Arnulf Grubler

Lecture 1. Urbanization

Dr. Arnulf Grubler points to urbanization and the most important human dynamic unfolding globally. There are two types of global change one where where transformation occurs in a system that is completely interconnected (T1) and another (T2) where change occurs at the local scale, but it's ubiquitous (e.g., urbanization and traffic jams).

Urbanization, however, forms nodes that support the changes of type T1. Cities is where spatial innovation happen, they are infrastructure hubs. This is set against two types of phenomena, one encompassing global changes (i.e. infrastructure hubs, spatial innovation centers, integrated policy design) and the second being local/regional scale issues (i.e. population, growth, transportation and agricultural productivity).

Pre -1700, city growth was limited by agricultural surplus. Post-1700, urbanization was enabled by agricultural growth (industrialization, division of labor, new transportation technology). This is seen in historical data. In our current global context, the internet is urban, a result of agglomeration externalities. Population growth will happen in cities. Energy use per capita in most cities is below national average. Still, problems of access to energy, jobs, and health; lack of security, resilience and reliability; pollution; efficiency, and clean supply. There is much greater disparities in cities. While mega cities are an important aspect of urbanization, understanding the urbanizing issues and challenges that cities under 500,000 population pose is significant (see Dhakal 2008). Small cities are dominating urbanization. This presents a challenge in planning for sustainability in small cities because there is not enough capital and management capacity (and economies of scale). For example, approximately 40% of China's CO_2 is produced by its top 35 cities. Many cities (European data) feature lower than national average per capita energy consumption. Significant numbers of people (1 billion) are currently living in slums and 1.7 billion people are without electricity. In order to provide energy however would require an investment of $1.5 trillion. Cities are beyond 50% in terms of population, energy use, GDP, etc.. Giving energy to the urban poor would not be very costly. Only 160 million people breathe clean are. Over 1 billion need improved air quality. Socio-economic growth increases vulnerability of systems, i.e. we have more infrastructure and capital invested, so there is a greater risk of exposure.

Grubler points to a hierarchy of drivers of Urban Energy use: 1) spatial division of labor (trade, industry structure), 2) Urban form (public transportation, cars, etc.), 3) Efficiency, 4) Energy systems integration (co-gen, combined cycle, etc.), 5) fuel substitution (renewables). He offers a series of urban sustainability opportunities such as: Co-location, energy cascading, High metabolism, recycling of wastes, wastes as energy source, High density, high quality pub. transportation

Agglomeration and network externalities, innovation hubs and centers, mobilization of capital and action. Yet a number of constraints may be barriers to achieve such sustainability, these are: energy demand and pollution density, heat island, capital intensive infrastructure and consumer take back effects.

One of the main points that Grubler puts forth is a paradox where the largest leverage points are from system integration, but this is most difficult due to policy fragmentation.

In summary:

Hierarchy of urban energy and CO2 reduction strategies, in decreasing order of importance:

1. Spatial division of labor (trade flows across boundaries is extremely important and a lot of energy is used for exports and imports, industry structure)
2. Urban form (to favor public transport)
3. Efficiency of energy end-use
4. Existing systems integration
5. Fuel substitution

Greatest potential in reducing energy end-use in building. Vienna has a different model from the US, they have fully integrated utility companies owned by the city.

Urban sustainability opportunities:

1. Co-location of multitude of uses, cogeneration of energy
2. High metabolism: opportunities for recycling waste as energy resource
3. High density: public transport
4. Nodes of problem solving

Constraints to the above:

1. Energy demand and pollution is great
2. Heat island effect
3. Capital intensity
4. Consumer take-back (more on this below)
5. Policy paradox: cities are the largest leverage points, but require coordination of multiple actors

Grubler advocates for the traditional approaches of sustainable urbanization, rather than recognizing that there are limits to the positive externalities of urban growth.

Lecture 2. Industrialization

In Dr. Grubler's second lecture, he starts with the Kuznets curve of structural change to illustrate primary sector processes that transform industrialization to service. Different opportunities for emissions mitigation, depending on industrial structure. Ours is an economy based on selling material things. US has more material+energy/capita/year than other industrialized countries (industrial metabolistic flow is much greater). The magnitude of flow is what is needed to frame the discussion of sustainability. Grubler stresses that industry is a big machine whose single purpose is to maximize output and output growth through: economies of scale, standardization, increasing returns, technological change, new materials, processes, products and lower costs to increase consumption. Costs improve via technology change, but adoption can still take a long time. Additionally, there are a number of significant environmental implications:

1. Output growth, leading to mass consumption amplifying traditional impacts
2. New impacts (new toxic substances)
3. Point-source impacts amplified by dispersed consumption and end-of-life (disposal)
4. Impacts moderated by increased "decoupling" (relative dematerialization, i.e. emissions reduced, triggered by environmental regulation. Industry is responsive to these, but households not so much).

Therefore, point source (industrial plants) impacts amplified by diffuse consumption, use, and end of life. The use phase is highly distributed (see electronics disposal). All impacts are moderated by a persistent trend of decoupling of material use and economic activity. For example, certain categories of metal emissions have been declining because of environmental regulation--metal is one realm of human activity that is responsive to regulation.

