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G^2EDPS's First Module & Its First Extension Modules

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Abstract: 100% renewable worldwide power grid (Global Grid) system needs a Global Grid Electricity Demand Prediction System (G^2EDPS) with very short, short, medium and long term forecasting consoles. This paper presents the 1st core module and its 10 extension modules in the long term prediction console. A type 1 Mamdani like Fuzzy Inference System (FIS) with 7 triangle membership functions and 49 rules is designed for 2 input and 1 output variables for a 100 year forecasting period. The maximum absolute percentage errors (MAP), the mean absolute percentage errors (MAPE), and the Symmetric MAPE (SMAPE) of the best core module and its extension modules are respectively 0, 24; 0, 08; 0, 05 and 0, 22; 0, 07; 0, 05.

Keywords: Global Grid, Electricity Demand, Fuzzy Inference System, Mamdani, Prediction

1. Introduction

Electricity is the center of our modern daily life. It is consumed in homes, on streets, and at factories at most of our daily activities. The electricity can be generated from either non-renewable energy sources or renewable energy sources within the current electricity generation technologies. Oil, coal, gas, and nuclear are grouped in the non-renewable energy sources. Hydropower, geothermal, wind, solar, and ocean are grouped in the renewable energy sources. Non-renewable energy sources shall run out in the future. Hence, the scientific studies on modeling and developing of 100% renewable energy sources should be more important than the studies on non-renewable energy sources in near to mid future.

There are some conceptual 100% renewable power grids (e. g. European Supergrid Concept [1], Global Grid Concept [2], Supergrid Concept for America [3], DESERTEC Concept [4], Gobitec Concept, Asian Super Grid Concept [5, 6]). The Global Grid is described by Chatzivasileiadis et. al. as "a grid spanning the whole planet and connecting most of the large power plants in the world" [2] (see "Fig. 1" for Global Grid).

The Global Grid Prediction Systems (G^2PS) [7] are developed to serve them (specifically to Global Grid). It has two major units (Global Grid Electricity Demand Prediction System: G^2EDPS, Global Grid Peak Power Prediction System: G^2P^3S) [7] (please be informed that projection, prediction, forecast are used in same meaning in this study). These systems shall work with all provinces, sub-regions, countries, large regions, multinational grids, Supergrids and Global Grid in all time horizons (e.g. immediate: less than 1 month, short-run: 1−3 months, medium-term: 3 months−2 years, long-run: 2 years or more; some electricity grid related forecasting studies short-range: up to a week a head, medium-range: up to 10 years ahead, long-range: 50 years ahead) [7] (see [8, 9, 10, 11, 12].

The long run forecasting is used for the strategic planning such as preparing the expansion plans of the electrification grids and the energy management systems [8, 9, 10, 11, 12].

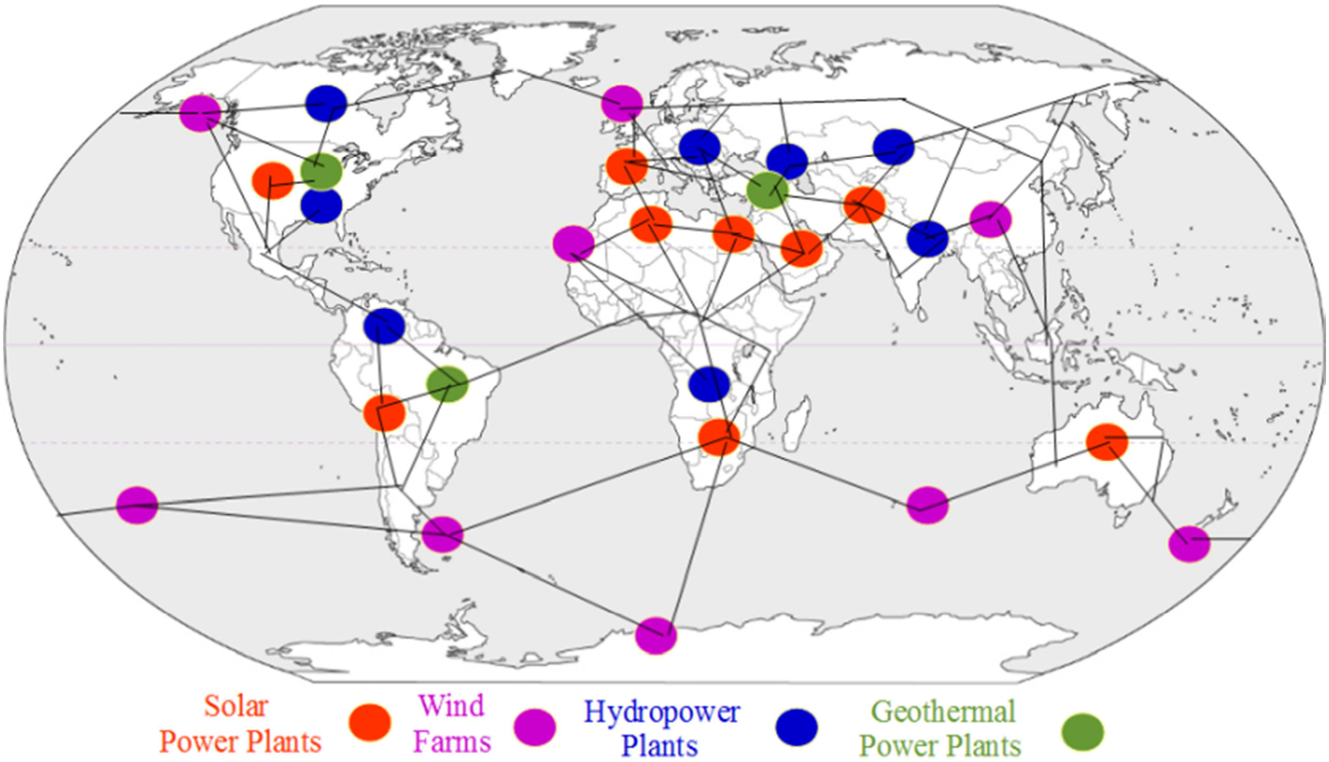


Figure 1. *Global Grid* (see [2], basemap by the Johomaps http://www.johomaps.com/, generated by Apache OpenOffice 4.1.1 Draw http://www.openoffice.org/ & Paint.NET http://www.getpaint.net/index.htm) (*not to scale, fictitious and for information purposes only so that no representation of power plants locations and transmission lines).*

This study presents an interim milestone (part) of an ongoing research, development and demonstration (RD^3) program (project, effort) as publicized the G^{2}EDPS's 1st core module and its extension modules in the long term prediction console, which run on Scilab [13], R [14], RStudio [15], Microsoft Office Excel [16], Apache OpenOffice Calc [17] (long range period: 100 years ahead).

2. Literature Review

The current literature review was completed on only some of the academic publication online database and journals by only some key terms and phrases in June 2015 (from 11th of June to 01st of July: 20 days period). The keywords were first selected from some previous research studies and documents in the literature. Then new key terms were added by the author and connected with others. They were used in a narrowing content manner (from large to narrow scope or general to specific). The keywords were (1) "Fuzzy Logic Inference System" and "Electricity", (2) "Fuzzy Logic Inference System" and "Forecast", (3) "Fuzzy Logic Inference System" and "Demand", (4) "Fuzzy Logic Inference System" and "Electricity" and "Forecast", (5) "Fuzzy Logic Inference System" and "Electricity" and "Demand", (6) "Fuzzy Logic Inference System" and "Electricity" and "Forecast" and "Demand", (7) "Fuzzy Inference System" and "Electricity", (8) "Fuzzy Inference System" and "Forecast", (9) "Fuzzy Inference System" and "Demand", (10) "Fuzzy Inference System" and "Electricity" and "Forecast", (11) "Fuzzy Inference System" and "Electricity" and "Demand", (12) "Fuzzy Inference System" and "Electricity" and "Forecast" and "Demand", (13) "Fuzzy Control System" and "Electricity", (14) "Fuzzy Control System" and "Forecast", (15) "Fuzzy Control System" and "Demand", (16) "Fuzzy Control System" and "Electricity" and "Forecast", (17) "Fuzzy Control System" and "Electricity" and "Demand", (18) "Fuzzy Control System" and "Electricity" and "Forecast" and "Demand", (19) "Fuzzy Rule System" and "Electricity", (20) "Fuzzy Rule System" and "Forecast", (21) "Fuzzy Rule System" and "Demand", (22) "Fuzzy Rule System" and "Electricity" and "Forecast", (23) "Fuzzy Rule System" and "Electricity" and "Demand", (24) "Fuzzy Rule System" and "Electricity" and "Forecast" and "Demand". There were 15 academic publication online database in this study. The reviewed documents were only journal papers, conference papers, books and chapters of books. Bachelor dissertations, master thesis, and doctor of philosophy thesis weren't taken into consideration, likewise, reports and technical articles in magazines weren't reviewed in this study. The advanced and expert search options were used on the database websites. The search results were grouped under 5 classes (all, relevant, irrelevant, not close or far or indirect relation, close or direct relation) as in the electronic supplementary file. The studies such as electricity price forecasting were grouped under indirect relation set. The power load and electricity demand research documents were positioned in the direct relation set. Some of the search results were presented in a very short and well organized way in “Fig. 2”.

