GIGATON PROBLEMS REQUIRE GIGATON SOLUTIONS: URBAN SYSTEMS AND TECHNOLOGY OPPORTUNITIES

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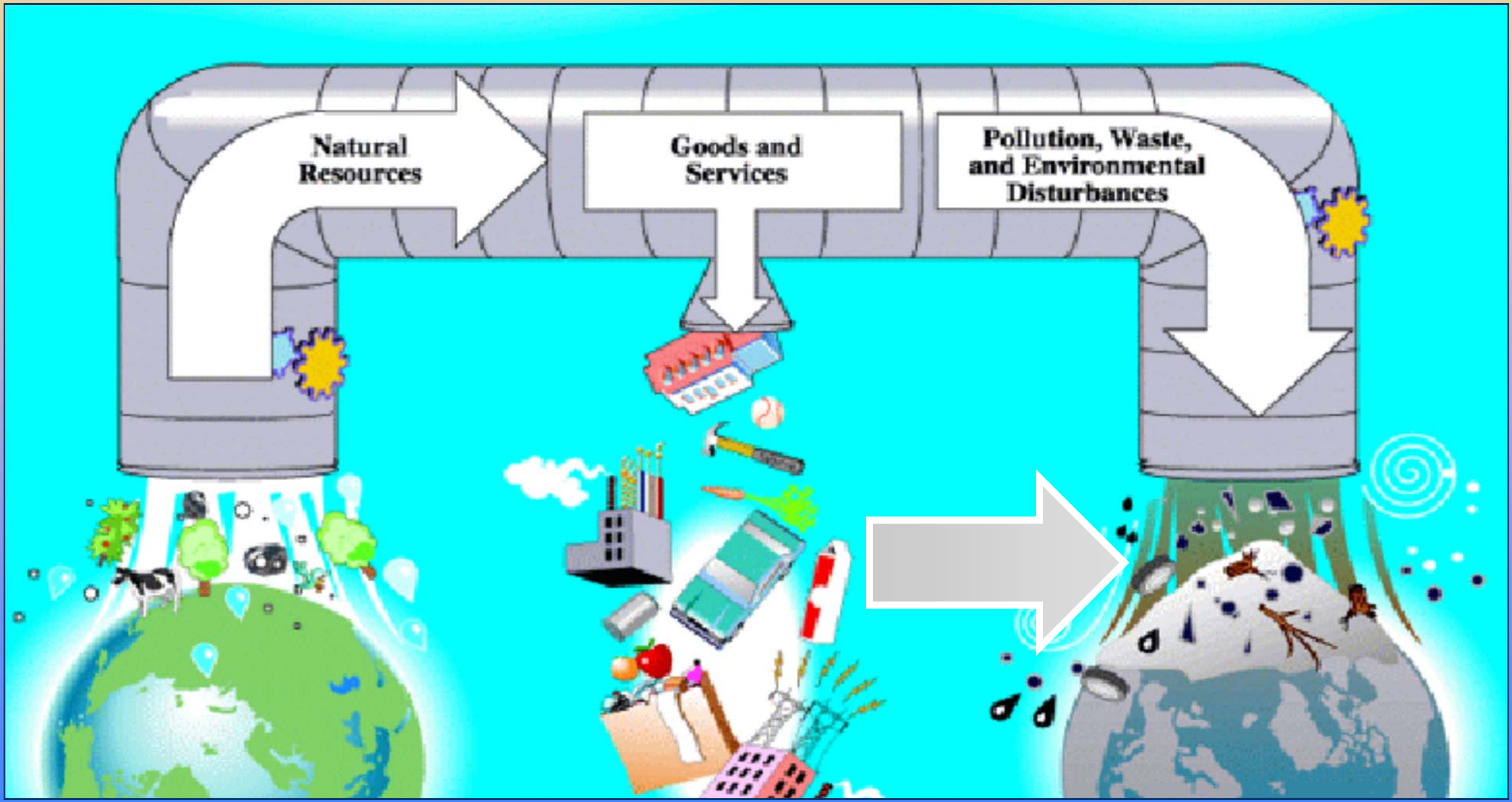
Increasing Material and Energy Uses Depletes Resources and Impacts the Environment:

Engineering alone is not the answer. How many hybrids can the earth sustain? We need to think about reducing demand at the systems level.



Credit: Jonathan Lash (2005)

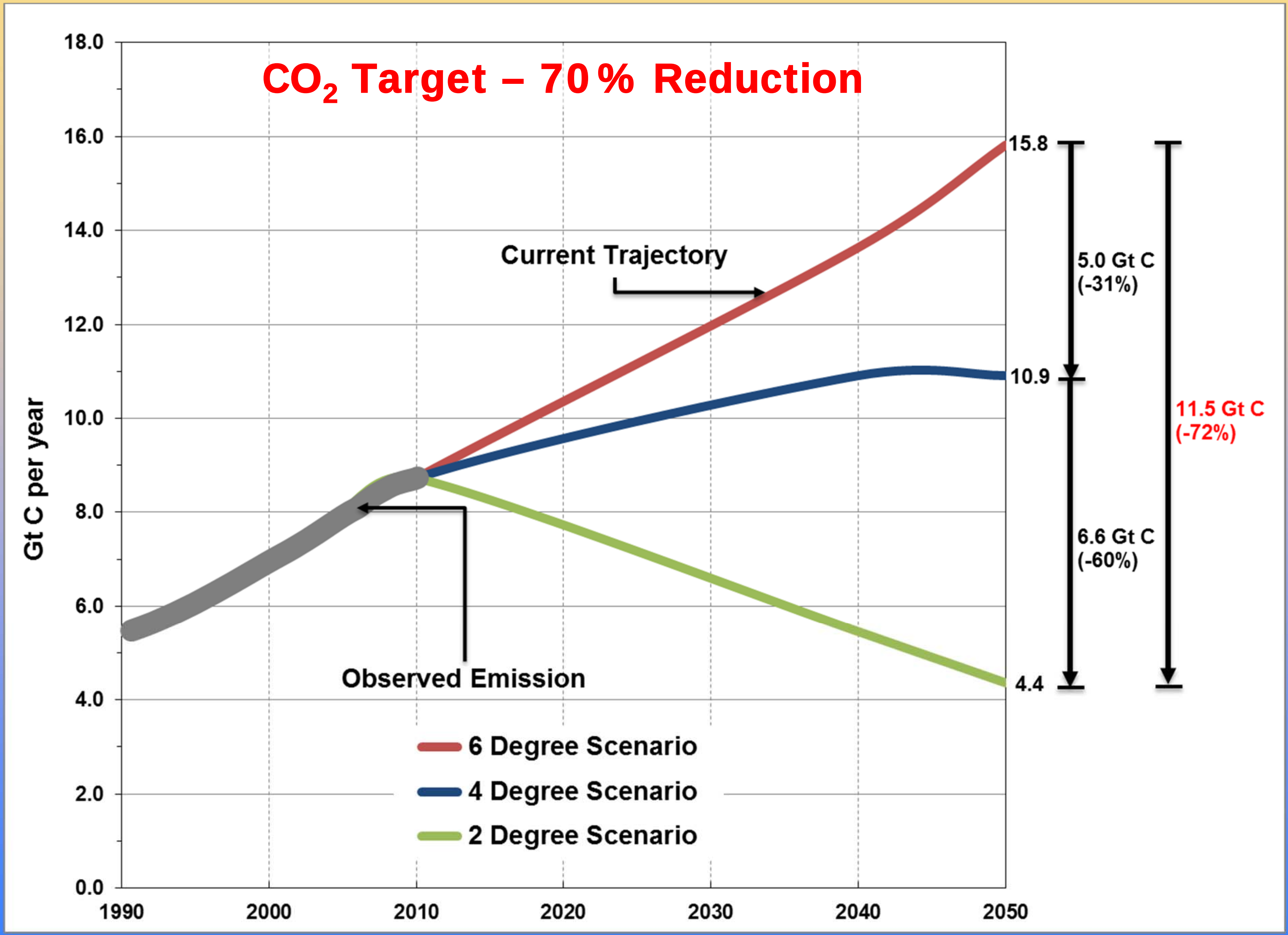
Sustainable Urban Systems

- We need to recreate the anthrosphere to exist within the means of nature. That is, use renewable resources that nature provides and generate waste nature can assimilate without overwhelming natural cycles.
- This will require us to examine the interactions between the natural, engineered, social and economic systems.

