JOURNAL OF ENERGY SYSTEMS

2022, *6*(2)

2602-2052 DOI: 10.30521/jes.1021838 Research Article

Development progress of power prediction robot and platform: Its world level very long term prototyping example

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Submitted: *10.11.2021*
Accepted: *27.04.2022*
Published: *30.06.2022*

Abstract: Global Power Prediction Systems prototype version 2021 is presented with its system decomposition, scope, geographical/administrative/power grid decompositions, and similar. "Welcome", "sign-up", "log-in", and "non-registered user main" web-interfaces are designed as draft on Quant UX. Map canvas is given as world political map with/without world power grid layers on QGIS 3.16.7-Hannover. Data input file is prepared based on several sources (1971-2018). It includes minimum and maximum values due to source value differences. 70/30 principle is applied for train/test splitting (training/testing sets: 1971-2003/2004-2018). 10 models are prepared on R version 4.1.1 with RStudio 2021.09.0+351. These are R::base(lm), R::base(glm), R::tidymodels::parsnip(engine("lm")), R::tidymodels::parsnip(engine("glmnet")) with lasso regularization, R::tidymodels::parsnip(engine("glmnet")) with ridge regularization, R::forecast(auto.arima) auto autoregressive integrated moving average (ARIMA), R::forecast(arima) ARIMA(1,1,2), and ARIMA(1,1,8). Electricity demand in kilowatt-hours at the World level zone for up to 500-years (2019-2519) prediction period with only 1-year interval is forecasted. The best model is the auto ARIMA (mean absolute percentage error MAPE and symmetric mean absolute percentage error SMAPE for minimum and maximum electricity consumption respectively 1,1652; 6,6471; 1,1622; 6,9043). Ex-post and ex-ante plots with 80%-95% confidence intervals are prepared in R::tidyverse::ggplot2. There are 3 alternative scripts (long, short, RStudio Cloud). Their respective runtimes are 41,45; 25,44; and 43,33 seconds. Ex-ante 500-year period (2019-2519) is indicative and informative.

Keywords: *Global power prediction system, Platform, Power, Prototyping, Robot*

Cite this paper as:	Saracoglu, B.Ö., Development progress of power prediction robot and platform: Its world level very long term prototyping example. *Journal of Energy Systems* 2022; *6*(2): 253-289, DOI: 10.30521/jes.1021838

Nomenclature	
α	Alpha Demo Versions
β	Beta Demo Versions
ACF	Autocorrelation and Cross-Correlation Function
AI	Artificial Intelligence
API	Application Programming Interface
approx.	approximate
ARIMA	Autoregressive Integrated Moving Average
Covid-19 or COVID-19	Coronavirus 2019 or Coronavirus disease 2019 or coronavirus 2 (SARS-CoV-2)
D&D	Development, and Demonstration
D3&D	Development, Demonstration, Deployment, And Diffusion
DNI	Direct Normal Irradiation
DSO	Distribution System Operator
EDA	Exploratory Data Analysis
ESM	Electronic Supplementary Files
GIS	Geographic Information Systems
GP2D/G2PD/GPPD	Global Power Plant Developers (synonymous acronym of GP2D, G2PD or GPPD)
GP2E/G2PE/GPPE	Global Power Plant Engineers (synonymous acronym of GP2E, G2PE or GPPE)
GP2O/G2PO/GPPO	Global Power Plant Owners (synonymous acronym of GP2O, G2PO or GPPO)
GP2S/G2PS/GPPS	Global Power Prediction Systems (synonymous acronym of GP2S, G2PS or GPPS)
GPCPS	Global Power Consumption Prediction Systems

Journal of Energy Systems

2022, 6(2)

2602-2052

DOI: 10.30521/jes.1021838

Research Article

GPCPS-CPS	Global Power Consumption Prediction Systems Cost (Price) Prediction System
GPCPS-EPS	Global Power Consumption Prediction Systems Electricity Prediction System
GPCPS-OM	Global Power Consumption Prediction Systems O&M Prediction System
GPCPS-P2S	Global Power Consumption Prediction Systems Power Prediction System
GPCPS-P2S-MaP2S	Global Power Consumption Prediction Systems Maximum Power Prediction System
GPCPS-P2S-MiP2S	Global Power Consumption Prediction Systems Minimum Power Prediction System
GPCPS-P3S	Global Power Consumption Prediction Systems Peak Power Prediction System
GPCPS-PSPS	Global Power Consumption Prediction Systems Power Storage Prediction System
GPDPS	Global Power Distribution Prediction Systems
GPDPS-CPS	Global Power Distribution Prediction Systems Cost Prediction Systems
GPDPS-EPS	Global Power Distribution Prediction Systems Electricity Flow Prediction Systems
GPDPS-OM	Global Power Distribution Prediction Systems O&M Prediction Systems
GPDPS-PFPS	Global Power Distribution Prediction Systems Power Flow Prediction Systems
GPDPS-PFPS-MaPFPS	Global Power Distribution Prediction Systems Maximum Power Flow Prediction Systems
GPDPS-PFPS-MiPFPS	Global Power Distribution Prediction Systems Minimum Power Flow Prediction Systems
GPDPS-P2FPS	Global Power Distribution Prediction Systems Peak Power Flow Prediction Systems
GPDPS-PSFPS	Global Power Distribution Prediction Systems Power Storage Flow Prediction Systems
GPGPS	Global Power Generation Prediction Systems
GPGPS-CPS	Global Power Generation Prediction Systems Cost Prediction Systems
GPGPS-EPS	Global Power Generation Prediction Systems Electricity Prediction Systems
GPGPS-OM	Global Power Generation Prediction Systems Operations and Maintenance Prediction Systems
GPGPS-P2S	Global Power Generation Prediction Systems Power Prediction Systems
GPGPS-P2S-MaP2S	Global Power Generation Prediction Systems Maximum Power Prediction Systems
GPGPS-P2S-MiP2S	Global Power Generation Prediction Systems Minimum Power Prediction Systems
GPGPS-P3S	Global Power Generation Prediction Systems Peak Power Prediction Systems
GPGPS-PSPS	Global Power Generation Prediction Systems Power Storage Prediction Systems
GPTPS	Global Power Transmission Prediction Systems
GPTPS-CPS	Global Power Transmission Prediction Systems Cost Prediction Systems
GPTPS-EPS	Global Power Transmission Prediction Systems Electricity Flow Prediction Systems
GPTPS-OM	Global Power Transmission Prediction Systems O&M Prediction Systems
GPTPS-PFPS	Global Power Transmission Prediction Systems Power Flow Prediction Systems
GPTPS-PFPS-MaPFPS	Global Power Transmission Prediction Systems Maximum Power Flow Prediction Systems
GPTPS-PFPS-MiPFPS	Global Power Transmission Prediction Systems Minimum Power Flow Prediction Systems
GPTPS-P2FPS	Global Power Transmission Prediction Systems Peak Power Flow Prediction Systems
GPTPS-PSFPS	Global Power Transmission Prediction Systems Power Storage Flow Prediction Systems
ID	Identity Document
IEA	International Energy Agency
KiB	Kibibyte (binary prefix, ISO/IEC 80000, International Organization for Standardization: ISO, International Electrotechnical Commission: IEC)
kWh	kilowatt-hour
MAPE	Mean Absolute Percentage Error
ML	Machine Learning
MW	Megawatt
NREL	National Renewable Energy Laboratory
OAHIDR	Original Anatolian Honeybees Investment Decision Robot
OS	Operating System
O&M	Operations and Maintenance
PACF	Partial Autocorrelation and Cross-Correlation Function
PhD.	Doctor of Philosophy
prototype	Prototype Versions
Turkiye	Turkey (instead of Turkey due to linguistics/language related trouble/problem, word roots under investigation)
RD3&D	Research, Development, Demonstration, Deployment, And Diffusion
SMAPE	Symmetric Mean Absolute Percentage Error
TSO	Transmission System Operator
TWh	terawatt-hour
UN	United Nations
U.S.A	United States of America
WB	World Bank

1. INTRODUCTION

This paper presents the development achievements of the proposed robot and platform called "*Global Power Prediction Systems GP2S/G2PS/GPPS*" (Appendix.A.1, Electronic Supplementary Files: ESM.1-3, ESM.1-49). It is expert-driven, event-driven, data-driven, and fact-based. It is a worldwide real-time geographic information systems (GIS) based web and device application. It runs on all devices like desktops, laptops, and smartphones. It is possible to fully develop (*GP2S*) in today's technological and technical artificial intelligence (AI) capabilities. Hence, it is not a utopia. (*GP2S*) and its related proposed robots and platforms (e.g. *Global Power Plant Developers GP2D/G2PD/GPPD*, *Global Power Plant Engineers GP2E/G2PE/GPPE, Global Power Plant Owners GP2O/G2PO/GPPO*) are all sorts of patentable ideas like other patent granted ideas [1-34] (patents [35-42]) (Appendix.A.2, ESM.4). The titles of these robots and platforms have changed during their research, development, demonstration, deployment, and diffusion (RD3&D) periods. They may be revised or changed in the following development activities too. They are the global solutions for some global problems like emissions, power, and warming (ESM.5). In brief, the first aim and motivation of this article are to publicize the D3&D progresses of (*GP2S*) prototype with some of its design components and examples.

(*GP2S*) is far beyond the currently available tools, in other words far ahead of this century. A few of its unique properties are accountability, collaboration, collectivity, generality, intelligency, flexibility, enlarge-ability, extension-ability, reliability, report-ability, scalability, self-enlarge-ability, self-expandability, self-report-ability, self-learning-ability, and transparency. It is designed for all forecasting time horizons with all-time intervals in all regions (zones) of the World (Appendix.A.3-5, ESM.6-10). It can also include Mars, Moon, and the Universe in the future. The zones may be administrative, geographical, and/or power system divisions. (*GP2S*) has many design elements (hundreds, thousands, or millions) such as consoles and modules (Appendix.A.6, ESM.11). There are many different roles on (*GP2S*) like power producer, transmission system operator, power consumer, robot and platform developer, and robot and platform evaluator (ESM.12-13). Some people may have many roles at the same time on (*GP2S*). All developers will be able to access anything on (*GP2S*) to develop anything for (*GP2S*), even robots' and platforms' self-developing capabilities would get mature enough. All developers may prepare their re-runnable, repeatable, reproducible, reusable, and replicable contributions with any open-source computer language and tool as per their preference (ESM.14-18). While (*GP2S*) has been developed, demonstrated, deployed, and diffused over time, the prototype, alpha (α), and beta (β) demo versions will also be presented to all end-users to get their feedback (ESM.11). Only the final stable, secure and safe robot and platform will officially be used with only a few best-performed forecasting models and designs by the end-users (user roles, power project developer roles) (ESM.12-13). A general optimization algorithm is developed and presented for all modules and model series for their learning, feedback, and selection loop in this study too (ESM.19). All currently available developers' communities, platforms, and tools in the World, that may somehow be related to (*GP2S*), have taken into consideration for adaptation, collaboration, cooperation, data, information, integration, and preference issues during (*GP2S*)'s D3&D stages (ESM.20-27). Developers using those platforms and tools all over the World may join the development activities of (*GP2S*) in the following years. (*GP2S*) may take their attention and interest, so that any developer can contribute and build any part or some parts of it. It should be noted that (*GP2S*) will help to decrease all costs of power generation, transmission, distribution, and consumption (e.g. environmental, monetary, raw material) through its automatic decision-making, management, operation, and optimization capabilities. It will enable experienced engineers, and experts in absolutely and/or relatively developed and rich countries (e.g. China, Germany, Norway, U.S.A., Turkiye: Turkey) to present the best cheapest decarbonized interconnected %100 renewable power super grids and global grid (ESM.10), and the best cheapest decarbonized remote %100 renewable power grids (separate) including all futuristic philosophies. Moreover, those experts will help other engineers and researchers in the inexperienced countries and grids (interconnected, separate or remote) or directly design all elements in the inexperienced countries for free (charge free) (e.g. Afghanistan, Chad, Congo, Iraq, Libya, Mozambique, Uganda, Rwanda, Somalia, Sudan, Syria) [7,11-16,26,43,44]. In short, the second aim and motivation of this publication are to contribute a small part of the huge (*GP2S*) prototype related to its very-long-term time horizon (up to 500-years) with only 1-year interval at the World level region example in the *Global Power Consumption Prediction Systems* (*GPCPS*) subsystems (Appendix.A.1, ESM.3).

This research paper is presented in 5 sections. Section 2 presents the literature. Section 3 presents the ongoing wire framing and prototyping activities. Section 4 presents conclusions and section 5 gives information about a small portion of the future works.

2. LITERATURE REVIEW

The publications in only the English language have been collected since the 2010s. The publications have been taken into account for each system element (component, object) for their development and improvement. The literature is mentioned without any comparison, criticism, explanation, or discussion considering the publisher's page limit and research paper's scope. The cited publications are only for presenting the available products, software, and literature. All citations in all publications in the literature are evaluated by their authors' subjective evaluations. There is not any objective system and approach in the scientific community yet. The number of citations of a publication, the total number of publications of an author, the granted research funds of a researcher, the academic positions and titles of academic staff, also universities, states, organizations, or similar means scientifically nothing (no importance for comparisons), because of many scientific facts [45-51]. Naturally, the problem is humankind. It is a good or bad, innocent or criminal problem. In other words, any type of measures does not show the quality of a publication or the talent of an academic or a researcher. In contrast, the transparency in the publication processes and publications means scientifically something. It is important and meaningful. Likewise, the current citations are the author's own decisions (random or not), but the transparency and importance of this paper and (*GP2S*) are undoubting and obvious according to the author's point of view.

