

shown on the Subcontractor's signed certificate of current cost or pricing data. The Subcontractor shall also comply with any CAS (or modifications to CAS) which hereafter become applicable to a subcontract or lower-tier subcontract of the Subcontractor. Such compliance shall be required prospectively from the date of applicability to such subcontract or lower-tier subcontract.

4.
    - (i) Agree to an equitable adjustment as provided in the Changes clause of this subcontract if the subcontract cost is affected by a change which, pursuant to subparagraph (A)(3) of this clause, the Subcontractor is required to make to the Subcontractor's established cost accounting practices.
    - (ii) Negotiate with the NREL Subcontract Administrator to determine the terms and conditions under which a change may be made to a cost accounting practice, other than a change made under other provisions of subparagraph (A)(4) of this clause; provided that no agreement may be made under this provision that will increase costs paid by NREL/Government.
    - (iii) When the parties agree to a change to a cost accounting practice, other than a change under subdivision (A)(4)(i), or (A)(4)(iv) of this clause, negotiate an equitable adjustment as provided in the Changes clause of this subcontract.
    - (iv) Agree to an equitable adjustment as provided in the Changes clause of this subcontract, if the subcontract cost is materially affected by an OMB Circular A-21 accounting principle amendment which, on becoming effective after the date of subcontract award, requires the Subcontractor to make a change to the Subcontractor's established cost accounting practices.
  5. Agree to an adjustment of the subcontract price or cost allowance, as appropriate, if the Subcontractor or a lower-tier subcontractor fails to comply with an applicable Cost Accounting Standard, or to follow any cost accounting practice consistently and such failure results in any increased costs paid by NREL/Government. Such adjustment shall provide for recovery of the increased costs to NREL/Government, together with interest thereon computed at the annual rate established under section 6621 of the Internal Revenue Code of 1986 (26 U.S.C. 6621) for such period, from the time the payment by NREL/Government was made to the time the adjustment is effected. In no case shall NREL/Government recover costs greater than the increased cost to NREL/Government, in the aggregate, on the relevant subcontract subject to the price adjustment, unless the Subcontractor made a change in its cost accounting practices of which it was aware or should have been aware at the time of price negotiations and which it failed to disclose to NREL/Government.
- B. If the parties fail to agree whether the Subcontractor or a lower-tier subcontractor has complied with an applicable CAS or a CAS rule or regulation in 48 CFR 9903 and as to any cost adjustment demanded by NREL/Government, such failure to agree will constitute a dispute under the Contract Disputes Clause of this subcontract.

- C. The Subcontractor shall permit any authorized representatives of NREL/Government to examine and make copies of any documents, papers, or records relating to compliance with the requirements of this clause.
- D. The Subcontractor shall include in all negotiated lower-tier subcontracts which the Subcontractor enters into, the substance of this clause, except paragraph (B), and shall require such inclusion in all other subcontracts, of any tier, including the obligation to comply with all applicable CAS in effect on the lower-tier subcontractor's award date or, if the lower-tier subcontractor has submitted cost or pricing data, on the date of final agreement on price as shown on the lower-tier subcontractor's signed Certificate of Current Cost or Pricing Data, except that --
  - 1. If the lower-tier subcontract is awarded to a business unit which pursuant to 48 CFR 9903.201-2 is subject to other types of CAS coverage, the substance of the applicable clause set forth in 48 CFR 9903.201-4 shall be inserted;
  - 2. This requirement shall apply only to negotiated lower-tier subcontracts in excess of \$500,000; and
  - 3. The requirement shall not apply to negotiated lower-tier subcontracts otherwise exempt from the requirement to include a CAS clause as specified in 48 CFR 9903.201-1.

**CLAUSE 11 - ADMINISTRATION OF COST ACCOUNTING STANDARDS (APR 1996)**

*Derived from FAR 52.230-6 (FD)*

For the purpose of administering the Cost Accounting Standards (CAS) requirements under this subcontract, the Subcontractor shall take the steps outlined in paragraphs (A) through (G) of this clause:

- A. Submit to the NREL Subcontract Administrator a description of any cost accounting practice change, the total potential impact of the change on subcontracts containing a CAS clause, and a general dollar magnitude of the change which identifies the potential shift of costs between CAS-covered subcontracts by subcontract type (i.e., firm-fixed-price, incentive, cost-plus-fixed fee, etc.) and other Subcontractor business activity. As related to CAS-covered subcontracts, the analysis should identify the potential impact on funds of the various Agencies/Departments (i.e., Department of Energy, National Aeronautics and Space Administration, Army, Navy, Air Force, other Department of Defense, other Government) as follows:
  - 1. For any change in cost accounting practices required in accordance with subparagraph (A)(3) and subdivision (A)(4)(i) of the clause at FAR 52.230-2, Cost Accounting Standards; or subparagraph (A)(3) and subdivisions (A)(4)(i) or (A)(4)(iv) of the clause at FAR 52.230-5, Cost Accounting Standards -- Educational Institution; within sixty (60) days (or such other date as may be mutually agreed to) after award of a subcontract requiring this change.
  - 2. For any change in cost accounting practices proposed in accordance with subdivision (A)(4)(ii) or (iii) of the clauses at FAR 52.230-2, Cost Accounting Standards, and FAR 52.230-5, Cost

Accounting Standards -- Educational Institution; or with subparagraph (A)(3) of the clause at FAR 52.230-3, Disclosure and Consistency of Cost Accounting Practices, not less than 60 days (or such other date as may be mutually agreed to) before the effective date of the proposed change.

