

# Mega- and Gigacities and their Challenges for Energy and Electrical Systems

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IIASA and FES Yale University

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Stanford University December 9, 2004

# Points for Discussion

- Urbanization (current + projections)
- Is continued urbanization plausible? (yes)
- Energy challenges of cities  
(power density)
- Urbanization and electricity use  
(where are the lights?)
- Gigacities (from city stars to city galaxies)
- Implications (need for new infrastructures  
and zero-emission energy = ele + H<sub>2</sub>)

# Cities

~50 % of world population (~2007)

>80? % of world GDP (few data)

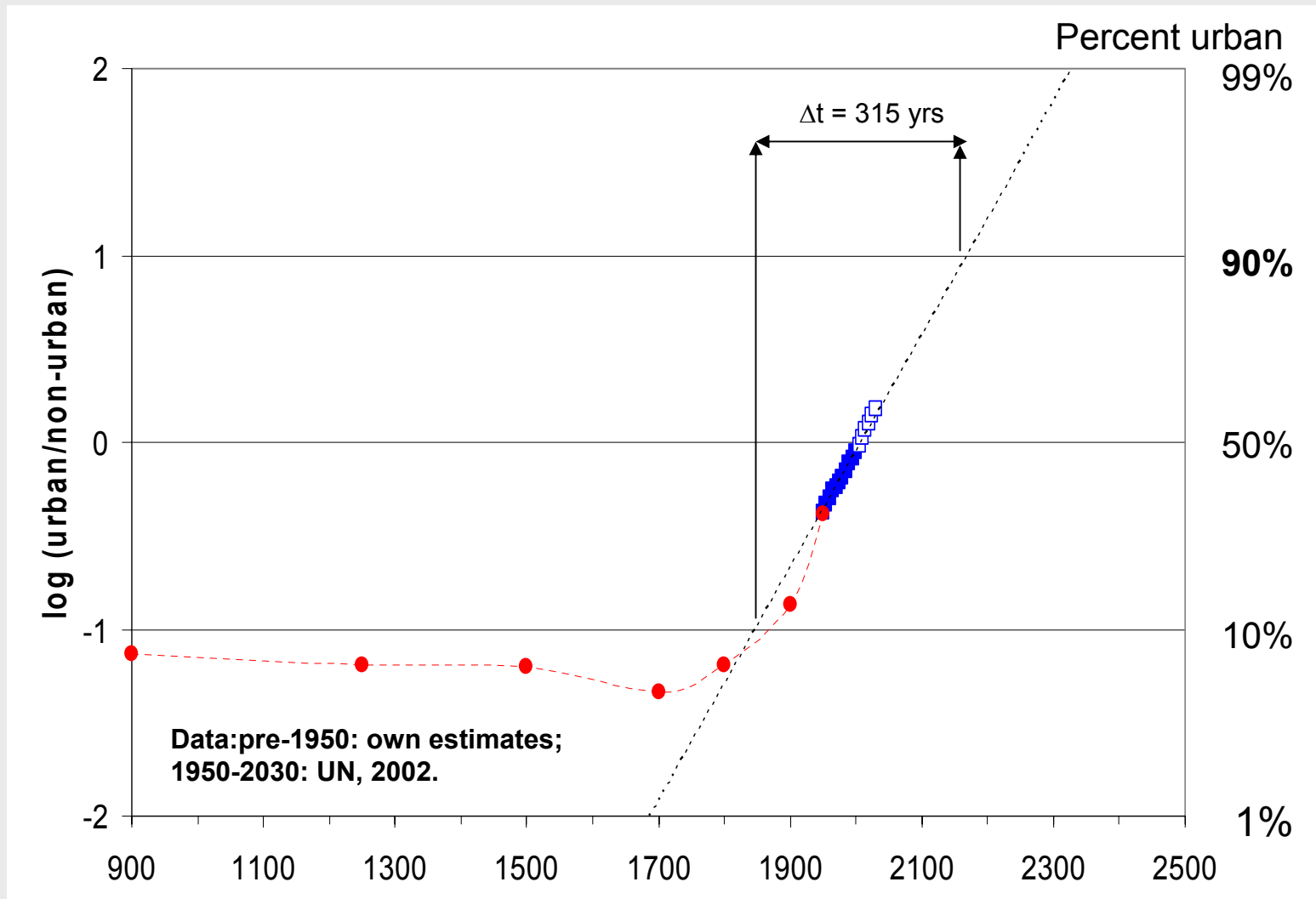
>80? % of world electricity (no data)

~95 % of world internet sites and traffic  
(good data)

# Urbanization

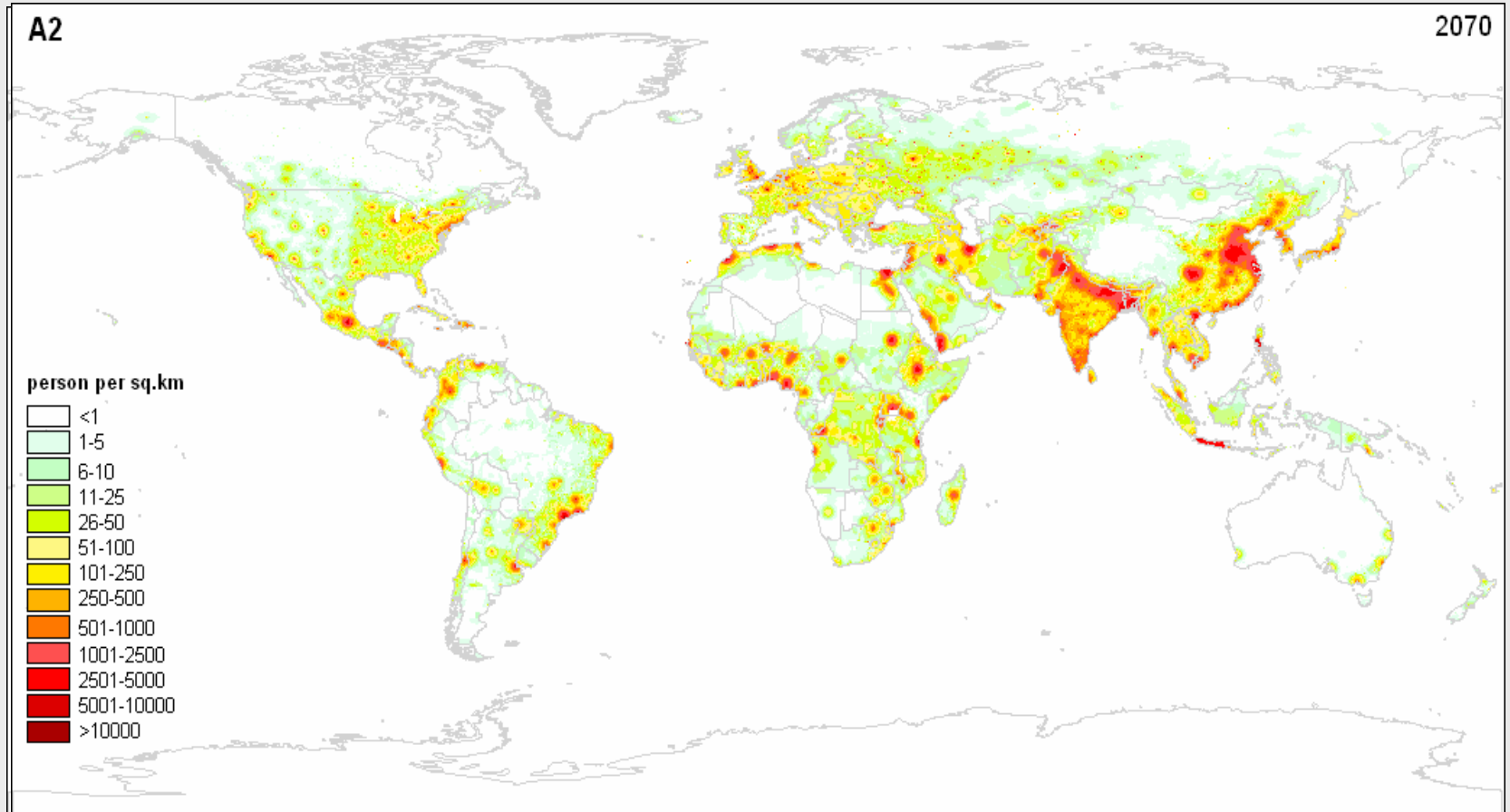
- Pre-1700: Limited by agricultural surplus production: <10% urban
- Size limit: Size of empire reach and availability of transport infrastructure  
First „Megacity“: Changan, China 800 AD (canals)
- Post 1700: Urbanization enabled by agricultural productivity growth, division of labor, new transport infrastructures (railways)
- ~2000: Mid-point. 50% urban globally
- Asymptotic state: >90% by >2100?

# World Urbanization



# Population Density

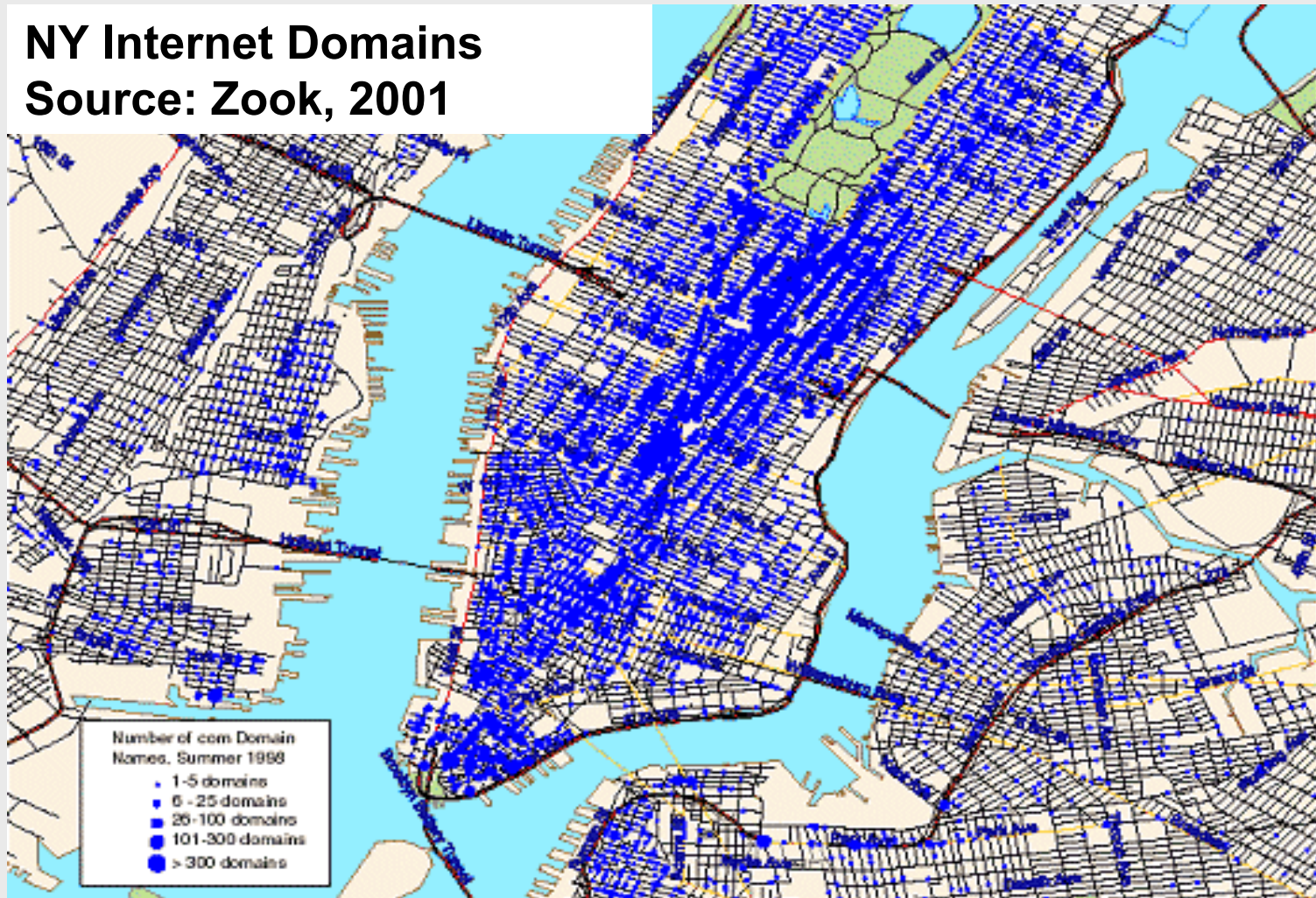
## 1990 and Two Scenarios for 2070



# Does Space Matter?:

*“[the] report of my death was an exaggeration”* (Mark Twain)

