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How to assess and manage energy performance of numerous telecommunication base stations: Evidence in China

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HIGHLIGHTS

- 196 TBSs from four main climate zones of China are surveyed.
- Millions of TBSs in China can be divided into 448 typical scenarios.
- The benchmark system of these scenarios can be organized into four simple charts.
- The ventilation cooling can eliminate negative impact of poor envelops and COPs.
- Establishing telecom industrial standards for TBSs is reasonable and feasible.

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ABSTRACT

Existing calculated benchmarking methods and main energy performance assessment schemes often lack the practical ability to manage the energy performance of a vast number of widespread telecommunication base stations (TBSs). Therefore, on the basis of a TBS survey, this paper puts forward the dynamic simulation and sensitivity analysis method to allow the new rule "one energy benchmark for a group of similar TBSs" rather than the traditional rule "one benchmark for one assessed building". The new method reasonably limits the number of benchmarks and a feasible benchmark system is established for managing numerous TBSs. The results indicate that, first, more than one million TBSs distributed in a large area of China can be divided into 448 typical scenarios. Second, the benchmarks for reasonable energy use of these scenarios can be organized into four simple benchmarking charts. Third, the attempt to establish further challenging energy benchmarks shows that the most energy-saving measure in TBSs, i.e., ventilation cooling, can fully eliminate the negative impact of poor configurations of envelops and cooling coefficients of performance (COP). Finally, establishing telecom industrial standards for locating the reasonable TBS energy consumption level even in giant countries appears feasible.

1. Introduction

Telecommunication base stations (TBSs) are the basic units of the telecommunications network and consume more energy than other public buildings due to their high internal heat density and special operating schedule [1,2]. By 2013, China has established more than 2.11 million base stations for data processing and data transmission with a robust increasing trend [3–5]. In 2013, China Mobile, China Unicom and China Telecom (just three operators in China) consumed about 15.7, 13.0 and 13.5 billion kilowatt-hours, respectively, according to their sustainability reports, at least one third of which are due to TBSs [6]. SASAC (State-owned Assets Supervision and Administration Commission) of China, as the regulating department of these Chinese telecom operators, formulated "The Central Enterprise Interim Measures for the Supervision and Administration of Energy Conservation and Emissions Reduction" in 2010 [7], and it set the three operators as the category of Focused enterprise from the General enterprise in 2013 [8–10], requiring full-time staff for energy-saving management and periodical reporting energy uses.

Accordingly, China Mobile Communications Corporation (CMCC), the largest mobile service provider in the world, has been carrying out its "Green Action Plan" for successive eight years since 2007. As one of the key priorities, a huge building monitoring

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system (BMS) is being set up, which is planned to monitor at least 140 thousand existing TBSs (10% of its total 1.4 million TBSs) and 50% of newly-built ones of CMCC. Thanks to this sensor network, the real-time power consumption of every monitored base station is available now. However, some problems arise now. For instance, which base stations consume an eligible amount of electricity? Which base stations consume more than the reasonable consumption level? What is the proper energy benchmark table for these TBSs? Failure to define and find abnormal consumptions will make the energy management of TBSs worthless in fact.

There are three main reasons for the lack of energy benchmark of TBSs. First, the verified TBS data are missing in existing commercial building energy consumption surveys, such as the Commercial Building Energy Consumption Survey (CBECS) [11]. Lacking data is a fatal problem in benchmark establishment, no matter by simulation or by statistical method. Second, existing energy performance assessment programs either adopt unsatisfactory energy performance indicators for TBSs, or seem much too costly and unrealistic to assess and manage energy consumption levels of each TBS individually (see Section 2 for details). Third, such methods still lack in order to divide a huge number of TBSs into a tractable number of groups with a common TBS energy consumption level for each group, which makes it possible to manage the energy consumption of millions of TBSs. Under this circumstance, this study aims to bridge these gaps and set up a strategic energy benchmark system for managing the energy consumption of enormous TBSs, which are distributed in a board region and have a variety of envelopes, internal heat gains and cooling capacities.

The main contribution of this paper can be summarized as follows. First, 196 TBSs from four main climate zones of China are surveyed and the statistical data are derived for the first time. Second, based on the survey and dynamic simulations, new methods are put forward, which can compress enormous TBSs to a manageable number of typical TBS scenarios from the perspective of energy consumption. Third, an energy benchmark system for TBSs is proposed, which shows that energy consumption levels of millions of TBSs across China can be managed by four or five simple charts.

