The 10th Science and Technology Foresight Survey

～Material Devise Process Field～

Science and Technology Foresight as a Platform for "MONOZUKURI"

/-Manufacturing-/

Hidenori Gamo , NISTEP

Outline

1. S & T Fields , Detail items and Topics
2. When to Implement Important Topics in a Real-world
3. R & D Characteristics and Prioritized Policy
4. Time and Period for Realization
5. Future Topics for MONOZUKURI
6. Summary

1.1 Science and Technology Fields

NISTEP

Request for cooperation

Professional Organizations such as Academic Societies and Associations

Committees by field

① ICT and Analytics

②Health, Medical care and Life Sciences

③ Agriculture, Forestry and Fisheries, Food and Biotechnology

④ Space, Ocean, Earth and Science Infrastructure

⑤ Environment, Resources and Energy

⑥Material, Device and Process

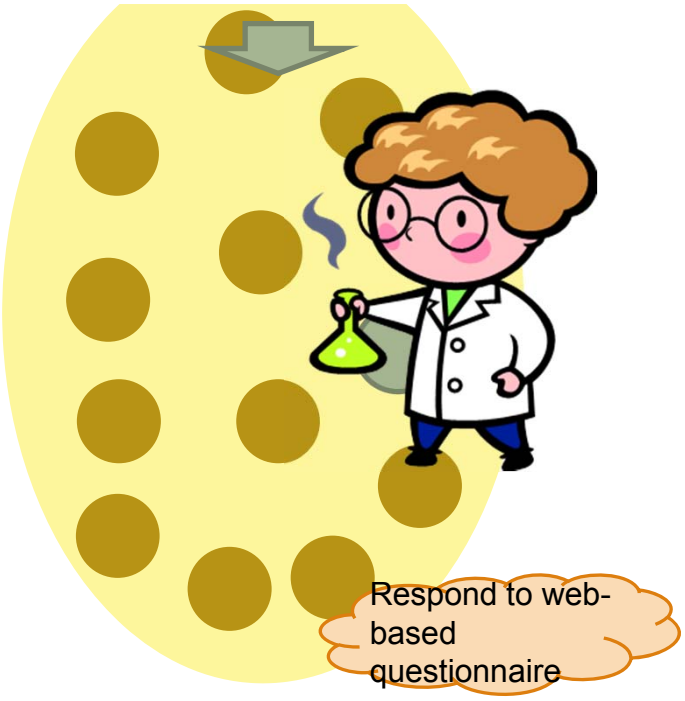
⑦ Social Infrastructure

⑧Service-oriented Society

Provide S&T topics

Evaluate the importance

Experts in each field



Committee on Scenario Analysis

Future Society Vision Review Workshop (FY2013)

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1.2 Material, Device and Process Field
: Detail Items

○ Material, Device and Process Field is positioned as a cross cutting core science technology to solve societal issues including environment, energy, biotechnology and infrastructure.

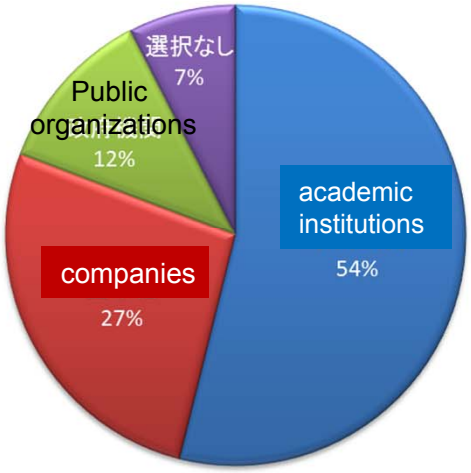
○S&T topics in this field is classified into Core (advanced material and manufacturing), Tool（modeling & simulation, and measurement & analysis) and Application（devise system）, and can be systematized from basic to application seamlessly.

