Reference Keys:	
(Note: This video contains a very large amount of data. I did my upmost to verify and double-check, but nobody's perfect, and I missed a few things (hence the error key). So I'm grateful for corrections	
[1]	Note: This means there's a comment adding additional information or pointing out a point of interest in order to flesh out the point being made in the video, or for an interesting fact that didn't work in the video
[2]	Context: The fact in the video isn't wrong - but it'd be a disservice to not provide additional context for clarity sake
[3]	Error: The thing I said was wrong and not caught in time; or was wrong and removed but created a video glitch (like a reference miscount)

Ref. Number	Quote	Time Stamp	"You can't possibly expect me to eat this dry!" (Sauce)	Link (if available)	Additional Sauces/POIs and Links (if available)
1 [4]	"According to the official Soviet count..."	0:00:25	IAEA Chernobyl FAQs (Accessed 2021)	https://www.iaea.org/newscenter/focus/chernobyl/faqs	https://www.chernobyltissuebank.com/useful-links
				https://www.oecd-nea.org/jcms/pl_13598/chernobyl-assessment-of-radiological-and-health-impacts-2002?details=true	UNSCEAR (1988) Sources, Effects and Risks of Ionizing Radiation (https://www.unscear.org/docs/publications/1988/UNSCEAR_1988_Report.pdf)
2	"Well, in 2005, the UN released a report ..."	0:00:40	UN Meetings Coverage & Press Releases (2005) Chernobyl: The True Scale of the Accident - Press Release	https://www.un.org/press/en/2005/dev2539.doc.htm	
[5]	"But according to the International Atomic Energy Agency..."	0:07:26	The Chernobyl Forum (2005) Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts.	https://www.iaea.org/sites/default/files/chernobyl.pdf	IAEA (1996) Documentación Relativa Al Accidente De Chernobil Presentada Por Belarus; INFCIRC/511 (https://www.iaea.org/sites/default/files/infcirc511_sp.pdf)
	"Some studies take only the nearby countries into account..."	0:09:12	The Chernobyl Forum (2005) Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts.	https://www.iaea.org/sites/default/files/chernobyl.pdf	WHO (2006) Health effects of the Chernobyl accident and special health care programmes
	"So the UN reports concerned themselves with the 3 Soviet Republics..."	0:09:18	The Chernobyl Forum (2005) Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts.	https://www.iaea.org/sites/default/files/chernobyl.pdf	WHO (2006) Health effects of the Chernobyl accident and special health care programmes
	"By the mid 1990s, 5% of the Ukrainian budget was allocated to fund projects dealing with the consequences of the Chernobyl accident..."	0:48:30	The Chernobyl Forum (2005) Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts.	https://www.iaea.org/sites/default/files/chernobyl.pdf	
	"In 1991, Belarus spent 22.3% of its budget on Chernobyl aid..."	0:48:45	The Chernobyl Forum (2005) Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts.	https://www.iaea.org/sites/default/files/chernobyl.pdf	
	"The report argues: 'Persistent myths..."	1:17:03	UN Meetings Coverage & Press Releases (2005) Chernobyl: The True Scale of the Accident - Press Release	https://www.un.org/press/en/2005/dev2539.doc.htm	
	"It isn't helped by the fact that the WHO report was..."	1:25:15	The Chernobyl Forum (2005) Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts.	https://www.iaea.org/sites/default/files/chernobyl.pdf	
3	"In 2006, the UN updated their number..."	0:00:51	Science Alert (Accessed 2021) Chernobyl	https://www.sciencealert.com/chernobyl	The Sixth Carbon Budget and Welsh emissions targets (2020) Call for Evidence, Page 8, Question 30 (https://www.theccc.org.uk/wp-content/uploads/2020/07/Joan-Pye-Project-response-The-Sixth-Carbon-Budget-and-Welsh-emissions-targets-Call-for-Evidence.pdf)
					Imperial College London (2020) Professor Gerry Thomas; Why We Shouldn't Fear Radiation (https://www.youtube.com/watch?v=agzrhxZD5kc)
					How many deaths did the Chernobyl and Fukushima nuclear disaster cause? (https://hci.iwr.uni-heidelberg.de/system/files/private/downloads/1880071462/raphael-hirsch_chernobyl-fukushima.pdf)
					UNSCEAR (2006) Volume II: (https://www.unscear.org/docs/publications/2006/UNSCEAR_2006_Report_Vol.II.pdf)
4	"I know Kurzgesagt did a video on this..."	0:02:18	Kurzgesagt (2021) Worst Nuclear Accidents in History	https://www.youtube.com/watch?v=Jzfpyo-q-RM	
5	"The 2005 World Health Organisation projected death rate..."	0:03:17	WHO (2006) Health effects of the Chernobyl accident and special health care programmes - Chapter 7; Table 12	https://www.who.int/publications/i/item/9241594179	
	"Some studies take only the nearby countries into account..."	0:09:12	WHO (2006) Health effects of the Chernobyl accident and special health care programmes	https://www.who.int/publications/i/item/9241594179	UNSCEAR (2000) Volume II, Annex J, p453
	"So the UN reports concerned themselves with the 3 Soviet Republics..."	0:09:18	WHO (2006) Health effects of the Chernobyl accident and special health care programmes	https://www.who.int/publications/i/item/9241594179	UNSCEAR (2000) Volume II, Annex J, p454
[6]	"That means that if there are long term impacts as a result of Chernobyl, its too early to make a call one way or the other. ..."	0:24:18	WHO (2006) Health effects of the Chernobyl accident and special health care programmes	https://www.who.int/publications/i/item/9241594179	WHO (2016) 1986-2016: Chernobyl at 30 (https://cdn.who.int/media/docs/default-source/documents/publications/1986-2016-chernobyl-at-30476d83ab-985d-416f-b936-576b0c0ca17f.pdf?sfvrsn=434dbe67_1&download=true)
6	"Estimates from the International Journal of Cancer..."	0:03:22	Cardis et. al (2006) Estimates of the cancer burden in Europe from radioactive fallout from the Chernobyl accident; International Journal of Cancer	https://onlinelibrary.wiley.com/doi/10.1002/ijc.22037	
	"...and most of the studies aren't actually able to because of limitations in their methodologies. ..."	0:24:13	Cardis et. al (2006) Estimates of the cancer burden in Europe from radioactive fallout from the Chernobyl accident; International Journal of Cancer	https://onlinelibrary.wiley.com/doi/10.1002/ijc.22037	
7	"The Union of Concerned Scientists estimated..."	0:03:27	Gronlund (2011) How Many Cancers Did Chernobyl Really Cause? - Updated Version	https://allthingsnuclear.org/lgronlund/how-many-cancers-did-chernobyl-really-cause-updated/	
	"The Union of Concerned Scientists reasoned that since the impacts of Chernobyl affected the entire northern hemisphere..."	0:09:30	Gronlund (2011) How Many Cancers Did Chernobyl Really Cause? - Updated Version	https://allthingsnuclear.org/lgronlund/how-many-cancers-did-chernobyl-really-cause-updated/	
8	"The Ukrainian NRCRM says..."	0:03:32	Sushko et. al. (2018) Problems Of Medical Expertise For Diseases That Bring To Disability And Death As A Result Of Radiation Exposure Influence In Conditions Of The Chernobyl Catastrophe In Remote Postaccidental Period; Problems of radiation medicine and radiobiology	http://radiationproblems.org.ua/23_2018/NRCRM_2018_Paper_32.pdf	NRCRM (2017) Health Effects of Chernobyl Thirty Years Aftermath (https://web.archive.org/web/20190730070943/http://nrcrm.gov.ua/downloads/2017/monograph_last.pdf)
HELLO! THERE SHOULD BE A REFERENCE 9 HERE. The reason there isn't is because I made an error. I originally said that the OECD had a projected death toll in its countries of 23,000. The 23,000 number comes from Dr Ian Farilie and was calculated by applying the LNT projection model to the collective doses recorded by the OECD in this report (https://www.oecd-nea.org/upload/docs/application/pdf/2020-09/the_radiological_impact_of_the_chernobyl_accident_in_oecd_countries.pdf). The OECD never cited this number. It wasn't an official OECD number. I didn't catch that error until too late in the process and had to cut it out. I fucked up, and I'm sorry :(					
10	"A report commissioned by European Green groups..."	0:03:45	Farilie et. al. (2006) The Other Report On Chernobyl (TORCH); Greens/EFA in the European Parliament	http://www.chernobylreport.org/torch.pdf	
11	"They updated this in 2016..."	0:04:00	Farilie (2016) TORCH-2016: An Independent Scientific Evaluation of the health-related effects of the Chernobyl Disaster	https://www.global2000.at/sites/global/files/GLOBAL_TORCH%202016_rz_WEB_KORR.pdf	
12		0:04:15	Greenpeace (2006) The Chernobyl Catastrophe: Consequences on Human Health	https://wayback.archive-it.org/9650/20200406055927/http://p3-raw.greenpeace.org/international/Global/international/planet-2/report/2006/4/chernobylhealthreport.pdf	
13	"One very controversial report by Yablokov..."	0:04:21	Yablokov et. al. (2009) Chernobyl: Consequences of the Catastrophe for People and the Environment; Annals of the New York Academy of Sciences	https://archive.org/details/YablokovChernobylBook/page/n9/mode/2up?view=theater	
	"The Yablokov book from earlier..."	0:51:25	Yablokov et. al. (2009) Chernobyl: Consequences of the Catastrophe for People and the Environment; Annals of the New York Academy of Sciences	https://archive.org/details/YablokovChernobylBook/page/n9/mode/2up?view=theater	
14	"Our best data on what radiation exposure does to a person..."	0:05:14	Normile (2020) Aftermath: By allowing scientists to study their suffering, atomic bomb survivors have transformed our understanding of radiation's health effects; Science	https://www.science.org/content/article/how-atomic-bomb-survivors-have-transformed-our-understanding-radiation-s-impacts	Douple et. al. (2011) Long-term Radiation-Related Health Effects in a Unique Human Population: Lessons Learned from the Atomic Bomb Survivors of Hiroshima and Nagasaki; Disaster Med Public Health Prep (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3907953/)
15	"In the book Radium Girls..."	0:05:26	Kate Moore (2017) The Radium Girls: The Dark Story of America's Shining Women. Sourcebooks	https://www.kate-moore.com/the-radium-girls	
