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Long term objectives include the development and transformation of the Circular Economy, into a more practical system for the industrial ecosystem to navigate the twin challenges of the scarcity of technology minerals and the transitioning away from fossil fuels.

Prologue

The task to phase out fossil fuels is at hand. The current society and its industrial systems are heavily dependent on fossil fuels, oil in particular. Yet the oil and petroleum supply may soon become unreliable. It is possible peak oil is in our past in November 2018, and costs of production of petroleum products are rising. The proposed Green Transition has a series of logistical challenges which make it impractical. One of those challenges is a shortfall in mineral supply. Natural resources of all kinds will soon become much more valuable.

Society is now required to develop a plan to transition away from fossil fuels and become more self-reliant for the supply of raw materials. We are required to develop a new relationship with energy, minerals, economics, technology, the environment, and each other. The conventional Circular Economy won't work as hoped because it is thermodynamically out of balance.

This paper proposes an evolution of the Circular Economy, the Resource Balanced Economy.

Key words: Energy, resources, Circular Economy, complexity

"When we speak of man, we have a conception of humanity as a whole, and before applying scientific methods to, the investigation of his movement we must accept this as a physical fact. But can anyone doubt today that all the millions of individuals and all the innumerable types and characters constitute an entity or a unit? Though free to think and act, we are held together, like the stars in the firmament, with ties inseparable.These ties cannot be seen, but we can feel them."

The problem of increasing human energy (Nikola Tesla, 1900)

"It's not in the stars to hold our destiny but in ourselves."

Julius Caesar (William Shakespeare, 1599)

1 INTRODUCTION

The world is changing at a fundamental level, and in a systemic scope. This change is affecting the economic markets, industrial output and is eroding the energy support systems that facilitate our global system to operate. The existing fossil fuel based Linear Economy has been struggling to maintain growth for the last few decades.

Energy is the master resource. It allows and facilitates all physical work done, the development of technology and allows human population to live in such complex high density settlements like modern cities. Energy consumption correlates directly with the real economy (Bradley and Fulmer 2008). The real economy is the part of the economy that is concerned with actually producing goods and services, as opposed to the part of the economy that is concerned with buying and selling on the financial markets.

A case can be made that we are a petroleum based society and are still highly dependent on fossil fuels for many fundamental industrial needs. In addition to the environmental need to phase pout fossil fuels, the future outlook for the industrial system to continue using oil as an energy source is not very stable. Most of existing oil producing fields are declining at an annual rate of 5 to 7%. Most oil deposits were discovered in the 1960s and 1970s (Michaux 2019). Since then, discovery rates have declined consistently. For every barrel of oil we discover, we consume approximately between three and four. Peak oil will happen at some point, the question is when. There was a peak in global crude oil production in November 2018 (OECD statistics, EIA monthly statistics). It is still too early to call this as the date of Peak Oil. Due to possible future developments, it is prudent to wait until five years have passed beyond the peak (Simmons 2005). The longer this peak remains the record, the harder that record is to break. This is due to most (81%) of the producing oil fields declining at a rate of 5 to 7% a year (Fustier et al. 2016, HSBC). In 2020, about 12 months after this peak, the Covid-19 pandemic quarantine measures were applied worldwide, resulting in the sharp contraction of total liquids production. Since then, total liquids production increased greatly, to August 2022, where given the rate of change, the peak in November 2018 could soon be surpassed.

It is apparent that the goal of industrial scale transition away from fossil fuels into non-fossil fuel systems is a much larger task than current thinking allows for (Michaux 2021a). To achieve this objective, among other things, an unprecedented demand for minerals will be required. Most minerals required for the renewable energy transition have not been mined in bulk quantities before. Many of the technology metals already have primary resource mining supply risks.

So, the existing fossil fuels system is under stress and strain, and the 'after oil' plan is needed now. The proposed Green Transition faces serious practical limitations in feasibility. An entirely new plan is required.

1.1 Complexity and a changing world

Our global system that we live in can be modelled as an evolving CAS (Complex Adaptative System) that is maintained internally by keystone-hubs operating within their stability domains, and externally by energy and resource flows (Korowicz 2012). Korowicz (2012) proposed that this global system has a self-organizing behavior of a CAS in which regions with largely localized dependencies coalesced into a singular integrated system that spans across the World. Those keystone hubs are adaptive to the conditions in which they co-evolved, based around the economic conditions and energy productivity of the past century. But when those conditions change, particularly if economic growth is reversed, they undergo a critical transition and radically simplify in complexity. The system behavior can be modeled using the CAS architecture, where global economic growth, increasing complexity, connectedness, interdependence, and the speed of industrial processes is associated with available energy and capital.

That complexity has become a fundamental signature of the global industrial system. The technology that is so popular in global markets is produced as a function of the most complex six continent just-in-time supply system the world has ever known.

The structural form of the globalized economy has been undergoing profound change that has barely been recognized in analysis; that complexity has been rising, and it is dependent on fossil fuel energy (Korowicz 2012). This is true even if it does not have its very own indicators or appear in economic models. Further, as our dependencies have grown in complexity, we have become more vulnerable to extreme economic shocks and stresses. Yet we take for granted those very dependencies (Korowicz 2012).

Civilization is always and everywhere a thermodynamic phenomenon

David Korowicz 2012

The most important parameter for defining this transformation is energy flows through this globalized economy. From a biological point of view, the quantity of energy inputted into an organism dictates the size and complexity of that organism. It the organism starts to receive less energy; it will be required to shrink in size and become less complex. This basic concept can be transferred to other descriptive models, for example industrial activity and physical work done which translates into economic value. All economic activity is subject to the laws of thermodynamics. By the transformation of low entropy energy (more properly, exergy) into higher entropy heat, work can be done (Szargut 2005 and Korowicz 2012). All Complex Adaptative Systems could be seen as open thermodynamic systems, where they are maintained by energy and raw material flows between their structural parts. This means that energy flow, in the form adaptive to any given system (food, fertilizer, light, heat, electricity, or fossil fuels), is generally a determining condition of the systems' stability.

Future projections of global energy demand are usually developed on past behavior, with no understanding of finite limits or depleting resources. Generally, reserves have been projected on by past production and demand has been defined by population growth and economic GDP. What this means is that the after-oil plan is needed now. It needs to be developed and commissioned in a fashion where parts of it could be operation in four to five years.

It is apparent that the goal of industrial scale transition away from fossil fuels into non-fossil fuel systems is a much larger task than current thinking allows for. To achieve this objective, among other things, an unprecedented demand for minerals will be required. Most minerals required for the renewable energy transition have not been mined in bulk quantities before. Many of the technology metals already have primary resource mining supply risks

The majority of infrastructure and technology units needed to phase out fossil fuels has yet to be manufactured (Michaux 2021a). Recycling cannot be done on products that have yet to be manufactured. In the current system, demand for metals of all kinds have been increasing, just as the grade of ores processed has been decreasing (Michaux 2021b).

1.2 The fundamental problem

So, what has happened? Why are these issues being observed now? Why are both the fossil based Linear Economy (in supporting energy resource) and The Green Transition (in construction of the new energy source) facing such challenges, at almost the same time? It is postulated that the paradigm behind the current industrial business model has misunderstood the true nature of commodities industry, at a time when supply of those commodities has become very costly.

At the heart of the ecomodernism paradigm is the idea of decoupling, the assumption that the use of technology can break the link between human lifestyles and their ecological impact, which currently has no strong evidence to support it. This is not possible in the long term.

The whole commodity sector was considered to be a market phenomenon, not a series of finite non-renewable natural resources, that had engineering bottlenecks in extraction. Technology development has a development cycle of two to four years and seemed to assume that the supply of energy and raw materials were all a function of market price. Once the capital was available, the market could be created. A case can be made that to date, most technological innovation has been energy blind and mineral blind.

Most of the thinking behind technology innovation has been done to evolve technology, assuming energy and raw materials supply will always be a function of market forces. Commodity industrial operations (like a mine) can take decades to develop. Innovation applied to the sourcing of metals from mining has been comparatively slow, large in capital investment, and improvements are usually small step changes (observation by author from past experience).

All three sectors are now in trouble. It is possible that peak crude oil production is in our past, and the planned green transition is not practical in its current form. The quality of mineral resources has been declining for decades and further access to mineral resources without fossil fuel energy. In addition to all this, available capital is getting harder to secure, and debt is saturating the international financial system in all sectors. So, what ever happens next, it will be done according to a new set of limitations in comparison to anything humanity has attempted before.

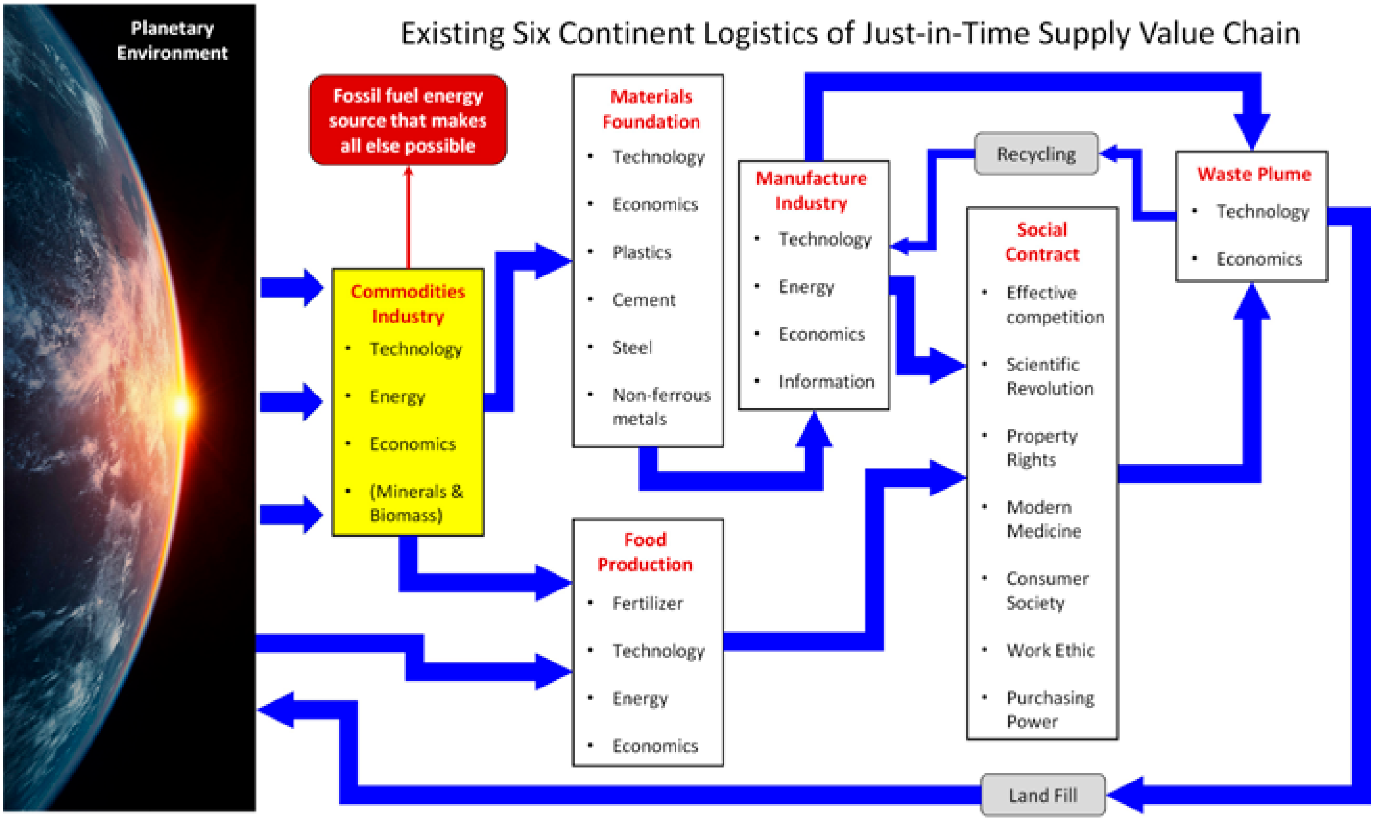
Work done so far suggests that the hope that technology will somehow deliver a new energy system does not honor the concept that that energy has to come from somewhere. The Green Transition is heavily dependent on the supply of metals from mining at least in the next few decades. The thermodynamics suggest this will not work. Energy efficiency applied to technology is not open ended. It is a one time saving, after which wholly new technologies must be invented or application systems are significantly changed. In general, this is a diminishing return with fixed theoretical limits, where each change/improvement saves less and less with each iteration. This suggests that an entirely new energy system and industrial paradigm is needed urgently.

In addition to these challenges, Human society is also consuming the available renewable resources (the products of ecosystems) at a greater rate than they can regenerate. If this was a mining operation being described, this would be described as stripping the asset for short term gain at the cost of long term legacy value. Or alternatively, very poor stewardship of the resource.

Figure 1 shows a process flow chart of how our society currently uses industry to harvest natural resources from the planetary environment. The fundamental origin of the problems in the challenges our society now faces is a misunderstanding of what the commodities industry really does for our society. This is true for the fossil fuels energy systems (oil, gas, and coal), and is also true for the mining of minerals (which were to be the natural resources supporting the Green Transition). Any future planning will acknowledge an evolution of the commodities sector, and a revolution in how the commodities sector supports society and its industrial systems.

In the current economic paradigm, planning has been around economics and technology development. Yet the commodities sector really has four aspects: minerals, economics, technology, and energy. Any genuine investigation that accounts for physical actions in the extraction of natural resources will have to include all four aspects and acknowledge that those natural resources are harvested from the planetary environment. This recognition has been missing from the calculus of strategic planners for some time. Any future plan for industrial reform will have to allow for this basic concept.

Figure 1. Existing six continent macro scale logistics of just-in-time supply value chain



Source: Simon Michaux

At its foundation, the current industrial system was and still is based around the consumption of natural resources, which were considered to be infinite. The very idea that there might be system based limits to the global extraction of resources is considered foolish by the current economic market. The volume of manufacture was influenced by the consumption demand of products. Growth and expansion with no considered limits of any kind was the underlying paradigm.

It is to be stated that we are not running out of resources. The entire Andes Mountain range is one giant copper deposit of extremely low grade. What is now facing seriously practical constraints is out industrial capability to extract useful quantities of metals from those resources in an economically viable form (Michaux 2021b).

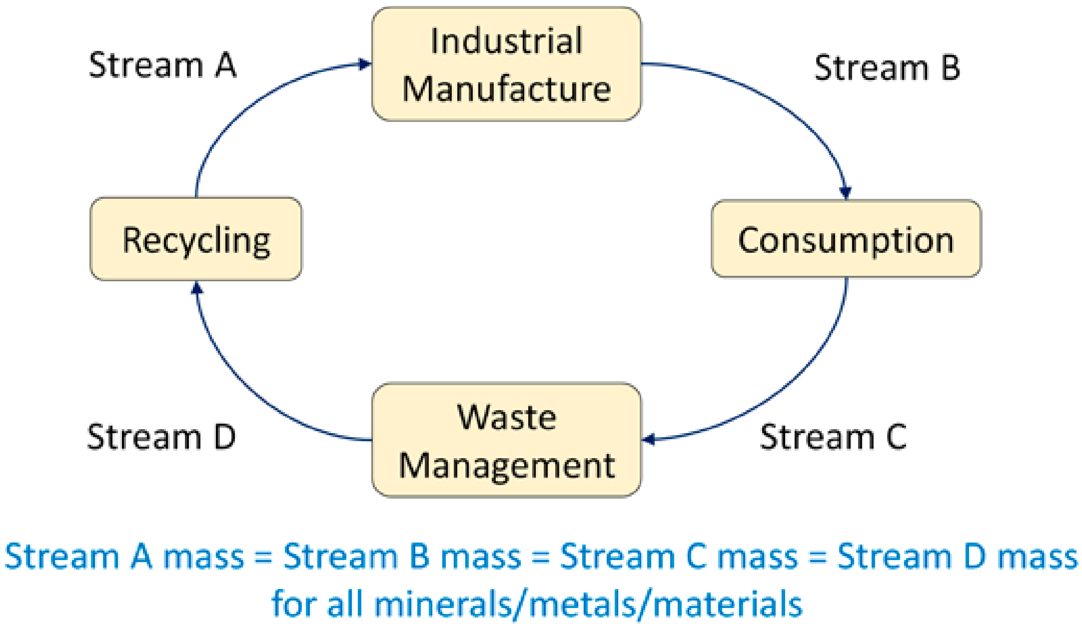
So, a new plan is required. There are several strategic plans to consider, for example The Steady State Economy (Daly 1973). The Circular Economy (European Commission 2019) another proposed plan, but it is not useful in its current form but could be seen as a steppingstone to something else.

2 THE CLASSICAL CIRCULAR ECONOMY

The Circular Economy has been proposed as a way of transforming European society in how it manages raw material flows internally into a more sustainable architecture. The circular economy is a systems framework that provides a set of systems based principles to transition from the current dominant linear economy (extract metal from mining, manufacture, ending in waste stored in landfill) to a high value industrial economy that designs at waste at the outset, keeps products and materials in use at the highest value for the longest time through the application of waste management strategies, typically the so-called 3R's: reduce, reuse and recycling. A more sustainable relationship with the environment is to be actively developed. A successful Circular Economy in theory would reduce demand for virgin materials, dramatically increases resource productivity at all stages of the value chain.

