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Modelling and Simulation of Utility Service Provision for Sustainable Communities

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***Abstract*—Utility service provision is designed to satisfy basic human needs. The main objective of the research is to investigate mathematical methods for evaluating the feasibility of using a more efficient approach for utility services provision, compared to the current diversity of utility products delivered to households. Possibilities for alternative utility service provision that lead to more sustainable solutions include reducing the number of delivered utility products, on-site recycling and use of locally available natural resources. The core of the proposed approach is the simulation system that enables carrying out feasibility study of so-called transformation graph, which describes direct transformations and indirect transformations of the utility products into defined services. The simulation system was implemented in C# and .NET 3.5, while the XML database was implemented using eXist-db. The XML database stores information about all devices, utility products, services and technologies that can be used to define and solve services-provision problems. An example of such problem and its solution is presented in this paper. This research is a part of the All-in-One Project.**

***Keywords*—Modelling, simulation, utility provision, graphs, transformations, sustainable development.**

I. Introduction

UTILITY service provision is designed to satisfy basic human needs, such as adequate quantity and quality of drinking water, adequate level of comfort, adequate level of personal hygiene etc. For many years scientists and engineers have been working on improvements of ways to deliver utility products to households, as well as removing unnecessary and/or unwanted products. Today each utility product such as water, gas, electricity, etc. is delivered to end-users via separate infrastructure, see [1]. This leads to problems not only with installation, managing or maintenance, but also raises questions, such as: which option is the best to heat a house, is there any cheaper solution for waste removal, are there any more sustainable or more environmentally friendly solutions, etc. On the other hand, the utility companies are looking for new solutions to reduce the cost and improve efficiency of providing services to customers.

The main objective of the research reported in this paper is to investigate mathematical methods for evaluating the feasibility of alternative approaches to utility services provision. Possibilities for such alternative approaches include reducing the number of delivered utility products, on-site recycling and use of locally available natural resources. In this approach households can be treated as input-output systems as presented in Fig. 1. The potential for recycling the waste products are indicated by green arrows. Red arrows in Fig. 1 show utility products that cannot be recycled or used in any way and therefore have to be removed from the system. Additionally some utility products can be acquired from the local resources, e.g. water from rain, air or ground; energy/electricity from sun, wind or ground. Furthermore, some products can be replaced by other products, for instance gas can be replaced by electricity, heat can be provided by gas or electricity. Hence, the complexity of the utility infrastructure could be significantly reduced, but this depends on local conditions and available natural resources. Benefits of such reduction in complexity are discussed in e.g. [2].

The core of the proposed approach is the simulation system that enables carrying out feasibility study of utility service provision scenarios, considering both direct transformations (e.g., cooking with gas or cooking with electricity) and indirect transformations (e.g., grey water from baths and showers can be recycled and used in dishwashers or washing machines) of the utility products into defined services. The approach also considers automatic generation of potential alternative approaches, using knowledge base of present and future technologies and devices.

The purpose of the developed simulation system is to help with the decision making process when designing alternative approaches to utility services provision. The simulation system is composed of the following blocks: an interface to define service-provision problem, an interface to define candidate solutions (transformation graphs), a computational engine to analyse the feasibility of solutions and a common XML

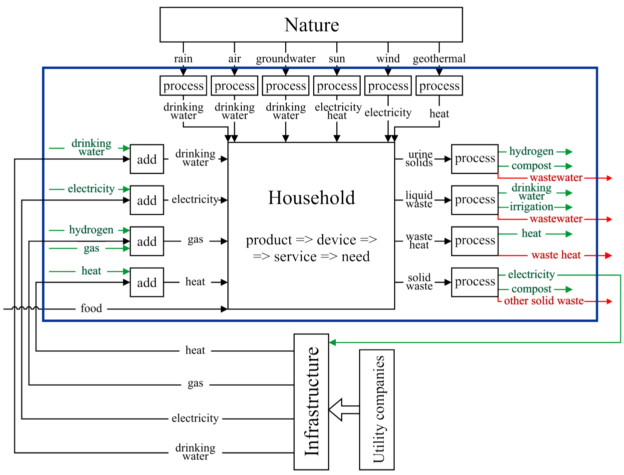

Fig. 1. Conceptualisation of a household, [1].

