Appendix 5: Review of adaptation options and measures

Adaptation Strategies for European Cities: Final Report

This is part of the Final Report of the project ”Adaptation Strategies for European Cities” which has been compiled by Ricardo-AEA for the European Commission Directorate General Climate Action

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REVIEW ADAPTATION OPTIONS

26 April 2013
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C03031.000374.0100

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Contents

1 Introduction

In this note we describe the review of adaptation options (task 1.2.3). We start with the aim and outputs of the review (1). Then we describe our approach(2). At the end we have presented our results.

With this note the following attachments are included:
Annex I: Database of source material (version 16 April 2012)
Annex II: Long list of Adaptation options (version 16 April 2012)
Annex III: List of good practice adaptation options (updated version, presented in this note)
Annex IV: Factsheets good practice adaptation options (new products, separate documents)

2 Aim and outputs

The review of adaptation options should contribute to the assessment of the state of play of adaptation on city level within Europe. Secondly, the review should provide usefull information for the development of training material (task 3). At last, the results of the review will be available for stakeholders on the webbased platform.

Regarding these aims, we have formulated the following outputs of the review:

1. Searchable and filterable Excel spreadsheet containing a long list of adaptation options as appendix for the first progress report;
2. Factsheets with information of good adaptation practices and options that will be:
   a. Used for the analysis (see output 3)
   b. Available on the web-based platform/ CLH
3. Preliminary conclusions based on analysis of adaptation options about:
   a. State of play of climate adaptation options on city level in Europe;
   b. Useful insights for training material;

3 Approach

We distinguished in our working process to obtain the review of good practice adaptation options three steps:

I. Selection of good adaptation options
II. Describing of good adaptation options
III. Conduct analysis and report

Below we give an explanation of each step.

Ad I.) Selection of good adaptation options

We have undertaken the following steps to define good practice adaptation options that we will review in-depth:

1. Inventory of source material and consulting key players in climate issues among Europe;
2. Creating a long list of adaptation options;
3. Analysing and clustering of adaptation options;
4. Selecting good practice adaptation options that will be reviewed in-depth.

Hereunder we describe each step more detailed.

Ad 1) Inventory of source material

By internet search, contacts in our network and scientific internet libraries we found over 40 source materials (documents, reports, books, websites) that contain information about worldwide adaptation options.

Our database is checked by some experts within our professional network.

The database is given in annex I.

Ad 2) Creating a long list of adaptation options

We have scanned the public available source material that contain information on adaptation options in Europe. We filtered from the material all mentioned options and put them in a long list of over 200 adaptation options (see annex II).

A quick scan through the source material beyond Europe gave us the impression that there are no other options described than we have already listed.

We have searched for options to obtain a long list with a good geographical spread in Europe.

For each options we determined the primary climate impact it focusses on (according to the given source material) and city information. We distinguished the following primary climate impacts for cities:

- Heat stress;
- Flood risk (sea);
- Flood risk (river);
- Flood risk (storm water run-off)
- Drought;

On basis of this categorization we checked whether we obtained a coverage of all considered adaptation option regarding the climate impacts.

In annex II we have put our long list of adaptation options.

Ad 3) Analysing and clustering of adaptation options;
We reduced the number of adaptation options into a smaller number of types of options by:

- Removing identical options;
- Clustering similar adaptation options (from different stage in the policy and planning process up to implementing and maintenance).

This step resulted in a list of approximately 75 adaptation options.

Ad 4) Selecting good practices adaptation options
As a next step we identified 'good practices'. We therefore analyzed (quick-scan) the short list of options with help of the following questions:

- Has the option been applied in practice?
- Has the option been proven or are effects on reducing the climate impact(s) strongly expected?
- Has the option been proven or is strongly expected that no negative effects on social goals occur?

Finally, our long list has been checked by some experts within our professional network.

The selection of good practices has resulted in a list of adaptation options that will be reviewed in detail (next paragraph). In annex III we have put our list of good practice adaptation options.

Ad II.) Describe good practice adaptation options
We described in more detail the list of good practice adaptation options we obtained in the former step. We made a factsheet of each option. The main aim of the factsheets is providing overviews and information for stakeholders and training material about the scope of possible adaptation options. We selected the following aspects in order to describe the options:

- Name of the option;
- Related sector;
- Spatial scale: building – street – neighbourhood – city
- Graphic image or picture that shows the option
- Summary/ description of option
- Effectiveness: aim on climate impact, other effects (positive/ negative);
- Financial aspects
- Organization: responsibilities
- Management and maintenance: intensity of management (qualitative indication)
- Other considerations
- Information sources: examples of cities / references (websites / reports)

We have based this set of aspects on templates that are successfully used in comparable projects (a.o. OURCOAST, national projects).

We obtained information to proceed in the factsheets by internet research (see annex I), contacts with:

- National colleagues and relations with working experience and/ or wide professional network in Europe and worldwide (eg Knowledge for Climate, Wageningen University, IIASA);
- International colleagues from Belgium, United Kingdom, Germany, Poland, Czech republic and Romania;
- International relations in our professional network from France (Rouen), Belgium, Italy (Genua), Finland (Oulu), Sweden (Malmo), Greece, Slovakia, Poland (Warsaw, Wroclaw).

In total we have contacted about 10 (inter)national colleagues and about 35 (inter)national relations in the working field of climate change and adaptation. Our contacts in Poland confirmed the less experience and activities in the field of climate change and spatial developments in the eastern part of Europe.
The communications with relations are still continuing. We will add new gathered information (eg about adaptation options in Slovakia) in the final version of this note.

In Annex IV we have given the factsheets.

During the elaboration of the adaptation options we found out that valuable information of each type of adaption option was not always actually public available. If this was the case, we stated 'white spots' in the factsheet. For some options we found out the descriptions tend to be highly similar. Then we decided to summarize both options into one. For example: the option 'Construction and design of buildings to increase water use efficiency' we incorporated in the option 'Water saving measures'. And we included the option 'Improve drainage' into the option 'Reduce hardened surface'.

Ad III.) Conduct analysis and report

We analyzed the following results to draw up qualitative statements regarding the aims of the review:

- Database of source material;
- Long list adaptation options;
- Short list good practice options;
- Factsheets of good practice options.

The analyses focusses on the following questions:

1. What can be stated about the state of play of adaptation options on city level in Europe?
    a. Geographical distribution of knowledge about adaptation options;
    b. Geographical distribution of available adaptation options;
    c. Attention that is given to different climate impacts;
    d. Application of various types of measures;
    e. (cost)-effectiveness of measures;
    f. Approaches and experiences with adaptation among European cities
    g. Applicability of measures among European cities

4 Analysis results

State of Play of adaptation measures on city level

Geographical distribution of knowledge and adaptation options

There is a large amount of information sources giving an overview or only mention possible adaptation options and examples in practice. There is only a few detailed and quantitative information available about the effectiveness and other relevant characteristics (costs, management aspects, etc.) available.

Most good practices, case studies and documents with information about adaptation options we found are published by city authorities and other organizations in the North and North-West of Europe. It seems, at least in East and South Europe countries, environmental organizations have more attention for climate change impacts than city authorities. It is therefore to be expected that the adaptive capacity of North-West European cities is higher than this capacity in central south and south-west Europe.
ESPON calculated adaptive capacity using a weighted combination of the economic, infrastructural, technological and institutional capacity, as well as the knowledge and awareness in these regions. A combination of these factors thus leads to a adaptive capacity, and at least for now, it is impossible to say which of these is the main limiting factor According to ESPON (2011) these regions facing high potential climate impacts, but have low adaptive capacity.

There's no indication that the lack of information from East and South-Europe is related to awareness or knowledge level about climate adaptation. It's not the case that adaptation measures do not exist in these regions, although there might be less good practices than in north-western Europe. Maybe they are not recognised as adaptation options (business as usual) and/ or there is less (political) commitment to identify and address climate issues. Language barriers might also be a cause (at least partly) for the lack of information about adaptation options in South and East Europe in our review, since we studied only (public available) Dutch or English written information.

In our opinion the main reasons for the disbalance in information, knowledge and good practices are:

- In Northern and Northwestern countries national governments have funded several large research programmes (e.g. Knowledge for Climate in The Netherlands, Climate-KIC initiative in Northwest Europe). We have no information about national governmental funding or research programmes in East and South-Europe.
- Furthermore, an important cause might be the less investments in spatial developments and economic growth in East and South European countries. We experienced that in North and West Europe, climate adaptation is often linked, or integrated, with other spatial developments (site development).

Attention for different climate impacts among Europe

The good practice adaptation options are distributed between the five climate impacts, as following:

- 11 options aiming at reducing impacts from flooding of seas;

- 13 on flooding of rivers;
- 13 on flooding by storm water runoff;
- 12 on heat stress;
- 6 on drought.

Thus, there is more attendance for reducing the impacts of flooding and there is a small deficit in attendance to develop adaptation options for drought. No good practices were found about how to deal with periods of extreme cold!

The high presence of adaptation options regarding flooding may be explained by the acute and high risks (mortality) for inhabitants of flood prone areas flooding of rivers and seas poses. This risk is taken serious and therefore relatively a lot of effort and investments are focusing on the development of (innovative) adaptation options. Examples include among others, implementing sand engines (Netherlands), flood risk forecasting systems (Hamburg, Germany) and flood proof urban development (Nijmegen, The Netherlands)

The relationship between adaptation options reducing drought impacts and heat stress need to be considered. The number of adaptation options regarding these impacts can be biased, because there are many good practice options using water or vegetation. Mostly these options are indicated in the source materials as aiming at reducing drought impacts , while these options have a positive effect on lowering temperatures also (reducing heat stress). Thus, these options are counted twice in the table above

The lack of adaptation options aiming at reducing drought impacts might also be explained by the fact that regions facing future drought spells are located in South-East Europe (EPSON, 2011). We just noticed that we face a lack of information from those regions in this review.

Types of measures

We grouped the good practice adaptation options into 3 distinctive groups:

- Hard, technical based, adaptation options
- Hard, system based, adaptation options
- Soft options (like governance, regulation, legislation)

We have found 13 hard technical based types of options, 8 hard system based types of options and 9 soft types options. So, there is more attention paid to hard adaptation options.

(Cost-)effectiveness of measures

There is only a few detailed and quantitative information available about the effectiveness and other relevant characteristics (costs, management aspects, etc.) available. In general most adaptation options do not implicit high additional construction or implementation costs, when these options are incorporated early in the planning process. Also stand alone measures might have no high construction and implementation costs, as for example orientation (regarding wind an sun) of new buildings. The more innovative adaptation options (mainly aiming at decreasing flooding impacts, like sand barriers) are at this time still highly expensive and the planning process highly complicated, because of the experimental character. This might change in future if projects are carried out successfully.

As discussed above, combined with existing plans on adjusting blue and green infrastructure, several climate impacts can be addressed (multi benefits), and are therefore cost-effective. Examples are blue green infrastructures that reduce the impact of drought, heat and increase biodiversity and recreational attractiveness of the city. Indirectly these measures stimulate social goals. Parks as meeting places can have positive sociological effect on people and green and nature have positive psychological effects on people.

Approaches and experiences of adaptation

Implementation of adaptation measures seems to be accelerated by incorporating adaptation into existing and ongoing developments, work plans etc. Quite a number of the measures considered by this study have been incorporated into new development or construction projects. This observation highlights the importance of incorporating adaptation into existing development/redevelopment timescales and work plans. Key factors determining the success of this approach are the availability of financial resources, added value to the urban habitat, acceptance by stakeholders, cost reducing (added adaptation measures do not significantly effect costs of 'big' infrastructural projects. Further analysis will be undertaken on these options.

On city scale or part of the city there tends to be a movement towards combining the so called 'technical' measures (like building dykes, construction of buildings) with more (eco)system based measures (ecosystems services like constructing or restoring wetlands, blue-green infrastructure);

There tends to be a movement in research institutes as well in private companies towards applying a more holistic approach. The possibilities of integrated system approaches are explored to deal with urban challenges. Considering cities as urban ecosystems and learning from ecosystems are key in many ongoing and new projects.

Even with the focus on urban areas, the role of ecosystem services is crucial for supporting adaptation: expanding blue-green infrastructure such as parks, forests, wetlands, green walls and roofs, wherever feasible and sustainable, brings multiple benefits. Such infrastructure serves to provide a cooling effect on cities as well as playing a role in managing floods, and will often bring efficiency and mitigation benefits too.

Applicability of measures among European cities

The extent to which adaptation measures are applicable and can be extrapolated across European cities depends mainly on the governance structures and the economic situation that are present. The more spatial investments are planned, the easier to incorporate, with limited costs, climate adaptation options in these plans.

Secondly, geographical aspects determine applicability of proven measures across Europe. To reduce impacts of flooding from rivers, it is important to consider the location of a city on the scale of the river system. Upstream it is the most effective to store water, midstream it is the most effective to expand the river bed to slow down water drainage lower streams. At last, in lower stream areas it is the most effective to drainage water. Another climate change effect where geographical differentiation is relevant is heat stress. Southern and Eastern European countries have already a history in facing heat stress impacts. Their built environment is already more adapted to heat impacts (orientation on wind and sun, narrow streets, high buildings, shaded shopping lanes) than North-European cities. Therefore, the range of options to implement in the built environment are less, and soft measures are maybe more effective.
On local scale, aspects as soil types and water levels are important to consider before implementing hard measures as for instance warmth-cold storage.

Regarding soft measures the applicability of adaptation measures is very country specific or even city specific. Cultural aspects (norms, values, traditions) need to be considered to implement measures effectively. For example, behaviour of a population affects effectiveness of evacuation routes. To develop effective policies for efficient water use at household level, cultural behaviors related to water use (i.e. car washing) need to be understand by policy makers. However, for some hard measures cultural aspects need to be considered as well. The ability of people to swim influences the possibility to construct water areas in cities.

Annex I Database of source material

ID	Author(s)	Year	Title	Subtitle	Journal	Publisher	Relevant Pages for Options	Read and options in longlist (if applicable)	Adaptation strategies	Adaptation options	Adaptation tools & guidances	Description	Cities	Heat stress	Flooding	Drought	Water stress
1	Barth B. (red)	(under construction)	Planning for Climate Change	A strategic, value-based Approach for Urban Planners		UN Habitat	108-110	1	x	x		Roadmap strategic planning for urban planners		x	x	x	x
2	Gill, Handley, Ennos, Pauleit	2007	Adapting cities for climate change	the role of the green infrastructure	Built Environment	Alexandrine Press		1	x	x		Potential of the Green Infrastructure in the urban environment	Greater Manchester area	x	x	x	x
3	Kirshen, Ruth, Anderson	2008	Interdependencies of urban climate change impacts and adapatation strategies	a case study of Metropolitan Boston USA	Climate Change		115	2	x	x	x	Interrelations amoung infrastructure systems	Boston				
4	Birkmann et al	2010	Adaptive urban governanceadaptation strategies to climate change	new challenges for the second generation of urban	Sustainable Science			2	x			Review of the effect of climate change on cities and proposed adaptation strategies	Singapore; New York; Halifax; Boston; Rotterdam	x	x	x	x
5	Lindley et al.	2006	Adaptation Strategies for Climate Change in the Urban Environment	Assessing Climate Change Related Risk in UK Urban Areas	Journal of Risk Research	Routledge		2			x	Reviews adaptation strategies, risk assessment methodology					
6	Hunt & Watkiss	2011	Climate change impacts and adaptation in cities	a review of the literature	Climate Change		31	1	x	x	x	Recent review of impacts and adaptations	London; New York	x	x	x	x
7	OECD	2010	Cities and Climate Change		BOOK	OECD						pm					
8			Promising Practices in Adaptation & Resilience	A Resource Guide for Local Leaders		Institute for Sustainable Communities	45 and 88	2	x		x	pm	Miami, Chicago, New York, Toronto, London, Seattle, New Orleans, Florida				
9			Adapting urban water systems to climate change	Case Study new York City		SWITCH	5	2	x	x		Adaptation measures and key success factors	New York		x		x
10		2009	City of Melbourne	Climate Change Adaptation Strategy			93>111	2	x	x		Adaptation actions	Melbourne	x	x	x	x
11	Ligeti	2007	Climate change adaptations options for Toronto's urban forest			Clean Air Partnership	11>21	2	x	x		Adaptation options for urban forests	Toronto	x	x	x	x
12	Aerts et al	2009	Connecting Delta Cities	Coastal cities, flood risk management and adaptation to climate change		o.a. Arcadis, KVR	52>84	see 13	x	x	x	Adaptation in Delta Cities for coastal flooding (coastal impact)	New York; Rotterdam; Jakarta		x		
13	Dircke, Aerts, molenaar	2010	Connecting Delta Cities	Sharing knowledge and working on adaptation to climate change		o.a. VU Amsterdam, Arcadis	37; 55; 67; 79; 97; 109	1	x	x	x	Adaptation in Delta Cities for coastal flooding (coastal impact)	New York; Rotterdam; Jakarta; London; New Orleans; Hong Kong; Tokio; Ho Chi Minh City		x		
14		2008	German Strategy for Adaptation to Climate Change			The Federal Government	16>47	2	x		x	Integrated approach for risk assessment and action					
15	Van Ierland et al.	2007	Routeplanner	Naar een Klimaatbestendig Nederland			18>27; 30>51	1		x		A whole list of options! (table 1)		x	x	x	x
16	City of London	2007	Rising to the Challenge	The City of London Climate Change Adaptation Strategy		City of London Corporation	16>19; 23>26; 30>35; 37>40; Appendix 2	1	x	x	x	The indicated pages list adaptation options	London	x	x	x	x
17	Döpp, Albers	2008	Klimaatverandering in Nederland	Uitdagingen voor een leefbare stad		TNO	8>13	1	x	x	x	The indicated pages list adaptation options/strategies	Netherlands	x	x	x	x
18		2011	Guide to Climate Change Adaptation in Cities			The World Bank Group	Chapter 6	2	x		x	Has some adaptation options but not in European cities		x	x	x	x
19	Bambrick et al	2011	Climate Change and Health in the Urban Environment	Adaptation Opportunities in Australian Cities	Asia-Pacific Journal of Public Health		71>75	2	x	x	x	Health related policies and strategies and lists some options	Australia	x		x	
20	Carmin, Anguelovski, Roberts	2012	Urban Climate Adaptation in the Global South	Planning in an Emerging Policy Domain	Journal of Planning Education and Research			2	x	x		Review of case studies; but focuses mainly of the planning process	Durban; Quito	x	x	x	x

