

Nuclear Innovation 2050

www.oecd-nea.org/ndd/ni2050/

Fiona Rayment

Chair of NEA NI2050 Advisory Panel

NUCLEAR INNOVATION 2050

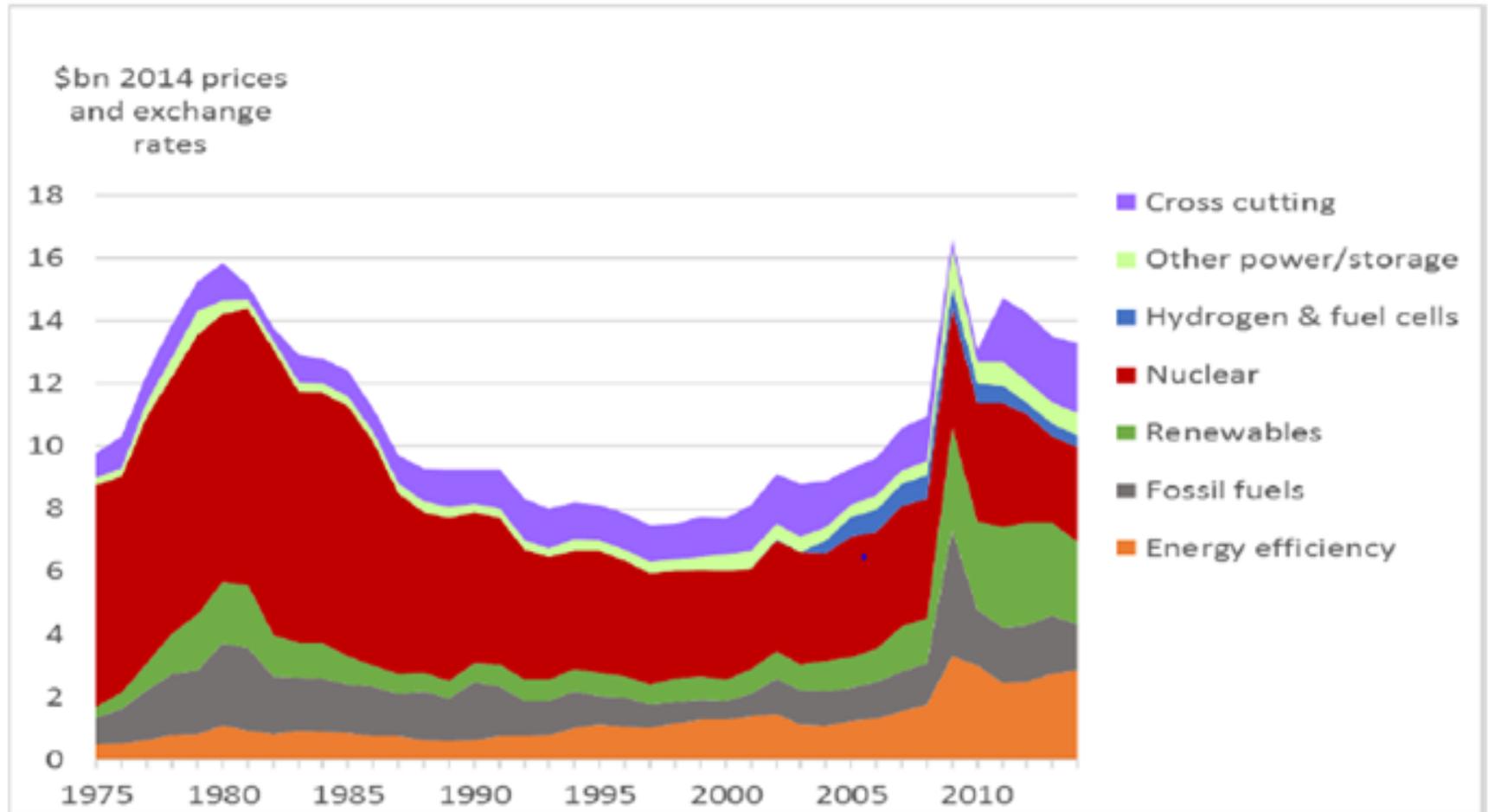
An NEA initiative to accelerate R&D and market deployment of innovative nuclear fission technologies to contribute to a sustainable energy future



A Broad NEA Initiative

Building a co-operative framework enabling innovative fit-for-purpose nuclear fission technologies that will accelerate R&D and market deployment to contribute to a sustainable energy future