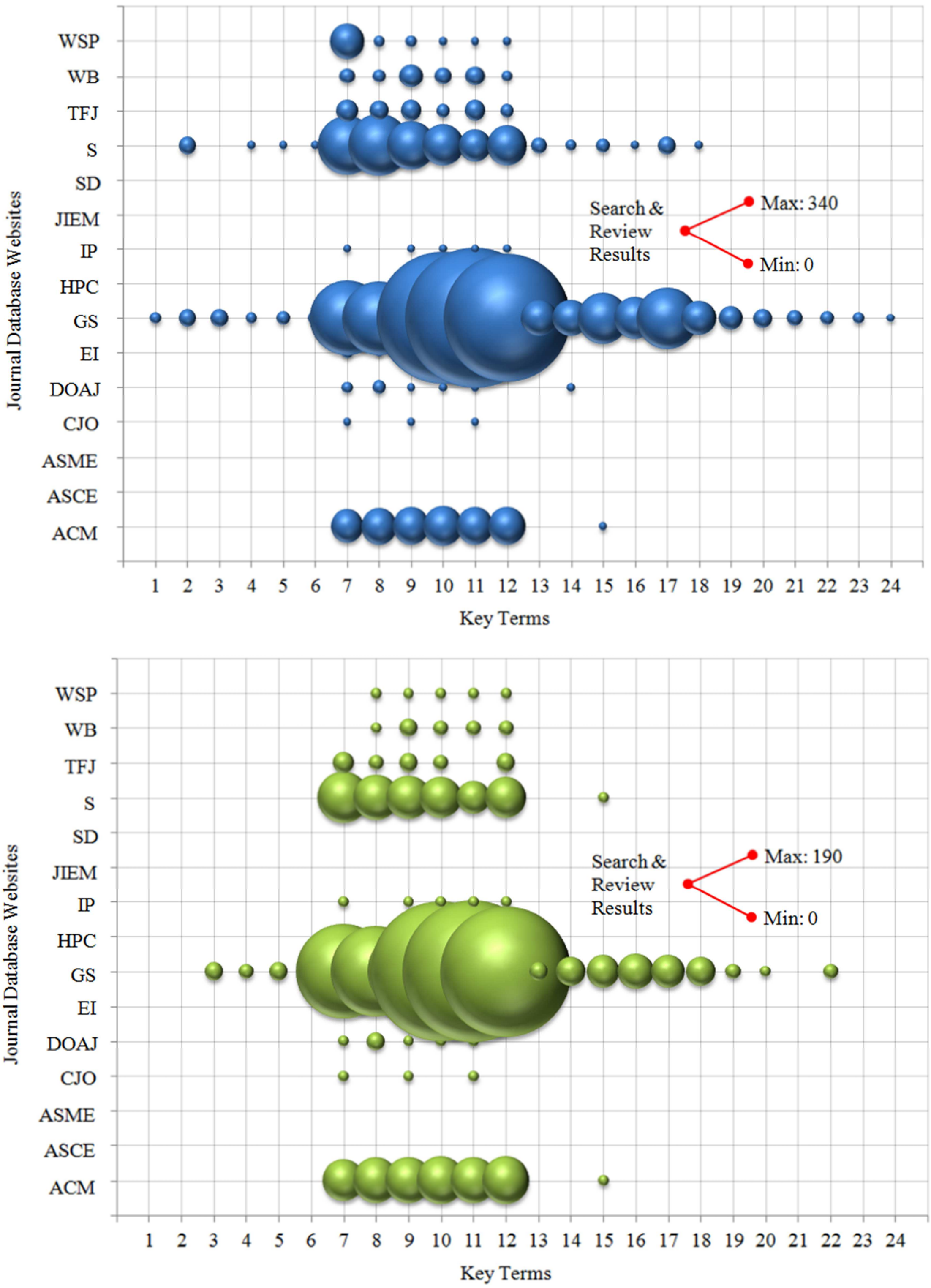


Figure 2. *Literature review summary (1: ACM Digital Library-ACM [18], 2: ASCE Online Research Library-ASCE [19], 3: American Society of Mechanical Engineers-ASME [20], 4: Cambridge Journals Online-CJO [21], 5: Directory of Open Access Journals-DOAJ [22], 6: Emerald Insight-EI [23], 7: Google Scholar-GS [24], 8: Hindawi Publishing Corporation-HPC [25], 9: Inderscience Publishers-IP [26], 10: Journal of Industrial Engineering and Management-JIEM [27], 11: Science Direct-SD [28], 12: Springer-S [29], 13: Taylor & Francis Online/Journals-TFJ [30], 14: Wiley-Blackwell/Wiley Online Library-WB [31], 15: World Scientific Publishing-WSP [32]), visualization generated by the bubble graph of Microsoft Office Excel 2007 & Paint. NET (left: top, right: bottom).*

The detailed review was performed only on English documents. The documents in other languages were eliminated, as a result there were 245 documents in this review. The titles, the keywords and the abstracts were read carefully.

It was understood that these studies could be grouped according to their scope such as smart grids (e. g. [33]), classical or conventional grids (transmission and distribution) (e. g. [34]), and household applications (e. g. [37]). Moreover, the power systems forecasting horizons in the literature were diversified as the real time/very short term (minutes to a day) (e. g. [36]), the short term (a day to a week) (e. g. [37]), the medium term (a week to a year) (e. g. [38]) and the long term (more than a year often upto ten years) (e. g. [39]) (see [40]). Hence, only the long term studies were investigated in detail in this review. There were more than 40 studies. Some of these studies were compared their models with the actual historical data (model and comparison on historical data). There weren't any future projections in these studies. On the other hand, some of the studies presented the future forecast. Al-zahra et. al. tried to forecast (next 2 years: January 2012 to December 2013) the demand of Basra city by Box-Jenkins and Neuro-Fuzzy Modeling [41]. Tasaodian et. al. projected the following 8 years (2008-2015) demand in the Group of Eight (G8) Industrialized Nations (U. S. A, Canada, Germany, United Kingdom, Japan, France, Italy) by an adaptive network based fuzzy inference system (ANFIS) [42]. Azadeh et. al. worked on an ANFIS model for the next 7 years (2009-2015) in the Netherlands, Luxembourg, Ireland, and Italy [43]. Bazmi et. al. studied on an ANFIS network for predictions (next 19 years: 2012 to 2030) in Malaysia [44]. There were also some other important and interesting studies within the similar topics, approaches, scopes and forecasting horizons. The maximum forecasting period was 20 years in these documents (future projection studies).

The literature review was finalized in 25 days (11/06/2015 to 01/07/2015: search, review, classify; 01/07/2015 to 05/07/2015: investigate, prepare). This detailed and widened literature review exposed that some researchers were interested in the power systems forecasting subject, however there weren't any publications found on the long term forecasting of the Global Grid Concept.

This study is most probably the first research on this concept, so that it has its own very unique difficulties. The main challenge is the concept itself. Another challenge is its forecasting horizon (long term: 100 years).

3. G²EDPS, Its First Core Module & Core Module's Extensions

The G²EDPS consists of several consoles and modules with bottom up and side by side level approaches [7]. On the bottom up designs, the future electricity consumption (G²EDPS) will be predicted from one of the smallest units up to the largest units (i. e. provinces to countries, to regions, finally to the world). On the side by side (SS code) level approaches, the future electricity demand shall be predicted directly. It has simple, backwards and forwards computation considerations. It shall be a generic system (flexible, intelligent, self-enlargeable, self-expanding, self-reporting, self-learning). It will have direct connection and relation to the data and information sources. It has a globally unique data warehouse (e. g. temperature, population, time, and consumption) (common for G²PS), a global unique forecast accuracy metrics pool (common for G²PS), several different prediction core modules and their extension modules with heuristics and optimizations (different or common for G²EDPS and G²P³S) "Fig. 3".

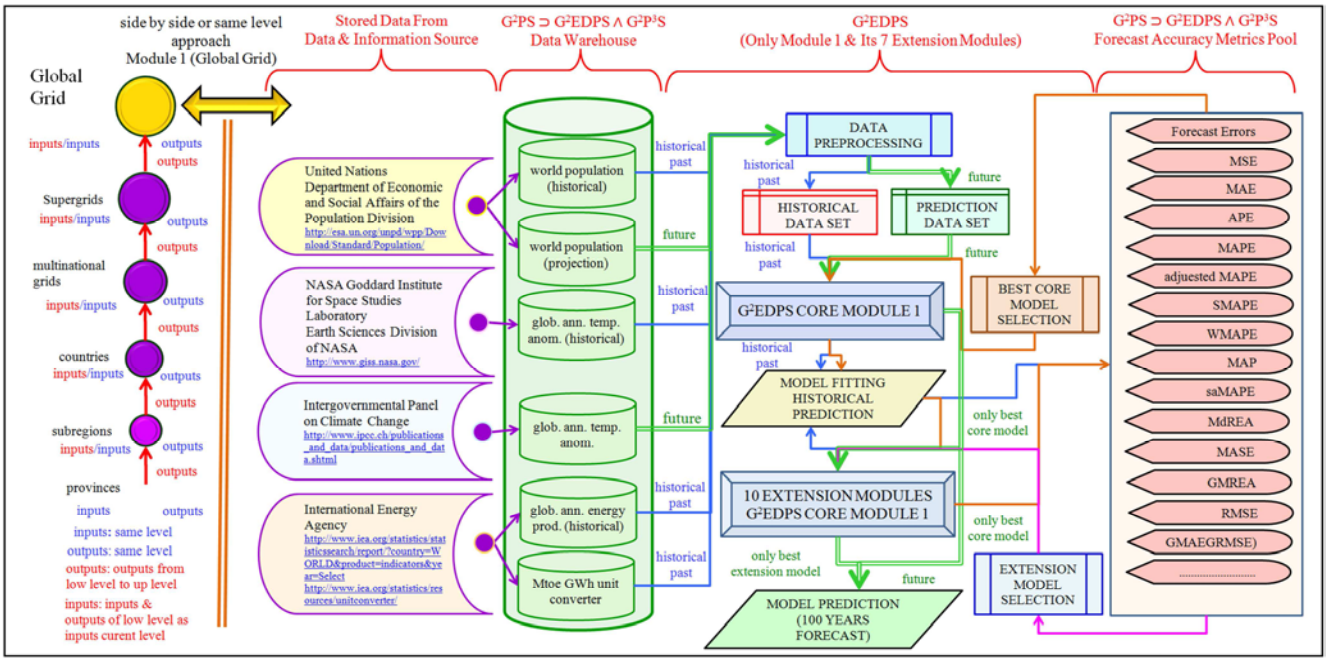


Figure 3. *G²EDPS system level description (left), 1st Module: GGED-SS-C-T1MFIS7TMF-2VPGATA-100YPP-2015 description (right) by Excel 2007 & Paint. NET.*

The G²EDPS 1st core module's forecasting model (long term prediction console) is a side by side approach for the

Global Grid electricity demand with a one node type 1 (fuzzy) Mamdani [45, 46] like fuzzy inference system (FIS) with 7 triangle fuzzy membership functions (MF) and 2 input (world population, global annual temperature anomalies) and 1 output (Global Grid annual electricity demand) variables on the international basis for a 100 years ahead prediction period. This type of FIS is preferred in this study, because of its expert knowledge capturing capability [45, 46, 47].

