World's Port Cities
Exposure to extreme water levels, effect of climate mitigation and adaptation costs

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Coastal Urban trends

Rising local and global risks

- Population
  - Growing coastal population
  - Urbanising world
  - Urbanising coastal zone
- Subsiding cities, especially in deltas
- Climate change and sea-level rise
- A reactive approach to adaptation

Hamburg
1962

Netherlands
1953

New Orleans 2005

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Flooding in Coastal Cities

some examples

- Galveston 1900 – 6,000 to 12,000 deaths (largest US death toll)
- Miami 1927 – 372 deaths (most costly US storm, after wealth normalisation)
- London 1928 – 10 deaths (Westminster under water)
- Osaka 1934, 1950, 1961 – 3,036, 534 and 191 deaths, respectively
- Hong Kong 1937 Typhoon – 11,000 deaths
- Rotterdam and London 1953 – 1,836 deaths in Netherlands and 307 deaths in UK (but potentially 10,000 deaths avoided in Rotterdam – so a near miss)
- Hamburg 1962 – 300 deaths
- New Orleans 2005 – 1,462 deaths; $81 billion direct damage and much greater indirect damage;

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Projects:

- OECD (www.oecd.org): Ranking port cities with high exposure to extreme water levels
- AVOID (www.avoid.uk.net) : The benefits of climate mitigation on port city exposure
- World Bank (http://beta.worldbank.org/climatechange/): The economics of adaptation to climate change

OECD

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Ranking port cities with high exposure to extreme water levels

- Focuses on the 1 in 100 year event in cities with > one million population in 2005
- Population exposure by elevation
- Considers all the relevant drivers of flood exposure
  - Socio-economic (demographic and economic)
  - human-induced subsidence
  - sea-level rise
  - storms
- Considers high-end (or 'worst-case') scenarios to bound potential changes
- Compares current exposure with projections for 2070

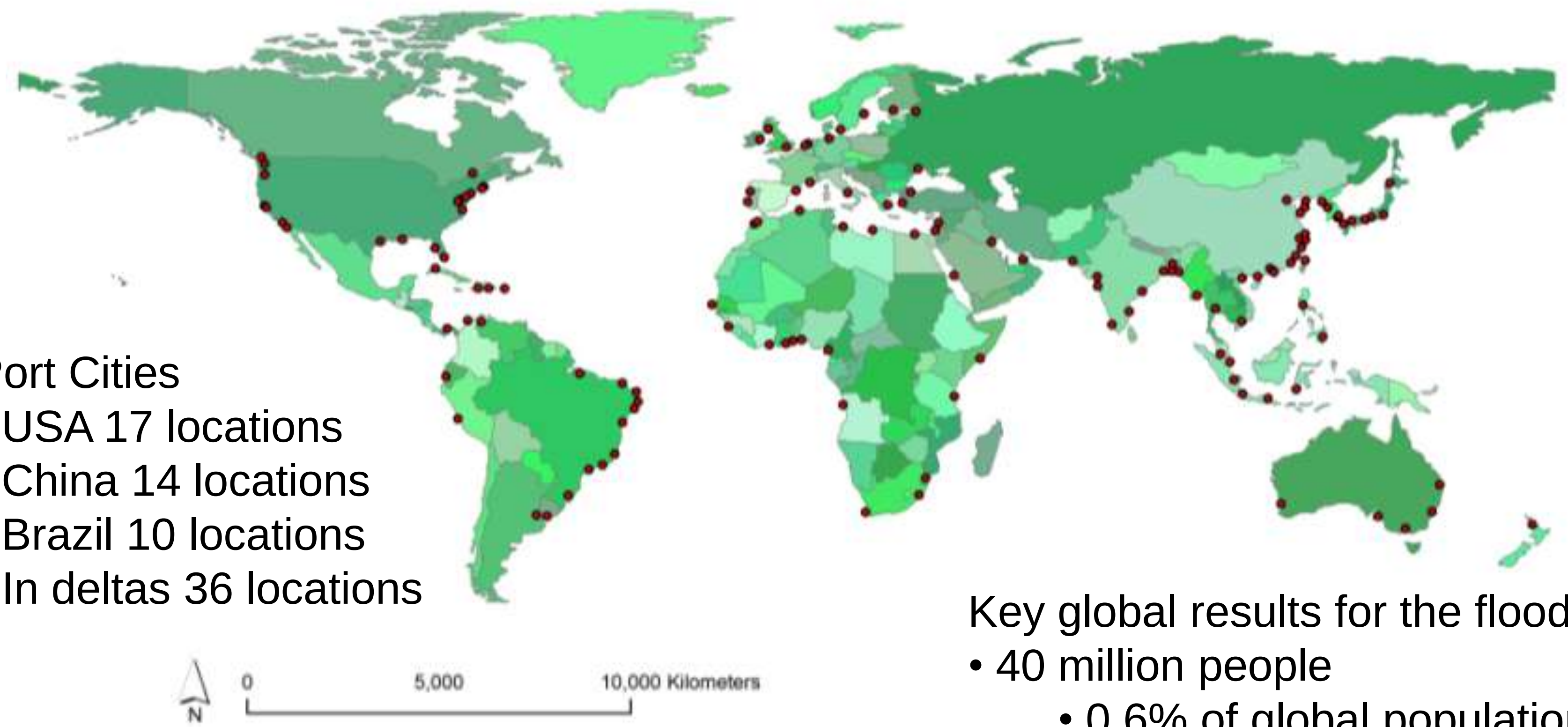
OECD

Future projections

- Population and economic growth
  - Single scenario from the OECD ENV-Linkages model
  - Assets linked to population and GDP/capita by a constant multiplier (5)
- Natural subsidence/uplift
  - From the DIVA global database
- Global sea-level rise
  - 0.5 m rise -- after Rahmstorf (2007) -- larger than IPCC AR4 (2007)
- More intense storms and higher storm surges
  - Assumed increased intensity of 100-year storms consistent with IPCC (2007) -- tropical storms and selected extra-tropical storms
- Potential human-induced subsidence
  - Considered an average subsidence up to 0.5 m across the 100 year flood plain in all susceptible cities

Port city locations

≥1 million population in 2005 – 136 locations

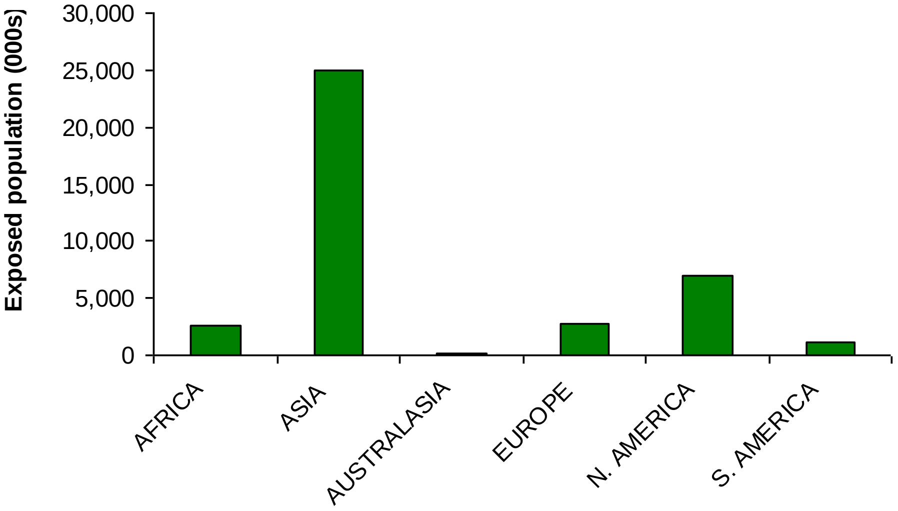


Port Cities
- USA 17 locations
- China 14 locations
- Brazil 10 locations
- In deltas 36 locations

