MANUFACTURING INSIGHTS

Manufacturing Alternative Energy Systems

SCENE 1.
CG: FBI warning
white text centered on black to blue gradient

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SCENE 2.
CG: white text centered on black to blue gradient

This program was produced
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National Center for Manufacturing Sciences

SCENE 3.
tape 40, 01:00:00-01:00:12
SME logo, with music

SCENE 4.

CG: Title of video

MUSIC UP AND UNDER

NARRATION (VO):

Manufacturing Insights, Manufacturing Engineering Magazine's video series for process improvement. This program will explore several new developments in manufacturing of selected alternative energy systems and how they will impact the energy generation and utilization markets of the future, while reducing our dependence on fossil fuels.

SCENE 5.

CG: STM Power
STM Tape 2 B Roll
film of STM building with logo
Tape 2: 2:22:42

NARRATION (VO):

First we take you to STM Power to see how they are using advanced sterling engine technology to convert waste heat and gas into electricity.

SCENE 6.

CG: Uni-Solar
Uni-Solar CD (Still photos of Uni-Solar panels in application and logo)

NARRATION (VO):

We then traveled to United Solar Ovonic who has commercialized a continuous thin-film deposition process to mass-manufacture flexible, lightweight and highly versatile photovoltaics from silicon materials.

SCENE 7.
CG: UTC Fuel Cells
UTC Tape 7 B Roll
07:20:12 (building sign)
07:18:27 – 07:18:33 (space shuttle FC)

NARRATION (VO):

And finally, we talked to UTC Fuel Cells to focus on the manufacturing of key fuel cell components, devices and systems targeted for stationary and transportation applications.

SCENE 8.

Use still shots of Uni-solar panels, wind turbine and wave if available, UTC fuel cell shot

NARRATION (VO):

To meet the demands of our ever growing consumption of energy, mankind has attempted to harness the power from the sun, wind, waves and the use of mechanical systems to provide new and cleaner forms of power.

SCENE 9.

NARRATION (VO):

Global warming, corporate environmental stewardship, the increasing price of oil, natural gas and other finite energy resources also serve as market drivers for investments in alternative energy systems. Across the globe nations are gearing up to ensure their energy security by making commitments to a diverse portfolio of renewable power sources.

SCENE 10. **Use shot of fuel cells in operation (auto), laptop, cell phone with picture image, coal burning power plant (use photos found on-line)**	NARRATION (VO): The next generation of portable electronics, automobiles and other products we buy are also demanding more power with the environmental benefits of operating cleaner than existing power sources.
SCENE 11.	NARRATION (VO): Only through advancements in manufacturing and engineering are these new technologies likely to find themselves into future products on a mass scale.
SCENE 12.	NARRATION (VO): What are alternative energy producers doing to meet the cost and performance demands to make this a reality?
SCENE 13.	NARRATION (VO): To grasp a better understanding of alternative energy technologies, we traveled to STM in Ann Arbor Michigan and spoke with Mark Oehmke on the uniqueness of their unique engine technology.
SCENE 14. **STM Tape 1 MO** **01:15:45 – 01:16:25** **CG Title: Mark Oehmke, Vice President of Sales & Marketing** **B-Roll** **Use video footage supplied by STM that shows internal working of product**	Probably the most unique part about the STM product is it's external combustion, in that the fuel and air mix external to the pistons, allowing for a hot burning temperature there, where you don't find that on an internal combustion engine. That does make some challenging parts of our manufacturing process and testing as well. Some things have to be done differently. We do use a liquid gas within the engine. In our particular case, we use hydrogen. With the hydrogen, we reproduce it on board to allow the heat to go from the hydrogen, the hot side of the engine, to the cool side of the engine, and in between there it pushes the pistons downward.

SCENE 15.

STM Tape 1 MO
01:16:33 – 01:16:45
(drop in still photos provided by STM…pictures of engines working in different application)

Our beachhead markets we're going after right now are landfills, agriculture digesters and waste water treatment plants. We're looking at some other markets though in liquid fuel, along with burning unburned paint VOC's.

SCENE 16.

STM Tape 1 MO
01:16:56 – 01:17:18

On any new product there's a feeling of "I don't want to be the first person to own it or the first company to make a mistake." So we have some hurdles to cross, if you will, with early adopters. We need to get into those markets that are beachhead markets where people say "I've seen it, I've seen it actually working out there at these particular landfills and waste water treatment sites, and I have confidence in it."

