DR. KUTSCHER: WELL, THANKS VERY MUCH, ROB.
25 AND THANK YOU, ROB AND MELINDA, FOR
0597
1 INVITING ME TO THIS MEETING. I HAVE REALLY BEEN
2 ENJOYING IT. I'VE BEEN LEARNING A LOT, ALTHOUGH I
3 MUST SAY A LOT OF THE FACTS THAT HAVE BEEN PRESENTED
4 ARE QUITE SOBERING.
5 I WORK FOR THE NATIONAL RENEWABLE ENERGY
6 LABORATORY, WHICH IS A DEPARTMENT OF ENERGY LAB IN
7 GOLDEN, COLORADO. THERE ARE ABOUT 1,200 OF US THAT
8 WORK ON RENEWABLE ENERGY TECHNOLOGIES. BUT MOST OF
9 WHAT I'M GOING TO BE TALKING ABOUT WAS NOT DONE BY
10 NREL; IT WAS DONE BY VOLUNTEERS FOR THE AMERICAN
11 SOLAR ENERGY SOCIETY. SO I DO WANT TO MAKE THAT
12 CLEAR AT THE OUTSET.
13 OKAY. THAT IS MY SON, AND I WANTED TO
14 MENTION THAT MY WIFE AND SON AND I REALLY ENJOY
15 SNORKELING. SO I THINK ALL OF US ARE
16 CONCERNED ABOUT CLIMATE CHANGE FROM THE GLOBAL
17 IMPACT. WE'RE CONCERNED ABOUT WHAT'S GOING TO HAPPEN
18 IN AFRICA, WHAT'S GOING TO HAPPEN IN BANGLADESH; BUT,
19 ALSO, ALL OF US HAVE SOME INDIVIDUAL THINGS ABOUT
20 CLIMATE CHANGE THAT TEND TO AFFECT US. AND FOR US,
21 IT'S WHAT HAPPENS TO THE CORAL REEFS. AND WE SAW
22 SOME VERY GOOD PRESENTATIONS ON THAT YESTERDAY.
23 THIS IS A PICTURE I TOOK OF MY SON IN THE
24 CARIBBEAN. THIS IS ABOUT TWO YEARS, THREE YEARS AGO.
25 AND THESE ARE SOME PHOTOS IN THE CARIBBEAN THAT WE
0598
1 TOOK, SHOWING VERY LUSH CORAL REEFS, VERY
2 THRIVING CORAL REEFS. AGAIN, THIS IS ABOUT THREE
3 YEARS AGO.
4 AND THEN IN MARCH OF 2006, THIS WAS
5 THE HEADLINE: "CARIBBEAN CORAL SUFFERS RECORD
6 DIE-OFF. WORLD'S CORAL REEF LOSS 'AN UNDERWATER
7 HOLOCAUST.'"
8 NOW, AS WAS MENTIONED YESTERDAY, CORAL CAN
9 SURVIVE A SHORT PERIOD OF TIME OF ELEVATED
10 TEMPERATURES, WHERE IT GETS BLEACHED BUT IT CAN COME
11 BACK. BUT THIS IS A CASE WHERE THE SEA SURFACE
12 TEMPERATURES WERE ELEVATED FOR SUCH A PERIOD OF TIME
13 THAT MUCH OF THE CORAL DIED PERMANENTLY. SO THIS A
14 VERY SERIOUS SITUATION. IT'S A SERIOUS SITUATION
15 HERE IN HAWAII, AS WELL.
16 THIS WAS THE JUNE 2006 ISSUE OF "NATIONAL
17 GEOGRAPHIC" MAGAZINE: "THE BIG THAW, ICE ON THE RUN,
18 SEAS ON THE RISE." "NATIONAL GEOGRAPHIC" HAS REALLY
19 DONE A WONDERFUL JOB OF GETTING THE MESSAGE OUT ABOUT
20 HOW SERIOUS THIS PROBLEM IS.
21 AND I GUESS WHAT I WOULD LIKE TO EMPHASIZE
22 IS THE URGENCY OF THE PROBLEM. IF YOU LOOK AT SUMMER
23 SEA ICE IN THE ARCTIC, AS WE LEARNED, IT DROPPED
24 25 PERCENT BETWEEN 2006 AND 2007. THE NATIONAL SNOW
25 AND ICE DATA CENTER IN BOULDER, PEOPLE THERE ARE NOW
0599
1 PREDICTING WE COULD LOSE ALL SUMMER SEA ICE BY AS
2 SOON AS THE YEAR 2030. NOW, IF YOU CONSIDER THAT THE

PLANET HAS HAD THAT PERMANENT POLAR ICE CAPS FOR PERHAPS A MILLION YEARS, TO THINK THAT WITHIN OUR LIFETIMES OR CERTAINLY WITHIN THE LIFETIMES OF OUR CHILDREN, THAT'S NO LONGER GOING TO BE THE CASE, TO ME, THAT'S VERY, VERY SERIOUS.

I WAS ALSO ASTOUNDED TO FIND THAT SOME OF THE GLACIERS IN GREENLAND ARE RETREATING NOW AT AN AVERAGE SPEED OF 5 FEET PER HOUR. WHEN I THINK OF SOMETHING MOVING AT A GLACIAL PACE, I DON'T THINK OF 5 FEET PER HOUR. SO I THINK AL GORE IS RIGHT WHEN HE TALKS ABOUT THIS BEING AN EMERGENCY.

