GOA 2100

Sustainable Cities
International Urban Design Competition

India Team
World Gas Conference, June 2003
Tokyo, Japan

The Goa 2100 logo was developed by visualizing the logistic leveling off of the exponential growth trend of the 20th century to a more sustainable state by 2100. This is enabled through the negative feedback of reduced population growth, consumption and anthropogenic emissions driven by greater equity, efficiency and ecological sustainability symbolized in the contra-rotating 'infinity' symbol.

Cities . . .

The blood of the villages is the cement with which the edifice of the cities is built. - M K Gandhi

Cities have been engines of growth of empire, trade and culture

for over 5,000 years. [17,58] These human artifacts extract resources

from across the planet and transform them within complex ecologies. [12,29,57]

Rome footprint, c. 100 ACE

Dholavira, India, c. 3500 - 2500 BCE

They also spew waste into the ecosystem threatening
living systems across the globe [29,60]

The secret of the sustainability of ancient Indian
cities lay in :
- a balanced regional rurban hierarchy
- a high regional self-sufficiency for food,
  water and energy
- a culture of community and sufficiency, and
- a long inter-generational view of the future

Many cities have lived for over a millennium,
evolving functions and forms very different
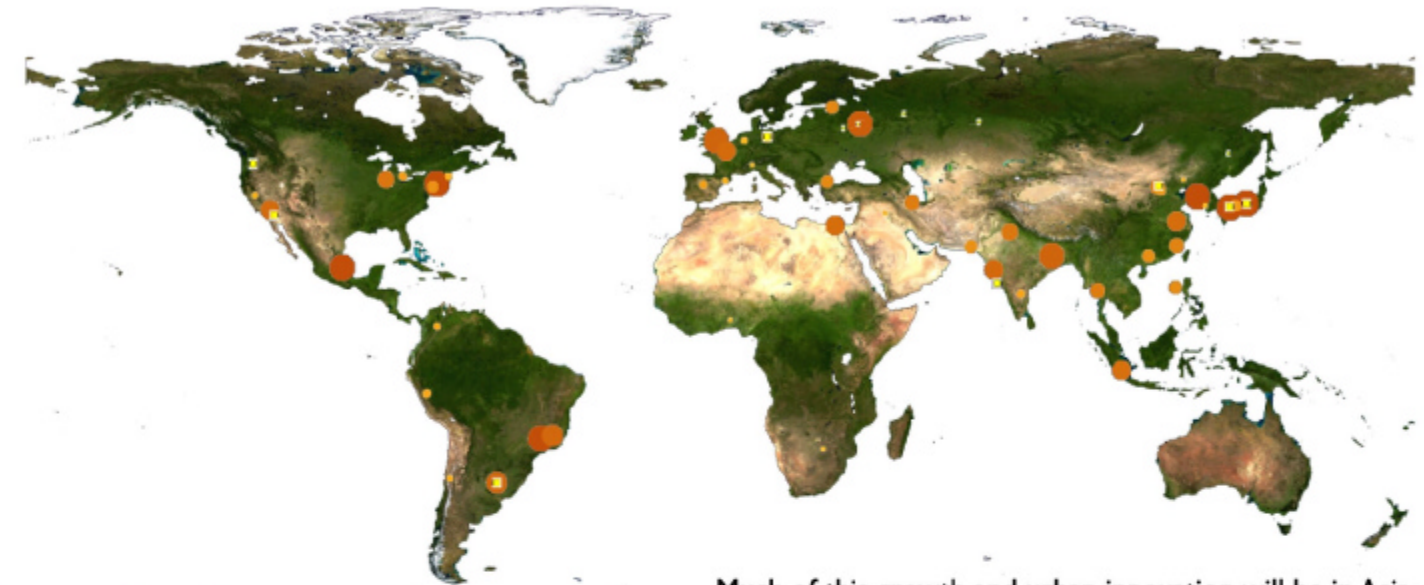from that of the westernized industrial city. [57,90]

South Asia has witnessed many cycles of
urban expansion and decline since 3500 BCE. [73]

World cities 2500 BE to 1500 ACE

2500 BCE to 1800 BCE	1800 BCE to 1000 BCE	1000 BCE to 650 BCE
650 BCE to 100 ACE	100 ACE to 622 ACE	622 ACE to 1100 ACE
1100 ACE to 1400 ACE	1400 ACE to 1700 ACE	1700 ACE to 1900 ACE

The world will be predominantly urban in the first quarter of the 21st century.

Much of this growth and urban innovation will be in Asia,

along the coasts and in the tropics. [47,81]

water
energy
food

Bombay footprint, c. 2000 ACE
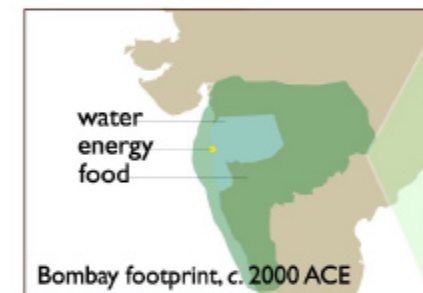
Mega-cities like Bombay are creations

of global trade, industrial growth and

empire, but are inherently unsustainable. [29,57]

Addressing endemic urban poverty; a fossil fuel addicted metabolism

and **dispersal of huge ecological footprints will require a new urbanism:**

networked, human-scale and low-throughput.

This new urbanism is
only possible in smaller
urban centers like Panjim, Goa

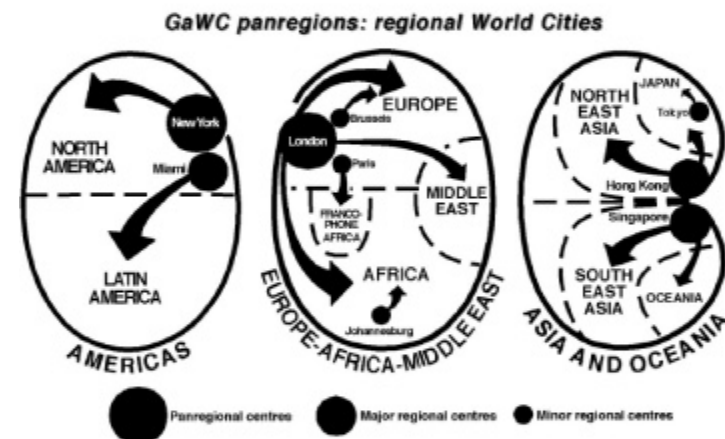**Are cities unsustainable** in a sustainable world?

The 21st century will be marked by world population stabilisation at up to 10 billion; severe regional freshwater stress, health and food security challenges; loss of most natural forests; rising CO_2 concentrations and sea-level rise in an era of unprecedented rise in human wealth, knowledge and quality of life for a few. [40, 50, 69, 82, 86, 91]

GaWC panregions: regional World Cities
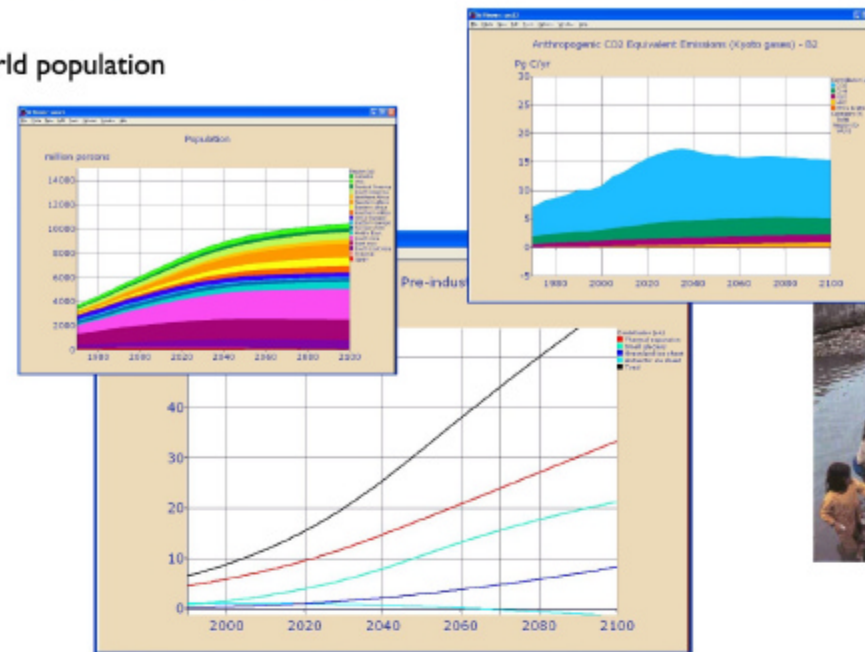
Scenario Structure with Illustrative Patterns

Scenario	Population	Economy	Environment	Equity	Technology	Conflict
Conventional Worlds						
Market Forces						
Policy Reform						
Barbarization						
Breakdown						
Fortress World						
Great Transitions						
Eco-Communalism						
New Sustainability Paradigm						

The role of the nation-state, global corporations and civil society will be redefined as world-cities and regions jockey for dominance in a networked world. [14, 44, 70, 76, 79]

Some of these alternative futures have huge economic, social and environmental costs. Others are more benign and potentially liberating for the bulk of humanity in keepingwith the Millennium Development Goals and Agenda 21. [15, 21, 80, 82]

Resolving this may lead to a re-alignment of the global political economy and the redefinition of many social, management and environmental sciences into a new Sustainability theory and practice. [9, 11, 32, 72, 24]

The intensity of these trends can vary considerably based on the ethical, socio-economic, technological and governance-related choices we make. [10, 50]

This will lead to new conflicts and alliances induced by the increasing co-option of net primary production, fossil fuels, wealth and the lifetimes of poorer populations by knowledge and technology-enabled societies. [20, 25, 39, 87]

Most current analytical methods are inadequate to explore this terrain. Scenario-based dynamic modelling is the most advanced available tool to explore the multiple bifurcations and uncertainty associated with these futures.

The IPCC-SRES scenarios provide some indication of possible trajectories for India and Goa over the 21st century. The B2 scenario was chosen as the most appropriate to benchmark the Goa 2100 design against. The SEI-Tellus Polestar model was also used to explore long-range regional possibilities apart from a custom model building effort for Greater Panjim.

. . . because a sustainable city **cannot exist** in an unsustainable world

India: the challenge of **Sustainability**

Let us, set the … national vision (for India) … to make it one of the largest economies of the world, where the countrymen live well above the poverty line, their education and health is of high standard, … bringing all-round prosperity and … the ability to sustain and improve these over very long periods of time …
– A P J Abdul Kalam, space scientist and President of India [1]

Indian RUrbanism
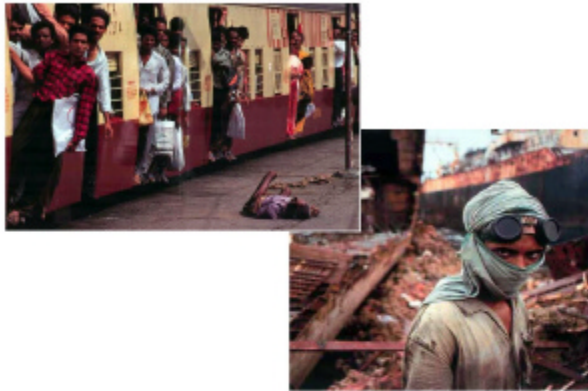
Overpopulation: Poverty, dirty industry and overpopulation put increasing pressure on the environment. Low levels of human development, inadequate fossil fuels and investment capital and degrading public institutions constrain economic development. This poverty of physical and human resources and good governance lies at the core of the sustainability debate. [3, 16, 54, 61, 66, 85]

Nevertheless, food self-sufficiency, a rapid growth in literacy and the growth of renewable energy use and water conservation and are positive signs.
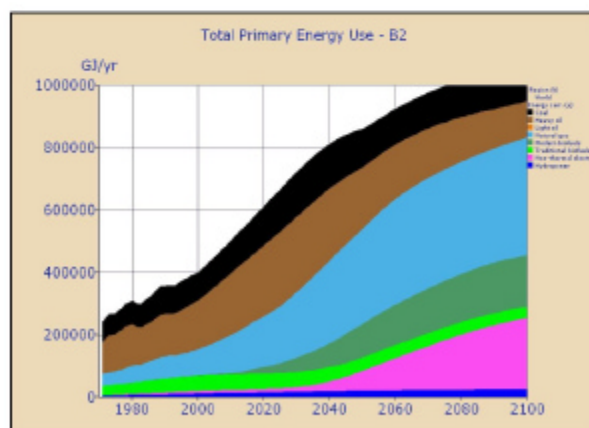
IPCC B2 scenario Predominantly cropland
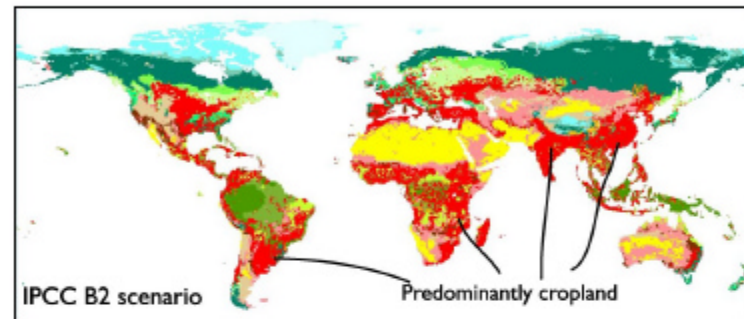
Land: most forests will be lost to cropland, but food security may be maintained with post-Green revolution eco-technologies and empowerment of local communities. [4, 16, 78]

Water: Over 70 percent will live in water stress, conjunctive use, agricultural end-use efficiency, zero-emission urban and industrial eco-technology and local regulation and social control can change this. [5, 16, 28, 78]

Environment: carrying capacity will be severely strained. Contracting ecological footprints while maintaining entitlements for the vulnerable, using Factor 4 efficiency, effective regulation and social control on consumerism will be necessary. [16, 88, 89]

Development: Over 200 million poor people will live in India - the largest concentration in the world. Sustainable livelihood initiatives alone can reduce, but not eliminate poverty. Expanding literacy and health will facilitate social change and help stabilize population. [1, 78]

Technology: often heightens contradictions, but will provide fillip to export-led growth and the development of domestic markets. [1, 3, 49]
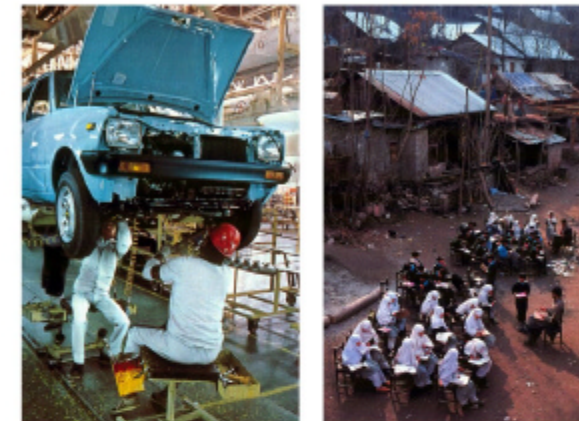
Conflict: international, regional, inter-community - hovers below the surface, erupting in occasional spasms of violence. New social movements rise to address perennial challenges of caste, gender, religious and ethnic exploitation. [18, 33]
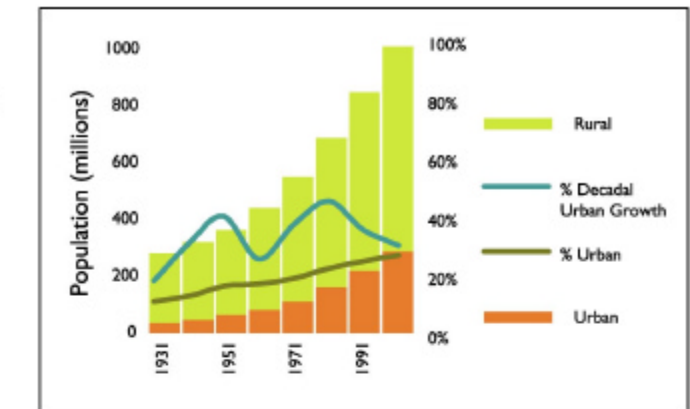
Good governance: with the weakening of the State, onslaught of global forces and erosion of social and public institutions will be challenging. Devolution, empowerment of women, communities and minorities and the rise of new political formations may lead to a new plural political settlement. [18, 35]

Cities will be the fulcrum of these social, economic and environmental transformations.

