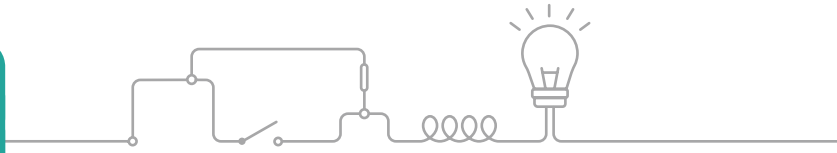
LESSON A6

LEARNING MORE ABOUT CARBON CYCLE TRANSITIONS – COMBUSTION AND ENERGY – HUMAN ACTIVITIES



MAIN SUBJECTS
Natural sciences / Physics / Chemistry

DURATION
~ Preparation: 10 min
~ Activity: 1h30

AGE GROUP
12-15 years

LEARNING OUTCOMES
After previously introducing the carbon cycle, this lesson illustrates by experiential learning, how carbon moves from one reservoir (fossil fuels and land animals) to another (atmosphere).

During this lesson, students will learn that:

~ Sources of energy can be classified as renewable and non-renewable.
~ Combustion of fossil fuels or wood produces energy and releases CO_2 into the atmosphere.
~ Fermentation occurring in the stomach of cattle produces methane, which gets released into the atmosphere.
~ This methane can be used instead of fossil fuel as a cheap source of energy.
~ Gases released into the atmosphere through combustion and fermentation contribute to the greenhouse effect and therefore to global warming.

KEYWORDS
Carbon, methane, fermentation, non-renewable and renewable energy

TEACHING METHOD
Experimentation, documentary analysis

PREPARATION 10 MIN

TEACHER TIP
This optional lesson focuses on some flows of the carbon cycle: combustion and fermentation. It is better if this follows the previous lesson on the carbon cycle, and it can be given alongside lesson A5, which deals with other carbon flows.

EQUIPMENT

- **WORKSHEETS A6.1** and **A6.2** (can be showed to the whole class).
- **WORKSHEETS A6.3, A6.4** and **A6.5** (one copy for each pair of students).
- Two small glass jars with lids, preferably with a spout to prevent the CO_2 from coming out too quickly.
- A little piece of charcoal (well burned) or wood or a cork, small enough to easily fit into the jar - consider taking samples of the same weight. You can also use different materials, depending on what you choose or your students' suggestions (diesel, peat, etc.)
- Fire protection gloves.
- A lighter or matchbox.
- A clamp to hold the piece of coal / wood.
- Limewater. (To make this: dissolve some calcium hydroxide in water, allow it to stand for some time and then pour out the clear solution on top into a fresh container, ensuring that the undissolved precipitate remains behind. Make sure that the container is tightly closed. Use the clear limewater solution for your experiment).

INTRODUCTION 10 MIN

Ask students to discuss what they have already learnt in the previous lesson about the Earth's carbon reservoirs and the flows of carbon atoms between them. Explain that this lesson is going to focus on human activities that play a part in the carbon cycle. In order to study these activities, they will have to help a farmer who raises cattle and who wants to reduce his impact on the environment. He currently uses fossil fuels as his main energy source, but he just saw the documents in **WORKSHEET A6.1** and is a bit sceptical about the link between fossil-fuel use and carbon dioxide emissions. Your students will have to convince him that fossil fuel use is responsible for carbon dioxide emissions and to persuade him to use an alternative source of energy.

PROCEDURE 1H10 MIN

PART 1: COMBUSTION 40 MIN

Here are some key questions to lead a whole class discussion about energy. Record your students' responses on the whiteboard.

1. Distribute or show to the whole class **WORKSHEET A6.1**, and have your students analyse it. *What can you observe about fossil fuel related CO_2 emissions since 1850? How can you explain it?* (human activities: transport, electricity production, industries, etc.)