3. For any failure to comply with an applicable CAS or to follow a disclosed practice (as contemplated by subparagraph (A)(5) at FAR 52.230-2, Cost Accounting Standards, and FAR 52.230-5, Cost Accounting Standards -- Educational Institution; or by subparagraph (A)(4) at FAR 52.230-3, Disclosure and Consistency of Cost Accounting Practices):

- (i) Within sixty (60) days (or such other date as may be mutually agreed to) after the date of agreement with the initial finding of noncompliance, or
- (ii) In the event of Subcontractor disagreement with the initial finding of noncompliance, within sixty (60) days of the date the Subcontractor is notified by the NREL Subcontract Administrator of the determination of noncompliance.

- B. After an NREL Subcontract Administrator, or cognizant Federal agency official, determination of materiality, submit a cost impact proposal in the form and manner specified by the NREL Subcontract Administrator within sixty (60) days (or such other date as may be mutually agreed to) after the date of determination of the adequacy and compliance of a change submitted pursuant to paragraph (A) of this clause. The cost impact proposal shall be in sufficient detail to permit evaluation, determination, and negotiation of the cost impact upon each separate CAS-covered subcontract and lower-tier subcontract.

1. Cost impact proposals submitted for changes in cost accounting practices required in accordance with subparagraph (A)(3) and subdivision (A)(4)(i) of the clause at FAR 52.230-2, Cost Accounting Standards; or subparagraph (A)(3) and subdivisions (A)(4)(i) or (A)(4)(iv) of the clause at FAR 52.230-5, Cost Accounting Standards -- Educational Institution; shall identify the applicable standard or cost principle and all subcontracts and lower-tier subcontracts containing the clauses entitled Cost Accounting Standards or Cost Accounting Standards -- Educational Institution, which have an award date before the effective date of that standard or cost principle.
2. Cost impact proposals submitted for any change in cost accounting practices proposed in accordance with subdivisions (A)(4)(ii) or (iii) of the clauses at FAR 52.230-2, Cost Accounting Standards, and FAR 52.230-5, Cost Accounting Standards -- Educational Institution; or with subparagraph (A)(3) of the clause at FAR 52.230-3, Disclosure and Consistency of Cost Accounting Practices; shall identify all subcontracts and lower-tier subcontracts containing the clauses at FAR 52.230-2, Cost Accounting Standards, FAR 52.230-5, Cost Accounting Standards -- Educational Institution, and FAR 52.230-3, Disclosure and Consistency of Cost Accounting Practices.
3. Cost impact proposals submitted for failure to comply with an applicable CAS or to follow a disclosed practice as contemplated by subparagraph (A)(5) of the clauses at FAR 52.230-2, Cost Accounting Standards, and FAR 52.230-5, Cost Accounting Standards -- Educational Institution; or by subparagraph (A)(4) of the clause at FAR 52.230-3, Disclosure and Consistency of Cost

Accounting Practices, shall identify the cost impact on each separate CAS covered subcontract from the date of failure to comply until the noncompliance is corrected.

- C. If the submissions required by paragraphs (A) and (B) of this clause are not submitted within the specified time, or any extension granted by the NREL Subcontract Administrator, an amount not to exceed ten (10) percent of each subsequent amount determined payable related to the Subcontractor's CAS-covered prime subcontracts, up to the estimated general dollar magnitude of the cost impact, may be withheld until such time as the required submission has been provided in the form and manner specified by the NREL Subcontract Administrator.
- D. Agree to appropriate subcontract and lower-tier subcontract amendments to reflect adjustments established in accordance with subparagraphs (A)(4) and (A)(5) of the clauses at FAR 52.230-2 and 52.230-5; or with subparagraphs (A)(3) or (A)(4) of the Disclosure and Consistency of Cost Accounting Practices clause at FAR 52.230-3.
- E. For all lower-tier subcontracts subject to the clauses at FAR 52.230-2, 52.230-3, or 52.230-5 --
  - 1. So state in the body of the lower-tier subcontract, in the letter of award, or in both (self-deleting clauses shall not be used); and
  - 2. Include the substance of this clause in all negotiated subcontracts. In addition, within thirty (30) days after award of the lower-tier subcontract, submit the following information to the Subcontractor's cognizant subcontract administration office for transmittal to the subcontract administrative office cognizant of the lower-tier subcontractor's facility:
    - (i) Lower-tier Subcontractor's name and lower-tier subcontract number.
    - (ii) Dollar amount and date of award.
    - (iii) Name of Subcontractor making the award.
    - (iv) Any changes the lower-tier subcontractor has made or proposes to make to cost accounting practices that affect prime subcontracts or lower-tier subcontracts containing the clauses at FAR 52.230-2, 52.230-3, or 52.230-5, unless these changes have already been reported. If award of the lower-tier subcontract results in making one or more CAS effective for the first time, this fact shall also be reported.
- F. Notify the NREL Subcontract Administrator in writing of any adjustments required to lower-tier subcontracts under this subcontract and agree to an adjustment, based on them, to this subcontract price or estimated cost and fee. This notice is due within thirty (30) days after proposed lower-tier subcontract adjustments are received and shall include a proposal for adjusting the higher-tier subcontract or the prime contract appropriately.
- G. For lower-tier subcontracts containing the clauses at FAR 52.230-2 or 52.230-5, require the lower-tier subcontractor to comply with all Standards in effect on the date of award or of final agreement on price, as shown on the lower-tier subcontractor's signed Certificate of Current Cost or Pricing Data, whichever is earlier.

