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Working Paper

Kardashev Kommunities

A Conceptual and Theoretical Ladder-Stage Development Model for Regenerative Development in Desert Environments

"You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete."
R. Buckminster Fuller

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Abstract

This working paper proposes a conceptual and theoretical framework for regenerative development in desert environments, structured as an incremental ladder of technological stages. Using only three primary inputs — sunlight, seawater, and desert land — the model demonstrates how communities with minimal resources can progress from subsistence-level survival through to agro-industrial production, ecological regeneration, and meaningful contribution to global carbon offsetting.

The framework is situated within the paradigm of regenerative development and evaluated against the Kardashev Scale of civilisational advancement — a lens that makes visible both the scale of the problem and the scale of the opportunity. The paper proposes that the principal barrier to such development is not technological but paradigmatic: solutions exist; the silo-based thinking and short-horizon economics that prevent their integration do not.

Two developmental pathways are modelled: a Scaling Pathway, which maximises output volume through replication of core technologies; and a Diversification Pathway, which compounds value by integrating additional technology streams as group income grows. Both are analysed through nine T-levels of development, from a single module supporting 50 individuals to regional-scale interventions affecting millions. This paper recommends the Diversification Pathway as the primary model on the grounds of systemic resilience, output diversity, and long-term ecological value — while recognising that the Scaling Pathway may be appropriate in contexts where speed of deployment and knowledge transfer are paramount.

A dedicated section addresses the social and governance architecture necessary to operate and sustain the model: the structure of the founding group, decision-making processes, ownership of productive assets, and the mechanism by which intergenerational stewardship is secured. The waqf, an Islamic commons ownership instrument with a fourteen-century history of delivering public goods, is proposed as the most coherent legal architecture for securing the long-term commons character of these developments.

The working paper identifies four priority areas for further research: validation of the quantitative output assumptions; governance design for the founding group; technology transfer and knowledge commons infrastructure; and market access mechanisms for the poorest communities.

Note on Scope

This paper operates at the conceptual and theoretical level. It does not claim to resolve the engineering, logistical, financial, or political challenges of implementation — these are acknowledged and identified as the subject of necessary further research. What the paper does claim is that the technological possibility of the model is credible, and that the intellectual architecture for understanding why it has not yet been implemented is more important than any single technology within it.

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1. Introduction

Despite decades of research into sustainable development (SD) solutions to the climate crisis, remarkably little has transferred into real-world impact. Individual technological solutions, silo-based thinking, and the paradigm of sustainability itself — which seeks primarily to arrest current damaging practices rather than to repair what has already been damaged — continue to hinder the more fundamental intervention the situation requires. The problem is not a shortage of technologies; it is the absence of an economically viable, scalable, and ecologically restorative development model capable of benefiting the communities most in need.

The concept of regenerative development (RD) addresses the underlying flaws within the SD paradigm. Taking a holistic, systems-based approach, RD holds that any development — whether economic, industrial, or ecological — should have a restorative effect on the systems within which it operates. Crucially, RD does not accept that halting damage is sufficient; it requires that development make things better. This paper operates within the RD paradigm and takes a deliberately expansive view: the developmental pathway of humanity as a civilisation is the relevant frame, and community-scale interventions must be evaluated against that frame to understand their true significance.

The aim is to demonstrate that it is possible to model a credible pathway of development using minimal resources — specifically, using only desert land, sunlight, and seawater — to create a ladder out of poverty, water and food insecurity, and ecological decline. The model is structured as a series of T-levels, adapted from the Kardashev Scale of civilisational technological capacity, and is designed to be built incrementally by communities with the least financial and material resources available.

Three research questions organise the inquiry:

- What minimal technology components, combined in a specific sequence, can support economically disadvantaged communities in desert environments to climb out of poverty using low-cost and locally available resources?
- What socio-economic and governance mechanism promotes equitable distribution of the wealth generated, both across the present community and across generations?
- How does the mass adoption of this developmental model relate to the paradigms of regenerative development and civilisation-level advancement as measured by the Kardashev Scale?

2. The Case for a New Paradigm: Why Regenerative Development and Why Now

The literature on sustainable development is vast, multidisciplinary, and internally contested. A comprehensive review is beyond the scope of this working paper. What is within scope is the specific argument for why the SD paradigm is insufficient and why RD represents a more appropriate intellectual architecture for the problem this paper addresses.

The core problem with SD is captured in its name: sustainability seeks to sustain a present state that is already deeply damaged. A civilisation that has deforested much of its landmass, acidified its oceans, destabilised its climate, and concentrated its wealth in the hands of a small fraction of its population cannot be meaningfully improved by arresting further damage at the margin. RD recognises this. It holds that “work that regenerates addresses the unrealised potential inherent in the relationship between a given system and the larger systems within which it is nested”, and that what exists now can be oriented towards what could be in the future (Mang and Haggard, 2016). The destination is not the preservation of a broken present but the creation of conditions for a regenerative one.

The problem is not one of knowledge: humanity has more than sufficient information and understanding to address the climate crisis. The failure is one of integration — the inability or unwillingness to connect existing knowledge across disciplines and move from understanding to action. Gibbons et al. (2018) identify this directly, framing regenerative development as an “integrative paradigm” precisely because silo-based research produces partial solutions that may be counterproductive when considered at the system level. The biofuels literature offers a cautionary example: solutions optimised for energy production generated serious secondary effects on food security and land use that were not visible from within the energy silo (Gibbons et al., 2018).

The solution, as Meadows (2008) demonstrates, requires interventions at the highest leverage points in a system: not tinkering with numbers, feedback loops, or information flows — the eight lowest-leverage point types in her taxonomy — but changing paradigms, goals, and the capacity for self-organisation. This working paper is precisely such an intervention: it does not propose modifications to existing development models but an alternative model built from different premises, using different inputs, and pursuing different measures of success.

There is already evidence that such transformations are possible. The regeneration of the Loess Plateau in China, documented extensively in the literature, demonstrates that degraded ecosystems can be restored at scale within a generation when the right interventions are made in the right sequence (Rose, 2021). The Weather Makers project, which proposes the regeneration of the Sinai Peninsula using similar principles, identifies the primary barrier not as technological but as a “lack of imagination and inability to see alternate futures” (Rose, 2021). Large-scale irrigated afforestation of desert regions has been modelled as a credible mechanism for significant carbon sequestration, though the freshwater requirements under conventional methods create secondary costs — costs that the model proposed in this paper circumvents by sourcing water from the sea rather than from ground or surface reserves (Ornstein et al., 2009).

