ICOS International Cooperation On Semiconductors

WORKSHOP

Key Emerging Technologies for future Industrial Applications

Warsaw, Poland
May 12-13th, 2025

Standardization to promote international cooperation in nanoelectronics

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Standardization to promote international cooperation in nanoelectronics

International Standardization, IEC TC113 (Nanoelectronics)
Convenor
WG7 (Reliability),WG13 (Wafer-Scale System Integration)

IEEE International Roadmap for Devices and Systems (IRDS)：Beyond CMOS Int. Co-leader,
MtM / Energy Harvester, ESHS Int. Strategic Committee

IEEE EDS Speciality Conference
Ad Hoc Committee Chair

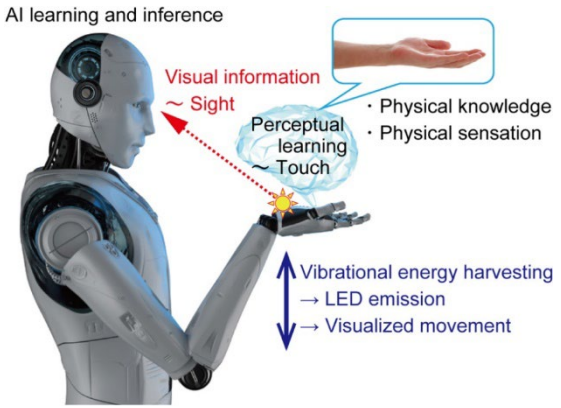

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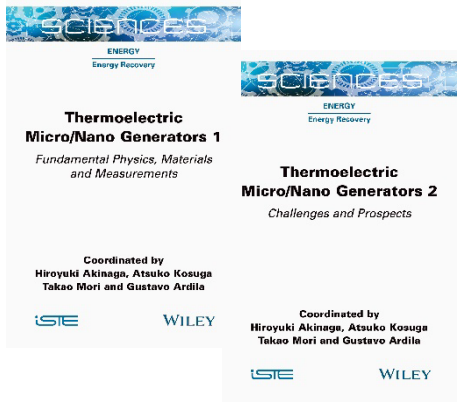
Fig. 6. Possible future of energy harvesting technology.
H. Akinaga, *Jpn. J. Appl. Phys.* 59, 110201 (2020)
https://doi.org/10.35848/1347-4065/abbfa0



Current interests:
Nonvolatile memory
AI devices, Novel computing
Energy harvesting
Nanofabrication
International standardization

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SCIENCES - Energy Recovery
Thermoelectric Micro/Nano Generators 1
Fundamental Physics, Materials and Measurements
https://iste.co.uk/book.php?id=2071
Thermoelectric Micro/Nano Generators 2
Challenges and Prospects
https://iste.co.uk/book.php?id=2072

Standardization to promote international cooperation in nanoelectronics

Structure

1. What can we expect from international standardization?
2. IEC TC113 activities
3. Int. standards related to Beyond CMOS devices
4. Green materials
5. Scope and possibilities of international cooperation

What can we expect from international standardization?

➢ Standardization According to the Stage of Development

- **Early Development Stage:**
  Terminology and units
- **Peak Development Stage:**
  - Characterization
  - Reliability, durability
  - Others

Standards for Technology Development

Benefit R&D as common infrastructure

Spur R&D as part of inseparable wheels in combination with road mapping (such as IRDS)

- **Early Stage of Business Development:**
  Interface/Safety

Standards for Business Promotion

- **Peak Stage of Business Development:**
  Product standards

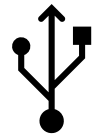
Standards for Users

*Approaches vary by industry type.

What can we expect from international standardization?

- Standardization to create new market

Type1: Compatibility standards



Type of requirement: Defining (or Opening) common specifications

Utilized to: Expand the market for peripheral businesses; a win-win situation where everyone gains.