☆ 92 S&T topics are identified through academic-industry-IAI Experts Committee

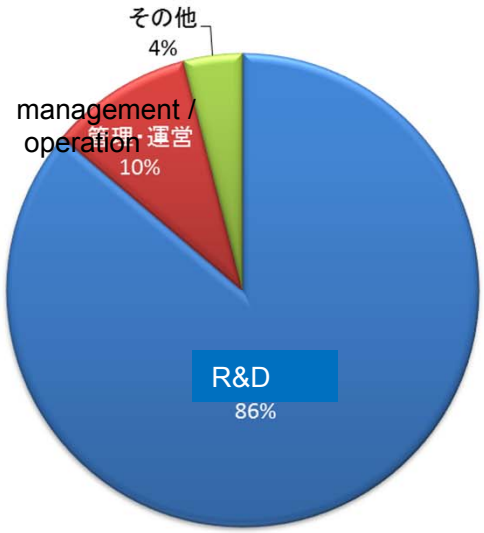
Phase	Detail Items	# of Topics	Classified Elements
Core	1. Creation of advanced material and function	17	Inorganic material, polymers, self-assembly, self-healing materials, power semiconductor, organic semiconductor, etc.
	2. Advanced Manufacturing	13	Added manufacturing, on-demand production, personal production, bulk-variant production, on-demand fab-system, Bio-printing, etc.
Tool	3.Modeling & Simulation	12	Multiphysics or multiscale simulation, function & structure prediction simulation, materials-informatics, etc.
	4. Measurement and analysis method of advanced material and device	12	Space time resolution analysis, real-time 3D visualization, operand analysis, catalytic reaction process , electronic microscope, polarized neutron, etc.
Application	5. Application device system （ICT and nanotechnology）	12	Printable LSI, graphene, one chip integrated circuit, low power consumption memory, single spin information device, quantum cryptographic communication, single photon, etc.
	6. Application device system （Environment and energy）	21	Thermoelectric element, solar cell , hot water generation, artificial nuclear transmutation, secondary battery, rare metal, fuel cell, hydrogen storage, artificial photosynthesis, etc.
	7. Application device system （Infrastructure）	5	Monitoring, metal-ceramic bonding, carbon structural materials, etc.
	＊Application device system in life science is classified into biotechnology and medical care field		

Characteristics of Respondents

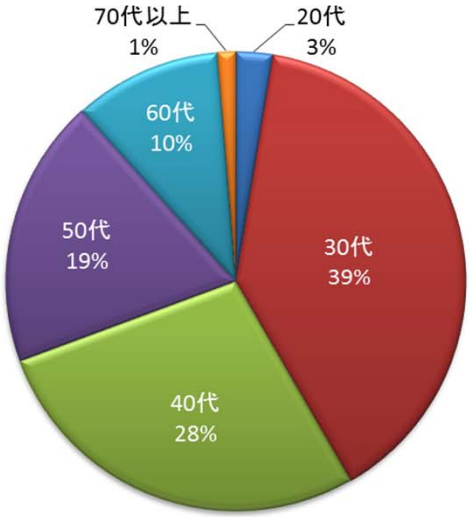
Institution



Position



Age



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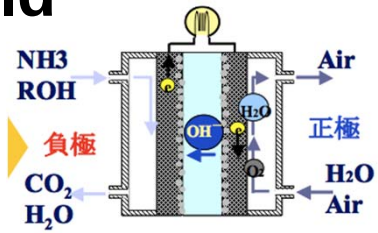
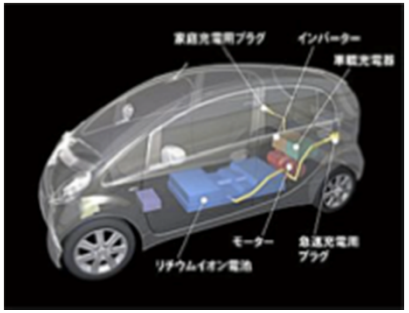
2. Top 15 S&T Topics with High Importance: When to Implement in a Real-World

Solar cell (efficiency of more than 50%)

High-efficiency fuel cells for motor vehicles which do not use rare metals.

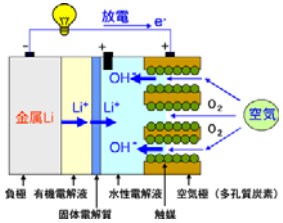


A rechargeable automotive battery capable of a range of 500km.

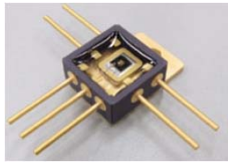


Lightweight carbon-based structural materials for use in large-scale structures.

Recyclable air battery.



Practical power semiconductors for electrical use which have lower losses than SiC or GaN.



1 chip computer with low power consumption

2015 2025 2030 2035 2040

Small health monitoring technology for buildings.

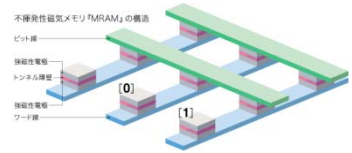
Simulation technology that integrates synthesis process simulation, fabrication process simulation, and function prediction abilities.

