LIFE GreenYourRoute: A European innovative logistic platform for last mile delivery of goods in urban environment

Deliverable B4.2: *Testing and evaluation report of GYR platform*

Partner responsible for this report: UTH

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Abbreviations

GYR	GreenYourRoute project

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Abstract

GreenYourRoute technical team with the support of demonstrators, performed a series of test in order to evaluate the GYR platform and its applications (i.e. web and mobile apps) against 6 criteria i.e. functionality, usability, interface, compatibility, performance and security. The testing phase was part of the iterative development of GreenYourRoute platform and its application. Iterative development was preferred to the classical waterfall lifecycle, as the latter is used in cases where we have no changes when demonstrating a system in an operational environment. The iterative development (see Figure 1 below) included mainly 4 steps: a) the pilot demonstration phase of the apps into the operational environment of the demonstrators, b) the evaluation phase by the users/demonstrators of the results obtained by the pilot demonstration, c) the revision phase of the apps based on the obtained results, and finally d) the testing phase of the apps.

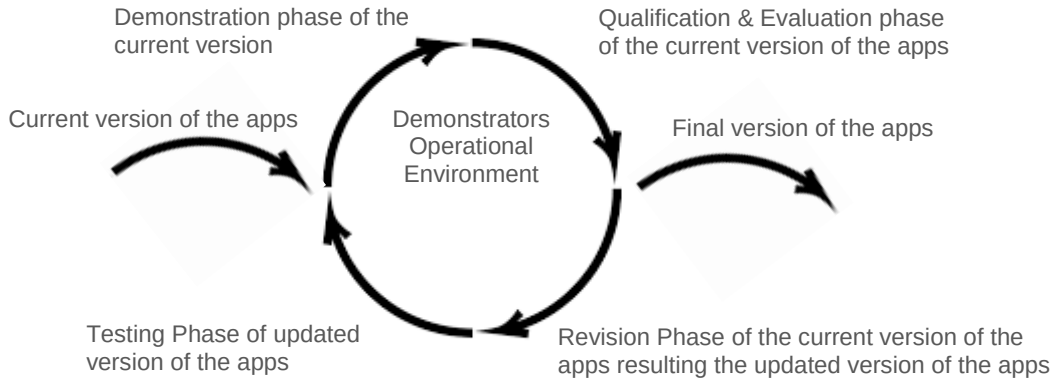

Figure 1: Iterative development of GreenYourRoute platform and applications

Based on the suggestions provided by demonstrators and the evaluation and testing results, a fine-tuning of different services of the GYR platform and its apps was occurred in order to build-up their final version. This fine-tuning included adjustments of the previous versions to satisfy the needs of demonstrators as well as potential new users. These adjustments included improvements on the user interfaces, available web toolboxes, uploading and downloading of data, statistics records and comprehensibility of the routing solutions. After tests were passed and related issues were resolved, the final version of the GYR platform and its apps was available for integration to demonstrators' environment. These final versions of the apps are fully functional versions (e.g. fully functional user interface) including fully functional components (e.g. fully functional solution approach).

GYR team selects high combinatorial real numerical examples not only to evaluate the robustness of GYR apps but also in order to follow green procurement rules and get maximum environmental advantage during the second demonstration phase (e.g. maximum of PM reduction during testing). The energy saving of higher combinatorial examples (ex. 10 vehicles visiting 200 points) is significant higher comparing less combinatorial examples (ex. 1 vehicle visiting 3 points). An optimization tool integrated into the apps, has more to optimize when the problem is more complicated.

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The 1st demonstration phase, implemented during Action B4 of the LIFE GreenYourRoute project, was significant critical for the development of GYR innovative logistic platform for last mile delivery of goods for sustainable mobility in urban regions. The business requirements of demonstration were taken under consideration to develop a platform highly marketable and useful for logistic companies. A deeply consideration of the business and operational requirements guarantees that the developed service is easy compatible and replicable and allows GYR team to understand further the market where GYR company is introduced.