Type2: "Measure" (evaluation criteria) standards

Type of requirement: Evaluation methods and minimum standards for quality, functionality, performance, etc.

Utilized to: Prevent market competition leads to a downward spiral of producing cheaper but inferior products. Ensure reasonable profit for the provider and satisfaction for the customer.

Type3: Standards to define needs from social challenges

Type of requirement: Essential requirements for solving specific social challenges

Utilized to: Create new markets in society

***Market-making capability = Problem-solving ability × Rule-making ability (to prevent unreasonable competition)**

Revised based on Dr. Yoshiaki Ichikawa's material.
Yoshiaki Ichikawa (Dr.)
Chairperson of Committee of International Standardization Promotion in Data Society Alliance, Japan / Visiting Professor of Center for Rule-making Strategies in Tama University, Japan

IEC TC113 activities

TC113 Officer

Chair:
Mr. Won-Kyu Park (KR)
Secretary:
Mr Norbert Fabricius (DE)

Joint Working Groups ISO TC229

JWG1: Terminology and nomenclature
Convenor: Mr Greg Peter Lopinski (CA)
JWG2: Measurement and characterization
Convenor: Mr Hideki Hashimoto (JP)

AG4: Chairman Advisory Group

TC113 is sometimes referred to as a "horizontal TC". This is because that TC113 handles standardization for various technologies and products associated with nanotechnology as a fundamental technology of them, as opposed to other standardization TCs which are set up independently for specific technologies or products. Therefore, it is necessary to cooperate with other TCs in a cross-disciplinary and strategic manner.

Working Groups

WG3: Performance assessment
Convenor: Mr Shinichi Yorozu (JP)
WG7: Reliability
Convenor: Mr Hiroyuki Akinaga (JP)

