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**Product Renovation and shared ownership: sustainable routes to satisfying the
World's growing demand for goods**

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ABSTRACT

It has been estimated that by 2030 the number of people who are wealthy enough to be considered as middle class consumers will have tripled. This will have a dramatic impact on the demands for primary materials and energy. Much work has been carried out on sustainable ways of meeting the World's energy demands and some work has been carried out on the sustainable production and consumption of goods. It has been estimated that with improvements in design and manufacturing it is possible to reduce the primary material requirements by 30% to produce the current demand for goods. Whilst this is a crucial step on the production side, there will still be a doubling of primary material requirements by the end of the century because of an absolute rise in demand for goods and services. It is therefore clear that the consumption of products must also be explored. This is a key areas of research for the UK INDEMAND centre, which is investigating ways of reducing the UK's industrial energy demand and demand for energy intensive materials. Our ongoing work shows that two strategies would result in considerable reductions in the demand for primary materials: product longevity and using goods more intensively (which may requires increased durability). Product longevity and durability are not new ideas, but ones that can be applied across a raft of goods as methods of reducing the consumption of materials. With long life products there is a potential risk of outdated design and obsolescence, consequently there is a need to ensure upgradability and adaptability are incorporated at the design stage. If products last longer, then the production of new products can be diverted to emerging markets rather than the

market for replacement goods. There are many goods which are only used occasionally, these goods do not normally wear out. The total demand for such could be drastically reduced if they were shared with other people. Sharing of goods has traditionally been conducted between friends or by hiring equipment. The use of modern communication systems and social media could enable the development of sharing co-ops and swap spaces that will increase the utilisation of goods and hence reduce the demand for new goods. This could also increase access to a range of goods for those on low incomes. From a series of workshops it has been found that the principal challenges are sociological rather than technological. This paper contains a discussion of these challenges and explores possible futures where these two strategies have been adopted. In addition, the barriers and opportunities that these strategies offer for consumers and businesses are identified, and areas where government policy could be instigated to bring about change are highlighted.

INTRODUCTION

It has been estimated that the global middle class will rise from 1.8 billion in 2009 to 4.9 billion in 2030 [1]. Assuming that they will aspire to a western consumerist lifestyle this will result in a proportional rise in the demand for goods and services needing industrial products. This will have a severe impact on the demand for primary materials (steel, aluminum, plastics, cement etc.) and the industrial energy demand needed to make them into finished goods. At the same time there is a general consensus that something needs to be done to reduce GHG emissions globally [7]. The International Energy Agency

(IEA) estimate that to avoid damaging climate change the global greenhouse gas (GHG) emission will need to be lowered by 50% from today's level by 2050. Some sectors of the global economy are easier to decarbonize than others. It is recognized that industrial production is hard to decarbonize and this is reflected in the IEA's decarbonization target of a reduction by 23% for this sector. It is hard to see how these two aspirations can be reconciled with current business practices. This paper estimates the extent of the problem, looks at techniques that can help ameliorate it and reports the finding of a workshop that discussed opportunities, drivers and barriers to changing business practices so that they can prosper in a world where there are limits to expansion.

NOMENCLATURE

E total global greenhouse gas emissions from global industry.

N is the number of a hypothetical typical goods that would need to be manufactured to produce the same global environmental impact as global industry.

S is a multi-dimensional measure of the global demand for the service provided by goods.

U is utilization a multi-dimensional measure of how much use is made of a particular good.

the following suffixes are used :

- D for direct emissions
- P for emissions associated with primary material production
- M for emissions associated with the manufacturing, distribution and retailing of goods
- I for indirect emissions
- Numerical suffixes represent years

Impact of emission target on industrial production

The IEA estimate that industry accounts for 40% of GHG emissions. 56% of industrial GHG emissions come from the production of primary materials that are used to make other goods. Manufacturing processes account for the remaining emissions.

Not all industrial emissions come from the industrial plants themselves. Around 31% of all industrial emissions are indirect emissions i.e. those associated with electricity generation, material transport, and fuel production. These are subject to different emission targets.