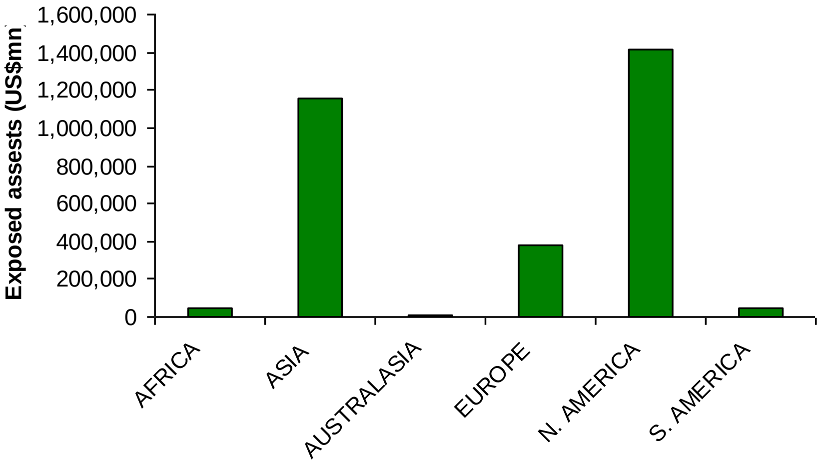
Key global results for the flood plain
- 40 million people
    - 0.6% of global population
    - (10% of port city population)
- US $3000 billion of assets
    - 5% of global GDP

Exposure by Continent

in 2005



(a) Population



(b) Assets

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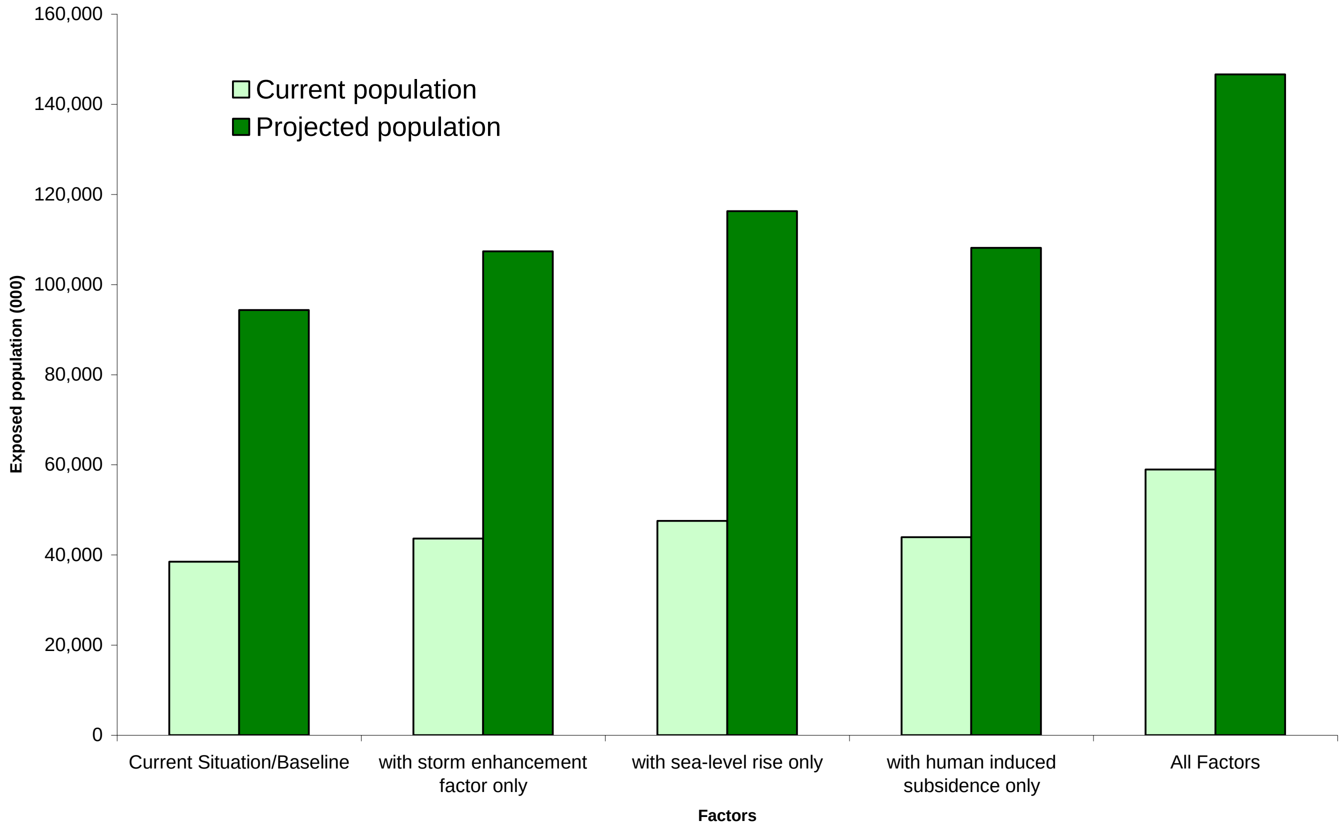
Global population exposure

Influence of different change factors: 2005 to 2070s



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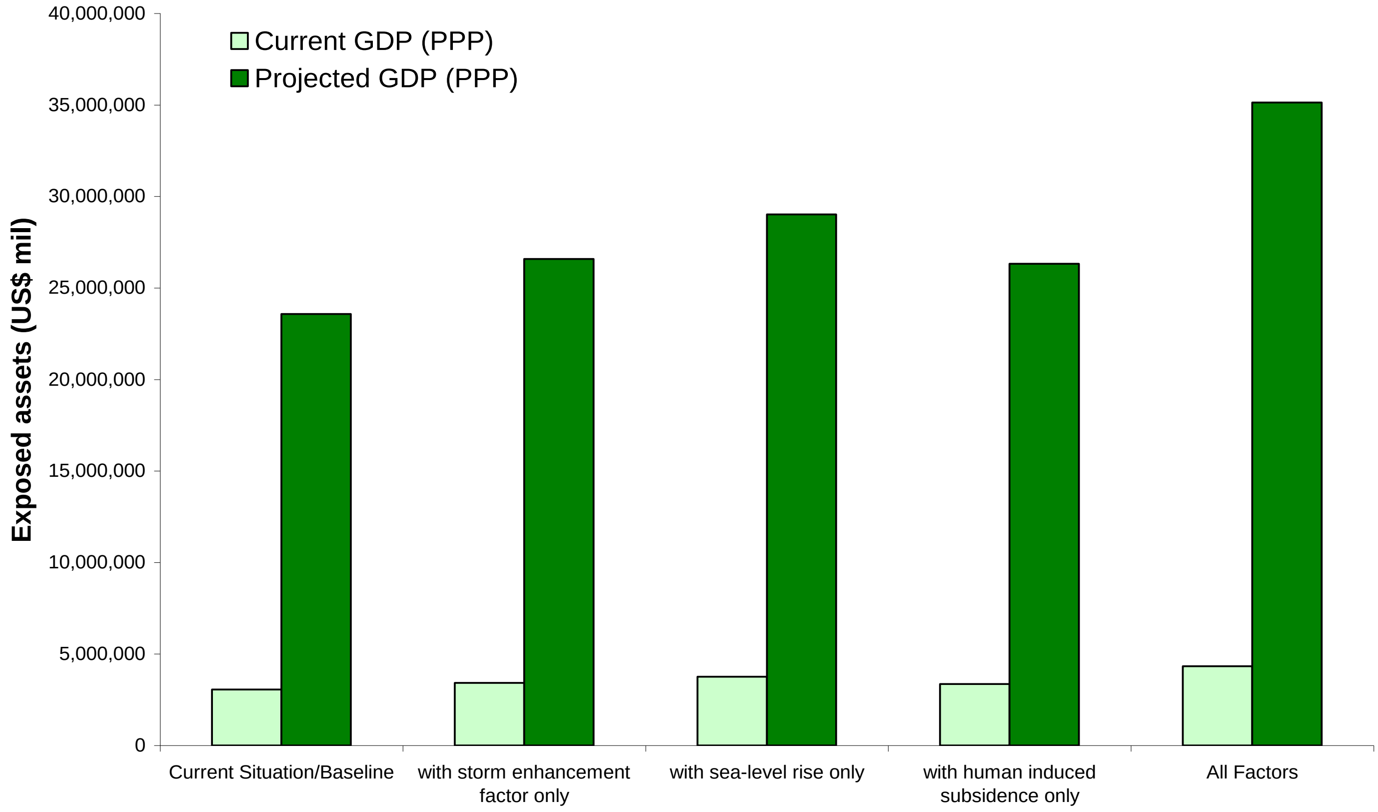
Global asset exposure

