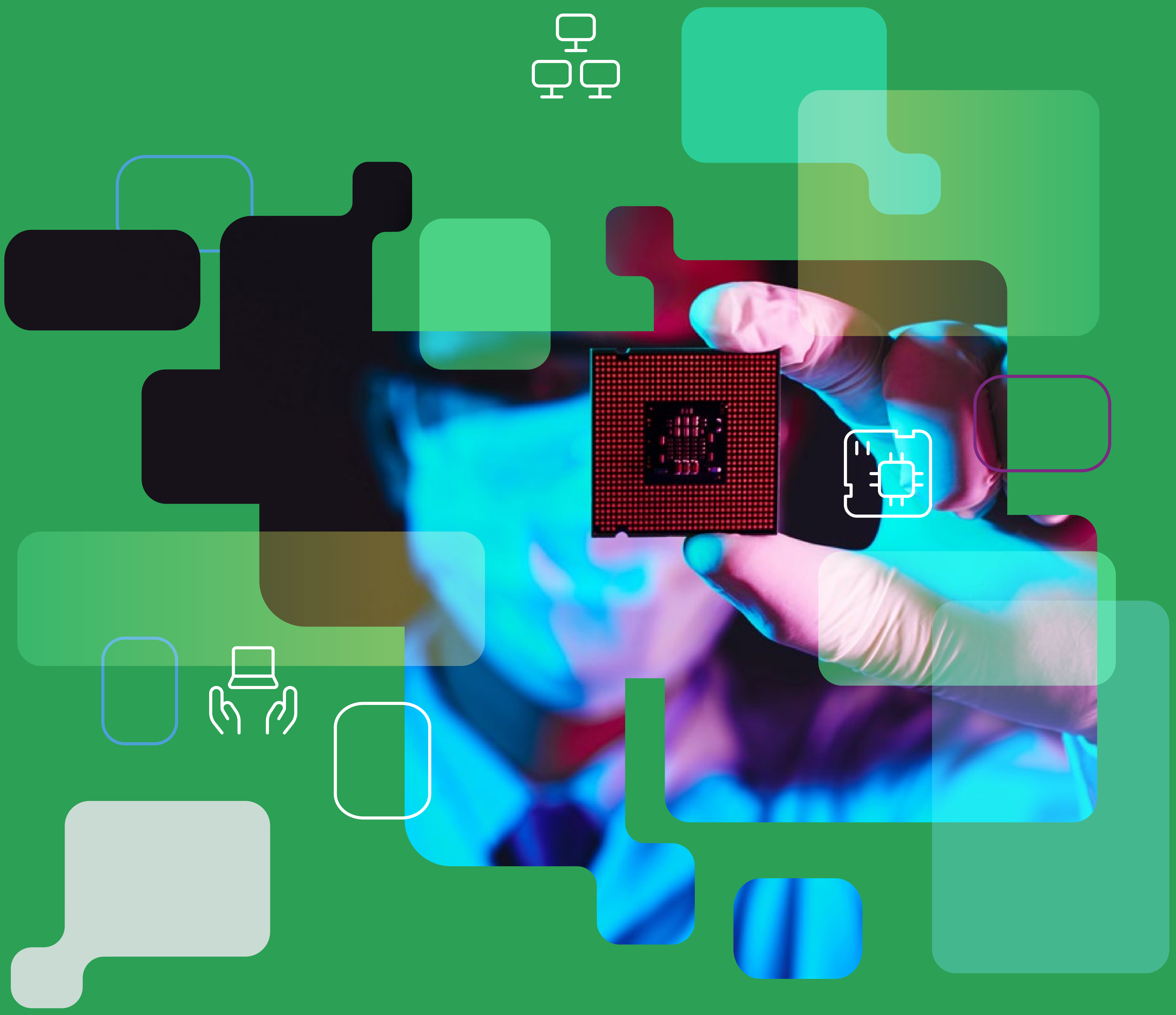
