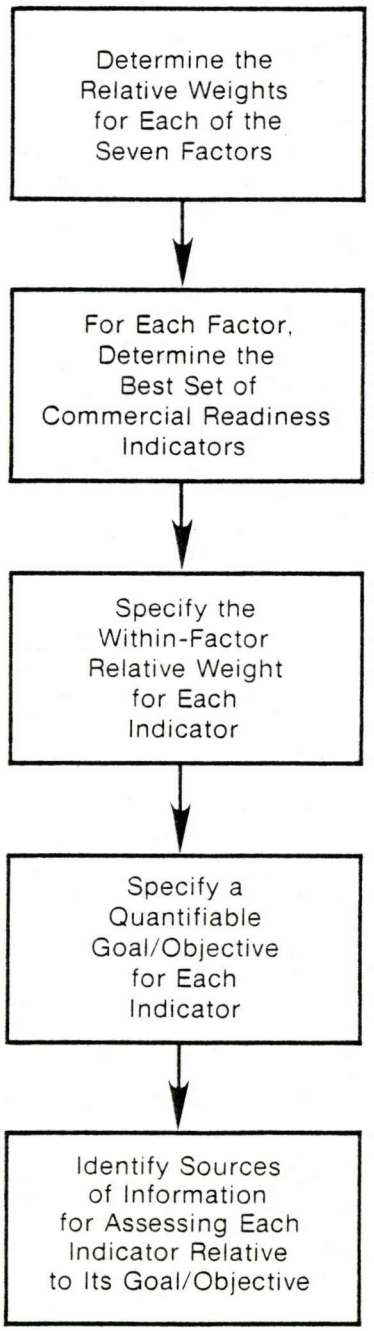


Figure 2-3. Steps Involved in Specifying and Establishing Goals/Objectives for Commercial Readiness Indicators

is vital in performing the above-mentioned computations to identify explicitly the assessment time frame.

2.5.1 Indicator Readiness (IR_i) Ratings

For each indicator, given its goal/objective, the indicator readiness rating is obtained by:

- Comparing the status of the indicator--as of the assessment time frame--to its goal at commercial readiness
- Translating the difference between the current status and the goal into a numerical rating.

Hence, the indicator readiness rating (IR_i) for indicator i is the quantitative measure of how that indicator fares--as of the assessment time frame--relative to its goal/objective. Indicator readiness rating has the following properties:

- Scale: $0 \leq IR_i \leq 1$
- $IR_i = 0$: no real progress has been made in attaining the goal-objective established for indicator i, as of the assessment time frame.
- $IR_i = 1$: the goal/objective established for indicator i has been met or exceeded.
- $0 < IR_i < 1$: some progress has been made in meeting the goal/objective defined for indicator i.
- If $0 < IR_i < 1$, then $(1.0 - IR_i)$ represents the progress that must be achieved in order to reach the goal.

The precision with which the indicator readiness ratings can be determined, as well as the ease or difficulty in performing the computations, are directly related to the manner in which the goals/objectives are specified. Specification of a numerical goal--where possible--for an indicator facilitates computation of IR_i and increases its precision. For example:

- Indicator: number of central WECS manufacturers
- Goal specified for the indicator at commercial readiness: entry of at least 50% of the 10 largest producers of conventional generating equipment into the manufacture and sale of wind systems
- Current status as of the end of 1978: 2 of the 10 largest producers manufacture and market wind systems for utility application
- Indicator readiness rating: since two of five producers satisfy the conditions stated in the goal, IR = 0.4
- Progress yet to be attained: encourage at least three more conventional equipment producers to begin wind manufacturing and marketing ventures.

Indicators for which qualitative goals/objectives have been established are the most troublesome to assess precisely. By definition, if a goal is expressed qualitatively, it is either met or not met--hence, the indicator has a readiness rating of 1.0 or 0.0. This problem is ameliorated, however, if for such indicators the readiness rating is used to express:

- Relative progress towards the goal/objective, or
- The "quality" of the progress.

A hypothetical example clarifies this issue:

- Factor: Government initiatives
- Indicator: Federal tax credit program for utilities
- Goal established for the indicator at commercial readiness: Establishment of a multiyear federal tax credit program providing at least a 10% investment tax credit for utilities acquiring wind systems
- Indicator current status as of the end of 1978: No federal tax credit program was in effect. However, a tax credit bill--providing a 12% investment tax credit for utilities acquiring wind systems between 1978 and 1985--was approved by the House Energy Committee. The full House is expected to consider the bill in late 1979.
- Indicator readiness rating: IR_i - 0.2
- Rationale for the indicator readiness rating: Although no legislation was in effect, progress had been made in 1978 towards enactment of such legislation. Hence, the readiness rating provides a numerical measure of progression towards the goal.

In the above example, different analysts might assign different readiness ratings to the indicator because the goal is qualitatively expressed. However, the exact value is not particularly important. The important issue is that the goal has not been met. During the current fiscal year, efforts must be devoted to attaining it. Also, if the exact value of the rating were important, its impact on the CRI figure of merit could be easily assessed via a sensitivity analysis.

Table 3-3 (of Section 3.3) shows examples of indicator readiness ratings.

2.5.2 Factor Readiness (FR_f) Ratings

For factor f, the factor readiness rating FR_f (f = 1, 2, . . . , 7) is the numerical measure of factor progress. It is computed by summing the products of the indicator ratings and indicator weights:

$$FR_f = \sum_{i=1}^{L_f} w_i \, IR_i$$

where

FR_f = factor readiness rating for factor f

i = i^{th} indicator included under factor f

w_i = relative weight of the i^{th} indicator

IR_i = indicator readiness rating for indicator i

L_f = number of indicators included under factor f.

The factor readiness rating has the following properties:

- Scale: $0 \leq FR_f \leq 100$
- $FR_f = 0$: no progress towards commercial readiness has been made in any of the indicators included under factor f
- $FR_f = 100$: all indicators associated with factor f meet or exceed their goals/objectives.

If $FR_f < 100$, there are indicators associated with factor f for which $IR_i \neq 1.0$. Hence, efforts should be devoted to achieve the goals established for such indicators.

2.6 COMPUTATION OF THE CRI FIGURE OF MERIT

The figure of merit (FOM) entered into the CRI equation is derived from the seven factor readiness ratings as described in Section 2.5:

$$\text{CRI figure of merit} = \sum_{f=1}^{7} W_f \, FR_f$$

where

f = factor number

W_f = relative weight assigned to the f^{th} factor

FR_f = factor readiness rating for the f^{th} factor.

The CRI figure of merit has the following characteristics:

- It represents an overall measure of commercial readiness that embraces all players and issues that determine or facilitate commercialization
- Scale: 0 - 100
- CRI figure of merit = 0 if and only if each of the seven commercial readiness factors have zero readiness ratings
- CRI figure of merit = 100 only if the readiness rating for each factor is 100, implying that the goal/objective established for every indicator has been met or exceeded.

2.7 CRI RATING AND CRI EQUATION

For any solar technology/application, the CRI rating is a function of:

- CRI figure of merit
- Time.

CRI rating is obtained by entering the two values into the CRI equation:

$$CRI(I,J,K,t,FOM) = \left\{ \frac{(FOM) \cdot \exp\left[\left(\frac{t - t_o}{\beta}\right)\left(1 - \frac{1}{FOM}\right)\right]}{1 + \alpha \cdot (FOM) \cdot \exp\left[\left(\frac{t - t_o}{\beta}\right)\left(1 - \frac{1}{FOM}\right)\right]} \right\} 100$$

where

I = solar technology (e.g., central wind)

J = conventional competition (e.g., gas turbine generator)

K = application (e.g., generation of electric power)

t = time at which commercial readiness is being assessed (e.g., 1978)

FOM = CRI figure of merit

t_o = time at which CRI equals some reference value CRI_o

α = scale factor

β = time constant.

Properties and characteristics of the CRI rating and CRI equation are described in Section 2.3.

2.8 CRA METHODOLOGY: SUMMARY

As mentioned earlier, the SERI CRA methodology consists of a structured framework and a computational algorithm. The major steps involved in applying it were presented in Sections 2.3 through 2.7. The following is a summary of the methodology.

For a given solar technology, utilization of the methodology requires:

- Specification of all applications/markets of interest--CRI ratings are generated for applications/markets, and not for a solar technology

- Specification of the time snapshot (e.g., end of calendar year 1978) covered by the readiness assessment.

For each application, the principal steps involved in generating the CRI rating are as follows:

1. Specify weights for the seven commercial readiness factors:
   - End-user requirements
   - Producer requirements
   - Costs and economics
   - Technology requirements
   - Government initiatives
   - Legal/institutional/environmental issues
   - Market development.
2. For each factor, specify and assign weights to all applicable commercial readiness indicators.
3. For each indicator identified in step 2, specify a goal/objective (preferably numerical) at commercial readiness.
4. For the time period covered by the assessment, determine--qualitatively and quantitatively--the current status of each indicator relative to its goal/objective.
5. For each indicator, translate the current status findings of step 4 into a numerical indicator readiness rating IR_i where:
   - $0 \leq IR_i \leq 1$
   - $IR_i = 0$ indicates that no significant progress has been made in achieving the goal/objective established for indicator i
   - $IR_i = 1$ indicates that the goal/objective specified for indicator i has been met or exceeded.
6. Using the indicator readiness ratings developed in step 5, compute the factor readiness ratings:

$$FR_f = \sum_i w_i IR_i$$

where

FR_f = readiness rating for the f^{th} factor

f = factor number ($f = 1,2, \ldots, 7$)

i = indicator number

w_i = relative weight of the i^{th} indicator associated with the f^{th} factor.

7. From the factor readiness ratings generated in step 6, compute the CRI figure of merit (FOM)

$$FOM = \sum_f W_f FR_f$$

where

W_f = relative weight of the f^{th} factor

FR_f = readiness rating for the f^{th} factor.

8. Specify values for the constants appearing in the CRI equation.

9. Compute the CRI rating for the subject solar technology/application by entering the CRI figure of merit developed in step 7 into the CRI equation.

SECTION 3.0

EXAMPLE OF APPLICATION OF THE CRA METHODOLOGY: CENTRAL WIND SYSTEMS/LARGE UTILITIES

This section provides an example of utilization of the CRA methodology: assessment of the commercial readiness of wind machines for generating electricity by large utilities. See SERI report TR-431-368 [1] for a complete assessment.

3.1 CENTRAL WIND SYSTEMS/LARGE UTILITY MARKET: MACRO DESCRIPTION

- Large utilities: public, investor-owned, and cooperative electric companies having a peak demand greater than 10 MW
- Competition for wind systems: intermediate and peak load conventional generating equipment:
  - Diesel
  - Gas turbine
  - Oil
- Assessment time period: as of the end of calendar year 1978.

For large utilities, the DOE/NASA MOD-2 wind machine was selected as the reference system. Prime contractor for this machine is Boeing Engineering and Construction Company. Major MOD-2 characteristics are as follows:

- Rated power: 2500 kW at a wind speed of 27.7 mph
- Axis: horizontal
- Propeller type: two-bladed
- Rotor diameter: 300 ft
- Cut-in wind speed: 14 mph
- Cut-out wind speed: 45 mph
- Tower height: 200 ft at the hub
- Tower construction: 150 ft long, 10-ft diameter cylindrical steel tube, flaring out to 21 ft at the base.

For the one hundredth machine, the DOE/NASA goal is generation of electricity at a cost of less than $0.04/kWh.

Utilities are expected to employ wind machines in farms consisting of at least five machines. SERI examined commercial readiness on the basis of wind farms of 25 MOD-2 machines. Figure 3-1 depicts the wind farm configuration. The 25 machines are organized into five-machine clusters. The spacing between machines is at least 10 rotor diameters. Each machine incorporates a step-up transformer that increases the output voltage to 13.8 kV for transmission to a cluster substation.

