Towards Cost-Effective Utility Business Models
Selecting a Communication Architecture for the Rollout of New Smart Energy Services

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Abstract: The IT architecture for meter reading and utility services is at the core of new business models and has a decisive role as an enabler for resource efficiency measures. The communication architecture used by those services has significant impact on cost, flexibility and speed of new service rollout. This article describes how the dominant system model for meter reading came about, what alternative models exist, and what trade-offs those models have for rollout of new services by different stakeholders. Control of a self learning home automation system by dynamic tariff information (Real-Time-Pricing) is given as an application example.

1 History of the Utility Centric ICT Architecture for Smart Metering

Technology advances in the last 50 years as well as decreasing prices for integrated circuits and communication have driven the move from mechanical towards electronic meters, from manual to automated reading, and from annual or monthly readings towards more frequent readings, e. g. in a 15 minute period. The interesting aspect here is the approach taken to implement these straightforward developments – either as a dedicated system solution for a specific problem or as a generic infrastructure serving multiple purposes with similar demands. Such demands are:

- Ubiquity – meters can be almost anywhere in an area served by electric energy and other metered services.
- Medium reliability – a system with extreme geographic distribution may not be dependent on the availability of a single element or communication branch.
- Cost efficiency – low communication cost per application using the ICT infrastructure. It is desirable when nodes and communication do not incur a fixed monthly cost or cost per transferred byte, because a fixed monthly cost per element may break many business cases and a fixed cost of data may render cost estimates unpredictable. As an example, assume you calculated the communication cost based on the small amount of meter data to be transferred and are confronted with several firmware upgrades of meters which involve a significantly higher data transfer volume.

In the beginning, generic use of the smart metering infrastructure was in focus. Theodore Paraskevakos, one of the frontrunners of automatic meter reading, applied his invention of Caller ID transmission in telecommunications to fields as diverse as meter reading (Paraskevakos and Bushman, 1980), sensor communication – at the heart of today's Internet of Things (IoT) –, the transmission of video rentals and other applications. With technology progress, the dedicated optimization of systems for the readout of billions of meters got more attention. Potential customers for such systems – sales or distribution units of utilities, or dedicated meter reading service providers – usually have no business in providing communication services for elements outside their meter and distribution control infrastructure. Instead, they are interested in a complete fulfillment of their customer-side tasks by a single infrastructure:

- Automated meter reading at defined times and transmission of the reading data to a data center,
- Software update for all elements of the meter infrastructure, such as the meters themselves, concentrators and data hubs,
- Configuration of meter infrastructure elements,

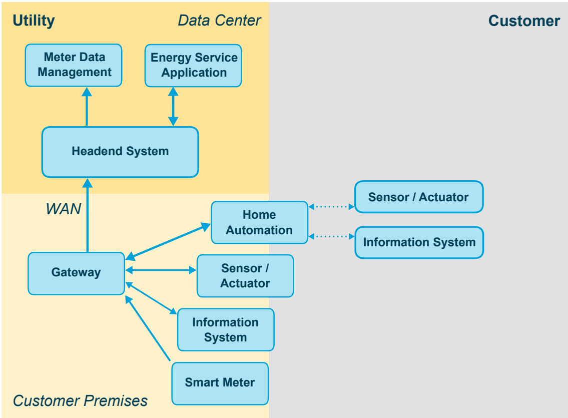

Figure 1: Traditional model for the Advanced Metering Infrastructure. The utility's area of responsibility is depicted on the left, the customer's on the right. In some components (e. g. home automation, sensors and actuators), the sphere of influence overlaps or depends on the service model.

- Securing bidirectional communication to inhibit tampering with reading data as well as modification of firmware running on meters or other elements of the metering infrastructure.

Such customers are almost always confined to a region or a country, and are subject to a long history of national or regional regulation. Thus their interest for globally standardized solutions is low, since potential cost benefits by global purchasing are offset by the effort to convince the regulator to drop national requirements in conflict with global solutions. This is reflected in the large number of physical[1] and logical communication protocols employed in meter reading systems. For each solution, this means a smaller market and less competition within its region. For a system, this means less compatibility among potential solution components. Besides the fact that national specifics in regulation hinder the definition and adoption of global standards in the metering field, the use of this infrastructure for services beyond its scope and provided by other organizations would create additional legal and administrative complications. As long as the cost of an exclusive meter reading infrastructure can be offloaded to customers and/or citizens, traditional utilities will have little incentive to engage in services reusing the metering infrastructure.