**MODIFICATION NO. 1  
TO  
DEFINITIZED SUBCONTRACT NO. ZDO-2-30628-09**

**CONTRACTING PARTY:** MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY  
DIVISION

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.

**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE  
MANUFACTURING OF STRING RIBBON Si PV MODULES"

**SUBCONTRACT TYPE:** COST SHARING - PHASED

**PERIOD OF PERFORMANCE:** PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 03/31/04  
PHASE III: 04/01/04 THROUGH 05/31/05

<b>SUBCONTRACT AMOUNT:</b>	<u>NREL'S COST SHARE</u>	<u>SUBCONTRACTOR'S COST SHARE</u>	<u>TOTAL</u>
ORIGINAL	\$2,998,203.00 - 50%	\$2,998,203.00 - 50%	\$5,996,406.00
MOD. 1:	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
TOTAL:	\$2,998,203.00	\$2,998,203.00	\$5,996,406.00

**PAYMENT TERMS:** NET 30

**SUBCONTRACTOR'S  
REMITTANCE NAME  
AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

<b>FUNDED AMOUNT AND TASK CHARGE NUMBER:</b>	LETTER SUBCONTRACT:	\$ 750,000.00 - PVP26282
	DEFINITIZED SUBCONTRACT:	\$ 250,000.00 - PVP26282
	MOD. 1:	<u>\$ 500,000.00</u> - PVP26282
	TOTAL:	\$1,500,000.00

**REVISION:**

In accordance with Article 2 - The Period of Performance, Paragraphs A and B and Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraphs D and E, the Subcontractor is hereby authorized to proceed with Phase II under Definitized Subcontract No. ZDO-2-30628-09. By reason of this authorization, the allotted amount available for payment by NREL and the obligated amount are hereby increased and the following changes are hereby made to this subcontract:

1. Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraphs D and E are hereby modified as follows:
  - a. Paragraph D is hereby modified to increase the amount that has been allotted and is available for payment of NREL's estimated share of allowable costs for a portion of the work under this subcontract by "\$500,000.00" from "\$1,000,000.00" to "\$1,500,000.00". It is estimated that the allotted amount will cover work under this subcontract through 09/30/03.
  - b. Paragraph E is hereby deleted in its entirety and replaced with the following:

"E. The Subcontractor is authorized by NREL's execution of this subcontract modification to perform that portion of Phase I and Phase II work for which funds have been allotted in Paragraph D above."
2. By reason of the foregoing, there is neither an increase nor a decrease in the total estimated cost or the cost sharing ratio of the parties hereto for each phase and for the entire subcontract.

Except as provided herein, all other terms and conditions of this subcontract remain in full force and effect.

AUTHORIZED: MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

BY: *Christie Johnson*  
TITLE: *Jr. Contract Administrator*  
DATE: *01/24/03*

**MODIFICATION NO. 2  
TO  
DEFINITIZED SUBCONTRACT NO. ZDO-2-30628-09**

**CONTRACTING PARTY:** MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY  
DIVISION

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.

**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE  
MANUFACTURING OF STRING RIBBON Si PV MODULES"

**SUBCONTRACT TYPE:** COST SHARING - PHASED

**PERIOD OF PERFORMANCE:** PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 03/31/04  
PHASE III: 04/01/04 THROUGH 05/31/05

**SUBCONTRACT AMOUNT:**

	NREL'S <u>COST SHARE</u>	SUBCONTRACTOR'S <u>COST SHARE</u>	<u>TOTAL</u>
ORIGINAL	\$2,998,203.00 - 50%	\$2,998,203.00 - 50%	\$5,996,406.00
MOD. 1:	0.00	0.00	0.00
MOD. 2:	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
TOTAL:	\$2,998,203.00	\$2,998,203.00	\$5,996,406.00

**PAYMENT TERMS:** NET 30

**SUBCONTRACTOR'S  
REMITTANCE NAME  
AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

**FUNDED AMOUNT AND  
TASK CHARGE NUMBER:**

LETTER SUBCONTRACT:	\$ 750,000.00 - PVP26282
DEFINITIZED SUBCONTRACT:	\$ 250,000.00 - PVP26282
MOD. 1:	\$ 500,000.00 - PVP36282
MOD. 2:	<u>\$ 80,000.00</u> - PVP36282
TOTAL:	\$1,580,000.00

**REVISION:**

In accordance with Article 2 - The Period of Performance, Paragraphs A and B, and Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraph D, the Subcontractor is hereby authorized to continue the Phase II work effort under Subcontract No. ZDO-2-30628-09. By reason of this authorization, the allotted amount available for payment by NREL and the obligated amount are hereby increased and the following changes are hereby made to this subcontract:

1. Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraph D is hereby modified to increase the amount that has been allotted and is available for payment of NREL's estimated share of allowable costs under this subcontract by "\$80,000.00" from "\$1,500,000.00" to "\$1,580,000.00". It is estimated that the allotted amount will cover work under this subcontract through 11/30/03.
2. Appendix A, Statement of Work, dated September 18, 2002 is hereby deleted in its entirety and replaced with the attached Appendix A-1, Statement of Work, dated August 19, 2003". The new Appendix A-1 reflects changes to the work effort as described under Phase II, Task 14.
3. By reason of the foregoing, there is neither an increase nor a decrease in the total estimated cost or the cost sharing ratio of the parties hereto for each phase and for the entire subcontract.

