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Can Gamification be Used for Spatial Energy Data Collection? Experiences Gained from the Development of the HotCity Game to Collect Urban Waste Heat Sources

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1 ABSTRACT

Availability of reliable data is one of the most important elements for fact-based decisions. Urban planning and spatial energy planning often suffers from a lack of availability of good, validated and up-to-date data sets. Furthermore, integrated spatial and energy planning needs to incorporate new spatially distributed energy sources and understand how these sources can be used in the future to meet climate protection targets. These new energy sources can be, for example, waste heat from industrial food production, local industrial/commercial enterprises, data centers, or urban infrastructure such as tunnels and metro stations. The utilization of such waste heat sources in heating networks has been demonstrated several times, however, their proper identification in an urban environment can be challenging, especially for smaller and unconventional sources (Schmidt, 2020).

Gamification as an innovative way to collect the needed data was investigated within a national funded research project called “HotCity”. Gamification builds on the use of game mechanics in contexts that are, by nature, unrelated to the game (Deterding, 2011). Within the project the HotCity-App was developed enabling users to spatially report and evaluate different sources of waste heat. The gamification of data collection was also intended to raise awareness of waste heat and energy use on the one hand, and to facilitate the collection of data from small energy sources on the other. For the first time, the game framework is secured using a blockchain and mapped by means of a token[1] system. The HotCity-App was tested in the Austrian cities Vienna and Graz as a proof of concept to analyse if and how the gamification approach can deliver valid results.

The HotCity-App, the game, makes it possible to identify and georeference also smaller sources of waste heat in order to use the available energy. Two test runs were each conducted in Graz and Vienna, which provided helpful feedback from the testers regarding promising features as well as showed barriers reducing the success of this data collection approach. An interactive web-application for the data collected with the HotCity-Appwas further developed to visualize the reported potential waste heat sources and to interactively evaluate the economic feasibility of using the waste heat sources under different frame conditions.

The paper will elaborate the game development, discuss the gamification approach and the lessons learned during the proof of concept project. We will further give an outlook of additional data types for integrated urban energy planning, which could be collected by this approach.

Keywords: mobile app, waste heat, energy planning, data collection, gamification

2 INTRODUCTION AND CHALLENGE

The energy system of the future will consist most likely of many different decentralized units (e.g. rooftop PV panels, individual heat pumps etc.). For the development of districts with high energy efficiency and

[1] https://en.bitcoinwiki.org/wiki/Token, tested 07.06.21

increased use of locally available and sustainable energy sources, a detailed spatial identification of possible energy potentials is necessary in order to plan cost-efficiently and future-proof. In particular waste heat from industry (foundries, food production...) and commerce (data centers, supermarkets...) as well as urban infrastructure (tunnels[2], metro stations[3]) can make an important contribution to heating and hot water production in plus-energy districts. While "low-hanging-fruits" such as waste heat from large scale industrial plants are already widely used, the identification of smaller sources is associated with various difficulties (Schmidt, 2020). Many larger cities already have a data set, e.g., Open Government Data, which is usually not up-to-date enough, not sufficiently detailed (spatially) and often does not contain all necessary data. Due to the often chosen top-down methodology for the identification of the waste heat potential, i.e., using a survey of the largest pollutant emitters (e.g. Brueckner etal., 2014), smaller sources are not recorded, which therefore do not appear in these databases.

Gamification, on the other hand, offers the possibility of generating targeted incentive systems for data collection (crowdsourcing/crowd collecting). Games like "Pokemon Go" have shown which undreamt-of dynamics can be created.Within the project HotCity funded by the BMK[4] a Game (the HotCity-App) was developed, enabling users to spatially report and evaluate new potentials of waste heat. The application to collect waste heat was chosen to be exemplarily for other spatial energy data. The gamification of data collection for waste heat was also intended to raise the general awareness of the topic and to facilitate the collection of data from small energy sources that are normally not considered in top-down methodologies.

