DR. FRIEDMANN: THANK YOU VERY MUCH.
AND I WOULD LIKE TO ALSO THANK ROB FOR INVITING ME TO THIS AND, ALSO, FOR THE CONFERENCE ORGANIZERS, FOR NOT ONLY FOR HOSTING THIS OUTSTANDING CONFERENCE, BUT FOR GIVING ME THE OPPORTUNITY TO ADDRESS SUCH AN AUGUST AND HIGH-TECH AUDIENCE TODAY.
FOR THOSE OF YOU WHO HAVEN'T HEARD ME TALK BEFORE, BUCKLE UP, I TALK FAST.
THIS IS BASICALLY -- FALLS INTO THE CATEGORY OF NO CARBON-FREE EARTH LEFT BEHIND. AND WE REALLY SHOULD BE THINKING IN THIS CONTEXT TODAY BECAUSE, ACTUALLY, THE FUTURE IS OPAQUE. ALL OPTIONS SHOULD BE ON THE TABLE IN THE NEAR TERM, AND THAT MEANS WE ACTUALLY HAVE QUITE A LOT OF WORK IN FRONT OF US.
ONE OF THE IMPORTANT CONSIDERATIONS IN THAT IS CARBON CAPTURE AND SEQUESTRATION AND WHERE IT SHOULD FIT IN. AND THIS IS A MAP SHOWING YOU A
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LITTLE BIT ABOUT WHAT WE KNOW ABOUT CARBON CAPTURE AND SEQUESTRATION TODAY. I'M GOING TO TAKE A SECOND EXPLAINING IT. THE RED STARS ARE WHERE WE HAVE BEEN DOING IT AT COMMERCIAL SCALE FOR A NUMBER OF YEARS. THIS IS TO DISABUSE YOU OF THE NOTION THAT THIS IS SOMEHOW SOME TECHNOLOGY WHICH WAS NOT READY FOR PRIME TIME AND WE HAVE TO WAIT UNTIL 2020 TO HAVE SOME ACTION ON IT. WE HAVE ACTUALLY BEEN DOING IT IN THE NORTH SEA FOR 11 YEARS AT SLEIPNER. WE HAVE BEEN INJECTING CO2 AND MONITORING IT AT WEYBURN FOR SIX OR SEVEN YEARS, AND IN ALGERIA FOR ABOUT THREE OR FOUR YEARS.
WE'VE ACTUALLY BEEN INJECTING CO2 UNDERGROUND FOR A LOT LONGER THAN THAT. THESE GREEN STARS ARE PLACES WHERE WE'VE BEEN INJECTING IT UNDERGROUND FOR ENHANCED OIL RECOVERY; AND EVEN IN TRINIDAD, SINCE 1972; IN THE U.S., SINCE ABOUT THE SAME TIME. SO FOR 30, 35 YEARS WE'VE BEEN INJECTING CARBON DIOXIDE UNDERGROUND.
FOR CAPTURE AND SEPARATION, WE'VE BEEN SEPARATING CARBON DIOXIDE FROM INDUSTRIAL FLOW STREAMS FOR 70 OR 80 YEARS. NO MIRACLE IS REQUIRED FOR THIS TECHNOLOGY. AND THE LEVEL OF INTEREST FOR THIS IS REPRESENTED BY THE YELLOW STARS. THE YELLOW STARS ARE WHERE THERE ARE LARGE COMMERCIAL PROJECTS
0622
THAT ARE GOING TO COME ON LINE IN THE NEXT COUPLE OF YEARS. THE BIGGEST OF THESE IS PROBABLY GORGON, WHERE THEY'LL BE INJECTING 6 TO 8 MILLION TONS OF CARBON DIOXIDE UNDERGROUND STARTING IN 2009, AND THAT IS BASICALLY THE SCALE OF A 1,000-MEGAWATT POWER PLANT. SO WE'RE READY TO GO AND WE KNOW QUITE A BIT FROM WHAT WE'VE DONE.
IN CASE YOU NEED TO SKIP OUT FOR SOME REASON, HERE'S THE CONCLUSIONS.
(LAUGHTER)
AS I TRIED TO SAY BEFORE, WE KNOW A LOT. CURRENT KNOWLEDGE STRONGLY SUGGESTS THAT THIS IS

GOING TO WORK; AND THAT WE CAN DO IT AT SCALE, AND THAT IT'S ACTIONABLE TODAY. THERE ARE SCIENCE AND TECHNOLOGY GAPS. I DON'T WANT TO LEAVE YOU WITH THE IMPRESSION THAT THERE IS NO WORK TO BE DONE. WHAT WE KNOW ABOUT THOSE GAPS APPEARS TO BE RESOLVABLE.

ANOTHER WAY TO SAY THIS, AND THIS IS FROM RECENT CONGRESSIONAL TESTIMONY: TODAY WE KNOW ENOUGH TO SITE A PROJECT, OPERATE IT, MONITOR IT, AND CLOSE IT SAFELY AND EFFECTIVELY.

WE, ACTUALLY, KNOW ALL THOSE THINGS. WE DON'T NECESSARILY KNOW HOW TO DO THAT AT A NATIONAL OR A GLOBAL SCALE. THAT'S A DIFFERENT SET OF QUESTIONS. THE KEY ISSUE IN CARBON CAPTURE AND

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SEQUESTRATION IS THE ISSUE OF SCALE, AND I WILL SPEND SOME TIME TALKING ABOUT THAT.

ONCE YOU GET PAST THIS, YOU IMMEDIATELY HIT THE DEPLOYMENT ISSUES. THERE'S A NUMBER OF REGULATORY, LEGAL, AND OPERATIONAL CONCERNS THAT CONFRONT US. THE KEY PIECE OF INFORMATION THAT WE NEED -- AND ROB TALKED ABOUT THIS YESTERDAY -- IT NEEDS TO BE GATHERED IN LARGE PROJECTS; AND THE LARGE PROJECTS THAT WE LOOKED AT TO DATE HAVEN'T GIVEN US THIS INFORMATION BECAUSE WE HAVEN'T BEEN ASKING THOSE KINDS OF QUESTIONS, AND WE NEED TO DO THAT.

