March 2019

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The Urban Lab of Europe !

The Urban infra revolution project Journal N° 2

*Project led by the **City of Lappeenranta***

CIRCULAR ECONOMY

European Union
European Regional Development Fund

Région Hauts-de-France

The Urban infra revolution project

Urban infra revolution will test new solutions to reduce CO_2-emissions in urban construction development. Sidestreams from industry (ashes, green liquor dregs, tailings, construction waste) will be utilized in urban construction by combining them into a high-value material to replace concrete. Novel material formulas will be created containing suitable side streams to be used as geopolymer binder (replacing cement) and as inorganic aggregates in geocomposites. An innovative bio-fibre reinforced geo-composites will be developed to achieve the high standards of construction industry. Automated, on-site, fast and versatile additive manufacturing construction system, without molds, will be tested in comprehensive urban scale. The material and the piloted technology will be multifunctional and enable aesthetic design with revolutionary shapes with very low CO_2 emissions. Selected pilot structures will be manufactured within the urban infra and their properties are tested in real climate conditions. To implement and finally benefit locally the project results, a viable sustainable business ecosystem will be designed and environmental and socioeconomic impacts assessed.

Partnership

- City of Lappeenranta
- Apila Group
- UPM Kymmene
- Lappeenranta University of Technology
- Fimatec
- Outotec
- Imatra Region Development Company Ltd.
- Nordkalk
- Design Reform
- Metsä Group
- Saimaan ammattikorkeakoulu
- Total Design
- Stora Enso Oyj

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1. Executive summary

The second edition of Journal describes and analyses the progress of the Urban infra revolution project in the last six months, from October 2018 to March 2019. During this period the progress of the main tasks for the project is in line with project schedule.

The second section is a short information about the current project. Additionally it also reminds the most important information about the project and their goals in the context of activities for sustainable development that Lappeenranta has undertaken.

The next section provides an update about the project status, especially in the area of development of technical solutions. It is dedicated to innovative aspects in the project, especially to three main innovative area: material, production process and products. It gives the necessary information about the previous steps and gives the information about current technological challenges. It is worth to stress that the project has highly innovative nature and introduce the technological process that have not been implemented before. It defines new standards and because of that requires an intensive scientific research. In this part, there are also described the difficulties, barriers and challenges linked to the innovative nature of the projects.

The next part of the Journal presents implementation status of the project. The project started in November 2017. During the first year, the significant progress in technological aspects has been achieved. In the same time, the management structure has been established and the first steps into project dissemination and results explanation has been made. This section presents the activities that are undertaken for creating the right conditions and lowering the barriers in the particular project area such as: leadership for implementation, public procurement, integrated cross-departmental working, adopting a participative approach, monitoring and evaluation, communicating with target beneficiaries, upscaling and others. This part is strictly connected with next chapter ‘lesson learned’.

The last section is summarizing the state of the project, with a short presentation of the steps that will be provided in the nearest future. The main conclusion is that the project is very well on track and delivers results, despite some delays. It is also worth to stress that some activities has been done to ensure the sustainability of the project after the UIA funding ends.

2. Introduction

As outlined in the previous Journal, the Urban infra revolution is a high innovative urban development project that conjugates three major innovative aspects: materials, process and product. The expected result of the project is to design new materials for additive manufacturing, composite with tailored properties that are in the same time environmentally friendly and cost effective. This composites should: close the loop of construction material, be applicable for extreme (arctic) weather conditions, be reinforced with bio-fibres and be based on local industry wastes.

Over the past months, project partners have been busy with developing the different ingredients of the future system. The main efforts was dedicated to material development – composite for construction industry with reduced life cycle costs. As a results of the project more than 20 raw materials (ashes, green liquor dregs, tailings, construction waste) has been carefully investigated. Based on this, the composites based on geopolymer matrix with fibre reinforcement has been designed. The most promising matrix materials are side streams form mining industry (limestone and rock salt) and fly ashes form bio-mass combustion (fly ashes), including paper manufacturing. It is particularly important because Finland is one of the leading countries in the world in micro- and nano-scale cellulose composites. As the reinforcement to composites are applied bio-fibers. The innovation itself is potentially the first manufacturing method demonstrating fully closed loop construction: on-site built, local waste based and fully recyclable construction materials.

