Exuberant "Magic Carpet" Giga-Project Macro-Imagineering

The Arabian/Persian Gulf Shallow Draft PV-Raft Giga-Project

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Resumo: Processos naturais e atividades antropogênicas afetam de forma variável a diversidade climática e ecossistêmica das nações ao redor do Golfo Pérsico-Arábico. O *Magic Carpet Giga-Project*, proposto como uma contramedida de enfrentamento da aridez dos ambientes regionais, é concebido como uma vasta jangada flutuante com painéis fotovoltaicos, disposta sobre o Golfo. Conectada por cabos elétricos a instalações terrestres, a energia poderia ser fornecida para cidades e para aplicações industriais que incluiriam enormes usinas de dessalinização de água do mar para uso municipal em geral. A adaptação espacial e marítima na forma de caminhos de aproximação e desvios será necessária em razão das rotas marítimas existentes, bem como do acesso adequado às plataformas da indústria petrolífera *offshore* que pontilham o Golfo. Os macroprojetos "The Line" e "The Loop" serão áreas bem delimitadas com vegetação controlada pelo clima, enquanto o "Magic Carpet" pode se tornar um esteio de dessalinização e fornecimento de eletricidade para a futura infraestrutura básica de cada estado do Golfo.

Palavras-chave: Macroengenharia, Arábia Saudita, NEOM, jangada fotovoltaica flutuante, Golfo Pérsico-Arábico, Golfo da Califórnia.

Abstract: Natural processes and anthropogenic activities variably affect climate variability and meteorological drought in ecosystem-nations surrounding the Arabian-Persian Gulf. The Magic Carpet Giga-project, proposed as a counter measure to aridification of the regional environments, is envisaged as a vast floating PV-panel studded raft in the Gulf. Connected by electrical cables to land-based facilities, power could be provided for cities and industrial applications that would include enormous seawater desalination plants for municipal and commercial applications. Spatial and sea lane accommodation in the form of approach ways and bypasses will be necessary for designated sea-lanes, as well as according access to in-place offshore petroleum industry platforms dotting the Gulf. "The Line" and "The Loop" macro-projects are to be climate-controlled, vegetated enclosures whilst the "Magic Carpet" may become an electricity-desalination mainstay of the future basic infrastructure of every Gulf ecosystem-state.

Keywords: Giga-project, Saudi Arabia, NEOM, floating photovoltaic raft, Arabian-Persian Gulf, Gulf of California.

Nomenclature:

E	electrical energy provided by the whole PV array, kWh
h_0	global heat transfer coefficient from the photovoltaic cell to the environment medium through the glass cover, $W/(m^2K)$
H	daily solar global irradiation, kWh/m^2
I	solar global irradiance, W/m^2
P	daily electrical PV energy per unit surface area, kWh/m^2
T	temperature, °C
U_{Lm}	global heat transfer coefficient of the PV module, $W/(m^2K)$
U_b	heat transfer coefficient from the photovoltaic cell to the environment through the Tedlar layer

Subscripts

c	solar cell
g	glass
m	solar module
med	medium/mean
ref	reference
T	Tedlar

Greek letters

α	absorptance
β	packing factor
η	PV cell efficiency
τ	transmittance

1 Introduction

Multi-society human civilizations tend to rapidly progresses in multiple fields of endeavor when there is a lively presence of disruptive or incremental science and technology [1]. The emerging field of real-world Generative AI computer systems, actual versus new instances, cannot yet access unforeseeable creativity that allows *Homo sapiens* to modify the Earth's bioshell, by reshaping it incrementally or drastically according to sometimes markedly capricious wants and life-supporting most urgent needs. Therefore, it is not only necessary but prudent for human beings to project and enact the "World of Tomorrow" with the help of focused research science and accessible proved technology. In part, "*Imagination*" (the faculty or action of forming new ideas, or images or concepts of external objects not present to the human senses) is an aspect of human thinking that focuses on the future health and happiness of the individual or social group. In this vein of imagineering, this report elucidates a proposal for a spatially gigantic barge-like floating solar-power station in the marine environment. This proposed modular floating electricity-generation public utility, which if built and fully installed, could be shared by shoreline states of the Arabian-Persian Gulf region. From above, this engineered enormous raft would have the fanciful appearance of a giant carpet, sort of a "magical" rug composed of numerous modular mats that could produce electricity for the Gulf region's coastal and inland populations.

Human civilization nowadays appears to be utterly enamored, enraptured, and captivated by concepts of global relationships of air-seawater temperatures and investable monetary capital [2]. As a matter of fact, modern societies are today incessantly pestered by a near permanent, society-wide media-induced imagined sense of eminent climatological and social crisis. This media blitz is an electronic virtual informational immersion that posits an unavoidable planetary bath of heating air and expanding ocean water volume because of human action. The risky management of atmospheric heating and expanding ocean volume has become a political means of deferring apocalypse. Since the onset of the envisaged crisis, several Gulf ecosystem-nations have, however, undertaken vast and expensive climate change countermeasures to purportedly sustain their continued existence [3]!

The use of the term "*exuberant*" does not, necessarily, indicate preference toward absurd and wasteful forms of new human civilization-sustaining infrastructure. The authors do not desire, intend, or plan to replace the natural endemic with the pseudo-Edenic. Nevertheless, it is appreciated that Gulf states are anxious to quickly alter stale internal social developmental trends, unproductive and outdated habits of thought, as well as some erroneous popular notions of what is technically possible and appropriate for national long-term survival. The accountant-tabulated financial cost over-run of the Suez Canal's construction was 1900%, but that linear dredged channel was needed by humankind's then near-global cargo and passenger shipping-enriched civilization and was, thus, completed timely [4-5].

The Industrial Revolution, which commenced during the 18th Century, probably ought to have been designated "The Infrastructure Revolution". The Earth's bioshell has been variously impacted by anthropogenic advancements (*e.g.*, engineering works, urbanization, agriculture, forestry) over time and geographical space. Nowadays, industrial design and engineering are being increasingly accomplished by Generative AI. Naturally, most biogeophysical impacts of giga-projects occur during different phases of development. That is, environmental impactful modifications occur primarily after the completion (or decommissioning) of giga-projects as would be anticipated with the largest kind of technical system so far built by human civilization, distributing, and delivering specialized services, material and materiel, and assets to organizations, households, and corporations. Prudent observations dictate that most giga-projects in the Middle East must eventually be required to function during major dust and sandstorms, as well as the postulated impending increase in year-round ambient air temperature.