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database. Both interfaces and the computational engine are developed in C# and .NET 3.5, while the XML database is implemented using eXist-db, an open source native XML database system. The purpose of the XML database is to store information about all devices, utility products and services, which can be used to define services-provision problems and candidate solutions using corresponding interfaces. Services-provision problems and candidate solutions are defined using XML format and can also be stored in the database. At the current state of development the system enables manual definition of a potential solution to a problem, in form of a transformation graph, followed by simulation and evaluation of feasibility of a solution.

Being a part of the All-in-One project [3], this research considers also futuristic scenarios; this is reflected by the fact that some devices in the database are under development and not yet available.

The paper is structured as follows: in Section II approach towards modelling of utility service provision is demonstrated and some basic definitions are introduced. This is followed by Section III where methodology is described. In Section IV results are presented. Description of future work can be found in Section V and conclusion in Section VI.

II. Modelling Utility – Service Provision

It is a challenging task to create a model of utility-service provision. According to Franck [4], the ten main general characteristics of scientific models are that they:

1) Provide a simplified representation of the reality.
2) Represent what is considered to be essential to this reality.
3) Are testable.
4) Under the scientific approach, the models themselves become the object of study.
5) Are conceptual.
6) Allow the possibility of measurements and calculation.
7) Allow explanation of the reality.
8) Are a fictive representation of the reality.
9) Represent system.
10) Are isomorphic to the system that they represent.

Some of these characteristics (e.g. 1, 2, 5, 7 or 8) are more general than others (e.g. 3, 4, 6, 9 and 10). On the other hand, some types of models represent some of these characteristics better than others, see [5].

A. Definitions

In this subsection some basic definitions used in this paper are introduced, which at the same time form elements of the proposed approach to model utility service provision.

A *fundamental need* is something that is necessary for an individual to live a healthy life. Fundamental needs are distinguished from wants. According to [6], we can all recognise that there are things in life that we might want that we do not need and things that we might need that we do not want. It is sometimes suggested that needs are absolute, while wants are relative. Fundamental needs remain the same at all times and are uninfluenced by cultural changes, see [7]. What is changing is the way in which these needs are satisfied. There are many theories devoted to human needs. The most known was proposed by psychologist Abraham Maslow [8], [9]. His work is often represented in a form of pyramid, where the most basic – physiological needs (for oxygen, water, nutrients, homeostasis, excretion, sleep, sex, etc.) are at the bottom and the need for self-actualisation (self-fulfilment through achievement) is at the top. The second need is related to safety: physical security, security of resources, livelihood, family and possessions. The next ones are love and belonging (relationships, family, friendship and sexual intimacy) and self-esteem (self-identity and respect, confidence and respect from others). Before his death, Maslow added two more needs: cognitive (the need to acquire knowledge and understanding) and aesthetic (the need for creativity and the appreciation of beauty and structure), see [6]. In this research only the basic fundamental needs are taken into consideration because they can be satisfied by provision of utility products. Thus we investigate the following needs: access to information, access to transportation, adequate level of personal hygiene, adequate quantity and quality of drinking water, clean and safe environment, clothes, economic security, entertainment/leisure, sexual activity, access to education, adequate level of comfort, adequate nutritional food, mental and physical health, physical activity, physical security, provision of adequate sanitation, rest and regeneration, social communication and interaction [2].

A *secondary need* is derived from fundamental need (e.g. adequate nutritional food can be split into two secondary needs: *hot food* and *cold food*). In contrast to fundamental needs, they may change in time or vary for different cultures, [7]. However, not all fundamental needs can be split into secondary needs. In the context of this research, utility services and products provided by one or several utilities satisfy directly some but not necessarily all secondary needs. The fundamental needs are satisfied by the provision of utility products and utility services indirectly.

A *product* is a substance that is delivered by utility to end users (*utility product*), produced locally through transformations (*by-product*) or harvested locally from natural resources (*products from nature*). By *utility products* we understand electricity, water, gas, etc. *By-products* include clean water from recycling, solid waste than can be processed (e.g. in solid waste burners), greywater from showers or washing machines, etc. Electricity obtained from solar irradiation or wind, water harvested from rain are examples of *products from nature*. The products are necessary to satisfy human needs, but some of them can be used to replace the others (i.e. water can be harvested from rain and recycling and thus reducing the need to deliver utility product *drinking water*).