16	"According to the main, parental All-Union Distribution Register..."	0:06:53	Ilyin, L (1995) Chernobyl: myth and reality.; Megalopolis	https://www.abebooks.co.uk/first-edition/Chernobyl-Myth-Reality-Ilyin-L-A/22768958352/bd	Belyakov et. al.(2000) Chernobyl Liquidators. The People and the Doses; IRPA-10: 10. International Congress of the International Radiation Protection Association (https://www.irpa.net/irpa10/cdrom/00666.pdf)
17	"The report from the Russian National Medical Dosimetric Registry..."	0:06:57	Belyakov et. al.(2000) Chernobyl Liquidators. The People and the Doses; IRPA-10: 10. International Congress of the International Radiation Protection Association	https://www.irpa.net/irpa10/cdrom/00666.pdf	Belyakov et. al.(2000) Chernobyl Liquidators. The People and the Doses; IRPA-10: 10. International Congress of the International Radiation Protection Association (https://www.irpa.net/irpa10/cdrom/00666.pdf)
			Liktarev & Chumak (1995) Overview of the Chernobyl liquidator database. In: 44th Annual Meeting of the Radiation Research Society		IAEA/Tysb et. al. (1988) Preparation of an all-union distribution register of persons exposed to the effects of radiation as a result of the Chernobyl accident, with a view to evaluating exposure doses and making a long term public health forecast (https://inis.iaea.org/collection/NCLCollectionStore/_Public/20/075/20075974.pdf?r=1)
18	"The United Nations Scientific Committee on the Effects of Atomic Radiation..."	0:07:28	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"More than 5 million people..."	0:08:11	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"Of the latter about 116 000 living in the 30 km "exclusion zone"..."	0:08:24	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
[7]	"UNSCEAR analyses liquidators, evacuees..."	0:08:45	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"...AND the whole European continent..."	0:08:49	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"Due to the long-term nature of some forms of radiation..."	0:10:24	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"Chernobyl radiation is still detectable in much of the former Soviet Republics agricultural supply chain..."	0:10:26	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"The nature of the soil meant radionuclides could easily diffuse into plants which grow in the soil...."	0:10:59	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"The soil in the Ukraine still holds onto a lot of this residual radiation..."	0:11:07	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"...that continues to find its way into food supply chains..."	0:11:09	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"Radioactive isotopes of Caesium and Strontium are still higher..."	0:11:13	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"Particularly North Wales..."	0:11:43	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"The temporary permissible levels within the Soviet bloc were far hgiher..."	0:13:03	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	санитарный врач СССР П.Н.Бургасов (1986) Временные допустимые содержания радиоактивного йода-131 в питьевой воде и пищевых продуктах на период ликвидации последствий аварий [Chief state sanitary doctor of the USSR P. N. Burgasov (1986) Temporary permissible contents of radioactive iodine-131 in drinking water and food products for the period of liquidation of consequences of accidents (https://www.myslenedrevo.com.ua/uk/Sci/HistSources/Chornobyl/1986/05/07/VremennyeDopustimye.html)
	"In the immediate aftermath of the disaster..."	0:13:25	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"...which meant milk from private farms were allowed to enter the food chain with radiocaesium levels far higher than those allowed..."	0:13:39	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"These limits were maintained until the collapse of the Soviet Union before being reduced..."	0:13:45	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"Increased radiation for most of the exposed populations..."	0:15:13	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"There is no clear observable evidence to date that this has increased the incidence of cancers..."	0:15:18	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"The UNSCEAR report argues the amount of radiation people were exposed to may have been overestimated..."	0:15:37	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"Because of these huge uncertainties, it's virtually impossible to assess the ultimate death toll..."	0:20:10	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"Which is why the UNSCEAR report said: The present understanding of the late effects of protracted exposure..."	0:21:04	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"UNSCEAR went on to clarify: The Committee has decided not to use models to project absolute numbers of effects in populations..."	0:21:29	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"Apart from the large increase in thyroid cancer incidence in young people..."	0:23:27	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"no clearly demonstrated radiation-related increases in cancer risk..."	0:23:32	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"For many, many people - their radiation dosage was so low, it might be impossible to tease out carcinogenic effects..."	0:23:37	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"...the fact that no other radiation-related health effect has yet been clearly demonstrated does not mean that no increase has occurred..."	0:23:47	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"There was no continuity, and no overarching panel looking at how science should be done...."	0:25:51	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
	"Because of the inconsistencies of state responses...."	0:26:03	UNSCEAR (2008) Report Vol. II Annex D - Health effects due to radiation from the Chernobyl accident	https://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf	
19	"Ukraine has an entirely independent registry..."	0:07:42	NRCRM (2017) Health Effects of Chernobyl Thirty Years Aftermath	https://web.archive.org/web/20190730070943/http://nrcrm.gov.ua/downloads/2017/monograph_last.pdf	
20	"The number the International Atomic Energy Agency uses for Belarusian liquidators..."	0:07:49	Kotava et. al. (2012) Creation and development of the State Registry of persons exposed to radiation as a result of the Chernobyl accident and other radiological emergencies in the Republic of Belarus; Prog Health Sci	https://www.umb.edu.pl/photo/pliki/progress-file/phs/phs_2012_2/7-11_kotava.pdf	Sosnouskaya et. al. (2008) Creation of the Uniform Chernobyl register of Russia and Belarus; International Congress of the International Radiation Protection Association (https://inis.iaea.org/collection/NCLCollectionStore/_Public/43/032/43032722.pdf)
					Belarussian Ministry of Health (1997) Public Health in the Republic of Belarus. An Official Statistics Collection //
21	"But the World Bank uses victim numbers established by Belarusian Law..."	0:07:55	World Bank (2002) Belarus: Chernobyl Review	https://openknowledge.worldbank.org/handle/10986/15332	Decree of Council of Ministers of Republic of Belarus No. 283 of 5 May 1993 "About creation of the Belarussian state register of the persons who have undergone to influence of radiation owing to accident on Chernobyl atomic power station;
	"In their 2002 report on Belarus' Chernobyl Programs, the World Bank was critical of Belarus..."	1:17:53	World Bank (2002) Belarus: Chernobyl Review	https://openknowledge.worldbank.org/handle/10986/15333	Article No. 63 of the Law of Republic of Belarus "About Social Protection Of Citizens Affected By Chernobyl APS Catastrophe"
22	"The Belarusian Ministry of Health recorded ..."	0:08:04	Scribner (2008) Recreation Of Chernobyl Trauma In Svetlana Aleksiyevich's Chernobyl'skaya Molitva; University of Missouri-Columbia	https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/5713/research.pdf?sequence=3	
23	"Among them about 400 000 in the area of 'strict radiation control'..."	0:08:17	Balonov et. al. (2011) Encyclopedia of Environmental Health Vol. V; Radiation Exposures Due to the Chernobyl Accident	https://www.sciencedirect.com/science/article/pii/B9780124095489020157	Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts. The Chernobyl Forum 2003 - 2005
					Soviet Life; Economic and Social Council of the United Nations (1990) Economic and Social Consequences of the Chernobyl Accident (http://soviethistory.msu.edu/1985-2/meltdown-in-chernobyl/meltdown-in-chernobyl-texts/economic-and-social-consequences-of-the-chernobyl-accident/)
24	"Basically, the EU is hungry for berries..."	0:09:50	CBI (2021) The European market potential for fresh blueberries	https://www.cbi.eu/market-information/fresh-fruit-vegetables/blueberries/market-potential	
25	"Women in the Polesia region of Ukraine..."	0:10:00	Brown and Martynyuk (2016) The harvests of Chernobyl; Aeon	https://aeon.co/essays/ukraine-s-berry-pickers-are-reaping-a-radioactive-bounty?utm_source=Aeon+Newsletter&utm_campaign=2cf3c8862f-EMAIL_CAMPAIGN_2016_11_29&utm_medium=email&utm_term=0_411a82e59d-2cf3c8862f-69376553	
26	"Chernobyl radiation is still detectable in much of the former Soviet Republics agricultural supply chain..."	0:10:26	Labunska et. al. (2018) Current radiological situation in areas of Ukraine contaminated by the Chornobyl accident: Part 2. Strontium-90 transfer to culinary grains and forest woods from soils of Ivankiv district. Environment International	https://www.sciencedirect.com/science/article/pii/S0160412020322376	Smith et. al. (2000) Chernobyl's legacy in food and water; Nature (https://www.nature.com/articles/35012139)
	"...that continues to find its way into food supply chains..."	0:11:11	Labunska et. al. (2018) Current radiological situation in areas of Ukraine contaminated by the Chornobyl accident: Part 2. Strontium-90 transfer to culinary grains and forest woods from soils of Ivankiv district. Environment International	https://www.sciencedirect.com/science/article/pii/S0160412020322376	Smith et. al (2005) Chernobyl: Catastrophe and Consequences Chapter 3: Radioactivity in terrestrial ecosystems (https://link.springer.com/chapter/10.1007/3-540-28079-0_3)
