Abstract—This paper analyses the theoretical aspects of the use of solar energy and water storage for sustainable electric energy supply. Proposed hybrid concept observed as an open energy system that behaves according to the local conditions and renewable energy source technology used. Sustainability of hybrid system is based on stable water and energy budget of power plant in the planning period. The key relationship for system design and interdependence between electric power of solar generator and working volume of water (energy) storage is set. Water storage is a main functional element of the proposed concept that allows efficient harvesting of sun energy as well as water resources and thus significantly affects on the features of hybrid solutions. The developed theoretical relationships and proposed hybrid system indicators have been tested on two different climate areas, as paradigms of Continental and Mediterranean climate. Based on obtained results it has been concluded that presented hybrid concept of solar-hydro systems provides a promising basis for the development of sustainable energy systems.

Keywords—Solar Energy; Hydro Energy; Renewable Energy Sources; Sustainable Energy Supply; Hybrid Power Plant

I. INTRODUCTION

The current technological development and use of renewable energy sources (RES) are not yet a complete and productive alternative to conventional energy sources. The problem is that the most important RES sources, such as solar and wind energy, cannot be directly directed toward energy consumption, and the remaining stable and controllable sources, such as hydro, geothermal, bio and others do not have sufficient capacity and are not available everywhere. Solar and wind energy cannot produce energy continuously and supply a consumer, so it is necessary to hybridize them with conventional sources through the electric power system (EPS) or use energy storages. The problem of using these sources is somewhat resolved for small sources and energy users, but is far from an acceptable solution for regional or larger EPS [1–3]. Significant research is performed in solving this problem, but still without a satisfactory solution [4].

This means that the present planning methodology of intermittent RES (wind, photovoltaic (PV), solar thermal (ST)) share in energy supply in EPS has serious problems, if they are to have significant share in energy balance. Therefore, the solution of global energy sustainability is still a long-term goal without coverage in the currently applicable technical solutions. However, using intermittent RES in EPS instead of conventional plants lead to reduction of CO₂ emission and conservation of non-renewable resources.

The author’s hypothesis is that the reliable solution should be sought in the very same processes that occur in the environment, with the use of solar energy and water.

The sun is an inexhaustible source of energy that occurs more or less regularly every day in most areas where people live. This means that energy is globally and more or less regularly available and inexhaustible for humans use. Water is a natural resource for transfer and storage of energy. It is a process that constantly takes place in the nature, through hydrological cycle. Therefore, the solution to complete sustainability of electric energy production lies in the use of sun and water. The technical solution is a hybrid power plant RES-storage HE where water storage is used for energy charge and discharge. The sustainability of electric energy production is based on use of free intermittent solar energy and built water storage, RES generators and HE. This paper will elaborate solar generators, Photovoltaic (PV), Solar Thermal (ST), but the basic postulates also apply to other intermittent RES (e.g. wind energy).

II. SUSTAINABILITY OF GREEN ENERGY PRODUCTION

Proposed hybrid concept of electric energy system production is an “open system” which has particular order of energy production and transformation and with continuous interaction with its environment. The interaction is in form of energy and water transfers into and out of the system boundary. Sun as primary energy source is used for primary electric energy production by RES solar transformation processes with one of existing technology PV or ST. The electric energy is produced in accordance with available sun radiation during the day sunlight (ERES). This primary electrical energy is used by pump station (PS) to transfer water from lower ground level to higher ground level at particular location where is stored in water storage. The stored water in water storage is potential hydro energy, or electric energy storage. Stored water is in next step of system processes used for hydro energy production (secondary electric energy production) at particular hydro-electric plant (HE), all in accordance with consumer, or EPS energy, demand, Fig. 1. In this concept water storage is element which guarantees sustainability of green energy production in accordance with consumer needs based on intermittent electric energy production by solar power plants.

So, sun intermittent and uncontrollable green energy are used for creation an artificial hydro energy potential used for fully controllable electric energy production in accordance with needs of consumer or EPS (EHE). The major benefit of such hybridization is controllable electric energy production based on non-controllable electric energy input, or stochastic energy input. Water which has been used for energy transport, storage and production, circulate within system in accordance with degree of regulation between primary electric energy production and energy use by consumer, as well as particular
system configuration. In the same time, system constantly more or less exchange water with environment/water resources in accordance with system configuration characteristics, climate and management needs. Lower storage can be finite-conventional or unconstrained like sea, while upper storage is always finite. In case of unconstrained lower storage water flow through system between unconstrained lower storage and finite-constrained upper storage, without impact on water budget of lower storage and water resource.

