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Innovative Technologies and Organizations in Global Energy Systems

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***Abstract*—This course will examine a broad range of global energy systems including electricity generation, electricity end use, transportation and infrastructure. Discussions will be based on two key trends: (a) the increasing ability to deploy technologies and engineering systems globally, and (b) innovative organizations, many driven by entrepreneurship (for profit and social) and entrepreneurial finance techniques. The course will consider these types of innovations in the context of developed economies, rapidly developing economies such as India and China, and the developing world.**

***Index Terms*— global energy systems, electricity generation, electricity end user, transportation and infrastructure, deploy technologies, innovative organizations.**

I. INTRODUCTION

The concept of a technological innovation system was introduced as part of a wider theoretical school, called the innovation system approach. Innovation is a collective activity. It takes place within the context of a wider system. This wider system is coined 'the innovation system' or 'the innovation ecosystem'. The concept of the innovation system stresses that the flow of technology and information among people, enterprises and institutions is key to an innovative process.

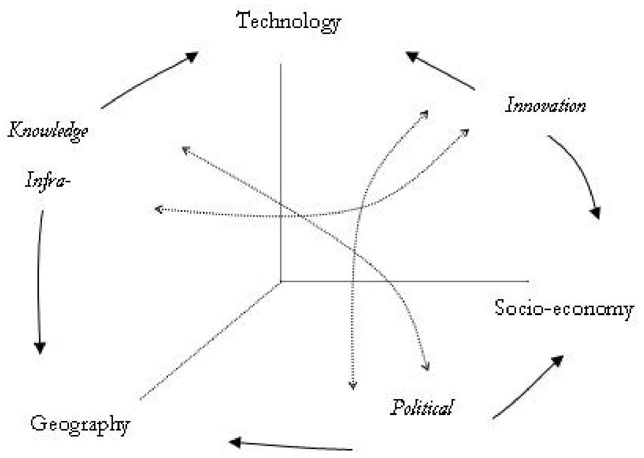

Fig: Innovation System

Innovation systems have been categorized into geographical innovation systems, sectoral innovation systems and technological innovation systems.These three approaches to analyse innovation systems represent three analytical dimensions of the interaction among an ecology of actors (See figure 1). Geographically positioned units of analysis (e.g., firms, institutions), economic exchange relations, and (technological) novelty production cannot be reduced to one another. However, these independent dimensions can be expected to interact to varying extents. Given these specifications, one can create a model of the three dimensions and their interaction terms as shown in figure 1. Technological Innovation System is a concept developed within the context of the Innovation System approach focusing on explaining the nature and rate of technological change.

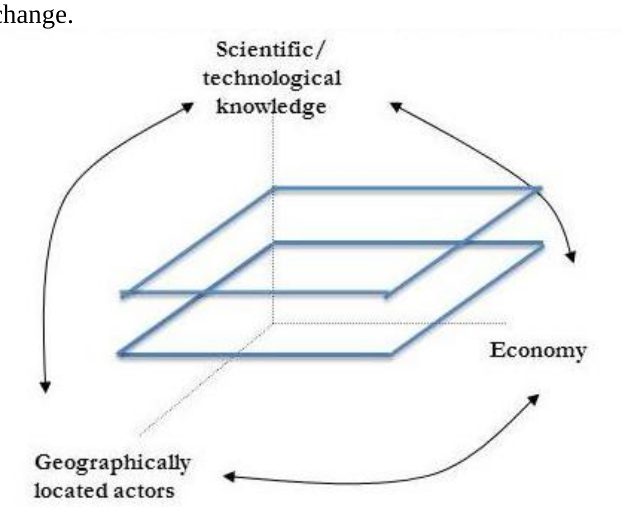

Fig: Technological Innovation System

The central idea behind this approach is that determinants of technological change are not (only) to be found in individual firms or in research institutes, but (also) in a broad societal structure in which firms, as well as knowledge institutes, are embedded. Since the 1980s, innovation system studies have pointed out the influence of societal structures on technological change, and indirectly on long-term economic growth, within nations, sectors or technological fields. The purpose of analyzing a Technological Innovation System is to analyze and evaluate the development of a particular technological field in terms of the structures and processes that support or hamper it. Besides its particular focus, there are two, more analytical, features that set the Technological Innovation System approach apart from other innovation system approaches. Firstly, the Technological Innovation System concept emphasizes that stimulating knowledge flows is not sufficient to induce technological change and economic performance. There is a need to exploit this knowledge in order to create new business opportunities. This stresses the importance of individuals as sources of innovation, something which is sometimes overseen in the, more macro-oriented, nationally or sectorally oriented innovation system approaches.

