ACADEMIC RESEARCH PATHS AND STATISTICS ON ELECTROCHEMICAL PROCESSES OF USED FUEL REPROCESSING IN DIFFERENT NATIONS

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VIRGINIA COMMONWEALTH UNIVERSITY

FOUR STEPS TO SUCCESSFUL TECHNOLOGY ROADMAP DEVELOPMENT

1. Development of a clear understanding of the current state objectives (e.g. R&D needs, educational high impact factor, experimental cost, etc.),
2. Identification of desired end state of the program including performance targets, operating model improvement, and guiding principles including disseminating the results,
3. Gap analysis to evaluate different closure strategies between the existing and future research outcomes which may affect the technological design, process, and functional profit, and
4. Prioritization and evaluation with respect to data collection to identify what is feasible and what has the highest outcome value.

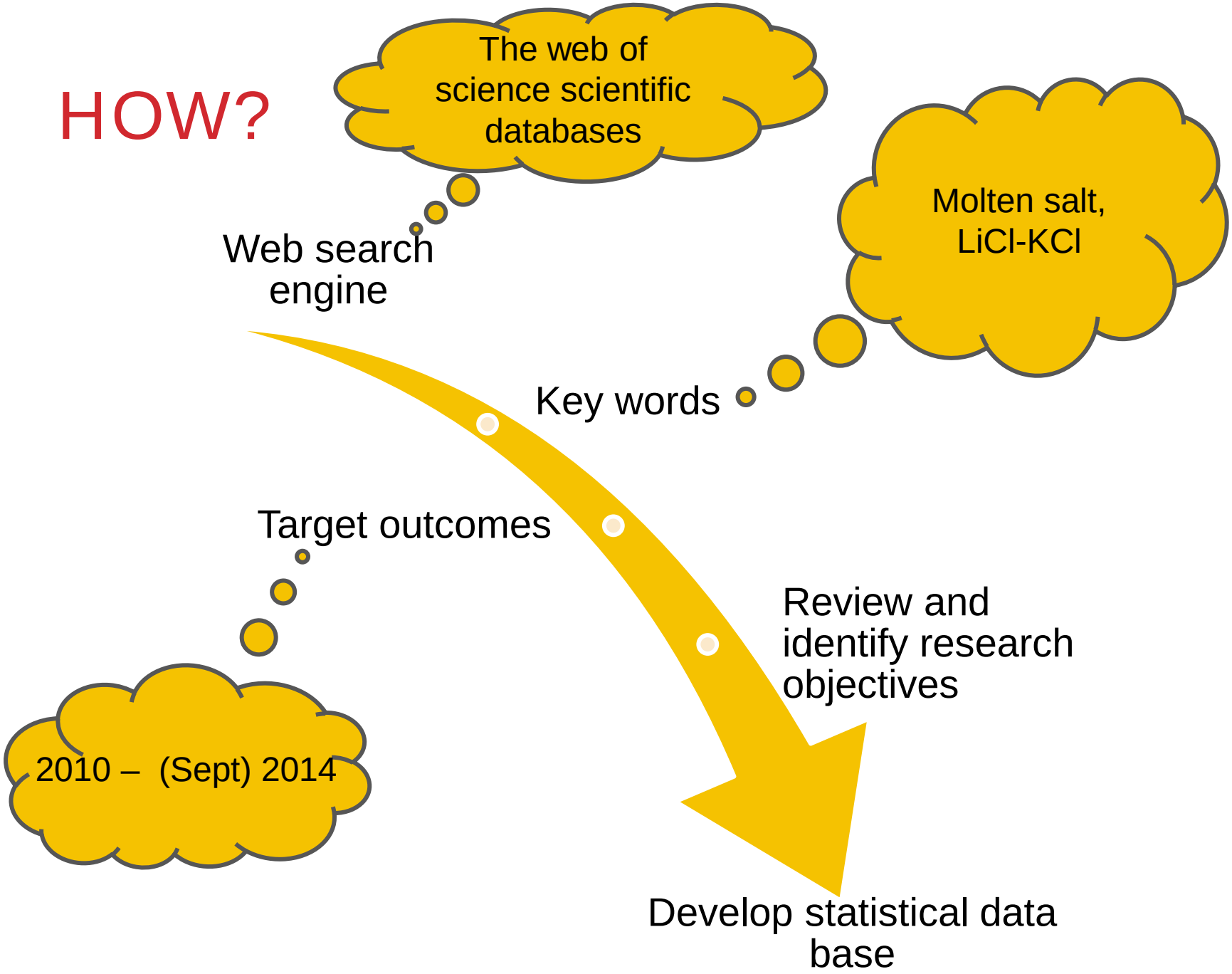
MOTIVATION AND OBJECTIVES

- **Motivation:**
  - To develop a core-team of qualified research groups in order to provide relevant data to benefit future directions of pyroprocessing technology
- **Objectives:**
  - Provide technical data review, assessment and qualification
    - Define basic R&D needs
    - Define workforce on educational needs and components
    - Identify possible collaborators
    - Develops routines for distribution of safe and secure data sets
    - Identifies data and resource gaps
  - Find strategic solutions and plans to support technology

APPROACH

- Perform network data base analysis to identify
  - Leading research topic areas,
  - Leading research nations,
  - Research percentage distributions, and
  - Gaps and possible paths for building strong research efforts.

HOW?


The web of science scientific databases
Web search engine
Molten salt, LiCl-KCl
Key words
Target outcomes
Review and identify research objectives
2010 – (Sept) 2014
Develop statistical data base

RESEARCH AREAS

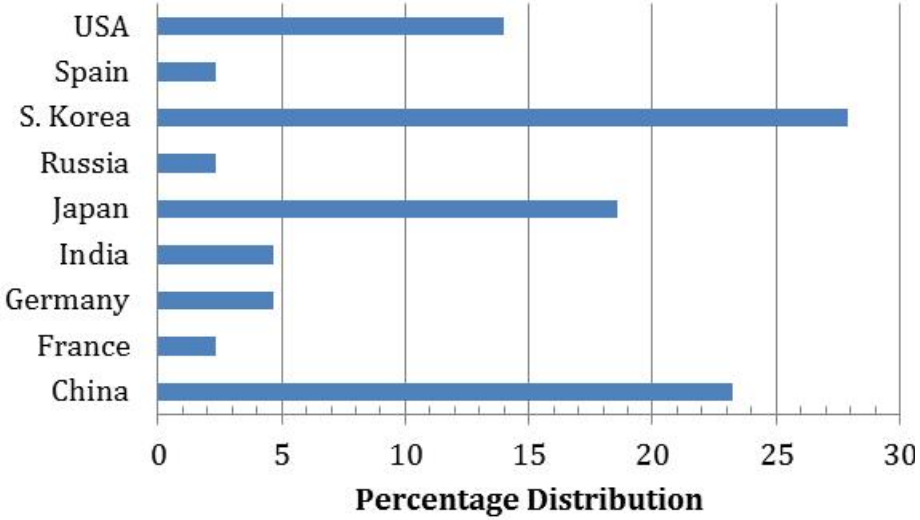
1. Literature review and development
2. Electrolytic oxide reduction and oxide fuel treatment
3. Chemical and physical process of molten salt
4. Electrochemical separation
5. Safeguards and salt monitoring
6. Waste processing
7. Modeling and simulation

OBTAINED DATA

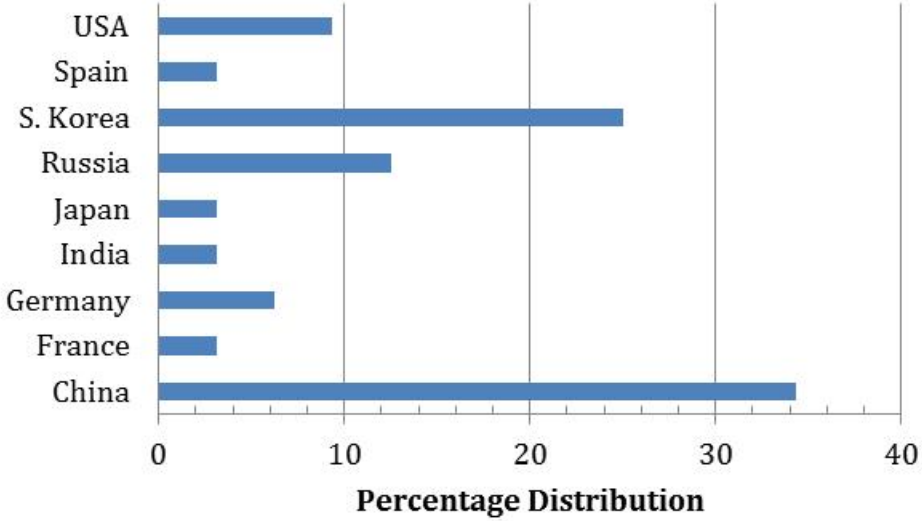
- 193 published articles from different nations
- 2010 (43 papers), 2011 (32 papers), 2012 (35 papers), 2013 (49 papers), and 2014 (34 papers)
- Introduction—pyroprocessing, nuclear energy, citation related to nuclear reprocessing
- Funding sources
- Collaborations
- Possible research PIs