R&D Public BUDGETS/SCOPES

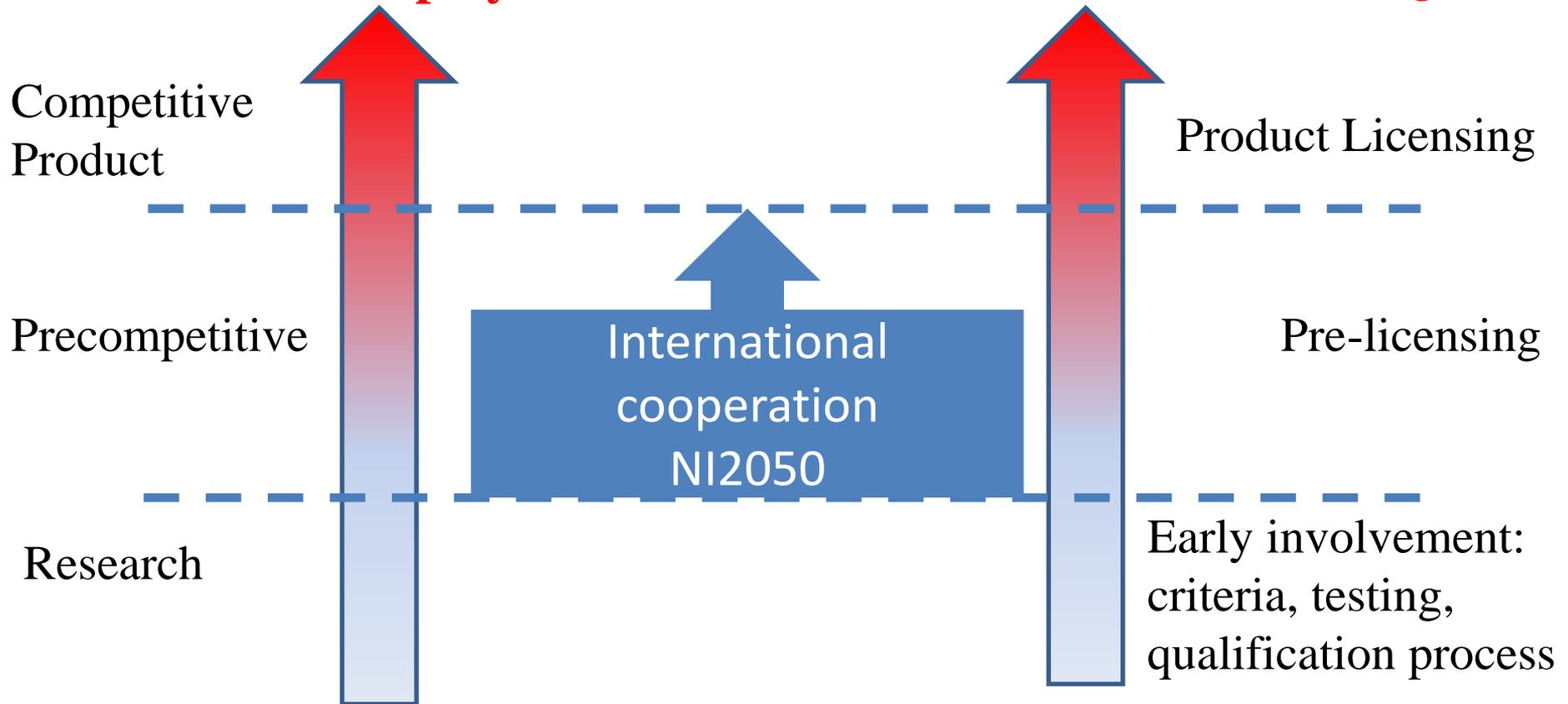


Source: Energy Technology RD&D, IEA (2015).

TECHNOLOGY AND LICENSING READINESS

From research to deployment...

... with effective involvement of regulators



Nuclear Innovation Headwinds

INFRASTRUCTURE

- Unlike many other areas of innovation, nuclear technology often requires the availability of special facilities (test reactor, hot cells, test loops, etc.) and nuclear-skilled workers.
- Tests using fissile materials require appropriate facilities, trained workforce, security and licencing.
- **Much of the global infrastructure was built more than 40 years ago and is shrinking steadily.**

REGULATORY

- The job of nuclear regulatory organisations today is to assure public safety, not to promote innovation.
- Regulators in most countries will not actively participate in technology development – but will wait for the finished technology to be presented for approval.
- **Regulators are often perceived by researchers and industry as a barrier to innovation.**

