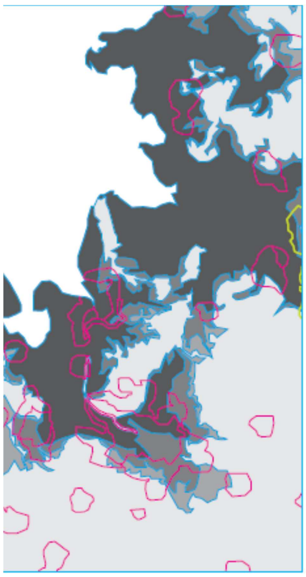
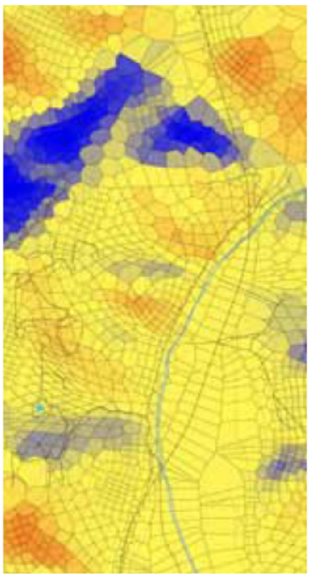
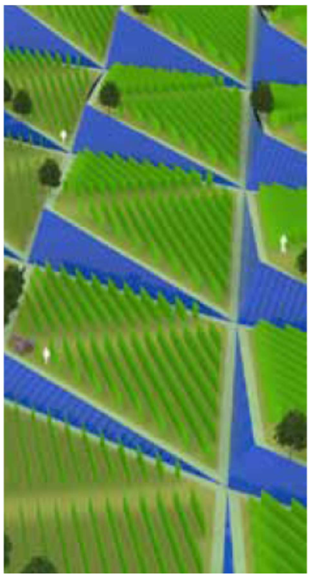
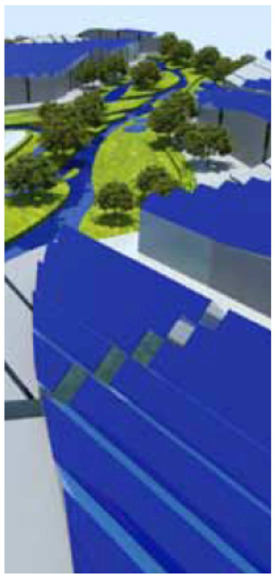
European Commission

JRC SCIENTIFIC AND POLICY REPORTS

LAND INTEGRATED PHOTOVOLTAICS

The New Energy Landscape of Europe

Simone Giostra
Foreword by Heinz Ossenbrink

2013

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Joint Research Centre

European Commission
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LAND INTEGRATED PHOTOVOLTAICS

The New Energy Landscape of Europe

Simone Giostra
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Foreword

At the time of writing, almost 3% of Europe's electricity is delivered by photovoltaic cells. And, in many European countries, at costs which are lower than the citizen would pay for conventional electricity. The great dream since 30 years, to deliver inexhaustible, clean energy at low costs is close to becoming a reality, and it becomes visible. Yet many citizens oppose the deployment of large solar farms and it is understandable as the beauty of our landscapes is a much needed contrast to our busy world.

This gives the PV community a new, more cultural duty: energy systems will surround us in a much different way than open pits for lignite or large oil platforms. PV will be on our own homes, intended to be passed on to our children and grandchildren, it will be in urban spaces, and cover also parts of our beautiful landscapes. And continuing the gift of the architects and designers of the past, whose works we can admire today, it is our duty to invest equally in the design of PV systems, as they will be around longer than the current generation of engineers, scientists and architects. We must leave to the generations to come a cultural experience of this new form of energy, or said much better, to give new energy a form.

It is for this reason that this book was conceived: to display an approach to photovoltaics, where in good architectural tradition form is given to function, and applied to make PV farms part of our natural environment, bringing forward the concept of a performative landscape, much the same as we are used to seeing in vineyards, agglomerations of greenhouses or in the patches of agricultural land.

Simone Giostra took part in the first PV | Forms | Landscapes event in 2011, and his visions for designing PV landscapes merit distribution to a wider audience, including PV experts, projects developers, public decision makers and, most importantly, the citizen.

The Joint Research Centre, as the science service of the European Commission, is pleased to publish this work with the subtitle "The New Energy Landscape of Europe", in order to carry forward this view and to raise the awareness of future PV project developers.

I hope that the JRC can in this way contribute to making PV energy acceptable and profitable for each citizen and convey the message:
Design PV electricity well, and make it a gift for our children and grandchildren.

Or, in short: make dreams become reality, soon.

Heinz Ossenbrink
Joint Research Centre

Prologue

Photovoltaics | Forms | Landscapes

*Solar energy influences the form that a landscape takes, shaping a structured mosaic in which it is possible to recognize a certain number of heterogeneous patterns (Forman R. T. T., Land Mosaics). Fr*om this perspective, landforms and plants are produced by solar energy in different times.

Today our energy needs, and the way we feed them, have a huge and visible influence on our landscapes. Intensive monoculture agricultural fields, clusters of agricultural greenhouses, as well as large solar (photovoltaic) fields are the expression of an increasing energy need that cannot but generate highly recognizable patterns (studied so to maximize the solar energy collection and the energy generation, while minimizing the land use) that modify the original landscape patterns.
In the past, the food (still energy) requirements of a community were probably the starting point for creating very valuable cultural landscapes: vineries and olive groves have made many regions famous all around the world. Is it imaginable that a similar cultural process might happen also to the way we generate energy through renewables?

Experience tells that the number of photovoltaic installations that are giving our landscapes new forms has been ever increasing in the recent years. The consequence of such a rapid diffusion of large photovoltaic fields in the landscape is often a generally opposing attitude of the public, which perceives the presence of these technological elements as intrusive to general aesthetics of the landscape.

However, tens of thousands of blue modules spread out in the landscape tell us also of the endeavour and the need we have today to generate the energy we require for our daily activities, by using renewable energy generation systems to preserve the planet, and our future life. So, it is a matter of culture.

What is missing?

While an agricultural field is perceived via a certain aesthetical code as a matter of culture (often adding value to the landscape), and its effectiveness relies on a balanced ("good") relationship with the environment, this does not necessarily happen in the case of solar fields. These are still conceived as technical elements, just put on the ground, which "abuse" the land, without contributing to an equilibrium. The form is based on a simplified list of rules (orientation, slope, dimension, etc.), mainly based on economic factors, and generally without any other consideration.

To change this it is necessary that the topic of new energy is discussed as a cultural issue, and not only as a technical one.

Photovoltaics | Forms | Landscapes is series of annual events, serving as discussion framework, to investigate the new phenomena associated with the rapid spread of large photovoltaic systems. It promotes reflection on the implications for our way of living and on what new issues for design could arise. This is done at all the scales: from modules, to buildings, to cities, to landscapes.

The vision proposed by Photovoltaics | Forms | Landscapes connects the regional scale with a “planetary” scale: the growing and “sudden” expansion of photovoltaics into the (even farming) landscape needs to be perceived as an answer to the growing need of energy for increasingly populated human settlements, do not contain their energy footprint.
The future requires a new approach for an integrated design, which acknowledges not only our footprint of living (the “physical” footprint), but takes also into account our ecological footprint, created indeed by our energy and nutrition needs, if we are committed to sustain human life on Earth, guaranteeing a positive outcome of future population expansion.
Before actually advancing to such a new design, a re-thinking is needed to see the landscape and its constituting elements not only by traditional (such as natural / anthropogenic) categories, but also considering new dimensions stemming from energy use and energy generation. The design process which assumes a production / consumption role for the landscape needs to orient itself towards energy self-sufficiency of the communities living within the landscape, by integrating the energy and nutrition footprint into the project domain.
The proposition is in fact the requirement towards the vision of a “designed, performative” landscape, where photovoltaic systems appear as productive elements ,capable of reconciling today’s and future human needs and of achieving a balance between production and consumption (net zero energy community).

This approach requires a paradigm-shift even before the design phase: it is about knowing how to perceive our energy needs as a project variable which influences directly the forms of settlements.

Alessandra Scognamiglio
ENEA

CONTENTS

THEORETICAL FRAME

0.1 Overview

Open field photovoltaic installation in Germany

"It's the culture, stupid!"
The European Union member states are committed to installing a total of 84,000 MW worth of photovoltaic systems by 2020, in order to help meet the target of 20% energy share from renewable sources, as mandated by Directive 2009/26/EC. Most importantly, a major portion of the new capacity will have to be installed as very large, open-field power plants.

Much of the efforts to date by the photovoltaic industry and energy policy makers have been directed at creating efficient and economically viable models for the implementation of PV technology in the built environment. Today, however, growing public opposition to large-scale installations is becoming a significant obstacle to greatly expanding the photovoltaic installed capacity and to fulfilling the promises of independency from fossil fuels.

If EU member states are to reach the target mandated by the European Commission, then social, aesthetic and cultural concerns – not just technical ones – must be addressed as well.

Accordingly, the present concept for a demonstration of Land Integrated Photovoltaics aims at providing a culturally acceptable model for large-scale photovoltaic installations across the European landscape, in the context of the new energy policies of the European Union.

Beyond the Urban/Rural Divide
The establishment of the City – from its very inception – is the result of a fundamental separation between places of consumption – located within the city limits – and places of production, where enough surpluses of raw materials and food are created to support city development. The impact of cities on places elsewhere, be it hinterlands or places far away – the so-called city footprint – is of extraordinary proportions. Yet the public at large, including policy makers and urban planners, seems utterly oblivious to the basic requirements of a functioning city: waste management and sewage treatment, air and water filtration, energy and heat generation, food production and processing are by and large still considered engineering annoyances to be hidden away or disregard altogether.

As a result, the dislocation of production activities has only increased since the industrial revolution: over the past 150 years, the massive loss of natural land to the combined effect of relentless expansion of urban areas, modern infrastructures and extraction of minerals, resulted in a drastic reduction of biodiversity, in air and water pollution, and the depletion of natural resources.

We believe that the key to reverting the current trend is the re-integration of places of production - including energy infrastructures - within the built environment.

Brown coal mining in Lausitz, Germany (J. Henry Fair)

From Centralized to Distributed
Historically, energy production has been based on a centralized model, where large power plants produce hundreds of megawatts in a single location. New energy technologies - such as photovoltaic, solar thermal, geothermal and wind micro-turbines - bring the promise of a decentralized model, with power produced at or near the point of consumption, with many advantages over the standard centralized model, in terms of both energy gains and reduced line losses. Interestingly, there is also a much lower pollution, noise, and visual impact associated to these technologies, allowing for the production plant to be near or in the city.

Sunlight is an ubiquitous natural resource that can be found everywhere, yet current models of large-scale, open-field photovoltaic installations follow the paradigm of extractive industries - which depends on localized resources that only occur in small sporadic areas.
The current study explores alternative logics of distribution that are not based exclusively on space efficiency or economy of scale; instead, it conceives of photovoltaic panels as a modular component distributed over large areas of land, enabling self-sufficient residential and productive districts.

A New Planning Model
Energy infrastructures, together with farming and other productive activities once removed from urban life, are already gaining currency as credible complement to traditional development in revitalizing declining postindustrial cities in the US - such as Buffalo and Detroit - by using empty lots to grow vegetables and to produce power.

We believe that the combined effect of distributed generation and community-owned power models, together with the new European Directive 2010/31/EU on energy performance of buildings, will have powerful implications in urban and rural areas across Europe.

Recognizing the impending energy revolution as the driver for transforming current planning practices, the present demonstration project proposes the synergetic integration of productive activities, energy infrastructures, natural resources and urban fabric in a radical new model of land development.

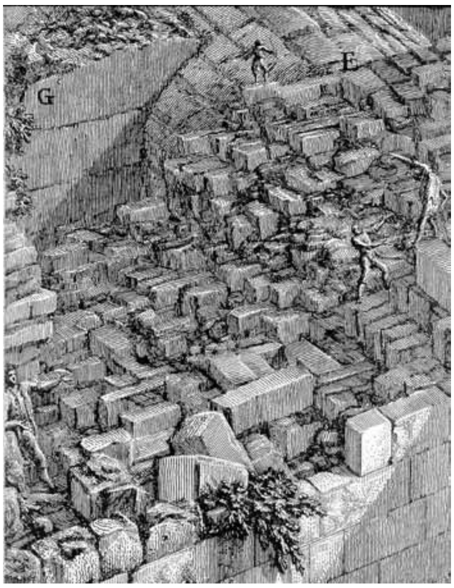
The project aims at identifying opportunities to supply the anthropized environment with solar energy technology systems, in ways that are more efficient, less costly and more sustainable than current energy production systems. Most importantly, the research attempts an investigation of both the cultural and the technological overlay of human activities, in order to identify strategies of occupations that are compatible with preexisting uses and that respect the natural vocation of the land.

0.2 The European Landscape


Lorenzetti's '*Gli Effetti del Buon Governo*' in Siena, Italy (1339)

The central premise of the present study is that public opposition to large-scale photovoltaic installations may stem from widespread misconception on the historic transformation of the countryside across Europe over the past two thousand years.
The idea of uncontaminated nature and the presumption of a boundary between the natural and the built environment, for instance, is largely a myth. Notwithstanding the idealistic division between the safety of man-made artefacts and the threat of wilderness, conveniently demarcated by a paper-like city wall in a Lorenzetti painting from the 14th Century, the two domains have been interweaving from the very emergence of mankind.

The vanishing line
In the iconography of city walls, Piranesi offers perhaps the earliest account of a blurred boundary dividing architecture and nature, where it's no longer possible, or even meaningful, to identify the distinctive qualities of either domain. Rows of orderly placed stone blocks undergo a series of gradual shifts and raptures, becoming the organic and porous substrate where roots take hold. The dichotomy between Nature and Architecture, Piranesi suggests, is only a matter of scale, or resolution, and it's no more than a semantic distinction invented to serve a dialectic account of reality.
The dominant idea of landscape today is the one that was forged by the romantic tradition of uncorrupted na-



Piranesi's illustration of a city wall

ture, perhaps best illustrated in the famous painting '*The Wanderer above the Sea of Fog*' by Caspar David Friedrich (1818): an idealized image of nature that serves a country's national pride as well as the tourist industry, but where a vast energy infrastructure has no place.


The 'Wanderer above the Sea of Fog' by Friedrich (1818)

Social agenda
In Edouart Manet's '*Le dejeuner sur l'herbe*' (1862), a domesticated version of nature is the object of enjoyment by a group of middle-class young urbanites; this time, nature is not longer the place of production nor a threatening environment, but the backdrop for the entertainment and leisure of a newly established social class. The appreciation for a rural environment divorced from its potential for creation of material value is a clear indicator of the progressive emancipation of urban societies from its earlier dependence on agricultural production. The Land progressively loses its "guardians" and becomes increasingly vulnerable to abuses or plain obsolescence.

The other half
As a remarkable result of the idealization of nature, the European identity clings to a handful of glorified natural reserves and architectural treasures that became global cultural icons. Meanwhile, the massive loss of natural land to the combined effect of relentless expansion of urban areas, modern infrastructures and extraction of natural resources has been removed from the collective consciousness.
As advanced societies become increasingly dependent on the mass production of industrialized agriculture and vast mining operations, the places of production and extraction are being gradually relocated in remote areas of the planet, often outside the control of environmental agencies and away from public scrutiny.


Edouart Manet's '*Le dejeuner sur l'herbe*' (1862)

City wall in the 21st Century
Interestingly, even in the master plan for *Masdar City* by Foster and Partners, arguably the most advanced vision for a sustainable city currently under construction, the places of production (energy, water purification, waste management) are clearly separated from the places of consumption by a city wall and they are conveniently invisible to the very people that entirely depend on these systems for their survival. The city planner makes no effort in integrating these two realms or in reconciling the vast array of mechanical systems with its environment.


Masdar City by Foster and Partners

0.3 Opportunities for Land Integrated Photovoltaics

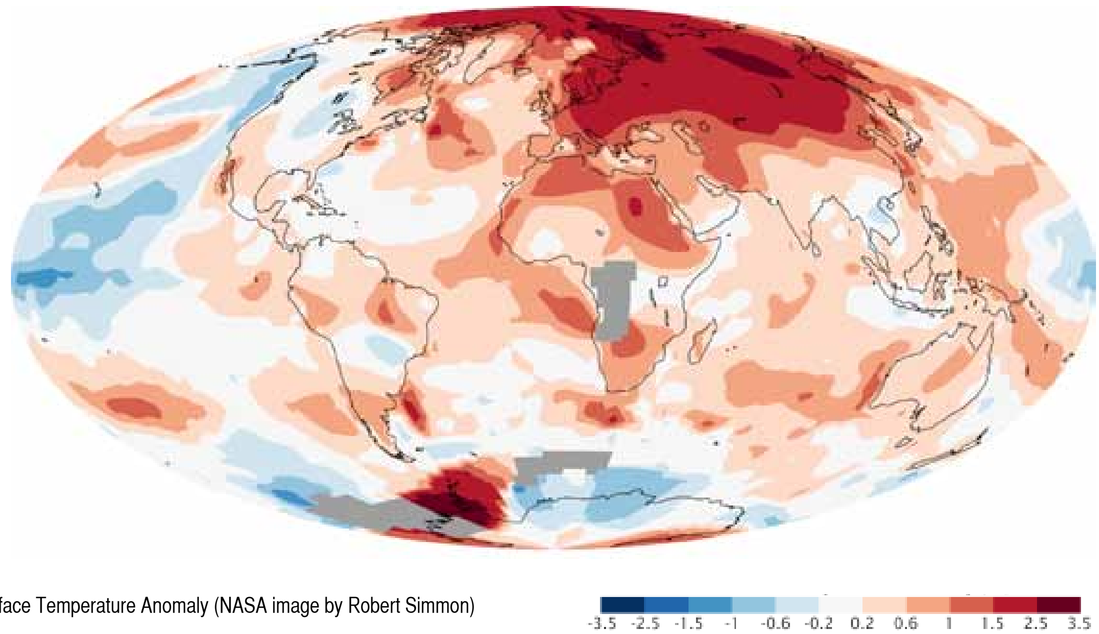
Crafting nature
Landscapes reflect the living synthesis of people and place, integrating their physical origins and the cultural overlay of human presence, often created over millennia. In all cases, the natural environment is therefore the result of human activities.
In some case, like with windmills as landmarks in Holland, the necessity to harvest energy from natural resources defined the self-image of a region and its sense of place that differentiates it from other regions.

The value of infrastructure
Infrastructure systems supported human activities in the natural environment for centuries, offering speed, safety and comfort to movement of people and goods, assisting agricultural activities through the effective use of natural resources and providing an efficient way of dividing the land. Interestingly, many infrastructure components are multifunctional and fully integrated to the landscape: for instance, trees were placed in rows along the main roads connecting Paris to the centres of the Napoleonic empire, providing for a distributed source of firewood, acting as natural containment against land erosion and, at the same time, shading the troops along the routes of extended military campaigns.
Accordingly, the central premise of the project is that existing infrastructure, such as transportation systems, water supply, power grids and telecommunications networks, might provide for both a logic of occupation and a physical support to Land Integrated Photovoltaics systems. In return, a capillary network of photovoltaic installations would extend and reinforce existing infrastructures, monitoring and protecting the environment and supporting human activities.

Environmental emergencies
While the natural environment is the result of human activities, our actions during the last 50 years have altered ecosystems to an extent and a degree unprecedented in human history. One of the most tangible consequences of our collective alienation from the logics and the cycles of nature is our increasing vulnerability to catastrophic events.
On the other hand, it is generally accepted that human presence in critically unstable areas of Europe is not only unavoidable, in view of a fast-expanding population and the resulting scarcity of natural resources, but also indispensable to the conservation and sustainable use of


Bucolic energy technology in Holland


Examples of anthropized landscape



2008 Surface Temperature Anomaly (NASA image by Robert Simmon)

its ecosystems.
Increasingly larger budgets are being devoted to the protection of vulnerable communities and the preservation of valuable natural resources in critical areas, such as costal cities, earthquake-prone regions, and zones exposed to landslides. Similarly, a number of traditional industries in rural areas across Europe are no longer competitive and are being subsidized by governments. Hence a second premise of the research is that energy infrastructures can be utilized for containment, mitigation and monitoring, if not resolution, of environmental emergencies across Europe.
In this scenario, part of the vast financial resources required for materials and technologies deployed in environmental protection projects and emergency rescue efforts would be re-directed toward the installation of large-scale photovoltaic energy infrastructures.
In return, the supply of energy from locally available renewables would support the creation and maintenance of emergency infrastructures and help managing the crisis at hand.

Synergy and survival
We believe that the synergetic integration of photovoltaic technology to existing infrastructure networks would generates multiple efficiencies and cost saving opportunities, determining the potential for large-scale applications of photovoltaic systems in the European landscape.

Similarly, newly created photovoltaic infrastructures would provide for additional opportunities to equip the land with a distributed network of active and interactive systems, effectively monitoring and improving the performance of the landscape.

0.4 Research Methodology

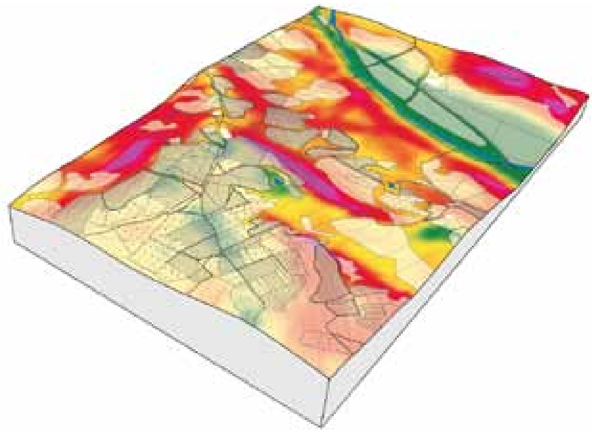
Invisible forces
In one of his seminal writings, Buckminster Fuller declares: “[…] Forms are inherently visible and no longer can ‘form follow functions’, because the significant functions are invisible.” Accordingly, the present research recognizes the emergence of these “invisible forces” in shaping our environment. The planning of a new energy infrastructure shall be guided by sunlight, wind pressure, thermal storage potential, water drainage, slope orientation, and other natural features intrinsic to the land.

Areas of interest were selected based on sun exposure and other relevant factors, using satellite imagery, GIS and historic data publicly available. Within the selected areas, existing infrastructures and other physical systems were surveyed, in order to identify opportunities of integration. Issues of visibility, economy of scale, synergy with additional systems and services, accessibility and maintenance, productivity and efficiency were evaluated before selecting one or more areas for development.

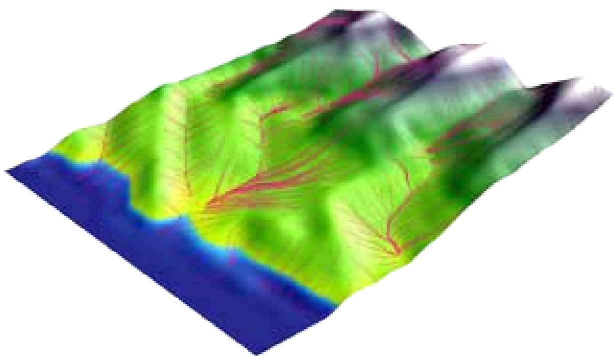
Tessellation
Generally, traditional land subdivision is the result of accumulated processes of state appropriation, inheritance, or exploitation and extraction of surpluses by the industry. In all cases, it’s never a logical or efficient use of natural resources and preservation of the environment.

In fact, it is the fragmentary and irrational land division that often leads to the inefficient use of resources, as well as to expensive public infrastructure work and prohibitive emergency response efforts. We argue that in areas undergoing critical transformations or afflicted by a chronic state of emergency, a radical re-configuration of land parcels is the necessary step in implementing remediation efforts and toward re-establishing a sustainable balance of the ecosystem.

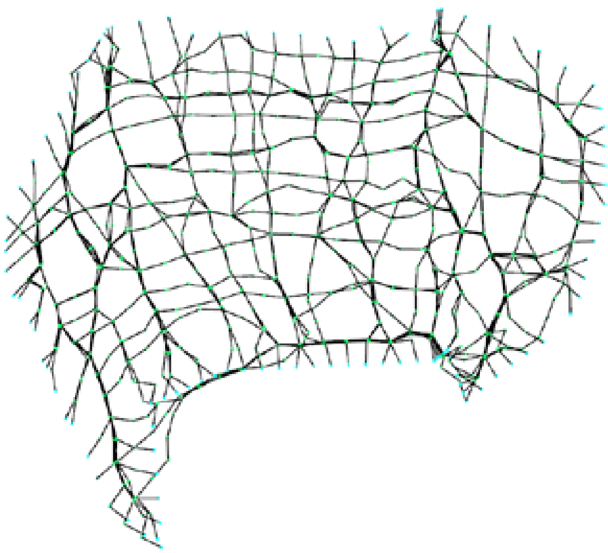
All three demonstration projects’ first act is to develop a new logic of tessellation that is appropriate to the particular forces acting on each specific ecosystem.
It should be noted that in many cases the environmental emergency results from political and economic forces and from the failure of the government to act in defence of the environment. In the present study, the parametric design process that produces the new land parcels responds exclusively to natural forces and land features.



Environmental analyses of relevant parameters (Montalcino, Italy)



Water Flow Lines Analyses using a 3-D topographic model (Almeria, Spain)



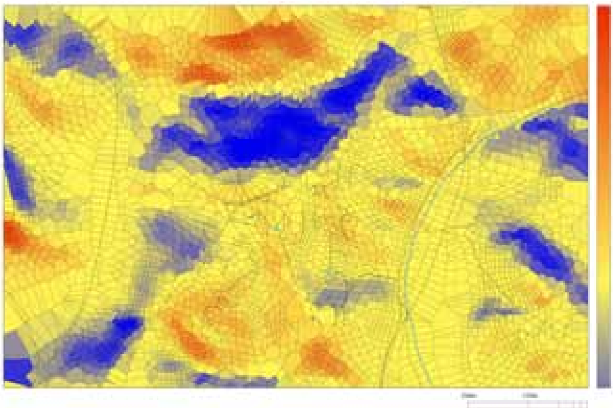
Rule-based manipulation of water flow lines using algorithms (Almeria, Spain)

Energy analysis and mapping
The resulting tessellation of the land allows for an effective and detailed evaluation of the relevant energy forces associated to each tassel.
Using environmental analysis software, we produced a series of different maps for quantitative analyses of relevant parameters; as a result, each new land parcel was defined by values of solar radiation, slope angle, surface water drainage, soil content, and other indicators of environmental performance.

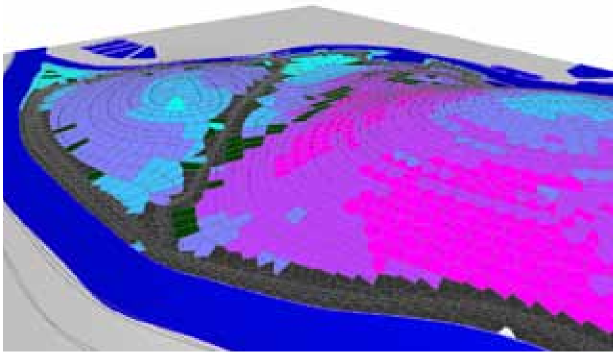
Colour-coded maps resulting from the analyses offer a explicit, intuitive reading of large portions of land, while retaining a level of precision in the underlying data-sets associated to the maps. The particular digital format in which they are written makes them ideal as bases for further manipulations and association to geometric properties via parametric design software.

Land use allocation
A particular combination of parameters may indicate the ability of a given parcel to perform a specific task, that is, it reveals the "vocation" of a lot for certain land uses, including - but not limited to - its potential for energy generation. Slope or gradient might be an indicator of vulnerability to land erosion, or additional costs associated to earth retention.
Similarly, the ability of the parcel to drain groundwater might be connected to salinity levels, or other factors that might affect its intended use.
Preexisting land uses are obviously a crucial factor in determining the new roles and they were maintained whenever possible, in an effort to minimize unnecessary conflicts with established property rights.

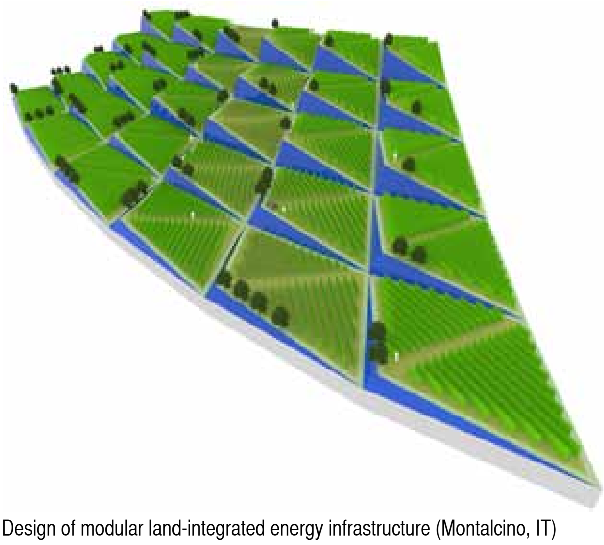
Modular infrastructure
A limited number of typologies of intervention was associated to each family of parcels: design strategies were then translated into physical infrastructures, using modular system components with the ability to adjust to local conditions and to respond "point-by-point" to the originating data set. In all cases, the particular design response was triggered by the associated environmental maps. The resulting modular system - whether dwellings, energy infrastructure, or productive units - was engineered to integrate with existing networks and with additional systems components that might be appropriate to the site.



Solar radiation map using environmental analysis software (Montalcino, Italy)



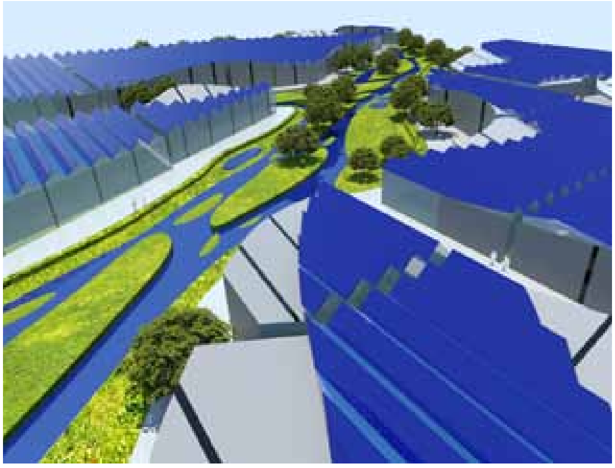
Land use allocation using parametric software (Hamburg, Germany)



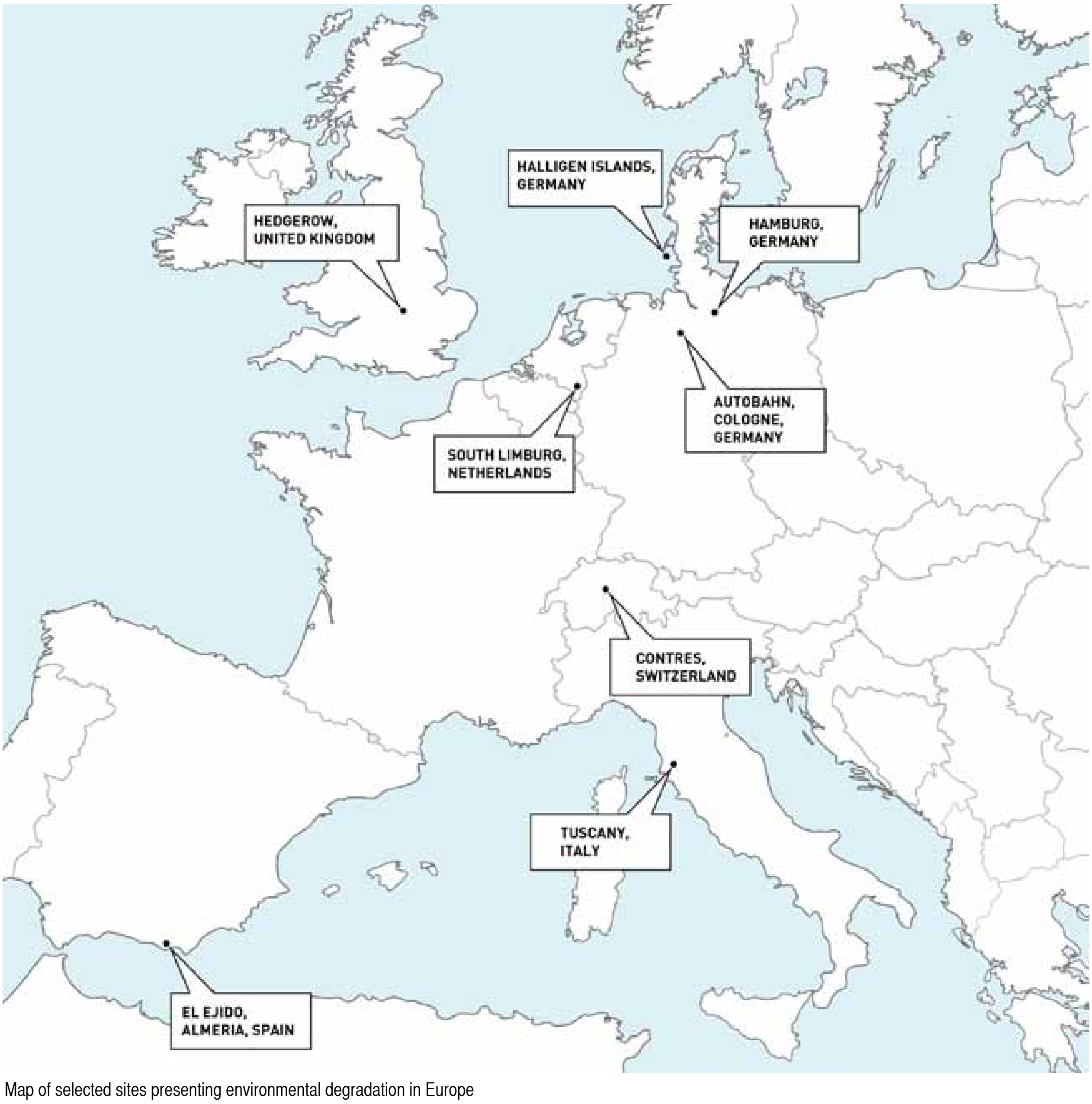
Design of modular land-integrated energy infrastructure (Montalcino, IT)

Evaluating performance
Preliminary design solutions were tested repeatedly through an iterative process and a progressive optimization of the energy performance of the given solution.
A comprehensive evaluation of energy performance and other benefits resulting from the system integration are also part of the present study. Quantitative energy analyses are complemented by graphical material for evaluation of visual impact and integration to the landscape.

Design integration
The integration of the different typology units into the landscape shows the variety of design solutions and the ability of the new infrastructure to adapt to specific site conditions. Suggestions on the technical implementation of the proposed architecture conclude the research, together with a series of rudimentary renderings intended to give a first, unapologetic view of a radically new energy landscape.


Simulation of energy infrastructure integrated in the landscape (Almeria, Spain)

0.5 Environmental Emergencies in Europe

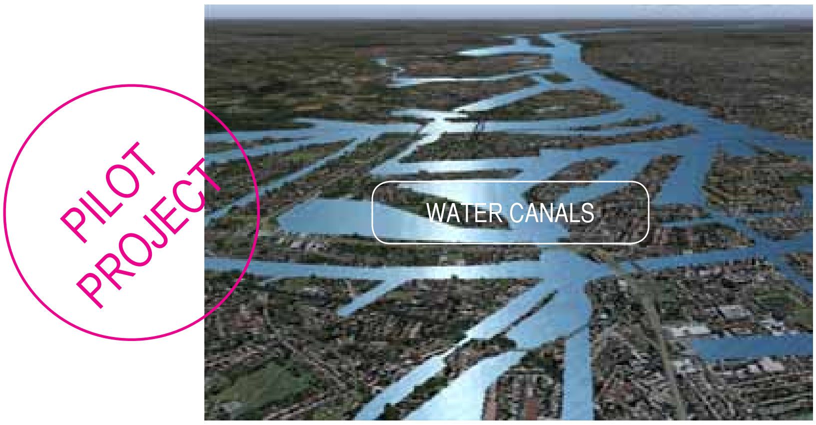


Map of selected sites presenting environmental degradation in Europe

Site selection

A large number of potential sites have been identified to demonstrate the application of the technology, based on opportunities of integration, cultural significance, and existing environmental emergencies that could benefit from the implementation of open-field photovoltaic systems.

Transportation Infrastructure near Cologne, Germany



Water canals in the Hamburg Area, Germany

Hedgerows in the United Kingdom (Source: National Geographic Society)

'El Mar de Plastico' in Almeria, Spain

Ecosystem fragmentation near Cologne, Germany
Road infrastructure is ubiquitous and rapidly growing, yet the logic of transportation networks are seldom compatible with the ecosystems they traverse; in most cases, transportation projects make no attempt at integrating with the surrounding environment.
Highways impact the environment in a variety of ways, including noise, air pollution and potential loss of living quality. Wildlife and plants, in concert with humans, suffer from habitat destruction and various forms of pollution. In addition, while facilitating transportation for humans, highways do the opposite for wildlife. Ecosystems suffer fragmentation; habitats and biomes that had worked in cohesion are separated. Migratory species find their progress blocked; some may be separated into genetic islands, impoverishing future biodiversity and leading to local extinctions.

Rising tides in Hamburg, Germany
The Hamburg region in the north of Germany is a low-elevation coastal zone with high-density population, where the natural dynamic process of the Elbe estuary have been affected by the many attempts to manipulate the river with man-made barriers and waterways. The North Sea flood of 1962 was a natural disaster with enormous consequences for the city of Hamburg, where the homes of 60,000 people were destroyed, and the death toll amounted to 315. After the Elbe river was hit by a 100 year flood In 2002, the City of Hamburg and the Regional Government have been making various commitments to protecting the area. With substantial federal and state funding available for large-scale infrastructure projects, it is time to rethink the old models of development in the city and to pursue an integrated vision of sustainable flood protection with the contribution of solar energy.

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Hedgerow removal in the UK
The mosaic of small fields bounded by a network of hedgerows, some of which are irregular, are species-rich and clearly ancient. Their purposes were to enclose livestock and to demarcate boundaries, both between owners and between parishes. Hedgerow removal is part of the transition of arable land from low-intensity to high-intensity farming. Hedgerows serve as important wildlife corridors, especially in the United Kingdom, where they link the country's fractured ancient woodland. They serve as a habitat for birds and other animals and to stabilise the soil and prevent erosion and leaching of minerals and plant nutrients. Removal thus weakens the soil and leads to erosion. Hedgerow removal has been occurring since World War I, as technology made intensive farming possible, and the increasing population demanded more food from the land.