Except as provided herein, all other terms and conditions of this subcontract remain in full force and effect.

AUTHORIZED: MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

BY:

TITLE:

DATE:

*Robert Johnson*  
*Sr. Contract Administrator*  
*09/12/03*



**Appendix A-1**  
Statement of Work for Evergreen Solar, Inc.  
**Innovative Approaches to Low Cost Module Manufacturing  
of String Ribbon Si PV Modules**

ZDO-2-30628-09

August 19, 2003

## **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 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 through 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 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 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% 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 these smaller cells, and show automation capability for finishing the small high-voltage module. This task is expected to result in the demonstration of a manufacturing process capable of producing a high voltage, small module product.



### **3.24 Task 24 Debug And Test Module Manufacturing Equipment Used To Produce Frameless, Monolithic Modules**

EVERGREEN shall develop, debug, and test production size module manufacturing equipment used to produce frameless, monolithic modules. Evergreen shall demonstrate production worthy speed (time to form a completed module) and quality with a yield of 99%. This task is expected to result in demonstration of speed, quality, and yield for the processes and equipment developed in Tasks 15, 16, and 17.

### **3.25 Task 25 Develop, Debug, And Test Robotic Pick And Place Machine**

EVERGREEN shall develop, debug, and test the robotic pick and place machine designed in task 18. Evergreen shall demonstrate positional accuracy estimated to be plus or minus 0.005" or as determined from additional tests with actual equipment. This task is expected to result in a robotic pick and place machine satisfying manufacturing requirements

### **3.26 Task 26 In Line Diagnostics-3**

EVERGREEN shall 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. To accomplish this task, Evergreen shall bring together the inputs from RSView on all the machines used to make frameless and monolithic modules and integrate these inputs into a real-time response system for machine control. This task is expected to result in in-line diagnostics for real time control for frameless and monolithic module manufacturing.

### **3.27 Task 27 Demonstrate State Of The Art Si Ribbon Manufacturing Capability To Make Monolithic Modules**

EVERGREEN shall demonstrate the automated production of monolithic modules through the delivery of test results from the manufacturing line based on process improvements developed in the subcontract. The test shall be an actual run and the goal shall be a 99% yield from a run of 100 consecutive modules. This task is expected to result in a demonstration of the production of a frameless, monolithic module produced from highly automated, cost-effective high yield string ribbon Si manufacturing equipment and provide NREL data to characterize the improvements made by Evergreen under this subcontract.

## **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	X				
Task 2	X	X	X	X					
Task 3	X	X	X	X	X	X	∇		
Task 4									
Task 5	X	X	X	X	X	X	∇		
Task 6	X	X	X	X	X	X			
Task 7	X	X	X	X	X	X	∇		
Task 8	X	X	X	X	X	X	∇		
Task 9	X	X	X	X	X	X	∇		
Monthly Reports		15th	15th	15th	15th	15th	15th		
Annual Report							draft 15 <sup>th</sup>		Final 30 <sup>th</sup>

**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
Task 10	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	∇		
Task 13	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 14	X	X	X	X	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	∇		
Task 17						X	X	X	X	X	X			
Task 18				X	X	X	X	X	X					
Task 19							X	X	X	X	X	∇		
Monthly Reports	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	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Task 20							X	X	X	X	X	∇		
Task 21										X	X	∇		
Task 22	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 23			X	X	X	X	X	X						
Task 24			X	X	X	X	X	X	X	X	X	∇		
Task 25	X	X	X	X	X	X								
Task 26									X	X	X	∇		
Task 27									X	X	X	∇		
Monthly Reports		15th	15th	15th	15th	15th	15th	15th	15th	15th	15th	15th		
Annual Report												draft 15th		Final 30th

*Final*

## 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 15<sup>th</sup> 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-2.2.4	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-2.3.6	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 March 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 robotic pick and place machine (Task 25)

#### Milestones due no later than September 30, 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 no later than December 31, 2004

- 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 no later than March 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)
- m-3.4.8 Complete demonstration of manufacturing capability (Task 27)
- m-3.4.9 Demonstrate capability to make 100 modules at a yield 99% (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

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-1.1.1	Report on results for scaling up process for uniform mixing of dopant. (Task 1)	2	October 31, 2002
D-1.1.2	One sample of 3" wide ribbon grown per M-1.1.2. (Task 1)	1	October 31, 2002
D-1.1.3	Report on a suitable solvent drying procedure. (Task 1)		October 31, 2002
D-1.1.4	Report on suitable transport of doped feedstock in feeder. (Task 1)		October 31, 2002
D-1.1.5	Report on chemical and optical characterization of surface oxide. (Task 2)		October 31, 2002
D-1.1.6	Report on feasibility of a simple optical method for oxide determination. (Task 2)		October 31, 2002
D-1.1.7	Ribbon sample grown without any surface oxide. (Task 2)	1	October 31, 2002
D-1.1.8	Report describing concept for prototype decal application machine. (Task 6)		October 31, 2002
D-1.1.9	Report describing design for prototype machine. (Task 6)		October 31, 2002
D-1.1.10	Example of thinner backskin sheets. (Task 8)		October 31, 2002
D-1.2.1	Report on installation of mixing equipment. (Task 1)		October 31, 2002