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Secondly, the Technological Innovation System approach often focuses on system dynamics. The focus on entrepreneurial action has encouraged scholars to consider a Technological Innovation System as something to be built up over time. This was already put forward by Carlsson and Stankiewicz: Technological Innovation Systems are defined in terms of knowledge/competence flows rather than flows of ordinary goods and services. They consist of dynamic knowledge and competence networks. In the presence of an entrepreneur and sufficient critical mass, such networks can be transformed into development blocks, i.e. synergistic clusters of firms and technologies within an industry or a group of industries. This means that a Technological Innovation System may be analyzed in terms of its system components or in terms of its dynamics. Both perspectives will be explained below. The technological innovation system is a concept developed within the scientific field of innovation studies which serves to explain the nature and rate of technological change. A Technological Innovation System can be defined as 'a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology'. The approach may be applied to at least three levels of analysis: to a technology in the sense of a knowledge field, to a productor an artifact, or to a set of related products and artifacts aimed at satisfying a particular (societal) function'. With respect to the latter, the approach has especially proven itself in explaining why and how sustainable (energy) technologies have developed and diffused into a society,

II. STRUCTURE OF INNOVATION SYSTEM

A Technological Innovation System can be defined as the set of actors and rules that influence the speed and direction of technological change in a specific technological area.

The concept of the innovation system stresses that the flow of technology and information among people, enterprises and institutions is key to an innovative process. All innovation systems can be characterized by the same basic building blocks or components. These are actors, institutions, networks and technology.

A. Actors

Actors involve organizations contributing to a technology, as a developer or adopter, or indirectly as a regulator, financier, etc. It is the actors of a Technological Innovation System that, through choices and actions, actually generate, diffuse and utilize technologies. The potential variety of relevant actors is enormous, ranging from private actors to public actors, and from technology developers to technology adopters. The development of a Technological Innovation System will depend on the interrelations between all these actors. For example, entrepreneurs are unlikely to start investing in their businesses if governments are unwilling to support them financially.

B. Institutions

Institutional structures are at the core of the innovation system concept. It is common to consider institutions as 'the rules of the game in a society, or, more formally, the humanly devised constraints that shape human interaction'. A distinction can be made between formal institutions and informal institutions, with formal institutions being the rules that are codified and enforced by some authority, and informal institutions being more tacit and organically shaped by the collective interaction of actors. Informal institutions can be normative or cognitive. The normative rules are social norms and values with moral significance, whereas cognitive rules can be regarded as collective mind frames, or social paradigms.

C. Technological factors

Technological structures consist of artifacts and the technological infrastructures in which they are integrated. They also involve the techno-economic workings of such artifacts, including costs, safety, and reliability. These features are crucial for understanding the feedback mechanisms between technological change and institutional change. For example, if R&D subsidy schemes supporting technology development should result in improvements with regard to the safety and reliability of applications, this would pave the way for more elaborate support schemes, including practical demonstrations. These may, in turn, benefit technological improvements even more. It should, however, be noted here that the importance of technological features has often been neglected by scholars. The structural factors are merely the elements that make up the system. Industry associations, research communities, policy networks, user-supplier relations etc. are all examples of networks. An analysis of structures typically yields insight into systemic features - complementarities and conflicts - that constitute drivers and barriers for technology diffusion at a certain moment or within a given period in time.

III. DYNAMICS OF INNOVATION SYSTEM

Innovation processes are multifaceted. Different studies usually focus on different topics of innovation without being integrated into a complete innovation system. Factors like knowledge diversity, spatial proximity and strategy relationship are key elements of innovation.

Knowledge can be categorized differently and no single taxonomy can describe the concept of knowledge completely and precisely. Different people in the system have different knowledge levels and knowledge processing activities. Higher knowledge diversity refers to lower knowledge commonality in team members. This is beneficial in provides sources of variety in organization's knowledge base and forms primitive absorptive capacity however knowledge commonality is beneficial for efficiency.

Physical distance between the actors of the innovation system affects the performance of interunit networks or formation of interunit linkages. Spatial proximity plays an important role in communication between the team and therefore in building an effective innovative system. Spatial proximity plays an important role in innovation or knowledge activities such as technology transfer.

High degree of strategic relationship among organization unit implies high degree of common prior knowledge which enhances communication and knowledge sharing among units. Units which are strategically related share common interests and so have higher resource/knowledge sharing which helps in building effective system.

