# Analysing ICT in prospective scenarios to help reveal undone computer science

Undone Computer Science 2024

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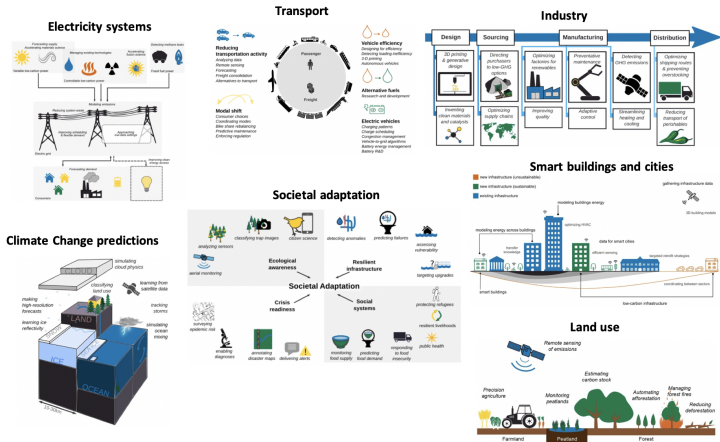## Who are we?

▷ Professors in computer science at university and engineer school

▷ Thematic conversion: from data science to study of environmental impacts of digital technologies

▷ Some topics of interest
  - Both: AI & environment, materiality of ICT, ICT & sustainability, teaching around these topics
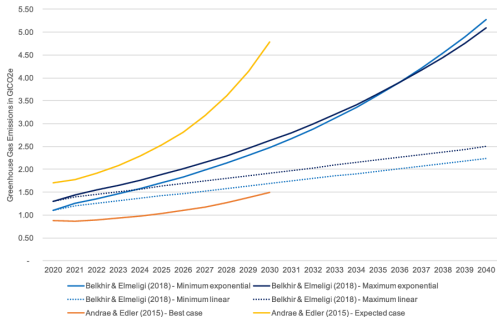
Information and Communication Technologies (ICT):

▷ Solution to solve climate change (e.g. [Rolnick et al. 2019])?

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▷ But increasing environmental impacts (e.g. [Freitag et al. 2021]):

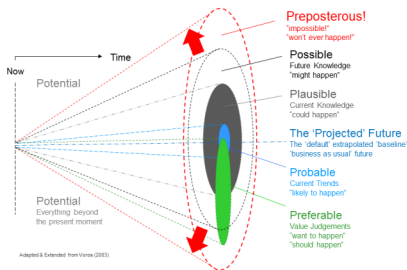## Motivation

Information and communication Technologies (ICT):

▷ Solution to solve climate change (e.g. [Rolnick et al. 2019])

▷ But increasing environmental and societal impacts (e.g. [Freitag et al. 2021])

⟶ Which ICT research should or should not be conducted from a sustainability perspective?

# Motivation and contribution

Collectively defining ICT research questions requires to envision desirable futures

▷ Many prospective studies are made to develop imagination and/or drive ecological transition.

▷ How do scenarios envision the role of ICT in the future?



Source : J. Voros, Big History and anticipation: Using Big History as a framework for global foresight, Handbook of anticipation:

Theoretical and applied aspects of the use of future in decision making, 2017

## Motivation and contribution

Collectively defining ICT research questions requires to envision desirable futures

▷ Many prospective studies are made to develop imagination and/or drive ecological transition.

▷ How do scenarios envision the role of ICT in the future?

**Contributions:**

▷ Analysis of ICT in prospective studies through the definition of a set of variables to guide the analysis

▷ Identification of challenges that should be addressed as research questions to enable or avoid these scenarios

## Studies selection

Analysis of 14 prospective studies
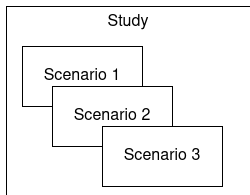
- ▷ Selection criteria:
    - Accessibility
    - Different spatial perimeters: countries (France)/world (bias towards global North vision)
    - General and domain-specific (energy and ICT)
    - Narrative and quantitative studies
- ▷ Comments:
    - Not exhaustive
    - Mostly oriented towards climate change

