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AI, BIG DATA AND ROBOTICS FOR THE PLANET- THE DOUBLE-EDGED SWORD

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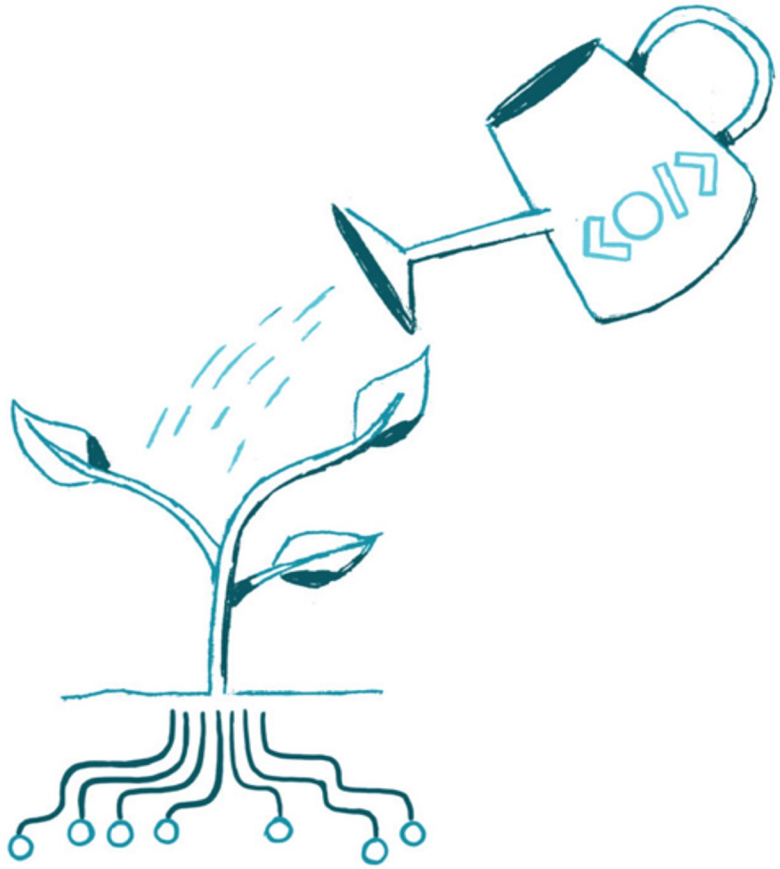
President Digital for Planet – D4P

AT WORK TO MAKE IT HAPPEN!

DIGITAL FOR PLANET –

D4P is a **non-profit association** at work **to** develop and foster the adoption of **green digital technologies** that respect and contribute to the economic, societal and environmental **sustainability of our planet**

It has been founded by MARTEL INNOVATE that works in close collaboration with D4P to ensure its growth and impact



#togetherisbetter #aloneisimpossible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CHARTING THE COURSE FOR A
SUSTAINABLE FUTURE

MAIN ENVIRONMENTAL CHALLENGES

ACCORDING TO THE WORLD ECONOMIC FORUM'S GLOBAL RISKS REPORT

- **Pollution**: air, water, and soil contamination.
- **Biodiversity loss**: habitat destruction, species extinction.
- **Resource depletion**: overconsumption of natural resources.
- **Climate change**: rising global temperatures, extreme weather events.
- **Waste management**: increasing volumes of waste (including e-waste) and inadequate disposal methods.

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These environmental problems have far-reaching consequences, not only for the natural world but also for **human societies and economies.** They affect everything from food security and medicine to climate regulation and the air we breathe.