The first literature cluster is the long-term forecasting time horizon of electricity consumption prediction topic that includes studies like Sorjamaa et.al (2007), Karabulut et.al (2008), Hong (2009), Hyndman and Fan (2009), Azadeh et.al (2011), Dilaver and Hunt (2011), Lee and Tong (2011), Ghanbari et.al (2013), Akarsu (2017), and Hamzacebi et.al (2019) [52-61]. Some of those studies can be grouped under the long-term forecasting time horizon of load or peak load prediction topic too.

The second literature cluster is the medium-term forecasting time horizon of electricity consumption prediction topic that includes studies like Abiyev (2009), Azadeh et.al. (2009), Bunnoon et.al. (2009), Azadeh et.al. (2011), Moreno-Chaparro et.al (2011), Erol et.al (2012), Iranmanesh et.al (2012), Marwala and Twala (2014), Xiong et.al (2014), and Hassan et.al (2015) [62-71]. Some of those studies can be grouped under the medium-term forecasting time horizon of load prediction topic too.

The third literature cluster is the short-term forecasting time horizon of electricity consumption prediction topic that includes studies like Jain et.al. (2009), Mordjaoui et.al (2010), Centra (2011), Duan et.al (2011), Gabr et.al (2011), Jain and Jain (2013), Barzamini et.al (2014), Shayeghi and Ghasemi (2015), Elamin and Fukushige (2018), and Jun et.al (2018) [72-81]. Some of those studies can be grouped under the short-term forecasting time horizon of load prediction topic too.

The fourth literature cluster is the very-short-term forecasting time horizon of electricity consumption prediction topic that includes studies like Liu et.al (1996), Sachdeva et.al (2011), Ismail and Mansor (2011), Cardenas et.al (2012), Helmy et.al (2012), Mohamed et.al (2012), Deshani et.al (2013), Hu et.al (2013), Moraes et.al (2013), and Wang et.al (2018) [82-91]. Some of those studies can be grouped under the very-short-term forecasting time horizon of load prediction topic too.

The fifth literature cluster is the price forecasting of electricity consumption topic that includes studies like Esfahani (2011), Gupta et.al (2013), Hassan et.al (2014), Jun and Peiwen (2018), Ugurlu et.al. (2018), Gayretli et.al (2019), Wang et.al (2019), Gianfreda et.al (2020), Yang et.al (2020), and Zhang and Troitzsch (2021) [92-101]. Those studies are not only in the scope of (*GP2S*), but also some of them are in the scope of (*GP2D*), (*GP2E*), and (*GP2O*). It is worth mentioning that the critical monetary/financial forecasting item in the current proposed robots and platforms is the cost, not the price because these proposed robots and platforms recommend radical changes in the power markets. They are crowd-based and equity-based systems, in other words, development and investment participation. They try to minimize and stabilize the price by minimizing the cost (cost-price predictability, non-volatility, stability, trustworthiness). Hence, these robots and platforms are radical and recommend radical changes to all communities all over the World as soon as possible to take action against climate change, emissions, and environmental conservation, protection, rehabilitation, and restoration. They may be the most efficient systems in all aspects.

The sixth literature cluster is the long to very-short-term forecasting time horizon of peak power demand prediction topic that includes studies like Ismail (2009), Goia et.al (2010), Asad (2012), AboGaleela et.al (2013), Arfoa (2015), Sonika et.al (2015), Khuntia et.al (2016), Ogurlu and Cetinkaya (2016), Ozerdem et.al (2017), and McNeil et.al (2019) [102-111]. Some of those studies can be grouped under the long to very-short-term forecasting time horizon of load prediction topic too.

Many other clusters can also be presented with other publications in the literature like NREL (2012) (National Renewable Energy Laboratory: NREL) in demand, generation, cost, and similar; Ciabattoni et.al (2014) in home energy consumption; Barasa et.al (2016) in 100% renewable electricity generation in Sub-Saharan Africa; Mai et.al (2016) in power generation costs; Bogdanov et.al (2017) in 100% electricity generation in Kazakhstan; Alduailij et.al (2020) in smart buildings energy consumption; Brinkman et.al (2021) in renewable integration of U.S.A, Canada, and Mexico (North America); Gammon and Sallah (2021) in electric vehicle recharging load demand; Li et.al (2021) in wind power consumption capacity; and Weinand et.al (2021) in cost efficiency of decentralized energy systems [112-121], however, it is not necessary and possible to cite all of them in this paper. It is important to note that (*GP2S*), and some parts of (*GP2D*), (*GP2E*), and (*GP2O*) cover the scope of all or some parts of those studies in the literature.

In this section, it is also crucial to mention some available tools and web pages too (ESM.20): Australian Energy Market Operator in Australia; Hourly Electric Grid Monitor, Cambium, Open Energy Information in U.S.A.; European Transmission System Operators in Europe; TenneT in Germany and Netherlands; Load Dispatch Information System in Turkiye; Global Solar Atlas; Global Wind Atlas; and International Renewable Energy Agency Global Atlas for Renewable Energy.

In short, millions of documents and information sources have been studied and investigated during the RD3&D stages of (*GP2S*). It is realized that there is nothing similar to (*GP2S*) in the World. There is not even any idea, invention, academic, scientific and popular publication, web page, or any similar source in the same perspective. (*GP2S*) is powerful, unifying, and unique. Moreover, (*GP2D*), (*GP2E*), and (*GP2O*) are also proven breakthrough ideas integrated and run altogether to protect the Planet Earth and to design and operate the best power grids. It is hoped that their importance will be understood in the following years, and they will be developed and run by the next human generations with different version perspectives like only humans, humans and robots, and only robots.

3. WORLD LEVEL VERY LONG TERM PROTOTYPING EXAMPLE

(*GP2S*) may gain attention and importance with the AI strategies and initiatives of developed, high-tech, and prosperous communities and countries like China, Russia, and U.S.A. [12-17,122-125]. (*GP2S*) is also a direct solution in the power industry for general transparency and reproducibility criticisms of the

AI research too [126]. It does not have any web address or website yet. It may get a globally accepted web address like the international organizations' websites of United Nations, International Energy Agency, or World Energy Council (ESM.28, ESM.48). (*GP2S*) may get data and information at the same, top or bottom levels from the current data sources during its D&D period (ESM.8-10, ESM.16-17). It has some common design elements like "*data universe*", and "*forecast accuracy metrics universe*" that can serve in all subsystems like *(GPCPS)* and integrated systems like (*GP2E*) (ESM.11). Ultimately, it aims to predict in the shortest time interval and the longest time horizon for all zones in almost real-time conditions with high precision through its direct data gathering systems. For example, fictitious time-location: 21/08/2050 21:58:28, Tokyo; forecasting power demand (Megawatt: MW), 20/01/2500 10:00:00-11:00:00, Ankara. The developers will be able to present anything related to (*GP2S*) at any time. They can present not only positive findings but also negative findings for experience sharing and also teaching machines how to learn and how to teach themselves. Accordingly, the current development and demonstration progress of (*GP2S*) as a deliverable item or document is presented in this section.

3.1. Lessons Learned in the Previous Development Activities and GP2S Models

The crucial technical experiences in the previous D3&D activities of (*GP2S*) are shortly as follows [5-7,11-17]:

1. Building automatic forecasting systems are possible.

2. Exploratory data analysis (EDA) is a must, whenever there is some data (data-driven *GP2S*).

3. Whenever there is not any data or the available data is not sufficient, experts (expert-driven *GP2S*) and specially developed models play important roles. Those models should take into account the similarities and differences of the study zones.

4. Whenever any event occurs like a pandemic (e.g. Covid-19), event-driven models take their actions (event-driven *GP2S*).

5. Everything in (*GP2S*) should be based on the facts.

6. It is wise to use a combination of data, expert and event-driven approaches simultaneously.

7. Whenever there is some data, simple linear regression model is always a good initialization [12]. It is very simple and effective for understanding variables.

8. There are many methods in the literature like time-series (based on the previous values of the same variable on the time axis), regression, fuzzy, grey (based on the same variable and/or any other variable), and similar.

Each method has its pros and cons. Designing a system founded on only one method is a poor development approach. All methods should be investigated. (9) When applying statistics in AI including machine learning (ML) and automating them, special care must be given (see "lie with statistics", "common statistical mistakes" [127-129]) (ESM.29). (10) Automating fuzzification, defuzzification, ruling and rulemaking, greyification, and similar are possible [12,14-16,25,130-133]. (7) Least number of features is always better for models if they can be reasonably accurate, because they are cheap in the cost of data, model, and computation. For instance, one input variable is better than two input variables, two input variables are better than three input variables. (8) To reach the best models, it may be meaningful to use many methods and models at the same time (e.g. Autoregressive Integrated Moving Average (ARIMA) + regression). (9) There may be some global models serving all time-frames [14-16]. Those sorts of global models should also be studied very well. (10) Benchmarking and baselining are crucial. Benchmark and baseline models should be presented very well.

According to these experiences, the development and demonstration of (*GP2S*) have been continued and the current improvements are made and presented in this publication.

3.2. Some Crucial System Design Elements and Their Reasoning

The proposed (*GP2S*) is a huge system (robot and platform) so its D3&D processes are strictly obeyed the systems engineering principles like logical decomposition, and product validation [134,135]. Each system element (component, object) serves only one purpose. A few system elements of the current system diagram under D&D are given in Table 1 (ESM.11).

Table 1. A few crucial system elements of (GP2S) prototype version 2020.

System design element	Automatic data & information collection	
Design element	Reasoning	Discussion
Consumption side sensors & devices	(*GP2S*) is fed and run with consumption data at its consumption side. Without any data, it cannot act and operate as per its design principles. Correct, accurate, and real/near-real-time data acquisition is the key and core competence in (*GP2S*). Data must be geographical base. That location data and information allow defining administrative and power grid division data and information too. More importantly, data also helps experts to learn and understand the phenomenon in all aspects and perspectives. While consumption data is taken into consideration, all related and relevant data and information are also taken into account and collected concurrently. More specifically, data and information related to consumption must also be collected like climate, weather, personal attitudes, equipment, and appliances like refrigerators, dishwashers, and water heaters. Hence, consumption side sensors and devices system element is crucial and necessary by the time being.	There are already many sensors and devices that can measure the consumption. They should be designed as accurate and precise as possible, also connected to data centers in real/near-real-time principles. Wireless or similar communication technologies must be used. Moreover, data must be shared on real/near-time basis with consumers, because that data and information are consumers' rights. That sort of data and information can be managed with small applications too. There already some tools in the product market for these kinds of purposes. Precautionary actions and consideration for private personal rights have to be always taken into account. Personal rights (e.g. private life, family life, home, correspondence) are personal rights and nobody has the right to violate them. Permissions must be taken in advance. All data and information must be shared appropriately. For instance, data and information can be shared anonymously with developers during D&D studies. In the operation phases of (*GP2S*), personal data and information will be handled by secure and safe protocols.
Generation side sensors & devices	(*GP2S*) is fed and run with generation data at its generation side. Without any data, it cannot act and operate as per its design principles. Correct, accurate, and real/near-real-time data acquisition is the key and core competence in (*GP2S*). Data must be geographical base. That location data and information allow defining administrative and power grid division data and information too. More importantly, data also helps experts to learn and understand the phenomenon in all aspects and perspectives. While generation data is taken into consideration, all related and relevant data and information are also taken into account and collected concurrently. More specifically, data and information related to generation must also	There are already many sensors and devices that can measure the generation or production. They should be designed as accurate and precise as possible, also connected to data centers in real/near-real-time principles. Wireless or similar communication technologies must be used. Moreover, data must be shared in real/near-time with power producers and their investors, because that data and information are power producers' and investors' rights. That sort of data and information can be managed with small applications too. There are already some tools in the product market for these kinds of purposes. Precautionary actions and consideration of private life, family life, home, and correspondence rights have to be always taken into account.

	be collected like climate, weather, and equipment like turbines, generators, and direct normal irradiation (DNI). Hence, generation side sensors and devices system element is crucial and necessary by the time being.	Personal rights are personal rights and nobody has the right to violate them. Permissions must be taken in advance. All data and information must be shared appropriately. For instance, data and information can be shared with developers in only power plant-wise, not with investors' details.
System design element	Automatic exploratory data analysis & principle data fitting	
Design element	Reasoning	Discussion
Model Features Selectors	(*GP2S*) is capable of adding and using all possible features in the Universe. Models may use only one feature, a few, some, many, or all features. Until the full automation, features may be selected by expert approaches. While features are selected by experts and model developers, AI models for feature selection may be applied and compared with experts' decisions. The causation must be presented for each model to build up a huge dataset for reasoning to teach machines to prepare models with their causation descriptions. Hence, model features selectors system element is crucial and necessary by the time being.	All features must be found and presented as large information sources. Each feature must be studied very well. All data and information related to features must be presented in detail. They must be GIS-based as much as possible. It must be remembered or never be forgotten that AI and ML can come up with very accurate models, but they may not be reasonable and meaningful (see "lie with statistics", "common statistical mistakes", "spurious correlations" [127-129]) (ESM.29).
Modules Preparators, Descriptive Statisticians	Descriptive statistics are very important for (*GP2S*) because it describes and summarizes data very well. All items related to descriptive statistics must be calculated and presented to users and developers. For instance, measures of central tendency like mean, median, and mode; and measures of dispersion or variability like mean absolute deviation, variance, standard deviation, range, quartiles, skewness, and the Kurtosis. Hence, modules preparators, and descriptive statisticians system element is crucial and necessary by the time being.	The scope and details of descriptive statistics must be different for users and developers. Users may request less information about descriptive statistics than developers. Moreover, some users may request more items of descriptive statistics, than other users. Similarly, some developers may request more items of descriptive statistics, than other developers. Hence, all descriptive statistics-related items must be calculated in real/near-real-time principles, and presented to users and developers as per their preferences.
Modules Preparators, Inferential Statisticians	Inferential statistics is very important for (*GP2S*) because it provides information or general patterns about a large group from a sample data about that large group very well. It also provides information about some or all large groups from some or all sample data. It compares the differences between two or more data groups with some hypothesis testing, the Pearson's and/or the Spearman's r test, and the Chi-square test of independence or similar for different purposes. Hence, modules preparators and inferential statisticians system element is crucial and necessary by the time being.	The scope and details of inferential statistics must be different for users and developers. Users may request less information about inferential statistics than developers. Moreover, some users may request more items of inferential statistics, than other users. And some users may request none of them. Similarly, some developers may request more items of inferential statistics, than other developers. And some developers request none. Hence, all inferential statistics-related items must be calculated in real/near-real-time principles and presented to users and developers as per their preferences.
Modules Preparators, Simple	Simple regression is very important for (*GP2S*) because it provides straightforward information about relationships and approximations of some or all features very	The scope and details of simple regressions must be different for users and developers. Users may request less information about simple regressions than developers.