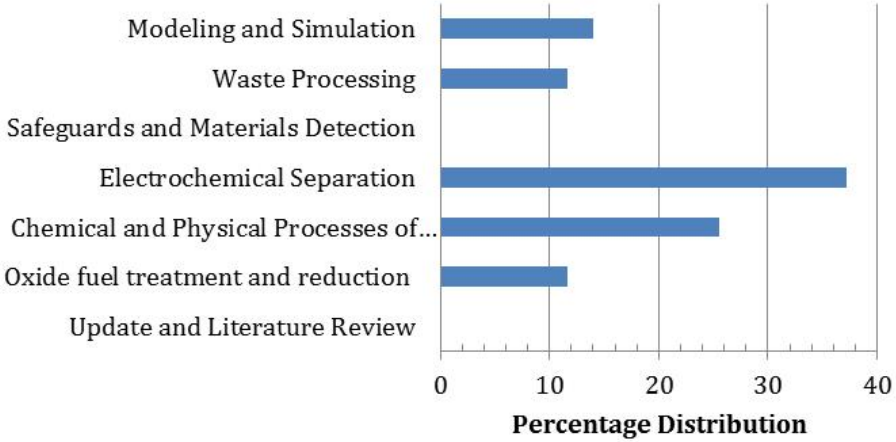
RESEARCH DISTRIBUTION

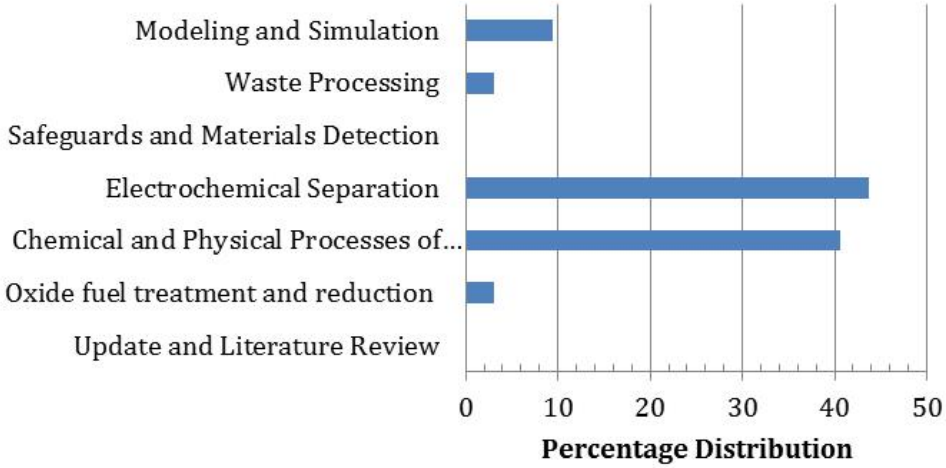
2010



2011

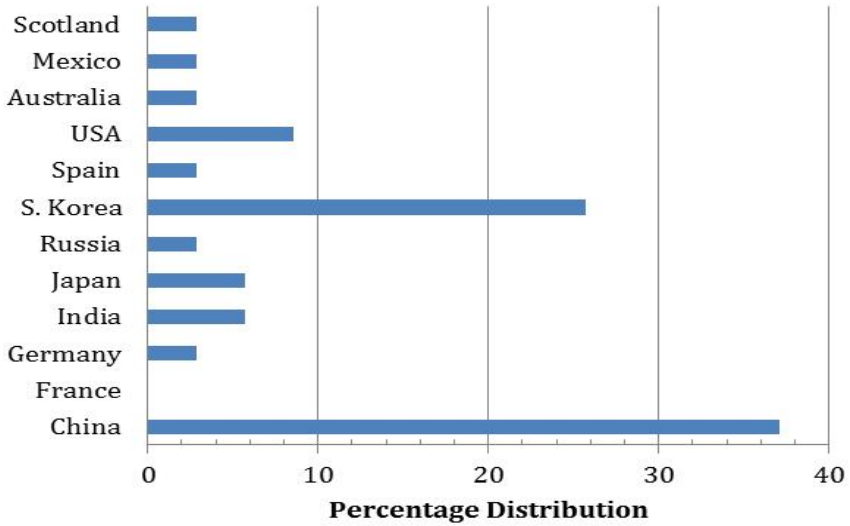




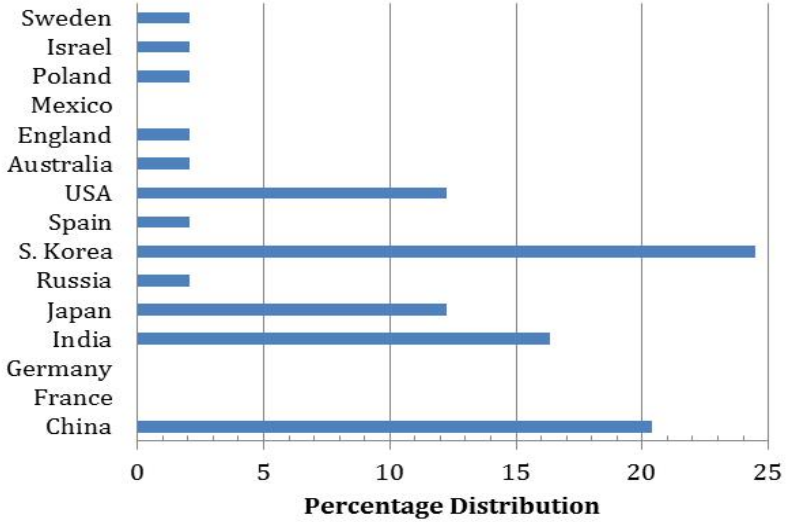


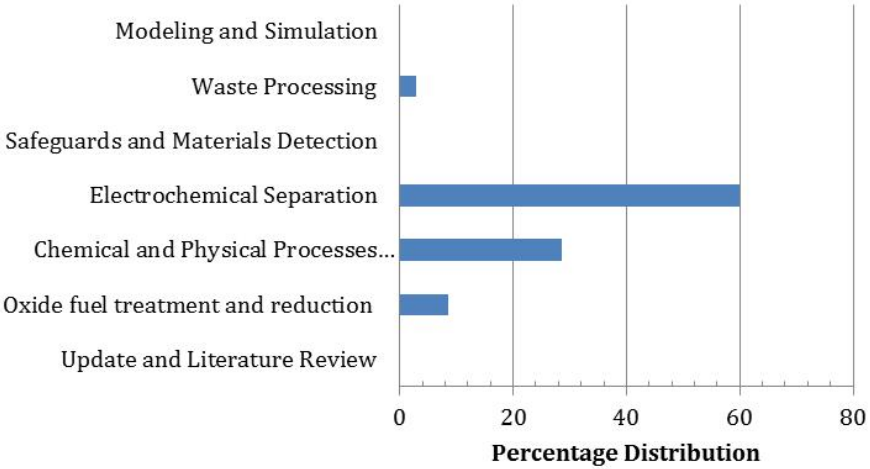
RESEARCH DISTRIBUTION

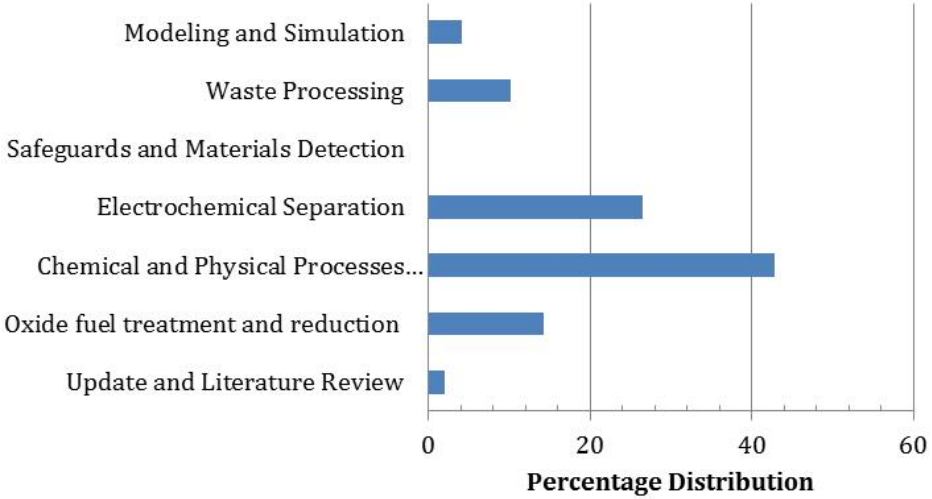
2012



2013

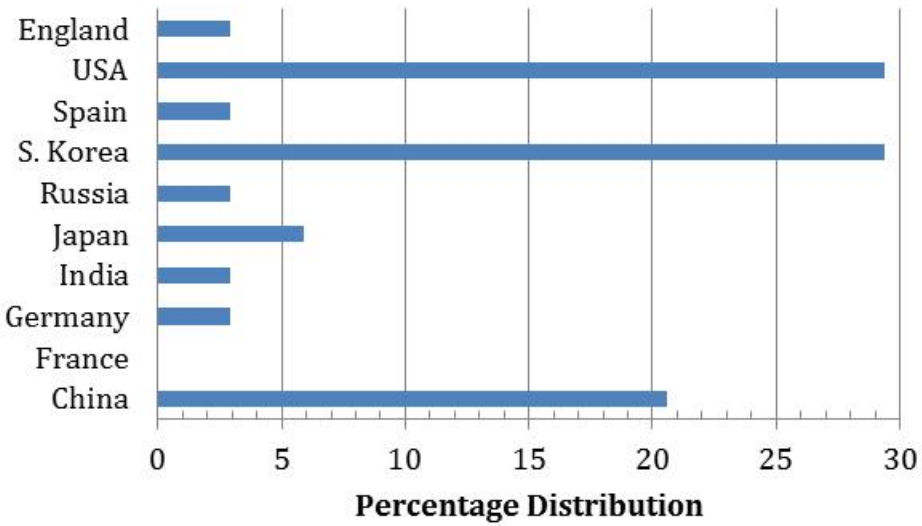


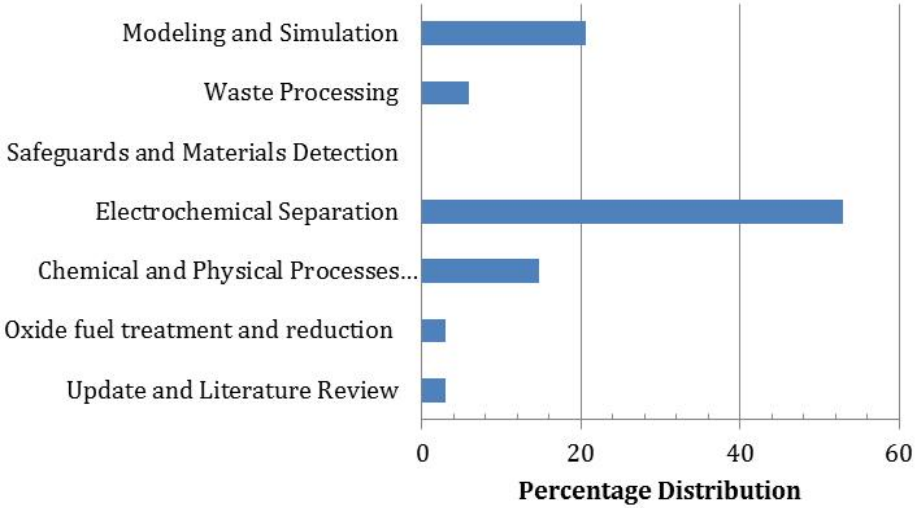




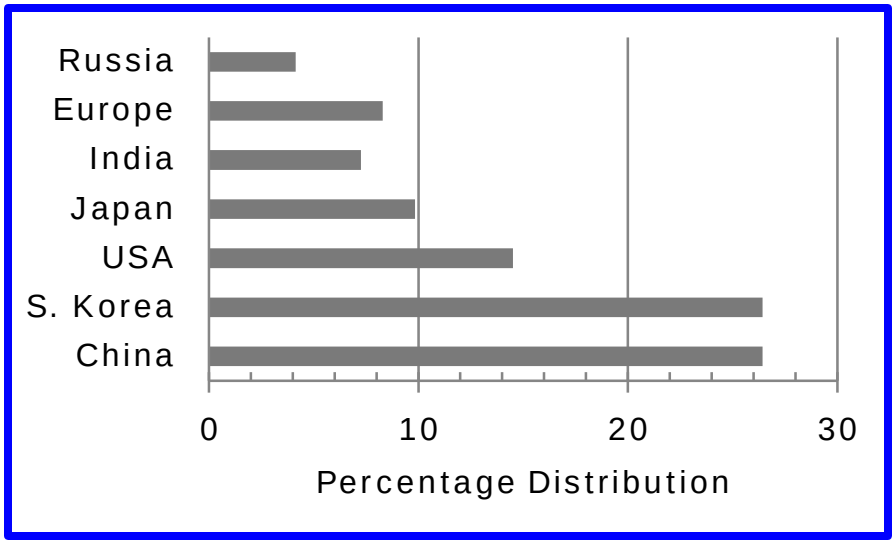
RESEARCH DISTRIBUTION

2014



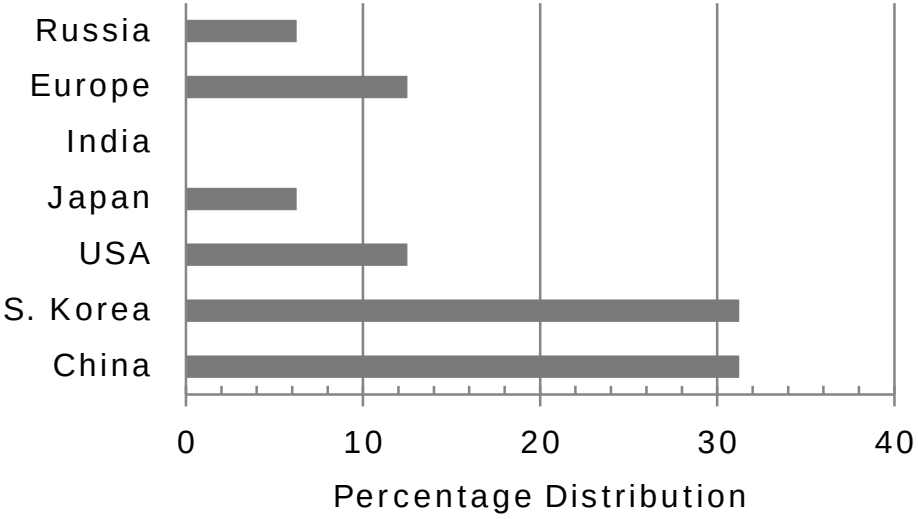


2010-2014

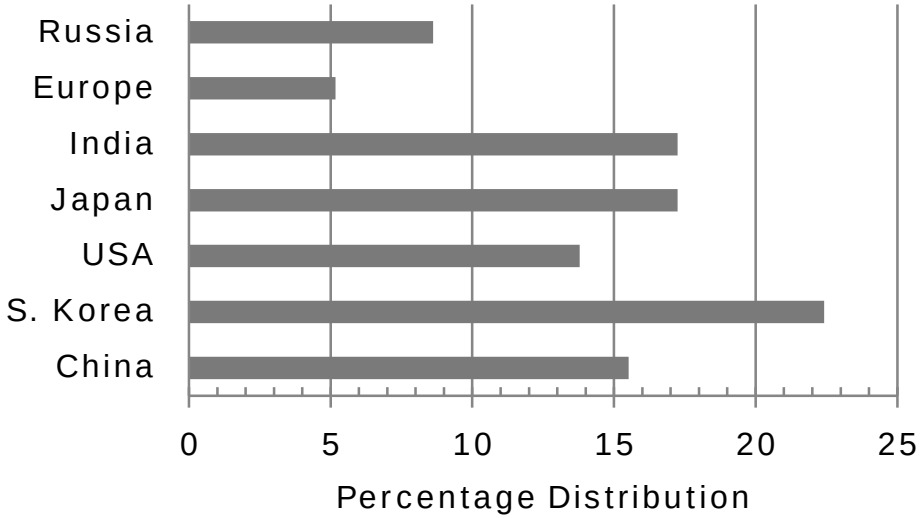


RESEARCH AREA, 2010-2014

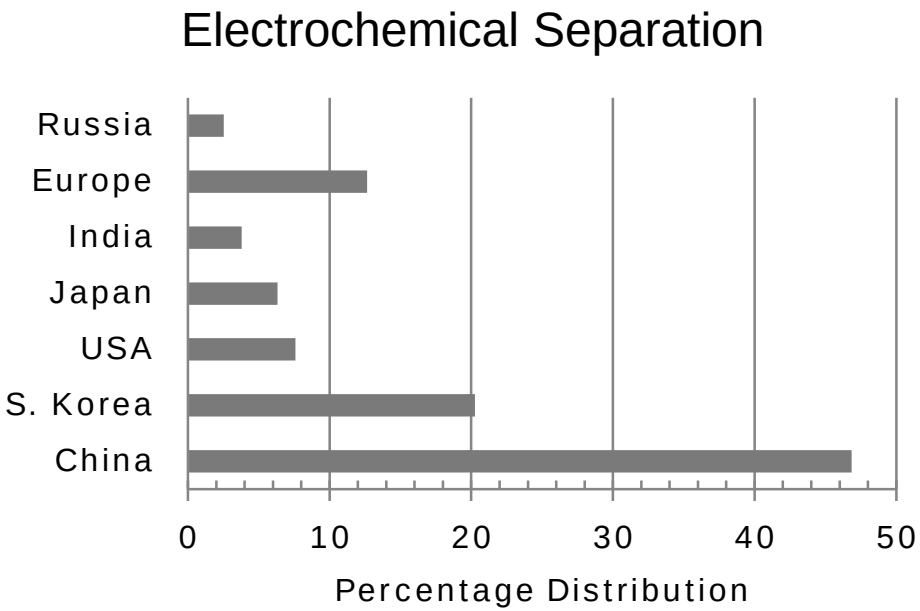
Oxide Reduction or Oxide fuel treatment

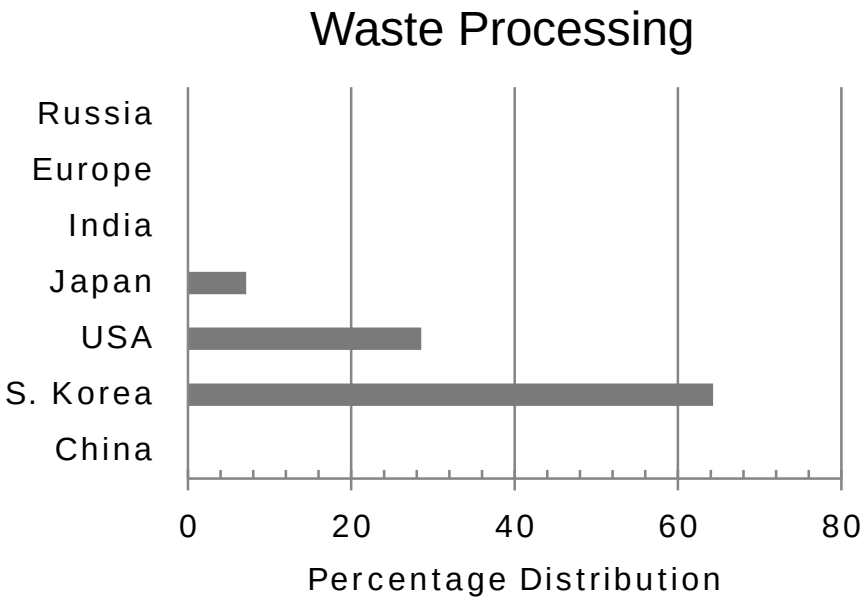


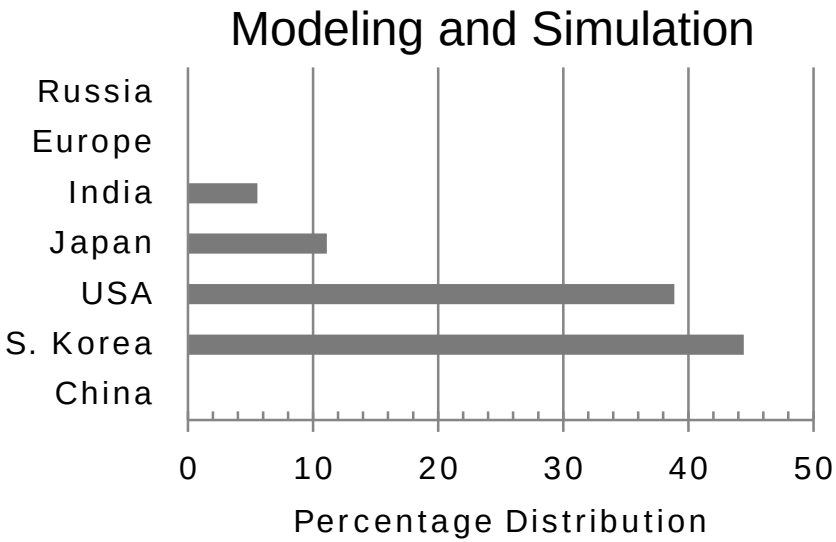
Chemical & Physical Process of Molten Salt



RESEARCH AREA, 2010-2014







TOPICS IN 2010

	Nation	Topics
Experiment	China	$CeNi_4Cu$ alloy, Mg-Li-Ce-La alloy, Al-Li-Mg alloy, Mg-Li-Sm alloy, Beta Phase Mg-Li alloy, Mg-Li-Mn alloy, Mg-Li-Yb, Mg-Yb
