Narrator: THE WORLD NEEDS ENERGY. AND NEARLY 80% OF IT COMES FROM BURNING FOSSIL FUELS -- OIL, NATURAL GAS, AND COAL. BUT BURNING THESE FUELS EMITS CARBON DIOXIDE A GREENHOUSE GAS THAT CONTRIBUTES TO CLIMATE CHANGE. HOW CAN WE CONTINUE TO SUPPLY YOUR EVER-GROWING NEED FOR POWER WITHOUT DAMAGING THE ENVIRONMENT? ONE POSSIBILITY IS TO PUT THE CARBON DIOXIDE BACK WHERE IT CAME FROM -- IN UNDERGROUND ROCK FORMATIONS. THE MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP IS INVESTIGATING THIS STRATEGY WHICH WILL HELP MITIGATE THE EFFECTS OF THE CONTINUED USE OF FOSSIL FUELS FOR ENERGY. RENEWABLE ENERGY SOURCES
ARE ANOTHER OPTION.
AND IN GOLDEN, COLORADO
THE NATURAL RENEWABLE
ENERGY LABORATORY
IS TRYING TO SCALE UP
PROCESSES FOR CREATING
BIOFUELS
FROM THE PRODUCTS OF
AMERICAN FARMS
THEIR GOAL IS TO SUPPLY
UP TO A THIRD OF THE
COUNTRY’S GASOLINE NEEDS
WITHIN 25 YEARS.

BOTH PROJECTS ARE PUSHING
THE LIMITS OF MODERN SCIENCE
IN HOPES OF LEADING THE WAY
TO A MORE SUSTAINABLE ENERGY
FUTURE.

40% OF THE WORLD’S
ELECTRICITY COMES FROM COAL.
COAL IS THE FOSSILIZED REMAINS
OF ANCIENT VEGETATION.
AND WITH GLOBAL RESERVES
THAT COULD LAST OVER 250
YEARS
IT IS THE CHEAPEST AND MOST
ABUNDANT
NON-RENEWABLE ENERGY
SOURCE AVAILABLE.
BUT BURNING COAL PRODUCES
EXHAUST PRODUCTS INCLUDING NOT JUST WATER VAPOR WHICH IS MOST OF WHAT WE SEE COMING OUT OF SMOKESTACKS BUT ALSO CARBON DIOXIDE AN INVISIBLE GREENHOUSE GAS THAT CONTRIBUTES TO CLIMATE CHANGE.

AS THE NEED FOR ENERGY AROUND THE WORLD CONTINUES TO GROW NEW COAL-FIRED POWER PLANTS THAT WILL LAST 50 YEARS OR MORE COME ONLINE EVERY WEEK. COAL WILL POWER THE WORLD FOR DECADES.

HOW CAN WE CONTINUE TO USE THIS INEXPENSIVE AND PLENTIFUL RESOURCE WITHOUT FURTHER DAMAGING THE ENVIRONMENT?

Dr. Gupta: THE WAY TO TAKE CARE OF REDUCING CARBON DIOXIDE IS YOU HAVE MULTIPLE OPTIONS. DEFINITELY YOU NEED TO INCREASE THE EFFICIENCY OF YOUR ENERGY USE.

YOU ALSO NEED TO LOOK AT RENEWABLE ENERGY SOURCES
LIKE SOLAR ENERGY, WIND ENERGY.

BUT IT IS CLEARLY RECOGNIZED BY THE RESEARCH COMMUNITY THAT YOU NEED A THIRD SET OF TECHNOLOGIES THAT CAN PROVIDE A MEANS TO KEEP USING FOSSIL FUELS ESPECIALLY COAL, WHICH IS OUR MOST ABUNDANT FOSSIL FUEL IN AN ENVIRONMENTALLY SOUND MANNER.

Narrator: NEERAJ GUPTA IS A GEOLOGIST WITH BATTELLE MEMORIAL INSTITUTE A SCIENCE AND TECHNOLOGY ENTERPRISE THAT IS RESEARCHING THE FEASIBILITY AND COST OF CAPTURING CARBON DIOXIDE FROM POWER PLANTS AND INJECTING IT INTO UNDERGROUND ROCK FORMATIONS A PROCESS CALLED CARBON CAPTURE AND SEQUESTRATION.

Dr. Gupta: WE CALL IT CCS.

YOU ARE PUTTING THE CO2 BACK INTO THE GROUND.

