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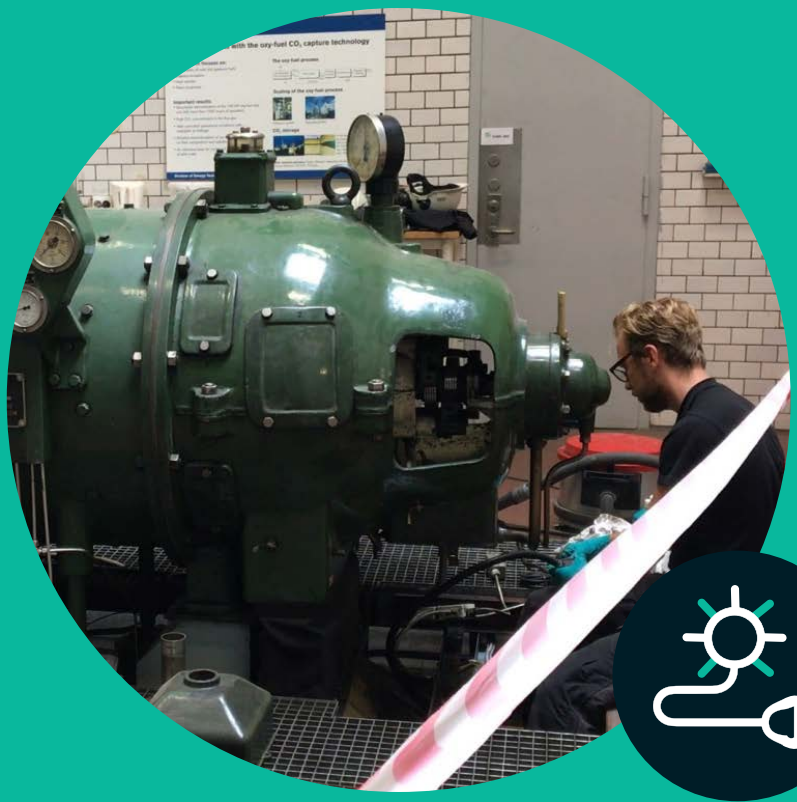
URBAN INNOVATIVE ACTIONS

The Urban Lab of Europe !

The FED project
Journal N° 4

*Project led by the **City of Gothenburg***



ENERGY TRANSITION

European Union
European Regional Development Fund

Région Hauts-de-France

The FED project

With this project, the city of Gothenburg aims to develop, demonstrate and replicate a novel district level energy system, integrating electric power, as well as heating and cooling. This solution embraces and enhances the use of technologies such as PVs, heat-pumps and energy storage into a larger system. To overcome the main challenges, the proposed solution contains advancements in system development and operation, business logistics, legal framework as well as stakeholders' acceptance.

The FED solution consists of three cornerstones:

FED demonstrator area – the selected demonstration is located at a campus with about 15 000 end-users. It has a well-balanced set of property owners, energy infrastructure, and users, including prosumers as well as buildings with different needs and usage profiles. The area is exempted from the law of concession for electricity distribution, providing the opportunity to test and validate a local energy market. The prerequisites to optimize the use of primary and secondary energy using intermediate storage are well developed, as they are for generation, storage and distribution.

FED system solution – our solution will optimise the use of low-grade energy to replace primary energy. Adding fossil-free energy sources while optimising different buildings usage profiles; one building's energy needs will be balanced with the surplus of another. Intermediate storage, fundamental to be a success, consists of heating storage in the building's structure, an innovative cooling storage using phase changing material and batteries for electricity. An ICT service will host the local market and provide the connection to the outside world of spot prices and weather forecasts. The smart agents connect and trade within the system that provides the flexibility to support future volatile energy markets

FED business solution – create new sustainable markets. The success of FED depends on cooperation and energy exchange between several stakeholders. To make it happen, a local energy market creating business value for each stakeholder will be developed.

Partnership:

- Göteborg Stad- City of Gothenburg
- Johanneberg Science Park AB
- Göteborg Energi AB
- Business Region Göteborg AB
- Chalmersfastigheter AB
- Akademiska hus AB
- Chalmers University of Technology
- RISE
- Ericsson AB

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1. Executive Summary

This fourth Journal on the FED project in Gothenburg is based on a visit to the Johanneberg campus in February 2019. Spirits were high as the FED system has been operational since early January and the project has started its last year of implementation in very good shape. Johanneberg Science Park released a special video on the system: https://youtu.be/O_I4jXdPryM.