Slowdown of urbanisation: India lives in its villages. Its population may stabilize at fewer than 1.5 billion by 2050 with a rural majority. Urbanisation (now under 30%) has been decelerating for 20 years, even though the country has the second largest population in the world. [3, 55]

As the only tropical team in this competition, a shortlist of eight possible (less than a million population) cities was developed across India.

A detailed analysis helped select Panjim, Goa as representative of the region and international context, with its coastal location, rich biodiversity and resource base, post-colonial and convivial culture.

Total Primary Energy Use - B2

Energy: this century will be based on gas, coal and an enlarging niche for renewable energy. Improved accessibility and functioning markets will enable balanced regional development. [4, 49, 77]

Keeping a balance between the urban and the rural - RUrbanism - is the central challenge of sustainable urbanism in India. This project demonstrates that this new urbanism is possible - one that values human time and meaningful work, reduces poverty and deprivation, redefines consumption and shrinks ecological footprints - by balancing relationships between natural, physical, financial and human capital in a way that frees human time to create economic wealth, well-being and high culture.

Replicable, tropical coastal RUrbanism can be demonstrated

Greater Panjim (GP)

Panjim, the capital of the small western Indian state of Goa with an urban area of about 170 sq. km. and a population of 113,000. This urban, RUrban, rural and marine agglomeration is the chosen unit of analysis and design.[7,34]

Located in the lower watersheds of the Mandovi river basin facing the Arabian Sea, its rich natural resource base and community-centric culture provides a powerful basis for an indigenously lead transition using renewable energy, gas, local food production with water and energy conservation. This is made possible by a culture of sufficiency and local governance, where non-material needs can be met non-materially.[7,19,74]

Water and nature areas are interwoven into the urban fabric, yet both traditional and contemporary elements are well-balanced and integrated.[7]
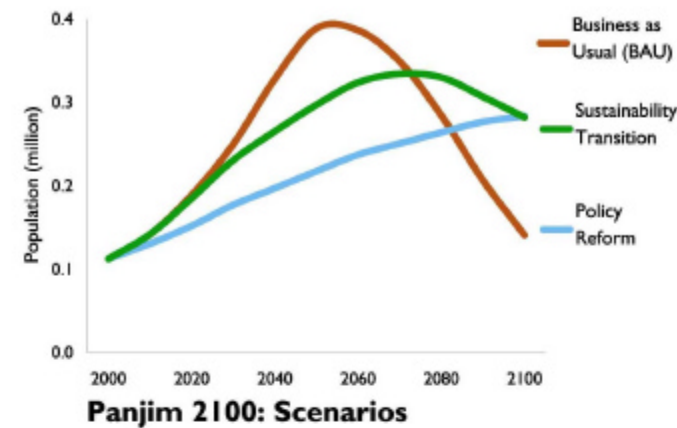
Greater Panjim
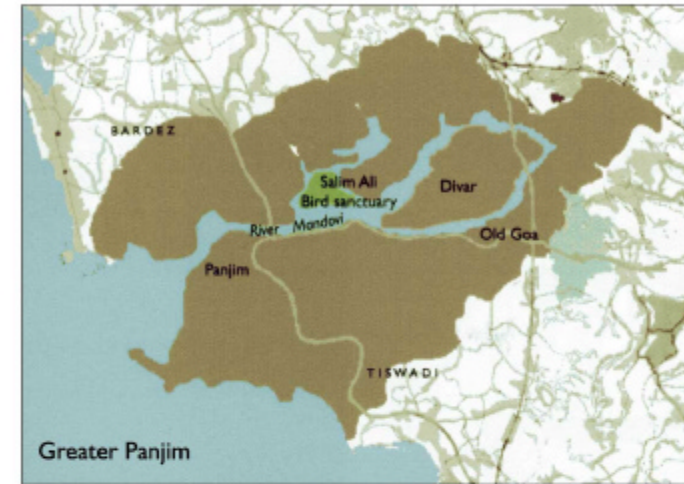
Old Goa: a 15th century world-city, capital of the colonial Portuguese empire, abandoned because of repeated epidemics linked to poor adaptation to the tropical environment, is now a world heritage site.[7]

Old Goa, c. 16th century

Old Goa today

Mandovi Bridge

Mangroves

Rice farming

Fishing village

Church

Salt pans

Panjim town

Waterfront architecture

Bird sanctuary

Many types of land cover: water, orchard, marsh, mangrove, khazan (traditional saline water agriculture), and urban

As a coastal city, it **faces the loss of prime land, world famous beaches, and potable ground water** due to global warming and rising sea levels
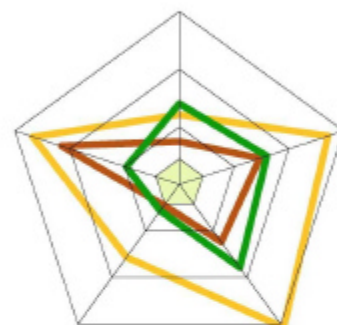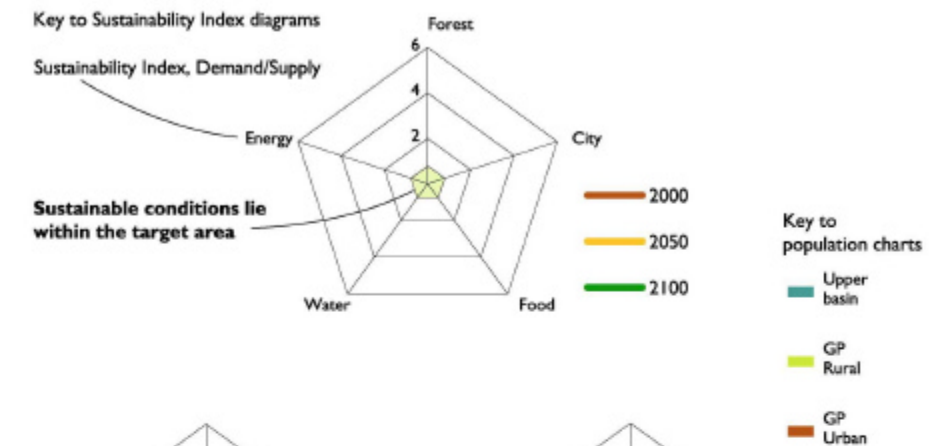
Greater Panjim: future **scenarios**

Goa is a small self-contained ecological and cultural region that has retained its identity in spite of almost 500 years of colonial rule. Change has been relatively slow in the state, but that is altering rapidly. Opportunities are appearing in the IT, bio-technology and eco-tourism sectors. [34]

Goa 2100 scenarios have been adapted from a set of global and national scenarios produced by RIVM, the Global Scenario Group and TERI. They have been significantly adapted to match the reality of Goa, but are still only illustrative and not definitive.

Panjim 2100: Scenarios

Business as Usual (BAU)
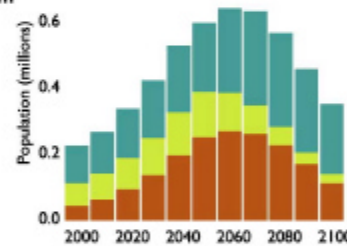Sustainability Transition
Policy Reform

Hence, multiple potential development pathways are now opening. Three were selected for more rigorous analysis and design by this project. Each performs very differently in achieving sustainability of long-term resource security: [2, 4, 65, 75]

Key to Sustainability Index diagrams
Sustainability Index, Demand/Supply

Sustainable conditions lie within the target area

2000
2050
2100

Key to population charts
Upper basin
GP Rural
GP Urban

Mandovi basin   Greater Panjim

Business-as-usual (BAU)

Maintaining a contemporary trajectory of reactive development, leading to rapid economic, population and urban growth driven largely by in-migration in search of the fabled Goan lifestyle, leading to the devastating the environment and the easy-going 'fish, curry and rice' Konkani culture, leaving Panjim looking like the corridor towns that ring Bombay by 2050

The city is conceived within its ecological region, the entire Mandovi basin, from the hills of the Western Ghats to the ocean, with about six times the area of the city and about twice its population. [7, 53]

Mandovi basin   Greater Panjim
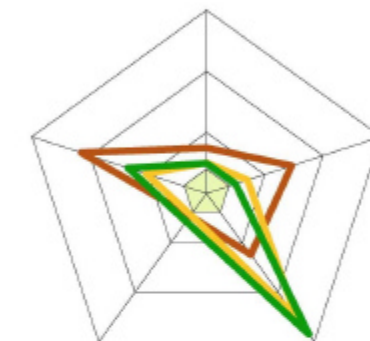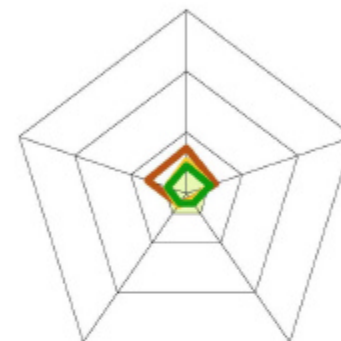
Sustainability Transition
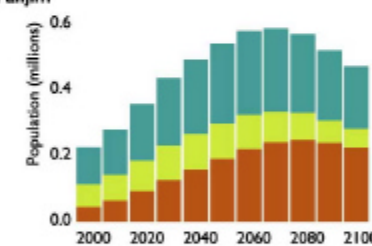
A radical departure led by a process of intense community consensus building to rejuvenate local governance leading to: urban consolidation to reduce footprints and return to human-scale; integrated regional agro-forestry and ecosystem regeneration; transformation of energy and water systems, transportation and communication networks; building a high-tech green economy and transforming the identity of the city. A medium-term redevelopment plan receives international funding as commercially viable. Panjim becomes one of the top-5 quality of life cities in the Asia-Pacific region by 2030.

Mandovi basin   Greater Panjim
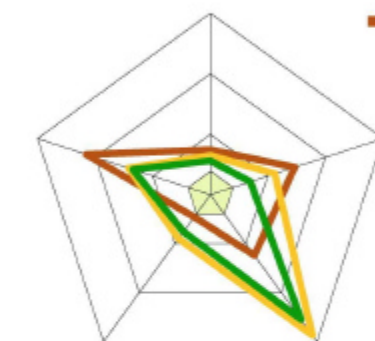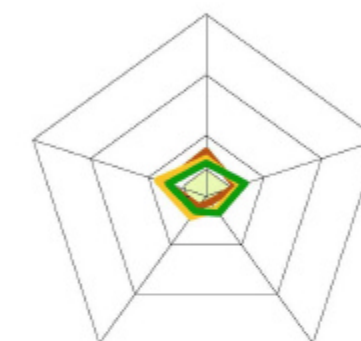
Policy Reform
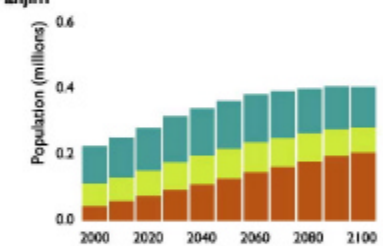
A good governance, community and environment centric pathway that attempts to restrict population growth, improve human development and implement a local Agenda 21 while seeking to attract investment in clean industries (e.g. tourism and IT). Quality of life above the national average, but unplanned development and urban sprawl, the global blight of consumerism, degraded beaches and crowded roads makes Goa just another destination on the backpacker and charter tour map.

Sustainability demands that the **regional ecological footprint** lies within the Mandovi basin

Business-as-usual (BAU) scenario leads to **economic and population growth** . . .

GOA
2100   6

Explosive urbanization swallows forest land and khazan

Urban Ecological Succession in GP

Urban (H)
Urban (L)
Waste
Khazan
Field
Orchard
Forest
Laterite
Grass
Pond
Mangrove
Marsh
River
Beach

B A U

Forest

Field

City

Waste

Night view 2000

Spiraling resource demand and insecurity gobbles up capital
required for future industry and the provision of social services.
Rich neighborhoods become richer and wall out the city.

Unviable, hence ungovernable: needing to extract,
but nothing to extract.

A1

A2

A3

Greater Panjim B A U 2100

Dona Paula 2100

Rapid inequitable economic growth
increases poverty and unemployment,
and the emergence of a rentier class.

Rural areas degrade, unable to provide food and ecological services

Panjim 2100

Competition for scarce resources leads to
social conflict which undermines the potential
for an export-led growth strategy.

. . . **massive immigration, poverty and resource overshoot,**
generating cancerous urban sprawl and collapse
of environmental services

Night view 2000

Renewable energy, sustainable transport and IT links enable consolidation of smaller urban nuclei, while dynamic components can swell or shrink, allowing interplay of city, forest and field[6, 30, 38]

Resource security and contained demand makes energy, resources and savings available for efficient technology - recycling, reproduction, maintenance and de-construction - and the sunrise sectors of biotechnology, IT, advanced materials, human contact and info-edutainment

Urban Ecological Succession in GP

Sustainability Transition

Legend: Urban (H), Urban (L), Waste, Khazan, Field, Orchard, Forest, Laterite, Grass, Pond, Mangrove, Marsh, River, Beach

Forest

City — Field

Panjim 2050

Greater Panjim Sustainability Transition 2050

Old Goa 2050
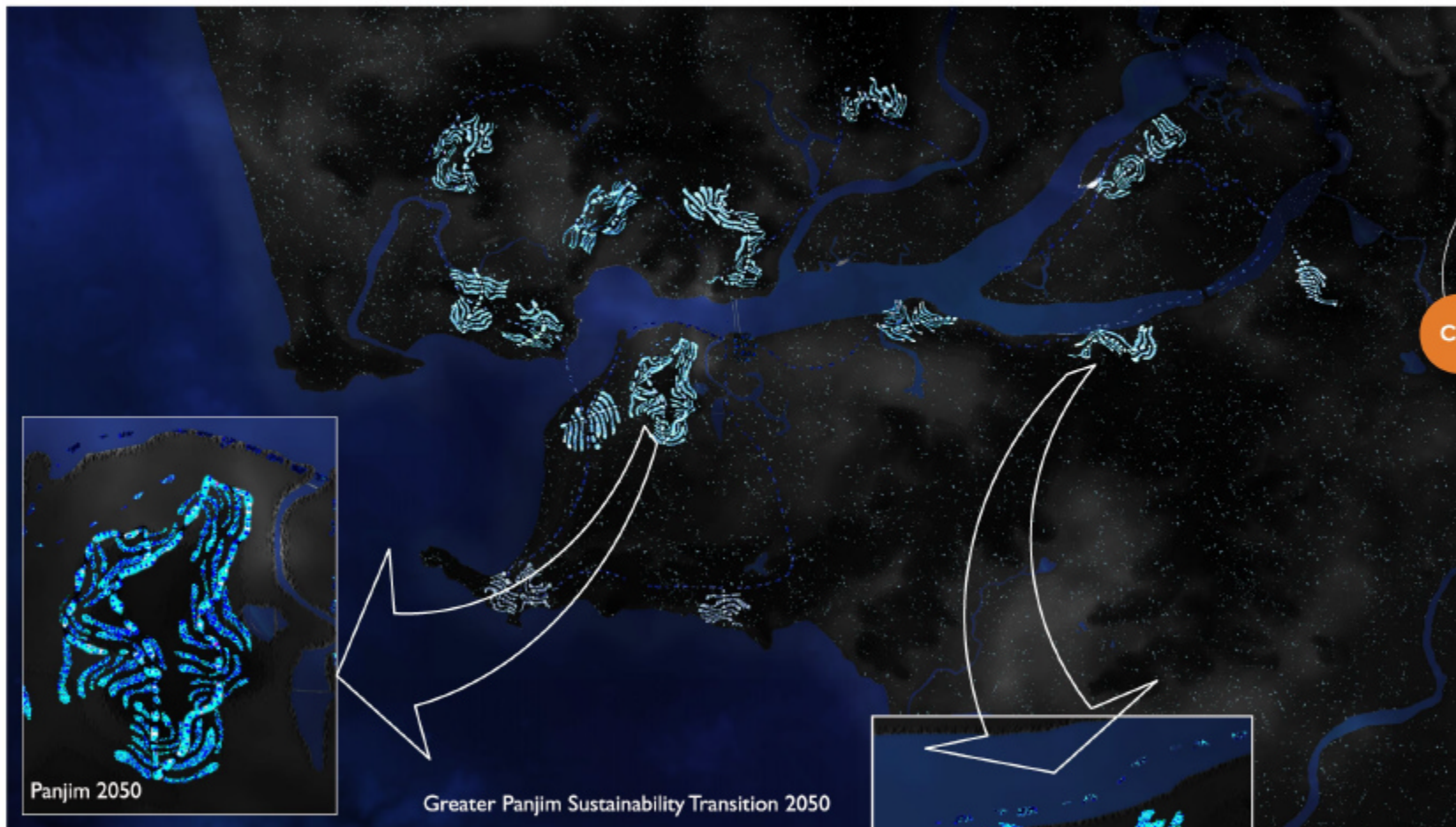
Based on creating governable cells with viable urban nuclei* that develop according to resource availability, natural limits of pedestrian mobility, and shared neighborhood cultural identity, creating an efficient, adaptive, low-stress infrastructure [6, 13, 53, 64, 68]