> **TEACHER TIP**
> In this worksheet we provide two levels of difficulty: the first graph is for younger students, whereas the second one may be used with more advanced pupils. The latter focuses on the five countries that are responsible for most of the CO_2 emissions and may be used to address climate justice issues. It is up to you to choose which one is best suited to your students' level.

2. If you choose to use the second part of **WORKSHEET A6.1**: first ask the students to analyse the graph in order to identify which countries contribute most to CO_2 emissions, and also how the proportions have changed over the past decades. Next, conduct a debate in your class on whether all countries should cut their emissions equally or the cuts should be in proportion to contributions to CO_2 emissions. *Should any other factors such as development index, quality of life, etc. be considered?* Ask them to justify their responses.

3. Explain that many major human activities rely on energy, and mostly on fossil fuels for supplying that energy. *Since fossil fuels are burned in order to be used, how can you prove to the farmer that fossil fuel combustion generates carbon dioxide? Can you think of an experiment?*

4. Here is the kind of experiment you might set up (you can either choose to do this experiment as a teacher demonstration or the students could carry it out themselves in groups).

- Light the piece of coal or wood.
- Put it in a jar and close it immediately, to allow the coal/wood to burn inside. Wait until the coal/wood stops burning.
- Taking care that the air inside the jar, containing carbon dioxide, does not escape, quickly and carefully remove the wood/coal (wearing protective gloves) and pour in some limewater.
- Secure the lid of the jar and shake it. If the students have performed experiments using limewater before, have them recall how it reacts with carbon dioxide; if not, explain the reaction.
- As a control, pour the same amount of limewater into another empty jar and shake.
- Place the two jars next to each other and observe.
- The students will observe that the limewater becomes cloudy in the first jar but not in the second, indicating that CO_2 has been produced during combustion.

> **TEACHER TIP**
> If this experiment is carried out by groups of students, have them test different combustible substances of the same weight to see if all of them produce CO_2 and which ones produce more CO_2 (measured indirectly by how cloudy the limewater gets).

5. Have all the groups share and compile their results to draw conclusions from collective data: the combustion of different materials (including fossil fuels) produces CO_2, and the amount of CO_2 that is produced depends on the material. By using fossil fuels, humans increase carbon movement into the atmosphere.

6. Explain to your students that now the farmer is convinced that fossil fuel use leads to CO_2 emissions, and they will have to help him to find an alternative source of energy. *Which sources of energy do you know?* You may show or distribute **WORKSHEET A6.2** in order to have them identify different sources of energy. *What are the differences between renewable and non-renewable energy?* Renewable energy comes from sources that do not run out or that can be replenished within a short period of time, such as wind, water, sun, biomass and geothermal. On the other hand, non-renewable energy comes from sources that cannot be restored within a short period of time, such as oil, coal, natural gas and nuclear energy.

PART 2: FERMENTATION 30 MIN

1. Explain to your students that they will now focus on a renewable source of energy which is called "biomass" – meaning it is made up of organic matter produced by living beings. In our farmer's case, one thing he can do is develop a process that uses "biogas". In order to explain to the farmer how he could use this kind of energy, tell your students that they will work together in groups of 6, each pair of students focusing on one aspect of biogas use.

Altogether, as a group, they will have to find the answer to the following questions:

- *What is biogas?*
- *Where does it come from?*
- *How could it be used?*
- *Why is it a good idea to use biogas instead of allowing methane to escape into the atmosphere?*
- *Why can we consider it as a renewable energy?*

2. In order to do this, each pair of students will have a specific role in their group—distribute **WORKSHEETS A6.3** to **A6.5**, according to their role:

- *Veterinarian:* **WORKSHEET A6.3**
- *Environmental activist:* **WORKSHEET A6.4**
- *Engineer:* **WORKSHEET A6.5**

3. Each pair of "experts" has to analyse their documents to find the information needed.

BACKGROUND FOR TEACHERS

Combustion and fermentation are parts of the carbon cycle that produce carbon dioxide, which is then released into the atmosphere.