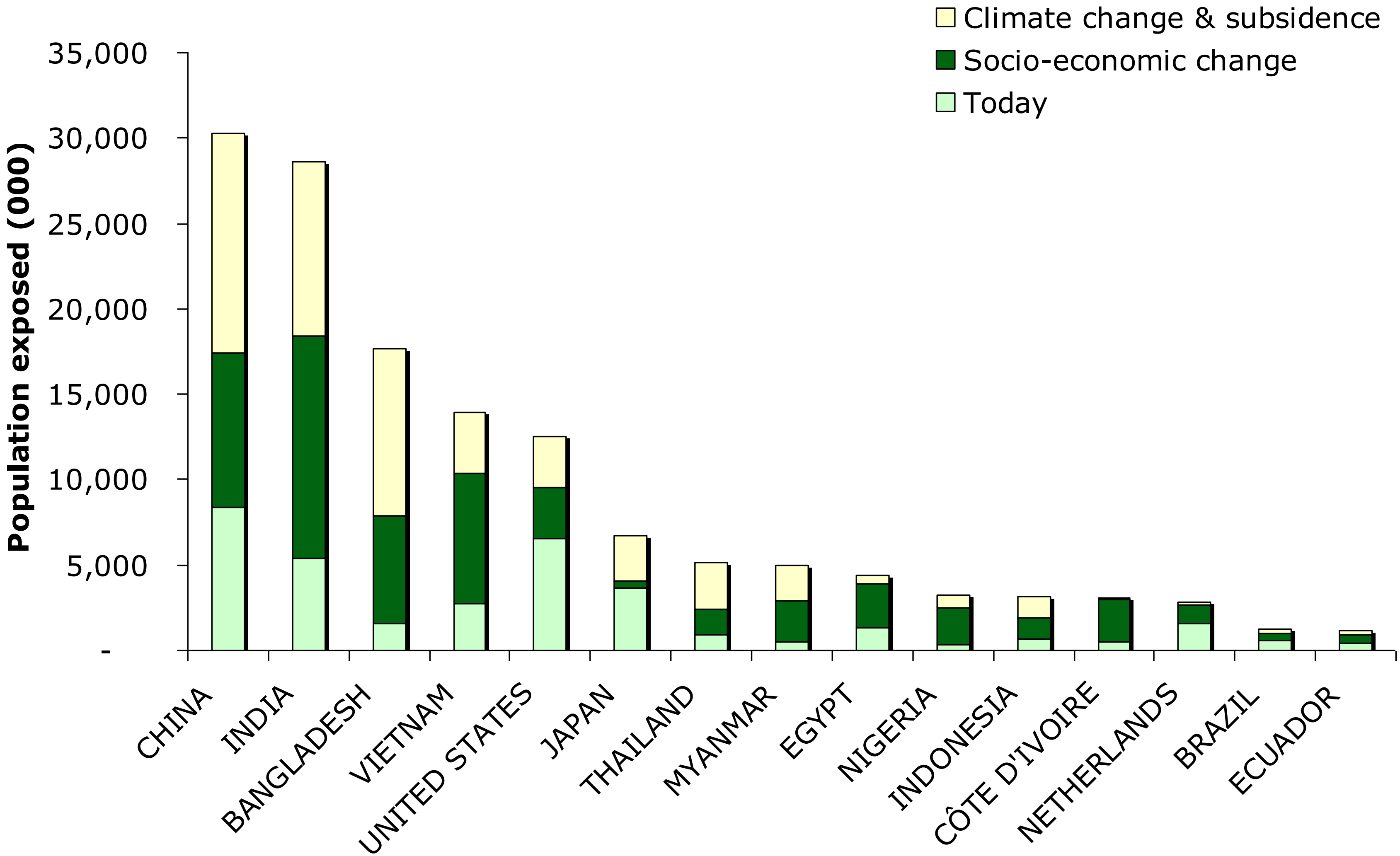
Influence of different change factors: 2005 to 2070s