There have been some delays, most prominently in the installation of the new 6500 kW steam boiler, which is paradoxically, one of the more conventional production units in the system. On the other end of the novelty spectrum is the PCM (Phase Change Material) storage that is delayed slightly because the new building it will serve is still under construction. Of course, a mitigation method has been found.

Another example of just how advanced the FED system is, is that it was hard to order the equipment to actively manage the load production of PV systems. This really shows how fast developments are going in the energy sector.

These are examples of technical challenges that are really not uncommon in integrated projects like the FED, in fact I have been surprised by the short list. I have described the sound management structure in earlier journals.

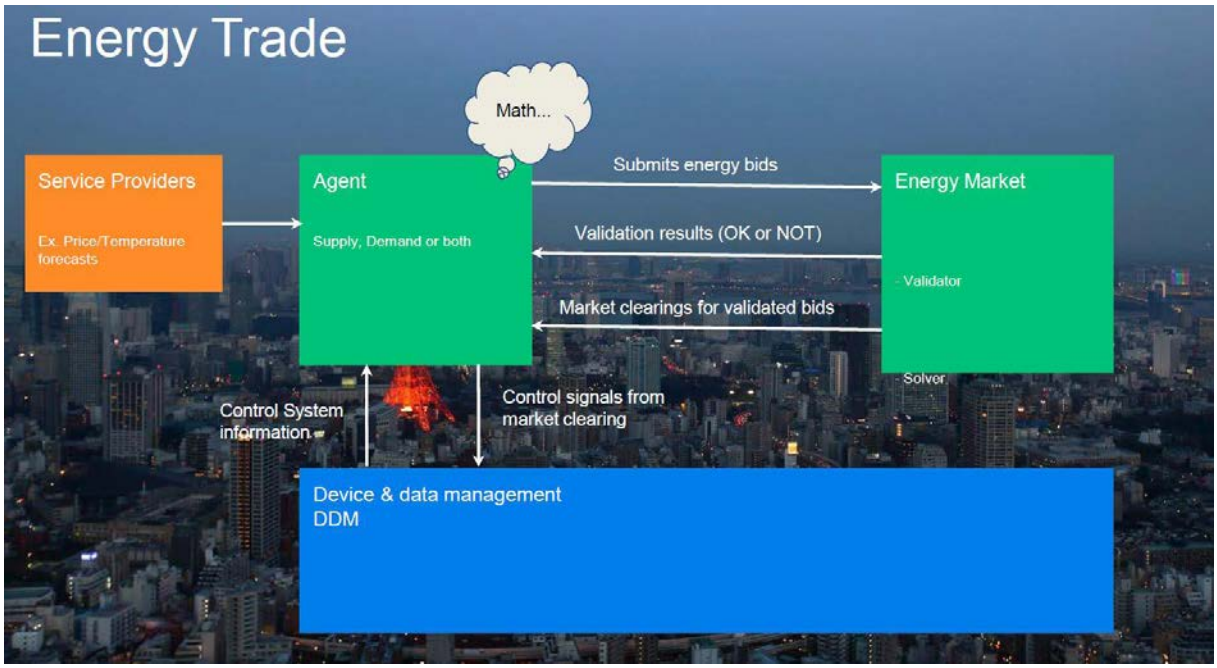
In our discussions in February the topics quickly moved to upscaling, European interest and the various approaches available. Denmark and the Netherlands appear to be the first countries to test the waters. Financial sustainability and upscaling are two topics that have been among the identified challenges by the UIA and will receive much attention in 2019.

2. Project implementation update

Where does the FED stand March 2019?

The implementation phase of the project is approaching the end and the system runs. Most investment and commissioning projects (power plant, solar cells, energy storages, heat pumps) have been completed. The digital connections via control systems, smart agents and IoT platform indeed enabled the FED system including market place to start on January 9, 2019. It has not stopped since.

