Appendix A1

Statement of Work for Evergreen Solar, Inc.

Innovative Approaches to Low Cost Module Manufacturing of String Ribbon Si PV Modules

ZDO-2-30628-09

June 19, 2002

1.0 BACKGROUND

The U.S. Department of Energy (DOE), in cooperation with the U.S. Photovoltaics (PV) Industry, has the objective of retaining and enhancing U.S. leadership in the world market. To further this objective, the Photovoltaic Manufacturing Technology (PVMaT) project was initiated in FY 1990 to form a partnership between DOE and the U.S. PV industry, assisting in the improvement of module manufacturing processes and in the substantial reduction of module manufacturing cost. The goals of the project were to improve PV manufacturing processes and products for terrestrial applications, accelerate PV manufacturing cost reduction, lay the foundation for significantly increased production capacity, and assist the U.S. industry in retaining and enhancing its world leadership role in the commercial development and manufacture of terrestrial PV systems. The focus of the program emphasized research and development (R&D) manufacturing process issues.

Four solicitations have been completed since inception of the PVMaT Project and a fifth solicitation is near completion. These solicitations addressed, respectively: (1) process-specific R&D on PV module manufacturing (open only to companies that completed successfully a preliminary problem-definition phase; (2) generic research on problems of interest to all, or to a large portion of the PV industry; (3) process-specific R&D on PV module manufacturing; (4) product-driven PV manufacturing R&D addressing process-specific problems, as well as manufacturing improvements for balance-of-systems (BOS) components and system design improvements; and (5) PV module manufacturing technology and PV system and component technology.

The FY2000 solicitation, "PV Manufacturing R&D — In-Line Diagnostics and Intelligent Processing in Manufacturing Scale-Up," was a continuation of the PV Manufacturing R&D Project that focused on further accelerating the PVMaT achievements and was designed to be impartial to various PV technologies and manufacturing approaches. The goals are to improve PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up (100-MW level). Letters of Interest under this solicitation were to address areas of work that could include, but were not be limited to, issues such as improvement of module manufacturing processes; system and system component packaging, system integration, manufacturing and assembly; product manufacturing flexibility; and balance-of-system development including storage and quality control. The primary emphasis was on new and improved in-line diagnostics and monitoring with real-time feedback for optimal process control and increased yield in the fabrication of PV modules, systems, and other system components.

During this subcontract, Evergreen Solar, Inc. (hereafter referred to as "Evergreen" in this document) will address the goals of improved PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up. To accomplish these

To accomplish this task, Evergreen shall demonstrate a mixing method with satisfactory uniformity, develop a suitable solvent drying procedure and develop equipment which will not contaminate the feedstock silicon. This task is expected to result in a production worthy doping method and apparatus that produces satisfactory ribbon growth and cell efficiencies.

3.2 Task 2 Growth Of Surface Oxide Free Ribbon-1

EVERGREEN shall find a simple optical method to detect surface oxide on Si ribbon as it grows and develop an easily implementable method that provides data needed for in-situ correction. To accomplish this task, Evergreen shall develop a detailed characterization of surface oxide layers and develop a simple method for optical detection. This task is expected to result in the development of an optical method for collecting data needed to implement real-time corrective action during crystal growth (see task 11 in Phase II) that can eliminate all etch steps between growth and diffusion for Si ribbon.

3.3 Task 3 Improve Starting Lifetime Of As-Grown String Ribbon -1

EVERGREEN shall improve the starting lifetime of as-grown string ribbon through better purification of hot zone component materials to reduce transition metals and the development of coatings that are more impermeable for hot zone components. DLTS shall be used to verify the lifetime improvements. To accomplish this task, Evergreen shall investigate coatings to reduce permeability, investigate improved purification methods for graphite parts, investigate new configurations in hot zone parts, perform in-house lifetime measurements, obtain DLTS results through university contacts, and obtain string ribbon characterization through interaction with Georgia Tech. This task is expected to result in improvement in starting lifetime through reduced transition metals in string ribbon.

3.4 Task 4 12% Efficient Wrap-around Cell

EVERGREEN shall improve cell-processing leading to a 12% efficient wrap-around cell. Evergreen will achieve the efficiency gains in this task by both improvements in starting lifetime (Task 3) and advances in cell processing, especially plasma nitride passivation and firing through contacts. To accomplish this task, Evergreen shall perform cell processing of higher lifetime material, optimization of plasma nitride processes, and optimization of metallization firing processes. This task is expected to result in 12% wrap-around cells.

3.5 Task 5 Improve Devices Through Lowered Series Resistance And Increased Shunt Resistance

EVERGREEN shall develop techniques to improve their wrap-around cell by achieving lowered series resistance through changes in finger cross section and increased shunt resistance through materials science studies on pastes and dielectric layers. To accomplish this task, Evergreen will develop methods to improve finger cross section, perform Ag paste studies to improve wrap around ribbon edge, investigate appropriate dielectric layers, and develop methods for reduction of edge leakage. This task is expected to result in improved fill factors for 120 sq. cm. wrap-around contact cells

3.6 Task 6 Design And Develop A Prototype Machine To Apply Wrap-around Decals

assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase II task-oriented research through reporting requirements detailed in sections 4, 5, and 6.

3.10 Task 10 Improve Starting Lifetime Of As-Grown String Ribbon -2

EVERGREEN shall continue to improve the starting lifetime of as-grown string ribbon through better control of thermal and mechanical perturbations to minimize dislocation formation. To accomplish this task, Evergreen shall make use of vibration control and more uniform thermal environment to obtain lower dislocation content. Evergreen shall redesign their crystal growth hot zone to improve the thermal uniformity, design and develop techniques for vibration damping during growth, and perform dislocation density mapping to guide other efforts in this task. This task is expected to result in higher starting lifetimes through reduced dislocation density

3.11 Task 11 Growth Of Surface Oxide Free Ribbon-2

EVERGREEN shall develop a better understanding of oxygen ingress from the exit slits and convection in the region around the hot zone through a better understanding of convection in the hot zone. In addition, Evergreen shall design new techniques to utilize the improved understanding of oxygen ingress and reduce the oxygen available that creates undesired oxide on newly grown ribbon. To accomplish this task, Evergreen shall redesign their Ar introduction techniques and develop methods to reduce convection in the hot zone region. This task is expected to result in oxide free ribbon and eliminate all etch steps between growth and diffusion for Si ribbon.

3.12 Task 12 13 % Wrap-around Cells

EVERGREEN shall improve efficiency through optimized nitride passivation for both front and rear surfaces and development of a method to form a good back contact. To accomplish this task, Evergreen shall develop, deploy, and test a boat for double sided passivation and develop and test Al paste that can fire through nitride. This task is expected to result in 13 % wrap-around cells.

3.13 Task 13 Design, Develop, and Test a Production-worthy Machine to Apply Wrap-around Decals

EVERGREEN shall design, develop, and test a machine to apply wrap-around decals for high volume production rates on the order of 1000 cells/hr. The design shall make use of an Allen Bradley PLC that will feed process data into a central computer. This task is expected to result in the development of a production-worthy machine that automates the application of wrap-around decals.

3.14 Task 14 Continuous Lamination Process

EVERGREEN shall develop a continuous, non-vacuum lamination process that eliminates cell cracking and which is suitable for high volume production. To accomplish this task, Evergreen shall find process conditions (such as roller temperature, pre heat temperature, speed, and roller pressure) whereby cell cracking is eliminated. Evergreen shall then develop suitable process conditions for high volume manufacturing. This task is expected to result in a high volume, continuous non-vacuum

PHASE III - Third Year

During Phase III, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase III efforts shall address the demonstration of improved starting lifetime of as-grown string ribbon from a production-capable system, continued improvements on wrap-around cells leading to 14% efficiency, continued testing and fine tuning to demonstrate manufacturing line worthiness for a decal application machine. Evergreen shall also design and develop an improved small high voltage module, debug, test, and fine-tune module manufacturing equipment used for frameless, monolithic modules, debug, test, and fine-tune a robotic pick and place machine for automated monolithic module layout, and continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. And finally Evergreen shall demonstrate their state of the art manufacturing capability to make monolithic modules. EVERGREEN shall report all progress from this Phase III task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

3.20 Task 20 Demonstrate Improved Starting Lifetime On Production-Capable System

EVERGREEN shall demonstrate the results of the work on impurity reduction (Task 3) and dislocation reduction (Task 10) on a production crystal growth system so as to produce a higher average and tighter distribution of starting lifetime. Presently the lifetimes vary from <1 to >10 microseconds. The goal here will to eliminate the lower end of the distribution. This task is expected to result in starting lifetimes of 5 to >10 microseconds.

3.21 Task 21 14% Efficient Wrap-around Contact Cells

EVERGREEN shall combine advances made in Tasks 12 and 20 to routinely make 14% cells. To accomplish this task, Evergreen shall make cells utilizing the advances developed during Phase II to produce cells on production-worthy equipment developed for performing tasks 12 and 20. This task is expected to result in 14% wrap-around contact cells.

3.22 Task 22 Fine-Tune And Test Wrap-around Decal Application Machine

EVERGREEN shall demonstrate, fine-tune, and test a production worthy wrap-around decal application machine with a goal of achieving throughput of 1000 cells/hr at > 95% yield. To accomplish this task, Evergreen shall execute an iterative process of fine-tuning and testing their wrap-around decal application machine at high volume. This task is expected to result in a complete debugging of their wrap-around decal application machine and a demonstration of production-worthiness.

