# An Informational Model as a Guideline to Design Sustainable Green SLA (GSLA)

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***Abstract*—Recently, Service Level Agreement (SLA) and green SLA (GSLA) becomes very important for both the service providers/vendors and as well as for the users/customers. There are many ways to inform users/customers about various services with its inherent execution functionalities and even non-functional/Quality of Service (QoS) aspects through SLAs. However, these basic SLAs actually do not cover eco-efficient green issues or IT ethics issues for sustainable development. That is why green SLA (GSLA) already came into play for achieving sustainability in the industry. Nevertheless, the current practice of GSLA in the industry do not respect the sustainability at all. GSLA defined as a formal agreement incorporating all the traditional commitments respecting some green computing parameters such as carbon footprint, energy consumption etc. Therefore, there are still gaps for achieving sustainability through existing GSLA. To reach the goal of achieving sustainability and getting more customers, many IT (Information Technology) and ICT (Information and Communication Technology) business are looking for a real GSLA which would meet the ecological, economical and ethical aspects (3Es) of sustainability. This research discovers the missing parameters and introduce new parameters under sustainability hoods. In addition, it defines GSLA of sustainability with new green performance indicators and their measurable units. It also discovers the management complexity of proposed new GSLA through designing a general informational model and identifies various new entities and their effects with other entities under three pillars of sustainability. The ICT engineer could use the informational model as a guideline to design a sustainable GSLA for the industry. Therefore, the proposed model could help different service providers/vendors to define their future business strategies for the upcoming sustainable society.**

***Keywords*—SLA; GSLA; Green Computing; Sustainability; IT ethics; Informational model**

## I. INTRODUCTION

Nowadays, cloud and grid computing and many data centers acts as most promising service providers. These computing and communication industry provides different services in compare to traditional computing with some scalability benefits. At the same time, cloud services are offered at various levels: Infrastructure, Platform and Software as a Service [1, 2]. At each level, they maintain a SLA with respect to their parties. SLA is defined as a formal document between an IT service provider and one or more customer outlining Service Commitment [3]. The main issue is that most of these traditional/basic SLA actually do not cover eco-efficient green issues. The growth rate of SLA in recent time is increasing as well as the need of GSLA for actual sustainability achievement in IT industry [4]. Presently, the revolution of ICTs and ITs in daily average life has also resulted in the increase of Green House Gas (GHG), due to continual increase in global "carbon footprint''. In 2007, the ICT sector produced as much GHG as the aero industry and is projected to grow rapidly [5, 6]. If ICT has a negative impact on environment, it can be also be used for greening the other human activities (logistic, city, industry etc) in this new society. Indeed, the dimensions of green informatics and green computing contributions are: the reduction of energy consumption, the rise of environmental awareness, the effective communication for environmental issues and the environmental monitoring and surveillance systems, as a means to protect and restore natural ecosystems potential [7]. At the same time, many IT and ICT industries or service providers need to think about their business scope in the light of green perspective to achieve sustainability. However, the IT and ICT sectors mostly concern about energy or power consumption, carbon, recycling and productivity issues under greening computing lens whereas the practicing of sustainability is still far away from reality. In addition, most of the recent IT and ICT industries overlooked many green parameters under sustainability lens due lack of proper guidance to identify new parameters. Therefore, with the increase attention that green informatics and sustainability practice within our society, it is timely to not only conduct SLAs for traditional/basic computing performance metrics or only on energy or carbon footprint issues, but also to relate the effort of conducting green computing with respect to 3Es of (Ecology, Economy and Ethics) sustainability pillars [4]. Therefore, the journey of sustainable GSLA is getting importance in ICT business world. This research digs down for finding more new green performance indicators for developing a new sustainable GSLA under three pillars. In addition, a new GSLA proposed, which covers all the existing green performance indicators as well as some other missing indicators covering three pillars of sustainability. Finally, GSLA research demonstrates the management complexity of interactions between all the performance indicators using an informational model and also tries to analyze all relationships and different level of effects for most of the green parameters to achieve sustainable GSLA.

The rest of the work is organized as follows- the next background section discusses briefly about existing theory and practical works on basic SLA and GSLA's form different service providers. The existing GSLA subsection actually shows currents trends of the industry to practice sustainability under greening lens. The identification of new green

indicators section discovers the most important missing performance indicators for future sustainable GSLA under 3Es of sustainability pillars. Moreover, defining new GSLA using informational model section helps the ICT engineers to define and manage future sustainable GSLA with newly identified missing green parameters to respect true sustainability. Finally, the conclusion gives brief discussion about few challenges and future plan of this sustainable GSLA research.

## II. Background Study

The details literature review and analysis are based on existing work in the field of SLA, GSLA, green computing, energy optimization in IT industry, impact of ICT on environment and natural resource, IT ethics issues, IT for Sustainability etc. In the findings, GSLA research divides its work based on basic SLA and then existing GSLA for different types of services from their providers. The rigorous literature review and their details analysis for SLAs found in [4].

