Software System Migration to Cloud-native Architectures for SME-sized Software Vendors

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Abstract. Independent software vendors (ISVs) are often faced with the need to migrate their software products as software-as-a-service (SaaS) solutions to the cloud. We document and evaluate four case studies by considering various factors that the respective companies need to consider in a cloud migration process. We look at migration project as a software re-engineering activity, involving project planning, cloud architecture design and architecture transformation. Specifically for software vendors, a cloud migration opens opportunities such as the possibility of modernising their software through re-engineering their product architecture. However, small and mid-size enterprises (SMEs) often do not have the required cloud expertise to plan and implement a cloud migration.

While many experience reports exist, there is new impetus in the domain resulting from the drive towards cloud-native architecture and other developments particularly in the cloud PaaS space. This allows software modernisation as part of a wider software evolution strategy. We present such a modernising architecture evolution process here. While there is a higher initial cost, the benefits of cloud-native architectures turn out to be advantageous in the long run.
Keywords: Cloud Migration, Architecture Evolution, Software Modernisation, Cost Models, Cloud Native, ISV, SME.

1 Introduction

Migration to the cloud is done by Independent Software Vendors (ISVs) either because they see advantages of providing their products as Software-as-a-Service solutions through the cloud or are forced through change in customer demand and requirements to do so. The problems for companies aiming to migrate to the cloud is that it is often difficult to scope and determine the costs of a migration project, because of

- misconceptions about benefits and risks of cloud-based provisioning of software,
- unclear expectations resulting from different cloud service and deployment models.

From a software engineering perspective, which is at the core of the ISV's business, problems emerge. What of the existing architecture is migratable? What is the extent of re-engineering necessary to make migration work? What target architecture is most beneficial? Specifically for software vendors, a cloud migration opens opportunities

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such as the possibility of modernising their product through re-engineering their legacy software architecture through the replacement of existing code/architecture, but also of supporting tools/services, and development processes. Sample concerns include webification or the use of software product lines for bespoke products. Re-engineering might also simply be necessary due to non-suitable licenses for some components or the need to upgrade due to interoperability concerns. SMEs, even though technology providers, often do not have the required cloud expertise to plan and implement a migration.

Many experience reports investigate cloud benefits and risks for companies. Only a few look at the software vendor perspective, where not only the existing on-premise IT system needs to be moved, but where in addition

- development and continuous maintenance and re-engineering in the cloud needs to be considered as this is part of the core business for software developers.
- the costing needs to consider the costs for deploying software in the cloud, but also to develop a monetisation model that reconciles these costs with income to be generated from an entirely different revenue model for the software product.

Moreover, specifically in the cloud PaaS space there is a lot of activity that merits a fresh look at software development and provisioning in and through the cloud. This includes the trend towards cloud-native architectures [4] as a new architectural style suitable for the cloud that help to better control quality and costs [23].

We present an incremental, pattern-based migration process that includes early experimentation and performance testing [21]. We analyse four case studies by considering various factors that the respective companies need to consider in this context. These case studies are from different sectors, including banking, document management, food and insurances. We have been involved in the migrations as consultants in various stages from initial feasibility analysis to full multi-stage system migration. The trend towards cloud-native architectures is essentially a componentisation of the application architecture in terms of cloud infrastructure and platform services such as storage (infrastructure) or databases and integrationware (platform). We illustrate how re-engineering towards cloud-native architectures addresses technical ISV concerns, but also costing to estimate and manage expenses for a cloud-deployed solution.

We start with an introduction of a process model towards a cloud-native architecture in Section 2. We then introduce and discuss the use cases in Section 3. In Section 4, we look at experimentation to determine the scope of the migration and re-engineering project and in Section 5, we note observations, before discussing related work and concluding in Sections 6 and 7.

2 Migration Framework – towards Cloud-Native Architectures

As part of our studies, we have surveyed several consultants and solution providers in the cloud platform (PaaS) space to define a common PaaS-specific migration process [6]. Figure 1 shows this process tailored to ISV needs. Central in this process are software architecture concerns (such as stateless architectures) and re-engineering to modernise software (driven by different reasons as discussed above).