However, the generic infrastructure tasks listed above led utilities to plan value-added services of their own on top of the meter reading communication infrastructure. A typical service area is the optimized use of electrical energy – e. g. by identifying energy-intensive devices or by optimizing the time-of-use according to the utility's incentives. Naturally, the utilities plan to offer these services over the infrastructure they control (see Figure 1). At consumers' homes, small offices or workshops, this can be achieved by adding a communication link between the meter infrastructure and a home automation system – either an existing one or a system delivered to the customer as part of a service contract. As shown in Figure 1, sensors, actuators and information systems can be connected directly to the utility driven infrastructure. This model is used in classic ripple control or with the in-home display of an external meter. Or, sensors, actuators and information systems can be connected to a home automation system which in turn is influenced by information issued by the utility via its infrastructure. For the sole purpose of meter reading dedicated large scale system rollouts have started about 15 years ago and will be extending well into the 2030s. This has happened in parallel to the buildup of other communication infrastructure and in parallel to the almost ubiquitous availability of smartphones supporting WiFi and mobile data. The pace of alternative communication system rollouts will further accelerate with IoT sensor deployment and with applications that rely more and more on online connectivity. It is not necessarily a bad thing to have several dedicated systems performing similar tasks. Some criteria to decide whether an additional communication system is useful are total cost, total system complexity (especially complexity of applications relying on several communication systems) and the speed of innovation rollout (which may be higher in a dedicated system). Our question is: Which system architecture supports innovation in the energy and utility markets, which are subject to rapid changes – some of them with the potential to be disruptive? To this end, we will look at two examples of cost and complexity drivers. Then we discuss the evolution of the economic and regulatory landscape in its influence on the usefulness of architecture choices. We have a look at communication systems available in homes and small enterprises and discuss which architecture enables fast and cost-effective rollout of new business models. For this architecture, we describe a sample application which is currently being realized.

2 Examples for Cost and Complexity Drivers

Using a dedicated communication infrastructure means all costs have to be covered by the applications having access to and using this infrastructure. In

[1] Narrowband powerline communication like Echelon, Prime, G3, broadband powerline communication, Wireless MBus, LoRa, Sigfox, GPRS, LTE, Zigbee, WiFi and Low Power WiFi dialects, just to name a few.

the extreme case of smart metering, only an annual reading is necessary to bill a classic residential tariff. In this case, the meter reading infrastructure has to transmit no more than a few bytes of useful payload every year. When we assume that the operational cost for a smart metering infrastructure is up to 50 Euro a year compared to a classic Ferraris meter with annual reading, and that the meter reading can be coded in a 50 byte data unit, we get communication costs of 1 Euro per byte. When 15 minute readings are required and transmitted we transmit 35 kByte per Euro communication cost, or 29.26 Euro per MByte of payload. This is a considerable price, even compared with the most expensive volume-based mobile data tariffs. When other applications want to use this communication infrastructure, its owner will tend to charge a prohibitively high cost, so that many applications will become economically unfeasible over this infrastructure. Thus, third parties very probably will use another available communication infrastructure.

As mentioned before, the variety of communication protocols in dedicated metering infrastructures increase cost and complexity. This is illustrated by the requirement of a separate display (In-Home Display) for smart meters in some countries. A separate display makes sense when the customer has no access to the meter itself, e. g. when the meters for several apartments are located in the basement of an apartment complex or when the meters are mounted on a nearby pole to inhibit tampering. Smart meters often have built-in wireless MBus or PLC modems, but a greater choice of In-Home Displays exists with Zigbee modems. If the utility does not want to buy all components from a single source, it is often penalized by the need for gateways with protocol conversion. In addition, data content, presentation and data security from time to time necessitate software and configuration updates. Therefore, a secure software distribution and activation platform has to be developed or extended for each new integration component like an In-Home Display. To develop and maintain such a platform is costly and incurs permanent operating expenses. Furthermore, professional displays generally offer limited functionality at a higher price than consumer goods. When we look at the In-Home Display problem a second time, the question is whether we need an In-Home Display at all. Any old smartphone has more functionality and – most importantly – comes with a well-established software distribution platform. Better still, a smartphone is available at almost all customers, who have no interest in yet another display hardware (Gosden, 2015). The requirement to use this superior and customer-friendly solution is support of WiFi, the most widespread communication solution. By doing that, solutions from other industries are immediately available to the utility industry, yielding immediate cost and customer satisfaction benefits. The consideration for regulation is not to specify technical detail, which is often based on a specific solution approach and risks to mandate inferior solutions after new approaches have become available (see (UK Department of Energy & Climate Change, 2016) for an example of the lengthy and cumbersome process to scale back on technical detail in regulation).

