ENERGY for the COMMON GOOD

PREPARING FOR A STAR POWERED FUTURE, TODAY.

Fusion energy has the potential to significantly alter the fight against climate change – but only if we take immediate action to support its development.

Fusion Energy 101

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Prepared by Tourmaline Group LLC for
exclusive use of Energy for the Common Good.

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Preparing the way for fusion energy, today

Who is Energy for the Common Good?

Energy for the Common Good is a not-for-profit organization that advocates for the use of zero carbon energy, in time to make a difference.

What is our fusion mission?

Energy for the Common Good (ECG) is building a voice for fusion energy with the existing climate and clean energy community. Our mission is to prepare leaders in energy, environmental regulation, and policy to be ready to implement safe, non-carbon innovations as soon as they are available. Through coalitions, forums, and small groups, we encourage evaluation of fusion's potential to replace our electric grid's fossil baseload; to find confidence in its waste footprint; and to see the many industrial applications available from the various device types and output ranges under development. Through education, communication, and strategic partnerships, ECG seeks to ensure demand for fusion energy as soon as the industry can deliver it.

Why is it important to support development of fusion energy?

Fusion energy has the potential to significantly alter the fight against climate change – but only if we immediately implement an accelerated and strategic roadmap to support the development, adoption, and expansion of this zero-carbon, energy dense, and efficient power source, now.

The Biden Administration has set a goal of transitioning the U.S. electricity sector out of fossil fuels by 2035 -- an immense undertaking requiring the replacement of 63% of current U.S. electricity generation with clean energy sources. The Administration has further announced its intent to reduce net greenhouse gas emissions in America to zero by 2050. Replacing fossil fuel generation in America and around the world, to stop global temperatures from continuing to rise, will require a diversity of noncarbon energy sources. NGOs, environmental advocates, conservation organizations, regulatory agencies, and government stakeholders all play a vital role in determining what sources of clean energy are developed.

The same fusion energy that powers our sun and all the stars can power humanity as well.

The energy dense, consistent power generation that fusion has the capacity to provide will be a critical partner in the growth of renewables. Through our communication and outreach efforts, ECG is working with stakeholders—regulators, investors, utilities, and public advocates alike—to build support for fusion and to ensure that the means for rapid development and deployment are created well before the first commercial fusion devices are built.

Our experiences in renewable energy policy, finance, and commercial project development have taught us that new technologies coming to a mature space require transparency, regulation, financial backing, and infrastructure as key predefined components.

ECG believes a climate educated consumer will support adding fusion to our energy mix.

We propose building market confidence in fusion by creating a shared vision of its roles, similar to the work that created the rapid adoption of renewable energy, such as wind and solar, and subsequent build up.

While the physicists and engineers build, Energy for the Common Good advocates.

What is fusion energy?

Fusion energy is the same kind of energy that fuels our sun, and all the stars in the universe. It is the energy that is released when two atoms are fused together during what is termed a "thermo-nuclear fusion reaction"[1]. It requires high temperatures to heat gases to a point where it joins two hydrogen atoms, thereby releasing energy.

It is clean, and naturally occurring in nature. We call it star power. The same fusion energy that powers the sun and all of our stars can power humanity as well.

Not the kind of nuclear you know about…

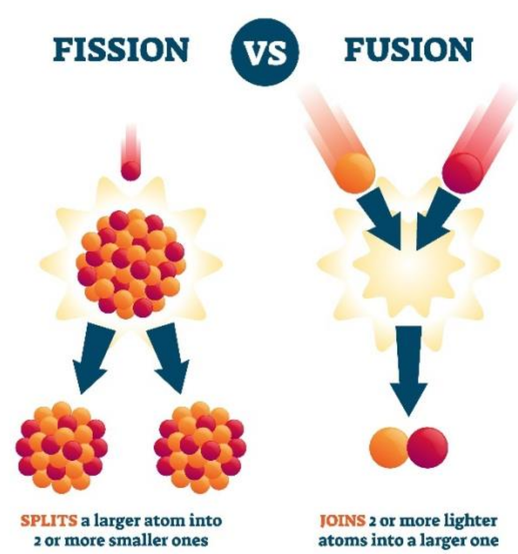
The word "nuclear" is turbo-charged with fear for many people. This is because, currently, we only have one type of nuclear technology, namely fission.