	Korea	U^{3+}, Sm^{2+}, Yb^{2+} (electronic absorption), $EuCl_3$ (fluorescence), CsCl-Zeolite, Eu^{2+}, and Al^{3+}
	USA	ZrN & HfN, U metal, Zeolite, $GdCl_3$, $NdCl_3$
	Japan	Oxide fuel, Si, Al, Zr nano-coated, counter current extraction, Diaphragm, Li_2O, $TaCl_5$
	Russia	$UO_2Cl_4^{2-}$
	India	TiN, ZrN, Ti-Si-N coating, Ni-W, 316L SS, Inconel 625 alloy
	Germany	UCl_3-$NdCl_3$, Oxide-hydroxides
	France	Co^{2+}, Sn^{2+}
	Spain	Tire rubber for energy storage
Model	Japan	Anodic behavior, U-Zr alloy
	Korea	Electro-fluid analysis, 3D multispecies
	USA	Salt density, zeolite

TOPICS IN 2011

	Nation	Topics
Experiment	China	Mg-Li-Al-Zn, Al-Li-Y, $NbCl_5$-Al_2Cl_3, Mg-Li-Al-La, Mg-Li-Sm, Mg-Li-Er, Zr, La^{3+}, Sb^{3+}, Mg-Li-Gd
	Korea	Nd^{3+} and Tb^{3+} (laser induced fluorescence), U^{3+}(UV-Vis), $CaOSiO_2$-P_2O_5, $CeCl_3$, $NdCl_3$, $LaCl_3$, ReO_3
	USA	Cr-Mo alloy
	Japan	La, Pr, Nd, Gd, Y, Sc metals
	Russia	Pr, Sm, Er, Yb
	India	U-Zr
	Germany	SiC fibres, U-Pu-Al alloy
	Spain	Sm
Model	India	U-Zr
	USA	U-Zr, 2D