COMBUSTION

Combustion– also called "burning" –consists of a chemical reaction between a **combustible material** (e.g., wood) and an **oxidiser,** generally oxygen. Combustion of fossil fuels involves burning of organic carbon (coal, oil, natural gas, etc.) which liberates carbon dioxide and water, according to the chemical reaction:

$$\underset{\text{methane}}{CH_4} + 2\,\underset{\text{dioxygen}}{O_2} \xrightarrow{\text{combustion}} \underset{\text{carbon dioxide}}{CO_2} + \underset{\text{water}}{2\,H_2O} + \text{heat}$$

This equation indicates that combustion of methane releases carbon dioxide (CO_2), which formed 65% of the total GHG emissions in 2010[1]. Thus, combustion leads to global warming by producing CO_2. Methane is only one example amongst many–wood or coal combustion also releases carbon dioxide, as follows:

Coal combustion:

$$\underset{\text{coal}}{C} + \underset{\text{dioxygen}}{O_2} \xrightarrow{\text{combustion}} \underset{\text{carbon dioxide}}{CO_2} + \text{heat}$$

Wood combustion:
(if we consider that it contains only cellulose):

$$\underset{\text{wood cellulose}}{C_6H_{10}O_5} + 6\,\underset{\text{dioxygen}}{O_2} \xrightarrow{\text{combustion}} \underset{\text{carbon dioxide}}{6\,CO_2} + \underset{\text{water}}{5\,H_2O} + \text{heat}$$

FERMENTATION

Fermentation occurs naturally in living animals; in cows' stomachs, for example, numerous methanogenic bacteria generate methane from molecules found in the grass chewed by the cow. The difference with combustion lies in the nature of carbon molecules produced, since **fermentation releases methane (CH_4) and not carbon dioxide.** This methane is then released directly into the atmosphere from the cows passing wind (farts and burps), and even from their dung, contributing to the greenhouse effect.

This is a good example to demonstrate that tackling climate change does not necessarily involve only the elimination or reduction of CO_2 emissions because there are also other greenhouse gases involved. Moreover, **methane is even worse for global warming than carbon dioxide** because the "warming capacity" of one ton of methane is 28 times greater than the same amount of CO_2.

Recently, a method called **"methanisation"** has been developed for using methane to produce energy. In this process, biogas (which contains methane) is produced from food wastes and cow dung through fermentation. This biogas is stored in a closed container and distributed through pipelines with valves at different points. It is then used for various purposes like cooking, producing hot water or heat for houses, etc. This is an efficient way to both reduce waste and produce cheap energy. This method is used in some countries and represented 14% of the total energy consumption of the world in 2014[2].

1 https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data
2 https://www.worldbioenergy.org/uploads/WBA%20GBS%202017_hq.pdf

WRAP-UP 10 MIN

In groups of 6, students can now present what they learned (how does methane form, why it may present a threat to climate, and how some waste may be used as a source of renewable energy), in the form of a digital presentation or a giant drawing or poster.

Their presentation should explain:

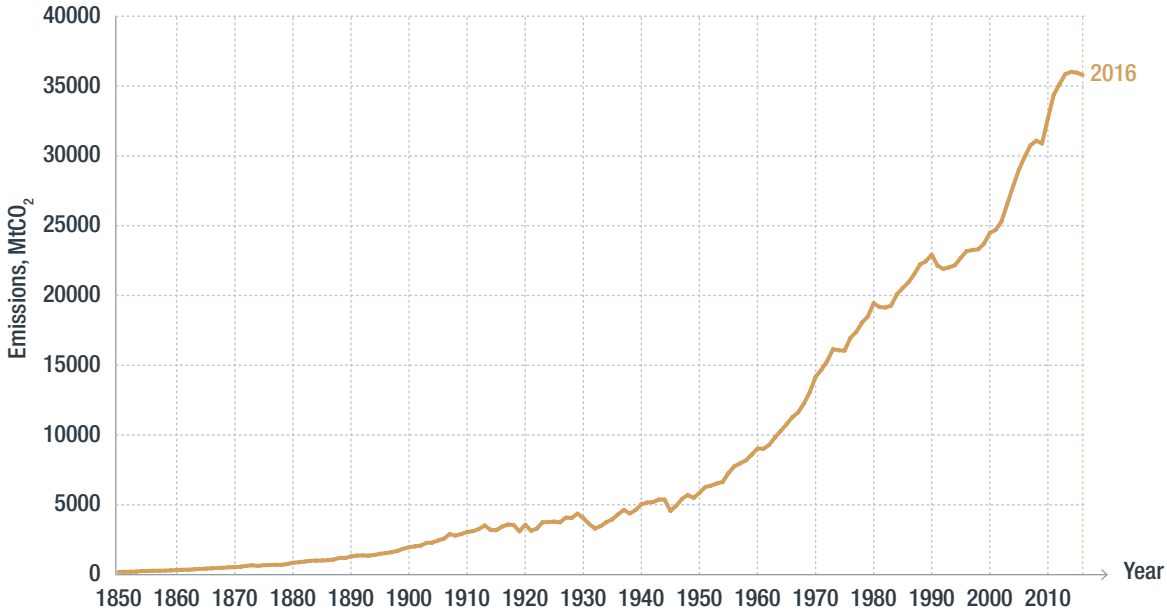
- The link between fossil fuel use and carbon dioxide emissions and its impacts on the atmosphere (the combustion produces carbon dioxide that moves quickly from fossil fuel reservoirs to the atmosphere).
- The link between cattle breeding and temperature rise (cattle produce methane during fermentation that warms up the atmosphere).
- The use we – as humans – make of these processes (both processes produce energy; methane emissions could be reduced by turning methane produced by cattle into biogas, leading to energy production).
- The pros and cons of the use of these processes (combustion is the most used and produces a huge amount of energy, but it is not renewable; biogas is a cheap and easy way to obtain energy in many parts of the world, but is currently underdeveloped and needs infrastructure).

WORKSHEET A6.1

DOCUMENT 1: FOSSIL FUEL RELATED CO_2 EMISSIONS IN THE WORLD, BETWEEN 1850 AND 2016

TRAINEE

This document shows fossil fuel related CO_2 emissions worldwide since 1850.