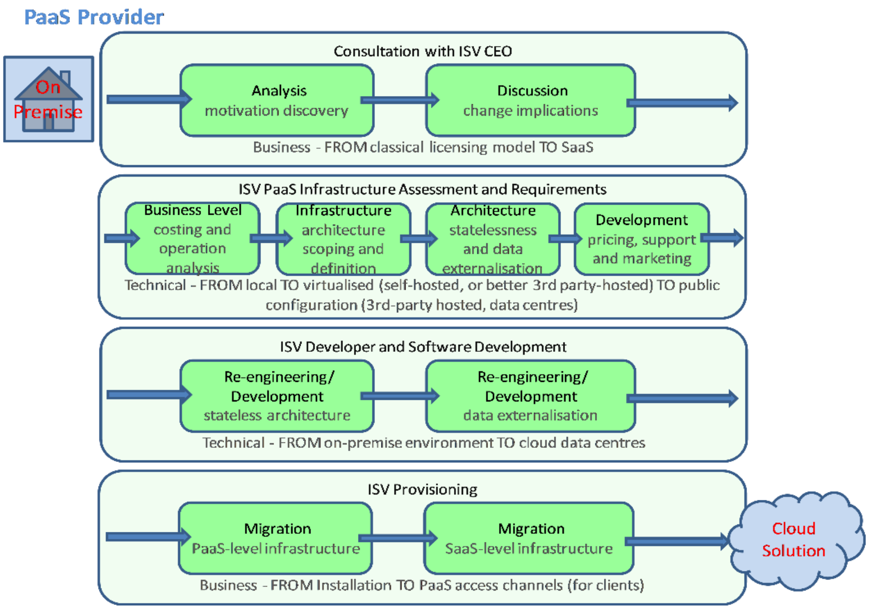

Fig. 1. PaaS Migration Process with four main Stages and individual Tasks.

For the architectural migration, we use a pattern-based approach using individual migration patterns to define the migration process in several steps. We use a catalogue of migration patterns that describe simple architectural transformations for specific scenarios (e.g., for simple cloudification in an IaaS solution). Each pattern defines a re-engineering step [6]. The 15 patterns can be broadly categorized into: (i) relocations of a single component into the cloud, (ii) replacements of a component by a cloud-native service, (iii) distribution of several components across several cloud service providers.

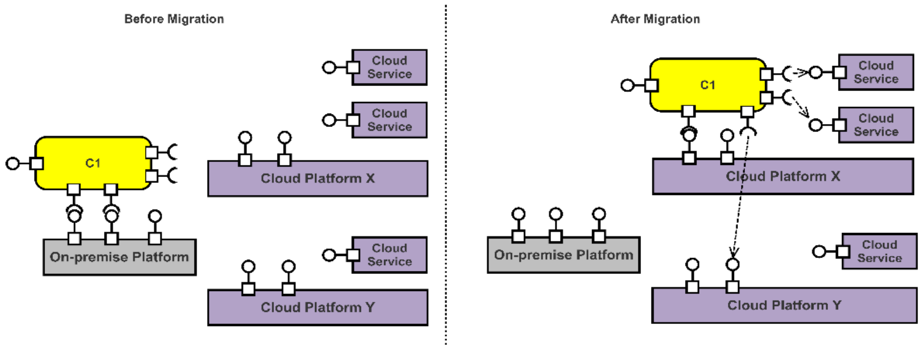

Fig. 2. Multi-Cloud Relocation

Many patterns directly address the introduction of a cloud-native service [22]. A sample pattern is the Multi-Cloud Relocation (Figure 2), specified as follows:

- Definition: A component re-hosted (or relocated) on a cloud platform is enhanced by using the environmental services of the other cloud platforms.
- Problem: Enhancing the availability of an application without the significant architecture change, and without incurring capital expenditure for on-premise hardware.
- Solution: Leverage cloud platform environment services to improve availability, e.g., live migration from existing platform to the target in case of service outage.
- Benefits: As component re-hosting in multiple cloud platforms and improve availability and avoid vendor lock-in.
- Risks: Cloud providers do not provide the necessary services to enable application to run in multiple cloud platforms without re-architecting or rewriting the code.

