**ENEN+**

**List of e-materials for the secondary school level pupils**

*This list includes different e-materials: pdf documents, power point presentations, animations, infographics and videos. The content of each link is briefly commented. Some web pages appear in several categories since they include information on more than one subject. Most of the resources of this list are free access. Those that are for payment are identified, as well as those that require creating an account.*

# Basic knowledge about the nuclear field

*What do you know about radiation? Are you aware that radiation is present in your daily life? What sources of radiation can you name? Do you think you can sense radiation? What have you heard about the effects of radiation? Can you think of a positive one? Can you imagine how radiation is used in everyday life with beneficial effects? What is the relationship between radiation and radioactivity? What about the nuclear decay processes? What nuclear reaction processes do you know? Do you understand why the fission process is a source of energy? Do you know that energy from the sun is due to the nuclear fusion reactions occurring inside the core? Find out all the answers and many other questions!*

* 1. <http://www.passmyexams.co.uk/GCSE/physics/index.html>

This site provides general information about radioactivity, radiation properties, uses, effects and so on, also explaining half-life and chain reaction concepts, by means of animations and videos. Language: English.

* 1. <http://www2.lbl.gov/abc/>

Resource (mainly presentations) for high school teachers and students about radiation and energy, nuclear reactions, decay modes, among others. It also includes a glossary of nuclear science terms. Language: English.

* 1. <https://study.com/academy/lesson/nuclear-power-lesson-plan.html>

Web page with information (video) about radioactive decay (Chapter 8). An account is needed (30-days free, 59.99 $/month). Language: English.

* 1. <http://nuclearsafety.gc.ca/eng/resources/educational-resources/index.cfm>

Very complete and interesting web page from the Canadian Nuclear Safety Commission (CNSC) provides infographics about radiation, electromagnetic spectrum, etc. It also gives an introduction to radiation: what is, types, sources, effects, glossary of terms, etc. Language: English

 (<http://nuclearsafety.gc.ca/eng/resources/radiation/index.cfm>).

* 1. <https://www.youtube.com/watch?v=Zw0pHT47AAU>

4-minutes video from the CNSC explaining what radiation is (runner for the PIME Award). Language: English.

* 1. <http://www.nuclearscienceweek.org/get-involved/lessons_and_resources/>

Very interesting resources for teachers, classified by the level for which they are designed, and by categories, including nuclear basics (half-life concept, radioactive decay, etc.). It is about PDF documents and some of them include game (for example to explain how a nuclear chain reaction works) or debate proposals (for example about the benefits and concerns of current energy issues). Language : English.

* 1. <http://watisradioactievestraling.tudelft.nl/en/>

Animation about the radiation concept, what is, sources, etc. This page also includes some videos (<http://watisradioactievestraling.tudelft.nl/en/movies>) about these issues. A quiz is also available as well as FAQ classified by topics (daily life and radiation effects). Moreover, an email address is provided to solve specific questions about radiation (whatisnuclearradiation@gmail.com). Language: English and Dutch.

* 1. <https://www.neok12.com/Nuclear-Power.htm>

Educational videos (~ 2-10 minutes) and games for kids about nuclear issues: what is radiation, radioactive decay, type of radioactive particles, fission and fusion reactions, and so on. Language: English.

* 1. <https://www.onlinemathlearning.com/igcse-physics.html>

Videos about radioactivity, half-life and such concepts. Language: English.

* 1. <https://educators.brainpop.com/bp-topic/radioactivity/>

Movie about radioactivity. This web page also provide materials both for teachers and students to be used on tablets. It is a non-free resource for which registration is required. G suite for education (free for schools). Language: English.

* 1. <http://mocomi.com/>

Articles about radiation and radioactivity, designed for pupils from 7-14. Language: English.

* + 1. <http://nuclearconnect.org/know-nuclear/science>

Brief articles about radiation, biological effects, and radiation detection. Language: English.

* 1. <https://www.niauk.org/wp-content/uploads/2017/08/nia_facts_170809web.pdf>

Recommended PDF document which includes a section dedicated to explain radiation. Language: English.

* 1. <https://www.foronuclear.org/es/el-experto-te-cuenta/119909-que-sabes-de-la-radiacion>

Summary about radiation : concept, sources, classification. Language : English, Spanish.