SO JUST LIKE YOU PRODUCE FOSSIL FUELS
LIKE COAL AND OIL AND GAS FROM THE DEEP GEOLOGIC FORMATIONS FROM THE SEDIMENTARY LAYERS YOU'RE USING THE SAME TYPE OF LAYERS AND PUTTING CO2 BACK INTO THE GROUND WHERE IT CAME FROM.

Narrator: IN BELMONT COUNTY, OHIO BATTELLE IS COLLABORATING WITH FirstEnergy CORP. WHO IS HOSTING THE PROJECT AT THEIR R.E. BURGER COAL-FIRED POWER PLANT. STEPS AWAY FROM THE PLANT, CREWS WORK AROUND THE CLOCK DRILLING A 2 1/2-KILOMETER, OR 8,000-FOOT, HOLE SEARCHING FOR RESERVOIRS DEEP UNDERGROUND THAT CAN HOLD THE PLANT'S CARBON DIOXIDE. THIS IS ONE OF BATTELLE MEMORIAL INSTITUTE'S RESEARCH SITES THAT ARE A PART OF THE MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP.
ONE OF SEVEN U.S. DEPARTMENT OF ENERGY PROGRAMS BEING CONDUCTED ACROSS THE UNITED STATES THAT ARE STUDYING CARBON CAPTURE AND SEQUESTRATION AS ONE OPTION FOR MITIGATING CLIMATE CHANGE.

CO2 IS ROUTINELY SEPARATED AND CAPTURED AS A BY PRODUCT FROM INDUSTRIAL PROCESSES. BUT THESE CAPTURE TECHNOLOGIES ARE NOT COST-EFFECTIVE ON THIS SCALE AND ARE BEING FURTHER DEVELOPED. THE OBSTACLE FOR SEQUESTRATION, HOWEVER, IS NOT COST. FOR YEARS, CARBON DIOXIDE HAS BEEN PUMPED INTO THE GROUND TO ENHANCE OIL RECOVERY. THE CHALLENGE NOW IS TO TEST THIS TECHNOLOGY FOR LONG-TERM STORAGE. PHIL JAGUCKI IS A GEOLOGIST ON THE PROJECT.

Jagucki: CARBON DIOXIDE IS
INJECTED INTO THE GROUND EVERY DAY. BUT WE WANT TO PUT IT IN AND KEEP IT DOWN THERE AND WE NEED TO FIND WAYS TO MONITOR IT SO THAT WE CAN VERIFY THAT IT'S STAYING UNDERGROUND THAT IT'S BEHAVING AS WE INTENDED OR AS WE HAD PLANNED. AND SO THAT'S THE KNOWLEDGE GAP THAT WE HAVE TO FILL. WHEN IS THE LAST SURVEY? IF YOU THINK OF THE ANALOGY OF THE OIL AND GAS FIELDS THAT MATERIAL HAS BEEN DOWN THERE FOR MILLIONS OF YEARS. WHEN WE PUT CO2 IN IT SHOULD REMAIN THERE FOR MILLIONS OF YEARS.


Dr. Gupta: YOU CAN IMAGINE, FOR EXAMPLE MAYBE A SPONGE.
AND IF YOU PUT A DROP OF WATER ON SOME PIECES OF ROCK THAT WATER IS IMMEDIATELY ABSORBED.

Narrator: NEAR THE SURFACE POROUS ROCKS LIKE THESE ACT AS AQUIFERS FOR DRINKING WATER.
BUT AS YOU GET DEEPER, THIS IS NOT THE CASE.
LAYERS OF POROUS ROCK CAN CONTAIN OIL, GAS OR IN THIS CASE, BRINE, OR SALTY WATER.
Dr. Gupta: YOU WANT TO MAKE SURE THAT THE CO₂ THAT YOU INJECT IS DEEPER THAN ANY FRESHWATER SOURCES OF GROUNDWATER.
SO AS YOU GO DEEPER THAT HIGH-SALINITY WATER IS NOT USEABLE NOW OR IN THE FORESEEABLE FUTURE FOR ANY OTHER USES.
THAT'S WHY IT CAN BE USED FOR INJECTION.

Narrator: THESE BRINE, OR SALTY RESERVOIRS CAN BE AN IDEAL LOCATION FOR
CARBON SEQUESTRATION. BUT JUST AS CRITICAL AS THEIR POROSITY IS THEIR PERMEABILITY ALLOWING THE CARBON DIOXIDE TO MOVE THROUGH THE ROCK’S PORES. BUT PERMEABILITY CAN ENABLE THE CO₂ TO MOVE UPWARDS AND ESCAPE TO THE SURFACE MAKING A NONPOROUS IMPERMEABLE LAYER ABOVE THE RESERVOIR KNOWN AS CAP ROCK ANOTHER IMPORTANT, NECESSARY CHARACTERISTIC.