OUT OF THESE, THE THREE THAT I'M GOING TO SPEND A LITTLE TIME TALKING ABOUT: SITE CHARACTERIZATION, MONITORING, AND HAZARD ASSESSMENT, TO GET US OVER THE HUMP.

NOW, THIS IS JUST A SECOND FOR FRAMING, AND REALLY JUST A SECOND. THIS ONE I DON'T HAVE TO EXPLAIN TO YOU ALL. YOU KNOW WHERE WE ARE ON THIS DIAGRAM.

THIS IS A DIFFERENT DIAGRAM. THIS WAS PUT TOGETHER BY JERRY STOKES AT PNNL. THIS IS THE AMOUNT OF ENERGY THAT THE GLOBE HAS CONSUMED SINCE THE INDUSTRIAL REVOLUTION. A COUPLE OF POINTS FROM THIS: ONE, WE HAVE NEVER USED LESS OF ANY KIND OF ENERGY, EVER. WE USE MORE WOOD THAN WE USED TO. WE USE MORE

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COAL THAN WE USED TO. WE USE MORE OIL AND GAS THAN WE USED TO. WE'VE NEVER USED LESS OF ANYTHING.

THE OTHER THING IS, BASICALLY FROM THAT LIGHT BLUE BAR DOWN, ALL OF THAT EMITS CARBON DIOXIDE, 85 PERCENT OF THE NETWORK TODAY EMITS CARBON DIOXIDE. IF ALL FUTURE ENERGY GROWTH IS WITH CARBON-FREE ENERGY SUPPLIES -- AND I DON'T NEED TO STRESS HOW DIFFICULT THAT IS AND HOW HARD THAT IS -- WE'RE STILL GOING TO BE EMITTING THIS PART. WE STILL HAVE THE 8.4 GIGATONS OF CARBON THAT ROB MENTIONED YESTERDAY. THIS IS A KEY PIECE OF THE REASON WHY WE HAVE THIS URGENCY. AND I HAVE BEEN VERY PLEASED TO FIND THAT THE VIDEO GAME INDUSTRY IS ALREADY ON TOP OF THIS.

(LAUGHTER)

AND I DON'T KNOW WHETHER THIS IS A DIESEL HYBRID OR NOT, BUT THEY CLEARLY SEE A CERTAIN URGENCY

AROUND HANDLING THE CARBON PROBLEM.
THIS IS ABOUT WHERE WE ARE AS A SOCIETY.
SO ONCE WE GET ORIENTED TOWARDS FIXING THINGS, CARBON CAPTURE AND SEQUESTRATION BECOMES ATTRACTIVE.
THESE THINGS THAT WE KNOW TODAY -- AND THIS CAME FROM AN IPCC SPECIAL REPORT ON CARBON DIOXIDE SEQUESTRATION THAT WAS PUBLISHED A COUPLE OF YEARS AGO, 2005. THE POTENTIAL IS SOMEWHERE BETWEEN 15 AND

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50 PERCENT; EASY NUMBERS TO REMEMBER. ANOTHER WAY TO SAY THIS IS YOU CAN GET SOMEWHERE BETWEEN ONE AND FOUR WEDGES OUT OF ROB'S WEDGE BOX; AND THOSE ARE QUESTIONS OF HOW THINGS ARE DEPLOYED AND WHAT YOU CAN DO. THE LOW END IS BASED ON THE FACT THAT WE ALREADY PRODUCE MORE OIL AND GAS THAN THAT VOLUME REPRESENTS, SO WE KNOW THAT WE CAN HANDLE THAT VOLUME OF MATERIAL. CRUDELY SPEAKING, ANOTHER WAY TO THINK ABOUT THIS IS THAT THE ENTIRE OIL AND GAS INDUSTRY OF THE WORLD IS ABOUT 25 PERCENT ON A VOLUME BASIS, SO WE CAN GET THAT. WE MIGHT BE ABLE TO GET THIS. IT'S A KEY PIECE OF THE PORTFOLIO. BASED ON WHAT WE KNOW TODAY, IT IS COST -- YOU'RE GOING TO BE DOING THIS WITH CONSERVATION, WITH EFFICIENCY, WITH NUCLEAR, WITH RENEWABLES. THE FACT THAT YOU CAN GET UP TO HALF DOESN'T MEAN YOU CAN GET ALL OF IT. THIS AIN'T THE PANACEA, BUT IT GETS YOU PRETTY FAR.
TODAY IT IS COST-COMPETITIVE WITH OTHER CARBON-FREE OPTIONS, AND IT ENABLES OTHER LIKE HYDROGEN TRANSPORTATION. IT DOES USE PROVEN TECHNOLOGY. YOU CAN APPLY IT TODAY TO NEW PLANTS, SOMETHING THAT PEOPLE DON'T TALK ABOUT BECAUSE IT IS MORE COSTLY. IT MAY NOT BE THE BEST ENGINEERING, BUT YOU CAN APPLY IT TO EXISTING PLANTS. THERE'S ACTUALLY NO REASON WHY YOU CAN'T STRAP A

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POST-COMBUSTION CAPTURE DEVICE ONTO A POWER PLANT TODAY.
AND THE COSTS TODAY ARE HIGH, BUT THERE ARE DRAMATIC GROUNDS FOR COST REDUCTION ON A THERMODYNAMIC BASIS. WE ARE ONLY DOING THE CAPTURE AND SEPARATION TODAY AT ABOUT A 5 TO 10 PERCENT EFFICIENCY; AND THAT'S THE BIG COST ELEMENT. I WILL SPEND A BIT MORE TIME TALKING ABOUT THAT.
THE PUNCH LINE, IT'S ACTIONABLE, WE CAN DO IT NOW. IT'S SCALEABLE. WE CAN DO IT AT THE LEVELS WE NEED TO. AND IT'S COST-COMPETITIVE.
SO WHAT ARE WE DOING? THIS IS NOT ROCKET SCIENCE; THIS IS ROCK SCIENCE. YOU SEPARATE YOUR CO2, YOU STUFF IT UNDERGROUND. AND THERE'S A COUPLE OF PLACES YOU CAN DO IT. SALINE FORMATIONS ARE THE LARGEST CAPACITY. CONSERVATIVE RENDERING OF THAT IS 22,000 GIGATONS. I'VE PUBLISHED AN ESTIMATE WHICH SAYS WE HAVE 10,000 GIGATONS OF GLOBAL STORAGE CAPACITY. THAT NUMBER IS ACTUALLY PRETTY CONSERVATIVE; THE MORE WE STUDY THIS, THE BIGGER IT GETS. IT'S REASONABLE TO IMAGINE THAT WE MIGHT HAVE AS MUCH AS A FACTOR OF 10 LARGER THAN THAT.