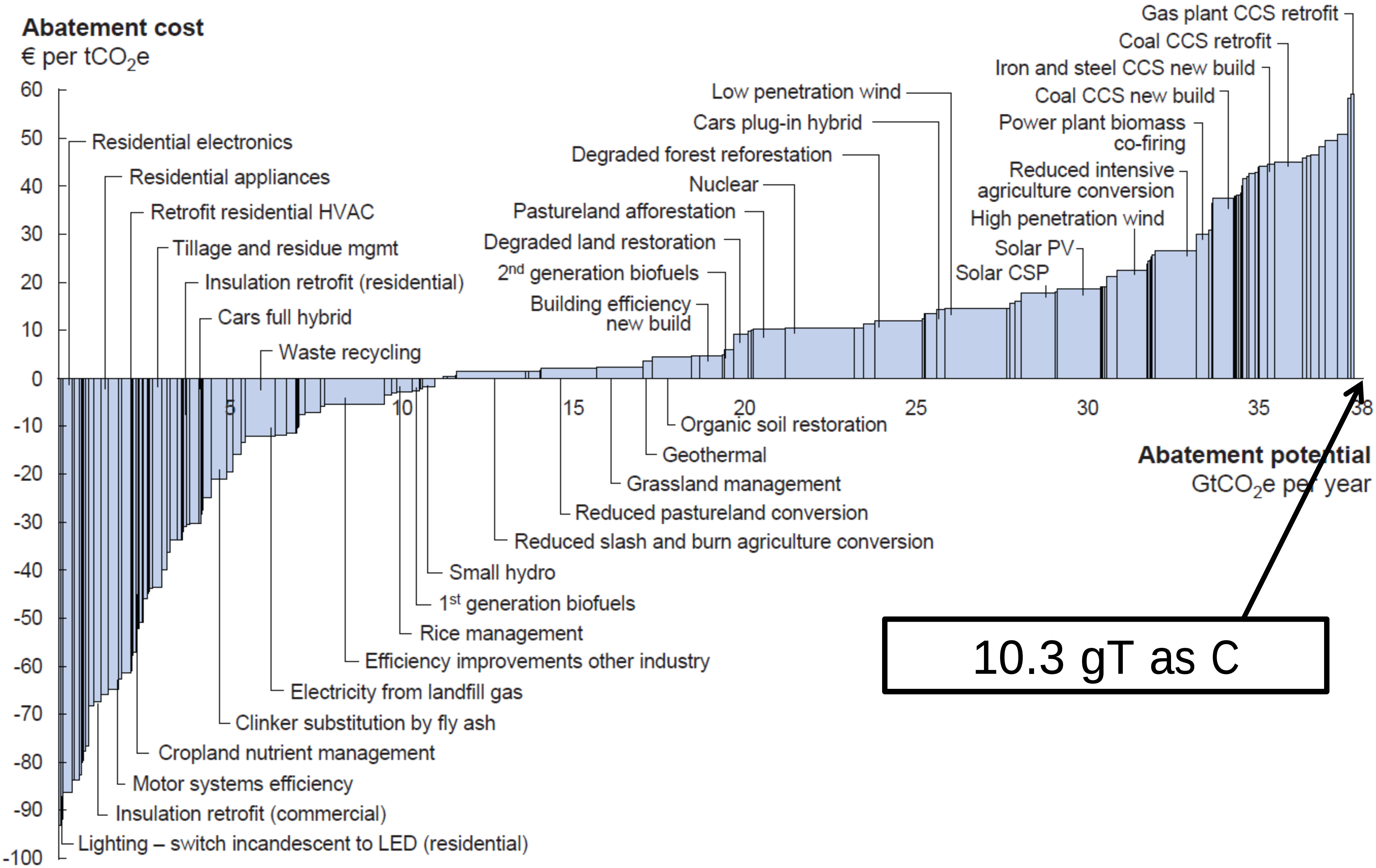
Sustainable Urban Systems

- Generate waste nature can assimilate without overwhelming natural cycles.
- Need to look fate of toxics, N (Protein and wastewater), P (100 years of minable P left), Water, C, etc. cycles.
- Lets look at Carbon.

Choosing the future energy system



Global GHG abatement cost curve beyond business-as-usual – 2030



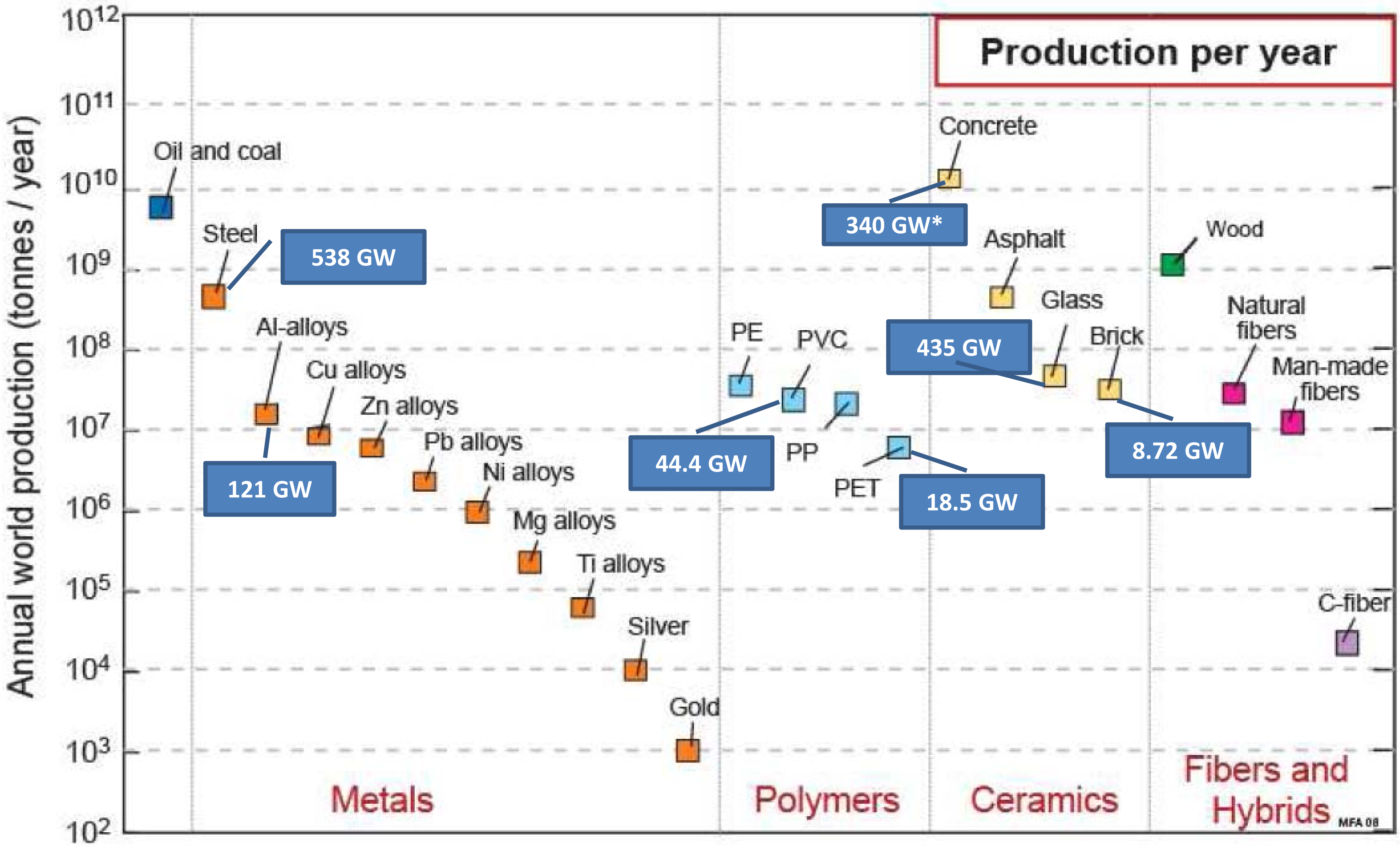
Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.

Source: Global GHG Abatement Cost Curve v2.0

Sustainable Urban Systems

- Use renewable resources that nature provides.
- Of the 70 gigatons of material in the yearly world economy only 29% is renewable (assuming biomass is renewable)

Resource Consumption for Material Production (Energy Required for top 7 materials 1.5 TW - 10%)

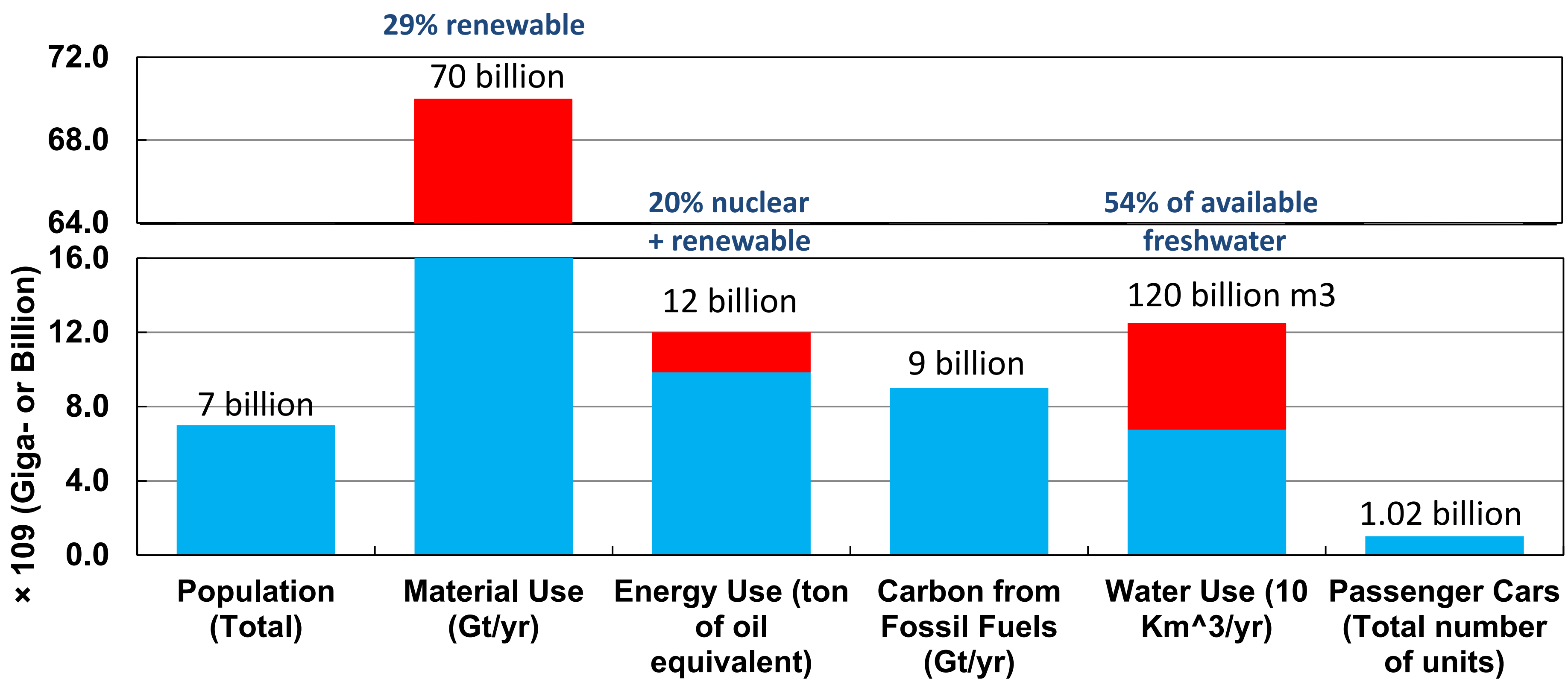


Credit: Mike Ashby

•Ratio based on mix design for 30 MPa compressive strength at 28 days (http://www.ctre.iastate.edu/pubs/sustainable/strublesustainable.pdf)

