Università degli Studi di Padova

DATA CENTER SUSTAINABILITY

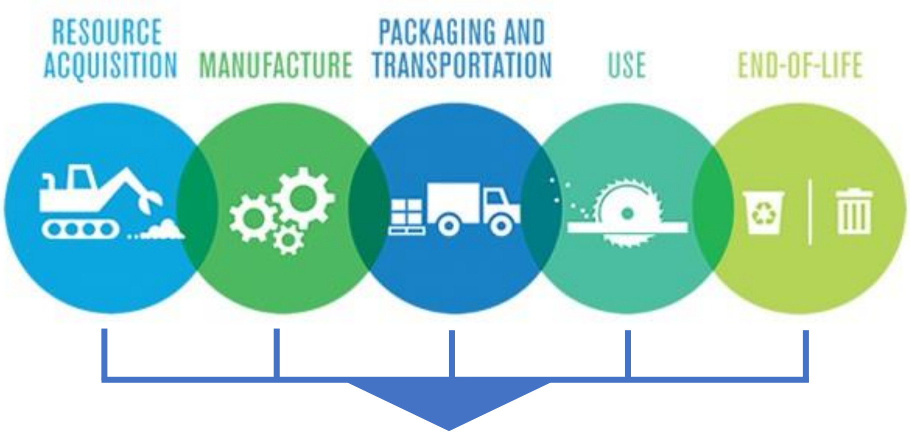
Best practices and future scenarios

LCA of the VSIX data center

Analysis of the environmental impacts of a data center over its life cycle

Padova, 16 December 2022

Life Cycle Assessment (LCA)



ENVIRONMENTAL IMPACTS

Literature review

	Shah et al. (2011)	Shah et al. (2012)	Lettieri (2012)	Whitehead, Shah et al. (2015)
CASE STUDY	Hypothetical data center	Real data center	Hypothetical data center	Real data center
LCA APPROACH	Hybrid: streamlined process LCA + EIO-LCA	Streamlined	Hybrid: process-based + EIO-LCA (Screening LCA)	Hybrid: process- + EIO-LCA (Screening LCA)
ENVIRONMENTAL IMPACTS	Energy, GWP, Total toxic releases, PM-10	13 impact categories	GWP	11 impact categories
DATA COLLECTION & MODELING	- Data from existing process LCA models (servers) - Cost data (other equipment, electricity) - EIO models	Representation through 28 parameters, with impact factors from the industry	Data from existing studies	- Primary data: quantities and/or costs - Secondary data: from process-based LCA studies - Energy model - EIO model
SYSTEM BOUNDARIES & GRANULARITY	4 systems: IT, Cooling, Power Supply and Building + main components	Similar to the 2011 study	6 pieces of equipment: Building shell, Servers, Room level PDU, UPS, CRAC unit, Chiller	7 systems: IT, Structural, Mechanical, Electrical, Fire, Public health, and External + sub-systems, components and materials
LIFE CYCLE STAGES	Embedded (incl. End of Life?) and Operational impacts	Similar to the 2011 study	Resource extraction and manufacturing, Operation, Transportation, and End-of-Life	Manufacturing, Transport to site, Operation, and End of Life (only transport)

The aims of the research

- **Identify hotspots**: trace the impacts of processes, going into the detail of components, sub-components, materials, energy, …
- **Provide data centers with a viable LCA methodology** to «simplify the complexity» of their facility

CASE STUDY of a real data center:

VSIX – University of Padua

→ Internet Exchange Point (IXP)