Water scarcity in Almeria, Spain
Agriculture is a significant user of water resources in Europe, particularly in Spain, where the land cultivated by irrigation in 1999 covered 3.7 million ha, that is, 14.5% of usable agricultural land and 55% of total agricultural production. Irrigation today represents 80% of the total water demand in Spain and nearly 90% of actual water consumption. Almeria is the epicentre of southern Spain's two billion-euro a-year agricultural industry; also, it is at the forefront in pollution of water and aquatic ecosystems, salinisation of groundwater sources, and racial segregation of the cheap immigrant labour force. Located in Europe's driest desert, Almeria has the greatest concentration of greenhouses in the world: 'el mar de plastico' - or sea of plastic - extends over 22.000 ha in the Campo de Dalias area, producing million of tons of produce for European markets.

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Landslides in Vorderrhein Valley, Switzerland

Ecosystem loss in the Halligen Islands, Germany

PILOT PROJECT

Traditional wine making in Montalcino, Italy

Soil erosion and surface runoff in South Limburg, The Netherlands

Landslides in Vorderrhein Valley, Switzerland
The north slope of the high Vorderrhein Valley and of the Urseren Valley, eastern Switzerland, is marked by a series of rock slope instabilities of a very peculiar type. Among these landslides, the zone of Cuolm da Vi above the touristic resort of Sedrun presents a high level of activity since some thirty years.
The danger for the resort of Sedrun does not result directly from the movements of the unstable mass, but from the very significant sediment flows in the Drun Torrent. The formation of a dam by a localized slide at the toe of the large instability phenomenon, followed by its sudden failure, would have dramatic consequences: destruction of the regional railway line and of the national road connecting the Rhine and Rhone Valleys, and devastation of the centre of the touristic resort itself.

Ecosystem loss in the Halligen Islands, Germany
The Halligen are ten small German islands without protective dikes in the North Frisian Islands, shaped by the tides of the North Sea: occasional flooding has created a distinctive ecosystem, with fertile meadows where sea lavender blossoms in summer, and plants and animals depend on the occasional influx of salt water. But this delicate balance could tip if sea levels rise: dwellings and commercial buildings are built upon meter-high man-made hills, called Warften in German, to guard against storm tides. The Halligen Islands are a cautionary tale of ecosystem loss in coastal areas as a result of human industrial activities, particularly through the construction of dikes and the extraction of peat, and - most recently - through gas extraction and reclamation of intertidal basins. They also offer an exemplar opportunity to rethink coastal defence strategies with the help of energy infrastructures.

= ?

Updating wine production in Tuscany, Italy
While Tuscany's reputation for idyllic landscape, well preserved historic monuments and high-quality living standards remains largely intact, the region faces a radical transformation in its traditional values and structures. Cyclical economic crises among wine producers resulted in a massive selling of historic terroirs to foreign companies, mainly Japanese and more recently Chinese investors. Insofar as landscapes are the result of human activities over centuries, the Tuscan landscape today is the reflection of a society that no longer exists. Unregulated immigration from China and the north African region, the collapse of traditional industry, such as textile and mining, and the decline of agriculture itself, pose a challenge to maintaining a balance between preservation of cultural, artistic and landscape assets, and the transformation into a modern economy.

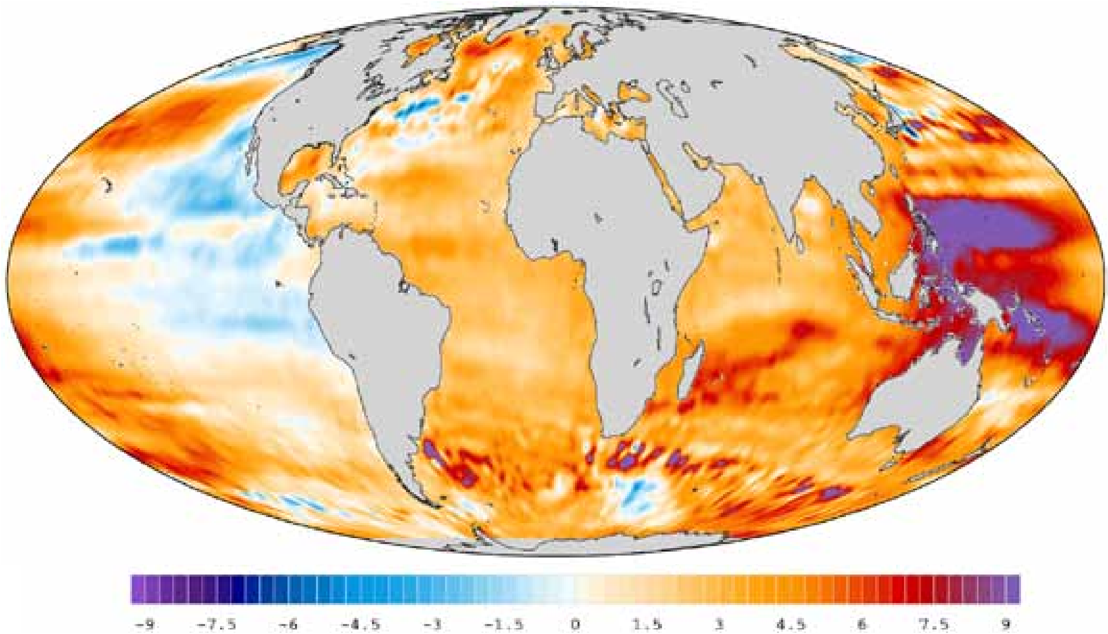
Soil erosion in South Limburg, The Netherlands
Soil erosion and surface runoff have always been problems concomitant with intensive agricultural land use in hilly areas. These problems can be exacerbated by soil and geology, as is the case in the rolling hills of South Limburg - a *landstreek* of The Netherlands - where soils developed on loess are especially vulnerable. Since people started clearing the forests, soil erosion processes and human actions have created the characteristic landforms of dry valleys. Moreover there has been a change in land use and in the kinds of crops grown in South Limburg. Between 1960 and 1986, the kinds of crops which give rise to a higher erosion risk, such as maize and sugar beet, have increased, replacing cereals such as winter wheat. Runoff with a high sediment load causes obstructed waterways and choked up sewers, causing damage to roads, gardens and houses.

DEMONSTRATION PROJECTS

1. Hamburg, Germany

1.1 Rising Tides

Global emergency
Over 600 million people live in coastal areas that are less than 10 meters above sea level, and two-thirds of the world's cities that have populations over five million are located in these at-risk areas. With sea level projected to rise at an accelerated rate for at least several centuries, very large numbers of people in vulnerable locations are going to be forced to relocate. Even the best-case scenarios indicate that a rising sea level would have a wide range of impacts on coastal environments and infrastructure. Effects are likely to include coastal erosion, wetland and coastal plain flooding, salinization of aquifers and soils, and a loss of habitats for fish, birds, and other wildlife and plants.



Global sea level trends (in mm/year) during the period 1993-2010 (Source: NOAA Satellite and Information Service)

Current sea level rise has occurred at a mean rate of 1.8 mm per year for the past century, and more recently, during the satellite altimetry era of sea level measurement, at rates in the range of 2.9-3.4 ± 0.4-0.6 mm per year from 1993–2010. One 2008 study suggests that there has been a reduction in the prior rate of sea level rise by 2 mm/yr from 2005 to a level of 1 mm/yr.

In 2011, JPL (US) projected sea level rise of 32 cm (12.6 inches) by the year 2050, with contribution from the following sources:

Antarctic and Greenland ice sheets:	15 cm -	5.9 inches
Glacial ice caps:	8 cm -	3.1 inches
Ocean thermal expansion:	9 cm -	3.5 inches

The Hamburg case
Hamburg is named Germany's "Gateway to the World" and is the largest port in Germany. The history of the port is almost as old as the history of Hamburg herself. Founded on May 7, 1189 by Frederick I for its strategic location, it has been Central Europe's main port for centuries and enabled Hamburg to develop early as a leading city of trade with a rich and proud bourgeoisie. The Port of Hamburg is also one of Hamburg's largest attractions, both as a living, industrial and logistic center but also as a backdrop for modern culture and the port's history. Among these are various museum ships, musical theaters, bars, restaurants and hotels - and even a floating boat church.


A canal in the center of Hamburg

A troubled history
The North Sea flood of 1962 was a natural disaster affecting mainly the coastal regions of Germany and in particular the city of Hamburg in the night of February 16. In total, the homes of about 60,000 people were destroyed, and the death toll amounted to 315.
The flood was caused by the Vincinette low-pressure system, approaching the German Bight from the southern Polar Sea. A European windstorm with peak wind speeds of 200 km/h pushed water into the German Bight, leading to a water surge the dykes could not withstand. Breaches along the coast and the rivers Elbe and Weser led to widespread flooding of huge areas.


Satellite image of the Hamburg docks area

In Hamburg, on the river Elbe, but a full 50 km away from the coast, the residential area of Wilhelmsburg was most affected.

In 2002 the Elbe river was hit by a 100 year flood of high socioeconomic impact in both the Czech Republic and Germany. Following this flood, the International Commission for the Protection of the Elbe River (ICPER) issued a hydrological modelling study in the framework of the Action Plan for the flood protection in the Elbe river basin on the impact of retention polders, dyke-shifts and reservoirs on discharge in the Elbe river. The port of Hamburg, serviced by the Elbe, is the largest international hub in Germany and key to maintaining the fisheries, agriculture, nature conservation, tourism, navigation, and economy. Erosion and sedimentation determine the natural dynamic process of the estuary, and have been negatively effected by the many attempts to manipulate the river with man-made barriers and waterways.

New models of development

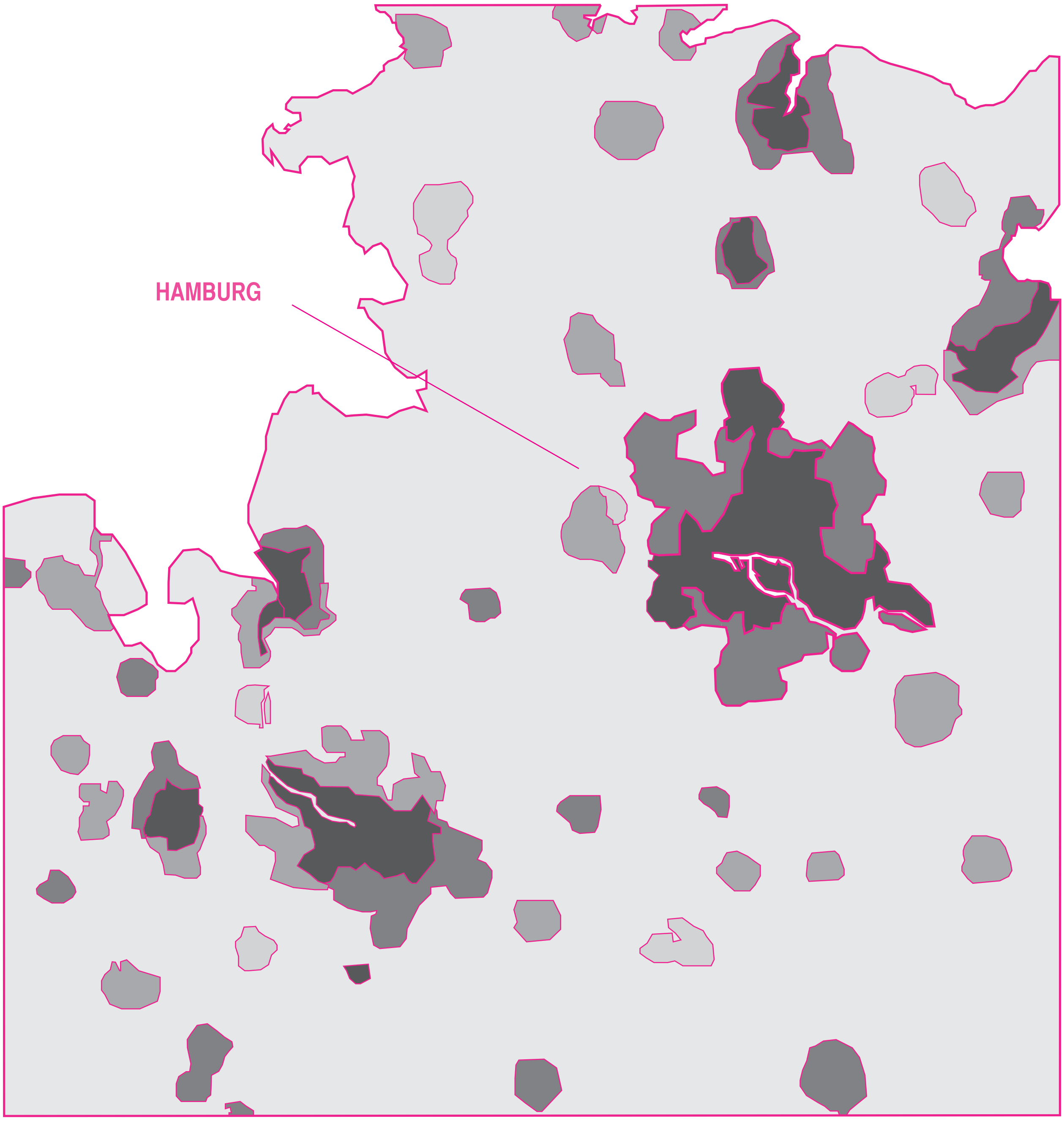
Hafen City Hamburg is a project of city-planning where the old port warehouses of Hamburg are being replaced with offices, hotels, shops, official buildings, and residential areas. The project is the largest rebuilding project in Europe in terms of land area (approximately 2,2 km2). When completely developed, it will be home to about 12,000 people and the workplace of 40,000 people mostly in office complexes.

Interestingly, all new buildings in HafenCity are elevated on plinths made of mounds of compacted fill ("Warften" in German). On the exposed windward sides, such as the southern sides of Strandkai and Uberseequartier, the external perimeter will actually lie 8.3 to 8.6 meters above sea level. It is the responsibility of private developers to put these artificial compacted bases in place, avoiding any need for financing of flood-protection measures by the government – ahead of the sale and deployment of the sites concerned.

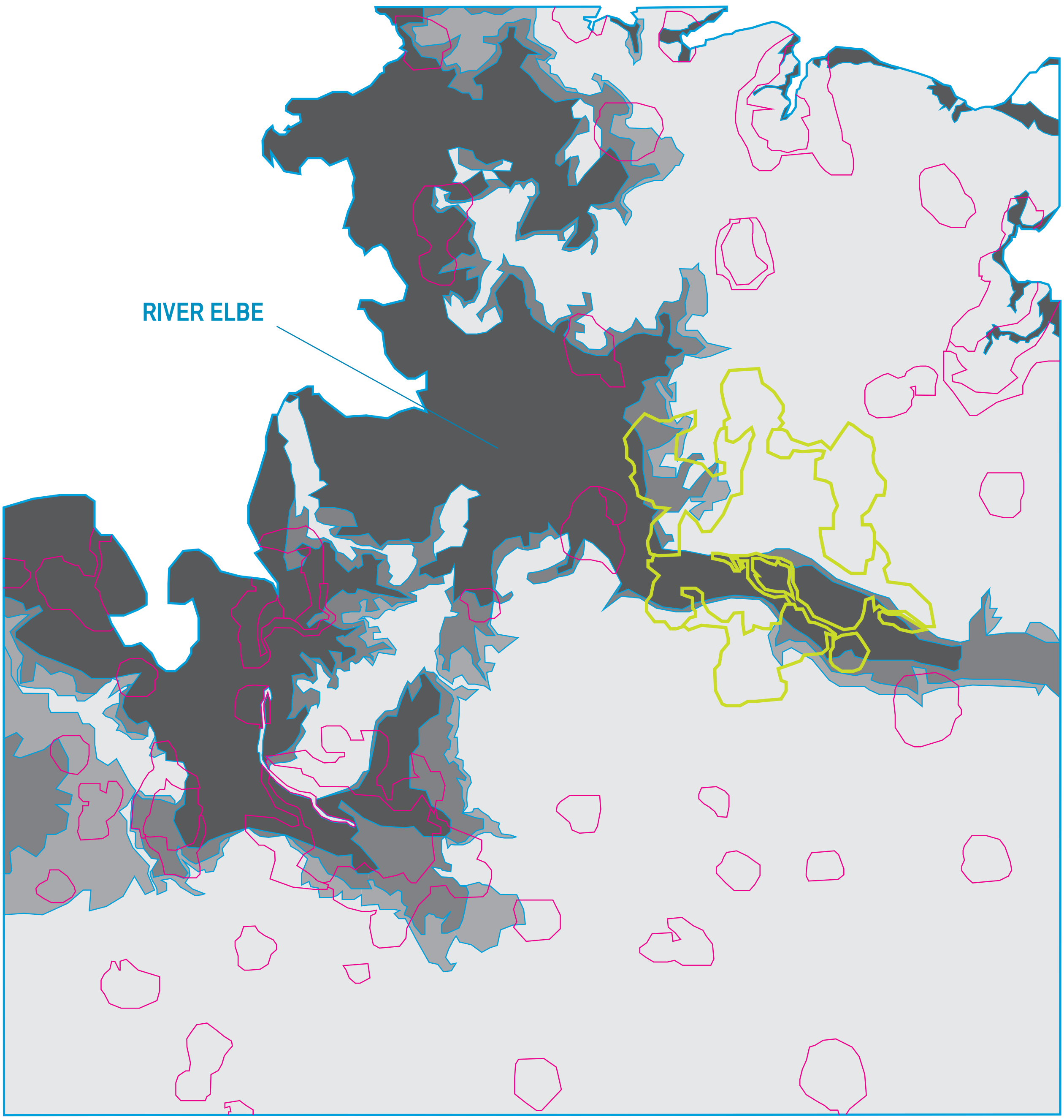
Image of the flood in 1962

Rendering of the proposed Hafen City in Hamburg

Population vs. elevation
A comparative analysis of low-elevation coastal zones and population densities in Europe highlights the critical overlapping of the low-elevation river Elbe basin with the high-density population in the Hamburg region.

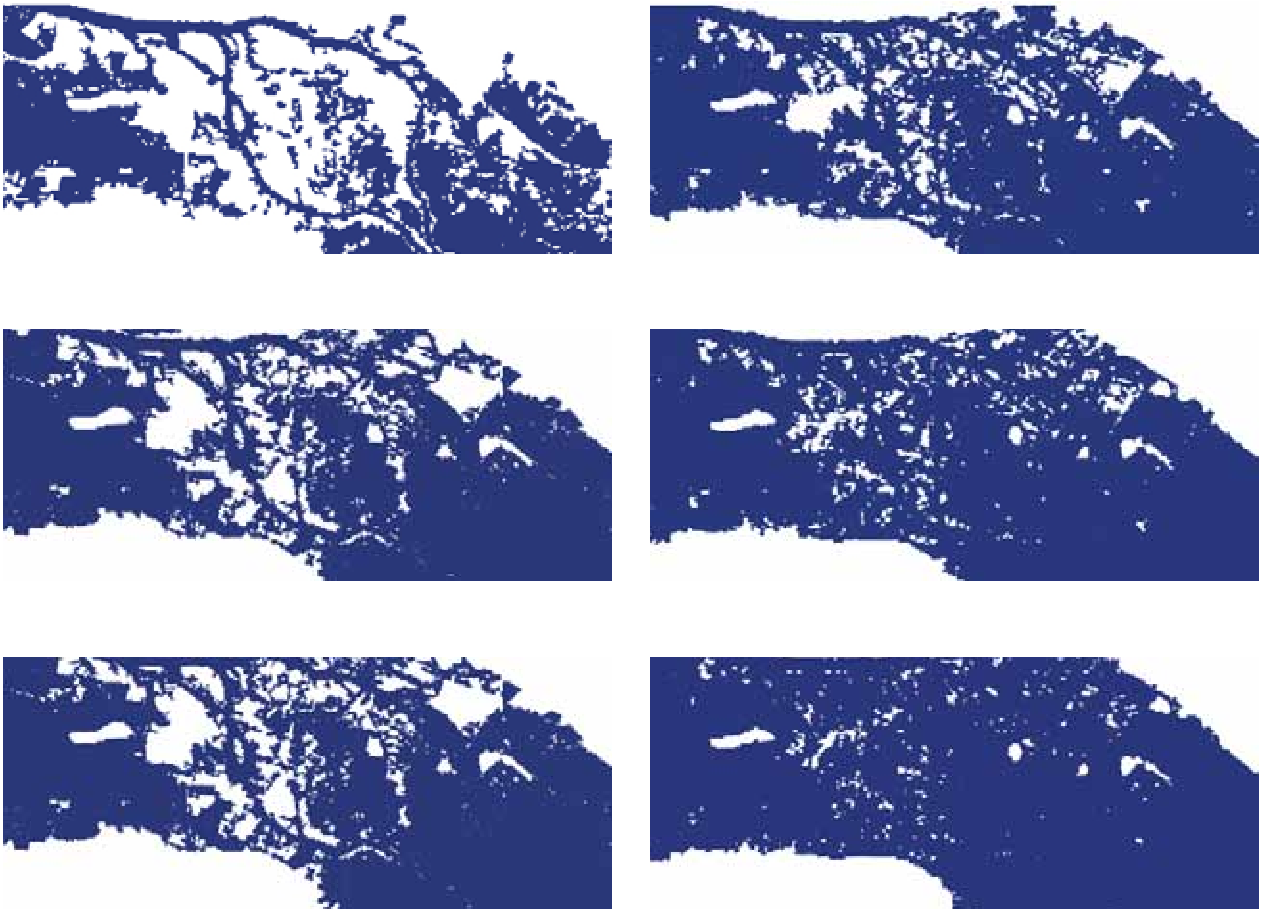


Population densities in north-west Germany



Low elevation zones in the same area

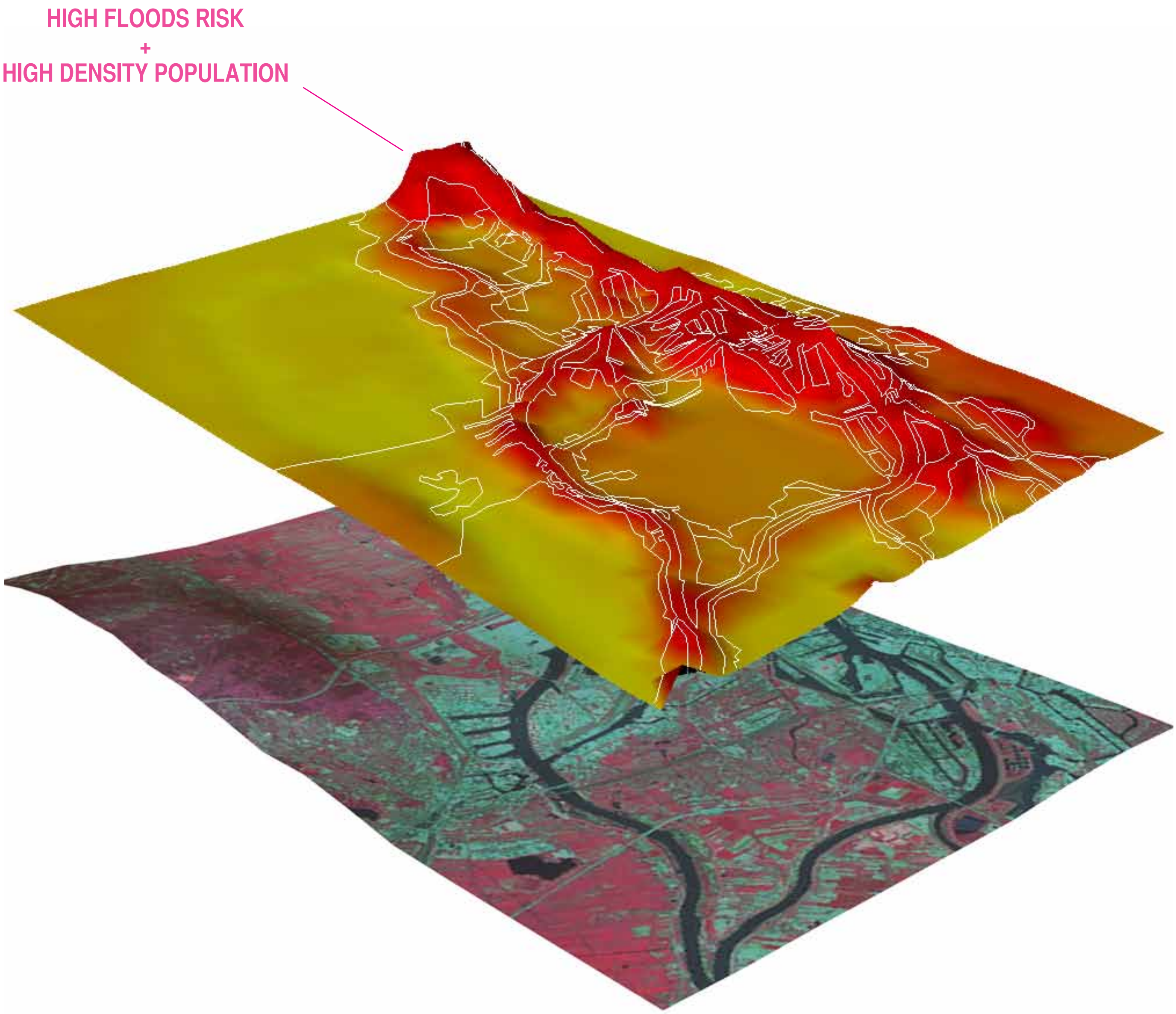
1.2 Site Analysis



Flood predictions for the Hamburg city centre area based on the global average of 2.9-3.4 mm/year rises (projected from 2015-2040)

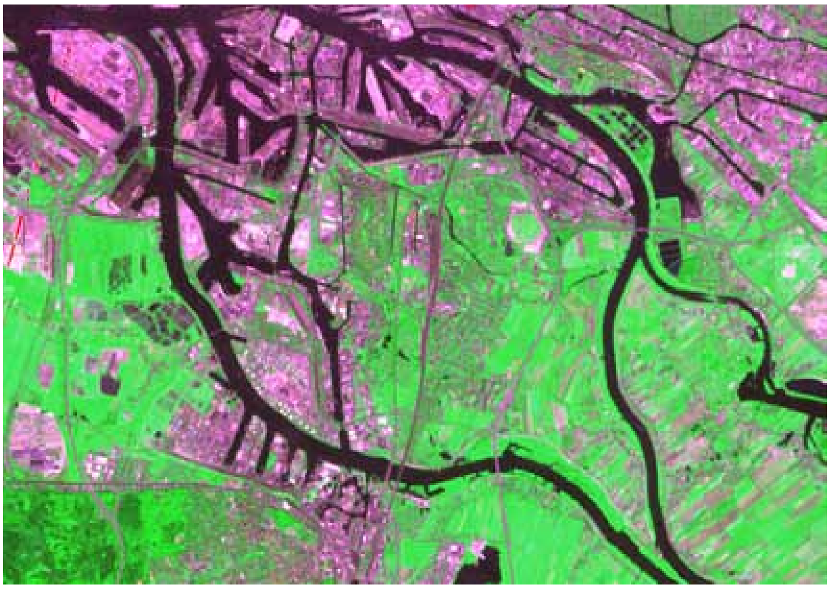
Flood predictions

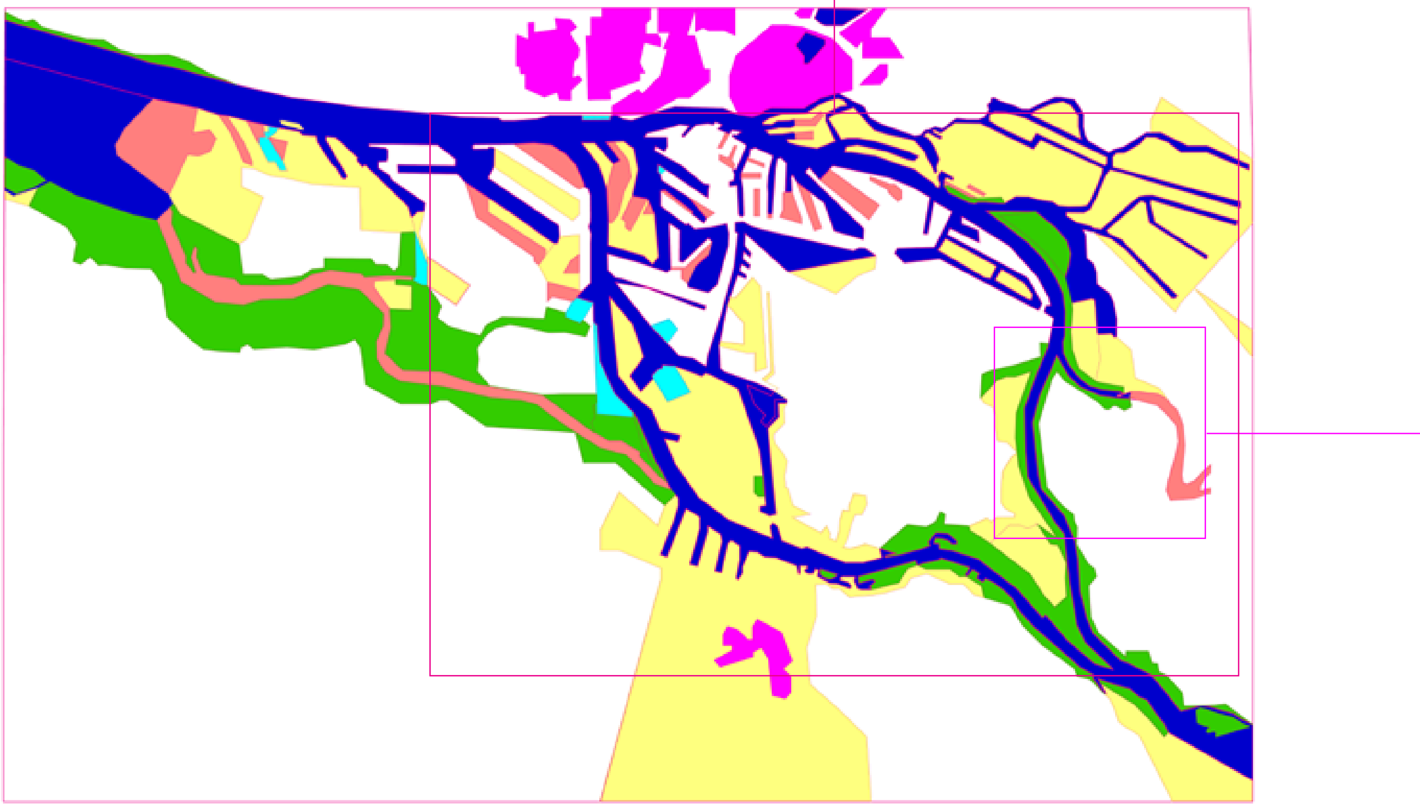
Acceleration of sea level rise in the areas surrounding the Elbe river - due to the combined effect of climate change and dredging for port use - would have a negative impact on the ecosystem, and pose a heavy burden on coastal protection and the safety of the hinterland. The current plan for flood protection is being implemented at a cost of over 600 millions and it includes over 100 kilometres of dikes and flood walls, as well as 6 storm surge barrages, 6 sluices, 27 pumping stations, and 38 flood water gates. Most importantly, the plan will prevent floods caused by sea level rise only up to 30 cm.



Flood risks analysis

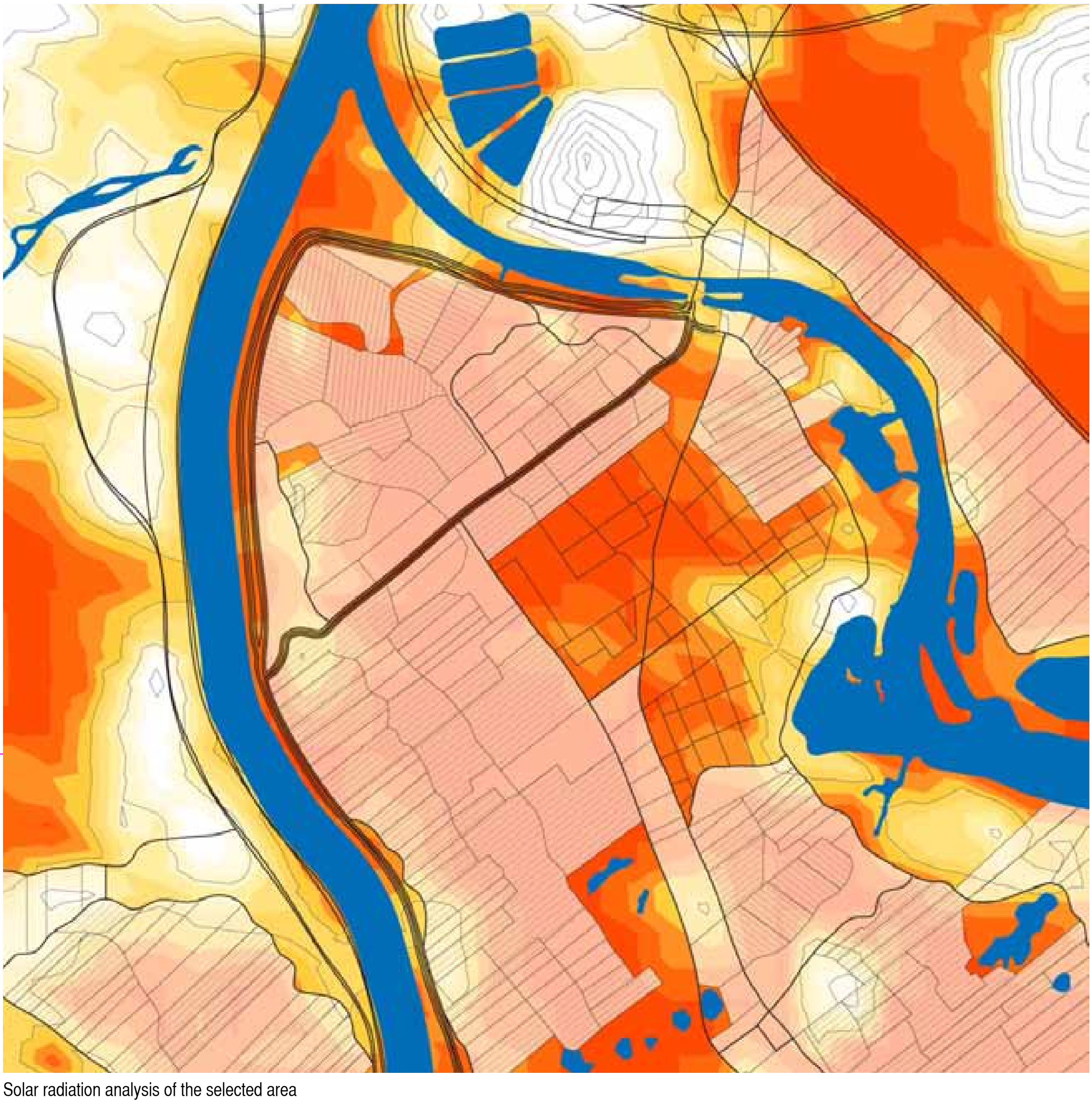
With 4 million people living in the 19 square km of Hamburg's metropolitan region, exploring the relationship between population density, land use, and topography allows for the identification of higher risk zones.
Areas where topography is low are highly vulnerable to floods; high populations in these vulnerable flood zones present added risks of extensive damage to buildings and economic activities.
The map above - interpolating data of flood zones and population density - highlights areas of particular relevance for a pilot project.


Map of Hamburg's waterways highlighting land use


Waterways qualification map

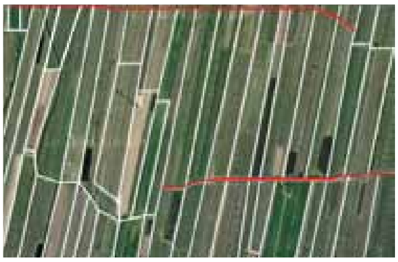
Waterways system qualification

- Dense Urban Zones
- Natural Waterways
- Industrial Zones
- Man-made Waterways
- Destroyed Natural Waterways
- Agriculture Flood Zones
- Underdeveloped Zones


Solar radiation analysis of the selected area

Site selection
Based on the sequences of mapping, the selected site includes agricultural and urban zones, it has potential for growth in population density and it is vulnerable to floods due to its bordering waterways and low topographic location. Also, the site shows good solar radiation levels, suggesting a design strategy where the use of extensive photovoltaic systems can be part of the solutions.

1.3 Design Strategy



1 - Long plots perpendicular to boundary line

2 - Irregular plots conforming to change in gradient

3 - Radial configuration around attraction point

Satellite image of selected site

Analysis of land morphology
Three types of fabrics are preexisting in Hamburg's land structure:

1 - Strong boundary lines such as rivers and main roads generate a dense aggregation of long rectangular plots that remain constantly perpendicular to the boundary.

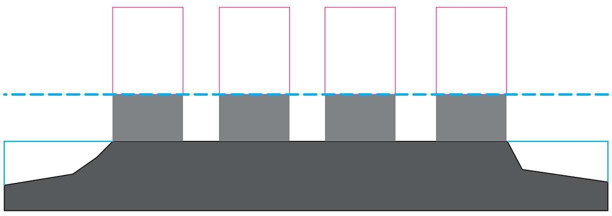
2 - In zones with topographical changes and steeper slope, the plots begin to change proportion from long rectangles to shorter blocks, breaking apart from the grid and adjusting to contour lines and land features.

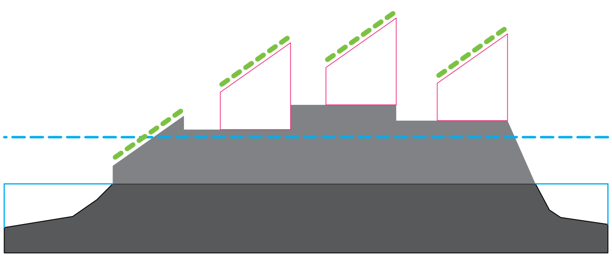
3 - Dense urban centres act as the driving force for the third typology, which is radial. The plots are smaller, but proportionally rectangular with the long edge rotating parallel to the centroid.

Parametric modelling

A rule-based model reproduces the logic of aggregation found in the historic land morphology of Hamburg, using algorithms that mimic the geometric properties of the existing fabric. The parametric model uses existing waterways, historic developments, and infrastructure as base components for generating a new morphology and a land subdivision.