Gigaton Problems Need Gigaton Solutions - Let a Million Flowers Bloom

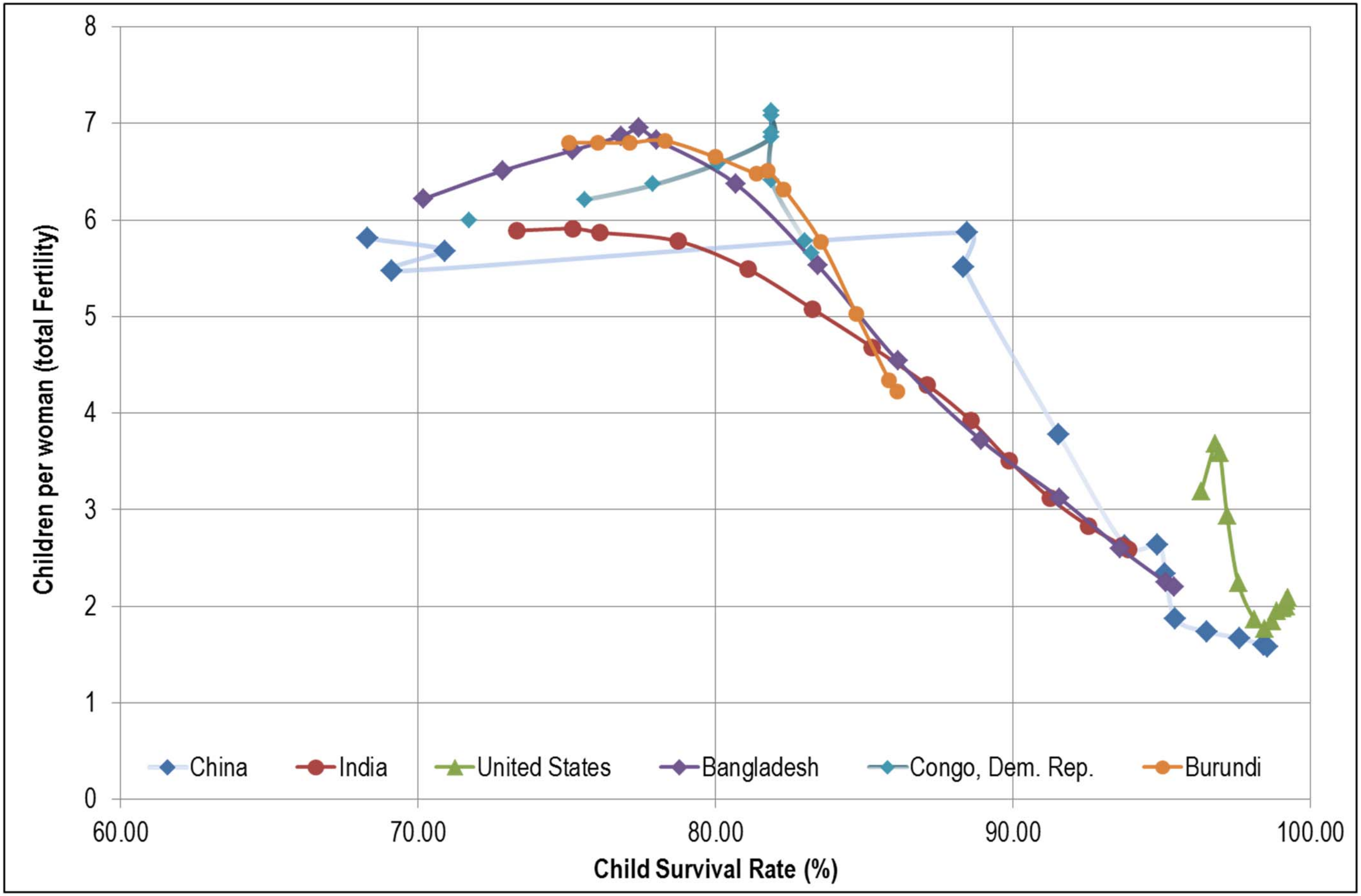
- With ***7 billion people*** using ***70 Gt of materials***, ***12 Gtoe of energy***, ***120 Gm³ of water*** and emitting ***9 Gt of Carbon*** per year globally, a shift of scale and paradigm is needed to address the issues of global sustainability.
- From an egalitarian point of view, we should expect this to increase by a factor of 9 for 9 billion people in 2050, if every one has the same life style and uses today's technologies.



Note: Material use includes food

Population Management

Total fertility vs. Child Survival Rate (%)Time-trend (1950-2010)



Pessimist ⟷ Optimist

Pragmatic
Possibilist

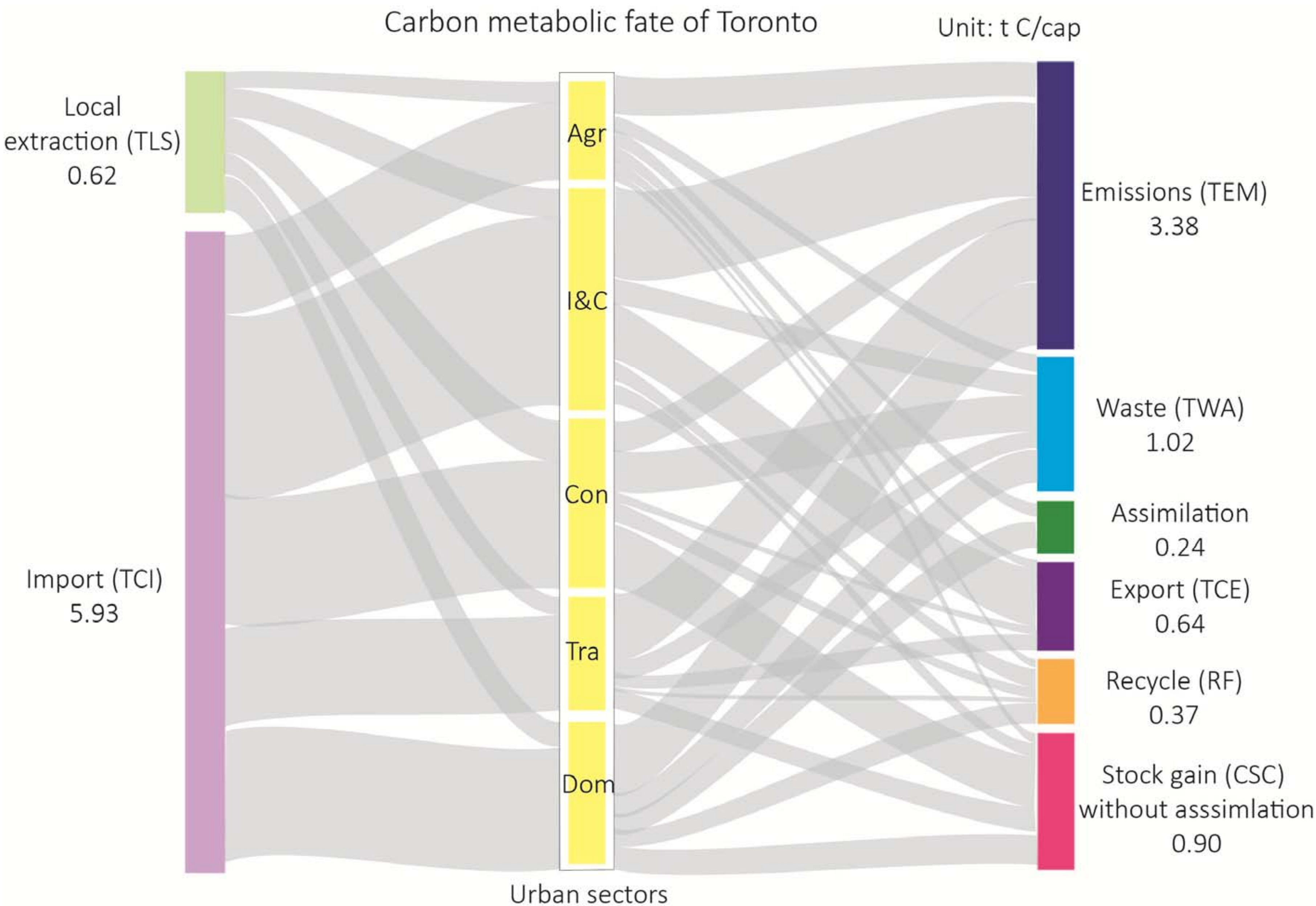
Thoughts on Solving the Gigaton Problem

- High performance buildings
- Efficient power generation
- Electrification of transportation
- Enhancing ecosystem services or avoiding their destruction
- Mandates for product performance and take back
- Market drivers for energy efficiency (SEAR 16 versus 13 etc.)
- Smart grid
- Distributed power and water generation
- Biomass reforming to create fuels, commodity chemicals, specialty chemicals
- Integrated resource recovery (metals, nutrients, energy etc from waste or shall I say byproducts)
- Policy issues that relate to the above
- Econometrics and economic flows that favor the above
- Devise a market or stipulate mandates that gets gigatinventors, gigainvestors and gigaentrepreneurs on task.

INFRASTRUCTURE ECOLOGY

Sustainable Urban Systems

- **Sustainable Urban Systems: Key questions**
  - How are energy, materials, information, and water utilized by the different configurations and populations of systems?
  - How can we reduce energy, emissions, materials and water inputs and increase the creation of wealth and comfort?
  - How do “communities of infrastructure” emerge from the cultural, physical, and economic conditions of the region?
- **Infrastructure Ecology:**
  - **A Hyper Nexus of material use, water, energy, transportation, land use/planning, commercial and residential buildings, community design, and socioeconomics as they occur in urban environments.**



Sankey Diagram: Agr: Agriculture; I&C: Industry and commercial; Con: Construction; Dom: Domestic; Tra: Transportation

Interconnections within Urban Infrastructure Systems

Water for Energy:

- Average consumptive use in US: 2.0 Gal/kWh
  - 0.5 Gal/kWh for thermoelectric; 18.0 Gal/kWh for hydroelectric

Energy for Water:

- 4% of total electricity consumption in US for water and wastewater sector; 19% in California
  - 80% of the requirement is for conveyance and distribution

Energy for Transportation:

- 28% of the total energy consumption in the US (in 2008)

Transportation and Land Use:

- Empirical estimates suggest that one new highway built through a central city reduces its central-city population by about 18%.
- **Land Use, Water and Energy:**
- Use of rainwater harvesting and other LID techniques in the urban area of southern California would result in a savings of 573–1225 GWh per year.

