Network sustainability, green metrics, data models, and instrumentation

Alexander Clemm ludwig@clemm.org & Marisol Palmero mpalmero@cisco.com

Approaches to improve sustainability

- Plenty of opportunities to explore: pollution-aware traffic steering, energy-aware VNF placement, schemes to retire idling resources, …

- Structuring Challenges and Opportunities – draft-irtf-nmrg-green-ps

Architecture		Management
Protocol	Network	
Equipment		
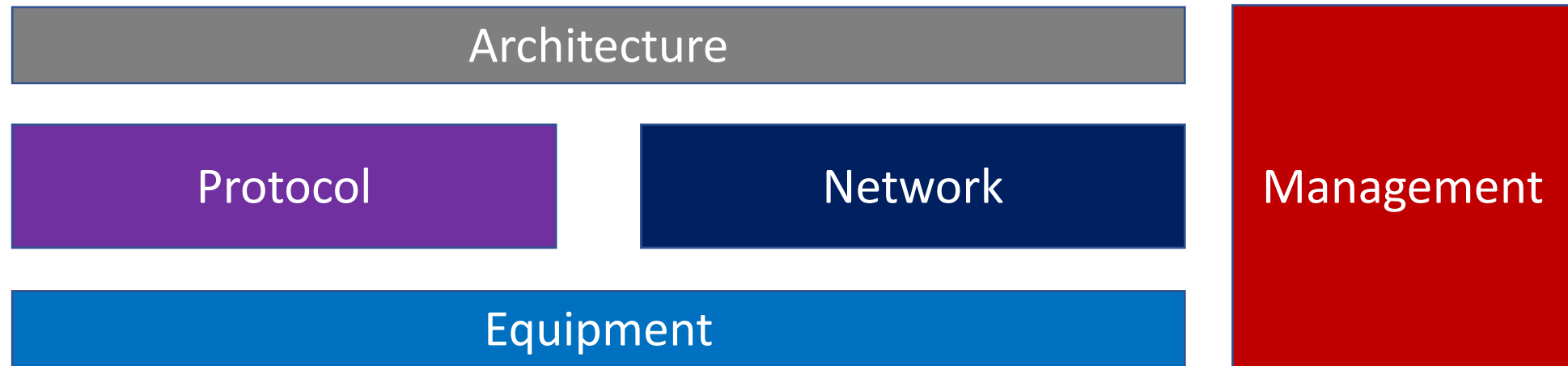
- What is actionable for us? Which areas promise the greatest impact? What are the enablers?
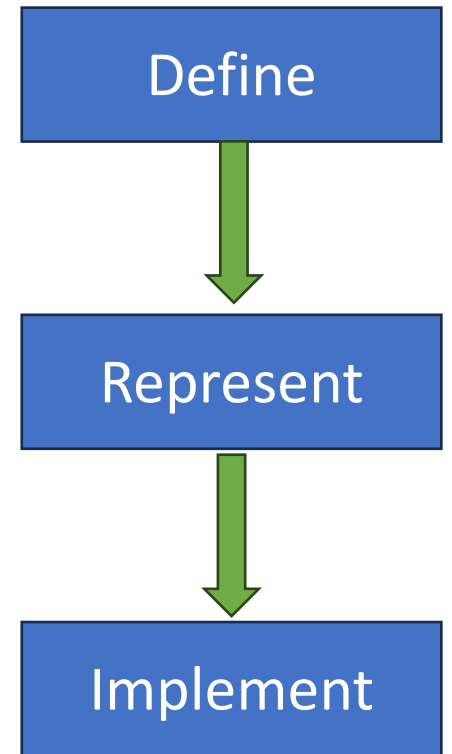
The relevance of data

- "You cannot manage what you cannot measure" (Peter Drucker)
  - Compare effectiveness of alternatives
  - Quantify impact (cost/benefit analysis)
  - Enable control loops
- Foundational requirement hence:
  data that can be used to observe, assess, quantify "environmental impact"
- This happens to also be actionable in IETF
  - Everybody will need this
  - Standardized data will facilitate solutions
  - Hence a priority for E-Impact (we hope)