The combination of patterns defines a staged process as a migration path which in the individual steps is driven by selection criteria (e.g., time to market or introduction of new capabilities) [18,19]. Migration paths are sequential compositions of these patterns on a source architecture [17]. A cloud-native architecture as the target of this step-wise migration is build up from individual services provided in the cloud, such as the cloud services indicated in the pattern above. Step-wise migration into cloud could happen as follows, if a fully cloud-native solution is aimed at:

- The on-premise system can be packaged into VMs as a first non-native solution, i.e., license fees occur as usual. A business problem is scaling out, i.e. adding more VMs, means adding more license fees for every replicated component. A technical problem is copies of data storage that are not in sync if multiple VMs are in use.
- In order to address the problems, we can refactor and extract storage, i.e. use data-as-a-service. This alleviates the technical problem of different copies of data.
- Another step is to package the whole DBMS into single machine, which alleviates the licence fee issue for DBMS and simplifies data management. However, the business problem that other licence fees still occur multiple times remains.
- The final step(s) are then to fully move to PaaS services (e.g., Azure SQL server), which alleviates as far as possible licensing fees issue.

This results in a so-called cloud-native architecture, which is generally characterised as scalable and elastic due to cloud service support such as scaling engines, clusterable and multi-tenant due to cloud virtualization principles being applied, and pay-per-use and self-service as two other cloud principles. This has better scalability characteristics as platform tools can be used to manage performance. It also allows better licensing and cost management. Thus, this addresses both technical and business problems.

3 Use Cases – Documentation of Four ISV Cloud Migrations

3.1 Description Framework

We document the use cases in two ways. Firstly, in a pre-migration view looking from an analytical, pre-migration perspective at the companies, following the concerns from Table 1. Table 1 provides a list of concerns that should be elicited prior to migration

[1]. Then, for the migration execution, we report on the main actual migration stages that follows largely the process outlined in Figure 1.

Table 1. Migration Concerns

Concern	**Concern of the Respective Activity**
Setting/Application	Description of the sector & classification of the application in question
Expectation/Driver	The drivers and a distinction of migration benefits and expectations that potential users are aware of (their vision)
Ignorance	Factors that have been overlooked (their 'ignorance')
Concerns	Specific problems/ constraints that need to be addressed

The migration execution follows the process of Figure 1, with the actual architecture migration follows the migration path defined through the pattern application.

Table 2. Use Cases – Pre-migration categorisation of factors

	UC1 – Banking	**UC2 – Insurance**	**UC3 – Food**	**UC4 – Doc. Managemen**
Setting and Application	*Sector*: Financial services. *Application*: comprehensive (ATM, Internet banking)	*Sector*: Insurance product. *Application*: multiple products with policy database, CRM and telephony (call centre) support	*Sector*: Food. *Application*: Sector-specific ERP system	*Sector*: Business Solution. *Application*: Document processing
Expectation Drivers	Cloudification. Internationalisation. SaaS product	Internationalisation. Scalability	Internationalisation. SaaS product	SaaS product
Concerns	Data location. Vendor lock-in	Data location	Data location	Data location
Ignorance	Implications of different layers	Cost	Cost	Implications of different layers

3.2 Pre-Migration Analysis

Following Table 1, we summarise the case studies as in Table 2. The factors already indicate a need for re-engineering. A SaaS product requires cloud metering services to be added to monitor consumption. Internationalisation is typically part of an expansion strategy that needs to be supported by scalability. Cost as a concern requires equally individually monitorable and adaptable services.

As a staged migration process, we carried out the following tasks as described in Table 3, following the outline from the process presented in Figure 1.

Table 3. Migration Tasks.

	UC1 Banking	**UC2 Insurance**	**UC3 Food**	**UC4 – Doc. Management**	***Notes on Architecture***

