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Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market

EXECUTIVE SUMMARY

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TABLE OF CONTENTS

1. Abstract

The study on “Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market” is a 16-month service contract funded by the European Commission, Directorate-General for Communication Networks, Content and Technology, which addresses the issue of exponentially growth in energy consumption due to the expansion of cloud services at a European level, covering all aspects related to the underlying technological and structural base. An overview over the relevant technological developments, as well as current voluntary and regulatory policy instruments are developed and provide insights into potentials for a reduction of energy consumption as well as suitable policy options (including Green Public Procurement) to foster eco-friendly efficient cloud services and an energy efficient data centre and network landscapes.

The final study report provides a compilation of all study activities and presents the final findings.

2. Executive Summary

The study on “Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market” which has been funded by the European Commission, Directorate-General for Communication Networks, Content and Technology, addresses the issue of the exponential growth in energy consumption due to the expansion of cloud services at a European level, as well the development of voluntary and regulatory policy instruments. In addition, suitable policy options are provided with a view to fostering ecofriendly efficient cloud services and an energy-efficient data centre and network landscape.

These topics are explored in the study, which consists of three main parts: an overview, a technological assessment and a policy analysis.

The technological part includes an analysis and modelling of the future energy demand of data centres across the EU Member States (Task 1), a technological analysis (Task 2) and an assessment of research and technological developments (RTD) (Task 4). The technology part was concluded at a stakeholder workshop with recommendations for RTD policy.

The policy analysis starts with an overview of policy instruments and the current framework for private and public procurement in the EU. The results of the analysis of existing approaches, available instruments, best practices and the results from the gap analysis (Task 3 and 5) served as a basis for the recommendations. The recommendations for policy instruments for energy-efficient cloud computing were discussed with stakeholders at a validation workshop (Task 6).

The analysis and modelling of the future energy demand of data centres across the EU Member States shows that the energy consumption of data centres in the EU28 increased from 53.9 TWh/a to 76.8 TWh/a between 2010 and 2018. This means that in 2018, data centres accounted for 2.7% of the electricity demand in the EU28. Ongoing digitisation and especially the increasing availability of cloud services are leading to a significant growth in data centre capacities. This growth is so strong that it has more than off-set the significant efficiency gains achieved at all levels (hardware, software, data centre infrastructure) and consequently, the total energy consumption of data centres in Europe has risen. Compared to 2018, the energy consumption of data centres is expected to increase by 21% to 92.6 TWh/a by 2025. While the share of cloud data centres accounted for 10% of data centre energy consumption in 2010, it increased to 35% in 2018 and is expected to rise to 60% in 2025. The share of edge data centres will also increase significantly in the future. By 2025, edge data centres are expected to account for 12% of the energy consumption of data centres in EU28.

Regionally, the biggest data centres are located in Northern and Western Europe. These regions were responsible for 82% of the energy consumption of data centres in 2018. By the year 2025, this proportion will rise to 87%. Especially for the energy consumption of data centres in Northern Europe a strong increase of 48% from 26.3 to 38.9 TWh/a is predicted for the period 2018 to 2025. The range of possible future developments in Europe is wide. If all potentials are exploited, however, it will be possible to reduce the energy consumption of data centres to the 2010 level.

The main driver for improving the computing capacity to energy consumption ratio over the past decades has been the continuous improvement of computing performance, also called Moore's Law. As the demand for computing capacity has steadily increased, the total energy demand of ICT equipment has grown as well, but at a much slower rate in relative terms. Whether the fundamental physical conditions will allow Moore's Law to continue to provide further efficiency gains is a subject of controversy.

Infrastructure efficiency and the PUE of data centres have improved over the past few years. The remaining energy-efficiency potentials are becoming smaller as technology is moving closer towards the physical limits. At the same time, unlocking the remaining potentials is becoming more complicated. Energy aware software development plays a major role in the efficiency of cloud computing, especially when it comes to compute intensive applications like crypto mining and AI. Transmission in data networks is becoming more efficient in terms of energy consumption per GB, but total energy consumption is expected to further increase due to additional networks. The rollout of new access networks (e.g. 5G, FTTH) is very fast and the goals are ambitious. At the same time, old network technologies cannot be phased out because of existing equipment inventories. This can lead to further increases in energy consumption, especially in mobile networks.