[8]	"Research in the Rivne communities of Northern Ukraine..."	0:11:22	Labunska et. al (2018) Current radiological situation in areas of Ukraine contaminated by the Chornobyl accident: Part 1. Human dietary exposure to Caesium-137 and possible mitigation measures; Environment International	https://www.sciencedirect.com/science/article/pii/S0160412017321542	Smith et. al. (1999) Temporal Change in Fallout 137Cs in Terrestrial and Aquatic Systems: A Whole Ecosystem Approach; Env. Sci. Tech (https://pubs.acs.org/doi/abs/10.1021/es980670t)
27	"The Northern regions of Ukraine are dominated by Histosols..."	0:10:42	DeSa (2018) Investing In Ukraine: Will Fortune Favor The Bold?; GAI Gazzette	https://www.globalaginvesting.com/investing-ukraine-will-fortune-favor-bold/	Baliuk et. al. (2017) Ukrainian chernozems as a factor in global food security and resilience of agriculture to climate change; Global Synopsium on soil organic carbon (https://www.researchgate.net/publication/316689831_Ukrainian_chernozems_as_a_factor_in_global_food_security_and_resilience_of_agriculture_to_climate_change)
28	"Chernobyl kicked up a lot of dust and radioactive debris into the atmosphere..."	0:10:49	IRSN (2005) The Chernobyl Plume : Modelling atmospheric dispersion of caesium-137 across Europe following the Chernobyl accident	https://www.irsn.fr/EN/publications/thematic-safety/chernobyl/Pages/The-Chernobyl-Plume.aspx	https://www.youtube.com/watch?v=mqu_I29WioM
29	"They get into cows and sheep, and their milk and meat enters the market...."	0:11:04	Rai & Kawabati (2020) The Dynamics of Radio-Cesium in Soils and Mechanism of Cesium Uptake Into Higher Plants: Newly Elucidated Mechanism of Cesium Uptake Into Rice Plants; Frontiers in Plant Science	https://www.frontiersin.org/articles/10.3389/fpls.2020.00528/full	IAEA (2006) Classification of soil systems on the basis of transfer factors of radionuclides from soil to reference plants; Proceedings of a final research coordination meeting organized by the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture (https://www-pub.iaea.org/MTCD/Publications/PDF/te_1497_web.pdf)
30	"In the UK, to stop potentially irradiated foods entering the supply chain..."	0:11:36	Hickman (2009) Sheep farmers still stuck under a Chernobyl cloud; Guardian	https://www.theguardian.com/uk/2009/dec/29/sheep-farmers-chernobyl-meat-restricted	UNSCEAR (2008) Sources and Effects of Ionising Radiation; Figure XI. Surface ground deposition of caesium-137 released in Europe after the Chernobyl accident (https://www.unscear.org/docs/JfigXI.pdf)
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246	"Scientists knew about the RBMKs positive void coefficient. They knew way back in 1973..."	1:38:26	IAEA (1992) The Chernobyl Accident: Updating of INSAG-1 - INSAG-7: A report by the International Nuclear Safety Advisory Group	https://www-pub.iaea.org/MTCD/publications/PDF/Pub913e_web.pdf	
	"They knew that pushing the AZ-5 when the Leningrad reactor ran out of control in 1975 caused a partial meltdown..."	1:38:40	IAEA (1992) The Chernobyl Accident: Updating of INSAG-1 - INSAG-7: A report by the International Nuclear Safety Advisory Group	https://www-pub.iaea.org/MTCD/publications/PDF/Pub913e_web.pdf	Abakumov (2012) Анализ причин и обстоятельств аварии 1975 года на 1-м блоке ЛАЭС (комментарий инженера-физика, участника и очевидца событий) [Analysis of the Causes and Circumstances of the 1975 Accident at the Leningrad NPP Unit 1 (commentary by a physicist, participant and eyewitness of the event)] (http://accident.ru/Accid75.html)
	"The Ministry of Medium Machine Building suppressed the research... Just one day after the partial meltdown in Leningrad..."	1:39:23	IAEA (1992) The Chernobyl Accident: Updating of INSAG-1 - INSAG-7: A report by the International Nuclear Safety Advisory Group	https://www-pub.iaea.org/MTCD/publications/PDF/Pub913e_web.pdf	
NB			Доллежаль, Ю. Корякин (1979) «Атомная энергетика: достижения и проблемы», Коммунист [Dollezhal & Koriakin (1979) Nuclear Energy: Achievements and Problems; Communist] Republished in Problems in Economics	https://www.tandfonline.com/doi/abs/10.2753/PET1061-199123023	Александров (1979) Научно-технический прогресс и атомная энергетика; Проблемы мира и социализма [Alexandrov (1979) Scientific and technical progress and nuclear energy; Problems of peace and socialism] (http://elib.biblioatom.ru/text/aleksandrov_sobranie-trudov_t4_2014/go,84/)
					Curtis (1992) Pandora's Box: A Fable From the Age of Science -- E6: A is for Atom; BBC
	"In 1980, the Research and Development Institute of Power Engineering (NIKIET) conducted a study that listed nine major failings in the RBMK design..."	1:39:50	IAEA (1992) The Chernobyl Accident: Updating of INSAG-1 - INSAG-7: A report by the International Nuclear Safety Advisory Group	https://www-pub.iaea.org/MTCD/publications/PDF/Pub913e_web.pdf	
247	"They knew the RBMK emergency shutdown button - the AZ-5 - wasn't designed to bring the reactor's operation to an abrupt stop..."	1:38:35	Center for Research into the Liberation Movement (TsDVR) (1987) Intelligence Message on the Chernobyl Accident; History and Public Policy Program Digital Archive, HDA SBU, f. 11, spr. 992, t. 30	https://digitalarchive.wilsoncenter.org/document/134311.pdf?v=734c6d2166feae2dfe0dc7d6b0a319d7	
	"They knew the reactor was unwieldy..."		Diamond (1986) Design Flaws, Known To Moscow, Called Major Factor At Chernobyl; New York Times	https://www.nytimes.com/1986/08/26/world/design-flaws-known-to-moscow-called-major-factor-at-chernobyl.html	
	"They knew the RBMK had insufficient protective systems..."	1:38:48	Center for Research into the Liberation Movement (TsDVR) (1987) Intelligence Message on the Chernobyl Accident; History and Public Policy Program Digital Archive, HDA SBU, f. 11, spr. 992, t. 30	https://digitalarchive.wilsoncenter.org/document/134311.pdf?v=734c6d2166feae2dfe0dc7d6b0a319d7	The Chernobyl Dossier of the KGB: From Construction to the Accident: October 16, 1981
248	"They knew the lack of a containment dome was an issue..."	1:38:51	Center for Research into the Liberation Movement (TsDVR) (1984) "Report from Colonel M.A. Turko, Director of the 6th Department of the KGB Administration, to the Director of the Pripyat City Department of the Ukr. SSR KGB Administration for the City of Kiev and Kiev Oblast, Lieutenant Colonel Comrade Iu. V	https://digitalarchive.wilsoncenter.org/document/134295.pdf?v=f12118e320b231b6785ae693c546c6b5	
249 [62]	"The Water Water reactors were slow to build..."	1:38:58	Potter (1990) Soviet Decision Making For Chernobyl: An Analysis Of System Performance And Policy Change; National Council For Soviet And East European Research	https://www.ucis.pitt.edu/nceeer/1990-802-12-Potter.pdf	Schmid (2015) Producing Power: The Pre-Chernobyl History of the Soviet Nuclear Industry; MIT Press
250	"...and the RBMK could be made on-site with locally produced concrete..."	1:38:59	Schmid (2015) Producing Power: The Pre-Chernobyl History of the Soviet Nuclear Industry; MIT Press	https://mitpress.mit.edu/books/producing-power	Petrosyants (1982) Nuclear Power Development in the USSR; IAEA (https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull15-3/15304790209.pdf)
	"Its modular design meant the Soviets could build huge 1000MW reactors cheaper, and faster..."	1:39:02	Schmid (2015) Producing Power: The Pre-Chernobyl History of the Soviet Nuclear Industry; MIT Press		Semenov (1983) Nuclear power in the Soviet Union; IAEA Bulletin (https://www.iaea.org/sites/default/files/25204744759.pdf)
					Kelly et. al. (1982) The Economics of Nuclear Power in the Soviet Union; Soviet Studies (https://www.jstor.org/stable/151629)
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251	"Besides, Water-Water reactors weren't as uniquely Soviet as the RBMK was..."	1:39:14	Josephson (2000) Red Atom: Russia's Nuclear Power Program from Stalin to Today; University of Pittsburgh Press	https://upittpress.org/books/9780822958819/	Schmid (2015) Producing Power: The Pre-Chernobyl History of the Soviet Nuclear Industry; MIT Press
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252	"Chernobyl's construction was rushed, and it routinely cut corners regarding safety..."	1:39:41	USSR COMMITTEE OF STATE SECURITY (1975) Memorandum on Chernobl Construction	https://web.archive.org/web/19991022070305/http://lcweb.loc.gov/exhibits/archives/n2constr.html	Ковалевська (1986) Не приватна справа; Літературна Україна [Kovalevska (1986) Not a private matter; Literatura Ukrainy] (https://www.myslenedrevo.com.ua/uk/Sci/HistSources/Chornobyl/Prolog/NePryvatnaSprava.html)
					Дятлов (2005) Чернобыль. Как это было [Dyatlov (2005) Chernobyl: How it was (or how it happened depending on your translation)] (http://www.lib.ru/MEMUARY/CHERNOBYL/dyatlow.txt)
253	"The reactor was so difficult to manage it physically and mentally drained the workers tasked to control it..."	1:39:46	Higginbotham (2019) Midnight in Chernobyl; Transworld Publishers	https://www.waterstones.com/book/midnight-in-chernobyl/adam-higginbotham/9780552172899	USSR COMMITTEE OF STATE SECURITY (1975) Memorandum on Chernobl Construction (translation: https://web.archive.org/web/19991022070305/http://lcweb.loc.gov/exhibits/archives/n2constr.html)
					Original Archive Document pg.1: https://web.archive.org/web/20000819033846/http://lcweb.loc.gov/exhibits/archives/n3const1.gif
					Original Archive Document pg.2: https://web.archive.org/web/20000819033852/http://lcweb.loc.gov/exhibits/archives/n3const2.gif
					The Chernobyl Dossier of the KGB: From Construction to the Accident: January 5, 1983
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254	"NIKIET, for their part, issued a new set of safety guidelines for the RBMKs operation..."	1:40:04	З архівів ВУЧК-ГПУ-НКВД-КДБ (2001) Чорнобиль: трагедія в документах і матеріалах [From archives of VUChK-GPU-NKVD-KGB (2001) Chernobyl: A tragedy in documents and materials]	https://chtyvo.org.ua/authors/Danyliuk_Yurii/Z_arkhiviv_VUChK-HPU-NKVD-KHB_N1_16/	