3.23 Task 23 Design And Develop An Improved Small, High Voltage Module

EVERGREEN shall design and develop a high voltage small monolithic module suitable for automated production. To accomplish this task, Evergreen shall demonstrate the viability of laser cutting large wrap-around cells into smaller wrap-around cells, demonstrate adequate reliability for

4.1 TASK SCHEDULE

Task Schedules are broken down into separate Phase I, Phase II, and Phase III efforts to correspond to the three one-year phases of the subcontract. EVERGREEN shall perform these tasks according to the following phased schedules:

PHASE I

EVERGREEN shall perform and complete Tasks 1 through 9 during the first year, Phase I, of this subcontract according to the following schedule:

Months	J	A	S	O	N	D	J	F	M	A	M	J	J	A
Task 1	X	X	X	X	X	X								
Task 2	X	X	X	X	X									
Task 3				X	X	X	X	X	X	X	X	X		
Task 4										X	X	X		
Task 5	X	X	X	X	X	X	X	X	X	X	X	X		
Task 6	X	X	X	X	X	X	X							
Task 7						X	X	X	X	X	X	X		
Task 8	X	X	X	X	X	X	X	X	X	X	X	X		
Task 9	X	X	X	X	X	X	X	X	X	X	X	X		
Monthly Reports		15th	15th	15th	15th	15th	15th	15th	15th	15th	15th	15th		
Annual Report												draft 15th		final 30th

PHASE II

EVERGREEN shall perform and complete Tasks 10 through 19 during the second year, Phase II, of this subcontract according to the following schedule:

Months	J	A	S	O	N	D	J	F	M	A	M	J	J	A
Task 10	X	X	X	X	X	X	X	X	X	X	X	X		
Task 11	X	X	X	X	X	X								
Task 12						X	X	X	X	X	X	X		
Task 13	X	X	X	X	X	X	X	X	X	X	X	X		
Task 14			X	X	X	X	X	X	X					
Task 15			X	X	X	X	X	X	X	X	X			
Task 16					X	X	X	X	X	X	X	X		
Task 17						X	X	X	X	X	X			
Task 18				X	X	X	X	X	X					
Task 19							X	X	X	X	X	X		
Monthly Reports		15th	15th	15th	15th	15th	15th	15th	15th	15th	15th	15th		
Annual Report												draft 15th		final 30th

Milestones due on December 31, 2002

m-1.2.1	Install mixing equipment	(Task 1)
m-1.2.2	Grow ribbon using feedstock mixed in new equipment	(Task 1)
m-1.2.3	Show no negative impact on efficiency from new doping process	(Task 1)
m-1.2.4	Identify contact cross section changes for screen printing	(Task 5)
m-1.2.5	Decision on whether or not to study alternative printing method	(Task 5)
m-1.2.6	Dielectric layers selected	(Task 5)
m-1.2.7	Prototype machine developed and tested	(Task 6)
m-1.2.8	Demonstrate cross-linked thinner backskin sheets	(Task 8)
m-1.2.9	Choose conductive ink for printing onto backskin	(Task 9)
m-1.2.10	Demonstrate ease of printing of conductive material	(Task 9)

Milestones due on March 31, 2003

m-1.3.1	Demonstrate coating with reduced permeability	(Task 3)
m-1.3.2	Network for all new crystal growth machines established	(Task 7)
m-1.3.3	Bulk resistivity and laser cutting data connected to the network	(Task 7)
m-1.3.4	Initiate qualification tests	(Task 8)
m-1.3.5	Initiate in-house accelerated testing	(Task 8)
m-1.3.6	Demonstrate adequate performance under thermal cycling	(Task 9)
m-1.3.7	Demonstrate adequate performance under humidity freeze	(Task 9)

Milestones due on June 31, 2003

m-1.4.1	Test graphite parts for improved purification	(Task 3)
m-1.4.2	Test novel hot zone parts' configurations	(Task 3)
m-1.4.3	Demonstrate lifetime gains from M-1.3.1-M-1.3.3	(Task 3)
m-1.4.4	Verify M-1.3.4 with DLTS	(Task 3)
m-1.4.5	R and D cells from Ga. Tech with efficiency > 15.5%	(Task 3)
m-1.4.6	Optimize plasma nitride process	(Task 4)
m-1.4.7	Optimize metallization firing process	(Task 4)
m-1.4.8	Demonstrate fabrication of 120 sq. cm., 12% wrap-around cells	(Task 4)
m-1.4.9	Demonstrate reduced series resistance	(Task 5)
m-1.4.10	Demonstrate increased shunt resistance	(Task 5)
m-1.4.11	Demonstrate process monitoring using SPC charts	(Task 7)
m-1.4.12	Complete accelerated testing	(Task 8)

m-2.4.3	Establish data processing for decal application machine	(Task 13)
m-2.4.4	Develop method to form backskin edge	(Task 15)
m-2.4.5	Complete design of machine to form sealed leads	(Task 16)
m-2.4.6	Complete development of machine to form sealed leads	(Task 16)
m-2.4.7	Complete development of monolithic module manufacturing method	(Task 17)
m-2.4.8	Complete development of automatic bulk resistivity measurement	(Task 19)
m-2.4.9	Complete incorporation of RS View in module machine designs	(Task 19)

PHASE III

Milestones due on September 30, 2004

m-3.1.1	Complete debug of robotic pick and place machine	(Task 25)

Milestones due on December 31, 2004

m-3.2.1	Complete debug of wrap-around decal application machine	(Task 22)
m-3.2.2	Demonstrate viability of laser cutting small cells from large cells	(Task 23)
m-3.2.3	Complete running of robotic pick and place machine	(Task 25)
m-3.2.4	Complete demonstration of positional accuracy and repeatability	(Task 25)

Milestones due on March 31, 2005

m-3.3.1	Demonstrate impurity reduction on production machine	(Task 20)
m-3.3.2	Demonstrate dislocation reduction on production machine	(Task 20)
m-3.3.3	Complete reliability studies on high-voltage small modules	(Task 23)
m-3.3.4	Complete automation for high-voltage small modules	(Task 23)
m-3.3.5	Complete speed and quality demonstration for manufacture of frameless, monolithic module	(Task 24)

Milestones due on June 31, 2005

m-3.4.1	Demonstrate starting lifetimes of 5 to >10 microseconds	(Task 20)
m-3.4.2	Advances made in Tasks 12 and 20 brought together	(Task 21)
m-3.4.3	Demonstrate 14% wrap-around contact cells	(Task 21)
m-3.4.4	Complete testing of wrap-around decal application machine	(Task 22)
m-3.4.5	Complete yield demonstration for manufacture of frameless, monolithic module	(Task 24)
m-3.4.6	Complete development of RS View on all automated machines for modules	(Task 26)
m-3.4.7	Complete integration of all inputs into a central collection point	(Task 26)

D-1.2.1	Report on installation of mixing equipment. (Task 1)		End of Second Quarter
D-1.2.2	One sample of 3" wide doped ribbon. (Task 1)	1	End of Second Quarter
D-1.2.3	Two 12% cells made with feedstock doped with new doping process. (Task 1)	2	End of Second Quarter
D-1.2.4	Report on finger cross section through screen-printing. (Task 5)		End of Second Quarter
D-1.2.5	Report on decision to study alternative printing methods. (Task 5)		End of Second Quarter
D-1.2.6	Report on dielectric layers selected. (Task 5)		End of Second Quarter
D-1.2.7	Report on development and testing of prototype machine. (Task 6)		End of Second Quarter
D-1.2.8	One cell from prototype machine. (Task 6)	1	End of Second Quarter
D-1.2.9	Example of cross-linked thinner backskin . (Task 8)		End of Second Quarter
D-1.2.10	Report on ink choice. (Task 9)		End of Second Quarter
D-1.2.11	One sample of printed conductive material on backskin. (Task 9)		End of Second Quarter
D-1.3.1	Report on coating with reduced permeability. (Task 3)		End of Third Quarter
D-1.3.2	Report on establishment of network for new crystal growth machines. (Task 7)		End of Third Quarter
D-1.3.3	Report on resistivity and laser cutting data added to the network. (Task 7)		End of Third Quarter
D-1.3.4	Report on initiation of in-house accelerated tests and qualification tests. (Task 8)		End of Third Quarter
D-1.3.5	One backskin sample. (Task 8)	1	End of Third Quarter
D-1.3.6	Report on performance under thermal cycling and humidity freeze. (Task 9)		End of Third Quarter
D-1.3.7	Report on completed accelerated tests. (Task 9)		End of Third Quarter
D-1.4.1	Report on tests of improved purification graphite parts. (Task 3)		End of Fourth Quarter
D-1.4.2	Report on novel hot zone parts' configurations. (Task 3)		End of Fourth Quarter
D-1.4.3	Report on lifetime gains (and DLTS verification) from M-1.3.1-M-1.3.3. (Task 3)		End of Fourth Quarter
D-1.4.4	One >15% R&D cell. (Task 3)	1	End of Fourth Quarter

