Synergies between Data Centres and Energy Systems

Final Report

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Authors:

EY: Axel Wion, Dennis Heatubun

Borderstep Institute: Simon Hinterholzer

AIT: Ralf-Roman Schmidt, Nicolas Pardo-Garcia, Nicolas Marx, Verena Alton

RP legalitax: Carla Bonacci

Catherine Banet

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Directorate-General for Communications Networks, Content and Technology
Directorate E – Future Networks
Unit E.2 – Cloud and Software

Contact: CNECT-E2@ec.europa.eu

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TABLE OF CONTENTS

TABLE OF CONTENTS 5
ABSTRACT 6
ABSTRAIT 7
EXECUTIVE SUMMARY 8
RESUME 13
1. INTRODUCTION 20
   a. Purpose of the report 20
   b. Overview of the report 20
   c. Objectives of the study 20
   d. Scope of the study 21
2. TASK 1: COMPREHENSIVE MAPPING, FEASIBILITY AND EFFECTIVENESS OF INTEGRATING DATA CENTRES INTO ENERGY AND WATER SYSTEMS 22
   a. Aim and objectives 22
   b. Methodology 22
   c. Results 23
3. TASK 2: MAPPING OF DRIVERS, OBSTACLES AND POTENTIAL OPPORTUNITIES 28
   a. Aim and objectives 28
   b. Methodology 29
   c. Results 29
4. TASK 3: COMPARISON WITH OTHER ENERGY AND EMISSION-INTENSIVE SECTORS 33
   a. Aim and objectives 33
   b. Methodology 34
   c. Results 35
5. TASK 4: CASE STUDIES 37
   a. Aim and objectives 37
   b. Methodology 37
   c. Results 38
6. TASK 5: POLICY RECOMMENDATIONS 40
   a. Aim and objectives 40
   b. Methodology 40
   c. Results 41
ANNEX 1: REGULATORY ANALYSIS 47
ANNEX 2: IDENTIFIED DRIVERS AND OBSTACLES 57
ANNEX 3: MATRIX OF RECOMMENDATIONS 58
BIBLIOGRAPHY 66
LIST OF ABBREVIATIONS 74

ABSTRACT

The **"Synergies between Data Centres and Energy Systems"** study explores the **integration of data centres into energy (electricity, heat and water) systems** in order to achieve the **Green Deal** and **Digital Decade goals** for extremely energy-efficient and climate-neutral data centres by 2030. The study provides a comprehensive analysis the challenges and opportunities for a successful integration, technological innovations in the sector, stakeholder engagement and coordinated policymaking to support the transition into a sustainable and energy-efficient data centre industry.

The study **maps current initiatives to reduce energy consumption and improve the integration process**, highlighting the underutilised potential of data centre waste heat as a sustainable energy source. It also examines the integration of data centres with green electricity grids and renewable energy sources to reduce carbon footprints.

The **legislative and regulatory framework** is then analysed, revealing a potential for refining the regulatory framework for the integration of data centres into energy grids (e.g., clear definition and guidelines are hampering the integration into energy systems). The research identifies drivers such as **energy efficiency incentives** and **environmental protection**, in addition to opportunities like **waste heat recovery promotion**, while obstacles include **regulatory costs** and **unclear legal provisions**.

Comparing **data centre with other energy and emission-intensive sectors**, the study suggests that **Best Available Techniques (BAT)** from these sectors could be transferred to data centres for energy efficiency gains. In-depth case studies performed then reveal key levers for sustainability in data centres, including **local integration of renewable energy, demand response**, **24/7 carbon-free electricity (24/7CFE)** and other energy efficiency measures. Challenges such as integrating data centres into **heating networks**, overcoming **seasonal heat demand discrepancies**, and **reducing water consumption** through advanced cooling systems and **alternative water sources** are also discussed.

Finally, the study offers potential **policy recommendations** to overcome barriers in energy infrastructure, technical innovation, social and environmental aspects, and regulatory framework. The recommendations propose **incentives for sustainable operations**, **enhancements in energy efficiency** and **renewable energy use** and **detailed provisions for waste energy use in urban planning**. The study team formulates **19 actionable advices on the topic of R&D, engagement and coordination** to address opportunities and limitations in achieving **energy-efficient and climate-neutral data centres by 2030**.

ABSTRAIT

L'étude **« Synergies entre les centres de données et les systèmes énergétiques » explore l'intégration des centres de données dans les systèmes énergétiques (électricité, chaleur et eau**) afin d'atteindre les objectifs du **Pacte Vert** et de la **Décennie Numérique** pour des centres de données extrêmement efficaces sur le plan énergétique et neutres sur le plan climatique d'ici 2030. L'étude fournit une analyse complète des défis et des opportunités pour une intégration réussie, des innovations technologiques dans le secteur, de l'engagement des parties prenantes et de la coordination de l'élaboration des politiques pour soutenir la transition vers une industrie des centres de données durable et économe en énergie.

L'étude présente les **initiatives actuelles visant à réduire la consommation d'énergie et à améliorer le processus d'intégration**, en soulignant le potentiel sous-exploité de la chaleur résiduelle des centres de données en tant que source d'énergie durable. Elle examine également l'intégration des centres de données dans les réseaux électriques verts et les sources d'énergie renouvelables afin de réduire l'empreinte carbone.

Le **cadre législatif et réglementaire** est ensuite analysé, révélant un potentiel d'amélioration du cadre réglementaire pour l'intégration des centres de données dans les réseaux énergétiques (par exemple, une définition et des lignes directrices claires entravent l'intégration dans les systèmes énergétiques). La recherche identifie des moteurs tels que les **incitations à l'efficacité énergétique et la protection de l'environnement**, ainsi que des opportunités telles que la **promotion de la récupération de la chaleur perdue**, tandis que les obstacles comprennent les **coûts réglementaires et les dispositions légales peu claires.**

En comparant En comparant les centres de données avec d'autres secteurs à forte consommation d'énergie et d'émissions, l'étude suggère que les **meilleures techniques disponibles (MTD)** de ces secteurs pourraient être transférées aux centres de données pour obtenir des **gains d'efficacité énergétique**. Des études de cas approfondies révèlent ensuite les principaux leviers de la durabilité dans les centres de données, notamment l'intégration locale des **énergies renouvelables**, la réponse à la demande, l'électricité sans **carbone 24/7 (24/7CFE)** et d'autres mesures d'efficacité énergétique. Des défis tels que **l'intégration des centres de données dans les réseaux de chauffage**, la résolution des **écarts saisonniers de demande de chaleur** et la **réduction de la consommation d'eau** grâce à des systèmes de refroidissement avancés et à des sources d'eau alternatives sont également abordés.

Enfin, l'étude propose des **recommandations politiques potentielles** pour surmonter les obstacles liés à l'infrastructure énergétique, à l'innovation technique, aux aspects sociaux et environnementaux et au cadre réglementaire. Les recommandations proposent des **incitations pour des opérations durables**, des **améliorations de l'efficacité énergétique** et de **l'utilisation des énergies renouvelables**, ainsi que des dispositions détaillées pour **l'utilisation de l'énergie des déchets dans la planification urbaine**. L'équipe chargée de l'étude formule **19 conseils pratiques en matière de R&D, d'engagement et de coordination** afin **d'exploiter les possibilités et les limites des centres de données efficaces sur le plan énergétique et neutres sur le plan climatique d'ici à 2030.**

EXECUTIVE SUMMARY

The study “Synergies between Data Centres and Energy Systems” aims to learn how data centres can be more effectively integrated into energy networks in order to achieve the Green Deal and Digital Decade goals of having extremely energy-efficiect and climate-neutral data centres by 2030. In that sense, the study will focus on how local energy systems can use the waste heat and water generated by data centre operations. The study contains five work packages, for which the main outcomes are delineated below.

Comprehensive mapping, feasibility and effectiveness of integrating data centres into energy and water systems

The first topic focuses on the mapping of the latest research and deployment initiatives, from the experimental to the more established, that aim to reduce the energy consumption and improve integration of data centres into the energy and water systems. The results are then divided into the three areas, namely data centres and heat systems, electricity systems and and water systems.

In the heat systems, despite the growing energy demands of data centres and the potential to reuse their waste heat as a sustainable alternative to fossil fuels, this practice remains largely underutilised. The effectiveness of data centre waste heat recovery depends on the cooling technique used, either liquid cooling, including on-chip and immersion cooling, or air cooling, which heavily determines the temperature of the waste heat. Nevertheless, heat is often required at a much higher temperature, which is why heat pumps crucial in heat recovery. Options include a central heat pump for a heat network or a decentralised pumps of the 4th and 5th generation networks, depending on a trade-off of economies of scale with the amount of heat losses and individual temperature requirements.

The feasibility of waste heat recovery also depends on the distance between the data centre to the heat offtaker, which influences heat losses and the economic costs. Moreover, the fluctuation of heat demand profile of potential offtakers may also affect the level of waste heat utilisation as data centres generally possess a flat load profile, although this can be supported by a heat storage. Consequently, the meaningful use of waste heat is highly site dependent. At European level, climatic conditions also determine for which purposes and to what extent waste heat can be used.

Along the study, almost 70 research and industry projects on data centres and heat systems were identified, of which the interviewed experts revealed a strong growth of heat reuse practices in data centres. The stakeholders surveyed answered that the technology is already viable, but less so from an economic perspective, especially without intervention.

Additionally, in relation to the electricity systems, data centres, particularly in major European cities, are facing increasing pressure to adopt sustainable practices due to their substantial energy consumption and greenhouse gas emissions. Efforts to reduce this energy demand are in line with enhancements in power supply infrastructure. Integrating data centres with green electricity grids, prioritising local renewable energy sources, and providing grid flexibility services are key strategies for reducing their carbon footprint and reducing energy losses during transport. Moreover, research suggests that a combination of wind, solar, and battery storage can contribute to achieve 24/7 climate-neutral energy for data centres at a minimal additional cost. More granular green Power Purchase Agreements (PPAs) and flexibility services are recommended to ensure a closer match between green energy generation and data centre consumption.

The European Commission highlights the growing need for flexibility in the EU's electricity system, with data centres playing a crucial role thanks to their ability to shift workloads temporally and geographically. By adjusting operations to coincide with the availability of

green energy, data centres can significantly reduce emissions. They can also contribute to grid stability by utilising unused capacities and exploring alternative technologies such as fuel cells.

The research identified 28 industry and research projects to address energy sector challenges, half of which initiated by industry players, indicating that some approaches are already present in the market. However, the stakeholders denoted that the topic of 24/7 green electricity and power flexibility is much less important than heat reuse. In the short term, the technologies are seen to be not yet feasible, although strong support is perceived for the future after 2025.

Lastly, in the water systems, the water consumption and water circularity in data centres have become critical issues. The European summer's dryness has underscored the the problem of water scarcity, which has led to conflicts with drinking water supply and other vital uses. In the US, data centres are expected to consume a large volume of water, which poses significant challenges in lieu of global warming. Data centres rely on water for evaporative cooling, air humidification, and indirect consumption for electricity generation. The lack of transparency on water usage in data centres has complicated water management efforts, emphasising the need for their integration into water systems.

Data centres employ various cooling methods, such as closed-loop, free cooling, and warm-water cooling, to manage heat. Free cooling, whether direct or indirect, utilises water or air as heat transfer medium and is energy-efficient, especially in cooler climates, but may require active refrigeration during hotter periods. Hot water or liquid cooling avoids evaporation issues and allows more efficient waste heat reuse. Data centres are increasingly exploring alternative water sources like seawater or groundwater, using separate cooling circuits and heat exchanges to minimise environmental impact.

Several industry projects have been initiated to conserve water, utilise non-potable sources and return water to natural reservoirs. Most survey participants regard technological water-saving measures as already feasible today. However, only a third consider water-saving technologies economically viable now. Interestingly, while water prices are relatively higher in regions with scarcity, low prices elsewhere offer little financial incentive for data centres to adopt water-efficient cooling technologies or alternative water sources, although some operators have begun implementing such solutions.

Mapping of drivers, obstacles and potential opportunities

The second topic revolves around the mapping of drivers, obstacles and potential opportunities for the successful integration of data centres into the general energy systems. The starting point of the analysis is to identify areas for improvement within the data centre legislative and regulatory framework in Europe. The research begins by establishing a definition for data centres, which reveals a lack of a clear, legally binding definition at the Member States level, creating classification challenges for land planning and taxation framework. This absence of a standardised definition subsequently hinders the legal classification of data centres and their integration into energy systems.

The analysis identifies a diverse range of stakeholders in the data centre domain, including public authorities and private stakeholders. Public authorities at EU, national, regional and local levels can significantly influence data centres through policymaking, while local authorities specifically play a crucial role in managing grid networks and natural resources. The challenge lies in harmonising these different levels of governance with the differing interests of private stakeholders.

Data centres are generally perceived as large energy consumers, while also offering the possibility produce electricity or heat in a circular and sustainable energy system. However, legal and economic feasibility issues arise when considering data centres' role in energy production through waste heat and wastewater.

Accordingly, the legislative analysis maps the drivers, obstacles and potential opportunities for the synergies between data centres and energy systems. Recurring drivers include efforts to reduce energy consumption, with incentives for energy efficiency at all governmental levels in Europe. Sustainability and environmental protection are also key drivers, with several legislative and policy instruments promoting these requirements. The increasing use and development of renewable energies across different legislative frameworks is also beneficial to meet environmental targets.

Nevertheless, obstacles to these objectives include the costs and practical difficulties deriving from the implementation and/or compliance with regulations, which have often led to ineffective implementation, also due to the non-binding nature of some acts. Unclear formulation of legal provisions has been detected in several Member States, in addition to the lack of clarity and specificity. Meanwhile, potential opportunities on the integration of data centres into water and energy systems are specifically linked to measures and legal instruments from which they have been derived, including the promotion of the recovery and usage of waste heat through various measures, such as incentive schemes for renewable energy use and strategic land and energy infrastructure planning.

Finally, the analysis on public opposition/support cases for data centres uncovers that environmental, energy consumption and socioeconomic concerns drive the opposition groups, while the support is driven by economic, digitalisation and green energy promotion benefits. The large number of cases won by opposition groups has shown that public concerns are being considered by regulatory authorities in the establishment of data centres. This is in line with the stirring effects of data centres on renewable energy projects, with many large data centre operators being at the forefront of such projects and sustainable practices, including to achive 100% carbon-free data centres through approaches such as carbon offsetting, power purchase agreements (PPAs) and 24/7 carbon-free electricity (CFE).

Comparison with other energy and emission-intensive sectors

The next topic compares how other energy and emission-intensive sectors address the issue of integrating data centres in the energy and water systems. The findings highlight the potential for Best Available Techniques (BAT) from Energy Intensive Industries (EII) to be effectively transferred to data centres, offering a promising synergies for sustainable cross-sectoral application. A total of 35 BATs were identified from seven different industrial sectors. Out of these, eight were analysed in detail to understand the technologies used, their benefits and transferrability.

On heating systems, the research focuses on the potential to reuse waste heat and replace fossil fuels. Waste heat is, a by-product of many industrial processes including data centres, is largely under-utilised. Techniques such as combined heat and power (CHP) systems and heat pumps can support significant energy efficiency gains and cost savings, if the lack of nearby heat consumers can be addressed.

Additionally, on electric power systems, data centres can generate their own power through on-site renewable energy sources, for example, and can help with the stability of the overall power grid, as well as their own resilience and reliability.

Lastly, on water systems, data centres typically consume large quantities of water for cooling, and they stand to benefit from advanced water management techniques developed in other industries to reduce burden on public water supply, such as utilising alternative water sources, although it may increase the cost of water treatment. Not only saving water, these techniques can reduce environmental impact of data centre operations.

Case studies

Stemming from the previous topics, in-depth case studies were performed on concrete examples of successful integration of data centres in the energy and water systems. The analysis has identified key levers for improving sustainability in data centres across three main areas: energy, heat and water.

For the energy levers, the local integration of renewable energy sources offers significant benefits by allowing electricity to be used where it is generated, thus, not only reducing the grid load, but also promoting green electricity. Moreover, demand response enables data centers to adjust their energy consumption in response to grid demands, thereby aiding in grid stability and reduce the curtailment of renewable energies. The 24/7 carbon-free electricity approach is another critical lever, with data centres securing clean energy through power purchase agreements (PPAs) tailored to meet their needs. Lastly, energy efficiency measures are vital for reducing the strain on the grid and improving sustainability by utilising advanced technologies and optimising operations.

On the topic of heat, integrating data centers into existing heating networks allows them to contribute to the broader energy ecosystem. This, however, comes with challenges such as the need for high temperature and reliable heat supply and establishing profitable contracts with heat network operators. Overcoming seasonal discrepancies in heat demand is another hurdle. To address this, data centres can store excess heat during cooler months and use thermal energy storage systems to balance the supply and demand throughout the year. Additionally, matching waste heat with heat demand requires strategic positioning of data centres near heat consumers or networks or exploring alternative uses for waste heat, such as in agriculture or aquaculture, to optimise energy sustainability.

Reducing water consumption another key lever, especially in cooling processes. By implementing free cooling and closed-loop systems, data centres can significantly cut down on water usage. The use of alternative water sources is also a key strategy, particularly in regions with scarce drinking water supply. Utilising desalinated seawater in coastal areas or treated wastewater for cooling, as demonstrated by Project Natick and Lefdal Mine Data Center, can relieve pressure on potable water supply and promote a circular water economy.

Policy recommendations

The policy recommendations on the integration of data centres into energy systems derive from the drivers and obstacles that have been identified throughout the study, which are delineated across four thematic barriers: energy infrastructure, technical innovation, social and environmental factors, and regulatory framework. These recommendations are subsequently categorised under three main topics:

- Incentives & Best Practices: The findings suggests that there is a room for improvement in EU and Member States legislations to develop economic incentives and best practices to promote sustainable operations in data centres. Stakeholders agree that current legislation does not fully align with the digital industry's sustainability efforts and its contribution to green energy.
- Energy Consumptions & Renewables: The findings reveal the potential to enhance regulations and policies at the EU and MS levels to improve energy efficiency and the use of renewable energies in data centres. Some MS could make voluntary schemes mandatory to encourage broader application. Stakeholders agree that such measures could significantly impact the integration, but are concerned about the potential administrative burden.
- Urban Planning & Waste Energy Policies: The findings recommend introducing more detailed provisions to facilitate the use of waste energy from data centres,

especially in the urban planning framework. Stakeholders agree that data centre operators face barriers in sharing waste heat and suggest solutions such as developing heating networks, promoting offtakers for waste heat, and clarifying obligations for heat providers.