WHERE WE'RE GOING TO START IS IN DEPLETED OIL AND GAS FIELDS. FIRST OF ALL, YOU CAN GET ADDITIONAL OIL OR GAS OUT OF THE GROUND AS AN

ECONOMIC INCENTIVE TO HELP COVER THE COST. SECOND OF ALL, THE LIGHT'S GOOD. WE'VE DRILLED A LOT OF WELLS, AND WE KNOW WHAT THE ROCKS LOOK LIKE, WHICH IS AN IMPORTANT CONSIDERATION IN THIS.

SO WHAT DO YOU NEED TO DO THIS? FIRST ORDER OF BUSINESS IS YOU NEED A HIGH-CONCENTRATION STREAM OF CO2, SOMETHING LIKE 95 PERCENT. OTHERWISE, YOU'RE COMPRESSING NITROGEN, WHICH IS, YOU KNOW, KIND OF SILLY.

THERE ARE A NUMBER OF PATHWAYS TO DO THIS; AND THE SPEAKERS THE FIRST DAY, ACTUALLY, MENTIONED A NUMBER OF THESE: PRECOMBUSTION SEPARATION FROM, SAY, GASIFICATION PLANTS. JUST A POINT OF CLARIFICATION: A GASIFICATION PLANT DOES NOT IN AND OF ITSELF CAPTURE AND SEQUESTER CARBON DIOXIDE. YOU ACTUALLY HAVE TO DO THAT STEP IN ADDITION. BUT YOU CAN ALSO BURN IN A PURE OXYGEN ENVIRONMENT, OR YOU CAN DO POST-COMBUSTION CAPTURE AND SEPARATION. AND THESE ARE ALL PERFECTLY GOOD PATHWAYS TO GET TO THIS END.

IF YOU LOOK AT THE COST TODAY, ALL THREE APPROACHES APPEAR EQUALLY VIABLE; AND, ALSO, ALL THREE APPROACHES APPEAR TO HAVE THE SAME LEVEL OF COST SAVINGS IN FRONT OF THEM FROM A THERMODYNAMIC BASIS AND FROM A REASONABLE TECHNOLOGY BASIS. SO TODAY IF YOU WERE TO DO THIS, SAY, AT A

POST-COMBUSTION CAPTURE, 40 TO 60 BUCKS A TON FOR THE CAPTURE AND SEPARATION; FOR A GASIFICATION PLANT, 30 TO 50 BUCKS; OXYGEN-FIRED, ABOUT THE SAME AS POST-COMBUSTION CAPTURE, EXCEPT WE HAVE A LOT LESS EXPERIENCE WITH THAT. THAT ASTERISK THERE IS THE NOT-QUITE-READY-FOR-PRIME-TIME PART OF THIS CONVERSATION.

THERE ARE, HOWEVER, LOW-COST OPPORTUNITIES. IN THIS PIECE, THE $5 TO $10 HERE IS BASICALLY THE COST OF COMPRESSION AND TRANSPORTATION. THESE ARE PLACES WHERE WE ALREADY HAVE PURE STREAMS OF CO2 READY TO STUFF SOMEPLACE. THESE COME FROM PLACES LIKE THE HYDROGEN PLANTS AND REFINERIES, FERTILIZER PLANTS, WASTE STREAM FROM ETHANOL PLANTS, NATURAL GAS PROCESSING FACILITIES, FERTILIZER PLANTS, ALL THESE SORTS OF THINGS. AND THOSE ARE COAL-TO-LIQUIDS PLANTS, OR SYNTHETIC NATURAL GAS PLANTS ALSO COULD DO THAT SORT OF THING. AND SO THESE ARE PLACES WHERE YOU ALREADY HAD THESE HIGH CONCENTRATIONS, SO ALL YOU NEED TO DO IS ACTUALLY COMPRESS THEM TO HYDROSTATIC PRESSURES AND DEPTH AND INJECT THEM IN A SUITABLE LOCATION.

WE HAVE DONE THESE THINGS TO A LIMITED EXTENT ALREADY. AGAIN, THESE ARE TECHNOLOGIES WHICH WE HAVE EXPERIENCE WITH AND WHICH WE CAN DEPLOY.

THE NUMBER ONE QUESTION I AM ASKED IS:

WHAT HAPPENS AFTER YOU INJECT? OR IS IT SAFE? OR WILL IT REDUCE MY PROPERTY VALUES? OR WILL IT KILL MY ORPHANAGE? OR SOME VERSION OF THIS. YOU KNOW, WHAT HAPPENS AFTER THE CO2 GOES UNDERGROUND. DOES IT STAY THERE?

THE GOOD NEWS IS THAT THE STORAGE MECHANISMS ARE SUFFICIENTLY WELL UNDERSTOOD TO BE CONFIDENT OF HOW THESE THINGS WILL WORK. FOR STARTERS, YOU HAVE MULTIPLE TRAPPING MECHANISMS. THE FIRST OF THESE WILL BE PHYSICAL TRAPPINGS. SO LET'S SAY YOU'RE GOING TO INJECT INTO THIS GRAY UNIT HERE. THE OVERLYING RED UNIT IS IMPERMEABLE. AND BASICALLY WHAT YOU'RE DOING IS YOU'RE CREATING A LITTLE CO2 FIELD INSTEAD OF, SAY, AN OIL FIELD. THE CAP ROCK TRAPS IT FROM ITS BUOYANCY. SUPERCRITICAL CO2 IS BUOYANT IN THE CRUST AND THE FLOW TO THE SURFACE. THE CAP ROCK KEEPS IT IN PLACE. AND THIS CAN EITHER BE A GEOMETRICAL CLOSURE, LIKE THIS ONE, OR BASICALLY A HYDRODYNAMIC SORT OF TRAPPING MECHANISM.

