



Study on frugal innovation and reengineering of traditional techniques

Key Findings from the Final Report

SHORT VERSION

Call for Tenders PP-02381-2015

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Abstract

This study explores the potential of technology-based frugal innovation for European industry, entrepreneurs and citizens. Frugal innovation relates to the process of reducing a solution to exactly those, often basic, functionalities that users will need, thus economising on resources and cost. To that end, solutions have to be developed consciously, recognising constraints, building on a spirit of open innovation and openness to the world. While firms and entrepreneurs from emerging economies display unrivalled capacity to cut cost and leverage local knowledge, European firms may find opportunity in leveraging Europe's existing portfolio of technologies. However, most frugal innovation results at the level of solution integration and delivery rather than that of basic technological development. To build a dynamic support system for frugal innovation in Europe, therefore, further actors capable of technology exploitation will have to be mobilised, their interface with existing technology developers strengthened, their access to foreign markets improved, and an active role of development agencies, NGOs and research organisations in pursuing and procuring global challenge-oriented projects promoted. In summary, support policy should recognise that European firms should not and will not win a race to the bottom on price. Instead, it should champion smart frugal solutions with good customer-orientation, quality and sustainability. Where genuinely poor populations lack means to acquire such slightly more expensive frugal solutions, international collaboration could support dissemination.

1 Introduction

This study explores the potential of frugal innovation for Europe, in particular its industrial potential and identifies opportunities to support the development and design of technology-based frugal innovation. It makes suggestions as to how this potential could best be exploited in support of smart, sustainable and inclusive growth through research and innovation policy.

“More value for more people from less resource”

The concept of frugal innovation has its roots in developing and emerging economies where resources are severely constrained. Frugal innovators have a clear focus on user needs and prioritise only the features that are most important to potential customers. By doing so, they can create solutions that are substantially more affordable for a broader range of users than alternatives. In addition, because they limit resource inputs, frugal solutions can – at least theoretically – be more environmentally or socially sustainable.

Frugal innovation is an umbrella term that covers a broad spectrum of activity from ‘grassroots innovation’ (famous examples include the Jaipur Foot or Mitticool Fridge) through to activity by large firms aimed at serving growing customer bases in emerging economies. Since it starts from user needs, rather than availability of technology, frugal innovation does not necessarily produce technologically advanced solutions. Some well-known examples simply involve ingeniously re-using existing technologies to provide new solutions. Nevertheless, technological development and frugal innovation are not mutually exclusive. A starting assumption for this project was that new technologies (like organic photovoltaics) and production processes (like 3D printing) could open up many more opportunities for frugal innovation.

More than just cheap

Another starting point for this study was that, while some multinational firms, like Siemens and GE, are successfully developing ‘frugal’ products for emerging economy markets, most European enterprises continue to focus on premium segments of overseas market. These, however, are shrinking, while the purchasing power of ‘emerging middle classes’ grows. At the same time, non-premium demand is gaining momentum in Europe itself, and European firms are at put risk of losing ground to companies from countries like India and China that are more experienced in developing solutions for resource-constrained customers.

Early during the conceptual phase of this project, it became clear that European businesses will rarely be successful in marketing innovations by focusing solely on lowering prices. In that segment, boundaries between frugal innovation and cheap mass production become blurred, ethical and regulatory issues keep European firms from competing on the same terms with overseas competitors and technological competence usually plays a subordinate role. Likewise, European entrepreneurs are unlikely to play a substantial role in ‘grassroots innovation’ where, once more, technological expertise is less important, while in-depth knowledge of local customs and everyday problems is essential – and hard for external actors to acquire.

So, what is Europe’s ‘frugal niche’? Which could be future ‘frugal innovations with European characteristics’? While frugal innovation that directly builds on the dedicated development of genuinely novel technology is currently rare, this study demonstrates that combining European competences in technology development with emerging economy lessons in the field of frugal innovation can produce successful technology-based frugal innovation. However, substantial policy efforts are needed to support a conscious exploitation of key enabling and other relevant industrial technologies – to promote and prompt frugal innovation and thus open up new opportunities for Europe’s industry, entrepreneurs and citizens.

Methodology and case studies

The study started with a literature review and scoping interviews to explore the concept of frugal innovation, the role of technology and opportunities for European firms and innovators – in overseas markets and Europe itself. This conceptual phase culminated in the production of an interim report, which proposed eight hypotheses:

- 1 A mentality for frugal innovation is not limited to emerging economies,
- 2 In Europe, technological development is still mostly performed with a focus on excellence,
- 3 Much technological development lacks openness and remains disconnected from users,
- 4 New technologies may be platforms on which frugal solutions can be developed,
- 5 More and more European customers display an openness to purchase frugal solutions,
- 6 Emerging economies markets provide a great potential for frugal solutions,
- 7 Many companies with good ideas will find it hard to scale the provision of frugal solutions,
- 8 Increased access to frugal solutions is not unanimously positive.

Following this, ten case studies were produced. In total, these were based on 43 telephone or personal interviews with European managers, entrepreneurs, researchers and experts, as well as a detailed review of relevant documentation.

