

DAFTAR PUSTAKA

- [1] J. Hansen *et al.*, “Climate impact of increasing atmospheric carbon dioxide,” *Science* (80-.), vol. 213, no. 4511, pp. 957–966, Aug. 1981.
- [2] J. Hansen *et al.*, “Ice melt, sea level rise and superstorms: Evidence from paleoclimate data, climate modeling, and modern observations that 2 °c global warming could be dangerous,” *Atmos. Chem. Phys.*, vol. 16, no. 6, pp. 3761–3812, Mar. 2016.
- [3] D. K. Ray, P. C. West, M. Clark, J. S. Gerber, A. V. Prishchepov, and S. Chatterjee, “Climate change has likely already affected global food production,” *PLoS One*, vol. 14, no. 5, p. e0217148, May 2019.
- [4] M. Springmann *et al.*, “Global and regional health effects of future food production under climate change: A modelling study,” *Lancet*, vol. 387, no. 10031, pp. 1937–1946, May 2016.
- [5] O. Hoegh-Guldberg *et al.*, “Coral reefs under rapid climate change and ocean acidification,” *Science (New York, N.Y.)*, vol. 318, no. 5857. American Association for the Advancement of Science, pp. 1737–1742, 14-Dec-2007.
- [6] J. Cook *et al.*, “Quantifying the consensus on anthropogenic global warming in the scientific literature,” *Environ. Res. Lett.*, vol. 8, no. 2, p. 024024, May 2013.
- [7] Government of Indonesia, *Presidential Decree No. 22 Year 2017 on National Energy Masterplan*. 2017.
- [8] J. Hansen *et al.*, “Young people’s burden: Requirement of negative CO2 emissions,” *Earth Syst. Dyn.*, vol. 8, no. 3, pp. 577–616, Jul. 2017.
- [9] D. Tong *et al.*, “Committed emissions from existing energy infrastructure jeopardize 1.5 °C climate target,” *Nature*, vol. 572, no. 7769, pp. 373–377, Aug. 2019.
- [10] M. Maulidia, P. Dargusch, P. Ashworth, and F. Ardiansyah, “Rethinking renewable energy targets and electricity sector reform in Indonesia: A private sector perspective,” *Renew. Sustain. Energy Rev.*, vol. 101, pp. 231–247, 2019.
- [11] P. A. Kharecha and J. E. Hansen, “Prevented mortality and greenhouse gas emissions from historical and projected nuclear power,” *Environ. Sci. Technol.*, vol. 47, no. 9, pp. 4889–4895, 2013.
- [12] S. Hong, C. J. A. Bradshaw, and B. W. Brook, “South Korean energy scenarios show how nuclear power can reduce future energy and environmental costs,” *Energy Policy*, vol. 74, no. C, pp. 569–578, 2014.
- [13] S. A. Qvist and B. W. Brook, “Environmental and health impacts of a policy to phase out nuclear power in Sweden,” *Energy Policy*, vol. 84, pp. 1–10, 2015.
- [14] S. Hong, S. Qvist, and B. W. Brook, “Economic and environmental costs of replacing nuclear fission with solar and wind energy in Sweden,” *Energy Policy*, vol. 112, no. January, pp. 56–66, 2018.
- [15] J. Serp *et al.*, “The molten salt reactor (MSR) in generation IV: Overview and perspectives,” *Prog. Nucl. Energy*, vol. 77, pp. 308–319, 2014.
- [16] O. Ashraf, A. Rykhlevskii, G. V Tikhomirov, and K. D. Huff, “Strategies for thorium fuel cycle transition in the SD-TMSR,” *Ann. Nucl. Energy*, vol. 148, p. 107656, 2020.
- [17] B. Hombourger, J. Křepel, and A. Pautz, “The EQL0D fuel cycle procedure and its application to the transition to equilibrium of selected molten salt reactor designs,” *Ann. Nucl. Energy*, vol. 144, p. 107504, 2020.
- [18] C. Y. Zou, C. Z. Cai, C. G. Yu, J. H. Wu, and J. G. Chen, “Transition to thorium

- fuel cycle for TMSR,” *Nucl. Eng. Des.*, vol. 330, pp. 420–428, 2018.
- [19] C. Zou, G. Zhu, C. Yu, Y. Zou, and J. Chen, “Preliminary study on TRUs utilization in a small modular Th-based molten salt reactor (smTMSR),” *Nucl. Eng. Des.*, vol. 339, no. April, pp. 75–82, 2018.