Cross -disciplinary WG

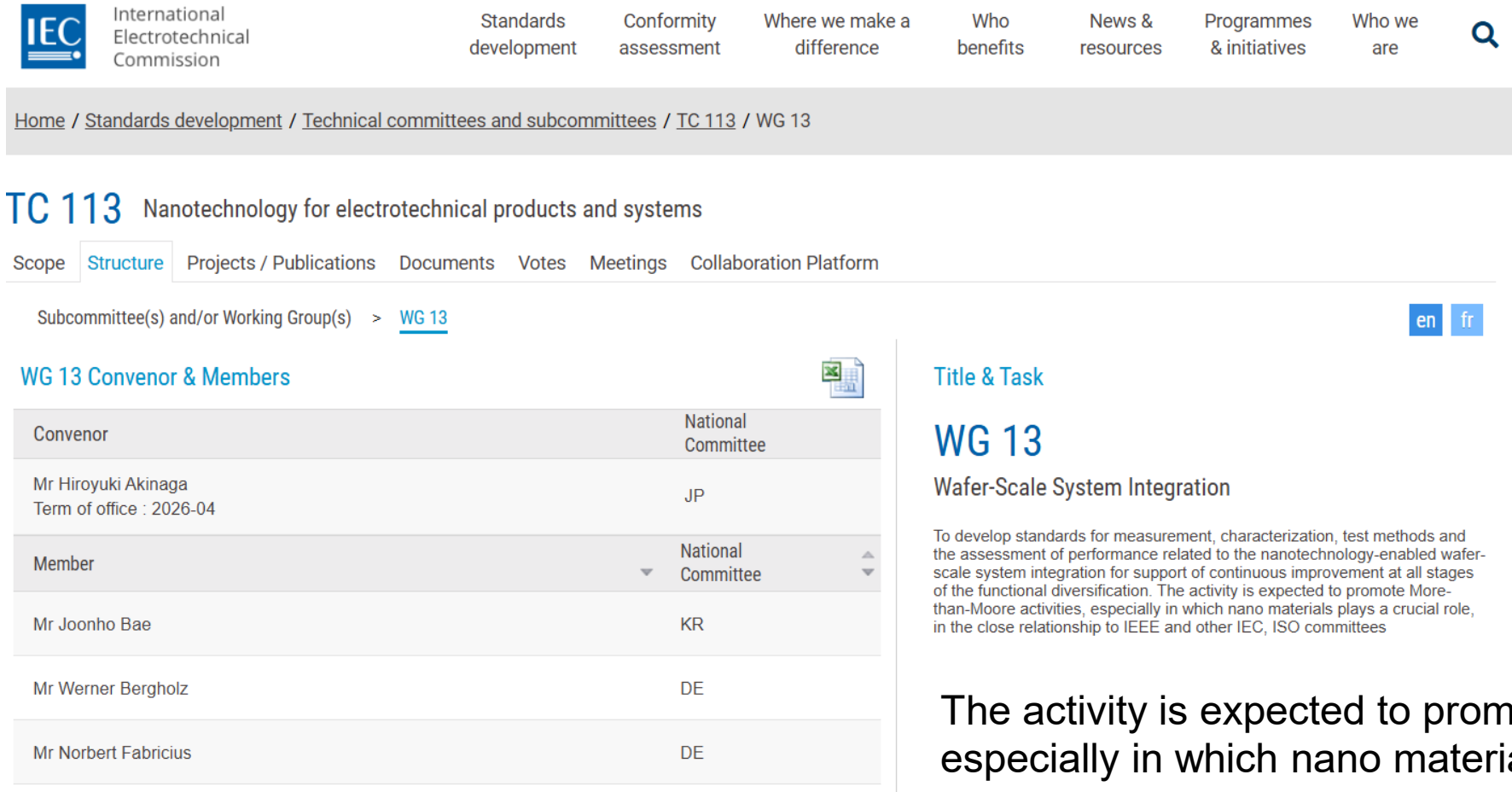
WG8: Graphene related materials/Carbon nanotube materials
Convenor: Mr Tadashi Sakai (JP), Mr Won Jong Yoo (KR)
WG9: Nano-Enabled Photovoltaics Thin Film Organic/Nano Electronics,
Convenor: Mr Shinji Aramaki (JP)
WG10: Luminescent nanomaterials
Convenor: Ms Yiqun WANG (CN)
WG11: Nano-enabled energy storage
Convenor: Mr Nobuhiro Kuriyama (JP)
WG13: Wafer-Scale System Integration
Convenor: Mr Hiroyuki Akinaga (JP)
WG14: Electromagnetic compatibility
Convenor: Mr Haeseong Lee (KR)

WG13 established in 2023

Technology-oriented WG (since 2014)

IEC TC113 activities

TC 113: Nanotechnology for electrotechnical products and systems



IEC International Electrotechnical Commission

Standards development | Conformity assessment | Where we make a difference | Who benefits | News & resources | Programmes & initiatives | Who we are

Home / Standards development / Technical committees and subcommittees / TC 113 / WG 13

TC 113 Nanotechnology for electrotechnical products and systems

Scope | Structure | Projects / Publications | Documents | Votes | Meetings | Collaboration Platform

Subcommittee(s) and/or Working Group(s) > WG 13

en fr

WG 13 Convenor & Members

Convenor	National Committee
Mr Hiroyuki Akinaga Term of office : 2026-04	JP

Member	National Committee
Mr Joonho Bae	KR
Mr Werner Bergholz	DE
Mr Norbert Fabricius	DE

Title & Task

WG 13

Wafer-Scale System Integration

To develop standards for measurement, characterization, test methods and the assessment of performance related to the nanotechnology-enabled wafer-scale system integration for support of continuous improvement at all stages of the functional diversification. The activity is expected to promote More-than-Moore activities, especially in which nano materials plays a crucial role, in the close relationship to IEEE and other IEC, ISO committees

