Born and not made: designing the productive city.

Greg Keeffe
Professor of Architecture + Urbanism
School of Natural and Built Environment,

www.gregkeeffe.co.uk
www.technoscape.org.uk
World Problems

Over population
Diminished resources
Water shortage
Food crisis
Energy Crises
Global warming
The big question
What’s the best way
to predict the future..?
Our current position

1960-2008
- Ecological Footprint

2008-2050, Scenarios
- Moderate business-as-usual
- Rapid reduction

Professor Greg Keeffe
Factor 4 Urbanism
Half as much, twice as effectively
Factor 6 Urbanism
One third as much, twice as efficiently

Australia ecological footprint
How many Londons do we need??

....Around 293.......

The ecological footprint of Londoners is 293 times the size of London. The area of London and the UK are superimposed for a clearer comparison.

The ecological footprint of Londoners, by component:

- Food: 41%
- Energy: 10%
- Transport: 5%
- Materials & waste: 44%
- Water: 0.3%
- Degraded land: 0.7%
Synergetic Urbanism

The city is a super-organism

The city is a system of resource flows

Process-based not aesthetic

In the city - Waste is food

The city is Ecological lives within its bio-region and it exploits its niche

Biodiverse

Carbon – neutral

Life-affirming
Biomimetic design
Gaia theory and life

“Life is an ecological property; it is only an individual property for a brief flash of time…

a oneness of varied complex biological systems, all making continuous and subtle trades with one another, joined by the common goal of using to the utmost all that the present environment has to offer in terms of energy and raw materials “

James Lovelock Gaia 1972

Joseph Priestley 1788

The bell jar
Hydra symbiotic pair
City as Superorganism

The city is Ecological
It lives within its bio-region - a living thing.

Therefore must obey rules of evolutionary development

**modularity**: Living things are modular: they are organized into distinct parts. Often these parts are repeated, such as fingers, ribs, and body segments.

**developmental plasticity**: here we focus on the idea of the genotype and phenotype.
Exaptive city
Exaptation is the evolution of function of some element of a living thing that was not originally produced for that function.
City as Superorganism

**Spandrel city**
A spandrel is where a new function develops from the evolution of another element aimed at another adaptation.

Irrigation [agriculture]
City as Superorganism

Atavistic city
This city will revert to an earlier type that is still present in its DNA or formal make-up… that can be rediscovered and re-energised to produce a sustainable underpinning for the new city. In this project, the city engages with future climate change and carbon transition by looking back and re-installs a previous operating system….
City as Superorganism

Phenotypic plasticity city
Here the phenotype of the city morphs due to external forces. These forces create a phenotype that is dramatically different than the original genotype, usually it is behaviour that changes rather than genetics… You may use allometric engineering to choose your city adaptation.
City as Superorganism

**Vestige City**
Here the city uses redundant infrastructure to regenerate itself. These vestige elements (such as old railroads or factories) can be re-used to develop a sustainable future.

Professor Greg Keeffe
The Sustainable city will be:
The Sustainable city will be: pet-free
### Ecological big hitters

#### In London

<table>
<thead>
<tr>
<th>Activity</th>
<th>Count (in thousands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat eating</td>
<td>5800</td>
</tr>
<tr>
<td>Pet food</td>
<td>3100</td>
</tr>
<tr>
<td>Milk drinking</td>
<td>2500</td>
</tr>
<tr>
<td>Cars</td>
<td>2100</td>
</tr>
</tbody>
</table>

In ‘000’s of gha

Source: City Limits 2005.

www.citylimits.org
Belfast diet impact spatialized: in production land and CO2 sequestration of process by forest.
Get more for less
Get more for less: Make synergies!
Speculate to accumulate!
Energy Synergy

Professor Greg Keeffe
From Val-despair to Val d’Isere

Photovoltaic
World Cup Skiing
Nelson UK
Consume less!
Consume less!