**NY Internet Domains**  
**Source: Zook, 2001**

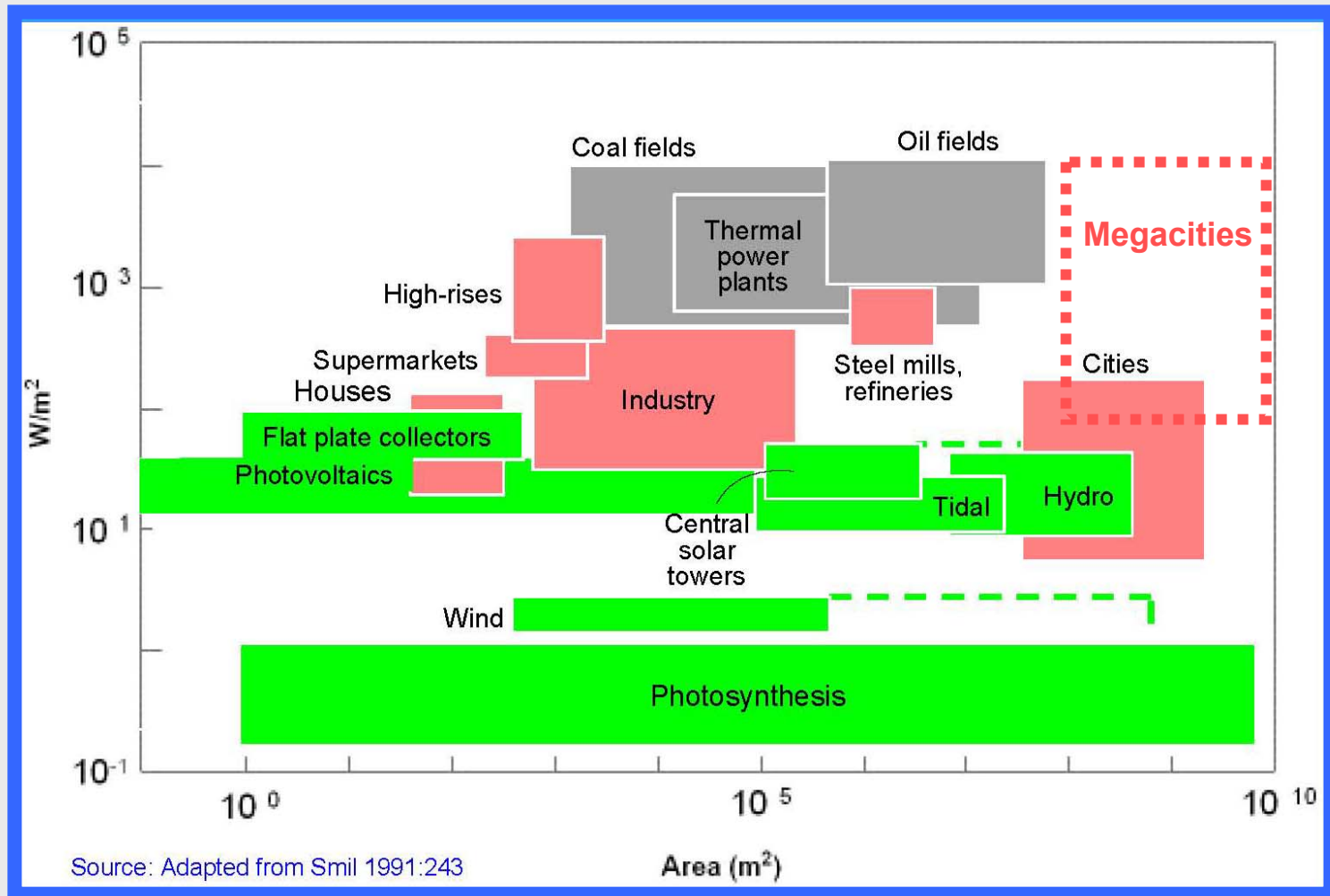


# Energy and Electricity Challenges of Cities

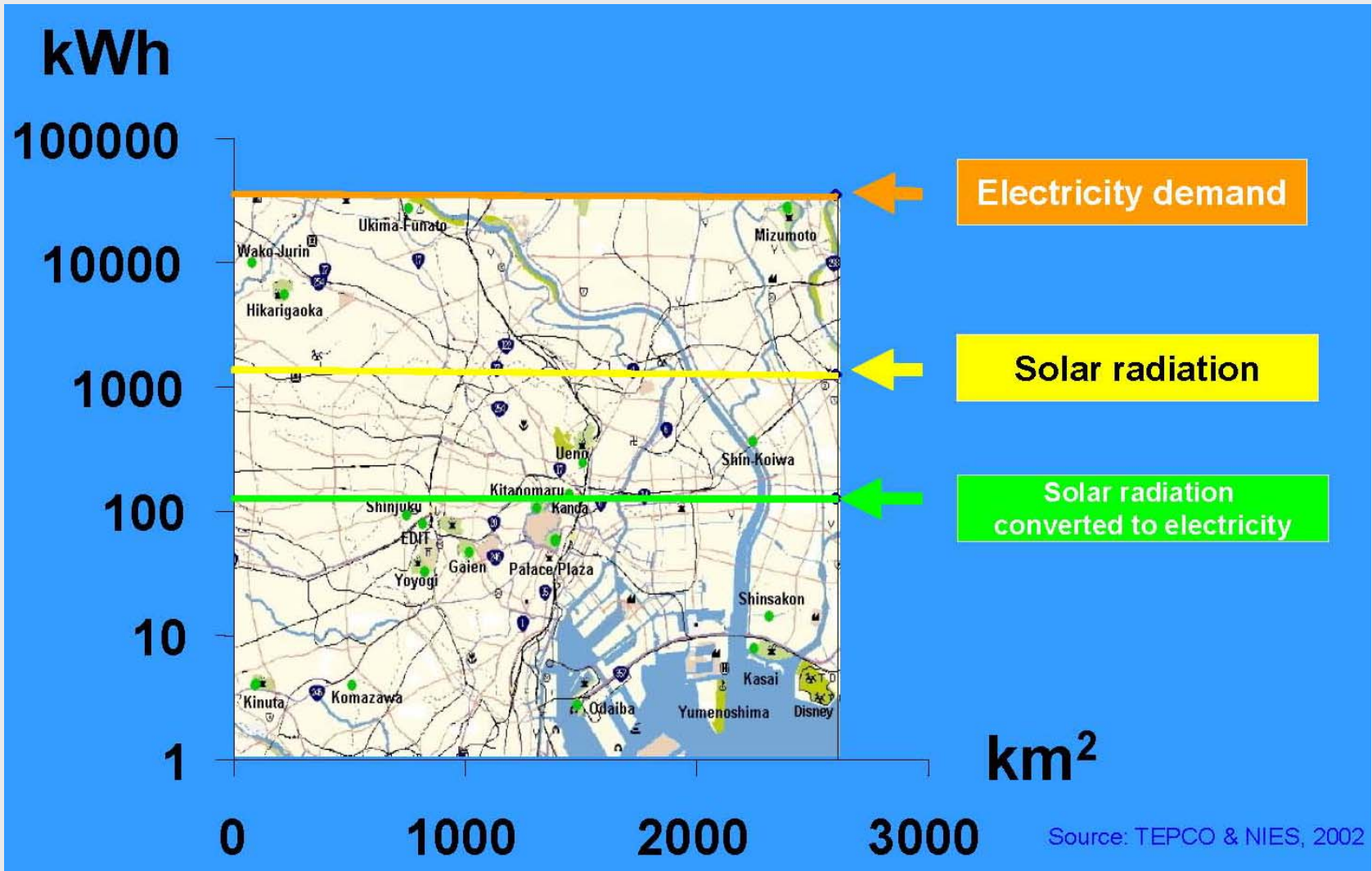
- Spatial mismatch demand – supply  
(vast imports)
- Enormous power densities  
(limiting supply options)
- Vulnerability requires extreme reliability
- Congestion needs high tech solutions
- Assimilative capacity of environment  
extremely limited (need for zero emissions)



