

## Executive Summary

**A. Introduction:** There is always need for systematic statistics for evidence based S&T policy. This project is devoted to contribute some of the understanding towards this process of policy formulation. S&T sector is always a dynamic & evolving, thus there is a need to shift from overall assessment of S&T sector towards evaluation of R&D activities, spillovers from these activities in respective thematic areas leading towards more specific innovation indicators linking R&D activities to improving quality of processes and products, aimed at not only successful commercialization but also contributing to human development and sustainability.

Though developing countries greatly need and demand cross-nationally comparable R&D statistics at the global level, there is lack of willingness to provide and share information by institutions, universities and industries. Also, there is a lack of demand by policy makers and other users i.e. industry associations, think tanks, academia which contributed to lack of motivation and scarcity of R&D statistics. Indicators should not be seen as the sole source of information. In the case of developing countries, here is a whole body of knowledge regarding the STI systems missing or only occasionally available. While R&D statistics are widely seen as a relevant tool for evidence-based policy-making, high-level demand for these statistics is still far from being universal". Globally, "Researchers have moved from the simple concepts of inputs and outputs to concepts of inputs, throughputs, outputs, and impacts at *various stages of the process*. Therefore according to recent studies there has to be effort to move away and beyond the simplistic indicators which give partial picture of R&D and its utility.

**B. Significance of R&D Output Indicators:** The challenge of the project was not only to understand the trends of innovative activity over time but also the factors influencing them. Developing a systems approach which enables the researchers and policymakers to integrate the actors and the activity inside the system. Activity includes R&D, invention, innovation, diffusion of practices or technologies, and human resource development. Larger aim of the project lies in the outcome/output and long term impacts on socio-economic development.

Project addresses the urgent need to measure/create indicators which are more relevant to R&D and also examine more closely the possibility of linking these *output indicators* to that of *innovation indicators*. Developing indicators that show openness to national and international competition, ease of entry of firms (domestic and foreign) in an economy, capture regulatory barriers. Capturing knowledge creation and diffusion within innovation system is crucial to map the indicators. Measuring the varied

Benchmarks, Regulation/Compliance Benchmarks. All the newly identified indicators were classified according to these nine broad categories so as to connect them to nearest possible techno-industrial activity.

Some of the trends which were recorded as major attributes of emerging indicators during the process of brainstorming sessions, interviews with academic experts and through response sheets are:

- 1) Process, Methods and Instruments contributing to enhancement of efficiency of scientific activities, projects and organization: Efficiency in terms of time and cost
- 2) Degree of user-customer satisfaction and user participation in research-development planning
- 3) Different levels of compliances in terms of regulation, competition, market trends, technology benchmarks/standards
- 4) Capability development through state of the art technology, testing and laboratory infrastructure facilities
- 5) Linkages of technology transfer, prototype development and *novel* commercialization techniques
- 6) Innovation in designing of product
- 7) Innovation in delivery of services especially in Information Technology/Telecom and Pharma/Biotech
- 8) Rate of product/service development (with respect to technology obsolescence)
- 9) Energy efficiency
- 10) Periodic assessment/evaluation mechanism of projects, experiments, R&D activities
- 11) Sponsored research projects operational in organization
- 12) Collaborations in skill building, capacity development of scientists through exchange of intellectual and technology resources
- 13) Contribution in niche area of specialized knowledge field through publications & patents (typically traditional indicator but important to reemphasize it because of its form of codified knowledge form)
- 14) Introduction of diversity of products and services and its frequency
- 15) Technology enhancements to reshape the industry standards/benchmarks
- 16) Correlation between amount of funding and its outcome in terms of knowledge, revenue and socio-economic impact (New indicator measuring contribution to knowledge system and social welfare *vis-à-vis* funding pattern needs to be defined)

- 17) Employment generated due to particular technology, product and service developed, marketed and diffused
- 18) Legal documents depicting licensing, technology transfer, compliance certificates, Non Disclosure Agreements, Infringement Suit, Non-infringement agreement