* 1. <https://www.iaea.org/Publications/Factsheets/English/radlife>

IAEA web page with information about the ionizing radiations, types of radiations, radiation dose concept, a little explication about the levels of radiation and an explication of risk and benefits of radiations: This material has a higher level than others. Language: English.

* 1. <https://www.nuclear-power.net/nuclear-power/nuclear-reactions/>

Explanation about what a nuclear reaction is, types and notation. Language: English.

* 1. [https://chem.libretexts.org/Textbook\_Maps/General\_Chemistry/Map%3A\_Chemistry\_(Averill\_and\_Eldredge)/20%3A\_Nuclear\_Chemistry/20.2%3A\_Nuclear\_Reactions](https://chem.libretexts.org/Textbook_Maps/General_Chemistry/Map%3A_Chemistry_%28Averill_and_Eldredge%29/20%3A_Nuclear_Chemistry/20.2%3A_Nuclear_Reactions)

This section of the web page explains the common modes of nuclear decay. Language : English.

* 1. <https://kids.kiddle.co/Nuclear_reaction>

A brief description of nuclear reactions and some uses of them. Language: English.

* 1. <https://t2.lanl.gov/nis/tour/sch002.html>

More complete description of nuclear reactions, nuclear radiation types, and targets and products of nuclear reactions. Language: English.

* 1. <https://www.neok12.com/video/Nuclear-Power/zX776b4667715960595b0055.htm>

Educational video explaining nuclear reactions, designed for pupils from 8-12. Language: English.

* 1. <http://mocomi.com/nuclear-fission-and-nuclear-fusion/>

Movie about nuclear fission and fusion, for students from 7-14. Language: English.

* 1. <http://highschools.sckcen.be/nl/Educatief_materiaal>

Material about nuclear fusion for pupils and teachers. Language: Dutch and French.

# Different sectors:

## Nuclear energy

*Energy is the key factor that supports economic growth, people's welfare and development. Electric energy can be produced by various means: using fossil fuel, nuclear fuel, water power, wind power, geothermal power, solar, etc. In Power Plants electricity is produced using a heat source that heats water up to the point that is turned into steam. The steam is then used in steam turbines that rotate in order to produce electrical energy. In Classic Power Plants fossil fuel is used to produce heat. A Nuclear Power Plant is similar to a Classic Power Plant but for heating we replaced burn of fossil fuels with nuclear reactions (such as nuclear fission, nuclear decay and nuclear fusion). In the same time we removed a pollution source and we replace it with an environmental friendly solution.*

*At present, the majority of Nuclear Power Plants use nuclear fission to produce electricity. Fission is a reaction in which a nucleus of an atom splits into smaller parts. Because of the fact that enormous energy is present in the bonds that hold together the nucleus, when splitting apart, this energy is released in the form of heat.*

*Nuclear power is the one that fights climate change, that powers your house, your school, your hospital and your electric car. With 450 Nuclear Reactors worldwide, generating about 11% of electricity demand worldwide and, with 58 reactors under construction and more than 150 planned, Nuclear Power is the most reliable and available power source in the world.*

* 1. <http://www.passmyexams.co.uk/GCSE/physics/index.html>

This site provides a short description of nuclear reactors, including some animations. Language : English.

* 1. <https://study.com/academy/lesson/nuclear-power-lesson-plan.html> Web page with a video related to nuclear energy (Chapter 5). An account is needed (30-days free, 59.99 $/month) Language: English.
	2. <http://www.nuclearscienceweek.org/get-involved/lessons_and_resources/>

Resources for teachers, classified by the level for which they are designed and by categories, including nuclear energy. It is about PDF documents and some of them include game or debate proposals. Language: English.

1. <https://www.neok12.com/Nuclear-Power.htm>

Educational videos (5-10 minutes) and games for kids. Among these videos there are some explaining how energy from nuclear fission and fusion is obtained. Language: English.

1. <https://www.calacademy.org/educators/lesson-plans/nuclear-energy-whats-your-reaction>

Web page with PDF documents and videos about nuclear energy from the California Academy of Science. It also includes activity plans to be followed by teachers. Language: English (some videos also in Spanish).