Service is a process of satisfying a *secondary need*, e.g. supply of drinking water, nutrition, partial body cleaning, etc.

A *device* is an appliance that uses technologies to transform one or many products into another products (e.g. three-blade wind turbine transforms wind energy into electrical power, or diesel generator that transforms diesel fuel to electrical energy) and/or into services (e.g. kitchen tap transforms utility product *drinking water* into a service *drinking water* or electric space heater transforms utility product *electricity* into a service *thermal comfort – heating*). A device can have more than one transformation defined, for example device kitchen tap can transform utility product *drinking water* into service *drinking water*, or can transform utility product *drinking water* into service *washing dishes* and product *greywater*, see Fig. 2.

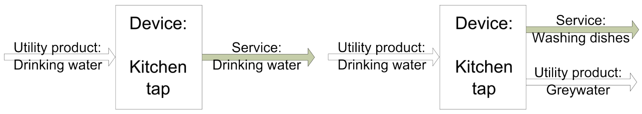

Fig. 2. Example of alternative inputs/outputs configurations for the same device.

There is also a possibility for a device to have different inputs, but the same outputs. For example, a device washing machine can have as an input *drinking water* and *electricity* or *clean water* and *electricity*. In both cases it will deliver the same service *clean clothes* and product *greywater* as output (see Fig. 3).

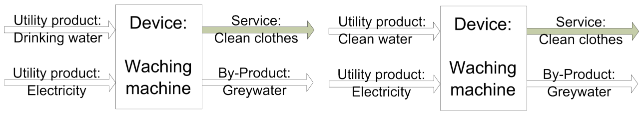

Fig. 3. Example of alternative inputs/outputs configurations for the same device.

Scenario consists of a set of requirements and constraints. At the current state of development it includes required services (with number of units of each service) and year for which particular scenario is tested for. Availability of local natural resources is specified as a functions of time to enable modelling of daily and seasonal variations. Additional constraints limit the amount of different utility products that can be supplied or removed by the infrastructure. Maximum amounts of utility products that can be supplied and/or removed by the infrastructure are also specified as functions of time. Furthermore a user can define which products can be supplied or removed from the infrastructure.

Technologies are required by devices to transform one or more products into another product(s), for example device *shower with electric water heater* uses technologies: water pump and power generation.

Transformation graph is an attempt to model utility service provision at household or community level, using the information about devices stored in the XML database, which will be discussed in the following section. In this graph each node is a device and each edge is a utility product or service carrier.

The concept of *sustainability* and *sustainable development* has been associated with great variety of human activities. They are related to the use of naturally available resources, non-renewable mineral and energy resources. According to Hasna, [10], sustainability refers to a development of all aspects of human life affecting sustenance. Sustainable development according to Allan (see [11]) is the development that is likely to achieve lasting satisfaction of human needs and improvement of the quality of life under conditions that ecosystem and/or species are utilized at levels and in ways that allow them to keep renewing themselves. In 1987 the World Commission on Environment and Development introduced the most widely known definition of sustainable development:
"... is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs", [12]. However, there are many other definitions in the literature, see e.g. [13] or [14].

B. Needs Requirement Analysis

An important step of this research was needs requirement analysis – a general review of daily activities of end-users in domestic environment to identify the needs that are being addressed by services provided by each utility product. The fundamental needs that can be indirectly satisfied by utility service provision were identified. The needs that are considered were listed in the previous subsection. The next step was the division of previously defined fundamental needs into secondary needs. As mentioned before, secondary needs can be satisfied by services directly. Therefore, fundamental needs were divided into secondary needs, which were subdivided into services.