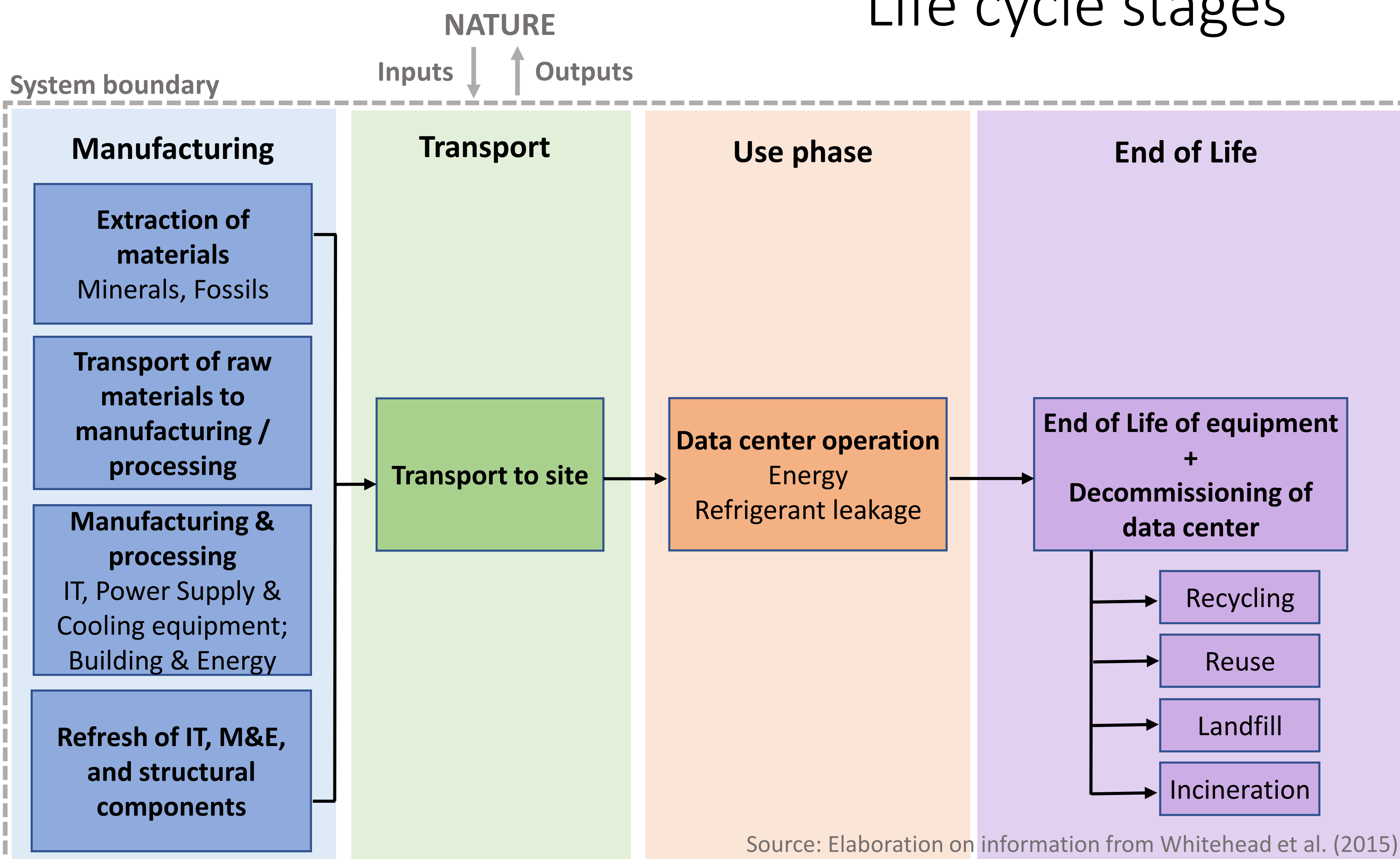
→ Data center (colocation service)

LCA Goal and Scope:

1-year operation of the VSIX Tier II facility, 84 kW IT

LCA FUNCTIONAL UNIT

System boundaries & Life cycle stages

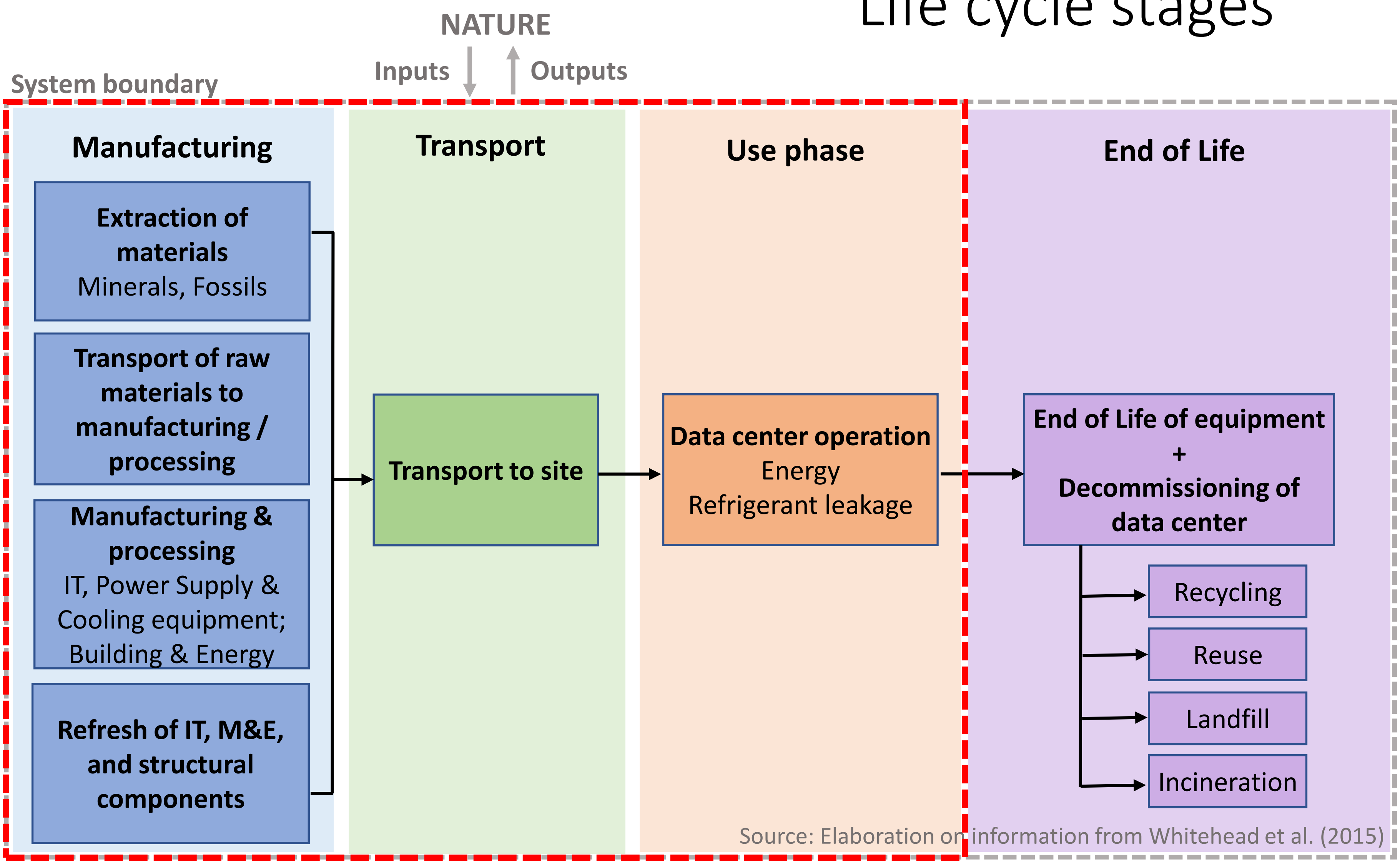


Source: Elaboration on information from Whitehead et al. (2015)

Hp. **100% virgin materials**

OMITTED

System boundaries & Life cycle stages



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OMITTED

Data collection and assumptions

System	Equipment categories
IT	Network equipment (incl. 10 sub-cat.)
	Optic drawers
	Server & storage
	Cable management panels
	Patch panels
	Front rack cover panels
	Rack trays
	Consoles
	Computers
	Rack Enclosures
	Network cables - copper
	Network cables - optical fiber
Power Supply	PDUs
	Power supply - misc. (incl. 5 sub-cat.)
	Power distribution - misc.
	Batteries
	Power system with rectifiers and batteries
	UPS - incl. batteries
	Switchboards
	Backup generator
	Power cables
Cooling	Outdoor units
	Indoor units
	Piping
	Refrigerant - incl. refill
Building	-

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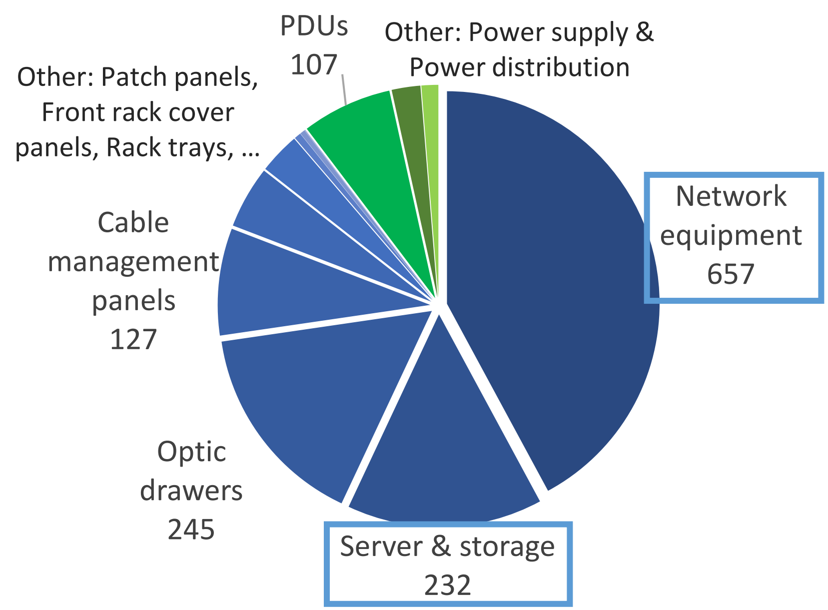
Building	-