SCENE 17.

STM Tape 1 MO
01:17:37 – 01:17:51
Tape 2 B Roll
02:14:10
02:13:38

We offer a technology that allows us to burn a non-pipeline fuel, something that's totally renewable. We always are working on how to get rid of the methane, the second most popular greenhouse gas in the world. How can we do that? We can burn that with our particular engine.

SCENE 18.

STM Tape 1 MO
01:20:36:16 – 01:21:11

Tape 2 B Roll
02:21:30 – 02:21:38

We're taking a lot of different tours here. Almost every week we have different people from all parts of the world coming in here. They're bringing us samples, they're bringing us ideas, what they've got to burn, what they need to get rid of. It doesn't matter if it's biomass or biofuels, they're looking at some way to get rid of their particular concern in their particular part of the world. So we're as flexible as we can be in allowing testing here. We have in here different ways we can test different liquid fuels and different gaseous fuels for the customer. They'll bring over samples of five gallons or more, and we'll go to work on it and find out the feasibility.

SCENE 19.
STM Tape 1 MO
01:18:26 – 01:18:34
Tape 2 B Roll
02:09:11
02:10:32 – 02:10:45

We're also working at the same time to try to get our production speed up through work with our suppliers. Our suppliers are a key ingredient to making this whole product work.

SCENE 20.
STM Tape 2 B Roll
02:11:30 - 02:11:40
02:19:10
02:20:50 – 02:20:55

NARRATION (VO):

The STM Sterling engine features over 400

different suppliers for their product.

SCENE 21.

STM Tape 1 MO
01:19:01 – 01:19:24

What we got to do to get to a lower cost is we're going to have to source potentially other suppliers in the same market and we are also going to have to increase our volume. Our volumes for this year is for 225 units, Next year we move up to 600, the following year 1500. When we have more products out there, the suppliers should be more lenient in working with us and giving us better conditions, terms and prices.

SCENE 22.

NARRATION (VO):

An external combustion engine adapts similar manufacturing procedures used with current automotive engine technology.

SCENE 23.

STM Tape 2 GW
02:02:30 – 02:02:50
CG Title: Gordon Wright, Vice President of Engineering

The way we verified the sterling engine, we basically copied the process from heavy duty diesel engines for off highway and on-highway equipment. We tried to run the same number of engines, the same number of hours, with the same life and reliability expectations as the heavy duty diesel.

SCENE 24.

STM Tape 2 GW
02:03:38 – 02:04:11
Tape 2 B Roll
02:22:24 – 02:22:30

Some of the better practices we've instituted here that we've borrowed from other development industries, the off highway industry and somewhat the on highway automotive industry, is the Design Failure Mode Effects Analysis. We've done what we call the DFMEA on all the subsystems and parts within the generator set. We're looking to see how we can design the engine to make sure that any issues in quality can be detected and dealt with while it's inside the plant.

SCENE 25.

NARRATION (VO):

The external combustion engine runs at very high temperatures. This requires careful consideration and sometimes limitations on material selections for engine components

SCENE 26.

STM Tape 2 GW
02:04:58 – 02:05:22
Tape 2 B Roll
02:15:40 - 02:15:46

We've got a lot of different materials. We use a lot of stainless steels. We also use Inconel material in the heating system, and we also use Hastelloy X in some of the high temperature applications. Then as the temperature drops down we use a material called 253MA, which is also a high temperature stainless steel in the heating system.

SCENE 27.

STM Tape 2 GW
02:05:59 – 02:06:24
Tape 2 B Roll
02:11:58
02:12:46 – 02:12:57

We likely won't be replacing any of these key materials, because we'll be pushing the engine to higher and higher outputs. So we'll probably keep the same materials, we'll just work at lower cost ways of processing the material, as far as the high temperature materials. In the lower cost materials, the cast irons and the regular steels, we will be looking at going to simpler materials in those applications.

SCENE 28.

STM Tape 2 GW
02:06:41 – 02:06:52
Tape 2 B Roll
02:16:05 - 02:16:20

Most of the barriers we need to solve moving forward are processing issues. We need to come up with better ways of processing the designs, so we'll have to modify the designs to make them easier to process.