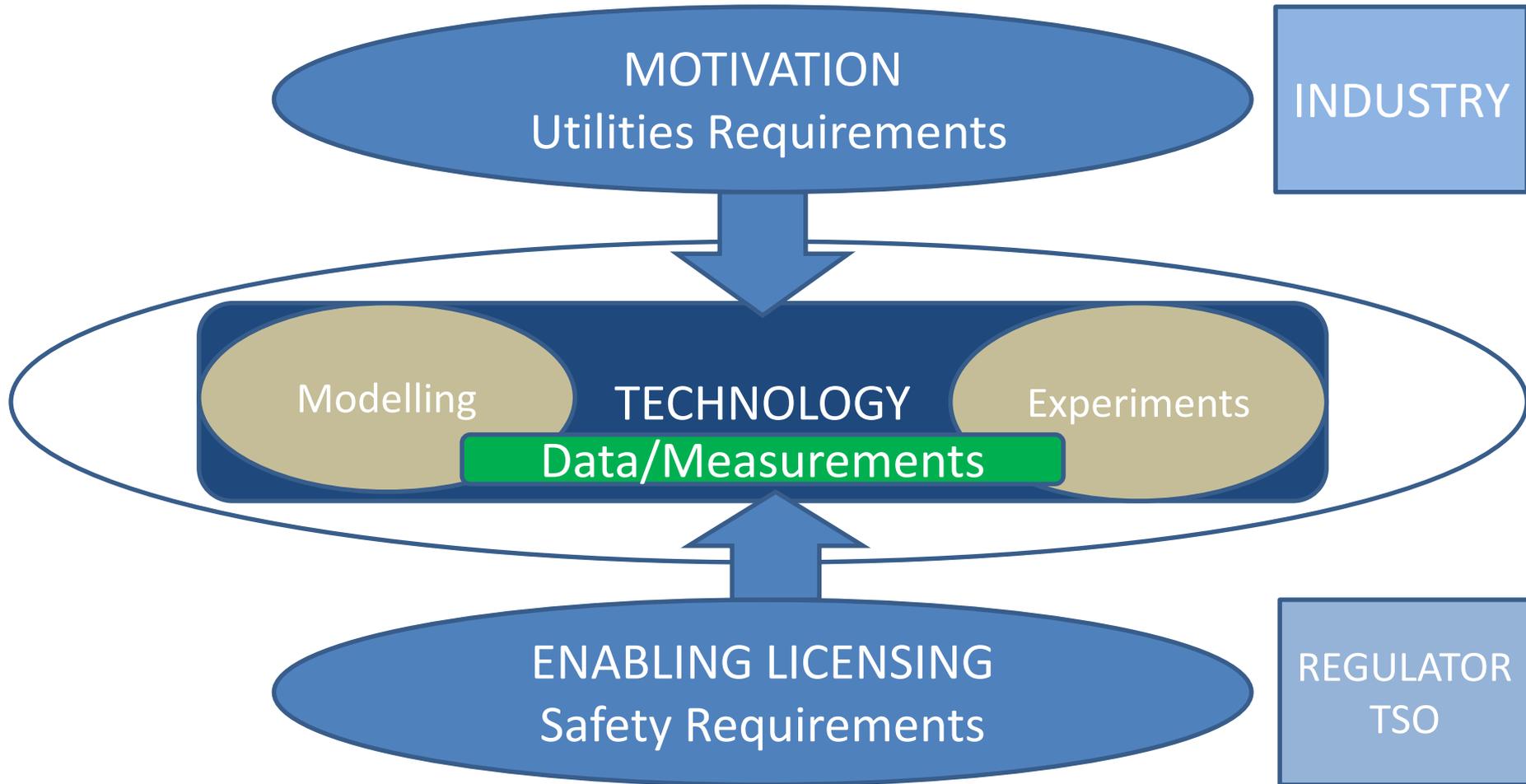
COST

- Nuclear technology research budgets have been under pressure in most countries for the last decade.
- Nuclear technology often requires an order-of-magnitude increase in funding to transition between research and engineering-scale demonstration.
- **The cost and risk of nuclear technology innovation has become prohibitive in many countries.**

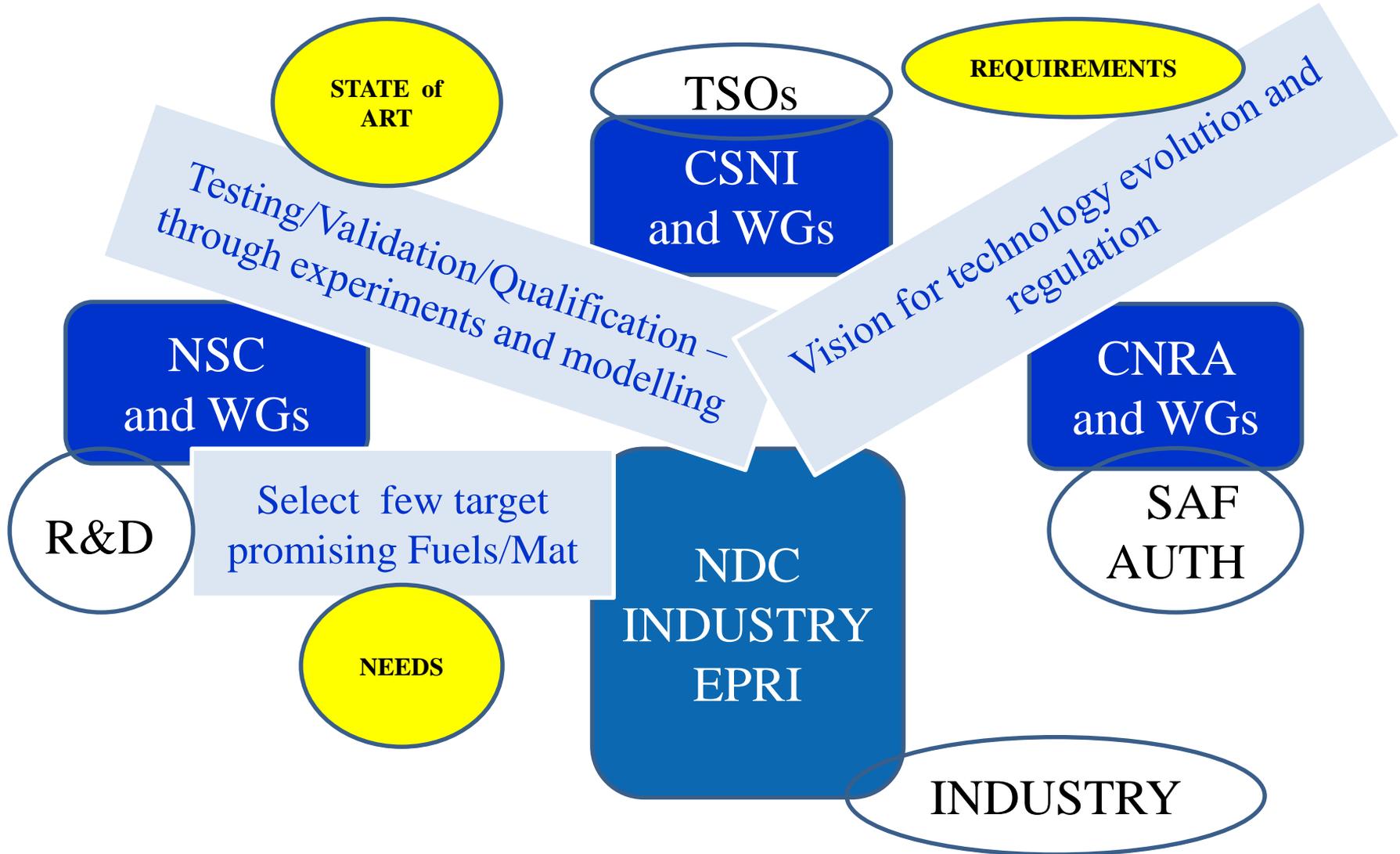
As main high level outcomes, NI2050 has

- opened the way for high level discussions on the role nuclear energy could play in the longer term « carbon neutral » future, with new reactors and fuel cycles, and with new usages of nuclear heat, leading to an increased flexibility at system level, for a better integration of nuclear with renewables
- confirmed that innovation in technology evolution is a necessary contributor to safety & economics
- recognised that success depends on regulatory engagement early on within the innovation process whilst still enabling regulatory independence.
- supported the creation of the « Multilateral Fuel and Material Testing Capacity » project, by showing the value of collaboration to improve the qualification of fuels and materials