Thereafter, the study team formulates 19 actionable advices, consisting of 11 legal advice and eight non-legal ones, across three areas of recommendation (R&D, engagement, and coordination) to address the opportunities and limitations identified. These actions aim to enhance technological innovation, encourage collaboration, and harmonise policymaking efforts, while offering a roadmap with the steps to take for each key stakeholder involved to achieve energy-efficient and climate-neutral data centres by 2030 in line with the Green Deal and Digital Decade goals. The actions are listed below:

- **R&D:**
  - Roll-out of energy efficient hardware, software and other new practices,
  - Integration of water saving/reuse processes,
  - Integration of heat reuse practices,
  - Development and integration of 24/7 CFE.
- **Engagement:**
  - Engaging authorities and communities about the synergies between data centres and energy grids,
  - Reviewing EU Code of Conduct and amend Best Practices guidelines,
  - Establishing incentive schemes based on EU Taxonomy Climate Delegated Act,
  - Revising the Energy Taxation Directive,
  - Developing French regulatory framework,
  - Developing Italian regulatory framework.
- **Coordination:**
  - Adjustment of network charges and pricing signals to reflect new and large loads,
  - Systematic integration of data centres into policymaking and infrastructure planning,
  - Establishing clear regulatory frameworks and more coordination in policymaking,
  - Mandating the application of GPP Criteria for DCs,
  - Developing Electricity Market Regulation,
  - Revising Regulation on minimum requirements for water reuse,
  - Coordinating legislation to Luxembourg example,
  - Coordinating legislation to Germany example,
  - Coordinating legislation to the Netherlands example.

RESUME

L'étude « Synergies entre les centres de données et les systèmes énergétiques » vise à déterminer comment les centres de données peuvent être intégrés plus efficacement dans les réseaux énergétiques afin d'atteindre les objectifs du Green Deal et de la Décennie numérique, à savoir disposer de centres de données extrêmement efficaces sur le plan énergétique et neutres sur le plan climatique d'ici à 2030. En ce sens, l'étude se concentrera sur la manière dont les systèmes énergétiques locaux peuvent utiliser la chaleur résiduelle et l'eau générées par les opérations des centres de données. L'étude comprend cinq modules de travail, dont les principaux résultats sont décrits ci-dessous.

Cartographie complète, faisabilité et efficacité de l'intégration des centres de données dans les systèmes d'énergie et d'eau

Le premier thème porte sur la cartographie des dernières initiatives de recherche et de déploiement, des plus expérimentales aux plus établies, qui visent à réduire la consommation d'énergie et à améliorer l'intégration des centres de données dans les systèmes d'énergie et d'eau. Les résultats sont ensuite divisés en trois domaines, à savoir les centres de données et les systèmes thermiques, les systèmes électriques et les systèmes hydrauliques.

Dans les systèmes thermiques, malgré la demande croissante d'énergie des centres de données et la possibilité de réutiliser leur chaleur résiduelle comme alternative durable aux combustibles fossiles, cette pratique reste largement sous-utilisée. L'efficacité de la récupération de la chaleur résiduelle des centres de données dépend de la technique de refroidissement utilisée, soit le refroidissement par liquide, y compris le refroidissement sur puce et par immersion, soit le refroidissement par air, qui détermine fortement la température de la chaleur résiduelle. Néanmoins, la chaleur est souvent requise à une température beaucoup plus élevée, ce qui explique pourquoi les pompes à chaleur sont cruciales pour la récupération de la chaleur. Les options comprennent une pompe à chaleur centrale pour un réseau de chaleur ou des pompes décentralisées des réseaux de 4ème et 5ème génération, en fonction d'un compromis entre les économies d'échelle, la quantité de pertes de chaleur et les exigences individuelles en matière de température.

La faisabilité de la récupération de la chaleur perdue dépend également de la distance entre le centre de données et le fournisseur de chaleur, qui influe sur les pertes de chaleur et les coûts économiques. En outre, la fluctuation du profil de la demande de chaleur des fournisseurs potentiels peut également affecter le niveau d'utilisation de la chaleur perdue, car les centres de données ont généralement un profil de charge plat, bien qu'il puisse être soutenu par un stockage de chaleur. Par conséquent, l'utilisation significative de la chaleur perdue dépend fortement du site. Au niveau européen, les conditions climatiques déterminent également à quelles fins et dans quelle mesure la chaleur perdue peut être utilisée.

L'étude a permis d'identifier près de 70 projets de recherche et d'industrie sur les centres de données et les systèmes de chauffage, parmi lesquels les experts interrogés ont révélé une forte croissance des pratiques de réutilisation de la chaleur dans les centres de données. Les parties prenantes interrogées ont répondu que la technologie est déjà viable, mais qu'elle l'est moins d'un point de vue économique, en particulier sans intervention.

En outre, en ce qui concerne les systèmes électriques, les centres de données, en particulier dans les grandes villes européennes, sont soumis à une pression croissante pour adopter des pratiques durables en raison de leur consommation d'énergie et de leurs émissions de gaz à effet de serre considérables. Les efforts visant à réduire cette demande d'énergie vont de pair avec l'amélioration des infrastructures d'approvisionnement en électricité. L'intégration des centres de données dans des réseaux électriques verts, la priorité donnée aux sources d'énergie renouvelables locales et la fourniture de services de

flexibilité du réseau sont des stratégies clés pour réduire leur empreinte carbone et les pertes d'énergie pendant le transport. En outre, des recherches suggèrent qu'une combinaison d'énergie éolienne, solaire et de stockage par batterie peut contribuer à fournir aux centres de données une énergie neutre pour le climat 24 heures sur 24, 7 jours sur 7, pour un coût supplémentaire minime. Des contrats d'achat d'électricité verte plus granulaires et des services de flexibilité sont recommandés pour assurer une meilleure adéquation entre la production d'énergie verte et la consommation des centres de données.

La Commission européenne souligne le besoin croissant de flexibilité dans le système électrique de l'UE, les centres de données jouant un rôle crucial grâce à leur capacité à déplacer les charges de travail dans le temps et dans l'espace. En ajustant leurs activités pour qu'elles coïncident avec la disponibilité de l'énergie verte, les centres de données peuvent réduire les émissions de manière significative. Ils peuvent également contribuer à la stabilité du réseau en utilisant les capacités inutilisées et en explorant des technologies alternatives telles que les piles à combustible.

L'étude a recensé 28 projets industriels et de recherche visant à relever les défis du secteur de l'énergie, dont la moitié ont été lancés par des acteurs industriels, ce qui indique que certaines approches sont déjà présentes sur le marché. Toutefois, les parties prenantes ont indiqué que la question de l'électricité verte 24/7 et de la flexibilité de l'énergie est beaucoup moins importante que la réutilisation de la chaleur. À court terme, les technologies sont considérées comme n'étant pas encore réalisables, bien qu'un fort soutien soit perçu pour l'avenir après 2025.

Enfin, dans les systèmes d'eau, la consommation d'eau et la circularité de l'eau dans les centres de données sont devenues des questions critiques. La sécheresse de l'été européen a mis en évidence le problème de la pénurie d'eau, qui a entraîné des conflits avec l'approvisionnement en eau potable et d'autres utilisations vitales. Aux États-Unis, on s'attend à ce que les centres de données consomment un grand volume d'eau, ce qui pose des problèmes importants en raison du réchauffement climatique. Les centres de données utilisent l'eau pour le refroidissement par évaporation, l'humidification de l'air et la consommation indirecte pour la production d'électricité. Le manque de transparence sur l'utilisation de l'eau dans les centres de données a compliqué les efforts de gestion de l'eau, soulignant la nécessité de les intégrer dans les systèmes de gestion de l'eau.

Pour gérer la chaleur, les centres de données utilisent différentes méthodes de refroidissement, telles que le refroidissement en boucle fermée, le refroidissement libre et le refroidissement par eau chaude. Le refroidissement libre, qu'il soit direct ou indirect, utilise l'eau ou l'air comme moyen de transfert de la chaleur et est économe en énergie, en particulier dans les climats plus frais, mais peut nécessiter une réfrigération active pendant les périodes plus chaudes. Le refroidissement par eau chaude ou liquide évite les problèmes d'évaporation et permet une réutilisation plus efficace de la chaleur perdue. Les centres de données explorent de plus en plus d'autres sources d'eau, comme l'eau de mer ou les eaux souterraines, en utilisant des circuits de refroidissement et des échanges de chaleur séparés pour minimiser l'impact sur l'environnement.

Plusieurs projets industriels ont été lancés pour économiser l'eau, utiliser des sources non potables et retourner l'eau dans les réservoirs naturels. La plupart des participants à l'enquête considèrent que les mesures technologiques d'économie d'eau sont déjà réalisables aujourd'hui. Toutefois, seul un tiers d'entre eux considèrent que ces technologies sont économiquement viables aujourd'hui. Il est intéressant de noter que si les prix de l'eau sont relativement plus élevés dans les régions où elle est rare, les prix peu élevés dans les autres régions n'incitent guère les centres de données à adopter des technologies de refroidissement économes en eau ou des sources d'eau alternatives, bien que certains opérateurs aient commencé à mettre en œuvre de telles solutions.

Cartographie des moteurs, des obstacles et des opportunités potentielles

Le deuxième thème porte sur la cartographie des moteurs, des obstacles et des opportunités potentielles pour l'intégration réussie des centres de données dans les systèmes énergétiques généraux. Le point de départ de l'analyse est l'identification des points à améliorer dans le cadre législatif et réglementaire des centres de données en Europe. La recherche commence par l'établissement d'une définition des centres de données, qui révèle l'absence d'une définition claire et juridiquement contraignante au niveau des États membres, ce qui crée des problèmes de classification pour l'aménagement du territoire et le cadre fiscal. Cette absence de définition normalisée entrave ensuite la classification juridique des centres de données et leur intégration dans les systèmes énergétiques.

L'analyse identifie un large éventail de parties prenantes dans le domaine des centres de données, y compris les autorités publiques et les parties prenantes privées. Les autorités publiques aux niveaux européen, national, régional et local peuvent influencer de manière significative les centres de données par l'élaboration de politiques, tandis que les autorités locales jouent un rôle crucial dans la gestion des réseaux de distribution et des ressources naturelles. Le défi consiste à harmoniser ces différents niveaux de gouvernance avec les intérêts divergents des parties prenantes privées.

Les centres de données sont généralement perçus comme de gros consommateurs d'énergie, tout en offrant la possibilité de produire de l'électricité ou de la chaleur dans le cadre d'un système énergétique circulaire et durable. Toutefois, des questions de faisabilité juridique et économique se posent lorsque l'on envisage le rôle des centres de données dans la production d'énergie à partir de la chaleur résiduelle et des eaux usées.

En conséquence, l'analyse législative met en évidence les moteurs, les obstacles et les opportunités potentielles pour les synergies entre les centres de données et les systèmes énergétiques. Parmi les facteurs récurrents figurent les efforts de réduction de la consommation d'énergie, avec des incitations à l'efficacité énergétique à tous les niveaux gouvernementaux en Europe. La durabilité et la protection de l'environnement sont également des facteurs clés, plusieurs instruments législatifs et politiques favorisant ces exigences. L'utilisation et le développement croissants des énergies renouvelables dans différents cadres législatifs sont également bénéfiques pour atteindre les objectifs environnementaux.

Néanmoins, les obstacles à ces objectifs comprennent les coûts et les difficultés pratiques découlant de la mise en œuvre et/ou du respect des réglementations, qui ont souvent conduit à une mise en œuvre inefficace, également en raison de la nature non contraignante de certains actes. Une formulation imprécise des dispositions légales a été détectée dans plusieurs États membres, en plus du manque de clarté et de spécificité. Par ailleurs, les possibilités d'intégration des centres de données dans les systèmes de distribution d'eau et d'énergie sont spécifiquement liées aux mesures et aux instruments juridiques dont elles découlent, notamment la promotion de la récupération et de l'utilisation de la chaleur perdue par le biais de diverses mesures, telles que les systèmes d'incitation à l'utilisation des énergies renouvelables et la planification stratégique des infrastructures foncières et énergétiques.

Enfin, l'analyse des cas d'opposition/de soutien du public aux centres de données révèle que les groupes d'opposition sont motivés par des préoccupations environnementales, de consommation d'énergie et socio-économiques, tandis que le soutien est motivé par des avantages économiques, de numérisation et de promotion de l'énergie verte. Le grand nombre d'affaires gagnées par les groupes d'opposition a montré que les autorités réglementaires prennent en compte les préoccupations du public dans l'établissement des centres de données. Cela est conforme aux effets stimulants des centres de données sur les projets d'énergie renouvelable, de nombreux grands opérateurs de centres de données

étant à l'avant-garde de ces projets et des pratiques durables, y compris pour atteindre des centres de données 100 % sans carbone grâce à des approches telles que la compensation carbone, les accords d'achat d'électricité (AAE) et l'électricité sans carbone 24 heures sur 24 et 7 jours sur 7 (CFE).

Comparaison avec d'autres secteurs à forte intensité énergétique et d'émissions

Le thème suivant compare la manière dont d'autres secteurs à forte consommation d'énergie et d'émissions abordent la question de l'intégration des centres de données dans les systèmes d'énergie et d'eau. Les résultats mettent en évidence le potentiel des meilleures techniques disponibles (MTD) des industries à forte consommation d'énergie à être transférées efficacement aux centres de données, offrant ainsi des synergies prometteuses pour une application intersectorielle durable. Au total, 35 MTD ont été identifiées dans sept secteurs industriels différents. Huit d'entre elles ont été analysées en détail pour comprendre les technologies utilisées, leurs avantages et leur transférabilité.

En ce qui concerne les systèmes de chauffage, la recherche se concentre sur le potentiel de réutilisation de la chaleur perdue et de remplacement des combustibles fossiles. La chaleur perdue, sous-produit de nombreux processus industriels, y compris les centres de données, est largement sous-utilisée. Des techniques telles que les systèmes de production combinée de chaleur et d'électricité (PCCE) et les pompes à chaleur peuvent permettre d'importants gains d'efficacité énergétique et des économies de coûts, si l'on peut remédier à l'absence de consommateurs de chaleur à proximité.

En outre, en ce qui concerne les systèmes électriques, les centres de données peuvent produire leur propre énergie grâce à des sources d'énergie renouvelables sur site, par exemple, et contribuer à la stabilité de l'ensemble du réseau électrique, ainsi qu'à leur propre résilience et fiabilité.

Enfin, en ce qui concerne les systèmes d'eau, les centres de données consomment généralement de grandes quantités d'eau pour le refroidissement, et ils peuvent bénéficier des techniques avancées de gestion de l'eau développées dans d'autres industries pour réduire la charge sur l'approvisionnement public en eau, telles que l'utilisation de sources d'eau alternatives, bien que cela puisse augmenter le coût du traitement de l'eau. Ces techniques permettent non seulement d'économiser de l'eau, mais aussi de réduire l'impact environnemental des activités des centres de données.

Études de cas

À partir des thèmes précédents, des études de cas approfondies ont été réalisées sur des exemples concrets d'intégration réussie de centres de données dans les systèmes d'énergie et d'eau. L'analyse a permis d'identifier les principaux leviers d'amélioration de la durabilité dans les centres de données dans trois domaines principaux : l'énergie, la chaleur et l'eau.

En ce qui concerne les leviers énergétiques, l'intégration locale des sources d'énergie renouvelables offre des avantages significatifs en permettant d'utiliser l'électricité là où elle est produite, ce qui permet non seulement de réduire la charge du réseau, mais aussi de promouvoir l'électricité verte. En outre, la réponse à la demande permet aux centres de données d'ajuster leur consommation d'énergie en fonction de la demande du réseau, ce qui contribue à la stabilité du réseau et réduit la réduction des énergies renouvelables. L'approche de l'électricité sans carbone 24 heures sur 24 et 7 jours sur 7 est un autre levier essentiel, les centres de données s'assurant une énergie propre grâce à des contrats d'achat d'électricité (CAE) adaptés à leurs besoins. Enfin, les mesures d'efficacité énergétique sont essentielles pour réduire la pression sur le réseau et améliorer la durabilité en utilisant des technologies avancées et en optimisant les opérations.

En ce qui concerne la chaleur, l'intégration des centres de données dans les réseaux de chauffage existants leur permet de contribuer à l'écosystème énergétique au sens large. Cela s'accompagne toutefois de défis tels que la nécessité d'une température élevée et d'un approvisionnement en chaleur fiable, ainsi que l'établissement de contrats rentables avec les opérateurs de réseaux de chaleur. Surmonter les variations saisonnières de la demande de chaleur est un autre obstacle. Pour y remédier, les centres de données peuvent stocker la chaleur excédentaire pendant les mois les plus frais et utiliser des systèmes de stockage de l'énergie thermique pour équilibrer l'offre et la demande tout au long de l'année. En outre, l'adéquation entre la chaleur résiduelle et la demande de chaleur nécessite un positionnement stratégique des centres de données à proximité des consommateurs ou des réseaux de chaleur, ou l'exploration d'autres utilisations de la chaleur résiduelle, telles que l'agriculture ou l'aquaculture, afin d'optimiser la durabilité énergétique.

La réduction de la consommation d'eau est un autre levier essentiel, en particulier dans les processus de refroidissement. En mettant en œuvre des systèmes de refroidissement libre et en boucle fermée, les centres de données peuvent réduire de manière significative leur consommation d'eau. L'utilisation de sources d'eau alternatives est également une stratégie clé, en particulier dans les régions où l'approvisionnement en eau potable est rare. L'utilisation d'eau de mer dessalée dans les zones côtières ou d'eaux usées traitées pour le refroidissement, comme le démontrent le projet Natick et le centre de données de la mine de Lefdal, peut alléger la pression sur l'approvisionnement en eau potable et promouvoir une économie circulaire de l'eau.

Potentielles recommandations politiques

Les recommandations politiques potentielles sur l'intégration des centres de données dans les systèmes énergétiques découlent des moteurs et des obstacles identifiés tout au long de l'étude, qui sont répartis entre quatre barrières thématiques : l'infrastructure énergétique, l'innovation technique, les facteurs sociaux et environnementaux, et le cadre réglementaire. Ces recommandations sont ensuite classées en trois catégories principales :

- Incitations et meilleures pratiques : Les résultats suggèrent que les législations de l'UE et des États membres peuvent être améliorées afin de développer des incitations économiques et des meilleures pratiques pour promouvoir les opérations durables dans les centres de données. Les parties prenantes conviennent que la législation actuelle ne s'aligne pas totalement sur les efforts de durabilité de l'industrie numérique et sur sa contribution à l'énergie verte.
- Consommation d'énergie et énergies renouvelables : Les résultats révèlent la possibilité de renforcer les réglementations et les politiques au niveau de l'UE et des États membres afin d'améliorer l'efficacité énergétique et l'utilisation des énergies renouvelables dans les centres de données. Certains États membres pourraient rendre obligatoires des programmes volontaires afin d'encourager une application plus large. Les parties prenantes conviennent que de telles mesures pourraient avoir un impact significatif sur l'intégration, mais s'inquiètent de la charge administrative potentielle.
- Politiques en matière d'urbanisme et d'énergie résiduelle : Les conclusions recommandent d'introduire des dispositions plus détaillées pour faciliter l'utilisation de l'énergie résiduelle des centres de données, en particulier dans le cadre de la planification urbaine. Les parties prenantes reconnaissent que les exploitants de centres de données se heurtent à des obstacles dans le partage de la chaleur résiduelle et suggèrent des solutions telles que le développement de réseaux de chauffage, la promotion de fournisseurs de chaleur résiduelle et la clarification des obligations pour les fournisseurs de chaleur.

