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## Green IT scheduling for data center powered with renewable energy

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In recent years, the question of the energy consumption of data centers has become more and more important, and several studies raised the possibility of using renewable energy to power them. The intermittent nature of commonly used renewable energy sources is a major drawback of using them directly on-site. In this paper, we present an approach for scheduling batch jobs with due date constraints, which takes into account the availability of the renewable energy to reduce the need of brown energy and therefore running cost. The approach we propose differs from the existing methods by providing a scheduling algorithm agnostic of the electrical infrastructure. A separated system, managing the renewable sources, provides an arbitrary objective function, which is used to guide the scheduling heuristic. We implemented our approach in a data center simulator, and evaluated it by considering a small-scale center powered with solar panels and connected to the electrical grid. The relationship between the flexibility allowed by the user negotiated SLAs and the behavior of the algorithm is studied, and compared to existing approaches from the literature. Our experiments show a reduction of brown energy consumption up to 49% and a cost saving up to 51%, compared to a traditional scheduler unaware of renewable availability.

*Keywords:* Renewable energy, Online scheduling, Data center, Energy aware scheduling

**1. Introduction**

Today more than ever, the energy consumption generated by the growing use of information and communication technologies (ICT) is a major issue, from both economical and ecological points of view. The emergence and development of grid computing and cloud computing paradigms, during the last decade, caused the increase of data centers, as much in number than in size. Data centers are becoming a significant part of the global electrical consumption. Their total consumption in 2012 was estimated to almost 270 TWh [1]. This is roughly equivalent to 1.4% of the worldwide electrical consumption, while the complete ICT sector (excluding manufacturing) accounts for 4.7% of it. According to the same study, the data center power needs increased annually by 5% between 2006 and 2012. The projections for the next decade suggest higher growth rate in a near future. For the year 2030, the data centers alone may use between 3% (best case) and 13% (worst scenario) of the global electricity production [2].

Because of the current energy consumption of the ICT sector and its growing requirement, the responsibility of big companies in term of greenhouse gas emission and pollution in general is often pointed out. However, ICT firms seem involved in reducing their ecological impact more than other industry sectors by buying renewable energy for

their needs, with several companies such as Intel or Adobe covering all their consumption in U.S. by this way [3]. This is also pointed out by Greenpeace, in their Click Clean report<sup>1</sup> claiming that, between 2011 and 2016, 16 of the major internet companies made “a meaningful long-term commitment to be 100% renewably powered”. Their are many reasons for this recent change in companies behaviors. Radu [4] studied the determinants of Green ICT adoption in general, pointing out economic, ethical and regulatory-related reasons, such as long term cost reduction, pro-environment grants, organization strategy and image.

The transition toward sustainable energy, not only for data centers, is one of the important global topic of this century. Krakowski et al. [5] study several scenarios for increased penetration of renewable energies in the French electrical mix. Multiple scenarios target 100% penetration in 2050, showing feasibility, cost and limitations of each. The authors also compare their results to a previous prospective study from the french environment and energy management agency (ADEME)<sup>2</sup> with similar objective but using different methods. Other agencies and researchers published similar studies for other regions, such as Elliston et al. for Australia [6]. These studies show that renew-

<sup>1</sup>«Clicking Clean: Who is winning the race to build a green internet?», <http://www.clickclean.org/downloads/ClickClean2016/20HiRes.pdf>

<sup>2</sup>«A 100% renewable electricity mix? Analyses and optimisations», <http://www.ademe.fr/en/a-100-renewable-electricity-mix-analyses-and-optimisations>

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