

New Frameworks for Urban Sustainability Assessments: Linking Complexity, Information and Policy

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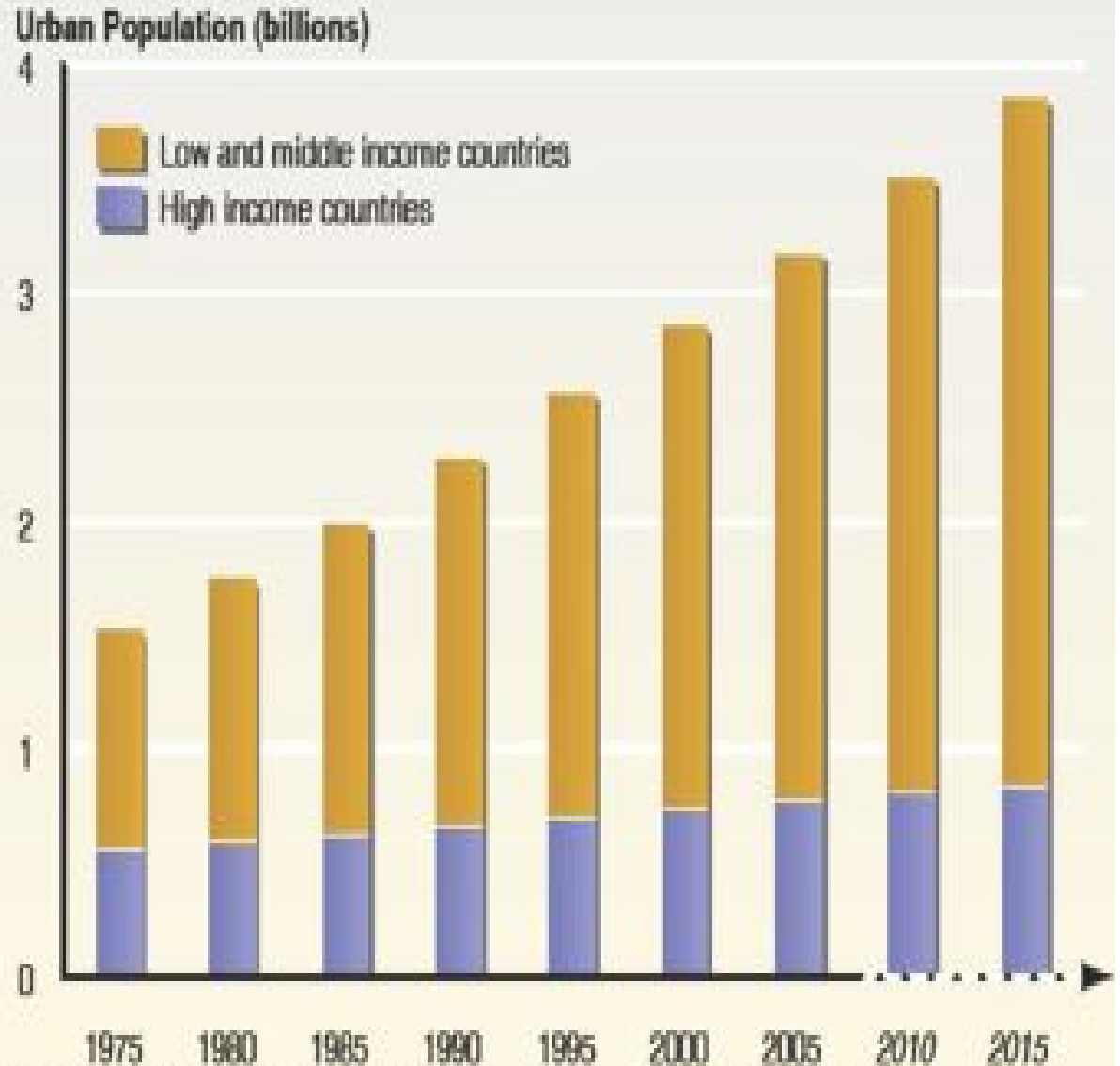
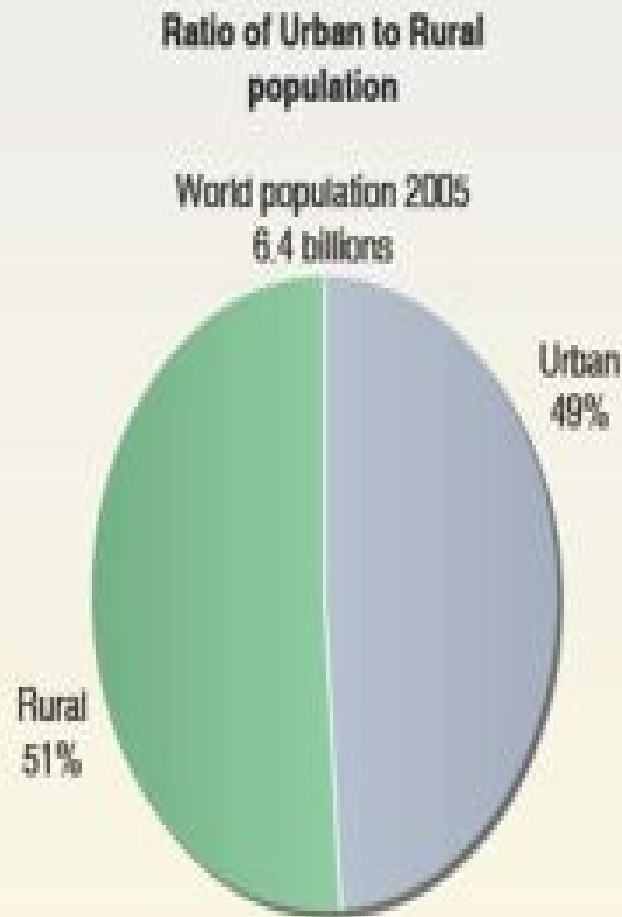
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Why Worry about Urban Regions?

