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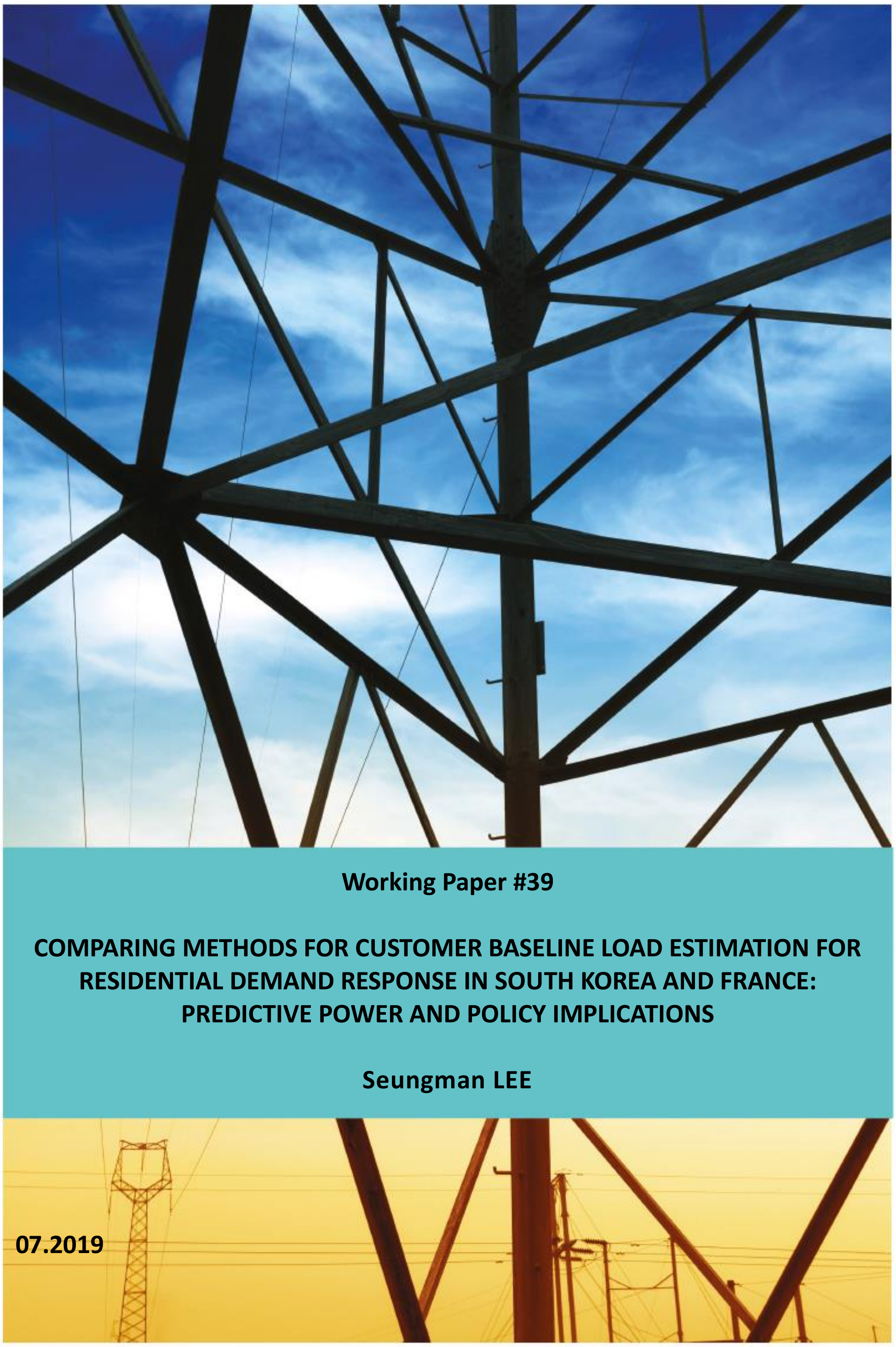

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COMPARING METHODS FOR CUSTOMER BASELINE LOAD ESTIMATION FOR RESIDENTIAL DEMAND RESPONSE IN SOUTH KOREA AND FRANCE: PREDICTIVE POWER AND POLICY IMPLICATIONS

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COMPARING METHODS FOR CUSTOMER BASELINE LOAD ESTIMATION FOR RESIDENTIAL DEMAND RESPONSE IN SOUTH KOREA AND FRANCE: PREDICTIVE POWER AND POLICY IMPLICATIONS

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Abstract

Worldwide concern on climate change and paradigm shifts in the electricity sector towards more flexibility contribute to making Demand-side management (DSM) an increasingly important element for establishing the demand and supply balance. In particular, Demand Response (DR) is expected to improve the security of electricity supply by reducing peak demand, reduce CO_2 emissions, contribute to the integration of variable renewable energy (VRE) and minimize overall costs. DR activities are complex and depend on a number of technical, meteorological and behavioral parameters. It is thus instructive to compare the DR pilot programs launched in different countries, such as the Notification d'Échange de Blocs d'Effacement (NEBEF) mechanism in France in 2013 or the market-based DR programs in South Korea in 2014. Among the different economic issues at stake, the estimation of the *Customer Baseline Load (CBL)* emerges as a key component for defining the nature, performance, and costs of different DR programs. Based on the re-scaled load profile for an average household, this research thoroughly examines the performance of several CBL estimation methods in the context of the South Korean and French DR mechanisms. In particular, it is shown how optimizing the methodologies for CBL estimation allows improving the incentives for DR participation. For instance, the more accurate CBL estimation methods currently in use in South Korea could significantly enhance the potential for DR also in the context of the French electricity market. To assess this potential quantitatively, different CBL methodologies are integrated into a Cost-Benefit Analysis (CBA), which allows determining both overall changes in consumer surplus and the profits of private operators. The results of this research on CBL estimation methods are indeed relevant for public policy-making as well as for the design of industrial and commercial DR programs.

Keywords: Demand Response (DR), Customer Baseline Load (CBL), Korean Demand Resource Trading Market (DRTM), NEBEF, Load Aggregator (LA).

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Disclaimer: The views and opinions expressed in this paper are those of the authors and do not necessarily reflect those of the partners of the CEEM.

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I. INTRODUCTION

1.1. Contexts and Market-based Demand Response Mechanisms in South Korea and France

South Korea has a huge reliance on fuel imports to meet 98% of its fossil fuel consumption [31], and it has been experiencing the highest average annual growth rate (9.2%)[1] in electricity consumption among the OECD countries since 1974 [10, p. xvii]. In addition, before the introduction of the market-based DR program in December 2014, South Korea faced a series of problems regarding reliability and security of electricity supply as illustrated by the unprecedented rotating blackout on September 15th in 2011. This issue is one of the motivations for South Korea to actively promoting Demand Response (DR) [6].

Despite its huge requirement of energy, it is getting more difficult to meet the demand from the supply-side. In fact, these days the South Korean government is facing the difficulties to search for the available power plant sites for additional capacity and infrastructure both due to public's low-level acceptance for the power installations and the enhancement of the environmental regulations. One of the examples is the case of the 'Miryang Transmission Tower Construction Conflict' in South Korea. It is the conflict between the local residents in 'Miryang' and the Korea Electric Power Corporation (KEPCO) since 2002, and for the recent years (2012–2014) it has been much more serious drawing public attention. With DR, the government could avoid constructing additional capacity and transmission distribution infrastructure. In this context, DR and peak consumption management are strategic issues for the South Korean government [5].

The environmental issue is also one of the reasons for South Korea to be interested in DR. The South Korean government put emphasis on the 'Green Growth' policy, and the government is very well aware of the advantage of DR in terms of the reduction of the CO_2 emissions. In addition to the environmental advantages, there is an additional economic motivation for South Korea. The South Korean government included DR (the inauguration of the demand-side resource market) into the 'Creative Economy Initiative' because it could create a new market and jobs encouraging the related industries, which means it can play as a driver for economic growth.

Moreover, in order to achieve the policy objective to reduce the reliance on nuclear power and fossil fuel imports, the government is promoting greater Demand-side Management (DSM) [30]. More recently the new South Korean government of the president Moon set the new energy policy since May 10th in 2017. The president Moon promised to phase out nuclear power and the government announced the 'Energy Transition (Nuclear Phase-out) Roadmap' on October 24th in 2017. In the roadmap, the government declared to drop existing plans to build new nuclear power plants and not to extend the lifespan of nuclear reactors in operation. The president also pledged to per-

[1] In detail, it was 11.6% between 1974 and 2000, and it was 4.5% between 2000 and 2015 [10, p. II.34]. The following countries are Turkey (7.7%), Chile (5.5%), Iceland (5.5%), and Mexico (5.2%) during the period between 1974 and 2015.

manently shut down at least 10 aged coal-fired power plants. Instead of the nuclear and coal-fired power plants, the government is to increase the share of the Variable Renewable Energy (VRE) from 7% now to 20% by 2030 ['8th Basic Plan for Electricity Supply and Demand (2017–2031)' published on December 15th, 2017].

Actually, in the past, the DSM programs were based mainly on load management, energy efficiency and the government-led DSM programs with the fund from the government. In April 2014, the legislation was passed in South Korea allowing DR to participate in its wholesale market, and the market-oriented Demand Response Mechanism (DRM), called the Demand Resource Trading Market (DRTM), was introduced on November 25th, 2014 in South Korea. According to Korea Power Exchange (KPX), which is the South Korean DR system operator, since the inauguration in 2014, in 2014, 2015, and 2016, as the achievement of operating the DRTM, it has reduced totally 632,229 MWh. The total registered capacity of demand resources at the market was 3,886 MW as of 2016, mainly from the manufacturing industry (58.8%)—21.6% from the service industry, 17.4% from the commercial industry, and 2.2% from the agricultural industry.

The main motivations for the introduction of DR in France are affordability and sustainability, especially for the most expensive peak loads during a cold winter.[2] With these motivations in mind and based on the French **Law No. 2013-312**, known as the '**Loi Brottes**' (**Brottes Law**),[3] the French DRM, called La Notification d'Échange de Blocs d' Effacement (NEBEF)[4], was introduced in the day-ahead wholesale market in December 2013. The test phase of the NEBEF mechanism by Réseau de transport d'électricité (RTE), which is the French Transmission System Operator (TSO) and DR system operator, took one year from December 2013 to December 2014. After that, the decree, **Décret n° 2014-764 du 3 juillet 2014**[5] complemented the regulatory framework. Also, with **Délibération de la CRE du 17 décembre 2014**,[6] La Commission de Régulation de l'Énergie (CRE) has extended the experimental process and turned it into a new set of rules.

Since then, Règles NEBEF 1, the initial regulation on the NEBEF mechanism, has been developing, and the latest regulation on the NEBEF mechanism is 'NEBEF 3.1'[7] [27]

[2] It was estimated that with a price-based DR program, for example, dynamic pricing, it could result in a 6% cut of the peak load on the French electricity production system [7].

[3] Its full title is 'LOI no 2013-312 du 15 avril 2013 visant à préparer la transition vers un système énergétique sobre et portant diverses dispositions sur la tarification de l'eau et sur les éoliennes'. 'La version initiale' is [On-line], Available: https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000027310001&categorieLien=id

[4] Originally it was called as 'Electricity Load Reductions' in English, but recently it is translated literally as the 'Block Exchange Notification of Demand Response (NEBEF) mechanism'.

[5] Its full title is 'Décret n° 2014-764 du 3 juillet 2014 relatif aux effacements de consommation d'électricité'. [On-line], Available: https://www.legifrance.gouv.fr/eli/decret/2014/7/3/DEVR1327315D/jo/texte

[6] Its full title is 'Délibération de la Commission de régulation de l'énergie du 17 décembre 2014 portant approbation des règles pour la valorisation des effacements de consommation sur les marchés de l'énergie'. [On-line], Available: http://www.cre.fr/documents/deliberations/approbation/effacements-de-consommation2/consulter-la-deliberation

[7] **Règles NEBEF 3.1** is the latest rules regarding the selling of demand reduction on the energy markets. Its full title is les 'Règles pour la valorisation des effacements de consommation sur les marchés de

which is in effect since Jan. 1st, 2018. Thanks to these law, decree, and regulations, since 2013 it is possible to value load curtailment in the energy market (day-ahead market, and since 2017 intraday market) and balancing market [22, p. 132], that is, the resources of DR can participate in those market competing with other generation resources. Now it leads to the full participation of DR in all the existing market structure in France [17]. France is the only country in Europe to allow DR operators to participate directly in the wholesale market as a resource (direct participation) [32, p. 13]. At the initial stage of the NEBEF mechanism in 2014, the total volume of NEBEF was quite small—about 620 MWh because it was experimental, not very well organized yet, and not very well known among potential participants. After the one-year test phase, in 2015 the total volume of NEBEF increased to about 2,970 MWh, about five times of the amount in 2014, and it was activated mainly in November and December. As time goes by, NEBEF has been significantly developed both in terms of the total volume (about 20,622 MWh) and the frequency of activation in 2016. In 2016 NEBEF was much more frequently activated during the peak periods than the past two years. It means that it works better considering the intrinsic objectives of the NEBEF mechanism. In addition, the shape of the actualized NEBEF is getting similar to the shape of the French Load Duration Curve (LDC).

1.2. Importance and Difficulties of the Accurate CBL Estimation Methods

When a system operator introduces and operates a DR program, it is quite important to understand the issues around the concept of 'Customer Baseline Load (CBL)' (or customer baseline). CBL can be regarded as the 'unbiased estimate of load,' the 'reference load,' or the 'counterfactual load'. It represents (and is an estimate of) what the usage would have been among treatment group customers had they not been exposed to the treatment. Also, it serves as the foundation for all the following analyses, such as Cost-Benefit Analysis (CBA), Decision-making Analysis, Sensitivity Analysis (SA), and so forth [4, pp. 1–3].

Many economists think that price-based (implicit) DR system is an efficient way to reach the socially optimal price-responsive demand [2, p. 69]. However, there exist several barriers against such DR programs: one of them is the difficulty of determining a proper CBL. For a system operator, it is easy to calculate and remunerate for electricity production (generation). However, it is hard to calculate the exact amount of electricity reduction. Therefore, determining the CBL is the prerequisite to calculating the payment for the participants and for the CBA.

DR depends critically on the choice of CBL [2, pp. 71–73]. A wrong CBL can create distorted incentive and gaming opportunities. Chao [2, p. 75] suggested a 'contractual customer baseline approach' rather than an administratively determined customer baseline which could undermine the efficiency of DR programs and cause the double payment issue. In practice, it is interesting to observe that when the New York Independent

l'énergie NEBEF 3.1'. In addition to Règles NEBEF 3.1, there is another rule, so-called **Règles SI NEBEF 3.1**. This is the NEBEF IT rules which concern the access to the information systems such as the RTE information system and the information system of the Distribution System Operator (DSO). [On-line], Available: https://clients.rte-france.com/htm/fr/offre/telecharge/2018_01_01_Regles_SI_NEBEF_3.1.0.pdf

System Operator (NYISO) in the U.S. changed the method to calculate and set the CBL resulting in more tightened criteria for qualification, there were fewer DR resources registered as Special Case Resources (SCRs) [8, p. 11].[8]

Despite the importance of the CBL, it is quite difficult to properly construct a CBL for each participant in a DR program, especially for residential customers because it is difficult to measure customer's individual, subjective, and characteristic load pattern. Basically, the methods to estimate CBLs are based on the previous load patterns of customers by using some formulas, therefore, it cannot be perfect itself.

There will be adverse effects if there are either underestimation or overestimation of CBL [20, 23]. If there is the underestimation of CBL, participants' actual reduction will be underestimated and participants' efforts to reduce loads are not well appreciated. Therefore, the proper payment or incentives are not given to them. In the end, it will decrease their motivations to participate in the DR program, as a result, they would cancel the contract with the Load Aggregator (LA) and exit from the DR market [13, p. 122]. If there is the overestimation of CBL, the DR system operator ends up paying more remuneration than the actual amount for the LAs (and in the end, for the participants), and it will decrease the motivation of the DR program operator to run the DR program.

Due to this imperfect method to establish CBLs, there would be motivations for participants to manipulate their daily load patterns in order to get paid greater financial remuneration than it should be. Chao [2], Hatton and Charpentier [9], Jiang, Farid, and Youcef-Toumi [11], and Léautier [18] are well aware of the fact that the baseline is subject to manipulation because DR participants have a greater awareness of their facilities than the regulatory agencies responsible for estimating the baseline (it is about the information asymmetry). An intentionally inflated baseline is shown to result in an inefficient resource dispatch, high system costs, and undesirable social welfare.

1.3. Objective and Scope of the Research

As abovementioned, even though both of the DRMs of South Korea and France are in the developing trends, it seems that the South Korean DRTM is performing better than French NEBEF mechanism in terms of the total volume of trade on the market, the frequency of activation, and so forth. We could take into account many different aspects between two DRMs to explain the different levels of achievement since their inaugurations. First of all, the nature of the platforms in which demand-side resources are traded is different. For South Korean DRTM, the wholesale market is a Cost-based Pool (CBP) in KPX while it is a price bidding system in European Power Exchange (EPEX) for French NEBEF. Also, in France demand-side resources can participate in all the electricity markets, such as the wholesale market (NEBEF), capacity market, ancillary services, and reserves market, but the DRTM is the only market open to DR in South Korea. Moreover, there are two types of DR program, 'Peak Reduction DR' and 'Economic DR', in South Korean DRTM, but there is only one type DR, kind of 'Economic DR', for French NEBEF. There is also a difference between them in terms

[8] The Federal Energy Regulatory Commission (FERC) added one more factor for this decrease in the DR resource registered as SCRs that relatively low capacity prices in NYISO in recent years may have also contributed to less participation in it [8, p. 11].

of the remuneration for the DR resources. In South Korea, it is paid at the level of SMP, but in France, it is paid at the level of (SMP $-$ *Versement*)—*Versement*, a transfer to retailers/utilities.

Among the differences, the difference of CBL estimation methods between the two DRMs seems to be the most important and fundamental because it is the first step and base to calculate the ultimate remuneration that can decrease or increase the motivation of DR participation. Considering these aspects, it is expected that figuring out the impact of different CBL estimation methods on the DR markets by comparing two DRM of South Korea and France will provide us, to some extent, the explanation for the different levels of the performance. In addition, comparing and investigating the CBL estimation methods give us relatively more rooms to easily improve the DR market design and ameliorate the performance of French NEBEF mechanism compared to making a modification of given market conditions such as a price bidding system or CBP.

Therefore, the objective of this study is ultimately to provide meaningful policy implications for a better DR market design in terms of accurate CBL estimation methods. To that end, I will examine the currently used different CBL estimation methods in South Korea and France and assess them in terms of the accuracy in order to find out the best one. It is expected that if one CBL estimation method performs better than others in one country, then it could significantly improve the performance of the DR mechanism in another country. Also, this CBL will be a base element for the following CBA and SA for a DR program.

The subject of this research is explicit (incentive-based) DR programs, not implicit (price-based) DR programs. In addition, the focus will be placed on the residential sector, rather than industrial or commercial sectors. The target countries for the analysis are South Korea and France. In this comparative analysis on the different CBL methods, the simple mathematical model of linear algebra will be utilized when I try to obtain a re-scale downed average household's load profile from the aggregated national load profile and when I try to construct the experimental CBLs.

This article is structured as follows. In Section 2 various methods for establishing CBLs and the criteria for the assessment of the CBL accuracy will be reviewed. And then based on these CBL estimation methods and country-specific CBLs, I am going to establish the experimental CBLs using the re-scale downed load profile for an average household for each country, South Korea and France, in Section 3. The established CBLs as the results will be shown and their accuracy assessments will be discussed in Section 4. Finally, in Section 5 by taking into consideration the results and discussions on the established CBLs with different methods, meaningful policy implications will be drawn for a better DR market design.