All four phases of the iterative development (i.e. the demonstration, the evaluation, the revision, and the testing phase) are part of the development of the apps. For this reason, GYR team decided to present the full details of the development of the apps including the testing and evaluation results in the Deliverable 3.2: Report on the development of the web and mobile application. The testing and evaluation results are described in Deliverable 3.2 as "Documents" (i.e. 11 documents for the web app and 10 documents for the mobile apps). In the current deliverable, we present the criteria against which the apps were tested and evaluated resulting their final versions.

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1 Introduction

GreenYoruRoute platform including web and mobile applications could be considered as a distributed system including a large number of users distributed all over the world and accessing it simultaneously, different execution environments with heterogeneous components such as different programming languages, different provided web services etc. composed of different hardware, network connections, operating systems. At the same time the system (i.e. GYR platform) has the ability of generating software components such as visualizing routing plans at run time according to user inputs (i.e. daily routing data) and server status (i.e. cost matrix generation, routing optimization algorithm).

The GreenYourRoute platform includes several components. The main components of the platform with their connections are presented in the following figure:

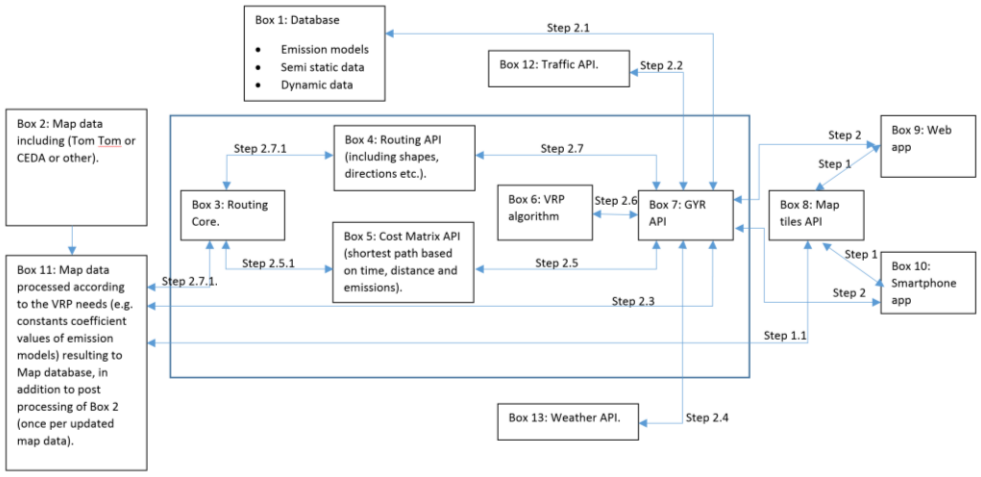

Figure 2: GreenYourRoute structure

The system includes several components referred to Figure 2 as "Box" which one of them has an important role for its operation. Additionally, these components have specific connection rules represented by software referred to Figure 2 as "Step".

Box 1 represents the GreenYourRoute database where static and dynamic data are stored (more details about GreenYourRoute database one may find in Deliverable B1.2). Box 2 includes map data coming from external service such as Tom Tom and Goolge maps. Box 3 includes the modeling approach and the optimization algorithm of the platform. Box 3 generates the optimal routing plan. Box 4 is the API of Box 3. Box 4 is an important component for the GYR platform as it fully support the replicability and extensibility of the GYR service (i.e. ITACA use this API into its routing system). Box 5 generates the cost matrix of a daily routing plan necessary for the definition of the optimal from environmental and socio-economic point of view. The cost matrix includes the distance between the visiting point as well as the time and the environmental impact travelling from one visiting point to the other. Box 6 includes the optimization algorithm and the modeling approach developed for the definition of the routing plans. Box 7 is the main API of the system i.e. the heart of the system. Box 7 implements the connection between the UI of the apps, the optimization algorithm, the

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map data, the external API (i.e. weather API, traffic API) and the database. Box 8 includes the map tiles necessary for the visualization of the routing plans. Box 9 and Box 10 are the user interface of the web and mobile apps. Box 11 is an intermediate to map data Box 2, Box 3, Box 7 and Box 8 and its main role is to retrieve specific data necessary to define the optimal daily routing plans. Finally, Box 12 and Box 13 are external components of GYR service necessary to define weather data and traffic data for the transport network where the visiting point are located.