D-2.3.2	Report on design and deployment of boat for double sided passivation. (Task 12)		End of Seventh Quarter
D-2.3.3	Report on adequate firing through of Al paste. (Task 12)		End of Seventh Quarter
D-2.3.4	Report on development and testing of decal application machine. (Task 13)		End of Seventh Quarter
D-2.3.5	Report on hot roll lamination process for full module. (Task 14)		End of Seventh Quarter
D-2.3.6	One typical full module produced with hot roll lamination process. (Task 14)	1	End of Seventh Quarter
D-2.3.7	Report on choice of method to form backskin edge. (Task 15)		End of Seventh Quarter
D-2.3.8	Report on development of backskin modification machine. (Task 16)		End of Seventh Quarter
D-2.3.9	Report on design of a machine to form sealed leads. (Task 16)		End of Seventh Quarter
D-2.3.10	Report on decision for monolithic module manufacturing method. (Task 17)		End of Seventh Quarter
D-2.3.11	Report on pick and place machine design. (Task 18)		End of Seventh Quarter
D-2.3.12	Report on design of automatic bulk resistivity measurement. (Task 19)		End of Seventh Quarter
D-2.4.1	Report on improved lifetimes and dislocation maps. (Task 10)		End of Eighth Quarter
D-2.4.2	One 13% wrap-around cell. (Task 12)	1	End of Eighth Quarter
D-2.4.3	One sample from and report on decal application machine with data processing. (Task 13)		End of Eighth Quarter
D-2.4.4	One sample from and report on decal application machine with data processing. (Task 13)	1	End of Eighth Quarter
D-2.4.5	Report on process to make frameless modules. (Task 15)		End of Eighth Quarter
D-2.4.6	Report on manufacturing equipment for frameless modules. (Task 16)		End of Eighth Quarter
D-2.4.7	Report on development of monolithic module manufacturing method for shrinkage control. (Task 17)		End of Eighth Quarter
D-2.4.8	One sample demonstrating monolithic module manufacturing method for shrinkage control. (Task 17)	1	End of Eighth Quarter
D-2.4.9	Report on development of automatic bulk resistivity measurement. (Task 19)		End of Eighth Quarter

D-3.4.6	Report on development of RS View on all automated machines for modules. (Task 26)		End of Twelfth Quarter
D-3.4.7	Report on integration of all inputs into a central collection point. (Task 26)		End of Twelfth Quarter
D-3.4.8	Report on demonstration of manufacturing capability. (Task 27)		End of Twelfth Quarter
D-3.4.9	Report on module fabrication yield. (Task 27)		End of Twelfth Quarter
D-3.4.10	Two monolithic modules typical of 100 module run sent to NREL. (Task 27)	2	End of Twelfth Quarter

Deliverables that are not reports shall be sent to the Technical Monitor at the following address:

National Renewable Energy Laboratory
ATTENTION: C. Edwin Witt, MS#3214
1617 Cole Boulevard
Golden, Colorado 80401

with a copy of the transmittal letter sent to the Contract Administrator at:

National Renewable Energy Laboratory
ATTENTION: Christie Johnson, MS#2713
1617 Cole Boulevard
Golden, Colorado 80401

Deliverables identified as reports in the above schedule in this section may be delivered as attachments to the Monthly Technical Status Report (MTSR) corresponding to the final month for the quarter in which that report deliverable is due. If an MTSR is not due in the final month of the quarter (as is the case at the end of each phase when an annual or the final report is due), the deliverable reports due at that time shall be delivered one item with separate sections. In any of these cases, each deliverable report shall be clearly identifiable as a distinct section.

5.2 PRESENTATIONS AND PUBLICATIONS

EVERGREEN shall attend NREL Subcontractor Annual Review Meetings to be held at a place and time specified by NREL. EVERGREEN shall present a complete discussion of work performed under this subcontract at such meetings and submit one reproducible master copy of the presentation material prior to this review, as specified by the NREL Technical Monitor.

Technical Monitoring Team Members as described in Section 5.4, with a copy of their transmittal letters sent to the Technical Monitor.

5.4 REQUIRED REPORTS

EVERGREEN shall be required to prepare and submit the following reports indicated below. If the period of performance for this subcontract begins during the first through the fifteenth of a month, then that month is considered the first full month of the subcontract for reporting purposes. If the period of performance for this subcontract begins during the sixteenth through the end of the month, then the first full month of the subcontract for reporting purposes is the following month. For example, if the period of performance start date is January 10, then January is the first full month for reporting purposes: whereas, if the period of performance start date is January 20, then February is the first full month for reporting purposes.

A. MONTHLY TECHNICAL STATUS REPORT:

The Monthly Technical Status Report is to be formatted to communicate to NREL an assessment of subcontract status, explain variances and problems, report on the accomplishment of performance milestones and/or program deliverables, and discuss any other achievements or areas of concern. This report should be three to six pages written in a letter format with emphasis placed on the status rather than a description of the progress. An introductory paragraph will be included in each monthly report that provides a highlight of the month's activities. **Copies of this report are due on or before fifteen (15) days after completion of each month** [two (2) copies to the NREL Technical Monitor (TM), one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the NREL Contract Administrator].

B. ANNUAL TECHNICAL PROGRESS REPORT

The Annual Technical Progress Reports are to be structured as formal technical reports, both in draft and final version, which describe all significant work performed during each year of the subcontract. **Copies of the draft Annual Technical Progress Report are due on or before fifteen (15) days prior to the completion date for each year's research effort under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team (TMT) members, one (1) copy for the NREL TMT member, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make these corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Annual Technical Progress Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site, see **B1** Guidelines below), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** If the subcontracted effort in the following year is not authorized and funded by NREL, then that year's Annual Technical Progress Report shall be designated as the Final Technical Report (see description below) and the period of performance for

6.0 PERFORMANCE EVALUATION

The performance of EVERGREEN will be monitored and evaluated by the following means:

i) Monthly Technical Status Reports consisting of a report of program status relative to milestone and program schedules (3-6 pages);
ii) Annual Technical Progress Reports;
iii) A Final Technical Report covering work done under the subcontract;
iv) Monthly Subcontract Management Summary Reports prepared on NREL Form 619A;
v) Up to two On-Site Visits by a PVMaT-selected evaluation team to EVERGREEN per phase – these visits shall entail presentations and demonstrations by EVERGREEN; and
vi) Participation by EVERGREEN in up to two contractor Program Review Meetings per Phase as designated by PV Manufacturing R&D (PVM R&D) project management personnel.

During the subcontract, on-site presentations and demonstration reviews will be conducted by a PVM R&D review committee consisting of members selected by PVM R&D project management staff. These meetings will be critical program evaluation points. The progress of EVERGREEN will be assessed at this time by reviewing past accomplishments and future program plans.

The progress of EVERGREEN will also be monitored by telephone conversations and by possible additional on-site visits by the NREL technical evaluation team at the discretion of the NREL technical monitor for the subcontract.

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ZDO-2-30628-09

March 24, 2004

1.0 BACKGROUND

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Four solicitations have been completed since inception of the PVMaT Project and a fifth solicitation is near completion. These solicitations addressed, respectively: (1) process-specific R&D on PV module manufacturing (open only to companies that completed successfully a preliminary problem-definition phase; (2) generic research on problems of interest to all, or to a large portion of the PV industry; (3) process-specific R&D on PV module manufacturing; (4) product-driven PV manufacturing R&D addressing process-specific problems, as well as manufacturing improvements for balance-of-systems (BOS) components and system design improvements; and (5) PV module manufacturing technology and PV system and component technology.

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optimal process control and increased yield in the fabrication of PV modules, systems, and other system components.

During this subcontract, Evergreen Solar, Inc. (hereafter referred to as "Evergreen" in this document) will address the goals of improved PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up. To accomplish these goals, Evergreen will focus their efforts on their second-generation technology. These advances would be: further cost reduction in the production of wafers by the String Ribbon technique; high efficiency wrap-around contact solar cells; development and deployment of the manufacturing technology to make frameless modules based on polymers developed in Evergreen Solar's first PVMaT contract (1995 –1997); and the culmination of all these developments- monolithic modules. These developments will be accompanied with extensive use of manufacturing science techniques especially in the areas of diagnostics and statistical process control. Evergreen will also work toward PVMaT goals by developing quality assurance and ES&H programs in keeping with local, State, and Federal regulations as applicable.

2.0 OBJECTIVE

The objective of this subcontract over its three-phase duration is to continue the development of Evergreen's String Ribbon Si PV technology resulting in an advanced generation of crystalline silicon PV module manufacturing technology applied to a virtually continuous fully integrated manufacturing line. The final goal of this line will be the production of frameless modules using wrap-around contacts on String Ribbon solar cells and made in a monolithic module configuration. Specific objectives include methods for improving surface and bulk quality of as-grown ribbon, techniques for wrap-around solar cell efficiency improvement, extensive reliability testing under accelerated conditions, developing low cost manufacturing to make frameless modules in general and monolithic modules in particular, and in line diagnostics throughout the production line. To further the high efficiency work, close interaction with Prof. Rohatgi's group at Georgia Tech will be pursued.

3.0 SCOPE OF WORK

The subcontract shall consist of three phases and will be incrementally funded. Evergreen shall complete the investigations described in the following tasks and provide a detailed summary of this work in its reports and deliverables.

PHASE I

During Phase I, Evergreen shall perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. These efforts shall address the scale-up of a previously developed laboratory scale technique to a production worthy doping method, growth of surface oxide free ribbon, improved starting lifetime of as-grown string ribbon, 12% efficient wrap-around cells, and device improvements on wrap-around cells. Evergreen shall design and develop a prototype machine to apply wrap-around decals.