### A. Basic SLAs

In the findings on existing empirical work, firstly this research splits its outcomes based on basic SLAs for different types of domain from various providers such as Network, Compute, Storage and Multimedia [8]. Most of the performance indicators in basic SLA sections are quantitative parameters and they are simple to evaluate, control and monitor. Thus, it is easy to respect most of the basic performance indicators from both customer and providers side. In addition, there is no eco-efficient green parameters included in basic/traditional SLA parameters.

*SLA for Network, Compute, Storage and Multimedia domain:*

The basic SLAs for network specifies service level commitments which are applied to measure and evaluate network performance and give proper support for their clients. Usually, from different network service provider, the following performance indicators found in their SLAs are [4]- *Network Availability, Delay, Latency, Packet Delivery Ratio, Jitter, Congestion, Flow Completion time, Response time, Bandwidth, Utilization, MTBF (Mean Time Between Failure), MTRS (Mean Time to Restore Services), Solution time, Resolution time, LAN/WAN period of operation, LAN/WAN Service Time, Internet access across Firewall, RAS (Remote access Services).* Some indicators like *Bandwidth, Utilization, and Congestion* are related to link capacity whereas *Availability, Delay, Jitter, Response Time* etc. associated with time related information for different network service providers.

Most the cloud, grid service companies provides computing service to their consumers. The basic SLA parameter and their measurement unit for computing domains are [4], -: *Broad Network Accessibility, Multi-tenancy, Rapid Elasticity, Scalability, Resource Pooling Time, Solution Time, Response Time, Availability (MTBF & MTTR), Capacity, Virtualization, Delay, Resolution Time and Logging & Monitoring.* Here, *Broad Network Accessibility, Multi-tenancy* and *Logging & Monitoring* are informative indicators presented in their SLAs.

The storage domains are typically handled by cloud storage provider. Interestingly, today's cloud storage SLAs just ensure uptime guarantee but not data availability and data protection. In some case, traditional SLAs just mention about data storage security and backup but there is no proper authority or standard to check their commitments. Some common basic SLA performance indicator [4] for storage services are as follows-: *Availability, Response Time, Maximum Down Time, Uptime, Failure Frequency, Period of Operation, Service Time, Accessibility, Backup, Physical Storage Backup, Transportation for Backup, Size, Data Accessibility, Security.*

Multimedia service domain SLAs are classified into three broad application areas- Audio, Video and Data. It is challenging to monitor and evaluate some qualitative indicator such as *Mean Opinion Score (MOS)* and *Lip Synchronization* for one-way video, conferencing or in videophone. Most of the SLA indicators for multimedia domain for different applications are *Information Loss (PLR), Jitter, One-way Delay, MOS, Lip Synchronization,* and *Security Policy* [4].

### B. Existing GSLAs

Currently, several IT and ICT industries, cloud providers provide their GSLAs under green computing practice. Here, recent GSLAs are mainly focused only on energy/ power, carbon footprint, green energy, recycling issues. Additionally, several existing GSLA also demonstrates their productivity issues with necessary monitoring unit. In addition, various research draws attention only on minimizing energy consumption while improving networking performance on wireless connection under green computing hood [9, 10]. All these performance indicators (Table I) help various service providers and consumers either to design or to choose services mainly with respect to energy consumption, renewable energy usages, carbon emission issues and productivity issues in recent time. However, the IT industry needs to find out new parameters/indicators for achieving sustainability as current trends of the society shows that people are much more concerned about sustainability in this scope.

Table I depicts the performance indicators and their unit for different services considering green computing practices. The table has several headings. *Green Computing Domain* mentions the category of green computing practices in IT industry; *Performance Indicator Name* is the notion which used an evaluating, monitoring metric for defining performance in GSLAs, and then their measurable unit as *Unit* column.

TABLE I. Performance Indicator for Different Services Considering Existing Gsla [4]

| Green Computing Domain | Performance Indicator Name | Unit |
|---|---|---|
| | Total Power Consumption | kW-h (Kilowatt-hour) |
| | PUE (Power Usages Effectiveness ) | Number (1.0 to ∞) Or Dimensionless |
| | DCiE ( Data Center Infrastructure Efficience) | % (Percentage) |
| | CPE (Compute Power Efficiency) | Watts |

| | | |
|---|---|---|
| Energy/ Power | SPECPower | Watt |
| | JouleSort | kW/J |
| | WUE (Water Usages Effectiveness) | Liter/kW-h |
| | TDP (Thermal Design Power) | Watts |
| | ERF (Energy Reuse Factor) | Number [0 to 1.0] |
| | ERE (Energy Reuse Effectiveness) | Number [0 to ∞] |
| | GEC (Green Energy Co-efficient) | Number [0 to 1.0] |
| | ITEE (IT Equipment Energy Efficiency) | % (Percentage) |
| | ITEU (IT Equipment Utilization) | Number |
| | HVAC (Heating, Ventilation, Air-conditioning) Effectiveness | Dimensionless |
| | Cooling System Efficiency | kW/ton |
| Carbon footprint | CUE(Carbon Usages Effectiveness) | KgCO2 per kW-h |
| | DPPE (Data Center Performance Per Energy) | Number [0 to 1] |
| Recycling | e-Wastage Or IT Wastage | Gm (Gram) |
| | Recycling | % (Percentage) |
| Productivity | DCP (Data Center Productivity) | Not Available |
| | DCeP (Data Center Energy Productivity) | Not Available |
| | Analysis Tool | Not Known |
| | EnergyBench | Numeral Rating |
| | ScE (Server Compute Efficiency) | % (Percentage) |
| Costing Information | Energy/Power Cost | Currency [according to country] |
| Others | SWaP (Space, Wattage and Performance) | Not Available |
| | Air Management Metric | F (Fahrenheit) |
| | UPS System Efficiency | % (Percentage) |