Multiscale simulation technology to project how chemical reactions at the electron-scale affect macro-scale physical properties, functions, degradation, and destruction of substances.

Artificial photosynthesis technology (efficiency of more than 1%).

Multiphysics material simulation technology for multiple scales

Wideband width and low power consumption memory



Multiphysics simulation technology

Simulation technology that does not predict functions and physical properties based on structural information but rather predicts the structure itself using the desired functions and physical properties as inputs.

3.1 R & D Characteristics
Importance and Global Competitiveness

- Topic groups with high importance and high global competitiveness

  “ Application device system” : 8 topics

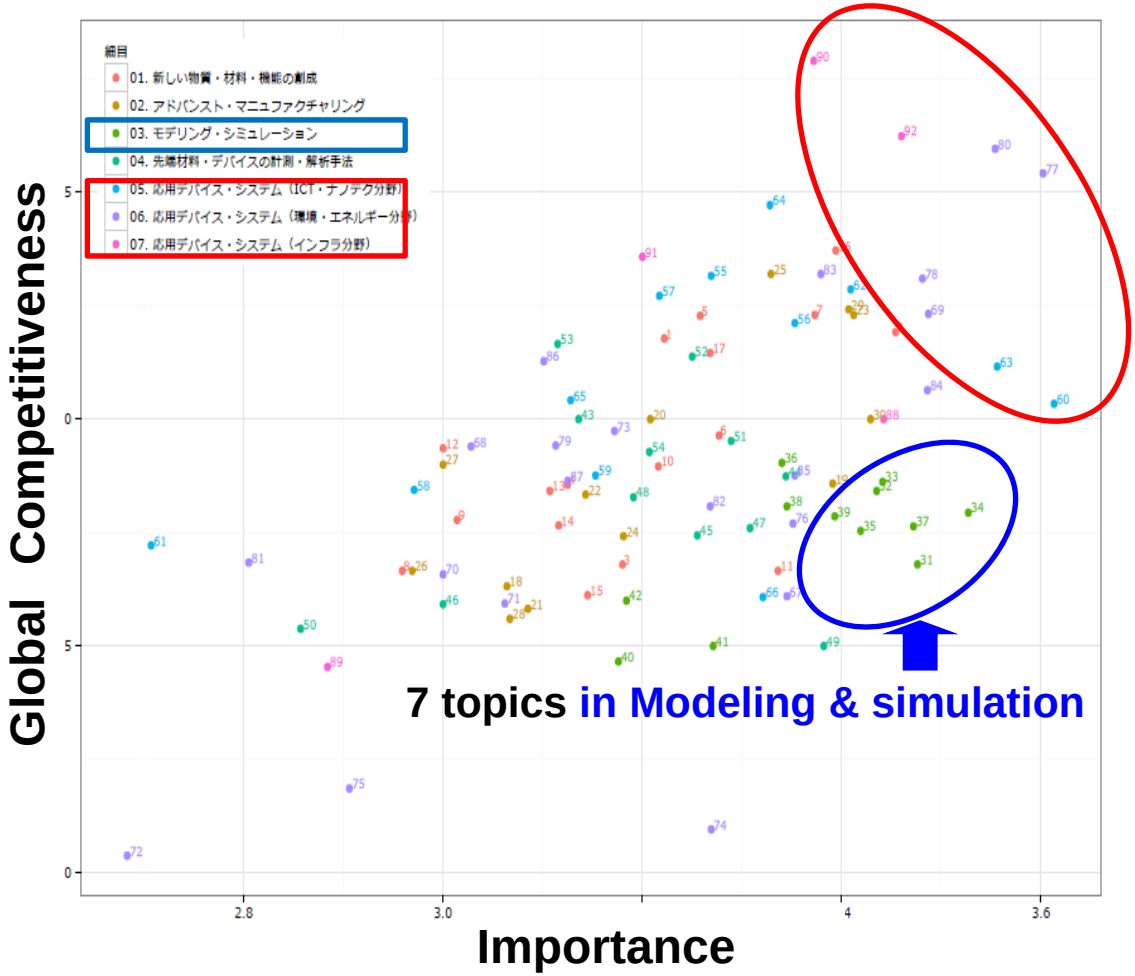
  （Environment & energy ）: 4 topics

  （Infrastructure） : 2 topics

  （ICT & nanotechnology）: 2 topics

- Topic groups with high importance but with low global competitiveness
  - **“Modeling & simulation”** : 7 topics