Step in the parametric tessellation process using Grasshopper


Land fill efforts are linked to individual buildings in Hafen City

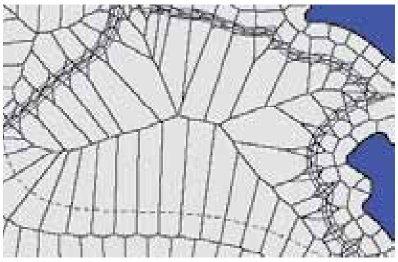

Land fill as planning strategy in the demonstration project

Land fill as integrated infrastructure

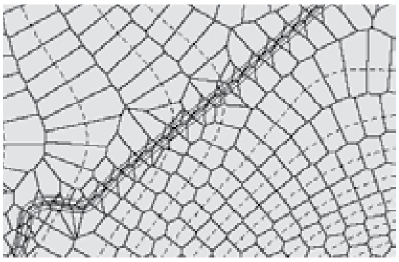
The main premise of the project is that land fill is part of the solution in the large majority of past and present flood protection projects in the Hamburg area. In fact, Hafen City relies on a massive 8-meter land fill over the entire area for protection from floods, as each individual new building will have to be elevated on plinths made of mounds of compacted fill.

We argue that such effort would be incomparably more effective and less expensive if was planned and implemented as a well integrated component of the overall development strategy. Accordingly, our project starts with creating an artificial hill on the area defined by the water canals, using a volume of compacted fill comparable to the one anticipated for the Hafen City project. In turn, the newly created slope will generate multiple benefits and synergetic opportunities, including south-facing slopes for solar energy generation.

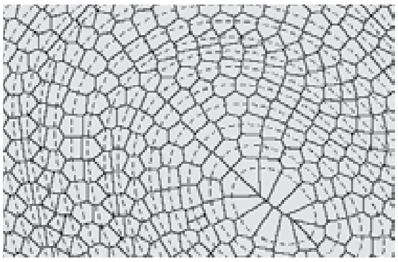
1.4 Environmental Analysis



1 - Long plots perpendicular to boundary line

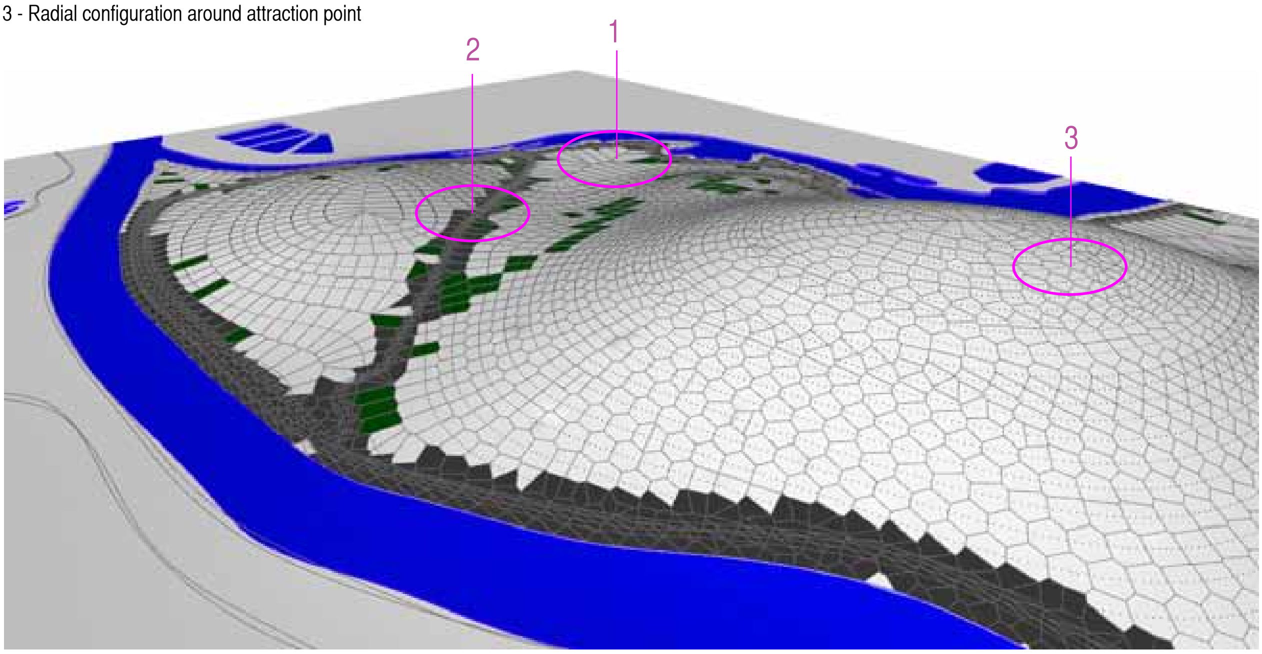


2 - Irregular plots conforming to change in gradient



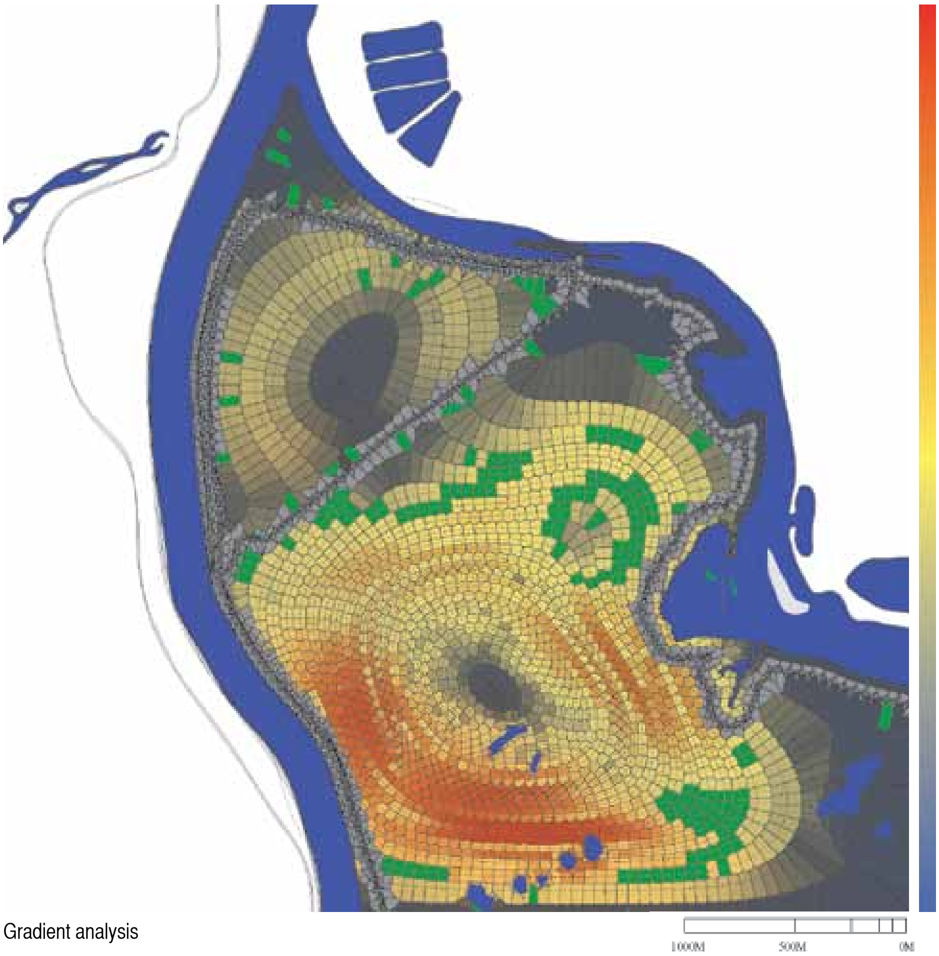
3 - Radial configuration around attraction point

Land tessellation
In the new subdivision, size, proportion, orientation, and density of parcels are determined by control points, orienting lines, and topography:
1 - Areas that are defined by primary boundary conditions, such as water canals or highways, tend toward a dense subdivision of long parcels facing the boundary component on a narrow side; this is the result of property taxes that historically were proportional to length of street front. Also, in a family economy regime, survival depended on the ability to trade by facing a public street. Some of these conditions are still relevant today, hence long plots were maintained.
2 - Plots that face a change in gradient have the ability to transform so as to adjust direction and proportion to the prevailing slope, resulting in more equal-sided units.
3- When facing points of attraction, such as historic developments, monuments, or topographic peaks, the grid has the ability to inflect in a radial fashion.
The iterative nature of the process allows for continuous monitoring of the geometric characteristics of each unit and for progressive calibration of the parcels.
The same digital platform also includes environmental analysis tools for quick evaluation of energy potentials and other performance values.
The parametric tessellation provide a finite number of land parcels that can be easily analysed for relevant values such as slope and ground orientation.



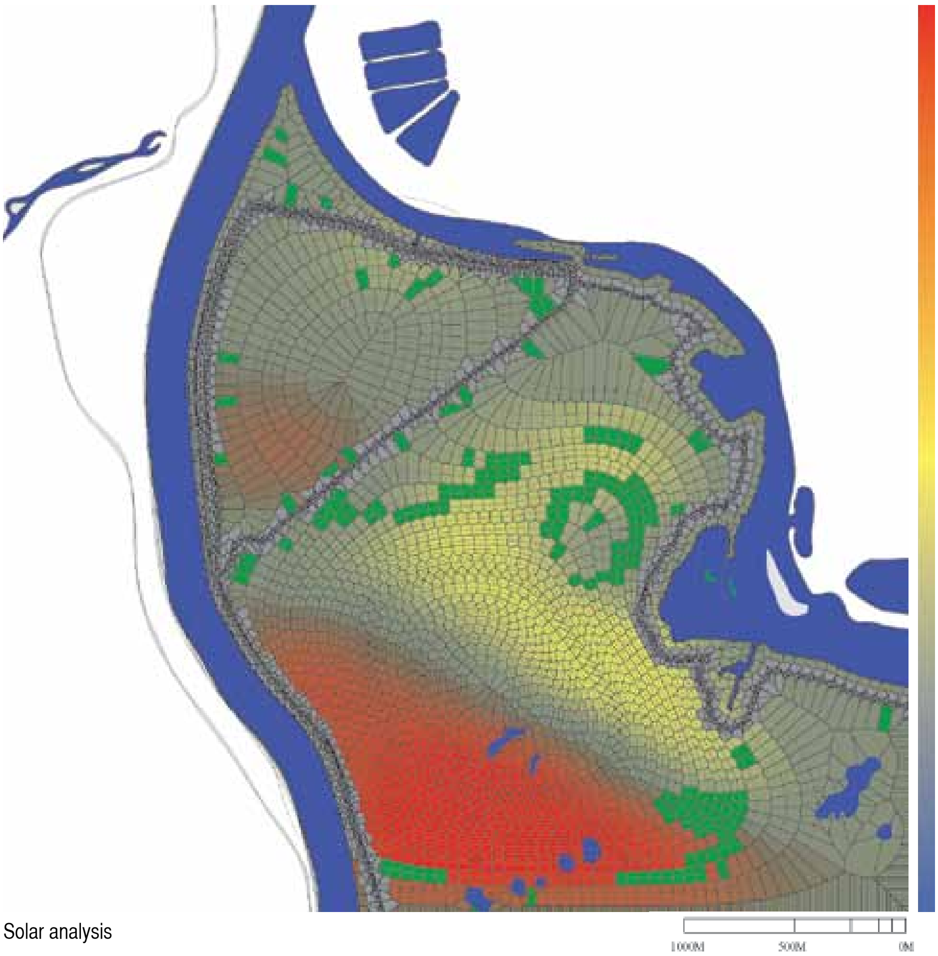
Aerial view of tessellation model

Gradient Analysis
Topography is very relevant in terms of integrating the new structures to the ground, as foundations and retaining walls depend on gradient. Slope analysis also offers indication of potential water retention and quality of drainage. Location of forested areas also relates to gradient, as trees attenuate soil erosion on steep slopes.



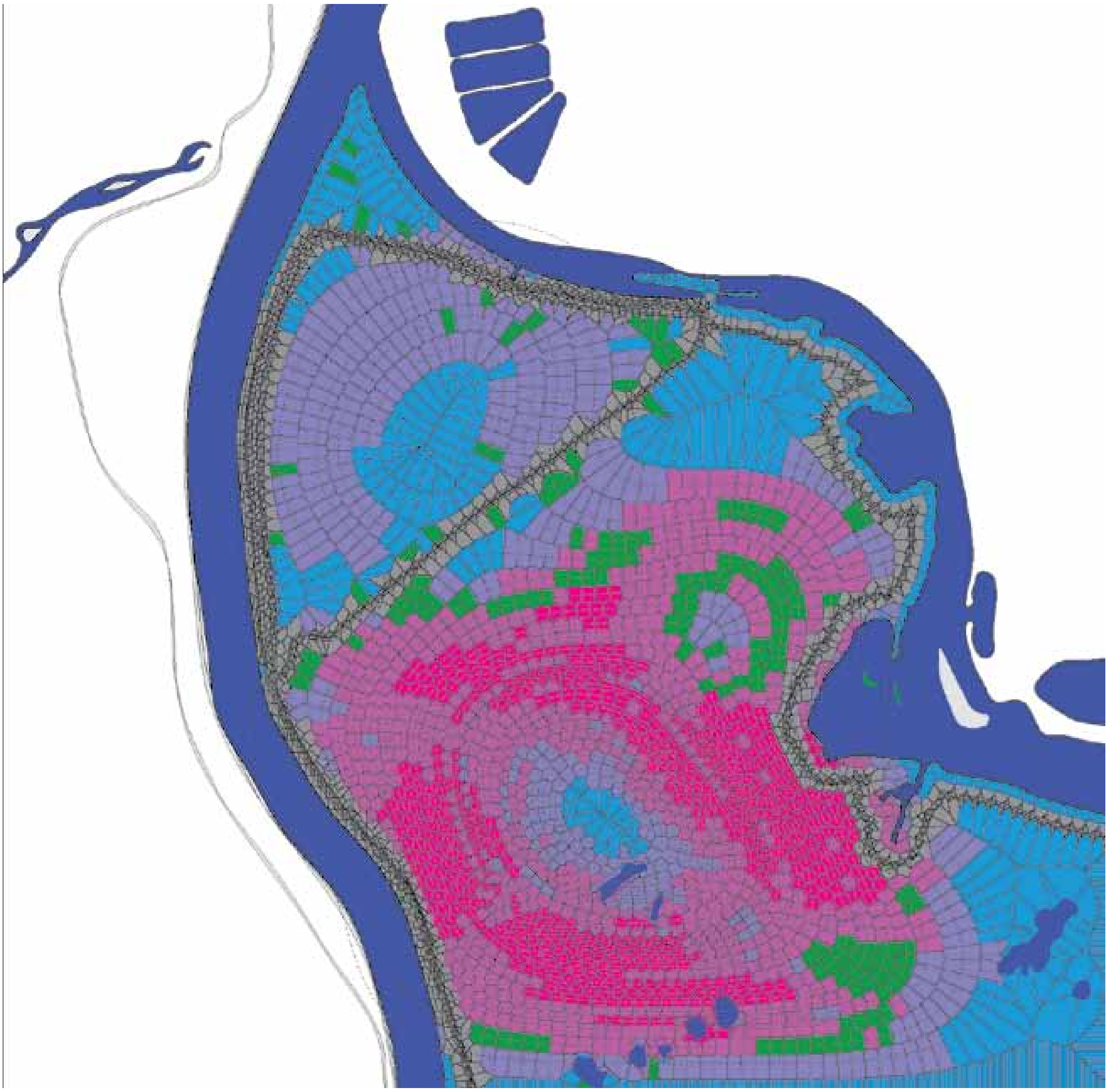
Gradient analysis

Solar Analyses
Sun radiation is perhaps the main indicator for locating the new structures within suitable land. In combination with topography analysis, the energy potential of the site determines the most appropriate use for each parcel.



Solar analysis

1.5 Typologies of Intervention

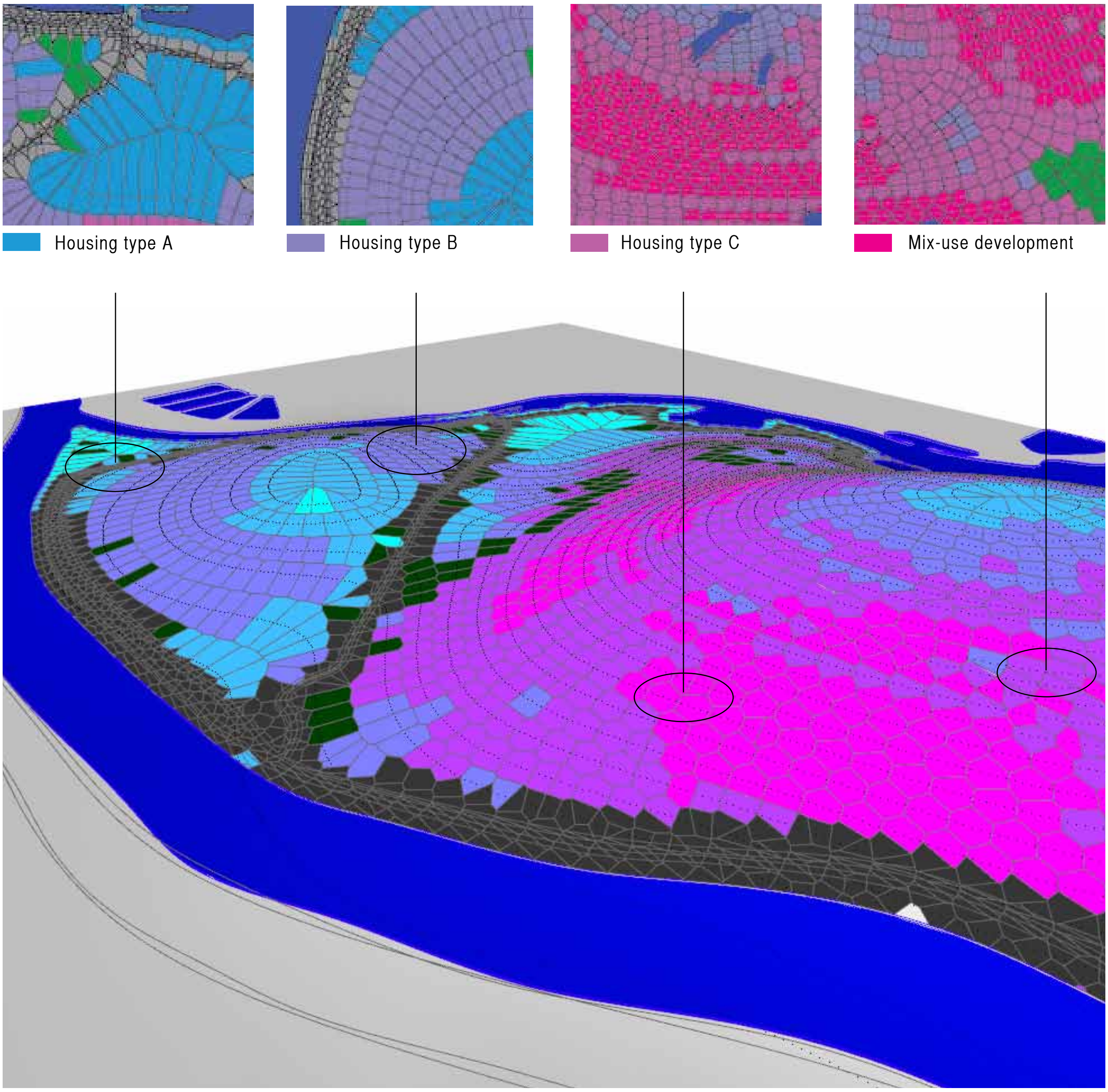


Typology allocation map

- Housing type A
- Housing type B
- Housing type C
- Mix-use development
- Forest

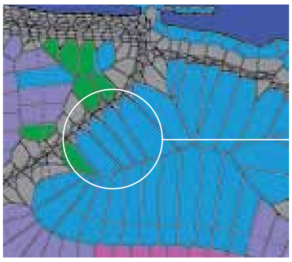
Typology allocation

The new structures include solar energy installations large enough for a zero energy building (ZEB) community. Specific housing typologies are associated with particular configurations of land features and environmental characteristics, as indicated for each parcel by the analytical maps: social housing is located on flat land and long lots (type A); single-family housing is mostly



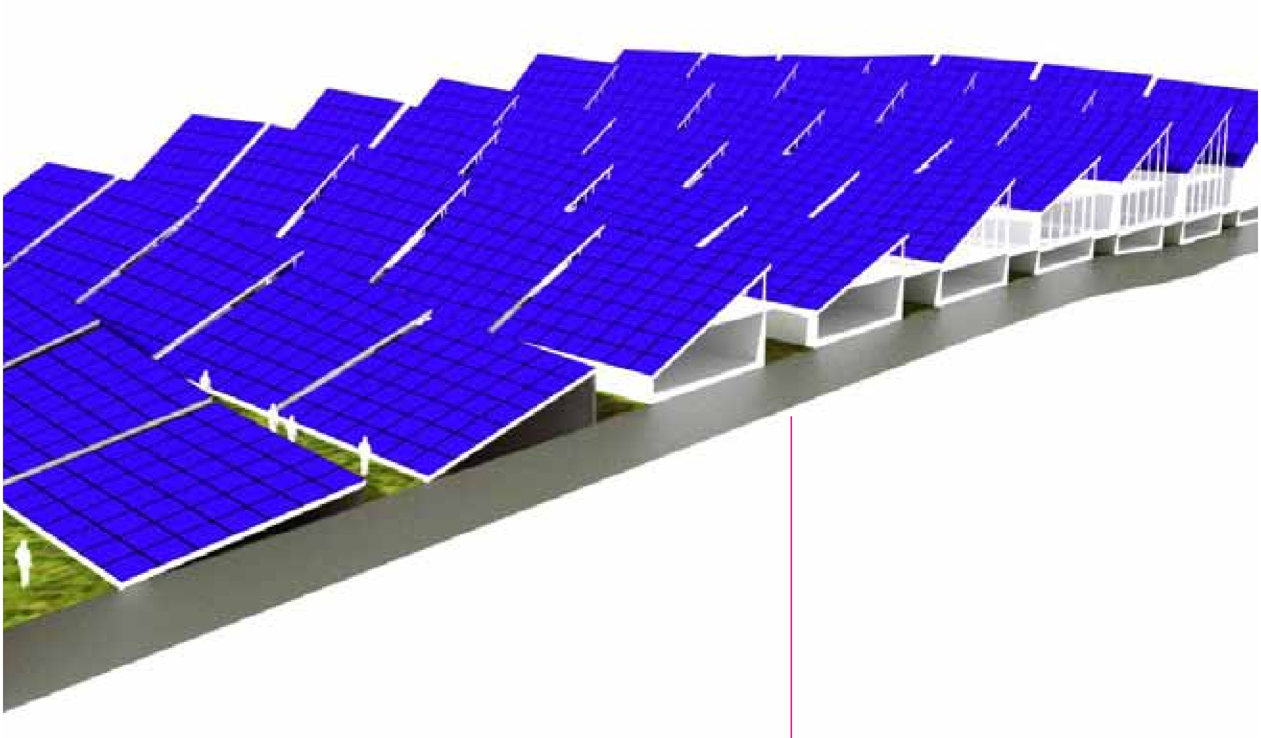
Aerial view of the typology allocation 3-D model

located on smaller plots with low slope (type B) and on lots with steep gradients (type C); mix-use developments are located on medium grade slopes. All typologies are fully integrated to the topography and have the ability to parametrically adjust to the specific conditions of each plot. Trees and natural parks are located in response to preexisting forested areas, low energy potentials and/or requirements for land retention.

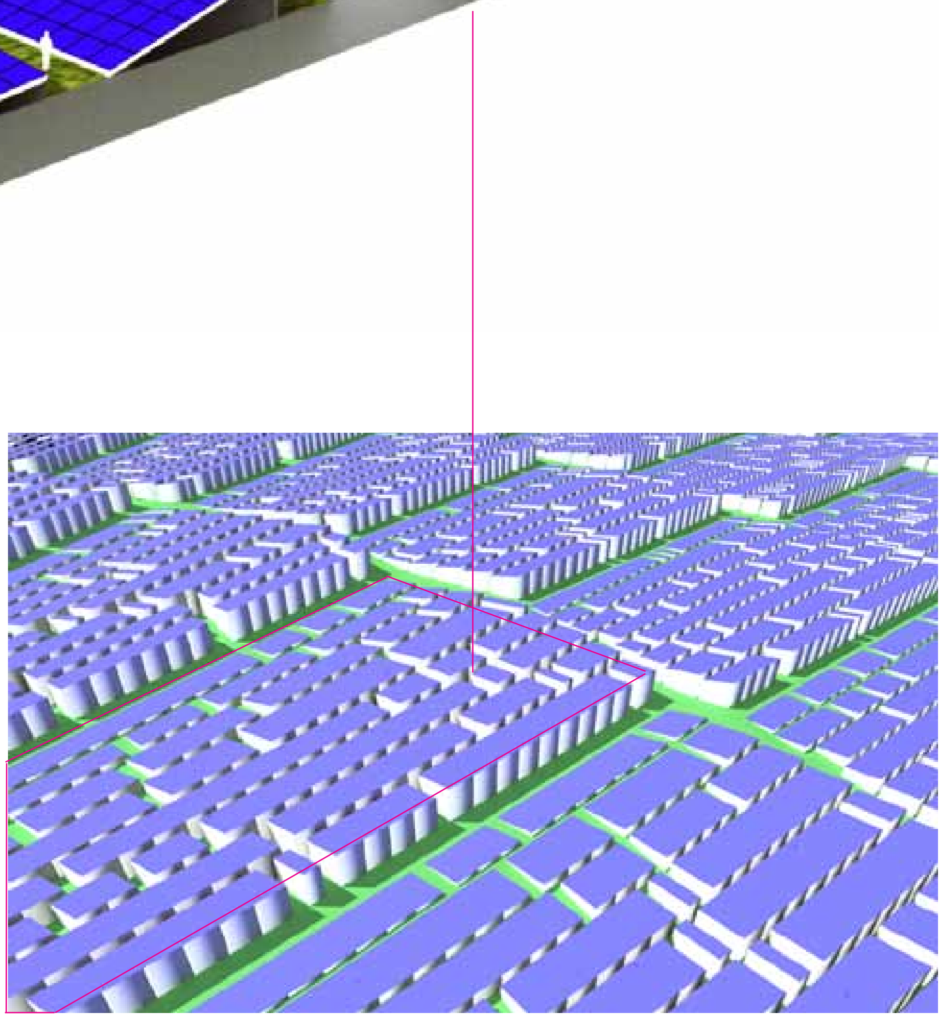


Housing - Typology A

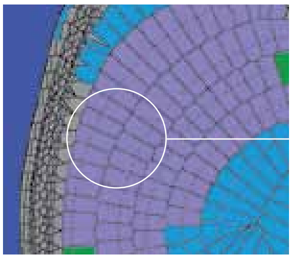
Long plots with relatively flat topography and constant orientation are well suit for photovoltaic fields integrated with low-income row housing. The inclination of roofs and land integrated modules reflects the relative orientation and solar exposure levels of each plot.



Rendering of a Type A housing plot

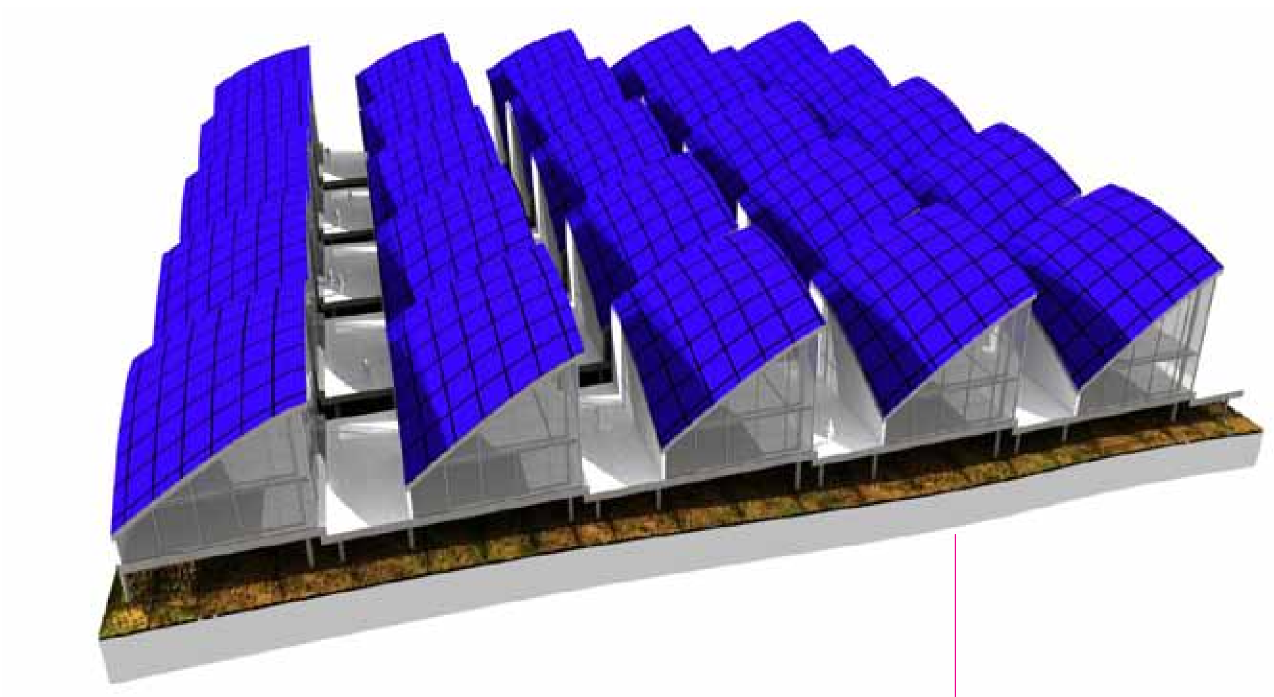


Aerial view of a Type A housing sector

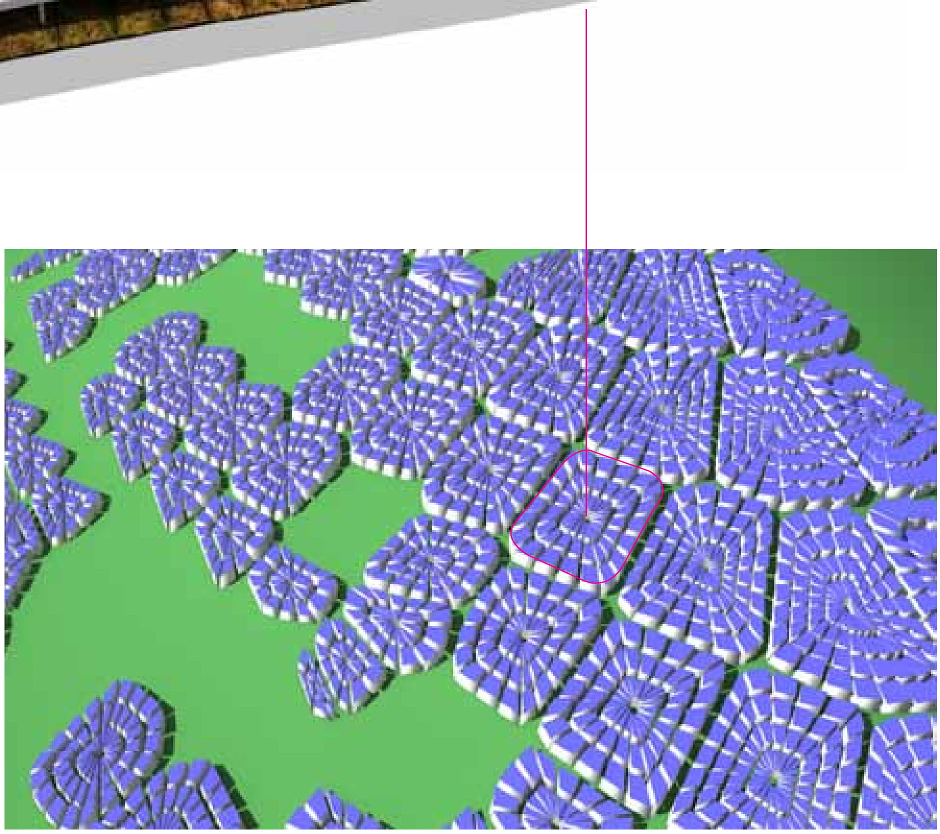


Housing - Typology B

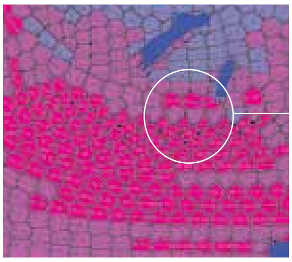
Medium-size plots with low inclination and constant orientation are developed into photovoltaic fields integrated with individual housing units. The development shows a solar declination of “mat” buildings, with a communal plinth - containing parking and protected by retaining walls against floods - and vertical accessibility to individual units from public roads within the podium.



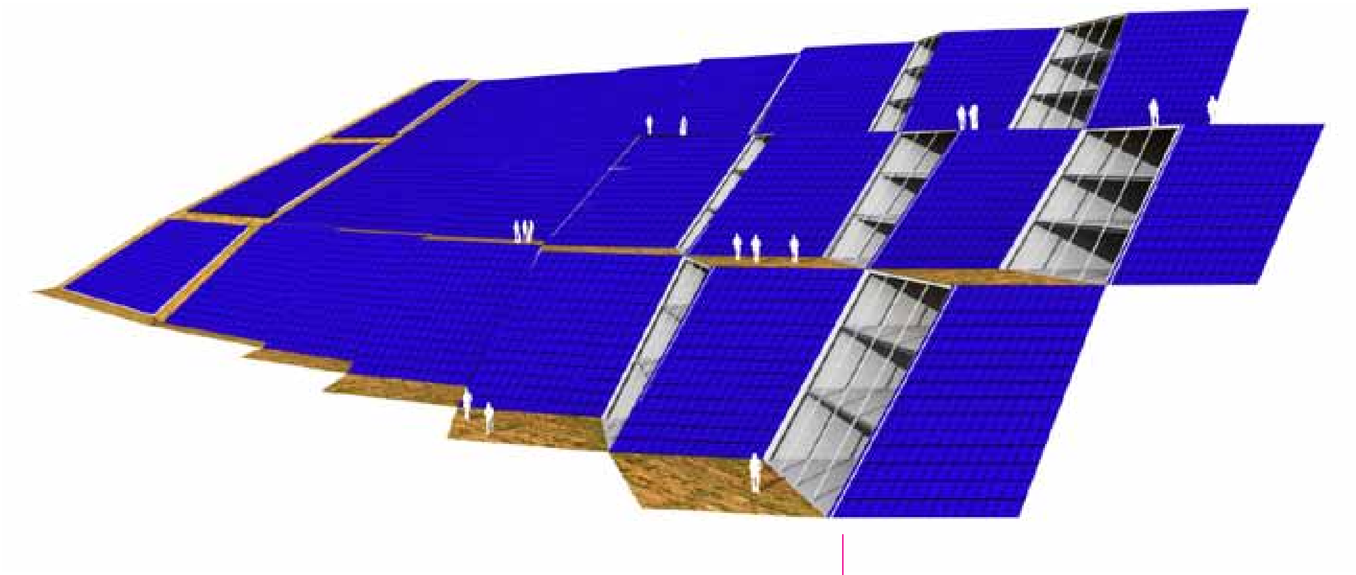
Rendering of a Type B housing plot



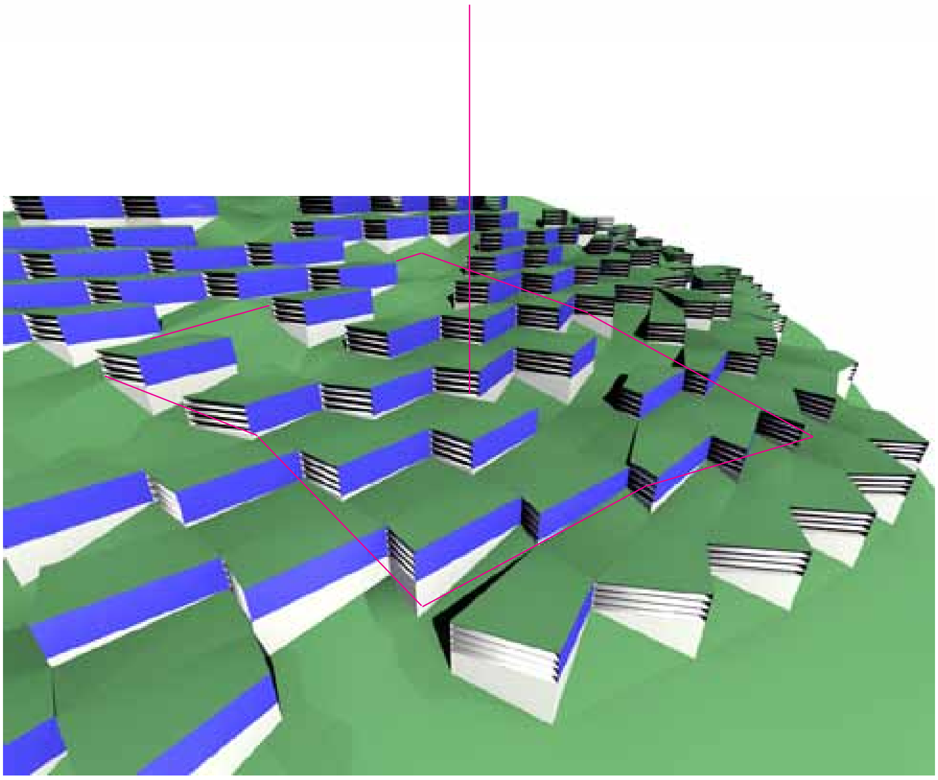
Aerial view of a Type B housing sector



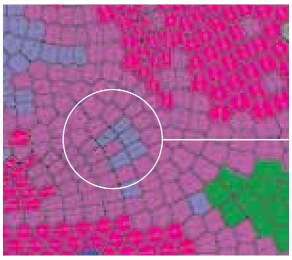
Housing - Typology C
Short plots with high inclination and variable orientation are nested within the slope and feature private gardens and open views toward the water. This typology takes advantage of the land fill construction to achieve full integration with the ground. The relative orientation and solar exposure levels determine each building's footprint and geometry.