* https://www.weforum.org/agenda/2024/01/global-risks-report-2024/

THE GREEN PROMISE OF ICT

ICT FOR SUSTAINABLE DEVELOPMENT

Either isolated or combined, ICT and in particular ADR technologies **have a huge potential to help address environmental challenges across various sectors and for different applications** by:

- More efficient use of resources
- Optimising Processes and Supply Chains
- Improving Environmental Monitoring and Analysis
- Optimising Resource Management and Efficiency
- Supporting Better Informed and Timely Decision Making

SOME PROMISING PROJECTIONS

- International Energy Agency (IEA):
  - From their 2021 report, "*Net Zero by 2050: A Roadmap for the Global Energy Sector*" digital technologies like smart grids and building automation could deliver up to 17% of the global CO2 emissions reductions needed to achieve net zero by 2050.
- Accenture Strategy
  - A 2020 report by Accenture, "*Sustainable by Design: Reimagine Fashion for a Circular Economy*," projects that AI-powered supply chain optimization in the fashion industry could lead to a **30% reduction in material waste** by 2030.
- McKinsey & Company:
  - A 2020 McKinsey report, "*Climate Tech and the trillion-dollar opportunity*," estimates that digital solutions like precision agriculture and smart manufacturing could generate **$3.5 trillion** in annual benefits by 2030, with significant environmental benefits alongside economic ones.
- Several other reports from **WEF, BEREC, OECD, ITU, GSMA** also provide several forecasts and projections

BUT THERE IS A REBOUND EFFECT

DIGITAL TECHNOLOGIES AND THEIR OVERCONSUMPTION ARE ALSO A BIG PART OF THE PROBLEM

ENERGY CONSUMPTION

- A study by McKinsey & Company estimates that by 2030, **ICT could be responsible for up to 20%** of global electricity demand

CO2 FOOTPRINT

- The lifecycle of digital devices, from production to disposal, generates **about 4-6% of global GHG emissions** – SHIFT project.
- This share is projected to rise sharply**, potentially reaching 8% by 2025**. Data centres alone account for 45% of the ICT emissions.

TECHNOLOGY IS DAMAGING THE ENVIRONMENT

- Production, use and disposal of ICT pollute and destroy - the Global E-waste Monitor 2023 by the UN University reported a **57.4 million metric tons of e-waste generated globally in 2021**. Only 17.4% was documented as properly collected and recycled.

TECHNOLOGY IS INDUCING OVERCONSUMPTION

- Enforcing culture of consumerism and, disposability
- Replacement rather than repair approach