2.1 Gamification as a bottom-up method for identifying energy-oriented data

The massive distribution and market penetration of digital games (approx. 37 billion dollars in sales in 2020 in the USA alone as stated by Statista, 2021) is impressive. For example, 510 million people are currently actively playing games (5.3 million in Austria as stated by ÖVUS, 2019), with an average age of 35. Gamification is based on the use of game mechanics in contexts that are, by nature, unrelated to games (Deterding, 2011). The aim of gamification usually is to apply the motivational and feedback techniques that have been tried and tested in games. Games provide clear goals (Hunicke et al., 2004; e.g. quests), they reward (Vorderer et al., 2004; e.g. badges, level-ups), they allow to compete or cooperate with others (Yee, 2006; e.g. in the form of rankings, multiplayer elements) and they provide an interactive framework for different experiences and skills (Ivory & Kalyanaraman, 2007; Jansz, 2005).

Gamification has already been successfully used in various application areas to promote participation, such as in the context of civic courage (Coronado & Vasquez, 2014), citizen participation (Thiel & Lehner, 2015), e-learning (Barata et al., 2013) and e-government (Al-Yafi & El-Masri, 2016). The application of gamification has also yielded positive results in the mobility sector, e.g. in terms of promoting sustainable forms of mobility (Kazhamiakin, Raman et al., 2015).

Pfeiffer et al. (2020) coined a new definition of Gamification: “Gamification is the use of game mechanics as a further dimension within and around both gaming and non-gaming contexts, in an endeavour to nudge participants to perform certain actions, by adopting a playful attitude”. This definition shows that gamification can also take place within games, whenever further elements outside the core mechanics and the core storyline are used to get the players to explore certain content. Furthermore, the definition also shows the relation to the principle of nudging and that gamification can be seen as one of the tools to trigger behaviourchange.

2.2 Blockchain Technology as a transparent way of handlingreward systems

Due to its decentralisation, transparency and security is the blockchain technologyoften part of technological and social discourses (Buhl et al., 2017) and is being treated as a disruptive innovator for a wide range of applications: from transaction processing to land registry entries to logistics chains, the intermediary is to be eliminated in the future (Hopf & Picot, 2018). Previous crypto technologies such as Bitcoin and Ethereum rely on "proof of work" and reward "miners", who keep the entire network alive and validate all transactions, for solving randomly generated computing tasks. The computing power required for this increases linearly

[2] https://sciencev1.orf.at/science/news/154441.html tested 07.06.21
[3] https://www.reuseheat.eu/berlin/tested 07.06.21
[4] Federal Ministry Republic of Austria for Climate Action, Environment, Energy, Mobility, Innovation and Technology

with the difficulty of the computing tasks and consumes more and more resources. This is where new blockchain technologies such as "Ardor" or "NXT" come into play, which are based on a "proof of stake" algorithm and are much more energy-efficient. Here, it is not about computing power in the form of graphics card performance or CPU-power, but about holding a certain stake in the network-maintenance token, other aspects like the total time of taking part as a verification node and a certain aspect of randomness. Regardless of the approach, the peer-to-peer principle, the strong encryption and the permanent and validatable storage of information represent an opportunity for diverse industries - including, of course, the gaming industry (Pfeiffer et al., 2020).

Ardor offers the possibility to generate utility tokens on the child chain Ignis. Approval models can be set up around these created tokens and therefore the set of rules can be specified. Furthermore, there is the possibility to develop smart contracts. As a bonus, there is also a ready-made marketplace that can be used within the scope of the decentralised applications (DApps) generated using the Ardor blockchain and its child chain Ignis.

In HotCity, the blockchain was used to prevent cheating on the one hand and to ensure transparency for the players on the other. It was used to automate the management of redeemed prizes and rewards and to reduce the administrative effort to a minimum. The concept involved incentives (such as coffee vouchers) - mapped on a blockchain token - that could be redeemed at project partners. Double spending or counterfeiting of vouchers can thus be avoided. In addition, the accounting settlement can be automated. For example, similar to a current accounting system, the partners could send the tokens to our billing account on a monthly basis, thus triggering the transfer of Euro funds from the game operator to the prize provider.