Technology Review	available technologies and solutions for cloud-based transaction, card and customer storage and processing	available technologies and solutions for cloud-based insurance storage and processing	available technologies and solutions for cloud-based ERP solutions	network concerns for high-speed up/download, services for in-cloud document processing	*Components such as storage, high-performant networks, ERP systems or transaction processing indicate re-engineering focus*
Business analysis	investigate security and monitoring/auditing options for cloud-based banking processing	investigate security and monitoring/ auditing options for cloud-based insurance processing (focus data integrity and location as products offered cross-boarder)	investigate legal (rather than linguistic) localisation requirements regarding the deployment (the ERP system is provided to customers across Europe, but also China)	business analysis to investigate security/data privacy regulations	*Indicates the benefits of cloud-native architectures*
Migration & Architecture	focus on feasibility and efficacy of process-aware migration of banking admin and operations management systems into scalable cloud architecture	focus on implementing business process-aware migration of insurance admin & operations management (policy, accounts, CRM, telephony) into distributed cloud architecture	focus on feasibility and efficacy of process-aware migration of ERP system features (15 core modules) into scalable cloud architecture	development of a 2-staged incremental migration plan (IaaS and PaaS) to migrate a document scanning, storage and processing to scalable cloud architectures.	*Defines the scope of a re-engineering process towards a cloud-native architecture*
Test & Evaluation	evaluate scalability of cloud-based integrated banking service configurations	evaluate scalability of distributed cloud-based integrated insurance service configurations	evaluate scalability of cloud-based integrated ERP service configuration for different markets	Testing of cloud-specific properties: Scalability, Performance, Integration, Security	*Explains why a cloud-native architecture is useful for technical and cost reasons*

3.3 Migration and Architecture Case Study

We detail two activities from the 'Migration and Architecture' task for the Document Management case study. This illustrates the re-engineering process in more detail.

The first decision was to consider the configuration and management of both IaaS and PaaS solutions for the Document Image Processing system (DIP) using MS Azure as the default platform. Both solutions were part of a stage plan to make a first virtualized version quickly available and then re-engineer properly in a second phase. The creation of a virtualised DIP system for deployment on a cloud IaaS solution thus preceded the componentisation at PaaS level. Here specifically storage, document processing components and integration with other services was considered. This is essentially a stepwise architecture evolution towards a cloud-native architecture.

Securing all parts of the system in both IaaS and PaaS configuration is another task. Data (document) protection and tenant isolation is a strong requirement, as are authentication, authorization, backup and recovery management. These requirements need decisions regarding a private cloud setting (for isolation) and the use of additional services for ID management and backup/recovery. Our patterns allow this to be modelled. Security policies need to be defined for the cloud and security mechanisms configured.

4 Experimentation For Migration, Testing and Evaluation

Experimentation plays a major role during the migration and architecture re-engineering to address the Testing and Evaluation task. Experimentation of prototypes of the partly or fully cloud-native re-engineered architectures is required to evaluate options in a realistic setting. As for instance scalability was an important concern, driven by the business aim of the companies to expand, at early stages we did feasibility tests to validate a proposed architecture [7]. A motivation for experimentation was also to carry out a cost-vs-performance experiment, i.e., to consider sometimes different options and compare them technically, but rank them under consideration of the costs they would create. In the introduction of cloud-native architecture, we have already pointed out the importance of financial concerns (e.g., licences) in the re-engineering process.

A key question for ISVs is to validate a cloud-based business model with expenses and revenues prior to fully embarking on a cloud-based architecture. There is always a trade-off between the quality, e.g., performance of services in the cloud, the income they generate and the cost that these incur.

In Figure 3, storage services are compared in terms of performance and consumption (which is essentially a cost metric). It allows to decide which cloud-native service to use from the options considered in the test. What experimentation shows in general is:

- the difference between PaaS/IaaS/SaaS solutions (as consumer and provider)
- scalability of different target architecture options
- integration and interoperation problems
- how to structure and cost a staged migration (plan derivation)

Experimental feasibility and validation studies have played a key role in our migration process to validate re-engineering options before fully implementing these. How to do experimental feasibility studies is outlined here. We have defined source and possible target architectures and have selected critical components that can be replaced by cloud-native service, e.g. high volume data processing to test scalability of storage (DB) or communications infrastructure to test integration/communications scalability.

This experimentation often results in a prototype evaluation of a partly cloud-native cloud architecture. Rather than just cloudifying a system in a virtual machine, we often selected a component such as data storage and have experimented with different cloud-native storage options, including for instance a mix of traditional RDBM and other table/blob storage formats as we have done for the document management system.

Partial experimentation with cloud-native prototypes allows to consider a fully cloud-native architecture to be discussed with realistic technical (e.g. scalability) and cost assumptions (storage, access). Only realistic costs for cloud operation allow a charging model for their own product to be developed and validated.