Structure



« NI2050 Fuels/Mat » and existing NEA Groups



Innovation for the Future of Nuclear Energy – A Global Forum

Gyeongju, Korea June 10 - 12 June 2019

Key Outcomes

NI 2050 Future Focus

- Going forward we will be focusing on both nuclear and non-nuclear innovations that enable nuclear to continue to be an important part of any future clean, sustainable and affordable energy mix.
- Initial areas of focus:
 - Fuels and materials (Nuclear Innovation)
 - Advanced manufacturing and digital systems (Innovation into Nuclear)
 - Using nuclear energy beyond electricity (Innovation for better integration in the wide low carbon energy system)

Nuclear Innovation 2050

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Marc DEFFRENNES
Secretariat NEA NI2050

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NI 2050 ACTIVITY REPORT

Acknowledgment

1. Introduction: from the initial “Project” to the broader “Initiative”
2. Budget and Scope of Member Countries nuclear R&D programmes
3. Aim and Concepts of NI2050
4. Priority Topics for concrete focussed innovation Roadmaps (Templates)
5. Next step: from Roadmaps (Templates) towards Programmes for Action – the case of Advanced Nuclear Fuels and Materials
6. Ways and Means for implementation
7. Conclusions, recommendations and way forward
8. Annexes, Reference Document and NI2050 Website

NI2050 “Templates” Topics (Final End 2018)

Target Area/TOPIC	Leaders	Groups Engaged
Accident Tolerant and Advanced Fuels	K. Pasamehmetoglu, INL N. Chauvin, CEA	NSC (WPFC, WPMM, EGISM, EGATFL), CSNI (WGFS) + FIDES
Severe Accident Knowledge and Management	G. Bruna/D Jacquemain, IRSN	CSNI (SAREF, WGAMA) ETSON, NUGENIA
Passive Safety Systems	G. Bruna/JM Evrard, IRSN	CSNI (WGAMA) ETSON
LTO Gen II 80 Years: Ageing Management	A. Al Mazouzi, EDF	CSNI (WIAGE) NUGENIA
NPP Decommissioning	M Pierracinni, EDF	RWMC/CDLM
Advanced Materials (Gen IV)	L. Malerba, SCKCEN/CIEMAT	NSC (WPFC, WPMM) + FIDES, EERA JPNM, GIF
Advanced Components (Gen IV)	H. Kamide, JAEA	GIF, CSNI/CNRA (GSAR/WGRNR)
Fuel Cycle Chemistry/Recycling (P&T)	H. Ait Abderrahim + al., SCKCEN	NSC (WPFC), CSNI (WGFCs)
Heat Production and Cogeneration	D. Hittner, NC2I	PRIME/GEMINI (NC2I, NGNP, JAEA, KAERI)
Modelling and Simulation	T. Valentine, ORNL	NSC (WPMM, EGMPEBV)
Measures and Instrumentation	G. Bignan, CEA	ANIMMA, NSC FIDES
Infrastructures and Demos	All	NSC FIDES, CSNI (ia TAREF), DB (RTFDB)

Nuclear Innovation 2050 WEBSITE

www.oecd-nea.org/ndd/ni2050/



Innovation for the Future of Nuclear Energy – A Global Forum

Gyeongju, Korea
June 10-12, 2019

JUNE 10-12 2019
GYEONGJU SOUTH KOREA

BREAK DOWN BARRIERS
ACT NOW

BRIGHT FUTURE

CLEAN energy

Safe & TRANSPARENT

TECHNOLOGY & INNOVATION

INNOVATION FOR THE FUTURE of NUCLEAR ENERGY

A.I. ✓ **TECHNOLOGY & PROCESS INNOVATION**
A.R.

✓ **CONVERGENCE**

✓ **COMMUNICATION with PUBLIC**

TRANSPARENCY
CO-OPERATION
SUPPORT

WHAT IS OUR LEGACY?

23 PLANTS

26 PLANTS

ON TIME
ON BUDGET



JAE HOON CHUNG
PRESIDENT - CEO KHNP

NEIL WILMSHURST
VICE PRES. EPRI

YOUNG JOON JOO
DEPUTY MINISTER
MIN. TRADE, INDUSTRY
& ENERGY

- 1978
- 1. NUCLEAR SAFETY
- 2. ECONOMIC FEASIBILITY
- 3. DISPOSAL OF NUCLEAR RESIDUAL

HOW CAN WE COME TOGETHER TO RE-DEFINE THIS INDUSTRY?

ADDRESS CLIMATE CHANGE

IS IT GOOD ENOUGH?

WHAT WOULD GRETA SAY?

Why Not US?

KOREAN ECONOMY

WE COLLABORATE WELL

LET'S TALK POSITIVELY

IMAGE

WHY WILL PEOPLE JOIN

WE ARE VERY NIMBLE

IS THAT PROJECTION GOOD ENOUGH?

