Grand challenges: a new type of innovation policies?
Or old wine in new bottles?

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Abstract

The paper discusses two concepts that are used to make reference to government oriented R&D programs: "mission-oriented" and "grand-challenge" ones. The paper shows the second is displacing the first, but that both could be used as synonyms, as both make reference to innovation programs that are supported from the very basic fundamental research, to incentives for adoption.

For several decades, innovation policy was either part of larger industrial policies, often called "mission-oriented industrial policies" or confined to smaller innovation programs that fell mostly in two types: fiscal support for R&D, often used by large corporations, and non-reimbursable grants for R&D in small and medium-sized enterprises.

In the last two decades one new type of innovation policy has emerged and another one has tended to decline. "Grand challenge policies" occupies more and more space in the innovation policy literature, while "mission-oriented policy" – often assimilated to industrial policy - has tended to wane. This paper discusses whether the two concepts point to the same type of policy or indicate the emergence of a new policy.

Mission-oriented technology policies

Carmichael (1981) and Ergas (1987) were among the first to use the concept of mission-oriented science and technology (MOST) policies. Carmichael (1981) addresses the issue of how public mission-oriented spending affects private spending on R&D. Ergas wrote about "mission-oriented countries" which included France, the United Kingdom and the United States. These countries applied mission-oriented research programs defined as "big science deployed to meet big problems" (Ergas, 1987, p. 53). The main feature of these mission-oriented R&D programs was concentration. It means that their goals were centrally designed to meet the needs of some specific agency or ministry. Technologies that tended to use such type of policy were those with strategic importance, such as aerospace, electronics and nuclear energy. R&D subsidies were distributed among a small number of large firms. Success factors included the technical expertise, financial autonomy and operating autonomy of the operating agencies, the quality of the incentives and penalties provided to the suppliers, and the checks and balances implemented to prevent these agencies from extending indefinitely their mandates.

Chris Freeman (1996) made a more subtle and important distinction between old mission-oriented programs aiming at aerospace, or defense, and the new mission-oriented ones searching the solution to environmental, health or social problems. The first ones are characterized by top-down design and implementation of projects, a short number of participants, mostly large companies and government departments with a clear mandate to produce a piece of equipment. The second and more modern set of programs has usually more participants, including SMEs and consumers, and their goal is far from delivering new weapons, but to produce new drugs, or new environmental climate-friendly energy technology. Table 1 summarizes the distinction between the two types of mission-oriented programs.

(Table 1 here)

Mission-oriented policies are created with the aim of generating and exploiting radical innovation. Their ideal is to create entirely new industries based on new technologies. So they tend to compete in the early phase of the industry life cycle and emphasize "heroic" efforts in "big science and technology," or major programs. These programs, historically mostly defense and aerospace-related, are highly sophisticated and often have put more emphasis on performance than on cost.

Mission-oriented programs are “science and technology push” initiatives. They also emphasize national self-reliance. They are far more “product-oriented” than process-oriented. These mission-oriented programs are habitually useful in displaying new technologies for the civilian markets to adopt. It happened with computers (the Strategic Computer Program), semiconductors (the Very High Speed Integration Circuit Program), and aircraft turbines. It is also happening with solar PV technologies that started to be developed and used on satellites and aircraft in the late 1950s and early 1960s. “ (Chiang, 1990)

These programs have helped to realize large techno-economic transitions, combining the much-criticized linear model with the systemic innovation model (Freeman, 1996). The old mission-oriented programs were more linear and more frequent in aerospace, defense and nuclear-related activities. According to Freeman, the new mission-oriented programs have more environmental goals and may have more effects on the entire economic structure. They also require both incremental and radical innovation. The following table summarizes the differences between old and new mission-oriented projects. Note that Freeman is making explicit reference to green technologies twenty years before they become competitive with fossil fuels.