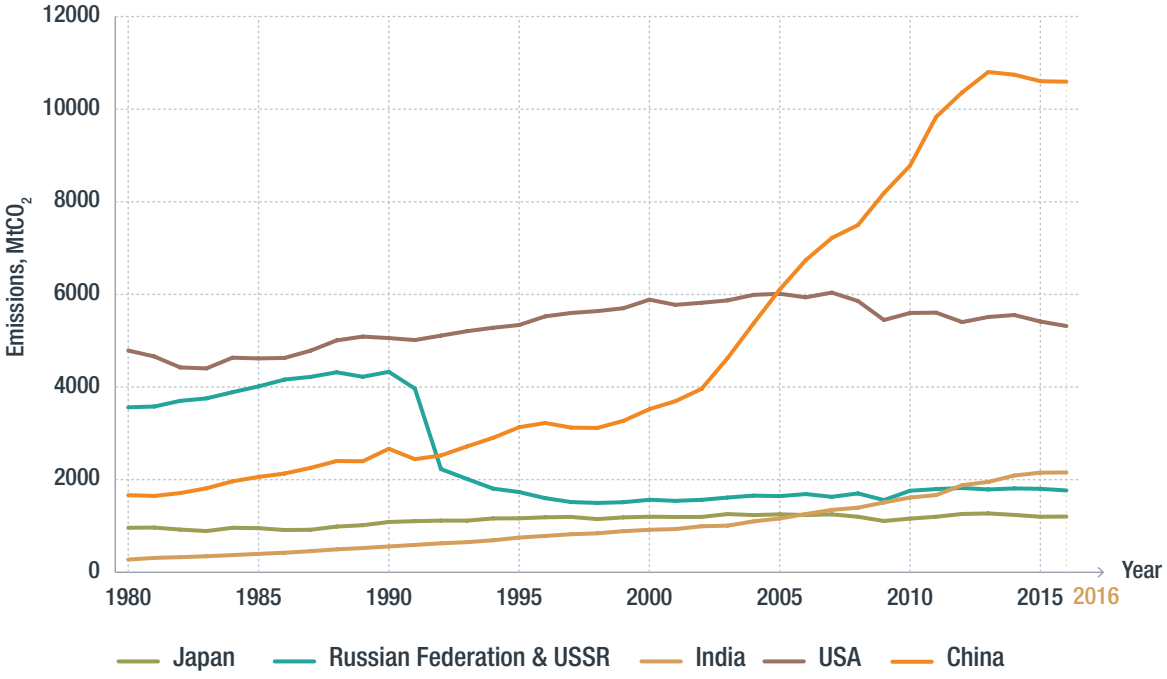


$MtCO_2$ means "million tonnes of carbon dioxide".
Source: US EIA Historical Statistics for 1980-2016. US Energy Information Administration, World Bank, Gampinder.org, via: https://www.theshiftdataportal.org

DOCUMENT 2: CO_2 EMISSIONS FROM FOSSIL FUELS BETWEEN 1980 AND 2016

CURIOUS

This document presents the CO_2 emissions from fossil fuels for 5 countries since 1980.



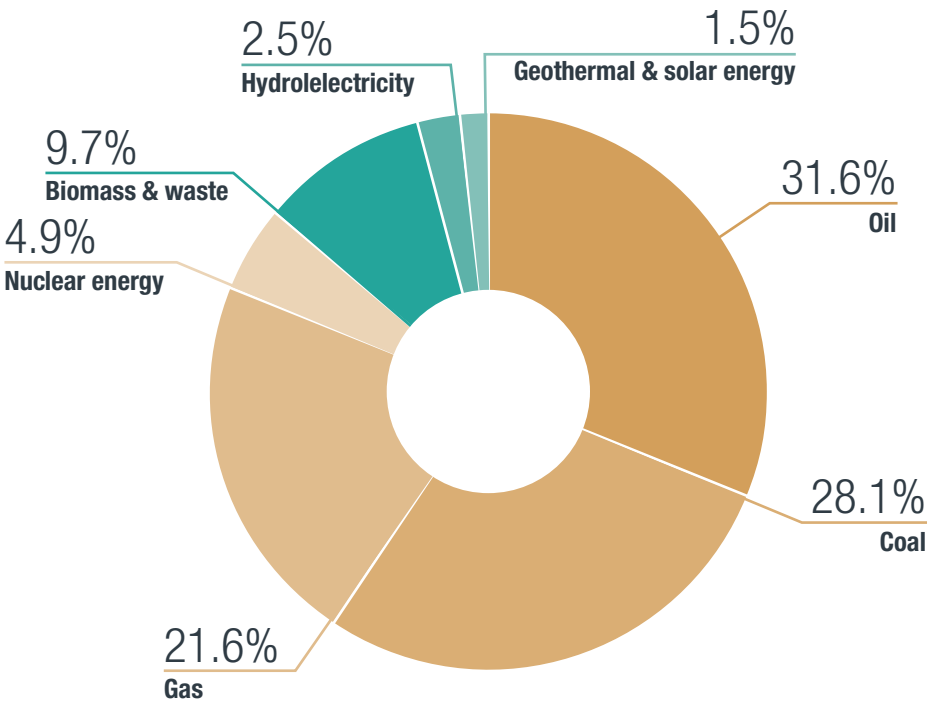
$MtCO_2$ means "million tonnes of carbon dioxide".
Source: US EIA Historical Statistics for 1980–2016. US Energy Information Administration, World Bank, Gampinder.org, via: https://www.theshiftdataportal.org

WORKSHEET A6.2

TRAINEE

This document shows the distribution of energy used according to the source:

- What is the main source of energy in the world today?
- Is it a renewable or non-renewable resource?