Make shops smaller
**McDONALDS UK: Food Miles**

- **ALASKAN POLLOCK:** From sustainable fisheries off the coast of Alaska, Alaskan Pollock is shipped to McDonald's processing sites to make the infamous 'Filet-o-Fish'.

- **WHEAT:** Of the 13,700 tonnes of wheat used annually by McDonald's, some of this is sourced from North America.

- **DEHYDRATED ONIONS:** McDonald's UK sources its dehydrated onions all the way from California to use in its burgers.

- **CHERRY TOMATOES:** Depending upon availability, cherry tomatoes are sourced from either Morocco or Spain.

- **CHICKENS:** Depending upon availability, some of the chickens are sourced from Thailand.

- **HERKINS:** The gherkins, found on some burgers, are grown in Turkey.

- **CHEESE SLICES:** Milk is sent from England to Ireland, to be processed and turned into cheese slices.

- **CARROTS:** For 1 month of the year they are sourced from France.

- **TOMATO KETCHUP:** Sourced from Portugal.

- **CUCUMBERS:** Depending on availability, sometimes the cucumbers come from Poland.

- **LETTUCES:** For 6 months in the winter, lettuces are sourced from Spain.

- **HOKI:** From a sustainable source, Hoki is fished off the coast of New Zealand. The fish are frozen and then shipped to Poland or Denmark to be processed. They are then flown to the UK and sold as fish fingers.

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**THE JOURNEY OF HOKI FISH:**

1. Fishing off the coast of New Zealand
2. Processing of fish in either Denmark or Poland
3. Distribution centres around the UK
4. Served at local Restaurants
### McDONALDS: The ‘Size’ of each restaurant

<table>
<thead>
<tr>
<th>Food Type</th>
<th>Conditions</th>
<th>Tonnage Per Year</th>
<th>No. of KG Restaurant per Day</th>
<th>No. or KG required per restaurant</th>
<th>Yield Tonnes per Year</th>
<th>Feed Tonnes per Animal (m²)</th>
<th>Space Required for Food (m²)</th>
<th>Total Space Required (m²)</th>
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<tbody>
<tr>
<td>Beef</td>
<td>Kept</td>
<td>33.900</td>
<td>367.000</td>
<td>66.72</td>
<td>97.90</td>
<td>6076</td>
<td>2.658</td>
<td>2.658</td>
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<tr>
<td>Poultry</td>
<td>Freedom Foods</td>
<td>14.6000</td>
<td>33</td>
<td>1.368</td>
<td>57.31</td>
<td>14 birds/m²</td>
<td>71.224</td>
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<tr>
<td></td>
<td>Free Range</td>
<td>14.6000</td>
<td>33</td>
<td>1.848</td>
<td>76.66</td>
<td>12 birds/m²+1m²</td>
<td>95.910</td>
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<tr>
<td></td>
<td>Organic</td>
<td>14.6000</td>
<td>33</td>
<td>2.673</td>
<td>119.6</td>
<td>12 birds/m²+2m²</td>
<td>137.039</td>
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<tr>
<td>Eggs</td>
<td>Freedom Foods</td>
<td>81.0000</td>
<td>175</td>
<td>63.875</td>
<td>250 eggs</td>
<td>10.22</td>
<td>9 hens/m²</td>
<td>12.545</td>
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<tr>
<td></td>
<td>Free Range</td>
<td>81.0000</td>
<td>175</td>
<td>63.875</td>
<td>250 eggs</td>
<td>10.22</td>
<td>0.25 hens/m²</td>
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<td>Pork</td>
<td>50% Organic diet</td>
<td>4.6000</td>
<td>657</td>
<td>1.5</td>
<td>548.00</td>
<td>664</td>
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<tr>
<td></td>
<td>100% Organic</td>
<td>4.6000</td>
<td>657</td>
<td>1.5</td>
<td>548.00</td>
<td>1724</td>
<td>936.886</td>
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<td>Fish</td>
<td>Alaska Pollock</td>
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<tr>
<td>Fish Substitute</td>
<td>Trout</td>
<td>10 Kg</td>
<td>3.658 Kg</td>
<td>10.11</td>
<td>1.456</td>
<td>15.014</td>
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<tr>
<td></td>
<td>Wheat</td>
<td>13.700</td>
<td>11.200</td>
<td>3.08</td>
<td>15.914</td>
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<tr>
<td>Potatoes</td>
<td>176.900</td>
<td>354 Kg</td>
<td>143.916 Kg</td>
<td>11.90</td>
<td>57.800</td>
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<tr>
<td>Lettuce</td>
<td>18.000.00</td>
<td>41</td>
<td>4.146 Kg</td>
<td>121.410 Kg</td>
<td>500</td>
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<tr>
<td>Shrimp</td>
<td>3.2 Kg</td>
<td>6.42 Kg</td>
<td>4</td>
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<td>Tomatoes</td>
<td>10.500</td>
<td>1.487 Kg</td>
<td>2.60</td>
<td>7.851</td>
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<tr>
<td>Onions</td>
<td>34 Kg</td>
<td>12.810 Kg</td>
<td>6.4</td>
<td>4.900</td>
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<tr>
<td>Carrots</td>
<td>180</td>
<td>0.4 Kg</td>
<td>147.04 Kg</td>
<td>8.90</td>
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<tr>
<td>Oil (Rape/S.O)</td>
<td>4.900 metric</td>
<td>8.9 Kg</td>
<td>126.7 Kg</td>
<td>1.25</td>
<td>10.927</td>
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<tr>
<td>Cheese Slices</td>
<td>614.000.00</td>
<td>1373</td>
<td>501.145</td>
<td>4.090</td>
<td>4.090</td>
<td>4.090</td>
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<td>Abattoirs</td>
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<td><strong>Totals</strong></td>
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<td><strong>3.228.898</strong></td>
<td><strong>3.228.898</strong></td>
<td><strong>3.228.898</strong></td>
</tr>
</tbody>
</table>