Each study may include several scenarios, representing alternative futures

Analysis of 14 prospective studies → 35 scenarios

| Study | Scenario name | Year | Study | Scenario name | Year |
|---|---|---|---|---|---|
| IPCC | IPCC | 2022 | | Centralised Market-driven | |
| | Business-As-Usual | | Danish Design Center (DDC) | Centralised Society-driven | 2020 |
| | Frugal Generation | | | Distributed Market-driven | |
| Ademe Transition 2050 | Regional Cooperation | 2022 | | Distributed Society-driven | |
| | Green Technologies | | SNBC | Baseline | 2020 |
| | Restauration Gamble | | | Baseline | |
| negaWatt | negaWatt | 2021 | RTE | Extensive Reindustrialisation | 2022 |
| EU green deal | EU green deal | 2019 | | Sufficiency | |
| | Great decoupling | | | Acceleration 2030 | |
| Eionet | Ecotopia | 2022 | Shift | PTEF | 2020 |
| | Unity in adversity | | France 2072 | Digital society | 2018 |
| | Technocracy for the common good | | | Collective society | |
| | Greentocracy | | | Planetary destabilization | |
| Arup | Post Anthropocene | 2019 | Digitalization&Anthropocene (D&A) | Green but inhumane | 2022 |
| | Extinction Express | | | Deliberate for the good | |
| | Humans Inc. | | | Renowed | |
| | | | CNIL | Meddling | |
| | | | | Home Sour Home | 2021 |
| | | | Digital Challenge | Quebec 2040 | 2022 |

# Definition of variables for analysis

3 types of variables:

| | | |
|---|---|---|
| **Typology** | Level: | Study |
| | Objective: | General overview of the study |
| **Societal variables** | Level: | Scenario |
| | Objective: | non ICT-specific variables that influence scenarios |
| **ICT variables** | Level: | Scenario |
| | Objective: | ICT-specific variables present in scenarios |

# Scenario typology

Variables taken from [Van Notten et al. 2003]



- Nature of the data
- Method of data collection
- Nature of the resources
- Nature of institutional conditions

Process design

Project goal

- Inclusion of norms
- Vantage point
- Subject
- Time scale
- Spatial scales

Scenario typology

- Temporal nature
- Nature of the variables
- Nature of the dynamics
- Level of deviation
- Level of integration