Corporate movie producers of Hollywood, Bollywood, or other entertainment industries elsewhere have not yet offered audiences the grand experience of a fictitious popular film depicting the dire effects of drought because it is simply not an entertaining geohazard-de-jour. Because drought cumulatively reduces national wealth increase while simultaneously induced large-scale human migration motivated by poor living and travel conditions (6-7), it lacks widespread public interest when human imaginations have difficulty coping with the vast adversities associated with persistent drought. In Britain, drought may have forced the switchover from stream-power to steam-power! The viability of many major watermill-powered industries in Britain were weakened by episodic post-1770 AD droughts and, thus, the European Industrial Revolution was a consequence, it is now theorized [8-9]. Early-2023, Dubai announced the prospective 93-kilometer-long roofed giga-project named "The Loop", a combination jogging, bicycling and walking pathway to protect users from desert heat as well as stormy weather.

Commercial films occasionally critique modern-day engineering and architectural projects. For example, Jacques Tati (1907-1982) offered ***Mon Uncle*** (1958) and ***Playtime*** (1967) both of which displayed entertaining comedy assessments of early-20th Century obsessions with kinetic motion and spare geometries [10]. Brazil's capital city, Brasilia (assembled 1956-1960), has long been assessed as a uniquely planned entirely new city composed of enormous modern-styled buildings set in a tropical jungle environment. Unfortunately, the expanse of pavement between buildings for arterial boulevards is so wide that pedestrians perceive them as heat sinks that cannot easily be traversed on foot. Turning to a middle latitude example in the desert Middle East, many people deride the vast concentrations of Arabian/Persian Gulf modern skyscrapers are as essentially "glassed refrigerators in the desert" [11].

However, the control of interior temperature and humidity in buildings is the basic reason for any kind of roofed architectural effort [12]. These types of modern edifices are not designed to be entirely practical but rather to influence human belief systems and cultural identity. Today, about 117 million people live in ecosystemcontrolled urban areas bordering the Gulf. Little appreciated is the prediction that Gulf climate change models indicate a marked near-term future warming and humidification of the air during the 21^{st} Century. If these model predictions come to pass, outdoor physical labor will become problematic and almost intolerable, perhaps deadly [13]. If the environment becomes so harsh, as computer models predict, persons working outdoors will theoretically have to be encapsulated by non-pressurized body-chilling garments separating wearers from weather conditions. Such harsh environmental conditions would be demonstrably averse to good quality human health — certainly something more than still common female burqas and voluminous fabric male robes [14].

2 *Solvitur ambulando* ("it is solved by walking")

HRH Prince Mohammed bin Salman, on 25 October 2017, publicly announced a future for a unitary mirror-facade linear Saudi Arabian city-skyscraper, nicknamed "The Line." The proposal features topographical sitting atop the generally flat barren desert landscape approximately extending along the line of 28^0 North Latitude, starting slightly beyond the Gulf of Aqaba's seashore [15]. With His Royal Highness the Prince as its paladin, the NEOM giga-project (the NEOM acronym refers to a vision of a "New Future") is Saudi Arabia's most unique infrastructure development planning region to date, **Fig. 1**. "The Line" **Fig. 2**, is a term that refers to the resulting *walkable* linear city (described by the phrase "from any location in the structure just a 5-minute ramble to adjacent uncovered Nature"). NEOM's singular geographical feature [16], when completed, will perhaps eventually be tenanted by ~9,000,000 international residents. It will be connected by a paved extra-basement road and railway to the April 2016-proposed Saudi Arabia-Egypt Bridge intended by the Kingdom of Saudi Arabia and Egypt to span (via Tiran Island) the navigable entrance of the Gulf of Aqaba.

"The Line" (construction commenced during April 2022) will be a carless multi-module city-skyscraper. This significant structure will be approximately 0.2 km wide by 170 km long and will have an overall foundational ground footprint of about 34 square kilometers. Corridor-confined high-speed automated mass transit subways will connect the modular communities that will be situated intermittently along its length. Surely, that bodes future physical connection to places located beyond the terminals at both ends of "The Line." Its mapped ends, when extended imaginatively, intersect with the Arabian/Persian Gulf and the Gulf of Suez. In effect, "The Line" physically exemplifies the geopolitical concept of the *hinterland* where the inland landscape along the same line of latitude opens that interior landmass to habitation and industrialization [17]. With a non-pitted mirrored glass façade [18], "The Line" will reflect during summer 13 hours and 55 minutes of sunshine and 10 hours 22 minutes during winter and possibly even create a minimal windbreak-rain shadow effect! There is also the technical possibility the structure will be illuminated during nighttime like a billboard, possibly the world's largest! Although Saudi Arabia has ~10.8% of the USA's population, it has already initiated the expensive construction of a linked elements building where "The Line" is equal to ~0.04% of the USA's existing building floor space [19]!

Figure 1. General location of Saudi Arabia's present construction of 26,500 square kilometer NEOM region development (Google Image).

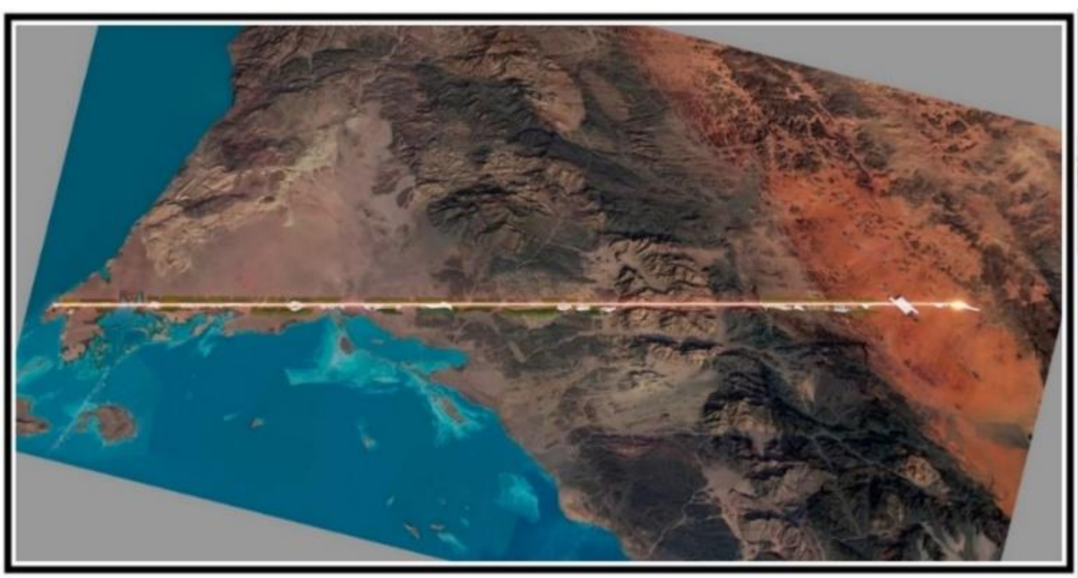

Figure 2. Extent of "The Line" envisioned as a part of world civilization set aside for those who wish to change regional Nature. Overlain on a satellite image of the dusty worksite resembles the 100-kilometer-long conveyer belt moving mined phosphate between Bou Craa and El Aaiun, Western Sahara. As a result of "The Line" ongoing ground excavation and disturbance of surficial materials associated with dunes and sandplains, dust storms are likely to occur. (Google Image redone by JMH).