**THE SPACE REQUIRED:**

The boxes below represent the spaces required for each different food source.

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**McDONALDS FOOD CONSUMPTION:**

There are approximately 1,925 McDonald’s Restaurants up and down the UK. Each one has food deliveries 3-5 times a week. Nationwide McDonalds serve almost 2,000,000 people daily. Each person orders their food but is blissfully unaware of the amount of energy and resources that have gone into providing them with their meal. The last column in the table opposite shows how much space goes into providing food for 1 restaurant for a year. The figures for fish could not be calculated as they would require a small portion of the ocean.

The average size of a McDonalds in the UK is approximately 381m², however each restaurant actual size is almost 4 million kg.

Nationwide McDonalds uses 913 tonnes of food each day, which is approximately 7433 kg of food per restaurant per day.

On a global scale, McDonalds uses 23,033 tonnes of food per day, which equals 8,407,048 tonnes annually.
SELF SUFFICIENT McDonalds: Zero Food Miles

VERTICAL McDonalds:
The average size of a UK McDonalds Restaurant is 381m². Using this as a basic footprint guide, the diagram below indicates what a self sufficient McDonalds would look like.

CHICKEN:
To house all the broilers for chicken meat would require 376 levels at approximately 1.127 KM high

PORK:
To house all the pigs would require 2463 levels at a total of 7.449 KM

BEEF:
It would require approximately 6979 levels just for cows alone. This would account for 20.94 KM of the overall structure.

A PASSENGER JET:
To give an example of how high the structure is, a standard passenger plane flies at around 10.5 KM

30.39KM HIGH!

ISLINGTON McDonalds:
The site in Islington is approximately 89,000m². If we use that as the footprint for our self sustained McDonalds restaurant we get different results. The new building would be 43 stories tall, reaching 129 m high. The new Mega McDonalds would dominate the cityscape of Liverpool.