These boxes necessities connection rules (referred to as "Step") for their communication and connection. The description of each one of the "Step" presented in Figure 2 is:

- Step 1 includes request from user for map tiles and the response of the Box 8 with tiles. This step is implemented through Box 8 and Box 11.
- Step 1.1 includes request from the Map database of the appropriate tiles.
- Step 2 gets a routing request based on the daily routing needs and sends back the response of Box 7 including the complete routing plan.
- Step 2.1 includes the query to the database for appropriate data, e.g. vehicles, customers, emission models, traffic and weather data.
- Step 2.2 includes consumption (request and response) of the traffic API for additional traffic data (real time).
- Step 2.3 includes the query to the database for appropriate data (request and response).
- Step 2.4 includes consumption (request and response) of the weather API for additional weather data (real time).
- Step 2.5 includes request for the cost matrix of the routing needs and gives back to Box 7 the distance, time and emission matrixes.
- Step 2.5.1 implements the communication between Box 3 and Box 5.
- Step 2.5.1.1 includes request for map data to be used in Box 3 and sends request for map data for solution visualization.
- Step 2.6 sends to Box 6 the cost matrixes and routing needs (defined by Step 2 request) and gives back the routing plan.
- Step 2.7 sends request for shapes and directions according to the routing planning (VRP: Vehicle routing problem) solution and receives the shapes with associated directions.
- Step 2.7.1 implements the communication between Box 3 and Box 4.

Note: Connection between Box 2 and Box 11 does not have any numbering, as it is not part of a routing request. It is a pre-processing procedure of the Map data in order to build up the Map database as expected by box 3. This map database should be updated each time that map data in box 2 are updated by the provider of this data (i.e. TomTom and Google).

The performed tests against the 6 selected criteria were implemented executing test scenarios for each one of the demonstrators. GYR team ensured that test cases cover necessary boundary conditions. Furthermore, invalid inputs by the user are followed by an appropriate error notification. GYR team developed a group of 80 representative examples for each one of demonstrators (i.e. ATHINAKI, PLUS, KOUKOUZELIS, CEDA and ITACA). Each group of

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examples included 60 examples representing average conditions of each demonstrator for each month of the year 2019 (i.e. five examples per month) and 20 examples, which represented extreme conditions of each demonstrator. The extreme conditions corresponds to the conditions where the total number of orders are too high or too low and the total number of available fleet of vehicle is too high or too low. GreenYourRoute technical team performed the tests using a manual approaches as well as an automated approaches.

The first level of tests includes the functionality tests (section 2) of the platform and applications, the second includes the usability tests (Section 3), the third includes the interface tests (Section 4), the forth the compatibility tests (Section 5), the fifth the performance tests (Section 6) and the sixth the security tests (Section 7).

2 Functionality

The functionality tests included testing of the developed forms for input data, cookies, how HTML elements are to be displayed on screen as well as testing associated with the routing data consistency and integrity. The functional tests were instrumental in verifying the functionalities of each & every aspect of the GreenYouRoute applications. Functionality testing were performed to verify that GYR web and mobile apps performs and functions correctly according to design specifications defined by the demonstrators in sub-action B4.1 during the 1st period of demonstration. During functionality testing, GYR technical team checked the text input, the menu functions and the core application functions which were installed on the localized virtual machines at UTH server room where the GYR server was setup.

The main objective of functional testing was to ensure that all of the functionalities of the GYR web and mobile applications function smoothly without issues. Functional testing verified whether the developed links (i.e. the steps presented in Figure 2) are operating correctly, testing cookies, reviewing forms (e.g. order form) on all webpages and mobile screens, evaluating partially database security, and validating CSS and HTML.

The functionality testing of the applications had to rely first on the test of the software components (i.e. Boxes) and the relationships between them (i.e. Steps).

Functional testing included testing of the web and mobile app from the perspective of user interface (web and mobile apps), GreenYourRoute database, and more. Interactions between the client (i.e. website) and the server (i.e. APIs) were also tested as a part of functional testing.