## III. Identification of New Green Indicators

Fig.1 depicts the overall idea to define new sustainable GSLA as well as gives the idea of this research. In current focus, the traditional performance based parameters and few green parameters resides together to provide current GSLA in the industry. In existing GSLAs, most of the performance indicators mainly concentrate on energy consumption issues and productivity concern in cloud and grid computing industry (Table I). In addition, the ICT engineers could easily evaluate and monitor these parameters at hardware level or software level. However, the existing GSLA do not consider recycling, radio wave, toxic material usage, noise, light pollution for sustainable development. Moreover, people's interaction and IT ethics issues, such as user satisfaction, intellectual property right, user reliability, confidentiality etc are also missing in current GSLA. Therefore, the new focus part discovers the concepts of 3Es relationship with current GSLA, which could be used as a guideline for the ICT engineer to design and respect all the parameters of sustainable GSLAs. Next section discusses the proposed new performance indicators of GSLA for achieving sustainability from 3Es perspectives (Ecological, Economical and Ethical).

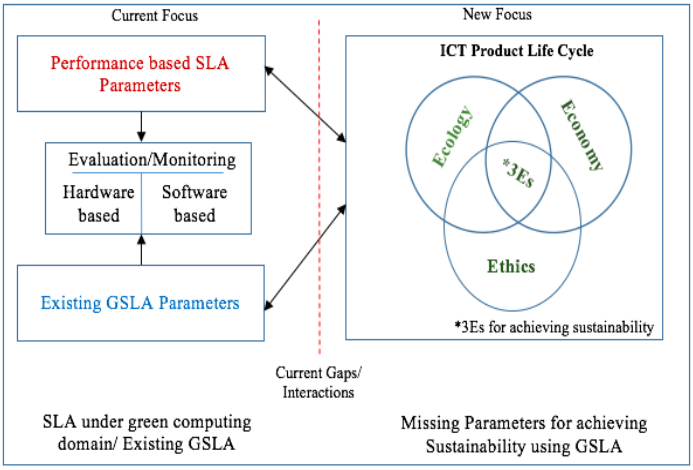


Fig. 1. Overview of GSLA (Green SLA) for achieving Sustainability

### A. Ecological Point

*Recycling*- The recycling of ICT equipment impose into their whole life cycle. This is a very complex indicator and need to be sub divide as reuse, refurbish, sub-cycling and up cycling. According to [8,11], the Recyclability Rate of an equipment ranges from 0 to 1. Again, at each stage of recycling, it needs to be considers the *CUE*, *GEC*, *Energy Cost* (Table I) because recyclability includes energy consumption and carbon emission simultaneously. Recycling has direct relationship with eWastage and pollution as it helps to reduce global magnitude of e-waste. On the other hand, if recycling procedure is not well managed then it could pollute air, water and soil. Recycling information should put into new GSLA according to government laws, directives such as Waste Electrical and Electronic Equipment (WEEE) Directive (2012/19/EU) by European Union (EU). There are also some voluntary recycler standards in US like *e-Steward and Responsible Recycling (R2) Practices*.

*Toxic Material Information*- Electric and Electronic products contain several toxic materials such as Beryllium, Cadmium, Lead, and Mercury etc. These chemical elements and their compound both cause serious health hazards and also make environment polluted [12, 13]. Beryllium is used in manufacturing computer motherboard and is acutely & chronically toxic to humans mainly affecting their lungs [12]. Cadmium and its compounds is used in some switches, many laptop's batteries and in some older CRTs monitor as phosphor coating. These materials and its compounds are also toxic to human, which affects kidneys in the long run [12]. Lead is usually used for primary electric solder on printed circuit boards. Lead could damage to the nervous system and blood system in human body [12, 13] and also causes severe air pollution. In some switching devices and batteries, mercury could be used which is highly toxic. Mercury has a high level impact on human nervous system [12, 13]. All these toxic material should have a safety limit and needs to be defined or restricted by third party or governing body such as Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (2002/95/EC) from EU commonly known as RoHS Directive. The information about

the usage of these toxic materials in IT and ICT field should be stated clearly for making SLA greener.