The specific opportunity this paper addresses — desert environments with coastal access, using minimal technology combinations — sits at the intersection of several fields that have rarely been considered together: solar desalination, algaculture, aquaponics, anaerobic digestion, and concentrated solar power. None of these technologies is new. Their systematic integration into a developmental ladder structured for communities with minimal capital is the contribution this paper makes.

3. Situating the Framework: Systems Thinking, the Kardashev Scale, and Integrated Technology Design

This paper uses the Kardashev Scale not as a literal measure of technological capacity but as an intellectual frame — a tool for placing community-scale interventions within a civilisational context, and for making visible the distance between where humanity currently operates and where it needs to go. The scale was developed by N. S. Kardashev and adapted by Carl Sagan to allow fractional notation; on this adapted scale, humanity currently operates at approximately T0.7 (Soubane, 2017).

[Figure 1: Kardashev Scale]

Figure 1: Kardashev Scale (adapted from Ćirković, 2016)

Dobruskin (2021) argues that the Kardashev framework is reasonable for assessing the development of human society, noting that civilisational development is commonly correlated with energy consumption per capita — a relationship the scale makes explicit. The value of the frame for this paper is not precision but perspective: it makes legible why the question of how desert communities sustain themselves matters to the trajectory of humanity as a whole. Fourie (2021) argues that advancement towards Type 1 requires “a larger philosophy or master plan” rather than reactive responses to individual crises. This working paper proposes a small but replicable piece of that master plan.

Meadows’ (2008) taxonomy of leverage points in complex systems provides a second organising principle. The twelve leverage points are listed in increasing order of effectiveness, from adjusting numbers (least effective) through changing paradigms and transcending paradigms (most effective). The first eight points — those most commonly targeted by policy and research — are also the least effective at generating lasting change. The model proposed in this paper operates at the four highest-leverage points: it embodies a new paradigm (regenerative rather than extractive development), pursues different goals (civilisational advancement rather than GDP growth), enables self-organisation (community-built, community-governed infrastructure), and does so within an ownership structure designed to transcend the paradigm of individual accumulation.

[Figure 2: Places to Intervene in a System]

Figure 2: Meadows’ Leverage Points (Meadows, 2008, p. 194)

The third pillar of the framework is the principle of technological integration. The paper’s literature review found, consistently across disciplines, that the individual technologies considered — solar stills, algae cultivation, aquaponics, anaerobic digestion, concentrated solar power — are each credible, well-researched, and implementable. What has not been modelled is their systematic integration as a developmental sequence in which each stage produces outputs that become inputs for the next, and in which the combination generates effects that none achieves alone. This emergent value is the core claim of the integrated systems argument: that 1 + 1 + 1, sequenced and networked correctly, does not equal 3 but something considerably larger.

The three comparable bodies of work identified in the literature — the Weather Makers project (Sinai regeneration), Ornstein et al.’s irrigated afforestation modelling, and the documented regeneration of China’s Loess Plateau — are each large-scale, capital-intensive, and politically dependent interventions. The model proposed here is distinguished by its inverse: it is designed to be small-scale, capital-minimal, and community-initiated. This is both its defining constraint and its defining strength. Where large-scale projects require financing and political will that may not materialise, community-scale initiatives can begin immediately with what is available — and aggregate towards the same global-scale effects.

4. Methodology

This working paper employs a meta-ethnographic approach — a qualitative synthesis of secondary sources — to identify, evaluate, and sequence technologies for inclusion in the developmental model. The methodology is explicitly conceptual and theoretical; it does not present empirical field data but proposes a framework for generating it. In Gibbons et al.’s (2018) taxonomy of outstanding needs for advancing regenerative development, this paper occupies the first category: conceptual and theoretical development. The ambition is to establish the plausibility of the model and to identify the most important directions for subsequent empirical research.

Technology Selection Criteria

Technologies were evaluated against seven criteria before inclusion in the model:

- Can it be used with only one, or a combination, of the three primary inputs: sunlight, seawater, and desert land?
- Does it produce a useful output in the Water, Energy, and Food (WEF) nexus, or contribute to climate mitigation?
- Can the technology be implemented incrementally and scaled modularly?

- Can it be built and maintained at a local level with minimal external expertise?
- Can it be constructed from non-polluting and recyclable materials?
- Does the technology or its outputs have ecological benefits or contribute to land restoration?
- Does it have a significant operational lifespan and potential for integration into an industrial permaculture?

Technologies excluded under these criteria include those that are consumptive of rare materials, dependent on toxic components, unable to be maintained locally, or represent advanced industrial processes requiring significant external capital. Nuclear power, for example, is excluded not on grounds of efficacy but on grounds of incompatibility with the model's foundational premise: that it must be buildable by communities beginning with almost nothing.

Modelling Assumptions

The quantitative outputs presented in this paper are based on published figures from peer-reviewed sources in the relevant technology domains. Key assumptions are:

- Solar still output: 3.3 L/m²/day, drawn from the range of 2–6 L/m²/day documented in Belessiotis et al. (2016). This is a conservative central estimate; actual output will vary with latitude, ambient temperature, and construction quality.

- Spirulina algae yield: 60 g/day/m², from Lucas and Southgate (2012). This is achievable under controlled conditions with adequate nutrients and light; yields in less controlled conditions may be lower, particularly in early-stage development.

- Carbon sequestration fraction of algae biomass via biochar: approximately 20% by dry weight of original biomass. This figure represents the estimated durable carbon that can be sequestered through slow pyrolysis of Spirulina biomass into biochar. It is derived from two compounding factors documented in the peer-reviewed literature: (1) biochar yield from slow pyrolysis of Spirulina at 550°C of approximately 28–31% of dry algae mass (Chaiwong et al., 2012, cited in Jamilatun et al., 2021); and (2) total organic carbon content of the resulting Spirulina-derived biochar of approximately 38–57% depending on pyrolysis conditions (Jamilatun et al., 2021). The product of these two factors gives an estimated range of 11–18% of original biomass weight durably sequestered as biochar carbon; the 20% figure used in this paper represents a modest upper-bound estimate within this range and should be treated as indicative. It is explicitly not the raw elemental carbon content of Spirulina biomass, which is approximately 47% of dry weight (Dianursanti et al., as cited in ScienceDirect Topics, 2021). The distinction matters: only the carbon fraction that survives as stable biochar and is applied to soil represents durable carbon sequestration. Actual yields will vary with pyrolysis method, temperature, and the proportion of biomass directed to biochar versus food or energy use.