Ericsson has provided the following picture to illustrate the trade that takes place, continuously, in the FED system:



Legend The energy trade system in the FED

To build our understanding of this, this chapter describes the three components of the market system that came together in the second half of 2018. The market part is ultimately programmed/ developed by Ericsson, but needs supply & demand via Chalmersfastigheter and Akademiska Hus, not to forget Goteborg Energi. All have been supported by technical consultant Bengt Dahlgren. We will learn that some hardware will be installed a little later, but before summer, so that full advantage will be taken from the sun. After all, July 2018 was the hottest since 1756 when measuring begun[1].

[1] https://www.thelocal.se/20180731/sweden-had-its-hottest-ever-july-breaking-several-weather-records

Summary of the system

The system can be seen in three components:

1. **The FED Marketsystem**
   The FED market system enables trading of energy and energy related services by AI Agents, running autonomously and continuously 24/7.

2. **The Ericsson IoT Accelerator**
   The Ericsson IoT Accelerator is a cloud based horizontal cross-industry offering comprising of platform services and professional services, for service providers and industry.

3. **Physical infrastructure**
   FED allows for the connection of a multitude of infrastructure and facilities, including buildings, power plants and power grids.

Chalmers Power Central (KC)

Chalmers Power Central (KC) is – of course – a complex process facility. The productions units themselves require knowledge and a full understanding of the limitations and interdependence between different operation modes, use of boilers, district heating, heating and cooling pumps, etc. The integration of the facility in the FED system and allowing for external control required close co-operation between facility owner and FED system developer and operator.

For the FED system to work there must be an efficient two-way communication between the facilities and the market system. This has put some added requirements to update and adapt the facility owners' systems. The last category is in one way the most complex, these are the functions that have been developed and added to the existing or new control systems for the FED system. These include functions that are not required for normal facility control and monitoring.

A new data server, development of new functionality and services for both existing and new building control systems, the major update of the control system for the Power centre as well as replacing and/or completing meters are examples of the work accomplished over the last half year. Additionally, a simplified system for utilizing energy storage in buildings has been developed and implemented.

At the moment of writing (March 2019), there are 9 different types of agents described with 4 new types to be added soon. There is a total of 31 agents and the market solver has approximately 500 cleared bids per hour (Including final and projected bids).

Sketch of products and services in the FED market

Work regarding FED control system and hardware has been led by Akademiska Hus with parts of work led by Chalmersfastigheter. The FED local energy market and trading system has been developed by Goteborg Energi and Ericsson in particular with regards to coordination and integration to the FED local energy market and trading system. The work regarding connectivity between facility control system and FED market system has been a collaboration involving all partners related to the issue.

PV-systems, electricity and batteries

For the three existing PV installations there have been no added functions for the control and monitoring. The measurement data from the energy meters is just uploaded to the FED market system. For five of the seven new PV installations the control system have been updated to allow for control of active and reactive power from the panels.

An important experience from this project is that the industry is not used to requirements to be able to control active and reactive power in PV and this has led to an added workload and development work to reach a solution. It is likely that in the future these types of requirements will be more common and require less work to implement.

Other electricity is produced within the FED system by the steam turbine at KC and by PV panels. Additional electricity is provided from the municipal electric grid owned by Göteborg Energi. As discussed, the steam turbine is located at KC and is connected to the new steam boiler (P2). The turbine itself has been fully renovated and updated to allow for automatic control of delivered power.

Heat storage in buildings

Energy storage in buildings means that the thermal mass in the building structure is used to store heating and cooling energy. This type of storage thereby provides flexibility to the FED market system. For efficient use it is important that the future heating / cooling load can be estimated with sufficient precision and that the corresponding technical system for heating and/or cooling can be controlled. The stored energy in the buildings allows reduced power to the heating/cooling systems in a building and can thereby reduce peak loads.

Seven buildings on campus have an advanced building control system (EVi) installed. This system uses measured data from the building to learn how to optimize the set point and flows in the technical systems to reduce energy use. This system in FED has had further functions added to it to allow for calculating and delivering prognosis for heating, cooling and electric energy. The simplified versions in four buildings use the existing installations and control the hydronic heating system but not the ventilation system heating.

Cooling and cooling storage

There are two cooling storages included as part of FED. The PCM storage control system is developed as part of a new building (AWL). The FED project includes coordination with that project and work to integrate and implement additional functions in order to calculate prognosis of cooling requirements, status for storage and added functions for starting / stopping FED operation. Since the new building is not finished and in full operation, the PCM storage will need to operate with a simulated cooling load representing the future building. This has required additional work and functions to be added to the control system and interface.