The GYR team implemented also several test for user flow on different web pages of the web application and different screens on the mobile applications identifying broken links and verifying inter-linking of the pre-final version of the apps. The GYR team run exploratory and edge test scenarios to verify if the functionalities cater to every type of input, which were inserted manually, automatically by an external provider (e.g. Tom Tom) or uploading a file following specific format.

The functionality testing included also the examination of potential faults in the web and mobile apps content. These faults could be significant errors corresponding to incorrect

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information, violation of the intellectual property laws or less significant such as typographical errors. In any case, GYR technical team in close collaboration with the users of GYR platform (i.e. representatives of the demonstrators) identified these fault before the release of the final version of GYR apps.

GYR database testing was part of the functionality testing of the GYR service. GYR database testing was mainly part of Action B1 of LIFE GreenYourRoute project. GYR web and mobile apps present static (i.e. cost matrix, elevation of road) as well as dynamic (i.e. visiting points, traffic conditions) content. GYR database has a sophisticated design as presented in Deliverable B1.2 in order to cater the needs of GYR service. GYR technical team using the database management system developed for testing extracted the necessary data for the 80 test scenarios descripted in the introduction of the current deliverable. The data were transmitted to the client environment of the web and mobile apps for display. Then the test users of the demonstrators verified with the support of the technical team that the whole data management approach results the correct data visualization. The test users ensured to the technical team that valid data were passed between the client and the server from the interface layers (e.g. the step 2.1, 2.5, 2.7.1 in Figure 2). Additionally, GYR technical team tested that the apps processes the developed scripts correctly, extracts the necessary data to the appropriate format and passes correctly to the GYR server-side with the appropriate SQL queries (e.g. the steps 2.7, 2.6, 2 in Figure 2).

3 Usability

Usability testing was a demanding and important testing phase of the web and mobile app. The user experience is critical for the successful integration of GYR service into the highly demanding business environment of 3PL companies and for the successful replication of GYR service into the business environment of different type of users (e.g. routing planning service providers, waste collection management authorities etc.). Usability test was implemented involving several representatives of the demonstrators (i.e. test users).

The usability testing did not involve functional tests. The usability tests involved non-functional tests, which focused on users' experience. The usability tests were performed based on the requirements defined in sub-action B4.1 by the demonstrator of the project. The usability tests included, the representatives of the demonstrators called test users, the requirements of the demonstrators and the facilitators, members of the technical team who guided and trained the test users on how to use the apps without influencing their behavior.

Usability testing included 2 steps: 1) The 1st step was the definition of the objectives based on the demonstrators requirements, and 2) The 2nd step was to find the appropriate end users of each demonstrator. The test users selected were between the personnel responsible for the manual daily routing planning of the companies involved into the project.

Usability aspects of the product were very important, else GYR's potential customers might not be interesting to use GYR service. The usability testing became extremely important, as the features in the product were tested from an end-user's perspective.

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To maximize the benefits of usability testing, GYR technical team gave access to GYR platform for testing to as large as possible potential users. The main menu for planning, optimizing and monitoring of routing plans, the drop-down list, the forms, the edit and delete functionalities etc. were tested by the end-users.

The test users which are representatives of the demonstrators as well as part of the technical team are defined in the beginning of the usability testing period. Specially care had taken for users with disabilities. Member of the technical team of UTH, is a person with disabilities and he was a key person for the usability tests.

Usability testing aimed also to verify to what extent GYR applications are developed in a such way that they could be considered by the users as easy to use. The design of the platform (sub-action B3.1) and the implementation of the user interface (sub-action B3.2-3.3) both affected usability. Thus, usability testing was mainly centered around testing the user interface of both web and mobile apps: issues concerning the correct content rendering (e.g. graphics, text editing format, languages) as well as the clarity of messages (i.e. error messages, informatics messages), prompts, and commands that were to be considered and verified.

Usability is a critical issue for an application. Indeed, it may determine the success of the application. As a consequence, an application's front-end and the way users interact with it often are aspects that are given greater care and attention during the application's iterative development process (i.e. Action B3). When web and mobile apps usability testing was carried out, issues related to an application's navigation completeness, correctness, and conciseness were also considered and verified. The requirement defined by the demonstrators in sub-activity B4.1 are tested by the user of the apps concerning their usability.