# Spatial Power Densities of Energy Production and Consumption

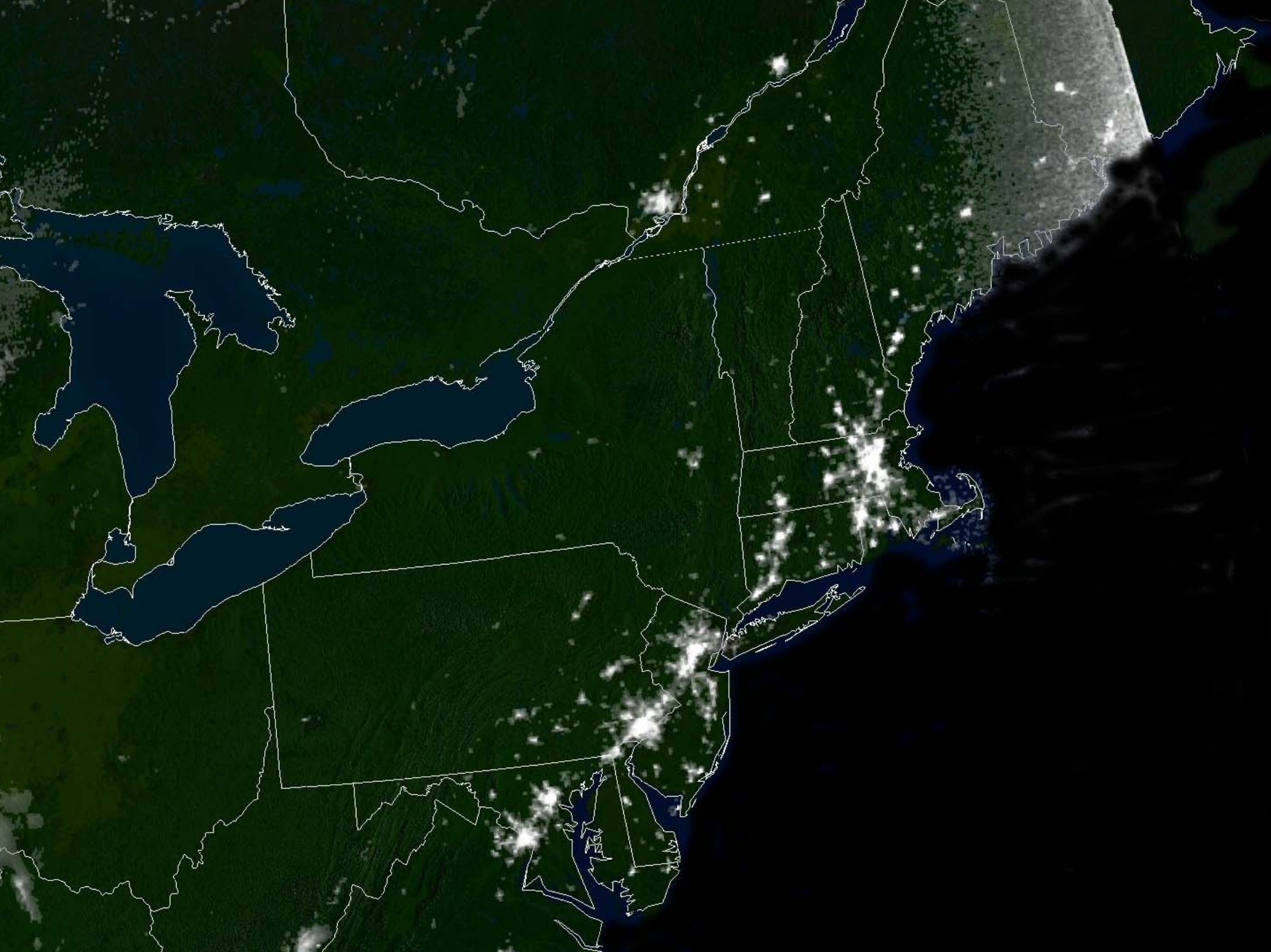


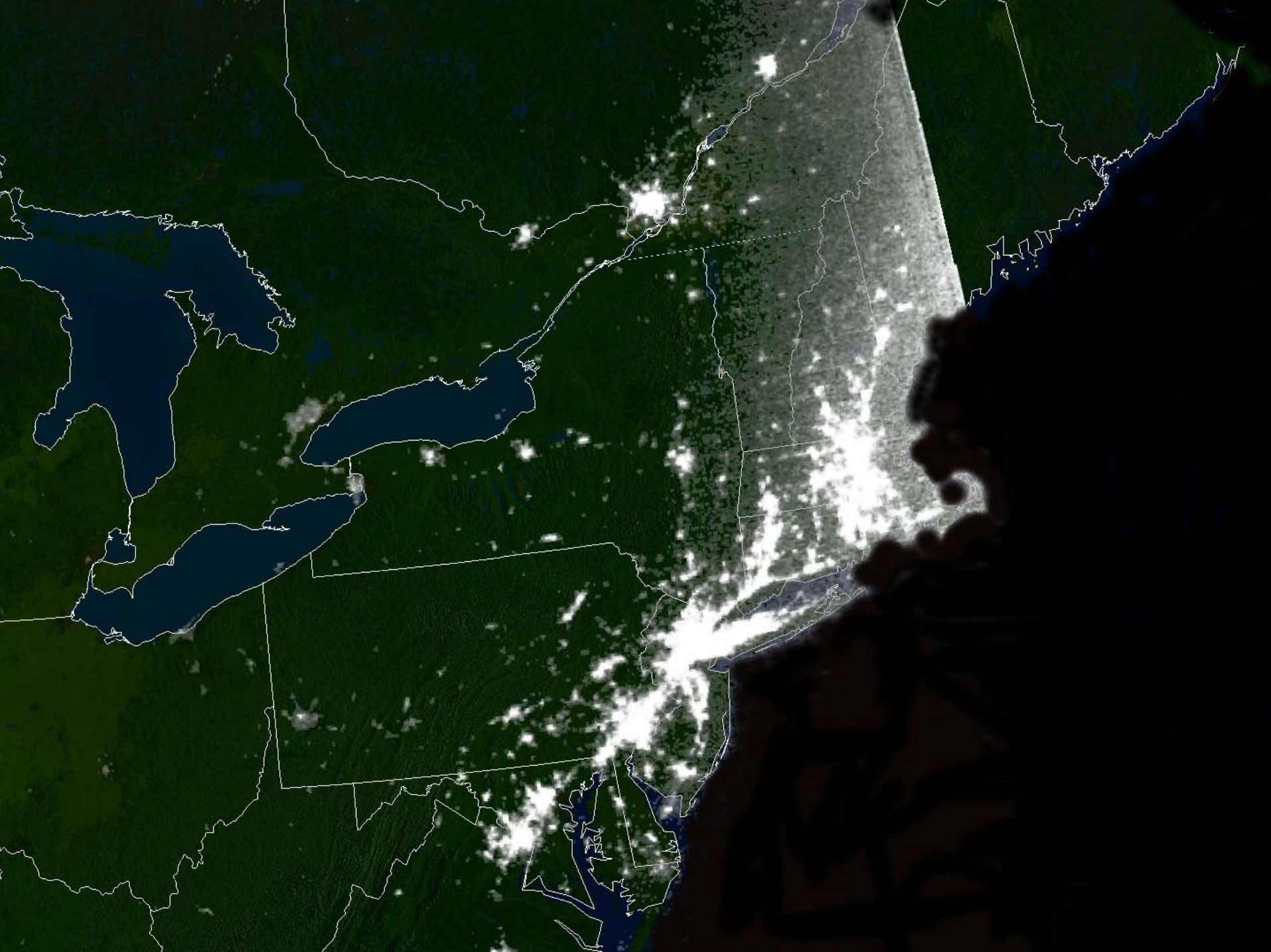
# Tokyo Electricity Demand and Solar Supply Potential



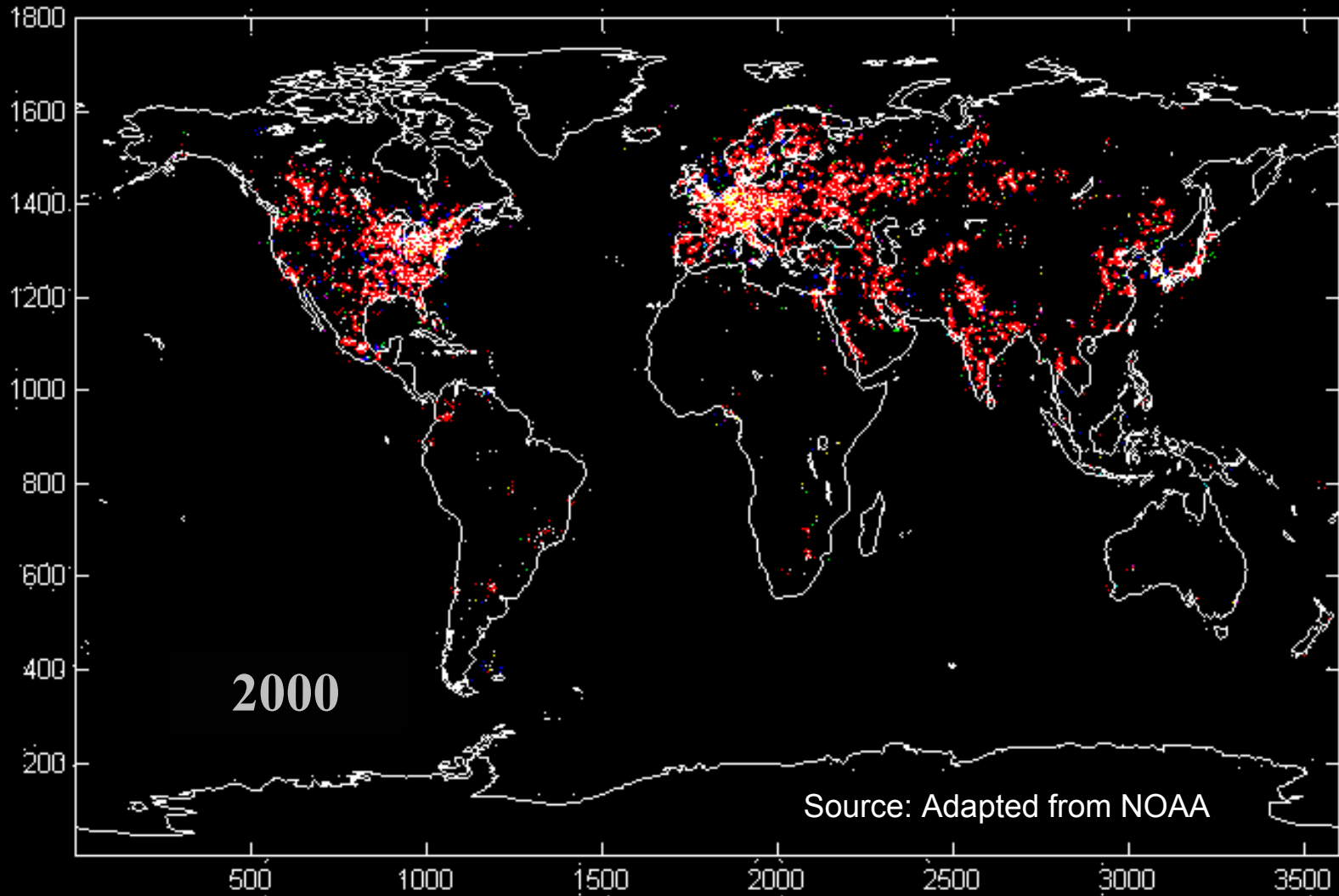
# *Let there be Light...*

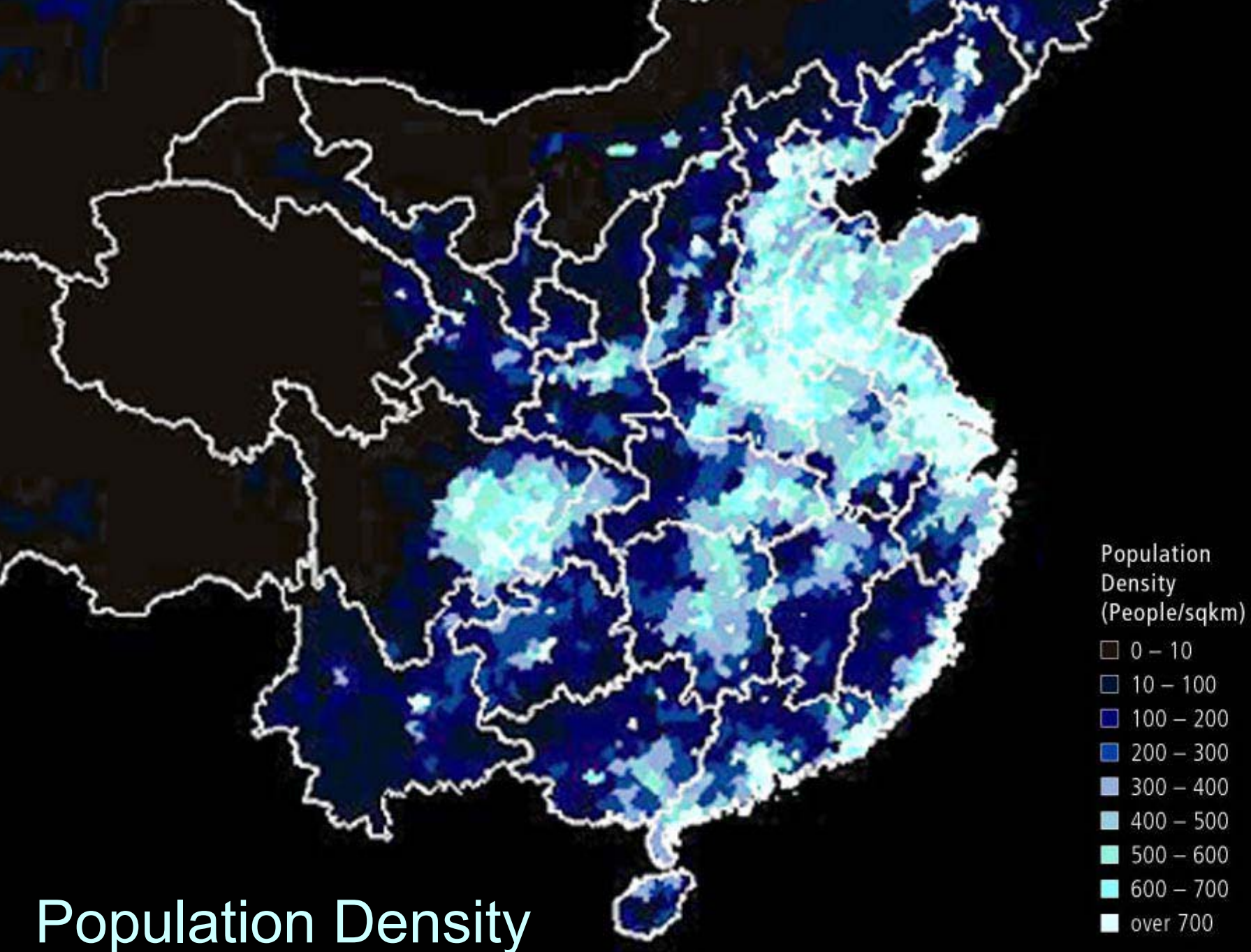
- Indicator of vulnerability (black-outs)
- Show potential demand  
(combined with socio-economic data)
- Formal modeling (high correlation with GDP and electricity use)
- Simulating (spatially explicit) futures