Most importantly, the Urban infra revolution project has also succeeded in developing the additive manufacturing technology (AM). The first step of works in this area should be finished in June 2019. The second challenge will be implementing the new materials for this process, including the reinforcement by bio-fibres. The next challenge will be process stabilization, ensuring that it will be performant and replicable.

One of the project task is also the development of the awareness of the society connected with the needs of turning the local economy into a circular economy. The need of developing new eco-friendly materials, technology and products is a result for planned outcomes. It is worth to remind that outcomes ofr the project contribute directly to the ambitious goal on carbon free and waste free cities by reducing the amount of unutilised waste from local industries and lowering CO_2 emissions. The project aims are holistic solutions for developing climate change adaptation and mitigation that enhance the storage of carbon in process of raw material sourcing, manufacturing, transportation, installation and assembly. The project allows to introduce the circular economy through 3D printable and recyclable geopolymer composites made by side-streams, including significantly reducing CO_2 emissions.

3. Project update

3.1 Material development

Till the beginning of the project, a lot of works has been done, especially in the area of material development (Figure 1). The next challenge is connected with preparing the techniques applied for manufacturing the novel composites. It is worth to remind that the project put its emphasis on new products, through a functionalized approach that will bring strong societal and environmental impacts, including energy efficiency, reduction of carbon footprint, waste reduction and the development of the idea of circular economy through their application into practice.

Team members in laboratory – works on material recipes

The project approach is based on a highly innovative solution, which combines material innovation and modern manufacturing technologies, such as additive manufacturing (AM). The production should be close to the building site, use local raw materials and close the material loop in order to diminish the CO_2 emissions of urban building and enhance zero waste arctic cities.

However, the first step of the project's works on composites has been successfully finished, while there are still some delays connected with the works on technology. After the finishing technology development there will be some additional trials in material required. The main risk in this stage is connected with implementation new material into additive technology. However the consortium is prepared for this challenge, it is still some risk that performance of the technology do not meet the expectations/demands.

The one of the potential technical problem is small amount of research connected with durability, especially long-term durability data, for composites based on geopolymer matrix. Because of that some additional research should be implemented into the project after the final technology performance. The other limitation for wide use geopolymers is also a common problem with efflorescence caused by excess sodium oxide remaining unreacted in materials. Geopolymers are created by reaction between alkaline solutions and solid aluminiosilicates. The activation process required high pH. In some cases unreacted sodium oxide create white efflorescence on the surface – it is sodium carbonate heptahydrate $Na_2CO_3 \cdot 7H_2O$. It could be a large problem, because it decrease not only aesthetic value for the final products, but also

mechanical properties of the material. However, the proper design of manufacturing process could eliminate this barrier. Nevertheless, additional tests for final material should be performed.

The potential barrier is also using as a raw materials the wastes that came from industrial processes. It could be not only technological problem connected with changes of raw material in case of their production form wastes, but also some potential problems with society awareness. The technological solution in this case is quite simple, usually the process required the introduction of additional quality procedures and temporary repetitiveness leaching tests. The idea of using side streams in central city constructions may awake concerns about health and safety and environmental safety in public. This presumable resistance is overcome by the dialogue with authorities and by creating transparent product acceptance procedure for the product including the physical and chemical properties of the material.

3.2 Process development

Nowadays, the most important technical challenge for the Urban infra revolution project is the development of the AM technology that will be suitable for innovative composites. This step should be finalized till June 2019. It is worth to mention that currently AM is a rapidly developing industrial sector and, potentially, a disruptive technology. AM technology is an answer for new challenges such as resources saving and energy effectiveness. Unfortunately, the full exploitation of 3D AM processes is currently limited due to the in-process and in-service performance of the available materials' sets, especially in application in construction industry: '*While 3D printing techniques have been successfully applied in a wide range of industries such as aerospace and automotive, its application in concrete construction industry is still in its infancy*[1]'. Currently, only some prototype solution in the area of geopolymers material were designed in Australia, China and Russia[2]. They are based mainly for powder-based technology and have a lot of limitations. The limitations are mainly connected with used materials. The further development of this technology required improvements to design new materials, to assess materials performance and to improve processing strategies. The current state-of-art in this area is presented in Table 1.

