Nuclear Innovation 2050

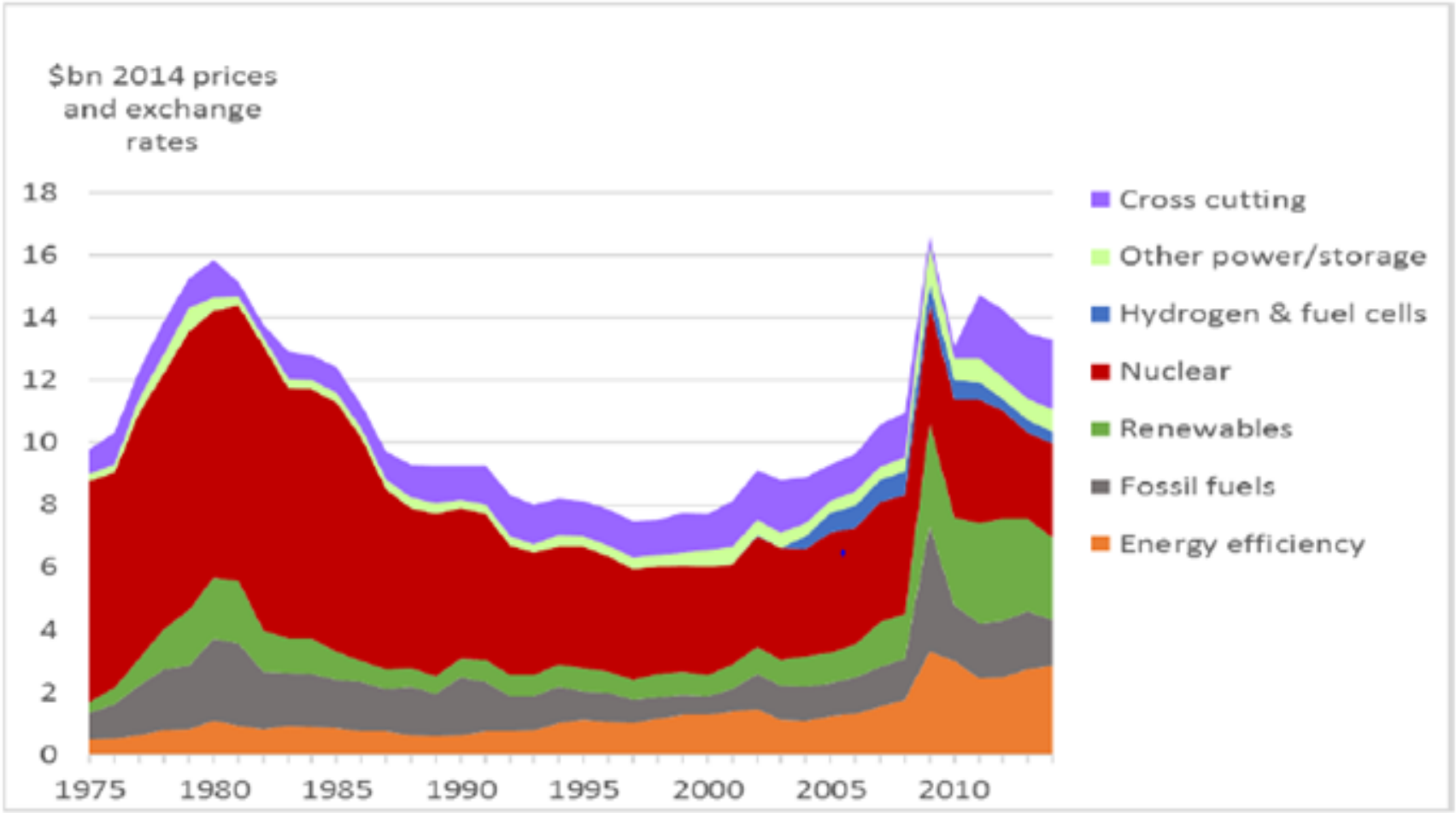
www.oecd-nea.org/ndd/ni2050/

Fiona Rayment
Chair of NEA NI2050 Advisory Panel

A Broad NEA Initiative

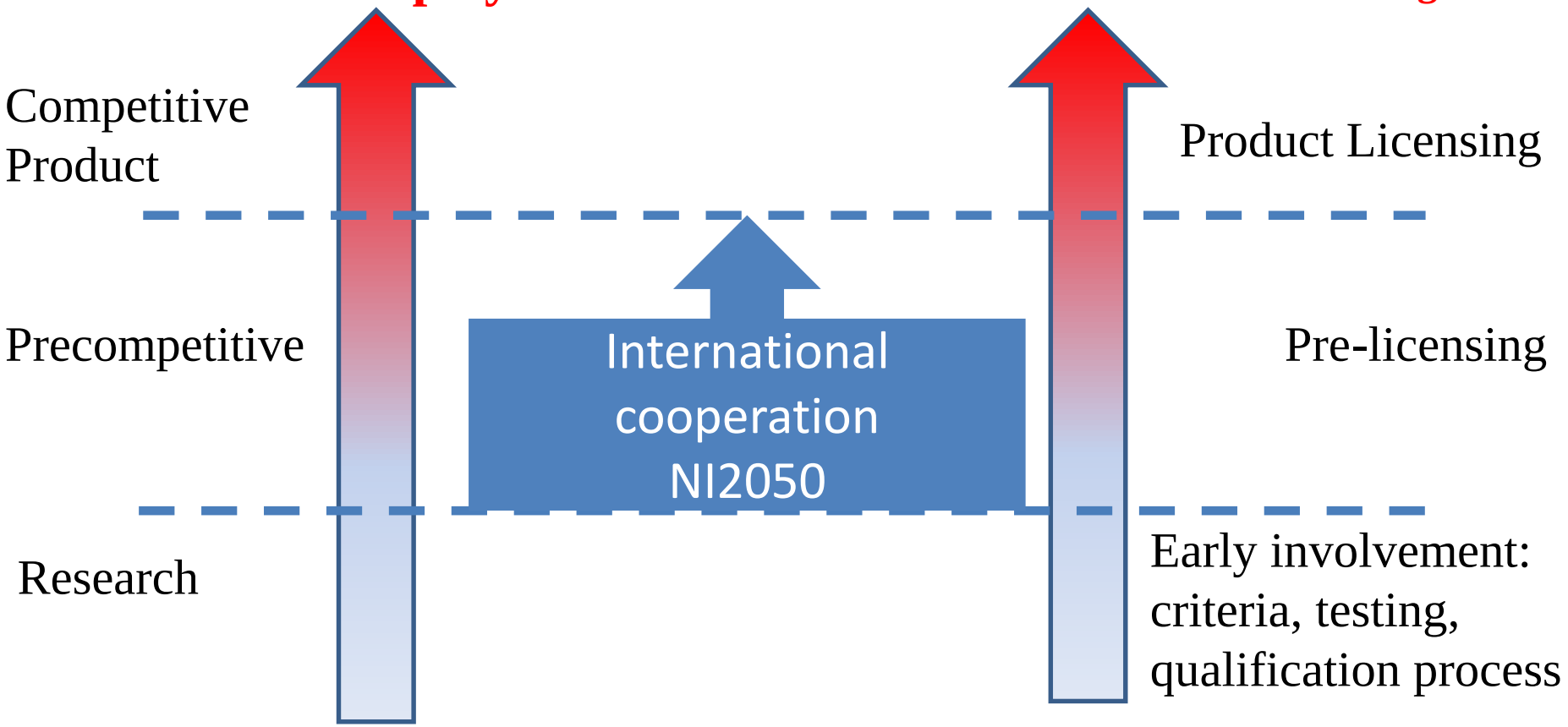
Building a co-operative framework enabling innovative fit-for-purpose nuclear fission technologies that will accelerate R&D and market deployment to contribute to a sustainable energy future

R&D Public BUDGETS/SCOPES



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

TECHNOLOGY AND LICENSING READINESS



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.