3 Regulation and Economic Developments

Utility services belong to basic needs and competition on the physical access is rarely feasible for the supply of energy, water, gas or long-distance heating. Therefore utility services including metering, transmission and remuneration of meter readings are highly regulated. Also regulated is the unbundling of generation, transmission, distribution and sale of electric energy. In Germany, the operation of metering points is defined as an additional role; due to the security solution specific to Germany (BSI-Gateway, smart metering system) the meter point operator has additional regulated tasks (Smart Metering Gateway Administration). The combination of role unbundling and regulation of network charges results in side-effects, which render offering new services via traditional market roles unprofitable. For example, sales is burdened with higher network charges when energy consumption of private households deviates from standard load profiles.

Offering further energy services is usually unregulated business, at least if they are organizationally separated from the regulated market roles, based on a separate contract (opt-in), and obtain the required meter readings (where necessary) with consent of the customer using other ways than the official smart meter gateway. Economically, the energy provider market is developing towards more complex contractual relationships: Distributed energy generation provides manifold possibilities for optimizing the local or regional utilization of renewable energy sources by personal and regional use. This helps to reduce necessary investment in transmission, and to share the resulting savings. Presently, only one sales contract per end-customer is foreseen. With self-consumption and the future possibility of local peer-to-peer selling, the traditional energy sales contract will carry less value in terms of energy delivered and more in terms of an insurance to provide a supply guarantee that steps in when locally produced energy is not available in sufficient quantity. This will – at a pace the regulator allows – lead to a considerable increase of connection fees. Possibly, this increase will be compensated by a decrease in the kilowatt-hour rate. In any case, the share of sales, and presumably also the total revenue, that depends on metered and priced readings in compliance with regulation will decrease. Therefore, the economic benefit of the metering infrastructure will decrease further, the "cost of smart metering" to "energy consumption revenue" ratio will become less and less favorable, as long as there are no other applications that use the metering infrastructure.

Applications going beyond pure energy supply usually require hardware on the customer side. The development in the area of home and office automation solutions is currently very dynamic, regarding both the functionality provided as well as interfaces offered for device and solution integration. For a utility company, selecting a home automation solution or a home automation portfolio and integrating it with its communication infrastructure therefore poses a high risk. Any choice would have to be accompanied by continuous market observation, and must be updated if required, entailing new integration efforts. The customers' quality demands on a solution recommended by the utility company are higher than those on one purchased directly from some retailer, putting additional pressure on the utility's ability to compete. Also, home automation provides many functions (comfort, security, entertainment, amongst others) which are neither in the utility's focus nor is it the customer's expectation that the utility excels in all application areas of home automation. And even if the utility or its energy service provider offers an attractive package, the customer may be uncomfortable with external control of his private sphere. If the hardware on the customer side is linked via the same communication infrastructure that is used for meter readings, the provider is not free regarding the integration. In addition to that, specific German regulation requires that data flows which are not defined yet in the smart meter gateway specification must be cleared by the Federal Network Agency (Bundesnetzagentur) and the Federal agency for Information System Security (Bundesamt für Sicherheit in der Informationstechnik, BSI). Using the regulated infrastructure for unregulated services therefore poses a high project risk. This is an inherent problem, as it cannot be the duty of regulation to identify possible innovative business models before the market does, and adjust the rules proactively to these business models.

Thus, the regulated and the new unregulated services in the energy sector should be separated, both organizationally and regarding the communication infrastructures, if delays and uncertainty factors are to be avoided when launching new services.