The blockchain system for the HotCity-Apphad to meet the following basic requirements:

- It must be a fully decentralised public blockchain.
- Users can, if they want, run a node of the blockchain on one of their devices, such as a laptop or mobile phone.
- We can use approval models to ensure that various conditions are met. One of these conditions is that the tokens cannot be transferred to other unregistered wallets.
- Identity management can potentially be implemented. In our case, this would be a possible connection of decentralized identifiers[5] (DIDs).
- Users do not need cryptocurrencies to pay network fees, we can take care of this as an operator with bundling accounts.
- Individual transactions must be manageable in terms of costs, even if the crypto market fluctuates massively.
- Messages attached to transactions must be encryptable.
- However, it must be possible to generate shared keys. To make the information readable for authorised parties.
- It needs the possibility to programme lightweight smart contracts, in our case it is the exchange of the different token classes, as part of the game mechanics.

3 THE HOTCITY APP

3.1 GameMechanics &Dynamics

The basic idea of the HotCity App is that users can move through the city and identify possible waste heat sources. In the past, a good understanding has been developed of possible waste heat sources and their characteristics. Chimneys indicate the location of (industrial) processes using combustion and might therefore generate waste heat; and recooling units indicate large waste heat potentials from data centres or other cooling processes. Users of the HotCity App can identify chimneys and recooling units by taking a photo or doing some internet research, e.g. using Google Mapssearch.

[5] https://www.w3.org/TR/did-core/#dfn-decentralized-identifiers tested 07.06.21

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The user (the player) can take a photo in the HotCity App to identify the object of a possible waste heat source. Additionally, the user also needs to provide information about the type of object (chimney, recooling unit). The user can then mark the exact GPS position of the object on the map. The last step for the user is to crop a satellite image of the set GPS position only showing the waste heat source. After that the potential waste heat source is saved to the map of the game and the user is rewarded with heat tokens. Now every user can give additional information about this specific waste heat source andverify the object,its size, height and number of units.

The cities where the game can be played are segmented in areas through a grid. Each area can be conquered by a single player or a team. The player or team with the most identified waste heat sources wins the area.

The gamification concept is also extended through a high score system for single players and teams based on their heat score (a number calculated based on the user's earned tokens – see next paragraph). The heat score from earned tokens also unlocks numerous badges (e.g. "Heat Runner", "Heat Scout", "Conqueror") inside the app. The head score also puts gamers into a ranking system (e.g. "Rookie", "Amateur", "Master")

The app also incorporates a basic voucher incentive system, where earned tokens can be redeemed for voucher of partners (such as coffee to go).

All those features add additional layers of gamification elements to the app (see also next paragraph).

The gamification framework consists of three utility tokens realised within the blockchain Ardor and its child chain Ignisthat represent points: bronze, silver and gold tokens. Users receive bronze tokens for simple tasks such as uploading unconfirmed images and later receive points with higher value, when heat sources are confirmedby other payers. These tokens can later be redeemed for incentives, with better incentives distributed for gold tokens than for bronze tokens. As a further game mechanic, tokens can be exchanged for each other, e.g., 10 silver tokens result in 1 golden token. Furthermore, all badges are displayed as tokens.

3.2 App Development

3.2.1 Frontend of the HotCity App

The HotCity App uses a hybrid app technology with a single code base based on the hybrid app framework Ionic including Capacitor[6] as container, which delivers the app to different platforms (in this project iOS and Android).