D-1.2.2	One sample of 3" wide doped ribbon. (Task 1)	1	October 31, 2002
D-1.2.3	Two 12% cells made with feedstock doped with new doping process. (Task 1)	2	October 31, 2002
D-1.2.4	Report on finger cross section through screen-printing. (Task 5)		October 31, 2002
D-1.2.5	Report on decision to study alternative printing methods. (Task 5)		October 31, 2002
D-1.2.6	Report on dielectric layers selected. (Task 5)		October 31, 2002
D-1.2.7	Report on development and testing of prototype machine. (Task 6)		October 31, 2002
D-1.2.8	One cell from prototype machine. (Task 6)	1	October 31, 2002
D-1.2.9	Example of cross-linked thinner backskin . (Task 8)		October 31, 2002
D-1.2.10	Report on ink choice. (Task 9)		October 31, 2002
D-1.2.11	One sample of printed conductive material on backskin. (Task 9)		October 31, 2002
D-1.3.1	Report on coating with reduced permeability. (Task 3)		January 31, 2003
D-1.3.2	Report on establishment of network for new crystal growth machines. (Task 7)		January 31, 2003
D-1.3.3	Report on resistivity and laser cutting data added to the network. (Task 7)		January 31, 2003
D-1.3.4	Report on initiation of in-house accelerated tests and qualification tests. (Task 8)		January 31, 2003
D-1.3.5	One backskin sample. (Task 8)	1	January 31, 2003
D-1.3.6	Report on performance under thermal cycling and humidity freeze. (Task 9)		January 31, 2003
D-1.3.7	Report on completed accelerated tests. (Task 9)		January 31, 2003
D-1.4.1	Report on tests of improved purification graphite parts. (Task 3)		March 31, 2003
D-1.4.2	Report on novel hot zone parts' configurations. (Task 3)		March 31, 2003
D-1.4.3	Report on lifetime gains (and DLTS verification) from M-1.3.1-M-1.3.3.		March 31, 2003

	(Task 3)		
D-1.4.4	One >15% R&D cell. (Task 3)	1	March 31, 2003
D-1.4.5	Report on optimization of plasma nitride process. (Task 4)		March 31, 2003
D-1.4.6	Report on optimization of metallization firing process. (Task 4)		March 31, 2003
D-1.4.7	One 120 sq. cm., 12% wrap-around cell and I-V Data. (Task 4)	1	March 31, 2003
D-1.4.8	Report on reduced series and shunt resistance. (Task 5)		March 31, 2003
D-1.4.9	One cell demonstrating device improvements due to contact improvements. (Task 5)	1	March 31, 2003
D-1.4.10	Report on real time process monitoring using SPC charts. (Task 7)		March 31, 2003
D-1.4.11	One sample of printed conductive material on backskin. (Task 9)	1	March 31, 2003

## PHASE II

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-2.1.1	Report on reduced oxygen in hot zone. (Task 11)		June 30, 2003
D-2.1.2	Report on design for alternate method to introduce Ar. (Task 11)		June 30, 2003
D-2.1.3	Report on design of production-worthy decal application machine. (Task 13)		June 30, 2003
D-2.1.5	Report on choice of method to modify backskin. (Task 15)		June 30, 2003
D-2.1.6	Report on Gemini hot zone redesign (Task 14)		June 30, 2003
D-2.1.7	14% full area cell made on Gemini ribbon (Task 14)		June 30, 2003
D-2.2.1	Report on hot zone redesign. (Task 10)		September 30, 2003
D-2.2.2	Report on redesign of ambient gas flow pattern. (Task 11)		September 30, 2003
D-2.2.3	One oxide free ribbon sample. (Task 12)	1	September 30, 2003
D-2.2.5	Report on method to modify backskin. (Task 15)		September 30, 2003

D-2.2.6	Report on design of backskin modification machine. (Task 16)		September 30, 2003
D-2.2.7	Report on identification of pick and place robot. (Task 18)		September 30, 2003
D-2.2.8	Report on testing of redesigned hot zone (Task 14)		September 30, 2003
D-2.2.9	Report of comparison to single ribbon of Gemini yield and uptime (Task 14)		September 30, 2003
D-2.3.1	Report on design and implementation of vibration damping. (Task 10)		December 31, 2003
D-2.3.2	Report on design and deployment of boat for double sided passivation. (Task 12)		December 31, 2003
D-2.3.3	Report on adequate firing through of Al paste. (Task 12)		December 31, 2003
D-2.3.4	Report on development and testing of decal application machine. (Task 13)		December 31, 2003
D-2.3.7	Report on choice of method to form backskin edge. (Task 15)		December 31, 2003
D-2.3.8	Report on development of backskin modification machine. (Task 16)		December 31, 2003
→ D-2.3.9	Report on design of a machine to form sealed leads. (Task 16)		December 31, 2003 05/31/04
→ D-2.3.10	Report on decision for monolithic module manufacturing method. (Task 17)		December 31, 2003 05/31/04
→ D-2.3.11	Report on pick and place machine design. (Task 18)		December 31, 2003 05/31/04
D-2.3.12	Report on design of automatic bulk resistivity measurement. (Task 19)		December 31, 2003
D-2.3.13	Report on elimination of inside surface oxide stripe (Task 14)		December 31, 2003
D-2.3.14	Report on reduced variation in front to back thickness (Task 14)		December 31, 2003
D-2.3.15	Report on running of full cluster of 20 retrofit machines (Task 14)		December 31, 2003
D-2.4.1	Report on improved lifetimes and dislocation maps. (Task 10)		March 31, 2004
D-2.4.2	One 13% wrap-around cell. (Task 12)	1	March 31, 2004
D-2.4.3	One sample from and report on decal application machine with data		March 31, 2004