L'équipe chargée de l'étude formule ensuite 19 conseils pratiques, dont 11 conseils juridiques et 8 conseils non juridiques, dans trois domaines de recommandation (R&D, engagement et coordination) afin d'aborder les opportunités et les limites identifiées. Ces actions visent à renforcer l'innovation technologique, à encourager la collaboration et à harmoniser les efforts d'élaboration des politiques, tout en offrant une feuille de route avec les étapes à suivre pour chaque acteur clé concerné afin de réaliser des centres de données efficaces sur le plan énergétique et neutres sur le plan climatique d'ici 2030, conformément aux objectifs du Green Deal et de la Décennie numérique. Les actions sont énumérées ci-dessous :

- **R&D:**
  - Mise en place de matériel et de logiciels économes en énergie et d'autres nouvelles pratiques,
  - Intégration de processus d'économie et de réutilisation de l'eau
  - Intégration des pratiques de réutilisation de la chaleur,
  - Développement et intégration d'énergie décarbonnée sur l'ensemble du cycle (CFE 24/7).
- **Sensibilisation:**
  - Sensibiliser les autorités et les communautés aux synergies entre les centres de données et les réseaux énergétiques,
  - Réviser le code de conduite de l'UE et modifier les lignes directrices sur les meilleures pratiques,
  - Mettre en place des systèmes d'incitation basés sur l'acte délégué de l'UE relatif à la taxonomie climatique,
  - Réviser la directive sur la taxation de l'énergie,
  - Développer le cadre réglementaire français,
  - Développer le cadre réglementaire italien.
- **Coordination:**
  - Ajustement des redevances de réseau et des signaux de tarification pour tenir compte des charges nouvelles et importantes,
  - Intégration systématique des centres de données dans l'élaboration des politiques et la planification des infrastructures,
  - Etablissement de cadres réglementaires clairs et une plus grande coordination dans l'élaboration des politiques,
  - Rendre obligatoire l'application des critères des marchés publics écologiques pour les centres de données,
  - Développer la réglementation du marché de l'électricité,
  - Réviser le règlement sur les exigences minimales pour la réutilisation de l'eau,
  - Coordonner la législation avec l'exemple du Luxembourg,
  - Coordonner la législation avec l'exemple de l'Allemagne

1. Introduction

a. Purpose of the report

This document represents deliverable D0.4, the 'Final Report' for the project entitled 'Synergies between Data Centres and Energy Systems' and has been produced by EY together with our partners, AIT, Borderstep Institute, Prof. Catherine Banet and RP legalitax for the European Commission.

This Final Report is prepared in parallel with the organisation of the Final Meeting, for which any requests, inputs and comments arising from the Final Meeting will be taken into account for the delivery of the Final Report.

b. Overview of the report

This section briefly presents an overview of the Chapters within this report:

- **Chapter 1: Introduction** – explains the purpose of the report and provides an overview of its structure, as well as the objectives and scope of the study.
- **Chapter 2: Executive summary** – summarises the findings from Tasks 1, 2, 3, 4 and 5.
- **Chapter 3** to **Chapter 7** each presents the aim and objectives, methodology and outcomes of Task 1: Comprehensive mapping, feasibility and effectiveness of integrating data centres into energy and water systems, Task 2: Mapping of drivers, obstacles and potential opportunities, Task 3: Comparison with other energy and emission-intensive sectors, Task 4: Case studies and Task 5: Policy recommendations.

c. Objectives of the study

As presented in the proposal and the inception report, the main objective of the study is to learn how data centres can be more effectively integrated into energy networks in order to achieve the Green Deal and Digital Decade goals of having extremely energy-efficient and climate-neutral data centres by 2030. In that sense, the study will focus on how local energy systems can use the waste heat and water generated by data centre operations.

In order to achieve this primary objective, the study aims to obtain data and knowledge on five sub-objectives (SOs), assigned to each specific task as follows:

- **Task 1:** Provide a clear and comprehensive mapping of the latest research and deployment initiatives, from the experimental to the more established, that aim to reduce the energy consumption and improve energy system integration of data centres.
- **Task 2:** Mapping of drivers, obstacles and potential opportunities for the successful integration of data centres into the general energy systems.
- **Task 3:** Compare how other energy and emission-intensive sectors address the issue of integrating data centres in the energy and water systems grids and lessons to be learnt for data centres.
- **Task 4:** In-depth case studies on concrete examples of successful integration of data centres in the energy (all forms and carriers) and water systems.
- **Task 5:** Identify policy recommendations to improve such integration.

In the end, the study aims to provide recommendations and actionable advice designed to address identified drivers and barriers for the synergies between data centres and the

energy grid. All recommendations and advice will be supported by a thorough analysis of concrete examples, ranging from research to business cases.

d. Scope of the study

The scope of the study comprises a number of research angles, namely technological, regulatory, economic, sociological and deep policy analysis. Meanwhile, the geographical coverage of the study encompasses the EU27, while elements related to non-EU MSs will still be considered whenever relevant.

In line with the study objective, the consortium expects to master a broad range of elements in the analysis. The scope of the study is thus expected to range from the Green Deal to technical and engineering brief on the feasibility and efficiency of the use on the local energy grids of waste heat and water coming from data centres

Additionally, this study will analyse domains related to the EU's digital decade and all elements that could help achieve the target of carbon-neutral, highly efficient data centres by 2030. To be able to select the most appropriate cases, the study will use both primary and secondary data collection methods. It will consider the available literature and ongoing developments in the subject matter, as well as consulting with key stakeholders (e.g. national authorities, private entities, regulators, external experts) for inputs throughout the project.

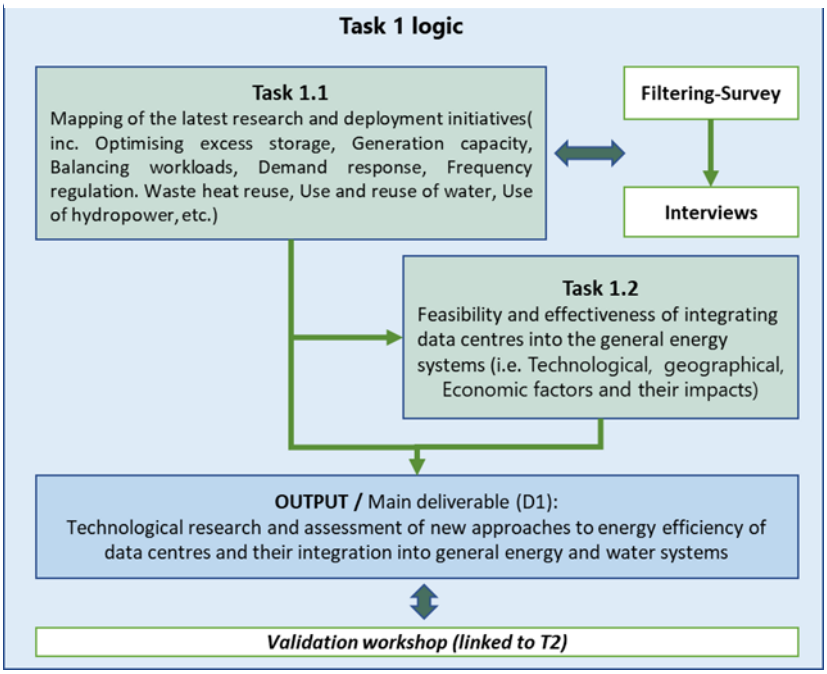
2. Task 1: Comprehensive mapping, feasibility and effectiveness of integrating data centres into energy and water systems

a. Aim and objectives

The aim of Task 1 is to provide a clear and comprehensive mapping of the latest research and deployment initiatives that aim to reduce the energy consumption and improve energy system integration of data centres. It encompasses initiatives from the experimental stage to the more established ones. For example, dynamic workload shifting to create for demand response or shifting workloads to other geographic locations (i.e. the so called “carbon aware computing”). More established initiatives could for example cover an extensive use of waste heat, which has not yet been applied in many regions because of different technological, societal and regulatory reasons. For the first step, Task 1 should map these initiatives and then assess the feasibility and effectiveness of the approaches.

The figure below summarises the logic behind task 1.

Figure 1 : Task 1 logic



b. Methodology

In order to maximise the identified number of existing initiatives, research projects and practical implementations, an extensive desk research was carried out. This included a literature search of relevant journals and academic portals. Data centre specific portals and online magazines were also searched to identify suitable projects. In addition, the websites of major IT companies and associations were searched for their white papers, press releases and other publications to identify relevant projects and technologies.

An online survey of experts was also conducted. In particular, people and companies were contacted who were either directly involved in data centres and cloud services or experts in the field of electricity, heat and water supply. The aim of the survey was not only to identify and describe further projects, but also to evaluate the use of technologies to integrate data centres into these utility systems in terms of their feasibility and financial viability. The survey was conducted from February 1 to March 28, 2023. A total of 159 experts and stakeholders were invited to participate, 92 opened the survey and answered at least the privacy

question. All other questions were voluntary and were answered by between 40 and 90 people.

International experts were consulted on specific technical issues with structured interviews. The experts were selected on the basis of their expertise in the specific topics. Care was taken to ensure a reasonable balance of experts on electricity, heat and water. The interviews then focused on one or a maximum of two technology areas, depending on whether the expert was able to make statements on them. Some technologies also have interactive effects, so it was necessary to talk about both areas. Six experts were interviewed from academia, seven from IT companies and data centres, and two from associations. The interviews were conducted between February 20 to April 12, 2023. Each interview lasted between 40 and 105 minutes.

c. Results

The results of the task were submitted to DG CNECT in a 70-page deliverable at the end of May 2023. This deliverable comprehensively presents the results of Task 1, which are summarised below. As in the aforementioned deliverable, the results are divided into the areas of: data centres and heat systems, data centres and electricity systems and data centres and water systems.

i. Data centres and heat systems

Current situation and technological approaches

The energy that data centres mainly use in the form of electrical energy is almost completely converted into heat. As the energy requirements of data centres in Europe increase (Hintemann et al., 2020), so too does the potential usable heat from data centres to replace heat in other places, that is currently still generated using fossil fuels. However, exhaust heat from data centres in Europe is currently still very rarely reused.

In terms of technologies, it plays a very important role in waste heat utilisation whether the cooling in the data centre at the IT itself is primarily done with air or with fluids such as water. Among other things, this determines the temperature level of the waste heat that can be provided without further upgrading of a heat pump. In the case of liquid cooling, on-chip cooling has historically been established in high-performance computing (e.g. supercomputers), but in recent years immersion cooling (where the IT is directly immersed in an electrically non-conductive fluid) has also been increasingly discussed. An intermediate solution between air cooling and liquid cooling is provided by so-called rear-door cooling and in-row cooling, where the air-water heat exchanger is located much closer to the IT and therefore at least enables higher air volume flows.

However, the heat is often required at a much higher temperature level, which is why heat pumps play a key role in heat recovery in data centres. Even in air-cooled data centres, a waste heat temperature of 30°C-35°C is possible as a source temperature for heat pumps all year round, which means that heat pumps can achieve high annual COPs and provide heat much more efficiently than heat pumps that rely on outside air. Basically, a distinction can be made here between a central heat pump and a warm to hot heat network of 60-80°C or the direct feed into cold heat networks of the 4th and 5th generation, where heat pumps are installed at the respective consumption points, if required at all. While the first option allows for a relatively low-cost heat pump due to economies of scale, the second option results in lower heat losses in the network and heat pumps that are tailored to the individual heat consumers, taking into account their individual temperature requirements.

Furthermore, the distance between the heat consumer and the data centre is of course a very important factor in the use of waste heat, both technically in terms of heat losses in the pipe, and economically, as the subsequent laying of heat pipes is often very costly, especially in urban areas. While commercial data centres typically have a very flat load

profile throughout the year, the heat demand for most typical applications, such as building heating, fluctuates greatly depending on the outside temperature, which is why a high level of waste heat utilisation is only possible with heat storage or if the data centre is undersized compared to the supply area in bivalent operation with another heat generator.

Given the difficulty of transporting heat over long distances described above, it is understandable that meaningful use of waste heat is highly site dependent. Higher rates of waste heat recovery are technically and economically feasible only if the size ratio of the data centre and the heat consumer and their heat generation and consumption profiles are roughly compatible (Lechner et al., 2023). The size of a data centre, which in practice ranges from a few kilowatts to triple-digit megawatts, therefore plays a very important role. For very large data centres in the double to triple-digit megawatt range, there are actually only a few locations where their waste heat can be used in a meaningful proportion.

Ongoing projects and initiatives

For the field of data centres and heat systems, a total of 69 research and industry projects and initiatives was identified, in which 41 of them are industry implementations and 28 are research projects. There is a sharp increase of new projects between 2015 and 2022, which shows the increasing importance of this topic. The interviewed experts confirmed the strong growth of heat reuse in data centres.

Geographic dependencies

As described above, waste heat utilisation does not only depend on the supplier of the waste heat - there must always be one or more suitable users for the heat, that is provided. Of particular note here is the significantly higher energy demand in large cities compared to the countryside and also, at European level, the very different climatic boundary conditions between more northerly and more southerly regions will determine for which purposes and to what extent waste heat can be used.

Feasibility

In the online survey, more than 60% ranked the technological feasibility as currently viable, but only 20% from an economic perspective. Only a few participants (10-20%) assume, heat reuse will be feasible without intervention by 2025, both from a technical and economic perspective. Only very few (<5%) of the participants say heat reuse is not viable from a technological point of view. These results align very well with the statements that were mad in the interviews.

ii. Data centres and heat systems

Current situation and technological approaches

The growing demand for energy in data centres, particularly in key regions like Frankfurt, London, Amsterdam, and Paris, has triggered heightened pressure from various stakeholders for these centres to adopt more environmentally friendly operations. Sustainability in power generation and the synchronisation of power supply and demand are critical concerns. Data centres' energy consumption significantly contributes to greenhouse gas emissions, representing a notable portion of total EU emissions (Hintemann et al., 2020). Efforts to curb energy demand in data centres are viewed as complementary to enhancements in power supply infrastructure, with numerous energy-saving opportunities identified across hardware and software technologies. Integrating data centres with electric grids to support green transitions is vital, emphasising real-time matching between green electricity generation and consumption. It's advised that new data centres prioritise locally generated green electricity to minimise environmental impact and transmission losses. Leveraging on-site renewable energy generation, such as photovoltaics, can further reduce energy losses during transport. Additionally, data centres

can play at least a small role in providing flexibility services to the electricity grid, assisting in managing the intermittency of renewable energy sources like wind and solar power.

Research by Riepin and Brown (2022) delves into the feasibility of achieving 24/7 climate-neutral energy for data centres in Europe, suggesting that 90-95% of this goal can be met with wind and solar power supplemented by battery storage, with a minimal cost premium compared to traditional annual renewable energy sources. Brown (2023) advocates for more granular green Power Purchase Agreements (PPAs) that can be traded hourly, ensuring green electricity matches consumption times. Additionally, data centres can leverage flexibility services to balance internal demands or provide support to the broader electricity grid, fostering a holistic approach to achieving carbon-neutral energy systems. Furthermore, achieving full decarbonisation requires addressing longer-term flexibility challenges while adapting to local variations in renewable energy sources and ensuring grid stability during peak demand periods.

The European Commission's document emphasises the growing need for flexibility in the EU's electricity system, foreseeing a rise to 24% of total demand by 2030 and 30% by 2050 (European Commission, 2023 p.11). Data centres offer inherent flexibility, enabling temporal and geographic workload shifts, and the use of unused storage and generation capacities. These strategies, alongside exploring alternatives like fuel cells, could bolster data centres' adaptability to renewable energy and diminish reliance on fossil fuels, fostering a more sustainable energy ecosystem.

Data centres can optimise energy usage by shifting less time-sensitive workloads to periods with higher availability of green energy, potentially reducing emissions by up to 20% during weekends and 5% by postponing tasks to the next working day (Wiesner et al., 2021). Moreover, data centres offer geographical flexibility, enabling workload shifts to regions with favourable ecological energy production, reducing transmission losses and avoiding shutdowns due to grid bottlenecks. Additionally, leveraging unused storage and generation capacities, such as utilising existing emergency generators for short-term stabilisation or transitioning to fuel cells, presents opportunities for data centres to enhance reliability and reduce dependency on fossil-fuel power plants.

Ongoing projects and initiatives

The research identified 14 industry implementations and 14 research projects, half of which were initiated by industry players, indicating that some approaches are already present in the market. These initiatives aim to achieve objectives such as demand response, energy-autonomous cloud data centres, power flexibility, carbon-aware computing, aligning AI applications with renewable energy availability, backup power via fuel cells, and developing edge data centres, showcasing diverse efforts to address energy sector challenges.

Geographic dependencies

In the electricity sector, geographical factors heavily influence energy generation, with wind power often concentrated in coastal and lowland areas, while solar power tends to be stronger in southern regions. Data centres, on the other hand, are clustered around major internet hubs like Frankfurt, London, Amsterdam, Paris (FLAP market), and Dublin in Europe, leading to potential supply bottlenecks in local power grids. To address these challenges, data centres could strategically distribute across regions with varied renewable energy potentials or alternative generation technologies like geothermal or biomass. Additionally, innovative approaches such as load shifting within the power grid can help alleviate grid congestion, ensuring uninterrupted service provision to users, although certain applications may require robust infrastructure and minimal latency for seamless operation.

Feasibility

The participants of the online survey considered the topic of 24/7 green electricity and power flexibility much less important than heat reuse. While 38% state that it is already viable from a technical point of view, only 15% consider that it is the case from an economic point of view and 22% from a regulatory point of view. For the short-term future, about 18% see technological viability, 15% economic viability and 13% regulatory viability. For the future after 2025, on the other hand, opportunities are seen with strong support from the side of technological (35%) economic (50%) and regulatory feasibility (44%). In general, only 10% see 24/7 green supply and flexibility as not viable from a technological, 21% from an economic and 22% from a regulatory point of view.

iii. Data centres and water systems

Current situation and technological approaches

The issue of water consumption and water circularity in data centres has emerged as a critical concern alongside energy demand and greenhouse gas emissions. However, there is a lack of transparency and data on this topic. The European summer's dryness has underscored the issue of water scarcity, which has led to conflicts with the drinking water supply and other vital uses, such as agriculture and industry. In the United States, data centres are projected to consume a staggering volume of water, primarily driven by the indirect water consumption for electricity generation. This poses significant challenges as global warming progresses. The reliance on drinking water for data centres conflicts with essential needs, amplifying the impact on local communities and production systems. Categorically, water usage in data centres spans evaporative cooling, air humidification, and indirect consumption through electricity generation, further complicating water management efforts. Despite attempts to gauge water usage effectiveness, the absence of transparent data hampers effective assessment and management of this critical issue. Consequently, the integration of data centres into water systems and water cycles is a crucial factor for the sustainable operation of data centres.

Data centres employ a variety of cooling strategies, including closed-loop, free cooling, and warm-water cooling, to manage heat efficiently. Free cooling, whether direct or indirect, utilises water or air as a heat-transfer medium, offering energy efficiency, particularly in cooler climates. Indirect free cooling involves the use of a liquid, such as a water-glycol mixture, to transport heat. This process often requires the use of an active refrigeration system in order to achieve optimal performance, particularly during hot summers. Hot water or liquid cooling enables the dissipation of heat without the issue of evaporation, thus allowing for the efficient reuse of waste heat even in high-temperature conditions. Furthermore, data centres are increasingly exploring alternative water sources, such as seawater or groundwater, employing separate cooling circuits and heat exchangers in order to maintain system integrity and efficiency while minimising environmental impact.