**Figure 1** Basic technological elements of the sustainable electric energy production system

In this concept intermittent sun energy and external energy are transformed by solar (PV or ST) generator to internal electric energy (primary production), which is transformed in mechanical energy of the pumps (primary consumption). Mechanical energy is transformed into hydraulic energy that delivering water in water storage where is stored as new artificial potential hydraulic energy. This hydraulic energy is further transform again in mechanical energy by turbines (secondary consumption), which are used for generation of electric energy in accordance with consumer needs (secondary production). During these processes of energy production and transforming part of electric energy is lost as thermal or hydraulic energy.

The main benefit of the proposed concept is in transformation of intermittent solar radiation into reliable continuous electric energy supply in accordance with consumer needs as conventional hydroelectric power plants, but without consumption of oxygen, fossil fuel, nuclear fuel and so without emission and any production residuals.

The primary source of (solar) energy cannot be depleted and can be treated as infinite for the purpose of the study. Since the system is the so-called radiant energy system, the hybrid power plant can operate continuously with the necessary maintenance and operation and existence of energy carrier-water. Since other resources are not needed for power plant work, it is obvious that proposed power plant is fully sustainable if water budget of the system is sustained. Since water budget can be based on sea water theoretically there are no constrains for sustainable energy production.

III. WATER STORAGE AND GREEN ENERGY PRODUCTION

**A. Power System Configuration and Energy Production**

The key driving elements of the plant are:

- RES (PV, ST) power plant;
- Pump Station (PS);
- Energy storage unit (water storage);
- Hydroelectric (HE) power plant, as it is presented on Fig. 1.

The proposed hybrid power plant consists of RES (PV, ST) and HE power plant where RES sources are in serial connection with HE to the power system. Water-energy storage has two pipelines: one for charge and second for discharge. PV or ST power plants deliver their energy when is available to pump station (PS) which pump (charge) water into water storage of HE power plants which then serve for daily, weekly and seasonal energy storage, while the consumer is supplied from HE power plants by use of water discharge from storage as required (peak and of-peak) [5, 6].

PV or ST power plants are also in parallel (direct) connection, in relation to the PS, with the regional EPS. With 2 water pipelines connected with storage and 2 electric energy lines from renewable energy power plant to pump station and to EPS, basic configuration of production unit of proposed plant is the complete.

The proposed solution is integrated with local environment, climate and natural water resources on the best possible way with minimum negative environmental impacts and maximal possible productivity. It can be integrated with fresh as well as sea water resources as well as built resources as existing HE and reservoirs [7, 8]. In case that natural water is used to charge upper storage than internal energy of hybrid system increases. This combination with natural water charge can be achieved at existing hydro electric power plants, on the rivers with temporary flow, by rain harvesting, as well as on hydro potentials which are not feasible due to particular hydrological characteristics [9].

The total system of the proposed solution is practically made up of two different parts: a sub-system of interest (build elements), hybrid power plant and sub-system surroundings (natural elements). The energy of surroundings of the system “sun” are so large that can be considered as an unlimited energy reservoir so that no matter how much is transformed to sub-system (hybrid power plant) the energy of the
surroundings will remain. Energy of the build system is constrained and function of RES capacity and water storage capacity.

The whole system work is generated by productivity of solar panels in order to produce artificial water resources \( V_{PS} \) defined with water pumped at higher hydro energy potential by mechanical work of FPS, for a single time step \( i \):

\[
V_{PS(i)} = \frac{P_{el(RE)} \cdot E_{PS(i)}}{C_{RES} \cdot 2.72 \cdot H_{SP(i)}} \text{ (m}^3\text{)}
\]  

Where \( C_{RES} \) is the power overall coefficient related to the type of RES plant configuration and local climate conditions, \( H_{SPS} \) is net pumping head, \( P_{el} \) available power of RES power station \( P_a, E_S \) and available solar energy \([7, 8]\).

