

Koroush SHIRVAN

Atlantic Richfield Career Development Professor in Energy Studies

Nuclear Innovation in Fission Technologies

Co-Director of RTC for Utility Executives

Executive Director of ATF IRP

PI of MIT ARC-20 ARDP Project

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EDUCATION

Sept. 2012 **Ph.D. Nuclear Science and Engineering**
Massachusetts Institute of Technology, Cambridge, Massachusetts
Major: Reactor Design and Analysis
Minor: Probabilistic Risk Assessment

Ph.D. Dissertation Title: Development of Optimized Core Design and Analysis
Methods for High Power Density BWRs
Ph.D. Supervisor: Professor Mujid Kazimi (late)

May 2010 **Masters of Science in Nuclear Science and Engineering**
Massachusetts Institute of Technology, Cambridge, Massachusetts

MS Thesis Title: Optimization of Small Integral Light Water Reactors
MS Supervisor: Professor Mujid Kazimi (late)

May 2008 **Bachelor of Science in Nuclear Engineering**
University of Florida, Gainesville, Florida
Graduated with Summa Cum Laude (Highest Honors)

WORK EXPERIENCE

Sept 2008 – Sept 2012	Research / Teaching Assistant
Sept 2012 – Dec 2016	Research Scientist
Jan 2017 – June 2017	Principal Scientist
July 2017 – June 2022	Assistant Professor
July 2019 – June 2023	John Clark Hardwick (1986) Career Development Professor
July 2022 – Present	Associate Professor
July 2023 – Present	Atlantic Richfield Career Development Professor in Energy Studies
	Center for Advanced Nuclear Energy Systems (CANES)
	Department of Nuclear Engineering
	Massachusetts Institute of Technology

Research Activities

Research work primarily includes integrated modeling and simulation (M&S) informed experimentation, advanced data analytics and their applications for advanced reactor technology. Specific recent research/education responsibilities include:

- Present: Supervise 12 PhD, 6 Masters, 1 Post-Docs and 5 research scientists.
- 2022-Present: **Executive Director of MITR ATF** (Accident Tolerant Fuel) IRP on in-pile and out-of-pile testing of coated Zircaloy and SiC/SiC cladding to study impact of water chemistry, CRUD and irradiation on ATF normal operation in collaboration with all nuclear vendors in the U.S.
- 2022-Present: PI of **ATF impact on SMR** (Small Modular Reactors) Safety and Performance in collaboration with NuScale, Lightbridge, Holtec, Rolls-Royce and GE-Hitachi.
- 2022-Present: Co-PI of Requirements for Nuclear Reactors for decarbonization of oil/gas industry and **lead nuclear designer of cost-effective microreactor** technology in collaboration with EDF, ExxonMobil, Shell and Equinor.
- 2022-Present: Co-PI and Lead on cost of **Graphite Disposal** for Advanced Reactors including development of a tool to support advanced reactor fuel cycle backend and decommissioning supported by DOE IRP grant.
- 2021-Present: **PI of ARC-20 DOE Award as part of ARDP** (Advanced Reactor Demonstration Program) on Horizontal High Temperature Gas Reactor Design to reduce both Cost and Construction Risk in collaboration with University of Michigan, Buffalo and Argonne National Lab.
- 2020-Present: **PI of nuclear thermal propulsion fuel** accelerated testing funded by NASA focused on construction and deployment of high temperature (>2000 K) facility under hydrogen flow inside the MIT reactor.
- 2020-2023: PI of use of **additive manufacturing** for nuclear energy including high-fidelity analysis and uncertainty quantification of the transformational challenge reactor concepts funded by DOE NEUP and multi-component nanostructured fast reactor cladding funded by Plasma Processes under DOE SBIR.
- 2020-Present: **PI of Compact Steam Generator (CSG)** development for advanced reactor applications, by focusing on two-phase flow dynamics in small diameter channels funded by DOE NEUP.
- 2020-Present: **Co-PI of ARPA-E GEMINA** grants to lower the operation and maintenance of advanced reactor through use of digital twinning and rethinking the lifetime of structures and components (including **optimization of nuclear waste management**).
- 2020-Present: PI of development of **economic tool** for small modular reactor cost and uncertainty assessment (LWRs) funded by Fortum. The tool has been **open-sourced** < <https://github.com/mit-crpg/TIMCAT>> and cited in various nuclear energy studies.
- 2019-Present: **PI of development of reinforcement learning (RL) code package for core design optimization** (PWRs and BWRs) funded by Exelon/Constellation. The software is in active use by industry. The RL hybrid algorithms have been open-sourced: < <https://neorl.readthedocs.io/en/latest/>>
- 2019-2022: Co-PI of development of fiber optics sensors for advanced reactors, focusing on implications for fast MSRs funded by ARPA-E and led by NETL.
- 2018-2021: **PI of optimization of EDF Small Modular Reactor** focusing on improving Economics, Safety and deployment.
- 2018-2021: PI of ATF-FLEX NEUP focused on combining ATF and FLEX technologies to improve plant coping time.
- 2018-2021: Co-PI of impact of equipment based seismic isolation on advanced reactor economics funded by ARPA-E and led by University of Buffalo.

- 2015-2019: **Executive Director of Accident Tolerant Fuel Integrated Research Project** – Responsible for project organization involving multiple universities and industry partners. Technical lead on both experimental and simulation effort at MIT related to coated Zircaloy cladding with Chromium and Moly/FeCrAl and fuel with additives/dopants. Simulation work is focused on development of ATF material models and their validation in TRACE and MOOSE/BISON tools.
- 2015-2022: Principal Investigator of Fuel-in-Fiber Concept (SBIR subcontract) – Responsible for project on use of additive manufacturing technique to produce high purity SiC fibers and allow online fuel deposition to produce more compact TRISO-type fuel. Work involves investigating SiC fibers corrosion performance in autoclave and characterize their mechanical behavior to inform M&S models to design an optimum new fuel concept.
- 2015-16: PI of Uranium Nitride fuel performance for AP1000 (ExxonMobil)
- 2015-16: PI of Thorium-Plutonium fuel performance (Lockheed-Martin).
- 2012-2020: Reduced Moderated Boiling Water Reactor Safety Assessment (DOE NEUP, HITACHI-GE Nuclear) – Responsible for code development capability for system level safety and stability assessment and fuel performance of MOX fuel.
- 2012-Present: SiC clad for LWRs (CTP, Lockheed Martin, Westinghouse, General Atomics, Plasma Pros) – Responsible for the R&D of the ceramic matrix composite SiC cladding and coated composite cladding.
- 2013-2020: Chair of MIT CASL (simulation hub) Education activities – Responsible for development of fuel performance education material with MOOSE/BISON and co-organizer of a two week CASL school covering multi-physics simulation topics.
- Development of reactor system and perform safety analysis for nuclear reactors including BWRs, PWRs, Small Modular Reactors, Sodium and Lead Bismuth Fast Reactors and Light Water Breeders.
- Performing both Validation through experimentation and Verification through high fidelity simulation in areas of thermal hydraulics and fuel performance.
- Development of methodology for design of Light Water Reactor (LWR) cores using coupled multi-physics analysis.
- Power cycle optimization including Rankine and Supercritical CO₂ cycles
- Development of single and two-phase CFD and empirical models for performance analysis of nuclear fuels and safety systems.
- Development of methods for BWR two-phase stability in both frequency/ time domains.
- Technology selection of nuclear reactor concepts for different energy applications.

