Low Carbon Industrial Manufacturing Parks

10 Principles for a Low Carbon Future

Acknowledgements
The work presented in this document has been conducted in the context of project 296010 LOCIMAP. This coordination and support action is funded by the European Commission. Their support is appreciated.

The partners in the project are NEPIC, BASF, Link2Energy, ECSPP, INSEAD, Sembcorp, PTS, IVL Svenska, Kokkola Industrial Park, Kalundborg Kommune, Parsons Brinkerhoff, Cemex, Terreal, BFI.
This report acknowledges the collaborative effort of the above organisations.

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Contact
LOCIMAP Secretariat
E: mail@locimap.eu, T: +31 70 312 39 27, I: www.locimap.eu

1. Introduction

At one of the LOCIMAP steering groups at The Hague a chance remark was made that what we need to underpin the future of manufacturing in Europe is a new industrial revolution. The context was of course a comment on the magnitude of the change that this project was looking to define in order to make a tangible impact of the competitiveness of the European industry. From the outset the ambition was to show how to go much further than the squeezing out a few percentage points in process efficiency. Rather the goal was to explore the potential for a step change in performance in Europe.

Conscious also of the old adage that "if you always do what you've always done then you always get what you've always got" this challenge for an industrial revolution further emboldened the project to be courageous in its thinking. The LOCIMAP project has therefore looked to explore a range of parameters that could make such a change and has examined not only technical but also economic and business (and even political) factors.

Even before a presentation of the options the reader may already, and rightly, be thinking that any such technical changes, no matter how good, may be replicated globally and therefore any grounds for optimism may be as respite rather than a long term solution. We would still be left in the longer term with the original question as to how we secure the competitiveness of the European manufacturing base.

The response to this is, in part, to refer to the potential of the closed loop economy. Europe of all the major continents has the longest industrial history and a relatively stable population and therefore if we can indeed close the material loops then we may consider that we have most of our inventory residing within the existing techno-sphere.

Coupled with the high-value innovative and entrepreneurial landscape that we need to make this happen do we indeed have the format for this new industrial revolution? This, and how we might take steps towards this within a low carbon economy, specifically within the context of industrial parks, is what the LOCIMAP project has sought to inform.

2. Background

Europe's 2020 growth strategy commits to limiting greenhouse gas emissions by 20 % compared to 1990 levels, creating 20 % of our energy needs from renewables and increasing our energy efficiency by 20 %.

Further, the SPIRE PPP within the Horizon 2020 programme, aims at realising two key resource and energy efficiency targets with a time horizon of 2030.

- *A reduction in fossil energy intensity of up to 30% from current levels through a combination of, for example, introduction of novel energy-saving processes (including enhanced use of optimised techniques, monitoring and modelling via ICT tools), process intensification, energy recovery, sustainable water management, cogeneration-heat-and-power and progressive introduction of alternative (renewable) energy sources within the process cycle.*

- *A reduction of up to 20% in non-renewable, primary raw material intensity compared to current levels, by increasing chemical and physical transformation yields and/or using secondary (through optimised recycling processes) and renewable raw materials. This may require more sophisticated and more processed raw materials.*

Both of these ambitions have been at the focus of what the LOCIMAP partners sought to address.

3. Guiding Principles

The following 10 tenets are put forward by the LOCIMAP project as shaping principles for a low carbon economy and future industrial parks:

1.0 ***Industrial Symbiosis*** *is the cornerstone of not only a low carbon industrial manufacturing park but a low carbon economy. Though this business principle, if not the name, has been in operation as long as industry has existed it is greatly under-exploited (see Process integration below).*

A study of a number of sector road maps reveal them, in the main, to be just that; highly professional but in many cases introvert. The LOCIMAP project however has demonstrated the power behind the application of industrial symbiosis which is realized by sectors working together. The name is not as important as the action; whether the branding is industrial symbiosis, clustering or closed loop economy the driver for the uptake is simply that of best practice business delivering environmental benefits.

However the call from the project is to deploy this principle in a bold and strategic way. Why shouldn't the blast furnace off-gas from the iron & steel industry be used as syngas within the chemical industry. To illustrate the point; many factories within the chemical/petrochemical industry have as the unavoidable result of the processes we have developed and despite the efforts of generations of engineers, significant quantities of low grade heat; many food factories have a demand for cooling. The potential for the chemical industry supplying refrigeration capacity through absorption chilling opens up a solution that is not available within single sectors. This is a far ranging comment since it implies a breadth of imagination at not only the business and engineering level but also that of strategic planning.