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IV. FUNCTIONS OF INNOVATION SYSTEM

Structures involve elements that are relatively stable over time. Nevertheless, for many technologies, especially newly emerging ones, these structures are not yet fully in place.For this reason, mostly, the scholars have recently enriched the literature on Technological Innovation Systems with studies that focus on the build-up of structures over time. The central idea of this approach is to consider all activities that contribute to the development, diffusion, and use of innovations as system functions. These system functions are to be understood as types of activities that influence the build-up of a Technological Innovation System. Each system function may be 'fulfilled' in a variety of ways. The premise is that, in order to properly develop, the system should positively fulfil all system functions. Various 'lists' of system functions have been constructed.

A. Seven system functions

As an example, the seven system functions defined by Suurs are explained here.

1) Entrepreneurial activities

The classic role of the entrepreneur is to translate knowledge into business opportunities, and eventually innovations. The entrepreneur does this by performing market-oriented experiments that establish change, both to the emerging technology and to the institutions that surround it. The Entrepreneurial Activities involve projects aimed to prove the usefulness of the emerging technology in a practical and/or commercial environment. Such projects typically take the form of experiments and demonstrations

2) Knowledge development

The Knowledge Development function involves learning activities, mostly on the emerging technology, but also on markets, networks, users etc. There are various types of learning activities, the most important categories being learning-by-searching and learning-by-doing. The former concerns R&D activities in basic science, whereas the latter involves learning activities in a practical context, for example in the form of laboratory experiments or adoption trials

3) Knowledge diffusion / knowledge exchange

The characteristic organization structure of a Technological Innovation System is that of the network. The primary function of networks is to facilitate the exchange of knowledge between all the actors involved in it. Knowledge Diffusion activities involve partnerships between actors, for example technology developers, but also meetings like workshops and conferences. The important role of Knowledge Diffusion stems from Lundvall's notion of interactive learning as the raison-d'être of any innovation system. The innovation system approach stresses that innovation happens only where actors of different backgrounds interact. A special form of interactive learning is learning-by-using, which involves learning activities based on the experience of users of technological innovations, for example through user-producer interactions.

4) Guidance of the search

The Guidance of the Search function refers to activities that shape the needs, requirements and expectations of actors with respect to their (further) support of the emerging technology. Guidance of the Search refers to individual choices related to the technology but it may also take the form of hard institutions, for example policy targets. It also refers to promises and expectations as expressed by various actors in the community. Guidance of the Search can be positive or negative. A positive Guidance of the Search means a convergence of positive signals - expectations, promises, policy directives - in a particular direction of technology development. If negative, there will be a digression, or, even worse, a rejection of development altogether. This convergence is important since, usually, various technological options exist within an emerging technological field, all of which require investments in order to develop further

5) Market formation

Emerging technologies cannot be expected to compete with incumbent technologies. In order to stimulate innovation, it is usually necessary to create artificial (niche) markets. The Market Formation function involves activities that contribute to the creation of a demand for the emerging technology, for example by financially supporting the use of the emerging technology, or by taxing the use of competing technologies. Market Formation is especially important in the field of sustainable energy technologies, since, in this case, there usually is a strong normative legitimation for the intervention in market dynamics.

6) Resource mobilization

Resource Mobilization refers to the allocation of financial, material and human capital. The access to such capital factors is necessary for all other developments. Typical activities involved in this system function are investments and subsidies. They can also involve the deployment of generic infrastructures such as educational systems, large R&D facilities or refueling infrastructures. In some cases, the mobilization of natural resources, such as biomass, oil or natural gas is important as well. The Resource Mobilization function represents a basic economic variable. Its importance is obvious: an emerging technology cannot be supported in any way if there are no financial or natural means, or if there are no actors present with the right skills and competences.

7) Support from advocacy coalitions

The rise of an emerging technology often leads to resistance from actors with interests in the incumbent energy system. In order for a Technological Innovation System to develop, other actors must counteract this inertia. This can be done by urging authorities to reorganize the institutional configuration of the system. The Support from Advocacy Coalitions function involves political lobbies and advice activities on behalf of interest groups. This system function may be regarded as a special form of Guidance of the Search. After all, lobbies and advices are pleas in favor of particular technologies. The essential feature which sets this category apart is that advocacy coalitions do not have the power, like for example governments, to change formal institutions directly. Instead, they employ the power of persuasion. The notion of the advocacy coalition is based on the work of Sabatier

V. ACQUIRING NEW TECHNOLOGIES AND CAPABILITIES

To improve competitiveness and retain sustainability, firms require new technologies and capabilities. In this age of rapid innovation and complexity, it is challenging for the firms to develop internally and remain competitive at the same time.