Each case study focuses on a specific area of interest, rather than one particular firm or other organisation so that a broader perspective could be taken. They included:

- Transition from technology to application in water treatment,
- Propagation of cost effective organic photovoltaics by validation in emerging countries,
- Printed electronics as a platform technology for frugal healthcare applications,
- Combining local emerging market knowledge and high-tech in frugal prosthetics,
- Frugal innovations on European markets,
- Inclusive, low-threshold innovation in FabLabs and maker spaces,
- Frugal innovation and the circular economy,
- Frugal innovation for refugees and displaced people,
- Embedding a frugal mindset: universities as hubs for frugal innovation,
- The scope of frugal innovation and traditional techniques for buildings and housing

The case studies were designed to test and further explore the hypotheses set out in the conceptual phase. Each case study is written up in detail in the full final report.

2 Main findings

Can European innovators develop a 'frugal mindset'?

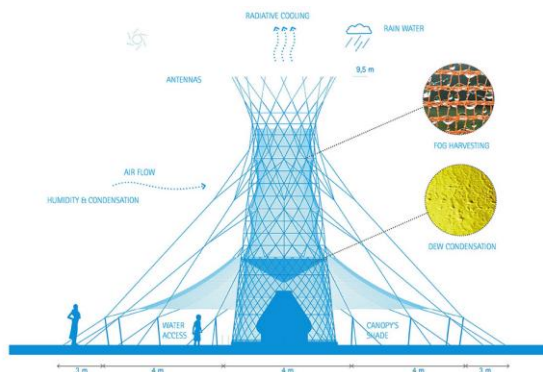
In its interim report, the study argued that **a mentality for frugal innovation and technological recombination is not exclusive to emerging economies** and that even in technology-driven contexts frugal mindsets can be (re)gained through active engagement with frugal markets in and outside Europe.

The case study analysis identified a number of examples in which European enterprises adopted approaches to solution development that can be considered frugal in both ambition and process. Most of these involved often substantial effort in reinterpreting existing technologies for new applications. Cases in which entirely new technologies are needed to resolve frugal challenges, in contrast, were rare.

The study found that technology component manufacturers tended to consider development processes from established perspectives, seeing high-end, premium applications as their primary market. However, new attitudes can be found originating from young, philanthropic-minded firms or environmentally-inspired entrepreneurs. At the same time, some more integrated corporations that sell large scale to individual customers and can draw on existing technological portfolios see additional markets and have the resources to set up new or separate development teams uninhibited from existing traditions.

*In a case study of **WarkaWater**, the study established that cultural and societal environments can be crucial for the successful implementation and uptake of frugal innovations and that – at the same time – technological development can be important to make them fit for that purpose. Very often, public procurers at different levels of developing countries tend to prefer top-end solutions even if these can hardly be provided for everyone. In consequence, many villages and communities are left with traditional techniques that while still providing a good cultural fit at the same time cannot provide the social recognition that comes with a modern solution and – indeed – remain in various ways technologically deficient. Using the example of Warka's water harvesting towers, this study illustrated that while traditional techniques can be used as an inspiration for the suitable cultural fitting of future solutions – targeted and well-informed technological development of the materials and design can put not only their efficacy but also their socioeconomic impact on an entirely different level. By developing water harvesting nets out of new, biomimetic materials water harvesting installations can be made lighter and more effective at low prices while, in parallel, ICT applications can enhance their basic social function.*

Picture Source: © **Warka Water**, minor clippings to fit to page



Moreover, a notable interest in frugal approaches can be identified among NGOs and applied research and technology organisations (RTOs) as both are more challenge-driven than market-driven. Many NGOs have to develop solutions for frugal environments in pursuit of their mission, while many applied RTOs are at least partially funded to find solutions for socio-economic challenges. In both, cases, technological development forms a means to an end.

Overall, the case studies suggested that a mentality of frugal innovation is indeed not exclusive to emerging economies, but that the types of organisations motivated to explore 'frugal' opportunities in Europe may be different. At the same time, it is important to recognise that there are some players, like component producers, who – for good reasons – do not see frugal innovation as relevant to them.

Does frugal innovation mean re-thinking routines of technology development?

This study's interim report argued that current **routines of technology development will have to be substantially re-thought to enable frugal solutions**, by more consciously taking into account user needs and resource constraints as a framework for the development of solutions, considering them at earlier stages and involving additional actors.

The case study analysis underlines the essential role that technological recombination plays in the process of frugal innovation. Most technology-based frugal innovations will not require the development of an entirely new technology.

*Using the case of **Ottobock prosthetics**, the study established that there is middle ground in frugal innovation. Most often, frugal prosthetics is illustrated with the example of the Jaipur Leg, an extremely affordable, yet also fairly standardised solution for users living in genuine poverty. Beyond this, however, this study established that even minor technological improvements can yield substantial added value at the lower end of the price spectrum, most notably in combination with delivery and servicing models.*



In summary, there was clear evidence that – despite their designer's undisputed ingenuity – "extremely frugal" prosthetic solutions will, at least initially, come with compromises regarding durability, quality and personal fit that discourage slightly more affluent customer groups. The example analysed in the case study, however, illustrated that a number of these shortcomings can be tackled by the targeted use of existing high-tech while maintaining a substantially lower price level than is common in Europe or in the U.S. With a view to the substantial markets that they could unlock at the lower end of emerging middle classes, such solutions can certainly still be considered frugal. At the same time, the case study underlined that delivery and local training will be central in pursuing this particular ambition.