[1] Nematollahi B. et all., 2017, *Current Progress of 3D Concrete Printing Technologies*, 34th International Symposium on Automation and Robotics in Construction (ISARC 2017), 8.

[2] Xia M. and Sanjayan J., 2016, *Method of formulating geopolymer for 3D printing for construction applications,* Materials and Design, 110, 382–390.

Table 1. The state-of-art for AM technologies, including the Urban infra revolution project.

Country	Existing technology	Main limitation	Source of information
Russia	AM technology - 3 D printing for geopolymers is developed by RENCA company. The company has working prototype. It was tested in relevant environment.	The technology is presented as working solutions, but according to the information presented by the RENCA company on the conference in France (2018). The technology is not stable and required mixing manually. Recipes are individually created for each customer.	https://youtu.be/pKekH5beIZU https://youtu.be/hXdE8ozDfhg www.geobeton.ru, www.apis-cor.com, http://renca.org/ Information presented by RENCA on GEOCAMP 2018
China	- Printing mainly from powder. - Printing based on long steel fiber. - Addition short fiber glass.	Some information about theoretical concept and information about laboratory prototype.	Lim J.H., Panda B., Pham Q.-C., 2018, Improving flexural characteristics of 3D printed geopolymer composite with in-process steel cable reinforcement, Constr. & Building Mat. 178, 32-41. Panda B., Tan M.J., 2018, Experimental study on mix proportion and fresh properties of fly ash based geopolymer for 3D concrete printing, Ceramics International, 44, 10258-10265.
Italy	The project WASP declared development 3D technology form different materials.	There is lack of detailed information about geopolymers.	www.wasproject.it
Australia	Swinburne University in Melbourne work on the technology. Laboratory prototype have been done.	Lack of information about possible applications.	https://www.youtube.com/watch?v=6v8sYuJdRqw
Singapore	Cooperation in consortium. Laboratory prototype have been done.	Lack of information about possible applications.	https://www.youtube.com/watch?v=1ZyMd8CaONQ
Belgium	KULeuven created the group called SREMat. The prototype has not been created yet.	The group starts his work in 2018.	https://www.mtm.kuleuven.be/Onderzoek/sremat
Finland	Project financed by UIA. The prototype has not been created yet.	It starts in November 2017	https://www.uia-initiative.eu/en/city/lappeenranta

Development of 3D printers for ceramics, including geopolymer composites in challenging task. It is required technical knowledge from many areas. The main challenges are connected with: proper design of mixing process, optimization a nozzle construction (materials of nozzle, dimensions, potential effectiveness and critical work parameters), an optimization of construction according the thickness of the layers (coherency between materials properties and technical solutions) and modifications according to filling percentage, filling geometry (parameters of the work such as effectiveness of 3D printing). However, the AM technology brings very clear benefits, especially require minimal human involvement in the building/assembly process are a necessity when infrastructure are situated where environmental conditions are harsh. Because of that is seems to be promising for Finland's climate - arctic weather conditions. The potential technical problem in this case could be limitation connected with temperature. Low temperatures significantly reduce the curing process for geopolymers and in case of temperature below zero it could be impossible to initiate.

The most important challenges that will be undertaken during the next stage of the project is to solve the problems that currently exists for 3D printing technology for ceramic materials, including increasing the durability, 3D printing in low temperature, using changeable materials during the 3D printing process and process control – increasing the quality of final products.

3.3 Product development

The project's main implementation will be new innovative products and new industrial scale technology that enhance the local industry business and accelerate the employment possibilities in circular economy. The first step to design planned products has been undertaken. The project incorporates urban design, as the gained exquisite process of structures allows novel functionality with more flexible, unique design in infrastructure. Using the 3D modelling some possible models for further application has been designed.