Water and energy consumption in households varies over time. Depending on the time interval, the consumption might be changing daily. Usually there is a morning peak around 8 am when people are getting ready to work, then moderate mid-day usage lasting till 4 pm, an evening and relatively small late night peak when people are coming back and subdued low night usage until 4 am, see [15]. Also, the consumption is different during the weekdays and the weekend. There are also seasonal changes, for example people are using more energy in the winter to heat up their houses, and in the summer water consumption might increase due to flower and garden watering, etc. Average water consumption in the UK is estimated to about 150 litres per person per day, see [16]. Approximately 7% of that water is used for drinking and cooking. Therefore not all of the water used within a household has to be treated to potable quality. Some of non-potable water needs could be met in an alternative way, for example water from baths, showers and sinks could be recycled and reused for garden watering. Also, rainwater could be harvested and processed [16]. In 2011 domestic consumption was 26% of total UK final consumption of energy products, see [17]. This energy is used for space and water heating, cooking, lighting and electrical appliances. Household energy demand depends on many factors, e.g. space heating is highly dependent on technical factors such as the type of dwelling, its levels of insulation and the efficiency of the heating mechanism; energy use for water heating and wet appliances, such as dishwashers and washing machines, depends on technical factors such as the efficiency of the appliances, as well as lifestyle choices such as the number of times clothes are worn before being washed, or the frequency of and time taken showering [18]. In the UK, as in other affluent countries, at least one computer is found in most homes, analogue television and radio equipment is being supplemented by digital equipment, and the stocks of mobile telephones, sound systems, videos, DVDs, camcorders, answering machines, digital cameras, printers and scanners are growing rapidly, see [19]. Total household energy use is therefore complex to model, as it should take account of a wide variety of technical and lifestyle factors, see [18].

III. Methodology

At the current state of development the methodology progresses in the following steps:

1) Determination of the year for which the utility-service provision problem is considered.
2) Definition of the services to be provided with number of units and time horizon.
3) Selection of the devices required to solve the problem.
4) Definition of product(s) that can be supplied (including naturally available resources) or removed.
5) Definition of the storages for products, and their capacities.
6) Definition of the transformation graph(s) that satisfies the constraints.
7) Simulation of the previously defined graph and calculation of balances of all products and services.
8) Visualisation of the final results for human decision makers.

A. XML Database

The XML database is implemented within the eXist [20] environment. eXist is an open source database management system entirely built on XML technology, also called a native XML database. Unlike most relational database management systems, eXist uses XQuery, which is a World Wide Web Consortium (W3C) Recommendation, to manipulate its data.

As mentioned earlier, information about products, services, devices and technologies is stored in the XML database. All of them can be stored and manipulated in the database using a purposely developed software with graphical interface (see Fig. 4). The XML database is searchable and can support constraint satisfaction or objective function optimisation queries. As of September 2012 there are over 90 devices, over 30 products, over 20 services and over 80 technologies stored in the database. Each of them has some compulsory fields; for devices these are: *device name*, *device description*, *input/output transformation*, *used technologies* and *maximum throughput (per hour)*. The *maximum throughput* is related to efficiency of the transformation processes, as it defines how many units of products or services can be produced or satisfied by the device. The ratio between required input and produced output is fixed (i.e. no dynamics). For products the compulsory fields are as follows: *product name*, *product description* and *units*. For services we have *service name* and *service description*. Finally, for technologies: *technology name*, *technology description* and *year available*. Most of devices currently stored in the database are existing appliances or devices currently emerging/under development. However, some of them are hypothetical devices which may emerge in the future. Therefore, each device is tagged with *year of availability* to enable modelling of existing, near future, and science-fiction approaches to utility services provision, see [1]. There is also place for additional optional fields, for example cost, dimensions, CO_2 emission, etc., which will be used in the future analyses.

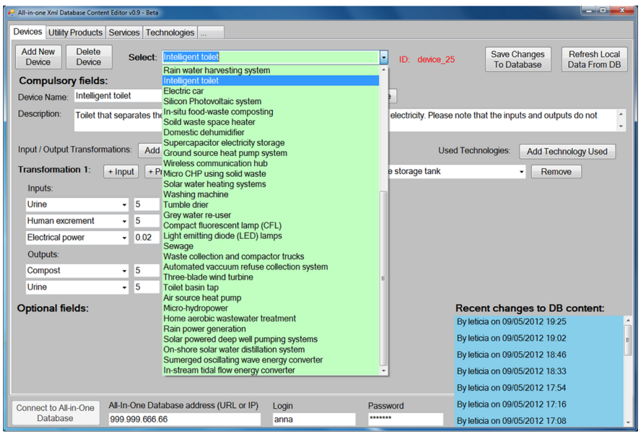

Fig. 4. GUI for data implementation.

