



**INSTITUTE FOR STRATEGY
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Institution: **Institute for Strategy and Competitiveness at Harvard Business School**

Institution Contact: Christian Ketels

Contact's address, phone number, and email address:

Harvard Business School
Soldiers Field Road
Boston, MA 02163
(617) 384-5935
cketels@hbs.edu

I. Introduction

This document contains the response of a research team from the Institute for Strategy and Competitiveness at Harvard Business School to the EERE Commercialization RFI published by the Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE). Additional input was provided by researchers at the Fox School of Business at Temple University and MIT Sloan School of Management, as well as representatives of TCI, a global network of professionals active in cluster development.

The process of innovation has evolved significantly over recent decades, challenging governments to rethink the policies and programs they use to support innovation. What are some of the new characteristics of innovation that governments need to consider? First, innovation processes increasingly occur in networks of multiple companies, including specialized R&D firms, educational and research institutions, users, and other institutions. Second, innovation is highly concentrated in particular geographies, and linkages across locations arise between different hot spots, not across the board. And third, innovations that address key societal needs like the provision of reliable and sustainable energy require systemic changes across many institutions and technologies, not just individual scientific breakthroughs.

In light of such changes, understanding the role of location, locational context, and collaboration has become ever more important. A range of concepts that focus on these issues - from clusters to ecosystems to innovation systems - have gained popularity. Clusters, defined as groups of closely related industries co-located in a given region, focus the attention on firms and their value creation. Clusters are focal points where new, marketable ideas are born and translated into economically meaningful solutions and activity. Clusters emerge naturally in market processes, but many government policies affect their evolution. The local externalities that are inherent to clusters provide a role for government to enhance the economic impact that clusters can generate.

Pages 2 - 4 include the responses to the questions posed in the RFI; pages 5 - 7 provide additional comments and references. Our responses provide a short perspective on the insights from the available research in this field done by us and others. We would welcome the opportunity to discuss them more fully in a follow-up meeting, especially in their specific relevance for the energy field.

II. CATEGORY 5 Responses: Cluster Development

1. What are the key elements of clusters that result in enhanced competitiveness?

This broader question can be broken down into three different aspects that highlight particularly important dimensions of the role of clusters: what are the participants that make up a cluster, what are the mechanisms that drive clusters, and what is role of clusters in a broader concept of competitiveness?

Clusters are in the academic literature defined as “groups of closely related and complementary industries operating within a particular region.” This definition captures three important aspects of participants that distinguish clusters from more traditional categories:

1. Clusters capture the presence of *groups of related industries*, as opposed to specialization in narrow industries. Clusters are thus much more related to economies of scope and the value of related varieties than to economies of scale.
2. Clusters include *firms but also research and educational institutions, relevant government agencies, and institutions for collaboration*. The concept of clusters recognizes the broader range of institutions that influence the performance and competitiveness of companies in a cluster.
3. Clusters are distinctively *geographically bound* phenomena; they are not national or virtual. They reflect the unique impact that nearby institutions have on a firm and its ability to create value.

The geographic nature of clusters relates to the mechanisms that give rise to the emergence of clusters: Clusters exist because local spillovers create benefits from proximity. Proximity drives linkages through deep, specialized labor markets and supplier networks, knowledge spillovers, and more intense local rivalry. These linkages become stronger as a cluster grows in size, especially once a cluster reaches critical mass.

Clusters are conceptually part of a broader framework of competitiveness that explains why certain locations are able to support higher performance, both overall and in specific industries. A few key observations from this framework are particularly important for policy makers:

- Clusters are one *dimension of competitiveness*, but they also reflect the quality of other factors that drive economic performance. In particular, clusters emerge in response to advantageous business environment conditions, in a process that ultimately becomes self-reinforcing as a cluster reaches critical mass.
- Clusters *directly benefit* firms by allowing them to attain higher levels of productivity and innovation. But clusters also create *indirect benefits* by enabling firms to better leverage existing business environment qualities, and by contributing to a region’s social capital, a critical driver of regional prosperity.
- While clusters and many of their benefits emerge naturally in the market process, *collective action* in clusters – leveraging joint opportunities to create value and upgrade the business environment in targeted ways – does not. It requires leadership and is often a process where public support can help to kick-start and sustain collaboration.

2. How can the effective elements of clusters be measured?

Clusters can be optimally measured by their presence and performance, their competitiveness, and the potential of cluster-based policies to have an impact in a given cluster.

In terms of identifying where clusters have emerged as the result of a natural market process, the revealed impact in terms of actual co-location and performance is critical.

- First, *cluster mapping* uses data on co-location patterns and industry linkages to empirically define cluster categories in terms of groups of related industries. These definitions provide the standards for clusters to be comparably assessed across locations (see the U.S. EDA-sponsored cluster mapping website led by the Institute for Strategy and Competitiveness at <http://clustermapping.us>).
- Second, the *actual specialization patterns* of regions in terms of these cluster categories and their constituent industries are then the first measure of cluster performance. This data captures the locational

decisions of companies, as well as the relative impact of location on company growth. It can be used to identify the regions have developed strengths in particular cluster categories and the clusters that have reached critical mass in a particular region.