WE MUST ACT NOW, THE PLANET CALLS

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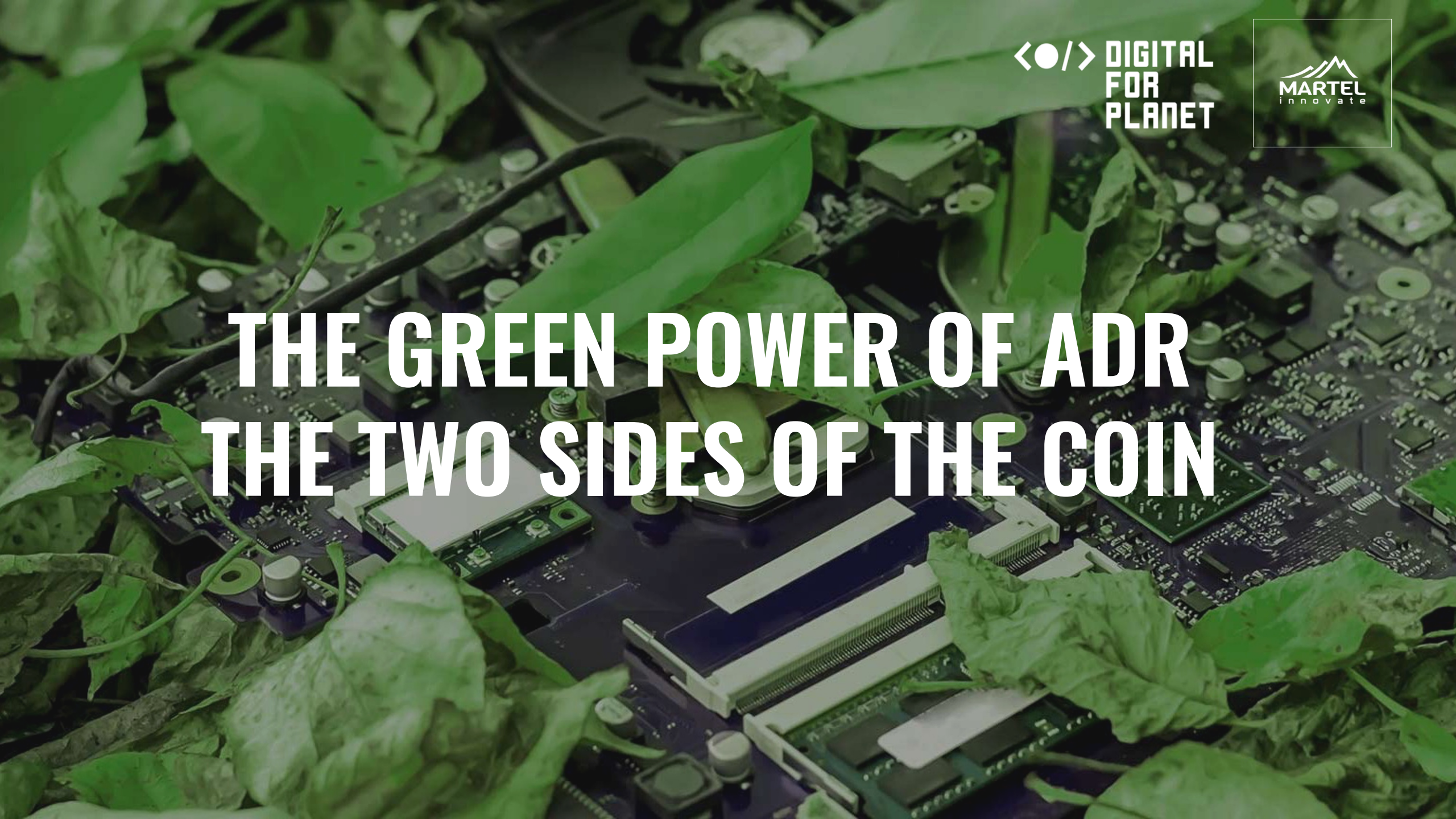
THE BALANCE OF POSITIVE VS NEGATIVE OUTCOMES OF ICT DEPENDS ON SEVERAL FACTORS

WE NEED GREENING DIGITAL TECHNOLOGIES FOR THE SUSTAINABLE DEVELOPMENT OF OUR SOCIETY

CHARTING A COURSE FOR GREEN DIGITALISATION

TO MAKE SURE THAT THE POSITIVE EFFECTS OF DIGITAL TECHNOLOGIES OUTWEIGH THEIR NEGATIVE IMPACT, IT IS NECESSARY TO ACT AT SEVERAL LEVELS:

- Technological advancements - sustainability by design
- Policy and Regulations - to standardise, prevent and protect, while providing incentives for greener choices and sharing best practices
- Individual and Organisational behaviour - educate to sustainability and promote responsible choices
- Collaboration and Awareness - multi-stakeholder and global approach, raising understanding at individual and organisational level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THE GREEN POWER OF ADR
THE TWO SIDES OF THE COIN

ADR IN ACTION – A BROAD IMPACT

ARTIFICIAL INTELLIGENCE

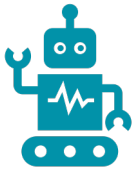
- Predictive analytics for climate modelling and weather forecasting.
- Optimization of energy usage in buildings and industrial processes.
- AI-powered advanced CO2/GHG monitoring.

BIG DATA

- Monitoring environmental changes and identifying trends.
- Monitoring, predicting, and environmental challenges and disasters prevention.
- Data analytics for informed decision-making in resource management.