If we want to achieve the IEA target industrial emission (E) for 2030 will be

$$E_{2030} = 0.77E_{2010}$$

If we consider direct emission in 2010

$$E_D = 0.69 E = E_{PD} + E_{MD}$$

with

$$E_{PD} = 0.56 E_D = 0.4E$$

and

$$E_{MD} = 0.44E_D = 0.3E$$

For indirect emissions

$$E_I = 0.31E$$

Industrial plants and processes are subject to ongoing improvements which will result in reductions of GHG emissions.

Not all industrial plants are designed or operated to minimize emissions. Estimates of the GHG savings that may be made by adopting world's best practice in individual primary material sectors are given in [2]. An emissions weighted average was calculated for all the sectors which gave a potential GHG saving of 24%.

Primary materials tend not to be used in their basic form and it has been estimated that by improvements in manufacturing practice and improved product design it should be possible to improve material efficiency by 30% [5,6]. If these improvements were made, the emissions associated with primary materials used in goods could be reduced to 53%.

An estimation of the potential GHG emission savings for the manufacturing sector can be inferred from estimations of potential energy saving. The IEA estimate that by adopting best practices it should be possible to reduce specific industrial energy demand by 20 to 30 % [2], This is consistent with estimates in other literature [3,4].

From the IEA world Energy Outlook [8] it looks likely that the reduction in carbon intensity of electricity generation could be in the order of 30% to 60% by 2030.

If we assume that the savings identified above have been made by 2030 we have

$$E_{2030} = 0.55E + 0.47E_{PD} + 0.7E_{MD} = 0.57E_{2010}$$

for the same level of production so production can be increased without breaking the emission target but only by the following amount:

$$N_{2030} \frac{0.77}{0.57} N_{2010} = 1.35N_{2010}$$

If demand increases are proportional to the increase in the global middle class the demand for services provided by the goods is:

$$S_{2030} = \frac{4.9}{1.8} S_{2010} = 2.7S_{2010}$$

Clearly even if the best available practice is adopted across World industry it will not be possible to produce enough goods to meet this demand and stay within the IEA's industrial emission target. An alternative strategy is to see if the utility provided by goods can be provided with a reduced supply of new goods. There are two ways this can be achieved, making goods last longer so they don't need replacing so often and sharing infrequently used items amongst groups of users to reduce demand for actual goods.

If the service supplied by the goods is defined as

$$S = UN$$

$$U_{2030} = \frac{S_{2030}}{N_{2030}} = \frac{2.7S_{2010}}{1.35N_{2010}} = 2U_{2010}$$

This looks like a high target. However, if cars are considered as an example in a 2008 report on UK car ownership (published before the car scrappage scheme was introduced) prepared for the RAC foundation [9] it was reported that cars were scrapped at a steady rate from 9 to 20 years old with 50% of cars being scrapped by the time they were 14 years old. To get the required improvement in utilizations by increasing product life would require an increase in the average life to 28 years. Although this is a considerable extension it is technically possible as demonstrated by the number of classic cars in everyday use [10,27].

Alternatively as most of the growth in the middle class is predicted to be in urban areas, vehicle utilizations can be improved by joining car clubs. It has been reported that car clubs have around 4.3 member per cars [11] so a doubling of car utilization could be achieved if 65% of people used car clubs rather than owning their own cars.

Either of these approaches could be adopted, but would appear to be a major change in the way we approach car ownership. However in combination, they become less extreme and the same outcome is achieved by extending the average car life to 21 years and 33% of the populations using car clubs.

There are a number of ways to achieve longer product life and higher utilization. In most cases there will need to be new business models developed to enable these strategies to be adopted in a way that is advantageous to the business community, consumers and the wider community.

STRATERIES FOR INCREASING PRODUCT LONGEVITY

The environmental benefits of increased product longevity have been recognized, reduction in the need for replacement products leading to reduced requirements for raw materials, lower industrial energy requirements and reduced volumes of end of life waste to deal with [12,6]. There are a number of different strategies for increasing product life and the appropriate one needs to be selected for each type of good. The following strategies: product durability, Serviceability, upgradability refurbishment/remanufacture and alternative use are outlined in the following sections

Durability

Most products have components that suffer wear or are prone to damage. The impact of this can be mitigated during design through the provision of more durable components, resulting in a product with a longer life span. This approach could have some of the following drawbacks:

- uses more material or more sophisticated materials resulting in a higher production cost
- increased weight may increase operational energy requirement
- increased weight and bulkiness may make the object harder to use
- locks the user into an old design with limited opportunity to improve performance
- limited repeat sales for manufacture

Serviceability

An alternative approach where the product is designed to be deconstructed and maintained so that parts that are susceptible to ware and damage can be readily replaced.