Grubler points out that in regards to CO2 emissions per capita the US has gone down a high-intensity pathway, while Japan chose a high-efficiency. Still, emissions have grown. In industrialized nations, this is flat, but in SE Asia there is rapid growth . Due to environmental regulations and costs, industry may relocate to other countries. Ways to avoid this is through import tariffs and joint caps. He mentions where there is emission reduction potential in industry:

1. Inherent incentive structure for cost minimization (the only true homo economicus) because of competition, so it's an easier sector to regulate
2. Locus for innovation and entrepreneurship within sector, but also spillovers to other sectors
3. Globalized
4. Relative importance (in terms of GDP) declines with success (productivity growth)

Therefore there are a series of free lunches and take backs due to technological innovations. Free lunches due to technological innovations, which sometimes occur without need for environmental regulation:

1. Efficiency improvements
2. Miniaturization, light-weight
3. Material substitution

Take backs due to technological innovations:

1. New demands (e.g., e-commerce, which is worse in terms of energy use and emissions than traditional book marketing because of delivery)
2. Higher quality, comfort and safety
3. Changes in consumer behavior

For example, gains in industrial efficiency have led to increased levels of consumption, oversetting environmental improvements by the industrial sector. It is important to distinguish between technology transfer versus technology diffusion. The former is the traditional approach, where a "benevolent" agency imposes a foreign technology but ignores the local needs in terms of application and maintenance. The latter requires identifying and financially supporting a local investor or entrepreneur who can adapt technology to local needs.

Grubler also points out that e-commerce is worse for energy use than book stores because of the energy intensity of courier services. We would do better with regional/local distribution hubs (Kapur based on Matthews et. al, 2002). He notes that a central neighborhood delivery point can reduce this.

In addition, there have been MPG improvements, but we drive more, with fewer people in the car however, consumer behavior has eaten up all the benefits. For developing countries, technological transfer can support efficiency frontier and Grubler mentions that all of the highest efficiency solar thermal collectors already come from China and that prices play an important role (i.e. energy prices have always been high in Japan).

Grubler addresses ways to deal with leakage in this lecture, he mentions that there are many proposals such as import tariffs (but there are issues around measurement). Also developing joint caps may deal with the issue of leakage. Grubler does not believe in technological transfer - "throw it over the fence". However, he does believe in technological diffusion which he says will ensure that there is some actor (entrepreneur) with an incentive to make sure that it works. The model that we've tested the most is the military industrial complex. He does not think that the climate negotiators have any understanding of technology transfer of diffusion. It is largely a political negotiation. In response to a question regarding lock-ins, he mentions that they are very difficult to address after a window of opportunity of fluid decision making. For example, the period when people are heading out of their childhood homes and choosing their way of life moving forward.

Lecture 3. Innovation Life Cycle

For Grubler there is a continuum between invention (new knowledge, research) and innovation (new application of knowledge, R&D) and time progresses when it is produced. We must consider niche and diffusion in issues in understanding the lag between innovation and invention and there is no shortening of stochastic variation. So if we have to act now, then we have to use whatever has been invented within the last 40 years. This is why we need to emphasize on diffusion:

1. Significance of innovation only when widely applied
2. Generally life cycle phase taking longest
3. Equalizing force (not homogeneity): Importance for DCs
4. Availability of descriptive and causal formal models
5. Diffusion <u>and</u> substitution

Logistic growth of diffusion while they're not substituted, then they decline as substituted by other innovations. He also posits that the substitution rate is influenced by the time it takes for the old innovation to retire (e.g., horse versus cars, substitution time is 13 years, the useful life of a horse). Diffusion processes operate at levels of technology (size, performance, efficiency) and industry (production and use, regional global markets).

Grubler emphasizes that the larger the market, the slower the rate of change. He illustrates the commonalities across diffusion environments (e.g., central planning of USSR versus market of US) and indicates that the exception is found in social change (e.g. diffusion of literacy). Therefore, social systems change much faster than technological.

We all must consider:

Macro variables:

1. Involves time and space (S-curve and spatial hierarchy centers)
2. First mover vs. follower: longest (slowest) diffusion time and highest adoption (first mover) vs. catch-up faster but at lower adoption levels of adoption (follower).
3. Market size vs speed and impact: large size and impact = slower diffusion; small size and impact (Fashion) = fast diffusion

Determinants of diffusion speed:

1. Type of adoption decision (individual, collective, authoritative)
2. Type of communication channels (mass media vs. word-of-mouth; mass media is ineffective in adoption, word-of-mouth if MUCH more powerful!)
3. Nature of social system (interconnection, sources of learning: internal vs. external).
4. Existence and efforts of change agents
5. <u>Perceived</u> attributes of innovation:
    a. Relative advantage (e.g., perfomance costs)
    b. Adoption effort (investment size)
    c. Compatibility (technological, social integration)
    d. Observability (social visibility, learn from neighbors)
    e. Trialability (learning from own experience)

Grubler also states that change is not really accelerating, it's more a myth than reality. These are mostly incremental innovations in maturing markets that piggy-back on existing infrastructures with growing capital stock, so there's more to change which gives the impression that change is faster. The basic diffusion patterns in time and space remain unchanged. Big hits require more time. Even the Internet took about 25 years of public R&D efforts before it was commercialized.

Technological systems (interrelatedness):

1. Increasing interdependence: Change constrained by the slowest component

2. To date: poor theoretical/empirical understanding, but this will be central in solving climate change
3. Key importance in transformative change
4. Insights from agent-based model of evolution of complexity (Ma, Grubler, Arthur, Nakicenovic IIASA IR-08-02). The agents are technologies, random walk model of invention discovery and stochastic combination with other technologies into energy chains and systems. Evolutionary programming to select successful combination of technologies. Observation is a systematic increase in complexity and an ultimate decline because of limited resources. A parameter called "impatience" determines how long the diversity in technology is maintained, but at an economic price. If you let the system run by its internal dynamics, you will have more technology combinations that get older, and this slows us down for changes! If we need to change the system fast, we need a mechanism of creative destruction to destroy old technologies! In the US, we keep grandfathering old technologies!