ROBOTICS

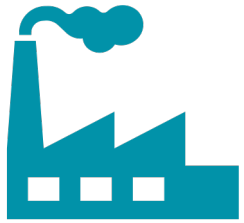
- Precision agriculture to reduce waste and increase efficiency.
- Environmental monitoring through autonomous drones and underwater robots.
- Predictive for inspections of pipelines, power lines, or other critical infrastructure.



ADR FOR SELECTED VERTICALS

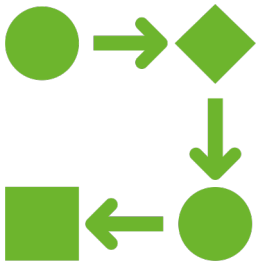
CHALLENGES ACROSS TRANSPORT, CONSTRUCTION, MANUFACTURING

- Efficiency and Optimization: Across all three sectors, inefficiency leads to wasted resources, time, and money. This can manifest as traffic congestion, construction delays, and production line stoppages.
- Safety: Worker safety is a major concern, especially in construction and manufacturing. Additionally, transportation accidents have a significant human and economic cost.
- Sustainability: Reducing the environmental impact of these sectors is crucial. This includes lowering greenhouse gas emissions, minimising waste, and optimising resource usage.
- Labour Shortages: An ageing workforce and a skill gap in some areas are challenges across all three sectors.



THE POTENTIAL OF ADR SOLUTIONS (1)

- OPTIMISING PROCESSES:
  - AI can analyse data to identify bottlenecks and inefficiencies.
  - Big data provides historical and real-time data for analysis.
  - Robotics can automate repetitive tasks, improving efficiency.
  - *R&D: Advanced AI algorithms for complex process optimization, real-time data integration with physical systems*



- ENHANCING SAFETY:
  - AI-powered sensors and monitoring systems can identify potential hazards and prevent accidents.
  - Robotics can take over dangerous tasks.
  - *R&D: Improved sensor technology for real-time hazard detection, AI for risk assessment and proactive safety measures*

THE POTENTIAL OF ADR SOLUTIONS (2)

- SUSTAINABILITY SOLUTIONS:
  - AI can optimise resource usage and energy consumption.
  - Big data can track environmental impact and identify areas for improvement.
  - Robotics can be used in recycling and waste management.
  - *R&D: AI for life cycle assessment of materials and products, Big Data for environmental impact modelling, robots for sustainable material handling)*
- ADDRESSING LABOUR SHORTAGES:
  - Robots can handle repetitive tasks, freeing up human workers for higher-level activities.
  - AI can assist with training and upskilling the workforce.
  - *R&D: Collaborative robots (common sense!) for safe human-machine interaction, AI-powered training programs for specific skills*

*ADR solutions have the potential **to cut global Greenhouse Gas (GHG) emissions in other sectors by 15% by 2030**: AI alone, for instance, is capable of shaving 5 to 10% off of global GHG emissions**

*https://www.digital4planet.org/leveraging-data-for-climate-action-event-report/

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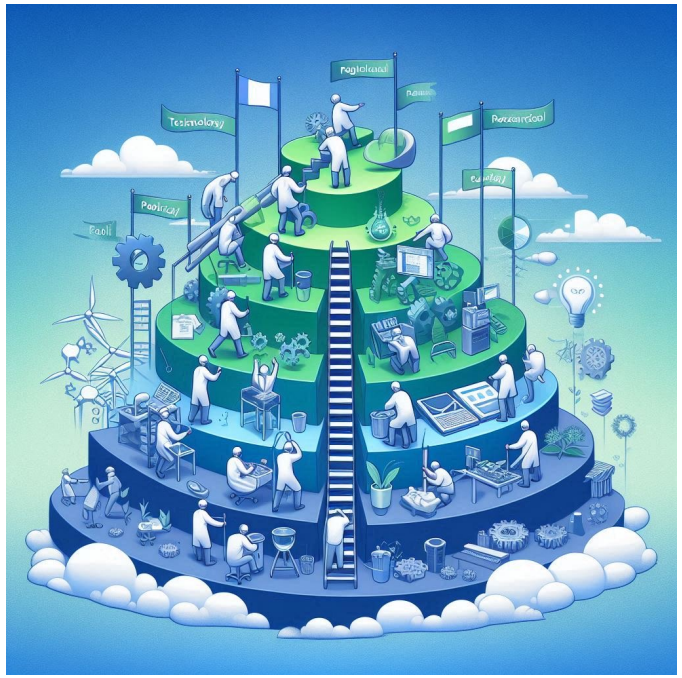
WHAT DOES IT TAKE TO GET THERE?