(Table 1 here)

Recently, Mowery (2012) as well as Mazzucato and Penna (2015) use MOST concepts. Mowery (2012) equates both concepts (grand challenges and mission-oriented policies) and asks whether the experience acquired by governments in defense missions can be used in other sectors. He underlines the fact that using the mission-oriented R&D programs in environmental and health societal challenges have some similarities with defense R&D missions: both require a long-term program of investments, in fundamental research, as well as in technological development and demonstration. A major difference according to him is that these other missions will require an extensive public support in demonstration and adoption. We will see that this remark applies perfectly well in renewable technologies.
Mazzucato and Penna (2015) noted that in the past some of these mission-oriented R&D projects covered the entire phases of the projects, from basic research to adoption and use, and took the risks. Cost-benefit analysis would have stopped these projects including biotechnology, Internet, nanotechnologies and renewable energies. The traditional Keynesian approach argues that investments in infrastructure draw rapidly the economy out of the recession. But they argue that mission-oriented programs may take the lead not in the short-term pull, but in the long term slow-growth quagmire in which market economies are being stuck.

Yet, mission-oriented policies existed since the 1940s and 1950s, particularly in the defense sector (Amanatidou et al, 2014). In their beginnings, MOST were more nationally oriented than they are today. They included for instance, programs to produce turbojet aircraft in Germany, the United Kingdom and the United States during World War II, to produce rockets first in Germany and then in the United States after WWII. Also, programs to produce semiconductors and computers in the United States in the 1950s and 1960s fall under this category. The National Aeronautics and Space Administration (NASA) was described as leading, during the 1960s, the US largest mission-oriented program ever assembled; over 400,000 people were working in space projects in government, industry and university in 1966 (US Committee on the Survey of Materials Science and Engineering, vol. 2, 1975).

Grand challenge policies

Grand challenge policies, at least using that conceptual label, appeared much later, in the 1980s and 1990s, and they addressed more variegated economic and social problems, including climate change, demographics, health and energy (Rhisiart, 2013). Ulnicane (2016) argued that even if mission-oriented policies and grand challenges innovation policies are similar in several aspects, such as big efforts to solve economic and social problems, grand challenges are different in the sense that they tend to tackle more health and social issues, and are less defense-oriented than MOST. Also, the frontiers of these social problems are less clearly defined than those of mission-oriented policies, and the evaluation methods are similarly less clear.

Compare for instance a typical large mission-oriented project in the defense industry, such as providing suitable aircraft turbines to advanced military jets, or the Moon Landing missions, with a grand challenge policy such as the Human Genome Project and the Human Proteome Project (grand challenge programs). The first is clearly delimitated. The responsible organization is permanent or at least long-term (the NASA). The other are less so, because they are more upstream, and closer to the fundamental science than to products in the market.

Solar technology as a grand challenge

The list of grand challenges programs and projects increases by the day. The US Academy of Engineering has published its own list. Research centres and teams have their own ones (Giulivi, 2014).

Solar photovoltaic technology has made astounding progress since its emergence in the 1950s. The efficiency of solar panels has made great leaps and it is becoming the most likely candidate to replace this century fossil fuel technology. Yet, before this technology displaces coal, oil, and gas, several technological problems must be solved, such as advancing the efficiency and reducing cost of solar cell technology, that is moving towards cheaper perovskite materials, developing large rechargeable batteries, economic mechatronics, solar glasses, and power inverters changing direct current to alternate current. In addition, our market economies are addict to fossil fuels, and they will need major reconversions before they adopt solar PV technologies.

Both MOST and grand challenge innovation policies often support industries in the early phase of their life cycle. The paper will compare the two concepts, and examine the solar grand challenge policy and compare it with completed previous grand challenges such as the Human Genome Project. We will argue that both concepts (mission-oriented and grand challenge policies) are complementary, that they are often not applied to the same disciplines and industries, and that successful grand challenges programs will most probably become established R&D organizations with mission-oriented policies, if and when the grand challenge temporary organization opens up major research areas with commercial applications that need to be explored in the long term.

Solar PV public R&D organizations include the Fraunhofer Institute for Solar Energy Systems, headquartered in Freiburg, Germany, and founded in 1981, the largest solar energy R&D institute in Europe. Also, the New Renewable Energy Laboratory in the United States, much smaller than its German counterpart, has produced important advances in solar PV technology[1]. China, the world's largest producer of solar PV technology, does not have a unified organization for R&D, development and construction of PV power plants. Under these conditions the Chinese solar industry suffers from manufacturing overcapacity, under-developed internal market, and deteriorating international markets (Sun et al, 2014).