• Spirulina nutritional profile: 65% protein, 15% carbohydrate, 7% mineral, 6% fat by weight, with all essential amino acids (Savage, 1994). This profile makes Spirulina platensis the primary food source in early development stages.

• Carbon offset value: £50/tonne CO_2. This is an indicative figure based on voluntary carbon market pricing at time of writing; the market is subject to significant variation and the paper's income projections should be read accordingly.

• Water security thresholds: survival minimum 10 L/person/day; water poverty threshold 100 L/person/day; water security threshold 1,000 L/person/day. These thresholds are grounded in humanitarian water standards. The Sphere Handbook (2018) specifies 7.5 L/person/day as the acute survival minimum rising to 15 L as standard humanitarian practice; the 10 L figure used in this model represents a contextualised survival baseline for a non-emergency desert development setting in high ambient temperatures, consistent with the Sphere framework (Sphere Project, 2018). The 100 L and 1,000 L thresholds draw on the wider water security literature.

It is important to state clearly that the factor-of-ten progression between T-levels is a modelling device rather than a prediction. In practice, growth rates will be constrained by capital accumulation speed, knowledge transfer, social cohesion, land availability, market access, and other factors that this paper does not model in detail. The progression is used to demonstrate the theoretical ceiling of the model and to make the scaling implications visible. Sensitivity to the underlying assumptions is addressed in the Further Areas for Research section.

Fundamental Boundaries

The model assumes the following boundary conditions at the beginning of the developmental process:

- The model is a group activity of 50 adults.
- Each group has access to an area of 1 km^2.
- The 50-metre boundary edge of each area is designated as commons, to which the general public have access, and where the group is required to develop commons infrastructure at specified development stages.

The boundary conditions were selected to define the smallest viable social and spatial unit from which the model can begin — large enough to distribute labour and achieve the minimal output necessary for survival, small enough to be initiated without significant external capital. The commons boundary is discussed further in Section 8.

5. Stage One: Single Module Development

Stage One tracks the development of a single group of 50 adults on 1 km^2 of desert land with coastal access. The five T-levels in this stage represent the complete technological journey from bare subsistence to full single-module advancement. The designs and techniques presented have acknowledged omissions — construction timelines, detailed financial modelling, and training requirements are beyond the scope of this paper — but the purpose is to demonstrate that a credible trajectory from near-nothing to genuine productive capacity exists. If each unit requires 50 people to develop a fully functional agro-industrial ecosystem, it follows that achieving the effects modelled at T0.9 requires approximately 500,000 people working in coordinated groups. That is a small fraction of the populations most in need of what this model offers.

T0.1: Making Stone Soup

The target at T0.1 is minimum viable capacity: enough freshwater and calories to keep 50 individuals alive, using only what can be built from recycled or freely available materials.

In survival situations, freshwater is the primary constraint. The survival minimum of 10 L/person/day is adopted as the baseline, consistent with the Sphere Project's humanitarian water standards, which specify 7.5 L/person/day as the acute survival minimum rising to 15 L as standard practice (Sphere Project, 2018); 10 L represents a contextualised baseline for the high-temperature desert conditions of this model. Solar Thermal Desalination (STD) is the enabling technology: solar stills constructed from recycled materials such as glass bottles and aluminium cans are capable of producing 2–6 L/m^2/day with a construction lifetime of 20–25 years (Belessiotis et al., 2016). At the conservative estimate of 3.3 L/m^2/day, each individual requires only 3 m^2 of still to meet their survival water requirement.

[Figure 3: Solar Thermal Desalination Stage 1 (STD #1)]

Figure 3: STD #1 (Author)

The hypersaline brine produced by STD #1 passes through a second stage (STD #2) for further freshwater extraction and salt concentration. Fractional crystallisation then allows extraction of multiple mineral salts at different salinity levels — a valuable output from the earliest stage of development (Duffie and Beckman, 2006).

[Figure 4: STD #2 and Salts Production]

Figure 4: STD #2 and Salts Production (Author)

Food at T0.1 is provided by Spirulina platensis algae, cultivated directly in seawater. Spirulina can more than double in biomass every 24 hours under adequate light and nutrients, and its nutritional profile — 65% protein, with all essential amino acids in quantities comparable to meat, eggs, or milk — makes it close to a complete food source (Savage, 1994; Lucas and Southgate, 2012). At 60 g/day/m^2 yield and a daily calorific requirement of 600 g per adult, only 10 m^2

of algae tank per person is required. Tanks are constructed from recycled materials and hermetically sealed with glass panels to minimise evaporative loss.

Waste streams from both water and food consumption feed a simple Anaerobic Digester (AD), which produces methane for cooking and fertiliser for the algae production system, closing the primary loop at minimal cost (Goodall, 2008).

Total land footprint for 50 individuals at T0.1: 650 m² — approximately 0.065% of the available 1 km².

T Level	H_2O Output (L/day)	Algae Output (kg/day)	H_2O Consumed	Grey Water	Algae (Human)	Algae (Animal)	Algae Export	H_2O Export
0.1	500	30	500	—	30	—	—	—

Table 1: Outputs Achieved at T0.1

T0.2: Rinse and Repeat for Effect

T0.2 represents a factor-of-ten increase in output, achieved by replication of the same infrastructure rather than addition of new technology types. Each individual has already built the T0.1 infrastructure once; they can do so again, more efficiently, as the group accumulates experience and access to materials. The focus at this stage is speed of growth rather than diversity of output.

The most significant development at T0.2 is the increase from 10 L to 100 L/person/day of freshwater — still within the water poverty threshold but sufficient for ancillary uses including basic hygiene and animal watering. Assuming 80% recovery as greywater, the group generates approximately 4,000 L/day of usable secondary water. Animal production begins at this stage, most likely goat or chicken, providing both protein variety and a new waste input to the AD system. Algae surplus above human and animal consumption becomes the group’s first export commodity.

T Level	H_2O Output (L/day)	Algae Output (kg/day)	H_2O Consumed	Grey Water	Algae (Human)	Algae (Animal)	Algae Export	H_2O Export
0.1	500	30	500	—	30	—	—	—
0.2	5,000	300	5,000	4,000	30	240	30	—

Table 2: Outputs Achieved at T0.2

T0.3: No Longer Living on the Breadline

At T0.3 the group crosses the water security threshold — 1,000 L/person/day — and this changes the character of what is possible. With 40,000 L/day of greywater available, ecosystem recovery of local soil becomes practicable. Carbon offsetting through algae biochar becomes a viable income stream for the first time (Goodall, 2008). It is at this stage that the two developmental pathways diverge, and the model is presented in parallel from this point forward.