The first activity regarding the choice of the products (and the area of application new technology), strongly engaged local community. The first step has been undertaken in April 2018, when the competition called New City Products, has been organized. People could suggest what kind of urban products will be built as pilot products using the new technology. In May 2018, the Jury selected 5, best ideas for the final, out of the 15 applications received. The finalists were Skateboard parc, Hugging statue, Welcome to Saimaa sculpture, Saimaa seal sculpture and scale model series about "Vyborg through history" (Figure 2.).

Possible application for the project results – material and technology
Source: UIA website

The finalists were invited to the workshop, where ideas were introduced more detailed to designers, who made illustrations of the ideas to be presented in public voting. In June 2018, there was an online public voting and the winning project has been skateboard parc, with 87% of the votes. The winning idea will be further developed in cooperation with the authors of the idea.

4. Implementation status

4.1 Leadership for implementation

The leadership is fully in line with procedures presented in the grant application. It is provided by the project leader - the city of Lappeenranta and supported by proper bodies such as Steering Committee. The main management bodies has been established according to project schedule.

The leadership and coordination, despite some delays, is well provided. The leadership of the project is strong, on the level of the project as well as on work package level, including day-by-day management. The work packages are strongly interrelated functionally; frequent contacts and briefings makes sure that the leaders are well informed about the progress in each domain.

4.2 Public procurement

Concerning, the public procurment procedures is worth to notice that they were implemented in first stage of the project (first half year). It has been realized in a traditional way, without any problems. The public procurement procedures predicted for the project have been successfully finished. The project do not predict more procedures connected with public procurement.

4.3 Integrated cross-departmental working

The different department engagement initiatives have been, so far, a success in terms of both coordination and impact. The cooperation between the departments goes smoothly and common activities are successfully implemented i.a. the competition called New City Products and common training activities.

4.4 Adopting a participative approach

Going forward, it is beneficial to strengthen the cooperation and innovation capacity of the consortium. The project has a large number of participating organizations from different sectors: 4 SMEs (Apila Group Ltd.; FIMATEC Finnish Intelligent Module Apartments Oy; Design Reform Ltd.; Totaldesign Ltd.), 5 private enterprises (UPM-Kymmene Oyj; Outotec Ltd.; Nordkalk Corporation; Metsäliitto Cooperative; Stora Enso International Oy), 2 higher education and research institutes (Lappeenranta University of Technology; Saimaa University of Applied Sciences) and 1 Region Development Company – Imatra. Participation of the private sector and higher education/knowledge institutes is well developed and key players are partners in the project. There are engagement in different project activities.

The project partners fully understand their role in the project and cooperate amongst each other. Neverthless, a constant work in this area is needed, to successfully implement further tasks in the project.

4.5 Monitoring and evaluation

The evaluation and risk management system is really important for the large projects like the Urban infra revolution. In this respect, the city of Lappeenranta has implemented an indicators-based system to monitor and measure project performance. The system is based on the indicators from the grant application. They monitor the indicators periodically and update the data. Wherever possible, indicators are consolidated and benchmarked against best practice standards.

4.6 Communicating with target beneficiaries

The communication campaign is well coordinated and it has proved to be successful. The planned goals are achieved. The administration will facilitate citizens relationship with and different project aspects, as well as the overall coordination. However, in this case a constant effort is required.

In the next period, it is essential to communicate effective messages about the results and outcomes of the project, including potential added values. The challenges are related to the proper target area and groups. It is a key challenge to highlight and showcase good practices, to show that collaboration gives real returns in the area of innovation. This is a matter of visualising successes and present the prototype solution.

4.7 Upscaling

Upscaling will be a challenge in local and regional level as well as in the area of transfer the knowlage to large scale. The current focus should be on the full delivery of the project and on the performance of a fully working new system's prototype. After that, the key aspect will be the communication of early success stories. The most important challenge, in the application of geopolymers, is legislation. The solution represents new construction materials which existing product standardization and regulations cannot be directly applied. A main barrier is the lack of proper regulations and standards in Finland. The practical applications of final products required additional tests for materials and products as well as preparing appropriate products acceptance procedure. Moreover, revolutionary materials and construction designs may also face lack of trust from the regulated, conservative construction industry.

Another problem is scaling up the solution to the national or international level. Because of project specify (using the local resources), the technology will require some changes to adapt it to the local streams of waste products and its use as a raw material. Another issue is highlighting the importance of running a scenario analysis on the legal and administrative aspects during the new products implementation in foreign countries.