Accessibility testing was also implemented in the frame of usability testing. Accessibility testing is considered a particular type of usability testing whose aim is to verify that the access to GYR web and mobile apps' content were allowed even in the presence of reduced hardware and software configurations on the client side (e.g. browser configurations) or in the presence of users with disabilities.

In the case of Web applications, accessibility rules such as the one provided by the Web Content Accessibility Guidelines have been established, so that accessibility testing represents verification the compliance of an application with such rules. The application itself is generally the main cause of accessibility problems, even when accessibility failures may be due to the configuration of the running environment (e.g. browsers where the execution of scripts is disabled).

The three phases of usability testing implemented were: 1) Explorative, 2) Assessment and 3) Comparative:

- The explorative phase: GYR technical team considered the explorative phase in the early stages of the testing process and before the iterative development of the pre-final version of the apps. The idea was that the earlier developers run usability testing in the process, the lesser the risk to the GYR service.

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- The assessment phase: The assessment phase describes the user's assessment of the product. It was an end-to-end test execution and analyzed the GYR service effectiveness and user satisfaction.
- The comparative phase: The comparative phase involved comparing the GYR service with the manual definition of the routing planning based on experience.

Finally, in the frame of the usability testing phase, GYR technical team implemented periodically some additional tests concerning the interactivity, the layout, the readability, the display, the time sensitivity, and the personalization of the web and mobile apps.

4 Interface

The user interface testing focused on the performance of the web and mobile application's graphical user interface. The commonly occurring UI defects were tested and improved in the frame of the iterative development of the apps. UI testing identified several issues including the alignment of the buttons of the apps, the resizing issues of windows and pop-up menus, overlapping of different forms in different windows of the apps, the browsing issues when different browsers are used, the content of the fields, the correct presentation of messages including errors etc.

The test users, selected for the usability tests having a checklist prepared by GYR technical team, ensured that the components of the frontend interface were passed tests related to fonts, color schemes, hyperlinks, UI components, alignment, content, and expected (based on the requirements defined in sub action B4.1) behavior of the UI.

The selected test users, during interface testing, with the support of the GYR technical team found the errors of the most updated version of the apps and inform GYR developers to revise their UI. The errors were related to: 1) the data entry into the forms and the content display as well as 2) related to the navigation links.

- *Data and forms*
  The interface testing checked that the mandatory data fields and forms were properly placed in the main screen of the apps. The test users tested the apps to ensure that the data inserted in a form were properly transmitted into the GYR database and they had the proper width and type. The user experience was also affected (as in any app) by the appropriate default values in the pop-up menus of the apps. The test users tested the default values and made several recommendations in order to use default values without the use of the pull-down menus. On the top, the test users evaluated the auto-complete functionalities. The apps were tested under several browsers conditions (e.g. refresh, back button etc.) so the already entered data into a form were not corrupted. Another important component of the UI was the error messages. The test users evaluated the obtain error messages when the apps are not properly used or when an operation is performed.
- *Navigation links*
  Each navigation link was tested to ensure that the proper content object or function is reached (i.e. specific pages were opened, external links were fully functional etc.). In addition, the links within each content object were exercised to uncover bad URLs or

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links to improper content objects or functions and the links to external services (i.e. traffic and weather APIs) were tested for accuracy and availability.

5 Compatibility

The compatibility testing included the browser compatibility, the platform compatibility, and the mobile device compatibility. The compatibility testing ensured that the apps experience is uniform across browsers and devices that maybe in use by the end users. Different browsers and different type of mobile devised were tested.

Compatibility testing ensured that the apps runs as expected on the GYR running environment that has various combinations of hardware, software, and middleware (i.e. "Box" and "Step").

Compatibility Testing included test of the apps within different environments such as different computers, display devices, operating systems, browsers, and network connections.

The issues solved were downloading (e.g. routing plan) and uploading (e.g. data of orders) speed, page layout difference between different browsers and mobile devices, font styles and forms display.