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21	Revi	2008	Climate change risk	An adaptation and mitigation agenda for Indian cities	Environment and Urbanization		218 and up	2	x		x	Indian climate change adaptation strategies	India	x	x	x	x
22	Wardekker	2011	Climate change impact assessment and adaptation under uncertainty		PhD dissertation	Utrecht University	65>69	2	x			Focusing mainly on policies and strategies	Rotterdam and others	x	x	x	x
23	Alcoforado, Andrade, Lopes, Vasconcelos	2008	Application of climatic guidelines to urban planning	The example of Lisbon (Portugal)	Landscape and Urban Planning		7>9	1	x	x	x	Presenting a case study	Lisbon	x		x	
24	Rosenzweig et al	2011	Climate Change and Cities	First Assessment Report of the Urban Climate Change Research Network	BOOK	Cambridge University Press											
25	Mees, Driessen	2011	Adaptation to climate change in urban areas	climate-greening London, Rotterdam, and Toronto	Climate Law	IOS Press		2	x		x		London; Rotterdam; Toronto				
26	De Bruin et al	2009	Adapting to climate change in The Netherlands	an inventory of climate adaptation options and ranking alternatives	Climatic Change		18>21	1	x	x			Netherlands	x	x	x	x
27	Georgi et al	2012	Urban adaptation to climate change in Europe	Cities' challenges, opportunities, and supportive national and European policies			34>39;58>64;74>77	1	x	x	x	Overview urban adaptation strategies and options	Europe	x	x	x	x
28	Döpp et al	2011	Kennismontage	Hitte en klimaat in de stad		Climate Proof Cities Consortium	26>43	1	x	x	x	Focusing on heat in the city, also gives an overview of literature on adaptation strategies (!)	Netherlands	x			
29		2011	Maatregelenoverzicht Klimaatadaptatie	Rapport		Min E&I	12	1		x		Report showing most promising options for cities	Netherlands	x	x	x	x
30		2011	Maatregelenoverzicht Klimaatadaptatie	Factsheets van Maatregelen		Min E&I	all	1		x		155 fact sheets with adaptation options	Netherlands	x	x	x	x
31		2011	Maatregelenoverzicht Klimaatadaptatie	Overzicht Maatregelen		Min E&I	all	1		x		All options listed	Netherlands	x	x	x	x
32		2009	San Francisco Bay	Preparing for the next level		Arcadis	63>65;74>75	1	x	x	x		San Francisco		x		
33		2009	San Francisco Bay	Appendix Measures		Arcadis	8>47; 68>72	1	x	x			San Francisco		x		
34	Marttila et al	2005	Finland's National Strategy for Adaptation to Climate Change		(OURCOAST database)	Ministry of Agriculture and Forestry of Finland	172 and up	1	x	x							
35		2010	Catchment Flood Risk Management Plan		(OURCOAST database)	Lee CFRAMS		1		x							
36		2009	Views and Experiences from the Netherlands Commission for Environmental Assessment		(OURCOAST database)	Netherlands Commission for Environmental Assessment	17;18;	2	x		x	Focuses mainly on strategies		x	x	x	x
37	Pickaver		Detached breakwaters to create sand bars in a beach recovery programme		(OURCOAST database)	EUROSIAN case study	7 and up	1	x	x	x	The use of detached breakwaters to create sand bars and recover eroded beaches for recreational use as well as protect soft-rock cliff faces from further erosion	Liseleje-Hyllingebjerg		x		
38	Prinos	2004	Soft techniques for coastal protection in Greece		(OURCOAST database)	Aristotle University of Thessaloniki		1	x	x		Design and implementation of detached submerged breakwaters and beach nourishment for the protection of a Greek coast	Paralia Katerinis		x		
39			Malta: Use of leakage control in water management strategy		(OURCOAST database)	Water Services Corporation		1	x	x		Water leakage control from supply pipelines	Malta				x
40		2007	Coastal Reinforcement Noordwijk	What is happening on the beach in Noordwijk?	(OURCOAST database)	Hoogheemraadschap van Rijnland,		1		x		Building a dyke as a protective sea defence and disguising it as a dune so it forms a continuation with the dune system either side	Noordwijk		x		
41	Larsen et al	2011	Green Building and Climate Resilience	Understanding impacts and preparing for changing conditions		University of Michigan; US Green Building Control	83 and up	1	x	x	x	Overview of adaptation options for buildings in cities		x	x	x	x
42		2010	Chicago Climate Action Plan	Our City. Our Future.		Chicago Climate Task Force	50>54	2	x	x	x	Overview of Chicago's climate action plan	Chicago	x	x	x	x
43			www.adaptatiescan.nl							x		Website with adaptation options in Netherlands					
44		2009	Climate ready estuaries	Synthesis of adaptation options for coastal areas		EPA		2		x				x	x	x	x
45			RDMcampus.nl									website with innovative adaptation options in the city	Rotterdam		x		x

Annex II Long list of adaptation options

Option nr	Source ID	Description of adaptation option	Heat stress	Drought	Flooding	Storm water run off	Cities
1	34	Planning of water services			x		Finland
2	34	Land use planning to reduce flood risks and especially to avoid construction in flood areas			x		Finland
3	34	Planning of trenching and stormwater services			x		Finland
4	34	Raising of flood banks			x		Finland
5	34	Construction of reserve water intake plants			x	x	Finland
6	34	Interconnection of the networks of water supply plants			x		Finland
7	34	Expansion of water supply and sewerage networks			x		Finland
8	34	Construction of properties farther away from flood areas			x		Finland
9	34	Construction of irrigation systems			x		Finland
10	34	Joining the network of a water services company / choosing the location for a well and maintaining its condition			x	x	Finland
11	34	Maintenance of the structures (road body, ditches, bridges and culverts) and condition of road network, particularly on smaller roads and gravel roads as floods and rains increase and ground frost diminishes			x	x	Finland
12	34	Maintenance of the structures (railway beds) and condition of railways while floods and rains increase and ground frost diminishes			x		Finland
13	34	The impacts of a potential increase in wind velocity will be taken into consideration with regard to the existing building stock and new constructions					Finland
14	34	Preparedness planning must pay attention to backup systems for the distribution and production of electricity	x	x	x	x	Finland
15	34	Insurance operations: Development of technology to reduce risks	x	x	x	x	Finland
16	35	Tidal and/or Flood forecasting system, combined with a targeted public awareness and education campaign and individual property protection / flood-proofing			x		Multiple cities in Scotland
17	35	Permanent flood walls/embankments			x		Multiple cities in Scotland
18	35	Proactive maintenance of existing flood defence embankment at Tower			x		Blarney and Tower
19	37	The use of detached breakwaters to create sand bars and recover eroded beaches for recreational use as well as protect soft-rock cliff faces from further erosion.			x		Liseleje-Hyllingebjerg
20	38	Design and implementation of detached submerged breakwaters and beach nourishment for the protection of a Greek coast			x		Paralia Katerinis
21	39	Water leakage control from supply pipelines has been developed to become a strategically important component for water resource management. It has been used to reach an optimum economic balance between water supply and water demand		x			Malta
22	40	Building a dyke as a protective sea defence and disguising it as a dune so it forms a continuation with the dune system either side. The new dyke-in-dune, as well as offering defence also acts as an ecological corridor			x		Noordwijk
23	30	Using geomorphology and soil when arranging - option 1					Netherlands
24	30	Soil structure improvement - e.g. more black soil in gardens - option 2					Netherlands
25	30	Penetrable roads/concrete - option 14	x		x		Netherlands
26	30	Less paving of private properties - option 15	x				Netherlands
27	30	Water passing pavements - option 16			x		Netherlands
28	30	Fields - option 19	x		x	x	Netherlands
29	30	Greener shoulders en traffic sides - option 20	x		x	x	Netherlands
30	30	Street trees - option 22	x		x	x	Netherlands
31	30	Temporary nature on undeveloped terrains - option 27	x		x	x	Netherlands
32	30	Vegetation in neighbourhoods - option 28	x		x	x	Netherlands
33	30	Greening of rooms - option 29	x		x	x	Netherlands
34	30	More green areas - option 31	x		x	x	Netherlands
35	30	Urban farming - option 33	x	x	x		Netherlands
36	30	New crops for allotment and vegetable gardens - option 36		x	x	x	Netherlands
37	30	Salty crops - option 37		x			Netherlands
38	30	Seperated sewerage / drinking water pipelines - option 39		x	x	x	Netherlands
39	30	Shallow canals, isolating wells/springs - option 66		x	x		Netherlands
40	30	Shadowing buildings - option 79	x				Netherlands
41	30	Screens above roads - option 81	x				Netherlands
42	30	natural ventilation in buidlings - option 88	x				Netherlands
43	30	filters in ventilation systems - option 90	x				Netherlands
44	30	Terraces at catering industry - option 91	x	x			Netherlands
45	30	Achitecture, focus on sun and wind - option 92	x	x			Netherlands
46	30	Isolating, heat preventing buildings - option 94	x				Netherlands
47	30	Extending roofs provide shading to buildings - option 97	x				Netherlands
48	30	Bedrooms on north sides of house - option 98	x				Netherlands
49	16	assigning responsibility for coordination and liaison on flood risk management to a named officer			x		London

Option nr	Source ID	Description of adaptation option	Heat stress	Drought	Flooding	Storm water run off	Cities
50	16	Implement Sustainable Drainage Systems. An alternative to traditional approaches to managing runoff from buildings and hardstanding.			x	x	London
51	16	Green roofs	x		x	x	London
52	16	Using one-way valves in drainage pipes to prevent back-up of water into buildings			x		London
53	16	Using removable flood barriers and other removable flood protection products			x		London
54	16	Using flood-resilient materials			x		London
55	16	Locating electrical services and boilers above likely maximum flood level			x		London
56	16	Raising damp-proof courses			x		London
57	16	water consumption be limited to 125 litres per person per day using the 'Water Efficiency Calculator for New Dwellings'		x			London
58	16	gardens are fitted with water-efficient irrigation systems		x			London
59	16	West Ham Park nursery grows over 250,000 bedding plants in a planting medium that has reduced need for watering by 50%. The nursery also provides its clients with drought-tolerant plants.	x	x			London
60	16	Implement rainwater harvesting systems		x			London
61	16	Greywater recycling		x			London
62	16	Implement mechanism in buildings to reduce water use (and increase water use efficiency)		x			London
63	16	More green areas in the city	x				London
64	16	repair of historic drinking fountains and installing new fountains in the City	x				London
65	16	Shading windows by installing shutters or blinds reduces solar gain and so internal heat build-up is reduced	x				London
66	16	A cool roof or 'white roof' can reduce the temperature of a building's roof dramatically, and hence also reduce the Urban Heat Island effect	x				London
67	16	'Cool pavements' are comprised of light coloured material with high solar reflectivity and good water permeability: reducing high urban temperatures and encourage water storage and thus allow evaporative cooling	x				London
68	16	Extending roofs provide shading to buildings	x				London
69	16	Heat Health Warning Systems predict the risk of dangerous heatwaves using meteorological information.	x				London
70	17	A floating road			x		Netherlands
71	23	make sure that the H/W ratio (i.e. the ratio between the height (H) of the buildings and the width (W) of the streets) is kept under 1	x				Lisbon
72	23	maximize the vegetated surfaces, including roof gardens	x				Lisbon
73	23	when renovating buildings, opt for light colours and materials with low thermal admittance	x				Lisbon
74	23	promote ventilation paths alongside large freeways or in between the city districts	x				Lisbon
75	23	create large green areas next to each newly-built urbanised neighbourhood quarter	x				Lisbon
76	26	Water storage on farmland		x	x		Netherlands
77	26	Restoration of ecosystems directly depending on water quantity and quality			x		Netherlands
78	26	Moving powerplants to coast	x		x	x	Netherlands
79	26	Reconnecting water systems in Delta area			x		Netherlands
80	26	Enhancing capacity of sluices and weirs			x		Netherlands
81	26	Reduce waste water discharge during drought periods		x			Netherlands
82	26	Emergency systems revision for tunnels and subways			x		Netherlands
83	27	Building insulation to keep the inside cool and Shadow blends at buildings	x				Manchester
84	27	Passive cooling of buildings	x				Manchester
85	27	Shadowing urban space and Ventilation of urban space by intelligent urban design	x				Manchester
86	27	Boosting green infrastructure, like green urban areas, open water, trees, green walls and roofs	x				Manchester
87	27	Ensuring that fresh air from green areas outside the city can flow in	x				Manchester
88	27	Make new buildings and infrastructure flooding proof by appropriate design and material			x		
89	27	Maintenance / upgrade of drainage system			x		
90	27	Temporal water storage in basins or fascines			x		
91	27	Separate treatment of rain water, disconnect from sewage, improved drainage into the ground			x		
92	27	Innovative design of buildings and places like elevated entrances, building on piles, floating houses, temporarily water storage, green roofs			x		
93	27	Dams; flood defences			x		
94	27	Avoid / remove impervious surfaces wherever possible			x		

Option nr	Source ID	Description of adaptation option	Heat stress	Drought	Flooding	Storm water run off	Cities
95	27	Maintain and further boost green infrastructure in cities, in particular parks and gardens, wetlands, water bodies but also green roofs			x		
96	27	Re-naturalisation of rivers and wetlands			x		
97	27	Water saving measures (Grey water recycling / Ground water recharge / Rain water harvesting / Supply from more remote areas)		x			
98	27	Desalination		x			
99	27	Rain water storage in wetlands and water bodies for later use		x			
100	27	Maintain and manage green areas outside and inside the cities to ensure water storage instead of high run-offs		x			
101	27	Use vegetation which is adapted to water scarcity		x			
102	28	Greening of cities: public areas (forests, gardens, parks); trees; green roofs	x	x	x		
103	28	Spraying of water (fountains)	x				
104	28	Raise albedo of buidlings (roofs/walls)	x				
105	28	Wetting of streets ("Uchimizu") and roofs	x				
106	33	Adaptive mounts			x		Zierikzee
107	33	Flood resistant housing			x		
108	33	Floating Houses			x		
109	33	Flood proof urban development			x		Hamburg
110	33	Closed fixed barrier			x		Aflsuitdijk, the netherlands
111	33	Storm Surge Barrier			x		Eastern Scheldt, The Netherlands
112	33	Floating Sector Gates			x		Rotterdam
113	33	Raise seawall			x		Vlissingen, Netherlands
114	33	Glass overtopping walls for defence against floodings			x		Dronten, Netherlands
115	33	Houses as structural part of levee system			x		Dordrecht, Netherlands
116	33	Fresh water retention in lakes		x		x	Ijsselmeer, Netherlands
117	33	Water retention in parking garage		x		x	Rotterdam
118	33	Open water in urban environment	x	x		x	Noordwaard, the Netherlands
119	1	Repair and strenghten existing climate defenses (storm sewers, sea walls, dikes, channels, reservoirs)			x	x	
120	1	Climate proof vulnerable infrastructure in hazard areas			x	x	
121	1	New infrastructure in low hazard area			x	x	
122	1	Coastal Flood Prediction and Mapping			x	x	
123	1	Early warning system for disaster events			x		
124	1	New flood protection infrastructure			x		
125	1	Improve building codes			x		
126	1	Material use for infrastructure/buildings (reflective materials, green roofs, white roofs, etc.)	x			x	
127	2	Green infrastructure	x	x		x	Greater Manchester Area
128	6	Building design (shading, efficient cooling, green roofs, natural ventilation, heat-wave plans)	x	x			London
129	6	Improve forecasting and warning			x		London
130	6	Flood proofing buildings			x		London
131	13	retrofitting buildings			x	x	Rotterdam, London
132	13	Multifunctional urban flood protection			x	x	Rotterdam
133	13	Floating houses			x	x	Rotterdam
134	13	Retrofitting ponds and canals			x	x	Rotterdam
135	13	Green roofs			x	x	Rotterdam
136	13	Water Plaza's (playground + water storage)			x	x	Rotterdam
137	13	Parking garage as water storage			x	x	Rotterdam
138	13	New barriers			x		London
139	13	Urban green cover				x	London
140	41	High performance glazing (buildings)	x				
141	41	Interior and exterior shading devices in buildings	x				
142	41	High albedo roofing					
143	41	Orientation of a building	x			x	
144	41	Retention ponds	x			x	
145	41	High albedo paving	x				
146	41	Covered or shaded parking	x			x	
147	41	Elevated first floors			x	x	
148	41	Cross ventilation	x				
149	41	Thermal Zoning	x				
150	41	Ceiling Fans	x				
151	41	Passive solar design	x				
152	41	Increased thermal mass	x				
153	41	Evaporative cooling towers	x				
154	41	Earth Cooling/sheltering	x				
155	41	Greywater system rough out		x			
156	41	HVAC condensate capture		x			
157	41	Reclaimed water use		x			
158	41	Sewage backflow preventer		x			
159	41	Water catchment systems / cistern		x			

Option nr	Source ID	Description of adaptation option	Heat stress	Drought	Flooding	Storm water run off	Cities
160	41	Emergency management plan			x		
161	15	Integrated nature and water management			x		
162	15	Integrated coastal zone management			x		
163	15	Evacuation plans			x		
164	15	Design spatial planning - construct new housing and infrastructure			x		
165	15	Re-enforcement of dikes and dams, including weak spots			x		
166	15	Adaptation of high ways, secondary dikes to create compartments			x		
167	15	Widening the coastal defence area			x		
168	15	Fresh water storage to flush brackish water out during dry periods		x	x		
169	15	Construct buildings differently in such a way that there is less need for air-conditioning/heating	x				
170	29-31	Using warmth- and cold storage (WKO)	x				
171	29-31	Luchtzakken/Airbag Water Storage (in een watergang)	x				
172	29-31	Verdiepingen, baggeren in rivier of ander open water					
173	29-31	Baggeren van rivierbed					
174	29-31	Kruipruimteloos bouwen			x	x	
175	29-31	Hoogbouw			x		
176	29-31	Compartimenteren: dubbele wandstrategie	x				
177	29-31	Drijvende of Amfibische woningen					
178	29-31	Straten ophogen als evacuatieroutes			x	x	
179	29-31	Eigen noodvoorziening (noodstroom, drinkwater)	x				
180	4	Restricted development in high flood risk areas			x		London
181	4	Public contingency plans			x		London
182	4	Flood insurance			x		London
183	4	Changing consumer behavior		x			London
184	4	Improved water efficiency standards		x			London
185	4	Development of a comprehensive water strategy		x			London
186	4	Increasing awareness of heat-related stress, threats and its management	x				London
187	4	Heat-health alert system and updated response plan	x				London
188	4	Improve flood warning			x		
189	4	Rules and regulations for water use restrictions		x			
190	4	Integrated water resource planning		x			
191	4	Awareness campaigns		x			
192	4	Increased training in ecological fire management		x			
193	4	Air quality management system	x				
194	4	Public education on climate related health threats	x				
195	4	Maps of flood evacuation zones			x		New York
196	4	Task force to protect vital/critical infrastructures			x		New York
197	4	Community specific planning — working with vulnerable neighbourhoods			x	x	New York
198	4	Flood proofing of infrastructures			x		Rotterdam
199	4	Flood proofing of new buildings			x		
200	4	Update the heat response plan	x				Chicago
201	4	Basement Flooding Protection Subsidy Program			x	x	Toronto

Annex III List of good practice adaptation options

Nr	Type of adaptation option	Heat stress	Drought	Flooding (Sea)	Flooding (River)	Storm water run off
1	***Construction and design of buildings***	x				
2	***Orientation of buildings and open spaces***	x				
3	***Green roofs and walls***	x				x
4	***Raise albedo***	x				
5	***Provide shading***	x				
6a	***Reinforce flood protection infrastructure (River)***				x	
6b	***Reinforce flood protection infrastructure (Sea)***			x		
7	***Flood proof infrastructure***			x	x	x
8a	***Innovative flood protection options (River)***				x	
8b	***Innovative flood protection options (Sea)***			x		
9	***Enhancing capacity of waters***				x	x
10	***Geothermal heating and cooling***	x				
11	***Public green areas***	x				x
12	***Urban farming and gardening***	x	x			x
13	***Land use planning to reduce flood risks***			x	x	
14	***Flood forecasting and warning systems***			x	x	x
15	***Heat health warning system***	x				
16	***Improve regulations for building***			x	x	x
17	***Evacuation and contingency management plans***	x		x	x	x
18	***Water saving measures***		x			
19	***Crisis management***		x	x	x	x
20	***Extend water supply services***	x				
21	***Floating and amphibian housing***				x	
22	***Public education and awareness campaigns***	x	x	x	x	x
23	***Reduce hardened surfaces***					x
24	***Compartmentalization***			x		
25	***Water management plans***		x	x	x	x
26	***Water retention***		x		x	x
	Total	12	6	11	13	13