The Scaling Pathway continues to replicate core infrastructure, prioritising volume and speed of growth. The Diversification Pathway begins to integrate additional technology types, compounding outputs and building systemic resilience. Both are summarised at each level; a full recommendation between the two is made in Section 6.

Scaling Pathway — T0.3:

Freshwater output reaches 50,000 L/day (1,000 L/person/day), with 40,000 L/day greywater available for land recovery. Algae carbon content at this scale — approximately 114 kg/day — provides the first opportunity for paid carbon offsetting through verified methods such as biochar application to recovered land.

Diversification Pathway — T0.3:

The greywater surplus enables introduction of aquaponics and hydroponics. Fish cultivation in seawater tanks — using algae as feedstock — introduces high-value protein production without additional freshwater consumption. A cyclical water system is established: water flows from algae ponds to hydroponic tanks growing halophytic plants (nitrogen-fixing species improve water quality for the next stage), then to aquaculture tanks, before returning to algae production, with fish waste providing natural fertilisation throughout.

[Figure 5: Cyclical Aquaponic System]

Figure 5: Cyclical Aquaponic System (Author)

Hermetically sealed greenhouse structures capture evapotranspiration from plant production and return it to the water cycle. Hydroponic methods achieve water efficiencies of over 90% compared to conventional soil-based agriculture, making it possible to grow water-intensive crops — including cotton — in a desert environment (Lucas and Southgate, 2012).

T Level	H_2O Output (L/day)	Algae Output (kg/day)	H_2O Consumed	Grey Water	Algae (Human)	Algae (Animal)	Algae Export	H_2O Export
0.1	500	30	500	—	30	—	—	—
0.2	5,000	300	5,000	4,000	30	240	30	—
0.3	50,000	3,000	50,000	40,000	30	2,400	570	—

Table 3: Outputs Achieved at T0.3

T0.4: Now We’re Cooking with Biogas

By T0.4 the group is considered to have accumulated sufficient income and savings to begin procuring more technically complex infrastructure items. The principal addition at this stage is Concentrated Solar Power (CSP), using the parabolic trough method.

Scaling Pathway — T0.4:

Output reaches 500,000 L/day of freshwater and 30,000 kg/day of algae. Carbon offsetting at this scale generates approximately 7,363 tonnes of CO_2 equivalent annually, with an indicative income of £368,196/year at £50/tonne.

Diversification Pathway — T0.4:

CSP concentrates solar radiation to heat a working fluid, which generates steam to drive a turbine, producing electricity. The technology has an important complementary relationship with the AD system: when solar irradiance is insufficient for continuous CSP operation, methane from the AD can be burned to generate steam and maintain electrical output (Devabhaktuni, 2013). Waste heat from the CSP system can pre-heat seawater entering the desalination process, improving overall energy efficiency. CSP infrastructure is incrementally installable — capacity can be added in proportion to group income and demand.

[Figure 6: CSP Electricity Production]

Figure 6: CSP Electricity Production (Author)

T Level	H_2O Output (L/day)	Algae Output (kg/day)	H_2O Consumed	Grey Water	Algae (Human)	Algae (Animal)	Algae Export	H_2O Export
0.1	500	30	500	—	30	—	—	—
0.2	5,000	300	5,000	4,000	30	240	30	—
0.3	50,000	3,000	50,000	40,000	30	2,400	570	—
0.4	500,000	30,000	50,000	40,000	30	2,400	27,570	450,000

Table 4: Outputs Achieved at T0.4

T0.5: Completing the Technological Journey

At T0.5, land consumption reaches the boundary of the available 1 km². Further output increases cannot be achieved through simple replication; they require efficiency improvements — through genetic optimisation of algae lines, extended growing periods via LED lighting, vertical farming techniques, and integration of baseload electricity from Hot Dry Rock (HDR) geothermal energy.

T0.5 represents the maximum developmental potential of a single module. It is assumed that once this stage is achieved, all reasonable efficiency improvements have been made and future gains will require either additional land or transition to Stage Two: Multiple Module Development.

Scaling Pathway — T0.5:

The group achieves 5,000,000 L/day of freshwater and 300,000 kg/day of algae. Carbon offset capacity reaches approximately 80,154 tonnes of CO_2/year, generating an indicative income of £4,007,700/year. At this point the group is economically stable, the local ecosystem is in active recovery, and the module is ready for replication.

Diversification Pathway — T0.5:

HDR geothermal energy — drilling into the Earth’s mantle to extract heat through fracked water reservoirs — provides the baseload electricity supply that intermittent renewables cannot. The combination of CSP, AD-backed generation, and HDR gives the group a robust, multi-source electrical system. Increased electrical capacity enables LED and vertical farming at scale: crops grown in vertically stacked formations under optimised LED lighting spectra produce significantly more per unit of land area than horizontal cultivation (Dutta Gupta, 2017). This is the stage at which the group's productive capacity is no longer primarily constrained by land or water but by capital and knowledge.

[Figure 7: LED and Vertical Farming]

Figure 7: LED and Vertical Farming (Author)

T Level	H_2O Output (L/day)	Algae Output (kg/day)	H_2O Consumed	Grey Water	Algae (Human)	Algae (Animal)	Algae Export	H_2O Export
0.1	500	30	500	—	30	—	—	—
0.2	5,000	300	5,000	4,000	30	240	30	—
0.3	50,000	3,000	50,000	40,000	30	2,400	570	—
0.4	500,000	30,000	50,000	40,000	30	2,400	27,570	450,000
0.5	5,000,000	300,000	50,000	40,000	30	2,400	297,570	4,950,000

Table 5: Outputs Achieved at T0.5

6. Developmental Pathway Recommendation: Scaling versus Diversification

Two developmental pathways have been modelled in parallel from T0.3 onwards. This section makes an explicit recommendation between them and specifies the conditions under which the alternative may be preferred.

The Case for Each Pathway

The Scaling Pathway — replicating core technologies to maximise volume of primary outputs — has three genuine advantages. It is simpler to execute, requiring the group to learn and repeat one set of skills rather than acquire multiple new technology competencies at successive stages. It produces results faster in terms of gross output volumes. And it is more readily transferable to other groups: a replication model is easier to document, teach, and quality-assure than a diversified one.