- About half of the earth's population now lives in urban regions (75% in developed countries)
- Global urbanization continues to increase at a rapid rate
- Cities, in aggregate, are large consumers (of materials and energy), but also large producers of capital, employment, goods, and services
- Urban regions have unique and complex problems in need of solution (e.g. infrastructure renewal, care of their populations, congestion, social equality)

Urban population: status and trends



Sources: Food and Agriculture Organization statistical databases (FAOSTAT); Country income according to World Bank 2005.

Urban Systems

- Are complex, usually self-organizing systems that exhibit “emergent behavior”
- Established essentially for economic reasons
- Grow in proportion to the economic surplus that they are able to capture
- Consist of layers of financial, infrastructure, material (stocks and flows), energy and information transfers that operate at spatial scales and evolve over time
- Serve as the home of millions who dwell there, each seeking to attain his/her aspirations

An example: Chicago

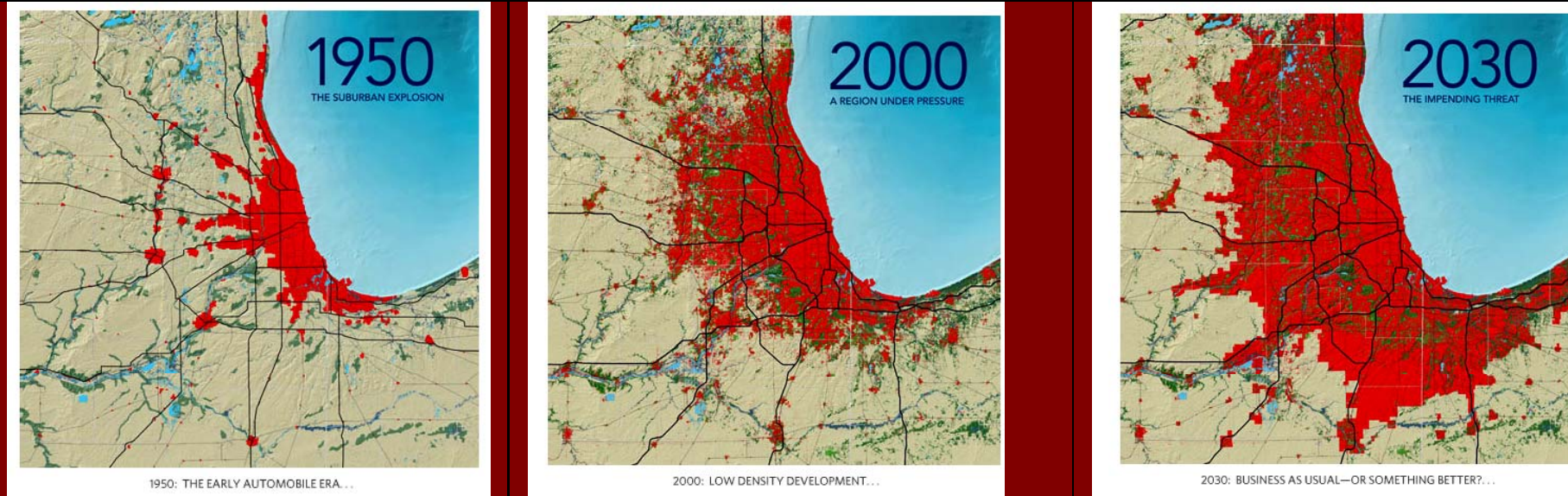


Figure 1. Urban growth in the Chicago metropolitan region. (Source: *Revealing Chicago: An Aerial Portrait* by Terry Evans, a collaboration between Openlands project and Chicago Metropolis 2020)

- Projected growth based on current trends
- We plan and build accordingly
- Economic, social and environmental implications?