4 Existing Systems and Further Applications

For system optimization the following communication systems common to residential or office areas can be considered:

1. Communication infrastructure for smart meter readings: regulated; completion of nationwide roll-out in Germany by 2032.
2. Internet via landline, cable or mobile modem, usually with WiFi access point: 2016 available in 89.3% of all households (Statistisches Bundesamt, 2017a). Under control of the owner/tenant, regarding contracts as well as availability, which depends, e. g., on whether the modem is turned on or whether the current WiFi password is known to the clients.
3. Internet via smartphone, maybe with WiFi access point: used in 2017 by 70.5% of all persons aged 10 and above living Germany (Statistisches Bundesamt, 2017b). Controlled by the smartphone user; physical presence of the user, active device as well as availability of data connection via mobile network required.
4. Public WiFi: Currently low availability in households, with increasing tendency in densely populated areas.

For the regulated application of meter readings the communication systems 2-4 were rejected early on, as they are outside the control of the provider, and their use by the provider might entail considerable coordination effort between provider and communication contract holder.

By bundling energy and internet supply it would be quite possible to integrate the communication modem in the meter, thus guaranteeing the uninterrupted function of the modem under control of the utility company or the internet provider. As an opt-in offer this kind of bundling would be unobjectionable – the network separation between smart meter system and the customer's home network could be realized without difficulty using logical network separation functionality provided by modern modems. This model promises considerable savings, as only a single communication infrastructure and its operation is required, refinanced by two utilizations. Unfortunately big utility companies had substantial concerns, fearing that telecommunication providers would become competitors in the energy sector, and that they would facilitate market entry by this bundling model. Still, this approach is an excellent business model for municipal utilities that hold shares in local telecommunication providers.

Generally, concerns regarding the reliability of customer-provided infrastructure cease to apply when the service is in the customer's self-interest. In the application example presented in this paper (Section 6) this is obtained by providing tariff information via the customer's internet link, resulting in lower energy costs and optimization of the utilization of the customer's own energy sources and storages.

Public WiFi (item no. 4) is the only technology available independently of contracts with mobile network operators in virtually any smartphone[2]. The fact that public WiFi access points become more widespread is powered by several strongly growing applications, as it uses the most pervasive wireless communication technology with the most affordable chip-sets. It is therefore suitable for communicating with all sensors and actuators that are connected to a power supply or have sufficient ambient energy at their disposal for energy harvesting. For local control and inspection applications, a common smartphone can be used over WiFi with authentification; dedicated maintenance hardware is not required. Further applications for public WiFi are in-house location-based services and connectivity offers for citizens and customers. All these reasons will lead to public WiFi coverage increase in city regions, albeit not a coverage that will ever come close to 100% of all supplier end-points.

If – as in the case of smart metering – no real-time communication is required[3], in many cases a secure connection over any smart phone can be used[4]. This requires that smartphone users get incentives for the data transport. As data transmission using a dedicated infrastructure is very expensive (cf. Section 2), the budget for such a reward is sufficiently large. A study performed by the TU Munich is available that compares costs between traditional meter reading and readings using existing smartphones (Schwab et al., 2016).

To conclude: Several communication devices are available that can be accessed in households, as well as several applications refinancing a joint communication infrastructure, thus lowering the application-specific costs of communication considerably.

[2]Bluetooth is not much worse regarding modem pervasiveness, but less attractive due to its short range and lower bandwidth.

[3]For billing a monthly transmission of 15-minute readings is sufficient even for real-time pricing. For measuring feedback in demand-response applications a higher rate makes sense; as feedback-measuring is a statistical evaluation, obviously not all meter points have to be transmitted for each feedback-round, as long as the readings can be stored in the meter or concentrator sufficiently long.

[4]In Germany the requirements for a smart meter system specify that a permanent tunneled connection is mandatory.

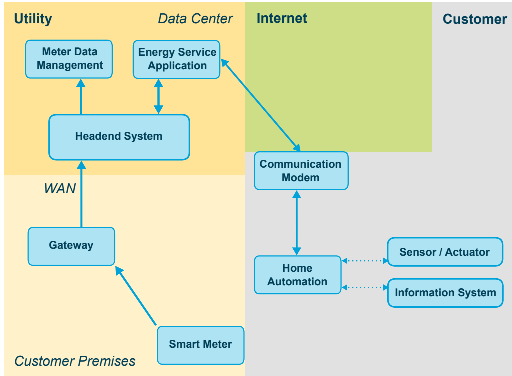

Figure 2: Providing energy services through dedicated *and* public communication systems.