An ideal Circular Economy would collect 100% of the industrial ecosystem waste, and then recycle 100% of all the different metals/minerals/materials in each stream, where there is no final waste at all. This assumes the mass and metal/material content of all internal macro streams shown in Figure 2 would be equal. That is, the mass of metals and materials being sourced from recycled waste would equal the mass of metals and materials required for manufacture, to match consumption demand.

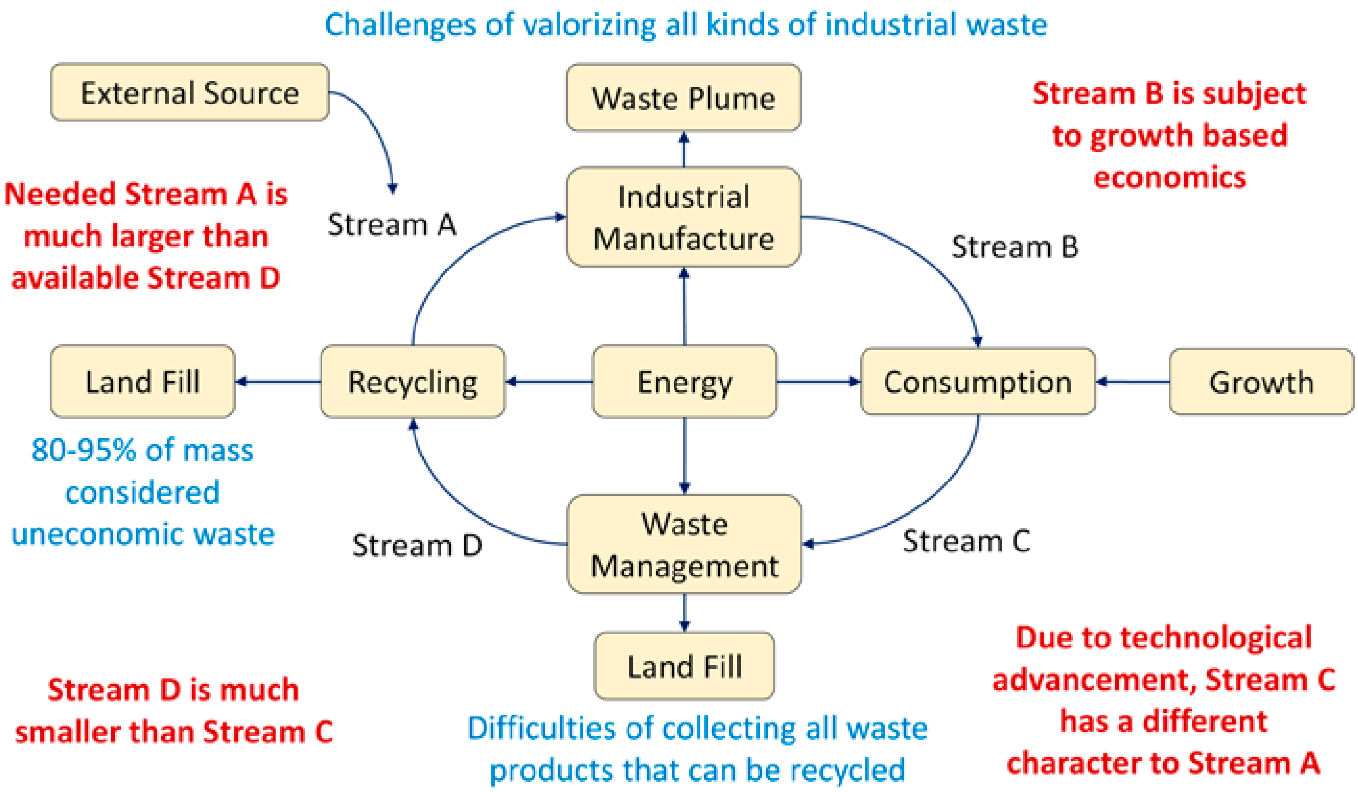
Figure 2. The idealized Circular Economy material streams



Source: Simon Michaux

This would not be possible under the current standard practices for several reasons. Any given recycling process plant will be optimized to recover one primary metal. Sometimes, a polymetallic plant is constructed that also targets two or three secondary metals, accepting a reduction in recovery efficiency. The rest of the material (which could be 95% of the stream mass) is considered waste that is not economic to process and is often put in landfill. The implications here is that most of the material masses of the internal material flows that could be subject to recycling, would still end up in land fill, losing the majority of the metals and materials.

Figure 3. Material streams in a fully functioning Circular Economy



Source: Simon Michaux

Also, there are enormous practical logistical challenges in collecting all the waste streams that can be recycled. This is part due to the nature of each waste stream, and due to not enough of the community participating in recycling at the collection point.

For a recycling process plant to deliver effective recovery, its feedstock is required to be mostly made up of the same EOL waste product, of which the process plant has been designed to recover a target metal from that waste product. What ideally should happen then, is the EOL waste products should be sorted in appropriate streams, and the 'right' waste streams are sent to the 'right' process plant. Achieving this has been logistically very difficult, with only very basic sorting being achieved for some of the waste streams. Each process plant usually has highly variable feedstock, in context of what the process plant has been optimized to process. As result, recoveries are generally lower than they could be if the feedstock was more optimized. A more realistic macro scale flowchart of the material streams of a Circular Economy is shown in Figure 3. Each of the streams are very different in mass, raw materials are required from an external source (from mining for example), and large masses of materials are lost to landfill.

The Circular Economy in its conventional form is not thermodynamically balanced. That being stated, it could be seen as a steppingstone to something else and would be the most likely area of study to develop a true replacement for the fossil fuel energy based system.

3 DEVELOP A NEW SYSTEM BASED ON A NEW PARADIGM

Developing a new plan in context of the many large-scale challenges we face will be challenging. No doubt, that carrying out that plan will be even more difficult. This will involve reducing energy consumption, raw material consumption, and a comprehensive change in what materials we use, why, and where we source them from. The human industrial footprint will probably have to shrink in size of inputs and outputs and settle into a new equilibrium. The paradigm of the last serval thousand years of growth based economics will transition to something that does not require growth in size or complexity. This will not be a choice but a reality based requirement to meet system growth restraints. As time goes on, it will be harder to do things that depend on existing technology due to contracting energy and disrupted technology manufacture. The existing system will deteriorate as the new (much smaller) one is developing from a very basic foundation, and then grow in complexity over time.

Part of the process of industrial transformation, could be modelled as a Fibonacci sequence of piling up complexity becoming too complex for the system to carry sustainably (Tainter 1988). As this complex system was developed in many layers like an onion, it may unravel in layers.

So, an entirely new concept should be developed to meet the primary four challenges.

1. The energy systems that will be required to be developed will be fundamentally different to the existing fossil fuel based systems. As a direct consequence, the nature of industrial activity that sues energy will have to evolve into a completely new form.

2. A new relationship with the environment reflecting ecological reality will be required.

3. How raw materials is sourced will have to be very different to what it is now. Whatever this becomes, it will have to reflect the quality of what resources are available, the technological capability to extract those resources, and the quantities extracted limited by physical reality.

4. The restructuring of society resulting in an entirely new social contract. Ho we perceive the environment, energy, resources, and each other will have to transform into something that reflects the new reality.

This proposed system will have to meet the following challenges:

- Possible global peak crude oil production, in conjunction with the global gas market supply being heavily influenced by geopolitics. This will probably mean peak energy consumption per capita.

- Human society is part of the environment, as opposed to separate to it. Our long term survival is linked to the long term stability of biodiversity life systems on a planetary scale.

- The Planetary environment is in a state of deterioration (United Nations 2019). Industrial pollution in several forms is overloading the planetary scale environmental cycles (Steffen *et al* 2015). Species die off is happening at a very high rate compared to historical background rates (Ceballos *et al* 2015). Oceans are acidifying (Dryden *et al* 2021). Arable land is degrading, and the soil food web is contracting (Bogard 2017).

- The end of growth-based economics is upon us, correlating with peak energy per capita consumption. This results in a requirement for a reduction in complexity in all sectors as a function of contracting available supply of energy.

- Collapse of the ICE transport network, due to nonlinear and unreliable supply of gasoline and diesel fuel.

- Manufactured goods shortages of all kinds. The complex 6 continent Just-In-Time supply system of manufacture goods becomes highly unreliable and expensive.

- Metal shortages are really mineral shortages. The quality of mineral resources that are left are much lower grade and are more expensive to extract that what was available 100 years ago.

- There is a shortfall of regional industrial capability to manufacture components and finished goods.

- The phasing out of most petrochemical based plastics.

- Phasing out of most petrochemical fertilizers, herbicides, and pesticides. The production of food will need to be restructured

The key to achieving something useful in this task will be to look at all aspects from a different direction. All macro scale problems that current society faces should be considered together in a dynamic systems context. They will all have to be faced in the same few decades.

All possible solutions should also be considered both in how they might change the architecture the system that describes all the problem challenges, and how they coexist with each other. The solution paradigm should include the orthodox, unorthodox, and previously rejected ideas, given that what is now considered economically viable is very different. When the orthodox methodologies prove to be inadequate, turn to the unorthodox, or accept failure. Use the past and previously rejected unorthodox ideas differently in conjunction with present cutting-edge technology, to create a new paradigm, where future limitations could be seen in a new light. All stakeholders who might be affected by the challenges presented, and all whom might provide possible solutions should be considered in this developmental calculus. All aspects of this examination and development should account for reality based empirical evidence and demonstrated biophysical ecological limitations.

This proposed system could access the following historically unprecedented opportunities:

- Science and engineering have never been so developed.

- Technology and industrial capacity I have never been so capable as it is now.

- Education of both genders is at all time historical high.

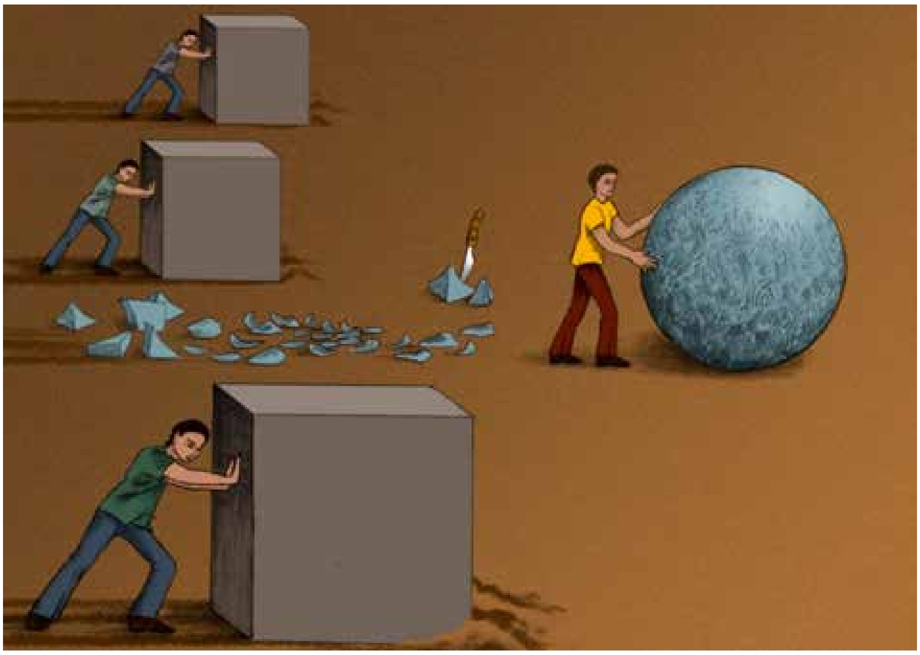
- Communication both domestically and internationally is at an all time high in capability. The information transfer that the internet make possible has transformed society. Ideas of all kinds can be transferred around the world in seconds.

- The rule of law and order is considered the norm and is what most people wish to accomplish for the world they wish to live in. This means we will preferentially find a way to cooperate.

- Most people now believe we all have human rights. Historically this was not always the case. This means we will preferentially seek a solution that is beneficial for all humanity, where in the historical past we solved our problems with the conquest mentality.

Attempting to predict how a complex system may evolve as a consequence of its structural parts becoming unreliable is very difficult (Coveney & Highfield 1991). Just so, attempting to define what system might replace it could be seen as futile. Instead, this report attempts to understand what basic structures and approaches might work and why existing patterns might not. Should we see the natural environment in a different fashion? Is our society part of the natural environment, or are we separate to it? What does a truly sustainable human society look like? What are basic steps of evolution to get there?

Figure 4. Develop what works in the new industrial circumstances as opposed to what used to work



Source: Tania Michaux

What is proposed here is that human society and the industrial system that supports it would evolve to a new equilibrium, that involves a different relation with energy and raw natural resources (biomass and minerals). Concepts like biomimicry (Benyus 1997) could be useful, where behaviour of natural life systems like a forest responding to a serious change in its environment could be used to predict how a complex industrial network might respond to a fundamental change. James Lovelock proposed that a macro scale ecosystem would respond to a structural change in its environment with a change in what the dominant species are (Lovelock 1995). The existing dominant species became successful due to the existing environmental conditions. As new but significantly different conditions happen, that dominant species would do as well, and starts to die off. As a natural forest is made up of a very large number of different species of flora and fauna (termed biodiversity), some of the previously less numerous species could find the new conditions optimal for growth. This group of species would take over through aggressive competition for resources and become the dominant paradigm. While the species makeup would change, the stability of the forest as a whole would be maintained through significant environmental change. This is the reason why species biodiversity is important. Radical change seems to be the only constant when examining the planetary environment in a geological time frame (Stanley 1987). Significant change in both climate and the kinds of flora and fauna species happens regularly on a planetary scale. The best way a large ecosystem can maintain long term stability through great change is by having whatever solution it needs already established in its genetic library. This is why diversity of ideas is crucial for the long-term stability for the human species.

An industrial system could behave the same way if something as fundamental as the form and quantity of energy and availability of raw materials was to change (Figure 4). So instead of trying to develop a new plan based on assumptions, examine how the existing industrial system might respond to the perceived incoming changes, and what alternatives might be able to function more optimally in the changed conditions. This is in recognition that all past historical attempts of economic/industrial control at the large scale were proven to be futile after a few decades.

A new social contract will have to evolve around these new structures as well as reducing social power gradients by orders of magnitude, and nurturing the evolution of small, human scale ecologies of mutual care. Concept of "repairing the cultural immune system of human societies" will also be required in the long term.

Current society has lost many of the skills we might find useful in this transition. Many of us will be looking at a very steep learning curve. In many ways, the current society is like a blank slate, ready to be retooled and reimagined. The generation to do this may have to be stronger than the generation of people who fought World War II. This will be a challenge. As always in the past, members of society have stepped up to meet the challenge. These members may not be our current leaders.

In this era of fundamental change, we will be required to innovate like never before. We will be required to consider and develop genuine firsts and situational firsts for solutions in every part of our society (Bosi 2022).

- Evolution – doing things better
- Revolutionary – doing better things
- Accidental – exploiting the unexpected

All of these problems are byproducts of the same systemic problem. Human society (in its current form) is consuming resources at too greater rate and has been producing industrial pollution at an ever increasing quantity over a sustained time. The industrial system must become more balanced with the natural environment. Over the last century in particular, industrial pollution in numerous forms have been overloading parts of the planetary environment. The business model for the last 200 years has been an increase dependency on technology within the paradigm of decoupling from nature. This trend is now required to reverse, as it has shown to not account for the dependency on finite non-renewable natural resources.

A major fork in the road approaches in how we deal with these unprecedented challenges. How we meet those challenges will decide who really are and what kind of world we want to live in. Do we turn against each other, or do we work together? Does our culture rise to the challenge and change the way it relates to its people, and the environment, or will we become subject to natural selection in the face of adversity?

How do we do things now that allows for long range development to merge with the environment in sustainable balance in the long term? How do we avoid a species failure in the time frame of 1000 years? What direction should we develop in? What window of operation should we aim for in the short, medium and long time frames?

4 THE RESOURCE BALANCED ECONOMY DECISION MAKING INFORMATION FLOW SYSTEM

The proposed restructure of the Circular Economy is a Resource Balanced Economy (RBE) with the harmonious integration of statistical entropy coupled with material flow analysis of each resource. A Resource Balanced Economy is that of a system where gross industrial output and gross domestic product, is mainly derived from natural resources, but is limited in scope and action by exergy thermodynamics. The objective metrics of this RBE converge around long term sustainability of all stakeholders. Systems network theory is proposed to be the mathematical foundation of the development this form of Resource Balanced Economy (Kossiakoff *et al* 2011 and Dennis *et al* 2009).

The proposed Resource Balanced Economy is an evolution of the Resource Based Economy, with the integration of exergy as a limit derived decision tool. The original concept of the Resource Based Economy was popularized by the Venus Project (https://www.thevenusproject.com/), and its founder Jacque Fresco (Fresco 2018) in the year 2000. Since then it has been through several generations of development. Later, the Zeitgeist Movement (https://www.thezeitgeistmovement.com/) and its founder, Peter Joseph also popularized this concept.