Regression Fitters	well. It helps model development very much. Hence, modules preparators, simple regression fitters system element is crucial and necessary by the time being.	Moreover, some users may request more items of simple regressions, than other users. And some users may request none of them. Similarly, some developers may request more items of simple regressions, than other developers. And some developers request none. Hence, all simple regressions-related items must be calculated in real/near-real-time principles and presented to users and developers as per their preferences.
Modules Preparators, Simple Probability Distribution Fitters	Probability distributions are very important for (*GP2S*) because they provide straightforward information about the nature of variability and approximations of some or all features very well. They help model development very much. Hence, modules preparators, simple probability distribution fitters system element is crucial and necessary by the time being.	The scope and details of probability distributions must be different for users and developers. Users may request less information about probability distributions than developers. Moreover, some users may request more items of probability distributions, than other users. And some users may request none of them. Similarly, some developers may request more items of probability distributions, than other developers. And some developers request none. Hence, all probability distributions related items must be calculated in real/near-real-time principles and presented to users and developers as per their preferences.
System design element	Automatic best models presentation	
Design element	Reasoning	Discussion
The Best Models Listers-Selectors	Any prepared model is valuable for (*GP2S*). All those models will be stored in the memory to teach (*GP2S*), how to learn and build new models, and to find the best model by itself (self-enlarge-ability, self-expandability, self-report-ability, self-learning-ability). 3 different best-model-lists are thought in its current version. The top 100 models, the top 50 models, and the top 10 models can be presented appropriately. The top 5 models (the top five forecasters) will be concurrently run in the real/near-real-time principles according to the current plans. That may be reduced to the best 3 models, the best 2 models, and the best model in the future. Hence, the best models listers-selectors and system element is crucial and necessary by the time being.	All prepared models have the opportunity to compete with others in the real/near-real-time principles. In other words, forecasting competitions can be made directly in the real/near-real-time in (*GP2S*). All developers will be able to get information about the history of forecasting competitions on real/near-real time. (*GP2S*) standardizes forecasting competitions and makes them real/near-real-time in power industry (for forecasting competitions [136]). Moreover, (*GP2S*) integrates forecasting journals and preprints (ESM.11). Developers can present their preprints on available and new preprint websites and afterward directly forward their works to journals like the Journal of Forecasting, the International Journal of Forecasting, and the Journal of the American Statistical Association (for forecasting journals [137])
The Best Models Displays & Reports	The top 5 models will be displayed in real/near-real-time principles according to the preference of users and developers. Hence, the best models displays & reports system element is crucial and necessary by the time being.	Only a few best models should be run on real/near-real-time principles, because of the cost considerations like run times. It is thought that those top 5 models will cover the whole possibility space forever. Whenever it is realized that some other models in the (*GP2S*) memory perform better, because of anything new, those models can be run in real/near-real-time.

System design element	Automatic forecasting accuracy calculation	
Design element	Reasoning	Discussion
Forecast Accuracy Metrics Universe	Forecasting measures are very important for (*GP2S*), They help developers to compare their models with others. Hence, (*GP2S*) standardizes forecasting accuracy, precision, or performance metrics and presents a common practice tool for developers. (ESM.11, ESM.30). “Forecast Accuracy Metrics Universe” handles to manage all available and new forecasting accuracy, precision, or performance metrics [10,12,14-17,25]. Hence, the forecast accuracy metrics universe system element is crucial and necessary by the time being.	There are many forecasting accuracy, precision, or performance metrics in the literature. Some publications present some metrics, and some other publications present some other metrics. Those sorts of metric differences make model comparisons impossible. (*GP2S*) solve that major improperness with its “Forecast Accuracy Metrics Universe”. Developers will be able to use it directly. All metrics in the Universe will be calculated automatically. Hence, selection of the best models will be easier and more correct.

3.3. Some Prototyping and Wireframing Elements and Their Reasoning

There are many web pages of (*GP2S*) like “welcome”, “help center”, “open issues”, “sign-up”, “private user main”, “non-registered user main”, and “developers main”, that run on any operating system (OS) (ESM.31-32). Some of those web pages may also have some links to social media applications like Facebook, Twitter, TikTok, and WhatsApp for communication and public relations (ESM.48). Hence, all web-interfaces (user-interfaces) need to be designed one by one with great care. That activity requires thinking a lot and takes time. Those web pages should be user-friendly and cost-effectively in respect of many factors like file sizes (minimization of storage hard disk and similar medium’s material consumption in the World [32]). For instance, there is not any need for advertisements, banners, and unnecessary news or activities info. In this D&D period, 3 important screens have been designed as draft based on the cognitive ergonomics principles and presented in Table 2 and Fig.1 (*Appendix.B.1*, ESM.33).

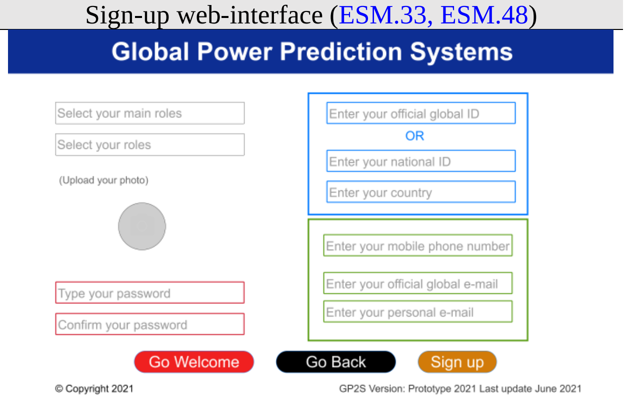
Welcome web-interface (ESM.33, ESM.48)	Sign-up web-interface (ESM.33, ESM.48)
	

Figure 1. G2PS prototype 2020.

All current D&D activities are finalized with free and open-source software. There are many available prototyping and wireframing software (ESM.34). Some of them are free and open-source, which are in the same philosophy of (*GP2S*), so they are taken into consideration. The most interesting ones found during the current D&D activities are Penpot and Quant UX (ESM.48). Both of them are used during this study, but all activities are finalized and presented in Quant UX, because it has light color screen version, widgets, simulation, and similar capabilities. “Welcome”, “sign up”, and “log in” web-interfaces with all its elements (components, objects) are directly built on Quant UX in this study. There is not any additional scripting or coding necessary. The icons are designed on spreadsheet software and presented as image files by using Paint3D (ESM.48). “Non-registered user” web-interface has some important elements such as “map canvas”, “downloads”, “plots”, and “statistics”. Mapping tasks are finalized with free and open-source software, QGIS 3.16.7-Hannover (ESM.33, ESM.35, ESM.48, ESM WORLD.qgz). Python and R (ESM.36) with their integrated software like Jupyter Notebook, R Markdown, and RStudio are powerful and great statistical computing, AI-ML software for plotting, statistics, and modeling (ESM.14, ESM.48). R version 4.1.1 (2021-08-10) "Kick Things" with RStudio 2021.09.0+351 "Ghost Orchid" Release is used in this study for backward-looking (ex-post) and forward-looking (ex-ante) analysis and predictions with some 3rd party packages. A few base built-in and 3rd party package functions on R are also called and run in the current models. "Map canvas", "plots", and "statistics" elements are tried to be designed similar to QGIS and RStudio (e.g. menu toolbar, map navigation, attributes toolbar, layers list/browser panel) in this D&D period for user easiness and familiarity, because some developers of QGIS, SAGA GIS, R, RStudio, Python, and similar may be interested in developing (*GP2S*) in the near future too (ESM.48).

Table 2. Some design elements of (GP2S) web pages.

Web interface:	Welcome screen view	
Design element	Reasoning	Discussion
Log-in	(*GP2S*) stores many personal data and information. For instance, any power consumer can access specific and private consumption data and information. If a consumer may have a factory in Afghanistan, a farm in Somalia, and a house in Turkey, that consumer can access all power consumption data of that factory, that farm and that house in anywhere and anytime. Similarly, a power plant investor may have some share in a small hydropower plant in Georgia, a photovoltaics power plant in Turkiye, and a pumped-storage hydropower plant in China, that investor can access all power generation data of each power plant and summary of total generation data in anywhere and anytime. Hence, secure and safe access is crucial and log-in button is necessary by the time being. Log-in element is designed for that purpose on the welcome webpage.	According to many sensitive data and information related to privacy issues, secure and safe access on a log-in webpage with password protection and other protection means are necessary. By the time being, only password protection is designed for (*GP2S*). In the future, all biometric methods like fingerprint, eye iris, face, voice recognition, security, and protection applications will be adapted to (*GP2S*). Log-in should be easy and fast, if possible without any typing effort.
Sign-up	(*GP2S*) is in its early D&D stages. Hence, it is not integrated with any e-government systems yet. Moreover, many countries have not had any e-government applications yet. Hence, sign-up button is necessary by the time being. Sign-up element is designed for that purpose on the welcome webpage.	Sign-up will match user consumption and generation data and information directly. Hence, it requires preinstalled databases. By the time being, there is not any automatic registration designed for (*GP2S*). In the future, registration will not be necessary and can be done automatically with the birth of a human being (new birth, newborn). In the early stages, sign-up should be easy and fast, if possible without any typing effort. At the mature stages, sign-up can fully be eliminated.
Non-registered	(*GP2S*) has many private and non-private data and information. There are many data and information on it, that do not require any sign-up and log-in, because they are not sensitive, and private. They are public releases. They should be and must be public releases. Anybody who wants to access that data and information can access it with one click, direct web address, or link. Hence, non-registered button is necessary by the	(*GP2S*) presents all non-private data and information without any registration requirement. Only private data and information will be presented by asking for registration. Also, developers can access developers tools, and specific data and information by registration. Nothing can be developed without any registration because (*GP2S*) will monitor and track development activities and gives some

	time being. Non-registered element is designed for that purpose on the welcome webpage.	bonuses to developers. Developers can directly get some financial and social advantages so that their registration is necessary. Power and energy consumption of the World, continents, countries, transmission system operators (TSO), distribution system operators (DSO), provinces, towns, villages, and smaller or larger regions are presented as public release without any registration.
Web interface:	Sign-up screen view	
Design element	Reasoning	Discussion
Global Identity Document (Global ID, Official Global ID)	Nowadays, there is not any "global ID" application in the World. (*GP2S*) recommends to the World to start thinking, accepting, and applying "global ID" approach. Any human in the World should have a "global ID" that will help coordination of all human related activities. If that recommendation is accepted, then sign-up procedure needs only "global ID" information. Hence, "enter your official global ID" button is necessary by the time being. "Enter your official global ID" element is designed for that purpose on the sign-up webpage.	There are many global problems, so that global solutions are necessary (ESM.5). (*GP2S*) proposes and recommends "global ID" to solve those global problems. "Global ID" is a necessity for other proposed and recommended global systems during this study too like "Global Population Systems", "Global Food Systems", "Global Water Systems", and "Global Health Systems" (ESM.3). When "global ID" is accepted and applied, there is not any need for "national ID", and "country" information. Above all, there is no need for passports and country ID cards anymore in real life too. In addition, there is no need for credit cards, traveler checks, public bus tickets, plane tickets, or similar. Everything will be simpler with "global ID" (think Z generation: born 1995- (ESM.37)). For example evacuation, immigration, migration, search and rescue, and refugee problems can be solved with "global ID" (Table 2 Note 1). In the future, "global ID" can be given automatically with the birth of human beings (new birth, newborn). (see Note 1)
Global e-mail (Official Global e-mail)	Nowadays, there is not any "official global e-mail" approach in the World. (*GP2S*) recommends to the World to start thinking, accepting, and applying "official global e-mail" approach. Any human in the World should have an "official global e-mail" that will help to communication with official organizations without any paperwork (paperless lifestyle, paper-free lifestyle, paperless office, paper-free office) and misinformation risk. If that recommendation is accepted, then the sign-up procedure needs only "official global e-mail" information. Hence, "official global e-mail" is necessary by the time being. "Official global e-mail" element is designed for that purpose on the sign-up webpage.	(*GP2S*) proposes and recommends "official global e-mail" to solve global problems (ESM.5). "Official global e-mail" is a necessity for other proposed and recommended global systems (ESM.3). When "official global e-mail" is accepted and applied, there is not any need for paperwork and additional human power to handle communication with international and national official organizations. Everything will be simpler with "official global e-mail". In the future, an "official global e-mail" can be given automatically with the birth of human beings (new birth, newborn).
Role	(*GP2S*) has many roles (ESM.12-13). Main roles are "user", "project developer", and "(*GP2S*) developer". Those main roles have their roles. "Project developer" and "(*GP2S*)	(*GP2S*) gives opportunity to all developers to be a part of a large community. It is open to anybody and everybody who want to contribute to

