14 March 2012

Work Package 1.2

Threat Analysis

Expert Group on the security and resilience of Communication networks and Information systems for Smart Grids

Version 7.2

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1. Introduction

This work package contains extensive threat taxonomy for Smart Grids. Pruned versions of the threat taxonomy are presented for each of the Smart Grid Components sets I and II (as identified in WP1.1). Some initial thoughts are presented on attack avenues. As the intended result needs to be unclassified, details of attack avenues are not presented here. A number of policy and research challenges have been identified by this team.

1.1. Mission, vision and goals

In order to be aware of the various threats that are relevant to Smart Grids, the team designed an *all hazards* threat taxonomy taking into account threats that may harm Smart Grid stakeholders. The analysis and weighting of these threats makes it easier to determine how measures can be taken in order to mitigate the overall risk of Smart Grid operations *across service-chains* of *multiple organisations* which may even be competitors.

In consistency with the overall mission of the Expert Group, the WP 1.2 objective is to address all actors involved in providing a reliable energy service with a taxonomy of threats that need to be considered when developing and deploying Smart Grid infrastructures in the European Union.

This threat identification step encompasses both the information and the infrastructure dimensions of Smart Grids and comprises (1) threats to the confidentiality, availability and integrity of data in the system, (2) threats to the resilience, security and proper use of the infrastructure as a whole, (3) threats to the environment of Smart Grid operations, and (4) inter-organisational related threats.

1.2. Strategy

Strategic tasking. The team was tasked to research which threat taxonomies are already available and to assess to which extend these taxonomies would hold specifically for Smart Grid security.

The team was also tasked to identify key deliberate attack avenues and scenarios, encompassing the full palette for example from individual fraud attempts to large scale attacks against the Smart Grid infrastructure.

Understanding. The team task takes the WP1.1 results as input; the output of WP1.2 will be used to assess risk and to create a list of identified policy and technical challenges.

As the threat landscape for Smart Grids may evolve, the WP1.2 deliverable is developed in a way which allows the re-use of the approach, both by the EU, Member States and other stakeholders.

Caveat. Given its short lifetime and limited, voluntary resources, and dependency on the WP 1.1 developments and results, the team came to the conclusion that the completion of the first task was feasible and that the second task effort exceeds by far what decently may be expected by the Commission from unsponsored work. Such an effort anyway requires a clear EU view on how to balance the all hazard risk with the hostile intent avenues. Moreover, an elaboration on attack avenues requires a discussion on the *required information security classification* of the attack avenue analysis results.

1.3. Scope

The overall scope of the work of the Expert Group is the security and resilience of communication and information systems that determine the performance of the physical - Smart Grid enhanced - energy infrastructure in the end.

Given (1) existing threat analysis and mitigation methods in daily use at power grid operators, and (2) time constraints, the WP 1.2 team focused its work on **threats**[1] that may harm the resilience and reliability of energy grids **by the addition of Smart Grid hardware, software, services and operations.**

Note: as part of a balanced risk analysis, operators need to consider their current sets of threats and augment them with the threats to the new Smart Grid operations, services and components.

1.4. Team

Team leader:

- Eric Luiijf, TNO, The Netherlands.
  M.Sc. in Mathematics at the Technical University Delft in 1975. Officer in the Royal Netherlands Navy for his duties. He joined the TNO end of 1977. Since 1995, he works as Principal Consultant Information Operations and Critical (Information) Infrastructure Protection (C(I)IP). He supports the Dutch Government on policy and technology related issues regarding C(I)IP, Cyber Operations and National Risk Assessment. He has been involved in many national and EU studies on C(I)IP including VITA, IRRIIS, DIESIS, EURACOM, and RECIPE. Eric maintains a unique database on CI disruptions, cascading effects and consequences based upon public sources. Eric is part-time employed by the Dutch Centre for Protection of National Infrastructure (CPNI.NL) as ICS and Smart Grid security expert. His SCADA Good Practices book has been translated into English, Japanese and Italian. Eric has been interviewed many times by national and international press, radio and TV, and has published many popular articles, reports, and scientific publications.

Team members:

- Elyoenai Egozcue, S21sec, Spain.
  M.Sc. in Telecommunications Engineer from the UPNA University of Pamplona, Spain. Master Thesis on the study of integrated QoS in IP over WDM networks at the VUB University of Brussels, Belgium. Security researcher at S21sec Labs since 2006 on RFID, MPLS and biometrics. From 2008 to 2011, technical manager of various research projects at national and European level, dealing with digital security of control systems used in Critical Infrastructures. Visible head of S21sec for the 7th Framework Programme's INSPIRE project. Since 2011, project manager of several R&D and customer-oriented projects on ICS/SCADA and Smart Grid security. These projects include technical consultancy and assessments as well as compliance consultancy on nuclear power plants, gas and electricity distribution and advanced metering infrastructures. Additionally, Elyoenai Egozcue has been in charge of leading two key projects on ICS and Smart Grid Security in Europe commissioned to S21sec by the European Network and Information Security Agency (ENISA).

1.5. Background

A large number of actors – many of them being competitors - have to assure the power grid balance in a dynamically changing physical grid with a wide variety of power generators (Micro Power Producers (MPP), Independent Power Producers (IPP) and bulk generation), a higher dynamics of load due to intelligent appliances while providing more reliable services, higher efficiency, less CO2 against lower costs (e.g., see EU's 20/20/20 objectives [EC2020]). Considering the unbundled liberalised energy market in Europe, the fully fletched energy Smart Grid comprises the following actors:

- end-users: consumers and businesses with dynamic load request through smart appliances and electric vehicle power storage,
- prosumers: consumers and businesses with micro-power production (MPP) or combined heat-power abilities which may dynamically trade produced power and supply it to the grid,
- distribution system operators (DSO),
- independent power producers (IPP), e.g., renewables, small wind power production,
- transmission system operators (TSO),
- bulk generation and 'bulk' renewables (e.g., wind farm) operators,
- market operators and shippers (various kinds),
- energy (power, gas, CO2 rights) exchanges (spot market).

[1] Any entity, action, or occurrence, whether natural or man-made, that has or indicates the potential to pose violence or danger to life, information, operations, environment, economy, operations, property, social stability and coherence, functioning of government and society, and/or territorial security.

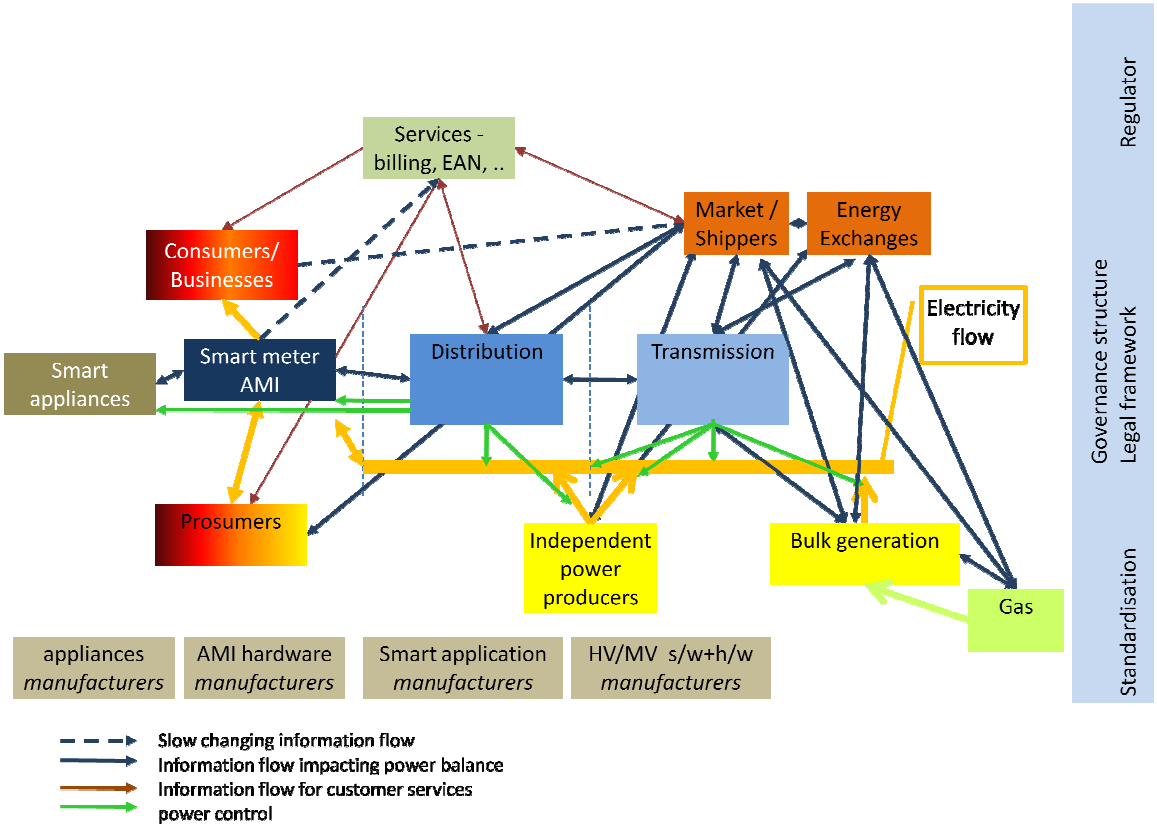


Figure 1: Overview of Smart Grid actors (source: TNO, 2012)

Apart from these actors directly involved in maintaining the balance between load and supply of the total energy grid and securing the physical energy flow, other parties are involved in the energy provisioning chain:

- third party service providers: meter operator, billing, financial services for loading/unloading electric vehicle batteries, and weather information services,
- secondary market operators (e.g., CO_2, steam),
- Smart Grid equipment manufacturers,
- Smart Grid operations, planning and optimisation application providers (Central Management Systems),
- Smart Grid (information) *services* application providers (for end users, MPP, IPP, ...),
- third party provided information and communication technology (ICT) services, e.g. certificate providers/trustees.

Another set of stakeholders is involved in the dynamics of the Smart Grid developments and operation: the legislator(s) and the regulator(s) at various levels (EU, Member State, ...). And last, not but least, the manufacturers and system integrators which provide smart appliances (home environment), Smart Grid components, Advanced Metering Infrastructure (AMI) components, and Smart Grid service software.

Comparing the Smart Grid understanding in the USA with EU's main Smart Grid objectives, we observe major differences. Most nations in Europe have a very reliable power supply (see Figure 2). An average outage in the range of twenty to thirty minutes/year per customer and an average duration of one and a half hours of a disruption is not uncommon. In the USA and Canada, no (recent) public figures of average power outage duration per customer are available. Outages of multiple days and multiple times per year per customer occur. In the USA Smart Grids shall help to resolve this grid unreliability problem where Europe is focussing on the 20-20-20 goals:

- coping with the massive introduction and use of electric vehicles,
- introduction of smart energy appliances at home,
- a major shift in generation to local generated power, e.g., solar panels, and wind power,
- a major shift in generation, such as wind farms and renewable energy sources.

Threats to the fully fletched smart energy grid system may harm a single actor directly, but also may stem from or passed on by an upstream service provider or a downstream customer/prosumer (or his/hers appliances).