IT rack equipment: (PRIMARY DATA)

Number of Rack Units (U):



+ N. and avg size of HHDs & SSDs

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Facility equipment: (PRIMARY DATA)

- Number
- Mass
- Dimensions (lenght, volume, surface, …)
- Technical data
- …

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Building	-

ASSUMPTIONS, FOR EACH PIECE OF EQUIPMENT:

- **Transport to site**: distances & modes of transportation
- **Lifetimes**
  - VSIX data center: 30 years
  - Building: 60 years
  - Server, storage and networking equipment: 5 years
  - Batteries: 7 years
  - Other: 10-30 years

OPERATION OF THE DATA CENTER: (PRIMARY DATA)

- **Energy**:
  - Electricity consumption + generation mix
  - Diesel consumption (backup genset)
- **Refrigerant leakage**

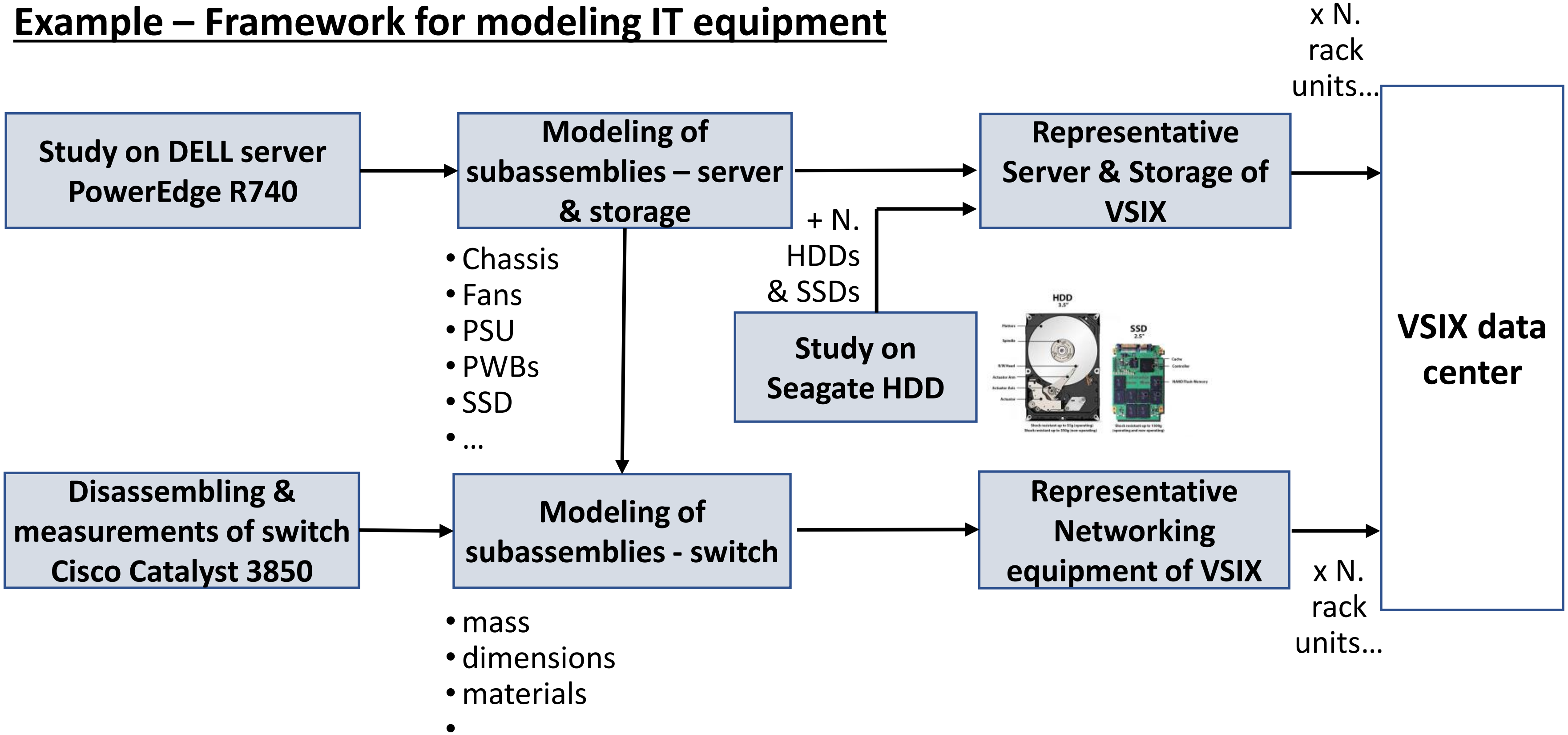
Modeling of components

Our steps:

- **Standards and guidelines** (LCA of ICT goods and services): ETSI, ITU, Carbon Trust & GeSi, The Green Grid
- Request of data to **manufacturers** → no success (sensitive information)

→ Data from **existing LCA studies to create our own model** for each type of equipment

Example – Framework for modeling IT equipment



Modeling of components

Database: Ecoinvent

Software: SimaPro PhD

ENVIRONMENTAL DATASETS

Example – Modeling the server mainboard

Components	Sub-components/materials/processes	N. units	Caracteristics	m.u.	Materials / Processes / Assemblies
PWB - Mainboard, incl. CPU	Mainboard PWB	1	1,3630	kg	Dataset modeled from Ecoinvent data
area [cm2]	Mainboard connectors	1			
1924,7	Coin cell	1	0,0016	kg	Battery cell, Li-ion {GLO}| market for | APOS, S
