China's Nuclear Expansion: Limits and Risks

Ch 5 Environmental Issues and Once Through Cooling

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Introduction

Environmental impacts associated with once-through cooling (OTC) remain one of the major impediments to siting nuclear power plants in the United States. Specifically, the impingement and entrainment of native species in the suction pipes of OTC plants as well as the discharge of warm water into cooler waters can cause tremendous impact on the surrounding habitat and biota. This chapter briefly addresses China's uncertain environmental regulation schemes to deal with these impacts, as well as alternative technologies.

Despite climate envoy Xie Zhenua's recent statement at the UNFCCC meeting in Durban that China would be willing to "bear the obligations of a legally binding committment" by 2020, China has historically not taken a strong international anti-climate change stance[1]. As the world's greatest carbon emitter, this may not come as a surprise. Still, environmental concerns increasingly deserve and achieve attention. For instance, China ratified its 12th five-year plan on 5 March 2011, indicating amongst other things, its plan to reduce pollution, increase energy efficiency, stability and cleanliness and also to continue construction of nuclear power plants.[2]

While nuclear power doesn't directly contribute to CO2 released into the atmosphere, and is therefore considered cleaner than coal-fired plants, several serious environmental transgressions can be attributed to this energy source. These include radioactive tailings from uranium mining, adverse effects of spent fuel on the surrounding environment, and of course any damage caused by accidents. Infrequently discussed are the negative effects due to cooling methods. This chapter explores the environmental ramifications of once-through cooling (OTC).

Environmental impacts associated with OTC remain one of the major impediments to proper siting of nuclear power plants. Specifically, the impingement and entrainment of native species in the suction pipes of OTC plants as well as the discharge of warm water into cooler waters can cause tremendous impact on the surrounding habitat and biota. This chapter discusses these environmental ramifications as they relate to China. The OTC process will be described; ecological disturbances and potentially threatened species will be explained; China's ecological regulation schemes will briefly be discussed; and finally, alternative cooling techniques will be addressed.

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[1] Hart, Melanie. "Reading China's Climate Change Tea Leaves," Climate Progress, Dec 9, 2011, accessed Dec 9, 2011. http://thinkprogress.org/romm/2011/12/09/385436/china-climate-change-tea-leaves/

[2] APCO. "China's 12th Five-Year Plan: How it actually works and what's in store for the next five years," Dec 10, 2010, accessed Dec 9, 2011. http://www.apcoworldwide.com/content/pdfs/chinas_12th_five-year_plan.pdf

Once-Through Cooling and Ecological Disturbances

Once-through cooling refers to a wet cooling technique used to absorb and dissipate the massive amount of heat produced by nuclear fission. More than 60% of the heat created by nuclear reactors is surplus heat which must be removed.[3] Currently, all Chinese nuclear power plants utilize OTC. Nuclear plants are often situated coastally or riverside in order to take advantage of this relatively cheap method of cooling the fuel cells. Water is abstracted into the reactor where it flows over the fuel cells to absorb their heat, and this warmed water is dumped back into the same body of water. OTC systems are considered best availabe technique in regards to best energy efficiency when dealing with large quantities of low level heat.[4] A generic site discharge point might be found 15 meters from shore, at a depth of 5 meters below water level, to diminish disturbance to sediment.[5]

While cheap, OTC confers several environmental concerns: impingement, entrainment, thermal and biocide pollution, changes in water flow, and turbidity. Because OTC relies on water pumped through pipes from the natural environment, creatures living in the area may accidentally be pulled into the pipes. To minimize clogged mechanics, pipes are affixed with screens. Unfortunately, this is not a fail-safe precaution. Organisms that are larger than the screen become 'impinged'--sucked to the screen (such as fish or shrimp), and smaller organisms (larvae, zooplankton, etc) become 'entrained'--swept along with the flow of water, often sheared by the high pressure. Both result in fish kills. Most entrained biota (90%) measure less than 200mm in length, as these are unable to swim away from abstraction pipes.[6]