**E) Common and comprehensive Indicators across different sectors, R&D labs derived through brainstorming sessions, response sheets and interviews of senior scientists of public R&D labs are categorized as under:-**

**1) Human Resource:**

- 1) Number and types of fellowships being won by Research students/experts in institutions
- 2) Internal training system
- 3) Presentation of research paper in reputed conferences
- 4) Mobility of researchers between institutes and industries
- 5) Ph.D. scholars and Post Doctoral Students graduated
- 6) Membership of National/International Academies of Sciences and Engineering
- 7) National/International Awards Scientific/Technological Excellence

**2) Technology:**

- 1) Development of process specific instruments (Advanced manufacturing)
- 2) New drug discovery, delivery systems and manufacturing of drugs (Pharma)
- 3) Laboratory/ Experimentation testing methods/processes, technology evaluation facilities
- 4) Technology infrastructure (all sectors)
- 5) Computational Simulation facilities available for designing of products
- 6) Number of pilot projects in operation
- 7) Number of spin offs
- 8) Fuel efficient products/services
- 9) Technical consultancy services provided
- 10) Technologies transferred
- 11) Prototype manufacturing facility setup
- 12) Technology Incubators (for entrepreneurship development)
- 13) Field trials conducted

**3) Impact (Economic / Trade / Market / Social Impact):**

- 1) Commercialization of prototypes
- 2) Acquisition of know how (Cost of know how paid/ compensation paid)

- 3) Return on investments
- 4) R&D Intensity
- 5) Licensing fees
- 6) Royalties generated
- 7) Employment generated
- 8) Empowerment
- 9) Access
- 10) Equity and inclusion
- 11) Affordability
- 12) Relevance

**4) Knowledge:**

- 1) Citations for research paper published
- 2) Original Research Paper published in peer reviewed journals
- 3) Average impact factor of research publications

**5) Intellectual Property Rights:**

- 1) Ability to secure/protect Intellectual Property
- 2) Number of patents/utility patents, copyrights, designs, trademarks filed
- 3) Number of patents/utility patents, copyrights, designs, trademarks secured
- 4) Number of patents/utility patents, copyrights, designs, trademarks commercialized

**6) Management/Planning/Collaboration:**

- 1) Project review mechanisms
- 2) Participation in industrial clusters/ collaborations/consortiums
- 3) Participation in academic collaboration
- 4) Technology assets/laboratory facilities sharing
- 5) High quality benchmarks for product development
- 6) Non Disclosure Agreements
- 7) Intramural and Extramural projects in operation

**7) Performance benchmarks:**

- 1) Cost reduction
- 2) Time period in which research/manufacturing project is completed
- 3) International benchmarks being followed by R&D organization

**8) User Benchmarks (User satisfaction/user adaptation):**

- 1) Customer rating
- 2) User satisfaction
- 3) Compatibility of user's convenience standards

**9) Regulation/Compliance:**

- 1) Compliance of sustainability/environment friendly standards
- 2) Regulatory/Certification filings (pharma sector)

There are multiple roles that indicators play from time to time like *informing policy* (comparison of research institutions, countries, etc.), for evaluation (Research evaluation, Indicators in grant allocation processes), for strategic positioning, Indicators for foresight (Mapping knowledge dynamics), Indicators for visibility of work (citations, patents and other outputs of knowledge); possible indicators compiled out of brainstorming sessions, interviews and response sheets are distilled as mentioned above. To make credible assessment of the investment and impact of S&T system, agencies, institutions, networks, actors and channels involved in R&D, the all these roles need to be complemented with robust data which is reportable, verifiable and assessable for larger input to evidence based policy planning. Then and then only it is possible to push the debate about *indicator driven* S&T policy planning and performance evaluation of R&D activities in system.