weight [kg]	CPU with housing	2	1,2840	kg	
2,6486					
	Heatsink**	2	0,6600	kg	Aluminium, primary, ingot {RoW}| market for | APOS, S
	Plastic mount	2	0,0156	kg	Plastic injection moulded part
	Thermal paste	2	0,0014	kg	Solder, paste, Sn95.5Ag3.9Cu0.6, for electronics industry {GLO}| market for | APOS, S (a)
	CPU socket on mainboard				
	stainless steel	2	0,3896	kg	Steel sheet (ECCS)/GLO
	plastic	2	0,0026	kg	Plastic injection moulded part
			1,0692	**kg**	
	CPU:	2	**0,2144**	**kg**	
	Substrate for active components (2-layer rigid...)		0,0286	kg	Epoxy resin insulator, SiO2 {GLO}| market for | APOS, S (b)
	Solder paste SnAg3.5		0,0018	kg	Solder, paste, Sn95.5Ag3.9Cu0.6, for electronics industry {GLO}| market for | APOS, S
	Gold, primary (in Electronics)		1,9895E-08	kg	Gold {GLO}| market for | APOS, S
	Wafer manufacturing for bare dice		0,0014	m2	Wafer, fabricated, for integrated circuit {GLO}| market for | APOS, S
	Housing IC		0	kg	-
	Lead frame		0	kg	-
	Mixer, global average electricity back-end...		0,2060	MJ	Electricity, low voltage {CN}| market group for | APOS, S (c)
	Copper sheet		0,1072	kg	Copper-rich materials {GLO}| market for copper-rich materials | APOS, S
	Capacitor ceramic MLCC 0603 (6mg)		150	pcs	Capacitor, film type, for through-hole mounting {GLO}| market for | APOS, S (d)
	Silicone rubber (RTV-2, condensation)		0,0014	kg	Synthetic rubber {GLO}| market for | APOS, S

(a) dato specifico per "thermal paste" non disponibile in SimaPro (b) hp uno dei materiali più comuni cioè epoxy resin (c) hp mix energetico della Cina, dove è prodotta la mainboard (d) hp uno dei tipi di capacitori disponibili in SimaPro/Ecoinvent