Though it may not be always practicable for the two sectors to be cheek by jowl geographically this does not prevent them having a thermodynamic umbilical link. Again, these examples draw in the requirement to be strategic and to include local government, planners and politicians alongside business and engineering.

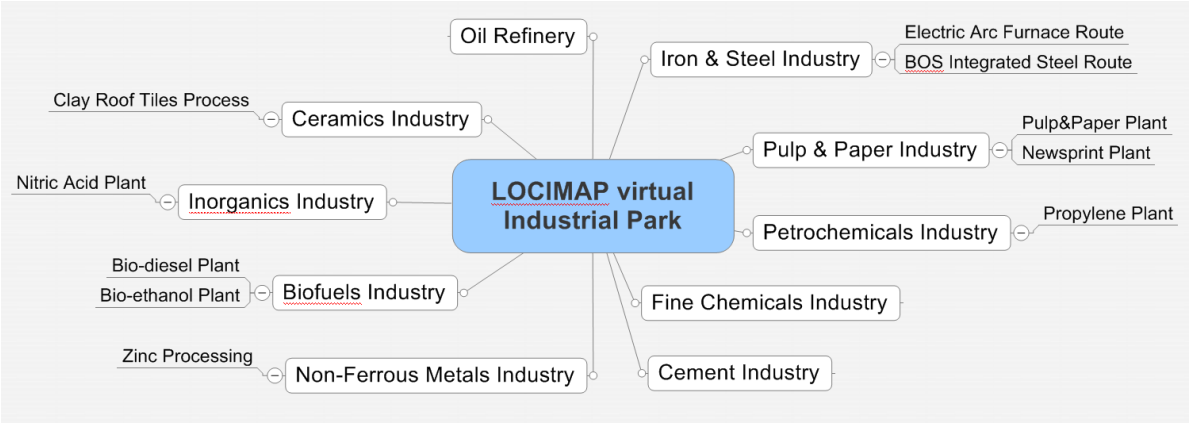
There is naturally a high degree of focus within LOCIMAP on 'short-radius' synergies within the LOCIMAP industrial park i.e. those involved primarily in the integration of heat and power. The project has prepared a guide to the selection and development of heat and power supply networks for future industrial parks which will prove useful in looking at new opportunities.

However it is also recognized that 'long-radius' synergies involving material transfers from further afield can be highly beneficial. The carbon credit for use of material by-products against the extraction and processing of virgin materials is quantifiable.

Whether each future park would benefit from having its own technology centre for evaluating those optimum utility configurations in a dynamic setting; for assessing new opportunities for the valorization of by-products and for the deployment of new technology is a question posed by the project. There are certainly examples of this across Europe (CPI at Wilton, Chemelot Campus).[1]

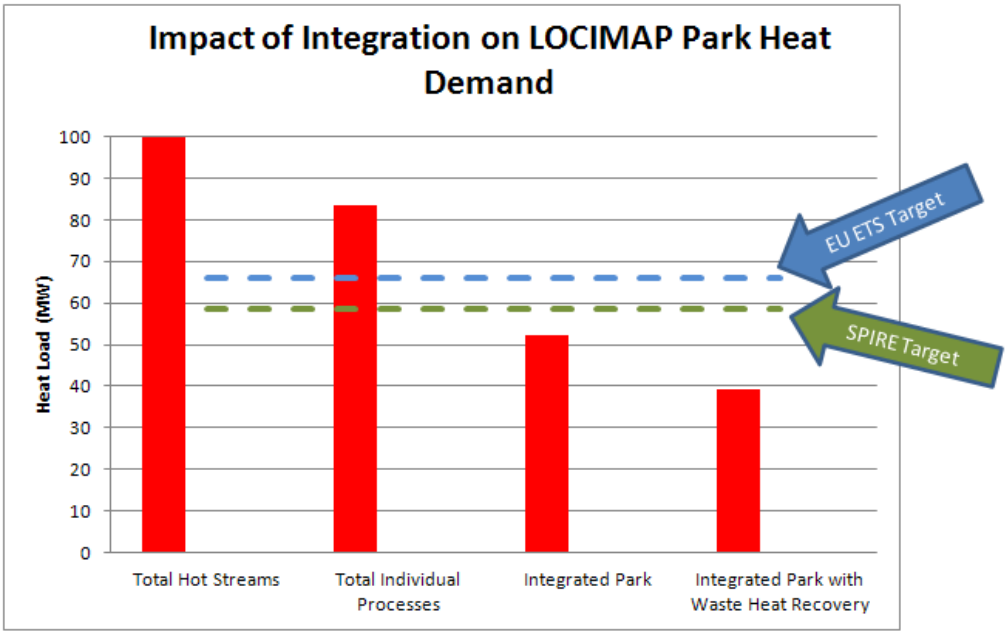
[1] *For further discussion on the impact of Industrial Symbiosis see LOCIMAP White Paper 2*