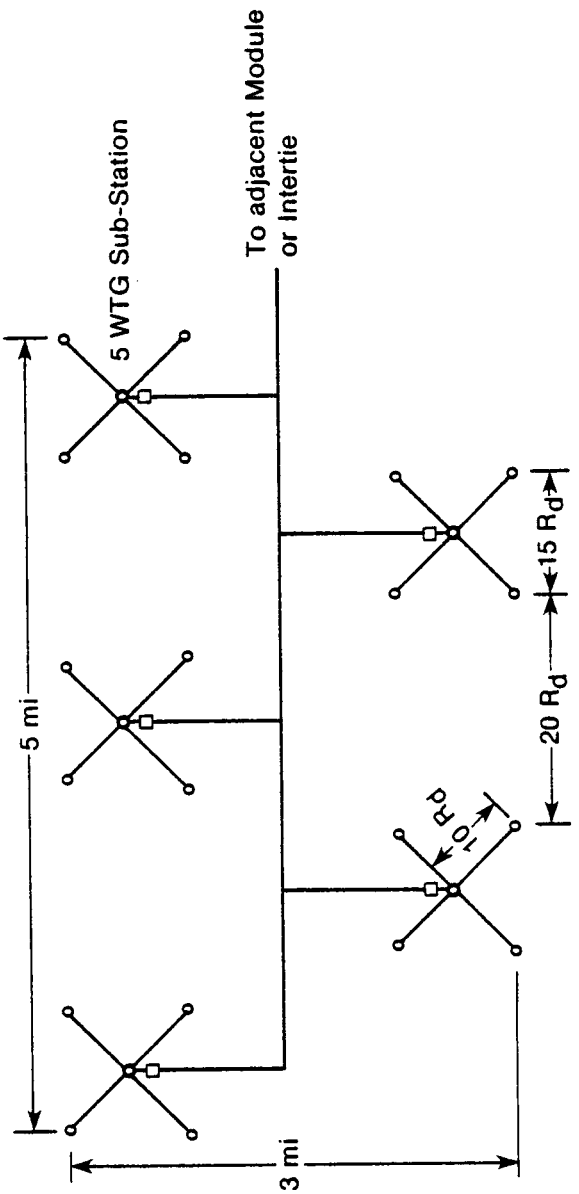


Figure 3-1. Schematic Diagram - 25 WTG Wind Farm Module, Large Utility Application

Wind farm cost elements include:

- Wind machines
- Transportation of machines to site
- Land acquisition
- Land preparation
- Wind machine installation
- Transformers
- Substations
- Safety systems and equipment
- Power conditioning equipment.

3.2 COMMERCIAL READINESS FACTORS AND INDICATORS: RELATIVE WEIGHTS

Table 3-1 shows each of the seven factors and their associated indicators. Factor and indicator weights are also shown. The bases for the weights are as follows:

- Factor and indicator analyses by the SERI project staff
- Factor and indicator reviews by:
  - Other SERI branches
  - Representative producers
  - Representative utilities.

3.3 COMMERCIAL READINESS INDICATORS: GOALS/OBJECTIVES AND RATIONALES

For each of the seven factors, Tables 3-2 through 3-8 show:

- Associated indicators
- Goal/objective established for each indicator at commercial readiness
- Rationale(s) behind the goals/objectives.

For the central wind/large utility application, commercial readiness is a function of 41 indicators. Appendix A shows the current status of each indicator relative to its goal, as of the end of 1978.

When the set of indicators was initially developed some indicators were included several times, appearing under more than one factor. For example, in addition to the four indicators listed in Table 3-1 under "Producer Requirements," other issues of extreme importance to producers were:

- Federal financial incentives for end users
- State financial incentives for end users
- Federal financial incentives for producers
- State financial incentives for producers
- Utility interconnection issues
- Federal procurement program.

Producers recommended, for example, that Congress authorize and fund a federal central wind procurement program. For such a program, the Federal Government

Table 3-1. COMMERCIAL READINESS FACTORS AND INDICATORS: RELATIVE WEIGHTS

Solar Technology/Application: Central Wind Systems/Large Utilities

Commercial Readiness Factors Associated Indicators	Factor Weight (Scale: 0-1)	Indicator Weight (Scale: 0-100)
End-User Requirements (Noneconomic):	0.10	
• Availability of Financing		15
• Availability of Insurance		10
• WECS Mechanical Reliability		40
• Dispatch Techniques		10
• Availability of Wind Resource Data		10
• Availability of Responsive and Reliable WECS-Specific Design, Installation, Spares, and Maintenance Services		15
		100
Producer Requirements:	0.08	
• Availability and Cost of Capital		15
• Return on Investment		50
• Availability of Product Liability Insurance		10
• Utility Rate Structures		25
		100
Cost and Economics:	0.24	
• System Installed Cost		100
		100
Technology Requirements:	0.20	
• Rotor Assembly		20
• Drive Train		12
• Yaw		10
• Tower Assembly		10
• Other WECS Subsystems and Installation		12
• Operation and Maintenance		6
• System Performance		20
• Transients		10
		100

Table 3-1. COMMERCIAL READINESS FACTORS AND INDICATORS: RELATIVE WEIGHTS (concluded)

Solar Technology/Application: Central Wind Systems/Large Utilities

Commercial Readiness Factors Associated Indicators	Factor Weight (Scale: 0-1)	Indicator Weight (Scale: 0-100)
Government Initiatives:	0.14	
• Federal Procurement Program		35
• Federal Wind Program RD&D Funding Distribution (Annual)		20
• Federal Funding Plans		15
• Federal Special Financial Incentives for Producers		7
• State Special Financial Incentives for Producers		3
• Federal Special Financial Incentives for Utilities		12
• State Special Financial Incentives for Utilities		8
		100
Legal/Institutional/Environmental Issues:	0.10	
• Television Signal Interference		15
• Aesthetics		5
• Noise/Infrasound		5
• Wind Rights		30
• Safety/Liability Issues		10
• Land Use		10
• Utility Interconnection Issues		25
		100
Market Development:	0.14	
• Extent of Cumulative Market Penetration		50
• Extent and Quality of Published Market Development/Marketing Research Information		5
• Number of Central WECS Manufacturers		15
• Consensus Standards		5
• Industry, Professional, and Trade Journals		5
• Strong, Respected, and Active Trade Association		5
• End-User Awareness		15
		100

Table 3-2. COMMERCIAL READINESS INDICATORS: WEIGHTS, GOALS, AND RATIONALES

Factor: End-User Requirements

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales	Source(s)
WECS Mechanical Reliability	40	• WECS mechanical reliability at least equal to those for a conventional coal or oil-fired plant -WECS availability of at least 90%.	• Utilities demand reliability in all of their generating equipment. • According to EPRI, annual availability of oil-fired equipment averages 80.2%. • NASA-Lewis/DOE goal for the MOD-OA wind machine is 90% availability.	• SERI discussions with utilities • EPRI • NASA-Lewis/DOE
Availability of Financing	15	• Capital availability to utilities from traditional sources (or mechanisms) and at rates approximately equal to those for acquiring conventional generating equipment.	• Expensive capital or capital available only under restrictive terms -Constitutes barriers to market acceptance -Serves to increase the cost of producing energy	• SERI
Availability of Property and Liability Insurance	10	• WECS property and liability insurance available to utilities from traditional insurers and at rates comparable to those for conventional generating equipment.	• Recommendation of DOE Large Wind Systems Commercialization Task Force. • Expensive insurance or unavailability of insurance barriers to market acceptance.	• DOE Wind Systems Commercialization Plan

Table 3-2. COMMERCIAL READINESS INDICATORS: WEIGHTS, GOALS AND RATIONALES (concluded)

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales	Source(s)
Availability of Responsive, Reliable, and Experienced WECS-Specific Design, Installation, Parts, and Maintenance Services	15	• Entry of 50% of the largest manufacturers of conventional generating equipment into central WECS production. • Entry of 50% of the 10 largest utility A&E firms into central WECS design.	• Manufacturers of conventional equipment entering WECS have their own presently existing power systems service network. This can be used for providing services for WECS. • A&E's are a major factor in providing design installation services. Their entry is essential for development of the industry infrastructure.	• SERI • EPRI • GE • Westinghouse
Dispatch Techniques	10	• Utility planning models that permit analysis of wind systems in the utility's mix of generating equipment. • Validated techniques and algorithms form the dispatch of WECS-produced electricity.	• Existing dispatching techniques are not capable of addressing wind generators.	• GE/EPRI study conversations with utilities • DOE Wind Commercialization Task Force
Availability of Wind Resource Data	10	• Systematic collection and cataloging of wind resource data at the sub-county level--data suitable for central WECS site identification--for the 10 states having the greatest central-WECS market potential.	• Major need as determined by two-year GE/EPRI study. • Utilities mention need for wind resource data for appropriate siting.	• GE/EPRI • SERI survey of representative utilities

Table 3-3. COMMERCIAL READINESS INDICATORS: WEIGHTS, GOALS, AND RATIONALES

Factor: Producer Requirements

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales	Source(s)
Availability and Cost of Capital	15	• Capital available to central WECS producers from traditional sources (or via traditional mechanisms) and at customary rates and terms.	• Availability and cost of capital are among the most important criteria used by industrial firms in determining to undertake a new venture. • Availability and cost of capital affects product cost, thereby affecting selling price. • Expensive capital and restrictive terms discourages entry into WECS production.	• Standard & Poor's Stock Market Encyclopedia • SERI discussions with WECS producers
Return on Investment	50	• Return on investment (ROI) at least equal to the traditional average annual ROI attained by producers of conventional generating equipment.	• Expected return on investment is the single most important criterion used by industrial firms in determining whether to invest in a new business venture.	• Standard & Poor's Stock Market Encyclopedia • Moody's Investor Fact Sheets • SERI discussions with representative WECS producers
Availability of Product Liability Insurance	10	• Product liability insurance available to central WECS producers from traditional insurers at rates and terms comparable to those for conventional generating equipment.	• Recommendation of the DOE Large Wind Systems Commercialization Task Force. • Nonavailability of competitively-priced product liability insurance: -Increases product costs, -Discourages entry of potential producers.	• INA Special Risks • Commercialization Strategy Report for Large Wind Systems (DOE)

Table 3-3. COMMERCIAL READINESS INDICATORS: WEIGHTS, GOALS, AND RATIONALES (concluded)

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales	Source(s)
Utility Rate Structures	25	• Formulation and implementation of utility rate structures favorable to central wind systems in the 10 states having the greatest central WECS potential--rates cognizant of: -Fuel savings -Wind capacity credit.	• Recommendation of the DOE Large Wind Systems Commercialization Task Force. • Rate structures unfavorable to WECS utilization constitutes a barrier to market acceptance and discourages producer acceptance.	• SERI discussion with representative utilities • Commercialization Strategy Report for Large Wind Systems (DOE)

Table 3-4. COMMERCIAL READINESS INDICATORS: WEIGHTS, GOALS, AND RATIONALES

Solar Technology/Application: Central Wind/Large Utilities

Factor: Costs and Ecomonics

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales	Source(s)
System Installed Cost	100	• System installed cost of $800/kW (1978 $).	• System installed cost goal established by DOE. • A system installed cost of $800/kW is equivalent approximately to a levelized cost of energy of $0.04/kWh.	• DOE

Table 3-5. COMMERCIAL READINESS INDICATORS: WEIGHTS, GOALS, AND RATIONALES

Solar Technology/Application: Large Utilities

Factor: Technology Requirements

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales	Source(s)
Rotor Assembly	20	• Rotor subsystem cost of $349,000 (1978 $) for the 100th MOD-2.	• 100th MOD-2 is expected to be economically competitive in many areas of the United States with good wind sites if the cost goal is met.	• NASA/Lewis • Boeing
Drive Train (Gearbox, Generator, Shafts, Rotor Brake)	12	• Drive train subsystem cost of $402,000 (1978 $) for the 100th MOD-2.	• 100th MOD-2 is expected to be economically competitive in many areas of the United States with good wind resources if the cost goal is met.	• NASA/Lewis • Boeing
Nacelle (Structure, Shroud, Hydraulic, Yaw System)	10	• Nacelle cost of $195,000 (1978 $) for the 100th MOD-2.	• 100th MOD-2 is expected to be economically competitive in many areas of the United States with good wind resources if the cost goal is met.	• NASA/Lewis • Boeing
Tower Assembly	10	• Tower cost of $287,000 (1978 $) for the 100th MOD-2.	• 100th MOD-2 is expected to be economically competitive in many areas of the United States with good wind resources if the cost goal is met.	• Tetra Tech
Other Subsystems and Installations	12	• Cost $422,000 (1978 $) for the 100th MOD-2.	• DOE/NASA/Boeing cost goal.	• DOE • NASA/Lewis • Boeing