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Merger, acquisition and alliance are some of the ways to achieve this, but the primary driver is the desire to obtain valuable resources. Many acquisitions failed to achieve their objectives and resulted in poor performance because of improper implementation.

1) Improper documentation and changing implicit knowledge makes it difficult to share information during acquisition
2) For acquired firm symbolic and cultural independence which is the base of technology and capabilities are more important than administrative independence.
3) Detailed knowledge exchange and integrations are difficult when the acquired firm is large and high performing.
4) Management of executives from acquired firm is critical in terms of promotions and pay incentives to utilize their talent and value their expertise.
5) Transfer of technologies and capabilities are most difficult task to manage because of complications of acquisition implementation. The risk of losing implicit knowledge is always associated with the fast pace acquisition.

Preservation of tacit knowledge, employees and literature are always delicate during and after acquisition. Strategic management of all these resources is a very important factor for a successful acquisition.Increase in acquisitions in our global business environment has pushed us to evaluate the key stake holders of acquisition very carefully before implementation. It is imperative for the acquirer to understand this relationship and apply it to its advantage. Retention is only possible when resources are exchanged and managed without affecting their independence

VI. GLOBAL ENERGY INNOVATIVE SYSTEM

Energy technology innovation has played central role in the evolution and advancement of the energy sector. The majorchallenges facing the energy systemensuring adequacy supply of energy services at low cost while mitigating adverse local and global environmental impacts will doubtless require further innovation (i.e., research, development, demonstration and deployment) in energy technologies.

Technological advances have driven the long evolutionof the energy sector, operating to increase energy'sbenefits while reducing its costs and risks. Such advanceshave expanded energy supplies, increased the efficiencyof transformation of raw energy resources into desirableend-use forms, improved the availability and quality ofenergy services while lowering their monetary costs, andreduced the adverse environmental impacts that resultfromenergy extraction, conversion, and use. But recenttrends in the organization of the energy sector in manycountries, combined with an increasing recognition ofthe urgency of traditional as well as new challengesfacing it, have raised concerns about national andinternational capabilities to bring forth adequate innovationsto meet those challenges in the decades ahead.

The confluence of several trends like fluctuating prices of energy, pressures on the short-term output leading to a shorter-term focus in industrial research efforts appears to bereshaping both the willingness and the capacity of theenergy sector to innovate.

The pace of technological innovation in energy technologies has shown large variations over time. More recently, due to climate change and energy security concerns, interest in alternative energy technologies has been growing once again.In recent years there has been a boom in energy innovation, as measured by patents, which is dominated by solar and wind conversion technologies.

Advances in technology are an important part of the solution. The technology advance can

- Reduce of the costs of energy end-use forms to consumers,
- reduce costs of energy services by increasing end-use efficiency
- Increase the productivity of manufacturing
- Reduce dependence on oil in the USA and elsewhere
- Increase the reliability &resilience of energy systemsagainst disruptions
- Minimize the environmentalimpacts of energy-resourceexploration, extraction, andtransport
- Reduce the emissions ofhazardous air pollutants
- Improve the safety andproliferation resistance ofnuclear energy
- Slow the build-up of greenhousegases
- Enhance the prospects forenvironmentally sustainable &politically stabilizing economicdevelopment

Benefits of technology advance in one's own country include

- lower cost & improved reliability of energy services
- reduced need for energy imports
- reduced local & regional environmental impacts of energy
- reduced risks from domestic nuclear-energy operations

Benefits of technology advance in all other countries include

- reduced world oil prices and vulnerability
- reduced transboundary pollution & greenhouse gases
- reduced transboundary nuclear risks
- economic & security benefits of sustainable development

Corresponding incentives for cooperation include

- increase the pace & reduce the cost of energy-technology innovationfor application in one's own country
- address the global dimensions of energy challenges by accelerated
- development & deployment of innovations worldwide

Despite importance of technology advances for energy systems, knowledge of how it works is limited. Learning by doing is an important part of technologyinnovation, but how it works and how it can be predictedremain inadequately understood.These shortcomings in our understanding imperil effectivepolicy-making. Lack of knowledge of how energy-technologyinnovation actually works has led to inadequate representation of theinnovation process in the energy-economic computer models used toforecast the results of different policy choices Reason for the limited knowledge is due to the below factors.

- The simplest measure of inputs to the innovation process isoutlays for energy R&D, but even these are poorly characterized –boundaries are fuzzy, private-sector data are incomplete.
- Output measures for R&D – publications, patents, performancemeasures for technologies, sales – are often difficult to correlatewith specific inputs.