Scenario content
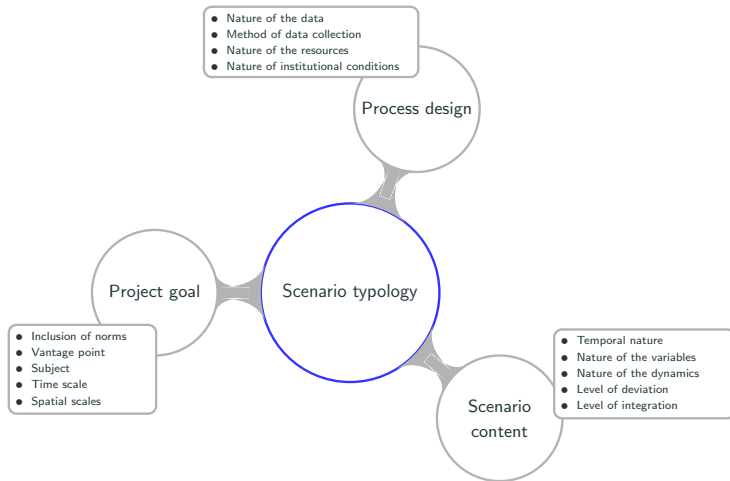
# Scenarios typology

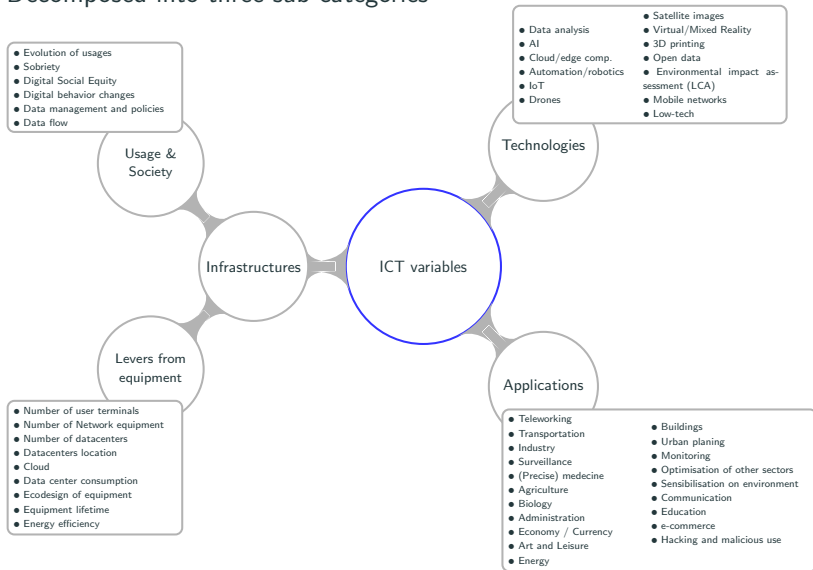| Study | Normative (probable or preferable) - Descriptive (possible) | Vantage point | Subject | Time scale | Spatial scale *(perimeter)* | Data | Method of data collection | Resources | Institutional conditions | Temporal nature | Variables | Dynamics | Level of deviation *(range of possible futures)* | Level of integration (high=interdisciplinary) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IPCC | norma... | backc... | issue-... | long te... | global/... | qualita... | partici... | extens... | constr... | chain | hetero... | trend | alterna... | high |
| Ademe Transition 2050 | norma... | foreca... | area-b... | long te... | nation... | quantit... | partici... | ? | ? | chain | hetero... | trend | alterna... | high |
| negaWatt | norma... | foreca... | issue-... | long te... | nation... | quantit... | partici... | ? | open | chain | hetero... | trend | alterna... | high |
| EU green deal | norma... | backc... | issue-... | long te... | global/... | qualita... | partici... | ? | constr... | chain | hetero... | trend | conve... | high |
| Eionet | descri... | foreca... | issue-... | long te... | global/... | qualita... | partici... | limited | constr... | snapshot | hetero... | periph... | alterna... | high |
| Arup | descri... | backc... | issue-... | long te... | global/... | qualita... | partici... | ? | open | chain | hetero... | periph... | alterna... | high |
| Danish Design Center (DDC) | descri... | backc... | issue-... | long te... | global/... | qualita... | partici... | limited | constr... | snapshot | hetero... | periph... | alterna... | high |
| SNBC | norma... | backc... | issue-... | long te... | nation... | quantit... | partici... | extens... | constr... | chain | hetero... | trend | conve... | high |
| RTE | norma... | backc... | area-b... | long te... | global/... | quantit... | partici... | extens... | constr... | chain | hetero... | trend | conve... | high |
| Shift | norma... | backc... | area-b... | long te... | nation... | quantit... | partici... | limited | open | snapshot | hetero... | trend | conve... | low |
| France 2072 | norma... | foreca... | area-b... | long te... | nation... | quantit... | desk r... | limited | open | snapshot | hetero... | periph... | alterna... | low |
| Digitalization&Anthropocene (D... | norma... | foreca... | issue-... | long te... | global/... | qualita... | partici... | limited | open | snapshot | homog... | periph... | alterna... | low |
| CNIL | descri... | backc... | issue-... | long te... | nation... | qualita... | partici... | ? | ? | chain | homog... | periph... | alterna... | low |
| Digital Challenge | descri... | foreca... | issue-... | long te... | nation... | qualita... | partici... | ? | ? | chain | homog... | periph... | alterna... | low |

Variables freely adapted from [Ademe 2021]
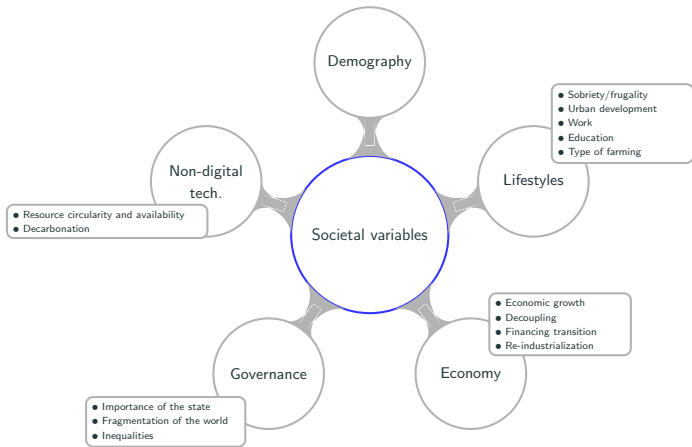