Since this flow is generated by power of solar cells determined by total size of \( A \) (m\(^2\)) and efficiency \( \eta_{oc} \) in accordance with:

\[
P_a = A \cdot 1000 \cdot \eta_{oc}
\]  

It is possible based on hydrological principles to define value of artificial rain generated by solar energy, used for hydro-energy production as one indicator of usefulness of the plant; i.e. as input productivity of the plant.

In natural hydrological system water flow is generated by rain, watershed surface and runoff coefficient while in proposed plant (build environment) water flow is generated directly by energy of sun instead of rainfall which is by the way also generated by solar energy in global natural hydrological processes, watershed surface is surface of panels and runoff coefficient is efficiency of panels. So the proposed electric energy system (build system) works similar to natural hydrological system generated by same primary energy sun. So the main input for sustainable energy production can be measured by value of so call “artificial annual rain”, or solar rain \( SR \) which can be determined from:

\[
SR(m) = \frac{V_{PS} (m^3/a)}{A(m^2)}
\]  

That is why productivity of the build power system can be measured by value of water depth (m) production per m\(^2\) of solar panels surface \( A \) (m\(^2\)/year) or solar rain \( SR \). However, the system has input and output productivity, which can define by specific power \( P_{sp} \) of HE:

\[
P_{sp} = 9.81 \cdot H_n \cdot \eta_t \text{ (kW/m}^2\text{s).}
\]  

Energetic/static property of the system is defined by the volume of water generated per surface of panels \( V_{PS}/A \) (m\(^3\)/m\(^2\)) in one time step or by specific energy production of HE:

\[
E_{sp} = \frac{E_{HE}}{V} = \frac{H_n}{367} \cdot \eta_t \text{ (kWh/m}^3\text{)}
\]  

Where \( H_n \) is net available drop; \( \eta_t \) is total efficiency of turbine and generator.

Different intermittent RES will have different productivity and production of specific rainfall and related inflow in water storage as well as specific power of HE and energy production. Input solar energy in the largest part of the day coincides with the dynamics of living in settlements and consequently the energy, consequently charge and discharge processes require smaller storage. This also means that electric energy production and consumption are easier to adjust by using solar energy (especially PV technology) than other intermittent RES. PV generator use less technological processes and elements in transformation of external energy in the system internal energy than ST generator and thus more perspective for development of proposed hybrid plant RES-HE.

The future increase of the solar generator efficiency \( \eta_{oc} \) will result in increase of annual rainfall \( SR \) as well as intensity of rainfall \( R_t \) (mm/m\(^2\)/h) generated by RES, i.e. hydro energy potential.

Starting from the above said, the usability of a particular location for the proposed electric power system can be measured by specific precipitation or solar rain \( SR \) which can be generated by RES of specific power \( RP \) in time period \( T \) (average year). Areas with better time series of insolation will generate higher hydro potential \( RP \) per unit of the power plant power.

\[
RP = \frac{SR}{P_{el}} \text{ (m/kW).}
\]  

Using the available natural precipitation (water inflow), the total gross energy potential of the power plant will increase. Thus areas with high insolation and precipitation (natural inflow) are obviously good locations for the proposed plant development.

The system defines the water and energy balance. Both balances must be greater than zero if the system is to be sustainable. Since the primary source of energy (sun) is inexhaustible, the energy balance can easily be met, providing the system is well designed and there is water balance maintenance.

Water in hybrid system is in upper storage \( W_{US} \), lower storage \( W_{LS} \) and pipes \( W_{PIPE} \):

\[
W_{hyb} = W_{US} + W_{LS} + W_{PIPE}
\]  

Hybrid system water balance is given by,

\[
\frac{dW_{hyb}}{dt} = W_{INT} + W_{NAT}/W_{CONS} - W_{EVAP} - W_{LOSS}
\]  

Where \( W_{INT} \) is the rate of intake water, \( W_{NAT} \) is the rate of natural inflow (rainfall, surface runoff), \( W_{CONS} \) is rate of water consumption (maintenance of ecological flow, water uses), \( W_{EVAP} \) is rate of evaporation from upper and lower storage, and \( W_{LOSS} \) is the rate of water losses from storages and pipes.