*Obsolescence Indication*- The services, process, product or technology used or produced by a company for profit will become obsolete after certain period. Therefore, it is a matter of urgency in ICT industry to indicate or label product's life time with obsolescence indicators [14] according to product's raw materials scarcity, demands, usages limit etc at different stage of product's life cycle. These indicators should be stated into new GSLA to create awareness for both customer levels and company levels for achieving sustainability. It might be complex to indicate or determine the obsolescence of ICT equipment because it depends on different variables associated with equipment's production cost, raw material scarcity, energy issues and user's interaction. Additionally, Optimum Obsolescence [15] or obsolescence management model [16] might help to decide when a product needs to be reused, recycled or land filled. There is no standard to indicate this parameter in SLAs till now but it might be related with product life cycle costing, recyclability rate indicators as well.

*Radio Wave Information*- The electromagnetic radiation emitted by electronic equipment in IT industry, is a controversial topic in scientific community. The health effects of radio waves were also studied and most of these studies found that the EMF (electromagnetic field) effects on the human body are not only depends on their field level but on their frequency ranges and energy [8, 11]. All studies claim that the unique non controversial effect of non ionizing EMF is thermal [11]. To avoid this electromagnetic effect, the government of each country defines maximum level of EMF generated by wireless antenna and their maximum *Specific Absorption Rate (SAR)* value [8]. The EMF levels and safety used following measuring units. *Gauss (G), Tesla (T)* for EMF values; *Gray (Gy)* and *Sievert (Sv)* for measuring radiation effects on human tissues [17]. These radio waves information should state in GSLA according to government's defined level clearly and precisely.

*Noise Pollution*- The network engineer who works in Data Centre might need guidelines and regulations to control noise pollution in his/her workplace. The noise generated from data center causes hearing loss permanently [18]. OSHA and NIOSH- these two US government agencies look after the limit of noise level in work places. The noise pollution level might be stated on a GSLA using decibel (dB) measuring unit. Moreover, the noise created by ICT equipment such as Ringtone of a cell phone might also responsible for some sort of pollution as it become disturbing and irritating for other peoples. This type of pollution might be subjective and easily prevented by increasing awareness among the cell phone users.

*Visual Pollution*- The aesthetic aspects of ICT industry, for example- installing an antenna in a beautiful landscape or on a roof top. This could create hypersensitivity affect [8] and these might be very much subjective to human being such as Perception of Affective Quality (PAQ) [19] is an individual's perception of an object's ability to change his/her neurophysiologic states as feeling either good or bad.

*Light Pollution*- Computer Screen generates light pollution affecting health [8]. According to American Optometric Association, Computer Vision Syndrome (CVS) causes headache, blur, dry eye, eyestrain, sleep disorder etc [20]. The safe computing practice and awareness might help to decrease CVS. There is still no standard or measurable unit for light pollution level but it should be mentioned in proposed new GSLA. The next Table II demonstrates the new GSLA indicators from ecological point of view and their proposed measurable units.

TABLE II. GSLA PROPOSAL UNDER ECOLOGICAL PILLAR OF SUSTAINABILITY

| **Performance Indicator Name** | | **Description** | **Unit** |
|---|---|---|---|
| Recycling Rate (RR) | Reuse | Amount of ICT product reuse/ percentage of ICT equipment refurbished/ percentage of IT equipment sub cycled or up cycling; | gm (gram) OR % (Percentage) OR RR[0~1] [8] |
| | Refurbish | | |
| | Recycle | | |
| Toxic material limit/ Toxic material Usage Level | | Information about using toxic material in ICT product and their limit level; | Preferred/ Acceptable |
| Obsolescence Indication Labeling | | Indication about the perfect time to change an ICT equipment; | Labeling according to laws |
| EMF Level/ Radiation Effect Level | | Amount of electromagnetic energy radiation; usually the strength is measured by frequency; | T (Tesla) / G (Gauss) OR Sv (Sievert) / Gy (Gray)[17] |
| Noise Pollution Level | | The noise emitted from ICT equipment e.g. Ringtone of Cell phone, noise in data center; | µdB/dB (micro decibels) |
| Visual Pollution Level | | The aesthetic aspect of ICT industry e.g. installing an antenna in a beautiful landscape or roof top; | Subjective OR *PAQ* [19] |
| Light Pollution Level | | The light pollution generated by ICT equipment e.g. Computer Screen; | Subjective |

## B. Economical Point

*Carbon Taxation*- A number of countries has implemented carbon taxes [21] or energy taxes and *Cap and Trade System* [22] that is very much effective to reduce Green House Gas (GHG) emissions while stimulating technological innovation and economic growth. The taxation may create political or social unrest in some cases; therefore, it may be difficult to impose. In 1990s, a carbon/energy tax was proposed at the EU level but failed due to industrial lobbying but in 2010 the European Commission implemented a Pan-European minimum tax on pollution under the European Union Greenhouse Gas Emissions Trading Scheme (EU ETS) [21] which is quite successful. According to this new plan, 4 to 30 euro would be charged per ton of carbon emission. On the other hand, in US, the *Cap and Trade* gave more assurance to decline GHG emission and also has some political advantages [22]. Therefore, according to different country's economic, social or political culture, carbon taxation or *Cap and Trade* policy should need to be established and this information need to put into the new GSLA.