Dr. Gupta: IT WOULD BE LIKE A PIECE OF SHALE-TYPE ROCK WHERE YOU PUT A DROP OF WATER AND IT DOESN'T GET ABSORBED VERY QUICKLY OR NOT AT ALL. THAT’S A CAP ROCK, AND THAT PREVENTS THE LEAKAGE OF CO₂. Narrator: WHEN SANDSTONE AND SHALE SAMPLES ARE BOTH INJECTED WITH BLUE DYE AND VIEWED UNDER THE SAME MAGNIFICATION
YOU CAN SEE THE DIFFERENCE BETWEEN AN IMPERMEABLE, NONPOROUS ROCK AND ONE WHICH IS POROUS AND PERMEABLE.

THE FIRST STEP IN LOOKING FOR POTENTIAL GEOLOGICAL STORAGE SITES WITH THESE CRITICAL CHARACTERISTICS IS A SEISMIC SURVEY OF THE POTENTIAL AREA. Jagucki: THE SEISMIC SURVEY ALLOWS US TO COVER A LARGER AREA WITHOUT HAVING TO DRILL WELLS EVERYWHERE. WE CAME OUT HERE WITH TRUCKS THAT ARE EQUIPPED TO VIBRATE THE GROUND. A LOT OF PEOPLE CALL THEM THUMPER TRUCKS. WE HAVE A SERIES OF MICROPHONES STUCK INTO THE GROUND TO MEASURE THAT SOUND AS IT PASSES DOWN AND THEN COMES BACK UP. AND WE RAN ABOUT FIVE MILES NORTH TO SOUTH
AND ABOUT FIVE MILES EAST TO WEST
SO THAT COVERS A FAIRLY LARGE AREA.

Narrator: THE PRELIMINARY IMAGES TRANSLATED FROM THE VIBRATIONS SUGGESTED THAT THE BELMONT COUNTY SITE WAS AN OPTIMAL, NON-FAULTED GEOLOGIC LOCATION FOR CARBON SEQUESTRATION SHOWING LAYERS OF POROUS SANDSTONE CAPPED BY EVEN THICKER LAYERS OF IMPERMEABLE ROCK. THE TWO LAYERS THEY ARE INTERESTED IN AS POTENTIAL INJECTION ZONES ARE THE ORISKANY LAYER WHICH IS AROUND 1,800 METERS, OR 6,000 FEET BELOW THE SURFACE, AND THE CLINTON LAYER ANOTHER 600 METERS, OR 2,000 FEET, LOWER.
THE NEXT STEP IS TO DRILL A WELL OVER 2,400 METERS, OR 8,000 FEET, DEEP TO CONFIRM THESE FINDINGS.
TO REACH THIS DEPTH
CREWS OF FOUR WORK 24 HOURS A DAY
DRILLING AT A RATE OF ABOUT TWO MINUTES PER FOOT
BY ADDING 30-FOOT SECTIONS OF DRILL PIPE ONE AT A TIME.
Meggyesy: BASICALLY, THEY'RE GONNA PICK THOSE UP
AND THEY ARE GOING TO PUT IT DOWN IN THE HOLE
AND PICK UP ANOTHER ONE. EVERY TIME THEY WANT TO DO SOMETHING WITH A BIT THEY HAVE TO PULL ALL OF THAT PIPE BACK OUT
AND THEY HAVE TO PUT IT ALL BACK IN AGAIN.
Narrator: AS THEY DRILL THE HOLE THEY CONTINUOUSLY TAKE ROCK SAMPLES TO DETERMINE IF THE LAYERS THEY SAW ON THE SEISMIC SURVEY ARE ACTUALLY THERE.
Meggyesy: WE HAVE A BUNCH OF VERY LARGE AIR COMPRESSORS BIGGER THAN A PICKUP TRUCK, THAT ARE BLOWING COMPRESSED AIR DOWN THROUGH THE DRILL PIPE, OUT THE BIT
AND IS PICKING UP THE DEBRIS AS WE’RE DRILLING.
IT'S LIFTING IT ALL THE WAY BACK UP OUT THE HOLE
AND IT BLOWS IT OUT AT THE BLOW PITS.

Jagucki: AS THAT FLUID COMES OUT
WE CAN LITERALLY HOLD A BUCKET UNDER THE END OF IT
AND WE GET SOME WATER AND CUTTINGS IN IT.
AND THEN WE GIVE THAT SAMPLE TO OUR MUD LOGGER
AND THE MUD LOGGER LOOKS AT THE CUTTINGS.
HE CAN TELL WHAT TYPE OF ROCK WE'RE IN.