AND THERE IS A METAPHOR THAT I LIKE TO USE, WHERE WE TEND TO -- WHEN WE RECOGNIZE SOMETHING AS AN EMERGENCY, WE TEND TO REALLY GET TOGETHER AND ADDRESS IT; AND I WANT TO GIVE AN EXAMPLE OF THAT.

I'M OLD ENOUGH TO REMEMBER THE APOLLO 13 INCIDENT WHEN IT ACTUALLY HAPPENED. SOME OF YOU, PERHAPS, REMEMBER IT FROM THE FILM; AND YOU MIGHT RECALL THAT WHAT HAPPENED WAS THERE WAS AN EXPLOSION ON THE SERVICE MODULE. THIS IS THE THIRD LUNAR MISSION, THIRD MANNED LUNAR MISSION. AND THERE WAS AN EXPLOSION ON THE SERVICE MODULE, AND THE ASTRONAUTS HAD TO RETREAT INTO THE LUNAR MODULE AND

0600

SURVIVE THERE. THE PROBLEM WAS THE COMMAND MODULE AND THE LUNAR MODULE WERE NOT MADE TO COMMUNICATE WITH EACH OTHER. AND SO THEY HAD TO FIGURE OUT A WAY TO TAKE THE CARBON DIOXIDE SCRUBBER OUT OF THE COMMAND MODULE AND MAKE IT WORK IN THE LUNAR MODULE; OTHERWISE, THEY WERE GOING TO DIE OF CARBON DIOXIDE POISONING. SO THIS WAS A CLEAR CRISIS THAT INVOLVED CARBON DIOXIDE BUILDUP. SO IF YOU'LL BEAR WITH ME FOR ONE MINUTE HERE.

(VIDEO SHOWN)

OKAY. OF COURSE, THAT CRISIS WAS AVERTED, AND THE ASTRONAUTS GOT BACK ALIVE; BUT IT WAS A SITUATION WHERE THEY RECOGNIZED THEY NEEDED TO DO SOMETHING, THEY DIDN'T HAVE TEN YEARS TO RESEARCH THE PROBLEM. THEY HAD TO LOOK AT WHAT THE ASTRONAUTS HAD AVAILABLE TO THEM. THEY HAD TO LOOK AT WHAT THEY HAD, HOW THEY COULD MAKE THAT WORK.

AND I THINK THAT'S WHAT WE NEED TO DO TODAY. WE NEED TO LOOK AT WHAT'S IN OUR CARDBOARD BOX. IF WE POUR THAT CARDBOARD BOX OUT, WHAT SOLUTIONS CAN WE IMMEDIATELY START TO APPLY.

HERE ARE ONES THAT COME TO MIND: ENERGY EFFICIENCY, RENEWABLE ENERGY, COAL WITH CARBON CAPTURE AND STORAGE, AND NUCLEAR POWER.

NOW, HELEN HOWES COVERED NUCLEAR POWER

0601

YESTERDAY AND, ALSO, DID A NICE JOB OF COVERING ENERGY EFFICIENCY, BUT POINTED OUT THAT PROBABLY THE FIRST NEW NUCLEAR POWER PLANT THAT WOULD COME ON LINE MIGHT BE 2016.

SO, CERTAINLY, WE NEED TO WORK ON THESE TECHNOLOGIES. BUT OUR STUDY FOCUSED ON THE FIRST TWO; AND WHAT I LIKE ABOUT THOSE FIRST TWO IS THAT

THEY'RE ACTUALLY ALL AVAILABLE NOW. WE CAN START DEPLOYING THEM TODAY; AND, IN FACT, WE ARE DEPLOYING THEM TODAY. SO THAT'S WHAT OUR STUDY FOCUSED ON.

ROB MENTIONED THIS CONFERENCE. WHAT WE DID IS WE BROUGHT IN SOME OF THE TOP CLIMATE SCIENTISTS IN THE WORLD IN THE SUMMER OF 2006 TO EDUCATE US, WE ENGINEERS IN THE RENEWABLE ENERGY COMMUNITY, ABOUT WHAT THE CLIMATE CHANGE SITUATION IS, WHAT NEEDS TO BE DONE, WHAT ARE THE GOALS WE NEED; AND YOU'LL RECOGNIZE MANY OF THE PEOPLE UP THERE. IF YOU'LL LOOK IN THE -- LOOK HERE IN THE LOWER RIGHT, THERE'S ROB, WHO WAS NICE ENOUGH TO GIVE TWO PRESENTATIONS AT THIS CONFERENCE.

WE ALSO BROUGHT IN ENERGY EXPERTS, ENERGY EFFICIENCY AND RENEWABLE ENERGY EXPERTS; AND IT WAS A SPECIAL TRACK WHERE THEY LAID OUT WHAT THEY THOUGHT, IN AN AGGRESSIVE CLIMATE-DRIVEN SCENARIO, THEY COULD DO; AND WE USED AS A TARGET YEAR THE YEAR 2030, BUT

0602

WITH THE INTENTION THAT DEPLOYMENT WOULD BEGIN RIGHT AWAY.

SO HERE ARE THE TECHNOLOGIES THAT WERE COVERED: ENERGY EFFICIENCY IN BUILDINGS, TRANSPORTATION, AND INDUSTRY; CONCENTRATING SOLAR POWER -- AND BECAUSE OF THE LIMITED TIME TODAY, I CAN'T GO INTO MUCH DETAIL ON ALL THESE DIFFERENT TECHNOLOGIES, SO THERE'S A LOT OF INTEREST IN CONCENTRATING SOLAR POWER, AND ROB ASKED ME TO FOCUS ON THAT, AND I WILL DO THAT -- PHOTOVOLTAICS, CONVERTING SUNLIGHT DIRECTLY TO ELECTRICITY; WIND POWER; BIOFUELS -- IN THAT CASE, WE'RE TALKING ABOUT CELLULOSIC ETHANOL -- BIOMASS; AND GEOTHERMAL.