* Not growth nuclei, but like living cell nuclei, serving specific high-density functions. A viable nucleus in this economic and geographic context contains 10,000-30,000 people, networked into a set of meta-communities forming a tissue of RUrban fabric
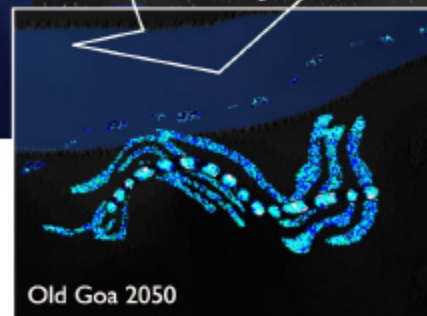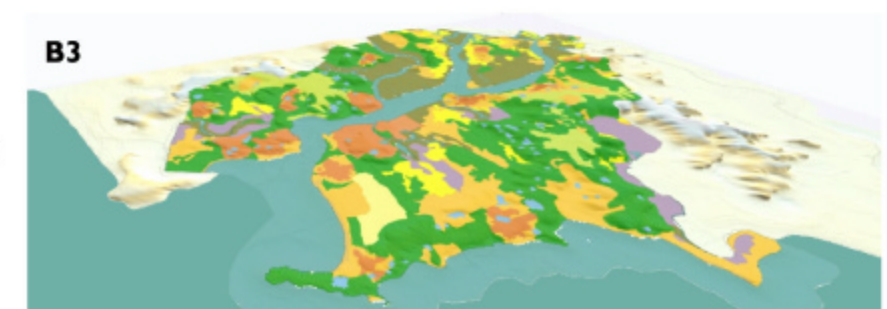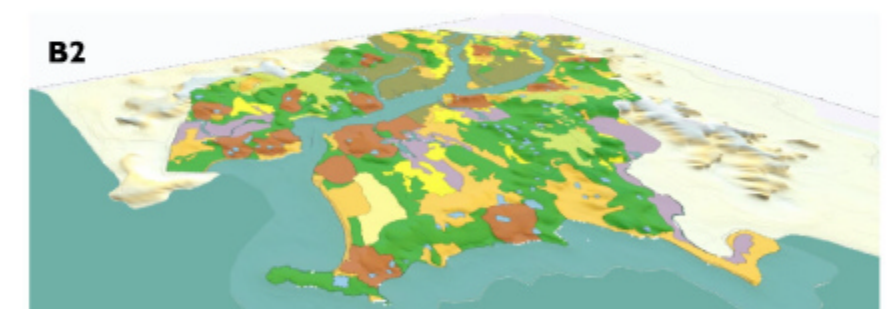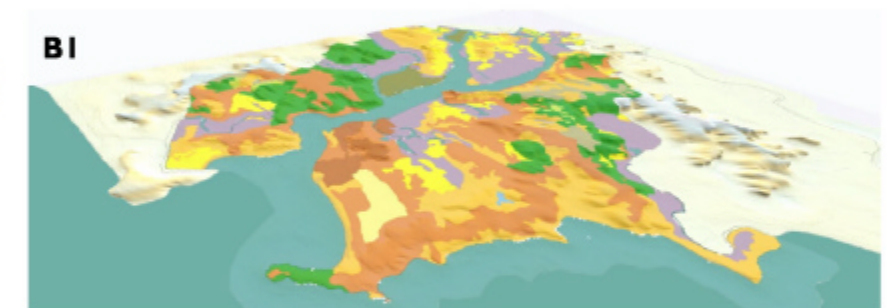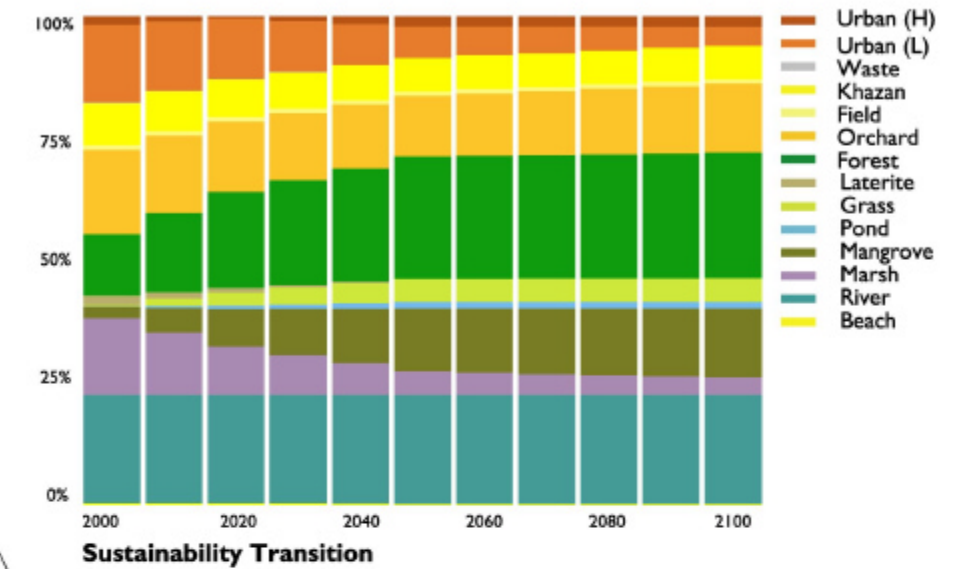
A viable city, providing primary ecological and economic services to its region [52, 56]

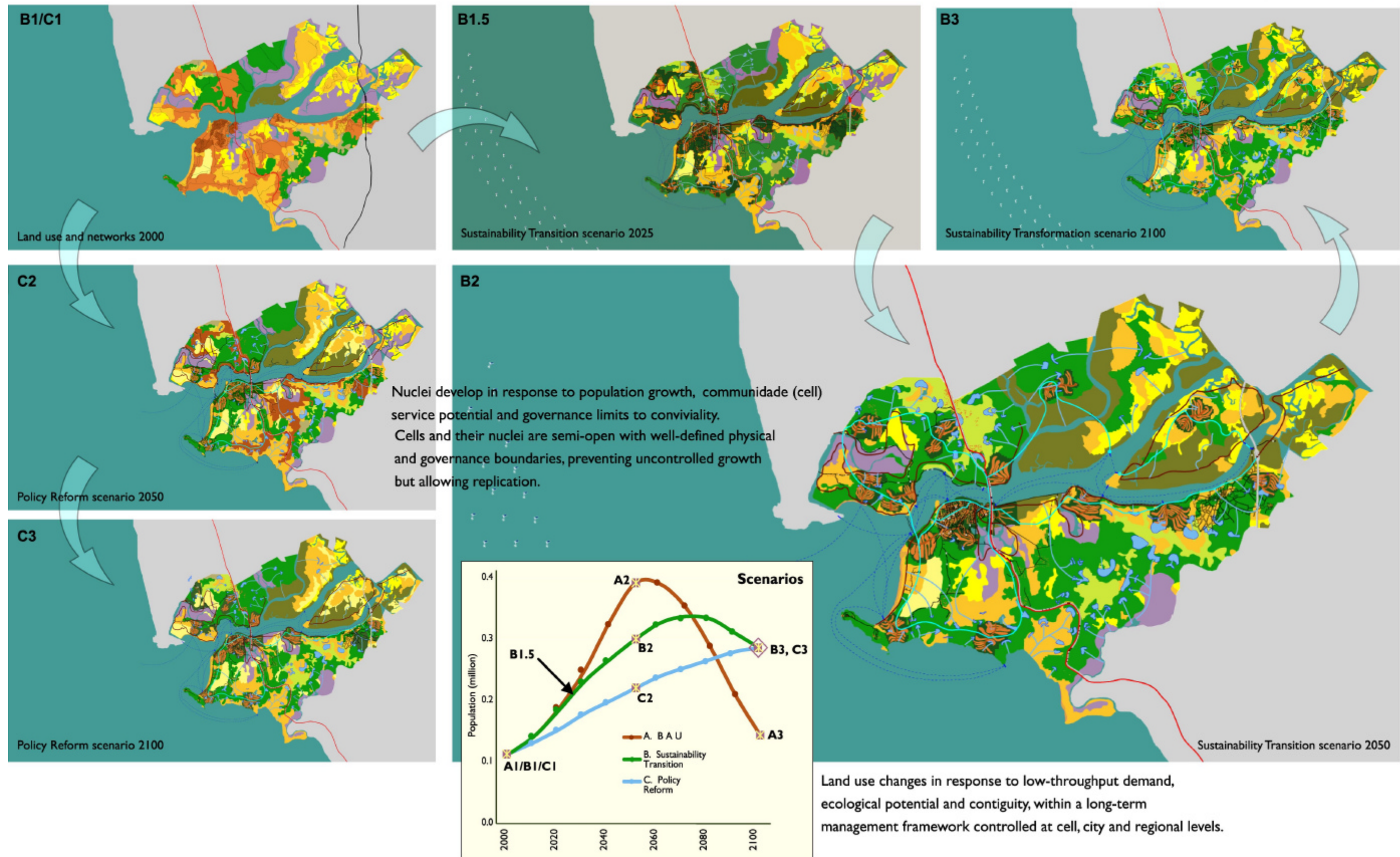Rural areas become viable in their own right with employment and quality of life that is better than the city [6, 48]

B1

B2

B3

. . . in **dynamic balance** with its region, state, nation and the world . . .

B1/C1

Land use and networks 2000

B1.5

Sustainability Transition scenario 2025

B3

Sustainability Transformation scenario 2100

C2

Policy Reform scenario 2050

C3

Policy Reform scenario 2100

B2

Nuclei develop in response to population growth, communidade (cell)
service potential and governance limits to conviviality.
Cells and their nuclei are semi-open with well-defined physical
and governance boundaries, preventing uncontrolled growth
but allowing replication.

Sustainability Transition scenario 2050

Land use changes in response to low-throughput demand,
ecological potential and contiguity, within a long-term
management framework controlled at cell, city and regional levels.

Scenarios

Population (million)

- A. B A U
- B. Sustainability Transition
- C. Policy Reform

A1/B1/C1 — A2 — B1.5 — B2 — C2 — B3, C3 — A3

. . . and sufficiently complex to withstand **changes in population, business cycles and social** transformation . . .

... can allow **120 million people*** to live on India's western coast ...

GOA
2100 9

Like all living systems, this living future subsists on renewable energy and sustainable food from terrestrial and offshore sources [41, 56]

Energy footprint

Regional: decentralized and biomass

Offshore: 70% centralized

RUrban: 30% decentralized

Area providing energy sufficiency

Six subsystems:
Governance
Work
Food
Water
Energy
Mobility

Coastal cities have the great advantage of utilizing marine resources. Panjim is no exception. Some terrestrial resource deficits (e.g. renewable energy) can be made up by using the additional coastline. [5]

The living city is not an island: its metabolism is **interlinked to surrounding ecosystems and its people and culture networked to other viable urban cells** to form a living and developing tissue, a net primary producer, not a parasitic system [13, 29, 38, 53]

Food footprint

Regional: including rice

RUrban: without rice

If non-vegetarian

Area providing vegetarian and sea food vsufficiency

Ghat
Chapora
Mandovi
Zuari
Sal
Talpona

Goa's watersheds

Instead of cities colonizing ecosystems to create fractured natural landscapes, dense urban islands emerge and melt into a sea of biodiversity.

Greater Panjim from space

Water footprint

Rooftop: all domestic

Regional: including rice

RUrban: without rice

Area providing water sufficiency

Poverty, income and entitlement deprivation - the bane of urban India - decline as participation and equity in economic and social life increases [3, 31, 36, 37]

A high quality of life and vibrant culture is possible within a dense but dispersed and dematerialized settlement structure, integrating a respect for ecological footprint with economic pragmatism. **This is financially viable, and can be done now.** [2, 10]

* 8% of India's population in 2050 on 5% of its land

... meeting people's basic needs **without endangering biodiversity**

In Goa, the communidade was the traditional unit of viable village self-governance, organized around an oligarchy of consensus and not adversarial franchise, controlling lands and managing water and public works in an ecologically consistent and socially equitable manner. [7,34]

Empowered to raise taxes and control land use, this basic cell becomes autonomous on local issues. The city addresses inter-communidade and regional governance, while fiscal federalism enables a viable link with the state and the nation.