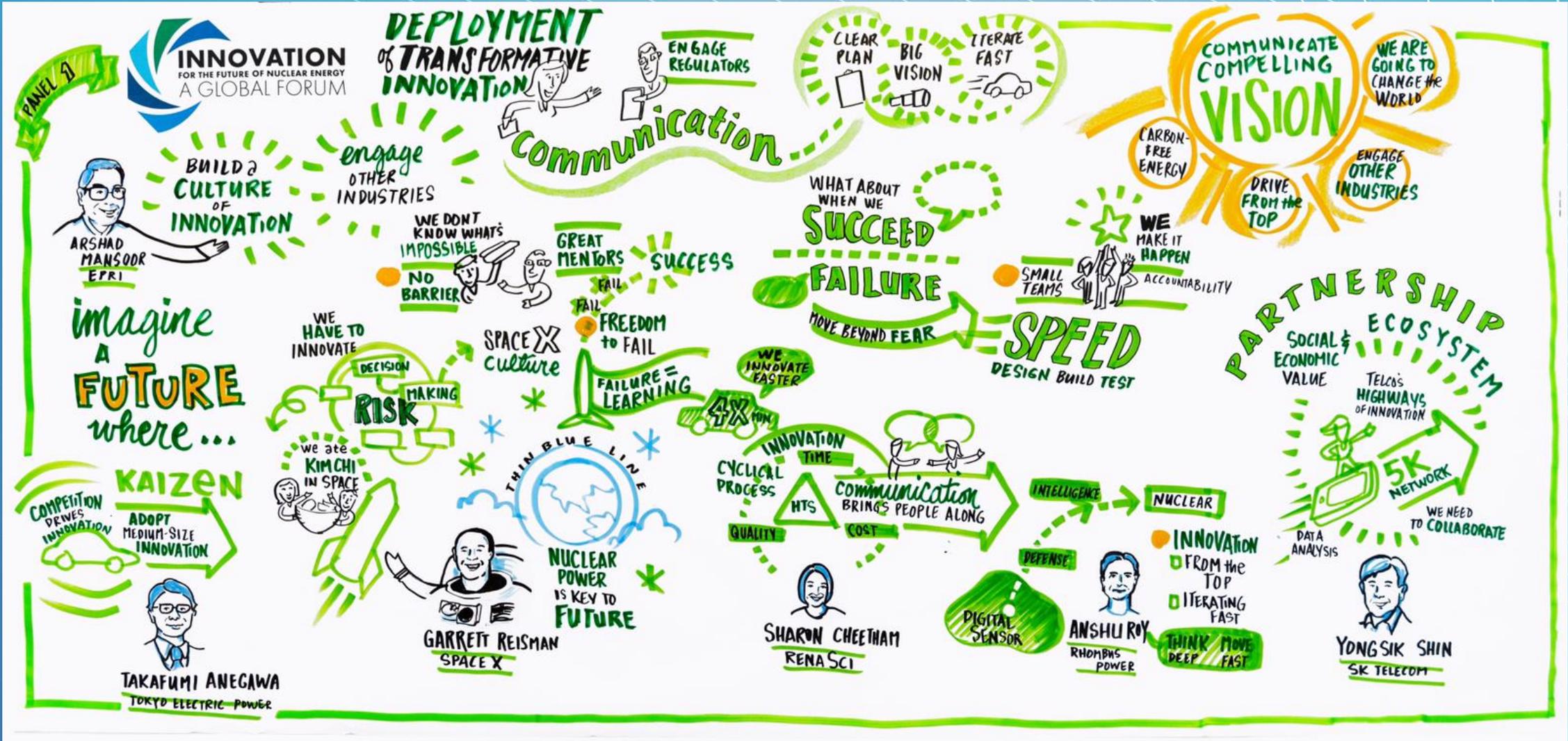
CO₂ REDUCTION
DECARBONIZATION

DIGITAL CONTROL ROOMS

HOW LONG WILL IT TAKE?



Welcome, Opening Remarks, and Keynote



PANEL 2

TRANSFORMING NUCLEAR FOR OUR FUTURE

CONTINUOUS IMPROVEMENT
look beyond...

GOOD QUESTIONS
SPARK INNOVATION



FRED DERMARKER
CANAD GROUP

SAFETY

PRA QUALITY

FUTURE

GAP
POPULATION
CURRENT



MASAYUKI YAMAMOTO
TEPCO

MAKE INNOVATION AS IMPORTANT AS DAY TO DAY...

encourage INNOVATION
SIMPLE TO USE
RELIABLE RESULTS

ACT NOW
ANTONOMONS OPERATION

FLEXIBLE POSITIVE
Self-Reliance
NUCLEAR INDUSTRY
ACCEPT CHANGE

DECISION MAKING

WHAT'S POSSIBLE DIGITAL
A.I.
DIG DATA

PROTECTION RELIABILITY
DIGITAL POWER PLANT



SHIN WHAN KIM
KEPCO ENGINEER'S

NUCLEAR-RENEWABLE HYBRID ENERGY SYSTEM

HOW TO GET PEOPLE TO **embrace CHANGE?**

UNDERSTAND NEEDS
Share INFORMATION

FOCUS ON BIGGER INITIATIVES



LEADER
IT'S MY JOB TO INFLUENCE & DRIVE CHANGE

INNOVATION CREATES HAPPINESS

VISION OF FUTURE

TECHNOLOGY

ENGAGE WITH REGULATORS

REGULATORS

INNOVATE TOGETHER WITH US

BUILD ON REGULATIONS

COMMUNITY
ENGAGE REGULATORS
CONVERSATIONS

WE NEED HELP:
MULTI-SCALE MONITOR INSTRUMENT'N
A.I.