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- The innovation "chain" – basic research, applied research, development,demonstration, diffusion – is more complex than once thoughtbecause of feedbacks and blurred boundaries.
- Progress from basic research to technology diffusion increasinglyinvolves partnerships & interactions, within and among sectors(firms, governments, universities, NGOs) that have scarcely beenmapped, not to say analyzed and understood.
- The phenomena that can lead to declining unit cost for a giventechnology over time are diverse and interactive.
- It remains difficult to sort out these phenomena analytically, for a particular technology

VII. RECOMMENDATIONS FOR BETTER GLOBAL INNOVATIVE SYSTEM

Current energy system is deficient in ways that can cause serious harm to our economy, our national security, and our environment. To correct these deficiencies, we must make a serious commitment to modernizing our energy system with cleaner, more efficient technologies. If we continue with the energy status quo, we will expose ourselves to risks that pose significant threats to our way of life.

A. Government involvement in energy

Government must play a key role in accelerating energy innovation. Government involvement is required since Innovations in energy technology can generate significant, quantifiable public benefits that are not reflected in the market price of energy. These benefits include cleaner air and improved public health, enhanced national security and international diplomacy, reduced risk of dangerous climate change, and protection from energy price shocks and related economic disruptions.

B. Strategy board setup and institutions

An independent national energy strategy board has to be created.The board should be external to the government, should include experts in energy technologies and associated markets, and should be politically neutral.

National Centers of Excellence in energy innovation should be created. Resourcesworking on the same problem should be within close proximity and not be spread across many institutions. These institutions should share operational objectives and be accountable to each other for results.

C. Energy RD&D spending and funding

Technology innovation requires expensive equipment, well-trained scientists, multi-year time horizons and flexibility in allocating funds. The energy business requires investments of capital at a scale that is beyond the risk threshold of most private-sector investors. The government must act to spur investments in energy innovation and mitigate risk for large-scale energy projects.

Funding should be set with multi-year commitments, managed according to well-defined performance goals, focused on technologies that can achieve significant scale, and be freed from political interference and earmarking.

D. Prioritize technologies

Technologies should be prioritized to attain maximum benefits. Priorities within this effort should go to technologies that

- increase efficiency of conversion & end use
- promote deployment of locally appropriate renewables
- respond to public concerns about nuclear energy
- allow carbon sequestration

There is vast room for improvement in our energy system. Energy innovation is a commitment to long-term prosperity.On the other hand, if we starve energy research, there is no doubt that there will have constrained future options.

VIII. PROCESS OF TECHNOLOGICAL INNOVATION

A. System Engineering

Systems engineering covers the whole of the development of a system, and deals with the management of the transformation of needs, expectations and constraints within a product and supporting them throughout the life cycle of the product. There are 3 steps in building an innovation system:

1) Systems Review

In order to develop the right innovation system we need to understand the current state of innovation in your organization by:

- Reviewing both formal and informal systems and processes
- Understanding attitudes to innovation, by interviewing key stakeholders and staff members
- Understanding the requirements and resources required – from a staff perspective
- Identifying the key outputs required

The problem when trying to formulate such a definition is that one can seem to be defining a different concept, in this case the concept of method as set out in existing definitions

2) Systems Design

Designing an innovation system that integrates and interfaces with your current processes, methods and strategies is important in ensuring continuity of information and effective delivery of innovation projects. The design process will:

- Provide you with an innovation systems model that interfaces and integrates with your current systems, processes and people

Scientific method refers to a body of techniques for investigating phenomena, acquiring new knowledge, or correcting and integrating previous knowledge

3) Systems Implementation

Once we have identified the best systems model for your organization, we can develop a better understanding of what systems and processes are currently available and what will best suit your requirements. This systems analysis will assist you to:

- Effectively integrate new systems with your current processes, programmes and platforms
- Create a detailed implementation plan for your innovation system

