Of Society and Technology

Sanat Mohanty

Where will technology go? What can tech-nology do? These questions lie at the centre of one set of debates with regards to the direction of technology development, policies on resources and technologies, their need and utilization and the social, political and environmental impact of these choices. These include current and emerging technologies that may impact energy (nuclear fission based energy and biofuels), waste management, food production, transportation, etc. They also include future technologies such as nuclear fusion.

One school of thought (pointing to the environmental impact of the rapidly growing fossil-fuel energy based economy) argues that ruling authorities must take responsibility for the impact of their decisions. Another group argues that the cost of not using these resources or using alternative processes is too high, and speculates that technologies developed in future-fusion, perhaps–will resolve these questions. One response to such a thought process argues that policies cannot be based on miracles and uses heuristics to point out why such technologies may or may not be feasible given the history of technology development–but that is also speculation.

Such discussions have taken place around the question of waste management–primarily in urban settings. Waste to energy was a dominant technical philosophy that received much support (and continues to in the southern hemisphere despite much opposition). Technologists, urban planners, health experts and social experts have all weighed in on this topic. In the last decade, most of that discussion (and development) had been laid to rest in the US, Europe and Japan owing to the generation of highly toxic chemicals (dioxins) and a plethora of other pollutants. However, it is a discussion that is opening up again with a new set of technologies being presented.

Another large discussion that impacts energy policy significantly is brewing around the policies of bio-based energy. One set of researchers and policymakers argue that such a process may not be economically feasible. Another school argues that this strategy is bound to fail based on the amount of land necessary to develop this energy. On the other hand, other researchers claim that bio-based energy can be generated using mainly waste land (based on current use patterns) and using the right kinds of cropping cycles. Another set points out that such a technology has the potential for zero carbon emission into the atmosphere. Yet another group argues that appropriate technologies for bio-based refining could use the 'waste streams' from the process to develop chemicals (just like the petrochemical industry) leading to renewable (and hence green) energy and materials policies. These claims are countered by the first groups by pointing to the absence of efficiency, for example. The latter groups argue back by showing that petrochemical industry needed billions of dollars to develop its efficiencies. Into these discussions, another group of researchers with expertise in sociology and political science jump in with their comments on the impact of changing cropping cycles, effect of cash crops on small farmers, geo-political impact of lower dependence on petro-based energy, among others.

These are few examples of discussions and policy direction on issues of how people (and nations) solve pressing problems around energy use, waste management, water, agriculture, etc. There are a variety of perspectives around each of these issues, each quite informed in its own right and each rising from a superimposition of technology, economics, sociology, political science, among others. How can one really address the technologies that are being presented to resolve these problems when there are complex nuances that even technical experts and social and political scientists do not quite understand?

The scenario gets even murkier when people recognize that there is much as stake–not only from the perspective of people, of the future of communities and nations but also from the perspective of economics. Billion dollar profits are often riding on the direction of these policies and it is naive to think that they do not influence research directions and policies. So this is not a simple objective technical analysis.

Often conclusions are based on assumptions which are often not explicitly stated and are speculative. They are driven by politics and economics, not necessarily by science or data. There was no sudden learning that led to the slashing of the budgets of National Renewable Energy Labs nor were there any new findings that led to allocation of large funds to this institution. Similarly, the claim by the UK government that nuclear energy will be the next wave of clean, sustainable energy was politically driven. In fact, a court in UK pointed out that the process to arrive at this conclusion was neither transparent nor did it take all perspectives into account and must be re-initiated. Public speculation has often been the façade for such policy moves.

Given these different influences, are there tools that can better help understand the feasibility and impact of technologies and hence direct the trajectory of policies? Which technologies and what policies are truly sustainable?

The first real set of analytical tools that allow concerned people to understand these technologies and the derived policies are based on data and on trends. These trends, however, cannot be taken at face value and must be understood in the context of their assumptions and the conclusions they present. The model or idealized systems developed to study these issues either simplified or are designed for a specific purpose or to prove a point.

These studies pointing in opposite directions often make implicit assumptions that must be ferreted. How does this model study truly compare with current realities of petro-based energy? Will an economy of scale make bio-fuel more feasible compared to the model study? Can it be more decentralized and hence more accessible? Has the study accounted for cost of chemical-based inputs? What is the value of chemicals derived from the effluents? What is the efficiency? While the data is generated within a model system and with specific assumptions, it is interpreted more broadly (in the absence of any other choice) to make policy decisions. Policies that result are significantly defined by the background of the policy makers and their leanings. Thus, in a certain political climate, energy policies based on bio-fuels become feasible; in another climate (based on the same data) they might become unfeasible.

Similarly, studies on nuclear energy show different aspects of generation, and distribution. One set of data shows that nuclear energy can be a clean fuel without issues of global warming and environmental pollution. On the other hand, residents of Chernobyl will disagree. At the same time, proponents will argue that reactors and the technology have become more robust and reliable. Opponents will however argue that experts have not begun to look at the radioactive waste (and its treatment) from decommissioning of nuclear reactors and that will be significant. In addition, others have also pointed out that ordinary people truly do not know given the layers of secrecy surrounding most nuclear installations and their operations and do not really know how safe they are. Opponents will also argue that Uranium is not a finite resource either and under current consumption rates at 3.5 million tons will last 50 years. This analysis also estimates that if all of today's energy needs (15,000 terawatt-hours) were met through nuclear energy world's nuclear fuel would last between 3 and 4 years. Proponents will argue that energy from other fuels like Thorium are becoming feasible thus making this technology more viable. Again, from the cost perspective, analysts have argued the cost of nuclear based energy does not compare feasibly to fossil-fuel based energy. Past investigative reports show that British nuclear energy producers (private corporations) may have been subsidized by tax payers to keep the product competitive. Yet again, nuclear energy proponents have different counter-arguments. First—that the cost of cleaner energy has to be borne by society. Second—that economy of scale would make a difference. Third —the ineffectiveness of an institution cannot be held against the feasibility of a technology. These divergent conclusions are correct within the context of their studies.