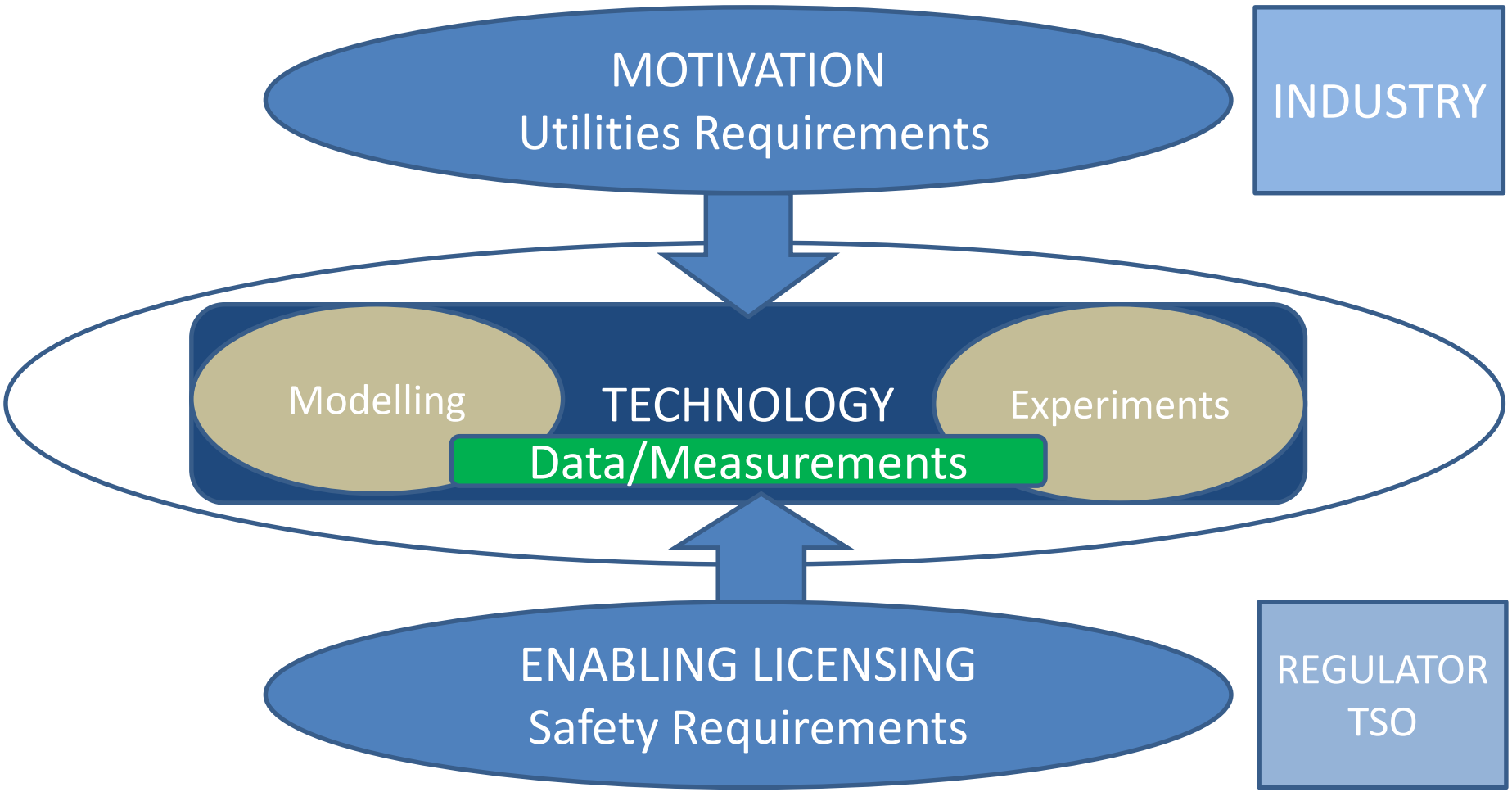
COST

- 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.