5 Optimizing Provider Organization and ICT-Environment

Respecting costs, complexity and regulation, the follow conclusions can be derived:

- Additional services beyond the regulated ones should make use of generic communication infrastructures and interfaces (LAN, WiFi) in order to avoid high costs for development and operation and an increase in project risk.
- The communication infrastructure does not need to be the property of the provider, as delivering unregulated services is always an opt-in model. This implies the customer's interest in service delivery and provides the service provider with a motivation for a customer-centric approach.
- The service should make use of control standards, or, if not possible, combine quasi-standards to control or influence smart home products to avoid the need for custom hardware.

Thus, it seems advisable that new energy and provider services are delivered using an existing communication infrastructure as shown in Figure 2. The protection of data privacy is governed by generic consumer protection and privacy rules. Those rules are much more generic than specific requirements on the handling of meter data and thus apply even to new business models that did not exist when the regulation was written.

The regulation and role concept of intelligent metering systems are of no relevance in terms of additional energy services, as they are not regulated energy delivery services. In this system model, subsidiary companies of energy providers and other third party energy service companies may provide their service by conclusion of a contract with the customer.

In Germany regulations demand intelligent metering systems to only use tunneled connections, other

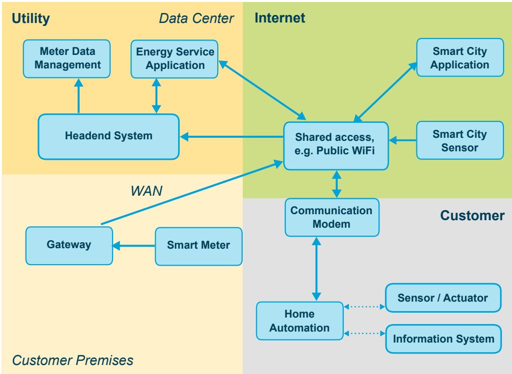

Figure 3: Communication in shared infrastructures.

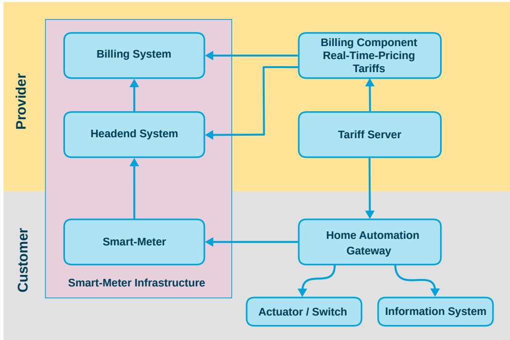

Figure 4: Adaptive home automation guided by dynamic tariffs.

countries may not regulate the communication, thus not enforcing a dedicated communication infrastructure [5]. This is shown in Figure 3.

The communication architectures in Figure 2 and Figure 3 are heavily affecting the system costs and variety of providers. As a side effect it is also lowering the entry threshold for IoT applications. Thus, if smart metering is utilizing and investing in a shared infrastructure, it will support the development of additional local applications. The previous chapter has shown that it is possible for alternative providers to provide services without accessing the smart meter infrastructure. Even the lack of access to energy consumption readings of the meter operator can be substituted by measuring consumption using one or several additional calibrated meters within the customer's electric circuit. Possible deviations within the range of the calibration tolerance are in most cases insignificant and manipulations can be detected by comparison with the readings of the energy provider. In a regulated energy market, traditional energy providers do not have the possibility to prevent alternative services, they only get to choose their communication architecture and the resulting investment costs of their services. The cooperation with alternative service providers also results in substantial cost reduction and increase of customer benefits for traditional providers of energy services and energy delivery.

6 Application Example

Highly dynamic energy tariffs, known as Real-Time-Pricing (RTP), are an example for additional energy services. In (Wenninger et al., 2017) we describe a generic, incentive-based load shifting method that operates independently from the energy provider's infrastructure by using RTP and a Home-Automation-Gateway (HAG, see Figure 4). Based on the same infrastructure, instead of providing highly dynamic prices as an incentive for load shifting, it is possible to implement a bonus system where the customer will be provided with an inducement in form of a bonus while having a static energy tariff.