The water returned from the plant into the environment is approximately 13^{o}C warmer than the surrounding water, causing an unnatural temperature gradient, or thermal pollution[7]. Many organisms cannot withstand this increased temperature, while others may flourish and thus eliminate a normal ecology. Higher water temperatures often increase organisms' metabolic rates while oxygen's dissolving capacity decreases (approximately 0.2mg/L reduction in oxygen

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[3] Liu, Rock. "Closed-Cycle Cooling Technology for Nuclear Power Plants," Nuclear Power News, Dynabond, Nov 16, 2010, accessed Nov 23, 2011. http://www.dynabondpowertech.com/en/nuclear-power-news/topic-of-the-month/30-topic-of-the-month/3445-closed-cycle-cooling-technology-for-nuclear-power-plants

[4] Eisenstatt, L. R. "Generic Assessment of the Impacts of Cooling Options for the Candidate Nuclear Power Plant AP1000," 2010. https://www.ukap1000application.com/PDFDocs/Safety/UKP-GW-GL-034.pdf

[5] Eisenstatt, L. R. "Generic Assessment of the Impacts of Cooling Options for the Candidate Nuclear Power Plant AP1000," 2010. https://www.ukap1000application.com/PDFDocs/Safety/UKP-GW-GL-034.pdf

[6] Eisenstatt, L. R. "Generic Assessment of the Impacts of Cooling Options for the Candidate Nuclear Power Plant AP1000," 2010. https://www.ukap1000application.com/PDFDocs/Safety/UKP-GW-GL-034.pdf

[7] Eisenstatt, L. R. "Generic Assessment of the Impacts of Cooling Options for the Candidate Nuclear Power Plant AP1000," 2010. https://www.ukap1000application.com/PDFDocs/Safety/UKP-GW-GL-034.pdf

solubility per 1°C increase in temperature) causing many marine organisms to suffocate.[8][9] If a creature survives high temperature and lack of oxygen, it often succumbs to food shortage.

Secondary ecological considerations with OTC include biocide pollution and potential increased flow rate and turbidity. If anti-scaling chemicals or antifoulants are used along the course of the pipes in warm weather, these biocides may leach into the warmed water and cause additional, chemical pollution leading to potential toxicity in invertebrates and risk of bioaccumulation in their predators. Chlorine in the form of sodium hypochlorite is widely used.[10] Frequent cleaning is one alternative to the usage of biocides. Monitoring systems and attention to proper dosing should be employed to minimise discharge. Discharge of water as well as thermal plume may contribute to increased water flow rate.[11] If discharge interferes with sediment, turbidity may ensue.

Potentially Affected Species

Once-through cooling systems may directly or indirectly negatively affect common populations of species such as mammals, fish, benthic communities (molluscs, copepods, corals, polychaete worms, crustaceans, maerl), macroalgae, plankton, vascular plants (seagrass, marsh plants), and amphibians.[12] Daya Bay Nuclear Power base, for instance, uses more than 25 million cubic meters of water per day to cool the turbines. Calculations in Appendix B estimate that approximately 9.18 million fish and 15.3 billion fish larvae succumb to impingement and entrainment at Daya Bay every year.

These cooling systems may also indirectly negatively affect threatened species (International Union for Conservation of Nature, or IUCN, 'red-listed' species), as they depend on the smaller, common species in their diets. Improper siting of reactors in China along coasts and waterways where these species thrive might negatively affect the diets or habitats of the following red-listed species: Chinese sturgeon, Asian small-clawed otter, Steller's sea eagle, and narrow-ridged finless porpoise. (See Figure 1, Table 1, and selection criteria in Appendix A). Though the map in Figure 5 is from 2008, and is therefore not strictly current, one can see how the habitat ranges of these species overlaps with many of the planned sites.