The information stored in the XML database can be represented as a hypergraph where, in the contrary to the transformation graph, products are nodes and devices are links between them. Typically a device has more than one inputs and many outputs, hence it connects more than two nodes, see [21]. The hypergraph, which represents complete information from the database is called a master graph. The paths on the master graph from utility product *A* to service *B* show which transformations are required to satisfy *B* by supplying *A*. They also show what transformation are required to transform product *A* into product *B*, see [1].

B. Generation and Simulation of Transformation Graphs

One of main aims of utility service provision is the best use of delivered utility products, by-products, and naturally available resources. Of course the most important one is to satisfy human needs by delivering appropriate services. Devices that are required to achieve that can be connected with each other giving a transformation graph, see example in Fig. 5. Simulation of such transformation graphs considers only a snap-shot, i.e. no time horizon. There are two ways of creating such graphs. First is manual. A user has to hand-pick from the database all devices that (in his opinion) deliver the required services by transforming products into another. At this point user can decide which by-products are recycled or re-used. Next step is to create a transformation graph in an XML file. Here the user has to specify the connections between supplies and devices and services. The developed simulation system checks the feasibility of that solution, calculates balances of all products and services; provides amount-to-be-removed and amount-to-be-supplied for each product, see [2].

Second way of creating the transformation graph is automatic. Given the list of requirements and constrains:

- devices stored in the knowledge base and year they are going to be available;
- required services;
- availability of local natural resources;

- limitations of the amount of utility products that can be supplied;
- specification of the products that need to be removed;

initial transformation graph consisting only of service demand nodes is automatically constructed. Subsequently, an iterative algorithm searches the knowledge base for suitable devices, inserts them into the transformation graph, simulates the graph and analyses the results to decide what needs to be done (e.g. what kind of device needs to be inserted) during the next iteration. In our current heuristic approach, such suitable devices are those that either: (i) satisfy the specified service demands, (ii) acquire useful utility products from locally available natural resources, (iii) recycle by-products of devices already in the graph to produce useful utility products. If during a particular iteration more than one device satisfies some criteria (e.g. a device that produces service *A* needs to be inserted and two such devices exist in the knowledge base), then the current transformation graph is copied and the algorithm proceeds with both copies independently. Consequently, the final output of the algorithm is a collection of transformation graphs that satisfy the specified requirements and constraints. At the current state of development only one layer is implemented (supply – device – service) and by-products are not reused. Like in the manual case, scenario has to be defined and loaded to the simulation system, but the output is a set of transformation graphs.

A second approach towards transformation graphs is currently investigated. Advanced storage technology is essential for the concept of sustainable communities to become a reality, see [1]. Hence, in contrast to the previous approach, storage for each product is introduced. It concerns both substance storage such as water or gas/hydrogen and energy such as electricity or heat. Product storages have some defined capacity and four thresholds:

- remove threshold – push product to removal when stored amount is higher than this threshold;
- push to device threshold – push product to device connected to storage output when stored amount is higher than this threshold;
- pull from device threshold – pull product from device connected to storage input when stored amount is lower than this threshold;
- supply threshold – pull product from supply when stored amount is lower than this threshold;

In this case a user has to define devices that are used in the transformation graph and specify which devices deliver the required services. Simulation of transformation graphs with storage is fully developed (example results are demonstrated in Section IV), while an automatic generation of such transformation graphs is currently under development. Simulation is carried out over a specified time horizon; this allows to model time-varying service demands, local resource availability, supply limitation, etc.

IV. Results and Discussion

A. *Generation and Simulation of Transformation Graphs without Storage*

Consider the following example. We want to deliver one unit of each of the following services: *full body cleaning*, *thermal comfort – heating*, *nutrition* and *washing dishes*. The year that the scenario is tested for is 2012. In the database (as of September 2012) there are 3 devices that can deliver service *full body cleaning*, 6 devices that can deliver service *thermal comfort – heating*, 6 devices that can deliver service *nutrition* and one that can deliver service *washing dishes*. Natural resources are not used in this example, but grey water is reused (there are two devices in the database to do so), as well as organic waste (also two devices for that purpose). Based on that information, a transformation graph was created manually, see Fig. 5. The feasibility of that graph was conducted using the simulator and the results are as follows. Products that need to be supplied:

- drinking water – 43 l;
- electrical power – 89 kWh;
- food – 2 kg;

are indicated in green in Fig. 5.