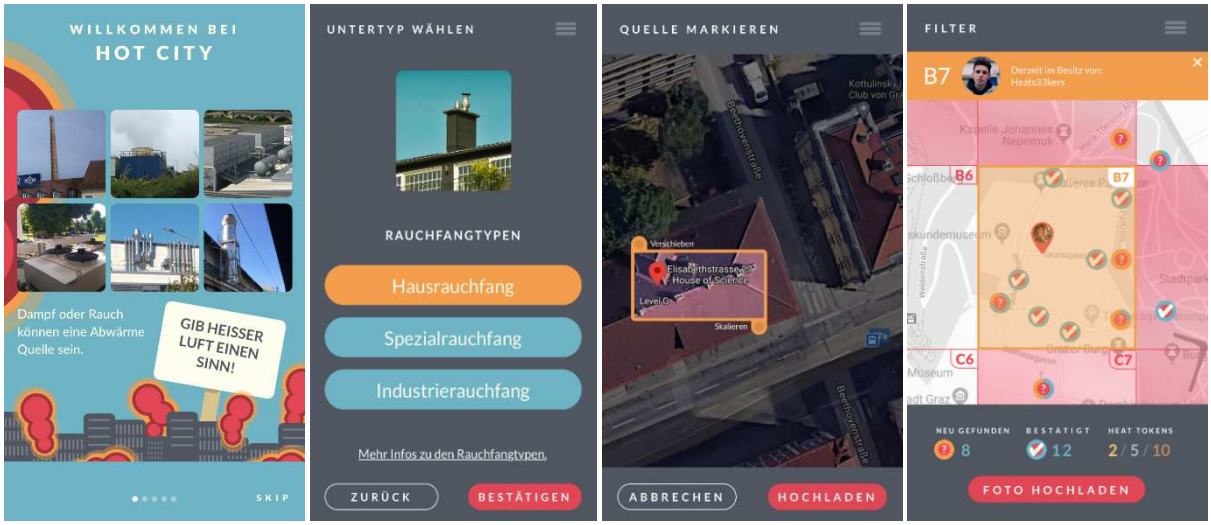

Fig. 1: HotCity App Screens

The structure of Ionic is web-based (HTML5, CSS3 & Sass[7]), based on Angular (JavaScript/TypeScript) and uses an open-source mobile user interface component toolkit as well as several plugins to bridge native functionalities with the web-based code base. As a framework, Ionic offers a cross-platform delivery feature set to address the native functions of the operating systems such as camera, GPS or memory. In addition,

[6] Capacitor is a cross-platform native runtime for web apps and provides native app container for packaging and deploying Ioinic apps to various mobile and desktop platforms. https://capacitorjs.com
[7] https://sass-lang.com/

native SDKs can be easily integrated. This serves as a solution for smartphones of newer generations (Android > 4.4, iOS > 10). Another advantage is the development using web technologies, so that the apps developed in Ionic can also be made available as a PWA.[8]

The app is connected to a backend via an API to process data collection, data enrichment, user profile information and blockchain related verification mechanisms for gamification (see next paragraph). The following figure shows main screens of the HotCity App.

3.2.2 Backend of the HotCity App

The actual transfer of the respective assets takes place entirely on the blockchain. A lightweight contract (cf. smart contract) was developed for this purpose, which, in conjunction with the API, ensures that the assets are transferred correctly.This contract is initially triggered by the backend and contains, for example, information about which "heatspot" has triggered an asset transfer. The lightweight contract then calls the API and checks whether the entries and information are valid and correct and then transfers them. In a freely definable period of time, the API checks whether the asset transfer was successful. If, for example, the transfer of the assets fails due to technical circumstances or insufficient fee, a new process takes place.

The Ardor node primarily manages and executes the lightweight contracts for the transfer of the application. As already mentioned, the API acts as a validation unit for this contract and only transfers assets or badges if the correct information is available.

In summary, blockchain technologies in the HotCity project secure those relevant parts of the game where values for the players or project partners are affected. On the one hand, tokens, badges and vouchers earned and, on the other hand, the accounting modalities. All other data, such as the description of the potential heat sources, are saved in a conventional database, which is continuously backed up. Transactions on the blockchain, as accessed from the graphical interface of the main account full-node as well as a triggered badge are displayed in figure 2.