Sustainability of the system require stable water budget in planning period \( T \):

\[
(W_{INT} + W_{NAT}) \geq (W_{CONS} + W_{EVAP} + W_{LOSS})
\]  

and also that lower storage has sufficient capacity for water pumping into upper storage in each time step \( i \):

\[
W_{RES(i)} \geq W_{LS(i)}
\]  

Where \( W_{RES(i)} \) is the rate of water pumped into upper storage by PV or ST energy and \( W_{LS(i)} \) is lower storage capacity, in time step \( i \).
Lower and upper storage has a purpose to balance inflow and outflow water in the planning period.

The system works by principles of energy conservation law where the energy input into the hybrid system are solar energy $Q$ and water resources input energy $E_{Nat}(i)$ and output energy is demand of consume $E_{CONs}$ or energy supply EPS.

Energy balance in the hybrid power system is:

$$\frac{E_{sys}}{dt} = Q + E_{Nat} - E_{CONs} - E_{LOSS}$$  \hspace{1cm} (11)

Where, $E_{LOSS}$ is rate of losses of energy in the system.

This energy balance is supported by water balance of the power plant. For the system energy production sustainability is necessary to maintenance water balance in upper storage and so provides sufficient water resources for water pumping into upper storage.

The upper storage energy-water balance for a single time step $i$ is expressed as:

$$E_{He(i)} = E_{He(i-1)} + E_{RES(i)} + E_{Nat(i)} - E_{HE(i)} - E_{EVAP(i)} - E_{LOSS(i)}$$  \hspace{1cm} (12)

Where: $E_{He(i)}$ is total reservoir stored energy in time period $i$; $E_{Nat(i)}$ is total natural potential energy inflow over time period $i$; $E_{RES(i)}$ is total energy inflow over time period $i$ generated (pumped) by energy from RES (solar generator); $E_{He(i)}$ is the decision variable or total hydro energy outflow over time period $i$; and $E_{EVAP(i)}$ and $E_{LOSS(i)}$ is energy outflow corresponding to the losses (evaporated volume and other losses) from the reservoir over time period $i$.

Equation (12) represents energy and water balance, since energy $E_{He(i)}$ is product of water volume $V_{He(i)}$ and mean productivity of HE $\zeta_{HE}$:

$$E_{He(i)} = V_{He(i)} \cdot \zeta_{HE}$$  \hspace{1cm} (13)

In an open system, as is the proposed power plant, inflow and discharge are controlled by the built elements (PS and HE, inflow gates, outflow gates, etc.) and uncontrollable by natural processes (evaporation, surface inflow, rainfall, etc.). The change in storage content of the finite reservoir is calculated by mass storage equation. This equation is described in accordance with the configuration of the hybrid power plant which can have: one or two storages, natural inflows and leakage, artificial inflows, etc. However, inflow into storage can be controlled by work of PS which is supplied by uncontrolled electric energy from RES.

Upper storage volume is the result of balance estimation between water inflow generated by RES energy and controllable water outfall generated by consumer energy demand, as well as uncontrolled inflows (surface water, rainfall, infiltration) and outfalls (evaporation, leakage, and spill).

Therefore, storage in this concept has an impact not only on the production planning of hydropower but also to plan the flow of water, i.e. power of RES. Both are controlled by the planner. In this way the concept creates the preconditions for sustainable production of green energy, where the key role has water storage. Storage define power of RES generator and power of HE, which is not the case with the current concept hybridization of intermittent RES and EPS, as well as the current approach to planning storage HE power plant. The combination of different capacity for charge of water (the power of RES) and discharge of storage is possible with different storage sizes to plan the production of hydropower to meet base load or peak load or other load requirements and needed energy reserve.

Volume of lower storage depends on capacity of the water resources used. If available capacity is constantly larger than water quantities needed for water pumping, than lower storage practically is not necessary. For example if sea water is used. In case that available capacity is constrained, then lower storage is needed to balance inflow and outflow. Water circulates between lower and upper storage, but with different flow characteristics. Volume of storage is function of available capacity of water resource which can be constantly used, outflow generated by pumping needs and inflow from HE plant, as well as natural processes (evaporation, rainfall, and others).