	developer" roles are special roles and need approval and acceptance in many cases because they will be able to reach any data and information to develop anything. The activities of those people have to be checked in the system. Hence, "select your main roles" and "select your roles" are necessary by the time being. "Select your main roles" and "select your roles" elements are designed for that purpose on the sign-up webpage.	power industry, and (*GP2S*) robot and platform. It does not discriminate and marginalize anybody (no alienation, othering, marginalization, and similar). It does not have any political view. It does not polarize anybody. It does not torture and/or kill anybody. It aims for environmental recovery, freedom, justice, peace, and prosperity in the World. On the other hand, it is not an unorganized platform. It is not Dingo's stable (Dingo's Stables in Istanbul, Turkiye). Strict rules and regulations will be executed to protect the rights of users and developers. Nobody is allowed to act criminally and stupidly on (*GP2S*). Everything will be under control. New developers will always be reviewed and educated by senior and experienced developers. New developers will step by step get new levels with their successions (step by step, level by level). They will learn how to learn, how to develop, how to present, and how to teach to newcomers.
Web interface:	Non-registered user main screen view	
Design element	Reasoning	Discussion
Map Canvas	(*GP2S*) tries to make anything and everything simple. Map canvas helps to visualize any study area in the World. It is related to the zone system element, which is a selective element. Moreover, zones can be selected on the map canvas too. In addition, any study zones on the map canvas can be downloadable in all open and free formats and the most used formats like *.qgz (QGIS), and *.kml (Google Earth Web). They can be printed in *.pdf and similar too. Hence, "map canvas" is necessary by the time being. "Map canvas" element is designed for that purpose on the non-registered user webpage.	Map canvas is a great tool for interactions and visualizations on the web-interface. The design philosophy of (*GP2S*) is simplicity and collectivity, so the map canvas is tried to be designed as other free and open tools. As a result, users will be familiar with the web-interface and can use (*GP2S*) easily. Users can select different layers with ease and get information about them too. Moreover, (GP2S) may take the attention and interest of free and open-source software developers like QGIS, SAGA, R, RStudio, and Python with this approach too.
Backward Looking (Ex-post)	The past is crucial for (*GP2S*) because it is expert-driven, event-driven, data-driven, and fact-based. It always has simple and complex on time backwards computations. It presents historical data in a plot according to the time horizon and time interval selection by users. It also gives descriptive statistics and similar information. It expresses the ex-post analysis in a plot with a model selection option. There will be only data view, data and simple linear regression (linear model fitting) analysis with or without confidence band view, and data with each top 5 models (the top five forecaster) and their confidence bands views as options in the selection box. Hence, "backward-looking" is necessary by the time being. "Backward-looking" element is designed for that purpose on the non-registered user webpage.	Backward-looking (ex-post) is a must to understand the phenomenon. Plotting the data helps a lot for interactions and visualizations on the web-interface. Simple linear regression is very helpful to see the trends. The top 5 models (the top five forecasters) run concurrently in real/near-real-time principles in (*GP2S*) so that they can be presented instantaneously. In the future, some time-series models like autoregressive, fuzzy, grey, or neural networks time series can be used as benchmark and baseline models. Then they can always be presented in this section with the top 5 models unless otherwise, they are not in the top 5 models.

Forward Looking (Ex-ante)	Actually, (*GP2S*) is developed to predict the future. It is a prediction robot and platform (system). It always has simple and complex on time forward computations. It presents projection data in a plot according to the time-horizon and time-interval selection options by users. It also gives prediction data and similar information. It expresses the ex-ante analysis in only one section with different models option. There will be simple linear regression (linear model fitting) analysis view and each top 5 models (top five forecasters) views as options in the selection box. Hence, "forward-looking" is necessary by the time being. "Forward-looking" element is designed for that purpose on the non-registered user webpage.	Forward-looking (ex-ante) is the aim of (*GP2S*). Plotting projections helps a lot for interactions and visualizations on the web-interface. Simple linear regression and the top 5 models (top five forecasters) run concurrently in real/near-real-time principles in (*GP2S*), so that they can be presented instantaneously. In the future, some time series models like autoregressive, fuzzy, grey, or neural networks time series can be used as benchmark and baseline models. Then they can always be presented in this section with the top 5 models unless otherwise, they are not in top 5 models.

Note 1*: For example evacuation, immigration, migration, search and rescue, and refugee problems like in Iraq, Libya, and Syria civil wars and wars, also climate change immigration, migration, and refugee problems like in North Africa, and Greater Central Asia, and Turkiye's immigration and refugee crisis (approx. 4-6 million or more) (ESM.38). Only a few of those immigrants and refugees may move back to their territories, where they lived before. They had their past lives (past), now they have their new lives (new), and they will have their new future lives (new future). Many of them have had their children in Turkiye. Those children are now in their 10s-20s. Most probably, those children, so their parents, may want to live in Turkiye or move to Europe and America. The demographic structures have already changed or have been changed. Most probably, nobody can stop that anymore. It is already too late for these regions like Bosnia and Herzegovina, Kosovo, and others. Iraq, Syria, Turkiye, Iran, Libya, and similar ones already lost that strategic game (think about game theory, decision- making, decision makers, and experts). The losers in this life and most probably the afterlife are Turkiye, Iran, Iraq, Syria, Libya, and similar [138]. The winners, who knows? Sufficient data and information are required to guess the future. In 10 years (2020-2030) and may be more or less (2020-.....) very strange things may happen in these regions too, especially Iran, Turkiye, Lebanon, and similar like the ones between 2000-2010 and 2010-2020. A land swaps approach may be required in the future. That land swaps approach should be a clear-cut, meaningful, rational, resalable, safe, and secure approach. Fair common practice valuations, asset valuations, estate valuations, property valuations, and value evaluations are necessary for that land swaps approach. An appropriate management is a must as a result of that demographic change. There are not any sufficient records and tracking systems in the World for those kinds of things yet. "Global ID" and "global e-mail" are recommended solutions for the management of data and information.*

3.4. 1971-2018 Ex-Post and 2019-2519 Ex-Ante Outcomes on Non-Registered User Web Interface

Although (*GP2S*) is of course going to be run with primary data sources (ESM.11), any data sources can be used during its D&D period. There are 3 main non-primary data sources in this study (Table 3, ESM.40-42). The data preprocessing is necessary in this study, because there is not any direct dataset available (Eq.1-6). That activity is performed on spreadsheet software. All calculations are in kilowatt-hours (kWh) unit, but the plots are presented in terawatt-hour (TWh) unit in consideration of accuracy, precision, performance and visualization (ESM.42). After unit conversions and calculations, 7 datasets are prepared for 3 input datasets of the current models.

Table 3. Data source details.

Data source	World Bank Open Data (ESM.40-42, ESM.48) (WB)
Dataset	Electric power consumption (kWh per capita)
Notes	It is not even a secondary source. It is probably a quaternary or later source. Its data incorporates with International Energy Agency (IEA). IEA might be its source. It is available for 1971-2014. It is directly downloaded from the webpage in *.csv format. It is effortless to get it. The data is in 2 decimals number precision.
Dataset	Population total
Notes	It is not even a secondary source. It is probably a quaternary or later source. Its data incorporates with United Nations (UN). UN might be its source. It is available for 1960-2020. It is directly downloaded from the webpage in *.csv format. It is effortless to get it. The data is in 0 decimal number precision.
Data source	International Energy Agency (ESM.40-42, ESM.48) (IEA)
Dataset	Electricity consumption (TWh)
Notes	It is not even a secondary source. It is probably a tertiary or later source. It is available for 1990-2018. Its 5 years periodical version can be downloaded from the webpage in *.csv format. Others are read and typed manually in 1 decimal precision (natural eye reading). It is arduous to get and prepare it. The data is in 2 decimals number precision.

Dataset	Electricity consumption/population (MWh per capita)
Notes	It is not even a secondary source. It is probably a tertiary or later source. It is available for 1990-2018. Its 5 years periodical version can be downloaded from the webpage in *.csv format. Others are read and typed manually in 1 decimal precision (natural eye reading). It is arduous to get and prepare it. Some data is in 2 decimals number precision. Some data in 1 decimal number precision.
Data source	United Nations (ESM.40-42, ESM.48) (UN)
Dataset	Electricity - Final energy consumption Kilowatt-hours, million
Notes	It is not even a secondary source. It is probably a tertiary or later source. It is available for 1990-2019. It is directly downloaded from the webpage in *.csv format. It is effortless to get it, but data preparation is necessary. There is not any World data in the file. Some data has more than 10 decimals number precision. It seems impossible.
Dataset	Electricity - Gross demand Kilowatt-hours, million
Notes	It is not even a secondary source. It is probably a tertiary or later source. It is available for 1990-2019. It is directly downloaded from the webpage in *.csv format. It is effortless to get it, but data preparation is necessary. There is not any World data in the file. Some data has more than 10 decimals number precision. It seems impossible.
Dataset	Annual Total Population at Mid-Year (thousands)
Notes	It is not even a secondary source. It is probably a tertiary or later source. It is available for 1990-2019. It is directly downloaded from the webpage in *.csv format. It is effortless to get it. The data is in 0 decimals number precision.
Data preprocessing	Unit conversion
IEA	"Electricity consumption (TWh)" is converted into "Electricity consumption (kWh)" (ESM.41-42)
IEA	"Electricity consumption/population (MWh per capita)" is converted into "Electricity consumption (kWh per capita)" (ESM.41-42)
UN	"Electricity-Final energy consumption Kilowatt-hours, million" is converted into "Electricity-Final energy consumption (kWh)" (ESM.41-42)
UN	"Electricity-Gross demand Kilowatt-hours, million" is converted into "Electricity-Gross demand (kWh)" (ESM.41-42)
UN	"Annual Total Population at Mid-Year (thousands)" is converted into "Annual Total Population at Mid-Year" (ESM.41-42)
Data preprocessing	Equations
WB	$"consumption\ (kWh)" = "consumption\ (kWh\ per\ capita)" \times "Population\ total"$ (1) electric power consumption: consumption
WB + IEA	$\text{consumption (kWh)} = \text{consumption/population (kWh per capita)} \times "Population\ total"$ (2) electricity consumption/population (MWh per capita): consumption/population (MWh per capita)
IEA + UN	$\text{consumption (kWh)} = \text{consumption/population (kWh per capita)} \times "Annual\ Total\ Population\ at\ Mid-Year"$ (3) electricity consumption/population (MWh per capita): consumption/population (MWh per capita)
Data preprocessing	Data correction
UN	There are missing and also technically impossible data in the UN datasets. For instance: Barbados, "Electricity-Final energy consumption", "2016", "Kilowatt-hours, million", "977.886110666667",""; India, "Electricity-Final energy consumption", "2017", "Kilowatt-hours, million", "1130328.44444444", ""; Costa Rica, "Electricity-Gross demand", "2015", "Kilowatt-hours, million", "10581.7313888889", ""; Kyrgyzstan, "Electricity-Gross demand", "2019", "Kilowatt-hours, million", "-2", ""; Russian Federation, "Electricity - Gross demand", "2019", "Kilowatt-hours, million", "-18431", "" ; Saudi Arabia, "Electricity - Gross demand", "2019", "Kilowatt-hours, million", "-30", "". The measurements cannot be so much accurate and precise in (kWh) unit. It seems impossible. Under these conditions, the numeric precision is kept the same in the summation calculations but rounded. The negative values are added to the previous year data and used with this assumption (Eq.4). The spreadsheet calculations precision is kept as the default. The final findings of the total

	electricity consumption (kWh) values are stored as 0 decimal number precisions in consideration of the accuracy and precision in (kWh). The equation for negative values $consumption_i = consumption_{i-1} + consumption_i$ (4) where i represents the year
Data preprocessing	Data cleaning
UN	There are missing and technically impossible data in the UN datasets. For instance: a count of 200 in 1990, 202 in 1991, 225 in 1991, 226 in 1994, and 72 in 2019. The number of countries in the World in 1990 or similar is not checked in this study, but a count of 72 in 2019 is not possible. It shows that the data and information flow or gathering has not been finalized yet. Hence, the value in 2019 is not taken into account in this study. As a result, the dataset is until 2019 (ESM.41).
Data preprocessing	Data splitting
WB + IEA + UN	The total electricity consumption (kWh) is calculated in 7 different datasets (ESM.41). WB-based dataset contains data for 1971-2014. WB+UN-based dataset contains data in 1971-2014. IEA-based dataset contains data for 1990-2018. IEA+WB-based dataset contains data in 1990-2018. IEA+UN-based dataset contains data for 1990-2018. UN-based dataset (final energy) contains data for 1990-2017. UN-based dataset (gross energy) contains data for 1990-2017. 1990 is the first data splitting point (1971-1989). 2015 is the second data splitting point (1990-2014). Hence, there are 3 data periods (1971-1989, 1990-2014, and 2015-2018). There are 2 different values for 1971-1989, 7 different values for 1990-2014, and 5 different values for 2015-2018.
Data preprocessing	Data merging
WB + IEA + UN	Some values are not as single values. There are multiple values on the same time axis. The values are not the same in the time-series dataset in the current study (ESM.41). The differences cause ambiguity, unsharpness, and uncertainty directly due to data, and data sources. There is not any self-maximum or self-minimum dataset among those 7 datasets. For instance, the difference between the preprocessed UN (Electricity - Gross demand Kilowatt-hours) and the preprocessed WB consumption (kWh) ranges between -228410943132 and 24314950670. That finding means that all gross demand values are not larger than others. Some of them are smaller and some of them are larger. However, the difference between the preprocessed UN (Electricity - Final energy consumption Kilowatt-hours) and the preprocessed WB consumption (kWh) ranges between -2845247249451 and -1423553567958. That finding means that all final demand values are smaller than the WB dataset. Accordingly, the current model deals with that ambiguity, unsharpness, and uncertainty by finding ranges of minimum and maximum values. The only improper data increasing or decreasing occurs in the minimum values of 1990 (9847807855574 kWh in 1989, 9811951366211 in 1990, 9974979090122 in 1991). That is not appropriate with the 7 datasets. That improperness is solved with linear interpolation of values in 1989 and 1991 (Eq.5). The new value in 1990 is reasonable and compatible with other datasets (9847807855574 in 1989, 9911393472848 in 1990, 9974979090122 in 1991). Linear interpolation: $consumption_i = consumption_x + (consumption_y - consumption_x) \times \frac{(i-x)}{(y-x)}$ (5) where *i* represents the year that the consumption value is found with linear interpolation *x* represents the previous year (go one point back in the time-series) used for linear interpolation *y* represents the future year (go one point forward in the time-series) used for linear interpolation $consumption_i$, $consumption_x$, $consumption_y$ are consumption values in those years Afterward, minimum, average (arithmetic mean, simple average), and maximum values are found and prepared for 1971-2018 as the ready-to-use dataset of this study in *.txt, *.csv formats. The simple arithmetic mean is used for the calculation of the average values (Eq.6). Simple arithmetic mean: average $consumption_i = \frac{(maximum\ consumption_i - minimum\ consumption_i)}{2}$ (6)

	The dataset files are ready to read by open source programming languages and tools like R + RStudio. There are 3 columns (year, minimum, maximum) in the file. The arithmetic mean can be calculated with a small scripting.