The HAG fulfills the task of automatically shifting loads under the premise of respecting the customers' habits when using appliances. This minimizes the risk that load shifts would have negative effects on the customers' habits, which would lead to issues regarding user acceptance of the automation system. We achieve this by creating user profiles based on high resolution energy data, which provides insight into the residents' appliance usage habits. Based on this profiling, it is possible to predict the probability of appliance usage, thus only scheduling load shifting tasks within the user's comfort zone. Through an information system the customer can be provided with incentives for manual load shifting of appliances that cannot be controlled automatically by the HAG. The operation of such systems requires requesting current energy tariffs from a tariff server as well as high resolution energy data provided by a smart meter. Additionally, the HAG requires access to local appliances such as washing machine, dish washer or climate control. From a demand side management (DSM) point of view, only the combination can generate a surplus from the operation of smart meters. For example, in Germany the planned smart meter infrastructure will not allow energy providers to have access to high resolution energy data, but only to aggregated data that is of relevance for billing purposes. Hence, the required high resolution data must be extracted locally through an interface. This interface acts as a bridge between the regulated smart meter infrastructure and, e. g., the local WiFi. Likewise, it is possible to install an additional unregulated smart meter which will gather the required data,

[5]In case the provider makes use of mobile communication standards such as GPRS or LTE, the metering system does already utilize a non-dedicated communication system.

especially in a bonus based system.

The benefits of such an architecture goes beyond overcoming regulations, as the high resolution and therefore sensitive data must not leave the household as they may solely be used within the HAG. Having a smart meter independent infrastructure also provides the possibility for, but is not limited to, a local, smartphone-based information system where the user profiles stay within the user's local network and therefore are not transmitted to any third-party. On the contrary, it is possible to develop cloud-based DSM business models, where the high resolution data is centralized on a server, accessible over an internet connection.

This provided example shows, that by adapting the communication infrastructure, even with the regulated smart meter infrastructure it is possible to develop new and innovative business models which make use of high resolution energy data.

7 Conclusion and Outlook

The considerations and examples in the article show that the communication part of the ICT system design heavily influences the range of offers to customers, market success and costs for delivering public services and optional unregulated services. The ability to reuse an existing infrastructure and to easily extend the offered service is a key success factor of big internet companies. However, innovative services are not limited to big internet companies: small and local companies have the ability to develop such services, and they are even more capable of reaching customers whom they already have a business-relationship with. Overcoming the entry threshold is much easier if no custom hardware and protocols are required to deliver new services. In the area of smart energy, smart utility, smart city, and IoT, a positive competition and cooperation between internet providers, energy providers, and municipalities will arise in the coming years. For economic efficiency reasons, they will almost exclusively make use of generic communications infrastructures to stay competitive in a fast moving market.

REFERENCES

Gosden, E. (2015). Ministers 'wasting millions' on energy display gadgets for every home. `http://www.telegraph.co.uk/news/earth/energy/12058239/article.html`.

Paraskevakos, T. G. and Bushman, T. W. (1980). Apparatus and method for remote sensor monitoring, metering and control. US Patent 4241237.

Schwab, B., Lutz, M., and Heiler, T. (2016). Analyse einer Geschäftsidee: Anreizsetzung zur Nutzung existierender Kommunikationssysteme für intelligente Zähler. Projektstudium, Technische Universität München, Lehrstuhl für Technologie- und Innovationsmanagement.

Statistisches Bundesamt (2017a). Equipment of households with information and communication technology – Germany. `https://www.destatis.de/EN/FactsFigures/SocietyState/IncomeConsumptionLivingConditions/EquipmentConsumerDurables/Tables/Tables_Germany_ICT.html`.

Statistisches Bundesamt (2017b). Press release Nr. 430 - 05.12.2016: 81% of internet users are using it on smartphones. `https://www.destatis.de/DE/PresseService/Presse/Pressemitteilungen/2016/12/PD16_430_63931.html`.

UK Department of Energy & Climate Change (2016). In-Home Display Licence Conditions: Consultation response – Smart Metering Implementation Programme. `https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/497078/IHD_Policy_Framework_Licence_Conditions_Post_Consultation_Decisions_Final_for_Publication.pdf`.

Wenninger, M., Schmidt, J., and Goeller, T. (2017). Appliance Usage Prediction for the Smart Home with an Application to Energy Demand Side Management – And Why Accuracy is not a Good Performance Metric for this Problem. In *6th Int. Conf. on Smart Cities and Green ICT Systems (SMARTGREENS)*, pages 143–150, Porto, Portugal.