System electric energy production (supply) $E_{CONs(i)}$ for the single time step is:

$$E_{CONs(i)} = E_{CONs(i-1)} + E_{HE(i)} + E_{DRES(i)}$$  \hspace{1cm} (14)

Where $E_{DRES(i)}$ is electric energy which RES source directly supplies the energy power system in time $i$ (from time to time), as market secondary energy. However, unlike $E_{HE(i)}$ which is a control variable, this electric energy supply is a random and uncontrollable variable and therefore less important for an EPS if not used for other hybridizations. The energy value $(E_{DRES(i)})$ decreases if the upper storage volume increases. In positive infinite storage volume (infinite storage) all energy can be stored into water storage.

Total energy production is:

$$E_{CONs} = \sum_{i=1}^{T} E_{CONs(i)}$$  \hspace{1cm} (15)

Where, $T$ is total period used for production of energy (year).

Losses occur in energy conversion between different types of energy (solar, electric, mechanical, and hydraulic) from one to the other, $E_{RES}$ into $E_{HE}$. Total production electric energy losses $E_{LOSS}$ in period $T$ are:

$$E_{LOSS} = E_{RES} - E_{HE} - E_{DRES}$$  \hspace{1cm} (16)

Losses are inevitable and are the price paid for the fully controlled and sustainable green energy production. Internal energy losses are not so big, considering that the efficiency of pumps and turbines is very high (more than 95%). However, the biggest losses still occur in the production of primary energy, i.e. in the transfer of solar into electric energy, about 86%. PV generators of new generation can significantly reduce these losses and it is expected that they will be reduced to less than 60% with the tendency to 40% \([10]\). As solar energy is free of cost, this does not affect the costs of the system. However, increased efficiency will reduce construction costs and allow easier implementation due to reduction in size of the power plant.

It can be assumed that the losses in the hybrid system are acceptable especially if it takes into account that the basic resource for the energy production is free of charge and that the proposed concept has no losses and consumption of traditional energy resources when the RES does not work.
B. Upper Water Storage and Power of Primary Energy Sources

In proposed power system primary electric energy source $P_{el}$ is defined by general formula [7]:

$$ P_{el(RES)} \cdot E_S = C_{RES} \cdot 2.72 \cdot H_{os} \cdot V_p \quad (kW), \quad (17) $$

Different combinations of $P_{el}$ (W) and $V_0$ (m³) within the framework of a possible construction, it is possible to achieve the required annual electricity production.

Based on previous research results and analyses, it is concluded that for the hybrid system is valid the general theoretical relation (ideal conditions):

$$ P_{el} \cdot V_0 \approx \text{const.}, \quad (18) $$

Where $P_{el}$ is power of RES source (W) and $V_0$ is water storage for production of hydro energy in the planning period $T$ (m³). Functional dependence of $P_{el} = f(V_0)$ can be different, but given the physical features, this dependence the most precise describes $ln$ and exponential functions.

The value of $\text{const.}$, i.e. the so-called Constant-H, based on one climatologically year, is indicator or measure of the effectiveness or usefulness of the available energy i.e. entropy of the system. The product of $P_{el}$ (W) and $V_0$ (m³) of the hybrid system is similar to entropy for the particular system design characteristics and climate. Different climate, design, combinations of $P_{el}$ and $V_0$, and RES technology will produce different Constant-H. That is why, Constant-H is indicator of the usefulness of proposed power plants RES-HE of different combinations of primary source of electric energy with HE: Photovoltaic (PV) and Solar Thermal (ST) including additional hybridization with different type of water resources.

Equation (20) clearly shows that greater possibilities of energy storing lead to better use of primary electric energy, in periods when it is available. That it is energy which can be consumed, and it is presented by water storage. Therefore, the unused primary production of electric energy is minimized. Bigger storage enables better balancing of production and consumption of electric energy, allowing the meeting of the needs with smaller installed power of RES for primary production of electric energy.

This basically means that for each location (climate) and the problem being solved (energy demand), there is an optimum combination $P_{el} \cdot V_0$ that should be defined by an appropriate design methodology.

In real application working volume of the system is constraint by local ecological and topographical characteristics while it operational volume $V_0$ is results of design processes.