II. LITERATURE REVIEW: CBL ESTIMATION METHODS AND ITS ACCURACY ASSESSMENTS

In general, we can categorize the methods (or techniques) of establishing CBLs into two: the conventional and unconventional techniques. For the conventional techniques, again, there are roughly two techniques: day matching (or match) methods and the method of regression analysis[9]. For the unconventional methods, there is a data-driven baseline load estimation method, that is a data mining approach [19, 20].

The basic idea of day matching methods is that we take a short historical period close to the *event day* and calculate CBLs ($\text{CBL}^{\text{avg.}}$) by simply averaging the data of the previous non-event days [first choosing *reference days*, and then among reference days choosing *similar non-event days* for the calculation]. For day matching methods, there are also various methods depending on how many days you consider for reference days and similar non-event days, how you exclude some days from reference days to select similar non-event days, how you reflect the changes in the temperature of the event day [Weather Sensitivity Adjustment (WSA) option],[10] how you reflect the changes of the electricity consumption pattern or amount [Symmetric Additive Adjustment (SAA) option][11] of the event day, what kind of other options you allow for the participants, and so forth. For example, '3 Days Types', '7 Days Types', 'Average 6/10 (=Mid 6/10)', 'Average 6/10 + SAA option', 'Max 4/5', 'Max 4/5 + SAA option', 'High 3/10', 'High 3/10 + SAA option', and so forth.

In the U.S., California Independent System Operator (CAISO) uses the method called the 'Baseline Type I' of the North American Energy Standards Board (NAESB)'s Measurement and Verification Standard [12]. Ten similar non-event days are used for the 'Baseline Type I'. New England Independent System Operator (ISO) uses five similar non-event days prior to the DR event day. PJM Interconnection used to use the highest four days out of five reference days in order to calculate the baseline, however, it changed the way where PJM Interconnection suggests nine basic CBL methods[12] and the load aggregators can choose the best methods for their clients (participants) [13, pp. 125–126]. It changed again, and now there are different default methodologies depending on the specific program and type of DR product [21, 23]. In South Korea, in the past, like PJM Interconnection, KPX used to use the four most energy-intensive days among the last five days, but recently it changed the methods to the six similar non-event days out of ten reference days[13] removing two highest and two lowest days.

[9] For the research that utilized the regression analysis to establish CBLs, please refer to the followings: Woo and Herter [35]; Braithwait et al. [1]; Coughlin et al. [3]; Sharifi, Fathi, and Vahidinasab [28].

[10] WSA is one of the options for the modification of the calculated CBL considering the impact of weather conditions on power consumption.

[11] SAA is one of the options for the modification of the calculated CBL considering the difference of the electricity consumption pattern.

[12] For the nine basic CBL methods, there are '3 Days Types', '3 Days Types with SAA', '3 Days Types with WSA', '7 Days Types', '7 Days Types with SAA', 'Max base load', 'Metered generation', 'Same day (3+2)' and 'Match day (3 day average)'.

[13] It is generally accepted that the duration of approximately 10 days reasonably represents the expected consumption for normal operation [20, p. 10250].

As conventional and typical methods, day matching methods are frequently utilized in reality because it is relatively simple compared to other more complex methods. Therefore, it is quite easy for the participants to understand the concept of CBL and the process of its calculation. Moreover, many of the previous researches on CBL have found that this typical and conventional method has almost the same accuracy comparing to others. In South Korea, as practical research, Won et al. [34, p. 1] conducted a case study for the real South Korean customers and concluded that the simple statistical method is better than the complex regression method to determine a CBL for very random loads.

On top of the basic day matching methods with simple average, there is a little bit improved method that uses the Weighted Moving Average (WMA). By giving more weights to the more recent days to the DR event day it can reflect the recent changes in the data such as the recent dramatical temperature changes or socio- and economic-events [33].

After establishing the CBL, we need to assess the accuracy of the estimated CBL in order to decide whether or not we can rely on the CBL estimation method and can accept the estimated CBL. In general, to verify the accuracy of the calculated CBL we can calculate the estimation error by comparing the actual electricity load and the estimated CBL [20, p. 10252]. Based on this general idea, there are three mainly used criteria: Average Relative Error (ARE) (`Eq.: ARE` in Appendix), Mean Absolute Percentage Error (MAPE) (`Eq.: MAPE` in Appendix) and Relative Root Mean Squared Error (RRMSE) (`Eq.: RRMSE` in Appendix).

ARE is the average estimation error for all the verifying time splots of the CBL. If ARE is close to 0 (zero), it means there is the high accuracy of the estimated CBL. If it is greater than 0, it means the overestimated CBL, and if it is less than 0, it means underestimated CBL. MAPE is almost the same with ARE except that it uses the absolute value of the difference between the CBL and the actual electricity load and that it is expressed in percentage. RRMSE is more complicated than the previous criteria to verify the accuracy of the estimated CBL. The smaller RRMSE, the better CBLs. Among the three criteria of ARE, MAPE, and RRMSE, one is sufficient for the accuracy assessment of the established CBL, but for the sake of the demonstrative analysis, MAPE and RRMSE will be utilized for the accuracy assessment of the established CBLs of South Korea and France in Section 4.

III. ESTABLISHING CBLS FOR SOUTH KOREAN AND FRENCH DR PROGRAMS

3.1. A CBL for an Average Household in South Korea

As can be seen in the following heatmap of loads in 2016, South Korea (Fig. 1), in general, the peak load happens both in summer and winter during a year and from 9 a.m. to 12 p.m. and from 13 p.m. to 18 p.m. a day. During the summer peak, the high usage of electricity comes from the cooling by using air-conditioning devices. However, during the winter peak, the electric appliances for heating are not widely used as much as in France. Also, Figure 2 shows the increasing trend of the peak load of South Korea. In summer, 2013, the South Korean people had to turn off the air-conditioners at all government and public office buildings when the nation faced a power crisis because several nuclear power plants had to temporarily shut down after the nuclear scandal. These experiences of inconvenience are the direct motivations for the South Korean government to realize a need to come up with different measures for the security of electricity supply and to focus on DR.

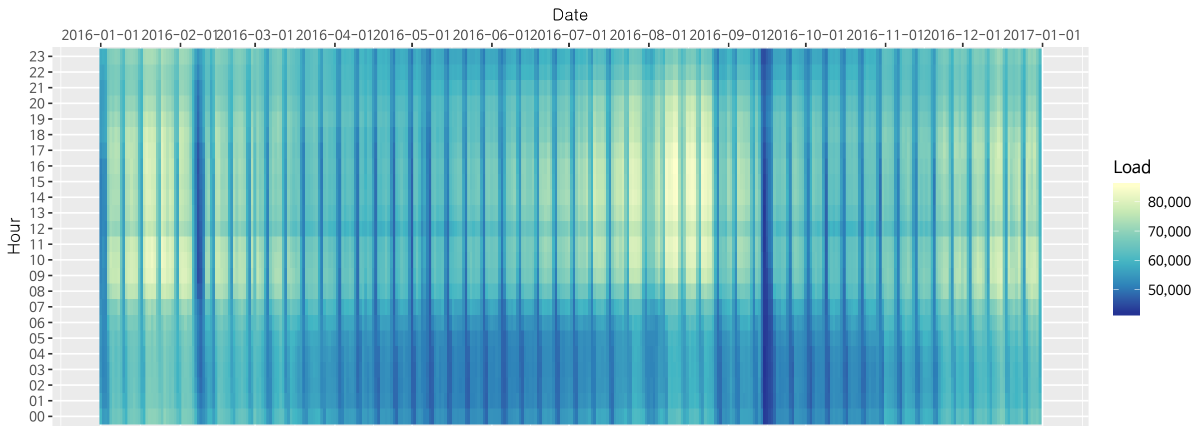

Figure 1: Heatmap of Loads, South Korea in 2016 (MW)

Source: "Public Information Sharing System on Electricity Demand and Supply", KPX, [On-line], Available: `https://openapi.kpx.or.kr/sukub.do#`

Comparison to France: Fig. 4

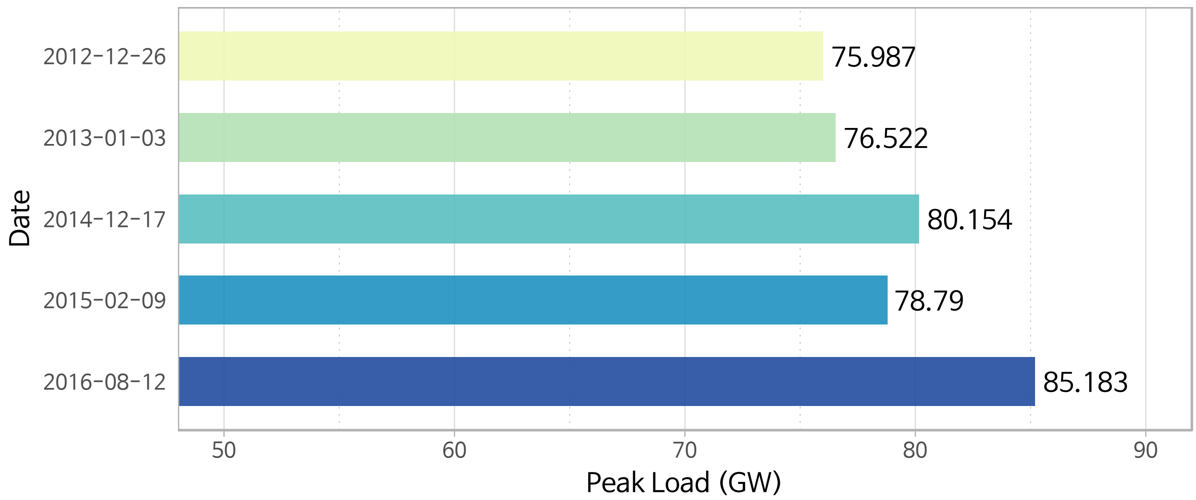

Figure 2: Peak Load of South Korea from 2012 to 2016 (GW)

Source: "Operational Performance of Electric Power System", Electric Power Statistics Information System (EPSIS), [On-line], Available: `http://epsis.kpx.or.kr/epsisnew/selectEkifBoardList.do?menuId=090120&boardId=003120`

Comparison to France: Fig. 5

The focus date for the analysis is the peak day that happened on Friday, August 12^{th} in 2016 (Fig. 2). Therefore, let us assume that the event time of the DR event day is from

17:00 to 19:00 (one block consisting of two-time slots, $t = 17h$ and $t = 18h$) on Friday, August 12th in 2016.

In order to obtain the electricity load (consumption) profile of an average household for a certain period (similar non-event days), we can re-scale down the aggregated national load profile using the information on the 'proportion of residential sector to the total loads' and the 'total number of the contracted households'. In fact, the load pattern of the aggregated load and the effective load pattern of the residential sector are obviously different. However, under the circumstance in which the real-time hourly load data for the residential sector is not available, using a re-scaled load profile may also be helpful to draw some insight and implications throughout the analysis.

In 2016, the proportion of the residential sector to the total loads was about 13.3%, and the total number of contracted households was about 14.6 million (14,626,290).[14] The following Figure 3 shows the number of residential customers by region in 2016, South Korea. Examining this figure (and others in Appendix),[15] we can identify the possible target area or group in order to exploit the maximum level of the DR mechanism.

[14] In 2015, it was 12.9% and 14,419,050. For the detailed information on the electricity consumption share by usage or sector, the number of clients by usage and area, please, refer to the site of "Electricity Big Data Center" operated by KEPCO, [On-line], Available: https://home.kepco.co.kr/kepco/BD/BDBAPP001/BDBAPP001.do?menuCd=FN33020101; KEPCO, 2018, *STATISTICS OF ELECTRIC POWER IN KOREA*, [On-line], Available: https://goo.gl/fDxG1Y

[15] Please, refer to other figures and the table for the total consumption (Fig. A.1), average consumption (Fig. A.2) in the residential sector by region, and the list of the top 5 regions (Tab. A.1) in 2016, South Korea in Supplementary Figures & Tables of Appendix.

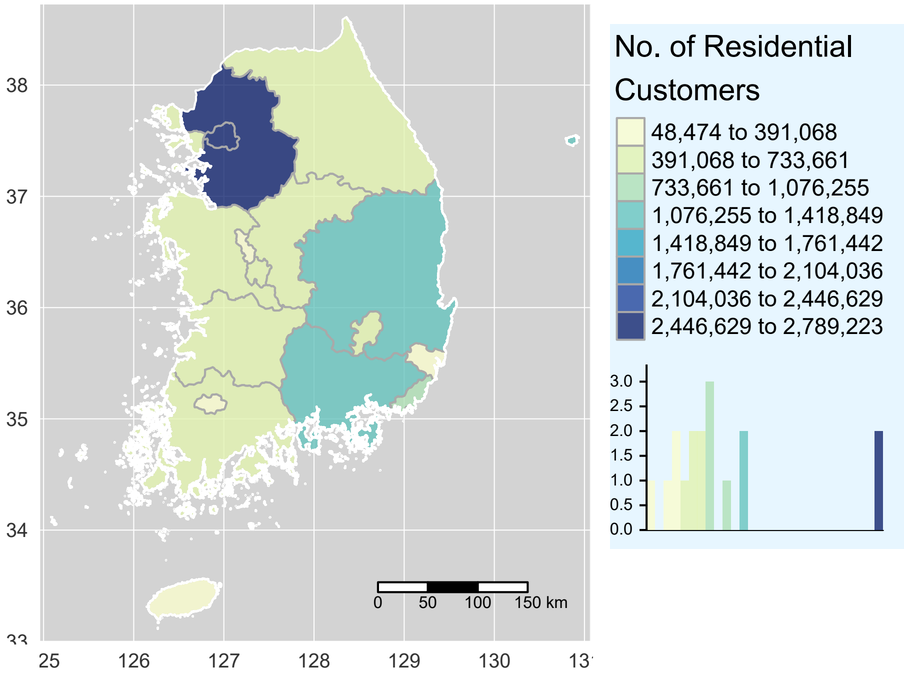

Figure 3: The Number of Residential Customers by Region, 2016 in South Korea

Source: "Electricity Big Data Center" operated by KEPCO, [On-line], Available: https://home.kepco.co.kr/kepco/BD/BDBAPP004/BDBAPP004.do?menuCd=FN33020104

With this approach, we can obtain the re-scaled load profile of an average household (W) from the aggregated load (MW) like the following:

$$\mathbf{L}^{\mathbf{agg.}}_{\mathbf{366\times 24}} = \begin{array}{c} \\ 1 \\ 2 \\ \vdots \\ 366 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & \dots & 24 \end{array} \\ \begin{pmatrix} \ell_{1,1} & \ell_{1,2} & \cdots & \ell_{1,24} \\ \ell_{2,1} & \ell_{2,2} & \cdots & \ell_{2,24} \\ \vdots & \vdots & \ddots & \vdots \\ \ell_{366,1} & \ell_{366,2} & \cdots & \ell_{366,24} \end{pmatrix} \end{array}$$

(Eq.: Aggregated National Load Profile, South Korea)

$$\mathbf{L}^{\mathbf{avg.res.}}_{\mathbf{366\times 24}} = \frac{13.3}{100} \times \frac{1}{14,626,290} \times 1,000 \times 1,000 \times \mathbf{L}^{\mathbf{agg.}}_{\mathbf{366\times 24}}$$

(Eq.: Re-scaled Load Profile, South Korea)

where,

$$\begin{cases} \mathbf{L}^{\text{agg.}}_{366\times 24} & : \text{ a matrix of aggregated national loads, 366 rows} \times 24 \text{ columns, in 2016 (there were 366 days in 2016),} \\ \mathbf{L}^{\text{avg.res.}}_{366\times 24} & : \text{ a matrix of re-scaled loads of an average household in (W), 366 rows} \times 24 \text{ columns,} \\ \ell_{d,t} & : \text{ actual load at the time slot t and on the day of d, } d \in D = \{1, 2, \ldots, 366\},\ t \in T = \{1, 2, \ldots, 24\}. \end{cases}$$

In South Korea, KPX basically uses the WMA method based on the day matching method [20]. Among the 10 reference days, the highest two days and lowest two days are excluded in terms of the amount of the total electricity consumption [therefore, it is Mid(6/10)]. The weights are 0.10, 0.15, 0.15, 0.15, 0.20, and 0.25 for the most recent days respectively (`Eq.: Weights`). It means putting more emphasis on more recent day's energy loads by assigning heavier weights.

$$\begin{aligned} \mathbf{CBL}^{\mathbf{WMA}} &= \mathbf{w}^{\mathbf{T}} \cdot \mathbf{S}^{\mathbf{6}} \\ &= \begin{pmatrix} \omega_6 & \ldots & \omega_1 \end{pmatrix} \cdot \begin{pmatrix} \ell_{d-6,1} & \ell_{d-6,2} & \ldots & \ell_{d-6,24} \\ \ell_{d-5,1} & \ell_{d-5,2} & \ldots & \ell_{d-5,24} \\ \vdots & \vdots & \ddots & \vdots \\ \ell_{d-1,1} & \ell_{d-1,2} & \ldots & \ell_{d-1,24} \end{pmatrix} \\ &= \begin{pmatrix} \text{CBL}_1^{\text{WMA}} & \text{CBL}_2^{\text{WMA}} & \ldots & \text{CBL}_{24}^{\text{WMA}} \end{pmatrix} \end{aligned} \qquad \text{(Eq.: } \mathbf{CBL}^{\mathbf{WMA}}\text{)}$$

where,

$$\begin{cases} \text{CBL}^{\mathbf{WMA}} & : \text{ a vector of CBL which is calculated with the weighted moving average method,} \\ \omega^{\mathbf{T}} & : \text{ a transposed vector of the weights for } i^{th} \text{ day before the DR event day,} \\ \mathbf{S}^{\mathbf{6}} & : \text{ a matrix of the similar non-event 6 days,} \\ \ell_{d-i,t} & : \text{ actual load at the time slot of } t \text{ and on the day of } (d\text{-}i)\ (i^{th} \text{ day before the DR event day).} \end{cases}$$

$$\mathbf{w}^{\mathbf{T}} = \begin{pmatrix} \omega_6 & \ldots & \omega_1 \end{pmatrix} = \begin{pmatrix} 0.10 & 0.15 & 0.15 & 0.15 & 0.20 & 0.25 \end{pmatrix} \qquad \text{(Eq.: Weights)}$$

Once we calculate the CBL by using the WMA and the day matching method, it is necessary to adjust (or update) the CBL reflecting the difference between the preliminarily estimated CBL and the actual electricity load prior to the DR event time. We can adjust the CBL proportionally or additively. First, the following is the proportionally adjusted CBL, and for the Proportional Adjustment Coefficient (PAC) (or adjustment factor), we use the proportion of the average actual electricity load at the time of $t-1$ and $t-2$ on the DR event day over the average CBL at the time of $t-1$ and $t-2$ on the DR event day.

$$\text{Updated } \mathbf{CBL^{PAC}_{d,t}} = \text{Proportional Adjustment Coefficient} \times \mathbf{CBL^{WMA}_{d,t}}$$

$$\begin{aligned} \mathbf{CBL^{WMA} \cdot PAC} &= \text{PAC} \cdot \mathbf{CBL^{WMA}} \\ &= \text{PAC} \cdot \begin{pmatrix} \text{CBL}^{\text{WMA}}_1 & \text{CBL}^{\text{WMA}}_2 & \dots & \text{CBL}^{\text{WMA}}_{24} \end{pmatrix} \end{aligned} \qquad (\text{Eq.: } \mathbf{CBL^{WMA} \cdot PAC})$$

where,

- $\mathrm{CBL^{WMA} \cdot PAC}$: a vector of proportionally adjusted CBL,
- PAC : Proportional Adjustment Coefficient for the weighted moving average method,
- $\ell_{d,t-1}$: the load (demand) at the time of *t-1*, and on the day of (*d*),
- $\ell_{d,t-2}$: the load (demand) at the time of *t*-2, and on the day of (*d*),
- $\text{CBL}_{d,t-1}$: the estimated CBL at the time of *t*-1, and on the day of (*d*),
- $\text{CBL}_{d,t-2}$: the estimated CBL at the time of *t*-2, and on the day of (*d*).