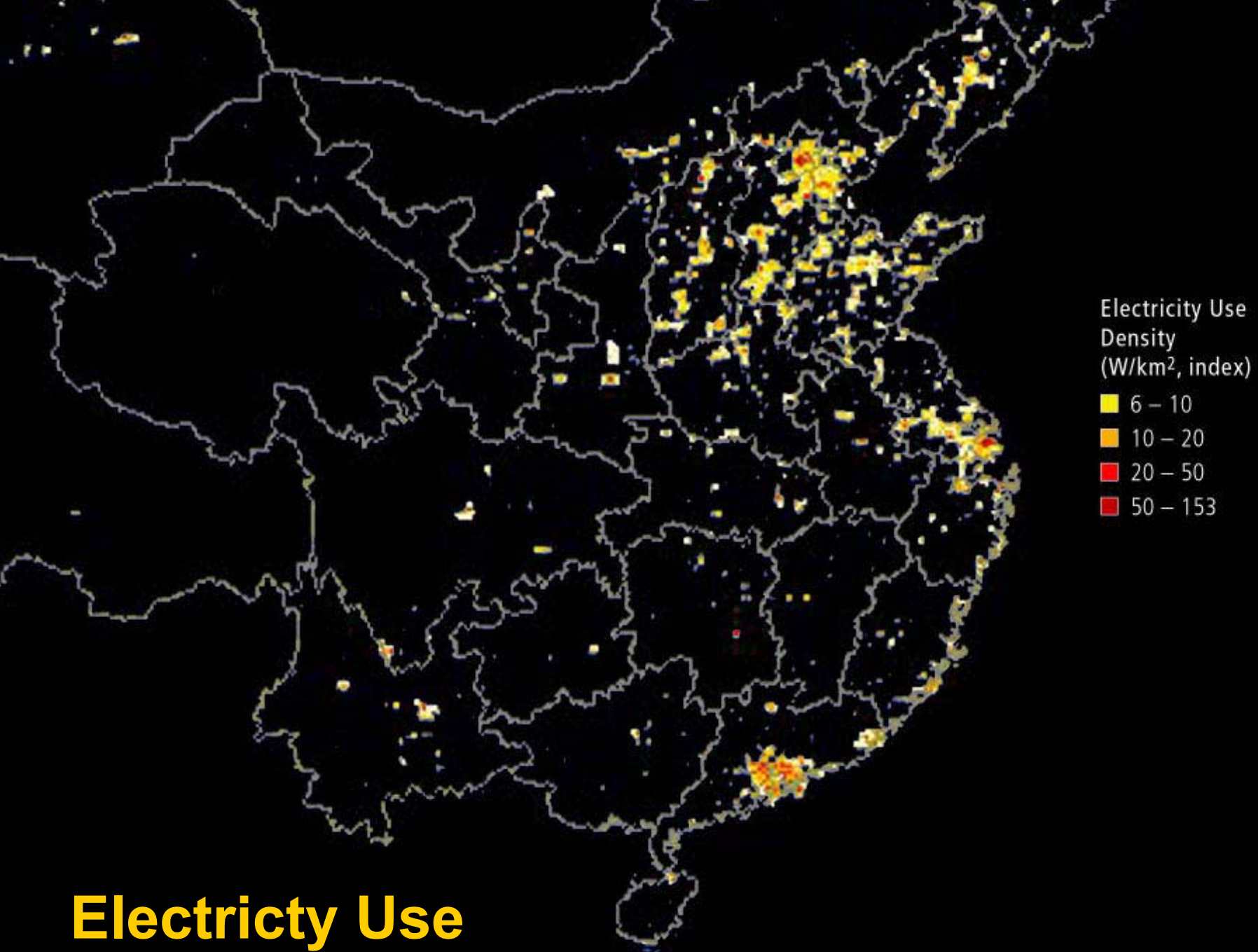


# Night Luminosity Map



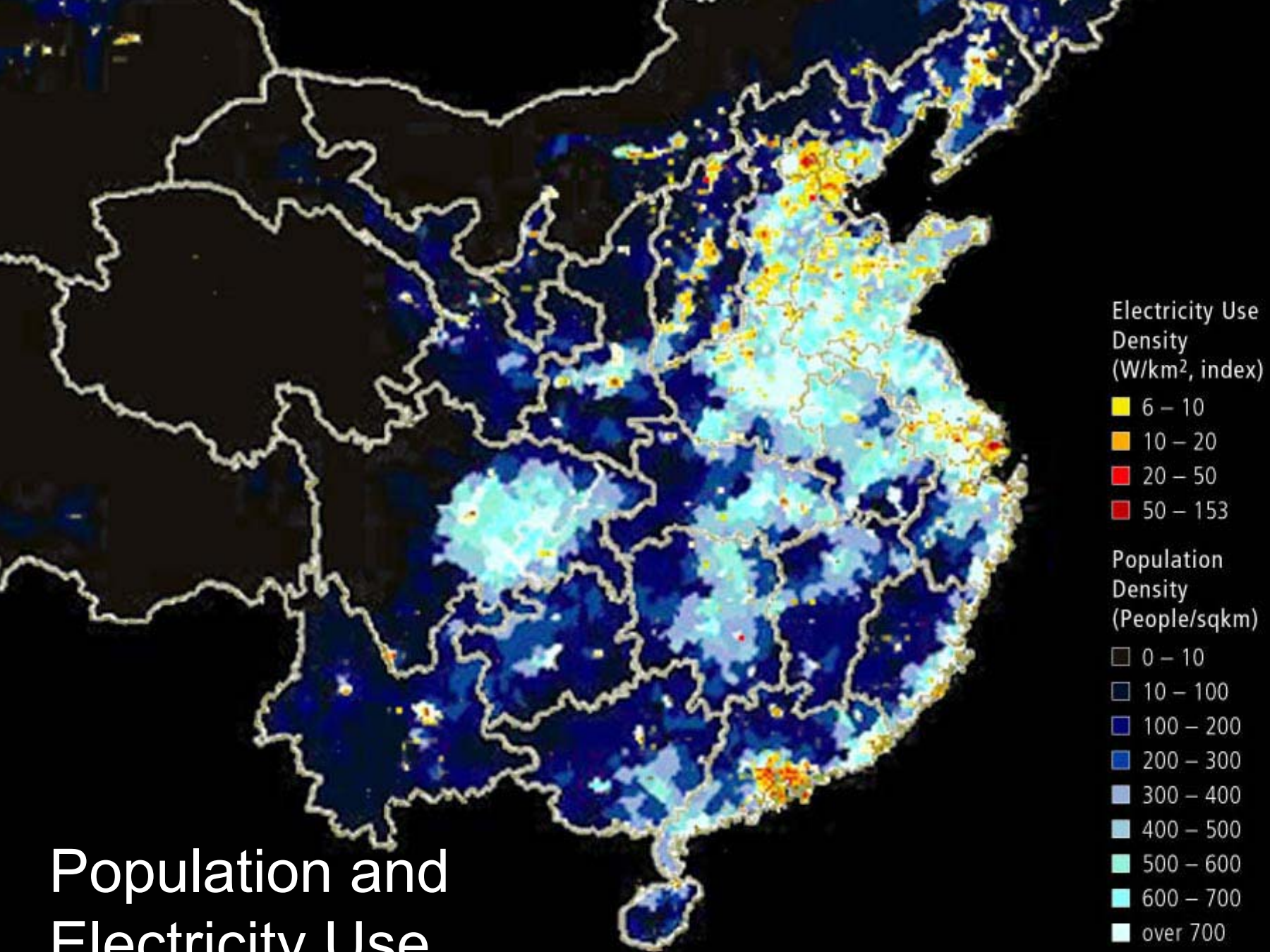


Population Density



**Electricity Use**

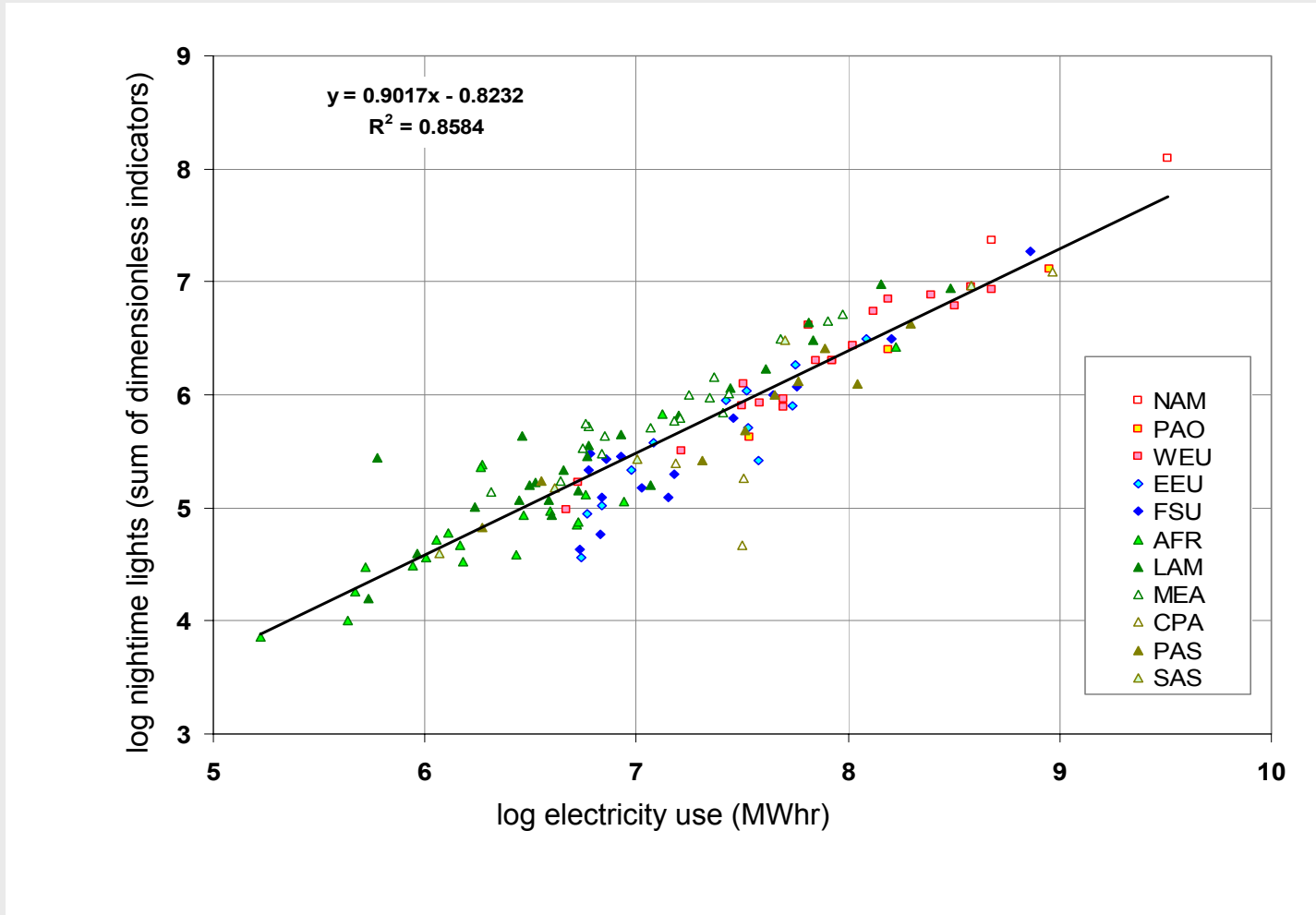




# Population and Electricity Use

# Nighttime Lights vs. Electricity Use

for 135 countries by region in 1996