The interval $V_{min} < V_0 < V_{max}$ which is called the boundary layer, serves as transition from the $P_{el(max)}$ value to the $P_{el(min)}$ value. The width of boundary value is merely conventional, since theoretically the solution never becomes exactly equal to zero. The minimum value $P_{el(min)}$ is conditioned by the possibility of constructing the storage ($V_{max}$) at a location, therefore:

$$ P_{el(1)/V_0-V_{max}} = P_{el(min)} \quad (19) $$

As the daily insolation is always shorter than the planned period of daily energy production (24 hours), minimum daily insolation, compared to the planned production of energy, determines the minimum dimensions of the storage volume and thus the maximum required power of the solar power plant:

$$ P_{el(1)/V_0-V_{max}} = P_{el(min)} \quad (20) $$

The boundary layer defines the size of storage volumes that are necessary to ensure the continuity of the planned production.

If extreme values are known, Eq. (19) and (20), the trajectory of state changes and entropy of the proposed solution can be determined based on this relationship:

$$ P_{el} \cdot V_0^n = \text{Constant} - H, \quad (21) $$

Where exponent $n$ is defined by:

$$ n = \frac{\log P_{el(max)} - \log P_{el(min)}}{\log V_{0(max)} - \log V_{0(min)}} \quad (22) $$

Value of $n$ determine range of possible combinations of $P_{el}$ and $V_0$ and magnitude of change between $P_{el}$ and $V_0$: $\Delta P_{el} / \Delta V_0$. Locations (climate) with strong radiation and continuous daily $E_S$ time series with values hand by hand with energy demand will have smaller value of $n$ and value of Constant-H.

The exponent $n$ has theoretically value between $1<n<0$. For areas with unfavourable solar energy where all available solar energy has to be used to satisfy demand it is approaching to 1, but theoretically never becomes exactly equal to 1 since such situation require large (infinite) storage to balance charge and discharge energy; while for areas with favourable solar energy to satisfy demand it is approaching to 0, but theoretically the solution never becomes exactly equal to zero since solar radiation is not available during 24 hours while demand is required and so always small storage is necessary.

Different energy demand, configuration of proposed power system and climate will produce different Constant-H value or potential hydro energy production in the planning period. It means that knowing value of Constant-H for particular climate area it is possible to determine appropriate settings of $P_{el}$ and $V_0$ for different locations in accordance with energy demand.

The Equation (21) is a basis for selection of different alternative combinations of $P_{el}$ and $V_0$ or optimization of the power plant characteristics using standard economical approach. The concept of life cycle cost (LCC) is developed to be the best indicator of economical profitability of the system cost analysis. However, and multi-criterion method can be used to evaluate economical and non-economical characteristics of the plant (social, environmental).

IV. RESULTS AND APPLICATION

Minimum of maximum value of the power of RES generator has to be determined for the set volume $V_0$ for the observed planned period. Results for the Mediterranean climate conditions (Island of Vis, Croatia) and Continental climate conditions (Osijek, Croatia) were obtained for the PV and ST power plant, Figure 2. These results were obtained by modelling of power plant operation that should produce an annual energy consumption of 16.7 GWh in accordance with
planed within year consumption and Mediterranean and Continental climate conditions, Table 1 and 2.

The results fully confirm the assumed behavior of the hybrid power plant and confirm the assumption that the power plant is possible in different climate regions with different productivity. PV technology is able at both climate to generate every day some flow into upper storage while ST technology not. ST technology during winter period can not produce artificial flow in Mediterranean climate about 100 days and in Continental climate about 170 days. However, with appropriate storage, which is always bigger than in case of PV technology, required energy supply can be guaranteed.

The value of Constant-H of PV and ST generator for Mediterranean and Continental climate are based on theoretical expression (21) and presented in Table 3.

The value of artificial or solar rain SR of PV and ST generator for Mediterranean and Continental climate is presented in Table 4.