This core module has its own data preprocessing, knowledge base (database, rule base), fuzzifier, inference system, defuzzifier, best core model defuzzifier selection, extension improvements generation, best extension model, and 100 year projection reporting units.

The world population (both sexes combined, as of 1 July in thousands) is employed as the input variable. It is employed as the first input variable in this module, because of its influencing power on the electricity consumption. Its historical and future projection data are directly gathered from the Department of Economic and Social Affairs of the Population Division at the United Nations [48]. The description of this variable is exactly presented as it is on the official website "Total Population - Both Sexes. De facto population in a country, area or region as of 1 July of the year indicated" [48].

The historical data (year, world population (both sexes combined, as of 1 July (thousands))) is gathered and presented in “Tab. 1”.

Table 1. *World Population Historical.*

Year	Population	Year	Population	Year	Population
1950	2.525.779	1971	3.766.754	1992	5.494.900
1951	2.572.851	1972	3.842.874	1993	5.578.865
1952	2.619.292	1973	3.919.182	1994	5.661.086
1953	2.665.865	1974	3.995.305	1995	5.741.822
1954	2.713.172	1975	4.071.020	1996	5.821.017
1955	2.761.651	1976	4.146.136	1997	5.898.688
1956	2.811.572	1977	4.220.817	1998	5.975.304
1957	2.863.043	1978	4.295.665	1999	6.051.478
1958	2.916.030	1979	4.371.528	2000	6.127.700
1959	2.970.396	1980	4.449.049	2001	6.204.147
1960	3.026.003	1981	4.528.235	2002	6.280.854
1961	3.082.830	1982	4.608.962	2003	6.357.992
1962	3.141.072	1983	4.691.560	2004	6.435.706
1963	3.201.178	1984	4.776.393	2005	6.514.095
1964	3.263.739	1985	4.863.602	2006	6.593.228
1965	3.329.122	1986	4.953.377	2007	6.673.106
1966	3.397.475	1987	5.045.316	2008	6.753.649
1967	3.468.522	1988	5.138.215	2009	6.834.722
1968	3.541.675	1989	5.230.452	2010	6.916.183
1969	3.616.109	1990	5.320.817	-	-
1970	3.691.173	1991	5.408.909	-	-

Note 1: Data & Information: United Nations Population Division Department of Economic and Social Affairs, Website: http://esa.un.org/unpd/wpp/Download/Standard/Population/, File: WPP2015_POP_F01_1_TOTAL_POPULATION_BOTH_SEXES.xls, Year: 1950 – 2015, UN File: POP/DB/WPP/Rev.2015/POP/F01-1, Accessed On: 24.01.2016

Note 2: 2011-2014 World Population (both sexes combined, as of 1 July (thousands)) and 1950 - 1989 energy production (TWh) and 2014 data are not available, so that 1990 - 2010 period is selected for model fitting (green shading color) during data preprocessing.

The future projection data is taken from the same website. The projection data (year, population (both sexes combined, as of 1 July (thousands))) is gathered and presented in “Tab. 2”.

Table 2. *World Population Projection.*

Year	Population				
	Lower95	Lower80	Median	Upper80	Upper95
2015	7.349.472	7.349.472	7.349.472	7.349.472	7.349.472
2020	7.718.265	7.732.429	7.758.157	7.783.871	7.797.707
2025	8.054.448	8.086.117	8.141.661	8.198.591	8.230.400
2030	8.359.668	8.410.612	8.500.766	8.594.245	8.647.692
2035	8.638.850	8.709.742	8.838.908	8.971.473	9.043.542
2040	8.888.874	8.984.278	9.157.234	9.332.629	9.429.975
2045	9.105.225	9.230.597	9.453.892	9.684.406	9.808.098
2050	9.283.627	9.440.449	9.725.148	10.019.142	10.182.121
2055	9.418.858	9.618.295	9.968.809	10.335.839	10.539.949
2060	9.528.266	9.759.245	10.184.290	10.625.083	10.875.267
2065	9.613.759	9.875.261	10.375.719	10.901.275	11.197.399
2070	9.663.059	9.964.971	10.547.989	11.165.230	11.510.493
2075	9.690.335	10.031.829	10.701.653	11.413.755	11.815.985
2080	9.685.056	10.067.360	10.836.635	11.648.994	12.116.537
2085	9.668.375	10.087.756	10.953.525	11.876.928	12.422.420
2090	9.621.078	10.088.203	11.055.270	12.097.337	12.718.194
2095	9.567.482	10.075.172	11.142.461	12.298.786	13.002.043
2100	9.493.640	10.039.937	11.213.317	12.498.749	13.294.186

Note 1: Data & Information: United Nations Population Division Department of Economic and Social Affairs, Website: http://esa.un.org/unpd/wpp/Download/Probabilistic/Population/, File: UN_PPP2015_Output_PopTot.xls, Year: 2015-2100, UN File: POP/DB/PPP/Rev.2015/PPP/POPTOT, Accessed On: 24.01.2016.

Note 2: 2025, 2035, …, 2095, 2100 Global Annual Temperature Anomalies Projection (degrees Celsius) data are not available, so that 2020, 2030, …, 2080, 2090 are selected for model prediction (blue shading color) during data preprocessing.

The historical and future projection data of this module will concurrently be updated with the updates of the United Nations (UN).

The global annual temperature anomalies (degrees Celsius: °C) is also used as the input variable. The global annual temperature anomalies (degrees Celsius: °C) is used as the second input variable in this module, because it is a very well known and common measure in the climate research and the absolute temperature effects on the electricity consumption are well defined in the literature. This variable is very well distinguished by the following statement in the global climate research community: "reason to work with anomalies, rather than absolute temperature is that absolute temperature varies markedly in short distances, while monthly or annual temperature anomalies are representative of a much larger region" [49] (also personal communication with Reto Ruedy via e-mail). Its historical data are taken from the Goddard Institute for Space Studies Laboratory in the Earth Sciences Division of National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center [50]. The historical data (year, global annual temperature anomalies (degrees Celsius)) is gathered is gathered and presented in “Tab. 3”.

Table 3. *Global Annual Temperature Anomalies Historical (degrees Celsius).*

Year	Anomalies	Year	Anomalies	Year	Anomalies
1880	-0,19	1926	-0,09	1972	0,01
1881	-0,10	1927	-0,20	1973	0,15
1882	-0,08	1928	-0,21	1974	-0,08
1883	-0,19	1929	-0,35	1975	-0,01
1884	-0,26	1930	-0,13	1976	-0,11
1885	-0,30	1931	-0,08	1977	0,18
1886	-0,29	1932	-0,15	1978	0,07
1887	-0,32	1933	-0,27	1979	0,17
1888	-0,19	1934	-0,12	1980	0,28
1889	-0,10	1935	-0,18	1981	0,33
1890	-0,35	1936	-0,14	1982	0,13
1891	-0,23	1937	-0,01	1983	0,31
1892	-0,25	1938	-0,01	1984	0,16
1893	-0,28	1939	-0,02	1985	0,12
1894	-0,29	1940	0,09	1986	0,19
1895	-0,20	1941	0,13	1987	0,34
1896	-0,14	1942	0,10	1988	0,40
1897	-0,10	1943	0,14	1989	0,29
1898	-0,27	1944	0,26	1990	0,44
1899	-0,15	1945	0,13	1991	0,42
1900	-0,08	1946	-0,03	1992	0,23
1901	-0,14	1947	-0,04	1993	0,24
1902	-0,27	1948	-0,09	1994	0,32
1903	-0,35	1949	-0,09	1995	0,46
1904	-0,43	1950	-0,18	1996	0,34
1905	-0,27	1951	-0,07	1997	0,47
1906	-0,21	1952	0,01	1998	0,63
1907	-0,39	1953	0,08	1999	0,42
1908	-0,42	1954	-0,12	2000	0,42
1909	-0,46	1955	-0,14	2001	0,54
1910	-0,42	1956	-0,19	2002	0,63
1911	-0,44	1957	0,04	2003	0,62
1912	-0,34	1958	0,06	2004	0,54
1913	-0,33	1959	0,03	2005	0,69
1914	-0,15	1960	-0,03	2006	0,63
1915	-0,10	1961	0,05	2007	0,66
1916	-0,33	1962	0,02	2008	0,53
1917	-0,39	1963	0,06	2009	0,64
1918	-0,25	1964	-0,21	2010	0,72
1919	-0,22	1965	-0,10	2011	0,60
1920	-0,25	1966	-0,05	2012	0,63
1921	-0,20	1967	-0,03	2013	0,65
1922	-0,26	1968	-0,07	2014	0,74
1923	-0,23	1969	0,06	2015	0,87
1924	-0,27	1970	0,03	-	-
1925	-0,19	1971	-0,09	-	-

Note 1: Data & Information: National Aeronautics and Space Administration Goddard Space Flight Center Sciences and Exploration Directorate Earth Sciences Division, Website: http://data.giss.nasa.gov/gistemp/graphs_v3/Fig.A2.txt, File: Fig.A2.txt, Year: 1951-1980, NASA File: "Global Land-Ocean Temperature Index (C) (Anomaly with Base: 1951-1980), Accessed On: 24.01.2016.