2.0 ***Process Integration and the application of Pinch Technology***. *If the challenge is to deliver a low carbon economy then we need to base the design of that (industrial) economy on thermodynamic principles! Pinch technology is a well-established technique that enables us to define minimum utility consumption for individual processes. Within LOCIMAP we have used this approach to define the optimum energy target from the integration of pairs of quite disparate processes and ultimately a virtual industrial park combining processes from the chemical, petrochemical, pulp and paper, fine chemical, bio-fuel together with those from the iron & steel and non-ferrous metal industries.*



Sectors involved in the LOCIMAP study

The heat exchanger networks that results from the assemblies are necessarily complex and raise issues of operability and (potentially) ownership although as we have found modern ICT will solve this issue.



If the size of the prize from this level of integration is small there is little drive for pursuing the concept. However from the LOCIMAP work we conclude that the prize is very high. In fact it is so high that such integrated systems could deliver not only the EU 2020 targets but those set by the SPIRE project also. In contrast with the ever increasing squeeze on existing assets through resource efficiency (which clearly the project supports and which parks and clusters within the project have been very successfully implementing) this benefit is rather based on the strategic co-location of industries that can operate symbiotically at the thermodynamic and business level.

Such a strategic shift raises big questions. How can we engineer such systems without compromising safety or system resilience? These questions have been considered to some degree in how we might use the utility systems to provide the interface between these disparate sectors with their own requirements for maintenance schedules, uptime profiles etc…

3.0 *Most of the sector roadmaps cite* ***Technology*** *advances as part of the plan for 2020 and 2050 targets. Within these plans most instances are given are sector specific e.g. application of the ULCOS process within the iron&steel industry, deployment of high-efficiency kilns as examples of material changes such as the development of artificial pozzolanas within the cement industry that bring about a reduction in CO_2 footprint.*

LOCIMAP has brought together an array of existing and emerging technologies that specifically have an impact on the ability to recover and to transfer heat from one process to another and which are key to achieving the ambitions set out in 2.0. Further the management of such integrated systems will demand an over-arching control philosophy and deployment of ICT (see LOCIMAP White Paper 3).

4.0 ***Residual "low grade" heat*** *presents a major opportunity for further improving the already good CO_2 performance of our industrial parks. A change in mindset we suggest is needed so that its use is considered as part of the overall process design.*

Whilst district heating systems for residential areas are good they suffer from high seasonality of demand; what is required is a constant demand of industrial proportions. LOCIMAP proposes for example the development of district cooling systems powered by residual heat through absorption chilling systems. This may need bold planning moves such as the co-location of food industry, with its typical high demand for refrigeration, cold stores, data centres etc… alongside the sources of residual heat e.g. the chemical, petrochemical, power industries.

Not all residual heat is low grade. By way of example the energy flows through an integrated steel complex dwarf those of most other industries and the ability to recover waste heat from the cooling of products and from the slags, though inevitably tricky and a technological challenge (that is being grasped) is a significant source of potential high grade heat and hence of reduced emissions.

The recovery of heat is clearly only of value if there is a home for it. Industrial clustering on parks or around them is paramount in order to capitalize on this potential (see 2.0 above). The challenge is clear; how can we better integrate our industries and thereby deliver CO_2 emissions rather than just subject them to carbon leakage pressures.