$$\text{PAC} = \frac{(\ell_{d,t-1} + \ell_{d,t-2})}{2} \div \frac{(\text{CBL}^{\text{WMA}}_{d,t-1} + \text{CBL}^{\text{WMA}}_{d,t-2})}{2} \qquad (\text{Eq.: PAC})$$

Second, the following is the additively adjusted CBL, and for the SAA option, we use the following adjustment coefficient and add it to the preliminarily estimated CBL at the time of t.

$$\text{Updated } \mathbf{CBL^{SAA}_{d,t}} = \mathbf{CBL^{WMA}_{d,t}} + \text{SAA}$$

$$\begin{aligned} \mathbf{CBL^{WMA} + SAA} &= \text{SAA} + \mathbf{CBL^{WMA}} \\ &= \text{SAA} + \begin{pmatrix} \text{CBL}^{\text{WMA}}_1 & \text{CBL}^{\text{WMA}}_2 & \dots & \text{CBL}^{\text{WMA}}_{24} \end{pmatrix} \end{aligned}$$

$$(\text{Eq.: } \mathbf{CBL^{WMA} + SAA})$$

where,

- $\mathrm{CBL^{WMA} + SAA}$: a vector of CBL with Symmetric Additive Adjustment,
- SAA : additive adjustment coefficient for the SAA option,
- $\ell_{d,t-1}$: the load (demand) at the time of *t-1*, and on the day of (*d*),
- $\ell_{d,t-2}$: the load (demand) at the time of *t*-2, and on the day of (*d*),
- $\text{CBL}_{d,t-1}$: the estimated CBL at the time of *t*-1, and on the day of (*d*),
- $\text{CBL}_{d,t-2}$: the estimated CBL at the time of *t*-2, and on the day of (*d*).

$$\mathrm{SAA} = \max\left\{\frac{(\ell_{d,t-1} - \mathrm{CBL}_{d,t-1}) + (\ell_{d,t-2} - \mathrm{CBL}_{d,t-2})}{2}, 0\right\} \qquad \text{(Eq.: SAA)}$$

3.2. A CBL for an Average Household in France

According to Smart Energy Demand Coalition (SEDC) [29, p. 10], it seems that at least until 2017, there was no consensus as to the methodology for CBL estimation in France, especially for NEBEF. Actually, from NEBEF 1.0 to NBEF 3.1 [27], there has been a number of experiments and tests in order to find the best methodology for CBL estimation. In the most recent regulation of NEBEF, that is NEBEF 3.1, now there are several methods to establish CBLs for the participants, such as 'Méthode du rectangle à double référence corrigée', 'Méthode du rectangle algébrique site à site', 'Méthode par prévision de consommation' and 'Méthode par historique de consommation'. Considering the importance of the accurate CBL estimation methods and the fact that if we could provide several possible methods to the DR participants so that the participants can find the most suitable CBL methods for them, then it can increase their motivation to participate in it [29, p. 81], it will be meaningful to test several CBL methods and to suggest better CBL methods for the NEBEF mechanism in France. Therefore, here I find the contribution of this section of the research by comparing different CBL calculation methods between South Korea and France.

Compared to the heatmap of South Korea's loads in 2016 (Fig. 1), in general in France, the peak load happens in winter a year and from 8 a.m. to 13 p.m. and from 18 p.m. to 20 p.m. a day (Fig. 4) [For the last decade from 2007 to 2016, all the peak loads of France happened at 7 p.m. (19:00) in winter (Fig. 5)]. During the winter peak, the high usage of electricity comes from using the electric appliances for heating and cooking in the evening. However, during summer, it shows the low usage of electricity because the rate of the installation and utilization of the air-conditioning appliances for cooling is low (the low penetration of air-conditioning system) in France compared to South Korea.

In order to establish and assess a demonstrative CBL for France's NEBEF mechanism, I focus on 7 p.m. (19:00–20:00, the two-time slots for $t = 37$ and $t = 38$ for 30 minute interval a day) on Monday, January 18th in 2016, which was the peak demand in 2016 for France (Fig. 5). In the framework of the NEBEF mechanism, there are two types of the electricity consumption clients: 1. a Profiled Client ('un Site de Soutirage Profilé'); 2. a Client with the Advanced Metering Infrastructure (AMI) ('un Site de Soutirage Télérelevé'). It was planned to deploy the AMI (Smart Metering) by 2020 — three million smart meters between 2014 and 2016, and then 32 million smart meters from 2017 to 2020 [16]. Because explicit DR is largely based on the AMI, I concern only with the residential clients equipped with the AMI ('un Site de Soutirage Télérelevé') in this study.

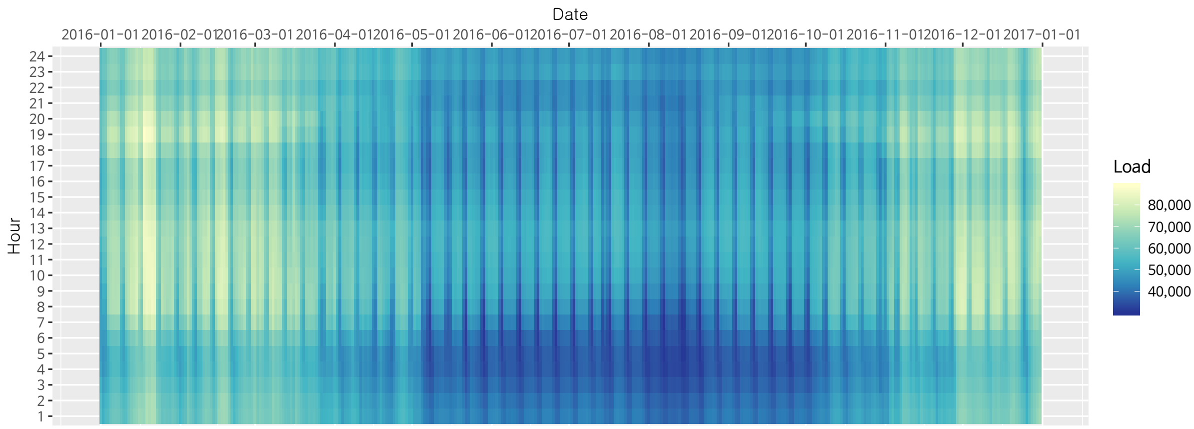

Figure 4: Heatmap of Loads, France in 2016 (MW)

Source: 'Data provided by ENTSO-E', ENTSO-E, "Consumption Data", [On-line], Available: `https://www.entsoe.eu/data/data-portal/consumption/Pages/default.aspx`

Comparison to Korea: Fig. 1

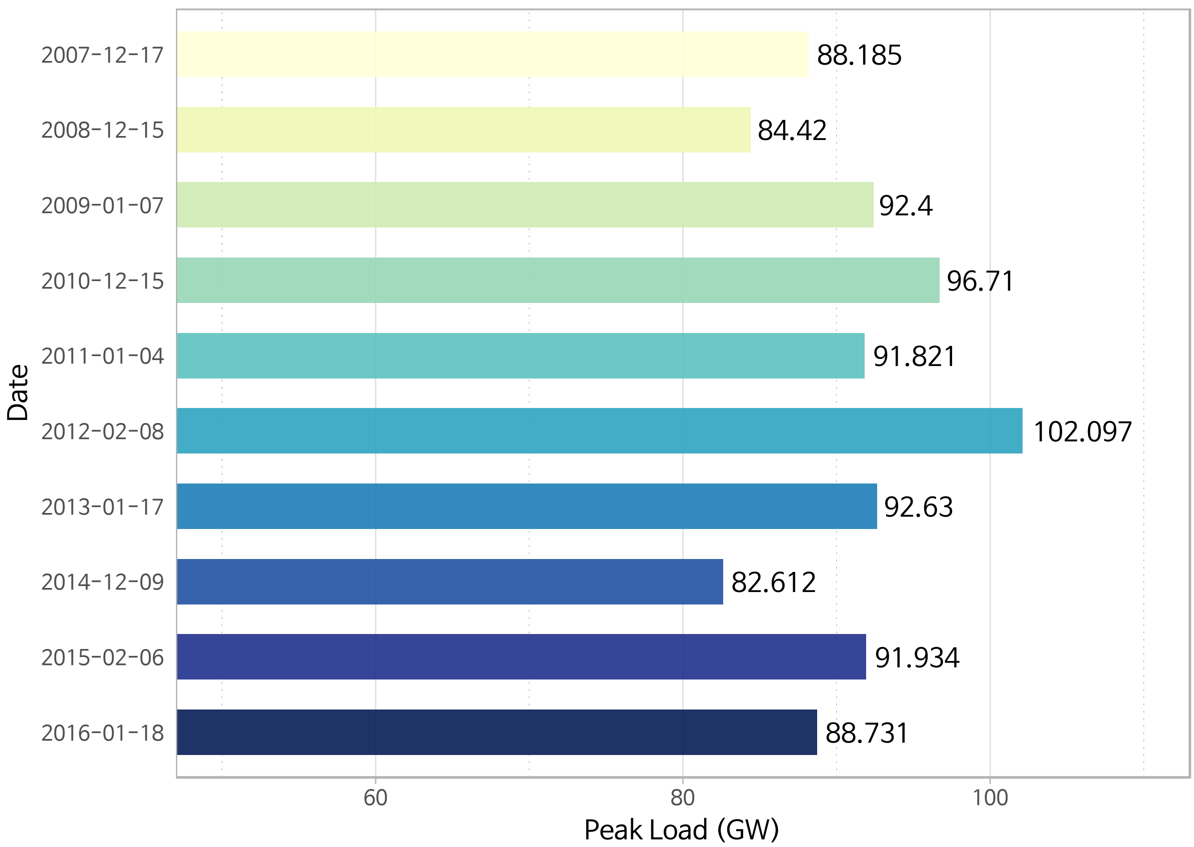

Figure 5: France's Peak Demand over the Past Decade (Since 2007, GW)

Source: *Generation Adequacy Report: on the electricity supply-demand balance in France*, by RTE [26, p. 33]; RTE's PORTAIL CLIENTS, "Historique des consommations journalières en puissance", [On-line], Available: `https://clients.rte-france.com/lang/fr/clients_traders_fournisseurs/vie/vie_stats_conso_inst.jsp`

Comparison to Korea: Fig. 2

In NEBEF mechanism, the load duration curve ('Courbe de Consommation') for a residential client with the AMI is constructed for every 10 minutes ('Pas 10 minutes'), and the CBL ('Courbe de Référence') is established for every 30 minutes ('Pas Demi-Horaire') — this is the difference between France's NEBEF mechanism and South Korea's DRTM, in which both of the load duration curve and CBL are established with one hour interval. However, with the difficulties to obtain an actual load dataset for every 10 minutes which was tele-measured by the AMI, I re-scale down the aggregated national load duration curve measured for every 30 minutes to build a load duration curve and CBL for an average French household — the same approach with the South Korean CBL.

In 2016, the residential sector accounted for 36% of France's total electricity consumptions [24].[16] As of March 31st, 2016, the total number of residential clients, that is households, was 31,889,000 [14, p. 6].[17]

The following Figure 6 shows the number of residential customers by 'Département' in 2016, France. Examining this figure (and others in Appendix),[18] we can identify the possible target area or group in order to exploit the maximum level of the DR mechanism.

[16] Business sector 27%, heavy industry 17%, and SMEs/SMI 10%. For the percentage of residential sector in 2000, 2005, 2010, 2014, 2015, it is 33.4%, 32.8%, 36.4%, 35.2%, 35.9%, respectively. It can be calculated referring to the following document: [10, p. III.197, Table 3a. Summary electricity production and consumption1 (TWh)].

[17] As of December 31st, 2015, it was 31,790,000, as of December 31st, 2017, it was 32,396,000, and as of March 31st, 2018, it was 32,508,000 [15].

[18] Please, refer to other figures and the table for the total consumption (Fig. A.3), average consumption (Fig. A.4) in the residential sector by Département, and the list of the top 10 Départements (Tab. A.2) in 2016, France in Supplementary Figures & Tables of Appendix.

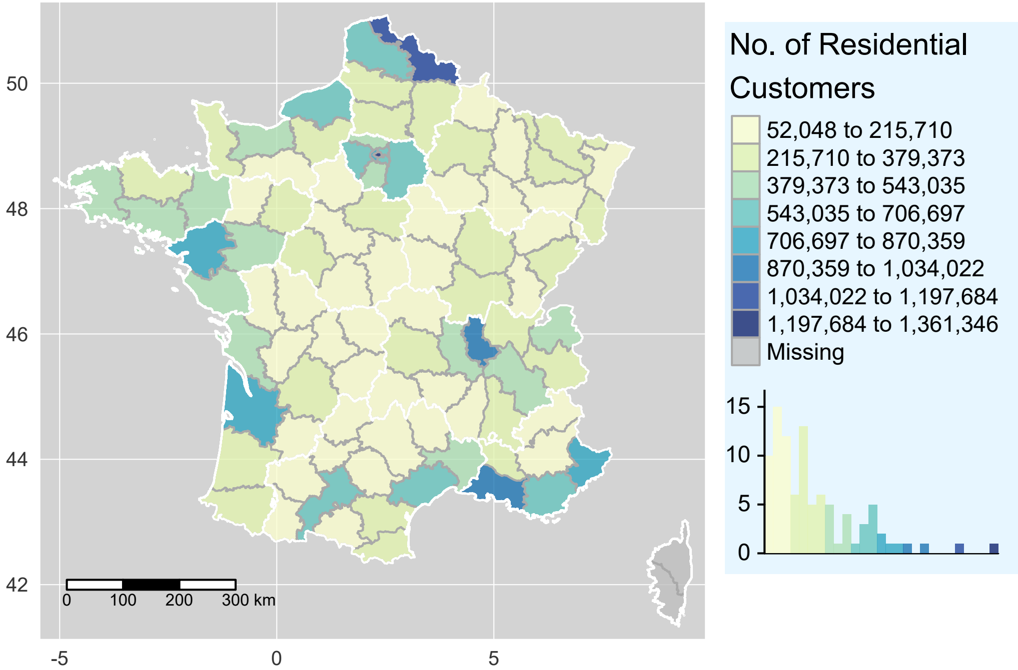

Figure 6: The Number of Residential Customers by Département, 2016 in France

Source: "Consommation électrique annuelle à la maille département", 2018, by Enedis, [On-line], Available: https://goo.gl/kqVMi2

According to the abovementioned information on the residential sector in France, we can obtain the following re-scaled load profile of an average household (W) from the aggregated national load (MW).

$$\mathbf{L}^{\mathbf{agg.}}_{\mathbf{366\times 144}} = \begin{array}{c} \\ 1 \\ 2 \\ \vdots \\ 366 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & \ldots & 144 \end{array} \\ \begin{pmatrix} \ell_{1,1} & \ell_{1,2} & \cdots & \ell_{1,144} \\ \ell_{2,1} & \ell_{2,2} & \cdots & \ell_{2,144} \\ \vdots & \vdots & \ddots & \vdots \\ \ell_{366,1} & \ell_{366,2} & \cdots & \ell_{366,144} \end{pmatrix} \end{array} \approx \mathbf{L}^{\mathbf{agg.}}_{\mathbf{366\times 48}} = \begin{array}{c} \\ 1 \\ 2 \\ \vdots \\ 366 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & \ldots & 48 \end{array} \\ \begin{pmatrix} \ell_{1,1} & \ell_{1,2} & \cdots & \ell_{1,48} \\ \ell_{2,1} & \ell_{2,2} & \cdots & \ell_{2,48} \\ \vdots & \vdots & \ddots & \vdots \\ \ell_{366,1} & \ell_{366,2} & \cdots & \ell_{366,48} \end{pmatrix} \end{array}$$

(Eq.: Aggregated National Load Profile, France)

$$\mathbf{L}^{\mathbf{avg.res.}}_{\mathbf{366\times 48}} = \frac{36}{100} \times \frac{1}{31,889,000} \times 1,000 \times 1,000 \times \mathbf{L}^{\mathbf{agg.}}_{\mathbf{366\times 48}}$$

(Eq.: Re-scaled Load Profile, France)

where,

$\mathbf{L}^{\text{agg.}}_{366\times144}$	:	a matrix of aggregated national loads of France measured for every 10 minutes, 366 rows × 144 (= 24 × 6) columns, in 2016 (there were 366 days in 2016),
$\mathbf{L}^{\text{agg.}}_{366\times48}$	:	a matrix of aggregated national loads of France measured for every 30 minutes, 366 rows × 48 (= 24 × 2) columns,
$\mathbf{L}^{\text{avg.res.}}_{366\times48}$	:	a matrix of re-scaled loads of an average household of France in (W), 366 rows × 48 (= 24 × 2) columns,
$l_{d,t}$	:	actual load at the time slot t and on the day of d, $d \in D = \{1, 2, \ldots, 366\}$, $t \in T = \{1, 2, \ldots, 144\}$ for a load measured by 10 minute interval, $t \in T = \{1, 2, \ldots, 48\}$ for a load measured by 30 minute interval.

In the NEBEF mechanism (in NBEF 3.1), there are mainly four methods for establishing a CBL:[19]

1. Méthode du rectangle à double référence corrigée,
2. Méthode du rectangle algébrique site à site,
3. Méthode par prévision de consommation,
4. Méthode par historique de consommation.

The first method of 'Méthode du rectangle à double référence corrigée' is the default method of NEBEF both for 'un Site de Soutirage Profilé' and 'un Site de Soutirage Télérelevé'. Also, it is one of the family of 'les méthodes du rectangle' which includes 'méthode du rectangle simple', 'méthode du rectangle à double référence' and 'méthode du rectangle à double référence corrigée'.[20] This family of the method uses the loads before and after the DR events. Even though this first method is default both for 'un Site de Soutirage Profilé' and 'un Site de Soutirage Télérelevé', it seems like more suitable for 'un Site de Soutirage Profilé' because there is no available previous historical data for 'un Site de Soutirage Profilé' so it cannot help relying only on the load record of the DR event day. If an LA ('l'Opérateur d'Effacement') wants to apply other methods to establishing a CBL, then it can declare the method when it creates a Load Shedding Entity ('Entité d'Effacement (EDE)').[21]

The second method of 'Méthode du rectangle algébrique site à site' is only applicable to the Profiled Load Shedding Entities ('Entités d'Effacement Profilées') consisting of more than three thousand (3,000) of 'Sites de Soutirage Profilés'. This method is just the algebraic sum of the applications of the first method of 'Méthode du rectangle à

[19] It seems that at the experimental phase, the panel data analysis was also tested for a possible CBL estimation method. For this, please refer to the following: [25, pp. 60–61].

[20] In order to better understand the family of 'les méthodes du rectangle', please refer to the following document: [25, pp. 55–57].

[21] One Load Shedding Entity (Entité d'Effacement) consists of more than one site of an electricity customer ('des Sites de Soutirage Profilé' or 'des Sites de Soutirage Télérelevé'). Also, a Perimeter of Load Shedding consists of more than one Load Shedding Entity. On the top level, a Load Aggregator may have several Perimeters of Load Shedding. Therefore, we can see the following hierarchical levels: Sites de Soutirage ⇒ Entités d'Effacement ⇒ Périmètre d'Effacement ⇒ l'Opérateur d'Effacement.

double référence corrigée' to each of its consisting clients.

The third method of 'Méthode par prévision de consommation' is applicable only to the Tele-measured Load Shedding Entities ('Entités d'Effacement Télérelevées'). If an LA wants to utilize this method, it needs to declare this method when it creates the Load Shedding Entity, and then it transfers the data to RTE.