A brief summary of emerging & evolving indicators of scientific research and development captured through primary survey have been summarized in the table which follows in the subsequent pages.

| <b>Emerging and Evolving Indicators of Research and Development – Generic Perspective</b> |                               |  |  |  |
|---|-------------------------------|--|--|--|
| <b>Sr. No.</b>  | <b>Category of Indicators</b> | <b>Sub-category</b>  | <b>Elementary Steps of R&amp;D Cycle</b> | <b>Identified Indicators</b>   |
| <b>1.</b>   | <b>Human Resources</b>        | <b>i) Capacity Building (Knowledge /Skills)</b>                                      |  |  |
|   |                               | <b>ii) Human Resource Transfer (Foreign faculty and Scientists)</b>                  | Input/Output                             |  |
|   |                               |  | Input                                    | 1. PhD program   |
|   |                               |  | Process                                  | 2. Skill enhancement by way of workshops, seminars & trainings   |
|   |                               |  | Input                                    | 3. Periodic and structured cross-functional review meeting to monitor the progress of R&D  |
|   |                               |  | Input                                    | 4. Number of doctorates/engineers hired / R&D manpower: Size, Qualification and skills   |
|   |                               |  | Input                                    | 5. National & International Seminars /Symposium attended by R&D staff  |
|   |                               |  | Input                                    | 6. Presentation of papers in national /international technical forums  |
|   |                               |  | Input                                    | 7. Number of R&D personnel employed  |
|   |                               |  | Input                                    | 8. Number and types of fellowships being won by Research students/experts in institutions  |
|   |                               |  | Input (intangible)                       | 9. Freedom and Facilitation for Research   |
|   |                               |  | Input                                    | 10. Number of Emeritus Scientists in Position / Pool Scientists in position  |
|   |                               |  | Output                                   | 11. Number of Awardees of National Recognition: i. S.S. Bhatnagar, ii. Padma Awardees (cumulative)   |
| <b>2.</b>   | <b>Technology</b>             | <b>i) Superior technology innovations /development</b>                               | Process                                  | 1. Type of R&D being performed. Process/Innovative /Inventive R&D  |
|   |                               | <b>ii) Technology Infrastructure</b>   | Output                                   | 2. New technology introduction and solution with improved quality, reliability and low cost  |
|   |                               | <b>iii) Technology Transfer (No. of New Products developed from same technology)</b> | Output                                   | 3. New technology initiatives (eg. biocatalysis, supercritical fluid technology, use of ionic technology, nanotechnology, green chemistry) |

|  |  |  |                |   |
|--|--|--|----------------|---|
|  |  | <b>iv) Consultancy Services rendered</b>                 | Input/Process  | 4. Development of technology and filing of patent   |
|  |  | <b>v) Adaptation of tools and advance systems</b>        | Process/output | 5. Transfer of Process for production of recombinant – technology to private industry / New process development transferred   |
|  |  | <b>vi) Incubators (for entrepreneurship development)</b> | Process/output | 6. Developing complex technologies and complex molecules  |
|  |  | <b>vii) Technology Evaluation</b>                        | Output         | 7. Percentage utilization of your lab equipments/capital assets/databases   |
|  |  |  | Process        | 8. Fairly well equipped facility that includes bacteriology, serology, virology, cell culture, pathology and molecular biology  |
|  |  |  | Output         | 9. Technology transfer/transfer of intellectual know how to different products / Technological know hows, processes, management systems / Number of technology transfers leading to filing new technology initiative applications |
|  |  |  | Output         | 10. Development technology which is transferred to the commercial partner and which is successfully commercialized  |
|  |  |  | Process/output | 11. Energy consumption in communication equipments per operation  |
|  |  |  | Outcome        | 12. Open Innovation   |
|  |  |  | Process/output | 13. Labs for development and testing  |
|  |  |  | Output         | 14. Development of standards, increased strength of organization.   |
|  |  |  | Output         | 15. New technologies like hybrid developed  |
|  |  |  | Output         | 16. Product design and Development  |
|  |  |  | Process/output | 17. Design & conceptualization of products  |
|  |  |  | Output         | 18. Alternate & light weight material development through advance plastic & material technologies   |
|  |  |  | Output         | 19. Development of process specific instruments   |
|  |  |  | Process/output | 20. Internal Experimentation/ Lab infrastructure  |
|  |  |  | Process/output | 21. Prototype Manufacturing capability  |
|  |  |  | Output         | 22. Technology successfully licensed  |
|  |  |  | Output         | 23. Milestones in technology development  |
|  |  |  | Output         | 24. Number of invention disclosure  |
|  |  |  | Process/Output | 25. Field trials  |
|  |  |  | Output         | 26. Translation of basic research   |
|  |  |  | Output         | 27. Total number of projects  |