TOPICS IN 2012

	Nation	Topics
Experiment	China	Mg-Li-La, Mg-Li-Yb, Al-Li-Eu, Eu_2O_3, Sm_2O_3, Mg-Li-Ag, 304SS, 316SS, Q235A, Carbon film on TiO_2, AlLi, Al_2Li_3/Al_4Li_9, Mg-Li-Sn, Sm-Al, Ti-TiOC-carbon film, Pb
	Korea	Ce^{3+}, Sm^{3+} , Dy^{3+}, U^{3+} , $ZrCl_4$, Zircalloy
	USA	Lithium Drawdown, CsCl, $SrCl_2$, $LaCl_3$, $CeCl_3$, $NdCl_3$, MOX
	Japan	NH_3, Nd^{3+}, Dy^{3+}
	Russia	Sm, Corrosion, La
	India	Graphite, Zirconia coated, $LaCl_3$
	Australia	La^{3+}
	Spain	Scandium, Y
	Germany	Pu-Al alloy
	Mexico	Li and Cu corrosion

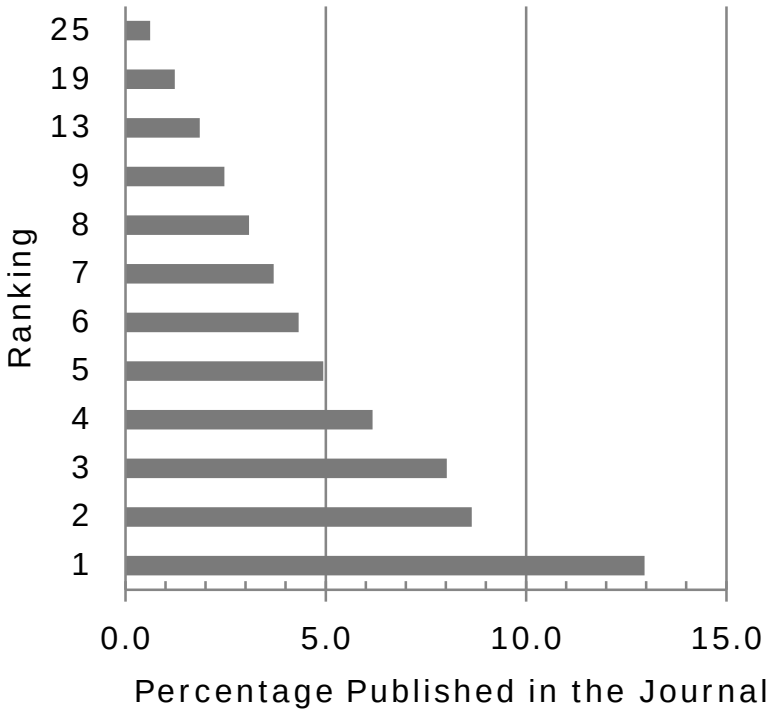
TOPICS IN 2013

	Nation	Topics
Experiment	China	ThO_2, Eu_2O_3, Nb-Al, Gd_2O_3, UCl_3, $CeCl_3$, Th-Zn alloy, TiC, Al-Li, Mg-Zn-Li-Ca, Al-Li-Er, $NdCl_3$
	Korea	$CeCl_3$, Li_3PO_4, $LaCl_3$, $NdCl_3$, $PrCl_3$, SiC, UCl_3, boron doped diamond UO_2, Ho^{3+}
	USA	$EuCl_3$, $GdNiO_3$, $EuNiO_3$, Zeolite, CsCl, $SrCl_2$
	Japan	$GdCl_3$, UCl_3 , $UO_2Cl_4^{2-}$, SiO_2, Gd, Dy, Yb, Y, La, Ce, Pr, Sm
	Russia	$NdCl_3$
	India	$Gd_2Ti_2O_7$, Yttria, Zirconia, La, Ce, U-Sn
	Australia	$ZrCl_4$
	Poland	SiO_2
	France	Co^{2+}, Sn^{2+}
	Spain	Sm^{3+}, CsCl
Model	India	Anodic behavior
	USA	Thermodynamics

TOPICS IN 2014

	Nation	Topics
Experiment	China	$CeCl_3$, $ThCl_4$, Ni-Tb, Sm-Sm_2O_3, Gd_2O_3, Ti^{2+}, Ti^{3+}, Sm^{3+}, Zn^{2+}, Er^{3+}, Al^{3+}
	Korea	$LaCl_3$, Glass $Ln_2O_3^-$, U-anode, Zr, Zircalloy
	USA	$ErCl_3$, UCl_3 , $LaCl_3$, Tb, Ti_5Si_3 (nano study), $ReCl_3$ and $CeCl_3$ (LIBS)
	Japan	Zeolite-I, Br, Te
	Russia	$NdCl_3$
	India	Carbon corrosion
	Germany	U-Pu-Zr
	England	WO_3
	Spain	Sc-Al
Model	Korea	Zircalloy, $ZrCl_4$
	USA	Molecular dynamics

PUBLICATION LIST



Ranking	Journal
1	Electrochimica Acta
2	Journal of Nuclear Materials
3	Journal of Radioanalytical and Nuclear Chemistry
4	Journal of Electrochemical Society
5	Journal of Nuclear Science and Technology
6	Journal of Rare Earth
7	Metallurgical and Materials Transaction B
8	Molten Salt and Ionic Liquid
9	Russian Journal of Electrochemistry
	Russian Journal of Physical Chemistry A
	Journal of Alloys and Compounds
	Acta Metallurgical Sinica
13	International Journal of Electrochemical Science
	Journal of Applied Electrochemistry
	Nuclear Technology
	Journal of Luminescence
	Transaction of Nonferrous Metals Society of China
	Electrochemistry Communications
19	Chemical Physics Letters
	Nuclear Engineering and Technology
	Rare Metals
	Corrosion
	Physical Chemistry Chemical Physics
	Chemical Research in Chinese Universities

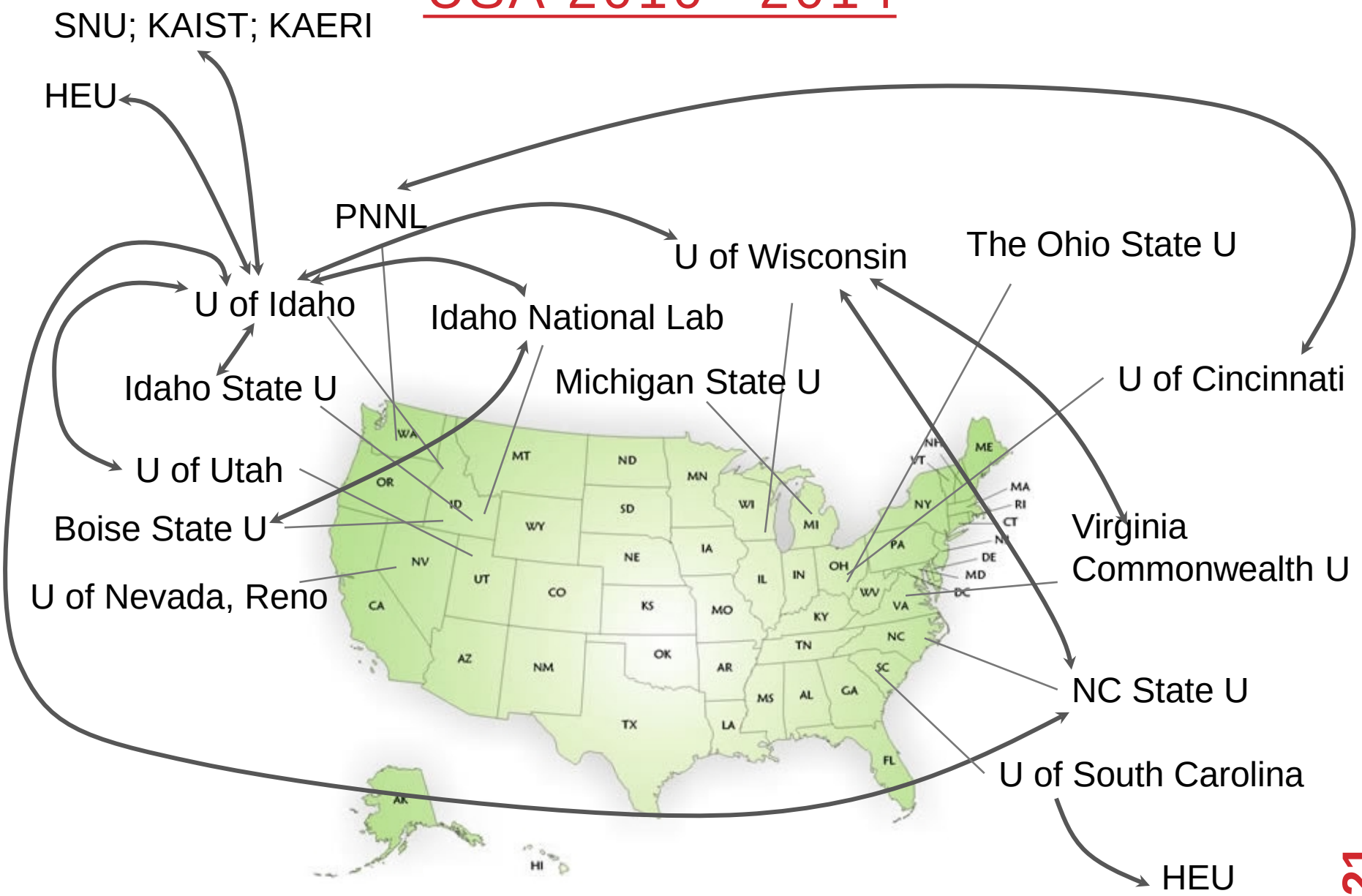
FUNDING SOURCES/AGENCIES

Nation	Sources/Agencies
USA	1. Idaho National Laboratory (INL) through the U.S. Department of Energy (US DOE) within the U.S./Republic of Korea International Nuclear Energy Research Initiative (I-NERI) program. 2. Laboratory Directed Research Development 3. US DOE – Nuclear Energy University Program 4. China Scholarship Council (Harbin Engineering University (HEU)) 5. University's Startup
China	1. High Technology R&D Program of China 2. National Natural Science Foundation of China 3. Fundamental Research Funds for the Central Universities 4. Foundation for University Key Teacher of Heilongjian Province 5. Basic Research Foundation of HEU 6. Special Foundation of China and Heilongjian Postdoctoral Science Foundation 7. China Postdoctoral Science Foundation 8. Major Research Plan "Breeding and Transmutation of Nuclear Fuel in Advanced Nuclear Fission Energy System" of the Natural Science Foundation of China 9. Chinese Academy Sciences—Strategic Priority Research Program 10. Key Laboratory of Superlight Materials and Surface Technology, Ministry of Education 11. Ministry of Science and Technology of China 12. Program for New Century Excellent Talents in University 13. Program of the Co-Construction with Beijing Municipal Commission of Education of China