80%

of the global energy consumption comes from fossil fuels (oil, gas, coal)

FOSSIL FUEL

RENEWABLE ENERGIES

In 50 years, the **global population** has increased **2.5 times** but the **energy consumption** has increased **5 times!**

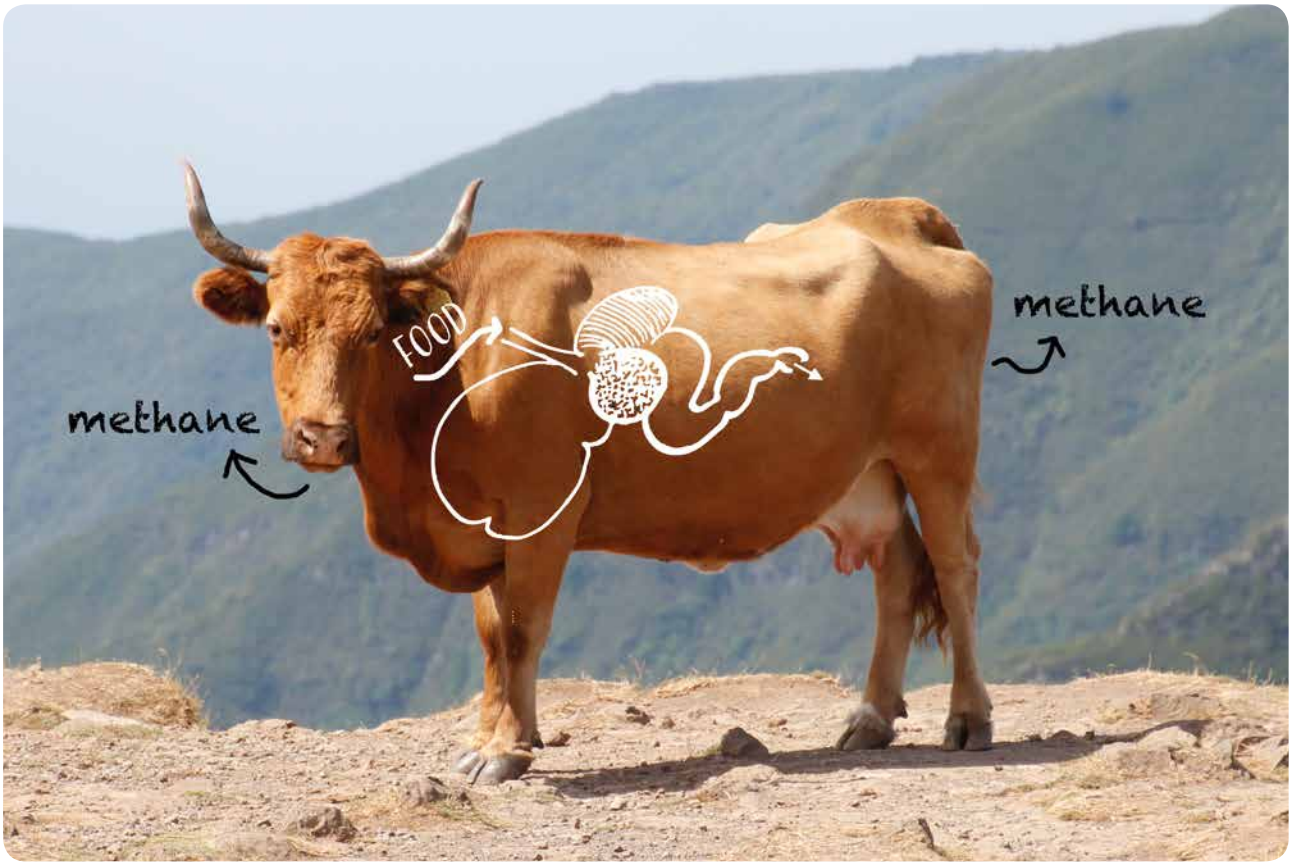
Source: Adapted from the guide “Comment agir pour la planète?”, ADEME.