[1] https://www.youtube.com/watch?v=Oo8iEL6SqgI

In the West, the rapid adoption of solar PV technology required, as Freeman (1996) had argued, policies that encouraged its adoption. They appeared mainly in the form of Feed-in-Tariffs (FIT). These policies required utilities to acquire electricity from independent suppliers of either solar, wind or other renewable source at a price reflecting the cost of producing these forms of energy. In 1990, Germany passed a law on renewables, according to which utilities were asked to buy electricity from renewable sources at a percentage of the residential electricity price. In 2000, Renewable Energy Sources Act enlarged the incentives, and as the cost of renewable energy diminished so did the price of electricity for the consumers. The German law was modified several times, and it was also imitated in other EU countries. As of early 2014, some 73 countries and 28 states had adopted this incentive[2]. The European Union has been the most eager adopter of solar PV technology among the Western regions, and China is now becoming the hub of both production and adoption of this energy equipment (Jenner et al, 2013).

In the United States, the most powerful incentive for the adoption of solar PV since 2006 has been the Solar Investment Tax Credit (ITC). Since its inception the growth of solar PV installation has grown by more than 60% annual rate a year.

Conclusion

The paper concludes with Mazzucato and Penna (2015) that great challenge and mission-oriented policies should occupy a preeminent position among the explanations of government support for innovation. The rise of science-based industries and the rapid development of product and process technologies based on them requires much more than tax credits for R&D and small grants for SMEs, which are much better adapted for incremental innovation. However, some conceptual clarification is required. It includes the following items:

1. Mission-oriented and grand-challenge policies are similar types of government interventions in innovation?

[2] https://energypedia.info/wiki/Feed-in_Tariffs_(FIT)

2. These policies overlap the same stages of R&D, from basic research to market approval. Yet, mission-oriented policies more linked to industry and government users than to academia, thus closer to users, while grand challenges are more science-based, and their fundamental stages are longer and more complex.
3. Thus, the success of grand challenges requires complementary policies to insure the adoption of the products and processes stemming from these R&D activities. In the case of solar PV technologies, feed-in-tariffs are these policies. They transfer part of the burden to the taxpayer.

Bibliography

Amanatidou, E., P. Cunningham, A. Gök, I. Garefi (2014): "Using Evaluation Research as a Means for Policy Analysis in a 'New' Mission-Oriented Policy Context", Minerva, 52: 417-438.

Carmichael, J. (1981): "The effects of mission-oriented public R&D spending on private industry", The Journal of Finance, 36 (3): 617-627.

Chiang, J. T. (1990): "From mission-oriented to diffusion oriented paradigm: new trend of US industrial technology policy", Technovation, 11 (6): 339-356.

Edquist, C., J. M. Zabala-Iturriagagoitia (2012): "Public procurement for innovation as mission-oriented innovation policy", Research Policy, 41: 17757-1769.

Ergas, H. (1987): "The importance of technology policy", In: Dasgupta, P., Stoneman, P. (Eds.), Economic Policy and Technological Performance, Cambridge Univ. Press, pp. 51-96.

Fagerberg, J. (2016): "Innovation policy: rationales, lessons and challenges", Journal of Economic Surveys, (in press).

Giulivi, C. (2014): "Grand challenges in cellular biochemistry: the 'next-gen' biochemistry", Front. Chem., 2: 22; doi: 10.3389/fchem.2014.00022.

Jenner, S., F. Groba and J. Indvik (2013): "Assessing the strength and effectiveness of of renewable electricity feed-in-tariffs in the European Union", Energy Policy, 52: 385-401.

Mazzucato, M. and C. R. Penna (Eds.)(2015): Mission-oriented Finance for Innovation, London, Rowman and Littlefield.

Mowery, D. (2912): "Defense-related R&D as a model for "grand-challenges" technology policies", Research Policy, 41 (10): 1703-1715.

Rhisiart, M. (2013):"Foresight and "grand challenges" within research and innovation policies", Foresight, 15 (1): 29 – 39.

Sun, H, Q. Zhi, Y. Wibo, Q. Yiang and J. Su (2014): "China's photovoltaic industry development: the status quo, problems and approaches", Applied Energy, 118 (1): 221-230.

Ulnicane, I. (2016): "'Grand challenges' concept: a return to big ideas in science, technology and innovation policy?" Int. J. of Foresight and Innovation Policy, 11 (1/2/3): 5-22.

US Committee on the Survey of Materials Science and Engineering (1975): vol. 2 of Materials and Man's Needs: The needs, priorities and opportunities for Materials Research, Washington DC, National Academies Press.