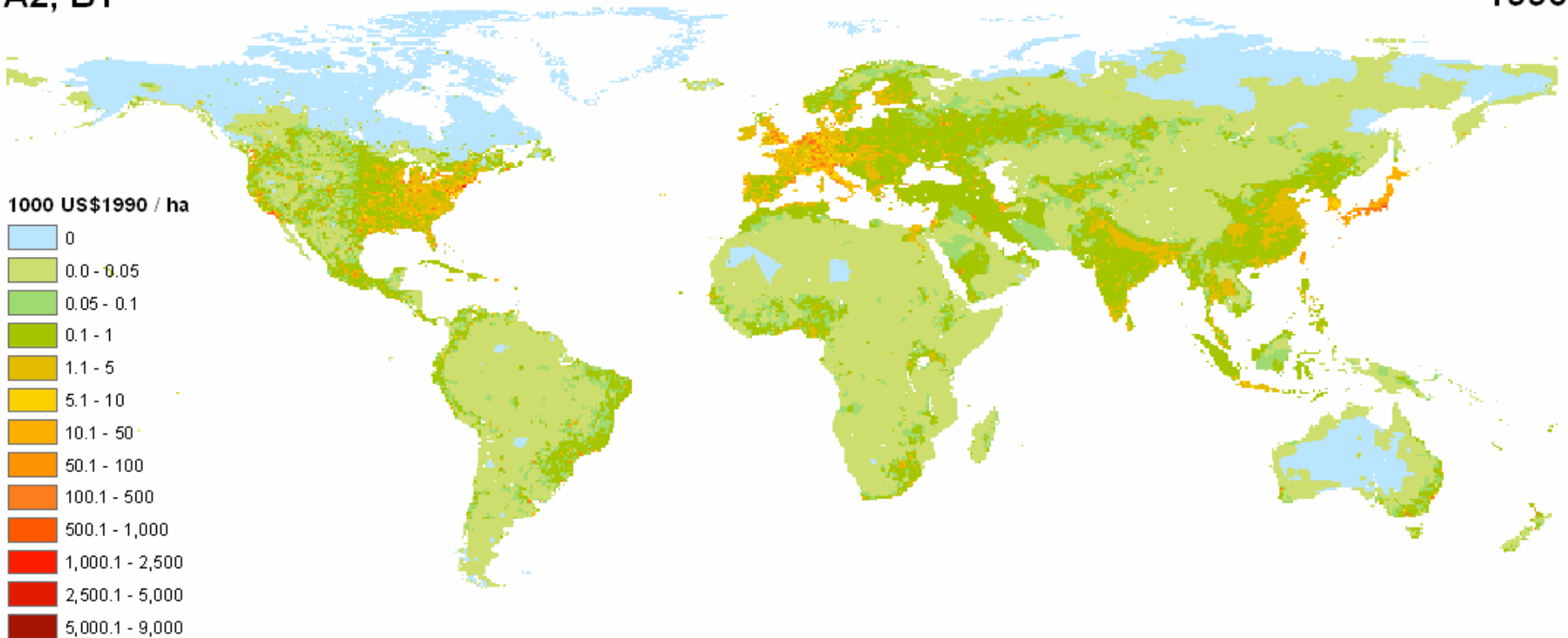


# Electrification Scenarios

(using GDP as proxy indicator)

A2, B1

1990

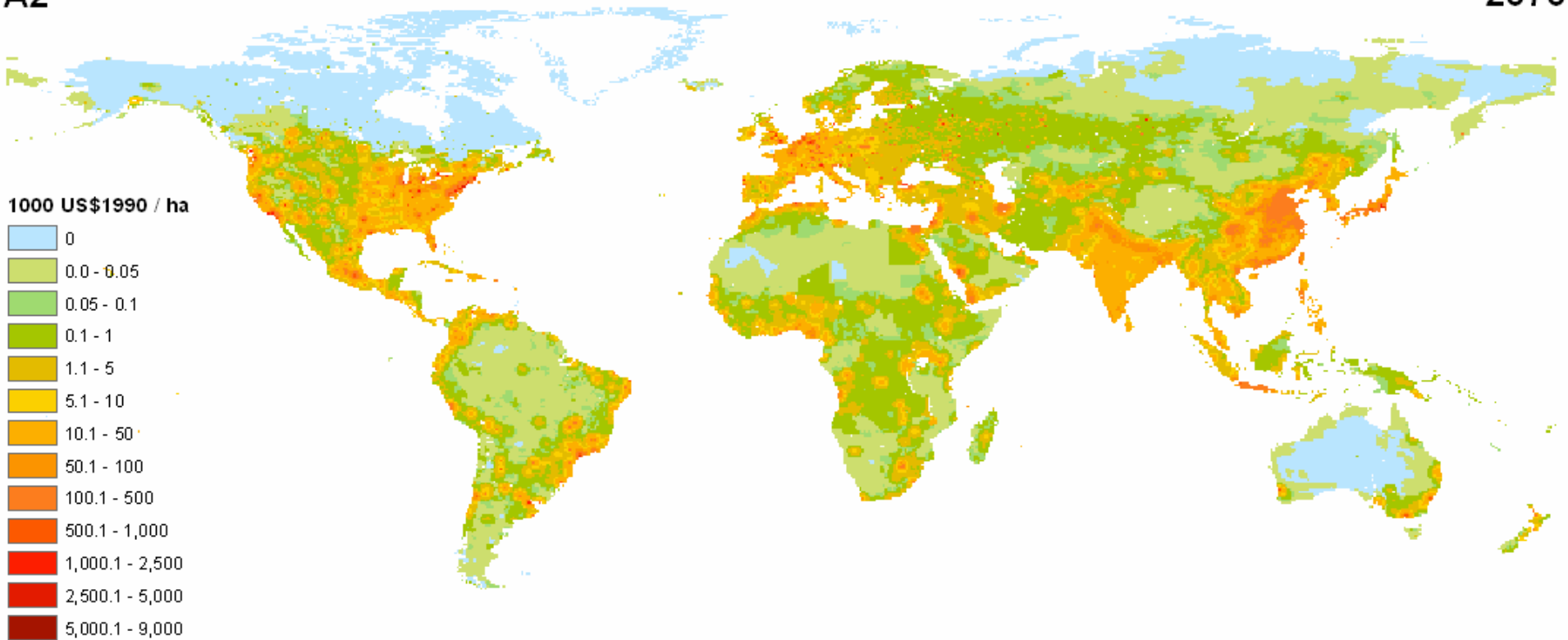


# Electrification Scenarios

(using GDP as proxy indicator)

A2

2070

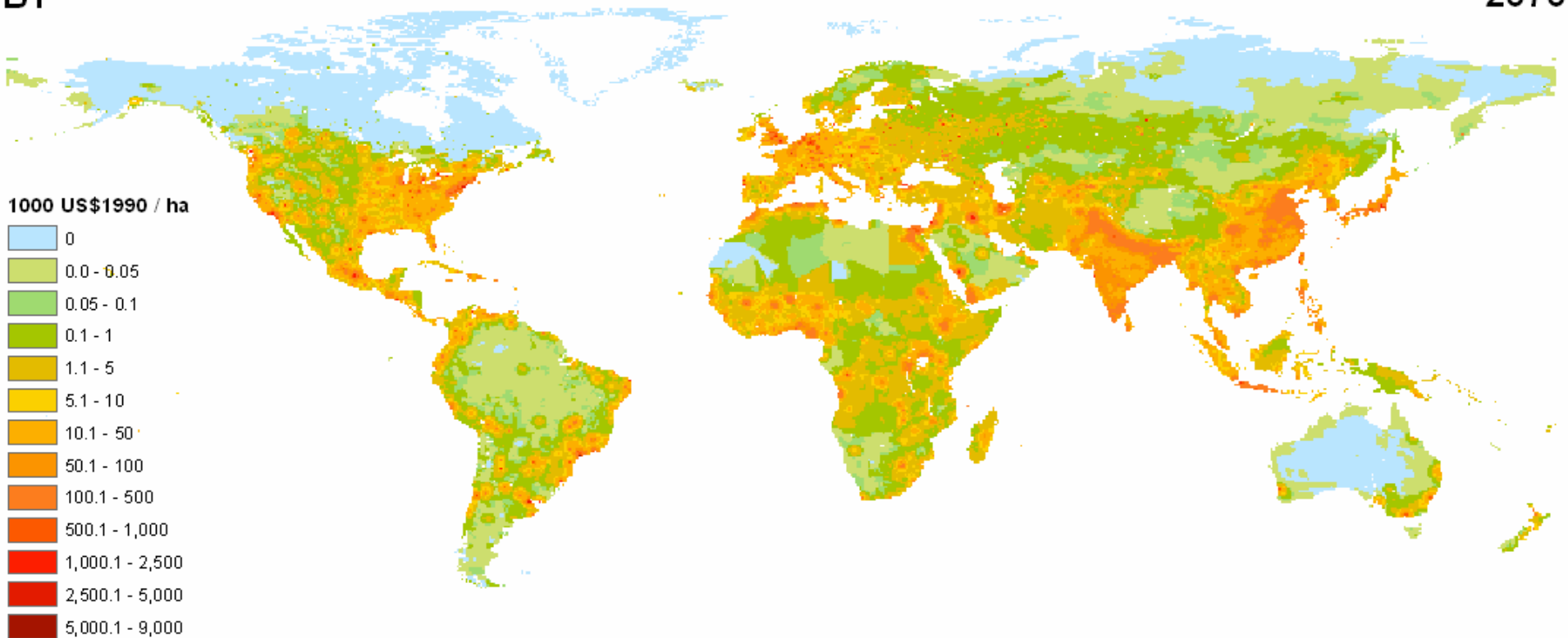


# Electrification Scenarios

(using GDP as proxy indicator)