Two Views of Cities and CO₂

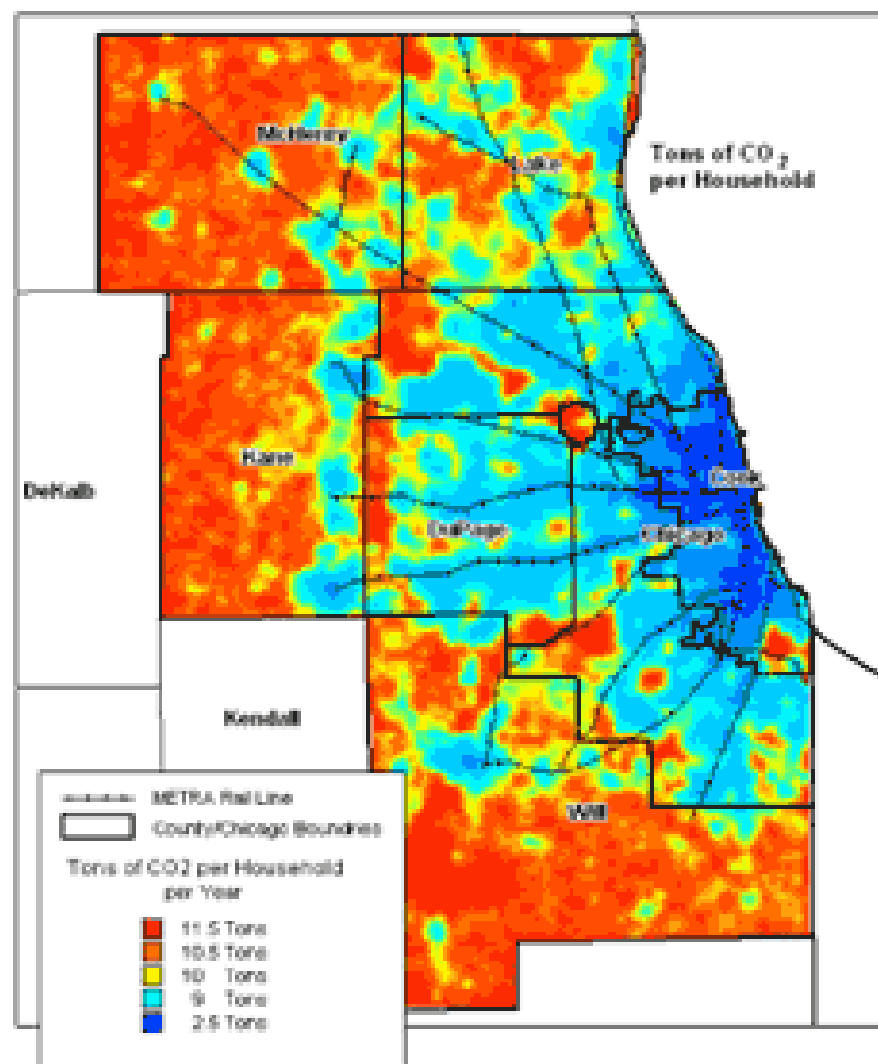
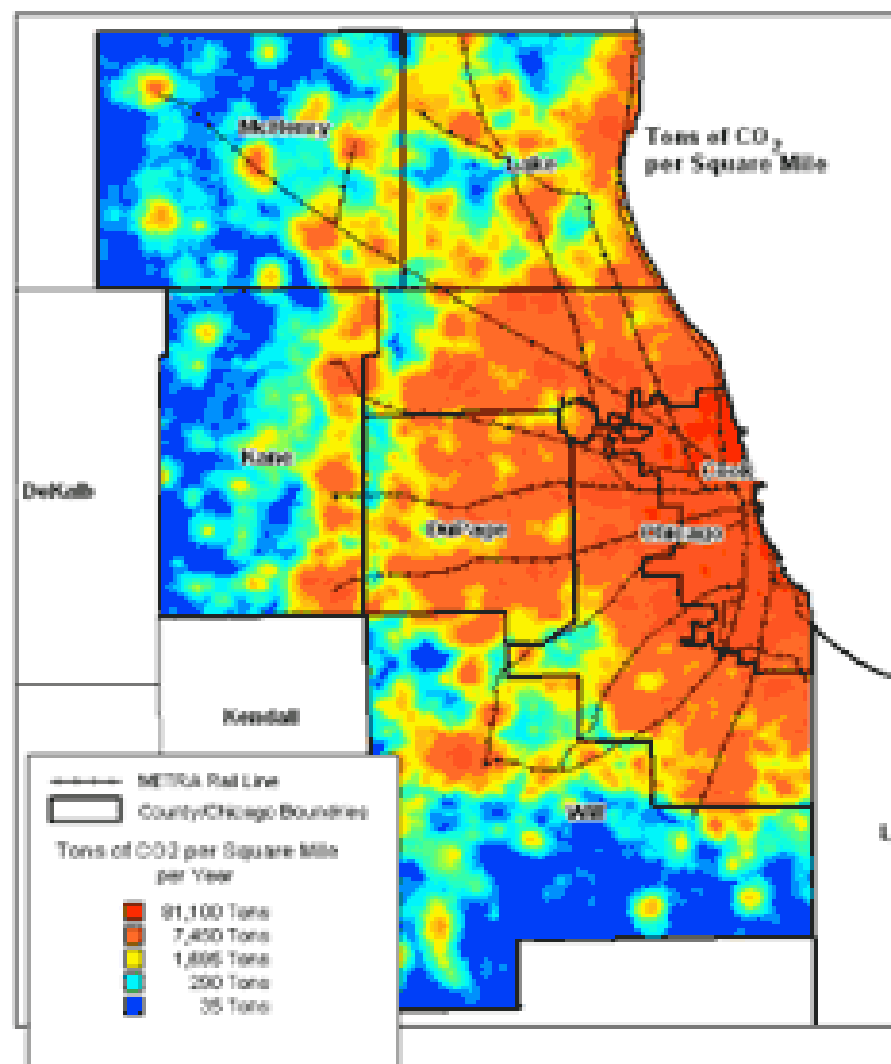
CO₂ Generated by Automobiles in the Chicago Region per Year

Traditional View:

Cities produce large amounts of GHGs.

Emerging View:

City dwellers produce relatively low amounts of GHGs.



Each color represents one fifth of the land area on each map.

Research purpose

- Questions
 - What are the environmental consequences of specific urban spatial patterns?
 - What is the relationship between “sustainability” and “livability” of urban regions, and the best policies for improving both?
 - Are there new forward-looking metrics that we should be measuring and interpreting?
- Goal
 - Develop assessment framework to test the sustainability of urban policies

Agent Based Modeling

- ABM is a modeling technique for simulating a system's behavior over time.
- It can combine time, space, and identity into a single universe.
- A bottom-up approach (i.e. from micro to macro)
- Used when
 - (1) a system is at least partly regulated through interacting agents
 - (2) the system is **complex**
 - (3) it exhibits **emergent properties**

Complex systems

A system is a collection of parts that function together. Complex systems usually have certain properties:

- Often composed of many parts
- Relationships among at least some parts are non-linear and contain feedback loops
- Often have a memory (i.e. prior states may have an influence on present states)
- May be nested (i.e. complex systems may themselves be composed of complex systems)
- Behavior over time is often difficult to predict.

Emergent Behavior

Emergent behavior is that property of a system that is observed when structures and patterns develop from micro-level interactions. The emergent behavior cannot be predicted by observing exclusively single interactions among parts.

Components of ABM

An ABM model consists of

- ***agents*** that independently interact on
- ***spaces*** (grids or networks) over time
- according to a ***time*** schedule determined by the modeler.

AGENTS

- In ABM, agents are *decision-making entities*.
Examples:
 - individuals (e.g., consumers, producers, developers, investors),
 - social groupings (e.g. families, firms, communities, government agencies),
 - institutions (e.g. markets, regulatory or health care systems)

Properties of agents

- Autonomous (self-activation and self-determinism based on private internal processes)
- Agents are situated in space and time (they reside in networks and upon lattice-like neighborhoods)
- Interact within the grid they live on and with other agents (i.e. agents can learn from each other), typically the nearby ones (i.e. social communication)
- Capable of evolving, allowing unanticipated behaviors to emerge. Can adapt their behavior according to the changing environment (i.e. undergo goal-directed learning)

And...