Why "The Line" [20]? Prior to 1960, Saudi experience with the natural environment was mostly direct and, even for those acclimated to it, mostly uncomfortable. In effect, after the populace became commonly aware of doable architectural options to disconnect or protect from desert harshness, many sought to do so. As the Kingdom of Saudi Arabia endured rapid infrastructural upgrades, the most familiar element of which were industrial pipelines, its population became adjusted to the pleasantries of air-conditioned shopping malls, some of which were equipped with skybridges that enclosed pedestrian walkways linking two or more buildings at height. The module-cities spaced along the route could function as valves governing the flows of people, desalinated seawater [21], electricity, fuels, and manufacturing materials [22]. "The Line" is thus a symbolism-intense giga-project [23-25]. Although more substantial and imposing, "The Line" might be perceived as a semi-replication of ***The Running Fence*** artwork installed by Christo (1935-2020) across 40 km of a northern California coastal landscape during 1976 and which penetrated the Pacific Ocean a short distance [26]. The seaward most part of "The Line" is supposed to extend as a narrow, 500-meter-tall pier-settlement into the nearshore Gulf of Aqaba shallows! The linear form of spatial development is appropriated where the structure is used as a connecting element of more complex geographical installations [27].

3 Societal prolongations via exuberant elongated floating PV Magic Carpet giga-project

Perhaps the *next* essential Saudi Arabia linear giga-project planning region might well be the multi-nationally shared Arabian-Persian Gulf. The primal paradise, the idyllic Garden of Eden that is described in *The Bible*, may be submerged by ancient rises in sea-level where the 21st Century Arabian-Persian Gulf exists. Remnants of prior civilizations may be embedded in the seabed at its northern end [28], the central section [29] at its southern end [30], or even elsewhere [31]! The Mesopotamian marshlands lie mostly within southern Iraq and a part of southwestern Iran. Depending on the season, the marshes cover 1,100-2,800 square kilometers and are settled by the Ma'dan, or Marsh Arabs. People there sometimes still live on traditional woven artificial islands entirely fabricated from wild reeds, but in the past many more did so, perhaps since the 4th Millenia BC, and so its society forms today a vanishing cultural heritage. A disappearing cultural heritage (canonical heritage) often is assessed to be urgently preservable, while critical heritage is usually taken to mean a burden on those alive needing to be categorized as a threat to maintenance of social order. A sustaining perspective must be chosen if there is to be a long-term future for the Marsh Arabs. The 21st Century Ma'dan people fish and directly affect the northern Arabian/Persian Gulf's commercial marine life, particularly shrimp (*Metapernaeus affinis*). Therefore, Kuwait and the Ma'dan people are economically networked and, thus, it may portend the Ma'dan become increasingly maritime labor; a future of living on seawater may not be such a radical shift from the way Ma'dan nowadays live, work, and play!

Climate change is a ubiquitous popular topic amongst vicinal dwellers of the Arabian/Persian Gulf. Yet, some geographical researchers expect Iran's Lut Desert, currently the world's hottest place during summer, to remain a viable commercial ecotourism attraction [32]. Along with meteorological drought and anthropogenically induced desertification, tropical cyclones seem to constitute a new natural hazard for the people and government of Iran, and perhaps others as well [33]. The probability of tropical storms occurring in the Arabian/Persian Gulf are allegedly "very low" [34]; yet, increasing surface seawater temperatures, driven by a warming regional climate as well as floating anthropogenic contaminants (from oil-spills [35], discharged sewage and industrial waste water) may induce conditions favorable to the perseverance of tropical cyclones therein. The Arabian/Persian Gulf, with an average depth of ~36 meters and a volume of ~8,630 cubic kilometers, is easily heated by enduring hot seasonal weather conditions [36]. Waves generated by tropical cyclones within the Arabian/Persian Gulf may not, however, exceed those measured in the North Sea. A pioneering offshore floating solar PV array rafting technology innovated and installed by the Zon-op-Zee Project on the North Sea remained intact during inclement conditions for several years, enduring winds of 62 knots and waves >5 m in height; the mats were designed to survive 10 m waves [37]! A generic floating Magic Carpet Giga-project can be summarized by the following components: (I) the float, (II) PV modules and their support, and (III) the associated electrical equipment. The float and its various necessary attachments tend to (I) attenuate wave action, (II) reduce normal and extraordinary solar irradiation, and (III) lower both ambient air and immediate contact seawater temperatures of the Arabia/Persian Gulf. Facts associated with such shadowing and moored or anchored stable devices was first completely determined by 2020 [38]. Of course, every necessary prospective mooring or anchorage would be thoroughly investigated via divers and/or bathy-drones [39].

Figure 3. The photovoltaic Magic Carpet giga-project, spanning ~5^0 of latitude and ~4^0 of longitude, shown here as a rectangular single architectural element, but which, when realized, will more likely not be one single floating base for

PV panels in order to accommodate shipping lanes as well as the clutter of existing offshore industrial facilities such as drilling and production oil-rigs. It is desirable that the array of floating PV mat-modules, the interlocked PV rafts, should be invisible to an adult human gazing seaward. Ultimately, it is possible that the rafts may coat ~24% of the Arabian-Persian Gulf surface. And, like Peru's famed Nazca Lines, the "Magic Carpet" will finally attain the status of global tourist attraction, viewable too by Earth-orbiting space tourists. (Image courtesy of JMH).