VETERINARIAN

Your mission: You are a veterinarian and you have to explain to the farmer how he may 'use' his cows as a source of energy. Using the following document, explain what happens when cows graze and how this could be used as a source of energy.

Cows – like other ruminants – have a peculiar stomach: in fact, they have 4! Each "pocket" of the stomach contains millions of microbes that break down grasses into useable energy for the cow. During this process, **they also produce methane** – a gas rich in carbon – that is released into the atmosphere through cows' burps, farts and dung. If we can't collect the **methane** from burps and farts, maybe we can at least use the portion coming from dung?

The natural gas that is used as a source of energy in some housing or industries is composed of 90% methane, and can be produced by the **decomposition of cow dung** and other organic matter.

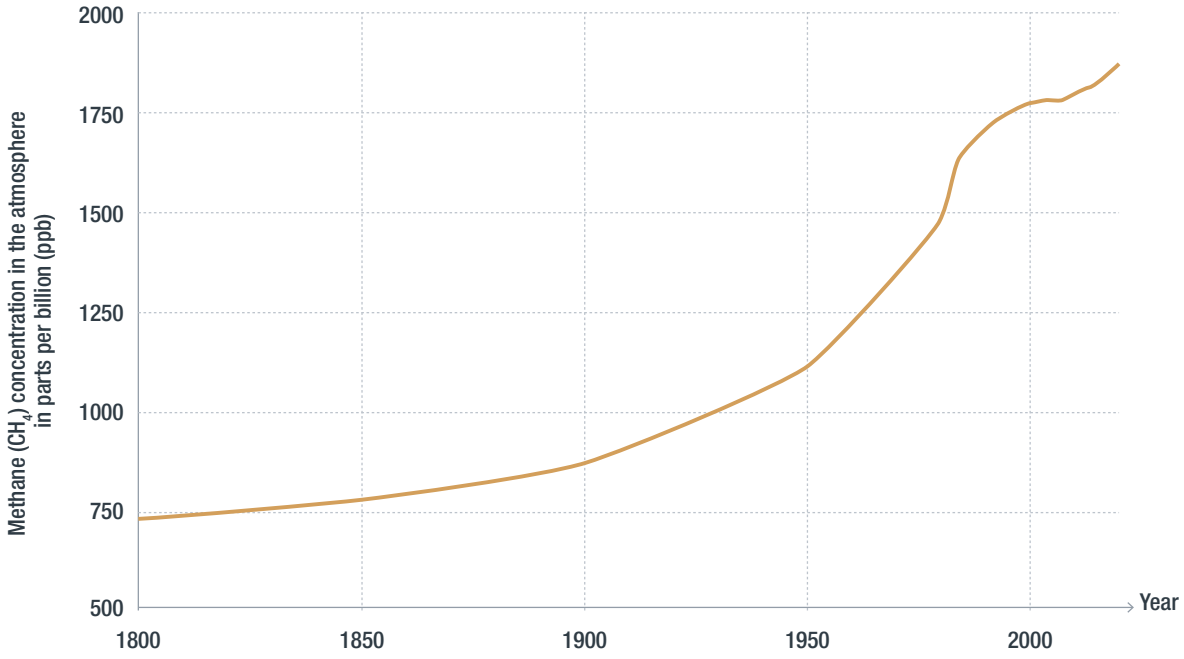


ENVIRONMENTAL ACTIVIST

Your mission: You are an environmental activist and you have to explain to the farmer why cows may constitute a threat to the climate. Using the following document, explain how methane levels have evolved over the last century and why it may represent a problem.