	processing. (Task 13)		
D-2.4.4	One sample from and report on decal application machine with data processing. (Task 13)	1	March 31, 2004
D-2.4.5	Report on process to make frameless modules. (Task 15)		March 31, 2004
D-2.4.6	Report on manufacturing equipment for frameless modules. (Task 16)		March 31, 2004
D-2.4.7	Report on development of monolithic module manufacturing method for shrinkage control. (Task 17)		March 31, 2004
D-2.4.8	One sample demonstrating monolithic module manufacturing method for shrinkage control. (Task 17)	1	March 31, 2004
D-2.4.9	Report on development of automatic bulk resistivity measurement. (Task 19)		March 31, 2004
D-2.4.10	Report on incorporation of RS View in module machine designs. (Task 19)		March 31, 2004
D-2.4.11	Report on running of 100 new Gemini machines (Task 14)		March 31, 2004
D-2.4.12	Report on implementation of in-line diagnostics on all Gemini machines (Task 14)		March 31, 2004

**PHASE III**

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-3.1.1	Report on debug of robotic pick and place machine. (Task 25)		June 30, 2004
D-3.2.1	Report on debug of wrap-around decal application machine. (Task 22)		September 30, 2004
D-3.2.2	Small cells cut from larger cell with laser. (Task 23)	6	September 30, 2004
D-3.2.3	Report on running of robotic pick and place machine. (Task 25)		September 30, 2004
D-3.2.4	Report on demonstration of positional accuracy and repeatability. (Task 25)		September 30, 2004
D-3.3.1	Report on impurity reduction on production machine. (Task 20)		December 31, 2004
D-3.3.2	Report on dislocation reduction on production machine. (Task 20)		December 31, 2004

D-3.3.3	Report on reliability of high-voltage small modules. (Task 23)		December 31, 2004
D-3.3.4	Report on completion of automation for high-voltage small modules. (Task 23)		December 31, 2004
D-3.3.4	Two prototype high-voltage small modules. (Task 23)	2	December 31, 2004
D-3.3.5	Report on speed and quality demonstration. (Task 24)		December 31, 2004
D-3.4.1	Report on starting material lifetimes of 5 to >10 microseconds. (Task 20)		March 31, 2005
D-3.4.1	One sample of starting material with lifetimes of 5 to >10 microseconds. (Task 20)	1	March 31, 2005
D-3.4.2	Report on advances made in Tasks 12 and 20 brought together. (Task 21)		March 31, 2005
D-3.4.3	Report on 14% wrap-around contact cells. (Task 21)		March 31, 2005
D-3.4.3	Two typical cells characterizing efforts for 14% wrap-around cells. (Task 21)	2	March 31, 2005
D-3.4.4	Report on testing (yield and throughput) of wrap-around decal application machine. (Task 22)		March 31, 2005
D-3.4.5	Report on yield demonstration. (Task 24)		March 31, 2005
D-3.4.6	Report on development of RS View on all automated machines for modules. (Task 26)		March 31, 2005
D-3.4.7	Report on integration of all inputs into a central collection point. (Task 26)		March 31, 2005
D-3.4.8	Report on demonstration of manufacturing capability. (Task 27)		March 31, 2005
D-3.4.9	Report on module fabrication yield. (Task 27)		March 31, 2005
D-3.4.10	Two monolithic modules typical of 100 module run sent to NREL. (Task 27)	2	March 31, 2005

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

National Renewable Energy Laboratory  
ATTENTION: David Mooney, 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 (1) 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: David Mooney, 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)
  - Pagemaker (.pm)
  - Photoshop (.psd)
  - Illustrator (.ai)
  - Freehand (.fh)
  - Corel Draw (.cdr)
  - Framemaker (.fm)
  - 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 in hard copy only.
- f. For all calculations in support of subcontract reports that are conducted in ASPEN+, an electronic copy of INPUT, REPORT and BACKUP (if Model Manager is used) must be submitted with all reports. Additionally, if costing or sizing calculations are conducted in a spreadsheet [no process calculations (heat and material balances) in spreadsheet format are

permitted], a copy of the fully documented MS Excel file shall be supplied. Note that vendor quotes and other non-original material can be supplied in hard copy.

- g. A fully executed release shall be supplied to NREL with all photographs, regardless of whether such photographs are delivered to NREL electronically or in hard copy. Such release shall certify that the National Renewable Energy Laboratory and the United States Government is granted a non-exclusive, paid-up, irrevocable, worldwide license to publish such photographs in any medium or reproduce such photographs or allow others to do so for United States Government purposes.
- h. The Subcontractor may contact NREL Publication Services at (303) 275-3644 with questions regarding technical guidance concerning the submission of subcontract report deliverables as electronic files or exceptions to electronic files for graphics and images.