*Civil Engineering Cost*- The cost of civil engineering includes building cost, antenna setup cost, digging tranches for

cabling etc. The building costing also need to consider designing cost, manufacturing cost, renovation cost and finally dismantling cost of an IT facility or data center. All these costing information should come into proposed new GSLA. The cost of civil engineering is also associated with carbon emission indicators in each step. It is important to note here that; the new green datacenter have an environmental impact in their lifespan. For example, most of the green datacenter uses natural resources (air, water) for cooling purpose but also at the same time it dissipates heat directly to the atmosphere, which might create imbalance in the surrounding eco-system of that datacenter.

Table III showed the economic performance indicators and their measuring unit for evaluating new GSLA.

TABLE III. GSLA PROPOSAL UNDER ECONOMIC PILLAR OF SUSTAINABILITY

| Performance Indicator Name | | Description | Unit |
|---|---|---|---|
| Carbon Tax | | Tax for carbon content on fuel in most case; this should be charged according to government laws; | Currency (dollar) |
| Civil Engineering Cost | | Information about costing related building, antenna installation, digging for cabling etc.; | Currency (dollar) |
| Cooling Cost | | Amount of cooling cost in a data center or percentages of renewable energy usage for cooling; | Currency (dollar) |
| ICT Product Life Cost | Manufacturing | Considering the whole life cycle of an ICT product and their costing; LCA assessment need to consider here; | Currency (dollar) |
| | Purchasing | | |
| | Delivery | | |
| | Operational | | |
| | Dismantling | | |

*Cooling Cost*- The cooling system costing information need to be mentioned into the new GSLA. It includes energy (electric power, renewable energy) costing, infrastructure (humidity, temperature monitoring) and transportation costing for cooling the whole site. This indicator might become complicated because of *HVAC, Air Management Metric* and *Cooling System Efficiency* indicators in existing GSLA (Table I) and these might need to define newly.

*ICT Product Life Cost*- ICT product life costing consider the whole life cycle of a product cost including mainly manufacturing from raw materials, purchasing, delivery, operational and dismantling. Operational cost has association with utility cost such as energy and maintenance costing and dismantling cost also has association with recycle or refurbishment costing. Again, the life cycle assessment LCA [23] need to be considered in this parameter. ICT Product life cost indicators, thus become very complex to assess and monitor in GSLA.

### C. Ethical Point

Mostly, the green computing practice focuses on the ecological, economical point but usually neglect human's interaction and ethical aspects [8]. The use of ethics in IT and ICT field covers many indicators such as *Satisfaction level, Intellectual Property Right, Reliability, Confidentiality, Security and Privacy, Gender/Salary/Productivity Information*. All of these indicators are usually subjective and informative, thus making new GSLA assessment difficult. For example, *Customer Satisfaction Index (CSI)* could be used for evaluating satisfaction level of a customer through designing and analyzing survey. In addition, User satisfaction could be rated from 0 to 5, where 0 indicates worst level of satisfaction and 5 is the preferred level. Moreover, the ICT Company should analyze social responsibilities towards *Customers, Employee and Community* [8, 24].

Table IV gives the idea of these responsibilities as performance indicators with respect to ethics for greening SLA to achieve sustainability.

TABLE IV. GSLA PROPOSAL UNDER ETHICS PILLAR OF SUSTAINABILITY

| Performance Indicator Name | | Description | Unit |
|---|---|---|---|
| Satisfaction level [Customer, Employee, Community] | | Whether the customer, employee and community are satisfied with; [usually defined by third party or community] | *CSI* Rating [25,26,27] |
| Intellectual Property Right [Customer, Employee, Community] | | IPR means copyright, patents of user's data; no hacking; royalty etc. ; | YES/NO |
| User Reliability | | Whether customer reliability preserved by the company ; reliability between employee and company; | Test based Rating |
| Confidentiality | | Information should be kept confidentially and also available for customer, employee or for community; | Test based Rating |
| Security & Privacy | Authentication & Authorization | Rules regarding security and privacy should clearly state and defined or not; usually it could be defined third party or government law. | High / Medium / Low<br>OR<br>Preferred/ Acceptable |
| | Access Control & Privilege Management | | |
| | Data Geographic | | |
| | Data Integrity | | |
| | Transparency | | |
| | Physical Security | | |
| | Termination Management | | |
| Gender Balance Information (only industry oriented) | | The information about gender balance in an organization; | YES/NO |
| Salary Balance Information (only industry oriented) | | The salary balance of an organization in IT industry; | YES/NO |

## IV. DEFINING GSLA USING INFORMATIONAL MODEL

In the previous section, this research found most of the important performance indicators with respect to three pillars of sustainability and this will definitely help ICT and IT service providers to develop and design their existing GSLA more greener for achieving sustainability as well as making more profit in their businesses. However, ICT engineer would face some challenges to incorporate, manage and finding the relationship between all new performance indicators for GSLA under three pillars of sustainability in future. This GSLA research tries to help ICT engineers to define new GSLA using an informational model. The general global view of GSLA indicators with respect to three pillars are shown in Fig.3 and then the relationships, interdependencies and management complexity among the new indicators and

existing indicators are depicted with discovering some important new entities under sustainability lens.