NOW, OBVIOUSLY, ESTIMATES VARY AS TO WHAT WE NEED TO DO IN THE U.S. -- I SHOULD POINT OUT THIS WAS JUST A U.S. STUDY -- BUT WE PROBABLY NEED TO BE IN THE RANGE OF SAVING ABOUT 1,100 TO 1,300 MILLION TONS OF CARBON PER YEAR BY THE YEAR 2030. SO KEEP THE AVERAGE NUMBER OF ABOUT 1,200 IN MIND. BECAUSE WHAT I'M GOING TO DO AS I GO THROUGH THIS, I'M GOING TO SHOW YOU WHAT THE EXPERTS CAME UP WITH AS TO WHAT THEY FELT THEY COULD BE DOING BY THE YEAR 2030
.

THE BIG ONE IS ENERGY EFFICIENCY; AND AS OTHER PEOPLE HERE HAVE POINTED OUT, THERE'S JUST A

0603

TREMENDOUS AMOUNT THAT COULD BE GAINED FROM ENERGY EFFICIENCY, AT VERY, VERY REASONABLE COSTS; IN FACT, AT NEGATIVE COST.

BUILDINGS REPRESENT 40 PERCENT OF IMPROVEMENTS; IN ENVELOPE DESIGN, DAYLIGHTING, BETTER LIGHTS -- CLEARLY, REPLACEMENT OF INCANDESCENTS WITH COMPACT FLUORESCENTS AND EVENTUALLY WITH LED SOLID STATE LIGHTING -- BUILDING AND APPLIANCE EFFICIENCY STANDARDS.

IN TRANSPORTATION, EMPHASIS IS ON LIGHTER-WEIGHT VEHICLES, PUBLIC TRANSPORTATION, AND ALSO DEVELOPING PLUG-IN HYBRID ELECTRIC VEHICLES.

AND THERE WAS A SPECIAL CHAPTER IN OUR REPORT -- THIS ULTIMATELY LED TO A 200-PAGE REPORT, I'LL TALK ABOUT THAT AT THE END -- BUT WE HAD A SPECIAL CHAPTER ON PLUG-IN HYBRIDS.

AND THEN IN INDUSTRY, HEAT RECOVERY, IMPROVED MOTORS, AND COMBINED HEAT AND POWER.

SO HERE ARE THE SAVINGS. THESE ARE HUGE FOR ENERGY EFFICIENCY. AND THIS STUDY WAS DONE BY JOEL SWISHER OF THE ROCKY MOUNTAIN INSTITUTE, WHICH IS AMORY LOVINS' ORGANIZATION.

ELECTRICITY, 20 PERCENT SAVINGS OFF A 2030 PROJECTION WOULD SAVE 218 MILLION TONS OF CARBON PER YEAR -- REMEMBER THAT WE FELT WE NEEDED TO BE

0604

SOMEWHERE IN THE RANGE OF 1,200 -- AT COSTS RANGING FROM FREE TO 4 CENTS PER KILOWATT HOUR. THOSE ARE THE COSTS OF SAVED ENERGY.

AND YOU CAN SEE THE SAVINGS OF OIL AND GAS THERE, ALSO VERY LARGE.

WHEN YOU ADD THEM ALL UP, SAVINGS OF 688 MILLION TONS OF CARBON PER YEAR. THAT'S ACTUALLY MORE THAN HALF OF WHAT WE THINK IS NEEDED.

OKAY, CONCENTRATING SOLAR POWER. MOST OF YOU ARE PROBABLY FAMILIAR WITH PHOTOVOLTAICS, CONVERTING SUNLIGHT DIRECTLY TO ELECTRICITY. BUT IN FACT, THERE'S TREMENDOUS POTENTIAL FOR THIS PARTICULAR TECHNOLOGY; AND ONE OF THE INDUSTRY REPRESENTATIVES TALKS ABOUT CONCENTRATING SOLAR POWER AS BEING "THE OTHER WHITE MEAT." THEY DON'T QUITE GET AS MUCH ATTENTION AS THE HIGH-TECH PHOTOVOLTAICS.

THIS WAS THE FIRST NEW CONCENTRATING SOLAR POWER PLANT IN THE UNITED STATES SINCE THE 1990S. IT'S A SMALL ONE. IT'S A 1-MEGAWATT PLANT IN TUCSON, ARIZONA. IT WAS DEDICATED ABOUT A YEAR AND A HALF AGO. THOSE ARE PARABOLIC TROUGH COLLECTORS; AND BASICALLY WHAT HAPPENS IN THIS TECHNOLOGY IS YOU HEAT A FLUID TO A VERY HIGH TEMPERATURE, ULTIMATELY BOIL WATER TO PRODUCE STEAM.

NOW, THERE ARE A VARIETY, ACTUALLY, OF

0605

TECHNOLOGIES THAT COULD BE USED IN CONCENTRATING SOLAR POWER. WE DIVIDED THEM INTO DISPATCHABLE, MEANING THAT ELECTRICITY COULD BE SENT OUT ONTO THE GRID WHEN IT IS NEEDED; OR NONDISPATCHABLE, MEANING ELECTRICITY IS JUST PRODUCED WHEN THE SUN SHINES. SO THESE BOTTOM TWO, A STIRLING ENGINE AT A PARABOLIC DISH GENERATES ELECTRICITY OR CONCENTRATING PV. THESE ARE PROMISING TECHNOLOGIES; BUT, AGAIN, THEY DON'T NECESSARILY DELIVER ELECTRICITY WHEN IT'S NEEDED.