▷ To envision what governance, life and society look like in the future
▷ Not the same level of details and information among scenarios
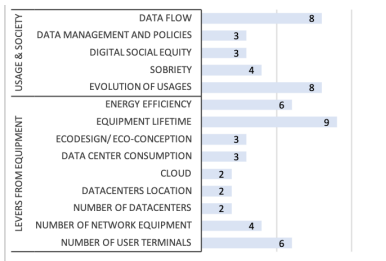
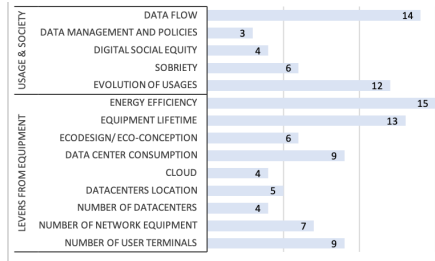# ICT variables

## Decomposed into three sub-categories



**Usage & Society**
- Evolution of usages
- Sobriety
- Digital Social Equity
- Digital behavior changes
- Data management and policies
- Data flow

**Technologies**
- Data analysis
- AI
- Cloud/edge comp.
- Automation/robotics
- IoT
- Drones
- Satellite images
- Virtual/Mixed Reality
- 3D printing
- Open data
- Environmental impact assessment (LCA)
- Mobile networks
- Low-tech

**Infrastructures**

**ICT variables**

**Levers from equipment**
- Number of user terminals
- Number of Network equipment
- Number of datacenters
- Datacenters location
- Cloud
- Data center consumption
- Ecodesign of equipment
- Equipment lifetime
- Energy efficiency

**Applications**
- Teleworking
- Transportation
- Industry
- Surveillance
- (Precise) medecine
- Agriculture
- Biology
- Administration
- Economy / Currency
- Art and Leisure
- Energy
- Buildings
- Urban planing
- Monitoring
- Optimisation of other sectors
- Sensibilisation on environment
- Communication
- Education
- e-commerce
- Hacking and malicious use

# Results for ICT variables

1. **Infrastructures:** Usage & Society ; Levers from equipment
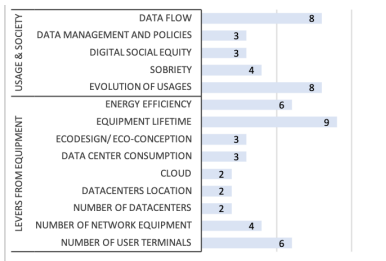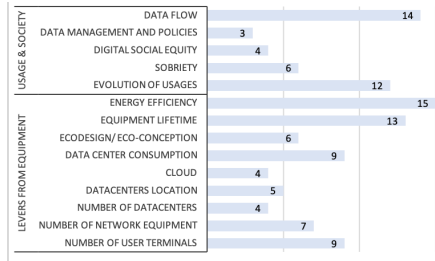   ▷ Provide tendencies on the use of ICT, regulation and materiality
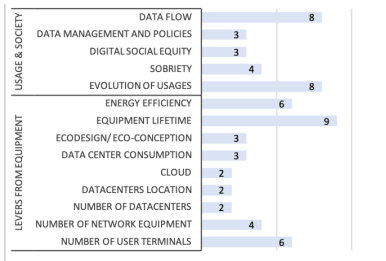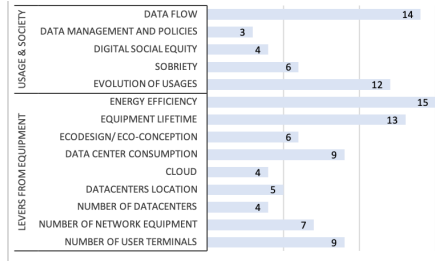


Study level



Scenario level

1. **Infrastructures:** Usage & Society ; Levers from equipment
   ▷ Provide tendencies on the use of ICT, regulation and materiality