Option nr	Cluster	Double	Description of adaptation option	Sector	Heat stress	Drought	Flooding	Storm water runoff	Cities	In practice	No large negative impacts on social goals	Proven or expected effectiveness of the option
13	42, 84, 143, 148, 149, 169		Passive cooling of buildings. Considering natural ventilation and the increase in wind velocity when redesigning existing building stock and new constructions. Construct buildings differently in such a way that there is less need for air-conditioning/heating. Thermal zoning. Orientation of buildings.	Buildings	x				(Finland), Netherlands, Manchester, London	1	1	1
45			Architecture, focus on sun and wind	Buildings	x	x			Netherlands	1	1	1
46	33, 43, 48, 83, 150,176		Inside buildings: isolating, (bed)rooms on north sides of buildings, ceiling fans, double walls (compartements), greening of rooms, evaporative cooling towers, filters in ventilation systems.	Buildings	x				Netherlands	1	1	1
51	72, 86, 92, 95, 102, 128,135		Buildings with green roofs, roof gardens and green walls	Buildings	x		x	x	London	1	1	1
52		x	Using one-way valves in drainage pipes to prevent back-up of water into buildings	Buildings			x		London	1	0	1
54	88, 107, 130, 131		Using flood proof and resilient materials when constructing new building or retrofitting buildings	Buildings			x		London, Rotterdam, Manchester	1	1	1
62			Implement mechanism in buildings to reduce water use (and increase water use efficiency)	Buildings		x			London	1	1	0
92	147, 174, 175		Innovative design of buildings and places like elevated entrances, building on piles, floating houses, temporarily water storage, green roofs	Buildings			x			1	1	0
108	92, 133, 177		Floating Houses	Buildings			x			1	0	1
117	137, 90, 159, 105		Water retention in cities (parking garage; basins/fascines/cisterns; on squares/streets;	Buildings		x		x	Rotterdam	1	0	1
143		x	Orientation of a building	Buildings	x			x				
179			Eigen noodvoorziening (noodstroom, drinkwater)	Buildings	x					1	1	1
33		x	Greening of rooms	Buildings	x				Netherlands			
43		x	Filters in ventilation systems	Buildings	x				Netherlands			
48		x	Bedrooms on north sides of house	Buildings	x				Netherlands			
84		x	Passive cooling of buildings	Buildings	x				Manchester			
107		x	Flood resistant housing	Buildings			x					
147		x	Elevated first floors	Buildings			x	x				
150		x	Ceiling Fans	Buildings	x							
169		x	Construct buildings differently in such a way that there is less need for air-conditioning/heating	Buildings	x							
174		x	Kruipruimteloos bouwen	Buildings			x	x				
175		x	Hoogbouw	Buildings			x					
176		x	Compartimenteren: dubbele wandstrategie	Buildings	x							
50			Implement Sustainable Drainage Systems. An alternative to traditional approaches to managing runoff from buildings and hardstanding.	Buildings; Infrastructure			x	x	London	1	0	
55			Locating electrical services and boilers above likely maximum flood level	Buildings; Infrastructure			x		London	1	1	
66	67, 73, 104, 126, 140, 142, 145, 151		Raise albedo of buildings (roofs, walls, glazing) and pavement by using light coloured materials with high solar reflectivity and low thermal admittance.	Buildings; Infrastructure	x				London	1	1	1
71			make sure that the H/W ratio (i.e. the ratio between the height (H) of the buildings and the width (W) of the streets) is kept under 1	Buildings; Infrastructure	x				Lisbon	1	1	
87	74		Ensuring that fresh air from green areas outside the city can flow in and promote ventilation paths alongside large freeways or in between the city districts	Buildings; Infrastructure	x				Manchester, Lisbon	1	1	1
90	159	x	Temporal water storage in basins, fascines, cisterns	Buildings; Infrastructure			x					
115			Houses as structural part of levee system	Buildings; Infrastructure			x		Dordrecht, Netherlands	1	1	
109			Flood proof urban development	Buildings; Infrastructure; Water			x		Hamburg	1	1	1
40	41, 47, 65, 68, 85, 128, 141, 146		Shadowing buildings, roads and parkingplaces by putting up shutters, blinds, screens and extending rooftops	Buildings; Public area	x				Netherlands	1	1	1
153		x	Evaporative cooling towers	Buildings; Public area	x						1	
12		x	Maintenance of the structures (railway beds) and condition of railways while floods and rains increase and ground frost diminishes	Infrastructure			x		(Finland)			
27		x	Water passing pavements	Infrastructure			x		Netherlands			
4	113, 114		Raising flood banks, seawalls, and walls (with glass overtopping)	Infrastructure			x		(Finland), Vlissingen, Dronten	1	1	1
5			Construction of reserve water intake plants	Infrastructure			x	x	(Finland)	1	0	1
6		x	Interconnection of the networks of water supply plants	Infrastructure			x		(Finland)			
7	52, 6, 38, 91, 158, 21		Sewerage system changes/water supply (expansion; prevent back-up of sewerage water by using one-way valves; prevent leakage; interconnection of networks of water supply plants; seperated sewerage-drinking-rainwater water pipelines	Infrastructure			x		(Finland)	1	0	1
9		x	Construction of irrigation systems	Infrastructure			x		(Finland)			
11	12		Maintenance of the structures (railwat beds, road body, ditches, bridges and culverts) and condition of road network and railways, particularly on smaller roads and gravel roads as floods and rains increase and ground frost diminishes	Infrastructure			x	x	(Finland)	1	1	1
17	22, 93, 110, 111, 124, 138		Contructing permanent flood protection infrastructure (floodwalls, embankments, dykes, dams, barriers)	Infrastructure			x		(Scotland), Noordwijk, Afsluitdijk, Rotterdam, London	1	1	1
18	89, 119, 165		Repair, strenghten and maintain existing flood protection infrastructure (storm sewers, seawalls, dykes, channels, reservoirs, drainage systems)	Infrastructure			x		Blarney and Tower	1	1	1
19	20		Use of detached (submerged) breakwaters to create sand bars and recover eroded beaches for recreational use as well as protect coast.	Infrastructure			x		Liseleje-Hyllingebjerg, Paralia Katerinis	1	1	1
25	27, 94		Penetrable concrete, roads, pavement and avoid/remove impervious surfaces wherever possible	Infrastructure	x		x		Netherlands	1	1	0
26			Less paving of private properties	Infrastructure	x				Netherlands		0	0
38		x	Seperated sewerage / drinking water pipelines	Infrastructure		x	x	x	Netherlands			
39			Shallow canals, isolating wells/springs	Infrastructure		x	x		Netherlands	1	0	1
53	112		Using removable flood barriers and other removable flood protection products like floating sector gates	Infrastructure			x		London, Vlissingen	1	1	1
70			A floating road	Infrastructure			x		Netherlands	1	1	0
78			Moving powerplants to coast	Infrastructure	x		x	x	Netherlands	0	1	0

Option nr	Cluster	Double	Description of adaptation option	Sector	Heat stress	Drought	Flooding	Storm water runoff	Cities	In practice	No large negative impacts on social goals	Proven or expected effectiveness of the option
80			Enhancing capacity of sluices and weirs	Infrastructure			x		Netherlands	1	1	1
91		x	Separate treatment of rain water, disconnect from sewage, improved drainage into the ground	Infrastructure			x					
120			Climate proof vulnerable infrastructure in hazard areas	Infrastructure			x	x		1	0	0
158		x	Sewage backflow preventer	Infrastructure		x						
166			Adaptation of high ways, secondary dikes to create compartments	Infrastructure			x			1	1	0
170			Using warmth- and cold storage (WKO)	Infrastructure; Buildings	x					1	1	1
178		x	Straten ophogen als evacuatieroutes	Infrastructure			x	x				
74		x	promote ventilation paths alongside large freeways or in between the city districts	Infrastructure	x				Lisbon			
89		x	Maintenance / upgrade of drainage system	Infrastructure			x					
94		x	Avoid / remove impervious surfaces wherever possible	Infrastructure			x					
105		x	Wetting of streets ("Uchimizu") and roofs	Infrastructure; Buildings;	x							
167			Widening the coastal defence area	Infrastructure; Public area			x			1	1	1
23			Using geomorphology and soil when arranging	Public area					Netherlands	1	1	0
24			Soil structure improvement - e.g. more black soil in gardens	Public area					Netherlands	1	1	0
28	29, 30, 31, 32, 34, 63, 72, 75, 86, 95, 100, 102, 127, 139		Maximizing green area in cities (fields, parks, gardens, water bodies, street trees, traffic shoulders, nature on undeveloped terrains)	Public area	x		x	x	Netherlands, Rotterdam, Londod, Lisbon, Manchester	1	1	1
35	36, 37, 59		Urban farming and gardening (new crops/salty crops/using drought tolerant vegetation)	Public area	x	x	x		Netherlands	1	1	1
36		x	New crops for allotment and vegetable gardens	Public area		x	x	x	Netherlands			
37		x	Salty crops	Public area		x			Netherlands			
58		x	gardens are fitted with water-efficient irrigation systems	Public area		x			London			
59	101	x	Use of drought-tolerant plants/trees and planting medium that reduces the need for watering.	Public area	x	x			London			
64	103		Spraying and providing water by repairing historic drinking fountains and installing new fountains in the city	Public area	x				London	1	0	1
76	99, 116, 144, 168, 171		Water retention in nature and farmlands (by storing water on farmlands, in ponds, lakes, wetlands, waterbodies)	Public area		x	x		Netherlands	1	0	1
77	79, 134, 96		Restoration of natural ecosystems directly depending on water quantity and quality (reconnecting water systems in delta areas; retrofitting ponds/canals; restore rivers and wetlands)	Public area			x		Netherlands	1	1	1
1	3, 190		Integrated water resource planing / Planning of (storm)water services, trenching	Soft measure			x	x	(Finland)	1	0	0
2	8, 121, 164, 180		Land use planning to reduce flood risks, avoid construction in flood areas > new buildings/infrastructure in low hazard areas	Soft measure			x		(Finland)	1	1	1
3		x	Planning of trenching and stormwater services	Soft measure			x		(Finland)			
10			Joining the network of a water services company / choosing the location for a well and maintaining its condition	Soft measure			x	x	(Finland)	0	1	0
14			Preparedness planning must pay attention to backup systems for the distribution and production of electricity	Soft measure	x	x	x	x	(Finland)	1	1	0
15		x	Insurance operations: Development of technology to reduce risks	Soft measure	x	x	x	x	(Finland)			
16	122, 123, 129, 188		Tidal and/or Flood forecasting system, early warning system, combined with a targeted public awareness and education campaign and individual property protection / flood proofing	Soft measure			x		Multiple cities in Scotland	1	1	1
21		x	Prevent water leakage from pipelines	Soft measure		x			Malta			
49		x	assigning responsibility for coordination and liaison on flood risk management to a named officer	Soft measure			x		London			
57		x	water consumption be limited to 125 litres per person per day using the 'Water Efficiency Calculator for New Dwellings'	Soft measure		x			London			
69	187, 200		Heat Health Warning Systems predict the risk of dangerous heatwaves using meteorological information.	Soft measure	x				London		1	1
82		x	Emergency systems revision for tunnels and subways	Soft measure			x		Netherlands			
122		x	Coastal Flood Prediction and Mapping	Soft measure			x	x				
123		x	Early warning system for disaster events	Soft measure			x					
125	198, 199		Flood proofing new buildings/infrastructure; improve building codes	Soft measure			x			1	1	1
129		x	Improve forecasting and warning	Soft measure			x		London			
160	82, 163, 181, 192, 195, 49, 178		Emergency management plans (improvements and revisions tunnels/subways; evacuation plans; public coningency plans; increased training in fire management; mapping flood evacuation zones, name an officer for flood risk management, raising streetlevels for evacuation routes)	Soft measure; infrastructure	x	x	x		Netherlands, London,	1	1	1
161			Integrated nature and water management	Soft measure			x			1	1	1
162			Integrated coastal zone management	Soft measure			x			1	1	1
163		x	Evacuation plans	Soft measure			x					
181		x	Public contingency plans	Soft measure			x		London			
182	15		Insurances (flood insurance; insurance operations should develop technologies to reduce risks)	Soft measure			x		London	0	1	0
183		x	Changing consumer behavior	Soft measure		x			London			
184		x	Improved water efficiency standards	Soft measure		x			London			
185			Development of a comprehensive water strategy	Soft measure		x			London	1	1	0
186	191, 194		Increasing awareness of heat-related stress, threats and its management	Soft measure	x				London	0	1	0
187		x	Heat-health alert system and updated response plan	Soft measure	x				London			
188		x	Improve flood warning	Soft measure			x					
189	184; 57; 183		Rules and regulations for water use restrictions	Soft measure		x				0	1	1
190		x	Integrated water resource planning	Soft measure		x						
192		x	Increased training in ecological fire management	Soft measure		x						
193			Air quality management system	Soft measure	x					0	1	0
195		x	Maps of flood evacuation zones	Soft measure			x		New York			
196			Task force to protect vital/critical infrastructures	Soft measure			x		New York	0	1	0
197			Community specific planning — working with vulnerable neighbourhoods	Soft measure			x	x	New York	1	1	0
198		x	Flood proofing of infrastructures	Soft measure			x		Rotterdam			
199		x	Flood proofing of new buildings	Soft measure			x					
201			Basement Flooding Protection Subsidy Program	Soft measure			x	x	Toronto	1	1	0
180		x	Restricted development in high flood risk areas	Soft measure			x		London			
191		x	Awareness campaigns	Soft measure		x						
194		x	Public education on climate related health threats	Soft measure	x							
200		x	Update the heat response plan	Soft measure	x				Chicago			
20		x	Design and implementation of detached submerged breakwaters and beach nourishment for the protection of a Greek coast	Water			x					

Option nr	Cluster	Double	Description of adaptation option	Sector	Heat stress	Drought	Flooding	Storm water runoff	Cities	In practice	No large negative impacts on social goals	Proven or expected effectiveness of the option
60		x	Implement rainwater harvesting systems	Water		x			London			
61		x	Greywater recycling	Water		x			London			
81		x	Reduce waste water discharge during drought periods	Water		x			Netherlands			
103		x	Spraying of water (fountains)	Water	x							
173		x	Baggeren van rivierbed	Water								
79		x	Reconnecting water systems in Delta area	Water			x		Netherlands			
98			Desalination	Water		x				1	1	0
99	116, 144	x	Rain water storage in wetlands, water bodies, lakes and ponds	Water		x						
134		x	Retrofitting ponds and canals	Water			x	x	Rotterdam			
157		x	Reclaimed water use	Water		x						
168		x	Fresh water storage to flush brackish water out during dry periods	Water		x	x					
171		x	Luchtzakken/Airbag Water Storage (in een watergang)	Water	x							
172	173		Verdiepingen, baggeren in rivier of ander open water	Water						1	0	0
96		x	Re-naturalisation of rivers and wetlands	Water; Public area			x					
97	60, 61, 81, 58, 9, 157		Water saving measures (water-efficient irrigation in gardens, grey water recycling, ground water recharge, rain water harvesting, supply from more remote areas, reduce waste water discharge, reclaimed water use)	Water; Public area		x				1	1	1
118	136		Open water in urban environment	Water; Public area	x	x	x	x	Noordwaard, the Netherlands, Rotterdam	1	0	1
8		x	Construction of properties farther away from flood areas				x		(Finland)			
22		x	Building a dyke as a protective sea defence and disguising it as a dune so it forms a continuation with the dune system either side. The new dyke-in-dune, as well as offering defence also acts as an ecological corridor				x		Noordwijk			
29		x	Greener shoulders en traffic sides - option 20		x		x	x	Netherlands			
30		x	Street trees - option 22		x		x	x	Netherlands			
31		x	Temporary nature on undeveloped terrains - option 27		x		x	x	Netherlands			
32		x	Vegetation in neighbourhoods - option 28		x		x	x	Netherlands			
34		x	More green areas - option 31		x		x	x	Netherlands			
41		x	Screens above roads - option 81		x				Netherlands			
42		x	natural ventilation in buidlings - option 88		x				Netherlands			
47		x	Extending roofs provide shading to buildings - option 97		x				Netherlands			
63		x	More green areas in the city		x				London			
65		x	Shading windows by installing shutters or blinds reduces solar gain and so internal heat build-up is reduced		x				London			
67		x	'Cool pavements' are comprised of light coloured material with high solar reflectivity and good water permeability: reducing high urban temperatures and encourage water storage and thus allow evaporative cooling		x				London			
68		x	Extending roofs provide shading to buildings		x				London			
72		x	maximize the vegetated surfaces, including roof gardens		x				Lisbon			
73		x	when renovating buildings, opt for light colours and materials with low thermal admittance		x				Lisbon			
75		x	create large green areas next to each newly-built urbanised neighbourhood quarter		x				Lisbon			
83		x	Building insulation to keep the inside cool and Shadow blends at buildings		x				Manchester			
85		x	Shadowing urban space and Ventilation of urban space by intelligent urban design		x				Manchester			
86		x	Boosting green infrastructure, like green urban areas, open water, trees, green walls and roofs		x				Manchester			
88		x	Make new buildings and infrastructure flooding proof by appropriate design and material				x					
93		x	Dams; flood defences				x					
95		x	Maintain and further boost green infrastructure in cities, in particular parks and gardens, wetlands, water bodies but also green roofs				x					
100		x	Maintain and manage green areas outside and inside the cities to ensure water storage instead of high run-offs			x						
101		x	Use vegetation which is adapted to water scarcity			x						
102		x	Greening of cities: public areas (forests, gardens, parks); trees; green roofs		x	x	x					
104		x	Raise albedo of buidlings (roofs/walls)		x							
110		x	Closed fixed barrier				x		Aflsuitdijk, the netherlands			
111		x	Storm Surge Barrier				x		Eastern Scheldt, The Netherlands			
112		x	Floating Sector Gates				x		Rotterdam			
113		x	Raise seawall				x		Vlissingen, Netherlands			
114		x	Glass overtopping walls for defence against floodings				x		Dronten, Netherlands			
116		x	Fresh water retention in lakes			x		x	Ijsselmeer, Netherlands			
119		x	Repair and strenghten existing climate defenses (storm sewers, sea walls, dikes, channels, reservoirs)				x	x				
121		x	New infrastructure in low hazard area				x	x				
124		x	New flood protection infrastructure				x					
126		x	Material use for infrastructure/buildings (reflective materials, green roofs, white roofs, etc.)		x			x				
127		x	Green infrastructure		x	x		x	Greater Manchester Area			
128		x	Building design (shading, efficient cooling, green roofs, natural ventilation, heat-wave plans)		x	x			London			
130		x	Flood proofing buildings				x		London			
131		x	retrofitting buildings				x	x	Rotterdam, London			
133		x	Floating houses				x	x	Rotterdam			
135		x	Green roofs				x	x	Rotterdam			
136		x	Water Plaza's (playground + water storage)				x	x	Rotterdam			
137		x	Parking garage as water storage				x	x	Rotterdam			
138		x	New barriers				x		London			
139		x	Urban green cover					x	London			
140		x	High performance glazing (buildings)		x							
141		x	Interior and exterior shading devices in buildings		x							
142		x	High albedo roofing									
144		x	Retention ponds		x			x				
145		x	High albedo paving		x							
146		x	Covered or shaded parking		x			x				
148		x	Cross ventilation		x							
149		x	Thermal Zoning		x							
151		x	Passive solar design		x							
159		x	Water catchment systems / cistern			x						

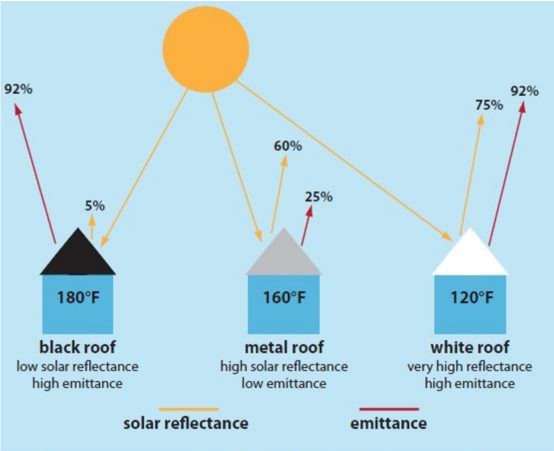
Option nr	Cluster	Double	Description of adaptation option	Sector	Heat stress	Drought	Flooding	Storm water runoff	Cities	In practice	No large negative impacts on social goals	Proven or expected effectiviness of the option
164		x	Design spatial planning - construct new housing and infrastructure				x					
165		x	Re-enforcement of dikes and dams, including weak spots				x					
177		x	Drijvende of Amfibische woningen									
44			Terraces at catering industry		x	x			Netherlands	1	1	0
56			Raising damp-proof courses				x		London	1	1	0
106			Adaptive mounts				x		Zierikzee	1	1	0
132			Multifunctional urban flood protection				x	x	Rotterdam	1	1	1
152			Increased thermal mass		x					1	1	1
154			Earth Cooling/sheltering		x					1	1	0
155			Greywater system rough out			x				1	1	1
156			HVAC condensate capture			x				0	1	0