THE OTHER TECHNOLOGIES AT THE TOP ARE ONES THAT CAN INVOLVE THERMAL STORAGE. AND SO WHEN YOU HAVE THERMAL STORAGE, YOU CAN PROVIDE ELECTRICITY AT OTHER TIMES. I'M GOING TO FOCUS ON PARABOLIC TROUGHS BECAUSE THAT'S WHAT WE HAVE THE MOST EXPERIENCE WITH.

THESE ARE CALLED THE SOLAR ELECTRIC GENERATING STATIONS; AND THEY HAVE BEEN OPERATING OUT

IN THE MOJAVE DESERT SINCE THE EARLY 1980S EXTREMELY RELIABLY. YOU CAN SEE THERE HOW THEIR CAPACITY HAS BEEN VERY LEVEL; AND YOU CAN SEE THAT THIS IS THE ACTUAL ELECTRICITY GENERATED IN GIGAWATT HOURS VERSUS TIME, AND AGAIN, VERY LEVEL ONCE ALL THE PLANTS ARE INSTALLED.

NOW, ORDINARILY, I ASK AN AUDIENCE IF THEY CAN GUESS WHAT HAPPENED IN 1991; BUT WITH ATMOSPHERIC

0606

SCIENTISTS HERE, I'M GUESSING THAT MOST OF YOU PROBABLY KNOW WHY THE POWER DROPPED IN 1991, AND IT WAS DUE TO THE ERUPTION OF MOUNT PINATUBO. IT SHOWS UP IN THE OUTPUT OF THESE SOLAR PLANTS.

BUT THIS IS 350 MEGAWATTS. AGAIN, THIS HAS BEEN PROVIDING RELIABLE ELECTRICITY FOR ABOUT 20 YEARS. SO THIS IS NOT SOME NEWFANGLED TECHNOLOGY.

THIS IS THE VALUE OF STORAGE. WHAT YOU CAN SEE HERE, THIS IS AN ACTUAL EXAMPLE, THIS IS FROM ARIZONA PUBLIC SERVICE; AND IT SHOWS YOU THE LOAD PROFILE -- THAT WOULD BE THIS BLUE LINE AS IT VARIES DURING THE DAY -- AND YOU CAN SEE THAT THE LOAD IS LATE AFTERNOON/EARLY EVENING. THE YELLOW LINE IS THE SOLAR. AND THERE IS A LOT OF OVERLAP. BUT IN FACT, WE WOULD BE MISSING SOME OF THAT PEAK. WHEN PEOPLE GET HOME FROM WORK, THEY TURN ON THEIR AIR CONDITIONERS, THEY TURN ON THEIR TELEVISIONS, THEY DO THEIR COOKING, ET CETERA. WITH THERMAL STORAGE -- AND THIS IS AN EXAMPLE OF SIX HOURS OF THERMAL STORAGE -- WE CAN FOLLOW THAT RED LINE, AND SO WE COULD TAKE ALL THIS SOLAR ENERGY THAT IS COLLECTED AND ACTUALLY MATCH THE LOAD PROFILE VERY NICELY. UTILITIES REALLY LIKE THAT CONCEPT.

THIS IS THE CONCENTRATING SOLAR POWER RESOURCE. IT'S IN THE SOUTHWEST PART OF THE UNITED

0607

STATES. NOW, UNLIKE PHOTOVOLTAICS, WHICH WE CAN USE DIRECT SOLAR RADIATION AND DIFFUSE SOLAR RADIATION, THESE TECHNOLOGIES CAN ONLY USE DIRECT SOLAR RADIATION. THAT'S THE STUFF THAT MAKES THE REALLY NICE SHARP SHADOW. AND THE REASON IS BECAUSE WE'RE FOCUSING THE SUNLIGHT. THESE PARABOLIC TROUGH COLLECTORS WILL TYPICALLY FOCUS THE SUNLIGHT TO A RATIO OF ABOUT 80 TO 1. THE IDEA IS WHEN YOU FOCUS THE SUNLIGHT ONTO A SMALL RECEIVER, A SMALL ABSORBER, YOU DECREASE THE AREA FOR HEAT LOSS. SO YOU CAN RUN AT HIGH TEMPERATURES, WHICH ARE NEEDED TO GET A GOOD POWER CYCLE EFFICIENCY FROM YOUR STEAM CYCLE, AND YOU KEEP THE LOSSES LOW. SO THIS RESOURCE IS FOCUSED ON THE SOUTHWEST PART OF THE UNITED STATES, AND THIS IS REALLY WORLD-CLASS RESOURCE. THIS IS REALLY ESSENTIALLY THE BEST RESOURCE IN THE WORLD.

NOW, WHAT WAS DONE IN THE STUDY IS VARIOUS FILTERS WERE APPLIED. WE LOOKED AT ONLY VALUES OF RADIATION ABOVE 6.75 KILOWATT HOURS PER SQUARE METER PER DAY. WE LOOKED AT ONLY AREAS THAT HAD LAND AVAILABLE AND LARGE CONTIGUOUS AREAS OF LAND AVAILABLE. AND FINALLY, ANYTHING WITH A GROUND SLOPE

GREATER THAN 1 PERCENT WAS ELIMINATED. SO THESE WERE VERY STRICT CRITERIA. WHEN THOSE STRICT FILTERS ARE APPLIED, YOU WIND UP WITH ALL THESE LITTLE SPOTS

0608

HERE. NOW, IF YOU ADD UP THE POTENTIAL ELECTRIC POWER GENERATION FROM JUST THOSE SPOTS, YOU GET 7,000 GIGAWATTS OR 7 MILLION MEGAWATTS. THAT'S ABOUT SEVEN TIMES THE U.S. ELECTRIC GENERATING CAPACITY. THAT'S AFTER THE FILTERS HAVE BEEN APPLIED.