They shall develop necessary in-line diagnostics to support crystal growth. Evergreen shall also perform work leading to backskin materials cost reduction and develop and use methods for accelerated testing of monolithic modules to demonstrate desired stability. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase I task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

3.1 Task 1 Scale-Up Of A Production Worthy Doping Method

Evergreen shall scale-up the laboratory scale technique already developed to a scale suitable for manufacturing feedstock silicon using liquid spin-on dopants. To accomplish this task, Evergreen shall demonstrate a mixing method with satisfactory uniformity, develop a suitable solvent drying procedure and develop equipment which will not contaminate the feedstock silicon. This task is expected to result in a production worthy doping method and apparatus that produces satisfactory ribbon growth and cell efficiencies.

3.2 Task 2 Growth Of Surface Oxide Free Ribbon-1

Evergreen shall find a simple optical method to detect surface oxide on Si ribbon as it grows and develop an easily implementable method that provides data needed for in-situ correction. To accomplish this task, Evergreen shall develop a detailed characterization of surface oxide layers and develop a simple method for optical detection. This task is expected to result in the development of an optical method for collecting data needed to implement real-time corrective action during crystal growth (see task 11 in Phase II) that can eliminate all etch steps between growth and diffusion for Si ribbon.

3.3 Task 3 Improve Starting Lifetime Of As-Grown String Ribbon -1

Evergreen shall improve the starting lifetime of as-grown string ribbon through better purification of hot zone component materials to reduce transition metals and the development of coatings that are more impermeable for hot zone components. DLTS shall be used to verify the lifetime improvements. To accomplish this task, Evergreen shall investigate coatings to reduce permeability, investigate improved purification methods for graphite parts, investigate new configurations in hot zone parts, perform in-house lifetime measurements, obtain DLTS results through university contacts, and obtain string ribbon characterization through interaction with Georgia Tech. This task is expected to result in improvement in starting lifetime through reduced transition metals in string ribbon.

3.4 Task 4 12% Efficient Wrap-around Cell

Evergreen shall improve cell-processing leading to a 12% efficient wrap-around cell. Evergreen will achieve the efficiency gains in this task by both improvements in starting lifetime (Task 3) and advances in cell processing, especially plasma nitride passivation and firing through contacts. To accomplish this task, Evergreen shall perform cell processing of higher lifetime material, optimization of plasma nitride processes, and optimization of metallization firing processes. This task is expected to result in 12% wrap-around cell.

3.5 Task 5 Improve Devices Through Lowered Series Resistance And Increased Shunt Resistance

Evergreen shall develop techniques to improve their wrap-around cell by achieving lowered series resistance through changes in finger cross section and increased shunt resistance through materials science studies on pastes and dielectric layers. To accomplish this task, Evergreen will develop methods to improve finger cross section, perform Ag paste studies to improve wrap around ribbon edge, investigate appropriate dielectric layers, and develop methods for reduction of edge leakage. This task is expected to result in improved fill factors for 120 sq. cm. wrap-around contact cells

3.6 Task 6 Design And Develop A Prototype Machine To Apply Wrap-around Decals

Evergreen shall develop a concept and prototype machine for applying wrap-around solar cells that will lead higher manufacturing line volume and yield. To accomplish this task, Evergreen shall develop a concept for prototype machine, design a prototype machine, develop the prototype machine, and test the prototype machine. This task is expected to result in the testing of a prototype decal application machine that will be the basis for development of a high volume production machine.

3.7 Task 7 In-Line Diagnostics-1

Evergreen shall develop a central database for in-line diagnostics in the crystal growth area to automatically generate SPC charts using the software package called RS View 32. To accomplish this task, Evergreen shall develop a data network for all new crystal growth machines, add bulk resistivity and laser cutter data to the network, and develop real time process monitoring using SPC charts. This task is expected to result in improved process control in the crystal growth area.

3.8 Task 8 Backskin Materials Cost Reduction

Evergreen shall develop processes to reduce cost of the backskin material by formulating thinner sheets of this material and then apply appropriate qualification tests, as well as in house accelerated tests, to the thinner sheets. To accomplish this task, Evergreen shall formulate thinner backskin, cross-link thinner backskin sheets, conduct qualification tests with thinner material, and perform in-house accelerated testing This task is expected to result in the development of a process to reduced backskin cost.

3.9 Task 9 Accelerated Testing Of Monolithic Modules

Evergreen shall study appropriate inks and printing properties and perform accelerated testing to establish the long term stability of the electrical bonds for material used in adhesive and conducting bars. To accomplish this task, Evergreen shall study various conductive inks, establish suitable printing properties for conductive material, and conduct accelerated testing of conductive material contacts. This task is expected to result in the development of practical printing method for the conductive material chosen, the demonstration of long term stability for contacts, and the demonstration of long term viability by the monolithic module.

PHASE II

During Phase II, Evergreen shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase II efforts shall address further improvement in the starting lifetime of as-grown string ribbon, continued work on growth of surface oxide free ribbon, continued improvements on wrap-around cells leading to 13% efficiency, the design, development, and initial testing of a machine to apply wrap-around decals, development of a continuous lamination process, design and development of manufacturing processes and equipment to make frameless modules, development of a manufacturing process to make monolithic modules, and the design of a robotic pick and place machine. In addition, Evergreen shall continue improving their in-line diagnostics capability through completion of the design for automating the collection and analysis of bulk resistivity measurements and the monitoring of module making machines. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase II task-oriented research through reporting requirements detailed in sections 4, 5, and 6.

3.10 Task 10 Improve Starting Lifetime Of As-Grown String Ribbon -2

Evergreen shall continue to improve the starting lifetime of as-grown string ribbon through better control of thermal and mechanical perturbations to minimize dislocation formation. To accomplish this task, Evergreen shall make use of vibration control and

more uniform thermal environment to obtain lower dislocation content. Evergreen shall redesign their crystal growth hot zone to improve the thermal uniformity, design and develop techniques for vibration damping during growth, and perform dislocation density mapping to guide other efforts in this task. This task is expected to result in higher starting lifetimes through reduced dislocation density.

3.11 Task 11 Growth Of Surface Oxide Free Ribbon-2

Evergreen shall develop a better understanding of oxygen ingress from the exit slits and convection in the region around the hot zone through a better understanding of convection in the hot zone. In addition, Evergreen shall design new techniques to utilize the improved understanding of oxygen ingress and reduce the oxygen available that creates undesired oxide on newly grown ribbon. To accomplish this task, Evergreen shall redesign their Ar introduction techniques and develop methods to reduce convection in the hot zone region. This task is expected to result in oxide free ribbon and eliminate all etch steps between growth and diffusion for Si ribbon.

3.12 Task 12 13 % Wrap-around Cells

Evergreen shall improve efficiency through optimized nitride passivation for both front and rear surfaces and development of a method to form a good back contact. To accomplish this task, Evergreen shall develop, deploy, and test a boat for double sided passivation and develop and test Al paste that can fire through nitride. This task is expected to result in 13 % wrap-around cells.

3.13 Task 13 Design, Develop, and Test a Production-worthy Machine to Apply Wrap-around Decals

Evergreen shall design, develop, and test a machine to apply wrap-around decals for high volume production rates on the order of 1000 cells/hr. The design shall make use of an Allen Bradley PLC that will feed process data into a central computer. This task is expected to result in the development of a production-worthy machine that automates the application of wrap-around decals.

3.14 Task 14 Implementation of Multiple Ribbon Growth

During Phase I of this program, project Gemini was launched and pilot production initiated. Gemini allows for the growth of two ribbons from a single crucible and represents an opportunity to lower significantly many of the costs of producing a ribbon substrate. In Phase II, the pilot line will continue and expand to the point where a significant fraction of the Subcontractor's crystal growth machines will be Gemini machines. In addition, during Phase II, considerable R&D work will continue on

improvements in the hot zone to increase production metrics such as yield and uptime. Also, in-line diagnostics will be continually upgraded to assist in reaching the production goals. Given the successful implementation of Gemini, the next platform for multiple ribbon growth – Quad – the growth of four ribbons from a single crucible- will be investigated with a view to bringing it to the stage of pre-implementation into production. This would not occur before the third year of this project, i.e. Phase 3.

3.15 Task 15 Develop a Manufacturing Process to Make Frameless Modules

Evergreen shall develop a low-cost, manufacturable technique to make frameless modules though close interaction with vendors and manufacturing personnel. To accomplish this task, Evergreen shall study alternative methods to modify their backskin for higher impermeability and study alternative methods to form a backskin edge. This task is expected to result in the development of a viable manufacturing process for frameless modules.

3.16 Task 16 Design Manufacturing Equipment to Make Frameless Modules

Evergreen shall design, develop and test low-capital cost equipment for high volume manufacturing of frameless modules. To accomplish this task, Evergreen shall design a suitable backskin modification machine for improved impermeability backskin, test the backskin modification machine for output with improved impermeability, design a machine to form sealed leads from the module, and test the machine to form the sealed leads. This task is expected to result in the design, development and testing of a backskin modification machine and design, development, and testing of a machine to form sealed electrical leads from the module.

3.17 Task 17 Develop a Manufacturing Process to Make Monolithic Modules

Evergreen shall develop a cost-effective, manufacturing method to control backskin shrinkage. To accomplish this task, Evergreen shall explore possible methods to control shrinkage, identify and select a promising method, and develop and test this method for adequacy in a manufacturing process. This task is expected to result in a method to control backskin shrinkage suitable for manufacturing.