RESIDUAL PHASE TRAPPING IS ANOTHER WAY TO DO IT. ESSENTIALLY, WHEN YOU INJECT A LOT OF CO2, IT'S CONTINUOUS, BUT IT BREAKS UP AS IT MIGRATES AWAY INTO THESE LITTLE BUBBLES, AND CAPILLARY FORCES ESSENTIALLY TRAP IT IN PLACE. IT'S THE SAME REASON

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YOU THROW YOUR CLOTHES IN THE DRYER EVEN AFTER YOU WRING THEM OUT, THEY'RE WET. YOU ACTUALLY HAVE FORCES THAT TRAP A SUBSTANTIAL VOLUME OF CO2 UNDERGROUND. THAT'S SENSITIVE TO PORE GEOMETRY. BUT ABOUT 25 PERCENT OF THE PORE VOLUME IN SOME CASES BASICALLY CAN'T BE MOVED OUT. YOU HAVE TO SWEEP IT OUT TO DO THAT. OVER TIME CO2 DISSOLVES. IT MAKES PERRIER, BASICALLY, IN THE SUBSURFACE. ONE OF THE ATTRACTIONS OF THAT IS THAT THAT PERRIER IS MORE DENSE THAN THE SURROUNDING WATER AND SO IT WILL ACTUALLY SINK, IT IS NO LONGER BUOYANT. OVER LONGER PERIODS OF TIME, THAT FORMS CARBONIC ACID THAT REACTS WITH ROCKS IN THE CRUST AND ACTUALLY FORMS NEW CARBONIC MINERALS IN THE CRUST. IN THAT CASE, THE ONLY WAY TO GET THE CO2 OUT IS THROUGH PLATE TECTONICS, AND IT IS REALLY A RATHER PERMANENT MECHANISM FOR STORAGE.

SOMETHING THAT IS ALSO IMPORTANT TO RECOGNIZE IS THAT IN SOME, YOU KNOW, INTEGRATED WAY, YOU BASICALLY TAKE CO2 THAT'S ORIGINALLY JUST TRAPPED STRUCTURALLY AND STRATOGRAPHICALLY, AND IT BEGINS TO MIGRATE INTO THESE OTHER TRAPPING MECHANISMS. BECAUSE YOU HAVE MULTIPLE TRAPPING MECHANISMS THAT OPERATE ON MULTIPLE LENGTH SCALES AND MULTIPLE TIME SCALES. SO THAT OVER TIME YOU ACTUALLY INCREASE THE

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SECURITY AND INCREASE THE PERFORMANCE OF YOUR SITE. AND I CAN'T STRESS THAT ENOUGH. AND THE FACT THAT YOU HAVE THESE MULTIPLE STORAGE MECHANISMS THAT BASICALLY GET BETTER OVER TIME IS ONE OF THE REASONS WHY THIS IS SUCH AN INTERESTING AND ATTRACTIVE TECHNOLOGY.

IF YOU WANT TO BREAK DOWN THE COSTS FOR THIS, THE BIG POLE IN THE TENT IS CAPTURE. AND AS I SAID BEFORE, THERE'S A LOT OF WORK THAT NEEDS TO BE DONE TO REDUCE THOSE COSTS. WE HAVEN'T REALLY DONE ANYWHERE NEAR AS MUCH OF THAT WORK AS WE COULD, BUT IT IS REASONABLE TO THINK WE MIGHT BE ABLE TO GET DOWN TO $10, $20 A TON AT SOME POINT IN THE NOT-TOO-DISTANT FUTURE.

THE COST OF STORAGE IS BASICALLY THE COST OF DRILLING WELLS AND MANAGING THE SITE. THAT IS SOMETHING ON THE ORDER OF 3 TO 8 BUCKS A TON, DEPENDING ON WHERE YOU'RE DOING IT.

THE COST OF MONITORING CO2 -- I'M GOING TO SPEND SOME MORE TIME TALKING ABOUT MONITORING -- IS A LOT LESS THAN A BUCK A TON, FOR THE MOST PART.

AND TO DO THE ASSESSMENT IS ON THE ORDERS OF PENNIES A TON.

SO THIS -- IT'S ALL ABOUT THIS, IT'S ALL ABOUT GETTING THE COSTS DOWN IN TERMS OF HOW THIS

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COMPETES WITH OTHER KINDS OF TECHNOLOGIES IN THE MARKETPLACE. BUT THE FIRST THING YOU DO IS ACTUALLY ASSESSMENT, AND THAT'S THE CHEAP PART. AS A SOCIETY, WE COULD CERTAINLY BE DOING THAT NOW FOR A VERY, VERY LOW COST AND GETTING ON WITH TRYING TO FIGURE OUT WHAT THIS LOOKS LIKE.

THIS IS THE GOOD NEWS PART OF THE STORY. NOW COMES THE TROUBLING PART OF THE STORY OR THE PART YOU NEED TO KEEP IN FRONT OF YOU. WE'RE TALKING ABOUT VERY LARGE VOLUMES OF STUFF. SO, LET'S SAY, FOR EXAMPLE, THAT SOMEBODY PASSES A LAW THAT BY 2020 ALL NEW COAL PLANTS IN THE UNITED STATES MUST HAVE CARBON CAPTURE AND SEQUESTRATION OR THEY CAN'T BE BUILT. WATCH THIS SPACE BECAUSE THESE LAWS ARE COMING YOUR WAY. AND IT'S REASONABLE TO BELIEVE THAT SOME PLACE IN THE WORLD WILL ACTUALLY PASS THIS LAW AT SOME POINT SOON.

SO WHAT DOES THAT MEAN? WELL, LET'S SAY YOU HAVE A 1,000-WATT POWER PLANT WITH AN 85-PERCENT CAPTURING CAPACITY FRACTURE, YOU CAPTURE 90 PERCENT OF THE CO2, AND YOU WANT TO DEAL WITH THAT. WELL, THAT WILL BE BETWEEN 5 TO 8 MILLION TONS OF CARBON DIOXIDE A YEAR. THE GOOD NEWS IS THAT'S A LOT OF CO2, SO IF YOU DO ONE PLANT, YOU GET A LOT OF ABATEMENT. THE BAD NEWS IS THAT'S A LOT OF CO2.

