The Resource Revolution Trainer:
Coupling Sustainability with Excellence

Session 3 Reading: Principles of Productivity

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3. PRINCIPLES OF PRODUCTVITY

This session introduces the five principles of the Resource Revolution as defined by Heck & Rogers (Chpt 3). Illustrative examples from among others the IRP Reports are included under the principle headings. This section provides company examples of the ***Experiment*** stage (2) of the *Zeronautics* transformation process as defined by John Elkington (2012). This stage requires openness to disruptive or transformative change rather than the continuous change that Total Quality Management (TQM) favours, one that limits experimentation to incrementalism. Applying the principles requires the type of experimentation encouraged by major cleantech award schemes.

Considering emerging market realities, the Experiment stage is also one that includes so-called "frugal innovation". Rather than seeking to adapt Western products to developing world conditions, frugal innovators take the needs of poor consumers as starting point and work backwards. They among others strips products down to their bare essentials. They include companies like the electric carmaker BYD from China, previously a battery company. Zeronauts in this stage are willing to break all the rules, embrace the role of failure in successful innovation and continue to learn by doing.

Let us go through the five principles of the Resource Revolution for business.

3.1 Substitution

The guiding principle for substitution is as follows: Look at every single resource your company uses in its core products and every single resource that customers use or consume, then look for higher-performing, less expensive, or less-scarce materials that might work as substitutes. An important qualification needs to be added. Do not think of the alternative resources as straight substitutes for the current bill of materials. Rather look at how substitutes can deliver superior **overall performance**.

While the IRP is aware of that ultimately substitution has its limits, what recommendations does it have on what needs most importantly to be substituted? The IRP Priority Products Report (2010) suggests, from a materials and dominant environmental impacts perspective, that *the following materials most importantly need better alternatives:*

- **Fossil fuels:** Its extraction is not only one of the most important material flow in mass terms, it is also one of the most important sources of environmental degradation. It is linked to mining and all its local ecosystem impacts and the combustion of the fuels for electricity, heat or transport.

- **Agricultural materials, especially animal products:** These are also a very important material flow in terms of their contribution to a large number of damaging impact categories. Animal products are important because more than half of the world's crops are used to feed animals, not people. With this comes damaging impact in terms of land and water use as well as pollution.

- **Extracting and refining materials such as plastics, iron and steel:** These are those materials used for their structural or material properties and not as energy source. They contribute significantly to a number of pollution- and resource-related impact categories.

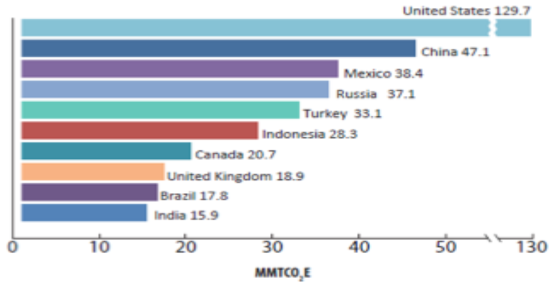
From an integrated perspective – considering the production (priority economic activities), consumption (priority consumption clusters) and materials perspective (priority materials), the IRP has highlighted priority areas for innovation as being *energy and fossil fuels, agrifood and materials*.

Amidst growing demand for materials in emerging markets, scarcity problems are envisaged for many materials that may not be supplemented by secondary production in the short term. Yet even if functional alternatives are not perfect from a scarcity or environmental impact point of view, they may bring about important improvements in the short to medium term. Consider for example the use of aluminium in cars, which reduces their weight and thereby contribute to a reduced need for fuel. Some alternatives may pose new challenges. Many proposed sustainable technologies for energy supply and mobility rely for a large part on the use of metals (e.g. applied in batteries and solar cells). The production of such infrastructure may therefore be energy as well as water intensive and enhance scarcity of certain resources.

Important for the business innovator is the need to consider how substitutes can deliver superior overall performance of the product delivered. An example of better overall performance can be taken from vehicles and fuel substitution. The bus manufacturer Proterra produces a hybrid bus with a light, carbon-composite body – substituting the combustion engine and metal. Ideal for city traffic, the bus is five times more fuel-efficient than traditional fossil-fuel city buses. And while traditional combustion engines can only burn the fuels they have been made for, the Proterra hybrid bus powered by whatever electricity source is most cost-efficiently available.