May 2007 – August 2008

**Core Design Intern
Southern Nuclear Company
Birmingham, Alabama**

PWR Core Analysis, Summer 2008

- Worked extensively on PWR Pellet Clad Interaction risk assessment and created new methodologies to analyze fuel performance during power changes.

Plant Vogtle Core Analysis, Summer 2007

- Created a new core design methodology used by industry to reduce CRUD deposition on fuel rods through utilization of neutronics, thermal hydraulics and plant chemistry assessment tools.

Teaching Experience

Teaching Instructor

Fall 14/Spring 18-21 MIT Nuclear Engineering 22.06: Engineering of Nuclear Systems

Fall 15/17 MIT Nuclear Engineering 22.033: Undergraduate Design (co-Instructor)

Spring 2016 MIT Mechanical Engineering 2.006: Fluids/Heat transfer (Recitation Ins.)

Fall 2017/19-23 MIT Nuclear Engineering 22.39: Nuclear Reactor Design and Safety

Spring 2022 MIT Nuclear Engineering 22.251: Nuclear Fuel Cycle

Instructor of several professional courses on nuclear technology for executives and nuclear community including RTC by INPO and MeV School.

SKILLS/EXPERIENCE

- Computer and Computational

- CANES Manager of Computer Software Repository and Cluster Systems
- Proficient in Fortran language and familiar with Python, C++, C#, Xml, JAVA, Visual Basic, Maple, Matlab, MOOSE, Goldsim, GNU, CMake, HDF5, git
- Open Source Software Development: NEORL ([GitHub](#)), TIMCAT ([GitHub](#))
- Expert User of major Nuclear Engineering modeling, analysis and licensing codes including:
 - **Radiation Transport:** ANC, CASMO, SIMULATE, S3K, MCNP5/X, SERPENT, SCALE, PARTISN, DRAGON, ROSA, MPACT, PARCS
 - **Thermal Hydraulics/CFD:** RETRAN, RELAP, TRACE, VIPRE, COBRA, MAAP, MELCOR, TRANSAT, FLUENT, CFX, STARCCM+, ASPEN
 - **Structural Materials and Nuclear Fuel:** ABAQUS, BOA, FRAPCON, FRAPTRAN, MOOSE, BISON, FALCON, SOLID WORKS, ADINA

- Experimental

- Design and conduct experiments with high temperature/pressure/voltage/radiation (in-reactor, ion, gamma)
- Materials characterization using Scanning Electron Microscopy (SEM), Focused Ion Beam (FIB) milling, energy-dispersive X-ray spectroscopy (EDX)

PROFESSIONAL ACTIVITIES

Symposium Co-Chair, Nuclear Fuel Modeling, TMS 2025	2023-Present
Assistant Technical Program Chair, Mathematics and Computation, ANS	2023-Present
Program Committee Member, CANES Symposium-Nuclear Everywhere	2023
Technical Program Member, PHYSOR 2023 and 2024	2022-Present
Technical Program Member, Advanced Reactor Safety	2022-Present
Compact Steam Generator Workshop, Lead Organizer	2022
MIT Climate Policy Working Group, Member	2022-Present
NEI Task Force for Power Uprate, Co-Organizer	2022-Present
Nuclear in District Application EPRI Working Group, Member	2022-Present
Clean Core Thorium Energy, Head of Fuel Design	2022-Present
Advisory Board Member, NUWARD TM Delivery Model	2022-Present
Scientific Advisory Board Member, SMR for an Eu Energy Mix (TANDEM)	2022-Present
PHYSOR Fuel Management Track Leader	2022
Advisory Board Member, DOE Industry FOA on Seismic Isolation	2021-Present
Constellation, Independent Contractor	2021-Present
NAC's Nuclear Fuel Manufacturing Oversight Certificate	2021
Probabilistic Safety Assessment Technical Program Committee	2021
American Nuclear Society Annual Meeting Asst. Tech. Prog. Chair	2021
MIT Reactor Safety Committee Member	2020-Present
American Nuclear Society Task Force on R&D Needs	2020-2021
Assistant Technical Program Chair for ICAPP Conference	2018
Organizer, Identifying Failure Modes of ATF Concepts Workshop	2018

American Society of Mechanical Engineers Member	2018-Present
Completed Multiphysics Model Validation Workshop	2017
Organizer, Modeling and Simulation of Near Term ATF Workshop	2017
American Ceramic Society, Member	2017-Present
American Society of Mechanical Engineers, Member	2017-Present
American Nuclear Society National/Annual Meeting Reviewer for 5 Tracks	2017-Present
Co-Director of Reactor Technology Course (RTC) for Utility Executives	2016-Present
Technical Program Committee for Nuclear Innovation Bootcamp	2016-2018
Director of Accident Tolerant Fuel (ATF) DOE Integrated Research Project	2015-2018
Technical Program Member, Int. Conf. on Advanced Ceramics & Composites	2015
Technical Advanced Reactor Track Leader for ICAPP Conference	2015
Member, EPRI Gen-IV Reactor Group	2015
Completed Micro and Nanotechnologies in Medicine Workshop	2014
Tech. Prog. Com. member for Nuclear Fuels and Structural Materials Conf.	2014
Consultant, >20 Major Companies on cost, safety, design, fuel	2013-Present
Technical Thermal Hydraulic Track Leader for ICAPP Conference	2013-Present
Chair of the MIT CASL Education Activity	2013-2020
Technical Program Committee member and chair for TopFuel Conference	2013
Referee, major nuclear journals including NED, NT, Progress, Anals, JNM	2012-Present
Member, ANS Small and Medium Sized Reactor Committee	2011-2012
Short Course: Modeling & Computational Multi Phase Flow (ETHZ)	2011
Co-Developers and Administrator of MIT NSE website in response to Fukushima-Daiichi Accident (more than one million hits in the first 5 days)	2011-2013
Delegate and Presenter at the Global Conference on Energy (Ishigaki, Japan)	2010
MIT International Energy Conference Organizer and Presenter	2010-2015
American Nuclear Society Member	2006-Present