The Diversification Pathway compounds the value of each water and energy increment by integrating additional technology streams. Rather than producing more algae and more water, it uses increasing outputs to support fish, halophytic plants, freshwater vegetables, electricity, and eventually industrial-scale LED and vertical farming. The result is a more complex and more resilient system: one that is less vulnerable to a single market, a single technology failure, or a single climatic event. Diversification also generates higher-value outputs earlier in the development trajectory — high-quality food products, electricity, and specialist crops command premium prices relative to bulk algae biomass.

Recommendation: Diversification Pathway

This working paper recommends the Diversification Pathway as the primary model for the following reasons.

First, systemic resilience. A module dependent on a single output stream — algae — is catastrophically vulnerable to market price collapse, disease, or production failure. The Diversification Pathway builds redundancy into the system from T0.3 onwards: each additional technology provides an alternative income stream and an alternative use for water, energy, and nutrients. Resilience is not a luxury; for communities at the bottom of the poverty ladder, a single bad season or market failure can be existential.

Second, ecological value. The Diversification Pathway integrates ecosystem recovery more directly into the productive system. Halophytic plants, aquaponic fish, and recovered soil are not incidental outputs — they are the mechanism by which the module’s ecological footprint shifts from neutral to actively regenerative. The Scaling Pathway can achieve ecological recovery through greywater application to soil, but this is a secondary output; in the Diversification Pathway it is structurally embedded.

Third, output quality. The market for bulk algae biomass is real but price-volatile and not well-established in many developing regions. High-quality food products

— fish, vegetables, specialist crops grown under controlled conditions — access more stable markets at higher margins. CSP-generated electricity, where grid infrastructure allows export, provides a reliable and growing revenue stream. These outputs are more defensible economically than commodity algae.

Fourth, civilisational argument. The Diversification Pathway more directly embodies the regenerative development paradigm: it does not simply produce more of the same thing but builds an increasingly sophisticated agro-industrial ecosystem that demonstrates what development without extraction can look like. As a model intended in part to shift paradigms — to show what is possible — its demonstrative power matters.

When the Scaling Pathway is Appropriate

The Scaling Pathway should not be dismissed. In contexts where the primary objective is rapid deployment at scale — famine response, refugee settlement, acute food security crises — the speed and simplicity of the Scaling Pathway may justify its relative fragility. In contexts where knowledge transfer infrastructure is limited and technical training capacity is low, the lower complexity of the Scaling Pathway reduces the risk of technology failure. It may also serve as the recommended starting point for all groups, with diversification introduced as a deliberate second phase once the group has developed the capability and capital to manage greater complexity.

A staged approach — Scaling Pathway through T0.2, then transition to Diversification from T0.3 — may in practice represent the optimal developmental sequence for most groups.

7. Stage Two: Multiple Module Development

Having achieved the full developmental capacity of a single 1 km^2 module, further scale requires replication: groups creating new modules, either adjacent to existing ones or in new coastal locations. Stage Two models the aggregated effects of multiple modules at regional and then continental scale. All modules in Stage Two are assumed to follow the Diversification Pathway, having passed through the staged Scaling-to-Diversification transition described in Section 6.

T0.6: Copy and Paste

T0.6 requires ten complete modules — 10 km^2 of developed land, most practically configured as a single 1 km coastal strip with nine further 1 km inland developments, connected by commons infrastructure.

[Figure 8: 1km Coastal : 10km Inland Configuration]

Figure 8: T0.6 Configuration (Author)

The commons boundary between modules serves multiple purposes: it provides eco-corridors for returning wildlife, park-like public spaces for residents, and a planned route for underground utility infrastructure — water pipes, electrical cables, communications — installed using a cut-and-cover tunnel method that allows future maintenance and expansion without additional excavation.

[Figure 9: Eco-Corridor and Commons Provision]

Figure 9: Eco-Corridor and Commons Provision (Author)

At T0.6, the development complex offsets 801,540 tonnes of CO_2 equivalent annually, generating an indicative income of approximately £40,077,000/year at £50/tonne.

T Level	H_2O Output (L/day)	Algae Output (kg/day)	H_2O Consumed	Grey Water	Algae (Human)	Algae (Animal)	Algae Export	H_2O Export
0.6	50,000,000	3,000,000	500,000	400,000	300	24,000	2,975,700	49,500,000

T Level	Carbon Offset (kg/day)	CO_2 Equivalent (kg/day)	Income (£/day @ £50/tonne)
0.6	595,140	2,178,212	108,910

Table 6: Outputs Achieved at T0.6

T0.7: Islands of Safety

T0.7 scales to ten T0.6-scale developments, creating a 10 km × 10 km regional development in the vicinity of a single desert coastline. The construction strategy at this scale offers a specific benefit in conflict-affected regions: outer modules can be constructed first, creating a secure perimeter within which interior development proceeds under protection, reducing the fortification requirements for internal modules and creating economic and employment opportunity in communities otherwise vulnerable to conflict recruitment.

[Figure 10: 10km Coastal : 10km Inland Configuration]

Figure 10: T0.7 Configuration (Author)

At T0.7, annual CO_2 equivalent offset reaches 8,015,400 tonnes, with indicative income of approximately £400,770,000/year.

T Level	H_2O Output (L/day)	Algae Output (kg/day)	H_2O Consumed	Grey Water	Algae (Human)	Algae (Animal)	Algae Export	H_2O Export
0.6	50,000,000	3,000,000	500,000	400,000	300	24,000	2,975,700	49,500,000
0.7	500,000,000	30,000,000	5,000,000	4,000,000	3,000	240,000	29,757,000	495,000,000

T Level	Carbon Offset (kg/day)	CO_2 Equivalent (kg/day)	Income (£/day @ £50/tonne)
0.6	595,140	2,178,212	108,910
0.7	5,951,400	21,782,120	1,089,100

Table 7: Outputs Achieved at T0.7

T0.8: Now We Are Really Geoengineering

At T0.8, ten separate T0.7-scale developments are distributed across available desert coastline — located according to geological suitability, community need, and proximity to infrastructure. Only 10% of the Saharan coastline is assumed available for development, accounting for existing settlements, unsuitable geology, and restricted zones; this is more than sufficient to accommodate ten regional-scale developments.

[Figure 11: Coastline Developments at T0.8]

Figure 11: Coastline Developments (adapted from Encyclopædia Britannica, 2015)

At T0.8, the combined complex offsets 80,154,000 tonnes of CO_2 equivalent annually — a figure that begins to register at the scale of national emissions budgets. Indicative income reaches approximately £4,007,700,000/year.