The connections between different distribution grids have in this case been well prepared and allowed for simple integration. When replicating or scaling up the FED system, it should be

Woodchips for the boilers producing heat and electricity

expected that grid integration can be problematic or more technically difficult. Difference in system pressure, fluid composition, temperature levels and so on means that it may be difficult to allow for full integration of distribution grids. Heat exchangers may be used to separate two grids and solve the above issues (at least partially). However, any heat exchangers would imply a loss in terms of temperature and will thereby reduce the overall system efficiency for energy transfer.

Heat in the FED system

Heat production for the FED system will consist of 2 boilers, heating from the 6 VKA units (heating and cooling pumps) and heat recovery from cooling units. The boilers (6000kW and 6500 kW) function both as research facilities and as production units for the campus heating system. The second boiler is delayed a bit but is a new boiler that produces steam. The steam will be used to produce electricity through the refurbished steam turbine. Depending on operating mode the new boiler can obviously also produce 100 % heating and no electricity. This boiler is a major new investment that adds to the overall capacity for the KC, both heating and electric energy. Furthermore, three VKA-units produce heat and cooling on demand and the cooling system in MC2 consists of 6 chillers and the heat from the condensers is recovered and used to heat the building.

System overview

Notes to Figure 3:

1. *Solar PV Modules*
2. *Boiler 1*
3. *Absorption Chillers, KC producing cooling*
4. *Heating and Cooling Pumps producing heating and cooling*
5. *Chiller system.*
6. *District heating connection from public network*
7. *Electric power connection from public network*
8. *Battery Storage, AWL*
9. *Heating and cooling pump*
10. *Steam Boiler 2 and Steam Turbine*
11. *Quick-Charging Battery storage*
12. *PCM Cooling Storage, AWL*
13. *Cooling storage tank*

3. Upscaling and financial viability

The infrastructure and control required for connecting all facilities included in FED and allowing for local market energy trading are fully operative. This consists of the distribution networks for heating, cooling and electric energy that are part of FED and the hardware that is connected to these. Connections to municipal grids are also included in this. Unfortunately, this does not mean that from today every city in Europe will implement the FED system. In fact, upscaling and financial viability are of enormous relevance and will need to get a lot of attention.

Introduction

The mission of the UIA is to support the Urban Agenda in a way in which it UIA gives urban authorities the opportunity to unlock their potential and test new ideas and solutions fostering a genuine bottom-up approach. It aims to see the knowledge generated by cities involved in UIA being made available to practitioners and policy makers in Europe and beyond.

Upscaling and financial viability will receive extra focus in 2019 with this chapter and then the zoom in after workshops in the Netherlands and Denmark. The other challenges are being discussed in the next chapter.

The original ambitions were:

- Initiation to implement successful solutions from the microgrid in large-scale refurbishment and new city districts in Gothenburg
- Map the European market relevant for local energy solutions
- Become a demonstration site for smart microgrids
- Present the FED-solution to at least 50 European cities
- At least 100 external delegation visits and displays at least three large conferences

Approximately 40 properties of the Campus area are included in the FED and the financial transactions for the different energy carriers can be measured. Within the area's clear boundaries, it is well suited with a test arena for the local energy supply of the future. The conclusions can thus be useful for cities in the EU that want to develop into a fossil-free society. Having said that, the district had a simple ownership structure and an exempt from the energy regulation that will not be so easily replicated. Some more comments on that in this video that was shot at the Kick-off Celsius Initiative meeting in Brussels: https://youtu.be/XthcpvL7-V0

When looking for upscaling opportunities, call always come for due diligence. Due to the system nature of the FED, the process will have to start in different fields:

- Financial due diligence
- Legal due diligence, including regulations
- Due diligence taxes
- Technical due diligence

Icon of the project, the refurbished steam to electricity unit

Building knowledge for Europe

JSP already reports that it receives great attention nationally and internationally, in the relevant circles for the FED project. It is proud of the many delegations who come to visit the campus Johanneberg and who will learn how a FED system can be part of the European energy transition.

It is still too early to write about the result of the marketplace. However, one result of the FED-project is already achieved and this result is even better than expected: FED has already contributed to the start of two large H2020 projects, one ERA-NET project, a Climate-KIC project and several projects with national or regional funding. With FED, Johanneberg Science Park and its partners create an urban lab on sustainable local energy systems.