HONORS & AWARDS

Elite Nuclear Engineering Fellowship (Univ. of Florida)	2006-08
Alpha Nu Sigma Nuclear Honor Society	2007-Present
TAU BETA PI Honor Society	2007-Present
Reinhold Rudenberg Memorial Award – MIT	2011
Signature Fission Doctorate Seminar Selectee – MIT	2012
Outstanding Student Service Award – MIT	2012
Outstanding Assistant Technical Program Chair – ICAPP	2018
NRC Young Faculty Fellowship Award	2018-2021
Young Professional TH Research Competition – ANS	2018
John Clark Hardwick (1986) Career Development Professorship	2020-June 2023
Best Paper – Nuclear Emerging Technologies for Space – ANS	2021
Faculty of the Year – Nuclear Science and Engineering – MIT ANS	2021
Best Poster – Nuclear Science and Engineering Research Symposium – MIT	2022
Reactor Technology Award, American Nuclear Society (ANS)	2022
Best Paper of Year (2021) - Journal of Nuclear Materials Editors	2022
Best Paper Award, Nuclear Reactor TH, Operation, and Safety (NUTHOS-13)	2022
Best Paper Award, International Conf. on Advanced Power Plants (ICAPP)	2023
Best Paper Award, American Nuclear Society Student Conference	2023
Landis Young Member Engineering Achievement Award - ANS	2023

PUBLICATIONS

Peer-Reviewed Journals/Conference Proceedings

Peer-Reviewed Accepted/Published Journals:

1. Seurin P., **Shirvan K.**, “Assessment of Reinforcement Learning Algorithms for Nuclear Power Plant Fuel Optimization,” Applied Intelligence, Accepted, Sept. 2023.
<https://arxiv.org/abs/2305.05812>
2. **Shirvan K.**, Buongiorno J., MacDonald R., Dunkin B., Cetiner S., Saito E., Conboy T., Forsberg C., “UO₂-fueled microreactors: Near-term solutions to emerging markets,” Nuclear Engineering and Design, Vol. 412, 112470, Oct. 2023. <https://doi.org/10.1016/j.nucengdes.2023.112470>
3. Wang Y.J., Baglietto E., **Shirvan K.**, “A two-level machine learning approach for predicting thermal striping in T-junctions with upstream elbow,” Numerical Heat Transfer, Part B: Fundamentals, *Invited Paper on Application of Machine Learning in Heat Transfer*, September, 2023. <https://doi.org/10.1080/10407790.2023.2253362>
4. Radaideh M., Du K., Seurin P., Seyler D., Gu X., Wang H., **Shirvan K.**, “NEORL: NeuroEvolution Optimization with Reinforcement Learning—Applications to carbon-free energy systems,” Nuclear Engineering and Design, Vol. 412, 112423, Oct 2023.
<https://doi.org/10.1080/10407790.2023.2253362>
5. Stewart W.R., **Shirvan K.**, “Construction schedule and cost risk for large and small light water reactors,” Nuclear Engineering and Design, Vol. 407, 112305, June 2023
<https://doi.org/10.1016/j.nucengdes.2023.112305>
6. Seshadri A, **Shirvan K.**, “Development of hydrothermal corrosion model and BWR metal coating for CVD SiC in light water reactors,” Journal of Nuclear Materials, Vol. 576154252, April 2023.
<https://doi.org/10.1016/j.jnucmat.2023.154252>
7. Stewart W.R., Gregory J., **Shirvan K.**, “Impact of modularization and site staffing on construction schedule of small and large water reactors,” Nuclear Engineering and Design, Vol. 397, 111922, Oct. 2022. <https://doi.org/10.1016/j.nucengdes.2022.111922>
8. Radaideh M., **Shirvan K.**, “PESA: Prioritized experience replay for parallel hybrid evolutionary and swarm algorithms - Application to nuclear fuel,” Nuclear Engineering and Technology, October 2022 <https://doi.org/10.1016/j.net.2022.05.001>
9. Jeong Y.S., Buric M., **Shirvan K.**, “Informing Performance Metrics of Advanced I&C Systems for Liquid Fueled Fast Molten Salt Reactors”, Nuclear Science and Engineering, Special Issue on Advanced Reactor Thermal Hydraulics Experiments and Modeling Supporting Verification and Validation Needs, Vol 197 2023. <https://doi.org/10.1080/00295639.2022.2102388>
10. Stewart W.R., **Shirvan K.**, “Capital cost estimation for advanced nuclear power plants,” Renewable and Sustainable Energy Reviews, Vol. 155, March 2022, 111880
<https://doi.org/10.1016/j.rser.2021.111880>
11. Che Y., Yurko J., Seurin P., **Shirvan K.**, “Machine learning-assisted surrogate construction for full-core fuel performance analysis,” Annals of Nuclear Energy, April 2022, 108905
<https://doi.org/10.1016/j.anucene.2021.108905>
12. Parsi S. S., Lal, K., M., Kosbab, B., Ingersoll E.D., **Shirvan K.**, Whittaker A., “Seismic Isolation: A Pathway to Standardized Advanced Nuclear Reactors,” Nuclear Engineering and Design, Vol. 387, 111445, Feb. 2022, 111445 <https://doi.org/10.1016/j.nucengdes.2021.111445>
13. Halimi A., **Shirvan K.**, “Impact of core power density on economics of a small integral PWR,” Nuclear Engineering and Design, Volume 385, 15 December 2021, 111488
<https://doi.org/10.1016/j.nucengdes.2021.111488>
14. Yook H., **Shirvan K.**, Phillips, Y. Lee, “Post-LOCA ductility of Cr-coated cladding and its embrittlement limit,” Journal of Nuclear Materials, Volume 558, January 2022, 153354
<https://doi.org/10.1016/j.jnucmat.2021.153354>