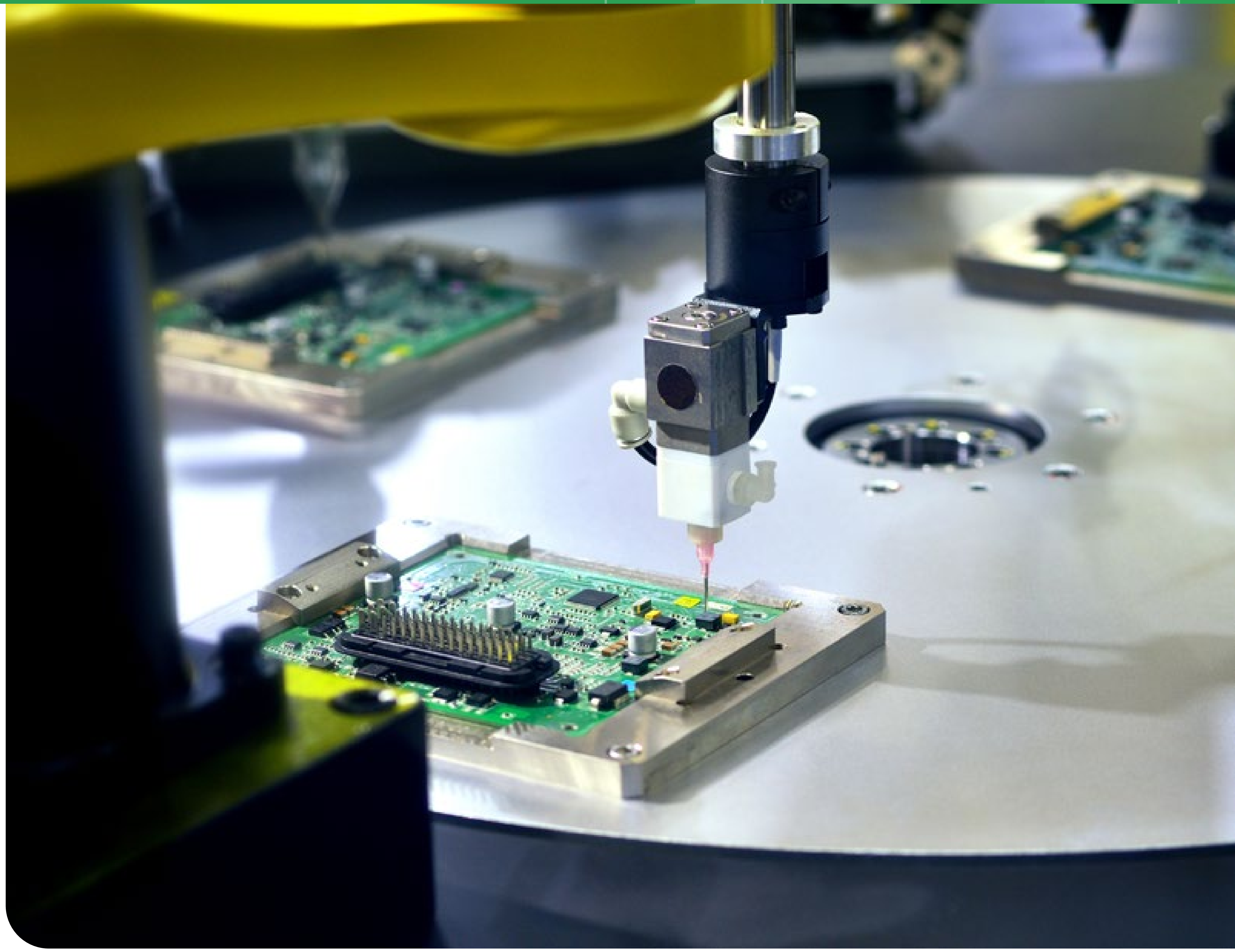
# Advanced Computing