Interconnections within Urban Infrastructure Systems

Water for Transportation:

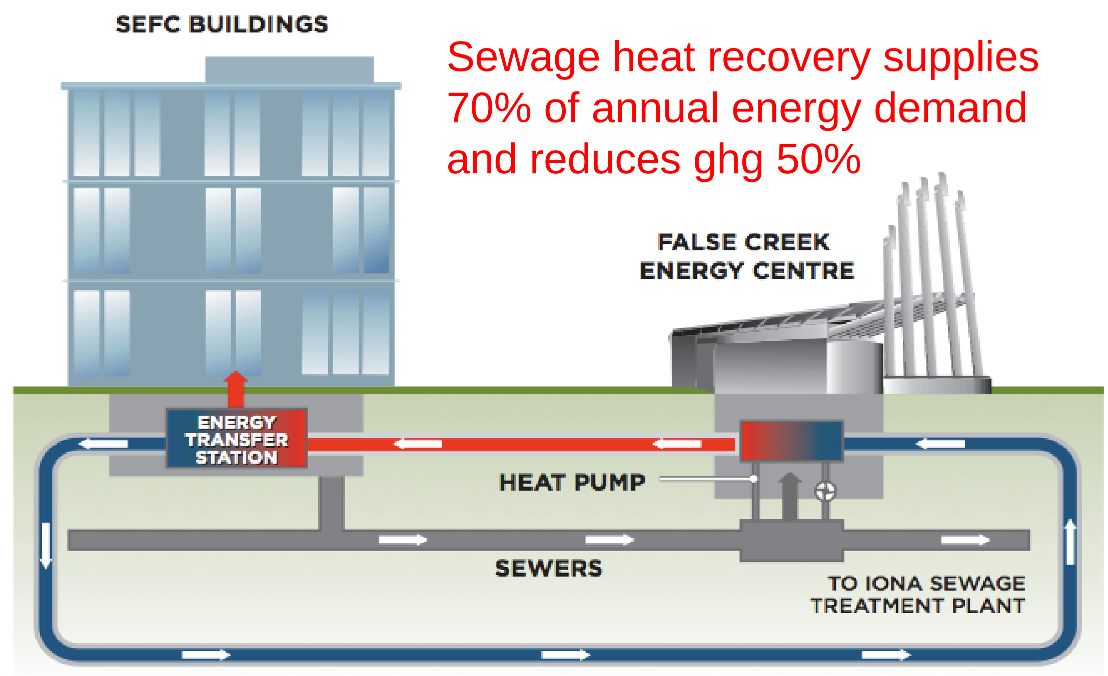
Impact of Biofuels

- The **water footprint for biofuels may be 10 to 1000 times higher than conventional gasoline** on a life-cycle per vehicle mile travelled basis depending on whether the feedstock crops are irrigated or not

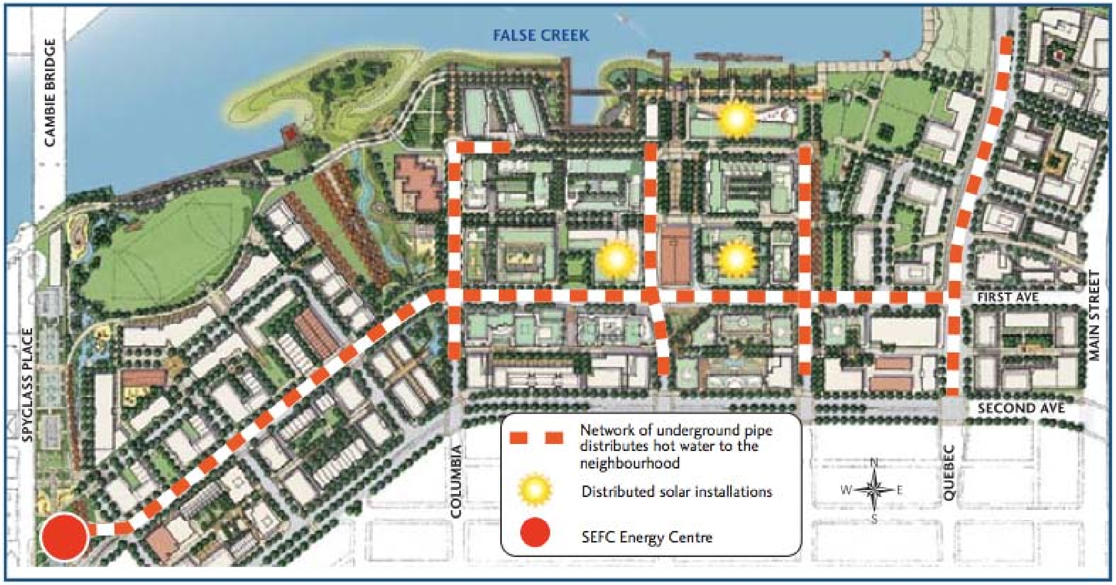
Impact of Automobile Electrification

- If **all personal transportation in the metropolitan Atlanta, GA region was electric, the increased water demand** (evaporative loss) needed to produce the electricity (under present generation mix) to charge the fleet of electric vehicles would be almost identical to the current domestic demand (estimated at **100 million gallons per day**)

False Creek Neighborhood Energy Utility
Vancouver, BC: City of Vancouver

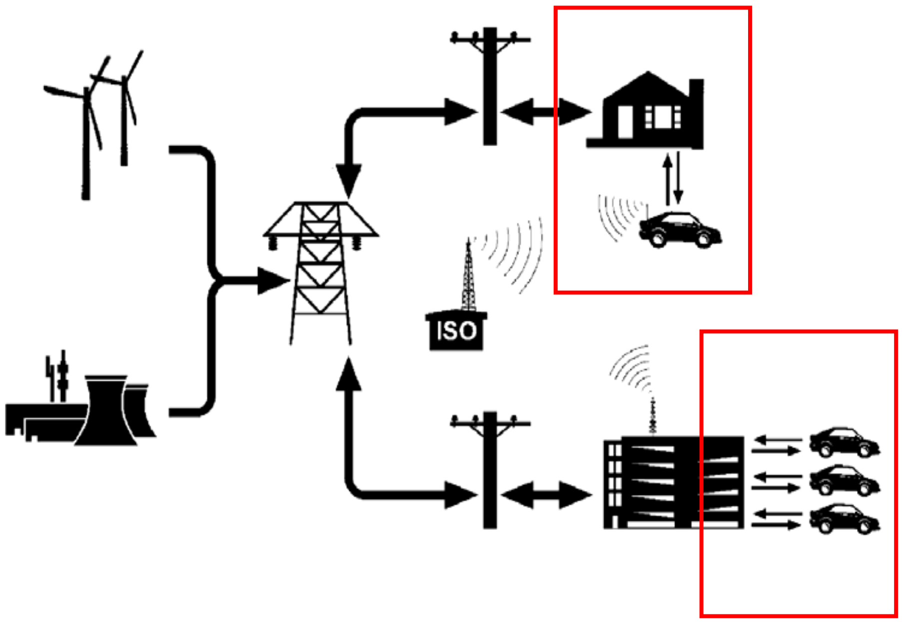


Sewage heat recovery supplies 70% of annual energy demand and reduces ghg 50%

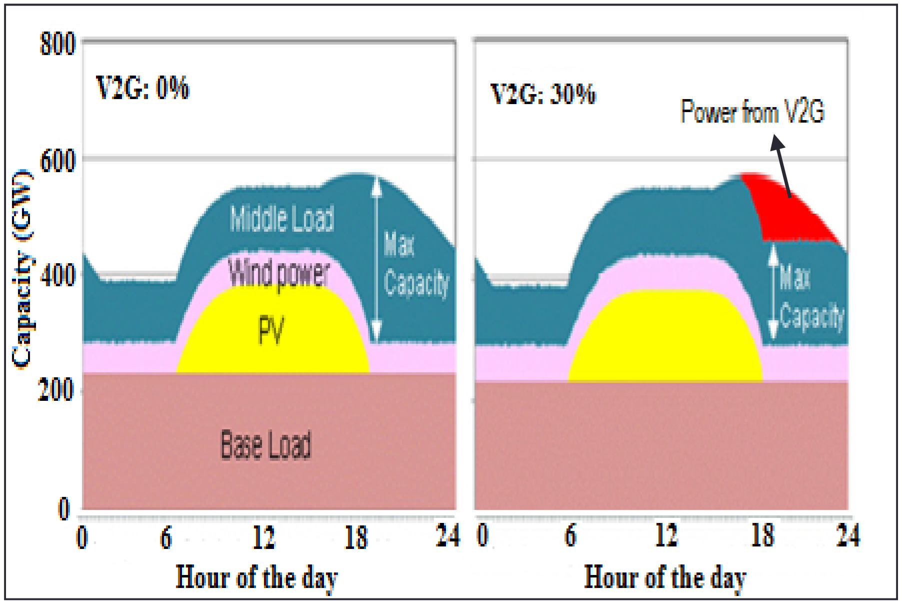


Plug-in Hybrid Electric Vehicles (PHEVs) and Vehicle-to-Grid (V2G) power

PHEVs can send power back to the grid when parked, and function as distributed storage for intermittent energy from renewable sources



Credit: Kempton and Tomić, 2005



US demand-supply balances during maximum demand with various V2G ratios in 2045

30% V2G penetration could reduce ~100 GW or about ⅓ of the total peak demand of ~300 GW in US by 2045