By-products that are produced and reused: greywater, clean water, drinking water, and organic waste. Devices *Greywater recycler*, *In-situ food-waste composting*, and *Filtration an UV water purification system* were used to process greywater, organic waste and clean water. Therefore, drinking water could be recovered and reused.

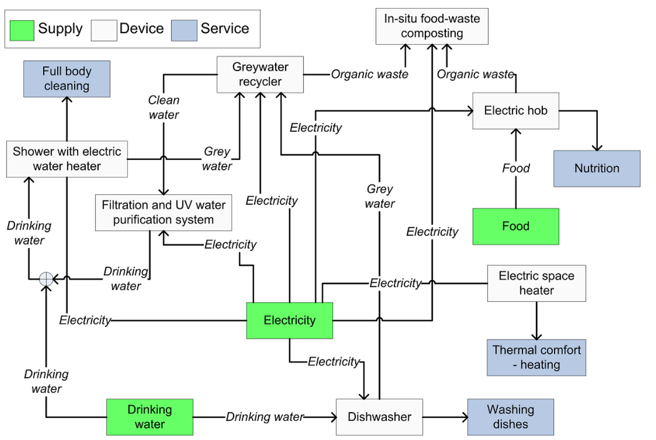

Fig. 5. Transformation graph with feedback loops.

All service demands (indicated in blue in Fig. 5) have been satisfied.

For the considered example 108 different transformation graphs were generated. Subsequently, the simulation system was used to automatically generate transformation graphs that satisfy the requirements. One of them is shown in Fig. 6. As it was mentioned before, at the current stage transformation graphs consist of one layer: supplies are connected to devices and then to services. There are no feedback loops, none of the products is reused. In the case shown in Fig. 6, 15 units of drinking water, and 102 units of electricity need to be supplied. Generation and calculation of all possible transformation graphs creates an opportunity for optimisation. There are many options, e.g. minimization of products that need-to-be removed, maximization of recycling, maximization of utilization of naturally available resources, etc.

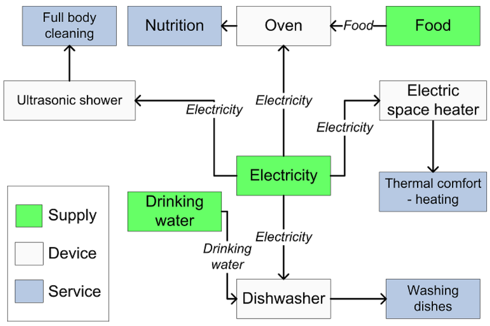

Fig. 6. Single layer transformation graph.

B. *Simulation of Transformation Graphs with Storage*

In this example storage for each product used in the transformation graph was introduced. In the previous example time horizon was not considered. However, water and energy consumption varies significantly throughout the day as discussed in Section II. Depending on the time interval, the consumption might be changing daily, there is usually a morning peak when people are getting ready to work, and then the consumption is higher in the evening, when people come back from work.

TABLE I
SERVICES

Time step	Full Body Cleaning	Thermal Comfort	Nutrition	Washing dishes
1	0	1	0	0
2	0	1	0	0
3	0	1	0	0
4	0	1	0	0
5	0	1	0	0
6	0	1	0	0
7	1	1	0	0
8	0	1	2	0
9	0	1	0	0
10	0	1	0	0
11	0	1	0	0
12	0	1	0	0
13	0	1	0	0
14	0	1	0	0
15	0	1	0	0
16	0	1	0	0
17	0	1	2	0
18	0	1	0	0
19	0	1	0	0
20	0	1	0	0
21	1	1	2	0
22	0	1	0	1
23	0	1	0	0
24	0	1	0	0

The required services are as follows one unit of service *full body cleaning* is required at 7 am and then at 9 pm; One unit of service *thermal comfort – heating* is required throughout the whole 24 hours; two units of service *nutrition* are required at 8 am, 5 pm and 9 pm; and one unit of service *washing dishes* at 11 pm (see Tab. I). A simple solution to that problem is presented in Fig. 7.

