

The Secrets of SDGs

7 AFFORDABLE AND
CLEAN ENERGY



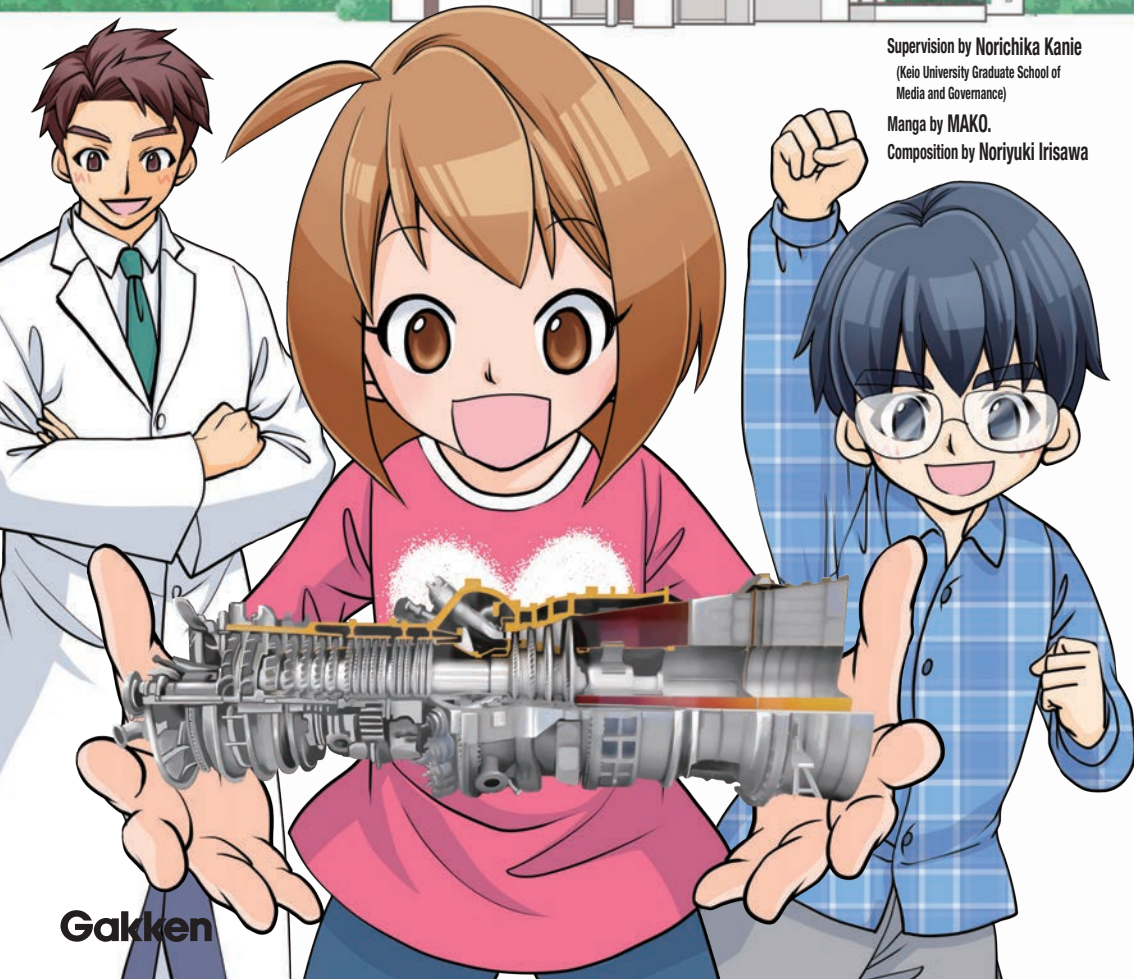
Affordable and Clean Energy

Mitsubishi Heavy Industries' Efforts

Supervision by Norichika Kanie
(Keio University Graduate School of
Media and Governance)

Manga by MAKO.

Composition by Noriyuki Irisawa



"Affordable and Clean Energy"

This is goal 7 of the SDGs.

There are nearly 800 million people in the world today who don't have access to electricity.

Everyone should be able to conveniently use electricity to live healthy lives.

But we also need to prevent global warming.

What can we do?

To solve that problem, let's think about new ways and technology to generate electrical energy, starting with hydrogen power!



SDGs (Sustainable Development Goals) are global goals set up by the world to be achieved by 2030.



Photo : imagenavi



No Poverty

There are two types of poverty: absolute poverty and relative poverty. The former is to be poor in a global sense. About 9% of the world's population lives on less than \$1.90 (about 200 yen) a day. The latter is to be poor compared to others in the same country. In Japan, approximately 2.8 million children (one in seven) cannot receive higher education due to poverty.



Zero Hunger

About one in nine people worldwide suffers from hunger daily. In addition, one in four children under the age of five suffers from stunting due to undernourishment. Hunger is a serious problem that is expected to spread in the future due to continued population growth. Cooperation from developed countries to promote sustainable agriculture is essential.

3 GOOD HEALTH AND WELL-BEING



Good Health and Well-Being

Approximately 5.3 million children worldwide under the age of five die each year. About half of these are infants under one month old. Millions, including adults, also die each year from various infectious diseases. This is due to poor sanitation and the lack of access to hospitals and vaccinations.

4 QUALITY EDUCATION



Quality Education

About 770 million people in the world cannot read or write. Of them, two-thirds are women. There are many children who cannot attend school because helping at home is considered more important than education. If they don't know how to read, write, or do arithmetic, they cannot get a well-paying job, and thus cannot escape poverty. It is important to raise awareness of education's benefits and help it spread more widely.

5 GENDER EQUALITY



Gender Equality

In addition to physical differences, men and women also have different norms and roles constructed by society. These socially-constructed differences are called gender. Many young girls worldwide are not allowed to attend school simply because they are girls. Each year, twelve million women are forced to marry before turning eighteen, regardless of their will. These inequalities must be reduced.

6 CLEAN WATER AND SANITATION



Clean Water and Sanitation

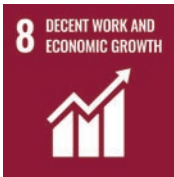
More than two million people die yearly from diarrheal diseases, and more than eight hundred children under the age of five pass away every day. The main reasons are a lack of sanitary toilets and of daily access to safe water. Many children cannot go to school because they must travel for hours to fetch water from distant water sources.

7 AFFORDABLE AND CLEAN ENERGY



Affordable and Clean Energy

Electricity is a convenient form of energy, but approximately eight hundred million people worldwide do not have stable access to it. There are also health problems caused by burning fuels to produce energy. We must expand access to electricity, but also prevent climate change and protect the environment. This is why renewable energy and hydrogen power generation are important.



Decent Work and Economic Growth

Approximately 150 million children in the world are forced to work due to poverty. In Japan, death by overwork is a persistent problem. Conversely, hundreds of millions of people worldwide are unemployed and looking for work. We must build a world where everyone can work in humane conditions with a sense of fulfillment.



Industry, Innovation and Infrastructure

Infrastructure refers to the systems and services we need to live in a society, such as roads, railroads, electricity, gas, phones, water, and sewage systems. Many people in the world do not have access to sufficient infrastructure. For worldwide growth, we must build a disaster-resilient, stable infrastructure and develop new technologies.



Reduced Inequalities

In today's world, the richest 10% make 40% of global income, while the poorest people earn only a combined total of 2–7%. We must help the poor achieve higher, more stable income. Inequality and discrimination based on race, ethnicity, religion, disability, and gender must also be eliminated.



Sustainable Cities and Communities

Today, nearly 3.5 billion people, about half of the world's population, live in cities, seeking work. However, densely populated cities have poor living conditions with more pollution and crime. These areas are also vulnerable to natural disasters. We need to create cities that are resilient to disasters and where a diversity of people can live safely.



Responsible Consumption and Production

Every year, about a third of the world's food (about 1.3 billion tons), is spoiled, lost, and wasted. In Japan, each person throws away the equivalent of one rice ball every day. Forest resources, aquatic resources, and underground resources such as oil will also run out if no action is taken. We must all work together to eliminate waste.

13 CLIMATE ACTION



Climate Action

Climate change is caused by greenhouse gases that humans produce, such as carbon dioxide. Climate change increases water vapor in the air, resulting in frequent abnormal weather events such as torrential rainfall, large typhoons, and droughts. Sea levels are rising, and land areas are being submerged. People around the world must work together to reduce greenhouse gases.

14 LIFE BELOW WATER



Life Below Water

Our oceans, rich with life, are being polluted by large amounts of garbage and wastewater produced by humans. Sea creatures are being poisoned by harmful substances, which are then consumed by humans, endangering their health. Some species are in danger of extinction due to overfishing.

15 LIFE ON LAND



Life on Land

The world's forests are shrinking. Logging is depleting trees in large amounts, destroying animal habitats. Invasive species introduced by humans are preying on native species. The loss of biodiversity and the destruction of ecosystems caused by humans are also beginning to seriously impact human life.

16 PEACE, JUSTICE AND STRONG INSTITUTIONS



Peace, Justice and Strong Institutions

Conflict and violence are difficult to eliminate from human society. About one in nine children worldwide live in areas of conflict. The rate of death before the age of five among these children is more than twice that of other regions. Improving the social environment through institutions such as governments and justice systems is considered an effective way to reduce conflicts.

17 PARTNERSHIPS FOR THE GOALS



Partnerships for the Goals

Humans cannot live alone. The same is true for nations. Both developed and developing countries must support and cooperate with each other on an equal footing. The world must work together to achieve the SDGs. It is essential that each individual becomes aware of these issues and actively works to build partnerships.

Dear Readers,

The *Gakken: Learning with Manga series* answers your questions and provides interesting information in comic book form.

- The Secrets of SDGs 7 includes many facts and figures to help you understand the future of energy.
- Trivia is included on almost every page.
- This book was made in cooperation with Mitsubishi Heavy Industries, which provided informational assistance and materials.
- Unlike English comics, which are read from left to right, Japanese manga are read from right to left.



The Secrets of SDGs

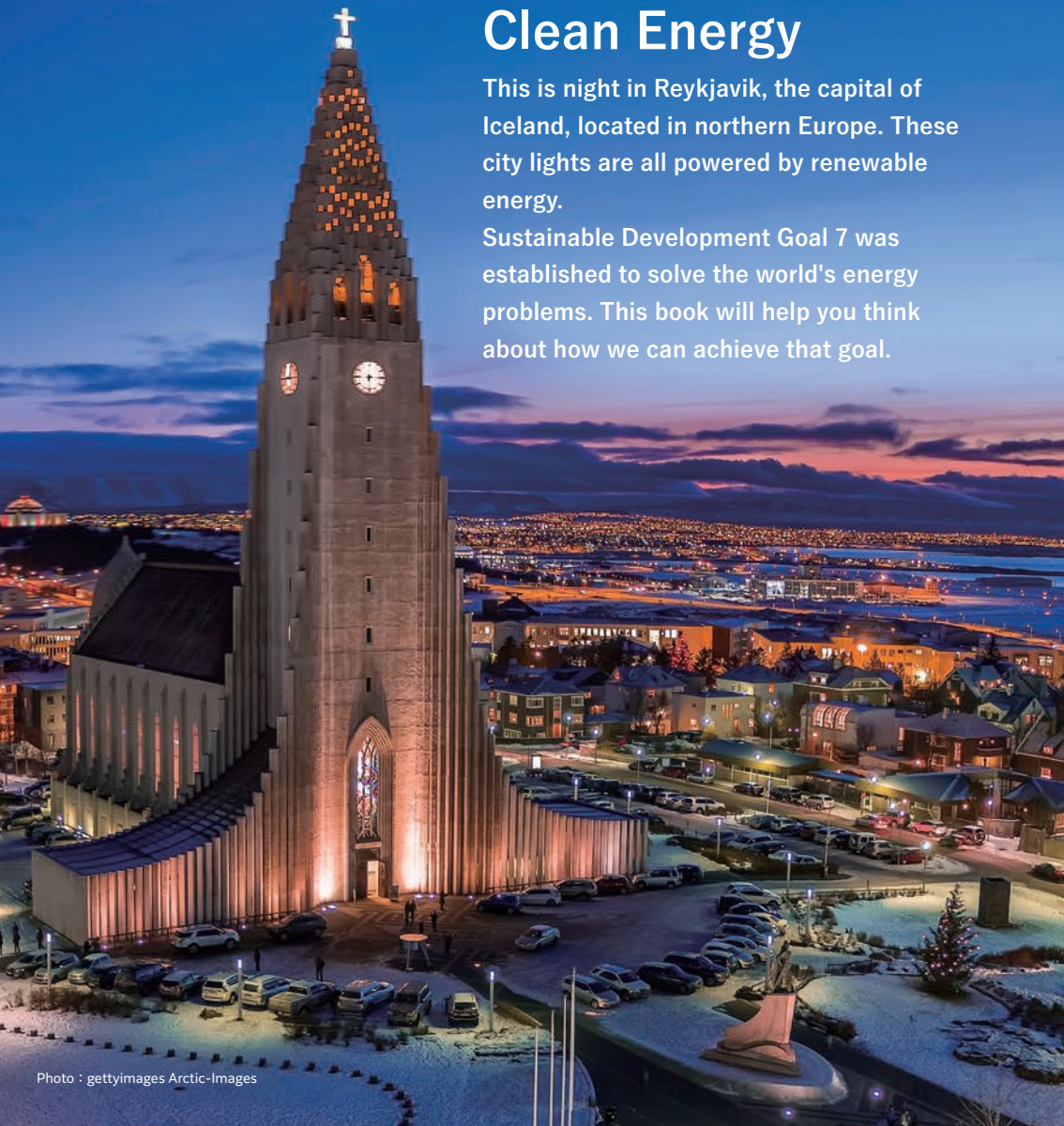
7 AFFORDABLE AND
CLEAN ENERGY



Affordable and Clean Energy

This is night in Reykjavik, the capital of Iceland, located in northern Europe. These city lights are all powered by renewable energy.

Sustainable Development Goal 7 was established to solve the world's energy problems. This book will help you think about how we can achieve that goal.



Energy Powers Our Lives

First, let's look at how energy is used in our daily lives. We use many appliances powered by electricity or fuel. These machines move, produce light and sound, provide heating and cooling, and perform many other actions to make our lives easier.

Microwave

Electricity → Heat

Hair Dryer

Electricity → Heat & Motion (Airflow)

Dishwasher

Electricity → Motion

Electric Stove

Electricity → Heat

Refrigerator

Electricity → Heat (Cooling)

LED Lamp

Electricity → Light

Electric Kettle

Electricity → Heat

These actions require power, which we call energy. Electrical energy is particularly useful because it can be easily converted into other forms of energy. To learn more, see page 39.

Washing Machine

Electricity → Motion

Bathtub

Fuel → Heat or
Electricity → Heat

Air Conditioner

Electricity → Heat & Heat (Cooling)

Lamp

Electricity → Light

Music Player

Electricity → Sound

Car

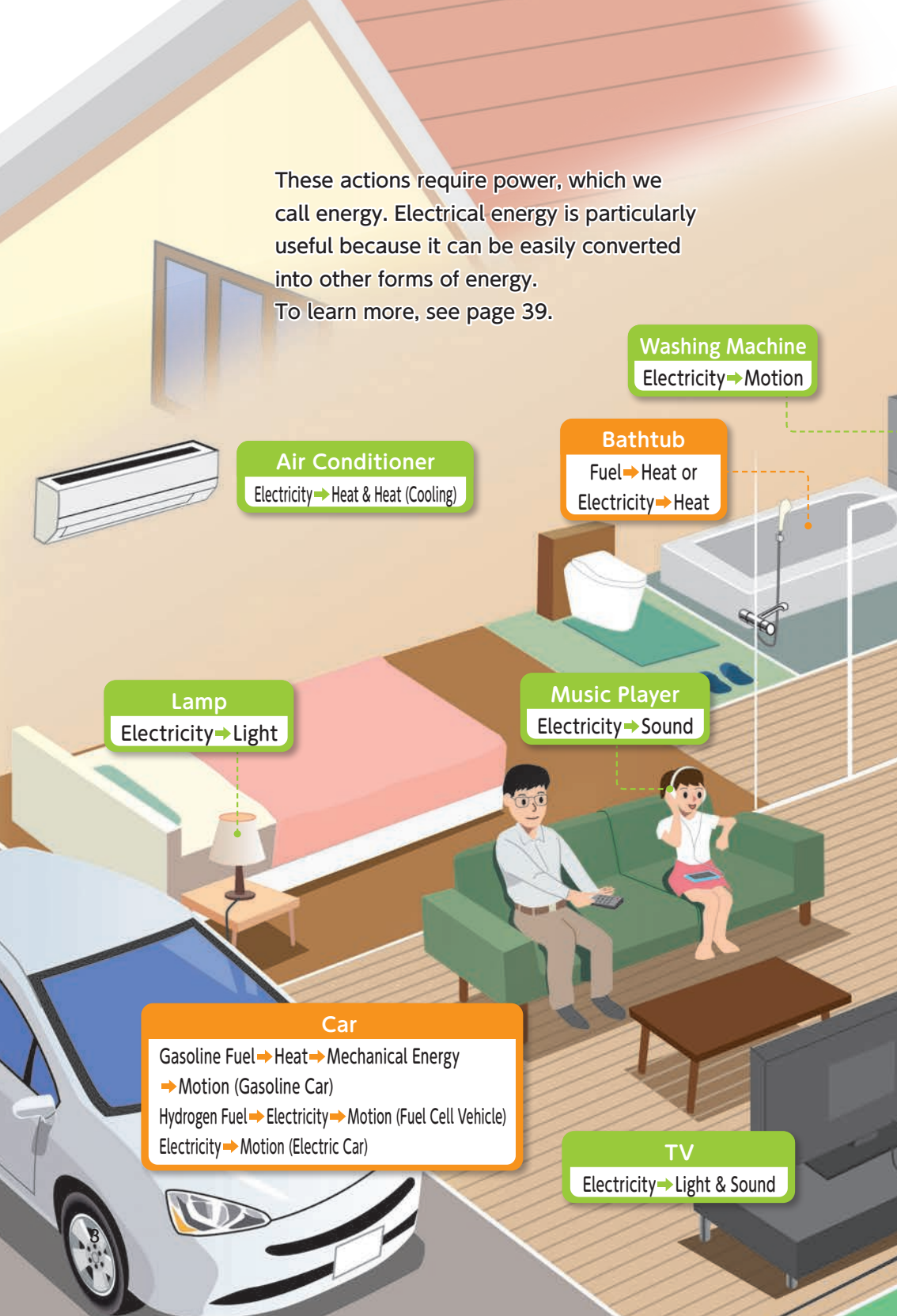
Gasoline Fuel → Heat → Mechanical Energy
→ Motion (Gasoline Car)

Hydrogen Fuel → Electricity → Motion (Fuel Cell Vehicle)

Electricity → Motion (Electric Car)

TV

Electricity → Light & Sound



A Gap in Resources

Some countries have more resources than others



Shutterstock.com

- ▲ The Kern River Oil Field of California in the United States. Only a certain number of countries have oil fields.

Some countries depend on other countries for resources



Shutterstock.com

- ▲ Atsumi Thermal Power Station (Aichi Prefecture, Japan). Oil imported to Japan on tankers is carried to it through these pipelines. Japan depends heavily on other countries for oil.

The World's Energy Problems

Energy is useful, but its production consumes resources and emits greenhouse gases. Let's see what kinds of problems this presents.

Resources such as oil, coal, and natural gas are only produced in certain areas. This means countries do not have equal access to resources.

Countries lacking in resources must buy from countries that are rich in resources. Because they're dependent on other countries, there is always a risk that the other country will cut off their supplies. This means the supply of resources is unstable.

Limited Resources

The Earth has plentiful resources, but they have a limit. We must think ahead for when they're gone.



A large coal mine in Russia.

Shutterstock.com

Climate Change

Greenhouse gases are increasing

When energy is produced or fuel is burned, greenhouse gases such as carbon dioxide, methane, and nitrous oxide are emitted. These emissions contribute to climate change.



▲ The number of cars and motorcycles is increasing in Kathmandu, the capital of Nepal. The large amount of exhaust emissions is becoming a problem.

Abnormal weather worldwide

Greenhouse gases prevent heat from escaping the Earth, thus warming the planet. This melts continental glaciers and increases the amount of seawater, causing ocean levels to rise in many areas. It is also connected to an increase in disasters caused by abnormal weather.



▲ A collapsing glacier. It is said that the Earth is losing a trillion tons of ice each year.



▲ Some countries are losing land to rising sea levels.



▲ Warmer air holds more water vapor, thus causing an increase in the occurrences of cloudbursts and related damage.



Villagers in Madagascar wash their clothes in the river and dry them on the bank because they have no electricity to power washing machines.

Kononchuk Alla / Shutterstock.com

Not Accessible to All

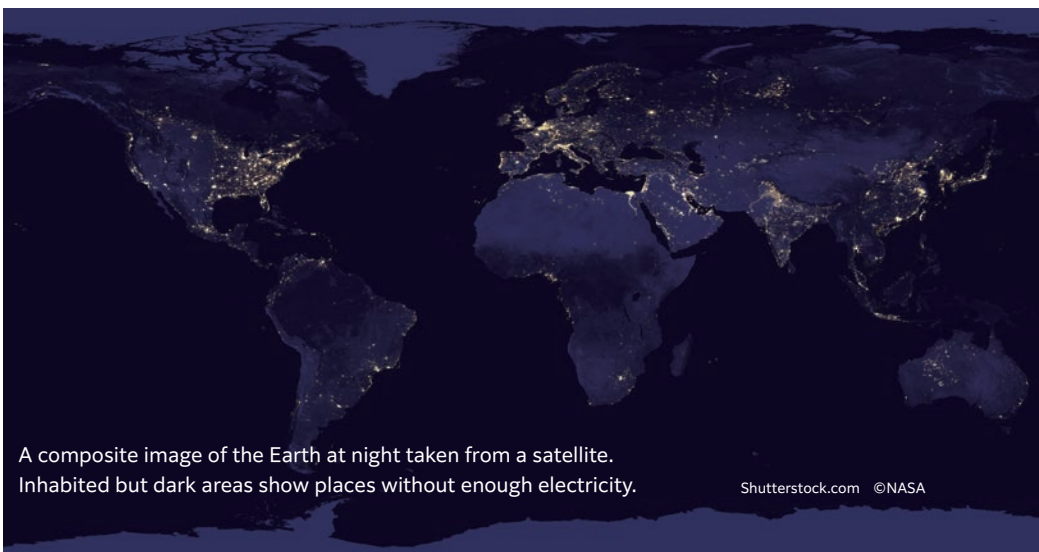
About eight hundred million people have no access to electricity



Children in a village in India attend class in a dark classroom because their school has no electricity.

Travel Stock / Shutterstock.com

Electricity is a very convenient energy source, but it requires power plants, power lines, and other facilities to be used. About one in ten people in the world still live without access to electricity.



A composite image of the Earth at night taken from a satellite. Inhabited but dark areas show places without enough electricity.

Shutterstock.com ©NASA

Sustainable Development Goal 7 aims to solve these issues

Affordable and Clean Energy

We have looked at some of the energy-related problems that Sustainable Development Goal 7 was established to solve. SDG 7 aims to ensure safe and reliable energy access for all while protecting the global environment. Let's look through some materials on energy and the significance of SDG 7 and think about energy-related issues together.

What can we do to make these things happen?



How can we ensure a stable supply of electrical energy?



How can we produce electricity while reducing climate change?



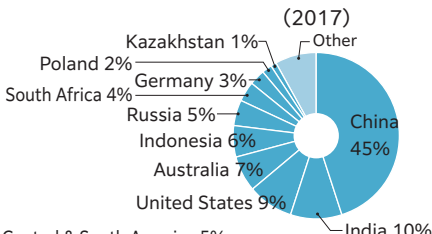
How can we provide electricity to everyone in the world?

What would you do? Let's look at more specific data.

Understand the reality of the world's energy through data.

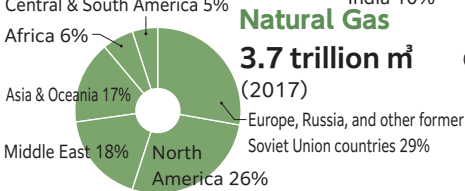
Coal

7.5 billion tons



Natural Gas

3.7 trillion m³ (2017)

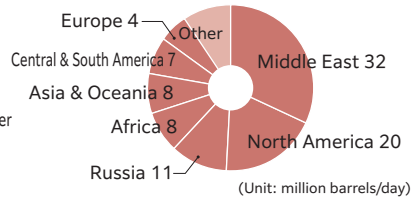


Uneven Distribution of Resources

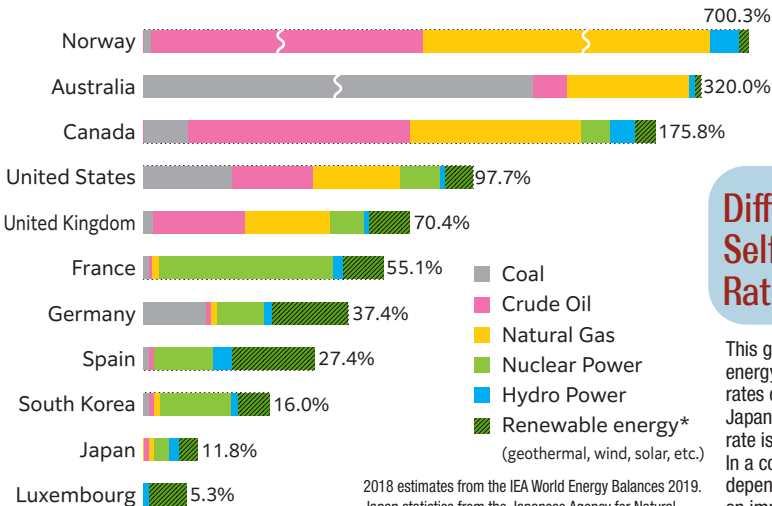
One-third of the world's crude oil is produced in the Middle East. Together with North America and Russia, they supply more than half of the oil in the world. Over three-quarters of the world's coal is produced by five countries. It is clear that distribution of resources is not even.

Crude Oil

93 million barrels per day (2017)



From the Japanese Agency for Natural Resources and Energy reporting of the BP Statistical Review of World Energy 2018 and IEA Coal Information 2018.

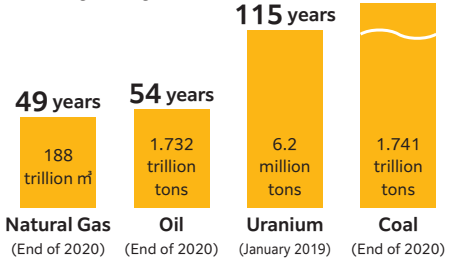


2018 estimates from the IEA World Energy Balances 2019. Japan statistics from the Japanese Agency for Natural Resources and Energy's FY 2018 General Energy Statistics.

Different Energy Self-Sufficiency Rates

This graph illustrates the energy self-sufficiency rates of different countries. Japan's self-sufficiency rate is currently very low. In a country like Japan that depends almost entirely on imported resources, a comfortable lifestyle cannot be taken for granted.

Remaining Mining Life and Reserves

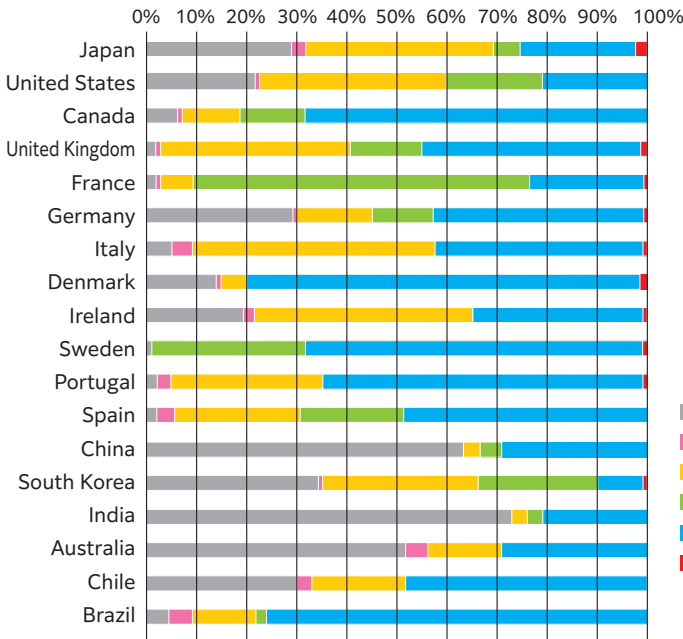


From Nuclear Power and Energy Charts 2019

Dwindling Resources

The resource extraction yield is slowly decreasing as resources are being depleted. What will the world be like when you're an adult?

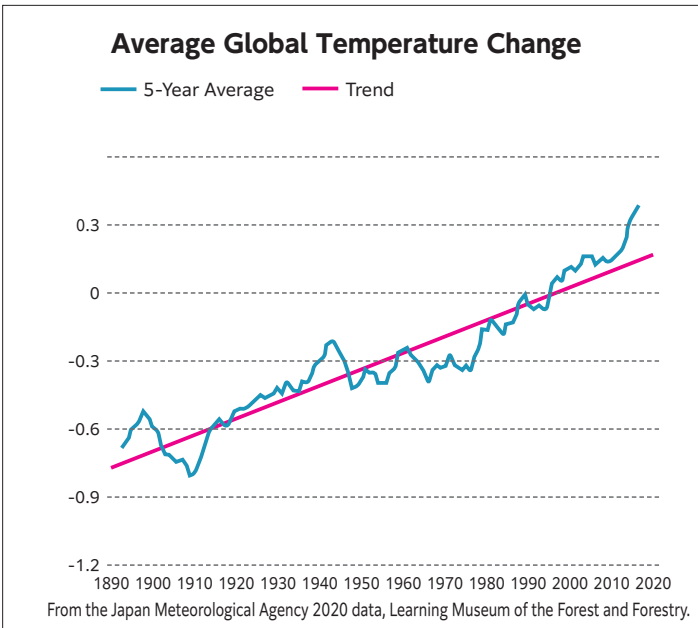
*Renewable energy is energy collected from natural sources that do not run out. It does not emit carbon dioxide.



Varying Ratios of Power Generation

Power generation methods vary as they are linked with the country's resources.

From the Renewable Energy Institute's March 2022 data.
 Source: IEA Monthly Electricity Statistics—data up to December 2021 (March 2022) (Downloaded March 16, 2022)



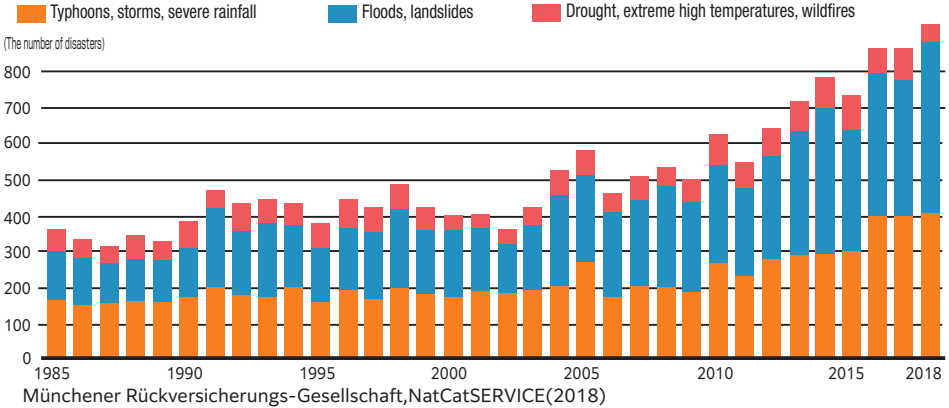
Increase in Average Global Temperature

This graph shows the average annual temperatures from 1891 to 2020. You can see the temperature has risen about 1°C (1.8°F) over 130 years. If no action is taken, the temperature will increase by another 1°C between 2041 to 2060.

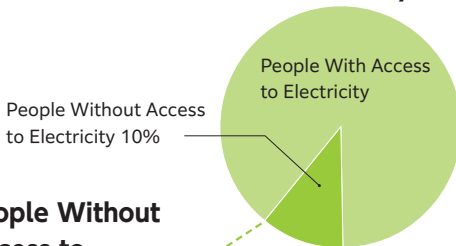
Increase in Climate-Related Natural Disasters

Floods caused by cloudbursts, typhoons, tornadoes, droughts, forest fires, and other natural disasters are increasing in frequency around us.