US Solar Energy Industries Association (2016): Solar Industry Data. (http://www.seia.org/research-resources/solar-industry-data)

Table 1: Old and new mission-oriented programs

Old: defense, aerospace and nuclear	New: environmental technologies
The mission is defined in terms of the number of technical achievements with little regard to economic feasibility	The mission is defined in terms of economically feasible technical solutions to particular environmental problems
The goals and direction of technological development are defined in advanced by a small group of experts	The direction of technical change is influenced by a wide range of actors including government, firms and consumers
Centralized control in a government administration	Decentralized control with a large number of involved agents
Diffusion of the results outside of the core of participants is of minor importance	Diffusion of the results is a central goal and is actively encouraged.
Limited to a small group of firms owing to emphasis on radical technologies	Emphasis of development of both incremental and radical innovation
Self-contained projects with little need for complementary policies and scant attention paid to coherence	Complementary policies vital for success and attention paid to coherence with other goals

Source: Freeman, 1996, p. 37

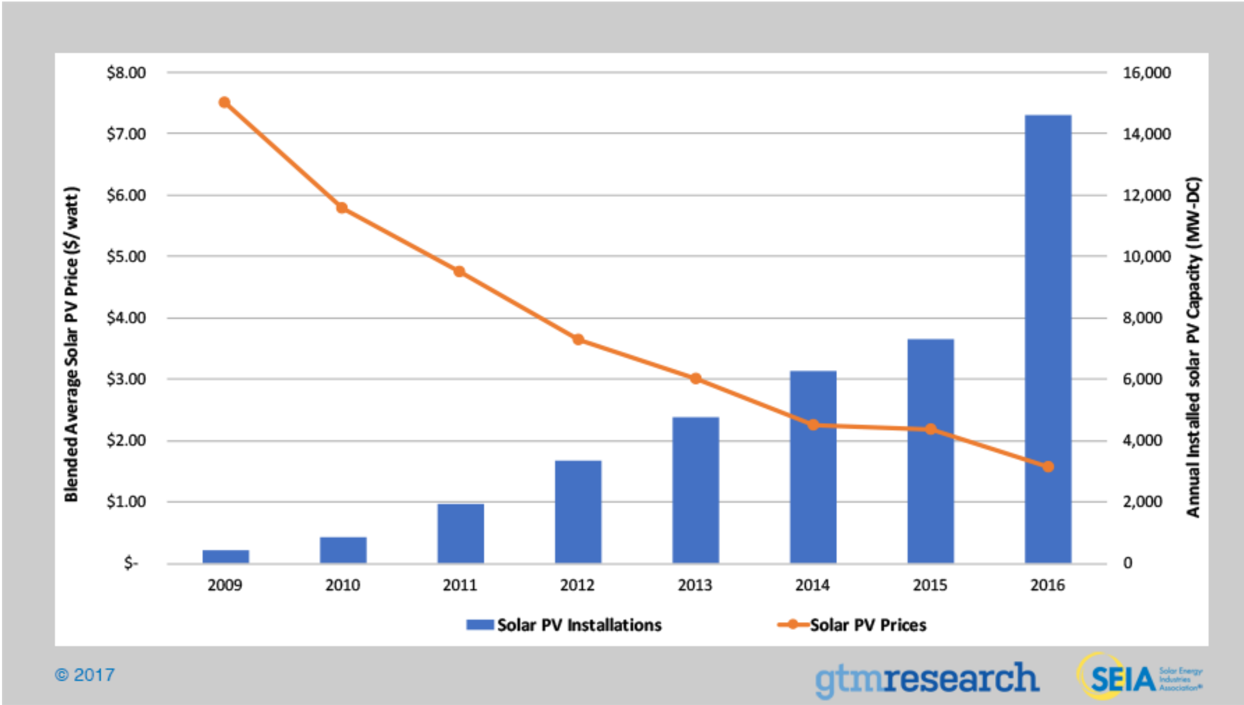
Table 2: Grand challenges, mission oriented and incremental innovation policies