IN THIS STUDY, THERE WERE VARIOUS ECONOMIC CRITERIA THAT WERE APPLIED. THERE WAS A MARKET DEPLOYMENT MODEL THAT WAS USED. SOLAR WAS COMPETED AGAINST WIND BETWEEN NOW AND 2030, AS WELL AS AGAINST FOSSIL FUELS. AND THIS PARTICULAR STUDY CAME UP WITH 80,000 MEGAWATTS OF CONCENTRATING SOLAR POWER BY THE YEAR 2030 IN AN AGGRESSIVE SCENARIO TO ADDRESS CLIMATE CHANGE. AND THAT'S WHERE THOSE MEGAWATTS WOULD BE LOCATED.

I WILL GIVE YOU AN IDEA OF WHAT'S HAPPENING IN THIS INDUSTRY. THIS IS AN INDUSTRY THAT'S REALLY TAKING OFF. I JUST CHECKED MY VOICE MAIL EARLIER THIS MORNING, AND I HAD SEVERAL MESSAGES FROM PEOPLE WANTING TO BUILD PLANTS, WANTING TO HAVE SOLAR RADIATION DATA. IT'S JUST IN THE LAST YEAR. IT REALLY IS INCREDIBLE WHAT'S HAPPENED IN THIS INDUSTRY. A LOT OF THIS IS DRIVEN BY THE STATE RENEWABLE PORTFOLIO STANDARDS--MANY PEOPLE NOW CALL THEM RENEWABLE ELECTRICITY STANDARDS--AND SO UTILITIES ARE TRYING TO MEET THESE STATE STANDARDS.

0609

BUT IF YOU LOOK ON THE RIGHT SIDE THERE, YOU CAN SEE HUNDREDS OF MEGAWATTS OF NEW PLANTS THAT ARE DESIGNED. THE SECOND ONE DOWN, NEVADA POWER, THAT'S A 64-MEGAWATT PLANT THAT WAS JUST BUILT OUTSIDE OF LAS VEGAS, IN BOULDER CITY. I VISITED IT A COUPLE OF MONTHS AGO; AND ACTUALLY, WHEN I WAS THERE, THEY WERE GENERATING 73 MEGAWATTS OF POWER FROM THAT FIELD.

NOW, WE'RE GENERALLY TALKING ABOUT LIMITING THIS ELECTRICITY TO THE SOUTHWEST; BUT IN EUROPE, THE GERMAN ORGANIZATION DLR DID A STUDY OF WHAT IF WE PUT PARABOLIC TROUGH COLLECTORS IN NORTH AFRICA AND WE TRANSPORT THAT ELECTRICITY ACROSS THE MEDITERRANEAN INTO EUROPE; AND THEY FOUND IT WAS VERY PRACTICAL TO DO THAT AT A VERY REASONABLE COST. IT WOULD ADD ABOUT 2 CENTS A KILOWATT HOUR.

IT'S CONCEIVABLE WE COULD DO THE SAME THING HERE. THIS WOULD BE USING HIGH-VOLTAGE DC TRANSMISSION LINES. THE DLR STUDY CONCLUDED THEY COULD TRANSMIT ELECTRICITY AS FAR AS 3,000 KILOMETERS AT A TRANSMISSION LOSS OF UNDER 10 PERCENT. THE NICE THING ABOUT DOING IT IN THIS COUNTRY, IF WE TAKE POWER FROM THE WEST AND MOVE IT TO THE EAST, IT'S THE RIGHT DIRECTION, BECAUSE WHEN THOSE EASTERN UTILITIES ARE GOING THROUGH THEIR PEAK LOADS, WE STILL HAVE

0610

PLENTY OF SUNSHINE IN THE WEST. SO EUROPE'S TRYING

TO MOVE IT NORTH, WE'D BE MOVING IT EAST. WE'RE MOVING IT IN THE RIGHT DIRECTION.

OKAY. SO IN THE CONCENTRATING SOLAR POWER STUDY, AS PART OF THIS SERIES THAT WAS DONE FOR THE CONFERENCE, IT WAS CONCLUDED 80,000 MEGAWATTS AT COSTS RANGING FROM 6 TO 13 CENTS A KILOWATT HOUR. PERHAPS DURING THE DISCUSSION PERIOD, I COULD EXPLAIN HOW WE INTEND TO GET THOSE COSTS FROM 13 CENTS DOWN TO 6 CENTS, BUT I THINK THE PLANS FOR DOING THAT ARE VERY REALISTIC. AGAIN, THAT IS DISPATCHABLE POWER WITH SIX HOURS OF STORAGE. THAT WOULD SAVE 63 MILLION TONS OF CARBON PER YEAR.

OKAY, PHOTOVOLTAICS. THE STUDY ON PV LOOKED AT ROOF-MOUNTED PHOTOVOLTAICS. SO THAT HERE IS THE RESOURCE IN THE U.S. AGAIN, YOU CAN USE NOT JUST DIRECT SOLAR RADIATION BUT DIFFUSE RADIATION. THESE ARE FLAT-PLATE MODULES THAT GO ON A ROOFTOP, SO EVEN IF IT IS HAZY WEATHER, THEY STILL COLLECT SUNLIGHT.