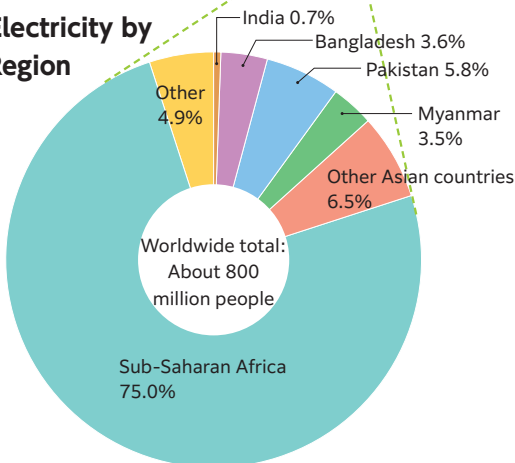
The Number of Climate-Related Natural Disasters



Global Access to Electricity



People Without Access to Electricity by Region



Charts based on the IEA's World Energy Outlook 2020.

Many People in Africa Are Without Electricity

Approximately 160 million people in developing countries in Asia and 600 million people in sub-Saharan Africa cannot lead healthy lives because they have no access to electricity.



▲ A woman carrying manure. Manure and wood are used for cooking and heating. These emit health-damaging smoke.

Denis Dymov / Shutterstock.com

How to Ensure a Stable Energy Supply While Protecting the Environment

Pros and Cons of Different Energy Sources

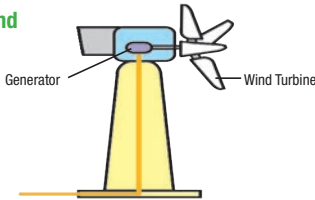
How can we produce energy so that everyone in the world can have equal access to electricity while protecting the global environment? Let's look at the pros and cons of each energy generation method.

Aside from solar power, electricity is produced by turning turbines and generators in various ways. Let's look at the pros and cons of each method.

- Green: The source of energy or fuel powering turbines and generators
- Pink: Pros
- Blue: Cons

Wind Energy

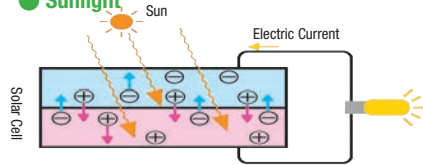
● Wind



- No carbon dioxide emissions.
- Won't run out.
- Inconsistent due to dependency on wind.

Solar Energy

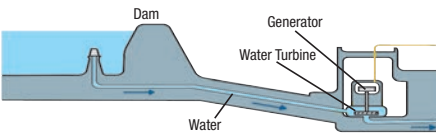
● Sunlight



- No carbon dioxide emissions.
- Won't run out.
- Inconsistent due to varying sunlight.

Hydro Power

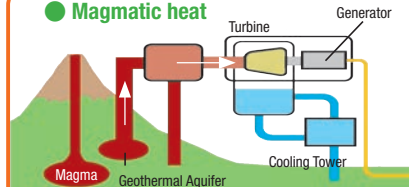
● Force of dam water



- No carbon dioxide emissions.
- The construction of dams requires timber harvesting, which has a large impact on the surrounding environment.

Geothermal Energy

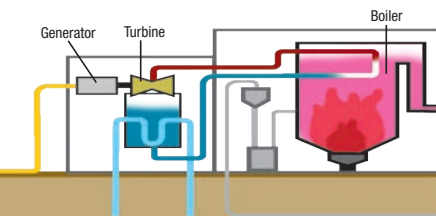
● Magmatic heat



- No carbon dioxide emissions.
- Plants can only be built in certain locations.

Thermal Power

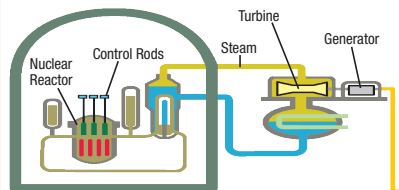
● Natural gas, coal, biomass, etc.



- Stable production of power.
- Can flexibly respond to changes in demand.
- Emits carbon dioxide.

Nuclear Power

● Thermal energy generated by nuclear fission



- Stable generation of large amount of electricity.
- Zero CO₂ emissions during operation.
- Need to dispose of radioactive waste, and to take safety measures in case of an accident.

In light of the situation we've just seen, some companies are taking action toward SDG 7. Let's take a look at their efforts.

Working Towards Sustainable Development Goal 7

Steps are already being taken toward solving energy issues and achieving Goal 7 of the SDGs. Let's look at the efforts of Mitsubishi Heavy Industries (MHI), a company involved in power generation systems.



CG render of a hydrogen power plant

Hydrogen Power

Hydrogen+Oxygen

Uses the energy from when water is made.

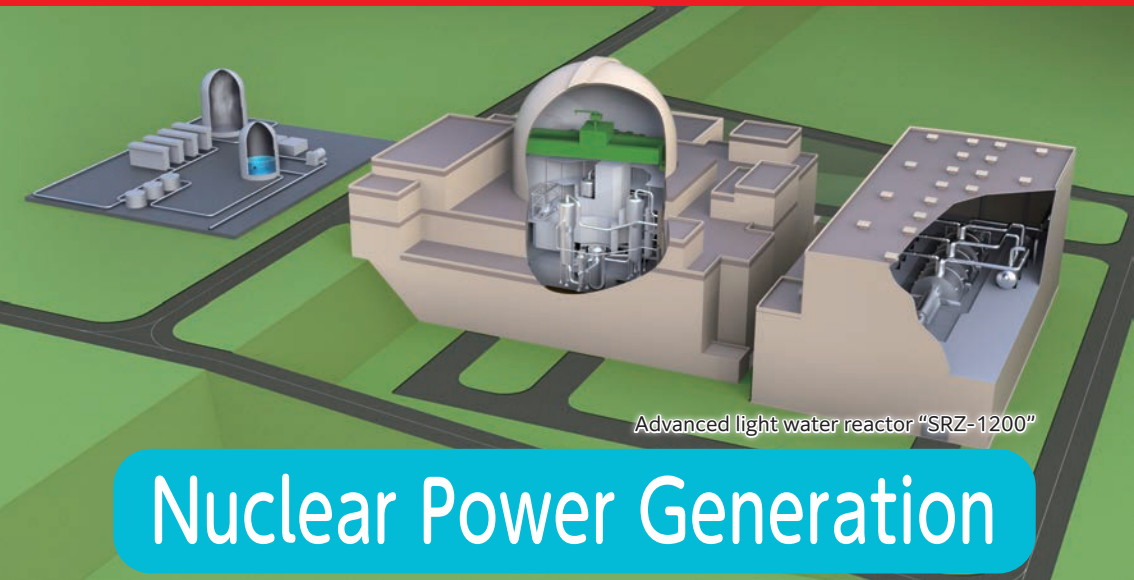
Because hydrogen does not emit carbon dioxide when burned, it is gaining attention as a critical energy resource. MHI's transition to hydrogen power production will begin in 2025, using a mix of 30% hydrogen and 70% natural gas fuel. This will reduce carbon dioxide emissions by 4.6 million tons* per year. In the future, hydrogen will be increased to 100%, achieving zero carbon dioxide emissions.

Plans are also underway to build a large-scale hydrogen power plant in Utah, U.S. Electricity generated by solar and wind power will be used to split water, producing hydrogen, which will then be used to generate electricity. The hydrogen will be stored in a large underground salt dome. MHI is involved in this project as well.

The Great Salt Lake in the U.S.



*Calculated at the power generation facility of the GTCC hydrogen power project in the U.S.



Advanced light water reactor "SRZ-1200"

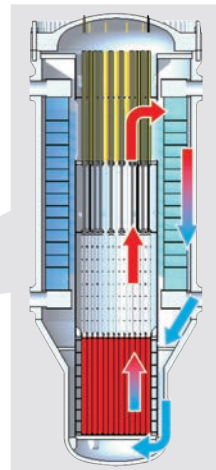
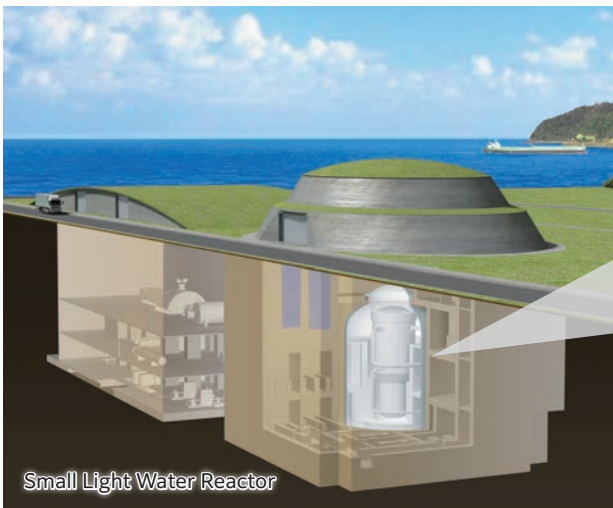
Nuclear Power Generation

Stable power source that does not emit CO₂ during operation and is not affected by weather change.

Nuclear power generation makes use of energy generated by the nuclear fission.

While renewable power generation is changed by weather conditions, nuclear power generation is a stable power source that does not emit CO₂ during operation and is not affected by weather change.

MHI is developing an advanced light water reactor "SRZ-1200" that will ensure the world's highest level of safety. Furthermore, MHI is also developing small light water reactor based on MHI's cultivated nuclear energy technology.





A carbon dioxide capture plant

Carbon Dioxide Capture Plant

Can recover more than 90% of carbon dioxide.

Reducing carbon dioxide emissions to zero is essential in combating climate change (Goal 13 of the SDGs). Therefore, it is necessary to make efforts to capture carbon dioxide from the air, too. MHI's carbon dioxide capture technology is capable of capturing over 90% of the carbon dioxide contained in flue gas from power plants and other sources. Utilizing the recovered carbon dioxide as a resource in the future is being studied.

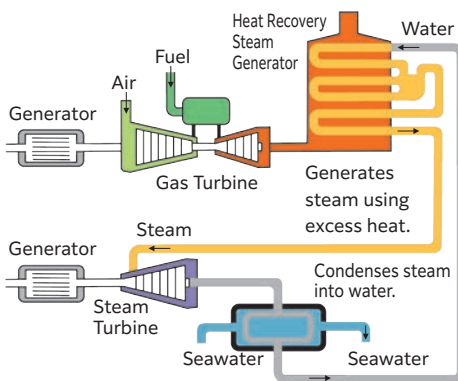
A GTCC facility. Thermal power is a power source that can flexibly adapt to demand and supports our daily lives.

New Type

Gas-Fired Power

Reduces carbon dioxide emissions by 65% compared to other generation methods.

How the GTCC (Gas Turbine Combined Cycle) Works



Excess heat from the gas turbine is also used to generate electricity in the steam turbine. This is a state-of-the-art facility that can significantly reduce carbon dioxide emissions.

Renewable energy is environment-friendly, but because energy generation depends on the weather, it requires storage batteries and systems that allow entire cities to share electricity. As such, MHI has plans to employ state-of-the-art gas turbines that significantly reduce CO₂ emissions to improve energy efficiency until a stable renewable energy system can be established.

Geothermal Power Generation

Rainwater heated by underground magma produces steam, which rotates a turbine, producing electricity.

**Uses renewable energy.
Generate electricity from the heat of magma.**

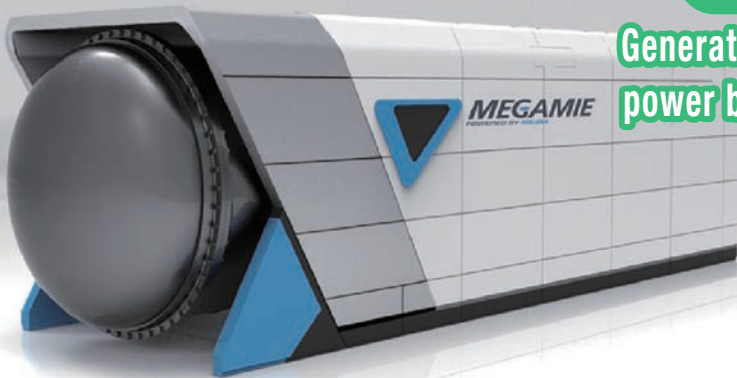


KenGen's 105MW Olkaria II Geothermal Power Plant. Source: Kenya Electricity Generating Company (KenGen) PLC

▲ A geothermal power plant in Kenya. With the construction of these power plants, Kenya's electrification rate increased from 32% (2014) to 75% (2018). Kenya generates more than 85% of its electricity from renewable sources.

Fuel Cells

**Generate the electrical
power by the chemical
reaction.**



▲ Solid oxide fuel cells (SOFC) provide the electricity and heat (which create steam and/or hot water). The system aims to contribute the zero carbon dioxide emissions by utilizing hydrogen as fuel.

The system which can generate the electrical power by the chemical reaction. Various kinds of GAS can be applied as fuel. (For ex. Hydrogen, biogas, etc)

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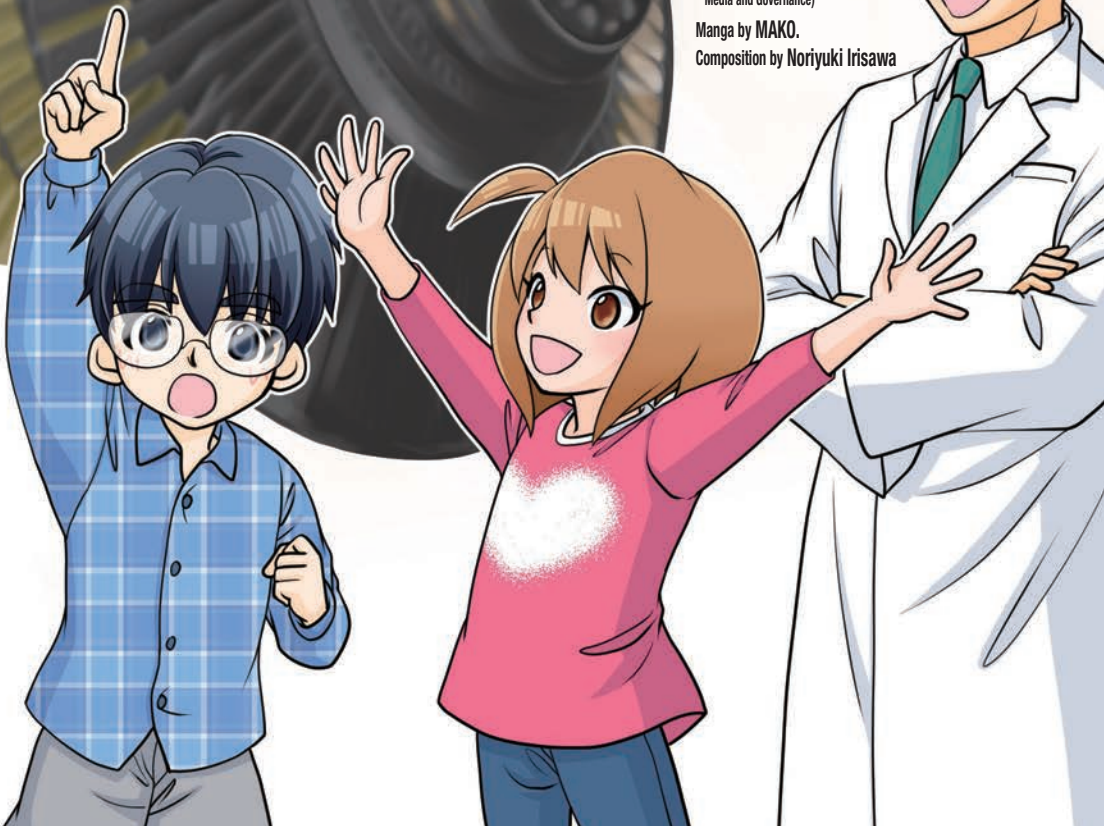


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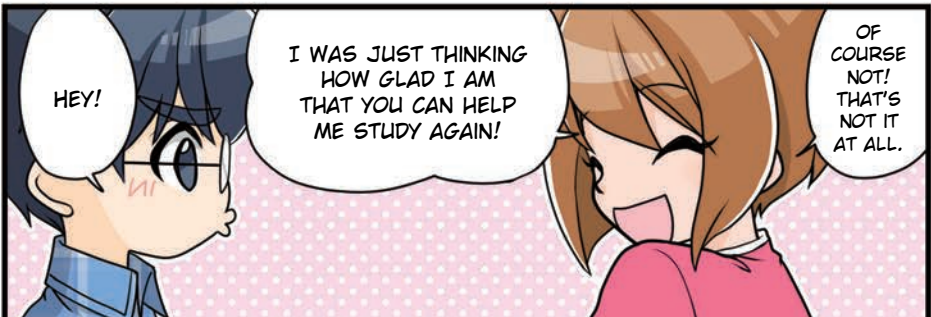
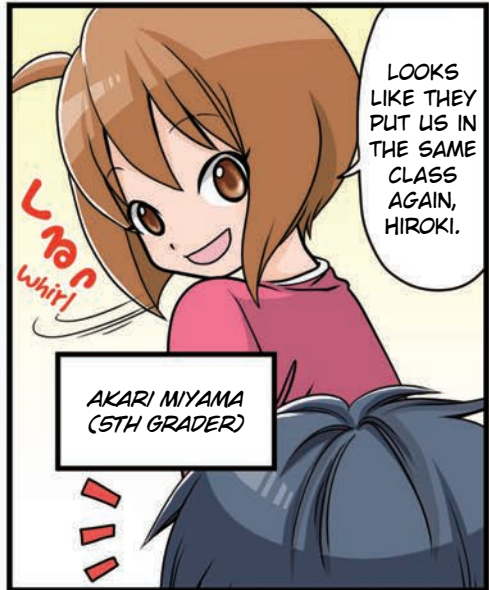
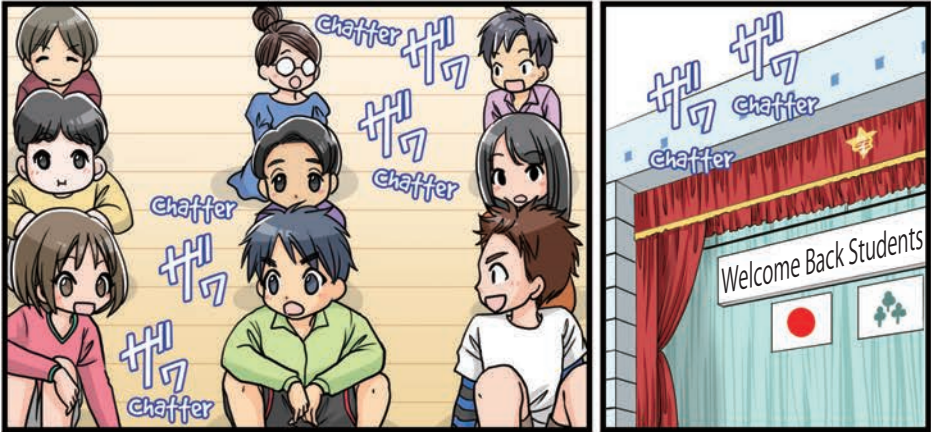
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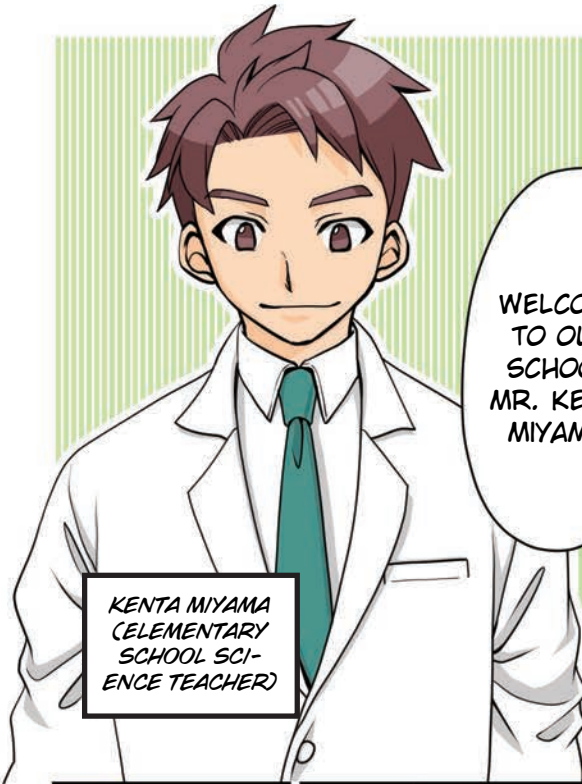
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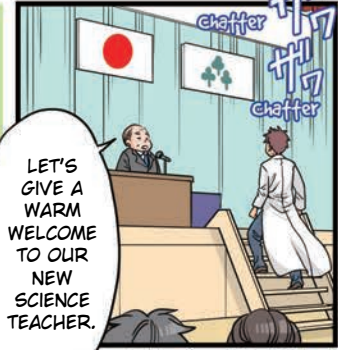
PROLOGUE



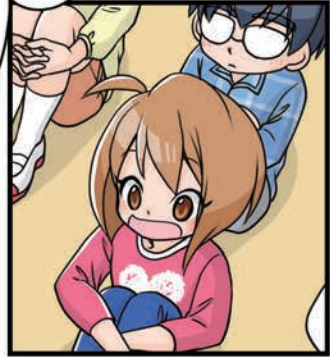


KENTA MIYAMA
(ELEMENTARY
SCHOOL SCIENCE
TEACHER)

WELCOME
TO OUR
SCHOOL,
MR. KENTA
MIYAMA!



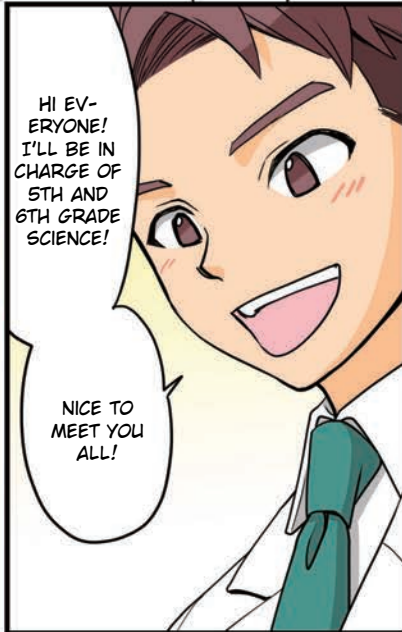
LET'S
GIVE A
WARM
WELCOME
TO OUR
NEW
SCIENCE
TEACHER.



NO WAY!
WHAT A
COINCIDENCE!

FOR
REAL
!?

HE'S MY
COUSIN...



HI EV-
ERYONE!
I'LL BE IN
CHARGE OF
5TH AND
6TH GRADE
SCIENCE!

NICE TO
MEET YOU
ALL!



NO WAY!
KENTA!?

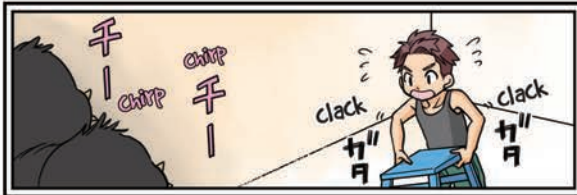
HE
HAS THE
SAME
LAST
NAME
AS YOU,
AKARI.

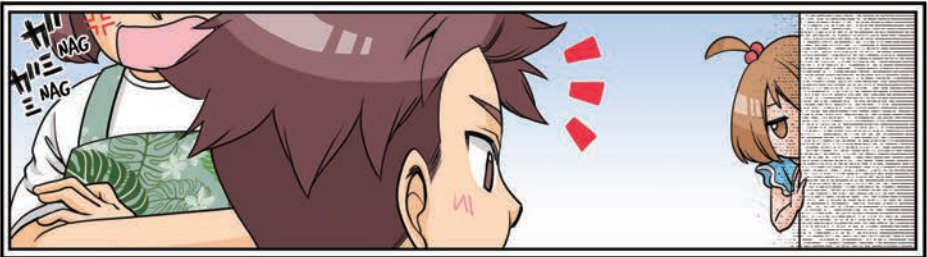
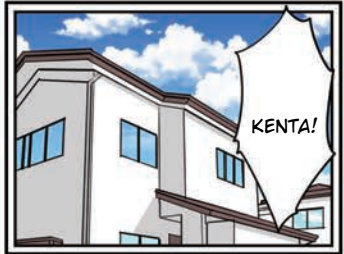
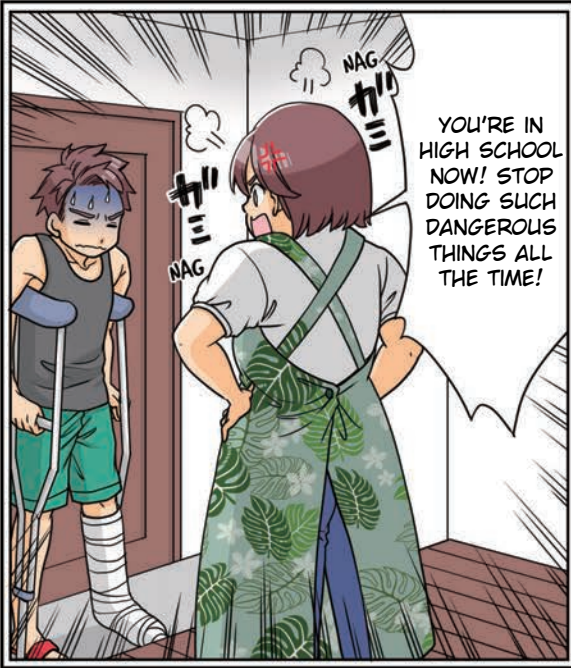


PROLOGUE

TRIVIA

JAPAN'S REVISED EFFORTS FOR ACHIEVING THE SDGs* LISTS "PLANET" AS A PRIORITY, WHICH FEATURES SDG 7 AIMS.







Aqueous Solutions

Science Lab

SPEAKING OF WHICH, DO YOU KNOW WHAT WATER IS MADE OF?

AS YOU CAN SEE, WATER IS A TYPE OF MATTER WHICH MANY THINGS CAN BE DISSOLVED IN.

NICE!
SOMEONE KNOWS THEIR STUFF.

SO... HYDROGEN AND OXYGEN?

WATER'S H₂O, RIGHT?

YOU JUST WANT TO DO AN EXPERIMENT.

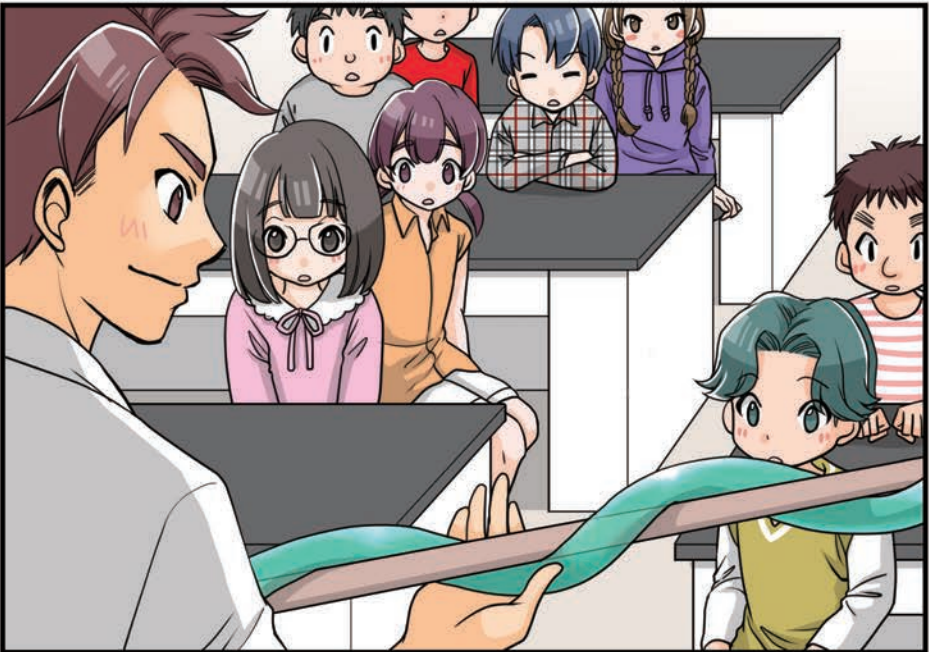
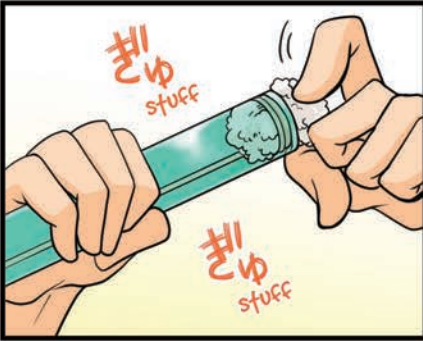
COMMEMORATE ...?

ぼんぼん Mutter

...WE'RE GOING TO MAKE REAL WATER WITH HYDROGEN AND OXYGEN!

TO COMMEMORATE OUR LESSON ON AQUEOUS SOLUTIONS...

Wooww!!
わあ~!!



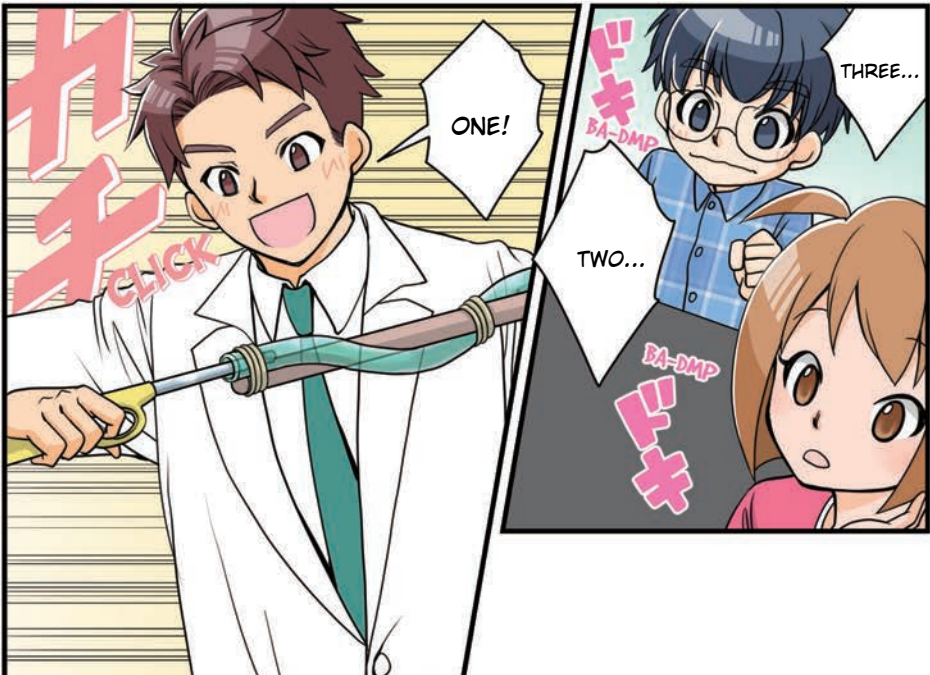
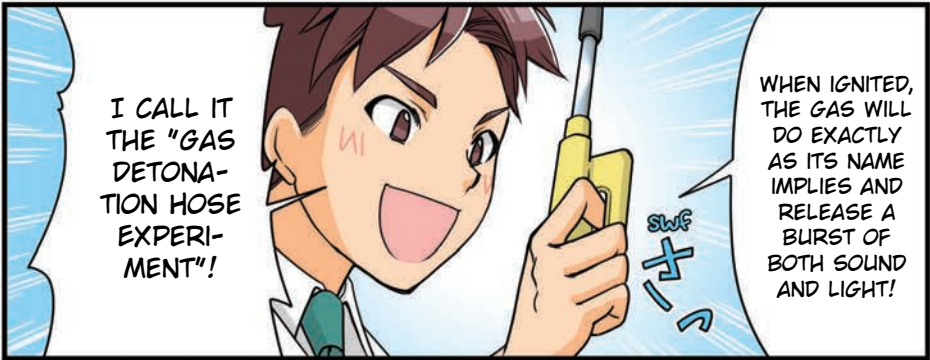
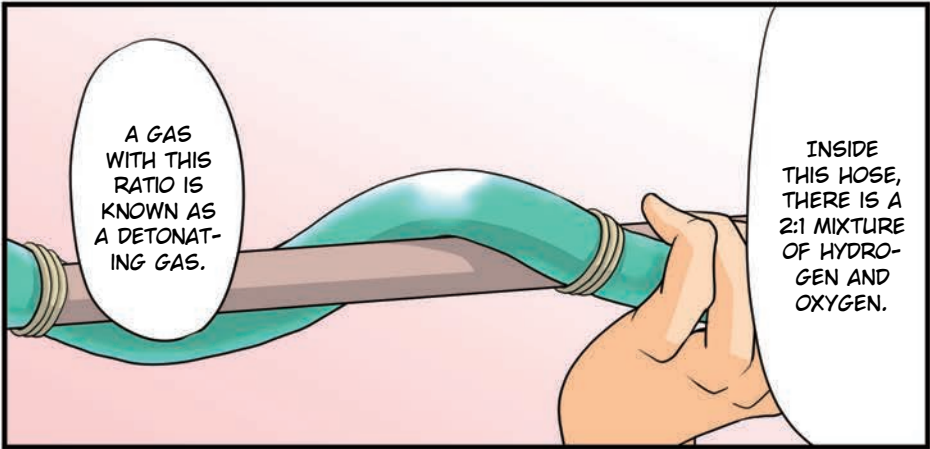
NOTE: NEVER DO THIS EXPERIMENT ON YOUR OWN. ALWAYS DO IT UNDER THE GUIDANCE OF A SCIENCE TEACHER.