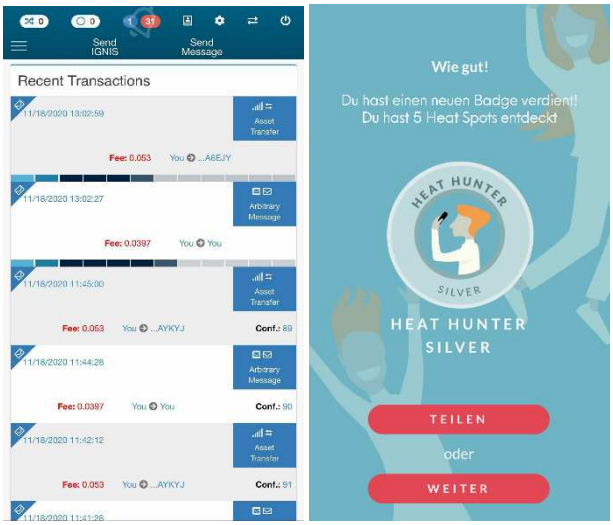

Fig. 2: Blockchain token transaction& visualisation of a triggered badge

4 HOTCITY FIELD TEST

The field test took place in two different phases during the winter 2020/2021. The first phase was performed in November 2020, while the second phase was launched mid of February 2021 for 2-3 weeks. For a part of the test persons, fees were awarded for at least 5-8 hours playing time. All participants received a briefing in advance in the form of a tutorial on the app and in the form of marked districts that showed a high potential in terms of waste heat sources. The responses were collected in anonymous form with a request for open

[8] PWA = Progressive Web Apps are web applications based on modern web browser standardswith additional features for desktop and mobile similar to mobile apps (e.g. notification system). Users can therefore put those web apps to the home screen of their smartphones. https://en.wikipedia.org/wiki/Progressive_web_application

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critical feedback. A total of 836 tokens were sent out for a) heat sources, divided into bronze, silver and gold and b) badges.

After a 2-3 week test phases, an online questionnaire was created and submitted using the "Survey Monkey" software. The item collection contained both open and closed questions with dichotomous and rating scaled gradations.A total of 31 people took part in the test and filled out the online questionnaire. The majority of the test persons (almost 68%) tested the app in Vienna, the rest (32%) in Graz.