B. Artifacts of Software Engineering

1) Processes and information systems

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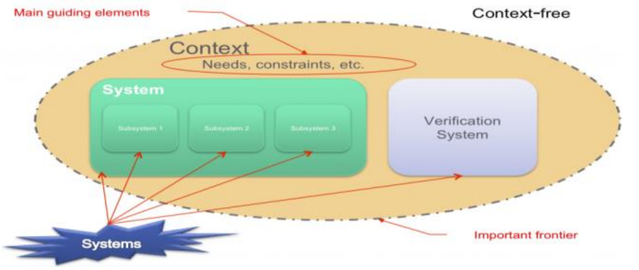
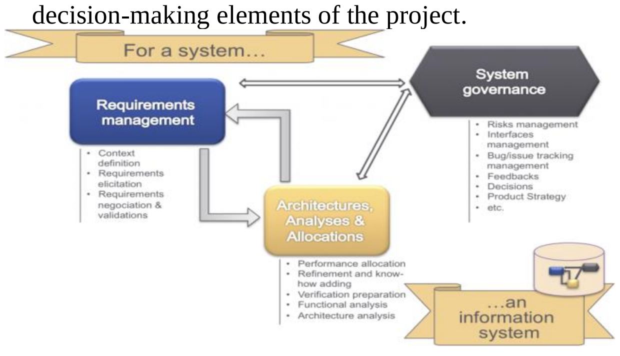


A widespread good practice in systems engineering is to consider that:

- The engineering of a given system is guided by a context which also needs to be defined.
- A system is made up of a set of sub-systems, each of which is an entirely independent system.
- A system must be verified using an appropriate system (set of procedures and resources for verification).

Three basic interactive processes may be distinguished in systems engineering, and each of these processes will deal with its own artifacts:

- Requirements management (or context management), which is fundamental because it defines the elements which will enable us to guide and monitor the activities involved in engineering a system.
- Architecture, analysis and allocation, which is the core activity of systems engineering, in that it produces the modelling artifacts for the system under consideration.
- System governance, which deals with the decision-making elements of the project.



Carrying out these processes leads to an information system whose purpose is to manage the coherence of the artifacts processed during the life cycle of a system.

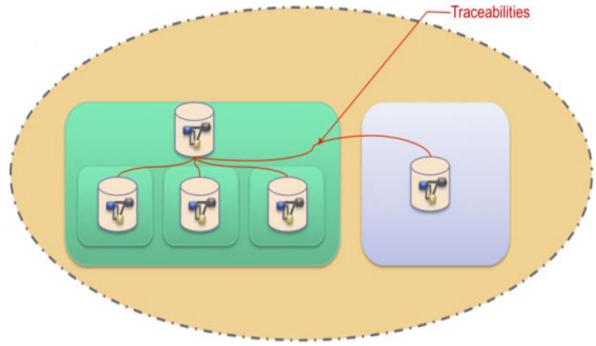
2) Cross-system traceability

As mentioned above, all systems (systems, subsystems and verification systems) have their own process and their own information system.

This is justified above all by the differences which may exist between these systems with regard to:

- teams involved;
- delivery milestones;
- level of maturity in engineering techniques;
- resources (tools) to support the information system;
- protection of industrial property on which some of the artifacts of a system may be based, by the organization responsible for their engineering.

For these reasons it is important to maintain a system to provide traceability between the different information systems:



3) Standards and architecture frameworks in systems engineering:

There are numerous standards available to help you understand, disseminate and support systems engineering, which:

- specify the objectives which need to be reached when introducing systems engineering (and particularly the processes),
- and provide accepted terminology.

a) Standards

The main relevant international and industry standards according to the French chapter of the INCOSE, (AFIS:www.afis.fr) are as follows:

- IEEE 1220:

Derived from the military standard MIL STD 499B, this IEEE standard, first published in 1994, focuses on technical systems engineering processes from requirements analysis to physical system definition.

The three processes of requirements analysis, functional analysis, allocation and synthesis, are highly detailed, and each contain verification or validation sub-processes.

The aim of the system analysis process is to analyse problems (conflicting requirements or alternative solutions) arising from the main processes in a multidisciplinary framework in order to facilitate decision-making.

The Information Systems Control process relates particularly to the technical management of systems engineering and the control of both system and project information.

- EIA 632:

This EIA standard supplements technical system definition processes, covering product implementation through to go-live (user handover). It also includes contract processes for purchase and supply.

The technical and contractual processes are framed:

i. by management processes (in their traditional form with the three subprocesses of planning, assessment, management)
ii. and by processes for evaluating the outputs of activities (verification process to verify that the activity was performed and validation process to verify that the output matches the requirement, these two processes together supplying evidence of conformity; together with system analysis processes covering choices made throughout the definition and thus optimisation of the system).