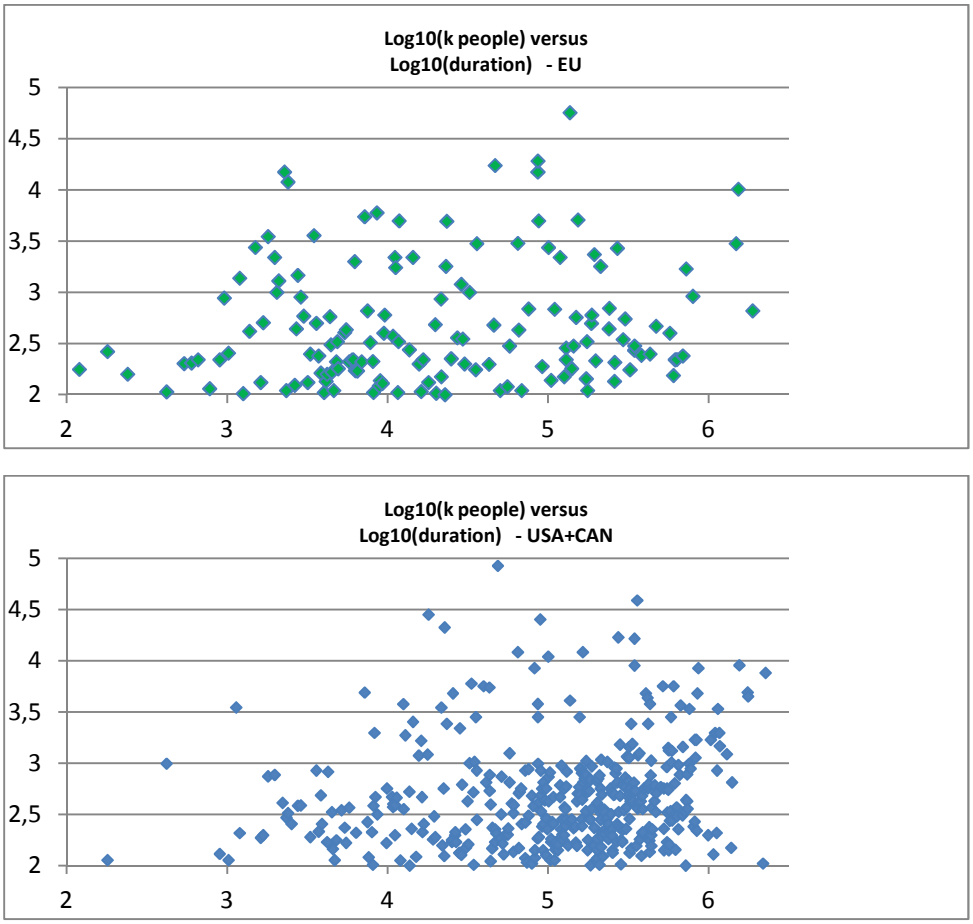


Figure 2: Power outage duration (horizontal) versus number of people affected (vertical) [source: TNO, status 13-1-2012]

	2	3	4	5	6	7
Duration	2 min	20 min	3 hours	1.25 days	11.5 days	4 months
# of people	100.000	1 million	10 million	100 million		

1.6. The complete Smart Grid threat taxonomy

The planned approach was to research which threat taxonomies are already available and to assess to which extend these taxonomies would hold specifically for Smart Grid security. The team first turned to the results of the EU PASR[2]-sponsored Vital Infrastructure Threats and Assurance (VITA) project. That study came to the conclusion that there is a lack of threat taxonomies for critical infrastructures such as Smart Grids which cover the all hazards spectrum. For that reason, the VITA project developed its own Extensible Threat Taxonomy for critical infrastructures. A full description of the method can be found in [Luiijf2008] and [Luiijf2006].

A short scan by the team did not reveal other threat taxonomies which could be of use. All other threat list developments found had a limited scope or came from a limited outlook. Therefore, the team decided to build its work on the aforementioned work of the VITA consortium and target and augment the results for the

[2] PASR = Preparatory Action on Security Research

specifics of the Smart Grid domain. In its tasking, the team was asked to consider the work done by other EU groups such as the SGIS which uses a set of threats and use cases. [3]

A quick scan of the materials of the SGIS (received mid of January 2012) revealed some essential differences:

- The SGIS discusses sabotage and terror as threats; VITA provides the arguments that this is wrong. One should consider the base threats. The human intent should be considered as a totally different level on top of the set of threats. The human intend is about probability, not the how.
- The SGIS approach mainly covers the Smart Grid area identified by WP 1.1 as Components Set I. The Smart Grid Components set II assets and the threats to it are hardly covered.
- Finally, the VITA threat taxonomy is one of the most extensive taxonomies for critical infrastructures that exists. To make the list usable, an intelligent grouping into sets of threats has to take place. Nevertheless, it is obvious that the current SGIS approach misses *essential* threats to the Smart Grid value chain given its focus on existing and to be augmented standards.

In short, the VITA threat taxonomy makes a sharp split between threats, threat cause categories (nature, human, or both), and human intent. The VITA approach makes clear that **activism, sabotage and terror are *not threats***. They just are an expression of human **intent *using* an *existing threat*** (or combination of existing threats). For example, the potential threat of snow causing an avalanche may be initiated by too much sun shine (nature), a stupid human (skiing at the wrong spot), intentionally by mountain safety troops launching a grenade, and a terrorist setting the avalanche off using a shoulder-fired rocket. The differences here are the intent and probability, but it is still the same threat!

The VITA approach therefore uses a three level approach: the first layer comprises all hazards organised in a taxonomy tree. The next layer analyses whether a hazard is just a natural phenomena which cannot be initiated by human influences (e.g., a storm), is a threat which exists only because humans created it (e.g., a technical threat), or is a threat that can be triggered both by natural and human influence causes (e.g., an earth quake, avalanche). The third and EU classified layer of the threat taxonomy shows which hazards can be used by humans with the intent to harm society, more specific: radicalising activists, terrorists, and rogue nation state actors.
Moreover, the VITA extensible threat taxonomy includes both threats with an instantaneous effect, and those which describe slow and very slow threat processes. It also covers those threats that have a very visible high incidence rate and those that have a very low probability and occurrence rate and which are often neglected due to that fact. The current 2012 (copyrighted) version of the earlier VITA threat taxonomy to critical infrastructures organises a set of over 440 threats.

The team started with that list, and given its task and scope, an initial pruning of this extensive set of all hazard threats took place. During the pruning, we removed all the threats to the energy grids covered by current operations ***and which are not amplified by the addition of Smart Grids organisation, services and components***. Then some specific threats for Smart Grids which were not captured yet by the VITA threat taxonomy were added. These additions stem from the threat taxonomy of the European Research Network on CIP in Annex 2 of [ERN2010] and input by the S21sec company. Then the threat taxonomy with 132 *additional* threats to the total energy system due to the *smart-gridisation* of the energy grid was drawn (Annex I).

1.7. Threats to the total Smart Grid system

The WP 1.1 team has identified two Components sets making up Smart Grids in relation to Figure 1: set I related to the regulated high voltage grids of TSO, DSO, and bulk generation, and set II related to DSO, local power production (IPP and prosumers), end-users, AMI, smart appliances, and electric vehicles.

However, before looking at the threats to assets that are part of the Components sets I and II in relation with *specific stakeholders*, we have to consider threats to the whole grid. As European Smart Grids in the end comprise up to hundreds or thousands energy suppliers, transmitters and distributors, millions of customers/prosumers and millions of smart appliances, electric vehicles, etceteras which *together* operate in the end the energy value-chains, also the (1) deliberate and (2) common mode failure threats to the multi-stakeholder value-chains need to be recognised. An example of (1) is the Western U.S. Energy Crisis of 2000

[3] Subject Expert Group 1 (2011) ICT security and resilience of Smart Grids: High Level Risk Analysis and Security Requirements

and 2001 where competing companies created a power demand supply gap with brownouts as a result. Therefore, Europe has to govern the total Smart Grid chain threats. The following threat challenges stand out:

Threat challenge 1: The subset of ICT-related threats dealing with the manipulation and disruption of the inter-organisational Smart Grid information chain that governs power supply.

Threat challenge 2: The subset of ICT-related threats dealing with the manipulation and disruption of the inter-organisational Smart Grid information chain that governs power demand.

Threat challenge 3: The subset of ICT-related threats dealing with the manipulation and disruption of the inter-organisational Smart Grid information chain balances power demand and supply at the various power grid levels.

Threat challenge 4: Earlier Smart Grid investments by a stakeholder could be of no or limited value due to the appearance of disruptive technology.

Threat challenge 5: Bulk generation, power transmission and distribution companies are used to slowly changing technology and long economic depreciation cycles, thirty to forty years are not uncommon. On the other hand, ICT has short technology aging cycles. The move to smart energy grids will require the aforementioned organisations to change their investment and depreciation cycles as well as incurring costs for continual ICT updates.

Threat challenge 6: The subset of ICT-related threats which may disrupt components that are deployed in massive rollouts, e.g. smart meters, smart appliances, electric vehicles. Crisis management of Smart Grid stakeholders need to be prepared for fast update cycles at hundred thousands to millions of customer and prosumer sites and/or pieces of equipment after the appearance of a vulnerability. When not mitigated in time, a vulnerability in such a component may cause criminals, activists or even terrorists to take control over (parts of) the ICT-side of the Smart Grid.

Threat challenge 7: Earlier Smart Grid investments could be of no or limited value due to adverse laws and ruling by EU, Member States or Regulators (e.g., export license control, privacy-related ruling not supported by hardware).

1.8. Threats to the Smart Grid Components set I

The Smart Grid Components set I comprises the assets related to the Security Guidelines from the EU as identified by WP 1.1. Annex II shows the resulting set of threats relevant to the Smart Grid Components set I. The Annex II threat set is derived from the extensive set of threats discussed above (Annex I) and comprises 100 threats. These threats obviously can be grouped in subsets that can e.g., be mitigated by product development, grid design and deployment; maintenance; organisational measures; education and training of personnel; etceteras.

Threat challenge 8 comprises the following non-exhaustive list of subsets of threats that may affect the Components set I assets:

1. Natural and environment threats to the Smart Grid equipment and cabling during its deployment in the field and technical locations (humidity, heat, cold, flooding, electromagnetic influencing including GIC, lightning, storm, earth movements, animals, fire, etc.). It is envisioned that the majority of equipment and cabling will be located in the field or in nearby 'huts', therefore a common mode failure of both the ICT-layer and the power supply chain in Smart Energy grids may occur.

2. Physical damage to key Smart Grid equipment (collateral damage, deliberate attacks).

3. Human factor aspects (e.g., insufficient information-security training and awareness of personnel, unavailability of key personnel).

4. Inappropriate algorithms, quality of software, information exchange and software services which control the energy grid supply and demand resources.

5. Maintenance related threats (patching, hardware replacement, etc.).

6. Dependency threats due to the use of (public) telecommunications in controlling the grid, Smart Grid equipment which requires electric power, and GNSS timing.

7. Improper information from weather services, e.g. due to manipulation of expected temperatures and wind strength.

8. Lack of black start ability for both the energy and the ICT-sides of a Smart Grid.

1.9. Threats to the Smart Grid Components set II

The Smart Grid Components set II comprises the assets related to the Security Guidelines which can be established by the individual control areas as identified by WP 1.1. Annex III shows the resulting set of threats relevant to the Smart Grid Components set II. The Annex III threat set is derived from the extensive set of threats discussed above (Annex I) and comprises 111 threats. As discussed above, these threats can be grouped in sets that can e.g., be mitigated by product development, grid design and deployment; maintenance; organisational measures; education and training of personnel; etceteras.

Threat challenge 9 comprises the following non-exhaustive following subsets of threats that may affect the Components set II assets:

1. Technology-Related Anger / non-acceptance of Smart Grid functionality and technology by consumers/prosumers.

2. Natural and environment threats to the Smart Grid equipment and cabling during its deployment in the field and technical locations (humidity, heat, cold, flooding, electromagnetic influencing, lightning, storm, earth movements, animals, etc.).

3. Product and value-added services related threats (large-scale counterfeiting of hardware, software vulnerabilities, maintenance / patching issues, drained battery-power, etc.), especially when dealing with mass-market equipment (Electric Vehicles, smart appliances, smart metering).

4. Threats to Smart grid components stemming from environmental factors at households, buildings, and factories (humidity, electromagnetic interference, signal jamming, etc.).