3.18 Task 18 Design a Robotic Pick and Place Machine

Evergreen shall design a robotic pick and place machine that can accurately position a wrap-around cell on the printed backskin. To accomplish this task, Evergreen shall identify a robot with desired properties and design a machine with that robot to perform the required pick and place activities needed to position the cell on the backskin. This task is expected to result in a pick and place machine with positional accuracy of plus or

minus 0.005".

3.19 Task 19 In-Line Diagnostics-2

Evergreen shall develop the necessary processes and equipment to incorporate bulk resistivity measurement into the automatic laser cutting station. Such equipment to perform the measurements, done manually during the Phase I, shall be designed to automatically perform the required measurements on the as grown wafers. In the module area, processes and equipment necessary to incorporate RSView into the machine designs shall also be developed and tested. This task is expected to result in in-line diagnostics for bulk resistivity measurement and automated monitoring of module making machines.

PHASE III

During Phase III, Evergreen shall continue to perform R&D needed to effect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase III efforts shall address the demonstration of improved starting lifetime of as-grown string ribbon from a production-capable system, continued improvements on Gemini II cells leading to 14.2% efficiency, continued testing and fine tuning to demonstrate manufacturing line worthiness for a decal application machine. Evergreen shall: design and develop an improved 120-W, Gemini II module; debug, test, and fine-tune module manufacturing equipment used for such modules; debug, test, and fine-tune a diffusion machine for automated in-line diffusion using the no-etch process; and continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. Finally, Evergreen shall demonstrate their state of the art manufacturing capability to make 120-W Gemini II modules at high yield and at a rate of 10-14 MW/year. Evergreen shall report all progress from this Phase III task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

3.20 Task 20 Demonstrate Improved Starting Lifetime On Production-Capable System

Evergreen shall demonstrate the results of the work on impurity reduction (Task 3) and dislocation reduction (Task 10) on a production crystal growth system so as to produce a higher average and tighter distribution of starting lifetime. Presently the lifetimes vary from <1 to >10 microseconds. The goal here will be to eliminate the lower end of the distribution. This task is expected to result in starting lifetimes of 5 to >10 microseconds.

3.21 Task 21 14.2% Efficient Gemini II Cells

Evergreen shall combine advances made in Task 20 to routinely make 14.2% cells on Gemini II ribbon. These advances shall include: improvements in starting lifetime (Task 20); continued control of surface oxide layers such the the no-etch process can continue to be utilized; and further, tighter control of the oxide layer on the as-grown ribbon surface allowing for higher sheet resistivities in the diffusion process. The latter should help in producing an improved blue response, and this, in turn, will result in a high short-circuit current (Jsc) value. At present, sheet resistivities are in the low to mid-40 Ω/square. The aim here would be to achieve values closer to 50 Ω/square. This work effort will be connected with Task 25 activities as well. In addition, a further advance will be in the decal formation and application processes, some of which will build on results from Task 22 activities.

The result of this task shall be a 14.2% efficient cell made from Gemini II string ribbon technology.

3.22 Task 22 Fine-Tune And Test Multi-Lane Decal Application Machine

Evergreen shall demonstrate, fine-tune, and test a production-worthy multi-lane decal application machine with a goal of achieving throughput of 1000 cells/hr at > 95% yield. To accomplish this task, Evergreen shall execute an iterative process of fine-tuning and testing their multi-lane decal application machine at high volume, demonstrating multi-lane capability.

This task is expected to result in a complete debugging of the decal application machine and a demonstration of production-worthiness.

3.23 Task 23 Develop 120-W Gemini II Module

Evergreen shall produce 120-W modules based on Gemini II ribbon technology based on the results of Tasks 20 and 21. At present, Evergreen manufactures a 115-W module using Gemini I and single ribbon cells. The 120-W modules will undergo accelerated environmental testing to be certain the modules meet all standard qualification requirements. In addition, Evergreen will target yields above 98% in module lamination.

This task is expected to result in the fabrication of 120-W, Gemini II modules with high module-lamination yields.

3.24 Task 24 Debug And Run Crystal Growth Furnaces for Gemini II

Evergreen shall procure additional Gemini II machines and retrofit earlier Gemini I machines or single ribbon machines following the completion of Tasks 14 and 23. The expected result for this task will be year-end yield and uptimes at least 10% absolute high than for Gemini I or single-ribbon furnaces at a volume rate between 10 and 14 MW/yr.

The expected result of this task will be the debugging of the Gemini II furnace technology in the form of new machines as well as retrofitted applications.

3.25 Task 25 High-Volume, Streamlined No-Etch/Diffusion Process

Evergreen shall streamline the existing machine sequence for the no-etch/diffusion process in order to achieve continuous material flow throughout this processing step. The no-etch process, developed at Evergreen, involves wafers going directly from crystal growth into diffusion without any etching or wet chemistry. Following the belt-furnace diffusion step, the diffusant glass is removed in a continuous, belt-like process where the wafers are always horizontal and never placed in carriers. Also, this process eliminates the need for any edge isolation. Evergreen now has the entire machine sequence to perform this process in a line with an ultimate capacity of 8-10 MW/yr. To reach these production rates, it will be necessary to run 10 cells across the full width of the 38"-wide belt. Furthermore, a successful belt-to-belt transfer to the diffusant-glass-removal machine will need to be devised. A considerable amount of debugging of this equipment and process optimization will be needed before this machine sequence is fully functional as a production line.

The expected result of this task is the development of production sequence to enable continuous material flow throughout the no-etch/diffusion process at an 8-10MW/yr rate.

3.26 Task 26 Develop and Implement In-Line Diagnostics for Gemini II

Evergreen shall continue to improve in-line diagnostics for Gemini II production. In-line diagnostic procedures that will be important for the Gemini II technology, particularly with the hot zone configuration labeled #6, include: 1) an improved thickness scanner; 2) an algorithm that automatically adjusts for melt-height changes; and 3) a central, computerized data collection system that will allow for analysis of the reasons for machine downtime.

The expected result of this task shall be the development and implementation of these diagnostic tools.

3.27 Task 27 Demonstrate Manufacturing Capability to Produce 120-W, Gemini II Modules with High Yields throughout Factory

Evergreen shall demonstrate its manufacturing capabilities through the production of 120-W, Gemini II modules with high yields throughout the manufacturing facility. This task will be the culmination of the complete work effort under this PV Manufacturing R&D subcontract, combining the results of Tasks 20 through 26. This task shall combine the results of: 1) developing a 14.2% efficiency cell; 2) realizing the manufacturing benefits of dual-ribbon growth through Gemini II furnaces; 3) a well-controlled diffusion process; 4) improvements in decal application and formation; and 5) greater control in module assembly and yields. The success of this task will have important implications for Evergreen — laying the foundation for the further expansion beyond the goal of year-end 2004 of a production capacity of 10-14 MW/yr.

The expected result of this task is a demonstration of an overall production yield improvement of 10%.

4.0 PROGRAM PLAN

The subcontracted research shall be conducted at Evergreen. The research shall be carried out according to the Task Schedule outlined below. All Milestones, Deliverables, and Reporting Requirements shall be met by Evergreen according to the schedules detailed in the appropriate sections that follow.

4.1 TASK SCHEDULE

Task Schedules are broken down into separate Phase I, Phase II, and Phase III efforts to correspond to the three phases of the subcontract. Evergreen shall perform these tasks according to the following phased schedules:

PHASE I

Evergreen shall perform and complete Tasks 1 through 9 during Phase I of this subcontract according to the following schedule:

Months	S	O	N	D	J	F	M	A	M
Task 1	△	X	X	X	X				
Task 2	△	X	X	X					
Task 3	△	X	X	X	X	X	▽		
Task 4					△	X	▽		
Task 5	△	X	X	X	X	X	▽		
Task 6	△	X	X	X	X	X			
Task 7	△	X	X	X	X	X	▽		
Task 8	△	X	X	X	X	X	▽		
Task 9	△	X	X	X	X	X	▽		
Monthly Reports		15th	15th	15th	15th	15th	15th		
Annual Report							draft 15th		Final 30th

PHASE II

Evergreen shall perform and complete Tasks 10 through 19 during Phase II of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
Task 10	△	X	X	X	X	X	X	X	X	X	X	X	X	▽		
Task 11	△	X	X	X	X	▽										
Task 12						△	X	X	X	X	X	X	X	▽		
Task 13	△	X	X	X	X	X	X	X	X	X	X	X	X	▽		
Task 14	△	X	X	X	X	X	X	X	X	X	X					
Task 15			△	X	X	X	X	X	X	X	▽					
Task 16					△	X	X	X	X	X	X	X	X	▽		
Task 17						△	X	X	X	X	X	X	X	▽		
Task 18				△	X	X	X	X	▽							
Task 19							△	X	X	X	X	X	X	▽		
Monthly Reports	15th	15th	15th	15th	15th	15th	15th	15th	15th	15th	15th	15th	15th	15th	15th	
Annual Report														Draft 15th		Final 30th

Phase III

Evergreen shall perform and complete Tasks 20 through 27 during Phase III of this subcontract according to the following schedule:

Months	J	J	A	S	O	N	D	J	F	M
Task 20			△	X	X	X	X	▽		
Task 21				△	X	X	X	▽		
Task 22					△	X	▽			
Task 23					△	X	X	▽		
Task 24	△	X	X	X	X	X	X	▽		
Task 25	△	X	▽							
Task 26	△	X	X	X	X	X	X	▽		
Task 27						△	X	▽		
Monthly Reports		15th	15th	15th	15th	15th	15th	15th		
Annual Report									Draft 15th	Final 31st

4.2 MILESTONES

Milestones are broken down into Phase I, Phase II, and Phase III milestones to correspond to the three phases of the subcontract. Evergreen shall perform tasks 1 through 27 in order to meet milestones and deliverables according to the below schedule. Although Milestones are shown as due by the end of three month periods, Evergreen shall regularly report on Milestone progress in its Monthly Reports due on the 15th of each month.