Engineers, notably in Japan [40], have compiled many research findings about very large floating structures. Some of these floating electrical power generators include a single massive sailing solar-cell ocean-going raft with a functional area of 25 square km [41], or about 0.0417% of the proposed Magic Carpet Giga-project. Although automation of shipping is on-going, it is not yet fully conceived as a unitary means of transportation. Because effective IMO maritime safety regulations remain purely formational, proposed grandiose schemes for totally unmanned vessels sailing the world's ocean and its many seaports may never be realized [42]. Also, shipbuilder's dreams of hull coatings that prevent attachment of marine organisms has yet to materialize. Biofouling, however, often can be removed without dry docking using robotic hull cleaners. One of the most pressing potential macro-problems of the Magic Carpet Giga-project is aerial biofouling caused by annually migrating birds that use the Arabian/Persian Gulf as a flyway. Aerial drones can possibly be deployed to shoo nesting or resting birds from most vital raft segments containing warm solar panels! Dust and sand grains blown onto the raft from can be blown away at low cost from the aerial surfaces of the Magic Carpet using downdrafts from hovering rotorcraft drones [43-44].

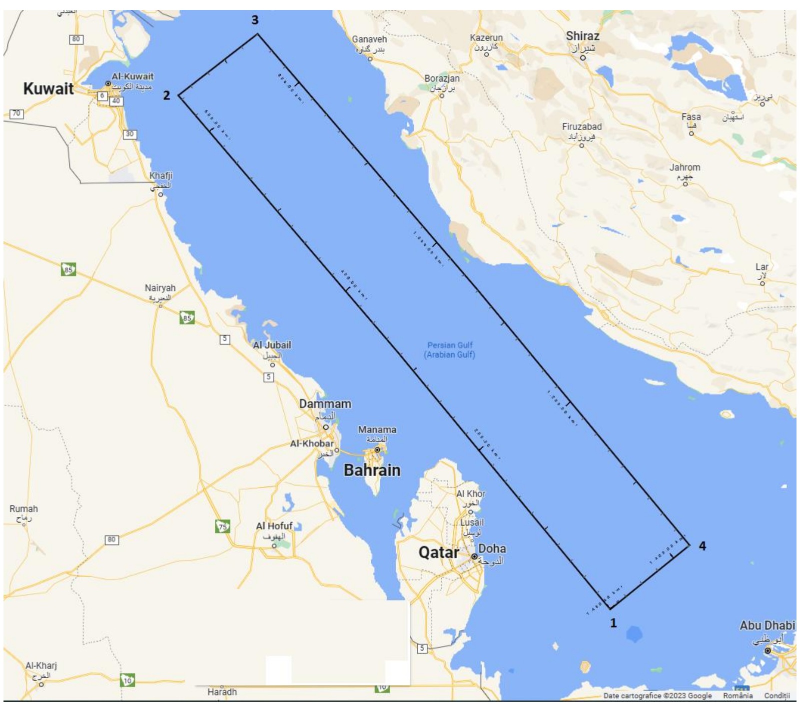

Figure 4. Hypothetic place of the PV power plant.

4. Magic Carpet Giga-project: PV solar-power generation calculations

4.1. Meteorological and radiometric data

The hypothetic field of PV modules covers the surface shown in Fig. A. The geographic coordinates of the corners of this figure are presented in Table A. The total surface of the field of PV modules is 62420.6 km^2.

Table 1. Geographic coordinates of the corners of the surface shown in Fig. 4.

Point number	Latitude (°N)	Longitude (°N)
1	24.8221	52.8469
2	29.2735	48.6575
3	29.7939	49.4266
4	25.3871	53.6170

Information about the air temperature and incident solar global irradiation is needed to estimate the performance of the PV power plant. Such kind of information may be found on the POWER platform. The NASA POWER Project provides meteorology, surface solar energy and climatology data for various needs: renewable energy, building energy efficiency and agricultural activities [45]. The surface solar energy data is freely available for download at a global scale with a spatial resolution of 1/2 by 1/2 arc degree longitude and latitude. The physical quantity extracted for this study is the All-Sky Insolation Incident on a Horizontal Surface (ALLSKY_SFC_SW_DWN). The solar radiation data provided by the POWER platform are taken from NASA's Global Energy and Water Exchanges - Surface Radiation Budget Project Release 3.0 archive and from NASA's CERES Fast Longwave and SHortwave Radiative Fluxes (FLASHFlux) project [46].

The monthly averaged values of the air temperature and incident solar global irradiation on a horizontal surface for the time interval 1984-2021 for all four points of Fig. 4 have been downloaded. Yearly averaged values have been computed for these two meteorological parameters (see Fig. 5). The air temperature slightly increases during the time interval 1984-2021, in good agreement with common perception that the air temperature has the tendency to increase on the whole global surface. Also, solar global irradiation shows a slight increasing tendency. The values of the air temperature, as well as those of solar global irradiation, in points 1 and 4 are close each other. This is to be expected, taking into account that the difference of latitude between the two points is small. A similar comment applies to the values of the meteorological parameters in points 2 and 3.