Narrator: AT APPROXIMATELY 1.8 KILOMETERS
OR 5,800 FEET, DOWN THE TEAM EXPECTS TO FIND THE SANDSTONE
THAT IS PART OF THE ORISKANY ROCK LAYER
ONE OF THE POTENTIAL INJECTION ZONES.
BUT SO FAR, THERE IS NO SIGN OF THAT LAYER.

Jagucki: WE LOGGED ANOTHER WELL
ABOUT 30 MILES NORTH OF HERE, AND THAT SANDSTONE WAS PRESENT. SOME OF OUR OTHER REGIONAL DATA TELLS US THAT IT'S HERE. BUT IT'S AT THIS PARTICULAR LOCATION. THAT'S WHY IT'S SO IMPORTANT TO GET SITE-SPECIFIC INFORMATION BECAUSE NO MATTER HOW GOOD YOUR REGIONAL INFORMATION IS UNTIL YOU VERIFY IT ON-SITE, YOU JUST DON'T KNOW.

Narrator: AT ABOUT 5,900 FEET THE SAND GRAINS FROM THE ORISKANY LAYER START TO APPEAR.

Jagucki: WE WERE GLAD WHEN WE FOUND THE ORISKANY SANDSTONE. THAT PROVIDES A GOOD POTENTIAL TARGET FOR US TO DO OUR EXPERIMENT. AND IT'S DEEP BELOW GROUND SURFACE. IT'S OVER A MILE DOWN. IT'S WELL CONTAINED. IT'S GOT THOUSANDS OF FEET OF SHALE ABOVE IT THAT FORM A VERY GOOD CONTAINMENT LAYER.
Narrator: ADDITIONAL TESTS ARE DONE. WELL LOGGING MEASURES FLUID LEVELS THAT ACT AS A PROXY OF POROSITY IN THE ROCK INDICATING LAYERS OF POROUS SANDSTONE AND NONPOROUS SHALE. AND CORE SAMPLES ARE COMPARED TO PREVIOUS EXAMPLES TAKEN OVER DECADES FROM OHIO GEOLOGICAL SURVEYS LAB. THIS DATA WILL PROVIDE THE EXACT DEPTH AND CHARACTERISTICS OF THE ROCK LAYERS. ONCE THESE EVALUATIONS ARE COMPLETE THE ROCK WILL BE TESTED BY INJECTING ABOUT TWO DAYS' WORTH OF PLANT CO2 EMISSIONS AND MONITORING WHETHER ANY OF IT IS LEAKING UP TO THE SURFACE. IF THIS TECHNOLOGY PROVES FEASIBLE AND ECONOMICALLY VIALBE
THEN CARBON SEQUESTRATION HOLDS GREAT PROMISE AS BEING PART OF THE SOLUTION TO CONTINUE TO PROVIDE AFFORDABLE ENERGY WITHOUT CONTRIBUTING TO CLIMATE CHANGE.

Dr. Gupta: WE HAVE TO CLEARLY RECOGNIZE THAT THIS IS ONE OF SEVERAL OPTIONS THAT WE HAVE TO DEPLOY.

IT IS NOT THE ONLY OPTION.

BUT THIS OPTION, IF IT CAN BE USED LIKE WE ARE TRYING TO SHOW WITH OUR RESEARCH WOULD BE A SIGNIFICANT PART OF THE PORTFOLIO OF TECHNOLOGIES FOR REDUCING CO2 EMISSIONS.

Narrator: CARBON CAPTURE AND SEQUESTRATION IS JUST ONE PART OF THE EFFORT IN PROVIDING A SUSTAINABLE ENERGY FUTURE.

RENEWABLE FORMS OF ENERGY, SUCH AS SOLAR AND WIND ALONG WITH ENERGY EFFICIENCY
ARE ALSO VITAL COMPONENTS TO
THIS STRATEGY
HOLDING PROMISE THAT WE WILL
BE ABLE TO MEET THE
CHALLENGE
OF POWERING OUR HOMES AND
OUR BUSINESSES
IN A LESS DAMAGING WAY.

BUT WE STILL NEED TO GET
AROUND
350 MILLION GALLONS OF
PETROLEUM
IS BURNED EVERY DAY IN THE
UNITED STATES
MOST OF IT FOR
TRANSPORTATION
EMITTING APPROXIMATELY 700
MILLION METRIC TONS
OF CARBON DIOXIDE A YEAR.
AND THE WORLDWIDE DEMAND
FOR FUEL IS ONLY GOING UP
CREATING A PRESSING NEED FOR
NEW RENEWABLE FUELS.