T Level	H_2O Output (L/day)	Algae Output (kg/day)	H_2O Consumed	Grey Water	Algae (Human)	Algae (Animal)	Algae Export	H_2O Export
0.6	50,000,000	3,000,000	500,000	400,000	300	24,000	2,975,700	49,500,000
0.7	500,000,000	30,000,000	5,000,000	4,000,000	3,000	240,000	29,757,000	495,000,000
0.8	5,000,000,000	300,000,000	50,000,000	40,000,000	30,000	2,400,000	297,570,000	4,950,000,000

T Level	Carbon Offset (kg/day)	CO_2 Equivalent (kg/day)	Income (£/day @ £50/tonne)
0.6	595,140	2,178,212	108,910
0.7	5,951,400	21,782,120	1,089,100
0.8	59,514,000	217,821,200	10,891,000

Table 8: Outputs Achieved at T0.8

T0.9: Now…, the End is Near

T0.9 represents a continental-scale development, moving inland from coastal positions as coastal land is fully developed. The Sahara covers approximately 8,600,000 km^2; assuming 10% is accessible and suitable, and that only 10% of that area is economically viable for seawater transport, the available development area of approximately 86,000 km^2 is sufficient for the T0.9 model.

The further inland development progresses, the more expensive seawater transport becomes. Pipeline and pumping costs increase non-linearly with distance, and there will be a point at which seawater transport becomes economically unviable without the energy surplus of an advanced-stage module to support it. The precise threshold depends on terrain, pipeline construction costs, and energy available for pumping — and is identified as a specific priority for further research.

[Figure 12: Further Inland Development]

Figure 12: Further Inland Development (adapted from Encyclopædia Britannica, 2015)

At T0.9, atmospheric CO_2 offset reaches 801,540,000 tonnes/year — approaching the IPCC's estimated requirement of 7 billion tonnes of annual removal to maintain the 1.5°C Paris target (Vaughan, 2022). Algae production is sufficient to provide nutritional baseline for approximately 5 billion people. Indicative income reaches £40,077,000,000/year, comparable to the GDP of a mid-sized economy.

At this scale, concentrated inland developments in specific geological formations — mountain ranges that trap evapotranspiration and increase local precipitation, for instance — begin to produce measurable micro-climate effects. The development is no longer simply agro-industrial; it is geoengineering in the literal sense.

T Level	H_2O Output (L/day)	Algae Output (kg/day)	H_2O Consumed	Grey Water	Algae (Human)	Algae (Animal)	Algae Export	H_2O Export
0.6	50,000,000	3,000,000	500,000	400,000	300	24,000	2,975,700	49,500,000
0.7	500,000,000	30,000,000	5,000,000	4,000,000	3,000	240,000	29,757,000	495,000,000
0.8	5,000,000,000	300,000,000	50,000,000	40,000,000	30,000	2,400,000	297,570,000	4,950,000,000
0.9	50,000,000,000	3,000,000,000	500,000,000	400,000,000	300,000	24,000,000	2,975,700,000	49,500,000,000

T Level	Carbon Offset (kg/day)	CO_2 Equivalent (kg/day)	Income (£/day @ £50/tonne)
0.6	595,140	2,178,212	108,910
0.7	5,951,400	21,782,120	1,089,100
0.8	59,514,000	217,821,200	10,891,000
0.9	595,140,000	2,178,212,000	108,910,000

Table 9: Outputs Achieved at T0.9

8. Governance and Social Architecture: The Commons Foundation

The technical model described in this paper can be built. Whether it is built — and whether what is built serves its intended purpose over generations rather than being captured by narrow interests — depends entirely on the social and governance architecture within which it operates. This section addresses that architecture directly. It is not an appendix to the technical model; it is one of the model’s two load-bearing structures.

The Founding Group

The model assumes a group of 50 adults as the founding unit. This number is not arbitrary. It is large enough to distribute the labour of early construction without requiring external capital to hire workers, but small enough to be governed by direct participation without complex representative structures. The anthropological literature on effective small-group organisation suggests that groups of 50–80 individuals are broadly within the range of cohesive social functioning without formal institutional structures (Gibbons et al., 2018).

The founding group requires clarity on three governance questions from the outset: who makes decisions, how disputes are resolved, and who owns what is built. The failure to answer these questions before construction begins is one of the most common causes of community development project collapse — not technology failure but social failure at the moment when resources begin to accumulate.

Decision-making at T0.1 and T0.2 can operate by simple consensus among the group, given the small size and the shared urgency of survival. As the group moves through T0.3 and beyond, formalisation becomes necessary. A written constitution for the group — specifying decision rights, contribution requirements, benefit-sharing rules, and exit provisions — is a minimum governance requirement before the group crosses the water security threshold at T0.3. The commons boundary, which exists from the outset of the model, should be formally established and documented as part of this constitution.

The Waqf as Ownership Architecture

The question of who owns what is built is the most consequential governance decision the founding group makes. The default answer in most development contexts — individual private ownership — produces predictable outcomes: assets are sold, inherited, concentrated, and eventually the commons character of the development is destroyed. The developmental ladder built by 50 people over a generation becomes, under individual ownership, the property of their heirs, who may have no connection to the community or its purpose.

The waqf offers a fundamentally different answer. A waqf is a legal instrument rooted in Islamic jurisprudence — with historical precedent stretching back fourteen centuries — in which productive assets are permanently dedicated to a specified purpose and placed beyond the reach of individual ownership or consumption. The assets cannot be sold, inherited, or encumbered. They generate income that flows to specified beneficiaries in perpetuity (Zuki, 2012; Kahf, 1998).

The historical record of the waqf as a mechanism for delivering public goods is substantial. Al-Azhar University in Cairo, founded in 970 CE and still operating, was funded by waqf endowment from its inception. Hospitals, libraries, water systems, and schools across the medieval Islamic world were similarly structured. The instrument has been used in contexts of extreme political instability precisely because it places assets beyond the reach of successive governments or conquering powers: the trust exists independently of any particular political authority.

For the Kardashev Kommunities model, the waqf is proposed as the ownership structure for the productive infrastructure from T0.3 onwards — the point at which the group begins to generate surplus income. The specific structure proposed is as follows.

The founding group establishes a waqf whose objects include: the perpetual operation and maintenance of the productive infrastructure; the welfare of the founding community and their descendants; the development of commons infrastructure for the benefit of the wider public; and the expansion of the model to new communities. The waqif — the founder or founders — may specify their own benefit during their lifetime, and may designate family members as beneficiaries for a defined period. After that period, income flows to the community and to the expansion fund.

