

BIOENERGY

A graphic introduction



SUPERGEN Bioenergy Hub

This comic is intended as an educational resource for schools, universities and the general public. Download the electronic version at:

www.supergen-bioenergy.net

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The EPSRC* SUPERGEN Bioenergy Hub aims to bring together industry, academia and other stakeholders to focus on the research and knowledge challenges associated with increasing the contribution of UK bioenergy to meet strategic environmental targets in a coherent, sustainable and cost-effective manner.

www.supergen-bioenergy.net

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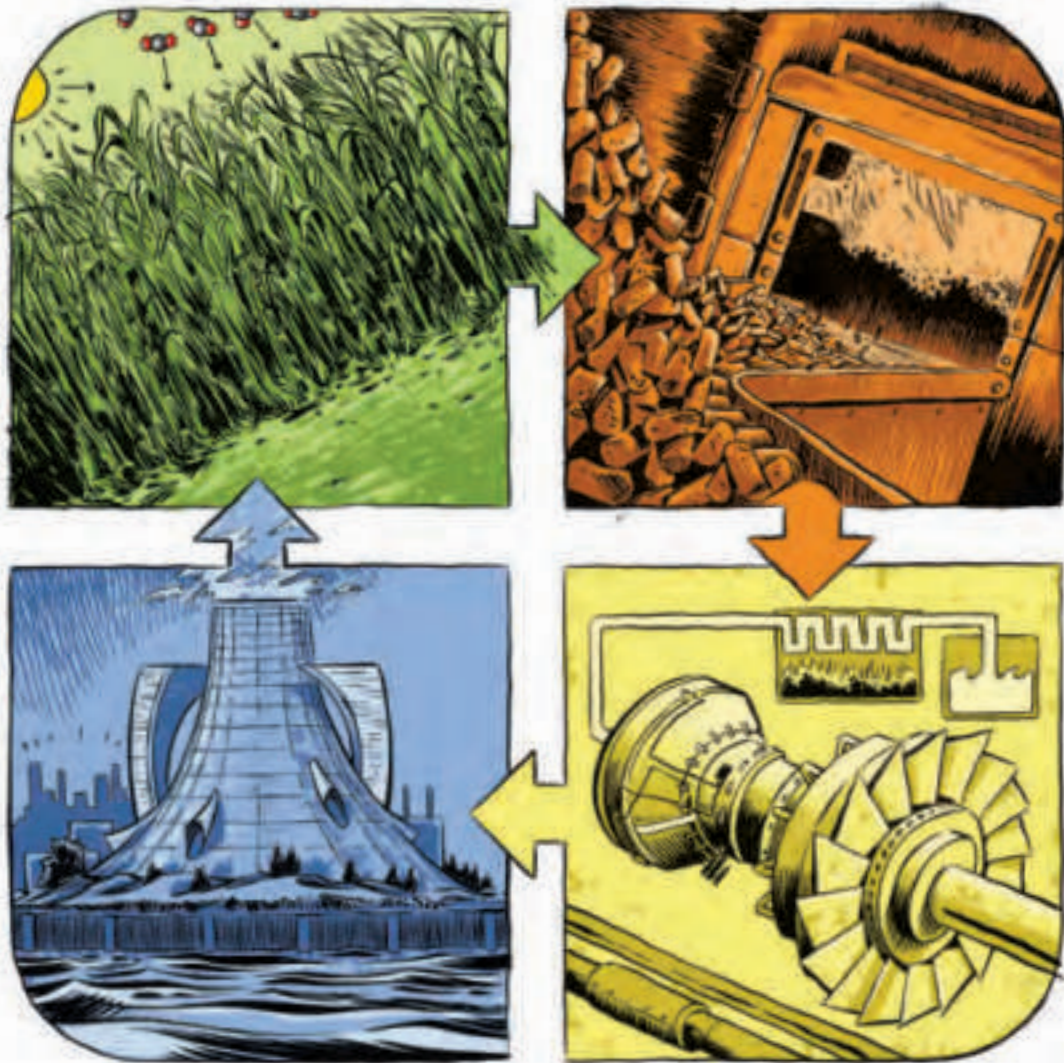
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* EPSRC: Engineering & Physical Sciences Research Council

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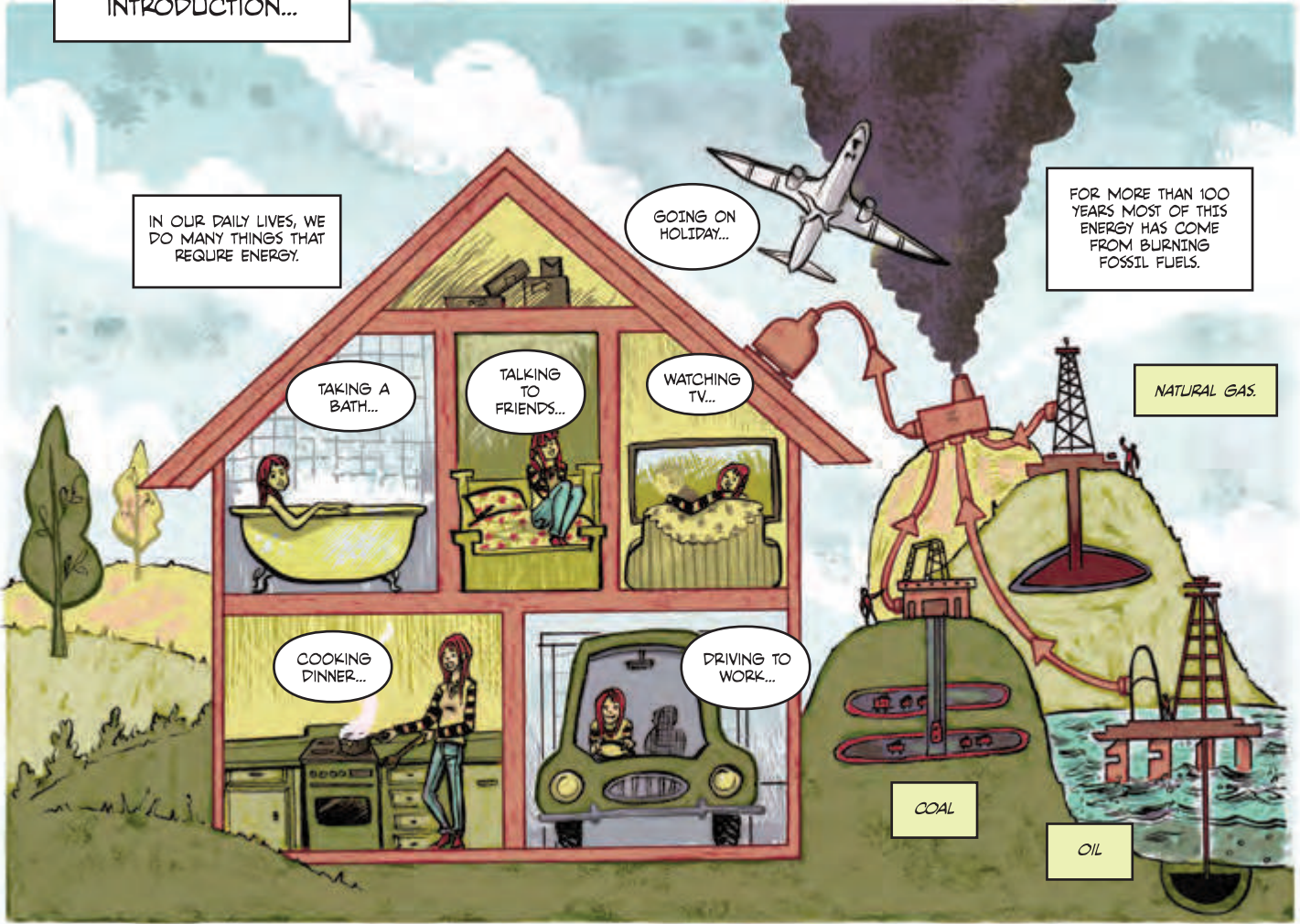
What is it?

Why use it?

What are the problems?

What are the solutions?

INTRODUCTION...



IN OUR DAILY LIVES, WE DO MANY THINGS THAT REQUIRE ENERGY.

GOING ON HOLIDAY...

FOR MORE THAN 100 YEARS MOST OF THIS ENERGY HAS COME FROM BURNING FOSSIL FUELS.

TAKING A BATH...

TALKING TO FRIENDS...

WATCHING TV...

NATURAL GAS.

COOKING DINNER...

DRIVING TO WORK...

COAL

OIL



BUT WHERE DO THESE FUELS COME FROM?



MILLIONS OF YEARS AGO, PLANTS GREW USING ENERGY FROM THE SUN AND CARBON DIOXIDE--JUST AS THEY DO TODAY.

<p>WHEN THEY DIED AND DECOMPOSED, THE CARBON IN THEIR TISSUES WAS BURIED...</p>	<p>...THEIR BURIED TISSUES TURNED INTO PEAT, THEN COAL IN A PROCESS THAT TOOK UP TO 300 MILLION YEARS!</p>	<p>A SIMILAR PROCESS TOOK PLACE IN THE OCEANS, WITH MICROSCOPIC PLANTS FORMING OIL AND GAS.</p>	<p>MILLIONS OF YEARS LATER, WE FIND THE COAL, OIL AND GAS AND DIG OR DRILL FOR IT.</p>

FOSSIL FUELS ARE LESS EXPENSIVE THAN OTHER FORMS OF ENERGY, THEY ARE VERY ENERGY DENSE, EASY TO STORE AND WIDELY AVAILABLE. SO WHAT'S THE PROBLEM WITH THEM?

THREE PROBLEMS

THEY HAVE LOCAL ENVIRONMENTAL IMPACTS...

...LIKE THE POOR AIR QUALITY WE SEE IN CITIES WORLDWIDE.

THEY'RE NOT RENEWABLE...

...AS WE USE THEM UP THEY BECOME MORE EXPENSIVE.

THE GREENHOUSE GASES RELEASED BY THEIR COMBUSTION CAUSE CLIMATE CHANGE.

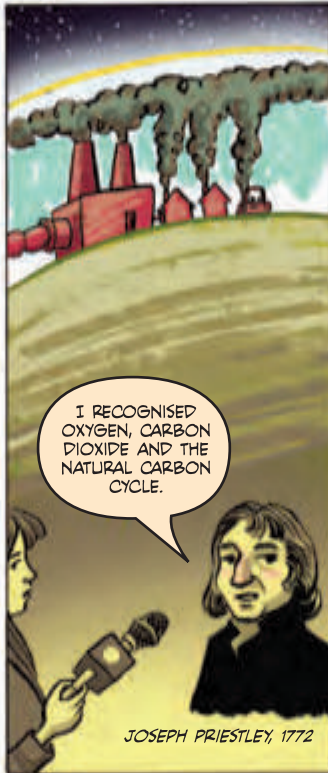
THIS IS THE MOST SERIOUS PROBLEM WITH FOSSIL FUELS, AND IS SOMETHING WE HAVE TO ADDRESS NOW.



WHAT IS CLIMATE CHANGE?

OUR FOSSIL FUEL CYCLE IS ALL ONE WAY. WE RELEASE THE CARBON THAT HAS BEEN UNDER THE GROUND FOR MILLIONS OF YEARS...

...AND WE'RE NOT TAKING IT BACK IN.



I RECOGNISED OXYGEN, CARBON DIOXIDE AND THE NATURAL CARBON CYCLE.

JOSEPH PRIESTLEY, 1772

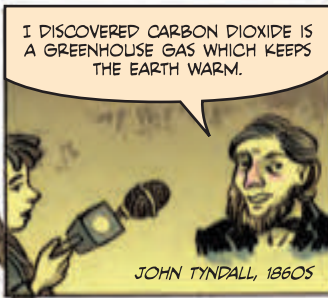
WHEN THE SUN'S ENERGY REACHES THE EARTH, SOME OF IT IS TRAPPED BY GASES IN THE ATMOSPHERE. THESE ARE KNOWN AS GREENHOUSE GASES.

THE HEAT THEY TRAP RAISES THE TEMPERATURE OF THE WHOLE PLANET. WITHOUT THEM, THE EARTH WOULD BE TOO COLD FOR HUMANS TO SURVIVE.

CARBON DIOXIDE (CO₂) IS ONE OF THESE GREENHOUSE GASES.

OTHERS ARE: METHANE (CH₄), NITROUS OXIDE (N₂O), CHLOROFLUOROCARBONS (CFCs).

WHEN HUMANS RELEASE MORE OF THESE GREENHOUSE GASES INTO THE ATMOSPHERE THROUGH BURNING FOSSIL FUELS, IT WARMS THE ATMOSPHERE FASTER THAN THE NATURAL WORLD (AND HUMAN SOCIETY) CAN ADAPT.



I DISCOVERED CARBON DIOXIDE IS A GREENHOUSE GAS WHICH KEEPS THE EARTH WARM.

JOHN TYNDALL, 1860S

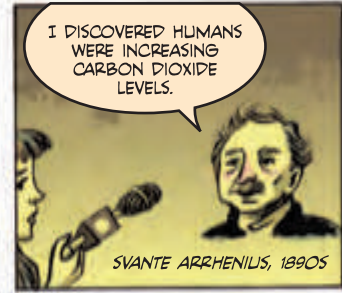


THIS WARMING MELTS ICE CAPS, RAISING SEA LEVELS...

...CAUSES STRONGER STORMS...

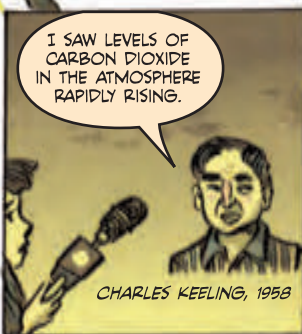
...FLOODS...

...DROUGHTS...



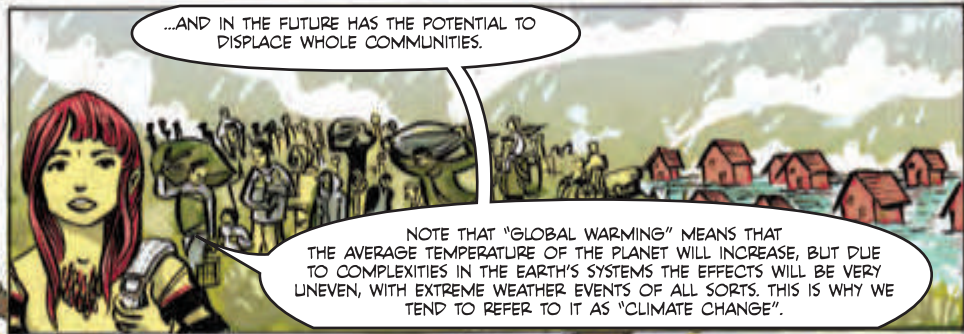
I DISCOVERED HUMANS WERE INCREASING CARBON DIOXIDE LEVELS.

SVANTE ARRHENIUS, 1890S



I SAW LEVELS OF CARBON DIOXIDE IN THE ATMOSPHERE RAPIDLY RISING.

CHARLES KEELING, 1958



...AND IN THE FUTURE HAS THE POTENTIAL TO DISPLACE WHOLE COMMUNITIES.

NOTE THAT "GLOBAL WARMING" MEANS THAT THE AVERAGE TEMPERATURE OF THE PLANET WILL INCREASE, BUT DUE TO COMPLEXITIES IN THE EARTH'S SYSTEMS THE EFFECTS WILL BE VERY UNEVEN, WITH EXTREME WEATHER EVENTS OF ALL SORTS. THIS IS WHY WE TEND TO REFER TO IT AS "CLIMATE CHANGE".

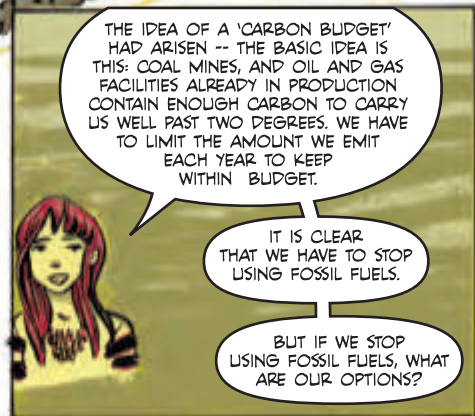


I INFORMED GOVERNMENTS THAT THIS WOULD BE A PROBLEM.

JAMES HANSEN, 1988



IN 2015, 195 NATIONS CAME TOGETHER TO COMMIT TO STOPPING GLOBAL TEMPERATURE FROM RISING MORE THAN 2°C, WITH AN AMBITION TO LIMIT IT TO NO MORE THAN 1.5°C.



THE IDEA OF A 'CARBON BUDGET' HAD ARISEN -- THE BASIC IDEA IS THIS: COAL MINES, AND OIL AND GAS FACILITIES ALREADY IN PRODUCTION CONTAIN ENOUGH CARBON TO CARRY US WELL PAST TWO DEGREES. WE HAVE TO LIMIT THE AMOUNT WE EMIT EACH YEAR TO KEEP WITHIN 'BUDGET'.

IT IS CLEAR THAT WE HAVE TO STOP USING FOSSIL FUELS.

BUT IF WE STOP USING FOSSIL FUELS, WHAT ARE OUR OPTIONS?

HOW CAN WE CHANGE THE ENERGY SYSTEM?

1 DEMAND REDUCTION

WE CAN TRY TO AVOID USING LOTS OF ENERGY, BUT THIS MEANS WE WILL HAVE TO CHANGE THE WAY WE LIVE.

THERE ARE VARIOUS WAYS TO USE LESS ENERGY:

DRIVE LESS

2 ENERGY EFFICIENCY

WE CAN BE MORE EFFICIENT IN THE WAY WE USE ENERGY -- DESIGNING BETTER TECHNOLOGIES AND USING THEM IN BETTER SYSTEMS.

TURN LIGHTS OUT

DEVELOPED COUNTRIES WASTE AND CONSUME TOO MUCH ENERGY AND NEED TO REDUCE DEMAND.

HOWEVER, DEVELOPING COUNTRIES NEED ENERGY TO LIFT THEM OUT OF POVERTY.

BUT SOMETIMES EFFICIENCIES CAN HAVE UNEXPECTED CONSEQUENCES.

QUALITY OF LIFE

ENERGY USAGE

DEVELOPED COUNTRIES

DEVELOPING COUNTRIES

A SMALL INCREASE IN ENERGY USE CAN DRAMATICALLY IMPROVE QUALITY OF LIFE.

NEW TECHNOLOGIES HAVE INCREASED THE EFFICIENCY OF FUEL USE IN CARS. THIS MAKES CARS CHEAPER TO RUN, WHICH MEANS MORE PEOPLE BUY THEM, AND DRIVE THEM FURTHER, CONSUMING MORE FUEL.

SO FOR MUCH OF THE WORLD, USING LESS ENERGY ISN'T AN OPTION.

WE WILL STILL NEED TO GET OUR ENERGY FROM SOMEWHERE.

CAN WE SUSTAIN OUR MODERN WORLD BY MOVING FROM A ONE-WAY FUEL CYCLE TO SOMETHING MORE CIRCULAR?

IT IS A FACT THAT ALL ENERGY USE HAS AN IMPACT--ON THE ENVIRONMENT, ON THE WAY WE LIVE...

THIS IS CALLED THE "REBOUND EFFECT" AND MEANS THAT REDUCING ENERGY USE THROUGH EFFICIENCIES MAY BE MORE DIFFICULT THAN IT SEEMS.