1. <http://mocomi.com/nuclear-energy/>

Educational video about nuclear energy for pupils from 6-13. Language: English.

1. <http://nuclearconnect.org/in-the-classroom/for-students/nuclear-energy>

Brief description about nuclear energy. Language: English.

1. <http://nuclearconnect.org/know-nuclear/applications/energy>

Short and clear article about nuclear energy with a video. This web page also includes a section (<http://nuclearconnect.org/know-nuclear/talking-nuclear/top-10-myths-about-nuclear-energy>) collecting mythbusters around nuclear energy. Language : English.

1. <https://www.youtube.com/watch?v=rcOFV4y5z8c>

5-minutes video explaning Nuclear Energy and how does it work? Language: English (with option of subtitles in several languages).

1. <https://www.youtube.com/watch?v=pVbLlnmxIbY>

Video that comments on 3 Reasons why nuclear energy is awesome! The other side of the coin is another video (<https://www.youtube.com/watch?v=HEYbgyL5n1g>) in which the cons of nuclear energy are detailed. Language: English (with option of subtitles).

1. <https://www.youtube.com/watch?v=ciStnd9Y2ak>

Opinion video of about 20 minutes entitled Why I changed my mind about nuclear power. Language: English (with subtitles option for Spanish, Portuguese or French).

1. <https://www.youtube.com/watch?v=Ta3z3pGK0vU>

National Geographic video explaining what nuclear energy is. Language: English (with subtitles option).

1. <https://www.youtube.com/watch?v=_UwexvaCMWA>

Video explaining how nuclear power plants work, focused on the PWR system. Language: English.

1. <https://www.youtube.com/watch?v=kwn8rAYgZVw>

Video of about 5 minutes from the IAEA about Nuclear Power in the 21st Century. Language: English.

1. <https://www.youtube.com/watch?v=gKL2QzYF16M>

Video from AREVA about the operation of a PWR reactor. Language: English.

1. <https://www.youtube.com/watch?v=t7FvxN_gkt4>

Video of about 4 minutes entitled “The Future Of Clean Nuclear Energy Is Coming”. Language: English.

1. <https://www.youtube.com/watch?v=v0R2MrckXm4>

Video about how to control a nuclear power plant with a duration of slightly more than 5 minutes. Language: English.

1. <https://www.youtube.com/watch?v=flXeSHwr9uM>

Very short video to explain the advantages of nuclear energy. Language: English.

## Medical applications

*Radioactivity and radioactive isotopes are frequently used in medicine and have an important role in both diagnostics and therapy.*

*The first diagnostic machines applied X-rays to get simple information about the patient’s body. To obtain more detailed information, other imaging techniques have been developed such as Computer Tomography (CT) and mammography. Nuclear medicine imaging systems for instance the gamma-camera, PET (Positron Emission Tomography) and SPECT (Single Photon Emission Computed Tomography) use radioactive isotopes injected in the patient’s body to visualize the function of organs and cell malformations.*

*Radioactivity can also be used for therapeutic purposes. Based on the location of the source two techniques can be distinguished. In nuclear medicine therapy, we use injected radiopharmaceuticals to treat or control cancer. External radiation therapy is a non-invasive technique to irradiate the patient with linear accelerator, cobalt unit, proton and heavy particles therapy. Brachytherapy is another form of radiation therapy, where sealed radioisotopes are placed directly in the tumour to concentrate high dose on a small area.*

1. <http://nuclearsafety.gc.ca/eng/resources/infographics/index.cfm>

Infographics published by the Canadian Nuclear Safety Commission about medical imaging and radiotherapy, nuclear medicine, diagnostic imaging, etc. This page also faces some nuclear Mythbusters related to medical applications (<http://nuclearsafety.gc.ca/eng/resources/infographics/index.cfm>). Language: English.

1. <http://watisradioactievestraling.tudelft.nl/en/faq>

Few FAQ classified by topics including medical applications. Language: English and Dutch.

1. <http://nuclearconnect.org/know-nuclear/applications/medical-uses>

Summary about nuclear applications in medicine. Language: English.