The original concept of the Resource Based Economy is the development of a system over time, where all resources, technology and services are available to everyone in the human population. This would be deployed without the use of money, credit, barter, or servitude of any kind, while maintaining basic human rights like privacy and free speech. For this to be attained, all resources must be declared as the heritage of all humans in a global context. All resources are defined as existing valuable commodities subject to mining, and the waste side stream secondary resources. The proposed Resource Balanced Economy is an evolution of this, which includes a thermodynamical exergy term as a limiting metric to produce a practical system.

A shift in paradigm in how society sees that natural environment is also required. That natural environment allows the long term habitation of our society and should be maintained accordingly. At the same time, all resources that support our society come from that environment. We must change our paradigm, so we see ourselves as part of the planetary environment, not consumers of it (the current Linear Economy paradigm).

What is proposed here is a fundamental restructuring of our entire industrial ecosystem, starting with an evolution of the social contract. The current system is in a state of stress, and much of the planet's leadership are making decisions that could be described as panic based. To meet this challenge of change at a time of stress, it is proposed that the principles of science guided by philosophy is engaged on a scale not seen historically. What is proposed is an unprecedented mobilization of scientific and technical alliances towards problem solving, without the interference of money or politics (implying a replacement system).

How do we develop a system that will converge on a methodology to meet the spectrum of human needs taking into account the most efficient and sustainable processes? The final outcome should be a symbiotic relationship with the natural environment is developed at a planetary scale. The proposed system is geared to maximize economic efficiency and true sustainability together, where the current Linear Economy only maximizes economic efficiency.

There are seven dominant considerations that could be developed as structural parts of the economic system.

1. Resource accounting
2. Embodied energy consumed vs. strategically useful outcome accounting
3. Management of dynamic equilibrium
4. Strategic design
5. Statistical entropy coupled with material flow analysis of each resource
6. Biophysical signatures
7. Technology application evolution/devolution over time

4.1 Resource accounting

The human population currently administers the global industrial ecosystem as if there are unlimited natural resources. In reality, the planet is a finite dynamically self-regulating system that has been relatively stable for time periods best measured in geological eras. The industrial eco-system has grown very quickly in size and complexity since the start of the first industrial revolution (IR1). The industrial paradigm has only a very limited perspective of approximately 250 years.

So, the global industrial ecosystem habitats a finite closed (mostly) biosphere, and it consumes finite non-renewable natural resources (metal, energy, materials) and renewable resources (sourced from flora and fauna).

Logically, to sustain the environmental habit for future generations, maximizing the use of each and every resource as effectively as possible, is required to leave resources for our descendants. This is the effective and sustainable management of the Carrying Capacity of the planetary environment.

It is recommended that all resources streams are characterized and managed in context of biophysical signatures. The field of biophysical science deals with the application of physics to biological processes and phenomena. This approach could be used to merge non-renewable resources like metals with renewable resources like trees, and industrial resource consumption into a single coherent system.

What is required, is the quantification of the global (and all subregions like Europe and the Nordic Frontier) natural resources in all their forms. We need to understand exactly what our industrial ecosystem requires and in what form. In parallel to this, an understanding on what these resources are needed for and in what applications. A new methodology of resource classification is now needed, as part of routine mapping, there is a dynamic system based link between what resources we have, what they are needed for and where they are needed.

The total global resources need to be mapped in various levels of precision (reserves & resources, etc.). A more sophisticated standard of resource classification is now appropriate where the following needs to be mapped for all useful raw materials. These resource mapping parameters need to be in a form where they can be used in an exergy industrial entropy analysis (Reuter *et al* 2006).

4.2 Embodied energy consumed vs. strategically useful outcome accounting

We are now stepping into a lower energy intensity world (Hall *et al* 2014, Schernikau & Smith 2023). All of the non-fossil fuel energy systems have a lower ERoEI ration and/or are not as flexible as fossil fuel sources like oil, gas and coal. Energy will become much more valuable. Society could well start managing its energy in a similar way to how money is managed now (extremely carefully).

At this time, many of the physical tasks undertaken by society are frivolous and simply not necessary. This is the outcome of a consumerist society, an economy based on whim and entertainment, as opposed to what is absolutely needed.

So now each industrial action and each consumption action now must be considered in context of what energy was consumed and would that be an intelligent use of resources. The question now asked is: should we do this?

Develop a new business model that underlies the industrial ecosystem, where what is done and, on whose behalf, shifts from making money to a resource based sustainable set of metrics. Some thought should be given to what those fundamental metrics should be. The current Linear Economy uses the metric of maximizing economic value in a globalized market, with the goal of free trade international law. This has led to the ever increasing consumption of resources and now that system is showing signs of strain. The Circular Economy is ultimately embedded in the same underlying paradigm of economic growth. A completely new approach in some form is required. So, what metric of efficiency should guide all decisions? Should just one of the concepts listed below, or should a combination be selected? Should they all be selected? How do we make this practical, as each addition would accelerate the complexity of the system as a whole?

- Economic
- Machine efficiency
- Energy efficiency
- Effective resource use
- Thermodynamics based exergy, enthalpy, and entropy
- Biophysical footprint
- Environmental footprint

The decision making system that this implies would have to have an energy term (exergy for example) and if possible, biophysical footprint term, and if possible an ecological footprint term.

4.3 Dynamic equilibrium

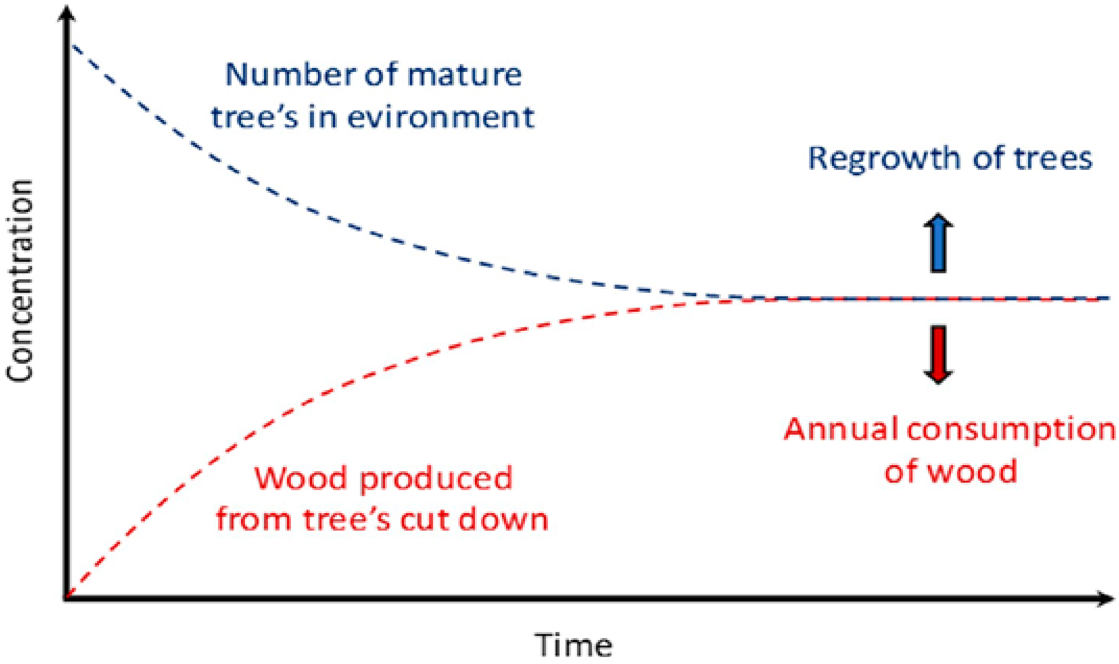
The Linear Economy monetary market model requires as much consumption as possible to keep the growing population employed and the economy operational. The outcome of this approach is obviously sustainable.

To manage natural resources sustainably in the long term, a method is required to track the consumption of resources against remaining quantity and resource regrowth (if possible). To do this effectively, the rates of change and regeneration of all resources and environmental markers need to be tracked to attempt to maintain dynamic equilibrium. For example, trees have a natural growth rate. Human society have been cutting down trees for wood resources for some time now. The cutting down of trees could be managed to be in equilibrium with tree growth.

A systems management protocol in how the data streams for resources is handled is proposed based around eh concept of dynamic equilibrium (Smith & Lewis 2011, Chung & Choi 2018).

Figure 5 shows and example of how dynamic equilibrium could be used to manage the harvesting of wood from forest plantations. The resource accounting of the number of trees and the health of the environment in context the environmental carrying capacity is mapped appropriately. The rate of tree regrowth was managed appropriately. The number of trees being cut down, could be closely managed by optimizing the consumption of wood.

Figure 5. A theoretical example of dynamic equilibrium, wood production from a forest



Source: Simon Michaux

4.4 Strategic design

Resource allocation must be optimized strategically and conservatively. This is not done very well currently, where arbitrary monetary realizations are managed in context of what can be afforded by the supplier (cost of production) vs the consumer (commodity price). This is not done in context of the most scientifically efficient and long term strategically sustainable usage could be. The life cycle longevity of each product is currently geared to make money, not last as long as possible. Recycling of those products are not considered at the design phase, where waste disposal is considered someone else's problem (resolved with waste landfill sites). Cost efficiency often results in technological inefficiency. An example of this concept is the European industrial production in context of environmental legislation and minimum wage laws in compassion to the same systems in China. China dominates the global industrial markets because their costs are much lower and environmental legislation regulating industrial pollution are very different.

All of these issues serve as inhibitors for truly sustainable design. In the development of long term strategic industrial ecosystem design the following should be considered where possible.

- Accept lower purity of materials as feedstock, reducing pressure on refining targets
- Design for recycling to be effective
- Design multiple parallel systems resourced by different minerals

4.5 The statistical entropy coupled with material flow analysis of each resource

The case has already been made that energy is the master resource. The collection of and the application use of is the very heart of any industrial ecosystem. The current Linear Economy has been made possible with the access to cheap abundant energy. Any new ecosystem will have to have energy as a structural foundation concept.

The development of the Circular Economy has been very effective at collecting the building blocks needed to make a systems replacement. The concept of recycling powered by renewable power systems like wind or solar is a necessary paradigm shift to move away from the Linear Economy. To do this involves a shift in focus away from energy resources (oil, gas, coal, and uranium) to mineral resources to manufacture batteries, solar panels, and wind turbines.

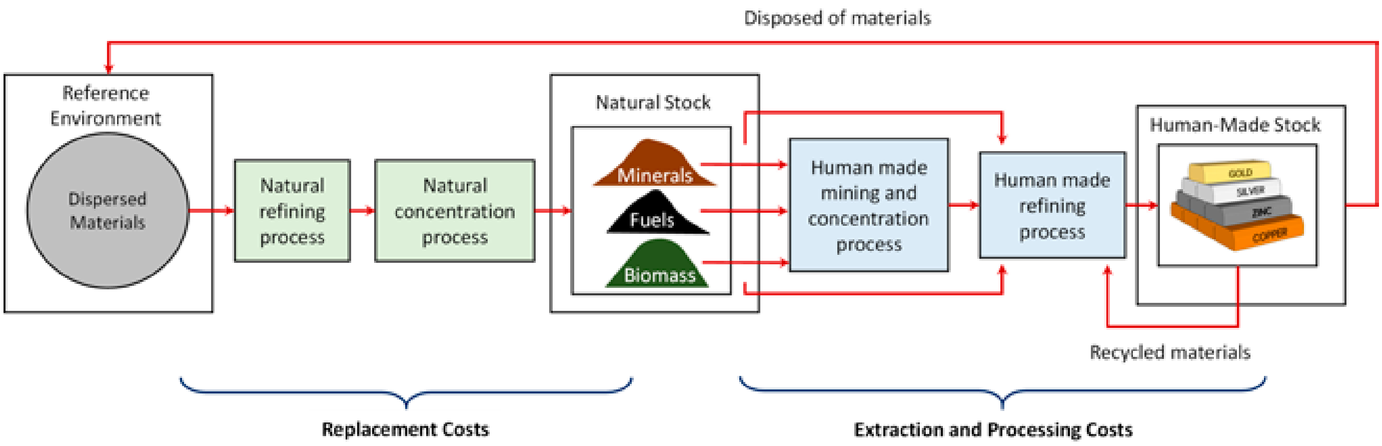
Recycling of metals are theoretically infinitely recyclable, but there are practical limitations based on the complexity in how products are designed. Most products are designed to the optimization of performance, not to be recycled. There is a degradation in quality with each round of recycling. There is an inherent need to develop methods capable of quantifying the efficiency of recycling systems, provide guidelines for optimization of existing technologies, and support the design of new products based on sound, scientific and engineering principles (Reuter *et al* 2006).

A methodology was presented in the literature (Velazquez-Martínez *et al* 2019 and Reuter *et al* 2006) that shows the use of statistical entropy coupled with material flow analysis as a basis for the optimization of separation and purification processes. This example was applied to lithium-ion battery recycling processes. Unlike other efficiency parameters, this approach provides an analysis of component concentration or dilution from a systemic perspective, taking into consideration products, by-products and waste streams. The use of secondary resources through for example recycling involve material losses or generation of undesired by-products. Balancing losses and recoveries into a single and logical assessment is a very useful tool. This methodology introduced an entropic association between the quality of final recoveries and the earlier stages of process separation. In doing so, a true audit of the effectiveness of the process could be conducted.

This approach involves the use of the concept of exergy. Exergy is uniquely suited to use as a global, strategic indicator of the sustainability of mineral resources as it allows direct comparison between all metals, minerals, and fuels. Exergy is the application of thermodynamics to the accounting of natural resources and material fluxes. It examines the real energy costs, that is, the replacement costs, relative to a standard reference environment (RE). Therefore, one can compare in the same units the costs of different industrial operations in context of natural resources: Exergy (in Joules, J).

In thermodynamics, the exergy of a system is the maximum useful work possible during a process that brings the system into equilibrium with a heat reservoir, reaching maximum entropy (Rant 1956). The maximum fraction of an energy form which (in a reversible process) can be transformed into work is called exergy. The remaining part is called anergy, and this corresponds to the waste heat (Honerkamp 2002). Using an exergy standard states makes it possible to express these enthalpy and entropy data as Exergy by using for example the methodology and standard states expressed in Szargut (2005).

Figure 6. The conceptual process of exergy



Source: Simon Michaux, ingot image by Craig Clark from Pixabay

When the surroundings are the reservoir, exergy is the potential of a system to cause a change as it achieves equilibrium with its environment. Exergy is the energy that is available to be used. After the system and surroundings reach equilibrium, the exergy is zero. Determining exergy was also the first goal of thermodynamics. The term "exergy" was coined in 1956 by Zoran Rant (1904–1972) by using the Greek ex and ergon meaning "from work" (Rant 1956 and Grubbström 2007).

Energy is neither created nor destroyed during a physical process, but changes from one form to another (as per the 1st Law of Thermodynamics). In contrast, exergy is always destroyed when a process is irreversible, for example loss of heat to the environment (As per the 2nd Law of Thermodynamics). This destruction is proportional to the entropy increase of the system together with its surroundings. The destroyed exergy has been called anergy (Honerkamp 2002).

It is proposed that the RBE uses the following forms of analysis in the management of resources.

- Mass losses of target element as well as associated elements
- Exergy
- Thermo-economics of industrial entropy
- Biophysical signatures
- Life Cycle Analysis

A useful way to quantify resource materials like metals in context of energy consumption or embedded energy previously consumed, is exergy. In thermodynamics, the exergy (in older usage, available work and/or availability) of a system is the maximum useful work possible during a process that brings the system into equilibrium with a heat reservoir. After the system and surroundings reach equilibrium, the exergy is zero.

5 POSSIBLE INNOVATIVE SOLUTIONS THAT WOULD CHANGE HOW THINGS ARE DONE

Figure 1 shows the architecture of the current human system. A deterioration of the capability of the commodities sector is putting the current system under stress and strain. What would help enormously, would be a series of technological breakthroughs that would change the systems architecture of Figure 1. Each of these ideas are unorthodox and have yet to be accepted by mainstream thinking. As conventional thinking is now struggling to maintain stability, the unorthodox may now be considered.

- Develop and produce thorium molten salt Small Modular Reactors (SMR) that uses thorium fluoride salt for fuel. Any aluminum industry (for example Iceland) is already set up for fluorine based fuels (the bath for reducing the alumina is fluorine based). This technology has a fuel cycle that is quite different to the conventional uranium nuclear fuel cycle (IAEA 2021, Zang *et al* 2018). Reactor fuel is much simpler to produce and does not require such complex handling procedures. The waste product is much smaller in quantity and does not require such long storage times.

- Geothermal heat reserves contain a lot of energy. The shallow wells have fluids around 50-700C, which is not hot enough to generate electricity but can be used for heating of buildings. At a depth of 8 to 15 km there are multiple heat reservoirs that have fluids hot enough to generate electricity. To date, most of this energy has been too deep for us to access in practical terms. If deep drilling technology could be developed in a fashion that allows many very deep holes (approximately 10 km) be drilled, then this could be a major energy source. (Friðleifsson *et al* 2014)

- Make ammonia fuel in industrial quantities using geothermal energy. New applications for ammonia being explored include renewable ammonia as a zero-carbon fuel in the maritime sector and for stationary power generation. Ammonia is also proposed as a hydrogen carrier for long-range transport (IRENA & AEA 2022).