Picture Source: © **Ottobock**, minor clippings to fit to page

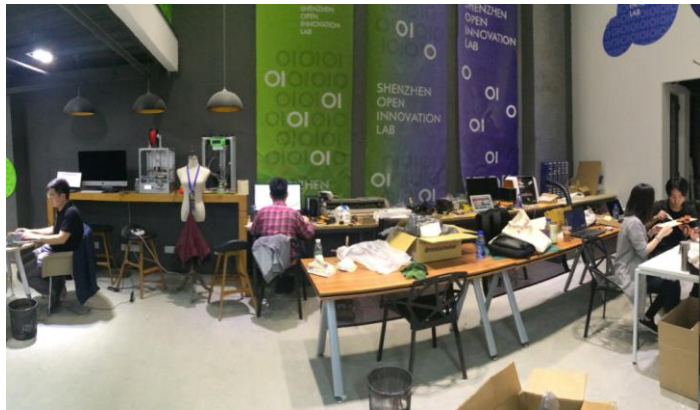
At their earliest stages of development, technologies are in most cases still too expensive and unreliable to fulfil basic criteria of frugality. However, development routines can be adapted in their later stages so that solutions reach a suitable price level and reliability faster – for example, after a first demonstration at Technology Readiness Level (TRL) 6 or TRL7 has been performed. In short, the very early process of developing of basic technologies does not necessarily need to be adapted to allow their later exploitation in frugal solutions. However, what remains missing is a process through which existing technologies, advanced or not, can be taken up in frugal solutions. The case studies showed that such processes of new ideation and exploration of options based on an existing portfolio of complex technologies is in itself a substantial effort that requires considerable manpower, time and qualification.

Are open innovation processes necessary for frugal innovation?

In its interim report, this study argued that **to achieve success in creating frugal solutions, firms will need to shift innovation practices towards more open models** as, currently, too many innovation processes remain contained within companies and fail to relevantly involve potential users – creating a "closed world of development" with a lack of market awareness.

In this respect, the case study analysis found that openness can help establish new routines and achieve frugal outcomes, but that not all frugal innovation processes are open. As outlined above, the range of European actors interested in frugal innovation is rather broad. Also, the concrete subject, as well as the market under consideration in particular projects, may in some cases come with a regulatory environment that limits openness.

*In a case study on **Makerspaces**, the study documented a dynamic trend towards broader user and citizen involvement in the innovation process. In various emerging economies, most famously in Southern China's IPR free 'institutional void', the involvement of manifold stakeholders in a flexible process of innovation and design has led to the infusion of precisely that understanding of user needs and cultural framework that is key to frugal innovation. Increasingly, these and other, related lessons are taken*



up in a worldwide trend of integrating open piloting environments, enabled by new platform technologies like 3-D printing, in the innovation process. While those engaged in such "Makerspaces" are interested, informed, committed and technologically savvy, they are usually not (yet) fully qualified in a formal sense, leave alone having gone through the process of establishing themselves as lead engineers with scope for decision. Through such environments, the threshold for participation in the innovation process could be notably lowered and the accessible pool of creativity and market knowledge immensely increased – even where institutional voids cannot be considered an option. Notably, more and more large companies are not only aware of but start to actively utilise the potential of such new platform.

Picture Source: © **Shenzhen Open Innovation Lab**, minor clippings to fit to page

In principle, several of the case studies suggested that "closed worlds of development" will often be difficult to transform. In particular when it comes to operations on foreign markets, firms have often found it essential to set up separate teams beyond the main R&D department. Moreover, since most European firms' employees lack language capabilities and cultural awareness to network locally, they have often found it difficult to easily transfer or adapt existing solutions to new markets. In the more successful cases, solutions had – at least from a certain point – been developed in cooperation between a local and a European team.

Although openness did not appear to be a necessary or sufficient condition for frugal outcomes, most case studies still found indications of a positive (or at least no negative) impact. In particular when it came to leveraging the entrepreneurial spirit of individuals able and willing to translate everyday experiences into a process of developing frugal solutions, open innovation was very beneficial. In emerging economies, however, a lack of infrastructure to support such local engagement remains a major obstacle.

Can advanced technologies open up new opportunities for frugal innovation?

The interim report hypothesised that **key enabling technologies (KETs) will open up new avenues for frugal innovation**. In particular, it posited that newly available technologies like various ICT applications, 3D printing and 'Industry 4.0' would enable cheap mass customisation and, with that, further processes of frugal innovation and production.