LEADERS



EXPERT

COLLABORATION

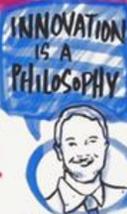


ABDERRAHIM AL MAZDUZI
NUGENTIA

ENCOURAGE BOTTOM UP INNOVATION

HOW DO YOU BRING R.O.I. INTO SOMETHING NOT DONE BEFORE
SPEED PURPOSE
INNOVATION VELOCITY
QUALITY PROCESS ENTERPRISE LOCAL ECOSYSTEM
CONNECT WITH THE ECOSYSTEM

HOW OFTEN DO YOU SEE INNOVATION INTEGRATED INTO everything



JASON WIGHT
PNGS - ONTARIO POWER

IS IT PHYSICS... OR IS IT ME?



TIM HAMONS + JIHYUN LEE
ART OF AWAKENING

MAKE IT EASY FOR PEOPLE TO INNOVATE
SAVE THE WORLD



PANEL 4 INNOVATION FOR THE NUCLEAR SECTOR

JUNE 10-12 2019 GYEONGJU, S. KOREA

TAKE A RISK... IT ALWAYS PAYS
MAKE THE VISION A REALITY



FIONA RAYMENT
NUCLEAR INNOVATION & RESEARCH

HOW CAN REGULATORS ENCOURAGE INNOVATION

REGULATORS
NEW RELATIONSHIP WITH
MORE STANDARDIZIN



ASK THE RIGHT QUESTIONS

TECHNOLOGY FOR HUMANITY
CARBON-FREE AFFORDABLE energy

BRING PEOPLE INTO THE INDUSTRY



COMMUNICATION

PUBLIC PERCEPTION

SIMPLE THINGS WE CAN DO...

MORE YOUNG PEOPLE
WORK OUTSIDE THE INDUSTRY

COLLECTIVE KNOWLEDGE



WHAT ARE WE DOING WITH IT?

HIGHER EDUCATION
CASE STUDIES DOCUMENTATION

COMPETENCE

OPERATIONAL MAINTENANCE

TECHNICAL & MANAGERIAL

WHAT'S RELEVANT?

HOW TO KEEP NUCLEAR COMPETITIVE RELEVANT?