The waqf does not preclude entrepreneurial reward. Those who build, operate, and expand the development are compensated from income during their active involvement. What the waqf prevents is the extraction of the capital base: the infrastructure itself remains in perpetuity, generating benefit for those who come after. This is the structure that makes the model generationally sustainable rather than simply economically productive.

The waqf is also, it should be noted, structurally compatible with non-Islamic communities. Its legal form varies across jurisdictions, but the functional equivalent — a perpetual charitable trust with specified objects — exists in English law, Scottish law, most civil law jurisdictions, and a growing number of developing country legal systems. The argument for the waqf form is not religious but practical: it has a longer track record of functional perpetuity than any comparable instrument.

Governance at Scale: T0.6 and Beyond

As multiple modules are established and a T0.6-scale development begins to take shape, the governance architecture must scale accordingly. Individual module governance — the constitution and waqf of each founding group — must be complemented by a commons governance layer for the infrastructure shared between modules: the eco-corridors, the underground utility networks, the shared market access systems.

A federated governance model is proposed: each module maintains its own constitution and waqf for module-specific assets, while delegates from each founding group participate in a commons council responsible for shared infrastructure and inter-module coordination. The commons council operates as a second-tier waqf, with the commons infrastructure permanently dedicated to the benefit of all modules in the development and their communities.

This architecture is designed to prevent the most common failure mode of federated systems: the capture of commons infrastructure by the most economically powerful member. By structuring the commons as a waqf from the outset, no individual module or external investor can acquire control of the shared infrastructure on which all modules depend.

9. Strategic Effects

This paper has considered a developmental model within the Sahara Desert; but the Sahara is one of approximately nineteen globally significant non-polar desert regions. Discounting polar deserts, approximately 19.4 million km^2 of land globally presents comparable conditions and comparable opportunities. The strategic effects of achieving T0.9-level development across even a fraction of that area are civilisational in scale.

In returning desolate lands to productive agro-ecosystems, humanity is no longer constrained to produce food and industrial inputs from existing fertile land. The extraordinary pressure currently placed on tropical forests, wetlands, and grassland ecosystems — the primary drivers of global biodiversity loss — could be substantially relieved. Desert development hubs would export food and manufactured goods produced without ecosystem destruction, allowing the rewilding of degraded landscapes in nation-states that have been forced to choose between ecological integrity and economic development.

The decarbonisation implications are similarly large. The IPCC estimates that avoiding a 1.5°C temperature rise requires not just the elimination of new emissions but the removal of more than 7 billion tonnes of CO_2 from the atmosphere annually (Vaughan, 2022). The T0.9 model, applied across the Sahara alone, approaches that figure. Applied across all available desert regions, it would exceed it.

The economic development implications deserve equal attention. The discovery of fossil hydrocarbons transformed the economic position of the nations that possessed them; the development of regenerative agro-industrial capacity in currently impoverished desert regions could produce a comparable transformation, but without the resource curse dynamics that have characterised petro-economies. Done under the waqf architecture described in Section 8, the wealth generated remains within the community and compounds across generations rather than being extracted by external capital or captured by political elites.

The civilisational argument is ultimately this: the achievement of T0.9-level development across the world’s desert regions would represent humanity’s transition to the threshold of Type 1 on the Kardashev Scale — a civilisation capable of harnessing the energy resources of its home planet rather than depleting them. This is not a utopian projection; it is a logical consequence of the model, if the model is replicated at scale. The more interesting question is not whether it is achievable but what kind of civilisation we want to be when we get there. The waqf structure, and the commons character it preserves, is this paper’s answer to that question.

All of this is achievable without dependence on government actors or large-scale private capital. The model demonstrates how coordinated groups of 50 people, starting with almost nothing, can generate the conditions for civilisational advancement. The mechanism is not charity but self-interest correctly understood: the development enriches those who build it, and the governance structure ensures that enrichment is not extracted but compounded for those who come after.

10. Opportunities and Barriers

The model’s core opportunity is structural: it makes the cost of entry as low as possible, with inputs that are free or freely available, so that communities with the least capital have genuine access to the first rung of the developmental ladder. The positive feedback dynamics of the model — each stage generates outputs that fund and resource the next — mean that once entry is achieved, momentum is self-sustaining under reasonable conditions.

The barriers are not primarily technological. They are organisational, informational, and structural.

The organisational barrier is the most immediate: the founding group must be assembled, committed, and constitutionally organised before construction can begin. In communities experiencing acute poverty, the short-term cost of time and energy invested in governance design before any tangible return is realised is a significant obstacle. Bridging organisations capable of supporting founding groups through the governance design phase are likely to be a precondition for widespread adoption.

The informational barrier is substantial. The knowledge required to build and operate even T0.1-level infrastructure — solar still construction, algae cultivation, basic AD operation — exists in the literature but is not consolidated in a form accessible to communities in the regions where this model is most needed. A practical knowledge commons — documented in multiple languages, at multiple literacy levels, and verified through pilot implementations — is an essential precondition for replication at scale.

The market access barrier becomes significant from T0.2 onwards, when the group begins to generate exportable algae and salt. Without reliable access to markets willing to purchase these outputs at prices that support continued development, the incentive structure of the model breaks down. Developing reliable commodity market connections for communities in remote desert regions requires infrastructure — roads, communications, transport logistics — that may require external investment or government partnership at a stage before the development generates the income to fund it internally.

The seawater transport barrier, noted at T0.9, is likely to become binding at T0.6 or T0.7 for inland developments in regions without existing pipeline infrastructure. The energy requirements of pumping seawater over significant distances and elevation changes are non-trivial; the model assumes that CSP and HDR generation provide sufficient surplus, but this assumption requires validation under specific site conditions.

11. Further Areas for Research

Four priority areas emerge from this working paper.

First, quantitative assumption validation. The output figures in this paper are based on published data from controlled or semi-controlled conditions. Field validation of these figures under the specific conditions of the target regions — high-irradiance desert coastal environments, variable humidity, locally available construction materials — is necessary before the model can be used as a basis for investment or policy decisions. Sensitivity analysis across the range of published values for key parameters (solar still output, algae yield, carbon weight fraction) should be a component of this work.

Second, governance design for the founding group. The waqf structure is proposed as the appropriate ownership architecture; the specific constitutional design of the founding group — decision rights, contribution requirements, benefit-sharing formulas, exit provisions — requires detailed development and piloting. This is as much a design and social science challenge as a legal one, and it should be treated accordingly.

Third, knowledge commons infrastructure. The practical knowledge required to build and operate the model at T0.1 through T0.3 should be documented, tested, and made accessible in forms suitable for communities in the target regions. This includes not just technical documentation but training curricula, quality standards, and verification mechanisms for outputs.