Note.1*: Data and information sources order as primary, secondary, tertiary, quaternary, quinary, senary, septenary, octonary, nonary, denary (ESM.48)*

According to these data source and data preprocessing activities 7 data files, that include time-series data in columns of "year", "minimum electricity consumption (kWh)", and "maximum electricity consumption (kWh)", are presented to researchers' communities on the World

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(ESM: RDGP2SWorld19712018Blank.csv, RDGP2SWorld19712018Blank.txt, RDGP2SWorld19712018Comma.csv,
RDGP2SWorld19712018Comma.txt, RDGP2SWorld19712018Semicolon.csv, RDGP2SWorld19712018Semicolon.txt,
RDGP2SWorld19712018Tab.tsv).
```

The coding/scripting/programming approach of all proposed robots and platforms (*GP2S*, *GP2D*, *GP2E*, *GP2O*) is the same, blocking (block, blocks). This blocking approach will hopefully make transitions (e.g. R to Python or Scilab to Python to R code transition automatically) very easy in the future (see TransCoder (ESM.48)). The current R script has a few blocks in this study. It consists of 16 main blocks such as (common) (1) clearing workspace and setting working directory, (2) checking missing packages and installing them, (4) finding data file directory or location and reading data files; (ex-post, backward-looking, historical analysis) (5) summarizing data, (6) executing, summarizing, and printing exploratory data analysis (EDA), (8) executing models for backward (e.g. linear regression, fuzzy, grey, ARIMA), (11) printing forecasting accuracy (forecast accuracy metrics universe); (ex-ante, forward-looking, projections) (14) executing models for forward (e.g. linear regression, fuzzy, grey, ARIMA) (ESM: GP2SWorldRScriptLongVersion.docx, GP2SWorldRCode.R). There are many available packages in R that can be used for D&D activities of (*GP2S*). All of them will be studied in detail and if necessary new ones should be published based on the strengths and weaknesses and properties of available packages. The following R packages are used in this study: Tidyverse 1.3.1, Tidymodels 0.1.4, ggExtra 0.9, forecast 8.15 [139-143]. The design of (*GP2S*) is founded directly running on the web, so its main design principle in data loading/calling activity is to install data file on web pages. There is not any web address, web page, and web file storage yet. Hence, the data file is read directly on the hard disk in this study. The read and write duration performances of some functions are tested in the current D&D activity too. The best and worst read duration performances in these data files are respectively R Tidyverse 1.3.1 read_table and R Tidyverse 1.3.1 read_csv functions [144,145]. The best and worst write duration performances in these data files are respectively R Tidyverse 1.3.1 read_delim and R Tidyverse 1.3.1 vroom_write functions.

Table 4. Data files and read write comparison.

Data source	File size	File size on disk	Read/write(6)	Times
read_csv …Comma.csv	1760 bytes	4096 bytes	0.678277 secs	21,2146
read_csv2 …Semicolon.csv	1760 bytes	4096 bytes	0.187845 secs	5,8753
read_tsv …Tab.tsv	1764 bytes	4096 bytes	0.1099031 secs	3,4375
read_delim …Blank.txt(1)	1760 bytes	4096 bytes	0.123899 secs	3,8752
read_table …Blank.txt	1760 bytes	4096 bytes	0.03197217 secs	1,0000
vroom …Comma.csv	1760 bytes	4096 bytes	0.157377 secs	4,9223
vroom …Semicolon.csv	1760 bytes	4096 bytes	0.1159 secs	3,6250
vroom …Tab.tsv	1764 bytes	4096 bytes	0.10991 secs	3,4377
write_csv …Comma.csv	478 bytes(2)	0 bytes	0.03397298 secs	1,2594
write_csv2 …Semicolon.csv	475 bytes(3)	0 bytes	0.03796601 secs	1,4075
write_tsv …Tab.tsv	478 bytes(4)	0 bytes	0.03008699 secs	1,1154
write_delim …Delim.txt	478 bytes(5)	0 bytes	0.02697492 secs	1,0000
vroom_write …CommaCSVVroom.csv	478 bytes	4096 bytes	0.02697706 secs	1,0001
vroom_write …SemicolonCSVVroom.csv	478 bytes	4096 bytes	0.05278111 secs	1,9567
vroom_write …TabVroom.csv	478 bytes	0 bytes	0.03297186 secs	1,2223

Note.1: (1) Blank is the one generated on spreadsheet software without any typing (e.g. tab), (2): Maximum data summary file: 478 bytes, minimum data summary file: 470 bytes; (3) Maximum data summary file: 475 bytes, minimum data summary file: 469 bytes; (4): Maximum data summary file: 478 bytes, minimum data summary file: 470 bytes; (5): Maximum data summary file: 478 bytes, minimum data summary file: 470 bytes; (6): Read, write duration at the run on 16/10/2021;

The design of (*GP2S*) runs and stores all models and methods in the World, so that 10 models are built in this study to present (*GP2S*) better (ESM: GP2SWorldRScriptLongVersion.docx, GP2SWorldRCode.R). These representative models are (Model 1) R base linear regression (lm) (Gaussian error distribution), (Model 2) R base generalized linear model (glm) (arbitrary response distributions, non-normal error distribution and normal error distribution/non-Gaussian error distribution and Gaussian error distribution) [146], (Model 3) R Tidymodels 0.1.4 parsnip linear regression (parsnip::linear_reg, engine("lm")) [146,147], (Model 4) R Tidymodels 0.1.4 parsnip generalized linear model with lasso regularization regression and "penalty = 0.001" (parsnip::linear_reg, engine("glmnet")), (Model 5) R Tidymodels 0.1.4 parsnip generalized linear model with ridge regularization regression and "penalty = 0.001" (parsnip::linear_reg, engine("glmnet")), (Model 6) R Tidymodels 0.1.4 parsnip generalized linear model with lasso regularization regression and "penalty = 1" (parsnip::linear_reg, engine("glmnet")), (Model 7) R Tidymodels 0.1.4 parsnip generalized linear model with ridge regularization regression and "penalty = 1" (parsnip::linear_reg, engine("glmnet")) [147-148], (Model 8) R forecast 8.15 automatic Autoregressive Integrated Moving Average (auto ARIMA) without seasonality (non-seasonal) (forecast::auto.arima), (Model 9) R forecast 8.15 ARIMA(1,1,2) (forecast::arima), and (Model 10) R forecast 8.15 ARIMA(1,1,8) (forecast::arima) [142-143]. All of them are scripted and executed with the following important preferences and details in this study: (a) generalized linear model (glm) is in its default error distribution, Gaussian error distribution; (b) parsnip generalized linear model with lasso regularization regression needs 2 input variables, so that a dummy variable is generated by year; (c) mixture = 1 is for pure lasso regularization regression, and mixture = 0 is for pure ridge regularization regression in Tidymodels 0.1.4 parsnip generalized linear model; (d) auto.arima function needs "seasonal=FALSE", and "lambda = "auto""; (e) ARIMA(p,d,q) models represent "p=order of the autoregressive part", "d=degree of first differencing involved", and "q=order of the moving average part"; (f) (p,d,q) for (1,1,2) and (1,1,8) is decided according to autocorrelation and cross-correlation function (ACF) and partial autocorrelation and cross-correlation function (PACF) plots in this study (ESM: GP2SWorldRScriptLongVersion.docx, GP2SWorldRCode.R).

Another important issue for models and scripts in this study is training sets and test sets (minimum electricity consumption, maximum electricity consumption) (ESM: GP2SWorldRScriptLongVersion.docx, GP2SWorldRCode.R). The datasets are split into 70/30 principle/rule. Hence, 1971-2003 is training period/set (70%) and 2004-2018 is testing period/set (30%). Although the dataset is rather small, that approach is sufficient in this D&D stage. Moreover, (*GP2S*) will handle it automatically, when it becomes mature.