- → Computing continuum
- → Energy sustainability in digital infrastructures
- → Protect sovereignty in digital infrastructure
- → Unconventional paradigms for computing
- → High-end computing in qualitative research fields

# Advanced (Research) Computing



Solving societal challenges with digital research infrastructure on a global scale requires a unique combination of computing, storage, and networking technologies. We face a future full of complex emerging scientific questions, a growing energy demand and a growing number of bottlenecks in the semiconductor supply chain, but also a growth in opportunities offered by technology. In the last 50 years Moore's law enabled transistor size to shrink by half every few years; this in turn has led to a doubling of performance and functionality within the same chip area. But transistor size soon reaches fundamental physical limits, and the growth trajectory is expected to flatten out.

This will challenge the development of digital ecosystems, including technologies for research computing. (see CompSys NL Manifesto) These challenges include addressing increasing energy demands while at the same time increasing productivity, avoiding technology monopoly, protecting sovereignty and encouraging diversification in the field of computational science, as illustrated by the trends below.

For the future of science and humanity, digital transformation is going to play a pivotal role. Therefore, its exploration should include cultural values, expertise development, knowledge creation and most importantly understanding market developments. Some maturing trends mentioned here are further described in other chapters.

TREND #1

# Computing continuum

**Public values**

Autonomy

Justice Integrity

Humanity Safety

**Readiness** WATCH PLAN ACT

**Drivers**

#Dataism #Globalization #Carbon footprint #Climate change #Power efficiency #Decentralization

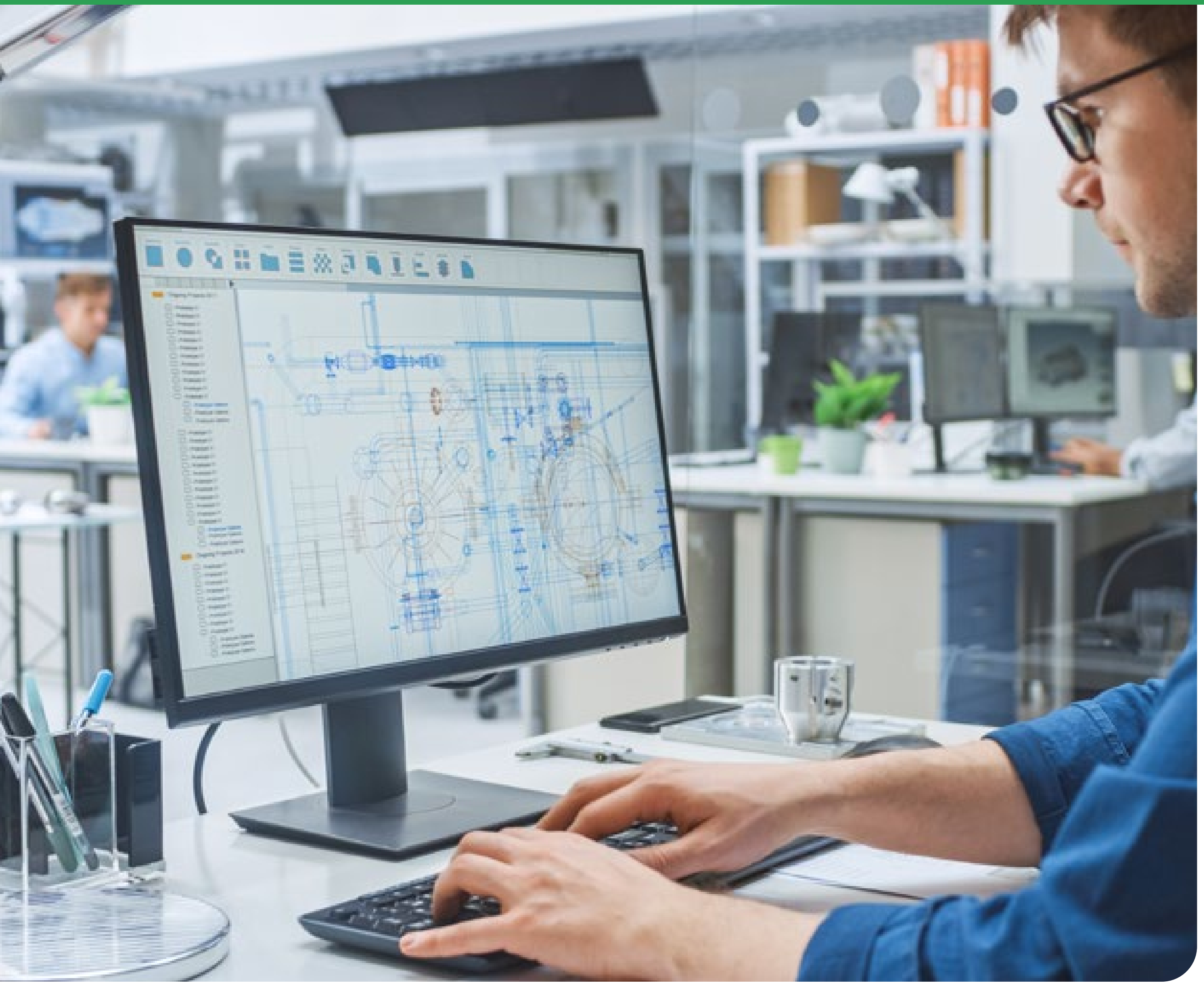
Applications like climate and earth observations, digital twins, drug discovery, protein folding, policy scenario analysis, high-energy physics et cetera require a large number of computing technologies and data infrastructures to work together. The need for high orders of magnitude of detailed modelling and simulation and also scaling data and meta-data, demands hyper-connected infrastructures with smooth accessibility and usage. It also requires efficient middlewares, programming models and research software leading to challenges for efficient usage and wider impact.