Rendering of a Type C housing plot

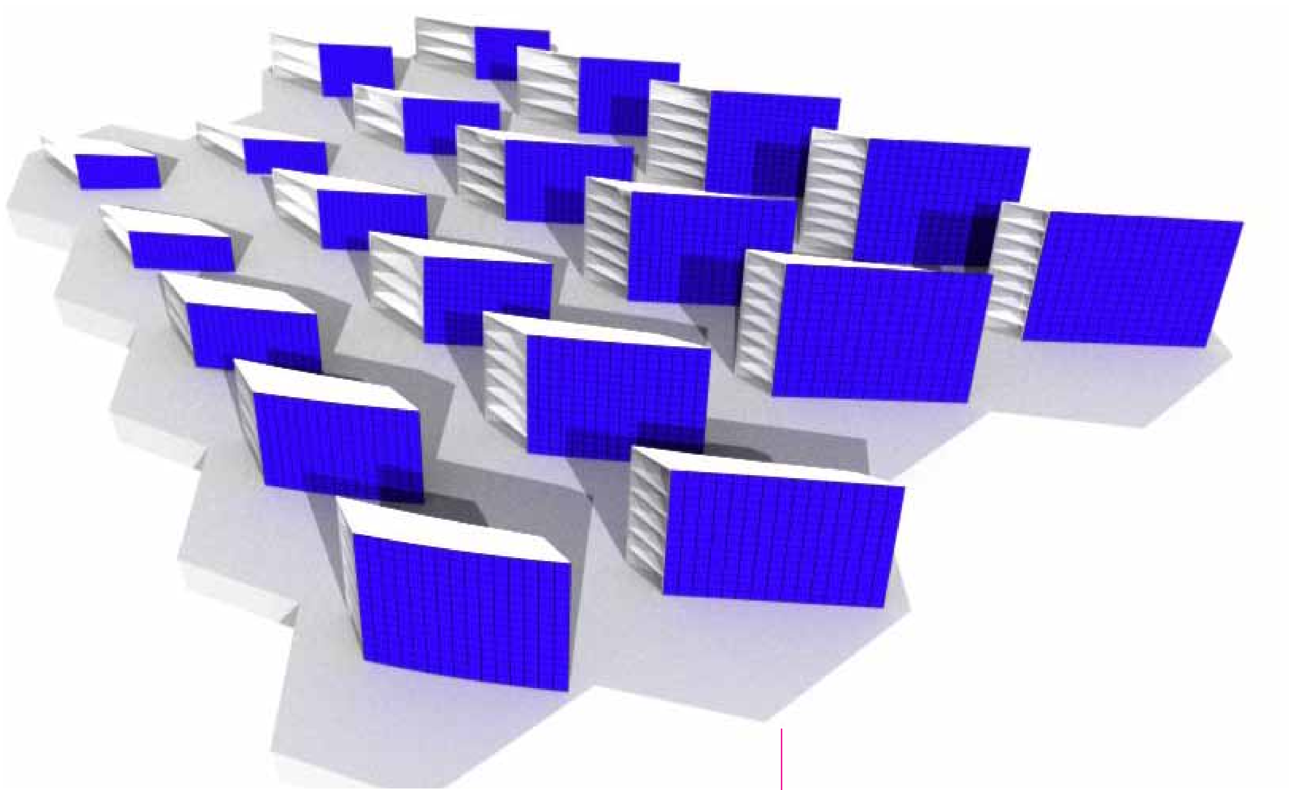


Aerial view of a Type C housing sector

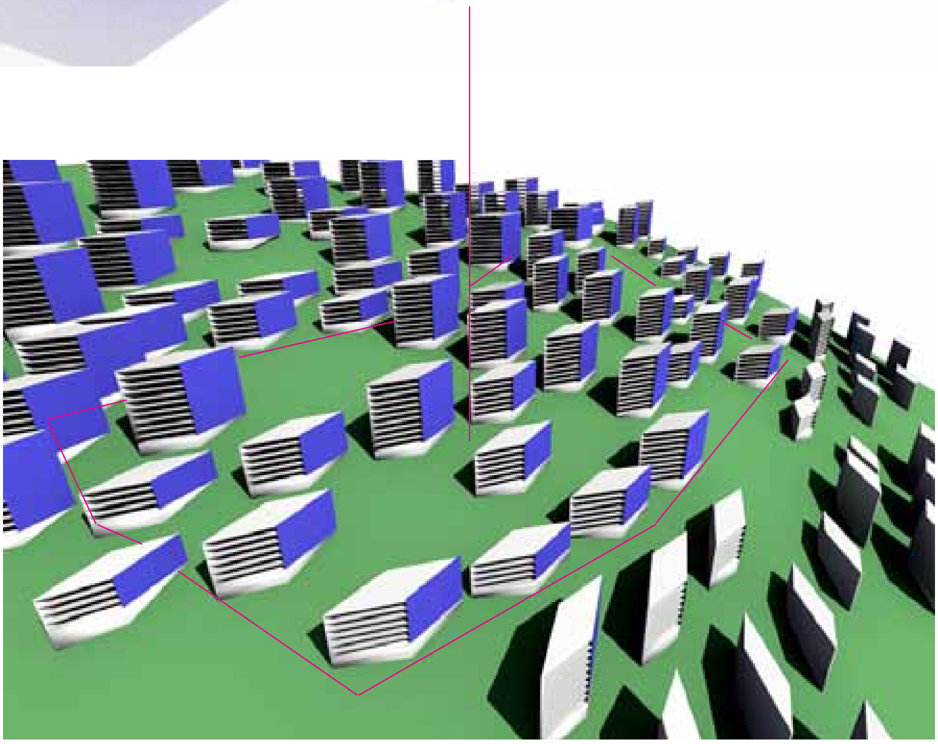


Mix-use Development

Compact plots with medium inclination and constant orientation are developed into photovoltaic fields integrated with mid-rise commercial units. Environmental parameter levels determine the height, the orientation, the footprint, and the spacing between the units, resulting in a lower-density development than previous typologies.



Rendering of a mix-use development plot

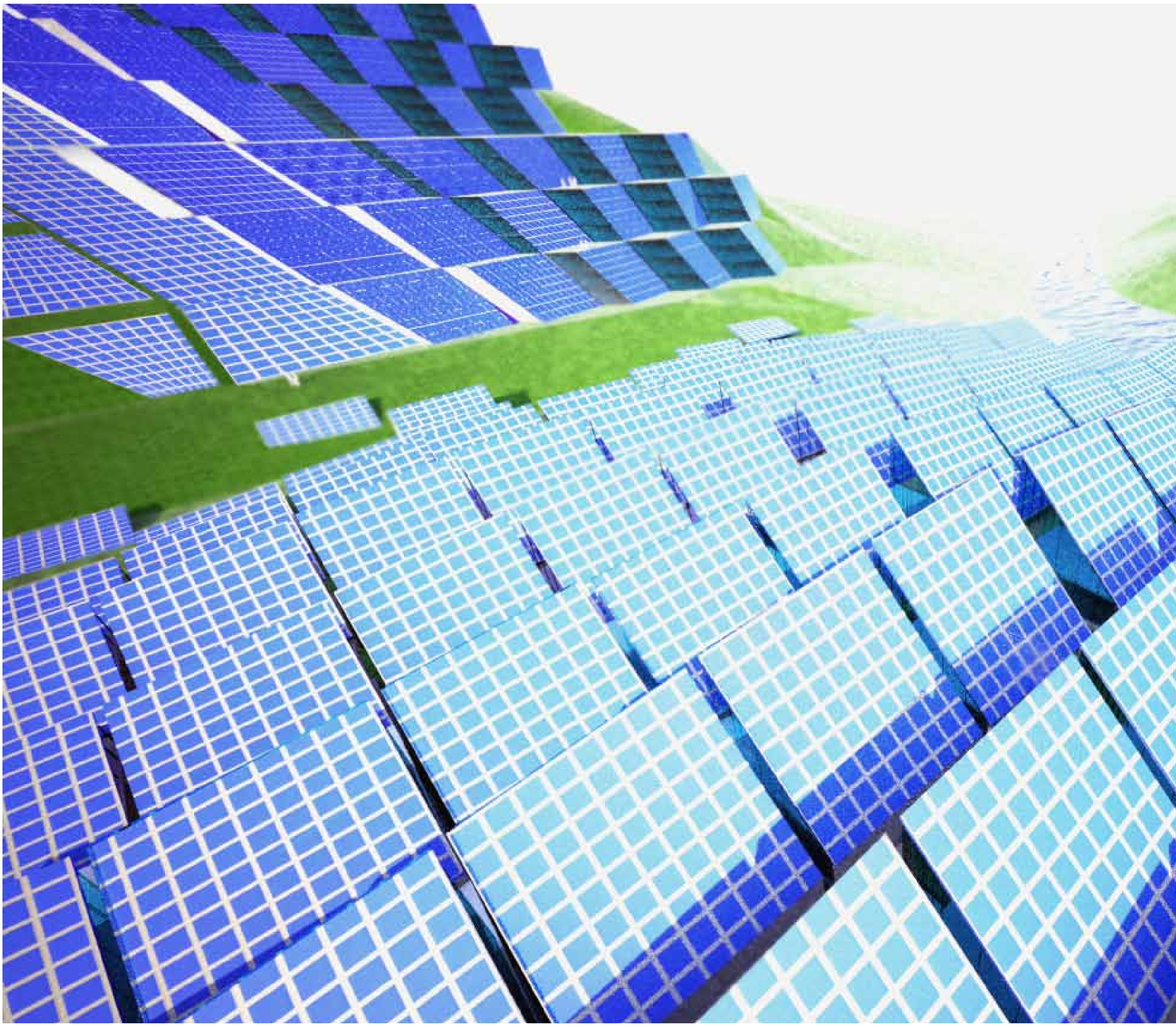


Aerial view of a mix-use development sector

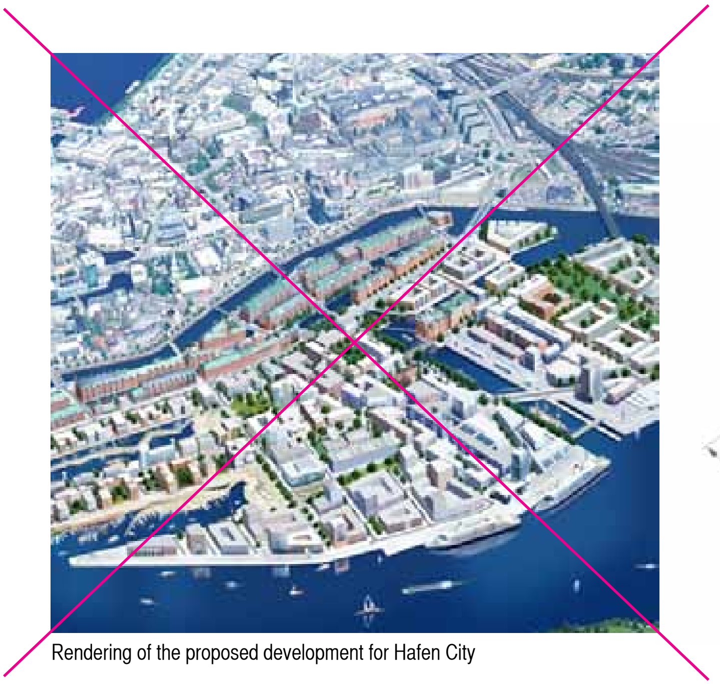
1.6 Design Integration

Solar-driven development

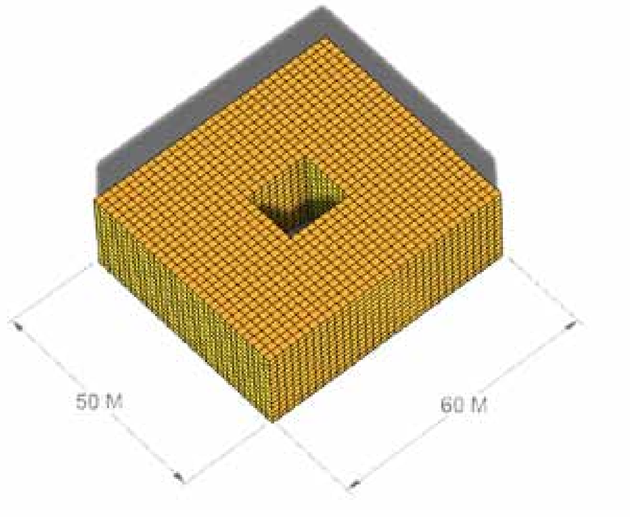
In contrast to current proposals for Hamburg - which follow established models of urban development derived from 19th century planning practice - we propose a new urban model based on energy potentials and other relevant land features. The result is a truly integrated model where solar harvesting systems, living units and the natural environment are part of the solution.

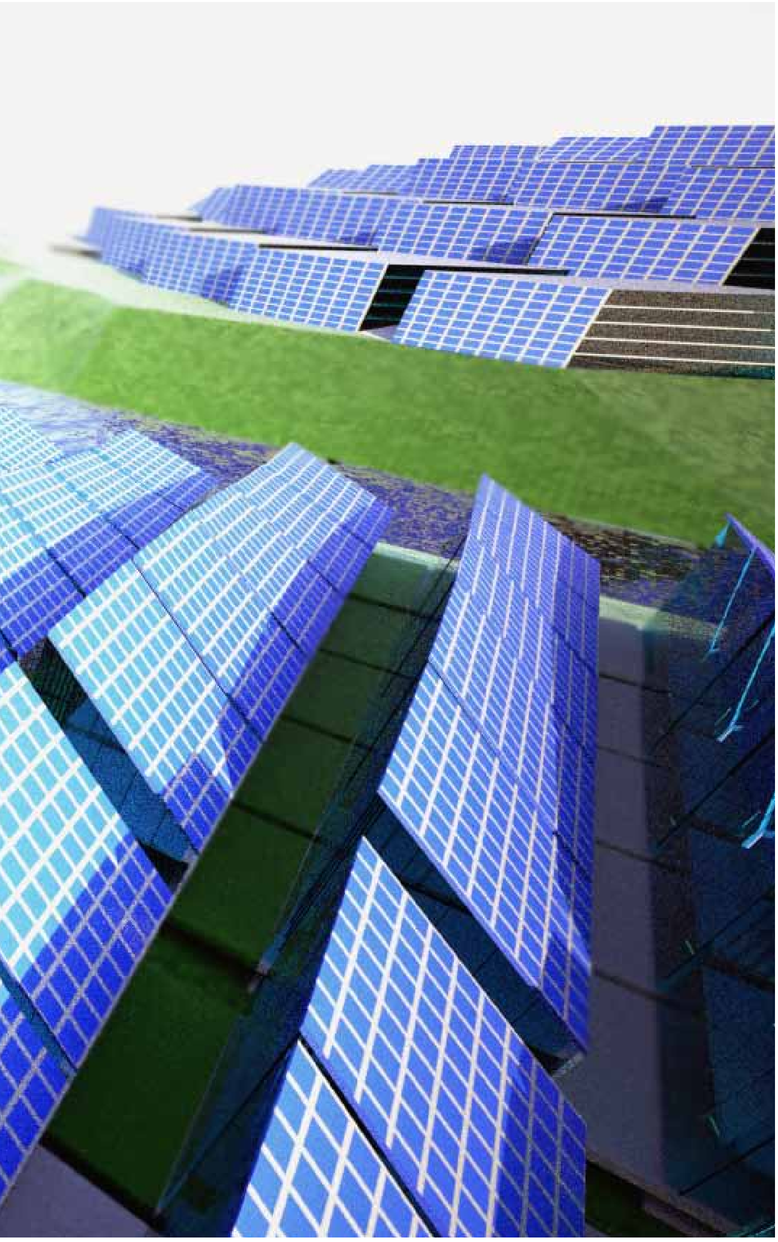


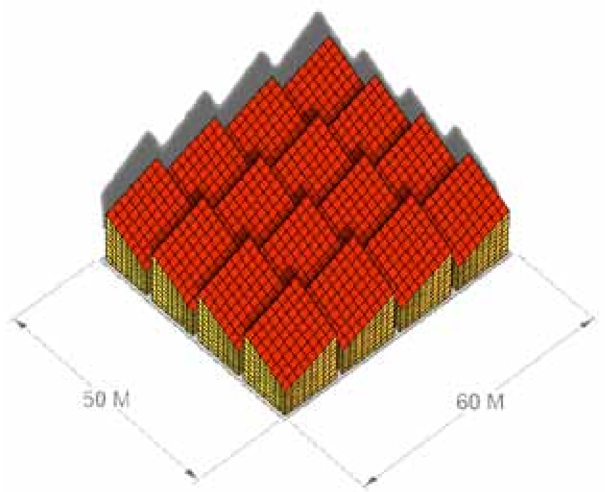
Aerial view of the integrated development



Rendering of the proposed development for Hafen City







Comparative analysis of energy potentials for the two models of developments

2. Almeria, Spain

2.1 Mar de Plastico

Satellite image of Iberian peninsula

Agriculture is a significant user of water resources in Europe, particularly in the south, where irrigation accounts for over 60 per cent of water use in most countries. In Spain, the land cultivated by irrigation in 1999 covered 3.7 million ha, that is, 14.5% of usable agricultural land and 55% of total agricultural production. Irrigation today represents 80% of the total water demand in Spain and nearly 90% of actual water consumption.

Located in Europe's driest desert, Almeria has the greatest concentration of greenhouses in the world: the 'mar de plastico' - or sea of plastic - extends over 22.000 ha in the Campo de Dalias area, producing million of tons of produce for European markets.
Initially fuelled by abundant aquifer water, today the sector is threatened by severe water shortage, resorting to hydroponics, massive desalination and cheap labour in order to remain competitive.

Satellite image of the Campo de Dalias area with 80,000 acres of greenhouse horticulture

Aerial view of the Campo de Dalias

Aerial view of greenhouses besieging a traditional village

Almeria is the epicentre of southern Spain's two billion-euro a year agricultural industry; also, it is at the forefront in pollution of water and aquatic ecosystems, salination of groundwater sources and severe pollution by nutrients, as well as racial segregation of the cheap immigrant labour force and ensuing social unrest.

Boom in Campo de Dalias
Almeria is perhaps the most radical example of landscape transformation in Europe, with its arid, sun-scorched land turned into 80,000 acres of greenhouse horticulture. The two main factors that have determined the explosion of irrigated agricultural production are the favourable climatic conditions and the supply of water.
In the coastal lowland of Campo de Dalias, with an average temperature of 20°C and about 3000 hours of annual sunshine, fruit and vegetables can be grown during the winter months without having to use expensive heating systems as in other places in Europe. This makes cultivation in "invernaderos" (greenhouses) extremely profitable, because the products can fetch high prices on the market. In the winter high season, some 1,000 trucks per day depart from El Ejido. 65 percent of the products are exported to EU countries (source: *A. Ecker; J. Attfield*).
However, water - the catalyst that started the transformation in the first place - has been in short supply for at least the past 2 decades.

Other factors that contributed to the "success" of Almeria includes:

- Spain joined the EU in 1986 and was able to export food products to European markets tariff-free;
- Changes in diet have contributed to an increase in vegetable consumption in Europe, opening windows of opportunities for vegetable growers;
- Greenhouse construction costs are low since many are homemade and all are primarily made of plastic;

Greenhouses, water tanks, housing, swimming pools compete for space in Almeria

Poor road infrastructure serving the greenhouses

View of the mountains to the north

Plastic sheeting becomes an environmental hazard after use

- Innovations in transportation have improved quality and lowered costs in shipping vegetables;
- Government support provided infrastructure, technical advice and sources of funding;
- The accidental discovery of the cultivation technique of sanding and the know-how of the first immigrant farmers with experience in this type of crop;
- A young and abundant workforce, with an enormous capacity for work and low risk aversion, and low labour costs, at about one third of those in the Netherlands.

A history of exploitation

Almeria has long been an area subjected to exploitation of resources either directly by occupying forces or indirectly through global markets: Romans and Moorish already subjected the land to crop and farming techniques previously unknown to Almeria; the demands of international markets have caused unsustainable extraction of resources from the region since.

Today, Almeria's environmental crisis results from a combination of local factors - such as the exploitation of natural resources - and global climatic changes. A sequence of intentional actions and unintended circumstances over the past 40 years created one of the largest horticulture industries worldwide in Europe's driest desert, in a region that used to be the poorest of all Spain's fifty provinces.

Over the years, the combined effect of international markets' demand for produce and the local government's focus on short term advantages resulted in unprecedented environmental degradation: deforestation and habitat destruction, soil erosion, depletion of surface and groundwater, illegal immigrations and social unrest are only a few of the social, economic and environmental crises threatening Almeria's very existence.

Environmental crisis

The province of Almeria is one of the driest regions of Europe and at the same time the most intensively irrigated. In the active regions on the coast, the agricultural industry places enormous pressure on natural water and soil reserves: to supply Campo de Dalias with water, fossil water reserves are currently extracted from a depth of 100 meters; water from the mountains to the north of the region is also fed to the growing areas from the Beninar Dam. The water supply deficiency amounts to some 50 hm^3 per year.

Today, to avoid placing an even greater burden on the groundwater reserves, the irrigation water is collected, recycled and reused. Purified sewage water and desalinated seawater processed in the desalination plant near Balerma reduces the consumption of groundwater, however, they require a disproportionate amount of electricity.


Discarded plastic lies at the edge of the road


Makeshift housing for the labour force


Four of the over 140.000 immigrant workers

Specialized crops require intensive fertilization and also need large quantities of agro-chemicals, causing pollution of water and aquatic ecosystems from nutrients and pesticides. Pesticide runoff into the soil and washing out into the groundwater increasingly result in damage to the quality of the groundwater. Cultivation in monoculture and the warm and moist climatic conditions in the greenhouses favour attacks by pests and mould. In addition, substantial volumes of pesticides also find their way into the groundwater from "*solarisacion*", disinfection of the soil with the aid of sunshine (source: *A. Ecker; J. Attfield*).

Irrigation also increased the rate of erosion of cultivated soils on slopes, leading to a deterioration in water quality downstream, due to silting. This leads to the subsequent desertification of some arid areas with light and erosion-prone soils, particularly on steep slopes.

Lowering of the groundwater table led to salination of water and land and contamination by minerals of groundwater sources. This is due to saltwater intrusion, as irrigated land is near to the coast, and to over-saturation and concentration of salts in the topsoils of irrigated land due to the increased circulation of water through them.

The area is also a hub for cheap immigrant labour and racial segregation, with as many as 140.000 immigrant workers doing back-breaking work under clear plastic sheets in 45 degrees for eight hours a day. Unsurprisingly, the labour market has been filled by many migrant workers from sub-Saharan Africa, Morocco and Eastern Europe.

Weaving a new land morphology

We argue that any remediation effort must re-establish a sustainable water management regime by a combination of collection and conservation measures, efficient irrigation systems, and the use of wind and solar energy to power water purification and desalination plants. Considering that the vast majority of existing greenhouses were built without any planning - in fact, the new structures mostly follow the preexisting agricultural land division - that water infrastructure is nonexisting and that transportation infrastructure is merely an afterthought, we believe that a radical re-configuration of land parcels is the necessary measure towards a rational approach to production and efficient use of resources. Moreover, the greenhouses are made with cheap, polluting materials, they use unsafe structural framing, and create unhealthy environmental conditions for the workers. We seek ways to implement the gradual replacement of the entire stock with efficient, prefabricated new structures.

Satellite image of site 1

Site Option 1

The first potential site presents all relevant conditions within a relatively small area: mountains, a flat area with a concentration of greenhouses, a man-made lagoon, main vehicular infrastructure, intermittent streams and coastline compressed within a 300-meter fascia west of the main Campo de Dalias.

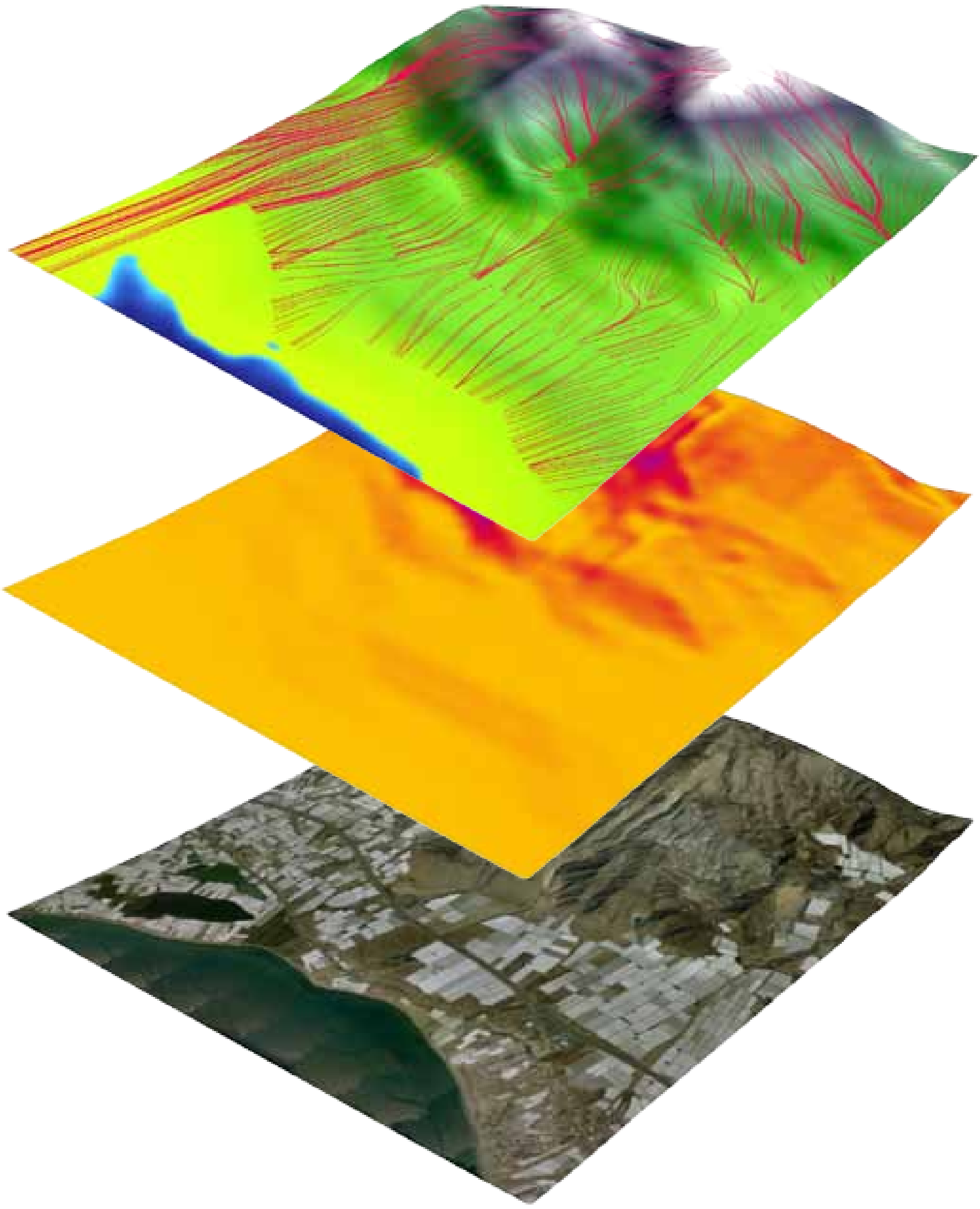
The site is particularly interesting for its network of water channels meandering throughout the flat area - following the logic of gravity, but also the politics of prevailing landowners - and water tanks dotting the landscape.

A preliminary simulation of water flow lines shows an emergent logic of tessellation that is unaffected by the inefficiencies of water politics, preexisting property lines and historic stratification.

Water flow lines

Slope gradient

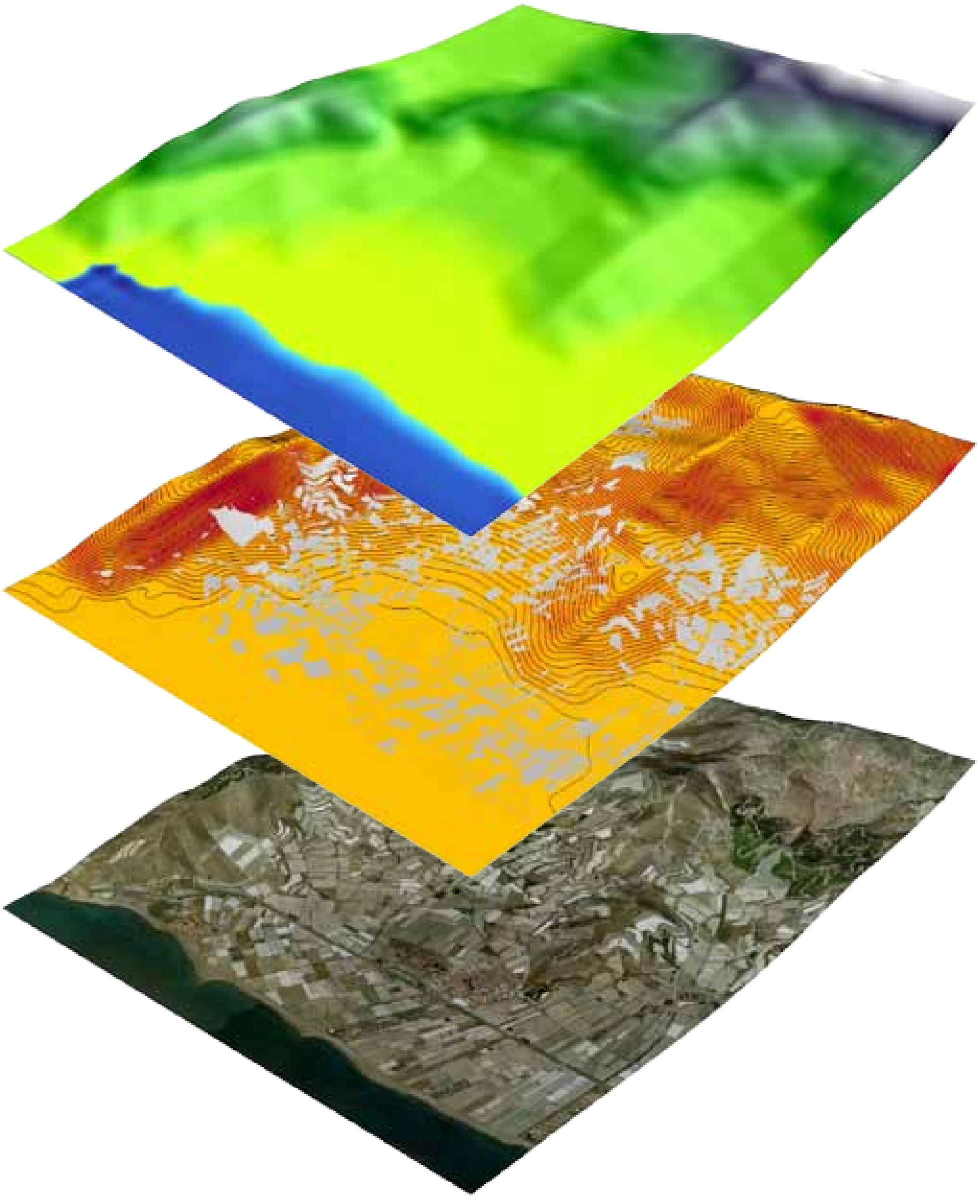
3D satellite image



Satellite image of site 2

Site Option 2

The second potential site presents an unusual morphology with greenhouses placed on severe gradient, adapting in shape to the contour lines and nesting within a terraced landscape. A comparative analysis shows the strict correlation between slope gradient and buildings' footprint, with increasingly narrow lots on steeper slopes; the comparative map also shows a few notable exceptions, where deeper buildings are set against a steep gradient, requiring massive excavation and ultimately resulting in highly visible eyesores within a relatively integrated landscape.



Terrain model

Slope vs. Buildings

3D satellite image

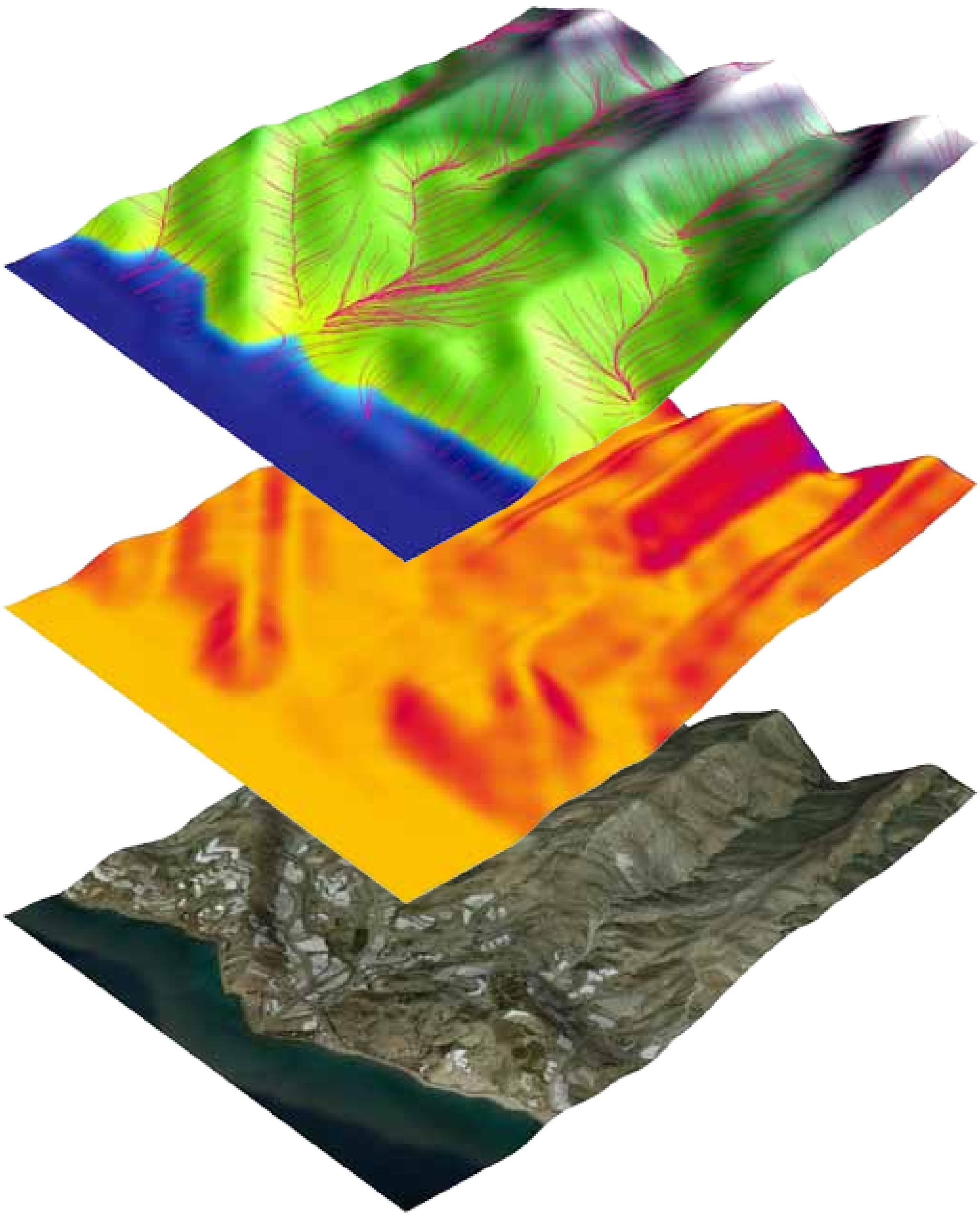

Satellite image of site 3

Site Option 3
In the third potential site, mountains extend almost to the sea, presenting deep valleys widening toward the coast line, with intermittent streams weaving between a constellation of greenhouses, residential building and the network of roads. Here water flow lines are well established and predictable, shaping property lots to adapt to the meandering streams, and occasionally inundating the floodplains and forcing the greenhouses to relocate.