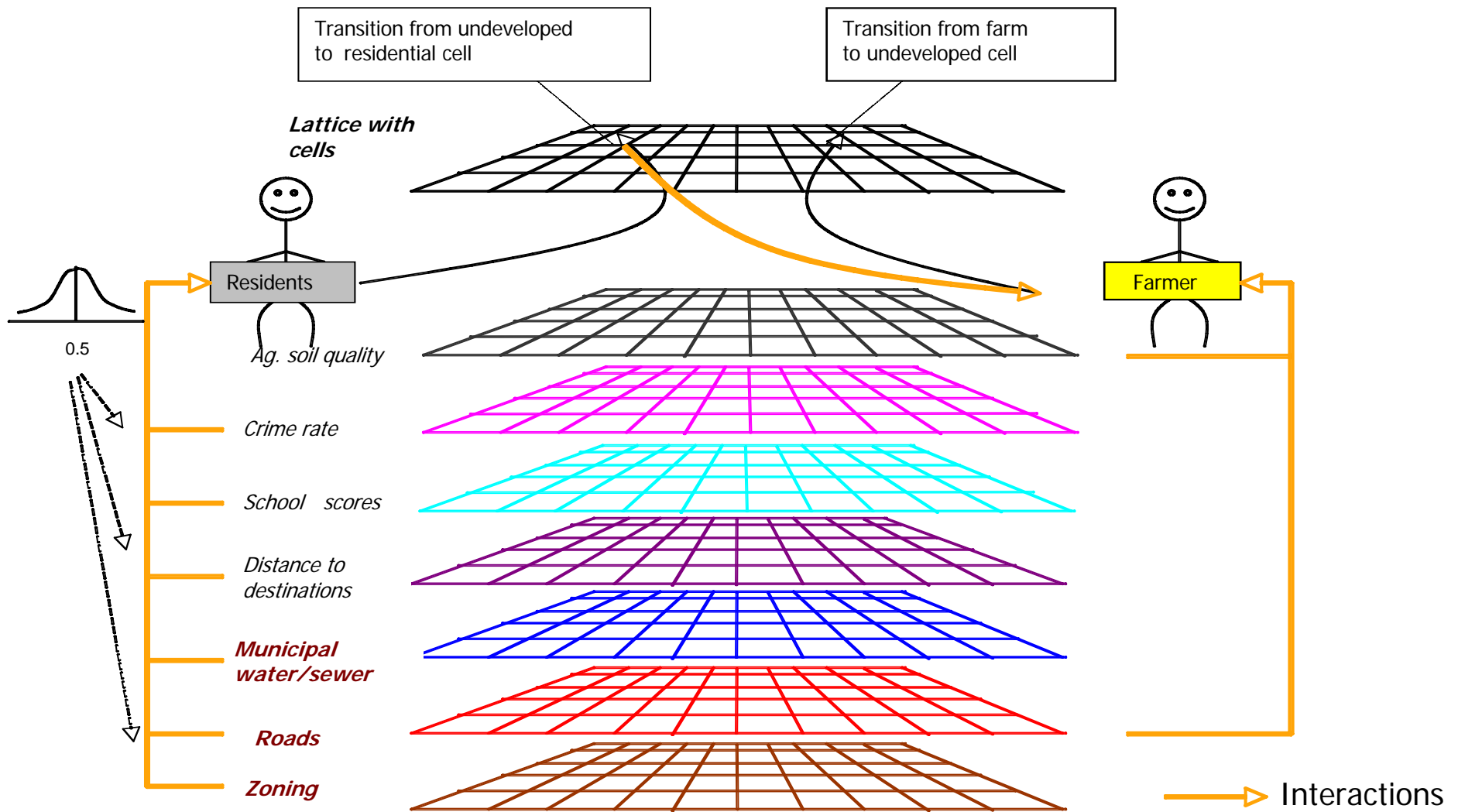
- Agents' behavior over time exhibits relational qualities (trust, status, reliability, as well as envy, irritability, and superstition)
- They are intelligent and purposeful, but ***not*** always wise

In What Does Urban Livability Consist ?

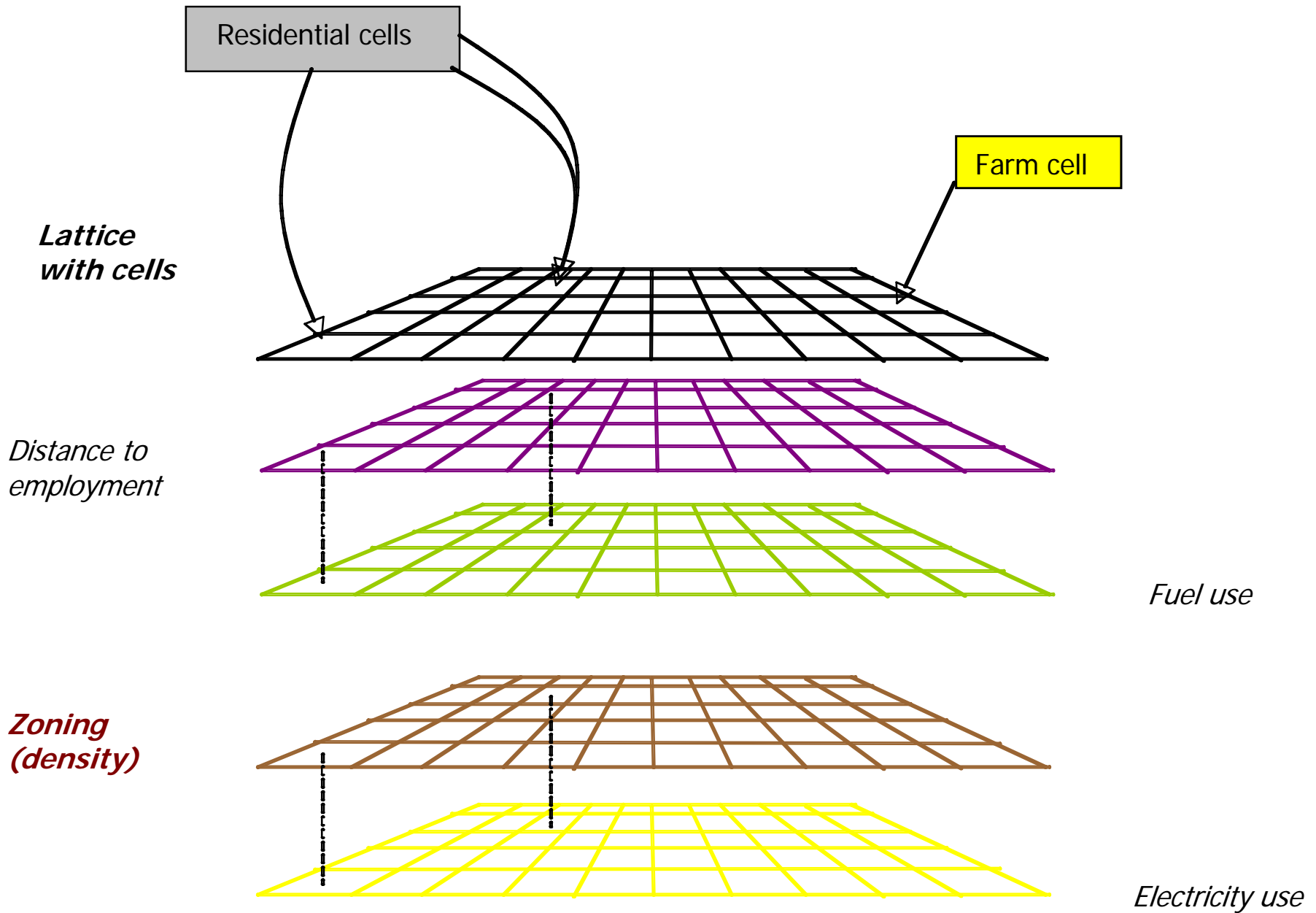
- Availability of basic resources (energy, food, materials)
- Social and environmental well-being (safety, health)?
- Centers of employment and job creation?
- Government functions (protection, legislation, planning, administration of justice)?
- Infrastructure management?
- Generation of vision, ideas and capital?
- Presence of knowledge-based institutions?
- Accessibility of the arts?
- Recreational opportunities?
- Others?