SCENE 29.

STM Tape 2 GW
02:07:05 – 02:07:13

At this point we are very low volume. As our volumes climb over the next 12-18 months, we'll be looking at lower cost processing methods.

SCENE 30.

STM Tape 2 GW
02:08:14 – 02:08:27

One of the real advantages of the sterling engine is its adaptability to a multitude of circumstances. We can burn a wide variety of fuels. We can be installed in very diverse places.

SCENE 31.

STM Tape 2 GW
02:08:33 – 02:08:40
B-Roll: Shot of STM engine in
STM Tape 2
2:19:50 – 02:19:54

The installation is quite simple, it's like putting your air conditioning condenser in your backyard.

SCENE 32.

NARRATION (VO):

United Solar Ovonic located in Auburn Hills, Michigan, developed a customized automation process for the manufacturing of their amorphous silicon solar cells. With over 220 employees, it has the world's largest thin-film photovoltaic manufacturing facility.

SCENE 33.

Tape 4 B-Roll
04:17:10:21 –04:17:21:13
(Ovonic Solar Cell Processor)

NARRATION (VO):

At the heart of their manufacturing facility is a machine the length of a football field that takes six, 1.5 mile long rolls of 0.005 inch thick stainless steel sheets at a time. The steel serves as the negative junction of the solar cell.

SCENE 34.

Tape 4 B-Roll
04:18:20:09 – 04:18:25:20
(Small steel sheet to demonstrate flexibility and lightweight features)

Tape 4 B-Roll
04:17:35:12 – 04:17:50:23
(4 Steel rolls)

Tape 4 B-Roll
04:22:44:12 – 04:23:02:13 (Pan of entire production line)

NARRATION (VO):

Over a 72 hour production cycle, it moves the steel sheets about 6 inches per minute, during which twelve distinct layers of solar cell materials are deposited, beginning with a sputtered Aluminum-Zinc Oxide layer that enhances the material’s optical conversion. This is followed by a continuous web-based silicon deposition process resulting in a less than 1 micron thick layer consisting of three distinct silicon solar cells stacked on top of each other, designed to absorb the majority of photonic energy falling on them. The silicon deposition process has in-situ diagnostics built into the process. Finally, a layer of Indium Tin Oxide is deposited as the anti-reflective transparent coating to serve as the cell’s positive junction. An additional top layer of oriented Teflon ensures a flexible, yet rugged solar cell panel sheet weighing less than 1 pound per square foot. The process also incorporates barcode on every manufactured photovoltaic sub-cell, which helps ensure process and product traceability.

SCENE 35. **Tape 4 B-Roll** **04:27:04:00 – 04:27:25:16** **(Close up of finished solar panel)** **Tape 4 B-Roll** **04:29:03:25 – 04:29:18:00** **(Barcoded solar panel)**	NARRATION (VO): UniSolar packages and markets finished solar cells as grid-connected, solar shingles or peel-and-stick panels. The solar cells are maintenance-free, and capable of performing consistently and reliably under both, high or low light conditions. The annual production capacity of the deposition machine is 30 Megawatts, which will produce enough solar modules to provide electricity to 15,000 homes per year.
SCENE 36.	NARRATION (VO): Dr. Subhendu Guha, President and CEO of United Solar Ovonic, explains the uniqueness of the UniSolar product line and how it impacts manufacturability.
SCENE 37. **Tape 3** **03:00:54:00 – 03:01:27:00** **CG Title: Dr. Subhendu Guha, President and CEO**	We are the only manufacturer of flexible products. What is important about the flexibility is that we can make products very long, very lightweight. Typically our products are 80 feet long, and it can be rolled up and shipped anywhere in the world. But what is more interesting is that the products have an adhesive on the back and a release paper, so that you ship it to the site. Supposing you have a roof, what you do is remove the release paper and stick it onto the roof. It’s so simple, so elegant.