THE U.S. HAS A VERY GOOD RESOURCE. NOW, GERMANY HAS BEEN THE WORLD LEADER FOR A NUMBER OF YEARS IN INSTALLING PV. AND IF YOU'LL LOOK AT THE RESOURCE IN GERMANY, IT'S NOT AS GOOD AS THE RESOURCE IN THE NORTHERNMOST PARTS OF OUR COUNTRY. WE

0611

ACTUALLY HAVE A MUCH BETTER RESOURCE THAN GERMANY DOES. THEY HAVE FEED-IN TARIFFS THAT ARE PUSHING DEPLOYMENT IN GERMANY.

THIS SHOWS YOU WHAT HAS HAPPENED TO PV MODULE PRICES. IF YOU'LL LOOK AT DOLLARS IN THE YEAR THEY WERE SOLD, THAT'S THE GREEN LINE; BUT IF YOU ACTUALLY PUT THEM ALL IN TERMS OF 2004 DOLLARS, SO YOU'RE TAKING INTO ACCOUNT INFLATION, WE CAN SEE IN THAT TOP CURVE DRAMATIC REDUCTIONS IN PV PRICES. AND THERE ARE A NUMBER OF NEW TECHNOLOGIES THAT ARE COMING OUT NOW AND A NUMBER OF MANUFACTURING IMPROVEMENTS, SO THAT I DO EXPECT PV PRICES TO CONTINUE TO DROP.

THESE ARE WORLDWIDE PV SHIPMENTS. WE'RE SEEING AN EXPONENTIAL GROWTH IN PV MODULE SHIPMENTS.

SO THIS STUDY CONCLUDED THAT ACROSS THE U.S. BY 2030, IT WOULD BE POSSIBLE TO INSTALL UP TO 200,000 MEGAWATTS PEAK OF PV. AND I'M NOT GOING TO GO INTO ALL THE DETAILS HERE; BUT BASICALLY, YOU HAVE TO TRANSLATE PEAK POWER TO AVERAGE POWER; AND PV HAS A RELATIVELY LOW CAPACITY FACTOR. IT DOESN'T HAVE STORAGE INVOLVED. SO THE CARBON -- THE WAY THE CARBON TRANSLATION WORKS, IS IT WINDS UP BEING SIMILAR TO CSP, EVEN THOUGH CSP WAS ONLY 80,000 MEGAWATTS. THE COSTS HERE ARE BETWEEN ABOUT 28 CENTS

0612

A KILOWATT HOUR TODAY; 6 CENTS, WE THINK, BY THE YEAR 2030. NOW, THAT IS COMPETING IN THE RETAIL MARKET, SO PV CAN AFFORD TO BE A LITTLE BIT MORE EXPENSIVE. SO THAT ALSO WOUND UP BEING 63 MILLION TONS OF CARBON PER YEAR.

WIND POWER, THIS IS WHERE THE WIND RESOURCE

IS IN THE U.S., ALONG THE APPALACHIANS AND IN THE CENTRAL PART OF THE U.S. AND UPPER MIDWEST. THIS IS WHAT'S HAPPENING TO WIND TECHNOLOGY; HUGE IMPROVEMENTS. THE REASON WIND POWER IS SELLING SO WELL NOW IS THEY HAVE GOTTEN THE COST WAY DOWN. THEY'VE GOT THE COST WAY DOWN BY MAKING THE ROTORS MUCH BIGGER, AND YOU CAN SEE THE ROTOR DIAMETER THERE. ROTORS NOW ARE LONGER THAN A BOEING 747, IF YOU CAN BELIEVE THAT, I MEAN, THE WING SPAN ACTUALLY OF A BOEING 747. SO THESE HAVE GOTTEN VERY, VERY LARGE; AND AS A RESULT, THEY HAVE GOTTEN ECONOMIES OF SCALE IN PRICING.

THE OTHER THING, TOO, WITH THESE BIG ROTORS, THEY DISCOVERED IF THEY DON'T PUT THEM UP HIGH, THE ROTORS HIT THE GROUND.

(LAUGHTER).

SO THEY'VE PUT THEM ON A TALLER TOWER. AND THE ADVANTAGE OF THAT IS YOU GET OUTSIDE THE BOUNDARY LAYER OF AIR FLOWING ALONG THE GROUND. SO YOU GET

0613

INTO HIGHER WIND SPEEDS WHEN YOU PUT THESE BIG ROTORS UP.

NOW, THERE IS A SPECIAL CHAPTER, I MENTIONED, IN OUR REPORT ON PLUG-IN HYBRID ELECTRIC VEHICLES. AND WHAT THIS SHOWS YOU IS THAT WITH PLUG-IN HYBRID ELECTRIC VEHICLES, IT REALLY ENABLES LARGE-SCALE DEPLOYMENT OF WIND. BECAUSE, ESSENTIALLY, ONE OF THE ISSUES WITH WIND IS YOU DON'T HAVE STORAGE, YOU JUST HAVE ELECTRICITY WHEN THE WIND BLOWS; BUT IF YOU HAVE PLUG-IN HYBRID ELECTRIC VEHICLES SITTING IN YOUR GARAGE AT NIGHT, THEY CAN USE THAT WIND POWER WHENEVER IT BLOWS. IT DOESN'T MATTER WHETHER THE BATTERY IS RECHARGING AT 2 A.M. OR 4 A.M.