5.0 *In much the same way as for residual heat it will be important to plan for* ***CO_2 storage or utilisation at*** *the heart of future industrial (LOCIMAP) parks. Whilst some products may be manufactured from flue-gas CO_2 e.g. cyclic carbonates, the market for these products is limited for the foreseeable future in comparison with present emissions. Other work is ongoing with respect to the growth of algae which fix c. 1.8te CO_2/te product and demonstrator plants exist for the growth of such using both heat and CO_2 emitted e.g. at Kalundborg.*

Whilst the LOCIMAP project has sought to minimize the release of carbon through intelligent synergies between industries, others are developing processes with CO_2 as a feedstock. But even

SEVENTH FRAMEWORK PROGRAMME

in the fully optimized system some release of carbon is inevitable and we should plan for it. Parks provide the best scale of operation to make this resource efficient.

Industrial Carbon Capture, Storage and Re-Use is potentially the ultimate back-stop and many of the individual sector road-maps forecast the importance of this technology within their 2050 view on CO_2 reductions. It will become increasingly important, and indeed an asset, for future industrial parks to be geographically located on a carbon capture and transportation highway umbilically linked to a carbon storage facility. Indeed the park provides the concentration of CO_2 emissions to make this feasible.

In this way carbon management, and even a carbon economy, will be at the heart of a future low carbon industrial park.

6.0 *The major opportunities within LOCIMAP, the optimisation of steam and power systems cannot be advanced by* ***Supply Chain Integration*** *unless the manufacturing units are co-located. It will clearly be an economic impossibility to integrate utility systems that rely on close proximity between partner organizations unless that is the case. The park concept is key to this.*

Within a CO_2 minimisation agenda supply chain integration is likely to be sub-servient to the industrial symbiosis objective. This is not the case now as the project has found from discussions on logistics issues. This will require re-configuration, or even a re-definition of the supply chain but this will need an effective powerful driver either of long term policy or of carbon price.

7.0 *The* ***Waste Industry*** *will play an increasing role within the industrial landscape of LOCIMAP parks through the provision of feedstock. Whilst industrial symbiosis and the exchange of industrial by-products as feedstocks is a vital ingredient of practices within future industrial parks the importance of post-consumer waste as a feedstock will also grow. For some elements e.g. copper, it is recorded that there is more material in the techno-sphere rather than the geo-sphere and there is much concern over the availability of a range of other 'critical raw materials'. In some cases the concentration of these materials is greater in the post-consumer and/or industrial wastes than in the virgin ore; some process are natural concentrators of the ore e.g. the levels of germanium and gallium in coal ashes is by definition almost 100 times that in the coal. Despite many critical raw materials being non-indigenous to Europe yet recycling and recovery rates are less than 1%.*

These changes in feedstock supply will have a bearing on energy demands and CO_2 emissions. The aluminium industry is a good and current case in point of an industry that has already shifted focus towards a recycled feedstock and shows the improved economics and environmental performance through the recycling of aluminium (cans) against the life-cycle implications of starting with the mining of bauxite.

Resource innovation, the recovery of component parts of 'waste streams', whether that is critical raw materials from mineral based industries, proteins and flavanoids from industrial food wastes or phosphates from water discharges. Avoiding the closure of material loops is not a future option; this is not a matter of principle but ultimately one of economics and the emerging industries will be not only technology driven but integral to a changing mix on the future industrial park. The LOCIMAP project has mapped out the present and future potential interconnectedness between the various sectors it has studied; in effect its own closed loop economy.

Again, to lean on the thermodynamic argument for materials as well as for our utility studies; the more dissipated our resources, the higher the entropy and the more the energy required to recover them. Better to sprout a new industry (on a future LOCIMAP park) to recover critical material from fly ash before we provide it as an ingredient to make cement.

However, to maximize the re-use of by-products, especially over larger geographical distances, there is a need to simplify the processes to transfer these materials across borders within the EU. Added burdens on bureaucracy and costs will hamper further development.

8.0 ***Green Chemistry*** *will also play an increasing role within LOCIMAP Industrial Parks. Notwithstanding the huge challenge of scale to displace fossil based economy there will be an increase in the presence of bio-based feedstocks that will reduce fossil carbon emissions in the supply chain through the development of the bio-refinery concept.*

Starting as high-value niche applications it is anticipated that there is scope for the switching of a percentage of the feedstocks composition to have a bio-origin either through the provision of bio-derived syngas into conventional processes for manufacture of ammonia; the production of bio-ethanol, bio-butanol from either the syngas route or the second/third generation fermentation processes etc.[2]

In much the same way as the comments on the waste industry, the impact of the application of green chemistry can be achieved within the future industrial park concept.