It is important to reiterate that all of these studies (and they are the best that can be done) were within narrow premises and smaller scopes. But when these conclusions are extended outside their scope to define broader policies, there are significant errors with grave impact. And yet, what other options do people have?

One option that presents itself as a way of analyzing technologies and their feasibility is to recourse to thermodynamics.

Thermodynamics is the knowledge of a material and of the possible processes of change of that material under different conditions. One can know a material by understanding the components of the material, their relationship to each other and the energy of the material. By understanding what relationships between the components of the material and the energy are feasible and what are not, one can predict feasible material structures and possible processes of change of that material. When one understands these processes, one also learns about flow of energy or work done during these processes. Two key parameters are the energy and the entropy of the material or the system of materials.

Technologies that are being deployed to help the world live better (more food, energy, etc) are actually hurting the world more than they are helping. The increased waste streams impact resources. They impact the ability to grow food and affect agricultural produce. They impact health of communities and subsequently their productivity and quality of life. Policies based on deployment of such technologies have high global economic and environmental costs.

The socio-political costs are also significant. As the cost of applying a technology increases, the technology is generally applied for that community that can afford it. At the same time, the high entropy stream from the process related to that technology will find its way to communities that cannot afford to use such technologies. That is, there is more high entropy waste than low entropy product (more negatively useful products than positively useful products) - yet people carry on since the low entropy product impacts a more socio-politically powerful section than the high entropy stream impacts.

For example, most urban wastes are dumped in smaller rural or semi-urban communities. It is true of cities in the USA, in South America and in India. For years in the past, waste was dumped in poor countries. These waste streams affect the agricultural produce in these communities, the health and productivity of these people and their quality of life. However, given that these communities are often economically disempowered or not important from a media perspective, it does not matter and nothing is heard about the impact of this low value, high entropy waste. For example, how many people know where the cities of Chennai (formerly Madras) or Minneapolis dump their solid wastes (high entropy streams from the sum total of urban processes)? Which communities gain from these technologies and which communities bear the cost?

Such a thermodynamic analysis thus shows that any future technology being envisioned today does not have the ability to resolve the resource, waste and related environmental problems.

For processes that are driven by solar energy, the energy source lies outside the Earth. Processes that use the sun as their source of energy can have the total entropy of their system decrease. The ONLY way to design processes with lower entropy products without an increased higher entropy waste stream is by using solar energy. Even while stating this, however, it is noteworthy that not all solar driven processes will result in reduced entropy on Earth.

One example where entropy is reduced would be naturally growing plants being used to produce food. The process creates more useful products (food) while also using less useful composts with solar energy as an input. On the other hand, creating bioreactors that grow large colonies of micro-organisms to produce certain chemicals may not result in lower entropies even though the micro-organisms' activities may be solar driven. One reason is that often the building and maintenance of such bioreactors requires other processes whose energy is derived from elsewhere. Similarly, collection of solar energy by photo voltaic may not be an entropy lowering process if the process to make photovoltaic cells results in larger high entropy waste streams. So also, while long-term solar driven degradation of bio-stock to produce fossil fuels is an entropy lowering process, fuel based processes that produce bio-fuels may not be entropy lowering.

Solar driven processes do work or produce low entropy (positively useful) products even while driving down the total entropy. Thus, they can accommodate some other processes with significant high entropy streams while still keeping the total entropy non-increasing or increasing at very low rates. In addition, the waste stream of an ideal thermodynamic process is dumped into an infinite reservoir—that is a reservoir that it is unaffected by the waste stream. However, in real systems today, the waste streams affect the reservoir (which can no longer be considered infinite), thus reducing the efficiency of the processes themselves.

Solar processes keep processes closer to ideal and hence more efficient. Both these roles are significant from the perspective of sustainability.

Future technologies—such as biotechnology and nanotechnology—are based on developing highly ordered materials, where molecules and cells are arranged just right. The thermodynamic arguments show that as the products are increasingly well ordered (have lower entropies), waste streams must have even higher entropies. The semiconductor industry is one of the most polluting industries. It has among the largest high entropy waste stream. Broad utilization of such technologies is not feasible in the world with growing resource limitation; such a model will actually reduce access to resources (through depletion of reservoirs), not increase resources.

Alternatively, this analysis concludes that only certain solar based technologies can be used without rapidly increasing the entropy on this closed system. Currently the society is designed on growth that is almost completely driven by fossil-fuel and nuclear energy sources. Solar based processes (agriculture) are being increasingly minimized and even there the process is becoming increasingly dependent on fossil fuel (pesticides, fertilizers, mechanization are all examples). A community that can sustain itself in the long term must be based on solar driven technologies to meet people's needs.

That is not to say that a community can/should have no technology that relies on other forms of energy. It will use fossil based energy, or other non-solar sources. However, the waste streams that are generated by these processes must be balanced by much larger set of solar driven processes—else, the rate of entropy produced by these non-solar based processes will accumulate at a rate that is much higher than the rate at which entropy is reduced by solar processes.

Finally, there is also a realization that perpetual machines are impossible. Technology cannot solve everything—there is a thermodynamic limit. All (non-solar based) processes produce more negatively useful streams even though these processes are meant to produce positively useful products. With increasing rates of production and growth, these negatively useful streams are accumulating faster than the positively useful products, choking people and communities. There is only one thermodynamic solution—which is to use the only source of energy outside the Earth. □□□