Another important issue for models and scripts in this study is the performance metrics (Forecast Accuracy Metrics Universe ESM.30). The performance metrics are calculated with Tidymodels 0.1.4 yardstick in this study (rmse: root mean squared error, rsq: R-squared, rsq_trad: R-squared traditional, msd: mean signed deviation, mae: mean absolute error, mpe: mean percentage error, mape: mean absolute percentage error, smape: symmetric mean absolute percentage error, mase: mean absolute scaled error, ccc: concordance correlation coefficient) [149]. The best model is the auto ARIMA according to MAPE (1,1652 for minimum electricity consumption, 6,6471 for maximum electricity consumption) and SMAPE (1,1622 for minimum electricity consumption, 6,9043 for maximum electricity consumption) measures. Hence, auto ARIMA and linear regression (lm) are run for the next 500 years period on annual basis (2019-2519) (ESM: GP2SWorldRScriptLongVersion.docx, GP2SWorldRCode.R).

The plots and their data files are very important in (*GP2S*). There are 3 graphical design elements on the "non-registered user main" webpage in the current prototype. The first one is map canvas, which is presented with QGIS 3.16.7-Hannover. It has world political map and world power grid map layers. World political map is available in QGIS 3.16.7-Hannover. World power grid map is supplied by 123map (ESM.48). All layers have been collected, prepared, presented, and integrated in the same manner in (*GP2S*). A representative downloadable file in *.kml format with its data platform (opendatasoft platform world administrative boundaries countries and territories) is also presented in this study (*Appendix.B.1*, ESM.33, ESM.48, ESM: Quant UX folder). The second and third ones are ex-post (backward-looking, historical) and ex-ante (forward-looking, projections), which are presented with Tidyverse 1.3.1 ggplot2 package [150]. As it can be seen on the webpage screen, there is a selective optional design approach, so that the following plots can be selected one by one or in combinations: ex-post (backward-looking, historical) plots “Top 1st”, “Top 2nd”, “Top 3rd”, “Top 4th”, “Top 5th”, “Simple Linear”, “Data only”, “Events major”; ex-ante (forward-looking, projections) plots “Top 1st”, “Top 2nd”, “Top 3rd”, “Top 4th”, “Top 5th”, “Simple Linear”. “Top 1st”, “Simple Linear” models plots, and “Data only” plot are presented in this study. The plots of “Top 1st”, and “Simple Linear” models are only presented Quant UX (Appendix.B.1, ESM.33, ESM: Quant UX folder, RWorld folder *.jpeg files).

More information related to models, methods, R packages, R scripting, and similar can be gathered from several sources [151-160].

After these D&D activities, 2 more scripting/coding versions are prepared and run in this study. One of them is the short version on R version 4.1.1 (2021-08-10) "Kick Things" with RStudio 2021.09.0+351 "Ghost Orchid" Release. Many checkpoints for development purposes are eliminated in this short version. This version runs with only one data input file as per design approach of (*GP2S*). The other one is the RStudio Cloud version (ESM.48). This cloud version is much closer to the design philosophy of (*GP2S*), because it is a web-based scripting platform. The current RStudio Cloud script runs with R version 4.1.0 on Ubuntu 20.04 (Focal) OS (ESM.48). This cloud version has only one data input file as per design approach of (*GP2S*). (ESM: GP2SWorldRScriptShortVersion.docx, GP2SWorldRCodeShort.R, GP2SWorldRScriptCloudVersion.docx).

The total execution times in seconds are respectively 41,45415 (long version without packages installation), 25,44283 (short version without packages installation), and 43,33 (RStudio Cloud version without installing and loading packages, memory usage: by R objects 238.459 kibibytes (KiB), by session 618.848 KiB, by system 318.320 KiB).

3.5. Observations, Lessons Learned, Experiences, and Ideas

As it is shown, that only one data platform is enough for the publication of data in our World. It is unnecessary, lavish, and wasteful to present the data on several different websites like EIA, UN, World Bank, or Opendatasoft Platform. There is no need to waste limited digital storage capacities on the World with the same or almost similar data and different webpage file capacities. It is waste of our limited Earth materials with their consumption and manufacturing of those storage mediums (e.g. emissions due to manufacturing, logistics, mining activities, also global chip crisis). Instead of spending all those resources on presenting data on different websites, it is wise to spend those resources to publish scientific documents as open access and improve the quality of data and the flexibility of its access on a worldwide unique website. Moreover, many more free open-source tools can be presented to our World with that wasted resources. For instance, the design and publication principles on the UNdata can be improved in due time like adopting some World Bank data webpage design elements (the ones better than the other ones) into the UNdata webpage (ESM.48). Also, direct data access with application programming interface (API) and similar can be organized.

There is a UN Global Platform (Data for the World, United Nations Statistics Big Data (ESM.48)). It does not work at all. If the UN Global Platform works appropriately and supports GP2S and others (GP2D, GP2E, GP2O) then all data required for GP2S and other recommended systems can be stored and presented on it. They can be accessed in real-time by GP2S and all other purposed systems in the World to make GP2S and all others more economically (cheaper).

If humans cannot change their life styles, attitudes, and continue living like today or in the past, then most probably there will not be any clean land, water, and air on the Earth. Humans have to change, not animals and plants do. It is a stupidity to wait or expect the Earth to change by itself with astrological and similar events.

It is worth mentioning the following issues in this section too. When the aim of IEA is studied, it can be expressed that its data-sharing approach is not appropriate for its aim. It is nonsense. It is not understood during this study, why IEA presents that data like in its current form. It is the poorness of such a wealthy international organization. It should be noted that when the files are read in R the files are read as it is, but when read in spreadsheet software like Microsoft Excel, the spreadsheet should be formatted as text before reading the files. Otherwise, some misreading data issues may be observed in the dataset. There are some strange issues in the UN data too as explained in the previous sections. The UN data experts should check all data with the data experts of the primary data sources before publishing any of them. Moreover, all data experts should check the data before their use and warn data publishers, if they observe anything strange. Data works are serious and important activities. Data experts should be hired for data activities by those kinds of international organizations. Data is crucial in our World.

(*GP2S*) is the solution for all those sorts of improperness. (*GP2S*), (*GP2D*), (*GP2E*), and (*GP2O*) are also powerful, unifying, and unique solutions. Similarly, UN Global Platform is very promising in the same or similar design philosophy. Of course, its scope is the largest in data perspective, if it is designed and run as it is claimed.

4. CONCLUSION