Table 3-5. COMMERCIAL READINESS INDICATORS: WEIGHTS, GOALS, AND RATIONALES (concluded)

Solar Technology/Application: Large Utilities

Factor: Technology Requirements

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales	Source(s)
O&M	6	• Annual O&M cost of $16,000 (1978 $) for the 100th MOD-2.	• DOE/NASA/Boeing cost goal.	• NASA/Lewis • Boeing
System Performance	20	• Rated power output of 2500 kW at a rated wind speed of 27.5 mph at the hub. • Maximum rotor power coefficient of 0.417. • Energy output of at least 9,750,000 kWh annually at a site having a wind speed of 14 mph at a 30-ft height (capacity factor of 0.45 and 90% availability). • Safe, reliable, unattended operation. • Survivable in a wind speed of 125 mph at the hub.	• System performance goals specified by DOE, NASA, and Boeing for the 100th MOD-2.	
Transients	10	• Compatibility of WECS output with utility network.	• DOE/NASA/Boeing cost goal.	• Boeing

Table 3-6. COMMERCIAL READINESS INDICATORS: WEIGHTS, GOALS, AND RATIONALES

Factor: Government Initiatives

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales	Source(s)
Federal Procurement Program	35	• Multiyear program to purchase a specified quantity of cost-effective and near cost-effective central WECS for integration into federal and quasi-federal electric systems.	• A federal procurements program is recommended by the DOE Large Wind Systems Commercialization Task Force. • Manufacturers of central WECS are in favor of such a program because it would guarantee a market for their product.	• DOE • SERI discussions with WECS producers
Federal RD&D Funding Distribution (annual)	20	• At least 50% of large wind system program RD&D budget allocated to commercialization activities (including demonstrations).	• Shifting of emphasis from technology development activities to commercialization and demonstration activities is a strong measure of approaching commercial readiness.	• Program Summary, Federal Wind Energy Program, December 1978.
Federal Funding Plans (multiyear)	15	• Existence of a formally instituted and approved, long-range (e.g., 5-year) central wind systems program articulating activities, schedules, and funding.	• Central WECS manufacturers have recommended that long-range, detailed plans be available as an aid to planning.	• SERI discussions with WECS producers
Federal Financial Incentives for Producers	7	• Multiyear array of incentive programs for producers: -Long-term, low-interest loans -Loan guarantees -Enhanced investment tax credits.	• Recommendations of large wind systems manufacturers. • Recommendations of DOE Large Wind Systems Commercialization Task Force. • Federal incentives for producers facilitate capital accumulation at favorable rates and relieve cash flow problems.	• SERI discussions with large WECS producers • Commercialization Strategy Report for Large Wind Systems

Table 3-6. COMMERCIAL READINESS INDICATORS: WEIGHTS, GOALS, AND RATIONALES (continued)

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales	Source(s)
State Financial Incentives for Producers	3	• Multiyear array of incentive programs for producers: -Income tax incentives -Property tax incentives -Other tax incentives. In at least 5 of the 10 states having greatest market potential for central WECS	• Recommendations of DOE Large Wind Systems Commercialization Task Force. • State incentives combine with federal incentives to make producer investment in a new technology even more economically attractive.	• Commercialization Strategy Report for Large Wind Systems
Federal Financial Incentives for Utilities	12	• Multiyear array of incentive programs for utilities: -Enhanced investment tax credits (investor-owned utility) -Low-interest loans -Loan guarantees -Planning grants -Accelerated depreciation -Cost sharing.	• Recommendations of Booz, Allen & Hamilton, Inc. • Recommendations of DOE Large Wind Systems Commercialization Task Force. • Recommendations of utilities involved in WECS experiments.	• Economic Incentives to Wind Systems Commercialization. Booz, Allen & Hamilton, Inc. August 1978. • Commercialization Strategy Report for Large Wind Systems • SERI discussions with utilities

Table 3-6. COMMERCIAL READINESS INDICATORS: WEIGHTS, GOALS, AND RATIONALES (concluded)

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales	Source(s)
State Financial Incentives for Utilities	8	• Multiyear array of incentive programs for utilities: -Income, property, and excise tax incentives for investor-owned utilities -Property and excise tax incentives for cooperatives -Other tax incentives for municipal utilities -Utility regulatory commission allowance of higher rates of return on investments in central WECS (for regulated utilities).	• Recommendations of DOE Large Wind Systems Commercialization Task Force. • The combination of state and federal incentives will enhance effects of each incentive. • Increased rate of return on utility investment in WECS is a positive financial incentive for regulated utilities.	• Commercialization Strategy Report for Large Wind Systems • Solar Law Reporter, Vol. 1 (No. 1), May/June 1978.

Table 3-7. COMMERCIAL READINESS INDICATORS: WEIGHTS, GOALS, AND RATIONALES

Factor: Legal/Institutional/Environmental Issues

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales	Source(s)
Television Signal Interference	15	• Availability of low-cost technical means for minimizing effects of central WECS-induced television signal interference.	• Increasing market penetration of central WECS at commercial readiness will mean decreased availability of remote siting options for avoiding TVI, and increased reliance on technical means for minimizing the problem.	• Environmental Readiness Document: Large and Small Wind Systems, DOE, Sept. 1978. • Taubenfield, Barriers to the Use of Wind Energy Machines
Aesthetics	5	• Minimization of uncertainty regarding central WECS and wind farm aesthetics.	• Statements are found throughout the literature to the effect that negative public reations to WECS and WECS farms may occur as a result of aesthetics.	Two sources above, plus: • Commercialization Strategy Report for Large Wind Systems, DOE • Solar Law Reporter, Vol.1 (No.1) May/June 1979. • Legal-Institutional Implications of WECS
Noise and Infrasound	5	• Central WECS noise output levels in compliance with EPA, OSHA, and state/local noise emissions standards. • Infrasonic output not exceeding 100 dB-SPL (sound pressure level decibels).	• OSHA standards apply to WECS noise production in the work environment (80 dB/8 hr). • EPA standards apply for audible noise beyond the exclusion zone. • Human discomfort can be caused at infrasonic levels (100 dB-SPL).	• Environmental Readiness Document: Large and Small Wind Systems, DOE, Sept. 1978. • Monterey Large WECS Workshop Proceedings, March 1979.

Table 3-7. COMMERCIAL READINESS INDICATORS: WEIGHTS, GOALS, AND RATIONALES (continued)

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales	Source(s)
Wind Rights	30	• Existence of legislation protecting access to wind flow for utilities with central WECS, in at least 5 of the 10 states having the greatest central WECS market potential.	• No existing legal doctrine is applicable to the wind access issue. • A continuous supply of unrestricted air flow in several directions is critical to cost-effective WECS operation. Air flow obstruction will hinder performance. • Wind rights legislation in place in at least half of the states having the greatest market potential will lead, or act as precedent for, wind rights legislation in other states.	• Legal-Institutional Implications of WECS. • Wind Energy: Legal Issues and Institutional Barriers. SERI/ TR-62-241. May 1979. • Taubenfield, Barriers to the Use of Wind Energy Machines.
Land Use	10	• Existence of legislation incorporating wind use considerations into state land-use planning and zoning procedures in at least 5 of the 10 states having the greatest central WECS market potential.	• State governments have power to mandate solar access considerations by appropriate planning and review commissions at regional, state, and local levels. • Review procedures for land-use impact of proposed electrical generation facilities are normally carried out at the state and local levels. • Changes in planning and zoning legislation have greater and more pervasive impact on land use than other state legislative responses such as easement laws. • Power plant siting statutes may not apply to WECS.	• "State Approaches to Solar Legislation: A Survey." Solar Law Reporter Vol. 1 (No. 1), May/June 1979. • Legal-Institutional Implications of Wind Energy Conversion Systems. George Washington University, Sept. 1977.

Table 3-7. COMMERCIAL READINESS INDICATORS: WEIGHTS, GOALS, AND RATIONALES (concluded)

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales	Source(s)
Safety/Liability Issues	10	• Manufacturers and utilities must adhere to applicable safety standards and regulations: -OSHA, FAA, and state safety regulations -Military engineering design criteria -IEEE and ANSI electrical codes -WECS specific standards.	• It is expected that OSHA and other safety regulations applying to operation and maintenance of electrical equipment and structural safety will apply to WECS. • Large WECS are sufficiently different in design and operation from other types of generating equipment to warrant their own set of design and operational guidelines.	• Legal-Institutional Implications of Wind Energy Conversion Systems. George Washington Univ. Sept. 1977. • Environmental Readiness Document: Large and Small Wind Systems, DOE, Sept. 1978. • 2500-kW Wind Turbine System for Electric Power Generation (MOD-2 project). Boeing, Nov. 1978.
Utility Interconnection Issues	25	• Existence of federal legislation assuring utilities with WECS of interconnection with bulk power suppliers and guaranteeing sale and buyback or power between utilities at fair rates. • PUC regulations or policies favorable to these issues in at least 5 of the 10 states having greatest central WECS market potential.	• Federal legislation is appropriate because wholesale power contracts are regulated by FERC (Federal Energy Regulatory Commission). • State level involvement is appropriate because enforcement of federal regulations is a function of state utility commissions.	• "Utility Rates and Solar Commercialization "Solar Law Reporter, Vol. 1 (No. 2), July/Aug. 1979.

Table 3-8. CENTRAL SYSTEMS COMMERCIAL READINESS INDICATORS: WEIGHTS, GOALS, AND RATIONALES

Factor: Market Development

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales	Source(s)
End-User Awareness	15	• Large utilities: at least 33% of the largest utilities in the 10 best states involved in wind programs--engineering studies, wind resource studies, demonstrations, etc. • Small utilities: at least 33% of the small utilities in the 10 best states involved in wind programs.	• Awareness of central WECS viability necessarily precedes purchases of WECS.	• EPRI study
Number of Central WECS Manufacturers	15	• Entry of 50% of the largest producers of conventional generating equipment into manufacturers of central WECS.	• Utilities prefer dealing with familiar vender. • Manufacturers of conventional power generating firms are, by and large, reputable and financially healthy. Increases respect for WECS industry by insurers, financiers, etc.	• SERI discussion with utilities • EPRI
Extent and Quality of Published Market Research/ Market Development Information	5	• Performance of systematic, comprehensive market research studies for at least 5 of 10 better states. • Studies available examining foreign market opportunities.	• Aid to producers in reducing market uncertainty about new technology.	• DOE Commercialization Strategy Reports • Comments of producers

Table 3-8. COMMERCIAL READINESS INDICATORS: WEIGHTS, GOALS, AND RATIONALES (continued)

Commercial Readiness Indicator	Indicator Weight	Goal/Objective at Commercial Readiness	Rationales	Source(s)
Consensus Standards	5	• Development, dissemination, and acceptance of industry-wide consensus standards, covering: -Mechanical structural performance -Safety and reliability -Operation and service.	• Provide assurance to end users of effective and reliable WECS.	• DOE Commercialization Strategy Reports
Industry, Professional, and Trade Journals	5	• At least six national wind-oriented professional and trade journals--each published quarterly, at least.	• Journals provide mechanisms for intra-industry communication, dissemination of research, and provide advertising outlets for producers.	• SERI
Strong, Respected, and Active Trade Association	5	• Evolution of at least one strong, respected, aggressive trade association for the WECS industry.	• Provides a forum for intra-industry communication. • Lobbying efforts can lead to favorable rulings and legislation.	• SERI
Extent of Market Penetration	50	• Penetration equal to that at acceleration phase of GE/EPRI market penetration curve (approx. 8.3 GW).	• A major feature in the definition of CR has been market penetration equal to that at the acceleration phase of a reputable market penetration curve.	• GE/EPRI • SERI

would commit to acquiring a specified quantity of wind machines for integration into federal or quasi-federal electric systems.

However, the above indicators are not unique to producers--they relate also to end-user requirements and federal initiatives. Hence, they are not included under "Producer Requirements." The rationale behind this approach is to minimize duplication of indicators. This principal was applied to all factors. Hence, it was possible to reduce the total number of indicators from 53 to 41.