Substitutions for fossil fuels include methane from landfills – which historically has been a wasted energy. Methane is a valuable fuel and can be burned in power stations and for industrial applications, and can also be liquefied, transported and distributed for purposes such as heating and cooking. Capturing and beneficially using the 40-60 percent methane in landfill gas can reduce greenhouse gas emissions as well as offset the use of other fossil fuels. The Figure below shows an estimate of the methane emissions from landfills in the top 10 emitting countries in 2010.

Figure x: Methane emissions from landfills in a top ten emitting countries (2010, Global Methane Institute):



CASE BOX – CHINA landfills and methane: The Gauantun landfill in China has been retrofitted to enable landfill gas capture and use. Following testing and pre-feasibility investigations conducted by the US EPA, a gas collection system consisting of 150 extraction wells was converted from existing passive vents. A 500-kilowatt (kW) reciprocating engine was installed in 2007 to generate electricity for the onsite leachate treatment plant, and a second 500kW engine was added in 2008. The project is annually reducing greenhouse gas emissions by 37,100 tons of CO2e from electricity generation and 500 tons of CO2e through direct use. Two additional engines will be added, bringing the total electric generating capacity to 2.5 megawatts (MW). There are plans to ultimately increase the power generating capacity to 4MW by the landfill closure date.

A promising substitution material in the building industry is bamboo. It is one of the fastest growing woody plants globally, reaching maturity three times faster than any other harvestable timber (three years on average). Bamboo is well established as a viable construction material, particularly in coastal zones and relatively poor, rural areas. There is growing application and sophistication in the use of bamboo in the construction industry, including as flat panels able to be used as floorboards and walls, large laminated sections for use in external joinery, to reinforcing concrete. Bamboo has natural structural advantages, including its strength and light weight, such that properly constructed bamboo buildings are inherently wind and earthquake resistant. With respect to its production resource requirements, research has for example examined the energy needed to produce 1m3 of bamboo per unit of stress compared with materials commonly used in construction. It found that steel requires 50 times for energy than bamboo.

What about substituting innovations in a bottom of the pyramid context? Take the case of indoor air pollution in poor communities. About 1.3 million people – mostly women and children – die prematurely every year because of exposure to indoor air pollution from burning biomass. Solutions to this include more efficient appliances, the introduction of which is less complicated and offer shorter payback periods. Other solutions are space and water-heating measures, ones that involve shell retrofitting and fuel switching that are often more expensive.

At household level in poor communities, solar thermal cookers present significant opportunities for substituting the use of biotic resources. Consider that two-and-a-half billion people in developing countries depend on biomass – wood, dung, charcoal and agricultural residues – to meet their cooking energy needs. Solar thermal cookers have been improved to achieve more than factor five efficiencies and are cost effective, relying on sunlight instead of biomass to cook food. *Solar Cookers International* operates in Kenya, providing cookers made from cardboard and aluminium foil and costing $10 each. They cook slowly, much like a Crock-Pot and require less than two hours of sunshine to cook a complete meal. A related challenge for all households is the amount of energy used to heat water – which accounts for the bulk of energy use related to water. Reducing the use of hot water or increasing the efficiency of hot water use can simultaneously reduce water and energy use. This illustrates how technology options that are complementary (not conflicting) can better achieve the goals of decoupling.

3.2 Eliminate waste

Measure your input materials, energy and water; compare that with your delivered product, and try to understand all the waste factors in between (such as leakage, scrap, idle machines and interruptions). This is the approach behind waste reduction as made famous by Toyota's "kaizen".

It seems straightforward, yet resource productivity has been completely overshadowed by labour productivity improvements in the last fifty years. Resource waste, for example of energy and its industrial forms steam or heat, including repeated heating and cooling, continues at surprising levels. Initial low hanging fruit improvements can easily enable manufacturers to reduce their energy and materials use by a third, to start with. It among others requires assessing how much energy or water is used throughout an entire process versus the amounts actually required at each step in the process. Your company may very well discover it is twice the amount technically required.

In the late 2000s McKinsey highlighted the water carbon efficiency relationship, citing the case of a mining company that saved 5 percent in costs of potable water after fixing leaks in a single pipeline. After reviewing the total costs associated with water usage, it noted that 40 percent of them were related to the energy necessary to run the pumps. In another example, IBM has seen how integrated water and energy management at a single plant enabled it to achieve savings of US$ 3 million while increasing output by 33 percent. This included a 27 percent reduction in water purchases, almost US$ 1 million in water treatment savings, and US$ 1.5 million in energy savings, without incurring any capital costs.