Option nr	Cluster	Double	Description of adaptation option	Sector	Heat stress	Drought	Flooding	Storm water runoff	Cities	In practice	No large negative impacts on social goals	Proven or expected effectiviness of the option
13	42, 84, 143, 148, 149, 169		Passive cooling of buildings. Considering natural ventilation and the increase in wind velocity when redesigning existing building stock and new constructions. Construct buildings differently in such a way that there is less need for air-conditioning/heating. Thermal zoning. Orientation of buildings.	Buildings	x				(Finland), Netherlands, Manchester, London	1	1	1
45			Architecture, focus on sun and wind	Buildings	x	x			Netherlands	1	1	1
46	33, 43, 48, 83, 150,176		Inside buildings: isolating, (bed)rooms on north sides of buildings, ceiling fans, double walls (compartements), greening of rooms, evaporative cooling towers, filters in ventilation systems.	Buildings	x				Netherlands	1	1	1
51	72, 86, 92, 95, 102, 128,135		Buildings with green roofs, roof gardens and green walls	Buildings	x		x	x	London	1	1	1
54	88, 107, 130, 131		Using flood proof and resilient materials when constructing new building or retrofitting buildings	Buildings			x		London, Rotterdam, Manchester	1	1	1
62			Implement mechanism in buildings to reduce water use (and increase water use efficiency)	Buildings		x			London	1	1	0
92	147, 174, 175		Innovative design of buildings and places like elevated entrances, building on piles, floating houses, temporarily water storage, green roofs	Buildings			x			1	1	0
108	92, 133, 177		Floating Houses	Buildings			x			1	0	1
117	137, 90, 159, 105		Water retention in cities (parking garage; basins/fascines/cisterns; on squares/streets;	Buildings		x		x	Rotterdam	1	0	1
179			Eigen noodvoorziening (noodstroom, drinkwater)	Buildings	x					1	1	1
50			Implement Sustainable Drainage Systems. An alternative to traditional approaches to managing runoff from buildings and hardstanding.	Buildings; Infrastructure			x	x	London	1	0	
55			Locating electrical services and boilers above likely maximum flood level	Buildings; Infrastructure			x		London	1	1	
66	67, 73, 104, 126, 140, 142, 145, 151		Raise albedo of buildings (roofs, walls, glazing) and pavement by using light coloured materials with high solar reflectivity and low thermal admittance.	Buildings; Infrastructure	x				London	1	1	1
71			make sure that the H/W ratio (i.e. the ratio between the height (H) of the buildings and the width (W) of the streets) is kept under 1	Buildings; Infrastructure	x				Lisbon	1	1	
87	74		Ensuring that fresh air from green areas outside the city can flow in and promote ventilation paths alongside large freeways or in between the city districts	Buildings; Infrastructure	x				Manchester, Lisbon	1	1	1
115			Houses as structural part of levee system	Buildings; Infrastructure			x		Dordrecht, Netherlands	1	1	
109			Flood proof urban development	Buildings; Infrastructure; Water			x		Hamburg	1	1	1
40	41, 47, 65, 68, 85, 128, 141, 146		Shadowing buildings, roads and parkingplaces by putting up shutters, blinds, screens and extending rooftops	Buildings; Public area	x				Netherlands	1	1	1
153		x	Evaporative cooling towers	Buildings; Public area	x						1	
4	113, 114		Raising flood banks, seawalls, and walls (with glass overtopping)	Infrastructure			x		(Finland), Vlissingen, Dronten	1	1	1
5			Construction of reserve water intake plants	Infrastructure			x	x	(Finland)	1	0	1
7	52, 6, 38, 91, 158, 21		Sewerage system changes/water supply (expansion; prevent back-up of sewerage water by using one-way valves; prevent leakage; interconnection of networks of water supply plants; seperated sewerage-drinking-rainwater water pipelines	Infrastructure			x		(Finland)	1	0	1
11	12		Maintenance of the structures (railwat beds, road body, ditches, bridges and culverts) and condition of road network and railways, particularly on smaller roads and gravel roads as floods and rains increase and ground frost diminishes	Infrastructure			x	x	(Finland)	1	1	1
17	22, 93, 110, 111, 124, 138		Contructing permanent flood protection infrastructure (floodwalls, embankments, dykes, dams, barriers)	Infrastructure			x		(Scotland), Noordwijk, Afsluitdijk, Rotterdam, London	1	1	1
18	89, 119, 165		Repair, strenghten and maintain existing flood protection infrastructure (storm sewers, seawalls, dykes, channels, reservoirs, drainage systems)	Infrastructure			x		Blarney and Tower	1	1	1
19	20		Use of detached (submerged) breakwaters to create sand bars and recover eroded beaches for recreational use as well as protect coast.	Infrastructure			x		Liseleje-Hyllingebjerg, Paralia Katerinis	1	1	1
25	27, 94		Penetrable concrete, roads, pavement and avoid/remove impervious surfaces wherever possible	Infrastructure	x		x		Netherlands	1	1	0
26			Less paving of private properties	Infrastructure	x				Netherlands		0	0
39			Shallow canals, isolating wells/springs	Infrastructure		x	x		Netherlands	1	0	1
53	112		Using removable flood barriers and other removable flood protection products like floating sector gates	Infrastructure			x		London, Vlissingen	1	1	1
70			A floating road	Infrastructure			x		Netherlands	1	1	0
78			Moving powerplants to coast	Infrastructure	x		x	x	Netherlands	0	1	0
80			Enhancing capacity of sluices and weirs	Infrastructure			x		Netherlands	1	1	1
120			Climate proof vulnerable infrastructure in hazard areas	Infrastructure			x	x		1	0	0
166			Adaptation of high ways, secondary dikes to create compartments	Infrastructure			x			1	1	0
170			Using warmth- and cold storage (WKO)	Infrastructure; Buildings	x					1	1	1
167			Widening the coastal defence area	Infrastructure; Public area			x			1	1	1
23			Using geomorphology and soil when arranging	Public area					Netherlands	1	1	0
24			Soil structure improvement - e.g. more black soil in gardens	Public area					Netherlands	1	1	0
28	29, 30, 31, 32, 34, 63, 72, 75, 86, 95, 100, 102, 127, 139		Maximizing green area in cities (fields, parks, gardens, water bodies, street trees, traffic shoulders, nature on undeveloped terrains)	Public area	x		x	x	Netherlands, Rotterdam, Londod, Lisbon, Manchester	1	1	1
35	36, 37, 59		Urban farming and gardening (new crops/salty crops/using drought tolerant vegetation)	Public area	x	x	x		Netherlands	1	1	1
64	103		Spraying and providing water by repairing historic drinking fountains and installing new fountains in the city	Public area	x				London	1	0	1
76	99, 116, 144, 168, 171		Water retention in nature and farmlands (by storing water on farmlands, in ponds, lakes, wetlands, waterbodies)	Public area		x	x		Netherlands	1	0	1

Option nr	Cluster	Double	Description of adaptation option	Sector	Heat stress	Drought	Flooding	Storm water runoff	Cities	In practice	No large negative impacts on social goals	Proven or expected effectiviness of the option
77	79, 134, 96		Restoration of natural ecosystems directly depending on water quantity and quality (reconnecting water systems in delta areas; retrofitting ponds/canals; restore rivers and wetlands)	Public area			x		Netherlands	1	1	1
1	3, 190		Integrated water resource planing / Planning of (storm)water services, trenching	Soft measure			x	x	(Finland)	1	0	0
2	8, 121, 164, 180		Land use planning to reduce flood risks, avoid construction in flood areas > new buildings/infrastructure in low hazard areas	Soft measure			x		(Finland)	1	1	1
10			Joining the network of a water services company / choosing the location for a well and maintaining its condition	Soft measure			x	x	(Finland)	0	1	0
14			Preparedness planning must pay attention to backup systems for the distribution and production of electricity	Soft measure	x	x	x	x	(Finland)	1	1	0
16	122, 123, 129, 188		Tidal and/or Flood forecasting system, early warning system, combined with a targeted public awareness and education campaign and individual property protection / flood proofing	Soft measure			x		Multiple cities in Scotland	1	1	1
69	187, 200		Heat Health Warning Systems predict the risk of dangerous heatwaves using meteorological information.	Soft measure	x				London		1	1
125	198, 199		Flood proofing new buildings/infrastructure; improve building codes	Soft measure			x			1	1	1
160	82, 163, 181, 192, 195, 49, 178		Emergency management plans (improvements and revisions tunnels/subways; evacuation plans; public coningency plans; increased training in fire management; mapping flood evacuation zones, name an officer for flood risk management, raising streetlevels for evacuation routes)	Soft measure; infrastructure	x	x	x		Netherlands, London,	1	1	1
161			Integrated nature and water management	Soft measure			x			1	1	1
162			Integrated coastal zone management	Soft measure			x			1	1	1
182	15		Insurances (flood insurance; insurance operations should develop technologies to reduce risks)	Soft measure			x		London	0	1	0
185			Development of a comprehensive water strategy	Soft measure		x			London	1	1	0
186	191, 194		Increasing awareness of heat-related stress, threats and its management	Soft measure	x				London	0	1	0
189	184; 57; 183		Rules and regulations for water use restrictions	Soft measure		x				0	1	1
193			Air quality management system	Soft measure	x					0	1	0
196			Task force to protect vital/critical infrastructures	Soft measure			x		New York	0	1	0
197			Community specific planning — working with vulnerable neighbourhoods	Soft measure			x	x	New York	1	1	0
201			Basement Flooding Protection Subsidy Program	Soft measure			x	x	Toronto	1	1	0
98			Desalination	Water		x				1	1	0
172	173		Verdiepingen, baggeren in rivier of ander open water	Water						1	0	0
97	60, 61, 81, 58, 9, 157		Water saving measures (water-efficient irrigation in gardens, grey water recycling, ground water recharge, rain water harvesting, supply from more remote areas, reduce waste water discharge, reclaimed water use)	Water; Public area		x				1	1	1
118	136		Open water in urban environment	Water; Public area	x	x	x	x	Noordwaard, the Netherlands, Rotterdam	1	0	1
44			Terraces at catering industry		x	x			Netherlands	1	1	0
56			Raising damp-proof courses				x		London	1	1	0
106			Adaptive mounts				x		Zierikzee	1	1	0
132			Multifunctional urban flood protection				x	x	Rotterdam	1	1	1
152			Increased thermal mass		x					1	1	1
154			Earth Cooling/sheltering		x					1	1	0
155			Greywater system rough out			x				1	1	1
156			HVAC condensate capture			x				0	1	0

Annex IV Factsheet good adaptation option

Adaptation option: Raising albedo of buildings and pavement	
Cluster:	Buildings / Infrastructure
Climate Impact:	Heat
Spatial scale:	Building / Street



On a hot, sunny, summer day, a black roof that reflects 5 percent of the sun's energy and emits more than 90 percent of the heat it absorbs can reach 180°F (82°C). A metal roof will reflect the majority of the sun's energy while releasing about a fourth of the heat that it absorbs and can warm to 160°F (71°C). A cool roof will reflect and emit the majority of the sun's energy and reach a peak temperature of 120°F (49°C).

Source: Lisa Gartland - Reducing Urban Heat Islands: Compendium of Strategies

Example of a cool roof
Source: Ron Whipples – SWD Urethane

Description

To maximize solar reflection in cities, and consequently lowering the temperatures, the albedo of buildings and pavements can be raised. Albedo refers to a material's ability to reflect solar wavelengths.
For buildings different options to raise the albedo are recommended:

- High albedo roofing, also known as light-coloured or cool roofing, reduces solar gain through a roof assembly
  - Constructing roofs of new buildings with light coloured materials
  - Whitening of existing roofs
- Constructing walls with:
  - Light coloured materials
  - Materials that have low thermal admittance
- Using high performance glazing. Well-specified glazing reflects unwanted solar heat gain and permits adequate visible light for day lighting. Typical glazing systems consist of a frame material, a spacer material, panes of glass, inert gas between panes and a selective coating on one or more surfaces of the glass.
- Moreover, the albedo of pavements can be raised by 'Cool pavements'. Pavement comprised of light coloured material with high solar reflectivity and good water permeability.

Effectiveness

Heat	▪ A cool roof or 'white roof' can reduce the temperature of a building's roof dramatically, and hence also reduce the Urban Heat Island effect. ▪ A cool roof transfers less heat to the building below, so the building stays cooler and uses less energy for air conditioning ▪ Cool roofs can reduce air temperatures inside buildings with and without air conditioning, helping to prevent heat-related illnesses and deaths.

Other effects	▪ 'Cool pavements' are reducing high urban temperatures by increased solar reflection and evaporative cooling. ▪ By lowering energy use, cool roofs decrease the production of associated air pollution and greenhouse gas emissions ▪ With their increased permeability 'cool pavements' enlarge the water storage capacity and thus reduce storm water runoff

Financial aspects

- The cost premium for cool roofs versus conventional roofing materials ranges from zero to €0.40 or €0.75 per square meter for most products, or from €0.75–€1.50 for a built-up roof with a cool coating used in place of smooth asphalt or aluminium coating.
- Especially for countries with relatively high electricity prices cool roofs give net benefits, compared with more traditional and active cooling. A Californian based study showed that net benefits of cool (white) roofs are €4.20 per m2. This number includes the price premium for cool roofing products and increased heating costs in the winter as well as summertime energy savings, savings from downsizing cooling equipment, and reduced labour and material costs over time due to the longer life of cool roofs compared with conventional roofs.

Organization

- The landlord is in charge for whitening its roofs, walls an replacing the windows.
- Governments / local authorities are responsible for creating cool pavements.

Management and maintenance

A key concern for cool roofs is maintaining their high solar reflectance over time. If a building's roof tends to collect large amounts of dirt or particulate matter, washing the roof according to the manufacturer's recommended maintenance procedures can help retain solar reflectance. Also, smoother surfaces and higher sloped surfaces tend to withstand weathering better. With proper maintenance, coatings are able to retain most of their solar reflectance and cool roofs tend to have a lifetime of 20 years.

Considerations

Information sources

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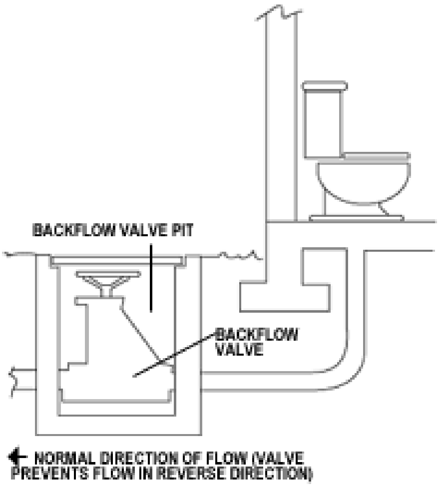
- Pacific Gas and Electric Company. 2006. Inclusion of Solar Reflectance and Thermal Emittance Prescriptive Requirements for Residential Roofs in Title 24. Sacramento, CA.
- United States Environmental Protection Agency –Reducing Urban Heat Islands: Compendium of Strategies, chapter on Cool Roofs. http://www.epa.gov/heatisld/resources/pdf/CoolRoofsCompendium.pdf

Case studies:

- Alcoforado, Andrade, Lopes, Vasconcelos. Application of climatic guidelines to urban planning: The example of Lisbon (Portugal). Landscape and Urban Planning 90 (2009) 56–65

Adaptation option: Construction and Design of Buildings	
Cluster:	Buildings
Climate Impact:	Flooding
Spatial scale:	Building

Flood resistance: building on piles
Source: San Francisco Bay: Preparing for the next level



Prevent sewer backflow with one-way valve
Source: www.gohsep.la.gov

Description

In flood prone areas, flooding can cause severe damage to building not prepared to deal with high water levels. In some flood prone areas, flooding can cause sewage from sanitary sewer lines to back up into buildings through drain pipes. A good way to protect buildings from sewage backups is to install one-way valves, which are designed to block drain pipes temporarily and prevent flow into the house. Beside these valves, there are several other methods that increase the flood resistance of buildings. Methods related to the construction and design of buildings:

- Construction of buildings
  - Buildings on piles / elevated first floors / elevated entrances
  - High buildings
  - Using flood proof materials
  - No crawlspace under buildings
- Design of buildings
  - Locate electrical services and boilers above flood level
  - Raising of damp-proof courses

Next to one-way valves this factsheet focuses on the adaptation option constructing high buildings.

Effectiveness

Flooding	▪ Pictured above is a gate valve (that is closed manually), which provides a stronger seal against flooding than simpler flap or check valves (closed automatically). Therefore the type of valve installed – and thus the effectiveness of the valve – depends on the risk of flooding in the area. ▪ High buildings face less flood damage because most floors will be above the flood level
Heat	▪ High buildings provide more shade and thus have a cooling effect on the air temperature ▪ When well positioned, high buildings can improve natural ventilation in cities and have a cooling effect on the air temperature
Other effects	▪ Sewer backflows not only cause damage that is difficult to repair but also create health hazards, installing one-way valves therefore has a positive effect on health

Financial aspects

- Having a plumber or contractor install one backflow valve will cost about €395 for a combined gate/flap valve or about €280 for a flap valve. These figures include the cost of excavation and back-filling.
- Construction of high buildings is cost efficient in densely populated regions with high land prices
- The recoup of investment for constructing high buildings and buildings on piles or buildings with elevated first floors can be >20 years because of the long life expectancy of buildings in cities

Organisation

- Installing one-way valves should be done by the landlord
- Planning the construction of high buildings in cities should be done by the local authorities

Management and maintenance

- One-way valves that operate automatically do not need management, valves that are manually operated logically need management when there is risk of flooding; Maintenance is not needed
- Once a high building is constructed there is no maintenance needed

Considerations

- One-way valves should only be used on the house drainage system. They should never be used on any sewer, as this could block flows from other properties.

Information sources

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- Raalten van D., Laan van der T., Wijsman P., Boeije L., Schellekens E., Dircke P., Pyke B., Moors E., Pelt van S., Elias E., Dijkman J., Travis W., McCrea B., LaClair J., Goldbeck S. *San Francisco Bay: Preparing for the Next Level*. Published by ARCADIS, Deltares, Alterra and BCDC, 2009.
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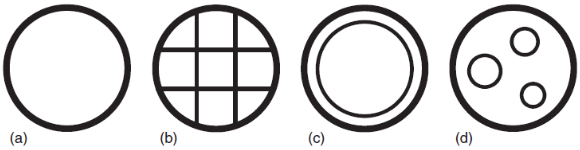
- Louisiana: Office of emergency preparedness. http://gohsep.la.gov/factsheets/floodssewerbackflowvalves.htm
- CIRIA – Flood resilience: improving the flood resistance of your home or business. http://www.ciria.org.uk/flooding/pdf/CIRIA_Advice_sheet_8.pdf

Adaptation option: Compartmentalization	
Cluster:	Infrastructure
Climate Impact:	Flooding (sea)
Spatial scale:	Regional

Example of compartmentalization in the Netherlands.
Source: Coördinatieplan Dijkring 14



Schematic representation of a plain dike ring area (a), a partitioned dike ring area (b), a secondary dike (c) and a dike ring with additional value protection (d).
Source: Flood damage reduction by compartmentalization of a dike ring.

Description

One of the options to reduce flood risk, other than strengthening the primary water defence structures, is to compartmentalize the to be protected region in zones, for example by dike ring areas. Compartmentalization either or both protects critical functions in the flood-prone area and reduces the flooded surface area. It diminishes the flood effects by dividing the area into compartments with the use of dikes. Four types of compartmentalization strategies are developed: a secondary dike to confine the flood to the coastal area, partition dikes to divide the region into smaller areas, value protection of towns and value protection of towns and villages. To reduce building of new dikes, existing line elements like highways, roads and tracks can be used as much as possible. Using existing line elements reduces the implementation costs and simplifies the fitting in the landscape.