5. Maintenance related threats (patching, hardware replacement, etc.).

6. Inappropriate algorithms, quality of software, information exchange and software services which control the energy grid supply and demand resources.

7. Dependency threats due to the use of (public) telecommunications in controlling the grid and Smart Grid equipment which requires electric power.

8. The deliberate disruption of financials services causing Electric Vehicles being unable to buy power to load their batteries or to deliver (sell) power from the batteries to the local grid.

1.10. Attack vectors / attack avenues

The identified sets of threats to the Smart Grid as a total and the specific Components sets I and II show that there is a manifold of opportunities to deliberately affect the functioning of Smart Grids. Risk analysis should consider the likelihood of **specific actor** types having **the opportunity** to **exploit vulnerabilities** of Smart

Grids by **effectuating a certain threat** to a **certain (set of) deployed Smart Grid component(s) or asset(s)** using a **certain motivation** and the **availability of means**, or:

Probability (deliberate attack avenue) =
F (*actor type, opportunity, vulnerability, threat, asset, attacker motivation, availability of means*)

Actor types (non-exhaustive list):
- Individuals (script kiddies, hacker, loosely collaborating set of hackers);
- Energy market actor (financial or market gain-oriented);
- Activist group (e.g., Anonymous, Gridprivacy);
- Organised crime;
- Terrorist individual or group;
- Rogue state-affiliated activities (cyber espionage, cyber conflict, cyber war).

Opportunity comprises elements like:
- Time (e.g., observation/information collection, attack development, time to mount the attack);
- Place (if physical or electromagnetic);
- Access (physical, connectivity, delayed);
- Bandwidth.

Vulnerability (expression of threat possible) in for instance:
- Demand – supply chain of organisations;
- Manufacturer chain of production;
- 3rd party service (design, installation, maintenance);
- 3rd party ICT-based services (e.g., PKI, financial services; billing services);
- Dependent (critical) services;
- Individual employee;
- Group of employees;
- Processes;
- Technical component (e.g,, hardware, software, firmware, network);
- Object environment.

Threats: see previous Sections (and Appendices I - III)

Potential target assets comprise for instance:
- A single technical component;
- Set of same components;
- Substations;
- Related infrastructure (buildings, hut, cabling);
- Antenna locations;
- 3rd party services;
- Interorganisational processes;
- Cross-organisations processes.

Attacker motivation comprises elements like:
- Conviction (political, religious);
- Money gain (booty, reward);
- Individual under coercion, duress, blackmail;
- Low risk (of being caught, of penal punishment);
- Personal satisfaction (intellectual challenge, technical curiosity, fun, grieve/revenge);
- Objectives of its State or organisation.

Availability of means comprises:
- Money;
- Weapons, explosives, chemicals, etc.;
- Hardware tools / equipment;
- Software tools;

- Knowledge (e.g., documentation, configuration information);
- Access to specimens of targeted equipment, systems, software, etceteras;
- Specific skills (technical, social engineering, …);
- Man & female power.

Scenarios and so-called 'use cases' may help to find and rank attack avenues that relate the function elements above in relation to the (potential) impact. However, any risk mitigation need to be balanced with the risk factors stemming from the all hazard threats.
Some highly-visible examples of attacks to Smart Grids from the threats and actors identified above:

- Deliberate energy market manipulation by changing Smart Grid information about the power demand or supply in a stressed market.
- A physical and/or cyber attack on a (small set of) single-point-of-failure Smart Grid component(s).
- Technology Related Anger (TRA) of Smart Grids amplified by a very active (set of) individual(s), e.g. peoples sending tweets like 'Smart Grid equipment radiation is deadly', while lacking a convincing mitigation strategy.
- Organised crime manipulating larger sets of consumer premises Smart Grid components or at the data concentrators, e.g. turning a large set of smart appliances off.
- Fraudulent information about demand or supply causing automatic measures taken which try to deal with non-existing power flows. Result may be a blackout and/or high financial losses.
- The AMI being an entrance point to the Smart Grid network for hackers/criminals.
- Privacy-related information in Smart Grid components / (wireless) network links of Smart Grids that is used by criminals or hackers to create reputation loss of one or more stakeholders or even TRA and/or massive technology-related distrust by citizens.

1.11. References

[EC2020] EC Climate and Energy Package 2020, http://ec.europa.eu/clima/policies/package/index_en.htm

[ERN2010] ERN-CIP Analysis of Needs & Requirements from the Member States, prepared by the ERN-CIP Task Force, JRC Ispra, Italy.

[Luiijf2008] Luiijf, H.A.M., Nieuwenhuijs, A.H. (2008) *"Extensible Threat Taxonomy for Critical Infrastructures", Int'l Journal on Critical Infrastructures*, Int'l J. Critical Infrastructures, Vol. 4, No. 4, pp.409-417.

[Luiijf2006] Luiijf H.A.M., *Threat Taxonomy for Critical Infrastructures and Critical Infrastructure Risk Aspects at EU-level,* EU VITA project Deliverables D1.1 and D1.2, July 2006.

Annex I – Threat taxonomy for Smart Grids (additional to current)

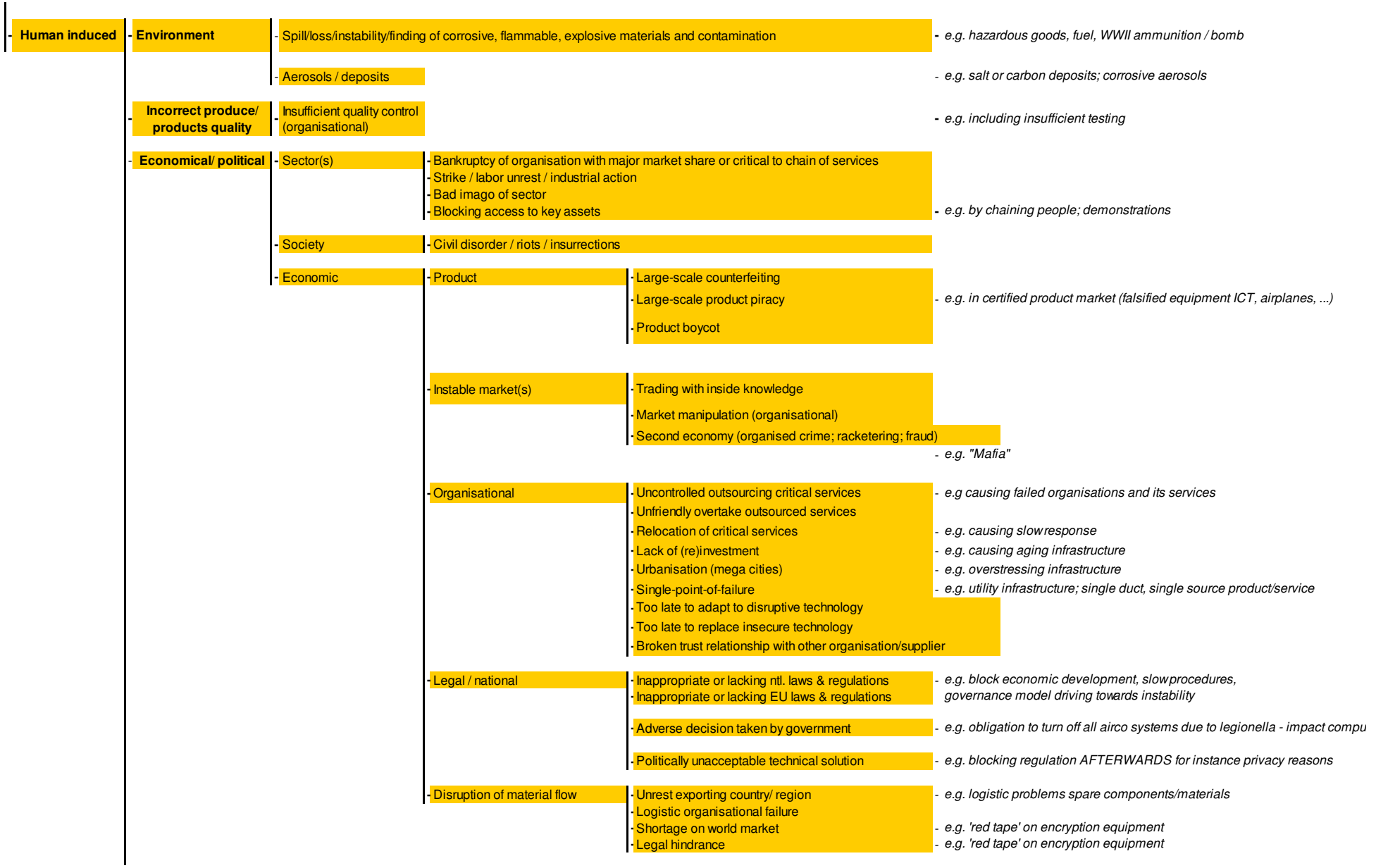
Critical infrastructure threat taxonomy - Threat cause classification - subset for Smart Grid

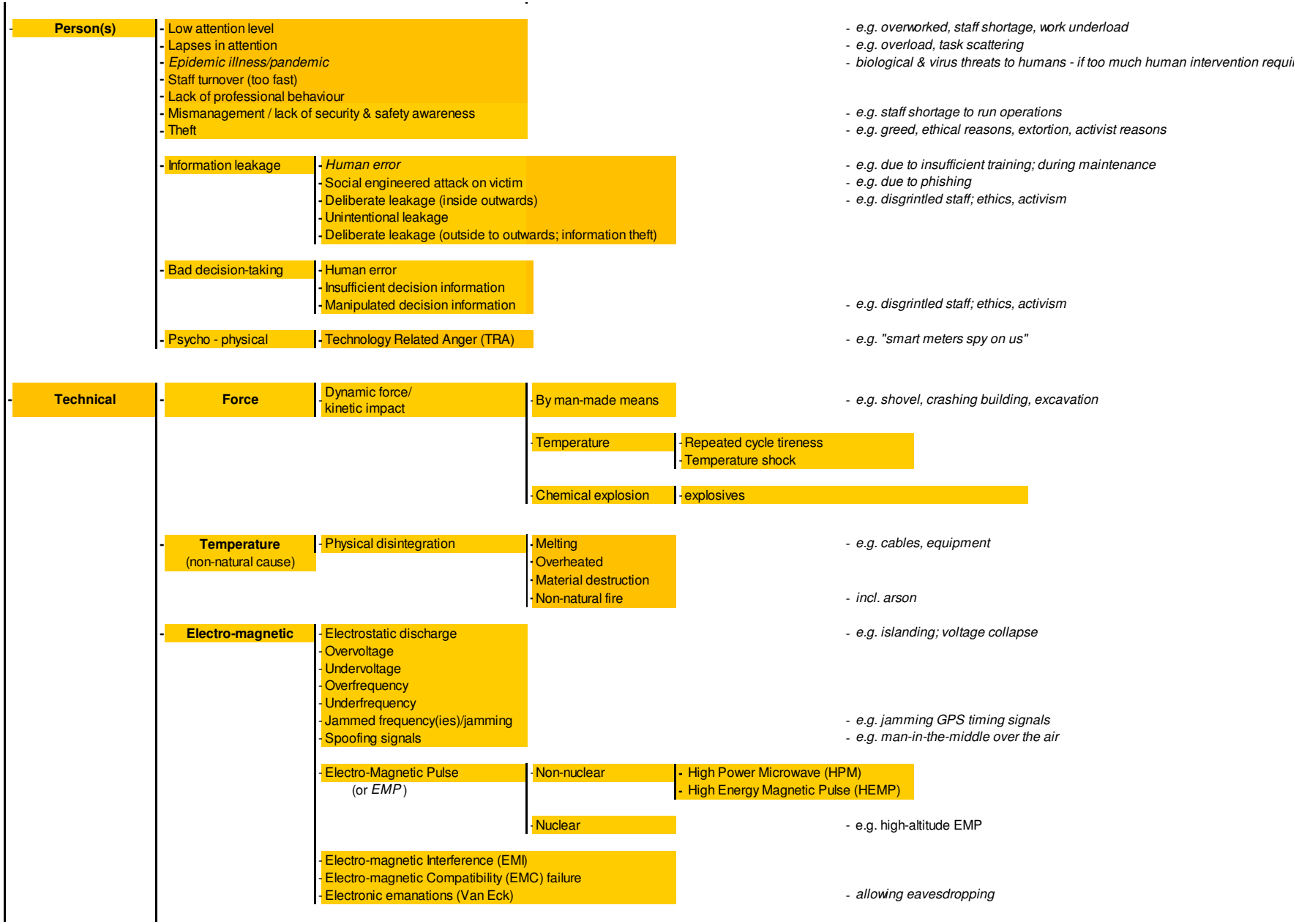
Base method ©TNO, VITA consortium 2005 - 2013