Look at resource use throughout an entire process is well served by the application of Life Cycle Assessment (LCA) tools. Volkswagen has drawn key insights from its application to track water use, as reported by the IRP Water report (2012 – see box below).

CASE BOX – VOLKSWAGEN AND WATER USE THROUGHTOUT A CAR LIFE CYCLE:
Volkswagen has been analysing the environmental effects of its cars and components by means of LCA for many years. Yet due to lack of data and appropriate impact assessment models, the consumption of freshwater has not been considered. Volkswagen therefore started a study to analyse the freshwater consumption of three specific models Polo, Golf and Passat along their product life cycles on both inventory and impact assessment levels.

The freshwater consumption throughout a car's life cycle is determined using the GaBi 4.3 software and internal LCA databases comprising several thousand datasets for materials and production steps. In order to obtain a regionalised water inventory, which is a prerequisite for a meaningful impact assessment, the total water consumption is allocated to different car material groups as a first step. The water consumption in these groups is then assigned top-down to the corresponding countries on the basis of import mixes, location of suppliers, production sites, etc. Based on this, country- and watershed-specific characterization factors are calculated and selected impact assessment methods for water consumption are applied to estimate the environmental consequences. Only freshwater consumption was considered.

It was found that for all three cars, more than 90 percent of the water was consumed in the production phase. Water consumption takes place in 43 countries, with less than 10 percent of the total consumed directly at the headquarter production site in Wolfsburg, Germany, mainly from painting and evaporation of cooling water. More than 70 percent of the total relates to steel and iron materials and polymers and 20 percent to special metals (gold, silver, and platinum group metals (PGM).

Possibilities for applying the Reduce-Re-use-Recycle (3R) approach are vast. Technologies saving metals and minerals include innovation in steel end use in construction, reduction in metal use, and saving materials from waste streams. As an example, the pressing out of metal components of different shapes and sizes from sheet metal leaves behind pieces of sheet metal that are not wanted and too small to use for other components. Intelligent organization of the different shapes to be pressed out can realize significant metal savings.

Furthermore, the arrival of 3D printing holds the prospect of leaving zero waste. While 3D printers initially only used plastics, they can now print in steel, titanium, gold and other metals. It is used to print various products including hip replacements and smart phone covers. In vehicle manufacturing, it will no longer be necessary to machine a sheet of steel for a door by subtractive manufacturing, punching out parts and creating pieces of scrap in the process. It will be possible to simply print a door panel in an additive or layering process.

For all of manufacturing, the additional benefit of 3D printing will be that parts will not have to be packaged and shipped but can be printed where they are needed. This will among others radically reduce inventory requirements.

Turning waste streams into value streams presents a blue ocean of innovation opportunity. Currently only 25 percent of the 4 billion tonnes of municipal waste produced each year is recovered or recycled. Only 15 percent of all electronic waste is recycled. Less than 1 percent of rare earth metals are recycled. The IRP Metals Recycling Rates Report (2011) found that the recycling rates of metals are in many cases far lower than their potential for reuse. Less than a third of some 60 metals studied have an end-of-life recycling rate above 50 percent and 34 elements are below 1 percent recycling, yet many of them are crucial to emerging clean technologies. The Ellen McArthur Foundation has highlighted economic benefits of recycling, putting forward a clear economic case for the concept of a Circular Economy.

CASE BOX: CARPET TILES: UK-based commercial carpet maker Desso set a goal to make all its products 100 per cent recyclable, while launching a scheme for the return of its and its competitors' carpets for recycling. Putting this goal into practice required design changes, and material substitution to use materials that can be recycled over and over again. Materials are evaluated against 19 human health and environment criteria, with the goal to use 100 percent materials that can be constantly recycled by 2020. This required a re-engineering of the firm's supply chain. More than 60 percent of the company's product range now contains recycled material, while the company aims to collect around 12,000 tonnes of carpets to feed into recycling during 2013.

Some 80 percent of the cost of manufacturing a product is determined during the design stage. It is at the **design** stage that critical decisions can be made to avoid and reduce waste, with respect to product and packaging. It is important therefore to think beyond production when considering ways to reduce waste. Products can be redesigned fundamentally to cut waste. And the best way of approaching this is to think of the whole value chain (suppliers upstream to users or consumers downstream) and not just about cutting the waste of your own company. As an example in value chain thinking, CostCo redesigns packaging so that its suppliers can reduce transportation costs and passes on the savings to its customers.