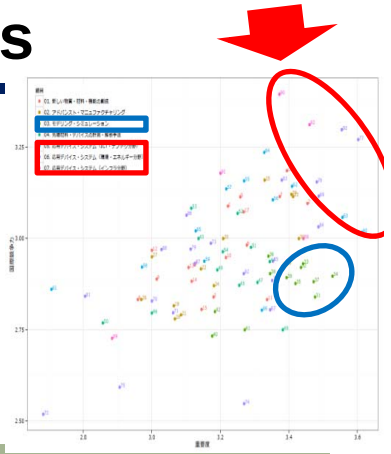
8 topics in Application device system



7 topics in Modeling & simulation

Calculate the Score based on selected score for importance/global competitiveness
（4：very high , 3：high , 2：low 1：very low）

3.1 R & D Characteristics
Importance and Global Competitiveness



・Topics with high importance and high global competitiveness

-Top rated topics are:

★Environment and energy application related secondary buttery, fuel cell, & solar cell.

★Infrastructure application related structural materials for construction.

★ICT & nanotechnology application related high performance & low power consumption memory & LSI.

- **Application device system** accounts for Top 8 topics

	Importance	Global Competitiveness	Detail items	Topics
1	3.6	3.3	**Application device system** (Environment/Energy)	A rechargeable automotive battery capable of a range of 500km (energy density of more than 1kWh/kg, and specific power of more than 1kW/kg) while maintaining the size and weight of current batteries.
2	3.6	3.3	**Application device system** (Environment/Energy)	High-efficiency fuel cells for motor vehicles which do not use rare metals.
3	3.5	3.3	**Application device system** (Infrastructure)	Lightweight carbon-based structural materials with high strength and corrosion resistance appropriate for use in large-scale structures such as super-large bridges.
4	3.4	3.4	**Application device system** (Infrastructure)	Tough, high-strength ferrous building materials with a yield strength of over 1,800MPa (three times that of existing steel) and a ductile-brittle transition temperature of below -40℃.
5	3.5	3.2	**Application device system** (Environment/Energy)	Air batteries with high energy density that use metals like magnesium and are easy to regenerate or recycle.
6	3.6	3.0	**Application device system** (ICT・nanotechnology)	Integrated circuit technology to that improves processing power without increasing the power consumption per unit area, enabling the creation of a single chip capable of approximating the performance of a current supercomputer.
7	3.6	3.1	**Application device system** (ICT・nanotechnology)	Memory that operates with 100 times the memory bandwidth and 1/100 the power consumption of current DRAM.
8	3.5	3.1	**Application device system** (Environment/Energy)	Solar cell with a conversion efficiency of more than 50%.

Importance/Global Competitiveness Score : Calculate selected score（4:very high , 3：high , 2：low 1：very low ）

3.1 R & D Characteristics
Importance and Global Competitiveness

- Topics with high importance but with low global competitiveness
  - Top rated topics are:
    All are "Modeling & simulation" topics

	Importance	Global Competitiveness	Detail items	Topics
1	3.5	2.9	Modeling & simulation	Simulation technology that does not predict functions and physical properties based on structural information but rather predicts the structure itself using the desired functions and physical properties as inputs.
2	3.5	2.8	Modeling & simulation	Multiphysics simulation technology to clarify the impact of various physical factors such as friction, shock, stress, fluid, electric fields, heat, light, etc. on chemical reactions that occur on surface of or interface between materials.
3	3.5	2.9	Modeling & simulation	Multiphysics material simulation technology for multiple scales including electronic scale, atomic scale, mesostructure scale, macrostructure scale, and industrial material scale.
4	3.4	2.9	Modeling & simulation	Simulation technology not only for material design but also dynamic process design that is based on quantum theory.
5	3.4	2.9	Modeling & simulation	Multiscale simulation technology to project how chemical reactions at the electron-scale affect macro-scale physical properties, functions, degradation, and destruction of substances.
6	3.4	2.9	Modeling & simulation	Simulation technology that integrates synthesis process simulation, fabrication process simulation, and function prediction abilities.
7	3.4	2.9	Modeling & simulation	Model optimization technology that connects the local and macro physical properties of materials by assimilating simulation data and measured data to achieve more precisely predictive models