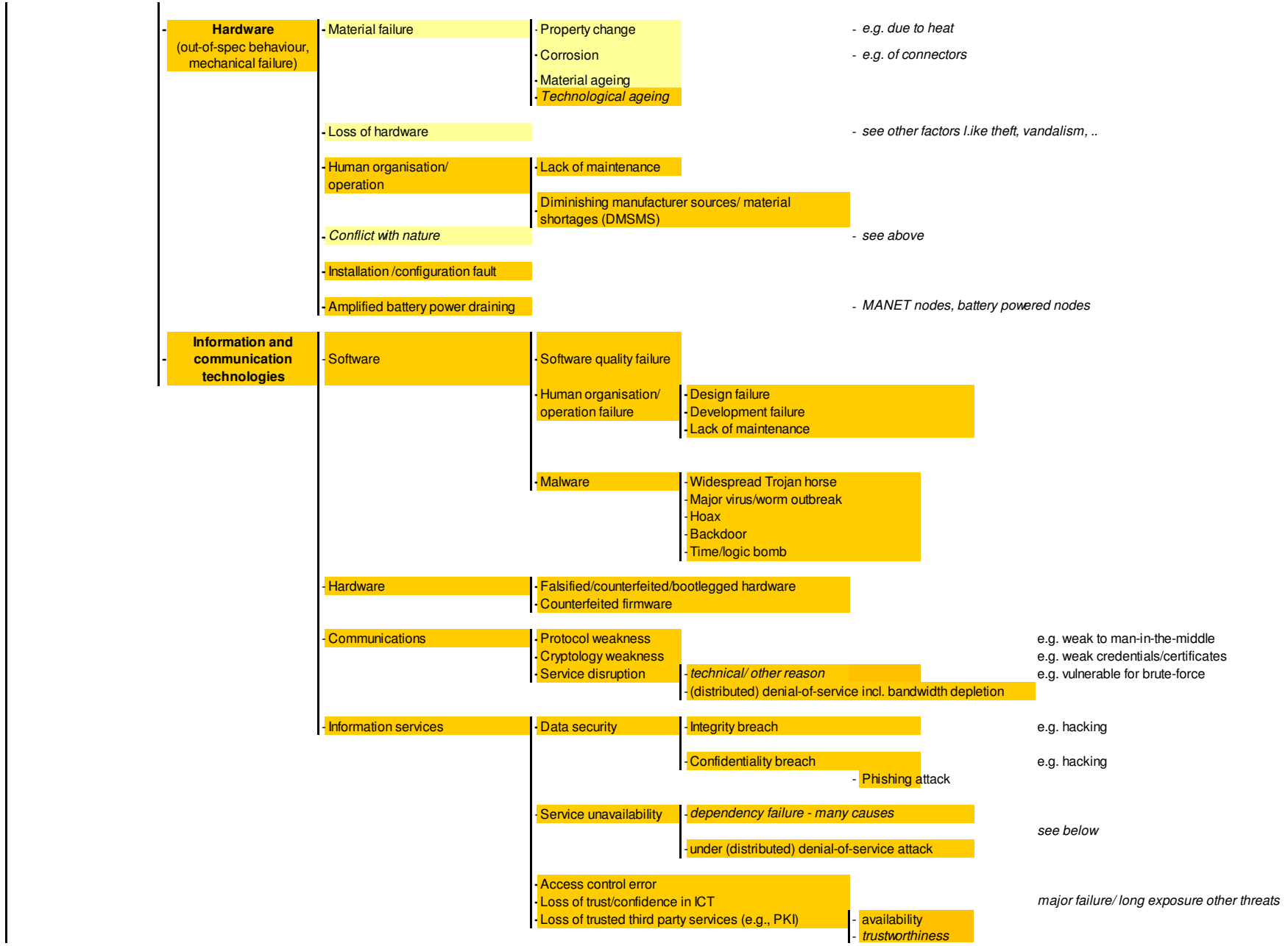
17-02-2012

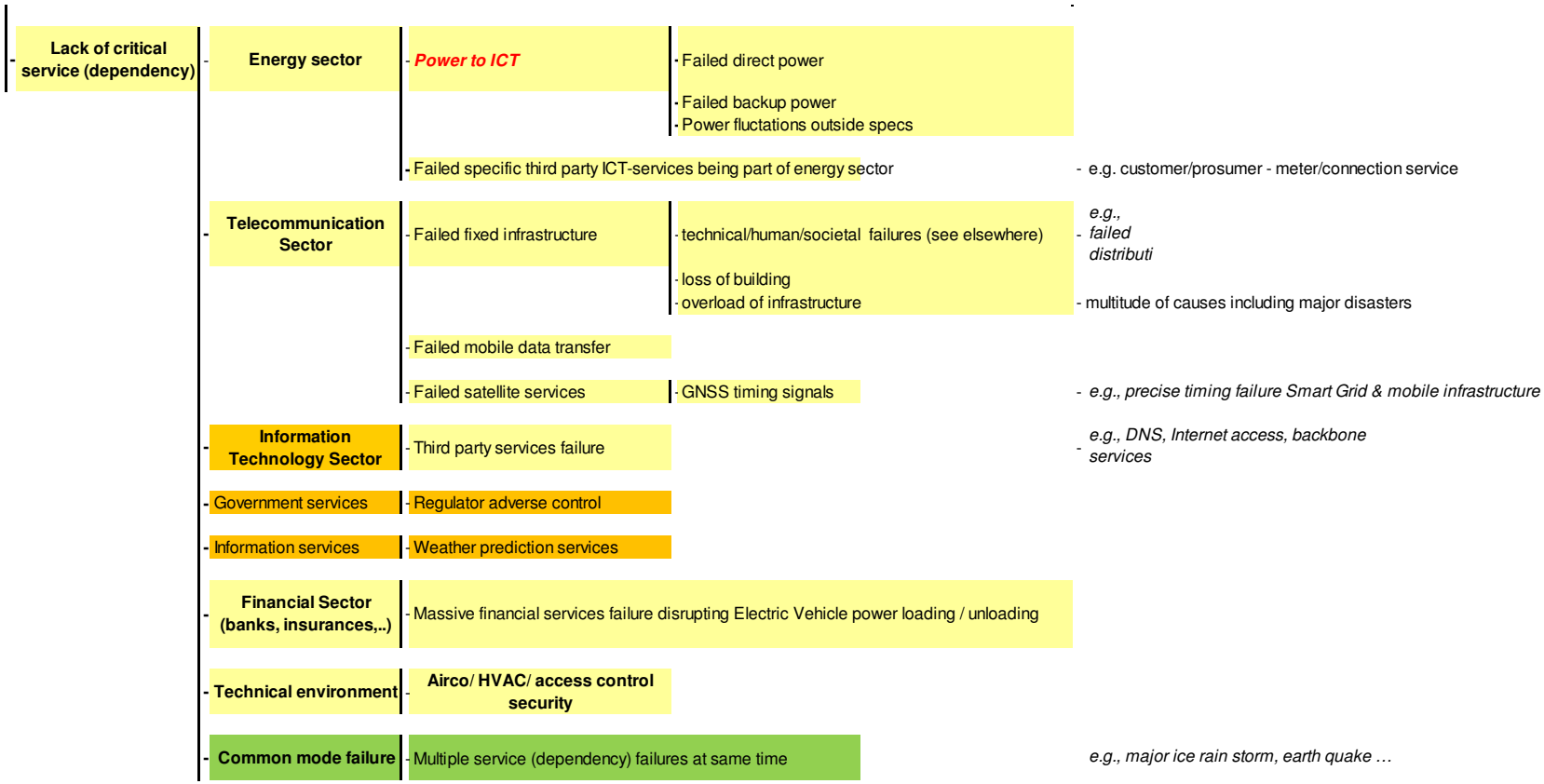
Nature only
Human and Nature
Human only

THREATS						
Nature/Natural	Earth	Earthquake	Kinetic energy release			*e.g. the shock waves*
		Landslide / rockfall	Landslide / rockfall			
		Ground settlement				*e.g. affecting cables weeks after flooding/heavy rain*
		Volcanic	Various physical effects			
	Air	Wind (too much)	Hurricane/major storm			
		Air temperature	Cold wave			
			Heat wave			
	Water	Snow	Various physical effects			
			Avalanche			
		Water (liquid form)	Physical force			
			Flooding / wetness			
		Humidity	too low humidity			*e.g. nature but also due to failing airco system*
			too high humidity			
	Natural radiation and natural EM-effects "ether"	Electro-magnetic	Electro-magnetic discharge	cloud-to-ground lightning		*e.g. EM, fire starter and air expansion impacts*
				cloud-to-cloud		*e.g. EM-impact on radiowave transmisssions*
			Radiation	Geomagnetic induced currents (GIC)		*after solar flare/flame burst / CME event*
	Fire (Nature)	Smoke				
		Physical disintegration				*e.g. soot particles from major forest fires*
	Biological	Vegetation, forest				*Nature in conflict with human infrastructure e.g. fallen tree*
		Animals				*every type of animal that gnawls, chases, bites, flies, crawls, makes love*


Human induced
Environment
Spill/loss/instability/finding of corrosive, flammable, explosive materials and contamination
e.g. hazardous goods, fuel, WWII ammunition / bomb
Aerosols / deposits
e.g. salt or carbon deposits; corrosive aerosols
Incorrect produce/ products quality
Insufficient quality control (organisational)
e.g. including insufficient testing
Economical/ political
Sector(s)
Bankruptcy of organisation with major market share or critical to chain of services
Strike / labor unrest / industrial action
Bad imago of sector
Blocking access to key assets
e.g. by chaining people; demonstrations
Society
Civil disorder / riots / insurrections
Economic
Product
Large-scale counterfeiting
Large-scale product piracy
e.g. in certified product market (falsified equipment ICT, airplanes, ...)
Product boycott
Instable market(s)
Trading with inside knowledge
Market manipulation (organisational)
Second economy (organised crime; racketering; fraud)
e.g. "Mafia"
Organisational
Uncontrolled outsourcing critical services
e.g causing failed organisations and its services
Unfriendly overtake outsourced services
Relocation of critical services
e.g. causing slow response
Lack of (re)investment
e.g. causing aging infrastructure
Urbanisation (mega cities)
e.g. overstressing infrastructure
Single-point-of-failure
e.g. utility infrastructure; single duct, single source product/service
Too late to adapt to disruptive technology
Too late to replace insecure technology
Broken trust relationship with other organisation/supplier
Legal / national
Inappropriate or lacking ntl. laws & regulations
e.g. block economic development, slow procedures, governance model driving towards instability
Inappropriate or lacking EU laws & regulations
Adverse decision taken by government
e.g. obligation to turn off all airco systems due to legionella - impact compu
Politically unacceptable technical solution
e.g. blocking regulation AFTERWARDS for instance privacy reasons
Disruption of material flow
Unrest exporting country/ region
e.g. logistic problems spare components/materials
Logistic organisational failure
Shortage on world market
e.g. 'red tape' on encryption equipment
Legal hindrance
e.g. 'red tape' on encryption equipment