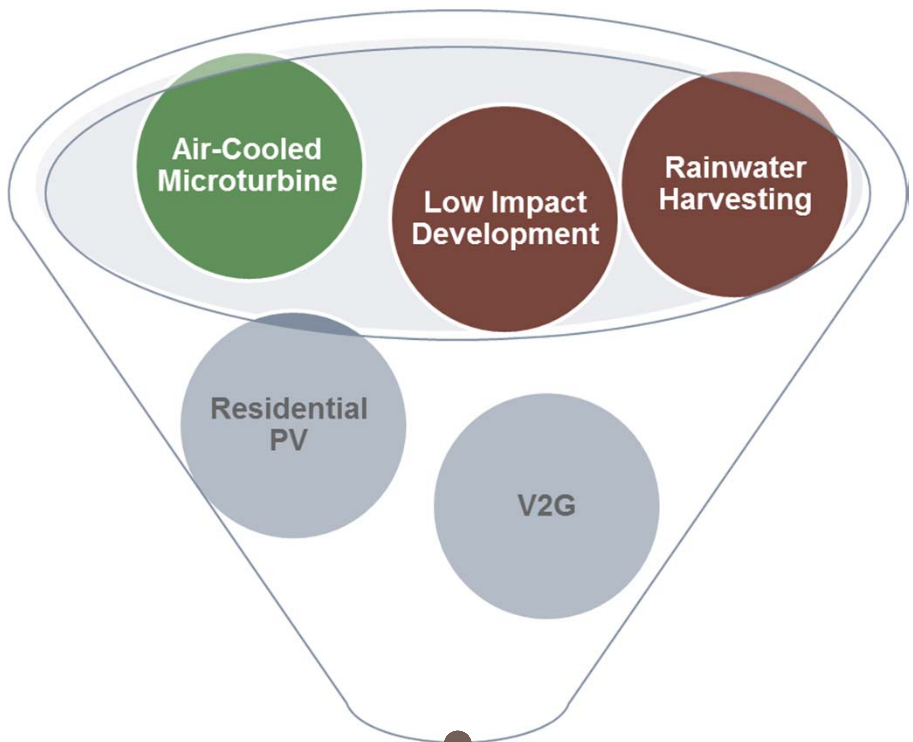
Source: Modelling Load Shifting Using Electric Vehicles in a Smart Grid Environment – © OECD/IEA 2010

INFRASTRUCTURAL SYMBIOSIS: REORGANIZING THE FLOWS FOR SYSTEM LEVEL OPTIMIZATION

The Synergistic Effects of *"Infrastructural Symbiosis"*

- Designing UIS using an infrastructure ecology approach alters and reorganizes energy and resource flows, allowing one to consider the potential synergistic effects arising from infrastructural symbiosis.

- The accumulated synergistic effects of this particular model of infrastructure ecology is significant:
  - reduced water and energy consumption,
  - lower dependence on centralized systems,
  - larger share of renewables in the electricity mix,
  - reduced vehicle-miles travelled, &
  - an increase in tax revenue.



Decentralized Water Production – Low Impact Development - LID Best Management Practices(BMPs)

- Bioretention
- Cistern
- Constructed Wetland
- Dry Pond
- Grassed Swale
- Green Roof
- Infiltration Basin
- Infiltration Trench
- Porous Pavement
- Rain Barrel
- Sand Filter
- Vegetated Filterstrip
- Wet Pond

Rain Barrel and Green Roof, Atlanta (Southface)

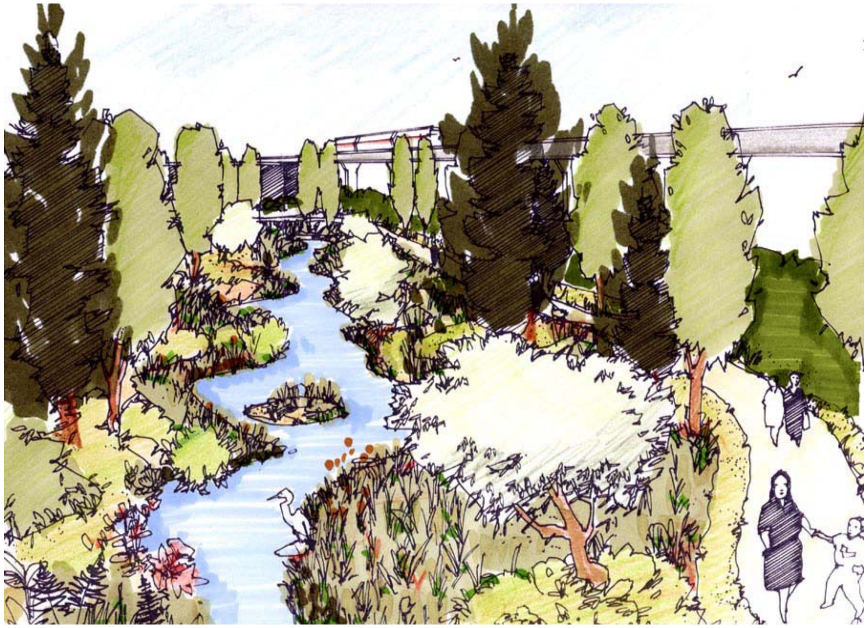
Sand filter near garages, NYC

Vegetated Swale, Vancouver(Crown Street)

Bioretention Basins

Case Study:
Storm Water Treatment for Vancouver

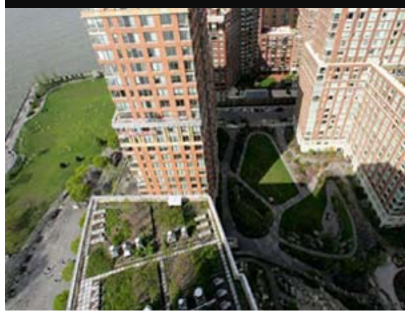
- It was estimated that there was a ***$4 billion expense*** to separate stormwater systems from wastewater. However, when they opted for LID technique implementation there was an estimated ***$400 million income*** from increased property value and associated tax revenue.
- The new concept was aptly titled "**From Pipe Dreams to Healthy Streams:** *A Vision for the Still Creek Watershed*"