C3P/NASA 2009 International Workshop
12th November 2009
Munich, Germany

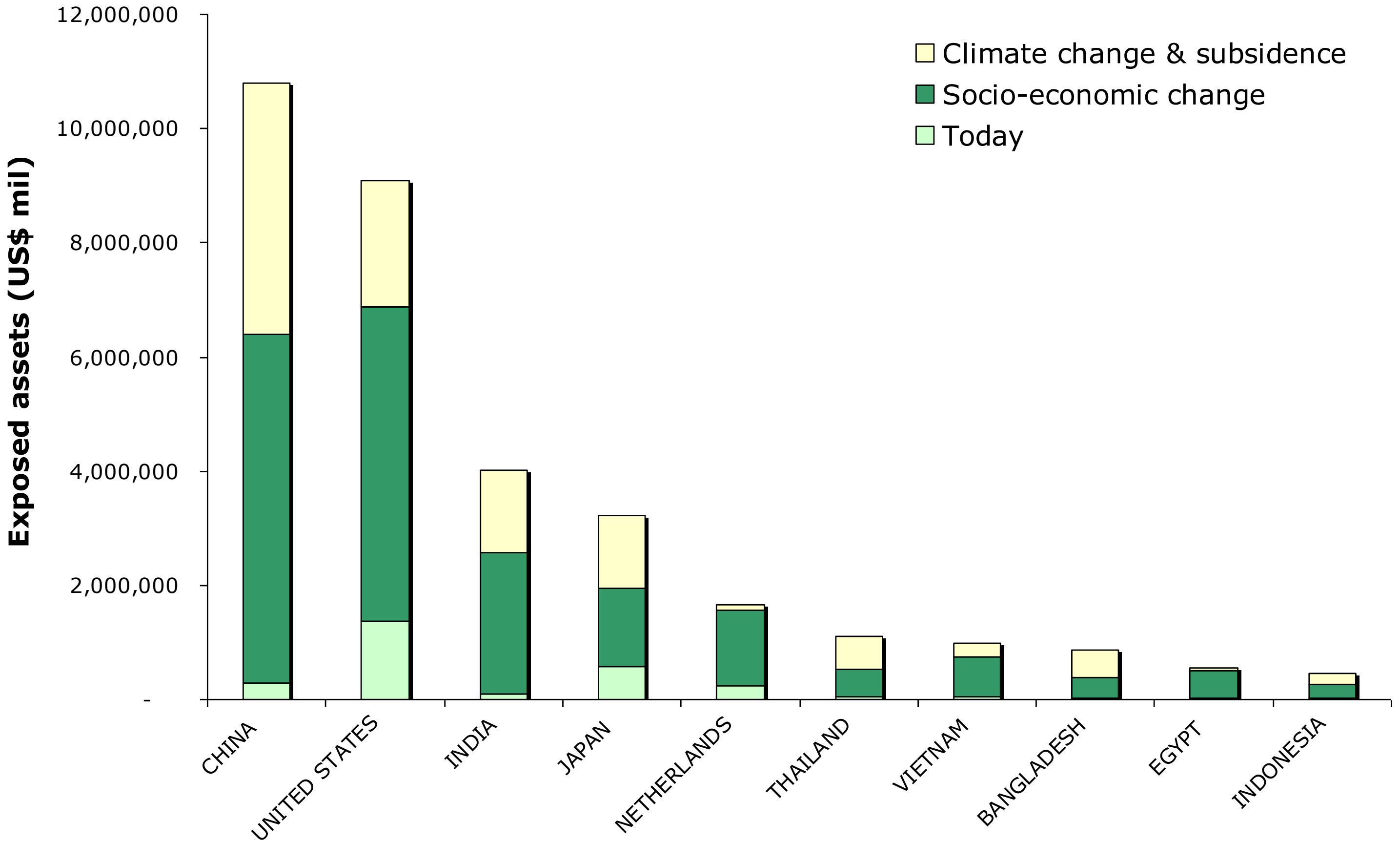
Population Exposure

Top 15 countries in 2070s



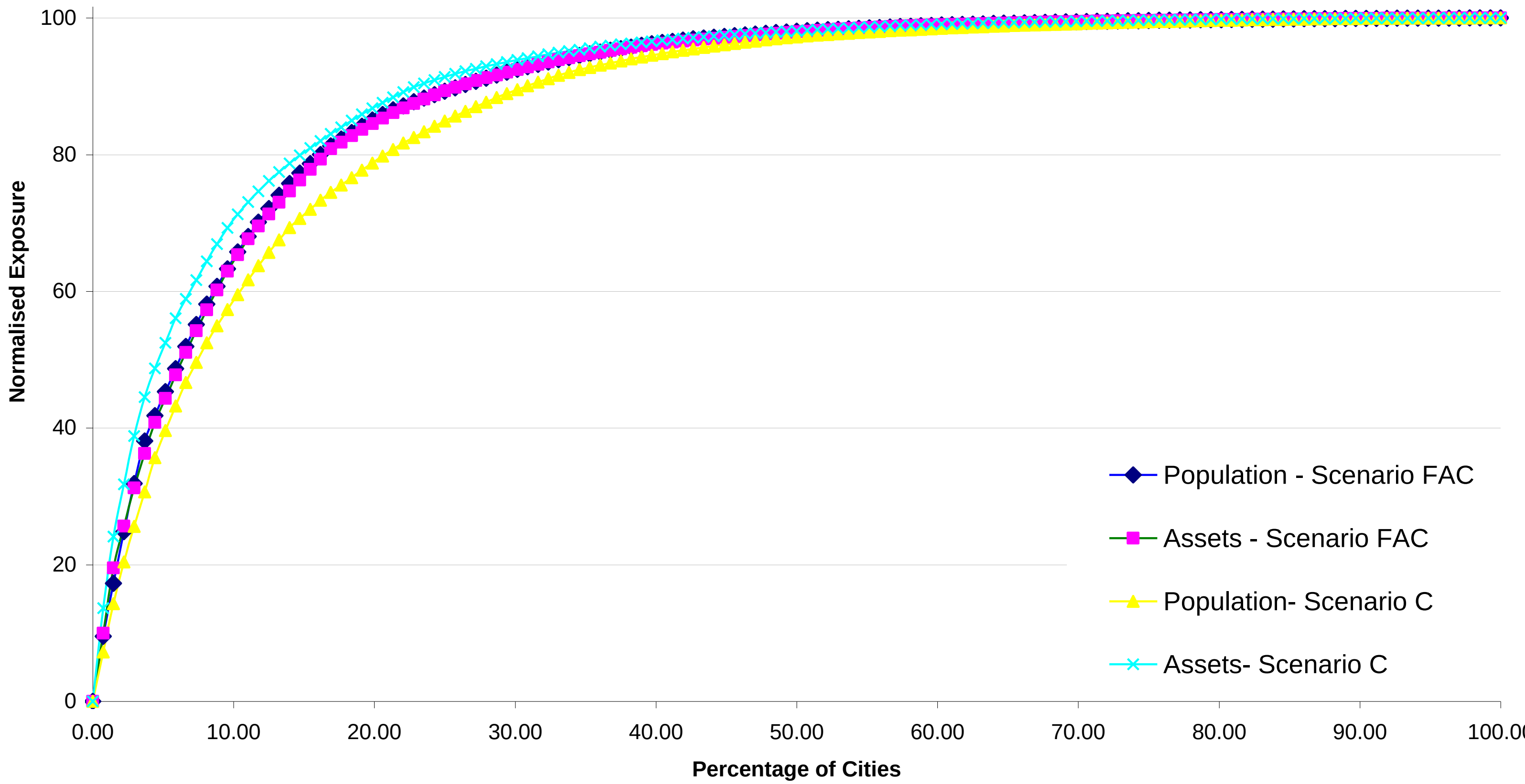
Asset Exposure

Top 10 countries in 2070s



Cumulative Global Exposure

Population and assets: Baseline (2005) and 2070s



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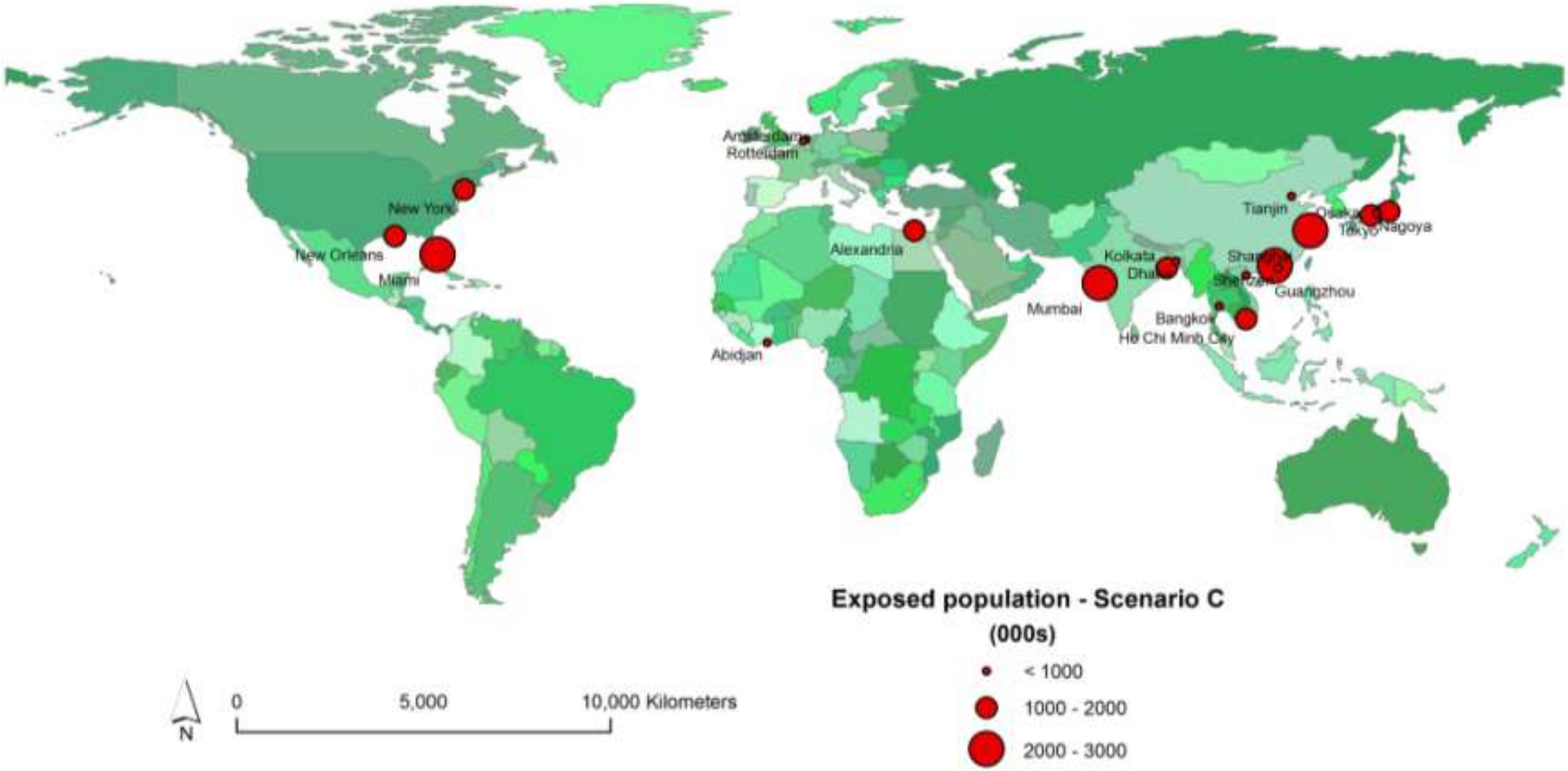
City Population Exposure