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[8] Mihursky, et al. "Thermal Pollution, Aquaculture and Pathobiology in Aquatic Systems," Journal of Wildlife Diseases Vol. 6, October 1970. Accessed Nov 23, 2011. http://www.jwildlifedis.org/content/6/4/347.full.pdf

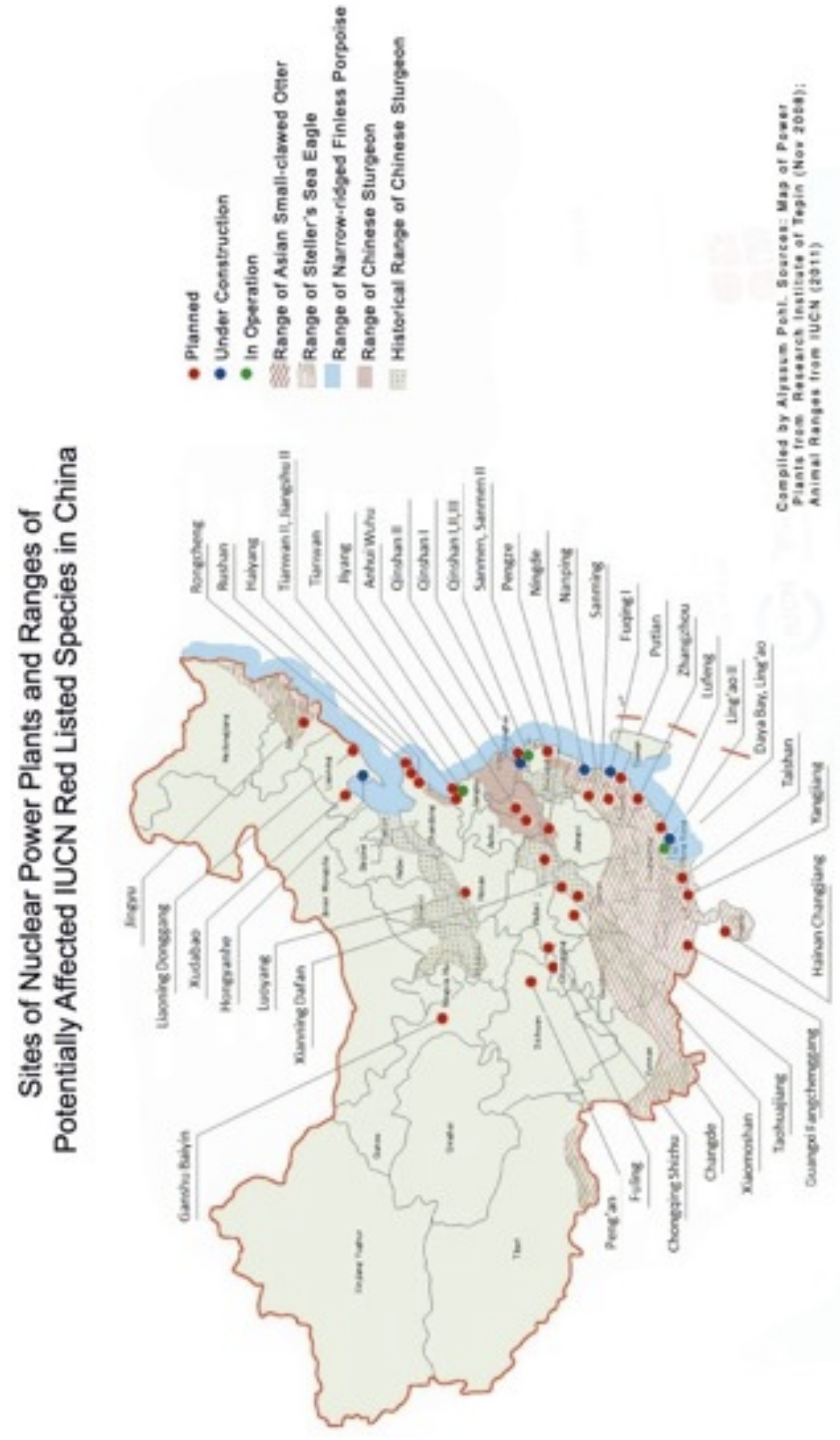
[9] Eisenstatt, L. R. "Generic Assessment of the Impacts of Cooling Options for the Candidate Nuclear Power Plant AP1000," 2010. https://www.ukap1000application.com/PDFDocs/Safety/UKP-GW-GL-034.pdf

[10] Eisenstatt, L. R. "Generic Assessment of the Impacts of Cooling Options for the Candidate Nuclear Power Plant AP1000," 2010. https://www.ukap1000application.com/PDFDocs/Safety/UKP-GW-GL-034.pdf