The provision of ICT resources through public cloud and edge computing offers several opportunities to increase energy-efficiency, compared to traditional data centres. Higher utilisation of compute resources, continuous renewal of custom made hardware and advantages of professional operations through cloud computing providers can lead to improved energy-efficiency. At the same time, however, cloud computing has a high risk of rebound effects due to its fast scalability and low financial entry barrier. The low hanging fruit of technology in energy-efficiency is identified and described in Task 2.

The ever increasing demand for central computing capacity in the EU due to digitisation requires high efficiency gains in order to prevent a rapid growth of energy consumption. Additional technological potentials for efficiency improvements exist already. Whether and how quickly these potentials can be tapped depends on a suitable RTD policy. An extensive dialogue with providers of cloud computing services, data centre operators, consulting firms, IT and energy experts and academic institutions has shown that there is broad agreement on the key technological areas, energy-efficiency potentials for cloud computing, the starting points for further improvements and RTD policy options.

Seven summary recommendations for a suitable RTD policy were formulated on the basis of the technology analysis and an extensive stakeholder consulting process, including an online survey, telephone interviews, and a validation workshop. In short, they are:

- Stipulate transparency requirements and foster uniform indicators for energy-efficiency
- Promote the use of cloud native optimisation tools for cloud computing
- Support technological innovation for specific issues
- Improve software efficiency

- Exploit the potential of SMEs and make SMEs cloud-ready
- Focus on researching emerging trends
- Integrate the energy-efficiency of cloud services into other RTD programmes

A screening exercise was performed investigating policy instruments and best practice examples in private and public procurement, in order to identify current practices, but also to define to which extent GPP has the potential to play a role in delivering energy-efficient cloud computing in Europe. In total, 195 sources of information relevant to procurement, Green Public Procurement, and cloud computing were identified and screened at EU and Member States level.

As regards GPP, the investigation produced the following results:

Public procurement accounts for a large share of Europe's GDP. The EU has already undertaken several actions to ensure the uptake of GPP in procurement practices, including voluntary actions such as procurement platforms and networks (e.g. ICLEI, GPP2020, The Procura +, etc.), guidelines for GPP, criteria, tools, and standards, and research projects, etc. EU actions on public procurement have a consistent focus on energy-efficiency in building, infrastructure and IT products, the vast majority of cases being related to end-user appliances. To date, the EU does not have a cloud specific procurement framework, which means that cloud service procurement has to go through the same process as any other service. In general, the topic energy-efficient cloud computing is not a mainstream argument in GPP.

The European Commission has published the documents "EU green public procurement criteria for data centres[1], server rooms and cloud services and the EU Code of Conduct on Data Centre Energy efficiency".

As evidenced by the analysis, the uptake and implementation of these criteria at the Member State level, especially in National Action Plans or in GPP, are still lagging behind. There is little awareness of cloud computing services in the GPP groups and platforms. There seems to be a knowledge gap in GPP groups (GPP competence centres and GPP Advisory Groups) when it comes to energy-efficient cloud computing. In addition, the people in these groups are mostly not those who are in charge of procuring cloud based services. The topic of energy efficient cloud computing has become a priority topic on the EU political agenda and important documents like the European strategy for Data (European Commission, 2020a) and the European Green Deal (European Commision, 2019e) have been adopted. The screening exercise for the EU Member States National Action Plans and Green Public Procurement has highlighted that the topic "energy-efficiency of cloud services and data centres" has not been included in any of the screened National Action Plans or sets of criteria. Hence, there are clearly gaps in the Member States when it comes to the inclusion of GPP criteria for energy-efficient cloud computing, and especially for data centres and server rooms, in National Action Plans.

As also evidenced by the analysis, there is still a high untapped potential for GPP to deliver energy-efficient cloud services. Especially the growing demand for digital services in the public sector should be used as a momentum to promote the inclusion of GPP criteria at the national level and their implementation at the regional level. The first step should indeed be the implementation of the EC criteria at the national level.