9.0 *A project deliverable highlighted the concerns by LOCIMAP partners regarding* ***Carbon Leakage.***

Each manufacturer, and each park, provided information on the legislative and taxation structures within which they operate. They commented on their driving forces in terms of the costs involved in related investments for improvement and in buying carbon credits. Beyond that they were invited to outline any company or sector initiatives at the 2050 time horizon. In essence the feedback the project confirmed that carbon trading has the potential to increase economic pressures on the more energy intensive sectors to leave the European economy. This will disproportionately affect parks.

The project further examined the present and future potential by-product linkages between the sectors represented within LOCIMAP. Whilst the loss of an industry sector from the European industrial mix has negative impact enough on the social and economic perspective the LOCIMAP studies have further highlighted the loss that an industry makes on the overall potential integration and optimisation which is far wider that when considering the industry in isolation. The loss in potential not only for heat and power integration but for material by-product integration and the closing of material loops has a quantifiable and negative impact on environmental performance of the whole. LOCIMAP makes the cases for the evaluation of the impact of CO_2 emissions not only those going up the stack, which the EU ETS addresses, but also for the inclusion of the desirable CO_2 reductions that are also enabled by that industry's presence.

The case is made for the retention and development of those industries which are world-leading in terms of CO_2. Diversity of industry types is seen as the cornerstone of successful industrial symbiosis and a low carbon park and the positive impact to the mix potential under-valued by the omission of bi-product synergy quantification.

10.0 *To realize the benefits identified in LOCIMAP it will be necessary to challenge existing* ***Approaches to Business****. These challenges are two-fold; the intra-park challenge of business co-operation of not just utility platform sharing but in the extreme the knitting together of some process operations in order to realize the minimum energy consumption targets and the extra-park collaboration between different industrial sectors e.g. the chemical and iron & steel industry or the chemical and food sectors and beyond to public-private sectors partnerships.*

The key advantage of the low carbon park is that it provides the location where minimum energy and lowest cost can exist together.

The model for that business may take many forms and will be determined by culture and public sector policy and support. Enlightened self-interest may prove sufficiently strong to engineer some of

[2] *(Ref. the Inbicon demonstrator process at Kalundborg) but also the emergence of new platform chemicals such as limonine from orange peel "Valorisation of Orange Peel Residues: Waste to Biochemicals and Nanoporous Materials". ChemSusChem (2012) 5(9), 1694-1697*

these changes. LOCIMAP has excellent exemplars from within its own partners as to what can be achieved already through industrial and industrial-municipal collaborations (ref the parks at Tarragona, Kokkola, Wilton and Kalundborg).

But, as explained in LOCIMAP White Paper 4 the low carbon future requires developments of new approaches and public engagement that can be effective in delivering business solutions at the park level. The project view is that the establishment of "Synergy Management Services" organisations is probably the best way to go. These need to be led by the park operator or by the industrial cluster with support from the local public sector with an interest in sustainability themselves.

4. In Summary

We conclude that the application of LOCIMAP principles, through the appropriate design of industrial parks and the development of opportunities for process integration, has the potential to exceed the targets set within EU ETS under which the majority of our participating industries operate and also the targets within SPIRE. The question is; what are the barriers to achieving this. The project sees three major ones.

- Some of the LOCIMAP opportunities are available now and can be implemented now within existing industrial clusters. What is needed is a culture change to think and work cross-sectorally. This process is not easy and will need stimulus but is essentially one of knowledge transfer. The mechanism is one of allowing normal business drivers to effect change once opportunities are visualised. This is the role of the "Synergy Management Organisation" proposed.

- The second barrier lies beyond industrialists, engineers and business owners and relates to local and national government and planning. A new investment is not best served by offering location at a number of green field sites; rather by the optimum integration with existing facilities. The answer to a low carbon economy is a thermodynamic one and planning needs to allow for this; even to the extent of (physically) linking the for example the chemical and food industry together! Policies need to be created which encourage such developments.