TABLE 1: MAPPING URBAN INFRA REVOLUTION AGAINST THE ESTABLISHED UIA CHALLENGES

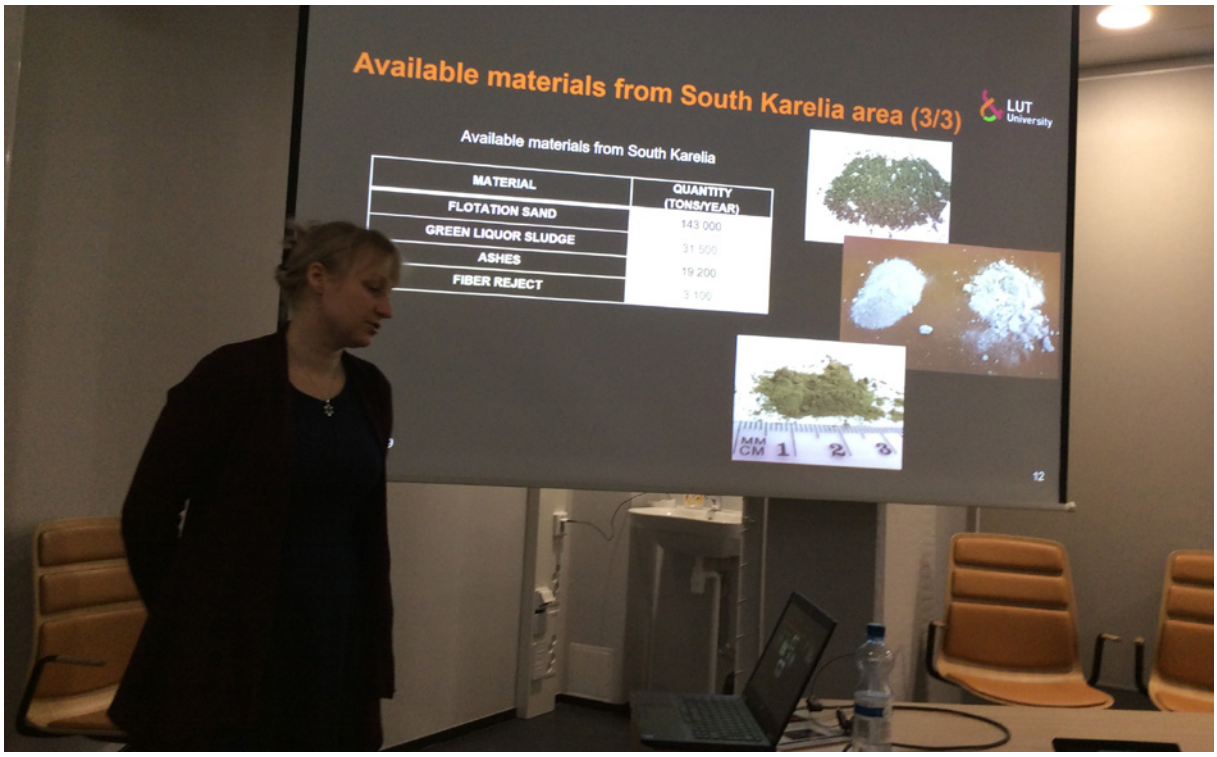
Challenge	Level	Observations
1. Leadership for implementation	Low	The leadership is clear, consistent, accepted by all partners, and it delivers results. The project leader is the city of Lappeenranta. An important elements in the consortium is also communication. The communication based on both traditional and modern ways of communication (via Internet and files on common server). The good communication is ensured by the consortium leader. All project partners participate in the decision making process. The management of the project is performed in a way to ensure active role of each of the partner.
2. Public procurement	Low	The public procurement procedures predicted for the project have been successfully finished. The procurement procedure was traditional; no specifically innovative types of procurement are applied in this case.
3. Integrated cross-departmental working	Low	The actions delivered by other departments are on time. The cross-departmental work is smooth. The city of Lappeenranta has established good working relationships with a number of other departments in the framework of the project. The previously mentioned organization of the competition called New City Products is a great example for excellent cooperation between different departments.
4. Adopting a participative approach	Low	The consortium is characterized by effective coordination mechanisms. The participative approach should be done in parallel with effective management and as thoroughly as the engagement and communication planning.
5. Monitoring and evaluation	Medium	According the previously planned schedule there are some slight delays in the project, but there is crucial element that will be continued during the project and, because of that, it needs more time to be successfully finished. Anyway, the city of Lappeenranta, as the project leader, has succeeded in delivering a robust (qualitative and quantitative) indicators-based monitoring and evaluation methodology as well as a risk management plan.