B1

2070

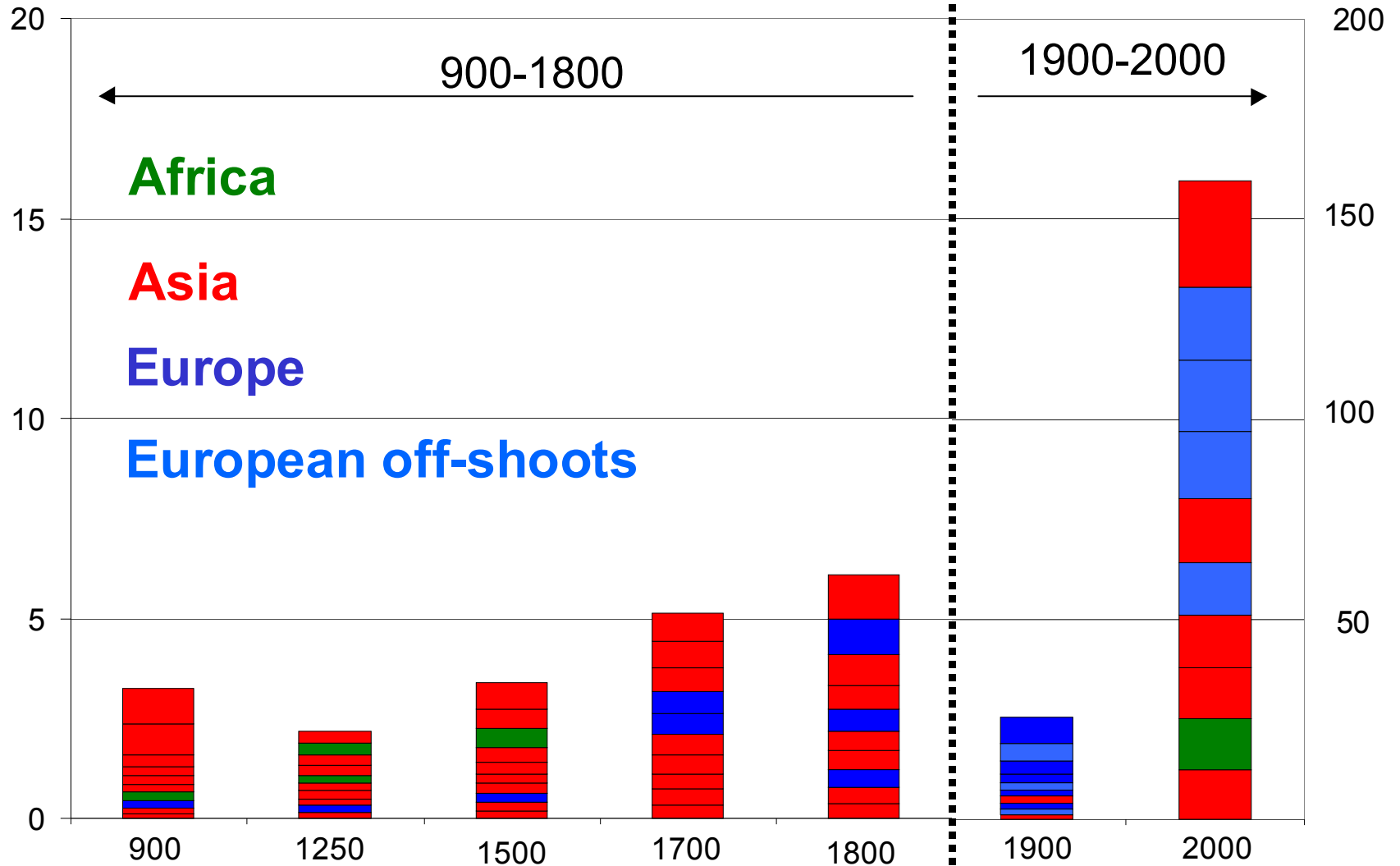


# From Mega- to Gigacities

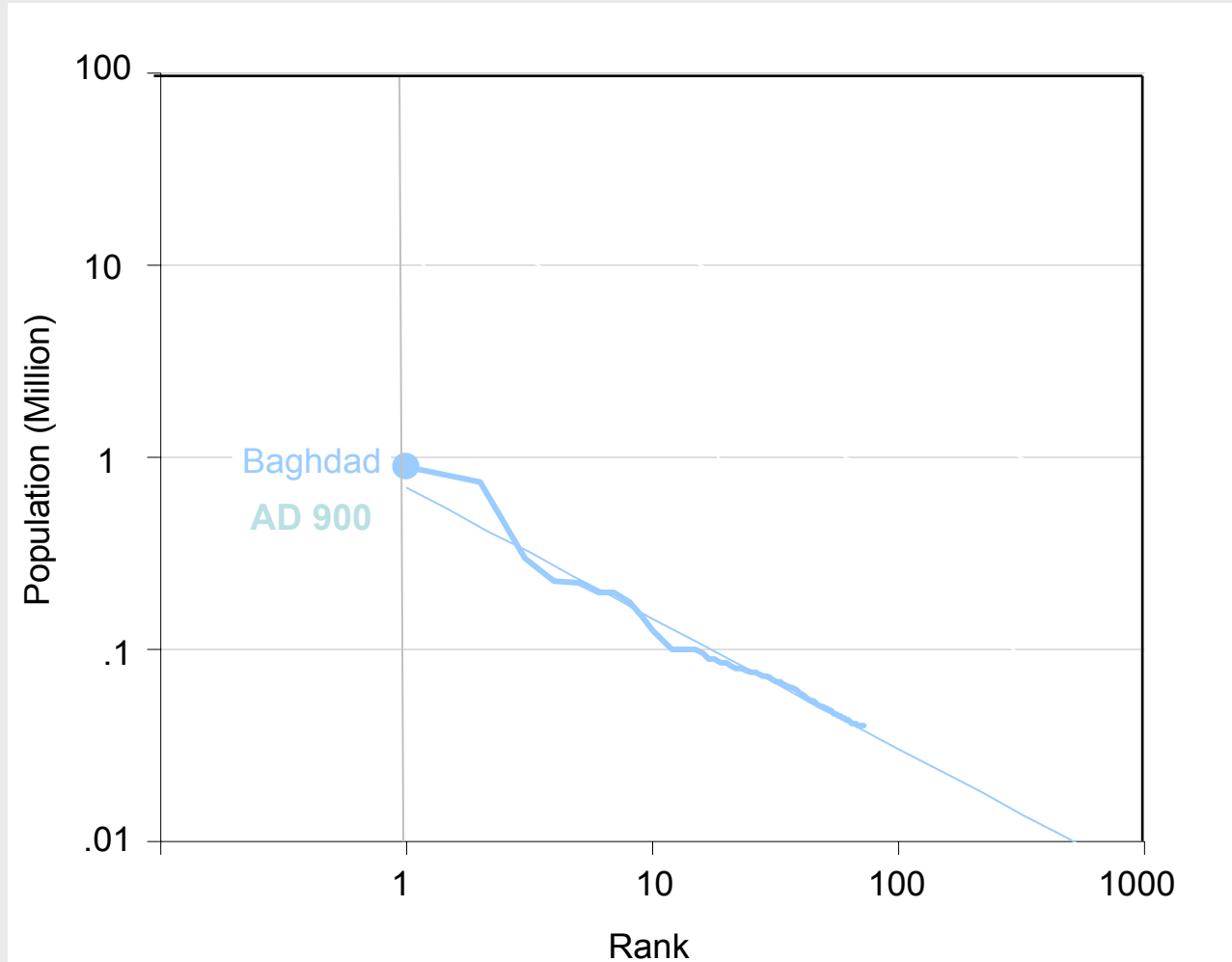
- Hierarchies in city size: rank-size (RS, Zipf)
- Stability of RS since 1000 AD
- Pre-1700: Max. city size: <1 Million (few stars, most in Asia)
- Post-1700: Max size: <10 Million (many stars, most in Europe+”offshoots”)
- Post 1900: Emergence of city clusters <100 Million (urban galaxies, dominance of Asia)
- Possible discontinuity in 2070 (demographics of declining population, Europe & China)

# 10 Largest Cities AD 900-2000

Data: T. Chandler, 1987; UN, 2003.