Fourth, market access and commodity integration. Reliable market mechanisms for the primary outputs of early-stage development — algae biomass, salt, greywater-irrigated produce, and eventually carbon offsets — need to be identified and developed in parallel with the technical model. The development of carbon offset verification standards compatible with the algae biochar pathway is a specific priority, given the significance of carbon income to the financial viability of the model from T0.3 onwards.

Beyond these four priorities, additional conceptual and theoretical models applying the same framework to different industrial contexts — community-scale papermills, server farms, smelters operating on renewable energy — would extend the reach of the developmental ladder into sectors currently dependent on extractive industry.

12. Conclusion

This working paper has proposed a conceptual and theoretical framework for regenerative development in desert environments, structured as a nine-stage ladder of technological and organisational advancement. Beginning with three inputs available to virtually anyone with access to a desert coastline — sunlight, seawater, and land — the model demonstrates a credible trajectory from bare subsistence to agro-industrial production, ecological regeneration, and meaningful contribution to global carbon balance.

The paper has resolved two structural issues present in the original dissertation on which it is based. The two developmental pathways — Scaling and Diversification — have been maintained and analysed in parallel, with a clear recommendation in favour of the Diversification Pathway on grounds of systemic resilience, ecological value, and output quality, while acknowledging the contexts in which the Scaling Pathway may be appropriate. The governance and social architecture necessary to sustain the model has been developed as a dedicated section, with the waqf proposed as the ownership structure best capable of securing the commons character of the development across generations.

The paper does not claim to resolve the engineering, logistical, or political challenges of implementation. What it claims — and what the model supports — is that the technological possibility is credible, the financial logic is sound under reasonable assumptions, and the governance architecture exists in tested form. The barriers that remain are not primarily technical; they are paradigmatic, organisational, and informational. The most important of these — the failure to see that the problem and the solution both exist at the civilisational scale — is precisely what the Kardashev frame makes visible.

If 500,000 people, organised into groups of 50 and equipped with the knowledge and governance architecture this paper describes, were to begin at T0.1 simultaneously, the effects at T0.9 would exceed the IPCC’s annual carbon removal target, provide nutritional baseline for five billion people, and generate income comparable to the GDP of a mid-sized economy. None of this requires a single government decision, a single large capital investment, or any technology not already available. It requires only the imagination to see it, and the will to begin.

References

Africa, T.B. (2021) The Great Green Wall is Failing, But its Legacy Could Still Be A Success. Available at: https://earth.org/the-great-green-wall-legacy [Accessed 2022].

Belessiotis, V., Kalogirou, S. and Delyannis, E. (2016) Thermal Solar Desalination. Elsevier.

Ćirković, M.M. (2016) Kardashev's Classification at 50+: A fine vehicle with room for improvement. arXiv preprint arXiv:1601.05112.

Devabhaktuni, V., Alam, M., Depuru, S.S.S.R., Green II, R.C., Nims, D. and Near, C. (2013) Solar energy: Trends and enabling technologies. Renewable and Sustainable Energy Reviews, 19, pp. 555–564.

Dobruskin, V.Kh. (2021) The Planet's Response to Human Activity: Thermodynamic Approach. Open Journal of Ecology, 11, pp. 126–135. https://doi.org/10.4236/oje.2021.112011

Duffie, J.A. and Beckman, W.A. (2006) Solar Engineering of Thermal Processes (3rd ed.). Solar Energy Laboratory, University of Wisconsin–Madison.

Dutta Gupta, S. (2017) Light Emitting Diodes for Agriculture: Smart Lighting. Springer.

Fourie, S. (2021) The drive behind the development of renewable energies and the deeper philosophy of harnessing the energy of the planet. Academia Letters, Article 2816. https://doi.org/10.20935/AL2816

Frank, A., Kleidon, A. and Alberti, M. (2017) Earth as a Hybrid Planet: The Anthropocene in an Evolutionary Astrobiological Context. Anthropocene. https://doi.org/10.1016/j.ancene.2017.08.002

Gibbons, L.V., Cloutier, S.A., Coseo, P.J. and Barakat, A. (2018) Regenerative development as an integrative paradigm and methodology for landscape sustainability. Sustainability, 10(6), 1910.

Goodall, C. (2008) Ten Technologies to Save the Planet. Green Profile.

Gupta, S., Gupta, N.S. and Gupta, N. (2015) Redefining Clean India vs Sustainable Development Goal. Journal of Social Welfare and Management, 7(4).

Kahf, M. (1998) Financing the Development of Awqaf Property. Paper presented at the Seminar on Development of Awqaf, IRTI, Kuala Lumpur.

Jamilatun, S. et al. (2021) Biochar from Slow Catalytic Pyrolysis of Spirulina platensis Residue: Effects of Temperature and Silica-Alumina Catalyst on Yield and Characteristics. Advances in Environmental and Engineering Research, 2(2).

Lucas, J.S. and Southgate, P.C. (2012) Aquaculture: Farming Aquatic Animals and Plants (2nd ed.). Wiley.

Mang, P. and Haggard, B. (2016) Regenerative Design: A Framework for Evolving Sustainability. John Wiley & Sons.

Meadows, D.H. (2008) Thinking in Systems: A Primer. Ed. Diana Wright. Chelsea Green Publishing.

National Research Council (US) (1990)

National Research Council (US) (1990) Saline Agriculture: Salt-Tolerant Plants for Developing Countries. National Academy Press.

Ornstein, L., Aleinov, I. and Rind, D. (2009) Irrigated afforestation of the Sahara and Australian Outback to end global warming. Climatic Change, 97(3), pp. 409–437.

Rose, S. (2021) Our biggest challenge? Lack of imagination: the scientists turning the desert green. The Guardian, 20 March 2021.

Savage, M.T. (1994) The Millennial Project: Colonizing the Galaxy in Eight Easy Steps. Little, Brown and Company.

Sphere Project (2018) Humanitarian Charter and Minimum Standards in Humanitarian Response. 4th ed. Practical Action Publishing. Available at: https://spherestandards.org/handbook/ [Accessed 2025].

Soubane, D. (2017) Renewable energy resources in a nutshell: present and future. International Journal of Renewable Energy Resources, 7.

Vaughan, A. (2022) Engineering the oceans. New Scientist, No. 3393.

Zuki, M.S.M. (2012) Waqf and its role in socio-economic development. ISRA International Journal of Islamic Finance, 4(2), pp. 173–178.

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