### A. General Model of Future GSLA

To achieve sustainability, the proposed *GSLA* entity should aggregate and satisfy all three entities in general model- *Ecology Pillar*, *Economy Pillar*, *Ethics Pillar*. Now, it the matter of urgency that, to achieve sustainability the ICT industry need to identify more new parameters from user's perspective under this three pillar too. It is important to indicate that, the *ICT Product Life Cycle* must need to include at the first level of GSLA model as this entity have direct relationship to calculate existing ecological, economical and ethical indicators, such as carbon emission, energy consumption, recycling, energy cost etc. The ICT product life cycle and its relationships with sustainability pillars coexist while developing future GSLA. Therefore, ***ICT Product Life Cycle*** also needs to define as new entities for achieving sustainability in the industry. The whole life cycle of an ICT product consists of following entities, - manufacturing, transportation, usage and dismantling entities (Fig.2). All these entities should directly connect to *GSLA* entity to respect global analysis of proposed model. The total GHG emission, total energy consumption and total costing of energy could not be estimated without considering all these product life cycle entities. Additionally, an environmental closed-loop supply (ECLS) [28] chain would need to be added with the proposed relationships as currently ICT products remanufacturing are getting importance in the industry. The ECLS chain would be helpful to improve economic and environmental performance of every product [28]. The interaction between ICT product life cycle and GSLA are shown first (Fig.2) and then the general global model of future GSLA is proposed (Fig.3) using UML class diagram notation.

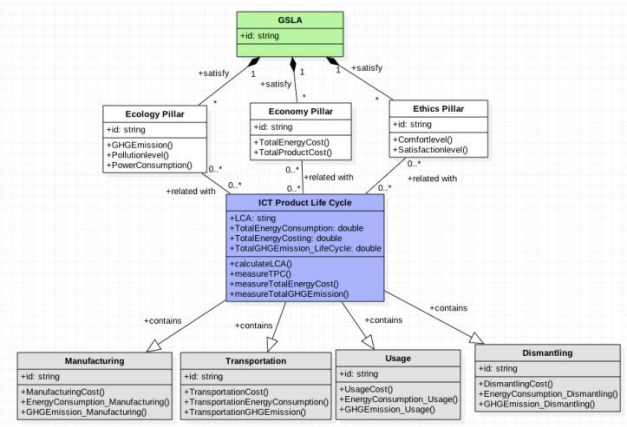


Fig. 2. Relationship between GSLA and ICT Product Life Cycle [4]