All these projects are connected in one way or another with the testbed of campus Johanneberg. Start-ups, established SMEs and larger companies are also invited to develop and demo their solutions together with the ecosystem. Five innovative solutions with SMEs are decided to be implemented in the campus area with relation to FED, which has – of course – also been presented in many national and international forums sharing the idea of a fossil-free energy system and ways to make this work.

List of projects:

- IRIS is a H2020 Smart Cities Lighthouse project with Utrecht, Nice and Gothenburg. Demos in Gothenburg on renewables and smart energy systems relates to FED. One of the IRIS demo with energy storages will also be a market participant in FED.
- UNITED GRID is a H2020 project lead by Chalmers together with partners in Sweden, the Netherlands and France. This research project will use the infrastructure from FED for smart grid demos.

- Swedish Energy Agency – A challenge from Sweden. A national initiative to help more solutions to the market. Collaboration to define needs and to help start-ups to verify their solution together with FED.
- UIA project on energy transition in Paris and Viladecans – workshop in Brussels to share knowledge, plan for more meetings in each city.
- Celsius Initiative is a project funded by Climate KIC and Swedish Energy Agency lead by JSP. The aim is to share knowledge to cities on renewable district heating and cooling. One part of the project is a think tank based on FED.

Cities

The importance of cities to create driving forces for change is growing in the world and in Europe. Urbanization is continuing at an increasing rate, and many cities are making powerful changes in many areas, such as digitalization, reduced climate impact, learning, etc. In many cases, cities are more vigorously engaged in development than states and countries. There is talk about the Smart city where robots roll by on the sidewalks, self-driving cars on the streets, homes that monitor data from humidity to energy optimization through sensors. In order to replicate FED and create economic driving forces, cities are an important tool for the EU. There are a lot of different financing schemes and programmes from mostly EU where cities can apply for funds for e. g Local Energy Cities. The city also is good as a system boundary and fits with the energy concession area in many cities.

Given the right conditions, the consortium sees mainly six potential investors in the replication of FED. These are the national countries, regions, local cities, companies in the energy sector, property owners or capital from professional investors like pension funds, infrastructure funds, venture capital funds, etc. More on that in the next Journal.

Financial viability

With the FED system running since January 2019, this Journal comes too early to say anything on the financial merits. It is reported that FED, in its current form, must be verified economically and technically from actual outcome after a runtime of at least six months. Only then it will be plausible to evaluate the economic benefit and to set the level of incentives that is needed to attract investors to invest when replication in Europe is at hand. Work on that will be done by Ericsson, Göteborg Energi, Chalmers and Rise.

When assessing the economic profitability of the various investments in FED, they will be viewed from three different perspectives:

- The FED area as a whole, actual outcome. The actual outcome of the approximately 10,000 transactions is assessed based on the various investments made and simultaneously some of the measured KPIs are translated into financial terms.
- FED area as a whole based on simulations. The simulation model in WP4 is used based on different investment perspectives and assessments how they affect the financial outcome.
- The potential economic interests of the respective stakeholders from a canvas

perspective and through the workshops carried out

It is important to stress that the investments in the FED system are much more about the system itself then the actual energy production or storage capacity. This makes sense because any future-proof system must be able to cope with changes and additions to itself, hence the costs of the particular artifact are not relevant. What is relevant of course, will be the efficiency of the new marketplace and that can be seen form a CO2 of financial point of view.

4. Challenges

Given the progress that has been described in the earlier chapters, the challenges framework that were introduced in the beginning of the journals could be adapted for the last 6 months as follows:

Leadership for implementation

Journal 3 has given detailed attention to the leadership role supplied to Johanneberg Science Park by the virtue of being in the middle of the Gothenburg innovation eco-system. The described period here has not seen a change in the role nor in the function of the institute. When looking at upscaling, a challenge can be the amount of effort that should be put into upscaling that is not part of the project. When a project finishes there's not always interest in upscaling actions that are not planned, nor budgeted. It was very good to see that there are already follow up projects being granted and it must also be noted that project partner Gothenburg Business Region is actively promoting its testbed strategy, of which the FED is a part.