- [20] V. Ignatiev *et al.*, “Molten salt actinide recycler and transforming system without and with Th-U support: Fuel cycle flexibility and key material properties,” *Ann. Nucl. Energy*, vol. 64, pp. 408–420, 2014.
- [21] O. Ashraf and G. V. Tikhomirov, “Thermal-and fast-spectrum molten salt reactors for minor actinides transmutation,” *Ann. Nucl. Energy*, vol. 148, p. 107751, 2020.
- [22] C. Yu *et al.*, “Minor actinide incineration and Th-U breeding in a small FLiNaK Molten Salt Fast Reactor,” *Ann. Nucl. Energy*, vol. 99, pp. 335–344, Jan. 2017.
- [23] C. Zou, C. Yu, J. Wu, X. Cai, and J. Chen, “Ameliorating the positive temperature feedback coefficient for an MSR fueled with transuranic elements,” *Ann. Nucl. Energy*, vol. 160, p. 108325, 2021.
- [24] L. Jorgensen and J. Devanney, “Using ThorCon to Downgrade Weapons Grade Plutonium,” 2016.
- [25] V. T. Tran, H. N. Tran, H. T. Nguyen, V. K. Hoang, and P. N. V. Ha, “Study on Transmutation of Minor Actinides as Burnable Poison in VVER-1000 Fuel Assembly,” *Sci. Technol. Nucl. Install.*, vol. 2019, 2019.
- [26] E. Cuoc, E. Shwageraus, A. Kasam, and I. Scott, “Core design of breed & burn molten salt fast reactor,” in *EPJ Web of Conferences*, 2021, vol. 247, p. 01004.
- [27] G. C. Li *et al.*, “Optimization of Th-U fuel breeding based on a single-fluid double-zone thorium molten salt reactor,” *Prog. Nucl. Energy*, vol. 108, pp. 144–151, 2018.
- [28] O. Ashraf, A. Rykhlevskii, G. V. Tikhomirov, and K. D. Huff, “Whole core analysis of the single-fluid double-zone thorium molten salt reactor (SD-TMSR),” *Ann. Nucl. Energy*, vol. 137, p. 107115, 2020.
- [29] L. Mathieu *et al.*, “The thorium molten salt reactor: Moving on from the MSBR,” *Prog. Nucl. Energy*, vol. 48, no. 7, pp. 664–679, 2006.
- [30] H. G. MacPherson, “Molten Salt Reactor Adventure,” *Nucl. Sci. Eng.*, vol. 90, no. 4, pp. 374–380, 1985.
- [31] D. LeBlanc, “Molten salt reactors: A new beginning for an old idea,” *Nucl. Eng. Des.*, vol. 240, no. 6, pp. 1644–1656, 2010.
- [32] J. Křepel *et al.*, “Fuel cycle advantages and dynamics features of liquid fueled MSR,” *Ann. Nucl. Energy*, vol. 64, pp. 380–397, 2014.
- [33] J. Wu *et al.*, “A novel concept for a molten salt reactor moderated by heavy water,” *Ann. Nucl. Energy*, vol. 132, pp. 391–403, 2019.
- [34] D. Heuer, E. Merle-Lucotte, M. Allibert, M. Brovchenko, V. Ghetta, and P. Rubiolo, “Towards the thorium fuel cycle with molten salt fast reactors,” *Ann. Nucl. Energy*, vol. 64, pp. 421–429, 2014.
- [35] L.-Y. He, G.-C. Li, S.-P. Xia, J.-G. Chen, Y. Zou, and G.-M. Liu, “Effect of ^{37}Cl enrichment on neutrons in a molten chloride salt fast reactor,” *Nucl. Sci. Tech.*, vol. 31, no. 3, p. 27, 2020.
- [36] L. Y. He *et al.*, “Th-U cycle performance analysis based on molten chloride salt and molten fluoride salt fast reactors,” *Nucl. Sci. Tech.*, vol. 31, no. 8, 2020.
- [37] Y. Jeong, J. Park, H. C. Lee, and D. Lee, “Equilibrium core design methods for molten salt breeder reactor based on two-cell model,” *J. Nucl. Sci. Technol.*, vol. 53, no. 4, pp. 529–536, 2016.
- [38] A. Rykhlevskii, J. W. Bae, and K. D. Huff, “Modeling and simulation of online

- reprocessing in the thorium-fueled molten salt breeder reactor,” *Ann. Nucl. Energy*, vol. 128, pp. 366–379, 2019.