- Re-engineer maritime shipping vessels to be smaller in size. Scale back required desired performance metrics in exchange for more energy efficient maritime transport. Consider for example a return to sail propelled shipping and/or sail assisted vessels.

- Re-tool the existing power grid into a network of microgrids, that can transfer power between them and can still function if part of the grid is temporarily shut down. Each grid supports a vital industrial or social activity like a smelter, or a hospital/school complex. Power could be transferred between micro grids. Each micro grid could also shut down if there is a maintenance issue without damaging other grids.

- Develop new electrical engineering technology that can cope with variable power supply (variable current, voltage, and frequency). At this time, electrical power is required to be sinusoidally clean and very stable. Any deviation would result in electronics being destroyed and the network prematurely aging. If an electrical technology was developed to cope with power blackouts, brownouts and shutdowns without damage, the need for a power buffer would be greatly reduced or even removed. Currently, wind and solar power generation are so intermittent in supply that a power buffer is needed.

- Develop and upscale the 3D printing technology. If it was possible to print products with a range of metals and materials, this technology could really change how manufacture supply chains are organized (Berman 2020 and Ruiz *et al* 2022). Would be possible to use a sustainable feedstock? Much of the existing global complex supply chain would not be needed.

- Develop and upscale nanotechnology to revolutionize what technology could be manufactured. Nanotechnology is the study and manipulation of matter in very small sizes (between one and one hundred nanometers) (Pokrajac *et al* 2021). This disruptive technology will allow stronger, lighter, and tougher materials to be generated than those currently used (for example graphene). This would have to be done in context of all other challenges listed though.

- The widespread use of hemp and bamboo as building products and manufacture feedstocks. Both plant species have engineering applications, that if fully utilized could revolutionize what gets produced in a sustainable fashion (Barbhuiya & Bhusan Das 2022, and Imadi *et al* 2014).

- Restructure money into a commodity backed finance system. The current fiat currency systems are showing signs of stress and strain and could be due for replacement (Rickards 2014). While historically a gold backed currency might be proposed, this is not actually what is most needed. Society has also a need to completely restructure its energy and industrial sectors. What is most needed is industrial commodities and metals of all kinds, not gold. Thus, a financial system could be based on what is most needed for the next century. All nations can then take part based on what they have in terms of resources in the ground and what they can bring to the table, as opposed to a scar city based gold reserve that would serve no other purpose.

- Develop small scale organic food growing (supplemented with industrial production of compost). Current practices of industrial agriculture and the use of petrochemical fertilizers, herbicides, and pesticides is degrading arable land at an unprecedented rate (Michaux 2021a, Cameron and Osborne 2015, Bogard 2017). Use permaculture methodology (Mollison 1988) to merge the growing of food with natural biodiversity in the local and regional environments. Do regular soil testing to develop the soil food web to a naturally sustainable state.

- Phase out the use of most plastics, where most existing applications are erroneous and wasteful. Use bioplastics in their place in high quality applications (Shen et al 2009).

- Consider investigations into unorthodox theoretical energy systems like The Zero Point Energy (ZPE), or the quantum vacuum (Abbot *et al*, Casmir 1948, Valone 2019). In the long term, human civilization requires a potent and concentrated energy source with a high ERoEI. A fundamental breakthrough is required, where all existing thinking bears no resemblance. While ZPE is not taken seriously be mainstream science at this time, it may be feasible if a paradigm shift happens. Past attempts at developing this beyond conceptual demonstration have been limited by engineering technology capacity. If nanotechnology and 3D printed was considered in conjunction to ZPE, then new energy production capability might be possible. Even if this proves to be useful, it would not be operational for many years.

This is not an exhaustive list of breakthrough disruptive technologies. However, if any of these were developed and applied to their full potential, the architecture of the industrial system would be radically changed. Supply chains could be shortened. How goods are manufactured and from what feed stock could all change. Everything in this list though would be required to develop and become functional with contracting global energy and raw material supply systems that which would become increasingly unreliable. Available feedstock materials could be of variable quality and grade.

6 DEVELOP INFORMATION DATA HANDLING SYSTEMS

To manage a system of unprecedented complexity (even at a small scale of a single city), an information handling system to make choices and give recommendations to government officials is to be developed. What is proposed is a tiered multi-phase system, that uses characterisation methods of all kinds to guide the sorting of raw material, refined material and manufactured goods, into and out of the appropriate process plants, managed by an entropy/enthalpy/exergy based dynamic interactive data decision tree. An example of this applied to mineral processing could be (Nad et al 2022).

The needs of each and every person in the catchment of the RBE cluster is linked and optimized to access to services and goods. Those needs are placed in a hierarchy (access to sanitation sewerage services is placed a greater priority than luxury products access). The goods and services are quantified by a library of system maps in how they work and what resources are needed to support them. All of this would be guided by the controlling paradigm, in context of legislation, administered by the democratically elected governance.

The flow of information through a system of such complexity would need to happen in a timely fashion to make decisions based on that information. Data from the appropriate characterisation of all waste streams, all feed input streams, output streams, side streams and consumption paths, is collected in time to make engineering decisions with what to do for the most effective response.

A system based predictive matrix of models are to use data relationships to make recommendations in how to handle resource streams in the industrial ecosystem. Practical logistical choices could be made from a spectrum of possible outcomes based on dynamic fuzzy logic predictive uncertainty, where potentiality of an outcome is modelled to probability into manifestation at the point of choice. Thus, there is a time component to the management of these proposed systems.

A coherent decision making in what to do with a given resource stream according to the controlling paradigm.

- What are the most valuable metals/minerals in this stream?
- What is the most effective series of process plants for this stream to pass through?
- Thermal entropy foundation for systems network decision making
- Where are they needed the most and by whom?
- Decide what trade-offs are worthwhile

Artificial intelligence (AI), Machine Learning (ML), and all their variations, could be considered as the administration tools to develop a decision making system to handle all this data. Artificial intelligence refers to the simulation of human intelligence in software that is programmed to think like humans and mimic their actions (Allen 2020). The stated objective in A.I development is to mimic human ability to apply learning of observed data and problem-solving for future actions.

Machine Learning is the use and development of computer systems that are able to learn and adapt without following explicit instructions, by using algorithms and statistical models to analyse and draw inferences from patterns in data (Ethem 2020, Jooshaki *et al* 2021).

To manage the movement of all the different minerals/metals/materials as they progress through the industrial ecosystem value chain, block chain technology is recommended to be applied. Blockchain technology is a new innovation from the information technology sector. It was originally developed to support a cryptocurrency called Bitcoin. A block chain is a growing database ledger of timestamped records. Each record is called a block and is linked using cryptography (Marvin 2017). Each block contains a cryptographic hash of the previous block, a timestamp, and transaction data (generally represented as a Merkle tree) (Balagurusamy *et al* 2019).

By design, a blockchain is resistant to modification of its data. This is because once recorded, the data in any given block cannot be altered retroactively without alteration of all subsequent blocks (Hyperledger 2019 and Alzahrani 2018).

For use as a distributed ledger, a blockchain is typically managed by a peer-to-peer network collectively adhering to a protocol for inter-node communication and validating new blocks. The blockchain has been could be described as an open, distributed ledger that can record transactions between two parties efficiently and in a verifiable and permanent way.

So, resource mapping could be then link with resource harvesting, using blockchain technology through the application of some ideas shown in Andoni et al (2019) and Janssen *et al* (2020) and Ma *et al* (2020).

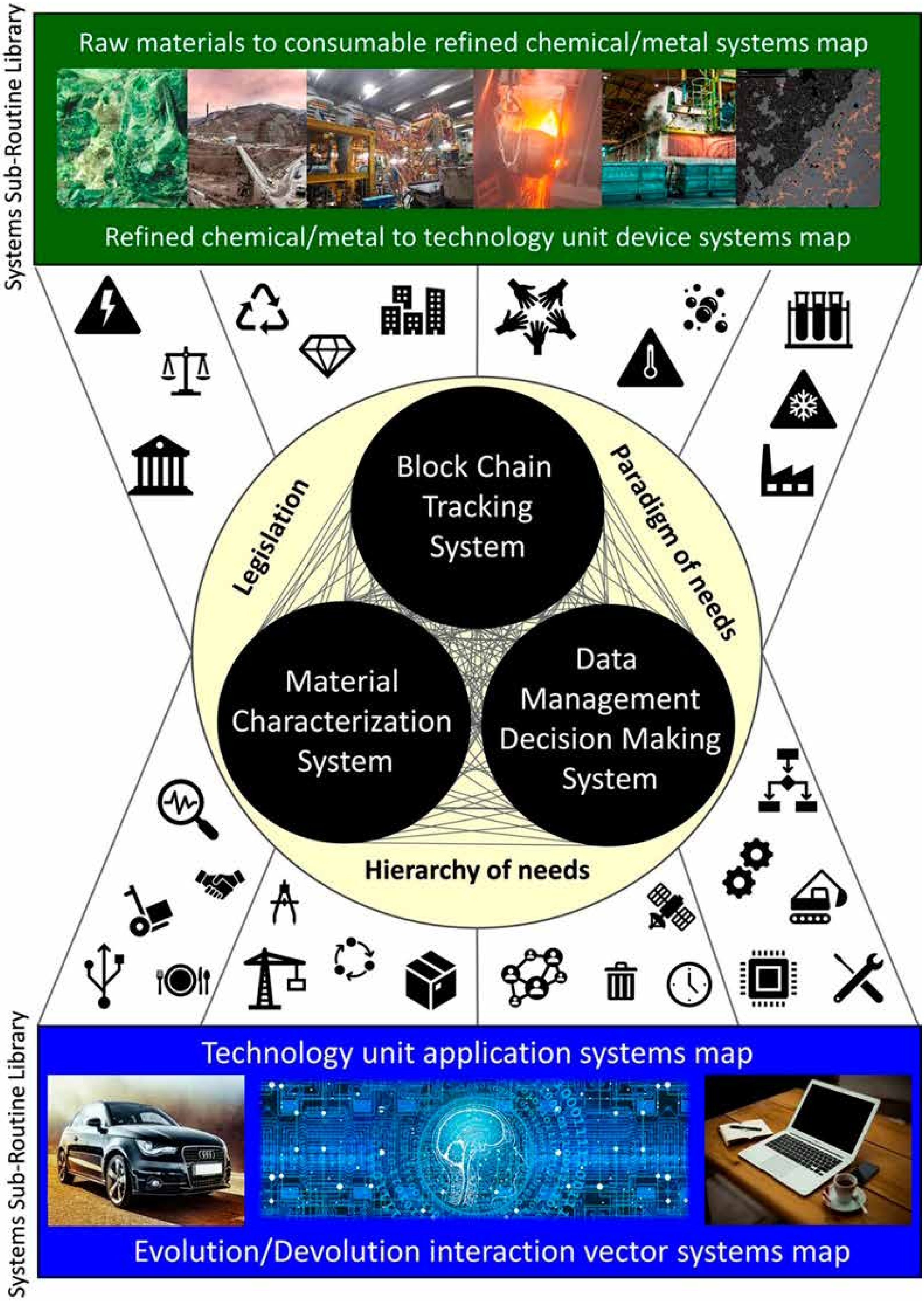
With the example of a unit of copper at the start of the value chain, it would be distributed as a trace element in a volume of mineralized rock. That copper would then be concentrated into a smaller volume, leaving some of that copper behind in waste rock and mineral processing tailings.

The copper concentrate is then refined into copper anodes (99.7% pure), where some of that copper would report to industrial waste. The pure copper is then used in wide variety of manufactured goods, where copper is made into alloys, electroplating, or is used in its 99.7% pure form. A portion of that manufacture process will have a reject stream, containing some copper. The original unit of copper is split into many different sub-proportions and spread over a wide geographical area. After the manufactured product is used, it is then discarded. If all goes well that product is subject to sorting and recycling. If not, it will be somehow valorised, or in the worst outcome, put in landfill. Some of the original copper unit will go into all three streams. The recycled portion would be shredded, sorted, and refined once more. The cycle repeats.

To track the original copper unit to all the places and sub-product streams was impossible a few years ago. Now with the invention of block chain, it could be possible. The copper unit could be tracked with a block chain ledger if each handling step was audited well enough. The estimated volumes in the block chain could be calibrated by appropriate characterization at important points in the value chain. This could be made much more effective if a way of tracing the origin of the coper material back to the original mineralized ore volume. A sophisticated form of characterization that could diagnose the origin of the copper and the processes it has been subject to would the ultimate goal.

How to design and develop Artificial Intelligence, Machine Learning (and all their variations) and a series blockchain ledgers for all of the target minerals/metals/materials into a coherent system that is of practical use is an enormous task of complexity never attempted before. No one person, or single technical discipline would be able to achieve this on their own. The kinds of information needed and processes to develop would have to be determined through dialog between multiple different technical areas. This is the development of the fourth industrial revolution to a slightly different paradigm to what is now planned.

Figure 7. The Resource Balanced Economy (The Constitution)



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7 THE INDUSTRIAL SYSTEM WILL REORGANIZE AROUND NEW PRINCIPLES

The source, quantity and form of energy is the guiding principle dictating the complexity, size, and architecture of any system (Graedel & Allenby 2010, Stevens 1976). This is true for any biological organism, industrial system, or human society. The sequence of influencing structures in a crude form could be as follows:

1. Power generation systems for heat and electricity generation will be constructed to harvest energy from a natural source. That natural source will take the place of fossil fuels. What ever this is will dictate what is possible for all other developments in an industrial society.

2. Industrial nodes and clusters will reorganize around the available power generation sources, based on their ability to deliver reliable electricity, heat and/or fuel. Where oil, gas and coal energy systems dictated industrial activity, now non-fossil fuel energy systems will be that controlling influence. This will include manufacture, and the sourcing of raw materials from recycling and mining.

3. Human population centers would then reorganize around industrial centers for employment. For example, the maritime port in the city of Rotterdam is the source economic activity and employment for much of the city. It gives the city a reason to be.

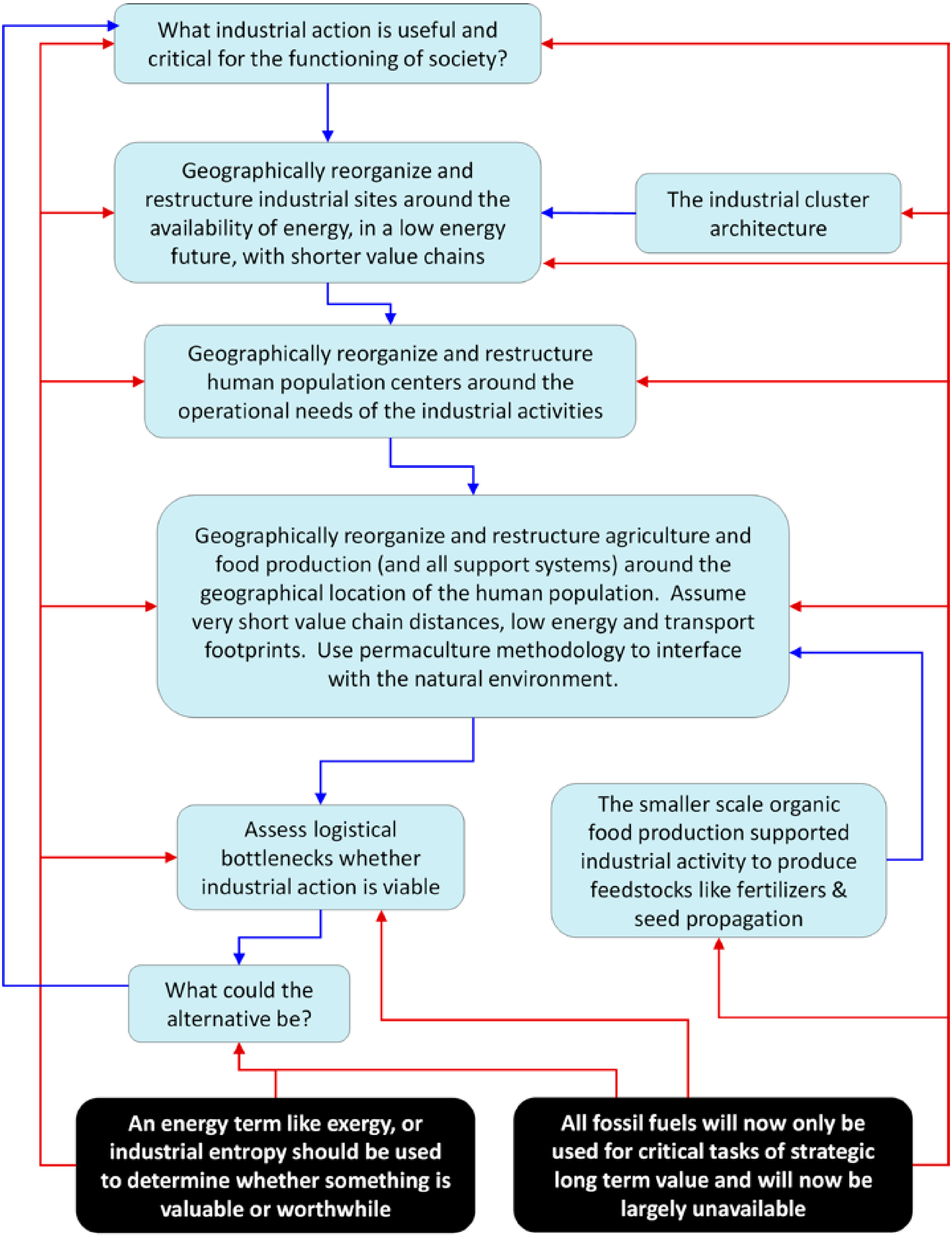
4. Food production would transform from its current form, where much of it is produced geographically remotely, to a more local and regional system. It is recommended that small scale organic food production is integrated into the population centers where possible. Food production would be tied to where human populations centers geographically are. This could influence the carrying capacity of the region in how many people could live in these population centers.