|    |                          |  |                 |  |
|----|--------------------------|--|-----------------|--|
| 3. | <b>Impact Indicators</b> | <b>Economic/Trade /Market Impact (see details at annexure 1.1)</b> | Input/output    | 1. Number of firms operating in the sector   |
|    |                          |  | Input           | 2. Return on investment on the expenditure in R&D  |
|    |                          |  | Output          | 3. To generate cost-effective resources  |
|    |                          |  | Output          | 4. Has the R&D effort resulted in a reduction of cost  |
|    |                          |  | Output/outcome  | 5. A new product that the market has accepted / Demand driven new Product Development  |
|    |                          |  | Output          | 6. Commercialization of R&D in terms of manufacturing and product creation   |
|    |                          |  | Output          | 7. Capability upgradation : R&D expenditures- Past, current, future  |
|    |                          |  | Output          | 8. Localization/Internationalization of design and components, import substitution   |
|    |                          |  | Output          | 9. Number of patents filed and the revenue earned  |
|    |                          |  | Output          | 10. License fee  |
|    |                          |  | Output          | 11. Royalties  |
|    |                          |  | Output          | 12. Total earnings from projects done for Indian & foreign business/industry (Rs. In crore) (industrial ECF, excluding Grant-in-Aid) |
|    |                          |  | Output          | 13. Development, transfer and diffusion of marketable technology   |
|    |                          |  | Process/output  | 14. Sponsored research projects (DST/DBT /ICAR/ICMR etc.)  |
| 4. |                          | <b>Social Impact (see details at annexure 1.1)</b>                 | Output          | 1) Technology outreach or demonstration (for public good, commercialization for promotion) / Accessibility of research               |
|    |                          |  | Process         | 2) Cost-effective affordable and quality products  |
|    |                          |  | Output          | 3) Diffusion of technology for social benefit  |
|    |                          |  | Output/ outcome | 4) Lowest cost of service  |
|    |                          |  | Outcome         | 5) Protection of environment   |
|    |                          |  | Input/outcome   | 6) Accessibility of research   |
|    |                          |  | Outcome         | 7) Solution to real life problems  |
|    |                          |  | Output          | 8) Opportunities of self employment generated  |
|    |                          |  | Process         | 9) Projects of development research  |
|    |                          |  | Output/outcome  | 10) Customer satisfaction  |