Also focused on the downstream, consumption side, Winnow Solutions is applying software, algorithms and scales to track food usage and consumption at restaurants (e.g. of hospitals and food services companies) to help them adjust their menus and portions to reduce **food waste** by half.

3.3 Increase circularity

Circularity in business is about finding value in products after their (initial) use. Consider the progress made by the aluminum industry in moving towards closing the loop and the prospect of becoming an industry based on secondary production or above-ground mining. As of 1970, in just one decade, the industry went from using 20 recycled material to 70 percent. Secondary production saves 95 percent of the energy required to produce new aluminium from bauxite ore (a process in which at least three quarters of the ore goes to waste). Members of the International Aluminium Institute have agreed to twelve sustainability objectives supported by 22 indicators. In the 2000s it developed a material resource mass-flow computer model to identify future recycling flows. The model projected that global recycled metal supply from post-consumer scrap will double by 2020 from a 2004 level of 6.7 million tonnes. Today the world's largest producer of aluminium, China, is increasing its secondary production while facing shortages in availability of scrap metals. In India and Brazil, where the highest recovery rates in the world for aluminum cans are found, poverty is a key factor in driving recycling.

Another example of above-ground mining comes from electronics and gold. The technology provider ATMI took note of the fact that e-waste contains a 100 times as much gold as the best ore in the world found in South Africa. Not being extracted, some 35 percent of the gold that is produced for medical, electrics and industrial uses annually gets thrown away (in the form of e-waste). In response, ATMI has developed a water-based solution, safe enough to drink, that dissolves the gold and extracts it from the e-waste. The machine used to do the extraction is the size of a shipping container. Their process contrasts with traditional highly toxic or energy intensive methods of extracting gold from e-waste through the use of acids or smelters. This invention comes from a company traditionally supplying the semiconductor and life science industries.

The key rule of thumb in circularity, noted Heck and Rogers (2014), is *the tighter (narrower) the loop (circuit), the greater the value captured and the stronger the competitive differentiation*. Reusing a phone is more valuable than reusing a chip, which again is more valuable than melting it or grinding it down to extract gold. In the US, eRecyclingCorps works with cell phone service providers to offer customers for example a US$ 50 rebate on the purchase of a new phone of they turn over their old phone. McKinsey has found that US$ 90 billion could be generated annually by refurbishing and reusing electronics.

The possibilities of closed-loop, circular systems in manufacturing include re-manufacturing. Drawing on the principles of industrial ecology, closed-cycle manufacturing is an ambitious approach to supply-side innovation. It refers to an ideal manufacturing system that maximizes the useful life of products and minimizes the waste and loss of valuable and scarce metals. At the product level, closed-cycle manufacturing achieves life-cycle efficiency by facilitating maintenance and repair, reconditioning and remanufacturing, with recycling at the end, in contrast to today's linear "throw-away" paradigm.

Remanufacturing has become increasingly significant in areas such as vehicle components, aircraft parts, compressors, electrical and data communications equipment, office furniture, vending machines, photocopiers, and printer cartridges. In the domain of office equipment, Xerox and Canon are among the companies that have advanced re-manufacturing extensively. Some companies have started to introduce specialized collection, sorting and dismantling plants around the world, either to save spare parts or to produce low-cost versions of their top-of-the line products. This encourages product redesign to facilitate the process.

Caterpillar is probably the world's largest re-manufacturer, with a global turnover of over US$1 billion and plants in three countries. About 70 per cent of a typical machine (by weight) can be re-used as such, while another 16 percent is recycled. Large diesel engines are routinely re-manufactured. Caterpillar has started to price some of its products at a significant percentage "below new" if a customer makes a deposit that will be refunded when the product is returned to Caterpillar at the end of its (current) life. Caterpillar aims to reach the point where zero percent of its products end up as waste in a landfill. It estimates that thanks to circularity it can use 85-95 percent less energy and material to produce a secondary product (as opposed to producing a primary from scratch).

The chemicals industry holds great potential for promoting circularity, among others though innovation in industrial ecology. In the last decade Bayer has achieved major reductions in GHG emissions profitably. The range of technologies employed include chemical process innovation, catalysts, co-generation and heat exchangers to capture, recover and reuse heat and power, as well as separation membrane technologies to replace energy intensive distillation processes. Similarly, as the example of its headquarter location with an industrial park shows, BASF has made impressive gains through the application of industrial ecology. Industrial symbiosis or eco-industrial parks presents another version of closed-cycle manufacturing at a broader systems level (as opposed to product level).