By analysing the case of **Peek Vision**, a UK based firm that has developed a suite of tools to turn a smartphone into an eye examination kit, this study shows how technological innovation can enable innovations in processes, which in turn generate frugal solutions. As a device, Peek Retina is up to 50 times cheaper than full-specification clinical equipment for retinal photography. Moreover, it has a distinct advantage in the way it enables human resources to be used more efficiently and in a way that enables more people to access services. Peek's solution means that tests can be delivered remotely by workers who are not healthcare professionals, with results sent easily to clinicians who can then advise on whether patients need further treatment or not. In a study in Kenya, Peek found that images captured by a lay technician with no healthcare background were no different in quality to those captured by an experienced ophthalmic clinical officer. This case study demonstrates that while lower-cost technologies play a role in creating frugal solutions, they are not the only factor in making innovations affordable. This may be even more pertinent in innovations in European health systems, where labour costs are much higher. For example, one interviewee noted that for wrist surgery, fixing fractures with wires has been shown to be equally effective and much cheaper than using metal plates fixed with screws. Nevertheless, for this type of surgery, the cost of either material is dwarfed by the costs of labour.



Picture Source: © **Peek Vision**, minor clippings to fit to page

While frugal projects rarely move the technological frontier in practice, many frugal solutions would have never started if there had not been a relevant shift in the technological frontier beforehand – a shift that could later be spotted and creatively exploited by a frugally motivated, ingenious entrepreneur.

By far the most relevant platform technology in this context is ICT. Due to the increasingly ubiquitous availability of 3G coverage and other wireless internet, smartphones have become multifunctional, frugal platforms for a large number of applications which would in the past have required different sets of dedicated equipment. The example of Peek Vision (in the case study on European markets for frugal innovation) demonstrates this well: Peek is a suite of smartphone applications and low-cost hardware that make visual acuity testing and retinal photography much cheaper and easier to carry out, even in isolated, rural environments. In a somewhat less direct manner, advanced materials have opened up further avenues for the design and embedding of photovoltaics, water filtration materials or electronic circuits in novel contexts of application which would in the past have been limited or excluded by the physical properties of incumbent solutions.

Is demand for frugal innovation growing in European markets?

In its interim report, this study argued that **European markets see rising demand for frugal solutions both based on needs and out of choice**. It hypothesized that drivers such as the refugee crisis, climate change, ongoing fiscal austerity and broader societal challenges like the ageing population would create more demand for frugal innovations and that the public sector itself was an important potential customer for these. In this respect, the analysis indicated that while theoretically there is a growing need for frugal solutions, in many cases this has not yet transformed into market demand. Overall, there seemed to be two key reasons for this.

First, many customers still appreciate the status that comes with purchasing higher-end products and services. While it may be considered “chic” to live frugally in certain urban environments where this choice of lifestyle which could, in principle, be easily replaced by other choices, citizens who are in jeopardy of losing their social status for good due to economic crises and other hardships are likely to feel differently about the desirability of frugal choices and are less willing to display their new need to live frugally. For the time being, most European citizens fortunately still have basic choices, even in times and environments of dire economic crisis. Consequently, price reductions on European markets will by definition have a lesser effect than in developing economies where a broad and disconnected bottom-of-pyramid population is cut off from many solutions altogether.

Second, many organisations that provide public services for the European population are still bound to guarantee quality coverage for everyone. In Germany's medical sector, for example, all citizens are entitled to the best possible prosthetic applications. Likewise, strict standards apply in the construction and environmental sectors that are usually not open for negotiation. While in some European Member States, public budgets are rapidly eroding and in others the substance and coverage of public health insurance is deteriorating, these trends' full impact still has to materialise. Also, the societal trends that will likely render the current social insurance systems dysfunctional at some point still have to develop their full momentum.

In summary, European markets provide a remarkable potential for frugal innovation, which, however, has yet to fully emerge. For the foreseeable future, both quality and appeal will be essential requirements to convince European customers of the desirability of frugal solutions.

Can frugal innovation provide an opportunity for EU firms in emerging markets?

This study's interim report re-iterated the broadly held belief that **frugal innovation can be a business opportunity for European firms in emerging markets**. Moreover, it suggested that exposure to emerging market contexts can help businesses understand how to operate and succeed in these different framework conditions – and eventually gain market readiness.

The case study analysis found that there is a real business opportunity in developing solutions for bottom-of-pyramid populations and middle classes in emerging markets, but that this is much less directly accessible than sometimes suggested. Existing studies documenting billions of additional potential customers only show one part of the equation. What they remain more silent about is the diversity of these markets. Moreover, many still underestimate well known difficulties of gaining 'market knowledge' in a completely unfamiliar environment.

European companies, even multinational corporations with local branches, are less than optimally positioned to beat their emerging economy competitors on price. Having to pay above average wages, to maintain acceptable labour standards and to avoid any potential law suits for damage in host countries, they have limited room for manoeuvre in a "race for the bottom" on price. At the same time, most European firms are insufficiently embedded in local context to identify "magic bullet", grassroots solutions more swiftly than their domestic competitors. Finally, most have a reputation to lose and a brand to defend.

Even if well intentioned, most smaller European companies and in particular start-ups have substantial difficulties engaging with international markets in the first place. This study confirmed well known problems around the lack of means for strategic planning, limited options for setting up specific local teams and difficulties dealing with foreign bureaucracy and regulations. In frugal innovation, additional difficulties arise from the need to collaborate with local partners to explore context-specific needs that domestic companies are not yet serving as well as to develop suitable models of delivery that fit with the local context and are at the same time affordable for a mid-sized firm.