PROLOGUE

TRIVIA

HYDROGEN GAS HAS BEEN USED IN GAS BALLOONS SINCE 1783.



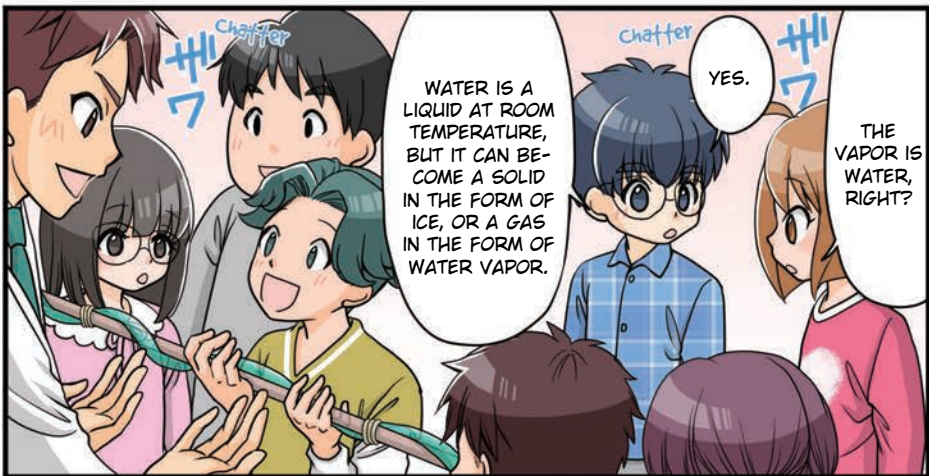
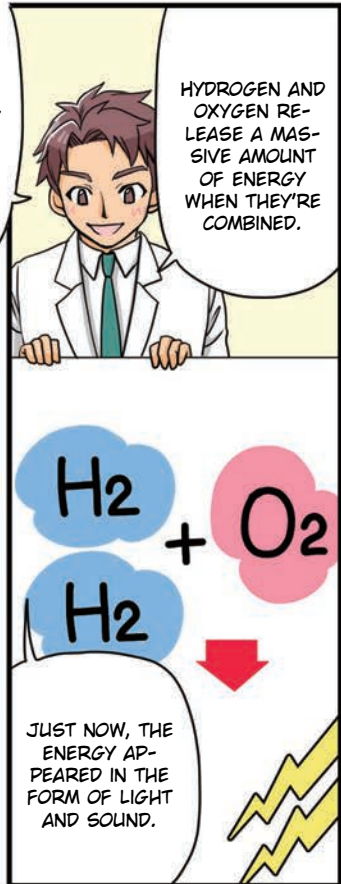
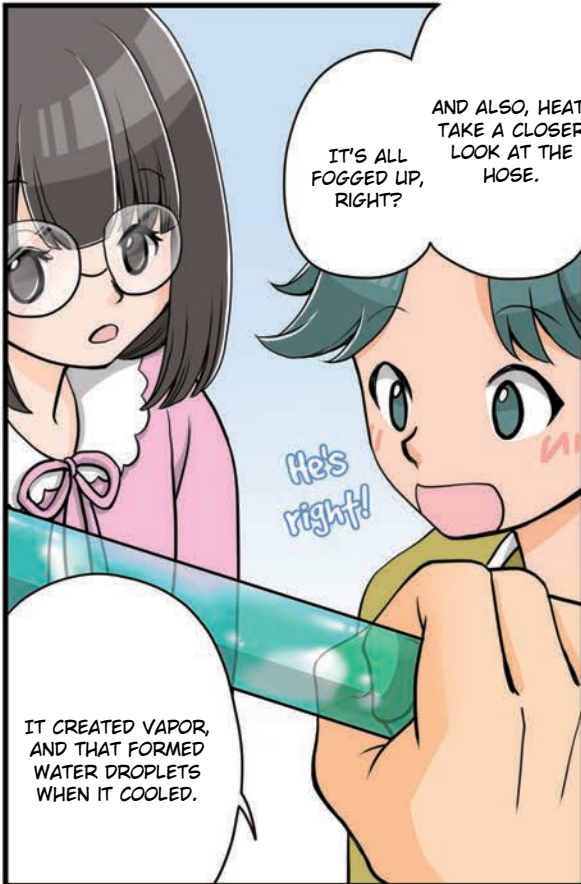


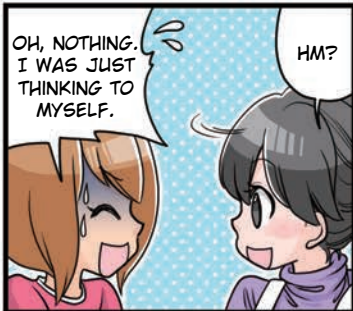
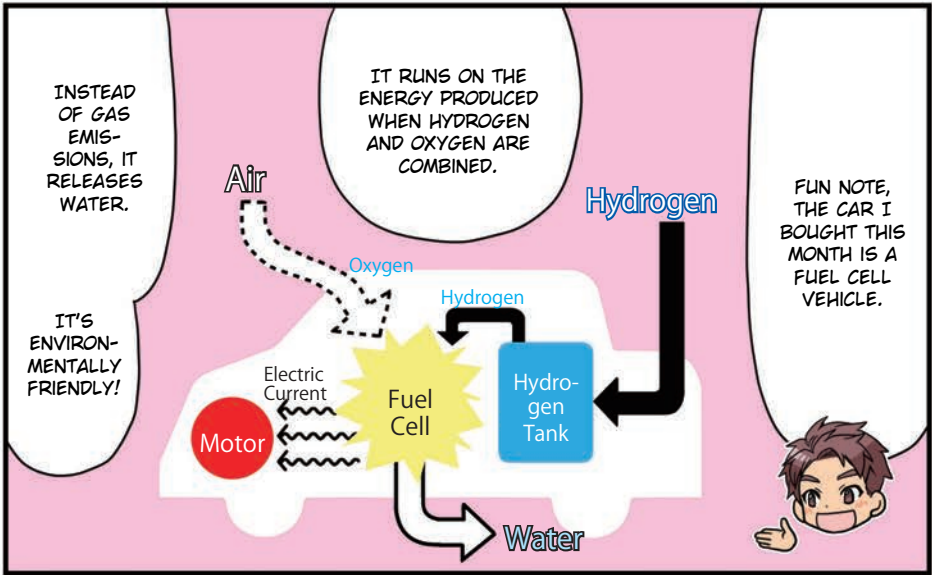


PROLOGUE

TRIVIA

IN SCIENCE, THE WORD "ENERGY" MEANS THE POWER TO MAKE SOMETHING MOVE, LIGHT UP, OR HEAT UP. CHECK PAGES 29 AND 39 FOR MORE INFORMATION.

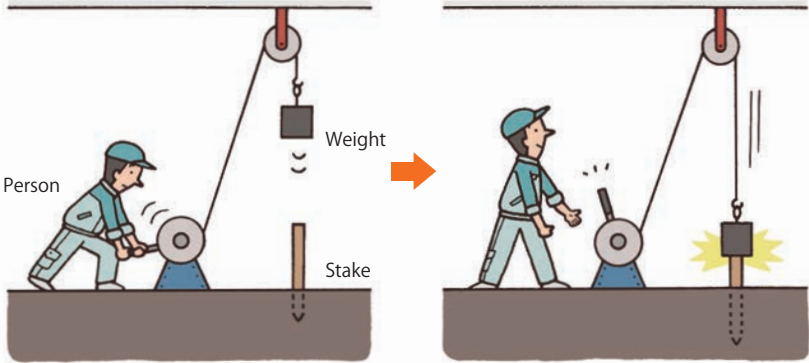






WHAT'S ENERGY? PART 1

IN SCIENTIFIC TERMS, MAKING SOMETHING MOVE OR PICKING SOMETHING UP IS CALLED "WORK." THE POWER THAT LETS SOMETHING WORK IS CALLED "ENERGY."



THE PERSON USES ENERGY TO WORK WHEN LIFTING A WEIGHT UP. THE ENERGY THE PERSON HAD IS TRANSFERRED TO THE WEIGHT THAT WAS RAISED INTO THE AIR.

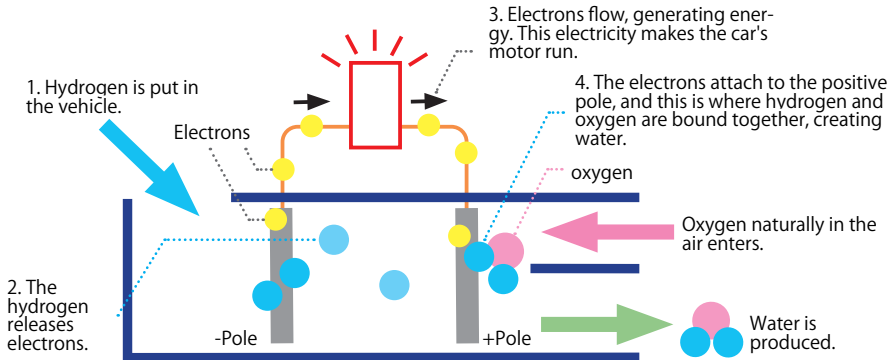
NOW THAT THE WEIGHT HAS ENERGY, IT WILL FALL DOWN, HITTING THE STAKE AND PERFORMING WORK ON IT. IN THIS WAY, ENERGY IS TRANSFERRED THROUGH WORK.

HOW FUEL CELL VEHICLES WORK

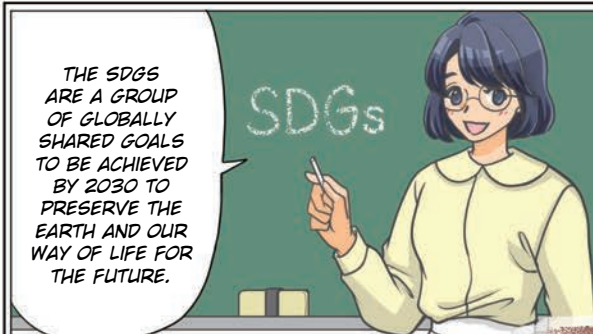
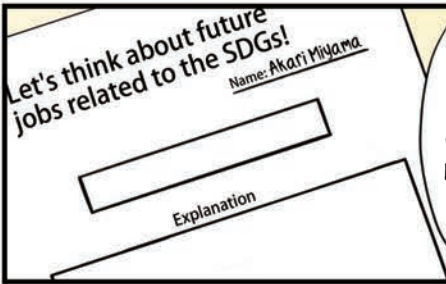
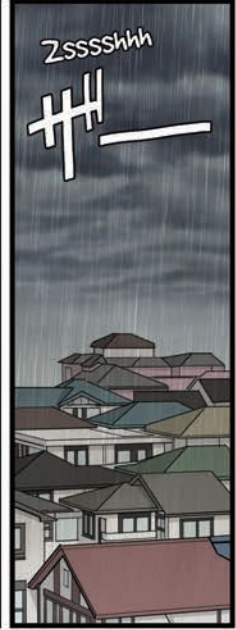
BECAUSE GASOLINE PERFORMS WORK WHEN IT MOVES A VEHICLE'S ENGINE, IT IS SAID TO HAVE ENERGY. HOWEVER, THE FUEL THAT A FUEL CELL VEHICLE USES ISN'T GASOLINE. IT'S HYDROGEN. A CHEMICAL REACTION USING HYDROGEN TO MAKE WATER CREATES ELECTRICITY, WHICH IS THEN USED AS ENERGY BY THE FUEL CELL.



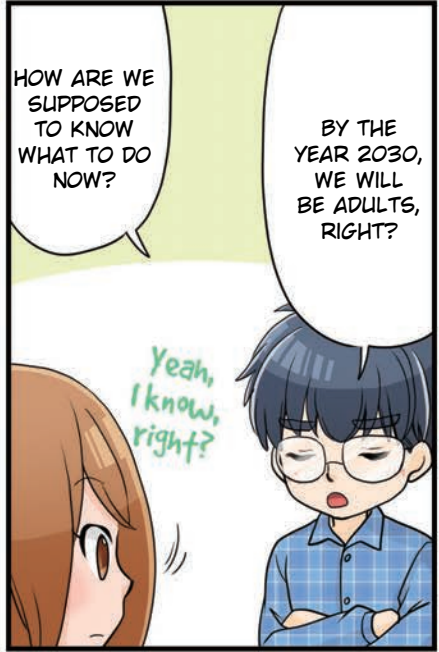
Fuel Cell Truck
Image: Tokyo R&D Co.,Ltd

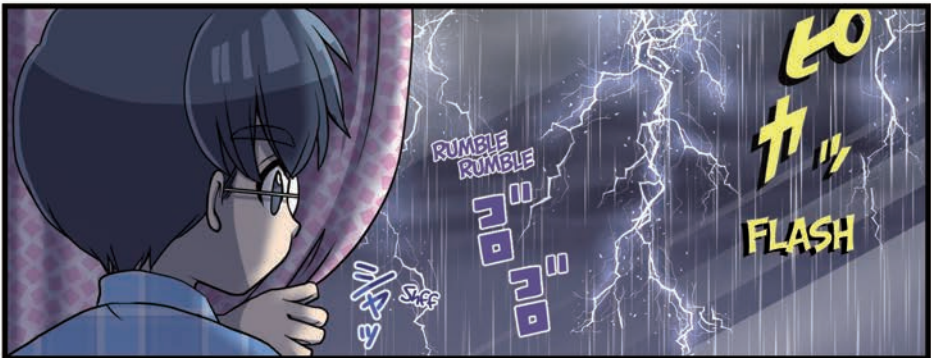
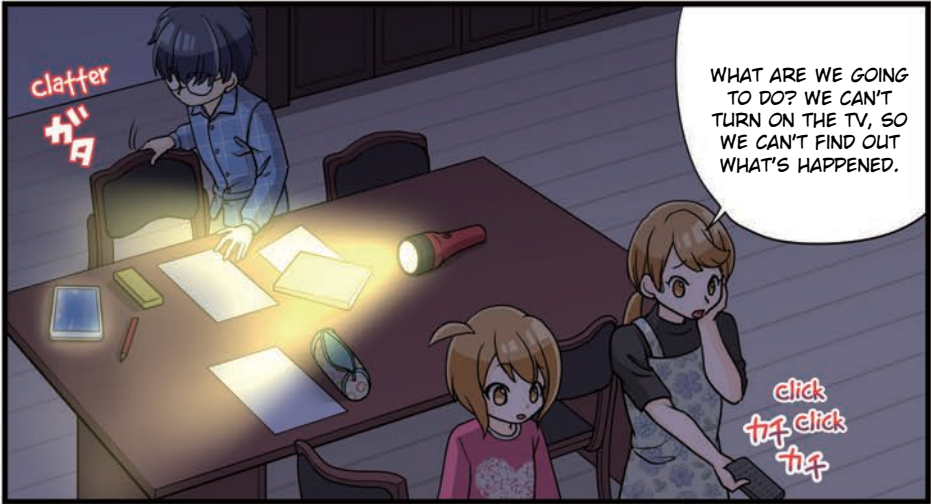
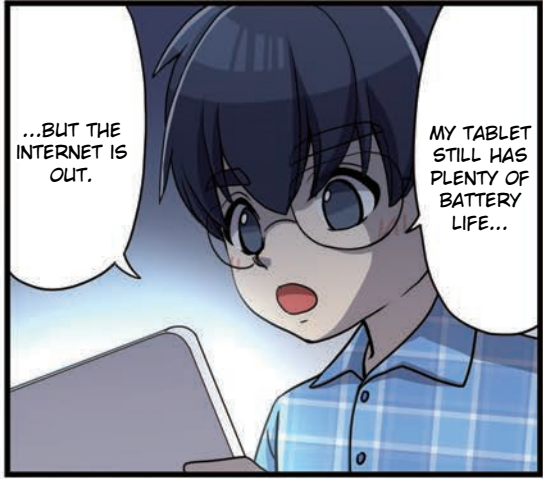


NO ENERGY? BIG PROBLEM!



THE SDGS ARE A GROUP OF GLOBALLY SHARED GOALS TO BE ACHIEVED BY 2030 TO PRESERVE THE EARTH AND OUR WAY OF LIFE FOR THE FUTURE.







CHAPTER 1: NO ENERGY? BIG PROBLEM!

TRIVIA

WHEN PREPARING TO LAUNCH A ROCKET, LARGE SECTIONS ARE FILLED WITH LIQUID HYDROGEN, WHICH IS FUEL, AND LIQUID OXYGEN, TO BURN THE FUEL.



L-h...
Silence

I WAS JUST ABOUT TO START PREPARING DINNER, TOO...

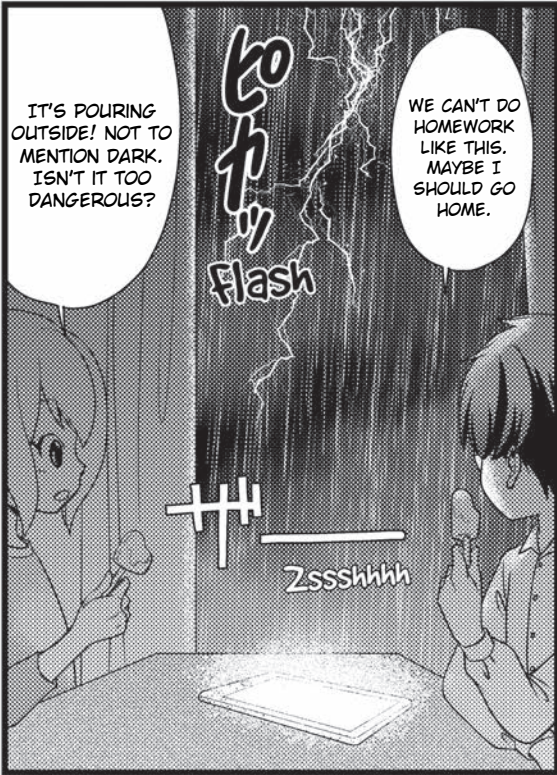
Oh, right.
THE FRIDGE DOESN'T HAVE POWER, EITHER.



+++ Zssshhhh

LOOKS LIKE THE WHOLE NEIGHBORHOOD IS OUT OF POWER.

Yikes!



IT'S POURING OUTSIDE! NOT TO MENTION DARK. ISN'T IT TOO DANGEROUS?

ゴッ
Flash

WE CAN'T DO HOMEWORK LIKE THIS. MAYBE I SHOULD GO HOME.

+++ Zssshhhh



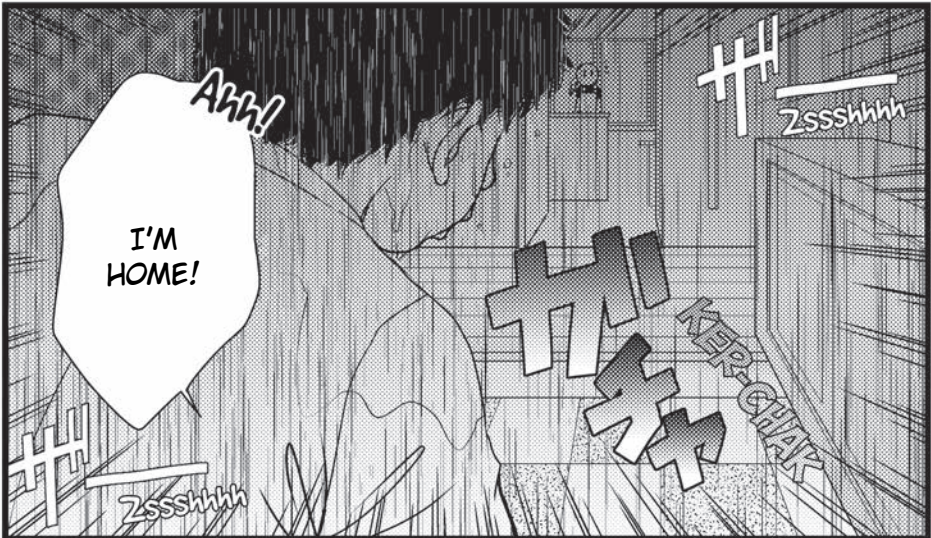
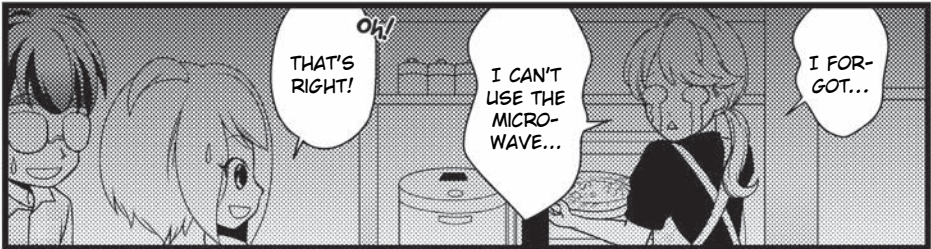
THAT MEANS THE ICE CREAM IN THE FREEZER IS GOING TO MELT.

GUESS WE HAVE TO EAT IT NOW!



TRIVIA

CURRENTLY, HYDROGEN IS USED IN FERTILIZER MANUFACTURING, SEMICONDUCTOR CAN ELECTRONIC COMPONENT PROCESSING, THE PETROCHEMICAL INDUSTRY, FOOD MANUFACTURING, AND MORE.

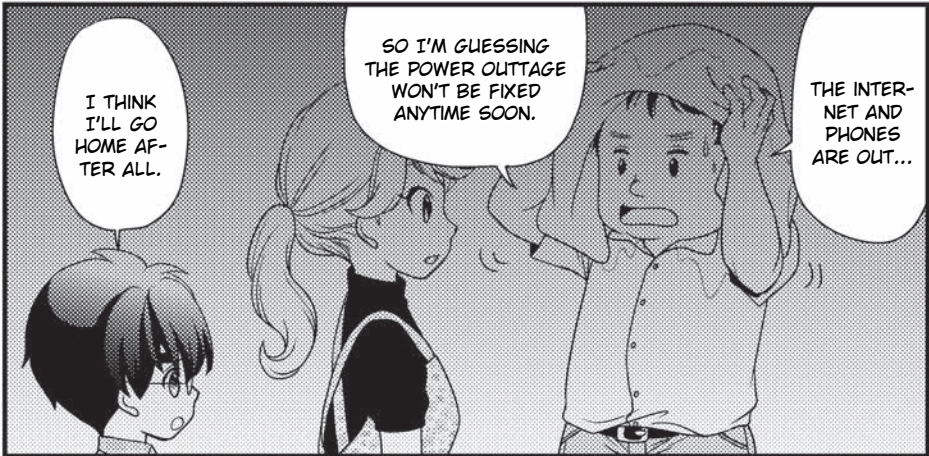
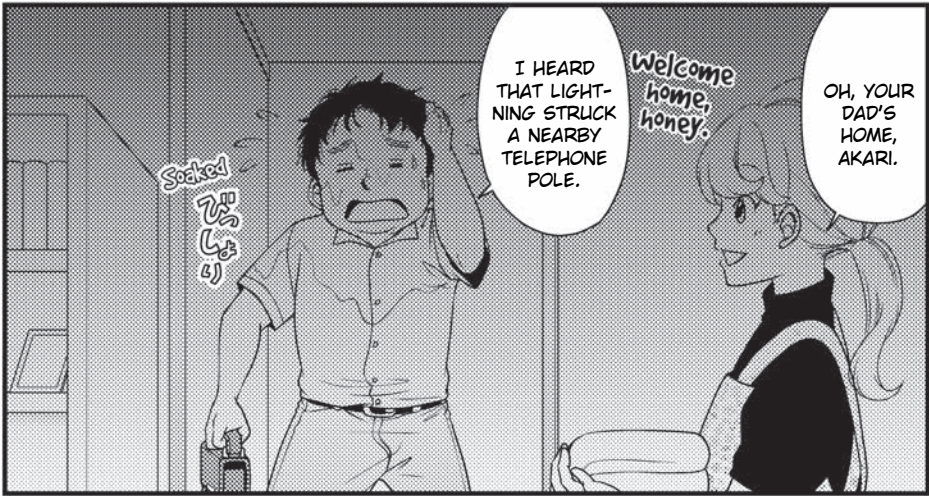


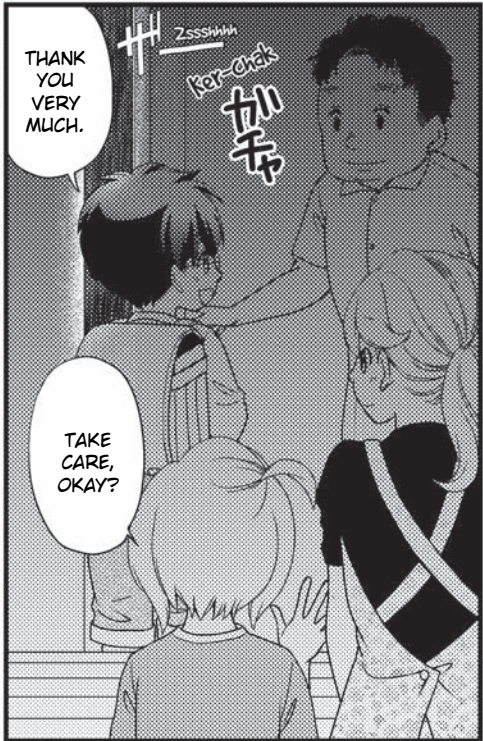
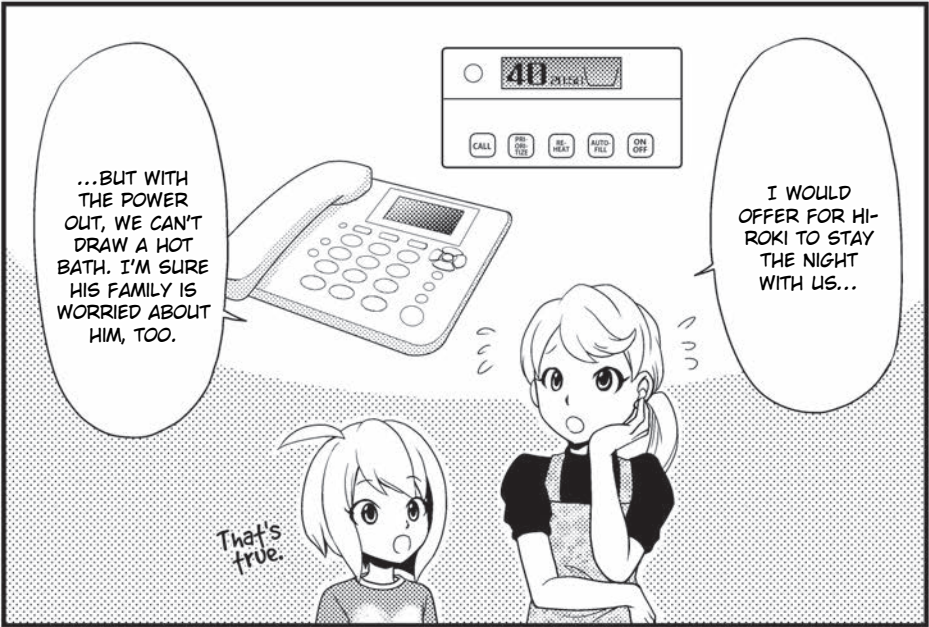


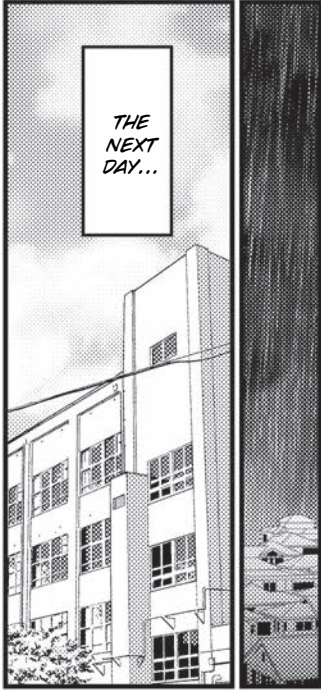
CHAPTER 1: NO ENERGY? BIG PROBLEM!

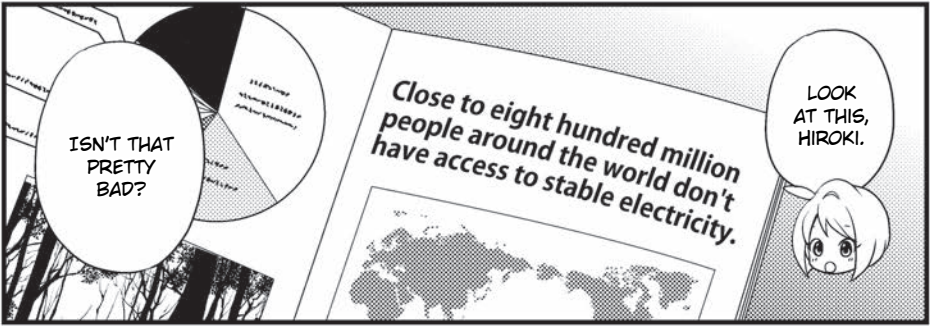
TRIVIA

JAPAN HAS SET A GOAL TO REDUCE GREENHOUSE GAS EMISSIONS BY AT LEAST 54% OF THEIR 2013 LEVELS BY THE YEAR 2030.