PHASE I

Milestones due no later than October 31, 2002

m-1.1.1	Demonstrate process steps for uniform mixing of dopant	(Task 1)
m-1.1.2	Grow ribbon with doped feedstock using demonstrated mixing procedure	(Task 1)
m-1.1.3	Demonstrate a suitable solvent drying procedure	(Task 1)
m-1.1.4	Show suitable transport in feeder	(Task 1)
m-1.1.5	Complete chemical and optical characterization of surface oxide	(Task 2)
m-1.1.6	Demonstrate feasibility of a simple optical method for oxide determination	(Task 2)
m-1.1.7	Concept for prototype decal application machine completed	(Task 6)
m-1.1.8	Design for prototype machine completed	(Task 6)
m-1.1.9	Thinner backskin sheets formulated	(Task 8)

Milestones due no later than October 31, 2002

m-1.2.1	Install mixing equipment	(Task 1)
m-1.2.2	Grow ribbon using feedstock mixed in new equipment	(Task 1)
m-1.2.3	Show no negative impact on efficiency from new doping process	(Task 1)
m-1.2.4	Identify contact cross section changes for screen printing	(Task 5)
m-1.2.5	Decision on whether or not to study alternative printing method	(Task 5)
m-1.2.6	Dielectric layers selected	(Task 5)
m-1.2.7	Prototype machine developed and tested	(Task 6)
m-1.2.8	Demonstrate cross-linked thinner backskin sheets	(Task 8)
m-1.2.9	Choose conductive ink for printing onto backskin	(Task 9)
m-1.2.10	Demonstrate ease of printing of conductive material	(Task 9)

Milestones due no later than January 31, 2003

m-1.3.1	Demonstrate coating with reduced permeability	(Task 3)
m-1.3.2	Network for all new crystal growth machines established	(Task 7)
m-1.3.3	Bulk resistivity and laser cutting data connected to the network	(Task 7)
m-1.3.4	Initiate qualification tests	(Task 8)
m-1.3.5	Initiate in-house accelerated testing	(Task 8)
m-1.3.6	Demonstrate adequate performance under thermal cycling	(Task 9)
m-1.3.7	Demonstrate adequate performance under humidity freeze	(Task 9)

Milestones due no later than, March 31, 2003

m-1.4.1	Test graphite parts for improved purification	(Task 3)
m-1.4.2	Test novel hot zone parts' configurations	(Task 3)
m-1.4.3	Demonstrate lifetime gains from M-1.3.1-M-1.3.3	(Task 3)
m-1.4.4	Verify M-1.3.4 with DLTS	(Task 3)
m-1.4.5	R and D cells from Ga. Tech with efficiency > 15.5%	(Task 3)
m-1.4.6	Optimize plasma nitride process	(Task 4)
m-1.4.7	Optimize metallization firing process	(Task 4)
m-1.4.8	Demonstrate fabrication of 120 sq. cm., 12% wrap-around cells	(Task 4)
m-1.4.9	Demonstrate reduced series resistance	(Task 5)
m-1.4.10	Demonstrate increased shunt resistance	(Task 5)
m-1.4.11	Demonstrate process monitoring using SPC charts	(Task 7)
m-1.4.12	Complete accelerated testing	(Task 8)
m-1.4.13	Complete accelerated tests	(Task 9)

PHASE II

Milestones due no later than June 30, 2003

m-2.1.1	Demonstrate reduced oxygen in hot zone	Task 11
m-2.1.2	Design for alternate method to introduce Ar into the hot zone	Task 11
m-2.1.3	Production-worthy decal application machine designed	Task 13
m-2.1.5	Identify method to modify backskin for higher impermeability	Task 15
m-2.1.6	Complete Gemini hot zone redesign and order parts	Task 14
m-2.1.7	14% cells on Gemini ribbon	Task 14

Milestones due no later than September 30, 2003

m-2.2.1	Establish hot zone redesign	Task 10
m-2.2.2	Demonstrate growth of oxide free ribbon	Task 11
m-2.2.3	*Eliminated from scope of work*	
m-2.2.4	Develop method to modify backskin	Task 15
m-2.2.5	Complete design of backskin modification machine	Task 16
m-2.2.6	Complete identification of pick and place robot	Task 18
m-2.2.7	Complete testing of redesigned hot zone	Task 14
m-2.2.8	Gemini yield and uptimes equivalent to single ribbon	Task 14

Milestones due no later than December 31, 2003

m-2.3.1	Complete design and implementation of vibration damping	Task 10
m-2.3.2	Complete design and deployment of boat for double sided passivation	Task 12
m-2.3.3	Demonstrate adequate firing through of Al paste	Task 12
m-2.3.4	Decal application machine developed and tested	Task 13
m-2.3.5	*Eliminated from scope of work*	
m-2.3.6	Identify method to form backskin edge	Task 15
m-2.3.7	Complete development of backskin modification machine	Task 16
m-2.3.8	Decision on monolithic module manufacturing method	Task 17
m-2.3.9	Complete design of pick and place machine	Task 18
m-2.3.10	Complete design for automatic bulk resistivity measurement	Task 19
m-2.3.11	Complete tests on elimination of inside surface oxide stripe	Task 14
m-2.3.12	Demonstrate reduced variation in front to back thickness	Task 14
m-2.3.13	Installation and running of full cluster of 20 retrofit machines	Task 14

Milestones due no later than May 31, 2004

m-2.4.1	Complete dislocation maps	Task 10
m-2.4.2	Demonstrate fabrication of 13% cells	Task 12
m-2.4.3	Establish data processing for decal application machine	Task 13
m-2.4.4	Develop method to form backskin edge	Task 15
m-2.4.5	Complete design of machine to form sealed leads	Task 16
m-2.4.6	Complete development of machine to form sealed leads	Task 16
m-2.4.7	Complete development of monolithic module manufacturing method	Task 17

m-2.4.8	Complete development of automatic bulk resistivity measurement	Task 19
m-2.4.9	Complete incorporation of RS View in module machine designs	Task 19
m-2.4.10	Installation and running of 100 new Gemini machines	Task 14
m-2.4.11	In-line diagnostics implemented on all Gemini machines	Task 14

PHASE III

Milestones due no later than June 30, 2004

m-3.1.1	Complete debug of multi-lane decal application machine	Task 22
m-3.1.2	Demonstrate diffusion uniformity across the ten-cell span	Task 25
m-3.1.3	Demonstrate diffusant glass etching uniformity across the ten-cell span	Task 25
m-3.1.4	Show thickness scanner accuracy of >5x	Task 26
m-3.1.5	Build and test prototype in laboratory	Task 26
m-3.1.6	Develop algorithm in laboratory	Task 26

Milestones due no later than September 30, 2004

m-3.2.1	Yield 10% higher than for Gemini I for two quarters on new furnaces	Task 24
m-3.2.2	Uptimes 10% higher than for Gemini I for two quarters on new furnaces	Task 24
m-3.2.3	Show belt speeds compatible with 8-10 MW/yr rate	Task 25
m-3.2.4	Demostration of production worthiness by running for three shifts/day for a month	Task 25
m-3.2.5	Build and test in-line diagnostics in pilot	Task 26
m-3.2.6	Test in-line diagnostic algorithm in pilot	Task 26

Milestones due no later than January 31, 2005

m-3.3.1	Demonstrate impurity reduction on Gemini II machine	Task 20
m-3.3.2	Demonstrate dislocation reduction on production machine	Task 20
m-3.3.3	Complete running of multi-lane decal application machine	Task 22
m-3.3.4	Form modules from Gemini II wafers that are 120W in pilot	Task 23
m-3.3.5	Demonstrate lamination yields of >98% in pilot	Task 23
m-3.3.6	Demonstrate qualification requirements met	Task 23
m-3.3.7	Demonstrate starting lifetimes of 5 to >10 microseconds	Task 20
m-3.3.8	14.2% Efficient Gemini II cells	Task 21

m-3.3.9	Advances made in Task 20 brought together	Task 21
m-3.3.10	Deploy in manufacturing	Task 23
m-3.3.11	Demonstrate lamination yields >98% in manufacturing	Task 23
m-3.3.12	Yield 10% higher than for Gemini I for two quarters on retrofits	Task 24
m-3.3.13	Uptime 10% higher than for Gemini I for two quarters on retrofits	Task 24
m-3.3.14	Production capacity of at least 10 MW/yr.	Task 24
m-3.3.15	Deploy algorithm in production	Task 26
m-3.3.16	Deploy in production	Task 26
m-3.3.17	Demonstrate high yields in crystal growth with manufacturing capability	Task 27
m-3.3.18	Demonstrate high yields in cell making with manufacturing capability	Task 27
m-3.3.19	Demonstrate high yields in module making with manufacturing capability	Task 27
m-3.3.20	Combine M-3.27.1, 2, and 3 to reach capacity of 10-14 MW/yr.	Task 27