FUNDING SOURCES/AGENCIES

Nation	Sources/Agencies
Korea	1. Seoul National University (SNU) 2. Russell Family Foundation 3. National Research Foundation of Korea (N1RF) 4. Korea Research Foundation 5. Nuclear R&D Program of the Korean Ministry of Science, ICT and Future Planning 6. Education and Research Promotion Program of KOREATECH 7. Ministry of Education, Science and Technology (MEST) 8. Global Frontier RD Program 9. Energy Efficiency & Resources of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) 10. Korea Government Ministry of Knowledge Economy
Japan	1. JST-CREST 2. Japan Society for the Promotion of Science (JSPS)
German, France	1. European Commission
Spain	1. Ministerio de Ciencia e Innovacion (Spain)
England	1. Royal Society 2. Royal Academy of Engineering 3. UK Engineering and Physical Sciences Research Council (EPSRC) 4. REFINE Consortium
Russia	1. Research & Development Operational Programme – ERDF 2. Science and Technology Assistance

REPORTED RESEARCH ACTIVITIES IN THE USA 2010 - 2014



REPORTED RESEARCH ACTIVITIES IN THE CHINA 2010 - 2014

USA

Chinese Academy of Science

Harbin Engineering U (HEU)

China Institute of Atomic Energy

U. Science and Tech

England

China Nuclear Power Tech. Research Institute

Northeastern U

Henan U

Wuhan U Science & Technology

East China U Science & Technology

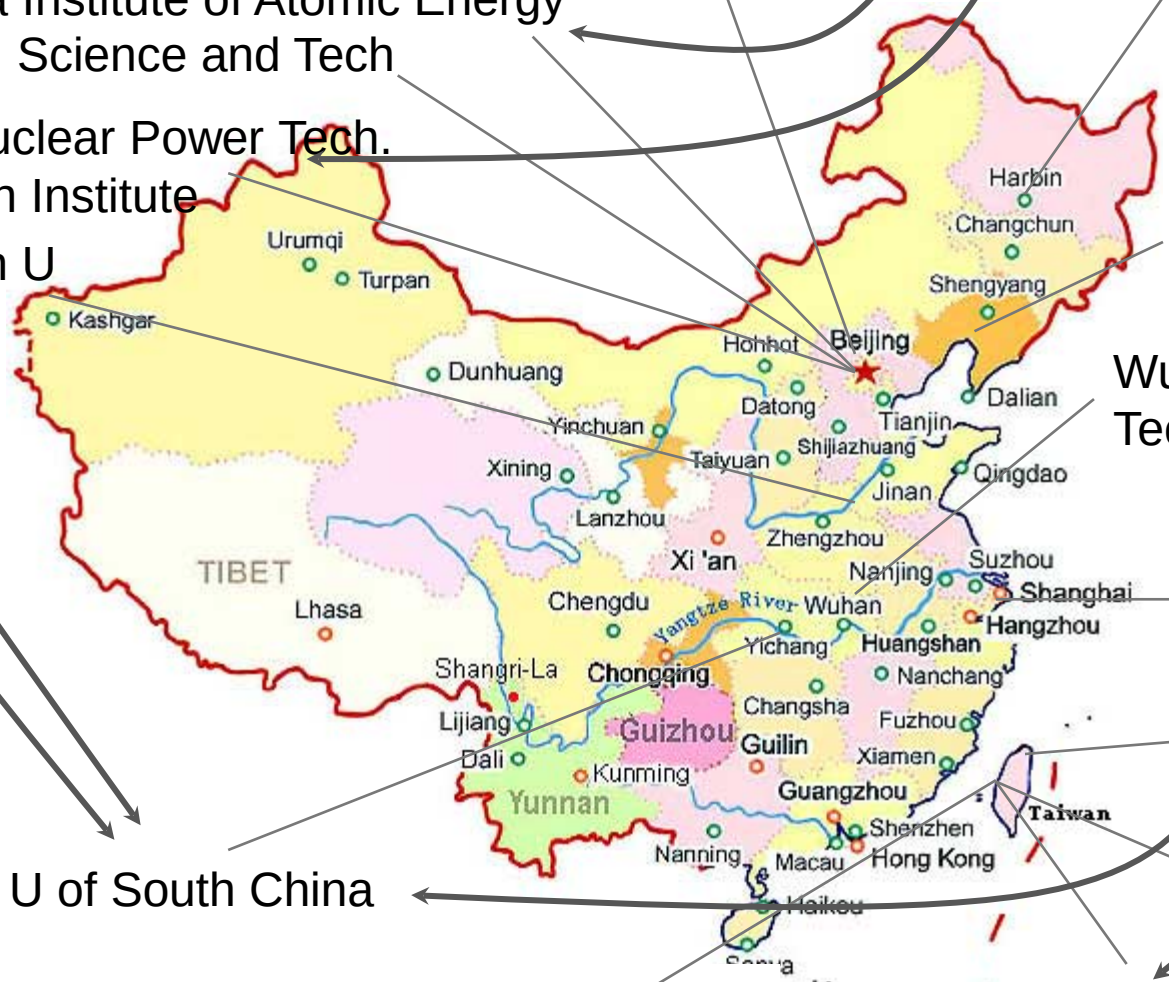
Soochow U

Hsiuping U of Science and Tech

U of South China

Industrial Tech Research Institute

Nat. Chung Hsing U



REPORTED RESEARCH ACTIVITIES IN THE KOREA 2010 - 2014

USA

USA

Seoul National University

Korea Atomic Energy Research Institute

Korea Advanced Inst. Science Tech

U. Sci & Tech, Taejon

Daegu Gyeongbuk Institute of Sci and Tech.

Korea U of Tech & Educ.

Soonchunhyang U

Hanyang U

Chungnam National U

Sunchon National U

REPORTED RESEARCH ACTIVITIES IN THE JAPAN 2010 - 2014

Japan Atomic Energy Agency

Central Res Inst of Electric Power Industry (CRIEPI)

U of Tokyo

Nat Inst Adv Ind Sci Tech

Kyoto U

Tohoku U

Panasonic Corp

Kayushu Inst Tech

Osaka U

Chiba U

Sweden

Doshisha U

REPORTED RESEARCH ACTIVITIES IN THE EUROPE 2010 - 2014

U Toronto

Indira Gandhi

Inst Met Niezelazny

Inst Nucl Chem & Tech

Russia Academy of Sciences

European Commission
Inst Transuranium Element

Royal Inst Techno

Vyatka State U

Res Institute Atomic React

German Aerosp Ctr
DLR

Inst High Temp
Electrochem

TU Begakademie
Freiberg

U College London

U Edinburg

U Leeds

U of Toulouse

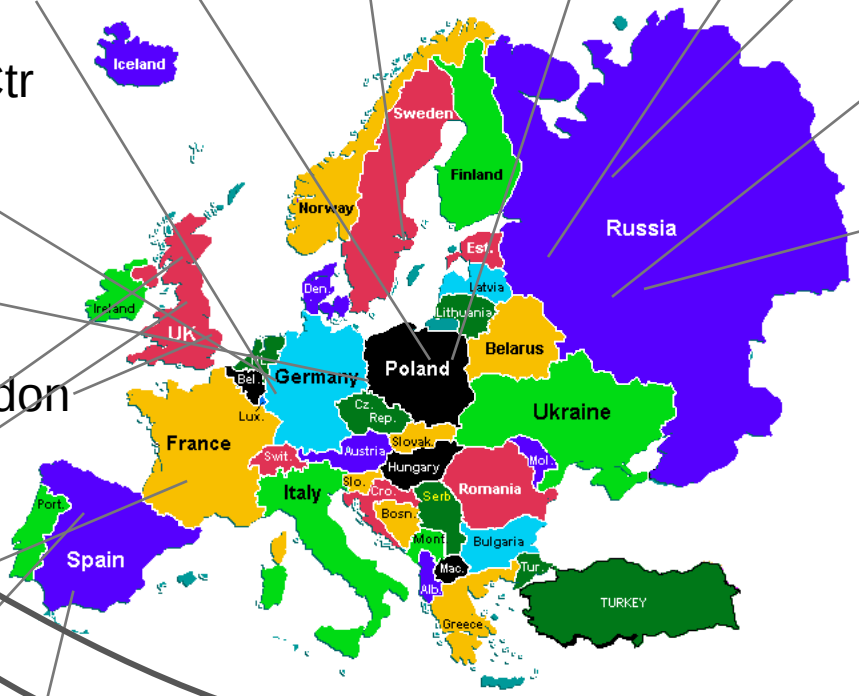
Valladolid U

U Extremadura

Wuhan U Sci & Tech

Australia Nucl Sci

U Autonoma Estado Hidalgo



REPORTED RESEARCH ACTIVITIES IN THE INDIA 2010 - 2014

Inst Nucl Chem & Tech (Poland)