CHICKEN:
To house all the broilers for chicken meat would require 15 floors at approximately 4.6m high

PORK:
To house all the pigs would require 10.5 floors at a total of 31.8m tall

BEEF:
It would require approximately 29.9 floors just for cows alone. This would account for 89.7m of the overall height of the structure.

LIVERPOOL METROPOLITAN CATHEDRAL:
Possibly one of Liverpool’s most famous historic landmarks. Standing at approximately 85m tall, this building would be swamped by the new ‘Mega Restaurant’.

Professor Greg Keeffe
MacDonald’s drive thru true size - with goat meat saves 215 hectares

MacDonald’s drive thru true size - vegetarian saves 370 hectares

Professor Greg Keeffe
**SELF SUFFICIENT McDonalds:** Vegetarian

**VERTICAL McDonalds:**
The average size of a UK McDonalds Restaurant is 3000m². Using this as a basic footprint guide, the diagram below indicates what a self-sufficient McDonalds would look like.

**ISLINGTON McDonalds:**
The site in Islington is approximately 89,000m². If we use that as the footprint for our self-sustained McDonalds restaurant we get different results. The new building would be just 2 stories tall, reaching 8m high. The new 'Mega McDonalds' would fit nicely into the cityscape of Liverpool.

**LIVERPOOL METROPOLITAN CATHEDRAL:**
Possibly one of Liverpool's most famous historic landmarks. Standing at approximately 85m tall, this building would be overshadowed by the new 'Mega Restaurant'.

**VEGGIE:**
The overall structure would be easier to manage. Natural light would be able to penetrate the centre of the building allowing the vegetables to grow. Other parts of the building could be lit with artificial lighting to control temperatures. With this control the manager could almost trick the plants into thinking it is a different season than it actually is allowing year round growing.

**A PASSENGER JET:**
To give an example of how high the structure is, a standard passenger plane flies at around 10.5 KM.

**POTATOES:**
For all the potatoes for hash browns and chips would require 136 floors of the McDonalds tower which is approximately 460m.

**LEGUMES, NUTS + SEEDS:**
For all the nuts and vegetables it would require 112 floors of the McDonalds tower which is approximately 360m.

**1.16KM HIGH**

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**Professor Greg Keeffe**

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**QUEEN'S UNIVERSITY BELFAST**
Think big!
Think big!
Grow by chunking
Alternative fuels: Algae

Most productive strains are Spirulina and Botryococcus Braunii

Natural oil content 45% dry weight – low in sulphur – biodegradable – in fact edible!

Grown in bio-reactors – translucent cultivation tanks

Can utilise waste Carbon Dioxide from power plants
Algae - biofuel

100,000 strains

Exceptionally rich in natural hydrocarbons.

100x yield of rape

Produce up to 150,000 litres of biodiesel per hectare/yr

New technologies could increase this to 3,000,000 l/ha

Continuous production cycle, unlike land crops

Carbon neutral
Liverpool – shrinking city
Urban Space

“space is a luxury in the modern city”  CABE 2004

In Liverpool 12% of all urban space is derelict or vacant

Professor Greg Keeffe
Biofuels
Rapeseed

The area of rapeseed needed to power Liverpool is about 900,000 hectares (shown in red).

Actually the area equates to the whole of Lancashire’s arable land (in green).
Synergetic City:

Bio-port free energy city, Liverpool
Bio Port

Self assembly urbanism.

Using waste streams of glass from across Europe
Locally produce algae arrays on an epic scale
Final form: 10 glass factories producing over 250,000 tonnes/yr carbon neutrally

Professor Greg Keeffe
Free Energy City: Some figures re energy

6000 Hectares of bioreactors
190 hectares of derelict docks
other land reclaimed from Mersey Estuary

Produces 900,000,000 litres of biodiesel pa

Split into a relay of sectors of 140 ha each with a bioreactor and 9MW CHP producing 78MWh electricity and over 600TJ heat enough for 23,000 homes

Whole development would produce twice Liverpool’s current demand for space-heating and power.