5.0 DELIVERABLES/REPORTING REQUIREMENTS

Evergreen shall prepare and submit reports and deliverables in accordance with the following Sections. Evergreen shall also supply NREL with samples of Evergreen cells and modules for collaborative and analytical efforts with NREL as directed by the technical monitor. In addition, Evergreen shall supply, according to the schedule indicated, the following representative samples of the current best device/material design and fabrication procedures:

5.1 DELIVERABLES

The Deliverables under this subcontract are divided into Phase I, Phase II, and Phase III deliverables to correspond to the three phases of the subcontract. Evergreen shall provide deliverables according to the following schedule:

PHASE I Deliverables

Deliverables due no later than October 31, 2002

No.	Deliverable Description	Quantity	Due Date
D-1.1.1	Report on results for scaling up process for uniform mixing of dopant	2	Task 1
D-1.1.2	One sample of 3" wide ribbon grown per M-1.1.2	1	Task 1
D-1.1.3	Report on a suitable solvent drying procedure		Task 1
D-1.1.4	Report on suitable transport of doped feedstock in feeder		Task 1
D-1.1.5	Report on chemical and optical characterization of surface oxide		Task 2
D-1.1.6	Report on feasibility of a simple optical method for oxide determination		Task 2
D-1.1.7	Ribbon sample grown without any surface oxide	1	Task 2
D-1.1.8	Report describing concept for prototype decal application machine		Task 6
D-1.1.9	Report describing design for prototype machine		Task 6
D-1.1.10	Example of thinner backskin sheets		Task 8

Deliverables due no later than October 31, 2002

No.	Deliverable Description	Quantity	Task #
D-1.2.1	Report on installation of mixing equipment		Task 1

No.	Deliverable Description	Quantity	Task #
D-1.2.2	One sample of 3" wide doped ribbon	1	Task 1
D-1.2.3	Two 12% cells made with feedstock doped with new doping process	2	Task 1
D-1.2.4	Report on finger cross section through screen-printing		Task 5
D-1.2.5	Report on decision to study alternative printing methods		Task 5
D-1.2.6	Report on dielectric layers selected		Task 5
D-1.2.7	Report on development and testing of prototype machine		Task 6
D-1.2.8	One cell from prototype machine	1	Task 6
D-1.2.9	Example of cross-linked thinner backskin		Task 8
D-1.2.10	Report on ink choice		Task 9
D-1.2.11	One sample of printed conductive material on backskin		Task 9

Deliverables due no later than January 31, 2003

No.	Deliverable Description	Quantity	Task #
D-1.3.1	Report on coating with reduced permeability		Task 3
D-1.3.2	Report on establishment of network for new crystal growth machines		Task 7
D-1.3.3	Report on resistivity and laser cutting data added to the network		Task 7
D-1.3.4	Report on initiation of in-house accelerated tests and qualification tests		Task 8
D-1.3.5	One backskin sample	1	Task 8
D-1.3.6	Report on performance under thermal cycling and humidity freeze		Task 9
D-1.3.7	Report on completed accelerated tests		Task 9

Deliverables due no later than March 31, 2003

No.	Deliverable Description	Quantity	Task #
D-1.4.1	Report on tests of improved purification graphite parts		Task 3
D-1.4.2	Report on novel hot zone parts' configurations		Task 3

No.	Deliverable Description	Quantity	Task #
D-1.4.3	Report on lifetime gains (and DLTS verification) from M-1.3.1-M-1.3.3		Task 3
D-1.4.4	One >15% R&D cell	1	Task 3
D-1.4.5	Report on optimization of plasma nitride process		Task 4
D-1.4.6	Report on optimization of metallization firing process		Task 4
D-1.4.7	One 120 sq. cm., 12% wrap-around cell and I-V Data	1	Task 4
D-1.4.8	Report on reduced series and shunt resistance		Task 5
D-1.4.9	One cell demonstrating device improvements due to contact improvements	1	Task 5
D-1.4.10	Report on real time process monitoring using SPC charts		Task 7
D-1.4.11	One sample of printed conductive material on backskin	1	Task 9

PHASE II Deliverables

Deliverables due no later than June 30, 2003

No.	Deliverable Description	Quantity	Task #
D-2.1.1	Report on reduced oxygen in hot zone.		Task 11
D-2.1.2	Report on design for alternate method to introduce Ar.		Task 11
D-2.1.3	Report on design of production-worthy decal application machine.		Task 13
D-2.1.5	Report on choice of method to modify backskin.		Task 15
D-2.1.6	Report on Gemini hot zone redesign		Task 14
D-2.1.7	14% full area cell made on Gemini ribbon	1	Task 14

Deliverables due no later than September 30, 2003

No.	Deliverable Description	Quantity	Task #
D-2.2.1	Report on hot zone redesign.		Task 10
D-2.2.2	Report on redesign of ambient gas flow pattern		Task 11
D-2.2.3	One oxide free ribbon sample	1	Task 12

No.	Deliverable Description	Quantity	Task #
D-2.2.4	*Eliminated from scope of work*		
D-2.2.5	Report on method to modify backskin		Task 15
D-2.2.6	Report on design of backskin modification machine		Task 16
D-2.2.7	Report on identification of pick and place robot		Task 18
D-2.2.8	Report on testing of redesigned hot zone		Task 14
D-2.2.9	Report of comparison to single ribbon of Gemini yield and uptime		Task 14

Deliverables due no later than December 31, 2003

No.	Deliverable Description	Quantity	Task #
D-2.3.1	Report on design and implementation of vibration damping		Task 10
D-2.3.2	Report on design and deployment of boat for double sided passivation		Task 12
D-2.3.3	Report on adequate firing through of Al paste		Task 12
D-2.3.4	Report on development and testing of decal application machine		Task 13
D-2.3.5	*Eliminated from scope of work*		
D-2.3.6	*Eliminated from scope of work*		
D-2.3.7	Report on choice of method to form backskin edge		Task 15
D-2.3.8	Report on development of backskin modification machine		Task 16
D-2.3.9	Report on design of a machine to form sealed leads		Task 16
D-2.3.10	Report on decision for monolithic module manufacturing method		Task 17
D-2.3.11	Report on pick and place machine design		Task 18
D-2.3.12	Report on design of automatic bulk resistivity measurement		Task 19
D-2.3.13	Report on elimination of inside surface oxide stripe		Task 14
D-2.3.14	Report on reduced variation in front to back thickness		Task 14
D-2.3.15	Report on running of full cluster of 20 retrofit machines		Task 14

Deliverables due no later than May 31, 2004

No.	Deliverable Description	Quantity	Task #
D-2.4.1	Report on improved lifetimes and dislocation maps		Task 10
D-2.4.2	One 13% wrap-around cell	1	Task 12
D-2.4.3	One sample from and report on decal application machine with data processing	1	Task 13
D-2.4.4	One sample from and report on decal application machine with data processing	1	Task 13
D-2.4.5	Report on process to make frameless modules		Task 15
D-2.4.6	Report on manufacturing equipment for frameless modules		Task 16
D-2.4.7	Report on development of monolithic module manufacturing method for shrinkage control		Task 17
D-2.4.8	One sample demonstrating monolithic module manufacturing method for shrinkage control	1	Task 17
D-2.4.9	Report on development of automatic bulk resistivity measurement		Task 19
D-2.4.10	Report on incorporation of RS View in module machine designs		Task 19
D-2.4.11	Report on running of 100 new Gemini machines		Task 14
D-2.4.12	Report on implementation of in-line diagnostics on all Gemini machines		Task 14

Phase III Deliverables

Deliverables due no later than June 30, 2004

Number	Description	Quantity	Task #
D-3.1.1	Report on debug of multi-lane decal application machine		Task 22
D-3.1.2	Report on diffusion uniformity across the ten cell span		Task 25
D-3.1.3	Report on diffusant glass etching uniformity across the ten cell span		Task 25
D-3.1.4	Report on thickness scanner accuracy of >5x		Task 26
D-3.1.5	Report on building and testing prototype in lab		Task 26

Number	Description	Quantity	Task #
D-3.1.6	Report on lab development of algorithm for melt height		Task 26

Deliverables due no later than September 30, 2004

Number	Description	Quantity	Task #
D-3.2.1	Report on yield 10% higher than for Gemini I		Task 24
D-3.2.2	Report on Uptimes 10% higher than for Gemini I		Task 24
D-3.2.3	Report on belt speeds compatible with 8-10 MW/yr rate		Task 25
D-3.2.4	Report on production worthiness by running for 3 shifts/day for a month		Task 25
D-3.2.5	Report on building and testing prototypes in pilot		Task 26
D-3.2.6	Report on testing of algorithm for melt height in pilot		Task 26
D-3.2.7	Report on development of centralized computer data of do downtime reasons		Task 26

Deliverables due no later than January 31, 2005

Number	Description	Quantity	Task #
D-3.3.1	Report on impurity reduction on Gemini II machine		Task 20
D-3.3.2	Report on dislocation reduction on production machine		Task 20
D-3.3.3	Report on deployment of algorithm in production		Task 26
D-3.3.4	Report on deployment in production of centralized computer data		Task 26
D-3.3.5	Report on deployment in manufacturing of thickness scanner		Task 26
D-3.3.6	Report on running of multi-lane decal application machine		Task 22
D-3.3.7	Report on demonstration of lamination yields of >98% in pilot		Task 23
D-3.3.8	Report on demonstration of meeting qualification requirements		Task 23
D-3.3.9	Report on starting lifetimes of 5 to >10 microseconds		Task 20
D-3.3.10	Report on advances made in Task 20		Task 21
D-3.3.11	Report on14.2% Efficient Gemini II cells		Task 21
D-3.3.12	14.2% Efficient Gemini II cells	2	Task 21
D-3.3.13	Report on deployment in manufacturing		Task 23
D-3.3.14	Report on lamination yields >98% in manufacturing		Task 23
D-3.3.15	120 W module sent to NREL	2	Task 23
D-3.3.16	Report on yields for retrofit machines		Task 24