Water flow lines

Slope gradient

3D satellite image

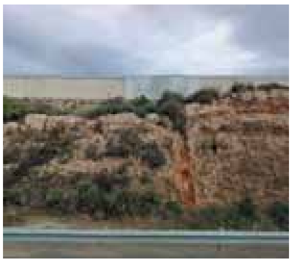


Satellite


03


05


Street View 01


02


03


05


Satellite 06


07


Street View 06


08


09

Satellite


12


Street View 10


11


12


13

Site Plan - Option 1

Street View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Satellite


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Street View


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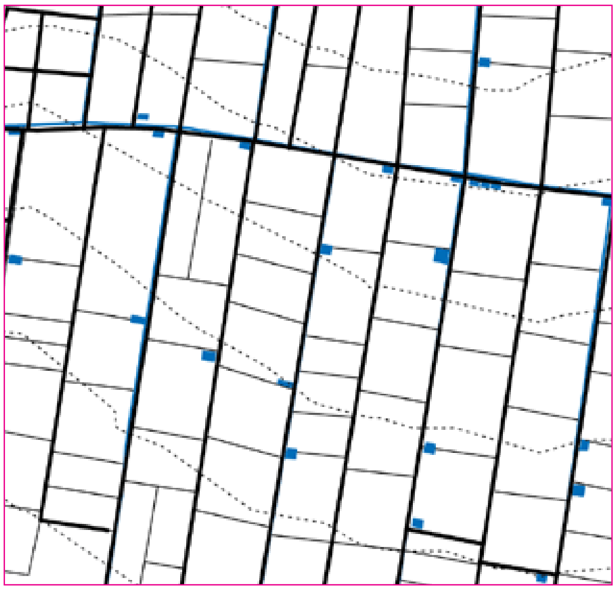
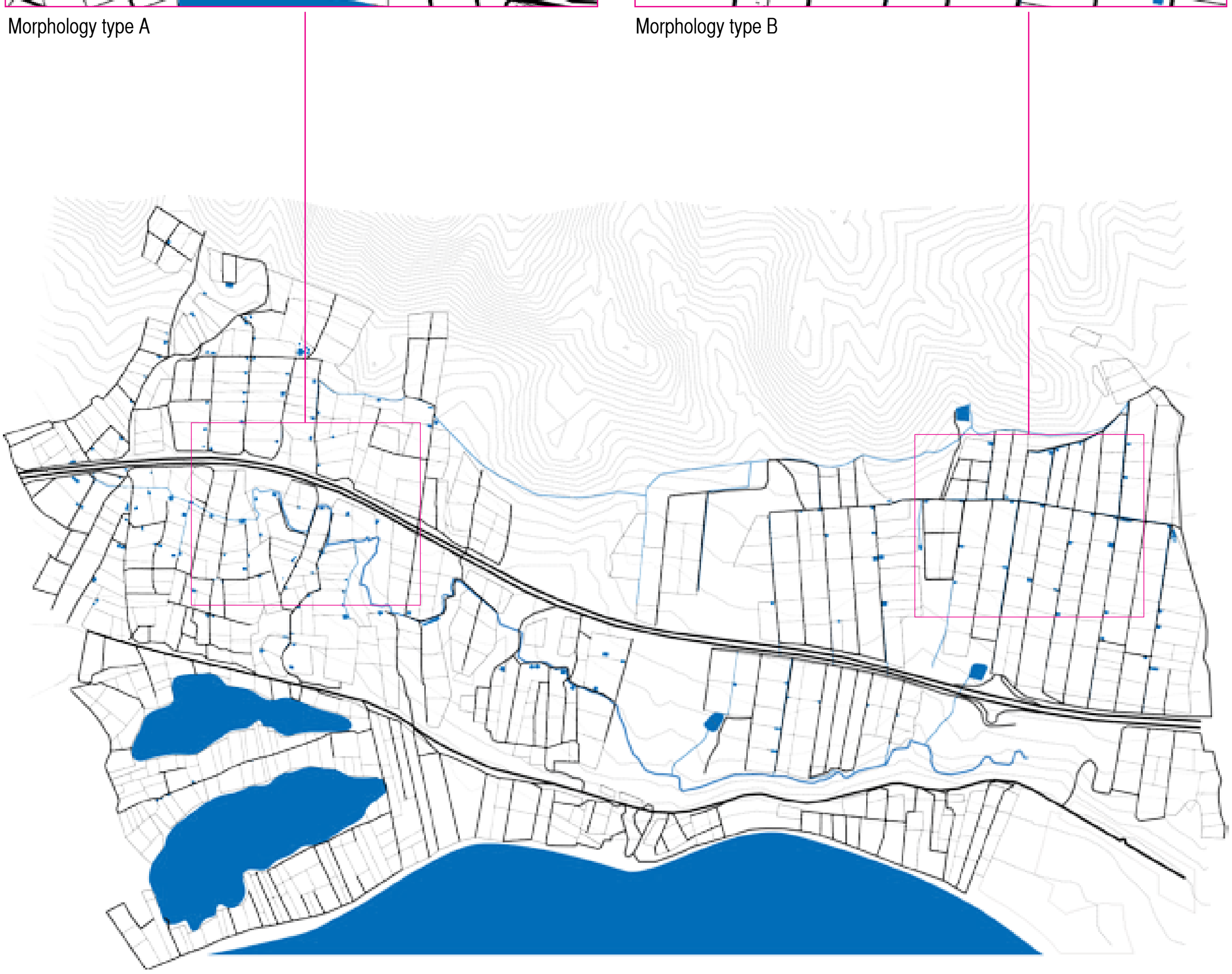
21

2.2 Site Analysis

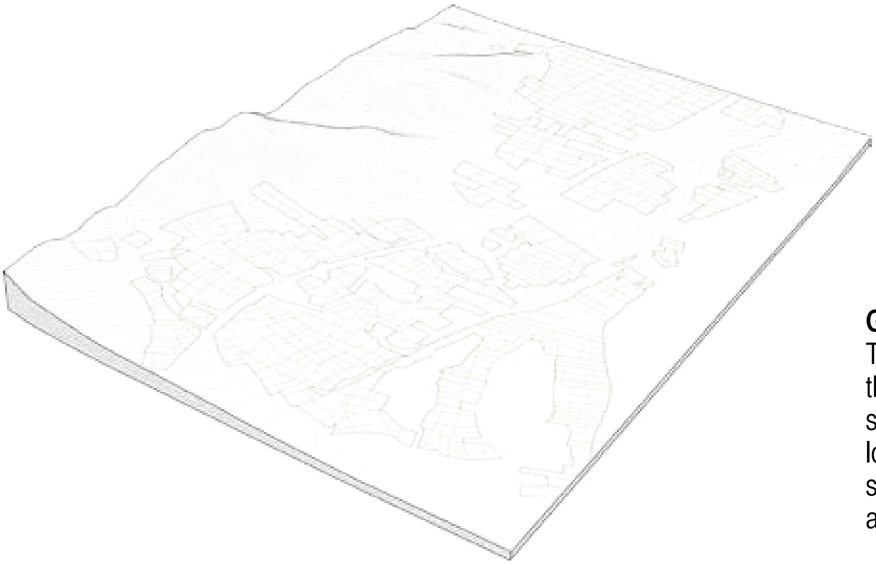
Morphology type A



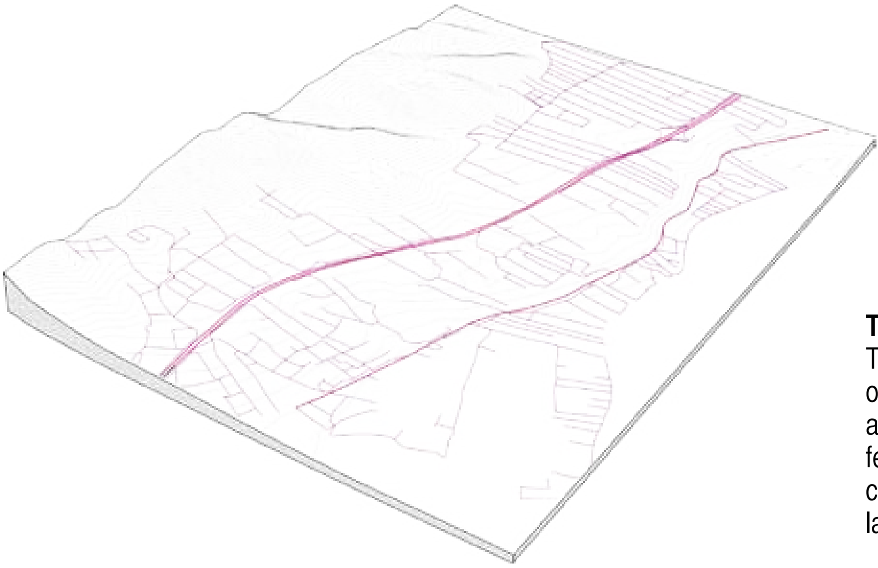
Morphology type B



Morphology analysis identifying main infrastructure components

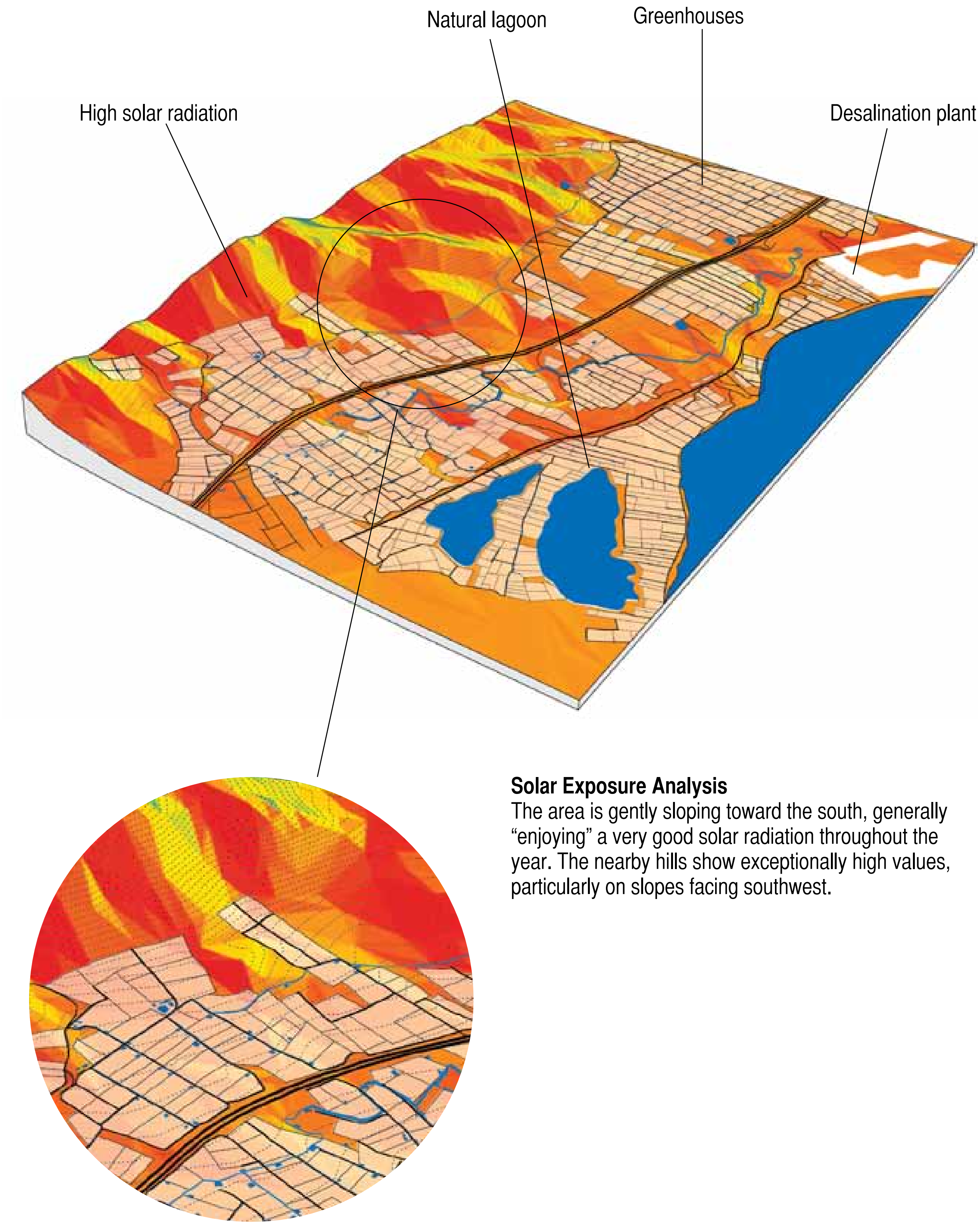


Greenhouses
The layout of greenhouses follows the preexisting agricultural field structure; the reduced size of the lots reflects the family economy scale that characterized agricultural activity in the area before the 1960s.

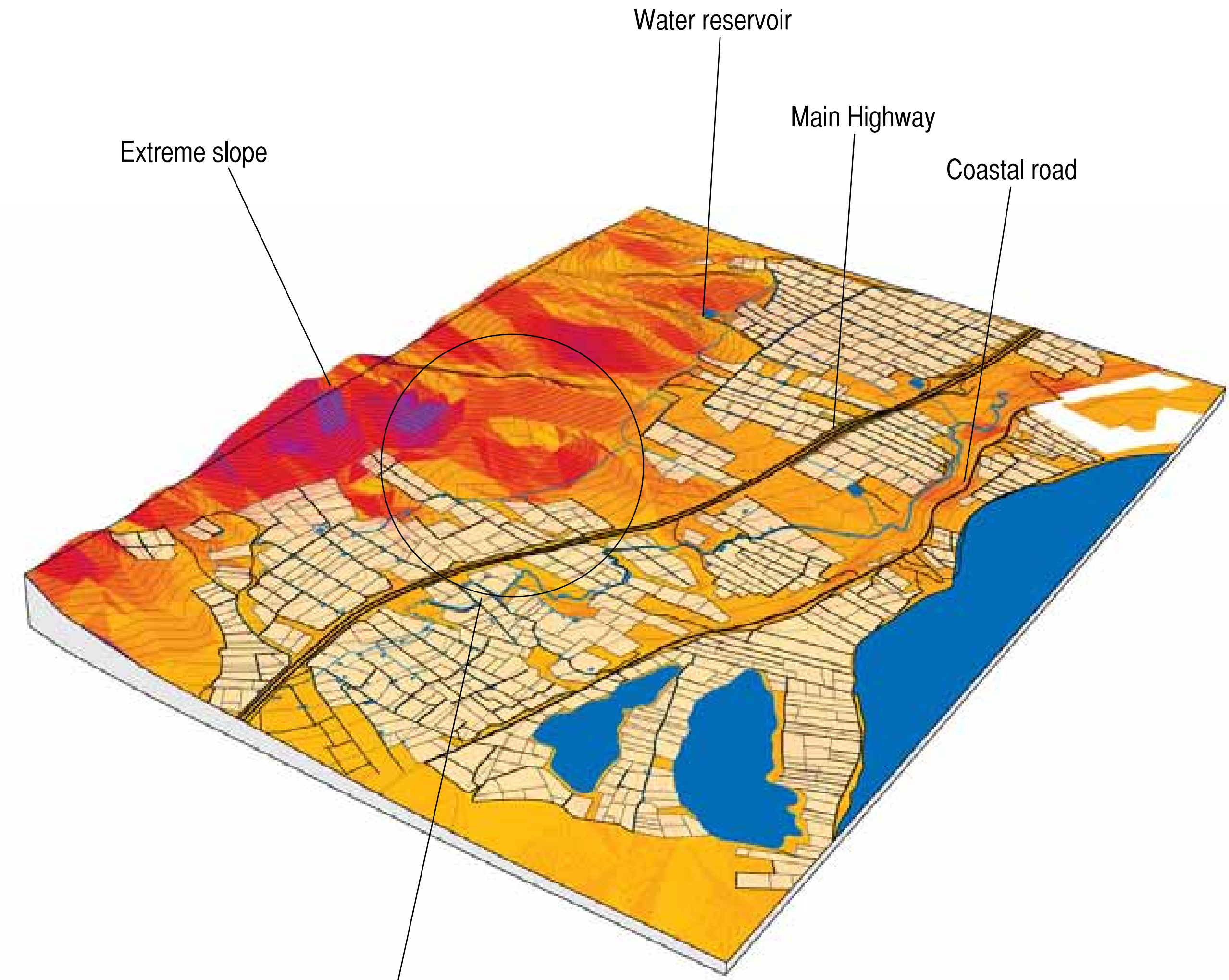


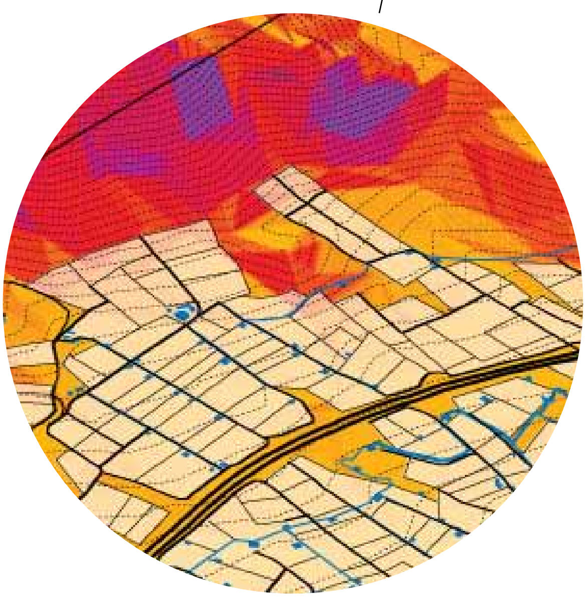
Transportation
The vehicular infrastructure consist of a network of local roads without apparent hierarchical order and with few connections to the highway crossing the area; many are just large enough for a truck to pass.

Water System
Canals running parallel to the coast-line and the present irrigation system are currently used for replenishing the local water tanks associated to individual greenhouses with fresh water.



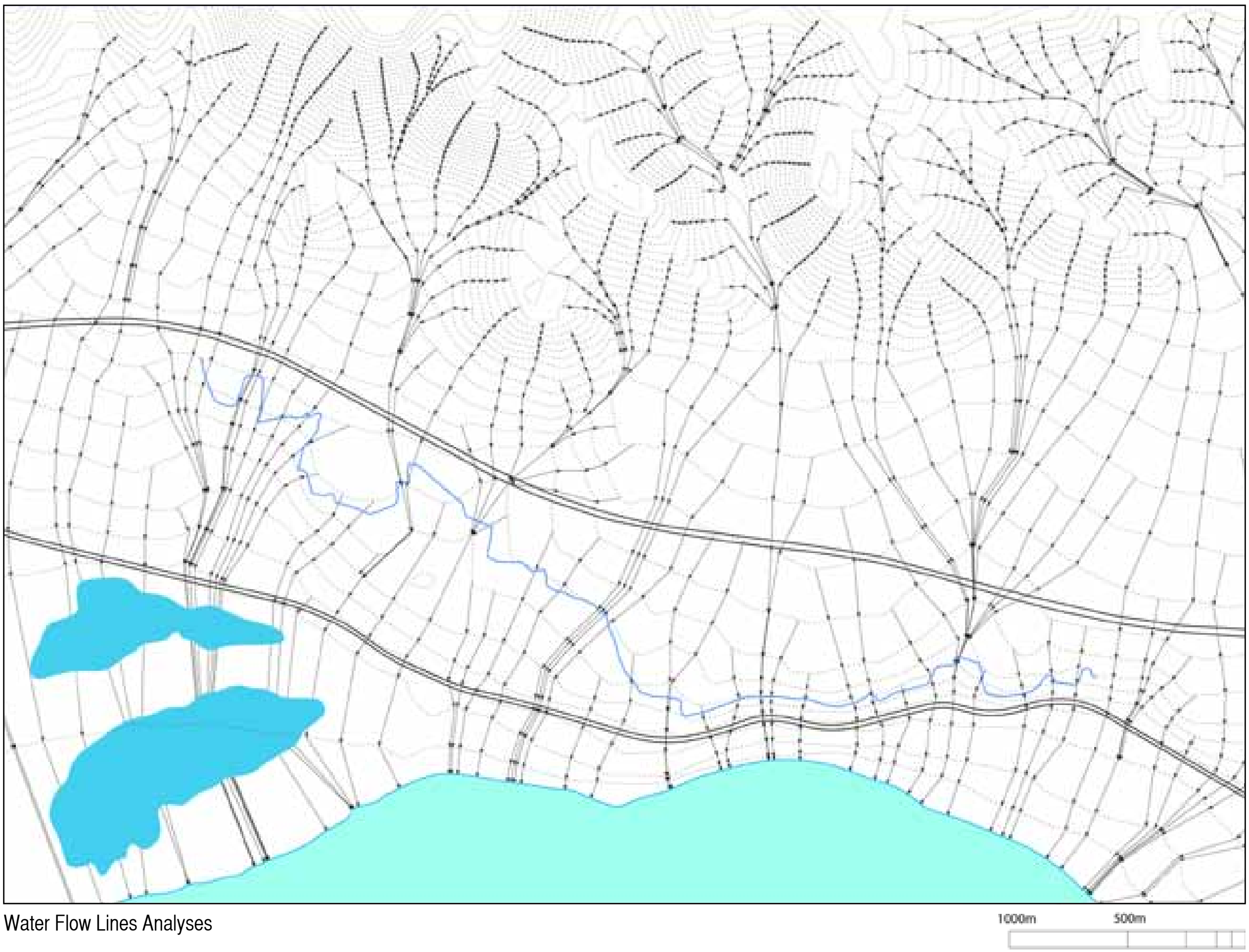
Solar Exposure Analysis
The area is gently sloping toward the south, generally "enjoying" a very good solar radiation throughout the year. The nearby hills show exceptionally high values, particularly on slopes facing southwest.





Topography Analysis
The very rudimental greenhouse construction is based on a structural frame unable to take the lateral load generated by tilted foundations; hence the almost total absence of greenhouses on the slopes surrounding the main Campo de Dalias area. The topography also reveals a natural correlation between gradient, water streams and canals, and geometry of the greenhouses' footprint.

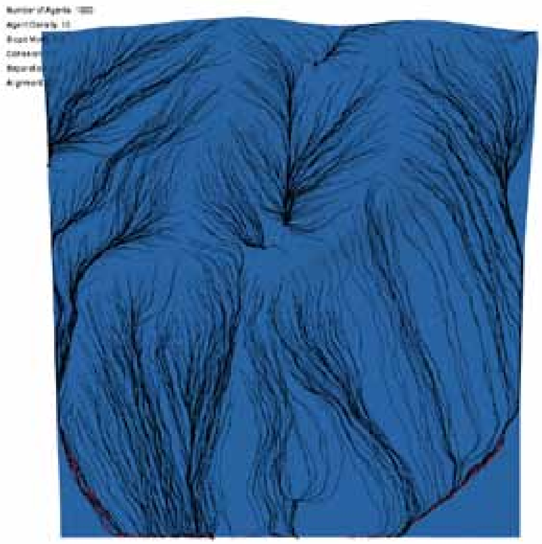
2.3 Tessellation Strategy



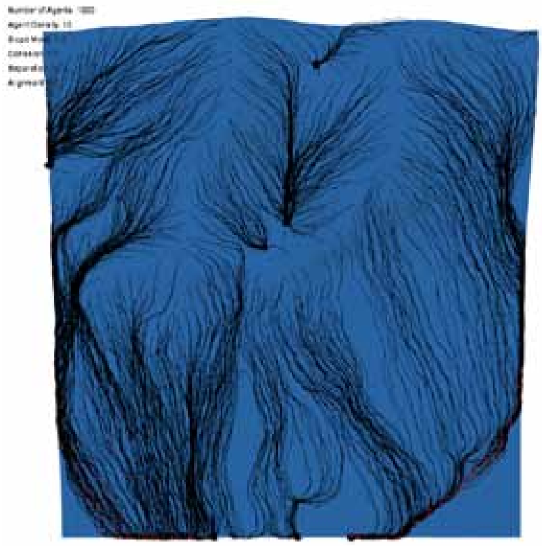
Water Flow Lines Analyses

Simulation Of Water Flow Lines

The main tessellation logic is derived from a simulation of water flow lines, using agents over an accurate 3D topographic model of the area; a set of parameters - water quantity, attraction capacity, reaction to gradient, etc. - are tested in different configurations to arrive to an optimal distribution of water lines.



Iteration 01

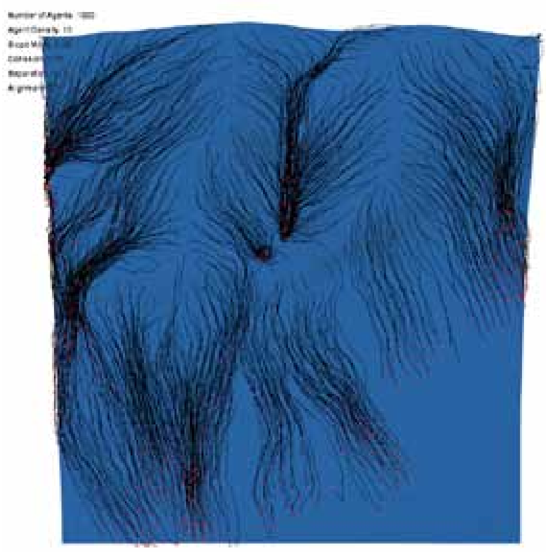


Iteration 02

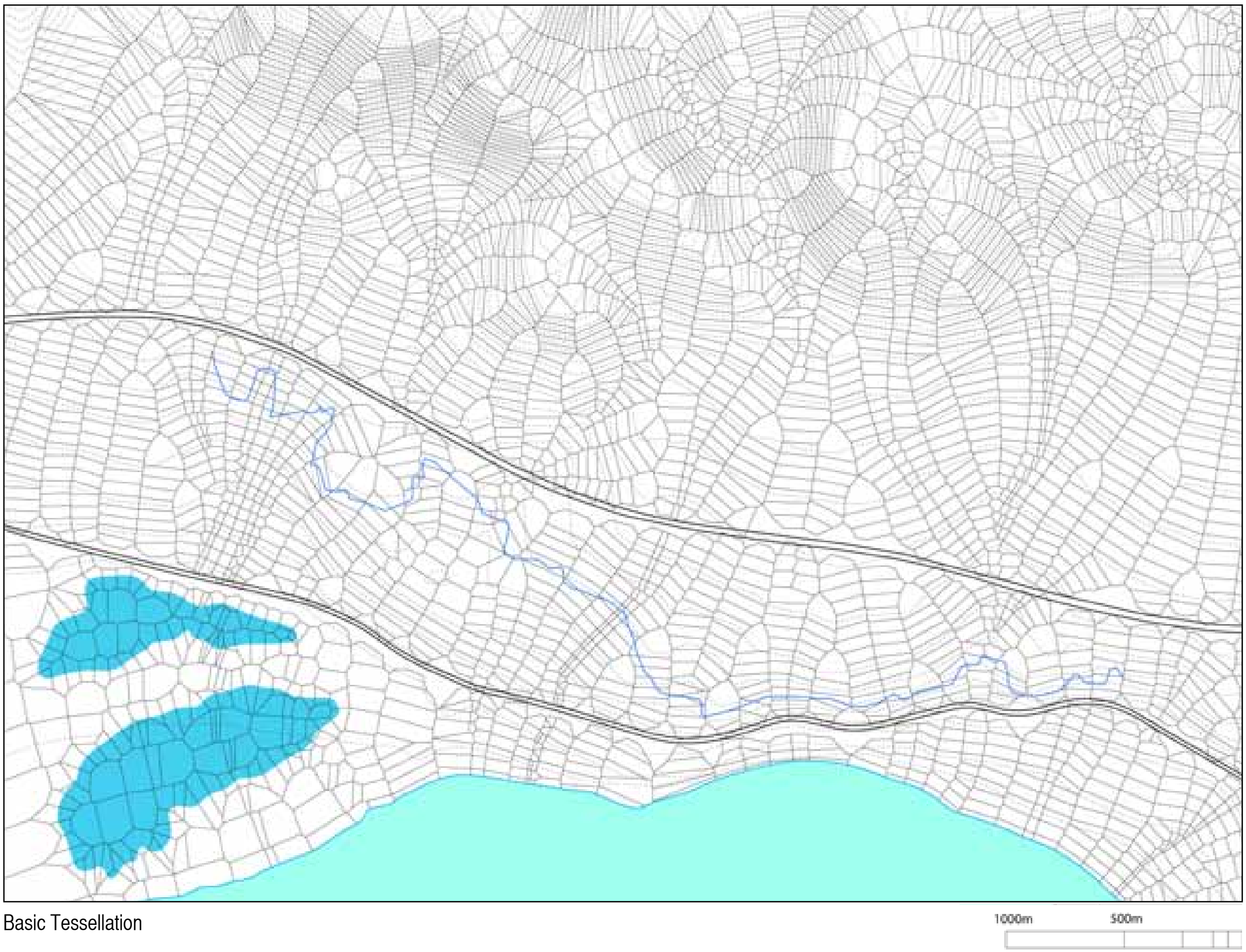
Iteration 03

Iteration 04

Iteration 05



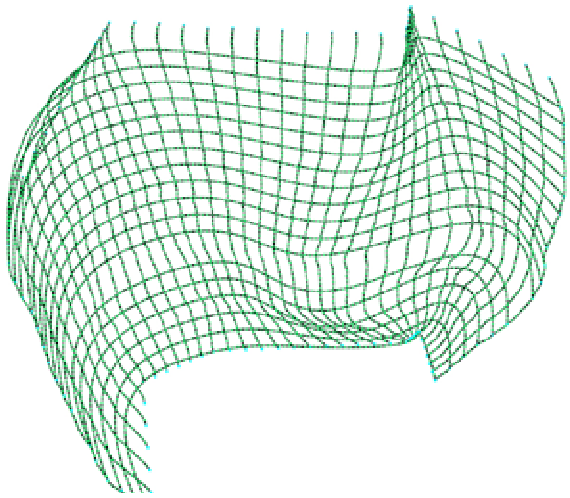
Iteration 06



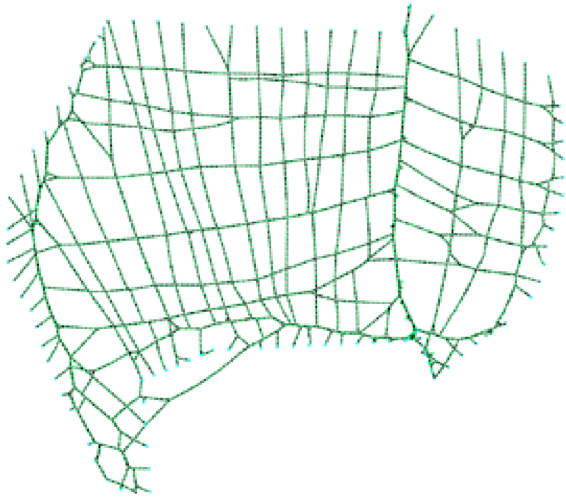
Basic Tessellation

System Path Optimization

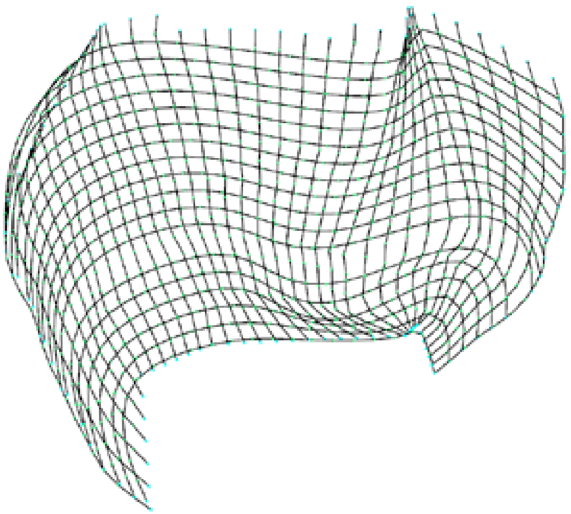
In the next step of the process, water flow lines become attractors with the ability to bundle up to form a consolidated mesh of connectors parallel to the coastline - to guarantee connectivity across the region - and perpendicular to the gradient, providing water distribution to the lots. The size and shape of the regions is determined by parameters associated to the attractors and calibrated to obtain a tessellation that is appropriate to the existing modes of agricultural activity, property structure, water distribution and transportation infrastructure.



Iteration 01



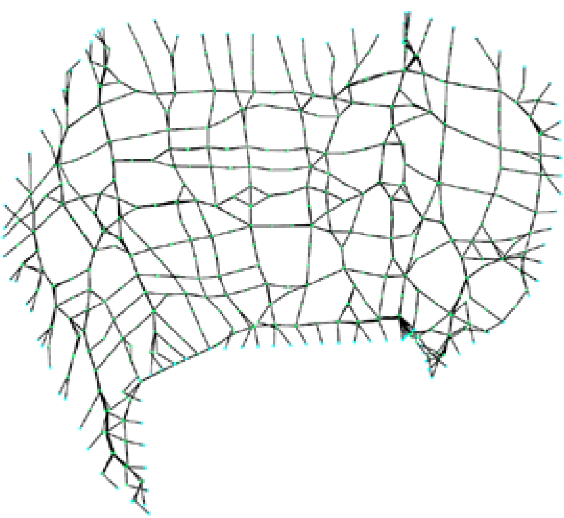
Iteration 02



Iteration 03

Iteration 04

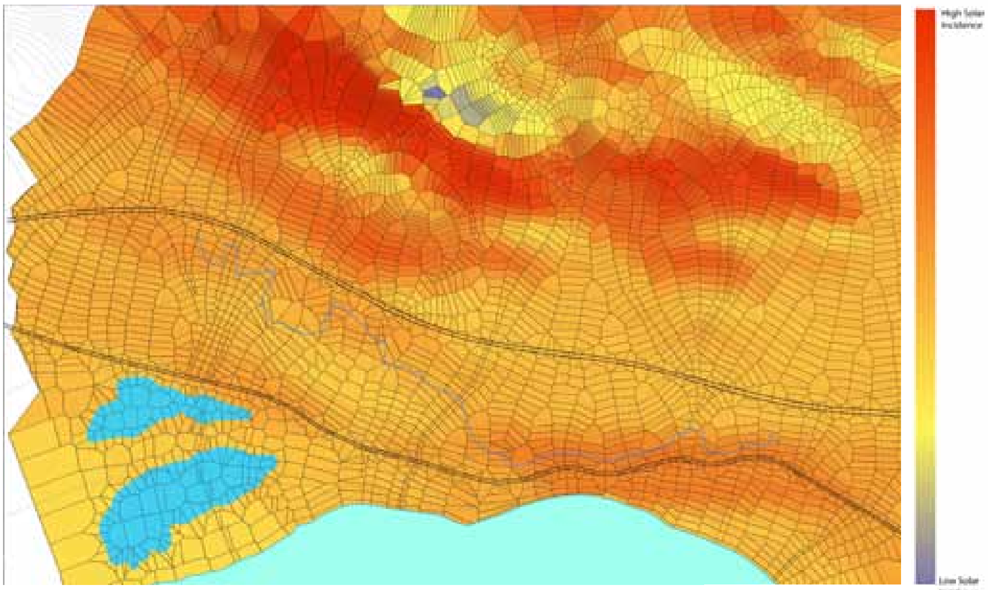
Iteration 05



Iteration 06

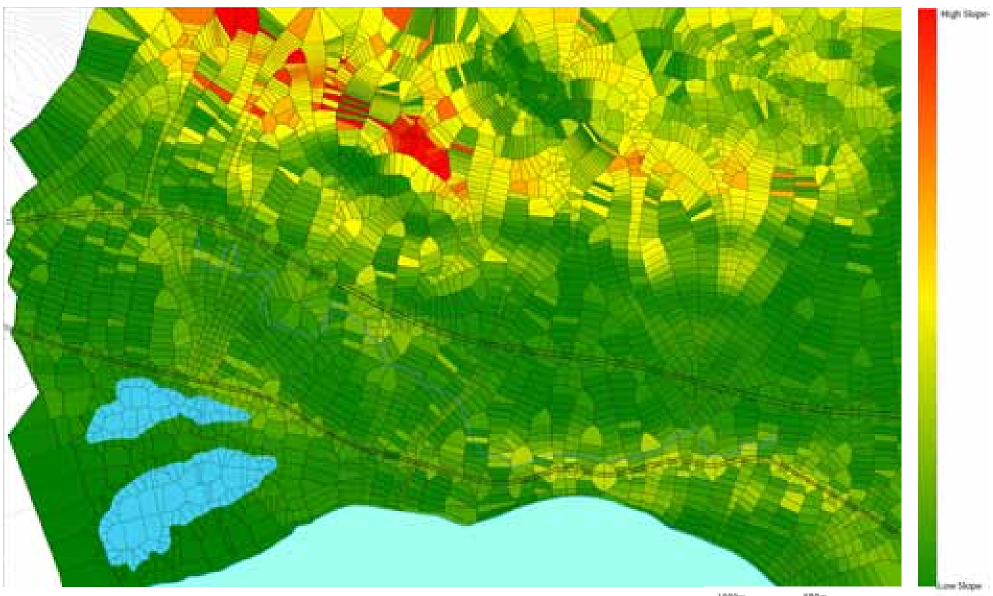
2.4 Environmental Analysis

Solar analysis
The south-facing plane has generally high levels of sun exposure, with areas of intense solar radiation on the slopes surrounding the low plain; currently, these areas are not used for greenhouses, offering a great opportunity to extend irrigated farming to areas that are potentially supported by solar energy.



Solar Exposure

Slope Analysis
The map of the topography showcases an obvious correlation with the solar exposure map, providing complementary information and qualifying the gradient of each tassel, so that appropriate typologies can be associated to specific slope inclination.
It also visualizes the threshold for lots that are not suitable for construction, due to excessive costs for excavation (red in the map).



Topography Slope

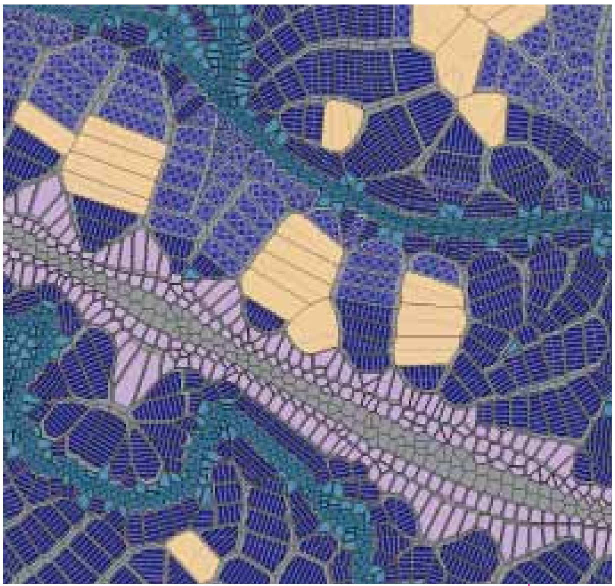
Tessellation Size
The size of lots mostly serves as control tool in fine-tuning the tessellation algorithm; lots that are too small or too large are subsequently redivided to fit a size range that is appropriate to the type of ownership and production economy in the area.

Tessellation Size

Land Use
Lots that fall within the boundaries of existing productive units are mostly allocated to new greenhouses; whenever possible, existing land uses are maintained, so as to avoid unnecessary opposition by present landowners to the new plan.

Land Use

2.5 Population and Typology Allocation



Sample area

Typologies Propagation
Based on the combination of particular features identified by the previous analysis, specific greenhouse typologies and land uses are associated to each parcel. Solar irradiation, slope inclination, existing land use, size, and water drainage define the most appropriate use for the lots. Specific typologies are developed based on these features, including:

A **Low slope / medium solar**
Areas with larger greenhouses, including urban parcels with dwellings and public properties

B **Medium slope / variable solar**
Areas with variable solar potential and moderate slope

C **High slope / high solar**
Areas with high solar potential and steep slope

Typologies Propagation

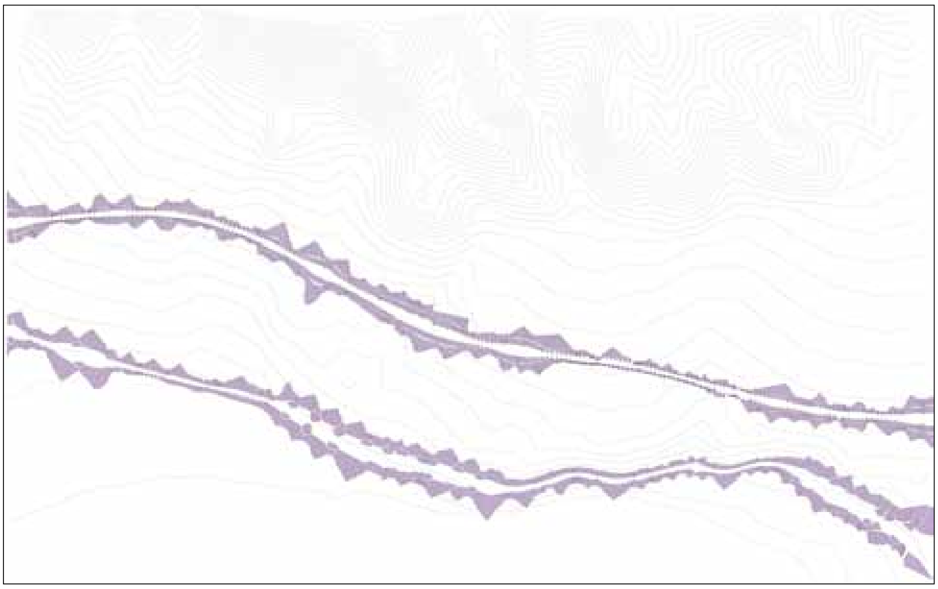
Typology A and B
The large majority of greenhouses are on low and medium slopes, where solar potential is generally good; the moderate gradient allows for larger footprints, while the morphology of the area is characterized by a regular network of water streams and adjacent road infrastructure.


Typology A and B

Typology C
The steepest slopes north of Campo di Dalia have the highest solar potential; greenhouses are integrated with the ground , following the traditional model of terraced farming. Greenhouse footprint is more compact and tend to adjust to contour lines, resulting in a more articulated and stratified morphology.