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IN THE SUBSURFACE, THAT LOOKS LIKE SOMEWHERE BETWEEN 120 AND 200,000 BARRELS A DAY AS A DENSE SUPERCRITICAL PHASE. THERE IS NOT A WELL ANYWHERE IN THE WORLD THAT GETS THAT KIND OF INJECTION RATES. THAT TELLS YOU IMMEDIATELY YOU NEED MULTIPLE WELLS AND SOME SUBSTANTIAL VOLUME. YOU HAVE TO DO IT FOR 60 YEARS. YOU HAVE TO DO IT FOR A LONG TIME. AND WHAT THAT MEANS IS OVER THE LIFETIME OF THAT FACILITY, YOU'RE GOING TO CREATE A CO2 FIELD THAT'S BETWEEN 3 AND 4 BILLION BARRELS IN SIZE. SO YOU MAKE A GIANT FIELD FOR EVERY ONE OF THESE PLANTS.

THE PLUME WILL BE POTENTIALLY QUITE LARGE. IT DEPENDS, OF COURSE, ON THE NUMBER OF UNITS YOU HAVE AND WHAT THEIR TOTAL VOLUME IS AND STUFF LIKE THAT. BUT YOU CAN IMAGINE 10-KILOMETER RADIUS, 30-KILOMETER RADIUS BY THE END OF THE DAY. AND YOU'RE PROBABLY GOING TO END UP INJECTING INTO MULTIPLE TARGETS. ALL OF THAT IS FINE. THERE IS NOTHING THAT'S SORT OF IMPOSSIBLE ABOUT THAT. THE KEY THING TO KEEP IN MIND IS ONE WEDGE IS 700 OF THESE THINGS. SO IT'S A LOT.

AS I'VE SAID BEFORE, WE'VE DONE THIS. THIS IS FROM SLEIPNER. ROB MENTIONED THIS YESTERDAY. WE'VE BEEN INJECTING A MILLION TONS OF CO2 INTO A SALINE FORMATION HERE SINCE 1996. AND THIS SHOWS THAT WE CAN DO IT. HERE'S THE SEISMIC VOLUME

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CROSS SECTIONS THROUGH IT.

FOR THOSE OF YOU WHO'VE NEVER LOOKED AT SEISMIC VOLUMES, THESE ARE LIKE, YOU KNOW, SONOGRAMS OR ULTRASOUND, YOU KNOW, IMAGES OF BABIES. IF YOU DON'T KNOW IT LOOKS LIKE A BABY, THEN YOU CAN'T INTERPRET IT.

SO WHAT I CAN TELL YOU HERE IS BASICALLY THIS IS THE TOP OF THE INJECTION RESERVOIR. AND WHAT YOU CAN SEE IS THE CO2 HAS NOT COME OUT OF IT. THERE HAVE BEEN REPEAT SURVEYS IN 2002, 2004. STILL NO LEAKAGE. THIS SURVEY COULD DETECT CONTIGUOUS LEAK OF 100,000 TONS OF CO2. IT HASN'T DONE SO. SO IT IS REASONABLE TO ASSUME THAT IT HAS GONE DOWN AND STAYED DOWN, AS ADVERTISED.

ANOTHER PLACE WHERE THEY HAVE BEEN DOING THIS AND MONITORING IT IS IN WEYBURN. HERE THEY'VE ACTUALLY TAKEN CO2 FROM AN OPERATING PLANT, A SYNTHETIC NATURAL GAS PLANT. THEY'VE BUILT A 125-MILE PIPELINE UP TO AN OIL FIELD IN SOUTHERN SASKATCHEWAN. THEY HAVE BEEN INJECTING IT FOR -- SINCE ABOUT 2000. THEY HAVE BEEN INJECTING ABOUT 5,000 TONS A DAY. SO, AGAIN, DECENT VOLUME HERE. THEY'RE GOING TO GET 130 MILLION BARRELS OUT OF THE GROUND FROM DOING THIS. AND AT THE END OF THE DAY, THEY'LL HAVE STORED 26 MILLION TONS OF CO2.

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NOW, THEY HAD A SUBSTANTIAL SCIENTIFIC PROGRAM HERE TO TRY TO UNDERSTAND WHAT THE CO2 MIGRATION LOOKED LIKE. THIS IS BEGINNING AND EXTENDING INTO A SECOND PHASE RIGHT NOW. THIS IS A GREAT SITE. THIS IS A PLACE WHERE YOU WOULD WANT TO INJECT A SUBSTANTIAL AMOUNT OF CO2. THESE UNITS HERE ARE ALL PLACES THAT ARE POTENTIAL RESERVOIRS. SO IF SOMETHING WERE TO GO WRONG HERE, YOU WOULD HAVE A NUMBER OF RESERVOIRS ABOVE THAT COULD ALSO HOLD CO2.

THESE ARE THE ROCK VOLUMES THAT ACTUALLY TRAP THE CO2 IN PLACE AND KEEP IT FROM MIGRATING OUT. LOTS AND LOTS OF SEALS, SO THAT'S THE GOOD NEWS.

THESE PEOPLE DID A VERY GOOD JOB ON THE SCIENCE BEHIND THIS. THEY ACTUALLY MAPPED A 200-KILOMETER RADIUS AROUND THIS SITE TO UNDERSTAND THE REGIONAL HYDROLOGY, AND PUT A LOT OF DILIGENCE

INTO A 10-KILOMETER AREA OUTSIDE THE FLOOD, TO REALLY UNDERSTAND THE GEOLOGY IN SOME DETAIL.

AND AGAIN, HERE YOU CAN SEE THE CO2 ONE YEAR AFTER INJECTION; TWO YEARS AFTER INJECTION. AND THEY CAN TRACK IT REASONABLY WELL.

OKAY. SO THAT, AGAIN, TELLS US THAT WE KNOW AN AWFUL LOT ABOUT THE ACTUAL DEPLOYMENT OF THIS. THESE STUDIES, HOWEVER, DON'T GIVE US THE ANSWERS TO THE KEY TECHNICAL QUESTIONS WE WANT, AND

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THEY DON'T GIVE US THE ANSWERS TO BUILDING A REGULATORY STRUCTURE THAT INFORMS COMPANIES HOW THEY CAN DO THIS SAFELY AND EFFECTIVELY.