Urban Sustainability Assessment Framework for Energy: USAFE

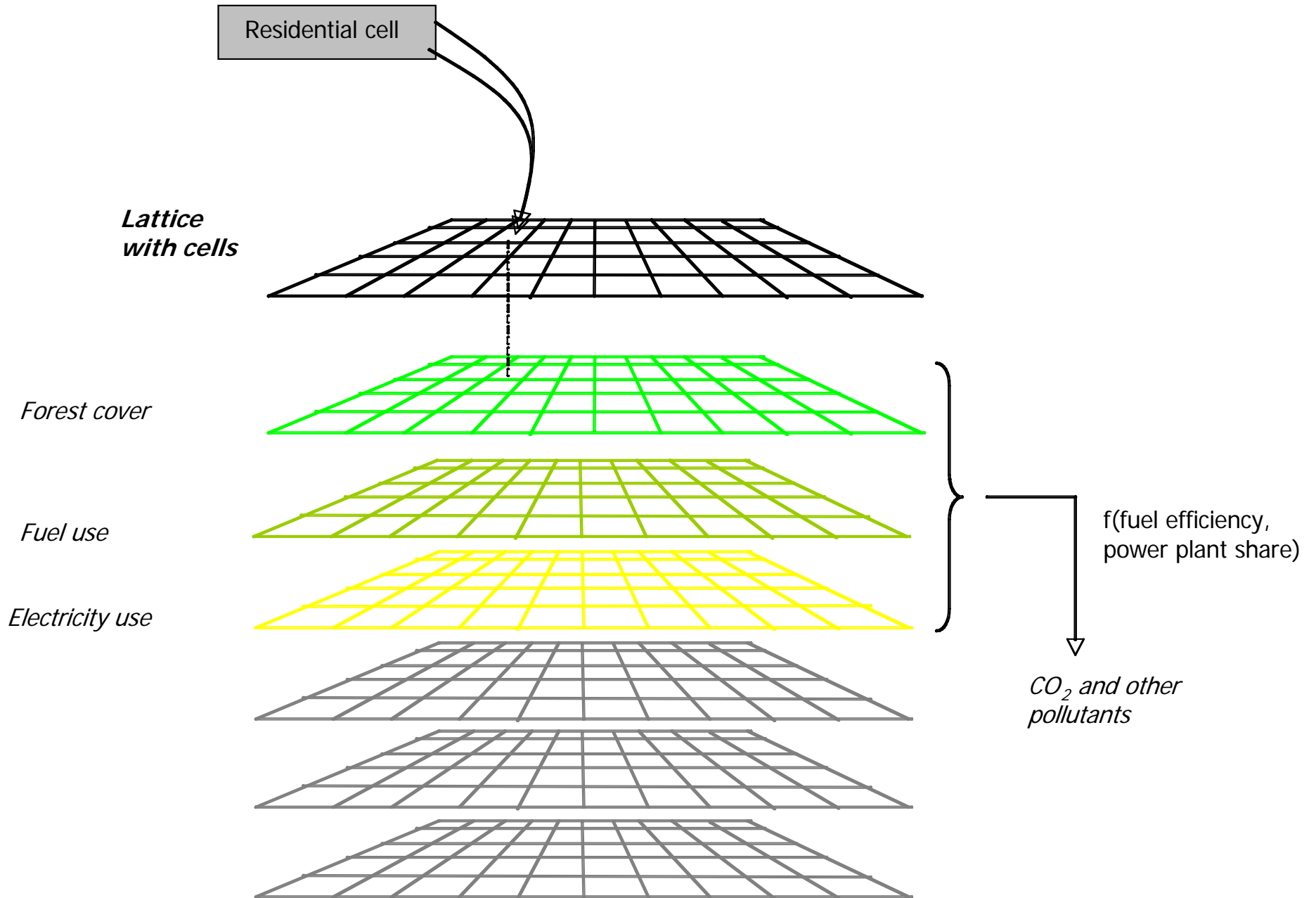
Land-use decision-making mechanisms




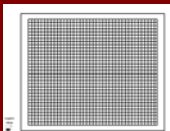





Energy consumption mechanisms: electricity and fuel



Air pollution emission



The default scenario

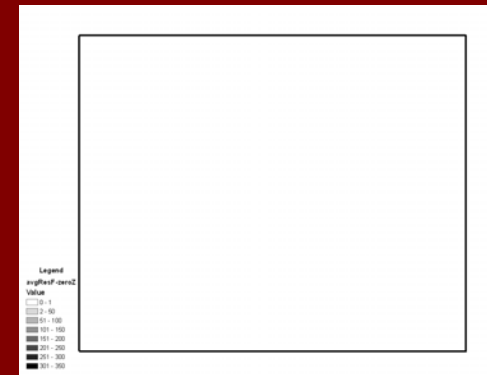
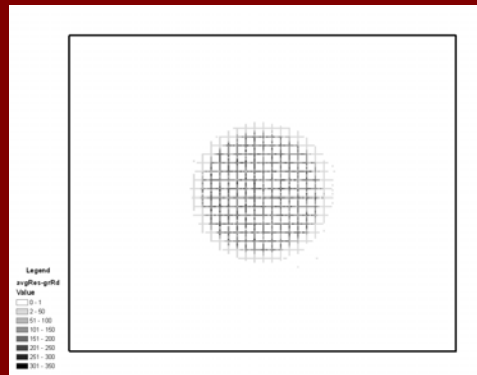
Parameters		Spatial input	
World size (cells)	200 x 166	Initial land use (farms)	
Households per time step	1000	Roads	
Undeveloped cells per time step	100	Water/sewer/septic (1)	
Mean preference value (all preferences)	0.5	Zoning (uniform_max)	
Surface of each cell (m ²)	63000.78 (~16 ac.)	Agricultural soils (0)	
Maximum energy per household (kWh/month)	1332.0	Distance to city	
Minimum energy per household (kWh/month)	555.0	School quality (0)	