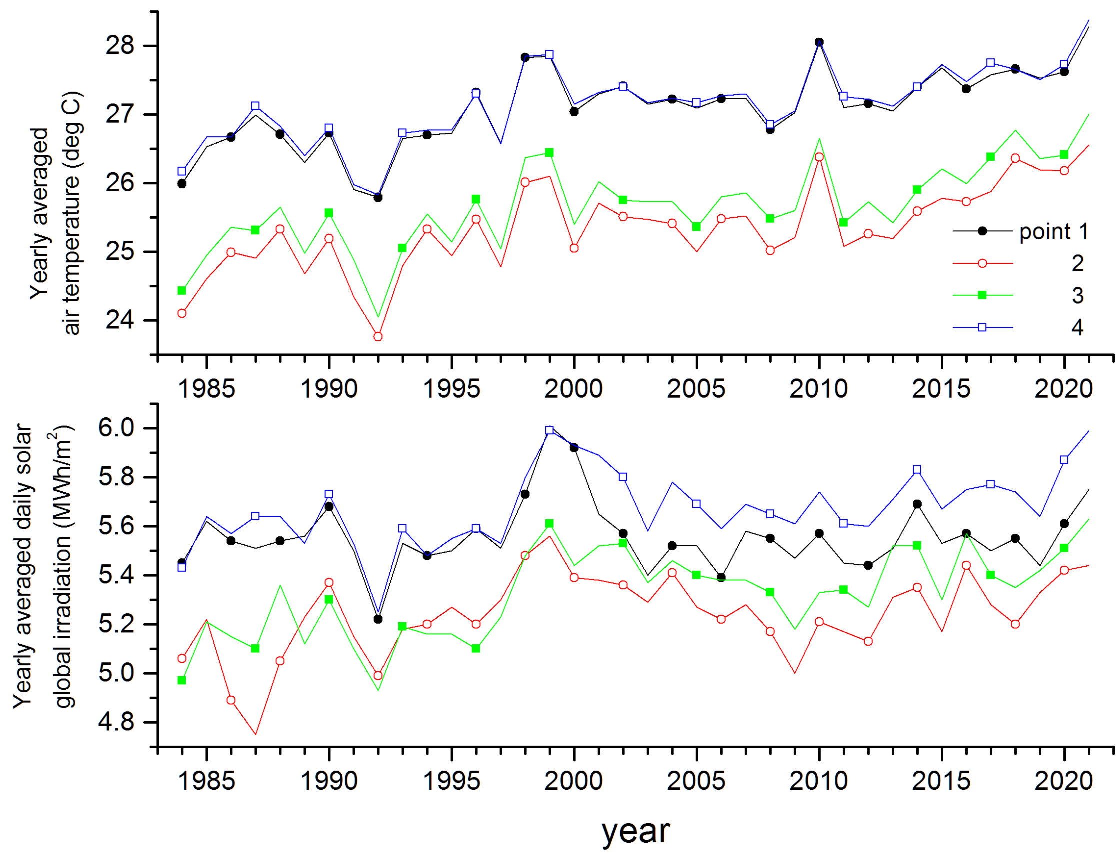

Figure 5. Yearly averaged values of air temperature and daily solar global irradiation on a horizontal surface during the time interval 1984-2021 for the four points of Fig. 4.

4.2. Evaluation of PV plant performance

The calculation procedure includes three stages:

1. Calculation of the monthly averaged efficiency of the PV cells and monthly averaged energy provided per unit surface area during the time period 1984 to 2021, in each of the four points that define the corners of the rectangular PV array;

2. Calculation of the surface averaged value of the monthly averaged daily energy provided by the PV array;

3. Calculation of the annual electrical energy provided by the whole rectangular PV array.

4.2.1. Calculation of the monthly averaged efficiency of the PV cell and monthly averaged energy provided per unit surface area

The calculation is performed for an opaque PV module (glass to Tedlar) with c-Si cells, with the structure shown in figure 6.

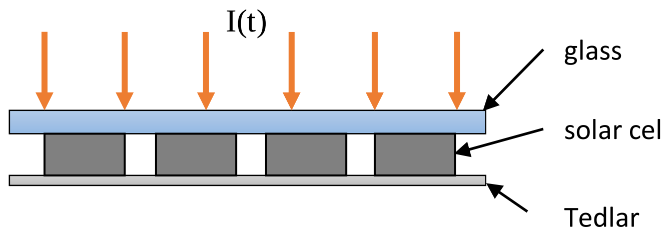

Figure 6. Cross section through opaque PV module.

The assumptions underlying the efficiency calculation are the following:

- the heat transfer from the PV cell to the environment is one dimensional;
- the PV module operates in quasi-steady state;
- resistive losses in the electrical circuit of the PV module are negligible.

The electrical efficiency of the PV cell, η_c, is obtained from the energy balance equation, taking into consideration the variation of efficiency with temperature [47]:

$$\eta_c(T_a, I) = \frac{\eta_{ref}\left[1-\beta_{ref}\left[(T_a(t)-T_{ref})+\frac{\tau_g[\alpha_c\beta_c+(1-\beta_c)\alpha_T]}{U_{Lm}}I(t)\right]\right]}{\left[1-\frac{\eta_{ref}\beta_{ref}\tau_g\beta_c}{U_{Lm}}I(t)\right]}, \quad (1)$$

where $U_{Lm} = U_b + h_0$, with $U_b = \left(\frac{L_T}{K_T} + \frac{1}{h_i}\right)^{-1}$, and η_{ref} is the electrical efficiency of the PV module at the reference temperature, T_{ref} and at reference incident solar irradiance of 1000 W/m^2. The quantity β_{ref} is the coefficient of variation of efficiency with temperature. The values of these parameters are usually given by the PV module manufacturer. For opaque PV modules with c-Si cells, these values are as follows: $\eta_{ref} = 0.15$, $\beta_{ref} = 0.0041\ \frac{1}{K}$. at $T_{ref} = 25$ °C [47].

The design parameters of the opaque PV modules based on c-Si cells, to be used in Eq. (1), have the typical values shown in table 2.

Table 2. Parameters of opaque PV modules based on c-Si cells, to be used in Eq. (1) [48]

Quantity	Symbol	Units	Value
Solar cell absorptance	α_c	-	0.9
Temperature coefficient	β_c	-	0.89
Tedlar transmittance	α_T	-	0.5
Glass transmittance	τ_g	-	0.95
Heat transfer coefficient on top face of PV cell	h_0	$W/(m^2K)$	$5.7 + 3.8 \cdot v$
Heat transfer coefficient on bottom face of PV cell	h_i	$W/(m^2K)$	$2.8 + 3.0 \cdot v$
Thickness of Tedlar layer	L_T	m	0.0005
Thermal conductivity of Tedlar layer	k_T	$W/(mK)$	0.033

The values of the wind speed, v used to calculate the quantities h_0 and h_i in Table 2 are $v = 0.5\ m/s$ and $v = 0.2\ m/s$, respectively.

The electric efficiency of the photovoltaic cell, given by Eq. (1), depends on the ambient temperature, $T_a(t)$ and solar global irradiance, $I(t)$, which are functions of time. These functions may be estimated as time averages, such as hourly, daily, monthly or annual average values.

In this study, values of monthly averaged air temperature, $T(t)$ °C and monthly averaged daily global horizontal irradiation, $H(t)\ \mathrm{kWh/m^2}$ were downloaded from the POWER database for the time period 1984 to 2021, for each of the four corners of the rectangular PV array. The data matrices provided by POWER were vectorized, resulting for each corner two column vectors, with 456 lines each (38 years x 12 months):

$T_{a,1_i}$ and H_{1_i} for point 1,

$T_{a,2_i}$ and H_{2_i} for point 2,

$T_{a,3_i}$ and H_{3_i} for point 3 and

$T_{a,4_i}$ and H_{4_i} for point 4, with $i = 1 \dots 456$.