## 7.0 PERFORMANCE EVALUATION

The performance of Evergreen Solar, Inc. 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) Up to two On-Site Visits by a PV Manufacturing R&D project selected evaluation team to Evergreen Solar, Inc. per phase – these visits shall entail presentations and demonstrations by Evergreen Solar, Inc.; and
- v) Participation by Evergreen Solar, Inc. in up to two contractor Program Review Meetings per Phase as designated by PV Manufacturing R&D project management personnel.

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

The progress of Evergreen Solar, Inc. 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.

**MODIFICATION NO. 3  
TO  
DEFINITIZED SUBCONTRACT NO. ZDO-2-30628-09**

**CONTRACTING PARTY:** MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY  
DIVISION

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.

**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE  
MANUFACTURING OF STRING RIBBON Si PV MODULES"

**SUBCONTRACT TYPE:** COST SHARING - PHASED

**PERIOD OF PERFORMANCE:** PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 03/31/04  
PHASE III: 04/01/04 THROUGH 05/31/05

<b>SUBCONTRACT AMOUNT:</b>	<u>NREL'S COST SHARE</u>	<u>SUBCONTRACTOR'S COST SHARE</u>	<u>TOTAL</u>
ORIGINAL	\$2,998,203.00 - 50%	\$2,998,203.00 - 50%	\$5,996,406.00
MOD. 1:	0.00	0.00	0.00
MOD. 2:	0.00	0.00	0.00
MOD. 3:	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
TOTAL:	\$2,998,203.00	\$2,998,203.00	\$5,996,406.00

**PAYMENT TERMS:** NET 30

**SUBCONTRACTOR'S  
REMITTANCE NAME  
AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

**FUNDED AMOUNT AND  
TASK CHARGE NUMBER:**

LETTER SUBCONTRACT:	\$ 750,000.00 - PVP26282
DEFINITIZED SUBCONTRACT:	\$ 250,000.00 - PVP26282
MOD. 1:	\$ 500,000.00 - PVP36282
MOD. 2:	\$ 80,000.00 - PVP36282
MOD. 3:	<u>\$ 170,000.00 - PVP46112</u>
TOTAL:	\$1,750,000.00

**REVISION:**

In accordance with Article 2 - The Period of Performance, Paragraphs A and B, and Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraph D, the Subcontractor is hereby authorized to continue the Phase II work effort under Subcontract No. ZDO-2-30628-09. By reason of this authorization, the allotted amount available for payment by NREL and the obligated amount are hereby increased and the following changes are hereby made to this subcontract:

1. Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraph D is hereby modified to increase the amount that has been allotted and is available for payment of NREL's estimated share of allowable costs under this subcontract by "\$170,000.00" from "\$1,580,000.00" to "\$1,750,000.00". It is estimated that the allotted amount will cover work under this subcontract through 01/31/04.
2. By reason of the foregoing, there is neither an increase nor a decrease in the total estimated cost or the cost sharing ratio of the parties hereto for each phase and for the entire subcontract.

Except as provided herein, all other terms and conditions of this subcontract remain in full force and effect.

AUTHORIZED: MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

BY: Christie Johnson

TITLE: Sr. Contract Administrator

DATE: 11/24/03

**MODIFICATION NO. 4  
TO  
DEFINITIZED SUBCONTRACT NO. ZDO-2-30628-09**

**CONTRACTING PARTY:** MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY  
DIVISION

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.

**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE  
MANUFACTURING OF STRING RIBBON Si PV MODULES"

**SUBCONTRACT TYPE:** COST SHARING - PHASED

**PERIOD OF PERFORMANCE:** PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 03/31/04  
PHASE III: 04/01/04 THROUGH 05/31/05

<b>SUBCONTRACT AMOUNT:</b>	<u>NREL'S COST SHARE</u>	<u>SUBCONTRACTOR'S COST SHARE</u>	<u>TOTAL</u>
ORIGINAL	\$2,998,203.00 - 50%	\$2,998,203.00 - 50%	\$5,996,406.00
MOD. 1:	0.00	0.00	0.00
MOD. 2:	0.00	0.00	0.00
MOD. 3:	0.00	0.00	0.00
MOD. 4:	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
<b>TOTAL:</b>	<u>\$2,998,203.00</u>	<u>\$2,998,203.00</u>	<u>\$5,996,406.00</u>

**PAYMENT TERMS:** NET 30

**SUBCONTRACTOR'S  
REMITTANCE NAME  
AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

**FUNDED AMOUNT AND  
TASK CHARGE NUMBER:**

LETTER SUBCONTRACT:	\$ 750,000.00 - PVP26282
DEFINITIZED SUBCONTRACT:	\$ 250,000.00 - PVP26282
MOD. 1:	\$ 500,000.00 - PVP36282
MOD. 2:	\$ 80,000.00 - PVP36282
MOD. 3:	\$ 170,000.00 - PVP46112
MOD. 4:	<u>\$ 248,638.00 - PVP46112</u>
<b>TOTAL:</b>	<b>\$1,998,638.00</b>

**REVISION:**

In accordance with Article 2 - The Period of Performance, Paragraphs A and B, and Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraph D, the Subcontractor is hereby authorized to complete the Phase II work effort under Subcontract No. ZDO-2-30628-09. By reason of this authorization, the allotted amount available for payment by NREL and the obligated amount are hereby increased and the following changes are hereby made to this subcontract:

1. Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraph D is hereby modified to increase the amount that has been allotted and is available for payment of NREL's estimated share of allowable costs under this subcontract by "\$248,638.00" from "\$1,750,000.00" to "\$1,998,638.00. It is estimated that the allotted amount will cover work under this subcontract through March 31, 2004.
2. By reason of the foregoing, there is neither an increase nor a decrease in the total estimated cost or the cost sharing ratio of the parties hereto for each phase and for the entire subcontract.