Note 2: 2011 - 2014 World Population (both sexes combined, as of 1 July (thousands)) and 1950 - 1989 energy production (TWh) and 2014 data are not available, so that 1990 - 2010 period is selected for model fitting (green shading color) during data preprocessing.

Its future projection data is gathered from the Intergovernmental Panel on Climate Change (IPCC), Annex II: Climate System Scenario Tables, Table AII.7.5. [51]. The projection data (Global Annual Temperature Anomalies Projection (degrees Celsius)) is gathered and presented in "Tab. 4".

Table 4. *Global Annual Temperature Anomalies Projection (degrees Celsius).*

Year	RCP2.6				
	5%	17%	50%	83%	95%
2010	0,19	0,33	0,36	0,52	0,62
2020	0,36	0,45	0,55	0,81	1,07
2030	0,47	0,56	0,74	1,02	1,24
2040	0,51	0,68	0,88	1,25	1,50
2050	0,49	0,71	0,94	1,37	1,65
2060	0,36	0,69	0,93	1,48	1,71
2070	0,20	0,70	0,89	1,49	1,71
2080	0,15	0,62	0,94	1,44	1,79
2090	0,18	0,58	0,94	1,53	1,79
RCP4.5					
2010	0,22	0,26	0,36	0,48	0,59
2020	0,39	0,48	0,59	0,74	0,83
2030	0,56	0,69	0,82	1,10	1,22
2040	0,64	0,86	1,04	1,35	1,57
2050	0,84	1,05	1,24	1,63	1,97
2060	0,90	1,13	1,44	1,90	2,19
2070	0,98	1,20	1,54	2,07	2,32
2080	0,98	1,27	1,62	2,25	2,54
2090	1,06	1,33	1,68	2,29	2,59
RCP6.0					
2010	0,21	0,26	0,36	0,47	0,64
2020	0,33	0,40	0,55	0,70	0,90
2030	0,40	0,59	0,74	0,92	1,17
2040	0,59	0,73	0,95	1,21	1,41
2050	0,69	0,92	1,15	1,52	1,81
2060	0,88	1,08	1,32	1,78	2,18
2070	1,08	1,28	1,58	2,14	2,52
2080	1,33	1,56	1,81	2,58	2,88
2090	1,51	1,72	2,03	2,92	3,24
RCP8.5					
2010	0,23	0,29	0,37	0,47	0,62
2020	0,37	0,51	0,66	0,84	0,99
2030	0,65	0,77	0,94	1,29	1,39
2040	0,93	1,13	1,29	1,68	1,77
2050	1,20	1,48	1,70	2,19	2,37
2060	1,55	1,88	2,16	2,74	2,99
2070	1,96	2,25	2,60	3,31	3,61
2080	2,31	2,65	3,05	3,93	4,22
2090	2,63	2,96	3,57	4,45	4,81
SRES A1B					
2010	0,15	0,22	0,34	0,44	0,62
2020	0,27	0,37	0,52	0,76	0,91
2030	0,47	0,59	0,82	1,04	1,38
2040	0,65	0,90	1,11	1,36	1,79
2050	0,92	1,14	1,55	1,65	2,14
2060	1,12	1,40	1,75	1,98	2,67
2070	1,40	1,60	2,14	2,39	3,12
2080	1,61	1,80	2,30	2,75	3,47
2090	1,76	1,96	2,54	3,05	3,84

Note 1: Data & Information: Intergovernmental Panel on Climate Change United Nations Environment Programme (UNEP) and World Meteorological Organization (WMO), Website: http://www.ipcc.ch/report/ar5/wg1/docs/WG1AR5_AIISM_Datafiles.xlsx, http://www.ipcc.ch/report/ar5/syr/, http://www.ipcc-data.org/syn/tar_scatter/csiro_error.html, http://www.climatechange2013.org/, File: WG1AR5_AIISM_Datafiles.xlsx, Year: 2010-2090, IPCC File: IPCC, 2013: Annex II: Climate System Scenario Tables [Prather, M., G. Flato, P. Friedlingstein, C. Jones, J.-F. Lamarque, H. Liao and P. Rasch (eds.)]. In: Climate Change 2013: The Physical, Accessed On: 25.01.2016.

Note 2: 2025, 2035,…., 2095, 2100 Global Annual Temperature Anomalies Projection (degrees Celsius) data are not available, so that 2020, 2030,…..,2080, 2090 are selected for model prediction (blue shading color) during data preprocessing.

The historical and future projection data of this module will concurrently be updated with the updates of the NASA (see [50], and the IPCC (see [51]).

The annual electricity demand of Global Grid (terawatt hour: TWh) is the output variable. Its historical data are based on the official records at the International Energy Agency (IEA) [52]. The historical data (year, energy production (Mtoe), total primary energy supply (TPES) (Mtoe), electricity consumption (TWh), energy production (TWh)) is gathered is gathered and presented in "Tab. 5".

Table 5. *Annual Electricity Demand of Global Grid Historical Data Calculation.*

Year	Energy production (Mtoe)	Total primary energy supply (TPES) (Mtoe)	Electricity consumption* (TWh)	Energy production (TWh)
1990	8.819,31	8.780,25	10.872,40	102.568,58
1991	8.836,01	8.841,25	11.187,85	102.762,80
1992	8.889,87	8.850,79	11.281,24	103.389,19
1993	8.920,27	8.937,59	11.492,15	103.742,74
1994	9.047,58	9.002,84	11.788,97	105.223,36
1995	9.274,09	9.235,89	12.171,42	107.857,67
1996	9.500,58	9.469,10	12.570,34	110.491,75
1997	9.622,95	9.562,07	12.875,27	111.914,91
1998	9.736,10	9.610,14	13.169,61	113.230,84
1999	9.754,28	9.820,01	13.530,76	113.442,28
2000	10.050,13	10.079,36	14.147,95	116.883,01
2001	10.213,66	10.160,82	14.287,61	118.784,87
2002	10.288,93	10.359,27	14.793,09	119.660,26
2003	10.713,71	10.717,70	15.360,73	124.600,45
2004	11.238,73	11.223,56	16.050,68	130.706,43
2005	11.599,70	11.507,02	16.755,03	134.904,51
2006	11.917,49	11.836,89	17.438,14	138.600,41
2007	12.094,84	12.109,90	18.253,17	140.662,99
2008	12.376,99	12.283,52	18.633,66	143.944,39
2009	12.294,16	12.195,83	18.531,21	142.981,08
2010	12.860,49	12.890,81	19.810,74	149.567,50
2011	13.216,16	13.128,95	20.460,85	153.703,94
2012	13.461,14	13.371,03	20.915,39	156.553,06
2013	13.594,11	13.541,28	21.537,90	158.099,50

Note 1: Data & Information: International Energy Agency, Website: http://www.iea.org/statistics/statisticssearch/report/?country=WORLD&product=indicators&year=Select, File: http://www.iea.org/publications/freepublications/publication/KeyWorld_Statistics_2015.pdf, Year: 1990-2013, IEA File: Website, Accessed On: 31.01.2016, Unit converter http://www.iea.org/statistics/resources/unitconverter/.

Note 2: 2011 - 2014 World Population (both sexes combined, as of 1 July (thousands)) and 1950 - 1989 energy production (TWh) and 2014 data are not available, so that 1990 - 2010 period is selected for model fitting (green shading color) during data preprocessing.

There are two important assumptions and approximations in this output. First, the annual energy production (Mtoe: million tonnes of oil equivalent) data on the IEA [53] can represent the annual electricity consumption of%100 Global Grid. Second, the direct conversion of annual energy production (Mtoe) to the total global annual electricity demand (tera: T: 1012) can be made by the IEA's unit convertor [53].

As a result, two input variables and one output variable are defined and used accordingly with an international basis for this one node Mamdani [45, 46, 47] like FIS in this G^2EDPS core module "Fig. 3".

The data preprocessing (cleaning, integration, transformation, reduction) unit investigates the annual data for two inputs and one output from their data files. When all input and output annual historical data is available, they are marked as available (historical) (green shading color). When at least one of the input and output data is not available, they are marked as not available (historical). The earliest and latest year in these classified data are found and all of the data (year, inputs, output) are extracted as historical data for model fitting (i.e. $t_{earliest.historical}$, $t_{latest.historical}$, t: year, $input_t$, $output_t$ ϵ model fitting set) of this G^2EDPS core module (historical data set: green shading color). The same approach is performed for the model prediction (blue shading color) of this G^2EDPS core module (prediction data set: $t_{earliest.prediction}$, $t_{latest.prediction}$) ("Fig. 3", "Tab. 1", "Tab. 2", "Tab. 3", "Tab. 4", "Tab. 5").

The fuzzification interface or fuzzifier unit of this core module works with 7 triangular MF based on the data preprocessing unit's outcomes ("Fig. 4", "Fig. 5"). The minimum and maximum values for the input and output in the historical and prediction data set are found and used for the minimum and maximum of the fuzzy membership functions' values ($data_{minimum}$, $data_{maximum}$ for inputs and $data_{minimum}$ for output). The maximum value of the output is calculated and defined as a sufficiently large value found by the linear regression approximation calculation ($data_{maximum}$ for output: largest regression value by all or some of the data). After the $data_{minimum}$, $data_{maximum}$ for inputs and output is defined the fuzzy membership functions are defined for similar 7 triangular functions ("Fig. 4"). When the historical and future projection data of this module will be updated by the NASA, the IPCC and the IEA, the fuzzification interface will be run and updated. 7 triangular fuzzy membership functions will be defined and presented publicly (open public websites).