Alternatives and Case Studies

Rainwater Harvesting

Green space & Onsite WW reclamation



Sewer Mining and Onsite WW reclamation

Energy Recovery

Nutrient Recovery

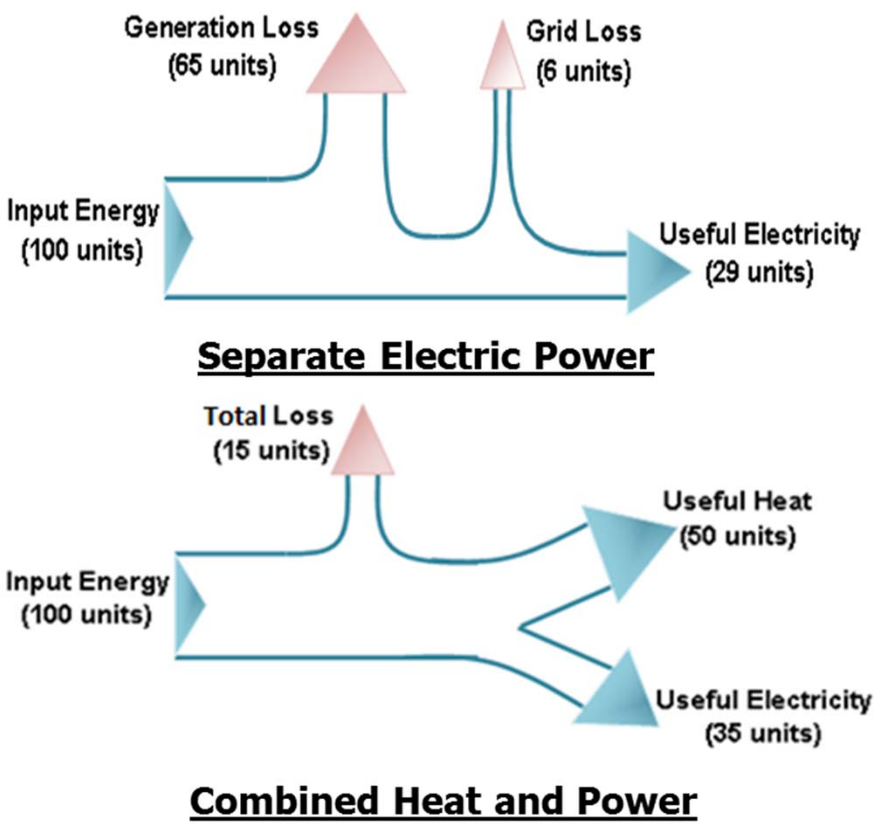
Smart Irrigator

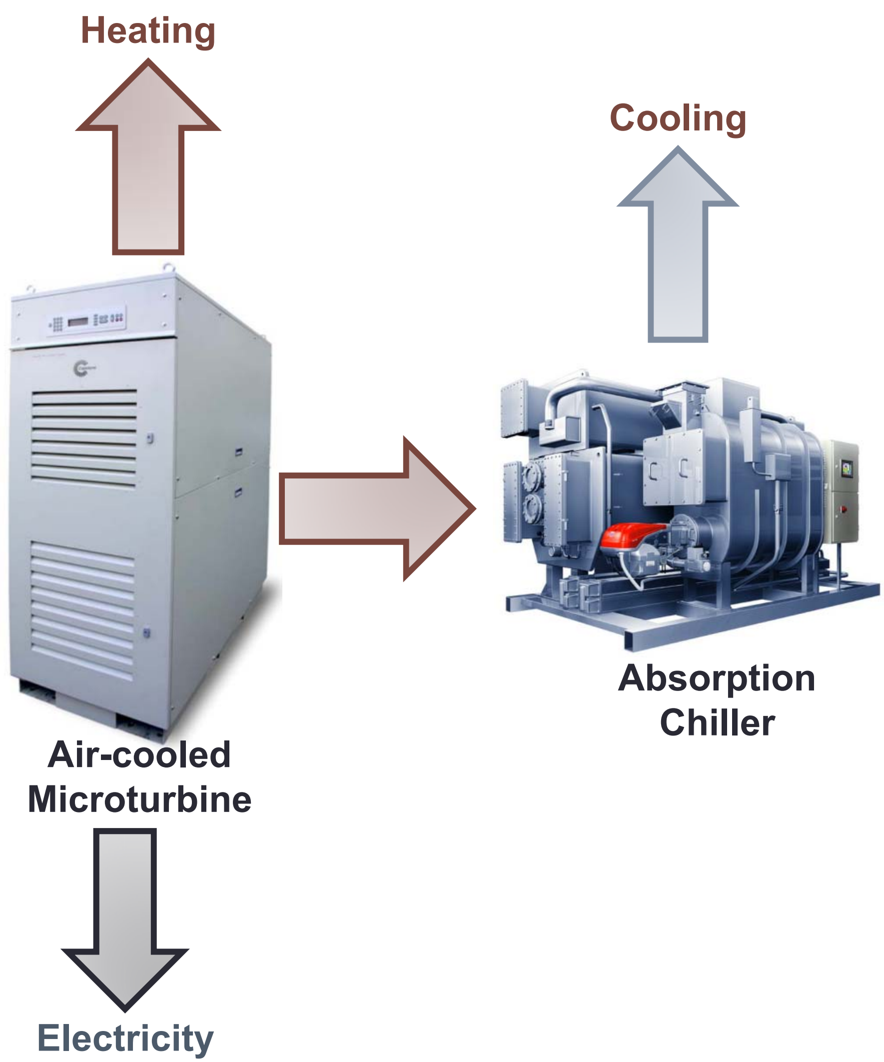
Small Flow Water Fixture

INFRASTRUCTURAL SYMBIOSIS

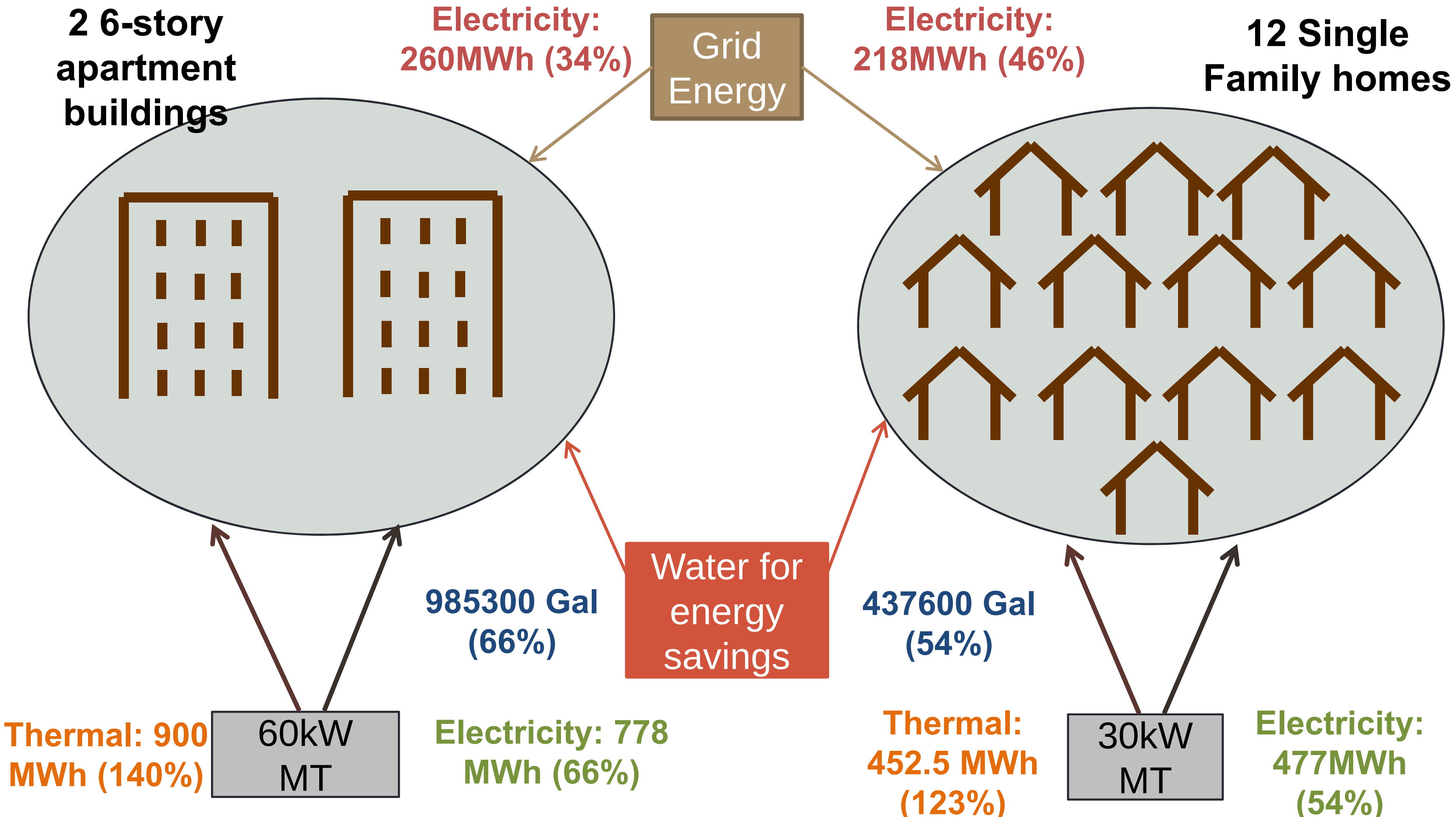
Decentralized Energy Production: Combined Heat and Power (CHP)