The last method of 'Méthode par historique de consommation' is also applicable only to the Tele-measured Load Shedding Entity. This method is equivalent to the 'conventional day matching (or match) method' that was mentioned in Section 2. As we have seen, in this category of the conventional day matching method there are a number of variants of this method and some of them are used in the U.S. and South Korea. In the NEBEF mechanism, there are four variants of this day matching method:

'Méthode par historique de consommation':

1. Moyenne 10 jours,
2. Médiane 10 jours,
3. Moyenne 4 semaines,
4. Médiane 4 semaines.

Since 'median' can be thought of as the 'fully trimmed mid-range', we can consider the methods of 'Médiane 10 jours' and 'Médiane 4 semaines' as 'Average 2/10 (=Mid 2/10)' and 'Average 2/4 (=Mid 2/4)', respectively.

Because I focus on the residential sector and the households equipped with the AMI, I do not consider the first and second method of 'Méthode du rectangle à double référence corrigée' and 'Méthode du rectangle algébrique site à site'. Moreover, in the regulation for the NEBEF mechanism, there are no specific formulas for the third method of 'Méthode par prévision de consommation', and it seems that it is up to LAs to choose any formulas to calculate the load estimations with this method. Therefore, I consider and utilize the last method of 'Méthode par historique de consommation' with its four variants in the following.

For the first variant of the method: 'Moyenne 10 jours',

$$\begin{aligned}
\mathbf{CBL^{avg.10}} &= \frac{1}{10}\mathbf{1}_{10}^{T}\cdot\mathbf{S^{10}} \\
&= \frac{1}{10}\begin{pmatrix} 1 & \dots & 1 \end{pmatrix}\cdot\begin{pmatrix} \ell_{d-10,1} & \ell_{d-10,2} & \dots & \ell_{d-10,48} \\ \ell_{d-9,1} & \ell_{d-9,2} & \dots & \ell_{d-9,48} \\ \vdots & \vdots & \ddots & \vdots \\ \ell_{d-1,1} & \ell_{d-1,2} & \dots & \ell_{d-1,48} \end{pmatrix} \qquad \text{(Eq.: } \mathbf{CBL^{avg.10}}\text{)} \\
&= \begin{pmatrix} \mathrm{CBL}_1^{\mathrm{avg.10}} & \mathrm{CBL}_2^{\mathrm{avg.10}} & \dots & \mathrm{CBL}_{48}^{\mathrm{avg.10}} \end{pmatrix}
\end{aligned}$$

where,

$$\left\{\begin{array}{lll} \mathbf{CBL}^{\mathbf{avg.10}} & : & \text{a vector of CBL which is calculated with the method of 'Moyenne 10 jours',} \\ \mathbf{1}_{10}^{T} & : & \text{a transposed vector of ten elements of } 1 \text{ (one), that is a sum vector,} \\ \mathbf{S^{10}} & : & \text{a matrix of the similar non-event 10 days consisting of the loads of the previous ten days,} \\ l_{d-i,t} & : & \text{actual load at the time slot of } t \text{ and on the day of } (d\text{-}i) \; (i^{th} \text{ day before the DR event day),} \\ & & i \in I = \{1, 2, \cdots, 10\}. \end{array}\right.$$

For the second variant of the method: 'Médiane 10 jours',

$$\begin{aligned} \mathbf{CBL^{med.10}} &= \text{Median}(\mathbf{S^{10}}) \\ &= \text{Median}\left(\begin{pmatrix} \ell_{d-10,1} & \ell_{d-10,2} & \dots & \ell_{d-10,48} \\ \ell_{d-9,1} & \ell_{d-9,2} & \dots & \ell_{d-9,48} \\ \vdots & \vdots & \ddots & \vdots \\ \ell_{d-1,1} & \ell_{d-1,2} & \dots & \ell_{d-1,48} \end{pmatrix}\right) \\ &= \begin{pmatrix} \text{Median}(\mathbf{s_1^{10}}) & \text{Median}(\mathbf{s_2^{10}}) & \dots & \text{Median}(\mathbf{s_{48}^{10}}) \end{pmatrix} \\ &= \begin{pmatrix} \text{CBL}_1^{\text{med.10}} & \text{CBL}_2^{\text{med.10}} & \dots & \text{CBL}_{48}^{\text{med.10}} \end{pmatrix} \end{aligned} \qquad (\text{Eq.: } \mathbf{CBL^{med.10}})$$

where,

$$\left\{\begin{array}{lll} \mathbf{CBL}^{\mathbf{med.10}} & : & \text{a vector of CBL which is calculated with the method of 'Médiane 10 jours',} \\ \mathbf{S^{10}} & : & \text{a matrix of the similar non-event days consisting of the loads of the previous ten days,} \\ l_{d-i,t} & : & \text{actual load at the time slot of } t \text{ and on the day of } (d\text{-}i) \; (i^{th} \text{ day before the DR event day),} \\ & & i \in I = \{1, 2, \cdots, 10\}, \\ \mathbf{s_t^{10}} & : & \text{the } t^{\text{th}} \text{ column vector of the matrix } \mathbf{S^{10}}\text{, and it is the loads of the previous ten days for each time slot t,} \\ & & t \in T = \{1, 2, \cdots, 48\}. \end{array}\right.$$

For the third variant of the method: 'Moyenne 4 semaines',

$$\begin{aligned} \mathbf{CBL^{avg.4}} &= \frac{1}{4}\mathbf{1}_4^T \cdot \mathbf{S^4} \\ &= \frac{1}{4}\begin{pmatrix} 1 & \dots & 1 \end{pmatrix} \cdot \begin{pmatrix} \ell_{d-28,1} & \ell_{d-28,2} & \dots & \ell_{d-28,48} \\ \ell_{d-21,1} & \ell_{d-21,2} & \dots & \ell_{d-21,48} \\ \ell_{d-14,1} & \ell_{d-14,2} & \dots & \ell_{d-14,48} \\ \ell_{d-7,1} & \ell_{d-7,2} & \dots & \ell_{d-7,48} \end{pmatrix} \\ &= \begin{pmatrix} \text{CBL}_1^{\text{avg.4}} & \text{CBL}_2^{\text{avg.4}} & \dots & \text{CBL}_{48}^{\text{avg.4}} \end{pmatrix} \end{aligned} \qquad (\text{Eq.: } \mathbf{CBL^{avg.4}})$$

where,

- $\text{CBL}^{\textbf{avg.4}}$: a vector of CBL which is calculated with the method of 'Moyenne 4 semaines',
- $\mathbf{1}_4^T$: a transposed vector of four elements of 1 (one), that is a sum vector,
- $\mathbf{S^4}$: a matrix of the similar non-event 4 days consisting of the loads of the previous four weeks on the same day (ex. Mon., $\cdots$, Fri.),
- $l_{d-i,t}$: actual load at the time slot of *t* and on the day of (*d*-*i*) (i^{th} day before the DR event day), $i \in I = \{7, 14, 21, 28\}$.

For the last variant of the method: 'Médiane 4 semaines',

$$\begin{aligned}
\mathbf{CBL^{med.4}} &= \text{Median}(\mathbf{S^4}) \\
&= \text{Median}\left(\begin{pmatrix} \ell_{d-28,1} & \ell_{d-28,2} & \dots & \ell_{d-28,48} \\ \ell_{d-21,1} & \ell_{d-21,2} & \dots & \ell_{d-21,48} \\ \ell_{d-14,1} & \ell_{d-14,2} & \dots & \ell_{d-14,48} \\ \ell_{d-7,1} & \ell_{d-7,2} & \dots & \ell_{d-7,48} \end{pmatrix}\right) \\
&= \begin{pmatrix} \text{Median}(\mathbf{s_1^4}) & \text{Median}(\mathbf{s_2^4}) & \dots & \text{Median}(\mathbf{s_{48}^4}) \end{pmatrix} \\
&= \begin{pmatrix} \text{CBL}_1^{\text{med.4}} & \text{CBL}_2^{\text{med.4}} & \dots & \text{CBL}_{48}^{\text{med.4}} \end{pmatrix}
\end{aligned} \qquad \text{(Eq.: } \mathbf{CBL^{med.4}}\text{)}$$

where,

- $\text{CBL}^{\textbf{med.4}}$: a vector of CBL which is calculated with the method of 'Médiane 4 semaines',
- $\mathbf{S^4}$: a matrix of the similar non-event 4 days consisting of the loads of the previous four weeks on the same day(ex. Mon., $\cdots$, Fri.),
- $l_{d-i,t}$: actual load at the time slot of *t* and on the day of (*d*-*i*) (i^{th} day before the DR event day), $i \in I = \{7, 14, 21, 28\}$,
- $\mathbf{s_t^4}$: the t^{th} column vector of the matrix $\mathbf{S^4}$, and it is the loads of the previous four weeks for each time slot t, $t \in T = \{1, 2, \cdots, 48\}$.

IV. RESULTS AND DISCUSSION

The following Figure 7 demonstrates the loads of the six similar non-event days which were used for the estimation and the four estimated CBLs based on different CBL estimation methods – simple average ($\text{CBL}^{\text{avg.}}$), weighted moving average (CBL^{WMA}), weighted moving average + proportional adjustment ($\text{CBL}^{\text{WMA}} \cdot \text{PAC}$) and weighted moving average + symmetric additive adjustment ($\text{CBL}^{\text{WMA}} + \text{SAA}$) for the South Korean case. Table 1 summarizes the actual loads and four estimated CBLs for the DR event times, $t = 17h$ and $t = 18h$.

As can be seen in Figure 7, the loads were in the increasing trend from the earliest day (2016/07/29) to the DR event day (2016/08/12 in red), which was the peak period. The estimated CBLs of $\text{CBL}^{\text{avg.}}$ in light yellow and CBL^{WMA} in yellow are about in the middle of the six similar non-event days, and the latter is slightly better than the former but not a big difference.

We can also visually notice that the two estimated CBLs of $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ in blue and $\text{CBL}^{\text{WMA}} + \text{SAA}$ in green are very close to the actual loads, and there is a very subtle difference between the two CBLs. Considering both of the figure and the table below, therefore, we can conclude that the two CBLs of $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$ perform much better than the two CBLs of $\text{CBL}^{\text{avg.}}$ and CBL^{WMA}, and between the two CBLs of $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$ the estimated CBL of $\text{CBL}^{\text{WMA}} + \text{SAA}$ is slightly better than another.

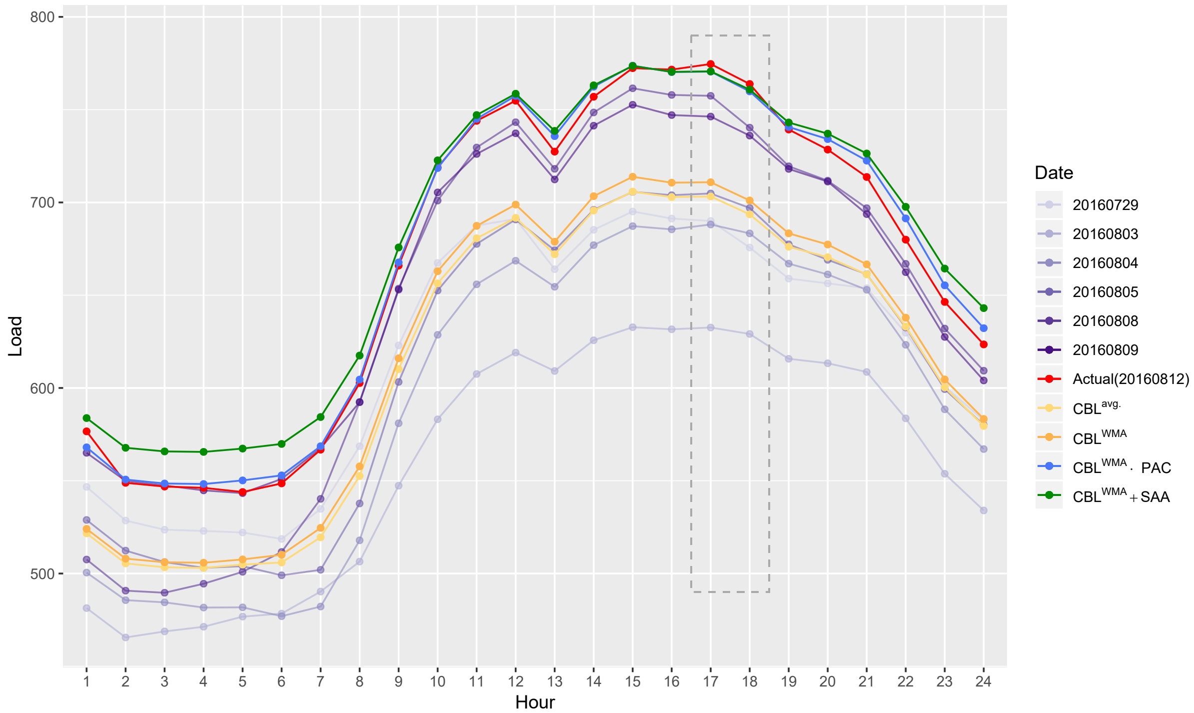

Figure 7: The Visual Comparison among the CBLs Established with Different Methods (South Korean DRTM)

Table 1: Summary of the Established CBLs for the Event Times (South Korean DRTM)

	2016-08-12			
	⋯	17h	18h	⋯
Actual Load	⋯	774.60	763.83	⋯
$\text{CBL}^{\text{avg.}}$	⋯	703.21	693.58	⋯
CBL^{WMA}	⋯	710.89	701.05	⋯
$\text{CBL}^{\text{WMA}} \cdot \text{PAC}$	⋯	770.52	759.86	⋯
$\text{CBL}^{\text{WMA}} + \text{SAA}$	⋯	770.63	760.80	⋯

On top of the visual observation, in order to numerically assess the four established CBLs with different methods, we measure MAPE and RRMSE for the four different CBLs, and then compare them. The following Figure 8 shows the results of the accuracy assessment for the four estimated CBLs in terms of MAPE and RRMSE, and Table 2 summarizes the results. The results are the same both in terms of MAPE and RRMSE. The estimated CBL of $\text{CBL}^{\text{WMA}}+\text{SAA}$ shows the least error both in the upper panel (MAPE) and the lower panel (RRMSE) in the figure—those are less than 0.5% which means the method performs surprisingly well. With this comparison of MAPE and RRMSE of the four different CBL methods, we can conclude that $\text{CBL}^{\text{WMA}} + \text{SAA}$ (symmetric additive adjustment) is the best, although there is no stark difference between the two methods $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$, proportional adjustment and additive adjustment, respectively.

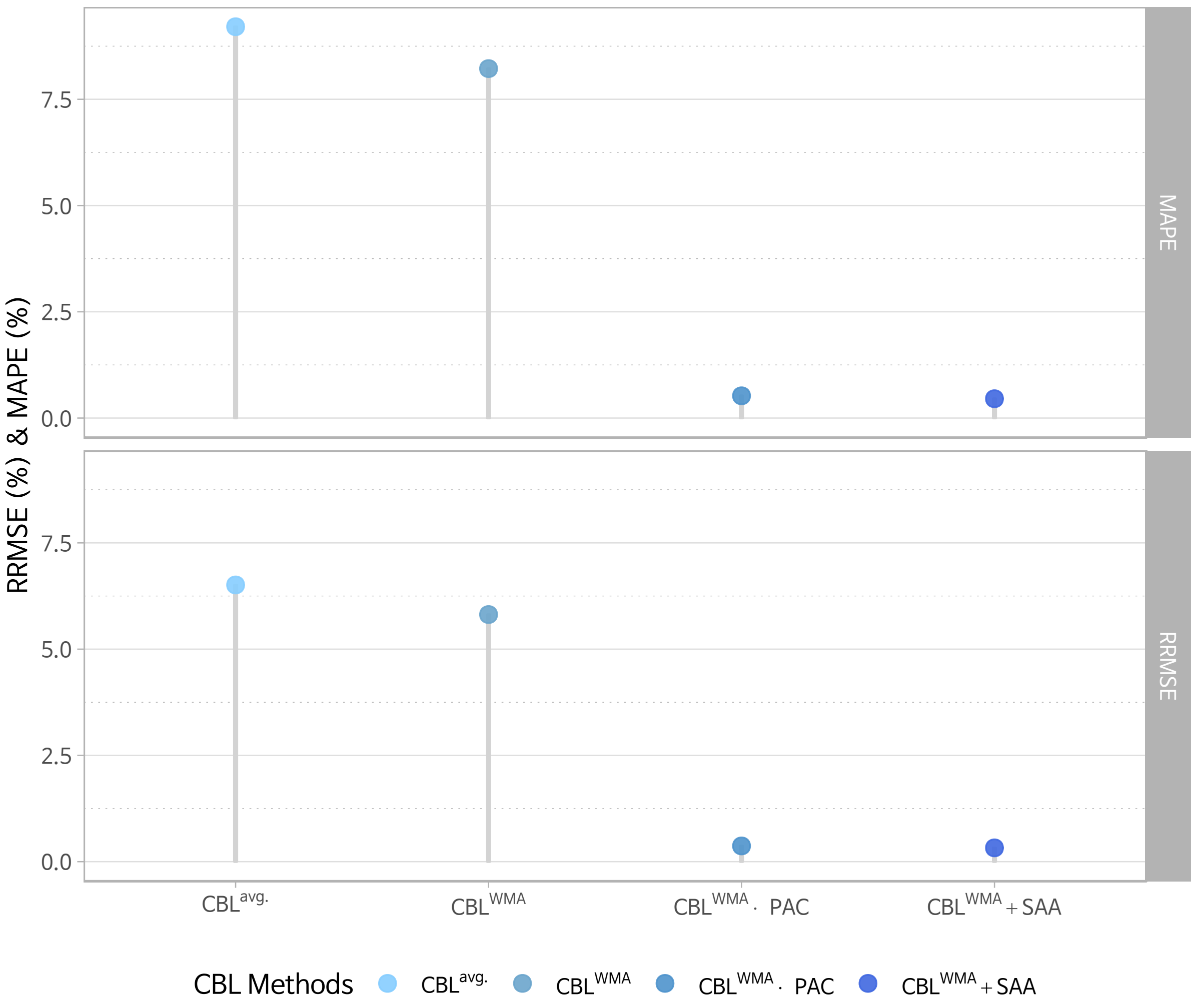

Figure 8: The CBL Accuracy Comparison (MAPE & RRMSE) among the CBLs Established with Different Methods (South Korean DRTM)

Table 2: The CBL Accuracy Comparison (MAPE and RRMSE) among the CBLs Established with Different Methods (South Korean DRTM)

	$CBL^{avg.}$	CBL^{WMA}	$CBL^{WMA} \cdot PAC$	$CBL^{WMA} + SAA$
MAPE	9.21%	8.22%	0.52%	0.45%
RRMSE	6.51%	5.81%	0.37%	0.32%

The following Figure 9 demonstrates the actual loads for every 30 minutes on Jan. 18th, 2016, the loads of the ten previous days[22] for the same time slots of the DR event times, and the two CBLs based on the method of 'Moyenne 10 jours' and 'Médiane 10 jours'

[22] When it comes to the ten previous days before Jan. 18th in 2016, I only included the working days and excluded the holidays and weekends. In this case, there was no holiday among the original ten previous days, therefore, I simply used the loads of Jan. 4th, 5th, 6th, 7th, 8th, 11th, 12th, 13th, 14th, and 15th in 2016.

for the French case. First of all, we can see that the actual loads were the highest loads — of course, because I chose the day of the peak demand, and we can see the increasing trend from the earliest day (2016-01-04) to the most recent day (2016-01-15), and finally the DR event day's (2016-01-18) actual loads in red.