The rule base of the inference system or decision making unit has predefined 49 rules (fixed, permanent) as follows “Tab. 6”:

Table 6. *GGED-SS-C-T1MFIS7TMF-2VPGATA-100YPP-2015 49 rules for 2 inputs and 1 output on Scilab 5.5.2 Script for Core Model.*

R1: IF (world population IS very very low) AND (global annual temperature anomalies IS almost the same) THEN (annual electricity demand of Global Grid (TWh) IS very very low) weigth=1
R2: IF (world population IS very very low) AND (global annual temperature anomalies IS fairly hotter) THEN (annual electricity demand of Global Grid (TWh) IS very very low) weigth=1
R3: IF (world population IS very very low) AND (global annual temperature anomalies IS rather hotter) THEN (annual electricity demand of Global Grid (TWh) IS very very low) weigth=1
R4: IF (world population IS very very low) AND (global annual temperature anomalies IS hotter) THEN (annual electricity demand of Global Grid (TWh) IS very very low) weigth=1
R5: IF (world population IS very very low) AND (global annual temperature anomalies IS very hotter) THEN (annual electricity demand of Global Grid (TWh) IS very low) weigth=1
R6: IF (world population IS very very low) AND (global annual temperature anomalies IS very very hotter) THEN (annual electricity demand of Global Grid (TWh) IS very low) weigth=1
R7: IF (world population IS very very low) AND (global annual temperature anomalies IS extremely hotter) THEN (annual electricity demand of Global Grid (TWh) IS very low) weigth=1
R8: IF (world population IS very low) AND (global annual temperature anomalies IS almost the same) THEN (annual electricity demand of Global Grid (TWh) IS very low) weigth=1
R9: IF (world population IS very low) AND (global annual temperature anomalies IS fairly hotter) THEN (annual electricity demand of Global Grid (TWh) IS very low) weigth=1
R10: IF (world population IS very low) AND (global annual temperature anomalies IS rather hotter) THEN (annual electricity demand of Global Grid (TWh) IS very low) weigth=1
R11: IF (world population IS very low) AND (global annual temperature anomalies IS hotter) THEN (annual electricity demand of Global Grid (TWh) IS very low) weigth=1
R12: IF (world population IS very low) AND (global annual temperature anomalies IS very hotter) THEN (annual electricity demand of Global Grid (TWh) IS low) weigth=1
R13: IF (world population IS very low) AND (global annual temperature anomalies IS very very hotter) THEN (annual electricity demand of Global Grid (TWh) IS low) weigth=1
R14: IF (world population IS very low) AND (global annual temperature anomalies IS extremely hotter) THEN (annual electricity demand of Global Grid (TWh) IS low) weigth=1
R15: IF (world population IS low) AND (global annual temperature anomalies IS almost the same) THEN (annual electricity demand of Global Grid (TWh) IS low) weigth=1
R16: IF (world population IS low) AND (global annual temperature anomalies IS fairly hotter) THEN (annual electricity demand of Global Grid (TWh) IS low) weigth=1
R17: IF (world population IS low) AND (global annual temperature anomalies IS rather hotter) THEN (annual electricity demand of Global Grid (TWh) IS low) weigth=1
R18: IF (world population IS low) AND (global annual temperature anomalies IS hotter) THEN (annual electricity demand of Global Grid (TWh) IS low) weigth=1
R19: IF (world population IS low) AND (global annual temperature anomalies IS very hotter) THEN (annual electricity demand of Global Grid (TWh) IS moderate) weigth=1
R20: IF (world population IS low) AND (global annual temperature anomalies IS very very hotter) THEN (annual electricity demand of Global Grid (TWh) IS moderate) weigth=1
R21: IF (world population IS low) AND (global annual temperature anomalies IS extremely hotter) THEN (annual electricity demand of Global Grid (TWh) IS moderate) weigth=1
R22: IF (world population IS moderate) AND (global annual temperature anomalies IS almost the same) THEN (annual electricity demand of Global Grid (TWh) IS moderate) weigth=1
R23: IF (world population IS moderate) AND (global annual temperature anomalies IS fairly hotter) THEN (annual electricity demand of Global Grid (TWh) IS moderate) weigth=1
R24: IF (world population IS moderate) AND (global annual temperature anomalies IS rather hotter) THEN (annual electricity demand of Global Grid (TWh) IS moderate) weigth=1
R25: IF (world population IS moderate) AND (global annual temperature anomalies IS hotter) THEN (annual electricity demand of Global Grid (TWh) IS moderate) weigth=1
R26: IF (world population IS moderate) AND (global annual temperature anomalies IS very hotter) THEN (annual electricity demand of Global Grid (TWh) IS high) weigth=1
R27: IF (world population IS moderate) AND (global annual temperature anomalies IS very very hotter) THEN (annual electricity demand of Global Grid (TWh) IS high) weigth=1
R28: IF (world population IS moderate) AND (global annual temperature anomalies IS extremely hotter) THEN (annual electricity demand of Global Grid (TWh) IS high) weigth=1
R29: IF (world population IS high) AND (global annual temperature anomalies IS almost the same) THEN (annual electricity demand of Global Grid (TWh) IS high) weigth=1
R30: IF (world population IS high) AND (global annual temperature anomalies IS fairly hotter) THEN (annual electricity demand of Global Grid (TWh) IS high) weigth=1
R31: IF (world population IS high) AND (global annual temperature anomalies IS rather hotter) THEN (annual electricity demand of Global Grid (TWh) IS high) weigth=1
R32: IF (world population IS high) AND (global annual temperature anomalies IS hotter) THEN (annual electricity demand of Global Grid (TWh) IS high) weigth=1
R33: IF (world population IS high) AND (global annual temperature anomalies IS very hotter) THEN (annual electricity demand of Global Grid (TWh) IS very high) weigth=1
R34: IF (world population IS high) AND (global annual temperature anomalies IS very very hotter) THEN (annual electricity demand of Global Grid (TWh) IS very high) weigth=1
R35: IF (world population IS high) AND (global annual temperature anomalies IS extremely hotter) THEN (annual electricity demand of Global Grid (TWh) IS very high) weigth=1
R36: IF (world population IS very high) AND (global annual temperature anomalies IS almost the same) THEN (annual electricity demand of Global Grid (TWh) IS very high) weigth=1
R37: IF (world population IS very high) AND (global annual temperature anomalies IS fairly hotter) THEN (annual electricity demand of Global Grid (TWh) IS very high) weigth=1
R38: IF (world population IS very high) AND (global annual temperature anomalies IS rather hotter) THEN (annual electricity demand of Global Grid (TWh) IS very high) weigth=1
R39: IF (world population IS very high) AND (global annual temperature anomalies IS hotter) THEN (annual electricity demand of Global Grid (TWh) IS very high) weigth=1
R40: IF (world population IS very high) AND (global annual temperature anomalies IS very hotter) THEN (annual electricity demand of Global Grid (TWh) IS very very high) weigth=1
R41: IF (world population IS very high) AND (global annual temperature anomalies IS very very hotter) THEN (annual electricity demand of Global Grid (TWh) IS very very high) weigth=1
R42: IF (world population IS very high) AND (global annual temperature anomalies IS extremely hotter) THEN (annual electricity demand of Global Grid (TWh) IS very very high) weigth=1
R43: IF (world population IS very very high) AND (global annual temperature anomalies IS almost the same) THEN (annual electricity demand of Global Grid (TWh) IS very very high) weigth=1
R44: IF (world population IS very very high) AND (global annual

temperature anomalies IS fairly hotter) THEN (annual electricity demand of Global Grid (TWh) IS very very high) weigth=1
R45: IF (world population IS very very high) AND (global annual temperature anomalies IS rather hotter) THEN (annual electricity demand of Global Grid (TWh) IS very very high) weigth=1
R46: IF (world population IS very very high) AND (global annual temperature anomalies IS hotter) THEN (annual electricity demand of Global Grid (TWh) IS very very high) weigth=1
R47: IF (world population IS very very high) AND (global annual temperature anomalies IS very hotter) THEN (annual electricity demand of Global Grid (TWh) IS very very high) weigth=1
R48: IF (world population IS very very high) AND (global annual temperature anomalies IS very very hotter) THEN (annual electricity demand of Global Grid (TWh) IS very very high) weigth=1
R49: IF (world population IS very very high) AND (global annual temperature anomalies IS extremely hotter) THEN (annual electricity demand of Global Grid (TWh) IS very very high) weigth=1

These predefined 49 rules are designed as unchangeable in the current design of this G^2EDPS 1st core module (long term prediction console) (fixed, permanent).

The defuzzification interface or defuzzifier unit performs concurrently by all defuzzification methods (e. g. shortest of maximum, mean of maximum, bisector of area, centroide, largest of maximum). When new defuzzification methods will be presented in the literature, they will be integrated into the defuzzifier unit of this G^2EDPS 1st core module.

The fuzzifier, rule base and surface graph of this G^2EDPS 1st core module's model is presented in "Fig. 4". "Fig. 5". and "Fig. 6".