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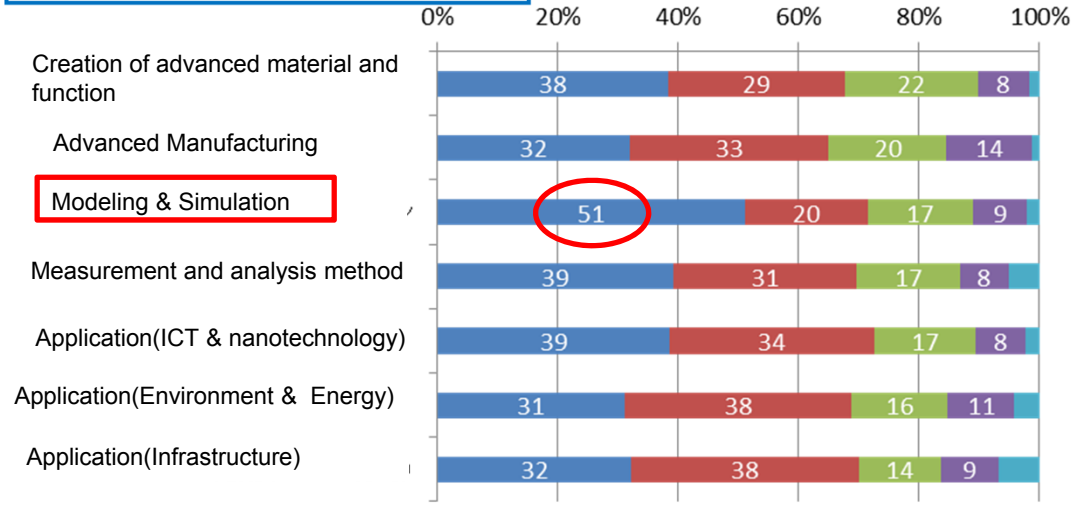
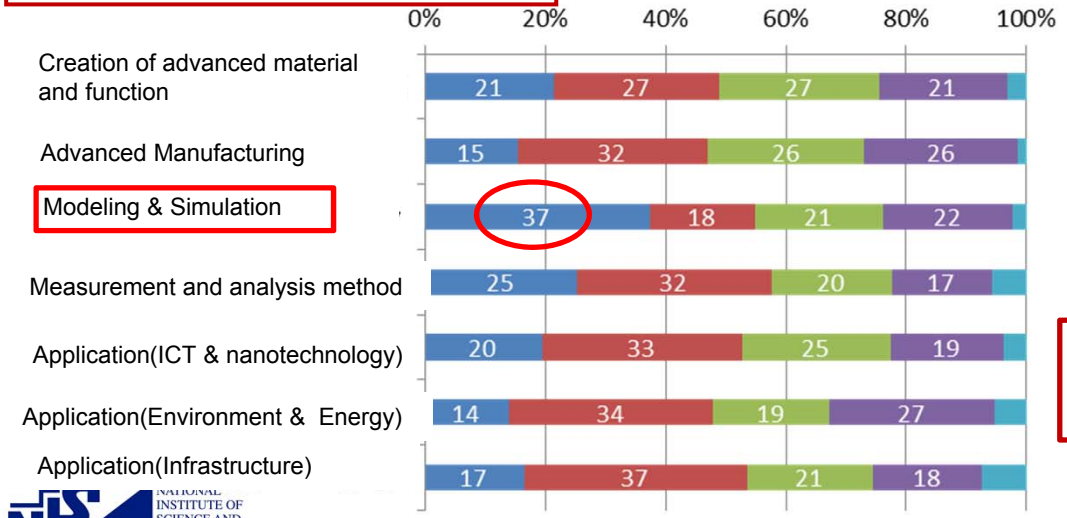
Importance/Global Competitiveness Score : Calculate selected score（4:very high , 3：high , 2：low 1：very low ）