See also: Edge-Cloud Continuum

## Orders of magnitude higher resolution

e.g. 1KM resolution for global Climate modelling, 10 times more data processing e.g. earth observation

open example



## Real-time sensing and data ingestion

(Edge / IOT / Wired and wireless networks)

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## Urgent computing

Disaster prevention, Hazard modelling

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## Federated solution (Cloud continuum)

Federated cloud-based infrastructure for science and research

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## Data visualisation for extreme scale modelling and simulation

Need of accelerated computing and I/O for in-situ visualization, digital twinning

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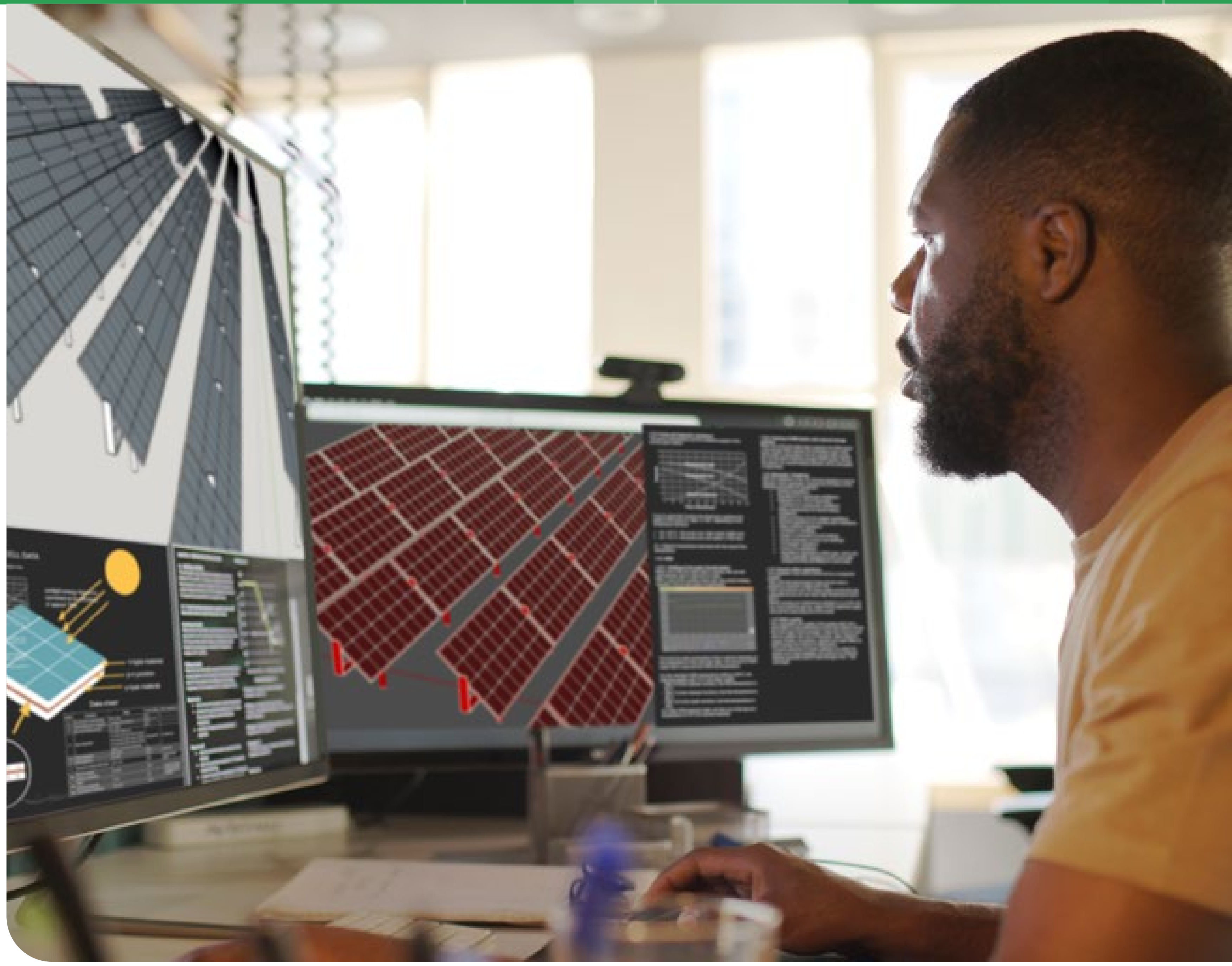
## IMPACT