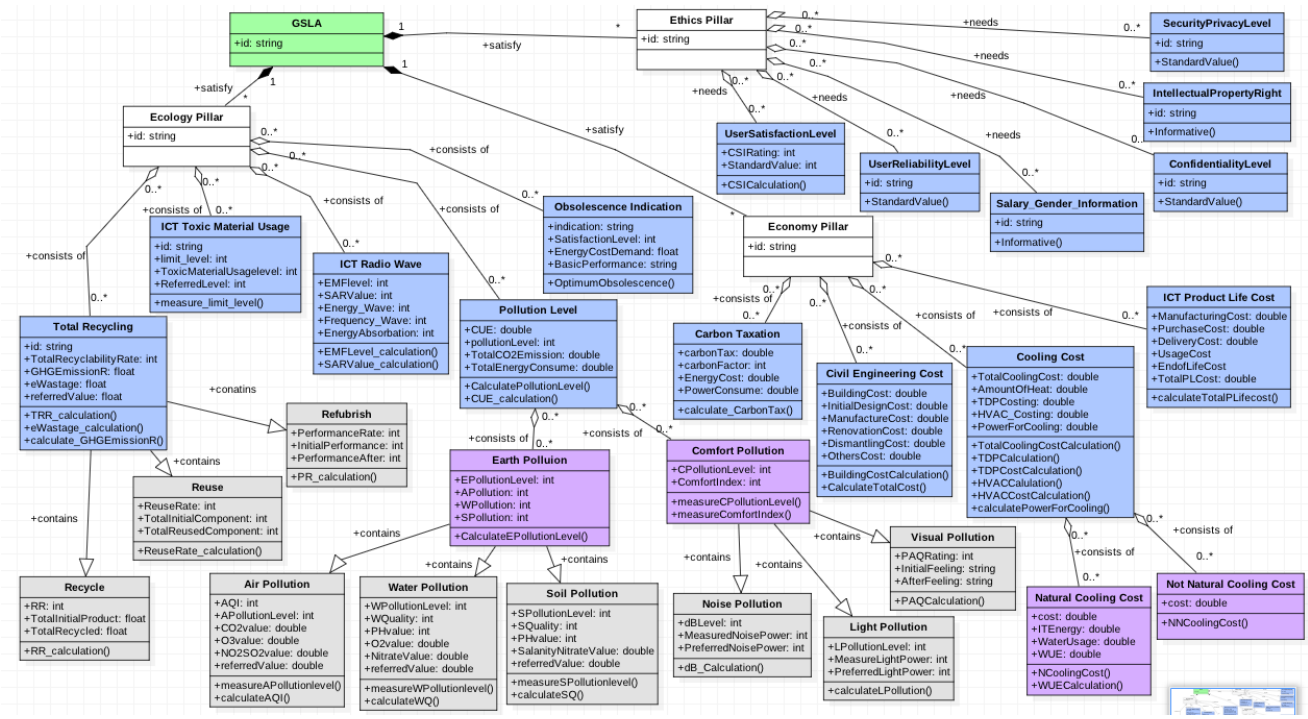


Fig. 3. General Model to define proposed GSLA

### B. Discussion about the genral model of sustaianble GSLA

In the proposed model (Fig.3), the *GSLA* entity should aggregate and satisfy all three main entities of sustainability achievement- *Ecology Pillar*, *Economy Pillar*, and *Ethics Pillar*.

Ecology Pillar entity is consisting of following missing indicators from existing GSLA work, Total Recycling, ICT Toxic Material Usage, ICT Radio Wave, Pollution level and Obsolescence Indication. Total Recycling is a complex indicator and it could compose of three other sub metrics- reuse, refurbish or recycling of an ICT product or equipment. However, for simplicity, it depicts as one entity in the proposed model. Moreover, Total Recycling entity might have direct relation with some already defined existing green indicators from, such as e-Wastage and Recycling (table I) under green computing domain. For example, recycling helps

to reduce global magnitude of e-waste as metals, plastics, glass and other materials could be recovered from ICT product through recycling procedure. In addition, eWastage entity has direct impact on existing carbon emission and energy consumption of green computing domain. Again, in the general model, Pollution level consists of two other sub-entities, - Earth Pollution, which have direct impact on environment and composed of three other entities (air, water and soil) and Comfort Pollution have direct relations with people's comfort (noise, light and visual pollution entity). Therefore, **Total Recycling** could be defined as new entities in the proposed GSLA. The main challenges to define this new Total Recycling entities is to gather all necessary information from other entities and monitoring their effect. Most of non-technical parameters under sustainability pillars in this entity need some laws and directives to derive exact information for the users. Again, **Obsolescence Indication** could be another entity in the ecological pillar of proposed GSLA. Obsolescence is relative information estimated from other useful existing criteria. It could be calculated from cost of energy, carbon/GHG emission, ICT product life cycle assessment and or pollution level. There is an interesting relation between obsolescence and people. Therefore, Obsolescence Indication entity has indirect relationship with Ethics Pillar entity in proposed GSLA model. There is also an interesting relationship between existing User Satisfaction indicator with this entity. For example, people often change their mobile phone frequently because it might become old fashioned to use it. However, there is still no available standard to define obsolescence indication. Obsolescence management of an ICT product could be defined according to some regulatory lever, education/training for user behaviors and recycling practice in the society. Next, the **Pollution Level** entity might take into account for future GSLA. There is an interesting relationship between Comfort Pollution sub-entities with Ethics pillar in proposed GSLA as ethical pollution is mostly concerned with people's comfort in their daily life. The Earth Pollution level entity consists of three other entities in general model, - Air, Water and Soil pollution and Air Pollution is directly responsible for GHG emission in the atmosphere. Air, water and soil pollution might have direct relations with Recycling, ICT Toxic Material Usages and ICT Radio Wave entity.

*Economy Pillar* entity for sustainable GSLA is composed of *Carbon Taxation, Civil Engineering Cost, Cooling Cost* and *ICT Product Life Cost* entities. Here, the cooling cost entity is an important indicator for data center and these costing could be estimated based on either natural cooling facility (water, air) or not natural cooling facility. Moreover, *Cooling Cost* entity need to evaluate and defined accurately with the help of existing indicators from Table I, such as *TDP, HVAC Effectiveness, Cooling system efficiency* etc. In the proposed model, *Cooling Cost* entity is actually consisting of two other sub-entities, - *Natural Cooling Cost* and *Not Natural Cooling Cost.* In addition, *Natural Cooling Cost* helps to derive existing *WUE* (table I) in the model as *WUE* indicator is the ratio between annual usage of water for cooling and the total energy used by IT equipment. In addition, ***Energy Cost*** might be defined as new entity under economic pillar for achieving sustainability. *Energy Cost* entity has direct relations with *ICT Product Life Cycle, Carbon Taxation etc.* The costing of energy depends on the types of energy sources used in the IT facility. Recently, there are two types of energy is considered, - renewable (solar, wind, tidal etc) and non-renewable (gas, natural gas, fuel etc) energy. However, different types of energy costing actually depend on different country's government policies, economic conditions, political culture, and industry growth etc.