THIS IS THE GROWTH OF U.S. WIND CAPACITY; AGAIN, EXPONENTIAL GROWTH. WE'RE NOW OVER 10,000 MEGAWATTS OF INSTALLED WIND CAPACITY IN THE U.S. FARMERS AND RANCHERS, WHEN THEY INSTALL THESE ON THEIR PROPERTY, THEY GET BETWEEN $3,000 AND $5,000 A YEAR FOR EACH TURBINE THAT THEY GET INSTALLED ON THEIR PROPERTY. IT’S A NO-BRAINER. A LOT OF FARMERS ARE MAKING MORE MONEY OUT OF THEIR WIND TURBINES THAN THEY'RE MAKING OUT OF THEIR CROPS, AND THEY CAN STILL GROW THEIR CROPS.

SO THIS STUDY LOOKED AT ULTIMATELY

0614

PROVIDING 20 PERCENT OF GRID ENERGY. THAT'S ABOUT THE AMOUNT IN DEMARK RIGHT NOW, ABOUT 20 PERCENT OF THEIR GRID ENERGY IS FROM WIND POWER, AND THAT WOULD BE 245,000 MEGAWATTS AT 3 TO 7 CENTS PER KILOWATT HOUR. WIND IS A BIG COMPONENT HERE. IT WOULD SAVE 180 MILLION TONS OF CARBON PER YEAR.

OKAY, BIOMASS AND BIOFUELS. LET ME FIRST SAY THAT IN TERMS OF BIOFUELS, WE'RE LOOKING AT CELLULOSIC ETHANOL, NOT CORN-BASED ETHANOL. ONE OF THE STUDIES AT NREL SHOWED THAT IF YOU LOOK AT CORN-BASED ETHANOL, THERE IS SOME SAVINGS IN CARBON

EMISSIONS COMPARED TO GASOLINE, BUT NOT A HUGE SAVINGS. SOME OTHER PEOPLE, DEPENDING ON HOW THEY DRAW THE SYSTEM BOUNDARIES, MAY CONCLUDE THAT THERE ACTUALLY IS MORE. BUT I THINK THE MOST RELIABLE STUDIES SHOW SOME IMPROVEMENT. BUT THERE IS A DRAMATIC REDUCTION IN CARBON EMISSIONS WHEN YOU GO TO THE OTHER TYPES OF PLANT MATERIAL. AND ALSO, YOU DON'T WANT TO BE COMPETING AGAINST FOOD CROPS; AND, I THINK THAT ONE OR TWO OF THE SPEAKERS MENTIONED THAT.

THIS IS HOW BIOMASS RESOURCES ARE DISTRIBUTED ACROSS THE UNITED STATES. BIOFUELS SAVINGS, THIS IS WHAT THE STUDY CAME UP WITH. AGAIN, LOOKING AT ETHANOL FROM CROP RESIDUES AND ENERGY CROPS, YOU WOULD SAVE 28 BILLION GALLONS OF GASOLINE

0615

BY 2030--THAT'S ABOUT 20 PERCENT OF TODAY'S CONSUMPTION--AT COSTS RANGING FROM $3.75 A GALLON TODAY TO 90 CENTS A GALLON BY 2030. THAT WOULD BE 58 MILLION TONS OF CARBON PER YEAR.

BIOMASS POWER, THIS IS TAKING WOOD RESIDUES AND MUNICIPAL DISCARDS AND BURNING THEM TO PRODUCE ELECTRICITY WITH POLLUTION CONTROLS; 45,000 MEGAWATTS, 5 TO 8 CENTS A KILOWATT HOUR, A SAVINGS OF 75 MILLION TONS OF CARBON PER YEAR.

THIS IS A SO-CALLED BINARY CYCLE GEOTHERMAL PLANT. THIS IS LOCATED IN NORTHERN CALIFORNIA IN THE MAMMOTH LAKES AREA. YOU CAN SEE IT ESSENTIALLY BLENDS INTO THE ENVIRONMENT. THEY PAINTED IT THAT WAY. THE SIERRA CLUB WAS MONITORING THIS PROJECT WHEN THEY BUILT IT. THESE ARE TEMPERATURES AT 6-KILOMETER DEPTH. WE'RE LOOKING AT DEEPER RESOURCES NOW BECAUSE WE ONLY HAVE 15,000 MEGAWATTS OF RESOURCES NEAR THE SURFACE LEFT. BUT FOR MORE POWER, WE'RE LOOKING AT DEEPER RESOURCES.

THIS STUDY, WHICH JEFF TESTER OF MIT WAS ONE OF THE CO-AUTHORS OF THIS STUDY; AND MIT RECENTLY

0616

CAME OUT WITH A BIG REPORT ON GEOTHERMAL POWER; AND THEY CONCLUDED 50,000 MEGAWATTS BY THE YEAR 2030, 90 PERCENT CAPACITY FACTOR. THE NICE THING ABOUT GEOTHERMAL IS IT GENERATES ELECTRICITY SEVEN DAYS A WEEK, 24 HOURS A DAY. USING 25 PERCENT EXISTING HYDROTHERMAL RESOURCES, EXPANDING THOSE EXISTING PLACES, AND ALSO 50 PERCENT FROM OIL AND GAS WELLS, AT COSTS RANGING FROM 5 TO 10 CENTS PER KILOWATT HOUR. 83 MILLION TONS OF CARBON PER YEAR.