Person(s)
Low attention level
Lapses in attention
Epidemic illness/pandemic
Staff turnover (too fast)
Lack of professional behaviour
Mismanagement / lack of security & safety awareness
Theft
Information leakage
Human error
Social engineered attack on victim
Deliberate leakage (inside outwards)
Unintentional leakage
Deliberate leakage (outside to outwards; information theft)
Bad decision-taking
Human error
Insufficient decision information
Manipulated decision information
Psycho - physical
Technology Related Anger (TRA)
Technical
Force
Dynamic force/ kinetic impact
By man-made means
Temperature
Repeated cycle tireness
Temperature shock
Chemical explosion
explosives
Temperature (non-natural cause)
Physical disintegration
Melting
Overheated
Material destruction
Non-natural fire
Electro-magnetic
Electrostatic discharge
Overvoltage
Undervoltage
Overfrequency
Underfrequency
Jammed frequency(ies)/jamming
Spoofing signals
Electro-Magnetic Pulse (or EMP)
Non-nuclear
High Power Microwave (HPM)
High Energy Magnetic Pulse (HEMP)
Nuclear
Electro-magnetic Interference (EMI)
Electro-magnetic Compatibility (EMC) failure
Electronic emanations (Van Eck)
e.g. overworked, staff shortage, work underload
e.g. overload, task scattering
biological & virus threats to humans - if too much human intervention requi
e.g. staff shortage to run operations
e.g. greed, ethical reasons, extortion, activist reasons
e.g. due to insufficient training; during maintenance
e.g. due to phishing
e.g. disgrintled staff; ethics, activism
e.g. disgrintled staff; ethics, activism
e.g. "smart meters spy on us"
e.g. shovel, crashing building, excavation
e.g. cables, equipment
incl. arson
e.g. islanding; voltage collapse
e.g. jamming GPS timing signals
e.g. man-in-the-middle over the air
e.g. high-altitude EMP
allowing eavesdropping


Hardware
(out-of-spec behaviour, mechanical failure)
Material failure
Property change
e.g. due to heat
Corrosion
e.g. of connectors
Material ageing
Technological ageing
Loss of hardware
see other factors l.ike theft, vandalism, ..
Human organisation/ operation
Lack of maintenance
Diminishing manufacturer sources/ material shortages (DMSMS)
Conflict with nature
see above
Installation /configuration fault
Amplified battery power draining
MANET nodes, battery powered nodes
Information and communication technologies
Software
Software quality failure
Human organisation/ operation failure
Design failure
Development failure
Lack of maintenance
Malware
Widespread Trojan horse
Major virus/worm outbreak
Hoax
Backdoor
Time/logic bomb
Hardware
Falsified/counterfeited/bootlegged hardware
Counterfeited firmware
Communications
Protocol weakness
e.g. weak to man-in-the-middle
Cryptology weakness
e.g. weak credentials/certificates
Service disruption
technical/ other reason
e.g. vulnerable for brute-force
(distributed) denial-of-service incl. bandwidth depletion
Information services
Data security
Integrity breach
e.g. hacking
Confidentiality breach
e.g. hacking
Phishing attack
Service unavailability
dependency failure - many causes
see below
under (distributed) denial-of-service attack
Access control error
Loss of trust/confidence in ICT
Loss of trusted third party services (e.g., PKI)
major failure/ long exposure other threats
availability
trustworthiness


Lack of critical service (dependency)
Energy sector
Power to ICT
Failed direct power
Failed backup power
Power fluctations outside specs
Failed specific third party ICT-services being part of energy sector
e.g. customer/prosumer - meter/connection service
Telecommunication Sector
Failed fixed infrastructure
technical/human/societal failures (see elsewhere)
e.g., failed distributi
loss of building
overload of infrastructure
multitude of causes including major disasters
Failed mobile data transfer
Failed satellite services
GNSS timing signals
e.g., precise timing failure Smart Grid & mobile infrastructure
Information Technology Sector
Third party services failure
e.g., DNS, Internet access, backbone services
Government services
Regulator adverse control
Information services
Weather prediction services
Financial Sector (banks, insurances,..)
Massive financial services failure disrupting Electric Vehicle power loading / unloading
Technical environment
Airco/ HVAC/ access control security
Common mode failure
Multiple service (dependency) failures at same time
e.g., major ice rain storm, earth quake …

Annex II – Threats to Components Set I (bulk – transmission – distribution)

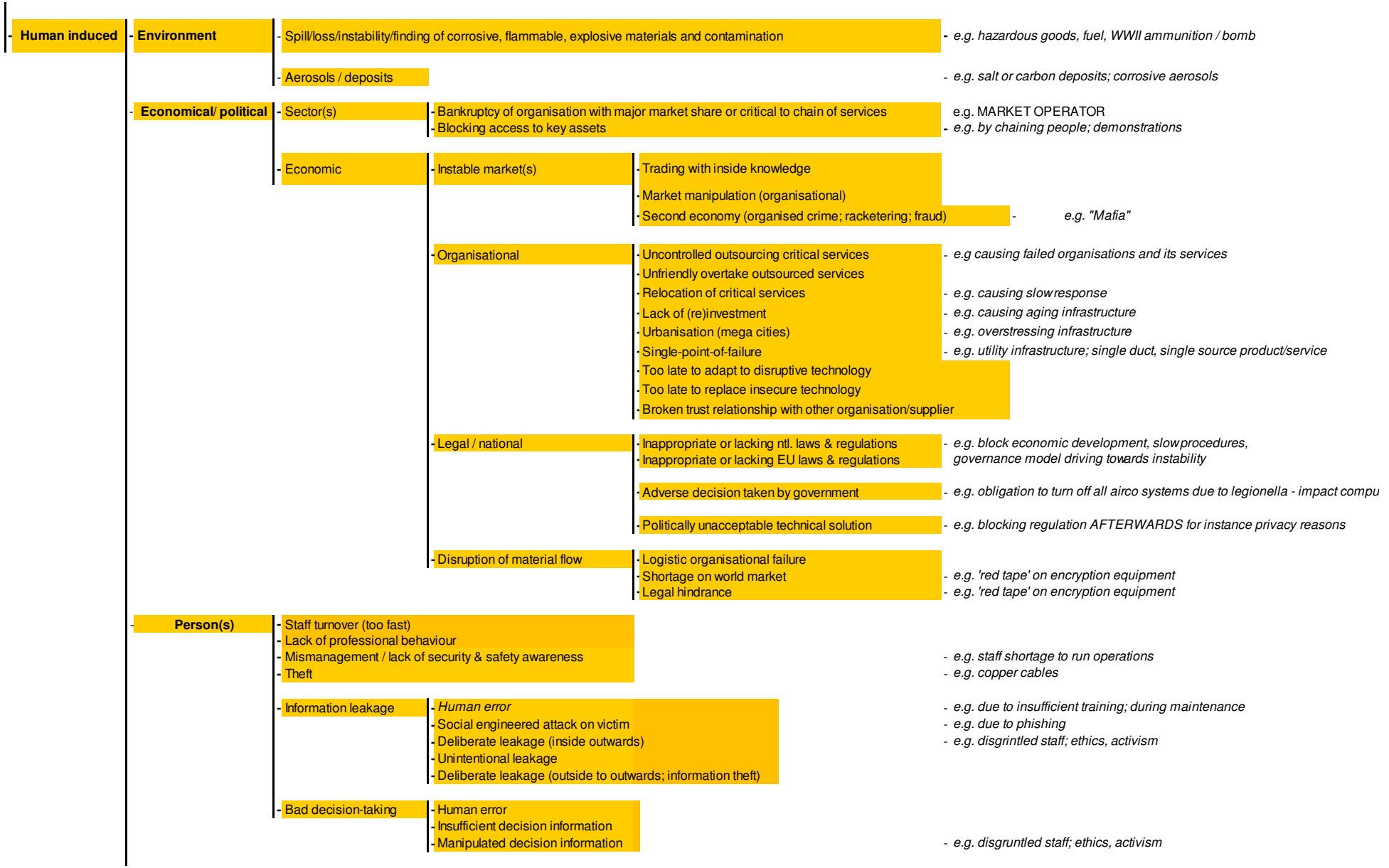
Critical infrastructure threat taxonomy - Threat cause classification - subset for Smart Grid

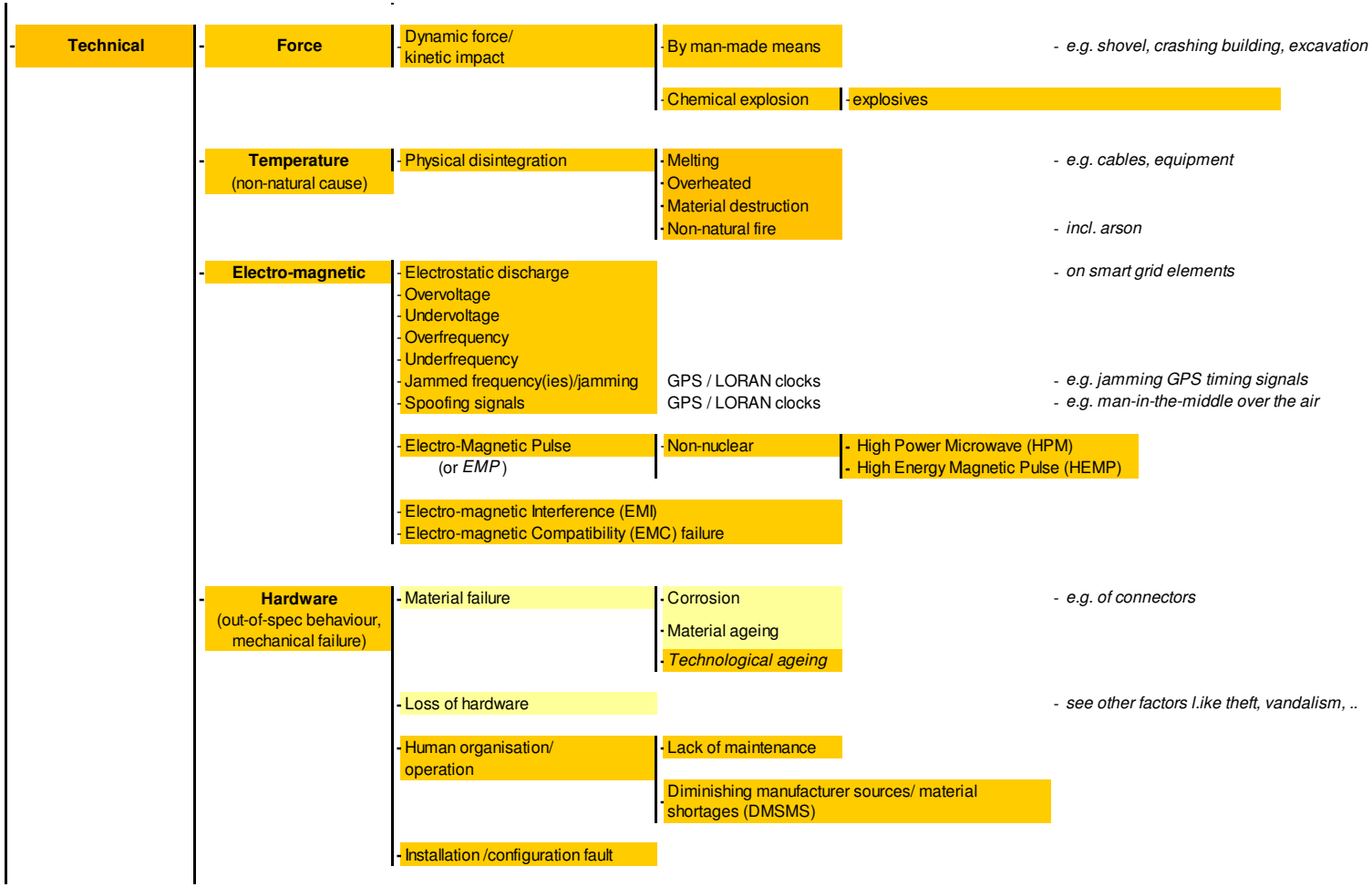
Base method ©TNO, VITA consortium 2005 - 2013