Current Top 20 cities



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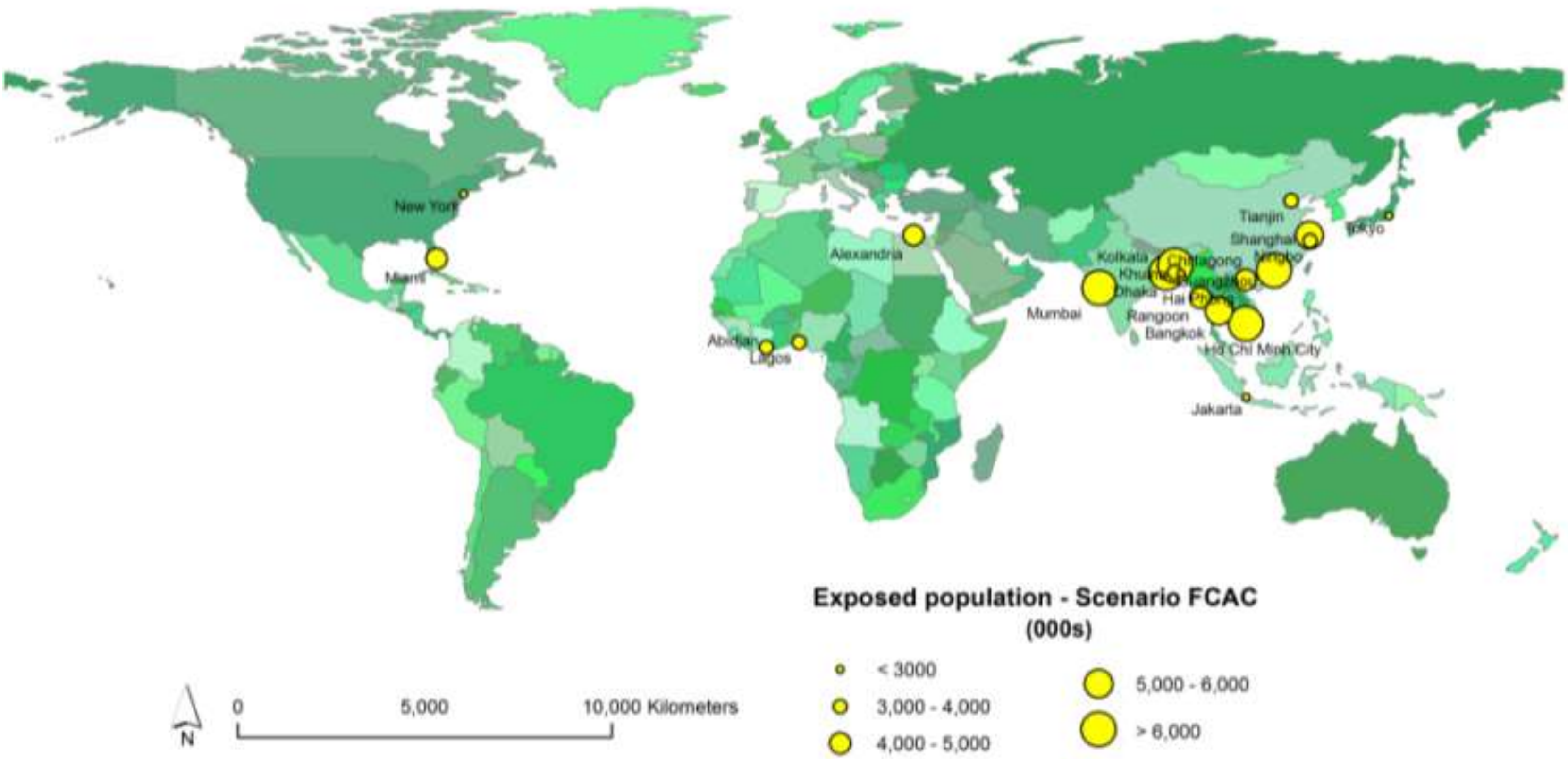
City Population Exposure

Top 20 cities in the 2070s



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City asset exposure

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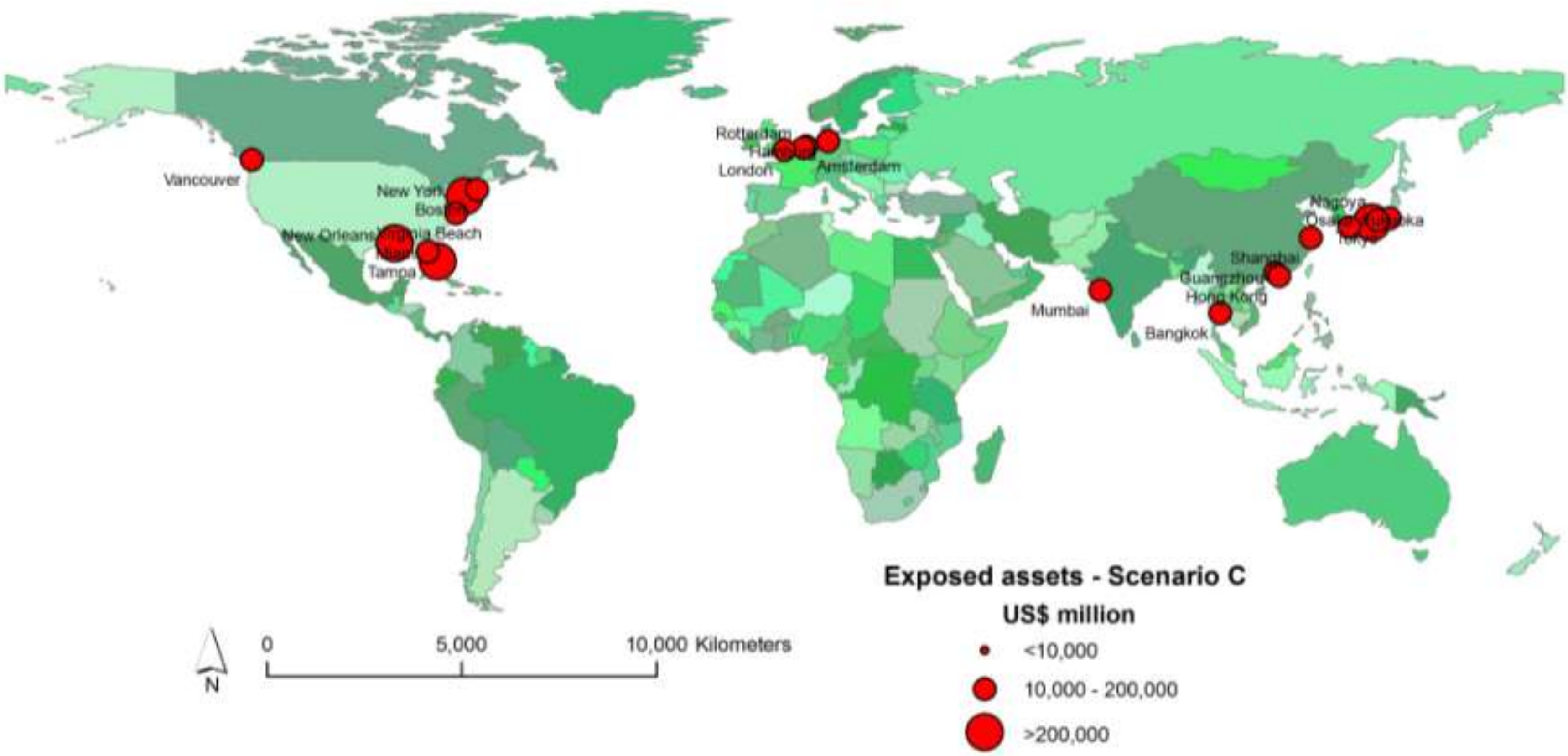