Challenge	Level	Observations
6. Communicating with target beneficiaries	Medium	The communication with target beneficiaries is a great challenge, because each urban investment must be accepted by all inhabitants (local legislation). The communication with target beneficiaries is very important element for successful introduction. In order to achieve this goal, a series of actions were promoted to reinforce the communication with target beneficiaries. The successful example is the previously mentioned organization of the competition called New City Products that spread the information between the local community and a large feedback has been achieved. Anyway the communication with the target users will be still one of the most important challenges in the next period of the project implementation. The idea of using side streams in central city constructions may awake concerns about health and safety and environmental safety in public. Therefore, the further informative activities are required. This presumable resistance is overcome by the dialogue with authorities and by creating a transparent product acceptance procedure for the product including the physical and chemical properties of the material. Another approach for overcoming the obstacles mentioned is active dialogue with public and construction industry as part of project in piloting, sustainability assessment and circular economy business models assessment. Virtual showrooms are utilized in simulating the future applications and innovative structures that do not exist yet, but are enabled by the innovative solution created.
7. Upscaling	Medium	The most important challenges are connected with upscaling according to technology as well as legislation. The solution represents new construction materials on which existing product standardization and regulations cannot be directly applied. This possible regulatory obstacle is taken into consideration by clarifying the relevant standards and regulations in early phase of the project and open dialogue with respective authorities. The most important challenge in this stage is legislation. The first activities in recognizing the topic has been made in the previous period. This possible regulatory obstacle is taken into consideration by clarifying the relevant standards and regulations in this early phase of the project and open dialogue with respective authorities. The required material and product property testing is carried out in order to have an identified product acceptance procedure for the material developed in the project. Revolutionary materials and construction designs may also face lack of trust from the regulated, conservative construction industry. Familiar technologies are easily prioritized over modern initiatives.

5. Lessons learned

The project implementation is a challenging task. The city of Lappeenranta takes up challenges connected with this. It is worth to stress that the project taking into consideration local needs, especially try to use the raw materials from local industry such as lime mining, waste sand or waste form paper mill production. The basement of the local economy encourage the regional companies to active participation in the project, including delivery a material, suggested new one and common research with the university.

The project also shows good cooperation between partners and exchanging between them. The project meeting are an opportunity to learn each other's and common discussion (Figure 3.).



Project meeting – exchanging the knowledge and discussion

The meetings also helps to exchange the knowledge between different project areas and gain necessary information to understand the whole project context. The dialogue helps to solve potential problems and discuss about optimization of the solutions. It also gain some data to further work and to find some potential weak points.

The important point is also engagement of the local community in the project activities and open dialogue with the society. The information activities are joined with events organized by the city of Lappeenranta for the local community. This kind of activities enforce the public awareness and acceptance for the implementation of the new solutions.

6. Conclusions and next steps

This journal has presented a recollection of the Urban infra revolution project progress since October 2018, as well as upcoming challenges and focus aspects. The article summarizes the key activities that took place in the last months in the Urban infra revolution project. All activities are under a well-advanced deployment phase. The project team is progressing in all open fronts, and the most important milestone has been accomplished in these past months. Despite slight delays the implementation of the project goes smoothly and the problems that appeared are solving as fast as possible. Nowadays, the Urban infra revolution project has almost reached its first core milestones: it has finalized a proper management system and is implementing its most innovative components, albeit with some delays. The journals highlighted overall positive implementation of the activities, also thanks to the quality of its project planning. The next Journal will evaluate the next steps of the implementation process in the light of the first results.

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.

Urban Innovative Actions

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