- [39] C. Zou, C. Yu, J. Wu, X. Cai, and J. Chen, “Transition to thorium fuel cycle in a small modular molten salt reactor based on a batch reprocessing mode,” *Ann. Nucl. Energy*, vol. 138, p. 107163, 2020.
- [40] B. M. Elsheikh, “Safety assessment of molten salt reactors in comparison with light water reactors,” *J. Radiat. Res. Appl. Sci.*, vol. 6, no. 2, pp. 63–70, 2013.
- [41] V. Singh, M. R. Lish, O. Chvála, and B. R. Upadhyaya, “Dynamics and control of molten-salt breeder reactor,” *Nucl. Eng. Technol.*, vol. 49, no. 5, pp. 887–895, 2017.
- [42] K. Furukawa *et al.*, “A road map for the realization of global-scale thorium breeding fuel cycle by single molten-fluoride flow,” *Energy Convers. Manag.*, vol. 49, no. 7, pp. 1832–1848, 2008.
- [43] M. Ifthacharo, S. Permana, and G. Saputra, “A Comparative Study of Th-U233 and Th-Pu Molten-Salt Reactor (MSR) with 2-region core,” *J. Phys. Conf. Ser.*, vol. 1493, no. 1, pp. 0–8, 2020.
- [44] I. K. Aji, S. Pramuditya, Novitrian, D. Irwanto, and A. Waris, “Delayed Neutrons Effect on Power Reactor with Variation of Fluid Fuel Velocity at MSR Fuji-12,” in *Journal of Physics: Conference Series*, 2017, vol. 799, p. 012004.
- [45] S. Q. Jaradat and A. B. Alajo, “Studies on the liquid fluoride thorium reactor: Comparative neutronics analysis of MCNP6.2 code with SRAC95 reactor analysis code based on FUJI-U3-(0),” *Nucl. Eng. Des.*, vol. 314, pp. 251–255, 2017.
- [46] C. Wulandari, A. Waris, S. Permana, and S. Pramuditya, “Plutonium and Minor Actinides Utilization in FUJI-U1 Molten Salt Reactor,” in *Journal of Physics: Conference Series*, 2019, vol. 1204, no. 1, p. 012132.
- [47] A. W. Harto, “Passive Compact Molten Salt Reactor (PCMSR), modular thermal breeder reactor with totally passive safety system,” in *AIP Conference Proceedings*, 2012, vol. 1448, no. 2012, pp. 82–95.
- [48] A. W. Harto, “Sustainable criticality analysis of PCMSR fuel using thorium as sustainable fuel and low enriched uranium as starting fuel,” *Int. J. Nucl. Energy Sci. Technol.*, vol. 9, no. 3, pp. 224–237, 2015.
- [49] A. W. Harto, “Nuclide composition analysis of PCMSR fuel using thorium as sustainable fuel and low enrich uranium as starting fuel,” *ARPJ. Eng. Appl. Sci.*, vol. 11, no. 6, pp. 3993–4000, 2016.
- [50] A. W. Harto, “Study on the Ability of PCMSR to Produce Valuable Isotopes as a By Product of Energy Generation,” *Indones. J. Phys. Nucl. Appl.*, vol. 3, no. 1, pp. 7–14, 2018.
- [51] D. Heuer, E. Merle-Lucotte, M. Allibert, M. Brovchenko, V. Ghetta, and P. Rubiolo, “Towards the thorium fuel cycle with molten salt fast reactors,” *Ann. Nucl. Energy*, vol. 64, pp. 421–429, Feb. 2014.
- [52] M. Allibert *et al.*, “Preliminary proliferation study of the molten salt fast reactor,” *EPJ Nucl. Sci. Technol.*, vol. 6, no. 5, pp. 1–7, 2020.
- [53] M. Santanoceto, M. Tibergh, Z. Perkó, S. Dulla, and D. Lathouwers, “Preliminary uncertainty and sensitivity analysis of the Molten Salt Fast Reactor steady-state using a Polynomial Chaos Expansion method,” *Ann. Nucl. Energy*, vol. 159, p. 108311, 2021.
- [54] C. Yu *et al.*, “Analysis of minor actinides transmutation for a Molten Salt Fast Reactor,” *Ann. Nucl. Energy*, vol. 85, pp. 597–604, Nov. 2015.
- [55] H. Liaoyuan, X. Shaopeng, C. Jingen, L. Guimin, W. Jianhui, and Z. Yang, “Th-

- U Breeding Performances in an Optimized Molten Chloride Salt Fast Reactor,” *Nucl. Sci. Eng.*, vol. 00, no. 00, pp. 1–18, 2020.