DOUGLAS: THE URGENCY TO FIND
RENEWABLE TRANSPORTATION
FUELS IS AT LEAST TWOFOLD.
ONE IS ENERGY SECURITY.
OUR NATION IS ALMOST WHOLLY
DEPENDENT
FOR TRANSPORTATION FUELS ON
PETROLEUM PRODUCTS.

OUR NATION IS ALMOST WHOLLY
DEPENDENT
FOR TRANSPORTATION FUELS ON
PETROLEUM PRODUCTS.
AND MOST OF THAT PETROLEUM COMES FROM OVERSEAS. AND IT IS BECOMING MORE AND MORE SCARCE AND HARDER AND HARDER TO FIND. IN ADDITION TO THAT BURNING OF PETROLEUM IN CARS, BUSES, PLANES HAS BEEN IDENTIFIED AS A PRIMARY CONTRIBUTOR TO THE AMOUNT OF CARBON DIOXIDE THAT'S GOING INTO THE ATMOSPHERE WHICH COULD CONTRIBUTE TO CLIMATE CHANGE. AND SO THERE'S AN ENVIRONMENTAL BENEFIT TO FINDING A RENEWABLE RESOURCE.

Narrator: AT THE NATIONAL RENEWABLE ENERGY LABORATORY OR NREL, IN GOLDEN, COLORADO SCIENTISTS AND ENGINEERS WORKING FOR NREL's BIOMASS PROGRAM ARE DEVELOPING NEW WAYS TO GET FUEL FROM PLANTS.
THEIR GOAL IS TO REPLACE A THIRD OF THE UNITED STATES’ GASOLINE CONSUMPTION WITH PLANT-BASED BIOFUELS, OR ETHANOL, BY THE YEAR 2030.

Douglas: WHEN YOU BURN FOSSIL FUELS YOU'RE RELEASING CARBON DIOXIDE THAT WAS FIXED IN THE EARTH MILLIONS OF YEARS AGO WHEN THOSE ANCIENT PLANTS DIED. BUT WHEN YOU'RE USING A BIO-BASED FUEL LIKE ETHANOL YOU'RE ACTUALLY ONLY RELEASING CARBON DIOXIDE THAT WAS ONLY RECENTLY FIXED BY THE PLANTS AND THEN THE PLANTS THAT YOU'RE GROWING FOR NEXT YEAR'S CROP WILL THEN FIX THAT CARBON BACK AGAIN. SO THE CARBON CYCLE IS NEARLY 100% COMPLETE.

Narrator: TODAY, MOST OF THE ETHANOL PRODUCED IN THE UNITED STATES COMES FROM CORN. THE PROCESS IS NOT MUCH
DIFFERENT
FROM THAT OF MAKING WINE OR
BREWING BEER.

IN LARGE-SCALE PLANTS ALL
OVER THE MIDWEST
THE STARCH IN CORN KERNELS IS
CONVERTED TO SUGARS
WHICH ARE THEN FERMENTED
WITH YEAST.

THE END PRODUCT OF THIS
FERMENTATION
IS THEN DISTILLED TO SEPARATE
THE ETHANOL.

BUT THERE ARE LIMITATIONS
TO INCREASING THE PRODUCTION
OF CORN ETHANOL.
CORN IS ALREADY A VALUABLE
COMMODITY.
IT IS AN INGREDIENT IN MANY OF
THE FOODS WE EAT
AND ALSO USED AS FEED FOR
LIVESTOCK.

Douglas: WE THINK WE CAN GO
TO ABOUT 15 BILLION GALLONS OF
ETHANOL A YEAR
FROM CORN KERNELS.