[11] Eisenstatt, L. R. "Generic Assessment of the Impacts of Cooling Options for the Candidate Nuclear Power Plant AP1000," 2010. https://www.ukap1000application.com/PDFDocs/Safety/UKP-GW-GL-034.pdf

[12] Eisenstatt, L. R. "Generic Assessment of the Impacts of Cooling Options for the Candidate Nuclear Power Plant AP1000," 2010. https://www.ukap1000application.com/PDFDocs/Safety/UKP-GW-GL-034.pdf

Figure 1: Sites of Nuclear Power Plants and Ranges of Potentially Affected IUCN Red-Listed Species in China[13,14]



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[13] Ejam. "Sites of Nuclear Power Plants in China," Research Institute of Tepia, modified Nov 2008, accessed Nov 23, 2011. http://www.buckinghampost.com/wp-content/uploads/2011/06/EJAM1-3-GA6-Fig.1small_Sites_of_Nuclear_Power_Plants_in_China.png

[14] IUCN Red List. Accessed Nov 23, 2011. http://www.iucn.org/about/work/programmes/species/red_list/

Table 1 : *IUCN Red-Listed Species and Specific Considerations*[15]

IUCN Red-Listed Species	Specific Considerations
Chinese Sturgeon (*Acipenser sinensis*)	Critically endangered. These sturgeon may or may not exist in the Pearl and Yangtze Rivers .[112] As anadromous fish, sturgeon spend their juvenile life in freshwater, and their adult life at sea until returning to freshwater to spawn. These sturgeon feed on zoobenthos and other bottom invertebrates, thus the food on which they depend in addition to the fish itself could be affected by side effects of OTC. Eggs and juvenile fish are more likely to be directly affected by inland, riparian nuclear power plants, though reactors situated on the sea coast may also have an indirect negative effect on adult sturgeon, assuming the food they eat are affected.
Asian Small-clawed Otter (*Aonyx cinerea*)	Vulnerable. Their habitat extends through Southern China.[112] Their diet mainly consists of crabs; thus these otters, in the vicinity of a nuclear reactor, could be negatively affected if a decrease in crabs occured due to OTC impingement, entrainment, and temperature changes.
Steller's Sea Eagle (*Haliaeetus pelagicus*)	Vulnerable. Their habitat includes a portion of Northeast China.[112] These eagles breed on sea coasts and inland near rivers or lakes. In autumn, they forage along rivers where dead salmon are abundant. If a reactor exists in these regions, the sea eagle's forage fish might decline, further threatening the birds' existence.
Narrow-ridged Finless Porpoise (*Neophocaena asiaeorientalis*)	Vulnerable.[112] They can be found in a narrow strip of water from the Taiwan Straight to Northern China, including the Yangtze River, and other rivers. These porpoises prefer waters with sandy or soft bottoms which means they likely do not inhabit the same places where nuclear power plants are cited, as plants are most often sited on bedrock.[113] However, these porpoises could be futher threatened if their diet--small fishes, cephalopods and crustaceans--were negatively affected by OTC reactors nearby their habitat.

China's Ecological Regulation Scheme Unclear

China's current legal framework was difficult to ascertain. Therefore, this is not a full examination of their ecological regulation scheme, but a summary of what information could be found.

China's State Council passed the "Medium- and Long-term Nuclear Power Development Plan (2005-2020)" on March 22, 2006,[16] which calls for future siting as well as environmental impact assessments (EIAs) on all planned nuclear power plants. In addtion to calculations regarding the doses of radioactivity that would be endured by normal operation of the plant, EIAs examine emergency management of nearby populations. It is unclear whether ecological impacts beyond radioactivity are considered.

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[15] IUCN Red List. Accessed Nov 23, 2011. http://www.iucn.org/about/work/programmes/species/red_list/

[16] Liyong, et al. "The subject deserving wide attention for nuclear power plant siting and environmental impact assessment." China Nuclear Power (No. 3 - 2009), modified November 10, 2009, accessed November 23, 2011. http://www.dynabondpowertech.com/en/nuclear-power-news/scientific-articles/116-china/2422-nuclear-power-plant-siting-and-environmental-impact-assessment.