1. <https://www.youtube.com/watch?v=4BRL7UcUZhY>

Video from the IAEA (International Atomic Energy Agency) about the role of nuclear techniques in medicine (diagnosis and treatment) and the implications of use radiation (quality and safety) specifying the role of IAEA in the area. This video has a suitable level for secondary school students. Language: English.

1. https://www.youtube.com/watch?v=v38-I58H2Uc&t=4s

Short video (~3 minutes) to introduce the basic concepts of nuclear medicine separated in diagnosis and treatment. Very clear and suitable for secondary school students. Language: English.

1. https://www.youtube.com/watch?v=wfPza-R2sAY

Video from the AIPES Nuclear Medicine Awareness Working group for introducing nuclear medicine (in a more completed way then the previous one). The different phases of nuclear medicine are detailed and application in the different medicine areas is commented. The level is suitable for secondary school students. Language: English.

1. <https://www.nibib.nih.gov/science-education/science-topics/nuclear-medicine>

Web page from the NIBIB (National Institute of Biomedical Imaging and Bioengineering). It includes a summary of nuclear medicine which advanced contents. Language: English.

1. http://www.eanm.org/publicpress/patient-info/sunny-tim/

Set of videos by EANM (European Association of Nuclear Medicine) suitable for secondary school level. These videos are pedagogical cartoons about some aspects of nuclear medicine. Language: English.

1. <https://cna.ca/technology/medicine/therapy/>

CAN (Canadian Nuclear Association) web page. Basics on radiotherapy (this topic is not dealt in the other links). Language: English.

1. <https://www.youtube.com/watch?v=ZgAi4wQLqZ0>

Learn Oncology video: In this video, the main concepts of how radiotherapy works are explained in an attractive and easy to understand way. This video explains basics on ionizing radiation and their effects in tumour and normal tissue. Language: English.

1. https://www.youtube.com/watch?v=XcaChXkQmbM

Video of about 4 minutes from LLUHealth, where nuclear medicine as a career profile is explained by real workers. Language: English.

## Radiation protection

*Radiation protection is defined by the International Atomic Energy Agency (IAEA) as "the protection of people from harmful effects of exposure to ionizing radiation, and the means for achieving this". Exposure can originate from a radiation source external to the human body or due to the intake of a radioactive material. Ionizing radiation is used in industry and medicine and can present a significant health hazard by causing microscopic damage to living cells, tissues and organisms. There are several special procedures for protection of workers, patients and the individuals of public or the population in general. The radiation protection principles are: justification (when the radiation exposure benefits outweigh the risks); dose limits (exposures should be below the established limits); optimisation (radiation exposure must be ALARA: As Low As Reasonably Achievable). The most important factors in external dose uptake are: time (minimize the exposure time); distance (maximize the distance from the radiation source) and source barriers (use shields and minimize the negative effects of radiation). Radiation protection instruments are used to indicate radiation hazards, and personal dosimeters and biodosimetry techniques are applied to measure personal dose uptake.*

1. <https://gnssn.iaea.org/CSN/TRAINING%20PACKAGES/Forms/AllItems.aspx>

Basic Training Course (power point presentations) on radiation protection and safety by the IAEA. Creating a free account is required. Language: English.

1. <https://www.iaea.org/topics/radiation-protection>

Information from the IAEA about radiation protection. Language: English.

1. <http://watisradioactievestraling.tudelft.nl/en/>

Animation which includes information about how to protect yourself from radiation and how to shield different types of radiation. A video showing how to block alpha, beta and gamma radiation is also available, as well as a quiz. Language: English and Dutch.

1. <http://nuclearconnect.org/know-nuclear/science>/protecting

Brief article about how to protect against radiation. Language: English.

1. <http://www.icrp.org/icrpaedia/toc.asp>

The web page of the International Commission on Radiological Protection (ICRP) has a specific site with the principles of radiological protection (“The System of Radiological Protection”) and a little definition of ionising radiation (“More about Ionising Radiation”). Language: English.

1. <https://www.csn.es/en/proteccion-radiologica>

The web page of the Spanish Nuclear Safety Council (CSN), which is the sole competent authority in Spain for nuclear safety and radiation protection matters, has a site with information about radiation protection and the specific tasks or activities to protect workers, the population and the environment. Language: Spanish.