15. Stewart W.R., Velez-Lopez, E., Wisner R., **Shirvan K.**, “Economic solution for low carbon process heat: A horizontal, compact high temperature gas reactor,” *Applied Energy*, Volume 304, 15 December 2021, 117650 <https://doi.org/10.1016/j.apenergy.2021.117650>
16. Seshadri A., Philips B., **Shirvan K.**, “Impact of Nuclear Environment on Hydrothermal Corrosion and Silica Transport for CVD SiC in Light Water Reactors,” *Journal of Nuclear Materials*, Vol. 556, Dec. 2021 <https://doi.org/10.1016/j.jnucmat.2021.153155>
17. Ma Z., **Shirvan K.**, Wu Y., Su G.H., “Numerical investigation of ballooning and burst for chromium coated zircaloy cladding,” *Nuclear Engineering and Design* Vol. 383, Nov. 2021 <https://doi.org/10.1016/j.nucengdes.2021.111420>
18. Bailly-Salins L., Borrel L., Jiang W., Spencer B.W., **Shirvan K.**, Couet A., “Modeling of High-Temperature Corrosion of Zirconium Alloys Using the eXtended Finite Element Method (X-FEM),” *Corrosion Science*, Volume 189, 15 August 2021, 109603 <https://doi.org/10.1016/j.corsci.2021.109603>
19. Jin Y., **Shirvan K.**, “Study of the Film Boiling Heat Transfer and Two-Phase Flow Interface Behavior Using Image Processing,” *International Journal of Heat and Mass Transfer*, Vol. 177, May, 2021. <https://doi.org/10.1016/j.ijheatmasstransfer.2021.121517>
20. Sukjai Y., **Shirvan K.**, “Fuel performance analysis of reduced moderated boiling water reactor for transuranic waste incineration,” *Progress in Nuclear Energy*, Vol. 137, 103738, July 2021. <https://doi.org/10.1016/j.pnucene.2021.103738>
21. Hazan J., Gauthier A., Pouillier E., **Shirvan K.**, “Semi-integral LOCA test of cold-spray chromium coated zircaloy-4 accident tolerant fuel cladding,” *Journal of Nuclear Materials*, Vol. 550, 152940, July, 2021. <https://doi.org/10.1016/j.jnucmat.2021.152940>
22. Radaideh M., Forget B., **Shirvan K.**, “Large-scale Design Optimisation of Boiling Water Reactor Bundles with Neuroevolution,” *Annals of Nuclear Energy*, Available Online, April 2021.
23. Radaideh M., **Shirvan K.**, “Rule-based reinforcement learning methodology to inform evolutionary algorithms for constrained optimization of engineering applications,” *Knowledge-Based Systems*, Vol. 217, 106836, April 2021. <https://doi.org/10.1016/j.knsys.2021.106836>
24. Seshadri, B. Philips, A.J. Dave, S. Harrison, J. Pegna, K. **Shirvan**, “Hydrothermal corrosion of laser printed SiC fibers under extreme environment,” *Journal of Nuclear Materials*, Vol.548, 2021, 152805. <https://doi.org/10.1016/j.jnucmat.2021.152805>
25. X. Zhao, R.K. Salko, K. **Shirvan**, “Improved departure from nucleate boiling prediction in rod bundles using a physics-informed machine learning-aided framework,” *Nuclear Engineering and Design*, Vol. 374, April 2021, 111084 <https://doi.org/10.1016/j.nucengdes.2021.111084>
26. He Y., **Shirvan K.**, Wu, Y., Su, G. “*Preliminary prediction for survival time of fuel rod under critical heat flux*,” *Annals of Nuclear Energy*, Vol. 151, 107896, Feb. 2021. <https://doi.org/10.1016/j.anucene.2020.107896>
27. Li W. **Shirvan K.**, “Multiphysics phase-field modeling of quasi-static cracking in uranium ceramic nuclear fuel,” *Ceramics International*, Vol. 47, Issue 1, P. 793-810, Jan. 2021 <https://doi.org/10.1016/j.ceramint.2020.08.191>
28. Jin Y., **Shirvan K.**, “Assessment of Coated Cladding Impact on Large-Break LOCA with TRACE-DAKOTA”, *Nuclear Engineering and Design*, Vol. 374, 111036, April 2021.
29. Che Y., Wu X., Pastore G., Li W., **Shirvan K.**, “Application of Kriging and Variational Bayesian Monte Carlo method for improved prediction of doped UO₂ fission gas release,” *Annals of Nuclear Energy*, Vol. 153, April 2021. <https://doi.org/10.1016/j.anucene.2020.108046>
30. Radaideh M., Wolverton I., Joseph J., Tusar J., Otgonbaatar U., Roy N., Forget B., **Shirvan K.**, “Physics-informed reinforcement learning optimization of nuclear assembly design,” *Nuclear Engineering and Design*, 110966, Vol. 372, Feb 2021, 110966. <https://doi.org/10.1016/j.nucengdes.2020.110966>
31. Cooper MWD, G Pastore, Y Che, C Matthews, A Forslund, CR Stanek, **K Shirvan**, T Tverberg, KA Gamble, B Mays, DA Andersson, “Fission Gas Diffusion and Release for CrO-Doped UO: From the Atomic to the Engineering Scale,” *Journal of Nuclear Materials*, in-Press 152590, Jan. 2021. <https://doi.org/10.1016/j.jnucmat.2020.152590>