Except as provided herein, all other terms and conditions of this subcontract remain in full force and effect.

AUTHORIZED: MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

BY: *Christi Johnson*

TITLE: *Sr. Contract Administrator*

DATE: *01/12/04*

**MODIFICATION NO. 5  
TO  
DEFINITIZED SUBCONTRACT NO. ZDO-2-30628-09**

**CONTRACTING PARTY:** MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY  
DIVISION

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.

**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE  
MANUFACTURING OF STRING RIBBON Si PV MODULES"

**SUBCONTRACT TYPE:** COST SHARING - PHASED

**PERIOD OF PERFORMANCE:** PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 05/31/04  
PHASE III: 06/01/04 THROUGH 07/31/05

<b>SUBCONTRACT AMOUNT:</b>	<u>NREL'S COST SHARE</u>	<u>SUBCONTRACTOR'S COST SHARE</u>	<u>TOTAL</u>
ORIGINAL	\$2,998,203.00 - 50%	\$2,998,203.00 - 50%	\$5,996,406.00
MOD. 1:	0.00	0.00	0.00
MOD. 2:	0.00	0.00	0.00
MOD. 3:	0.00	0.00	0.00
MOD. 4:	0.00	0.00	0.00
MOD. 5:	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
<b>TOTAL:</b>	<u>\$2,998,203.00</u>	<u>\$2,998,203.00</u>	<u>\$5,996,406.00</u>

**PAYMENT TERMS:** NET 30

**SUBCONTRACTOR'S  
REMITTANCE NAME  
AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

<b>FUNDED AMOUNT AND TASK CHARGE NUMBER:</b>	LETTER SUBCONTRACT:	\$ 750,000.00 - PVP26282
	DEFINITIZED SUBCONTRACT:	\$ 250,000.00 - PVP26282
	MOD. 1:	\$ 500,000.00 - PVP36282
	MOD. 2:	\$ 80,000.00 - PVP36282
	MOD. 3:	\$ 170,000.00 - PVP46112
	MOD. 4:	\$ 248,638.00 - PVP46112
	MOD. 5:	<u>\$ 0.00</u>
	<b>TOTAL:</b>	<b>\$1,998,638.00</b>



**REVISION:**

Subcontract No. ZDO-2-30628-09 is hereby modified as follows:

1. The Subcontract Cover Page is hereby modified to extend the Phase II period of performance by deleting the period of performance in its entirety and replacing it with the following:  
  
"PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 05/31/04  
PHASE III: 06/01/04 THROUGH 07/31/05"
  
2. **ARTICLE 2 - THE PERIOD OF PERFORMANCE** is hereby deleted in its entirety and replaced with the following:  
  
**"ARTICLE 2 - THE PERIOD OF PERFORMANCE**  
  
A. The period of performance under this subcontract shall be as follows:  
  
Phase I: 09/27/02 through 03/31/03  
Phase II: 04/01/03 through 05/31/04  
Phase III: 06/01/04 through 07/31/05  
  
B. Each of these periods may be extended by mutual written agreement of the parties. NREL will make a decision, based on its sole judgement, whether or not to continue and incrementally fund each Phase prior to the completion date of each Phase. If all Phases are authorized by NREL, the total period of performance for the subcontract would be thirty-four (34) months. If NREL should decide not to authorize a Phase, the subcontract shall be considered complete upon submittal of the final version of the Annual Technical Report, with corrections as specified by NREL, if any."
  
3. **ARTICLE 3 - ESTIMATED COSTS, COST SHARING, OBLIGATION OF FUNDS AND FINANCIAL LIMITATIONS**, Paragraph D is hereby modified to extend the period that the allotted amount will cover work under this subcontract through by deleting "March 31, 2004" and substituting "May 31, 2004".
  
4. **ARTICLE 11 SUBCONTRACT ADMINISTRATION RESPONSIBILITIES**, Paragraph C is hereby modified to delete "Dave Mooney, (303) 384-6782" as the NREL designated Technical Monitor for this subcontract, and substitute "Katie Brown, (303) 384-6576".
  
5. **ARTICLE 14 - NEGOTIATED AND CEILING INDIRECT RATES**, Paragraphs A and B are hereby modified to extend the "Subcontract Period Covered" by deleting "05/31/05" and substituting "07/31/05".
  
6. Appendix A-1, Statement of Work, dated August 19, 2003 is hereby modified to extend the deliverable due date for deliverables numbered D-2.3.9, D-2.3.10 and D-2.3.11 by deleting "December 31, 2003" and substituting May 31, 2004".

7. By reason of the foregoing, there is neither an increase nor a decrease in the total estimated cost or the cost sharing ratio of the parties hereto for each phase and for the entire subcontract.

Except as provided herein, all other terms and conditions of this subcontract remain in full force and effect.

AUTHORIZED: MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

BY: Christie Johnson  
TITLE: Sl. Contract Administrator  
DATE: 03/22/04