- Third, *actual economic outcomes* such as innovation, job growth, and profitability can then be measured for the clusters that have been identified, i.e. the regions in which a specific cluster category has reached critical mass (the literature has developed different criteria for measuring critical mass).

A number of factors can be analyzed to assess a cluster's underlying competitiveness:

- The *profile and specialization pattern* of economic activities reveals the critical mass that has developed and the potential for economies of scope and cross-industry dynamics, as well as of potential "holes" in the fabric of the cluster.
- The *quality of the individual nodes* of the cluster, such as the research institutions and companies present, which can be measured by indicators including innovation output and profitability.
- The *quality of the cluster-specific business environment* beyond related and supporting industries is given by the quality of available factor inputs (skills, infrastructure, capital, knowledge, and public services), the context for strategy and rivalry that drive performance and sophistication of local demand.
- The *level of actual collaboration* and joint action within the cluster, i.e. the nature and intensity of local linkages. The presence of institutions for collaboration, such as cluster initiatives, can be an important indicator of this measure, and network analysis can also be used.

To assess whether a cluster can benefit from government support, it is useful to look at three dimensions:

- *Strength of the underlying cluster.* There is clear empirical evidence that cluster efforts function much better if a critical mass has already emerged in the market process and if the focus is on enhancing linkages within the cluster.
- *Willingness and ability of the cluster to act.* Only a well-managed cluster organization, driven by a broad set of cluster participants, can design and implement effective action, and mobilize the cluster to take maximum advantage of government funding.
- *A coherent strategy and action plan.* Funding only makes a difference if the cluster organization has a clear understanding of how it can enhance the strategic position of the cluster and address specific bottlenecks that limit performance.

3. How can the effective elements of clusters be constructed or catalyzed?

The potential benefits of cluster-driven development efforts remain a topic of debate in both academic and policy realms. In our perspective, much of the differences in opinions reflect different underlying views about the specific policies and interventions subsumed under the notion of cluster policy (or cluster-driven economic development). Much of the criticism is directed at a heavily government-driven, interventionist approach that has little to do with the reality of most cluster efforts. Given this background, it is important to note what cluster policy is NOT:

- Cluster policy is *not about attracting companies* to generate a critical mass. While a strong cluster may attract companies, other institutions, and individuals with relevant skills, this constitutes a market response to the underlying nature of the cluster and its business environment. Policy should focus on these underlying drivers and their effective communication to potential investors. Only then will changes in critical mass be sustainable and valuable for the region.
- Cluster policy is *not about interventions that enhance the private profitability of firms* in a given location in ways that are not related to their level of productivity or innovation. For private profitability to align with the economic performance of a region, it needs to be based on strong productivity, rather than market restrictions or subsidies that achieve private profit by shifting value from the region's consumers and taxpayers to an individual firm.

Effective cluster policy focuses on upgrading the competitiveness of a cluster and its firms, and its ability to generate economic value. It encourages cluster development that is driven by the private sector and engages other institutions including government where they have a critical impact on the way companies can compete. It uses tools that raise productivity, innovation, and value creation and thus enables rivalry to occur at a higher level. Specifically, cluster policy should:

- Enhance the quality and intensity of linkages within a cluster.
- Improve cluster-specific business environment conditions, and the sophistication of firms in the cluster.
- Encourage private companies and other institutions to explore opportunities in areas of the cluster that are still weak in a given location.

4. What roles, if any, should Local, State and Federal government and non-profit organizations play to best support clusters?

A first priority for government policy should be to remove barriers to the emergence of clusters. Such barriers can result from regulations that limit market access or locational flexibility for companies, or the use of tax incentives and other tools to bias the locational decisions of firms against underlying economic factors.

While clusters emerge naturally, the upgrading of the cluster-specific business environment and joint value creation within the cluster require action. This action needs to be motivated by a view of overall returns to the cluster and the location, not just individual returns to one organization. Two approaches can be used:

- Organize existing economic policies (i.e. SME support, innovation policies, skill upgrading, investment attraction, and regional policies) around clusters.
- Support cluster initiatives as platforms for organized collaboration within clusters and for dialogue with government about cluster-specific priorities for public policy.

Cluster initiatives, too, often emerge in response to private sector leadership, whether from companies, academic institutions, or NGOs. Governments can and should reinforce these efforts, but they may need to play a more active role in supporting them in certain locations. How this can be done most effectively depends significantly on the specific local context, i.e. the institutional capacity, social capital, underlying cluster structure, and competitiveness challenges. More broadly, practical experience suggests that:

- Government *should* be open to support all existing and emerging clusters, and respond to market experience when reviewing decisions about support, participate in cluster initiatives, and be prepared to act on their recommendations, and enable the collection and dissemination of cluster-specific data.
- Government *may* initiate cluster initiatives and convene cluster groups, and co-finance the operations of a cluster initiative, especially of a secretariat to enable specific collaborative activities to emerge.
- Government *should not* pick favored clusters, restrict cluster initiatives membership by targeting “champions” or firms with specific attributes, and shelter clusters from competition.