Recapturing Lost Heat in Combined Heat & Power System





Building Energy Requirements Met by CHP Using Air Cooled Microturbines

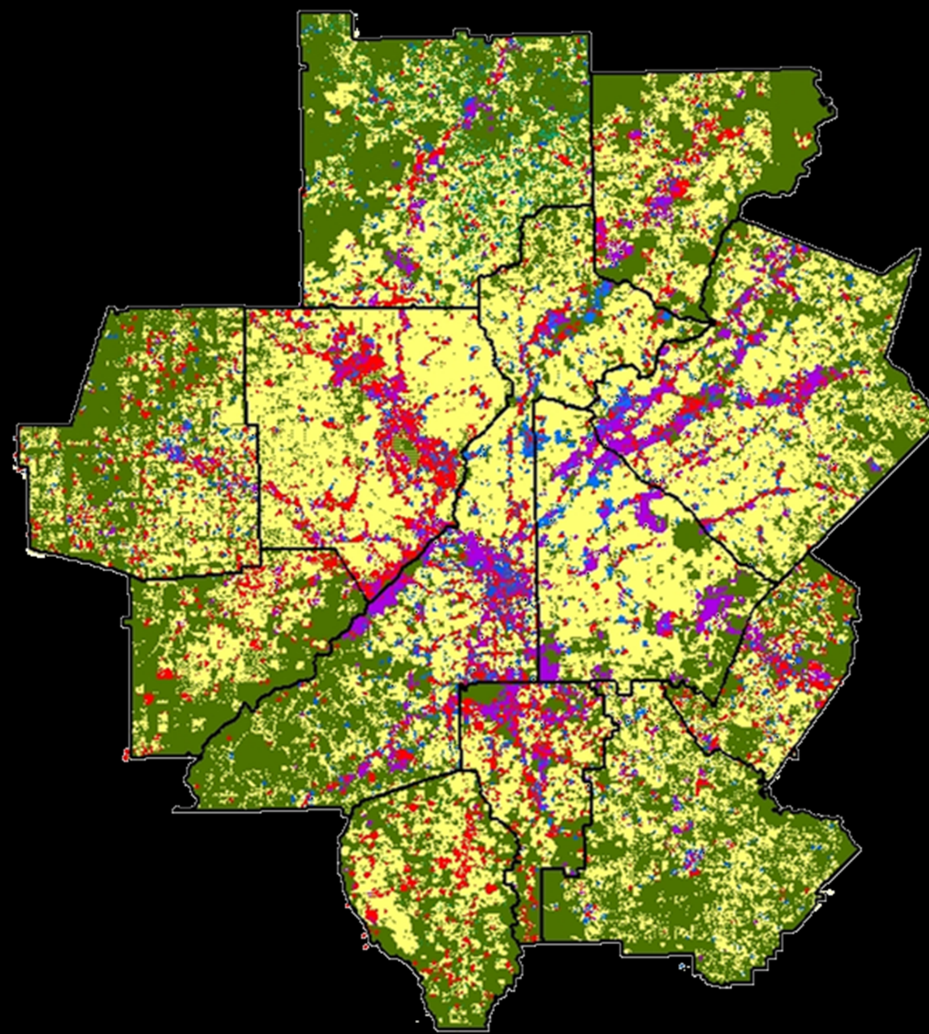


Thermal load includes heating and cooling demand

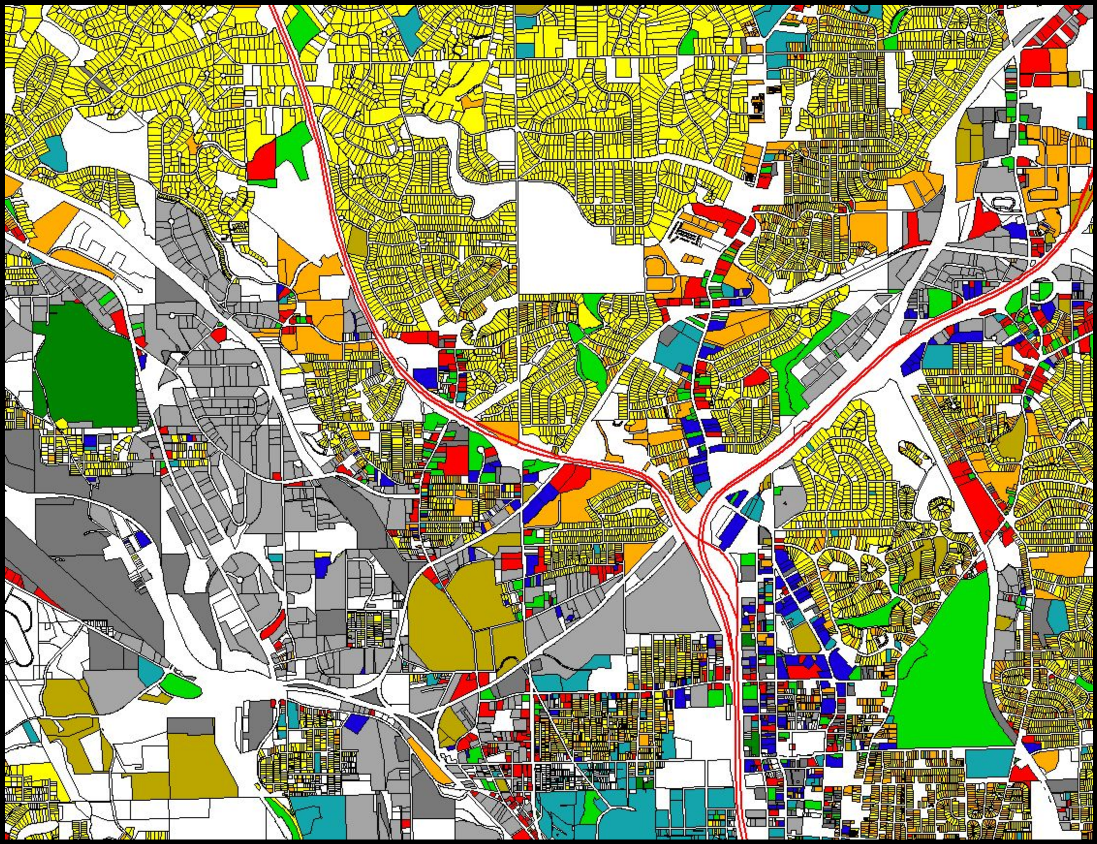
URBAN DEVELOPMENT SIMULATION AND LARGE SCALE WATER SAVINGS CARBON EMISSION REDUCTIONS FROM LID AND CHP

■SPATIAL DATABASES FOR URBAN MODELING - 1

- The SMARTRAQ project
  - Supports research on land use impact on transportation and air quality
  - 1.3 million parcels in the 13 metropolitan Atlanta non-attainment counties



▪SMARTRAQ DATA AND ATTRIBUTES

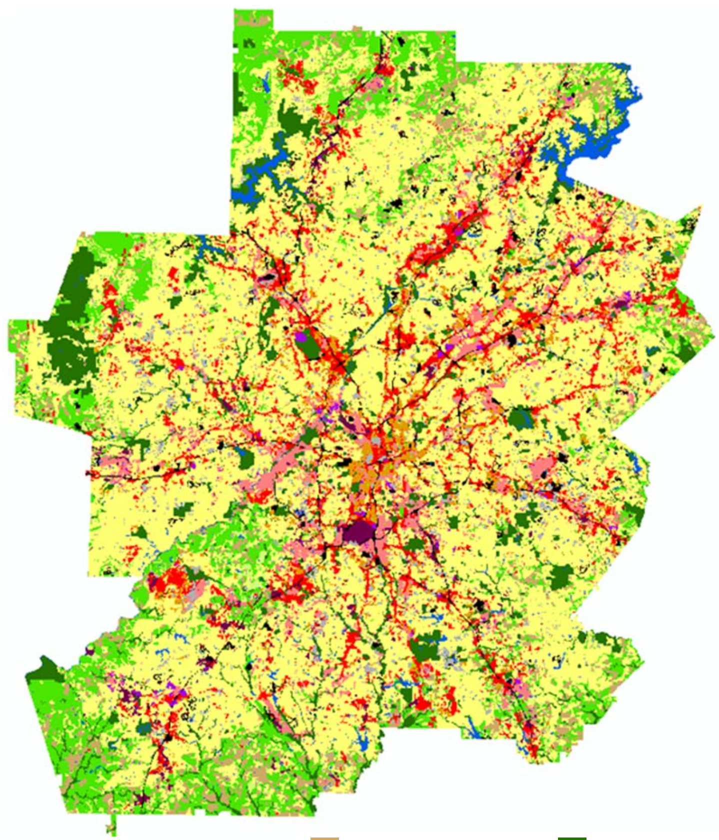


- Land Use Type
- Number of Units
- X,Y Coordinate
- Estimated Sq Feet
- Total Sq Feet

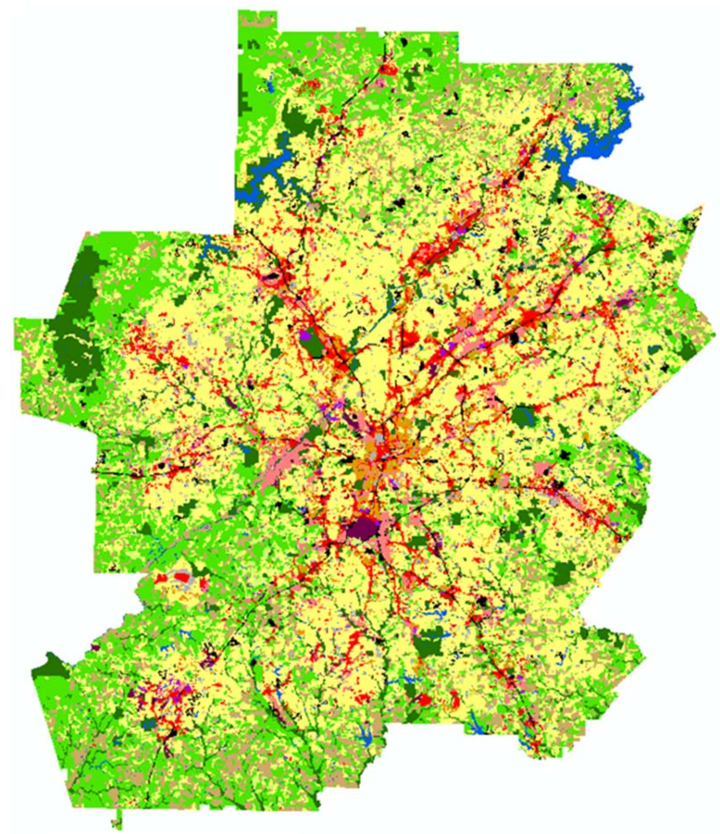
- Address
- Road Type
- City
- Zip Code
- Owner Occupied
- Commercial/Residential
- Zoning
- Sale Price
- Sale Date
- Tax Value
- Assessed Value
- Improvement Value
- Land Value
- Year Built
- No. of Stories
- Bedrooms
- Parking
- Acreage