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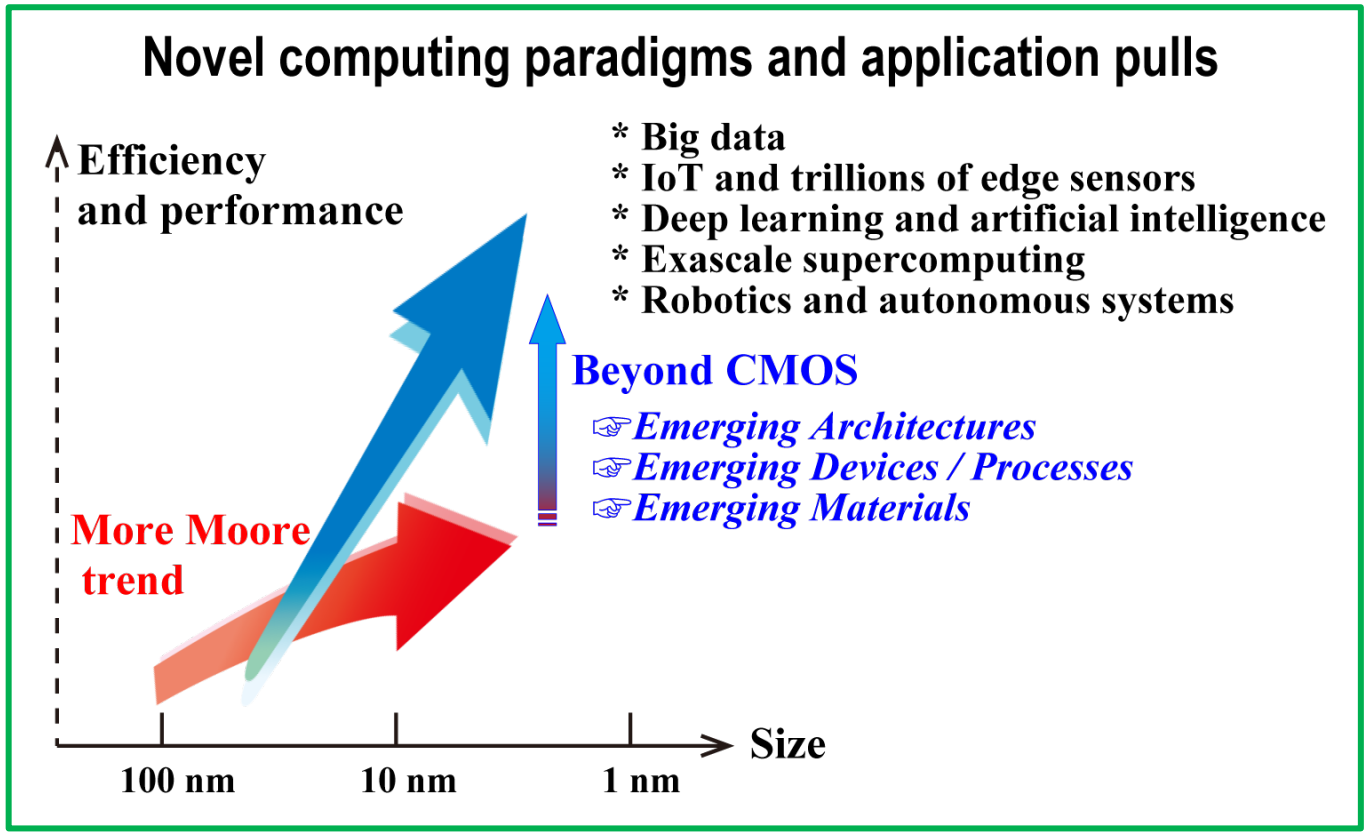
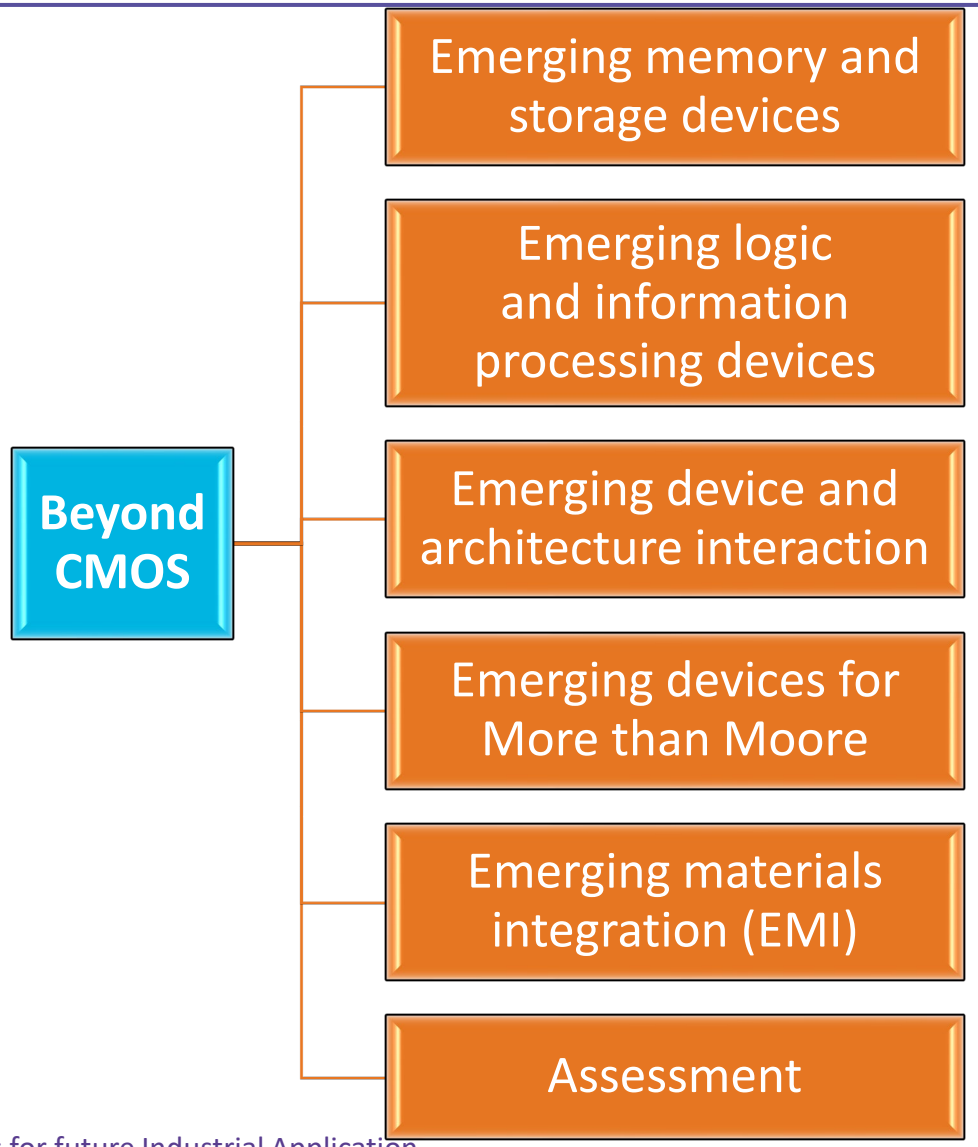
https://www.iec.ch/dyn/www/f?p=103:14:501383421995308::::FSP_ORG_ID,FSP_LANG_ID:27362,25?q=tc113