Fission is a process where one heavy weight atom is split into two smaller ones, thereby releasing energy. Typically the uranium atom is split, generating energy. Unfortunately, there are global security risks, and spent fuel storage considerations associated with fission.

Fusion, however, is a new and exciting clean source of energy – without security risks – that we can rely on to power a global human evolution.

Fusion is not the same as fission

Unlike the nuclear fission we have today which splits apart the heaviest weight atom (uranium or plutonium), fusion technology binds together two of the lightest weight atoms (hydrogen). While fusion is not yet commercially available, there are 14 plus private sector companies developing this technology today.

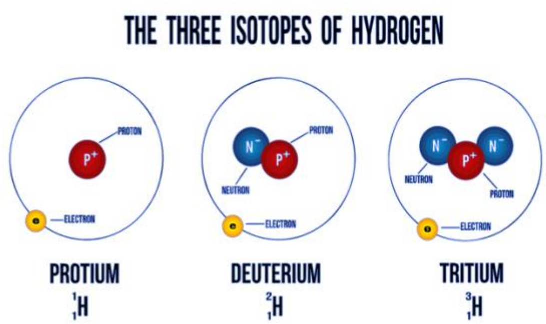


[1] We are not talking about cold fusion – that is for sci-fi novels.

Water is the primary feedstock for fusion (even sea water)

Fusion is powered by deuterium and tritium -- two types of heavier hydrogen isotopes.

Deuterium is found naturally in water – even seawater. Initially, tritium will have to be man-made, but fusion plants are being designed to generate tritium as part of normal operations[2].



- Deuterium has one neutron and a proton, and tritium has two neutrons and a proton.

- Deuterium can be taken from sea water.

- Tritium is produced naturally in the upper atmosphere of the Earth when cosmic rays interact with atmospheric gases. Unfortunately, we cannot capture the naturally occurring form. It can be made, however, in fission reactors.

Is tritium safe?

Tritium is a radioactive isotope. It has low energy, and its radiation is easy to shield from, but the concern is that because it is hydrogen, it can easily incorporate into bodily tissues. Whether it is dangerous to health would depend on the amount of exposure.

Its use in a fusion plant would require regulation to ensure its safety.

Technical background on tritium

Tritium is a radioactive hydrogen isotope with a 13-year half-life, which means that it loses half of its energy in 13 years.

There are of course safety considerations, but it is also important to keep these in perspective.

- Tritium's radioactivity is weak. It emits beta particles, which means it cannot pass through the skin surface.

- Wearing a tritium wrist watch will expose you to 0.06 mrem, and according to the EPA and the National Council on Radiation

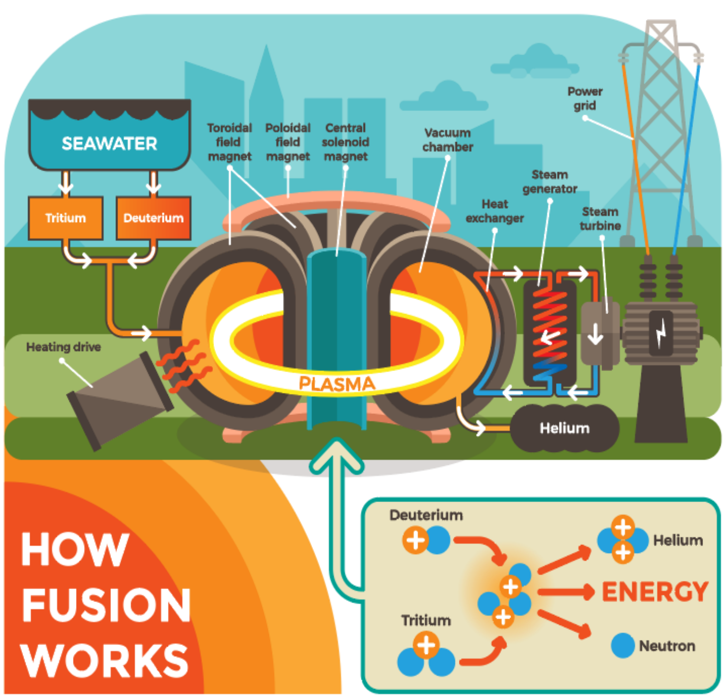
[2] Note that currently tritium cannot be sourced from fusion operations.