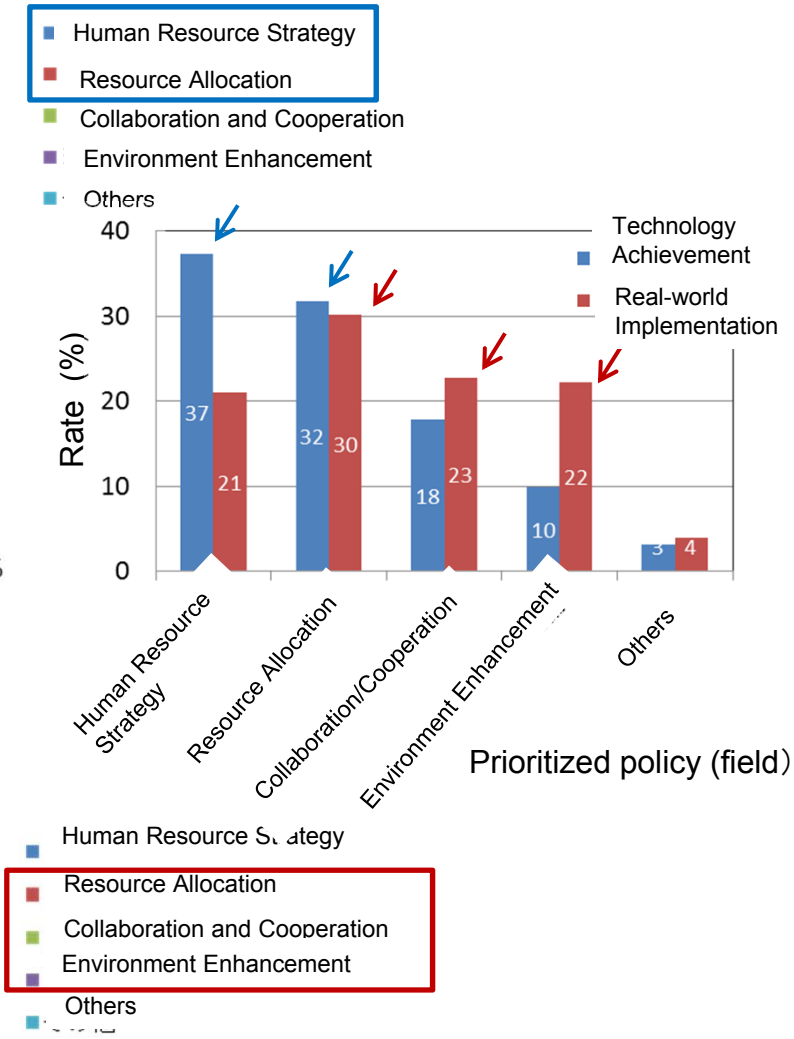
3.2 Prioritized Policy ＜Comparison of Detail items＞

Technology Achievement



Real-world Implementation





3.2 Prioritized Policy -1　Human Resource Strategy

- ”Modeling & simulation” related topics dominate top scores for both technology achievement and real-world implementation.

【 Technology Achievement 】

	Score	Detail Items	Topics
1	65	Modeling & simulation	Dynamic simulation technology that allows for the analysis of the selection rates, environmental effects (temperature, etc.), and many-body effects in catalytic reactions.
2	59	Modeling & simulation	Simulation technology not only for material design but also dynamic process design that is based on quantum theory.
3	57	Modeling & simulation	Multiscale simulation technology to project how chemical reactions at the electron-scale affect macro-scale physical properties, functions, degradation, and destruction of substances.
4	56	Modeling & simulation	Simulation technology that does not predict functions and physical properties based on structural information but rather predicts the structure itself using the desired functions and physical properties as inputs.
5	56	Modeling & simulation	Technology to estimate the structure or creation process of materials through materials science inverse problems by applying statistical mechanics techniques for information such as Bayesian estimation and neural networks.

【 Real-world Implementation 】

	Score	Detail Item	Topics
1	47	Modeling & simulation	Dynamic simulation technology that allows for the analysis of the selection rates, environmental effects (temperature, etc.), and many-body effects in catalytic reactions.
2	46	Modeling & simulation	Technology to estimate the structure or creation process of materials through materials science inverse problems by applying statistical mechanics techniques for information such as Bayesian estimation and neural networks.
3	44	Modeling & simulation	Multiscale simulation technology to project how chemical reactions at the electron-scale affect macro-scale physical properties, functions, degradation, and destruction of substances.
4	42	Modeling & simulation	Simulation technology not only for material design but also dynamic process design that is based on quantum theory.
5	42	Modeling & simulation	A physical property prediction tool that increases the speed of searching for new substances in large-scale materials data.

Score: % of Respondents

3.2 Prioritized Policy -2 Resource Allocation

- Application device system (environment & energy) topics rank high for both technology achievement and real world implementation.
- On-demand fab-system for semiconductor and secondary & air battery topics in technology achievement specifically rank high.