REPLACEMENTS FOR FOSSIL FUELS MUST SATISFY A NUMBER OF REQUIREMENTS:

**SUSTAINABILITY
SECURITY
AFFORDABILITY**

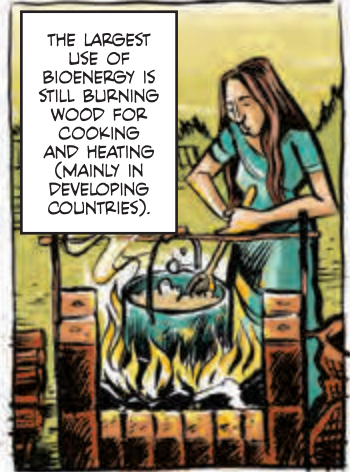
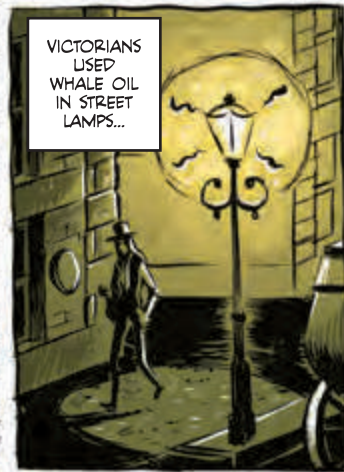
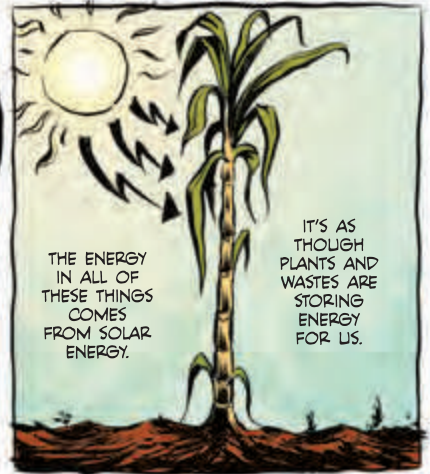
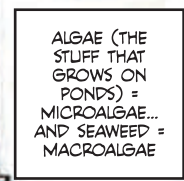
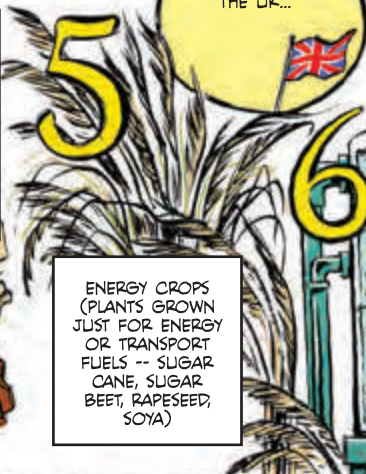
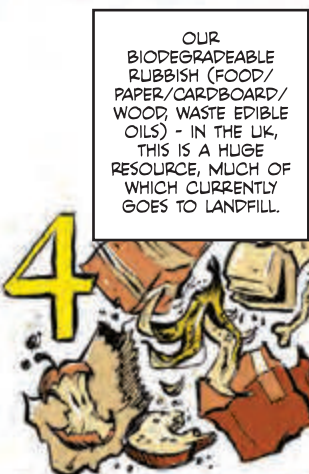
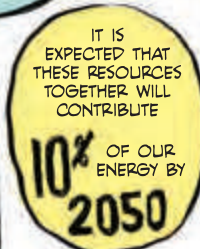
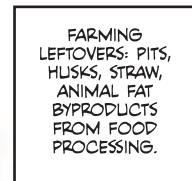
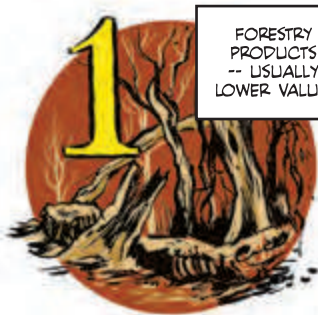
THE COMPLETE PICTURE OF OUR ENERGY FUTURE WILL PROBABLY INVOLVE LOTS OF DIFFERENT TECHNOLOGIES THAT WILL HAVE TO WORK TOGETHER.

BIOENERGY IS JUST ONE OF THESE...

...AND IN THE REST OF THIS COMIC IT'S THE ONE WE'RE GOING TO FOCUS ON.

N.B. NUCLEAR IS A REPLACEMENT FOR FOSSIL FUELS, BUT IS NOT RENEWABLE.

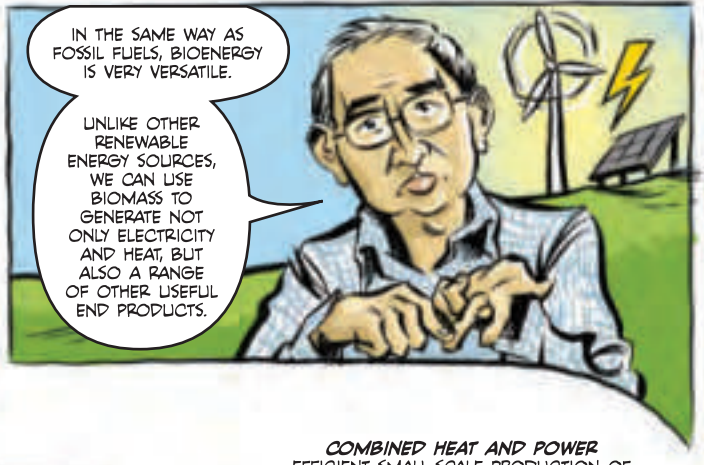
WHAT IS BIOENERGY?



WHAT CAN BIOENERGY BE USED FOR?



IF WE USE BIOENERGY PROPERLY, WE CAN HAVE THE BENEFITS OF FOSSIL FUELS WITHOUT CAUSING CLIMATE CHANGE.



IN THE SAME WAY AS FOSSIL FUELS, BIOENERGY IS VERY VERSATILE.
UNLIKE OTHER RENEWABLE ENERGY SOURCES, WE CAN USE BIOMASS TO GENERATE NOT ONLY ELECTRICITY AND HEAT, BUT ALSO A RANGE OF OTHER USEFUL END PRODUCTS.

HEAT

BIOMASS IS BURNED IN HIGHLY EFFICIENT BOILERS TO PRODUCE HEAT FOR DOMESTIC OR COMMERCIAL USE. HEAT REALLY SEEMS TO BE THE 'FORGOTTEN ENERGY' - AND 'BIOHEAT' IS SEEN AS VERY IMPORTANT FOR THE FUTURE.

COMBINED HEAT AND POWER

EFFICIENT SMALL-SCALE PRODUCTION OF BOTH ELECTRICITY AND HEAT IN ONE UNIT. IN HOT COUNTRIES, IT CAN BE INTEGRATED INTO COOLING SYSTEMS.

TRANSPORT FUELS

BIOMASS CAN PROVIDE ELECTRICITY FOR ELECTRIC VEHICLES, OR LIQUID FUELS LIKE BIODIESEL AND BIOETHANOL, AND EVEN BIOGAS.

DID YOU KNOW THAT YOUR CAR IS ALREADY USING BIOFUEL? IN THE UK, PETROL AND DIESEL CONTAIN UP TO 5% BIOETHANOL, AND 10% MIXES COULD BE ROLLED OUT SOON.

BIOPRODUCTS AND BIOPLASTICS

MADE THROUGH PROCESSES BASED ON BIOMASS. THESE STORE CARBON AND REDUCE THE NEED FOR PLASTIC MADE FROM FOSSIL FUELS.

THE BIOREFINERY CONCEPT

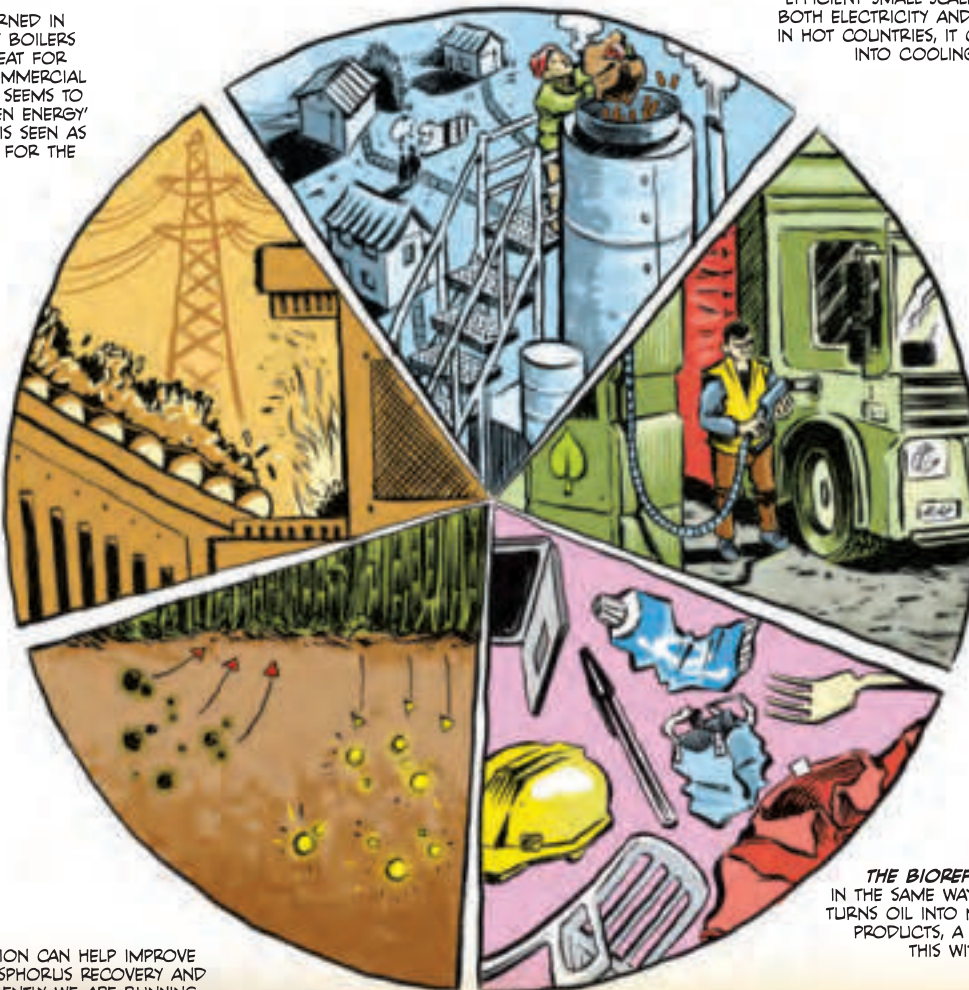
IN THE SAME WAY AS AN OIL REFINERY TURNS OIL INTO MANY CHEMICALS AND PRODUCTS, A BIOREFINERY DOES THIS WITH BIOMASS.

NEW RESEARCH IS FINDING WAYS TO RUN PROCESSES THAT USE WASTE FROM ONE PROCESS AS A FEEDSTOCK FOR ANOTHER, IMPROVING EFFICIENCY.

ELECTRICITY
BIOMASS CAN BE USED AS FUEL IN POWER STATIONS TO POWER TURBINES TO GENERATE ELECTRICITY. UNLIKE SOLAR OR WIND ENERGY, THIS IS NOT DEPENDENT ON THE WEATHER.

LAND REMEDIATION AND NUTRIENT RECOVERY
RESEARCHERS ARE EXPLORING WAYS TO ABSORB HARMFUL CONTAMINANTS FROM LAND BY GROWING ENERGY CROPS ON THEM. THIS WAY WE CAN RECLAIM THE LAND EITHER FOR BIOENERGY OR OTHER USES.

ANAEROBIC DIGESTION CAN HELP IMPROVE NITROGEN AND PHOSPHORUS RECOVERY AND RECYCLING -- CURRENTLY WE ARE RUNNING OUT OF PHOSPHORUS, AND NITROGEN CAN BE 'ENERGY-INTENSIVE' TO MAKE.



WITH ALL THESE CHOICES, WHAT IS THE HIGHEST PRIORITY?

THIS IS LIKELY TO BE DIFFERENT IN DIFFERENT PLACES, DEPENDING ON OTHER RESOURCES.

A COUNTRY THAT IS VERY WINDY MIGHT GENERATE A LOT OF ELECTRICITY FROM TURBINES, AND USE BIOENERGY FOR TRANSPORT FUELS INSTEAD.

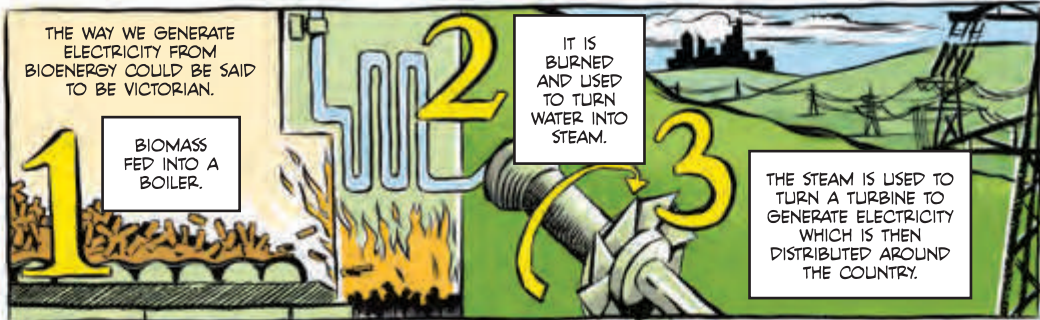
REMEMBER, BIOENERGY IS JUST ONE PART OF THE 'ENERGY MIX' - BUT YOU MAY BE SURPRISED TO KNOW THAT IN THE UK, IT PROVIDES A WHOPPING 70% OF ENERGY GENERATED FROM RENEWABLE SOURCES*



HOW IS BIOENERGY GENERATED?



THE TECHNOLOGIES USED TO TURN BIOMASS INTO ENERGY HAVE IN SOME CASES BEEN AROUND FOR A LONG TIME.

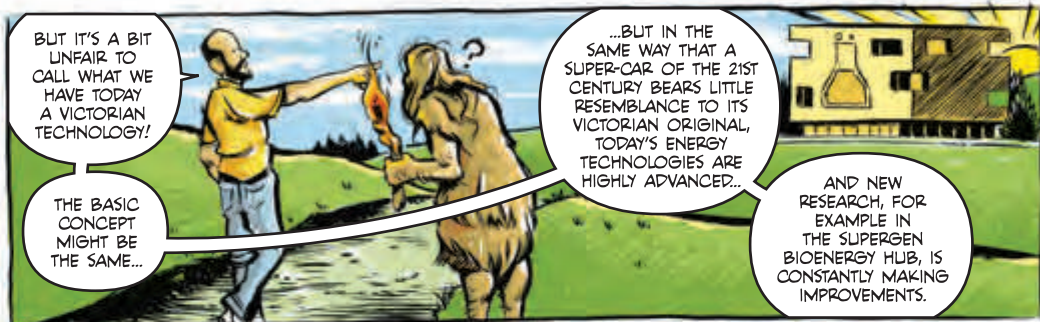


THE WAY WE GENERATE ELECTRICITY FROM BIOENERGY COULD BE SAID TO BE VICTORIAN.

BIOMASS FED INTO A BOILER.

IT IS BURNED AND USED TO TURN WATER INTO STEAM.

THE STEAM IS USED TO TURN A TURBINE TO GENERATE ELECTRICITY WHICH IS THEN DISTRIBUTED AROUND THE COUNTRY.

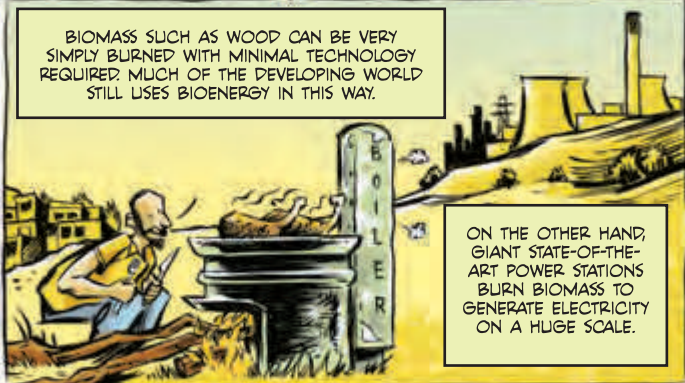
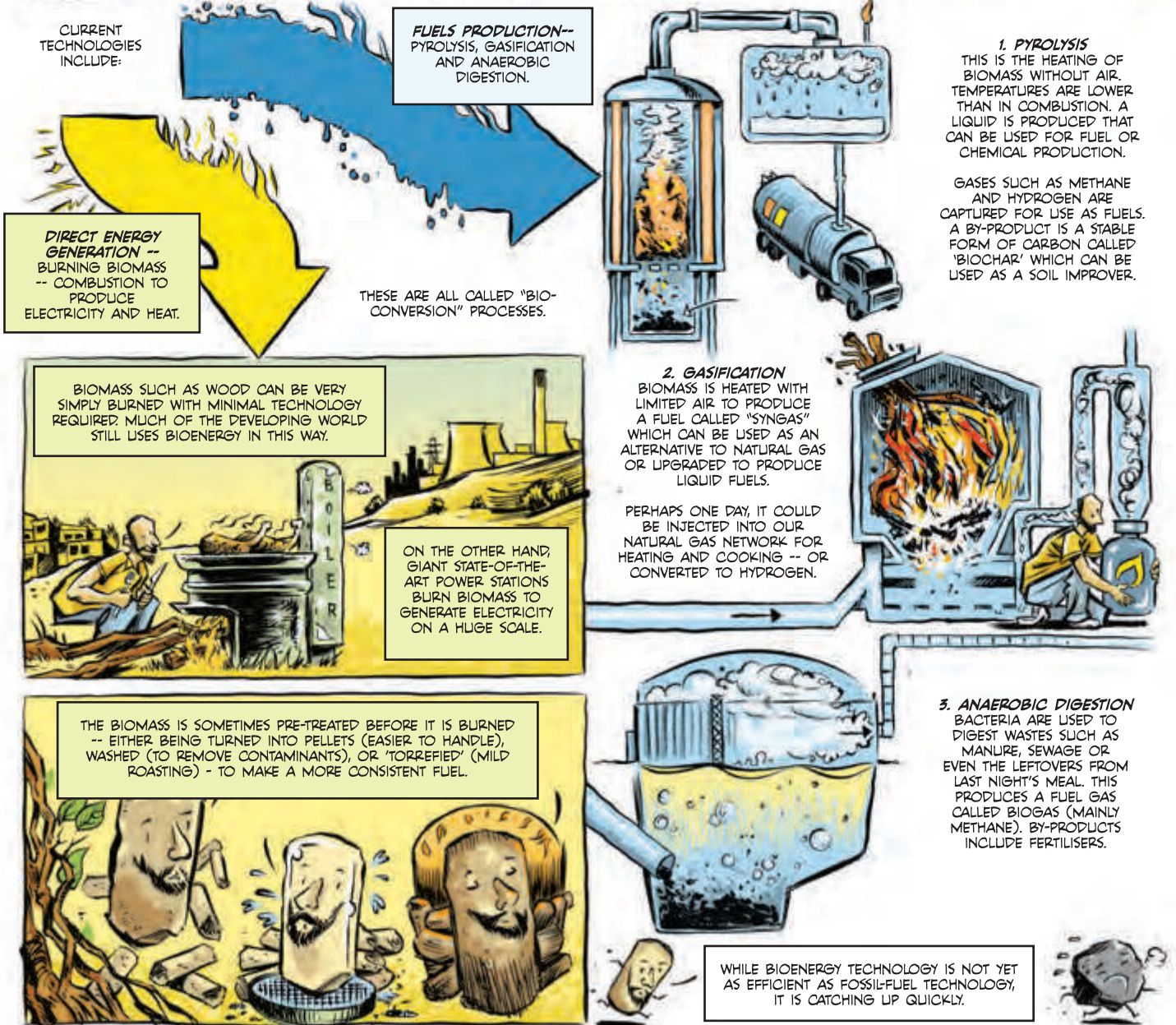


BUT IT'S A BIT UNFAIR TO CALL WHAT WE HAVE TODAY A VICTORIAN TECHNOLOGY!