BARRIERS
CLOSED; TOO EXPENSIVE



WILLIAM D. MAGWOOD IV
NUCLEAR ENERGY AGENCY

HOW TO GET TO WORK TOGETHER



GOVT PRIVATE SECTOR

SMALL MODULE REACTORS ARE THE FUTURE

EARLY DETECTION & DIAGNOSIS



YUNHO KIM
KHNP

OPTIMIZE DESIGN

CONSTRUCTION

DIGITAL TWIN

COST

HOW CAN WE BRING IT DOWN

REDUCE DISCRIMINATION

WORK WITH SCHOOLS + TEACHERS



TECHNOLOGY PARTNERSHIPS



JEFFREY MERRIFIELD
PILLSBURY WINTHROP SHAW PITTMAN LLP

BIG

KEEP NUCLEAR COMPETITIVE ATTRACTIVE

SMALL

FIND THE RIGHT

NOT ALL INNOVATIONS ARE WORTH DEVELOPING



PATRICK MORILHAT
EDF FRANCE

LOOK AT QUESTIONS A DIFFERENT WAY

TECHNOLOGY SCOUTS



NEIL WILMSHURST
EPRI

UNIVERSITIES

OUR ROLE: REDUCE COSTS

USE DATA

SAVE MONEY

INVITE PEOPLE TO THE INDUSTRY

TIM HAMONS
JHYUN LEE

ART-OF-AWAKENING



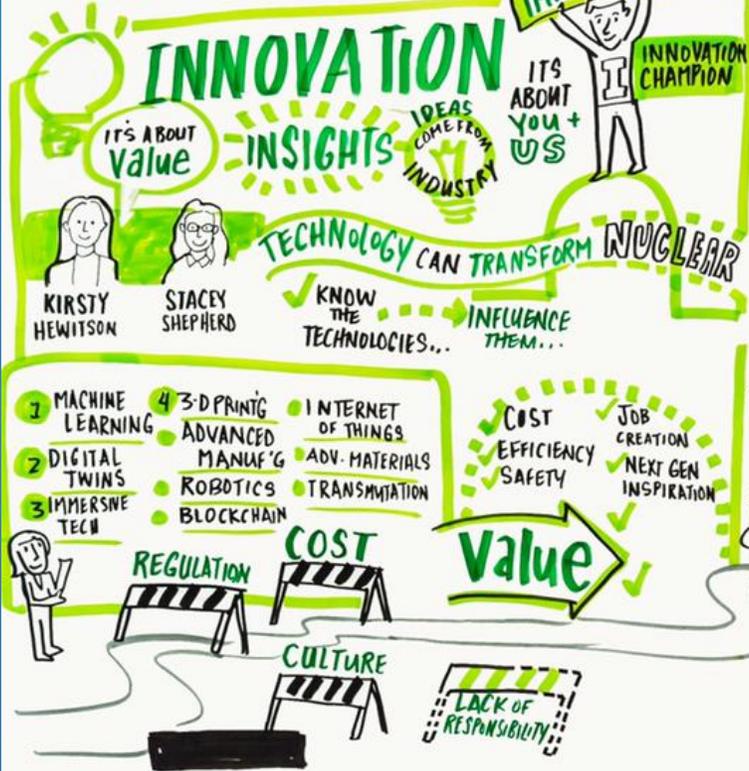
Innovation in the Nuclear Sector

JUNE 10-12 2019
GYEONGJU, SOUTH KOREA

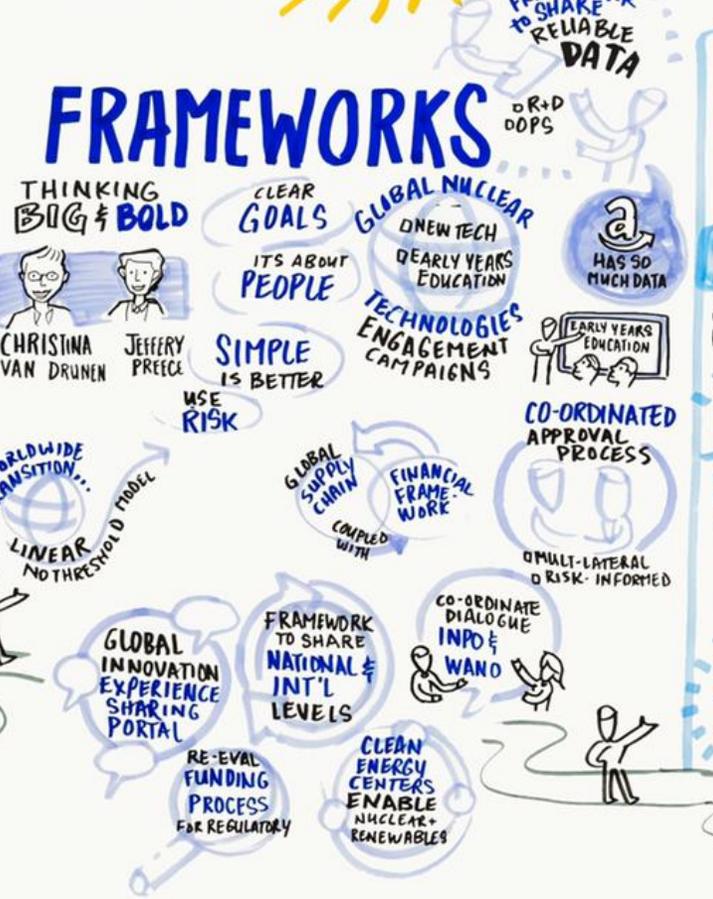
REGULATOR PERSPECTIVES ROUND TABLE



TIM HAMONS + JIHYUN LEE
ART OF AWAKENING



SMALL GROUP DISCUSSION INSIGHTS





ACTIONS to DEPLOY INNOVATION



Top 4 Innovations

1. **machine learning** to make better use of the 'big data' already available in the nuclear power sector for optimizing maintenance;
2. **using more innovative frameworks** for information exchange, to share data on research and development, operations and maintenance
3. **digital twinning** (the virtual recreation of a process into a computer-based model) to improve NPP performance and to reduce costs
4. **advanced manufacturing**, including 3D printing, to address supply chain challenges

Top Innovations from Each Category

Technology	Framework	Culture and Leadership
Machine Learning / Big Data	World wide transition from the linear no-threshold model	Accepting failure. Learning from failure.
Digital Twins	Global supply chain coupled with financial framework to reduce costs and improve efficiencies	Provide budget and resources.
Immersive Technologies	Coordinated, multi-lateral risk-informed regulatory approval process	Develop commitment and strategy
Advanced Manufacturing / 3D Printing	Frameworks to share comparable, reliable data - R&D, operations, maintenance	Improve diversity

“Now this is not the end. It is not even the **beginning** of the end. But it is, perhaps, the end of the **beginning.**”

-- Sir Winston Churchill

Top 12 Innovations

Top 12 Innovations that Were Ranked

- Machine learning/big data
- Digital twins
- Advanced manufacturing
- Immersive technologies
- Worldwide transition from the linear no-threshold model
- Framework to share comparable, reliable data – R&D, operations, maintenance
- Clean Energy Centers integrating nuclear and renewables
- Coordinated, multi-lateral risk-informed regulatory approval process
- Accepting / Learning from Failure
- Develop Commitment and Strategy
- Provide Budget, Resources
- Improve Diversity

Machine learning/big data

Examples:

- Replace reactor operator
- Automation of processes
- Predictive maintenance
- Guiding regulatory inspections

• Key Benefits:

- Operator efficiency
- Safety improvement
- Improved reliability
- Cost savings

• Technology Readiness:

- High – Technology mature and used in other industries

• Key Stakeholders:

- Supply chain
- Regulator
- Plant operator
- Vendor

Digital twins

Examples:

- Plant/sub-components/systems
- Fuel and waste casks
- Operating parameters
- Training/education applications

- Key Benefits:
 - Operational efficiency
 - Safety improvement
 - Cost savings
 - Public acceptance
 - Improved reliability
- Technology Readiness:
 - Medium – Technology ready for first use
 - High – Technology mature and used in other industries
- Key Stakeholders:
 - Supply chain
 - Regulator
 - Plant operator
 - Vendor

Advanced manufacturing

Examples:

- HIP
- Electron beam welding
- Component modularization and standardization

- Key Benefits:
 - Cost savings
 - Reduced inspections e.g. no welds
 - Fabrication speed
 - Reliability
- Technology Readiness:
 - Medium – Technology ready for first use
 - High – Technology mature and used in other industries
- Key Stakeholders:
 - Regulator
 - Plant operator
 - Vendor
 - Supply chain

Immersive technologies

Virtual reality, augmented reality

Examples:

- Maintenance
- Training
- Design validation

- Key Benefits:

- Improved engagement – fun!
- Cost savings
- Improved communication/knowledge transfer
- Environmental impact (less travel)

- Technology Readiness:

- High – Technology mature and used in other industries

- Key Stakeholders:

- Supply chain
- Regulator
- Plant operator

Worldwide transition from LNT model

- Endorsed by the World Health Organization
- Right-size emergency zones and precautionary actions