### Table 1: Energy Consumption, Solar Energy, Air Temperature, Precipitation and Evaporation for the Mediterranean Climate (Island of Vis, Croatia)

<table>
<thead>
<tr>
<th>Month</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
<th>XI</th>
<th>XII</th>
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</thead>
<tbody>
<tr>
<td>$E_{\text{el}}$(MV Ah/month)</td>
<td>1586.29</td>
<td>1418.34</td>
<td>1451.26</td>
<td>1173.53</td>
<td>1193.61</td>
<td>1473.25</td>
<td>2078.84</td>
<td>2078.77</td>
<td>1450.39</td>
<td>1212.78</td>
<td>1370.72</td>
<td>1559.72</td>
</tr>
<tr>
<td>$E_s$(kW/m$^2$ day)</td>
<td>1.7</td>
<td>2.8</td>
<td>4.4</td>
<td>4.8</td>
<td>6.1</td>
<td>6.8</td>
<td>7.3</td>
<td>5.7</td>
<td>4.4</td>
<td>3.2</td>
<td>1.8</td>
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<tr>
<td>$T_a$(°C/day)</td>
<td>9.8</td>
<td>9.5</td>
<td>11.4</td>
<td>14.3</td>
<td>19.4</td>
<td>23.4</td>
<td>25.9</td>
<td>25.6</td>
<td>21.4</td>
<td>18.4</td>
<td>14.0</td>
<td>11.1</td>
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<tr>
<td>$R$(mm/day)</td>
<td>2.1</td>
<td>0.8</td>
<td>4.0</td>
<td>1.7</td>
<td>0.1</td>
<td>0.8</td>
<td>1.7</td>
<td>3.7</td>
<td>4.2</td>
<td>3.0</td>
<td>4.4</td>
<td>2.3</td>
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<tr>
<td>$EV$(mm/month)</td>
<td>51.3</td>
<td>48.9</td>
<td>65.9</td>
<td>82.9</td>
<td>137.7</td>
<td>191.1</td>
<td>247.3</td>
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<td>151.8</td>
<td>115.9</td>
<td>75.5</td>
<td>58.9</td>
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### Table 2: Energy Consumption, Solar Energy, Air Temperature, Precipitation and Evaporation for Continental Climate (Osijek, Croatia)

<table>
<thead>
<tr>
<th>Month</th>
<th>I</th>
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<th>III</th>
<th>IV</th>
<th>V</th>
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<tr>
<td>$E_s$(kW/m$^2$ day)</td>
<td>1.2</td>
<td>1.6</td>
<td>3.0</td>
<td>4.4</td>
<td>5.5</td>
<td>5.7</td>
<td>5.8</td>
<td>5.3</td>
<td>4.1</td>
<td>2.6</td>
<td>1.3</td>
<td>0.9</td>
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<tr>
<td>$T_a$(°C/day)</td>
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<td>6.2</td>
<td>11.6</td>
<td>16.9</td>
<td>19.8</td>
<td>21.7</td>
<td>21.3</td>
<td>16.9</td>
<td>11.7</td>
<td>5.2</td>
<td>1.2</td>
</tr>
<tr>
<td>$R$(mm/day)</td>
<td>1.4</td>
<td>1.2</td>
<td>1.5</td>
<td>1.7</td>
<td>2.0</td>
<td>2.7</td>
<td>1.8</td>
<td>1.9</td>
<td>1.9</td>
<td>1.7</td>
<td>2.0</td>
<td>1.7</td>
</tr>
<tr>
<td>$EV$(mm/month)</td>
<td>0.0</td>
<td>0.0</td>
<td>13.2</td>
<td>31.8</td>
<td>55.8</td>
<td>69.6</td>
<td>81.0</td>
<td>72.6</td>
<td>49.2</td>
<td>25.2</td>
<td>10.2</td>
<td>0.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Climate</th>
<th>Solar Energy (kWh/m$^2$/a)</th>
<th>Constant-H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mediterranean</td>
<td>1575</td>
<td>47.14</td>
</tr>
<tr>
<td>Continental</td>
<td>1331</td>
<td>104.30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Climate</th>
<th>Solar Energy (kWh/m$^2$/a)</th>
<th>Solar Rain (SR) (m/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mediterranean</td>
<td>1575</td>
<td>PV(η=16%) 254</td>
</tr>
<tr>
<td>Continental</td>
<td>1331</td>
<td>207</td>
</tr>
</tbody>
</table>
The climate areas with stronger continuous solar radiation throughout the year will have smaller Constant-H. This area allows continuous production of a specified power with less power of RES generators and smaller volumes of storage, Figure 2. It is evident that the value of the Constant-H in areas with stronger insolation (Mediterranean climate) is less than in continental areas. It is also evident that Constant-H is greater for ST than PV technology in same climate areas, which means that PV is more electric energy productive than ST in proposed concept of power plant.