THE BASIC CONCEPT MIGHT BE THE SAME...

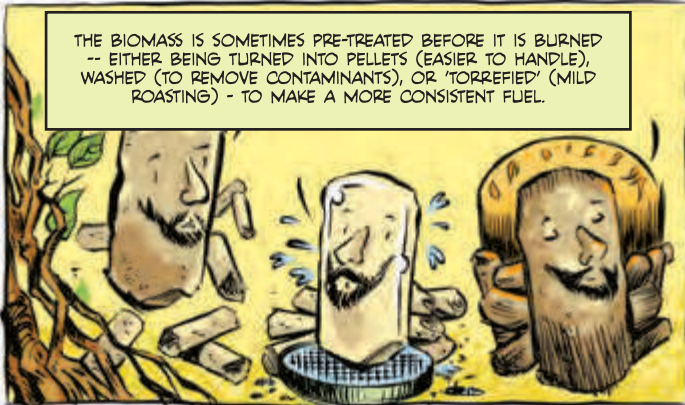
...BUT IN THE SAME WAY THAT A SUPER-CAR OF THE 21ST CENTURY BEARS LITTLE RESEMBLANCE TO ITS VICTORIAN ORIGINAL, TODAY'S ENERGY TECHNOLOGIES ARE HIGHLY ADVANCED...

AND NEW RESEARCH, FOR EXAMPLE IN THE SUPERGEN BIOENERGY HUB, IS CONSTANTLY MAKING IMPROVEMENTS.



BIOMASS SUCH AS WOOD CAN BE VERY SIMPLY BURNED WITH MINIMAL TECHNOLOGY REQUIRED. MUCH OF THE DEVELOPING WORLD STILL USES BIOENERGY IN THIS WAY.

ON THE OTHER HAND, GIANT STATE-OF-THE-ART POWER STATIONS BURN BIOMASS TO GENERATE ELECTRICITY ON A HUGE SCALE.



THE BIOMASS IS SOMETIMES PRE-TREATED BEFORE IT IS BURNED -- EITHER BEING TURNED INTO PELLETS (EASIER TO HANDLE), WASHED (TO REMOVE CONTAMINANTS), OR 'TORREFIED' (MILD ROASTING) - TO MAKE A MORE CONSISTENT FUEL.

WHAT ARE THE BENEFITS OF USING BIOENERGY?

1. IT'S ABUNDANT AND RENEWABLE (IF MANAGED CORRECTLY)

2. IT CAN DIRECTLY REPLACE FOSSIL FUELS, MEANING LESS REQUIREMENT FOR NEW INFRASTRUCTURE--AND IT CAN IMMEDIATELY REDUCE THE NEED FOR FOSSIL FUELS IN AREAS WITH HIGH ENERGY DEMAND LIKE HEAVY INDUSTRY AND TRANSPORT.

3. BECAUSE THERE ARE MANY SOURCES OF BIOENERGY, WHICH CAN BE MANAGED IN MANY DIFFERENT WAYS, IT CAN HELP WITH ENERGY SECURITY, FLEXIBILITY, AND AFFORDABILITY.

4. BIOENERGY CAN PROVIDE PRODUCTS LIKE BIOPLASTICS AND BIOCHAR WHICH FURTHER REDUCE OUR RELIANCE ON FOSSIL FUELS.

5. UNLIKE SOLAR AND WIND ENERGY, BIOMASS CAN BE EASILY STORED AND TRANSPORTED, MEANING IT CAN RESPOND TO CHANGES IN DEMAND.

6. PLANTING ENERGY CROPS CAN HELP FARMERS DIVERSIFY, AND CAN HAVE A POSITIVE IMPACT ON BIODIVERSITY.

7. IN REMOTE AREAS, IT MAY NOT BE VIABLE FOR COMMUNITIES TO GET ON THE ENERGY GRID. BIOENERGY CAN PROVIDE POWER THAT RUNS ON LOCAL RESOURCES, PROVIDING JOBS AND EMPOWERING LOCAL COMMUNITIES.

8. BIOENERGY WITH CARBON CAPTURE AND STORAGE (BECCS). THIS IS WHERE SO-CALLED "NET NEGATIVE CARBON EMISSIONS" CAN BE ACHIEVED BY CAPTURING THE CARBON DIOXIDE GIVEN OFF DURING COMBUSTION AND BURYING IT UNDERGROUND. IN THIS WAY, WE CAN ACTUALLY REMOVE CARBON DIOXIDE FROM THE ATMOSPHERE!

THIS IS CRITICAL FOR MEETING CLIMATE CHANGE TARGETS EVEN THOUGH THE SYSTEM HASN'T BEEN TESTED YET AT FULL SCALE.

CCS PIPELINE

STORAGE RESERVOIR FOR CARBON DIOXIDE

THE BENEFITS ABOVE SEEM QUITE STRAIGHTFORWARD, BUT NOW WE MOVE ONTO AN ISSUE WHICH IS MORE AMBIGUOUS...

CO₂

BIOENERGY -- DOES IT HELP US AVOID CAUSING CLIMATE CHANGE?

WE CAN BE CONFIDENT USING BIOENERGY AS IT IS 'CARBON NEUTRAL', SO-

NO WAY! I'VE HEARD THAT BIOENERGY IS WORSE THAN BURNING COAL!

YEAH -- WE RECKON THERE IS A "CARBON DEBT" WHEN YOU USE BIOENERGY!

HUH? WHAT DOES THAT MEAN?

OH DEAR. THE TERMS "CARBON NEUTRAL" AND "CARBON DEBT" TRY TO EXPRESS COMPLEX PROCESSES SIMPLY...

...BUT THEY'VE PROBABLY CAUSED MORE CONFUSION AND MISUNDERSTANDING THAN THEY'VE AVOIDED!

IT'S TOUGH, BUT LET ME TRY TO EXPLAIN.

$H_2CO_3 - E^{\circ}(CO_2)$
 $E^{\circ}(CH_4)$
 $2H\Delta P_{...}$

SO HERE'S A LUMP OF COAL...

...AND HERE'S SOME BIOMASS -- LET'S SAY, STRAW.

IT'S TRUE THAT AT THE MOMENT YOU BURN THEM, THEY BOTH RELEASE CARBON DIOXIDE INTO THE ATMOSPHERE...

...WHICH CAUSES CLIMATE CHANGE.

IT'S ALSO TRUE THAT MORE CARBON DIOXIDE IS RELEASED FROM STRAW THAN FROM COAL, TO GET THE SAME AMOUNT OF ENERGY.

THE KEY POINT IS THAT THAT STRAW ABSORBED CARBON DIOXIDE WHEN THE CROP GREW.

SO, IN THEORY, THE CARBON DIOXIDE ABSORBED WHEN THE CROP GREW BALANCES OUT THE CARBON DIOXIDE RELEASED WHEN THE CROP IS BURNT.

OVERALL, YOU DON'T ADD TO THE AMOUNT IN THE ATMOSPHERE.

THIS IS WHAT PEOPLE MEAN WHEN THEY SAY BIOENERGY IS CARBON NEUTRAL.

IT'S DIFFERENT FOR COAL, WHICH WAS FORMED FROM FOSSILISED PLANTS MILLIONS OF YEARS AGO, AS WE SAW AT THE BEGINNING.

WHEN YOU BURN IT, YOU RELEASE CARBON THAT HAD BEEN LOCKED UNDERGROUND FOR MILLIONS OF YEARS.

← 300 MILLION YEARS →

YOU SAY "IN THEORY" BIOENERGY IS CARBON NEUTRAL -- WHAT ABOUT IN REALITY?

YEAH -- IS IT ALWAYS CARBON NEUTRAL?

WELL, NO, ONLY IN CERTAIN SITUATIONS. THIS IS WHERE IT GETS COMPLICATED!

WHEN CROPS OR TREES HAVE BEEN GROWN LONG-TERM TO PRODUCE BIOENERGY, USUALLY THE BIOENERGY IS CARBON NEUTRAL, BECAUSE GROWTH AND HARVESTING REACH A CARBON BALANCE POINT.

WE'VE USED THE STRAW FROM OUR FARM TO HEAT BUILDINGS IN THE LOCAL COMMUNITY FOR YEARS!

I'VE MANAGED THE COPPICE TREES IN MY FOREST TO SUPPLY FUEL ALL MY LIFE, LIKE MY PARENTS DID BEFORE ME...

BUT WHEN YOU CHANGE THE WAY YOU MANAGE CROPS OR FORESTS TO PRODUCE MORE BIOENERGY THAN BEFORE, THIS DISTURBS THE CARBON BALANCE.

HEY -- I COULD SUSTAINABLY HARVEST A LOT MORE TREES TO PRODUCE MORE FUEL!

AND I COULD USE MORE OF MY STRAW TO MAKE FUEL, INSTEAD OF PLOUGHING IT BACK INTO THE SOIL!

FOR A PERIOD - WHILST OUT OF BALANCE - MORE CARBON DIOXIDE IS RELEASED INTO THE ATMOSPHERE THAN IS ABSORBED BY THE CROP OR THE FOREST.

AFTER A WHILE, PROVIDED YOU DON'T HARVEST MORE BIOMASS THAN THE LAND CAN SUPPORT, THE CROP OR FOREST FINDS A NEW CARBON BALANCE POINT.

THE BIOENERGY PRODUCED IS NOW "CARBON NEUTRAL" AND YOU CAN START MAKING UP FOR THE EXTRA CARBON DIOXIDE THAT WAS RELEASED.

THAT'S WHAT PEOPLE MEAN WHEN THEY SAY BIOENERGY INVOLVES A "CARBON DEBT".

DEPENDING ON WHAT THE TYPE OF CROP OR FOREST IS, AND WHAT YOU DO TO CHANGE IT, YOU MIGHT GET BACK INTO CARBON BALANCE AT ONCE...

...OR IT MIGHT TAKE DECADES...

...OR EVEN LONGER! IT'S REALLY VARIABLE!

THEN THERE ARE EVEN SOME CASES WHERE PRODUCING MORE BIOENERGY GIVES YOU A "CARBON BONUS" RATHER THAN A "CARBON DEBT".

I COULD IMPROVE THIS PIECE OF POOR UNUSED LAND BY PLANTING A CROP OR FOREST AND PRODUCING SOME FUEL*.

SO, SHOULD WE USE MORE BIOENERGY -- OR SHOULDN'T WE?

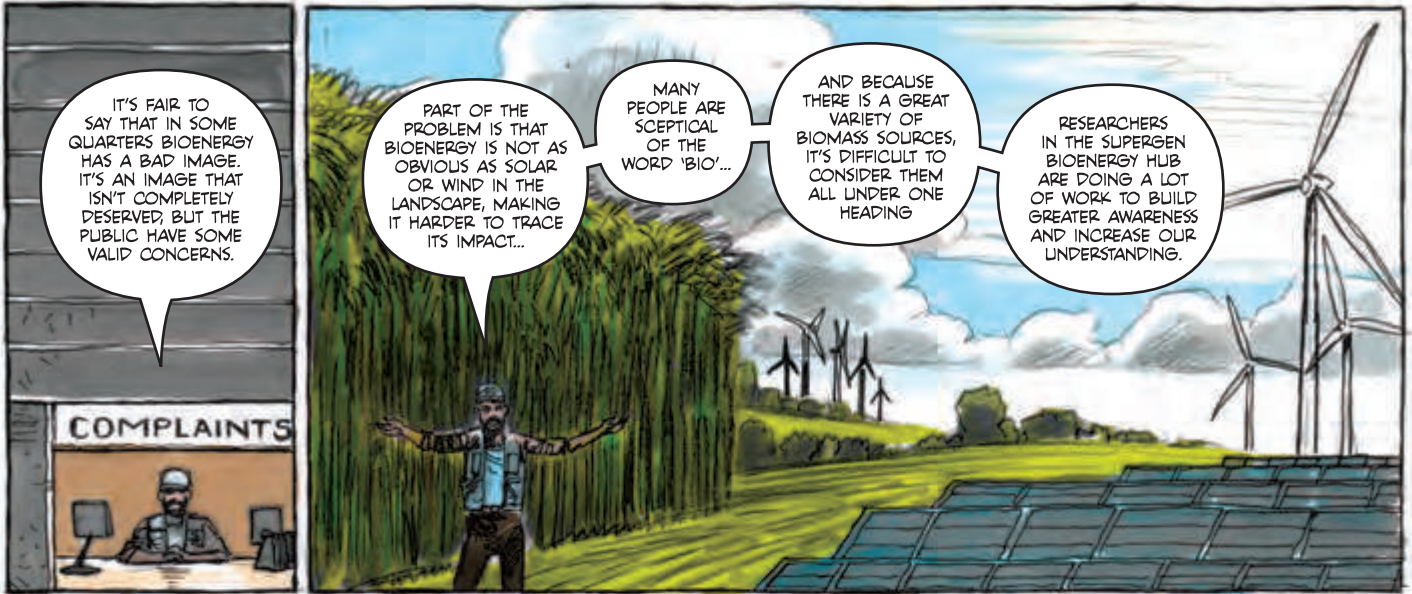
ARE THERE SAFE AMOUNTS OR TYPES OF BIOENERGY WE CAN USE? CAN WE GET IT RIGHT?

WELL, THESE ARE QUESTIONS THAT ARE BEING RESEARCHED BY SCIENTISTS LIKE THOSE IN THE SUPERGEN BIOENERGY HUB.

BASICALLY, WE HAVE TO USE BIOMASS TYPES THAT MAXIMISE THE CARBON BENEFITS AND MINIMISE THE DEBTS TO ENSURE WE REDUCE GREENHOUSE GAS EMISSIONS.

*BECAUSE THE GROWING CROP ALSO ABSORBS MORE CARBON DIOXIDE.

BIOENERGY -- SOME PROBLEMS, SOME SOLUTIONS



IT'S FAIR TO SAY THAT IN SOME QUARTERS BIOENERGY HAS A BAD IMAGE. IT'S AN IMAGE THAT ISN'T COMPLETELY DESERVED, BUT THE PUBLIC HAVE SOME VALID CONCERNS.

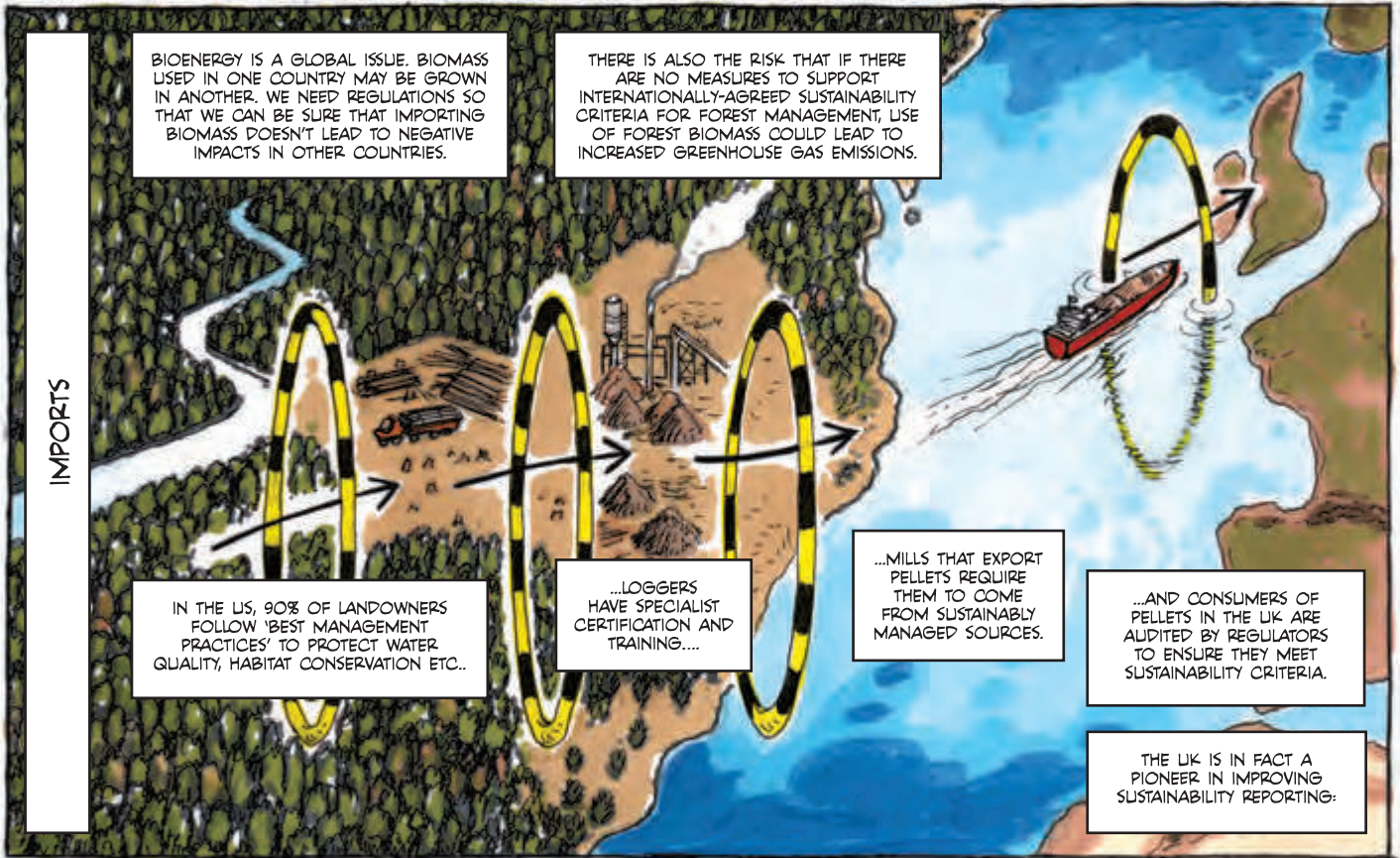
PART OF THE PROBLEM IS THAT BIOENERGY IS NOT AS OBVIOUS AS SOLAR OR WIND IN THE LANDSCAPE, MAKING IT HARDER TO TRACE ITS IMPACT...

MANY PEOPLE ARE SCEPTICAL OF THE WORD 'BIO'...

AND BECAUSE THERE IS A GREAT VARIETY OF BIOMASS SOURCES, IT'S DIFFICULT TO CONSIDER THEM ALL UNDER ONE HEADING

RESEARCHERS IN THE SUPERGEN BIOENERGY HUB ARE DOING A LOT OF WORK TO BUILD GREATER AWARENESS AND INCREASE OUR UNDERSTANDING.