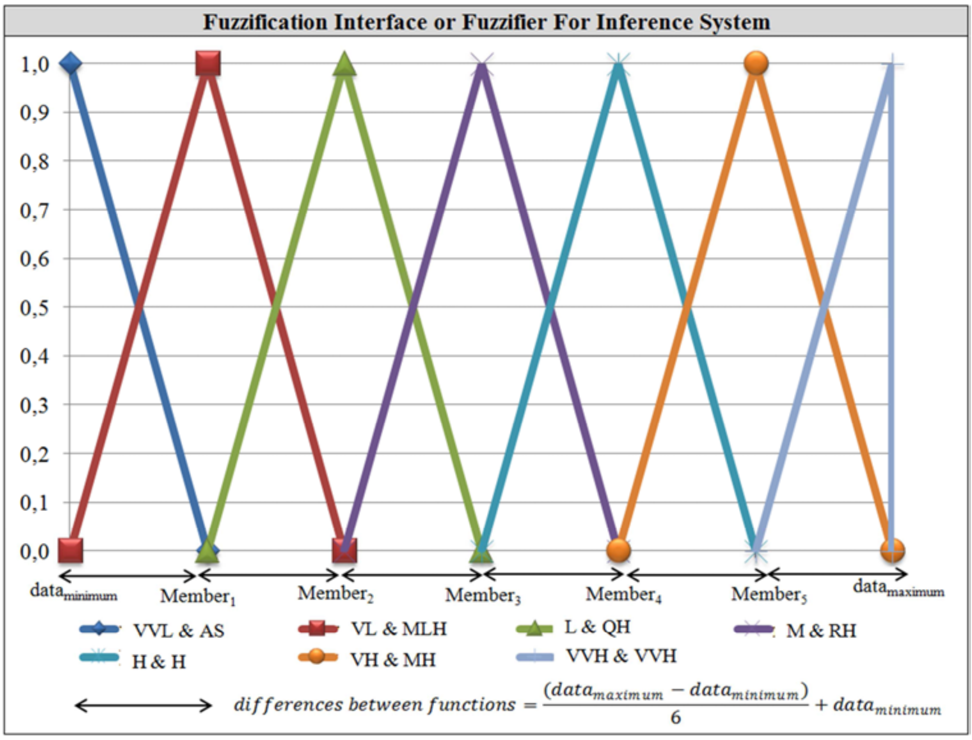


Figure 4. Fuzzifier by Excel 2007 & Paint. NET.

Rule Base For Inference System

			Global Temperature Anomalies (increasing →)								
			almost same	more or less hotter	quite hotter	rather hotter	hotter	much hotter	very very hotter		
Population (increasing ↓)			AS	MLH	QH	RH	H	MH	VVH		Electricity Demand (increasing ↓)
	very very low	VVL	VVL	VVL	VVL	VVL	VL	VL	VL	VVL	very very low
	very low	VL	VL	VL	VL	VL	L	L	L	VL	very low
	low	L	L	L	L	L	M	M	M	L	low
	moderate	M	M	M	M	M	H	H	H	M	moderate
	high	H	H	H	H	H	VH	VH	VH	H	high
	very high	VH	VH	VH	VH	VH	VVH	VVH	VVH	VH	very high
	very very high	VVH	VVH	VVH	VVH	VVH	VVH	VVH	VVH	VVH	very very high

Figure 5. Rule Base by Excel 2007 & Paint. NET.

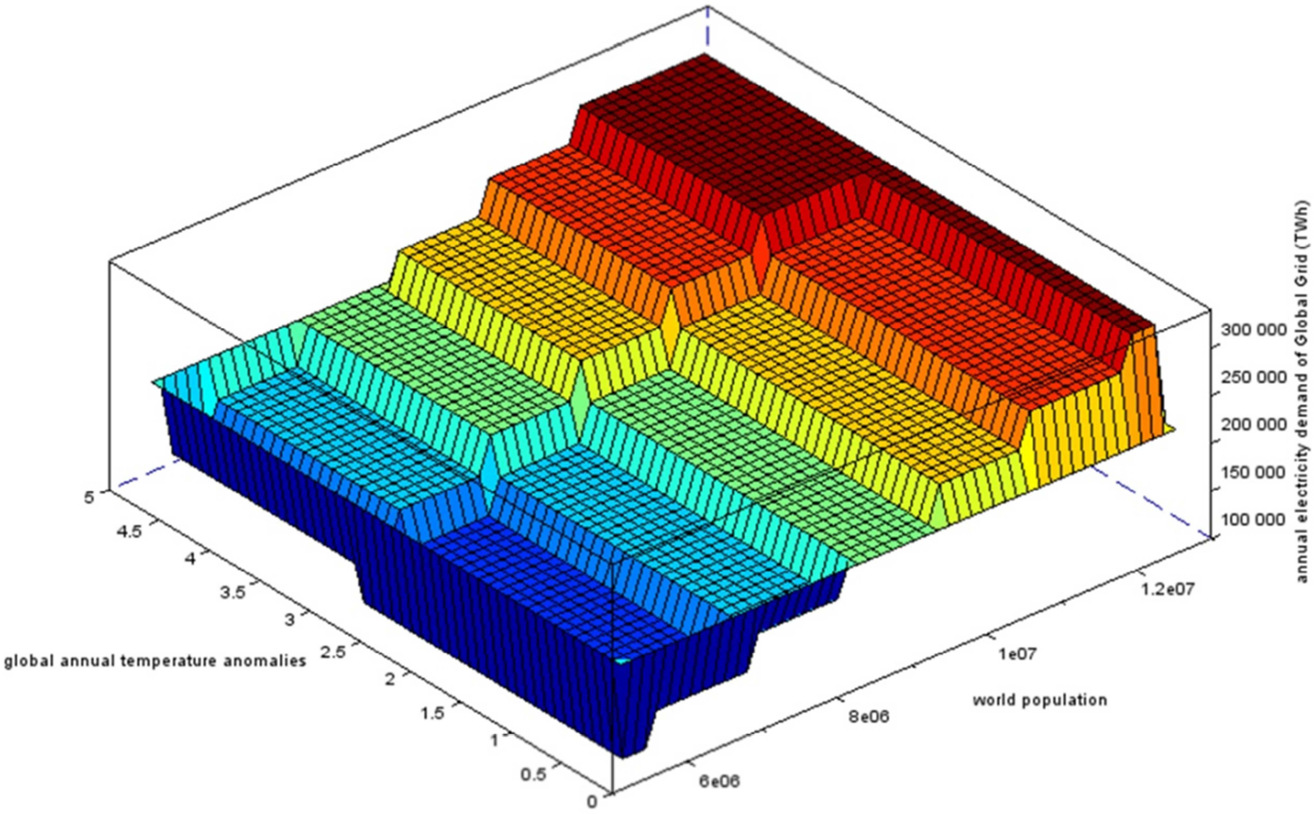


Figure 6. *Surface View GGED-SS-C-T1MFIS7TMF-2VPGATA-100YPP-2015, Fuzzy Logic Toolbox 0.4.6 Scilab 5.5.2 (sciFLT) & Paint. NET.*

The main Scilab script is as follows "Tab. 7":

Table 7. *GGED-SS-C-T1MFIS7TMF-2VPGATA-100YPP-2015 Scilab 5.5.2 Script For Core Model.*

```
// COREMODULE1: Type 1 Mamdani-Like Fuzzy Inference Systems 7 Triangular Membership Functions min t-norm max t-conorm or s-norm Fuzzy Toolbox 0.4.6 Scilab 5.5.2 SciFLT Model
COREMODULE1=newfls();
COREMODULE1.name="Global Grid Electricity Demand Prediction System G2EDPS Core Module 1";
COREMODULE1.comment="Global Grid Electricity Demand Prediction System Core Module 1 Model Side By Side Level Approach Type 1 Mamdani-Like Fuzzy Inference System With 7 Same Triangle Membership Functions For Inputs Population Global Annual Temperature Anomalies Development In 2016";
COREMODULE1.type="m";
COREMODULE1.SNorm="asum";
COREMODULE1.TNorm="aprod";
COREMODULE1.Comp="one";
COREMODULE1.ImpMethod="prod";
COREMODULE1.AggMethod="max";
// all defuzzification methods will be applied one by one!
COREMODULE1.defuzzMethod="som";
// first variable is world population 1990-2090 historical and projection
COREMODULE1=addvar(COREMODULE1,"input","world population",[5320817 12718194]);
COREMODULE1=addmf(COREMODULE1,"input",1,"very very low","trimf",[5320817 5320817 6553713]);
COREMODULE1=addmf(COREMODULE1,"input",1,"very low","trimf",[5320817 6553713 7786609]);
COREMODULE1=addmf(COREMODULE1,"input",1,"low","trimf",[6553713 7786609 9019505]);
COREMODULE1=addmf(COREMODULE1,"input",1,"moderate","trimf",[7786609 9019505 10252401]);
COREMODULE1=addmf(COREMODULE1,"input",1,"high","trimf",[9019505 10252401 11485298]);
COREMODULE1=addmf(COREMODULE1,"input",1,"very high","trimf",[10252401 11485298 12718194]);
COREMODULE1=addmf(COREMODULE1,"input",1,"very very high","trimf",[11485298 12718194 12718194]);
// second variable is global annual temperature anomalies 1990-2090 historical and projection
COREMODULE1=addvar(COREMODULE1,"input","global annual temperature anomalies",[0.15 4.81]);
COREMODULE1=addmf(COREMODULE1,"input",2,"almost the same","trimf",[0.15 0.15 0.93]);
COREMODULE1=addmf(COREMODULE1,"input",2,"fairly hotter","trimf",[0.15 0.93 1.71]);
COREMODULE1=addmf(COREMODULE1,"input",2,"rather hotter","trimf",[0.93 1.71 2.48]);
COREMODULE1=addmf(COREMODULE1,"input",2,"hotter","trimf",[1.71 2.48 3.26]);
COREMODULE1=addmf(COREMODULE1,"input",2,"very hotter","trimf",[2.48 3.26 4.03]);
COREMODULE1=addmf(COREMODULE1,"input",2,"very very hotter","trimf",[3.26 4.03 4.81]);
COREMODULE1=addmf(COREMODULE1,"input",2,"extremely hotter","trimf",[4.03 4.81 4.81]);
//output variable is annual electricity demand of Global Grid TWh 1990-2010 historical
// projection is calculated by this module 2015-2090 with 5 to 10 years periods
COREMODULE1=addvar(COREMODULE1,"output","annual electricity demand of Global Grid (TWh)",[102569 325730]);
COREMODULE1=addmf(COREMODULE1,"output",1,"very very low","trimf",[102569 102569 139762]);
COREMODULE1=addmf(COREMODULE1,"output",1,"very low","trimf",[102569 139762 176956]);
COREMODULE1=addmf(COREMODULE1,"output",1,"low","trimf",[13
```

```
9762 176956 214149]);
COREMODULE1=addmf(COREMODULE1,"output",1,"moderate","trimf
",[176956 214149 251343]);
COREMODULE1=addmf(COREMODULE1,"output",1,"high","trimf",[21
4149 251343 288536]);
COREMODULE1=addmf(COREMODULE1,"output",1,"very
high","trimf",[251343 288536 325730]);
COREMODULE1=addmf(COREMODULE1,"output",1,"very very
high","trimf",[288536 325730 325730]);
scf();clf();
plotvar(COREMODULE1,"input",[1 2]);
scf();clf();
plotvar(COREMODULE1,"output",1);
COREMODULE1=addrule(COREMODULE1,[ 1 1 1 1 1; 1 2 1 1 1; 1 3 1
1 1; 1 4 1 1 1; 1 5 2 1 1; 1 6 2 1 1; 1 7 2 1 1; 2 1 2 1 1; 2 2 2 1 1; 2 3 2 1 1;
2 4 2 1 1; 2 5 3 1 1; 2 6 3 1 1; 2 7 3 1 1; 3 1 3 1 1; 3 2 3 1 1; 3 3 3 1 1; 3 4 3
1 1; 3 5 4 1 1; 3 6 4 1 1; 3 7 4 1 1; 4 1 4 1 1; 4 2 4 1 1; 4 3 4 1 1; 4 4 4 1 1;
4 5 5 1 1; 4 6 5 1 1; 4 7 5 1 1; 5 1 5 1 1; 5 2 5 1 1; 5 3 5 1 1; 5 4 5 1 1; 5 5 6
1 1; 5 6 6 1 1; 5 7 6 1 1; 6 1 6 1 1; 6 2 6 1 1; 6 3 6 1 1; 6 4 6 1 1; 6 5 7 1 1;
6 6 7 1 1; 6 7 7 1 1; 7 1 7 1 1; 7 2 7 1 1; 7 3 7 1 1; 7 4 7 1 1; 7 5 7 1 1; 7 6 7
1 1; 7 7 7 1 1])
printrule(COREMODULE1);
```