*Ethics Pillar* entity could be the important parameter for sustainable GSLA development model as it has direct relationships and interactions with people and society. IT ethics needs following parameters to be associated in proposed model, *User Satisfaction Level, Reliability Level, Confidentiality Level, Intellectual Property Right, Security Privacy Level, Salary and Gender Balance Information.* Here, most of the parameters under ethics pillar are very much subjective and non-technical. Thus, it could be the most challenging part for ICT engineers to monitor, manage and assess these parameters in future. *User Satisfaction Level* could be measured and evaluated by using standard method of survey for specific services and then possible to calculate standard CSI [25,26] for that services. *Security Privacy Level, Intellectual Property Right* could be monitored by third party using government defined rules and regulation. Third party could monitor and update information periodically regarding *User Reliability Level, Confidentiality Level, Salary Gender Information* in future GSLA. In the model, salary and gender balance information are shown in one entity for simplicity and they might carry same type of informative attributes. Moreover, still there is no standard authority or third party to evaluate these ethical parameters. The ICT companies should also analyze their social responsibilities towards their customers, employee and community through developing IT Ethics program and guideline.

### *C. Identification of new entities for future GSLA*

Fig.3 shows the general view of proposed new GSLA definition and now the complexity of managing future GSLA discussed briefly in previous sub-section. In future, this research could elaborate the sustainability achievement in the IT and ICT industry by taking all important entities from the discussion of general model. These newly identified entities might have direct and indirect relationships and different level of effects with some existing and new green performance indicators. Therefore, this research identifies following central entities for sustainable future GSLA, - *ICT Product Life Cycle, Total Recycling, Obsolescence Indication, Pollution level, GHG Emission, Energy Consumption,* and *Energy Cost.* Among these, *GHG Emission, Energy Consumption* and *Energy Cost* are already defined entities in exiting GSLA work under green computing practice in the industry. All these newly identified entities would cover all the dependencies and respect all other existing and new indicators under three pillars of sustainability (Fig.1).

TABLE V. RELATIONSHIPS BETWEEN NEW AND EXISTING PARAMETERS FOR SUSTAINABLE GSLA

| Central Entity | Relationships | | |
|---|---|---|---|
| | **Direct** | **Indirect Important Effects** | **Indirect Small Effects** |
| Total Recycling | ICT Product Life; eWastage; Earth Pollution; Energy Consumption; GHG Emission; Energy Cost; Dismantling; | ICT Radio Wave; ICT Toxic Material Usage; Manufacturing | Comfort Pollution |
| Obsolescence Indication | ICT Product Life; ICT Performance; ICT Product Cost; | Pollution Level; Energy Consumption; GHG Emission | Ethics Pillar |
| GHG Emission | Total Recycling; Air Pollution; Carbon Taxation; Dismantling; Energy Consumption; | Obsolescence Indication; ICT Toxic Material Usage | Comfort Pollution |
| Energy Consumption | Total Recycling; ICT Product Life; ICT Product Cost; Energy Cost; Carbon Taxation; GHG Emission; ICT Radio Wave. | Obsolescence Indication; Cooling Cost | Building Cost |
| Pollution Level | ICT Product Life; Total Recycling; Energy Consumption; GHG Emission. | ICT Toxic Material; ICT Radio Wave; Obsolescence Indication | Ethics Pillar |
| ICT Product Life | Energy Consumption; GHG Emission; Pollution Level; Total Recycling; Energy Cost; | Obsolescence Indication; | ICT Product Cost; |
| Energy Cost | ICT Product Life; ICT Product Cost; Carbon Taxation; Energy Consumption. | Cooling Cost; Building Cost | Total Recycling. |

## V. CONCLUSION

This sustainable GSLA research discovers most of the recent day green indicators and their measurable unit (Table I) from various cloud service providers and as well as from some data centers. In addition, it discovers today's concerns are mainly on energy issues and productivity under greening lens. Missing performance indicators and their influences on GSLA with respect to 3Es are discussed and also identified in this research. Table II to Table IV lists all new proposed performance indicators and their measurable units for developing a new sustainable GSLA. Thus incorporating all new and existing indicators for future GSLA might be difficult and cumbersome work for the ICT engineers. The management complexity of all identified indicators in future sustainable GSLA would be the most challenging task. Therefore, the definition of GSLA section thus proposes an informational model to help ICT engineers to understand the interactions and important effects of various performance indicators. The informational model also helps to design a new sustainable GSLA and to derive new parameters under sustainability lens. Therefore, it could use a guideline for the ICT engineers in future. Still some challenges exist for designing sustainable GSLA research such as, some performance indicators need to be defined accurately which has association with other indicators; most of the subjective, qualitative indicators related with ethics issue need standardization or governed and authorized by proper laws and directives. The standardization of green indicators is one of the main issues as mentioned by ITU-T report (2012). Also, further research is necessary on monitoring and evaluating the indicators for a viable sustainable GSLA in the industry. The next steps of this research is to design all newly identified entities from the global model and finds out the evaluation procedure of this new sustainable GSLA.

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