Share of natural gas power plants	0.25		
Share of coal power plants	0.25		
Share of oil power plants	0.25		
Share of municipal waste power plants	0.25		
CO ₂ emission from natural gas (g/kWh)	514.82		
CO ₂ emission from coal (g/kWh)	1020.12		
CO ₂ emission from oil (g/kWh)	758.40		
CO ₂ emission from municipal waste (g/kWh)	1355.33		
Transportation fuel efficiency (miles/gal)	30.0		
Transportation CO ₂ coefficient (g/gal)	8744.611		

Minimum density zoning

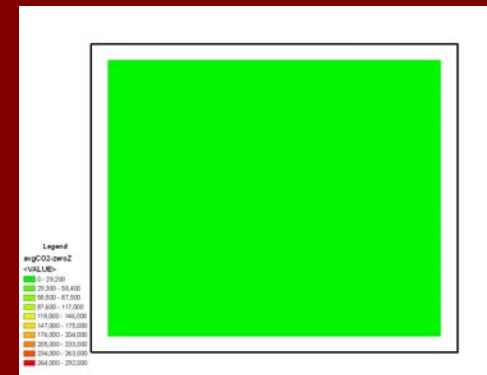
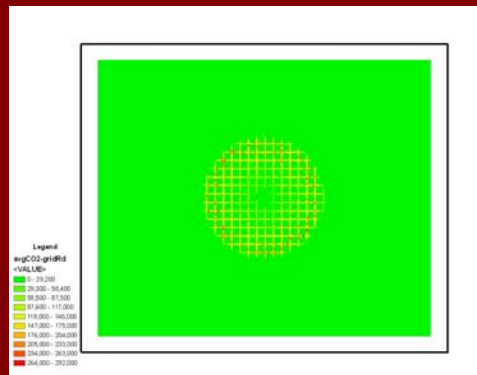
Default

Minimum density zoning

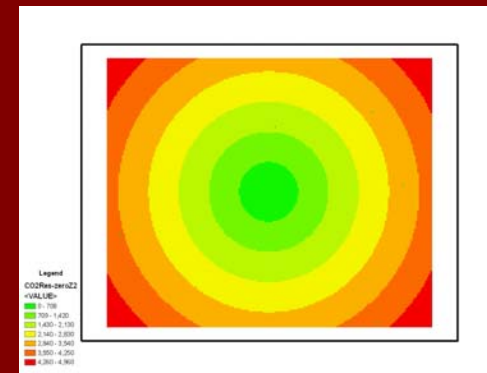
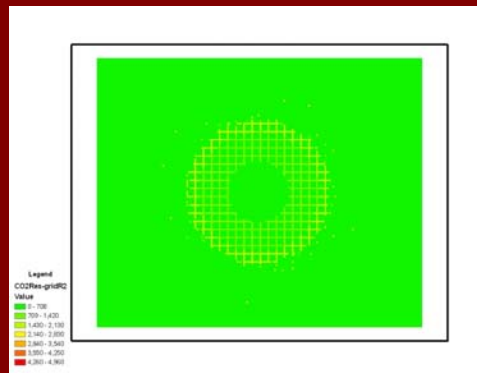
Resid./cell



CO₂ (Tn)/cell



CO₂ (Tn)/resid.

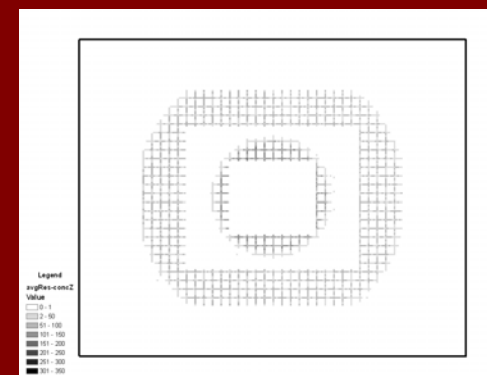
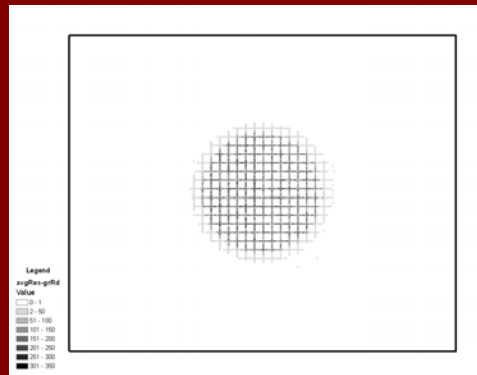