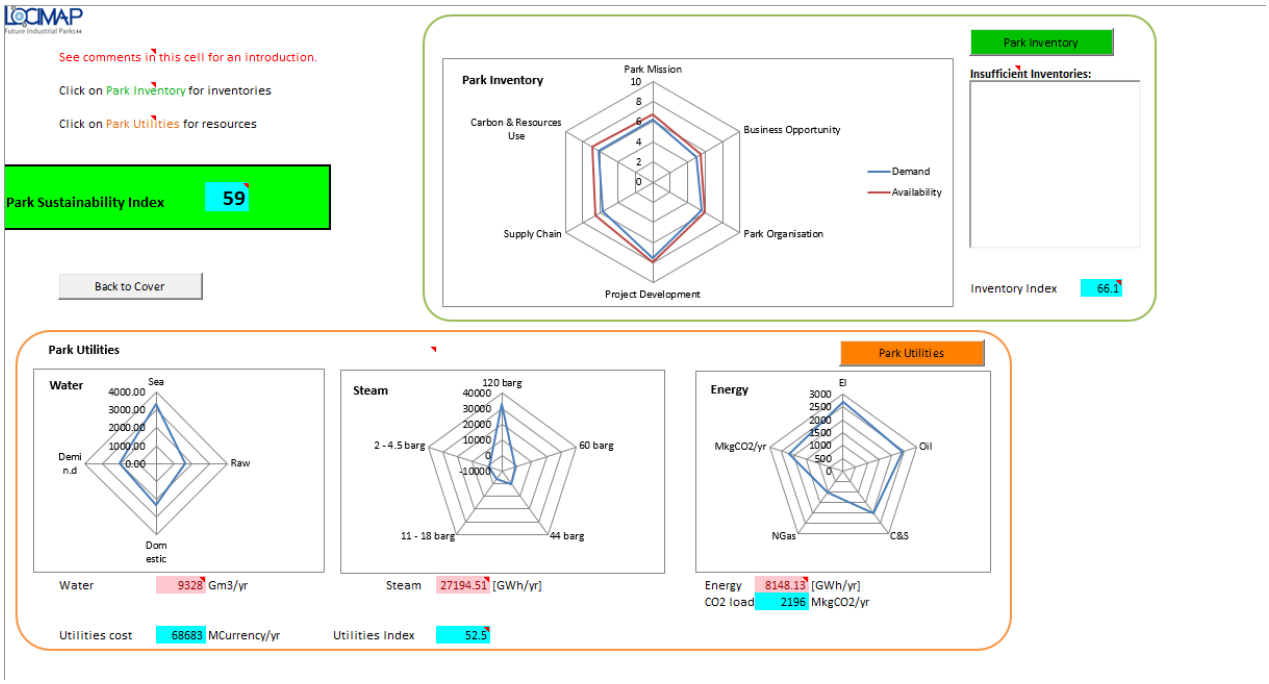
- The third barrier is that some of the opportunities are not economic under the existing policy and subsidy landscape. This becomes a societal and a political issue. What is the price of carbon? Do we still want a low carbon economy? If so how do we introduce measures that deliver the low carbon benefits without disadvantaging European manufacturing within a global playing field. Specifically creation of a low carbon park will need new low carbon energy sources to be found and integrated and industrial carbon capture and storage infrastructure to be created. This can be alongside the much longer term development of new materials and processes that are less carbon intensive.

These barriers can be quantified – but this needs to be done at the specific park level and requires the park residents and surrounding organisations to find a mechanism to fund the work in order to secure the investment needed.

5. Modelling the possibilities

One way of understanding the benefits of a low carbon park is to be able to model them and see how factors such as emissions and key elements of sustainability can be affected by integration on a park.

The project has produced such a modelling application which provides parks and other interested parties with the opportunity to explore options and demonstrate the benefits to potential investors.



We intend this will be useful in getting industry sectors to “look over the fence” and explore – as some of our partners have been doing – the benefits of Industrial Symbiosis.

6. Last Word

Can we go so far as to say we have the ingredients for a new industrial revolution? Does delivering low carbon manufacturing within the landscape of ‘closing loops’ contribute to this? What is the role of the waste industry and of green chemistry? Is what the project examines appropriate to high technology, entrepreneurial science based solutions? The LOCIMAP project has sought to inform opinion on all these points and provides a road map that helps decision and policy makers through the process and the choices available.

And finally, in answer to the question as to what to do to deliver a low carbon manufacturing park, the answer is not green, or 42, it’s thermodynamic!

LOCIMAP Project Team October 2014