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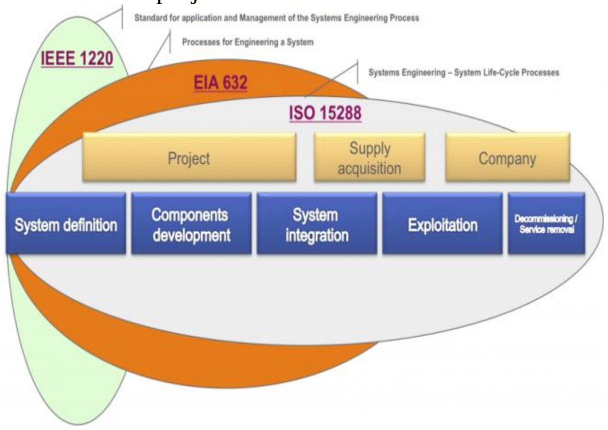
- ISO 15288:

This ISO standard, which was inspired in its form by ISO/CEI 12207–AFNOR Z 67-150 (Typology of software life cycle processes), was first published in 2003 and reviewed in 2008.It extends technical processes to the whole system life cycle, covering operations, operational maintenance and end-of-life processes.

This standard applies to the engineering of contributing systems which have their own life cycle (e.g. manufacturing, deployment, logistical support and decommissioning systems): an example would be the engineering of dismantling and waste processing systems for a nuclear installation.

It supplements project-related processes with “business” processes and whose purpose is to develop the potential of the IS organization by managing shared fields of activity to the benefit of IS projects.



b) Architecture frameworks

In addition to the standards focusing on “what”, there are also architecture frameworks, which deal with “how”.

Although these were only initially created for use with large projects, an architecture framework is essential in systems engineering and should always be present with a greater or lesser degree of formal definition depending on the project size within any organizationpracticing systems engineering.

An architecture framework enables one to specify/rationalize the resources which need to be implemented to control a systems engineering information system by setting a framework for describing an architecture and communicating/sharing around that architecture.

There even exists a standard defining what a system architecture should contain, and its associated framework: ISO/IEC/IEEE 42010.

4) Choosing deployment objectives

Deploying systems engineering in an organisation means setting up a toolkit (tools + methods).

This toolkit needs to be specified but before you specify your systems engineering toolkit, it is very important to set down what its guiding principles are:

a) Setting the guiding principles

As systems engineering depends fundamentally on collaboration between the various specialisms involved in developing a system, it seems natural that the watchword for a systems engineering toolkit should be “communication”, and this should be the basis around which the guiding principles are defined:

i. Communication in the systems engineering toolkit

This comes down to selecting which basic process (requirements management, architecture, analysis and allocation, system governance) holds the artifacts which will mainly be exchanged between the specialisms involved in systems engineering.

ii. Requirements-driven systems engineering

The concept of “requirement” is one which is easy to share, as it is very often associated with natural language and a consensus-based style of project documentation.For this reason, organizations offer relatively little resistance to change when systems engineering is deployed in this mode.Another aspect which makes this the most commonly chosen mode of deployment is that the need to deploy systems engineering in the organization coincides with a new need on the contractual relationship management front (this may be with the organization’s customers just as well as sub-contractors).If there is one artifact that is well suited to support contract management, it is the requirement.

One factor which can hold back the application of systems engineering in this mode, particularly in southern Europe, is the perception that the implementation of requirements-led systems engineering is not sufficiently technical or practically-oriented, and that in any case, contracts and specifications have always been successfully produced up to now.Implementing requirements-led systems engineering is thus perceived as an information system for quality and management teams, rather than as a tool for the systems engineer.

This attitude becomes less marked when an organization is also faced with new challenges to do with setting up multi-project specifications and contracts (controlled reuse, management of product lines, sophisticated configuration management).

iii. Model-driven systems engineering

This is the mode in which the greatest productivity gains can very clearly be obtained, which accounts for the buzz over the past ten years in the system engineering community around model-based systems engineering, or MBSE

This mode takes its techniques and tools from the world of software engineering (model transformations, model annotation, meta-modelling, ontologies, information systems “urbanization”, architecture frameworks), and has the advantage of being directly applicable to systems engineers in their day-to-day activities.

This mode of deployment also benefits from the marketing cachet of techniques with a high reputation (simulations, numerical models, etc.)

The flip side is that return on investment in this mode of deployment takes a relatively long time to realize:

- difficulty of obtaining consensus on the definition of business meta-models
- selection/customization of different tools for each meta-model/business area
- inevitable need to redesign training on systems engineering processes.