5. What private or public financing activity currently reinforces and capitalizes upon particular clusters and their activities?

6. What potential adaptation of current financing mechanisms or creation of new mechanisms could result in greater amounts of capital being applied to future growth industry clusters?

In our view, the focus on financing and mobilization of capital is problematic. Access to capital is important, but only part of the story. The presence of dynamic clusters and the existence of a market for these offerings are in most cases more important. With them in place, private financing tends to become available and does not need to be substituted by public venture funding which has a poor track record.

By structuring existing funding mechanisms around clusters (see answers to question #4), governments can achieve significantly higher impact. Policy makers can also assess the potential to create competitive markets for innovative solutions, especially in areas where the speed of the emergence of such markets is critically reliant on government decisions about procurement, regulation, and R&D investment.

III. Additional Comments

Clusters and future growth/emerging industries

Given the focus of the previous question on future growth industry clusters, we have added a few additional thoughts more specifically directed at the role of clusters in the area of future growth/emerging industries.

Governments everywhere are highly interested in new industries, industries that address challenges and markets not currently well served, or industries that generally are perceived to have large growth potential. These industries are, by definition, areas in which the clustering process has not yet fully played out. As entrepreneurs test different locations, their relative success and future locational decisions will drive cluster emergence. These industries are also areas where cluster initiatives usually do not exist, and where empirical evidence suggests that the risks of government intervention are high.

What does the cluster literature have to contribute? First, there is clear empirical evidence that entrepreneurship benefits from the presence of clusters – through firm entry, survival, and growth. Second, there is evidence that new industries tend to develop where existing economic activities provide relevant skills and capabilities. Both observations suggest that clusters should be part of the analytical toolkit for thinking about policies to enhance the potential of future growth/emerging industries.

What are the specific implications for government policy? Existing research and emerging practice point towards a number of key areas:

- Encourage existing cluster organizations to look for opportunities in adjacent fields (i.e. related clusters and related technologies).
- Focus investments on new industries and technologies in locations that provide the highest likelihood of success in terms of existing clusters and regional business environment conditions.
- Design cluster-based programs for future growth/emerging industries with different properties than cluster-based programs for existing clusters:
 - Clear performance milestones and exit mechanisms.
 - Focus on market exploration and generation of market knowledge, limited provision of capital to specific clusters (or worse, firms)
 - More flexible guidelines in terms of the (geographic, industry) boundaries of the cluster organization receiving support.

Areas of future research

Our work suggests that the growth of existing regional industries and the emergence of new regional industries depend crucially on the cluster composition in a region and across nearby regions. The cluster data and tools that we have developed through the U.S. Cluster Mapping Project (<http://clustermapping.us>) can be deployed to improve our understanding of the performance, diversification, and evolution of energy clusters and related clusters, in the U.S. and in other countries.

Clustering analysis allows us to assess the centrality of individual industries within a cluster and their linkages with other clusters. For example, Electric Power Generation (NAICS code: 221110) is a core industry within the Energy Generation and Distribution cluster. We can examine how the set of activities in this industry (i.e. hydroelectric, fossil, nuclear, and solar) relate to other industries and clusters. This analysis can help forecast innovation opportunities and the emergence of new activities.

Cluster structure can evolve over time. The core industries in terms of size and interdependencies with other industries can change over time, reflecting changes in the market and technology. Few studies have examined how the co-location patterns of industries change over time, or the role that the historical composition of industries in a region plays in shaping new industry growth and cluster diversification. Understanding the drivers of cluster evolution, particularly the types of firms and networks, is a crucial direction for future research.

Our methodology has been applied outside of the United States in, for example, Mexico, the EU, and Canada. Testing the way the cluster codes have been translated into other industrial classification systems can enhance the robustness of the methodology. The comparable cross-country datasets then available are powerful instruments for broader economic analysis to inform targeted competitiveness upgrading, but also specific policy measures to support internationalization of clusters and firms.

The existing quantitative research has, with few exceptions, focused on clusters as the co-location of related economic activities. There is much less systematic evidence on the presence of cluster initiatives, their available support through government programs, or the potential impact of these initiatives and policies on economic outcomes. There is some emerging evidence on these relationships from Europe, but very little is U.S.-specific or examines the particular characteristics of energy-related initiatives.

There is great untapped potential to collect and analyze this type of data with a focus on energy, especially given the recent emphasis that many countries have placed on improving renewable energy production and energy efficiency across other cluster categories, such as construction and electronics. The available evidence displays that the impact of cluster initiatives, and the government programs to optimally leverage their value and performance, depend strongly on how these efforts are managed, what they do, and what context they operate in. This presents a promising opportunity for future research in cluster development.

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