The structure of governance is cellular, hence viable at all scales

Urban lands and village boundaries

2000
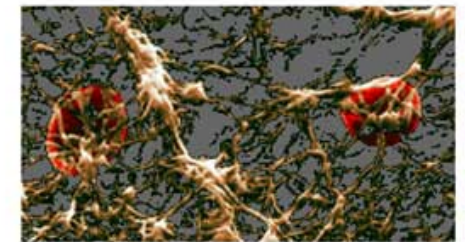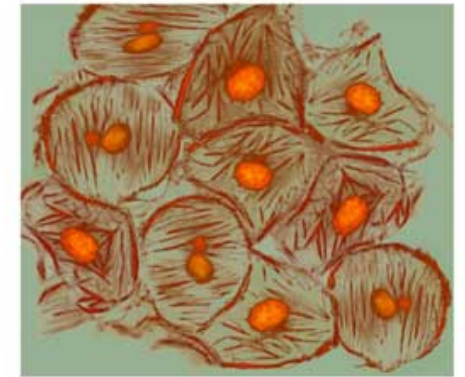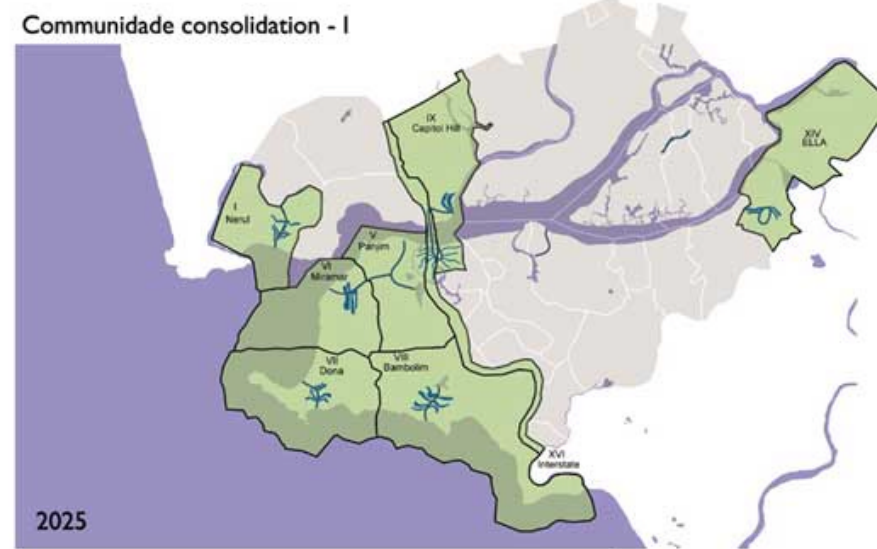
Overlaid by modern elected local councils, communidades are a shadow of their former selves. A new Constitutional amendment and transparency law provide the space and powers to change this. [62]

A primary organizing principle for a Sustainability Transition would be to transform and empower these communidades

Communidade consolidation - I

2025

Communidade consolidation - II

2050
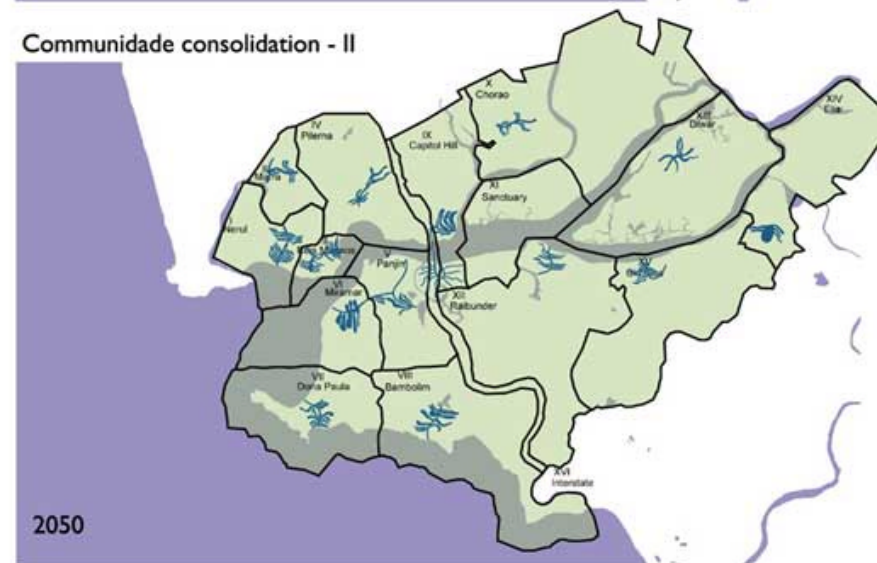
Communidades will be restructured around ecological and resource boundaries to enable better governance and viability. 23 villages will consolidate into 14 communidades over time, reflecting topography and resource boundaries, and changes in technology and communication.

Secretariat

Legislature on Capitol Hill

High court
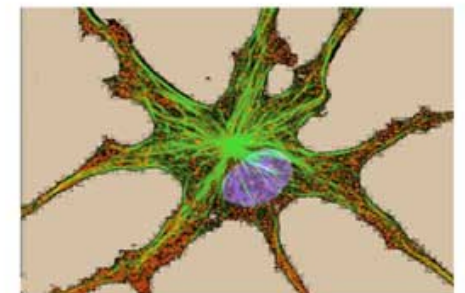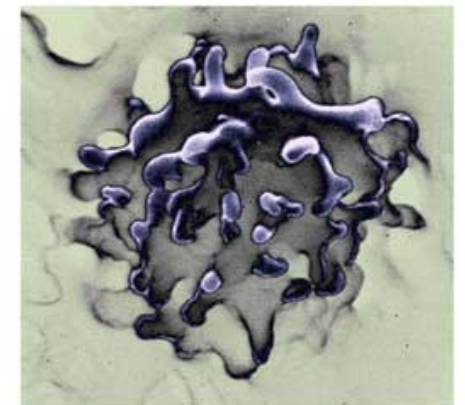
Connected by infrastructure and information networks, communidades can have a dynamic **urban or rural** character, adapting functional specialization to need

A Sustainability Transition builds **convivial livelihoods** and values

Spatio-temporal boundaries between home and office, field and forest blur with broadband wireless communication, virtual reality and sustainable transportation systems.

Remote and virtual work allows seamless office work from RUrban areas and agro-forestry in urban forests and home gardens. [14]

Yet, working with one's hands is an honored part of everyday life -

- growing food;
- tending the coconut palms and cashew orchards;
- recycling waste water in ecological sewage treatment facilities;
- protecting the mangroves and forests;

that provides rice, coconut, water and fish to the city

As is the -

- monthly production of a 1 MW wind turbine for export to Japan from Ella;
- stem cell therapy from the high-value medical biotechnology unit at Chorao;
- world-famous Panjim music conservatory that has daily web-casts with its conductor who works from Berlin;
- twenty-year long conservation effort at the Old Goa world heritage site and the pre-colonial temple tanks on Diwar;
- ten-minute long trip to watch birds fishing as the tide goes down in the Salim Ali bird sanctuary

Industrial labor markets exclude and limit human development through competition between unequals. In a services-led economy flexible patterns of work, exchange, leisure and learning develop displacing outmoded forms of wage compensation. [14]

In law and principle, the value of each person' life is similar to every others - *if the accumulation and use of time can be appropriately tracked.* [51]

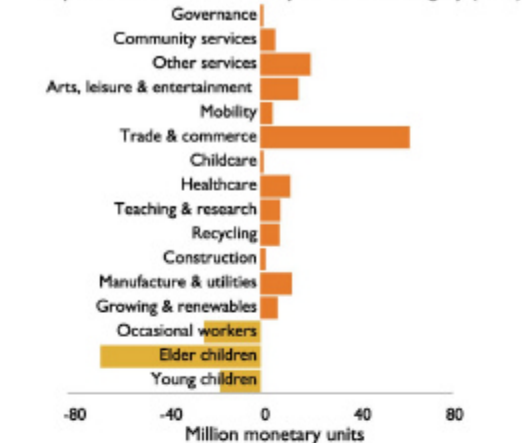## A new vocabulary of work and time-use:

- **Living**
- **Growing**
- **Processing**
- **Exchanging**, including:
  - **Trade**: retail and financial
  - **Moving**: people, goods and information
  - **Info-edutainment**: learning, media, and entertainment
  - **Human contact**: healing, caring, re-creating
  - **Cleaning** and maintaining
  - **Governance**: community, state, national

Greater Panjim Time-use Budget (2100)
(2.7 billion person hours per year)

PERSONAL TIME
HOUSEHOLD TIME
LEISURE TIME
COMMUNITY TIME

NEGOTIABLE TIME

- Studying
- Growing & renewables
- Manufacture & utilities
- Construction
- Recycling
- Teaching & research
- Healthcare
- Childcare
- Trade & commerce
- Mobility
- Arts, leisure & entertainment
- Other services

LifeTimes is a human capital currency for a sustainable economy.

Imputed Net Annual Income by Livelihood Category (2100)

Governance
Community services
Other services
Arts, leisure & entertainment
Mobility
Trade & commerce
Childcare
Healthcare
Teaching & research
Recycling
Construction
Manufacture & utilities
Growing & renewables
Occasional workers
Elder children
Young children

-80   -40   0   40   80
Million monetary units

LifeTime is measured in person hours, which can be traded to pay for human and professional services: from waste recycling and health care to entertainment. With IT and e-commerce support successful time-sharing programmes run across the world. Some even interface with conventional occupations with a wage premium on special education, skills and some livelihoods within socially determined bounds.

Progressive Livelihood policies

Universal secondary education,
but expensive tertiary education financed via future earnings
Gender neutral occupation structure and equal sharing of home making and childcare
Time use patterns structured to value the building of:

- Personal human capital (via learning and study) and
- Social capital (via participation in community service and governance)

Enabling cultural practices

Children don't work, except older children in community service
Child support is the right and duty of all adults
The aged only work at teaching, community service, governance and child care
All adults are involved in:

- Play, exercise and leisure for a physically and mentally active life
- Life-long learning with a time contribution to teaching-learning,
- Governance and community service to ensure a balance between paid and other time use

A socially mandated upper bound on the ratio between highest and lowest mean wages
Discounting of LifeTimes permitted only over a person's life, not transferable between generations

Even **3 meters of rain** in a rice-eating culture is not enough . . .

Land, food and water availability are intimately connected, hence their importance to sustainable resource planning. [4, 25, 27, 53, 56]

Indians (and Goans) have 3,200 sqm of land per capita, which shall reduce to about 2,000 sqm by 2050 - one-third of 'overpopulated' Europe. Therefore, the Goan water ration = 2,000 sqm x 2500 mm/yr = 13,600 liters per person per day (lpcd). Half of the land being flat and one-third of the water harvestable, yields only 1.1 kg of rice per person per day!


Without permaculture linked to multi-stage aquaculture and a vegetarian lifestyle Goa, like India today, will continue as a subsistence economy. [7, 41, 63, 56]

Sustainable cities in India have to be secure and self-sufficient for urban water, which is only about 15% of total water use. With the Sustainability Transition, Greater Panjim will import food from its region, providing goods and services in return. But the overall food footprint of the region shall stay within its boundary. Respecting water earmarked for irrigation shall create rural-urban partnership.

Water security can be achieved by:

- **Demanding less** (by conservation and efficient use)
- **Harvesting** at all scales (from the plateau and roofs)
- **Storing** (in ponds, tanks and aquifers)
- Treating pipes as **two-way** conduits (recycling white, gray, black, and green water)

Every water consumer is also a producer
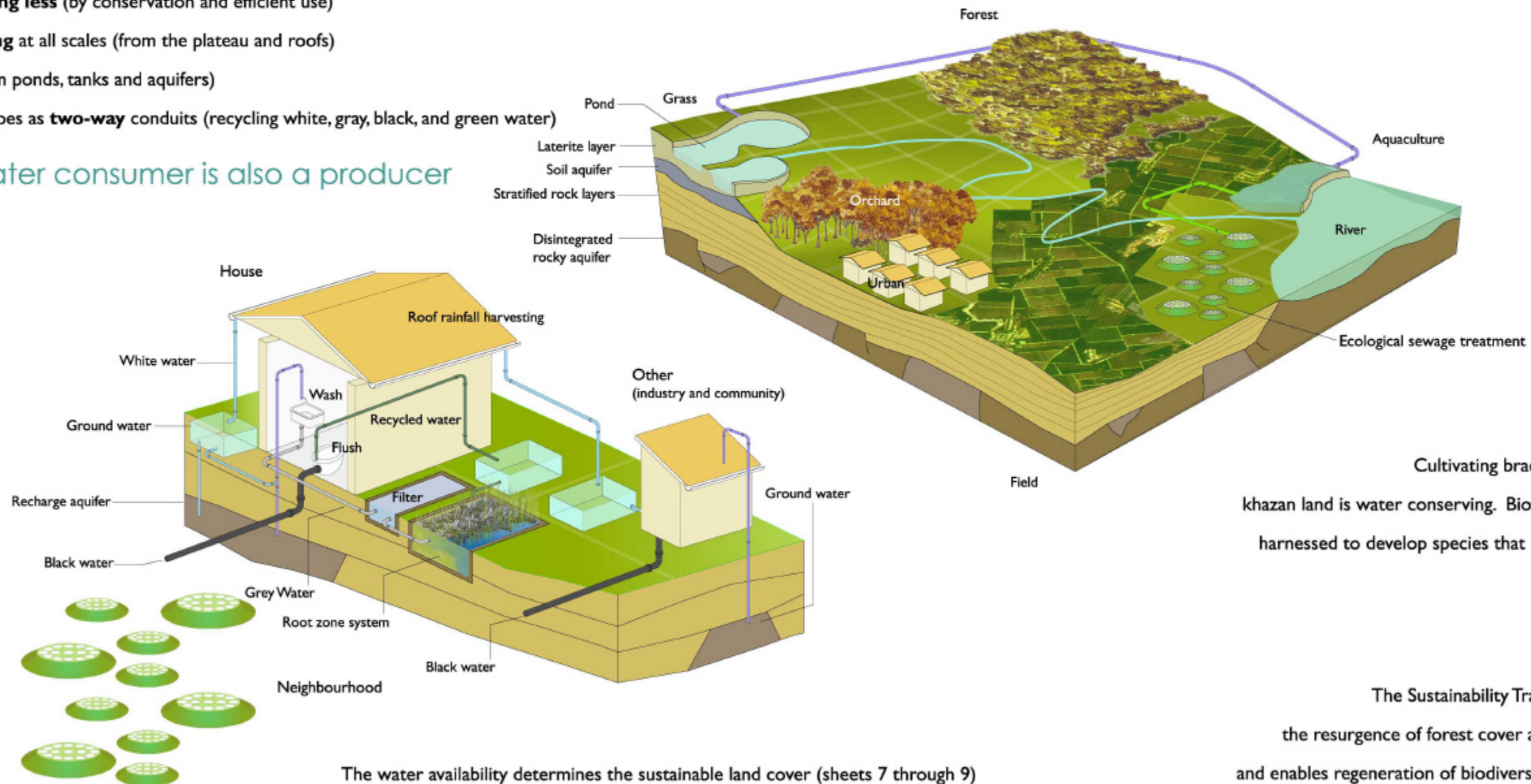
Cultivating brackish-water rice in khazan land is water conserving. Biotechnology will be harnessed to develop species that require less water.

The Sustainability Transition implies the resurgence of forest cover and mangroves, and enables regeneration of biodiversity and springs.

Ecological sewage treatment produces (in succession): algae, snails, carp, high value flowers, prawns and fish.

The water availability determines the sustainable land cover (sheets 7 through 9) and sets the roof area requirements for the urban nuclei.