This document shows the changes in methane (CH_4) levels in the atmosphere, since 1800.
Methane is a **greenhouse gas** that is produced in agriculture. It is more powerful than carbon dioxide, since it warms the atmosphere up to **30 times more than CO_2!**

EVOLUTION IN GLOBAL CH_4 LEVELS SINCE 1800



Source: Adapted from https://www.methanelevels.org

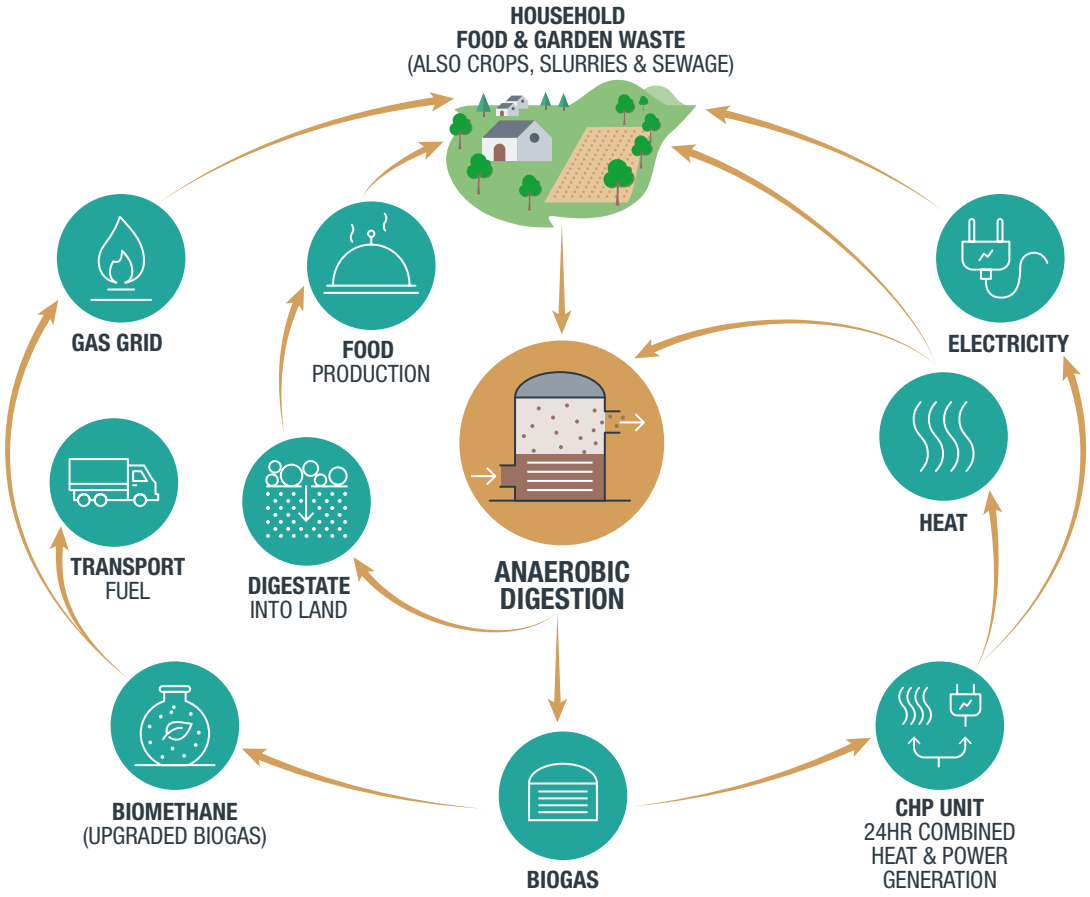
ENGINEER

Your mission: You are an engineer and you have to explain to the farmer how he can use his cow dung to produce energy. Using the following documents, explain how it is possible to produce biogas from waste and why it can be considered as a renewable energy source.

DOCUMENT 1: VIDEO ABOUT METHANIZATION

https://qrco.de/bcdqPr

DOCUMENT 2: THE DIFFERENT USES OF BIOGAS



Source: Adapted from https://adbioresources.org/about-ad/