This trend affects the collective ability of the research community to tackle complex scientific challenges using distributed computing ecosystems. Furthermore, the trend helps this community to accommodate a wide range of scientific applications and workflows in the future. Future education and training could use networked XR or edge computing systems to understand digital twins or to demonstrate art and culture prototypes for different geographical locations. Working towards a federated infrastructure in the Netherlands offers NL-based researchers opportunities to access various computing and data infrastructures for research.

TREND #2

# Energy sustainability in digital infrastructures

The surge in demand for advanced computing also leads to an exponential increase in our energy footprint. We should strive to reduce energy waste, improve efficiency and energy awareness for the entire value chain, from manufacturing to operations to decommissioning systems, while considering computing demands. We also need to involve community stakeholders in these efforts and communicate the results to all involved.



**Public values**

| | |
|---|---|
| Autonomy | |
| Justice | Integrity |
| Humanity | Personal development |

**Readiness** WATCH PLAN ACT

**Drivers**

#Power efficiency #Biodiversity #Climate change #Circular economy

## Push for energy efficient systems

Climate change, Green deal, Operational Cost, Energy / carbon accounting

open example

## Digital and green transition picking up in Netherlands / Europe

Disaster prevention, Hazard modelling

open example open example

## Electricity consumption for computing space expected to reach ~5-10% of global electricity consumption

open example open example open example

## IMPACT

Due to the substantial amounts of electricity required by digital facilities, rising energy costs and energy budgeting are no longer distant prospects. These are already impeding improvements in advanced computing solutions. Advanced computing facilities must therefore be planned with energy as a design principle. Improvements in energy use can be found across the spectrum. Funding agencies will need to prioritise energy awareness, optimization and develop innovative policies to minimise negative impact on publicly funded research infrastructure. This trend also underlines the necessity for more engagement and interaction about energy with the user community. Also, energy as a topic for computing should become part of academic training, curricula and courses.

TREND #3

# Protect sovereignty in digital infrastructure

**Public values**

- **Autonomy** — Freedom of choice | Independence of education
- Justice
- Humanity

**Readiness** WATCH PLAN ACT

**Drivers**

#Data governance #EU legislation #Privacy #Decentralization

Geopolitical tensions, global pandemics, growing dependence on global supply chains and emergence of private cloud providers have forced governments to formulate policies and introduce legal frameworks and laws to tackle technology sovereignty. The challenge is to strive for autonomy, effective investment of public money for research and avoid monopolisation of technological development by a small number of companies in the ecosystem.

More research universities adopting cloud providers for their computing needs and operations

open example    open example

### Chips are designed and owned by Big Tech

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### Connected Digital facility

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### Geographical chips act

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## IMPACT

The need for data and infrastructure sovereignty is probably higher than ever before, given the proliferation in data and processing techniques in recent years. However, the challenges to achieve this sovereignty are non-trivial and multifaceted.