- Key Benefits:
 - Operational efficiency / cost reduction
 - Safety Improvement
 - Enhance public trust
- Technology Readiness:
 - Medium – Framework developed with few use cases
- Key Stakeholders:
 - Legislator
 - Regulator
 - Utility
 - Vendor
 - Research Organizations

Framework to share comparable, reliable data – R&D, operations, maintenance

- Builds international database of operating data to enable AI and advanced analytics
- Optimizes operations and maintenance
- Decreases uncertainties in risk assessment
- Key Benefits:
 - Operational efficiency / cost reduction
 - Safety Improvement
- Technology Readiness:
 - Medium – Framework developed with few use cases
- Key Stakeholders:
 - Regulator
 - Utility
 - Vendor
 - Research Organizations
 - International organizations

Clean Energy Centers integrating nuclear and renewables

- Positions nuclear as a clean-energy enabler in public perception
- Advances integrated energy systems
- Sustains nuclear technology as an option
- Key Benefits:
 - Enhance public trust
- Technology Readiness:
 - High – Framework well developed and used broadly in other industries
- Key Stakeholders:
 - Utility, grid operator
 - Vendor
 - Research Organizations

Coordinated, multi-lateral, risk-informed regulatory approval process

- Increases regulatory certainty in export markets to underpin business case and financing
- Accelerates global deployment of innovations

- Key Benefits:
 - Operational efficiency / cost reduction
 - Enhance public trust
 - Regulatory efficiency
- Technology Readiness:
 - Low – Conceptual Framework
- Key Stakeholders:
 - Regulator
 - Utility
 - Vendor
 - Research Organizations
 - International organizations

Accepting / Learning from Failure

- Success for this innovation is to change behaviour and recognize that innovation involves learning from failures. Leaders expect some failures in innovation.
- Key Benefits:
 - Deploy innovations more effectively or faster
 - Reduce cost / increase efficiency
 - Ability to attract and retain top talent
- Organizational Readiness:
 - Low – May need substantial shifts in culture, organizations or relationships; Resistance expected
- Key Stakeholders:
 - Regulator
 - Utility
 - Vendor
 - Research Organizations

Develop Commitment and Strategy

- Success for this innovation is for employees to understand the importance of innovation and where to focus their innovation efforts.
- Key Benefits:
 - More diverse set of views (stimulate innovation)
 - Deploy innovations more effectively or faster
 - Enhanced safety / reduced uncertainty
 - Reduce cost / increase efficiency
 - Forward-looking industry leadership
 - Ability to attract and retain top talent
- Organizational Readiness:
 - Medium – May need moderate shifts in culture, organizations or relationships; Willingness is country-specific
 - High – Small changes to existing culture, organizations or relationships; Strong willingness for change globally
- Key Stakeholders:
 - Regulator
 - Utility
 - Vendor
 - Research Organizations

Provide Budget, Resources

- Success for this innovation is to provide adequate space and tools for innovation to be pursued such that innovators are energized.

- Key Benefits:
 - More diverse set of views (stimulate innovation)
 - Deploy innovations more effectively or faster
 - Enhanced safety / reduced uncertainty
 - Reduce cost / increase efficiency
 - Forward-looking industry leadership
 - Ability to attract and retain top talent
- Organizational Readiness:
 - Medium – May need moderate shifts in culture, organizations or relationships; Willingness is country-specific
- Key Stakeholders:
 - Legislator
 - Regulator
 - Utility
 - Vendor
 - Research Organizations

Improve Diversity

- Success for this innovation is to extend diversity to experiences and educational background, especially in recruitment practices and team building.

- Key Benefits:
 - More diverse set of views (stimulate innovation)
 - Reduce cost / increase efficiency
 - Forward-looking industry leadership
 - Ability to attract and retain top talent
- Organizational Readiness:
 - High – Small changes to existing culture, organizations or relationships; Strong willingness for change globally
- Key Stakeholders:
 - Legislator
 - Regulator
 - Utility
 - Vendor
 - Research Organizations

Lists of All 28 Innovations

Innovations - Technology

- Machine learning/big data
- Digital twins
- Immersive technologies
- 3D printing
- Advanced manufacturing
- Robotics
- Blockchain
- Internet of Things
- Advanced materials
- Transmutation

How can frameworks that help boost innovation be designed?

1. Worldwide transition from the linear no-threshold model
2. Global supply chain coupled with financial framework to reduce costs and improve efficiencies
3. Coordinated, multi-lateral risk-informed regulatory approval process
4. Framework to share comparable, reliable data – R&D, operations, maintenance
5. Coordinated, global nuclear technology public engagement campaign, including early-years education and new technologies
6. Global innovation sharing portal
7. Framework to share the risk of innovations at national and international levels
8. Consider opportunities to coordinate/enhance dialogue between INPO/WANO and safety authorities
9. Budgetary funding process for nuclear regulatory organizations (US/Canada)
10. Clean Energy Centers integrating nuclear and renewables

Innovations – Culture, Leadership & Collaboration

1. Foster an organizational culture of accepting and learning from failure [**culture**]
2. Leaders should grant sufficient time, budget, and resources for workers to innovate [**culture/leadership**]
3. Senior Leaders should develop a high-level commitment and strategy for innovation [**leadership**]
4. Designate 'innovation leaders' in the organization that report to institutional leadership or utilize dedicated teams that pursue innovative projects with clear scope [**leadership**]
5. Innovation activities should not be subject to the same hierarchical structure as operations [**leadership**]
6. Educate leaders on techniques and tools for leading innovation – leaders to set the stage, not have all the answers [**leadership**]
7. Improve on diversity beyond the traditional sense, including diversity of thought, experience & education [**collaboration**]
8. More effectively utilize information sharing platforms to accomplish shared objectives between institutions and international organizations [**collaboration**]