In broader environmental legislation terms, clause 36 in Chapter IV of the P.R. China Ocean Environmental Protection Act stipulates that "effective measures shall be used to ensure the temperature of discharged water complies with the national standard of the marine environment."[17] What, exactly, the national standard indicator is remains unclear.

Whether or how well these regulations are enforced, funded or staffed, or if they are sufficient is not clear. Liu suggests that future inland nuclear power plants will utilize closed-cycle cooling systems rather than OTC. Inland plant plans are currently delayed due to concerns about polluting rivers.[18] However, it is not clear whether this is due to conducting EIAs or to some other concern.

Alternatives

California's State Water Resources Control Board has issued the Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling which require plants to stop OTC and install alternative cooling systems to reduce the impact on aquatic organisms.[19] While no such ban exists in China, mitigation strategies as well as alternative technologies can help reduce the environmental impact of OTC.

Alternative uses for waste heat could be one way to minimize thermal pollution, but given the low-grade heat of discharge water, utilizing heat customers may not be a reasonable option. Modern plants are able to return some organisms to sea with the discharge water or via a dedicated return pipe, though delicate species have low survival rates.[20] Some plants use acoustic fish deterrant systems to dissuade animals from swimming too near the abstraction pipe. This only works for animals with hearing sensitivity, and causes auditory pollution.

Two alternative cooling systems exist: substratum intake systems and closed-cycle cooling systems. The former is still in the conception phase but would filter water from the sand bed below the body of water rather than taking it directly from the body of water itself, in an attempt to mitigate entrainment and impingement.[21] The latter, whether wet or dry, through a series of heat transfers, conveys the waste heat from turbines to the atmosphere via convection and evaporation. Wasted water can be as little as 5% what would have been discharged with

[17] Liu, Rock. "Closed-Cycle Cooling Technology for Nuclear Power Plants," Nuclear Power News, Dynabond, Nov 16, 2010, accessed Nov 23, 2011. http://www.dynabondpowertech.com/en/nuclear-power-news/topic-of-the-month/30-topic-of-the-month/3445-closed-cycle-cooling-technology-for-nuclear-power-plants

[18] WNA. "Nuclear Power in China," World Nuclear Association, modified Nov 30, 2011, accessed Dec 9, 2011. http://www.world-nuclear.org/info/inf63.html

[19] Liu, Rock. "Closed-Cycle Cooling Technology for Nuclear Power Plants," Nuclear Power News, Dynabond, Nov 16, 2010, accessed Nov 23, 2011. http://www.dynabondpowertech.com/en/nuclear-power-news/topic-of-the-month/30-topic-of-the-month/3445-closed-cycle-cooling-technology-for-nuclear-power-plants.

[20] Eisenstatt, L. R. "Generic Assessment of the Impacts of Cooling Options for the Candidate Nuclear Power Plant AP1000," 2010. https://www.ukap1000application.com/PDFDocs/Safety/UKP-GW-GL-034.pdf

[21] Stoecker, Roy. "Substratum Intake System: An Innovative Water Intake System for Power Generation Facilities," Environmental Consulting Insights, accessed Dec 11, 2011. http://www.eeaconsultants.com/news/spring2004/

OTC systems, and environmental impacts are correspondingly reduced.[22] Closed-cycle systems depend on proper siting regarding wind pressure and temperature.

New designs for OTC reactors, like the AP1000 promise a significantly smaller environmental impact due to reduced flow of water utilized (See Appendix B for specific calculations and comparison to Daya Bay).