Effectiveness

Flooding (sea):	Recently, several studies on the effectiveness of subdividing dike ring areas by means of compartmentalization dikes were published. These studies show that the total damage after a flood could indeed be smaller, but that the damage could also turn out to be larger on a local level (Theunissen et al., 2006). Alkema and Middelkoop (2005) argue that compartmentalization of a dike ring area can become effective in reducing flood risks only when compartmentalization dikes are strategically built or removed.

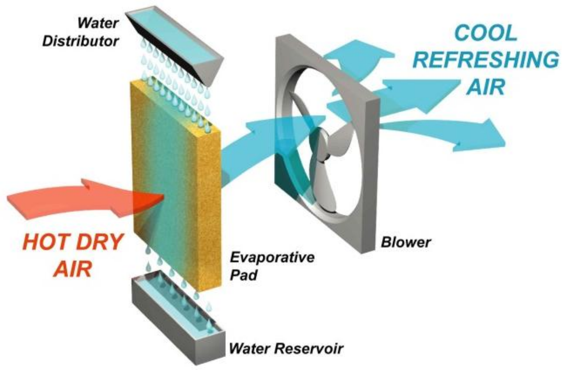
Financial aspects

Very cost intensive

Organization

Management and maintenance
Extra infrastructure to be management, maintained and monitored.
Considerations
Information sources
▪ *Coördinatieplan Dijkring 14*. Rijkswaterstaat, part of Dutch Ministry of Infrastructure and the Environment, published in 2010. ▪ Steinweg C.M., Lansink J., Van Reedt Dortland M.W.J., Hoekstra A.Y., Booij M.J., De Kok J.L. *Compartmentalization: reducing risk and overcoming uncertainties.* Geophysical Research Abstracts 10 (2008). ▪ Oost J., Hoekstra A.Y. *Flood damage reduction by compartmentalization of a dike ring: comparing the effectiveness of three strategies.* Journal of Flood Risk Management 2, pp. 315-321 (2009).

Adaptation option: Construction and Design of Buildings	
Cluster:	Buildings
Climate Impact:	Heat
Spatial scale:	Building



How Evaporative Cooling Works
Source: www.estexpert.com

Greening of Rooms
Source: www.newsinteriordesign.com

Description

To control indoor air temperature in response to the changing exterior climatic conditions different methods are available. Among others, these are for the construction and design of buildings:

- Construction of buildings:
  - Placing (bed)rooms on north side, on ground floor;
  - Thermal insulation (materials, double walls, high performance glazing, green roofs, coupling blue and green systems on buildings, eaves);
  - Stimulating passive cooling (increase of wind velocity, cross ventilation)
- Design of buildings
  - Air quality management system: evaporative cooling / thermal zoning
  - Placing of ceiling fans
  - Greening of rooms

This factsheet focusses on thermal insulation and the air quality management system.

Building insulation comes in many forms. In a narrow sense insulation can just refer to the insulation materials employed to slow unwanted heat loss or gain, such as: cellulose, glass wool, rock wool, etc., but it can also involve a range of designs and techniques to address the main modes of heat transfer (conduction, radiation and convection). In general, insulation reduces unwanted heat loss or gain and can decrease the energy demands of heating and cooling systems. In hot conditions, the greatest source of heat energy is solar radiation. This can enter buildings directly through windows or it can heat the building shell to a higher temperature than the ambient, increasing the heat transfer through the building envelope. Radiant barriers like double walls can be very effective in reducing radiant heat.

A more energy-efficient alternative for traditional air conditioners is the use of evaporative cooling, which cools the air through the evaporation of water. This technique works especially well in dry areas, where temperatures can drop significantly through the phase transition of liquid water to water vapour. This technique can for example be used in misting fans, that blow tiny water droplets in the air.

Effectiveness	
Heat	▪ Radiant barriers work in conjunction with an air space to reduce radiant heat transfer across the air space. Radiant or reflective insulation reflects heat instead of either absorbing it or letting it pass through. Radiant barriers are often seen used in reducing downward heat flow, because upward heat flow tends to be dominated by convection. This means that for attics, ceilings, and roofs, they are most effective in hot climates.[▪ Evaporative cooling can lower temperatures to about 15-24 °C, depending on the relative humidity and outside air temperature.
Other effects	▪ For regions with dry air the use of evaporative cooling comforts people by increasing the humidity. ▪ Because evaporative cooling uses water as a refrigerant, no special refrigerants that could be toxic or contribute to ozone depletion are needed

Financial aspects

- The costs of installing an evaporative cooler is about half the costs of a traditional air conditioner
- The costs of operating evaporative coolers is about a ¼ of the costs of a traditional air conditioner

Organization

- The landlord of the building is responsible for installing evaporative cooling

Management and maintenance

- There is no need for frequent maintenance.
- There are two mechanical parts (water pump and fan motor) that can be replaced relatively easy and at low-cost.

Considerations

- The insulation strategy of a building needs to be based on a careful consideration of the mode of energy transfer and the direction and intensity in which it moves. This may alter throughout the day and from season to season. It is important to choose an appropriate design, the correct combination of materials and building techniques to suit the particular situation. Regional climates make for different requirements. Building codes typically specify only the bare minimum; insulating beyond what code requires is often recommended.
- Constant ventilation inside a building significantly increases the amount of fresh air.
- The evaporative pad (see figure on top) used inside the cooler can also function as an air filter

Information sources

- Krigger, J. and Dorsi C. (2004). Residential Energy: Cost Savings and Comfort for Existing Buildings (4th ed.). Saturn Resource Management. p. 207.
- Marttila V., Granholm H., Laanikari J., Yrjölä T., Aalto A., Heikinheimo P., Honkatuki J., Järvinen H., Liski J., Merivirta R., Paunio M. (2005). Finland's National Strategy for Adaptation to Climate Change. Ministry of Agriculture and Forestry of Finland.
- *Maatregelenoverzicht Klimaatadaptatie*. Dutch Ministry of Infrastructure and Environment. Published in November 2011.
- Georgi B, Isoard S, Kurnik B, Swart R, Marinova N, Hove van B, Jacobs C , Klostermann J, Peltonen L, Kopperoinen L, Oinonen K, Havranek M, João Cruz M, Gregor M, Fons-Esteve J, Kazmierczak A, Keskitalo C, Juhola S, Krellenberg K, Bree van L. *Urban adaptation to climate change in Europe: Cities' challenges, opportunities, and supportive national and European policies.* European Environment Agency (2012)
- Larsen L., Rajkovich N., Leighton C., McCoy K., Calhoun K., Mallen E., Bush K., Enriquez J., Pyke C., McMahon S. and Kwok A. *Green Building and Climate Resilience: Understanding Impacts and Preparing for Changing Conditions.* University of Michigan; U.S. Green Building Council, 2011

Adaptation option: Crisis Management	
Cluster:	Governance
Climate Impact:	Drought / Flooding (rivers, sea, storm water runoff)
Spatial scale:	City

Training for crisis aid in flood situation.
Source: rescue3.nl

Description

In the future certain areas might face more drought spells or higher chances of flooding of rivers and seas or flooding caused by storm water runoff. The options presented here all fall within so-called crisis management. This means for example teaching people or organisations how they should react once a city is flooded or when a part of a city is on fire during a period with severe drought.

Adaptation options within crisis management include:

- Assigning the responsibility for coordination and liaison on flood risk management to a named officer;
- Increased training in crisis management and crisis aid;
- Community specific planning (working with vulnerable neighbourhoods);
- Establish a taskforce to protect vital infrastructure.

Effectiveness

The options presented here could be part of a cities' policy, in response to a crisis induced by a climate impact. It is difficult to quantify the effectiveness of these options.

Financial aspects

- Costs will be the training of people, salary for a new officer, etc.
- The return on investment will be returned in terms of saving people's lives during a crisis and reducing the impact on economic values.

Organisation

- Municipalities and local authorities are responsible for the organisation that enables their cities to manage a crisis.

Management and maintenance

- Periodically training of crisis situation and teaching of e.g. new management techniques is required

Considerations

-

Information sources

Case study:

- Marttila V., Granholm H., Laanikari J., Yrjölä T., Aalto A., Heikinheimo P., Honkatuki J., Järvinen H., Liski J., Merivirta R., Paunio M. (2005). *Finland's National Strategy for Adaptation to Climate Change*. Ministry of Agriculture and Forestry of Finland.
- *Rising to the Challenge – The City of London Climate Change Adaptation Strategy*. First Published May 2007. Revised and Updated January 2010.

Other literature:

- Georgi B, Isoard S, Kurnik B, Swart R, Marinova N, Hove van B, Jacobs C , Klostermann J, Peltonen L, Kopperoinen L, Oinonen K, Havranek M, João Cruz M, Gregor M, Fons-Esteve J, Kazmierczak A, Keskitalo C, Juhola S, Krellenberg K, Bree van L. *Urban adaptation to climate change in Europe: Cities' challenges, opportunities, and supportive national and European policies.* European Environment Agency (2012).

Adaptation option: Enhancing Capacity of Waters	
Cluster:	Water / Public Area
Climate Impact:	Flooding (storm water runoff, river)
Spatial scale:	Neighbourhood / City / Regional

Dredging of a river (shown here is the Hudson river in the USA) increases the water storage capacity.
Source: www.nicholas.duke.edu

Description

Enhancing the capacity of waters can be a relatively easy way to quickly reduce the risk of flooding of rivers and additional storm water runoff. These waters are already present and slight improvements or adjustments can lead to an increased water storage. Among others these options include:

- Enhancing capacity of sluices and weirs;
- Dredging of open waters;
- Reconnecting water systems;
- Construct shallow ditches;
- Enhancing storage capacity by flexible water level

Effectiveness

Flooding (river)	▪ All the given options above have a positive effect against flooding because they directly increase the water storage capacity of an area.
Flooding (storm water runoff)	▪ Mostly the construction of shallow ditches will have a positive effect on storm water runoff in cities. Via these ditches the water will be drained away quicker.

Financial aspects

- No information available.

Organisation

- Municipalities are responsible for constructing ditches and dredging local waters
- Local (and national) governments are responsible for enhancing the capacity of sluices and weirs and for reconnecting water systems

Management and maintenance

- Dredging of rivers should be done periodically to prevent them from becoming silted up
- Frequent management, maintenance and monitoring is needed for those options

Considerations

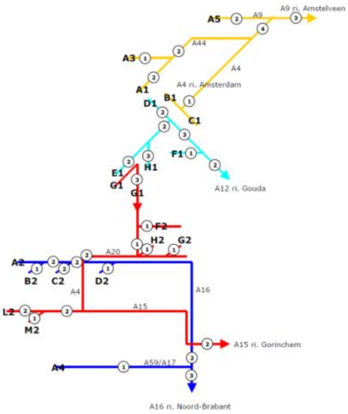
- These measures could be part of a local or regional (re)development

Information sources

- de Bruin K., Dellink R.B., Ruijs A., Bolwidt L. van Buuren A., Graveland J., de Groot R.S., Kuikman P.J., Reinhard S., Roetter R.P., Tassone V.C., Verhagen A., van Ierland E.C. *Adapting to climate change in the Netherlands: an inventory of climate adaptation options and ranking alternatives.* Climatic Change 95 (2009), pp. 23-45.
- *Maatregelenoverzicht Klimaatadaptatie*. Dutch Ministry of Infrastructure and the Environment. Published in November 2011.

Adaptation option: Evacuation and Contingency Management Plans	
Cluster:	Governance
Climate Impact:	Heat stress, Flooding (river, sea, storm water runoff)
Spatial scale:	City

Example of a regional protection area.
Source: Provincie Zuid-Holland, 2010



Example of flood evacuation plan: available lanes to estimate duration of evacuation.
Source: Provincie Zuid-Holland, 2010

Example of heatstress information.
Source: Hitteplan, RIVM
of flood evacuation plan: available lanes to estimate duration of evacuation.
Source: Provincie Zuid-Holland, 2010

Description	
Evacuation plans and public contingency plans help to reduce the negative effects of heat stress and flooding. Evacuation plans describe responsibilities, robust communication lines, solid infrastructure, vital city functions, evacuation routes and zones, vulnerable regions, traffic flows, exit routes by tunnels and bridges and concentrations of people as well as monitoring and forecasting procedures. Evacuation plans are valuable from a communication/awareness point of view: road signs with “evacuation route” provide a direct way to communicate that there is, for example, a flooding risk. Evacuation routes are predetermined paths which aim to safely and quickly move people from a certain area. These routes are designed in such a way that blockages can be avoided.	
Effectiveness	
Heat stress	▪ Heat response plans helps to prepare the public for heat stress during heat waves and give the necessary tools to deal with the heat during a heat wave. The plan reduces the risk on health problems due to heat waves.
Flooding (river, sea, storm water runoff)	▪ Evacuation and flood response plans helps to prepare the public for flood events and evacuation. The plan reduces the risk of victims and damage.
Financial aspects	
Appointing evacuation routes and updating response and contingency plans are relatively cheap. Visible measures like risk folders and evacuation plans raise more awareness among the public. An educated crowd responds better in times of a crisis, which saves money. Thus, the costs of raising awareness among the public by means of communication repays itself.	

Organization
▪ Governments / local authorities are responsible for evacuation plans, public contingency plans and heat response plans.
Management and maintenance
Changes in infrastructure and growth in a region will make current evacuation and contingency plans redundant. So a key concern for these kind of plans is to be updated regularly. Risks need to be reassessed and by using scenarios evacuation routes should be evaluated.
Considerations
Information sources
▪ Rising to the Challenge – The City of London Climate Change Adaptation Strategy. First Published May 2007. Revised and Updated January 2010. ▪ van Ierland E.C., de Bruin K., Delling R.B., Ruijs A. *A qualitative assessment of climate adaptation options and some estimates of adaptation costs.* Netherlands Policy Programme ARK, Routeplanner, 2007.Coordinatieplan Dijkring 14, Provincie Zuid-Holland, 2010 ▪ Hitteplan, RIVM, 2007

Adaptation option: Extend Water Supply Services	
Cluster:	Water
Climate Impact:	Heat
Spatial scale:	Region, City, Neighbourhood

Fountain "Jet d'Eau" in Geneva
Source: www.wikipedia.org

"Uchimizu"; a Japanese tradition of wetting the streets.
Source: www.japanfs.org

Description

Extending water supply services can help to reduce the negative effects of heat in several ways. This factsheet describes:

- Creating and/or repairing fountains for drinking and cooling;
- Cooling by water spray (fountains);
- Cooling by wetting streets.

Repairing historic drinking fountains and installing new ones creates more opportunities for people that who are experiencing the negative effects of heat in the city. They can use the water for drinking when feeling thirsty or they use the water to cool down.
Open water can decrease the air temperature by evaporation, absorption of heat and transport of heat. The cooling effect of flowing water is greater than that of water that is standing still. This has to do with better mixing of flowing water and air and also with the transport of heat. A water spray from a fountain has an even greater cooling effect because of the large contact surface of the water and air, which stimulates evaporation. When in contact with the skin, water spray can also have a cooling effect due to evaporation. Wetting of streets also has a cooling effect. Wetting is best done in the morning and afternoon in direct sunlight. This technique is commonly applied in Japan as part of tradition but also in some Mediterranean cities.

Effectiveness

Heat:	▪ When 1L/m² of water is applied, wetting of streets can decrease air temperatures by 2-4°C (Takahashi, Asakura *et al.*, 2010). ▪ Fountains can decrease surrounding air temperatures with 3°C and its cooling effect can be felt up to 35 meters away (Nishimura, Nomura *et al.*, 1998).
Other effects:	▪ Fountains also have social effects. Children play in fountains and people enjoy fountains in parks and squares; they serve as meeting places.

Financial aspects
Extending water supply services are low cost activities.
Organization
Local governments are responsible for extending water supply services like (drinking) fountains and wetting techniques.
Management and maintenance
Fountains require regular monitoring and maintenance for the water quality, filters and spray nozzles.
Considerations
Information sources
▪ Rising to the Challenge – The City of London Climate Change Adaptation Strategy. First Published May 2007. Revised and Updated January 2010. ▪ Kennismontage Hitte en Klimaat in de Stad. Climate Proof Cities Consortium, edited by Döpp, S., 2011. ▪ Nishimura, N., T. Nomura, et al. (1998). "Novel water facilities for creation of comfortable urban micrometeorology." Solar Energy 64(4): 197-207. ▪ Takahashi, R., A. Asakura, et al. (2010). Using snow melting pipes to verify the water sprinkling's effect over a wide area. Sustainable techniques and strategies in urban water management, 7th International Conference. Lyon, France, Novatech.

Adaptation option: Floating and Amphibious Housing	
Cluster:	Buildings
Climate Impact:	Flooding (river)
Spatial scale:	Building, Neighbourhood

Example of a floating pavilion in Rotterdam (Netherlands). Source: RDM Campus	Example of floating houses (Netherlands). Source: ARCADIS

Description

Floating and amphibious houses are built with a water body and are designed to adapt to rising water levels. Floating houses are permanently in the water, while amphibious houses are situated above the water and are designed to float when the water levels rise. These type of houses are popular in highly populated areas where there is a high demand for houses near or in water.

Effectiveness

Flooding (river)	▪ Because floating or amphibious houses adapt to rising water levels they are very effective in dealing with floods.
Other effects	▪ Living on water also reduces the negative effects of heat stress. ▪ Living on or near water results in a higher esteem for people, it improves their quality of life

Financial aspects

In a typical development plan the ground price has a determining factor. For building floating and amphibious housing the price of the water surface area is less critical. Usually the price of the water surface area is much lower than the typical ground price. These houses do bring higher building costs because of the adaptation measures needed for dealing with rising water levels. The building costs depend on the number of houses, the location, the integration of the water and the used materials/techniques. The investment is normally returned in less than 10 years.

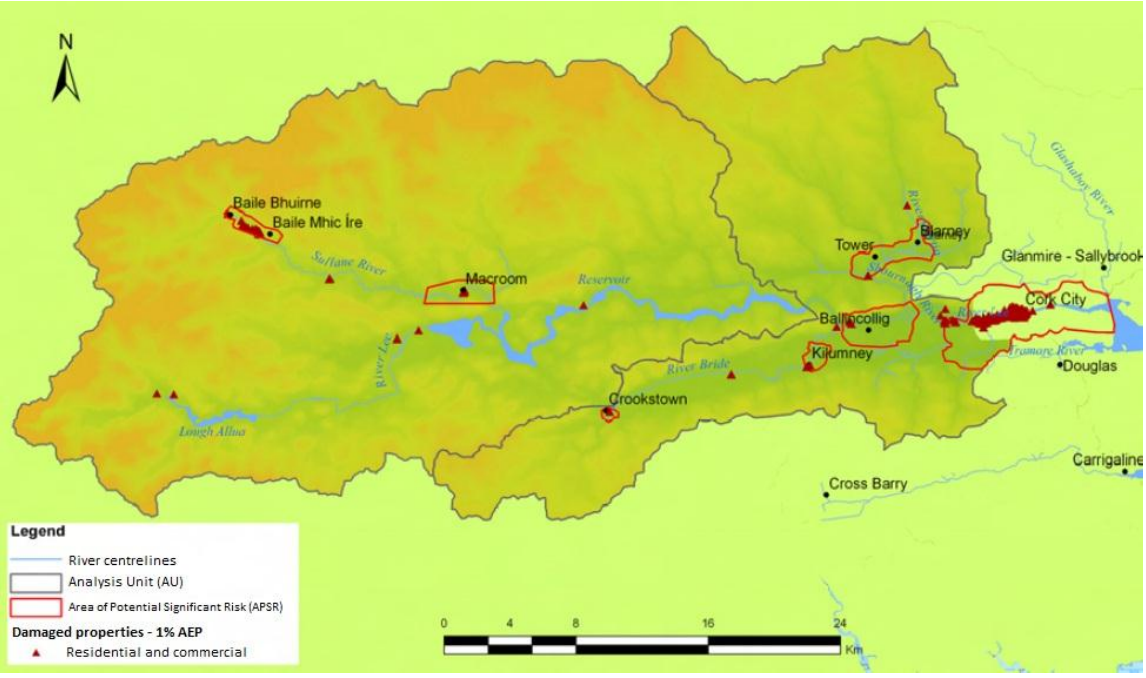
The flood resistant capacity of these houses have a positive effect on their value. If houses move with the swell they are less valued. The same is true for houses that are poorly accessible and are located further from the city and main transit line.