This strategy has the following potential drawbacks:

- higher cost associated with a undoable fixtures
- repair by poorly trained staff or the use of substandard replacement components reduce reliability
- locks the user into an old design with opportunity to improve performance limited to the replaceable components
- limited repeat sales for manufacture although this can be offset by increase in business for the manufactures authorized service agents

Historically most complex goods were serviceable, but improved manufacturing techniques and lubricants allowed sealed for life systems to became prevalent as a way to overcome the need to maintain a service infrastructure.

However providing servicing is carried out within a manufactures controlled environment it can be used to provide valuable intelligence into how the product degrades with use which can be fed back into new designs.

Upgradable

Until recently the ability to upgrade the performance of products has been limited to those that consist of a collection of modules or components that can be replaced with ones of an improved specification during the products operational life. However as more functionality is achieved by embedded intelligence and electronic controls there is a widening scope for in-service upgrades. Upgradability is a strategy that reduces the risk of technological redundancy for the consumer but this reduces the opportunity for the manufacturer to make repeat sales. However if the cost of materials and manufacturing represent a high proportion of the cost of a new product the manufacturers profit margin on the sale may be quite small and vulnerable to outside influences. Whereas the cost associated with an in house upgrade are likely to be under the manufacturers control and the profit margins can be much higher (while still representing a saving for the consumer). Consequently product upgrading can be as profitable as manufacture in the case of rapidly developing high tech products. The problem with designing for upgrade is that it depends on the designer having a good idea of the developments that are likely to happen. Likewise if consideration has been made for a future upgrade it constrains the designer of the upgrade to fit it within the accommodation made.

Refurbishment and Remanufacture

Refurbishment is the process of replacing or repairing worn parts of a product to considerable increase its service life. A product must be serviceable to be refurbished but whereas serviceability is about dealing with premature failure caused by a weak component refurbishment is undertaken on a wider range of components to increase the service life beyond its initial design life.

Remanufacture is the process of disassembly, cleaning, inspection, replacement of worn components and reassembly into a new product that is indistinguishable from one made of new components. This is an expensive procedure but can be cost effective on high value items that have components that ware at different rates. Assessment tools have been developed to evaluate the suitability of remanufacturing as a strategy for a particular item [13,14] There are established refurbishment businesses for a wide range of products including white goods and wind turbines [30, 15]. Remanufacturing is carried out on high value items like aero engines and construction equipment where in-service failures are either unacceptable or expensive [16].

Alternative use

The construction sector showcases many examples of alternative uses of materials, including reuse of salvaged steel beams, stone work, bricks, telegraph poles and railway sleepers [6,17,18]. The main niche for alternative use is as a way of utilizing obsolete or hard to recycle products. It is a mindset that treats old goods as a resource to be exploited rather than as a collection of materials to be recycled back into primary materials. Sometimes the alternative use may be in a different field for example the production of thermal insulation from a variety of waste goods [19] or the production of craft goods from discarded products. Improved coordination between the waste sector and product supply chain could expand this market and open up currently unforeseen opportunities.

Strategy selection criteria

There are clearly a number of tradeoffs to be considered when setting the design life for a product. The parameters that need to be considered have been grouped under six domains

- economic
 - purchase price
 - annualized purchase price
 - annual running cost
 - refurbishment cost
- material consideration
 - common material use
 - rare material use
 - ease of material recovery at end of life
 - material required for maintenance
- energy consideration
 - energy embodied in the construction of the good
 - annualized embedded energy
 - annual operational energy
 - energy needed for maintenance
 - energy needed to recycle
- environmental impacts
 - life time emission to land, water & air
 - annualized emission to land, water & air
 - local environment impact from manufacture
 - local environmental impact from use
 - local environmental impact from recycling
 - consequential environmental impact from energy and material use
- functional evolution
 - sensitivity to change in technology
 - sensitivity to fashion
- fragility
 - susceptibility to loose functionality over time
 - degradation of appearance over time

It is recognized that it is not possible to quantify each of these parameters to the same extent but as the purpose is to compare alternative strategies it may be sufficient to use a five point scale for many of the parameters.