Determine Actions

Monitor & Observe

Configure

Network
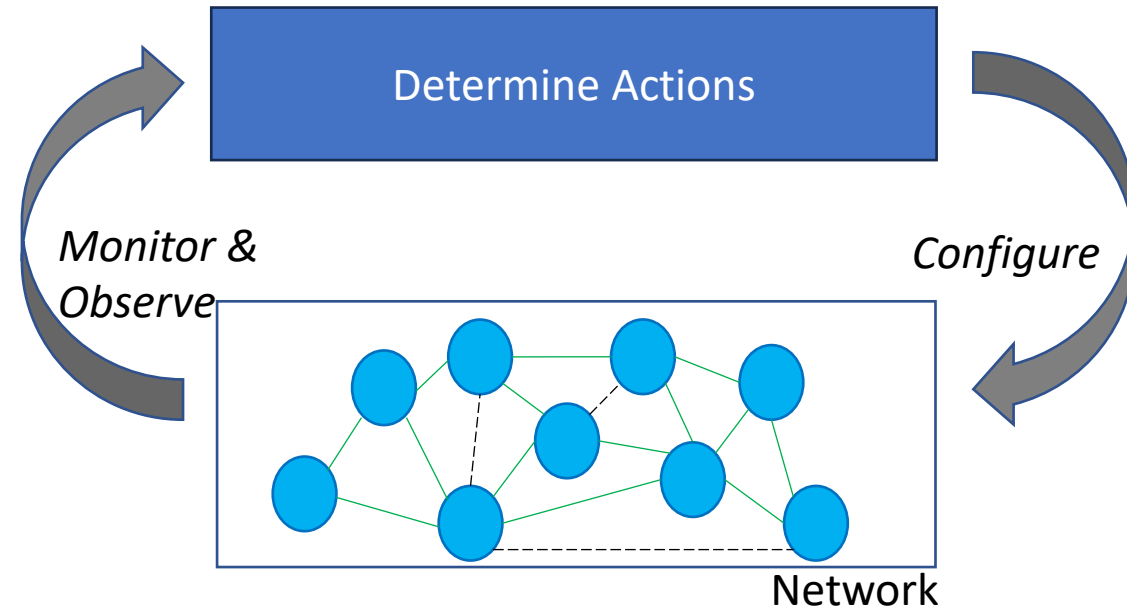
Metrics vs Data Models vs Instrumentation

- Metrics
  - What are the metrics that matter:
    for control loops, to assess and compare effectiveness
- Data Models
  - How do we represent and organize metrics
  - How to relate them to different entities
- Instrumentation
  - How do we implement software to provide actual data instances
  - May involve internal instrumentation on a device,
    but also measurements & supporting protocols

Define

Represent

Implement

Metrics

Green Networking Metrics: https://datatracker.ietf.org/doc/html/draft-cx-green-metrics-02

Traffic level	Packets, Flows	Paths
Physical level	Equipment/ Device	Network as a whole
	"Singular"	"Collective"
	can be obtained on a per-entity basis	*needs to be aggregated across multiple entities*

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Metrics

Green Networking Metrics: https://datatracker.ietf.org/doc/html/draft-cx-green-metrics-02

Traffic level	Packets, Flows	Paths → *Advanced, more speculative topics*
Physical level	Equipment/ Device	Network as a whole
The natural starting point →	"Singular" *can be obtained on a per-entity basis*	"Collective" *needs to be aggregated across multiple entities* ← *The end outcome of interest*