Beyond CMOS devices / IRDS

- The 2024 chapter updated





Training Accuracy Memory Device Benchmarking

- **Parallel outer product update operation possible with resistive arrays: enables efficient training**
- **Training is more challenging than inference – device programming characteristics are key**
- **<u>Ideal:</u> device conductance increases and decreases proportional to calculated weight update**
- **<u>Reality:</u> device programming characteristics alter the relationship between intended and actual update due to:**
  - **Nonlinear and asymmetric conductance change**
  - **Cycle to cycle random variability (write stochasticity)**
  - **Device to device random variability**
- **Also: training requires very high endurance (>10^{12})**

Ref.
S. Agarwal et al., "Resistive memory device requirements for a neural algorithm accelerator," 2016 International Joint Conference on Neural Networks (IJCNN), Vancouver, BC, Canada, 2016, pp. 929-938, doi: 10.1109/IJCNN.2016.7727298.

Int. standards related to Beyond CMOS devices

➢ Standardization Activity @ IEC TC113 WG3

Nanoscale metal-oxide interfacial devices are key devices for advancing cyber-physical systems as IoT devices, especially small and low-power AI chips.

To enable the development of smaller devices with lower power consumption, **R&D for non-von Neumann computing is becoming increasingly important**; for example, a device with a product sum circuit that records the learning process using analog resistance changes.

Standardization is underway to provide proper methods for evaluating the electronic state and properties of such metal-oxide interfacial devices that support IoT and AI-related technologies. Ongoing projects **include methods for evaluating thermal stability, a typical reliability criterion** that is essential for promoting the adoption of these devices in society.

Int. standards related to Beyond CMOS devices

➢ **Standardization Activity @ IEC TC113 WG3**

→ Establish and organize international standards for evaluation to build a healthy R&D environment

The evaluation standards developed in this project will **promote accurate communication and mutual understanding** not only among the materials/devices layer, but also among the layers of companies that develop instruments or perform measurement and evaluation, in other words, the supply chain.

62607-8-x Series @ IEC TC113 WG3

(62607-8-1) Determine defect states by TSC (Published)

(62607-8-2) Determine polarization properties by TSDC (Published)

(62607-8-3) Obtain quantitative index to evaluate the linearity of analog resistance change (Published)

(62607-8-4) Evaluate the electronic trap states by LFNS (Published)

(62607-8-5) Evaluate oxygen distribution as a function of temperature history using secondary ion mass spectrometry (SIMS) (NP stage)

(62607-8-6) Evaluate optical properties as a function of temperature history, including oxygen-related peaks in the absorption, using spectroscopic ellipsometry (SE) (NP stage)

→ Ultimately, the standards serve as a common basis for accelerating R&D. The social impact would be significant.

Beyond CMOS devices / IRDS

Nano-enabled metal-oxide interfacial devices

- 8-1: Electronic states of defect tested by TSC ✓
- 8-2: Dielectric properties tested by TSDC ✓
- 8-3: Analog resistance change and resistance fluctuation (Electrical resistance) ✓ — **Published in Oct. 2023**
- 8-4: Activation energy of electronic trap states (LFNS) — **In Approval Stage**

New Proposals 8-5: Thermal stability (Oxygen distribution measurement by SIMS) — **In Preliminary Stage (PWI)**

New Proposals 8-6: Thermal stability (Oxygen distribution measurement by Ellipsometry)

Subject of standardization: Metal-oxide interfacial devices

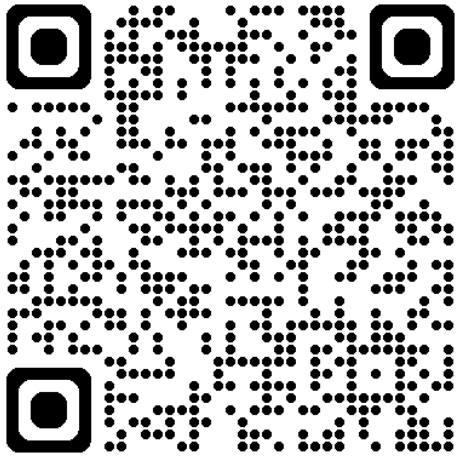
IoT devices or other key devices enable advancement of cyber-physical systems, especially AI chips with small size and low power consumption.