Organization

- Governments / local authorities are responsible for the realisation of these houses. At least, they have to assign in their policies and regulations the possibility, locations and conditions under which floating and amphibious housing is allowed
- This is an excellent option that can be realized in public-private initiatives (collaboration with architecture company)

Management and maintenance
These type of houses hardly need monitoring, the self-containing infrastructure of a floating neighbourhood does need periodic maintenance. The maintenance of buildings is the responsibility of the landlord.
Considerations
Information sources
▪ Dircke P., Aerts J., Molenaar A. Connecting Delta Cities, Sharing knowledge and working on adaptation to climate change. City of Rotterdam, 2010. ▪ Maatregelenoverzicht Klimaatadaptatie. Dutch Ministry of Infrastructure and the Environment. Published in November 2011. ▪ http://www.RDM Campus.nl

Adaptation option: Flood Forecasting and Warning Systems	
Cluster:	Governance
Climate Impact:	Flooding (sea / river / storm water runoff)
Spatial scale:	City / Regional



The picture shows the output of a flood risk warning system for the Lee Catchment area in Scotland. The red areas indicate an Area of Potential Significant Risk (APSR). Source: Draft Catchment Flood Risk Management Plan, 2010.

Description

For areas that face flood risks the following forecasting and warning systems can help reduce the impact of flooding:

- Tidal and/or flood forecasting systems;
- An early warning system for direct flood risks;
- Decision Support System in case of forecasted high water levels and flooding;Emergency systems for tunnels and subways.

The picture above shows an example of an output of a flood warning system in Scotland, where areas in red indicate the areas that face immediate flood risks. The information gained with these models can be used for land use planning, planning of evacuation routes, implementing adaptation options for flooding in these regions, etc.

Effectiveness

Flooding	▪ These are as well preventive measures against flooding, that will only be prove effective during or after flooding occurs. But also corrective measures in case of flooding and needed evacuation

Financial aspects

- The investment for warning systems will be returned once flooding occurs and lives are saved because adaptation options are implemented as a result of using the warning and forecasting systems

Organisation

- Local and national governments are responsible for the options listed here

Management and maintenance
▪ Annual monitoring of the functioning of the warning systems is recommended
Considerations
▪ In case of area development integrated implementing infrastructure (for instance cables) and sensor technology in order to realise an early warning system could be profitable
Information sources
Case studies ▪ *Draft Catchment Flood Risk Management Plan*. Lee Catchment Flood Risk Assessment and Management Study, Cork City Council, February 2010. Other literature ▪ Barth B, 2011. Planning for Climate Change: a Strategic, Values-Based Approach for Urban Planners. Version 1, published by UN HABITAT. ▪ Birkmann J., Garschagen M., Kraas F., Quang N. Adaptive urban governance: new challenges for the second generation of urban adaptation strategies to climate change. Sustainable Science 5 (2010), pp. 185-206. ▪ Hunt A. and Watkiss P. Climate change impacts and adaptation in cities: a review of the literature. Climatic Change 104 (2011), pp. 13-49.

Adaptation option: Flood Proof Infrastructure	
Cluster:	Infrastructure
Climate Impact:	Flooding (storm water runoff, sea and river)
Spatial scale:	Street / City

Floating road near Den Bosch, the Netherlands. Source: Dutch Ministry of Infrastructure and the Environment.

Elevated road used for evacuation routes when area is flooded, in Bangkok, Thailand. Source: AFP / Getty Images.

Description

Evacuation routes and infrastructure in cities that are prone to flooding need to be flood proofed. Available options to reduce the negative impacts of flooding are:

- Maintenance and condition of infrastructure;
- Using appropriate design and materials;
- Create floating roads;
- Create elevated roads for evacuation routes.

Floating roads are literally roads that float on the water. Ideally they are flexible in both time and space; they do not only float but can also move to accommodate a changing water level. Instead of a fixed bridge it consists of a series of floating pontoons on which vehicles can drive. On the other hands, elevated roads can look like a fixed bridge, but are longer and should form a labyrinth of streets leading to higher grounds. An elevated road can also be a road on top of a bank, thus elevated with sand. Elevated (or flood protected) roads are useful when a city is vulnerable for flooding, as in the picture above. When regular roads are turned into rivers, the citizens can still evacuate using the elevated (or flood protected) roads.

Effectiveness

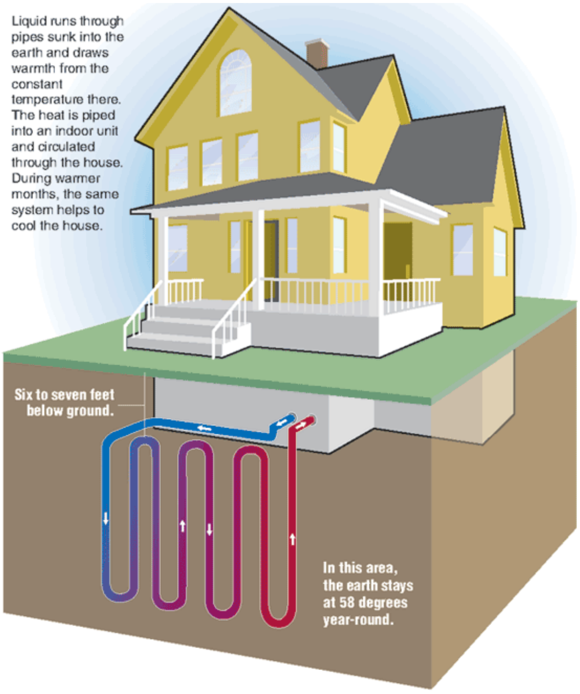
Flooding (storm water runoff)	▪ Elevated roads are effective against storm water runoff because they are normally situated higher than floodwaters reach
Flooding (sea, river)	▪ Because the banks of the floating road are reached via a ramp that can accommodate fluctuations in water level it is an effective adaptation option to flooding ▪ Elevated roads are effective against flooding because they are normally situated higher than the floodwaters reach

Financial aspects

- Floating roads are less expensive than bridges;
- Elevated roads on top of bank are cheaper to construct than bridge-like roads, but both investments will be returned once flooding occurred.

Organisation
▪ Local authorities and government are responsible for the realization and management of floating roads and elevated roads
Management and maintenance
▪ After construction, both floating and elevated roads do not need more maintenance than any other road.
Considerations
▪ Floating roads are more flexible than bridges and can also be useful as a bypass in the event of roadwork on a bridge or road along a canal
Information sources
▪ International Intervision Institute (website, 2012). http://www.iiinstitute.nl/sites/default/files/FloatingRoad_343.pdf ▪ Döpp S.P. and Albers R.A.W. *Klimaatverandering in Nederland: Uitdagingen voor een leefbare stad.* Netherlands Organisation for Applied Scientific Research (TNO), 2008. ▪ Georgi B, Isoard S, Kurnik B, Swart R, Marinova N, Hove van B, Jacobs C , Klostermann J, Peltonen L, Kopperoinen L, Oinonen K, Havranek M, João Cruz M, Gregor M, Fons-Esteve J, Kazmierczak A, Keskitalo C, Juhola S, Krellenberg K, Bree van L. *Urban adaptation to climate change in Europe: Cities' challenges, opportunities, and supportive national and European policies.* European Environment Agency (2012). ▪ *Maatregelenoverzicht Klimaatadaptatie*. Dutch Ministry of Infrastructure and Environment. Published in November 2011.

Adaptation option: Geothermal Heating and Cooling	
Cluster:	Buildings / Infrastructure
Climate Impact:	Heat
Spatial scale:	Building / Street



Geothermal heating and cooling. Source: www.hvac-trainingclass.com

Description

Geothermal heating and cooling is a method to store energy in soils at depths of 20-120 meters. During summers buildings can be cooled with pumping chilled groundwater up and then store the warmed water again in the soil. During winter this warmed water can be used to warm the house and the cooled down water is restored in the soil for the summer period. There are basically two types of geothermal heat pumps available: with a closed loop and an open loop. Closed heat pumps are for private use and small offices whereas open heat pumps are used for purposes with a large demand for cold and warmth.

Effectiveness

Heat	▪ Large effect on cooling of buildings in the summer
Other effects	▪ Geothermal heating is 100% renewable energy

Financial aspects

- Realisation costs are high: €260.000 more than installing a traditional heating system on building level
- Although they have relatively high realisation costs, geothermal heat pumps with an open loop have a recoup of investment after 5-8 years and pumps with a closed loop have a recoup of investment after 10-15 years

Organisation

- Installation of geothermal heat pumps is the responsibility of the landlord / manager of the building

Management and maintenance

- A geothermal heat pump requires periodical maintenance and monitoring to guarantee and check its functioning

Considerations

Information sources

- *Maatregelenoverzicht Klimaatadaptatie*. Dutch Ministry of Infrastructure and Environment. Published in November 2011.
- U.S. Department of Energy: National Renewable Energy Laboratory http://www.nrel.gov/docs/legosti/fy98/24782.pdf

Case studies:

- http://www.provincie.drenthe.nl/wko (Dutch website)

Adaptation option: Green roofs and walls	
Cluster:	Buildings
Climate Impacts:	Storm water runoff; Heat stress
Spatial scale:	Building

Source: Impression of city of Rotterdam
http://www.rotterdam.nl/eCache/TER/10/13/912.html

Source: City of Toronto, Canada
http://www.toronto.ca/greenroofs/what.htm

Description

Green roofs are roofs with vegetation and provide cooling in summer and thermal insulation in winter. There are three types of green roofs:

- Extensive green roofs: with robust and drought-tolerant vegetation
- Simple intensive green roofs: with a more diverse vegetation and more bushes
- Intensive green roofs: with trees and bushes and often in combination with terraces

Green walls are walls covered with vegetation. There are basically two types of green walls:

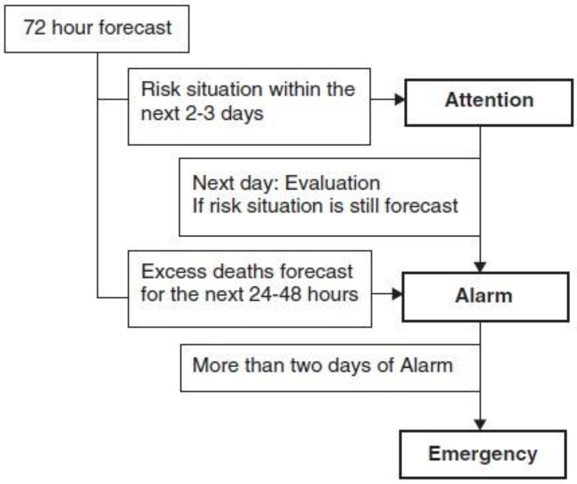
- Green facades: plants are growing directly on a wall (e.g. climbing plants) or are specially designed as a support structure (e.g. the shoot grows up the wall, but the plant is rooted in the ground)
- Living walls: the wall has modular panels that are often made of stainless steel containers, geotextiles, irrigation system, growing medium and vegetation

Effectiveness

Storm water runoff	▪ Water retention of 40-60% for extensive roofs ▪ Water retention of 60-90% for intensive roofs
Heat stress	▪ Reduction of temperature by 3-4°C inside buildings ▪ Enhancing evaporation in the urban areas
Other effects	▪ Reduced air pollution ▪ Reduced energy consumption and fuel costs ▪ Creating natural green spaces in urban areas ▪ Benefits for biodiversity

Financial aspects	
Realisation costs	▪ Starting from €45 per m^2 ▪ Realisation of green roofs is more expensive than the realisation of regular (bitumen) roofs
Return of investment time	▪ In the city green roofs yield between €2.45 – €7.93 per m^2 annually, as calculated by Klooster *et al.* (2008) ▪ On average the investment will be returned after 10 years ▪ Klooster *et al.* (2008) also concluded that green roofs are not beneficial for private parties
Organization	
The owner/landlord of the building is responsible for the realisation and management of the green roof and wall.	
Management and maintenance	
▪ No intense management required ▪ Periodical monitoring of green roofs is advised to check general condition of the vegetation, roof and wall	
Considerations	
▪ Green roofs protect the roof's waterproofing membrane, what results in almost a doubling of the roof's life expectancy	
Information sources	
▪ Rising to the Challenge - The City of London Climate Change Adaptation Strategy. First published May 2007, revised and updated January 2010. ▪ Maatregelenoverzicht Klimaatadaptatie. Dutch Ministry of Infrastructure and Environment. Published in November 2011. ▪ Klooster J., Moppes D. van, Bes E., Goedbloed D, (2008). Het rendement van groene daken in Rotterdam. H_2O p.23-25. ▪ www.livingroofs.org ▪ www.toronto.ca/greenroofs ▪ http://www.rotterdam.nl/eCache/TER/10/13/912.html ▪ http://www.bdcnetwork.com/6-things-you-need-know-about-green-walls	

Adaptation option: Heat Health Warning System	
Cluster:	Governance
Climate Impact:	Heat Stress
Spatial scale:	City / Regional



Example of a heat health warning system with three levels of alert (attention, alarm and emergency) used in the US. Since 2003 it is common to have warning systems with more than one level of response.
Source: Kovats & Kristie (2006)

Description

Heat waves can cause increased death rates, especially among older people. Heat health warning systems predict the risk of dangerous heat waves using meteorological information and can therefore warn these vulnerable people in advance.

Effectiveness

Heat stress: A heat health warning system is a preventive adaptation option

Financial aspects

- For heat health warning systems there are the initial costs, costs of maintaining the system and probably some costs per warning (direct and indirect).
- The return on investment for heat health warning systems will be once a heat wave is present and as a result of the warning system people's lives are saved.

Organisation

- Municipalities and local governments are in charge to implement this warning system

Management and maintenance

- Annual monitoring of the functioning of the warning system is required

Considerations

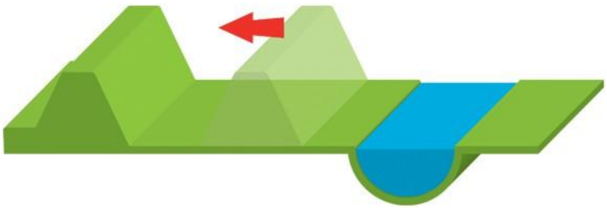
-

Information sources

- Birkmann J., Garschagen M., Kraas F., Quang N. Adaptive urban governance: new challenges for the second generation of urban adaptation strategies to climate change. Sustainable Science 5 (2010), pp. 185-206.
- Hunt A. and Watkiss P. Climate change impacts and adaptation in cities: a review of the literature. Climatic Change 104 (2011), pp. 13-49.
- Kovats, R.S. & Kristie, L.E. (2006). Heatwaves and public health in Europe. The European Journal of Public Health, 16, 592-599.
- Maatregelenoverzicht Klimaatadaptatie. Dutch Ministry of Infrastructure and the Environment. Published in November 2011.

Adaptation option: Innovative Flood Protection - River	
Cluster:	Water / Public Area
Climate Impact:	Flooding (river)
Spatial scale:	City / Regional

Bladder dam in the river IJssel in Kampen the Netherlands. Source: RTVOost.nl

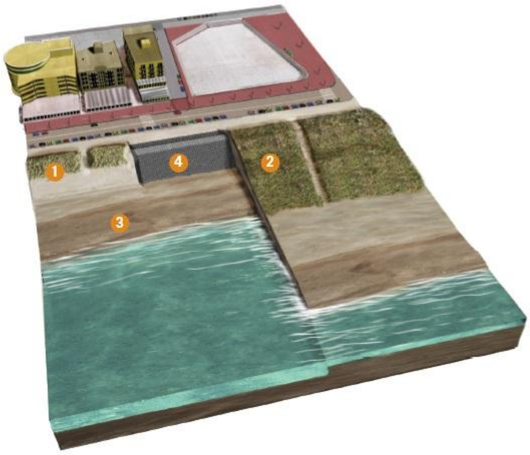


Relocating a dike land inwards, for instance at Cortenoever (Zutphen, the Netherlands). Source: Ruimtevoorderivier.nl

Description
Flooding of rivers is projected to occur more often in the future. Innovative options to adapt to this climate impact exist. One of these options is the relocation of a dike and creating high water channels parallel to the river. Other than these two, the options include the construction of innovative dams and options related to the riverbed or surrounding areas.: ▪ Bladder dam ▪ Eureka dam ▪ Lowering of floodplains ▪ Deepening summer bed ▪ Lowering groynes ▪ High water channel ▪ Depoldering ▪ Removing obstacles ▪ Providing reinforcement of a dyke partly by applying ecosystem services (for instance woods or swamps as integrated part of the protection zone) ▪ Smart levees; applying ICT in order to have real time information about the characteristics of the dyke and to reduce the need for physical measures When relocating a dike land inwards, the width of the floodplains increase and consequently provide more room for the river in case of flooding. Another option is the creation of one or more parallel channels that run parallel to the river and help to discharge excess water in case of a flood. Both options need to take into account existing infrastructure, buildings, roads and wetlands. These might need to be relocated or could be integrated in the new development.

Effectiveness	
Flooding (river)	▪ Relocating dikes land inwards and developing side channels creates more room for the river and thus effectively lowers the risk of flooding.
Other effects	▪ The creation of 'extra' floodplains and side channels prove to be an opportunity for the co-development of nature and recreational areas. It even can be an impulse for or combined with city development
Financial aspects	
▪ The return of investments for these kinds of options are returned in saving people's lives and economic values once they protect build enviroment from flooding.	
Organisation	
▪ These options should be organised by national governments and local governments, municipalities and water boards.	
Management and maintenance	
▪ Not much maintenance is required. The dykes should be monitored regularly. ▪ More technical options like a bladder dam require more monitoring and maintenance.	
Considerations	
▪ Bladder dams block all shipping traffic ▪ In case of needed flood protection also 'traditional' ways of flood protection should be considered (see fact sheet Reinforce Flood Protection)	
Information sources	
Case studies ▪ Relocation of dike to create extra water ways. (in Dutch) http://www.rws.nl/images/De%20kraan%20van%20Nederland_tcm174-293416.pdf Other sources ▪ http://www.floodcontrol2015.com/action-mitigation/outflow-regulation-during-high-water-levels ▪ http://www.wgs.nl/veilige-dijken/balgstuw-waterkering/ ▪ http://www.ruimtevoorderivier.nl/meta-navigatie/english/types-of-measures/	

Adaptation option: Innovative Flood Protection - Sea	
Cluster:	Water / Public Area
Climate Impact:	Flooding (sea)
Spatial scale:	City / Regional



Dike in the dunes. 1: The old dunes are too narrow. 2: Wider dunes provide protection. 3: The beach will remain as wide as before. 4: The dike, a powerful second buffer.
Source: Rijnland District Water Control Board, 2007.

Storm surge barrier with horizontal pivoting gates at Maeslantkering, Port of Rotterdam, the Netherlands.
Source: Raalten *et al.*, 2009.