4.1 Usability Score & Acceptance Rating

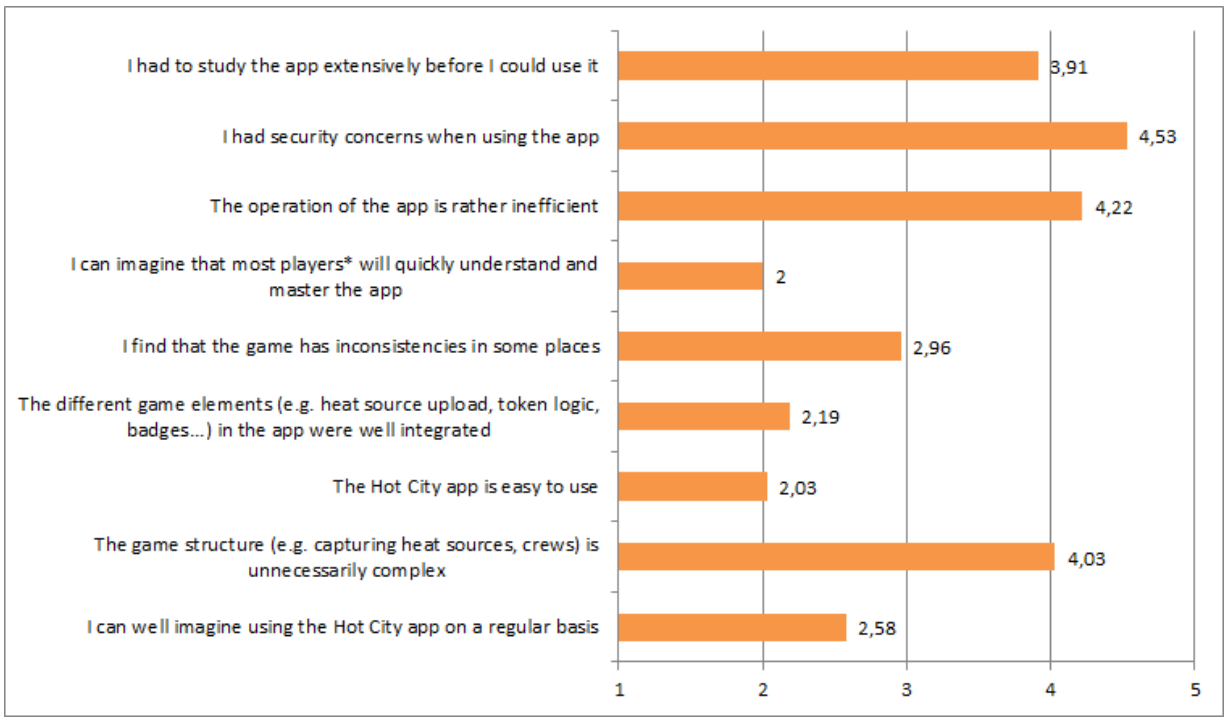

Fig. 3: Usability & Acceptance Score; low values are equal to high levels of agreement

Satisfactory values could be reported with regard to the usability & acceptance of the app. The usability is subjectively high (mean values from 2.0 to 2.58). The simple user interface (M=2.0) and the assessment of the comprehensibility for other users (M=2.03) are particularly noteworthy in this regard.

The normalised SUS (system usability scale) score is 79.675, which corresponds to an above average value (maximum = 100, minimum = 0).

4.2 App testing lessons learned

The results of the field test show high values for the acceptance of the app. The fun of play and the level of difficulty were also rated as appropriate. The standardised SUS score is in the upper fifth, a high subjective usability is thus evident.

The core functionality of the app - the search for waste heat sources, which was designed and integrated in accordance with the project goals - is seen as motivating by the users; compared to other game features, the entertainment value is particularly high.

With regard to the qualitative aspects, the design of the app, the game idea and the ease of use were praised by the test persons.

Problems were encountered with regard to GPS positioning, which sometimes did not work immediately and had to be corrected manually.[9] In addition, as the first phase of the field test in particular showed, it was sometimes difficult for the users to find suitable heat sources, and chimneys from private households, which are no valid waste heat sources, were often photographed. Through clearer communication and tutorials, this problem was alleviated in the second test phase.

[9] A technical problem here is that automatic GPS positioning reduces the duration of one battery load, thus a compromise has to be chosen, or using manual GPS postioning, which reduces the usability experience.

Suggestions for improvement mainly refer to an improved tutorial (phase I) and an automated location on the map of the potential waste heat sources.

Recommendations:

- Provide an optional tutorial video and a half-hour webinar to introduce and explain the app. As user segmentation in the future could include regular users, experts as well as community experts.Such a webinar is an efficient method for onboarding and providing the necessary skills to assess waste heat sources according to their potential.
- Simplify the registration process by publishing it in the app stores. The current process requires several steps, which cause a time delay for users and thus make "seamless onboarding" difficult. In addition, the release had to be done manually due to restrictive settings on company devices. A release in the app store would prevent such problems.
- Integration of a button to update one's GPS position within the app. This function facilitates correct positioning, and a "double-select" interaction for uploading photos should be introduced so that users can enter or readjust their GPS position correctly.
- Switching the map view to a satellite view. This makes it easier to recognise waste heat sources, and it is also possible to estimate the height of objects/heat sources using Google Earth 3D, for example.
- Integration of notifications for finding heat sources and invitations to groups. This also regularly encourages users to use the app, but a good balance must be struck so as not to exert a disruptive influence.
- The token logic should be adapted so that the confirmation of heat sources is only possible between different groups/crews. The "report" function for uploaded heat sources should be reframed to create a positive connotation and thus encourage use by users.

5 RESULTS

The current results have been established due to two test phases with a very small amount of payed testers, and thus can not enable to elaborate the total waste heat potentials in Vienna and Graz. The 31 test users found about 230 individual spots with a possible waste heat potential, and for about 10% of them, detailed information was collected. It has to be noticed that the test users werepayed for about 5-8 hours of testing including the survey and thus it can be assumed that only very limited time for searching was aquired.