3.4 RANK ORDERING OF THE COMMERCIAL READINESS INDICATORS

Table 3-1 shows the relative weights assigned to the factors and the within-factor relative weights assigned to the 41 indicators. With overall relative weight as the measure of importance, the 10 most important indicators are shown in Table 3-9. For each indicator, the overall relative weight was computed by multiplying the indicator weight by the factor weight.

Collectively, these 10 indicators relate to end-user and producer requirements, as well as actions that should be taken by the Federal Government. Consequently, if the government desires to accelerate central wind commercial readiness/commercialization, it should sponsor programs directed at meeting the goals/objectives established for the 10 best indicators.

3.5 FACTOR AND INDICATOR INTERRELATIONSHIPS

The seven commercial readiness factors are interdependent. For example, "Solar Energy Costs and Economics" is a function of "Technology Requirements." Other things being equal, the best way to improve a system's economics is to improve its technical performance. Similarly, "Government Initiatives" function to meet "Producer Requirements," "End-User Requirements (Noneconomic)," and "Economic Requirements."

Commercial readiness indicators also exhibit interdependencies. For example, many dependencies exist between the 10 most important indicators shown in Table 3-9.

Among these interrelationships are:

- "System installed cost"--the single most important indicator--is a function of "system performance," "rotor assembly," and "WECS mechanical reliability." However, if the systems economics is attractive but "wind rights" issues are unresolved, utilities will not buy it.
- "Cumulative market penetration" goal is attained only if the "system installed cost" goal is attained. Initially, one method for stimulating cumulative market penetration is a "federal procurement program."
- "Return on investment," a crucial issue for producers, is interrelated with "cumulative market penetration" and "federal procurement program."

Table 3-9. RANK ORDERING OF THE COMMERCIAL READINESS INDICATORS: 10 MOST IMPORTANT

Solar Technology/Application: Central Wind Systems/Large Utilities

Commercial Readiness Indicator	Factor With Which Associated	Indicator Overall Weight
System Installed Cost	• Costs and Economics	24.0
Cumulative Market Penetration	• Market Development	6.3
Federal Procurement Program	• Government Initiatives	4.9
System Performance	• Technology Requirements	4.0
Rotor Assembly	• Technology Requirements	4.0
Return on Investment	• Producer Requirements	4.0
Wind System Mechanical Reliability	• End-User Requirements Noneconomic)	4.0
Wind Rights	• Legal/Institutional/ Environmental Issues	3.0
Federal Wind Program RD&D Funding Distribution	• Government Initiatives	2.8
Utility Interconnection Issues	• Legal/Institutional/ Environmental Issues	2.5

Figure 3-2 graphically depicts several interrelationships among the indicators.

Factor and indicator interdependencies have ramifications with respect to federal programs sponsored to accelerate central WECS commercial readiness. It is more cost effective for DOE if it formulates and implements commercialization programs designed to achieve the goals defined for important commercial readiness indicators having a large multiplier effect (i.e., a large number of interdependencies). For example, Fig. 3-2 shows that a comprehensive, carefully planned multiyear federal procurement program will facilitate attainment of the goal defined for the following indicators:

- Cumulative market penetration
- Return on investment
- System performance
- System installed cost.

3.6 FACTOR AND INDICATOR COMMERCIAL READINESS: QUANTITATIVE ASSESSMENT

For each commercial readiness factor, Tables 3-10 through 3-16 show quantitatively the current status--as of the end of 1978--of each constituent indicator relative to its goal/objective.

Analysis of the tables show that no progress had been made in attaining the goals set for the following nine indicators:

- Utility rate structures
- Federal financial incentives for producers
- Federal financial incentives for utilities
- State financial incentives for producers
- Television signal interference
- Wind rights
- Utility interconnection issues
- Cumulative market penetration
- Consensus standards.

Of these 9, 3 are among the 10 most important as described in Section 4.3:

- Cumulative market penetration
- Wind rights
- Utility interconnection issues.

For this application there are no indicators for which the goal has been completely met or exceeded.

Table 3-17 shows the readiness ratings for each of the seven factors and the overall commercial readiness figure of merit for the central WECS/large utility application:

- Commercial Readiness Figure of Merit = $\sum_{f=1}^{7} FR_f W_f$

  f = f^{th} Commercial Readiness Factor ($f = 1, 2, \ldots, 7$)

  FR_f = Factor readiness for the f^{th} factor

  W_f = Relative weight of the f^{th} factor.

Table 3-17 shows that:

- Overall, the commercial readiness figure of merit for the central WECS/large utilities application is approximately 34.1 out of a possible 100.
- "Solar Energy Costs and Economics"--the factor having the greatest relative weight--is the factor in which the greatest progress towards commercial readiness has been made.
- "Legal/Institutional/Environmental Issues" has attained the least progress. In terms of relative importance, it ranks next to last. This result is not surprising since, traditionally, legal and institutional issues do not arise until significant market penetration develops.

3.7 CRI RATINGS FOR THE CENTRAL WECS APPLICATION

For the subject central WECS application the CRI equation is given by:

$$CRI(t,FOM) = \left\{ \frac{FOM \cdot \exp\left[\left(\frac{t-2000}{5.25}\right)\left(1-\frac{1}{FOM}\right)\right]}{1 + (1.1) \cdot FOM \cdot \exp\left[\left(\frac{t-2000}{5.25}\right)\left(1-\frac{1}{FOM}\right)\right]} \right\} 100$$

where

t_o = 2000 (i.e., the year in which market penetration is expected to take off)

α = 1.1 (scale factor)

β = 5.25 (time constant)

FOM = Commercial Readiness Figure of Merit

t = 1978 (i.e., assessment year)

Inserting the CRI figure of merit developed in Section 3.6 into the above equation, the following result is obtained:

- For large utilities, CRI (1978, 34.1) = 43.4

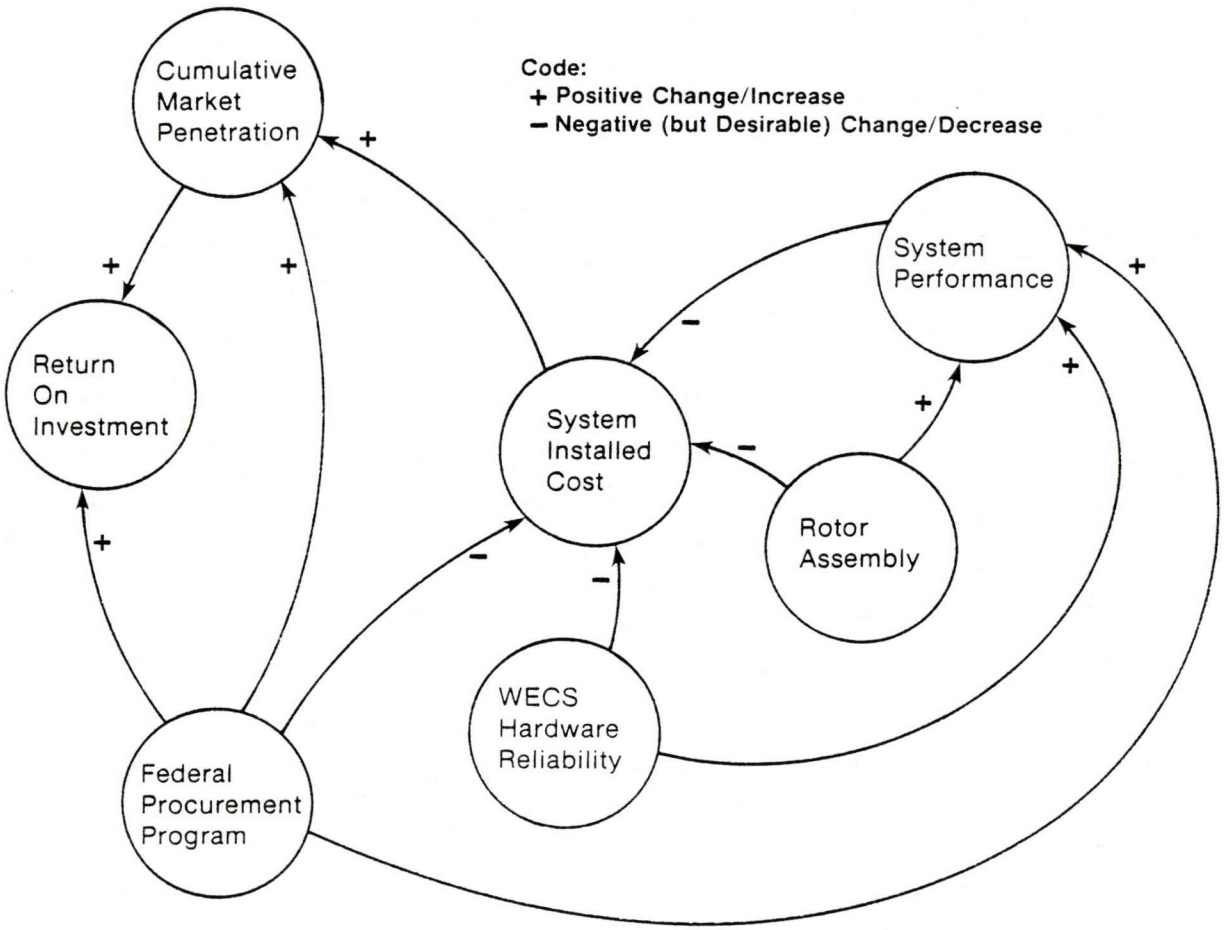


Figure 3-2. Examples of Inter-Relationships Between Commercial Readiness Indicators and the Nature of the Inter-Relations

Table 3-10. FACTOR READINESS RATING COMPUTATION

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: End-User Requirements (Noneconomic)

Indicators	Indicator Weight	Indicator Current Status Rating Relative to Goal (Scale: 0-1)	Weighted Indicator Rating
Availability and Cost of Capital	15	0.8	12.0
Availability of Insurance	10	0.2	2.0
WECS Mechanical Reliability	40	0.3	12.0
Dispatch Techniques	10	0.1	1.0
Availability of Wind Resource Data	10	0.1	1.0
Availability of Responsive and Reliable Central WECS Specific Design, Installation, Spares, and Maintenance Services	15	0.5	7.5

$FR = \sum_{i=1} (\text{Weighted Indicator Ratings})_i$ = 35.5 out of 100.

Table 3-11. FACTOR READINESS RATING COMPUTATION

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Producer Requirements

Indicators	Indicator Weight	Indicator Current Status Rating Relative to Goal (Scale: 0-1)	Weighted Indicator Rating
Availability and Cost of Capital	15	0.7	10.5
Return on Investment	50	0.1	5.0
Availability of Product Liability Insurance	10	0.7	7.0
Utility Rate Structures	25	0.0	0.0

$FR = \sum_{i=1} (\text{Weighted Indicator Ratings})_i$ = 22.5 out of 100.

Table 3-12. FACTOR READINESS RATING COMPUTATION

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Solar Energy Costs and Economics

Indicators	Indicator Weight	Indicator Current Status Rating Relative to Goal (Scale: 0-1)	Weighted Indicator Rating
System Installed Cost	100	0.6	60.0

$FR = \sum_{i=1} (\text{Weighted Indicator Ratings})_i$ = 60.0 out of 100.

Table 3-13. FACTOR READINESS RATING COMPUTATION

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Technology Requirements

Indicators	Indicator Weight	Indicator Current Status Rating Relative to Goal (Scale: 0-1)	Weighted Indicator Rating
Rotor Assembly	20	0.3	6.0
Drive Train	12	0.5	6.0
Nacelle	10	0.6	6.0
Tower Assembly	10	0.9	9.0
Other WECS Subsystems and Installations	12	0.5	6.0
O&M	6	0.2	1.2
System Performance	20	0.3	6.0
Transients	10	0.1	1.0

$FR = \sum_{i=1} (\text{Weighted Indicator Ratings})_i$ = 41.2 out of 100.