6 Performance

Once the functionality, usability, interface, compatibility of the apps were tested e.g. across different browser & external services combinations, GYR technical team started the performance testing to evaluate from the perspective of reliability and scalability the apps. Special attention was taken in order to guarantee that the performance of the apps would not be deteriorate when a large number of users are login.

The performance of the apps is affected by the performance of 1) Box 4 where the routing planning is optimized, 2) Box 5 and Box 3 where the cost matrix is generated, 3) Box 7 which is the main API of the platform and 4) the connections between the Boxes (i.e. "Step" as presented in Figure 2).

Performance testing were performed at different internet connections, different number of user and different size of data sets (e.g. orders, vehicle fleets, swifts etc.). GYR technical team performed several stress test in order to evaluate the CPU solution time of the modeling and solution approach developed in Action B2, evaluate the response time of the cost matrix generation and data mining for the daily routing planning and evaluate the response time of GYR API. The desired CPU solution time of Box 4 was defined to max 90 seconds and the response time of Box 5, Box3 and Box 7 was defined to max 5 seconds.

GYR apps compared to many other apps have the advantage that the number of user is a priory defined (i.e. the number of accounts is known). The main aspect affecting the performance of the GYR apps is the daily needs for routing planning. The number of orders to be served and the number of available vehicles are not known when an account is setup. GYR service does not know beforehand how many visiting points should be served and how vehicles may be used to serve these points. GYR team performed a large number of

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simulations before the real life practice period. Simultaneous request for the generation of different cost matrixes and simultaneous request for the solution of the vehicle routing problem are implemented. The main objective of the performance testing was to guarantee that GYR service is always available under specific and acceptable response times. The failures or errors covered by performance testing were mainly due to running environment faults (e.g. scarce resources, poorly deployed resources) of the back-end (i.e. GYR platform).

Finally, part of the performance testing was the stress testing. Stress testing was conducted to evaluate a GYR service and its components (i.e. web and mobile apps) at or beyond their limits of its specified requirements by the demonstrators. The response of the GYR service was evaluated at activity peaks that can exceed GYR platform limitations in order to verify if the system crashes or if the system is able to recover from such conditions.

7 Security

The security testing was an important component of the testing and evaluation process. The users of the app as well as potential user have to upload sensitive data into the GYR database. These data (described in details in Action B1) includes info about customers, volumes of products to deliver/pick-up, location of customers etc. These data should be transferred between GYR services and the database without any risk and they must be protected by any potential "hacking attack".

Security tests were performed by GYR technical team every time that a new version of the apps was released. Security tests checked the secure transmission, authentication, authorization. Cyber-attack is a threat for GYR platform and for this reason GYR team tested GYR platform against them to guarantee that GYR service never turns unavailable to its intended users by temporarily or indefinitely disrupting services of a host connected to a network.

Security testing aimed to verify the effectiveness of the overall apps defenses against undesired access of an unauthorized users. Security tests also verified, apps' capability to preserve system resources from improper use, and granting authorized users access to authorized services and data.

Security testing was designed by GYR technical team to avoid vulnerabilities of the client-side environment, the network communications that occur as data are passed from client to server and back again, and the server-side environment. To protect GYR platform including GYR database against these vulnerabilities, the following security elements were implemented and tested:

- Firewall: Network firewall guards GYR platform against malicious access from the outside the server, such as malware-infested websites or vulnerable open network ports. The network firewall was tested to guarantee limited access of internal users to outside connections
- Authentication: GYR verification mechanism that validates the identity of users, servers, and services allowing communication through "Steps" in-between "Boxes" was tested to allow communication only when both sides are verified by the GYR system.

• Encryption. GYR encoding mechanism that protects sensitive data by modifying it in a way that makes it impossible to read by those with malicious intent was tested as log as an updated version of GYR apps is released.
• Authorization. GYR filtering mechanism that allows access to the users, servers and services environment was tested using authorization scripts.

8 Conclusion

All tests passed successfully and the GYR apps were available for their integration in to the business operational environment of the five demonstrators of LIFE GYR project. After the integration, the real life practice of the apps started and continues until the end of the project in order to increase the environmental and socio-economic impact of the LIFE GYR project.

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