NB			Сидоренко (2002) «Управление атомной энергетикой»; Сидоренко В. А. Об атомной энергетике, атомных станциях, учителях, коллегах и о себе [Sidorenko (2002) "Nuclear Energy Management"; Sidorenko V. A. About nuclear energy, nuclear power plants, teachers, colleagues and about myself]	http://elib.biblioatom.ru/text/sidorenko_ob-atomnoy-energetike_2010/go,130/	
255	"costs could be reduced even more by building them without the concrete structure..."	1:40:12	Полушкин (1980) "Атомный богатырь". "Наука и жизнь" No. 11 [Polushkin (1980) Atomic Hero; Science and Life No. 11]	http://publ.lib.ru/ARCHIVES/N/"Nauka_i_jizn"/_"Nauka_i_jizn"_1980-89_.html	Schmid (2015) Producing Power: The Pre-Chernobyl History of the Soviet Nuclear Industry; MIT Press
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NB			Sredmash Scientific Technical Council (1971) General safety provisions nuclear power plants in the design, construction and operation, OKB-73 [Научно-технический совет Средмаш (1971) Общие положения обеспечения безопасности атомных электростанций при проектировании, строительстве и эксплуатации, ОКБ-73]	http://elib.biblioatom.ru/text/atomnaya-energiya_t54-2_1983/go,72/	https://inis.iaea.org/collection/NCLCollectionStore/_Public/28/034/28034590.pdf
			Schmid (2015) Producing Power: The Pre-Chernobyl History of the Soviet Nuclear Industry; MIT Press		
256	"In the glossy covers of English-language magazine Soviet Life..."	1:40:19	Soviet Life (Washington: Embassy of the Soviet Union in the USA, 1986) Peace and Plenty in Pripyat: The Nuclear Power Industry in Ukraine. Accessed from soviethistory.msu.edu	http://soviethistory.msu.edu/1985-2/meltdown-in-chernobyl/meltdown-in-chernobyl-texts/peace-and-plenty-in-pripyat/	
257	"The same conversations we had on April 26th, 1986 started almost immediately..."	1:41:09	Chernobyl, Fukushima, and preparedness for a "next one"; Bulletin of Atomic Scientists	https://thebulletin.org/roundtable/chernobyl-fukushima-and-preparedness-for-a-next-one/	
258	" Fukushima Daiichi was a well-defended nuclear plant by accepted standards, with robust, redundant layers of protection..."	1:41:55	Union of Concerned Scientists (2014) Fukushima: The Story of a Nuclear Disaster; The New Press	https://www.ucsusa.org/resources/fukushima-story-nuclear-disaster	
[63]	"A complacent and poorly regulated industry..."	1:42:30	Union of Concerned Scientists (2014) Fukushima: The Story of a Nuclear Disaster; The New Press	https://www.ucsusa.org/resources/fukushima-story-nuclear-disaster	Tillement (2018) How are nuclear risks managed in France?; The Conversation (https://theconversation.com/how-are-nuclear-risks-managed-in-france-99524)
					Synolakis et. al. (2015) The Fukushima accident was preventable; Philosophical Transactions of the Royal Society (https://royalsocietypublishing.org/doi/10.1098/rsta.2014.0379)
	"...one that considered such an event unlikely..."	1:42:32	Union of Concerned Scientists (2014) Fukushima: The Story of a Nuclear Disaster; The New Press	https://www.ucsusa.org/resources/fukushima-story-nuclear-disaster	S&P Global (2020) EDF lifts French reactor extension cost 2.5% to 49.4 billion euros (https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/electric-power/102920-edf-lifts-french-reactor-extension-cost-25-to-eur494-billion)
	"...one that thought it wasn't worth the cost and time to protect against such an event..."	1:42:34	Union of Concerned Scientists (2014) Fukushima: The Story of a Nuclear Disaster; The New Press	https://www.ucsusa.org/resources/fukushima-story-nuclear-disaster	
	"...one that didn't consider the possibility of multiple failures to safety controls all occurring at once..."	1:42:37	Union of Concerned Scientists (2014) Fukushima: The Story of a Nuclear Disaster; The New Press	https://www.ucsusa.org/resources/fukushima-story-nuclear-disaster	
259	"The current death toll at Fukushima is 573..."	1:42:04	Daily Yomiuri Online (2012) 573 deaths 'related to nuclear crisis'; nrc.gov	https://www.nrc.gov/docs/ML1234/ML12340A564.pdf	Thomas & May (2017) Editorial: Coping after a big nuclear accident; Process Safety and Environmental Protection (https://www.sciencedirect.com/science/article/abs/pii/S0957582017303166)
					Waddington et. al. (2017) J-value assessment of relocation measures following the nuclear power plant accidents at Chernobyl and Fukushima Daiichi; Process Safety and Environmental Protection (https://www.sciencedirect.com/science/article/pii/S0957582017300782)
260	"...only one is the result of radiation"	1:42:08	BBC News (2018) Japan confirms first Fukushima worker death from radiation; BBC	https://www.bbc.co.uk/news/world-asia-45423575	
261	"A large earthquake and tsunami in one of the most tectonically active parts of the planet..."	1:42:19	KCL Centre for Science & Security Studies (2021) Nuclear Security in Times of Crisis Case Study IV: Nuclear Security Reform in Japan following the 2011 Nuclear Disaster	https://www.kcl.ac.uk/csss/assets/nuclear-security-in-times-of-crisis-handbook.pdf	
NB			TEPCO (2011) Result of survey of Yunotake fault (summary)	https://www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/111227e6.pdf	
			Acton & Hibbs (2012) Why Fukushima Was Preventable; Carnegie Endowment for International Peace	https://carnegieendowment.org/2012/03/06/why-fukushima-was-preventable-pub-47361	
262	"And because of the industry's complacency, Japan reneged on its climate obligations..."	1:42:50	Yeo (2015) Japan's 2030 climate pledge leaves room for coal expansion; Carbon Brief	https://www.carbonbrief.org/japans-2030-climate-pledge-leaves-room-for-coal-expansion	Japans Ministry of Economy, Trade and Industry (2015) Press Release (https://web.archive.org/web/20150724004611/https://www.meti.go.jp/press/2015/07/20150716004/20150716004_2.pdf)
					Japan information on Appendix I of the Copenhagen Accord (2010) (http://unfccc.int/files/meetings/cop_15/copenhagen_accord/application/pdf/japancphaccord_app1.pdf)
[64]	"...and progress on reducing emissions has been slowed for everyone."	1:42:54	Jeffrey et. al. (2013) Japan: from frontrunner to laggard; Climate Action Tracker Policy Brief	https://climateactiontracker.org/documents/20/CAT_2013-11-15_JapanFromFrontrunnerToLaggard_PolicyBrief.pdf	Japanese Ministry for the Environment (2013) Emissions Report (http://www.env.go.jp/press/files/en/601.pdf)
263 [65]	"Statistically its one of the safest forms of energy we have..."	1:43:49	Our World In Data (Accessed 2021) Death rates from energy production per TWh	https://ourworldindata.org/grapher/death-rates-from-energy-production-per-twh	Sovacool et. al. (2016) Balancing Safety with Sustainability: Assessing the Risk of Accidents for Modern LowCarbon Energy Systems; Journal of Cleaner Production (https://www.sciencedirect.com/science/article/abs/pii/S0959652615009877)
					Markandya & Wilkinson (2007) Electricity generation and health; The Lancet (https://www.academia.edu/12681524/Electricity_generation_and_health)
264 [66]	"And the air pollution it keeps out of the atmosphere has saved thousands of lives..."	1:43:53	Kharecha & Hansen (2013) Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power; Environ. Sci. Technol.	https://pubs.acs.org/doi/abs/10.1021/es3051197?source=cen	
265	"Air pollution from fossil fuels kills 4 million people every single year..."	1:43:58	WHO (2021) Fact Sheet: Ambient (outdoor) air pollution	https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health	WHO (2016) Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease (https://web.archive.org/web/20161022035830/http://apps.who.int/iris/bitstream/10665/250141/1/9789241511353-eng.pdf)
[67]	10 years on from Fukushima...		UCS (2016) Preventing an American Fukushima Limited Progress Five Years after Japan's Nuclear Power Plant Disaster	https://www.ucsusa.org/sites/default/files/attach/2016/03/Preventing-American-Fukushima-full-report.pdf	Ayoub & Sornette (2021) Precursors and startling lessons: Statistical analysis of 1250 events with safety significance from the civil nuclear sector; Reliability Engineering & System Safety (https://www.sciencedirect.com/science/article/pii/S0951832021003410)
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					Vietti-Cook (2016) Staff requirements—SECY-15-0137—Proposed plans for resolving open Fukushima Tier 2 & 3 recommendations. SRM-SECY-15-0137 (http://pbadupws.nrc.gov/docs/ML1603/ ML16039A175.pdf)
					Perrow (2007) The Next Catastrophe: Reducing Our Vulnerabilities to Natural, Industrial, and Terrorist Disasters; Princeton University Press
					NRC (2014) Commission Response Sheet, COMSECY-13-0030, Staff evaluation and recommendation for Japan lessons learned—Tier 3 issue on expedited transfer of spent fuel
					NRC (2019) Recommendations for Enhancing the Reactor Oversight Process (https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML19070A050)
					NRC (2022) Special Inquiry into Counterfeit, Fraudulent, and Suspect Items in Operating Nuclear Power Plants (https://www.nrc.gov/docs/ML2204/ML22040A111.pdf)
					Bristol University Research (2022) The future of nuclear power — monitoring, modelling, and managing risk (https://www.bristol.ac.uk/research/impact/stories/nuclear-safety/?fbclid=IwAR22tW10VCn19zZig_vh0rsILQWKYI5QRwjYLx7TStvu0cCn3P9dWyp7dhg)
CARD: FYI, no it isn't	"The major drivers of cost are expensive containment domes and other non-specific safety measures we don't need..."	1:36:22	Eash-Gates et. al. (2020) Sources of Cost Overrun in Nuclear Power Plant Construction Call for a New Approach to Engineering Design; Joule	https://www.cell.com/joule/fulltext/S2542-4351(20)30458-X?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS254243512030458X%3Fshowall%3Dtrue	
CARD: FYI, no it isn't	"These voices argue the reason nuclear power is failing is because its drowning under red tape..."	1:36:19	Berthélemy et. al. (2015) Nuclear reactors' construction costs: The role of lead-time, standardization and technological progress; Energy Policy	https://www.sciencedirect.com/science/article/abs/pii/S0301421515001214?via%3Dihub	