IN THE UNITED STATES, WE'VE HAD A SUBSTANTIAL RESEARCH PROGRAM FOR AWHILE. LAST YEAR'S BUDGET WAS A HUNDRED MILLION DOLLARS. AGAIN, GIVEN THE FACT THAT WE'RE TALKING ABOUT THIS HUGE VOLUME OF CO2, THAT'S A PRETTY SMALL AMOUNT OF MONEY. BUT A DECADE AGO, IT WAS ABOUT $3 MILLION, SO IT HAS COME A LONG WAY.

THIS CAN BE BROKEN INTO THREE MAJOR COMPONENTS. FUTUREGEN, WHICH YOU'VE HEARD FOLKS TALK ABOUT YESTERDAY, A PROGRAM CALLED THE REGIONAL PARTNERSHIPS, WHICH I'LL GET INTO A BIT, AND A CORE R AND D PROGRAM ON A NUMBER OF THE TECHNICAL ISSUES.

THESE ARE SEVEN REGIONAL PARTNERSHIPS THAT NOW INCLUDE 5 CANADIAN PROVINCES, SOME 40 STATES -- 42 STATES, I'M SORRY -- AND SOME 600 ORGANIZATIONS THAT ARE INVOLVED IN THIS. THIS IS REALLY NOT A SCIENCE PROJECT; THIS IS AN INFRASTRUCTURE PROJECT, TO TRY TO UNDERSTAND WHAT DEPLOYMENT LOOKS LIKE IN TERMS OF A REGIONAL BASIS AND REGIONAL NEEDS.

WHERE ARE WE AS A COUNTRY? THE YELLOW STARS ON THIS MAP SHOW WHERE WE HAVE LARGE PROJECTS TODAY. DON'T LOOK TOO LONG.

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WE HAVE DONE MORE THAN THAT. THESE ARE PLACES WHERE WE'VE HAD SUBSTANTIAL SCIENTIFIC PROGRAMS AROUND SMALL INJECTIONS, SO WE CAN LEARN SOMETHING ABOUT WHAT WE NEED TO DO. THESE ARE THE PLANNED PROJECTS FOR THE REGIONAL PARTNERSHIPS. ABOUT FIVE OF THESE HAVE GONE FORWARD; THE REST ARE COMING ON IN THE NEXT COUPLE OF YEARS.

LET'S TALK ABOUT PLANNED LARGE PROJECTS BECAUSE ULTIMATELY IF WE'RE NOT DOING THIS AROUND LARGE PROJECTS, WE DON'T LEARN WHAT A LARGE-SCALE DEPLOYMENT LOOKS LIKE, AND SO THAT MATTERS QUITE A BIT. ONE OF THESE STARS IS GOING TO BE A FUTUREGEN PROJECT. WE DON'T KNOW WHICH ONE YET. THAT WILL BE ANNOUNCED, HOPEFULLY, VERY SOON, A WEEK OR TWO FROM NOW.

BP HAS ANNOUNCED THEIR CARSON PROJECT. THIS HAS TAKEN LONGER THAN EXPECTED TO GET OFF THE GROUND, BUT IT IS SCHEDULED TO COME ON LINE IN 2013, SOMETHING LIKE THAT. THIS IS SCHEDULED TO COME ON LINE 2012. THIS IS 275 MEGAWATTS, THIS IS 500 MEGAWATTS, SO WE'RE GETTING THERE.

THESE STARS ARE COMMERCIAL PROJECTS THAT HAVE BEEN ANNOUNCED AND WHICH PEOPLE ARE PUTTING FORWARD PAPERS TO THE PUC, IN WHICH THEY'RE ACTUALLY SAYING WE WANT TO BUILD A COAL PLANT HERE WITH CARBON

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CAPTURE AND SEQUESTRATION; CAN YOU PLEASE LET US PUT THIS INTO THE RATE BASE. THOSE ARE ALSO SCHEDULED TO COME ON LINE SOMETIME BETWEEN 2013 AND 2015. SO THIS IS NOT SOME FAR-FUTURE KIND OF THING. IT'S GOING TO BE IN THE NEXT FEW YEARS.

THE REGIONAL PARTNERSHIPS HAVE A PHASE 3 PROGRAM, IN WHICH THEY WERE EXPECTING TO DO SEVEN INJECTION PROJECTS ON THE ORDER OF A MILLION TONS PER YEAR. THREE OF THOSE HAVE NOW BEEN ANNOUNCED, AND THIS IS WHERE THE STARS ARE: ONE IN MISSISSIPPI, ONE PROBABLY IN WYOMING, AND ONE IN NORTH DAKOTA. SO THE GOOD NEWS IS WE'RE ACTUALLY GETTING OUR ACT TOGETHER BY 2010; BY 2012 WE'LL KNOW A BIT MORE. HERE'S THE BAD NEWS: THESE ARE THE PROPOSED NEW BILLS. EACH OF THOSE IS 6 MILLION TONS OF CO2 A YEAR. AS SOMEBODY MENTIONED THE FIRST DAY, I DON'T BELIEVE THOSE ARE ALL GOING TO ALL BE BUILT, BUT THAT'S THE TASK IN FRONT OF US, IS TO FIGURE OUT HOW TO MANAGE VOLUMES LIKE THAT.

THIS GETS US TO THE ISSUES OF DEPLOYMENT; AND REALLY, THERE'S A HANDFUL OF THINGS THAT WE NEED TO DO. SO THE YELLOW BOXES ARE TASKS THAT SOMEBODY HAS TO DO. YOU DO SOME SITE SCREENING AND CHARACTERIZATION. YOU ACTUALLY DO SOME OPERATIONAL INJECTION AND MONITORING. AND THESE ARE CHOICES THAT

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OPERATORS HAVE TO MAKE, A TASK THAT OPERATORS HAVE TO DO. AND THIS AFFECTS CAPITAL DEPLOYMENT AND ACTIONS ON THE GROUND. SO THEY WANT CLARITY ON THIS. THEY WANT TO KNOW THAT WHATEVER THEY'RE DOING HERE ACTUALLY PASSES MUSTER, IT SERVES THE NEEDS OF ALL STAKEHOLDERS.