Indira Gandhi Centre for Atomic Research

Bhabha Atomic Research Center

PSG Coll Technol

SRM U

Lady Doak College

MAJOR RESEARCH ACTIVITIES IN USA: NATIONAL LABS

INL, MFC, Separation Department
Lead: Guy Frederickson

ANL, Chemical Sciences and Engineering
Lead: Mark Williamson

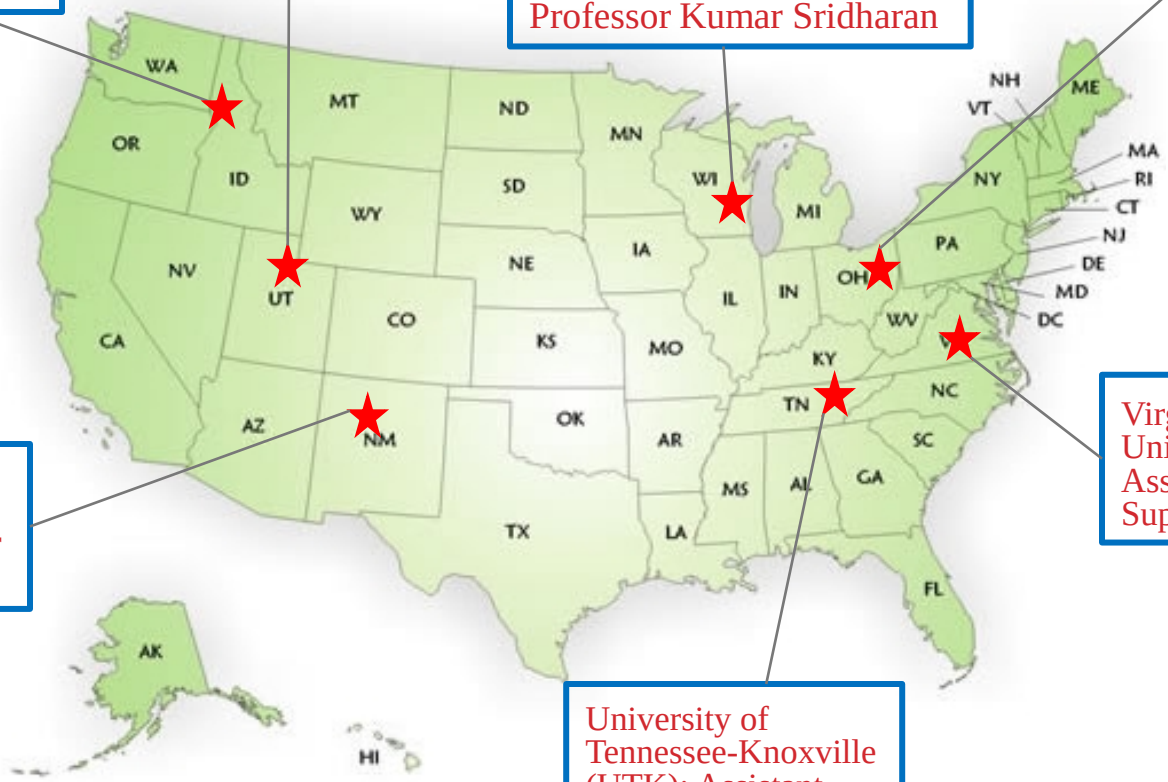
UNIVERSITIES CURRENTLY WITH SUBSTANTIAL ACTIVITY IN ELECTROCHEMICAL PROCESSING

University of Idaho (UI): Professor Batric Pesic

University of Utah (UU): Associate Professor Michael Simpson

University of Wisconsin-Madison (UW): Distinguished Research Professor Kumar Sridharan

The Ohio State University (OSU): Associate Professor Jinsuo Zhang



University of New Mexico (UNM): Assistant Professor Edward Blandford

Virginia Commonwealth University (VCU): Associate Professor Supathorn Phongikaroon

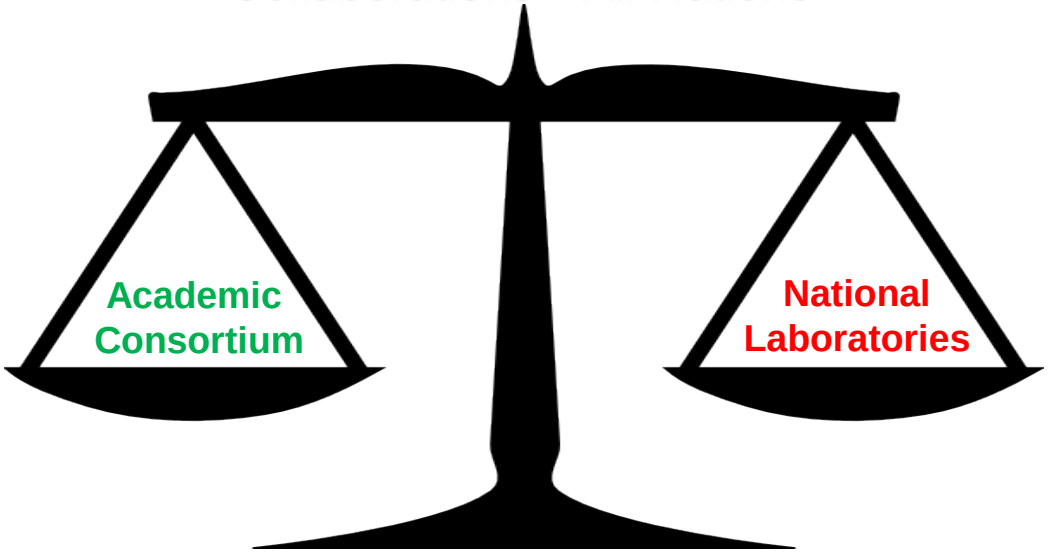
University of Tennessee-Knoxville (UTK): Assistant Professor Steven Skutnik

OTHER LEADING RESEARCHERS

- **China**
  - Wei-Qun Shi, Institute of High Energy Physics, Chinese Academy of Science
  - Mi-Lin Zhang, Harbin Engineering University
  - Zhijian Zhang, Harbin Engineering University
  - Hongmin Zhu, University of Science and Technology, Beijing
  - Y. G. Ouyang, China Insitute of Atomic Energy
  - Qian Xu, Northeastern University, China
- **Europe**
  - R. Malmbeck, Institute for Transuranium Elements, Germany
  - V. Gomez-Serrano, U. de Extremadura (UEX), Spain
  - A.V. Koyalevskii, Vyatka State University, Russia
  - A.V. Novoselova, Russian Academy of Sciences
  - A. Mount, U of Edinburg, U.K.
  - P.R. Shearing, UCL, U.K.
  - Y. Castrillejo, Universidad de Valladolid, Spain

SUMMARY: ROADMAP TO SUCCESS

Collaborations—All Nations



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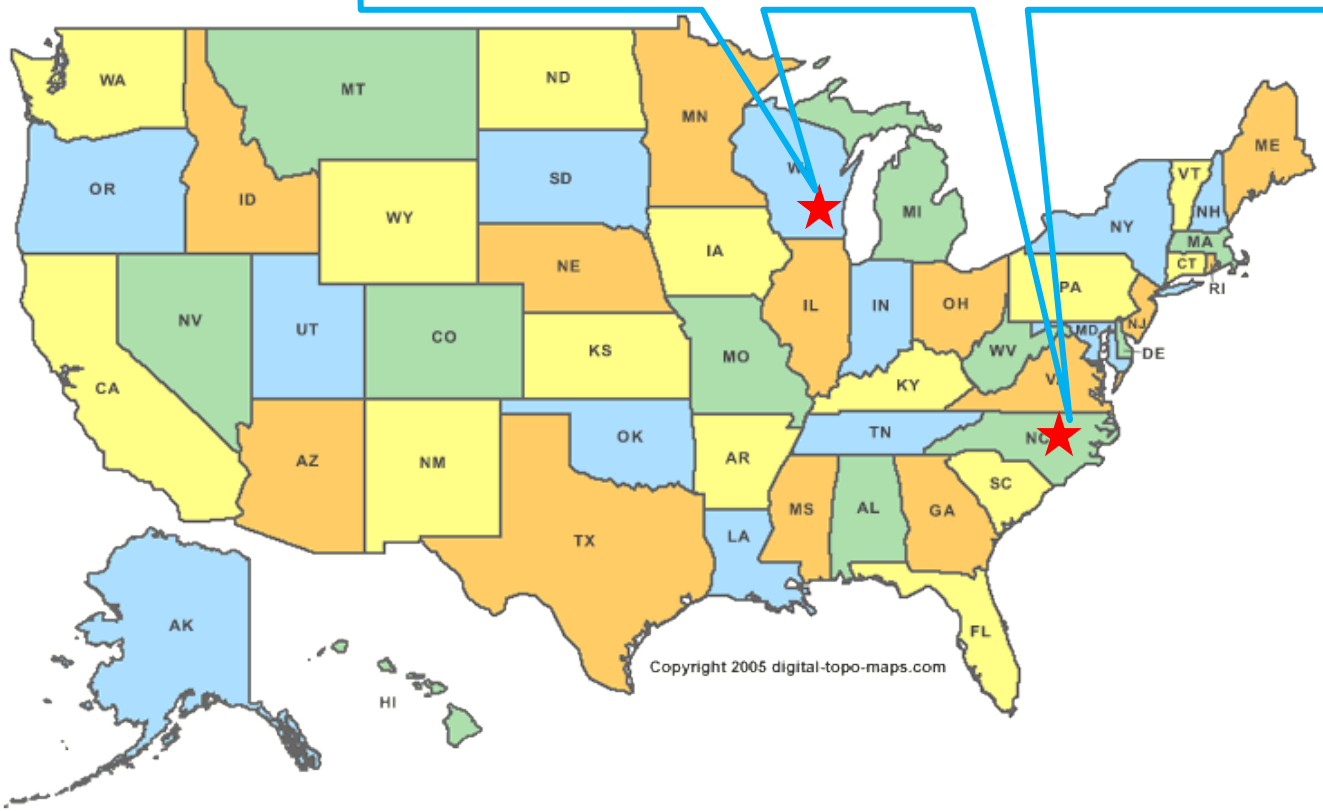
- Development of the current state objectives
- Identification of performance targets and outcomes
- Gap analysis on the R&D and **educational** components
- Evaluation and demonstration of scale-up capabilities from collected data

NEUP Nuclear Energy University Programs
U.S. Department of Energy

FY 2010

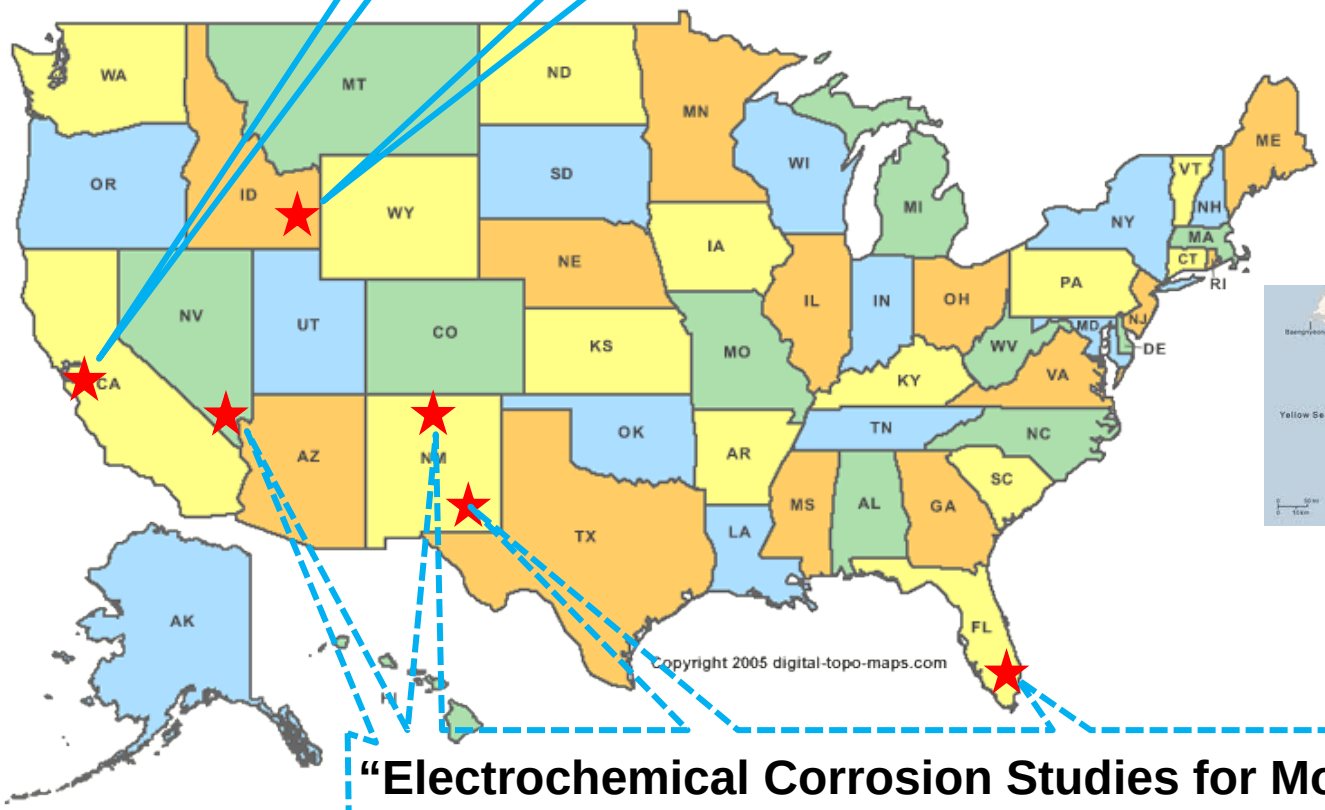
"Modeling Solute Thermokinetics in LiCl-KCl Molten Salt for Nuclear Waste Separation," D. Morgan (U of Wisconsin), J. Eapen (North Carolina State U), $616,073