BUT ANYTHING BEYOND THAT
THE COMPETITION BETWEEN FUEL
AND FOOD
STARTS TO TAKE PLACE.
AND SO TO GET MORE
THAN 15 BILLION GALLONS OF ETHANOL A YEAR
WE NEED TO GO TO OTHER METHODS.
AND THAT'S WHY WE'RE INTERESTED IN TRYING TO LEARN HOW TO ECONOMICALLY MAKE ETHANOL FROM THE CELLULOSIC MATERIALS -- THAT IS, THE STALKS, STEMS, LEAVES -- THE NONEDIBLE PARTS OF THE PLANT.
Narrator: CELLULOSIC MATERIAL, OR BIOMASS IS BASICALLY THE FIBROUS, WOODY AND GENERALLY INEDIBLE PORTIONS OF PLANTS. AND IT IS THE MOST PLENTIFUL BIOLOGICAL MATERIAL ON EARTH. THE CHALLENGE FOR NREL SCIENTISTS AND ENGINEERS LIKE ANDY ADEN IS TO DESIGN COST-EFFECTIVE CONVERSION PLANTS THAT CAN CREATE FUEL FROM MANY DIFFERENT TYPES OF BIOMASS.
Aden: THERE ARE LOTS OF DIFFERENT TYPES OF BIOMASS. THERE ARE AGRICULTURAL
RESIDUES, LIKE CORN STOVER OR WHEAT STRAW THINGS THAT ARE CURRENTLY LEFT IN THE FIELD AFTER THE GRAIN HAS BEEN HARVESTED.
THERE ARE WOOD TYPES OF FEED STOCKS THAT ARE BIOMASS -- WOOD CHIPS LIKE POPLAR, FOR EXAMPLE.
IT'S A VERY FAST-GROWING TREE AND YOU CAN POTENTIALLY HAVE PLANTATIONS OF THIS MATERIAL THAT CAN PRODUCE LARGE AMOUNTS OF BIOMASS FOR FUEL ALL THE WAY EVEN TO A PRAIRIE GRASS LIKE SWITCH GRASS.
THE BENEFITS OF THIS MATERIAL IS IT'S VERY DROUGHT-TOLERANT AND YOU CAN GET A LOT MORE TONNAGE OF THIS MATERIAL OFF OF AN ACRE OF LAND.
SO THERE ARE A LOT OF REASONS AND A LOT OF ADDITIONAL BENEFITS FOR USING BIOMASS AS A SOURCE OF ETHANOL AS OPPOSED TO JUST CORN GRAIN ONE OF WHICH IS THERE'S A LOT MORE OF IT OUT THERE
THE SECOND OF WHICH IS YOU AVOID THE FOOD-VERSUS-FUEL ISSUES.
THE THIRD POTENTIAL BENEFIT IS TO FARMERS IN RURAL AMERICA BECAUSE IT ADDS ADDITIONAL MARKETS FOR THEM TO SELL MATERIALS INTO.

Narrator: BUT THERE ARE MANY OBSTACLES IN CREATING ETHANOL FROM CELLULOSIC MATERIAL. THROUGH PHOTOSYNTHESIS PLANTS MAKE SUGARS THAT THEY USE FOR ENERGY TO GROW.
SOME OF THOSE SUGARS ARE BONDED TOGETHER AND STORED CREATING STARCHES, LIKE THE STARCH IN A CORN KERNEL THAT CAN BE USED LATER FOR ENERGY.
THESE STARCHES ARE EASILY BROKEN DOWN MAKING THEM AN ATTRACTIVE SOURCE FOR ETHANOL CONVERSION.
BUT SOME SUGARS ARE BONDED DIFFERENTLY, INTO LONG CHAINS LIKE STEEL GIRDERS WITHIN
PLANT CELL WALLS. SPECIFICALLY, THERE ARE THREE PRIMARY COMPONENTS OF BIOMASS -- CELLULOSE, HEMICELLULOSE, AND THE POLYMER LIGNIN WHICH FILLS THE REMAINING SPACES IN THE PLANT CELL WALL. PLANTS EVOLVED SO THAT THESE MATERIALS WOULD LAST A LONG TIME AND BE CHEMICALLY DIFFICULT TO BREAK DOWN MAKING THE BIOMASS CONVERSION PROCESS CHALLENGING. NREL HAS CREATED A PILOT PLANT TO TEST WAYS TO IMPROVE THE PROCESS OF BREAKING DOWN THE CELLULOSIC MATERIAL AND MAKE THE SUGARS AVAILABLE FOR FERMENTATION. THE FIRST STEP IN THE PROCESS IS PRETREATMENT. Aden: NATURE HAS REALLY MADE THESE MATERIALS TO BE RESISTANT TO BEING BROKEN DOWN. SO THAT'S WHY WE HAVE TO DO SOME PREPROCESSING.
TO BREAK APART THE CELLULOSE AND THE HEMICELLULOSE FROM THE LIGNIN.
AND THAT'S WHAT HAPPENS IN THE PRETREATMENT PART OF THE PROCESS.
WE START TO USE ACID AS A CHEMICAL HYDROLYSIS AGENT -- HYDROLYSIS REALLY MEANS ADDING WATER TO A REACTION -- TO BEGIN TO BREAK DOWN THE BIOMASS INTO ITS INDIVIDUAL PIECES AND GET SOME OF THE THOSE SUGARS INTO SOLUTION.
Narrator: THIS PRETREATMENT PROCESS RELEASES THE SUGARS IN THE HEMICELLULOSE.
BUT THE CELLULOSE REMAINS SOMEWHAT INTACT LEADING TO THE NEXT STEP IN BREAKING DOWN THE CELLULOSIC MATERIAL.
Aden: ONCE WE'VE PRETREATED THE BIOMASS WE BRING THAT PRETREATED BIOMASS, IN A SLURRY OR A PASTE INTO OUR FERMENTERS HERE. AND THIS IS WHERE WE ADD OUR CELLULASE ENZYME
INTO THE PROCESS.
CELLULASE ENZYME IS SIMPLY A
NATURAL PROTEIN
THAT ACTS AS A CATALYST TO
BREAK DOWN THE CELLULOSE
INTO ITS INDIVIDUAL SUGAR
UNITS.
ONCE WE HAVE THAT MIXTURE OF
SUGARS
THAT HAS COME FROM THE
PRETREATMENT
AND FROM USING THE ENZYMES
WE CAN FERMENT THAT MIXTURE
OF SUGARS THEN
INTO FUEL ETHANOL.