- [56] L. Y. He *et al.*, “Th–U cycle performance analysis based on molten chloride salt and molten fluoride salt fast reactors,” *Nucl. Sci. Tech.*, vol. 31, no. 8, pp. 1–13, 2020.
- [57] B. Liu, R. Jia, R. Han, X. Lyu, J. Han, and W. Li, “Minor actinide transmutation characteristics in AP1000,” *Ann. Nucl. Energy*, vol. 115, pp. 116–125, May 2018.
- [58] J. Washington and J. King, “Optimization of plutonium and minor actinide transmutation in an AP1000 fuel assembly via a genetic search algorithm,” *Nucl. Eng. Des.*, vol. 311, pp. 199–212, Jan. 2017.
- [59] B. Liu, J. Han, F. Liu, J. Sheng, and Z. Li, “Minor actinide transmutation in the lead-cooled fast reactor,” *Prog. Nucl. Energy*, vol. 119, p. 103148, Jan. 2020.
- [60] T. Takeda, “Minor actinides transmutation performance in a fast reactor,” *Ann. Nucl. Energy*, vol. 95, pp. 48–53, Sep. 2016.
- [61] T. Kooyman, L. Buiron, and G. Rimpault, “Optimization of minor actinide-bearing radial blankets for heterogeneous transmutation in fast reactors,” *Nucl. Sci. Eng.*, vol. 185, no. 2, pp. 335–350, 2017.
- [62] K. Allen and T. Knight, “Destruction rate analysis of transuranic targets in sodium-cooled fast reactor (SFR) assemblies using MCNPX and SCALE 6.0,” *Prog. Nucl. Energy*, vol. 52, no. 4, pp. 387–394, May 2010.
- [63] H. N. Tran, Y. Kato, P. H. Liem, V. K. Hoang, and S. M. T. Hoang, “Minor Actinide Transmutation in Supercritical-CO₂-Cooled and Sodium-Cooled Fast Reactors with Low Burnup Reactivity Swings,” *Nucl. Technol.*, vol. 205, no. 11, pp. 1460–1473, Nov. 2019.
- [64] M. B. Setiawan, S. Kuntjoro, I. Husnayani, P. M. Udiyani, and T. Surbakti, “Evaluation on transmutation of minor actinides discharged from PWR spent fuel in the RSG-GAS research reactor,” *Malaysian J. Fundam. Appl. Sci.*, vol. 15, no. 4, pp. 577–579, 2019.
- [65] R. A. P. Dwijayanto and M. Alfarisie, “Preliminary Study on Minor Actinide Incineration in RSG-GAS without Isotope Separation,” *GANENDRA Maj. IPTEK Nukl.*, vol. 21, no. 2, pp. 85–92, 2021.
- [66] A. Waris, I. K. Aji, S. Pramuditya, Widayani, and D. Irwanto, “Preliminary Study on LiF₄-ThF₄-PuF₄ Utilization as Fuel Salt of miniFUJI Molten Salt Reactor,” in *Journal of Physics: Conference Series*, 2016, vol. 739, p. 012004.
- [67] A. Waris, I. K. Aji, S. Pramuditya, Novitrian, S. Permana, and Z. Su’Ud, “Comparative Studies on Plutonium and Minor Actinides Utilization in Small Molten Salt Reactors with Various Powers and Core Sizes,” *Energy Procedia*, vol. 71, pp. 62–68, 2015.
- [68] A. Waris, V. Richardina, I. K. Aji, S. Permana, and Z. Su’Ud, “Preliminary study on plutonium and minor actinides utilization in thorims-nes minifuji reactor,” *Energy Convers. Manag.*, vol. 72, pp. 27–32, 2013.
- [69] O. Ashraf and G. V. Tikhomirov, “A methodology for evaluating the transmutation efficiency of long-lived minor actinides,” *Nucl. Eng. Des.*, vol. 377, p. 111128, 2021.
- [70] R. A. P. Dwijayanto and D. P. Hermawan, “Investigation on Inherent Safety of One Fluid-Molten Salt Reactor (OF-MSR) with Various Starting Fuel,” *Tri Dasa Mega*, vol. 22, no. 2, pp. 54–60, May 2020.
- [71] R. A. P. Dwijayanto, D. P. Hermawan, and A. W. Harto, “Preliminary Investigation on Neutronic Performance of Pu-started One Fluid-Molten Salt Reactor,” in *Prosiding Seminar Nasional Teknologi Energi Nuklir 2020*, 2020,

pp. 141–147.