Green materials / IRDS BC & EMI

Green materials

From the perspective of being able to appropriately respond to regulations, international standardization promotes the research and development of green materials.

Ref. A. Ueda, H. Akinaga, S. Agarwal, J. A Hagmann, S. Das, M. J Marinella and A. Chen, “Green materials in semiconductors: perspective from the IRDS beyond-CMOS roadmap”, Nanotechnology 36, 142001 (2025), https://iopscience.iop.org/article/10.1088/1361-6528/adb041.



Standardization to promote international cooperation in nanoelectronics

What is the essential infrastructure for our society?

IoT network to communicate and get information

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It is not always possible to get plenty of electricity.

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Energy harvesting will be a strong candidate for solving this issue, but the amount of power generated is not necessarily large enough.

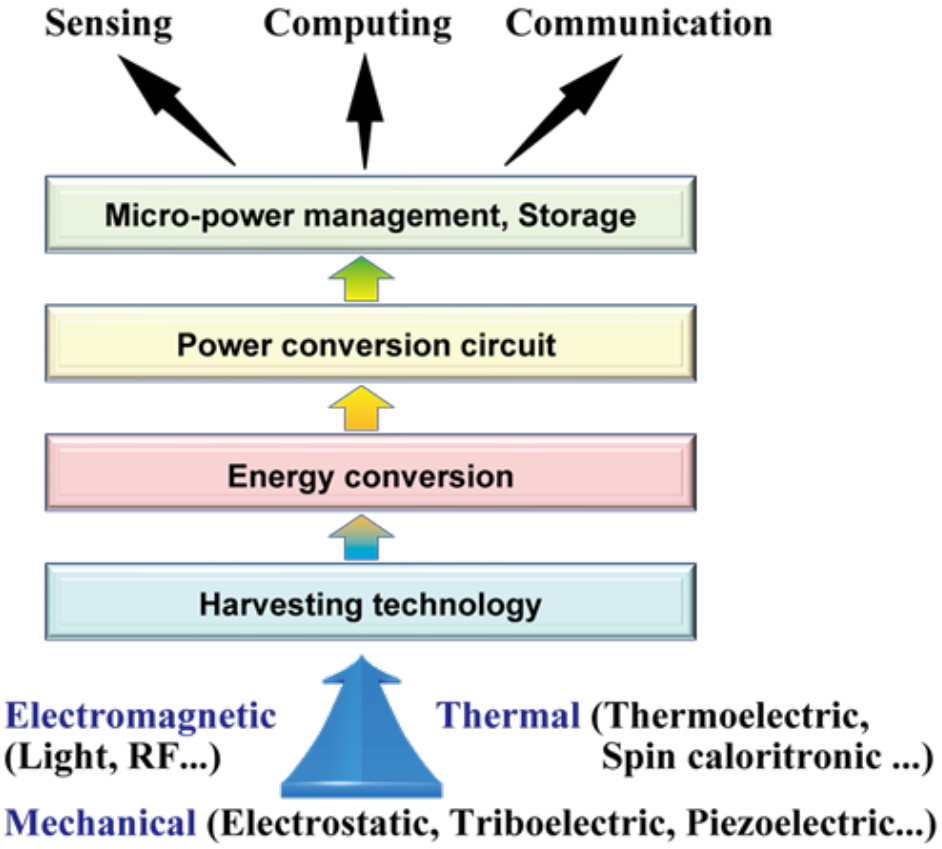

Figure MtM-2 Survey of energy harvesting technologies @ IRDS

Scope and possibilities of international cooperation

It is difficult to achieve an ideal all at once.
Even when we reach the top of a mountain, we often see the next peak.

Establish an international standard for appropriately evaluating the degree of SDG achievement.

Fulfill the responsibility to society, and even if achieving goals is difficult, it will become possible to promote sustainable efforts.

THANK YOU

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European Commission

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www.icos-semiconductors.eu