. . . unless **every raindrop is harvested and recycled** many times

India: a coal and imported oil economy with a high pool of non-commercial of energy. [77]
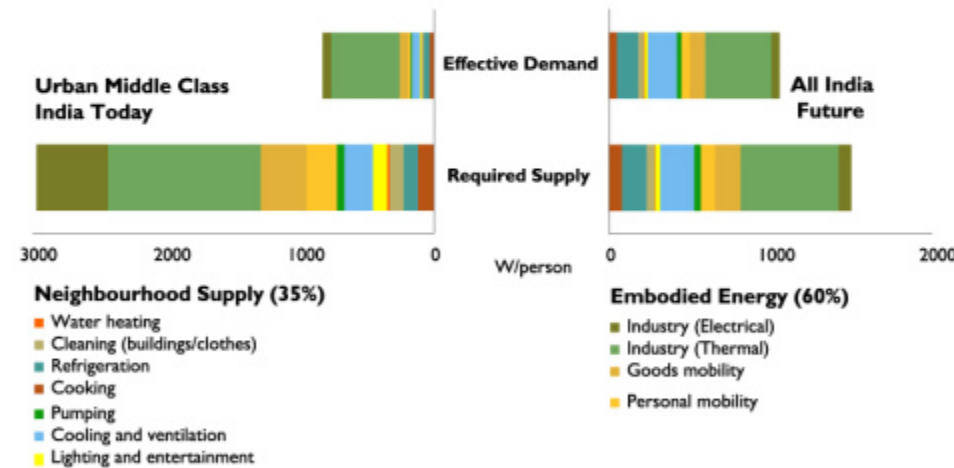
MAJOR ENERGY FLOWS
INDIA 2000
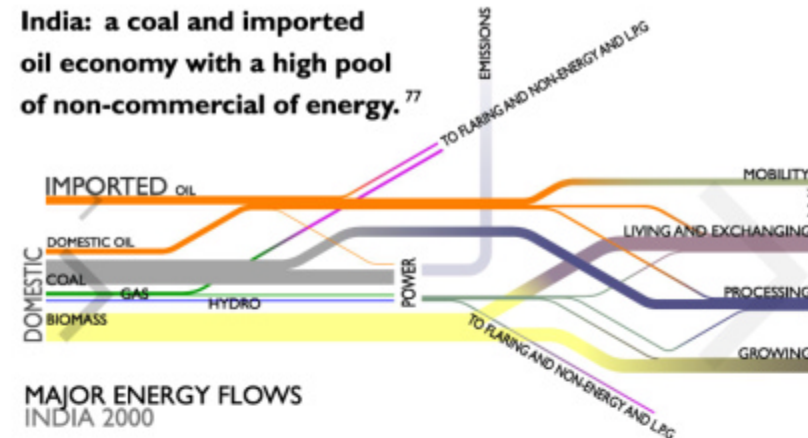
GHG emitting technologies dominate the supply today;
China is an equivalent energy economy. Biomass keeps the poor of India alive, but endangers forests (though the poor do not denude forests; exploitative industry does this with a ferocious efficiency).
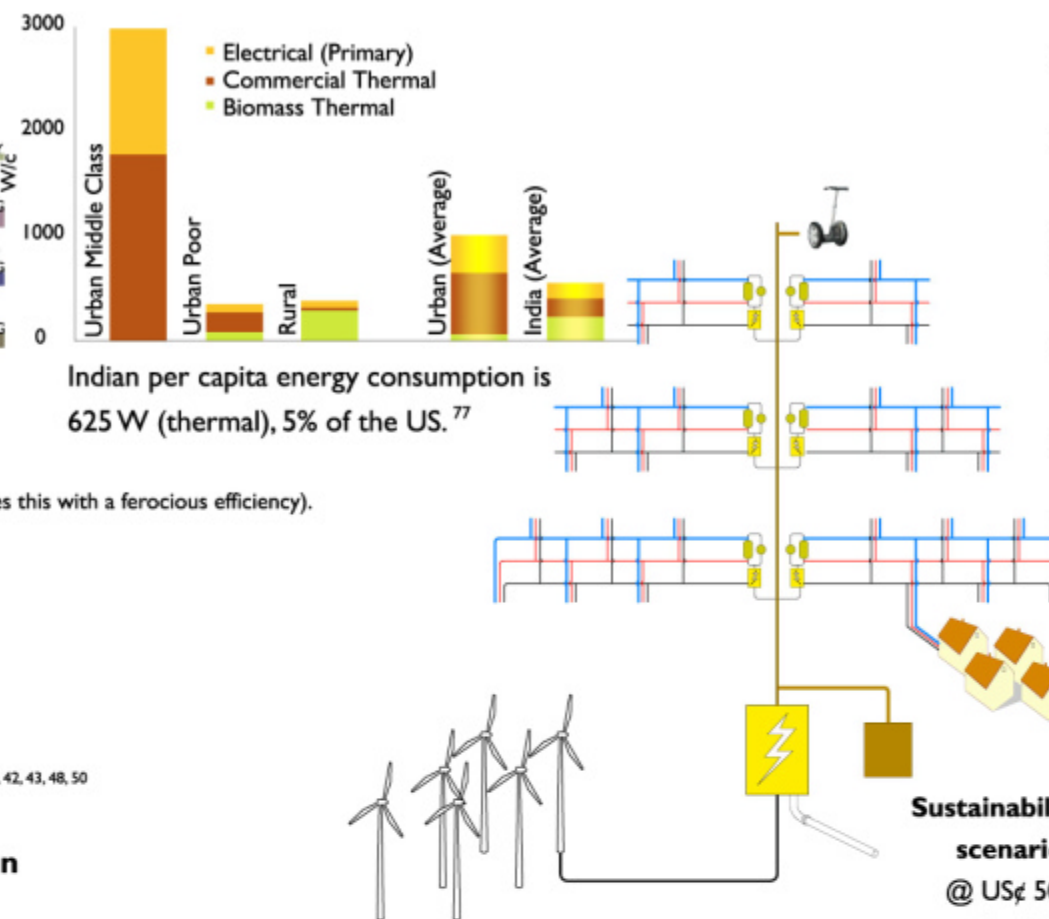
Energy demand scenarios:

- BAU would demand impractically high carbon sinks globally, especially if China is included. [4]

- Practical conservation and conscious, ethical limitations can **restrict demand with an acceptable future lifestyle**. [10, 30, 42, 43, 48, 50]

Energy Demand and Supply: Sustainability Transition

Urban Middle Class India Today

Effective Demand

All India Future

Required Supply

3000   2000   1000   0   W/person   0   1000   2000

Neighbourhood Supply (35%)
- Water heating
- Cleaning (buildings/clothes)
- Refrigeration
- Cooking
- Pumping
- Cooling and ventilation
- Lighting and entertainment

Embodied Energy (60%)
- Industry (Electrical)
- Industry (Thermal)
- Goods mobility
- Personal mobility

India: Two scenarios for increase of per capita consumption along with population increase

- Business-as-usual: 10 x today per capita (16 x gross), 6500 W/c
- Sustainability Transition: 2.5 x today per capita (4 x gross), 1500 W/c

---

Legend:
- Electrical (Primary)
- Commercial Thermal
- Biomass Thermal

Urban Middle Class | Urban Poor | Rural | Urban (Average) | India (Average)

Indian per capita energy consumption is 625 W (thermal), 5% of the US. [77]

Energy supply scenarios with coal as base

Attributes	1. Gas	2. Nuclear	3. Wind* (Eliminates this option)	4. Renewable** (Eliminates for now)	5. 'Magic'*** (Eliminates for now)
High-demand met?	Yes	Yes	No	No	Yes
Auto-storage?	Yes	Yes	No	No	Unknown
Possible soon/now?	Yes	Yes	Yes	No	No
Term applicable	Transition for 50 years	For 30 years till replaced	Now, forever, offshore soon	After 30 years, with wind*	Unknown
Renewable?	No	Yes, but waste!	Yes	Yes	Unknown
Disposable waste?	Ok for a while	NO!!	Yes	Yes	Yes
Zero emissions?	No	Yes	Yes	Yes	Yes
Secure for India?	NO!!	No	Yes	Yes	Unknown

* Including decentralized solar thermal and improved biomass, household and neighborhood production and conversion
** Direct solar photoelectrical, photo-biological hydrogen processes, biomass conversion, and related processes
*** Cold fusion, clean fission, something that cannot be anticipated today
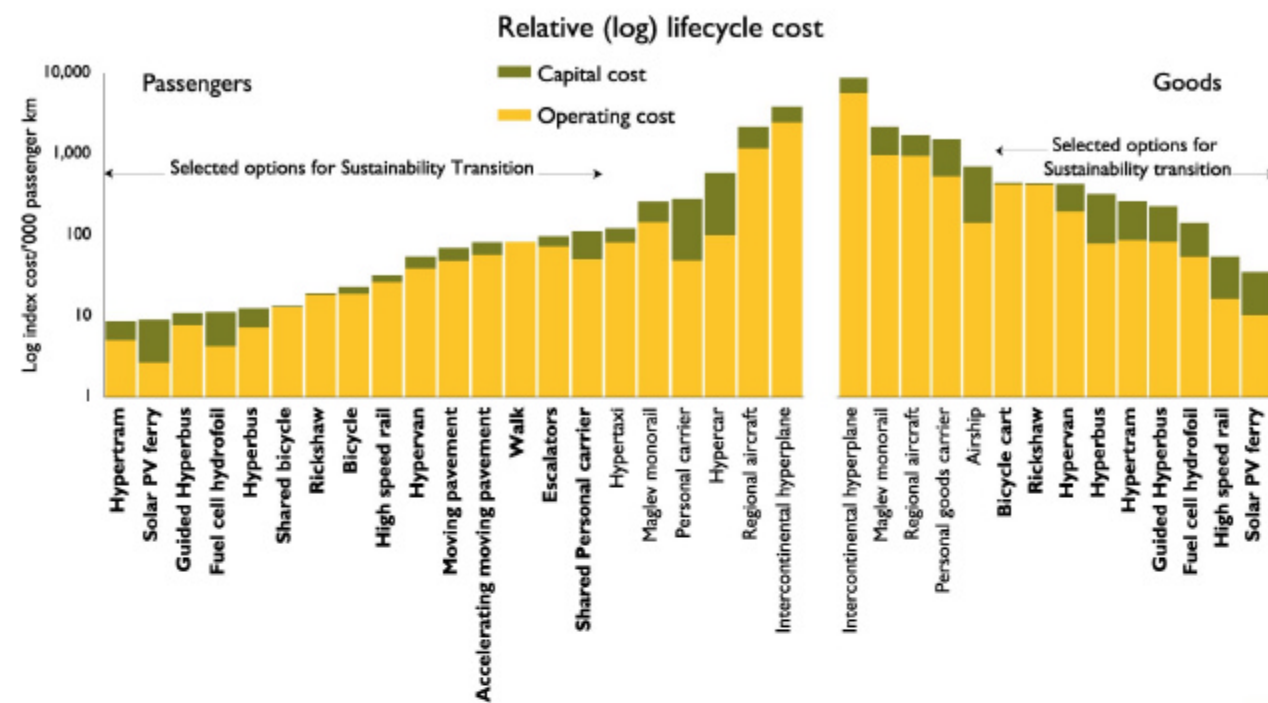
Insecure possibility

Possible with conservation

- **2004** Local electrical grids become legal with communidade empowerment
- **2006** Ella becomes node for manufacturing with a gas pipeline (and coal), rail, road and water
- **2010** Wind turbine manufacturing plant commissioned in Ella
- **2014** Nerul converts to Metal Hydride storage with ultra-high frequency distribution and grid backup
- **2018** Fuel Cells displace combustion engines for mobile, low temperature, processes
- **2020** Offshore wind farms overtake terrestrial power production; investment by Panjim, Dona Paula, and Miramar
- **2030** Chorao begins neighborhood Tri-generating fuel cells for stationary, high temperature, processes

Sustainability Energy Transition scenario of Greater Panjim @ US¢ 50 per person per day (equivalent to gas costs):
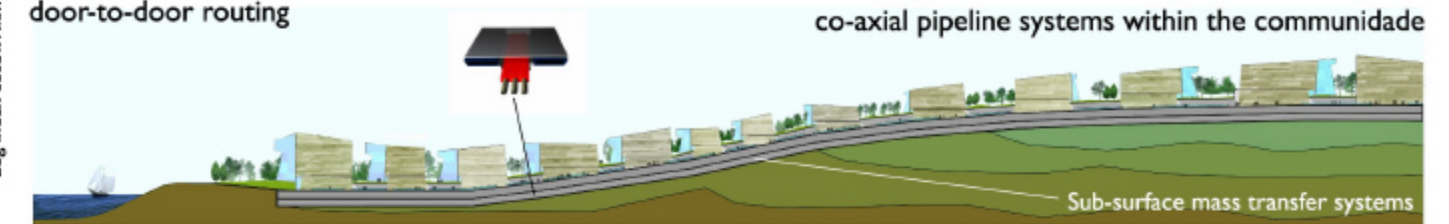
Ella

Water (and land) for biomass growth can be deployed for either food or energy in a tropical economy. Drawing on offshore resources in a post-fossil fuel era with technologies like wind harnessing does not reduce the biomass growth potential of the land. These are financially viable, first-choice technologies requiring rapid deployment. [42, 45, 46]

. . . and meeting it with **decentralized** production and **renewable** energy within a **Hydrogen** economy
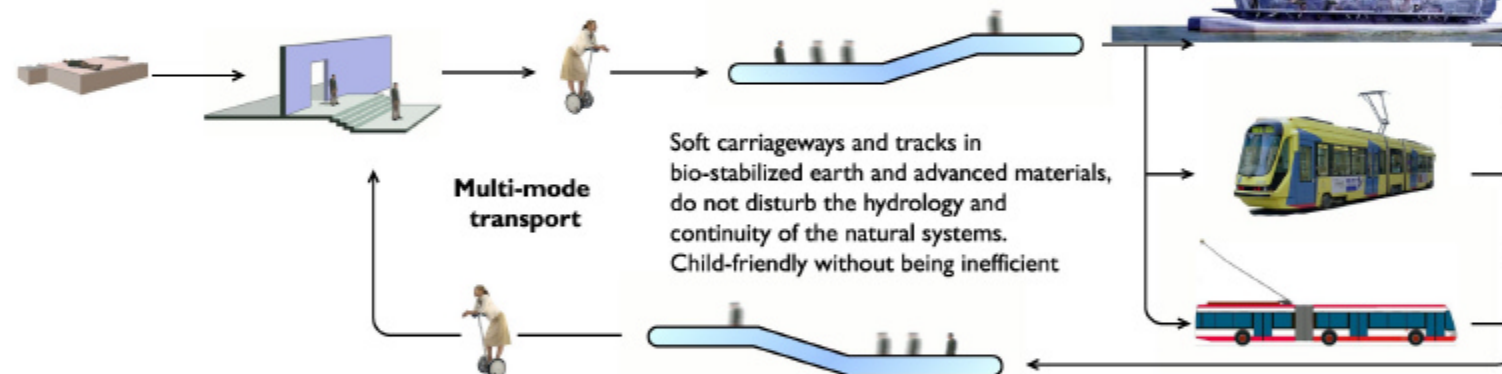
Relative (log) lifecycle cost

Passengers

■ Capital cost
■ Operating cost

Selected options for Sustainability Transition

Log index cost/'000 passenger km

10,000 / 1,000 / 100 / 10 / 1

Hypertram · Solar PV ferry · Guided Hyperbus · Fuel cell hydrofoil · Hyperbus · Shared bicycle · Rickshaw · Bicycle · High speed rail · Hypervan · Moving pavement · Accelerating moving pavement · Walk · Escalators · Shared Personal carrier · Hypertaxi · Maglev monorail · Personal carrier · Hypercar · Regional aircraft · Intercontinental hyperplane

Goods

Selected options for Sustainability transition

Log index cost/kT km

10,000 / 1,000 / 100 / 10 / 1

Intercontinental hyperplane · Maglev monorail · Regional aircraft · Airship · Bicycle cart · Rickshaw · Hypervan · Hyperbus · Hypertram · Guided Hyperbus · Fuel cell hydrofoil · High speed rail · Solar PV ferry

Containerised goods movement: on common rapid transport network using micro to full size containers with wireless tagging, automated mode transfer and door-to-door routing

Fluid transfer: Metal hydride, water and heat transfer: on intelligent co-axial pipeline systems within the communidade

Sub-surface mass transfer systems

Least (life cycle) cost systems using a unique mix of water, rail and pedestrian carriageways for both passengers and goods. Integrated high-density multi-modal systems mix high efficiency with accessibility [29, 68]

Local travel on pedestrian and child-friendly walkways: walking, cycling, skating combined with fuel cell based personal carriers, moving pavements and escalators [38, 89]

Multi-mode transport

Soft carriageways and tracks in bio-stabilized earth and advanced materials, do not disturb the hydrology and continuity of the natural systems. Child-friendly without being inefficient

Inter-communidade point-to-point common rapid transport network: a hypertram ring rail with hyperbus extension to low-density routes interlaced with solar river ferries and hydrogen powered hydrofoils

Hypertram on elevated carriageway

The mean transit time between locations in the city is 20 min and the maximum 45 min

HOME
POD
NODE
INTRA-CITY
INTER-CITY
INTERNATIONAL

3 min · 9 min · 19 min · 175 min · 365 min

Turn around times control the size of cells and their nuclei

The flexibility, weatherproofing and personalization of the personal car provided through a satellite-networked, information-rich transportation system providing mobility according to plan or on demand with online, context-sensitive, dynamic tariffs

Innovative transportation design enables urban consolidation to optimal densities and prevents cancerous ribbon development. A phased development plan permits flexible extension based on communidade and demand growth without being financially unviable.