Typology C

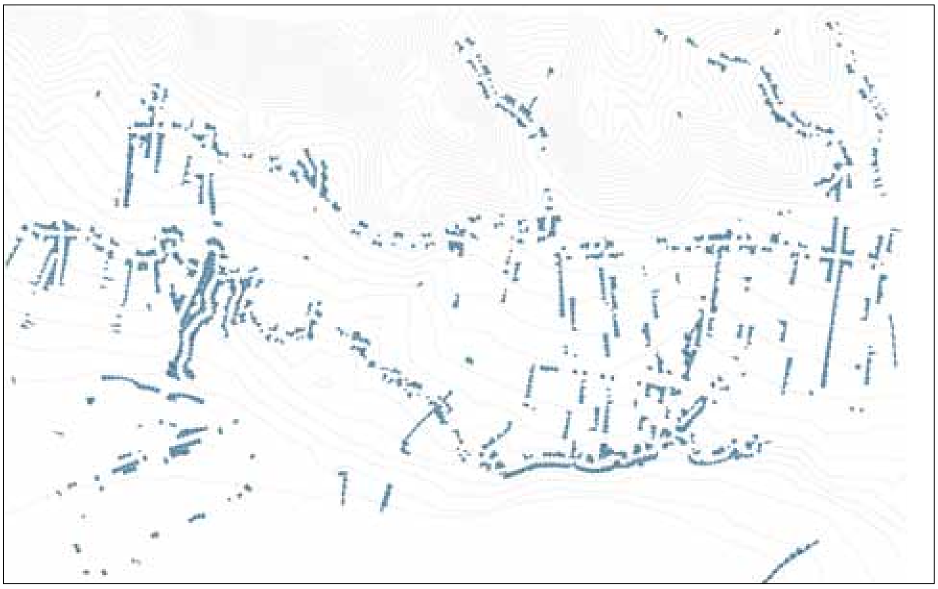
Urban Parcels
Greenhouses intersecting main transportation infrastructure - namely the existing highway and the coastal road - produce an urban edge condition where additional programmatic elements, such as social and public services, dwelling and supporting activities - are located.


Urban Parcels

Open Land
Areas with unsuitable conditions for either irrigated farming or solar energy production are left empty; this is the case of a very few parcels with special uses on the plain and some of the parcels on steeper terrain.

Open land

Reservoir
Water tanks are distributed along the new water lines and connect to the existing water supply system traversing the area.

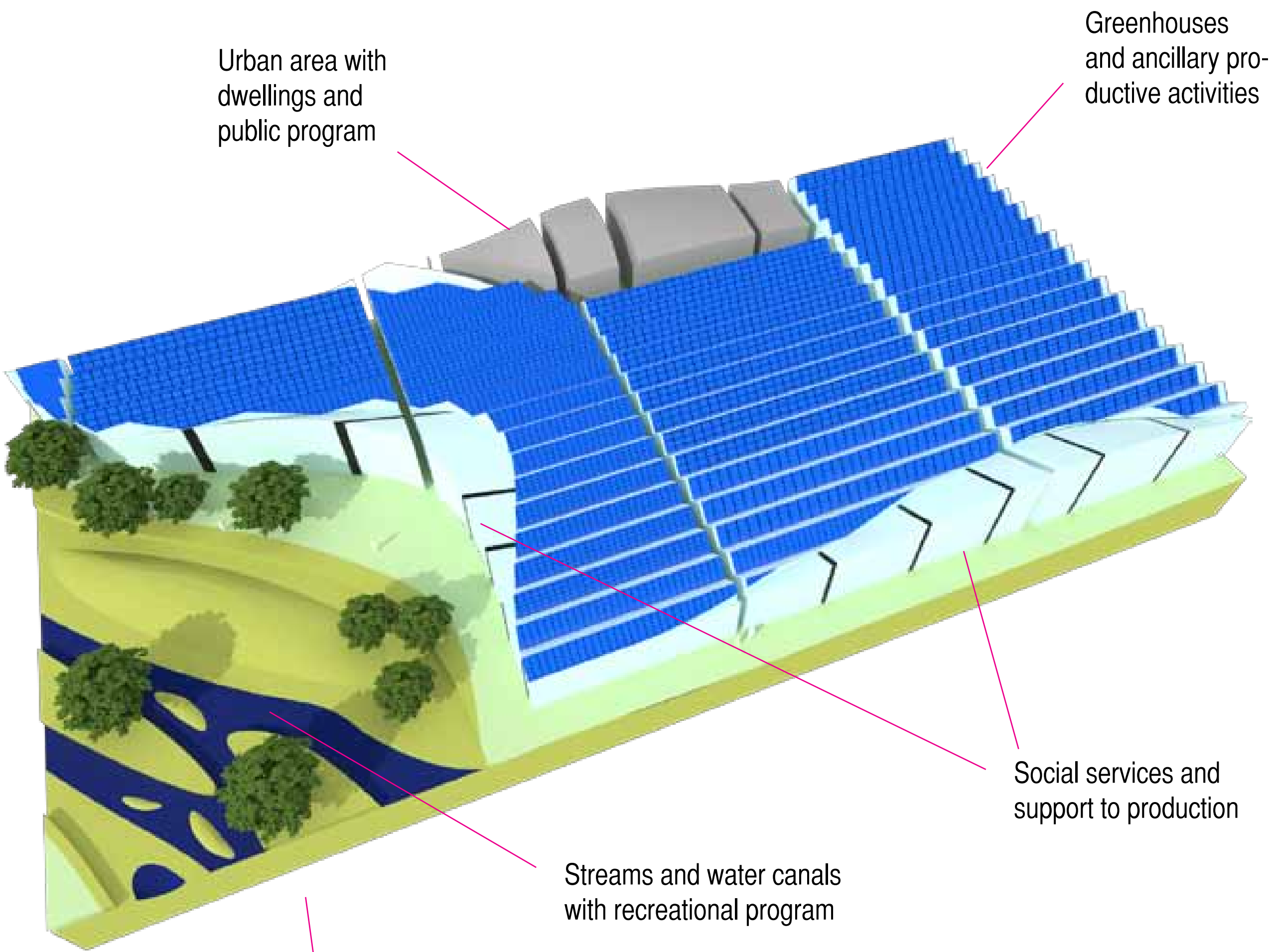


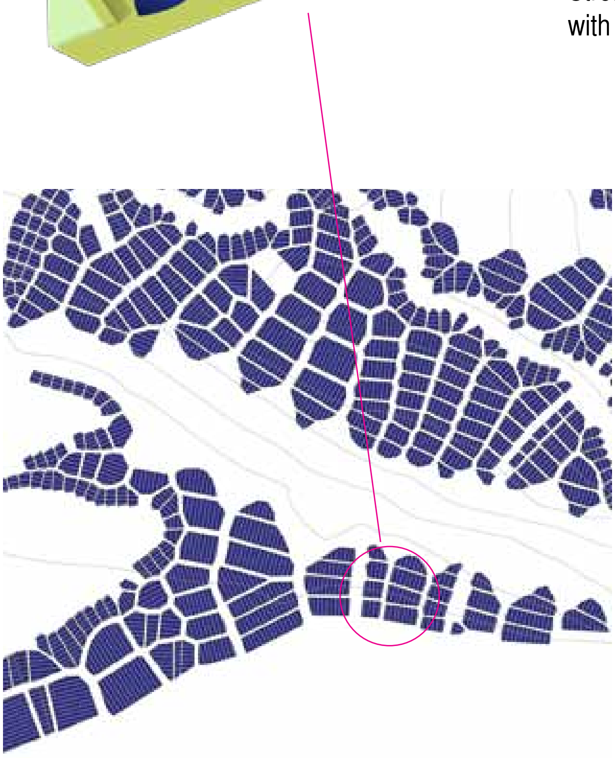
Reservoir

Water supply lines
Preexisting water pipes are integrated to the system of new drainage lines throughout the development.

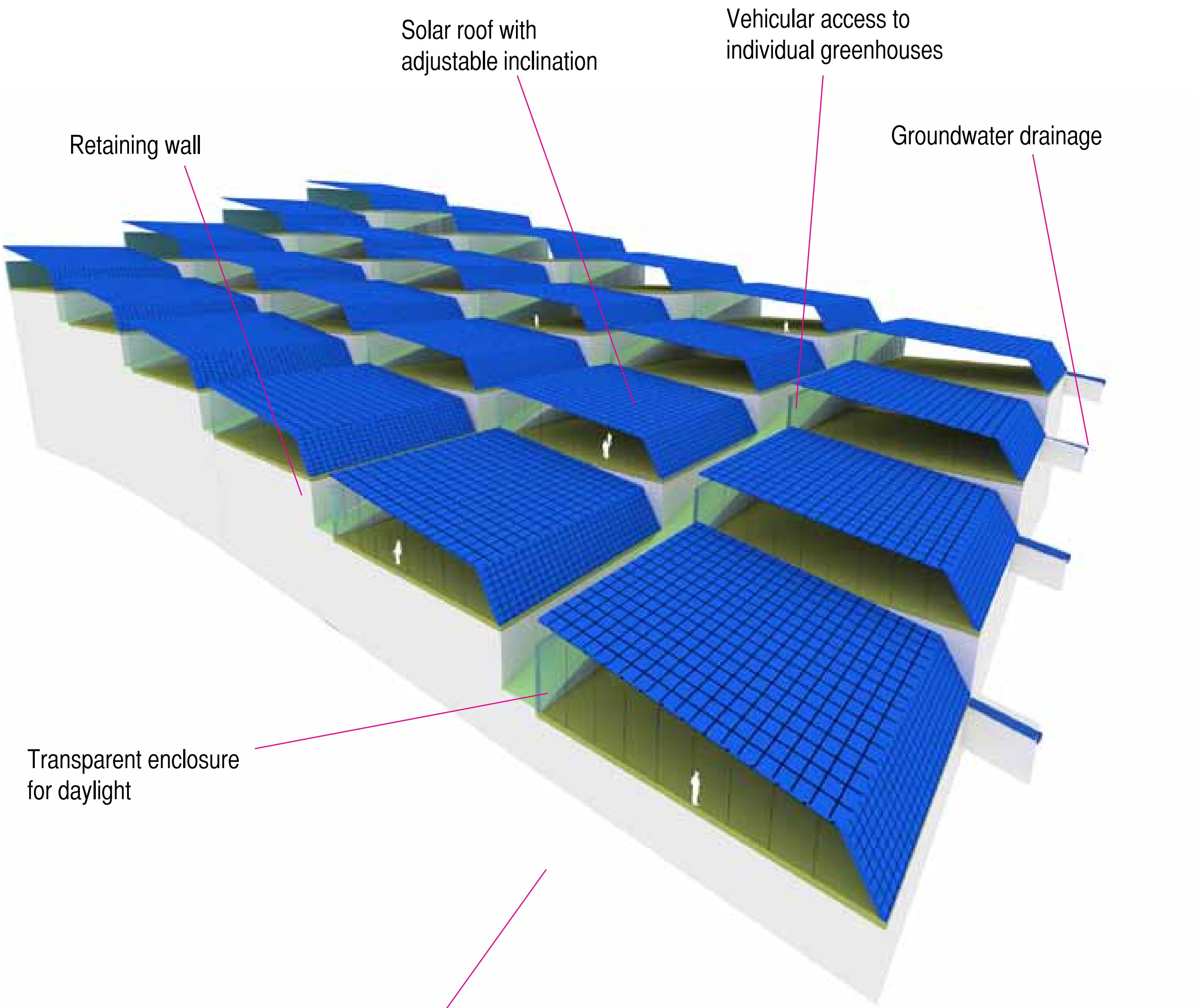
Water supply lines

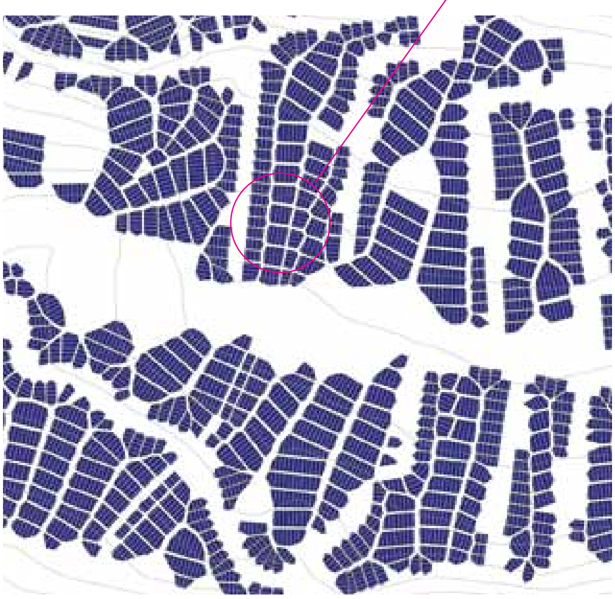
2.6 Typologies of Intervention





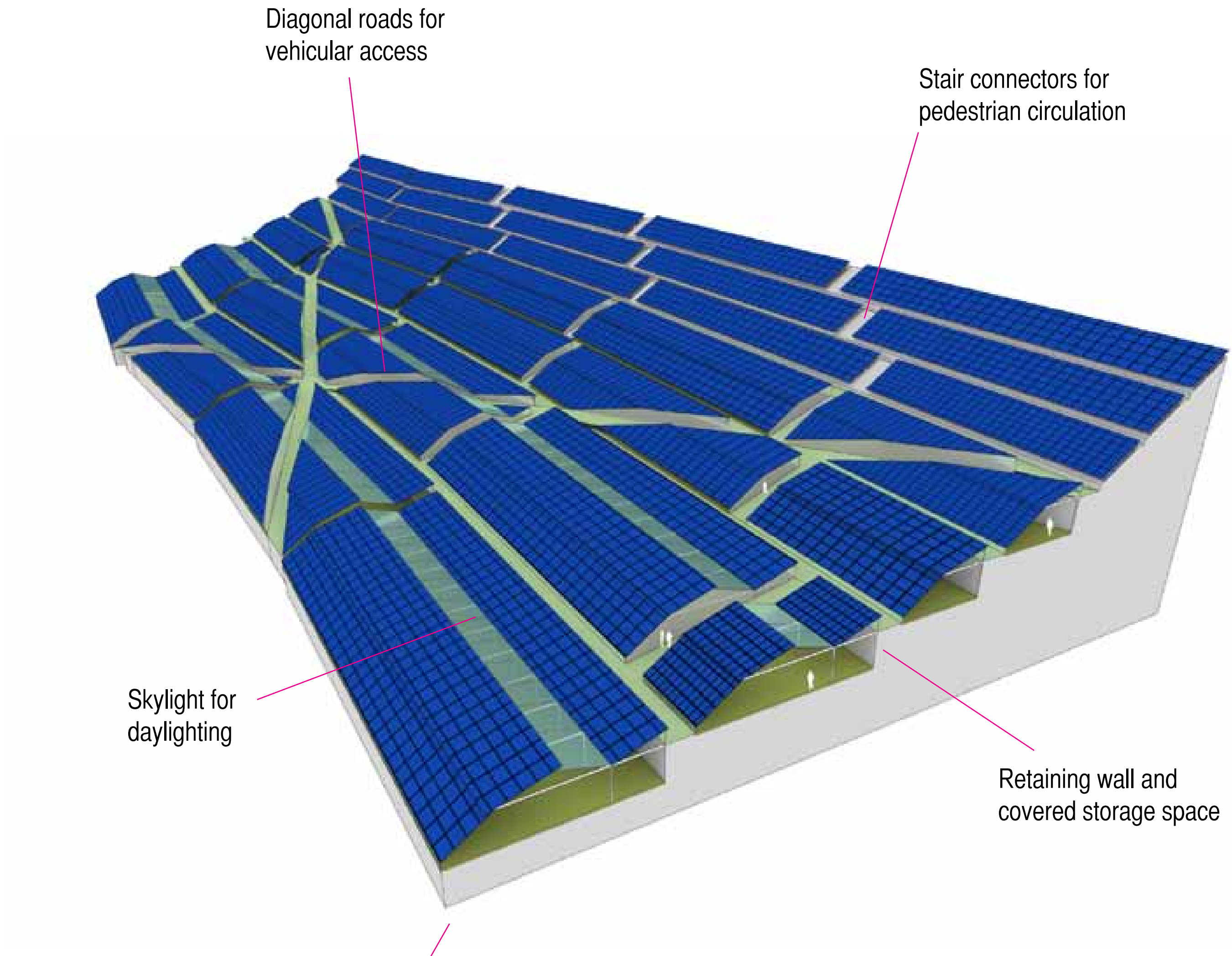
Typology A
This typology addresses the most common type of greenhouse on flat ground; the new tessellation follows the logic of water flow lines and topography. The resulting subdivision re-configures the existing land parcels by providing for rational water and vehicular infrastructure. The new tessellation also allocate areas adjacent to main access roads and natural features to urban dwelling and social services.

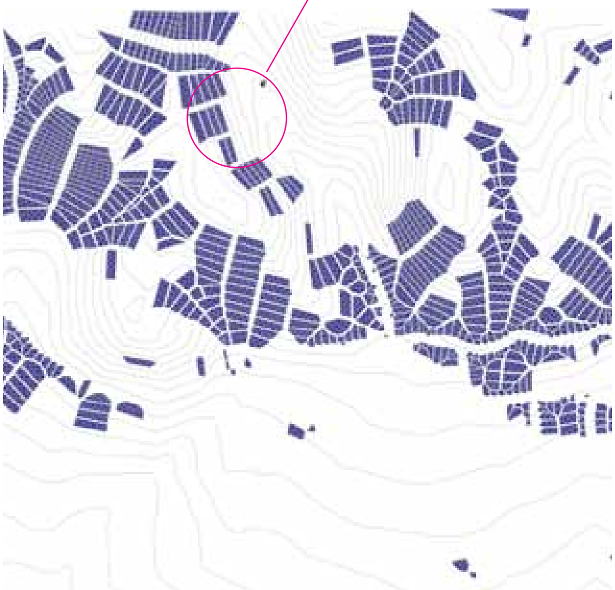




Typology B

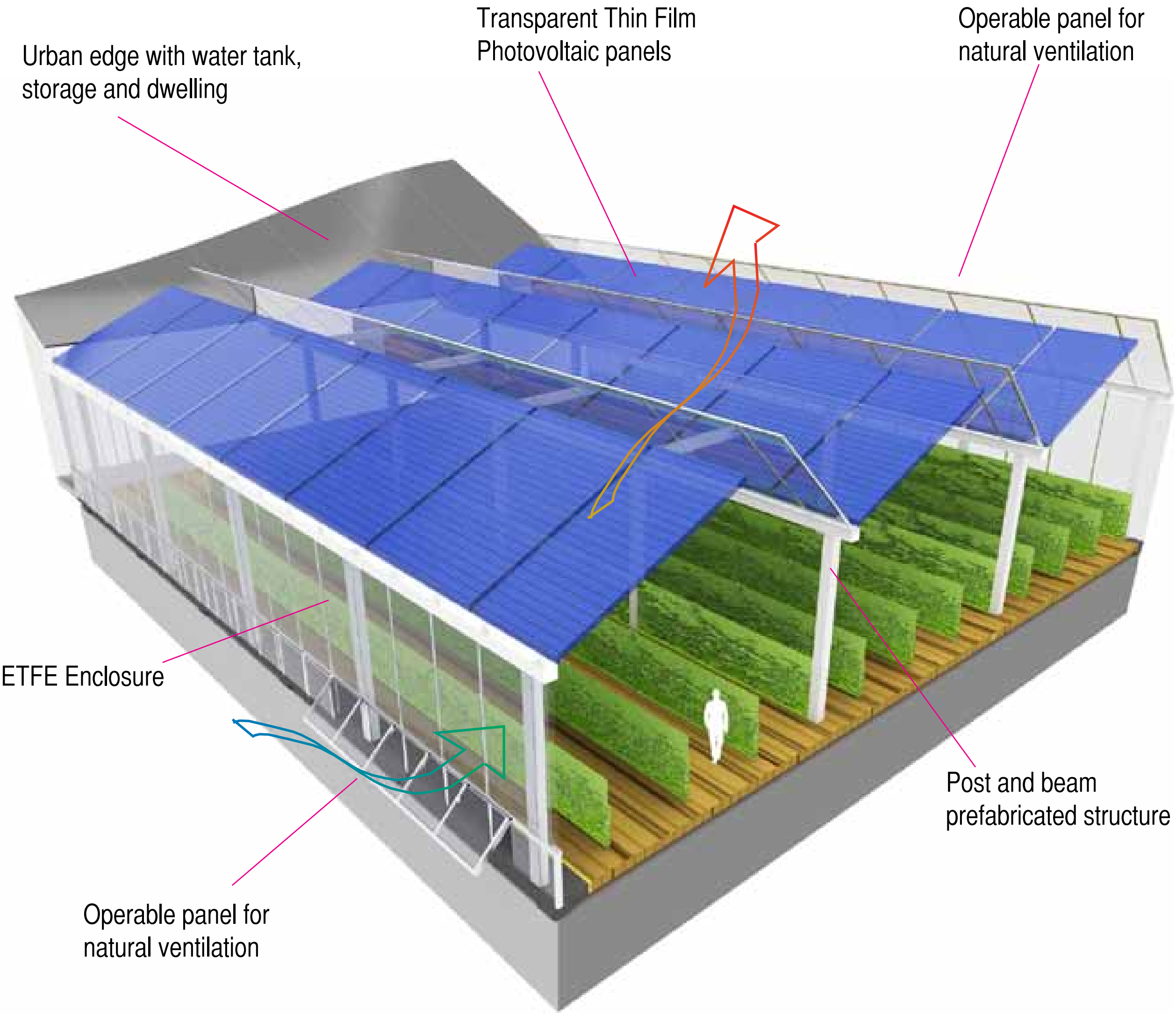
Typology B refers to areas with moderate slope and is based on a rational and economic approach to construction, using traditional retaining walls, minimum excavation and land fill, and a solar roof with flexible orientation so as to respond to that most appropriate orientation within a modular system. The tessellation provides for an efficient drainage and retention system, so groundwater is effectively intercepted and stored in locals tanks, as well as for vehicular access to individual greenhouses.





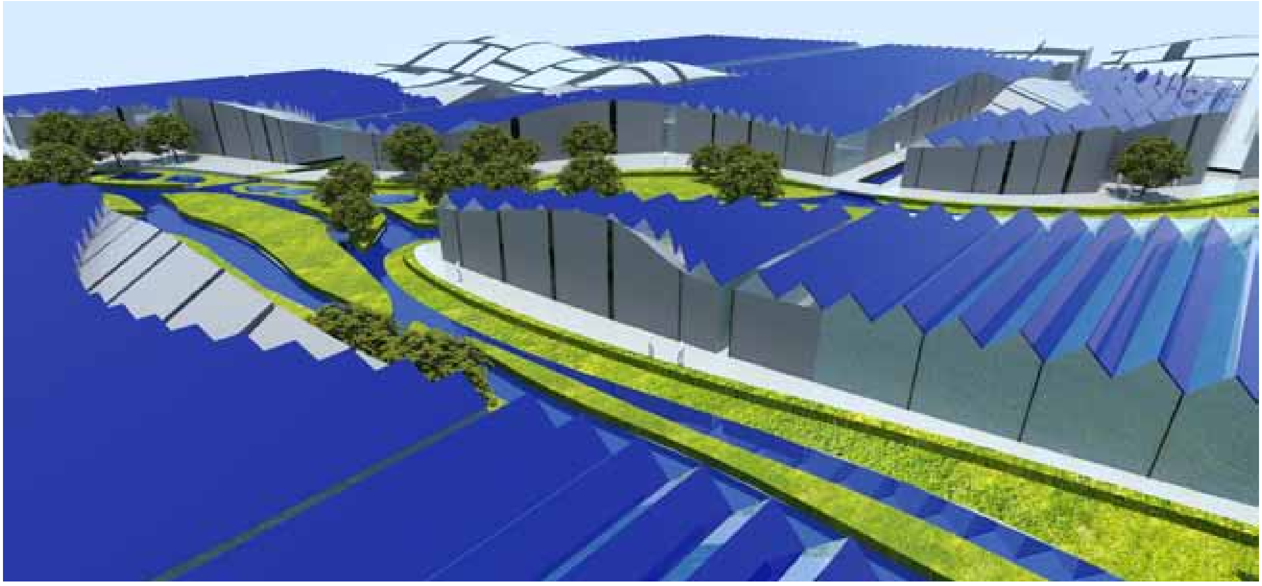
Typology C

This typology of greenhouses addresses the challenge of bringing irrigated agriculture to the hills, where the potential for solar power is the highest in the area.
The proposal uses the well established tradition of terraced farming, with the addition of diagonal roads that provide vehicular accessibility to individual greenhouses, while pedestrian circulation is facilitated by stair connectors. Retaining walls offer an economic way of building covered spaces for produce storage and for water tanks. The system can adjust to a wide range of gradients, transforming into a pure solar panel installation on the steepest slopes.

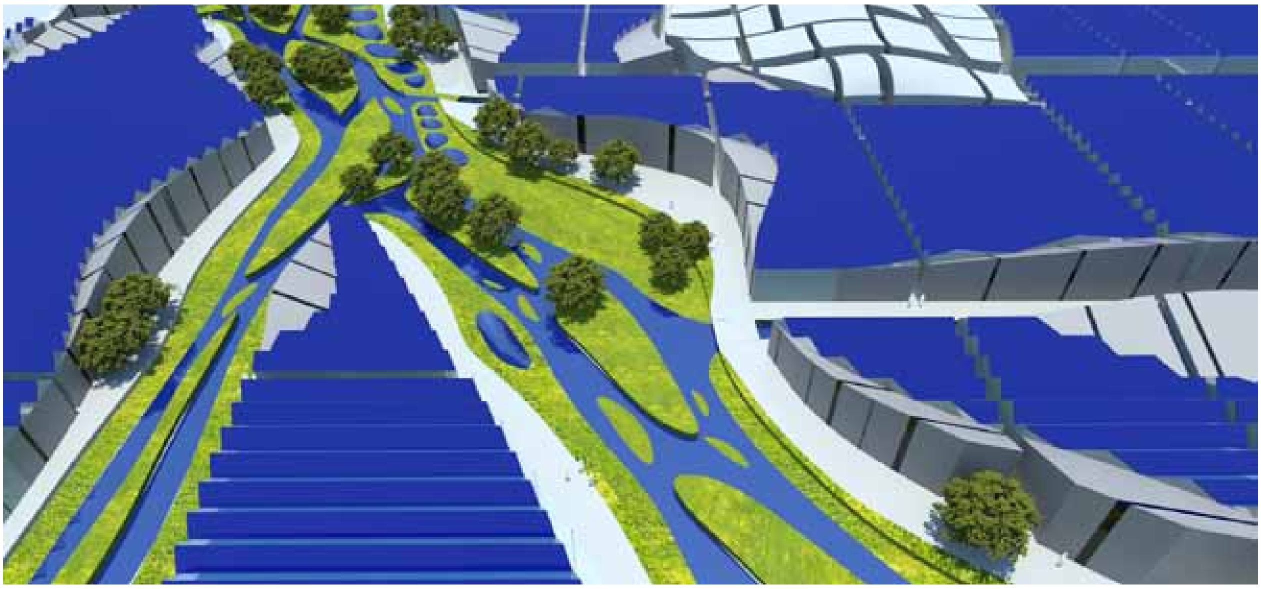


Technical implementation
The typical greenhouse unit is a modular structure with a regular 8 meter span between structural lines, in order to accommodate the metric specific to hydroponics, while maximizing the structural capability of typical post-and-beam prefabricated systems.
Walls are made of a light-weight enclosing material such as ETFE, while the roof is composed of south-facing semi-transparent thin-film solar panels - that let some daylight into the greenhouse - and operable glass panels for daylight and natural ventilation.
Whenever present, the urban edge provides for supporting spaces to farming, as well as water storage and dwellings.

2.7 Design Integration



View over urban edges facing one of the main water canals

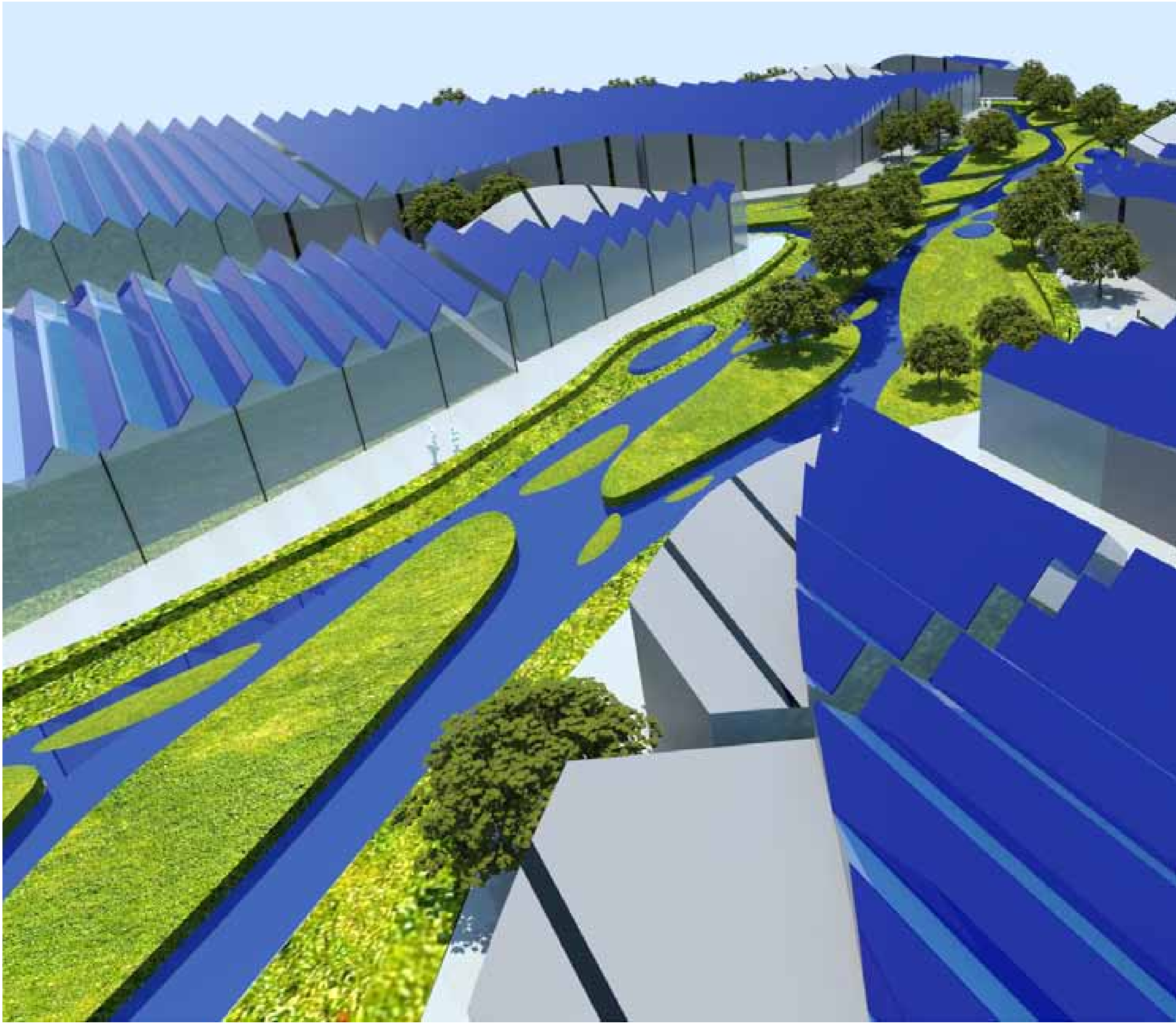


Intermittent water streams provide for public program and a space for outdoor activities

A vision for Almeria
The new landscape of Campo de Dalia presents a fully integrated system: groundwater drainage infrastructure - including natural recurring streams and artificial canals - weave through the new fabric of greenhouses, creating spaces for social gathering and public activities: these flood areas become the new public space that is entirely missing from Campo de Dalia in its current configuration.

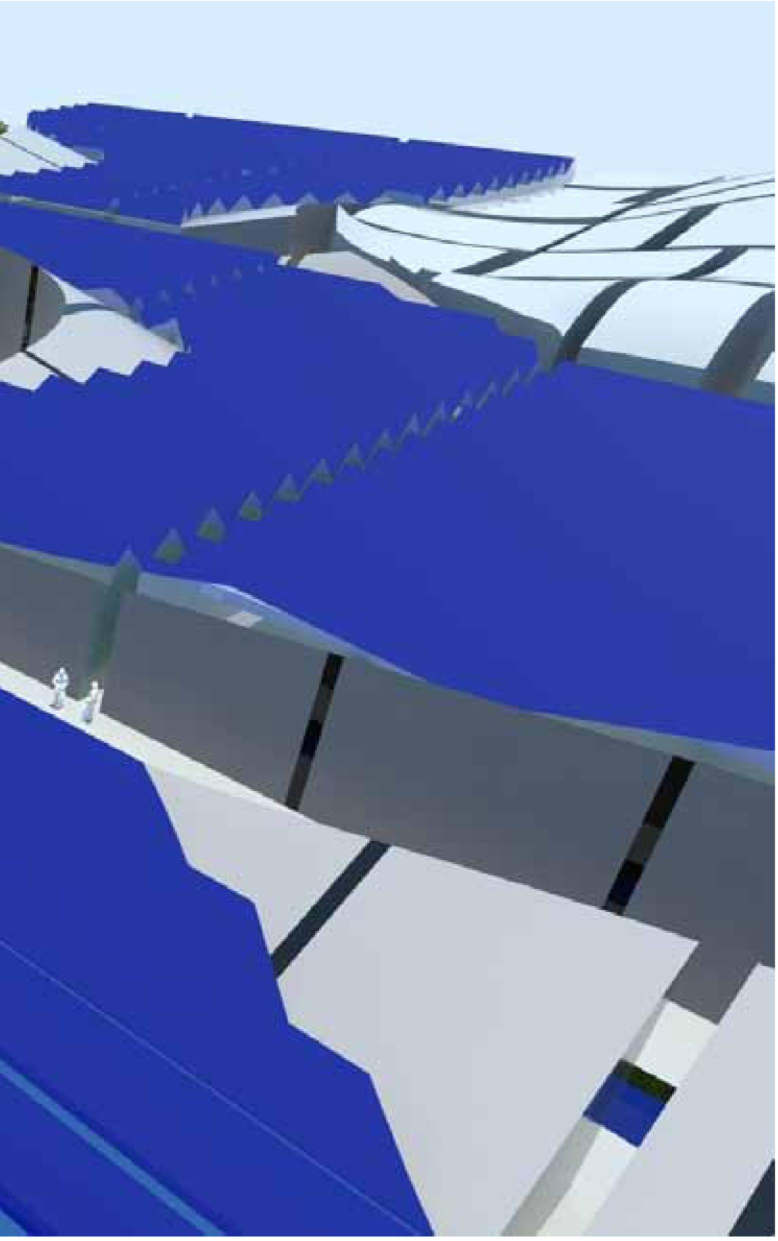
Integrated Community

Land parcels are efficiently divided by secondary vehicular roads and tertiary pedestrian streets into units of appropriate size to maximize agricultural production while promoting walking and cycling as modes of circulation.
Modular greenhouses oriented toward the prevailing sun direction cover between 80% and 90% of total land area, exceeding the existing green housing stock.
At the intersection of productive land parcels with flood areas and road infrastructure, greenhouses include a urban edge as interface for loading docks, administrative offices, storage space, and dwellings.
Areas that are particularly suited to habitation - or that include preexisting villages - are entirely allocated to housing and public program.



Bird-eye view looking south over a large portion of greenhouses


Urban edge along the main water canal



3. Montalcino, Italy

3.1 Tradition and Change

Satellite view of Italy

A fast-changing region
While Tuscany's reputation for idyllic landscape, well preserved historic monuments, and high-quality living standards remains largely intact, the region faces a radical transformation in its traditional values and structures. Cyclical economic crises among wine producers resulted in a massive selling of historic *terroirs* to foreign companies, mainly Japanese and more recently Chinese investors. Insofar as landscapes are the result of human activities over centuries, the Tuscan landscape today is the reflection of a society that does not longer exist. Unregulated immigration from China and the north African region, the collapse of traditional industry, such as textile and mining, and the decline of agriculture itself, pose a challenge to maintaining a balance between preservation of cultural, artistic and landscape assets, and the transformation into a modern economy.

Satellite view of Montalcino, Tuscany

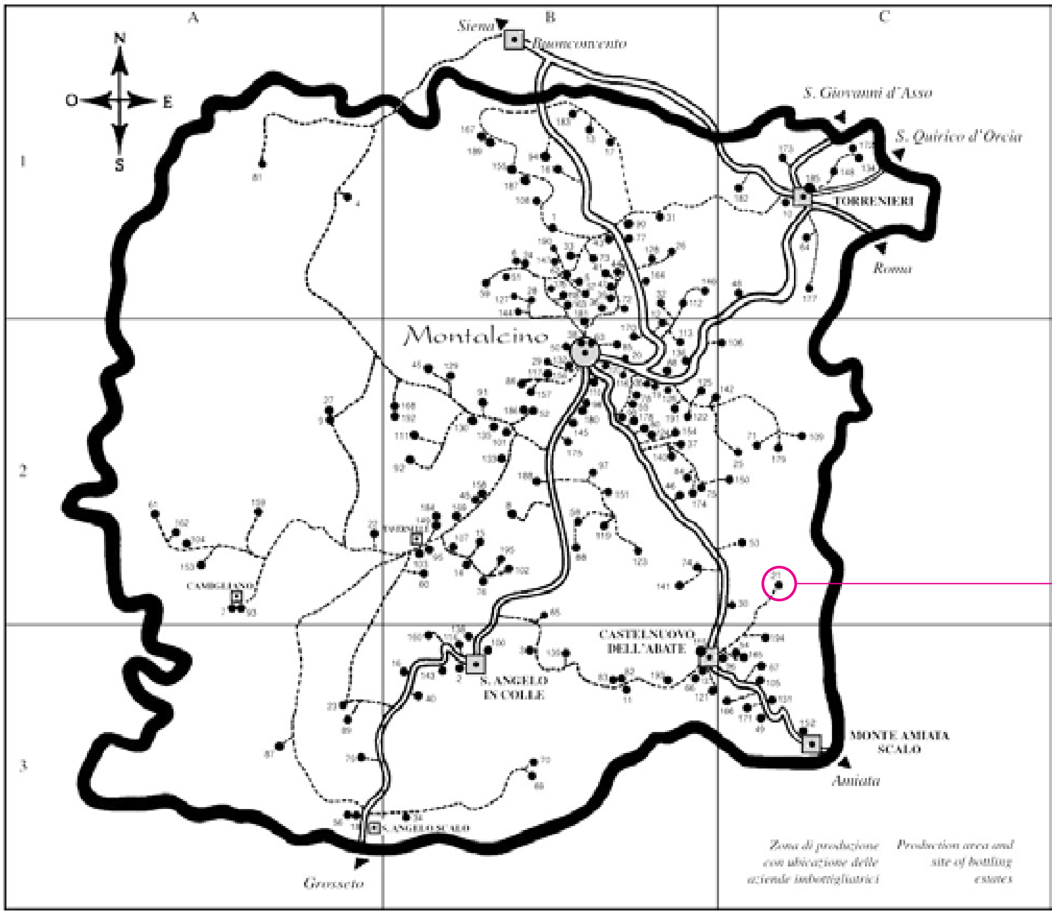
Typical Tuscan vineyards

We argue that the implementation of a new energy infrastructure might provide the much needed incentive to embrace the necessary transformation and to take an active role in shaping the new forms of energy landscape.