Plus 2TWh of spare electricity.
Bio Port: Carbon neutral, self-assembly city

Professor Greg Keeffe
Bio Port: Carbon neutral, self-assembly city
Think small!

Professor Greg Keeffe
Think small!

But perfectly formed
Invisible terrace:

Autonomous living machine

Professor Greg Keeffe
Use connected thinking
Nutritionally Complete:

zero carbon city carpet
Be productive
Be Productive: Make farms smaller
The Biospheric Foundation

Aquaponic urban laboratory and farm
Biospheric Foundation.

Circularity of food, energy + water.
Technical food system: aquaponic agriculture
Three pumps needed.

Total power needed 960 Watts
£3.60 per day
Miineralisation and filtration

84 containers
100Kg worms
Window systems

Professor Greg Keeffe
Polytunnel

Nutrient Film Technique (NFT system)

Professor Greg Keeffe
Reduce food miles
Reduce food miles:
Eat at the supermarket

Professor Greg Keeffe
Green genius Award

Food-producing
Bioclimatic office façade

With Saint Gobain Glass

Prototype food producing façade:
Building becomes cyborg

Hardware = technology
Software = biotic components
Interface = food management

Professor Greg Keeffe
Prototype food producing façade:
Building becomes cyborg

Hardware = technology
Software = biotic components
Interface = food management

Professor Greg Keeffe
Super-dupermarket
Super-dupermarket
Deployable Aquaponic and health pod

Live Project 2016
This project, working with Cando and charity Change for Climate Change, aims to change the lives of First Nation Tribes in Northern Canada. The aquaponic technical food system aims to improve health through better diet and meaningful work, in areas of extreme pollution and poverty in Edmonton.

Professor Greg Keeffe
Greatest Hits: Whitefield, Nelson - RIBA competition winner

Whitefield, Nelson Combined heat and power with interseasonal store

- Inter-seasonal store
- Undersown public space
- Low grade heat supplied by district main
- High grade heat supplied to inter-seasonal store
- Electricity supplied by public main
- Grid Connection
- Bio-diesel Store
- Diesel Reciprocating Engine
- Electricity Generator

Output

Demand

Output

Demand

January
February
March
April
May
June
July
August
September
October
November
December

Professor Greg Keeffe
Roeslare CityZEN carbon descent strategy plan

Research Project 2018 funded by EU FP7 Smart Cities
With TU Delft, U of Sienna and VITO
District heating / urban agriculture
Dubrovnik CityZEN carbon descent strategy plan

Research Project 2016 funded by EU FP7 Smart Cities
With TU Delft, U of Sienna and VITO
infrastructure in the city, that delivers fuel, energy and food for the ships.

Professor Greg Keeffe
Design for future climate: bioclimatic short-life re-adapted facade

The changing climate of the anthropocene will cause serious issues for architecture, as our once stationary ecological context begins to shift rapidly. Using weather data projections for the next 60 years, it was determined that the UK climate, will go on an incredible journey from cool Maritime through Mediterranean to Atlantic equatorial over the century.
Conclusion

Laws of living distributed systems.
1 Distribute being
2 Control from the bottom up
3 Cultivate increasing returns
4 Grow by chunking
5 Maximize the fringes
6 Honour your errors
7 Pursue no optima; have multiple goals
8 Seek persistent disequilibrium
9 Change changes itself.

Conclusion

Urban resilience can be created by holistic design

This sees cities as ecological in make-up: Site-specific, interlinked economic, social and environmental systems.

Unique: a phenotype

And thus design the city as an emergent super-organism

Professor Greg Keeffe  g.keeffe@qub.ac.uk
‘Any sufficiently advanced technology is indistinguishable from Nature. Basically, either advanced alien civilizations don't exist, or we can't see them because they are indistinguishable from natural systems. I vote for the latter.’