It would also be simplistic to assume that all emerging middle classes and cash-strapped public administrations in developing economies are eager to buy frugal products. Realistically, an immediate and unhampered response to frugal offerings can, if at all, be expected from those bottom-of-pyramid customers to whom European companies are unlikely to gain access. For emerging middle classes, in contrast, status is also important. In parallel, undue appreciation for "white elephants" continues to linger at various levels of public administration and it remains difficult to sell goods and solutions which do not at least bear a seal of quality or brand.

In summary, emerging markets provide a remarkable potential for frugal innovation. Promising approaches to leverage this potential, however, are far less obvious than commonly suggested and difficult to implement. Once more, quality and appeal will be essential requirements to convince customers of the desirability of frugal solutions.

Do frugal solutions find it difficult to scale up?

In its interim report, this study underlined that **achieving scale is a key challenge for frugal innovation**. With lower profit margins, solutions will only develop the required impact when delivered at large scale.

The case studies found that, eventually, frugal innovations need to be produced at some scale to achieve the required decrease in price. Several of the examples explored had 'frugal potential' but had not yet reached the scale they needed in order to reduce costs and become accessible to a wider customer base. This becomes even more important if it is accepted that, following the above argument, most European frugal solutions are likely to be 'smart, second cheapest' options, with a somewhat smaller initial price difference than bottom-of-pyramid 'mass frugal' that compromises on quality.

*With a view to **affordable energy efficient buildings**, the study underlined that with a view to increasing urbanisation the need to establish additional, durable, and at the same time affordable housing at large has emerged as a social challenge in emerging economies. In more developed economies, large amounts of existing standardised housing will have to be retrofitted in the nearer future at a scale that the market will not be able to address. Hence, existing technological solutions will have to be adapted and complemented to develop novel, more affordable construction and insulation materials as well as methods to fit them. More importantly, however, conservatism in public procurement, was perceived as an obstacle for solutions that often only reach a threshold of frugality at a certain scale – in both emerging and leading economies. Quite strongly, the analysis suggests that, in the construction sector cases to do 'more for more with less' have to be politically built and supported. Without specific legislative frameworks for its implementation, affordable retrofitting in the energy-related domain would not take place in Europe and without strong external backing, new concepts for mass housing are unlikely to gain a stronger foothold in developing economies. Additionally, and resonating with other cases, the study on building and housing suggests that the consideration of cultural and social framework will be crucial for successful frugal innovation in this domain that is so very strongly associated with people's daily living. However, it suggests that, without further technological input, traditional techniques (like clay architecture in developing countries) are per se not sufficient to respond to large scale challenges of urbanisation and retrofitting.*



Picture Source: © **Energiesprong** (in collaboration with BAM and Lefier), minor clippings to fit to page

Processes and techniques that involve automation in delivery need to be moved from the pilot and demonstration stage into mass application before their full frugal potential can be leveraged. In some cases, considerable effort is needed in creating new markets. The example of Energiesprong, an initiative to make retrofitting of European homes to improve energy efficiency much more widespread, demonstrates this well. Those promoting the initiative made considerable efforts to build partnerships and work with social housing providers in an attempt to create a large enough market to make the opportunity attractive for bigger firms. Overall, the case studies suggest that large-scale production of frugal solutions will have to be combined with customisation or at least customised delivery services which, by themselves, need to be frugal in nature. That notwithstanding, several interviewees underlined that, for mid-sized firms it remains very difficult to enter high-volume, low-margin markets from the beginning. In general, technology oriented companies do not have the capabilities to scale up production quickly, let alone in an unfamiliar country. Effectively, this is why many prefer entering the market through the low volume, high margin route.

In consequence, scale has to be a central consideration in all strategies to achieve economic or societal targets through frugal innovation. However, has to be considered from a much less mechanistic viewpoint than commonly done. Mere economies of scale do not yet make for frugal innovation. On the contrary, successful European frugal innovation will have to be customised to ensure customer utility and appeal – even at the price of overall volume.

Is frugal innovation always positive?

The interim report pointed out that **increasing access for more people is not by definition always positive** with a view to its ethical, ecological and social impact. It suggested that, from a sustainability and, ultimately, a policy perspective, there is a need to clearly differentiate between economically successful and desirable frugal innovations. Nevertheless, this study suggests that the types of frugal innovation that European firms are most likely to succeed with are also often likely to be considered desirable from a broader perspective.

This is because European firms are unlikely to excel in the traditional area of “mass frugal”, currently well mastered by Chinese and Indian firms, which is primarily driven by undercutting price-thresholds for profit motives. Most of the technology-based innovations that this study considered, in contrast, can only be successful in the segment of ‘second cheapest’ options, such as more durable and better fitted frugal prosthetics, by virtue of a strong focus on and adaptation to locally relevant needs. Moreover, some were tendered or prompted by public organisations or NGOs with at least an implicit ambition to ascertain and promote socially sustainable outcomes and avoid conflicting situations. While aid agencies are not exempt from creating conflicting outcomes, most of their studied activities in the area of frugal innovation have in fact been found to be motivated by the ambition to avoid exactly this by creating more adapted solutions closer to the needs of their target groups.