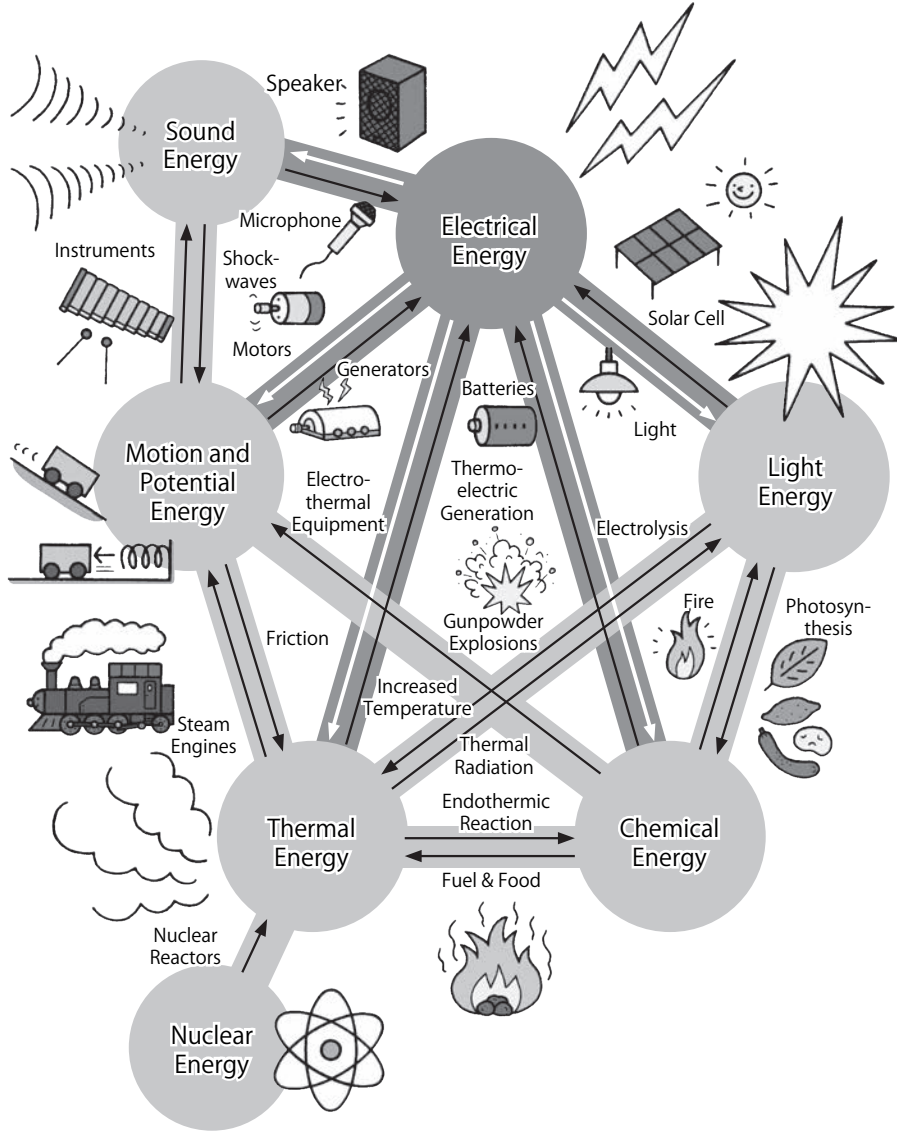




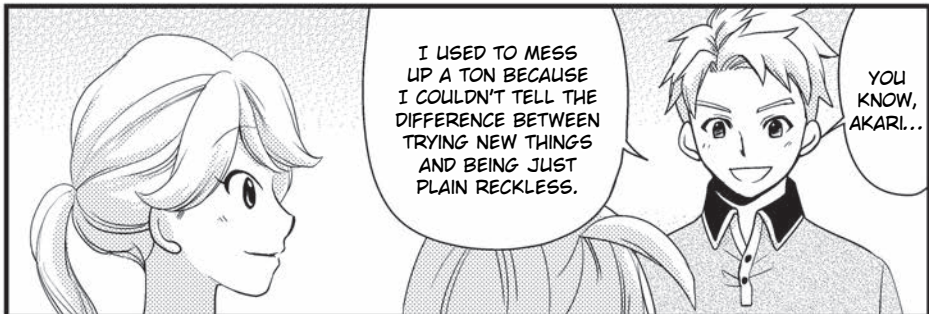
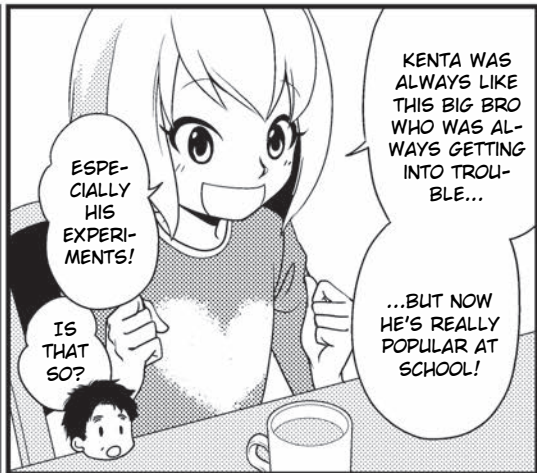
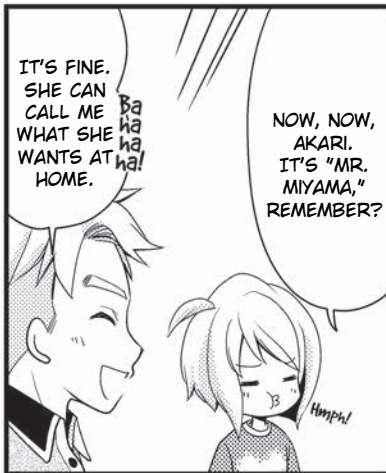
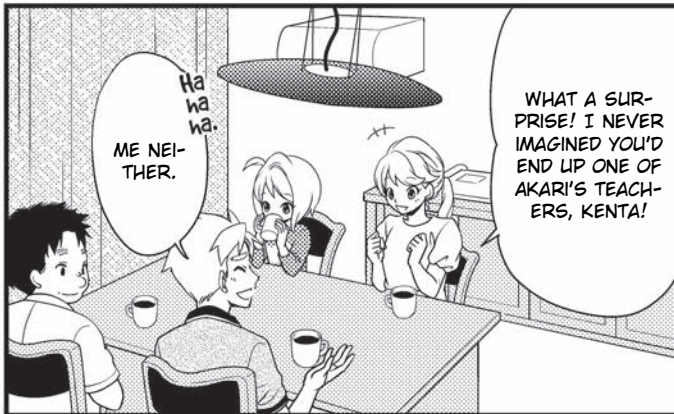
UNLIKE ELECTRICAL ENERGY, IT IS DIFFICULT TO TRANSFORM SOUND AND NUCLEAR ENERGY INTO VARIOUS OTHER FORMS OF ENERGY.

WHAT'S ENERGY? PART 2

MICROPHONES TRANSFORM SOUND ENERGY INTO ELECTRICAL ENERGY. LIGHTS CHANGE ELECTRICAL ENERGY INTO LIGHT ENERGY. THESE ARE EXAMPLES OF HOW ENERGY CAN CHANGE FORMS. THIS IS ESPECIALLY IMPORTANT FOR "ELECTRICAL ENERGY" WHICH IS A CONVENIENT, EASILY CHANGED FORM OF ENERGY.



HOW IS ELECTRICAL ENERGY CREATED?





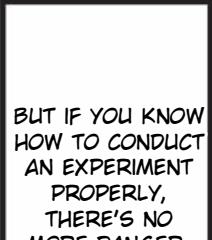
TRIVIA

JAPAN'S ELECTRIC COSTS ARE SOME OF THE MOST EXPENSIVE IN THE WORLD. THEY STARTED TO INCREASE IN THE AFTERMATH OF THE 2011 TOHOKU EARTHQUAKE AND TSUNAMI DISASTER.



NAH, I'VE STILL GOT A LONG WAY TO GO.

WELL, LOOK AT WHAT A FINE ADULT YOU'VE BECOME, KENTA.



BUT IF YOU KNOW HOW TO CONDUCT AN EXPERIMENT PROPERLY, THERE'S NO MORE DANGER. IT'S NOTHING BUT FUN!

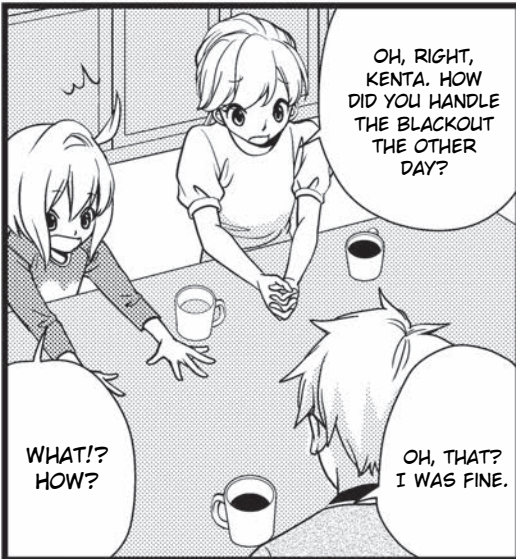


KENTA'S REALLY CHANGED NOW THAT HE'S ALL GROWN UP.

EXPERIMENTING WITHOUT BEING RECKLESS, HUH...



GRIP



OH, RIGHT, KENTA. HOW DID YOU HANDLE THE BLACKOUT THE OTHER DAY?

WHAT!? HOW?

OH, THAT? I WAS FINE.



I WONDER WHAT SORT OF GROWN-UP I'LL BECOME?

Space not out
あやあや

BA-DMP
ドキ
ドキ
ドキ
BA-DMP



I HAD NO PROBLEM BOILING WATER OR USING MY HOT PLATE TO COOK MYSELF SOME YUMMY STIR FRY.

WELL, MY CAR IS A FUEL CELL VEHICLE. IT GENERATES ELECTRICITY THROUGH A CHEMICAL REACTION BETWEEN HYDROGEN AND OXYGEN, SO I JUST USED THE ELECTRICITY IT GENERATED TO POWER MY HOME.

THAT'S HUH. PRETTY IMPRESSIVE.

Power Supply

warm

ホヤ

ホヤ

SIZZLE

WHEN THE WEATHER'S CLEAR, IT GENERATES ELECTRICITY USING SUNLIGHT. THAT WAY, EVEN IF THERE IS A BLACKOUT, I CAN STILL USE MY ELECTRONICS IF THEY'RE PLUGGED INTO AN OUTLET.

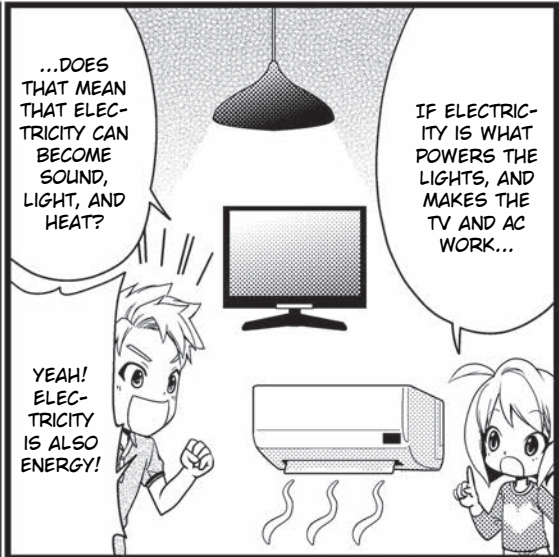
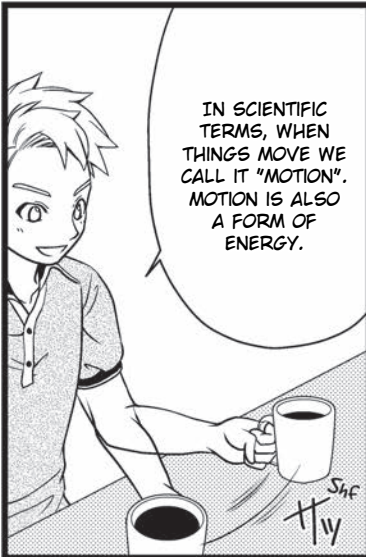
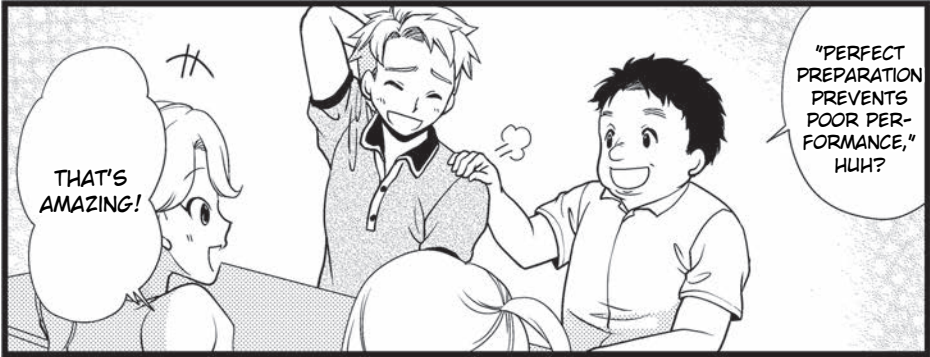
I'M ALSO ABLE TO STORE ELECTRICITY. I HAVE A SOLAR-POWERED CHARGING SYSTEM ON MY BALCONY.



CHAPTER 2: HOW IS ELECTRICAL ENERGY CREATED?

TRIVIA

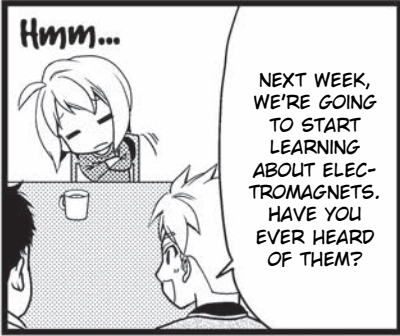
AN INCANDESCENT LIGHT BULB CHANGES ELECTRICITY INTO HEAT, THEN THAT HEAT CREATES LIGHT, BUT LED LIGHT BULBS DIRECTLY CONVERT ELECTRICITY INTO LIGHT, SO THEY SAVE ENERGY.





TRIVIA

THE EARTH IS A GIANT MAGNET. THE EARTH'S NORTH POLE IS A MAGNETIC SOUTH POLE, WHILE THE EARTH'S SOUTH POLE IS A MAGNETIC NORTH POLE. THAT IS WHY A COMPASS NEEDLE POINTS NORTH FOR N AND SOUTH FOR S.



Hmm...

NEXT WEEK, WE'RE GOING TO START LEARNING ABOUT ELECTROMAGNETS. HAVE YOU EVER HEARD OF THEM?



IN BOTH CASES, ELECTRICAL ENERGY IS BEING CONVERTED INTO MOTION ENERGY. ELECTRICAL ENERGY IS EASILY CHANGED INTO OTHER FORMS OF ENERGY MAKING IT VERY CONVENIENT.

FOR EXAMPLE, IF YOU POWER A VACUUM CLEANER WITH ELECTRICITY, ITS PARTS MOVE TO SUCK UP DIRT.

YOU MAKE AN ELEVATOR MOVE WITH ELECTRIC ENERGY TO CARRY PEOPLE.

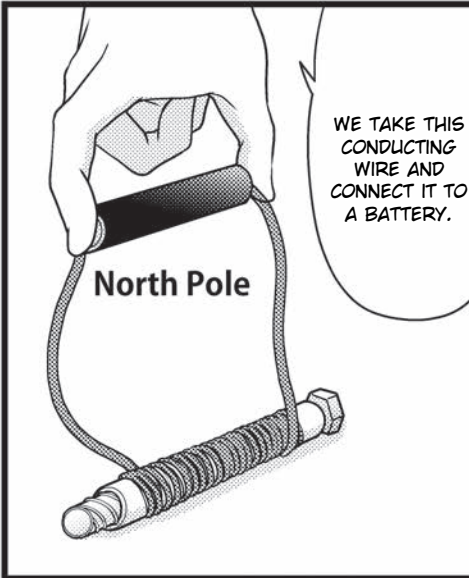
OH, SO THAT'S HOW IT WORKS.

Elevator



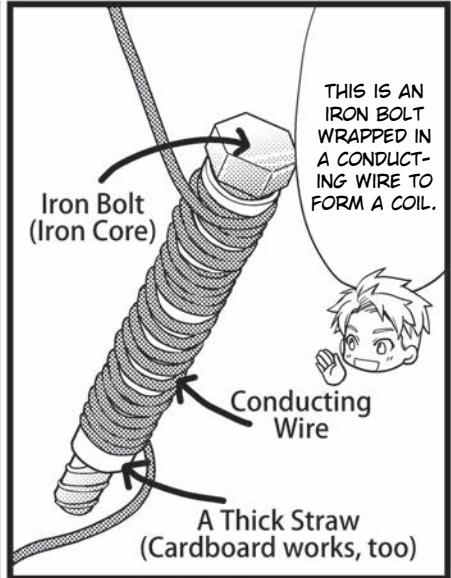
Rummage Rummage

YOU KNOW WHAT? I'VE GOT ONE ON ME.



North Pole

WE TAKE THIS CONDUCTING WIRE AND CONNECT IT TO A BATTERY.



Iron Bolt (Iron Core)

THIS IS AN IRON BOLT WRAPPED IN A CONDUCTING WIRE TO FORM A COIL.

Conducting Wire

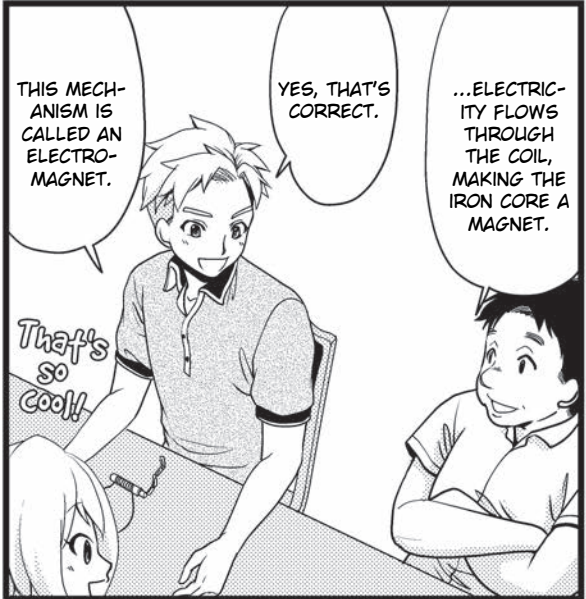
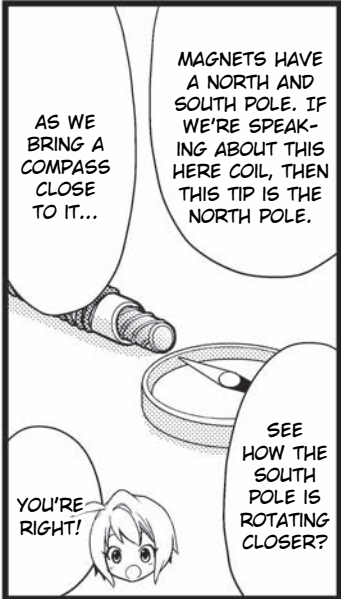
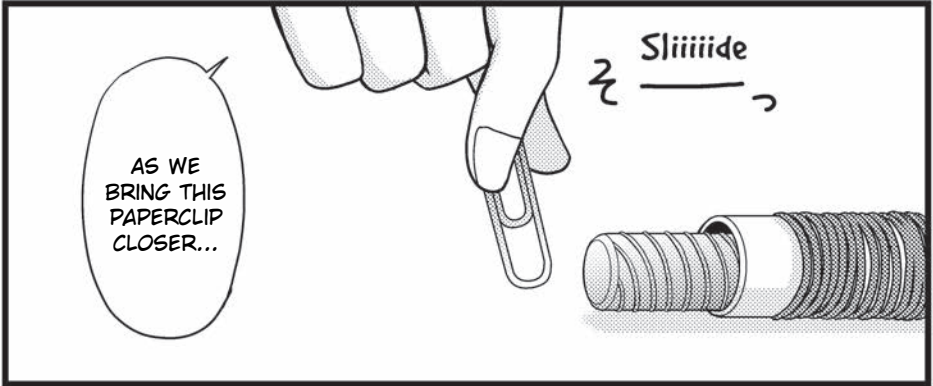
A Thick Straw (Cardboard works, too)

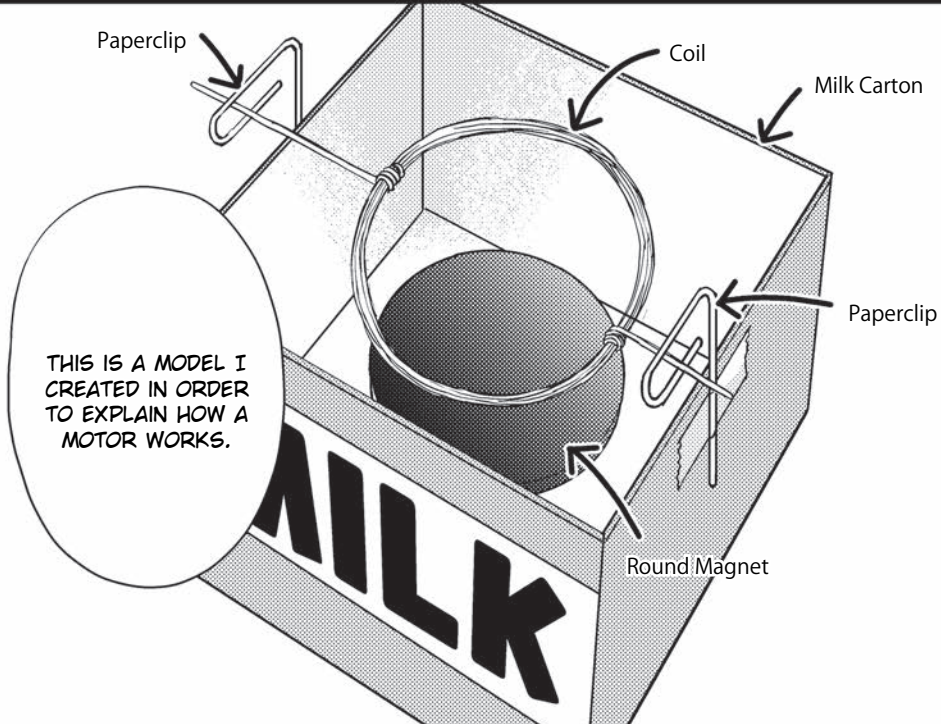
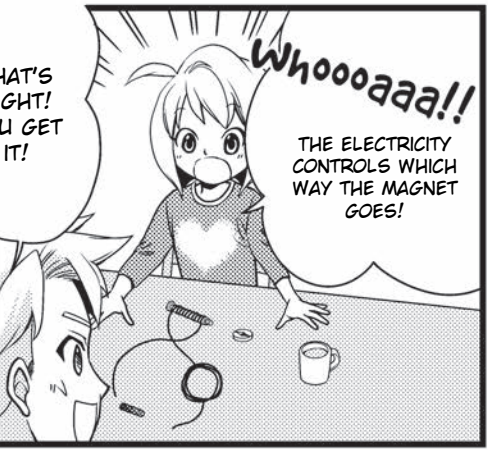
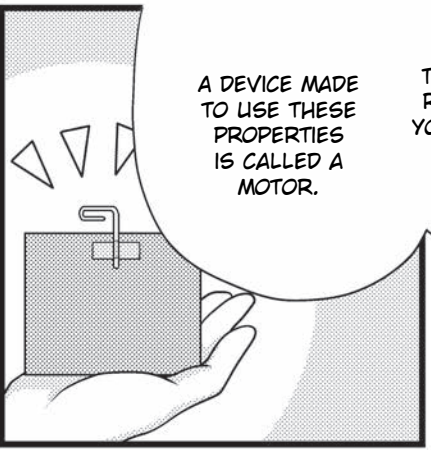
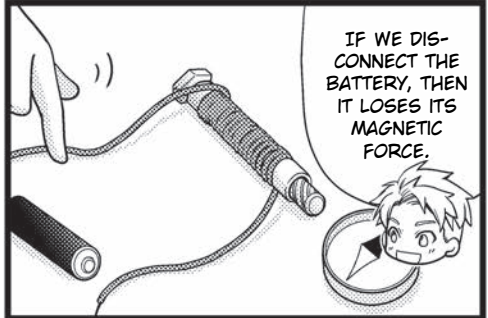
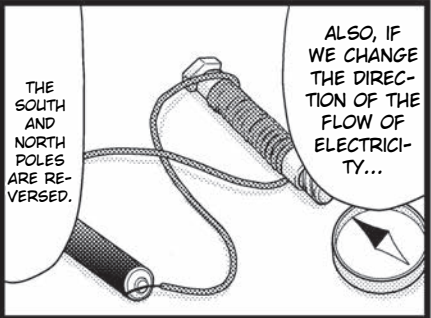


CHAPTER 2: HOW IS ELECTRICAL ENERGY CREATED?

TRIVIA

EACH TINY GRAIN INSIDE OF IRON HAS ITS OWN NORTH AND SOUTH POLES, BUT SINCE THEY ALL POINT IN DIFFERENT DIRECTIONS, A PIECE OF IRON DOES NOT HAVE MAGNETIC FORCE.



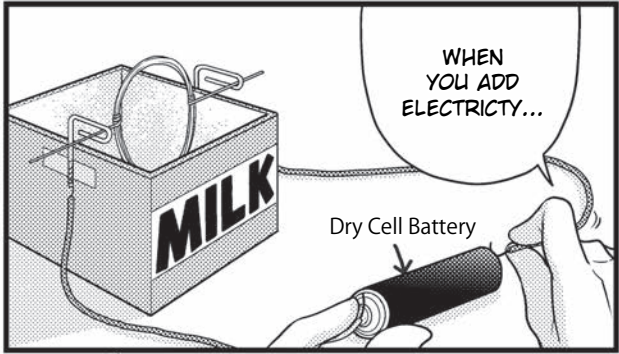


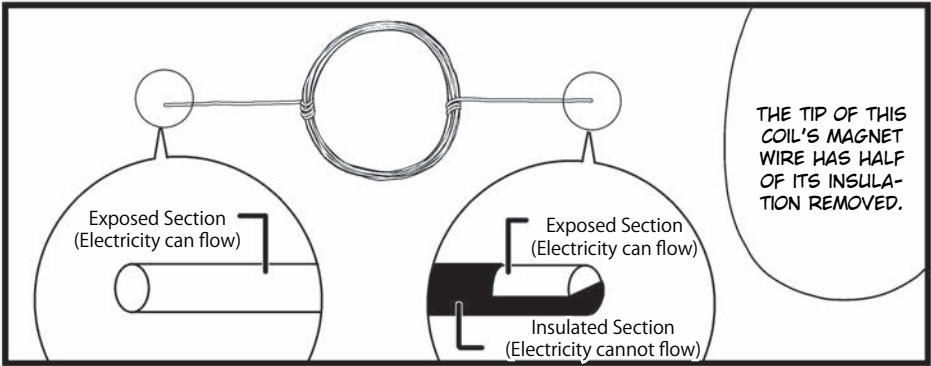


CHAPTER 2: HOW IS ELECTRICAL ENERGY CREATED?

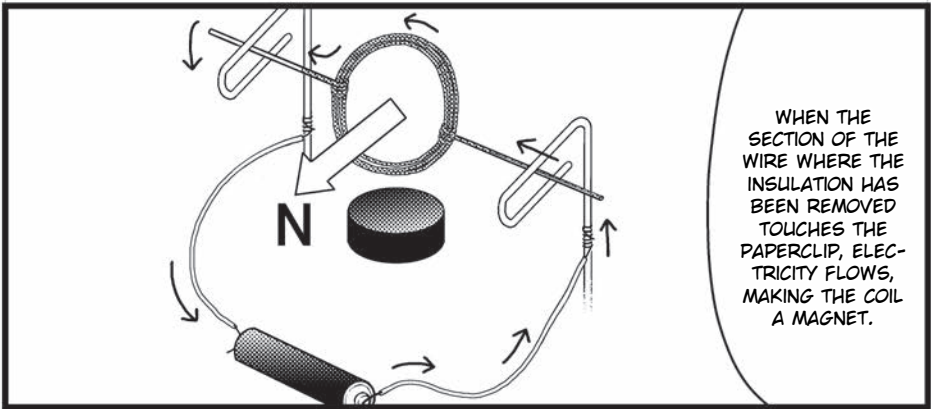
TRIVIA

THE LINEAR MOTOR CAR USES ELECTROMAGNETS. THEY ARE CONVENIENT BECAUSE THE POLES CAN BE REVERSED EASILY.





THE TIP OF THIS COIL'S MAGNET WIRE HAS HALF OF ITS INSULATION REMOVED.



WHEN THE SECTION OF THE WIRE WHERE THE INSULATION HAS BEEN REMOVED TOUCHES THE PAPERCLIP, ELECTRICITY FLOWS, MAKING THE COIL A MAGNET.

THE ELECTRICITY STOPS FLOWING.

WHAT HAPPENS IF, RIGHT THEN, THE INSULATED PART TOUCHES THE PAPERCLIP?

L-h
Silence

BUT THEN THE NORTH POLE WILL JUST CONTINUE TO BE DRAWN DOWN TOWARD THE MAGNET BELOW, SO THE SPINNING WILL STOP WHEN IT GETS TO THE BOTTOM, RIGHT?

THE PART UP HERE IS THE NORTH POLE, SO IT'S PULLED TOWARD THE SOUTH POLE OF THE MAGNET BELOW AND BEGINS TO SPIN.

HMM. YEAH, I SEE.



CHAPTER 2: HOW IS ELECTRICAL ENERGY CREATED?

TRIVIA

WHEN AN ELECTRICAL CURRENT FLOWS THROUGH A CONDUCTING WIRE, A MAGNETIC FIELD IS FORMED AROUND THE WIRE.

COOL!

SO THE NORTH POLE MOVES BACK UP TO THE TOP, THE NON-INSULATED PART TOUCHES THE PAPERCLIP, AND THE WHOLE THING REPEATS. THE ROTATIONAL MOVEMENT CAUSED BY THE CHANGE IN THE MAGNET CREATES A KIND OF MOTOR.

SO IT JUST KEEPS MOVING WITH THE MOMENTUM IT'S SAVED UP.

OH, I GET IT! THEN IT WON'T BE PULLED TOWARD THE MAGNET ANYMORE.

CORRECT. IF WE DO THAT, IT LOSES ITS MAGNETIC FORCE.

HAVING THREE COILS ALLOWS THE MOTOR TO ROTATE MORE SMOOTHLY.

OOH!

Magnet

Shaft

Magnet

Coil

Pin

THIS IS A REAL MOTOR. SEE HOW THERE ARE THREE COILS?

THE PARTS ON EITHER SIDE ARE MAGNETS.

REALLY?

MOTORS ARE USED FOR ALL SORTS OF THINGS.



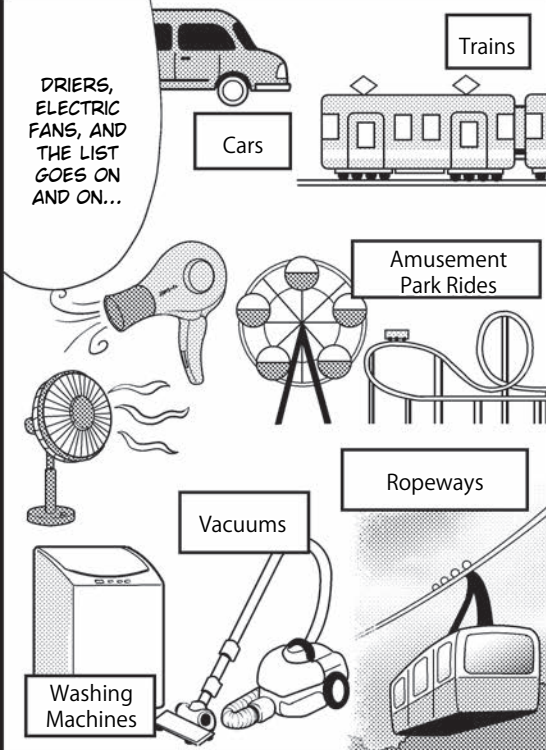
A 19TH CENTURY ENGLISH SCIENTIST.

WHO WAS SMART ENOUGH TO THINK UP THAT?



MICHAEL FARADAY
(1791-1867)
"THE FATHER OF ELECTROMAGNETISM"

DRIERS, ELECTRIC FANS, AND THE LIST GOES ON AND ON...



Cars

Trains

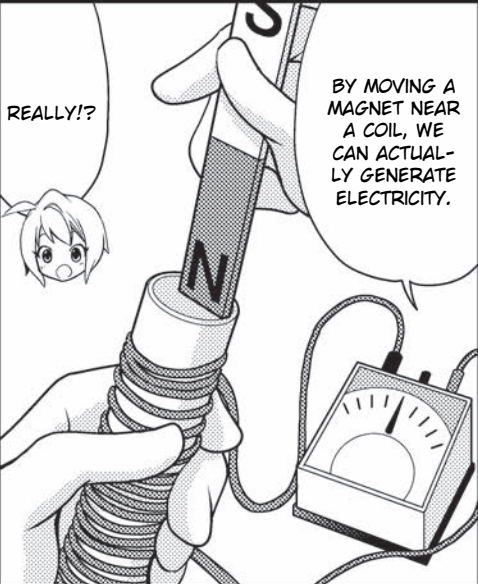
Amusement Park Rides

Ropeways

Vacuums

Washing Machines

REALLY!?

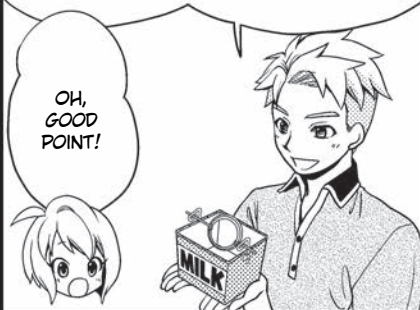


BY MOVING A MAGNET NEAR A COIL, WE CAN ACTUALLY GENERATE ELECTRICITY.

...SHOULDN'T MOTION ENERGY CONVERT INTO ELECTRICAL ENERGY?

NOW, THAT'S NOT ALL THERE IS TO IT. SINCE THE ELECTRICAL ENERGY CONVERTS TO MOTION ENERGY...

OH, GOOD POINT!