Concentric zoning

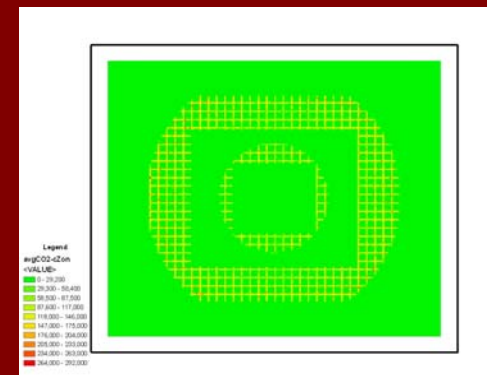
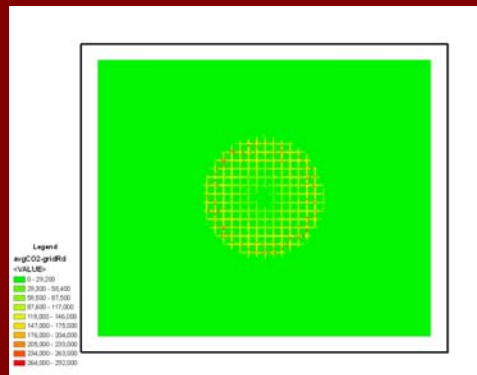
Default

Concentric zoning

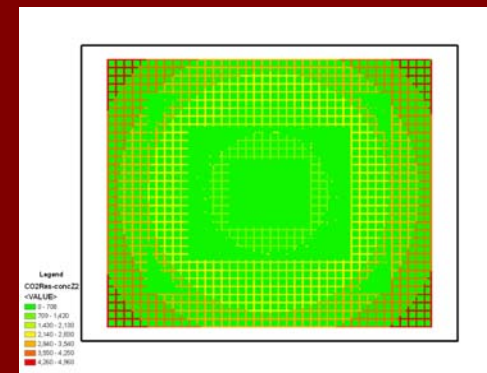
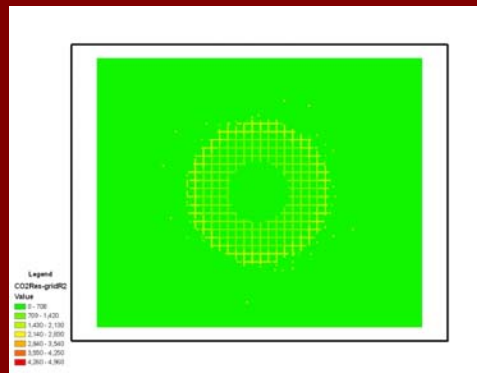
Resid./cell



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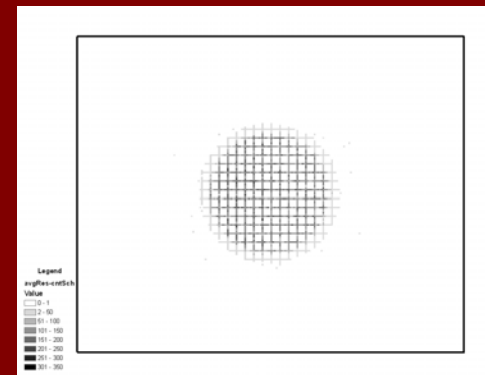
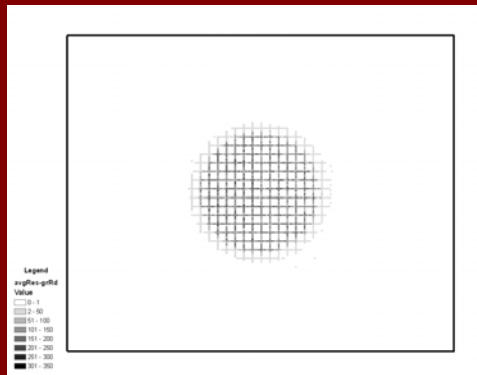


Good central schools

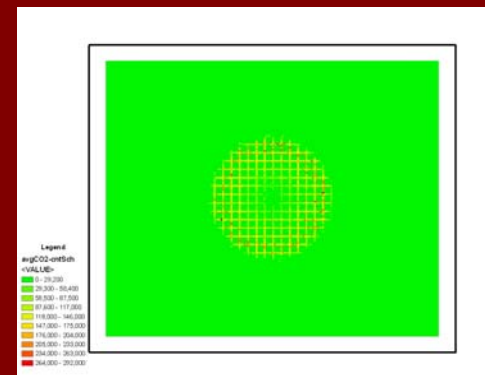
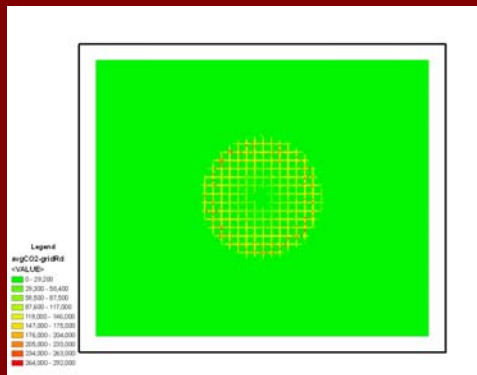
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Good central schools

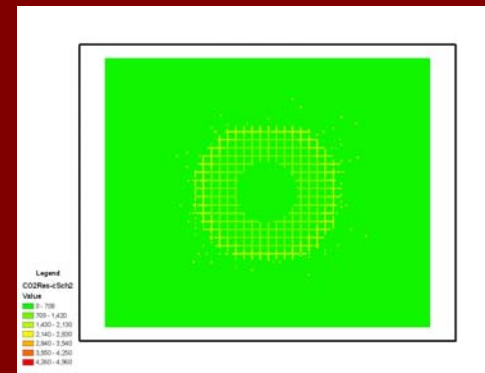
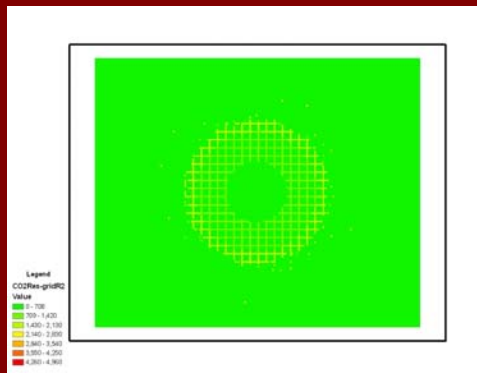
Resid./cell



CO₂ (Tn)/cell



CO₂ (Tn)/resid.