Also, we can verify that the two CBLs based on the method of 'Moyenne 10 jours' in blue and 'Médiane 10 jours' in green do not perform very well. It is worse than just the most recent day's loads themselves without any formula and calculation. Even though the CBL based on the method of 'Moyenne 10 jours' works slightly better than the CBL based on the method of 'Médiane 10 jours', there is no vivid difference between them.

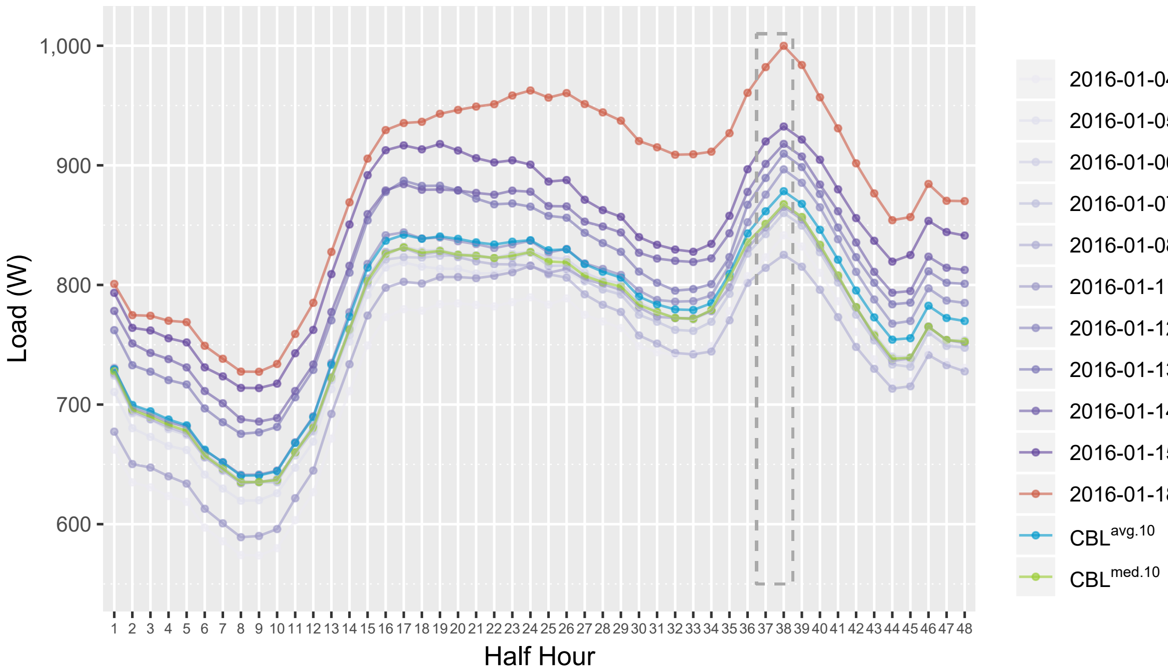

Figure 9: The Visual Comparison among the Loads of the Previous Ten Days, Actual Loads, CBLs based on the Ten Day Average and Median Method (French NEBEF)

The following Figure 10 demonstrates the actual loads for every 30 minutes on Jan. 18th, 2016 in red, the loads of the previous four weeks[23] on the same day, that is in this case Monday, and the two CBLs based on the method of 'Moyenne 4 semaines' in blue and 'Médiane 4 semaines' in green for the French case, too. This time, we can see again that the actual loads were the highest loads comparing the loads of the previous four weeks, which means that the increasing trend from the earliest day (2015-12-21) to the most recent day (2016-01-11), and finally the DR event day's (2016-01-18) actual loads.

Again, we can figure out that the two CBLs based on the method of 'Moyenne 4 semaines' and 'Médiane 4 semaines' do not perform very well. It is worse than just the most re-

[23] When it comes to the previous four weeks before Jan. 18th in 2016, I only included the working days and excluded the holidays and weekends. In this case, there was no holiday among the original previous four weeks, therefore, I simply used the loads of Dec. 21st, 28th in 2015, Jan. 4th, and 11th in 2016.

cent day's loads themselves without any formula and calculation. There is almost no difference between the two CBLs.

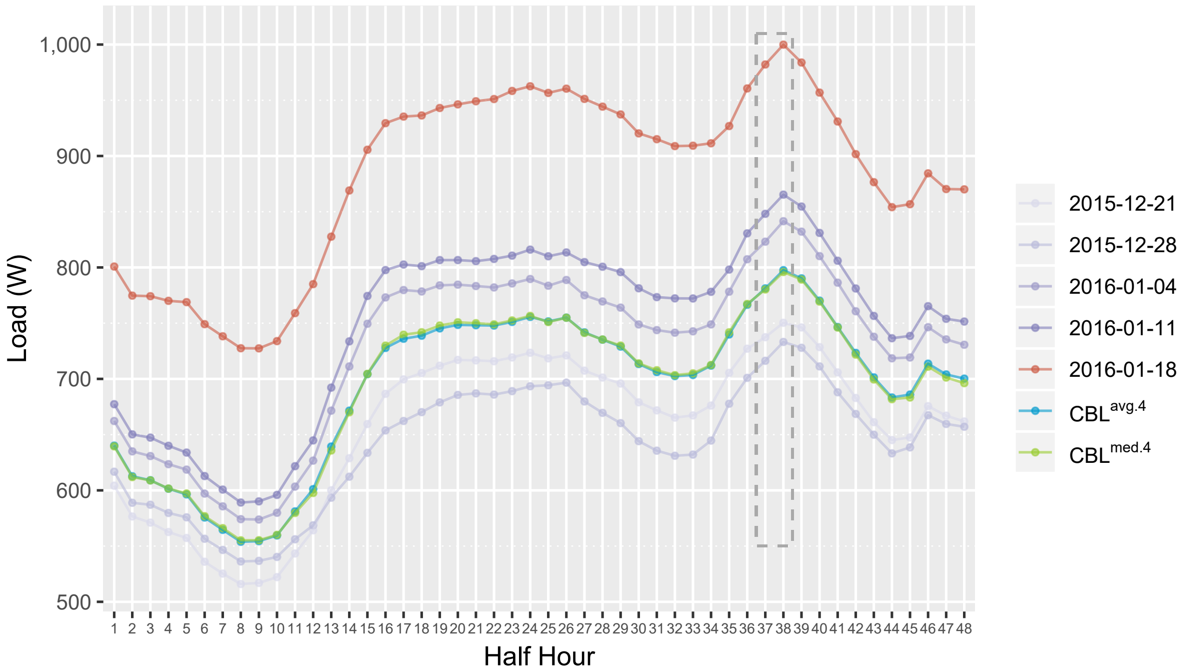

Figure 10: The Visual Comparison among the Loads of the Previous Four Weeks, Actual Load, CBLs based on the Four Week Average and Median Method (French NEBEF)

The following Figure 11 shows the actual loads of the day of the peak demand in red and the four calculated CBLs based on the four methods of 'Moyenne 10 semaines', 'Médiane 10 semaines', 'Moyenne 4 semaines' and 'Médiane 4 semaines'. It is easy to notice that all the four methods do not perform well although the two methods of 'Moyenne 10 semaines' and 'Médiane 10 semaines' outperform the other two methods of 'Moyenne 4 semaines' and 'Médiane 4 semaines'. Even though the four CBLs are established for all the time slots of the 30 minute interval, the dotted gray rectangle highlights the two-time slots of $t = 37$ and $t = 38$, that is 7 p.m. (19:00) — the time of the peak demand in 2016, France. With Table 3 we can verify the detailed numbers for the actual loads and four CBLs at the time slot $t = 37$ and $t = 38$.

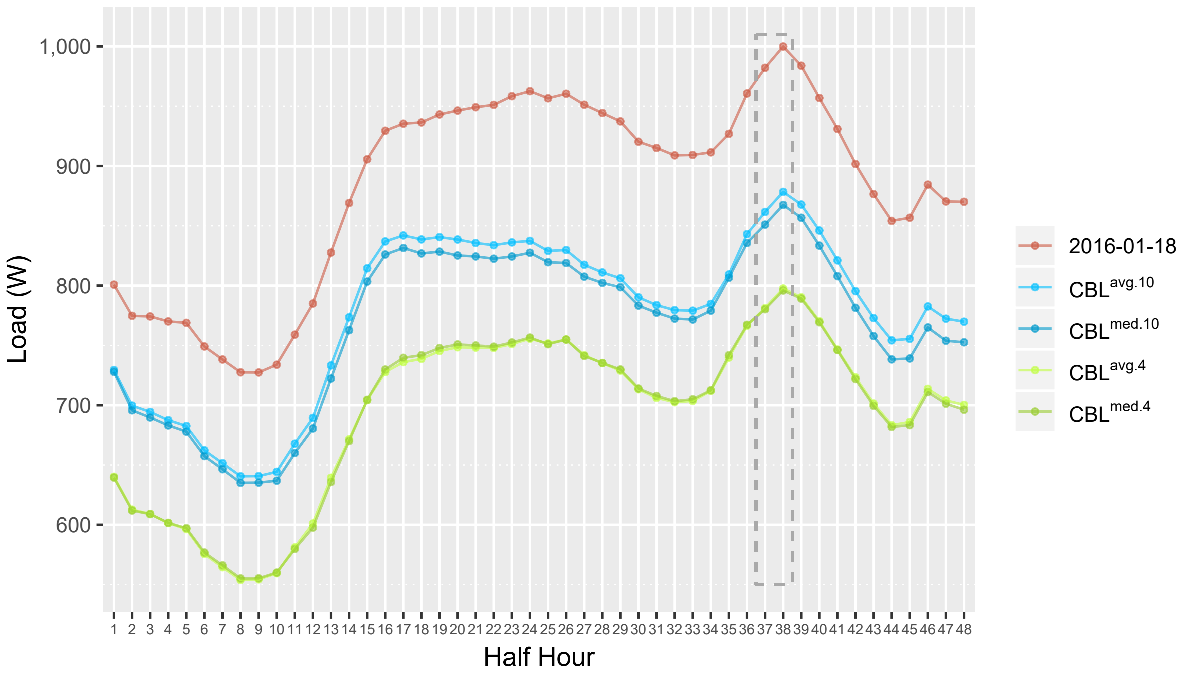

Figure 11: Comparing the Actual Loads with all the Four CBLs (French NEBEF)

Table 3: Summary of the Established CBLs for the NEBEF (DR) Event Times (French NEBEF)

	2016-01-18			
	$\cdots$	$t = 37$	$t = 38$	$\cdots$
Actual Load	$\cdots$	982.11	999.89	$\cdots$
$\text{CBL}^{\text{avg.10}}$	$\cdots$	861.60	878.36	$\cdots$
$\text{CBL}^{\text{med.10}}$	$\cdots$	850.99	867.45	$\cdots$
$\text{CBL}^{\text{avg.4}}$	$\cdots$	781.22	797.58	$\cdots$
$\text{CBL}^{\text{med.4}}$	$\cdots$	780.27	795.92	$\cdots$

In addition to the visual comparison between the actual loads and the four CBLs, we can measure the performance (accuracy) of the CBLs by calculating the estimation error between the actual loads and the four CBLs. In the NEBEF mechanism, the following Absolute Error ('Erreur absolue') is used in order to assess the quality of a CBL based on the method of 'Méthod par historique de consommation'.[24]

[24] [27, p. 64], 7.2.5.1 Indicateur de qualité pour la méthode «par historique de consommation».

$$\text{Erreur absolue}\,(\epsilon) = \frac{1}{N}\sum_{i=1}^{N}\frac{\left|\text{Référence historique de consommation}_i - \text{Consommation}_i\right|}{\text{Capacité d'Effacement Minimale du Site de Soutirage}}$$
$$\Rightarrow\ \text{Absolute Error}\,(\epsilon) = \frac{1}{N}\sum_{i=1}^{N}\frac{\left|\text{CBL}_{d,t} - \text{Actual Electricity Load}_{d,t}\right|}{\text{Minimum Capacity of Demand Response}}$$
(Eq.: Erreur absolue)

In terms of 'Capacité d'Effacement Minimale du Site de Soutirage' (Minimum Capacity of DR) in the abovementioned formula `Eq.: Erreur absolue`, it is declared by an LA at the initial stage. There is no specific formula of this Minimum Capacity of DR, and it seems that it is up to the LA. Therefore, it is difficult to set the proper level of 'Minimum Capacity of DR' at this stage in this article. For the sake of convenience of the analysis, I will use 'Actual Electricity Load' instead of 'Minimum Capacity of DR', then the abovementioned formula of the 'Absolute Error' becomes the formula of `Eq.: MAPE` in Section 2. In addition to MAPE, I also check out the formula of `Eq.: RRMSE` in the same Section 2 as I have applied them to the South Korean case's CBLs.

In the following Figure 12, we can compare the accuracies of all the four CBLs utilized in the NEBEF mechanism both in terms of MAPE and RRMSE. As we have compared them visually in Figure 11 and numerically in Table 3, MAPE and RRMSE tell us the same result that the two methods using previous ten days outperform the two methods using previous four weeks, and that the best one is based on the average ten days method ($\text{CBL}^{\text{avg.10}}$). Table 4 summarizes the result of the accuracy assessment for the four CBLs in terms of MAPE and RRMSE.

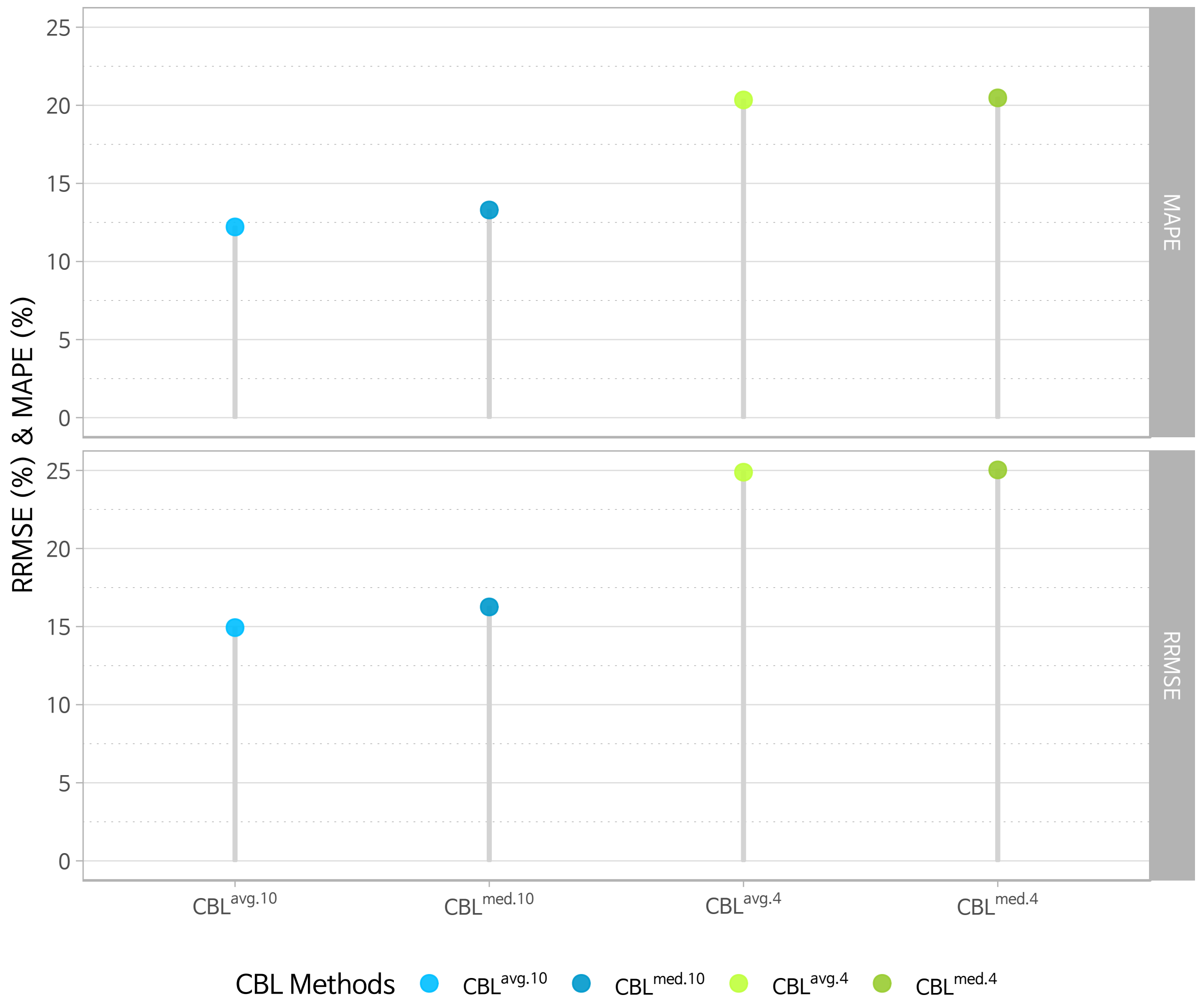

Figure 12: The CBL Accuracy Comparison (MAPE & RRMSE) among the CBLs Established with Different Methods (French NEBEF)

Table 4: The CBL Accuracy Comparison (MAPE and RRMSE) among the CBLs Established with Different Methods (French NEBEF)

	$\text{CBL}^{avg.10}$	$\text{CBL}^{med.10}$	$\text{CBL}^{avg.4}$	$\text{CBL}^{med.4}$
MAPE	12.21%	13.30%	20.34%	20.48%
RRMSE	14.94%	16.26%	24.89%	25.03%

In Subsection III.1 we could find out that the two CBL methods based on WMA with PAC and with SAA, those are $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$, respectively, demonstrated quite high and satisfactory performances for the baseline estimation of the South Korean case. Considering the result, it would be worthwhile applying these CBL methods to the French NEBEF mechanism in order to find out a room to improve the CBL estimation methodology.

The following Figure 13 shows that the two CBL methods again perform very well for the French NEBEF case, too. For the two time slots $t = 37$ and $t = 38$, there is almost no difference between them, $\text{CBL}^{\text{WMA}} + \text{SAA}$ in blue is better very slightly, though. We can check out this subtle difference with the summary Table 5.