The utilization of a product can be improved by product sharing schemes like car clubs or plant hire and selling or donating unwanted goods to new owners. The potential for these strategies is still under investigation but will hopefully be the subject of further papers from UK INDEMAND.

New business model Barriers and Drivers

Although there are a number of current and historic examples of businesses that use these life extension strategies it is likely that new business models will be needed to fully exploit a low material future (i.e. a future with a low demand for new primary materials). In particular if products last longer manufacturing and retail businesses will get less repeat sales. This means that they will have to either chase the developing markets (with undesirable consequences for their existing markets) or get involved with all phases of a product life so that they can get future income from the goods they sell. This shift from pure manufacturing into a broader provision of services where the manufacture provides an ongoing facility to their customers rather than just the equipment to realize a facility is known as servitization. This can allow companies to maintain their profits without having to maintain their sales of new goods. A trend towards the servitization of industry has been witnessed over recent years [22,24,25] this strategy could help businesses thrive in a low material economy.

Figure 1 shows the framework of activities that constitute a product life cycle in a low material future including those needed to enhance product life.

It should be noted that Figure 1 shares features of circular economic models [20,21] i.e. very high rates of primary material recycling. However it is not considered practical for global industrial to be solely reliant on recycled and renewable raw material in times of rapidly rising demand.

The main difference between the framework shown figure 1 and the traditional linear or circular economy models is a difference on the emphasis placed on maintenance, renovation and repair at the expense of manufacturing. This is to minimize the energy used to produce primary materials and reduce the need for raw material.

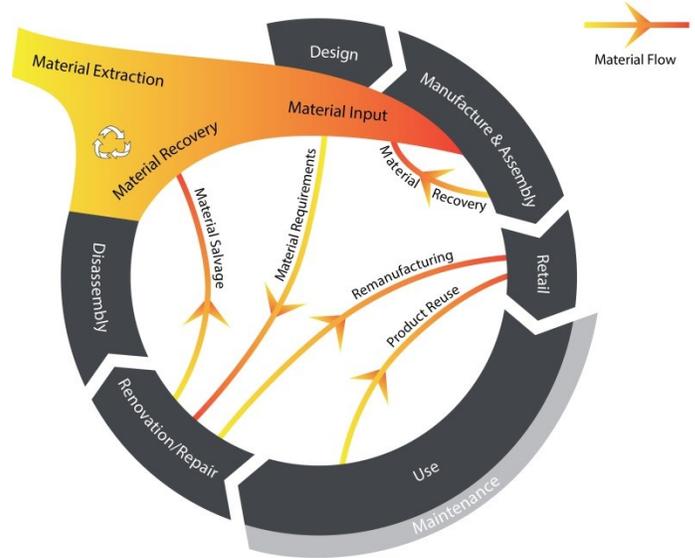


FIGURE 1 FRAMEWORK OF ACTIVITIES INVOLVED IN A PRODUCT LIFE CYCLE

This would involve a shift from centralized high volume highly specialized mass production facilities into smaller localized flexible batch production facilities. Many people may consider this a giant step backwards but advances in additive manufacturing, improved flexibility of robots and machine tools means that many of the original drivers for large scale production are diminishing in importance [22,23,28,29]. A move towards more localized production would allow increased customer involvement with the specification and design of the goods they buy and keep a higher proportion of the economic added value resulting from production in the region where the goods are purchased, produced and serviced.

Although advancement in flexible manufacturing facilities and servitization will encourage the adoption of practices which are consistent with a low material economy there are still a number of barriers inhibiting its adoption. These were explored within a stakeholder workshop [26], and outlined in the subsequent sections.

METHODOLOGY

Representatives of manufacturers, retailers, consultants, academics, government advisors and government department were asked to consider list of potential benefits, drivers and barriers and ask participants to rank them in order of importance. The participants were split into seven table of 7 or 8 people to encourage discussion.

The results of the ranking exercise are shown in Tables 1, 2 & 3. As the point of the exercise was to identify those factors that were considered significant it was decided to record all factors that at least one participant though was in their top 5 these are

shown in the “mentioned” column with those that were identified as being in the top 3 on any table shown in the “in top 3” column.