Note 1: Script for Smallest Of Max in Scilab 5.5.2 (Fuzzy Logic Toolbox 0.4.6 Scilab 5.5.2 (sciFLT)): see COREMODULE1. defuzzMethod="som"
Note 2: For Mean Of Max COREMODULE1. defuzzMethod="mom"; Bisector "bisector"; Centroide "centroide"; Largest Of Maximum "lom" script lines and codes are used instead of "som".
Note 3: open electronic supplementary files COREMODULE1bisector. fls, "centroide", "lom", "mom", "som".

This G^2EDPS 1st core module works with a common global unique forecast accuracy metrics pool, which includes the prediction scale-dependent error metrics (e. g. Mean Absolute Error: MAE, Geometric Mean Absolute Error: GMAE, Mean Square Error: MSE), percentage error metrics (e. g. Minimum Absolute Percentage Error: MinAP, Maximum Absolute Percentage Error: MAP, Mean Absolute Percentage Error: MAPE, symmetric MAPE: SMAPE), relative error metrics (e. g. Median Relative Absolute Error: MdRAE, Geometric Mean Relative Absolute Error: GMRAE), scale-free error metrics (e. g. Mean Absolute Scaled Error: MASE) [54, 55, 56, 57, 58]. The current version of the forecast accuracy metrics pool covers the following error metrics. Nowadays, they are calculated by Microsoft Office Excel [16] or Apache OpenOffice Calc [17]:

Forecast Errors:

$$e_t = Actual_t - Predicted_t \quad (1)$$

Mean Absolute Error (MAE):

$$MAE = \frac{1}{n}\sum_1^n |e_t| \quad (2)$$

Geometric Mean Absolute Error (GMAE):

$$GMAE = \left(\prod_{i=1}^n |e_t|\right)^{1/n} \quad (3)$$

Mean Square Error (MSE):

$$MSE = \frac{1}{n}\sum_1^n {e_t}^2 \quad (4)$$

Absolute Percentage Errors (APE):

$$APE_t = \frac{(|Actual_t - Predicted_t|)}{(Actual_t)} \quad (5)$$

Minimum Absolute Percentage Error (MinAP):

$$MinAP = min(APE_t) \quad (6)$$

Maximum Absolute Percentage Error (MAP):

$$MAP = max(APE_t) \quad (7)$$

Mean Absolute Percentage Error (MAPE):

$$MAPE = \frac{1}{n}\sum_1^n (APE_t) \quad (8)$$

Symmetric MAPE:

$$SMAPE = \frac{1}{n}\sum_1^n \left(\frac{|Predicted_t - Actual_t|}{\left(\frac{(|Predicted|_t + |Actual|_t)}{2}\right)}\right) \quad (9)$$

Relative Error:

$$r_t = \frac{e_t}{e^*{}_t} \quad (10)$$

Median Relative Absolute Error (MdRAE):

$$MdRAE = median(|r_t|) \quad (11)$$

Geometric Mean Relative Absolute Error (GMRAE):

$$GMRAE = \left(\prod_{i=1}^n |r_t|\right)^{1/n} \quad (12)$$

where Actual, Predicted, t, n, * represents respectively historical annual electricity demand of the Global Grid, forecasted/predicted annual electricity demand of the Global Grid, year, total number of years and benchmark model.

This G^2EDPS 1st core module has a best core model defuzzifier selection unit. The minimum SMAPE valued defuzzification model is first selected for the predictions. The minimum MAPE and MAP valued ones are selected after the minimum SMAPE valued ones. If there are more than one minimum SMAPE, MAPE and MAP valued models, all of them will be run for the 100 year projections.

The G^2EDPS 1st core module has 10 extension modules. These extensions try to find some model fitting improvements by some simplistic procedures (adjustment, correction or enhancement) based on the arithmetic average, mode, median, minimum, maximum and percentage of the forecast errors and absolute forecast errors. The first procedure calculates the arithmetic average (mean) of the forecast errors (e_t) and sum the prediction values with this calculated value. The second and third procedures work with the most repeated, observed, frequent value (mode) and the mid value (median) of the forecast errors (e_t) and the summation operator. The fourth and fifth procedures find the minimum and maximum of the absolute forecast errors ($|e_t|$) and sum the prediction values with the non-absolute values. The sixth procedure calculates the arithmetic average of the percentage values ($actual_t/predicted_t$) and multiply by this calculated value. The seventh, eighth, ninth and tenth procedures are similar to second, third, fourth and fifth together with sixth procedures. The following procedure

("Tab. 8") is presented for only the first one as representative for each one (all of them):

Table 8. *First extension module adjustment, correction or enhancement procedure (general procedure, free of coding and scripting languages).*

1 Input 1 Historical estimation by performed defuzzification FIS value
2 Input 2 Historical estimation forecast errors
3 Calculate Arithmetic average (mean) of forecast errors (adjustment, correction or enhancement)
4 Sum Arithmetic average (mean) of forecast errors to historical estimation by performed defuzzification FIS value
5 Output Adjusted estimation of performed defuzzification FIS value

Note 1: 10 extension modules have their own procedures.
Note 2: open electronic supplementary files for these modules

There is also a small best core model extensions model selection unit working with the same principles of the G²EDPS 1st best core model defuzzifier selection unit ("Fig. 3").

4. Analysis and Results (Module Fitting & 100 Year Forecasting)

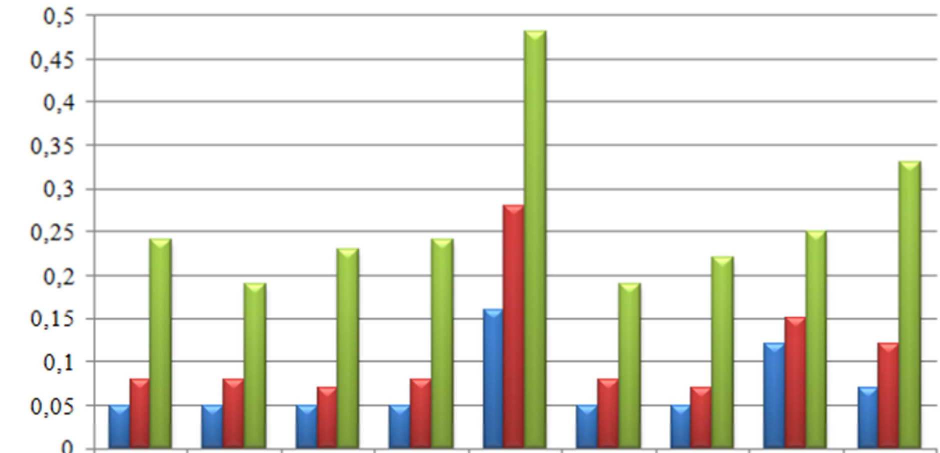
The first input variable's historical data (1950-2010) and future projection (2015-2100) are directly gathered from the UN (see [48]). The historical and future projection data will concurrently be updated with the UN (1950-2010→1950-2011 and so on; 2015-2100→2020-2105). The second input variable's historical data (1880-2015) is taken from the NASA (see [50]). Its future projection data (2010-2090) is gathered from the IPCC Annex II: Climate System Scenario Tables, Table AII.7.5. (see [51]). The historical and future projection data will concurrently be updated with the NASA, and the IPCC (1880-2015→1880-2016 and so on; 2010-2090→2020-2100). The output variable's historical data (1990-2013) is based on the official records at the IEA (see [52]). The Fuzzy Toolbox 0.4.6 for the Scilab 5.5.2 (sciFLT) [13] is used for the FIS computations. The model fitting or historical prediction report is gathered by sciFLT [13], Excel [16], Calc [17] ("Tab. 9".). The shortest of maximum defuzification method is selected for future forecasting/prediction based on the best core model defuzzifier selection unit ("Tab. 9"). The bisector and centroide defuzification methods presents errors, so that they are eliminated during the analysis (open electronic supplementary files).