COMPLAINTS



IMPORTS

BIOENERGY IS A GLOBAL ISSUE. BIOMASS USED IN ONE COUNTRY MAY BE GROWN IN ANOTHER. WE NEED REGULATIONS SO THAT WE CAN BE SURE THAT IMPORTING BIOMASS DOESN'T LEAD TO NEGATIVE IMPACTS IN OTHER COUNTRIES.

THERE IS ALSO THE RISK THAT IF THERE ARE NO MEASURES TO SUPPORT INTERNATIONALLY-AGREED SUSTAINABILITY CRITERIA FOR FOREST MANAGEMENT, USE OF FOREST BIOMASS COULD LEAD TO INCREASED GREENHOUSE GAS EMISSIONS.

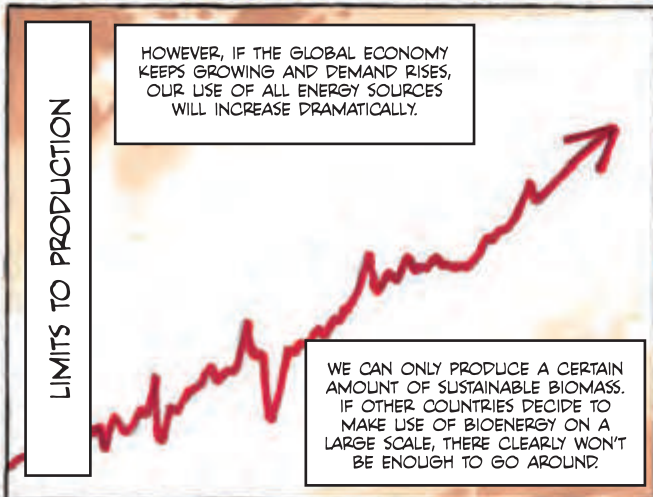
IN THE US, 90% OF LANDOWNERS FOLLOW 'BEST MANAGEMENT PRACTICES' TO PROTECT WATER QUALITY, HABITAT CONSERVATION ETC..

...LOGGERS HAVE SPECIALIST CERTIFICATION AND TRAINING....

...MILLS THAT EXPORT PELLETS REQUIRE THEM TO COME FROM SUSTAINABLY MANAGED SOURCES.

...AND CONSUMERS OF PELLETS IN THE UK ARE AUDITED BY REGULATORS TO ENSURE THEY MEET SUSTAINABILITY CRITERIA.

THE UK IS IN FACT A PIONEER IN IMPROVING SUSTAINABILITY REPORTING.



LIMITS TO PRODUCTION

HOWEVER, IF THE GLOBAL ECONOMY KEEPS GROWING AND DEMAND RISES, OUR USE OF ALL ENERGY SOURCES WILL INCREASE DRAMATICALLY.

WE CAN ONLY PRODUCE A CERTAIN AMOUNT OF SUSTAINABLE BIOMASS. IF OTHER COUNTRIES DECIDE TO MAKE USE OF BIOENERGY ON A LARGE SCALE, THERE CLEARLY WON'T BE ENOUGH TO GO AROUND.

WE'LL HAVE TO MAKE SOME TOUGH DECISIONS ABOUT HOW BEST TO USE IT...

...AND THESE DECISIONS MAY CHANGE AS OUR TECHNOLOGIES EVOLVE.



COMPETITION FOR LAND

THERE IS LOTS OF COMPETITION FOR PRIME AGRICULTURAL LAND.

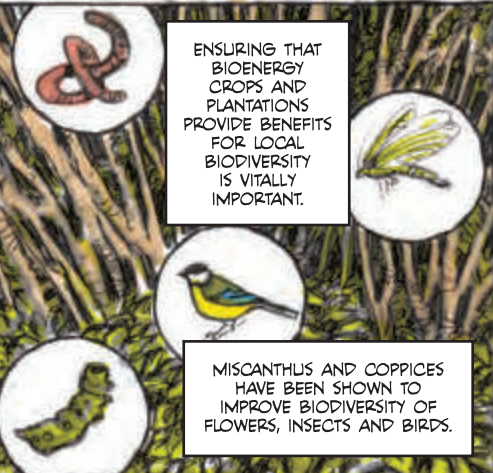
IN SOME PLACES ONLY THE POORER QUALITY LAND WILL BE AVAILABLE FOR BIOENERGY, IN WHICH CASE PRODUCTIVITY MIGHT SUFFER.



A SOLUTION MIGHT BE TO BREED ENERGY CROPS THAT CAN COPE WITH THESE POORER CONDITIONS.

BIODIVERSITY

ENSURING THAT BIOENERGY CROPS AND PLANTATIONS PROVIDE BENEFITS FOR LOCAL BIODIVERSITY IS VITALLY IMPORTANT.



MISCANTHUS AND COPPICES HAVE BEEN SHOWN TO IMPROVE BIODIVERSITY OF FLOWERS, INSECTS AND BIRDS.



ALSO, "CONTINUOUS COVER FORESTRY" AND OTHER AGRICULTURAL PRACTICES PROVIDE VARIETY IN CROP SPECIES AND TIMING OF HARVESTING.

THIS CREATES A "FOREST MOSAIC" - GREAT FOR BIODIVERSITY.

ENVIRONMENTAL DAMAGE

ENERGY CROPS SUCH AS MISCANTHUS AND COPPICES ARE "LOW INPUT" CROPS, REQUIRING FEWER FERTILISERS AND PESTICIDES THAN FOOD CROPS.

IF THEY ARE POSITIONED CAREFULLY, THEY CAN PROTECT WATER SYSTEMS FROM POLLUTANTS RUNNING OFF AGRICULTURAL LAND.



WE ALSO NEED TO UNDERSTAND THE IMPACT OF TAKING THINGS *OUT* OF THE ENVIRONMENT. FOR EXAMPLE, IS IT OK TO REMOVE ALL THE STRAW FROM AGRICULTURAL LAND?

COST

BIOENERGY IS A DIRECT REPLACEMENT FOR FOSSIL FUELS AS WE'VE SEEN.

IT IS CLAIMED TO BE A COST-EFFECTIVE WAY OF REDUCING GREENHOUSE GAS EMISSIONS.

HOWEVER IT IS LESS 'ENERGY DENSE', MEANING YOU HAVE TO USE MORE OF IT TO GET THE SAME ENERGY OUT.

IT'S LESS UNIFORM, REQUIRING DIVERSE TECHNOLOGIES FOR PROCESSING IT.

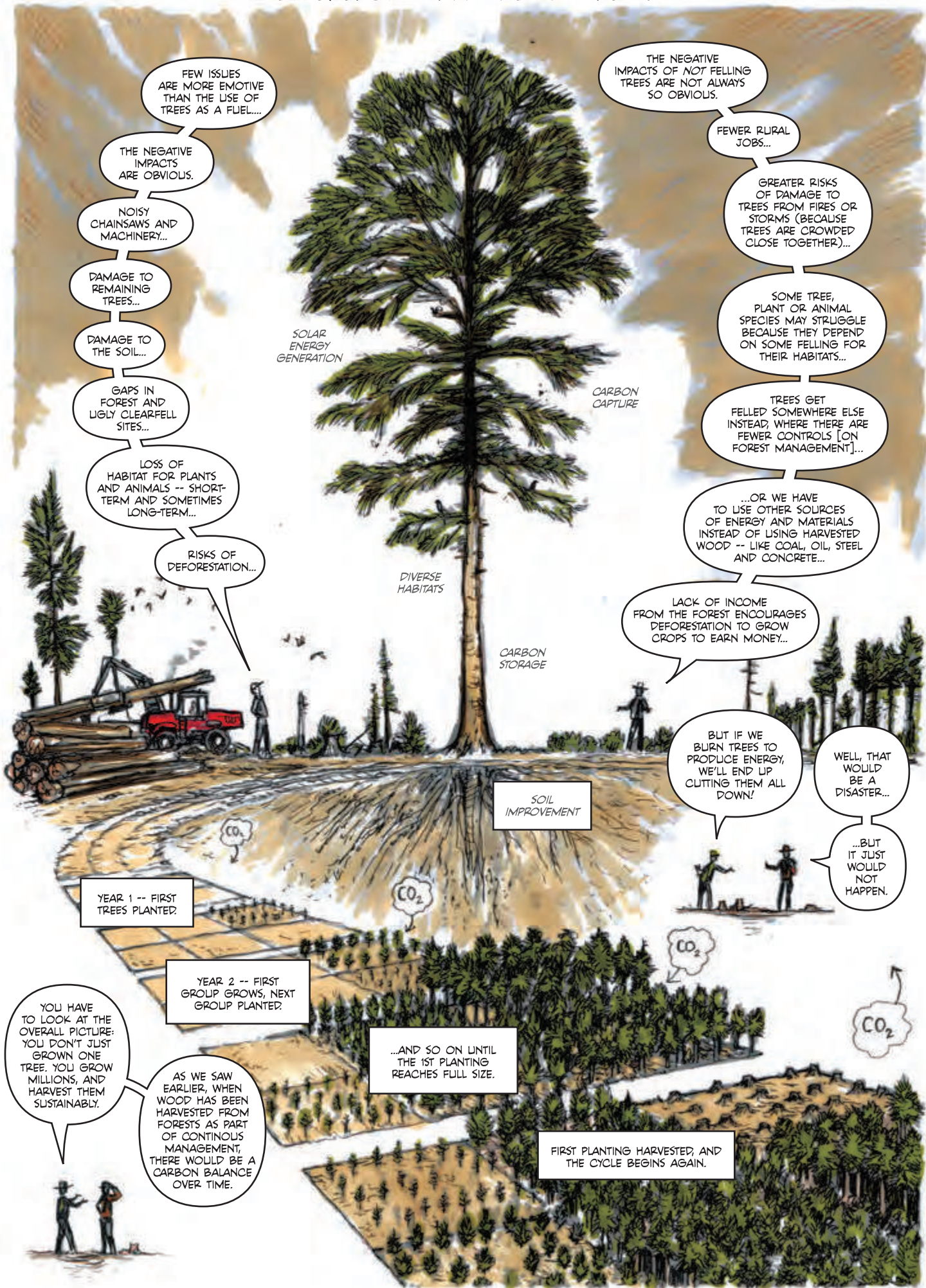
IT HAS TO BE STORED IN LARGE QUANTITIES -- AND THESE VOLUMES REQUIRE MORE TRAINS, TRUCKS AND CONVEYORS.

IT SOMETIMES HAS TO BE PROCESSED BEFORE USE IN POWER GENERATION OR TRANSPORT.



ALL OF THIS CAN MAKE IT MORE EXPENSIVE THAN FOSSIL FUELS. IF IT WASN'T FOR THE CARBON SAVINGS, IT WOULDN'T COMPETE.

BIOENERGY -- WHAT ABOUT TREES?



FEW ISSUES ARE MORE EMOTIVE THAN THE USE OF TREES AS A FUEL....

THE NEGATIVE IMPACTS ARE OBVIOUS.

NOISY CHAINSAWS AND MACHINERY...

DAMAGE TO REMAINING TREES...

DAMAGE TO THE SOIL...

GAPS IN FOREST AND UGLY CLEARFELL SITES...

LOSS OF HABITAT FOR PLANTS AND ANIMALS -- SHORT-TERM AND SOMETIMES LONG-TERM...

RISKS OF DEFORESTATION...

THE NEGATIVE IMPACTS OF NOT FELLING TREES ARE NOT ALWAYS SO OBVIOUS.

FEWER RURAL JOBS...

GREATER RISKS OF DAMAGE TO TREES FROM FIRES OR STORMS (BECAUSE TREES ARE CROWDED CLOSE TOGETHER)...

SOME TREE, PLANT OR ANIMAL SPECIES MAY STRUGGLE BECAUSE THEY DEPEND ON SOME FELLING FOR THEIR HABITATS...

TREES GET FELLED SOMEWHERE ELSE INSTEAD, WHERE THERE ARE FEWER CONTROLS [ON FOREST MANAGEMENT]...

...OR WE HAVE TO USE OTHER SOURCES OF ENERGY AND MATERIALS INSTEAD OF USING HARVESTED WOOD -- LIKE COAL, OIL, STEEL AND CONCRETE...

LACK OF INCOME FROM THE FOREST ENCOURAGES DEFORESTATION TO GROW CROPS TO EARN MONEY...

BUT IF WE BURN TREES TO PRODUCE ENERGY, WE'LL END UP CUTTING THEM ALL DOWN!

WELL, THAT WOULD BE A DISASTER...

...BUT IT JUST WOULD NOT HAPPEN.

YEAR 1 -- FIRST TREES PLANTED.

YEAR 2 -- FIRST GROUP GROWS, NEXT GROUP PLANTED.

...AND SO ON UNTIL THE 1ST PLANTING REACHES FULL SIZE.

FIRST PLANTING HARVESTED, AND THE CYCLE BEGINS AGAIN.

YOU HAVE TO LOOK AT THE OVERALL PICTURE: YOU DON'T JUST GROWN ONE TREE. YOU GROW MILLIONS, AND HARVEST THEM SUSTAINABLY.

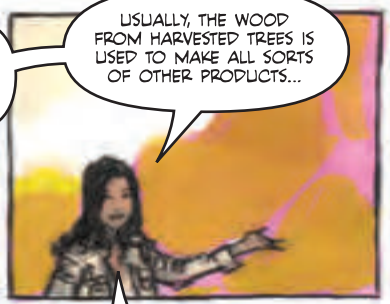
AS WE SAW EARLIER, WHEN WOOD HAS BEEN HARVESTED FROM FORESTS AS PART OF CONTINUOUS MANAGEMENT, THERE WOULD BE A CARBON BALANCE OVER TIME.



HOWEVER, WE'VE ALSO SEEN THAT THE SITUATION IS VERY DIFFERENT IF WE GREATLY INCREASE THE AMOUNT OF WOOD WE HARVEST FROM FORESTS.

THIS LEADS TO A 'CARBON DEBT' - WHICH CAN BE BIG WHEN MORE WHOLE TREES ARE HARVESTED FOR BIOENERGY.

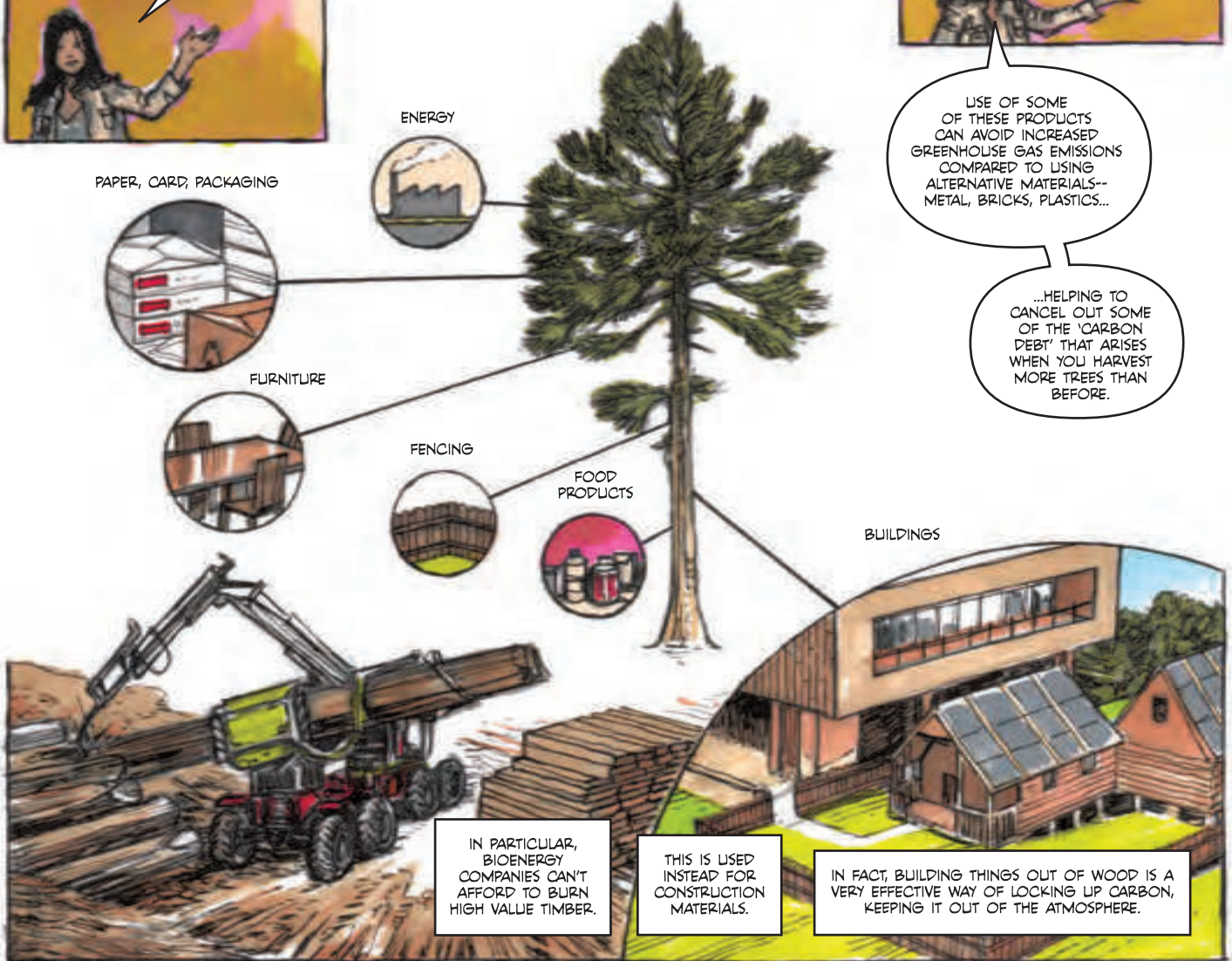
BUT THIS ISN'T THE WHOLE STORY:



USUALLY, THE WOOD FROM HARVESTED TREES IS USED TO MAKE ALL SORTS OF OTHER PRODUCTS...

USE OF SOME OF THESE PRODUCTS CAN AVOID INCREASED GREENHOUSE GAS EMISSIONS COMPARED TO USING ALTERNATIVE MATERIALS--METAL, BRICKS, PLASTICS...

...HELPING TO CANCEL OUT SOME OF THE 'CARBON DEBT' THAT ARISES WHEN YOU HARVEST MORE TREES THAN BEFORE.



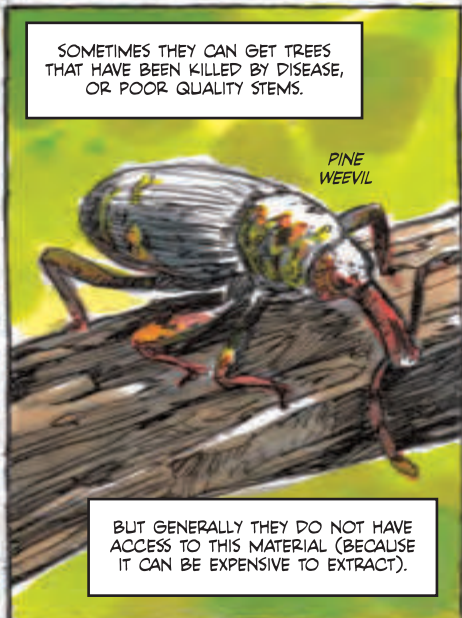
IN PARTICULAR, BIOENERGY COMPANIES CAN'T AFFORD TO BURN HIGH VALUE TIMBER.