1. <http://www.oecd-nea.org/brief/brief-10.html>

The web page of the Nuclear Energy Agency contains interesting documentation about radiological protection. Language: English.

1. <https://www-ns.iaea.org/downloads/rw/about-radiation-safety.pdf>

This link of the International Atomic Energy Agency web page contains a PDF file which talks about ionizing radiations and how protect us against them. This web page also includes an explanation about what radiation protection is and the main situations involvingexposure to radiation (<http://www-ns.iaea.org/tech-areas/radiation-safety/radiation-protection.asp?s=3&l=95>). Furthermore, chapter 1 of the IAEA´s document: “Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards” also provides basic information about radiation protection: <http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578_web-57265295.pdf>.

Moreover, videos bout radiological protection can be found at the IAEA´s YouTube channel. Examples of these videos are :

<https://www.iaea.org/newscenter/multimedia/videos/the-iaea-and-safety-radiation-protection-in-medicine>

Short video about radiological protection in nuclear medicine. It is explained the use of nuclear medicine, protocols and methods and treatments to reduce the damage of ionising radiations on patients.

<https://www.youtube.com/watch?v=uKkjrUtmg68>

In this video, it is explained the radiation safety topic. This video presents what is the IAEA organization and their functions. It explains what are ionising radiations and presents the basis of radiological protection.

<https://www.youtube.com/watch?v=5b1-I5jx1j4>

More specific video about occupational radiation protection (and also about industrial professions in the nuclear field).

Language: English.

1. <http://highschools.sckcen.be/nl/Educatief_materiaal>

Material for pupils and teachers about radiological protection. Language: Dutch and French.

## Waste management

*Radioactive waste is a by-product of nuclear power generation or nuclear technology, such as research and medicine. These materials are dangerous to the environment, and there are many regulations about their safe transportation, handling and processing. Radioactive waste can occur in different physical and chemical forms and the concentration of radionuclides depends on the applied technology. Radioactive waste can originate from the nuclear fuel cycle (uranium production, enrichment, fuel fabrication and reprocessing). Other sources include medical (diagnostics, therapy) and industrial wastes, as well as naturally occurring radioactive materials (NORM) that can be concentrated as a result of the processing or consumption of coal, oil and gas, and some minerals. Nuclear weapon testing and demonstration also result in radioactive waste.*

1. <http://www.passmyexams.co.uk/GCSE/physics/radioactive-waste.html>

This site provides a basic understanding about radioactive waste categories understanding. Language: English.

1. <https://study.com/academy/lesson/nuclear-power-lesson-plan.html>

G+Web page with videos for different lesson plans, including information about waste disposal methods of nuclear waste (Chapter 5). An account is needed (30-days free, 59.99 $/month) Language: English.

1. <http://nuclearsafety.gc.ca/eng/resources/educational-resources/index.cfm>

This link from the Canadian Nuclear Safety Commission provides explanation, infographics and a video about radioactive waste. Language: English.

1. <https://www-pub.iaea.org/books/iaeabooks/8420/Disposal-of-Radioactive-Waste>

PDF from the IAEA about specific requirements for the disposal of the radioactive waste. Language: English.

1. <https://www.iaea.org/newscenter/multimedia/videos/radioactive-waste-journey-disposal>

Video from the IAEA about radioactive waste. Language: English.

1. <http://www.nuclearscienceweek.org/get-involved/lessons_and_resources/>

Resources for teachers, classified by the level for which they are designed and by categories, including the nculear waste issue (nuclear safety category). It is about pdf documents and some of them include game or debate proposals. Language : English.

1. <http://watisradioactievestraling.tudelft.nl/en/movies>

Part of these videos deal with the radioactive contamination, and some questions in the quiz included in this web page are related to this issue. Language: English and Dutch.

1. <http://www.world-nuclear.org/nuclear-basics.aspx>

Web page of the World Nuclear Association with some information and explanations. Here is and specific section dedicated to radwastes : « What are nuclear wastes and how are they managed? ». Language: English.

1. <http://nuclearconnect.org/know-nuclear/science>/transporting

Brief article about how to transport nuclear waste. Language: English.

1. <https://www.niauk.org/wp-content/uploads/2017/08/nia_facts_170809web.pdf>

Recommended PDF document with a section dedicated to nuclear waste (page 10). Language : English.