PWB

CPU heatsink

CPU with socket & plastic mount

Results – Impact categories

Impact assessment methodology: CML-IA baseline / EU25

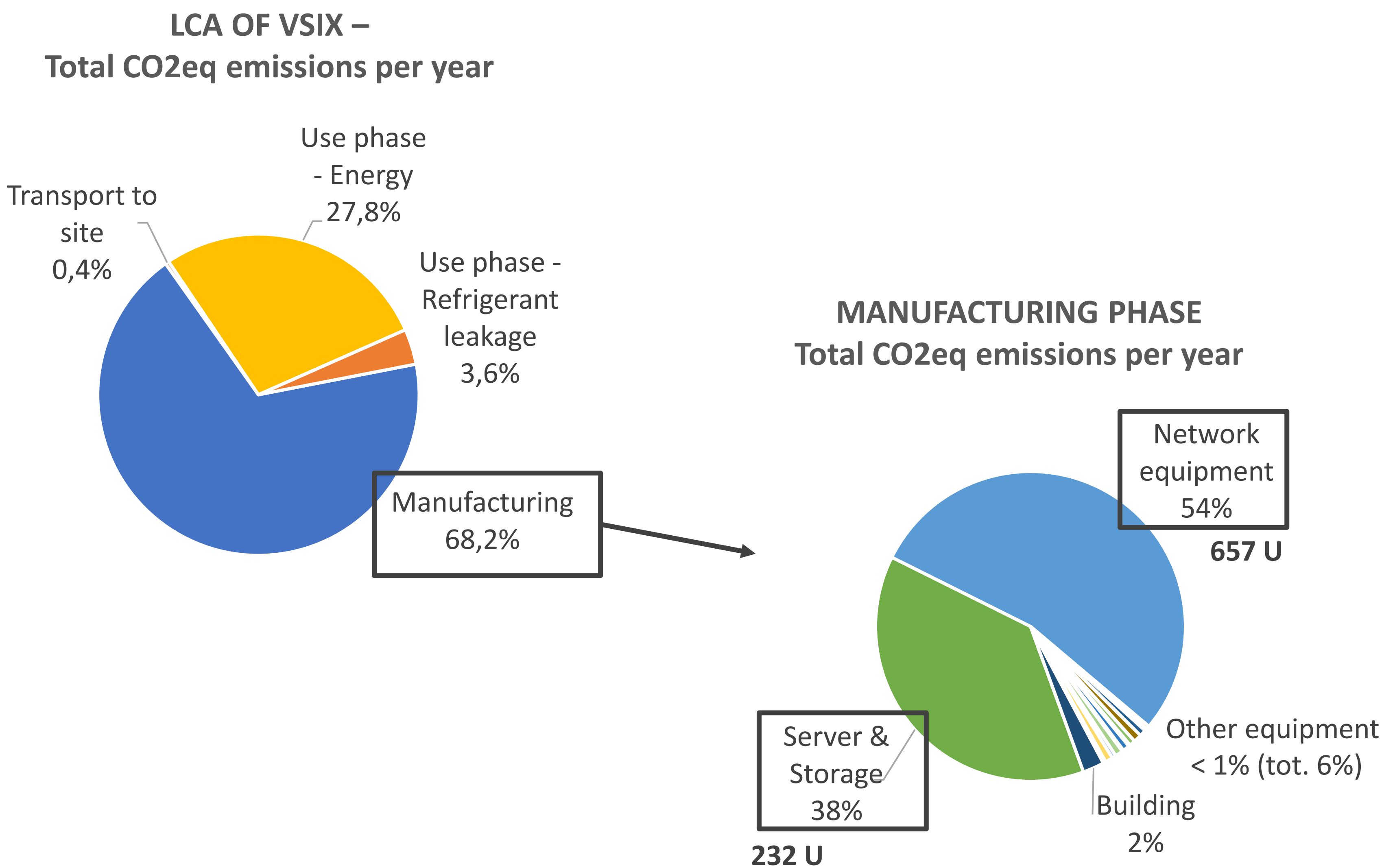
Impact category	Value	Unit
Abiotic depletion*	1,55E+01	kg Sb eq
Abiotic depletion* (fossil fuels)	1,31E+06	MJ
Global warming (GWP100a)	1,20E+05	kg CO2 eq
Ozone layer depletion (ODP)	1,27E-02	kg CFC-11 eq
Human toxicity	3,01E+05	kg 1,4-DB eq
Fresh water aquatic ecotoxicity	3,03E+05	kg 1,4-DB eq
Marine aquatic ecotoxicity	4,66E+08	kg 1,4-DB eq
Terrestrial ecotoxicity	4,67E+02	kg 1,4-DB eq
Photochemical oxidation	4,24E+01	kg C2H4 eq
Acidification	7,36E+02	kg SO2 eq
Eutrophication	3,02E+02	kg PO4--- eq