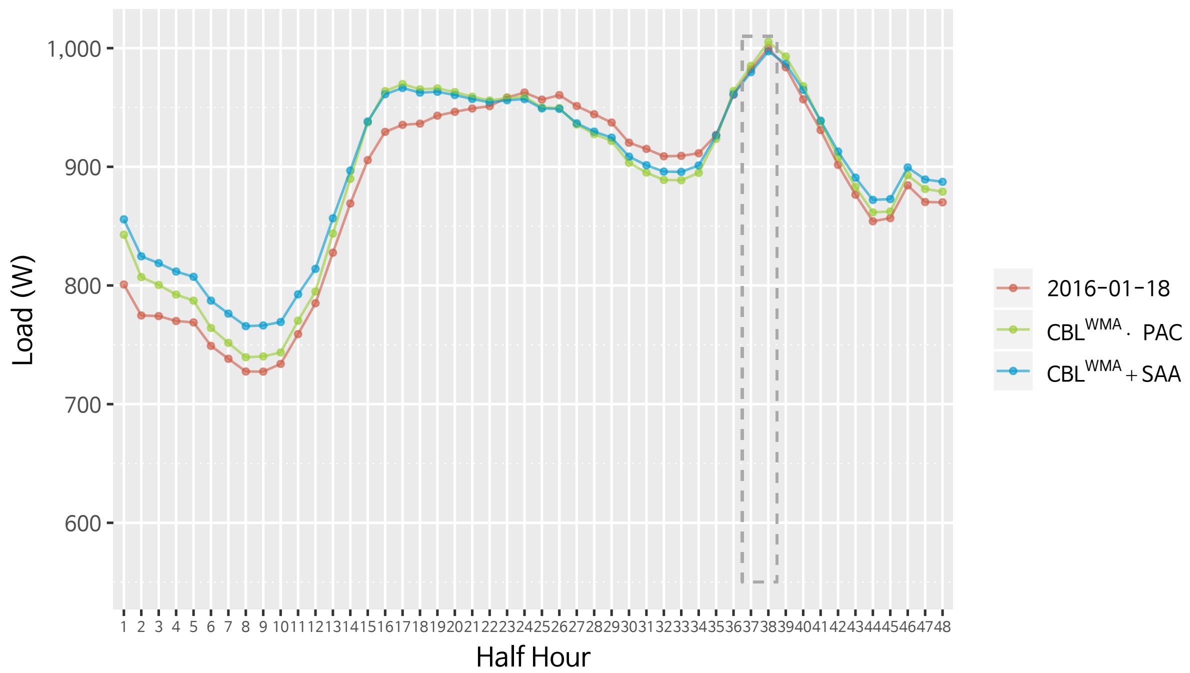

Figure 13: Comparing the Actual Loads with the Two CBL Methods of $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$ (French NEBEF)

Comparison to Four NEBEF CBL Methods: Fig. 11

Table 5: Summary of the Established CBLs for the NEBEF (DR) Event Times Applying $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$ (French NEBEF)

	2016-01-18			
	⋯	$t = 37$	$t = 38$	⋯
Actual Load	⋯	982.11	999.89	⋯
$\text{CBL}^{\text{WMA}} \cdot \text{PAC}$	⋯	985.02	1005.28	⋯
$\text{CBL}^{\text{WMA}} + \text{SAA}$	⋯	979.73	997.39	⋯

Comparison to Four NEBEF CBL Methods: Tab. 3

With the following Figure 14 and Table 6, we can easily notice the subtle difference between the two CBL methods. Comparing the accuracy of the four CBL methods (Fig. 12 and Tab. 4), it is a quite surprising improvement of the CBL estimation methodology — MAPE and RRMSE were 12.21% and 14.94% respectively for $\text{CBL}^{\text{avg.10}}$ (Table 4), but this time MAPE and RRMSE are only 0.245% and 0.246% respectively for $\text{CBL}^{\text{WMA}} + \text{SAA}$ (Table 6).

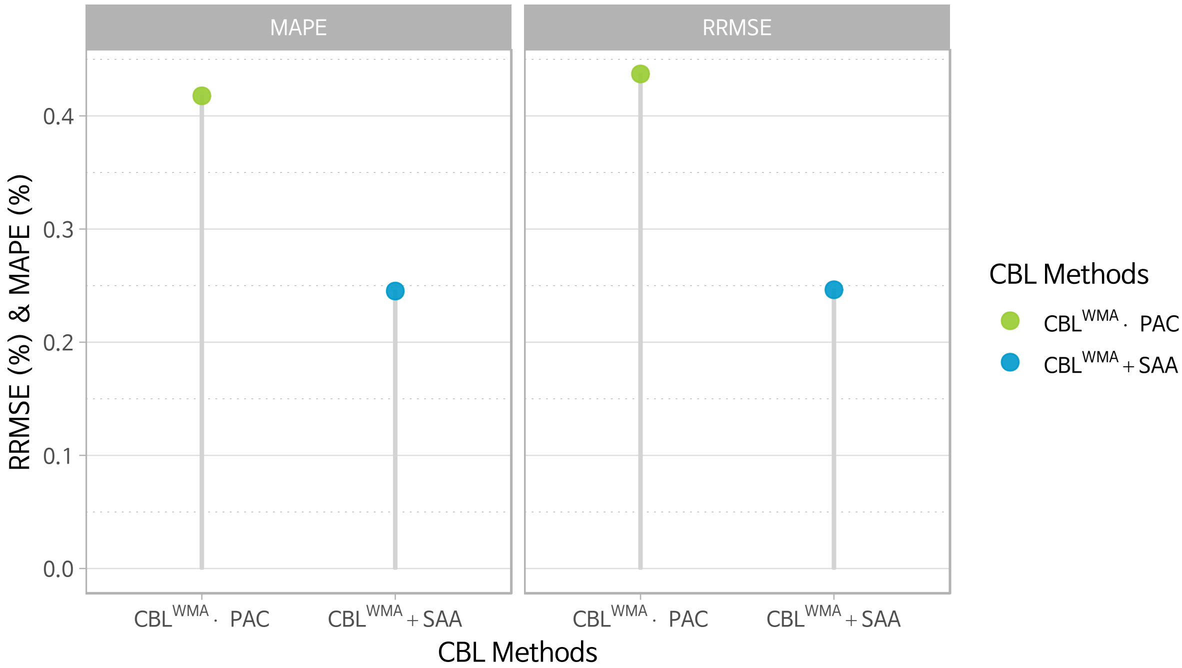

Figure 14: The CBL Accuracy Comparison (MAPE & RRMSE) between the Two CBL Methods of $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$ (French NEBEF)

Comparison to the Accuracies of Four NEBEF CBL Methods: Fig. 12

Table 6: The CBL Accuracy Comparison (MAPE and RRMSE) between the Two CBL Methods of $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$ (French NEBEF)

	$\text{CBL}^{\text{WMA}} \cdot \text{PAC}$	$\text{CBL}^{\text{WMA}} + \text{SAA}$
MAPE	0.418%	0.245%
RRMSE	0.437%	0.246%

Comparison to the Accuracies of Four NEBEF CBL Methods: Tab. 4

In addition to the analyses on the CBL estimation methods focusing on the peak loads both for South Korea and France, that is the cross-validation between two different countries, in order to figure out whether or not the results hold true with different load profiles during different seasons in a country, that is the cross-validation between different seasons in a country, I have conducted supplementary analyses (in Supplementary Figures & Tables of Appendix) with the different load profiles during winter for the Korean case and summer for the French case this time. As a result, in the Korean case, Figure A.5, Table A.3, Figure A.6, and Table A.4 show that the two CBL estimation methods with adjustment ($\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$) outperform the two simple CBL estimation methods ($\text{CBL}^{\text{avg.}}$ and CBL^{WMA}). Even though $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ is slightly better than $\text{CBL}^{\text{WMA}} + \text{SAA}$, there is no significant difference between them.

In the French case, as can be seen in Figure A.7, A.8, A.9, Table A.5, Figure A.10, and Table A.6, all the four CBL estimation methods of NEBEF do not perform well again although the error rates are relatively small this time—about 4–5%. In contrast, the two CBL estimation methods of South Korean DRTM perform very well again—around 0.1% in terms of MAPE and RRMSE. With these supplementary analyses, we could reconfirm that the two CBL estimation methods of South Korean DRTM are better than others, and it shows that the results are robust to the changes in load profiles of different seasons. The following Table 7 summarizes the results of the accuracy of CBL estimation methods in terms of MAPE and RRMSE. The gray cells highlight the best CBL estimation method with the smallest error rate.

Table 7: Overview of the Results: Accuracy of CBL Estimation Methods (MAPE & RRMSE)

	South Korea				France			
	Summer		Winter		Summer		Winter	
	2016-08-12		2016-01-21		2016-07-19		2016-01-18	
	MAPE	RRMSE	MAPE	RRMSE	MAPE	RRMSE	MAPE	RRMSE
$\text{CBL}^{\text{avg.}}$	9.21%	6.51%	6.34%	4.48%				
CBL^{WMA}	8.22%	5.81%	6.21%	4.39%				
$\text{CBL}^{\text{WMA}} \cdot \text{PAC}$	0.52%	0.37%	2.09%	1.48%	0.095%	0.101%	0.418%	0.437%
$\text{CBL}^{\text{WMA}} + \text{SAA}$	0.45%	0.32%	2.14%	1.52%	0.117%	0.125%	0.245%	0.246%
$\text{CBL}^{\text{avg.10}}$					4.36%	5.34%	12.21%	14.94%
$\text{CBL}^{\text{med.10}}$					3.37%	4.15%	13.30%	16.26%
$\text{CBL}^{\text{avg.4}}$					4.13%	5.03%	20.34%	24.89%
$\text{CBL}^{\text{med.4}}$					3.98%	4.86%	20.48%	25.03%

V. IMPLICATIONS AND CONCLUSION

In this comparative study, we found that the CBL estimation methods of South Korean DRTM, especially the two CBL methods of $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$, perform surprisingly very well with extremely low error rates about 0.5% while all the CBL estimation methods of NEBEF do not perform very well with high error rates about 12%–25%. In addition, when we applied the two CBL estimation methods of $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$ to the re-scaled French average household load profile to establish the CBL, it resulted in a high performance with extremely low error rates less than 0.5% again.

Furthermore, the results of the supplementary analyses on the different load profiles of different seasons are in line with the main results reconfirming that the two CBL estimation methods with adjustment ($\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$) are the best even if load profiles are more stochastic and volatile. Therefore, this cross-validation between different seasons in a country added the robustness of the research. With the results, this study provides a country, in particular, France, with a meaningful policy implication to ameliorate the CBL estimation methods of NEBEF and ultimately the DR market design.

Like the South Korean DRTM, the NEBEF mechanism is a quite recent market-oriented mechanism of DSM, so it is still evolving since the 'Règles NEBEF 1' in 2013. Even though it seems that RTE has tested many possible CBL estimation methods since the experimental phase, for example, the panel data analysis approach, it appears that RTE has not yet explicitly suggested or introduced the alternative options like PAC and SAA. According to the results of this research, the low performance and high error rates of the CBL estimation methods of NEBEF derived from the fact that it only relies on the simple average and median and does not use any adjustment options which could capture the recent changes of the load profile caused by whatever it is a temperature-based or socio-economic-based stochastic event.

As we have looked at the developing trends of both the South Korean and French DR mechanisms in terms of the volume and frequency, the importance of the NEBEF mechanism will be more significant with more intermittent Renewable Energy Sources (RESs) and the concern on climate change, sustainability and the security of electricity supply. In order to exploit the full-fledged DR mechanism in France, we need to pay more attention to the importance of the accurate CBL estimation methods which are the fundamental elements to encourage potential participants. As we have observed, the currently utilized CBL estimation methods are likely to result in the underestimation of the CBLs, in turn, results in that the actual efforts or reductions will be underappreciated than it is. These inaccurate CBL methods could undermine the French NEBEF mechanism despite its advantage such as the high-level openness of all the markets for the demand-side resources.

Furthermore, it is expected that the accurate CBL estimation methods can prevent the participants from intentional and malicious manipulation of their CBLs. It is a quite important point from the DR system operator's or LA's perspective. If the CBL estimation methods are very accurate, then there will be little room for participants to strategically manipulate their CBLs in order to get remunerated much more than it should be. Only with these well-defined CBL estimation methods which can avoid the underestimation or overestimation as measurement error and the strategic countervailing incentives, the optimality of DR programs can be guaranteed.

Considering abovementioned policy implications, this study provides a good opportunity to shed light on and to compare the CBL estimation methods of South Korea and France each other. It is rare to see this kind of comparative analysis between countries focusing on the CBL estimation methods in practice. One of the difficulties to conduct this kind of research is that it is not easy to obtain the real-time load profiles of an individual level household due to the issues of the privacy or information access. The approach in which we have used the re-scaled load profile from the aggregated national loads enabled this analysis. Moreover, the simple mathematical model of linear algebra made it clear and easier to understand the CBL calculation process and its analysis. Although this approach and the simple mathematical model of linear algebra were applied to the residential DR mechanism, they can be applied to other sectors, such as industrial and commercial DR programs because the approach and model used in this article are very generic. The very clear and distinct terms, simple but detailed equations and explanations will be helpful for the further studies on CBLs in many countries which are actively developing DR mechanisms.

On top of that, this study and the estimated CBLs will be a stepping stone or foundation for the further analysis such as the Decision-making Analysis based on CBA and SA. Without this part on CBLs it will be almost impossible to proceed to further researches or will face ambiguity of DR mechanisms. Only based on the accurately estimated CBLs, the actual load reduction, optimal remuneration level, marginal disutility for participants with load shedding and load shifting, behavioral change of the participants (electricity consumption pattern with DR), effectiveness of Time-of-Use (ToU) tariff scheme, and so forth can be dealt in an appropriate way.

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APPENDICES

List of Glossaries

event day	The day in which there is a call or order from the system operator to activate the DR program, and as a result, there will be an actual reduction of electricity consumption.	8
reference days	The candidates for the similar non-event days.	8
similar non-event days	The days that are used in the computation of CBL and it does not include the previous event days.	8

Acronym & Abbreviation

AMI	Advanced Metering Infrastructure	15
ARE	Average Relative Error	9
CAISO	California Independent System Operator	8
CBA	Cost-Benefit Analysis	5
CBL	Customer Baseline Load	5
CBP	Cost-based Pool	6
CRE	La Commission de Régulation de l'Énergie	4
DR	Demand Response	3
DRM	Demand Response Mechanism	4
DRTM	Demand Resource Trading Market	4
DSM	Demand-side Management	3
DSO	Distribution System Operator	4
EDE	Entité d'Effacement	19
EPEX	European Power Exchange	6
FERC	Federal Energy Regulatory Commission	5
ISO	Independent System Operator	8
KEPCO	Korea Electric Power Corporation	3
KPX	Korea Power Exchange	4
LA	Load Aggregator	6

LDC	Load Duration Curve	4
MAPE	Mean Absolute Percentage Error	9
NAESB	North American Energy Standards Board	8
NEBEF	La Notification d'Échange de Blocs d'Effacement	4
NYISO	New York Independent System Operator	5
PAC	Proportional Adjustment Coefficient	13
RES	Renewable Energy Source	34
RRMSE	Relative Root Mean Squared Error	9
RTE	Réseau de transport d'électricité	4
SA	Sensitivity Analysis	5
SAA	Symmetric Additive Adjustment	8
SCR	Special Case Resource	5
SEDC	Smart Energy Demand Coalition	15
ToU	Time-of-Use	34
TSO	Transmission System Operator	4
VRE	Variable Renewable Energy	3
WMA	Weighted Moving Average	9
WSA	Weather Sensitivity Adjustment	8

Notation & Nomenclature

$\mathrm{CBL}_{d,t}$	customer baseline load for the DR event day, d, at the event time, t, $d \in D = \{1,2,\ldots,365\}$, $t \in T = \{1,2,\ldots,24\}$, $\sum_{i=1}^{n}(\omega_i \times \ell_{d-i,t})$	50
$\textsc{cbl}^{\textbf{avg.}}$	a vector of CBL established with simple average method	8
$\textsc{cbl}^{\textbf{avg.4}}$	a vector of CBL which is calculated with the method of 'Moyenne 4 jours'	22
$\textsc{cbl}^{\textbf{avg.10}}$	a vector of CBL which is calculated with the method of 'Moyenne 10 jours'	20
$\textsc{cbl}^{\textbf{med.4}}$	a vector of CBL which is calculated with the method of 'Médiane 4 jours'	22
$\textsc{cbl}^{\textbf{med.10}}$	a vector of CBL which is calculated with the method of 'Médiane 10 jours'	21
$\textsc{cbl}^{\textbf{WMA}} \cdot \textsc{pac}$	a vector of proportionally adjusted CBL	14

$\text{CBL}^{\text{WMA}} + \text{SAA}$	a vector of CBL with Symmetric Additive Adjustment	14
CBL^{WMA}	a vector of CBL established with the weighted moving average method	13
$\ell_{d,t}$	actual load at the time slot t and on the day of d, $d \in D = \{1, 2, \ldots, 366\}$, $t \in T = \{1, 2, \ldots, 24\}$.	12
$\ell_{d-i,t}$	actual load at the time of t, and on the day of $d - i$ (i^{th} day before the DR event day)	13
$\mathbf{L}^{\text{agg.}}_{366\times 24}$	a matrix of aggregated loads, 366 rows × 24 columns, in 2016 (there were 366 days in 2016)	12
$\mathbf{L}^{\text{agg.}}_{366\times 144}$	a matrix of aggregated loads of France measured for every 10 minutes, 366 rows × 144 (=24 × 6) columns, in 2016 (there were 366 days in 2016)	18
$\mathbf{L}^{\text{agg.}}_{366\times 48}$	a matrix of aggregated loads of France measured for every 30 minutes, 366 rows × 48 (=24 × 2) columns, in 2016 (there were 366 days in 2016)	18
$\mathbf{L}^{\text{avg.res.}}_{366\times 24}$	a matrix of rescaled loads of an average household in (Wh), 366 rows × 24 columns	12
$\mathbf{L}^{\text{avg.res.}}_{366\times 48}$	a matrix of rescaled loads of an average household of France in (Wh), 366 rows × 48 (=24 × 2) columns	18
$\boldsymbol{\omega}^{\mathbf{T}}$	a transposed vector of the weights for i^{th} day before the DR event day,	13
PAC	Proportional Adjustment Coefficient for the weighted moving average method	14
$\mathbf{S^4}$	a matrix of the similar non-event 4 days	22
$\mathbf{S^6}$	a matrix of the similar non-event 6 days	13
$\mathbf{S^{10}}$	a matrix of the similar non-event 10 days	20
SAA	additive adjustment coefficient for the SAA option	14
t_e	DR event ending time	50
t_s	DR event starting time	50

A. SUPPLEMENTARY FIGURES & TABLES

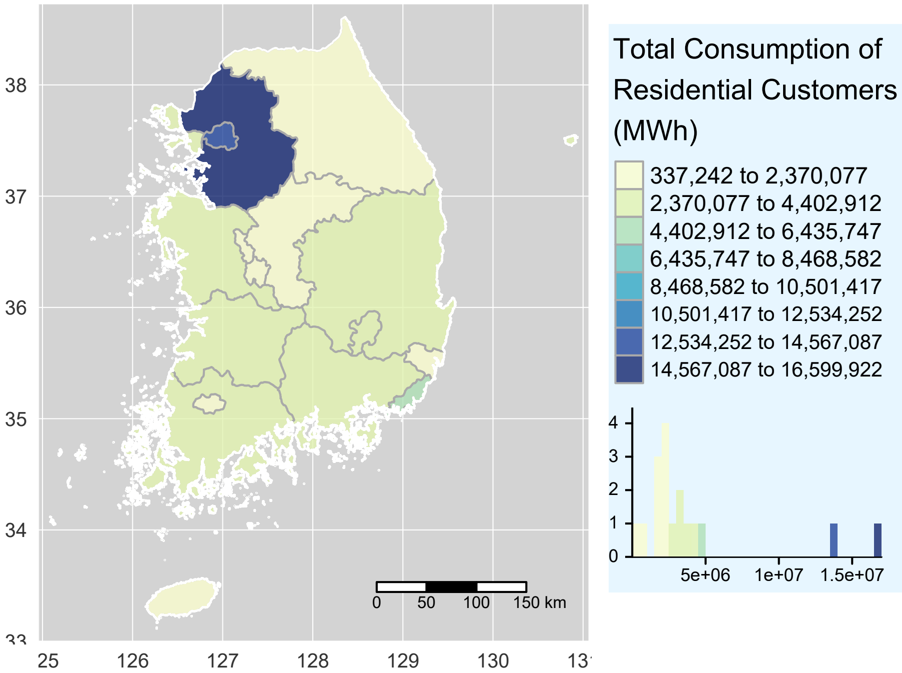

Figure A.1: The Total Consumption of Residential Customers by Region, 2016 in South Korea (MWh)

Source: "Electricity Big Data Center" operated by KEPCO, [On-line], Available: https://home.kepco.co.kr/kepco/BD/BDBAPP004/BDBAPP004.do?menuCd=FN33020104