Protection and Measurements (NCRP), the average annual radiation dose per person in the U.S. is 620 mrem.

Potassium in bananas is also radioactive

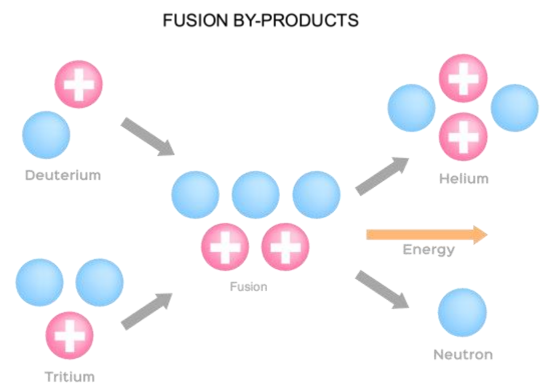
We are surrounded by radioactive substances we would never categorize as threatening. If you are curious, the EPA has an online calculator that estimates how much radioactivity you are exposed to annually based on your personal habits and where you live.

It is also interesting to know that potassium, a nutrient found in bananas among other things, is radioactive, and emits beta radiation and gamma rays.



What are the waste products of fusion energy technology?

The primary waste product, which would require appropriate oversight and regulation, are the structures from inside the device themselves. Currently, the best estimates are that every five to ten years these parts would need to be replaced.



The parts being disposed would need to be placed in a secure storage facility for 60 to 100 years, after which they could be recycled.

Other than parts replacement, helium is the primary waste from a fusion plant.

There are many devices being developed for fusion

The Tokamak is a widely used fusion device, but there are a variety of other devices being tested in private sector start-ups.

The term "tokamak" is a transliteration of a Russian acronym[3] which stands for "toroidal chamber with magnetic coils," or in very simple terms, a doughnut shaped magnetic chamber.

Inside the tokamak gases are heated to over a million degrees centigrade becoming a fusion generating plasma. The illustration in Figure 1 shows how deuterium is extracted from water and then fed into the tokamak where atoms are fused. The released energy heats water, which generates steam, turning the steam turbine and thereby generating electricity.

When was fusion discovered?

Nuclear fusion is not new nor invented: it is what powers our sun and all the stars in the universe. Scientists today are trying to emulate that natural process.

This naturally occurring process was first hypothesized about in 1926. A timeline of significant dates are listed below.

1926: British astrophysicist Arthur Eddington publishes a theory stating that the fusion of helium and hydrogen created star energy.

1934: Mark Oliphant, a student of physicist Ernest Rutherford discovers tritium. Physicist Ernest Rutherford fuses deuterium into helium, creating fusion in a lab setting for the first time.

1938: Hans Bethe (Nobel Prize, n.d.) proves that fusion is the source of energy from stars by fusing hydrogen nuclei with helium nuclei.

1950-1951: Andrei Sakharov and Igor Tamm create the design for the tokamak.

1973-1983: Joint European Torus (JET) the largest operational magnetic confinement plasma physics experiment was designed and constructed. JET was a success, achieving the first plasmas within the given time and budget confinements.

1985: The Geneva Superpower Summit leads to the formation of ITER, an international collaboration to develop fusion energy. "Iter" stands for "the way" in Latin, and its founding members were China, the European Union, India, Japan, Korea, Russia and the United States. ITER is now the largest fusion experiment in the world, functioning as a collaborative of 35 nations.

Where does fusion technology stand today?

Fusion suffered fits and starts since the 1980's, lacking robust funding. Funding from both public and private sources have increased, and **Energy for the Common**

[3] то(роида́льная) ка́(мера) (с) ма(гни́тными) к(ату́шками)

Good believes either a public or private company will be able to start supplying electricity to the grid by 2030.

Fusion has made considerable advancement over the last decade. It is now at the point where energy output is equal to energy input. The technology needs improvement, but the battle has almost been won.

According to Bloomberg NEF (Gadomski, 2019):

- $1.2 billion in cumulative investments have been made into commercial fusion as of December 2019
- There are 14 venture capital funded companies developing fusion technology[4].