Metrics space

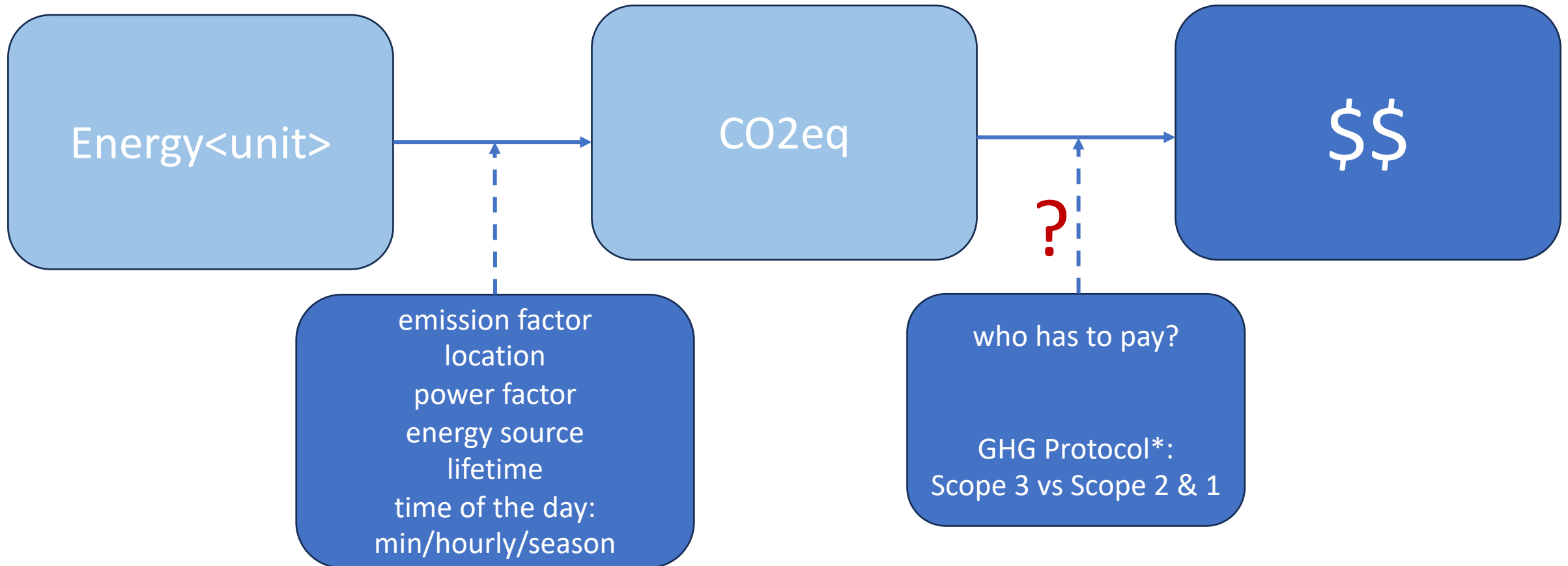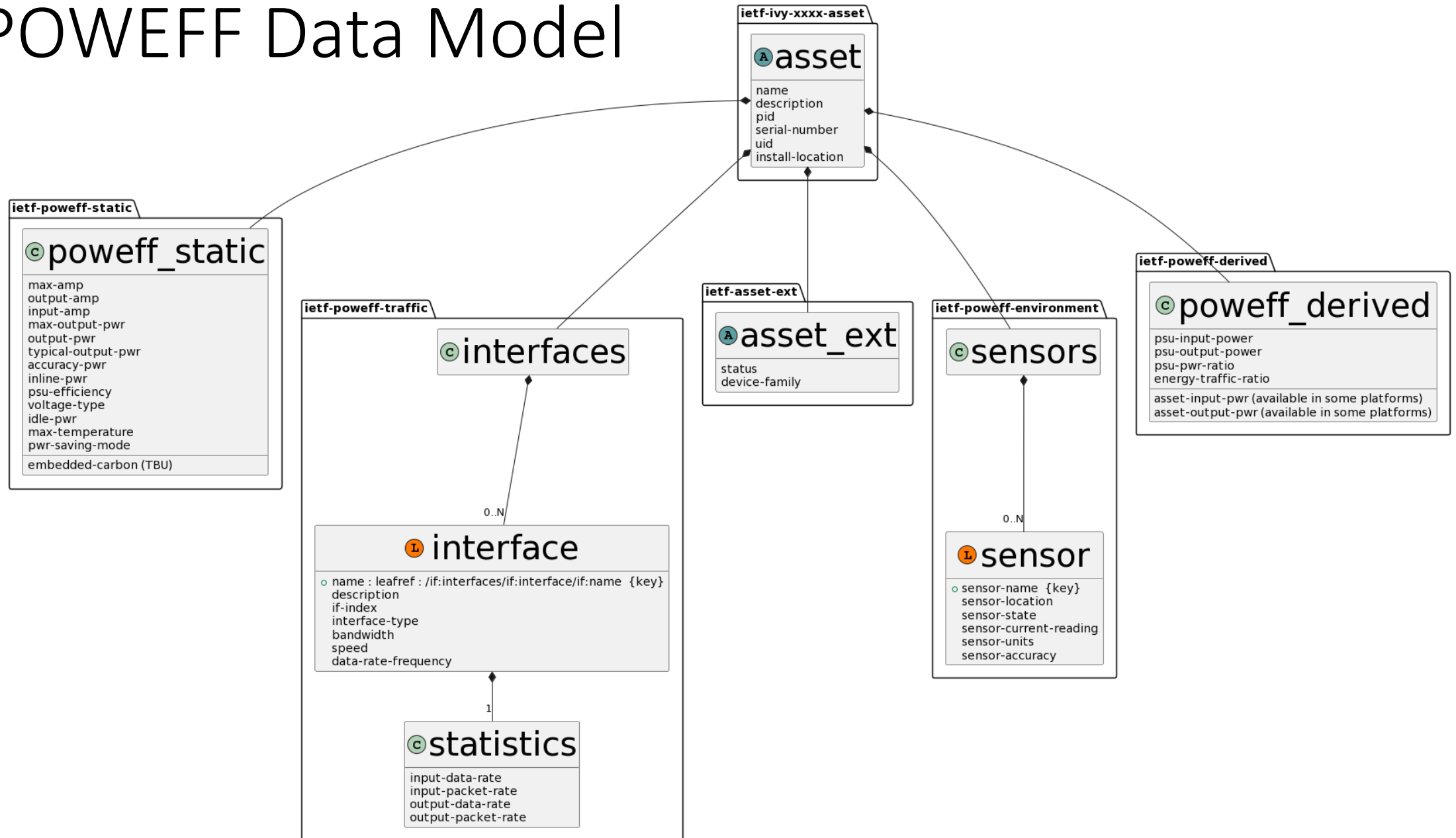| Equipment/ Device	Energy consumption, energy utilization efficiency
	Examples
	       Power consumption absolute / normalized, per chassis/line card/port, etc
	       Consumption ratings (datasheet stuff)
	But it is not just about equipment power but about greenhouse gas emissions
	       Account for sources (e.g. energy mix), deployment context (e.g. HVAC)
	       Conversion factors between "power" and "carbon"