The proposed *(GP2S)* is an extraordinary developer-friendly and user-friendly tool. It is very powerful for data, information and knowledge-gathering, acquisition, analysis, and sharing. Any time-horizon, any time-interval, any zone (location), any model, any method, and anything similar that may come to anybody's mind will be presented on *(GP2S)*. It helps to understand power generation, transmission, distribution, and consumption topics and their related phenomenon better. It enables developers to share their methods, models, codes, scripts, and findings without any restrictions. All developers and engineers will have the opportunity to focus different regions, time horizons, and intervals (ESM.3, ESM.6-8, ESM.11-13). It is a pathway for zero or negative emission power systems. It may be the most effective and economical solution for climate change actions.

The main development and demonstration achievements during this study are as follows: (1) *(GP2S)* prototype version 2021 is decomposed better (Appendix.A.*1*, ESM.3); (2) historical progress and relation of all proposed robots and platforms (*GP2D*, *GP2E*, *GP2O*) with *(GP2S)* is prepared and presented better (Appendix.A.*2*, ESM.4); (3) time horizons and intervals of *(GP2S)* is enlarged and defined better (time horizon: <1-minute to ≤500-years, time interval: 5-seconds to 50-years) (Appendix.A.3-4, ESM.6-7); (4) geographical, administrative and power grid decomposition of *(GP2S)* is prepared and presented better (Appendix.A.5, ESM.8); (5) system diagram of *(GP2S)* prototype is prepared and presented better (Appendix.A.6, *ESM.11*); (6) roles in *(GP2S)* prototype are prepared and presented for the first time (ESM.12-13); (7) general learning, feedback, and selection loop algorithm of modules and models for the full automation on *(GP2S)* prototype is prepared and presented for the first time (ESM.19); (8) the first web-app prototype design alternative of *(GP2S)* for Global Power Consumption Prediction Systems Electricity Prediction Systems (*GPCPS-EPS*), zone: World, time horizon: ≤ 500-years, time interval: 1-year is developed by using QGIS, R, R Studio, and Quant UX, and presented for the first time (Appendix.B.1, ESM.33, ESM.44-45), (9) 3 different scripting versions are presented with 10 models (R base (lm), R base (glm), R Tidymodels 0.1.4 parsnip (engine("lm"), R Tidymodels 0.1.4 parsnip with lasso regularization regression (engine("glmnet")), R Tidymodels 0.1.4 parsnip with ridge regularization regression (engine("glmnet")), R forecast 8.15 auto ARIMA (auto.arima), R forecast 8.15 ARIMA(1,1,2) (arima), and R forecast 8.15 ARIMA(1,1,8) (arima), (10) 2 flowcharts are presented to describe the study well, research study flowchart and R Script flowchart (Appendix.*C*, *ESM.46-47*).

The main development and demonstration limitations during this study are as follows: (1) data and information still depends on other parties, organizations or similar like IEA; (2) electricity consumption data and information is collection manually or semi-manually, there is not any integration yet; (3) there is not any attention and interest of any international and national organizations for this fully automatized free open data and information sharing approach yet, none of the organizations pay attention and interest to *(GP2S)* idea or its principles yet, each organization has its own and very different ideas and approaches, chaos (chaotic); (4) attention and interest of researchers and academics cannot be taken for *(GP2S)* idea or its principles yet, nobody pays attention and interest to this idea yet, each and everybody has their own and very different ideas and approaches; (5) everybody and every organization have their own agenda, there is not any common approach or unification, the World is inefficient and thriftless; (6) there is still only one free open source scripting software used, R; (6) there is still only one free open source GIS software used, QGIS; (7) there are still only two free open source wire-framing and prototyping tools used, Quant UX and penpot, everything is presented on Quant UX, (8) there is not any web address and web page yet, (9) there are still only a few R packages used, there is not any comparison of all available packages yet, (10) a new specific package have not been designed and built yet, (11) full optimization algorithm is still under development and demonstration phase, (12) there is still only one researcher who has proposed and worked in this robot and platform.

5. FUTURE RESEARCH WORKS

The main future development and demonstration works are as follows: (1) Although nobody and no organizations get interested in and pay attention to this robot and platform idea, it does not show or prove that *(GP2S)* idea is useless and worthless. The researcher thinks that it is the sole and ultimate solution for humankind and humanity, not because of being his idea and recommendation, but because of all its benefits like its design elements and inclusivity, (2) The lack of interest and attention of organizations, researchers, and academics maybe because they don't have the opportunity to transfer money to people they want to transfer (to their networks) due to availability and visibility of this idea or similar. In other words, they cannot seduce any fund or similar because of *(GP2S)* idea (ego, social networks, criminal, insane thoughts, see global consortium recommendation in this journal [12]). Or they don't want to produce any product in a similar scope of *(GP2S)* cheaply. Maybe they want to steal it and use it for their advantage. Maybe only they fail to grasp the importance of this idea. Whatever the reason is, nobody is interested in this idea, but the researcher will continue developing this robot and platform and try to present the best models for each and every time frame and zone. (3) Each and every available free data and information source will be found and comparatively studied. Their pros and cons will be reviewed and presented as much as possible. (4) It is hoped that some publications will be presented for all zones (locations) in the World in 10-20 years. (5) Some simple prototype versions will also be deployed as Shiny applications online to get feedback and comments. (6) “Turkiye” is preferred instead of “Turkey” in this text due to linguistics/language related trouble/problems [161]. If readers text/image-search, they will understand the problem. The historical usage and root of “Turkey” as a word will be studied in the future studies too (word roots under investigation).

This publication and its precedence and successor publications shall hopefully help foresighted humans to reshape our World.

Electronic Supplementary Files

The most important deliverable items are given in the Appendixes, so that there may never be expected any information lost. All electronic supplementary files are presented in the author’s researcher profiles like ResearchGate, GitHub, and Kaggle (*ESM.48*).

Acknowledgments

“We are very very small, but we are profoundly capable of very very big things.” Stephen Hawking. The author would like to thank Detlev Reiners (27/01/2021 e-mail, 123map GmbH & Co.KG Hanover