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City asset exposure

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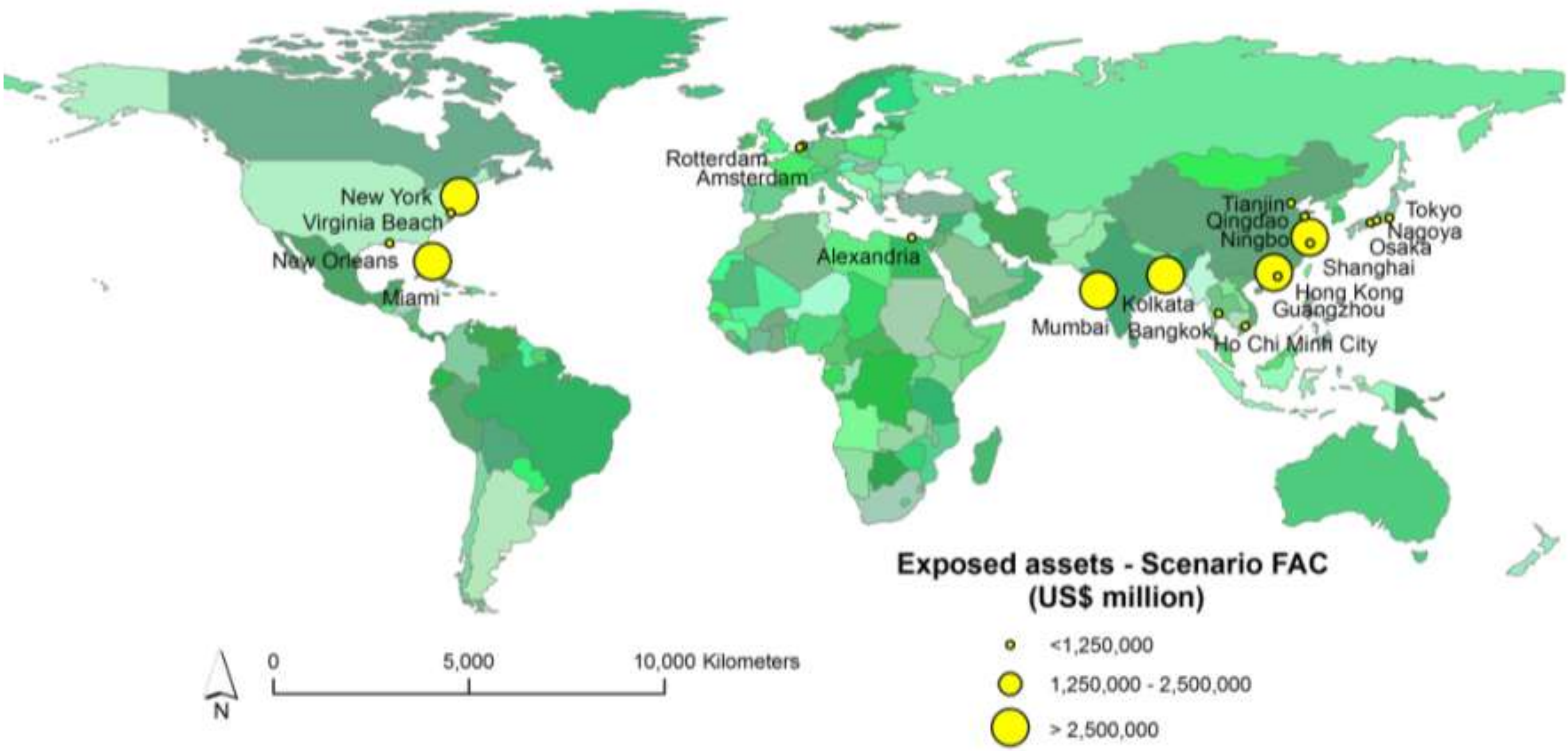
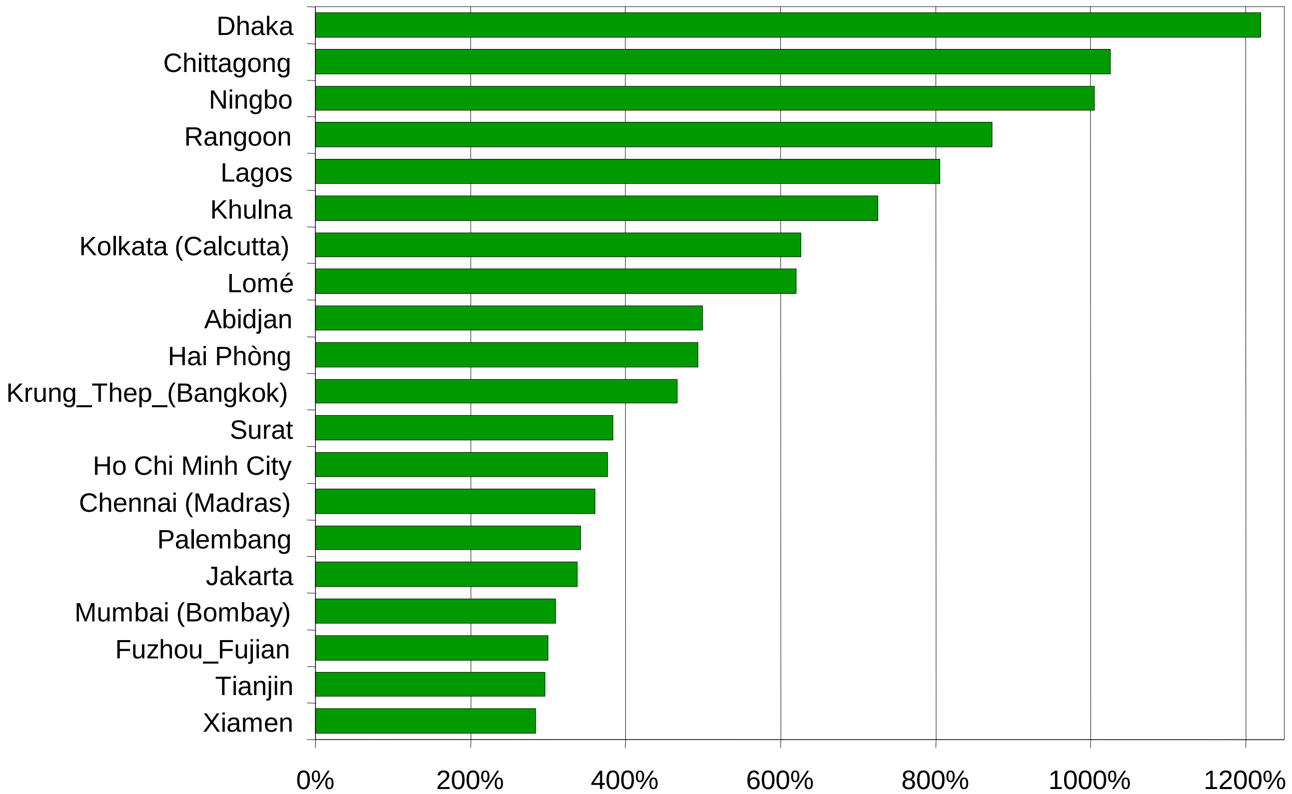