Ongoing projetcs and initiatives

A number of industry projects have been initiated with the objective of conserving water, utilising non-potable sources, and returning water to natural reservoirs. For instance, a European cloud provider employs liquid cooling with high temperature differentials in order to efficiently manage energy and water usage, particularly in warmer climates (Chehade, Hnayno, Jay, & Jay, 2023). In Marseille, water from a disused mine is repurposed for cooling, resulting in substantial energy savings on an annual basis . In a noteworthy research initiative, a data centre submerged in the sea operated autonomously, markedly reducing water consumption and mitigating IT component failures through innovative nitrogen isolation techniques (Roach, 2020).

Geographic dependencies

Water consumption poses a more significant challenge in arid regions compared to water-rich areas, with data centres often facing critical issues regarding drinking water usage.

Evaporative cooling, especially effective in warm, low-humidity environments, is most beneficial where water resources are scarce, prompting consideration of closed-loop cooling systems powered by on-site photovoltaic plants to address energy demands sustainably.

Feasibility

The majority of survey participants regard technological water-saving measures as feasible today or within the next few years, with some requiring strong support for implementation. However, around 6% believe these measures will never be feasible, even with substantial assistance. Despite this, only 33% consider water-saving technologies economically viable at present, with approximately 25% expecting viability by 2025, either with or without additional support. Interestingly, while water prices are relatively higher in regions with scarcity, low prices elsewhere offer little financial incentive for data centres to adopt water-efficient cooling technologies or alternative water sources, although some operators have begun implementing such solutions in response to growing environmental concerns and risks associated with reliance on traditional cooling methods.

iv. Interrelationships between technologies for integrating data centres into heat, power and water systems

The technologies utilised to enhance the interaction between data centres and utility systems often involve intricate connections with other energy and water systems. Renewable electricity generation, although beneficial for reducing greenhouse gas emissions, may still have significant water consumption requirements, particularly with options like hydropower and biofuels. Water-intensive processes such as electrolysis for green hydrogen production and lithium mining pose challenges to natural water cycles. Nevertheless, the decarbonisation of the electricity sector presents opportunities to minimise water consumption, especially with the closure of fossil thermal power plants. However, conflicts arise with evaporative cooling, which is effective in hot and dry climates but strains water resources. Conversely, water cooling systems offer advantages by facilitating waste heat utilisation, promoting energy efficiency, and supporting sustainable heating applications. Moreover, combined heat and power production and large-scale heat pumps demonstrate potential synergies for energy efficiency and short-term flexibility, requiring coordinated efforts and incentivised cooperation among stakeholders across various utility systems.

3. Task 2: Mapping of drivers, obstacles and potential opportunities

a. Aim and objectives

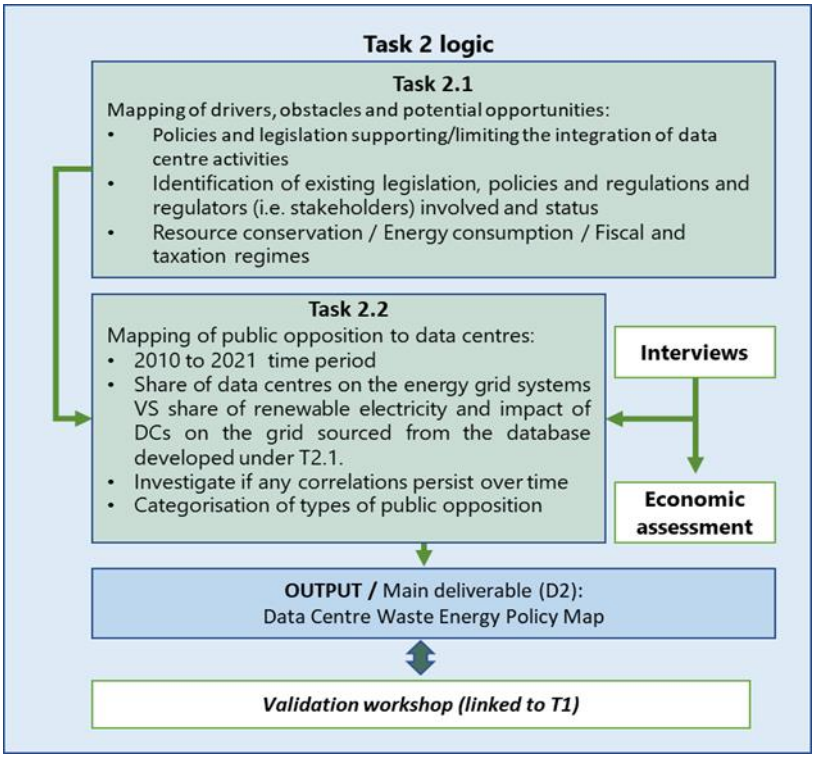
The objective of Task 2 is to ensure a complete mapping of the factors positively influencing and/or hindering successful data centre integration.

The starting point for this task is to exhaust all legislation at all governmental levels, from the federal to the local, that may help or harm the integration of data centre operations into the overall energy systems, while also looking for the best ways to integrate data centres into the overall energy systems. The mapping will encompass current legislation and regulations, such as planning laws and fiscal regimes, and it will identify the major players—from government agencies to business associations— who are crucial to the governance of the energy markets. The various energy mixes and primary power sources will also be included in this overview, along with an assessment of the country's or region's intensity of data centre presence in terms of its effects on energy consumption. The purpose is to establish a strong foundation on which the sound analysis needed to accomplish the following sub-objectives can be built, possibly using knowledge from Task 1. Under task 2.1 the mapping of drivers, obstacles and potential opportunities encompassed a detailed assessment of the legal and regulatory framework applicable to interactions between DCs and energy systems. This analysis covers relevant EU law and policies, as well as national legislation in six selected Member States. As part of the national case studies, the reasoning and grounds for public reactions (both public opposition and public support) to DCs have been assessed and analysed. Starting from the main drivers, obstacles and potential opportunities underlying both EU and the MSs regulatory framework, under task 2.1 the study formulates recommendations for improvements of the legislations.

To understand the motivations behind the opposition and how authorities have been/are handling them, cases of public opposition to an existing or planned data centre presence in their communities will be flagged and taken into consideration in the final analysis. Some of the most fundamental issues raised by the integration of data centres into electrical systems and the viability of the idea of "100% carbon-free data centres" will be best clarified through an economic analysis of the aforementioned subjects. This analysis will also quantify the potential for demand-response from data centres in Europe and extend the scope to also include co-location data centres.

The figure below summarises the logic behind Task 2.

Figure 2: Task 2 logic



b. Methodology

The methodological approach used for task 2.1 is based on in-depth desk research that involved identifying and analysing relevant EU regulatory sources related to the future integration of DCs into energy systems. The analysis is divided into two parts: the first part explores EU legislation, while the second part focuses on the perspective MSs. The six MSs (France, Germany, Ireland, Italy, Luxembourg, the Netherlands) have been selected for a comprehensive review, considering the level of detail and relevance of their specific legislations. Both regulatory sources directly addressing DCs and those related to other aspects were evaluated, including regulatory activities at different governmental and geographical levels (national, local, regional legislations). The analysis highlights the main drivers, obstacles, and potential opportunities for each analysed act and provides subsequent potential recommendations. As part of the MSs regulatory framework evaluation the analysis, the rationale, main reasoning, grounds for public reactions (both public opposition and public support) to DCs have been assessed and analysed. The consequences of such cases have not been neglected. This means that the study evaluated, e.g., if an opposition case led to the implementation of certain measures at local level or if a public support case implied the adoption of subsequent regulatory acts and or initiatives by MSs institutions at various government level.

c. Results

Task 2.1 has been approached in order to identify in the legislation and regulatory framework relevant to DCs there is room for improvement, leading to the identification of potential recommendations. The analysis started by **the definition of DCs in Europe.**[1] Starting the analysis recalling relevant definitions allowed the identification and then a

1 As provided by the Joint Research Centre of the European Commission in the EU Code of Conduct, and a publication in the EU Green Public Procurement (GPP) criteria for Data Centres, Server Rooms and Cloud Services, and subsequently, in Regulation (EU) 2022/132 and in the recast of the Energy Efficiency Directive (EED) (Article 2 n. 45).

comprehensive assessment of national and EU legislation, covering relevant instruments whose scope of application includes DCs, as defined above. In this regard, **one of the first main findings** of the analysis sis that while an EU definition can be extracted from the EU legal framework, a crucial point of the analysis is the **frequent absence of a clear, legally binding definition of DCs at the MSs level**. Consequently, it is difficult, without specific indications, to legally classify DCs for specific purposes. **Relevant examples of these gaps have been detected in land planning and taxation regulatory frameworks** often requiring DCs to be included in a destination of use or a specific economic activity. Hence, one of the major difficulties is classifying DCs according to their traditional categories, emerges because they do not conform to any of them or because they can be included in multiple categories. This creates difficulties in using legislative instruments relevant to DCs that can also be integrated in energy systems.

Another finding emerging from the regulatory analysis is the number and nature of stakeholders involved in the DCs domain, that include **public authorities** – exercising regulatory or administrative powers – and **private stakeholders** – having various interests in DCs including individuals or entities that are directly involved in the creation or operation of a DCs, such as owners, operators and landowners. In particular, EU and national public authorities, positioned at various levels of the administration, may significantly influence DCs by dictating general or specific policies, while regional and local authorities may exert a significant influence on the activities of DCs operators, particularly due to their involvement in the management of grid networks and local natural resources and on matters concerning land planning. This, trying to harmonise such competence with private stakeholders' interests that differ significantly.[2]

An additional layer of complexity results from **the identification of a dual role** that **DCs** in energy systems. DCs are generally perceived as large energy users and grid users. However, with the proper technical arrangements, they can become electricity or heat producers in circular and sustainable energy systems, also meeting the needs of the energy market by supplying flexibility products. A problematic element that emerged during the analysis is the legal and economic feasibility of the DCs role in the production of energy through waste heat and wastewater.

The legislative analysis of the EU, national, regional and local regulatory framework has been conducted with the objective of mapping and identifying **drivers, obstacles and potential opportunities**.

i) Further to the principal main findings briefly summaries, the regulatory and legislative analysis revealed that **recurring drivers**, both in the EU and Member States' regulatory framework, are closely related to **energy consumption**. There seems to be a concerted effort at all governmental levels in Europe to reduce energy consumption.[3] The same interest towards this theme can be found in every MSs legislation.[4] Additionally, the same drivers can be identified in **fiscal instruments,**[5] oftentimes, presenting fiscal incentives to encourage energy efficiency. Other recurring drivers, that can be found both at EU and MSs level, **are sustainability and the protection of the environment**, as proven by the number of the legislative and policy instruments and the variety of mechanisms implemented. Following this ratio, some acts introduced sustainability requirements for the digital sector.[6] The same efforts towards sustainability have guided the adoption by the EU of measures addressed to the digital sector[7]and have been mirrored by initiatives involving

2 Interests of economic nature, in environmental protection, preservation of resources (particularly water), management and reduction of energy consumption. Different actors will prioritise their own interests and conflict may arise.

3 Particularly by increasing energy efficiency and optimising the processes from which waste heat and/or wastewater can be reutilised. This effort has been the underlying rationale behind several specific EU regulatory initiatives (as evidenced by legislative instruments such as the Electricity Market Regulation, the Electricity Internal Market Directive, the Energy Efficiency Directive).

4 In the six analysed jurisdictions, the reduction of energy consumption and particularly the increase in energy efficiency are the main drivers of legislation and policies, at every analysed policy level.

5 EU's Energy Taxation Directive, as well as various measures in the majority of the analysed Member States.

6 The Regulation on ecodesign requirements, servers and data storage products.

7 The Corporate Social Responsibility Directive.

stakeholders.[8] Another way in which environmental issues were tackled was the introduction of rules on public procurement[9]. The concerns related to the protection of the environment and the need to reach climate and sustainability targets emerged as to be shared by all MSs.

Another main driver emerged during the regulatory analysis - **the increase in use and development of renewable energies** - originates from the combination of the two aforementioned groups of drivers (i.e environmental protection, sustainability and energy efficiency). It can be identified in the EU legislative framework and in several MSs (i.e **Italy** and **Luxembourg**). In this regard, the use and development of renewable energies is a mean to reach the environmental targets that the EU has imposed on its MSs. However, this generic driver is sometimes implemented by measures directly imposing the reuse and valorisation of waste heat through the imposition of specific targets (as evidenced by various national legislative instruments and policies, such as in France and the Netherlands). These measures emerged as particularly useful to DCs and their integration in energy systems and are suitable to pursue both sustainability objectives and energy efficiency objectives. MSs (the Netherlands and Luxembourg) include the management of resources in the legislation that has **spatial planning as its main driver and object**. In these instruments, spatial planning factors in the presence or in the lack of energy and water sources to determine whether it is appropriate to build certain facilities in specific locations.

Another driver, the **proper management of electricity demand**, can also be identified in the Iris legislation and the related driver of the **integration of DCs in water systems** emerged from the European legislation (Directive on minimum requirements for water reuse).

ii) The mapping of the EU and MSs legislation has led to the identification of various **obstacles** to the successful integration of DCs into energy and water systems. The most common one is related to **costs deriving from the implementation and/or compliance with policy documents and regulations.**[10]

Other obstacles, identified in the EU and in Germany legislations, are related to the **practical difficulties for DCs to meet specific criteria** and to the **non-binding nature of certain regulatory acts,** leading to an ineffective implementation level: the concerned stakeholders are not mandated to comply with certain requirements, they are often tasked with self-control mechanisms and may lack of sufficient guidance.

In MSs such as **France** and **Italy** examples of **unclear formulation of legal provisions** have been detected. The **lack of clarity and specificity** in potentially applicable legislative instruments is an obstacle to the implementation of the provisions. These provisions can have a positive impact on the integration of DCs into energy systems, but such gaps prevent their efficient implementation phase, often hindered also by the **vagueness in the wording** of the legislation or by other practical issues.

iii) The mapping of the EU and national legislation has also led to the identification of various **potential opportunities** for the successful integration of DCs into energy and water systems. These potential opportunities are specifically linked to measures and legal instruments from which they have been derived. A particularly relevant category of opportunity to integrate DCs into energy systems are those related to the **promotion of the recovery and usage of waste heat** through various measures. In the EU framework, the proposed revision of the **Renewable Energy Directive and the Energy Efficiency Directive** both encourage the recovery of waste heat. Heat recovery can be achieved through different mechanisms: for example, the Energy Efficiency Directive obliges MSs to ensure that DCs recover excess heat and deliver it to the district heating network, unless

8 The Green Digital Coalition

9 EU Green Public Procurement (GPP) criteria for Data Centres, Server Rooms and Cloud Services and Buying green! A handbook on green public procurement.

10 Among which the Regulation on ecodesign requirements, servers and data storage products, EU Green Public Procurement (GPP) criteria for Data Centres, Server Rooms and Cloud Services and some regulatory instruments in the French legislation.

they can demonstrate that it is not technically or economically feasible. Measures that generate this category of potential opportunities (the waste heat) have been identified in all the selected MS, however the degrees of specificity and frequency vary.[11]

Possibly the most frequent category of potential opportunities identified are those deriving from **measures aimed at reducing energy consumption and promoting energy efficiency**, identified both at EU and MSs levels.[12] Measures that generate these types of potential opportunities are frequently found in acts concerning energy management and vary in nature.

A specific type of potential opportunity derives from measure related to the **use of taxation schemes to promote energy efficiency and the use of renewable and recovery energy sources**. In the EU legal framework, an example is the revision of the Energy Taxation Directive. According to the proposal, the taxation will be adapted to the environmental impact of energy sources. Therefore, taxation rates will be more favourable for recovery energy sources (such as waste heat), this will motivate energy consumers to seek energy from recovered sources. At MSs level, France is a notable example. French DCs are granted a tax reduction for final energy consumption only if they satisfy specific conditions related to energy efficiency. This type of mechanism is particularly useful because it DCs with strong incentives while rendering this incentive conditional. This gives DCs a strong monetary motivation to adopt such practices. A closely related potential opportunity derives from the use of **financial incentives to promote energy efficiency and the reduction of energy consumption**. Notable examples of these schemes can be found at the level (i.e. Italy and Luxembourg), where incentives are targeted towards consumers who plan to improve energy efficiency and/or reduce energy consumption.

Another potential opportunity stems from measures aimed at **strengthening the energy infrastructure**. Taking measures that specifically concern district heating networks and the electricity grid management help mesh DCs with energy systems. At EU level example of such potential opportunity is given in the proposed revision of the Renewable Energy Directive. This focuses on the development of efficient heating and cooling infrastructure at a district level and aims to deepen local integration in the overall energy system. Measures like this are identifiable in various countries (i.e. France, Luxembourg, Ireland), while a different example of instrument that regulates the functioning of the electricity network, and from which potential opportunities of this category can be derived, is the Directive on common rules for the internal market for electricity.

Also relevant is the **strategic use of land planning to reduce energy consumption and manage resources.** Legislative instruments concerning this category of potential opportunities have been identified in MSs, specifically in the Netherlands, where plans have been introduced at the national, regional and local levels.

Another important category of potential opportunities is the **management of water resources and the reuse of wastewater**. It is important to stress that potential opportunities of this kind have been identified less frequently than those related to energy. In the EU, the Regulation on minimum requirements for water reuse presents potential opportunities related to this aspect. At the MSs level, water reuse policies have been identified in France and the Netherlands.

In light of the main drivers, obstacles and potential opportunities briefly summarised, as part of the regulatory and legislative analysis performed under task 2.1, **potential recommendations** (related to each act analysed both at EU and MSs level) have been provided for the further development of the regulatory framework. Such recommendations have been summarised in the tables attached to the present report. The potential

[11] In some MSs, such as Ireland and Luxembourg, waste heat is more frequently regulated and the target of specific measures, whereas in other Member States, such as Italy, even in instruments concerning energy efficiency and energy networks waste heat is rarely mentioned explicitly.

[12] At the EU level, the Code of Conduct on Energy Efficiency, the Regulation on Ecodesign Requirements, the Energy Efficiency Directive and the REPower EU. Examples of these potential opportunities can be identified in all MSs analysed.

recommendations have been successfully **validated** in the subsequent phases of the project.

On top of the regulatory analysis, the study team performed an analysis on identified **public opposition/support cases** to data centres. This analysis identified 32 cases of public opposition and 16 cases of public support between 2012 and 2023 in EU Member States such as Ireland, the Netherlands and Germany, as well as in other world regions including the UK and the US. Public opposition arises from concerns related to the **environmental, energy consumption and socioeconomic issues**, while public support is driven by **economic benefits**, the promotion of **digitalisation** and the potential for promoting **green energy** from data centres. The number of public opposition and support cases has been increasing in recent years with a significant rise observed from 2021 onwards, in which **44%** of the public opposition cases have been won by the opposition groups and 31% have been lost. This also indicates that in many of these cases, the concerns of public opposition groups have been taken into account by regulatory authorities for each respective case in the process of establishing a data centre.

Additionally, the team also conducted an analysis on the impact of data centres on **renewable energy projects**. From the findings, solid fossil fuels, oil and natural gas continue to dominate the energy mix in the EU27, while renewables, nuclear energy and other sources play a smaller, albeit growing role. The **industry sector** (as a proxy for the data centre industry), although not the largest energy consumer in the EU27, relies mostly on **electrical sources** with natural gas and renewables also accounting for a significant portion. Despite some fluctuations, the overall energy consumption for the industry sector has remained relatively stable from 2012 to 2021.