THIS IS USED INSTEAD FOR CONSTRUCTION MATERIALS.

IN FACT, BUILDING THINGS OUT OF WOOD IS A VERY EFFECTIVE WAY OF LOCKING UP CARBON, KEEPING IT OUT OF THE ATMOSPHERE.



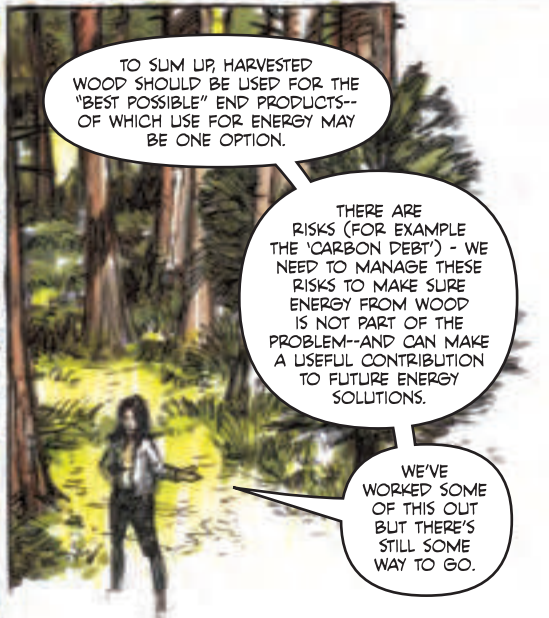
BIOENERGY COMPANIES GET THE LOWER VALUE MATERIALS (BRANCHES) OR WHERE SAWDUST OR PULP IS PRODUCED WHICH IS SURPLUS TO LOCAL NEEDS.



PINE WEEVIL

SOMETIMES THEY CAN GET TREES THAT HAVE BEEN KILLED BY DISEASE, OR POOR QUALITY STEMS.

BUT GENERALLY THEY DO NOT HAVE ACCESS TO THIS MATERIAL (BECAUSE IT CAN BE EXPENSIVE TO EXTRACT).

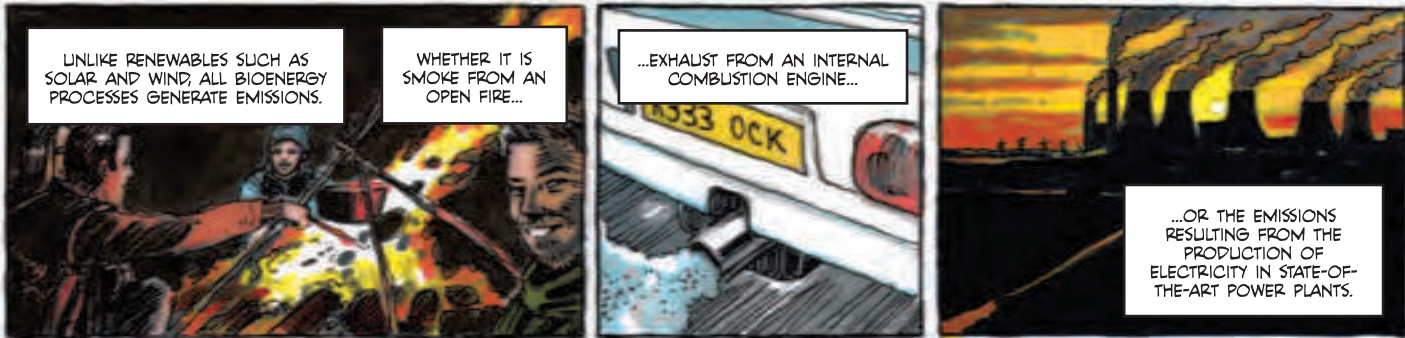


TO SUM UP, HARVESTED WOOD SHOULD BE USED FOR THE "BEST POSSIBLE" END PRODUCTS--OF WHICH USE FOR ENERGY MAY BE ONE OPTION.

THERE ARE RISKS (FOR EXAMPLE THE 'CARBON DEBT') - WE NEED TO MANAGE THESE RISKS TO MAKE SURE ENERGY FROM WOOD IS NOT PART OF THE PROBLEM--AND CAN MAKE A USEFUL CONTRIBUTION TO FUTURE ENERGY SOLUTIONS.

WE'VE WORKED SOME OF THIS OUT BUT THERE'S STILL SOME WAY TO GO.

BIOENERGY -- EMISSIONS

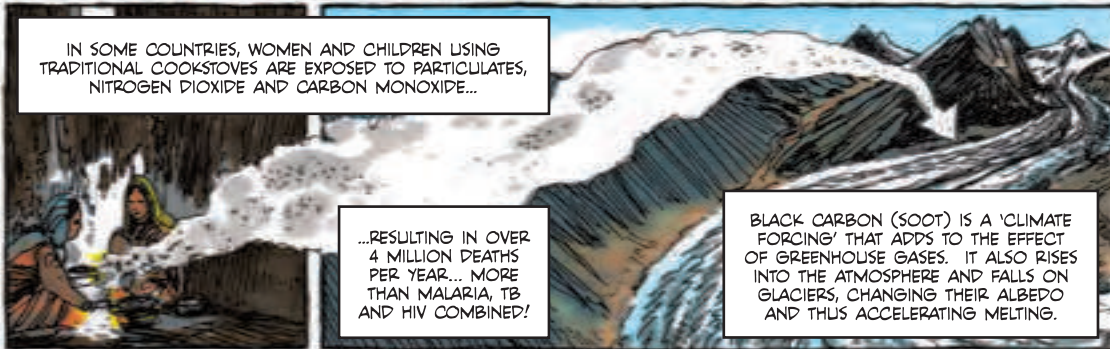


UNLIKE RENEWABLES SUCH AS SOLAR AND WIND, ALL BIOENERGY PROCESSES GENERATE EMISSIONS.

WHETHER IT IS SMOKE FROM AN OPEN FIRE...

...EXHAUST FROM AN INTERNAL COMBUSTION ENGINE...

...OR THE EMISSIONS RESULTING FROM THE PRODUCTION OF ELECTRICITY IN STATE-OF-THE-ART POWER PLANTS.



IN SOME COUNTRIES, WOMEN AND CHILDREN USING TRADITIONAL COOKSTOVES ARE EXPOSED TO PARTICULATES, NITROGEN DIOXIDE AND CARBON MONOXIDE...

...RESULTING IN OVER 4 MILLION DEATHS PER YEAR... MORE THAN MALARIA, TB AND HIV COMBINED!

BLACK CARBON (SOOT) IS A 'CLIMATE FORCING' THAT ADDS TO THE EFFECT OF GREENHOUSE GASES. IT ALSO RISES INTO THE ATMOSPHERE AND FALLS ON GLACIERS, CHANGING THEIR ALBEDO AND THUS ACCELERATING MELTING.



NOW, NEW CLEAN BURNING COOKSTOVES ARE HAVING A HUGE POSITIVE IMPACT ON HEALTH AND CLIMATE.

JUST AS WITH FOSSIL FUELS, THE EMISSIONS FROM BIOENERGY PROCESSES HAVE A NEGATIVE IMPACT ON AIR QUALITY, WHICH IS BEING ADDRESSED THROUGH NEW TECHNOLOGIES:

ACID RAIN
NO_x (NITRIC OXIDE + NITROGEN DIOXIDE) AND SO_x (SULPHUR DIOXIDE + SULPHUR TRIOXIDE) CAUSE ACID RAIN.

(HOWEVER, UNLIKE FOSSIL FUELS, THERE IS LITTLE SO_x IN BIOMASS EMISSIONS, AND NO_x FROM LARGE-SCALE COMBUSTION IS USUALLY LOWER (COMPARED TO COAL).

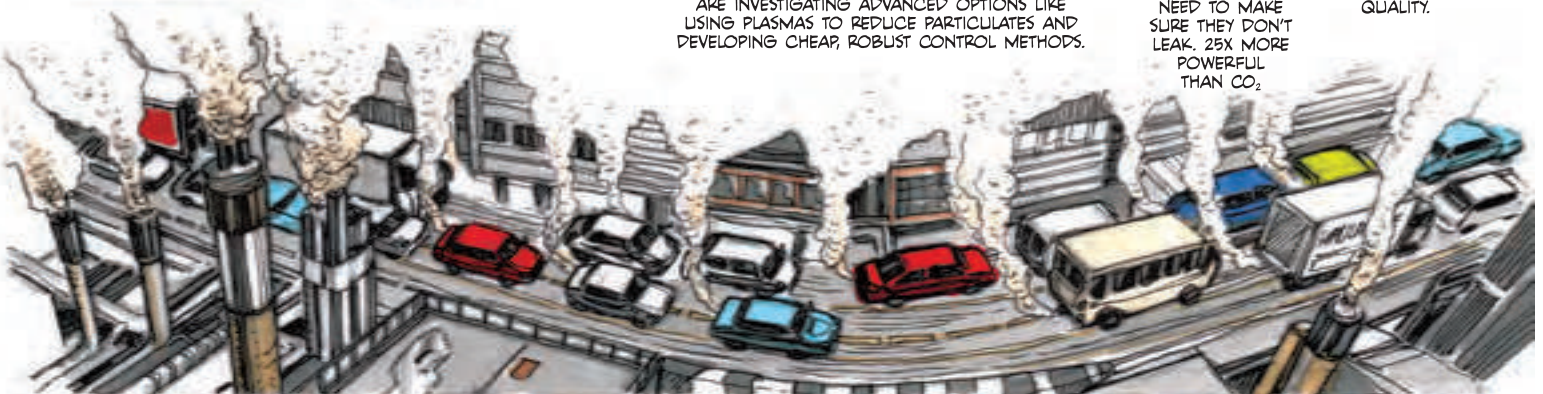
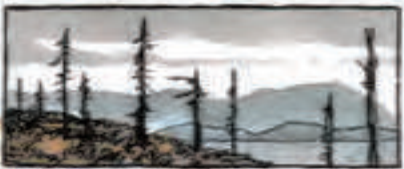
SMOG
HISTORICALLY THIS WAS THE RESULT OF BURNING COAL ON OPEN FIRES (SO_x AND SOOT). TODAY, IT IS CAUSED BY POWER STATIONS, CAR EXHAUSTS AND SMALLER-SCALE WOOD BURNERS (NO_x, SO_x, CARBON MONOXIDE, POLYCYCLIC AROMATIC COMPOUNDS (PAHS), VOLATILE ORGANIC COMPOUNDS (VOCs) - THESE ARE ALL HAZARDS TO RESPIRATORY HEALTH.

CLIMATE FORCING
SOME EMISSIONS HAVE A WARMING EFFECT, SOME ACTUALLY HAVE A COOLING EFFECT.

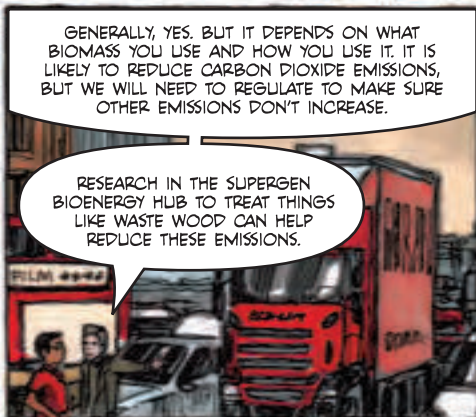
WARMING	COOLING
CARBON DIOXIDE (CO ₂)	SULPHUR DIOXIDE
NITROUS OXIDE (ARISES WHEN WE USE NITROGEN BASED FERTILISERS) - 300X MORE POWERFUL THAN CO ₂	PARTICULATES LIKE BLACK CARBON (SOOT) CAUSE 'GLOBAL DIMMING' MASKING THE EFFECT OF GLOBAL WARMING-- THIS COULD BE A PROBLEM AS WE BEGIN TO IMPROVE AIR QUALITY.
METHANE (FROM ANAEROBIC DIGESTION PLANTS) - WE NEED TO MAKE SURE THEY DON'T LEAK. 25X MORE POWERFUL THAN CO ₂	

LUCKILY, LARGE BIOENERGY FACILITIES ALREADY HAVE TECHNOLOGIES FITTED TO ABATE THESE EMISSIONS. IT IS MORE DIFFICULT TO CONTROL EMISSIONS FROM SMALLER-SCALE DEVICES AND TRANSPORT, BUT TECHNOLOGIES AND REGULATIONS ARE ACTING TO REDUCE THEM.

SUPERGEN BIOENERGY HUB RESEARCHERS ARE INVESTIGATING ADVANCED OPTIONS LIKE USING PLASMAS TO REDUCE PARTICULATES AND DEVELOPING CHEAP, ROBUST CONTROL METHODS.

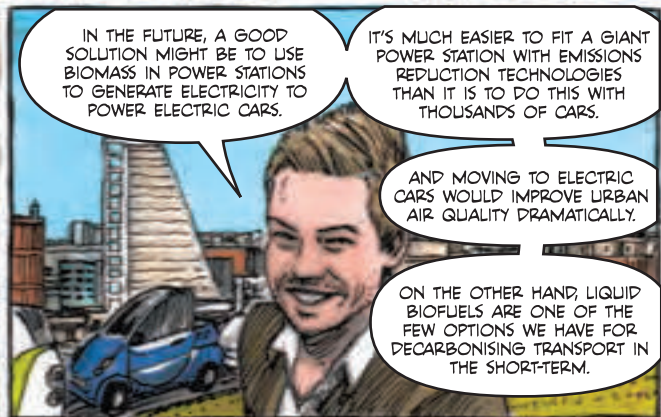


WHAT I'D LIKE TO KNOW IS: DOES BURNING BIOMASS RESULT IN LESS POLLUTION THAN BURNING FOSSIL FUELS?



GENERALLY, YES. BUT IT DEPENDS ON WHAT BIOMASS YOU USE AND HOW YOU USE IT. IT IS LIKELY TO REDUCE CARBON DIOXIDE EMISSIONS, BUT WE WILL NEED TO REGULATE TO MAKE SURE OTHER EMISSIONS DON'T INCREASE.

RESEARCH IN THE SUPERGEN BIOENERGY HUB TO TREAT THINGS LIKE WASTE WOOD CAN HELP REDUCE THESE EMISSIONS.



IN THE FUTURE, A GOOD SOLUTION MIGHT BE TO USE BIOMASS IN POWER STATIONS TO GENERATE ELECTRICITY TO POWER ELECTRIC CARS.

IT'S MUCH EASIER TO FIT A GIANT POWER STATION WITH EMISSIONS REDUCTION TECHNOLOGIES THAN IT IS TO DO THIS WITH THOUSANDS OF CARS.

AND MOVING TO ELECTRIC CARS WOULD IMPROVE URBAN AIR QUALITY DRAMATICALLY.

ON THE OTHER HAND, LIQUID BIOFUELS ARE ONE OF THE FEW OPTIONS WE HAVE FOR DECARBONISING TRANSPORT IN THE SHORT-TERM.

BIOENERGY -- LAND USE CHANGE

BIOMASS PRODUCTION CHANGES THE WAY LAND IS USED, AND THIS CAN HAVE POSITIVE AND NEGATIVE IMPACTS - DEPENDING ON WHERE YOU START AND WHERE YOU FINISH.

IF YOU START WITH A FOOD CROP:

- X HIGH CHEMICAL FERTILISER INPUTS
- X OFTEN LOW BIODIVERSITY
- X NEGATIVE IMPACTS ON WATER QUALITY
- X SOIL DEGRADATION
- X LOSS OF CARBON STORED IN SOIL



CONVERT TO A FOOD CROP USED FOR ENERGY:

- X SAME ENVIRONMENTAL IMPACTS FROM CULTIVATION
- X LOSS OF PRIME AGRICULTURAL LAND
- X COULD DISPLACE FOOD PRODUCTION ELSEWHERE



CONVERT TO GRASSES (LIKE MISCANTHUS) OR WOODY CROPS (LIKE WILLOW) USED FOR ENERGY:

- ✓ IMPROVEMENTS IN BIODIVERSITY (IN SOME CASES)
- ✓ LOWER FERTILISER USE (IN SOME CASES)
- ✓ POTENTIAL TO INCREASE CARBON STORED IN SOIL
- X LOSS OF PRIME AGRICULTURAL LAND
- X COULD DISPLACE FOOD PRODUCTION ELSEWHERE



CONVERT TO AGROFORESTRY (A MIXTURE OF ENERGY AND FOOD CROPS):

- ✓ FEWER FERTILISERS
- ✓ IMPROVES SOIL QUALITY
- ✓ PROTECTS WATERWAYS
- ✓ INCREASES BIODIVERSITY
- ✓ INCREASES CARBON STORED IN SOIL



CONVERT TO GRASSES (LIKE MISCANTHUS) OR WOODY CROPS (LIKE WILLOW) USED FOR ENERGY:

- ✓ PROTECTS SOILS FROM EROSION
- ✓ IMPROVED BIODIVERSITY
- X INCREASED USE OF FERTILISERS



IF YOU START WITH "MARGINAL LAND" (ABANDONED OR DEGRADED AGRICULTURAL LAND):

- X LOW BIODIVERSITY
- X SOIL EROSION



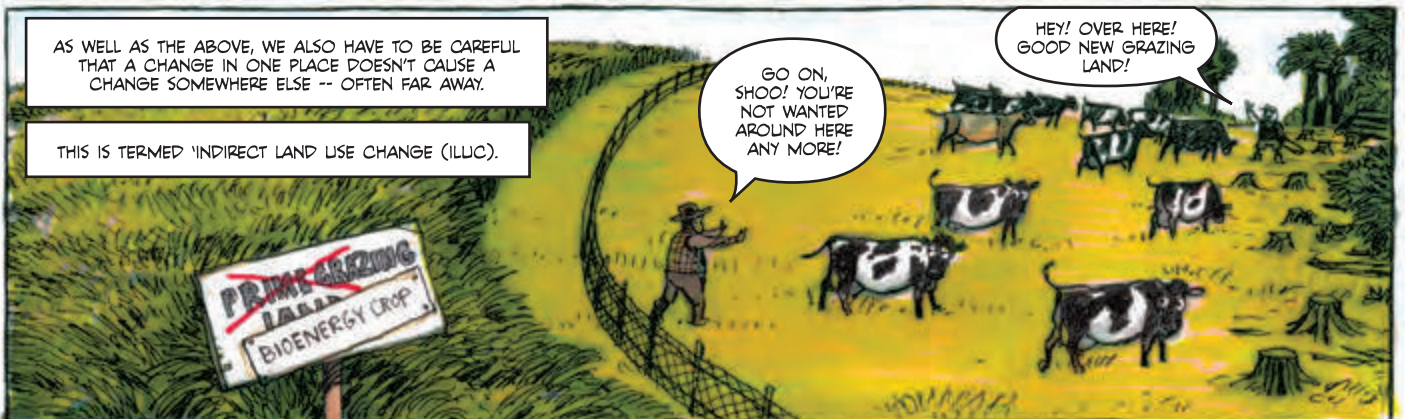
CONVERT TO FOREST FOR WOOD PRODUCTS AND BIOENERGY:

- ✓ DECREASED SOIL EROSION
- ✓ LARGE INCREASE IN CARBON STORED IN SOIL
- ✓ PROTECTS WATERWAYS AND WATER QUALITY
- ✓ LARGER INCREASE IN BIODIVERSITY



AS WELL AS THE ABOVE, WE ALSO HAVE TO BE CAREFUL THAT A CHANGE IN ONE PLACE DOESN'T CAUSE A CHANGE SOMEWHERE ELSE -- OFTEN FAR AWAY.