Sustainability Transition Phase I
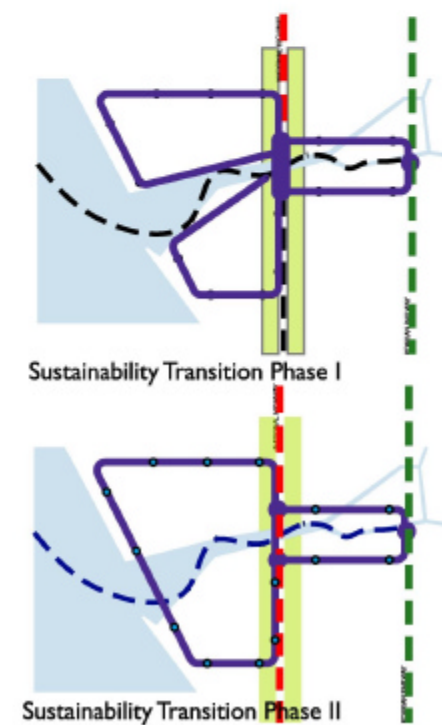
Sustainability Transition Phase II

Inter-city: high-speed links

- high-speed city-centre rail interchange makes air travel largely redundant,
- central rail line reduces traffic density on the interstate expressway that is buffered by a 0.5 km wide green zone,
- container ships from adjoining port service offshore areas and national and international trade

. . . can provide better service quality than the **inefficient personal car**

Urban **space and building form** affects water and energy security . . .

GOA 2100 15

A range of real cases were analyzed for current and future potential for more substantially harvesting water, heat and electricity in this climate, lifestyle and geography. The estimates were expressed against reduced future demand along with better technology, as a logarithm of the excess or shortfall of each resource, so as to make them comparable.

150 to 300 persons per Hectare (ppH) densities are most secure, but better lower than that density than higher

Two to five stories is secure, but better single story than high-rise

Covered area per person or ground coverage is not closely related to security, but Floor Area Ratio (FAR) from 50% to 150% provides optimal security, a lower FAR being better than higher

Density (ppH)

Wash
Flush
Thermal
Electrical

Height (in floors)

FAR
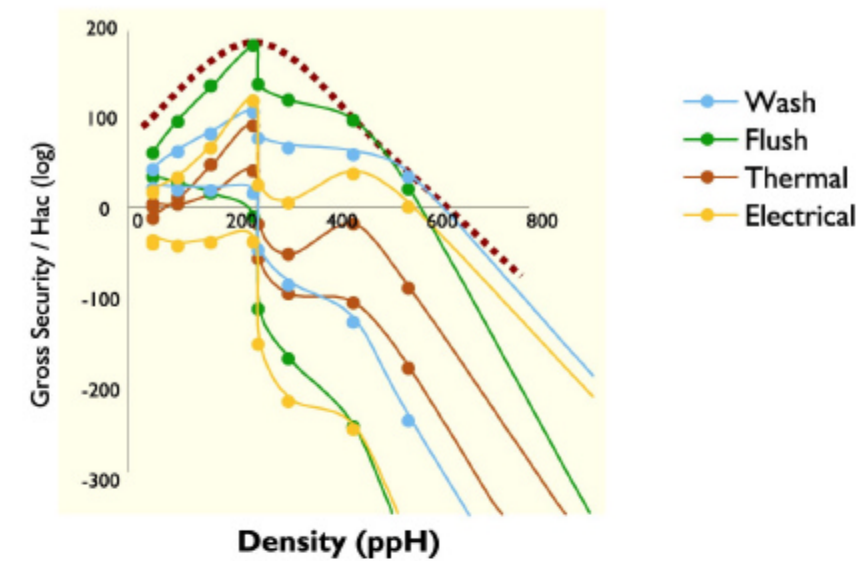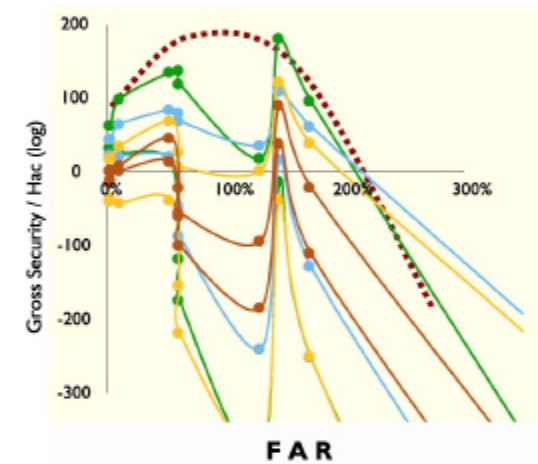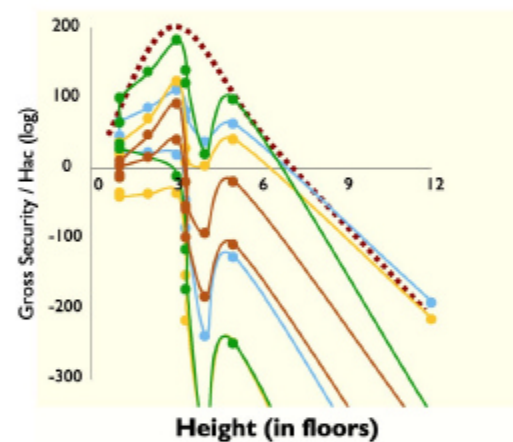
It is easier to be secure on water by following these principles than on energy

Thermal security is easier to achieve than electrical autonomy

Settlement structure and morphology, building height and density strongly affect the potential for local harnessing of food, water and energy.

There is an optimal set of settlement parameters that enable sustainability. This often matches the best vernacular forms.
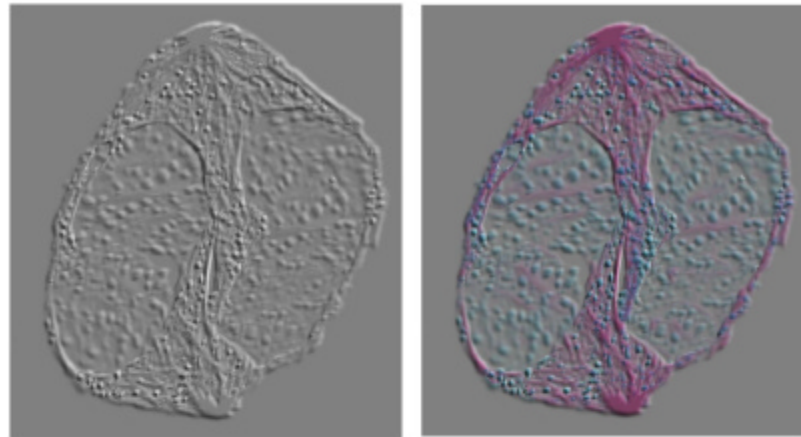

Nariman Point
Bombay
925 ppH

Panjim
Goa
560 ppH

Ballard Estate
Bombay
450 ppH
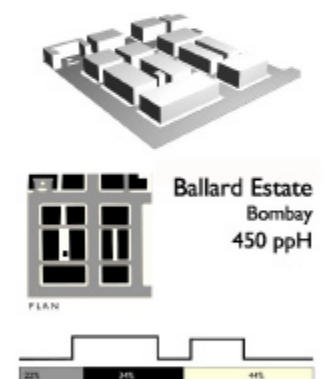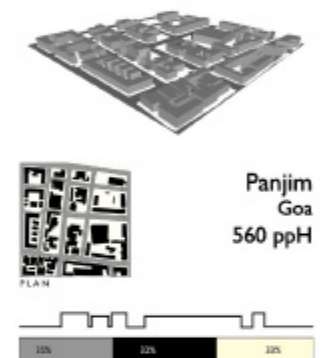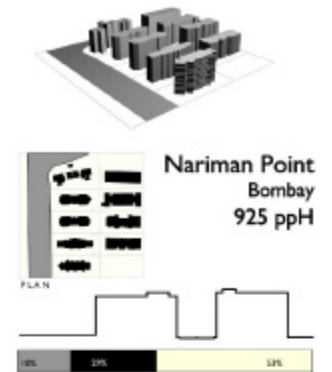
. . . allowing **autonomous decentralized harnessing** of resources . . .

Farming Village
Goa
50 ppH

Fishing Village
Goa
50 ppH

Calangute
Goa
100 ppH

Ribandar
Goa
165 ppH

Khotachai Wadi
Bombay
250 ppH

Dadar
Bombay
260 ppH

Campal
Goa
320 ppH
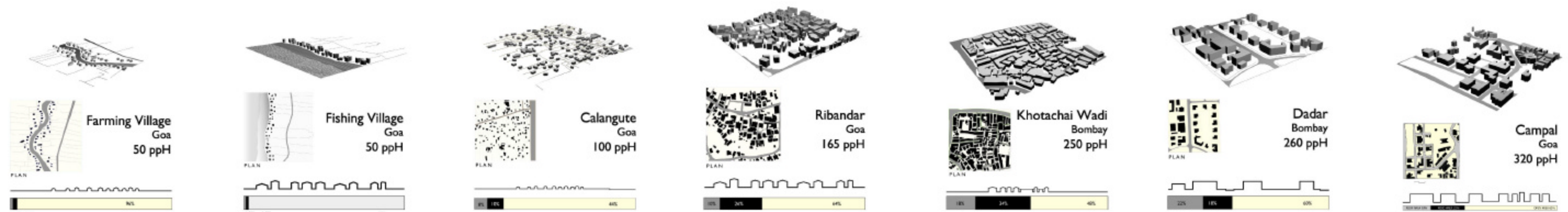
. . . yielding tangible pointers for planning a sustainable city
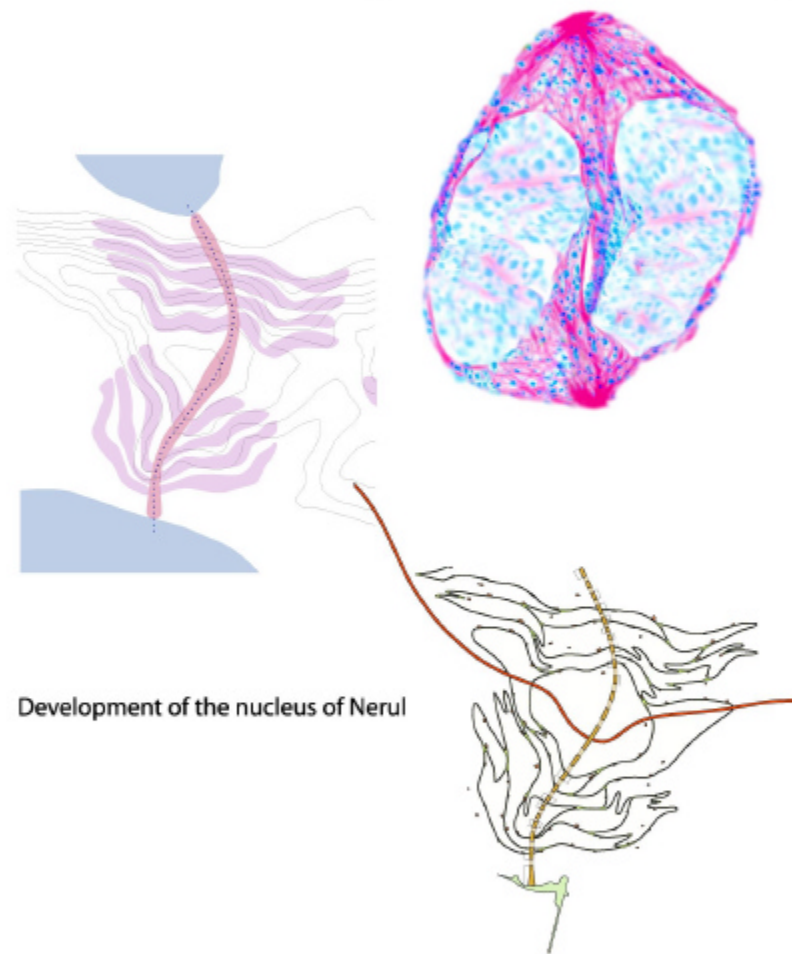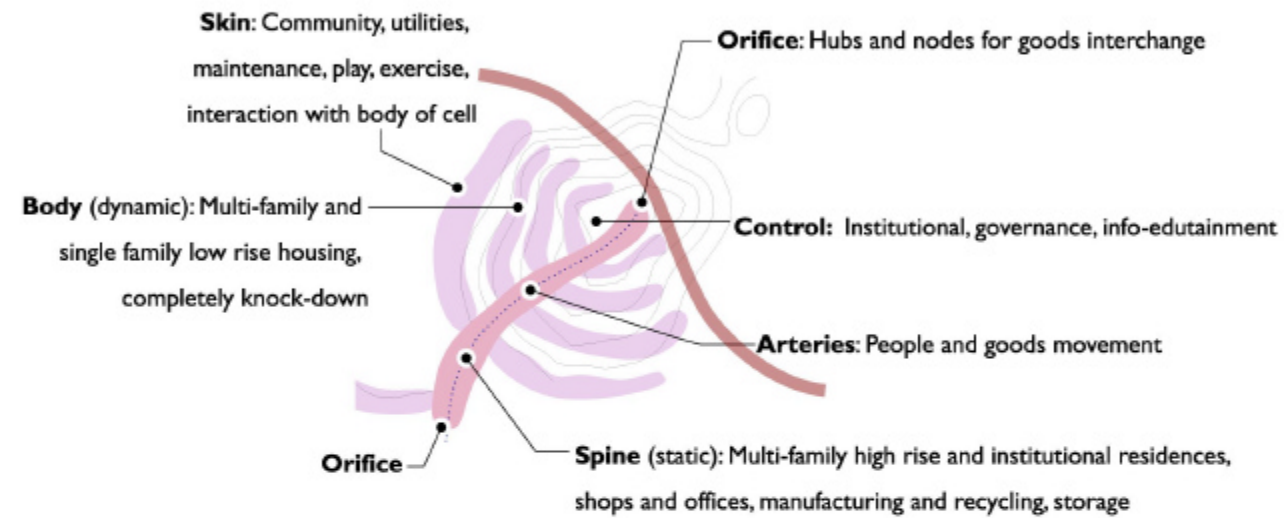
High investment, intensive, static components are concentrated in the center.

A spine-like linear arrangement links static components.

A hub connects the spine to nuclei in other cells.

Skin: Community, utilities, maintenance, play, exercise, interaction with body of cell

Orifice: Hubs and nodes for goods interchange

Body (dynamic): Multi-family and single family low rise housing, completely knock-down

Control: Institutional, governance, info-edutainment

Arteries: People and goods movement

Orifice

Spine (static): Multi-family high rise and institutional residences, shops and offices, manufacturing and recycling, storage

Development of the nucleus of Nerul

Pedestrian and cycle pathways enable horizontal movement.

Nature interpenetrates the body of the nucleus.

Each nucleus is bounded to prevent cancerous growth.

These skins inter-connect with the surrounding RUrban environment.

Walking time from one end to the other determines scale.

The spine provides all up-and-down mobility, mostly automated.

Networked services run through a subterranean tunnel.