NEUP Nuclear Energy University Programs
U.S. Department of Energy

FY 2012

"Measurement of Irradiated Pyroprocessing Sample via Laser Induced Breakdown Spectroscopy," S. Phongikaroon (U of Idaho), R. Russo (Lawrence Berkeley NL), M. Glazoff S. Rashkeev, and J. Giglio (INL), $820,000



Jong-Il Yun
KAIST

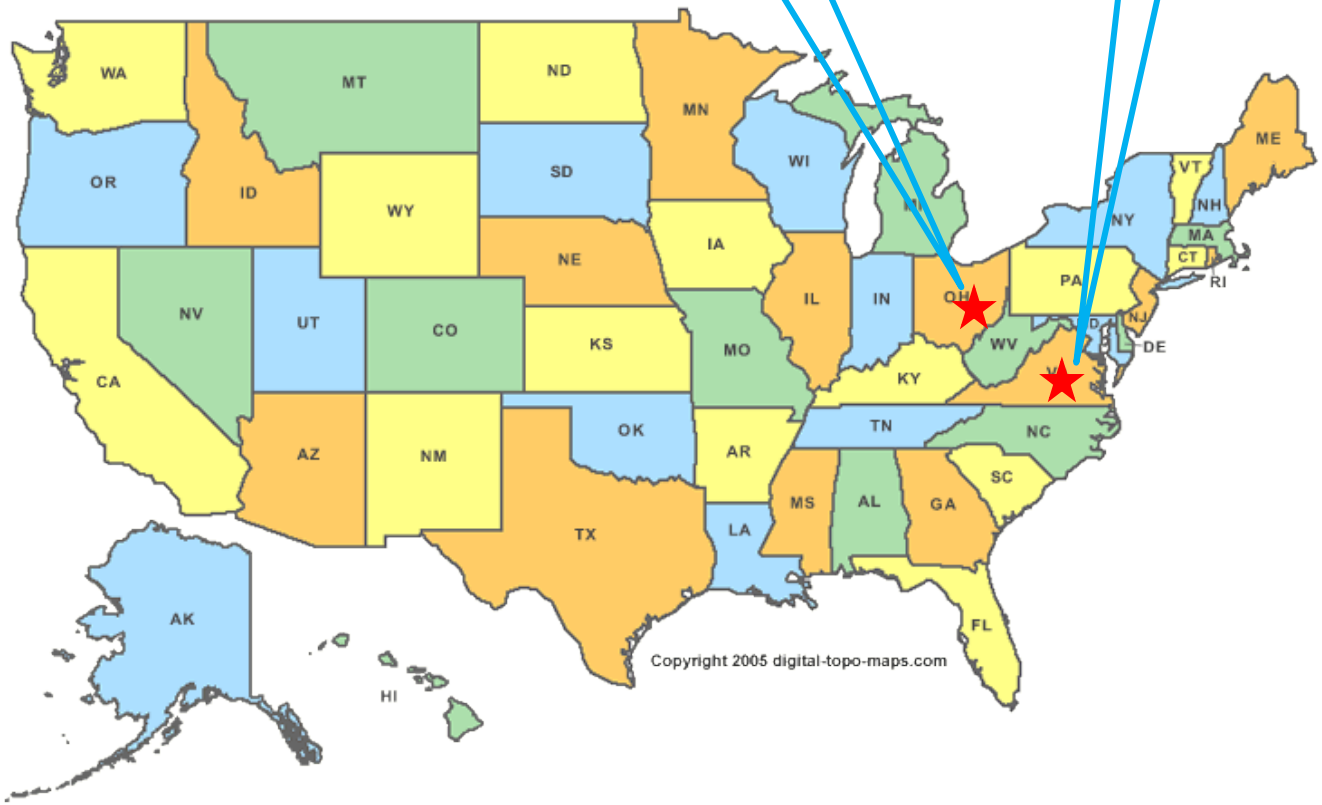
"Electrochemical Corrosion Studies for Modeling Metallic Waste Form Release Rates," K. Czerwinski, E. Kim (UNLV), G. Jarvinen, D. Kolman (LANL), D. Tamalis (Florida Memorial U), and P. Weck (Sandia NL), $790,000

Aqueous separation study that has a potential relation to pyroprocessing studies.

NEUP Nuclear Energy University Programs
U.S. Department of Energy

FY 2013

"Safeguards in Pyroprocessing: an Integrated Model Development and Measurement Data Analysis," J. Zhang (The Ohio State University), and S. Phongikaroon (Virginia Commonwealth University), $623,000



RESEARCH AND EDUCATIONAL CAPABILITIES

THE OHIO STATE UNIVERSITY

Prof. Jinsuo Zhang

Nuclear Engineering Program, Department of Mechanical and Aerospace Engineering

Education
- Ph.D., Zhejiang University, 2001, Fluid Mechanics
- B.S., Zhejiang University, 1997, Engineering Mechanics

Experience
- August 2012 to present, Associate Professor, Department of Mechanical and Aerospace Engineering
- September. 2004 to July 2012, Staff Scientist, Nuclear Design and Risk Analysis Group, Los Alamos National Laboratory
- December 2001 to July 2004, Post-Doctor Research Associate, Materials and Science and Technology, Los Alamos National Laboratory
- September 2004 to August 2007, Adjunct Faculty Member, Department of Mechanical Engineering, University of Nevada, Los Vegas
- 09/ 2009 to October 2013 , Adjunct Faculty Member, Department Chemical Engineering, Ohio University

Research Areas
- Models and experiments in the areas of materials compatibility, electrochemical separation and advanced nuclear fuel
- Chemical and electrochemical separation processes for molten salt mixtures including molten salt recycle
- Advanced technology for safeguarding nuclear fuel cycle facilities
- Molten salt cleanup system development
- Material degradation and corrosion

Publication: Total 64 articles in peer-reviewed journal, over 30 articles in electrochemistry (e.g. pyroprocessing, corrosion).
Funding: $623K (12/2013-11/2016) for pyroprocessing project funded by NEUP, About $490K (10/2009-9/2012) for Pyroprocessing funded by DOE-NEAMS

UNIVERSITY OF NEW MEXICO

Prof. Edward Blandford

Department of Chemical and Nuclear Engineering

Education
- Ph.D., University of California, Berkeley, 2010, Nuclear Engineering
- B.S., University of California, Los Angeles, 2002, Mechanical Engineering

Experience
- 2012- Assistant Professor, University of New Mexico, Chemical and Nuclear Engineering Department
- 2011-2012 Adjunct Research Assistant Professor, University of New Mexico, Chemical and Nuclear Engineering Dept.
- 2011-2012 Stanton Nuclear Security Fellow at CISAC, Stanford University
- 2010-2011 Postdoctoral Fellow at CISAC, Stanford University
- 2007-2010 Graduate Student Researcher, University of California, Berkeley, Nuclear Engineering
- 2003-2006 Project Manager, Steam Generator Management Program, Electric Power Research Institute
- 2002-2003 Member of the Technical Staff, Fuel Reliability Program, Electric Power Research Institute

Research Areas
- Echem system scale modeling and NDA simulation for signature-based safeguards approach
- Advanced process monitoring technology development for safeguarding nuclear fuel cycle facilities
- Sonomechanically-enhanced sparging technology development for molten salt systems
- Reduced-scale molten salt thermal-fluids experiments

Publication: Over 15 articles in pyroprocessing safeguards and fluoride salt thermal-fluids and mass transfer (e.g. fluoride salt-cooled technology development).

Funding: $460K in startup funding from UNM and $499K in NRC faculty development grant

UNIVERSITY OF TENNESSEE – KNOXVILLE

Prof. Steven Skutnik

Department of Nuclear Engineering

Education
- Ph.D., North Carolina State University, 2011, Nuclear Engineering
- M.S., Iowa State University, 2005, Nuclear Physics
- B.S., Iowa State University, 2002, Physics & Astronomy

Experience
- August 2012 to present, Assistant Professor, Department of Nuclear Engineering, University of Tennessee-Knoxville, Knoxville, TN
- October 2011 to July 2012, Postdoctoral Research Associate, Reactor Physics Group, Oak Ridge National Laboratory, Oak Ridge, TN

Awards and Honors
- ORAU, Ralph E. Powe Junior Faculty Enhancement Award, May 2014
- National Nuclear Security Administration, Nuclear Nonproliferation International Safeguards (NNIS) fellowship (2010-2011)
- J.D. Williams Student Paper Award, First Place, Institute of Nuclear Materials Management, 52nd Annual Meeting (2011)
- DOE Office of Fuel Cycle Technologies, First Place, Systems Analysis & Engineering, Fuel Cycle Innovation Awards (2010)

Research Areas
- Advanced modeling & simulation for reactor physics & nuclear fuel cycle applications
- Safeguards development for advanced nuclear fuel cycle facilities
- Nuclear waste management & waste form development
- Used nuclear fuel storage & management

Publication: N/A

Funding: $300K startup fund from University of Tennessee-Knoxville; $750K for (DOE-NEUP) for development of new nuclear fuel depletion modeling capabilities for the DOE fuel cycle simulator (CYCLUS)

UNIVERSITY OF UTAH

Prof. Michael F. Simpson

Department of Metallurgical Engineering

Education
- Ph.D., Princeton University, 1996, Chemical Engineering
- B.S., California Institute of Technology, 1991, Chemical Engineering

Experience
- August 2013 to present, Associate Professor, Department of Metallurgical Engineering, University of Utah, Salt Lake City, UT
- February 2005 to July 2013, Electrochemical Engineer, Idaho National Laboratory, Idaho Falls, ID
- February 1996 to January 2005, Chemical Engineer, Argonne National Laboratory-West, Idaho Falls, ID

Awards and Honors
- Pace Setter Award for outstanding contributions to the Argonne National Laboratory-West student internship program (October 2003)
- Employee outstanding annual achievement awards, Argonne National Laboratory-West, various years from 2000-2004.
- Graduation with Honors, California Institute of Technology (June 1991).