Narrator: THE ENZYMES USED
TO BREAK DOWN THE CELLULOSIC
MATERIAL
ARE AN EXPENSIVE PART OF THIS
PROCESS.
NREL's EXTENSIVE BIOCHEMICAL
LABORATORIES
ALONG WITH INDUSTRY
PARTNERS, HAVE BROUGHT THE
COST DOWN
FROM $5 PER GALLON OF
ETHANOL PRODUCED
TO ABOUT 20 CENTS PER GALLON.
BUT THIS COST HAS TO BE
REDUCED EVEN FURTHER
TO COMPETE WITH CORN
ETHANOL AND TRADITIONAL PETROLEUM.
BILL ADNEY IS RESEARCHING NEW WAYS TO IMPROVE THESE ENZYMES USING BIOTECHNOLOGY.
Dr. Adney: ENZYMES ARE IMPORTANT IN NATURE IN THE BREAKDOWN OF BIOMASS. THEY’RE FOUND ALL OVER THE PLACE, WHEN YOU THINK ABOUT IT. COMPOST PILES WOULD BE ONE EXAMPLE OF A PLACE WHERE YOU WOULD FIND CELLULOSE-DEGRADING ENZYMES. AND WE’VE LOOKED ALL SORTS OF PLACES.
Narrator: ONE PLACE THEY LOOKED WAS YELLOWSTONE NATIONAL PARK.
Dr. Adney: WE WERE LOOKING FOR ENZYMES THAT COULD SURVIVE AT HIGH TEMPERATURE. SO WE LOOKED AT SOME OF THE BIOMASS THAT'S DECAYING IN THE HOT SPRINGS.
Narrator: WHAT THEY FOUND WAS A BACTERIUM
THAT FEEDS ON THE ORGANIC DEBRIST HAT FALLS INTO HOT SPRINGS.
THE ENZYME THEY ISOLATED FROM THE BACTERIUM ATTACHES ITSELF TO THE CHAIN OF SUGARS IN CELLULOSE AND BREAKS IT APART.
Dr. Adney: THIS PARTICULAR ENZYME WE’VE DONE SOME ENGINEERING ON AND HAVE BEEN ABLE TO IMPROVE THE ACTIVITY BY ABOUT 12% TO 15%.

Narrator: WHILE THIS ENZYME BREAKS THE CHAIN IT DOES NOT RELEASE THE SUGARS. THAT IS THE JOB OF ANOTHER ENZYME ONE THAT WAS DISCOVERED NEARLY 50 YEARS AGO.
Dr. Adney: IN THE LATE '50s, EARLY '60s IT WAS AN ISSUE WITH THE ARMY UNIFORMS IN THE TROPIC AREAS. THEY FOUND THAT THEY WERE DEGRADING RAPIDLY. SO THE ARMY BEGAN TO INVESTIGATE WHY THIS WAS
OCCURRING.
AND ONE OF THE FIRST THINGS THEY ISOLATED WAS A FUNGUS THAT PRODUCED ENZYMES THAT BROKE DOWN THE COTTON MATERIAL FOUND IN THE SOLDERS’ UNIFORMS.
THESE ENZYMES ARE VERY UNIQUE.
THEY ARE TERMED PROCESSIVE ENZYMES.
SO ONCE THEY ATTACH TO A CHAIN, THEY MOVE PROCESSIVELY DOWN RELEASING THE SUGAR AS THEY MOVE ALONG.
THIS PARTICULAR ENZYME IS PROBABLY THE SINGLE MOST IMPORTANT ENZYME IN BIOMASS CONVERSION AT THIS TIME.
YET WE DON'T KNOW HOW IT REALLY WORKS.
Narrator: BY GAINING A BETTER UNDERSTANDING OF HOW THESE ENZYMES WORK AND ENGINEERING THEM TO FUNCTION MORE EFFECTIVELY RESEARCHERS AT NREL WILL IMPROVE THE BIOMASS-CONVERSION PROCESS
EVEN FURTHER.
ONCE THE ENZYMES HAVE BROKEN DOWN THE SUGAR CHAINS
FERMENTATION ORGANISMS ARE ADDED TO TURN THOSE SUGARS INTO ETHANOL.
IN THIS PART OF THE PROCESS, TOO, PROGRESS NEEDS TO BE MADE.