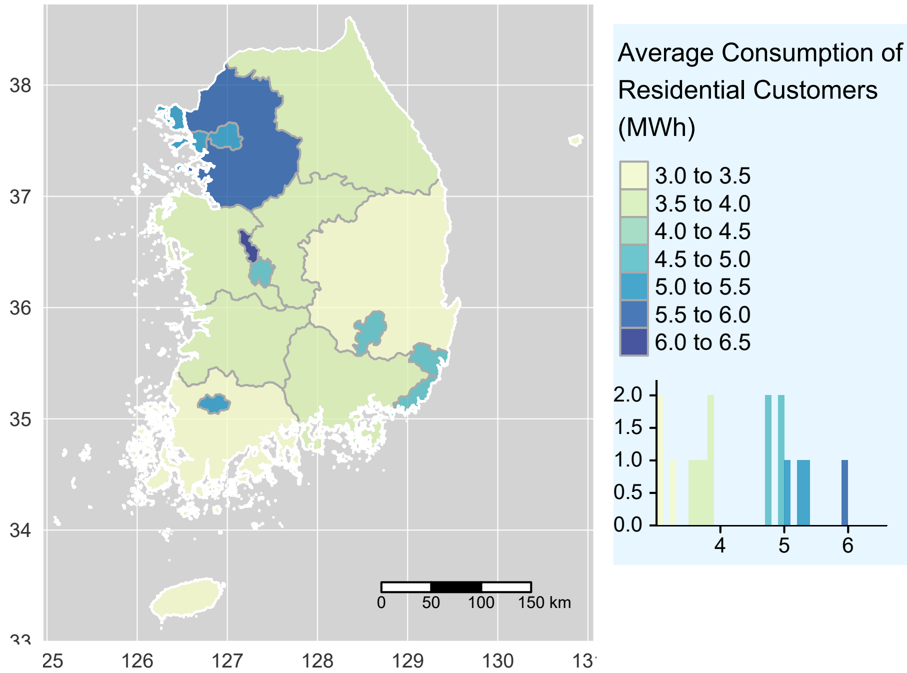

Figure A.2: The Average Consumption of Residential Customers by Region, 2016 in South Korea (MWh)

Source: "Electricity Big Data Center" operated by KEPCO, [On-line], Available: https://home.kepco.co.kr/kepco/BD/BDBAPP004/BDBAPP004.do?menuCd=FN33020104

Table A.1: The Top 5 Regions in terms of Number, Total Consumption, and Average Consumption in Residential Sector in South Korea

Rank	Region	No. Sites	Region	Total Conso. (MWh)	Region	Avg. Conso. (MWh)
1	Gyeonggi -do	2,789,223	Gyeonggi -do	16,599,922	Sejong	6.96
2	Seoul	2,718,481	Seoul	13,612,456	Gyeonggi -do	5.95
3	Gyeongsangnam -do	1,133,686	Busan	4,640,944	Incheon	5.39
4	Gyeongsangbuk -do	1,121,299	Gyeongsangnam -do	4,384,578	Gwangju	5.26
5	Busan	944,624	Incheon	391,532	Seoul	5.01

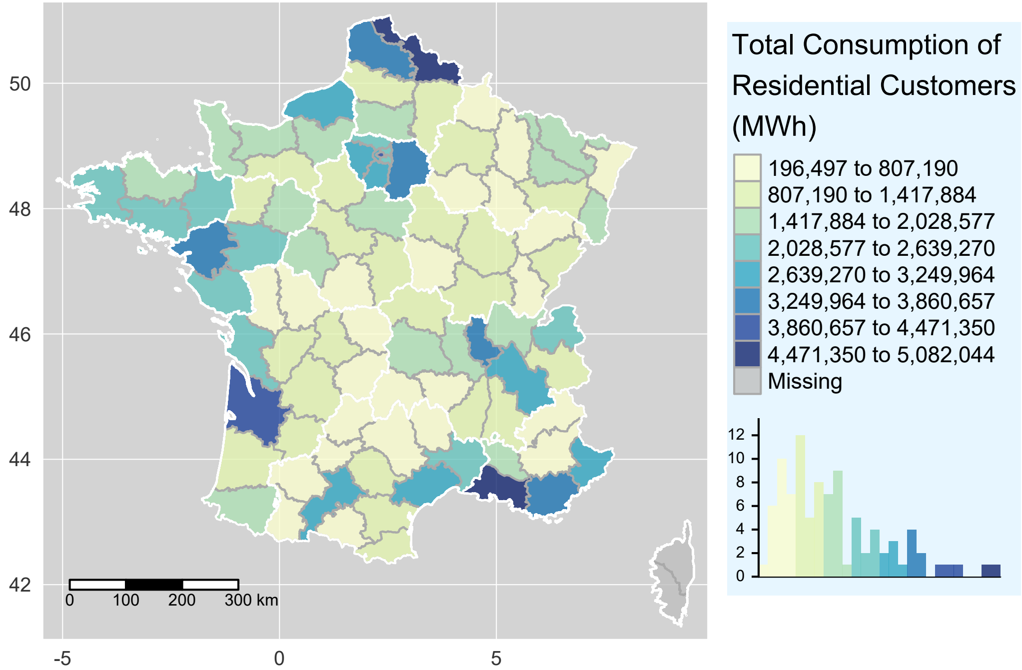

Figure A.3: The Total Consumption of Residential Customers by Département, 2016 in France (MWh)

Source: "Consommation électrique annuelle à la maille département", 2018, by Enedis, [On-line], Available: https://goo.gl/kqVMi2

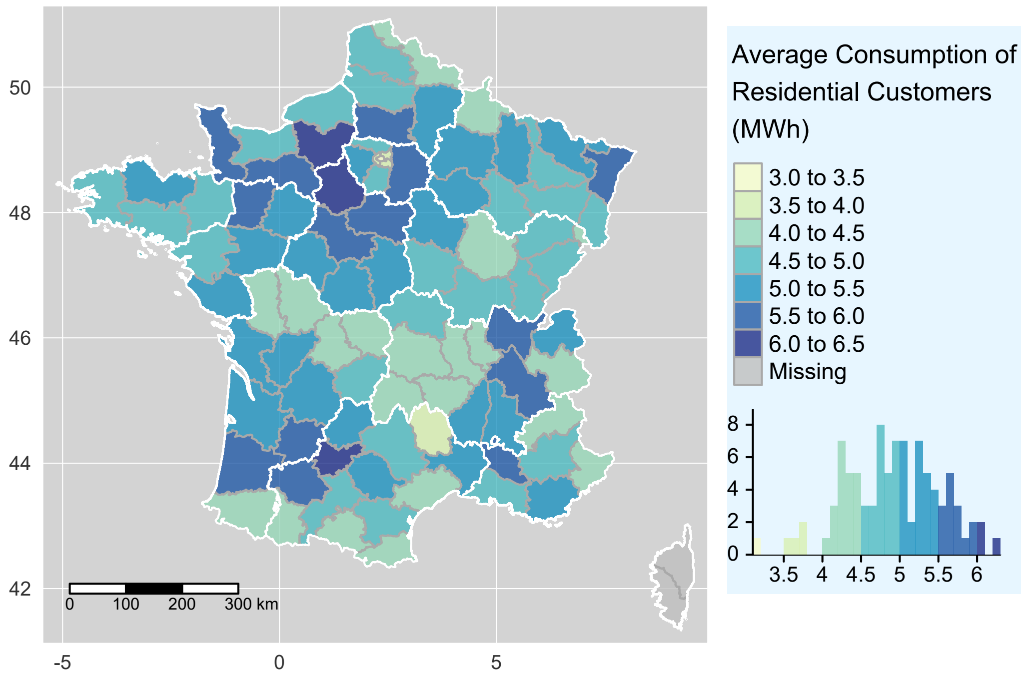

Figure A.4: The Average Consumption of Residential Customers by Département, 2016 in France (MWh)

Source: "Consommation électrique annuelle à la maille département", 2018, by Enedis, [On-line], Available: https://goo.gl/kqVMi2

Table A.2: The Top 10 Département in terms of Number, Total Consumption, and Average Consumption in Residential Sector in France

Rank	Dépt.	No. Sites	Dépt.	Total Conso. (MWh)	Dépt.	Avg. Conso. (MWh)
1	Paris	1,361,346	Nord	5,082,044	Eure	6.20
2	Nord	1,155,209	Bouches-du-Rhone	4,963,039	Tarn-et-Garonne	6.09
3	Bouches-du-Rhone	997,053	Paris	4,292,061	Eure-et-Loir	6.02
4	Rhone	889,003	Gironde	4,135,094	Ain	5.99
5	Gironde	818,101	Rhone	3,837,773	Vaucluse	5.98
6	Hauts-de-Seine	786,972	Var	3,590,573	Loir-et-Cher	5.80
7	Alpes-Maritimes	747,245	Loire-Atlantique	3,434,868	Gers	5.78
8	Loire-Atlantique	716,446	Seine-et-Marne	3,382,133	Mayenne	5.77
9	Var	683,842	Pas-de-Calais	3,262,666	Seine-et-Marne	5.75
10	Haute-Garonne	681,809	Haute-Garonne	3,243,072	Manche	5.69

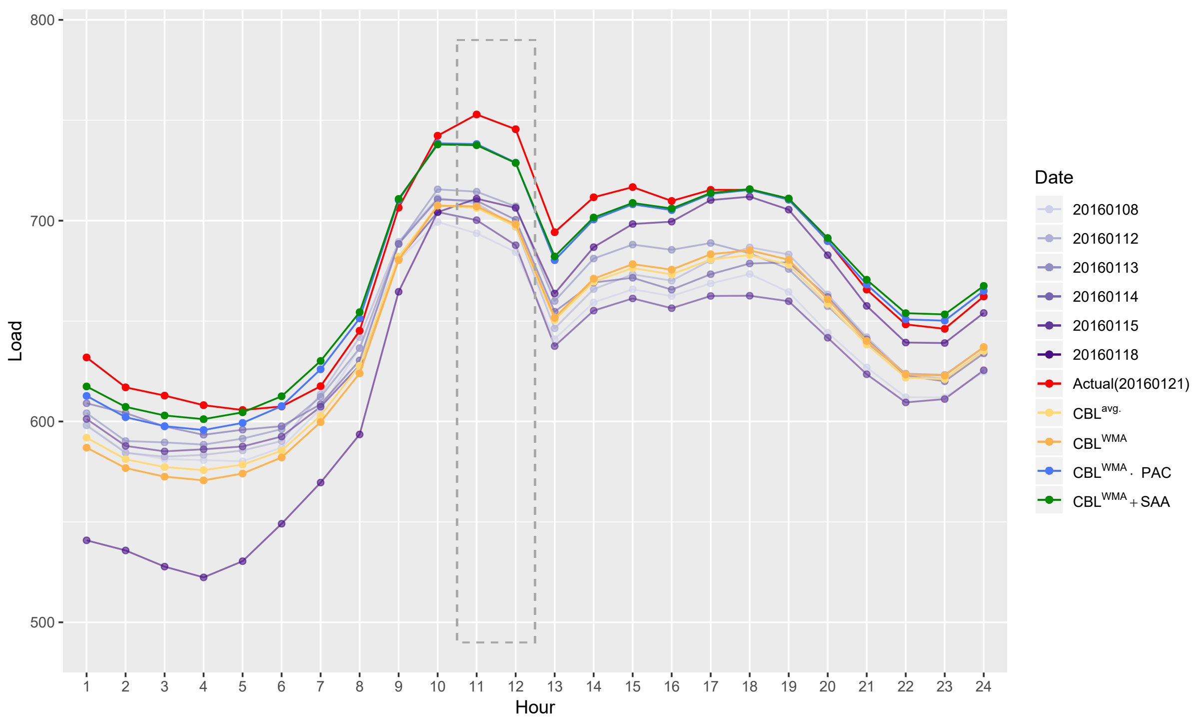

Figure A.5: The Visual Comparison among the CBLs Established with Different Methods (2016-01-21, South Korean DRTM)

Table A.3: Summary of the Established CBLs for the Event Times (2016-01-21, South Korean DRTM)

	2016-01-21			
	⋯	11h	12h	⋯
Actual Load	⋯	752.88	745.54	⋯
$\text{CBL}^{\text{avg.}}$	⋯	706.32	697.16	⋯
CBL^{WMA}	⋯	707.11	698.25	⋯
$\text{CBL}^{\text{WMA}} \cdot \text{PAC}$	⋯	738.16	728.91	⋯
$\text{CBL}^{\text{WMA}} + \text{SAA}$	⋯	737.58	728.72	⋯

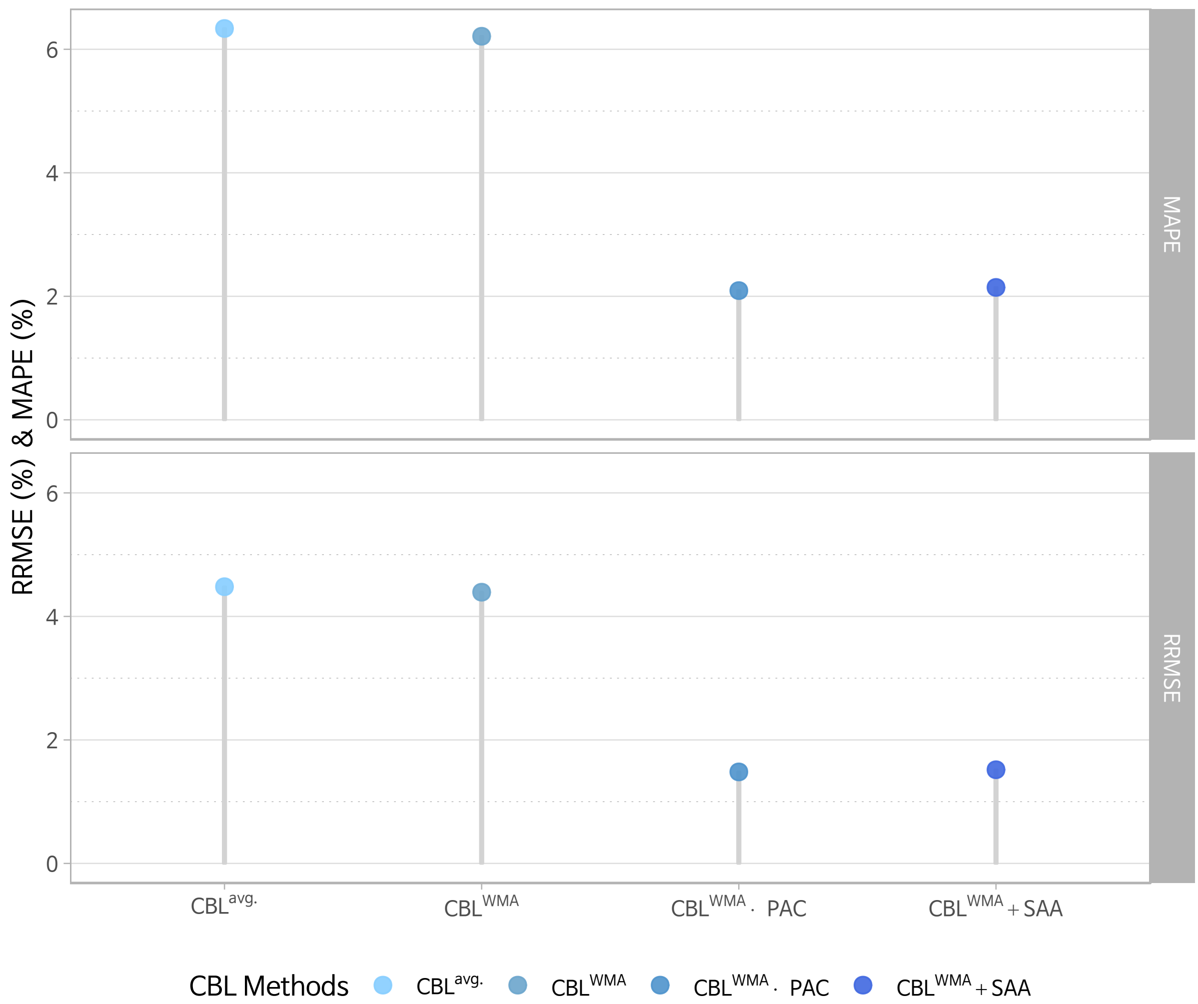

Figure A.6: The CBL Accuracy Comparison (MAPE & RRMSE) among the CBLs Established with Different Methods (2016-01-21, South Korean DRTM)

Table A.4: The CBL Accuracy Comparison (MAPE and RRMSE) among the CBLs Established with Different Methods (2016-01-21, South Korean DRTM)

	$\mathrm{CBL}^{avg.}$	CBL^{WMA}	$\mathrm{CBL}^{WMA} \cdot \mathrm{PAC}$	$\mathrm{CBL}^{WMA} + \mathrm{SAA}$
MAPE	6.34%	6.21%	2.09%	2.14%
RRMSE	4.48%	4.39%	1.48%	1.52%

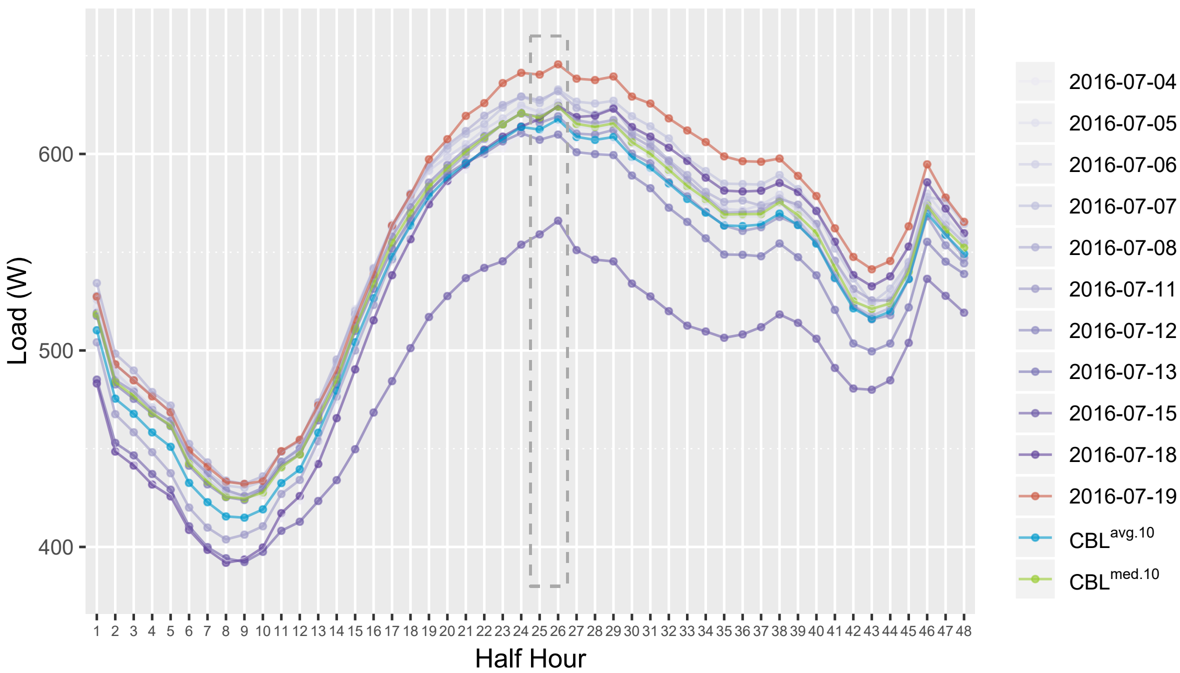

Figure A.7: The Visual Comparison among the Loads of the Previous Ten Days, Actual Loads, CBLs based on the Ten Day Average and Median Method (2016-07-19, French NEBEF)