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- **Human-centred Design:** Ensure ADR solutions are designed with human needs and well-being in mind, focusing on collaboration and not job displacement.
- **Cybersecurity Considerations:** Prioritise robust cybersecurity measures to protect against potential vulnerabilities in ADR systems.
- **Ethical Development:** Ensure responsible development and use of ADR technologies, considering potential biases and societal impacts
- **Standardisation and Regulation:** Establish clear sector-specific standards and regulations for the design, development, deployment, and life-cycle management of ADR technologies.
- **Focus on Interoperability:** Develop ADR solutions that can seamlessly integrate with infrastructure and data systems across different sectors, based on standardised data exchange protocols

...AND MOST OF ALL WE NEED TO DECARBONISE ADR!...

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ADR TECHNOLOGIES CANNOT GREEN THE PLANET IF THEY DO NOT BECOME GREENER

ADR ENVIRONMENTAL COST

HIGH ENERGY CONSUMPTION AND CARBON EMISSIONS

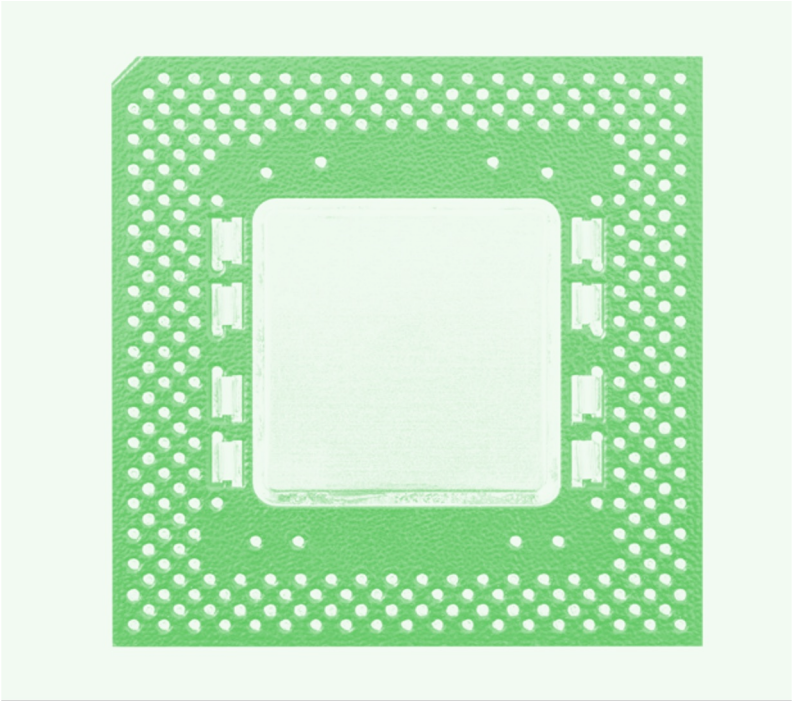
- *Training complex AI models (especially large ones) as well as inference*, requires a massive amount of electricity, which today is still produced mostly from fossil fuels.
- *Data centres are among the largest consumers of electricity globally*. **If data centres were a country, they would rank as the fifth-largest energy consumer**. If this energy is not green, clearly there is a huge consequent amount of CO2 emissions.
- *Robots, particularly those in industrial settings, consume energy during operation*. If this energy comes from non-renewable sources, it contributes to CO2 emissions.