Study level



Scenario level

▷ Examples for "Evolution of usages"
- Prioritization of uses after 2030 ([négaWatt 2021])
- Digital mutualization (Frugal generation, [Ademe 2021])
- Digit. deployment, Software not optimized (Green Tech., [Ademe 2021])
- Frequent software updates (Restauration Gamble, [Ademe 2021])
- New infrastructures must be justified, no high resolution videos, no cloud gaming (PTEF, [The Shift Project 2020])

# Results for ICT variables

**1. Infrastructures:** Usage & Society ; Levers from equipment

▷ Provide tendencies on the use of ICT, regulation and materiality



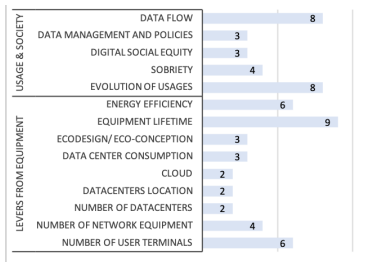Study level                  Scenario level

▷ Examples for "Sobriety"

- Sobriety of usage and purchase of goods from individuals and organizations (Quebec 2040, [Deron et al. 2022])
- Quota on digital use starting 2039 but possible to buy credits (Home Sour Home, [CNIL 2021])
- Limitations on individual consumption may be operationalized by a strong surveillance state (Green but inhumane, [Creutzig et al. 2022])
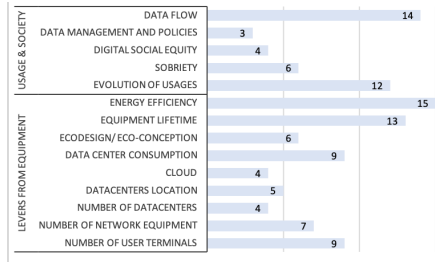
# Results for ICT variables

**1. Infrastructures:** Usage & Society ; Levers from equipment

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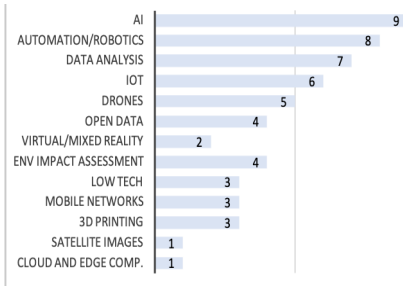


Study level                               Scenario level

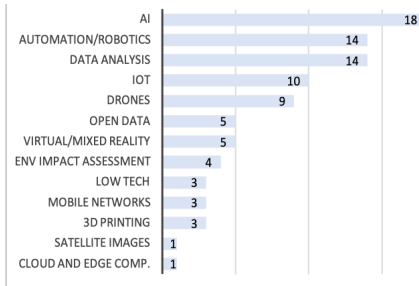▷ Examples for "Number of user terminals"

- Fewer screens (Sufficiency, [RTE 2022])
- Bounded equipment rate per person (PTEF, [The Shift Project 2020])
- Equipment mutualization in companies (Quebec 2040, [Deron et al. 2022])
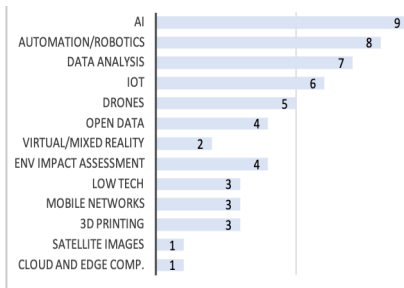
**2. Digital technologies** <u>explicitly</u> mentioned



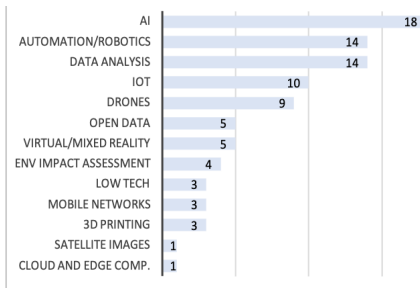| | Study level | Scenario level |
|---|---|---|
| AI | 9 | 18 |
| AUTOMATION/ROBOTICS | 8 | 14 |
| DATA ANALYSIS | 7 | 14 |
| IOT | 6 | 10 |
| DRONES | 5 | 9 |
| OPEN DATA | 4 | 5 |
| VIRTUAL/MIXED REALITY | 2 | 5 |
| ENV IMPACT ASSESSMENT | 4 | 4 |
| LOW TECH | 3 | 3 |
| MOBILE NETWORKS | 3 | 3 |
| 3D PRINTING | 3 | 3 |
| SATELLITE IMAGES | 1 | 1 |
| CLOUD AND EDGE COMP. | 1 | 1 |