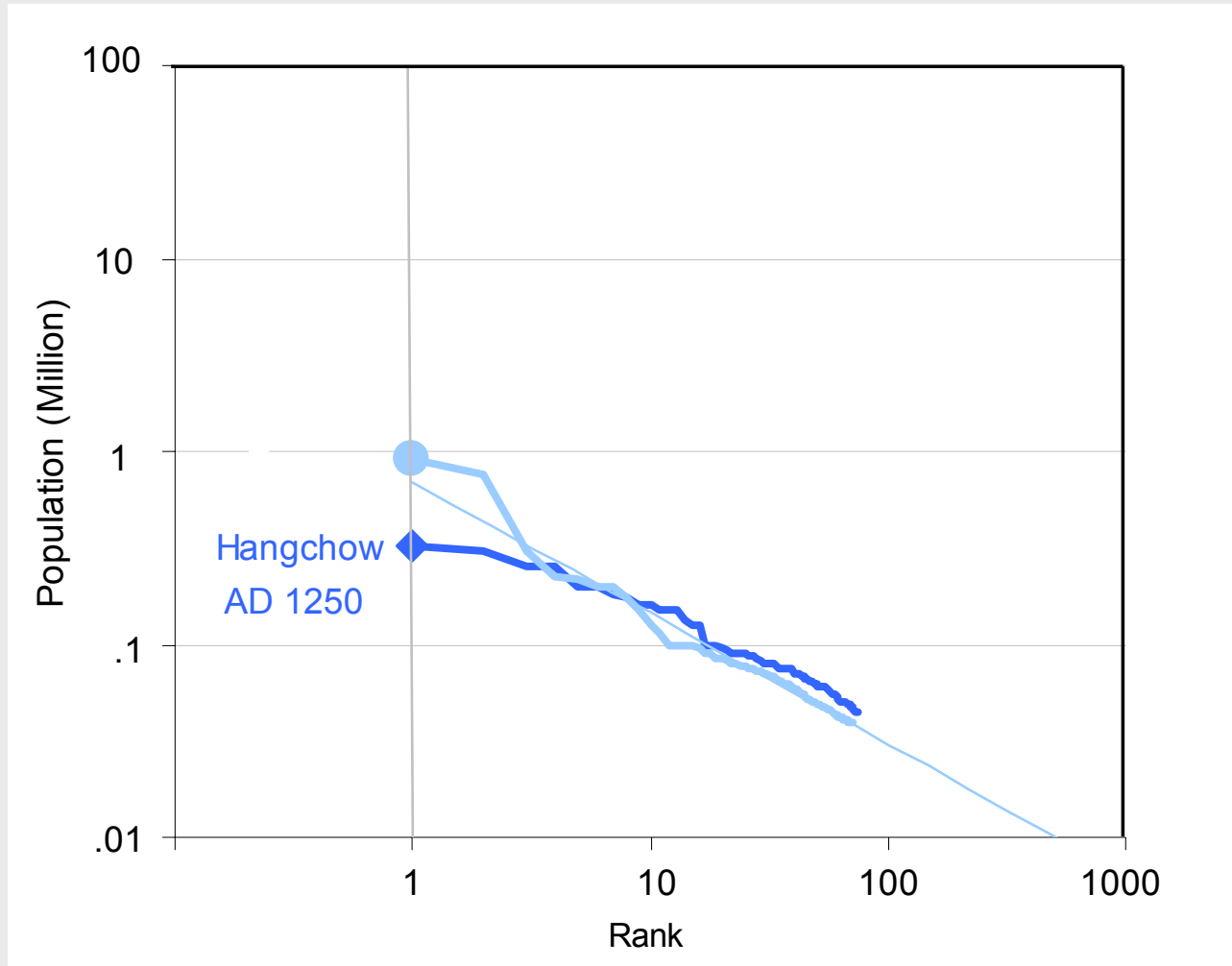


# City Hierarchies (Rank Size)

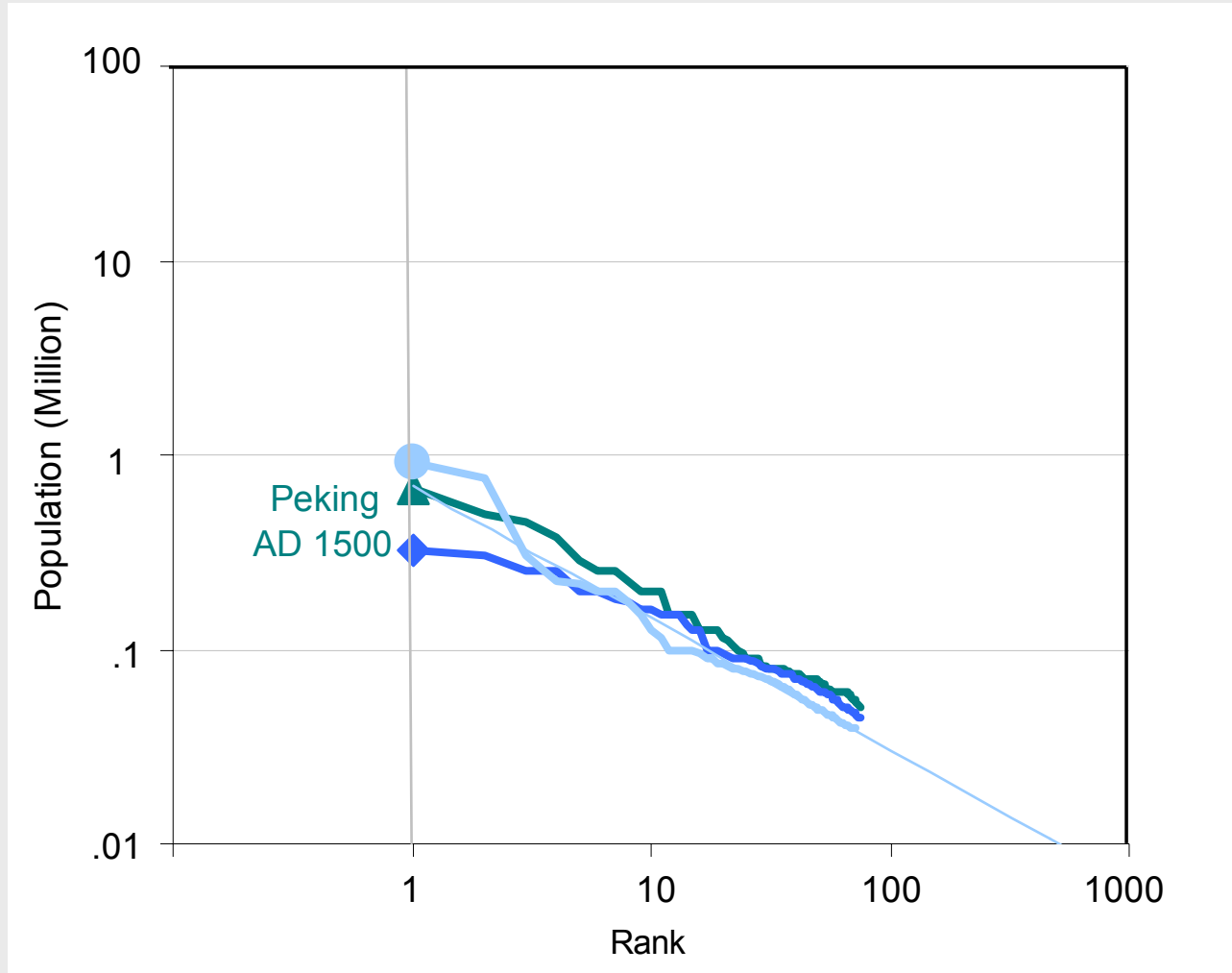




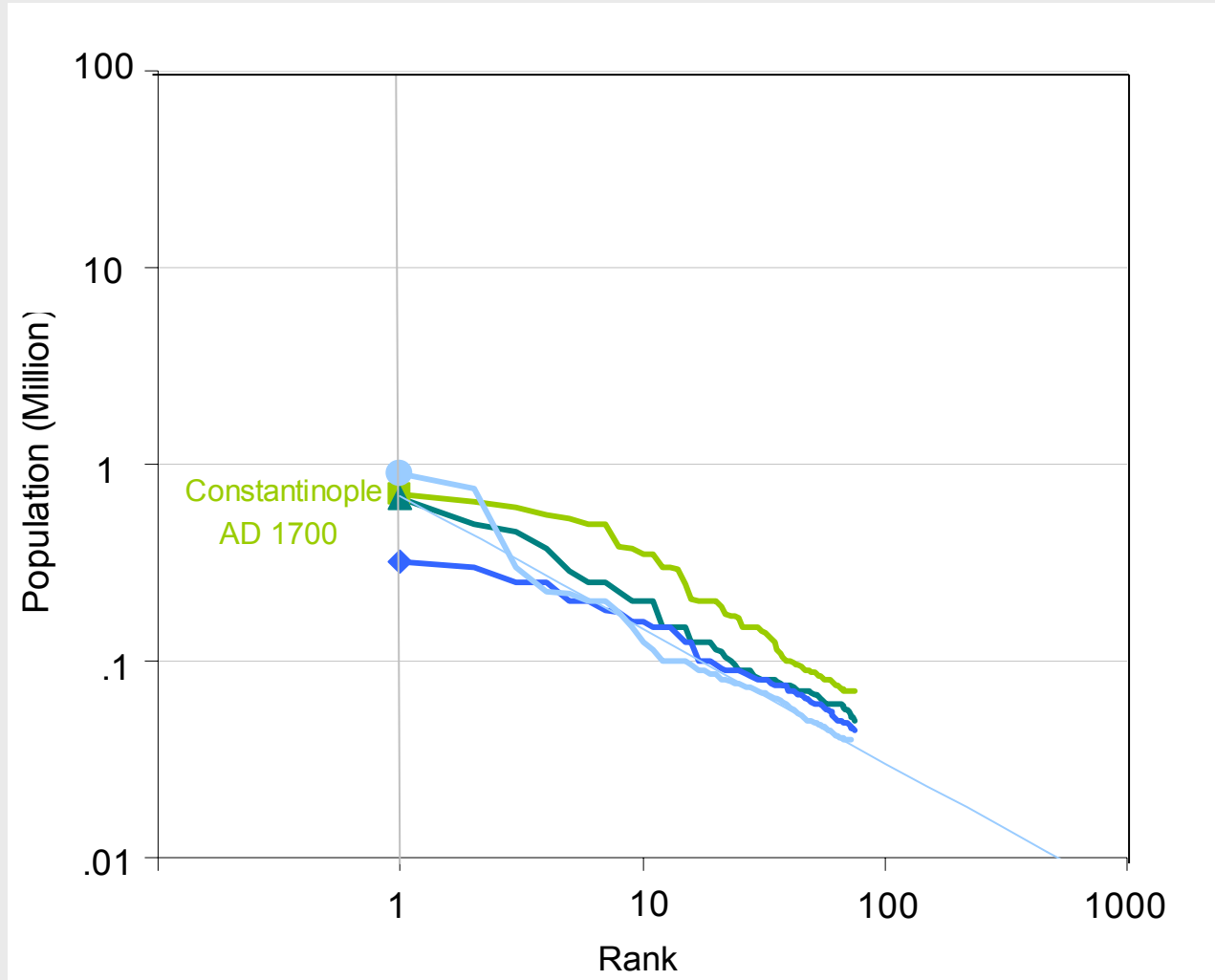
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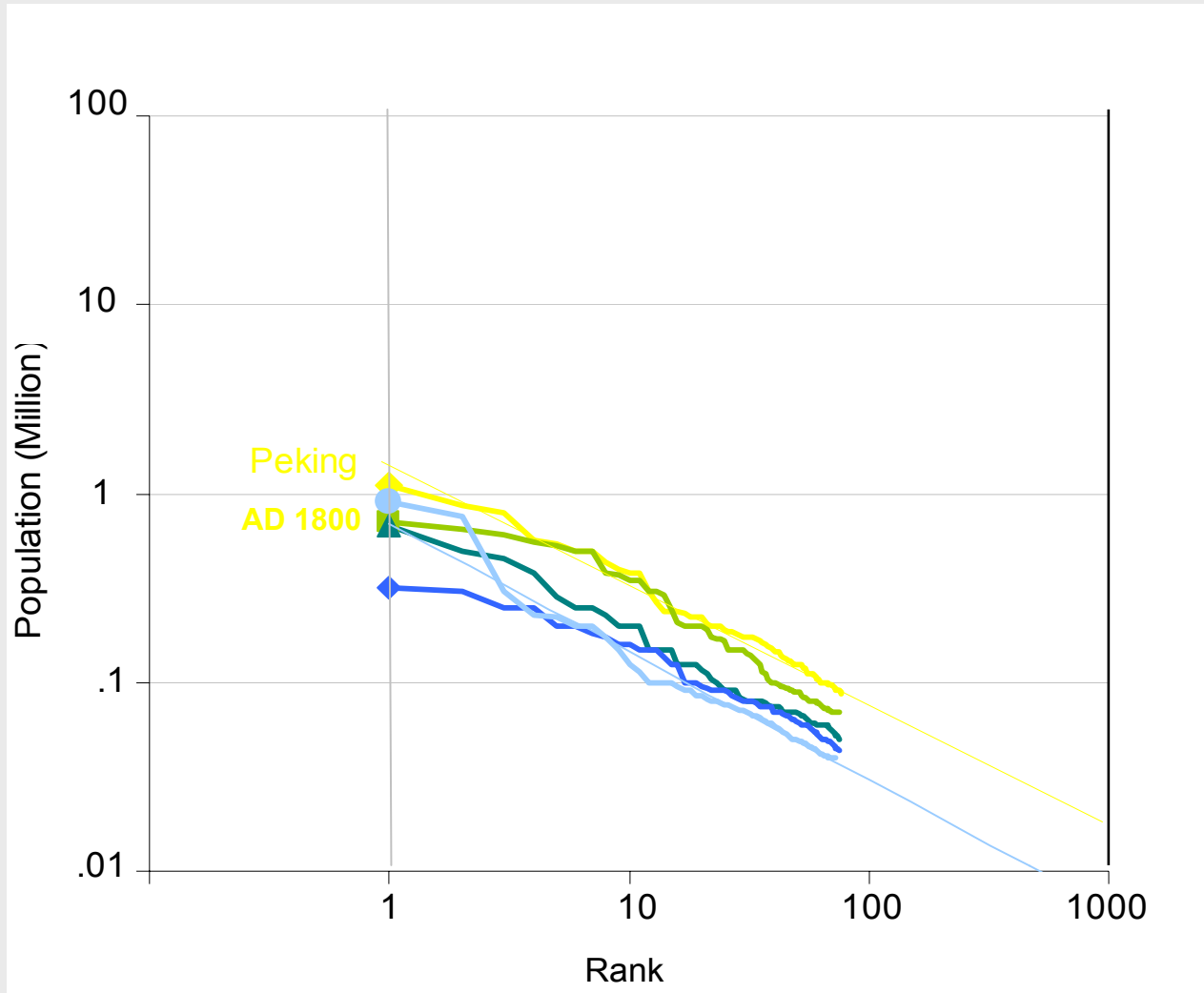
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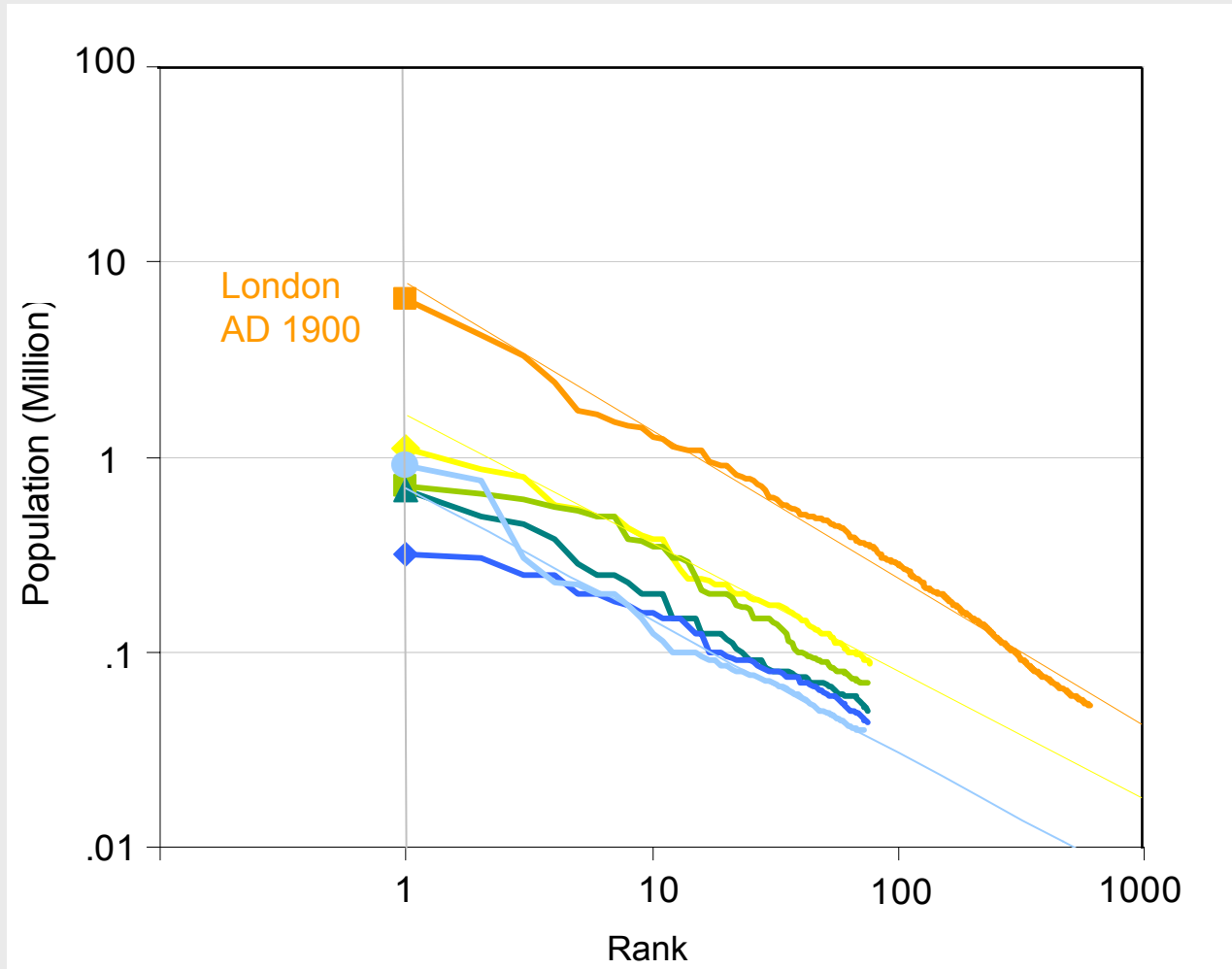