OKAY. WHAT HAPPENS WHEN YOU PUT ALL THIS TOGETHER? HERE'S A MAP OF THE U.S., AND THERE ARE TWO BARS THERE THAT SHOW AN 80-PERCENT REDUCTION AND A 60-PERCENT REDUCTION IN CARBON EMISSIONS, WHAT WOULD BE NEEDED TO BE ON THE PATH TO ACHIEVE THOSE EMISSIONS REDUCTIONS FROM TODAY'S VALUE BY MID-CENTURY. AND THE BAR ON THE LEFT SHOWS HOW MUCH WE CAN DO WITH THESE TECHNOLOGIES. SO CARBON REDUCTION FROM ENERGY EFFICIENCY, THAT'S 688 MILLION TONS OF CARBON PER YEAR IN 2030. WE

HAVE WIND POWER, THAT'S WHAT WOULD BE APPLIED. PHOTOVOLTAICS WOULD BE PRETTY MUCH ACROSS THE COUNTRY. CONCENTRATING SOLAR POWER IN THE SOUTHWEST. BIOFUELS AND BIOMASS AND GEOTHERMAL. AND THESE WOUND UP BEING PRETTY MUCH IN THE BALLPARK OF WHERE IT NEEDS TO BE. AND WE DIDN'T ACTUALLY PLAN THAT FROM THE BEGINNING. WE THOUGHT, WELL, WHATEVER GAP THERE IS, WE'LL SAY, OKAY, WE NEED TO BUILD NUCLEAR POWER

0617

PLANTS, WE NEED CARBON CAPTURE AND SEQUESTRATION. AND OF COURSE, IN ANY REAL SCENARIO, WE'RE GOING TO USE A COMBINATION OF ALL THOSE THINGS. BUT THE POINT IS THIS HAS A LOT OF POTENTIAL.

THIS IS HOW IT LOOKS ON A WEDGES CHART, FILLING THE TRIANGLE AS NEEDED. THAT BIG GRAY WEDGE IS ENERGY EFFICIENCY.

WHAT DOES IT COST? WE DID A COST CALCULATION. THIS IS HOW MANY BILLIONS OF DOLLARS A YEAR EACH OF THE RENEWABLES WOULD COST BETWEEN NOW AND 2030. THAT'S THE AVERAGE COST PER YEAR. THAT ADDS UP TO ABOUT $30 BILLION. ENERGY EFFICIENCY WOULD SAVE 108 BILLION. AND SO IF YOU PACKAGE IT ALL TOGETHER, YOU'RE ACTUALLY SAVING ABOUT $80 BILLION A YEAR.

NOW, YOU MAY ARGUE THAT, WE WEREN'T REALLY ACCURATE ON HOW MUCH ENERGY EFFICIENCY COSTS. MAYBE IT'S MORE EXPENSIVE THAN THAT, OR IT DOESN'T SAVE AS MUCH MONEY AS THAT. EVEN IF WE'RE PAYING A TOTAL OF $30 BILLION A YEAR FOR RENEWABLE ENERGY, THAT'S ABOUT A THIRD OF WHAT WE'RE PAYING ON THE IRAQ WAR. SO WE CAN MAKE THOSE KINDS OF INVESTMENTS WITHOUT DESTROYING THE ECONOMY.

AND THIS IS WHAT PERCENT OF THE GRID POWER WE WOULD HAVE; AND I JUST WANT TO POINT OUT THAT A NUMBER OF THESE CAN PROVIDE BASE LOAD POWER, IN OTHER

0618

WORDS, THEY HAVE STORAGE. AND THIS IS A STUDY DONE BY THE UNION OF CONCERNED SCIENTISTS. AND I'M KIND OF OUT OF TIME, SO I'M GOING TO RUN QUICKLY THROUGH THOSE, BUT YOU CAN LOOK AT THESE. AND THIS WILL BE IN THE PRESENTATION MATERIAL POSTED AFTER THE CONFERENCE.

BUT THESE ARE 185,000 NEW JOBS, $30 BILLION IN CONSUMER SAVINGS. THIS WAS A STUDY DONE BY UCS OF WHAT A 20-PERCENT NATIONAL RENEWABLE ELECTRICITY STANDARD WOULD DO. TREMENDOUS ECONOMIC BENEFITS.

THESE ARE ALL THE RENEWABLE ELECTRICITY STANDARDS; THERE'S 25 OF THEM IN STATES ACROSS THE COUNTRY RIGHT NOW.

I JUST WANT TO SHOW YOU, THIS IS THE SOLAR ELECTRIC POWER CONFERENCE. THREE YEARS AGO, 1,000 PEOPLE; THIS YEAR, 12,500 PEOPLE. THERE IS A TREMENDOUS AMOUNT OF VENTURE CAPITAL GOING INTO THIS.

SO WHEN YOU LOOK AT ALL THESE DIFFERENT TECHNOLOGIES, IT IS TRUE THAT THERE IS NO SILVER BULLET; BUT, IN FACT, IF YOU LOOK AT ALL OF THESE DIFFERENT TECHNOLOGIES, THERE'S A LOT THAT CAN BE DONE.

AND THIS IS THE REPORT. IT'S AVAILABLE AT

WWW.ASES.ORG/CLIMATECHANGE. I HAVE THE REPORT HERE. I HAD IT SENT FEDERAL EXPRESS, AND IT CLEARLY DID NOT QUITE MAKE IT THROUGH THE RAINSTORM WE HAD THE OTHER DAY. SO IT'S A BIT WRINKLED, BUT YOU'RE WELCOME TO TAKE A LOOK AT THIS.

AND IF YOU WANT FURTHER INFORMATION, THAT'S MY EMAIL ADDRESS.

AND IF YOU HAVE TIME TO SNORKEL, I RECOMMEND IT. THAT'S WHAT THE CORAL REEF LOOKS LIKE JUST A COUPLE OF MILES FROM HERE.

THANKS VERY MUCH.