Conclusions and Recommendations

All of China's current nuclear power plants utilize OTC. Environmental risks due to entrainment, impingement, biocide and thermal pollution, and changes in water flow exist not only for common species, but potentially for threatened species. China appears to have some Environmental Impact Assessment regulation in place, but it is unclear whether this, or other environmental legislation is well staffed, funded, or enforced. Depending on the technologies chosen, China will have to deal with the risk of damaging local ecosystems as they plan and site future plants. With increasing magnitude of expansion, a one-to-one ratio of negative effects exist, assuming similar technology is used. The pace of expansion does not correlate well with environmental impact, however the ability to invent or implement new problem-mitigating technologies decreases the faster expansion occurs. Finally, siting plants in areas where they are least likely to affect threatened species, as well as choosing technologies that use less water for cooling, or that minimize entrainment and impingement are vital to minimizing China's Eisenstatt, L. R. "Generic Assessment of the Impacts of Cooling Options for the Candidate Nuclear Power Plant AP1000," 2010. https://www.ukap1000application.com/PDFDocs/Safety/UKP-GW-GL-034.pdfenvironmental impact due to nuclear expansion. Regulatory oversight, implementation, and enforcement to support these types of decisions is necessary, but the reality of these aspects existence are unclear.

[22] Liu, Rock. "Closed-Cycle Cooling Technology for Nuclear Power Plants," Nuclear Power News, Dynabond, Nov 16, 2010, accessed Nov 23, 2011. http://www.dynabondpowertech.com/en/nuclear-power-news/topic-of-the-month/30-topic-of-the-month/3445-closed-cycle-cooling-technology-for-nuclear-power-plants.

Appendix A: IUCN Red List Search criteria:

Show taxa: Species

Search by location:

- East Asia
- Indian Ocean – eastern
- North Asia
- Pacific – northwest
- Pacific – southwest,
- Pacific – western central

Search by systems:

- Freshwater
- Marine
- Terrestrial

Match any threat:

- 3.3. Renewable energy
- 7.2.2. Abstraction of surface water (commercial use)
- 7.2.6. Abstraction of ground water (commercial use)
- 7.3. Other ecosystem modifications
- 9.6.2. Thermal pollution
- 9.6.4. Type Unknown/Unrecorded

Search by assessment:

- Categories: EX, EW, CR, EN, VU, DD

Appendix B: Rough Calculations

KNOWN

Daya Bay= 25 million m^3 water/day[23]
San Onofre Nuclear Generating Station (SONGS)= 2587 million gallons water/day * m^3/264.17 gallons= 9.8 million m^3 water/day[24]
3.6 million fish killed by SONGS in 2003
6 billion fish larvae killed/year at SONGS
Future possible plants:
AP1000 will be cooled by a flow of 3.27 million m^3 water/day[25]

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CALCULATIONS

To get a general sense of the scale of impact, assume 1:1 ratio of biota killed to volume of water utilized.

Daya Bay	AP1000
Daya Bay : SONGS 25 : 9.8 **2.55 : 1**	AP1000 : SONGS 3.27 : 9.8 **0.334 : 1**
3.6 million fish killed/year at SONGS * 2.55 Daya Bay/SONGS = **9.18 million fish killed by Daya Bay/year**	3.6 million fish killed/year at SONGS * 0.334 AP1000/SONGS = **1.2 million fish killed by AP1000/year**
6 billion fish larvae killed/year at SONGS * 2.55 Daya Bay/SONGS = **15.3 billion fish larvae killed by Daya Bay/year**	6 billion fish larvae killed/year at SONGS * 0.334 AP1000/SONGS = **2 billion fish larvae killed by AP1000/year**

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[23] Liu, Rock. "Closed-Cycle Cooling Technology for Nuclear Power Plants," Nuclear Power News, Dynabond, Nov 16, 2010, accessed Nov 23, 2011. http://www.dynabondpowertech.com/en/nuclear-power-news/topic-of-the-month/30-topic-of-the-month/3445-closed-cycle-cooling-technology-for-nuclear-power-plants

[24] Liu, Rock. "Closed-Cycle Cooling Technology for Nuclear Power Plants," Nuclear Power News, Dynabond, Nov 16, 2010, accessed Nov 23, 2011. http://www.dynabondpowertech.com/en/nuclear-power-news/topic-of-the-month/30-topic-of-the-month/3445-closed-cycle-cooling-technology-for-nuclear-power-plants

[25] Eisenstatt, L. R. "Generic Assessment of the Impacts of Cooling Options for the Candidate Nuclear Power Plant AP1000," 2010. https://www.ukap1000application.com/PDFDocs/Safety/UKP-GW-GL-034.pdf