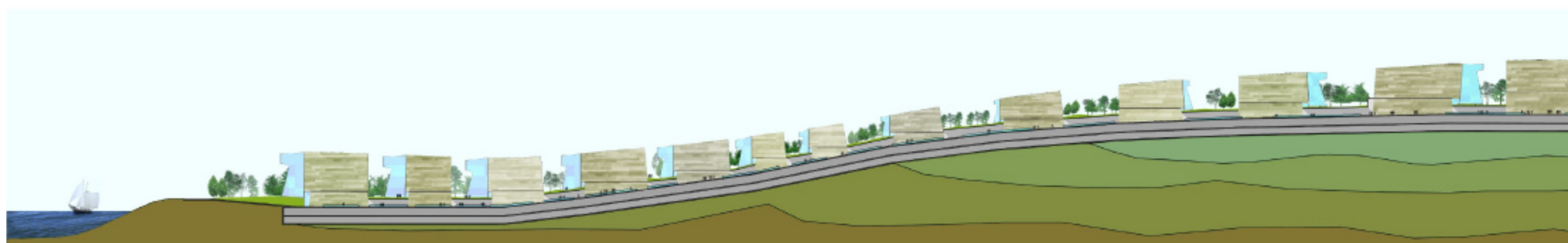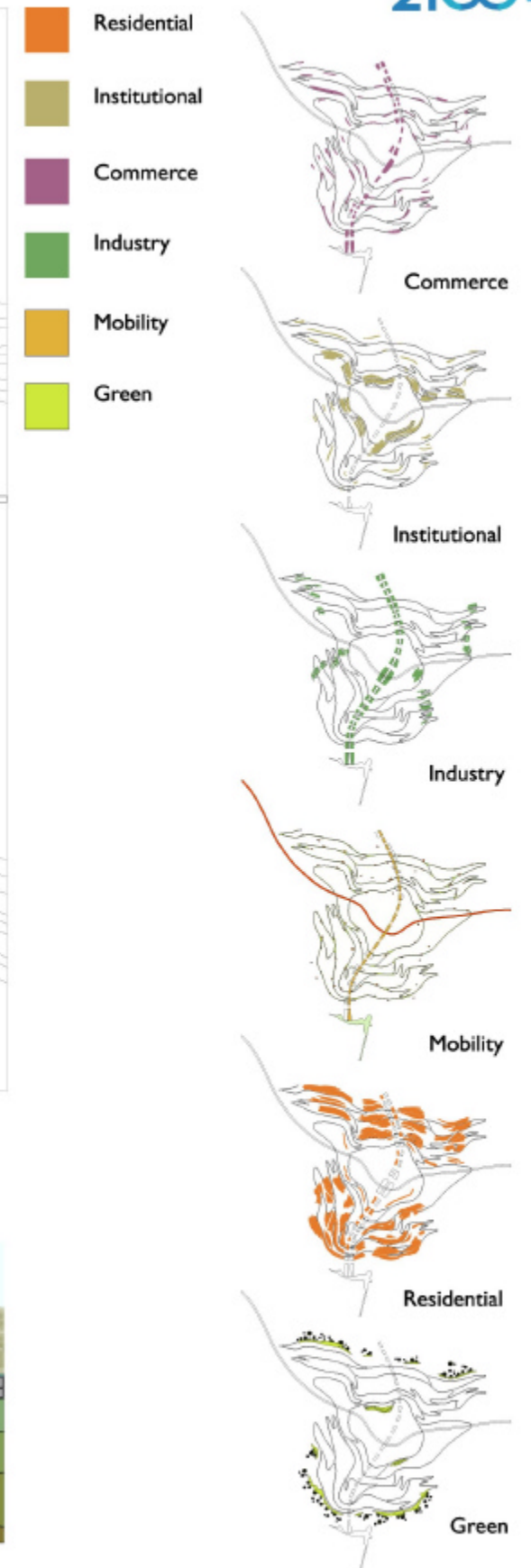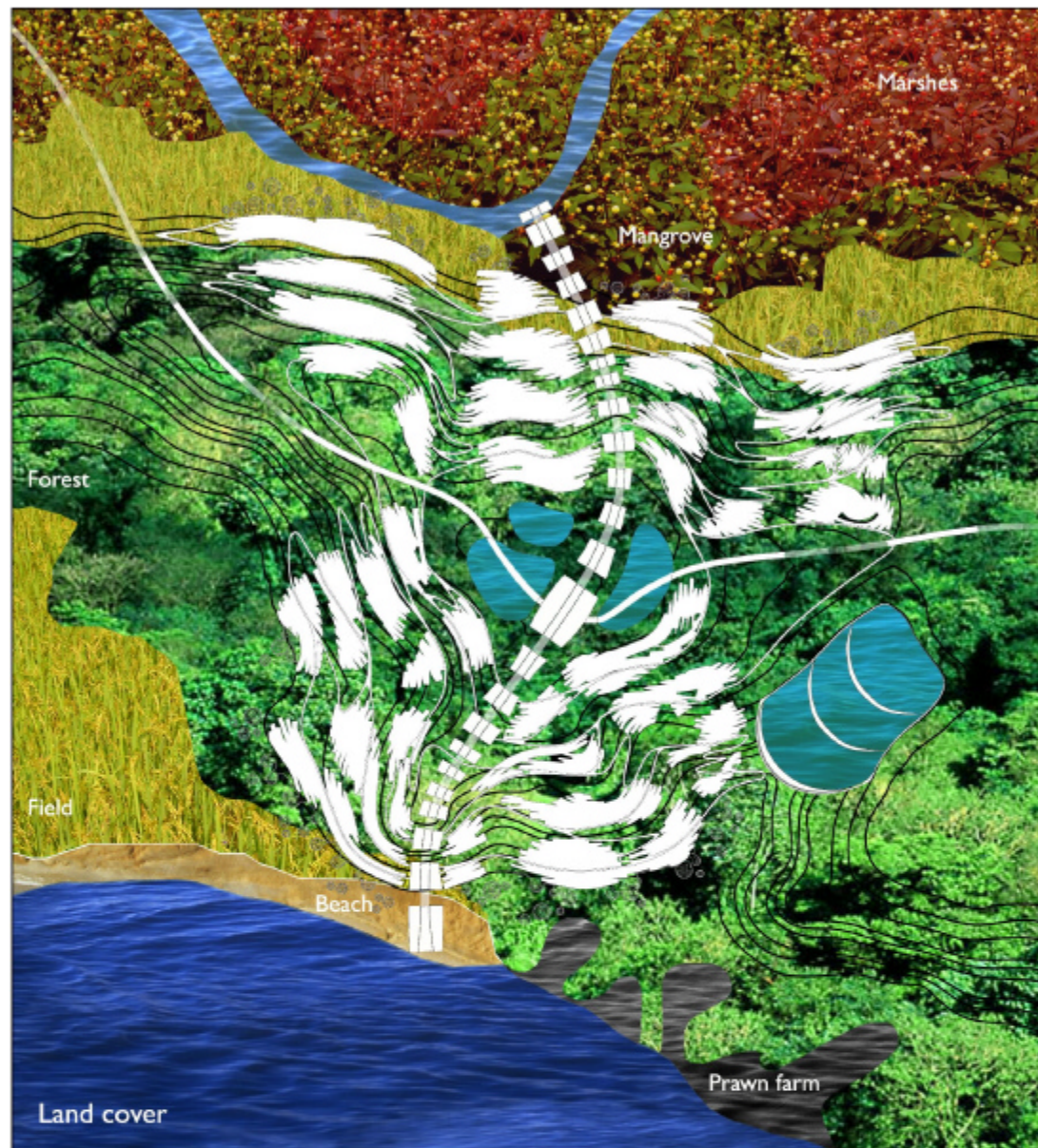Arterial goods and services networks also recycle waste.

The body of the nucleus is flexible, its density can swell or shrink, responding to changing population and economic needs.

Three spinal typologies

Double-ended   Trunk   Looped
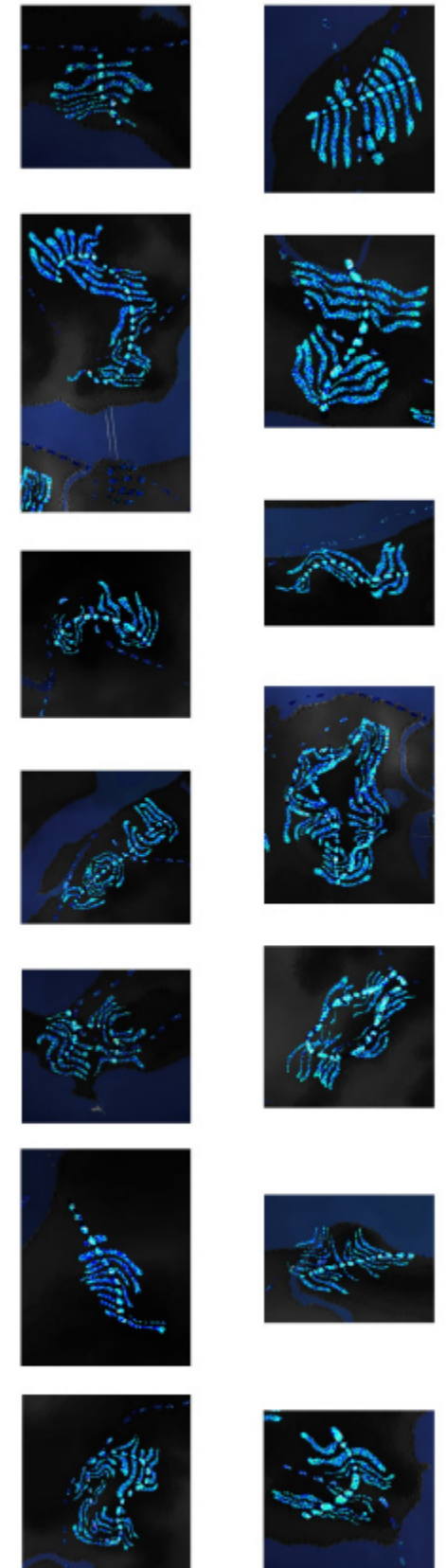
. . . celebrate the **static and dynamic** in a city

Land cover

Marshes
Mangrove
Forest
Field
Beach
Prawn farm

Nucleus land uses

Residential
Institutional
Commerce
Industry
Mobility
Green

Commerce

Institutional

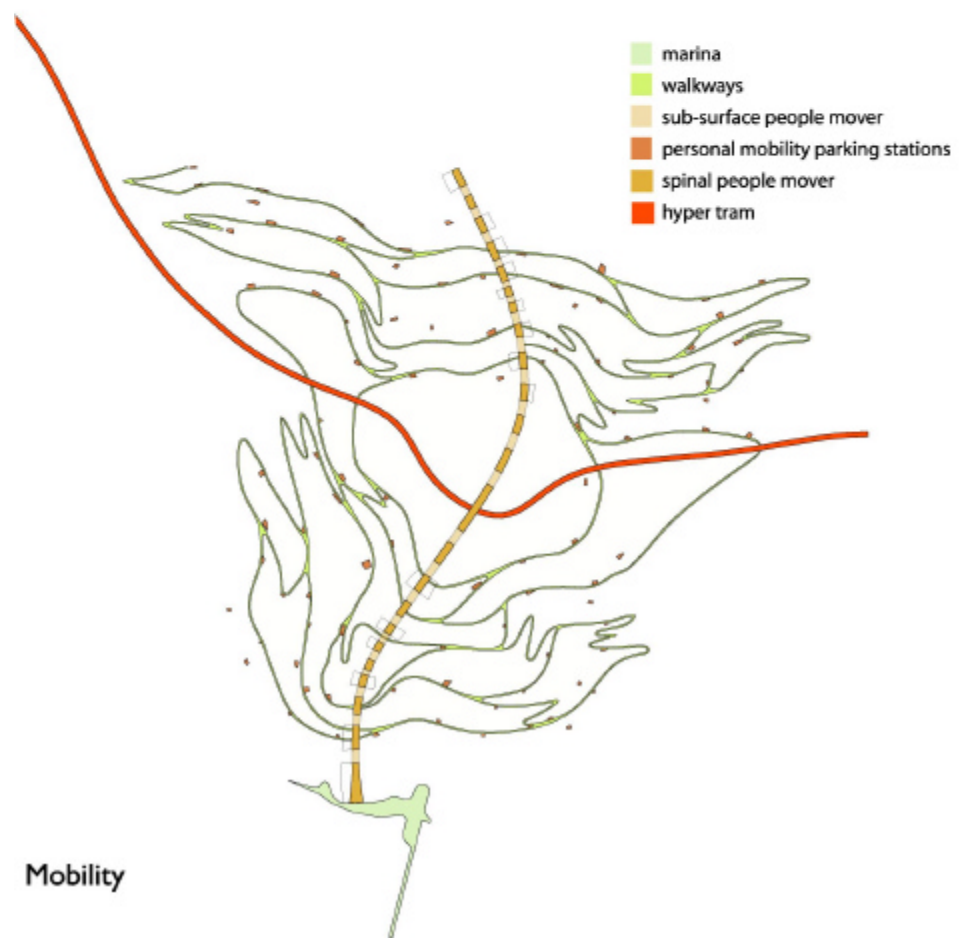Industry

Mobility

Residential

Green

Section along spine

. . . a leisure communidade which has **no waste**. No need to clean up after the party!

Nerul's structure. . .

ponds
aquifers
root zone treatment
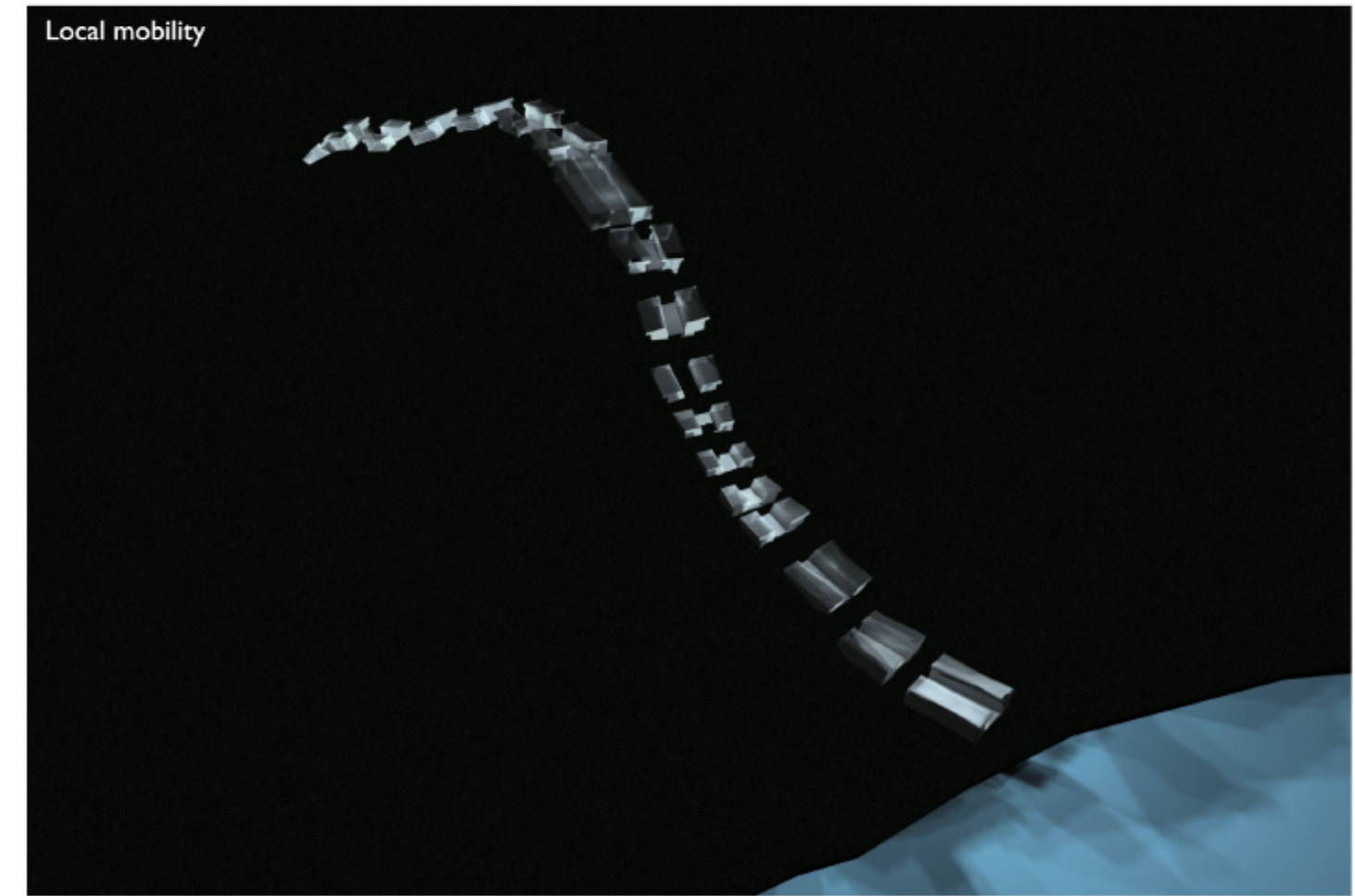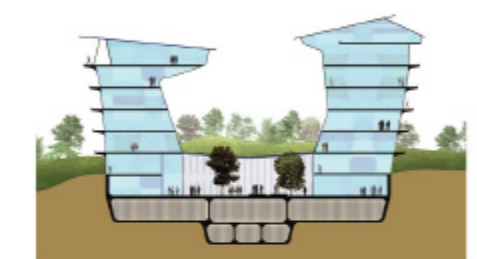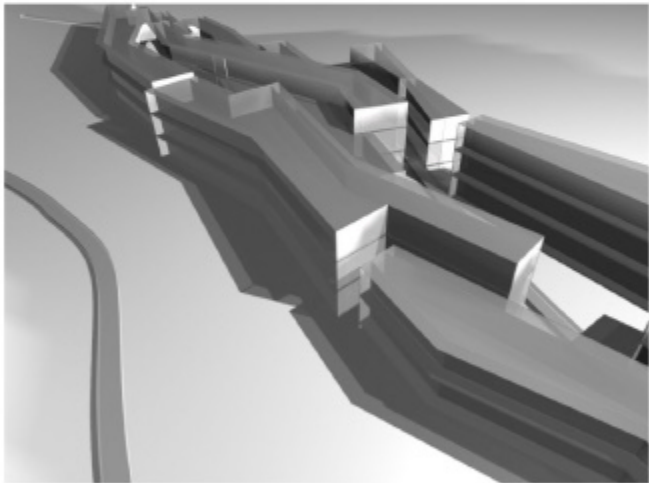ecological sewage treatment
roof - rain water harvesting