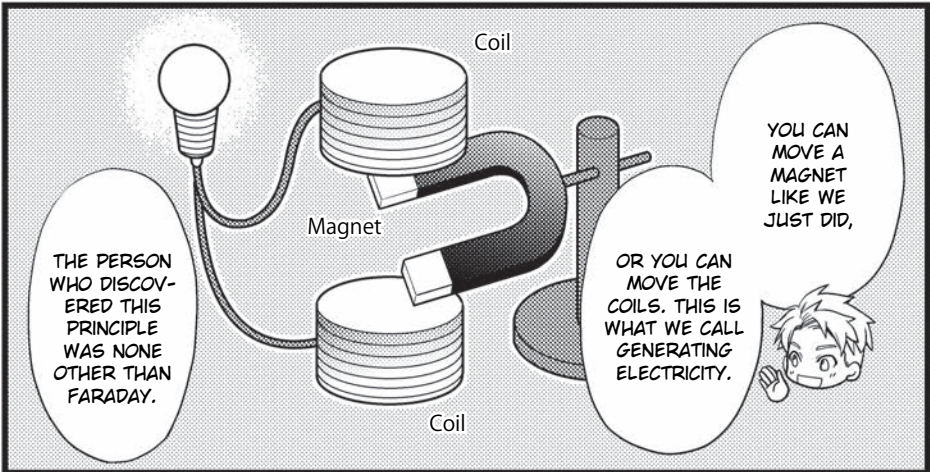
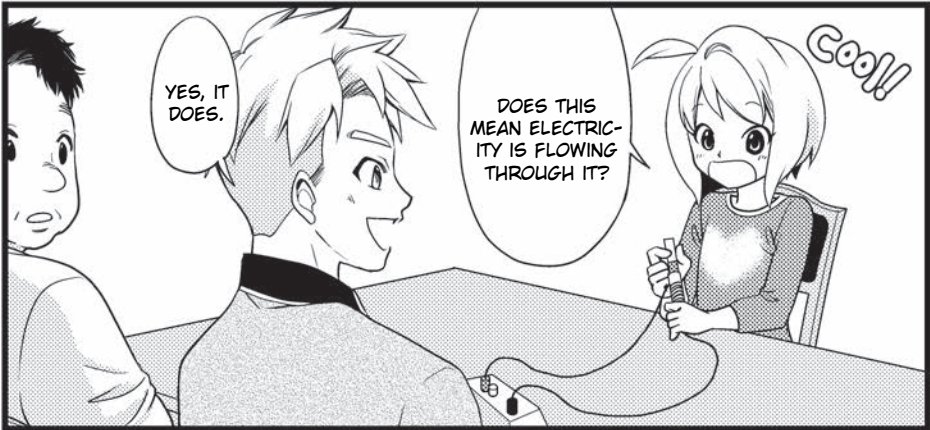
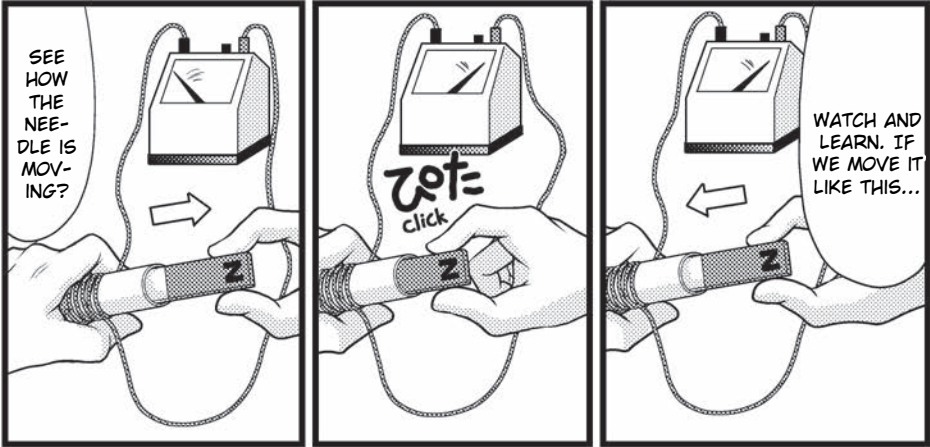


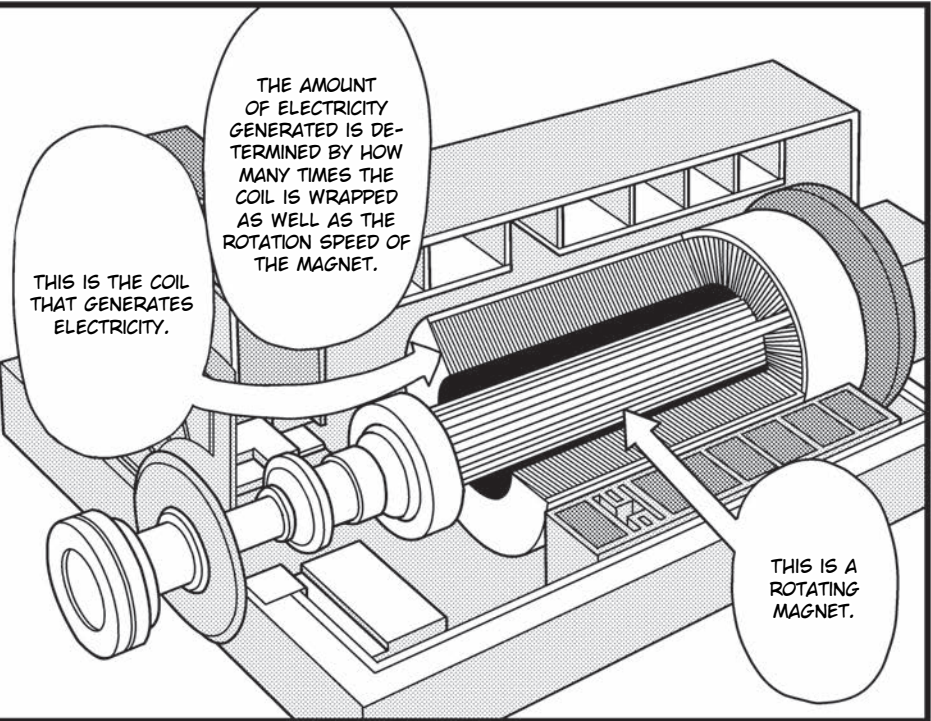
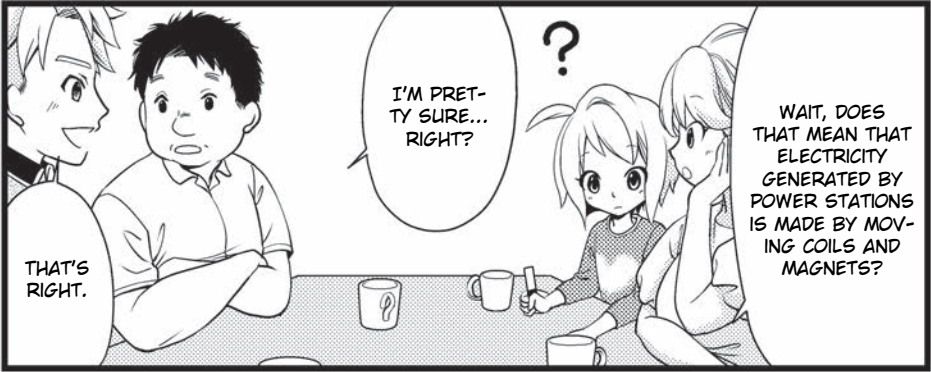


CHAPTER 2: HOW IS ELECTRICAL ENERGY CREATED?

TRIVIA

MOVING EITHER COILS OR MAGNETS INSIDE OF A MAGNETIC FIELD TO PRODUCE AN ELECTRIC CURRENT IS CALLED "ELECTROMAGNETIC INDUCTION."







CHAPTER 2: HOW IS ELECTRICAL ENERGY CREATED?

TRIVIA

WAVE POWER, WHICH GENERATES ELECTRICITY THROUGH THE RISING AND FALLING OF WAVES IN THE OCEAN, IS USED TO POWER LIGHTHOUSES AND OTHER THINGS. HOWEVER, IT IS NOT ALWAYS RELIABLE.

Energy

High place

Low place

THIS IS CALLED "POTENTIAL ENERGY."

THINGS IN HIGH PLACES POSSESS ENERGY. THIS IS BECAUSE THEY WANT TO FALL DOWNWARDS.

Hydroelectric Power

FOR EXAMPLE, THERE'S HYDROELECTRIC POWER. IT'S A FORM OF GENERATING ELECTRICITY THAT USES A DAM.

Dam

BOOM BOOM BOOM BOOM

WHOOOOOSH!

A DAM COLLECTS WATER AND THEN SYSTEMATICALLY MAKES IT FALL.

IT THEN USES THAT FALLING FORCE TO ROTATE THE IMPELLER.

Rotating Magnet

Coil

Generator

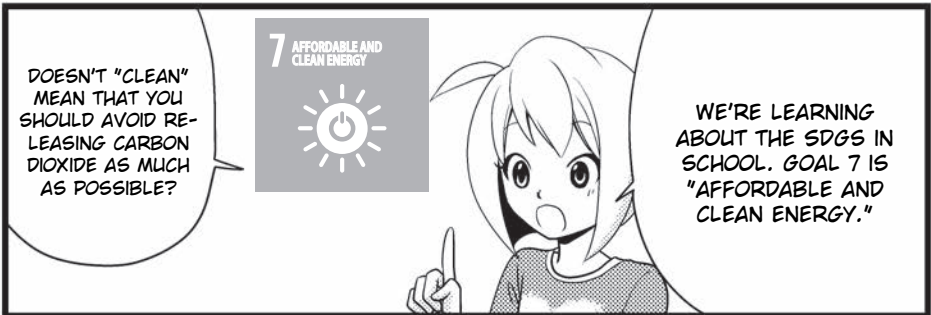
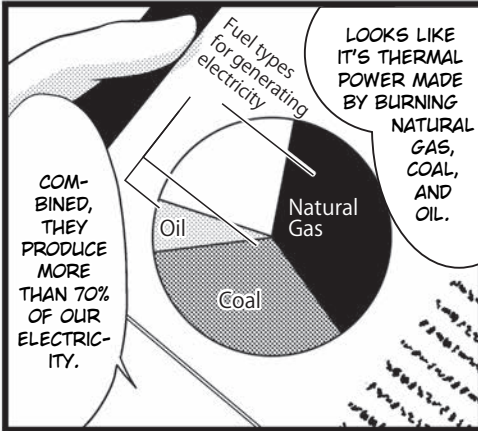
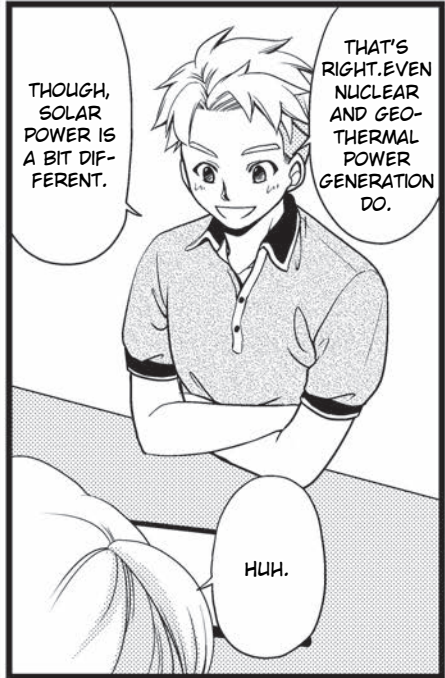
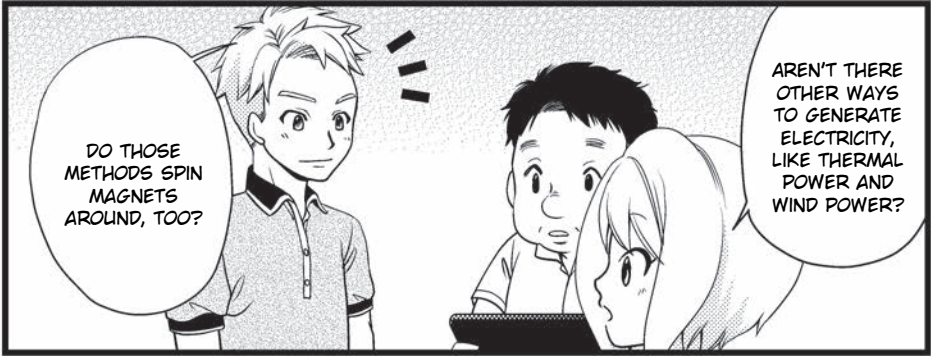
Water Turbine

THE IMPELLERS USED IN HYDROELECTRIC POWER ARE CALLED WATER TURBINES.



That's interesting.







CHAPTER 2: HOW IS ELECTRICAL ENERGY CREATED?

TRIVIA

RENEWABLE ENERGIES SUCH AS SOLAR, WIND, AND GEOTHERMAL ARE IMPORTANT LOW-CARBON ENERGY SOURCES BECAUSE THEY PRODUCE ELECTRICITY WITHOUT RELEASING GREENHOUSE GASES.

THAT MEANS THAT WE NEED TO CONTINUE TO REDUCE CARBON DIOXIDE EMISSIONS.

AS CLIMATE CHANGE CONTINUES, WE'RE GOING TO FACE EVEN BIGGER PROBLEMS LIKE EXTREME WEATHER AND RISING SEA LEVELS.

Drought

Melting Ice

Islands Sinking

CARBON DIOXIDE IS CONNECTED TO RISING TEMPERATURES.

CORRECT. BURNING EARTH'S PRECIOUS FOSSIL FUELS, SUCH AS OIL, COAL, AND NATURAL GAS, IS CONNECTED TO GLOBAL WARMING.

IT'S ALSO CALLED "RENEWABLE ENERGY."

WHAT'S NATURAL ENERGY?

THIS SAYS THAT KENYA GENERATES 85% OF THEIR ELECTRICITY USING NATURAL ENERGY, PARTICULARLY GEOTHERMAL ENERGY. THAT'S PRETTY REMARKABLE.

OH, WOW!

ZSSSHHHH

OH, I SEE...

BUT IT'S NOT ALWAYS RELIABLE. WE ARE TALKING ABOUT NATURE, AFTER ALL.

Whoosh

Whooooosh

Dried up

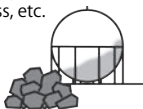



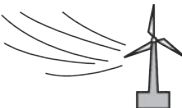
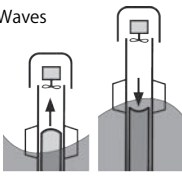
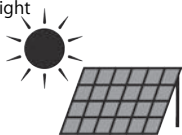
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IT MEANS WAYS OF GENERATING ELECTRICITY THAT USE NATURE'S FORCES LIKE WIND, SUNLIGHT, AND WATER. IT DOESN'T USE UP NATURAL RESOURCES AND DOESN'T RELEASE CARBON DIOXIDE.

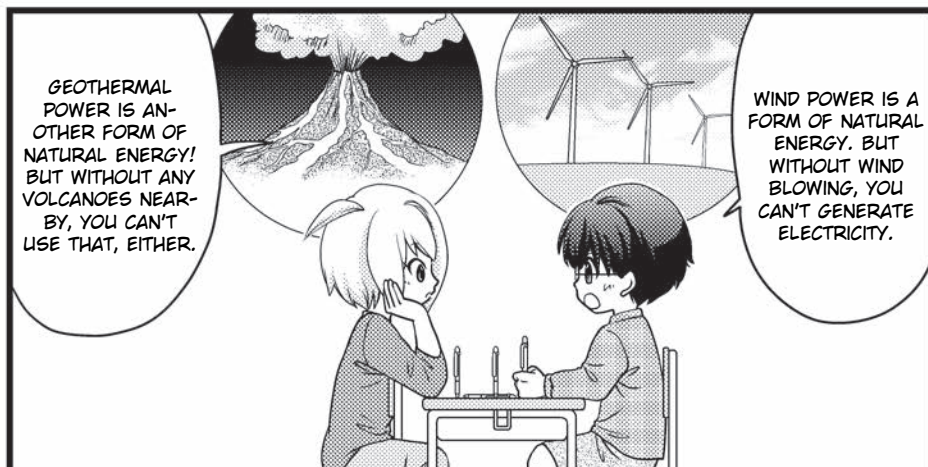


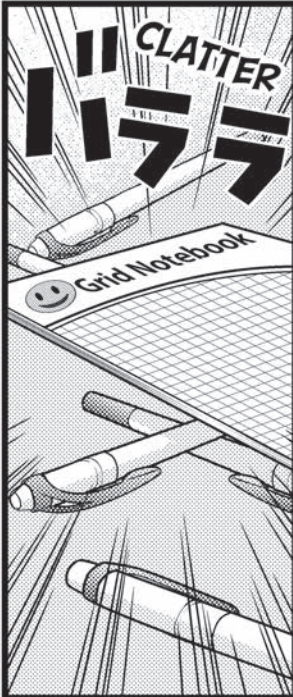
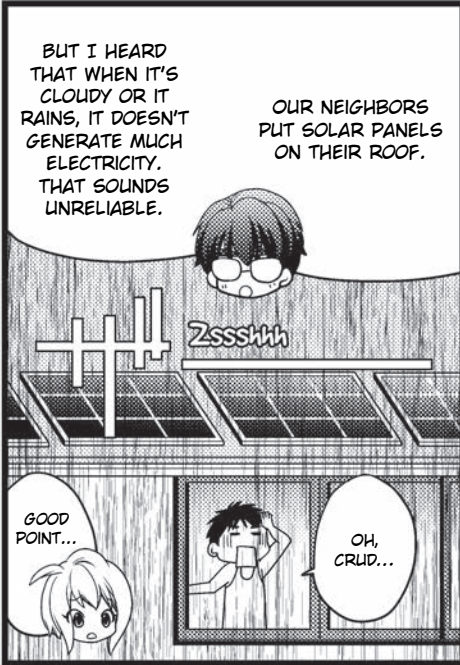
DIFFERENT WAYS TO GENERATE ELECTRICITY

THERE ARE MANY METHODS FOR GENERATING ELECTRICITY. NUMBERS ONE THROUGH SIX ROTATE MASSIVE COILS AND MAGNETS TO GENERATE ELECTRICITY. LET'S EXAMINE THE CHARACTERISTICS OF EACH.

Method	Fuel & Natural Resources	Benefits	Drawbacks
<p>1. Thermal Power Uses the heat created from burning fossil fuels to rotate turbines, which turn the generators.</p>	<p>Natural gas, coal, biomass, etc.</p> 	<ul style="list-style-type: none"> • Can reliably generate large amounts of electricity. • Amount of energy generated can be adjusted. 	<ul style="list-style-type: none"> • Produces carbon dioxide. • Natural resources are finite.
<p>2. Hydroelectric Power Uses the force of water falling to rotate turbines, which turn the generators.</p>	<p>Water in a dam</p> 	<ul style="list-style-type: none"> • Doesn't produce carbon dioxide. • If the dam has enough water, it can quickly generate electricity when needed. 	<ul style="list-style-type: none"> • Constructing dams has a massive impact on the surrounding environment.
<p>3. Geothermal Power Uses the heat from underground magma to rotate turbines, which turn the generators.</p>	<p>Magma</p> 	<ul style="list-style-type: none"> • Doesn't use up natural resources. • Doesn't produce carbon dioxide. • Can produce electricity around the clock and is unaffected by the weather. 	<ul style="list-style-type: none"> • Only available in certain areas.
<p>4. Nuclear Power Nuclear Power Generation makes use of thermal energy generated by the nuclear fission to turn the generator by rotating a turbine.</p>	<p>Uranium</p> 	<ul style="list-style-type: none"> • Stable generation of large amount of electricity with a small amount of fuel. • Zero CO₂ emissions during operation. 	<ul style="list-style-type: none"> • Radioactive waste. • Need to take safety measures in case of an accident.
<p>5. Wind Power Uses the power of wind to rotate propellers, which turn the generators.</p>	<p>Wind</p> 	<ul style="list-style-type: none"> • Doesn't use up natural resources. • Doesn't produce carbon dioxide. 	<ul style="list-style-type: none"> • Amount of electricity generated depends on the direction and strength of the wind.
<p>6. Wave Power Uses the rising and falling of waves to cause the expansion and contraction of air inside containers to rotate turbines.</p>	<p>Waves</p> 	<ul style="list-style-type: none"> • Doesn't use up natural resources. • Doesn't produce carbon dioxide. 	<ul style="list-style-type: none"> • Very difficult to construct structures that can withstand the frequently changing ocean environment and severe weather such as typhoons and high tides.
<p>7. Solar Power Uses sunlight to make the electrons inside solar batteries move, generating electricity.</p>	<p>Light</p> 	<ul style="list-style-type: none"> • Doesn't use up natural resources. • Doesn't produce carbon dioxide. 	<ul style="list-style-type: none"> • Amount of electricity generated depends on the weather.

THE SECRET WEAPON IS HYDROGEN POWER!







CHAPTER 3: THE SECRET WEAPON IS HYDROGEN POWER!

TRIVIA

SOLAR POWER USES SEMICONDUCTORS MADE FROM SILICON TO TAKE IN LIGHT AND CONVERT THE LIGHT ENERGY INTO ELECTRICAL ENERGY.



OH YEAH!
THE GAS DETONATION HOSE EXPERIMENT!

ENERGY... ENERGY...
HMM? REMEMBER THE HOSE EXPERIMENT FROM THE OTHER DAY...?



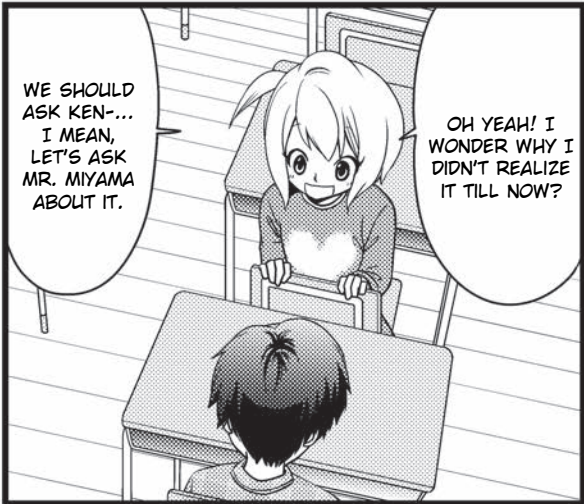
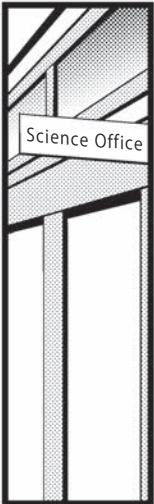
ISN'T THERE SOME OTHER FORM OF ENERGY OUT THERE...?



THAT'S RIGHT! I ALMOST FORGOT ABOUT THAT!

CLATTER
たた

THE ONE THAT COMBINES OXYGEN AND HYDROGEN! I WONDER IF WE COULD USE THAT ENERGY?



WE SHOULD ASK KEN... I MEAN, LET'S ASK MR. MIYAMA ABOUT IT.

OH YEAH! I WONDER WHY I DIDN'T REALIZE IT TILL NOW?





CHAPTER 3: THE SECRET WEAPON IS HYDROGEN POWER!

TRIVIA

NATURAL GAS, COAL, AND OIL ARE ANCIENT PLANTS AND ANIMALS THAT WERE BURIED UNDER THE EARTH AND SLOWLY TURNED INTO FOSSIL FUELS OVER A LONG PERIOD OF TIME.



FOR REAL!? THAT'S SO COOL!

AND WOULD YOU BELIEVE IT!? A FRIEND I WENT TO HIGH SCHOOL WITH WORKS AT THIS COMPANY ON THEIR HYDROGEN POWER PROJECT!



ME TOO!

I WANNA GO!

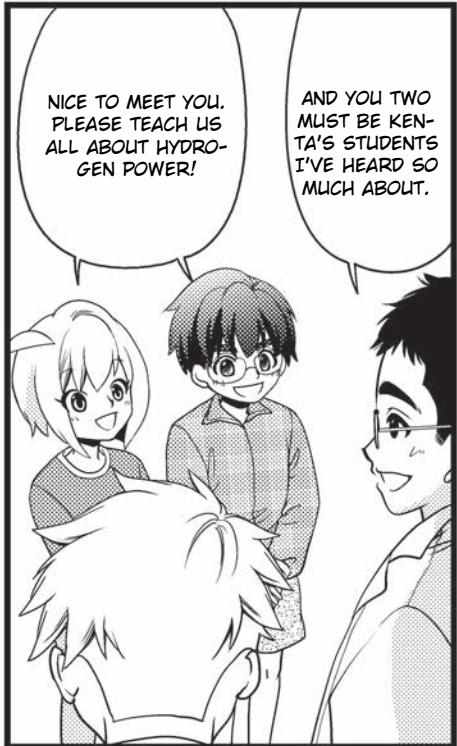
WANT TO GO MEET THEM WITH ME?

SO THEN I TOLD THEM I WAS INTERESTED AND ASKED IF THEY COULD TELL ME MORE, AND THEY SAID YES!



Excited
トキ トキ...

I WONDER WHAT HYDROGEN POWER GENERATION IS LIKE!





CHAPTER 3: THE SECRET WEAPON IS HYDROGEN POWER!

TRIVIA

NATURAL GAS IS THE GAS FOUND IN THE UPPER PORTIONS OF POCKETS OF OIL LOCATED IN THE EARTH.

UNLIKE NATURAL ENERGY, THERMAL POWER LETS US GENERATE JUST THE AMOUNT OF ELECTRICITY WE NEED, WHEN WE NEED IT.

Coal

Natural Gas

Oil

Thermal Power

THERMAL POWER GENERATES ELECTRICITY ACCORDING TO THE AMOUNT OF FUEL. IT'S CONVENIENT BECAUSE YOU CAN VARY IT BASED ON HOW MUCH FUEL YOU USE.

BUT THERMAL POWER GENERATION EMITS CARBON DIOXIDE.

EXACTLY. ACTUALLY, OUR THERMAL POWER GENERATION EQUIPMENT IS USED IN MORE THAN 60 COUNTRIES AROUND THE WORLD.

HOWEVER, THE FACT REMAINS THAT WE'RE PRODUCING CARBON DIOXIDE, SO WE AT MITSUBISHI ARE THINKING OF CONVERTING EVERYTHING OVER TO HYDROGEN POWER.

THAT'S BECAUSE HYDROGEN POWER DOESN'T PRODUCE CARBON DIOXIDE, RIGHT?

(g-CO₂/kWh)

Category	Carbon Dioxide Emission Rate (g-CO ₂ /kWh)
Coal-Fired Thermal Power	~900
Present	~450

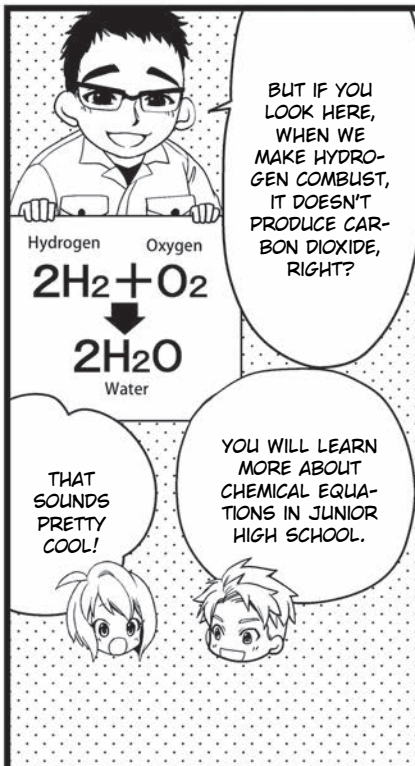
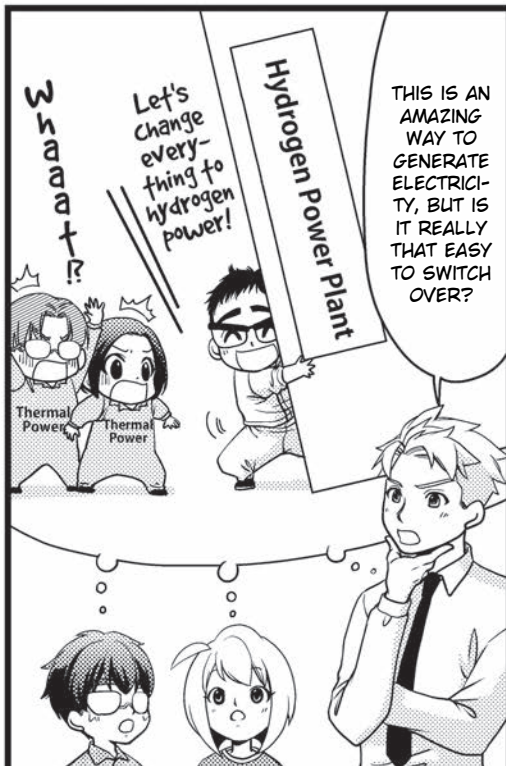
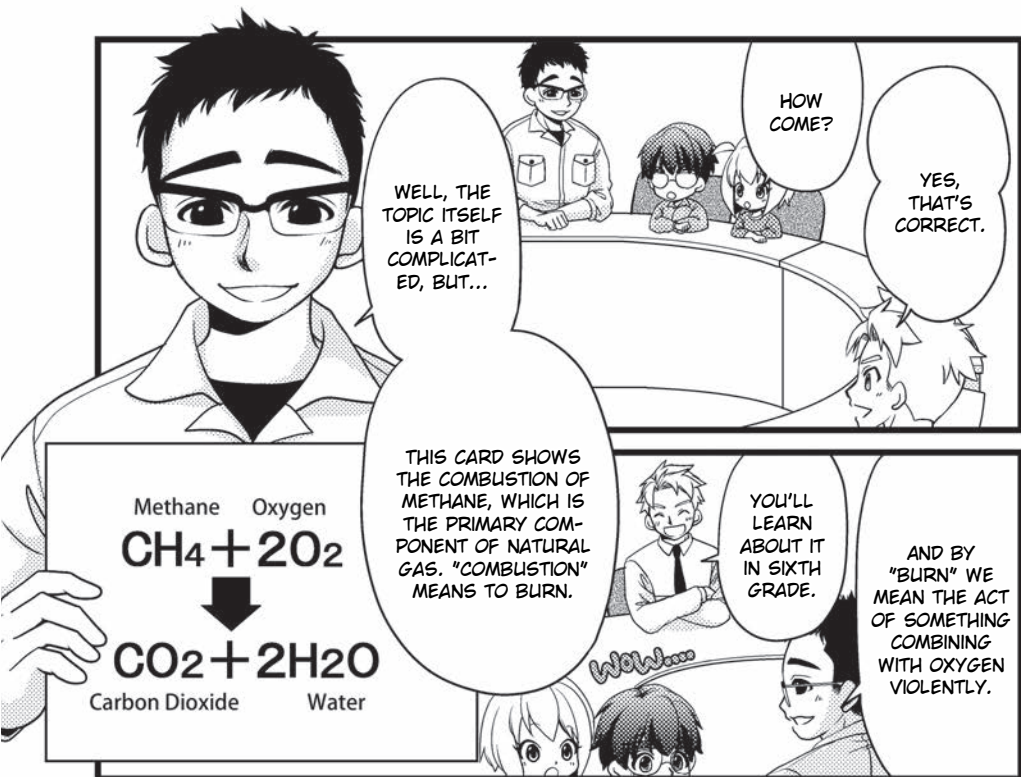
Carbon Dioxide Emission Rates

Coal-Fired Thermal Power

Present

YES, BUT THE TECHNOLOGY HAS MADE GREAT ADVANCEMENTS. THE NEWEST THERMAL POWER STATIONS, WHICH BURN NATURAL GAS, PRODUCE LESS THAN HALF OF THE CARBON DIOXIDE PRODUCED BY BURNING COAL. YET, IT STILL GENERATES THE SAME AMOUNT OF ELECTRICITY.

WOW, I HAD NO IDEA!





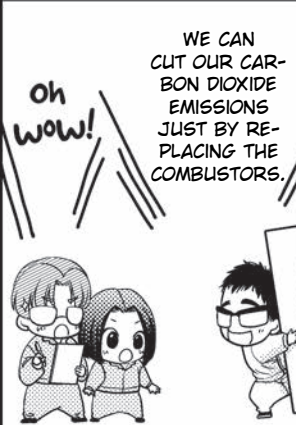
CHAPTER 3: THE SECRET WEAPON IS HYDROGEN POWER!

CHECK OUT PAGE 12 FOR MORE!



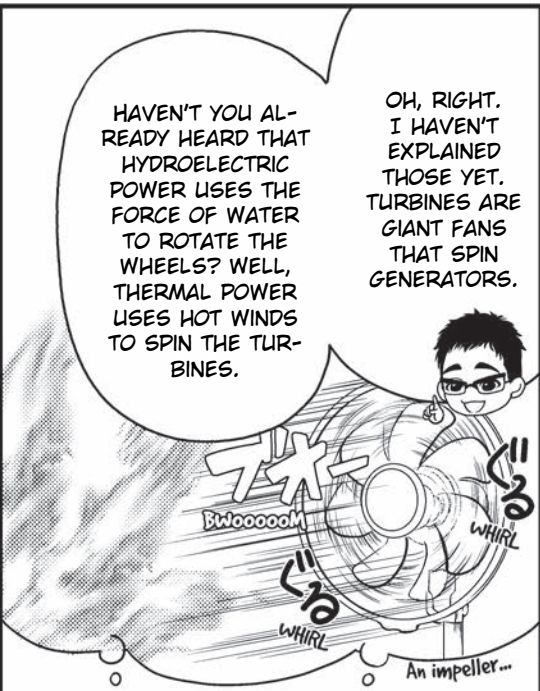
THAT'S WHY WE START BY MIXING THE FUEL SO THAT 30% OF IT IS HYDROGEN.