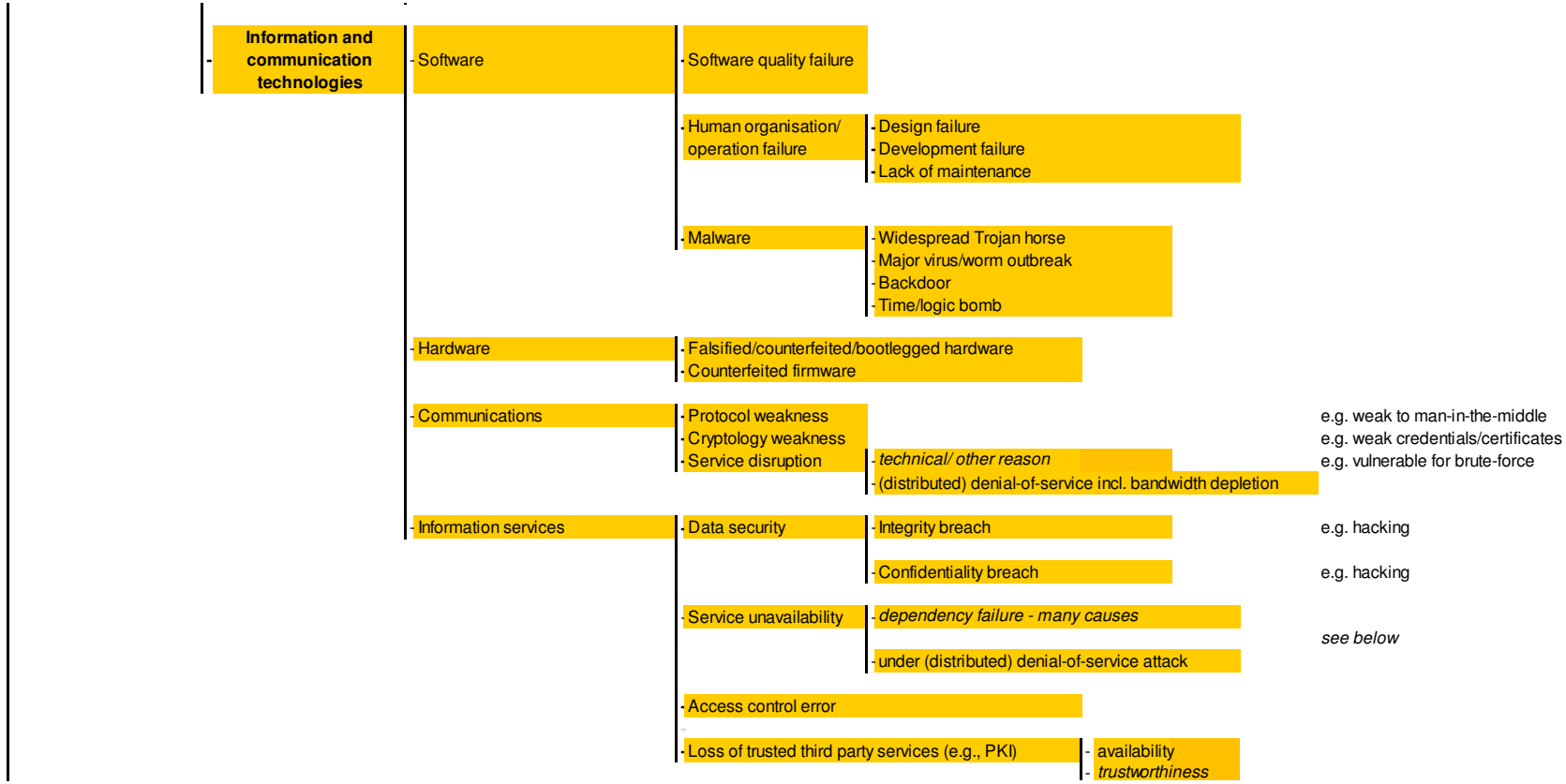
17-02-2012

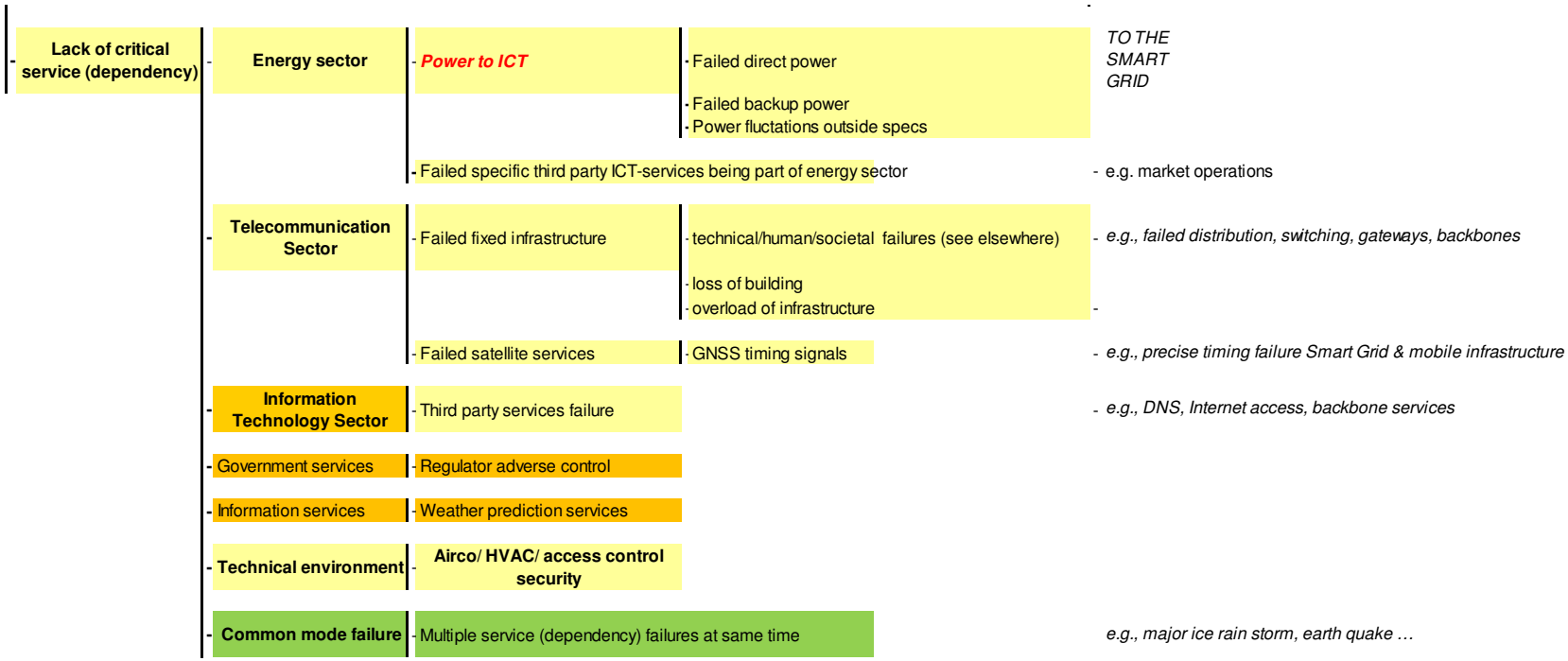
Nature only
Human and Nature
Human only

THREATS	**Nature/Natural**	**Earth**	Earthquake	Kinetic energy release		*e.g. the shock waves*
			Landslide / rockfall	Landslide / rockfall		
			Volcanic	Various physical effects		
		Air	Wind (too much)	Hurricane/major storm		
		Water	Water (liquid form)	Physical force		
				Flooding (wetness)		
			Humidity	too low humidity		
				too high humidity		
		Natural radiation and natural EM-effects "ether"	Electro-magnetic	Electro-magnetic discharge	cloud-to-ground lightning	*e.g. EM, fire starter and air expansion impacts*
					cloud-to-cloud	*e.g. EM-impact on radiowave transmisssions*
				Radiation	Geomagnetic induced currents (GIC)	*after solar flare/flame burst / CME event*
		Fire (Nature)	Physical disintegration			*e.g. soot particles from major forest fires*
		Biological	Animals			


Human induced
Environment
Spill/loss/instability/finding of corrosive, flammable, explosive materials and contamination
e.g. hazardous goods, fuel, WWII ammunition / bomb
Aerosols / deposits
e.g. salt or carbon deposits; corrosive aerosols
Economical/ political
Sector(s)
Bankruptcy of organisation with major market share or critical to chain of services
e.g. MARKET OPERATOR
Blocking access to key assets
e.g. by chaining people; demonstrations
Economic
Instable market(s)
Trading with inside knowledge
Market manipulation (organisational)
Second economy (organised crime; racketering; fraud)
e.g. "Mafia"
Organisational
Uncontrolled outsourcing critical services
e.g causing failed organisations and its services
Unfriendly overtake outsourced services
Relocation of critical services
e.g. causing slow response
Lack of (re)investment
e.g. causing aging infrastructure
Urbanisation (mega cities)
e.g. overstressing infrastructure
Single-point-of-failure
e.g. utility infrastructure; single duct, single source product/service
Too late to adapt to disruptive technology
Too late to replace insecure technology
Broken trust relationship with other organisation/supplier
Legal / national
Inappropriate or lacking ntl. laws & regulations
e.g. block economic development, slow procedures,
Inappropriate or lacking EU laws & regulations
governance model driving towards instability
Adverse decision taken by government
e.g. obligation to turn off all airco systems due to legionella - impact compu
Politically unacceptable technical solution
e.g. blocking regulation AFTERWARDS for instance privacy reasons
Disruption of material flow
Logistic organisational failure
Shortage on world market
e.g. 'red tape' on encryption equipment
Legal hindrance
e.g. 'red tape' on encryption equipment
Person(s)
Staff turnover (too fast)
Lack of professional behaviour
Mismanagement / lack of security & safety awareness
e.g. staff shortage to run operations
Theft
e.g. copper cables
Information leakage
Human error
e.g. due to insufficient training; during maintenance
Social engineered attack on victim
e.g. due to phishing
Deliberate leakage (inside outwards)
e.g. disgrintled staff; ethics, activism
Unintentional leakage
Deliberate leakage (outside to outwards; information theft)
Bad decision-taking
Human error
Insufficient decision information
Manipulated decision information
e.g. disgruntled staff; ethics, activism


Technical
Force
Dynamic force/ kinetic impact
By man-made means
e.g. shovel, crashing building, excavation
Chemical explosion
explosives
Temperature (non-natural cause)
Physical disintegration
Melting
Overheated
Material destruction
Non-natural fire
e.g. cables, equipment
incl. arson
Electro-magnetic
Electrostatic discharge
Overvoltage
Undervoltage
Overfrequency
Underfrequency
Jammed frequency(ies)/jamming
Spoofing signals
on smart grid elements
GPS / LORAN clocks
e.g. jamming GPS timing signals
GPS / LORAN clocks
e.g. man-in-the-middle over the air
Electro-Magnetic Pulse (or EMP)
Non-nuclear
High Power Microwave (HPM)
High Energy Magnetic Pulse (HEMP)
Electro-magnetic Interference (EMI)
Electro-magnetic Compatibility (EMC) failure
Hardware (out-of-spec behaviour, mechanical failure)
Material failure
Corrosion
Material ageing
Technological ageing
e.g. of connectors
Loss of hardware
see other factors l.ike theft, vandalism, ..
Human organisation/ operation
Lack of maintenance
Diminishing manufacturer sources/ material shortages (DMSMS)
Installation /configuration fault