Brunello di Montalcino

Brunello di Montalcino is a red Italian wine produced in the vineyards surrounding the town of Montalcino, a small medieval village located 564 metres (1,850 ft) above sea level in the province of Siena. The wine district is centred to the northeast of the village in densely wooden and hilly terrain.

Based on historic records, “Brunello” was already produced in the Montalcino area in the early 14th century; by the end of World War II, Brunello di Montalcino had developed a reputation as one of Italy’s rarest wines and today is one of the best-known and most expensive wines in the world. Currently, there are nearly 200 producers of Brunello di Montalcino, mostly small farmers and family estates, producing about 330,000 cases a year. Compared to the nearly 41,000 acres (17,000 ha) of planted land in Chianti, Montalcino is a relatively small wine region with around 3,000 acres (1,200 ha). Vineyards in Montalcino are planted in varied soils - including limestone, clay, schist, volcanic soil and a crumbly marl known as galestro - at altitudes ranging from 149 m to 500 m. This diversity in *terroir* contributes



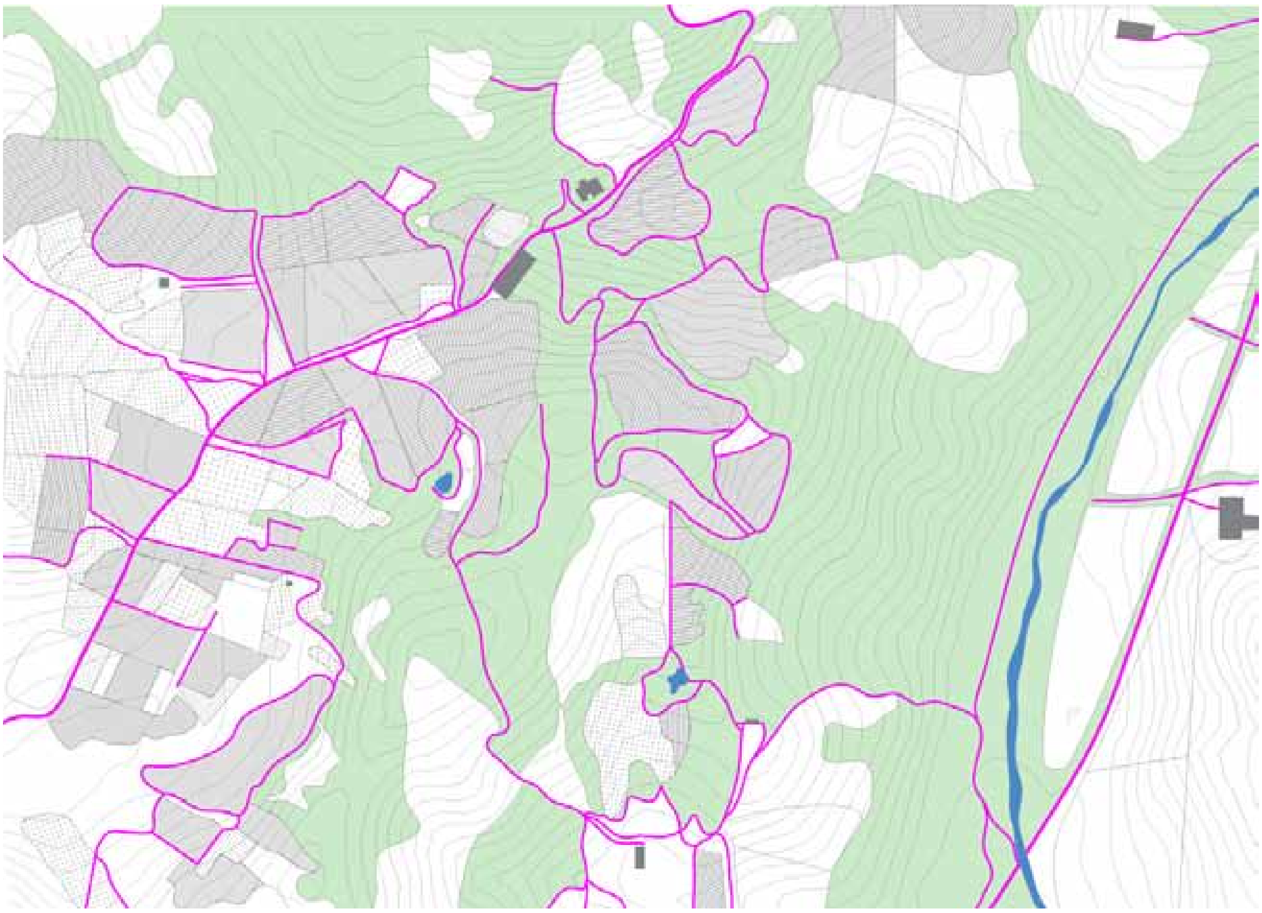
Montalcino Administrative borders with location of certified vineyards to the vast range in quality and potential complexity of Brunello di Montalcino (source: K. MacNeil The Wine Bible pg 382-384 Workman Publishing 2001)

Wine making and crime
In 2008, Italian authorities confiscated four producers of the 2003 Brunello on charges that they had committed fraud by including foreign varietals in the wine that they had then labeled as Brunello di Montalcino.

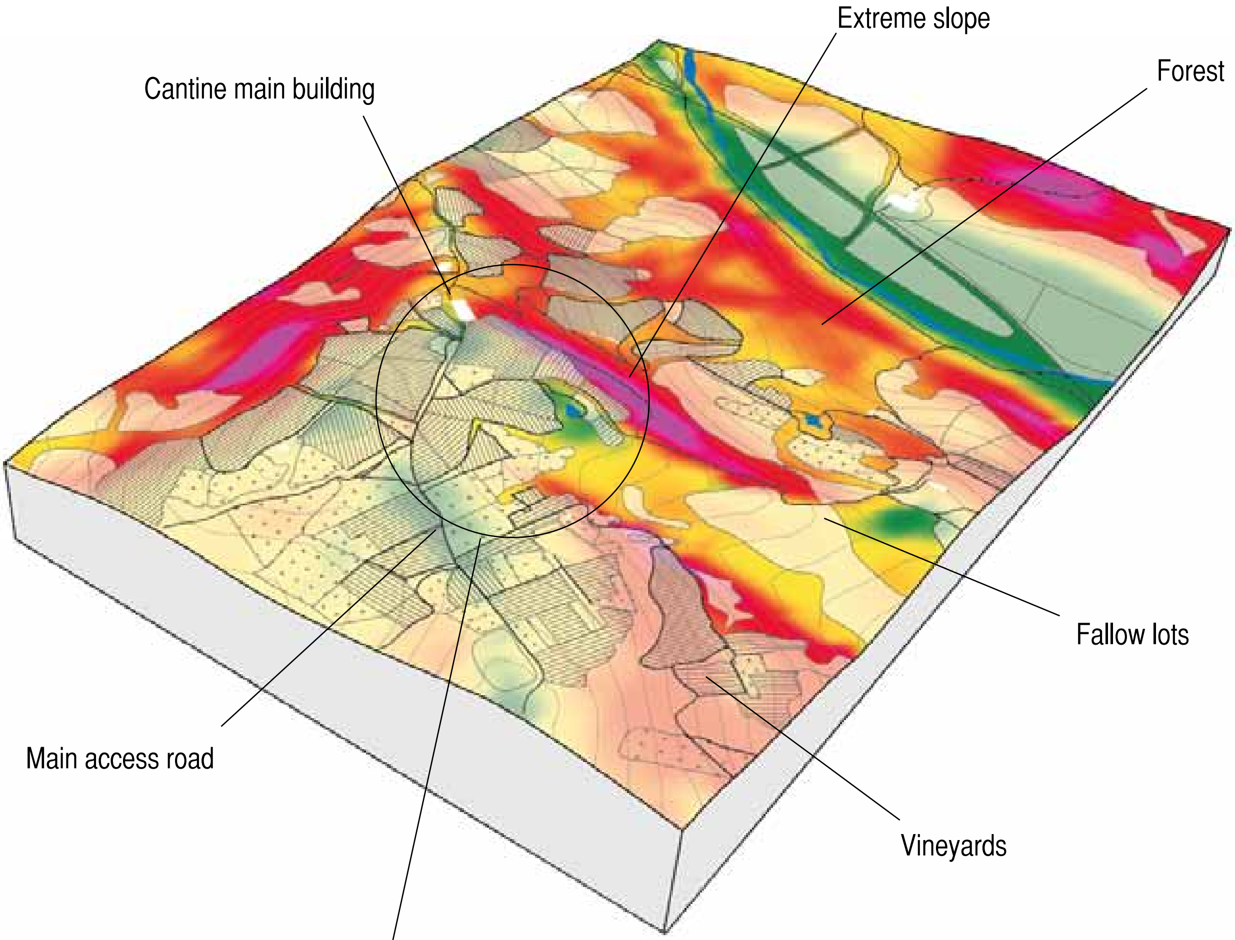
Also in 2008, reports surfaced that Italian authorities were investigating claims that several other major Brunello producers were adulterating their wines by using foreign or domestic grape varieties in violation of the DOCG regulations (source: *Cooke, Jo. "Brunello Under Fire: Italian authorities impound wines as part of an investigation." Wine Spectator. 03 April 2008*.)

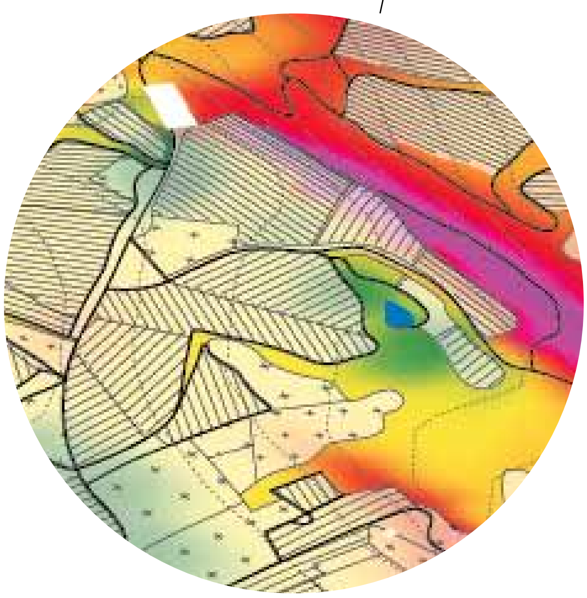
Cantine Mastrojanni Vineyards
Vineyards on the southern and western slopes receive more intense exposure to sunlight and more maritime winds which produces wines with unique power and complexity. Cantine Mastrojanni, like most top producers in the area, have vineyards on both slopes, and make use of a blend of both styles. They were chosen for a demonstration project due to the variety of exposure, land features, including a water stream and wooded areas, as well as a well structured road network.


Brunello grape

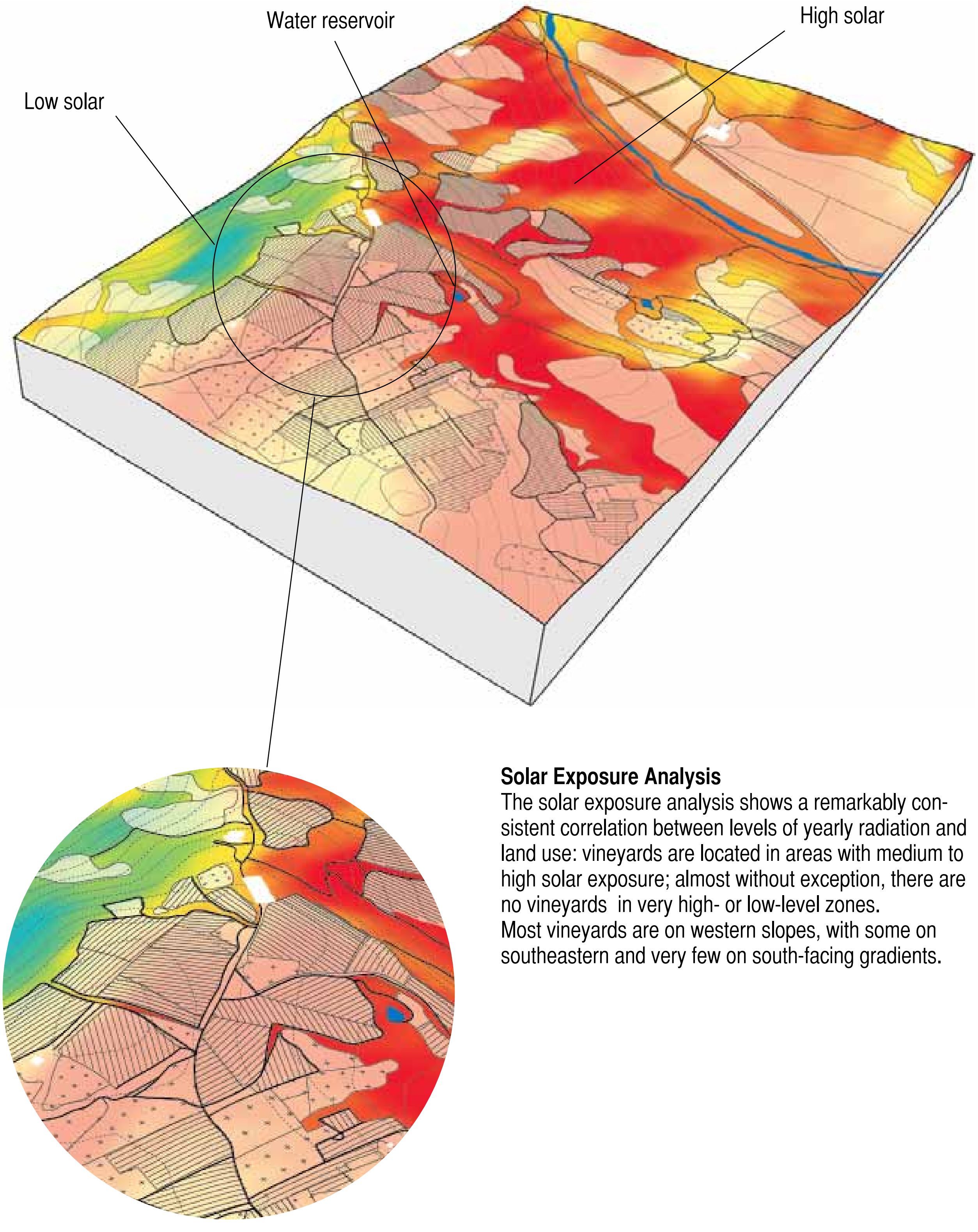

Cantine Mastrojanni Vineyard

3.2 Site Analysis





Topography Analysis
The sample site presents some of the typical characteristics of historic hillside settlements in central Italy: main roads follows contour lines to minimize gradients, often following the hilltop ridge; vineyards are tangent to roads, with trellises generally oriented perpendicular to the slope, to avoid transverse gradients that might cause a tractor to overturn. Bottom of valleys are forested - especially when a river is present; a number of fields within the terroir are kept inactive (fallow lots), allowing the replenishment of nutrients. There is a clear correlation between slope gradient and vineyards, with trellises placed over flatter areas and steeper slopes generally left forested.



Solar Exposure Analysis
The solar exposure analysis shows a remarkably consistent correlation between levels of yearly radiation and land use: vineyards are located in areas with medium to high solar exposure; almost without exception, there are no vineyards in very high- or low-level zones.
Most vineyards are on western slopes, with some on southeastern and very few on south-facing gradients.

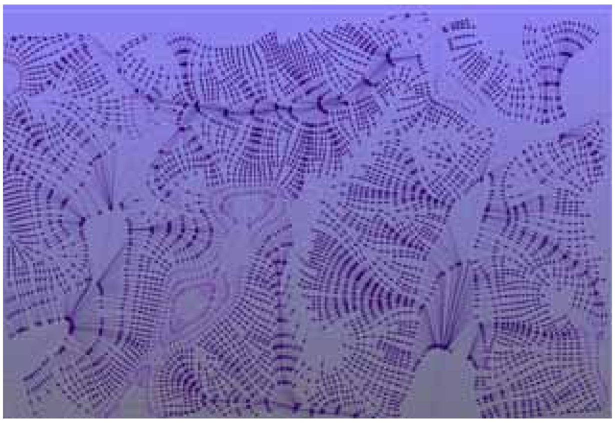
3.3 Tessellation Strategy

Base lines
The re-configuration of the land is based on existing and relevant features, such as contour lines - indicating the topography and the prevailing drainage basins, road infrastructure and ridgeways, main vineyard property lines, and other permanent components of the landscape. These elements provide the basis for a 3-D model of the selected area for all subsequent steps of the process.

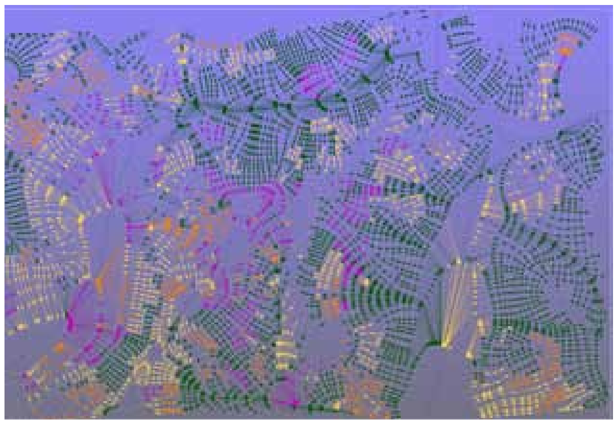
Base lines - colour-coded by use

Water Flow Lines

Hydrology - particularly good surface water drainage - is the first indicator of a proper land subdivision. This is especially important within an agricultural context, where water management for irrigation and other uses is paramount to a sustainable use of the land. Accordingly, the first step simulates the direction of surface water and identifies drainage basins within the selected area.



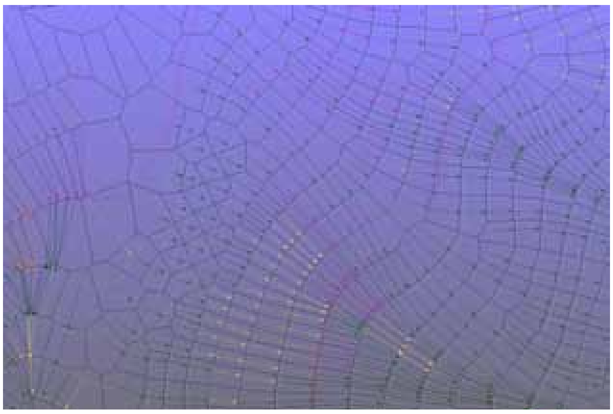
Water flow lines

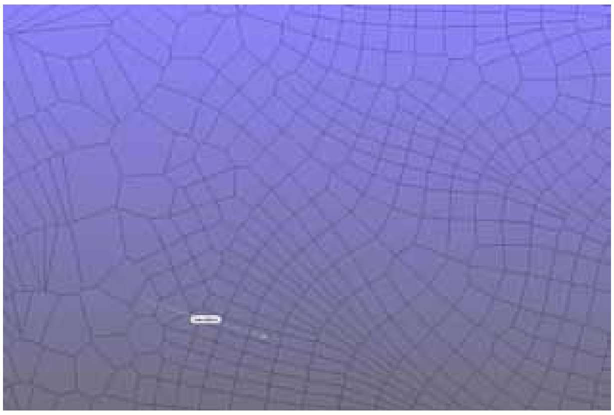


Calibration - colour-coded by use

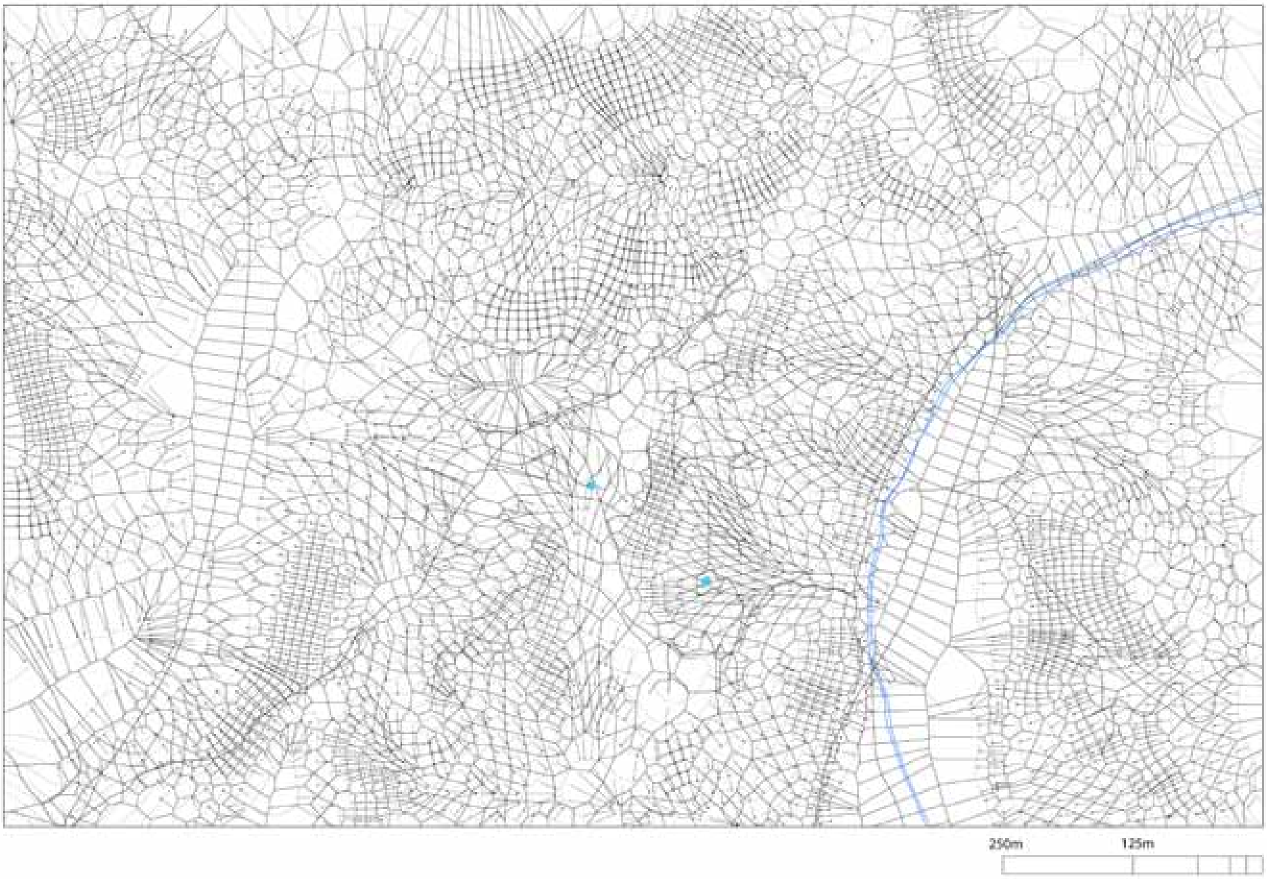
Calibration

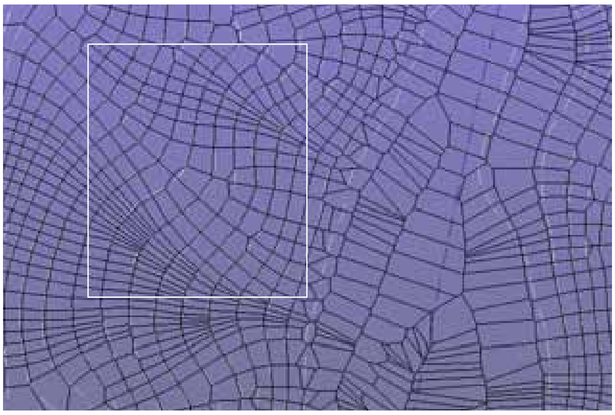
Water flow lines are then interpolated with contour lines and selected based on land use, as well as on relative distance between them. Lines that are too close are eliminated or redistributed.

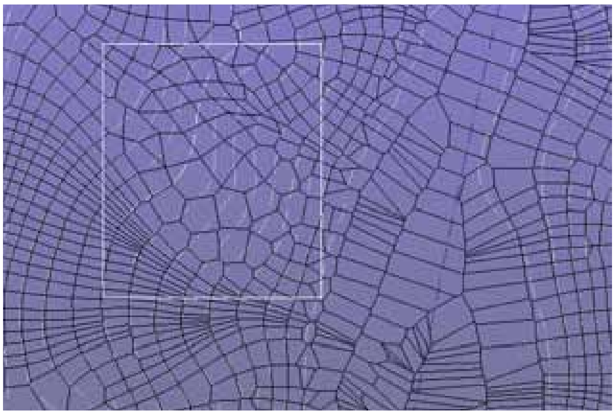

Lines culled by length


Initial tessellation based on water flow lines and contour lines

Tessellation
The consolidated water lines are the basis for a tessellation algorithm - based on Voronoi diagram - dividing the field into a number of regions. Initial parcels with extreme sizes or proportions are then re-configured through a relaxation of the grid.

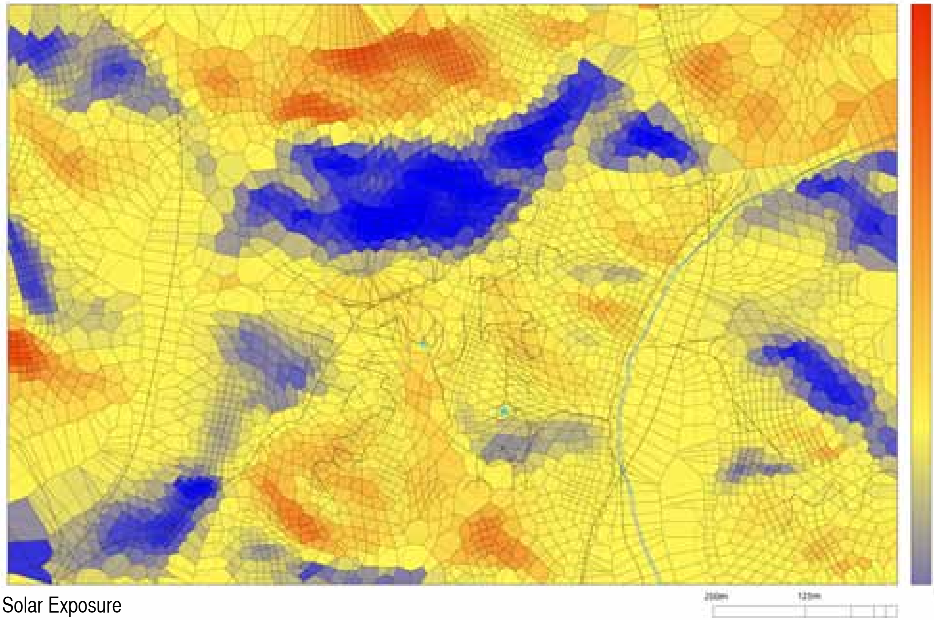



Relaxation of the grid

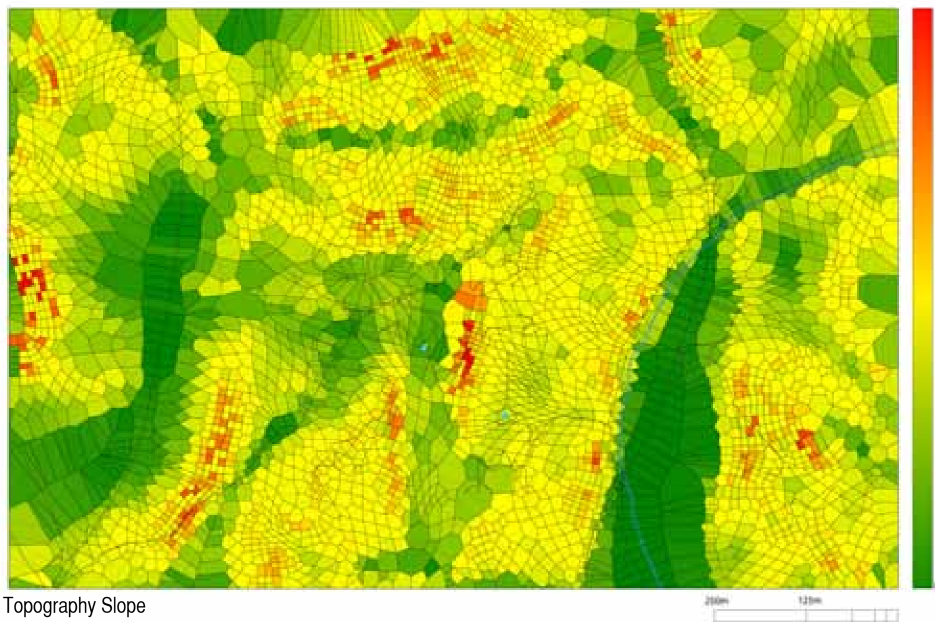

Final Voronoi tessellation

3.4 Environmental Analysis

Solar analysis
Solar radiation analysis identifies areas that are suitable for both vineyards and solar panels.


Solar Exposure

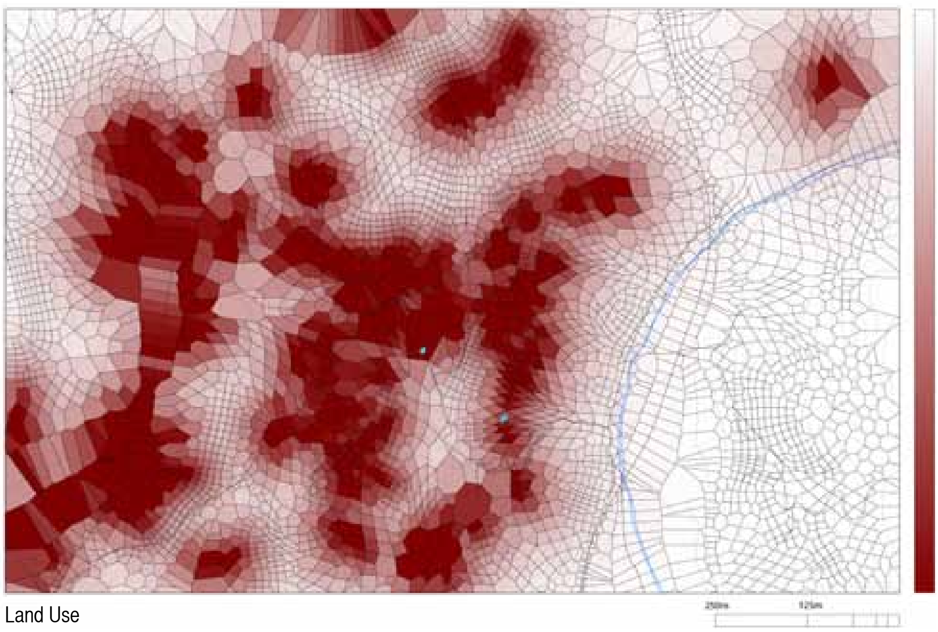
Topography Slope
The analysis of the topography, indicating slope levels, indicates parcels that facilitate the direct placement of solar panels using the natural inclination of the ground.
Natural slope also relates to surface water drainage, accessibility and transportation, as well as relative configuration of the vineyard to the slope.


Topography Slope

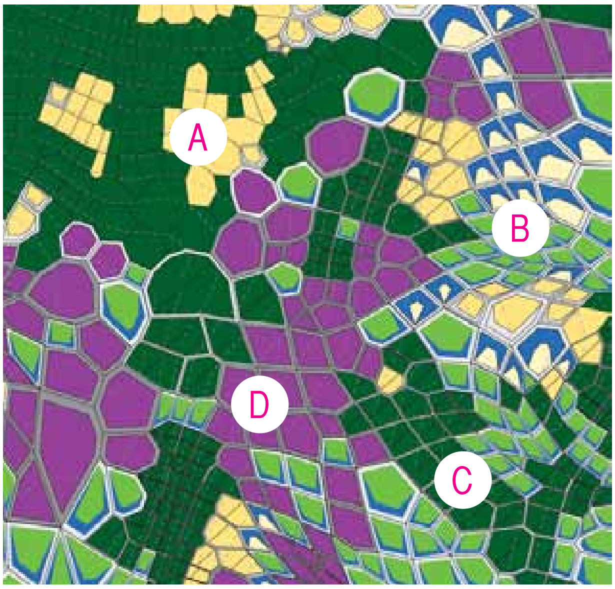
Tessellation Size
Parcel size evaluation relates to issues of property management and land value; it also provides for a verification method in allocating parcels to existing owners.


Tessellation Size

Land Use
Understanding the existing use of the land is paramount to respecting as much as possible the current configuration of the landscape.


Land Use

3.5 Land Use Allocation



Detail view

Qualification of land parcels
Based on particular combination of these parameters, each parcel shows a particular suitability toward a specific use of or program:

A **Fallow lots**
Lots that currently have no agricultural use

B **Low slope**
Lots with low or no slope

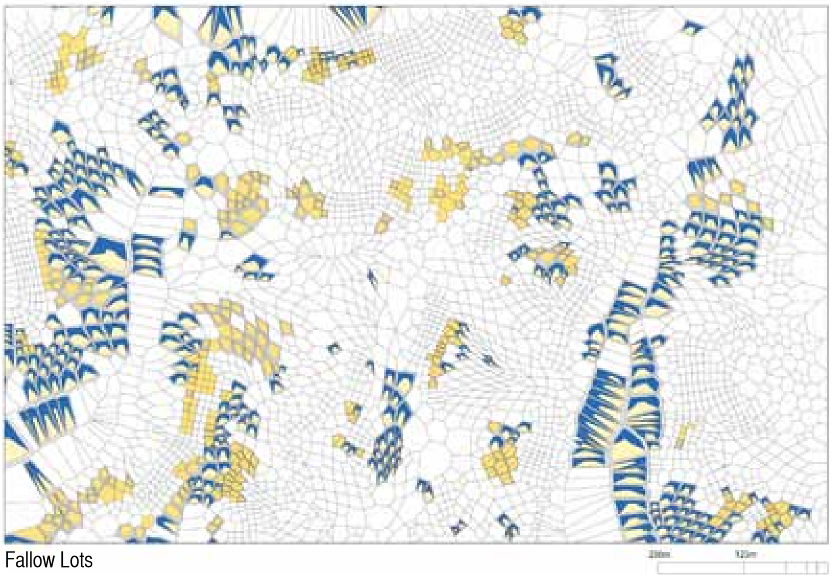
C **Low solar**
Lots with low energy potentials

D **Vineyards**
Lots with existing vineyards


Typologies Propagation

250m 125m

Fallow Lots
Fallow lots with a suitable orientation can be used for photovoltaic installations; also, they might be used for agricultural production other then grapes, thus requiring different solutions for solar panel integration.


Fallow Lots

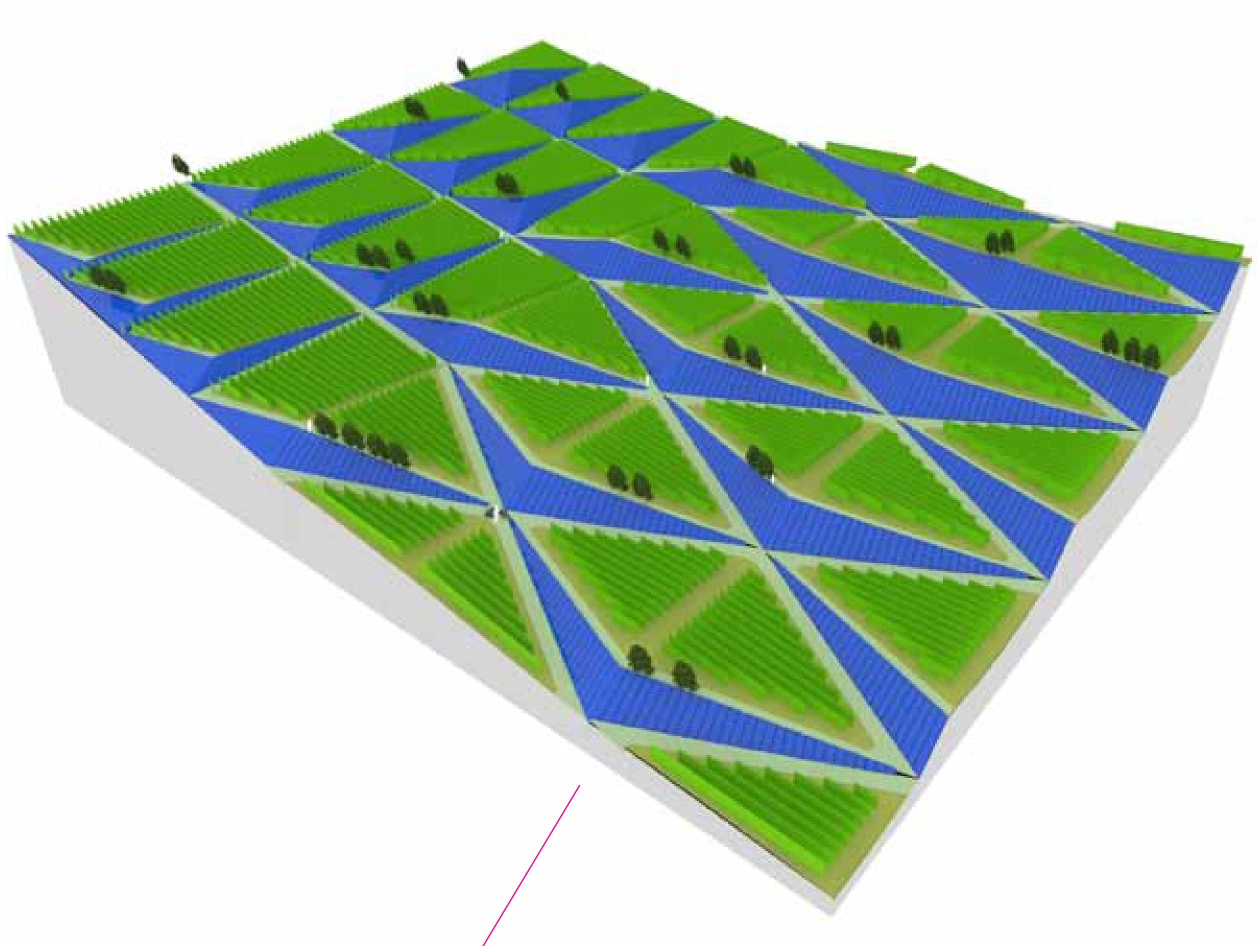
Vineyards
Existing vineyards indicate conditions best suited to growing grapes and they should be maintained whenever possible; the gradual replacement of older vineyards will allow the incremental implementation of the new solar regime.