Description

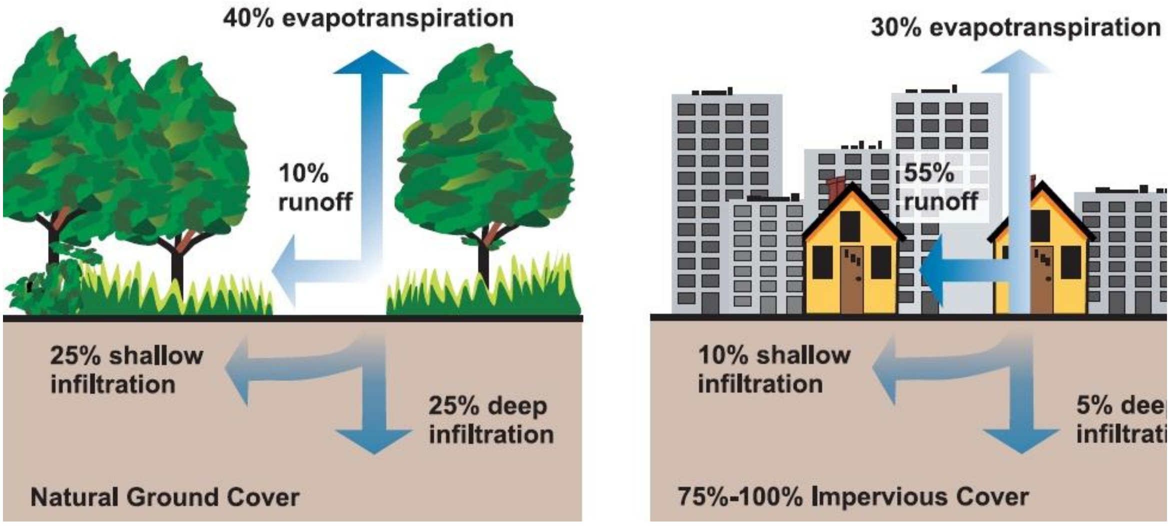
There are several methods to protect a build environment (cities, economical values) against flooding. Among these there are:

- Detached (submerged) breakwaters;
- Dike-in-dune system;
- More 'traditional' reinforcement measures combined with ecosystem services, serving as part of the protection system
- Integrated Coastal Zone Management (ICZM)
- Sand engine
- Barriers
  - Removable flood barriers;
  - Closed fixed barrier;
  - Storm surge barrier: horizontal pivoting gates.

This factsheets focuses on three options; dike in the dunes, horizontal pivoting gates as a storm surge barrier and the sand engine. The dike in the dune has a top layer of stone which keeps the sand underneath it in place. The storm surge barrier as pictured above is situated in the Port of Rotterdam. When water levels reach a certain height the gates will close and secure the city from flooding.
The Sand Engine is a man-made sand peninsula. By wind, waves and sea currents the sand will slowly spread along the coastline and will eventually be fully incorporated into new dunes and a broader beach. The first Sand Engine consists of 21.5 million cubic meters of sand and is made in the Netherlands. Dredging ships have obtained the sand 10 kilometres from the coast and used it to create a peninsula in the shape of a hook. Through this principle of "building with nature", the coast will grow in a natural way.

Effectiveness	
Flooding (sea)	▪ A dike in the dunes is an effective option against flooding. The widened dunes provide protection against heavy storms and the dike present within the dunes washes away less easily, functioning as a second buffer ▪ A storm surge barrier with horizontal pivoting gates provides, when closed, effective flood protection. ▪ A Sand Engine will eventually lead to a broader beach and new dunes and therefore will lower the risk of flooding.
Other effects	▪ The dike in the dunes offers more habitat for vegetation and animals and therefore has a positive effect on biodiversity ▪ The sand engine and dike in the dunes enlarge the beach area and therefore have a positive influence for human recreation
Financial aspects	
▪ Constructing the dike within the dunes in the Netherlands (with 1.15 km of beach to be reinforced) cost around €20 million. ▪ The costs of the construction of the storm surge barrier with floating sector gates were €450 million. ▪ The total costs to create the Sand Engine in the Netherlands were €70 million.	
Organisation	
▪ Local and national authorities and governments are responsible for constructing these kind of options	
Management and maintenance	
▪ After constructing of both the dike in the dune and the Sand Engine there is no maintenance needed. ▪ Periodical monitoring of the functioning of the horizontal pivoting gates (closing) is recommended ▪ An intelligent construction as the storm surge barriers requires high technical skilled maintenance people.	
Considerations	
▪ In case of needed flood protection also more traditional ways of protection could be considered (see factsheet Reinforce Flood Protection (sea)) ▪ Innovative ways of flood protection could be part of an integrated system approach (as Integrated Coastal Zone Management) and could be part of or the key factor for city and areal development	
Information sources	
Case studies ▪ Rijnland District Water Control Board, 2007. Coastal reinforcement Noordwijk: What is happening on the beach in Noordwijk? ▪ Pickaver and Skaarup. Detached breakwaters to create sandbars in a beach recovery programme in Hyllingebjerg-Liseleje (Denmark). EUROSIAN case study. ▪ Prinos, 2004. Soft techniques for coastal protection in Greece. Published in OURCOAST database. ▪ The Sand Engine - http://www.dezandmotor.nl/uploads/2012/02/factsheet-sand-engine-deltaduin-en.pdf Other sources ▪ Raalten van D., Laan van der T., Wijsman P., Boeije L., Schellekens E., Dircke P., Pyke B., Moors E., Pelt van S., Elias E., Dijkman J., Travis W., McCrea B., LaClair J., Goldbeck S. *San Francisco Bay: Preparing for the Next Level*. Published by ARCADIS, Deltares, Alterra, BCDC, 2009. ▪ http://www.deltawerken.com/Maeslant-barrier/330.html ▪ The Sand Engine - www.zandmotor.nl ▪ Steijn, R. et al., 2012. Integrated Coastal Zone Management: Our Coast. Published by the Directorate-General Environment ofb ythe European Commision	

Adaptation option: Land Use Planning to Reduce Flood Risks	
Cluster:	Public Area / Governance
Climate Impact:	Flooding
Spatial scale:	City / Regional



This pictures shows the difference in runoff and infiltration between urban and rural areas. In cities there is more runoff and less evapotranspiration and infiltration. Thus, when planning land uses the risks of flooding and storm water runoff should be considered. Source: U.S. Environmental Protection Agency, Washington, D.C.

Description

Some areas are more prone to flooding than others. Therefore, when planning new constructions in cities, there should, among others, be kept in mind that:

- Construction in flood areas should be avoided if possible;
- Urban development should be planned in low hazard areas;
- Development of buildings, housing, economical values etc. in flood risk areas should be restricted;
- Storm water services should be planned.

For existing flood prone areas, re-development should be considered, keeping the points above in mind.

Effectiveness

Flooding	▪ The effects of all the above listed options is to lower the risk of flooding and / or minimizing its impacts on cities
Other effects	▪ Planning of storm water services decreases the risk of flooding caused by storms

Financial aspects

- The financial aspects are unclear

Organisation

- Organising these options is most of time the responsibility of regional and local authorities and municipalities. The options should be discussed with the project developers.

Management and maintenance

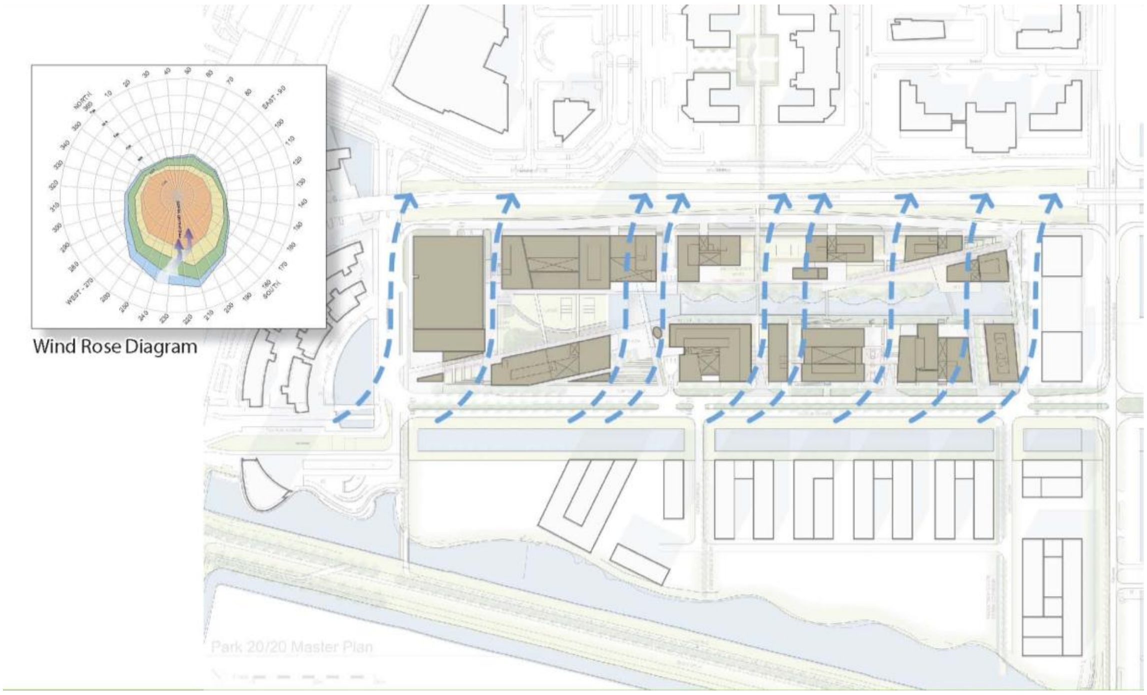
- No management is required

Considerations

Information sources

- Barth B, 2011. Planning for Climate Change: a Strategic, Values-Based Approach for Urban Planners. Version 1, published by UN HABITAT.
- de Bruin K., Dellink R.B., Ruijs A., Bolwidt L. van Buuren A., Graveland J., de Groot R.S., Kuikman P.J., Reinhard S., Roetter R.P., Tassone V.C., Verhagen A., van Ierland E.C. Adapting to climate change in the Netherlands: an inventory of climate adaptation options and ranking alternatives. Climatic Change 95 (2009), pp. 23-45.
- Marttila V., Granholm H., Laanikari J., Yrjölä T., Aalto A., Heikinheimo P., Honkatuki J., Järvinen H., Liski J., Merivirta R., Paunio M. (2005). Finland's National Strategy for Adaptation to Climate Change. Ministry of Agriculture and Forestry of Finland.
- U.S. Environmental Protection Agency, Washington, D.C. http://www.epa.gov/npdes/pubs/nps_urban-facts_final.pdf

Adaptation option: Orientation of buildings and open spaces	
Cluster:	Buildings / Public Area
Climate Impact:	Heat
Spatial scale:	Neighbourhood / City



Building orientation helps to capture prevailing breezes for site and building ventilation, a passive energy demand reduction strategy. Source: American Society of Landscape Architects (www.asla.org)

Description

Cities have higher temperatures than their surrounding areas (urban heat island effect). Lowering the temperatures can be realised by e.g. increasing the wind velocities inside the city. This can be done (when planning new buildings/neighbourhoods and redevelopment) by the orientation of the buildings, streets and open spaces and by keeping the H/W ratio <1 (i.e. ratio between height of a building and width of the street).To ensure that fresh cool air from green areas outside the city can flow in, one can:

- Plan the orientation of buildings and streets to increase ventilation in public areas;
- Keep H/W ratio <1 (i.e. ratio between height of a building and width of the street);
- Create ventilation paths alongside large freeways or in between city districts.

Effectiveness

Heat	▪ Creating a cooling breeze can easily lower the temperature up to 2-5°C. When the outside air temperature is colder, the cooling effect of wind is larger (wind chill factor).
Other effects	▪ Increased wind velocities in cities reduces the amount of air pollutants, thus having a positive effect on air quality and subsequently human health.

Financial aspects

- No extra costs

Organisation

- Responsible for the organisation are local governments, their city planners, private developers

Management and maintenance

- No management and maintenance required

Considerations
-
Information sources
▪ Georgi B, Isoard S, Kurnik B, Swart R, Marinova N, Hove van B, Jacobs C , Klostermann J, Peltonen L, Kopperoinen L, Oinonen K, Havranek M, João Cruz M, Gregor M, Fons-Esteve J, Kazmierczak A, Keskitalo C, Juhola S, Krellenberg K, Bree van L. *Urban adaptation to climate change in Europe: Cities' challenges, opportunities, and supportive national and European policies.* European Environment Agency (2012). **Case studies:** ▪ Alcoforado, Andrade, Lopes, Vasconcelos. Application of climatic guidelines to urban planning: The example of Lisbon (Portugal). Landscape and Urban Planning 90 (2009) 56–65.

Adaptation option: Public education and awareness campaigns	
Cluster:	All
Climate Impact:	All
Spatial scale:	Region, city

Example water-wise landscape watering (awareness). Source: wateruseitwisely.com

Warning for fire danger to raise public awareness. Source: gettyimages

Description

Public education and awareness campaigns are helpful components of flood, heat and drought action or warning plans. It proved to be of great importance to inform the population via mass media in case of crisis events. In Paris the City Council's Climate Plan encourages elderly and disabled citizens to be listed on a special extreme heat register. Through an emergency call number these vulnerable groups can acquire information on heat stress prevention measures and seek a home visit when necessary.

Awareness raising is usually one of the components of crisis action and warning plans. They usually comprise a menu of individual options to respond to and prepare for crisis events. Important aspects are communication lines, what is communicated to whom and when; advice for the public on how to deal with and prepare for crisis events; information for vulnerable population groups; preparedness of the health and social care system (staff training and planning, appropriate health care and the physical environment);

After the heat wave of 2003 several countries such as France, Hungary, Portugal, and UK established national heat response plans. In Spain this plan was established at the regional level, in the province of Catalonia, and also in several German federal states and the Netherlands such plans exist. The "Heat Alert" in Budapest is coupled with a Smog Alert System and an UV Alert System. It showed success in 2007, when excess mortality due to the extreme event had been lower in comparison to a similar period in 2003 (Paldy and Bobvos, 2010).

Effectiveness

All climate impacts:	Public education and awareness campaigns are important aspects when it comes to preparing the public for the negative effects of climate impacts like flood, heat and drought and dealing with a crisis situation.
Other effects:	

Financial aspects
Not applicable
Organization
Central government and local governments are the most important for managing public education and awareness campaigns and enhance the preparedness for emergency situations. During a crisis event, all relevant municipal stakeholders (e.g. municipal departments, meteorological services, hospitals and other medical institutions, schools, kinder-gardens, transport companies, mass media, local environmental protection organizations, companies) have their own "protocol of activities" and the mandate to carry out these actions.
Management and maintenance
Considerations
Information sources
▪ Urban adaptation to climate change in Europe. Cities' challenges, opportunities, and supportive national and European policies. Georgi et al. 2012 ▪ Rising to the challenge. The City of London Climate Change Adaptation Strategy. City of London, 2007. ▪ Shaw, R., Colley, M., and Connell, R. (2007). Climate change adaptation by design: a guide for sustainable communities. TCPA, London.

Adaptation option: Public Green-Blue Areas	
Cluster:	Public Area
Climate impact:	Flooding (storm water runoff), Heat
Spatial scale:	Neighbourhood / City

Public green area in a city.
Source: ARCADIS.

Victoria Park London.
Source: www.london-attractions.info

Description

Presence of vegetation, whether or not combined with open water, has a positive effect on different climate impacts, see below. This factsheet focuses on maximizing public green areas in cities. Green areas can include:

- Fields, parks and gardens ;
- Street trees and traffic shoulders;
- Nature on wastelands.

Effectiveness

Flooding (storm water runoff)	▪ Vegetation leads to increased water infiltration and therefore reduces the effects of storm water runoff. Green areas are capable of retaining more water than grey areas and, moreover, they slowly release the water afterwards.
Heat	▪ Vegetation and open water can lower the air temperature by 2-3°C;
Other effects	▪ Public green areas improve the air quality and subsequently have positive effects on human health. ▪ Public green areas in cities also have a positive effect on local biodiversity.

Financial aspects

- The realisation costs for green areas themselves are low, profits out of exploitation might be lower

Organisation

- Local governments are responsible for the implementation and management of green-blue areas

Management and maintenance
▪ Green-blue areas do not need much maintenance. Depending on the location and type of area periodic mowing, watering and planting of new vegetation may be required.
Considerations
▪ The adaptation options 'Green roofs and walls' and 'Urban farming and gardening' are comparable with this option.
Information sources
▪ Rising to the Challenge – The City of London Climate Change Adaptation Strategy. First Published May 2007. Revised and Updated January 2010. ▪ Larsen L., Rajkovich N., Leighton C., McCoy K., Calhoun K., Mallen E., Bush K., Enriquez J., Pyke C., McMahon S. and Kwok A. Green Building and Climate Resilience: Understanding Impacts and Preparing for Changing Conditions. University of Michigan; U.S. Green Building Council, 2011. ▪ Georgi B, Isoard S, Kurnik B, Swart R, Marinova N, Hove van B, Jacobs C , Klostermann J, Peltonen L, Kopperoinen L, Oinonen K, Havranek M, João Cruz M, Gregor M, Fons-Esteve J, Kazmierczak A, Keskitalo C, Juhola S, Krellenberg K, Bree van L. Urban adaptation to climate change in Europe: Cities' challenges, opportunities, and supportive national and European policies. European Environment Agency (2012). ▪ Maatregelenoverzicht Klimaatadaptatie. Dutch Ministry of Infrastructure and Environment. Published in November 2011. **Case studies:** ▪ Alcoforado, Andrade, Lopes, Vasconcelos. Application of climatic guidelines to urban planning: The example of Lisbon (Portugal). Landscape and Urban Planning 90 (2009) 56–65.

Adaptation option: Reduce Hardened Surface and Use of Water Passing Surfaces	
Cluster:	Infrastructure
Climate Impact:	Flooding (Storm water runoff)
Spatial scale:	Street, Building

Pervious road.
Source: www.rijkswaterstaat.nl

Water passing bricks used to create a parking lot.
Municipality of Presov, Slovakia

Description	
Reducing hardened, impervious surfaces in combination with the use of pervious roads, penetrable concrete and water passing pavements helps to enhance the infiltration of storm water runoff in underlying surfaces. It aims to reduce the negative impacts of storm water runoff, like flooded sewers and inaccessible roads. Another possible adaptation option to flooding is to construct tunnels with unhardened sides.	
Effectiveness	
Flooding (storm water runoff)	Reducing hardened and impervious surfaces greatly reduces the negative effects of storm water run-off. The same is true for water passing surfaces, which can transport up to 5.000 Litre of water per second per hectare.
Other effects	Reducing hardened surfaces and the use of water passing surfaces directly contributes to the repletion of groundwater. This helps to reduce the negative impacts of drought. Another side-effect in certain areas is the reduction of salination land subsidence. The water quality also improves when there is less overflow of sewers.
Financial aspects	
When compared to asphalt, the investment for water passing surfaces is about €130.000 per 2000 m2. Asphalt costs nearly €95.000 plus €60.000 for storm water runoff measures. So compared to asphalt, water passing surfaces are cheaper to realise. The costs for pervious surfaces like gardens, grasses and gravel are lower than hard surfaces like pavement. Reducing the hardened surface also has the added value of needing less investments in storm water run-off measures.	
Organization	
Central government and local governments are the most important for implementing water passing surfaces on a regional level.	
Management and maintenance	

Considerations
Information sources
▪ Georgi B, Isoard S, Kurnik B, Swart R, Marinova N, Hove van B, Jacobs C , Klostermann J, Peltonen L, Kopperoinen L, Oinonen K, Havranek M, João Cruz M, Gregor M, Fons-Esteve J, Kazmierczak A, Keskitalo C, Juhola S, Krellenberg K, Bree van L. *Urban adaptation to climate change in Europe: Cities' challenges, opportunities, and supportive national and European policies.* European Environment Agency (2012). ▪ *Maatregelenoverzicht Klimaatadaptatie*. Dutch Ministry of Infrastructure and the Environment. Published in November 2011. ▪ *http*://www.rijkswaterstaat.nl ▪ http://www.pavementinteractive.org

Adaptation option: Reinforce Flood Protection Infrastructure	
Cluster:	Public Area
Climate Impact:	Flooding (river)
Spatial scale:	City

Reinforcing the embankment of a river in Wales.
Source: www.walesonline.co.uk

Description

Flood prone areas often already have implemented adaptation options to face the risks of flooding. But predicted future climate impacts might have changed and therefore the flood protection infrastructure can use reinforcement. These reinforcements include the raising of:

- Embankments;
- Dykes;
- Dams;
- Barriers

Effectiveness

Flooding (river)	▪ Reinforcing the flood protection infrastructure has large positive effects on the water safety, because it significantly lowers the risk of flooding
Other effects	▪ Hydromorfological processes are influenced and tempered

Financial aspects

- Reinforcing the flood protection infrastructure is radical and costly, costs are most of times covered by the national government
- There is no direct return on investment. Flood protections increases safety of the people and lowers risks of damage to economic values

Organisation

- In the Netherlands water boards are responsible for formulating reinforcement programs and together with the government they are responsible for the realisation

Management and maintenance

- Periodical monitoring of the construction and reinforcements is required.