While the growth in **renewable energy capacity** provides opportunities for data centres to utilise more renewables, the **increasing energy demand** from data centres may outpace the growth. In that sense, data centres can have a positive effect on renewable projects by encouraging and broadening the adoption of **sustainable practices**, such as redistributing excess heat and investing in renewable energy sources. Large data centre operators are indeed leading the way in procuring renewables and contributing to the development of renewable energy capacity. However, further research and innovation are still needed to reduce data centre energy consumption and increase the use of renewable energy.

Approaches to achieve **100% carbon-free data centres** have been tried by data centre operators, including **carbon offsetting, power purchase agreement (PPA)** and **24/7 carbon-free electricity (CFE)**, for which large operators are at the forefront of this movement. However, the two first approaches run into limitations such as not matching the physical reality of the data centre area for carbon offsetting and not matching the reality of renewable energy production in the area for PPA, which prompts the launch of 24/7 in which renewable energy is sourced from the surroundings of the data centres and ensured to match DC needs at all times.

These findings on the correspondence between data centres and renewable energy projects, together with the analysis on public opposition cases, have fed into the formulation of **actionable advice** under **Task 5**.

4. Task 3: Comparison with other energy and emission-intensive sectors

a. Aim and objectives

Following the first validation workshop and the completion of the outcomes of Task 1 (comprehensive mapping) and Task 2 (drivers, obstacles and potential opportunities), it will

be essential to explore and assess lessons to be learnt and best practices from other sectors.

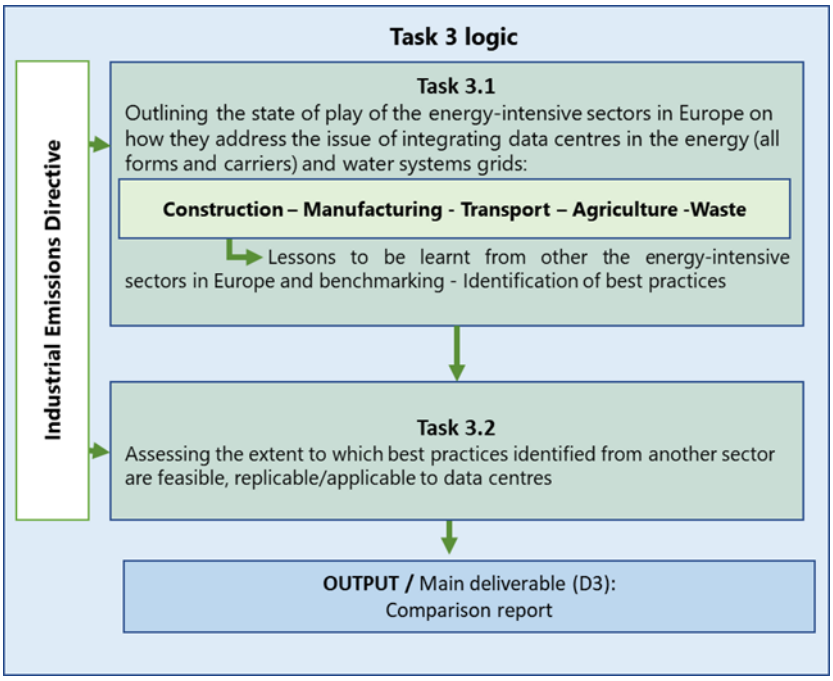
The first step to which is identifying relevant sectors to be considered "emission-intensive" in the EU27, while simultaneously being strategic to the EU's competitiveness and economy and, thus, relevant to accelerate the European Commission's strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050.

The second step of Task 3 will then consist of an in-depth literature review, combined with consultation with external stakeholders, as well as experience from the project partners (e.g. from the development of the NEFI decarbonisation scenarios, where interviews with stakeholders from the energy intensive industry were performed), on how these selected sectors address the issue of integrating data centres in the energy (all forms and carriers) and water systems grids. This exercise will allow the identification of best specific-sector practices and the mapping of useful lessons to be learnt for data centres.

Taking full consideration of the Industrial Emissions Directive (IED) pillars,[13] the outcome of task 2 will include the benchmarking feasibility of existing practices and an assessment of their replicability and transferability before finally, setting up a list of lessons to be learnt for data centres to achieving "highly energy efficient, sustainable and climate-neutral data centres by 2030".

The figure below summarises Task 3 logic.

Figure 3: Task 3 logic



b. Methodology

The methodology for identifying Best Available Techniques (BAT) in Energy Intensive Industries (EIIs) starts with a focus on how to improve synergies between these industries and their respective energy and water systems. This involves a comprehensive review of existing practices and technologies used in EIIs to identify those that are most effective in improving the integration and efficiency of energy and water use. The identification process

[13] Note: IED is based on several pillars, in particular (1) an integrated approach, (2) use of best available techniques, (3) flexibility, (4) inspections and (5) public participation.

uses extensive data collection from industry reports, scientific studies and technology assessments to compile a list of potential BATs. This first step ensures that the techniques selected have a sound basis in terms of proven effectiveness and relevance to current industrial practice.

Once a list of potential BATs has been compiled, these techniques are rigorously assessed for their transferability and replicability specifically in the context of data centres. This assessment is based on pre-defined evaluation criteria that include technological maturity, scalability, and their potential to contribute to the goal of a "100% carbon free data centre". The criteria are designed to assess the practical applicability of each BAT in different operating environments, ensuring that they are not only theoretically sound, but also feasible in real-world environments. This stage involves both qualitative and quantitative analysis to assess the effectiveness and adaptability of each technique, considering factors such as cost, barriers to implementation and potential benefits.

In the final stage, the eight most relevant BATs identified through the assessment process are subjected to an in-depth evaluation. This evaluation is carried out through a detailed literature review and expert interviews, focusing on several key indicators such as financial viability, environmental impact, potential for interconnection, energy efficiency and regulatory compliance. The literature review provides a broad understanding of each BAT's historical performance and theoretical underpinnings, while the expert interviews provide practical insights and professional judgements on its real-world applicability and effectiveness. This comprehensive approach ensures that the final selection of BATs is robust and highly relevant to achieving sustainable and efficient data centre operations.

c. Results

A key finding was the clear transferability and potential of Best Available Techniques (BAT) from Energy Intensive Industries (EII) to Data Centres (DC), resulting in promising synergies for sustainable cross-sectoral application. The implementation of BAT in data centres can reduce the significant energy demand and environmental impact of these facilities by using advanced technologies and processes developed in other EIIs. The success of these techniques in very demanding industrial environments suggests a high potential for equally effective application in data centres. Replication of these techniques can lead to significant energy savings, reduced emissions and improved operational efficiency, demonstrating that innovation in one sector can be beneficially transferred to another.

A comprehensive study identified 35 BATs from seven industrial sectors in eleven countries, illustrating the diversity of sustainable practices used worldwide. Of these 35 techniques, eight were analysed in detail to gain a deeper understanding of the technologies used, their benefits and transferability. This in-depth analysis includes an assessment of their implementation in different legal, environmental, and economic contexts to ensure that the lessons learned are generally applicable. The in-depth analysis of these techniques underlines the global commitment to sustainability and the sharing of knowledge that can lead to industry-wide improvements.

One important area that has been analysed is heating systems, with a focus on reusing waste heat and replacing fossil fuels. Waste heat, a by-product of many industrial processes including data centres, is a significant and often under-utilised resource. By capturing and reusing this waste heat, data centres can help to drastically reduce reliance on fossil fuels, leading to a significant reduction in greenhouse gas emissions. Technologies such as combined heat and power (CHP) (higher efficiency, but renewable fuels must be used to help reduce emissions) and heat pumps (district heating, grid flexibility) are particularly effective in this respect and have the potential for significant energy efficiency gains and cost savings if the lack of heat consumers can be overcome.

In the area of electric power systems, the focus is on the ability of data centres to generate their own power (n-site renewable energy generation - wind & PV) and provide services to the grid. This self-sufficiency not only increases the resilience and reliability of data centres, but also contributes to the stability of the overall power grid (reduction transmission losses and demand from the grid). By using renewable energy sources and/or participating in energy communities, data centres can meet their energy needs in a sustainable way.

Water systems are another critical aspect that emphasises water reuse and the use of alternative water sources. Data centres, which use large amounts of water for cooling, can greatly benefit from advanced water management techniques developed in other industries (e.g., matching actual use to actual demand), which would reduce the burden on the public water supply system, as well as reducing the cost of water procurement and possibly increasing the cost of water treatment. Techniques such as the use of non-potable water or rainwater harvesting for cooling processes can significantly reduce the amount of fresh water required by data centres, but may increase investment in control systems, treatment, and pumping as well as maintenance costs. Implementing these strategies not only saves water, but also reduces operating costs and environmental impact, demonstrating the overall commitment to sustainability and responsible resource management.

5. Task 4: Case studies

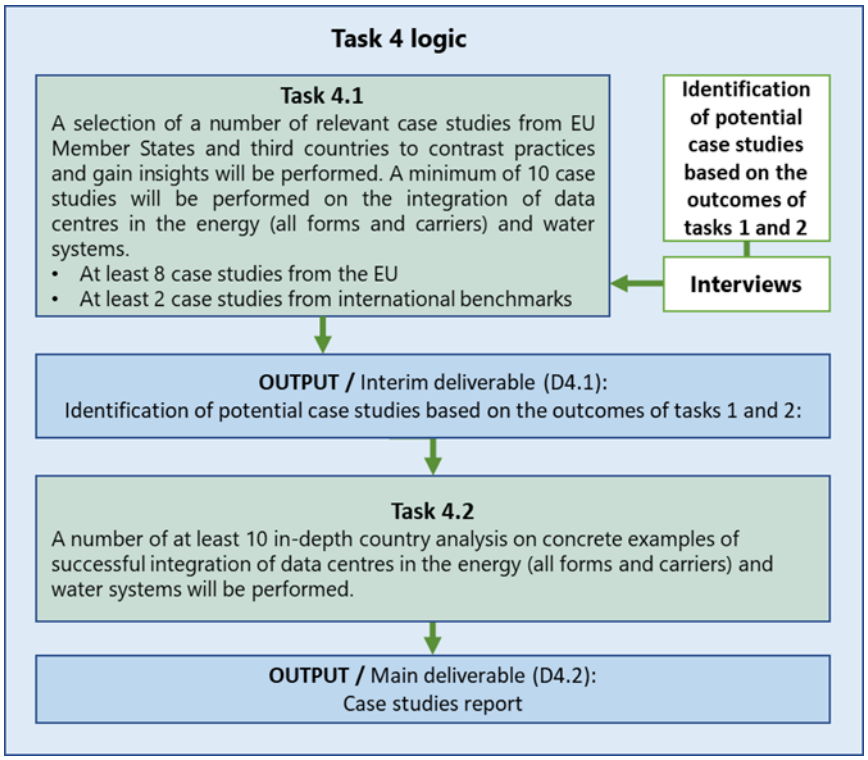
a. Aim and objectives

Under Task 4 and based on the prior findings from this study thus far, especially the outcomes of tasks 1 and 2, a number of in-depth case studies will be identified based on actual instances of successful integration of data centres in the energy (all forms and carriers) and water systems.

Those case studies will aim to cover all of the factors analysed in tasks 1 and 2, as well as qualitative and quantitative information on inputs (i.e. financial investments), outputs (e.g. the amount of energy reused, the number of jobs directly or indirectly created, etc.), and impacts on the local authority's or community's overall energy consumption. This activity will depend on a set of guidelines to direct the selection process in order to enable a successful and high-level identification on case studies.

The figure below summarises Task 4 logic.

Figure 4: Task 4 logic



b. Methodology

After thorough desk top research to identify potential data centres for further investigation. A long list of potential data centres was then compiled. This comprehensive list provided a broad overview of data centres. To refine the selection process, a scoring system was developed to evaluate the identified data centres. This system considered several factors, including energy efficiency, sustainability initiatives and operational capabilities. The aim was to prioritise those data centres that showed a high potential for successful implementation of BAT. Once the data centres had been assessed, a shortlist was drawn up for in-depth analysis. As part of this in-depth research, expert interviews were conducted with industry professionals and stakeholders.

c. Results

The main identified levers for “energy” (E), “heat” (H) and “water” (W) are: E1. Local integration with renewable energy sources, E2. Demand response. E3. 24/7 carbon-free electricity, E4. Energy efficiency measures, H1. Integation into existing heating networks, H2. Overcome seasonal discrepancies, H3. Match waste heat with heat demand, W1. Reduction of water consumption and W2. Use of alternative water sources.

Local integration (E1) of renewable energy sources offers significant benefits by allowing electricity to be used where it is generated. This approach not only reduces the load on the grid, but also promotes green electricity. Data centres located close to renewable energy sources, such as solar farms or wind turbines, can use clean energy directly, reducing transmission losses and improving the overall efficiency of energy use. Examples: windCORES, Lefdal Mine Data Centre.

Demand response (E2) provides a dynamic solution for balancing energy supply and demand in real time. Data centres equipped with demand response capabilities can adapt their energy consumption to the needs of the grid, helping to reduce congestion and curtailment of renewable energy sources. By shifting or reducing their energy consumption during peak periods or when the grid is under pressure, data centres can make a significant contribution to the stability and efficiency of the grid. This not only avoids wasted energy, but also ensures that renewable energy that might otherwise be curtailed is fully utilised. Implementing demand response measures also brings economic benefits, as data centres can benefit from lower energy prices during off-peak hours and avoid the higher costs associated with peak demand. Example: Google.

24/7 Zero Carbon Electricity Readiness (E3) is a proactive approach to achieving a sustainable energy supply. Data centres can secure clean energy through Power Purchase Agreements (PPAs) that are tailored to match their energy needs with carbon-free sources. Example: Google.

Energy efficiency measures (E4) are critical to maximising the sustainability of data centres and reducing the strain on the power grid. By using advanced technologies and optimising operations, data centres can significantly reduce their energy consumption. Measures such as improved cooling systems, etc. reduce the overall energy demand, which in turn reduces the load on power grids. Examples: OVHcloud, Cloud & Heat, Green IT Cube

Integrating data centres (H1) into existing heat networks can make them key components of a wider energy ecosystem. This integration presents a number of challenges, such as the need for high temperatures and reliable heat supply, efficient heat transfer and profitable contracts with heat network operators. Examples: Stockholm Data Parks, OVHcloud, Cloud & Heat, Green IT Cube.

Overcoming the seasonal discrepancy in heat demand (H2) is a major challenge. There is a high demand for heat in winter, while data centres often produce excess heat in summer that exceeds local demand. Thermal energy storage systems can store the excess heat generated in the summer for use in the winter, thereby balancing the seasonal variations in heat supply and demand. By effectively storing excess heat and releasing it when needed, data centres can ensure continuous, efficient use of waste heat throughout the year, helping to optimise heat networks. Example: Equinix.

Coordinating waste heat and heat demand (H3) requires strategic positioning and consideration of the location and/or alternative consumers. Locating data centres close to district heating networks enables waste heat to be transferred directly and efficiently. This proximity reduces energy losses and infrastructure costs, making integration more practical and beneficial. In addition to traditional district heating consumers, alternative applications for waste heat should also be considered. For example, agriculture can use waste heat to heat greenhouses to extend the growing season and improve crop yields. Aquaculture can

also benefit from the stable water temperatures provided by waste heat to improve fish farming. By diversifying the applications for waste heat, data centres can maximise their environmental and economic impact by supporting a variety of sectors while contributing to overall energy sustainability.

Reducing water consumption (W1) is a key lever for sustainable water management in data centres, especially in cooling processes. Conventional cooling methods are often based on evaporative cooling, which results in significant water losses. To reduce this, data centres can use free cooling and closed-loop systems. Free cooling uses the temperature of the ambient air to cool the system, significantly reducing or even eliminating the need for water. Closed-loop systems circulate water within a closed system, preventing evaporation and minimising water consumption. Examples: OVHcloud, Equinix.

The use of alternative water sources (W2) is another important strategy for improving water management in data centres, especially in regions where drinking water is scarce. Instead of relying on freshwater supplies, data centres can use alternative sources such as desalinated seawater or treated wastewater for cooling purposes. Desalination, which removes salt and other impurities from seawater, is a viable option in coastal regions where fresh water is scarce. Similarly, using treated wastewater for cooling can reduce pressure on drinking water supplies and promote a circular water economy. Examples: Project Natick, Lefdal Mine Data Center.

6. Task 5: Policy recommendations

a. Aim and objectives

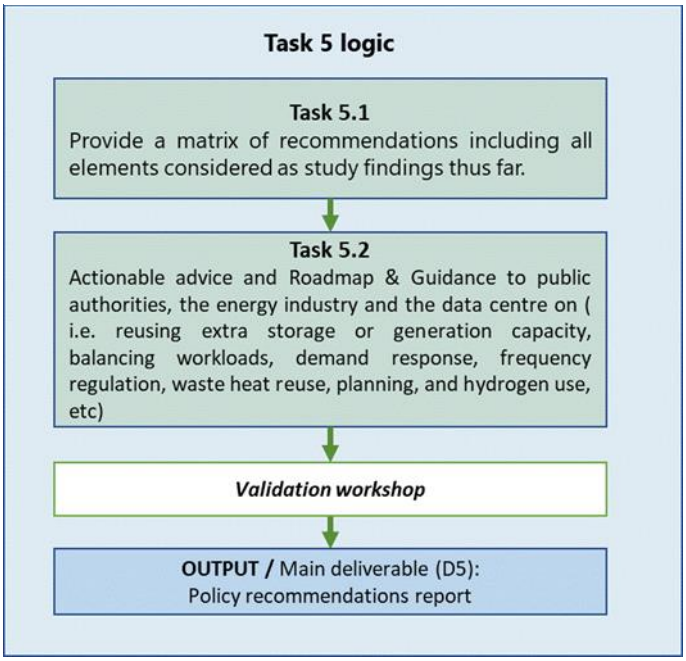
In order to reach the Green Deal and Digital Decade goals, which state that data centres should be highly energy-efficient and climate-neutral by 2030, Task 5 seeks to provide concrete policy recommendations and actionable guidance about how data centres might be better integrated into energy systems. Policy recommendations in particular will focus on how waste heat and water from data centre operations may be incorporated into regional energy grids.

High-level yet straightforward policy and fact-based recommendations will be created to give direction to government agencies, the energy sector, and the data centre industry on how to best incorporate surplus heat and water from data centres into energy systems and the opportunities offered by as-yet untapped practices such as reusing extra storage or generation capacity, balancing workloads, demand response, frequency regulation, waste heat reuse, planning, and hydrogen use.

The selection of the policy recommendations and actionable insights will be further challenged by experts and all findings will be discussed in detail through an expert validation panel to produce a final policy recommendation report. This expert validation panel (i.e. workshop) will certify the validity of the actions recommended and will encourage their thorough tailoring to fit the needs of stakeholders.

The figure below summarises Task 5 logic.

Figure 5: Task 5 logic



b. Methodology

An extensive exploratory work was carried out under this report. The policy recommendations built upon the technical and market drivers and barriers identified in previous parts of the study. These outputs fed into the drivers and obstacles for which the policy recommendations aimed to address with regards to the potential opportunities and/or limitations for the integration of data centres with the energy systems.