Skin

Water

photo-voltaic roof farms
main supply from off-shore wind farms
main spine electrical cable
heating system
cooling system
electrical system
tri-generators
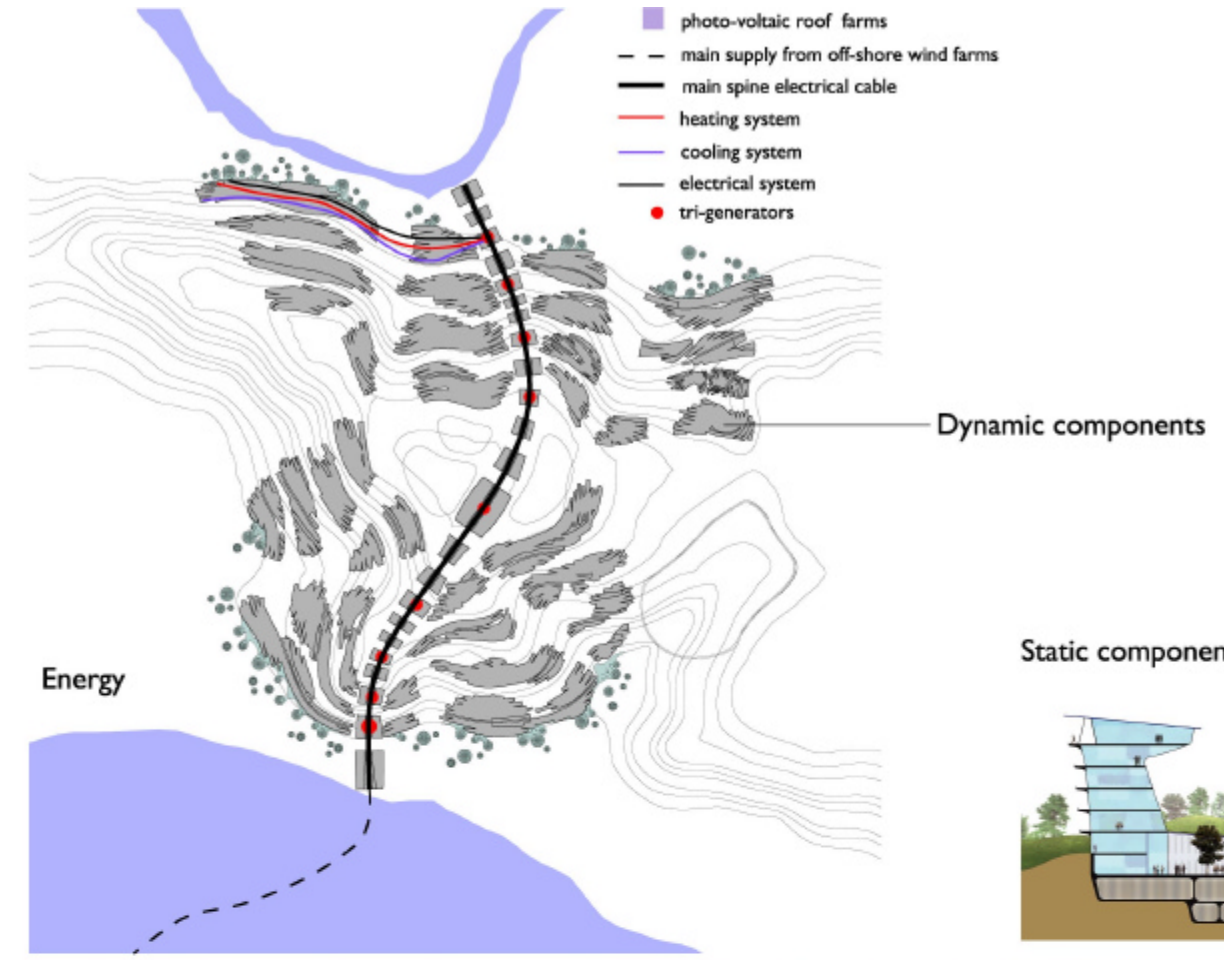
Dynamic components

Energy

Static components- spinal section

marina
walkways
sub-surface people mover
personal mobility parking stations
spinal people mover
hyper tram

Local mobility

Mobility

Capitol Hill- new fabric

spine

Panjim- old fabric

new fabric

spine

transport
interchange

Landuse

forest

old city

new fabric

mangroves

forest

field

Landcover

spine
national highway
high speed train terminus
street network
transport mode interchange
city light rail terminus
parking fingers

Detail of transport interchange

parking
parking   parking loop
parking   bridge   spine
parking   city light rail   high-speed train
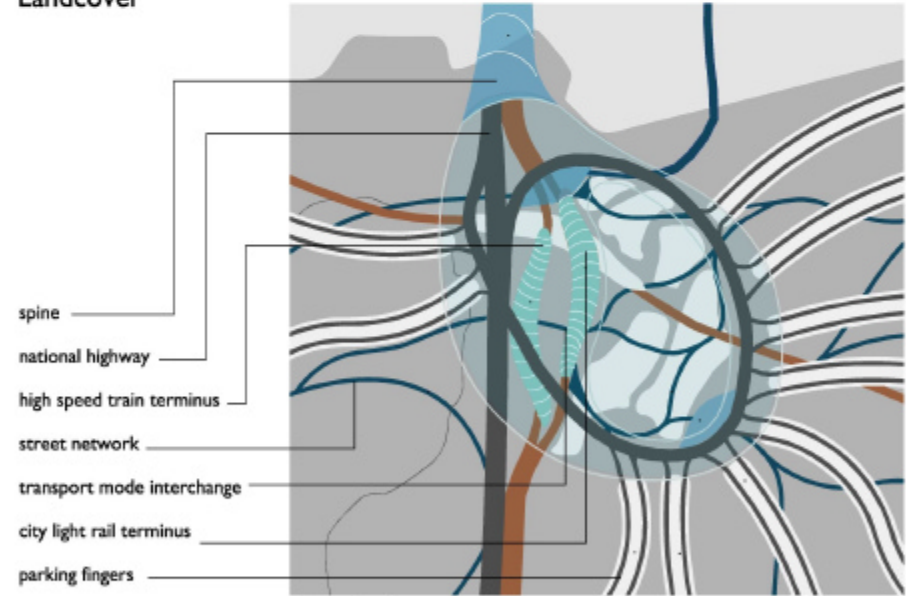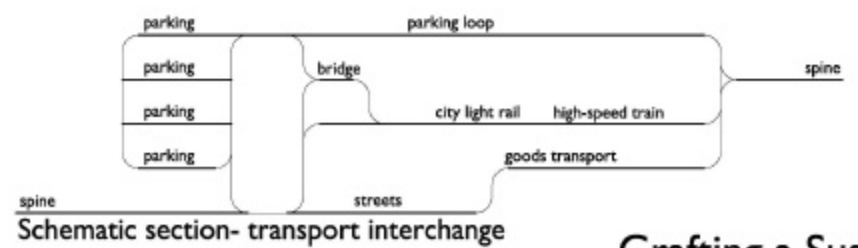parking   goods transport
spine   streets

Schematic section- transport interchange

Grafting a Sustainability Transition on an existing urban pattern. . .

Principles of Sustainable RUrbanism

This project is one of the few attempts since the late 1970s to develop an integrative theory of design that views cities as ecosystems that spans from the city neighborhood to regional scale over a century-long time horizon. A few heuristic insights from the process: [2, 6, 11, 12, 56, 64]

Three Goals [10, 11, 23, 48, 84]

Well-being of all people, communities and ecosystems (**Sufficiency and Equity**), using a minimal throughput of matter-energy-information (**Efficiency**), with least impact on nature, society and future generations (**Sustainability**)
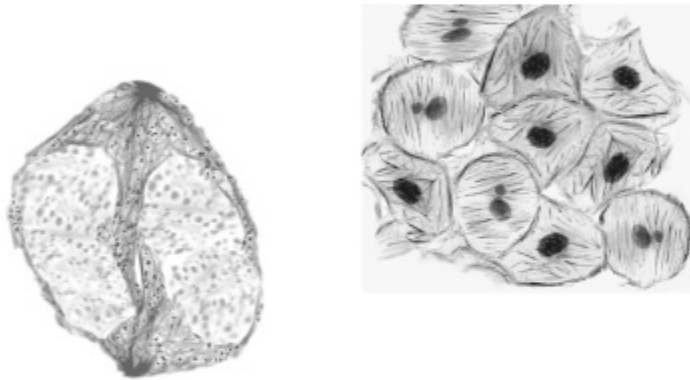
Seven Organizing Principles [10, 22, 48, 50, 53]

Satisfying the basic human needs of all people and providing them an equal opportunity to realize their human potential.
Material needs should be met materially and non-material needs non-materially.
Renewable resources should not be used faster than their regeneration rates.
Non-renewable resources should not be used faster than their substitution rates by renewable resources
Pollution and waste should not be produced faster than the rate of absorption, recycling or transformation
The Precautionary principle should be applied where the 'response' time is potentially less than the 'respite' time
'Free-energy' and resources should be available to enable redundancy, resilience and reproduction

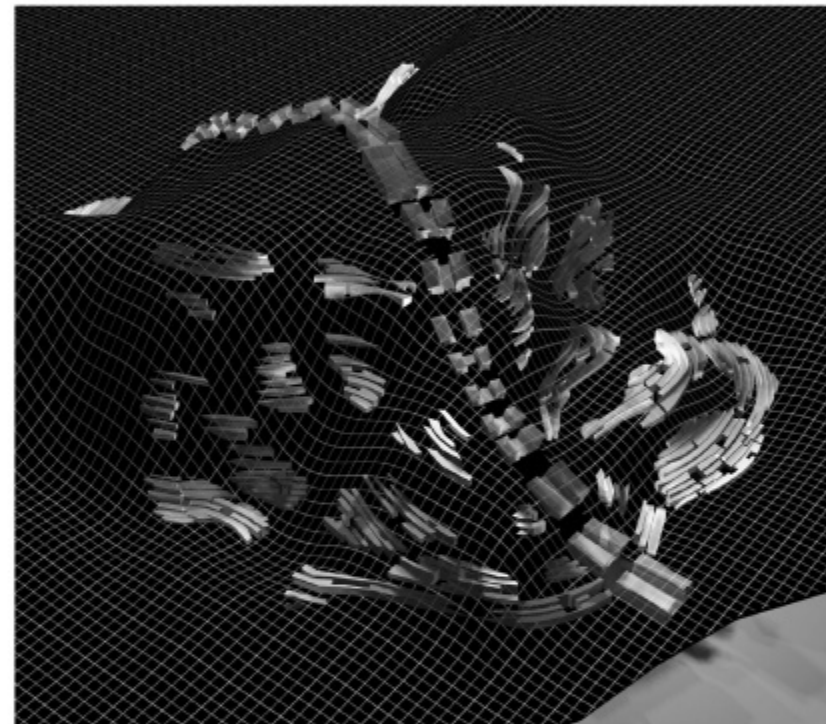## A Dynamic Fractal Morphology [6, 53]

Cellular structure: nuclei, cores, spines and skins
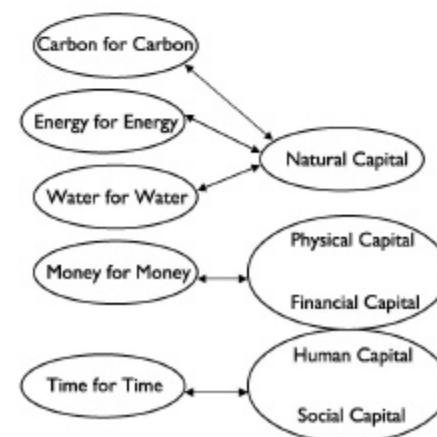Hierarchical networks adapting to topography
Optimal densities, settlement structure and heights enabling security
Contiguous and hyperlinked with interpenetration of living nets
Dynamic consolidation and nucleation around fractal boundaries and surfaces

Five Currencies for Five Capitals [51, 59]

Six Tactics to manage physical stocks and flows [38, 89, 56]

Use less with Factor 4 technologies for supply and social limits of sufficiency and equity on demand
Grow your own, tapping harvestable yields as autonomously as possible
Build two-way networks for security; every consumer is also a producer
Store a lot because renewable resource yields are often diurnal and seasonal
Transport less and over shorter distances using least life cycle cost technologies
e-xchange using intelligent wireless networks to enable real-time trade and delivery of goods

## Five Strategies for Land-use Management [9, 56, 41, 71]

Enable a long-term ecological succession from forest >> cropland >> city >> forest
Design the landscape first; situate the city in the interstitial niches
Land-use transition 'rules' governed by the demand for ecosystem services, resource potential, natural ecological succession and contiguity
Identify static and dynamic elements in the city, design the former, and provide a dynamic vocabulary for the latter to co-evolve with the landscape
Devolve governance and taxation to the lowest viable
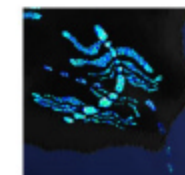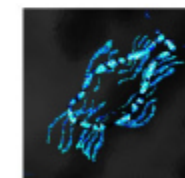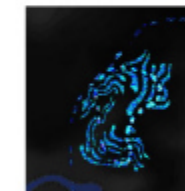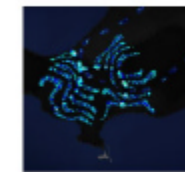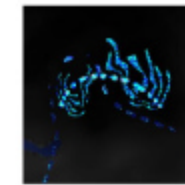
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India Team
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