WELL, WE WON'T BE ABLE TO DO IT IMMEDIATELY.



WE CAN CUT OUR CARBON DIOXIDE EMISSIONS JUST BY REPLACING THE COMBUSTORS.

THAT WAY WE JUST HAVE TO REPLACE THE COMBUSTORS IN THE GAS TURBINES.



HAVEN'T YOU ALREADY HEARD THAT HYDROELECTRIC POWER USES THE FORCE OF WATER TO ROTATE THE WHEELS? WELL, THERMAL POWER USES HOT WINDS TO SPIN THE TURBINES.

OH, RIGHT. I HAVEN'T EXPLAINED THOSE YET. TURBINES ARE GIANT FANS THAT SPIN GENERATORS.

An impeller...



I ALSO DON'T GET WHAT A COMBUSTOR IS.

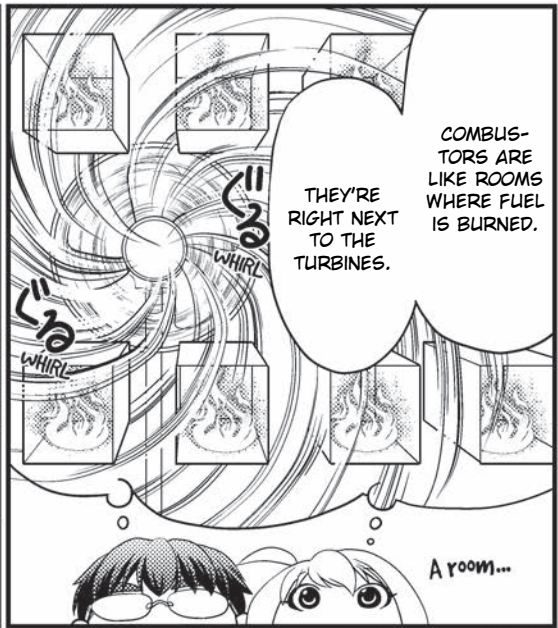
WAIT A SECOND. "TURBINE"? WHAT'S THAT?





WHEN YOU EXPLAIN IT LIKE THAT, IF ALL YOU HAVE TO DO IS REPLACE THE COMBUSTORS, IT DOES SEEM PRETTY EASY.

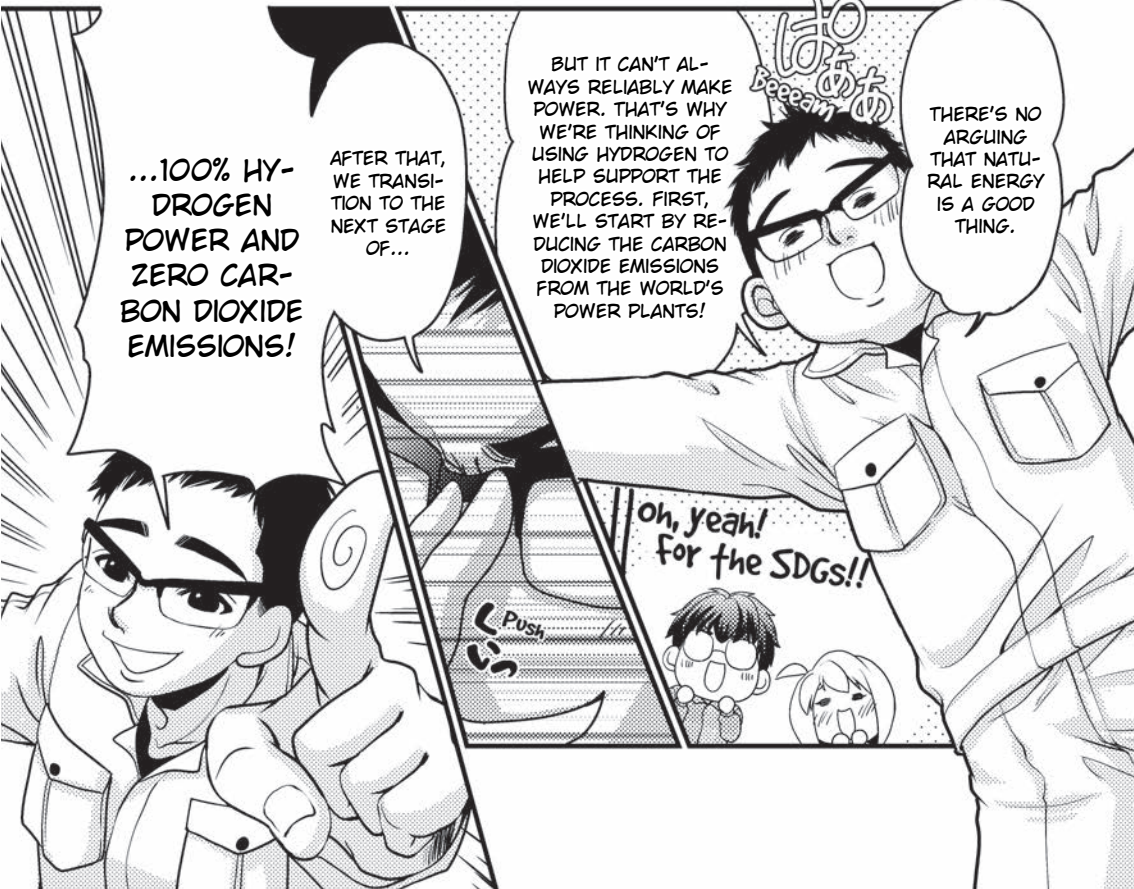
RIGHT?



THEY'RE RIGHT NEXT TO THE TURBINES.

COMBUSTORS ARE LIKE ROOMS WHERE FUEL IS BURNED.

A room...



...100% HYDROGEN POWER AND ZERO CARBON DIOXIDE EMISSIONS!

AFTER THAT, WE TRANSITION TO THE NEXT STAGE OF...

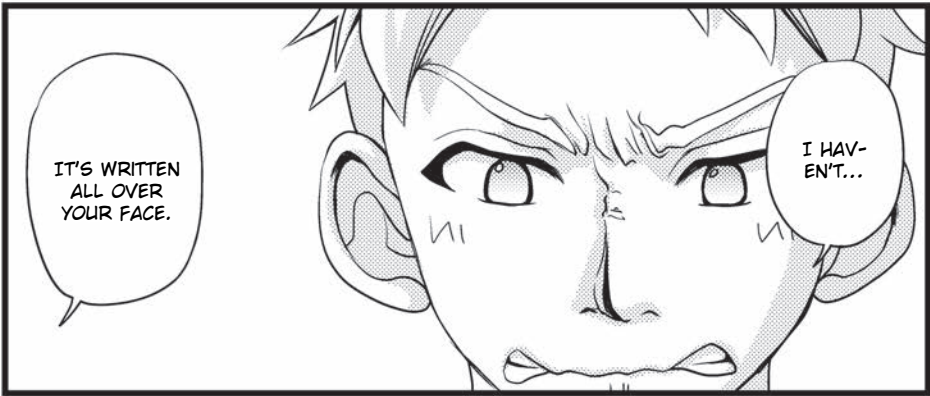
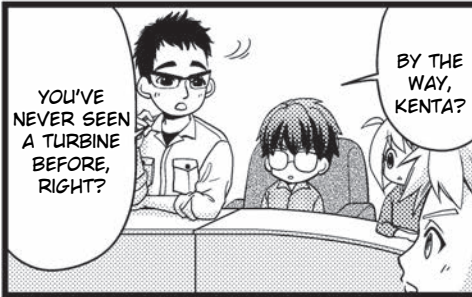
BUT IT CAN'T ALWAYS RELIABLY MAKE POWER. THAT'S WHY WE'RE THINKING OF USING HYDROGEN TO HELP SUPPORT THE PROCESS. FIRST, WE'LL START BY REDUCING THE CARBON DIOXIDE EMISSIONS FROM THE WORLD'S POWER PLANTS!

THERE'S NO ARGUING THAT NATURAL ENERGY IS A GOOD THING.

oh, yeah! for the SDGs!!

Push...

CHAPTER 3: THE SECRET WEAPON IS HYDROGEN POWER!





WHAT'S HYDROGEN?

Hydrogen only creates water when combusted. So, what is hydrogen exactly?

The Smallest Element

Everything in our world is made up of elements. There are more than a hundred different types. Oxygen, aluminum, and iron are all elements, and hydrogen is the smallest.

WATER IS SOMETHING EVERYONE'S FAMILIAR WITH.



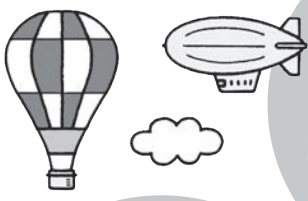
The Most Common Element in the Universe

Iron is the most common element on Earth. When we look at the universe, hydrogen is the most common, and it makes up almost 90% of everything. Our own sun is made up of about 85% hydrogen.



The Lightest Material

Hydrogen has one fourteenth the weight of air. It's the lightest material in the universe, and in older times, hydrogen gas was used to fill weather balloons and airships. Furthermore, hydrogen is harmless to the human body, colorless, transparent, tasteless, and odorless.

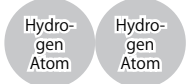


Ample in the Earth's Water

Most of the air we breathe doesn't have hydrogen in it, but there's a lot of it in our water. Water is made up of oxygen and hydrogen atoms and is denoted as H₂O.

Hydrogen's chemical symbol is H which comes from the "h" in "hydrogen." Hydrogen is a gas at room temperature, a liquid at -253°C (-423.4°F), and a solid at -259°C (-434.2°F).

Hydrogen Molecule H₂



Normally, when hydrogen is in gas form, it exists as a molecule made up of two hydrogen atoms.

Oxygen Atom



Water Molecule H₂O

Easily Burned

Hydrogen is a gas that burns very easily. It also burns very rapidly and at a high temperature. A characteristic of hydrogen is that it releases a massive amount of heat energy when burned.

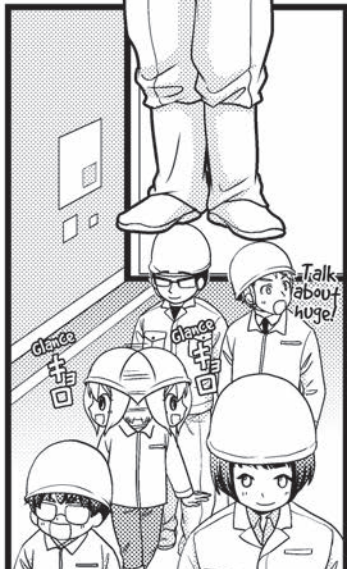
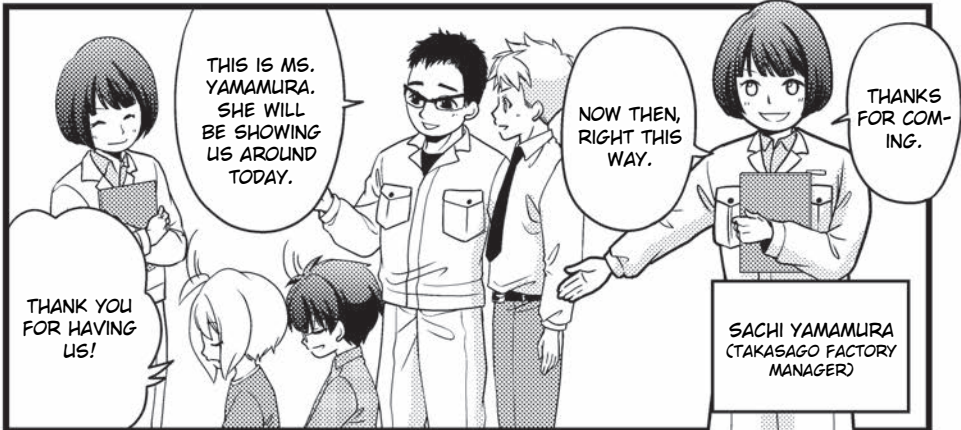
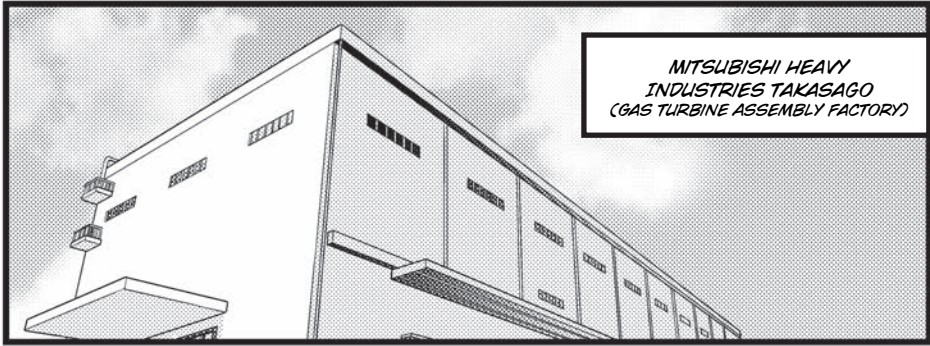


Burn to Turn into Water

When mixed with oxygen and ignited, it combusts, becoming water. Unlike other gases, this does not create carbon dioxide.



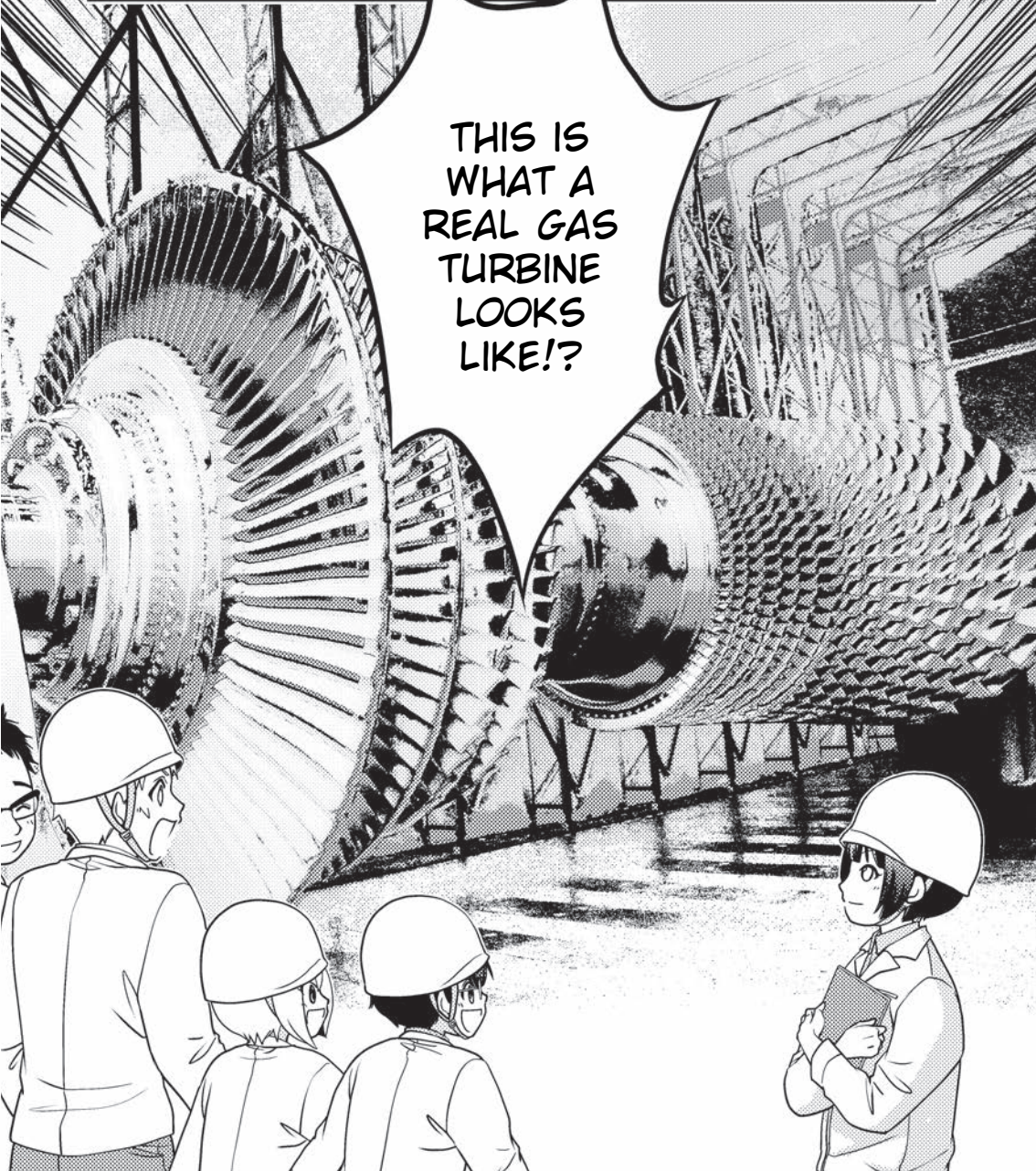
A CHANGING WORLD.





WHOA!!

THIS IS
WHAT A
REAL GAS
TURBINE
LOOKS
LIKE!?





CHAPTER 4: A CHANGING WORLD

TRIVIA

A MACHINE THAT GENERATES MOTION VIA A SPINNING SHAFT WITH BLADES ATTACHED IS CALLED A TURBINE. IT USES GAS (E.G. AIR), WATER, OR STEAM.



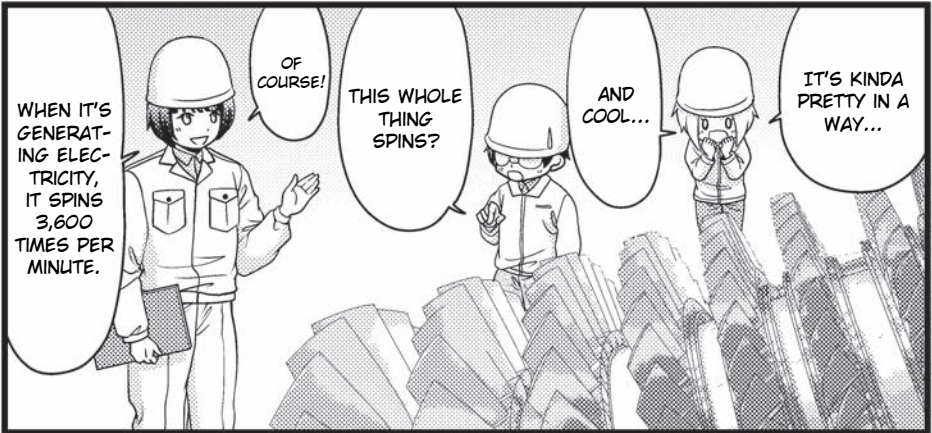
THOSE ARE CALLED BLADES.

LOOK AT ALL THE WINGS ON IT!



IT'S ABOUT FIFTEEN METERS IN LENGTH AND FIVE METERS IN DIAMETER.

I DIDN'T REALIZE THAT GAS TURBINES WERE THIS BIG!



WHEN IT'S GENERATING ELECTRICITY, IT SPINS 3,600 TIMES PER MINUTE.

OF COURSE!

THIS WHOLE THING SPINS?

AND COOL...

IT'S KINDA PRETTY IN A WAY...

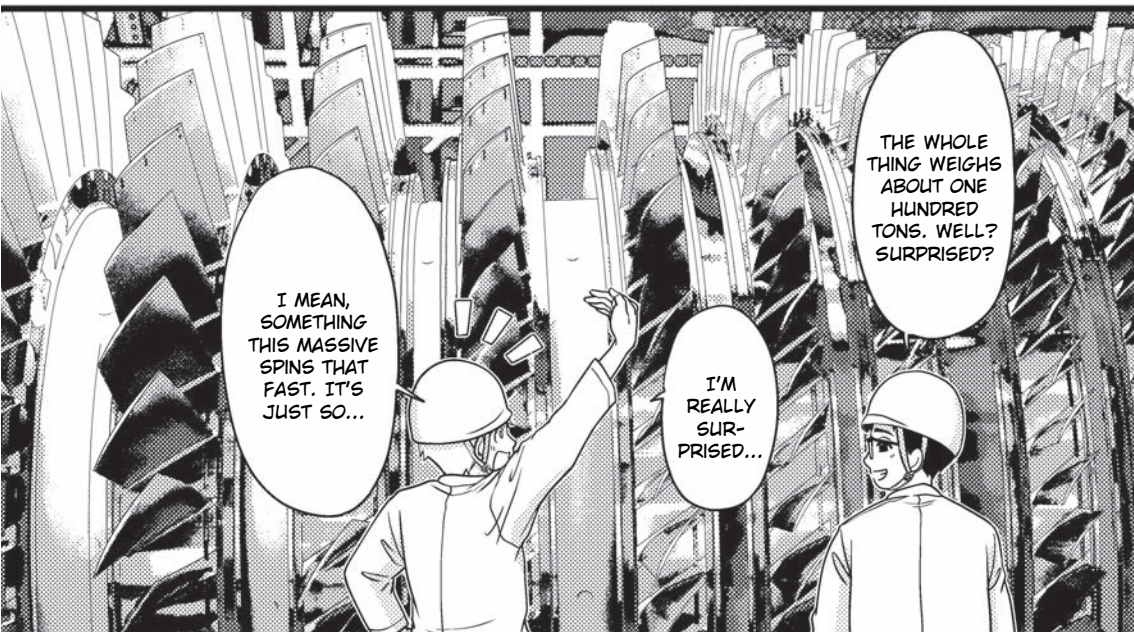
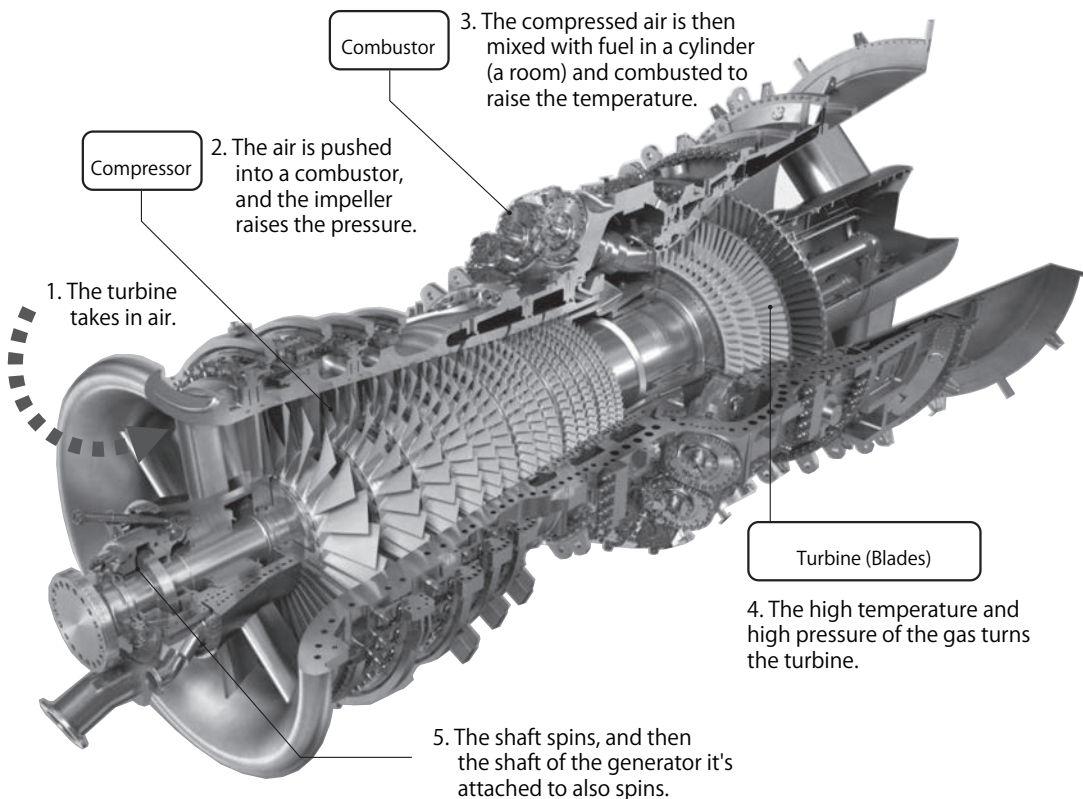


No way !!

IT SPINS SIXTY TIMES PER SECOND.

WHICH MEANS...

THE PARTS OF A GAS TURBINE

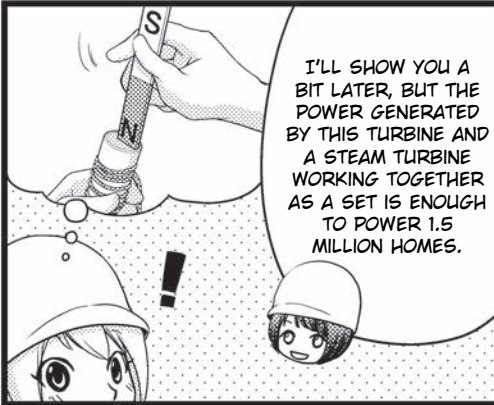




CHAPTER 4: A CHANGING WORLD

TRIVIA

ONE LITER OF AIR WEIGHS 1.3 GRAMS. SO, A ROOM THAT'S 5M X 4M X 3M HAS A VOLUME OF 60 SQUARE METERS, MEANING ALL OF THE AIR IN THAT ROOM WOULD WEIGH 78 KILOGRAMS.

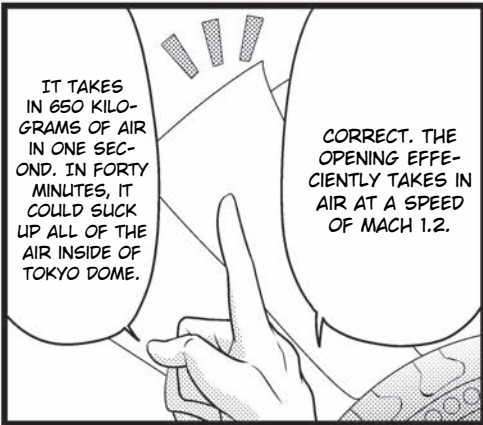


I'LL SHOW YOU A BIT LATER, BUT THE POWER GENERATED BY THIS TURBINE AND A STEAM TURBINE WORKING TOGETHER AS A SET IS ENOUGH TO POWER 1.5 MILLION HOMES.



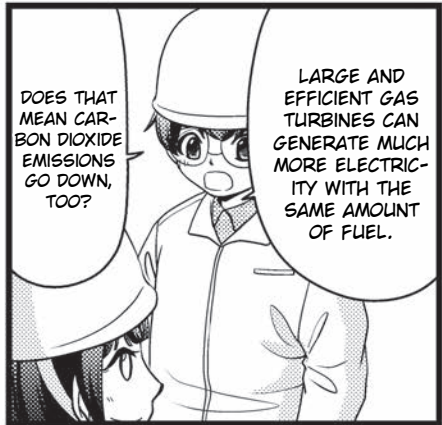
BECAUSE WE WANT TO PRODUCE THE MOST ELECTRICITY AT THE MOST EFFICIENT RATE.

WHY DOES IT SPIN SO FAST...?



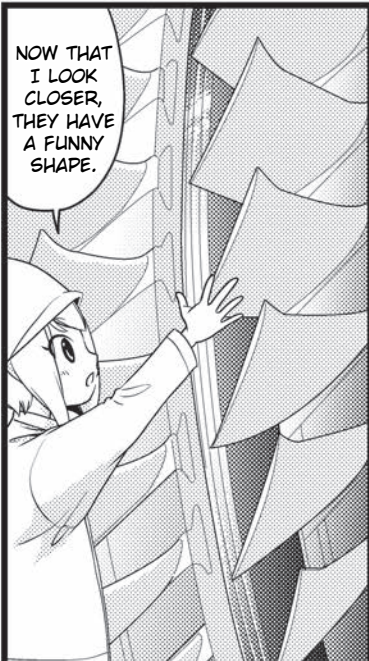
IT TAKES IN 650 KILOGRAMS OF AIR IN ONE SECOND. IN FORTY MINUTES, IT COULD SUCK UP ALL OF THE AIR INSIDE OF TOKYO DOME.

CORRECT. THE OPENING EFFICIENTLY TAKES IN AIR AT A SPEED OF MACH 1.2.



DOES THAT MEAN CARBON DIOXIDE EMISSIONS GO DOWN, TOO?

LARGE AND EFFICIENT GAS TURBINES CAN GENERATE MUCH MORE ELECTRICITY WITH THE SAME AMOUNT OF FUEL.



NOW THAT I LOOK CLOSER, THEY HAVE A FUNNY SHAPE.



THAT MEANS IT TAKES IN A LOT.

THAT'S SO COOL, I CAN'T EVEN IMAGINE!

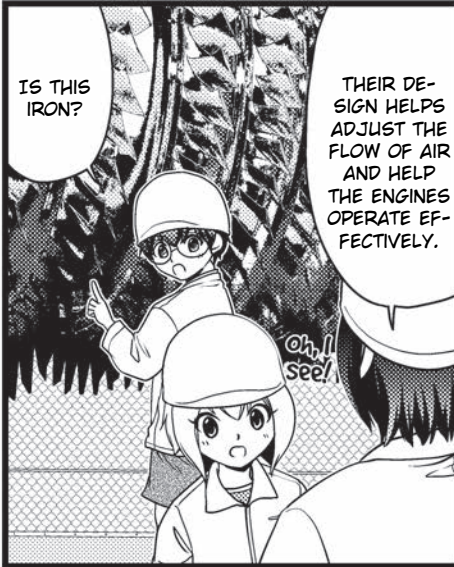


650 KILOGRAMS OF AIR IN ONE SECOND... WAIT, BUT AIR ISN'T VERY HEAVY, RIGHT?

MACH SPEED! IT MOVES 1.2 TIMES THE SPEED OF SOUND!



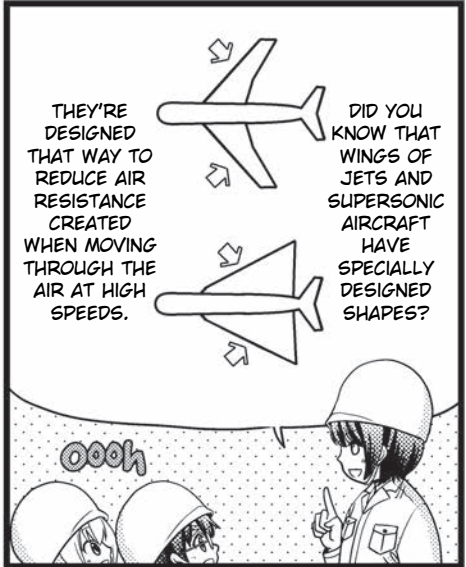
THE TEMPERATURE AT WHICH A SOLID BECOMES A LIQUID IS CALLED ITS MELTING POINT. IRON'S MELTING POINT IS 1538°C (2800.4°F), SO IT WILL MELT IN A TURBINE SINCE THE INTERNAL TEMPERATURE HITS 1650°C (3002°F).



IS THIS IRON?

THEIR DESIGN HELPS ADJUST THE FLOW OF AIR AND HELP THE ENGINES OPERATE EFFECTIVELY.

Oh!! See!



THEY'RE DESIGNED THAT WAY TO REDUCE AIR RESISTANCE CREATED WHEN MOVING THROUGH THE AIR AT HIGH SPEEDS.

DID YOU KNOW THAT WINGS OF JETS AND SUPERSONIC AIRCRAFT HAVE SPECIALLY DESIGNED SHAPES?

Ooooh



BUT IF IT MELTED, IT'D BECOME USELESS, SO WE ALSO WORK TO COOL THE BLADES.

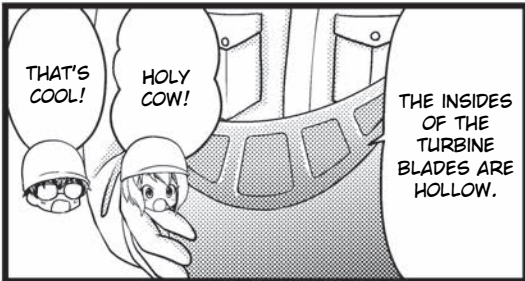
Yup.

HIGH SPEED MEANS HIGH TEMPERATURES, AFTER ALL.



IT'S MADE OF A SPECIAL METAL.

IT WOULD MELT IF IT WAS MADE OF NORMAL IRON. THIS GAS TURBINE HITS 1650°C* WHEN IT'S SPINNING.



THAT'S COOL!

HOLY COW!

THE INSIDES OF THE TURBINE BLADES ARE HOLLOW.



THE AIR FLOWS THROUGH THEM, COOLING THE BLADES. EVEN THOUGH THEY'RE COOLED, THE AIR STILL REACHES MORE THAN 400°C*.

*400°C = 752°F.