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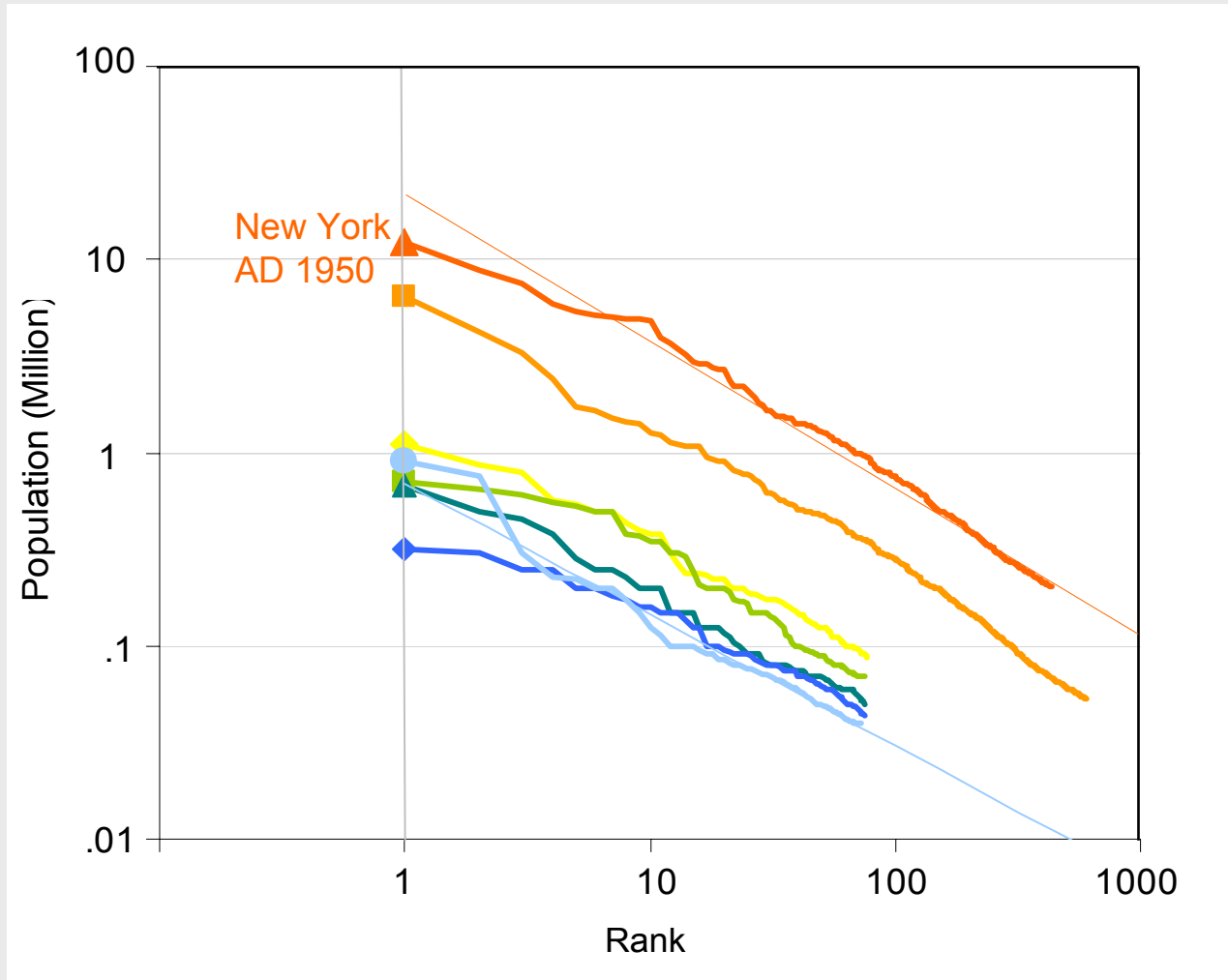
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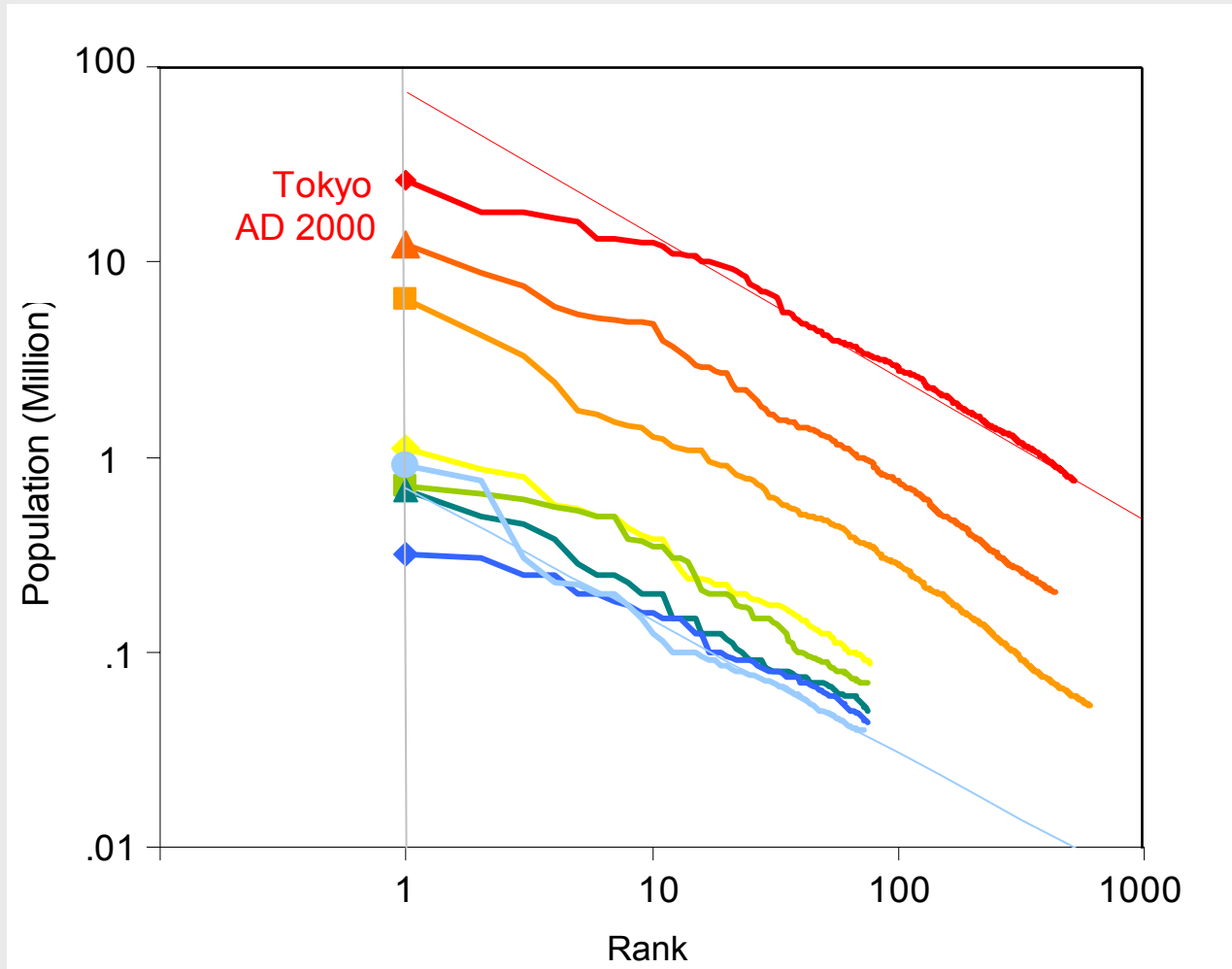
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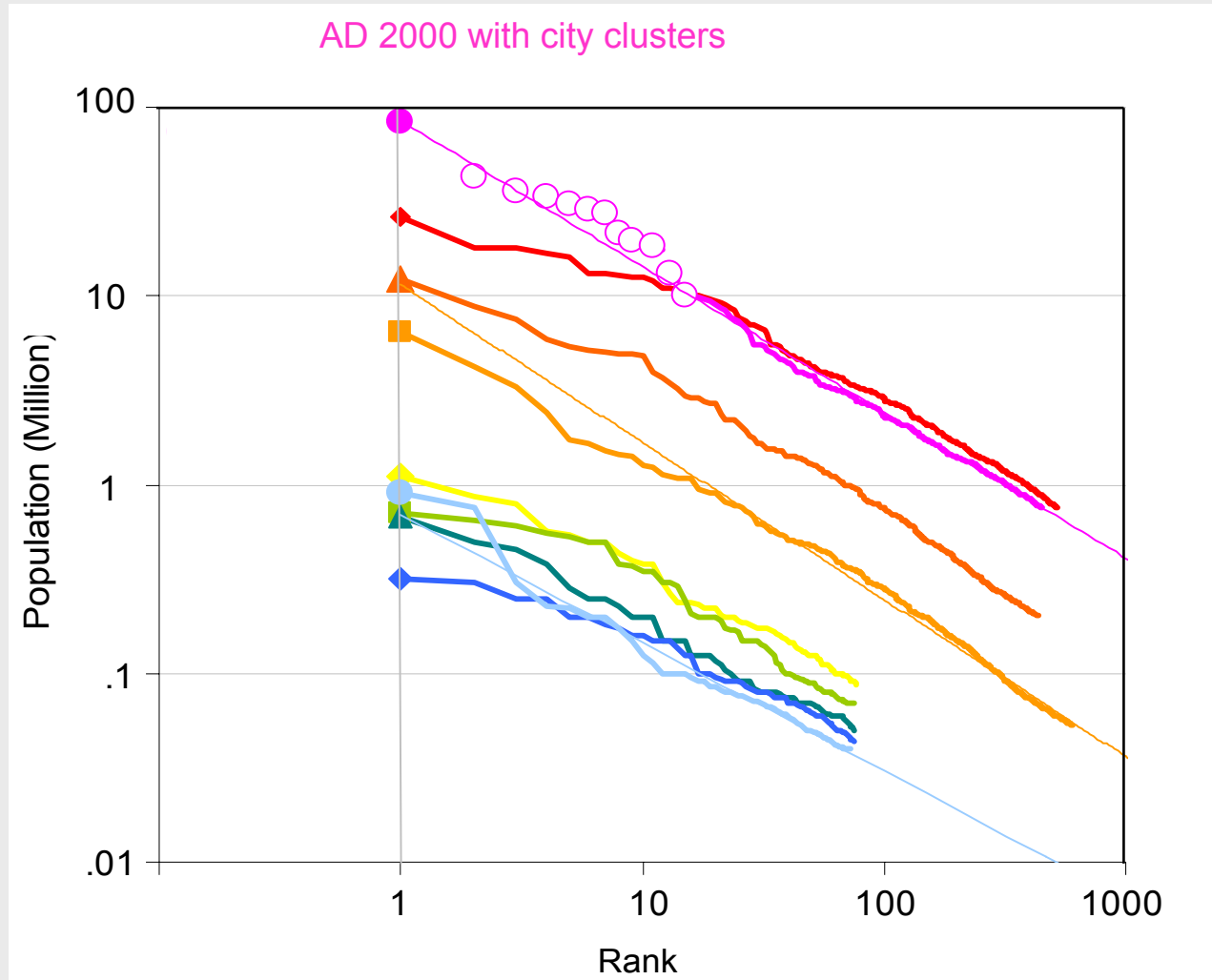
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