Conversion is a choice?

Energy<unit> → CO2eq → $$

emission factor
location
power factor
energy source
lifetime
time of the day:
min/hourly/season

?

who has to pay?

GHG Protocol*:
Scope 3 vs Scope 2 & 1

Not an inclusive list of possible factors: e.g. deployment context (e.g. HVAC / "building tax"), amortization of embedded carbon

Reference Green House Gas Protocol* https://ghgprotocol.org/

POWEFF Data Model

ietf-ivy-xxxx-asset

ⒶAsset

name
description
pid
serial-number
uid
install-location

ietf-poweff-static

ⒸPoweff_static

max-amp
output-amp
input-amp
max-output-pwr
output-pwr
typical-output-pwr
accuracy-pwr
inline-pwr
psu-efficiency
voltage-type
idle-pwr
max-temperature
pwr-saving-mode

embedded-carbon (TBU)

ietf-poweff-traffic

ⒸInterfaces

ietf-asset-ext

ⒶAsset_ext

status
device-family

ietf-poweff-environment

ⒸSensors

ietf-poweff-derived

ⒸPoweff_derived

psu-input-power
psu-output-power
psu-pwr-ratio
energy-traffic-ratio

asset-input-pwr (available in some platforms)
asset-output-pwr (available in some platforms)

0..N

Ⓛinterface

○ name : leafref : /if:interfaces/if:interface/if:name {key}
description
if-index
interface-type
bandwidth
speed
data-rate-frequency

0..N

Ⓛsensor

○ sensor-name {key}
sensor-location
sensor-state
sensor-current-reading
sensor-units
sensor-accuracy