32. Ryabikovskaya E., A. French, A. Gabriel, H. Kim, T. Wang, **K. Shirvan**, F. A. Garner, L. Shao, "Irradiation-induced swelling of pure chromium with 5 MeV Fe ions in the temperature range 450–650 °C," *Journal of Nuclear Materials*, Vol. 543, 152585, Jan. 2021. <https://doi.org/10.1016/j.jnucmat.2020.152585>
33. Li W., **Shirvan K.**, "Implications of SiC irradiation creep and annealing to UN-SiC fuel rod behavior," *Journal of Nuclear Materials*, Vol. 542, 152479, Dec. 2020. <https://doi.org/10.1016/j.jnucmat.2020.152479>
34. Ma Z., **Shirvan K.**, Wu Y., Su G., "A three-dimensional axial fuel relocation framework with discrete element method to support burnup extension," *Journal of Nuclear Materials*, Available Online, August 2020.
35. Jin Y., Wu X., **Shirvan K.**, "System Code Evaluation of Near-term Accident Tolerant Claddings during Pressurized Water Reactor Station Blackout Accidents," *Nuclear Engineering and Design*, Available Online, August 2020.
36. Jin Y., Cheung FB., **Shirvan K.**, Bajorek S.M., Tien K., Hoxie C.L., "Development of a New Spacer Grid Pressure Drop Model in Rod Bundle for the Post-Dryout Two-Phase Flow Regime during Reflood Transients," *Nuclear Engineering and Design*, Available Online, August 2020.
37. Jin Y., Cheung FB., **Shirvan K.**, Bajorek S.M., Tien K., Hoxie C.L., "Numerical investigation of rod bundle thermal-hydraulic behavior during reflood transients using COBRA-TF," *Annals of Nuclear Energy*, Vol. 148, 107708, Dec. 2020.
38. Seshadri A., Forrest E.C., **Shirvan K.**, "Why ionizing radiation enhances surface wettability," *Applied Surface Science*, Vol. 514, 145935, June 2020. <https://doi.org/10.1016/j.apsusc.2020.145935>
39. Li W., **Shirvan K.**, Pegna J., Harrison S., "Innovative accident tolerant fuel concept enabled through direct manufacturing technology," *Applied Energy*, Vol. 264, 114742 April 2020. <https://doi.org/10.1016/j.apenergy.2020.114742>
40. White P., **Shirvan K.**, "Impact of technology hazards and regulatory methods on commercial fusion development," *IEEE Transactions on Plasma Science*, Special Issue, Available Online. 10.1109/TPS.2020.2975183
41. Silva R. B., **Shirvan K.**, Cruz J.J., Marques R.P., Marques A.L.F., Piqueira J.R.C., "Advanced method for neutronics and system code coupling RELAP, PARCS, and MATLAB for instrumentation and control assessment," *Annals of Nuclear Energy*, October 2019. <https://doi.org/10.1016/j.anucene.2019.107098>
42. **Shirvan K.**, "Implications of accident tolerant fuels on thermal-hydraulic research" *Nuclear Engineering and Design*, Vol 358, March 2020. <https://doi.org/10.1016/j.nucengdes.2019.110432>
43. Zhao X., **Shirvan K.**, Salko R., "On the prediction of critical heat flux using a physics-informed machine learning-aided framework" *Applied Thermal Engineering*, Vol 164, 5, Available Online Oct 2019.
44. Li W., **Shirvan K.**, "Finite Element Analysis of the SiC/SiC Composite Clad Deformation in the Presence of Spacer Grids," *Annals of Nuclear Energy*, Available Online Oct 2019.
45. Wu X. **Shirvan K.**, "*System code evaluation of near-term accident tolerant claddings during boiling water reactor short-term and long-term station blackout accidents,*" *Nuclear Engineering and Design*, Available Online Oct 2019.
46. He Y., **Shirvan K.**, Wu Y., Su G., "*Fuel performance optimization of U3Si2-SiC design during normal, power ramp and RIA conditions,*" *Nuclear Engineering and Design*, Vol. 353, P. 110256, 2019.
47. Jin Y., Cheung FB., **Shirvan K.**, Bajorek S.M., Tien K., Hoxie C.L., "*Development of a droplet breakup model for dry spacer grid in the dispersed flow film boiling regime during reflood transients,*" *International Journal of Heat and Mass Transfer*, Vol. 143, P. 118544, 2019. <https://doi.org/10.1016/j.ijheatmasstransfer.2019.118544>
48. Wu X., **Shirvan K.**, Kozlowski T., "Demonstration of the relationship between sensitivity and identifiability for inverse uncertainty quantification," *Journal of Computational Physics*, Vol. 396, pp. 12-30, 2019. <https://doi.org/10.1016/j.jcp.2019.06.032>