[1] The document was published during the finalization of this report

In addition, the analysis also highlighted that several best practice examples in energy-efficient cloud computing, and especially data centres, can be identified throughout Europe. Best practice in energy-efficient data centres and server rooms includes a variety of approaches, in public as well as in private procurement. The most common approaches are:

- More efficient cooling systems
- Heat reuse, e.g. for district heating
- Virtualisation of software, optimal use of server capacity
- Energy efficient genomics
- Eco-design for infrastructure efficiency
- Use of renewable energy to supply data centres
- Construction of data centres in regions with a cold climate

Whereas many examples of implemented energy-efficient data centres can be found, little to no evidence is available for energy–efficient cloud services for networks, data transmission and coding. There are only examples in research, but they have never been commercialised.

As evidenced by the analysis, some EU Member States are developing their digital roadmaps (e.g. Austria, United Kingdom, Slovakia, Italy), but, environmental aspects are not taken into account. The roadmaps tend to focus on aspects like “paving the way towards a digital future” and on internet accessibility, covering data security, transmission, and the building of infrastructures, especially in the light of the digital transformation which is expected to happen in the next few years. National digital plans should therefore include energy-efficiency aspects for cloud services in the future, in order to put this important aspect on the political agenda.

For most of the analysed policy instruments of public and private procurement, no evaluations of their feasibility and effectiveness for energy-efficiency are available. But even if any effects on energy-efficiency could be shown in evaluations, it is possible that energy-efficiency improvements are at least partly due to other factors such as independent technological developments or economic trends, and are not only caused by a policy instrument.

The study reveals that due to the nature of cloud computing and the diversity of cloud service providers, no blueprint for a policy instrument or a policy instrument mix for energy-efficient cloud computing is available. The transferability of the results for policy instruments used in ICT or data centres to policy instruments suitable for cloud computing is restricted. Nevertheless, existing instruments can – to varying degrees – be used as a starting point or at least as an inspiration for further developments or new designs of such instruments. An example of such an instrument is the EU Code of Conduct on Data Centre Energy efficiency, which can be used as a solid basis for a step-by-step development of a Code of Conduct for cloud computing.

As with the recommendations for RTD (developed for the technology part of the study), the recommendations for policy instruments fostering energy-efficient cloud computing were presented at a stakeholder workshop. They include the following types of policy instruments:

- information and raising awareness measures
- transparency enhancing measures

- guidelines for energy-efficient cloud computing
- certification schemes
- labels
- incentives
- standards
- adaptations of the legislative framework
- options to stimulate energy efficient cloud computing in GPP
- policy awareness raising
- development & innovation fostering measures

During the workshop, recommendations were ranked by the participants, hence the outcome of the workshop is a series of validated and prioritised policy recommendations for energy-efficient cloud computing in the EU. One instrument alone will not be enough to sufficiently improve energy-efficiency in cloud computing. Additionally, some recommendations and policy instruments from the R&D work package (Task 4) will be needed either for complementary actions or as a basis for some of the recommendations listed under Task 6. E.g. better metrics might provide important information for the development of a cloud footprint or a virtual smart meter (see recommendation No 3).

While the study was being conducted, important policies and strategies were developed by the European Union that partly also refer to energy-efficient cloud computing, e.g. the European Green Deal (European Commission, 2019e) and the European strategy for data (European Commission, 2020a). The recommendations of the study need to be embedded in a framework for the digital sector such as the European Green Deal. Under the European Green Deal, the Commission will also consider measures to improve the energy-efficiency and circular economy performance of the digital sector itself, from broadband networks to data centres and ICT devices. The Commission will also assess the need for more transparency as regards the environmental impact of electronic communication services and more stringent measures when deploying new networks (European Commission, 2019e). Framework conditions for cloud computing are also a topic that is mentioned in the European strategy for data (European Commission, 2020a). As stated in the European strategy for data (European Commission, 2020a), the European Commission is planning that a coherent framework should be in place by 2020 for the different applicable rules (including self-regulation) for cloud services, in the form of a ‘cloud rulebook’. In the first instance, the ‘cloud rulebook’ will offer a compendium of existing cloud codes of conduct and certification on security, energy-efficiency, quality of service, data protection and data portability. In the area of energy-efficiency, earlier action will be considered. (European Commission, 2020a)

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