Information and communication technologies
Software
Software quality failure
Human organisation/ operation failure
Design failure
Development failure
Lack of maintenance
Malware
Widespread Trojan horse
Major virus/worm outbreak
Backdoor
Time/logic bomb
Hardware
Falsified/counterfeited/bootlegged hardware
Counterfeited firmware
Communications
Protocol weakness
Cryptology weakness
Service disruption
technical/ other reason
(distributed) denial-of-service incl. bandwidth depletion
e.g. weak to man-in-the-middle
e.g. weak credentials/certificates
e.g. vulnerable for brute-force
Information services
Data security
Integrity breach
Confidentiality breach
e.g. hacking
e.g. hacking
Service unavailability
dependency failure - many causes
under (distributed) denial-of-service attack
see below
Access control error
Loss of trusted third party services (e.g., PKI)
availability
trustworthiness

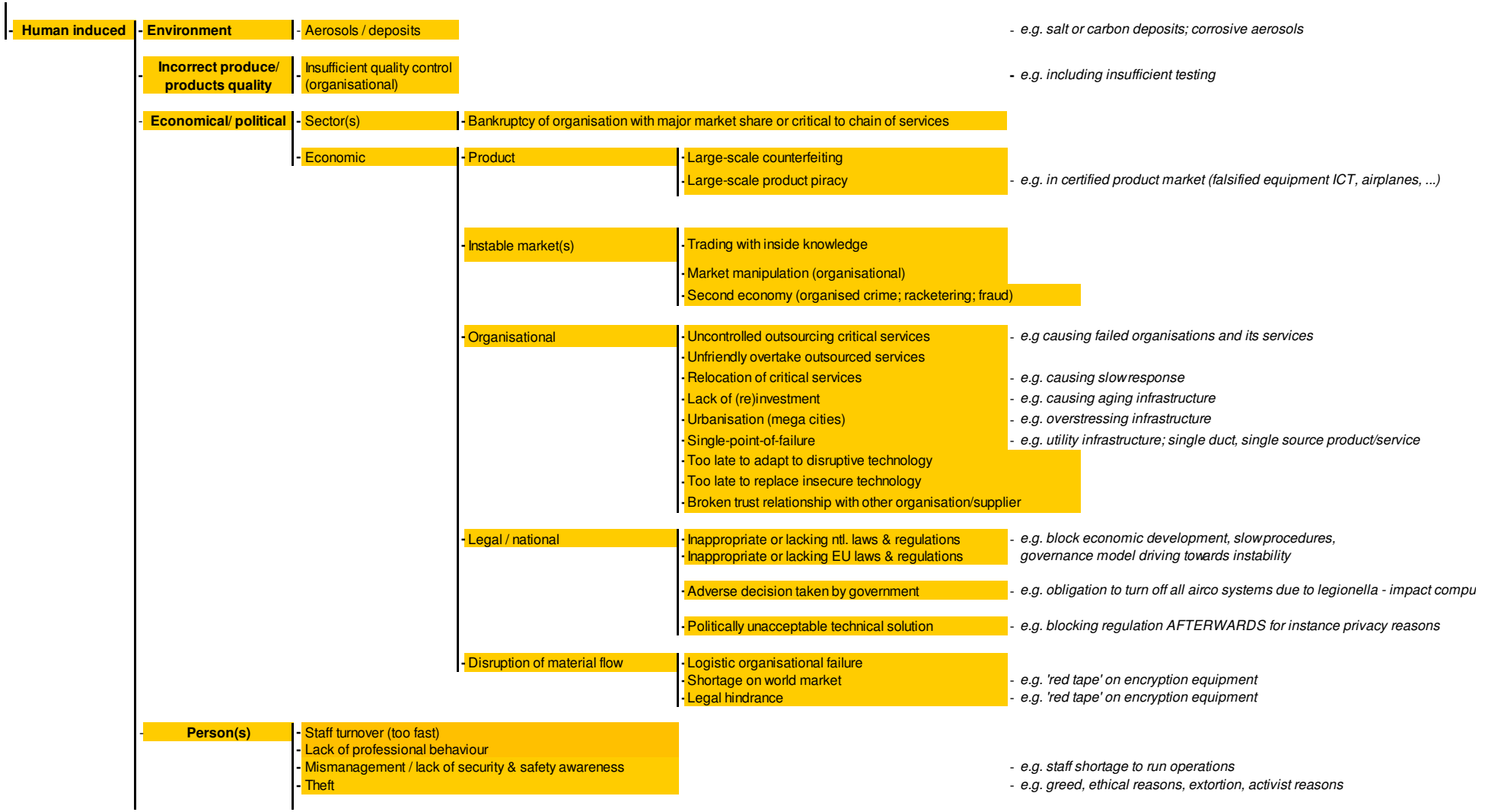

Lack of critical service (dependency)
Energy sector
Power to ICT
Failed direct power
Failed backup power
Power fluctations outside specs
TO THE SMART GRID
Failed specific third party ICT-services being part of energy sector
e.g. market operations
Telecommunication Sector
Failed fixed infrastructure
technical/human/societal failures (see elsewhere)
e.g., failed distribution, switching, gateways, backbones
loss of building
overload of infrastructure
Failed satellite services
GNSS timing signals
e.g., precise timing failure Smart Grid & mobile infrastructure
Information Technology Sector
Third party services failure
e.g., DNS, Internet access, backbone services
Government services
Regulator adverse control
Information services
Weather prediction services
Technical environment
Airco/ HVAC/ access control security
Common mode failure
Multiple service (dependency) failures at same time
e.g., major ice rain storm, earth quake …

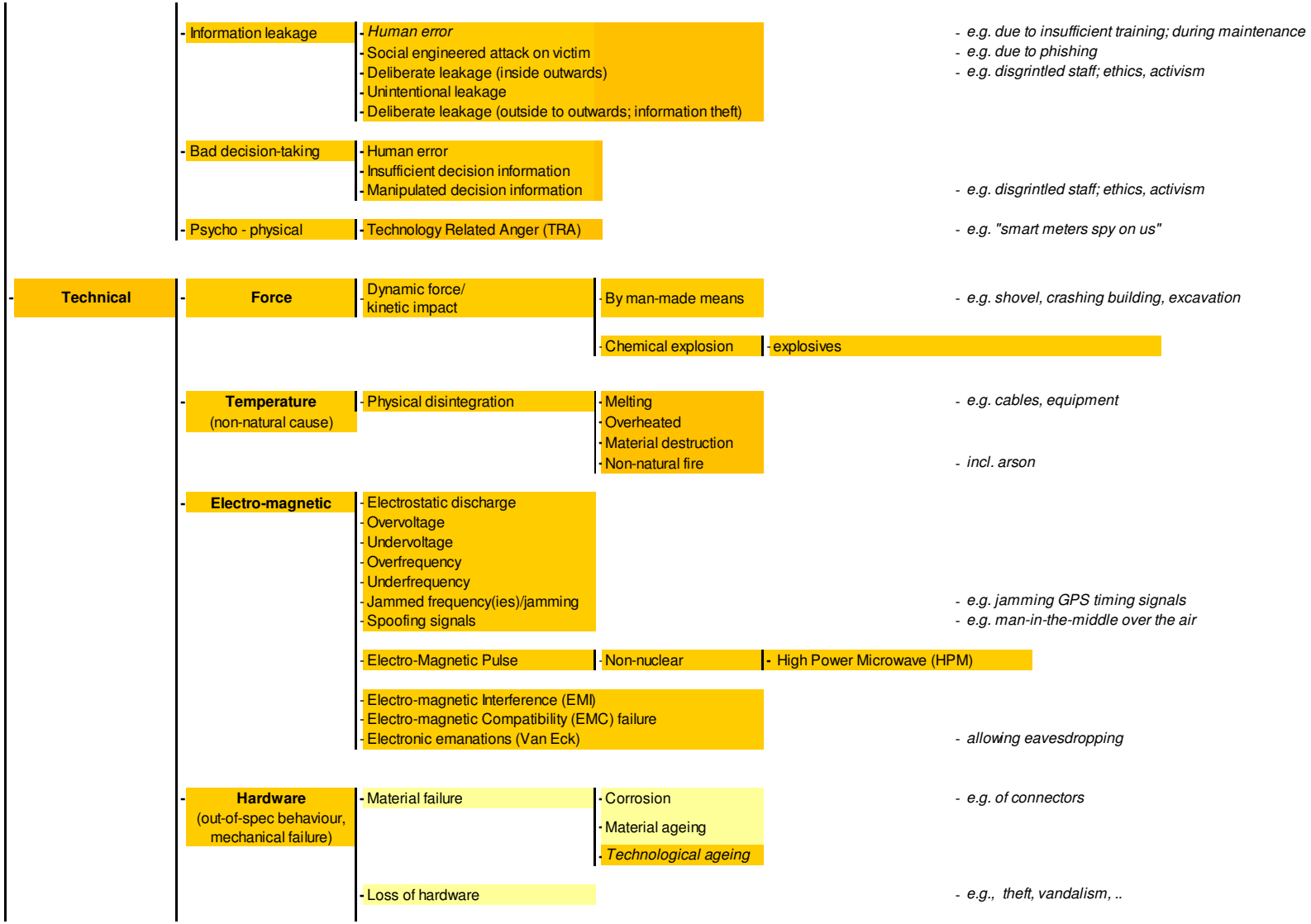
Annex III – Threats to Components Set II (consumers/prosumers – distribution – distributed generation)

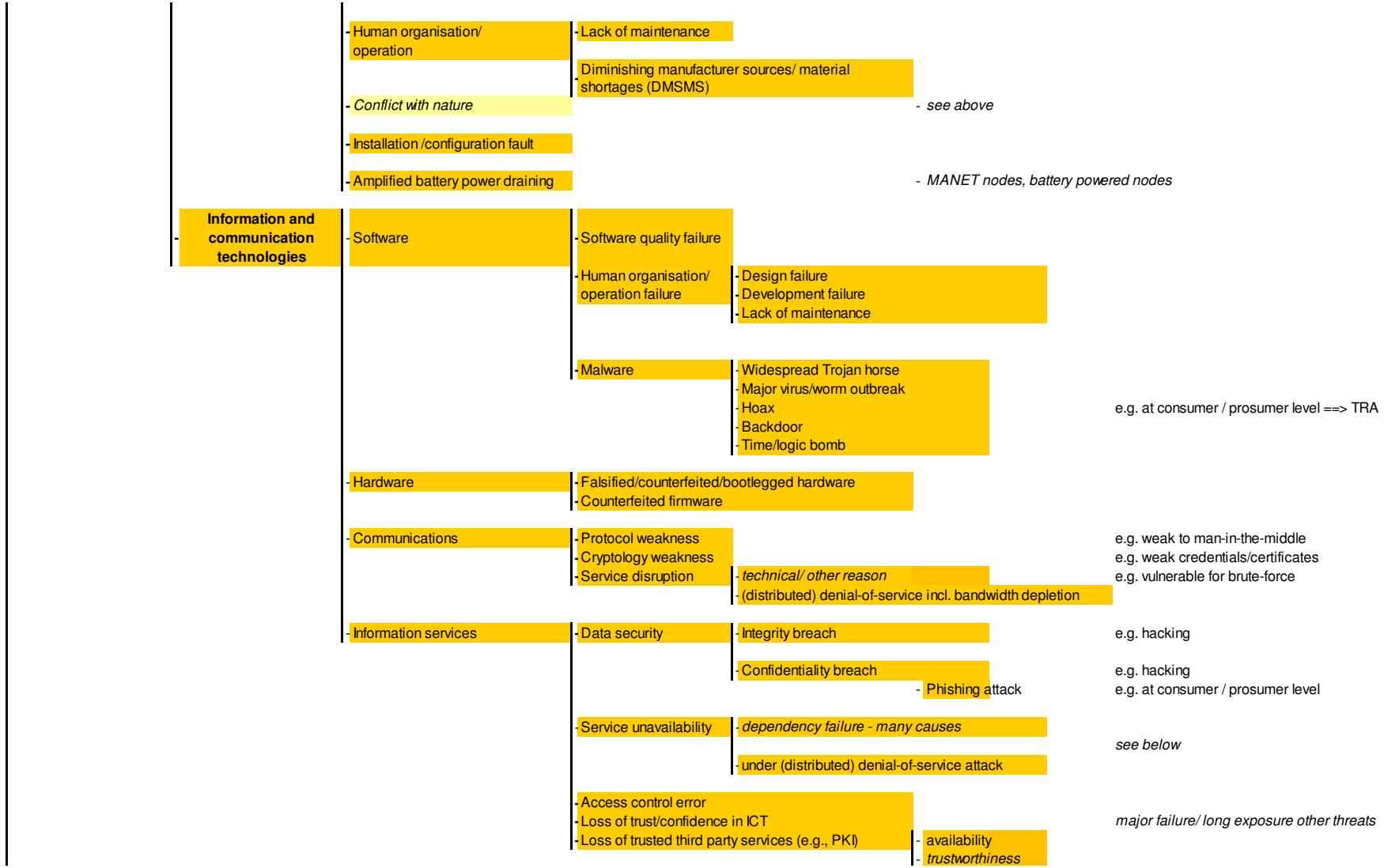
Critical infrastructure threat taxonomy - Threat cause classification - subset for Smart Grid

