HIGH DENSITY
Challenges and Opportunities

Symposium on Sustainable Urban Design – Case Studies and Design Workflows
Massachusetts Institute of Technology, May 6, 2013
Matthias Rudolph
BY 2050

$\text{CO}_2 \text{ TO ZERO}$

WE NEED TO REDUCE OUR EMISSIONS
WELCOME TO BREATHTAKING

TOKYO WATERPARK

WHERE YOU CAN WASH AWAY
THE STRESS OF AN
OVERCROWDED CITY
EFFICIENCY DRIVEN BY GADGETS
EFFICIENCY DRIVEN BY DESIGN
optimize …

source: Knippers Helbig
aerodynamic shape
drag coefficient

0.7

0.36

0.16

source: Knippers Helbig
MORE PEOPLE LIVE IN CITIES
WORLD POPULATION INCREASES CONSTANTLY
NEW CITIES / CITY EXTENSIONS ARE GROWING

10% lived in cities in 1900
50% is living in cities in 2007
75% will be living in cities in 2050
URBAN PLANNING FACES NEW CHALLENGES
CRITERIA CURRENTLY UNDERGO CHANGES
RE-ASSESSMENT OF EXISTING CRITERIA
AND ADDITIONAL GOALS

1. CARBON EMISSIONS

2. QUALITY OF URBAN LIFE

   QUALITY OF OUTDOOR ENVIRONMENT

   QUALITY OF INDOOR ENVIRONMENT
OPPORTUNITIES
DENSITY AND TRANSPORT ENERGY

Petroleum use p/a (average per capita) in MJ/a/capita vs. Density (persons per hectare)
TRANSPORT AND URBAN QUALITY
DENSITY AND INFRASTRUCTURE
Passiv House

GFZ 0.5

60% Heat Loss
15 ct/kWh (Grid + Loss)

Low Energy Buildings

GFZ 2

12% Heat Loss
3.5 ct/kWh (Grid + Loss)

Low Energy Buildings

GFZ 3

8% Heat Loss
2.7 ct/kWh (Grid + Loss)
CHALLENGES
URBAN QUALITY AND STREET LIFE

source: Jahn Gehl Architects
OUTDOOR COMFORT
OUTDOOR COMFORT
WIND

Photo: Panhandle Helicopter/ JR Hott
DAYLIGHT AND SOLAR ACCESS
PROCESS
IMPLEMENTATION OF DESIGN STRATEGIES

DEPENDENCY OF SCALE

SOLAR ACCESS, DAYLIGHT
ENERGY INFRASTRUCTURE
IMPLEMENTATION OF DESIGN STRATEGIES

PERFORMANCE BASED PROCESS

DAYLIGHT SOLAR ACCESS

PEDESTRIAN COMFORT

CARBON EMISSIONS
INTEGRATED DESIGN TEAM
CASE STUDIES

MASDAR, ABU DHABI
MASDAR
Abu Dhabi, VAE

FOSTER & PARTNERS
OBJECTIVES

Sustainability objectives
- Create outstanding living and working conditions
- Provide excellent air quality and thermal comfort
- Create a zero carbon development
- Develop technical concepts and rethink the way of living
- Replace fossil power by solar power

City of short distances
- City where living and working is close
- people walk instead of using he air conditioned car
Wie muss das Straßennetz angepasst werden um Tageslicht und thermischen Komfort zu optimieren?

Street Orientation

Street Dimension
45° PROVIDES BEST MICROCLIMATE

North/South

The North-South orientation of streets allows sunlight penetration, benefiting the urban structure with a subsequent increase in cooling load requirements.

East/West

An East/West alignment also results in an increase in cooling load requirements due to the street exposure of thermal walls to sunlight.

Northeast/Southwest

The diagonal grid provides optimal shading.

Northeast/Southwest

The northeast/southwest orientation of the city fabric provides optimal shading.
BLOCK HOT WINDS

Short Street below 75 – 100 m

The hot wind remains above the street!

Wind velocity profile [m/s] at 2m height above the ground
USE COOL WINDS

Night-time Cool Winds
TAGENLICH

ABU DHABI DOWNTOWN

Credits: Foster + Partners
INFRAROT

ABU DHABI DOWNTOWN

Air temperature 37°C
Radiant temperature 48°C
Building 38°C
Asphalt 57°C

Source: Foster + Partners research

Credits: Foster + Partners
TAGESLICHT

MASDAR INSTITUTE

39°C Air temperature

27°C

Credits: Foster + Partners
MASDAR INSTITUTE
Energy consumption for project site and 3.8 Mio m² buildings for UAE today standard towards Masdar guidelines.