Germany), Klaus Schaefers (08/08/2021 e-mail, Quant UX), Juan de la Cruz García, Andres Gonzalez, Clara García Vinola (08/08/2021 e-mail, Kaleidos, Penpot), all editors, anonymous reviewers, and journal staff of this publication for their comments, recommendations, support and help (*ESM.48*). Any opinion, method, data, information, graph, picture, photo, clause, sentence, finding, remark, conclusion, and recommendation expressed and presented herein are the author's, the authors', or the referenced authors' and do not necessarily reflect the views of any governmental, national or international parties, bodies or organizations. Please feel free to send your ideas, feedback, and criticisms to the author's e-mail at any time.

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APPENDIXES

Appendix A.

Appendix A.1.

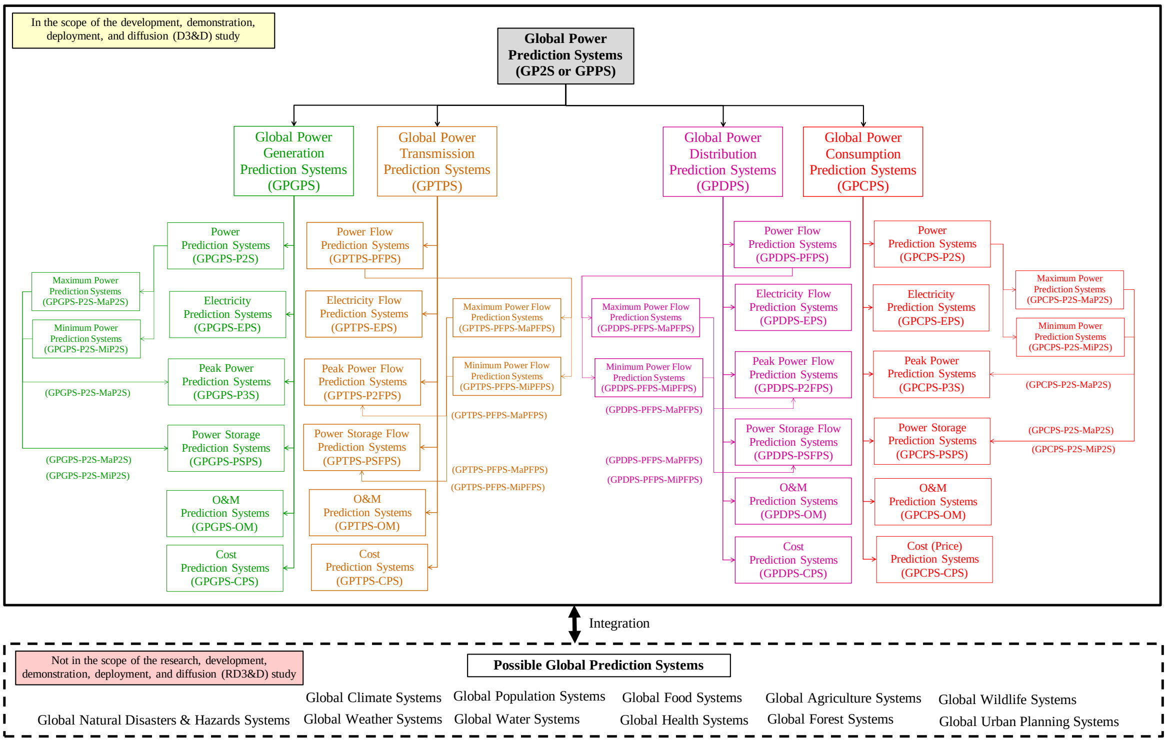


Figure A.1. The decomposition of GP2S prototype version 2021: its major items, subsystems, and their relations (the ideas of some other possible global prediction systems, which are not in the scope of this study, that are also presented with their integration possibility and necessity) (note: O&M: Operations and Maintenance) (see full size version in ESM)

Appendix A.2.

Table A.1. The short version of historical progress of proposed robots and platforms (the long version in ESM)(1)(2)

Year	Title	Acronym	Aim	Version	References
2020	Global Power Prediction Systems	GP2S	Consumption and Generation Prediction(3) or, in other words Demand and Supply Prediction	Prototype 2020	This study
2010	Prediction System	N/A(4)	Demand and Supply Prediction or, in other words Consumption and Generation Prediction	Idea(5)	N/P(6)
2021	Global Power Plant Developers	GP2D	The same as the original idea in 2010	Prototype 2021	PinP(7)
2010	Investment System	N/A(4)	Features identification Features selection Location alternatives generation Location alternatives elimination Location alternative selection	Idea(5)	N/P(6)
2020	Global Power Plant Engineers	GP2E	The same as the original idea in 2010	Prototype 2020	PinP(7)
2010	Design System	N/A(4)	Power Plant Design Alternatives Generation Power Plant Design Alternatives Elimination Power Plant Design Alternatives Selection	Idea(5)	N/P(6)
2021	Global Power Plant Owners	GP2O	The same as the original idea in 2010	Prototype 2020	PinP(7)
2010	Shareholder System	N/A(4)	Mass Crowd Private Investment	Idea(5)	N/P(6)

(1) All robots and platforms are integrated to the other one, the references show their interrelationships. (2) The intermediate development progress of robots and platforms with their publication info is in ESM. (3) Prediction: forecasting, prediction, and projection are all in the same meaning in these robots and platforms. (4) N/A: Not Available. (5) The idea in the author's mind after the experiences of the author's PhD. Thesis in 2009, and the commercial projects. (6) N/P: No Publication (7) PinP: Publication in preparation activities. When those activities are finalized all manuscripts will be submitted to journals.

Appendix A.3.

Table A.2. The scope of the proposed GP2S prototype version 2020 (consoles) (the full size version in ESM)

Forecasting Time Horizons (linguistically)	Forecasting Time Horizons (mathematically)	Time Intervals	Consoles (time windows, horizons)
Immediate Term (almost/near real-time)	less than 1 minute < 1 minute	5 seconds 15 seconds 30 seconds	Immediate (almost/near real-time)
Very Short Term	between 1 minute and 1 hour 1 minute ≤ < 1 hour	1 minute 5 minutes 10 minutes 15 minutes 30 minutes	Very Short Term
Short Term	between 1 hour and 1 day 1 hour ≤ < 1 day	1 hour	Short Term
Short To Medium Term	between 1 day and 1 week 1 day ≤ < 1 week	1 day midweek (Wednesday) weekends (Saturday, Sunday)	Short To Medium Term
Medium Term	between 1 week and 1 month 1 week ≤ < 1 month	1 week	Medium Term
Medium To Long Term	between 1 month and 1 year 1 month ≤ < 1 year	1 month 1 season	Medium To Long Term
Long Term	between 1 year and 10 years 1 year ≤ < 10 years	1 year 5 years	Long Term
Very Long Term	between 10 years and 500 years 10 years ≤ ≤ 500 years	1 year 5 years 10 years 50 years	Very Long Term

Appendix A.4.

Table A.3. The relationship matrix of data time intervals and forecasting consoles of the proposed GP2S prototype version 2020 (the full size version in ESM)

Time Intervals	Mathematical Operation				Consoles							
					Immediate (almost/near real-time) < 1 minute	Very Short Term 1 minute ≤ < 1 hour	Short Term 1 hour ≤ < 1 day	Short To Medium Term 1 day ≤ < 1 week	Medium Term 1 week ≤ < 1 month	Medium To Long Term 1 month ≤ < 1 year	Long Term 1 year ≤ < 10 years	Very Long Term 10 years ≤ ≤ 500 years
5 seconds	Sensor Device	N/A	N/A	N/A	•	•	•	•	•	•	•	•
15 seconds	∑	Sensor Device	N/A	N/A	•	•	•	•	•	•	•	•
30 seconds	∑	∑	Sensor Device	N/A	•	•	•	•	•	•	•	•
1 minute	∑	∑	∑	Sensor Device		•	•	•	•	•	•	•
5 minutes	∑	∑	∑	∑		•	•	•	•	•	•	•
10 minutes	∑	∑	∑	∑		•	•	•	•	•	•	•
15 minutes	∑	∑	∑	∑		•	•	•	•	•	•	•
30 minutes	∑	∑	∑	∑		•	•	•	•	•	•	•
1 hour	∑	∑	∑	∑			•	•	•	•	•	•
1 day	∑	∑	∑	∑				•	•	•	•	•
1 week	∑	∑	∑	∑					•	•	•	•
1 month	∑	∑	∑	∑						•	•	•
1 season	∑	∑	∑	∑						•	•	•
1 year	∑	∑	∑	∑							•	•
5 years	∑	∑	∑	∑							•	•
10 years	∑	∑	∑	∑								•
50 years	∑	∑	∑	∑								•

N/A: Not Applicable, The minimum time interval of the sensors will be adapted to the whole power grid.

Appendix A.5.

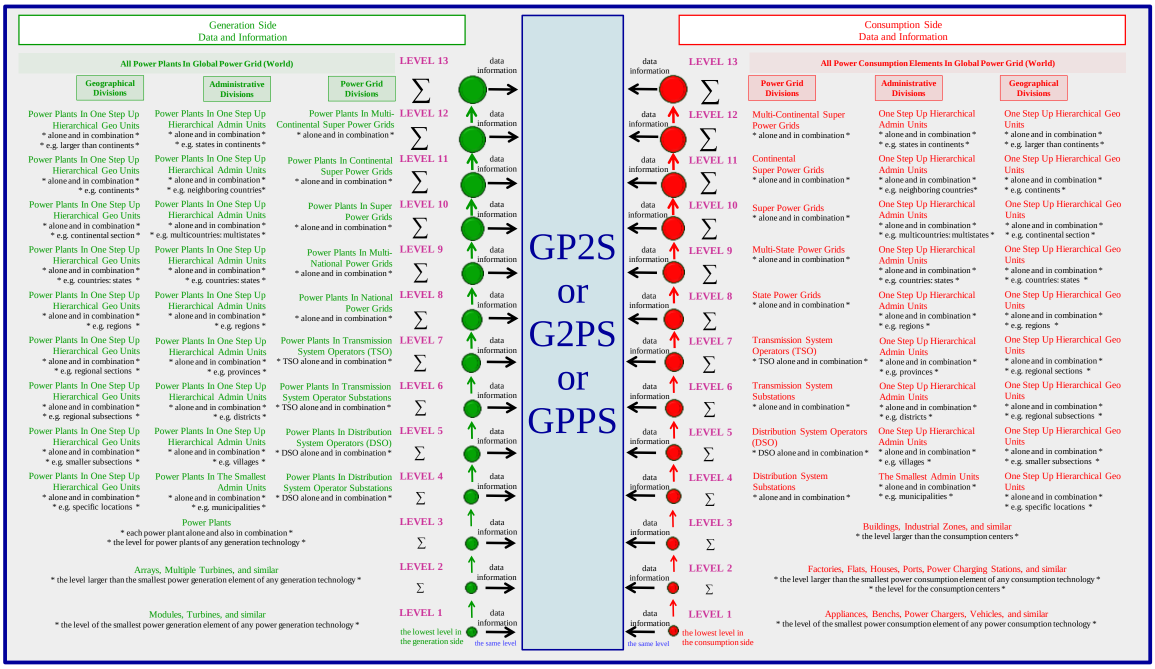


Figure A.2. The current geographical, administrative and power grid decomposition of the GP2S prototype version 2020 (the full size version in ESM)

Appendix A.6.

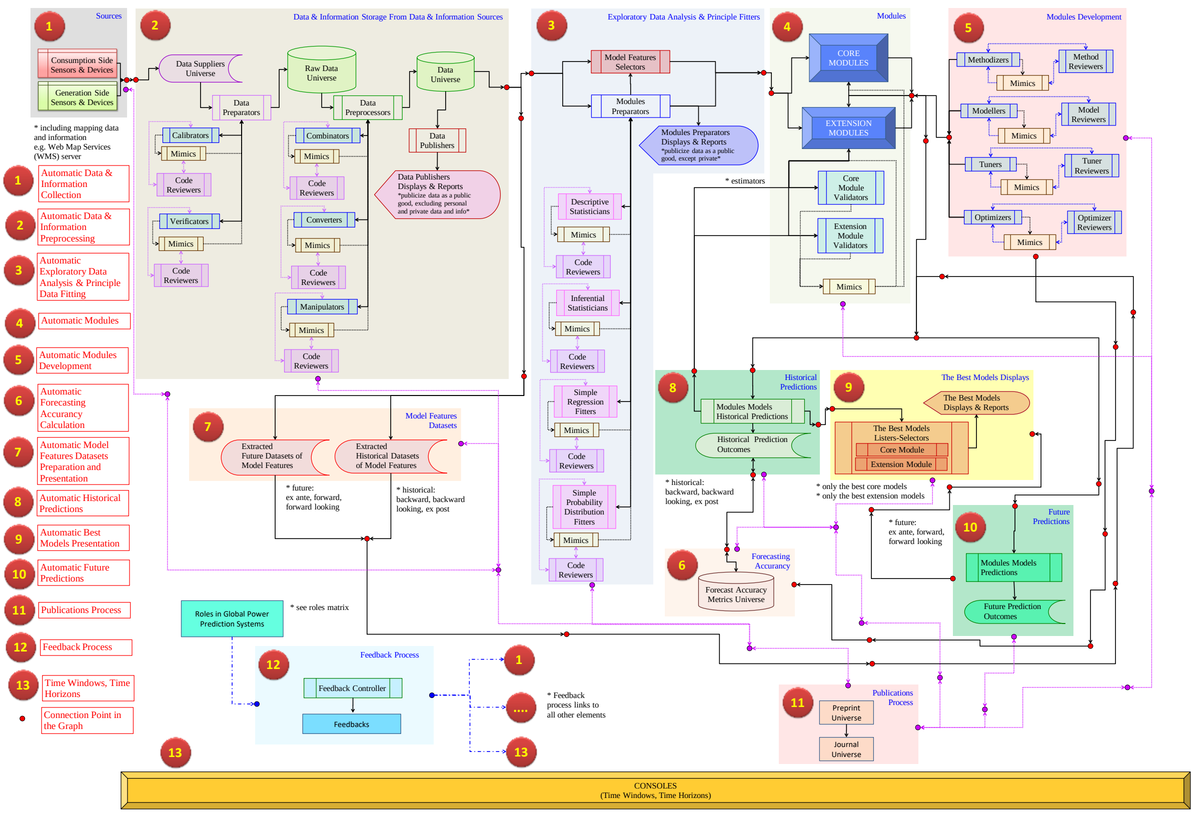
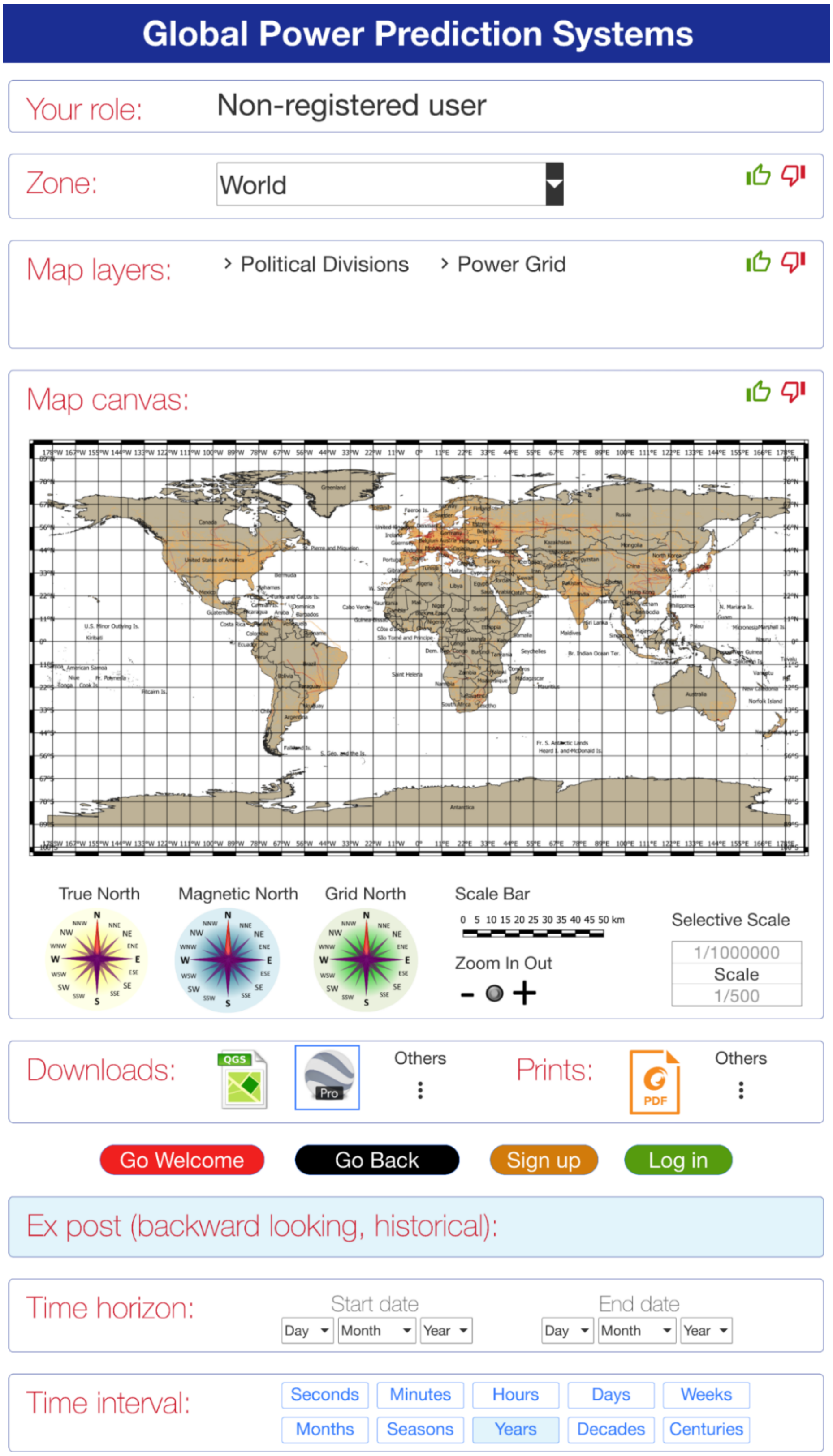


Figure A.3. The current system diagram of the GP2S prototype version 2020 (the full size version in ESM)

Appendix B.

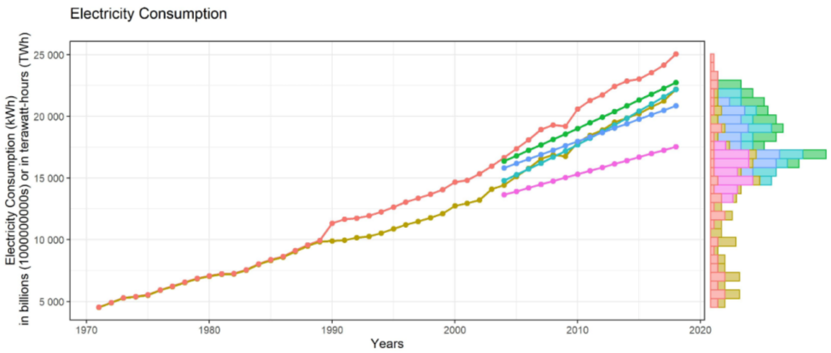
Appendix B.1.



* Continue in the next page

Models: ☑ Top 1st ☐ Top 3rd ☐ Top 5th ☐ Data only
☐ Top 2nd ☐ Top 4th ☑ Simple Linear ☐ Events major

Plot:



Downloads: TXT Others ⋮ Prints: PDF Others ⋮

Statistics:

Exploratory Data Analysis (EDA)

Minimum Electricity Consumption (kWh & TWh)

Counts: 48
Minimum: 4513201055677 & 4513
First Quartile: 7443282808836 & 7443
Median: 10713430149272 & 10713
Mean: 11860904471293 & 11861
Third Quartile: 15969083600269 & 15969
Maximum: 22217495096566 & 22217
Standard Deviation: 5088406386074
& 5088406
Interquartile Range: 8525800791433 & 8526
Range: 17704294040889 & 17704

Maximum Electricity Consumption (kWh & TWh)

Counts: 48
Minimum: 4531532506934 & 4532
First Quartile: 7486464897699 & 7486
Median: 12461456810077 & 12461
Mean: 13229305771151 & 13229
Third Quartile: 18307307420846 & 18307
Maximum: 25063189467156 & 25063
Standard Deviation: 6165432664996
& 6165433
Interquartile Range: 10820842523146 & 10821
Range: 20531656960222 & 20532

Models Performance

Minimum Electricity Consumption (kWh)

Simple Linear

MAPE: 14.328706702304759
SMAPE: 15.54783464862044

Top 1st Model

MAPE: 1.1651498053334746
SMAPE: 1.1622215118473913

Maximum Electricity Consumption (kWh)

Simple Linear

MAPE: 12.089855496651996
SMAPE: 12.937053360479434

Top 1st Model

MAPE: 6.647071953567867
SMAPE: 6.904382202692479

MAPE: Mean Absolute Percentage Error
SMAPE: Symmetric Mean Absolute Percentage Error

Downloads: TXT Others ⋮ Prints: PDF Others ⋮

Ex ante (forward looking, projections):

* decimals are in cooperate with R + RStudio script, and will be decided in the future.

* Continue in the next page

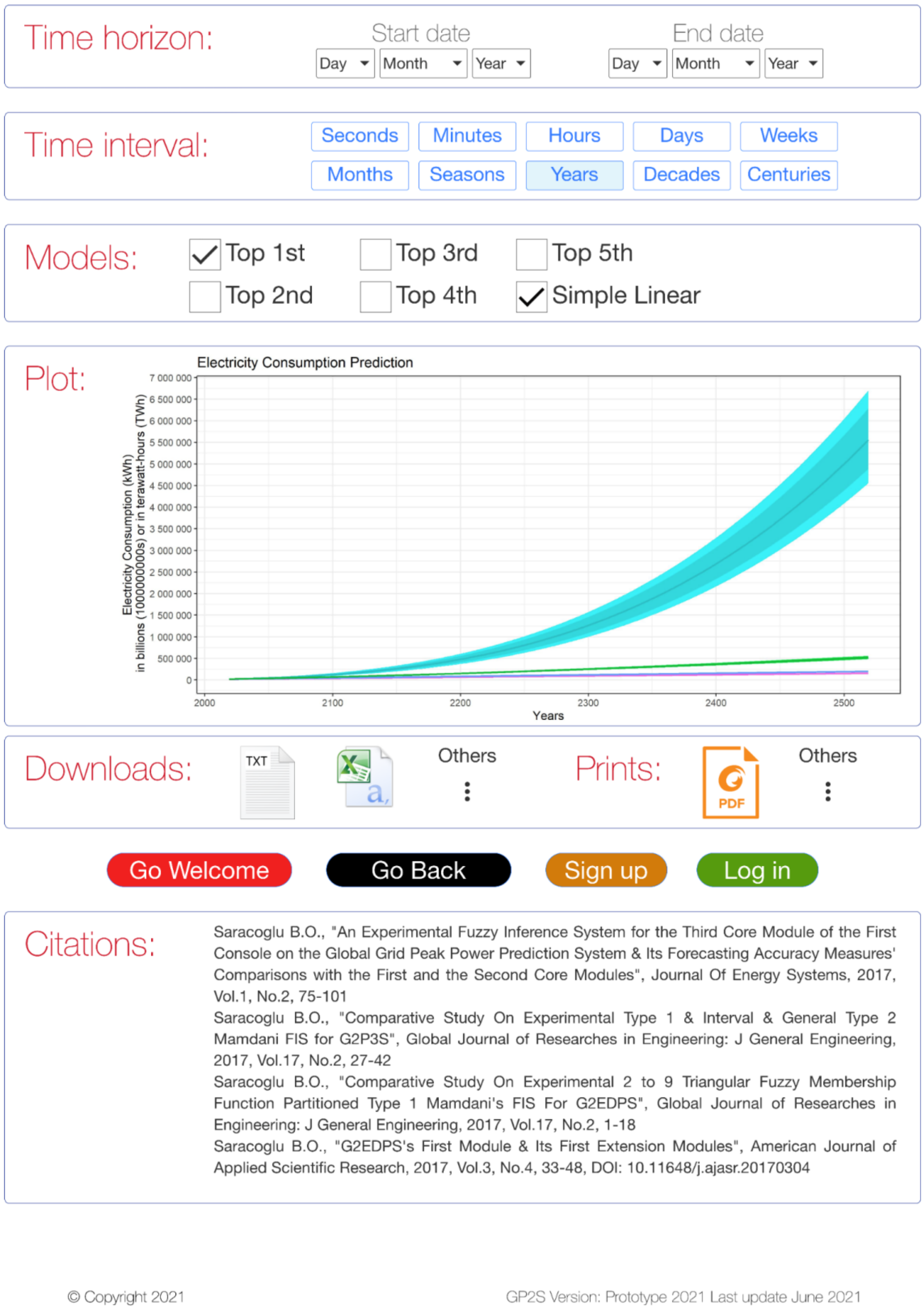


Figure B.1. "Non-registered user" webpage interface of the GP2S prototype version 2020 on Quant UX (the full size version in ESM)

Appendix C.

Appendix C.1.

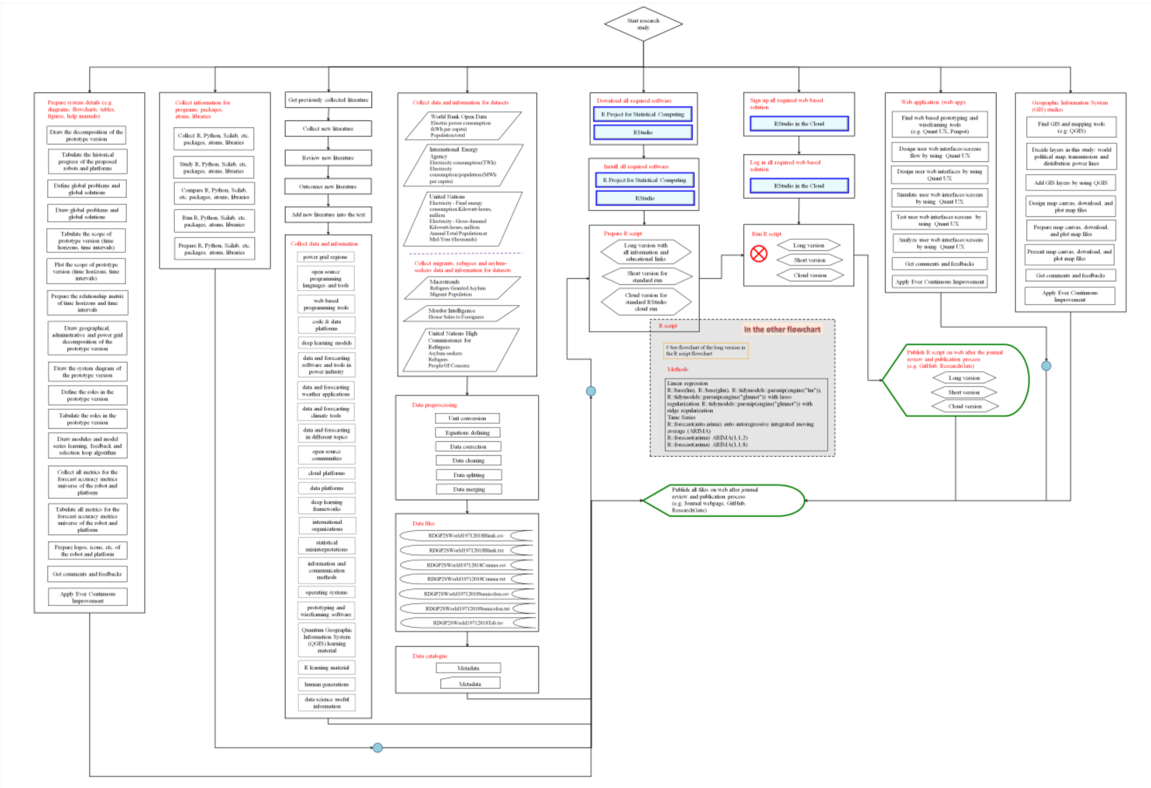


Figure C.1. Research study flowchart (the full size version in ESM)

Appendix C.2.

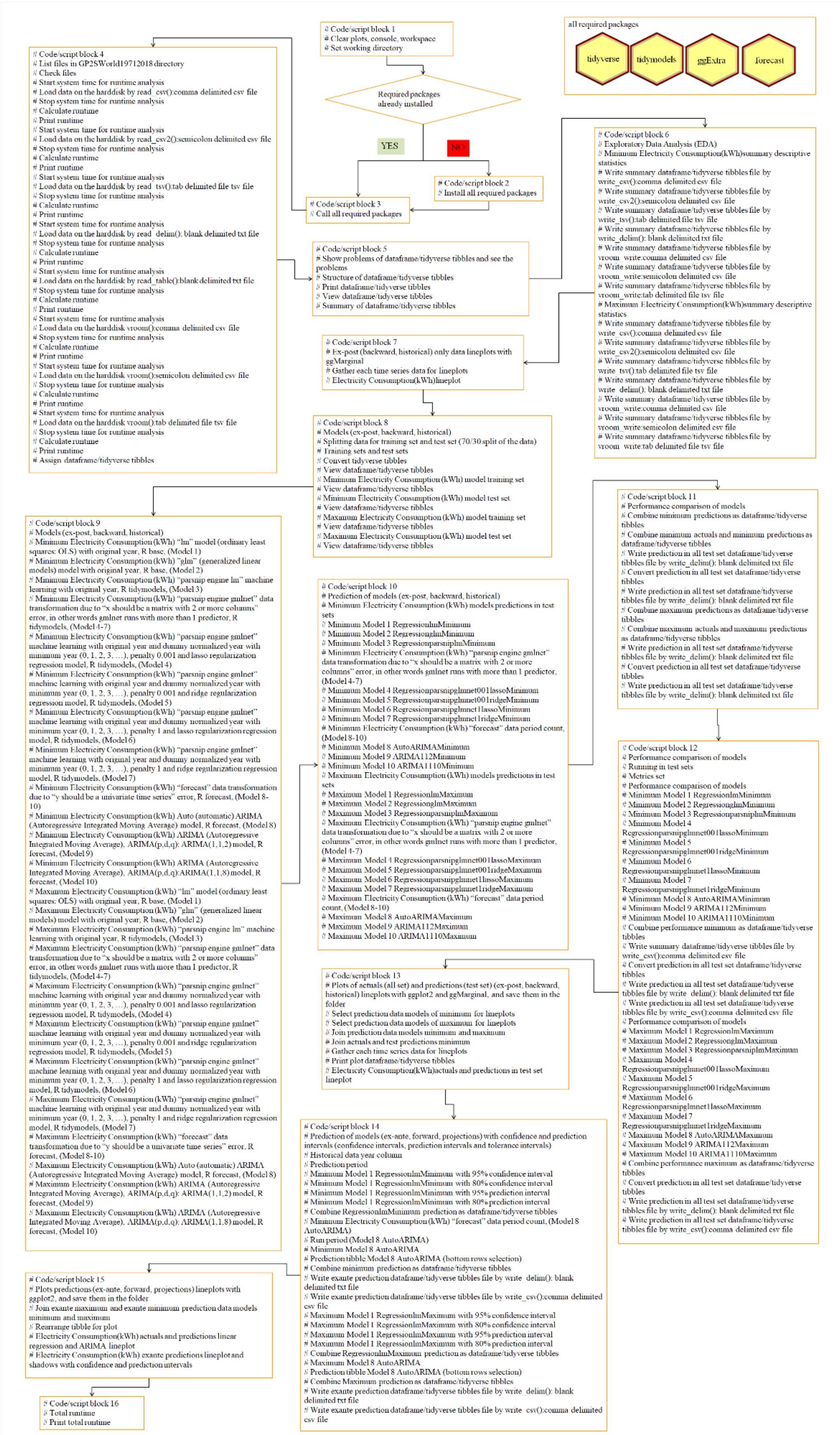


Figure C.2. R Script flowchart (the full size version in ESM)