While the sequence of influence s would go in order (1 to 4), if at any time something in this sequence is impractical, then either that impracticality bottleneck will have to be innovated away or the whole sequence would have to be redeveloped from first principles. Figures 8 and 9 show how this might evolve. The people developing their local supply chains will go through these loops multiple times until an equilibrium is reached. The future will be non-linear and unequally distributed. Each geographical region will have its own opportunities and challenges. The stabilized equilibrium outcome will be different for each geographical region. Thus, each region will have different products to trade.

Another way to approach how this might evolve is to use the Maslow Hierarchy of Needs (Maslow 1943) as a mapping tool in an unconventional context. Maslow's hierarchy of needs is a psychological model where a human individuals' most basic needs must be met before they become motivated to achieve higher-level more complex needs. Usually this is a social sciences tool. Consider now if this tool was used but now in context of an industrial task. Figure 10 shows a possible mapping of priorities for industrial activity using the Maslow concept. A factory for example needs material feedstock and energy to function. Material feedstock could be stockpiled for a time. Energy cannot be stored easily; it must be used as it is produced. Thus, energy is the priority to secure in the list of needs for industrial manufacture. This same principle could then be applied to other sectors. The sectors themselves could be linked together in the same analysis. Possible sectors to consider in this form:

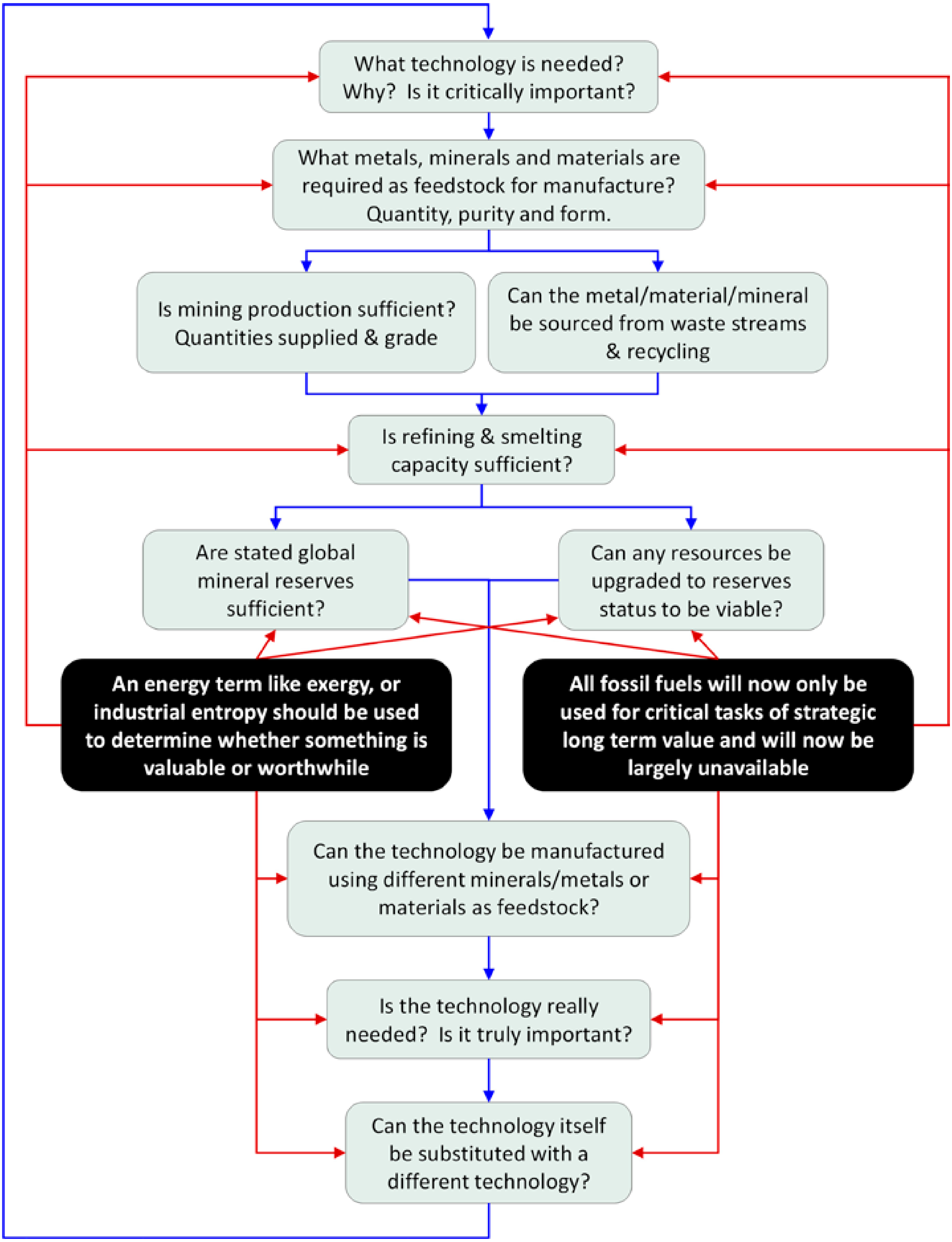
- Power production of electricity, heat, and fuel from energy sources
- Food production
- Heating of buildings
- Sanitation
- Raw material supply

Figure 8. Maslow Hierarchy of Needs development loop industry to society relationship



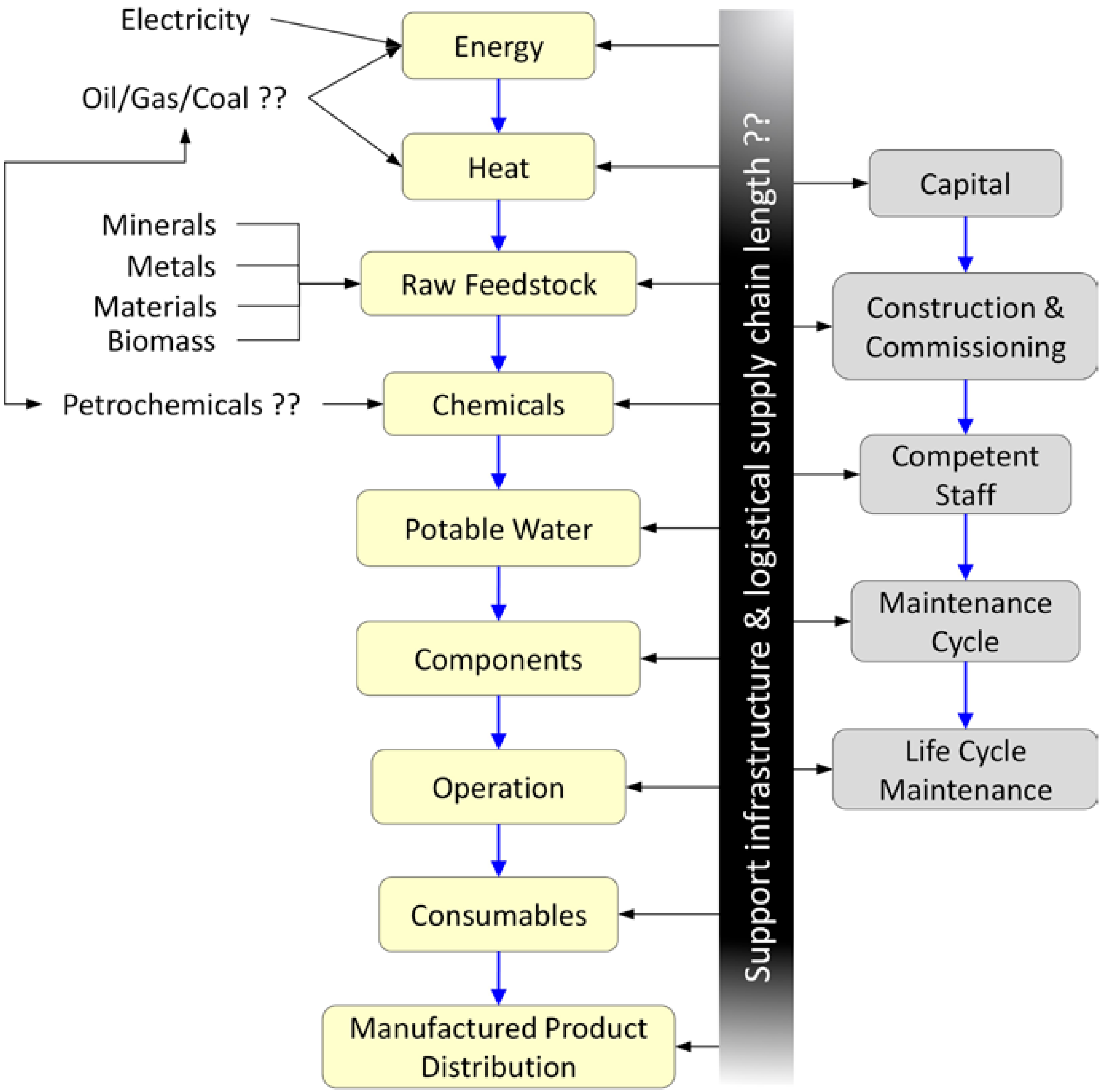
Source: Simon Michaux

Figure 9. Maslow Hierarchy of Needs development loop sourcing materials for manufacture



Source: Simon Michaux

Figure 10. Maslow Hierarchy of Needs in Context of Industrial Manufacture



Source: Simon Michaux

8 EVOLUTION OF THE ENERGY SECTOR

As previously stated, what form power generation will take and what natural energy source it would use is the primary task in developing the next industrial era. All industrial actions and the physical form of society would self-organize around the capability to access these energy sources.

The siting and commissioning of power plants will heavily influence the development of infrastructure and where industrial operations would be established. The method of power generation would be dependent on the natural energy resources it needs to function. For example, a coal fired thermal power station would need the infrastructure to receive bulk quantities of coal. What would influence the siting of such a coal fired thermal power station, could be the presence of a shipping port, or a suitable rail network to deliver the coal fuel (using the thinking in Figure 10). From there, power could be transmitted along a series of substations and power cables. Coal, like gas or nuclear, can be deployed in any weather conditions in a wide range of geographic locations, as long as their feedstock fuel is delivered in a timely fashion.

Hydropower is feasible only in very specific geographic locations. Solar and wind power are highly intermittent and are strongly influenced by seasonal weather variations. Geothermal power is dependent on the presence of a suitable heat reservoir at a shallow enough depth.

This is a pertinent discussion, as oil, gas and coal fired thermal power stations should now be phased out. Non fossil fuel power stations that could be built to replace them have geographic siting requirements that are quite different (apart from nuclear). The performance capabilities, and flexibility to adapt to circumstance of the non fossil fuel systems is very different to the oil, gas and coal fueled systems. In fact, it changes the architecture of the whole industrial system.

Then there is the time required to design, construct and commission new power plants, while the fossil fuel systems are being shut down. Industrial operations depend on reliable power delivery to stay viable. As most of the non-fossil fuel network has yet to be constructed, and would take decades to construct, fossil fuel energy systems will continue to be used for some time. Reality requires the recognition that fossil fuels will be needed to build the next industrial system. However, it could be the case that all fossil fuels will now only be used for critical tasks of strategic long term value and will now be largely unavailable. Fossil fuels may become unreliable for multiple reasons. Long term stability may soon be associated with non-fossil fuel systems.

In in 2020, 61.3% of global electricity production was based in fossil fuels, with almost all of manufacture dependent on fossil fuels (BP Statistics 2021). In Europe, 35% of electricity production in 2020 was fossil fuel based. The Nordic countries (Finland, Sweden, Norway, Denmark, Greenland, Iceland) all have well established and significantly sized non-fossil fuel power generation systems in operation now (Table 1). The Nordic countries already have a large industrial capability that is not dependent on fossil fuel sourced power.

Some non-fossil fuel electrical power generation systems are intermitted and not consistent in power delivery. To protect the grid and maintain reliable power delivery, a buffer of power storage of some kind is needed. This is termed stationary power storage. A power buffer backup of some form is a critical sub-system for an electricity power generation system that is intermittent, for example wind and solar. Existing electrical engineering technology depends on stable (no black outs), consistent and clean (sinusoidal, without power spikes), at a frequency of 50 Hz or 60 Hz in a very narrow specification bandwidth (Grigsby 2006 and Gottlieb 1997). This must happen at a resolution of a microsecond. Any variation in power supply quantity and quality has the capacity to destroy sensitive electrical equipment. Without a power buffer the electrical power grid would be subject to frequent black outs, brown outs and even system collapse could happen (Grigsby 2006).

Table 1. Energy Generation in 2020

Energy Source	Finland (TWh)	Sweden (TWh)	Iceland (TWh)	Norway (TWh)	Denmark (TWh)	Greenland (TWh)
Geothermal			5.96			
Hydropower	15.88	72.39	13.16	140.93	0.02	0.46
Wind	7.94	27.53	0.01	9.91	16.33	
Solar	0.22	1.05	0.01	0.13	1.18	
Nuclear	61.10	181.00	-	-	-	-
Bioenergy	11.57	11.18		0.24	5.92	0.03
Fossil fuel consumption						
Oil	108.33	163.89	0.03	108.33	0.08	
Gas	19.44	11.11	-	44.44	23.96	
Coal	41.67	22.22	0.0012	8.33	32.45	
Fossil fuel production						
Oil				1 069.96	40.71	
Gas				1 113.89	13.89	
Coal			-	-	-	

Source: BP Statistics 2021, IRENA energy profiles

How to develop and construct a large enough energy storage system to function as a power storage buffer to purpose of stabilizing wind and solar power generation grids is not known. All commercially available technologies examined work quite well at a small scale but are not viable when expanded (Schernikau & Smith 2023).

This needs to be looked at very carefully. Currently, power sharing between fossil fuel powered grids are how demand and supply are balanced across long term seasonal variations. A non-fossil fuel grid will have to develop its own methods of balancing supply and demand. At this time, there is no proven and costed energy storage solution that can take a wind/solar electricity generation system all the way to Net Zero emissions, or anything close to it (Schernikau & Smith 2023, McKinsey 2021 shows the data to support this).

Infrastructure would either evolve around those power stations or be planned and constructed with them. Road, rail, and maritime shipping ports. Industrial operations would then organize themselves around available power supply and infrastructure. For example, a factory making pipe fittings will locate itself where consistent and reliable concentrated electrical power, and delivery of the required feedstock materials are available. What would make this possible is the infrastructure of society. The power grid capability to deliver power across distance, and the transport vectors to deliver feedstock material.

It is entirely possible that the available quantity of energy may become somewhat less than what is now considered normal. As fossil fuels are transitioned out, society will struggle to construct and commission enough non-fossil fuel energy replacement systems to maintain existing capacity. The most probably vector for this to happen is the general unavailability of industrial machinery and technology goods on the market. Imports for such products may become difficult as the international supply chain struggles with a series of challenges. Then there is the matter of more non-fossil fuel infrastructure will be required to replace fossil fuel power installed capacity (in context of direct MW to MW). We are transitioning into a low energy world. How much lower remains to be seen. A case can be made that society will have to reduce its complexity and energy requirements. It all starts with the capability of the electrical power grid, and the natural resources it requires to operate.

9 EVOLUTION OF THE TRANSPORT SECTOR

The transition away from fossil fuels for the electrical power generation is in progress, with some support infrastructure already in place and is operating. This is not the case for the transport sector. Most of the global transport fleet in 2023 is still Internal Combustion Engine (ICE) powered, fueled with petroleum products. In 2020, only 1.1% of the global transport fleet were Electric Vehicle (EV) (self-propelled vehicles like cars, and trucks only) (IEA 2021). In a global context, 45% of passenger rail transport and 85% of rail freight is driven by diesel fuel locomotives (IEA 2019a). The maritime shipping fleet was ICE fueled with bunker fuel oil and the aviation industry was ICE fueled by jet fuel.

The technologies proposed (so far) to replace the ICE systems are EV and Hydrogen Fuel Cell (H2-Cell). Again, society may struggle with general unavailability of EV and H2-Cell vehicles on the market. There are a number of challenges to suppling enough of these vehicles (Michaux 2021, 2023a and Mills 2019), ranging from dependence on imports, to not enough manufacturing capacity to a significant shortfall in required minerals as resource feedstock (Mills 2020, Michaux 2023b). As mineral supplies of lithium, cobalt and nickel could become non-linear, lithium-ion battery chemistry systems may not be practical in large numbers. Develop in parallel a series of battery chemistries that are based on elements that do not face resource supply shortfalls (zinc, fluoride, sodium, etc.).