E-WASTE

- With rapid technological advancements, **hardware becomes obsolete quickly,** leading to increased electronic waste that can be harmful if not properly recycled.
- Often rather than repairing, **there is a culture of upgrading** – short life-cycle.

THE RESOURCE FOOTPRINT OF ADR

- The manufacturing of specialised hardware like GPUs needed for AI training and inference can have a **significant footprint due to resource extraction** and energy use.
- Data centres require **substantial physical resources** for construction and operation, including water and rare earth metals, which have a substantial extraction and processing impact.
- The production of robots requires substantial amounts of resources, including metals and plastics, which **can lead to environmental degradation and resource depletion**.



IMPACT ON NATURAL ECOSYSTEMS

- The resources required for AI systems can lead to **habitat destruction and biodiversity loss** as natural areas are exploited for materials.
- Cooling systems for data centres consume vast amounts of water, which can lead to **water scarcity and affect local ecosystems**
- The use and disposal of robots (or other hardware) **can create pollution.** For example, robots used in mining or bomb disposal may release harmful substances into the environment.
- Robotics can **disturb natural landscapes and ecosystems**, whether through their deployment in natural settings or the infrastructure needed to support them.
- Some robots can produce **noise that can disturb wildlife and humans**, and **electromagnetic radiation from robots can potentially harm** humans, plants and animals.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A BIG CHALLENGE:
DECARBONISING ADR
FOR NET ZERO

DECARBONISATION AGENDA FOR ADR

SUSTAINABLE AI AND BIG DATA

- Energy-efficient AI algorithms
- Responsible and optimised data collection and management
- Greener data centres technologies
- Greener edge nodes and devices
- Greener networks (6G/NTN)
- Life Cycle Assessment for ADR systems

SUSTAINABLE ROBOTICS

- Robotics for resource recovery and recycling
- Biodegradable and sustainable materials for robots
- Energy-efficient robotic Design
- Robotic design for reusability and repair
- Energy-aware robot swarms

DECARBONISATION AGENDA FOR ADR

ETHICAL AI AND DEVELOPMENT

- Bias detection and mitigation
- Explainability and transparency in AI
- Human-AI collaboration - a multidisciplinary challenge
- Responsibility and liability for design, deployment, and use of ADR systems

SOCIETAL AND POLICY REMARKS

- Analysing the future of work and reskilling, as well as bridging the digital divide
- Digital equity, accessibility, inclusion and circularity
- Digital efficiency vs sufficiency
- Regulation and governance

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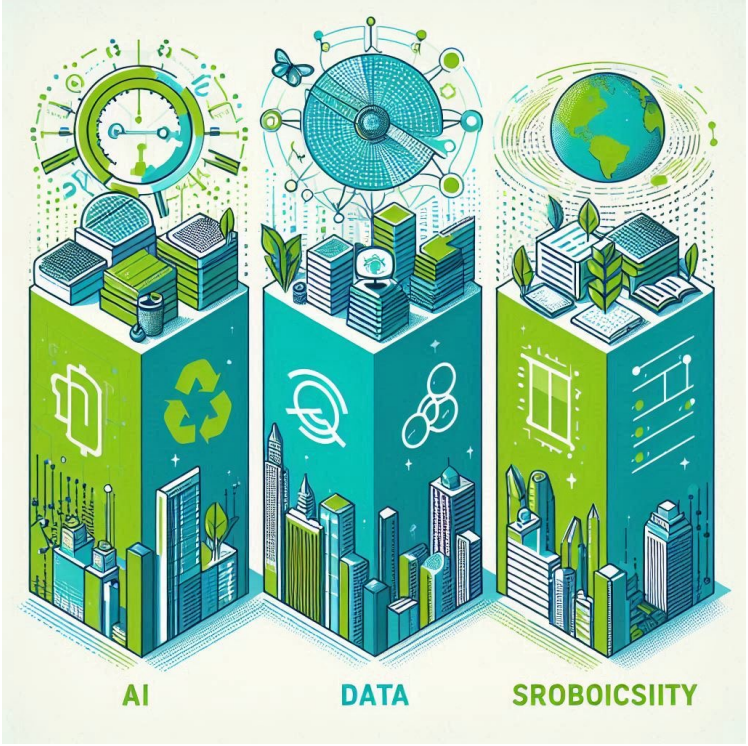
THIS IS NOT ENOUGH!