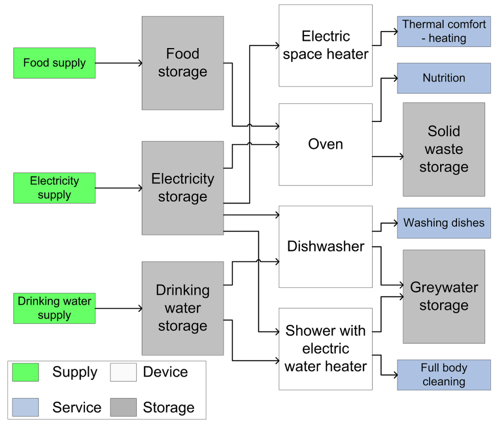

Fig. 7. Transformation graph with storage.

There are three supplies: food, electricity and drinking water. In this case, to satisfy all required services the following products need to be supplied/removed by the infrastructure:

Supply:

- Drinking water – 135 l,
- Electricity – 1212.15 kWh,
- Food – 6 kg.

Removal:

- Greywater – 135 l,
- Solid waste – 0.6 kg.

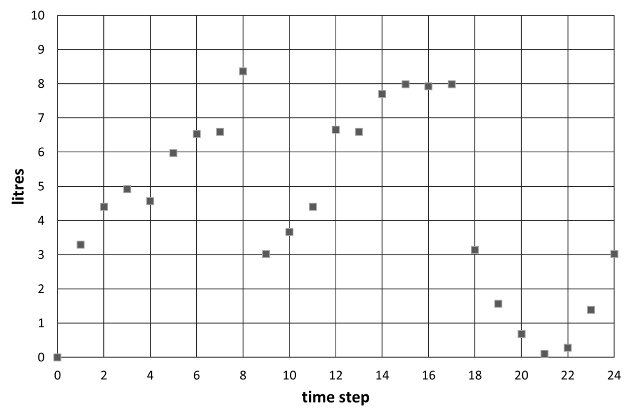

Fig. 8. Rainfall intensity.

We may now consider improvements to the utility service provision illustrated in Fig. 7. It can be observed that there is a possibility to reduce the amount of drinking water that needs to be supplied by recycling greywater and also by collecting and treating rainwater. The system allows to define maximum amount of each product that can be supplied. Detailed information about weather conditions can be found in numerous places, for example see The Met Office [22]. For this particular example we assume that it is raining throughout the whole 24 hours with intensity as illustrated in Fig. 8. The rainwater is collected and processed to the drinking quality using *Rainwater harvesting system*; the amount of rainwater that can be collected depends on the harvesting system and its parameters, see [23]. It would be advisable to invest in rainwater harvesting system in places that annual rainfall is high.

The greywater obtained from the shower and dishwasher can be collected and treated. Depending on the user, it can be treated to drinking quality, or used to flush the toilet. In the considered example both rainwater and greywater are transformed to clean water. Then, clean water is processed to drinking water. This could significantly reduce the amount of drinking water that needs to be delivered to a household. In this example the capacity of rainwater storage is 200 litres. By defining the thresholds (defined in Section III) in this storage, the system was forced to process rainwater to clean water when the level reaches 10 litres. In the greywater storage the *push to device threshold* forced this storage to process all of the greywater as soon as possible, taking the graywater recycler specification into consideration. In the drinking water storage the *pull from device threshold* was defined to force the device *Filtration and UV purification system* to process clean water till the level in the drinking water storage reached 160 litres.

An improved transformation graph is illustrated in Fig. 9; simulation results are discussed below. In the 7th and 21st time step 60 litres of greywater is produced, and in the 22nd step 15 litres. Levels of drinking water, clean water, greywater and rainwater during defined 24 times steps are showed in Fig. 10. There are also presented amounts of rainwater and greywater processed to clean water, and clean water processed to drinking water.

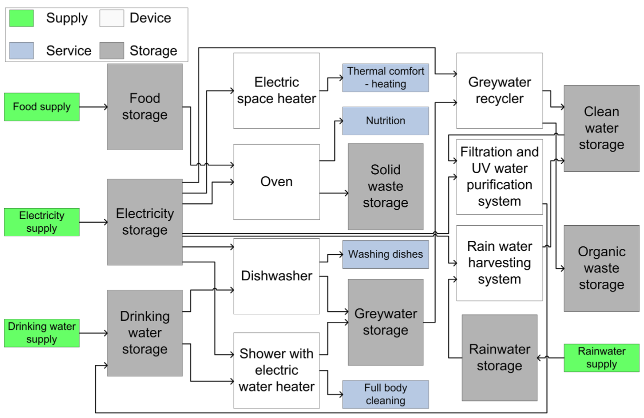

Fig. 9. Transformation graph with storage and recycling.