Each vector contains the monthly values of the parameters $T(t)$ and $H(t)$ in chronological order, starting with 1984, continuing with 1985, 1986, 1987 until 2021. Each year the values correspond to the sequence of months: January, February, March to December. For example, the vector T_{a1} contains on the first row the temperature value of January 1984, on the second row the temperature value of February 1984, on the third one the temperature value of March 1984, and so on until the end of 1984. The next line contains the temperature value for the month of January 1985 and so on until line 456, where the temperature for the month of December 2021 is stored.

Next, the daily averaged solar global irradiance I(t) (in W/m^2) is computed from the daily solar global irradiation H(t) (entering in kWh/m^2) by using the relationship:

$$I = 1000\,\frac{H}{24}. \quad (2)$$

Further, the electrical efficiency of the PV cell at each point and each month was calculated using Eq. (1). This resulted in four column vectors, one for each point:

$$\eta_{c,1_i} = \eta_c\left(T_{a,1_i}, I_{1_i}\right) \text{ for point 1,} \quad (3)$$

$$\eta_{c,2_i} = \eta_c\left(T_{a,2_i}, I_{2_i}\right) \text{ for point 2,} \quad (4)$$

$$\eta_{c,3_i} = \eta_c\left(T_{a,3_i}, I_{3_i}\right) \text{ for point 3 and} \quad (5)$$

$$\eta_{c,4_i} = \eta_c\left(T_{a,4_i}, I_{4_i}\right) \text{ for point 4, with } i = 1 \ldots 456. \quad (6)$$

Finally, the electrical energy, P_c, provided daily per unit surface area of the PV cells was determined, in kWh/m^2, at each point and for each month:

$$P_{c,1_i} = \eta_{c,1_i} \cdot H_{1_i}\,, \quad (7)$$

$$P_{c,2_i} = \eta_{c,2_i} \cdot H_{2_i}\,, \quad (8)$$

$$P_{c,3_i} = \eta_{c,3_i} \cdot H_{3_i} \text{ and} \quad (9)$$

$$P_{c,4_i} = \eta_{c,4_i} \cdot H_{4_i},\ i = 1 \ldots 456. \quad (10)$$

Next, the values of the parameters are calculated as averages on the four points that define the rectangular PV array.

4.2. Calculation of the surface averaged value of the monthly averaged daily energy provided by the PV array

Surface averaged monthly values of air temperature, daily solar global irradiation, PV efficiency and electrical energy provided daily per unit surface area by the PV cells are calculated as arithmetic averages of the values corresponding to the four points as follows:

- surface average monthly air temperature,

$$T_{a,med_i} = \frac{T_{a,1_i} + T_{a,2_i} + T_{a,3_i} + T_{a,4_i}}{4},\ [°C], \quad (11)$$

- surface average of monthly averaged daily solar global irradiation,

$$H_{\mathrm{med}_i} = \frac{H_{1_i}+H_{2_i}+H_{3_i}+H_{4_i}}{4}, \left[\frac{\mathrm{kWh}}{\mathrm{m}^2}\right], \quad (12)$$

- surface averaged monthly PV efficiency,

$$\eta_{\mathrm{c,med}_i} = \frac{\eta_{\mathrm{c},1_i}+\eta_{\mathrm{c},2_i}+\eta_{\mathrm{c},3_i}+\eta_{\mathrm{c},4_i}}{4} \text{ and} \quad (13)$$

- surface averaged electrical energy provided daily per unit surface area by the PV cells,

$$P_{\mathrm{c,med}_i} = \frac{P_{\mathrm{c},1_i}+P_{\mathrm{c},2_i}+P_{\mathrm{c},3_i}+P_{\mathrm{c},4_i}}{4}, \left[\frac{\mathrm{kWh}}{\mathrm{m}^2}\right], i = 1 \dots 456. \quad (14)$$

For the calculation of surface averaged electrical energy provided daily per unit surface area by the PV cells, the column vector *days* is defined, with 456 lines, containing the number of days corresponding to each month of the period 1984...2021. Thus, line 1 contains the value 31, representing the number of days in January 1984. The second line has the value 29 - the number of days in February 1984 (leap year). The third line contains the value 31, corresponding to March 1984 and so on, in chronological order. Line 12 contains the value 31, corresponding to December 1984. The next line contains the value 31, corresponding to January 1985. Line 14 contains the value 28, corresponding to February 1985 (normal year). The rest of the lines are completed similarly, in chronological order, until December 2021, considering leap years.

The electrical energy provided monthly by the PV array is calculated with the relationship:

$$E_{\mathrm{med}_i} = P_{\mathrm{c,med}_i} \cdot A \cdot \mathrm{days}_i \; [\mathrm{kWh}], i = 1 \dots 456. \quad (15)$$

where $\mathrm{A} = 62420.61\ km^2$ is the area of the rectangle defined by the four points, while days_i is the number of days in month *i*.

4.3. Calculation of the annual electrical energy provided by the whole rectangular PV array

The annual averaged values of air temperature, solar global irradiation, PV efficiency and electrical energy provided by the whole PV array are calculated, from 1984 till 2021, as arithmetic averages of the associated monthly values for each year.

It is noted with *j*, the index of the year of the time period 1984-2001, i.e. $j = 1 \dots 38$, and two vectors *a* and *b* are defined, which contain the indices of the beginning and end lines of each year in the vectors $T_{\mathrm{a,med}_i}$, H_{med_i}, $\eta_{\mathrm{c,med}_i}$ and $P_{\mathrm{c,med}_i}$, $i = 1 \dots 456$:

$$a_j = 12(j-1) + 1 \text{ and} \quad (16)$$

$$b_j = 12j. \quad (17)$$

For example, for $j = 1$, results $a = 1$ and $b = 12$,i.e. the first year, 1984, starts at line 1 (January) and ends at line 12 (December). The second year, 1985 ($j = 2$, $a = 13$ and $b = 24$) starts at line 13 (January) and ends at line 24 (December). Last year, 2021 ($j = 38$, $a = 445$ and $b = 456$) starts at line 445 (January) and ends at line 456 (December).