|    |   |   |               |   |
|----|---|---|---------------|---|
| 5. | <b>Knowledge Indicators (see details at annexure 1.1)</b> |   | Output        | 1) Publishing in peer reviewed and or high impact factor journals   |
|    |   |   | Output        | 2) Patents  |
|    |   |   | Output        | 3) Number of technical papers accepted /presented for publication [in leading Journal/Conference];i) International Journals/Book Chapter, ii) National Journals/Book Chapter  |
|    |   |   | Output        | 4) Number of articles published [in Recognized Magazine/Newspaper]; i) International  |
|    |   |   | Output        | 5) Acquisition of know how  |
|    |   |   | Output        | 6) Type of research paper cited (Idea paper, Method paper, Research Communication, Commentary, Opinion, Original Theoretical Paper, Empirical Paper and no. of pages of research communication) / Frequency and type of citation (Self-citation, Co-citation, Cross Reference, Forward Citation, Backward Citation) |
|    |   |   | Output        | 7) Generation of new knowledge & technology   |
|    |   |   |               | 8) Laboratory manuals developed   |
|    |   |   | Output        | 9) Membership of major international academies and learned societies / Membership of editorial boards of international peer reviewed journals   |
| 6. | <b>Intellectual Property Rights</b>                       | <b>i) Patents,<br/>ii) Copyrights,<br/>iii) Trademarks,<br/>iv) Utility models,<br/>v) Industrial designs</b> | Output        |   |
|    |   |   | Output        | 1. Non Disclosure Agreements with partners  |
|    |   |   | Output        | 2. Number of patents granted (National);<br>i) Patents granted, ii) Patents rejected,<br>iii) Patents withdrawn   |
|    |   |   | Output        | 3. Number of patents filed (International);<br>i) Provisional patents filed,<br>ii) Patents with full specification   |
|    |   |   | Output        | 4. Number of foreign patents filed and granted  |
| 7. | <b>Management / Planning/ Collaboration Practices</b>     |   | Input/outcome | 1) Collaboration with industries for commercialization  |

|            |                               |   |                 |   |
|------------|-------------------------------|---|-----------------|---|
|            |                               |   | Output/outcome  | 2) Generation of funds for the R&D activity   |
|            |                               |   | Output/outcome  | 3) Potential to attract R&D funding   |
|            |                               |   | Input/process   | 4) Minimal Financial support by government funding agencies   |
|            |                               |   | Input           | 5) Periodic/weekly plan for execution of R&D projects   |
|            |                               |   | Process         | 6) Client satisfaction Survey Parameters are:<br>i) Product overall satisfaction, ii) Likely to buy again, iii) Product recommendation, iv) Competitor satisfaction / Capturing customer need, technology trends is the focus area at conceptualization stage |
|            |                               |   | Output/outcome  | 7) In house IPR department which protects Intellectual property and know how generated  |
|            |                               |   | Process         | 8) Engagement/outsourcing with contract R&D firms   |
|            |                               |   | Process/output  | 9) New project development system (NPDS)  |
|            |                               |   | Input/process   | 10) Collaborative research projects / Industry sponsored projects   |
|            |                               |   | Input/process   | 11) Technology assessment and planning activities   |
|            |                               |   | Process/output  | 12) Extramural funding of the project   |
| <b>8.</b>  | <b>Performance Benchmarks</b> | <b>Higher Performance, better functionality, Wider applications</b> | Input/process   | 1) Completed projects translated in manufactured products which give leading technology edge vis-à-vis competitors  |
|            |                               |   | Output          | 2) Has the R&D effort resulted in an improved efficacy that has consequently resulted in an improvement of our bottom line  |
|            |                               |   | Outcome         | 3) How many deliverables were on time as per contract and as per committed terms, conditions and quality  |
|            |                               |   | Output          | 4) Product enhancements system / Performance enhancement  |
|            |                               |   | Input/process   | 5) Development of new benchmarks and standards  |
| <b>9.</b>  | <b>User Benchmarks</b>        | <b>User friendly</b>  | Output          | 1) How much ease and compatibility any application, process or product has in particular area of operation  |
|            |                               |   | Process/outcome | 2) Customer satisfaction index, Commercialization of prototypes and making technology user friendly   |
|            |                               |   | Output          | 3) Customer driven innovations  |
| <b>10.</b> | <b>Regulation /Compliance</b> |   | Outcome         | 1. Guidelines laid out by the regulatory authorities at every juncture  |

|  |  |  |                |   |
|--|--|--|----------------|---|
|  |  |  | Output         | 2. Number of DMF certification applications filed / ANDA certification applications filed (Biotech) |
|  |  |  | Output         | 3. Compliance with WHO standards  |
|  |  |  | Output/outcome | 4. Time duration for Pilot production, trials regulatory approval and commercial production         |
|  |  |  | Output/outcome | 5. Global Regulatory compliance solution design & evaluation  |