Table 3-14. FACTOR READINESS RATING COMPUTATION

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Government Initiatives

Indicators	Indicator Weight	Indicator Current Status Rating Relative to Goal (Scale: 0-1)	Weighted Indicator Rating
Federal Procurement Program	35	0.1	3.5
Federal Wind Program R&D Funding Distributive (Annual)	20	0.1	2.0
Federal Funding Plans	15	0.6	9.0
Federal Financial Incentives for Producers	7	0.0	0.0
State Financial Incentives for Producers	3	0.0	0.0
Federal Financial Incentives for Utilities	12	0.0	0.0
State Financial Incentives for Utilities	8	0.1	0.8

$FR = \sum_{i=1}$ (Weighted Indicator Ratings)$_i$ = 15.3 out of 100.

Table 3-15. FACTOR READINESS RATING COMPUTATION

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Legal/Institutional/Environmental Issues

Indicators	Indicator Current Status Rating Indicator Weight	Weighted Relative to Goal (Scale: 0-1)	Indicator Rating
Television Signal Interference	15	0.0	0.0
Aesthetics	5	0.2	1.0
Noise/Infrasound	5	0.2	1.0
Wind Rights	30	0.0	0.0
Safety/Liability Issues	10	0.2	2.0
Land Availability and Use	10	0.1	1.0
Utility Interconnection Issues	25	0.0	0.0

$FR = \sum_{i=1}$ (Weighted Indicator Ratings)$_i$ = 5.0 out of 100.

Table 3-16. FACTOR READINESS RATING COMPUTATION

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Market Development

Indicators	Indicator Weight	Indicator Current Status Rating Relative to Goal (Scale: 0-1)	Weighted Indicator Rating
Cumulative Market Penetration	50	0.0	0.0
Extent and Quality of Published Market Development/Research	5	0.1	0.5
Number of Manufacturers	15	0.5	7.5
Consensus Standards	5	0.0	0.0
Industry, Professional, and Trade Journals	5	0.8	4.0
Strong, Respected, and Active Trade Association	5	0.8	4.0
End-User Consciousness Level	15	0.6	9.0

$FR = \sum_{i=1}$ (Weighted Indicator Ratings)$_i$ = 25.0 out of 100.

Table 3-17. COMPUTATION OF CRI FIGURE OF MERIT

Solar Technology/Application: Central Wind Systems/Large Utilities

Year: 1978

Commercial Readiness Factors	Factor Weight	Factor Readiness (Scale: 0-1)	Weighted Factor Readiness
End-User Requirements (Noneconomic)	0.10	35.5	3.6
Producer Requirements	0.08	22.5	1.8
Solar Energy Costs and Economics	0.24	60.0	14.4
Technology Requirements	0.20	41.2	8.2
Government Initiatives	0.14	15.3	2.1
Legal/Institutional/ Environmental Issues	0.10	5.0	0.5
Market Development	0.14	25.0	3.5

CRI FOM = $\sum_{f=1}$ (Weighted Factor Ratings)$_f$ = 34.1 out of 100.

3.8 EXAMPLES OF SENSITIVITY ANALYSES

3.8.1 CRI Sensitivity to Commercial Readiness Figure of Merit

For the central WECS/large utilities application, the Commercial Readiness Figure of Merit was determined to be 34.1--giving a 1978 CRI rating of 43.4.

In Section 3.4 it was shown that, on the basis of overall relative weightings, the 10 most important indicators are:

- System installed cost
- Cumulative market penetration
- Federal procurement program
- System performance
- Rotor assembly
- Return on investment
- WECS mechanical reliability
- Wind rights
- Federal wind program RD&D funding distribution
- Utility interconnection issues.

Suppose that in 1978, the goals established for the 10 most important indicators had been met or exceeded--each therefore having a readiness rating of 1.0. If all other indicators retained their 1978 readiness ratings, the overall Commercial Readiness Figure of Merit would be 70.9, as shown in Table 3-18. Using this value in the CRI equation leads to a commercial readiness rating of 50.6. Consequently, attainment of the goals defined for the 10 most important indicators:

- Increases the Commercial Readiness Figure of Merit from 34.1 to 70.9 (an increase of 108%)
- Increases the CRI from 43.4 to 58.4 (an increase of 35%).

3.8.2 CRI Sensitivity to Time of the Assessment

CRI rating is a function of the Commercial Readiness Figure of Merit and the time at which the assessment is performed. The CRI equation is calibrated to the governing market penetration curve--market penetration being a function of time. Hence, for a given Commercial Readiness Figure of Merit, the CRI rating increases as the time is approached at which the market is expected to take off.

Examples of the sensitivity of the CRI rating for the central WECS/large utilities application to time are as follows:

- In 1978, the Commercial Readiness Figure of Merit of 34.1 led to a CRI rating of 43.4. If the assessment had been performed in 1985, the CRI rating would have been 68.1.
- Assuming the goals established for the 10 most important indicators were met, the 1978 Commercial Readiness Figure of Merit of 70.9 would give a CRI rating of 77.8 in 1985.

Table 3-18. COMMERCIAL READINESS FIGURE OF MERIT/SENSITIVITY ANALYSIS

Solar Technology/Application: Central Wind Systems/Large Utilities

Year: 1978

Commercial Readiness Factors	Factor Weight	Factor Readiness (Scale: 0-1)	Weighted Factor Readiness
End-User Requirements (Noneconomic)	0.10	66.5	6.65
Producer Requirements	0.08	67.5	5.40
Solar Energy Costs and Economics	0.24	100.0	24.00
Technology Requirements	0.20	54.0	10.80
Government Initiatives	0.14	60.3	8.44
Legal/Institutional/ Environmental Issues	0.10	60.3	6.00
Market Development	0.14	68.5	9.59

CRI FOM = $\sum_{f=1}$ (Weighted Factor Ratings)$_f$ = 70.9 out of 100.

SECTION 4.0

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APPENDIX A

CENTRAL WIND SYSTEMS/LARGE UTILITIES COMMERCIAL READINESS ASSESSMENT: QUALITATIVE ANALYSIS


SERI

SECTION 1.0

INTRODUCTION

Two of the central tasks in applying the SERI commercial readiness assessment methodology are to:

- Determine qualitatively and quantitatively the current status of each indicator relative to its goal/objective
- Translate the assessments above for each indicator into an indicator readiness rating IR_i (i = 1, 2, . . . , I)

This appendix provides the qualitative assessments--as of the end of calendar year 1978--assessing the commercial readiness of central wind systems for generating electricity by large utilities.

SECTION 2.0

QUALITATIVE ASSESSMENTS

For each of the subject indicators, Tables A-1 through A-41 show:

- Factor with which the indicator is associated
- Goal/objective established for the indicator at commercial readiness
- Qualitative assessment of the current status of the indicator relative to its goal/objective.

Table A-1. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: End-User Requirements (Noneconomic)

Indicator: WECS Mechanical Reliability

Indicator Goal/Objective:

- WECS mechanical reliability at least equal to that for a conventional coal- or oil-fired plant.
  - WECS availability of at least 90%

Current Status of Indicator:

- As of 1978, no statistically validated data base existed regarding the long term reliability of central WECS having power ratings in the range 200-2500 kW. The only published data regarding the reliability of large wind machines relates to the DOE/NASA MOD-0A machine (200 kW) at Clayton, N. Mex.
- According to Glasgow and Robbins, between March 1978 and January 1979 the Clayton MOD-0A sustained three extensive shutdowns totalling 50 days out of an operating period of 301 days. Problems included blade weakness and generator bearing failure. The blade was removed and returned to the factory for strengthening, and remounted.
- Excluding the blade change, during its first 10 months of operation, the availability of the Clayton MOD-0A increased from 70% initially to 90%. If the time for the blade change is included in the availability calculations, average availability for the machine during the 10-month period was about 60%.
- Since the MOD-0A is an experimental machine—having been in operation only for the last 10 months of 1978--much uncertainty exists regarding the long term mechanical reliability of WECS used to generate power commercially.

Table A-2. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: End-User Requirements (Noneconomic)

Indicator: Availability of Capital

Indicator Goal/Objective:

- Capital available to utilities from traditional sources (or mechanisms) and at rates approximately equal to those for acquiring conventional generating equipment

Current Status of Indicator:

- Analysis of electric utility capital acquisition and formation showed the utilities
  - Generate 40% of their capital needs internally
  - Acquire 60% of such needs externally (e.g., capital stock, bonds, commercial banks).
- SERI survey of representative investment banking firms (Merrill Lynch; Smith Barney Harris Upham and Company, and Stifel Nicolaus and Company) showed that the availability and rates on utility bond and stock issues depend largely on the financial health of the firm. A typical WECS project would have little overall impact on the perceived financial strength of a utility.
- The Rural Electrification Administration and the Cooperative Finance Corporation, which provide financing and loan guarantees for cooperative utilities, have no statutory restrictions against the financing of wind systems. Loan approvals or guarantees for such projects would depend largely upon satisfaction of the usual technical and economic criteria.
- According to representative public and private utilities and cognizant consulting firms approached by SERI, the availability of municipal bond funds is no problem; however, the bond rate cannot be predicted easily.
- Consequently, for large and small utilities, financing would be readily available through conventional mechanisms. As of 1978, no utility had financed a wind project. However, the availability of nondiscriminatory financing is uncertain.

Table A-3. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: End-User Requirements (Noneconomic)

Indicator: Availability of Property and Liability Insurance

Indicator Goal/Objective:

- WECS property and liability insurance available to utilities from traditional insurers and at rates comparable to those for conventional generating equipment

Current Status of Indicator:

- As of 1978, utility insurers had no systematic casualty and liability experience with central wind systems.
- SERI analysis of property and liability insurance patterns in the electric utility industry showed that many large companies self-insure themselves against property damage. For such utilities the availability of property insurance is academic.
- Utilities acquiring experimental and demonstration wind machines have been able to obtain property and liability coverage on them under existing insurance policies. Examples of such utilities include:
  - Clayton Municipal Electric System
  - Pennsylvania Power and Light
- Of 15 large insurance companies responding to a survey of the industry regarding property and liability coverage for utilities that acquire wind machines conducted by C. S. Draper Labs in 1978, only one--Aetna Life and Casualty-indicated that it was willing to provide coverage. However, rates were not addressed.

Table A-4. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: End-User Requirements

Indicator: Availability of a Responsive, Reliable, and Experienced WEC-Specific Design Installation, Parts, and Maintenance Services

Indicator Goal/Objective:

- Entry of 50% of the largest producers of conventional generating equipment into the production of central wind systems
- Entry of 50% of the 10 largest utility A&E firms into central WECS design

Current Status of Indicator:

- According to EPRI, the following firms produce 90% of the conventional generating equipment purchased by utilities
  - General Electric
  - Westinghouse
  - Combustion Engineering
  - J.R. McDermott (Babcock & Wilcox)
  - Allis Chalmers
  - Foster and Wheeler
- Of the six firms, only General Electric and Westinghouse have wind ventures. However, failure of more of the above firms to invest in central WECS technology is somewhat compensated for by the entry of other firms; e.g., Kaman Aerospace, Lockheed California, Boeing, United Technologies, WTG Energy Systems, and Bendix.
- Both General Electric and Westinghouse plan to use their existing field service networks to support their WECS customers.
- As of 1978, none of the 10 largest A&E firms catering to the utility industry were involved in wind farm design or construction activities.
- According to a General Electric representative, GE's Installation and Services Division will serve as a company's WECS A&E element.
- In summary, although no WECS design, installation, and construction activities are in progress, most of the mechanisms needed already exist. As the need arises, they can be geared up to service the WECS industry.

Table A-5. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: End-User Requirements (Noneconomic)

Indicator: Dispatch Techniques

Indicator Goal/Objective:

- Validated techniques and algorithms for the dispatch of WECS-produced electricity
- Utility planning models that permit analysis of wind systems in the utility's mix of generating equipment

Current Status of Indicator:

- As of 1978, no validated operational techniques and/or algorithms existed for the economic dispatch of electricity generated by wind machines.
- One limited effort was in progress in 1978:
  - Researchers at Michigan State University modified the Pennsylvania, New Jersey, Maryland (PJM) Pool dispatch simulation model to show the effects of wind machines on the pool.
- Utility planning models that permit analysis of wind systems in a utility's mix of generating equipment do not exist. Such models are expected to be developed when operational dispatch techniques are developed.
- Limited efforts completed or in progress during 1978 relating to planning models:
  - Argonne National Laboratory examined the effect of inclusion of wind machines on a utility's mix of generating equipment and the impact of wind systems on overall reliability and reserve requirements.
  - General Electric, in a study funded by EPRI, examined the effects of wind systems on loss-of-load probability for specific utilities.