The relation between frugal innovation and environmental sustainability, in contrast, remains ambiguous, at least on the societal level. Undoubtedly, many frugal projects analysed for the study have produced environmentally sustainable propositions that on a unit level notably reduce the footprint compared to incumbent solutions. That said, they could still increase it substantially at the aggregate level – taking into account how many prospective users have so far not had access to any solution at all.

Other than in the first case, this conflict will not easily resolve itself. At least when considered through the lens of technology, environmental sustainability comes at a price. Many methods for re-manufacturing and other activities related to the circular economy remain at a too early stage of development to be integrated in frugal solutions at competitive prices. Also, frugal innovators might be tempted to use materials that are mined and refined under unacceptable framework conditions or difficult to recycle.

Against this background, sustainability should become a key normative criterion for political support for frugal innovation, coupling it closely to the Circular Economy Package. To generate positive impact it is imperative that the resulting activities are not merely profit driven but socio-economically desirable in a comprehensive sense.

*Using the case of **Qarnot Computing**, a French company that found a way to use waste heat from computing for domestic heating, the study considered the relation between frugal innovation and the circular economy. Qarnot aimed to re-distribute the surplus heat of high performance computing to places where it will not be wasted – people’s homes. To that end, Qarnot has developed the Q.rad, a radiator that is connected to the internet and has three embedded microprocessors. The Q.rad generates heat by performing computing tasks remotely for commercial clients. Qarnot has also developed software that enables the distribution of computation across Qarnot’s network of Q.rads, adjusting levels of computation dependent on processing and heating demands. The result is a business model with two separate revenue streams. On the one hand, Qarnot sells competitively priced green computing power to clients such as banks, 3D animation studios and research labs. On the other, it sells Q.rads to property developers who want to install sustainable heating in new or renovated properties. The purchase of a Q.rad includes maintenance and replacement of the equipment every three to five years and Qarnot refunds users for the electricity consumed by the Q.rad. Each Q.rad records continuously its energy (kW/h) and computing (CPU) consumption. Since 2014, over 100 French households have been heated for free by Q.rads. This case helps show how companies operating in the circular economy often need to combine technological innovation with innovations in business models and services to create frugal solutions that are accessible to customers.*



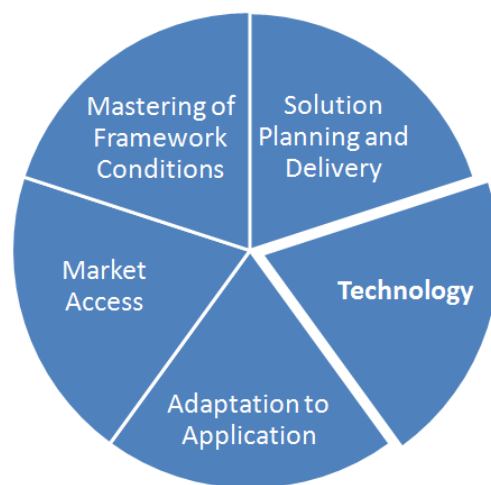
Picture Source: © **Qarnot Computing**, minor clippings to fit to page

3 Conclusions

In summary, the study gives evidence of promise and failure, ambition and success. While it cautions against naïve optimism about immediate opportunities for all, it identified not only obstacles but also strong sources of momentum and, in consequence, diverse opportunities to leverage frugal innovation for Europe's society and industry. With reference to the study's initial hypotheses, its findings can be summarised as follows:

1. Many Europeans pursue frugally inspired projects, often driven by altruistic motivation but at the same time confident that they will eventually become viable or even profitable.
2. The prevailing approach in firms with a primary focus on technology development remains non-frugal for good reasons, but new actors could be mobilised for frugal innovation.
3. There are several very positive examples of more open innovation models in Europe, even if most have not yet connected with the industrial mainstream.
4. Many technologies constitute relevant platforms for the design of future frugal solutions, even if the heralded industrial paradigm shift has yet to materialize.
5. There are clear trends that point towards greater demand for frugal solutions in Europe. However, it seems that often, customers are still hesitant about choosing frugal solutions due to the negative image associated with "buying affordably".
6. Most smaller firms face considerable challenges in the attempt to launch technology-based frugal solutions on emerging markets, and many have failed in the process.
7. Due to slow market reactions, it proves difficult to scale first ideas to broad applications. For many of the solutions reviewed, public sector demand could be an initial trigger.
8. To be considered worthy of public policy support, frugal projects should aim not only at achieving low prices but on proven quality and limited environmental footprint.

In summary, the study finds that, to prompt for successful technology-based frugal innovation, the exploitation of specific key enabling and industrial technologies is a necessary condition, but in itself not sufficient to guarantee socio-economically desirable outcomes.