49. He Y., **Shirvan K.**, Wu Y., Su G., “*Integrating a multi-layer deformation model in FRAPTRAN for accident tolerant fuel analysis*,” *Annals of Nuclear Energy*, Vol. 133, P. 441-454, 2019.
50. Li W., **Shirvan K.**, “*U3Si2-SiC fuel performance analysis in BISON during normal operation*,” *Annals of Nuclear Energy*, Vol. 132, P. 34-45, 2019.
51. Hiscox B., **Shirvan K.**, “*Reactor Physics Analysis of a New Accident Tolerant Fuel Called Fuel-in-Fibers*,” *Annals of Nuclear Energy*, Vol. 130, P. 473-482, 2019.
52. Sukjai Y., **Shirvan K.**, “*Enhancing FRAPCON fuel performance code for physical phenomena at high temperature and high burnup*,” *Journal of Nuclear Materials*, Vol 517, pp. 113-127, 2019.
53. Deng, Y., **Shirvan, K.**, Wu, Y., Su, G. “*Utilization of 3D fuel modeling capability of BISON to derive new insights in performance of advanced PWR fuel concepts*,” *Journal of Nuclear Materials*, Vol 516, pp. 271-288, 2019.
54. Li W., **Shirvan K.**, “*ABAQUS analysis of the SiC cladding fuel rod behavior under PWR normal operation conditions*” *Journal of Nuclear Materials*, Vol 515, pp. 14-27, 2019
55. Zhao X., Salko R., Wysocki A., **Shirvan K.**, “*Validation and Benchmarking of CTF for Single- and Two-Phase Flow*,” *Nuclear Technology*, Vol 205 pp. 338-351, 2019.
56. Seshadri A., Philips B., **Shirvan K.**, “*Towards Understanding the Effects of Irradiation on Quenching Heat Transfer*,” *Journal of Heat and Mass Transfer*, Vol 127 pp. 1087-1095, 2018.
57. Seshadri A., **Shirvan K.**, “*Quenching Heat Transfer Analysis of Accident Tolerant Coated Fuel Cladding*,” *Nuclear Engineering and Design*, Vol. 338 pp. 5-15, 2018.
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114. Aranda B., Baglietto E., **Shirvan K.**, "Validation of Multi-Phase CFD Frameworks for High Void Fraction Two-Phase Flows in Large Diameter Systems," 11th International Conference on Multiphase Flow, ICMF-2023.
115. Seshadri A., **Shirvan K.**, "Hydrothermal Corrosion behavior of Neutron Irradiated Additively Manufactured SiC fibers"47th International Conference and Expo on Advanced Ceramics and Composites (ICACC), Jan, 2023.
116. Williams D.J., Seurin S.R., **Shirvan K.**, "A Novel Framework for Accelerating Core Loading Pattern Optimization with Deep Learning Surrogate Models," ANS Annual Student Conference, Knoxville, April 2023.
117. Seurin S.R., **Shirvan K.**, "Can Advances in Artificial Intelligence Surpass Legacy Algorithms for PWR Core Optimization?," ANS Annual Student Conference, Knoxville, April 2023.
118. Carayannopoulos L., **Shirvan K.**, Carpenter D., "Simulation of Salt Loop Irradiation at the MITR," International Congress on Nuclear Power Plants (ICAPP), Gyeongju, Korea, April 2023.
119. Choi Y., **Shirvan K.**, "Assessment of NuScale Core Design with Helical Cruciform Fuel Rods," International Congress on Nuclear Power Plants (ICAPP), Gyeongju, Korea, April 2023.
120. Germonpré E., Buongiorno J., **Shirvan K.**, Lee J.I., Macdonald R., "An Economic Analysis of the Use of Nuclear Microreactors in Hydrogen Production," International Congress on Nuclear Power Plants (ICAPP), Gyeongju, Korea, April 2023.
121. Hines L., **Shirvan K.**, "Preliminary Investigation on Improving Economic Competitiveness of HTGRs with Design-to-Build Approach," April 2023.
122. Moore M., **Shirvan K.**, "Design Options to Address Submersion Incident Criticality LEU NTP Core," Nuclear and Emerging Technologies for Space (NETS), Idaho Falls, May 2023.
123. Cetiner N., Park G., **Shirvan K.**, Snead L., Carpenter D., Kohse G., "Design of an Irradiation Facility at MITR to Demonstrate NTP Operation Sequence", Nuclear and Emerging Technologies for Space (NETS), Idaho Falls, May 2023.
124. Espersen J., Garrison B., Linton K., **Shirvan K.** Brown N., "Preliminary Analysis of Reactivity Initiated Accident Separate Effects Mechanical Tests on Chromium-Coated Zirconium Cladding," Annual American Nuclear Society Meeting, Indianapolis, June 2023.
125. Gauthier V., **Shirvan K.**, "*Simultaneous Fuel Cracking and Pellet Cladding Mechanical Interaction using Multiphysics Phase-Field Modeling*", International Conference on Mathematics and Computational Methods Applied to Nuclear Science and Engineering (M&C), Niagara Falls, Aug 2023.
126. Seurin P., **Shirvan K.**, "*Pareto Envelope Augmented with Reinforcement Learning: Multi-Objective Reinforcement Learning-Based Approach for Pressurized Water Reactor Optimization,*" Niagara Falls, Aug 2023.
127. Aranda B., **Shirvan K.**, Baglietto E., "Flow Regime Scaling Study Aided by CFD for Large Diameter High Void Fraction Systems," 20th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-20), Washington DC. August 2023.
128. Wang Y.J., Baglietto E., **Shirvan K.**, "Application of Structure-Based Machine Learning Model on Thermal Striping Evaluation," 20th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-20), Washington DC. August 2023.
129. Kudriavtseva A., **Shirvan K.**, "Preliminary Radiation Shielding and Waste Assessment Study of High Temperature Gas Cooled Reactor," ANS Winter Meeting, Washington DC, Nov. 2023.
130. Halimi A., **Shirvan K.**, "Scoping Analysis of Fuel Costs and Spent Fuel Volume for Small Pressurized Water Reactors," ANS Winter Meeting, Washington DC, Nov. 2023.
131. Candido I., **Shirvan K.**, "Nuclear Operations and Maintenance: Cost and Staffing Modeling and Optimization," ANS Winter Meeting, Washington DC, Nov. 2023.
132. Mazzocco L., **Shirvan K.**, "Two-Batch Fuel Reshuffling Strategy for a Horizontal Compact High Temperature Gas Cooled Reactor," ANS Winter Meeting, Washington DC, Nov. 2023.

Invited Talks

1. **Shirvan K.**, “*Annular Fuel Design for LWRs*,” University of Reno-Nevada, April, 2013.
2. **Shirvan K.**, “*Fuel Performance with BISON*,” Consortium for Advanced Nuclear Simulation of LWRs Summer Workshop at ORNL, Knoxville, Tennessee, 2014 & 2015 & 2017 & 2018 & 2019.
3. **Shirvan K.**, Kazimi M.S., “*Neutronic Challenges of Advanced Boiling Water Reactor Designs*,” Reactor Physics of Non-Traditional LWR Fuel Design Special Session, PHYSOR, Kyoto, Japan, 2014.
4. **Shirvan K.**, “*Multi-layer Ceramic Matrix Composite Silicon Carbide Cladding for Light Water Reactors*,” Advanced Materials for Sustainable Nuclear Fission and Fusion Energy Special Session, International Conference on Advanced Ceramics & Composites, Daytona, Florida 2016.
5. **Shirvan K.**, “Assessment of the V&V Challenges of Accident Tolerant Fuels” Multiphysics Models Validation Workshop, NC State University, Raleigh NC, July 2017.
6. **Shirvan K.**, “Innovation in Nuclear Technology: Past, Present and Future,” Nuclear Innovation Bootcamp, UC Berkeley, Berkeley, CA, July 2017
7. **Shirvan K.**, “Advanced Fuels R&D: Challenges and Opportunities” Nuclear Power Institute of China (NPIC) Advanced Methods in Nuclear Reactor Design Workshop, Chengdu, China, October 2017
8. **Shirvan K.**, “Acceleration of Fuel Qualification using Modeling and Simulation” INL EROB & MFC Seminar, Idaho Falls, Idaho, April 2018
9. **Shirvan K.**, “Accident Tolerance Fuels R&D: Challenges and Opportunities”, GE-Hitachi Nuclear, Wilmington, North Carolina, Aug 2018.
10. **Shirvan K.**, “Implication of LWR Mechanical Failure Modes, Reactor Environment and Accident Tolerant Fuels on Thermal-Hydraulic Research,” International Seminar on Nuclear Reactor Core Thermal Hydraulics Analysis (ISReCTHA), Lecco, Italy, Aug 2018.
11. **Shirvan K.**, “The Safety and Economic Implications of ATFs,” International Uranium Fuel Seminar, Boston, MA, October, 2018.
12. **Shirvan K.**, “Accident Tolerant Fuel Data Gaps and Failure Modes” Advanced Fuels Campaign Annual Meeting, Gainesville, Florida, Dec 2018.
13. **Shirvan K.**, “Discussion on role of Modern Experimentation, Simulation and Data Processing to Support Nuclear Fuel R&D” Materials and Fuels Complex, Idaho National Laboratory, Feb 2019.
14. **Shirvan K.**, “Acceleration of Innovative Nuclear Fuel Development for Sustainability of the Existing Fleet,” Key Note Speaker, Applied Energy A+B Conference, May, 2019.
15. **Shirvan K.**, “Nuclear Material Study Using a Combined M and E,” MeV Summer School, Oakridge National Laboratory, July, 2019.
16. **Shirvan K.**, “System Codes Comparison for Time-to-Fuel Failure Analysis,” Enhanced Resilient Plant (ERP) Workshop, Idaho National Laboratory, July 2019.
17. **Shirvan K.**, “AI for Nuclear Core Design” Idaho National Laboratory, ML/AI Symposium 2.0, July, 2020.
18. **Shirvan K.**, “ATF Modelling,” MeV Summer School, Idaho National Laboratory, July, 2020.
19. **Shirvan K.**, “Impact of Licensing Methodology on High Burnup Fuel Assessment” Risk-Informed Systems Analysis (RISA) Pathway Stakeholder Engagement Virtual Meeting, Idaho National Laboratory, October, 2020
20. **Shirvan K.**, “Application of Artificial Intelligence Technology for Commercial Nuclear Fleet” Naval Nuclear Laboratory webinar, produced by Cutter Consortium, October, 2020.
21. **Shirvan K.**, “Nuclear Safety Characteristics of Generation III+ Large and Small Light Water Reactors,” Xi’an Jiaotong University, November, 2020.
22. **Shirvan K.**, “SMR Research and Development Trends in the U.S.”, Future Vision of Nuclear R&D WEBINAR – SMR, Korea Nuclear International Cooperation Foundation(KONICOF), November, 2020.
23. **Shirvan K.**, “MIT Contributions to CASL Education Program,” CASL Education Panel, CASL Symposium, ANS Winter Meeting, November, 2020.