Table A-6. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: End-User Requirements (Noneconomic)

Indicator: Availability of Wind Resource Data

Indicator Goal/Objective:

- Systematic collection and cataloging of wind resource data, suitable for central WECS site identification, at the subcounty level for the 10 states having the greatest central WECS market potential

Current Status of Indicator:

- As of 1978, wind resource data at the subcounty level and suitable for WECS siting were not available nationally.
- The best available comprehensive national wind resource assessments are those by:
  - Sandia
  - General Electric
  - Lockheed.

  However, for many areas of the nation, their results do not agree. One reason for the discrepencies is the current status of the state of the art.
- Wind resource and prospecting projects for the purpose of identifying good wind sites were underway in:
  - Washington
  - Oregon
  - California
  - Idaho
  - Wyoming.

Table A-7. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Systems/Large Utilities

Factor: Producer Requirements

Indicator: Availability and Cost of Capital

Indicator Goal/Objective:

- Capital available to central WECS producers from traditional sources (or via traditional mechanisms) and at customary rates and terms

Current Status of Indicator:

- Companies already involved in producing central WECS and companies proposing to invest in central WECS technology fall into three major categories:
  - Well-capitalized, traditional producers of conventional electric generating equipment (e.g., Westinghouse, General Electric).
  - Well-capitalized aerospace and materials firms that perceive central WECS technology as a new business venture (e.g., Boeing, ALCOA, Rockwell International).
  - Recently founded firms having innovative central WECS engineering concepts and/or patents but extremely limited capital and plant and no field service networks (e.g., WTG, Wind Power Systems).
- Analysis of the financial health of the actual and potential central WECS producers falling in the first two categories showed that these firms either have capital or can acquire it from traditional external sources and at customary rates.
  - However, although these firms have capital, analysis of their capital allocation procedures showed capital might not be available for central WECS proposals. Central WECS ventures must compete with other proposed undertakings for available capital.
- Firms in the last category face problems in acquiring capital at reasonable rates.

Table A-8. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Systems/Large Utilities

Factor: Producer Requirements

Indicator: Return on Investment

Indicator Goal/Objective:

- Annual return on investment (ROI) at least equal to the traditional average annual ROI attained by producers of conventional generating equipment

Current Status of Indicator:

- Average annual ROI attained by producers of conventional electric generating equipment: 14.3%
- ROI Range: 11.8-18.3%
- As of 1978, large central WECS sales in the United States were extremely limited
  - Cumulative installed units: six units
  - All sales have been for demonstrations and feasibility studies rather than the commercial production of electric power.
- Producers were not willing to reveal to SERI either their ROI objectives or the degree to which they are attaining them. However, since utilities have not yet begun to acquire wind machines for producing electricity commercially, it is possible to infer that producers are not attaining their ROI objectives.

Table A-9. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT: WIND ENERGY CONVERSION SYSTEMS

Solar Technology/Application: Central Systems/Large Utilities

Factor: Producer Requirements

Indicator: Availability of Product Liability Insurance

Indicator Goal/Objective:

- Product liability insurance available to central WECS producers for traditional insurers at rates and terms comparable to those for conventional generating equipment producers or
- Multiyear federal product liability insurance program

Current Status of Indicator:

- A SERI survey of representative product liability insurers showed that product liability insurance is available to central WECS producers via traditional insurers.
- Since the insurance industry has no long-term product liability experience with central wind machines, most insurers are writing policies providing for retrospective rates.
- Product liability insurance with retrospective rates have the following characteristics:
  - Initially, rates are either negotiated or established arbitrarily
  - During the life of the policy, rates can be adjusted up or down, depending upon liability experience.
- Consequently, product liability insurance is available; rates are uncertain.

Table A-10. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT: WIND ENERGY CONVERSION SYSTEMS

Solar Technology/Application: Central Systems/Large Utilities

Factor: Producer Requirements

Indicator: Utility Rate Structures

Indicator Goal/Objective:

- Formulation and implementation of utility rate structures favorable to central wind systems in the 10 states having the greatest central WECS potential--rates cognizant of:
  - Fuel savings
  - Wind capacity credit

Current Status of Indicator:

- 10 states having the greatest central WECS market potential (criteria: wind resource, projected demand for electricity, availability of federal lands, and cost of electricity):
  - California
  - Hawaii
  - Massachusetts
  - Nevada
  - New Mexico
  - New York
  - Oklahoma
  - Utah
  - New Hampshire
  - Colorado
- As of the end of 1978, no state had formulated and implemented a utility rate structure explicitly favorable to wind energy systems.

Table A-11. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT: WIND ENERGY CONVERSION SYSTEMS

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Costs and Economics

Indicator: System Installed Cost

Indicator Goal/Objective:

- System installed cost of $800/kW (1978 $) assuming:
  - Wind machine utilization factor of 44%
  - Wind machine used primarily to meet intermediate and peak loads
  - Costs are computed using traditional utility costing procedures

Current Status of Indicator:

- On the basis of Boeing and NASA/Lewis engineering cost estimates for the second MOD-2, a wind farm of 25 machines has an expected normalized installed cost of $1439/kW.
- Using the traditional revenue requirements utility planning model, this normalized cost translates into a cost of electricity of $0.076/kWh assuming:
  - Site having an average wind speed of 14 mph
  - Machine capacity factor of 44%
  - Fixed charge rate of 17%.
- Since at commercial readiness the goal for the subject indicator is $800/kW, as of the end of 1978, progress in attaining the goal is 56%.

Table A-12. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Technology Requirements

Indicator: Rotor Assembly

Indicator Goal/Objective:

- Rotor subsystem cost of $349,000 (1978 $) for the 100th MOD-2

Current Status of Indicator:

- For the second MOD-2, the rotor assembly cost was $1,040,000 (1978 $). However, to be consistent with the procedure used to determine the cost of the 100th MOD-2, additional cost of $168,000 must be included for testing and factory checkout. Hence, the total rotor assembly cost for the second MOD-2 is $1,208,000-, compared to the goal of $349,000.
- As of the end of 1978, neither the first nor second MOD-2 was installed and operating.
- The MOD-2's rotor diameter is 300 ft. It will be the first U.S. machine with an upwind rotor.
- On the basis of limited experience with the MOD-0A machines, fatigue loads on blades are expected to be severe. For example, the MOD-0A at Clayton, N.Mex. sustained three 1- to 2-in cracks on the leading edges of its 125-ft diameter blades after 1000 hours of operation.
- The second MOD-2 has steel blades. The 100th unit might have blades fabricated from other materials (e.g., composites, wood).
- Current machines (MOD-0A, WTG Energy Systems, MOD-1, etc.) employ rigid hubs; the MOD-2 uses a teetered hub.

Table A-13. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Technology Requirements

Indicator: Drive Train (gearbox, generator, shafts, rotor brake)

Indicator Goal/Objective:

- Drive train subsystem cost of $402,000 (1978 $) for the 100th MOD-2

Current Status of Indicator:

- Existing DOE central WECS (i.e., MOD-0, MOD-0A, and MOD-1) use conventional transmissions. The MOD-2 employs a compact planetary gear unit, giving it a gear ratio twice that of the MOD-1.
- The MOD-2's generator is synchronous AC.
- For the second MOD-2, the drive train subsystem cost is $630,000 (1978 $). However, in order to be consistent with the procedure used by NASA to compute drive train costs for the 100th MOD-2, additional amounts are needed: $25,000 for electronics and $106,000 for factory checkout and testing. Hence, total drive train cost for the second MOD-2 is $762,000, compared to the goal of $402,000.

Table A-14. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Technology Requirements

Indicator: Nacelle (structure, shroud, hydraulic and yaw systems)

Indicator Goal/Objective:

- Nacelle cost of $195,000 (1978 $) for the 100th MOD-2

Current Status of Indicator:

- For the second MOD-2, the nacelle subsystem cost is estimated to cost $190,000. However for consistency with 100th unit cost goals, additional amounts of $90,000 for electronics and $45,000 for factory checkout and testing must be added for a total cost of $325,000.

Table A-15. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Technology Requirements

Indicator: Tower Assembly

Indicator Goal/Objective:

- Tower cost of $287,000 (1978 $) for the 100th MOD-2

Current Status of Indicator:

- For the second MOD-2, the cost of the tower is estimated to be $200,000 (1978 $), according to NASA. However in order to be consistent with the procedure used to cost the 100th MOD-2, additional costs of $84,000 for electronics and $96,000 for factory checkout and testing must be added to the installation cost. Hence, the total tower cost for the second MOD-2 is $330,000--compared to the goal of $287,000.
- Current central WECS--MOD-0, MOD-0A, MOD-1, and WTG Energy Systems machines--use lattice towers. The MOD-2 will be the first large machine to use a steel shell tower.
- Although the MOD-2 tower is larger than that for the MOD-1 (200 ft versus 140 ft hub height), it will weigh less: 255,000 versus 320,000 lb.

Table A-16. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Technology Requirements

Indicator: Other Subsystems and Installation

Indicator Goal/Objective:

- Other subsystems and installation cost of $422,000 (1978 $) for the 100th MOD-2

Current Status of Indicator:

- For the second unit MOD-2, the other subsystems and installation cost is estimated by NASA to be $790,000. However, for consistency with 100th unit cost goals, an additional $125,000 for testing quality control and reporting must be added for a total cost of $915,000.

Table A-17. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Technology Requirements

Indicator: O&M

Indicator Goal/Objective:

- Annual O&M cost of $16,000 (1978 $) for the 100th MOD-2

Current Status of Indicator:

- Since no MOD-2s are installed and operating, no data are available regarding annual O&M costs.

Table A-18. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Technology Requirements

Indicator: Systems Performance

Indicator Goal/Objective:

- Rated power output of 2500 kW at a rated wind speed of 27.5 mph at the hub
- Maximum rotor power coefficient of 0.417
- Annual energy output of at least 9,750,000 kWh at a site having an average wind speed of 14 mph at a height of 30 ft
- Machine capable of safe, unattended, reliable operation

Current Status of Indicator:

- Since neither the first nor second MOD-2 has been installed, no experimental data are available regarding system performance. Long-term operational experience is needed to evaluate performance and reliability.
- Limited inferences can be drawn regarding MOD-2 performance on the basis of experience with the Clayton, N. Mex., MOD-0A.
  - According to NASA, the Clayton MOD-0A has been delivering 50-60% of the predicted energy output.
  - According to a University of Tennessee study the observed plant factor is 20%, significantly below the goal of 35%.
  - Machine availability can be reduced because of icing. Icing causes machine shutdown, since flying pieces of ice constitute a safety hazard.

Table A-19. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Technology Requirements

Indicator: Transients

Indicator Goal/Objective:

- Compatibility of WECS output with the utility network

Current Status of Indicator:

- As of the end of 1978, no systematic data base was available regarding WECS-utility network interactions.
- According to EPRI the issue of oscillatory interactions among wind turbine generators and between the wind turbine generators and the utility network will not be settled until experience is obtained involving multiple wind machines.

Table A-20. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Government Initiatives

Indicator: Federal Procurement Program

Indicator Goal/Objective:

- Multiyear federal program to purchase a specified quantity of cost-effective and near cost-effective central WECS for integration into federal and quasi-federal electric systems

Current Status of Indicator:

- As of the end of 1978, the Federal Wind Energy Program did not explicitly provide for a federal program to acquire production-model wind machines for integration into any of the eight federal and quasi-federal electric systems (e.g., TVA, Bonneville, etc.).
- Present DOE planning calls for the purchase of central WECS for testing and demonstration purposes. As part of this purchase program, DOE will give the producers a limited, guaranteed market.
- The FY77 and FY78 appropriations for the Bureau of Reclamation provided funds to perform feasibility studies for a wind energy farm at Medicine Bow, Wyo.