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	http://photo.ukrinform.ua/ukr/photosets/photoset.php?id=3283&alb=TRUE
National Chernobyl Museum	http://chornobylmuseum.kiev.ua/en/mainpage/
	https://www.facebook.com/NationalChernobylMuseum/photos

[1] Example note

[2] Note

[3] Note

[4] This will become a theme, but the immediate death toll has also been disputed. This claim is made by the Chernobyl Tissue Bank - who say there were 3 immediate deaths and 28 later deaths; not 2/29. The OECD paper says 2/29. as does the 1988 UNSCEAR report. So thats what I'm using.

It's hard to find the official Soviet numbers anywhere but UNSCEAR cites the Soviets for their 31 deaths.

[5] Interestingly enough, communications between Belarus and the IAEA put the total number of liquidators at 800,000

The official number still seems in the ballpark of ~600,000. But there's a lot of numbers floating around

[6] The WHO "Chernobyl at 30 Report", linked in the additional papers section says: "There is emerging evidence from other studies (workers in the nuclear industry and medically exposed populations) that low dose protracted exposures to ionising radiation increase the relative risk of cancer.

Such risk increase can only be validated through large, well-designed epidemiological studies of populations with well-characterized exposures from the Chernobyl accident. It should be noted that a general increase in cancer incidence has been reported in recent decades worldwide, which must be also taken into account when interpreting the results of the Chernobyl studies."

[7] When I say "analyses" here, I mean that UNSCEAR got its data from the state registries of the nations hit hardest by Chernobyl. It did not conduct lifespan studies of these cohorts. That's foreshadowing for later!

[8] Ukraine's Becquerel limit in milk is 100Bq per litre. This is a lot stricter than other places. In the US, acceptable milk contamination levels is 500 Bq per litre - which is in line with internationally accepted standards. In the EU it's 370 Bq per litre.

It's arguable the paper is conducting a sleight of hand. Like, yeah, kids are drinking milk 5x more radioactive than the Ukrainian state permits. But that's because the Ukrainian state is overly strict. If you said Ukrainian milk from the worst hit regions has radiation levels slightly higher than those considered acceptable by the EU (370Bq/l), or levels acceptable by the US, that sounds a lot less scary than "Kids are being exposed to 5x the legal dose of radiation in Ukraine"

This is the problem with relative sources

[9] To indicate how hard a lot of this is, one study looking at emergency workers between 1992 and 2009 looked at solid cancers and found an increase in the relative risk of developing solid cancers among Russian cleanup workers. However, it didn't find an increase in mortality. I've linked it in the additional notes

This is where focussing on death can get fraught. As anyone who has had cancer, or knows someone who has had cancer can attest to: cancer isn't fun. And focussing on just who dies from what illnesses can miss the quality of life reductions these diseases can cause. Thyroid cancer isn't a walk in the park. And while we should be grateful it's a treatable cancer, it can still be a life altering one.

[10] Darby's paper concerns itself with radon exposure but to highlight the limits and disagreement within the literature there is also a paper which looks at radon exposure therapy to treat various ailments and tentatively rules on the side of hormesis I've linked the paper in the additional notes

For due diligence sake, the paper stresses its hard to do double blind RCTs for radon therapy. And Double blind RCTs are the gold standard in medicine.

[11] A Systematic Review and meta analysis looking into cardiovascular illnesses and low level chronic exposure to radiation also found an increase in the relative risk of cardiovascular conditions with exposure. The study was limited in the same way as the others but I've included it in the additional notes.

The other studies in the additional noites are studies of low dose radiation exposure on NPP workers; and are supportive of LNT

[12] Studies included in Additional notes are supportive of LNT for A-bomb survivours and solid cancers

[13] In the additional notes I've included a link to the INWORKS cohort study of radiation workers (308297 workers – mean dose 24 mSv - follow-up 27 years) to illustrate this point:

Among 1000 workers; 216 died; 64 were caused by leukaemia or cancers - of which 1 was attributable to radiation

[14] I feel like I wouldn't be doing due diligence here if I didn't say that a paper or two on hormesis does not a contender to LNT make; but there are other studies that indicate the lowest radiation doses can cause molecular changes in the body that stop nasty things like chromosomal translocations. They're linked in the additional notes

[15] An additional reference is included to indicate that as radiation levels increase, the abundance of flora and fauna decreases. Its not as clear cut as this quote implies

[16] This study is a lab based study and not a field study into Chernobyl bees. An additional citation of field bee studies has been included as a cooberator

It should be noted that in the pulbication 'The Conversation' the author of the paper notes some field observations that indicate there's a high diversity of bees. However the bee study is also in line with field observations about other insects in the area - i.e. their populations fall as radiation increases - see additional notes.

[17] There's literally no good reason not to fund and build a Life Span Study.

Issues around LNT at low doses? They could be resolved with a lift span study.

Questions about whether it's worth evacuating people or guiding responses to accidents?
Could be resolved with a Life Span Study.

Even 'no evidence of health damage' after comprehensive investigation would be a valuable result. The fact it has ground to a standstill should be a point of frustration for all of us

[18] A commenter pointed out that the document linked focuses on Swedish Sami and may not be representative of the strides made by Sami in recent years

That's fair - I'm not tryin to downplay progress and have linked a 2021 study in the additional notes section that outlines how the nature and protections against discrimination have changed. But the wider observations by the OHCHR document holds across Norway, Sweden, Finland and parts of Russia which are home to Sami -- see the linked OpenDemocracy article for examples of modern day "Norwegianisation"

[19] So fun fact! The map shows a divided Berlin but I was recently informed by a commenter that the capital of West Germany was Bonn. I didn't know that so adding it as a tidbit here!

[20] ERROR! Germany's social democratic party was not in power. It was the CDU/FDP coalition that was in power between 1983 and 1987. I think the word ruling came from me not reading Becker's paper "Economic, Social And Political Consequences In Western Europe" paper carefully enough when they referred to the control the SDP had in certain states. This was a silly error. I'm sorry.

However, Chernobyl was the catalyst for the SDP to abandon advocating for the expansion of nuclear technology, and later calls for a phaseout. Just drop the word "ruling" and the sentence holds.

[21] For example, Hessen set an iodine 131 limit of 20 bq/l for milk, and the government of Nordrhein-Westfalen complained that the thresholds recommended by the SSK were too high.

[22] This apparent mismatch between what SCRPI was telling the public and the delay between these things occurring lead to Minister of Industry, Alain Madelin, setting up a body for "greater transparency of data"

As an aside, green groups are often characterised as anti nuclear power from the get-go, because we usually think of German greens. However in France the picture is much more nuanced. As I'll discuss in other notes, the initial opposition by Greens wasn't to the concept of nuclear power but to the lack of information - I've linked a piece from Le Monde in the additional notes from the 2nd May to illustrate this

[23] ERROR: So my community is really cool and I had an honest-to-God nuclear decomissioning worker for the UK reach out about this, and they pointed out that Le Monde and ol' Jezza Corbyn of Jezza Corbyn fame are wrong.

The highest dose received was 18 rem, or 180mSv. Enough per the stochastic model to raise the risk of cancers, but not enough of what would be needed to cause ARS.

As an aside: this is why its important to cross reference things, and why I like to treat this spreadsheet as something of a living document

[24] France's antinuclear movement was also neutered by the pro-nuclear Socialists taking power in 1981

[25] It also helped that Chernobyl catalysed German Greens and allowed them to become far more powerful as a political group; as well as giving them access to the internal levers of power in government. That tends to happen when you win elections

[26] The ban became government policy on the 13th June, but came into effect on the 20th

[27] I had nowhere else to put this but during my research I found this absolute gem from 'Evening, Kyiv' written by a Uni professor who was like "these greens are morons! Put a nuclear plant in my garden!"

Plus ça change!

[28] Gorbachev's liberalisation program, as laid out in his speech to the XVII Congress, was one of "socialist pluralism". He spoke of "publicity" and "restructuring" the Stalinist model of socialism by returning to "Leninist principles" and, by controlling this activity from above, to weaken reactionaries

Glasnost', as referenced in the paper "Glasnost v. Glasnost': A re-evaluation and reinterpretation of the Chernobyl disaster in Soviet media" argues glasnost as originally imagined is closer to Leninist views of a free press. It's "free" insofar as the dissent is dissent the government will tolerate. (If you want an idea of Leninist free speech, read Lenin's response to Kautsky's "The Dictatorship of the Proletariat" in the book "Democracy and Dictatorship". Lenin only mentions free press in passing, but Kautsky's essay was an acceptable level of dissent to the new Bolshevik government. Lenin's response gives you a flavour of socialist pluralism. Kautsky can write his essays saying that a Bolshevik dictatorship that abandoned democracy doesn't bode well for the Proletariat, on the condition that Lenin could call Kautsky a twat).