Overall, five main leverage points for promoting frugal innovation in Europe are identified:

- Inspired entrepreneurs with relevant ideas,
- Research and Technology Organisations (RTOs) and non-governmental organisations (NGOs) interested in resolving challenges in or for frugal environments,
- Small and medium-sized enterprises (SMEs) recognising the problems of over specification,
- Multinational corporations (MNCs) with established brands and recognised quality are interested in exploring options,
- Public administrations looking for smart, yet affordable solutions in both pre-commercial and everyday public procurement,
- Development agencies in search of reliable, large-scale solutions that at competitive prices help address development challenges in a more sustainable manner.

In Europe, there are obvious societal trends prompting frugal needs (e.g. demographic change leading to pressures on housing and public services, economic downturn and long term lack of real growth in incomes limiting consumers' buying power) and a substantial number of entrepreneurs, researchers and managers seek to creatively relate to them by proposing new ideas, solutions and business models. At the same time, more and more established firms begin to realise that current business models that focus on excellence and complexity exclude large customer segments and, in the long run, put their business at risk.

In general, the study suggests that the conceptual notion of frugal innovation is gaining ground in the considerations – and even actions – of various European stakeholder groups, even if few of them currently know it by that name. For example, a number of H2020 projects arguably already contain aspects of frugal innovation. With some degree of certainty, therefore, it can be concluded that targeted calls for proposals, promising support or visibility for related efforts, would meet with responses from a diverse set of relevant actors.

At the same time, there are some major obstacles, risks and bottlenecks. These include:

- Persistent user preferences for higher cost, higher prestige solutions,
- Limited opportunities for technology developers and frugal innovators to find out about each other's work and collaborate,
- Difficulties for European SMEs in establishing a presence in emerging markets,
- Lack of interest and conservatism among purchasing public authorities,
- Limited traction of open and inclusive innovation in Europe.

In short, frugal demand on European markets remains latent at the moment. Furthermore, there is a continuous need to exploit Europe's world-leading capabilities in the field of highly specified solutions. Quite clearly, traditional technology companies cannot and should not all be 'converted' to frugal innovation. However, they could be much better linked with those who can eventually develop frugal innovations. So far, the interface between these crucial stakeholders remains underdeveloped.

In summary, there is no shortage of either opportunities or obstacles. While future policy in support of frugal innovation could leverage substantial potential, support programmes could at the same time easily be futile if they address the wrong target groups.

Successful, "technology-based frugal innovation with European characteristics" will require a much broader set of capabilities than the ability to deliver technological excellence. Often, this capacity does not even constitute the main factor for why a specific frugal project succeeds or fails. Consequently, frugal innovation will have to be pursued by other actors with a broader range of capacities than traditional, technology-developing companies.

At the same time, frugal innovators often lack the ability to explore existing technologies or the means to finance such efforts. Many of them work in young firms or newly set-up units of larger organisations that could benefit from external partners, finance, education and training. Moreover, they need customers.

As this study underlines, frugal innovators from Europe are facing the difficult challenge of striking the middle ground between competitors' cheapest offers, i.e. prices they cannot undercut, and their own current solutions that are too expensive for broader target groups to afford. While this is difficult, several case studies underline that it can be done.

To succeed, European frugal innovation will depend on distinguishing its appeal, based on:

- Customer orientation,
- Credible quality,
- Durability and sustainability.

In the best possible case, European technological know-how can at the same time help realize all three of these requirements while, based on clever branding, motivate customers to pay a small price premium *within the frugal range*, i.e. below that price-threshold that makes a solution with that functionality affordable at all.

In summary, the largest potential of European frugal innovators will lie in the following three areas, in which they can stand out from domestic competitors:

- Smart and socially/environmentally responsible 'second-cheapest' solutions, aimed at consumers with constrained budgets, but who are not at the 'bottom of the pyramid',
- Aid-backed, challenge-oriented solutions for 'users at the bottom of the pyramid' whose individual affordability threshold European firms cannot meet on the market,
- Solutions based on dedicated technological development for public sector customers who buy larger systems or at large scale from the outset.

To promote such a development, the study suggests parallel, ideally integrated, efforts under the Industrial Leadership and Societal Challenges sections of Horizon 2020 as well as in several other related domains of European and Member State policy making.

4 Policy Recommendations

Which policy agendas could frugal innovation support?

This study suggests that frugal innovation could support strategic objectives in several policy areas including:

Research, development and innovation

Efforts to develop further exploitation strategies along the lines of frugal innovation and to promote a new mentality of development in education and training will help contribute to overcoming the infamous European paradox with respect to technology commercialisation. Support for frugal innovation builds logically on the vision of 'open science, open innovation, open to the world' and at the same time provides opportunities to affirm industrial leadership as well as new options to address societal challenges.

Competitiveness

Efforts to extend support for new, frugal business models both with respect to improving their technological basis and the development of markets through public procurement would help strengthen the competitive position of an additional group of European firms.

Sustainability: Climate change and energy, circular economy

Efforts to support smart and responsible frugal innovation with European characteristics would help build an alternative proposition to cheap mass production and thus in sum contribute to the achievement of sustainability related targets in the long run.

Education and skills

The development of new formats of education and the development of additional skills are prerequisites rather than outcomes of frugal innovation. They are much needed and should relate to all frugal innovation efforts in a systemic manner.