March of this year heralded three significant developments:

- National Academies of Science, Engineering and Medicine published a consensus study report titled *Bringing Fusion to the U.S. Grid*.
- Congressman Beyer launched a fusion bi-partisan fusion caucus in the House of Representatives, an effort facilitated by Energy for the Common Good.
- A private company, Commonwealth Fusion announced a site for its commercial fusion campus, where they plan to construct SPARC, a demonstration device to expected to produce net energy by mid-decade. Expectations are that they will be able to supply the U.S. grid by 2030.

Fusion & Social Justice

As we stated earlier, toxic waste is too often disposed of in areas with economically vulnerable populations and people of color.

Proper regulation and safety protocols will be paramount to operating a fusion plant, and ECG will always advocate for the concerns of the local communities to be heard. While we do not yet have a concrete plant proposal to review, some of the characteristics we believe will find endorsements are:

- The feedstock is water -- in fact, it can even be sea water.
- The size of the plant may vary, but ECG believes its physical footprint will not be larger than typical suburban high school.

[4] A list of companies developing fusion devices is available in Appendix I.

- The operation of the plant requires a range of technical skills at all levels of the educational system from union electric grid workers, up to PhD physicists – which may be a contributor to local job growth.

A bureaucratic emergency

It is an oxymoron, but we have an emergency in the lethargic, slow-paced regulatory oversight we affectionately call "bureaucracy."

As it stands today, fusion energy is being lumped in with fission with regards to oversight and regulation. Specifically, fusion is currently under legal statutes 10 CFR Part 20 and Part 30 to regulate health safety during the development phase of the technology.

However, as explained, fusion is not fission, and different regulation should be in place for the commercialization of the technology.

What's the problem?

Fusion is fundamentally different from fission –and therefore does not have the inherent radiation and proliferation risks posed by fission.

As engineers develop this technology, their efforts will be informed by regulatory mandates. Where these regulations do not address the risks of fusion, or impose limitations that are irrelevant, delays or stagnation can develop.

New regulation, commensurate with the health and safety risks of fusion is needed.

Fusion appropriate regulation

It is important that fusion is regulated thoughtfully, at a level commensurate with the risks that it poses.

The NRC (Nuclear Regulatory Commission) is charged with regulating fission and fusion. They are currently being asked to provide draft regulation for fusion development by the end of this year.

There is a concern in the fusion industry that the bulk of the proposed regulation will be being based on advanced fission.

Regulatory code will dictate what the new technology can and cannot do. The lack of a clearly defined regulatory scheme means these pre-commercial devices may require significant alterations after the code is released, which could be costly and inefficient.

The founders of Energy for the Common Good have been involved in advocating for green/clean energy technology since the 1980s. We have seen the hurdles that photovoltaic technology, and wind faced, and while the specifics may be different the essence of the problem is lack of familiarity, which leads to applying existing regs to completely new technology.

We cannot allow the same to happen with fusion.

Conclusion

Electricity produced by renewables is often capped[5] due to its inherent intermittency problem -- meaning when there is no wind or sun, there is no electricity[6]. New fusion energy technology has the capacity to solve the intermittency problem, enabling the US and the planet to reach carbon neutral energy targets in time to make a difference. Moreover, it can do so safely, without the dangers posed by nuclear fission.

Fusion technology has been under development since the 1970's and is now approaching the last 10 year stretch to reach market. This means that regulatory matters need to be carefully considered *now*, in advance of its arrival on the grid.

Waiting could mean that fusion dies before it is born. The nascent fusion industry needs regulation appropriate to its risks. If it is compromised by irrelevant regulation related to the fission industry, it could render the industry financially inviable.

It is critical that investors, policy makers, and clean energy advocacy groups are not only aware of its existence, but that they also understand the risks, benefits and action needed to ensure fusion becomes a reality.

[5] EIA's World Energy Projection System caps variable renewable energy sources at 65% -- See Section 3.4.

[6] Batteries are possible, but storage capacity is still limited. Applies to solar and wind. Hydropower is not intermittent, but can be affected by drought.