Gobachev, for the record, would disagree with my characterisation (he does so in his Memoirs), but he argued in Project Syndicate in 2006 that Chernobyl “opened the possibility of much greater freedom of expression, to the point that the system as we knew it could no longer continue.” So, yeah, Chernobyl accelerated Glasnost away from Glasnost-prime

[29] Sokolov wasn't doing this because he was enamoured with the goals of the green movement. The Green movement were openly calling for his resignation. Sokolov was angry that Moscow had failed to properly handle Chernobyl. As far as he was concerned, that's what caused the protests in the first place.

[30] ERROR: The photo is from August 1989 in Ukraine, the 30000 protest broke out in Minsk on September 30th 1989. This was a silly error and I should have caught it. Sorry

[31] Ukraine was the first to propose such a move; Belarus and Russia also had State Union-Republic programmes drawn up in the USSR for the years 1990-1992. These programmes were approved by the Supreme Soviet of the USSR on 25 April 1990.

[32] When I say "half the population were thrown into unemployment" that's an unintentional misreading of Petryna's sentence. She says that half the population found themselves in dead end industries which'd either be restructured or shut.

[33] According to the same author in her paper "Biological Citizenship" workers would also fake symptoms of ARS to leave the zone.

[34] CORRECTION: I say in the video that Ukraine and Belarus lack natural resources like oil and gas. Turns out Ukraine sits on the SECOND LARGEST GAS DEPOSITS IN EUROPE.

Doing a quick read around - during Soviet times, Ukraine produced a record of 68.7 billion cubic meters (bcm) of gas in 1976. At the time of independence in 1991, production was at 26.6 bcm, and fell in the 1990s to about 18 bcm. This massive production glut, not the lack of resources, is what drove them to try and secure a deal with Russia to import gas

[35] This arrangement took another turn when the Greens entered a coalition with Germany's SDP and threatened to pull £1bn in funding to new nuclear power plants in Ukraine and close Chernobyl

[36] Ukraine did this twice. Once for funding for a gas plant, and second for funding two new reactors in the area. This had a logical through-line to it: Ukrainian nuclear plants ran on Russian-produced enriched uranium, and Russia had already agreed to keep supplying Ukraine with nuclear fuel in exchange for Ukraine sacrificing its nuclear arsenal

[37] The nature of the opposition was also different. In France, the opposition wasn't on safety grounds per se; it was centered around opposition to the centralised French state and the central control of information. This can be seen in Le Monde reporting on the Ecology movement, who's focus was on lack of information

[38] It's worth noting that because of the inadequacies of Exxon's response, oil spilled in 1989 is still present in the environment and likely will be for decades to come (see additional notes)

[39] Exxon acted in a much worse way than this implies. Exxon subpoenaed everyone who might have had evidence damaging to Exxon. They subpoenaed fishermen for their tax returns; they subpoenaed sociologists who were researching how it damaged the social fabric of Prince William Sound.

By raising the burden of proof for compensation payments and appealing through every court ring in the US, Exxon could get away with not paying compensation for the damage they caused to people or the

environment. It's fucking wild how ghoulish Exxon acted.

[40] In Petryna's paper "Biological Citizenship" she notes a sharp increase in the number of Ukrainians claiming disability in 1991. As a World Bank consultant noted, "...virtually any disease is attributed to Chernobyl, and no effort is being made either to prove or disprove these claims that would satisfy standard epidemiological criteria of causality".

The sharp increase is also co-morbid with Ukraine's economy contracting 8% and the state withdrawing as a result of shock therapy mandated by the World Bank. As Petryna argues, welfare was a way for citizens to insulate themselves from an imploding economy by making claims to what Petryna calls "biological citizenship" -- a demand for, but limited access to, a form of social welfare based on medical, scientific, and legal criteria that recognises injury and compensate for it

Not to hammer on this point here, but to quote from Biological Citizens again: "Life Exposed: Biological Citizens after Chernobyl, elucidates how scientific knowledge and Cherobyl-related suffering were tooled to access social equity in a harsh market transition."

This isn't even that new or shocking. Things like drinking, smoking and poor diets that cause ill health are symptomatic of economic collapse and deindustrialisation. Life expectancy falls are often symptomatic of deindustrialisation. It's very visible in coal mining communities in the UK, for example, or in the failures of austerity politics. I've linked a book that goes into how deindustrialisation in the UKs coal country pushed people into incapacity benefits.

[41] The 1996 Report called the Ukrainian Chernobyl System "dead weight" on its less than ideal market transition - I've linked it in the Additional Sources section

Since aid was more or less tied to World Bank recommendations, they served as death nails to Ukraine's social welfare system. In June 1998, for example, the Ukrainian president ordered the halving of government contributions to the state-run Chernobyl Fund. He also abolished state requirements imposed on enterprises to make contributions to the fund

[42] NOTE: The IEA projections used in the video are slightly out of date. I've included the 2021 projections in the additional notes. These show renewables making up a larger total % of our energy consumption and capacity installations in both Stated Policies (STEPS) and Sustainable Development (SDS) Scenarios

EDIT: So I got into an argument on a UE stream (if you're reading this, zhe... I can't remember your handle but it ended with a 20. Anyways if you're reading this I'm sorry. I think we were talking past each other because messages fly by and you only get 200 characters) -- anyway the person I was trying to talk with made the claim about historic growth and displacement, and were conflating displacement and scaleup

Displacement refers to the amount of emissions averted or fossil fuels removed. Scaleup is the amount you build or deploy. This is important as a distinction

Now if you ignore the Cao et al (2016) paper -- which I get into in a different note but TL;DR they stack the deck -- and look at both the gross numbers in GW capacity and %, in 1970, nuclear deployed very quickly and slowed down - whereas renewables now are deploying as fast is not faster than nuclears historic. Based on the IEA's and BP Statistical Review, then nuclear and renewables make up about the same share of power.

But nuclear has averted nearly 50Gt worth of CO2, and nuclear/hydro make up 90% of averted emissions - over half of which is thanks to nuclear; and renewables haven't displaced anywhere near that, despite in terms of scaleup them now matching nuclear.

A 2012 paper looking as displacement called "Do Alternative Energy Sources Displace Fossil Fuels?" found

nuclear power displaces more fossil-fuel electricity than other sources, but still not a substantial amount, with a coefficient of -0.221. Hydropower displaces less, with a coefficient of -0.099. Non-hydro renewable sources have a positive coefficient of 0.048, so they're not displacing anything. But this coefficient is not significantly different from 0, indicating that renewables tend to simply be added to the energy mix without displacing fossil fuels.

The 2012 paper went from 1960 to 2009. But time goes further than that. And in that time renewables became a much bigger part of grids. National emissions in developed nations are lower than 2009. If you look at UK or Ireland, for example, their share of renewables has coincided with a reduction in coal and gas use. If you look at the US, coal has been hugely displaced by wind and solar and its beginning to force down gas generation.

So what's going on?

If you move the debate from econometrics (i.e. how many units of fossil fuel electricity are displaced by adding one unit of nonfossil fuel electricity) to one of geography, then the lack of fossil fuel displacement by renewables and nuclear is because of broader policy contexts, including cross-national inequalities, that have largely insulated fossil fuels from competition with alternative sources of electricity production outside of those nations with wealth

The thing is, looking at Our World in Data consumption, it's hard to see how much of a dent nuclear energy made. It only really applies to France and Sweden, because they had the power to leverage their economies to grow their nuclear sector. Fossil fuel use grew in nations which lacked that ability, so globally emissions rose - even if, when looking at geographically localised emissions (i.e. France), they fell

Nuclear has a bigger displacement because (A) it's been around for longer. Its only been since 2007 that renewables have actually displaced fossil fuels globally according to a 2022 study by Greiner et. al. called "When are fossil fuels displaced? An exploratory inquiry into the role of nuclear electricity production in the displacement of fossil fuels"

A big factor is time. But a bigger factor is regional inequalities insulating fossil fuels from displacement. You can look at the UK and see emissions fall, almost entirely due to wind energy. But globally gas and coal use is rising. Nuclear had its growth spurt at the right time, so to speak.

Also (B) according the the IEA, nuclear does seem to displace more co2 than wind or solar. It takes about 3GW wind and solar to displace the same amount of CO2 as 1GW nuclear. The thing is, we're building hundreds of GW worth of wind and solar; and 10s of GW worth of nuclear. This is why when you look at the IEAs modelling of avoided emissions, renewables avoided 0.2Gt worth of CO2 in 2018, and nuclear avoided 0.1Gt

Anyway if you're reading this, Z-something-20. I was wrong. But you weren't right, either!

[43] I chose the balanced pathway with no hydrogen to illustrate how decarbonising could work with existing technologies, so the displayed data comes from BEIS (see Additional Notes).

Again, because this took so long to make the UK Committee on Climate Change's 6th Carbon Budget came out during production; and the CCC sees a more limited role for nuclear in its balanced pathways - only including two operational nuclear power stations (HPC and Sizewell C)

[44] If you want some feel good news, our emissions are now lower than they were in 1879. Take that, doomers!