Most rapid population growth

Cities selected from the current Top 50



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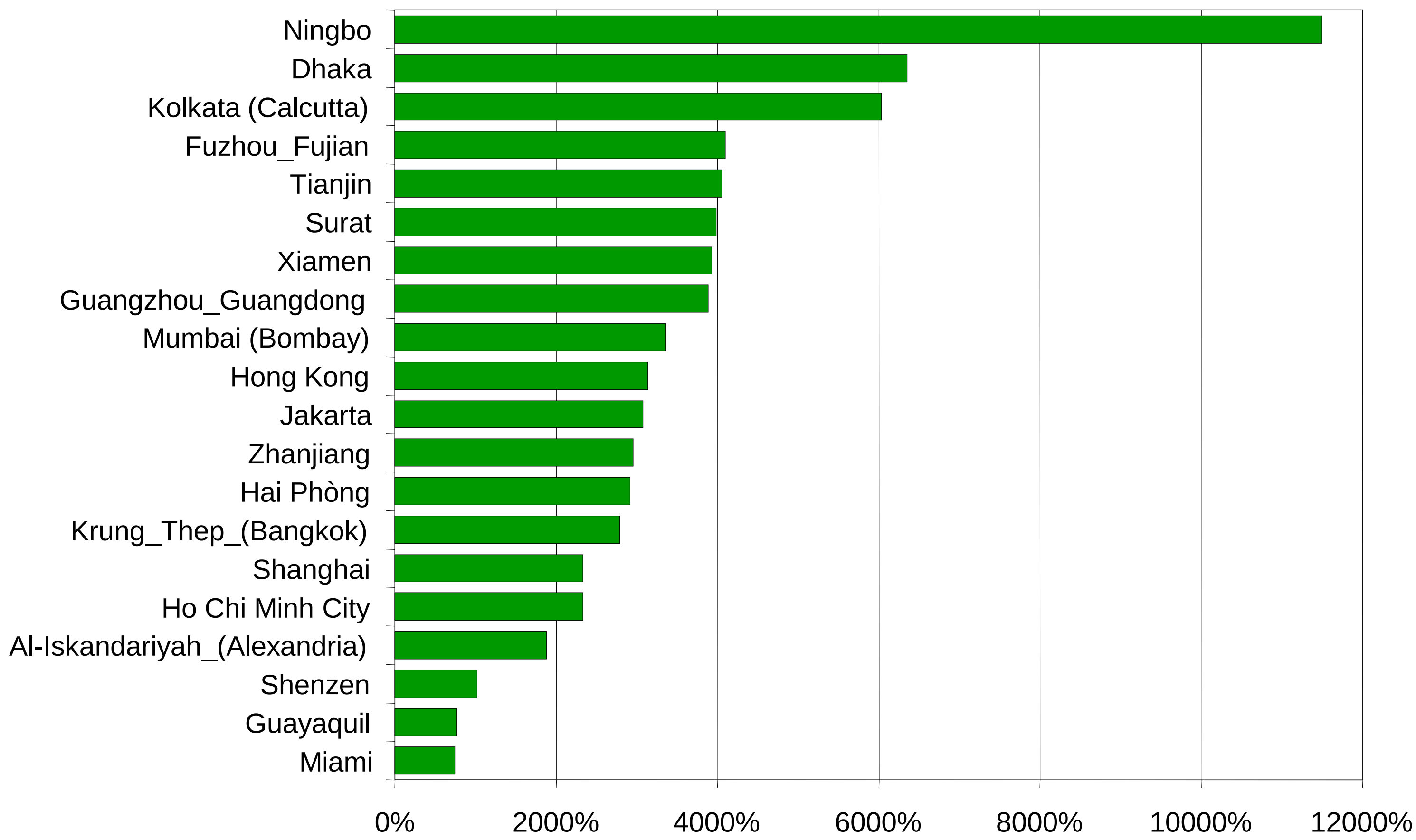

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AVOID

Benefits of climate mitigation on sea-level rise

- Same 136 coastal cities as the OECD project
- Explore the change in exposure due to global reduction of CO_2 emissions
- Climate projections from the UK Met Office (Hadley Centre)
- 3 main scenarios based on the A1B sres storyline
  - Unmitigated
  - Peak emissions in 2016 with an annual reduction in CO_2 emissions of 5%
  - Peak emissions in 2030 with an annual reduction in CO_2 emissions of 2%
- Used to generate global sea-level projections – spatially variable
- 3 urbanisation scenarios

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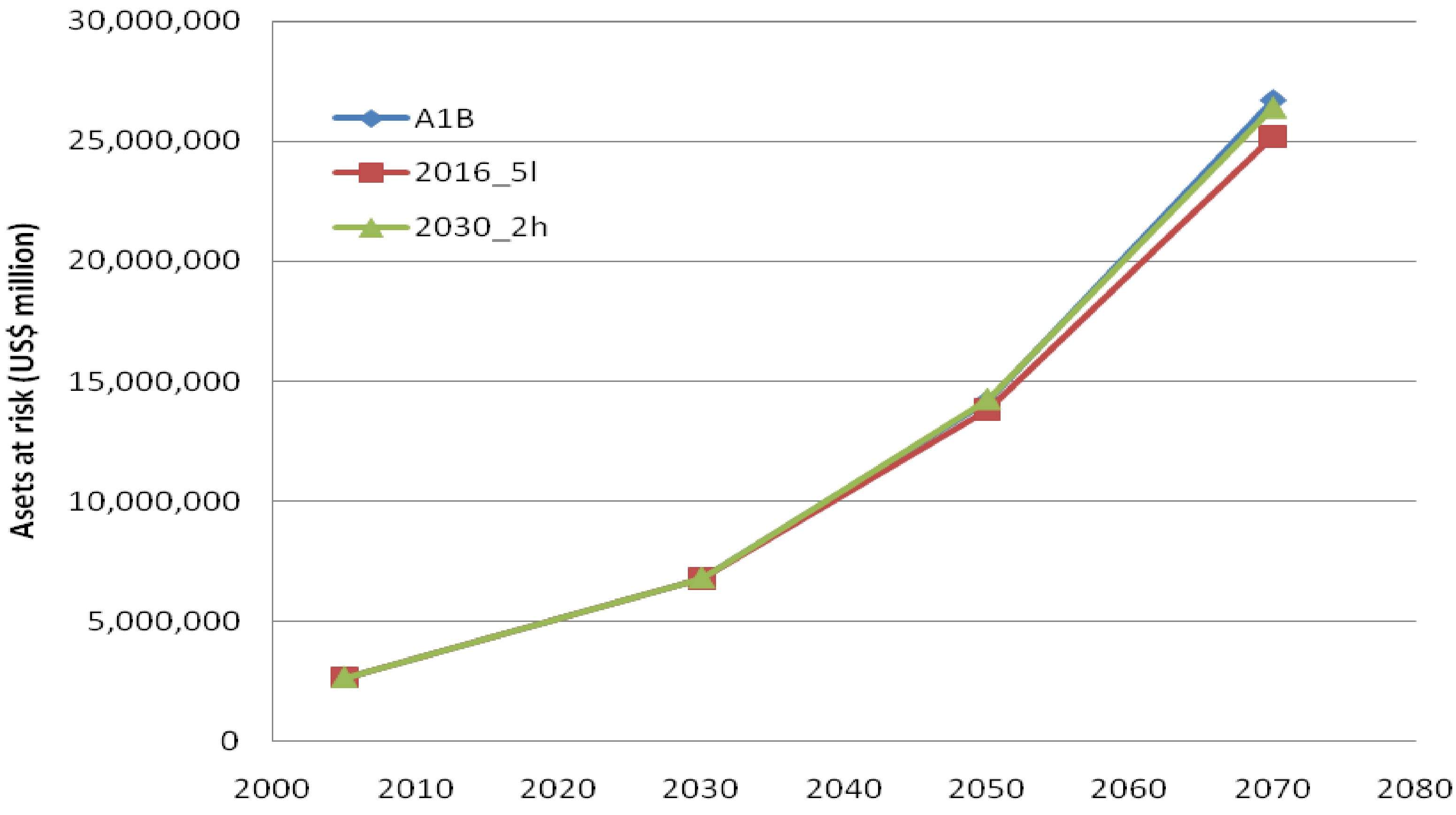
Exposure reduction
due to climate mitigation