Projected Growth Scenarios for Atlanta

Business As Usual
Year 2030



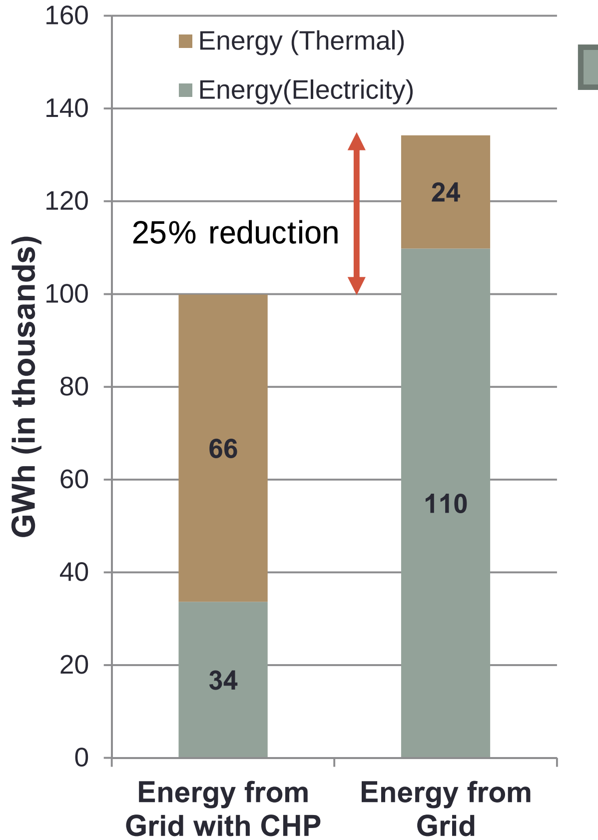
More Sustainable Development
Year 2030



Atlanta Energy and Water Demand Projections

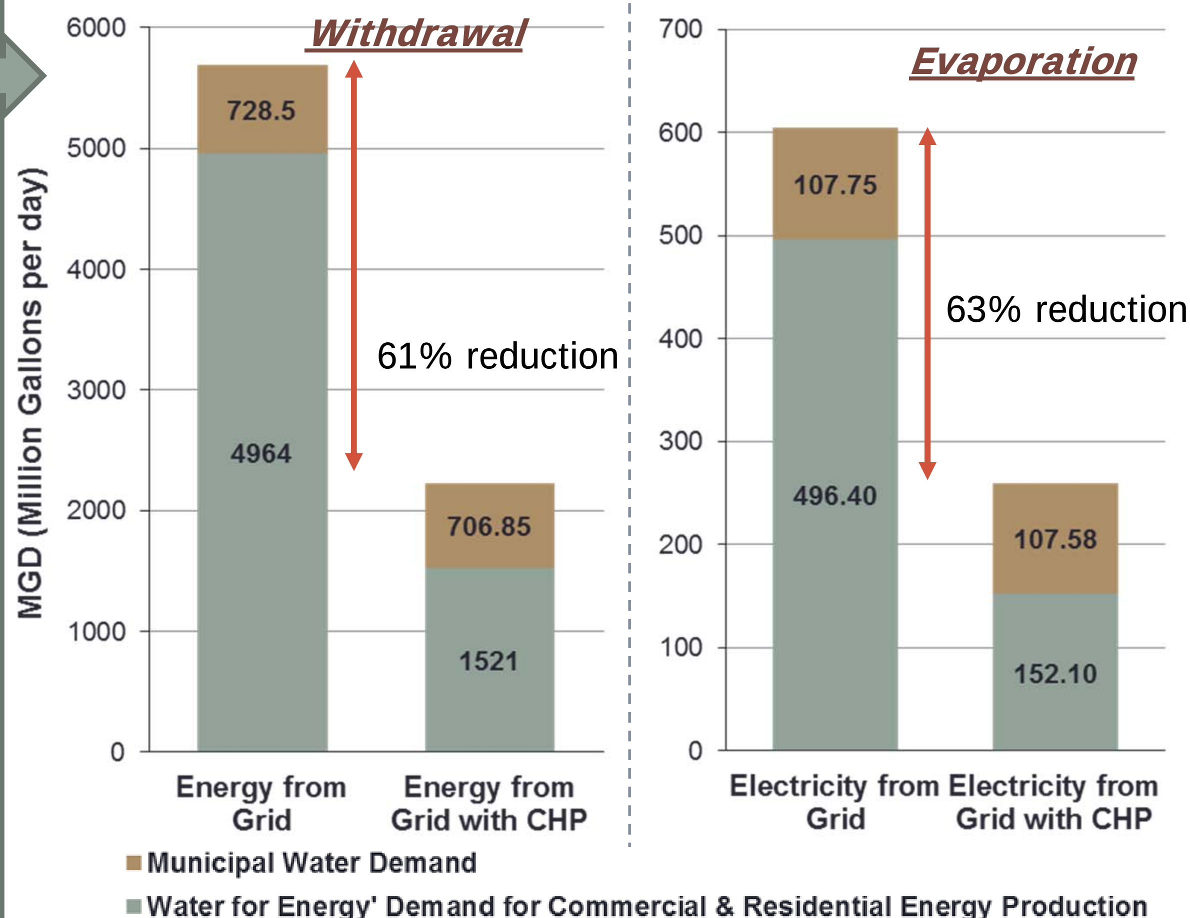
(with low flow fixtures + rooftop rainwater harvesting + decentralized CHP system)

More Sustainable Development Scenario



Residential + Commercial Energy Demand

(with Air Cooled Microturbines in a Decentralized CHP system)



Water Demand

(Withdrawal)

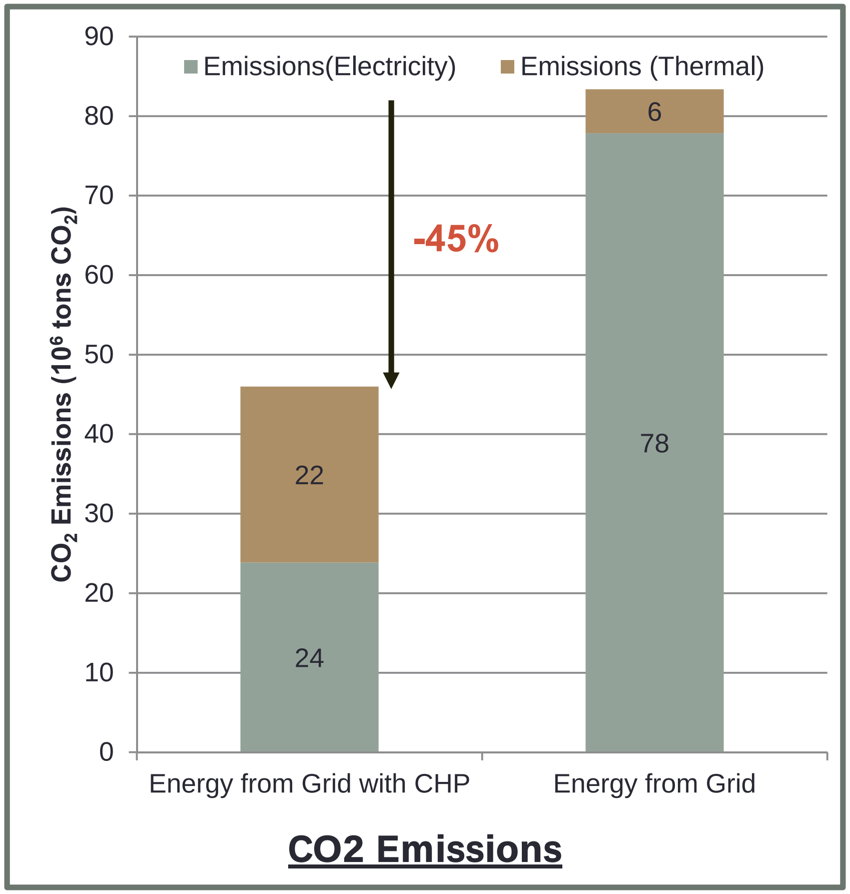
Water Consumption

(Evaporation)

Note: water for energy calculation does not include water needed for the extraction and transportation of the raw fuel.

Potential GHG and Cost Reductions in 2030

By 2030, implementation of CHP in all the residential and commercial buildings (new and existing) will reduce the CO_2 emissions by~ 0.04 Gt CO_2. for the Metro Atlanta region.



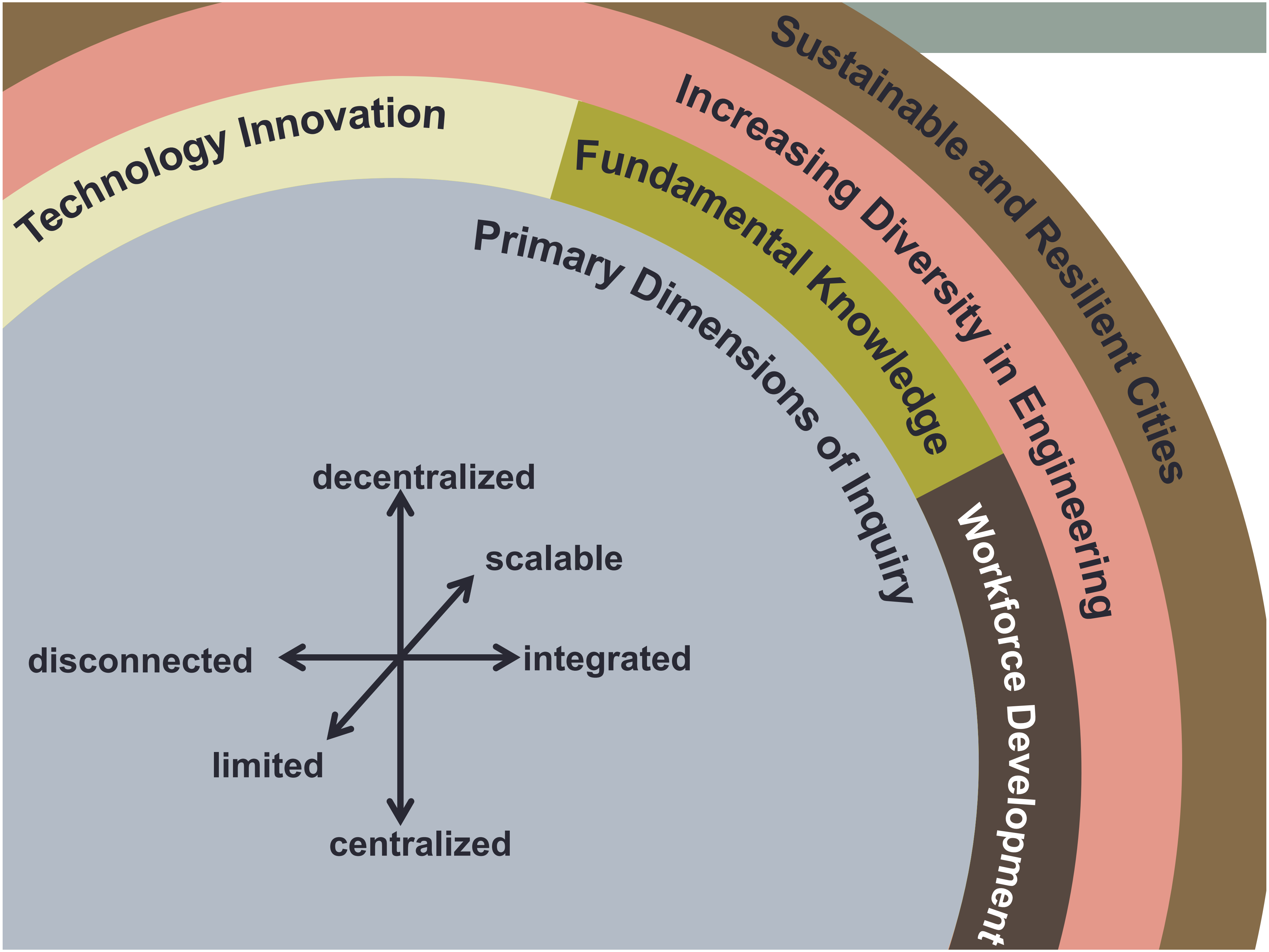
The costs reduction calculation is only based on the cost of natural gas and the cost of electricity from firms in the region.

The 2030 grid+CHP scenarios assumed residential and commercial units in the base year were also retrofitted with CHP systems

SUMMARY

Summary

- Urban Systems Are All Connected and More Efficiency Can be Achieved by Looking at Their Interactions
- Decentralized Energy and Combined Heat and Power Can Save Energy and Water
- Decentralized Water / Low Impact Development Can Save Water, Energy and Money
- Land Use/ Planning Is Vital in Reducing the Impact Of Urban Systems and Examining Their Interactions


Sustainable and Resilient Cities
Increasing Diversity in Engineering
Technology Innovation
Fundamental Knowledge
Workforce Development
Primary Dimensions of Inquiry
decentralized
scalable
disconnected
integrated
limited
centralized

Two Planets meet in Space

- **Arranging our ideological deck chairs on the Titanic**
- **Sooner or later, the earth will come into equilibrium; that is, resources generated will equal resources used. There are two fundamental questions: 1) Will humans be part of the new earth that is in equilibrium. 2) If humans are, will it be a comfortable place or a place wrought with armed conflict and social injustice because of limited resources.**

Credit: Volker Karthopf