Table A-21. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Government Initiatives

Indicator: Federal Wind Program RD&D Funding Distribution (Annual)

Indicator Goal/Objective:

- Allocation of at least 50% of the Large Wind Energy Program RD&D budget to commercialization activities and demonstration projects

Current Status of Indicator:

- For FY78, the budget for the Federal Large Wind Energy Systems Program was approximately $30,500,000, distributed as follows:
  - Program development and technology: $6.0 million
  - Intermediate systems development: $3.5 million
  - Large systems development: $30.0 million
  - Large systems demonstrations: $0.0
- Of the FY78 budget, approximately $357,000 was allocated to commercialization market development and demonstration projects:
  - Mission Analysis: $297,500
  - Applications Studies: $12,500
  - Legal/Social/Environmental Issues: $47,500
  - Demonstrations: $0.0.
- Approximately 1% of the FY78 funding was allocated for commercialization, demonstration, and market development issues.
- For large wind systems, the Federal Wind Program focused on technology development.

Table A-22. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Government Initiatives

Indicator: Federal Funding Plans

Indicator Goal/Objective:

- Existence of a formally instituted and approved long-range (e.g., 5-year) central wind systems program plan articulating activities, schedules, milestones, decision points, and funding

Current Status of Indicator:

- Budget authority plans for the Federal Wind Energy Program are detailed through FY85 in DOE draft report Wind Energy Multiyear Program Plan.

- Wind Energy Multiyear Program Plan does not specify funding plan details for all program elements. Therefore, planned allocations for commercialization activities and relative activity priorities cannot be determined.

  - According to the above-mentioned document, allocations for intermediate and large wind systems development is projected to increase through FY82 and then decline. Allocations for large wind system demonstration projects will increase through FY85.

Table A-23. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Government Initiatives

Indicator: Federal Special Financial Incentives for Producers

Indicator Goal/Objective:

- Multiyear array of special financial incentive programs for central WECS producers
  - 10-15 year long-term/low-interest loan program
  - 10-15 year loan guarantee program
  - Enhanced investment tax credit program
  - Accelerated depreciation

Current Status of Indicator:

- As of the end of 1978, no special federal financial incentives programs for WECS producers were in effect. Producers may take advantage of the National Energy and Business investment tax credit only if they utilize their own product.
- During 1978, the Federal Central WECS program concentrated on:
  - Technology development
  - Wind resource identification
  - Demonstrations (MOD-OA program).

Table A-24. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Government Initiatives

Indicator: State Special Financial Incentives for Producers

Indicator Goal/Objective:

- Multiyear array of state financial incentive programs for WECS producers in at least 5 of the 10 states having the greatest central WECS market potential:
  - Income tax incentives
  - Property tax exemption
  - Other tax incentives

Current Status of Indicator:

- As of the end of 1978, eight states (i.e., California*, Arizona, Colorado*, Hawaii*, Kansas, Massachusetts*, Montana, and North Dakota) provide income tax deductions or credits to corporations acquiring and using wind systems. WECS producers qualified for these deductions or credits only if they used wind systems.
- The following states provide property tax exemptions for wind systems

- Arizona	- Kansas	- New Jersey	- Tennessee
- Connecticut	- Massachusetts*	- Oregon	- Texas
- Hawaii*	- Michigan	- South Dakota	- Vermont
- Illinois	- New Hampshire*		

  WECS producers in these states qualify for the property tax exemptions only if they are WECS end users.
- As of the end of 1978, only Texas had enacted a limited financial incentives program specifically for WECS producers.
- Texas provides franchise tax exemptions for central WECS producers.

*States ranking in the top 10 in terms of central WECS market.

Table A-25. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Government Initiatives

Indicator: Federal Special Financial Incentives for Utilities

Indicator Goal/Objective:

- Multiyear array of special federal financial incentive programs for utilities:
  - Planning grant program
  - Enhanced investment tax credit program
  - Cost sharing program
  - Loan guarantee program
  - Long-term/low-interest loan program

Current Status of Indicator:

- As of the end of 1978, no special WECS-related federal financial incentive programs for utilities were in effect.
- Utilities did not qualify for the supplemental business energy tax credit provided for as part of the National Energy Act of 1978.
- During 1978, federal central WECS efforts focused on:
  - Technology development
  - Wind resource identification
  - Demonstrations.

Table A-26. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Government Initiatives

Indicator: State Special Financial Incentives for Utilities

Indicator Goal/Objective:

Multiyear array of state financial incentive programs for utilities in at least 5 of the 10 states having the greatest central WECS market potential:

- For investor-owned utilities
  - Income tax incentives/excise tax exemptions
  - Property tax exemptions
- For cooperative utilities
  - Property tax exemptions
  - Excise tax exemptions
- For municipally-owned utilities.
  - Excise tax exemptions
- Utility regulatory commission allowance of higher rates of return on investments in central WECS (for regulated utilities)

Current Status of Indicator:

- As of the end of 1978, none of the 50 states or the District of Columbia had enacted WECS-specific tax incentives programs for utilities.
- California and Kansas provide WECS financial incentives for electric companies via their utility regulatory processes:
  - In 1976, California enacted legislation allowing the State Public Utilities Commission (PUC) to authorize utilities an additional ROI of 0.5 to 1.0% on investment in nonconventional generating equipment.
  - A 1978 Kansas law allows the state PUC to authorize utilities an additional ROI of 0.5 to 2.0% on alternative energy investments, including central wind systems.

Table A-27. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Legal/Institutional/Environmental Issues

Indicator: Television Signal Interference

Indicator Goal/Objective:

- Low-cost technical means to minimize central WECS-induced television signal interference

Current Status of Indicator:

- As of the end of 1978, the extent to which operation of central wind machines or farms interferes with television signal reception in homes was undocumented.
- As WECS market penetration increases, there will be fewer possibilities for minimizing television signal interference through remote siting.
- The University of Michigan Radiation Laboratory in a study entitled "Electromagnetic Interference by Wind Turbine Generators" developed a model to quantify wind turbine-induced radio frequency interference. Employment of this model at Plum Brook, Ohio, (site of the NASA/DOE MOD-0 wind machine) showed no television interference (TVI) problems.
- No comprehensive, systematic, long-term measurements of WECS induced TVI have been made.
- No scientific/engineering studies have been funded specifically to identify low-cost technical solutions to TVI.
- SERI survey of representative utilities having WECS showed:
  - No TVI problems have been reported due to the operation of WECS at Clayton, N. Mex., Cuttyhunk Island, Mass., Hazleton, Penn., and Miami, Fla.
  - Blue Ridge Electrical Membership Corporation, site of the DOE/NASA MOD-1 has received two TVI complaints.
  - At Block Island, TVI effects are severe enough to require installation of a costly cable TV system.

Table A-29. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Legal/Institutional/Environmental Issues

Indicator: Noise/Infrasound

Indicator Goal/Objective:

- WECS noise output level in compliance with EPA, OSHA, and state/local noise emissions standards
- Infrasound output level of 100 dB-SPL (sound pressure level decibels) or less (i.e., the threshold of human discomfort)

Current Status of Indicator:

- Utilities operating wind systems fall under the cognizance of EPA and OSHA noise emissions standards.
- As of the end of 1978 no scientific data base existed that documented:
  - Noise emissions from large wind machines (e.g., MOD-OA, MOD-1, etc.)
  - Impact of WECS noise and infrasound emissions on human beings.
- Limited measurements of sound emissions from the Plum Brook, Ohio, MOD-O showed:
  - Maximum noise output of 64 dB--against a background noise level of 52-dB
  - At 800 ft from the turbine, turbine noise could not be distinguished from background noise
  - Infrasound level of 78 dB-SPL--well below the 100 dB-SPL threshold of human discomfort.
- SERI, in discussions with utilities having WECS, found that:
  - At Block Island, R.I., when more than 50 ft from the MOD-OA, turbine noise is not distinguishable from ambient wind noise.
  - At Boone, N.C., noise from the MOD-1 is not perceptible over ambient noise at a distance of 600 ft from the machine.
  - No complaints have been received by Clayton Municipal Electric System, Pennsylvania Power and Light, and Gosnold Power and Light (Cuttyhunk Island, Mass.) regarding noise.

Table A-30. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Legal/Institutional/Environmental Issues

Indicator: Wind Rights

Indicator Goal/Objective:

- Enacting of legislation protecting access to wind flow for utilities operating central wind systems in at least 5 of the 10 states having the greatest central WECS market potential

Current Status of Indicator:

- Ten states having the greatest central WECS market potential (criteria: wind resource, future demand for electricity, availability of federal lands and cost of electricity):
  - California
  - Hawaii
  - Massachusetts
  - Nevada
  - New Mexico
  - New York
  - Oklahoma
  - Utah
  - New Hampshire
  - Colorado
- Severity of the wind access problem increases with wind farm size and proximity to densely populated and built-up areas.
- As of the end of 1978, no state had enacted legislation which would protect utility access to an obstruction-free air corridor for operation of wind machines.
- At the present time utilities must assume responsibility for insuring wind flow. Methods for accomplishing this include:
  - Purchase of sufficient land around the WECS to insure wind flow
  - Purchase of negative easements on adjoining properties
  - Remote siting.

Table A-31. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Legal/Institutional/Environmental Issues

Indicator: Land Use

Indicator Goal/Objective:

- Enacting of legislation mandating the incorporating of wind usage considerations into state land-use planning procedures in at least 5 of the 10 states having the greatest central WECS market potential

Current Status of Indicator:

- As of the end of 1978 no state had enacted legislation mandating the incorporation of wind usage considerations into regional, state, county, or city land-use planning and zoning procedures. However, legislation enacted by California, Connecticut, Minnesota, and Oregon covering the incorporation of solar access in land-use planning serves as models for legislation addressing wind access.
- Utilities desiring to acquire wind systems must adhere to the formal review process required for conventional generating plant siting.
- In general, the utilities that have acquired WECS have sited them either on sites zoned for power plants or public-owned land.
- Pennsylvania Power and Light, Blue Ridge Electric Membership Corporation, Clayton Municipal Electric System, Gosnold Power and Light, and Block Island Power Company experienced no problems in the regulatory approval process associated with their acquisition of wind machines.

Table A-32. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Legal/Institutional/Environmental Issues

Indicator: Safety/Liability Issues

Indicator Goal/Objective:

- Manufacturer and utility adherence to applicable safety standards and regulations:
  - OSHA, FAA, and state safety regulations
  - MIL-STD-1472 military systems engineering design criteria
  - IEEE and ANSI electrical codes
  - WECS-specific standards

Current Status of Indicator:

- As of the end of 1978, no industry consensus standards covering WECS safety were in existence. Lack of data from operational machines has delayed the development of standards.
- Automatic disconnect devices are required to protect utility personnel from shock from grid-connected wind machines.
- Analysis of MOD-0A and MOD-2 design specifications showed that Westinghouse and Boeing, the respective builders, adhered to applicable safety criteria. The MOD-0A turbine incorporates two independent overspeed protection systems to prevent rotor failure, and modified tower designs to ensure tower integrity. Boeing has utilized OSHA, military, and IEEE and ANSI standards as general "design for safety" criteria and has incorporated several additional features into a comprehensive safety system for the MOD-2. As yet, no liability suits have arisen which involve large wind systems.
- Utilities surveyed by SERI indicate that they are taking similar or better worker and public safety precautions, for installation, operation, and maintenance for WECS as for conventional power plants:
  - Southern California Edison will determine OSHA and other requirements, and install a fence to restrict access to the turbine.
  - Pennsylvania Power and Light has sited its WECS at an existing substation and provided fencing and lightning protection.
  - Safety precautions at the Block Island, R.I., WECS site include regular inspections, a visitor control plan, an exclusion fence and utility personnel training. OSHA regulations have been incorporated in turbine design.
  - Clayton Municipal Electric Systems has provided fencing and lightning protection for its MOD-0A turbine. The machine will not operate if someone is in the tower. In addition, if the door of the control building is opened without disarming the security system, the machine shuts down.

Table A-33. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Legal/Institutional/Environmental Issues

Indicator: Utility Interconnection Issues

Indicator Goal/Objective:

- Federal legislation (or regulatory decree) mandating that utilities with wind systems can interconnect with other utilities and buy and sell power at fair rates
- State PUC regulations in at least 5 of the 10 best central WECS states assuring that utilities operating wind systems can interconnect with other utilities and buy from and sell power to them at fair rates.