3.4 Optimisation

Optimisation is about maximizing efficiency and effectiveness. In engineering this would refer to the process or methodology of making a design or system as fully functional or effective as possible. In computing it refers to writing programme instructions so as to maximize efficiency and speed. In mathematics it is about determining the maximum or minimum values of a specified function.

Opportunities for optimisation in business exist at various levels and in various sectors. System optimization can enable radical improvements in the use of electric motors. Electric motors can account for approximately 60-80 percent of industrial electricity use, driving pumps, fans, air compressors and materials processing and handling. In China electric motors used in industry account for around 60 percent of the country's total electricity consumption. The operational efficiency of these motors is 10-30 percent below international best practice, depending on the industry.

A guiding principle for the aspiring resource efficient company is to ask itself what expensive assets are used only a small part of the time or what resource-intensive equipment is active without performing a function. This could be construction equipment, shipping containers or trucks that return empty, or planes circling an airport waiting for congestion to clear. All these cases lend themselves to smart IT solutions that optimize routing, loading or sharing.

Consider some examples. Applied Materials has optimized its parts delivery by keeping track of all spare parts no matter where they are. Customers can find a nearby part to borrow until a new one can be shipped. This reminds of an old tradition in printed media, where the printers of competing daily newspapers often had an agreement to help one another out in times of emergency.

Today many airlines pool resources at airport hubs and provide each other spare parts. Komatsu, Japanese manufacturer of construction, mining, and industrial equipment, has created a market that enables customers to rent to and from each other. If you have Komatsu equipment that is sitting unused, the company will find some-one to use it. It is an example of a company converting equipment sales to services, or more importantly, introducing product-services-systems (PSSs).

New forms of PSSs have also made their way into the car manufacturing industry, considering the extreme inefficiencies behind how (often individual passenger) cars tend to be used. Mindful that most car owners don't use their cars 96 percent of the time, it was high time for car sharing schemes to enter the mainstream. More optimal use was also facilitated by the use of new software capabilities (including smartphone apps). As market interested grew, new start-ups such as Zipcar found itself acquired by Avis. Manufacturers such as BMW and Daimler started their own car-sharing programmes. And the efficiencies (including GPS monitoring) introduced by Uber are sending shock waves through the taxi industry.

3.5 Virtualisation and Dematerialisation

Virtualisation challenges business models. It is therefor a concept that many companies struggle with, as it involves (i) moving activities out of the physical world and/or (ii) stopping doing things since they have been automated. For some industries or business models this implies loss in revenues, such as a car manufacturer faced with customers driving less (while spending more time on social media) or a media company earning less from digital ads versus ads in printed magazines.

Without us realizing it, many of the items we have been using only five or ten years ago are now replaced by dematerialized products or services that fulfill the same function, often better. Consider books, radios, tickets, birthday cards, timetables, watches as well as thick manuals for managers or pilots now replaced by iPads. Today flashlights are going out of fashion as LED lights, for example the ones included in smartphones, replace them. And then there is the arrival of drones, pilotless plans used initially by the military, as well as developments underway by ICT giants and car manufacturers to produce driverless vehicles.

Importantly, the IRP Metals Risks and Challenges Report (2013) has highlighted the need to be aware of the side effects of new technologies. Consider the case of metals and renewable energy. A shift towards a renewable energy system implies that the metal intensity of energy production will increase faster. With respect to dematerialization in the context of sustainable metals management, it requires using less metal in a product to fulfill the same functions. This would reduce potential life cycle impacts accordingly. Again one has to be aware of possible side-effects, and dematerialization will have to be complemented by recycling. While recycling rates for many metals are at present low, system optimization and design for recycling can help much to further increase recycling rates world-wide. Products, their design and system design affect material use and recycling to facilitate resource efficiency.

EXERCISE QUESTIONS:

1. **Weigh the principles of productivity in terms of applicability to your business, and consider what goals you can set yourself in applying these.**

2. **Can you take an appointment with your R&D department to discuss possibilities for substitution of resource / material inputs?**

3. **Consider the rule of thumb in circularity, *the tighter (narrower) the loop (circuit), the greater the value captured and the stronger the competitive differentiation.* How does this apply to your business and its product range?**

4. **Looking at optimization, what expensive assets of your business are used only a small part of the time or what resource-intensive equipment is active without performing a function? Who can you take this up with?**

5. **Write a case for your CEO to commit your company to the goal of zero waste.**