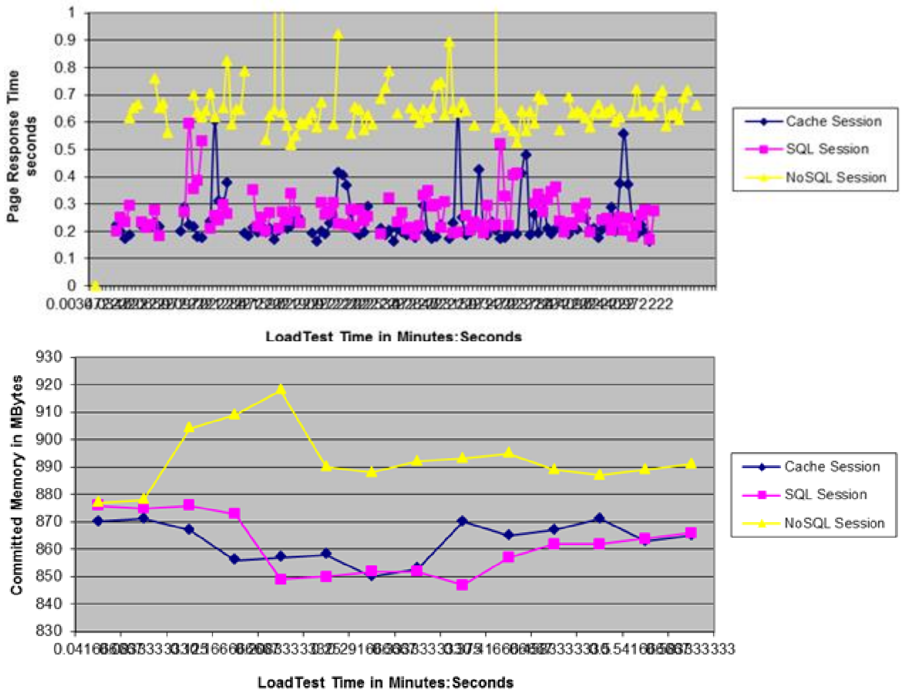

Fig. 3. Experimental results for storage component options (performance at the top and consumption at the bottom)

5 Observations

Surveys of the participating companies in the migration projects have revealed the following expectations and uncertainties. The drivers to consider a migration are the following expectations of improvement in relation to [6]: time to market improvement, inclusion of new capabilities, reduce operational cost, leverage investments, free up on-premise resources, scalability to support expansion, integration and access. These depend much on the sector and product type. The observations on clarifying concerns are essentially confirmed by all use cases considered.

While there was a clear business case at a high level to consider a cloud-based SaaS product, some problems emerged during the migration:

- Clarity of vision: Business reasons to go to cloud did exist, such as internationalisation and improve company value (being in the cloud). Technical reasons to go to cloud that accompany this were also clear (e.g., scalability to support expansion). Awareness of general concerns (business and technical) and barriers did exist, such as data protection. This was not always matched by full clarity about architectural options and possible cloud monetisation models.
- Understanding of cloud (all have impact on architecture and process selection): Technical concerns were understood, such as scalability or data protection as a requirement. However, the difference between provisioning models and cloud layers and their impact on the management effort at I/P/SaaS level in comparison. A possible vendor lock-in resulting from some architectural decisions (basic virtualisation versus fully cloud-native implementation) was not clear either. The business concern that was incompletely understood was the business model, i.e., the required revenue model change. In legal/governance terms, awareness of data protection and location issues was there, but needed further clarification of architectural impact of this.

Our solution to rectify the lack of understanding was a combination of experimentation as part of a migration:

- exploration and documentation of scenarios through the migration patterns
- experiments help to clarify cloud architecture and quality options
- experiments help to address business model misconceptions

Experiments help identifying architecture options and the costing of migrated software solutions. The architecture/cost mapping can be summarised as follows in Fig. 4. Components can be scaled, but this has a direct cost for the provider. This can increase the quality and can result in a higher cost for the user, depending on the pricing model used. More demand (for quality services) need to be fed back into a scaling engine to adapt the component and its infrastructure accordingly.

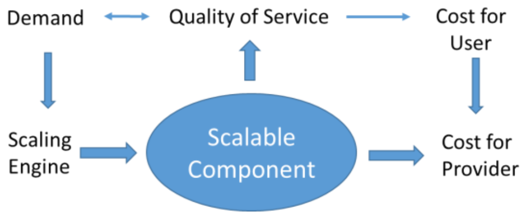

Fig. 4. Architecture-Quality-Cost Dependencies

The use cases have differed only with respect to two concerns: firstly, data protection requirements, which are stronger in the banking, insurance and financial services industry due to legal constraints. There are also legal constraints in the food section. These result in traceabilty requirements (answered through monitoring etc.) rather than data location decisions as for financial services.