Additional benefit of mitigation in 2016 rather than 2030 = 1,238,945 US$ million

Benefits of climate mitigation

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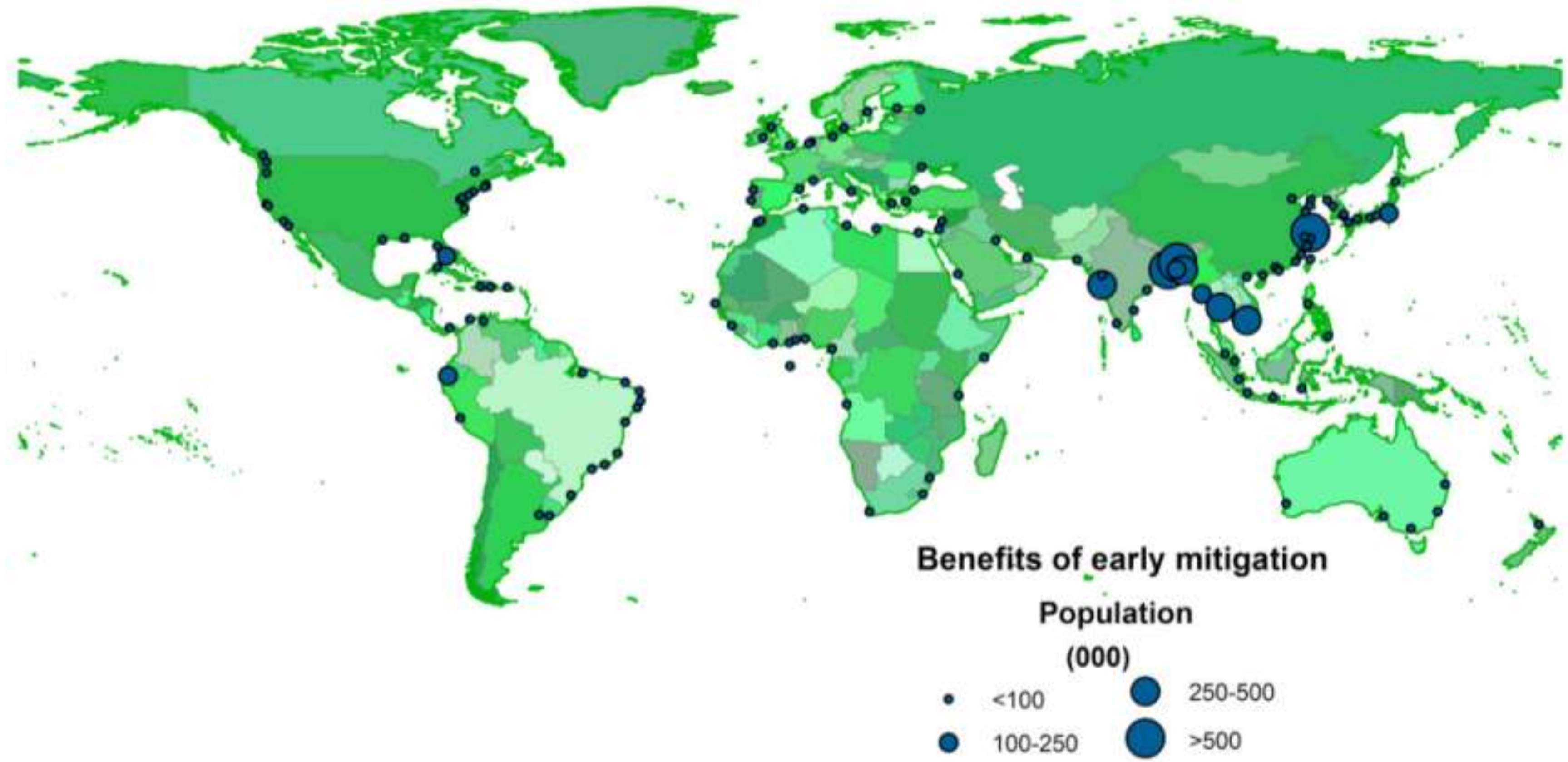

What about adaptation?

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The Thames Barrier – London, UK

Sea wall - UK

Rock armour - Trinidad

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Illustrative benefits of protection

City	Current Exposure		Approximate Protection Standard (Return period in years)	Annual Average Risk (Residual Risk)	
	Population (000)	Assets (US$ bil)		Population (000/yr)	Assets (US$ bil/yr)
London	397	60	1:1000	0.3	0.06
Shanghai	2,353	73	1:1000	2	0.07
Osaka	1,373	216	1:300	4.6	0.7
New York	1,540	320	1:100	15	3.2
Tokyo	1,110	174	1:1000	1	0.174
Amsterdam	839	128	1:10000	0.08	0.013
Rotterdam	752	115	1:10000	0.08	0.011
New Orleans	1124	234	1:200 (nominally)	5.1	1.168

World Bank

The economics of adaptation to sea-level rise

- Adaptation to sea-level rise by 2050
- Port upgrade – single event to raise ground level or working areas to account for anticipated change in sea level
- Dike construction and maintenance – change over time

Global Coastal defence costs by 2050 (High SLR)						Total by 2050 (US$ million)
	2010s	2020s	2030s	2040s		
Dike construction and maintenance costs	US$ millions/year					
	23,945	26,658	29,179	31,711		
Port upgrade	15,158					
						1,130,083

Conclusion

- Exposure to coastal flooding is large and growing;
- While all port cities are threatened, exposure is concentrated;
- Flood risk and management is a dynamic problem requiring proactive assessment;
- Whilst climate mitigation will provide benefits these will not be appreciable until the end of the century
- Adaptation in the form of coastal defences and port upgrade will be costly but in comparison to the value of the assets being protected
- Further work is needed on adaptation options and costs – e.g case studies

Acknowledgements

- Nicholls, R.J.[1], Hanson, S. [1], Herweijer, C.[2], Patmore, N. [2], Hallegatte, S.[3], Corfee-Morlot, J.[4], Chateau, J.[4], and Muir-Wood, R. [2]
  - 1. School of Civil Engineering and the Environment and Tyndall Centre for Climate Change Research, University of Southampton, Southampton SO17 1BJ UK
  - 2. Risk Management Solutions Limited, London, EC3R 8NB UK
  - 3. Centre International de Recherche sur l'Environnement et le Développement et Ecole Nationale de la Météorologie, Météo-France, Paris, France
  - 4. Organisation for Economic Co-operation and Development, Paris, France
- Report available: OECD Environmental Working paper 1

http://www.olis.oecd.org/olis/2007doc.nsf/linkto/env-wkp(2007)1

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