The averaged annual values of these quantities are calculated using the following relationships:

- annually averaged air temperature,

$$T_{\text{a,med,year}_j} = \frac{\sum_{k=a_j}^{b_j} T_{\text{a,med}_k}}{12} \;[°\text{C}], \tag{18}$$

- annually averaged daily solar global irradiation,

$$H_{\text{med,year}_j} = \frac{\sum_{k=a_j}^{b_j} H_{\text{med}_k}}{12} \left[\frac{\text{kWh}}{\text{m}^2}\right], \tag{19}$$

- annually averaged PV efficiency,

$$\eta_{\text{c,med,year}_j} = \frac{\sum_{k=a_j}^{b_j} \eta_{\text{c,med}_k}}{12}, \tag{20}$$

- annually averaged electrical power provided daily per unit surface by the PV cells,

$$P_{\text{med,year}_j} = \frac{\sum_{k=a_j}^{b_j} P_{\text{med}_k}}{12} \left[\frac{\text{kWh}}{\text{m}^2}\right], j = 1 \dots 38. \tag{21}$$

The annual electrical energy provided by the whole PV array, during the time period 1984 to 2021, is obtained by summing up the electrical energy, generated in the twelve months of each year:

$$E_{med.year_j} = \sum_{k=a_j}^{b_j} E_{med_k} \quad [kWh], \quad j = 1,38. \tag{22}$$

4.4. Results

Figure 7 shows the yearly averaged values of several quantities during the time interval 1984-2021. The yearly averaged daily solar irradiation on a horizontal surface ranges between 5.1 kWh/m^2 in 1993 and 5.9 kWh/m^2 in 1999 (Fig. 7(a)). Therefore, the variation of the incident solar energy is around 13% during this 38-year interval. This should be compared with the variation of the electrical energy provided yearly by the PV plant which ranges between about 16250 TWh in 1993 and 18250 TWh in 1999 (Fig. 7(d)). The variation of the electrical energy provided yearly during the time interval 1984-2021 is about 10%. The difference between the two percent values is explained by the fact that the electrical energy provided by the PV plant is not directly proportional with the incident solar energy.

The yearly averaged air temperature increased from 25.6 °C in 1984 to 27 °C in 2021 (Fig. 7(c)). This means a difference of temperature of about 1.4 °C. The range of variation of the yearly averaged air temperature is even larger since the minimum air temperature was in 1993 (24.6 °C). The efficiency of the PV modules decreases by increasing the ambient air temperature. This is easily observed by comparing Fig. 7(c) with Fig. 7(b). The efficiency is minimum in 1999 and 2021, when air temperature reached its largest values.

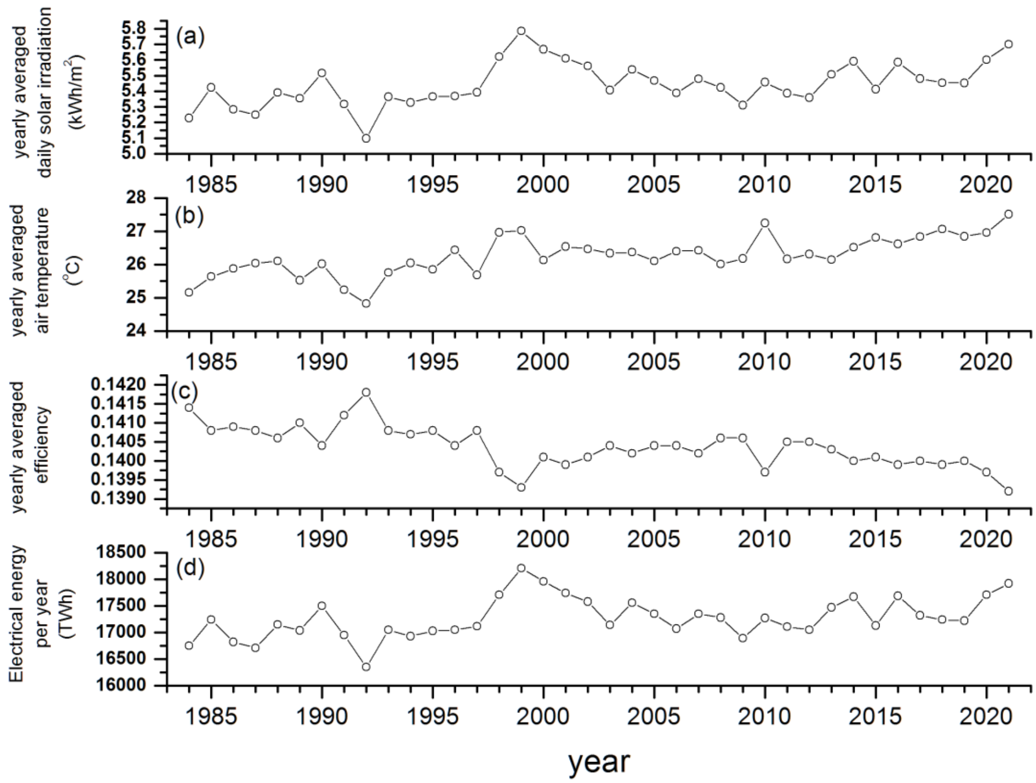

Figure 7. Yearly variation of several quantities. (a) Yearly averaged daily solar irradiation on a horizontal surface; (b) yearly averaged air temperature; (c) yearly averaged PV plant efficiency; (d) electrical energy provided yearly by the PV plant.

To give perspective to the present results, we may refer to the largest hydroelectric power plant operating on the Yangtze River at Yichang. Its installed power is 25000 MW. During 30 days months it generates about 16.2 TWh of electrical energy. The present PV plant will generate in June, in average, about 1800 TWh electricity, which means the equivalent of about 111 hydroelectric Yichang power plants. In December, the PV power plant has the smallest output, with 950 TWh of PV energy, which corresponds to about 58 hydroelectric Yichang power plants.

5. Desalination production of the Magic Carpet Giga-Project

Although Saudi Arabia has no permanent rivers, the essential technical configuration of "The Line" mimics a river in functionality. Since 2019, Saudi Arabia has operated the world's most productive desalinization plant, Ras Al-Khair, which manufactures ~1.4 million m3 of freshwater daily. Real-world observations as well as computer simulations show that the freshwater manufactory discharge brine alters the salinity of the whole Gulf as well as the Gulf's exchange seawater flows at the Hormuz Strait [49]. For northwestern Iran, its "locked-in" [50] degrading Lake Urmia. Due to areal contraction of the hyper-saline water area occurs because of a persistent regional drought, its 51,876 square km catchment is likely to become drier during the 21st Century [51]. Rather than enlarging Lake Urmia by importing costly desalinated water products from the Caspian Sea, a better result could be obtained using the Arabian/Persian Gulf Giga-project's PV-generated electricity: namely, by the cheaply pumped annual supply of ~10 cubic km of de-salted Gulf seawater to Lake Urmia via a long-distance pipeline. A similar overland piping system was previously proposed for southern California entailing the obvious potential for refilling of Utah's Great Salt Lake [52]. If this contriaved arid landscape installation seems like a lunatic renewal plan, it is perhaps appropriate to recall that Switzerland previously enrobed some of its skier-enjoyed mountainous landscape with vast swathes of geotextile sheeting to slow 21st Century glacial melt [53]. The potential volume of desalinated water producible by the proposed Magic Carpet would be in the hundreds of cubic kilometers!