Base on this results, it is possible to conclude that more solar energy productive climate areas will have smaller Constant-H for same energy demand or required energy production can be achieved with smaller $P_{el}$ and $V_o$ or A and $V_o$.

Data for artificial rain SR clearly show that PV technology generate more “water” than ST technology since PV technology have wither range of work in relation to $E_s$ than ST technology. With expected rise of efficiency of solar technology has wither range of work in relation to $E_s$ and does not linearly rise too and so volume of water pumped into upper storage and so hydro electric energy production.

Comparing indicators Constant-H and SR, it is possible to see that Mediterranean climate produce more effective available energy than Continental climate, (Constant-H is smaller) for both technology although the input water resources (artificial rain SR) is higher with PV technology. It is consequence of energy balance between production and demand. Available solar energy throughout the year in Mediterranean climate is more suitable for energy supply (demand) then Continental in this particular example.

So, the Mediterranean area and PV technology is very suitable for sustainable electric energy production by proposed power plant in accordance with planned energy demand in typical year. However, reliable electric energy supply can be achieved only with appropriate size of the storage.

Applying of water storage, the proposed solution ensures sustainable green energy supply with the same production characteristics as classical power plants. Hybrid plant is significantly more expensive to build, so that at the beginning period of exploitation it should be used at locations where ecological and economic benefits will be the greatest. Application strategy should have a top to bottom approach in relation to standard daily regime of energy consumption. This means that power plants should be used for peak shaving in daily energy consumption with tendency to peak levelling. This is the most expensive energy which is to be settled through the operation of HE, providing there is enough of it. In this application, water storage has relatively small dimensions and therefore it is more realistic to construct and is less expensive. Any other solution based on fossil fuels is very costly because the power plants used for peak shaving and levelling (peaking power plants) must constantly be kept in operational readiness which is expensive and constantly emits significant quantities of CO2.

Another important application is energy supply to isolated consumers who are far from the regional energy power system, as a local fully sustainable source of green energy. Using available State subsidies for green energy production proposed plant may be profitable for development and today.

V. CONCLUSION

The proposed concept of sustainable electric energy production is flexible in implementation, management, provides continuous supply of “green energy” and can be built in a wide range of climate areas, locations where man live. Electric energy production is based on solar energy and water which is used for energy storage and production.

Storage plays the key role in green energy production. It also enables green energy production in areas with seasonal insolation. Storage allows integration with the available hydro energy resources including lakes, existing reservoirs, temporary rivers, rivers with seasonal flow, and rain harvesting. The most successful integration is in the case when the hydrological resources well-complemented with solar resources as it is in the subtropical regions with winter rains and strong summer solar radiation.

Potential positive impacts of development and implementation of proposed concept are numerous and various; economic, social and environmental. The most prominent is the environmental impacts because CO2 emission is reduced, as well as other negative consequences associated with the use and combustion of fossil fuels and the operation of nuclear power plants. The use of water resources and their pollution and soil contamination is also reduced, because the proposed solution does not consume raw material and does not produce harmful gases, liquid or solid residues. Water circulates within the power plant and do not impact local water resources budget.

The general safety of the population is more favourable, and prerequisites for achieving social equity in the energy sector are created, because proposed concept is applicable in all countries and regions of the world (PV). All areas in which people live can use the sun as the primary energy for the operation of the hybrid plant and have available water resources.

It goes without saying that the primary energy is unlimited and free of cost. This means that improving the economic, social and ecological state is possible in all parts of the world. In this way proposed concept for sustainable electric energy production assumes a global dimension and creates the prerequisites for achieving sustainability objectives [11] and sustainable energy production objectives [12-16].

Proposed indicators Constant-H and Solar rain SR are useful tool for comparison and analyses of system application and productivity in different areas and development configurations.

Analyzed and presented basic theoretical settings of the plant and relationship between solar and hydro energy are suitable for hybrid system development and analysis.

REFERENCES