Appendix I – Companies currently developing fusion technology

Company Name	Type of Device	Bloomberg Investment Estimate (M)*	
Commonwealth Fusion	Tokamak	$	115
CTFusion	Steady state magnetic fusion	$	3
First Light Fusion	Intertial confinement	$	31
Fusion Energy Solutions of Hawaii	Velocity impact fusion		
General Fusion	Magnetically targeted fusion	$	200
Helion	Magneto-Intertial fusion	$	12
Hyperjet Fusion	Plasma jet driven magneto inertial fusion	$	2
Lawrenceville Plasma Physics	Focus fusion	$	7
Lockheed Martin	Magnetically-confined plasma	$	10
Princeton Fusion Systems	Field-reversed-configuration plasma	$	1
Proton Scientific	Inertial confinement	$	5
TAE Technologies	Self-confining plasma	$	700
Tokamak Energy	Spherical tokamak	$	65
Zap Energy	Z-pinch fusion	$	14
Source: BloombergNEF, Energy for the Common Good			
* Investment estimates are as of December 2019			

Appendix II – Summary of differences between fission and fusion

	FUSION	FISSION
Type of reaction	Fuses two light weight atoms into a heavier one.	Splits one heavy weight atom into two lighter ones.
Feedstock	Deuterium and Tritium (Water)	Uranium
Waste products	Helium	Radioactive materials
Other by-products	Radioactive parts that decay over 60 -100 years	Weaponized plutonium, radioactive waste that decays over thousands of years.
Must waste products be stored in secure facilities?	Not waste, but device parts yes	Yes
Possible to weaponize?	No	Yes
Safety	Safety protocols similar to current energy production	Nuclear safety protocols. Anti-proliferation agreements needed.
Energy input	Requires tremendous energy to fuse two light weight, stable, nuclei	Requires small amount of energy to split an unstable, heavy weight, nucleus
Energy output	3 - 4x greater than fission	Millions of times greater than combustion
Source: Bloomberg NEF, Energy for the Common Good		

Works Cited

Administration, U. E. (n.d.). Appendix A: British Thermal Units Conversion Factors. Washington DC.

Carbon Brief. (2019). *Carbonbrief.org.* Retrieved March 2, 2021, from https://www.carbonbrief.org/mapped-worlds-coal-power-plants.

Environmental Protection Agency. (2021, March). *Radiation Basics*. Retrieved from https://www.epa.gov/radiation/radiation-basics

EUROFusion. (n.d.). *Realizing Fusion Electricity*. Retrieved from https://www.euro-fusion.org/fusion/history-of-fusion/

Gadomski, C. (2019, December 19). Chasing Disruption With the Promise of Fusion. *Bloomberg NEF*.

ITER. (2021, March). *What is ITER?* Retrieved from https://www.iter.org/proj/inafewlines#1

Nobel Prize. (n.d.). *The Nobel Prize in Physics 1967*. Retrieved from Hans Albrecht Bethe: https://www.nobelprize.org/prizes/physics/1967/bethe/facts/

PhD, J. S. (2018, March 15). *McGill University Office of Science and Society* . Retrieved from Is it true that bananas are radioactive?: https://www.mcgill.ca/oss/article/you-asked/it-true-banana-radioactive

Roma, A. C., & Desai, S. S. (n.d.). *The Regulation of Fusion – A Practical and Innovation-Friendly Approach.* Washington, DC: Hogan Lovells.

Tirman, S. (2019). The 8 Best Tritium Watches. *HiConsumption*, https://hiconsumption.com/best-tritium-watches/. Retrieved from https://hiconsumption.com/best-tritium-watches/

US Energy Information Administration. (2020). *World Energy Projection System (WEPS): Electricity Model.* Retrieved March 2, 2021, from https://www.eia.gov/analysis/handbook/pdf/weps2020_electricity.pdf.

US Energy Information Administration. (n.d.). Energy Conversion Calculators. Washington DC.

US Environmental Protection Agency. (2002). Retrieved from EPA Facts About Tritium: https://www.nrc.gov/docs/ML0609/ML060960589.pdf

US Environmental Protection Agency. (2021, March). *Radiation Basics*. Retrieved from https://www.epa.gov/radiation/radiation-basics

US Environmental Protection Agency. (2021, March). *Radiation Dose Calculator*. Retrieved from Calculate Your Radiation Dose: https://www.epa.gov/radiation/calculate-your-radiation-dose

US Environmental Protection Agency. (2021, March). *Tritium in Exit Signs*. Retrieved from https://www.epa.gov/radtown/tritium-exit-signs

US Environmental Protection Agency. (2021, March). *What kinds of consumer products contain radioactive materials?* Retrieved from https://www.epa.gov/radiation/what-kinds-consumer-products-contain-radioactive-materials

World Nuclear Association. (2018, December). Plutonium. London.