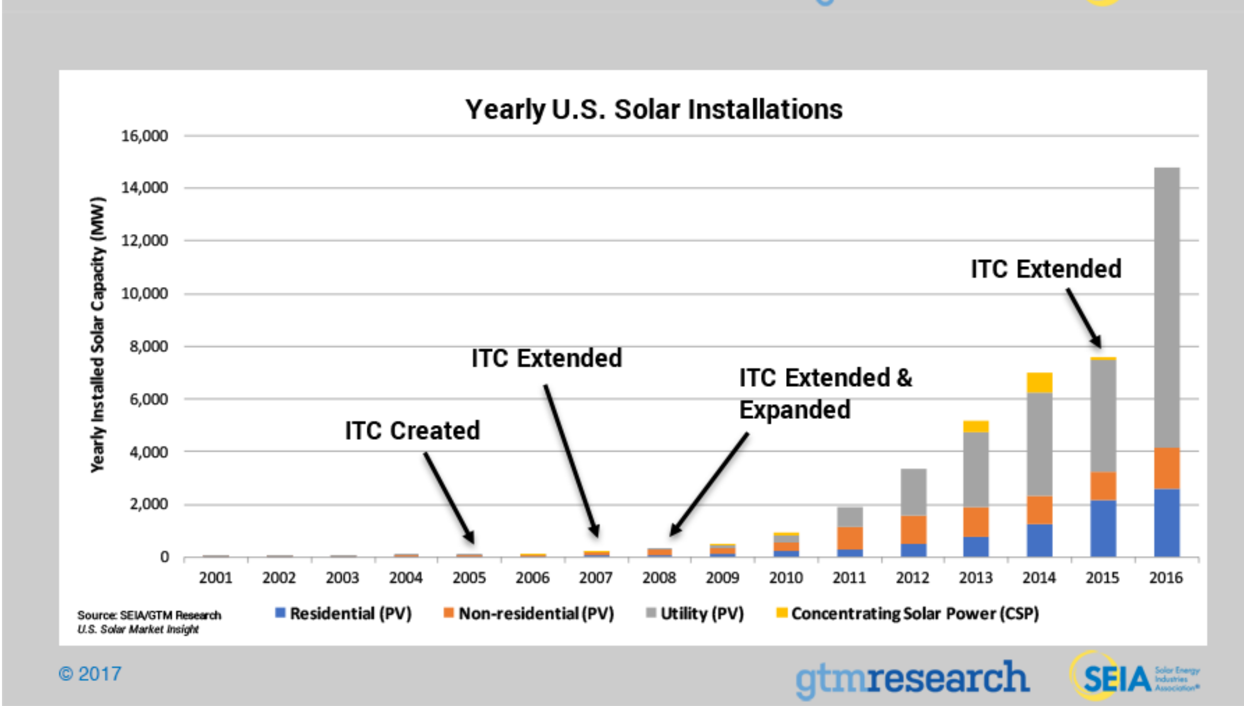
	Incremental innovation	**Mission-oriented policies**	**Grand challenges policies**
Time span	Permanent or long term program	Permanent or long term program	Short- to medium term program
Funding	Same or similar amount each year	Same or similar amount each year	Major upfront amount and annual disbursement for a fixed period of time
Goal	Induce incremental innovation	Continuous innovation support to important sectors, for radical or incremental innovation	Strong effort to solve a major social or technical problem or create a new innovation path
Examples	SBIR, USA (1982->) SR&ED, Canada (1977->)	Agriculture, defense, health, energy, transportation, space US Jet Propulsion Lab (early 1930s->) US NIH (1930->)	Human Genome Project International (1990-2003) Human Proteome Project International (2012-2022) US SunShot Initiative (2011/2020)
Initiative of projects	Companies	National Governments	National governments
Institutional forms	One agency runs the program (i. e. for SBIR, the US Small Business Administration)	Government laboratory, permanent program	National public/private partnerships and/or international coalition

Table 3: Mission-oriented and grand challenge policies: a bibliographic research

Keyword	Number of books, articles or chapters	Year of first Paper Publication	Number of citations of most cited paper	Subject of citations of most cited paper
Mission-oriented policy	89	1978	288	Mainstreaming ecosystem services
Mission-oriented innovation policy	26	1991	105	Government support to new industry creation
Grand-challenge policy	213	1992	608	Solar energy
Grand-challenge innovation policy	51	2003	208	Agricultural productivity & environment

Source: SCOPUS





Figures 1 and 2: US solar installations (2001-2016)

Source: US Solar Energy Industries Association (2017): Solar Industry Data.