24. **Shirvan K.**, “AI Application for Nuclear Engineering,” EPRI AI Reserve Pitch Symposium Lecture, May 2021.
25. **Shirvan K.**, "Peering Over the Horizon & Meeting Closeout" EPRI AI Reserve Pitch Symposium Closing Panel, held virtually, May 2021
26. **Shirvan K.**, "Machine Learning and Artificial Intelligence in Reactor Physics and Design" 2021 ANS Virtual Annual Meeting Panel, June 2021
27. **Shirvan K.**, "Recent Silicon-Carbide Research and Development Activities" 2021 SiC Annual Technical Workshop, July 2021
28. **Shirvan K.**, “Nuclear Energy Cost and Innovations that Matter,” Key Note Speaker, MIT A+B Applied Energy Symposium (Virtual Conference), Aug, 2021,
29. **Shirvan K.**, “Advanced Nuclear Technologies,” Nuclear Energy In a Low-Carbon Future: Key Facts and Issues, Clean Air Task Force (Virtual), Aug, 2021.
30. **Shirvan K.**, “Application of Studsvik Tools to LWR core optimization and advanced fuels engineering,” 2021 Studsvik International User Group Meeting, San Diego, California. Sept 2021
31. **Shirvan K.**, “Nuclear Energy Cost Drivers and Innovations that Matter,” University of California-Berkley Nuclear Engineering Colloquium Series, Oct 2021.
32. **Shirvan K.**, “Deep Dive in SMR Cost Drivers,” International Congress on Advances in Nuclear Power Plants (ICAPP), Plenary Chair (Virtual), Oct 2021 .
33. **Shirvan K.**, “Economic Solution for Low Carbon Process Heat: A Horizontal, Compact HTGR,” GAIN-EPRI-NEI Artificial Intelligence/Machine Learning Technologies for Advanced Reactors Virtual Workshop, Oct 2021.
34. **Shirvan K.**, “Advanced Nuclear Technologies” Infrastructure Design for Climate Change Course, Massachusetts Institute of Technology, Nov, 2021.
35. **Shirvan K.**, “Economic Solutions for Advanced Reactor Technologies,” Oak Ridge/Knoxville American Nuclear Society Local Section, Dec, 2021.
36. **Shirvan K.**, “Compact Steam Generator Technology R&D at MIT,” 3rd International Workshop on the Printed Circuit Steam Generator, Korea Atomic Energy Research Institute (Virtual), Dec, 2021.
37. **Shirvan K.**, “Nuclear Construction Estimation Tool (NCET),” Seminar to Nuclear Energy Institute (NEI) Task Force on Nuclear Construction Projects (Virtual), March, 2022.
38. **Shirvan K.**, “What is Exciting about Nuclear Fuel? Pretty Much Everything!,” NRE/MP Seminar series, Nuclear & Radiological Engineering and Medical Physics Programs, Georgia Institute of Technology (Virtual), April, 2022.
39. **Shirvan K.**, “Advanced Nuclear Prospect in U.S. and International Markets,” Nuclear Fireside Chat Series, J.P. Morgan (Virtual), April, 2022.
40. **Shirvan K.**, “Nuclear Cost Estimation Tool: Overview and Application,” Naval Nuclear Laboratory Special Seminar Series, May, 2022.
41. **Shirvan K.**, “Construction Cost Drivers and How to Address them by Design,” Construction Innovation Workshop for Advanced Nuclear Reactors, Charlotte, May, 2022.
42. **Shirvan K.**, “Economics of Nuclear Reactors,” MeV Summer School, Oakridge National Laboratory, July, 2022.
43. **Shirvan K.**, “Validation of Robustness in TCR Design Strategies,” DOE’s AMMT NEUP and Industry Project Meeting, Sept, 2022.
44. **Shirvan K.**, “Overview of SMR Research Activities at MIT,” TANDEM SMR Advisory Board Meeting, Sept, 2022.
45. **Shirvan K.**, “Progress on Fuel Performance Modeling of Accident Tolerant and High Burnup Fuels,” FAST User Group Meeting by NRC, Oct, 2022.
46. **Shirvan K.**, “Experiences from NE Advanced Reactor Demo Program: Horizontal Compact High Temperature Gas Reactor.” Public-Private Partnerships for Fusion Energy III, INFUSE Workshop, Seattle, Oct. 2022.