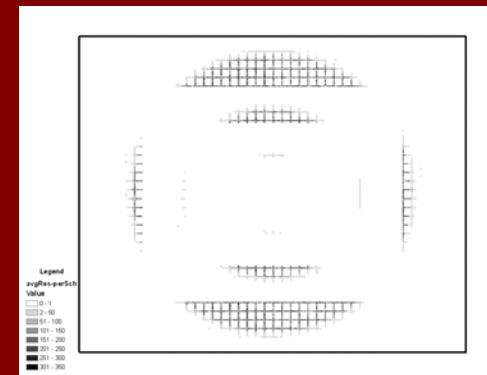
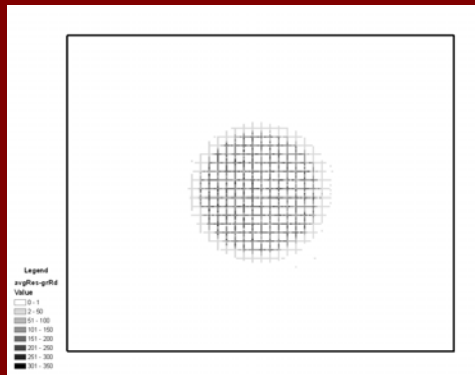


Good peripheral schools

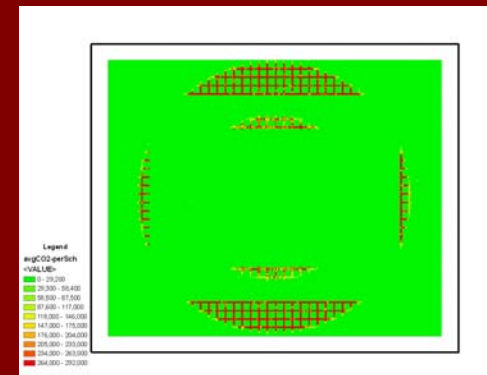
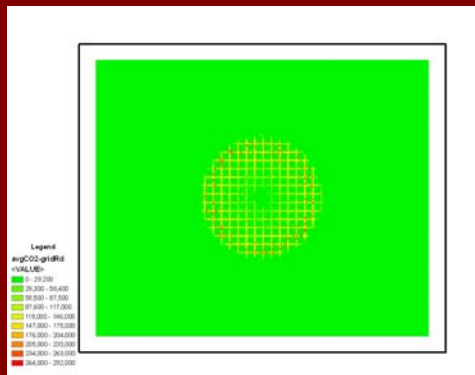
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Good peripheral schools

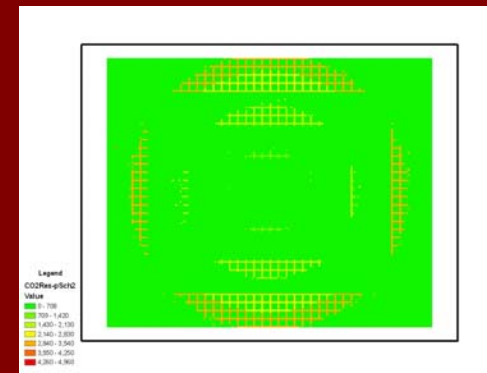
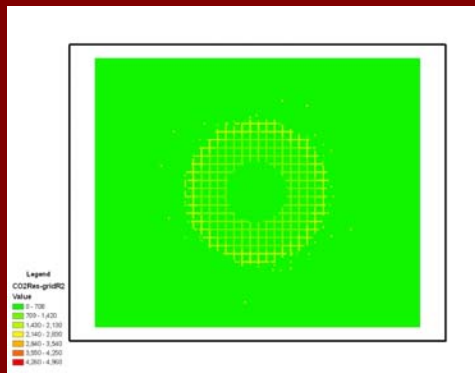
Resid./cell



CO2 (Tn)/cell



CO₂ (Tn)/resid.



Global values

Scenario	Residents	Electricity kWh	Fuel gal	CO2 Tn
Default scenario	199000.0	1.33E+09	2.02E+10	1.78E+08
Minimum density zoning	14622.6	2.34E+08	4.48E+09	3.93E+07
Concentric zoning	199000.0	2.43E+09	4.75E+10	4.18E+08
Good central schools	199000.0	1.33E+09	2.02E+10	1.78E+08
Good peripheral schools	199000.0	1.33E+09	6.00E+10	5.26E+08

- Differences

- Zoning: electricity, fuel and CO2
- Good peripheral schools: fuel and CO2

Policy implications: Research and practice

- Understanding how tradeoffs play out differently:
 - Preference for low density
 - Proximity to city
 - Good schools
- Different measures, different meanings and policy targets
- Within the context of this analysis, zoning and public school ranking may be more influential in determining urban form and consequent energy use and pollution emissions
- Land use and educational policies become environmental policies
- Technology not the only fix, but still important

Future work

- Current version of USAFE
 - Review and adjust mechanisms (preferences, land conversion, input maps)
 - Test technological scenarios (fuel efficiency, pollution prevention)
- Extensions to the model
 - Carbon assimilation
 - Effects on utility levels and distribution
 - Responses to energy crises
 - Testing economic instruments
 - Fuel taxes
 - Electricity taxes
 - Credits for forest cover

Assessing urban sustainability of possible futures

- Urban systems as our unit of analysis for assessing the sustainability of US economic activity.
- Integration of various analytical tools:
 - agent-based modeling
 - information assessments.
- Framework for continuous evaluation and adaptation of policies

Thank you!

- Questions?