A RADICAL AND HOLISTIC APPROACH

THE MAIN PILLARS

- Circular economy: we must make it happen by support transitioning the economy towards net zero
  - Reducing total carbon emissions by providing a consistent approach **to measuring the net impact of ICT** (and ADR more specifically)
  - Work on **Case Studies** across different sectors engaging different stakeholders
  - Provide **guidelines** for a different approach to design, development and use of ICT (and ADR more specifically)
- Actively pursue the concept of digital sufficiency at individual and organisational levels
- **Trying to dematerialise our society** providing for instance products as services is promising - assuming circularity of the economy



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FURTHER INVESTIGATION AND WORK

WE NEED CREDIBLE END-TO-END QUANTITATIVE ASSESSMENTS OF THE NET ENVIRONMENTAL IMPACT WITH AND WITHOUT A SPECIFIC TECHNOLOGICAL SOLUTION TO DRIVE DECISION-MAKING

- THE APPROPRIATE METRICS NEED TO BE DEFINED AND WE MUST BE AWARE OF THE SOCIO-TECHNICAL CONSEQUENCES OF CHOOSING ONE METRIC OVER ANOTHER
  - Carbon intensity vs Total Carbon Emission - size matters! Absolute CO2 emission counts, as well as all non-renewable resources consumption.
  - Time-based compensation is misleading - data centres overall consumption matters, not the fact that by putting them where it's colder they have less impact in some months!
- AI VS GHG: THERE IS A WAY OUT!
  - Sustainability is not only about GHG emissions reduction. Also, avoid proxy metrics - energy consumptions should not be a blanket replacement for CO2 emissions because it depends on the energy sources. Use more renewable energy sources!
- THE EMERGING CONNECTION AMONG AI, HPC, AND CLOUD-EDGE-IOT CONTINUUM.
  - ADR systems and solutions will be largely distributed. Therefore, the points on efficiency, sufficiency, metrics, and balancing trade-offs must be applied not only to computer nodes and data centres, but also to networks e.g., 5G/6G, HPC.

FURTHER INVESTIGATION AND WORK

TO BE EFFECTIVE WITHIN THE INCREASINGLY DYNAMIC AND COMPLEX CURRENT GEO-POLITICAL AND SOCIO-ECONOMIC CONTEXT, A WIDER AND BOLDER PERSPECTIVE IS UNAVOIDABLE.

- SUSTAINABILITY IS AN END-TO-END CONCEPT THAT SPANS ECONOMIC, SOCIETAL AND ENVIRONMENTAL DIMENSIONS.
  - A conceptual framework needs to cover all three - see Donut economics. This means we can reframe the problem as a Pareto optimisation one: different "optimal" solutions can be found by accounting for example for situatedness, path-dependency and finite budgets for non-renewable resources (or depletion rate limits for renewable ones). Which one to choose?
  - Unfortunately, the digital transformation carries an intrinsic risk of severing our understanding and decision-making processes from the unique and situated reality.
    - ADR technologies (especially AI) can exacerbate this risk due to the numerical nature of ML: **feature extraction, vector similarity, statistical analysis, and digital twinning can reduce different and unique instances of real-world objects to vectors/records of their measured attributes**.
    - Such **abstractions, coupled with the strong forces and interests towards the financialisation and fungibility of natural resources and ecosystems**, could seriously damage progress on the road to sustainability.