6. Dilemmas, reflections, and all that about Geoengineering in the Gulf region

The last of the great utopias created was undoubtedly that of a cybernetic society, in which all individuals start to connect with each other virtually through digital space, or so-called "cyberspace". The obvious reasons this conceptual utopia failed are the fuel for the dystopia that is experienced now. An example of the lack of interpersonal communication resides in the fact that individuals from the same family, sitting side by side in an airport, prefer to communicate on cell phones via WhatsApp! A preponderant dystopian factor is the gradual replacement of science by technology such as AI (Artificial Intelligence), and, consequently, at the same time, the replacement of hope based on actions by the empty promise of an induced immediacy consumerism. In the wake of this cybernetic dystopia, all the technologies that today make use of cyber applications, such as medicine and engineering, have been developing. Doctors and engineers turn their problems over to machines, becoming less and less able to think. To what extent engineering will set aside its social value to let itself be guided solely by market parameters referring to awesome but superfluous cybernetic items is still unknown. But not everything is lost. Robotics associated with artificial intelligence brought real utilities in the form of more and more sophisticated drones, extremely useful in geoengineering. Nevertheless, greatest expectations of survival as a species rest on creative engineering, not as individuals, which seems to be more a role for medicine. It is from the use of renewable resources, the preservation of biomes, the desalination of seawater, and the hydration of deserts that permit human life to stay on Earth for a longer time. All of this is imagined based on large scale solutions which only the human mind can conceive.

Geoengineering, or macro-engineering, is the engineering way to find giant technological solutions to macro problems. Thinking of the arid Sahara and its extension in the Arabian Peninsula requires application of macro-imagination to make these regions more livable and productive in order to create more inviting spaces for people who have occupied during millennia its desert margins and oases. Persian Gulf nations, however, are among the most socially disparate countries on Earth, a fact that makes their true geopolitical intentions somewhat doubtful when they launch themselves into large projects. The great Muslim traditions, which in many ways constitute one of the most beautiful cultural expressions of humanity, have suffered extensive distortions over the centuries in favor of retrograde visions of totalitarian and exclusionary politics. This trend was subsidized in the 20th Century by the dominance of abundant fossil resources in the region and it is possible that the same domination may prevail over other sources of energy. Unfortunately, only the fundamentalism of the governing radical factions gains diffusion in the Western world, not allowing to show family ties, music and art in general of the truest branch of Sunni and the Sufi lineages (the latter constituting a contemplative and moderate form of Islam that opposes extremist and fundamentalist doctrines), and other minority branches whose interpretations of *Koran*, *Sharia* and *Suna* are more open. Even though Saudi Arabia is the most representative country of Sunni belief, and even with the partial Sufi emancipation granted in 2005 by the Saud prince at the time, later made King Abdullah, died January 23, 2015, guaranteeing them the right to practice the *dhikr* at home (the remembrance of God, with all the rites and gestures that characterize it), segregation and radicalism are still evident. It is not by chance that some dominant radical groups have prohibited access to the literature of Muslim writers such as Omar Khayyam (1048-1131), al-Ghazali (1058-1111) and Rumi (1207-1273), all of Sufi perception and much quoted by Western philosophers, writers and theologians. In a nutshell, until now, the House of Saudi and its acolytes from the Arab Emirates of the Gulf have shown in their pharaonic projects only a concern for modernity with a view to perpetuating the riches under their guardianship after the decline of oil, something that does not convince in the sense of social progress. In Qatar, for example, recent reports from a fellow correspondent show a sad scenario of exclusion, despite the image that was sought to be disseminated during the last Football World Cup. In this country, advanced refrigeration techniques, even in open environments, consume tremendous amounts of energy, but only for a privileged minority.

The big question is to ascertain who "The Line" is intended for (who were the artificial islands of Dubai intended for?). Large geoengineering projects, as the Magic Carpet Giga-project, are increasingly inevitable judging by the enormous survival needs for energy of populations that grow uncontrollably. In the not-too-distant future, it is possible that there will be a need for similar magic solar carpets in orbit in order to meet future energy demands. The question remains; however, will they be inclusive, or will they further increase inequalities? In a world of scarcity, considering that more than 2 billion people still cook using fuels that are harmful to health and the environment, it seems more likely that true human nature will prove to be ruthless. Thus, it is incumbent on society to call for global directions that include large investments in macro-engineering for the perspective of quality of life, which constitutes one of the guidelines of engineering and of architecture and urbanism. The model of the reigning Houses in the Gulf has never been permeated by this vision, and probably never will be, unless strong international geopolitical pressure convinces them that inclusion is the best way to avoid the mass evasion of human heritage due to climate crises that are to possibly come. No region in the world can sustainably support population overload, however open it might be to immigration. As a concrete case, the appalling human conditions in conflict zones at the Middle East have caused thousands of refugees to seek shelter in Europe, exerting unprecedented socio-economic pressure. It is in this scenario that geoengineering presents itself as a macro-instrument of survival and sustainability for all people.

7. Conclusion

Deserts are mature ecosystems with very low desirable productivity due to severe freshwater limitations prompted by natural and sometimes anthropogenic low-precipitation and high-evaporation conditions, according to *The Arid Lands: History, Power, Knowledge* (MIT Press, 2016) by Diana K. Davis. Interestingly, the application of aerial and orbital remote sensing technology to major desert and desertification studies only commenced *around* 1991 [54]. Some experts now suggest a comprehensive reorganization of human civilization's food-production by prioritizing optimal food-growing regions via mechanized farming and irrigation [55]. Before the 1950s, the Campo de Dalias, located in Spain's province of Almeria, consisted mostly of scrubby wild vegetation, some pastureland peppered by a few small plots of seasonal crops. Today, 400 square kms of southeastern Spain are covered by greenhouses! The advantage of indoor controlled air quality agriculture is that there are almost no requirements for pesticides and greenhouse crops use ~10% of freshwater normally needed by crops raised outdoors. Attended by drones [56], smart greenhouses in Qatar already produce healthy crops [57]. Realization of the Magic Carpet Giga-project could feasibly initiate a huge increase in the GDPs of Arabian/Persian Gulf ecosystem-states because of food and fiber exportation.

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