This mode can of course be applied incrementally if a genuine systems engineering deployment plan is put together in advance and is part of the organization’s master plan.

iv. Feedback-driven systems engineering

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This mode of deployment is extremely effective if the quality of the system can only be assessed effectively when it is used in practice, for example a system to implement paperless business processes, or if a system is developed using an "agile" approach (Scrum, etc.).The watchword here is pragmatism, and feedback can be something very practical and reliable which very rapidly builds into a high-quality knowledge base.This mode also has the advantage of being minimally intrusive with regard to existing systems engineering techniques.However the danger is that one can lose control of this knowledge base if a clear strategy for its use is not defined.Another negative aspect of a feedback-based approach is that feedback is generally "negative". (People are naturally more inclined to say what doesn't work, hoping that this will help to get things changed, than to say what works well.) Hence it is important that the deployment should provide means to encourage positive feedback:In summary, this mode goes together with selecting the "system governance" process as the reference process; it is also very important not to confuse "governance" with "monitoring".

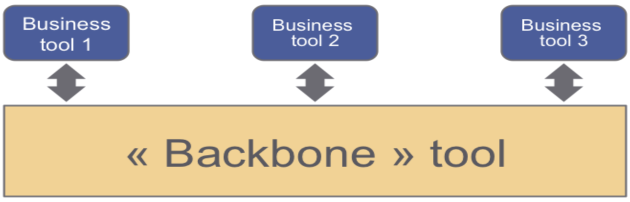
v. Communicating toolkit within the organization

This point is all too often underestimated. Deploying systems engineering processes within an organization requires a deployment plan to have been defined in advance, ideally as part of a master plan. Without substantial internal communication about the project, and the value of the effort required from those involved in improving/introducing systems engineering processes is not made sufficiently clear, the odds are that as soon as systems engineers are under pressure to deliver, the deployment process will stagnate and may even degrade the efficiency of the processes.

b) Building the information system:

Two types of information system architecture can be defined to support systems engineering:

i. Backbone architecture

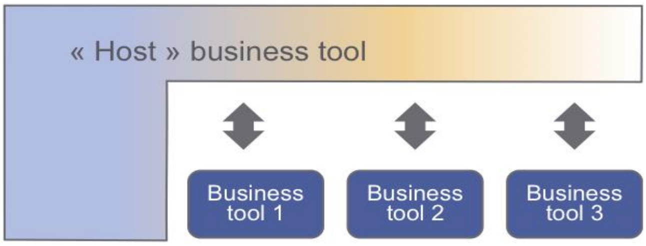


In this architecture, one can focus on one or more aspects of systems engineering (requirements management; architecture, analysis and allocation; governance).If this type of architecture is chosen, the tool selected to act as the backbone must have good facilities for:

- customization, so that business tools can be integrated without difficulty;
- security, so that access and permissions for all stakeholders in the systems engineering can be efficiently managed;
- handling distributed data, as the information system must be prepared to deal with "transverse" data which is distributed over a number of servers, or at least accessible from different sites;
- traceability, so that the links between systems and sub-systems can be managed;
- configuration management, to provide efficient means to manage reuse and variability (product line management) of Systems engineering artifacts.

This architecture is unquestionably the most durable and the most reliable in the long run, but is relatively costly in the early phases of deployment, and requires substantial commitment from company management.

ii. Host architecture



Another approach consists of selecting a tool which is fundamentally oriented towards a particular aspect of systems engineering (requirements management, architecture, analysis and allocation, governance):

A "host" business tool must have sufficiently robust capabilities in the following areas:

- the tool should have modules offering a solution (even if cursory) for other aspects of systems engineering (requirements management, architecture, analysis and allocation, governance);
- good facilities for customisation and adaptation, so as to integrate other tools or modify existing functionality;
- good security features for data managed by the tool.
- This architecture allows small-scale (project-oriented) deployment which may be relevant in that:
- deployment is based on a generally familiar business tool, which is generally centred on the " main " business line;
- deployment costs are generally better known and lower.

But it is important to keep in mind that such an architecture has its limitations with regard to adaptability:

- when it comes to a wider deployment, and particularly where the day-to-day use of a tool designed for one specialism needs to be "sold" to other specialisms;
- when the artifacts produced need to be reused, and variants managed.

IX. CONCLUSION

The world is facing major challenges in providing energy services to meet the future needs of the developed worldand the growing needs of developing countries. Need for innovation systems is the need of the hour. All innovation systems can be characterized by the same basic building blocks or components. These are actors, institutions, networks and technology.Technology is part of the innovation system as it enables and constrains the activities of actors in the innovation system.The important difference with the structure of the innovation system is that these system functions are much more evaluative in character. Focusing on functions allows us to address the performance of an innovation system. Building an innovation system involves three steps system review, design and implementation.

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