Research Areas
- Advanced chemical and electrochemical separation processes for molten salt mixtures
- Development of advanced monitoring technology for molten salts
- Development of alternative safeguards approaches for nuclear facilities
- Nuclear waste form development and waste management
- Development of liquid thorium salt fueled nuclear reactors

Publication: Over 15 articles in peer-reviewed journal in pyroprocessing technology.

Funding: $200K in FY-14 for pyroprocessing projects, $470K startup fund from University of Utah; Over $9M in competitive funding awarded before joining U. of Utah (Princeton U., Argonne National Laboratory, and Idaho National Laboratory)

UNIVERSITY OF WISCONSIN - MADISON

Prof. Kumar Sridharan

Department of Nuclear Engineering & also affiliate faculty Materials Science and Engineering

Education
- Ph.D., University of Wisconsin, Madison, 1989, Department of Materials Science and Engineering
- B.S., Indian Institute of Technology, Varanasi 1981, Metallurgical Engineering

Experience
- Distinguished Research Professor: Engineering Physics, University of Wisconsin-Madison (3/2008 – present)
- Research Professor:, Senior Scientist, Associate Scientist, Assistant Scientist, and Post-Doctoral Research Associate, University of Wisconsin, Madison (1989-2008)
- Graduate Student Research and Teaching Assistant(1982-89)
- Metallurgist, Allenco Steel, Philippines, 1981-82

Awards and Honors
- Elected Fellow of American Society for Materials (2008)
- University of Wisconsin, Madison's Bollinger Award for Academic Achievement (2012)
- University of Wisconsin, Madison's Chancellor's Award for Excellence in Research (2013)
- Editorial Board of journal *Advanced Materials and Processes* (2013 – present)

Research Areas
- Corrosion and electrochemistry
- Development of molten salts for nuclear applications
- Materials for nuclear energy systems
- Molten salt based pyroprocessing
- Dry cask storage of spent nuclear waste

Publication: Over 200 publications including six invited book chapters, journal articles, conference proceedings, published abstracts, and industrial and national laboratory reports.

Funding: About $15M in competitive grant funding over the last two decades; received over $1M in funding in FY-14; co-PI for $6M IRP grant with two other universities in the area of molten salt research and co-PI for $4M IRP grant with five other universities on dry cask used fuel storage; $450K/3yr. funding for research on LiCl-KCl nuclear waste processing in FY-08.

VIRGINIA COMMONWEALTH UNIVERSITY

Prof. Supathorn Phongikaroon

Department of Mechanical and Nuclear Engineering

Education
- Ph.D., University of Maryland, College Park, Maryland, 2001, Chemical Engineering
- B.S., University of Maryland, College Park, Maryland, 1997, Nuclear Engineering with secondary field in Chemical Engineering

Experience
- August 2007 to 2013, Assistant Professor, Department of Chemical Engineering and Nuclear Engineering Program, Idaho Falls, ID
- October 2004 to 2007, Chemical Engineer, Idaho National Laboratory (formerly known as Argonne National Laboratory-West), Idaho Falls, ID
- October 2001 to 2004, NRC Postdoctoral Fellowship, Naval Research Laboratory, Washington, DC

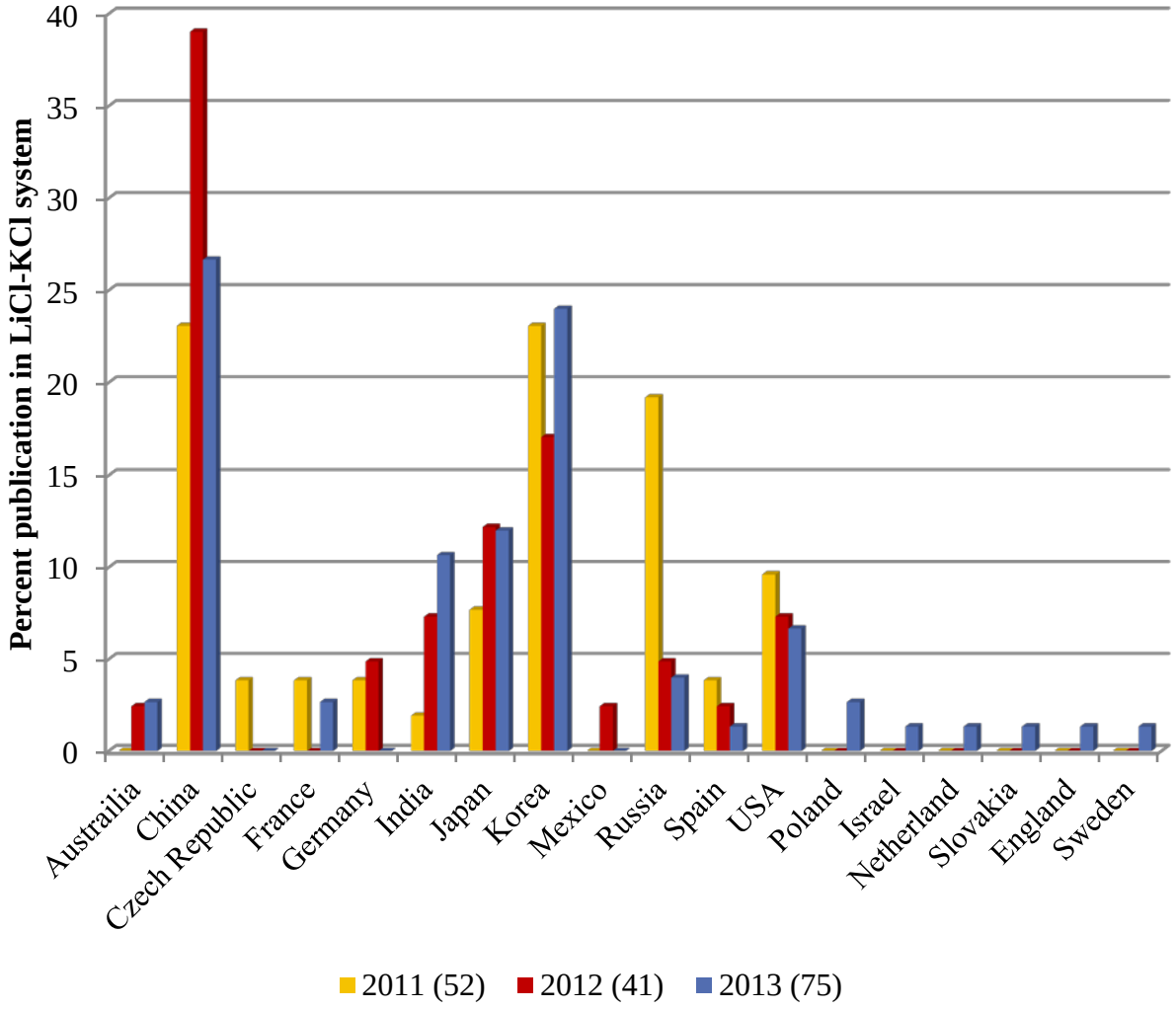
Awards and Honors
- Center for Advanced Energy Studies Outstanding Contributor, 2011
- Distinguished Teaching Assistant Award, the Center for Teaching Excellence, UMCP, 1998-1999
- UMCP AIChE Teaching Assistant Award, Department of Chemical Engineering, 1997-1998
- The American Nuclear Society Washington Chapter Senior Award—Senior in Nuclear Engineering with highest GPA, 1996-1997

Research Areas
- Pedagogy and research in the area of nuclear and chemical separation technology in Fuel Cycle Research and Development
- Electrochemical processes–theoretical and experimental studies in electrorefiner, electrolytic oxide reduction and chemistry, and ion exchange
- Special material detection and analysis via laser and mass spectroscopy techniques
- Interfacial phenomena and multi-phase flow systems involving in nuclear and chemical engineering applications

Publication: Over 15 articles in peer-reviewed journal in pyroprocessing technology.

Funding: Over $2.4 M on research activities in pyroprocessing technology

PUBLICATION IN MOLTEN SALT



Publication List

	2013	2012	2011
Austrailia	2	1	0
China	20	16	12
Czech Republic	0	0	2
France	2	0	2
Germany	0	2	2
India	8	3	1
Japan	9	5	4
Korea	18	7	12
Mexico	0	1	0
Russia	3	2	10
Spain	1	1	2
USA	5	3	5
Poland	2	0	0
Israel	1	0	0
Netherland	1	0	0
Slovakia	1	0	0
England	1	0	0
Sweden	1	0	0
Total	75	41	52

Information from Web of Knowledge

SIGNIFICANT FINDINGS

- **High and consistent interest in molten salt study from S. Korea.**
  - Published articles are either from KAERI or universities collaborating with KAERI or the governmental agencies.
- **Growth in molten salt interests among**
  - China,
    - Published articles are from universities with sponsorship from governmental agencies.
  - India, and
    - Published articles are mostly from the national laboratory.
  - Japan
    - Published articles are either from the laboratories or universities collaborating with laboratories/governmental agencies.
- **Low contribution from the U.S.**
  - For example, in 2013, 2 articles from the NEUP projects and 3 articles from Drs. Phongikaroon and Simpson collaborating with INL.

ACADEMIC CONSORTIUM

Academic Consortium

Active since 2010

The Ohio State U.
Electrochemical modeling and molten salt recycle and cleanup

Active since 1996

U. Of Utah
Molten salt electrochemistry and thermal analysis, waste form development, and safeguard

Active since 2004

VCU
Laser spectroscopy, molten salt transport processes and electrochemistry for materials accountability

U. Of New Mexico
Safeguards instrumentation and modeling

Active since 2013

U. Of Tennessee
Waste management and safeguards

Active since 2013

U. Of Wisconsin
Molten salt electrochemistry and thermal analysis

Active since 2009

GENERAL REQUEST FOR THE ACADEMIC CONSORTIUM

- **Involvement in the JFCS by having faculty affiliation to the associated national laboratory**
- **At least 2 graduate students per institution per year by DOE-NE or through a direct fellowship program (12 × $50 K/yr = $600 K/yr)**
- **Funding to support university educational workshops to enhance collaboration and support of DOE FCR&D program ($50 K/yr)**
- **Direct funding support to enhance experimental and computational capabilities toward the pyroprocessing technology ($500 K per 3 yr per institution = $3 M)**