Considerations

- In case of needed flood protection also innovative ways of flood protection should be considered (see fact sheet Innovative Flood protection)

Information sources

- Marttila V., Granholm H., Laanikari J., Yrjölä T., Aalto A., Heikinheimo P., Honkatuki J., Järvinen H., Liski J., Merivirta R., Paunio M. (2005). *Finland's National Strategy for Adaptation to Climate Change*. Ministry of Agriculture and Forestry of Finland.
- *Maatregelenoverzicht Klimaatadaptatie*. Dutch Ministry of Infrastructure and Environment. Published in November 2011.

Case studies:

- Raalten van D., Laan van der T., Wijsman P., Boeije L., Schellekens E., Dircke P., Pyke B., Moors E., Pelt van S., Elias E., Dijkman J., Travis W., McCrea B., LaClair J., Goldbeck S. *San Francisco Bay: Preparing for the Next Level*. Published by ARCADIS, Deltares, Alterra, BCDC, 2009

Adaptation option: Reinforce Flood Protection Infrastructure	
Cluster:	Public Area
Climate Impact:	Flooding (sea)
Spatial scale:	City

Glass overtopping walls as reinforced flood protection.
Source: Raalten *et al.* (2009)

Reinforcing a dyke in Andijk, the Netherlands.
Source: ARCADIS

Description

Flood prone areas often already have implemented adaptation options to face the risks of flooding. But predicted future climate impacts might have changed and therefore the flood protection infrastructure can use reinforcement. These reinforcements include:

- Raise of flood banks and (sea)walls;
- Raise embankments, dykes, dams and barriers;
- Place glass overtopping walls;
- Widening the coastal defence.

Effectiveness

Flooding (sea)	▪ Reinforcing the flood protection infrastructure has large positive effects on the water safety, because it significantly lowers the risk of flooding

Financial aspects

- Reinforcing the flood protection infrastructure is radical and costly, in the Netherlands costs are covered by the national government
- Investments are not directly returned, flood protections function only as increased safety of the people and economical values

Organisation

- National, regional and local governments (including water boards) are in charge to formulate reinforcement programs and realisation

Management and maintenance

- Frequent monitoring of the construction and reinforcements is required.

Considerations

- In case of needed flood protection also innovative ways of protection could be considered (see factsheet Innovative Flood Protection (sea))

Information sources

- Marttila V., Granholm H., Laanikari J., Yrjölä T., Aalto A., Heikinheimo P., Honkatuki J., Järvinen H., Liski J., Merivirta R., Paunio M. (2005). *Finland's National Strategy for Adaptation to Climate Change*. Ministry of Agriculture and Forestry of Finland.
- *Maatregelenoverzicht Klimaatadaptatie*. Dutch Ministry of Infrastructure and Environment. Published in November 2011.

Case studies:

- Raalten van D., Laan van der T., Wijsman P., Boeije L., Schellekens E., Dircke P., Pyke B., Moors E., Pelt van S., Elias E., Dijkman J., Travis W., McCrea B., LaClair J., Goldbeck S. *San Francisco Bay: Preparing for the Next Level*. Published by ARCADIS, Deltares, Alterra, BCDC, 2009

Adaptation option: Water management plans	
Cluster:	Water; Public Area
Climate Impact:	Drought, Flooding, Storm water runoff
Spatial scale:	Building, City, Region

Water restriction sign as part of water management plan.
Source: Frisco City Water Management Plan

Example water-wise landscape watering (awareness).
Source: wateruseitwisely.com

Description
Often solutions address water scarcity and flood risks by enhancing preparedness. Through public awareness campaigns individual action can be promoted. Integrated water resource planning and the development of a comprehensive water strategy help a city or region with water related issues. Water management plans can also be developed on the scale of a single building. For instance a drought management plan reduces drought related risks and therefore economic, social, and environmental drought impacts. They emphasize efficient use of existing water supplies and contain guidelines and drought contingency plans for public water suppliers, but also restrictions on water use, building regulation requirements, rationing schemes, special water tariffs or the reduction of low-value uses. Part of a drought plan could also be to temporarily raise the price of water to suppress demand. *London example*: Water efficiency in new dwellings and flats will be controlled under the Building Regulations Requirement G2. This requires that water consumption be limited to 125 litres per person per day using the 'Water Efficiency Calculator for New Dwellings' and a notice to that effect must be given to the Building Control Body. The calculator encourages the use of efficient fittings and appliances and 'non-wholesome' water such as harvested rainwater or reclaimed grey water for toilet flushing etc. The draft LDF core strategy policies on Utilities Infrastructure and Sustainable Development and Climate Change and Flood Risk include the requirement for buildings to incorporate measures to conserve water resources (and reduce impact on the drainage system).

Effectiveness	
Drought	▪ Drought management plans set rules and regulations for efficient water use and thereby reduce drought impacts;
Flooding	▪ Flood management plans set rules and regulations that aim to reduce the risk of floods and lower the impact and floods occur;
Storm water runoff	▪ Water management plans often address storm water runoff so that the negative impacts of storm water runoff can be reduced.
Financial aspects	
No information available.	
Organization	
Central government, local governments and water authorities are the most important authorities to formulate policies, rules and regulations for efficient water use.	
Management and maintenance	
Considerations	
The adaptation option 'Water saving measures' is related to this option.	
Information sources	
▪ Rising to the Challenge – The City of London Climate Change Adaptation Strategy. First Published May 2007. Revised and Updated January 2010. ▪ Georgi B, Isoard S, Kurnik B, Swart R, Marinova N, Hove van B, Jacobs C , Klostermann J, Peltonen L, Kopperoinen L, Oinonen K, Havranek M, João Cruz M, Gregor M, Fons-Esteve J, Kazmierczak A, Keskitalo C, Juhola S, Krellenberg K, Bree van L. Urban adaptation to climate change in Europe: Cities' challenges, opportunities, and supportive national and European policies. European Environment Agency (2012). ▪ http://www.ci.frisco.tx.us/departments/publicworks/water/Pages/default.aspx	

Adaptation option: Provide Shading	
Cluster:	Buildings / Infrastructure / Public Area
Climate Impact:	Heat
Spatial scale:	Building / Street

Blinds are flexible and can close when there is too much heat generated by incoming sunlight. Source: www.inhabitat.com

Extending rooftops provide shade to the building. Source: ARCADIS

Description

Shadowing buildings and streets will lower the amount of direct sunlight in summer and therefore lowers the temperature. Ideally, techniques to create shade should be flexible: they can be opened or removed in winter to allow direct sunlight. Flexible options include installing blinds on buildings or placing (canvas) sheets above streets. Shading can, next to buildings and streets, also be provided to parking areas. Another option to create additional shading in cities is to extend rooftops, which is not a flexible solution. In this factsheets extending rooftops and placing (Venetian) blinds are described.

Effectiveness

Heat
- Extended rooftops (eaves) have a large effect on reducing heat inside buildings.
- During summertime placed blinds have a strong effect on lowering temperatures inside buildings.

Other effects
- By lowering the temperatures inside buildings the extended rooftops reduce CO_2 emissions.
- Extended rooftops create nesting places for birds (swallows) and therefore have a positive effect on biodiversity.

Financial aspects

- Investing in extended rooftops (eaves) save the proprietor annual money on heating in winter and cooling in summer
- Buildings have relative long lifetimes and therefore the investment is easily recouped and will be profitable for a longer time (>20 years)
- Investing in blinds can be easily combined with the construction costs of the building
- The return of investment is quickly realised since costs are relatively low and blinds allow for a significant reduction in energy costs for cooling of the building during summer

Organisation

- The landlord is in charge for constructing extended rooftops and for placing blinds.

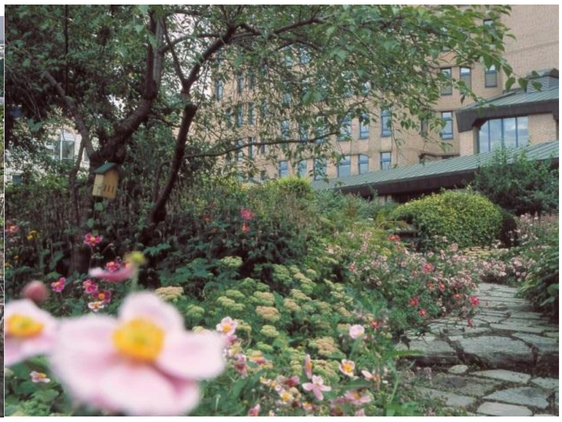
Management and maintenance

- Extended rooftops (eaves) and blinds need no maintenance / monitoring

Considerations
▪ Extended rooftops are most effective when placed on the south side of the building. ▪ See also: construction and design of buildings to reduce heat
Information sources
▪ *Maatregelenoverzicht Klimaatadaptatie*. Dutch Ministry of Infrastructure and Environment. Published in November 2011. ▪ *Rising to the Challenge – The City of London Climate Change Adaptation Strategy*. First Published May 2007. Revised and Updated January 2010. ▪ Hunt, A. and Watkiss, P., 2011. *Climate change impacts and adaptation in cities: a review of the literature*. Climatic Change, 104 (1), pp. 13-49. ▪ Larsen L., Rajkovich N., Leighton C., McCoy K., Calhoun K., Mallen E., Bush K., Enriquez J., Pyke C., McMahon S. and Kwok A. *Green Building and Climate Resilience: Understanding Impacts and Preparing for Changing Conditions*. University of Michigan; U.S. Green Building Council, 2011.

Adaptation option: Urban Farming and Gardening	
Cluster:	Public Area
Climate Impact:	Flooding (storm water runoff), Heat, Drought
Spatial scale:	Street / Neighbourhood

Urban farming. Source: nourishtheplanet.com



Urban gardening. Source: ARCADIS

Description

Urban farming and gardening, when compared to paved or asphalted grounds, has a positive contribution to climate adaptation. These green areas can be further adapted to climate impacts by introducing new vegetation and crops for allotment and vegetable gardens. They should be more resistant to droughts; such as saline vegetables and drought-tolerant plants and trees.

Effectiveness

Flooding (storm water runoff)	▪ Increasing the presence of vegetation will increase the water infiltration capacity of these areas, which in turn leads to better adaptation to storm water runoff;
Heat	▪ By providing shade and using the solar energy for their photosynthesis plants and trees have a cooling effect on their environment;
Drought	▪ When using more drought-tolerant plants water is saved that would otherwise be used for watering the plants; ▪ As a consequence of the increased water infiltration capacity the groundwater table will rise and this contributes to drought resistance ; ▪ When planting more saline vegetables and drought-tolerant vegetation there will be more food available during dry spells.
Other effects	▪ Urban farming and gardening attract a variety of fauna and thereby increases local biodiversity. Moreover, gardens are used as recreational and public meeting places for people.

Financial aspects

- Costs of urban gardens and farms are not high and can be combined with the planning and design of an area;
- Costs of purchasing crops are for the neighbourhood or the tenant;
- Benefits can be obtained by the yield of the land in the case of farming or by renting out allotment gardens.

Organisation

- Municipalities are responsible for the realisation of urban farming.

Management and maintenance
▪ The owner or manager of the areas are responsible for the management ▪ Maintenance is practiced by municipalities in the case of urban gardens or the renter in the case of urban farming.
Considerations
▪ The factsheets about the options "Green roofs and walls" and "Public green areas" show similar adaptation to the climatic impacts.
Information sources
▪ *Maatregelenoverzicht Klimaatadaptatie*. Dutch Ministry of Infrastructure and Environment. Published in November 2011. ▪ *Rising to the Challenge – The City of London Climate Change Adaptation Strategy*. First Published May 2007. Revised and Updated January 2010.

Adaptation option: Water Retention	
Cluster:	Buildings, Public area
Climate Impact:	Drought, Flooding (storm water runoff; river), Heat Stress
Spatial scale:	Building, Neighbourhood, Region

Example of a water retention area in a neighbourhood (Netherlands).
Source: ARCADIS

Example of a water square in the city.
Source: ARCADIS

Description

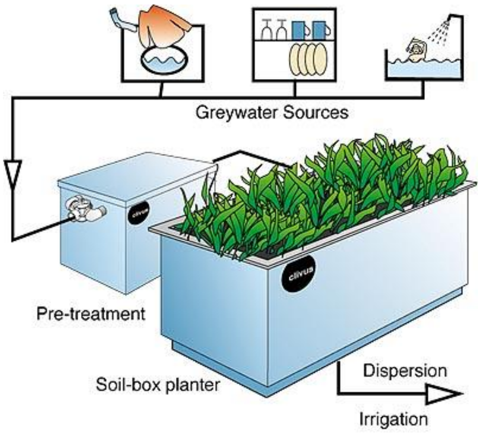
Water catchment systems typically consist of a range of water buffering measures and are designed to collect and store large quantities of (storm) water runoff and prevent sewer overflow, thereby reducing the negative effects of storm water runoff and floods. In addition, the collected water can be used during events of decreased precipitation, extended periods of drought, or extreme variation in water availability. Water catchment systems include cisterns, storage tanks, basins, ponds, extended sewers, water squares, waterparks, (constructed) wetlands, blue roofs and other types of collecting measures related to buildings. The capacity of soils and vegetation to retain water is an important flood prevention feature, causing a reduction of peak discharges across river basins. The way agricultural and forestry land is used is therefore relevant to flood risk management on the regional scale level.

- Cisterns, tanks, basins and ponds can be situated above or below ground. Storage capacity should be based on projected precipitation volumes in order to maximize the volume of water that can be captured during a storm event. Extended sewers and large diameter tubing also provide extra storage capacity below cities.
- Waterparks are in essence similar to a regular park, but they are located lower than the surrounding area and the vegetation is adapted to changing humidity levels. Besides water storage during storm events they also provide a pleasant green living area for daily use and the vegetation also provide cooling effects by evaporation.
- Water squares can be used in highly populated areas. Similar to waterparks, they are low-lying areas used for temporary water storage during heavy precipitation or flooding events. These squares are used daily as public meeting places.
- Blue roofs are an alternative to green roofs. They provide water storage on roofs without vegetation. The roof could also be used as a parking deck and hold water in case of a storm event. Blue roofs hold more water than green roofs (15mm versus 8mm).
- *Wadi's* are areas that can temporarily store large amounts of storm water runoff. Therefore they have the capacity to buffer and facilitate infiltration of storm water runoff into the soils.

The described water buffering measures are best used in combination.

Effectiveness	
Drought	▪ Because water is stored and can be used in the future, this option is very effective during events of decreased precipitation and extended periods of drought. Depending on the type of measure, the water stays in the system and can infiltrate the ground which reduces the negative effects of drought in soils.
Flooding (storm water runoff)	▪ This is a very effective option to collect and store large quantities of (storm) water runoff. Most measures don't need must space or have a multifunctional purpose, so that valuable space is not lost.
Flooding (river)	▪ Waterparks, squares and wetlands can be effective measures in the case of floods.
Heat stress	▪ Vegetation and open water (fountains) in waterparks and wetlands also contribute to reducing heat stress.
Other effects	▪ Water retention in the form of parks or ecosystems can lead to an increased biodiversity and increased social effects due to the creation of meeting places
Financial aspects	
Most measures require little extra costs when combined with planned works. Cisterns, storage tanks, basins and extending the sewer systems does require large investments and therefore integrating water storage right in the design of new city areas or redesigning existing is often cheaper. This also increases the attractiveness of public spaces.	
Organization	
▪ Usually the local government and the landowner are responsible for organising the water retention options ▪ For building specific options the landlord is responsible for the organisation	
Management and maintenance	
The functioning of cisterns, storage tanks, basins and sewers need periodic monitoring and require silt maintenance. Waterparks and squares need are in essence self-containing and only need monitoring during a short period after realisation.	
Considerations	
Information sources	
▪ Dircke P., Aerts J., Molenaar A. Connecting Delta Cities, Sharing knowledge and working on adaptation to climate change. City of Rotterdam, 2010. ▪ Georgi B, Isoard S, Kurnik B, Swart R, Marinova N, Hove van B, Jacobs C , Klostermann J, Peltonen L, Kopperoinen L, Oinonen K, Havranek M, João Cruz M, Gregor M, Fons-Esteve J, Kazmierczak A, Keskitalo C, Juhola S, Krellenberg K, Bree van L. Urban adaptation to climate change in Europe: Cities' challenges, opportunities, and supportive national and European policies. European Environment Agency (2012). ▪ Maatregelenoverzicht Klimaatadaptatie. Dutch Ministry of Infrastructure and the Environment. Published in November 2011. ▪ http://www.RDMcampus.nl	

Adaptation option: Water Saving Measures	
Cluster:	Water; Public area
Climate Impact:	Drought
Spatial Scale:	City, Neighbourhood, Building



Grey water recycling.
Source: Greywater.com

Efficient irrigation using smart irrigation technology.
Source: Ecoyards.com

Description

Generally cities have two options to react on water scarcity: decreasing water use or augmenting supply. Responding to water scarcity and droughts by:

- increasing water efficiency in buildings;
- water efficiency of water-using products in households, commercial business, industry and agriculture;
- reducing leakages in water networks;
- and trying to halt drought spells through technologies and good practices.

Grey measures: Local solutions are rainwater harvesting, ground water recharge and grey water recycling. Domestic water from baths, showers and washbasins can be re-used for toilet flushing but requires filtration and disinfection. Other grey options are:

- Install dual-flush and low-flush toilets. This can save more than half the water used for flushing toilets and cut household water use by up to 20%;
- Install waterless urinals;
- Install water efficient showers and smaller baths;
- Use water-efficient devices, such as ‘A-rated’ washing machines and dishwashers;
- Install spray taps;
- Minimise the amount of piping between boiler/hot water tank and tap, to reduce the need to ‘run’ the water;
- Install leak detection systems for major supplies;
- Install efficient irrigation systems

Soft measures: Through public awareness campaigns water conservation can be promoted, to encourage individual action. They emphasize efficient use of existing water supplies and contain guidelines and drought contingency plans for public water suppliers, but also restrictions on water use, rationing schemes, special water tariffs or the reduction of low-value uses. Alternatively, or additionally, the price of water can be temporarily raised to suppress demand.

Effectiveness	
Drought:	The benefits of grey measures include reducing household water demand and easing pressure on the main water supply, reducing upstream energy and environmental costs. Water saving technology and devices in households and industry as well as a proper maintenance of the supply system avoiding water losses due to leakages reduce in addition the overall demand.
Financial aspects	
Not apllicable	
Organization	
Central government, local governments and water authorities are the most important authorities for implementing water saving measures.	
Management and maintenance	
Grey water recycling: these systems require filtration, disinfection and maintenance to ensure that they function correctly and safely.	
Considerations	
This option is comparable with the option 'Rules and regulations for efficient water use'.	
Information sources	
▪ Georgi B, Isoard S, Kurnik B, Swart R, Marinova N, Hove van B, Jacobs C , Klostermann J, Peltonen L, Kopperoinen L, Oinonen K, Havranek M, João Cruz M, Gregor M, Fons-Esteve J, Kazmierczak A, Keskitalo C, Juhola S, Krellenberg K, Bree van L. *Urban adaptation to climate change in Europe: Cities' challenges, opportunities, and supportive national and European policies.* European Environment Agency (2012). ▪ (16) RISING TO THE CHALLENGE ▪ Shaw, R., Colley, M., and Connell, R. *Climate change adaptation by design: a guide for sustainable communities.* TCPA, London, 2007. ▪ http://www.greywater.com ▪ http://www.ecoyards.com	