After the successful validation of the regulatory, legal and policy recommendations developed under task 2.1, in task 5.1, the validated recommendations have been organised

into a specific Matrix of Recommendations which took into account various categorisation elements and points of evaluation, in order to extract – from each recommendation – related legal actions to be pursued for the implementation of the recommendations as actionable advices (validated policy recommendations matrix legal actions actionable advices). These actionable advices also entail soft non-legal measures, to achieve the end goal for each area of recommendation and to specify the steps and actors involved.

Please note that, to set up and develop the Matrix of Recommendations, the final validated legal recommendations (11) have been grouped around single regulatory acts analysed when related to the EU regulatory frameworks and have been grouped around the single MS when related to national legislations, in this case not considering a specific acts analysed at national level but merging together the underling rationale and main outcomes derived from the MS regulatory analysis performed during the project.

c. Results

The drivers and obstacles for integrating data centres into the energy systems build upon the findings of previous parts of the study and are categorised into four thematic barriers: namely energy infrastructure (consumption, transmission and reuse), technical innovation, social and environmental (corporate sustainability reporting / corporate commitment / reputation / shareholder commitment / community / local level approach) and regulatory framework. The policy recommendations then aim to address with regards to the potential opportunities and/or limitations on the synergies between data centres and energy systems.

The matrix of identified drivers/obstacles and the thematic barriers are included in the Annex.

Accordingly, the Matrix of Recommendations below took into account various categorisation elements and points of evaluation. These categorisation elements are:

- **Origin**, meaning the EU and/or MSs context from which each recommendation was extracted and/or derives.
- **Act**, meaning the legislative, institutional, policy or regulatory act from which each recommendation was extracted and/or derives.
- **Description** of the previously validated recommendations (11).
- **Legal actions (11)** - related to each recommendation - to be pursued at EU and/or at MSs level in order to implement such recommendations.
- **Term/timeline** (short/medium/long term) foreseen for the implementation of the legal actions.
- **Issues addressed**, meaning the drivers/obstacles that the legal actions may contribute overcoming.
- **Stakeholders** involved in the future implementation.

The categorisation of the validated policy recommendations in such matrix led the classification of each recommendation under **3 Main Preliminary Findings**, to be intended as main recurring Topics underling the policy recommendations evaluation.

i. Main Finding – Topic 1 “Incentives & Best Practices”

The Policy Recommendations identified suggested that both at EU and MS level there is space for improvement of legislations/policy instruments when it comes to the development of economic incentives (e.g. from the point of view of taxation, fiscal schemes and public funds, etc.) and for the improvement and specifications of best practices (e.g. GPP criteria, Taxonomy). Incentives and best practices are deemed crucial to help, sustain and incentivise the stakeholders (both public and private) operating in the DCs domain that plan or conduct their economic activities in sustainable manners, consequently promoting the overall integration of DCs into energy system. When asked to express an evaluation on

this finding, consulted stakeholders strongly or somehow agreed on the statement, revealing that from the perspective of the industry, legislations seem not to be fully aligned on: i) how the digital world function, ii) the fact that the DCs industry has been built to be sustainable and fully electrified and iii) the contribution that DCs domain gives on green energy. The opinions expressed confirmed the finding that there are, indeed, many legislation/policy measures that MSs can implement to support and facilitate DCs operators to procure carbon free energy to match their load, to be able to share their waste heat with nearby industry/district heating network and to enable DCs to participate in grid services by operating more flexibly.

ii. Main finding – Topic 2 "Energy Consumptions & Renewables"

Policy recommendations suggest that both at EU and MSs level there is possibility to promote and develop current regulations/policy instruments/directives, by introducing more specific and detailed provisions on energy efficiency of DCs and on renewable energies, also operating on general principles (e.g. non-discrimination principle). With specific regard to some MSs (e.g. Italy, Luxembourg), energy efficiency and promotion of renewables energies in DCs operations could be furtherly enhanced by switching mechanisms and schemes already existing from voluntary to mandatory for the stakeholders, by adding specifications and minor changes that could grant a wider application of positive schemes already in place. In expressing an opinion on the finding, the consulted stakeholders agreeing on the statement revealed that such measures could have indeed the greatest impact to unlock energy systems integration from all industries, not only DCs; while, on the other hand, the consultation revealed disagreement only regarding the point that introducing more legislation could add administrative burden.

iii. Main findings - Topic 3 "Urban Planning & Waste Energy Policies"

Policy Recommendations suggest that both at EU and at MS level, particularly in the implementation phase of regulations on waste energy resources, there are possibilities to introduce more detailed provisions to facilitate specifically the usage of waste energy from DCs. With specific regard to urban planning, at MS level virtuous existing regulatory models have been identified and could be successfully implemented in other MSs/Regions/Municipalities in order to contribute to the successful DCs integration into overall energy and systems. In expressing an opinion on the finding, the consulted stakeholders strongly agreed on the statement by providing important inputs: DCs operators face significant barriers to sharing their waste heat with third parties. Three barriers and potential solutions that policy makers could considered are: 1) lack of nearby heating network (local authorities should develop heating networks and work with DC operators and other industries to ensure those heating networks extend to these industrial facilities that can share waste heat); 2) Lack of nearby off takers for waste heat (local authorities can promote the development of adjacent activities that can act as off takers); 3) unclear obligations for heat providers (government authorities should develop a regulatory framework for heat recovery that does not penalise industries that cannot always make their heat available). While, on the other hand, the consultation revealed disagreement only with regard to the fact that regulators should focus on the need to develop network infrastructure and hear network in Member State such as the Netherlands.

A summary of the validated recommendations, categorised under these 3 main topics, is available in the table annexed to the present report.

iv. List of actions and potential policy recommendations

The categorisation of the policy recommendations under these 3 main topics (Incentives & Best Practices, Energy Consumptions & Renewables, Urban Planning & Waste Energy Policies) derived from the Matrix of Recommendations, led to the possibility to identify the related legal actions. The validations of both recommendations and legal actions allowed the categorisation of the legal actions under 3 areas of categorisation namely R&D,

Engagement, Cooperation of a proposed roadmap. Thanks to the categorisation of the legal actions under these 3 areas of the roadmap, related actionable advice have been identified, to be intended as actions that may help in the implementation of the proposed roadmap from the regulatory/policy point of view.

Thereafter, the study team formulated 19 actionable advice delineated across three areas of recommendation (R&D, engagement and coordination) to address the opportunities and limitations presented by the drivers and obstacles. The actions are formulated based on the 11 legal recommendations and eight non-legal actions based on soft measures to achieve the intended targets. The three areas of recommendation are:

- R&D highlights technological innovation in the data centre industry to enhance the energy efficiency and sustainability of data centres, such as water/heat reuse or innovative cooling techniques.
- Engagement focusses on encouraging collaborative efforts from all stakeholders relevant to the data centre industry.
- Coordination encompasses the harmonisation of efforts across multiple levels of policymaking, including the establishment of clear guidelines and regulations and the alignment of cross-level actors.

Each action is designed with a target in mind related to the Green Deal and Digital Decade goals of having extremely energy-efficient and climate-neutral data centres by 2030. The list of actions is presented in the table below.

Table 1: List of actions

Actionable Roadmaps	Actions	Target	Main Stakeholder
R&D	Roll-out of energy efficient hardware, software and other new practices	Industry-wide PUE of 1.3 (or 1.4 in warm climates) by 2025 for new DCs or by 2030 for existing DCs	DC operators
	Integration of water saving/reuse processes	Industry-wide WUE of 0.4 (or 0.5 in warmer climates) or below by 2030 for new DCs and 2040 for existing DCs	DC operators
	Integration of heat reuse practices	DCs to reuse as much heat as possible with regards to the heating demand from potential local heat off takers during certain times of the year. In regions where this is applicable, the minimum heat utilisation ratio of 0.1 as defined by the ERF should be reached by 2030.	DC operators
	Development and integration of 24/7 CFE	Industry-wide matching of electricity demand by 75% hourly and locally sourced carbon-free energy by 2025 and 100% by 2030	DC operators
Engagement	Engaging authorities and communities about the synergies between data centres and energy grids	Ensuring that 100% of authorities at all levels of governance in the EU dealing with DCs are aware of sustainable and energy efficient practices of DCs by 2030	Industry associations
Coordination	Adjustment of network charges and pricing signals to reflect new and large loads	Pricing models that accurately reflect systems costs from new and large loads and location specific costs for transmission and distribution, as well as pricing signals that encourage flexibility by 2030	Regulatory authorities
	Systematic integration of data centres into	DCs to be included in spatial planning processes and zoning ordinances at all levels of governance	Regulatory authorities

	policymaking and infrastructure planning	at the EU level by 2028 and at the national and local levels by 2030	
	Establishing clear regulatory frameworks and more coordination in policymaking	DCs/energy grids (water/heat/etc.) to be regulated through a specific provision in existing policy frameworks or through dedicated frameworks in a consistent manner across all levels of governance in the EU by 2030	Regulatory authorities

Similarly, the 11 **legal recommendations** are also clustered into the three areas of recommendations as above. These legal actions act in a complementary way to the eight actions as delineated in the table above to help with the implementation of the proposed roadmap from a regulatory/policy point-of-view. The grouping of the legal recommendations is presented in the table below.

Table 2: List of legal recommendations

Actionable Roadmaps	Actions	Target	Main Stakeholder
Engagement	Reviewing EU Code of Conduct and amend Best Practices guidelines	• Raise awareness, improve engagement and encourage a broader participation to the initiative; • Adapt the Best Practices to different conditions existing in different Member States; • Encourage transparency with the creation of a European Data Centre Registry.	Regulatory authorities
	Establishing incentive schemes based on EU Taxonomy Climate Delegated Act	• MS can create incentive schemes and make the access to the incentives conditional on compliance with useful European legislative acts, such as the Taxonomy, to promote engagement in virtuous activities and encourage the adoption of good practices; • EU can incentivise the implementation of legislative and non-legislative acts that facilitate the integration of DCs into energy systems by cross-referencing them in other (binding) legislative instruments.	Regulatory authorities
	Revising the Energy Taxation Directive	• EU to the implement a revision of the ETD - as set out by the proposal of COM (2021) 550 - in order to sustain DCs that are struggling to convert to the use of less polluting energy sources, due to geographical and economic reasons. In particular, the introduction of the system proposed may lead to tax breaks and provides incentives to DCs operators for using more renewables and clean energy, within the limits indicated by the proposal; • To favour and promote the engagement in sustainable operations and good practices, EU to include relevant taxation incentives for energy recovery at DCs in order to ensure a minimum level of harmonisation at MSs level in the taxation rates that may impact DCs operations and to search for alignment with the EED.	Regulatory authorities
	Developing French regulatory framework	• When it comes to wastewater, France (similarly to the EU and many other Member States) shall develop the regulatory framework relevant for DCs from various perspectives; • As for energy legislation, France shall strengthen and better develop the already existing useful initiatives.	Regulatory authorities
	Developing Italian regulatory framework	• Introduce measures that could favour energy efficiency, however they should be enhanced or modified to better address DCs and related concerns (i.e. waste heat and wastewater);	Regulatory authorities

		• Introduce more specific legislative instruments or, at least, specific provisions concerning DCs in existing energy-related plans and legislation; • Introduce measure to adhere to the specific regulatory competences at different governmental level (e.g. considering central competence of the State Government for energy and taxation schemes) and local (municipalities) competences for urban planning.	
Coordination	Mandating the application of GPP Criteria for DCs	• EU to make it mandatory for DC operators to apply requirements sets out in the EU Green Public Procurement (GPP) criteria for Data Centres, Server Rooms and Cloud Services (Joint Research Centre, 2020), to ensure an higher level of coordination and harmonisation in the application of the criteria in procurement procedures; • This, by evaluating if necessary an amendment of Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement, to make the application of GPP criteria explicit to DCs; • For compliance purposes, EU to consider the relevance of the JRC document to be updated and adapted to technological development, in order to ensure that other mechanisms, requirements, standards, are correctly harmonised with this new proposed mandatory approach.	Regulatory authorities
	Developing Electricity Market Regulation	• Complete the current regulatory framework on the electricity market by introducing more specific and detailed provisions on renewable and recovery energies, including at the early stage of grid planning; • Introduce a set of principles to clarify how to effectively and concretely apply the non-discrimination principle to DCs in order to protect them against measures that can unfairly limit their access to energy supplies. Reinforcing the non-discrimination where already defined (e.g. non-discrimination for congestion management solutions, grid access, etc.).	Regulatory authorities
	Revising Regulation on minimum requirements for water reuse	• Implementation guidelines to be revised by the EU Commission as from 2023 until 2028 to start with and then assessment of the need for more detailed provision in the regulation, considering that the legislative framework concerning the reuse of wastewater is still underdeveloped; • If the evaluation has positive outcomes, the EU could either amend the current regulations or decide to implement new legislative instruments to complete the current framework as part of the review process (art. 12 of the Water Reuse Regulation); • JRC to develop specific guidance for DCs, as already foreseen and provided for other industry sectors.	Regulatory authorities
	Coordinating legislation to Luxembourg example	To promote the widening of the scope of application of the positive schemes already implemented in the Luxembourg legislations.	Regulatory authorities
	Coordinating legislation to Germany example	Initiatives that are particularly advanced, such as those concerning urban planning, should therefore be promoted in order to further expand their effects.	Regulatory authorities
	Coordinating legislation to the Netherlands example	Suggest national governments of EU MS to take into account the same elements included in these Dutch legislations to allow the sustainable development of DCs, by considering their specific needs, territories and resources at national level	Regulatory authorities

Annex 1: Regulatory analysis

The tables below summarise main outcomes of the regulatory analysis performed under task 2.1, both at EU and MS level, reporting divers, obstacles potential opportunities and the subsequent potential recommendations extracted and derived from the various pieces of legislation analysed.

EU PERSPECTIVE

Table 3: Drivers, obstacles and potential opportunities detected in EU legislation

EU policies / legislations	Type of legislative / regulatory / policy instrument	Brief description of contents	Drivers	Potential Opportunities	Obstacles
Code of Conduct for Energy Efficiency in Data Centres	Code of conduct	The Code of Conduct encourages data centre operators and owners to minimise energy consumption through a list of best practices.	Energy efficiency.	• Raise awareness; • provide an open process and debate space; • assist stakeholders in developing and supplying cost effective and energy saving technologies, by suggesting best practices; • creating a set of simple measures for the current efficiencies and progress; • develop a set of principles that are consistent; • assist with procurement (through a reference to the Code of Conduct in the Taxonomy Regulation); • possibility to be qualified as an ecologically sustainable economic activity, through the references to the Code of Conduct contained in the Taxonomy Regulation. • possibility for the Code of Conduct to become a benchmark/point of reference for best practices (in absence of harmonised standards), through references to the CoC in other pieces of legislation (i.e Taxonomy Regulation).	• Ineffective implementation; • Insufficient guidance.

Regulation on ecodesign requirements - servers and data storage products	Legislative act	The Regulation sets out ecodesign requirements for placing servers and online data storage products on the market and for putting them into service.	Sustainability and reduction of energy consumption.	• Harmonise standards and promote product compliance control procedures; • drive market transformation, create new business opportunities and stimulate economic growth in the EU; • reduce energy consumption and gas emissions; • foster positive financial implication for manufacturers.	• Compliance costs.
Electricity Market Regulation	Legislative act	The Electricity Market Regulation creates a basis for the efficient development of the climate and energy objectives, It also sets out the fundamental principles for the creation of a functioning and integrated energy market, to establish fair rules for the cross-border exchange of electricity and to facilitate the creation of a well-functioning and transparent wholesale market.	Energy efficiency and management of energy supply.	• The existence of a clear and well-regulated legislative framework regarding energy markets is beneficial to data centres, considering it allows them to conduct and plan their activities in a legal environment characterised by clearly identified rules; • the non-discrimination principle benefits data centres insofar as it protects them from possible unfair decisions regarding capacity allocation; • the adoption of provisions targeted at resolving congestion problems may be of particular benefit to data centres, considering that in some past cases their connection to the electricity grid has been denied specifically because of congestion problems.	N/A
Electricity Market Directive	Legislative act	The Directive establishes common rules for generation, transmission, distribution, energy storage and supply of electricity. It aims at creating an integrated, competitive, consumer-centred, flexible, fair and transparent electricity market.	Grid planning and consumer protection	• The existence of a legislative framework is beneficial to data centres insofar as it allows them to program and develop their activities within clear and specific rules; • the definition of planning requirements for TSOs and DSOs that involve notably key grid users like DCs; • the focus on avoiding discrimination is positive to data centres because it protects them against measures that can unfairly limit their access to energy supplies; • in regulating congestion management, the Directive incentivises objectives, such as energy efficiency, demand response, energy storage and the improvement of flexibility services, whose pursuit favours data centres; • the guarantee of non-discrimination, transparency and of the use of market-based	N/A

				procedures in providing flexibility services is a source of beneficial opportunities for data centres, considering that it protects them from being the target of discriminating measures, therefore allowing them to benefit from them; • in protecting consumers from discrimination concerning the activities of transmission system operator, the Directive indicates that consumers cannot be refused a connection for future possible limitation or congestion in distant parts of the system. Such a provision is particularly significant for data centres and their full integration into energy systems, considering it protects them from being refused a connection because of concerns generated by data centres in other areas or for the future tenure of the system.	
EU Taxonomy Regulation and the Climate Delegated Act	Legislative act	The Taxonomy Regulation provides criteria to determine deciding whether an economic activity qualifies as ecologically sustainable.	Sustainability and Common criteria to define if economic activities and investments are ecologically sustainable	• Possibilities for data processing, hosting, and related activities to qualify as environmentally sustainable activities by complying with the common criteria provided for in the Regulation and the technical screening criteria provided for in delegated act, allowing them to benefit from economically sustainable investments; • the integration of data centres into overall energy and water systems is one of the technical screening criteria used to determine whether data processing, hosting, and related operations qualify as environmentally sustainable economic activities under the Regulation.	N/A
Corporate Social Responsibility Directive	Legislative act	The Directive (CSRD) introduces obligations related to sustainability reporting and applicable to large, small and medium-sized undertakings (with the exception of micro undertakings). It covers a wide range of topics, including environment, social and human factors.	Promotion of environmental sustainability	• Raise awareness within the industry; • the knowledge of relevant data and information can aid legislators in elaborating standards and initiatives that can be useful for the integration of data centres into energy and water systems; • the exchange of data can lead to an increase in cooperation between data centre operators, governmental entities and other private entities.	• The information reported must be interpreted considering the many differences between data centres located in areas with different environmental conditions and varying levels of access to resources. Interpreting and reporting data not considering this

					aspect might create obstacles for data centres, particularly with regard to their credibility vis-à-vis the consumers and to the introduction of standards and requirements that do not differentiate sufficiently between data centres operating in different conditions; • the Directive is applicable only to a limited number of data centres, considering that its scope of application only includes companies that exceed specific turnover thresholds or sizes.
Regulation on minimum requirements for water reuse	Legislative act	The directive sets out minimum requirements for reusing urban wastewater in agricultural irrigation	Integration of data centres in water systems.	• Data centres can be identified as sources of potentially useful wastewater.	N/A
EU Green Public Procurement (GPP) criteria for Data Centres, Server Rooms and Cloud Services	Publication by the Commission Joint Research Centre	The Green Public Procurement (GPP) criteria for Data Centres, Server Rooms and Cloud Services is a technical report which indicate specific criteria for green public procurement in the data centre industry.	Energy efficiency and reduction of the carbon footprint of data centres.	• Providers may need to invest in upgrading their facilities and equipment to meet the criteria, potentially leading to long-term savings on energy costs. • meeting the GPP criteria can increase the competitiveness of providers in the market, as more and more public procurers are seeking environmentally friendly services; • GPP criteria can also lead to increased innovation in the sector resulting in new and improved products and services being made available to the market; • GPP criteria provided for data centres represent an important guidance for public authorities,	N/A