Employment / jobs creation in the EU

As an additional business model, frugal innovation may reinforce the competitiveness of firms at a time when these are increasingly under pressure. In the short term, however, it will likely not develop sufficient momentum to influence larger dynamics on the job market.

Poverty reduction and social inclusion

By definition, much frugal innovation is a response to poverty and exclusion. The broader availability of solutions and open development processes enables participation and mitigates the felt impact of poverty. However, it will rather not tackle the roots of either problem.

What could policymakers do to promote frugal innovation?

A number of policy levers and fields are relevant in promoting frugal innovation. This study recommends the following six actions the area of **European research policy**:

1. Champion and promote existing success stories through awards

If the preconditions based on which frugal innovation can succeed become more widely known, more stakeholders will consider the option. Furthermore, awards would increase the visibility and recognition of frugal entrepreneurs among policy makers.

2. Calls supporting the uptake of existing technology for frugal purposes

Not all potential frugal innovators have an understanding of available industrial technologies while, at the same time, too few technology developers consider frugal exploitation an option. Initiatives aimed at uptake and application could improve this crucial interface.

3. Specific calls to nurture more open approaches to innovation

European, technology-based frugal innovation requires a particularly good understanding of user needs. Specific calls aiming at the involvement of new stakeholders in open innovation processes would further this understanding. Innovation needs to become more "plural".

4. Specific, challenge-oriented calls under Horizon 2020

If not yet in response to market demand, frugal innovations can be prompted as responses to societal challenges. Development agencies, NGOs and RTOs that have a mission to address these problems would be particularly relevant carriers of such initiatives.

5. Public-private collaboration platforms for frugal innovation

Europe has both a population of potential frugal innovators that does not yet engage with European research and innovation policy, and a large portfolio of technologies that could be applied in frugal solutions. Platforms could help to build new and better interfaces.

6. Calls supporting international collaboration and learning

In general, businesses can learn a lot from emerging country experiences and many may be interested in increasing their 'openness to the world' by exploring new markets, assessing risk and understanding user preferences before engaging in actual development projects.

In summary, **European Commission policy makers are in a good position to strengthen and develop a particularly European capacity for technology based frugal innovation.**

That said, **it will be important to take seriously the need to open up any future funding or award opportunity to a broader range of stakeholders than before**, to substantive involve relevant frugal entrepreneurs and international partners. Also, programmes preparing the ground through international learning should be considered an important building block.

In return, core support programmes for the development of specific industrial technologies should place **clear stipulations for what will be considered frugal**, including minimum levels of environmental sustainability and affordability. Ultimately, selections will have to be made by qualified experts taking into account sectoral and technology related specificities.

Beyond the immediate remit of research and innovation policy, this report puts forward the following recommendations to leverage additional momentum.

1. Reinforce support infrastructure for SMEs on emerging markets

Even though mentally open to the world, most European SMEs face obstacles in the attempt to understand emerging markets sufficiently to even conceive 'best-fit' second cheapest options, let alone set up competitive local delivery networks for them. This needs to change.

2. Deploy public procurement to prompt business model innovation

Many potential markets for frugal innovation have been found to develop more slowly than assumed, even where emerging societal challenges are evident. Hence, the public sector should support the development of frugal business models through targeted procurement.

3. Use international collaboration as a vehicle to unlock markets

As outlined above, foreign administrations can be conservative and/or unwilling to procure to foreign providers. Existing international collaboration under which local and global challenges are addressed with European money can be leveraged to unlock this blockade.

4. Leverage synergies between smart specialisation and frugal innovation

Regular consultation processes in the context of smart specialisation aim at understanding local needs for the application of technologies in European regions and to identify sources of expertise to meet them. This should be leveraged to inform future policy making.

5. Trigger new initiatives in the area of education

Frugal innovation raises specific, combined requirements with respect to new approaches to development as well as market research, intercultural cooperation and delivery strategies. New education and training efforts are needed to prepare stakeholders for these.

6. Ensure adequate regulation and flexibility in exploiting regulatory niches

While most regulation on European markets serves legitimate purposes, the development of path dependencies overly favouring incumbent technologies should be avoided. Also, firms should be encouraged to exploit options for the early-stage market launch of solutions.

Research policy can deliver an important contribution and support programmes in that domain may undoubtedly trigger further momentum elsewhere. To make frugal innovation a broadly accepted paradigm in European industry, however, sustained parallel efforts will be needed in various domains and should be propagated actively at European and Member State level.

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This study explores the potential of frugal innovation for Europe. Frugal innovation relates to the process of reducing a solution to exactly those, often basic, functionalities that users will need, thus economising on resources and cost. While firms and entrepreneurs from emerging economies display unrivalled capacity to cut cost and leverage local knowledge, European firms may find opportunity in leveraging Europe's existing portfolio of technologies. For this, further actors in the field of technology exploitation need to be mobilised, their interface with existing technology developers strengthened, and their access to foreign markets improved. European firms should not attempt to win a race to the bottom on price. Instead, policy support should champion smart frugal solutions with a slightly better customer-orientation, quality and sustainability than commonly available cheap mass produce.

Studies and reports