Table 9. *Forecast accuracy metrics (performance measures) for G²EDPS 1st core model.*

Accuracy Metrics	shortest of maximum	mean of maximum	largest of maximum
MAE	9032	14345	148778
GMAE	3004	5441	139665
MSE	3524780760	15975083517	564777853326
MinAP	0,00	0,00	-100,07
MAP	0,24	1,09	896,12
MAPE	0,08	0,13	44,07
SMAPE	0,05	0,07	1,01

Note 1: The best performance is selected by the best core model defuzzifier selection unit (yellow shading color)
Note 2: open electronic supplementary files

The G²EDPS 1st core model 10 extension modules are run on Excel [16], Calc [17] for model fitting. 2nd and 7th extensions can't present any numerical value in this study, because of their approaches (error for division by zero in current data set). Other extensions can work on the current data values and their performance measures are calculated by Excel [16], Calc [17]. Only 8th extension approach gives better performance in this study. The model fitting predictions are presented in "Fig. 7".



	C	E1	E3	E4	E5	E6	E8	E9	E10
SMAPE	0,05	0,05	0,05	0,05	0,16	0,05	0,05	0,12	0,07
MAPE	0,08	0,08	0,07	0,08	0,28	0,08	0,07	0,15	0,12
MAP	0,24	0,19	0,23	0,24	0,48	0,19	0,22	0,25	0,33

■ SMAPE ■ MAPE ■ MAP

Figure 7. *Rule Base by Excel 2007 Forecast accuracy metrics for core (C) model & extensions (E) by Excel 2007 & Paint. NET.*

According to this model fitting study of the G^2EDPS 1st core model and its extensions, the best core model (shortest of maximum) and its 8th extension are run for 2015, 2020, 2030, 2040, 2050, 2060, 2070, 2080 and 2090 for global population (Lower95, Lower80, Median, Upper80, Upper95) according to the UN (see [48]) and global annual temperature anomalies (5%, 17%, 50%, 83%, 95% predictions for each RCP2.6, RCP4.5, RCP6.0, RCP8.5, SRES A1B) according to the IPCC (see [51]). The 100 year forecast report is plotted for as such 2015, 176212; 2020, 176212; 2030, 176212; 2040, 214150; 2050, 214150; 2060, 214150; 2070, 252087; 2070, 252087; and 2090, 214150 by R [14], RStudio [15] ("Figure 8", "Table 10").

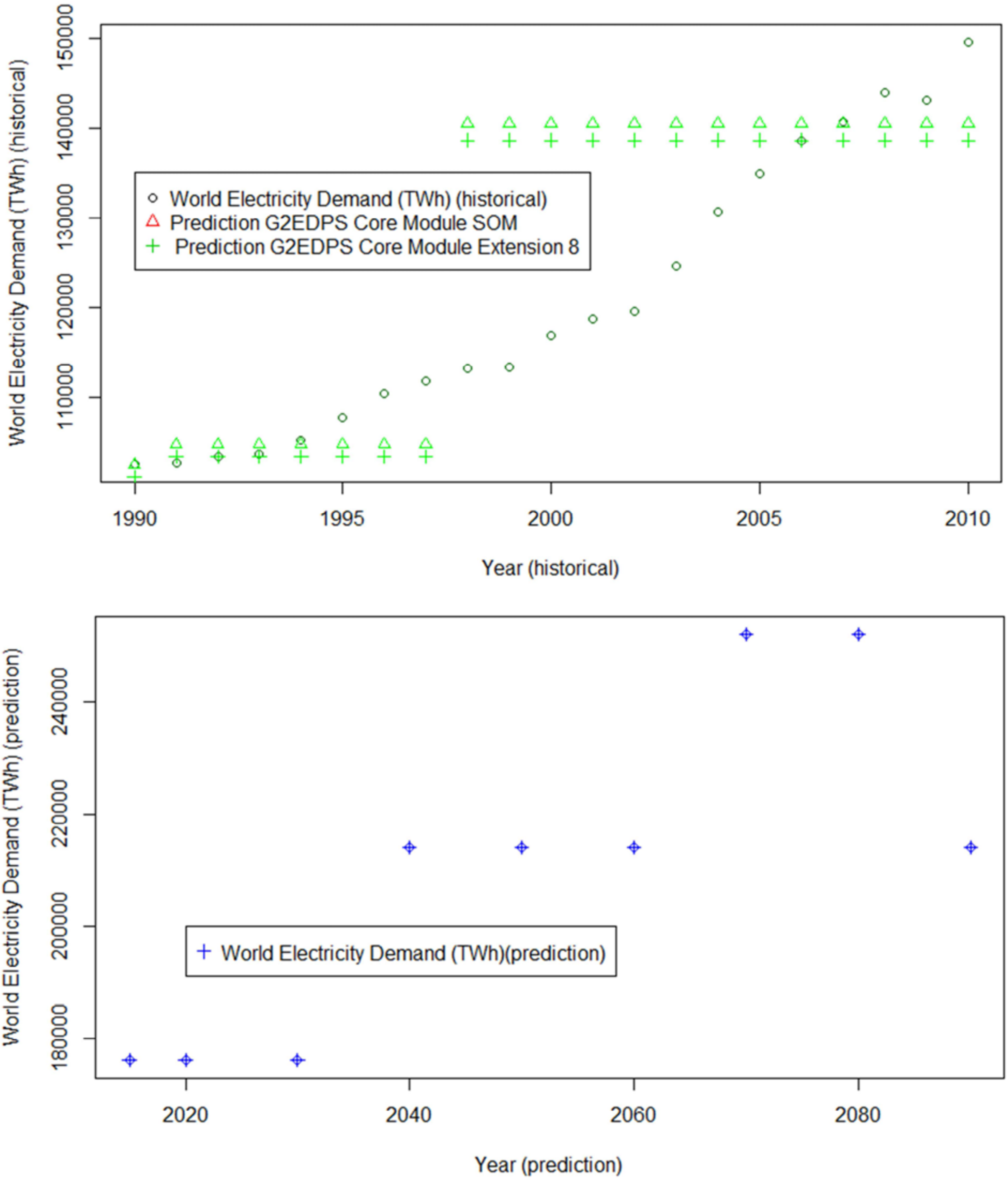


Figure 8. *Historical actual data and historical prediction core module and extension (only best fitted) (top), projection of Global Grid electricity demand (TWh) (bottom) visualization generated by the scatter graph without smoothing of R https://www.r-project.org/, RStudio https://www.rstudio.com/, & Paint. NET.*

Table 10. *RStudio Version 0.99.491 Scripts historical (top), projection (bottom).*

```
Year.Historical=c(1990,1991,1992,1993,1994,1995,1996,1997,1998,1999,
2000,2001,2002,2003,2004,2005,2006,2007,2008,2009,2010)
World.Electricity.Demand.TWh.Historical=c(102568.58,102762.80,10338
9.19,103742.74,105223.36,107857.67,110491.75,111914.91,113230.84,11
3442.28,116883.01,118784.87,119660.26,124600.45,130706.43,134904.51
,138600.41,140662.99,143944.39,142981.08,149567.50)
World.Electricity.Demand.TWh.Historical.Prediction.G2EDPS.CoreModul
eSOM=c(102569.00,104800.61,104800.61,104800.61,104800.61,104800.6
1,104800.61,104800.61,140506.37,140506.37,140506.37,140506.37,14050
6.37,140506.37,140506.37,140506.37,140506.37,140506.37,140506.37,14
0506.37,140506.37)
World.Electricity.Demand.TWh.Historical.Prediction.G2EDPS.CoreModul
eSOM.Extension8=c(101187.6327,103389.1881,103389.1881,103389.188
1,103389.1881,103389.1881,103389.1881,103389.1881,138614.0741,1386
14.0741,138614.0741,138614.0741,138614.0741,138614.0741,138614.074
1,138614.0741,138614.0741,138614.0741,138614.0741,138614.0741,1386
14.0741)
plot(Year.Historical, World.Electricity.Demand.TWh.Historical,
xlab="Year (historical)", ylab="World Electricity Demand (TWh)
(historical)", pch=1, col="darkgreen")
points(Year.Historical,World.Electricity.Demand.TWh.Historical.Predictio
n.G2EDPS.CoreModuleSOM, pch=2, col="green")
points(Year.Historical,World.Electricity.Demand.TWh.Historical.Predictio
n.G2EDPS.CoreModuleSOM.Extension8, pch=3, col="green")
legend(1990,135000,c("World Electricity Demand (TWh)
(historical)","Prediction G2EDPS Core Module SOM"," Prediction
G2EDPS Core Module Extension 8"),col=c(1,2,3),pch=c(1,2,3))
*************************************************************
Year.Prediction=c(2015,2020,2030,2040,2050,2060,2070,2080,2090)
World.Electricity.Demand.TWh.Prediction=c(176212,176212,176212,2141
50,214150,214150,252087,252087,214150)
plot(Year.Prediction, World.Electricity.Demand.TWh.Prediction,
xlab="Year (prediction)", ylab="World Electricity Demand (TWh)
(prediction)", pch=1, col="blue")
points(Year.Prediction,World.Electricity.Demand.TWh.Prediction, pch=3,
col="blue")
legend(2020,200000,c("World Electricity Demand
(TWh)(prediction)"),col=c(4),pch=c(3))
```

4. Conclusions

This paper presents the concepts of G^2PS, G^2EDPS, G^2P^3S and the details of designed G^2EDPS 1^{st} core module's forecasting model and its extensions. This RD^3 study shall continue for reaching new enhancements of this module and designing new modules and extensions.

It is believed and hoped that the concepts of G^2PS, G^2EDPS, G^2P^3S can be developed under the Open Source Initiative (OSI) (see [59]) and the Free Software Foundation (FSF) (see [60]) approaches by freewill supportive RD^3 engineers from all over the world.

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