【 Technology Achievement 】

	Score	Detail Item	Topics
1	**55**	Advanced Manufacturing	A fab system which is capable of producing a large variety of semiconductor devices or integrated circuit chips in small production volumes on-demand within a short period of time.
2	**53**	Application Device System （environment & energy）	A rechargeable automotive battery capable of a range of 500km (energy density of more than 1kWh/kg, and specific power of more than 1kW/kg) while maintaining the size and weight of current batteries.
3	**51**	Application Device System （environment & energy）	Air batteries with high energy density that use metals like magnesium and are easy to regenerate or recycle.
4	**50**	Application Device System （environment & energy）	Membrane separation technology to produce hydrogen from coal without the release of CO2.
5	**49**	Advanced Manufacturing	Ultraprecise process technology (including manufacturing, analysis, testing, and in-situ monitoring) on the angstrom order of size due to the advances in the sophistication of beam technology (such as ion, electron or laser), equipment control technology, and sensor technology.

Score: % of Respondents

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3.2 Prioritized Policy -3
Collaboration and Cooperation

- The core items, Creation of advanced material and function, and Advanced manufacturing, rank high both in technology achievement and in real world implementation.
- Practical use of material related topics in real world implementation specifically rank high.

【 Real-world Implementation 】

	Score	Detail Item	Topics
1	**36**	Creation of advanced material and function	Thermoelectric elements which can be in place of products such as water-cooled radiators, etc.
2	**35**	Creation of advanced material and function	Practical power semiconductors for electrical use which have lower losses than silicon carbide (SiC) or gallium nitride (GaN).
3	**33**	Creation of advanced material and function	Technology to artificially create bulk semiconductors based on the desired energy band obtained through calculations.
4	**32**	Advanced manufacturing	A technique to insert a substance with an attoliter order volume into a picoliter order closed space.
5	**32**	Advanced manufacturing	A system to facilitate the inheritance of skills from artisans (skilled workers, craftsmen, etc.) through the measurement and modeling of such skills and the archiving of the implicit knowledge involved.

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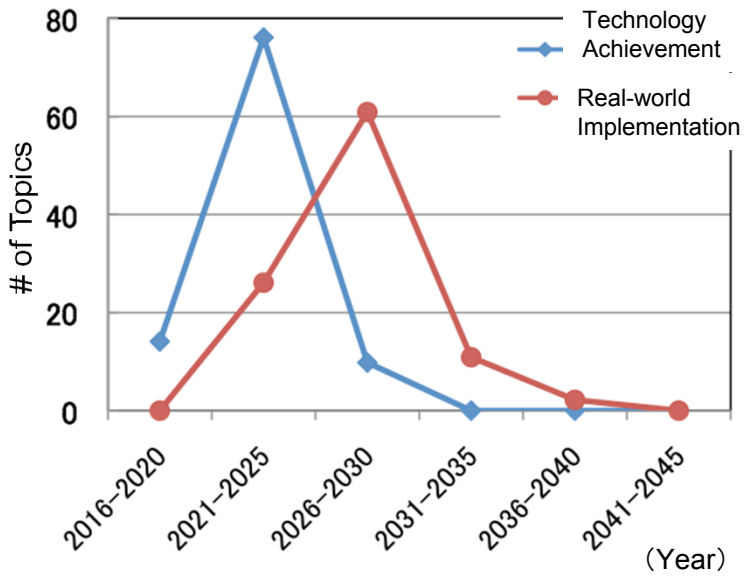
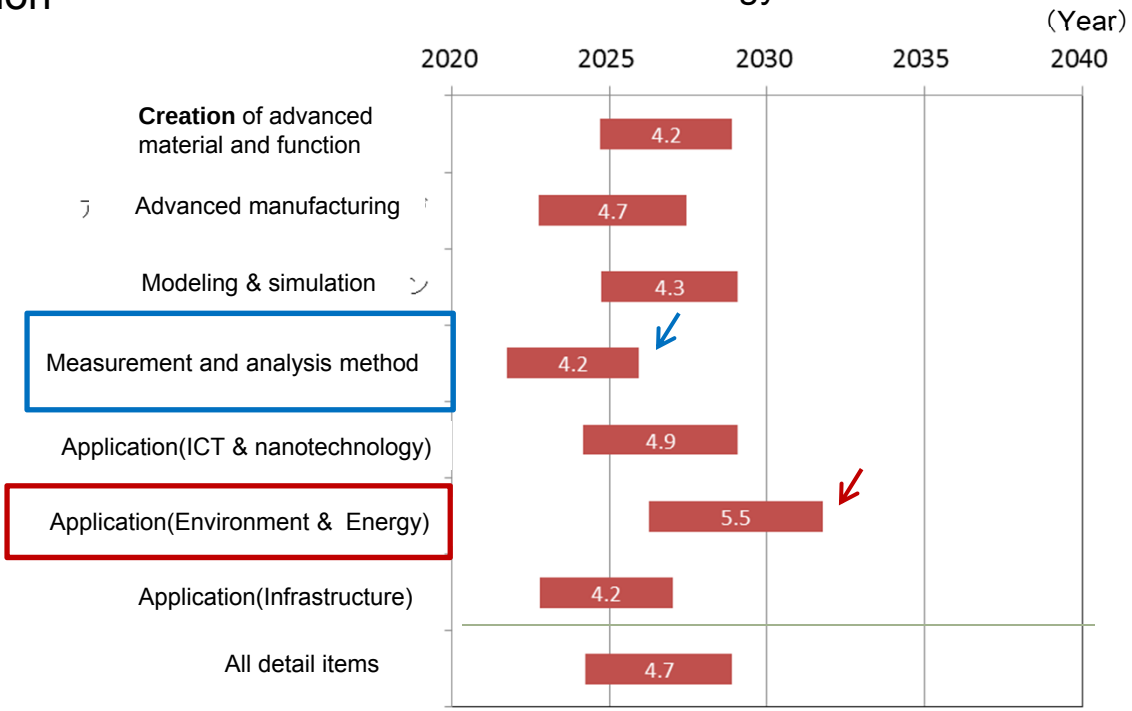
4. Time and Period for Realization