The transport sector may well contract in size and capability in ways that are unplanned and unfortunate for basic society needs. This will probably result in a reprioritization and re valuing of transport tasks within society. Currently, society is organized around the concept where most families have their own personal passenger car. That private passenger car fleet may become too expensive to operate in the way it does now. A solution could be to expand the communal transport fleets. The mandate of local city councils is to operate buses, trams, metro, and train. The number of vehicles operating and the distance they would travel could expand to attend to more of the basic needs of transport. This could well be expanded to include delivery trucks. As this would be an era of less physical actions of much higher quality, serious thought would be applied to whether a transport action should be taken. Walking and bicycles could become more prevalent. As the rail network would become more important, it could be possible that steam power locomotives (powered by biomass) could make a comeback in some form.

9.1 A possible EV to H2-Cell market split for vehicles

The performance metrics of EV's and H2-Cells were compared across multiple global transport systems (Michaux 2021a, Michaux 2023a). The mass of the EV battery compared to the mass of the equivalent system hydrogen fuel tank for each vehicle class shows a very clear pattern. The mass of the EV battery was on average 3.2 times the mass of the equivalent 700 barr hydrogen fuel tank. So, the H2-Cell could go 3.2 times further on the same energy storage mass. However, the electrical power needed to produce the hydrogen was 2.5 times charging the equivalent EV battery.

This can now be used to make a crude recommendation for comparing efficiencies of EV systems to Hydrogen fuel cell systems. It is then assumed that all short-range vehicle transport should be EV. This includes passenger cars, buses, commercial vans, and delivery trucks. All long-range transport and freight tasks (that would require extra power in application), are recommended to be powered with a hydrogen fuel cell. This includes long range trucking freight (Class 8 HCV), intercity rail transport (passenger and freight) and the maritime shipping fleet. Class 8 HCV trucks need to travel a very long range, which makes the H2-Cell system more efficient.

There are many market ready viable technology systems that could be either EV or H2-Cell for most of these vehicle classes. This crude market split between EV and H2-Cell vehicles is based on the holistic systems logistics of scaling up (including electrical power generation).

9.2 Maritime shipping

The required physical mass and volume of the battery makes the EV system not practical for maritime shipping and intercity rail freight.

The production, transport and storage of hydrogen is logistically quite difficult and expensive (IEA 2019b). An alternative could be to produce ammonia instead (IRENA & AEA 2022). The ammonia could be either used directly as a maritime fuel or transported then converted to hydrogen for use. It si to be remembered that there are efficiencies and energy losses with every transformation. A possible plan to consider could be to make large quantities of ammonia in Iceland, using geothermal energy. Ammonia could then be shipped out to every maritime shipping port in the region (Rotterdam, London, Helsinki, Amsterdam, etc.), where the required distribution infrastructure already exists. At these hubs, the ammonia could be transformed into further useful products. This could be the energy plan to support the whole region.

Re-engineer maritime shipping vessels to be smaller in size. Scale back required desired performance metrics in exchange for more energy efficient maritime transport. Consider for example a return to sail propelled shipping and/or sail assisted vessels.

9.3 Aviation

It is possible to produce jet fuel from biomass, in a fashion where jet aircraft can perform to specification (Liu, Yan & Chen 2013, Güell et al 2012). Biofuels could be the most practical path to maintain the aviation industry (Michaux 2021a). However, it is not clear though what would be the sustainable quantity of biomass that could be harvested from the environment.

Maintenance of all these systems would also have to be developed. Components and consumables would have to be made locally in some form.

10 RESTRUCTURE INDUSTRIAL ARCHITECTURE

The challenges the industrial sector now has to undertake the following tasks simultaneously, while navigating the difficulties already discussed:

- Develop a functional wide scale standalone non-fossil fuel power grid to generate electricity.

- Develop a functional non-fossil fuel transport network that has the capability to service society and industrial basic needs.

- Develop a functionally useful manufacturing sector that is non-fossil fuel in form.

- Bring all industrial systems into balance with the environment at the local, regional, and planetary scales. This has to be done in context of what natural resources are being extracted and what waste plume is being deposited back into the environment. The industrial system must become balanced in context to the carrying capacity of the environment at all scales.

- Conduct a Maslow hierarchy of needs analysis loop in context of industrial activity and capacity, optimized against all other parts of society (Figure 10). What is truly needed:
    - o for society to function – work back from there
    - o for industry to function – work back from there
    - o for the environment to stabilize – work back from there

- Reorganize industrial value chain around a low energy future and very short supply chains that are inconsistent in performance.

- Plan for a re-prioritization of industrial capacity. For example, hydrocarbon products would now be highly valuable. Also, there would be a lot of waste rubber and plastics. Recycle rubber and plastics with pyrolysis to produce a fuel oil, that with further refinement could be substituted for diesel fuel (Jahirul et al 2022). In this manner, clean up waste plastics and rubber from the environment.

- Plan for a systemic merging of energy and raw material feedstock supply with all industrial action
    - o they are no longer just costs of doing business, but are now rate determining steps

- Plan for an economy where some industrial capability can periodically shutdown and start-up without damage. Also, consider a possible period of dormancy over part of winter.

- Develop an engineering decision making system that can defined whether an industrial outcome is logistically sensible or economically viable to a new set of constraints (e.g., using exergy).

- Develop the capability to quickly find substitutions for material products, or industrial outcomes as their supply becomes non-linear, unreliable, or unavailable.

The current complex 6 continent supply chain that delivers manufacture goods to society all over the world will struggle to maintain capability. A case can be made that it will become unreliable and in some cases fragment entirely. So, in its place, a regional supply chain will develop. This regional supply chain will probably not be able to produce complex manufactured goods like semiconductor microchips. To produce a single semiconductor unit requires refined chemicals and exotic metals from all over the world, from many different geographic locations. The materials needed would also have to be such high purity standards, that far exceed many other applications. So, semiconductors could continue to be traded internationally, but probably in a different form to how it is done now.

This may not be practical in a regional scale system. The solution is to focus on developing capabilities around a series of critically important components and finished goods. This regional system must be much simpler in complexity. Less complex metal alloys would be used and less complex technology that can be made locally from regional scale resources. This would require the demands for performance quality to be scaled back, until a holistic systems equilibrium can be supported appropriately.

Each geographical region would have to become more self-sufficient at all five levels of the industrial value supply chain:

1. Exploration of and mining of minerals
2. Smelting and refining of metals and chemicals
   - steel, aluminium, copper, brass, lead, tin, zinc, tungsten, titanium, chromium, magnesium
   - sheet metal, bar, rod, pipes & fittings, I section beam, C section beam, etc.
   - glass, paper, ceramics, biodegradable polymers, and rubber
   - cement and fertilizers (or a substitution of)
   - Lubricants, etc.
3. Manufacture of components
   - electric motors, bearings, gaskets, nails & screw fasters, electrical components, drill bits, etc.
4. Manufacture of finished goods
   - tools, car tires, brake pads, mobile phones, consumables, pharmaceuticals, etc.
5. Recycling and valorisation of all waste streams

Europe in 2023 does not engage any of these five levels in quantities large enough to supply its own demand for materials, it imports them. If the international markets become more structurally volatile, then all five levels will have to be developed in the European region, to the point where Europe gains direct control over its own raw materials supply and demand. Europe would need to open a mining frontier. Smelting and refining capacity would have to be expanded. The manufacturing capability for basic components and goods will have to be developed.

10.1 The industrial cluster architecture

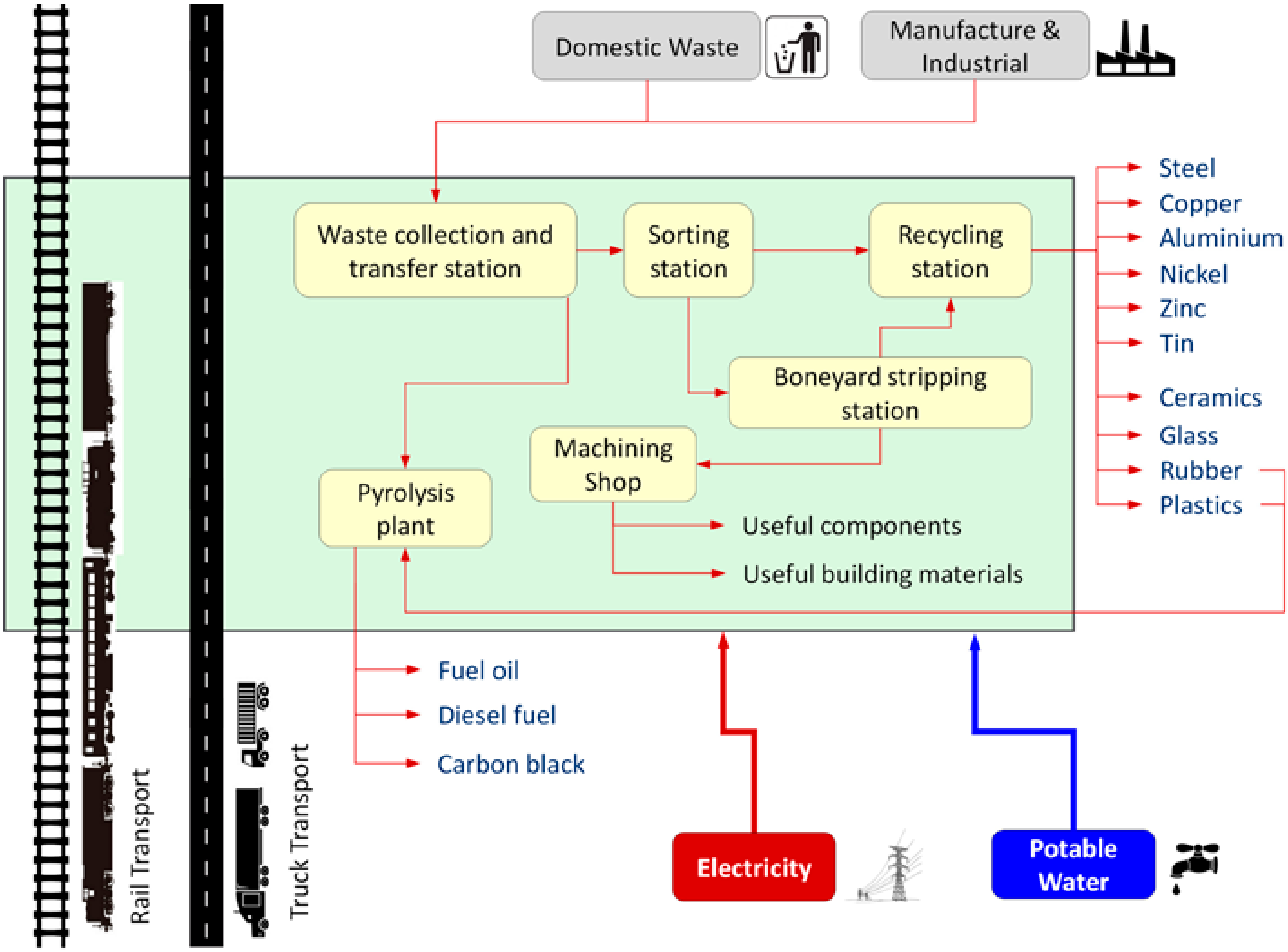
Due to the challenges the transport sector could face, the nature of the components supply chain for manufacture would have to be re-imagined. Movement of materials and manufactured goods would become more expensive and logistically difficult. The rail transport network could become the most effective way to move such materials across medium and long distances. Industrial operations could over time contract to sites along the rail transport lines. At the moment, most train stations are for the loading and unloading of passengers, with only a few freight terminals. What is proposed here is the train lines would physically go through factories and industrial sites to load and unload materials and goods.

The industrial cluster is now proposed, where multiple process plants and manufacturing plants that are part of the same value chain (or a related one), are located in the same industrial site. The waste products for each plant are characterized and valorised in some form. If possible, the outputs of one plant are used as feedstock inputs in another plant. This cluster would function in a similar fashion to a self-sufficient organic farm. All waste is transformed to be part of the surround system. Each cluster would have its own dedicated power generation plant and water treatment plant.

An example of this could be a recycling plant is expanded to include a waste transfer station, sorting station and also a pyrolysis plant. Instead of delivering a residue from Plant A by truck to Plant B several hundred kilometers, Plant B is now in the same building complex (Figure 11). Such a recycling station would not be working to just economic metrics but also other metrics like embodied energy and materials scarcity.

Currently, the production of manufactured goods is so easy to do that products are made on a different continent that are designed to be disposable. It makes more economic sense to design products to be used only once or twice then are thrown into the waste. The consumer is forced to be a customer again and buy a new unit. Thus, products are designed for short term performance, and then to be discarded as waste, not repaired.

Figure 11. A waste transfer to recycling industrial cluster



Source: Simon Michaux

In a material scarce world, where reuse before recycling is considered a strategic target, and the manufacture of components has become so expensive, a different approach is required. Also, the requirements for what needs to be made could be so volatile that on-the-fly problem solving would become highly useful.

What is proposed, is the reestablishment of the old Boneyard facility. This would function like an automotive wrecking yard. Old cars and trucks are collected at the end of their working life. A team of mechanics would take each car as it comes in and strips it of anything remotely useful. The useful products are stored out of the weather in a warehouse. This principle could be applied to all waste products that would go through a waste transfer station, manufacturing reject circuit, or industrial site waste product. Such a facility could collect old ICE vehicles, process them, and produce useful components and building materials. These could then be fed into a machine shop to make useful products for society. If semiconductors become so expensive and unavailable, could they be repurposed in this fashion?

A biomass industrial cluster also could be useful (Figure 12). Biomass and the forestry industry could the feedstock raw material source for many solutions to the described challenges. There are many sources of biomass that could be collected and processed at an industrial scale. Waste from the paper and forestry industry, waste food, some biological industrial waste.

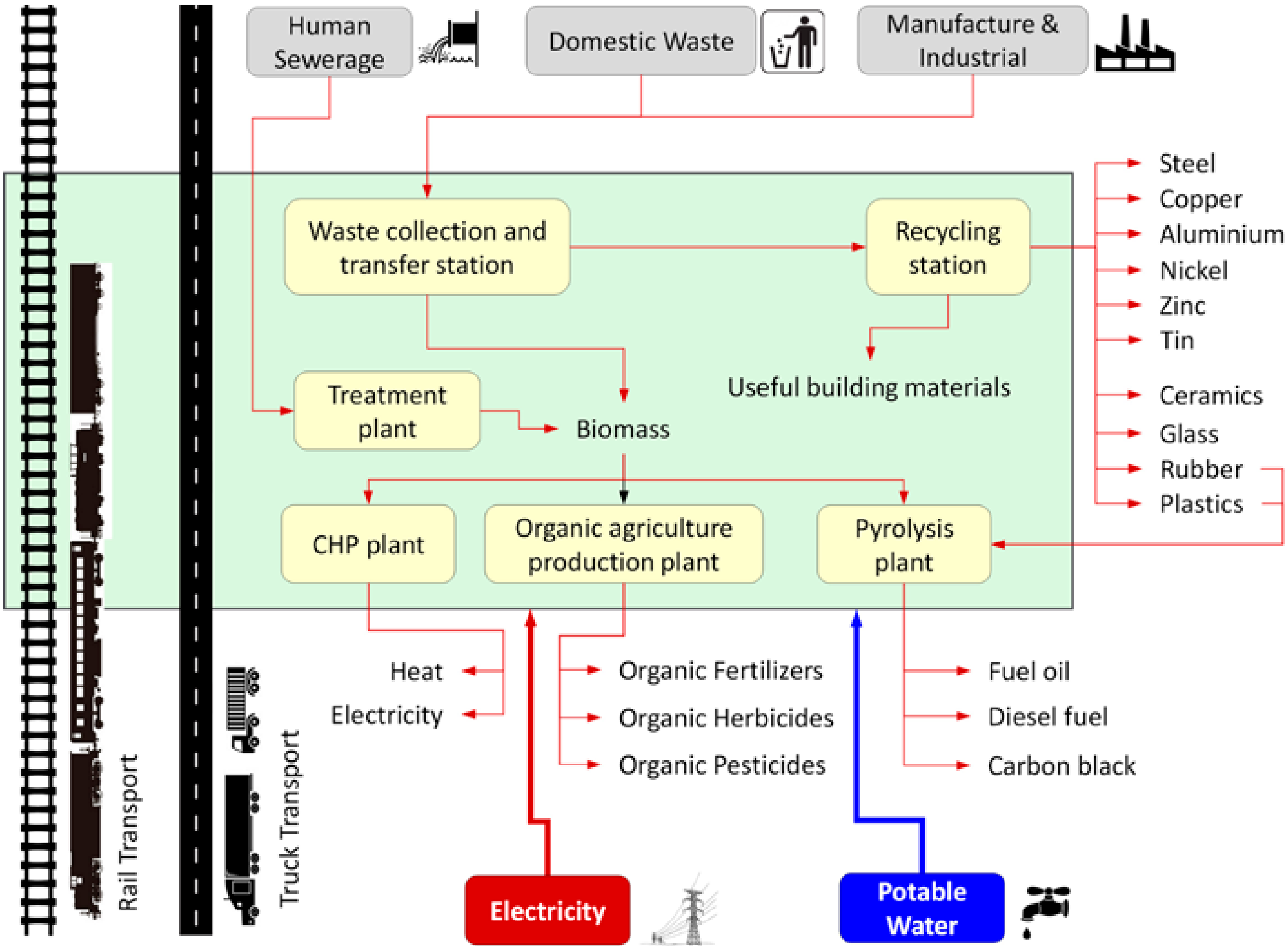
What to do with human sewerage is an unglamorous but very important discussion to have. If sewerage sanitation is not handled correctly, then society would be subject to unnecessary health problems. Additionally, petrochemical fertilizers should be phased out, as their inappropriate use has resulted in widespread land degradation (Bogard 2017) and something should be produced to take its place. Human sewerage has the nutrients to do this (Jenkins 2019) if it is processed appropriately. This is an example of taking a problem and transforming it into a solution.