Study level                    Scenario level

## 2. **Digital technologies** <u>explicitly</u> mentioned



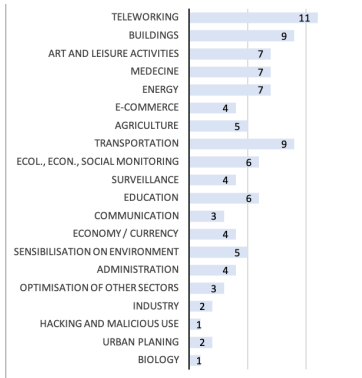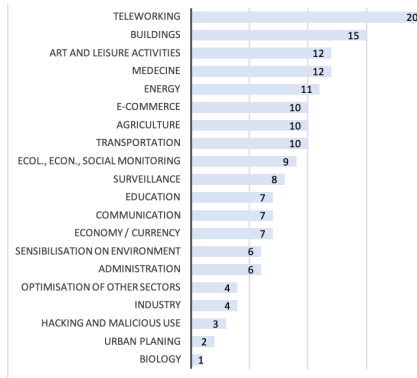| Study level | Scenario level |
| --- | --- |

▷ Examples for "AI"

- Implemented for individual and corporate gains. (Extinction Express, [Arup 2019])
- Everyone has, and knows, their carbon quota and daily spend; AI provides daily updates, and state governments penalize overspend. (Post Anthropocene, [Arup 2019])
- Automation and machine learning enable the implementation of a global universal basic income. (Humans Inc., [Arup 2019])

## 3. **Application domains** <u>explicitly</u> mentioned



| Study level | Scenario level |
|---|---|

# Results analysis

**Evolution of ICT**

- ▷ Every scenario involves ICT
- ▷ Our relationship to digital technologies is not questioned
- ▷ No significant change in equipment and applications wrt today's
- ▷ No disruptive technologies

**ICT as a driver of societal changes**

- ▷ Some structural changes come from innovations in ICT, such as teleworking or autonomous driving
- ▷ But ICT variables mostly remain consequences of other aspects of the scenarios
- ▷ Often application-oriented, omitting all the interconnection with infrastructures and technologies.

$\rightarrow$ **Challenge:** Development of prospective studies with a more systemic view of ICT

# Results analysis

**Resilience and climate change context**

▷ Some essential services (decarbonization, food supply, water management) depend on ICT

▷ Many scenarios give a central place to IT for green applications

▷ "The ubiquity of digital technology makes its resilience crucial to many aspects of society" [The Shift Project 2020]

▷ The absence of resilience variables constitutes a limitation of current studies

→ **Challenges:** Development of prospective studies that integrate resilience to ICT failure; Awareness to the need of developing resilient and secure ICT

# Results analysis

**ICT materiality**

▷ Only some scenarios mention the availability of critical resources, pure water, energy, or land (e.g., with resource colonies on the Moon and deep sea mining in Extinction express of Arup 2019, or in RTE 2022 scenarios for energy production)

▷ Consequent geopolitical tensions are sometimes discussed but do not seem to influence the integration of ICT

▷ No study mentions the geopolitical aspects related to the location of data centers and the installation of ICT infrastructures (e.g., underwater cables or satellites).

$\rightarrow$ **Challenges:** Research to reduce use of critical resources; Research to increase efficiency (with care)

# Results analysis

**Beyond climate change**

    ▷ All studies made from a climate change perspective, omitting other environmental issues

    ▷ Human centered

    ▷ Global North centered (chosen studies made in OECD countries)

→ **Challenges:** Analyze other different studies; Develop prospective studies that broaden their narrations.

## Conclusion

▷ Prospective studies develop imagination and can drive ecological transition.

▷ Current studies hardly question our relationship to technologies or the applications of IT in the Anthropocene.

▷ Designing prospective studies for ICT with sustainability perspective: an undone computer science that needs to be done

- To offer a more diverse and systemic view of the future of digital technologies
- To discuss, structure or fund other (or new) computer science research topics

*Thank You*

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