RESULTS AND DISCUSSIONS

Table 1 Participants’ perception of the benefits to industry from reduced material demand

| Benefits of reduced material demand | mentioned | in top 3 |
|---|-----------|----------|
| Reduced risk of material supply disruption | TRUE | TRUE |
| Less price volatility of materials | TRUE | TRUE |
| Potential for new business models | TRUE | FALSE |
| Reduced environmental impacts | TRUE | TRUE |
| Potential profits | TRUE | TRUE |
| Reduced material costs | TRUE | TRUE |
| Greener company image | TRUE | FALSE |
| prolonged commercial relationship with customer | TRUE | TRUE |
| Opportunities for collaborative partnerships | TRUE | TRUE |
| Benefit for society | TRUE | FALSE |

Table 2 Participants’ perception of drivers to move industry to reduce material demand

| Drivers to move industry towards reduced material demand | mentioned | in top 3 |
|--|-----------|----------|
| Material Scarcity | TRUE | FALSE |
| Disruption of material flows | TRUE | TRUE |
| Disruption of energy supply | TRUE | FALSE |
| User demand/attitudes | TRUE | TRUE |
| Policy | TRUE | TRUE |
| Carbon tax | TRUE | FALSE |
| Impacts on profitability | TRUE | TRUE |
| Future price and cost uncertainty for materials | TRUE | TRUE |
| Future price and cost uncertainty for energy | TRUE | TRUE |
| Reduced waste disposal cost | TRUE | FALSE |

Table 3 Participants’ perception of barriers to a low material future

| Potential Barriers to reduced material demand | mentioned | in top 3 |
|--|-----------|----------|
| Intellectual Property | FALSE | FALSE |
| Cost restraints | TRUE | TRUE |
| Lack of investment capital to develop & build new facilities | TRUE | FALSE |
| Lack of operational capital e.g. to store reused materials | TRUE | FALSE |
| Time constraints | TRUE | FALSE |
| Current policy requirements | TRUE | FALSE |
| Lack of knowledge | TRUE | TRUE |
| Lack of certification procedures for alternative practices i.e. reused steel | TRUE | FALSE |
| Complex supply chains | TRUE | TRUE |
| Complex information flows within the supply chain | TRUE | TRUE |
| Consumer perception | TRUE | TRUE |
| Consumer behavior | TRUE | TRUE |
| Producers/consumers locked-into the current economic/market system | TRUE | TRUE |
| The amount of price subsidizes in key materials, gas and petrol | FALSE | FALSE |
| Cultural expectation for new models | TRUE | TRUE |
| take back process unknown supply quality and quality | TRUE | FALSE |
| close loop supply chains & reverse loop supply chain could increase cost of logistics, transportation and energy | TRUE | TRUE |

Factors that were mentioned but did not make the top 3 are likely to be issues for particular industries. It was noticeable that intellectual property was not considered to be a barrier. This may be due to the presentation showing refurbishment and remanufacturing activities being carried out by the manufacturers or their licensed agents.

Cost issues were seen as a key barrier, but the ability to remove exposure and save material cost were also identified as potential benefits. The fact that subsidizes were not mentioned indicates that the participants did not consider these to be a major influence on costs.

Likewise user demand / attitudes were seen as drivers and consumer perception, behavior and expectation for new models

were seen as barriers. There is a rich literature on the drivers and influences on consumers at it would be wrong to assume that they are fixed. Further work is needed to explore this aspect.

CONCLUSIONS

The demand for goods from the expanding global middle class cannot be met using the predominant manufacturing business model without seriously compromising industrial emission targets.

However if product life and utilization is improved it should be able to meet the demand for service and stay within emission targets.

The fact that the risk of disruption in material supply was considered to be a more significant driver than absolute material scarcity is revealing. It indicates that even if new sources of key materials are found they will only have an impact if they become globally available and if trade in key material is not subject to political interference.

A number of benefits, drivers and barriers have been identified. It is noticeable that cost issues and consumer attitudes are considered to be both barriers and drivers indicating that more research is needed into these aspects to reveal their true impact.

The lack of knowledge relating to business models that incorporated life extension and product sharing was also identified as a barrier so further work in this field would also be a benefit to business.

Policy was identified as a driver and although current policy requirements were identified as an issue they were not considered to be a key one.

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