THIS IS TERMED 'INDIRECT LAND USE CHANGE (ILUC).



BIOENERGY -- FOOD VS FUEL

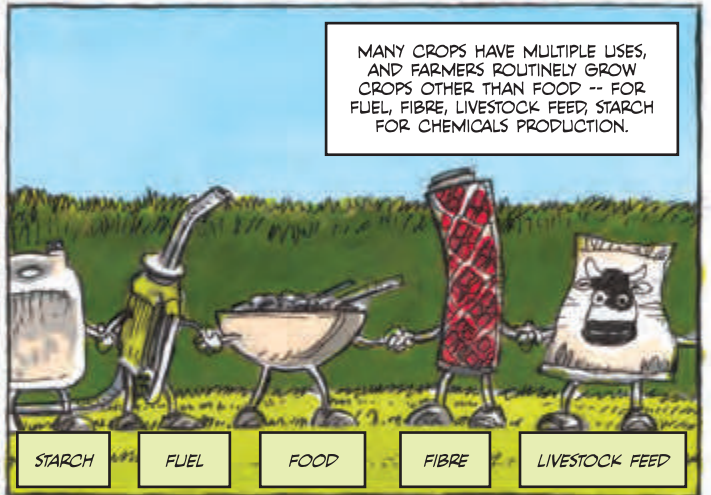
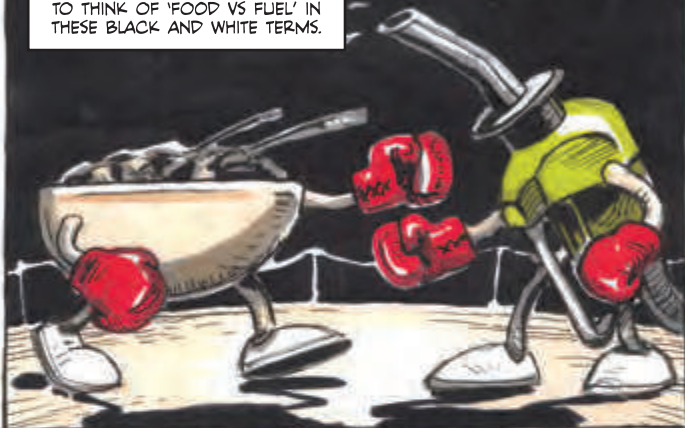
THERE IS A RISK THAT USING LAND TO PRODUCE BIOMASS FOR FUEL MIGHT RESULT IN CONFLICT WITH USE OF LAND FOR PRODUCING FOOD.

SOME ENVIRONMENTAL ORGANISATIONS HAVE WARNED THAT GROWING CROPS FOR FUEL RISKS EXACERBATING POVERTY IN THE GLOBAL SOUTH.



HOWEVER, IT MAY BE A MISTAKE TO THINK OF 'FOOD VS FUEL' IN THESE BLACK AND WHITE TERMS.

MANY CROPS HAVE MULTIPLE USES, AND FARMERS ROUTINELY GROW CROPS OTHER THAN FOOD -- FOR FUEL, FIBRE, LIVESTOCK FEED, STARCH FOR CHEMICALS PRODUCTION.



YEAR 1

YEAR 2

THE PROPORTION OF A CROP GROWN FOR FOOD WILL CHANGE FROM YEAR TO YEAR, DEPENDING ON A COMPLEX MIX OF FACTORS INCLUDING GLOBAL PRICES.

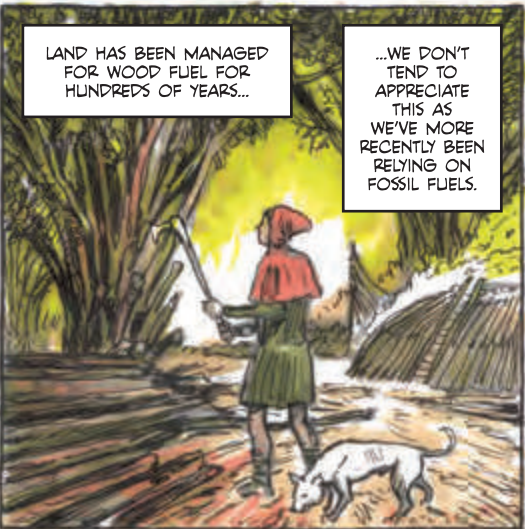


FARMING ALSO PROVIDES LOTS OF OTHER SERVICES (WHEN DONE RIGHT) - IT'S NOT JUST ABOUT PROVIDING ONE THING.



LAND HAS BEEN MANAGED FOR WOOD FUEL FOR HUNDREDS OF YEARS...

...WE DON'T TEND TO APPRECIATE THIS AS WE'VE MORE RECENTLY BEEN RELYING ON FOSSIL FUELS.



IT'S CLEAR THAT 'FOOD VS FUEL' IS A MAJOR OVERSIMPLIFICATION...

BUT IT DOES SERVE TO HIGHLIGHT THE DANGER OF OVERCONSUMPTION OF RESOURCES.

AND SHOWS THAT A LOT DEPENDS ON HOW WE MANAGE BIOENERGY.



HERE AT THE SUPERGEN BIOENERGY HUB, WE TAKE ALL THESE ISSUES VERY SERIOUSLY. OUR RESEARCH IS ALL ABOUT ASKING DIFFICULT AND AWKWARD QUESTIONS...

...IN ORDER TO UNDERSTAND WHAT THE IMPACT OF OUR CHOICES WILL BE.

LET'S LOOK AT ONE OF THE METHODS WE USE TO THINK THROUGH PROBLEMS AND COME UP WITH SOLUTIONS.



FUTURE #1--WHERE WE FAIL TO ACT

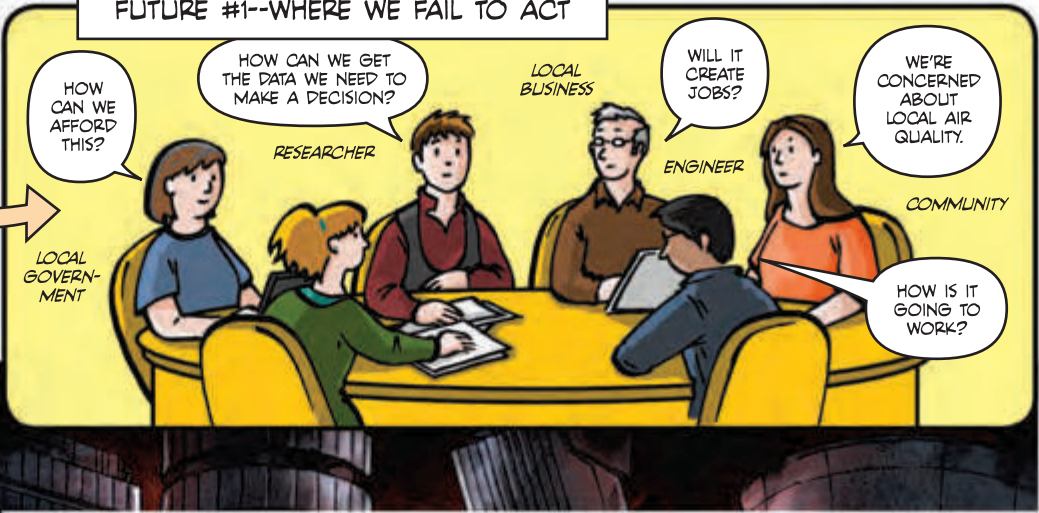
ONE WAY IS TO BRING PEOPLE TOGETHER TO COME UP WITH DIFFERENT STORIES OR VISIONS OF THE FUTURE.

EACH STORY LOOKS AT DIFFERENT WAYS BIOENERGY MIGHT BE IMPLEMENTED, AND WHAT THIS MIGHT MEAN.

THESE VISIONS ARE NOT "PREDICTIONS" -- THEY ARE THOUGHT EXPERIMENTS.

IN THE FIRST VISION, WE LOOK AT A FUTURE WHERE WE FAIL TO TAKE CLIMATE CHANGE SERIOUSLY, AND UPTAKE OF ALL THE RENEWABLE ENERGY TECHNOLOGIES HAPPENS TOO SLOWLY.

IT'S A STORY OF "TOO LITTLE, TOO LATE", OR "BUSINESS AS USUAL". THIS IS WHERE WE'RE HEADING IF WE DON'T GET OUR ACT TOGETHER!



2020s

2030s

2040s



GOVERNMENTS FOCUS MORE ON ECONOMIC GROWTH WITH LITTLE REGARD FOR CLIMATE CHANGE AGREEMENTS.

THEY FAIL TO INVEST IN RENEWABLE ENERGY TECHNOLOGIES.

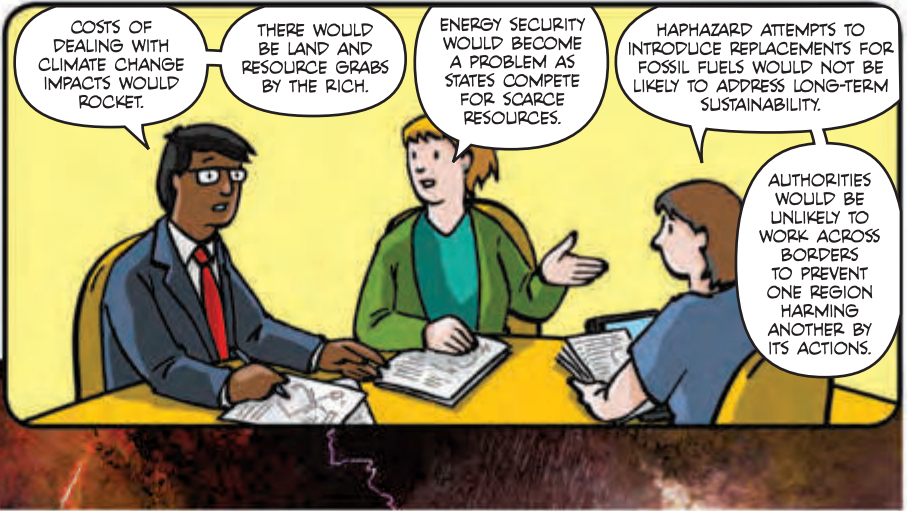
THEY ALSO GET RID OF REGULATIONS DESIGNED TO PREVENT NEGATIVE IMPACTS OF TECHNOLOGIES.





IN A SITUATION LIKE THIS, IT WOULD BE INCREDIBLY DIFFICULT TO TACKLE THE CHALLENGE OF CLIMATE CHANGE BY MOVING AWAY FROM FOSSIL FUELS.

2050s



COSTS OF DEALING WITH CLIMATE CHANGE IMPACTS WOULD ROCKET.

THERE WOULD BE LAND AND RESOURCE GRABS BY THE RICH.

ENERGY SECURITY WOULD BECOME A PROBLEM AS STATES COMPETE FOR SCARCE RESOURCES.

HAPHAZARD ATTEMPTS TO INTRODUCE REPLACEMENTS FOR FOSSIL FUELS WOULD NOT BE LIKELY TO ADDRESS LONG-TERM SUSTAINABILITY.

AUTHORITIES WOULD BE UNLIKELY TO WORK ACROSS BORDERS TO PREVENT ONE REGION HARMING ANOTHER BY ITS ACTIONS.

2060s

2070s

2080s



CLIMATE CHANGE ACCELERATES, LEADING TO UNPREDICTABLE WEATHER, AFFECTING WATER AVAILABILITY AND MAKING CROPS VULNERABLE TO DISEASE.

MOBILITY BECOMES MORE DIFFICULT AS OIL RESOURCES BECOME SCARCE AND PRICES ROCKET.

THERE MIGHT BE INCREASES IN CONFLICTS AND TENSIONS OVER LAND.

THE IMPACT OF FLOODING EVENTS WOULD BE WORSENERD DUE TO DEFORESTATION.

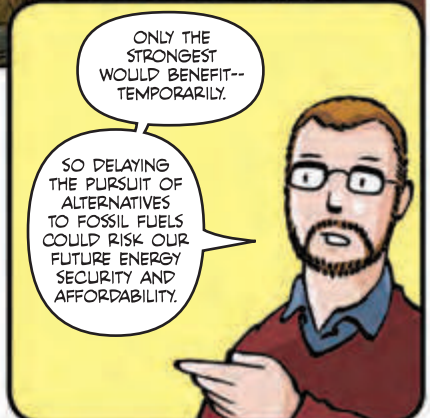
NUTRIENT EXHAUSTION, SOIL DEGRADATION AND DESERTIFICATION WOULD OCCUR AS A RESULT OF COMPETING PRESSURES FOR LAND -- FOOD, FUEL, FIBRES, LIVESTOCK FEED.



AT THE SAME TIME AS ALL THESE PROBLEMS, FOSSIL FUELS WOULD BE BECOMING UNAFFORDABLE.

KEEP OUT
MANTENGASE
AFUERA

IN THIS SITUATION, IT IS EASY TO SEE HOW A PANICKY RUSH FOR ALTERNATIVES TO FOSSIL FUELS COULD CAUSE CONFLICT.



ONLY THE STRONGEST WOULD BENEFIT-- TEMPORARILY.

SO DELAYING THE PURSUIT OF ALTERNATIVES TO FOSSIL FUELS COULD RISK OUR FUTURE ENERGY SECURITY AND AFFORDABILITY.

FUTURE #2--CENTRALISED, LARGE-SCALE BIOENERGY

THE PROBLEMS WHEN WE Muddle THROUGH WITHOUT CAREFUL PLANNING SEEM PRETTY OBVIOUS...

...SO WHAT MIGHT HAPPEN IF BIOENERGY WERE IMPLEMENTED IN A THOROUGH, WELL MAINTAINED WAY, WITH A FOCUS ON CREATING A HIGH-TECH, LARGE-SCALE BIOENERGY FUTURE?

WOULD WE AVOID THE PROBLEMS WE'VE JUST SEEN?

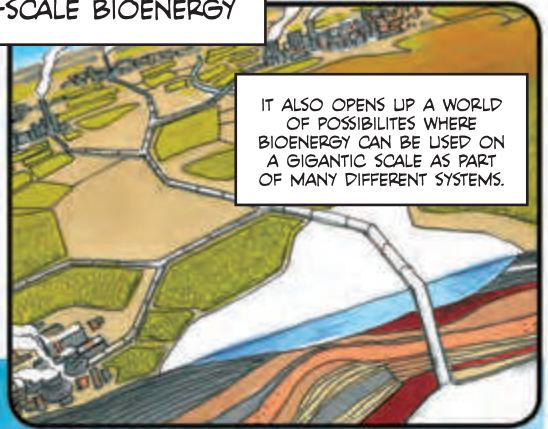
WE COULD USE A BIOENERGY WITH CARBON CAPTURE AND STORAGE SYSTEM (BECCS) TO EXTRACT CARBON DIOXIDE FROM THE ATMOSPHERE, MAKING IT MUCH MORE LIKELY THAT CARBON EMISSIONS REDUCTIONS COULD BE ACHIEVED.

BUT IS THIS REALISTIC?



ALL CLIMATE SCENARIOS WHERE WE KEEP BELOW 2°C RELY ON BECCS* BECAUSE IT SEEMS LIKE THE MOST PLAUSIBLE SOLUTION TO REMOVING CARBON DIOXIDE FROM THE ATMOSPHERE.

* SEE PAGE 8

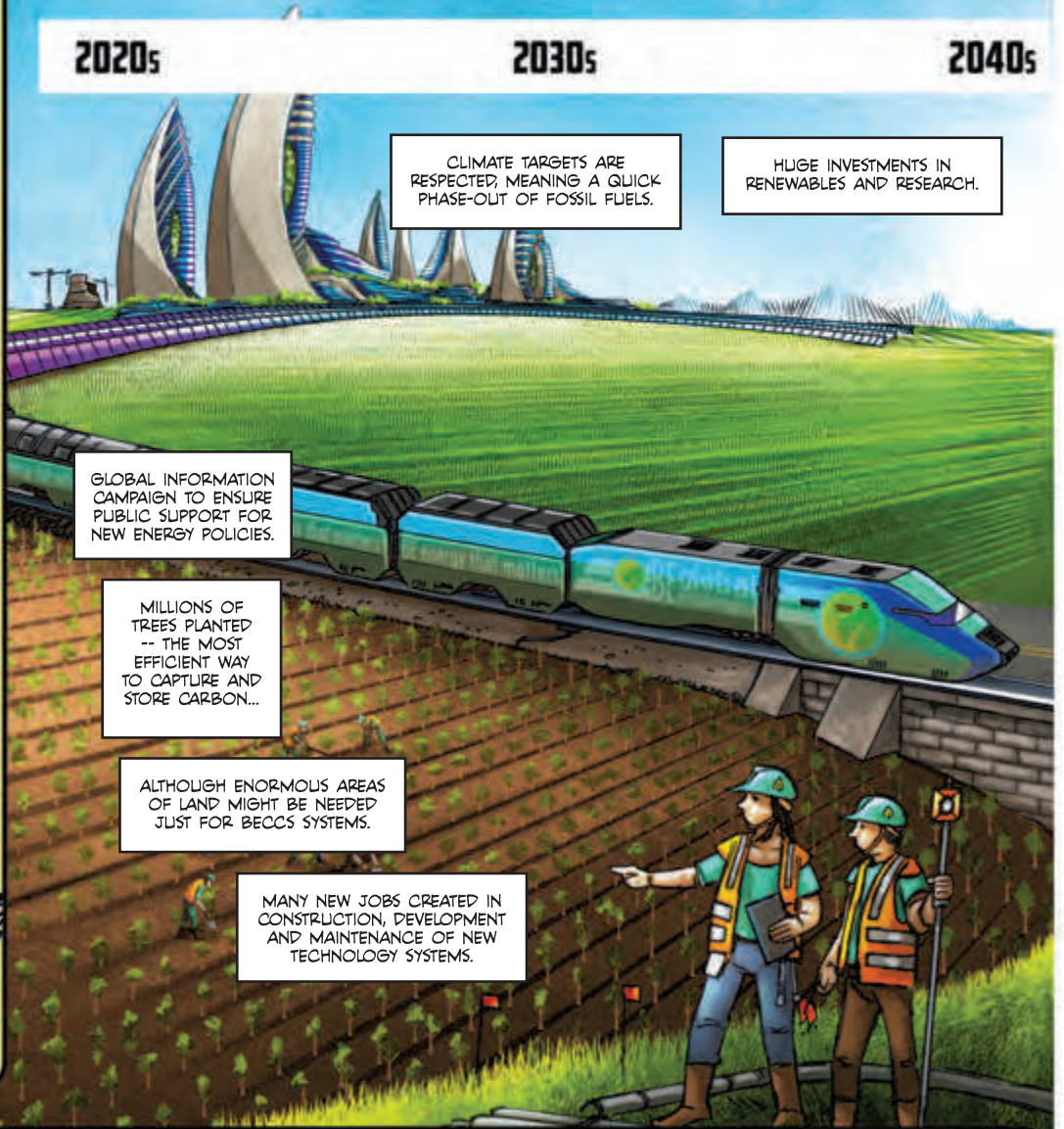


IT ALSO OPENS UP A WORLD OF POSSIBILITIES WHERE BIOENERGY CAN BE USED ON A GIGANTIC SCALE AS PART OF MANY DIFFERENT SYSTEMS.