- [72] J. R. Lamarsh, *Introduction To Nuclear Reactor Theory*. Boston: Addison-Wesley Publishing, 1966.
- [73] J. J. Duderstadt and L. J. Hamilton, *Nuclear Reactor Analysis*. New York: John Wiley and Sons, 1976.
- [74] C. Y. Zou *et al.*, “Optimization of temperature coefficient and breeding ratio for a graphite-moderated molten salt reactor,” *Nucl. Eng. Des.*, vol. 281, pp. 114–120, 2015.
- [75] Zuhair, Suwoto, T. Setiadipura, and J. C. Kuijper, “The effects of fuel type on control rod reactivity of pebble-bed reactor,” *Nukleonika*, vol. 64, no. 4, pp. 131–138, 2019.
- [76] Zuhair, Suwoto, T. Setiadipura, and Z. Su’ud, “Study on MCNP6.2 model in the calculation of kinetic parameters for pebble bed reactor,” *Acta Polytech.*, vol. 60, no. 2, pp. 175–184, 2020.
- [77] M. L. Fensin and M. Umbel, “Testing actinide fission yield treatment in CINDER90 for use in MCNP6.2 burnup calculations,” *Prog. Nucl. Energy*, vol. 85, pp. 719–728, 2015.
- [78] D. B. Pelowitz *et al.*, “MCNP6.2 User’s Manual,” 2013.
- [79] R. A. P. Dwijayanto, I. Husnayani, and Zuhair, “Characteristics of Radionuclides on Thorium-Cycle Experimental Power Reactor Spent Fuel,” *Urania J. Ilm. Daur Bahan Bakar Nukl.*, vol. 25, no. 2, pp. 127–140, Jun. 2019.
- [80] I. Husnayani and P. M. Udiyani, “Radionuclide Characteristics of RDE Spent Fuels,” *Tri Dasa Mega*, vol. 20, no. 2, pp. 69–76, 2018.
- [81] R. A. P. Dwijayanto, I. Husnayani, and Zuhair, “Assessing the OTTO Option: Thorium-Cycle Experimental Power Reactor Spent Fuel Characteristics,” *J. Sains dan Teknol. Nukl. Indones.*, vol. 21, no. 1, pp. 11–24, Feb. 2020.
- [82] A. Waris, I. K. Aji, S. Pramuditya, Novitrian, S. Permana, and Z. Su’ud, “Comparative Studies on Plutonium and Minor Actinides Utilization in Small Molten Salt Reactors with Various Powers and Core Sizes,” *Energy Procedia*, vol. 71, pp. 62–68, 2015.
- [83] S. Q. M. Jaradat, “Impact of thorium based molten salt reactor on the closure of the nuclear fuel cycle,” Missouri University of Science and Technology, 2015.
- [84] B. Liu, J. Han, F. Liu, J. Sheng, and Z. Li, “Minor actinide transmutation in the lead-cooled fast reactor,” *Prog. Nucl. Energy*, vol. 119, 2020.
- [85] K. F. Ma, C. G. Yu, X. Z. Cai, C. Y. Zou, and J. G. Chen, “Transmutation of ¹²⁹I in a single-fluid double-zone thorium molten salt reactor,” *Nucl. Sci. Tech.*, vol. 31, no. 1, pp. 1–12, 2020.
- [86] D. Moser, A. Wheeler, and O. Chvála, “Lattice optimization for graphite moderated molten salt reactors using low-enriched uranium fuel,” *Ann. Nucl. Energy*, vol. 110, pp. 1–10, 2017.
- [87] D. Hartanto, A. Alshamsi, A. Alsuwaidi, A. Bilkhair, H. A. Hukal, and M. Zubair, “Neutronics Assessment of Accident-Tolerant Fuel in Advanced Power Reactor 1400 (APR1400),” *Atom Indones.*, vol. 46, no. 3, pp. 177–186, 2020.
- [88] J. Park, Y. Jeong, H. C. Lee, and D. Lee, “Whole core analysis of molten salt breeder reactor with online fuel reprocessing,” *Int. J. Energy Res.*, vol. 39, pp. 1673–1680, 2015.
- [89] R. A. P. Dwijayanto, M. R. Oktavian, M. Y. A. Putra, and A. W. Harto, “Model Comparison of Passive Compact-Molten Salt Reactor Neutronic Design Using MCNP6.2 and Serpent-2,” *Atom Indones.*, vol. 47, no. 3, 2021.



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