Current Status of Indicator:

- As of the end of 1978, no federal legislation or Federal Energy Regulatory Commission (FERC) regulation was in effect mandating that utilities that operated wind systems could interconnect with other utilities and buy from and sell power to them at fair rates. The Public Utilities Regulatory Policy Act (PURPA) under the National Energy Act applies only to small power generators which are nonutility owned.
- Contracts between utilities with WECS and their bulk suppliers are subject to FERC approval. At this time, no utilities with WECS obtain power from outside suppliers.
- SERI discussions with state utility commissions indicate that applications for utility interconnections have not been made. The attitude of the commissions toward this issue is neutral. Regulations assuming interconnection and sale and buyback of power between utilities where WECS are involved have not been issued.

Table A-34. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Market Development/Large Utilities

Indicator: End-User Awareness

Indicator Goal/Objective:

- Large Utilities
  - At least 33% of the largest utilities (i.e., having generating capacities of at least 500 MW) in the 10 best central WECS states involved in wind programs: engineering studies, economic analyses, wind resource studies, demonstrations, etc.

Current Status of Indicator:

- Ten states having the greatest central WECS market potential (criteria: wind resource, future demand for electricity, availability of federal lands and cost of electricity):
  - California
  - Hawaii
  - Massachusetts
  - Nevada
  - New Mexico
  - New York
  - Oklahoma
  - Utah
  - New Hampshire
  - Colorado
- Large Utilities
  - Within the 10 best states, EPRI lists 35 utilities with generating capacities of at least 500 MW.
  - Of these 35, seven were engaged in wind programs during 1978:

    Consolidated Edison Company

    Hawaiian Electric Company

    Niagara Mohawk Power Company

    Pacific Gas and Electric Company

    Public Service Company of New Hampshire

    Rochester Gas and Electric

    Southern California Edison Company.

Consequently, about 20% of the large utilities in the 10 best states have wind programs.

Table A-35. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Market Development

Indicator: Number of Central WECS Manufacturers

Indicator Goal/Objective:

- Entry of at least 50% of the largest producers of conventional generating equipment into the production of central wind systems

Current Status of Indicator:

- According to EPRI, the following firms produce 90% of the conventional generating equipment procured by electric utilities.
  - General Electric
  - Westinghouse
  - Combustion Engineering
  - Foster and Wheeler
  - Brown Bavari
  - Allis Chalmers
  - J.R. McDermott (Babcock & Wilcox)
- As of the end of 1978, only General Electric and Westinghouse had made investments in central WECS technology.
- Although only two of the seven major producers of conventional generating equipment sponsored wind ventures, an array of other companies--having no traditional utility markets--have begun (or are considering) wind ventures:
  - ALCOA
  - Boeing
  - United Technologies
  - WTG Energy Systems
  - Wind Power Services
  - Lockheed
  - Koman

Table A-36. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Market Development

Indicator: Extent and quality of published market research/market development information

Indicator Goal/Objective:

- Performance of systematic comprehensive central WECS marketing research studies for at least 5 of the 10 states having the greatest WECS market potential: studies addressing market size and distribution, technical problems associated with market penetration, and alternative market development scenarios.

Current Status of Indicator:

- Performance of studies examining foreign market opportunities.
- The only published studies, to date, specifically addressing central WECS/utility applications are:
  - Wind Engineering Mission Analysis (General Electric)
  - Wind Energy Mission Analysis (Lockheed)
  - Requirements Assessment of Wind Power Plants in Electric Utility Systems (General Electric/EPRI).
- In the GE/EPRI study, market saturation quantity is first determined. Assuming a time at which initial market penetration begins, an S-shaped market penetration curve is fitted.
- The GE/EPRI and Lockheed studies segmented market potential data down to the level of electric utility regional reliability councils, but not to the state level. Market size and distribution data for the 10 better central WECS states are not available.
- The GE/EPRI study was conducted three years after the Mission Analyses. More detailed information on technical and economic issues are available. For instance, after considering the technical and economic limits on WECS market penetration for a particular utility, the GE/EPRI study arrived at a total expected market penetration by the year 2000 equal to 20% of that predicted in the GE Mission Analysis study.
- None of the above studies are geared towards the producer market development programs.
- One published study was available regarding small utilities: An Overview Assessment of Potential Small Electric Utility Applications of Wind Systems (SERI). This study does not provide market potential estimates for the small utility sector, rather it considers, over a national level, the correlation between wind regions and the locations of small utilities.
- No comprehensive, systematic studies or projections are available regarding foreign market opportunities.

Table A-37. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Market Development

Indicator: Consensus Standards

Indicator Goal/Objective:

- Development, dissemination, and acceptance of industry consensus standards--in conjunction with applicable federal elements (e.g., NBS, DOE, EPA) covering mechanical and structural performance, safety, reliability, operation, service, and a glossary of standardized terminology.

Current Status of Indicator:

- As of the end of 1978, no central WECS industry consensus standards existed.
- AWEA had written a first draft of a "Glossary of Terminology for Wind Energy Conversion Systems."
- AWEA had also written a draft of a "Standardized Test, Data Reduction Procedures" manual for the testing and generation of power curves.
- Federal efforts during 1978 focused on technology development. No significant funding was allocated for standards programs.

Table A-38. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Market Development

Indicator: Industry Professional and Trade Journals

Indicator Goal/Objective:

- At least six national wind-oriented professional and trade journals--each published at least quarterly--targeted at utilities, manufacturers, designers, installers, and other important market participants

Current Status of Indicator:

- As of the end of 1978, at least six national professional and trade journals catering to the important central WECS market participants and published at least quarterly were in existence.
  - Wind Engineering
  - Wind Energy Report
  - Wind Power Digest
  - Wind Technology Journal
  - Solar Energy
  - Solar Age

  Information about these journals is provided in Table A-39.
- The first four periodicals above are devoted exclusively to wind technology. The last two periodicals address nearly all solar technologies, including wind.
- Analysis of WECS producer market development activities showed that producers do not appear to be exploiting professional and trade journals catering to key utility equipment decision makers (e.g., executives, engineers, etc.)--magazines such as Electrical World.

Table A-39. EXAMPLE OF NATIONAL PROFESSIONAL AND TRADE JOURNALS CATERING TO THE CENTRAL WECS INDUSTRY

National Professional and Trade Journals	Publisher	Frequency of Publication	Type of Journal	Primary Target Audience
Wind Engineering	• Multi-Science Publishing Company London, England	• Quarterly	• Professional	• Scientists • Engineers • Designers
Wind Energy Report	• Wind Publishing Corporation New York, NY	• Monthly	• Trade	• End Users • Producers
Wind Power Digest	• American Wind Energy Association Bristol, IN	• Quarterly	• Trade	• End Users • Producers • Designers
Wind Technology Journal	• American Wind Energy Association Marston Mills, MA	• Quarterly	• Professional	• Engineers • Scientists • Designers
Solar Energy	• International Solar Energy Soc. Permagon Press Victoria, Australia	• Monthly	• Professional	• Engineers • Scientists • Designers
Solar Age	• American Section of the International Solar Energy Society	• Monthly	• Professional and Trade	• End Users • Producers • Designers

Table A-40. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Market Development

Indicator: Strong, Respected, and Active Trade Association

Indicator Goal/Objective:

- Evolution of at least one strong, respected, and aggressive trade association for central WECS producers, end users, designers, etc.

Current Status of Indicator:

- Criteria for a "strong, respected, and active" trade association
  - Membership consists of at least 50% of the producers
  - Member producers manufacture at least 50% of industry output (dollar value)
  - Association aggressively lobbies for the WECS community before Federal and State governments
  - Association has the support (or ear) of at least one chairperson of at least one energy-cognizant committee of the U.S. Congress.
- The focal trade association for the U.S. Central WECS industry is the American Wind Energy Association (AWEA), Washington, D.C., founded in 1974.
- AWEA membership: 750 individuals and firms, including 35 large and small corporations.
- AWEA published three journals
  - Wind Letter (Biweekly)
  - Wind Power Digest (Quarterly)
  - Wind Technology Journal (Quarterly).
- AWEA conducts a vigorous lobbying campaign before the Federal bureaucracy and Congress, testifying before the House Committee on Science and Technology and the Senate Natural Resources Committee.
- Solar Energy Industries Association (SEIA) also has an interest in wind technology but is concentrating on solar thermal technologies. AWEA and SEIA have not undertaken any joint wind ventures.

Table A-41. SOLAR TECHNOLOGY COMMERCIAL READINESS ASSESSMENT

Solar Technology/Application: Central Wind Systems/Large Utilities

Factor: Market Development

Indicator: Extent of Cumulative Market Penetration

Indicator Goal/Objective:

- Installed central WECS capacity equal to the market take-off stage as predicted in the General Electric/EPRI study market penetration curve--approximately 8.3 GW (equivalent to 4150 2-MW wind machines)

Current Status of Indicator:

- Figure A-1 shows the market penetration curve developed by General Electric in the study "Requirements Assessment of Wind Power Plants in Electric Utility Systems" sponsored by EPRI.
- As of the end of 1978, no U.S. electric utility had acquired any central wind machines for producing electricity commercially.
- During 1978, no U.S. wind machine having a power rating of at least 500 kW had been produced and demonstrated. At Boeing, work progressed on the MOD-2. General Electric was preparing to deliver the MOD-1 machine for installation at Boone, N.C.
- All of the large WECS operated by utilities in 1978 were for demonstration purposes or to study economic feasibility. Examples of utilities operating wind systems (or planning to acquire them) include:
  - Southern California Edison Company
  - Block Island Power Company
  - Clayton Municipal Electric System
  - Blue Ridge Electrical Membership Corporation
  - Gosnold Power and Light
  - Puerto Rico Water Resources Authority
  - Ohio Edison Company

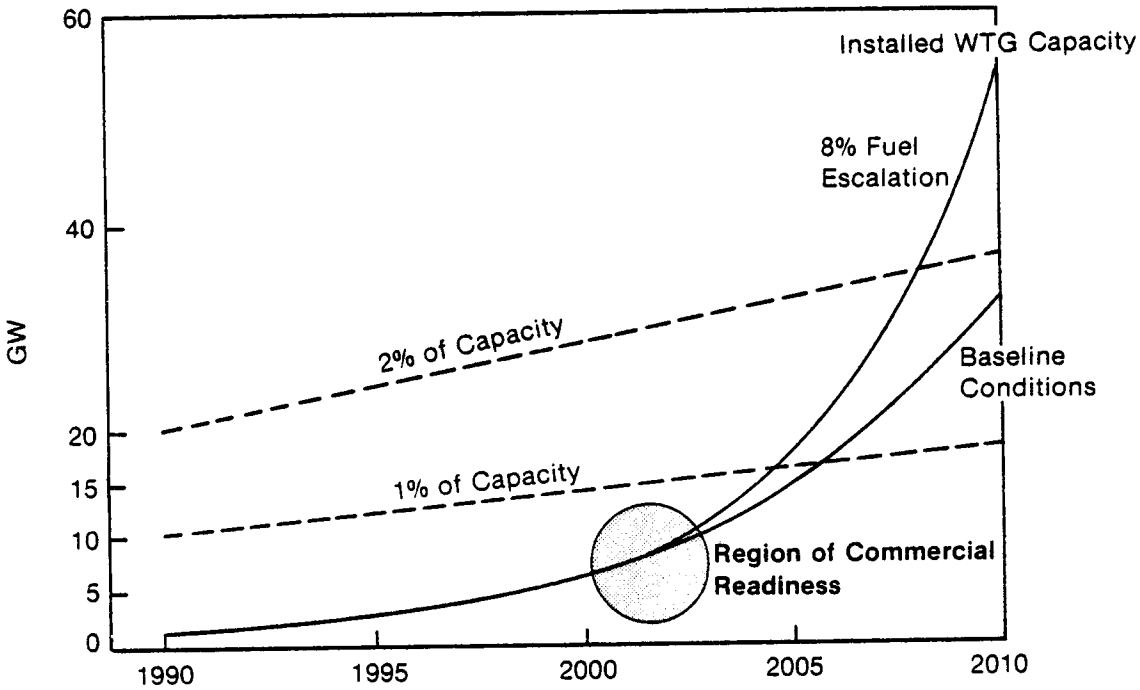

Figure A-1. Market Penetration Curve for the Electric Utility Sector Showing Region of Commercial Readiness

Source: Requirements Assessments of Wind Power Plants in the Electric Utility Sector—General Electric/EPRI