[45] So recently the IPCCs 2022 WG3 report came out and it shows an interesting paradox: the 2022 report makes a stronger case for expanding nuclear than the special report on 1.5C (see Chapter 6 on energy systems) but despite this, the role for nuclear energy in our future energy mixes doesn't radically change

despite the window for emissions cuts narrowing and the need for carbon mitigation becoming more pressing

Nuclear's role in climate mitigation never goes above the ~25% share stipulated by the industry's Harmony scenario. In the 1.5C scenario without overshoot, nuclear power's mean projection is 8% of the share of electricity by 2050. Which is slightly down on present and about the same as the Special Report on 1.5C. What differs is the ranges. In the WG3 report nuclears highest level is ~20% and it's lowest is ~5%. In the SR1.5 report, it's 27.5% and 1%. So more of a role, but also less of a role if you follow

[46] So according to the new working reports from the IPCC emissions need to peak in 2025 to stay below 2C. Yay.

[47] According to reporting by Carbon Brief it's actually gotten lower. That's bad; and UK emissions spiked in 2021. I'll let you draw your own conclusions

[48] The main mechanism for the UK developing low carbon energy is Contract for Difference for (CfDs). They were selected in 2010 because contracts are awarded in a series of competitive auctions, with the lowest price bids being successful. The Coalition government argued this would be most compatible with getting greener energy into the UK grid at the lowest possible cost by driving efficiency up and costs down. Which it did (see BEIS (2021))

An alternative modle which was rejected by the 2010 white paper were RABs - or Regulated Asset Bases. RABs work by providing a secure payback and return on investment for developers. They do this by effectively transferring risk from the private sector to consumers

RABs were rejected because, the Coalition government argued, RABs would sacrifice market benefits and competitive pressures for greater efficiency, optimal operation and innovation. They noted RABs work well in natural monopolies, because they essentially give a company monopoly power

As a result of CfDs failure to get nuclear power built, nuclear power plants are now financed using RABs. The reason the Conservatives are turning towards renewables is because RABs require the government to centrally determine the shape of the energy mix. Renewables slot nicely into a market system. Nuclear slots nicely into top-down systems. In the land where cost is King, Hyper-Thatcherites will always choose the market.

[49] This data is again slightly out of date. I was going of the WNA 2020 report when I wrote this. The WNA 2021 report has construction times down to 7 years

Some people will say I should have used the deployment data from Cao et al's paper. The reason I didn't is because it's crap.

[50] The World Nuclear Association was critical of the IEA's Net Zero by 2050 report. They said: "IEA’s Net Zero Emissions scenario puts too much faith in technologies that are uncertain, untested, or unreliable and fails to reflect both the size and scope of the contribution nuclear technologies could make"

When I read that I thought they were referring to SMRs. Because the IEA Net Zero report sees nuclear in two phases. The first is extending the lifetime of old reactors. The second is Small Modular Reactors leading the bulk of the buildout. But the WNA agreed with that. They were actually referring to battery storage.

I just found it interesting that most of the industry is looking to SMRs to overcome the costly economics of current nuclear power plants.

I think I'd be remis to point out but since I banged on about nuclear having political symbology its worth

brining up again. Because a great little report by the Good Energy Collective has argued SMRs could serve as a way to ensure a just transition for coal mining regions. And I like that they put nuclear innovation in the context of social justice.

AFAIK the concern among some academics is that First-of-a-Kind (FOAK) Small Modulars will suffer from the same issues as other FOAK reactors, and will suffer from reverse economies of scale. There's a school of thought that says rather than focus on innovation, the focus should be building more LWRs. I disagree with this, I think SMRs have the potential to bring costs down and allow mass scaling. But I thought it'd be worth to point this out.

[51] Nuclear skeptics, such as Joe Romm, argue that soaring costs are an inevitable side effect of building massive concrete-and-steel structures that need layers of radiation safeguards. Amory Lovins has made a similar argument in his book “The Origins of the Nuclear Fiasco” which essentially says cost rises seen in the 1970s are an inevitable part of an industry. The complexity of the technology inevitably increases, leading to inherent cost escalation trends that limit or reverse ‘learning’ (cost reduction).

I’m not persuaded by that. As the Lovering paper argues, in the early 2000s wind turbine costs were rising 10% a year in the US. We didn’t write off wind technology. We fixed it. And now wind is one of the cheapest ways to generate power. I think we can do the same for nuclear power.

The Lovering paper points to France and Japan as nations which controlled their cost escalations better than the US and UK, and points to South Korea as evidence that you can get lower costs with time.

For France, Japan, and South Korea - the countries usually only have one utility (EDF, TEPCO, KEPCO) and one builder (Areva) working closely together. They settled on a few standard reactor designs and built them over and over again, and would put multiple reactors on a single site.

South Korea also had a leg up from a licensee relationship with Westinghouse since the late 1980s when the US-based company supplied the 945 MWe System 80 nuclear steam supply for Yonggwang 3 and 4. Which was eventually adapted by KEPCO into Korean Standard Nuclear Plant (KNSP), then the OPR-1000. The current APR-1400 technology represents a further evolution of that design. The construction and power generation costs of the APR-1400 are reported to be 10% lower than those of OPR-1000 units

Now South Korea has some MAJOR scandals surrounding the safety of its nuclear fleet which may explain why its costs were actually as low as they were (see reference 239); and the Lovering data for South Korea isn't independently verified - but for now, central planning + standardisation + cheap money + building multiple reactors of the same type at once = controlled costs

This is part of the reason why SMRs are as attractive as they are. They should be much more receptive to learning based cost reductions, because they're "Granular" technologies -- small, cheap and modular. They scale up through replication: fitting lots and lots and lots of them over and over and over, as oppose to "Lumpy" technologies like conventional nuclear which are big, pricey and non-divisible. You don't scale them up by building lots. You do it by going big.

The reason granular technologies like solar panels on roofs are winning out is because they deploy faster, with lower cost barriers and less specialised capital requirements. Their small size means that they're less risky for investors because they have fewer cost overruns. And they're breeding grounds for innovation because they have really high learning rates (% cost reduction for each doubling of cumulative experience) and are less complicated. SMRs would make nuclear more granualr, and make standardisation easier. The issue is not regulation. Its standardisation.

These caveats aside, the bulk of the data and reporting on new nuclear power plants indicates that nuclear powers high overnight costs, massive cost overruns, and long construction times are the norn. Not the exception.

[52] Yes, this chart uses LCOE. LCOE is flawed. It misses a lot of things - such as how interest rates effect LCOE, and LCOE will likely make less sense as the world becomes more decarbonised. But (a) its fine for most things, and (b) nuclear energy doesn't perform as well on Undiscounted Cost of Energy (UCOE). It doesn't perform well on Total Cost of Energy (TCOE). It doesn't perform well under Discounted Costs Cost of Energy (DCCOE).

The only one nuclear does well on is Life Time Operations or LTO because they can operate for 60+ years. That doesn't change the fact they have high start-up costs. And thats the hurdle which needs clearing. High cost of construction combined with low cost of production is what creates the uncertain future liabilities which stop power plants getting built.

Which is a shame, because climate solutions which eschew nuclear power will be far more expensive than ones which embrace it. According to a paper linked in the additional notes: Firm low-carbon resources in tandem with renewables consistently lower decarbonized electricity system costs than systems that go for renewables alone

[53] This is confusing and I'm not sure how to explain it cleanly? The paper from Karitonov I linked (very good paper btw) says for a power plant with a discount rate of 7%, that takes 6 years to build and operates for 60 years will have a payback of 33 years. The Energypost.eu link concludes a discount rate of 8% means you never see a payback because of cost overruns. A 2015 IEA/NEA study of 22 countries found that, at a discount rate of 10 percent, the median cost of both natural gas and coal was lower than nuclear energy, making it more competitive. For context, the US gives a discount rate of 12.5%. Good luck recouping costs with that.

As an aside, LCOE calculations usually don't account for interest rates on loans for building. So a 3% Interest Rate on a nuclear power plant loan brings the LCOE down markedly. But the large upfront costs and risks mean nuclear power has high risks, and higher interest rates as a result. Again, the capital costs of a nuclear power plant need to be brought waaayyyy down to make it competitive.

Also obligatory link to the Illinois Energy Professor's video on payback because it's *chefs kiss*

EDIT: I recently got introduced to this blogger called Mr Sustainability who does this really good breakdown on nuclear economics and has an interactive graph. It is an absolutely phenomenal bit of writing and visualising because it lets you play around with interest rates and construction times, as well as overight costs and costs of energy. Even with the most favourable conditions (Construction times 5 years, interest rates 1%, electricity prices $150USD) a new powerplant nuclear is unprofitable for a decade

And if you have a lot of these plants around, supply and demand would invariably push the cost of electricity down. Which destabilises the favourable environment for nuclear where power costs are high.

Pinning all of the problems nuclear power faces on the three environmentalists who live in your local park and smell like cum all the time essentially means your argument boils down to: “Rich and powerful plutocrats could be making untold fortunes from cheap, limitless and efficient power, the only reason they don't is because those damn hippies won't let them"

Like - I’m sorry. This is not a smart person's argument

[54] Wind power can have higer payback periods due to its variability. A paper linked in the additional notes

section puts the payback period between 11 and 18 years. The news source DlBdk puts it at 10 - 15 years. Research into African wind potential shows wind energy has a payback period between 2 and 27 years, with the average between 5-12 years

[55] Same caveats apply. In the additional notes section a look at Sri Lankan household had a payback period between 3 and 11 years depending on consumption.

[56] One of the reasons the Russians and Chinese are building a lot of power plants right now is because Rosatom and CGN, Russias and Chinas respective state nuclear companies, are being floated by a lot of cheap government money

[57] Shellenberger is a crank who is pushing for 100% nuclear and his book is fucking shite. He, and other nuclear bros, have effectively ostracised themselves from the nuclear industry for being a crank. Like read Alex Gilbert's tweets about Shellenberger - they are savage.

I need to stress this, the World Nuclear Association - THE industry body - and WNA General Director Agneta Rising work towards the "Harmony" goal. Which sees nuclear energy providing 25% of the world's electricity by 2050.