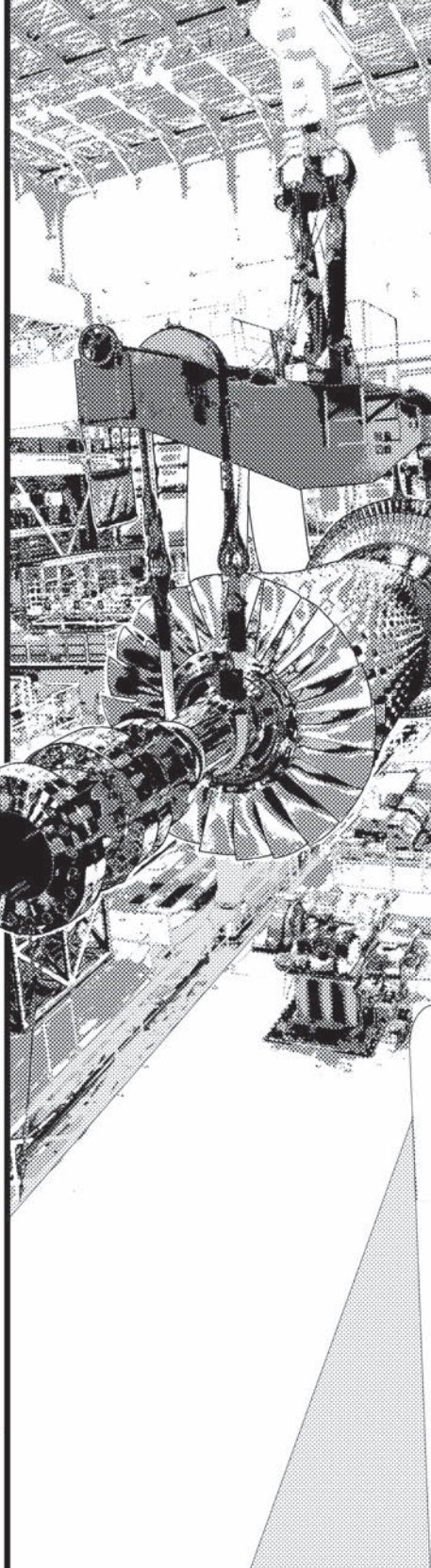
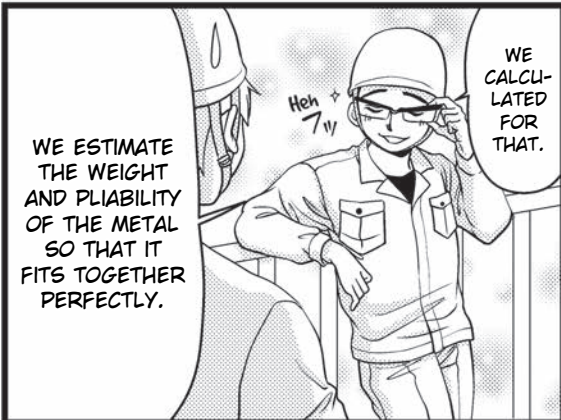
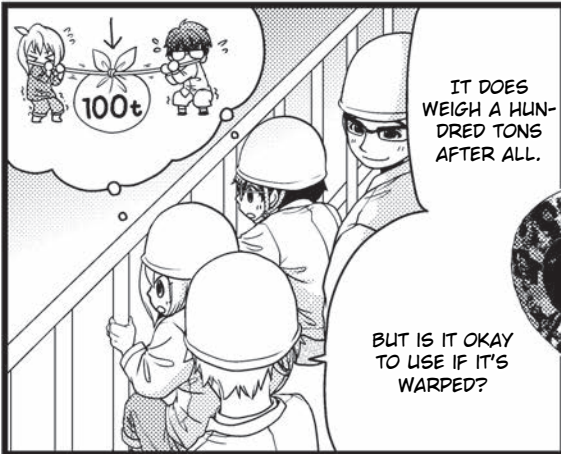
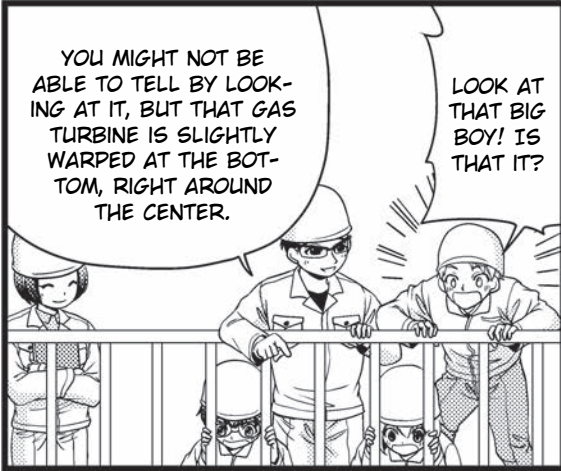
*1650°C = 3002°F.



CHAPTER 4: A CHANGING WORLD

TRIVIA

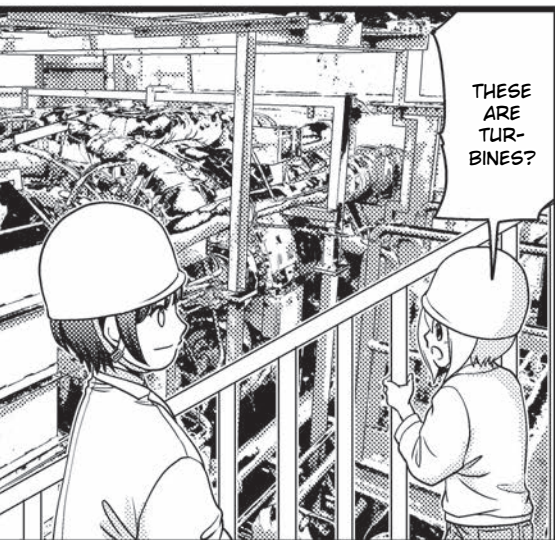
THE BLADES OF A GAS TURBINE ARE MADE FROM A SPECIAL NICKEL-BASE SUPERALLOY.





IT REALLY IS INCREDIBLY AWESOME.

IT'S SO BIG, BUT IT WAS CREATED WITH SO MUCH CARE...



THESE ARE TURBINES?



WE'RE NOT SPINNING ONE AT THE MOMENT, SO IT'S SAFE TO TAKE A LOOK.

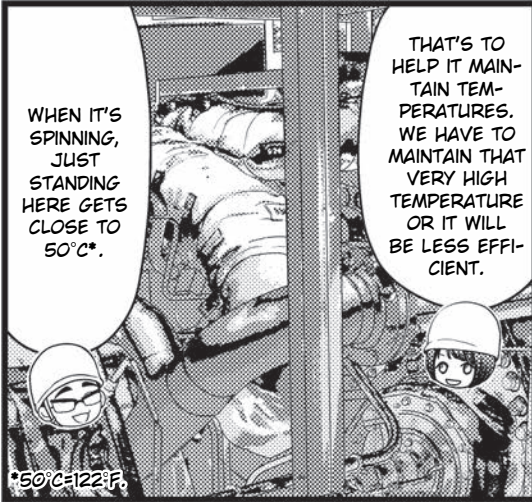
THIS IS WHERE WE TEST-SPIN THE TURBINES.



CHAPTER 4: A CHANGING WORLD

TRIVIA

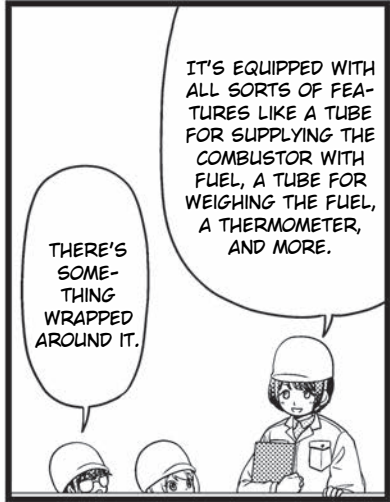
WHEN GAS IS COMPRESSED, IT HEATS UP. FOR EXAMPLE, IF YOU TAKE AIR AT 15°C (59°F) AND COMPRESS IT TO 25 ATM (OR 1/25TH ITS NORMAL VOLUME), IT REACHES A TEMPERATURE OF OVER 400°C (752°F).



WHEN IT'S SPINNING, JUST STANDING HERE GETS CLOSE TO 50°C*.

THAT'S TO HELP IT MAINTAIN TEMPERATURES. WE HAVE TO MAINTAIN THAT VERY HIGH TEMPERATURE OR IT WILL BE LESS EFFICIENT.

*50°C=122°F.



THERE'S SOMETHING WRAPPED AROUND IT.

IT'S EQUIPPED WITH ALL SORTS OF FEATURES LIKE A TUBE FOR SUPPLYING THE COMBUSTOR WITH FUEL, A TUBE FOR WEIGHING THE FUEL, A THERMOMETER, AND MORE.



THAT'S MORE THAN SIX TIMES FASTER THAN JAPAN'S BULLET TRAIN!

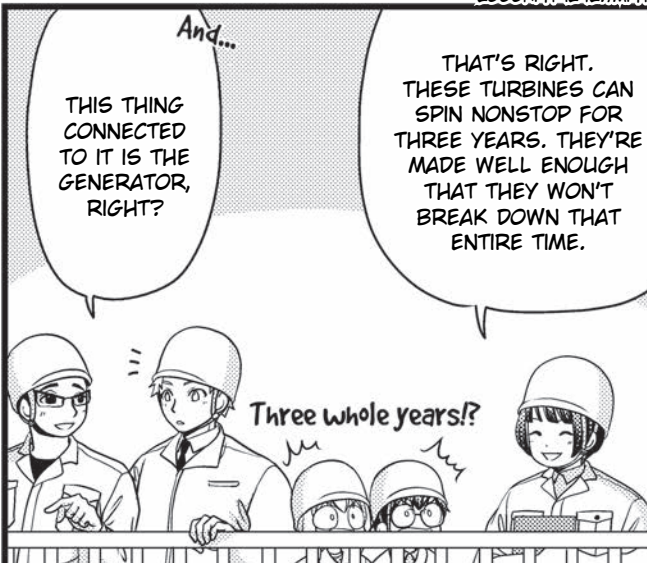
SINCE IT SPINS SIXTY TIMES IN ONE SECOND, THAT MEANS IT MOVES AT A SPEED OF TWO THOUSAND KILOMETERS PER HOUR*!

*2000KPH=1242.7MPH



REAL-
LY!?

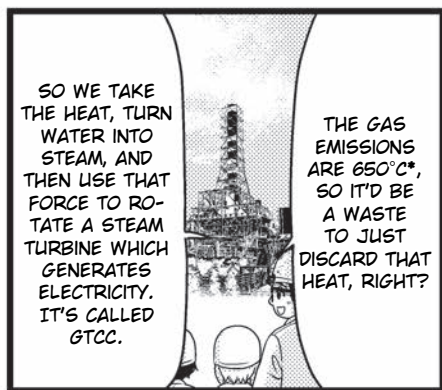
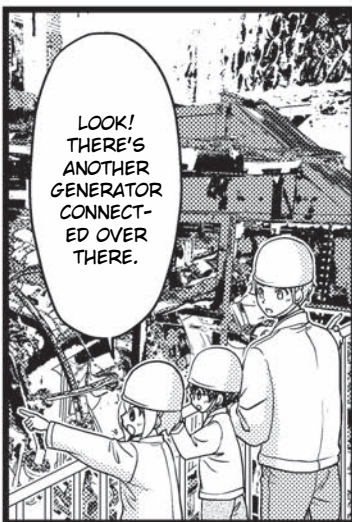
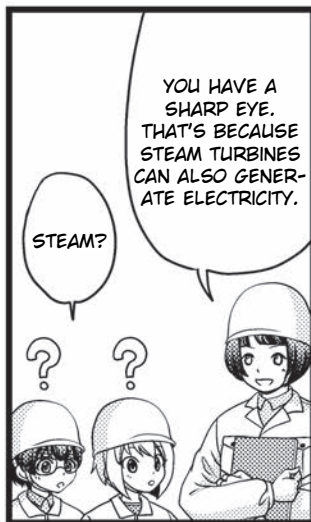
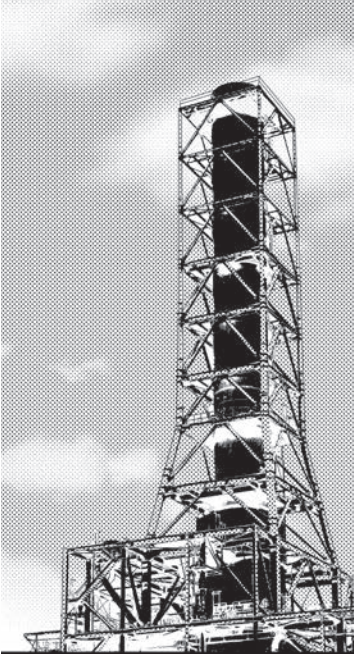
IT GETS REALLY LOUD, TOO.



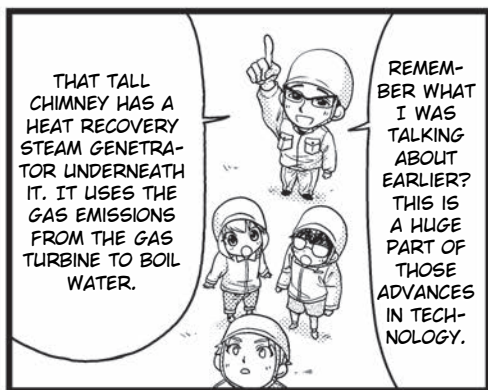
And... THIS THING CONNECTED TO IT IS THE GENERATOR, RIGHT?

THAT'S RIGHT. THESE TURBINES CAN SPIN NONSTOP FOR THREE YEARS. THEY'RE MADE WELL ENOUGH THAT THEY WON'T BREAK DOWN THAT ENTIRE TIME.

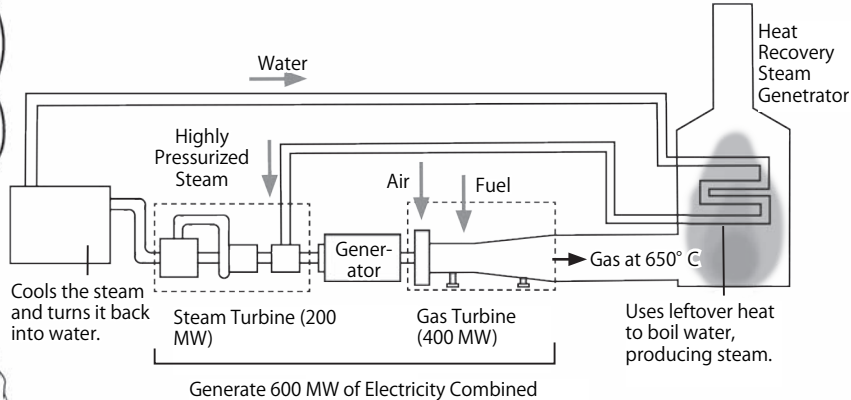
Three whole years?!



*650°C = 1202°F.



WHAT'S GTCC? (GAS TURBINE COMBINED CYCLE POWER PLANTS)





CHAPTER 4: A CHANGING WORLD

TRIVIA

BECAUSE GAS TURBINE COMBINED CYCLE POWER PLANTS BY MITSUBISHI HEAVY INDUSTRIES CONVERT HEAT INTO MOTION ENERGY, THEY ARE DESIGNED TO BE RELEASE THE LEAST WASTE POSSIBLE (AS OF 2020).

THIS PROCESS IS REFERRED TO AS "COMBINED CYCLE ELECTRICITY GENERATION."

SO WE'RE ALREADY REDUCING OUR CO₂ EMISSIONS!

WITH A DESIGN LIKE THIS, WE CAN USE THE SAME AMOUNT OF FUEL AS BEFORE BUT GENERATE 1.5 TIMES THE AMOUNT OF ELECTRICITY.

AND THAT FORCE MAKES THE PISTON ROTATE? IT'S LIKE A STEAM LOCOMOTIVE!

WHEN THE WATER CHANGES FROM A LIQUID TO A GAS IN THE FORM OF STEAM, ITS VOLUME INCREASES 1,700 TIMES.

Water

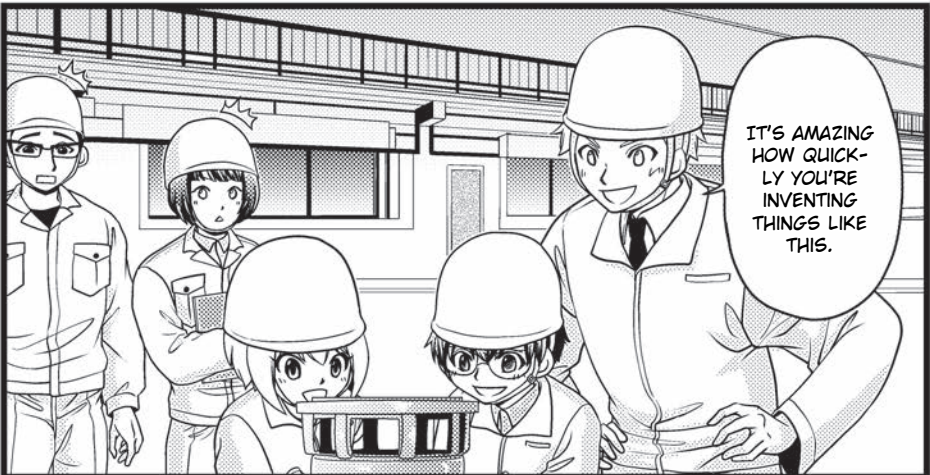
Steam

NO CO₂ EMISSIONS! IT WILL ONLY MAKE WATER!

AND THIS IS A COMBUSTOR FOR THE NEXT STAGE WHICH IS 100% HYDROGEN. WE'RE SO CLOSE TO FINISHING IT.

AND NOW IT'S TIME FOR WHAT WE'VE ALL BEEN WAITING FOR! THIS HERE IS A COMBUSTOR THAT HAS 30% OF ITS FUEL REPLACED WITH HYDROGEN!

WE ARE GOING TO SWAP THIS WITH A COMBUSTOR INSIDE THE GAS TURBINE WE SAW EARLIER.



IT'S AMAZING HOW QUICKLY YOU'RE INVENTING THINGS LIKE THIS.



HUH?



HOLD ON A SECOND.

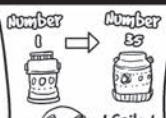


WELL, YEAH, THAT'S TRUE... THIS IS MY FIRST YEAR AT THE COMPANY.

NOW NOW, MR. ISHIDA. IT'S NOT LIKE YOU'VE EXPERIENCED THE WORK YOURSELF.

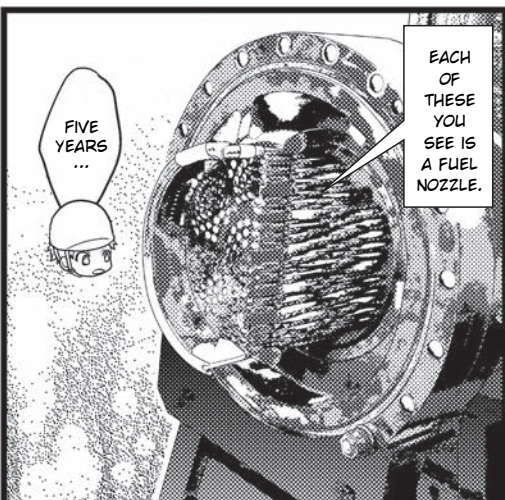


WE MAKE SLOW AND STEADY PROGRESS BY WORKING REALLY HARD AND FAILING COUNTLESS TIMES.



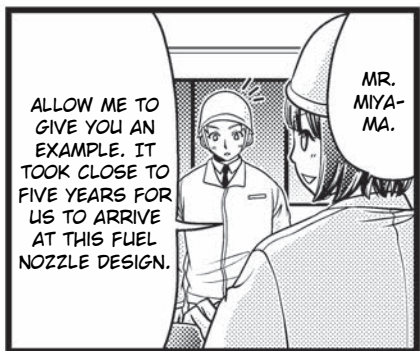
I failed again!

THESE THINGS DON'T GET INVENTED OVER-NIGHT, YOU KNOW.



FIVE YEARS ...

EACH OF THESE YOU SEE IS A FUEL NOZZLE.



ALLOW ME TO GIVE YOU AN EXAMPLE. IT TOOK CLOSE TO FIVE YEARS FOR US TO ARRIVE AT THIS FUEL NOZZLE DESIGN.

MR. MIYAMA.



CHAPTER 4: A CHANGING WORLD

TRIVIA

WHEN SOMETHING IS IN ROTATION, FORCE MOVES OUTWARD, AWAY FROM THE CENTER OF ROTATION. THIS IS CALLED CENTRIFUGAL FORCE. ONE BLADE OF A TURBINE REQUIRES ONE HUNDRED TONS OF CENTRIFUGAL FORCE TO MOVE.

WHEN WE MIX AIR AND HYDROGEN AND TRY TO BURN THEM...

Fuel Nozzle

WHILE HYDROGEN IS EASILY BURNED, THAT ALSO MAKES IT A DIFFICULT FUEL SOURCE TO WORK WITH.

BUT THE DOWNSIDE OF THAT IS THAT IT'S MORE LIKELY TO RE-LEASE NITROGEN OXIDE, WHICH POLLUTES THE AIR.

HOWEVER, IF WE INJECT THE AIR AND HYDROGEN SEPARATELY AND, TO A CERTAIN EXTENT, LIMIT THE LOCATION OF IGNITION, WE CAN PREVENT FLASHBACKS.

Air

Air

Fuel (Hydrogen)

Fuel Nozzle

Ignition Position

THAT'S RIGHT.

THAT MIGHT MELT THE PARTS ...

...IT CAN EASILY TRIGGER SOMETHING CALLED A FLASHBACK WHERE THE FLAME IGNITES BACKWARDS UP THE FUEL NOZZLE.

crackle X

crackle X

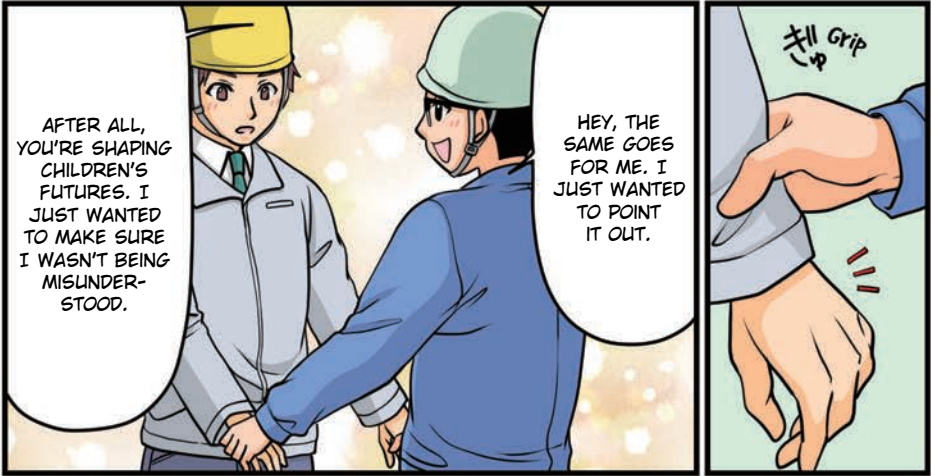
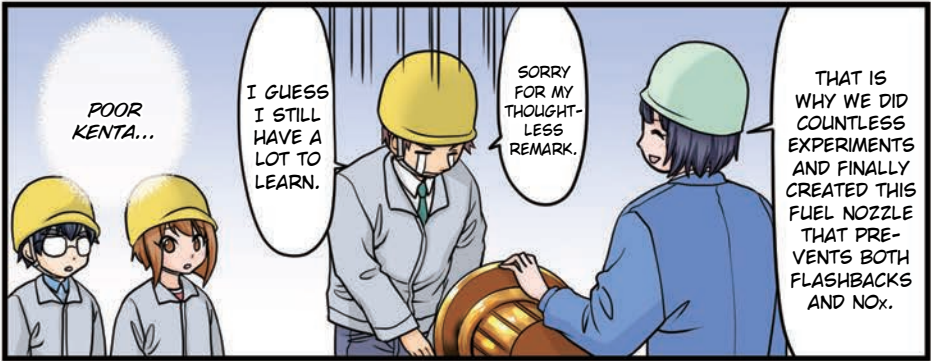
That's hot!

IT WOULD DESTROY THE ENVIRONMENT.

IF WE LOWER THE COMBUSTION TEMPERATURE, WE CAN PREVENT NO_x FROM BEING RELEASED, BUT IF WE DO, THEN WE ALSO LOWER THE EFFICIENCY OF THE MACHINERY. WE CAN'T PRIORITIZE EFFICIENCY AND ALLOW NO_x EMISSION.

YES.

NITROGEN OXIDE IS DENOTED AS NO_x. IT'S ONE OF THE CAUSES OF PHOTOCHEMICAL SMOG.



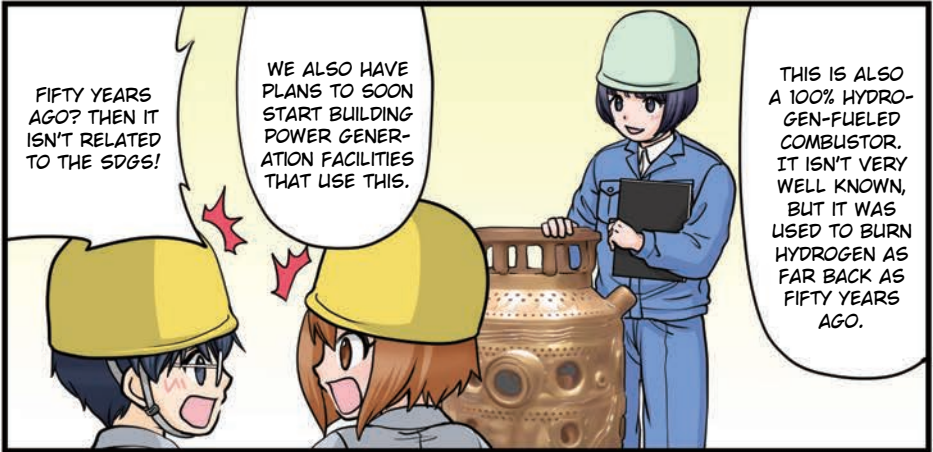
*FIT REFERS TO THE "FEED-IN TARIFF" SYSTEM AND IS A SPECIAL MEASURE INTRODUCED TO ENCOURAGE THE PROCUREMENT OF RENEWABLE ENERGY ELECTRICITY BY ELECTRICITY COMPANIES.



CHAPTER 4: A CHANGING WORLD

TRIVIA

RIISING SEA LEVELS AS A RESULT OF CLIMATE CHANGE ARE A SEVERE PROBLEM FOR COUNTRIES LIKE THE NETHERLANDS, WHICH HAVE A VERY LOW ELEVATION. THEY ARE IN DANGER OF LOSING A LARGE PART OF THEIR LAND.



FIFTY YEARS AGO? THEN IT ISN'T RELATED TO THE SDGS!

WE ALSO HAVE PLANS TO SOON START BUILDING POWER GENERATION FACILITIES THAT USE THIS.

THIS IS ALSO A 100% HYDROGEN-FUELED COMBUSTOR. IT ISN'T VERY WELL KNOWN, BUT IT WAS USED TO BURN HYDROGEN AS FAR BACK AS FIFTY YEARS AGO.

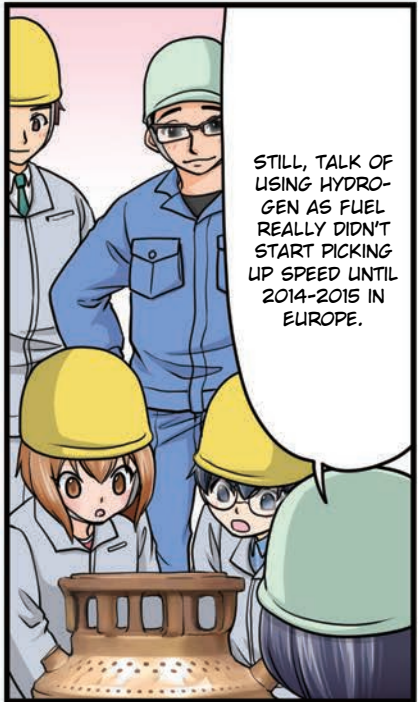


BOSS!



THAT'S WHY WE'RE WORKING HARD TO HURRY AND PREPARE GOOD-QUALITY PRODUCTS THAT HAVE BEEN TESTED SO THAT THEY'RE AVAILABLE FOR THE WORLD.

WE WANT WHAT WE MAKE TO BE AVAILABLE THE MOMENT IT'S NEEDED, AND WE WANT IT TO BE USED FOR A LONG, LONG TIME.



STILL, TALK OF USING HYDROGEN AS FUEL REALLY DIDN'T START PICKING UP SPEED UNTIL 2014-2015 IN EUROPE.



WHY DON'T WE GO CHECK IT OUT?

THE HYDROGEN FOR THE EXPERIMENT HAS ARRIVED!



WHEN YOU MAKE HYDROGEN, TOO, YOU HAVE TO MAKE SURE YOU DON'T RELEASE CO₂, RIGHT? WHEN HYDROGEN POWER TAKES OFF FOR REAL, HOW ARE YOU GOING TO PROCURE THE HYDROOGEN?

THE WORLD STILL HASN'T REACHED THE AGE OF HYDROGEN, SO IT'S NOT EASY TO GATHER HYDROGEN IN LARGE AMOUNTS.

SO THAT LONG THING OVER THERE HAS HYDROGEN IN IT, RIGHT?

DOES THAT MEAN YOU BURY CO₂ GAS IN THE GROUND!?

Factory

CO₂ CO₂

CO₂ CO₂

BUT FIRST, WE START BY CREATING HYDROGEN FROM NATURAL GAS. CO₂ IS RELEASED WHEN THAT HAPPENS,

BUT WE CAN STORE IT UNDERGROUND.

光光光!?

ONE DAY, WE WILL BE ABLE TO CREATE HYDROGEN THROUGH ELECTROLYSIS OF WATER, WHICH WILL BE POWERED THROUGH NATURAL ENERGY SOURCES LIKE WIND AND THE SUN.

Water

H₂

O₂

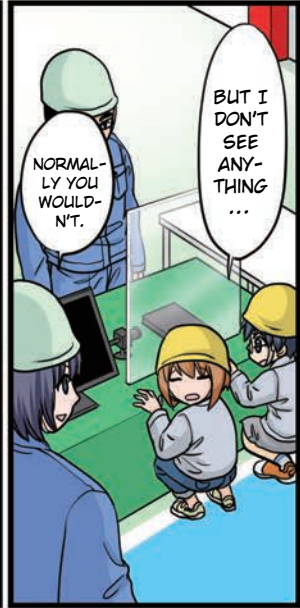
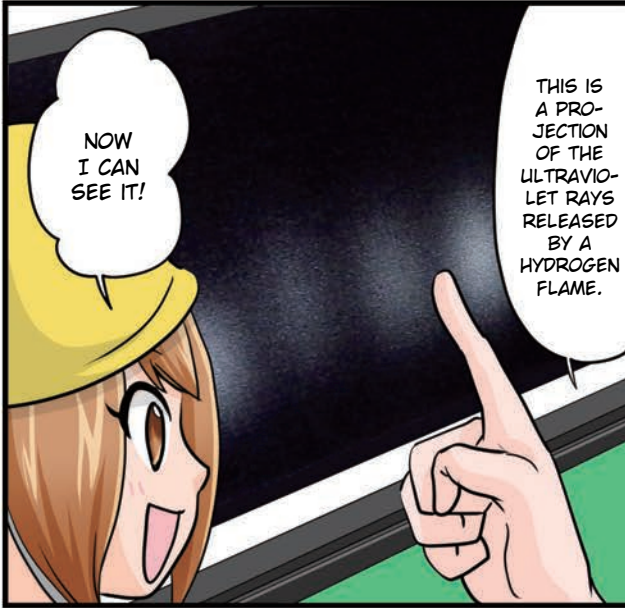
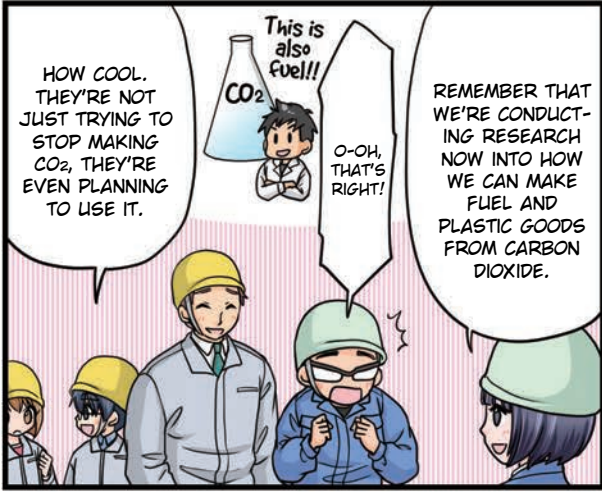
H₂O



CHAPTER 4: A CHANGING WORLD

TRIVIA

IT'S EASIER TO TURN AMMONIA INTO A LIQUID THAN HYDROGEN. AMMONIA ALSO HAS A GREATER CONCENTRATION OF HYDROGEN ATOMS BY VOLUME.