This proposes that what is called the industrial sector is optimized in a systems context and expanded to include mining, smelting, manufacture, waste handling, recycling and the biomass raw material streams.

How to achieve all this is another discussion. This proposed set of systems would have to be developed in stages, with priority and critical functions of society attended to first. This evolution could take several decades or more. What would this look like? The technology we would produce would be pre-transistor in complexity, coupled with 21st Century science and engineering capability.

The geopolitical future could be defined by alliances between industrial clusters as opposed to conventional political nation state entities. The Nordic countries already have established industry supported by non-fossil fuel power systems, the Nordic countries could preferentially connect with each other and establish trade agreements in this perceived economic market.

Figure 12. A biomass waste industrial cluster



Source: Simon Michaux

10.2 Design technology products to be recycled more effectively

Metals are theoretically infinitely recyclable. In practice, the functionality and design of consumer product complicate recycling due to their ever more complex structures producing unliberated low grade and complex recyclates (Reuter 2011). Metallurgical smelting technology is developing in sophistication with the more effective use of thermodynamics and transfer processes to achieve better recovery. The 2nd Law of Thermodynamics provides a limit of what can practically be recycled. This is determined by the complexity of the recyclates.

Process engineering simulation models are a prerequisite to designing sustainable systems as these can predict the metal/materials mass balance for recyclate grade/quality/losses/toxicity of streams (Reuter 2011). This is the link to industrial entropy, and if used appropriately, is the fundamental way of handling complex data from materials tracking system (Figure 7).

It will be very difficult to develop a truly closed loop industrial ecosystem that does not extract any resources from the environment, nor discards any waste into landfill. Evolving the industrial ecosystem in the direction of a closed loop is appropriate, however. To do this, a deep understanding of particle property and breakage physics and its relation to product design, metallurgical thermodynamics, and process technology. A series of Industrial Ecological Systems could be designed to link technology product design to metal recovery in metallurgical process recycling of discarded waste residue.

To design technology products in a form that allows for their more effective recycling, an understanding of how a consumer product moves through various stages of processing during which particles/recyclates are created. As these recyclates progress through the value chain, they would be subject to changing phases and compositions, eventually being transformed into molten metal and finished metal products, energy, or extruded plastics.

So, the design of the technology products needs to integrate all superior properties of metals/materials with an understanding of which materials are able to be recycled more effectively (in alloy and electroplating context as well as pure metal/material). In order to realize the link between design and metallurgy; and subsequent recycling; requires a detailed knowledge of all technology involved. Using an exergy standard states makes it possible to express these enthalpy and entropy data as Exergy by using for example the methodology and standard states expressed in Szargut (2005).

A product must be designed to:

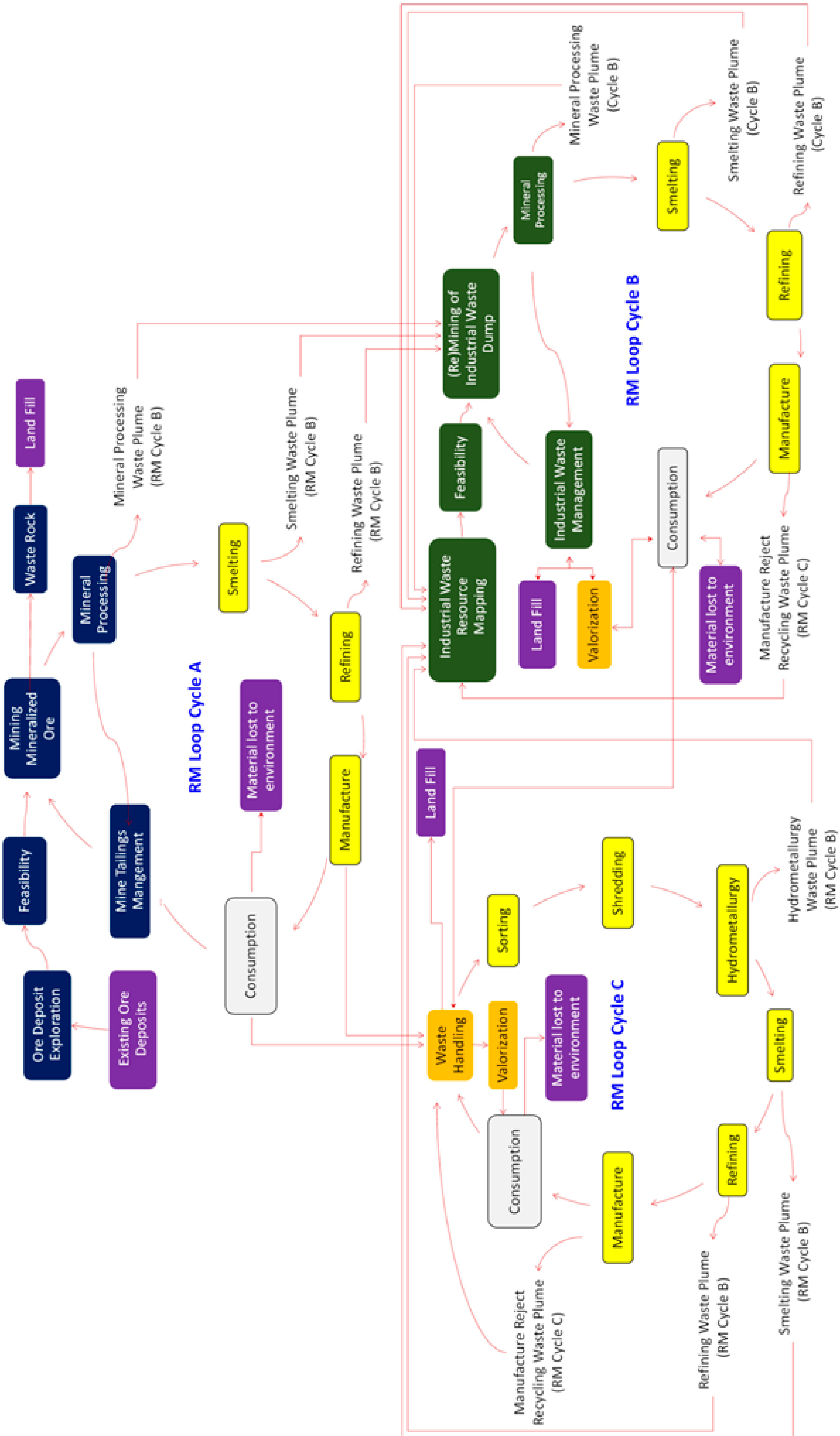
- Contain the maximum quantity of materials that are recyclable
- Be easily recycled through current or newly designed recycling processes
- Be cost effective to recycle whereby the cost to recycle does not exceed the value of its recycled materials
- Be free of hazardous materials that are not recyclable or impede the recycling process
- Minimize the time and cost involved to recycle the product
- Reduce the use of raw materials by including recycled materials and/or components
- Have a net gain in the overall recyclability of the product while reducing the overall negative impact on the environment

To achieve this challenging task, an understanding the link between product design and recycling effectiveness. An example of this could be the design of wind turbine blades to be recycled, where currently they are very difficult to recycle. Many of the end-of-life turbine blades are land filled (Symons 2022). A solution in Finland has been proposed to process the vast amounts of composites left over (Nehls 2023). It would be much more effective to design the blades to be recycled in the first place.

The character of recyclate grade of the shredded waste products is crucial for maximizing material and energy recovery. Just so, the minimizing energy usage and minimizing the entropy creation of the system in its complexity. This is a key to Design for Sustainability (Reuter 2011). Quantification of all residues and recyclates in terms of their grade/quality ensures that all materials in the system are accounted for. With the available tools, a good indication can be obtained what designs will have a good recyclability and what the thermodynamic limits would be in the recovery of the contained materials and energy. Sustainability development targets and supporting legislation should have a thermodynamic basis (including the second law), should reflect the limits of technology and well-designed metallurgical, energy recovery and recycling infrastructure (Reuter 2011).

In designing new products, the performance metrics should be reassessed in context for what is needed. For example, if a task was set to develop and manufacture a communications network, with the objective to talk to someone 800 km away (Helsinki to Rovaniemi for example), and send a text message, but only use local manufacturing and regional resources. How would this be done? The mobile phone handset could be made with 3D printing and have simple circuitry. The outcome would not resemble the latest iPhone, but something like the old Nokia handsets. Infrastructure in between would also be simpler.

Figure 13. Full raw materials value chain, RM Loop Cycles A, B and C integrated



Source: Simon Michaux

11 MANAGING RAW MATERIAL FLOWS

There is a requirement for pure metals and materials to supply manufacture of technology products. The source raw material to produce such pure metals and materials is almost always very impure and contains contaminants. In most cases, the desired metals and materials are trace elements in the source raw mineral stream.

How the value chain of a given material needs to be understood then quantified in a form that is useful for engineering based decision making. There are three raw material loop cycles to be modelled.

- RM Loop Cycle A: mining of mineralized ore to manufacture to waste handling disposal
- RM Loop Cycle B: re-mining of industrial waste dumps to manufacture to waste handling disposal
- RM Loop Cycle C: recycling of manufacture waste disposal products

All three need to be mapped in context of how they interact. All three in an integrated form would be used to describe the full value chain (Figure 13).

The Linear Economy has a paradigm that focuses on Raw Materials Loop Cycle A, the extraction of resources from the environment. The Circular Economy has a paradigm that focuses on Raw Materials Loop Cycle C, the extraction of resources from recycling of waste streams. Loop Cycle B, the extraction of resources from remining industrial waste streams and dumps, is partially addressed in the Circular Economy, but only partially. The proposed Resource Balanced Economy in the form shown in this paper requires all three Loop Cycles developed, mapped, and operating in an integrated fashion.

Currently, the commodities industry value chain is global in scope. This will have to change to become more regional scope. International trade and the commodities free market that has been in operation for decades may now struggle to function has it has in the past. International business partners may not be able to supply refined materials or manufactured goods like they used to. If the strategies proposed in this paper become the most practical and effective long term solution going forward, then each geographical region will have its own problems, and will attend to domestic requirements first before continuing international trade.

12 DEVELOP A NEW RELATIONSHIP WITH THE LOCAL AND PLANETARY ENVIRONMENTS

Stress points in the fossil fuel Linear Economy also imply that how we perceive the natural environment also needs to change. Much of current thought has a very idealistic view of how the planetary system works. An effective way to understand how the environment functions (and how the industrial ecosystem could sustainably interact with) is to model it as a gigantic complex system (Lovelock 2004).

It is now accepted in in the biological and ecological sciences that an organism's relation to the environment is fundamentally facilitated through the mode and manner by which it extracts energy from the environment, to maintain and improve its distance from thermodynamic equilibrium.

The power source for living systems is the sun. Those living systems can reproduce as well as collect, process, and exchange information. The outcome is the living systems can control and direct energy and matter they receive from their environments (Terzis & Arp 2011, and Hall *et al* 1992).

How human society has done this for the last few hundred years seems be with the paradigm that we are separate to the environment. It is there for us to make money from. Also, each nation has its own territory. Outside our own territory is not our concern. So, what happens for example in the ocean in international waters is not our concern. Current food production and industrial waste, management practices have resulted in the phosphorus and nitrogen cycles being overloaded on a planetary boundary scale (Steffen *et al* 2015), among other things.

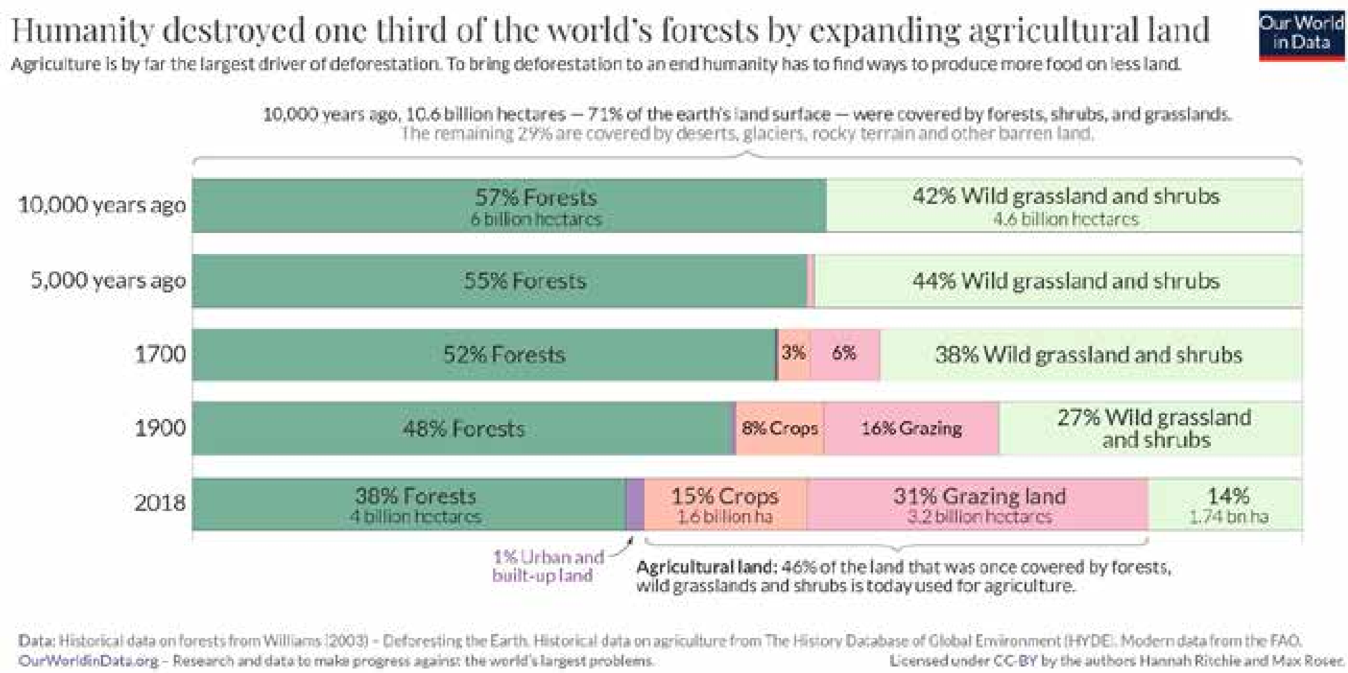
This must change. We must understand that we are part of the environment, and our long terms survival depends on its stability. New metrics are needed in waste plume management systems and cycles. Industrial waste plums of all kinds need to be contained and managed more effectively. The plastics need to be cleaned out of the oceans. All life systems have to be allowed to recover and stabilize.

Many proposed solutions like biofuels, or bioplastics require biomass to be harvested from the environment. The forestry industry would become strategically important as this would be how that biomass would be harvested. The quantities needed to do this and maintain existing capability is enormous and, in many cases, not feasible (Michaux 2021). A sustainability audit is required that examines both economic sustainability and biodiversity sustainability metrics (and an interface between the two) is needed to examine what is sensible to harvest from the environment. It will most certainly be less than what is desired.

The mining of minerals must be redeveloped in regions like Europe. The environmental movement and the mining industry must form a symbiotic partnership, or renewable technology like wind turbines, batteries and solar panels will not be manufactured and the Green Transition will not happen. How mining is organized could also be transformed. If the business model was not longer about just money but now also about the metals extracted, a new mining method could become viable. As a result of mine land rehabilitation, the soil food web could be reestablished, and a biodiversity hub could be developed. If done correctly, biodiversity corridors could also bet established between hubs.

Much of the loss of biodiversity and land degradation is related how food is produced now with industrial agriculture. Figure 14 shows how land use has changes as the human civilization has grown over the last 10 000 years. The amount of forest and grassland area has reduced, while the human system has expanded. The majority of the human system is made up of food production. Cities and industry represent on a few percent in 2018. That food production (most of it is petrochemically supported industrial agriculture). A case can be made that this is the source of the nutrient imbalance that is flowing into the water ways, which in conjunction with plastics industrial pollution is contributing to the overloading of the P and N planetary cycles and creating oceanic dead zones.