*Abiotic depletion = depletion of nonliving (abiotic) resources

120 tCO_2eq / year

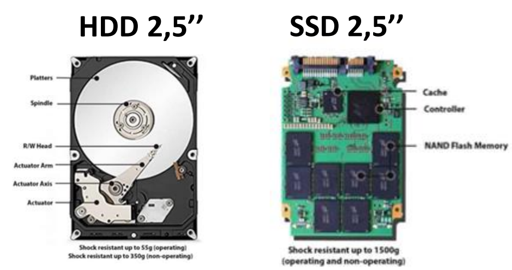
Global warming impact of the VSIX data center over its life cycle

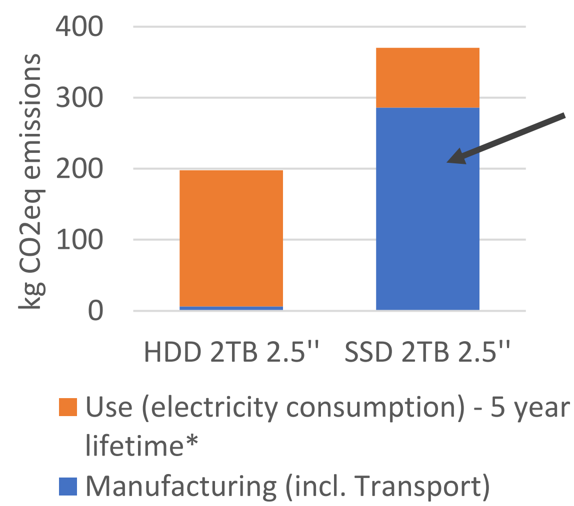
Results - GWP


LCA OF VSIX –
Total CO2eq emissions per year
Use phase - Energy 27,8%
Transport to site 0,4%
Use phase - Refrigerant leakage 3,6%
Manufacturing 68,2%
MANUFACTURING PHASE
Total CO2eq emissions per year
Network equipment 54%
657 U
Other equipment: < 1% (tot. 6%)
Building 2%
Server & Storage 38%
232 U

Results - GWP

Server & Storage (2U)	kg CO2 eq
Mixed boards	755
Disks (avg. data), of which:	292
SSD 2TB (N. 0,5)	143
HDD 6TB 3.5'' (N. 5,1)	123
HDD 2TB 2.5'' (N. 4,4)	26
Mainboard - S&S	128
PSU - S&S	101
Chassis - S&S	39
Fan - S&S	23
TOTAL	**1339**