SCENE 38. **Tape 4 B-Roll** **04:29:59:00 – 04:30:09:28** **(pan of a finished long solar cell panel)**	NARRATION (VO): To maximize its return on investment, Unisolar has combined innovative product design with an in-house developed high-volume manufacturing process for its flexible silicon-coated stainless steel substrates, and then introduced the products in the some of the world's most lucrative urban markets where the incentive is the greatest for diversifying the sources of electricity.
SCENE 39. **Tape 3** **03:04:16:16 – 03:05:23:07**	Today the fastest growing market segment, interestingly, is in urban areas, where two things are happening. Either the peak rate for electricity is high, and/or there is government subsidy, like in Germany, like in California. In these areas you don't have enough vacant space, but you have lots of vacant roofs. So we decided we are going to address that market first. That means we have to develop a product which can be put on the roof very easily. But when you put products on the roof, it has to be aesthetically pleasing also. So we developed a product which is aesthetically pleasing and can be put on the roof very easily. Then we realized that in order to penetrate that market, we've got to make alliances. We are a photovoltaic company, we know a lot about photovoltaics, but we know very little about roofs. So we made alliances with roofing material manufacturers, roofing contractors, and that is what has contributed to our success. We have grown in revenue more than 100 percent over the last year.
SCENE 40. **Tape 3:** **03:05:59:07 – 03:06:29:11**	What has been established is that our products do produce more kilowatt hours per kilowatt. So suppose you buy a conventional product which has a 100 watt rating. You buy our product, which also has a 100-watt rating. We produce more kilowatt hours out of that. The customers are more knowledgeable. They pay an electric bill which comes in terms of kilowatt hours. That is one thing that is happening, and that is why our product is being accepted more and more.

SCENE 41.

NARRATION (VO):

The uniqueness of UniSolar's product line can be largely attributed to their low, cost manufacturing process, successfully implemented on a continuous automated manufacturing system after overcoming some key technical challenges.

SCENE 42.

Tape 3:
03:06:53:13 – 03:08:01:14

One of the things is that, if you look at the conventional products, they are grown by a batch process. You grow a single crystal, you plot it, you do certain processes, it is a step by step process. From the early days we decided in order to be most cost effective, we have to have a continuous process. So at United Solar and at Energy Conversion Devices, we developed what we call a roll-to-roll process. That means we take a roll, which can be as long as 1.5 miles long, and we deposit the various layers on that stainless steel so that we can get a 1.5 mile long solar cell. Of course it is very challenging, because some of the layers that we put on there, they are 100 Angstroms thick. A human hair is 70 micron. One micron is 1 70^{th} of that. A hundred Angstrom is one hundredth of that, so you can see how thin the layers are. So we have to overcome a lot of technical challenges so we can deposit such thin layers over such a large area.

SCENE 43.

NARRATION (VO):

The road to commercial success involved transitioning of new nanotechnology-based silicon deposition processes from laboratory-scale to high-volume manufacturing, and was fraught with significant technical challenges requiring patient experimentation with materials and processes, and engineering innovation.

SCENE 44.

Tape 3:
03:09:22:16 – 03:10:03:20

You make a very small radius solar cell, and you get all excited that we have made a very high efficiency product. The next challenge is that, Okay, you have made a solar cell that is only a quarter centimeter square. Can you scale it up to one square foot? You do that. The next question is can you scale it up so that you can translate into a robust manufacturing process? That takes a really long time. You'll see our machines today. These are sixth or seventh generation machines. We did not come here overnight, we just had to go step by step, developing the technology for the cell, but also developing the technology for manufacturing those cells. It took us quite some time.

SCENE 45.

NARRATION (VO):

Gary Didio, Manufacturing Operations Manager at UniSolar, explains how the roll-to-roll manufacturing process is key to the low cost production of flexible solar cells, and how the technical and engineering challenges were overcome.

SCENE 46.

Tape 4:
04:03:12:08 – 04:03
CG Title: Gary Didio,
Manufacturing Operations Manager

We run six webs simultaneously, and we do the hydrogenated amorphous silicon. We do nine layers, creating three distinct devices. The challenge there was to be able to take that web through those chambers and keep that isolation of each of those distinct layers from each other. We successfully accomplished that with our gas gate technology. It keeps the isolation of those chambers. That, and I think the handling, as we grew in economy of scale. Our rolls used to be 800 meters long, now they're 2500 meters long, a lot of weight, so the size of that created different engineering challenges in the material handling aspect of that.

SCENE 47.

NARRATION (VO):

Unisolar's amorphous silicon deposition manufacturing process leverages proven technologies and practices used in the semi-conductor industry, and have no negative environmental impact.