Public procurement

Most countries in Europe consider the city as an important director of the energy transition. It is, however, understandably impossible for a city to simply procure a FED system. The testbed at the moment is a collaboration, working very well thanks to an exempt from the electricity law and partners that understand the necessity to cooperate. In 2019 further attention will be put to the role of the city in upscaling.

Public procurement can also be a huge barrier for start-ups or suppliers of novice materials and or solutions. Many of the assets in the FED project however are procured in a normal process, especially by Chalmers Fastigheter and Akademiska Hus. The connecting market, set up by Ericsson, is part of the project itself.

Integrated cross-departmental working

In the FED system, it is possible to add new agents that use a form of energy, or that supply a form of energy. It is also possible to add new services such as storage. Being able to allow different energy carriers, and to allow different types of demand and supply gives the FED a high level of resilience. To achieve this, the boundaries of the system had to be set clearly. The collaborators had to agree and understand what the FED system could do, and what it could not do. To define and program this has been a work between Goteborg Energi, Chalmers Fastigheter and Akademiska Hus. In the light of these challenges, it is a good example of cross-departmental working that simply has to happen to do complex, integrated projects, like the FED. This work has been the most demanding in the discussed period.

Adopting a participative approach

Participation has not been such an issue in the overall project implementation. At system level though, where the collaboration around the agents´ development really must work, where people from at least three different partners need to understand the same thing – that's where extra effort is needed and was supplied indeed. Long-term participation at system level may also be difficult when new suppliers of solutions (or buyers) can make separate deals outside the FED system. Connecting to the FED may give environmental efficiency that do not benefit a producer in such case, however knowledge on that does not exist yet.

Monitoring and evaluation

Since the FED system itself has been up and running since January 9, 2019, it can be monitored for almost a full year, before completion of the project. There are some (PV) facilities that are operational later than expected but since they will still be installed before the summer of 2019 it is expected that their results can be monitored long enough to contribute to an elaborated evaluation.

Financial sustainability

Financial sustainability and scalability are big drivers for the future of the FED application and have been touched upon in this Journal. Workshops in Denmark and the Netherlands are foreseen to build a European expert view upon the possibilities.

Communicating with target beneficiaries.

As discussed earlier, Johanneberg Science Park is well positioned to take care of the systems promotion. However, certain Scandinavian energy-mix characteristics (like a low CO2 profile on heat and electricity) will have to be translated to other national situations, or energy mixes, to disseminate some of the results.

5. Learning points and next steps

It seems that the largest learning point of establishing this world-first unique marketplace is that it can actually be done. That Gothenburg has realized the first system trading heat, cooling, electricity and services, such as storage in one marketplace. The FED marketplace. The system already clears 500 bids per hour with new agents being added as we write.

If you look carefully, you can also already see the project's biggest challenge. The upscaling of its solutions. For a municipality or a local utility like Goteborg Energi is not natural to look for upscaling potential, elsewhere in Europe. Upscaling within the own boundaries seems natural, but will depend on a flexibility in the energy laws that does not exist at the moment. The hardware providers of various elements of the model have their own business models so the question can be asked: "who is the sales manager of the FED?" This is a common problem with integrated projects and in particular viable when smart-gird solutions need to find their way into Europe.

One small disclaimer must be that the analysis of the results of the new marketplace are not available at the time of writing. Ultimately, these results will have tremendous influence on the desirability of upscaling for different stakeholders.

The next steps are about upscaling and learning what other locations and countries desire. Drivers can be:

- technical + infrastructure
- economical + market
- social
- financial
- legal + regulative

Sandra Greven, a student from the Technological University of Eindhoven, is involved in the development of the outreach. This will obviously get a lot of attention in the final year of the project with workshops already planned in Delft, the Netherlands and Aalborg, in Denmark.

Urban Innovative Actions (UIA) is an Initiative of the European Union that provides urban areas throughout Europe with resources to test new and unproven solutions to address urban challenges. Based on article 8 of ERDF, the Initiative has a total ERDF budget of EUR 372 million for 2014-2020.

UIA projects will produce a wealth of knowledge stemming from the implementation of the innovative solutions for sustainable urban development that are of interest for city practitioners and stakeholders across the EU. This journal is a paper written by a UIA Expert that captures and disseminates the lessons learnt from the project implementation and the good practices identified. The journals will be structured around the main challenges of implementation identified and faced at local level by UIA projects. They will be published on a regular basis on the UIA website.

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