Year for Realization / Implementation
Number of Topics



Year of Realization/Implementation

Realization Period
(Year of Real-world Implementation
－ Year of Technology Achievement)



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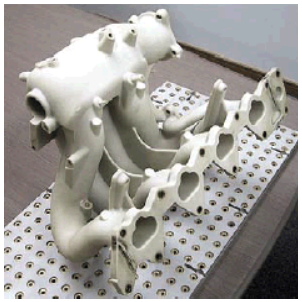
5. Future Topics for “MONOZUKURI”

Digital fabrication (3D printing)

Evaluated as relatively High Importance / Low Global Competitiveness



- A system to facilitate the inheritance of skills from skilled workers and the archiving of the implicit knowledge involved.
- Personal manufacturing of parts or products with the same precision and quality of mass-produced goods and similar items.
- Mass customization production methods for making parts with different shapes.
- Innovative production technology to directly build a three-dimensional solid shape from a liquid substrate without a template.
- On-demand production of maintenance parts for consumer products.
- Application of metamaterials to consumer products through additive manufacturing technologies.
- Manufacturing of replacement organs through bio-printing.

2015 — 2025 — 2030 — 2035 — 2040

- A physical property prediction tool that increases the speed of searching for new substances in large-scale materials data.
- Model optimization technology that connects the local and macro physical properties of materials by assimilating simulation data and measured data to achieve more precisely predictive models.
- Technology to estimate the structure or creation process of materials through materials science inverse problems by applying statistical mechanics techniques for information such as Bayesian estimation and neural networks.
- Development structural and functional materials through 3D modeling utilizing material informatics.

Material informatics

Evaluated as relatively High Importance / Low Global Competitiveness

SUMMARY

① Secondary buttery, fuel cell, & solar cell related topics in application device system and high performance & low power consumption memory & LSI related topics are rated as high importance. Both groups are directly linked to solve social issues about environment and energy.

② Compared to topic groups in core and tools, the topic groups in application device system which deal with ICT & nanotechnology, environment & energy, and infrastructure are overall rated as high importance as well as high global competitiveness. The topics attract attentions as the prioritized direction which leverage Japan's strength.

③ Most of the topics in Modeling & Simulation for tools are rated as high importance but low global competitiveness. Human Resource Strategy has high rate of being importance as the prioritized policy in technology achievement as well as in real world implementation. It is suggested to enhance the direction.

④ Creation of advanced material and function and Advanced manufacturing in the core phase include many topics requiring collaboration and cooperation as the prioritized policy. Systems for collaboration and bridge building among basic technology, tools and application are required.

⑤ In Digital fabrication, a future topic for manufacturing, most of the topics should be implemented by 2026 and all topics in Material informatics should be implemented in a real world by 2030.

→ Scenario research will be conducted for these topics titled as "MONOZUKURI, services, and knowledge society".

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Thank you for your attention