In the 7th time step there was demand for 60 litres of drinking water, but the maximum that could be obtained from rainwater was 20 litres. Therefore, 40 litres needed to be supplied in that time step. To sum up, in this case only 20 litres of drinking water needs to be supplied to deliver required amount of service *full body cleaning*. It is significant improvement compared to the previous solution where 135 litres of drinking water was needed to be supplied. However, the amount of electricity needed to make that solution a reality is greater than in the previous case. To process all harvested rainwater to drinking quality approximately 110 kWh of electricity is needed. Processing produced greywater needs another 135 kWh of electricity. The following products need to be supplied/removed by the infrastructure:

Supply:

- Drinking water – 30 l,
- Electricity – approx. 1500 kWh,
- Food – 6 kg,

Removal:

- Organic waste – 26 kg,
- Solid waste – 0.6 kg.

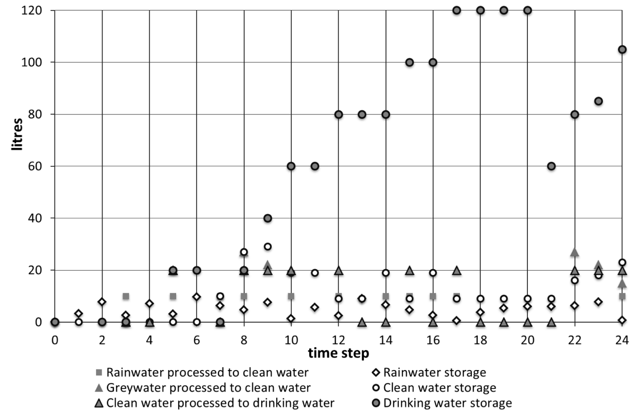

Fig. 10. Water level in storages during the time horizon.

Solid and organic waste produced in this case is not reused and therefore needs to be removed from the system. It depends on the user and available technologies which products can be transformed to different products.

This simple example shows how complex the utility-service provision problem is.

V. Future Work

The future work is focused on several aspects:

- **Use of graph methods to search paths in the master graph**. This will help to facilitate automatic database searches and will be useful for the decision making process if product(s) should be removed or if it can be transformed into another product(s). Using search algorithms it will be possible to find e.g. the shortest path between two products, or the path that requires minimal number of other products that are required to make that transformation possible.
- **Automatic generation of the transformation graphs with storage**. At the current state of development the user has to define transformation graph that will be examined, as shown in the examples earlier. Automatic generation will help in finding optimal or near optimal solutions to a specific problem.
- **Optimisation of the solution to a specific problem**. Based on user preferences the developed software can

help with finding solutions that will achieve the defined goals. These can include minimization of products that need-to-be-removed, minimization of the CO_2 emission, maximization of recycling, maximization of utilization of naturally available resources, minimization of products that need-to-be-supplied etc.

- **Store information about naturally available resources in the XML database**. At the current state of development data about weather conditions and other resources that can be of use needs to be implemented into scenario file. One of the aims for the future is to allow the user to choose the region he is interested in, and available data will be loaded from the database.
- **Extension of XML database**. The distinction between devices that can be used on the household and community level will be made.

VI. Conclusion

In research presented in this paper methodology and the development of a software system for evaluating feasibility of utility provision for a community or a single household was introduced. Human needs that can be satisfied by provision of utility products were identified as well as services that have to be delivered in order to satisfy those needs. XML database that stores information about all products, services and corresponding technologies/devices was developed. The description how the utility products are processed to provide services to humans using the information from the database is presented in the form of transformation graphs. Two types of graphs have been introduced, one where nodes represent devices and links represent products/by-products, and the hypergraph where nodes represent the products/by-products linked by the devices. In the second approach it is assumed that all products have storage, which is essential to support intermittent supplies in sustainable communities. A useful construct is a master graph, which represents complete content of the database; in the future the master graph concept will facilitate automatic database searches and optimisation of utility service provision.

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