Number	Description	Quantity	Task #
D-3.3.17	Report on uptimes for retrofit machines		Task 24
D-3.3.18	Report on production capacity of at least 10 MW/yr.		Task 24
D-3.3.19	Report on high yields in crystal growth with manufacturing capability		Task 27
D-3.3.20	Report on high yields in cell making with manufacturing capability		Task 27
D-3.3.21	Report on high yields in module making with manufacturing capability		Task 27

Deliverables that are not reports shall be sent to the Technical Monitor at the following address:

National Renewable Energy Laboratory
ATTENTION: Katie Brown, MS#3214
1617 Cole Boulevard
Golden, Colorado 80401

with a copy of the transmittal letter sent to the Contract Administrator at:

National Renewable Energy Laboratory
ATTENTION: Christie Johnson, MS#2713
1617 Cole Boulevard
Golden, Colorado 80401

Deliverables identified as reports in the above schedule in this section may be delivered as attachments to the Monthly Technical Status Report (MTSR) corresponding to the final month for the quarter in which that report deliverable is due. If an MTSR is not due in the final month of the quarter (as is the case at the end of each phase when an annual or the final report is due), the deliverable reports due at that time shall be delivered as one item with separate sections. In any of these cases, each deliverable report shall be clearly identifiable as a distinct section.

5.2 PRESENTATIONS AND PUBLICATIONS

Evergreen Solar, Inc. shall attend NREL Subcontractor Annual Review Meetings to be held at a place and time specified by NREL. Evergreen Solar, Inc. shall present a complete discussion of work performed under this subcontract at such meetings and submit one reproducible master copy of the presentation material prior to this review, as specified by the NREL Technical Monitor.

Presentations at scientific meetings and publications of research results in scientific journals are encouraged by the PV Manufacturing R&D Project, but must be approved in advance by the NREL Subcontract Administrator. Any costs to NREL that are to be incurred as a result of such presentations/publications must be included in the negotiated cost of the subcontract. The subcontractor is responsible for obtaining NREL's technical approval. Before a representative of Evergreen Solar, Inc. submits or presents a publication concerning the research effort under this subcontract (e.g., abstract, reprint of manuscript, etc.), Evergreen Solar, Inc. shall **submit two (2) copies to the NREL Technical Monitor, one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (I) copy to the Contract Administrator.**

Evergreen Solar, Inc. is reminded that the **technical approval** requirements, as specified above, also apply to reports requiring distribution outside of NREL.

Evergreen Solar, Inc. shall also be prepared to respond to requests for written information in summary form as required by the Technical Monitor to meet obligations to DOE. Such requests include, but are not limited to, Program Summaries (annually, 1-2 pages) and Summary Annual Reports (2-3 pages). These are the usual requested annually, and NREL does not at this time expect any others during the contract. They are in addition to other reporting requirements (below).

5.3 REPORTING REQUIREMENTS

Evergreen Solar, Inc. shall furnish reports in accordance with the "Required Reports," Section 5.4. These reports shall be sent to the NREL Technical Monitor at the following address:

National Renewable Energy Laboratory
ATTENTION: Katie Brown, MS#3214
1617 Cole Boulevard
Golden, Colorado 80401

with one copy of the report, and a copy of the transmittal letter to the Technical Monitor, being sent to the Contract Administrator at:

National Renewable Energy Laboratory
ATTENTION: Christie Johnson, MS#2713
1617 Cole Boulevard
Golden, Colorado 80401

Technical monitoring will be performed by NREL/Sandia Personnel and will be in compliance with DOE PV Manufacturing R&D project and NREL Procurement requirements. One copy of these reports shall also be sent to the Technical Monitoring Team Members as described in Section 5.4, with a copy of their transmittal letters sent to the Technical Monitor.

5.4 REQUIRED REPORTS

Evergreen Solar, Inc. shall be required to prepare and submit the following reports indicated below. If the period of performance for this subcontract begins during the first through the fifteenth of a month, then that month is considered the first full month of the subcontract for reporting purposes. If the period of performance for this subcontract begins during the sixteenth through the end of the month, then the first full month of the subcontract for reporting purposes is the following month. For example, if the period of performance start date is January 10, then January is the first full month for reporting purposes: whereas, if the period of performance start date is January 20, then February is the first full month for reporting purposes.

A. MONTHLY TECHNICAL STATUS REPORT:

The Monthly Technical Status Report shall be formatted to communicate to NREL an assessment of subcontract status, explain variances and problems, report on the accomplishment of performance milestones and/or program deliverables, and discuss any other achievements or areas of concern. This report should be three to six pages written in a letter format with emphasis placed on the status rather than a description of the progress. An introductory paragraph will be included in each monthly report that provides a highlight of the month's activities. **Copies of this report are due on or before fifteen (15) days after completion of each month** [two (2) copies to the NREL Technical Monitor (TM), one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the NREL Contract Administrator].

B. ANNUAL TECHNICAL PROGRESS REPORT

The Annual Technical Progress Reports shall be structured as formal technical reports, both in draft and final version, which describe all significant work performed during each phase of the subcontract. **Copies of the draft Annual Technical Progress Report are due on or before fifteen (15) days prior to the completion date for each phase's research effort under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team (TMT) members, one (1) copy for the NREL TMT member, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make these corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Annual Technical Progress Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site, see **B1** Guidelines below), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1)**

reproducible copy for the NREL Contract Administrator. If the subcontracted effort in the following phase is not authorized and funded by NREL, then that phase's Annual Technical Progress Report shall be designated as the Final Technical Report (see description below) and the period of performance for that phase shall be extended by three months to allow for the completion of this report as the Final Technical Report.

C. FINAL TECHNICAL REPORT

The Final Technical Report is to be structured as a formal technical report, both in draft and final version, which describes all significant work performed during the entire subcontract's period of performance. **Copies of the draft Final Technical Report are due on or before fifteen (15) days after the final phase's completion date for active research under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team members, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Final Technical Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** The subcontractor shall follow one of the formats (listed above in Section B1, Annual Technical Progress Report) for the electronic copies of the final version of this report.

6.0 Electronic Reporting Requirements for Subcontract Report Deliverables:

As set forth in Department of Energy Order 241.1A, NREL is required to submit in an electronic format all scientific and technical information, including subcontract report deliverables intended for public distribution, to the DOE Office of Scientific and Technical Information (OSTI). In addition, it is NREL's intention to post subcontract report deliverables containing publicly available information (e.g. non-confidential, non-protected, non-proprietary information) for distribution on the NREL Intranet or the Internet.

The Subcontractor shall provide the final approved version of report deliverables intended for public distribution as specified in the deliverable schedule of this Statement of Work in accordance with the following electronic reporting requirements:

a. The Subcontractor shall submit all report deliverables intended for public distribution (including status, annual, or final reports) as electronic files, preferably with all graphics and images embedded within the document.

The electronic files shall be submitted along with an accompanying hard (printed) copy(ies) of the report. Limited exceptions allowing some graphics and images to be submitted as hard copies only may be granted on a case-by-case basis. The exceptions process for graphics and images is described in Paragraph E below. It shall be made clear in the deliverable transmittal letter that certain graphics and images are supplied in hard copy only.

b. All final approved version submissions shall be delivered to NREL on PC or MAC-formatted media (3.5 inch disks, Zip and Jaz cartridges, or CD-ROM). Files of 1 Mb or less can be sent via e-mail to the 1) NREL technical monitor, 2) the NREL Subcontract Administrator or Associate (as specified in the Statement of Work).

c. The preferred format is a single electronic file that includes all of the text, figures, illustrations, and high-resolution digital photographs (or photographs should be scanned and incorporated in the text). Acceptable file formats are:

- Microsoft Word (v.6.0 or newer for PC or MAC)
- WordPerfect (v.6.1 or newer for PC)
- Microsoft PowerPoint
- Microsoft Excel

d. If it is not possible to include all of the graphics and images (figures, illustrations, and photographs) in the same file as the text, NREL will accept the text in one of the above formats and the graphics and images as separate electronic graphic or image files*. The native files for any page layout formats submitted shall be supplied. The following software is supported on both Mac and PC platforms:

- QuarkXPress (.qxd)
- Photoshop (.psd)
- Freehand (.fh)
- Framemaker (.fm)
- Pagemaker (.pm)
- Illustrator (.ai)
- Corel Draw (.cdr)
- Microsoft Publisher(.pub)

*The acceptable graphic or image file formats are: .eps, .tif, .gif, .jpg, .wpg, .wmf, .pct, .png, .bmp, .psd, .ai, .fh, .cdr. The preferred resolution for graphics or images is 150 to 300 dpi. Include all fonts that were used in creating the file.

e. In the rare case that the graphics or images cannot be supplied electronically, either incorporated within the text or as a separate electronic file, original hard copies will be accepted. The Subcontractor shall obtain prior approval from the Subcontract Administrator before submitting graphics or images in hard copies. It shall be made clear in the deliverable transmittal letter that certain graphics and images are supplied