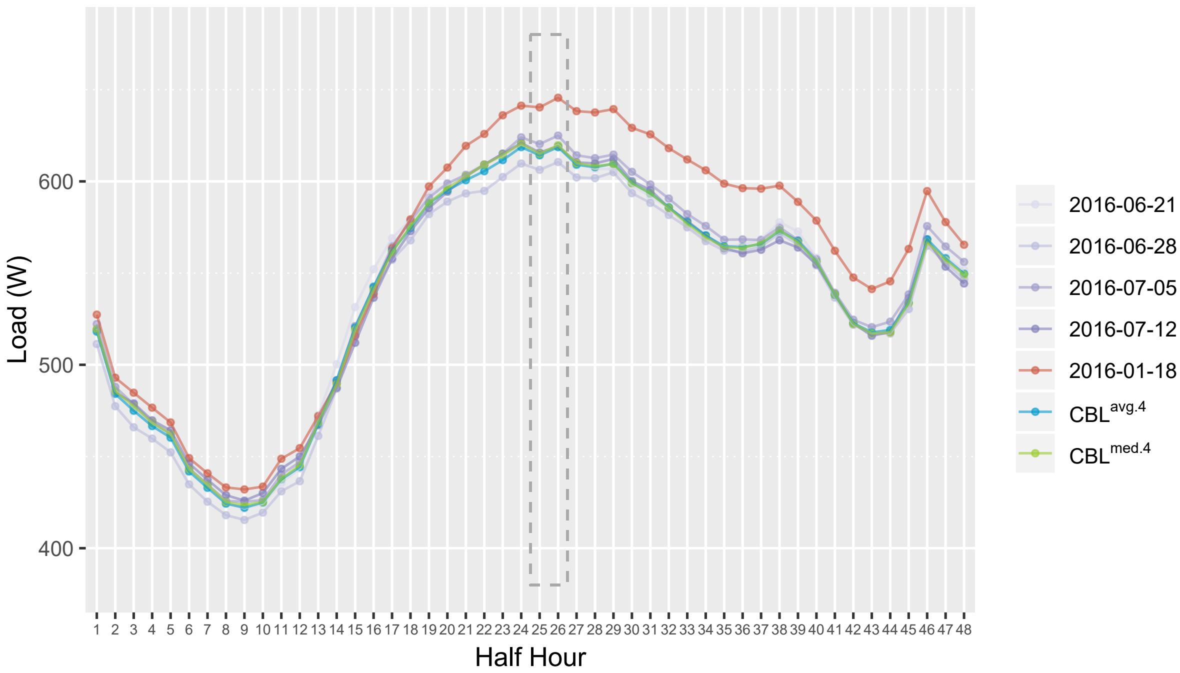

Figure A.8: The Visual Comparison among the Loads of the Previous Four Weeks, Actual Load, CBLs based on the Four Week Average and Median Method (2016-07-19, French NEBEF)

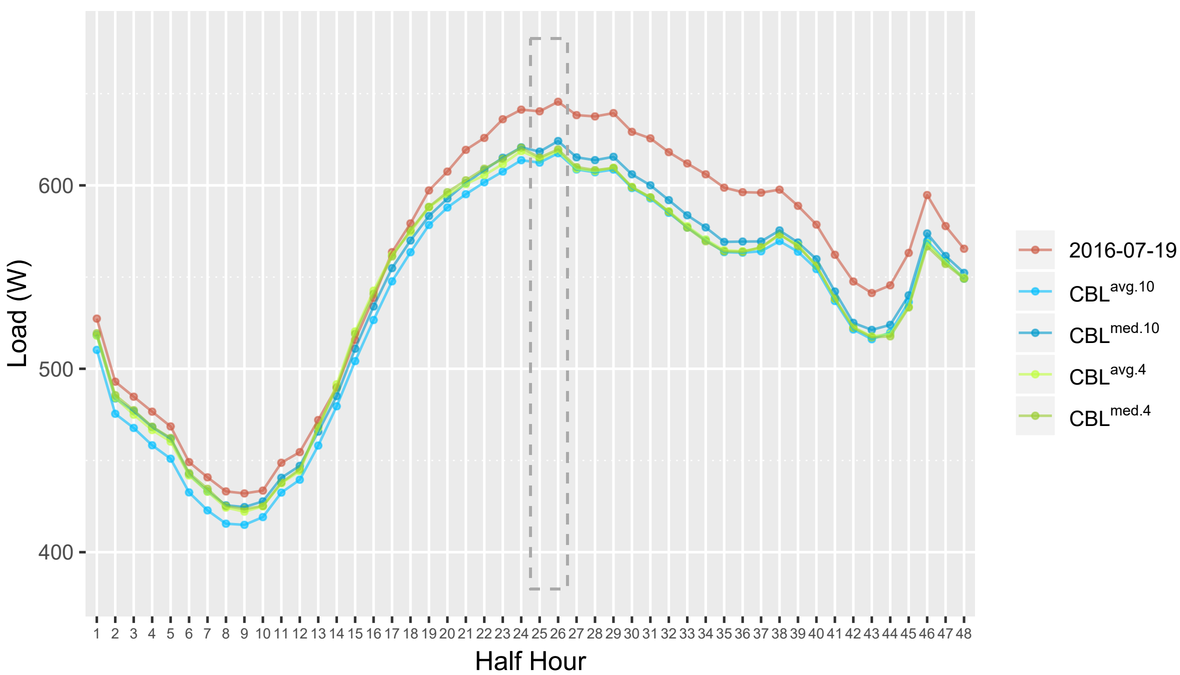

Figure A.9: Comparing the Actual Loads with all the Four CBLs (2016-07-19, French NEBEF)

Table A.5: Summary of the Established CBLs for the NEBEF (DR) Event Times (2016-07-19, French NEBEF)

	2016-07-19			
	$\cdots$	$t = 25$	$t = 26$	$\cdots$
Actual Load	$\cdots$	640.39	645.59	$\cdots$
$\text{CBL}^{\text{avg.10}}$	$\cdots$	612.40	617.53	$\cdots$
$\text{CBL}^{\text{med.10}}$	$\cdots$	618.41	624.18	$\cdots$
$\text{CBL}^{\text{avg.4}}$	$\cdots$	614.24	618.69	$\cdots$
$\text{CBL}^{\text{med.4}}$	$\cdots$	615.15	619.62	$\cdots$

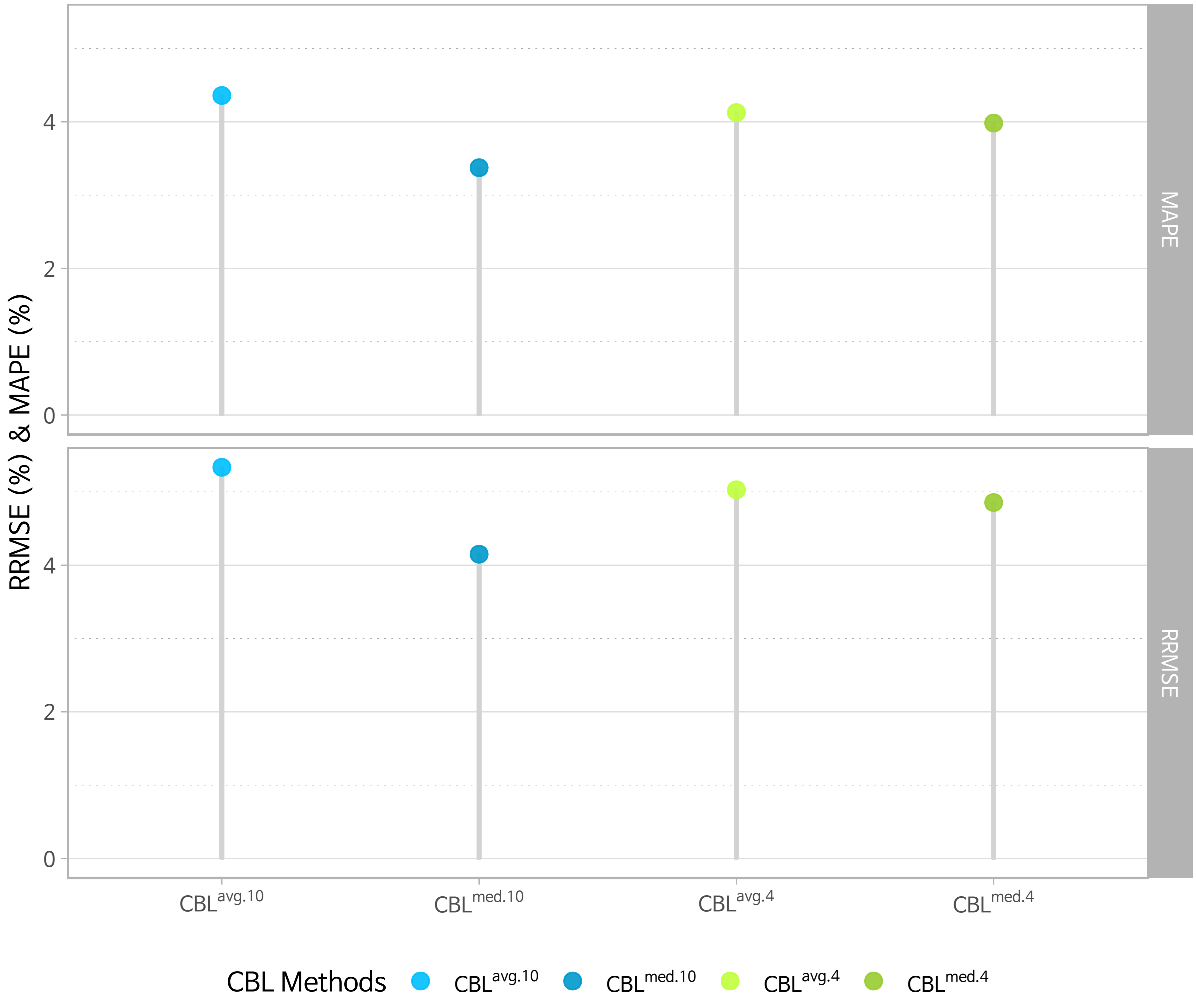

Figure A.10: The CBL Accuracy Comparison (MAPE & RRMSE) among the CBLs Established with Different Methods (2016-07-19, French NEBEF)

Table A.6: The CBL Accuracy Comparison (MAPE and RRMSE) among the CBLs Established with Different Methods (2016-07-19, French NEBEF)

	$\text{CBL}^{\text{avg.10}}$	$\text{CBL}^{\text{med.10}}$	$\text{CBL}^{\text{avg.4}}$	$\text{CBL}^{\text{med.4}}$
MAPE	4.36%	3.37%	4.13%	3.98%
RRMSE	5.34%	4.15%	5.03%	4.86%

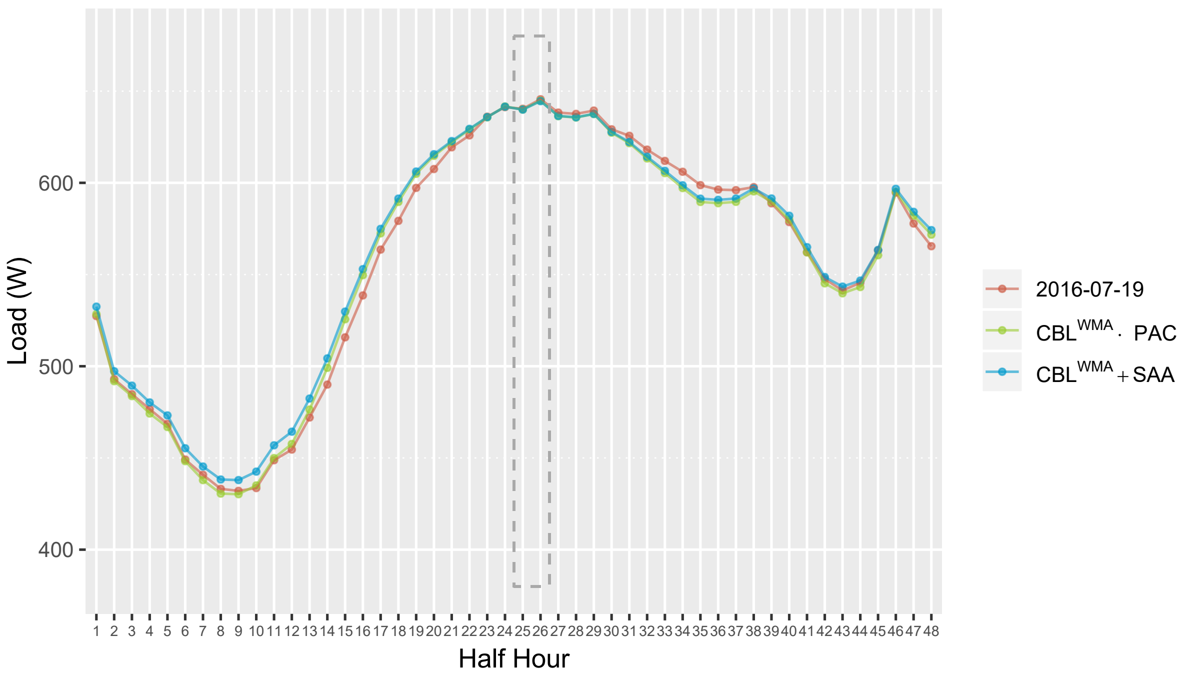

Figure A.11: Comparing the Actual Loads with the Two CBL Methods of $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$ (2016-07-19, French NEBEF)

Comparison to Four NEBEF CBL Methods: Fig. A.9

Table A.7: Summary of the Established CBLs for the NEBEF (DR) Event Times Applying $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$ (2016-07-19, French NEBEF)

	2016-07-19			
	⋯	$t = 25$	$t = 26$	⋯
Actual Load	⋯	640.39	645.59	⋯
$\text{CBL}^{\text{WMA}} \cdot \text{PAC}$	⋯	639.98	644.78	⋯
$\text{CBL}^{\text{WMA}} + \text{SAA}$	⋯	639.93	644.55	⋯

Comparison to Four NEBEF CBL Methods: Tab. A.5

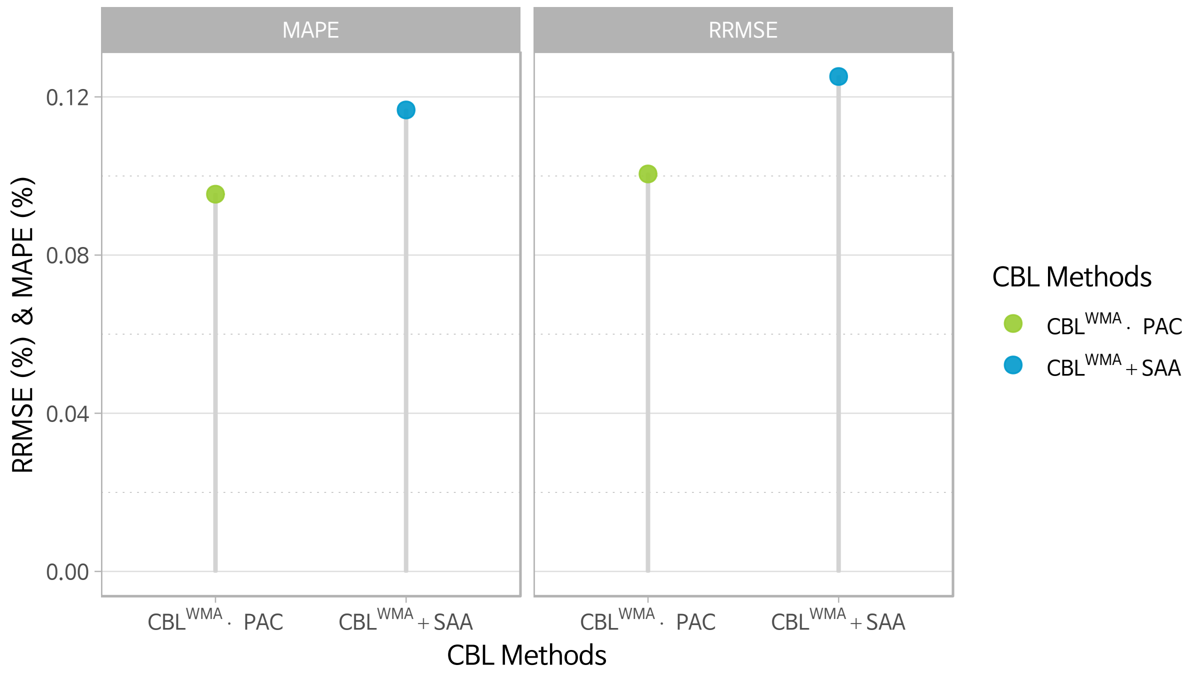

Figure A.12: The CBL Accuracy Comparison (MAPE & RRMSE) between the Two CBL Methods of $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$ (2016-07-19, French NEBEF)

Comparison to the Accuracies of Four NEBEF CBL Methods: Fig. A.10

Table A.8: The CBL Accuracy Comparison (MAPE and RRMSE) between the Two CBL Methods of $\text{CBL}^{\text{WMA}} \cdot \text{PAC}$ and $\text{CBL}^{\text{WMA}} + \text{SAA}$ (2016-07-19, French NEBEF)

	$\text{CBL}^{\text{WMA}} \cdot \text{PAC}$	$\text{CBL}^{\text{WMA}} + \text{SAA}$
MAPE	0.095%	0.117%
RRMSE	0.101%	0.125%

Comparison to the Accuracies of Four NEBEF CBL Methods: Tab. A.6

B. SUPPLEMENTARY EQUATIONS

$$\text{ARE} = \frac{1}{(t_e - t_s) + 1} \sum_{t=t_s}^{t_e} \frac{\text{CBL}_{d,t} - \ell_{d,t}}{\ell_{d,t}} \quad \text{(Eq.: ARE)}$$

where,

$$\begin{cases} (t_e - t_s) + 1 & : \text{DR event time intervals,} \\ t_s & : \text{DR event starting time,} \\ t_e & : \text{DR event ending time,} \\ \text{CBL}_{d,t} & : \text{customer baseline load for the DR event day, } d\text{, at the event time, } t\text{,} \\ & \quad d \in D = \{1, 2, \ldots, 365\}, t \in T = \{1, 2, \ldots, 24\}, \\ & \quad \sum_{i=1}^{n} (\omega_i \times \ell_{d-i,t}) \\ \ell_{d,t} & : \text{actual load at the time slot t and on the day of d,} \\ & \quad d \in D = \{1, 2, \ldots, 366\},\ t \in T = \{1, 2, \ldots, 24\}. \end{cases}$$

....

$$\text{MAPE} = \frac{1}{(t_e - t_s) + 1} \sum_{t=t_s}^{t_e} \frac{|\text{CBL}_{d,t} - \ell_{d,t}|}{\ell_{d,t}} \times 100 \qquad \text{(Eq.: MAPE)}$$

where,

$$\begin{cases} (t_e - t_s) + 1 & : \text{DR event time intervals,} \\ t_s & : \text{DR event starting time,} \\ t_e & : \text{DR event ending time,} \\ \text{CBL}_{d,t} & : \text{the estimated CBL during DR event period,} \\ \ell_{d,t} & : \text{actual load at the time slot t and on the day of d,} \\ & \quad d \in D = \{1, 2, \ldots, 366\},\ t \in T = \{1, 2, \ldots, 24\}. \end{cases}$$

....

$$\text{RRMSE} = \sqrt{\frac{1}{(t_e - t_s) + 1} \sum_{t=t_s}^{t_e} (\text{CBL}_{d,t} - \ell_{d,t})^2} \times \frac{1}{\frac{1}{(t_e - t_s)+1} \sum_{t=t_s}^{t_e} \ell_{d,t}} \times 100 \qquad \text{(Eq.: RRMSE)}$$

where,

$$\begin{cases} (t_e - t_s) + 1 & : \text{DR event time intervals,} \\ t_s & : \text{DR event starting time,} \\ t_e & : \text{DR event ending time,} \\ \text{CBL}_{d,t} & : \text{the estimated CBL during DR event period,} \\ \ell_{d,t} & : \text{actual load at the time slot t and on the day of d,} \\ & \quad d \in D = \{1, 2, \ldots, 366\},\ t \in T = \{1, 2, \ldots, 24\}. \end{cases}$$

....