2020s

2030s

2040s



CLIMATE TARGETS ARE RESPECTED, MEANING A QUICK PHASE-OUT OF FOSSIL FUELS.

HUGE INVESTMENTS IN RENEWABLES AND RESEARCH.

GLOBAL INFORMATION CAMPAIGN TO ENSURE PUBLIC SUPPORT FOR NEW ENERGY POLICIES.

MILLIONS OF TREES PLANTED -- THE MOST EFFICIENT WAY TO CAPTURE AND STORE CARBON...

ALTHOUGH ENORMOUS AREAS OF LAND MIGHT BE NEEDED JUST FOR BECCS SYSTEMS.

MANY NEW JOBS CREATED IN CONSTRUCTION, DEVELOPMENT AND MAINTENANCE OF NEW TECHNOLOGY SYSTEMS.

BECCS REQUIRES LARGE INFRASTRUCTURE LIKE GIANT POWER STATIONS THAT CAN BE FITTED WITH CARBON CAPTURE TECHNOLOGY.

BECCS CAN BE LOCATED NEAR A CLUSTER OF LARGE INDUSTRIAL SITES, MAKING IT EASIER TO INSTALL A COMMON CARBON DIOXIDE TRANSPORT PIPELINE.

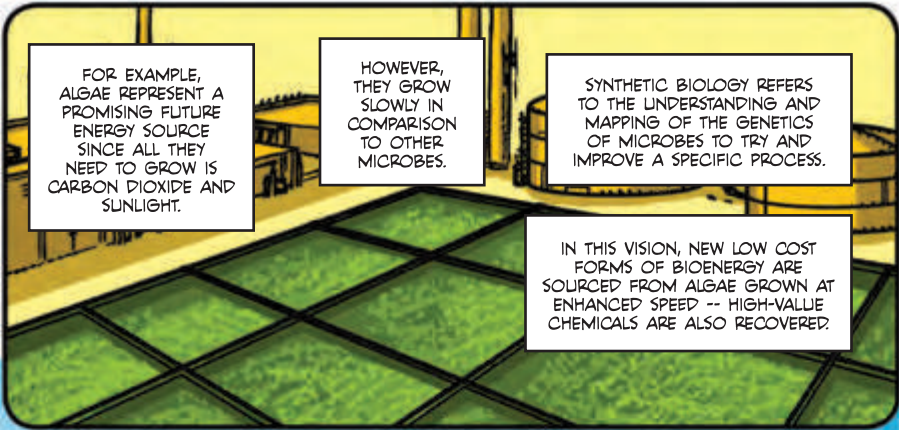


THE CARBON DIOXIDE CAN BE STORED IN DEPLETED OIL AND GAS RESERVOIRS. THIS TECHNOLOGY IS WELL-PROVEN, SO COULD BE IMPLEMENTED QUICKLY -- AT A COST.

BECCS WILL OF COURSE BE VERY COSTLY, BUT LESS COSTLY THAN THE ALTERNATIVES TO MEET CARBON REDUCTIONS AND CLIMATE CHANGE TARGETS.



IN THIS VISION, ANOTHER NEW TECHNOLOGY BROUGHT ONLINE IS SYNTHETIC BIOLOGY.



FOR EXAMPLE, ALGAE REPRESENT A PROMISING FUTURE ENERGY SOURCE SINCE ALL THEY NEED TO GROW IS CARBON DIOXIDE AND SUNLIGHT.

HOWEVER, THEY GROW SLOWLY IN COMPARISON TO OTHER MICROBES.

SYNTHETIC BIOLOGY REFERS TO THE UNDERSTANDING AND MAPPING OF THE GENETICS OF MICROBES TO TRY AND IMPROVE A SPECIFIC PROCESS.

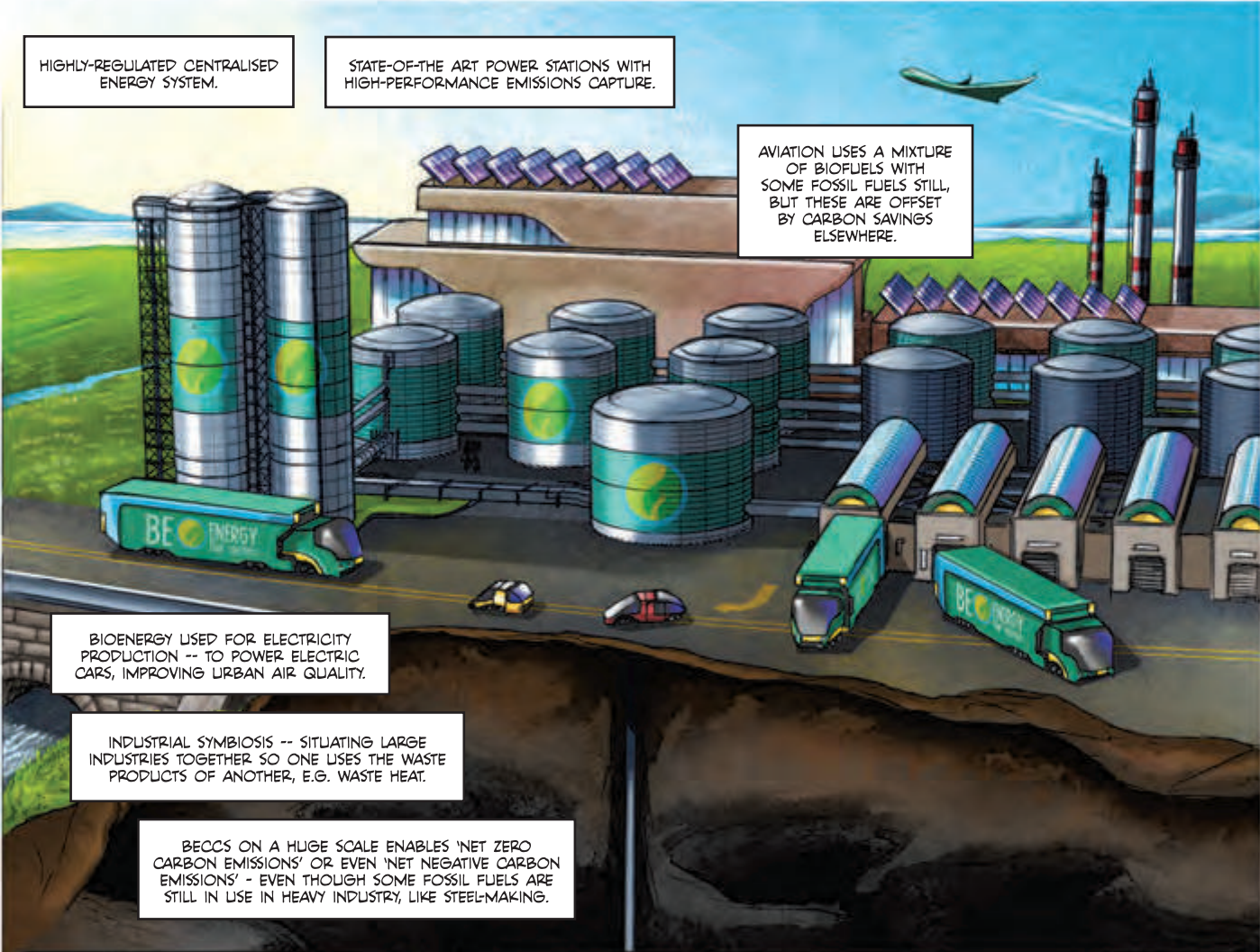
IN THIS VISION, NEW LOW COST FORMS OF BIOENERGY ARE SOURCED FROM ALGAE GROWN AT ENHANCED SPEED -- HIGH-VALUE CHEMICALS ARE ALSO RECOVERED.

2050s

2060s

2070s

2080s



HIGHLY-REGULATED CENTRALISED ENERGY SYSTEM.

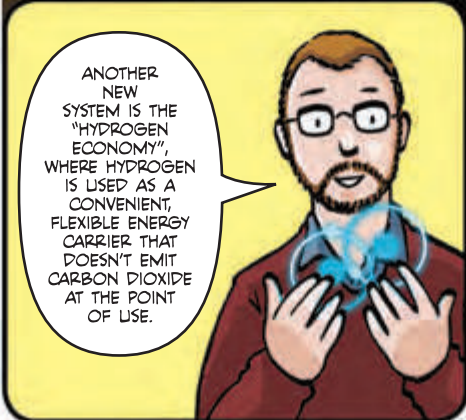
STATE-OF-THE ART POWER STATIONS WITH HIGH-PERFORMANCE EMISSIONS CAPTURE.

AVIATION USES A MIXTURE OF BIOFUELS WITH SOME FOSSIL FUELS STILL, BUT THESE ARE OFFSET BY CARBON SAVINGS ELSEWHERE.

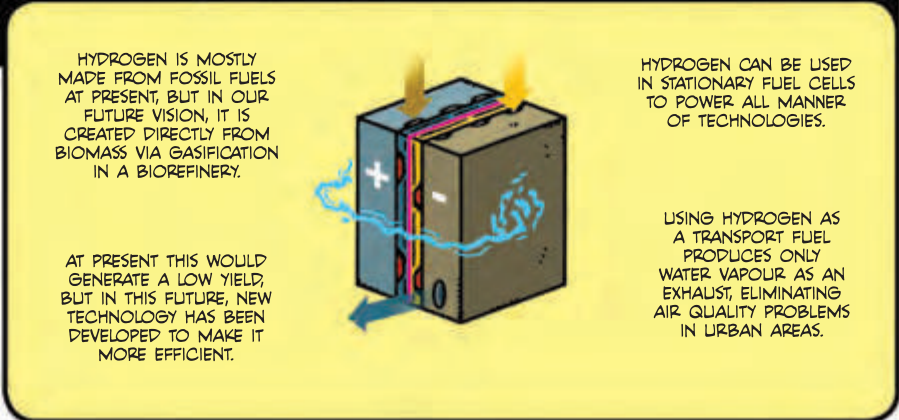
BIOENERGY USED FOR ELECTRICITY PRODUCTION -- TO POWER ELECTRIC CARS, IMPROVING URBAN AIR QUALITY.

INDUSTRIAL SYMBIOSIS -- SITUATING LARGE INDUSTRIES TOGETHER SO ONE USES THE WASTE PRODUCTS OF ANOTHER, E.G. WASTE HEAT.

BECCS ON A HUGE SCALE ENABLES 'NET ZERO CARBON EMISSIONS' OR EVEN 'NET NEGATIVE CARBON EMISSIONS' - EVEN THOUGH SOME FOSSIL FUELS ARE STILL IN USE IN HEAVY INDUSTRY, LIKE STEEL-MAKING.



ANOTHER NEW SYSTEM IS THE "HYDROGEN ECONOMY", WHERE HYDROGEN IS USED AS A CONVENIENT, FLEXIBLE ENERGY CARRIER THAT DOESN'T EMIT CARBON DIOXIDE AT THE POINT OF USE.



HYDROGEN IS MOSTLY MADE FROM FOSSIL FUELS AT PRESENT, BUT IN OUR FUTURE VISION, IT IS CREATED DIRECTLY FROM BIOMASS VIA GASIFICATION IN A BIOREFINERY.

HYDROGEN CAN BE USED IN STATIONARY FUEL CELLS TO POWER ALL MANNER OF TECHNOLOGIES.

AT PRESENT THIS WOULD GENERATE A LOW YIELD, BUT IN THIS FUTURE, NEW TECHNOLOGY HAS BEEN DEVELOPED TO MAKE IT MORE EFFICIENT.

USING HYDROGEN AS A TRANSPORT FUEL PRODUCES ONLY WATER VAPOUR AS AN EXHAUST, ELIMINATING AIR QUALITY PROBLEMS IN URBAN AREAS.

FUTURE #3--A DECENTRALISED BIOENERGY FUTURE

SO A SYSTEM OF PROVIDING ENERGY THAT IS CENTRALISED AND LARGE-SCALE MIGHT WORK. IT WOULD CERTAINLY ENABLE BECCS TO BECOME A REALITY.

BUT MIGHT THIS BE TOO AMBITIOUS? BECCS IS UNTESTED AT FULL-SCALE (ALTHOUGH THE DIFFERENT COMPONENTS OF THE PROCESS HAVE BEEN).

BECCS MIGHT BE COUNTER-PRODUCTIVE. IT IMPLIES THAT WE HAVE A 'GET OUT OF JAIL' CARD AND CAN CONTINUE ON OUR PRESENT COURSE, RELYING ON THE PROMISE OF BEING ABLE TO REMOVE CARBON DIOXIDE FROM THE ATMOSPHERE IN THE FUTURE.

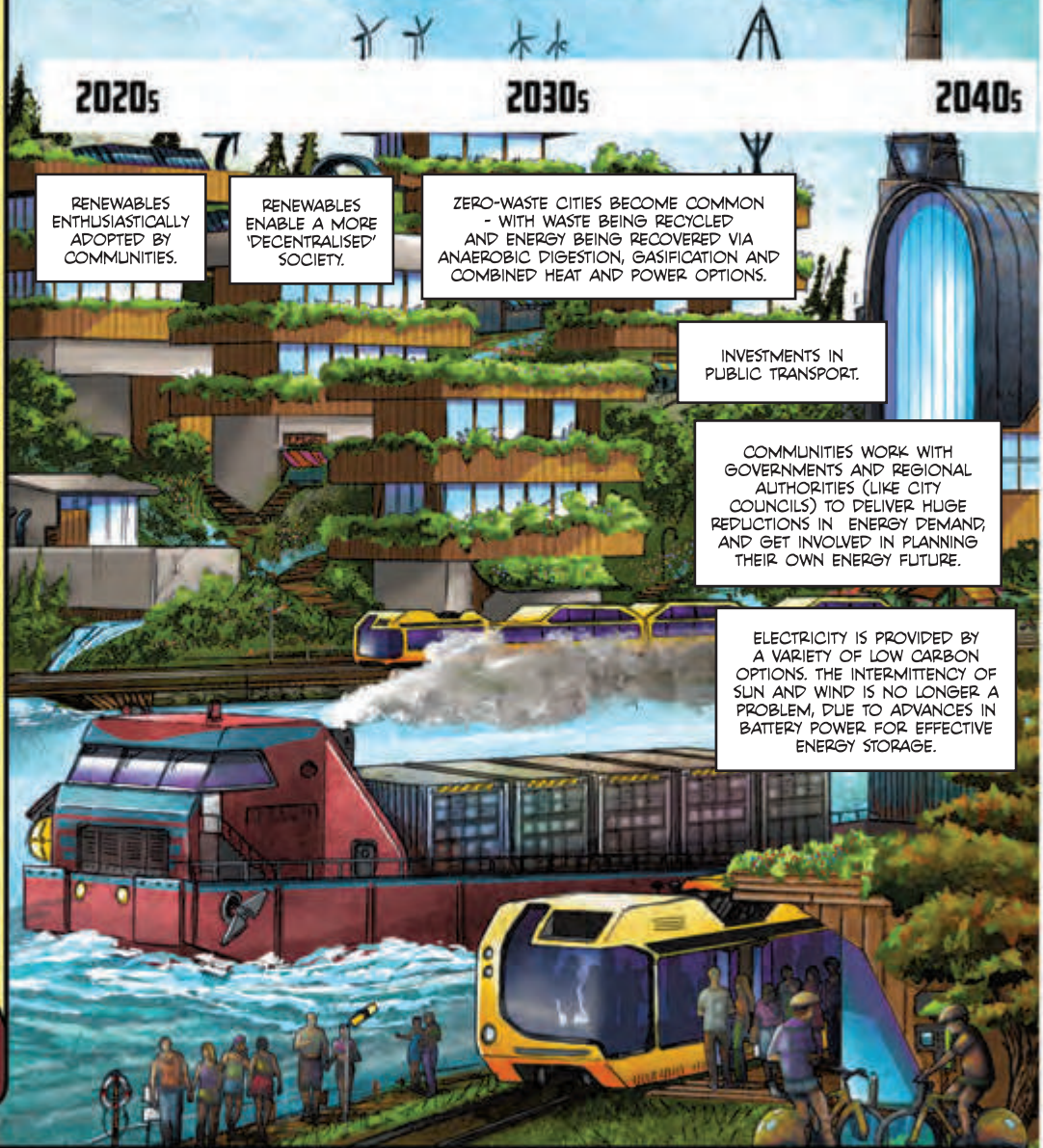
SO WHAT ARE THE OPTIONS AVAILABLE IF WE FOCUS ON A MORE SMALL-SCALE, LESS CENTRALISED APPROACH?



SO BECCS IS NOT AVAILABLE. THIS DRASTICALLY REDUCES OUR CHOICES. WE HAVE NO OPTION BUT TO MAKE VERY QUICK REDUCTIONS IN ENERGY DEMAND.

I'M PRETTY SURE WE NEED TO DO THAT REGARDLESS -- ENERGY DEMAND REDUCTION IS THE QUICKEST, LOWEST-COST WAY TO MAKE A DIFFERENCE -- WHATEVER COURSE WE TAKE.

BUT THIS WILL CHANGE THE WAY WE LIVE. WE'LL NEED TO FULLY IMPLEMENT A CIRCULAR ECONOMY BASED ON GETTING THE BEST USE OUT OF PRODUCTS BEFORE WE USE THEM FOR ENERGY.



2020s

2030s

2040s

RENEWABLES ENTHUSIASTICALLY ADOPTED BY COMMUNITIES.

RENEWABLES ENABLE A MORE 'DECENTRALISED' SOCIETY.

ZERO-WASTE CITIES BECOME COMMON - WITH WASTE BEING RECYCLED AND ENERGY BEING RECOVERED VIA ANAEROBIC DIGESTION, GASIFICATION AND COMBINED HEAT AND POWER OPTIONS.

INVESTMENTS IN PUBLIC TRANSPORT.

COMMUNITIES WORK WITH GOVERNMENTS AND REGIONAL AUTHORITIES (LIKE CITY COUNCILS) TO DELIVER HUGE REDUCTIONS IN ENERGY DEMAND, AND GET INVOLVED IN PLANNING THEIR OWN ENERGY FUTURE.

ELECTRICITY IS PROVIDED BY A VARIETY OF LOW CARBON OPTIONS. THE INTERMITTENCY OF SUN AND WIND IS NO LONGER A PROBLEM, DUE TO ADVANCES IN BATTERY POWER FOR EFFECTIVE ENERGY STORAGE.

BIOENERGY IS USED FOR AVIATION AND SHIPPING.

IN A WORLD OF MASSIVE DEMAND REDUCTION, THERE IS LESS NEED FOR MOVEMENT OF GOODS.

FLETTNER ROTORS

KYTOONS

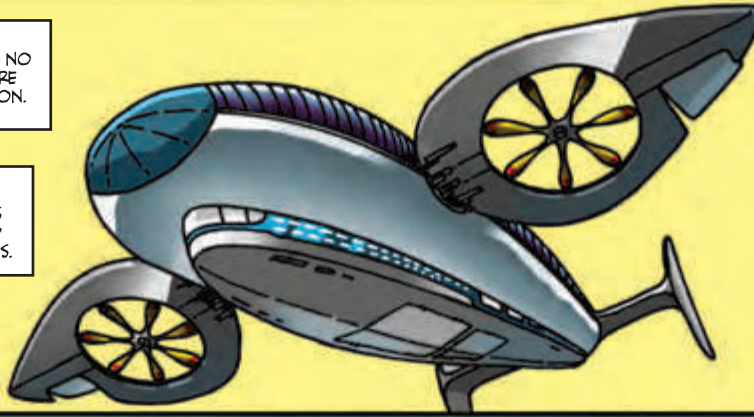
PARTICULARLY AS A LARGE FRACTION OF SHIPPING IN THE EARLY 21ST CENTURY INVOLVED MOVING FOSSIL FUELS AROUND.