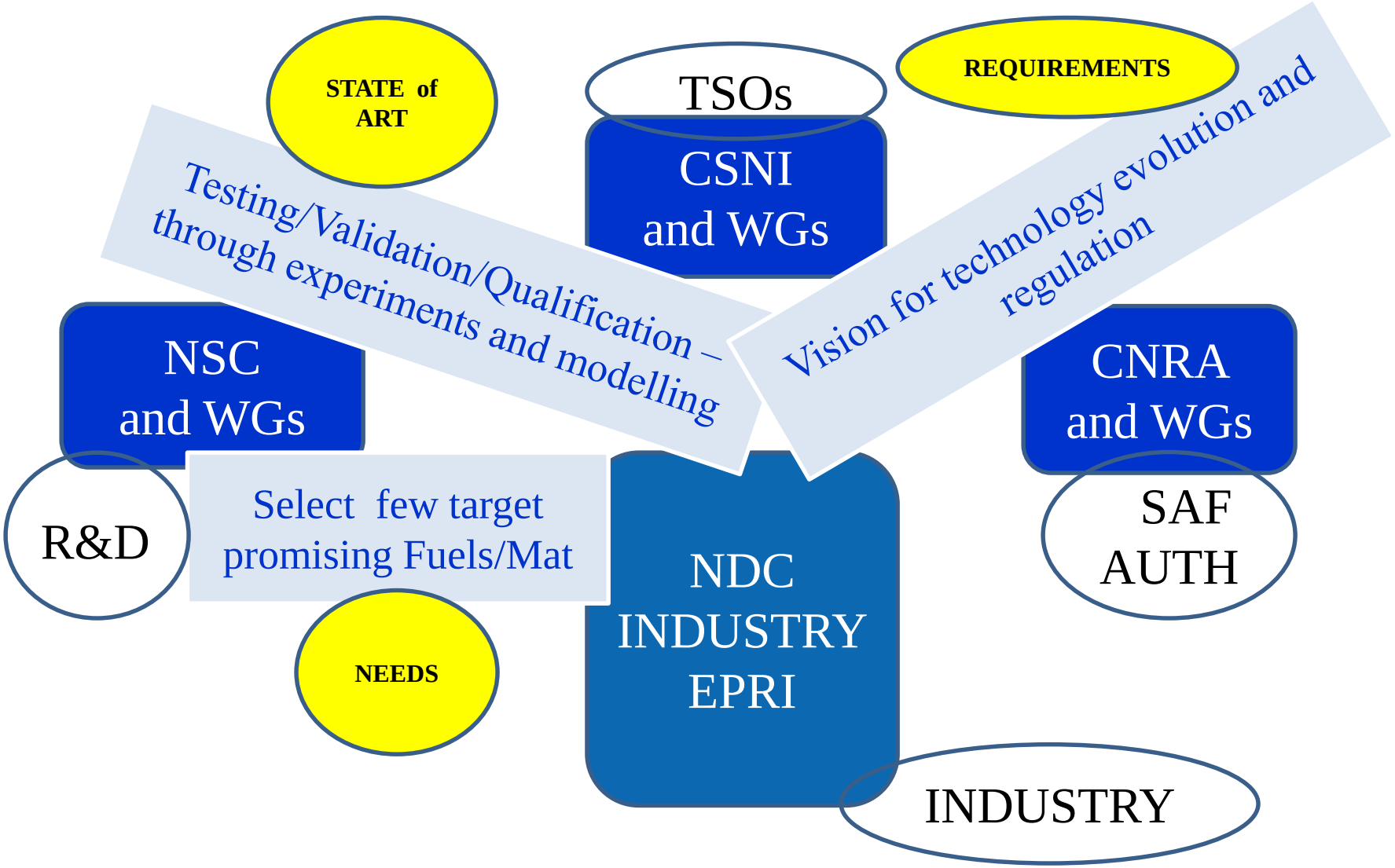
As main high level outcomes, NI2050 has

- 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)

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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

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Innovation for the Future of Nuclear Energy – A Global Forum