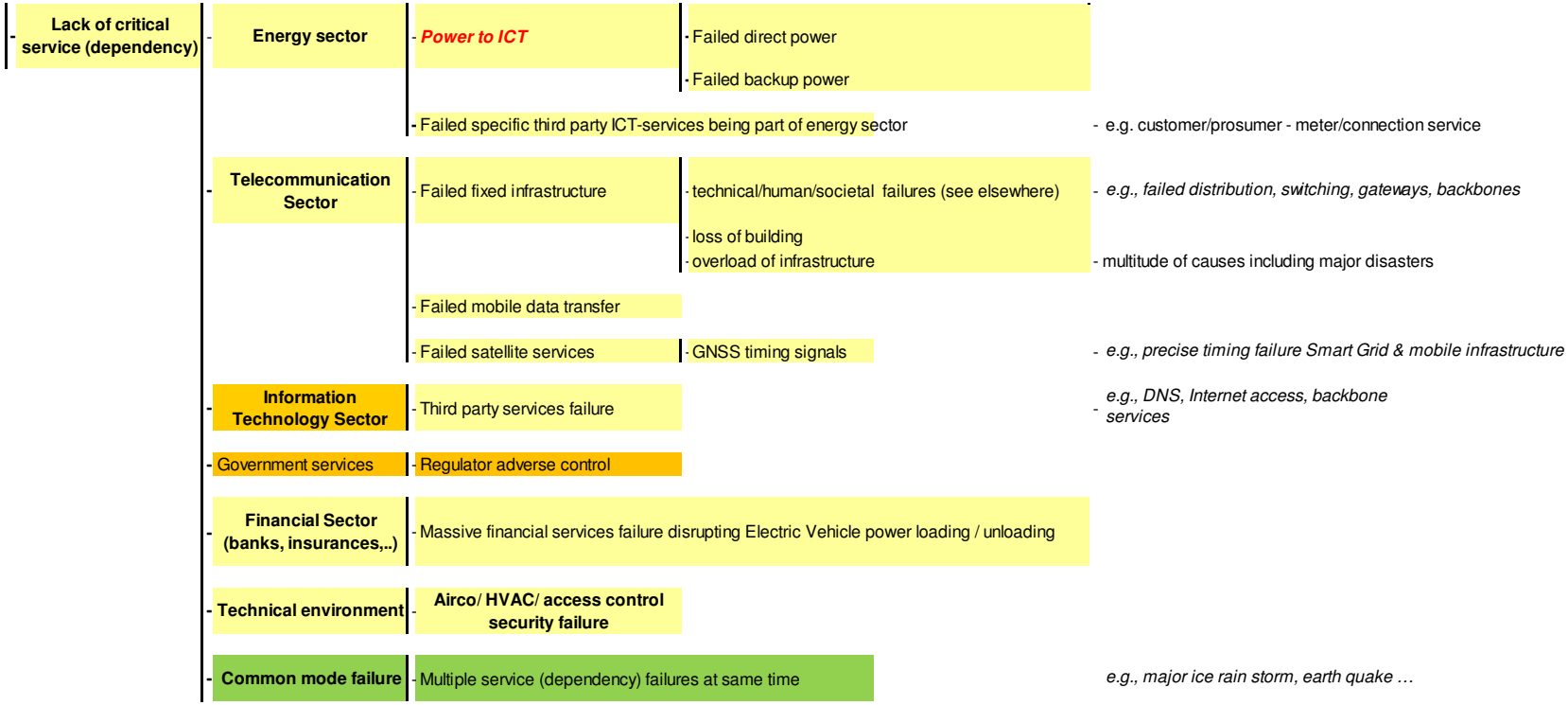
17-02-2012

Nature only							
Human and Nature							
Human only							
THREATS	**Nature/Natural**	**Earth**	Earthquake	Kinetic energy release			*e.g. the shock waves*
			Landslide / rockfall	Landslide / rockfall			
			Ground settlement				*e.g. affecting cables weeks after flooding/heavy rain*
			Volcanic	Various physical effects			
		Air	Air temperature	Cold wave			
				Heat wave			
		Water	Snow	Various physical effects			
			Water (liquid form)	Physical force			
				Flooding / wetness			
			Humidity	too low humidity	*ICT equipment is sensitive*		*e.g. nature but also due to failing airco system*
				too high humidity	*ICT equipment is sensitive*		
		Natural radiation and natural EM-effects "ether"	Electro-magnetic	Electro-magnetic discharge	cloud-to-ground lightning		*e.g. EM, fire starter and air expansion impacts*
					cloud-to-cloud		*e.g. EM-impact on radiowave transmisssions*
				Radiation	Geomagnetic induced currents (GIC)		*after solar flare/flame burst / CME event*
		Fire (Nature)	Smoke				
			Physical disintegration				*e.g. soot particles from major forest fires*
		Biological	Animals				*every type of animal that gnawls, chases, bites, flies, crawls, makes love*


Human induced
Environment
Aerosols / deposits
e.g. salt or carbon deposits; corrosive aerosols
Incorrect produce/ products quality
Insufficient quality control (organisational)
e.g. including insufficient testing
Economical/ political
Sector(s)
Bankruptcy of organisation with major market share or critical to chain of services
Economic
Product
Large-scale counterfeiting
Large-scale product piracy
e.g. in certified product market (falsified equipment ICT, airplanes, ...)
Instable market(s)
Trading with inside knowledge
Market manipulation (organisational)
Second economy (organised crime; racketering; fraud)
Organisational
Uncontrolled outsourcing critical services
e.g causing failed organisations and its services
Unfriendly overtake outsourced services
Relocation of critical services
e.g. causing slow response
Lack of (re)investment
e.g. causing aging infrastructure
Urbanisation (mega cities)
e.g. overstressing infrastructure
Single-point-of-failure
e.g. utility infrastructure; single duct, single source product/service
Too late to adapt to disruptive technology
Too late to replace insecure technology
Broken trust relationship with other organisation/supplier
Legal / national
Inappropriate or lacking ntl. laws & regulations
e.g. block economic development, slow procedures, governance model driving towards instability
Inappropriate or lacking EU laws & regulations
Adverse decision taken by government
e.g. obligation to turn off all airco systems due to legionella - impact compu
Politically unacceptable technical solution
e.g. blocking regulation AFTERWARDS for instance privacy reasons
Disruption of material flow
Logistic organisational failure
Shortage on world market
e.g. 'red tape' on encryption equipment
Legal hindrance
e.g. 'red tape' on encryption equipment
Person(s)
Staff turnover (too fast)
e.g. staff shortage to run operations
Lack of professional behaviour
Mismanagement / lack of security & safety awareness
Theft
e.g. greed, ethical reasons, extortion, activist reasons


Information leakage
Human error
Social engineered attack on victim
Deliberate leakage (inside outwards)
Unintentional leakage
Deliberate leakage (outside to outwards; information theft)
e.g. due to insufficient training; during maintenance
e.g. due to phishing
e.g. disgrintled staff; ethics, activism
Bad decision-taking
Human error
Insufficient decision information
Manipulated decision information
e.g. disgrintled staff; ethics, activism
Psycho - physical
Technology Related Anger (TRA)
e.g. "smart meters spy on us"
Technical
Force
Dynamic force/ kinetic impact
By man-made means
e.g. shovel, crashing building, excavation
Chemical explosion
explosives
Temperature (non-natural cause)
Physical disintegration
Melting
Overheated
Material destruction
Non-natural fire
e.g. cables, equipment
incl. arson
Electro-magnetic
Electrostatic discharge
Overvoltage
Undervoltage
Overfrequency
Underfrequency
Jammed frequency(ies)/jamming
Spoofing signals
e.g. jamming GPS timing signals
e.g. man-in-the-middle over the air
Electro-Magnetic Pulse
Non-nuclear
High Power Microwave (HPM)
Electro-magnetic Interference (EMI)
Electro-magnetic Compatibility (EMC) failure
Electronic emanations (Van Eck)
allowing eavesdropping
Hardware (out-of-spec behaviour, mechanical failure)
Material failure
Corrosion
Material ageing
Technological ageing
e.g. of connectors
Loss of hardware
e.g., theft, vandalism, ..


Human organisation/ operation
Lack of maintenance
Diminishing manufacturer sources/ material shortages (DMSMS)
Conflict with nature
see above
Installation /configuration fault
Amplified battery power draining
MANET nodes, battery powered nodes
Information and communication technologies
Software
Software quality failure
Human organisation/ operation failure
Design failure
Development failure
Lack of maintenance
Malware
Widespread Trojan horse
Major virus/worm outbreak
Hoax
Backdoor
Time/logic bomb
e.g. at consumer / prosumer level ==> TRA
Hardware
Falsified/counterfeited/bootlegged hardware
Counterfeited firmware
Communications
Protocol weakness
Cryptology weakness
Service disruption
technical/ other reason
(distributed) denial-of-service incl. bandwidth depletion
e.g. weak to man-in-the-middle
e.g. weak credentials/certificates
e.g. vulnerable for brute-force
Information services
Data security
Integrity breach
Confidentiality breach
Phishing attack
e.g. hacking
e.g. hacking
e.g. at consumer / prosumer level
Service unavailability
dependency failure - many causes
under (distributed) denial-of-service attack
see below
Access control error
Loss of trust/confidence in ICT
Loss of trusted third party services (e.g., PKI)
availability
trustworthiness
major failure/ long exposure other threats


Lack of critical service (dependency)
Energy sector
Power to ICT
Failed direct power
Failed backup power
Failed specific third party ICT-services being part of energy sector
e.g. customer/prosumer - meter/connection service
Telecommunication Sector
Failed fixed infrastructure
technical/human/societal failures (see elsewhere)
e.g., failed distribution, switching, gateways, backbones
loss of building
overload of infrastructure
multitude of causes including major disasters
Failed mobile data transfer
Failed satellite services
GNSS timing signals
e.g., precise timing failure Smart Grid & mobile infrastructure
Information Technology Sector
Third party services failure
e.g., DNS, Internet access, backbone services
Government services
Regulator adverse control
Financial Sector (banks, insurances,..)
Massive financial services failure disrupting Electric Vehicle power loading / unloading
Technical environment
Airco/ HVAC/ access control security failure
Common mode failure
Multiple service (dependency) failures at same time
e.g., major ice rain storm, earth quake …