FOR ESSENTIAL TRADE (INCLUDING MOVEMENT OF BIOMASS AROUND THE WORLD), SHIPPING IS STILL IMPORTANT AND POWERED BY BIOENERGY, IN COMBINATION WITH OTHER RENEWABLES.



SINCE USE OF FOSSIL FUELS IS NO LONGER VIABLE, BIOFUELS ARE THE ONLY OPTION FOR AVIATION.

NEW DESIGNS FOR AIRCRAFT ARE INTRODUCED -- PERHAPS INCORPORATING AIRSHIP AND FUTURE ENERGY TECHNOLOGIES.



IN THIS VISION, IT IS LIKELY THAT AIR TRAVEL WOULD BE EXPENSIVE AND UNAFFORDABLE FOR MOST.

2050s

2060s

2070s

2080s

LOCAL ENERGY GENERATION BECOMES IMPORTANT.

BIOMASS IS USED BY LOCAL COMMUNITIES RATHER THAN IN LARGE-SCALE POWER PLANTS, WITH COUNTRIES TAKING CHARGE OF THEIR OWN RESOURCES RATHER THAN TRADING.

USE OF BIOENERGY SOURCED LOCALLY FOR HEAT AND POWER, WITH EMISSIONS CONTROL TECHNOLOGIES IN PLACE.

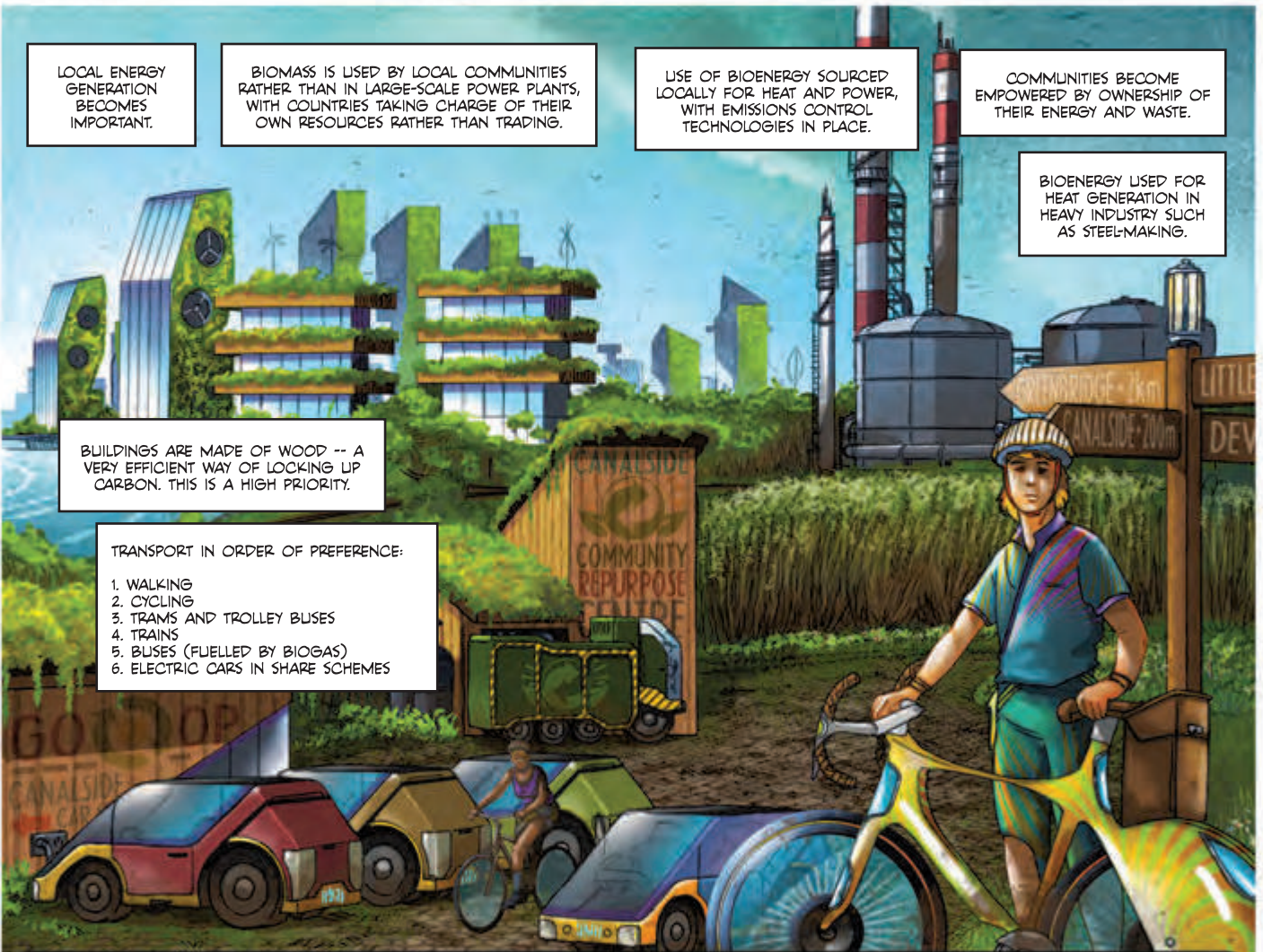
COMMUNITIES BECOME EMPOWERED BY OWNERSHIP OF THEIR ENERGY AND WASTE.

BIOENERGY USED FOR HEAT GENERATION IN HEAVY INDUSTRY SUCH AS STEEL-MAKING.

BUILDINGS ARE MADE OF WOOD -- A VERY EFFICIENT WAY OF LOCKING UP CARBON. THIS IS A HIGH PRIORITY.

TRANSPORT IN ORDER OF PREFERENCE:

1. WALKING
2. CYCLING
3. TRAMS AND TROLLEY BUSES
4. TRAINS
5. BUSES (FUELLED BY BIOGAS)
6. ELECTRIC CARS IN SHARE SCHEMES

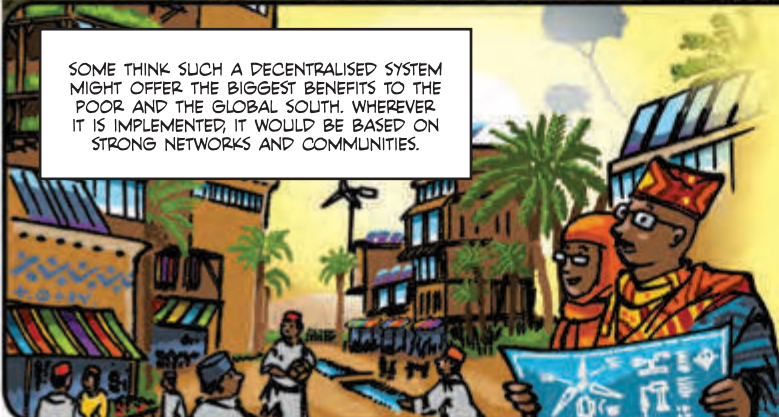


SOME THINK SUCH A DECENTRALISED SYSTEM MIGHT OFFER THE BIGGEST BENEFITS TO THE POOR AND THE GLOBAL SOUTH. WHEREVER IT IS IMPLEMENTED, IT WOULD BE BASED ON STRONG NETWORKS AND COMMUNITIES.

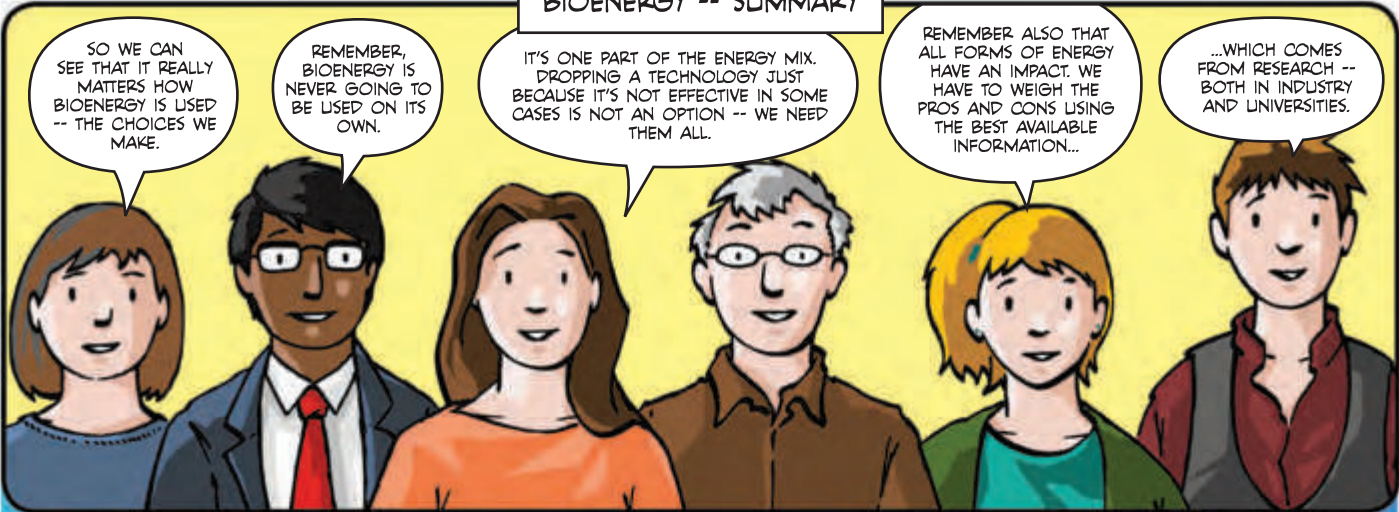
HOWEVER, IT'S LIKELY THAT COST WILL BE A BIG ISSUE IN ESTABLISHING SUCH A 'DECENTRALISED', COMMUNITY-SCALE SYSTEM.

STORIES OR VISIONS LIKE THESE ARE USEFUL IN HELPING US UNDERSTAND THE IMPACT OF THE TRANSITION TO RENEWABLE ENERGY TECHNOLOGIES, AND ITS IMPACT ON FAMILIES AND COMMUNITIES. THESE VISIONS ARE ONLY SKETCHES - A REALISTIC FUTURE MIGHT COMBINE MANY OF THE POINTS WE'VE COVERED.

IT'S THE CHOICES THAT WE MAKE NOW THAT WILL DETERMINE WHAT FUTURE WE HAVE.



BIOENERGY -- SUMMARY



SO WE CAN SEE THAT IT REALLY MATTERS HOW BIOENERGY IS USED -- THE CHOICES WE MAKE.

REMEMBER, BIOENERGY IS NEVER GOING TO BE USED ON ITS OWN.

IT'S ONE PART OF THE ENERGY MIX. DROPPING A TECHNOLOGY JUST BECAUSE IT'S NOT EFFECTIVE IN SOME CASES IS NOT AN OPTION -- WE NEED THEM ALL.

REMEMBER ALSO THAT ALL FORMS OF ENERGY HAVE AN IMPACT. WE HAVE TO WEIGH THE PROS AND CONS USING THE BEST AVAILABLE INFORMATION...

...WHICH COMES FROM RESEARCH -- BOTH IN INDUSTRY AND UNIVERSITIES.

THOSE ASPECTS OF OUR THOUGHT EXPERIMENTS WHICH ARE UNCLEAR PROMPT US TO DO MORE RESEARCH, TO MOVE TOWARDS A BETTER SYSTEM.

AN IDEAL BIOENERGY SYSTEM COULD BE RELIED UPON FOR AS LONG AS WE NEED IT -- FAR INTO THE FUTURE.

TO DO THAT, WE HAVE TO THINK OF THE WHOLE SYSTEM -- WHICH ENERGY SOURCES ARE MOST APPROPRIATE?



PRODUCTION WOULD KEEP PACE WITH CONSUMPTION.

IT WOULD AVOID HARMFUL ENVIRONMENTAL AND SOCIAL EFFECTS ELSEWHERE.

IT WOULD KEEP LEVELS OF CARBON DIOXIDE IN THE ATMOSPHERE IN BALANCE.

SUCH A SYSTEM WOULD PROVIDE CONTROLLABLE ENERGY TO COMPLEMENT INTERMITTENT ENERGY FROM SUN AND WIND.

IT WOULD NOT JUST BE COST EFFECTIVE, BUT THE LOWEST-COST WAY FOR US TO DECARBONISE.

IT WOULD HAVE A POSITIVE IMPACT ON WIDER SUSTAINABLE DEVELOPMENT GOALS.



WE DON'T KNOW FOR SURE WHAT IS GOING TO HAPPEN IN THE TRANSITION TO A LOW CARBON FUTURE.

WE MAY USE A LOT OF BIOENERGY OR WE MIGHT END UP RELYING MORE ON OTHER LOW-CARBON OPTIONS. IT ALL DEPENDS ON HOW WE PLAN THINGS, WHAT DECISIONS WE MAKE, AND THE COSTS.

BUT THE RESEARCHERS IN THE SUPERGEN BIOENERGY HUB ARE WORKING HARD TO ENSURE THAT WE DEVELOP THE TECHNOLOGIES ENOUGH TO HAVE THE OPTIONS AVAILABLE AND ENSURE THE BIOMASS WE USE IS SUSTAINABLE.

I THINK IF WE CAN CREATE SOMETHING APPROACHING THE SYSTEM ABOVE, IT COULD BE CRITICAL TO OUR FUTURE PROSPERITY.

BIOENERGY IS NOT "BAD" OR "GOOD" -- CONTEXT AND DETAILS ARE EVERYTHING.

IF YOU ARE INTERESTED TO FIND OUT MORE, VISIT THE SUPERGEN BIOENERGY HUB WEBSITE -- DETAILS OPPOSITE.



SUGGESTIONS FOR TEACHERS AND STUDENTS:

Think about the issues covered in this comic. Bioenergy is a complex subject and more research is needed, so there may not be clear answers to some of the issues raised (yet). As such, it is a good subject for testing your discussion and debating skills!

Topics for classroom debate:

Given what you've learned in this graphic novel, do you think we should use bioenergy more in the future?

What are the key issues you think we need to research?

The terms 'carbon balance', 'carbon debt' and 'carbon bonus' are difficult to communicate—how would you explain them to a friend or relative who has never heard these terms?

Are the visions of the future realistic? What would your future look like if you designed it?

How important do you think it is to actually try to remove carbon dioxide from the atmosphere (e.g. through carbon capture and storage)? Is this idea realistic?

FURTHER READING AND RESOURCES:

Visit the **SUPERGEN** website for information and links to other organisations: www.supergen-bioenergy.net

DECC 2050 ENERGY CALCULATOR
<http://2050-calculator-tool.decc.gov.uk/#/home>

DRAX ELECTRIC INSIGHTS: DATA ON ELECTRICITY USE IN THE UK
http://electricinsights.co.uk/#/homepage?&_k=c9a1xd

UK BIOENERGY STRATEGY
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48337/5142-bioenergy-strategy-.pdf

ETI INSIGHT REPORT: BIOENERGY PUBLIC PERCEPTIONS
<https://d2umxnkyjne36n.cloudfront.net/documents/Appendix-Public-Perceptions-2016.pdf?mtime=20161206163242>

COMMITTEE ON CLIMATE CHANGE: SECTORAL SCENARIOS FOR THE 5TH CARBON BUDGET <https://www.theccc.org.uk/wp-content/uploads/2015/11/Sectoral-scenarios-for-the-fifth-carbon-budget-Committee-on-Climate-Change.pdf>

CARBON IMPACTS OF BIOMASS CONSUMED IN THE EU: QUANTITATIVE ASSESSMENT. FINAL REPORT, PROJECT: DG ENER/C1/427 PART A: MAIN REPORT <https://ec.europa.eu/energy/sites/ener/files/documents/EU%20Carbon%20Impacts%20of%20Biomass%20Consumed%20in%20the%20EU%20final.pdf>

FOREST RESEARCH: CARBON IMPACTS OF USING BIOMASS IN BIOENERGY AND OTHER SECTORS: FORESTS DECC PROJECT TRN 242/08/2011 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/282812/DECC_carbon_impacts_final_report30th_January_2014.pdf

LINKS FROM THE EUROPEAN COMMISSION ON BIOENERGY AND BIOMASS SUSTAINABILITY
http://ec.europa.eu/research/energy/eu/index_en.cfm?pg=research-bioenergy AND <http://ec.europa.eu/energy/en/topics/renewable-energy/biomass>

PUBLICATIONS FROM THE INTERNATIONAL ENERGY AGENCY
<https://www.iea.org/topics/renewables/subtopics/bioenergy/publications/>

INFORMATION ABOUT BECCS:
<https://www.carbonbrief.org/beccs-the-story-of-climate-changes-saviour-technology>
(<http://www.eti.co.uk/insights/the-evidence-for-deploying-bioenergy-with-ccs-beccs-in-the-uk>)

FOR SCHOOLS:
http://www.bbc.co.uk/schools/gcsebitesize/science/triple_ocr_gateway/beyond_the_microscope/biofuels/revision/1/

<http://www.bbsrc.ac.uk/engagement/schools/keystage5/practical-biofuel-activities/>

INDEX (FOR EXPLANATION OF THE TERMS, TURN TO THE RELEVANT PAGE)

Acid rain- 15	Carbon debt- 10	Fertilisers- 7,16	Oil- 2
Algae- 5,21	Carbon dioxide- 3,15	Food vs fuel- 17	Phosphorus- 6
Anaerobic digestion- 7	Carbon neutral- 9	Forest mosaic- 12	Pyrolysis- 7
Aviation- 23	Climate change- 3	Fossil fuels- 2,3	Rebound effect- 4
Biochar- 7	Climate forcing- 15	Fracking- 18	Shipping- 22
Biodiversity- 12	Climate targets- 3,18	Gasification- 7	Smog- 15
Bioenergy- 5	Coal- 2,9	Glaciers- 15	Sustainability- 4,24
Bioenergy with carbon capture and storage (BECCS)- 8,20	Combined heat and power- 6	Global economy- 11	Synthetic biology- 21
Biofuels- 5	Combustion- 7	Global warming- 3	Tar sands- 18
Biogas- 7	Cookstoves- 15	Greenhouse gases- 3	Torrefaction (torrefied)- 7
Biomass- 5	Demand reduction- 4	Hydrogen economy- 21	Transport fuels- 6
Bioproducts (bioplastics)- 6	Electricity- 6	Imports- 11	Trees- 13
Biorefinery- 6	Emissions- 15	Land remediation- 6	Turbine- 7
Carbon bonus- 10	Energy- 2	Land use change- 16	Waste- 5
Carbon budget- 3	Energy efficiency- 4	Natural Gas- 2	Wood pellets- 5
	Erosion- 16	Nitrogen- 6	

BIOENERGY

What is it?

Why use it?

What are the problems?

What are the solutions?

A graphic introduction to bioenergy created by scientists in the national SuperGen Bioenergy Hub.

Accessible to anyone with an interest in climate change, energy systems and sustainability.

Includes suggestions for use in the classroom (Key Stage 3 and upwards)

www.supergen-bioenergy.net