Going for cloud-native has not been a goal for all use case companies from the outset. Many seek initially a simple cloudification to obtain some crucial cloud benefits quickly, without being aware of or considering the long-term cost perspective. The software solutions under consideration (see Table 3) are all reasonable complex and possible optimisations of their complex architectures would justify the cost for modernisation in the long-term from a software maintenance perspective. In order to properly manage the new revenue streams coming from the cloud-based delivery of the SaaS product against the expenses of development and operation, a cloud-native solution has clear advantages due to better control and more transparency of the actual costs.

The costs for running the software in the cloud (essentially the TCO Total Cost of Ownershop) can be predicted through experimentation with prototypical migration of central components. Based on this TCO estimation, a guide exist to analyse the economic viability of the software product in conjunction with the development of suitable payment models for the software product in question, be that pay-per-use, pay-per-user or another licence-oriented payment model for the end user.

6 Related Work

Cloud migration methodologies exist – see [2,20] for an overview of academic research. In industry, many consultants and service providers also offer support. For IaaS migration, with the existence of VM packaging standards such as OVF, some simplifying mechanisms exist that allow virtualised software to be easily migrated into and between clouds. Case studies do exist here, such as Li et al.'s coverage e of a partial migration [16]. For the SaaS space, many service providers offer tool support, e.g., data loaders that exist for instance for many products in the CRM space.

Less clear is the solution in the platform (PaaS) space. Here, general strategies for software evolution and re-engineering apply [11]. Methodologies and tool support are provided to determine the impact of changes, refactor code and analyse the semantic equivalence to software before and after evolution.

Specific to the cloud is Son's proposal for service selection [3] that takes resource efficiency into account, i.e., already considers a mix of performance and cost concerns. Gilia [13] also addresses service selection in this context. However, as Arshad et al. [5] and also Al-Roomi et al. [9] note, more attention needs to be paid to costing/pricing models for cloud services. Wang et al. [14] also look at pricing strategies for companies to operate a sustainable business model in the cloud. Xiong et al. [7] have made this interlinkage clear in their investigation of performance and cost trade-offs.

Menychtas et al. [12] suggest a model-driven approach to migration on-premise software to SaaS, but none of these specifically target cloud-native architectures at the PaaS level as we have done here. We have also used case studies to empirically support the value of cloud-nativeness in the cloud migration process. While we have considered SMEs in general, Giardino et al. [15] have also noted the difficulties that many companies, in their case start-ups, caused by technological uncertainty arising from new technology environments.

7 Conclusions

Independent software vendors (ISVs) are a specific group of cloud users that require a deeper understanding of architecture and cost concerns. In the cloud, an IaaS or PaaS deployed software product is made available as a SaaS solution to their customers. Particularly, for SMEs without cloud experience this knowledge does often not exist. For ISVs, the re-engineering of their software product for the cloud has turned out a critical aspect. Two important aspects here are:

- Cloud-native: More than for many in-house used cloud migrations, there is a need to componentise the product properly and implement this as far as possible as a cloud-native solution to enable an effective SaaS provisioning.
- Cost model: Cloud-native architecture allows to better control the costs for the provided software and align this with the charging and billing model for their product.

While cloud-nativeness is at the core an architectural concern, the fact that cloud-native makes cloud-based software more predictable in terms of licensing costs and also costs for scalability makes the link to cost an absolutely crucial one. Our solution towards cloud-natives is a structured migration process with two core components:

- A pattern-based approach to determine and analyse migration plans
- Early-stage experimentation as a means to address quality and cost considerations

The mapping between costs for developing and operating software in the cloud and income generated from providing the same software to customers through the cloud remains still a major challenge. Through experimentation with selected components, costs can be estimated in relation to varying demands and targeted quality of service.

What we have demonstrated through the use cases is the usefulness of cloud-native architectures for both quality considerations as well as cost calculation and management. However, due to the widely varying charging mechanisms, the development of a generic model remains an open challenge that we aim to address in the future.

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