Aden: IN THE CURRENT CORN-ETHANOL INDUSTRY THE YEAST THEY USE TO FERMENT THE GLUCOSE INTO ETHANOL IS VERY GOOD AT WHAT IT DOES. IN THIS PROCESS, WE HAVE A MIXTURE OF SUGARS -- GLUCOSE, XYLOSE, MANNOSE, AND OTHER SUGARS. WE HAVE ORGANISMS ENGINEERED TO BE ABLE TO FERMENT SOME OF THOSE SUGARS PRIMARILY GLUCOSE AND XYLOSE, AT THE SAME TIME BUT THEY DON'T DO IT AS EFFICIENTLY AS THEY NEED TO AND WE'D LIKE TO ENGINEER THEM TO DO OTHER SUGARS AS
WELL
TO MAKE THIS A MORE EFFICIENT PROCESS
AND GET MORE ETHANOL
FOR EVERY POUND OF BIOMASS
THAT WE BRING IN.
Narrator: AT NREL
THEY ARE CONTINUALLY
ENGINEERING THESE ORGANISMS
TO BECOME MORE EFFICIENT
IN HOPES OF ONE DAY
PRODUCING A SINGLE
FERMENTING ORGANISM
THAT CAN TOLERATE HIGH
CONCENTRATIONS OF ETHANOL
AND WORK ON ALL SUGARS AT ONCE.

BUT ALL OF THESE PROCESSES
TAKE A LOT OF ENERGY.
AND HERE IN THE PILOT PLANT
THEY ARE WORKING ON A SOLUTION TO THAT AS WELL
BY USING THE LAST REMAINING PIECE
OF THE CELLULOSIC MATERIAL,
THE LIGNIN.
Aden: THAT LIGNIN PLAYS A VERY IMPORTANT PART
IN THE ENERGY PICTURE OF THIS PROCESS.
BECAUSE CELLULOSIC BIOMASS
HAS THIS LIGNIN COMPONENT THAT CAN BE USED FOR A FUEL, YOU DON'T HAVE TO BUY COAL.
YOU DON'T HAVE TO BUY NATURAL GAS.
YOU CAN BE A SELF-SUSTAINING ENERGY PLANT LIKE THIS BY BURNING THIS LIGNIN RESIDUE.
YOU COULD NOT ONLY PROVIDE ALL OF THE ENERGY NEEDS FOR A PROCESSING PLANT SUCH AS THIS
YOU COULD ALSO POTENTIALLY SELL A GREEN ENERGY BYPRODUCT TO THE LOCAL POWER GRID.

Narrator: BY MAXIMIZING THE ENERGY POTENTIAL OF CELLULOSIC MATERIAL NREL's BIOMASS PROGRAM IS HELPING TO PAVE THE WAY TO A NEW ENERGY FUTURE.
Douglas: WITH ADDDED EFFICIENCIES WE THINK WE COULD VERY EASILY GET TO THE POINT WHERE HALF OR MORE OF THE LIQUID FUELS USED IN THE U.S. COULD BE GROWN HERE IN THE
U.S. ON AN ANNUAL AND CYCLICAL BASIS.
SO WE WOULD BE GROWING OUR OWN TRANSPORTATION FUEL.
Narrator: BIOMASS FUELS ALONG WITH OTHER RENEWABLE ENERGY SOURCES CARBON SEQUESTRATION NUCLEAR ENERGY, AND NEW EFFICIENCIES WILL ALL CONTRIBUTE TO PROVIDING AFFORDABLE ENERGY FOR OUR RAPIDLY INCREASING GLOBAL POPULATION AND REDUCE THE IMPACT OF CLIMATE-CHANGING GREENHOUSE GASES.

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