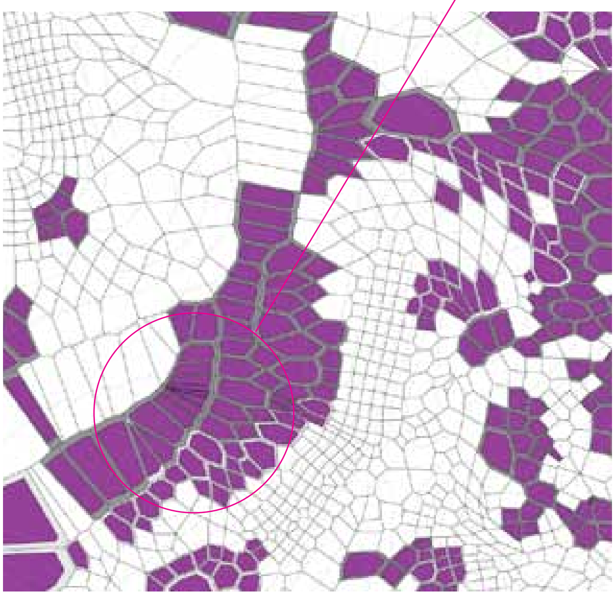

Vineyards

Low Slope
Low slope areas might be particularly indicated for intensive agricultural use, both for grapes and other crops.

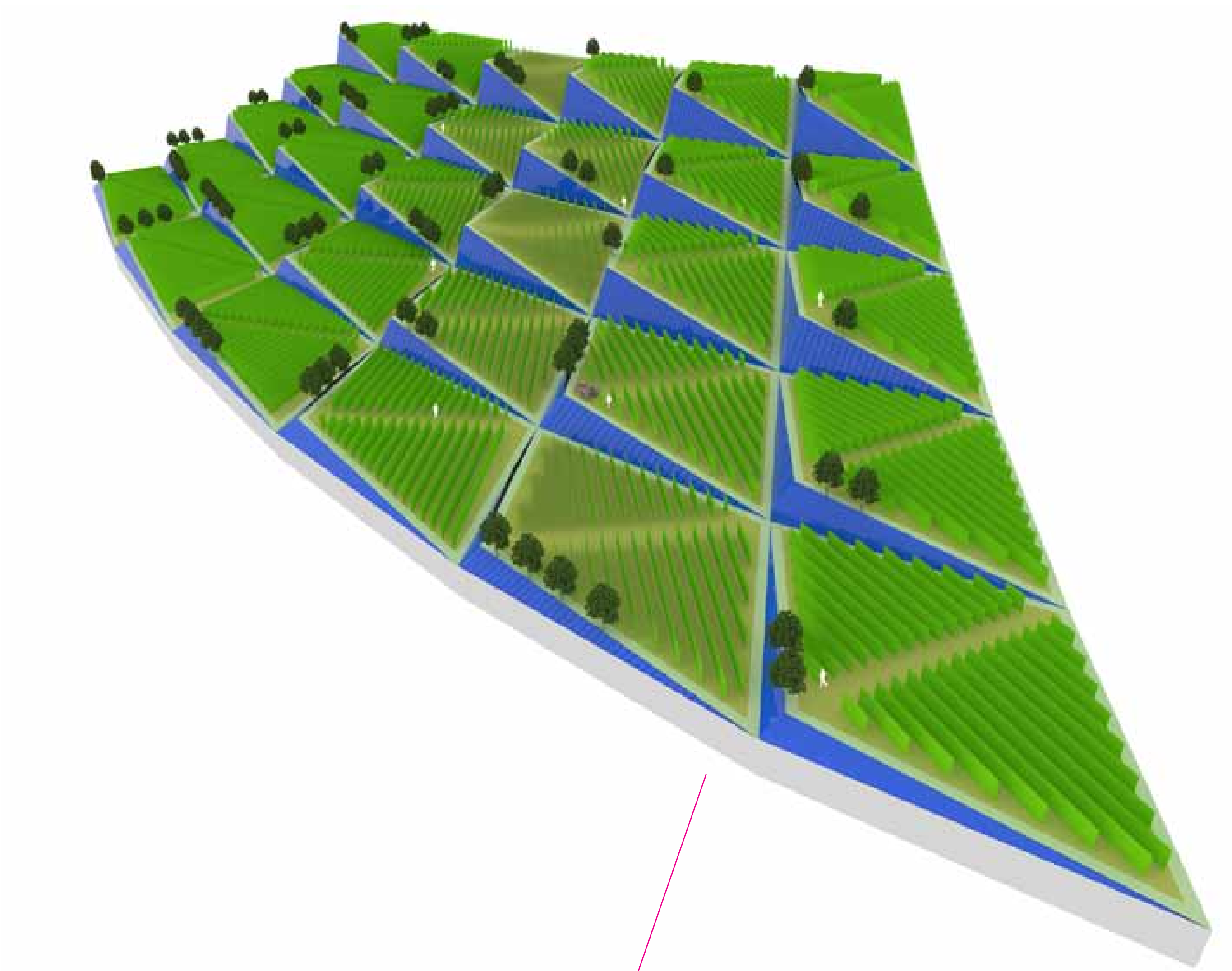

Low Slope

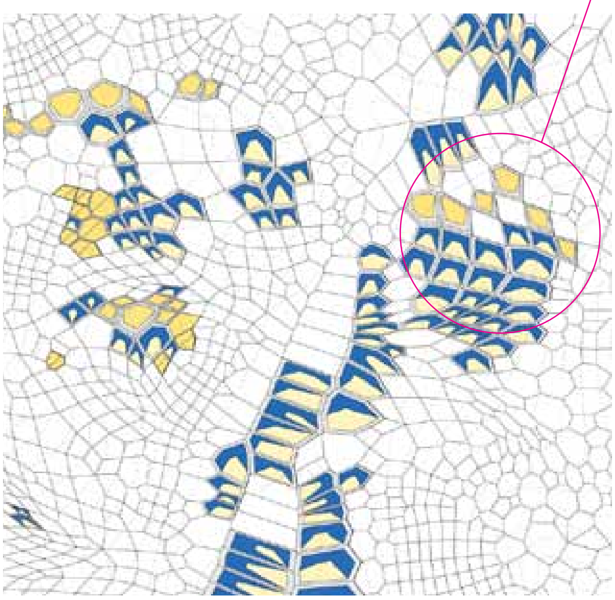
3.6 Typologies of Intervention





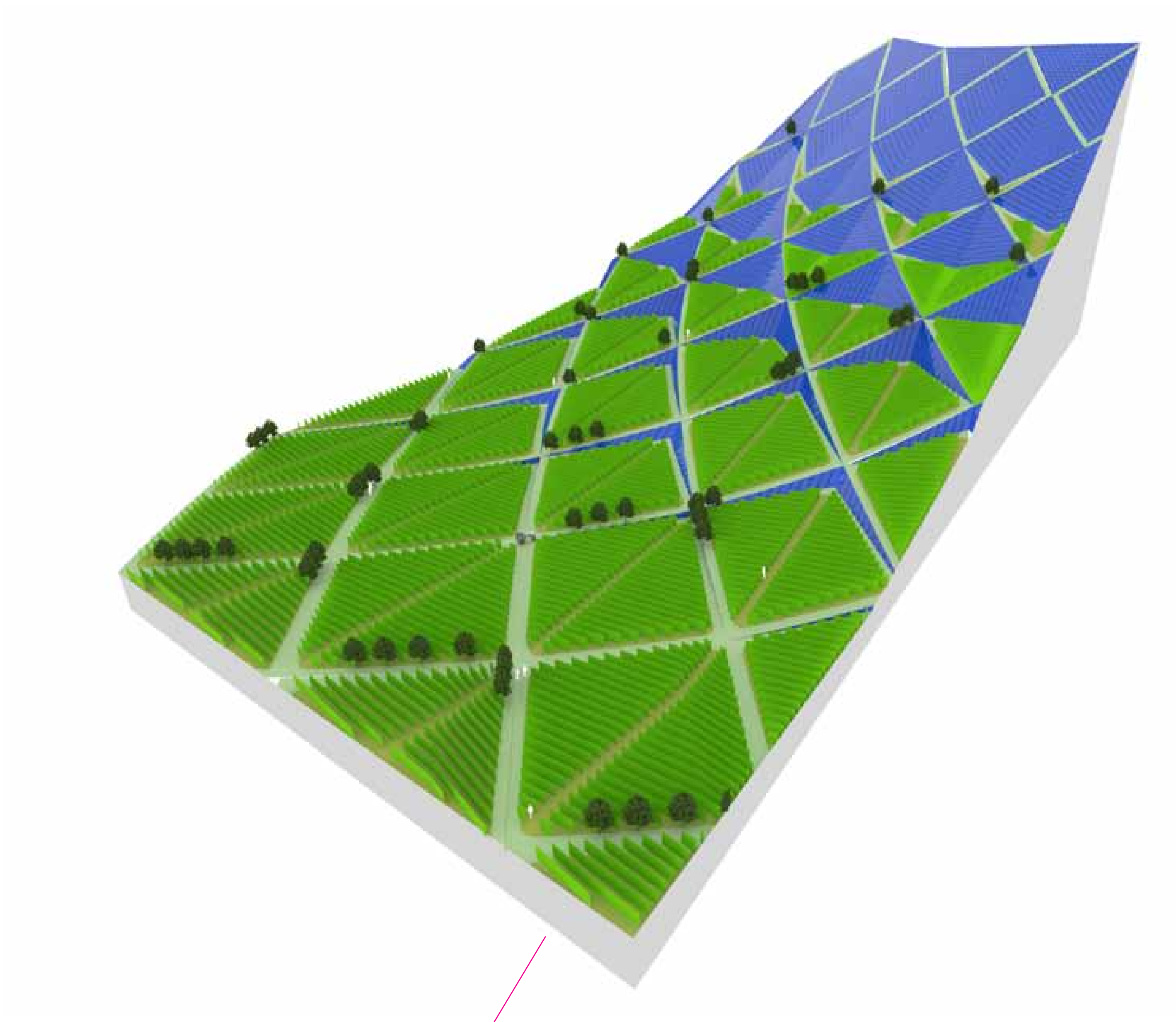
Existing Vineyards
In areas with high solar energy potentials - but where valuable existing vineyards must be maintained - the re-configuration of the ground should be minimal; whenever possible, the introduction of photovoltaics in limited quantities should improve the hydrology of the area, while providing for a moderate ground retaining effect.

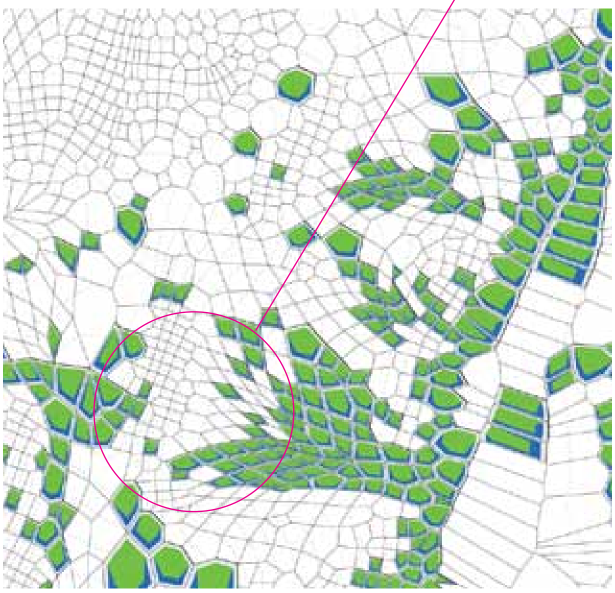




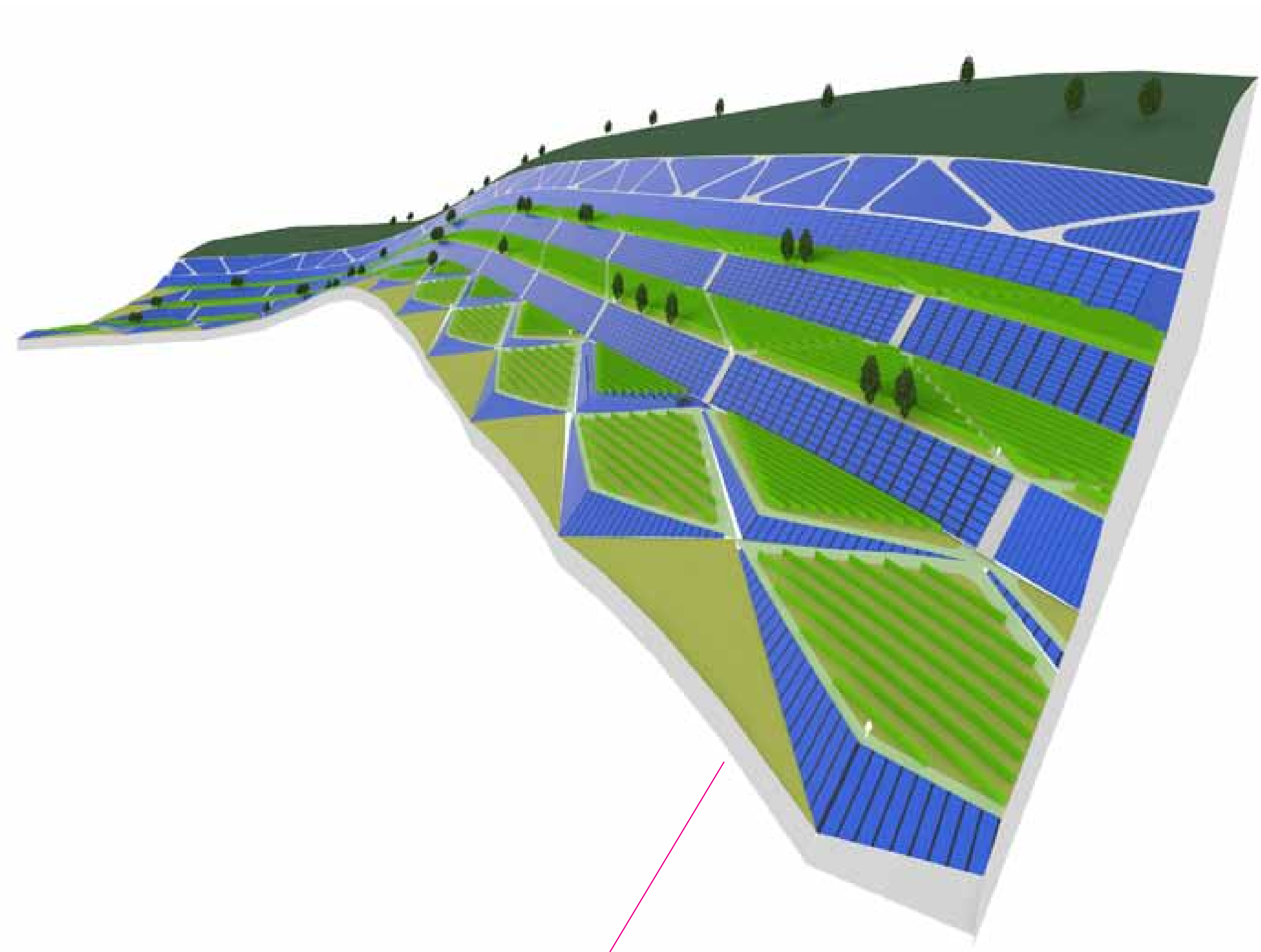
Virgin ground

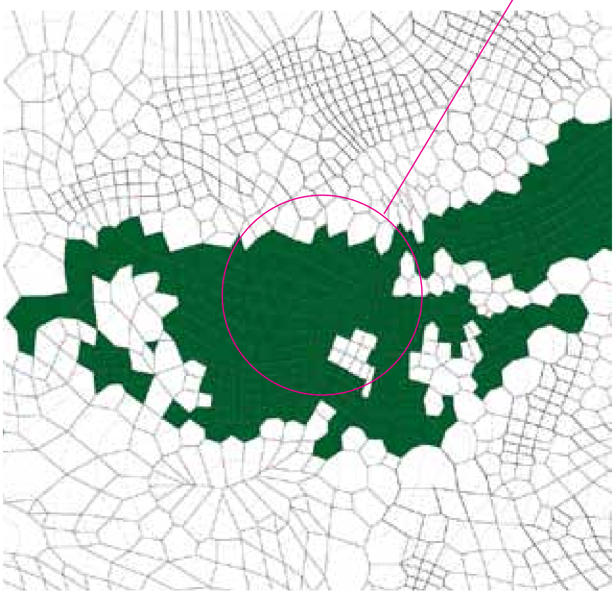
In areas that are currently not used for agricultural activities, the introduction of solar panels is more substantial, with a terracing configuration that guarantees the optimal orientation for the panels, while structuring the ground with access roads and a good drainage system.





High solar/slope to low solar/slope
This typology addresses slope with widely variable slope angle, as well as areas with extreme conditions of solar radiation. Low slope and/or low solar exposure result in a reduction of solar panels and a corresponding intensification of vineyards. In high slope areas, as well as in areas with high intensity of solar radiation, the system allows for a gradual replacement of cultivated areas with solar panels and earth-retaining systems.

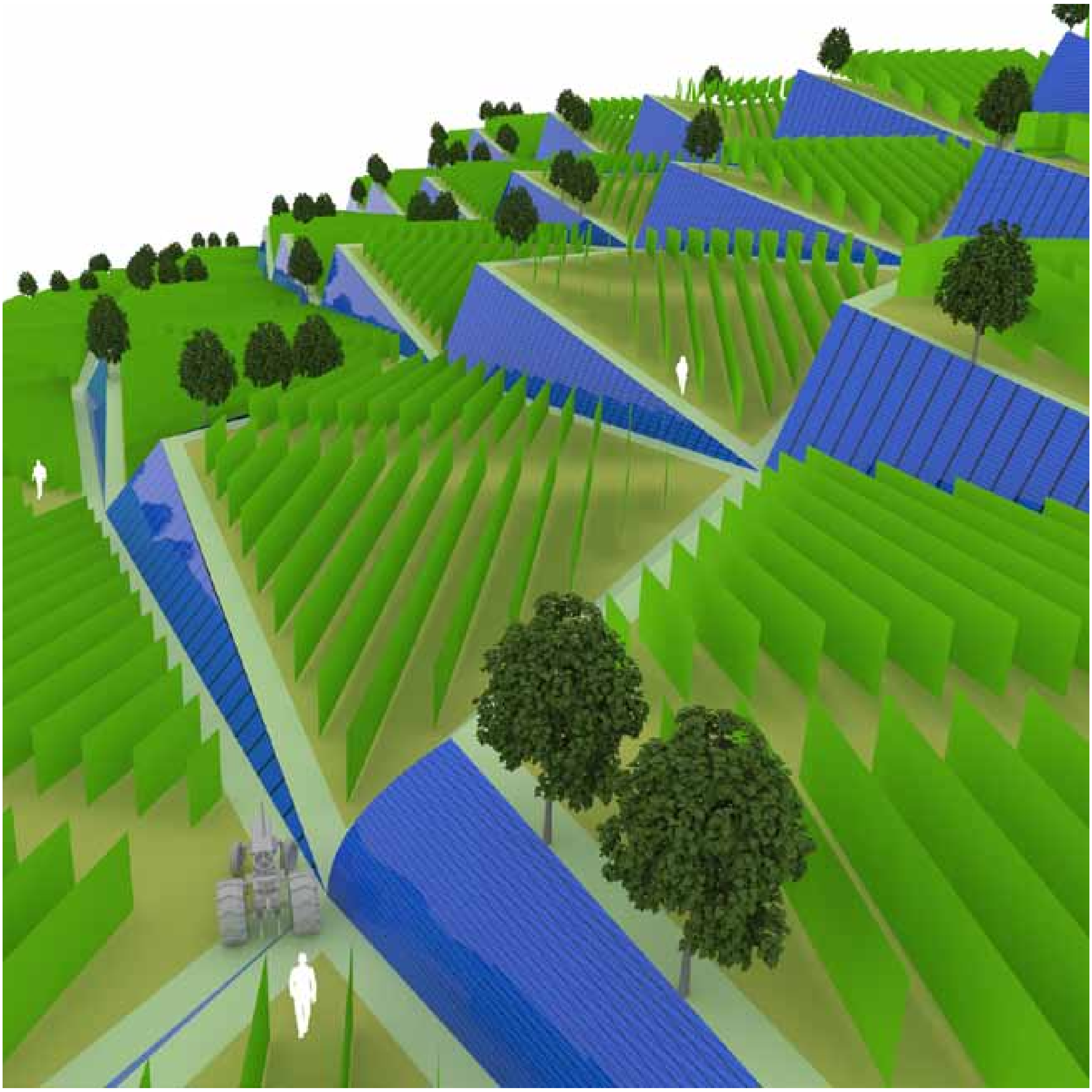




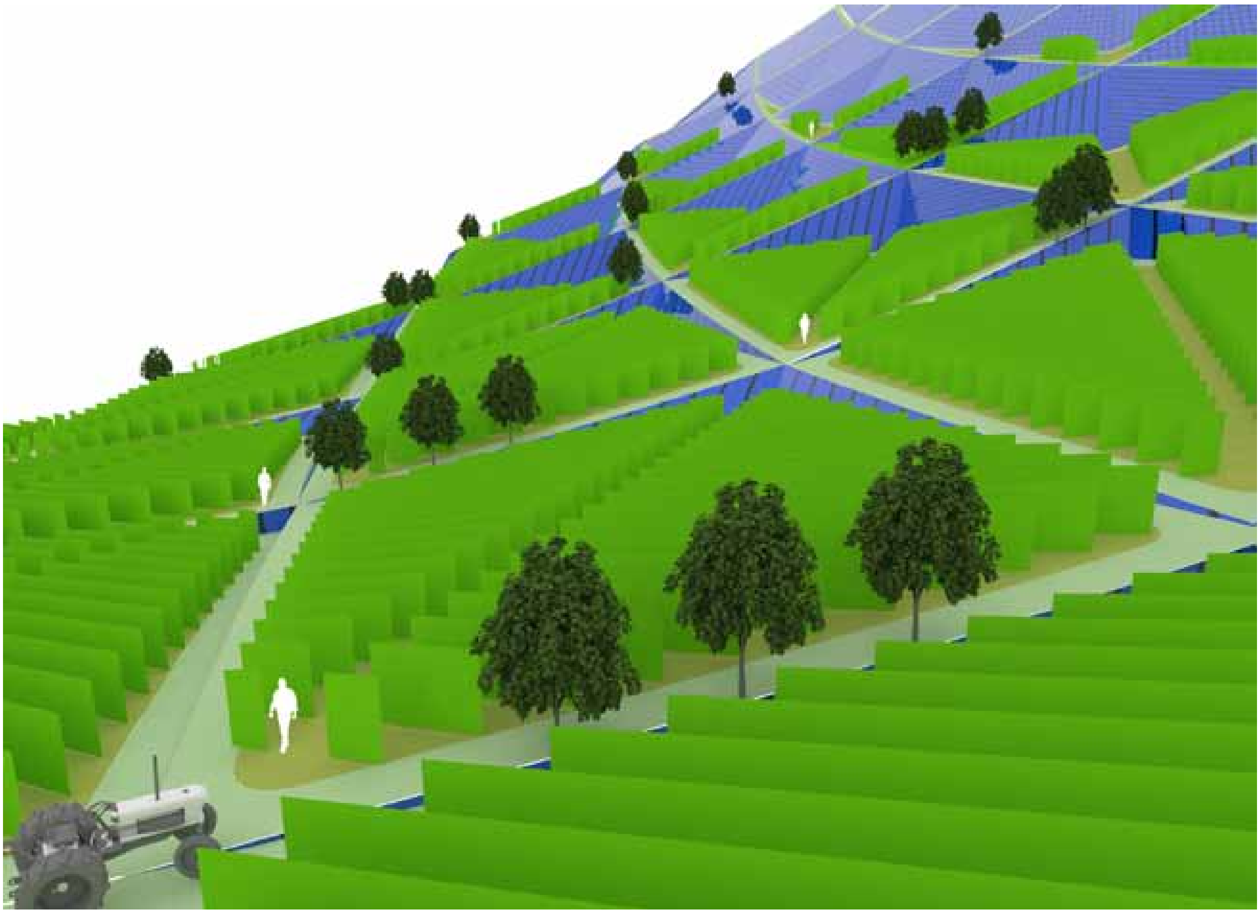
Special use areas

A different configuration of solar panels in long bands parallel to the contour lines allows for varied uses of farmland - including different crops, recreational and touristic activities - that require greater accessibility and the use of more traditional retaining walls.

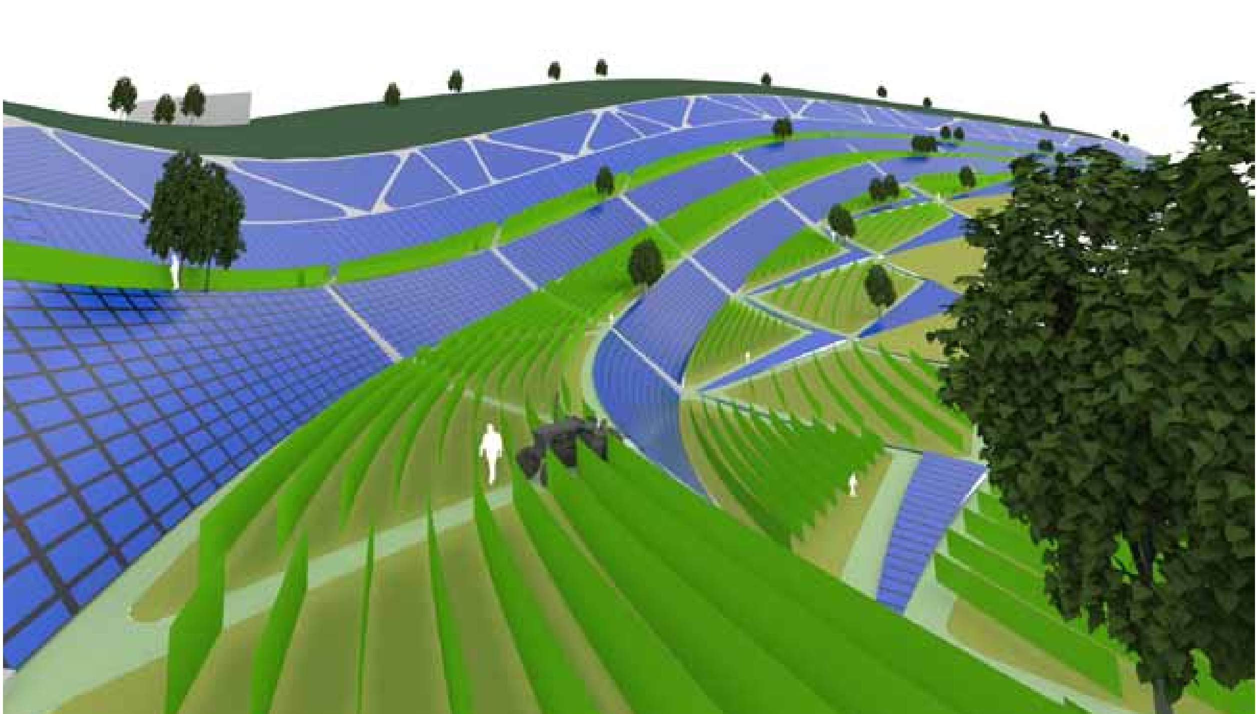
3.7 Design Integration



Intensive photovoltaic installation integrated to new vineyards in areas currently not in use

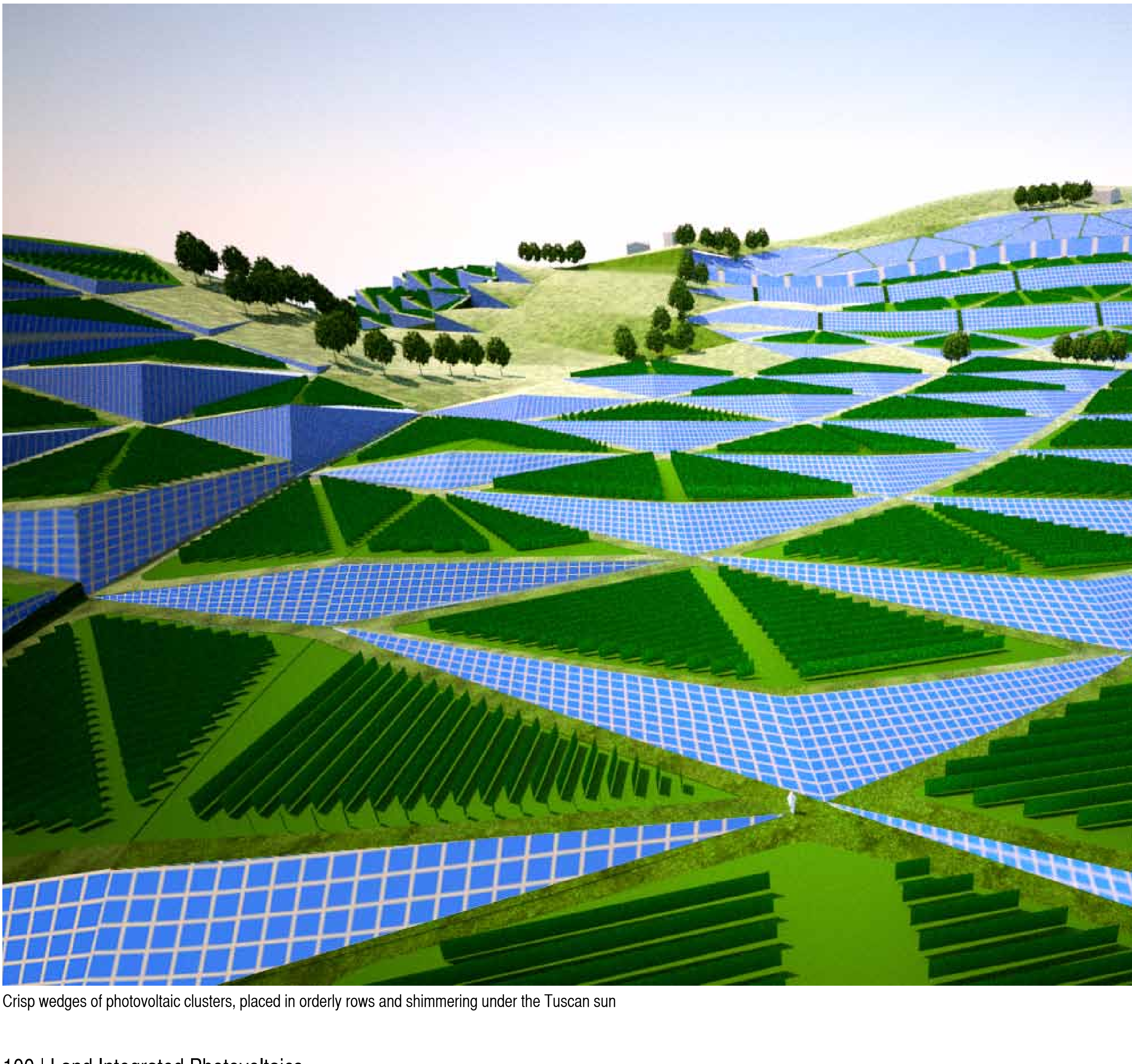


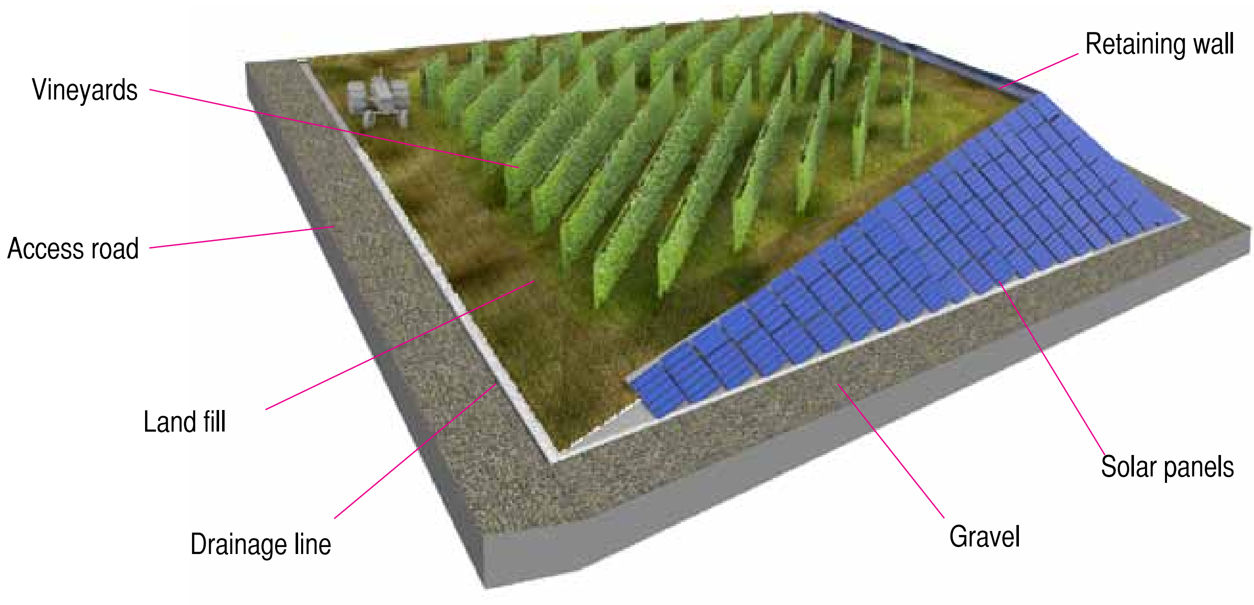
View of the transition from low slope/intense vineyards to high slope/intense photovoltaic system

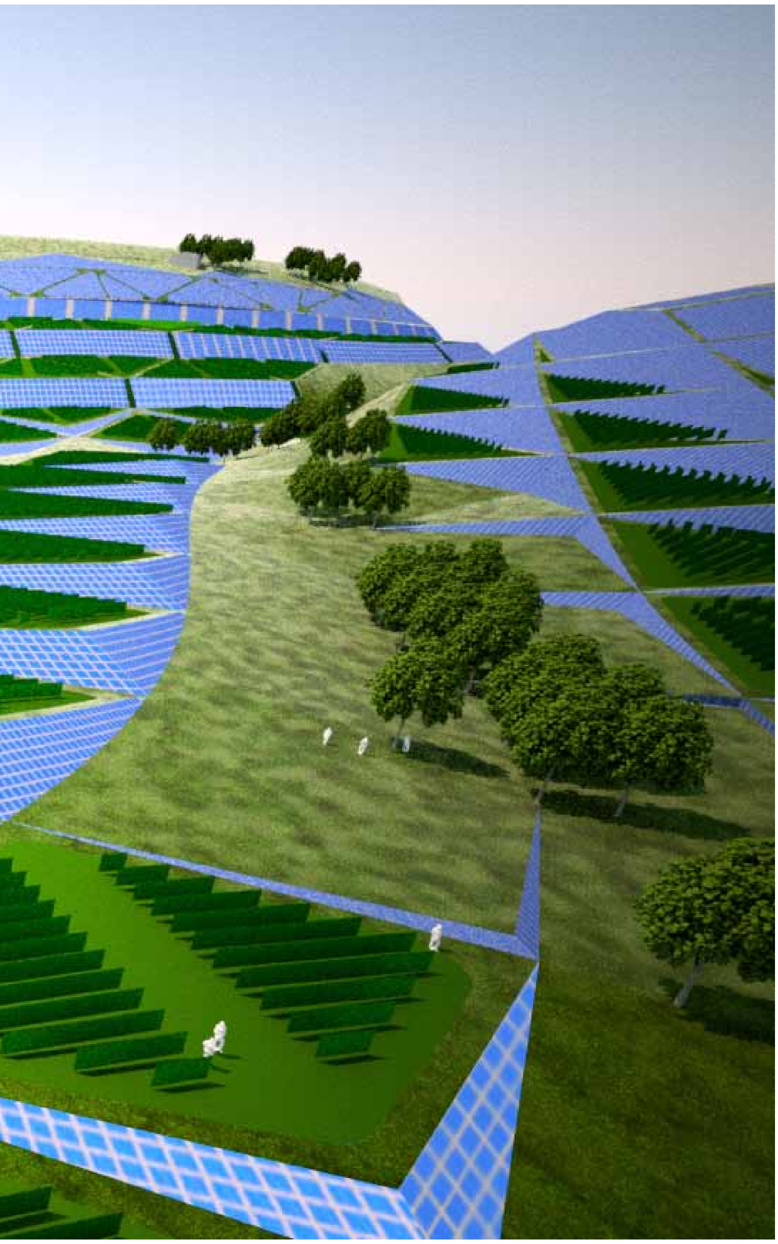


View of the special use area, with traditional retaining walls and direct vehicular access to vineyards

Technical implementation
Each section requires the construction of a retaining wall - made with locally available stones or cast on-site concrete - and the creation of a land fill with topsoil appropriate to growing grapes. Vineyards are located on top of the land fill and oriented perpendicular to the original slope. Solar panels are mounted on a metal framing attached to the retaining wall. The perimeter of each section allows for the natural evacuation of storm water , which is then collected in a tank at the bottom of the wall and feeds the irrigation system of the downhill section using gravity only. The perimeter road provide access to each section and connects the units diagonally across the slope. A storage space for tools and materials is also placed within the retaining wall; in some case, residential units can also be placed within the land fill.


Crisp wedges of photovoltaic clusters, placed in orderly rows and shimmering under the Tuscan sun


Vineyards
Access road
Land fill
Drainage line
Retaining wall
Solar panels
Gravel



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Abstract

Renewable energy technologies bring the promise of a decentralized model, with power produced at or near the point of consumption, allowing for the production plant to be near or in the city. The combined effect of distributed generation and community-owned power models, together with new requirements for energy performance of buildings, will have powerful implications in urban and rural areas across Europe. Recognizing the impending energy revolution as the driver for transforming current planning practices, the study proposes the synergetic integration of productive activities, energy infrastructures, natural resources and urban fabric in a radical new model of land development. The research attempts an investigation of both the cultural and the technological overlay of human activities, in order to identify strategies of occupations that are compatible with pre-existing uses and that respect the natural vocation of the land. The three demonstration projects explore the architectural language emerging from new forms of energy production, offering an unapologetic - and perhaps controversial - vision of energy landscape in Europe.

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