Firstly, there is the impact of Big Tech, with significant amounts of data being concentrated in the cloud storage of these major providers. Secondly, large cloud providers also provide easy-to-use tools to the research ecosystem for conducting data analysis. However, this also poses risks regarding data confidentiality and data lock-in. Thirdly, there is the issue of semiconductor manufacturing, which is now concentrated in three large companies. To address these risks a multi-level, hybrid ecosystem could be considered. In such a system, data with higher degrees of confidentiality would be processed using systems and techniques that grant sovereignty, whereas the bulk of data could be processed with ‘easy-to-use’ cloud tools.

Developing thought leadership on these topics and collaborating with the political establishment will help to improve legal framework and policies for the future and to deal with the sovereignty of computing research infrastructure in the long term. At the same time, the future needs and requirements of research and education communities need to be supported.

TREND #4

# Unconventional paradigms for computing

In the next two decades, our demand for computing is expected to increase exponentially. This increase implies new modelling techniques, generating new science and an unprecedented need for moving, storing, and processing data at different scales. This trend also implies breaking current technological limitations and exploring solutions beyond the standard roadmaps. A positive development is the rapid influx of public/private large-scale funding, for instance for topics like AI+HPC, quantum, photonics, et cetera. It is important to understand that these are not replacement technologies, but complement existing technologies or even help us explore new untapped science. Exploring emerging technology, e.g non-von Neumann architectures, dataflow to accelerator-driven computing, quantum and neuromorphic paradigms, tools and specialisations offers an alternative way to break current barriers and increase efficiency with limited resources. It also involves redesigning scientific applications to match with future infrastructure and hardware.

**Public values**

| | |
|---|---|
| Autonomy | Independence of education |
| Justice | Integrity |
| Humanity | Personal development |

**Readiness** WATCH PLAN ACT

**Drivers**

#Internationalization #Connectivity
#Automation #Digital literacy and skills

## Semiconductor technology reaching 2nm transistor lengths

Emergence of Chiplet for semiconductor chip design

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## Hybrid /mixed precision algorithms

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## Quantum-HPC integration with supercomputers

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## Machine learning enhanced scientific computing

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## Rise of brain inspired computing; In-memory

Neuromorphic computing

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## Unconventional computing chips

e.g. FPGA for data processing in the networks

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## IMPACT

Our ability to understand and experiment with unconventional paradigms, technologies and methodologies will help us explore opportunities together and develop expertise and competences to prepare for the use of new technologies. This ability also help us to support operational teams in choosing design, architecture, and hardware technologies in the next generation research computing systems. Finally, we can also make best use of public funds when future requirements, technology roadmaps and emerging applications are taken into account.

TREND #5

# High-end computing in qualitative research fields

**Public values**

| | |
|---|---|
| Autonomy | Freedom of education \| Privacy |
| Justice | Inclusivity \| Equality |
| Humanity | |

**Readiness** WATCH PLAN ACT

**Drivers**
#Dataism #Internationalization #Digital economy #Research environment #Privacy

A growing number of new communities in for instance social sciences, humanities, art, history, digital health, sports, and medicine have started using computing services for enhancing research and insights development. They regularly need expertise and support to map their research questions onto computing systems. This is mainly because the data they have at their disposal today is much larger than 5 years ago (a laptop is not enough). Furthermore, the statistical analysis and modelling tools they use have transformed into ML/Big Data workflows, and these require large computing power.

## Increased use of computing resources in social sciences, arts and humanities

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## Provisioning funding for software research engineers

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## Community specific project calls

e.g., for Humanities and social science, Linguistics, Health, Education, Science

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## IMPACT

Nurturing and supporting the compute requirements of these new emerging communities will in the long term lead to diversified usage of research infrastructure and sustainable business models. Strategically this will lead to the inclusion of talent and people from various backgrounds, ethnicities and cultures. Overall, designing solutions for these communities will ensure that computing becomes an accessible digital research infrastructure suitable for researchers from all domains.

# More about Advanced Computing

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## Continue reading

more info | communities