Figure 14. The impact of food production on existing life systems over time



Source: Our World in Data, https://ourworldindata.org/
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A few solutions can be proposed to mitigate this from continuing. Phase out or at least greatly reduce the application of petrochemical fertilizers, herbicides, and pesticides. Transform large scale industrial agriculture (done in geographically remote areas), into many small-scale organic farming operations done on a local scale to the population. Use the principles of permaculture (Mollison 1988) to merge growing of food with biodiversity species populations, where farms are also wildlife corridors. Establish the widespread rehabilitation of arable land that has degraded with the balancing of minerals and the addition of the appropriate organic matter. Engage the use of peat as a way of maintaining and developing the soil food web. Produce organic compost using unconventional sources of biomass like human sewerage, in large quantities with the use of industrial methodology.

This proposes quite a paradigm shift in how the human society interacts with the natural environment. We have to start to work with the natural biodiversity system, not against it. This would mean that a much higher proportion of the human population would be involved in the production of food.

It has been proposed that human society should give up meat products and eat insects instead as a source of protein (Ceurstemont 2020). Getting such a radical change in food for society may be difficult. It is also not clear if all health and safety concerns have been addressed (Schlüter *et al* 2016). In some insects, their exoskeleton contains cell components called chitin. Mammal consumption (humans are mammals) of chitin from insects has been implicated in inflammatory bowel disease, hepatitis, asthma and could be related to several types of solid tumors including glioblastoma, colon cancer, breast cancer (Eurich *et al* 2009). It is recommended that that more research be done before introducing such a product into the human food system. In the meantime, insects should not be included in human food.

Another solution is much more practical. Historically, most human diets were mostly vegetarian with the occasional consumption of meat. It is only in the last 100 years or so that humans consumed such large quantities of meat. It is recommended that society returns to this mostly vegetarian diet. We may need the calories from some meat, but not as much as we consume now. This in conjunction with growing crops in a much more harmonious context with natural biodiversity systems would go a long way to resolving this problem.

We have to establish a new relationship with the environment at an emotional belief level and at social perception level. It is clear that our industrial systems and food production systems are the sectors where stress and strain have originated. So, both of those sectors are where evolution is required to happen. Just so, food production needs to be integrated into society, in the same way industrial technology and resource management should be.

13 A NEW SOCIAL CONTRACT

Our technology and the raw materials that support it (energy in practical) is what allows us to live in such large and dense populations called cities. How we interact with those raw materials is changing, whether we like it or not. We must adapt in all ways. At the heart of everything, is our social contract, where people live together in society in accordance with an agreement that establishes moral and political rules of behavior.

The current Linear Economy has some very serious social imbalances. There is a wealth disparity between the wealthy developed nations and the resource rich economically poorer nations. This has developed over several centuries of time. Each of the wealthy nations have become dependent on the import of natural resources, often sourced from the resource rich yet economically poorer nations. This economic system is quite exploitive in nature and quite imbalanced (Perkins 2016).

We must do better if human society is to survive long term.

A thousand years ago, most people lived in a tribe or kingdom, where the dominant paradigm was conflict. If each tribe/Kingdom was not preparing to raid their neighbors for their resources, they were preparing to defend themselves from being raided themselves. Warfare was happening constantly and was not far from the thinking of many leaders (according to historical accounts). This affected almost everyone. As time has passed, the paradigm has shifted. For the last 80 years, most people in the western world now consider economic activity as the focus of their life's work (obviously this is the case in only some parts of the planet). For example, the majority of people in Europe would be shocked if they lost their homes and saw their neighbors killed in a military conflict and believe that their plans for wealth generation could be extended decades into the future. While this difference is not the case everywhere, it does represent quite a change in social contract, regarding how resources are secured.

The challenges society now faces are so fundamental and on such a large scale, that the existing social contract will be required to evolve into something very different. This difference will be of the caliber of the change from constant warfare to economic gain. In many respects the multiple challenges we now face is historically unprecedented in nature. As a direct consequence of this, the new social contract will have aspects to it not seen before.

We must develop a new relationship with energy, mineral resources, technology, economics, the environment, and each other. It may sound complex, but this is all one relationship, were all aspects are part of the same dynamically regulating network.

It is recommended that the understanding of how our social contract with each other in how we do things might evolve through the study of network system theory, following the same basic profile of a biological system through the use of biomimicry (Benyus 2002). Biomimicry is the emulation of the models, systems, and elements of nature for the purpose of solving complex human problems (Vincent *et al* 2006). This is an appropriate direction of development as it would be easier for the human society and supporting industrial system if it resembled the natural environment in architecture more closely at a structural level. In doing so, we may be more successful in merging with the planetary environment in a long term sustainable context.

How biomimicry could be used is as follows. There are a series of accepted concepts in the science of biology in the development of a biological network system. The flow of energy through a system acts to organise that system (Morowitz & Smith 2007). A stated previously, the size and complexity of a network is defined by the energy input to that system. Complex systems don't just manifest in complete form, they must evolve and develop from simpler systems over time. Our society will do the same and a new social contract will have to honour these principles.

In our current form, we are blissfully isolated from the consequences of our actions. We all do just our part, and we are often ignorant of what is really happening around us, or even because of us. When we purchase a product at a shopping mall, we usually have no idea how it was made or what from, let alone where those resources came from. We have no concept of waste plume associated with that product. When we throw the product away after use, we have no idea what happens to it. All of this must change. We must become at an individual level and a community level much more aware of what the knock-on consequences of our actions actually are.

In our current form, we are a very wasteful and materialistic society. We can no longer afford to do this for a variety of reasons. We must socially evolve so what we want, what we do and what we need all become the same thing. This is one of the consequences of our society stepping into a lower energy system. While there are some unprecedented challenges here, we must meet the coming energy contraction with open minds and open hearts. If we do not have a positive attitude in the face of such challenges, we may well be overwhelmed.

As with all other systems, a contraction in available energy dictates that system must become less complex. So, what would a less complex human system look like compared to today? Today, we have quite large groups of people called nation states. This arrangement has come about as a consequence of several centuries of high quality and calorifically dense energy sources. If we do step into a lower energy world, then our systems of administration would also have to become smaller. This implies the future would have a more decentralized political architecture, as a matter of necessity. What this could look like is a nation state remains a nation state, but most of the authority and significant decisions are made at a province or city council scale. National leadership would become an information transfer function.

13.1 The 4th Industrial Revolution and The Great Reset

A low energy future makes the concept of a global government, as proposed by the World Economic Forum (Schwab & Malleret 2020, 2021), seriously impractical. Such a large government would be more complex and more energy intensive. Also, both the challenges and the solutions to meet those challenges would be very different across different geographical areas. Being administered from one globally central would simply not work to the benefit of the people.

The 4th Industrial revolution, also proposed by World Economic Forum (Schwab 2017) is also not practical. The 4th Industrial Revolution (IR4 or Industry 4.0) is the ubiquitous scale up of automation of traditional existing manufacturing and industrial practices. This is to be done using modern state-of-the-art technology.

The planned 4th Industrial Revolution, is characterized by the fusion of the digital, biological, and physical worlds, as well as the growing utilization of new technologies such as artificial intelligence, cloud computing, robotics, 3D printing, the Internet of Things, and advanced wireless technologies (Schwab

2017). The high technology automation systems proposed by proponents of the Fourth Industrial Revolution (IR4) will require a very complex industrial ecosystem (Nasman *et al* 2017). The IR4 system will be much more complex than the current Linear Economy system in place now. From a biophysical exergy point of view this will not be practical in scope of complexity. Then there is the question of whether this should be done at all.

This is often referred to as SMART technology. One of the defining characteristics of this concept is the large-scale machine-to-machine communication (M2M) and the internet of things (IoT), which are integrated for increased automation, improved communication, and self-monitoring. This would require a whole new generation of technology applied to the production of SMART machines that can analyze and diagnose issues without the need for human intervention.

A SMART city is a city that uses a variety of electronic surveillance methods and sensors to collect data (McLaren & Agyeman). What is planned is the ubiquitous surveillance of all resource consumption by all people, 24 hours a day, 7 days a week. That data is used to manage assets, resources, and services efficiently. In theory, the locally collected data is used to improve the operations across the city.

This includes data collected from citizens, devices, buildings, and assets that is then processed and analyzed to monitor and manage traffic and transportation systems, power plants, utilities, water supply networks, waste, crime detection (Fourtané 2018), information systems, schools, libraries, hospitals, and other community services. This sensor network has often been referred to as the Internet of things (IoT) describes the network of physical objects (things) that are embedded with sensors and software, for the purpose of connecting and exchanging data with other devices and systems over the internet.

All of this is a testament to the technological development that has been achieved. There are, however, serious reservations for whether this approach should be used at all (Coombes 2015 & Stanford University Project CS181).

Each time in history that mass surveillance has been used, the human rights of the target society have suffered serious setbacks. AI surveillance technology is spreading at a faster rate to a wider range of countries than experts have commonly understood. At least seventy-five out of 176 countries globally are actively using AI technologies for surveillance purposes. This includes smart city/safe city platforms (fifty-six countries), facial recognition systems (sixty-four countries), and smart policing (fifty-two countries) (Muižnieks 2016 & Saptharishi 2014). Many of the surveillance measures that are currently being done, contradict international human rights law, as established by the European Court of Human Rights (Muižnieks 2016).

The Great Reset as proposed by the International Monetary Fund (Georgieva 2020), and now the World Economic Forum (Schwab & Malleret 2020, 2021). Among other things, this would require the use of the Internet of Things to administer the mass surveillance of society (Hinchliffe 2020). The Internet of Things (IoT) and the SMART grid is the paradigm behind the current surveillance state being unveiled around us now.

The question of should we do this, while important, can be avoided by simply changing how data is collected and from where. The objective is to collect data for resource consumptions of all kinds by all people, in as many places as possible. It is proposed that real time surveillance of all people in their own homes of them engaging in all activities is collected and archived in a central place. This is a much more sophisticated version of what the East German Stasi were doing, but for a different reason. The outcome is the State would micromanage each individual in context of what they did, how and when. The individual would have lost control of their lives. This would be an acceleration of the current actions that contradict international human rights law.

However, what the Internet of Things is trying to achieve is needed and serves a purpose in context of the optimization if society resource consumption. So, a change in what data is collected and where is proposed in a fashion that completely removes all the issues of trust and appropriateness of the current mass surveillance.

This paper proposed human society merges with the natural environment at the social behaviour level, not merging with technology and surveillance at a biological level.

13.2 Transhumanism

The merging of human beings with technology is referred to as the transhumanism movement. Transhumanism is a philosophical and intellectual movement which advocates the enhancement of the human condition by developing and making widely available sophisticated technologies that can greatly enhance longevity and cognition. The yet unknown consequences of transhumanism could be devastating for society (Livingstone 2015). Before biologically merging humans and society with technology, more investigation is required.

A perceived issue with this approach could be that the individual human and society in general become completely dependent on these technology system. The individual human as a self-sufficient entity could devolve in capability without the assistance of technological tools. There is also no actual need to do this. The transhumanism concept does not help society address the challenges in this paper and would require complex and sophisticated technology to achieve.

There is a lot of debate regarding how society has become dependent on technology and what the long term implications of that could be (Orlov 2017). On one hand, technology application is seen as the path to develop society for the benefit of all. On the other hand, it has been observed how society has become dependent on technology and the average person is now helpless without their mobile phone and the internet. The debate around what Artificial Intelligence (AI) contributes to humanity (or is detrimental) is also in this arena.

This debate may well be moot as widespread automation of all of societies tasks is dependent on a complex industrial ecosystem, supplied with vast quantities of natural resources (technology metals in particular) and abundant energy. The current industrial extraction and consumption of resources by the Linear Economy is exhibiting stress signatures. A case can be made that it will struggle to increase in complexity, due to the required increase in mineral resources required.

Orlov (2017) makes an excellent point though. We are required to understand at an individual level and at a nation state level the answer to the following question:

Does the Technosphere serve us, or do we serve the Technosphere?

The role of automation should be optimized for a low energy world, and where the human being is the strongest link in the ecosystem, not the weakest. Our relationship with technology must evolve into something more appropriate. The limitations of exergy and thermo-economics of industrial entropy should define when and where the technology of the 4th Industrial revolution should be applied.

14 THE WAY FORWARD

All historical human systems of resource management and governance (socialism, capitalism, feudalism, fascism, communism, tribalism etc.) have been based on the concept of growth, either through conquest or economic production. This has been dependent on an increasing consumption of energy. That is now likely to reverse for the first time ever, and available energy for society will contract.

An entirely new way of doing things is now needed. We either choose to work together, or we will turn on each other as a consequence of a scarcity of resources. We need to value things differently, where we value each other and not material things. As a civilization, it is time to grow up or fade away.

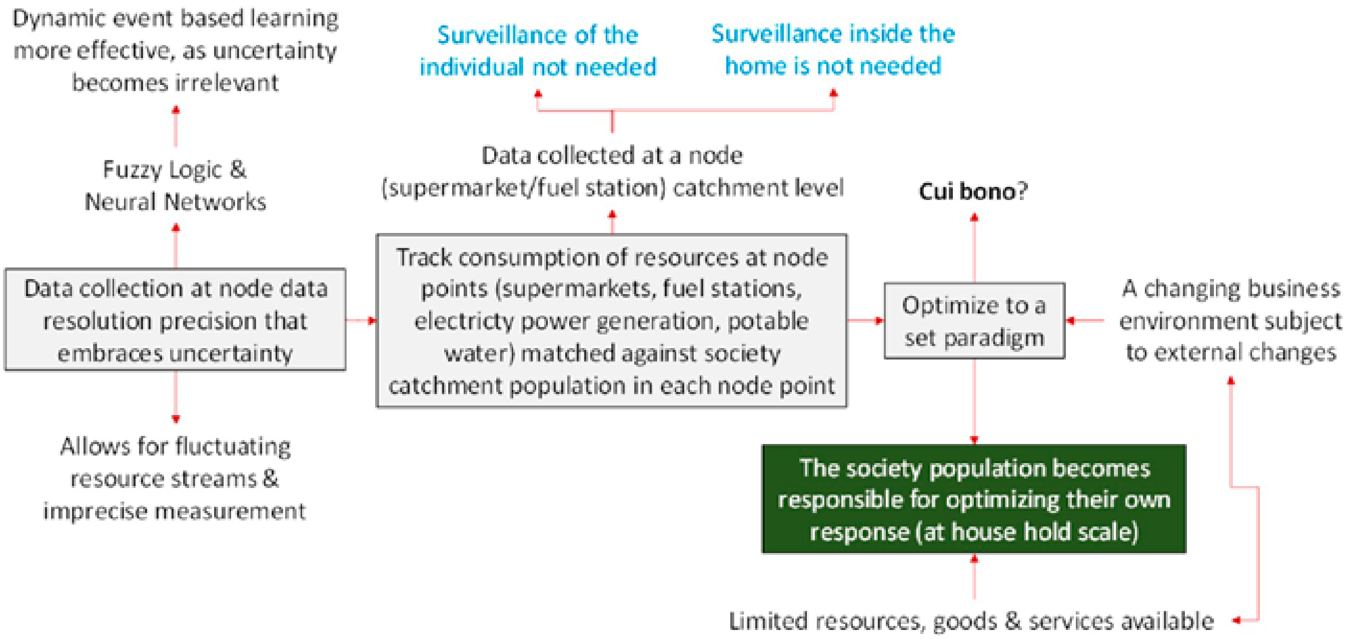
The social contract that is implied could be made up of elements of all past human societies, producing something not seen before. What this will look like is unknown.

As a fundamental issue will be a general lack of resources, elements of a top-down socialism architecture could be used to share resources to different regions. For this to work, each and every one of us must understand that we must share or go to war over resources. However, this system has always failed in the past, so it would require some differences. The human spirit requires the state of self-determination for what the future holds. History shows us that free market capitalism is the most effective an efficient way of progressing society. So, a bottom-up free market capitalism architecture could be used by each region to use those resources to produce useful goods.

How this will develop or even if this would work depends on the choice for society to communicate with open minds and hearts. As a society, we have to decide who we are and what kind of world we wish to live in.

In terms of data collection for the consumption of resources, Figure 15 shows a concept map, where the consumption of resources is tracked at the node point. A node is a device or data point in a larger network. In networking a node is either a connection point, a redistribution point, or a communication endpoint (Kossiakoff *et al* 2011). In this context, a node refers to a goods distribution point where society can access resources. For example: a supermarket for food, a fuel station for fuel, a power station for electricity, etc. The consumption of all resources in and out of each node could be matched against the population catchment the node serves. It is recommended that the network is structured using Fuzzy Logic and/or Neural Network theory. In doing so, uncertainty can be embraced and gives the network greater flexibility in modelling the flow of resources.

Figure 15. Data collection at node data resolution precision that embraces uncertainty



Source: Simon Michaux

The human species is about to evolve socially. The individual will now be required to become more capable, more self-aware, and less dependent on technology. As a society, with community groups, we must become wiser. For any of this to work, we all understand why this is and we collectively choose to do it. Social and industrial evolution is at the crossroads between ruin and the stars. What have we really learned? It really is up to us.

A possible response by society to some for the challenges discussed in this paper could be how society responds to an emergency like a hurricane or flood. Normal ways of doing things are suspended for a short time and society pulls together to attend to the needs of communities. In this working environment, the new equilibrium could be found, if we choose it.

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