The results have been evaluated on different levels: First the images uploaded by the testers have been checked by waste heat experts within the HotCity project team for validity (is it according to what we are looking for –as explained in the tutorial–,correct classification, correct GPS position). Second, the detailed input data to derive the waste heat potential were also validated by waste heat experts.

5.1 Visualisation and Economic feasibility evaluation of results

The data stored on the backend was accessed via the developed API, pre-processed and filtered to eliminate the waste heat proposals reported by the players, to be most likely wrong.Therefore R-Scripts have been developed which makes it easy to analyse the data after each test run.

5.1.1 Visualisation

A simple web-application was developed to simplify the evaluation process for experts and visualise the collected waste heat proposals by the tester.The following figure shows exemplarily one of these waste heat proposals, a re-cooler on the roof top of a building in Vienna.

5.1.2 Economic feasibility evaluator

Based on a limited amount of input parameters, a simplified economic feasibility calculation of waste heat utilisation is carried out in order to evaluate if the waste heat sources identified by the users can be actually used. Here, the characteristics of the waste heat sourceand possible heat consumers (e.g. nearby buildings) were compared with regard to: energy supply and demand, available and required temperature level (including the requirements for the integration of heat pumps if the source temperature is lower than the consumers temperature), economic factors, a possible pipe routing and substations. The economic evaluation

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of the utilization of the different waste heat potentials found by the users is done on the basis of the two key figures "profitability" and "payback time" and is indicated in the form of a "profitability score".

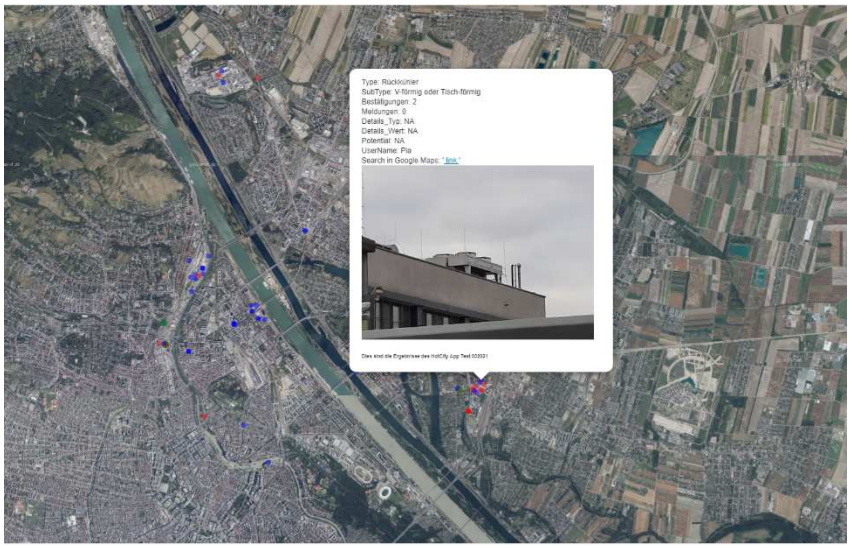

Fig. 4: Waste heat proposals result visualisation web-application screenshot

The results are displayed with help of "economic efficiency scores" i.e. a traffic light system (green, yellow, red), a comparison with a reference system for providing the heating service (e.g. gas boiler) is possible. It should be noted that these estimates are based on partly idealised assumptions. Nevertheless, the results indicatesif an economic use of waste heat sources seems to be realistic.

The developed method was implemened with R-Shiny[10] into an interactive web-application enabling users to evaluate, by chooosing the location and pathway, where the waste heat source would be needed. The following example shows the application (left side) as well as an example of evaluationfor a choosen pathway (right side).