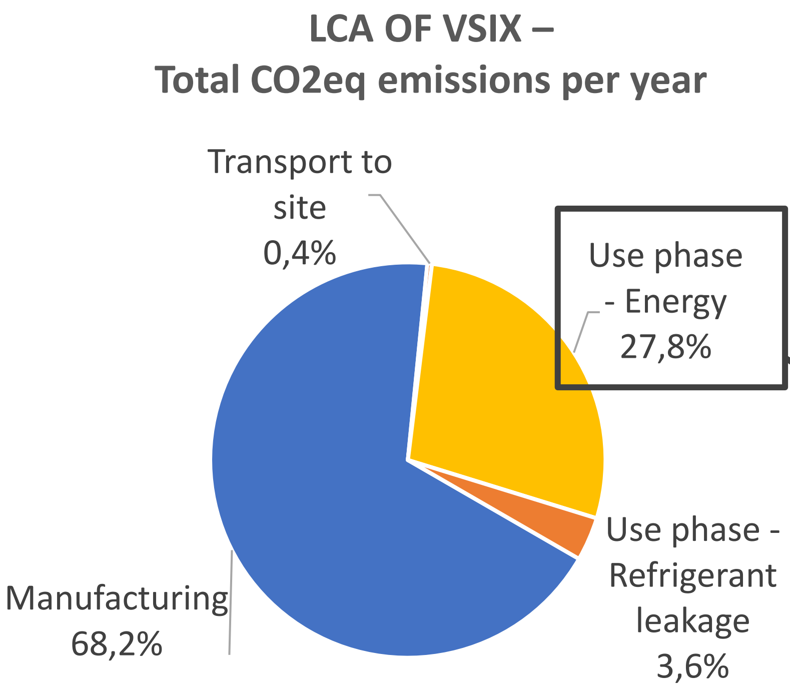


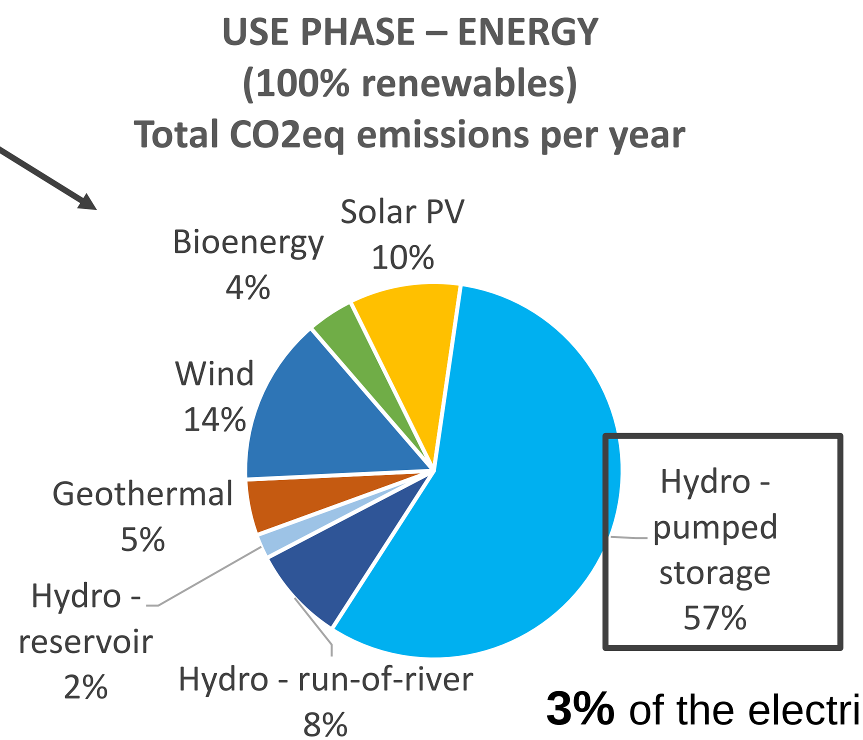


~98% due to **wafer manufacturing** for the production of **integrated circuits** (for the NAND Flash of the SSD)

*Electricity consumption (5 year lifetime): SSD: 118 kWh (data SSD Seagate Koho Model 1,92TB – from LCA 2016); HDD: 269 kWh (data HDD Seagate Barracuda Model 2TB; hp 50% operating mode (6,8 W), 50% idle mode (5,5 W))

Results - GWP





3% of the electricity purchased by VSIX

Implications & Conclusions

- VSIX's Global Warming Impact over its life cycle: **120 tCO_2eq/year**

  ~ A/R Venice-Naples by car, every day of the year

- Impact of **manufacturing**: **68%** over the whole life cycle (vs <20% previous studies, with fossils)

- **Operational** impact: limited to **31%**, thanks to **100% renewable electricity**
  - In case of electricity from the average Italian mix: overall LCA emissions would increase 4fold.
  - Analysis of the generation mix (hydro-pumped)
  - Impact will decrease with the decarbonization of the Italian energy system

- Impacts need to be traced within all the processes involved in the **supply chain** of data centers: **components, materials, energy, and processes** (e.g. SSDs vs HDDs)

  → Is it viable to find other materials or processes that will fulfil the same function…?

Limitations & Future research

- Improve detail (especially manufacturing and transport)
- Model specific components

→ Need of data from the supply chain & extensive (free) environmental databases

- End of Life, % of recycled materials
- Periodical updates of the LCA

Thank you for the attention!

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References

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2) *Shah, Amip J., Yuan Chen, and Cullen E. Bash. "Sources of Variability in Data Center Lifecycle Assessment."* IEEE International Symposium on Sustainable Systems and Technology (Institute of Electrical and Electronics Engineers), 2012

3) *Whitehead, B., Andrews, D., & Shah, A. "The life cycle assessment of a UK data centre."* International Journal of Life Cycle Assessment, 2015

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6) *" Methodology for the assessment of the environmental impact of information and communication technology goods, networks and services",* 2014 – ITU (International Telecommunication Union)

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8) *" Data center life cycle assessment guidelines",* 2012 – The Green Grid

9) "*LCA of Dell PowerEdge R740*" DELLTechnologies & thinkstep, 2019

10) "*Barracuda LP HDD Product Life Cycle Analysis*" Seagate, 2011