THERE'S ALSO DECISIONS THAT ARE MADE BY THESE BOXES; AND THESE COULD BE REGULATORS TO SAY, YEAH, GO AHEAD, WERE GOING TO PERMIT THIS PLANT; THEY COULD BE INVESTORS, THEY COULD BE INSURERS. THERE ARE A NUMBER OF PEOPLE WHO ARE GOING TO BE MAKING DECISIONS AT THESE KEY JUNCTURES.

WE STILL NEED TECHNICAL INFORMATION TO ADVISE THESE BOXES, AND THAT'S WHAT THE VALUE OF THE LARGE PROJECTS IS, IT WILL GIVE US THE INFORMATION TO END UP IN THE RIGHT PLACE ON THESE. AND BECAUSE OF THIS URGENCY, WE REALLY WANT TO PROCEED WITH THESE JUST AS QUICKLY AS POSSIBLE.

THAT GETS US AROUND THE BOTTLENECKS WHICH WE HAVE IDENTIFIED. ONE BOTTLENECK THAT I THINK IS INCREDIBLY IMPORTANT IS THESE OPERATIONAL PROTOCOLS. AND AGAIN, THAT JUST TELLS EVERYBODY WHAT THEY NEED TO DO TO BUILD A REGULATORY FRAMEWORK AND TO AVOID MESSING UP. AGAIN, WE KNOW HOW TO DO THIS ON A PROJECT BASIS; BUT ON A SOCIETAL BASIS, WE DON'T.

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SOMETHING TO MENTION QUICKLY IS THE HUMAN CAPITAL BOTTLENECK. PEOPLE WHO CAN DO THIS CAN GET PAID A LOT MORE TO DO THE SAME THING IN THE OIL AND GAS INDUSTRY, AND WE ARE FACING A REALLY CRIMINAL SHORTAGE IN GEOSCIENTISTS AROUND THIS TOPIC.

SO WHAT DO YOU NEED FOR A GOOD SITE? YOU NEED THREE THINGS: ICE. YOU NEED INJECTIVITY; YOU NEED CAPACITY; AND YOU NEED EFFECTIVE STORAGE. IF YOU DO NOT HAVE THESE THINGS, YOU DO NOT HAVE A PROJECT. AND IT'S ASTONISHING TO ME HOW OFTEN PEOPLE IMAGINE THAT IF THEY BUILD A COAL-FIRED POWER PLANT, THEY WILL FIND SEQUESTRATION SOMEWHERE NEAR IT. AND THIS TURNS OUT REALLY NOT TO BE THE TRUTH. IT'S A LOT EASIER TO MOVE A PLANT THAN IT IS TO MOVE THE CRUST. AND YOU NEED TO FIND THESE THINGS IN PLACE.

AGAIN, THE GOOD NEWS: WE KNOW HOW TO DO THIS. WE KNOW HOW TO ASSESS INJECTIVITY. THAT'S THE RATE TERM. YOU DRILL A WELL, AND YOU MEASURE THE PROPERTIES, AND YOU DO SOME INJECTION. WE KNOW HOW TO MEASURE THE CAPACITY. THAT'S BASICALLY AN INTEGRATION OVER THE PORE VOLUME. IT'S SENSITIVE TO THE PROCESS. THERE'S SOME UNCERTAINTY THERE, BUT WE KNOW HOW TO DO THIS. THERE'S NO MIRACLES REQUIRED.

SAME THING FOR EFFECTIVENESS. WE KNOW HOW TO DETERMINE IF A SITE'S GOING TO BE EFFECTIVE AND

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WILL KEEP CO2 UNDERGROUND FOR A LONG TIME.

I DON'T WANT TO MAKE THIS ALL SOUND GLIB. THERE REALLY ARE SUBSTANTIAL CONCERNS IN FRONT OF YOU. YOU DO NOT WANT CO2 TO LEAK OUT FOR A NUMBER OF REASONS. AT THE BOTTOM LEVEL, VERY HIGH CONCENTRATIONS, AND THIS IS LIKE 1 AND A HALF PERCENT CO2 IN THE ATMOSPHERE, CAN START CAUSING HUMAN HEALTH PROBLEMS. YOU PRETTY MUCH WANT TO AVOID THAT. YOU DON'T WANT TO CONTAMINATE GROUNDWATER. AND, OF COURSE, THE WHOLE POINT OF DOING THIS IS TO KEEP THE CO2 UNDERGROUND. IF IT LEAKS OUT, THAT IS SORT OF COUNTERPRODUCTIVE, AND YOU'RE SPENDING QUITE A BIT OF MONEY TO DO THIS. SO YOU REALLY WANT TO MAKE SURE THAT SOMETHING LIKE 99.9 PERCENT OF IT STAYS UNDERGROUND.

THE GOOD NEWS: WE UNDERSTAND WHAT WE NEED TO BE WORRIED ABOUT. IF YOU DO NOT HAVE A HIGH PERMEABILITY CONDUIT BACK TO THE SURFACE, THEN YOU'VE GOT NO PROBLEM. BECAUSE IF IT'S NOT HIGH PERMEABILITY, YOU CAN'T GET A LARGE VOLUME OUT QUICKLY. SO THAT'S THE THING YOU WORRY ABOUT.

THE 11 WORDS THAT DESCRIBE THE THINGS YOU NEED TO CARE ABOUT HERE ARE: WELLS, WELLS, WELLS, WELLS, WELLS, WELLS, FAULTS, FAULTS, WELLS, WELLS, AND WELLS. BECAUSE WELLS ARE PLACES WHERE ALL THOSE

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PROPERTIES IN THE CRUST THAT I TALKED ABOUT DON'T APPLY ANYMORE BECAUSE YOU'VE PUNCHED A HOLE THROUGH THEM, AND THE CO2 CAN COME BACK QUICKLY.