				who have to concretely apply the rules concerning green procurement.	
Buying green! A handbook on green public procurement	Guidance document	The Handbook is the European Commission's guidance aimed at helping public authorities purchase goods and services with a lower environmental impact.	Sustainability.	• Reduction in energy consumption; • improved resource management; • increased innovation; • increased competition; • improved public perception.	• Increased costs; • lack of standardisation; • lack of availability; • resistance to change.
Proposal for revisions of the Renewable Energy Directive	Legislative act	The revision of the Renewable Energy Directive is aimed at encouraging an increase in the use of renewable energy in heating, cooling and buildings.	Energy efficiency and increasing the use of renewable energies.	• By encouraging the development of efficient district heating and district cooling infrastructure, the revision of the Directive can benefit the integration of data centres in the system as energy consumers and heat producers.	N/A
Energy Taxation Directive and Proposal for the revision of the Directive (COM (2021)550)	Legislative act	The revision of the Energy Taxation Directive has as its objective to facilitate the transition from inefficient and polluting fuels to cleaner fuels.	Structural rules and minimum excise duty rates for the taxation of energy products.	• Taxation rate that are adapted to the environmental impact (e.g. tax breaks for DCs operators that use more renewable and clean energy) and tax rate more favourable to recovery energies can encourage the use of waste heat from data centres, thus favouring their integration in energy systems.	N/A
Directive of the European Parliament and of the Council on energy efficiency (recast)	Legislative Act	The Directive was conceived to achieve the 2030 climate target. It promotes "energy efficiency first" as an overall principle of EU energy policy and marks its importance and relevance in both its practical applications in policy and investment decisions.	Energy efficiency	• The introduction of sustainability indicators for data centres, if disseminated among data centre users, entities and organisations deploying cloud and data centre services, allows easier monitoring of data centres energy consumption; • obliging Member States to ensure that data centres recover excess heat and deliver it to the district heating network, unless not technically or economically feasible, contributes to the reuse of waste heat and the integration of data centres in energy systems.	N/A
REPowerEU plan by the European Commission	Policy plan	The REPowerEU Plan is aimed at further reducing the EU's dependence on Russian fossil fuel imports.	Energy efficiency	• Adoption of energy-efficient technologies; • reduction of overall energy consumption; • reduction of the EU's dependence on Russian fossil fuels.	N/A
Green Digital Coalition	Industry initiative supported by the EU authorities	The European Green Digital Coalition (EGDC) was founded by 26 CEOs of ICT companies who signed a	Green digital solutions	• Reduce energy consumption and emissions; • The implementation of consistent and comparable assessment methods.	N/A

		Declaration on Digital Day 2021 to support the EU's Green and Digital Transformation efficiency.			

Table 4: Summary of main potential recommendations for further improving the EU regulatory framework

N.	EU policies/legislations	Potential recommendations	Term
1	**Code of Conduct**	• increase the degree of value assigned to best practices related to the reuse of excess heat and water (e.g. paragraphs 1.3.3.7, 1.3.6.2 and 1.3.6.3), to raise the level of awareness among participants; • foresee additional benefit, alongside those already implemented (e.g. Code of Conduct promotion campaign, granting public recognition for participants for their efforts, EU Code of Conduct awards), to increase the number of participants who commit to best practices. Additional benefits may include financial support for participants who achieve the best results; and • rethink and organise the best practices (existing or new) taking into account regional/state-to-state differences in climate, access to renewable energy sources and business models which vary across the European Union (since e.g., to an operator located in a particular region, in order to implement the best practices, more efforts both in economic and organisational terms might be required in respect of operators in areas where environmental/economic/fiscal/regulatory conditions are more favourable, e.g., being located closer to renewable energy sources, having more taxation and financial support from local policies); and • foresee the creation of a European Data Centre Registry, to report energy consumption and material use transparently, useful in verifying the effective implementation of best practices and raising awareness of energy conservation. Considering that the practices have been drafted with the integration into energy and water system as an objective, it is evident that the Code of Conduct creates several potential opportunities for the achievement of this objective.	**Short**
2 and 3	**Electricity Market Regulation (Regulation (EU) 2019/943)**	• Include provisions explicitly mentioning recovered energy sources; • introduce specific provisions and principles regarding how to effectively apply the non-discrimination principle, particularly in cases of congestion, for instance, through implementing acts the Commission has the delegated power to adopt.	**Medium**
4	**EU Taxonomy Climate Delegated Act (Commission Del. Regulation (EU) 2021/2139)**	• Create, particularly at the Member States level, fiscal incentive schemes that are conditional upon the planned activity qualifying as sustainable under the Taxonomy framework to support and promote practices (i.e energy efficiency, management of water resources, reuse of waste heat, reuse of wastewater) that facilitate the integration of data centres in energy systems; • Include - into technical screening criteria for determining whether data processing, hosting, and related activities cause no significant harm ('DNSH') to climate change mitigation (listed in Annex II of Commission Delegated Regulation (EU) 2021/2139) - that the activity has been carried out in compliance with selected practices foreseen in the most recent version of the European Code of Conduct on Data Centre Energy Efficiency and not just the best practices with the maximum value of 5.	**Medium**
5	**Regulation on minimum requirements for water reuse (Regulation (EU) 2020/741)**	It can be recommendable, particularly in the implementation phase of the Regulation, introduce more detailed provisions to facilitate specifically the usage of wastewater supplied from data centres.	**Short**
6		A switch from voluntary to mandatory application of the GPP core criteria for publicly procured data centres and cloud services can be recommended, in order to both encourage the green transition of data centres and cloud computing	**Medium**

	GPP criteria for Data Centres, Server Rooms and Cloud Services	services in general and to provide an important signal to authorities to put the words into practice in their own areas of operation. Although the private market segment is considerably larger than the public one, and populated by several stakeholders having different capacities/possibilities to meet GPP criteria, the public sector has the potential to reach a critical mass and take the lead in the data centres and cloud services segment, given the growing digitalisation of government services. Moreover, it's crucial that small data centres have equitable access to the public data centre procurement market in the EU.	
7	**Energy Taxation Directive (Council Directive 003/96/EC) and COM (2021)55**	Implementation of the ETD as set out by the proposal of revision. Despite the fact that implementation of the proposed regime can impact data centres struggling to convert to the use of less polluting energy sources (geographical and economic reasons), the introduction of the system proposed by COM(2021) 550 may lead to tax breaks and provides incentives to data centres operators for using more renewable and clean energy, within the limits indicated by the proposal, consequently creating beneficial effects to the scope of the project.	**Medium**

MSs PERSPECTIVE

Table 5: Drivers, obstacles and potential opportunities detected in the legislation of the six selected MS

MS	Drivers	Potential Opportunities	Obstacles
FRANCE	1. Energy efficiency; 2. protection of the environment; 3. valorisation of waste heat; 4. diversification of energy resources; 5. reduction of energy consumption.	1. Promotion of energy efficiency; 2. promotion of measures regarding the reutilisation of waste heat; 3. promotion of measures aiming at strengthening the energy infrastructure (heat and cold networks); 4. conditionality of incentives and benefits on the adoption of energy efficient measures; 5. management of water resources.	1. Additional costs: 2. uncertainties and lack of clarity in relation to the interpretation of legal rules; 3. danger of unfairly targeting data centres.
GERMANY	1. Energy efficiency; 2. spatial planning; 3. reduction in energy consumption.	1. Promotion of waste heat recovery; 2. encouragement of a sustainable use of resources; 3. promotion of energy efficiency.	1. Difficulties in meeting criteria; 2. lack of renewable energy sources; 3. infrastructural fragilities creating difficulties for the reutilisation of recovery energies.
IRELAND	1. Data innovation; 2. energy efficiency; 3. green transition; 4. strengthening of the energy infrastructure; 5. management of electricity demand.	1. Promotion of the use of renewable and recovery energy sources; 2. promotion of measures to reduce energy consumption; 3. promotion of measures to increase energy efficiency; 4. encouragement of measures promoting flexibility of demand; 5. introduction of measures for the reutilisation of waste heat.	N/A
ITALY	1. Energy efficiency; 2. development of sustainable and renewable energy sources; 3. digitalisation; 4. reduction of finale energy consumption.	1. Promotion of energy efficiency through measures; 2. use of financial incentives to promote energy efficiency; 3. promotion of waste heat recovery.	1. Lack of specificity of the measures leading to uncertainties regarding their interpretation; 2. limited scope of application of potential useful measures; 3. lack of coordination between different government levels.
LUXEMBOURG	1. Energy efficiency; 2. increase in the use of renewable energies; 3. sustainability; 4. protection of the environment;	1. Use of financial incentives to promote energy efficiency; 2. promotion of the reutilisation of waste heat; 3. promotion of the strengthening of the digital infrastructure; 4. possibility of benefitting from various aids;	1. Favourable taxation schemes benefitting data centres indiscriminately (without considering energy efficiency and sustainability); 2. possible inappropriate use of planning measures;
THE NETHERLANDS	1. Waste heat recovery; 2. energy network; 3. digitalisation of the economy; 4. management of energy resources; 5. spatial planning; 6. sustainability;	1. Measures favouring the reuse of waste heat; 2. strategic use of land planning to reduce energy consumption and manage water resources.	N/A

Table 6: Potential recommendations for further improving the legislation in the six selected MSs

N.	MS	Legislation /Policy	Potential Recommendations	Term
1	FRANCE	Environmental Taxation in France	The legislation gives space to introduce deductions in water fees associated to the adoption of good practices, finalised at reusing wastewater.	Medium
2	FRANCE	Heat Funds	A potential recommendation is to allocate a higher percentage of resources to the fund, consequently creating and implementing more projects, financing more actors and favouring the integration of DCs into energy system.	Medium
3	FRANCE	Urban Planning Code	It is recommendable to clarify the classification of DCs according to the Urban planning code, but also to clarify the scope of the laws referring to the Urban planning code in order to define whether or not the tax breaks referred to apply to DCs.	Medium
4	FRANCE	Information report n° 555 (2019-2020)	A potential recommendation may be to foster the implementation of the Report's policy strategy at different governmental levels, such as regional and local levels.	Long
5	GERMANY	Frankfurt's Commercial Space Development Program (2021)	A recommended action would be to consider the Frankfurt's Commercial Space Development Program as a model to imitate and transpose it in other cities. This may create opportunities for data centres in respect of the scope of the project and, therefore, may contribute to the successful data centre integration into overall energy and water systems.	Long
6	ITALY	Italy Energy Strategy	A possible recommendation can be to expand the number of mandatory participants to the "White Certificates" scheme to include private entities, including data centres, whose current participation is voluntary.	Medium
7	ITALY	National Energy and Climate Plan	Strongly advise data centres stakeholders to prefer locations close to densely populated urban centres to align with the measures envisaged in the Plan.	Short
8	ITALY	National Energy and Climate Plan	Expand and facilitate access to *the "White Certificates*" and the "*Conto Termico*" schemes.	Medium
9	ITALY	National Energy and Climate Plan	increase the capacity of the National Fund for Energy Efficiency, directing the scheme to the promotion of measures dedicated to the Data, Information and Technology sector.	Short
10	ITALY	State budget for the financial year 2022 and multi-year budget for the three-year period 2022-2024	Include programming measures with a higher degree of specificity regarding efficient practices, perhaps mentioning explicitly the use of heat waste, and addressed at a broader category of enterprises.	Short
11	ITALY	National Recovery and Resilience Plan	Introduce new measures or modify the scope of the current one to better favour energy efficiency in cities other than metropolitan cities.	Medium
12	LUXEMBOURG	Law of 15 December 2020 relating to the climate	A possible recommendation can be to explicitly include amongst the objectives for which the fund is granted projects concerning recovered energy sources.	Short
13	LUXEMBOURG	Law on the electricity market	Since the exemption that - depending on the correct interpretation of "storage purposes" according to Luxembourg laws - can benefit significantly data centres, it	Medium

			would be recommendable to introduce conditions to the exemption. These conditions can perhaps introduce minimum requirements concerning energy efficiency or specific obligations to adopt good practices.	
14	**LUXEMBOURG**	**Bissen's General Development Plan**	In light of the analysis and the identified opportunities, a recommended action may relate to the adoption of local regulatory acts as the Bissen's PAG, providing for similar policies in relation to local needs.	**Long**
15	**THE NETHERLANDS**	**National Strategy on Planning**	A recommendation emerging from the national policies and the related opportunities is to suggest national governments of EU MSs (in any case considering their specific needs, territories and resources at national level) to take into account the same elements included in these Dutch legislations to allow the sustainable development of DCs.	**Long**

Annex 2: Identified drivers and obstacles

The drivers and obstacles for integrating data centres into the energy systems build upon the findings of previous parts of the study and are categorised into four thematic barriers: namely energy infrastructure (consumption, transmission and reuse), technical innovation, social and environmental (corporate sustainability reporting/corporate commitment/reputation/ shareholder commitment/community/local level approach) and regulatory framework. The policy recommendations then aim to address with regards to the potential opportunities and/or limitations on the synergies between data centres and energy systems.

The table below presents a matrix of identified drivers/obstacles and the thematic barriers.

Table 7: List of drivers/obstacles structured by thematic barriers

Drivers/Obstacles	Energy infrastructure	Technical innovation	Social and environmental	Regulatory framework
Development of new energy efficiency data centre practices		X		
Liquid cooling in data centres	(X)	X		
Water reuse	X			
Low temperature heat network	X			
Interconnection and network charges should reflect the location and/or system costs associated with new and large loads	(X)			X
Promotion of sustainable and energy efficient data centres in line with rising environmental concerns			X	
New certificates for 24/7 green energy			(X)	X
Increasing popularity of 24/7 CFE approach			X	
Increasing digitalisation driving up the demand for data centres and their rising energy consumption	X		(X)	
The need for specific and clear regulatory framework on the synergies between data centres and energy networks	(X)			X
The need coordination between different levels of policymaking	(X)			X
Financial incentives for grid support	(X)			X
New market opportunities	X			(X)
Consideration of locations with free cooling opportunities to relieve electricity and water grids	X			

Note: X signifies the primary thematic barrier that a driver/obstacle intersects with, while (X) indicates the secondary thematic barrier related to the driver/obstacle.

Annex 3: Matrix of recommendations

The tables below summarise the validated recommendations ad part of the Matrix of recommendations under task 5.1, categorised under the 3 Main Findings – Topics emerged (**Incentives & Best Practices, Energy Consumptions & Renewables, Urban Planning & Waste Energy Policies**).

Please note that, for the purposes of the table below, the final validated recommendations (11) have been grouped around single regulatory acts analysed when related to the EU regulatory frameworks and have been grouped around the single MSs when related to national legislations, in this case not considering a specific acts analysed at national level but merging together the underling rationale and main outcomes derived from the MSs regulatory analysis performed during the project.

The categorisation of the policy recommendations under the 3 main topics derived from the Matrix of Recommendations, led to the possibility to identify related legal actions. The validations of both recommendations and legal actions allowed the categorisation of the legal actions under 3 areas of categorisation, namely **R&D, Engagement, Cooperation**, of a proposed roadmap. Thanks to the categorisation of the legal actions under these 3 areas of the roadmap, related actionable advice have been identified and are to be intended as actions that may help in the implementation of the proposed roadmap from the regulatory/policy point of view.

Table 8: Matrix of recommendations and legal advice

EU/MSs acts, policies, legislations	Matrix of Recommendations	Main Findings - Topics	Actionable advice	Area of the Actionable Advice Roadmap
EU Code of Conduct	**i. Origin:** EU **ii. Act:** EU Code of Conduct **iii. Previously Validated Recommendations: i)** Increase the degree of value assigned to best practices related to the reuse of excess heat/water to raise the level of awareness among participants; **ii)** Foresee additional benefits alongside those already implemented (e.g. Code of Conduct promotion campaign, granting public recognition for participants for their efforts, EU Code of Conduct awards), to increase number of participants who commit to best practices. Additional benefits may include financial support for participants who achieve the best results; **iii)** Rethink and organise the best practices taking into account regional/state-to-state differences in climate, access to renewables and business models which vary across the EU (since e.g., to an operator located in a particular region, in order to implement the best practices, more economic and organisational efforts might be	**Incentives & Best Practices**	**Review the EU Code of Conduct and amend Best Practices guidelines** in order to raise awareness and encouraging broader participation and engagement to the initiative, adapting Best Practices to different conditions and encouraging transparency. To do it, normal steps to be taken are those annually adopted for the revision of the Code of Conduct and for the Best practices. For the creation of a European Data Centre Registry, it should be taken into account that a registry that may contribute to raise awareness, engagement and support and that can ensure transparency in the data available should be developed in compliance with regulatory framework pertaining sensitive information and/or covered by security	**Engagement**

	required in respect of operators in areas where environmental/economic/fiscal/regulatory conditions are more favourable, e.g., being located closer to renewables sources, or having more taxation and financial support from local policies); **iv)** Foresee the creation of a European DC Registry, to report energy consumption and material use transparently, useful in verifying the effective implementation of best practices and raising awareness of energy conservation. Considering that the practices have been drafted with the integration into energy and water system as an objective, it is evident that the Code of Conduct creates several potential opportunities for the achievement of this objective. **iv. Legal actions:** EU institutions to consider reviews and amendments to the Best practices guidelines as part of annual review process and, ultimately, of the Code of Conduct, in order to: 1. Raise awareness and encourage a broader participation; 2. Adapt the best practices to different conditions existing in different Member States; 3. Encourage transparency with the creation of a European Data Centre Registry, that can contribute to raise awareness and support and to ensure transparency, to be developed in respect to sensitive information covered by security issues (alignment with the Critical Entities Resilience Directive shall be assessed). **v. Term/timeline:** short. Feasibility: high thanks to Best practices document annual review process and to wide participation of DCs involved. **vi. Issues addressed:** the recommendation and action address potential issues, ineffectiveness or insufficient guidance in relation to the implementation phase of the Code of Conduct. **vii. Stakeholders:** EU institutions		issues. The alignment with the Critical Entities Resilience Directive must be assessed.	
EU Taxonomy Climate Delegated Act	**Origin:** EU / Member States **ii. Act:** EU Taxonomy Climate Delegated Act (EC Delegated Regulation (EU) 2021/2139) **iii. Previously Validated Recommendations: i)** Create, particularly at the MSs level, fiscal incentive schemes that are conditional upon the planned activity qualifying as sustainable under the Taxonomy framework to support and promote best practices (i.e. energy efficiency, management of water resources, reuse of waste heat, reuse of wastewater) that facilitate the integration of DCs in energy systems; **ii)** Include into technical screening criteria – used for determining whether data processing, hosting, and related activities cause no significant harm (DNSH) to climate change mitigation (as listed in Annex II of the Reg. – that the activities have been carried out in compliance with selected practices foreseen in the most recent version of the EU Code of Conduct on Data Centre Energy Efficiency and not just the best practices with the maximum value of 5. **iv. Legal actions:** i) Member States can create incentive schemes and make the access conditional on compliance with useful European legislative acts, such as the Taxonomy, to encourage the adoption of virtuous practices; ii) the European Union can incentivise the implementation of legislative and non-legislative acts that	**Incentives & Best Practices**	**Create incentives based on EU Taxonomy Climate Delegated Act** in order to make the access to incentive scheme conditional on compliance with useful EU legislative acts, such as Taxonomy, to engage and encourage industry participants to adopt virtuous practices. To do it, in compliance with principles for the allocation of competences in the EU, MSs shall promote at national level taxation/fiscal incentive schemes that are conditional upon a certain DCs activity qualifying as sustainable under the Taxonomy framework, in order to support and promote good practices (i.e energy efficiency, management of water resources, reuse of waste heat, reuse of wastewater); it may be also necessary to revise the Taxonomy act by including - into technical screening criteria for determining whether DCs activities cause no significant harm ('DNSH') to climate change mitigation - that the activity has been carried out in compliance with selected practices foreseen in the most recent version of	**Engagement**