AS PART OF THE RESEARCH AGENDA

LOOKING AHEAD

- Couple data extraction and processing with narratives, traces, and explainability.
- Preserve the identity of real-world counterparts of digital entities (“remember where the data comes from”).
- Keep each individual goal or optimization criterion separate and human-recognisable, avoiding scalarisation pitfalls.
- Couple numerical prediction or recommendations with alternative sanity checks and refutation procedures - some AI methods such as causal inference can offer that.


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SUSTAINABILITY IS NOT ENOUGH!
IT'S KEEPING THE FOOT STEADY ON THE GAS PEDAL WHEN WE REALLY NEED TO BRAKE AND GO IN REVERSE GEAR

REGENERATION - A FUNDAMENTAL CHANGE

The concept of regeneration goes beyond sustainability by aiming not just to maintain and do no harm, but to actively improve and restore the environment and ecosystems. While sustainability focuses on not degrading systems and maintaining them over time, regeneration seeks to renew and revitalize, leading to a net positive impact[1,2]

- **The pitfall of shifting baselines – typical human**: regenerating should not refer to any given fix point in the past, but be a constant push to improve the state and the resiliency of natural systems (there is no victory point)
- **Regeneration can and should span all the corresponding facets of sustainability**: **environmental** regeneration (e.g., rewilding projects[3]), but also **economic** regeneration (e.g., regenerative capitalism[4]) and **social** regeneration (e.g., regenerative cultures[5])

1. https://thesustainableagency.com/blog/what-does-regenerative-mean-within-sustainability/ -
2. https://medium.com/the-regenerative-transition/what-is-the-difference-between-regenerative-and-sustainable-f6c042985f11
3. https://www.weforum.org/agenda/2022/10/what-is-rewilding-nature/
4. https://www.weforum.org/agenda/2022/01/regenerative-capitalism-industry-explainer/
5. https://www.danielchristianwahl.com/daniels-blog/sustainability-is-not-enough-we-need-regenerative-cultures-rdjt7

A FORWARD-LOOKING PERSPECTIVE

- A regenerative vision of the dynamics of human activity, innovation, and discovery situated within the complex system of natural systems builds on complexity science to yield practical impact in several domains:
  - **EU Regenerative Urban Lighthouse** - the UPSURGE project[1]
  - **EU Regenerative Agriculture**[2] : not only contributes to environmental goals but also makes economic sense
  - **Managing complexity (and chaos) in times of crisis. A field guide for decision makers inspired by the Cynefin framework**[3] - Cooperation between the JRC and The Cynefin Co.

1. https://www.upsurge-project.eu/
2. https://knowledge4policy.ec.europa.eu/publication/regenerative-agriculture-compendium_en
3. https://publications.jrc.ec.europa.eu/repository/handle/JRC123629

CONCLUSIONS

- Sustainability: we can do better at many levels!
- Digitalisation must become a driver for decarbonisation
- To this purpose, we need a new approach to design, develop and use digital technologies, including ADR ones
- ADR technologies can play an essential role across several vertical domains to protect and restore the planet
- However, to minimise their rebound effect and ensure transition to net zero we need a radical approach across their entire life-cycle
- Several areas need more investigation and work in a multi-stakeholder and multi-disciplinary perspective
- We should move beyond sustainability and strive for regeneration

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THE POWERFUL TRIO OF AI, BIG DATA, AND ROBOTICS CAN BECOME THE ARCHITECTS OF A REGENERATIVE FUTURE, ANALYSING VAST DATASETS TO OPTIMIZE RESOURCE USE, GUIDE RESTORATION EFFORTS, AND ALLOW HUMANS AND ROBOTS TO HEAL OUR PLANET.

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