BUT WHEN YOU BURN THINGS THAT AREN'T LIVING, YOU GET ALL SORTS OF COLORS.

PLANTS AND ANIMALS CONTAIN CARBON IN THEM, SO THEY ALL TEND TO GIVE OFF THE SAME COLORS WHEN THEY BURN,



- Lithium (Red)
- Sodium (Yellow)
- Potassium (Red-Violet)
- Calcium (Orange)
- Barium (Yellow-Green)
- Copper (Blue-Green)

WOOD IS OBVIOUS, BUT GAS AND OIL USED TO BE PLANTS AND ANIMALS AT ONE POINT, TOO.

AKARI, MOST OF THE FIRE WE'RE USED TO SEEING IS MADE BY BURNING SOMETHING THAT WAS LIVING.

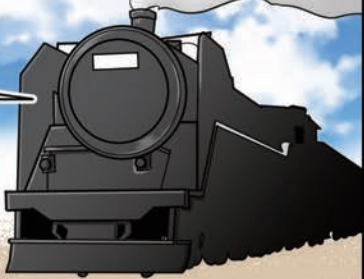


IT COULD JUST BE WE'VE ARRIVED AT AN ERA WHERE WE WILL BURN SOMETHING ELSE.

IT'S ONLY BEEN BETWEEN ABOUT 500,000 TO 750,000 YEARS SINCE HUMANS DISCOVERED FIRE. WE'VE BEEN BURNING LIVING THINGS AS FUEL AND GENERATING CO₂ THE WHOLE TIME.



THINK ABOUT THE COLORS YOU SEE IN FIREWORKS. AMONG THEM, HYDROGEN JUST HAPPENS TO BE COLORLESS.

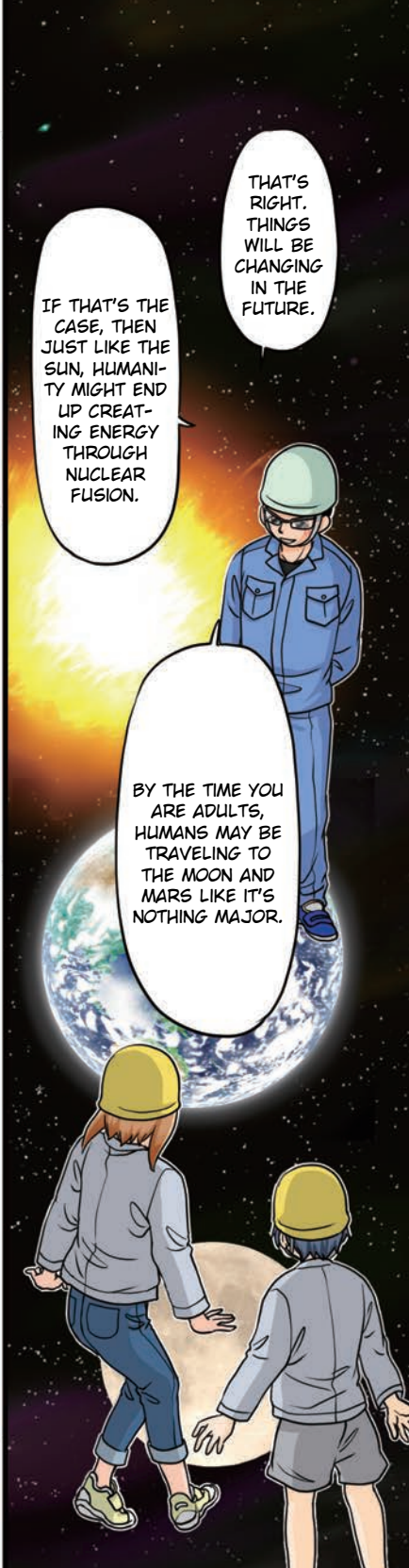
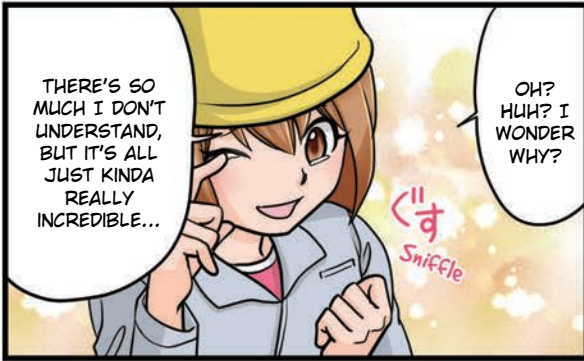
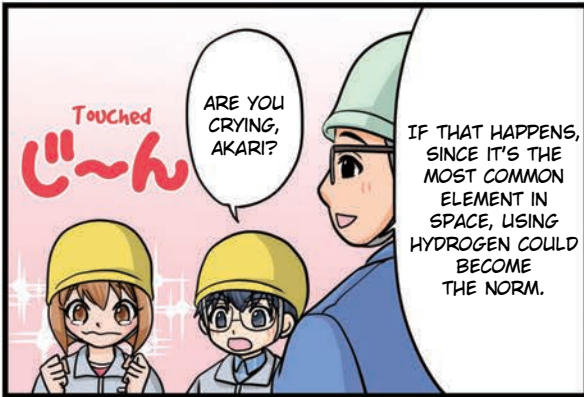




CHAPTER 4: A CHANGING WORLD

TRIVIA

USING AMMONIA IN THERMAL POWER ALSO DOESN'T PRODUCE CO₂, SO SOME POWER STATIONS ARE BEGINNING TO USE AMMONIA.



THAT'S RIGHT. THINGS WILL BE CHANGING IN THE FUTURE.

IF THAT'S THE CASE, THEN JUST LIKE THE SUN, HUMANITY MIGHT END UP CREATING ENERGY THROUGH NUCLEAR FUSION.

BY THE TIME YOU ARE ADULTS, HUMANS MAY BE TRAVELING TO THE MOON AND MARS LIKE IT'S NOTHING MAJOR.



EVEN COMPLICATED SHAPES CAN BE AUTOMATICALLY CREATED ACCORDING TO SPECIFICATIONS, WHICH SAVES TIME.

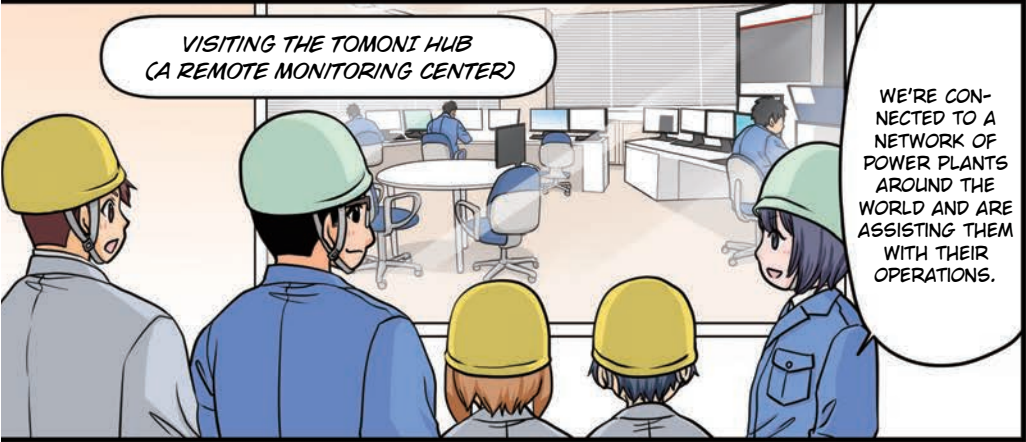


A 3D PRINTED METAL PROTOTYPE



OOOH! THAT'S COOL!

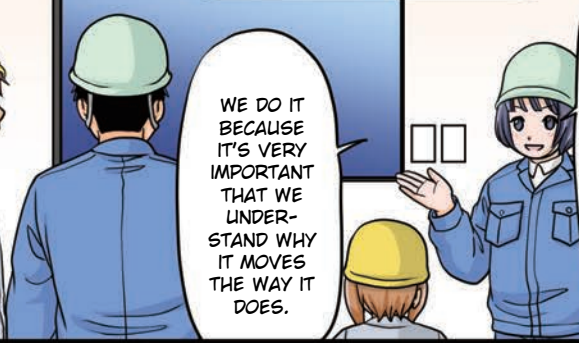
VISITING THE TOMONI HUB (A REMOTE MONITORING CENTER)



WE'RE CONNECTED TO A NETWORK OF POWER PLANTS AROUND THE WORLD AND ARE ASSISTING THEM WITH THEIR OPERATIONS.

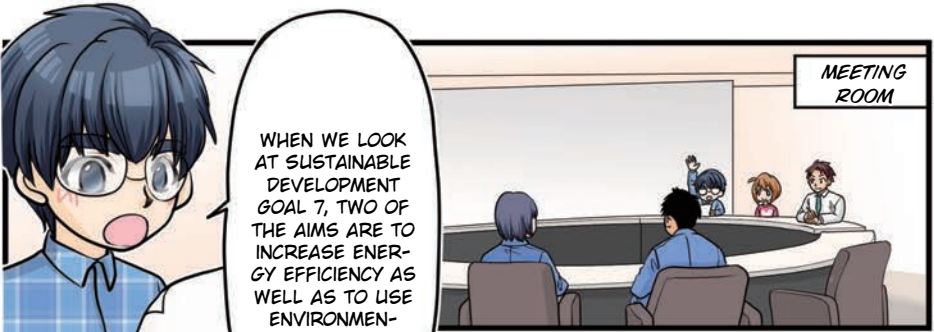
AI-GENERATED SIMULATION

AND THAT IS HOW THE THREE WERE GIVEN A TOUR OF THE FACILITIES.

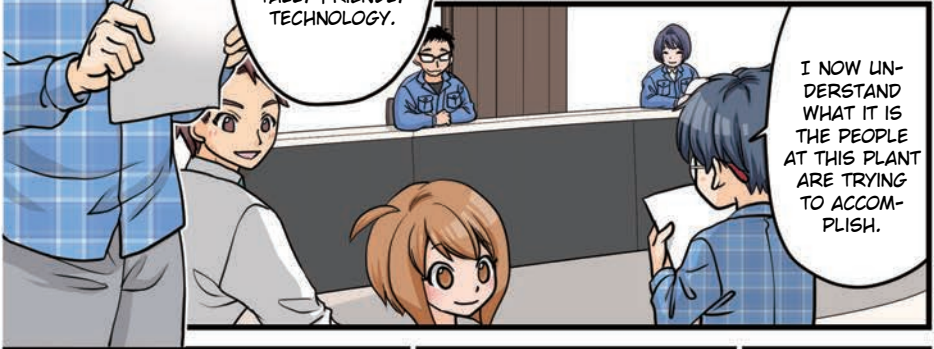


WE DO IT BECAUSE IT'S VERY IMPORTANT THAT WE UNDERSTAND WHY IT MOVES THE WAY IT DOES.

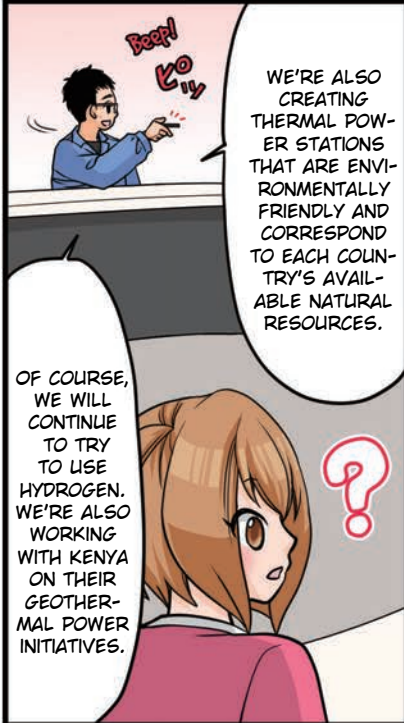
USING ARTIFICIAL INTELLIGENCE, WE CAN RUN SIMULATIONS TO SEE HOW GAS MOVES.



WHEN WE LOOK AT SUSTAINABLE DEVELOPMENT GOAL 7, TWO OF THE AIMS ARE TO INCREASE ENERGY EFFICIENCY AS WELL AS TO USE ENVIRONMENTALLY FRIENDLY TECHNOLOGY.

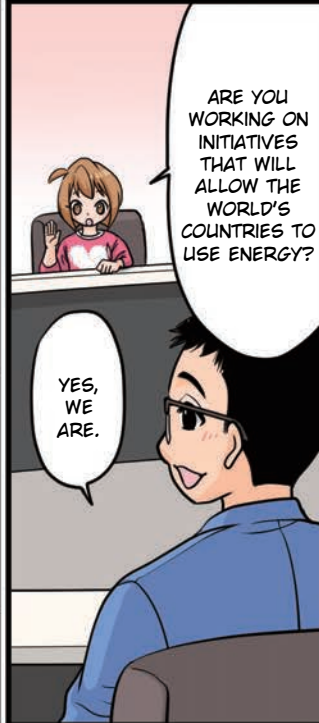


I NOW UNDERSTAND WHAT IT IS THE PEOPLE AT THIS PLANT ARE TRYING TO ACCOMPLISH.



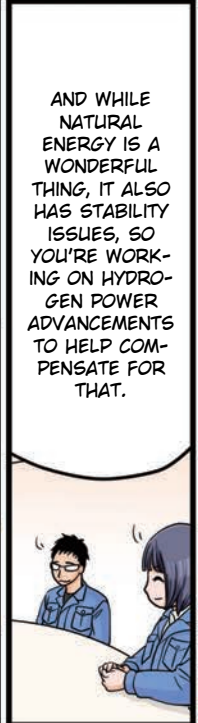
WE'RE ALSO CREATING THERMAL POWER STATIONS THAT ARE ENVIRONMENTALLY FRIENDLY AND CORRESPOND TO EACH COUNTRY'S AVAILABLE NATURAL RESOURCES.

OF COURSE, WE WILL CONTINUE TO TRY TO USE HYDROGEN. WE'RE ALSO WORKING WITH KENYA ON THEIR GEOTHERMAL POWER INITIATIVES.



ARE YOU WORKING ON INITIATIVES THAT WILL ALLOW THE WORLD'S COUNTRIES TO USE ENERGY?

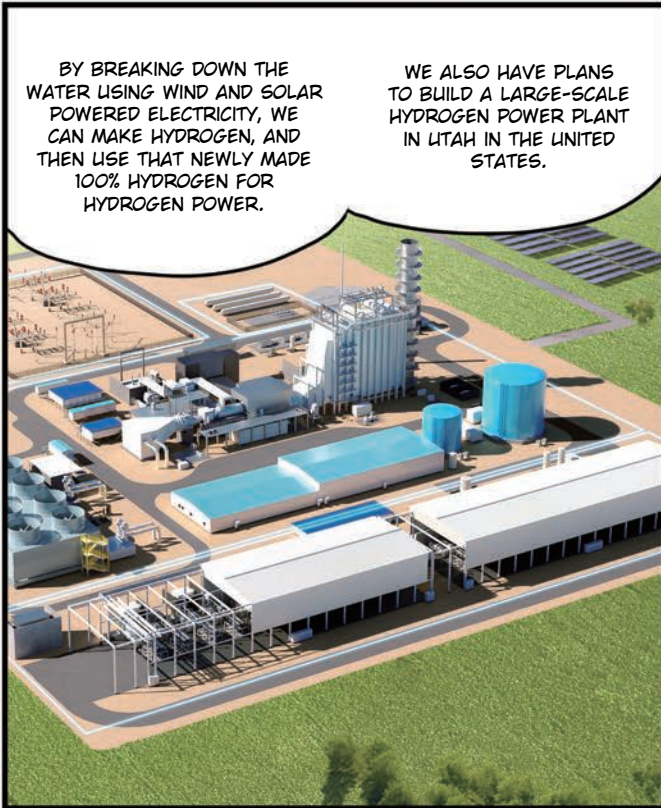
YES, WE ARE.



AND WHILE NATURAL ENERGY IS A WONDERFUL THING, IT ALSO HAS STABILITY ISSUES, SO YOU'RE WORKING ON HYDROGEN POWER ADVANCEMENTS TO HELP COMPENSATE FOR THAT.



LEO
FLICK



CHAPTER 4: A CHANGING WORLD

AND SO,
THEY
WERE
ALSO
ABLE TO
LEARN
ABOUT
THEIR
EFFORTS
FOR
GLOBAL
OUT-
REACH
AS WELL.

United Kingdom

Currently building a hydrogen power facility that aims to raise hydrogen power use from 30% to 100% hydrogen.

The Netherlands

Planning a 100% hydrogen power plant.

Southern United States

Construction of an electrical power plant to allow for a switch over to 100% hydrogen.

Utah, United States

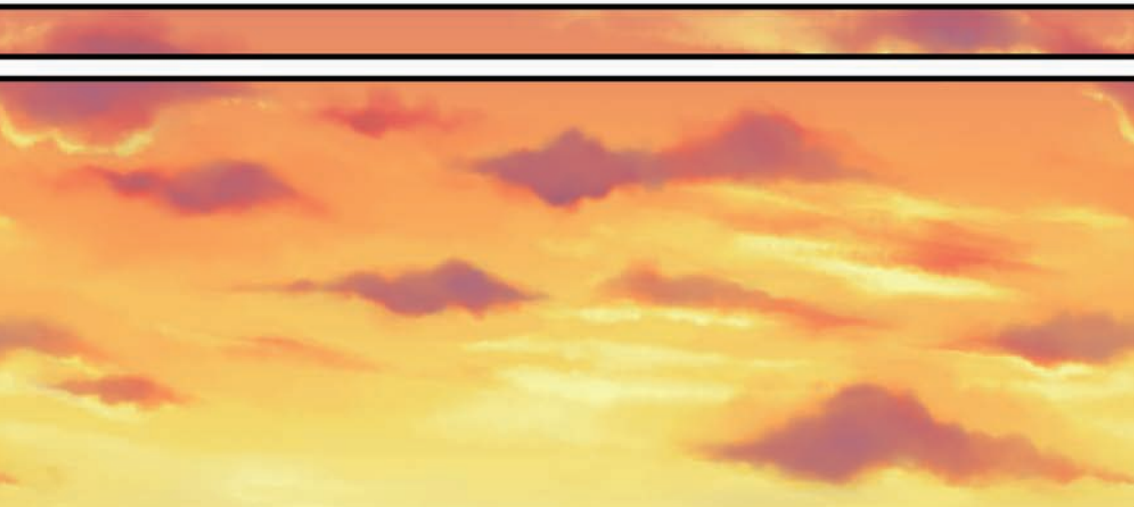
Hydrogen production and construction of a 100% hydrogen power plant.

Singapore

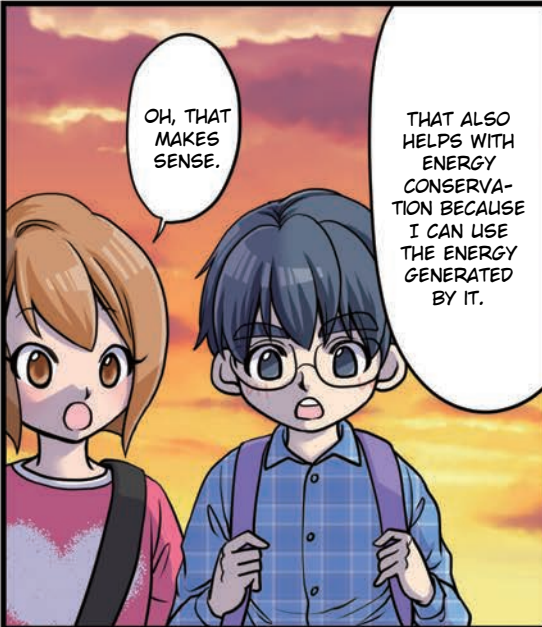
Construction of a 30% hydrogen power plant.

Southern Australia

Hydrogen and ammonia production via natural energy sources.



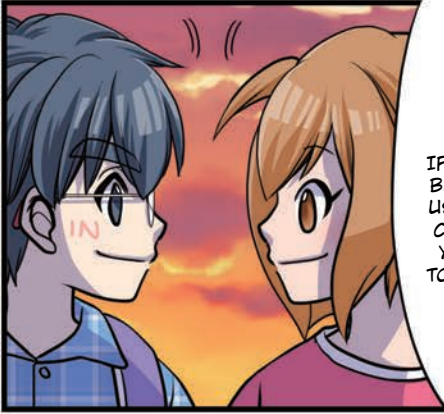
EPILOGUE



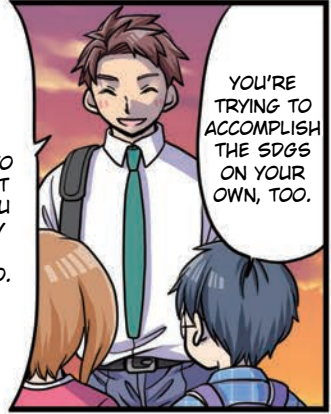


TRIVIA

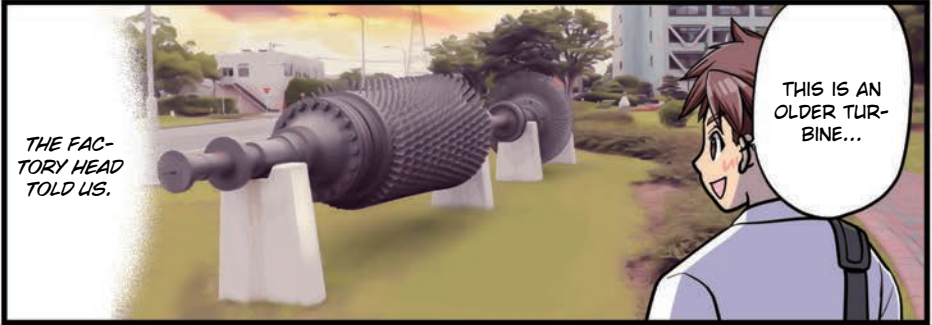
GAS TURBINE PRODUCTION USES BERNOULLI'S PRINCIPLE, THERMAL CONDUCTION, AN ADIABATIC COMPRESSION, AND OTHER CONCEPTS ARE TAUGHT IN MIDDLE SCHOOL AND HIGH SCHOOL SCIENCE CLASSROOMS.



IF YOU TWO TRY TO BE MINDFUL ABOUT USING ENERGY YOU CAN PROUDLY SAY YOU'RE WORKING TOWARD THEM TOO.

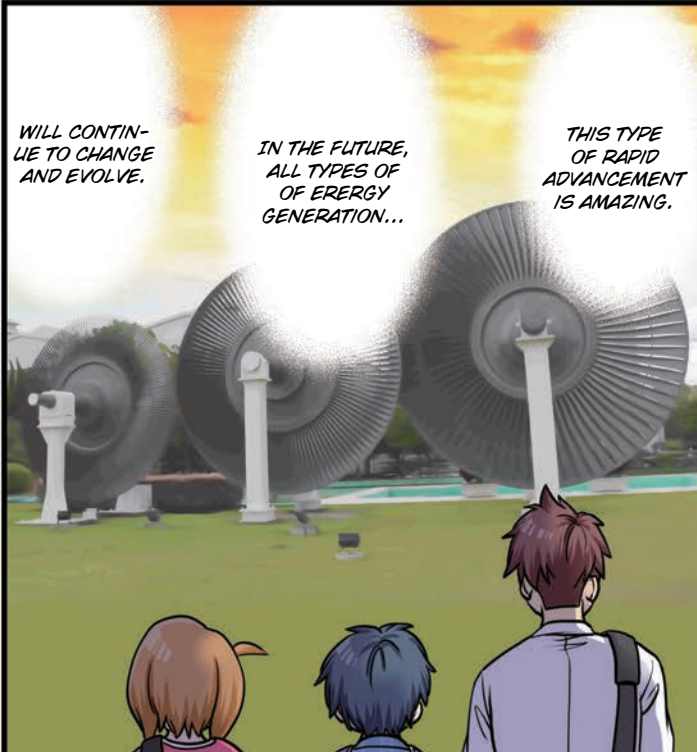


YOU'RE TRYING TO ACCOMPLISH THE SDGS ON YOUR OWN, TOO.



THE FACTORY HEAD TOLD US.

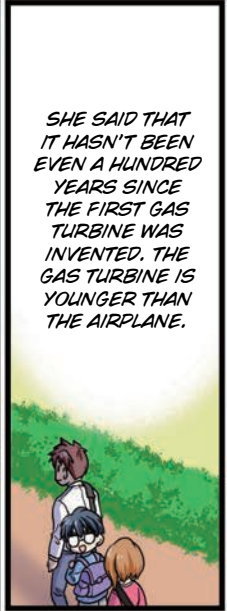
THIS IS AN OLDER TURBINE...



WILL CONTINUE TO CHANGE AND EVOLVE.

IN THE FUTURE, ALL TYPES OF ENERGY GENERATION...

THIS TYPE OF RAPID ADVANCEMENT IS AMAZING.



SHE SAID THAT IT HASN'T BEEN EVEN A HUNDRED YEARS SINCE THE FIRST GAS TURBINE WAS INVENTED. THE GAS TURBINE IS YOUNGER THAN THE AIRPLANE.



Let's think about future jobs related to the SDGs!

Name: Hiroki Tomono

Scientist

Explanation

I want to research energy!

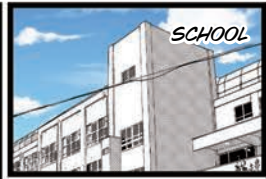
Let's think about future jobs related to the SDGs!

Name: Akari Miyama

Engineer

Explanation

To make things that will help all of humanity.



Let's think about future jobs related to the SDGs!

Name

Explanation

BUT STARTING TODAY, I'M NOW IN CHARGE OF TEACHING EVERYONE ABOUT THE SDGS.

YEAH, I KNOW.

THIS IS SUPPOSED TO BE GENERAL STUDY TIME. TODAY WE'RE LEARNING ABOUT SDGS.

My Grrr

Slide

HUH? MR. MIYAMA...?

IT'S NOT TIME FOR SCIENCE CLASS

...AND THEN I GOT ASKED TO TEACH YOU ALL ABOUT THE SDGS INSTEAD.

I TOLD THE PRINCIPAL THAT WE SHOULD PUT SOLAR PANELS ON THE ROOF OF THE SCHOOL...

Haha!!

THIS BOOK'S GOAL

IT'S BEEN A WHILE SINCE SOMEONE SAID THAT CHILDREN HAVE STOPPED READING BOOKS, BUT DESPITE THE EXISTENCE OF THAT VERY SITUATION, I WONDERED WHY COMIC BOOKS AND MANGA REMAIN POPULAR. I BELIEVE THAT IT IS BECAUSE MANGA AND COMIC BOOKS ARE EASY TO READ FOR CHILDREN, AND THEY FIND THEM ENJOYABLE.

OUR COMPANY THEN DECIDED TO AIM TO TURN EDUCATIONAL MATERIALS INTO A COMIC BOOK LIKE THIS ONE. IT NEEDED TO BE EDUCATIONAL WHILE ALSO MAKING IT POSSIBLE FOR CHILDREN TO WANT TO CONTINUE READING ALL THE WAY TO THE END WITHOUT RESISTANCE. THAT WAS WHAT LED TO THE BIRTH OF *THE GAKKEN: LEARNING WITH MANGA SERIES*. THE STORIES ARE COMPILED TO EXPOSE ELEMENTARY STUDENTS ENCOUNTER TO A VARIETY OF ASPECTS OF REAL SOCIETY WHICH ARE DEEPLY CONNECTED TO THEIR LIVES THROUGH AMPLE AND ACCURATE DATA AND FIGURES.

FURTHERMORE, THE SERIES ISN'T JUST SUITABLE AS EDUCATIONAL MATERIALS FOR GENERAL STUDIES TIME AT SCHOOL, BUT IS ALSO VERY WELL-RECEIVED FROM BOTH EDUCATORS AND PARENTS. *THE GAKKEN: LEARNING WITH MANGA SERIES* HAS ALSO BEEN DONATED TO ELEMENTARY SCHOOL LIBRARIES AND MAJOR PUBLIC LIBRARIES.

FEATURES OF *THE GAKKEN: LEARNING WITH MANGA SERIES*

● IMPARTS A VAST AMOUNT OF KNOWLEDGE

THIS BOOK ALLOWS CHILDREN TO ACQUIRE VAST AMOUNTS OF KNOWLEDGE THROUGH THE THEMES PRESENTED AND THEIR ARRANGEMENT, AS WELL AS HISTORY, WHILE PRESENTING IT IN AN EASY TO COMPREHEND FORMAT. EACH PAGE HAS A PIECE OF TRIVIA RELATED TO THE INFORMATION AND KNOWLEDGE PRESENTED ON THE PAGE.

● USEFUL FOR GENERAL STUDIES

THIS BOOK IS USEFUL FOR HELPING TO DRAW OUT A CHILD'S INTEREST AND CONCERNS DURING CLASSES SET ASIDE FOR GENERAL STUDIES.

● COMIC BOOK FORMAT

THIS ALLOWS CHILDREN WHO AREN'T THE STRONGEST OF READERS TO STILL ENJOY THE STORY AS THEY PROGRESS.

● BURSTING WITH INFORMATION

THIS BOOK FEATURES A WIDE BERTH OF PICTURES AND ILLUSTRATIONS. THEY'RE PRESENT TO ASSIST WITH UNDERSTANDING WHILE PROVIDING VALUE ON THEIR OWN AS DOCUMENTS.

● FEATURES THEMES & JOBS BASED ON MODERN SOCIETY.

THE STORIES ARE PREPARED WITH THE GOAL OF GETTING CHILDREN INTERESTED IN WORK AND MODERN SOCIETY IN AN EASILY UNDERSTOOD MANNER.

● FULFILLS THEIR DESIRE TO LEARN MORE

PRESENTS CHILDREN WITH SPECIALIZED INFORMATION ABOUT THE UNIQUE WORKINGS OF A COMPANY AND JOBS SO THAT IT WILL ANSWER THEIR QUESTIONS AND CONCERNS.

The Secrets of SDGs 7 Affordable and Clean Energy

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Mitsubishi Heavy Industries, Ltd.
- ▶ **Photographs and materials**
Mitsubishi Heavy Industries, Ltd.
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- ▶ **Cover / Book design**
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- ▶ **Editorial cooperation**
Sideranch Inc.
- ▶ **Editing & Production**
λ production
- ▶ **Planning**
Yomiurirengo Advertising Agency Co., Ltd.
- ▶ **Planning & Production**
Hiroaki Suzuki (Gakken Co., Ltd.)
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- ▶ **Desktop Publishing**
Adclair Co., Ltd.
- ▶ **Printing**
Dai Nippon Printing Co., Ltd.



- ▶ **Manga illustrations**
MAKO.

Manga artist and illustrator from Fukuoka, Japan.
Her representative works are “COMICxSTUDY Manga de Wakaru Chugaku Shakai Geography”, “Wangari Maathai (Gakken Manga NEW Sekai no Denki)” (Gakken), “47 Todofuken Hontou ha Kowai Mukashibanashi” (Rironsha), “Manga de Yoku Wakaru Badminton” (Oizumi Shoten), “Tetsugaku Friends” (PHP Institute), “Robot wo Ugokasou! mBot de Omoshiro Programming” (Ric Telecom), etc.

References

“Sekai ga Gutto Chikaku Naru SDGs to Bokura wo Tsunagu Hon” (Gakken)
“Gakken Perfect Course Chugaku Rika” (Gakken)

The content of this publication has not been approved by the United Nations and does not reflect the views of the United Nations or its office or Member States.
<https://www.un.org/sustainabledevelopment/>

Information on the “Learning with Manga series” (in Japanese)

[Gakken Manga Himitsu Bunko] <https://bpub.jp/gakken-himitsu>

[Gakken Manabista] <https://gakken.jp/manabista/himitsu>

[Gakken Kids Net] <https://kids.gakken.co.jp/himitsu/>

This publication is based on information current as of April 2022.

The *Gakken*: Learning with Manga series

The Secrets of SDGs 7
Affordable and Clean Energy

First Printing Mar.10, 2023

Manga illustrations — MAKO.

Composition — Noriyuki Irisawa

Publisher — Gakken Co., Ltd.

Printing — Dai Nippon Printing Co., Ltd.

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