SCENE 48.

Tape 3:
03:08:22:20 – 03:08:59:13

Photovoltaic is clean energy. We don't want to develop a product which is not environmentally benign, nor do you want to use a process which is not environmentally benign. We make our product using a process where we take a gas, like silane, and we break it up, and we make silicon that way. Silane is a gas which is extensively used in the integrated circuit industry. So we are very fortunate that many of the technology you need to handle the gas that meets all the environmental requirements, that has already been done.

SCENE 49.

NARRATION (VO):

Gary Didio further explains how other environmental and durability advantages accrue from Unisolar's thin-film based product design and environmentally benign manufacturing process:

SCENE 50.

Tape 4:
04:01:47:16 –04:01:58:10

The thin film technology is different in that the energy consumption is less, the raw material consumption is less. We have the highest payback on net energy than any other photovoltaic manufacturer.

SCENE 51.

TAPE 4
04:05:47:08 – 04:06:07:18

In our finished product, we've had to do a lot of engineering development of materials to make a product that could be out in the marketplace and last 20 years. There has been a lot of research and development and partnering with vendors to create materials that would be flexible, durable, UV stable, all those necessary things to be out in the environment.

SCENE 52.

NARRATION (VO):

Gary Didio describes the level of precision and real-time quality control that needs to be maintained throughout the production process in order to deliver a product that performs consistently and reliably in the field.

SCENE 53.

Tape 4:
04:04:18:24 – 04:05:18:14
Tape 4 B-Roll
04:17:12:17 – 04:17:19:30
(view of Ovonic Solar Cell Processor machine)
Tape 4 B-Roll
04:23:23:00 – 04:23:39:10
(RF Tuner device)
Tape 4 B-Roll
04:16:21:00 – 04:16:37:27
(viewing the Plasma discharge deposition process through window)

Our films, all 12 layers is only a micron thick, so the chemistry and the thickness of those layers are very critical, and we have a unique online quality assurance we do, which is nondestructive. We really incorporate that throughout the line, but where it's really unique is in the deposition technology. We have what we call capacitive coupling to the device, so we can actually look at the charge rate and the discharge rate of the device, and predict what its electrical properties are going to be when it comes out. So we're able to do that many places along the deposition of the amorphous silicon, and then we do a lot of spectrometer, looking at thicknesses of different films, and those things give us the quality control we need to be able to run the process continuously. It's a 24/7 plant, we run all the time, and we have a very highly trained staff that are able to look at those quality assurances and make sure everything is working properly.

SCENE 54.

NARRATION (VO):

The entire manufacturing facility involved in roll-to-roll processing is fully automated, sequenced, and uses Lean production concepts and Kanban to control inventory and material flow.

SCENE 55.

Tape 4
04:06:20:20 – 04:06:29:12

For the area I'm responsible for here in the deposition its probably the material flow and the systematic approach we've incorporated into the manufacturing process.

SCENE 56.

Tape 4
04:06:34:15 – 04:06:59:15
Tape 4 B-Roll
04:12:10:23 – 04:12:16:27
(Visual Display System)
Tape 4 B-Roll
04:13:35:26 – 04:13:46:17
(plant floor control)

But it is an umbrella of lean. We do Theory of Constraints, we do a lot of Kanban systems, a lot of Visual Management. We created four main metrics that we use that we drive the whole team toward. Those challenges are what has allowed us to scale up. As you scale up it becomes more costly, any downtime, everything becomes larger. So you have to continually improve that if you want to be successful on a large scale.

SCENE 57.

NARRATION (VO):

Didio summarizes the some of the immediate needs UniSolar wants to see addressed in order to grow its business in renewable energy generated from photovoltaic sources.

SCENE 58.

Tape 4:
04:10:54:26 – 04:11:17:10

I think the best thing is just more education in the marketplace. I think the whole industry as a whole is an infant technology and an infant marketplace. We need to continue to educate the public and help them understand the benefits of it, and hopefully get more sales through that. I think it's the right thing not just for our business, but for the world. I think the educational process in the marketplace is huge.

SCENE 59.
CG: credit roll
white text on black, fade up
mid-screen

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SCENE 60.
tape 40, 01:00:00-01:00:12
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