I'M GOING TO END UP SKIPPING OVER A FEW SLIDES AFTER THIS, BUT I WANT TO FOCUS ON THIS FOR

JUST A SECOND. A LOT OF PEOPLE ASK THE QUESTIONS ABOUT WHAT THE RISKS OF STORAGE ARE; AND RISKS, FORMALLY DEFINED, ARE THE INTERSECTION OF THE PRODUCT OF PROBABILITY AND CONSEQUENCE. TO UNDERSTAND WHAT THE CHANCES THAT SOMETHING WILL FAIL, AND IF IT DOES, WHAT HAPPENS IF YOU DO. IN THE GEOLOGY, THIS REALLY IS HARD TO COME BY BECAUSE OFTEN IT IS VERY HARD TO QUANTIFY THE PROBABILITY, AND IT IS REALLY HARD TO QUANTIFY THE CONSEQUENCE. SO IT IS ACTUALLY VERY HARD TO CHARACTERIZE AND QUANTIFY THE RISKS. ANOTHER WAY OF SAYING IT, AGAIN, IT'S NOT ROCKET SCIENCE, IT'S ROCK SCIENCE, BUT WE ACTUALLY UNDERSTAND ROCKET SCIENCE. WE DON'T UNDERSTAND THE ROCK SCIENCE SO MUCH.

THE COUNTERPART OF THIS IS WE UNDERSTAND THE HAZARDS REALLY WELL. HAZARDS ARE THINGS THAT ARE EASILY MAPPED AND PROVIDE A BASIS FOR ACTION LIKE FAULTS OR WELLS OR GROUNDWATER PROTECTION. SO YOU CAN ACTUALLY GO FORWARD AND SAY, I'VE GOT A SITE, I WANT TO MAKE SURE THERE IS NO ATMOSPHERIC RELEASE, I

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DON'T CONTAMINATE THE GROUNDWATER, I DON'T DO THINGS LIKE INDUCE EARTHQUAKES OR, YOU KNOW, CAUSE MECHANICAL FAILURE OF MY WELLS. WHAT DO I NEED TO HEAR ABOUT IT?

FOR ANY GIVEN SITE, YOU CAN PRIORITIZE THOSE THINGS AND SAY, THIS IS WHERE I NEED TO PUT MY EGGS. AND SOME PLACE LIKE THE TEXAS GULF COAST, YOU HAVE A ZILLION WELLS, SO FOCUS ON THE WELLS. AND THAT MEANS DO SOME MONITORING, DO SOME LOGGING, FIGURE OUT WHAT YOU NEED TO DO.

MOST PEOPLE DON'T RECOGNIZE THAT INHERENT TO THE TASK OF CARBON CAPTURE AND SEQUESTRATION IS MONITORING; THAT YOU NEED TO VERIFY IT'S GOING UNDERGROUND, IN PART, BECAUSE YOU'RE BEING PAID TO DO IT OR YOU'RE BEING CHARGED TO DO IT. THE GOOD NEWS IS THERE'S A HUGE NUMBER OF TOOLS TO DO THIS, AND WE UNDERSTAND THOSE TOOLS THROUGH COMMERCIAL OIL AND GAS OPERATIONS REALLY QUITE WELL.

HOW TO OPTIMIZE THESE? WHAT'S THE MINIMUM LEVEL OF DUE DILIGENCE? THESE ARE OPEN QUESTIONS. BUT CAN WE MONITOR IT? OH, YEAH, THAT'S NOT A PROBLEM.

LAST WORD ON CHINA, AND I REALLY DID WANT TO TAKE A SECOND TO TALK ABOUT THIS BECAUSE THIS IS SUCH AN IMPORTANT TOPIC. WHATEVER POLICY WE SET IN

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THE UNITED STATES, IT TURNS OUT WE DON'T SET POLICY IN CHINA. AND WE NEED A TECHNOLOGY OPTION THAT WORKS THERE. AND 70 PERCENT OF THEIR POWER IS COAL, AND THEY'RE DOING A LOT MORE COAL TO LIQUIDS, COAL TO METHANOL; YOU NAME IT, COAL IS THEIR RESOURCE; AND THEY'RE GOING FOR IT.

FROM A GEOLOGICAL PERSPECTIVE, CHINA IS PRETTY COMPLICATED. IT'S ACTUALLY TEN LITTLE CONTINENTS THAT GOT SLAPPED TOGETHER OVER THE PAST 660 MILLION YEARS. THE GOOD NEWS IS WE DON'T HAVE TO

FOCUS ON THAT; WE ONLY NEED TO FOCUS ON THOSE SIX YELLOW BASINS. THOSE SIX YELLOW BASINS ARE WHERE THE COAL IS AND WHERE THE POPULATION IS; AND IF WE CAN DO IT THERE, THEN THIS IS A VIABLE OPTION FOR CHINA FOR SUBSTANTIAL GREENHOUSE GAS ABATEMENT.

THE GOOD NEWS IS THAT THE AUSTRALIAN GOVERNMENT FIGURED THIS OUT, AND THEY'VE PUT TOGETHER A $6 MILLION TEAM TO DO THIS ASSESSMENT IN COLLABORATION WITH CHINA, AND THAT GOT THE GREEN LIGHT THIS SUMMER. SO WE'RE GOING TO FIGURE OUT THIS ON AN ASSESSMENT BASIS FAIRLY QUICKLY.

THE PROJECT BASIS IS ALSO QUITE HELPFUL. AND THIS IS WORK THAT WAS DONE AT PRINCETON BY A YOUNG SENIOR NAMED KAO-MING. AND HE WORKED WITH BOB WILLIAMS AND SAID, I'M GOING TO GO OUT AND LOOK AT A

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BUNCH OF PURE POINT SOURCES IN CHINA AND FIGURE OUT WHAT THIS LOOKS LIKE IT. AND THESE ARE FOUR OF THEM. THESE ARE THE PURE CO2 STREAMS AVAILABLE TODAY. IF YOU WENT THERE, YOU'D FIND A SMOKESTACK THAT IS EMITTING A MILLION TONS OF CO2 A YEAR THAT'S PURE, AND SO YOU CAN JUST COMPRESS IT AND INJECT IT NEARBY. THIS IS A 150-KILOMETER RADIUS. THESE ARE GAS FIELDS AND OIL FIELDS NEARBY. AND ALL THAT DOES IS IT LETS YOU KNOW THAT THERE'S VIABLE TARGETS THERE FOR THE STORAGE.

I'M GOING TO SKIP PAST THESE PARTS.

AGAIN, TO JUST CONCLUDE, THAT THIS IS A HUGELY INTERESTING AND IMPORTANT OPTION. AND AMONG THE ARROWS WE WANT IN OUR QUIVER; THIS IS A VERY, VERY PROMISING ONE.

THANK YOU VERY MUCH.