The rest of the paper is organized as follows. Section 2 reviews the benchmarking methods and main energy performance assessment schemes. Section 3 surveys the detailed inputs for required dynamic simulations. Section 4 divides the typical scenarios for TBSs and designs the main TBS benchmark charts, while Section 5 concludes the paper.

2. Review of benchmarking methods and energy performance assessment schemes

The pre-set benchmarks are often used to judge the energy performance of buildings, such as TBSs. For general lack of end-use sub-metering, the whole-building benchmarking is usually the only choice for TBSs, and there are two main methods to develop an appropriate reference benchmark, i.e., statistical benchmark and calculated benchmark [12–15].

The statistical benchmarks are often established by two basic models on the basis of energy databases, i.e., the simple normalized model [16–20] and the regression-based model [21,22]. Using the simple normalized model, the energy performance indicator (e.g. floor area-normalized energy use intensity (EUI)) is usually obtained by normalizing the energy use with floor area, which accounts for only one building feature that affects energy consumption. Some main energy performance assessment schemes belong to this, such as the Cal-Arch (US) [23], ASHRAE bEQ (US) [24] and MAEPECC (HK) [25]. Meanwhile, in order to account for the effect of other energy influential factors, the benchmarks will be constructed by using the regression-based model, such as the Energy Star (US) [26]. Specifically, Cal-Arch (US) compares the EUIs with the distributional table of similar buildings in the energy database of California's 1992 Commercial End Use Survey (CEUS) database. And ASHRAE bEQ apt for new and existing buildings compares the EUI of the assessed building with CBECS data. However, the TBS data are absent in these existing surveys and databases (such as CEUS or CBECS) [11,27] about energy use of commercial (i.e., retail, catering, accommodation, office, warehouse, education, healthcare, mixed use, and other) and residential buildings. What is worse, the gross power of telecom equipment in a TBS is determined by the local data traffic requirement in principle, but the area of a newly-built TBS often shows a standard size for self-built color steel envelope or stochastic for those rented brick wall buildings, which means the EUI is not applicable for TBS energy performance assessment and makes quite a lot of existing energy benchmarking studies helpless [16–20]. Similarly, the MAEPECC assessment process is also based on the EUI comparison, so the same problem exists. Besides, Energy Star is suitable for existing residential and commercial buildings. It compares the whole building energy use with the distributional benchmark tables established by regression models and resulting standard errors on the basis of CBECS [11]. Although the regression models may consider climate and other factors in the benchmarking process, the benchmarks derived from one zone (such as China) may undermine their usage in other zones of the world [12].

Because of these abovementioned problems, the calculated benchmarks appear better, which mainly include steady-state models [28] and dynamic simulations [29,30]. The steady-state models do not consider the time-varying heating/cooling loads, which will be taken into account in the dynamic simulation, so the latter is often accepted as the powerful tools for analyzing building energy performance. Typical inputs, which usually need a on-site survey to get, for a dynamic simulation may include temperature of outdoor air, solar radiation intensity, wind speed, location, design and construction data, thermal zones, internal heat gain, infiltration, usage profiles, system types and sizes, control schedules, HVAC components, etc. [31]. DOE-2 (eQUEST) [32], EnergyPlus [33] and TRNSYS [34] are well-known simulation tools and the details of mathematical simulation algorithms can be found in Ref. [35]. For a certain assessed building, one benchmark has to be established by simulation [12]. A self-reference building is built, whose shape, geometrical dimensions and functional layout are totally identical to the assessed building, and the simulated energy consumption is the benchmark. Many energy certifications and environmental assessment schemes, such as LEED (US) [36,37], BREAM (UK) and EPA-NR (EU), adopt this method.

Although the dynamic simulation method seems ideal for a single assessed building, it may be helpless in managing millions of TBSs because it is too complicated and costly. The rule "One benchmark for one assessed building" and enormous sites to be assessed result in unaffordable and exhausting on-site investigations. It is reported that, over the past five years, only about 500 LEED rated projects have been accomplished in Asia [37], let alone its inapplicability of most LEED sustainable credit points to TBSs [36,38]. Obviously, the dynamic simulation benchmarking method may be paralyzed in the case where lots of widely distributed similar buildings (e.g. TBSs) should be assessed and managed.

Under this circumstance, we put forward a new method based on a TBS survey and the dynamic simulations in this paper to allow a new rule "one benchmark for a group of similar assessed buildings", in order to reasonably and greatly reduce the number of needed benchmarks. It may improve the existing calculated benchmarking method and award it practical ability to manage a vast number of widespread sites.