1. <http://highschools.sckcen.be/nl/Educatief_materiaal>

Material (videos, brochures, etc.) for pupils and teachers about radioactive waste. Language: Dutch and French (videos also in English).

## Other

### Nuclear professions

*This section is devoted to provide descriptions of the different jobs related to nuclear science and technology. The goal is to find material about the careers in which nuclear knowledge is relevant for the performance of the job.*

1. <https://www.youtube.com/watch?v=1x_qV6WwYds>

Video of Imperial College London. In this video, teachers and graduate students explain their experience about nuclear engineering careers. Language: English.

1. <https://www.youtube.com/watch?v=F7FKc2RW1dM>

Video from Odessa National Polytechnic University. This video described in detail the work and responsibilities of a nuclear engineer. The format is not unsuitable but its contents are still interesting. Language: English.

1. <http://www.world-nuclear.org/nuclear-basics/the-nuclear-industry.aspx>

The web page of World Nuclear Association has a site with activities of the nuclear industry. Language: English.

1. https://www.youtube.com/watch?v=CsqVxlePM5Y

Old video of less than 2 minutes describing the work of a nuclear engineering in a nuclear power plant. Language: English.

1. <http://nuclearconnect.org/in-the-classroom/for-students/nuclear-engineering>

Section of the Center of Nuclear Science and Technology Information web page dedicated to explain the job of a nuclear engineer. In this same web page there are other sections dedicated with information about different careers related to nuclear (nuclear medicine technologists, Safety Professionals at the Nuclear Regulatory Commission, etc.) Language: English.

1. <http://www.nuc.berkeley.edu/resources/career>

Berkeley Nuclear Engineering Department web page. In the link provided below there is an outlook of the career of a nuclear engineer. Language: English.

1. http://www.westinghousenuclear.com/careers

Westinghouse web page with information about about the careers that this company look for. Language: English.

1. https://www.ge.com/careers/working-at-ge/job-functions

Same information as in the previous link, but for the General Electric company. Language: English.

1. https://www.niauk.org/wp-content/uploads/2017/08/nia\_facts\_170809web.pdf

Document from the Nuclear Industry Association with a specific chapter about careers in nuclear. Language: English.

1. <https://www.radiologyinfo.org/en/info.cfm?pg=professions-nuclear-medicine>

RadiologyInfo.org web page where different profiles of nuclear medicine are described in detail. Language: English.

### Other applications

1. <http://nuclearconnect.org/know-nuclear/applications>

Section of the Center for Nuclear Science and Technology Information web page regarding nuclear applications. Language: English.

1. <http://www.world-nuclear.org/nuclear-basics.aspx>

Web page from the World Nuclear Association with articles regarding the uses of nuclear technology in agriculture, medicine, etc. Language: English.

1. <https://www.foronuclear.org/en/ask-the-expert/120347-applications-nuclear-technology>

Complete summary about nuclear applications. Language : English, Spanish.

### Society and nuclear history

1. <http://nuclearsafety.gc.ca/eng/>

This web page published by the CNSC provides information about Canada’s nuclear history, including CNSC’s presidents, historical events, among others. In the same way new nuclear projects proposed in some Canadian communities are detailed. Publications by CNSC such as regulatory and licensing process documents for licensees, annual reports and information products can also be found. Language: English.

1. <http://www.nuclearscienceweek.org/get-involved/lessons_and_resources/>

Very interesting resources for teachers, classified by the level for which they are designed and by categories, including nuclear & society. It is about PDF documents and some of them include game or debate proposals. Language : English.

1. <https://www.niauk.org/wp-content/uploads/2017/08/nia_facts_170809web.pdf>

Recommended PDF document with a little bit of everything: nuclear history, benefits, what the public think, etc. Language: English.

1. <https://www.youtube.com/watch?v=ciStnd9Y2ak>

Opinion video of about 20 minutes entitled Why I changed my mind about nuclear power. Language: English (with subtitles option for Spanish, Portuguese or French).

1. http://www.wfsj.org/nuclear/

World Federation of Science Journalists web page with interesting information about nuclear history, controversies, stories of accidents, etc. Language: English.