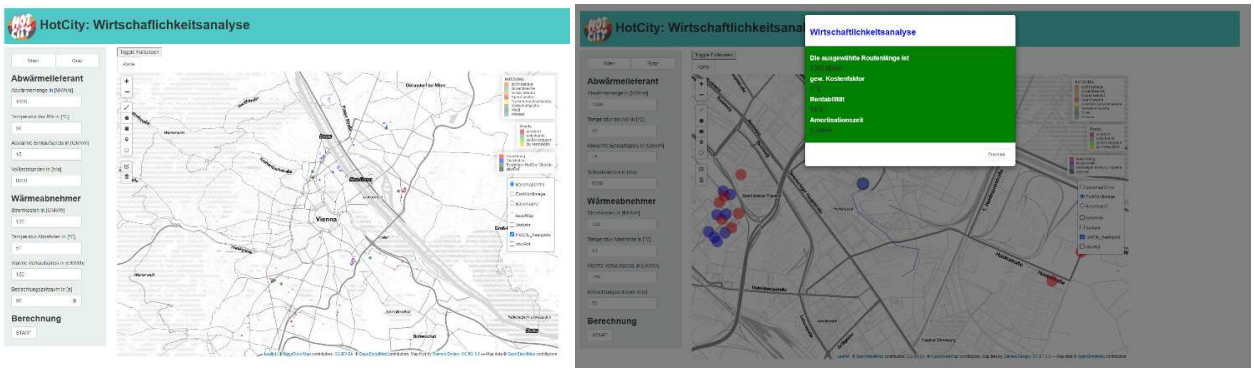

Fig. 5: Screenshots of the Economic feasibility evaluator web-application

6 CONCLUSION AND OUTLOOK

Gamification can be a promising way to identify urban energy data such as waste heat. The reward system could be secured in a transparent way using the energy-efficient proof of stake blockchain Ardor. The HotCity App has been sucessfully developed and tested in two Austrian cities. The two test phases have shown that the app seems to be very promising from a user point of view as the usability score shows. The lessons learned from the two test phases demonstrate that a good briefing (tutorial material) is important to gain useful results within the respective context. Compared to the already existing waste heat data for Vienna and Graz new promising waste heat proposals could be found, which have not been in the data sets so far and for some existing data sets an increased accuracy of the GPS position could be established thanks to the crowdsourcing approach. Interestingly even with the relatively low amout of testers a significant number of valid waste heat proposals could be found. However the tests also helped us to identify potential obstacles especially regarding details attached to heat spot entries which can be used for estimating the amount of

[10] https://shiny.rstudio.com/

waste heat for each waste heat proposal. The results indicate that these are hard to collect with the current app, thus more advanced users (experts) or higher incentives are needed to collect this information. The developed interactive evaluation tool (web-application) seems to be a very good starting point for experts (not necessarily players) in order to filter the most promising waste heat proposals and to estimate their actual potential.

6.1 Further data collection possibilities

The HotCity project aimed for a proof of concept if gamification is a valid method to collect useful spatial energy data in an efficient way, waste heat was only one example for this the following section discusses other possible use cases for the Game/App. The project also investigated conceptually which data and which methods are needed to collect energy-relevant data by means of gamification. In the project, the focus is basically on the topic of determining waste heat potential. However, in order to make more general statements about which energy-relevant data can be collected over-all via crowd-based methods, further data and possible sources were analysed.

The following core questions were addressed:

- How can the game be generalised and used to collect a wide range of energy-relevant data and applications?
- What data can be collected?
- How can the effort for the players on the one hand, and for the software developers with the greatest possible benefit be reduced?

When comparing the results from the players' point of view with the software developers' point of view, it is noticeable that the data that is easy to collect for players is quite difficult to implement for the software developers. For many of the data sets to be collected, the players can upload photos in the app, which is possible without much effort. The photo provided shouldthen be analysed using automated methods in order to derive energy-relevant data from it. Algorithms for image recognition should be applied or developed, which considerably increases the effort for the (software) developers.

The method of "self-assessment" is again time-consuming for players or only possible with expert knowledge anyway; on the programming side, this is implemented through forms so that the findings can be entered as free text or by means of guided questions.

In the course of the app development, a way was found to keep the complexity of the app as low as possible for the players, but still to design the functionalities for data collection and to choose the features of the app in such a way that the programming effort remains justifiable.

The gained results and the additional use cases discussed above vote for a further development of the prototype, especially as it seems that many of these still open issues can be solved with relative low effort and the applicability in different regions and contexts are high.

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