	facilitate the integration of data centres into energy systems by cross-referencing them in other (binding) legislative instruments. **v. Term/timeline:** medium **vi. Issues addressed:** rather than addressing issues and obstacles, the recommendation and action are based on potential opportunities given by the Act: i) at MSs level, it suggests the potential usefulness of creating incentive schemes based on compliance with the act; ii) at EU level, it suggests the possibility of inserting references to the act in other legislative instruments that are applicable to DCs. **vii. Stakeholders:** EU and MSs institutions		the European Code of Conduct on Data Centre Energy Efficiency.	
EU GPP criteria for Data Centers, Server Rooms and Cloud Services	**i. Origin:** EU **ii. Act:** GPP criteria for Data Centers, Server Rooms and Cloud Services **iii. Previously Validated Recommendations: i)** Switch from voluntary to mandatory application of the GPP core criteria for publicly procured DCs and cloud services, in order to both encourage the green transition of DCs and cloud computing services in general and to provide important signals to authorities. **ii)** Although the private market segment is considerably larger than the public one and populated by several stakeholders, having different capacities/possibilities to meet GPP criteria, the public sector has the potential to reach a critical mass and take the lead in the DCs and cloud services segment, given the growing digitalisation of government services. **iii)** Moreover, it's crucial that small DCs have equitable access to the public DCs procurement market in the EU. **iv. Legal actions:** EU to i) to make it mandatory to apply the requirements sets out in the EU Green Public Procurement criteria for DCs, Server Rooms and Cloud Services; 2) this, by evaluating if necessary an amendment of the Prurient Directive to make the application of GPP criteria explicit to DCs; 3) for compliance purposes, considering the relevance of the JRC document to be updated and adapted to technological development to ensure that other mechanisms, requirements, standards, are correctly harmonised with this new proposed mandatory approach. **v. Term/timeline:** medium. **vi. Issues addressed**: recommendation al legal action assess at the possibility of positive outcomes for the integration of data centres based on a broader application of GPP criteria. **vi. Stakeholders:** EU institutions	**Incentives & Best Practices**	**Mandate the application of the requirements sets out in the EU Green Public Procurement** (GPP) criteria for DCs, Server Rooms and Cloud Services to promote coordinated criteria in procurement procedures. To do it, it is necessary to take the normal legislative procedural steps for the revision of Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement; the updating of COM(2008) 397, Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan and COM(2003) 302, Integrated product to be harmonized accordingly and to adapt and update of the JRC document.	**Coordination**
EU Energy Taxation Directive	**i. Origin:** EU **ii. Act(s):** Energy Taxation Directive (Council Directive 003/96/EC) and COM (2021)55 **iii. Previously Validated Recommendations: i)** Implementation of the ETD as set out by the proposal of revision. **ii)** Despite the fact that implementation of the proposed regime can impact DCs struggling to convert to the use of less polluting energy sources (geographical and economic reasons), the introduction of the system proposed by COM(2021) 550 may lead to tax breaks and provides	**Incentives & Best Practices**	**Revise the Energy Taxation Directive** in order to Promote the adoption of the revised ETD to include relevant incentives for energy recovery at DCs, to promote engagement in virtuous initiatives and ensure minimum harmonisation level among MSs in the taxation rates. To do it, EU shall implement a revision of the ETD - as set out by the proposal of COM(2021) 550 - in order to sustain DCs that are struggling to convert to the use of less	**Engagement**

	incentives to data centres operators for using more renewable and clean energy, within the limits indicated by the proposal, consequently creating beneficial effects to the scope of the project. **iv. Legal actions**: The proposed revision of the ETD includes relevant incentives for energy recovery at DCs; this provision should be kept and implemented; the EC should foresee quick implementation of the Directive as amended, in order to ensure a certain level of minimum harmonisation at MSs level in the taxation rates that may impact DCs operations and to search for alignment with the EED. **v. Term/timeline:** medium **vi. Issues addressed**: recommendation and action are related to the proposal for a revision of the Directive. The proposed changes are deemed conducive to the integration of DCs into energy systems, as they address more broadly renewable and recovery energy. **vii. Stakeholders:** EU institutions		polluting energy sources, due to geographical and economic reasons. In particular, the introduction of the system proposed may lead to tax breaks and provides incentives to DCs operators for using more renewables and clean energy, within the limits indicated by the proposal. To favour and promote the engagement in sustainable operations and good practices, EU shall include relevant taxation incentives for energy recovery at DCs in order to ensure a minimum level of harmonization at MSs level in the taxation rates that may impact DCs operations and to search for alignment with the EED.	
France regulatory framework	**i. Origin:** Member State (France) **ii. Act(s):** 1. Environmental Taxation framework; 2. Heat funds; 3. Information report n° 555 (2019-2020) **iii. Previously Validated Recommendations:** i) France legislation gives space to introduce deductions in water fees associated to the adoption of good practices, finalised at reusing wastewater. ii) A potential recommendation is to allocate a higher percentage of resources to the French heat fund, consequently creating and implementing more projects, financing more actors and favouring the integration of DCs into energy system. iii) It is recommendable to clarify the classification of DCs according to the Urban planning code, but also to clarify the scope of the laws referring to the Urban planning code in order to define whether or not the tax breaks referred to apply to DCs. iv) A potential recommendation may be to foster the implementation of the Report's policy strategy at different governmental levels, such as regional and local levels. **iv. Legal actions:** When it comes to wastewater, France (similarly to the EU and many other Member States) needs to further develop the regulatory framework relevant for DCs (for example, legislation on Internal Tax on final energy consumption, TICFE, still lack of deductions in water fees associated to the adoption of practices focused on reusing wastewater). In France's case, the recommended action is to start by adding to the environmental taxation framework new dedicated initiatives for DCs. As for energy legislation, there are already useful initiatives, but they need to be strengthened and better developed (for example by pouring more resources in positive initiatives, clarifying ambiguous aspects and foster a better coordination between different governmental levels). **v. Term/timeline:** medium/long **vi. Issues addressed**: recommendations address various concerns identified in the French regulatory framework, such as the underdevelopment of the legislative framework and the need to strengthen and further clarify current provisions.	**Incentives & Best Practices**	**Develop the French regulatory framework for wastewater,** adding to environmental taxation regulatory framework new dedicated initiatives to promote useful initiatives for DCs. In order to do it, it necessary to implement the normal steps foreseen by the French regulatory framework for the revision of regulatory acts analysed and involved.	**Engagement**

	vii. Stakeholders: MSs institution (France)			
EU Electricity Market Regulation	**i. Origin: EU** **ii. Act: Electricity Market Regulation (Regulation (EU) 2019/943)** **iii. Previously Validated Recommendations: i)** Include provisions explicitly mentioning recovered energy sources. **ii)** Introduce specific provisions and principles regarding how to effectively apply the non-discrimination principle, particularly in cases of congestion, for instance, through implementing acts the Commission has the delegated power to adopt. **iv. Legal actions:** EU to adopt new acts (for example, implementing acts to the current regulations and directives) in order to: i) complete the current regulatory framework on the electricity market by introducing more specific and detailed provisions on renewable and recovery energies, including at the early stage of grid planning; ii) introduce a set of principles to clarify how to effectively and concretely apply the non-discrimination principle to DCs in order to protect them against measures that can unfairly limit their access to energy supplies. **v. Term/timeline:** medium/long **vi. Issues addressed**: i) the lack of specific provisions concerning recovery energy sources (such as waste heat). The reasoning is that more explicit provisions could be beneficial for DCs; ii) the regulatory framework on the discrimination principle could be further developed through the adoption of delegated acts. **vii. Stakeholders:** EU institutions	**Energy Consumptions & Renewables**	**Complete the current regulatory framework on the electricity market** by introducing more specific and detailed provisions on renewable and recovery energies to promote coordination in rates and fees. to implement such action, it is necessary to procedure for adoption of delegated acts under the Electricity Directive and revision of network codes/guidelines as possible way forward with particular attention to legislative competences and legal basis.	**Coordination**
Italy regulatory framework	**i. Origin:** Member State (Italy) **ii. Act(s):** 1. Italy Energy Strategy; 2. National Energy and Climate Plan; 3.National Energy and Climate Plan; 4.National Energy and Climate Plan; 5.State budget for the financial year 2022 and multi-year budget for the three-year period 2022-2024; 6.National Recovery and Resilience Plan. **iii. Previously Validated Recommendations: i)** Expand the number of mandatory participants to the "White Certificates" scheme to include private entities, including DCs whose current participation is voluntary. **ii)** Strongly advise DCs stakeholders to prefer locations close to densely populated urban centers to align with the measures envisaged in Italian plans.**iii)** Expand and facilitate access to the "White Certificates" and the "Conto Termico" schemes. **iv)** Increase the capacity of the National Fund for Energy Efficiency, directing the scheme to the promotion of measures dedicated to the Data, Information and Technology sector. **v)** Include programming measures with a higher degree of specificity regarding efficient practices, perhaps mentioning explicitly the use of heat waste, and addressed at a broader category of enterprises. **vi)** Introduce new measures or modify the scope of the current one to better favour energy efficiency in cities other than metropolitan cities.	**Energy Consumptions & Renewables**	**Develop Italian regulatory framework** in order to better address DCs need and related concerns. In order to do it, Italy should expand and facilitates the participation to efficient schemes already implemented (White Certificates, Conto Termico) to include private entities like DCs whose current participation is voluntary; Italy should advise DCs stakeholders to prefer locations close to densely populated urban centers to align with the measures envisaged national plans; Italy should promote specific measures dedicated to the Data, Information and Technology sector; Italy should introduce new measures or modify the scope of the current one to better favour energy efficiency in cities other than metropolitan cities.	**Engagement**

	iv. Legal action: In Italy the regulatory framework is still underdeveloped and requires significant interventions. I) there are measures that could favour energy efficiency, however they should be enhanced or modified to better address data centres and related concerns (i.e. waste heat and wastewater); 2. There is a general and pervasive need for more specific legislative instruments or at least specific provisions concerning DCs in existing energy-related plans and legislation. Ii) There is the need to target the specific regulatory competences at different government level (e.g. considering central competence of the State Government for energy and taxation schemes) and local (Municipalities) competences for urban planning. **v. Term/timeline:** medium/long **vi. Issues addressed:** recommendation and action are based on an extensive analysis of the Italian legislative framework, which has highlighted several concerns as emerged above. **vii. Stakeholders:** MSs institution (Italy)			
Luxembourg regulatory framework	**i. Origin:** Member State (Luxembourg) **ii. Act(s):** 1. Law of 15 December 2020 relating to the climate; 2. Law on the electricity market; 3. Bissen's General Development Plan. **iii. Previously Validated Recommendations: i)** A possible recommendation can be to explicitly include amongst the objectives for which the fund is granted projects concerning recovered energy sources. **ii)** Since the exemption that – depending on the correct interpretation of "storage purposes" according to Luxembourg laws – can benefit significantly DCs, it would be recommendable to introduce conditions to the exemption. These conditions can perhaps introduce minimum requirements concerning energy efficiency or specific obligations to adopt good practices. **iii)** In light of the analysis and the identified opportunities, a recommended action may relate to the adoption of local regulatory acts as the Bissen's PAG, providing for similar policies in relation to local needs. **iv. Legal Action:** In Luxembourg, the frameworks concerning energy law and environmental law are sufficiently developed. However, minor changes and additions could significantly improve the current framework by granting a wider application of positive schemes and by catering them to the concerns that are more significant to DCs. **v. Term/timeline:** short/medium **vi. Issues addressed**: recommendation and action are not based on specific and significant issues; they rather address the existing regulatory and policy instruments (to be followed as positive example) that could have positive effects and suggest minor amendments to grant a wider application. **vii. Stakeholders:** MSs institutions – Luxembourg	**Energy Consumptions & Renewables**	**Coordinate legislation** to Luxembourg environmental and energy law to promote coordination at MS level. To implement such actions, the procedural steps foreseen in the legislations regulatory framework should be taken: i) explicitly include amongst the objectives for which the fund is granted projects concerning recovered energy sources; ii) since exemption that - depending on the correct interpretation of "storage purposes" according to Luxembourg legislations - can benefit significantly DCs operation, introduce conditions to the exemption iii) relate to the adoption of local regulatory acts as the Bissen's PAG, providing for similar policies in relation to local needs.	**Coordination**
EU Regulation on minimum	**i. Origin:** EU **ii. Act/policy instrument/regulatory act:** Regulation on minimum requirements for water reuse (Regulation (EU) 2020/741)	**Urban Planning & Waste Energy Policies**	**Implement guidelines to be revised** by the EU Commission, assessing the need for more detailed provision in the regulation to promote coordination in rates	**Coordination**

requirements for water reuse	**iii. Previously Validated Recommendations:** In the implementation phase of the Regulation, to introduce more detailed provisions to facilitate specifically the usage of wastewater supplied from DCs. **iv. Legal actions**: **i)** implementation guidelines to be revised by the EU Commission as from 2023 until 2028 as a first step and then promote the assessment of the need for more detailed provision in the regulation, considering that the legislative framework concerning the reuse of wastewater is still underdeveloped; **ii)** If the evaluation has positive outcomes, the EU could either amend the current regulations or decide to implement new legislative instruments to complete the current framework as part of the review process (art. 12 of the Water Reuse Regulation); **iii)** JRC to develop specific guidance for DCs, as already foreseen and provided for other industry sectors. **v. Term/timeline:** short **vi. Issues addressed:** recommendation and action are drafted with the intention of encouraging reuse of wastewater from data centers. It therefore encourages, in the implementation phase and through non- legislative documents providing technical guidance by the authorities, to introduce more detailed provisions. **vii. Stakeholders:** EU institutions		and fees. To implement such action, it is necessary to i) engaging stakeholders in the revision process, including industry experts and representatives from DCs domain, to gather insights and perspectives on the current regulatory framework; ii) follow the normal steps for the regulatory revision ensuring close collaboration with the JRC to leverage their expertise in developing specific guidance for DCs, so that the guidance is tailored to the socio-economic and environmental conditions of DCs and addresses their specific challenges and needs.	
Germany regulatory framework	**i. Origin:** MS (Germany) **ii. Act(s)** Frankfurt's Commercial Space Development Program (2021) **iii. Previously Validated Recommendations: i)** To consider the Frankfurt's Commercial Space Development Program as a model to imitate and transpose it in other cities. **ii)** This may create opportunities for data centers in respect of the scope of the project and, therefore, may contribute to the successful data center integration into overall energy and water systems. **iv. Legal actions**: In Germany's case, the legislative framework is already significantly developed. Initiatives that are particularly advanced, such as those concerning urban planning, should therefore be promoted (initially, for example, through soft law instruments) in order to further expand their effects. **v. Term/timeline**: medium/long **vi. Issues addressed**: recommendation and action are based on the analysis of a plan that is, however, limited in application to a specific city. It therefore suggests considering the plan as a model to address both environmental and energy-related concerns through careful urban planning. **vii. Stakeholders**: MSs institutions (Germany)	**Urban Planning & Waste Energy Policies**	**Coordinate legislation to Germany** example of legislation on urban planning to promote coordination at MS level. To implement such action, it is necessary to promote the Frankfurt's Commercial Space Development Program as a model to imitate and transpose it in other cities.	**Coordination**
The Netherlands regulatory framework	**i. Origin:** MS (The Netherlands) **ii. Act(s):** National Strategy on Planning **iii. Previously Validated Recommendations:** A recommendation emerging from the national policies and the related opportunities is to suggest national governments of EU MSs (in any case considering their specific needs, territories and resources at national level) to take into account the same elements included in these Dutch legislations to allow the sustainable development of DCs.	**Urban Planning & Waste Energy Policies**	**Coordinating legislation** to The Netherlands example from the National Strategy on Planning to promote coordination at MS level. To implement the action, it is necessary to suggest national governments of EU MSs to take into account the same elements included in these Dutch legislations to allow the sustainable development of DCs, this by in any case considering their specific needs,	**Coordination**

	Legal actions: The Netherlands has addressed DCs with specific legislation. Despite some minor concerns, it shall therefore be considered an example of good practices in other MSs. **Term/timeline:** long **Issues addressed**: recommendation address the need to expand positive examples and encourage their use in all the European Member States. **Stakeholders:** MSs institutions (The Netherlands)		territories and resources at national level, therefore applying the same virtuous scheme without neglecting the consolation of the specific need. The Netherlands has indeed addressed DCs with specific legislation. Despite some minor concerns emerged during stakeholders' consultation, it shall therefore be considered an example of good practices in other MSs.	

Bibliography

Table 9: Bibliography

Code of Conduct for Energy Efficiency in Data Centres, Joint Research Centre (JRC)	Code Of Conduct	2022
Regulation on ecodesign requirements - servers and data storage products, Commission Regulation (EU) 2019/424	Legislation	2019
European Electricity Market Directive, EU Regulation 2019/943	Legislation	2019
Directive on common rules for the internal market for electricity, EU Directive (2019/944)	Legislation	2019
EU Taxonomy, EU Regulation 2020/852	Legislation	2020
EU Taxonomy Climate Delegated act, Commission delegated Regulation EU 2021/2139	Legislation	2021
Directive on minimum requirements for water reuse, EU Directive 2020/741	Legislation	2020
EU Green Public Procurement (GPP) criteria for Data Centres, Server Rooms and Cloud Services, JRC	Policy Documents	2020
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List of abbreviations

Table 10: List of abbreviation

Abbreviation	Definition
BAT	Best Available Technology
CFE	Carbon-Free Energy
CHP	Combined Heat and Power
DC	Data Centre
EED	Energy Efficiency Directive
EIIs	Emission Intensive Industries
ETD	Energy Taxation Directive
EU	European Union
FLAP	Frankfurt, London, Amsterdam, Paris
GPP	Green Public Procurement
IEA	International Energy Agency
IED	Industrial Emissions Directive
JRC	Joint Research Centre
MS	Member State
PPA	Power Purchase Agreement
PUE	Power Usage Effectiveness
R&D	Research and Development
SO	Sub-objectives
WUE	Water Usage Effectiveness
24/7CFE	24/7 carbon-free electricity

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