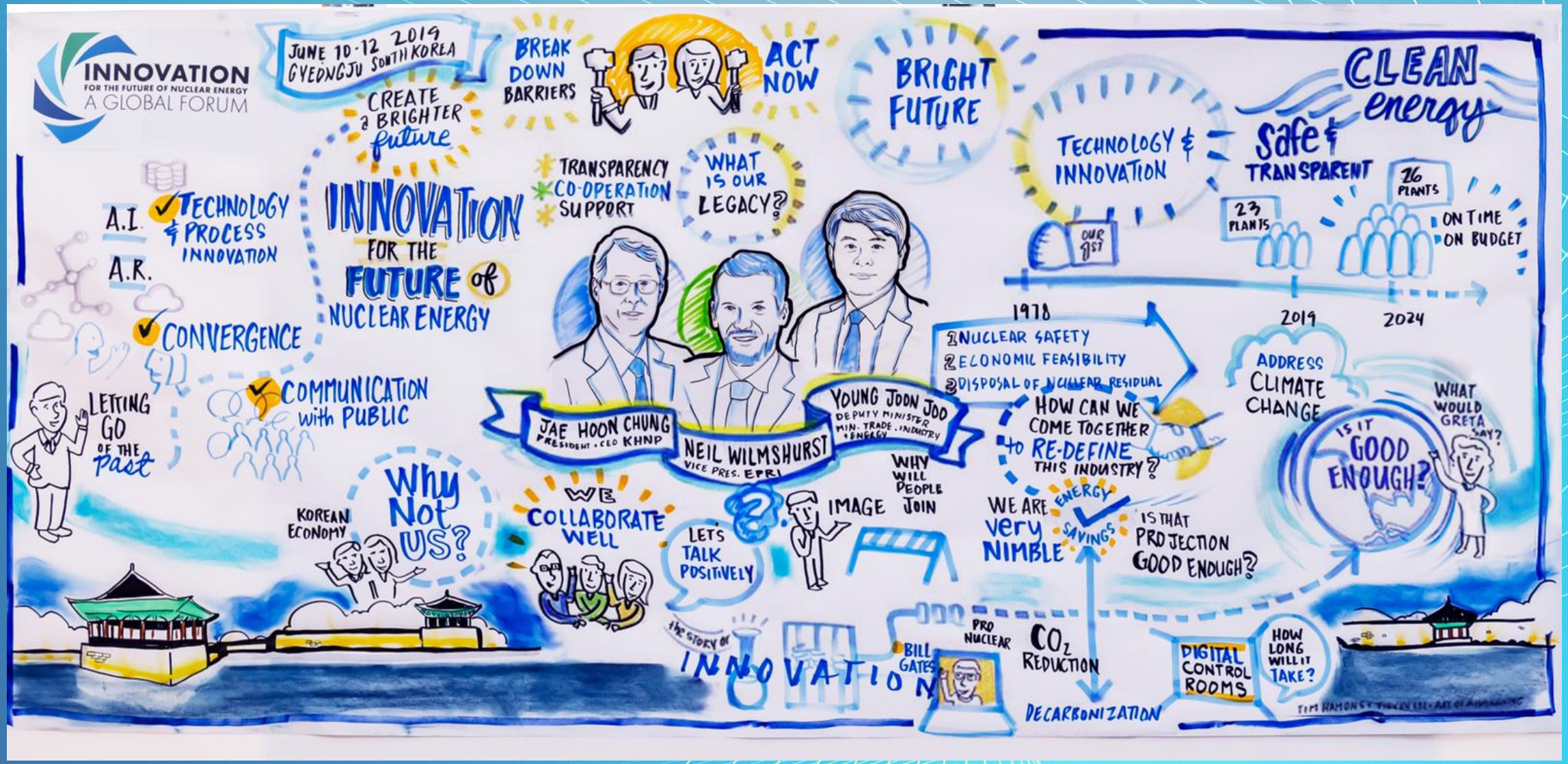
Gyeongju, Korea
June 10-12, 2019

EPRI ELECTRIC POWER RESEARCH INSTITUTE

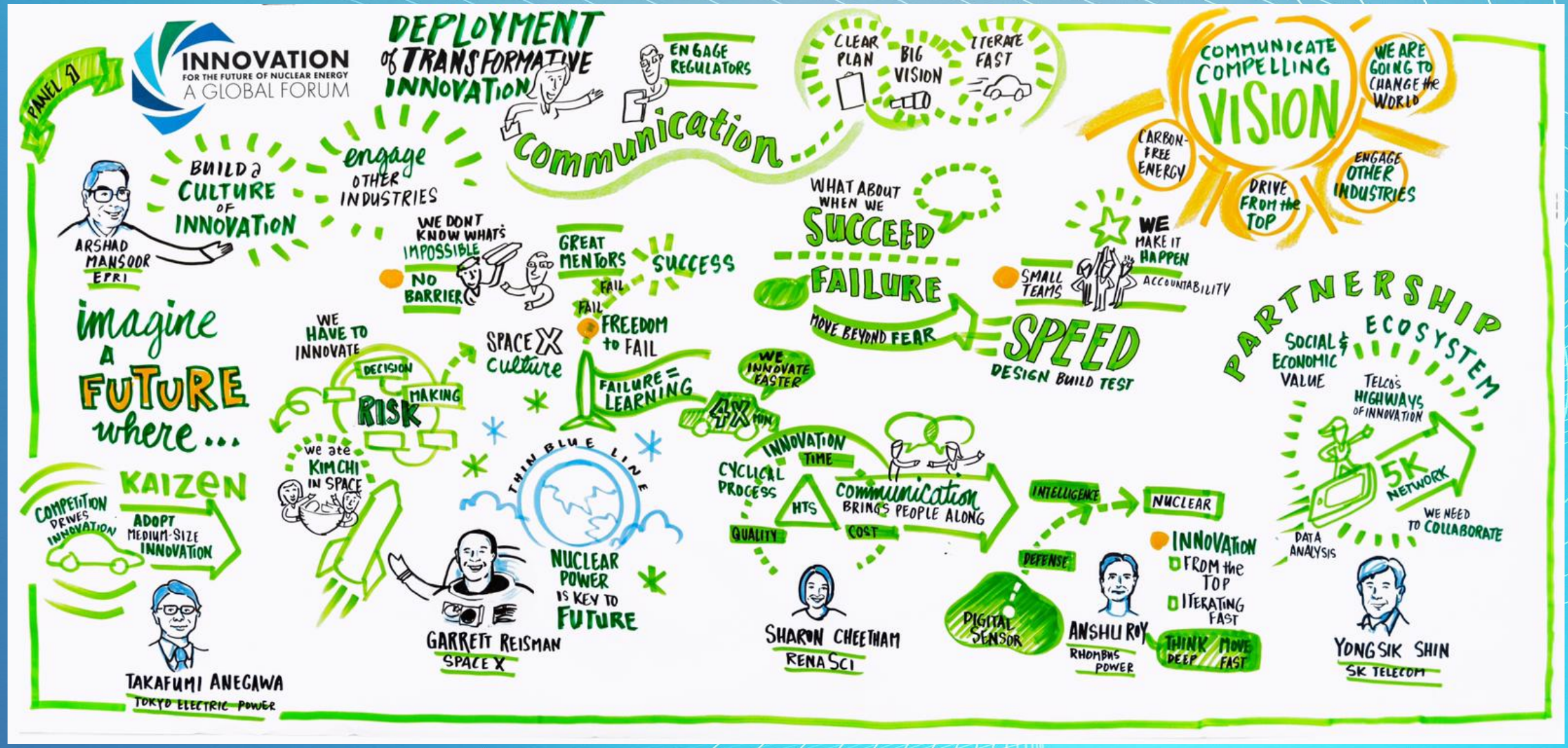
IAEA International Atomic Energy Agency

KHNP

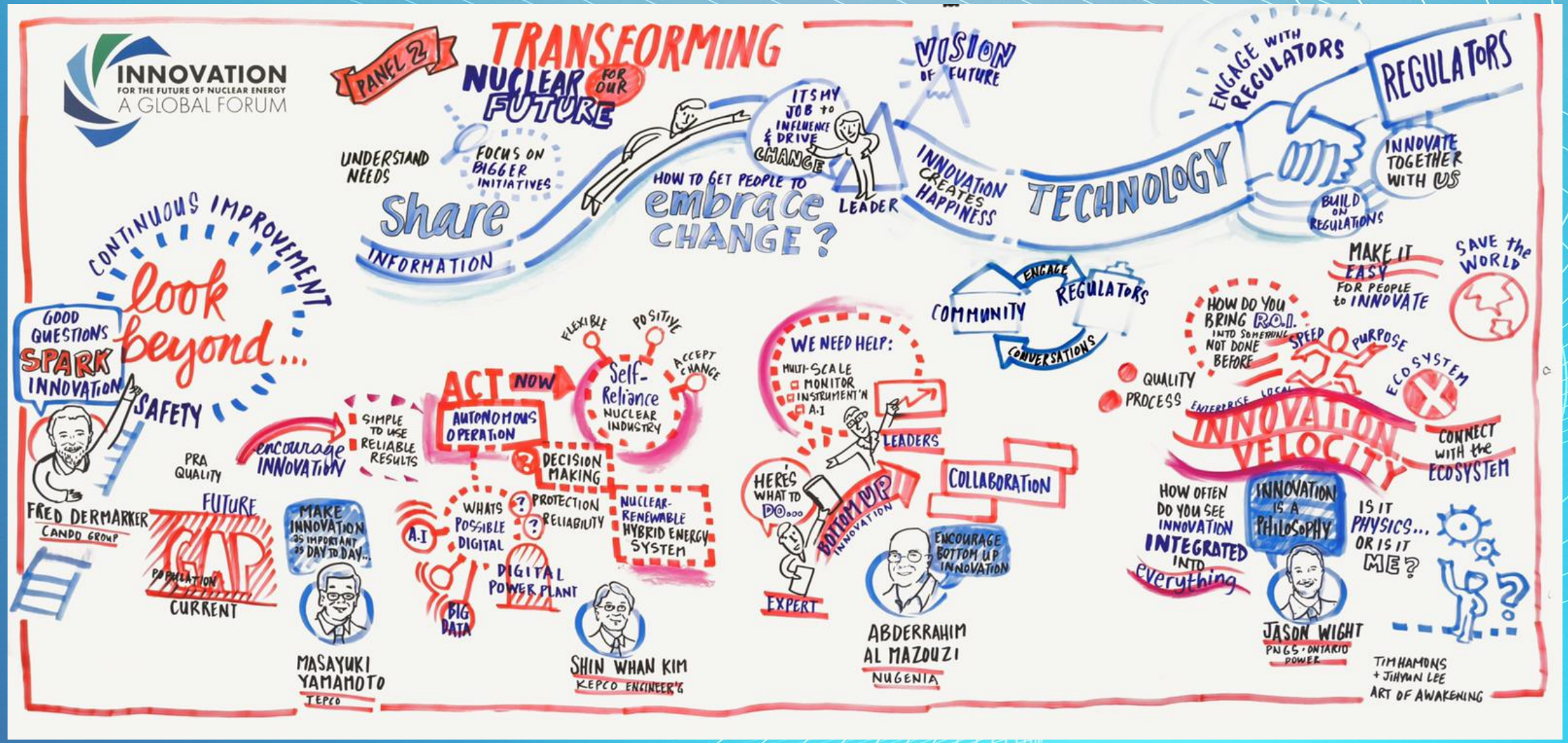
NATIONAL NUCLEAR LABORATORY



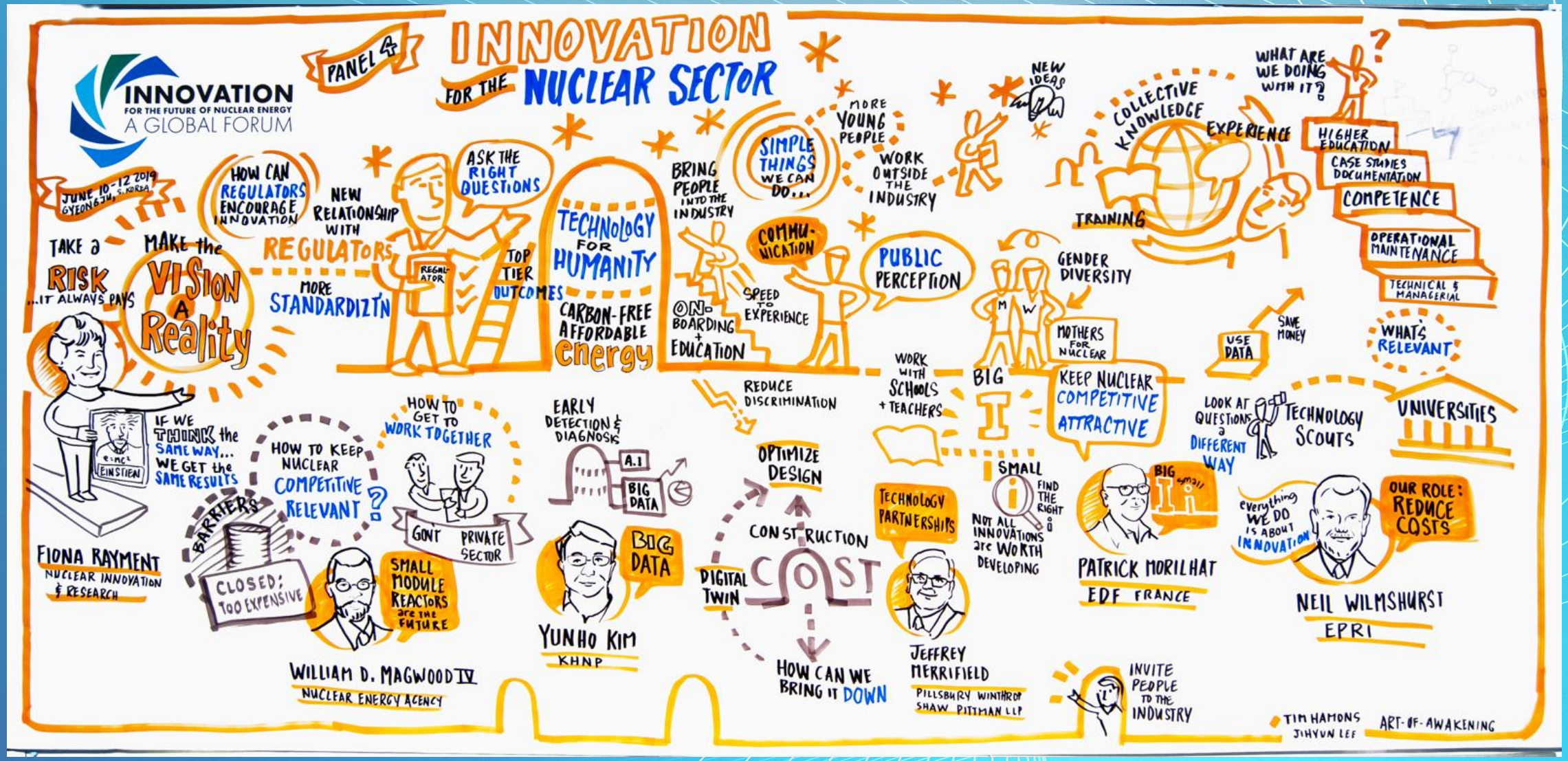
Welcome, Opening Remarks, and Keynote



Deployment of Transformative Innovation – Sharing Across Sectors

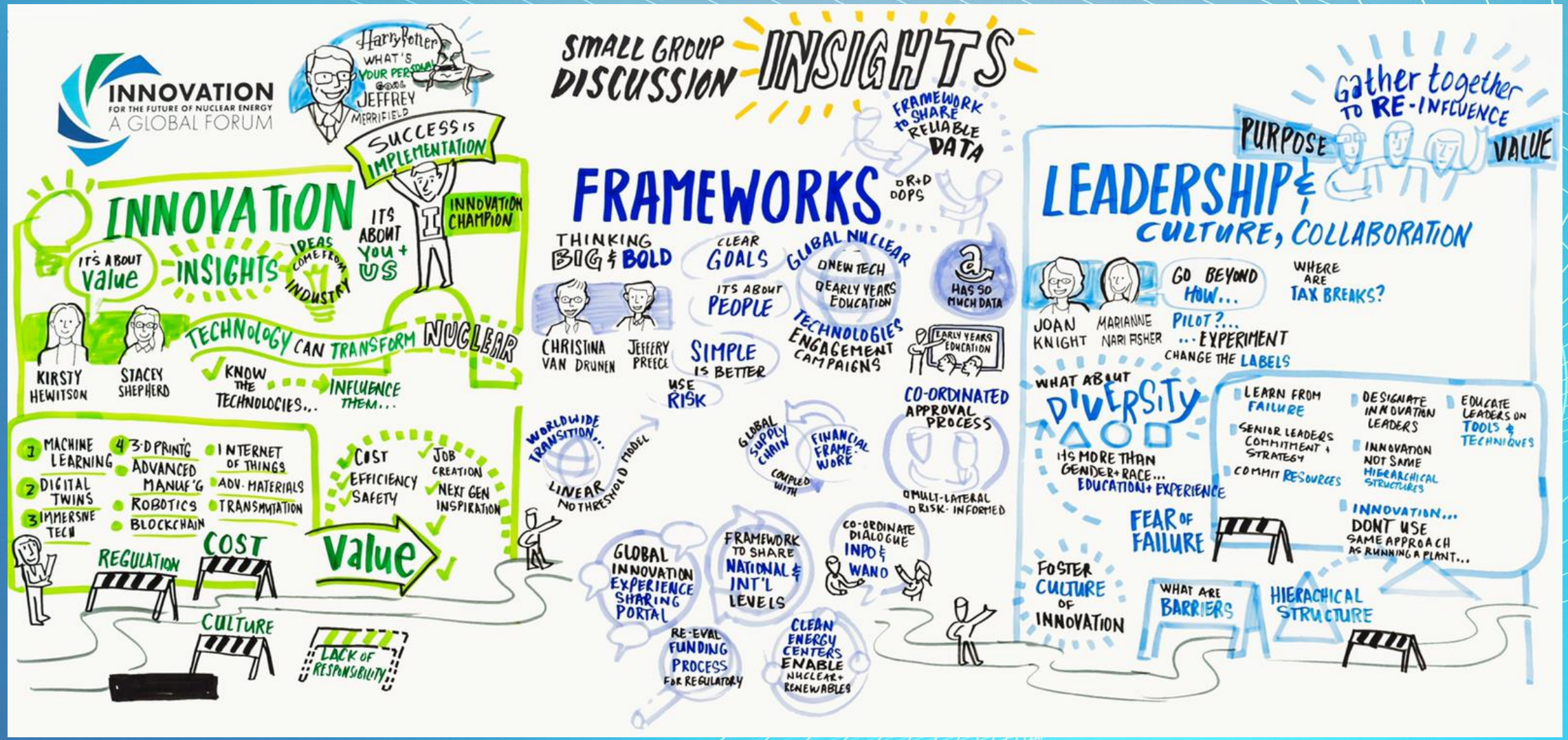


Transforming Nuclear for Our Future

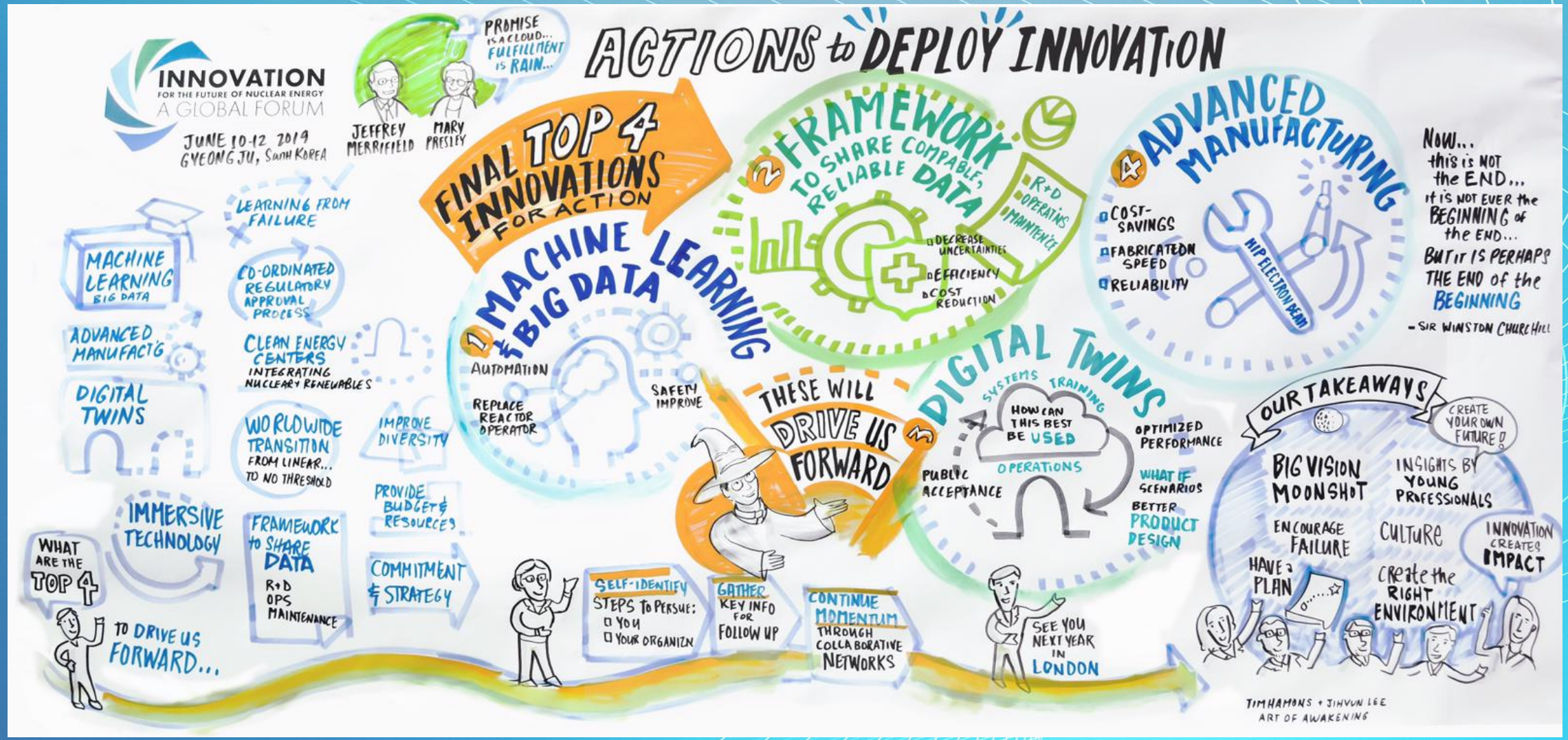


Innovation in the Nuclear Sector

Regulator Perspectives Roundtable



Small Group Discussion Insights



Actions to Deploy Innovations

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

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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

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Top 12 Innovations

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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

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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

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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

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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

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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

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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

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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

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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

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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

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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

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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

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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

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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
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  - Research Organizations

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Lists of All 28 Innovations

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Innovations - Technology

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

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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

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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**]

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