Annual electricity consumption [MWh/year]

- solar potential
- water distribution
- waste treatment
- energy distribution
- desalination
- on site traffic
- street lighting
- building operation

STRA TEGY
CARBON NEUTRAL CITY

-79%
Office floors in 2. to 5. story; 3 m clearance;
25 % of total area as top floor area with roof
working hours - 8\degree \text{ to } 19\degree; 6 \text{ days per week}
operation of AHU - 24 \text{ h / 7 d; based on working area; working: 1.5 acre; non-working: 0.75 acre}
artificial lighting - operation controlled depending on outdoor illuminance;
facade - 10 W/m\textsuperscript{2} based on net floor area
30\% glass; neutral solar control glass 50/25; 20 \% frame ratio;
operable, exterior shading device;
shading coefficient 0.3
facade - opaque facade ratio of 70 \%;
roof - 5 cm thermal insulation (outer surface)
20 cm thermal insulation (outer surface)
exposed ceiling - as thermal mass
infiltration - 0.15 acre during working hours;
0.05 acre in non working hours
design temperature - 24\degree \text{C / 65 \% r. hum. daytime}
28\degree \text{C in non working hours}
density - 20 m\textsuperscript{2} per occupant
internal heat gains - 5.3 W/m\textsuperscript{2} during working hours;
(office equipment) 2.65 W/m\textsuperscript{2} in non working hours
dem. demand of AHU - 0.6 kWh/1,000 m\textsuperscript{3}
sens. heat recovery - 80 \%
ZONES ENERGY SIMULATION
Masdar energy reduction 4th iteration compared to Abu Dhabi today

Reduction [%]

- Retail/Lab/Prod.
- Office/Research
- Office
- Housing/Hotel
- Education
- Total

Energy savings
ENERGY MONITORING

Residential energy number:
Reference 396 kWh/m²a
Designed 65.5 kWh/m²a
Measured 100 kWh/m²a
CASE STUDIES

HELSPINKI, FINLAND
JÄTKÄSAARI PENINSULA
LOW TO NO DEVELOPMENT

HELSINKI, FINLAND

BIG ARCHITECTS
JÄTKÄSAARI PENINSULA
LOW TO NO DEVELOPMENT

HELSINKI, FINLAND

Original jätkäsaari Masterplan
CLIMATE

HELSINKI, FINLAND
DAYLIGHT
SOLAR EXPOSURE
DAYLIGHT
SOLAR EXPOSURE
DAYLIGHT
SOLAR EXPOSURE
TAGESLICHT

BESONNUNG
SOLAR EXPOSURE HOURS

View from the EAST

View from the SOUTH

Number of hours receiving direct sunlight in [hours/day]
Maximum available hours of beam solar radiation on the not shaded plane: 11h
TYPOLOGIE

SOLID

VOID

STEPPE COURTYARD

CONTEMPORARY BLOCK

SNAKE

LONG SLABS

OPEN COURT YARDS

LITTLE TOWERS

SHORT SLABS
CARBON NEUTRAL CITY

PASSIVE STRATEGIES
- Wind Mitigation
- Passive Heating
- Natural Ventilation

SERVICE STRATEGIES
- Heat Exchangers
- Geothermal
- Radiant Heating

SUPPLY STRATEGIES
- Waste
- Solar
- Wind
TACTICS

MULTIPLE ENERGY SOURCES

**Diagram Description:**
- **WATER**
  - Chilled Ocean Hot Water
  - Stored Ferry Heat
- **GEOTHERMAL**
  - Geothermal
  - Evacuated Tube Collectors
- **SOLAR**
  - Photovoltaics Panels
- **WASTE**
  - Waste to Energy
- **WIND**
  - Excess power returned to National Power Grid

**Flow Chart:**
- Natural Resources/Technologies → Comfort
- **ELECTRICITY**
  - Heating
  - Cooling
  - Heating + Dehumidification
  - Transport
- **HEATING COOLING**
  - Hot Water
  - Cooling
  - Site Wide Power Distribution
STRATEGY

LOW CARBON INFRASTRUCTURE

ROOM HEATING
- Decentral Heat Storage
- Hot Radiant Floors
- High Efficient Heat Exchangers
- Supply 75°C
- Return 25°C
- High Temp Heat Source
- Biogas Cogen
- Waste heat from ferry ships

DOMESTIC WATER
- Hot Water
- Central Seasonal Heat Storage in Granite of Fäkansaari

AIR HANDLING
- Used Exhaust Air
- Outside Air
- High Efficient Heat Recovery System
- Used + Warm Room Air
- High Efficient Water to Air Heat Exchangers
SITE

ENERGY ASSETS

- heat lost from seawater (conventional)
- heat captured in containers
- Seasonal Storage
  - granite = excellent thermal storage
OUTLOOK
GRAND ADJUSTMENTS
DESIGNING DENSIFICATION

Solar access optimized densification

*Solar access optimized densification*
Designing for Climate Change

In summer 2003, 40,000 Europeans died as a cause of a heat wave. By 2050, this will be the typical summer.
LIVE AND WORK

HOW MANY PEOPLE SHOULD LIVE IN DOWNTOWN BOSTON IN THE FUTURE?
Forecasting is very difficult, especially about the future!

Mark Twain
Questions?