47. **Shirvan K.**, “Value Proposition and Challenges for Power Upgrading of Existing Fleet under IRA,” Nuclear Energy Institute Advanced Technology Fuel Task Force, Oct, 2022 (Virtual)
48. **Shirvan K.**, “Harnessing the 100 million fold potential of fission energy: Fuel and Design Optimization,” Chevron Webinar Series, Nov, 2022 (Virtual).
49. **Shirvan K.**, “Nuclear Fuel Design and Performance: Keys to Unlocking Economical Nuclear Energy” Oregon State University Seminar, Jan, 2023 (Virtual)
50. **Shirvan K.**, “Insights into Nuclear Energy Cost Drivers,” DOE’s Market Analysis Community of Practice (MACOP) Monthly Invited Talks, DOE’s Office of Technology Transitions, March, 2023
51. **Shirvan K.**, “Accident Tolerant Fuel Irradiations at MIT Reactor” NEI-EPRI-INL ATF Workshop, April, 2023 (Virtual)
52. **Shirvan K.**, “Enabling Technologies: Power Cycles, Heat Exchangers and Fuels,” Nuclear Everywhere Symposium, MIT, March, 2023.
53. **Shirvan K.**, “Nuclear Energy Overview and Cost Drivers,” Halliburton Labs Nuclear Energy Landscape Event, April, 2023
54. **Shirvan K.**, “Nuclear Fuel Design and Performance: Keys to Unlocking Economical Nuclear Energy” Argonne National Laboratory Seminar, April, 2023
55. **Shirvan K.**, “Deployment of Accident Tolerant Fuels in Small Modular Reactors,” IAEA 21st TWG Fuel Performance Technical Meeting, April, 2023 (Virtual)
56. **Shirvan K.**, “Nuclear Fuel Design and Performance: Keys to Unlocking Economical Nuclear Energy,” Argonne National Laboratory Seminar, April 2023.
57. **Shirvan K.**, “Small Modular Reactors, Gen IV,” Nuclear Innovation Bootcamp, Jamaica, June, 2023.
58. **Shirvan K.**, “ATF Modeling & Economics,” MeV Summer School, Idaho National Laboratory, July, 2023.
59. **Shirvan K.**, “Nuclear Energy Research & Development,” Seminar to ABS on Decarbonization of Shipping Industry with Nuclear Energy, July, 2023.
60. **Shirvan K.**, “Cost and Innovations for Nuclear in Canada,” Ontario Power Generation, Aug, 2023.
61. **Shirvan K.**, “SiC/SiC Cladding R&D: Progress and Challenges,” Keynote Presentation, International Conference and Expo on Advanced Ceramics and Composites (ICACC), Jan, 2024.
62. **Shirvan K.**, “Nuclear Cost Drivers”, Plenary Speaker, International Congress on Advances in Nuclear Power Plants (ICAPP), June 2024

Patents

Organically Cooled Nuclear Reactor for Enhanced Economics and Safety, U.S. Patent No. 20,150,348, 654. 3 Dec. 2015. Filed 27 May 2014.

Superhydrophobic Surfaces, U.S. Patent No. 16/842,110, 7 Apr. 2020. Filed June 18, 2019

Gamma Irradiated Interfaces with Enhanced Thermal Transport Properties, U.S. Patent No. 63/149,721. Filed Feb 16, 2021

Thorium-Based Fuel Design for Pressurized Heavy Water Reactors, US Patent No. 63/186,990, Filed May 11, 2021, Granted July 2023.

Major Reports/Other Publications

Kazimi, M.S., Hejzlar P., Shatilla Y., Feng B., Ko Y., Pilat E., **Shirvan K.**, Whitman J., and Hamed A., *A High Efficiency and Environmentally Friendly Nuclear Reactor (HEER) for Electricity and Hydrogen*, MIT-ANP-TR-125, October 2009.

Shirvan K., Smith K., *CRUD Collector Feasibility Study, CANES FINAL REPORT*, October, 2013.

Sukjai Y, Pilat E, **Shirvan K.**, Kazimi MS, *Silicon Carbide Performance as Cladding for Advanced Uranium and Thorium Fuels for Light Water Reactors*, MIT-ANP-TR-1492014

Shirvan, K., Ballinger R., Buongiorno J., Forsberg C., Kazimi M., Todreas N., *Advanced Offshore Seabed Reactors*, MIT-ANP-TR-155, MIT, Cambridge, August 2014.

Shirvan K., Daines G., Sukjai Y, Kang P., Li J., *Silicon Carbide Performance as Cladding for Advanced Uranium and Thorium Fuels for Light Water Reactors*, MIT-ANP-TR-167, 2016

Shaner S., **Shirvan K.**, Pilat E., Ballinger R., *Going Beyond 5 Percent Enrichment*, MIT-NFC-TR-134, CANES Report, 2016.

Shirvan K., Ballinger R. *Lead Bismuth Cooled Fast Reactor System Performance Verification and Validation*, MIT-ANP-TR-171, CANES Report, 2017.

Shirvan K., *Development of Accident Tolerant Fuel Options For Near Term Applications: Final Report*, DOE NEUP Project No. 15-8843, 2018.

Buongiorno J., **Shirvan K.**, Baglietto E., Forsberg C., Driscoll M., Einstein H., Macdonald I., W.R. Stewart, Velez-Lopez E., Johnston K., Hashimoto G., *Japan's Next Nuclear Energy*, MIT-ANP-TR-187 (REV 1), MIT, Cambridge, April 2020.

Curtis Smith, Koroush **Shirvan**, Jason Christensen, and Kurt Vedros, *Making emergency planning zones smarter: a risk-informed approach for new reactors*, Nuclear News, April 2021.

Mark Weimar, Ali Zbib, Don Todd, Jacopo Buongiorno, and Koroush **Shirvan**, *Techno-economic Assessment for Generation III+ Small Modular Reactor Deployments in the Pacific Northwest*, PNNL-30225, April 2021.

Shirvan K., Overnight Capital Cost of the Next AP1000, *Center for Advanced Nuclear Energy Systems*, MIT-ANP-TR-193, Massachusetts Institute of Technology, March 2022.

Stewart W.R., **Shirvan K.**, *Capital Cost Evaluation of Advanced Water-Cooled Reactor Designs With Consideration of Uncertainty and Risk*, *Center for Advanced Nuclear Energy Systems*, MIT-ANP-TR-194, Massachusetts Institute of Technology, June 2022.