Just let that sink in for a moment. The actual physical industry is not pushing for the hardline position of the nuclear bros. 25% kind of implies the rest of the electricity will come from other low carbon sources. I WONDER WHICH ONES!

[58] This is one of those "there are no atheists in foxholes" kind of things - i.e. no one actually believes we shouldn't commit to safety. What they really want to do is cut corners.

To use a real world example, South Korea has backed off nuclear power despite reducing costs and no major accidents. Why? Because corruption in KEPCO led them to flouting safety regulations. Major ones. Like not renewing and replacing Load center transformers that manage the flow of power to key emergency functions at reactors. Or faking safety certificates. Or not adding containment domes to reactors! Like what they did at Chernobyl!

In the words of a nuclear engineer at Dongguk University. "Only about 10% to 20% of the original safety additions were kept... They packaged the APR1400 as 'new' and safer, but the so-called optimization was essentially a regression to older standards. Because there were so few design changes compared to previous models, [KHNP] was able to build so many of them so quickly."

Ask yourself: is that *really* acceptable!?

[59] I find it fascinating that these arguments really don't change through time on either side. In the additional notes I've linked a copy of an opinion piece from the USSRs Chief Hydrogeologist in 1989 who argues that nuclear power when made safe is the best way forward to deal with climate change.

[60] To quote Legasov: "in VVER reactors, power is limited by the size of the reactor vessel, and in RBMK reactors, power is not limited by anything: you choose a huge graphite layer, make holes in it, insert channels and you can gain more power."

The RBMKs huge power output, and ability to massively expand their power output was ultimately why it was chosen

[61] A note from the UK Parliamentary Office of Science and Technology (POST note) is also dubious about the safety of the Soviets VVERs. Legasov, in his accounts of the Chernobyl accident, was also critical of the Soviets VVERs. According to Legasov, they lacked sufficient safety systems too.

However a VVER *IS* a safer reactor. Proponents of the VVER argued that it doesn't have a positive void coefficient but a negative void coefficient - when water is lost, reactivity decreases, because water serves as both the coolant and the moderator. This, in theory, makes VVERs safer. If there's an issue with the coolant system and the water level goes down, as the reactor got hotter the reactivity slows down, which leads to a shutdown. Because every other nation built VVERs (because of the negative void coefficient) it also opened the doors to greater international cooperation. VVER reactors also featured horizontal steam generators that provided more lag time under accident conditions than typical Western pressurised water designs, which relied on vertical steam generators. Finally, VVERs had regulations requiring containment structures around VVER reactors and stainless steel vessel walls to stop embrittlement.

[62] Also the RBMK was more suited to plutonium production for nuclear weapons

[63] The reason I'm going harder on TEPCO than the Greens is because it's TEPCO's fault.

Anti nuclear groups are reacting to the disaster. And their evidence that nuclear isn't safe is prima facie. A power plant exploded. Claims that the industry is safe ring hollow when a power plant exploded. And attempts to push back against that run into the issue that Greens can point to the prima facie fact a power plant exploded. Of course Greens are understandably concerned that it's not safe. A power plant exploded.

If TEPCO did a better job regulating the plant and were less complacent it's likely it wouldn't have exploded. While control of information about French power plants plays a part in their acceptance by the public, another is that they're really well regulated and have really high thresholds for safety. Which French operators meet. So conversations about safety proceed from the observable fact that their energy sources aren't a risk to them.

In fact, rather than rolling back oversight, France is intensifying inspections of their aging reactor fleet. After four decades of operation, many French reactors have begun to leak and crack. Keeping them operational will cost at least $61 billion. Despite the phenomenal cost, there are many - like me - who believe such an investment in the nuclear future is worthwhile.

To quote from a great article in the Conversation about French approaches to nuclear safety: "The French Institute for Radiological Protection and Nuclear Safety (IRSN) requires us to “imagine the unimaginable and prepare for it.” It confronts all those involved in nuclear safety with a critical challenge: how can we guarantee safety in the midst of unexpected events?"

In my opinion TEPCO's complacency gave ammunition to Green groups and undermined conversations about safety. And the nuclear shutdown had consequences for climate mitigation efforts. Ones that wouldn't have happened if they'd just done their job. So, yeah, it's their fault.

EDIT: Taking this directly from a commenter because I felt it was a good point:
"To those who say "Fukushima couldn't have been planned for", I'd direct their attention to the Onagawa Nuclear Power Plant, which survived higher shocks, endured higher waves and came out the other side safely, with people from the nearby town living at the plant as a shelter for months afterwards.

In most cases, the "One person is responsible for X" mentality isn't applicable, but I feel that not mentioning Yanosuke Hirai would be wrong. It was due to his influence on the engineering board that the 14.8 meter high seawall was built, and that the cooling water intakes were pushed further into the ocean, to account for when the water pulls back prior to a tsunami. He also inspired and shaped the company's safety culture, which persisted long after he'd left, which continually prepared for, trained for, and reevaluated the plant's readiness in cases of emergencies. Good articles for further information can be found by looking up "Learning from non-failure of Onagawa nuclear power station: an accident investigation over its life cycle" (Which is a scientific article) and "AICHE Profits over Safety Culture at Fukushima, Explains Report" (Article published by the American Institute for Chemical Engineers)

He died in 1986, 25 years before the defenses he pushed for kept the people who worked at and lived

around ONPP safe.

In the end of the video, Soup mentions the idea that Nuclear Power is safe, so long as people work hard to keep it so. I can think of few other examples that exemplify that concept than the Onagawa Nuclear Power Plant, and Yanosuke Hirai, a man who worked his entire career constantly trying to keep people safe. "

[64] So the CAT paper cited says quite explicitly that Japan shutting all its nuclear stations cannot account for the revising downwards of its emissions targets.

The Japanese Ministry for the Environment is quite clear that the main contributors are the release of refrigerants and higher petrol consumption. But also, the massive return to coal that was triggered by its nuclear shutoff didn't help.

[65] Someone in the comments pointed out that the Sovacool et al paper this claim is based on has a table (Table 2 if you're interested) that looks at deaths from 1950 to 2014, and that it seems unfair on OWID's part to exclude the large dam accidents from the overall fatality score for hydropower (like the one in Henan Province, China that killed 171,000 people) whilst including ones from nuclear accidents.

As far as I can tell from reading the Sovacool paper, the OWID figure for hydro is based on the normalised values in Table 2 and Figure 5 for hydroelectrity - which considers deaths from accidents per TWh, normalised for 1990-2014 data. Normalising for 1990-2013 ignores deaths from large accidents in the 1970s. So hydro does better, and so does nuclear power, because the 4000 deaths cited by Sovacool for Chernobyl are also excluded.

Data for nuclear and fossil fuel deaths also incorporates deaths from air pollution, based off of the Lancet paper they link. OWID combines both papers, and reconstructs the nuclear data to include 4007 deaths from Chernobyl, which pushes it above hydroelectric deaths.

OWID have a footnote about the issues using Sovacool's estimates for renewable fatalities, and how the data were normalised, since Sovacool considers supply chain deaths Our World In Data wouldn't. So they say deaths from solar may be overestimated. They don't, however, address the exclusion of hydroelectric deaths from the 1970s. So just keep that in mind when viewing the data. It's likely that hydroelectric deaths per TWh would be significantly higher if all of Sovacool's data were included

[66] I originally said "millions" and then corrected it to thousands because the millions cited in the paper is a projected potential number of lives that could be saved by mid century, and not as concrete as the 1970-2000 projection.

Fun fact: these projections and the projections used in Ref. 265 are based on an LNT style of modelling. Do with that what you will

[67] I hate having to post-hoc amend this document to include points not elaborated on in the video. However I know some people took issue with the comment "ten years on we seem determined to learn nothing". This is part anger at the watering down of regulations in a post Fukushima world, and part annoyance arlt the way we actually talk about accidents in the sector - which are a bit too zero-sum for my taste.

Two of Fukushima’s main lessons were
(1) nuclear plants need to have additional means of coping with a prolonged loss of electrical power; and
(2) plant owners need to ensure that their assessments of external hazards such as earthquakes and floods are accurate and up-to-date, and then implement additional measures where necessary to protect the plants from these hazards.

Following the Fukushima accident, the NRC required, among other things, that all US plant owners (1)

develop plans and acquire emergency (“FLEX”) equipment to provide backup power and cooling if power is lost for long periods; and (2) re-evaluate the earthquake and flooding hazard profiles at their sites based on updated information and methods.

However the NRC has not required a single plant to upgrade its defenses in response to these findings despite having the regulatory authority and responsibility to do so; and despite almost no US plant meeting the new FLEX requirements. The NRC has also been forced to close loopholes around the regulatory systems that nuclear companies in the US were bypassing. So no, I don't think the lesson "regulation should be embraced not eschewed" was learned. I've appended several studies into regulatory changes following Fukushima in the additional notes section

I also included a link to Charles Perrow's book, because it has a pertinent quote: "The NRC is as good a regulator as Congress permits it to be. Right now, Congress doesn’t want a good regulator", and in the years following the accident there's been a jurisdictional ambiguity around what the NRC's role is

EDIT: Not that I'm still thinking about that comment -- but someone who used to work in nuclear safety regulations reached out to me following the video and said that in 2019 the NRC recommended that commissioners significantly weaken or reduce safety inspections of the 59 aging nuclear power plants in the US; following the beat of the Nuclear Energy Institute, which lobbies on behalf of the nuclear power plant industry and has long sought weaker safety rules. So... Stick that somewhere in your brain!

Since Biden took office, the NRC's inspector general has said moves to relax these regulations have led to the NRC lacking adequate oversight to keep counterfeit or defective parts out of the US's nuclear power plants. Y'know, the thing that led to Fukushima failing. Almost like I didn't say that we learned nothing from Fukushima for no reason!!

EDIT 2: I found out through old PhD friends that the University of Bristol has got a new research group looking into nuclear energy risk management that's really cool. I've linked that as well