1

Ⓒstatistics

input-data-rate
input-packet-rate
output-data-rate
output-packet-rate

Metrics under POWEFF-derived

| Metric	Description
Energy consumption (kWh)	This represents the energy consumed by the device. Represented by the Power Draw
Power to traffic ratio (watts/Gbps)	Power measure on device (watts) / Traffic throughput (Kbps)
Extrapolated CO2 emissions (g CO2eq)	Use current energy consumption (kwh) and the device geo-location (e.g. -34.6037°, -58.3816°) to query carbon factor (ie from Electricy Maps) and calculate extrapolated CO2 emissions
PSU ratio (%)	Power supply efficiency (offered powered vs consumed power)

Sustainability Insights Framework
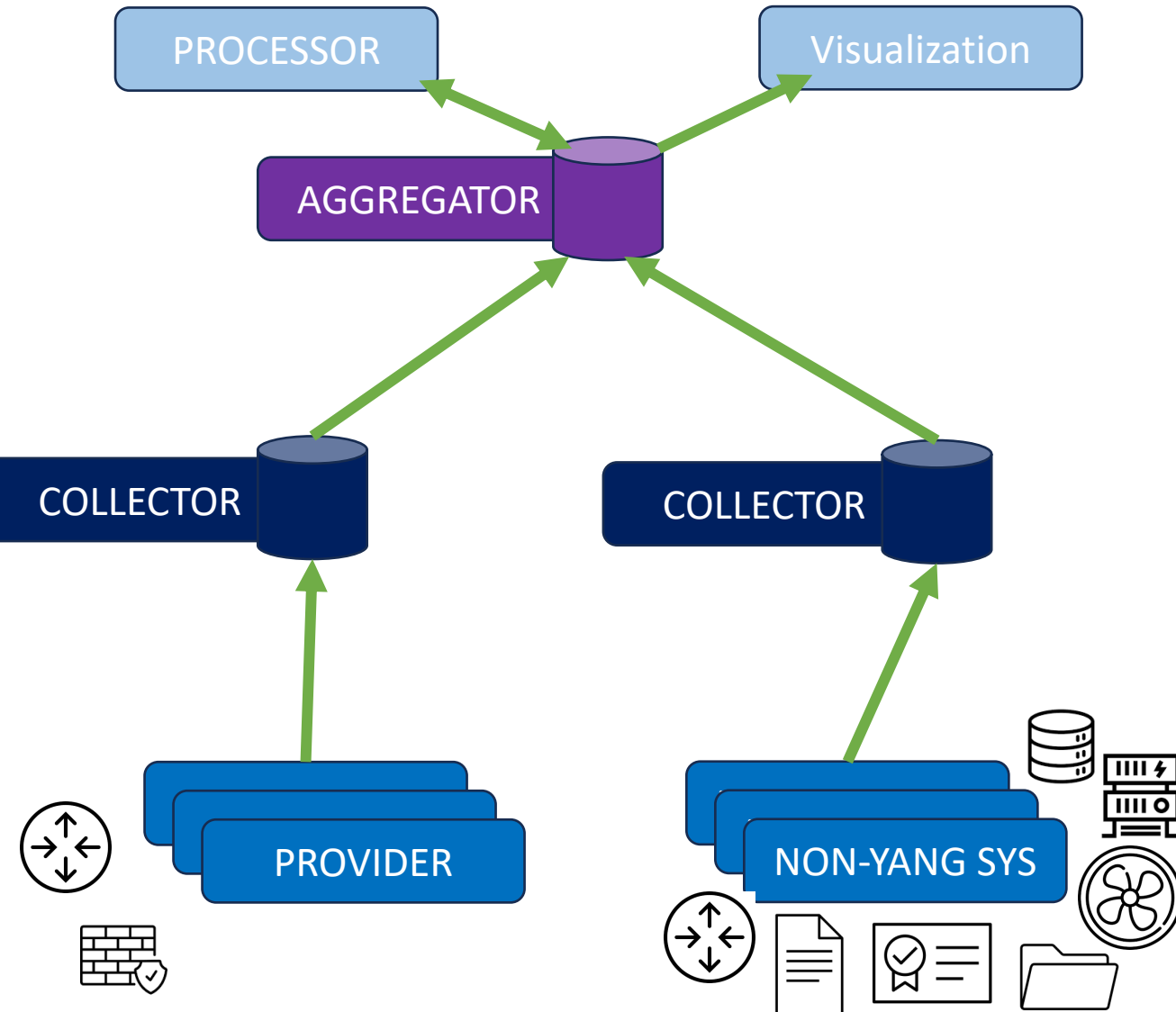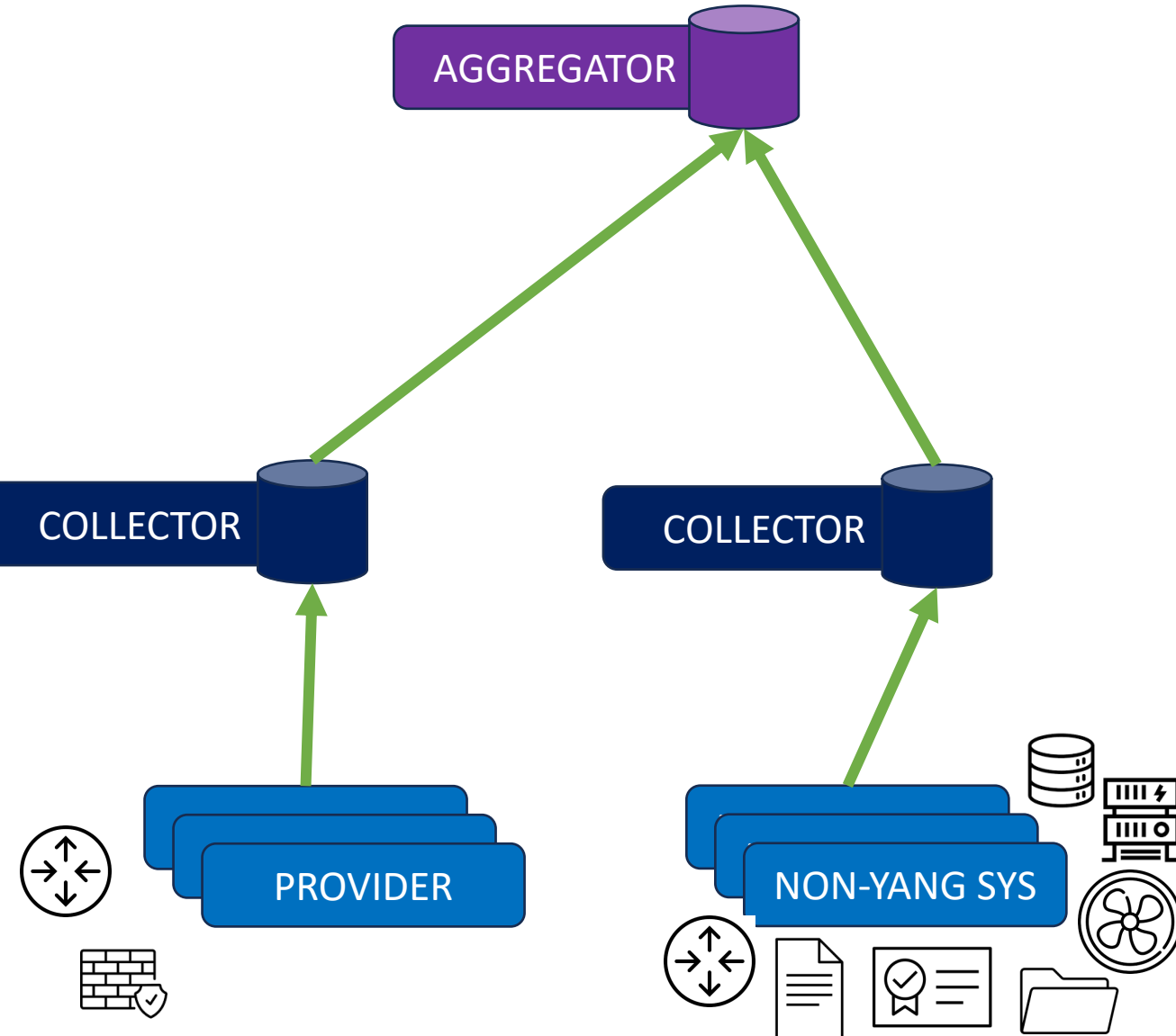

Data Standardization

- Where?

Sustainability Insights Framework
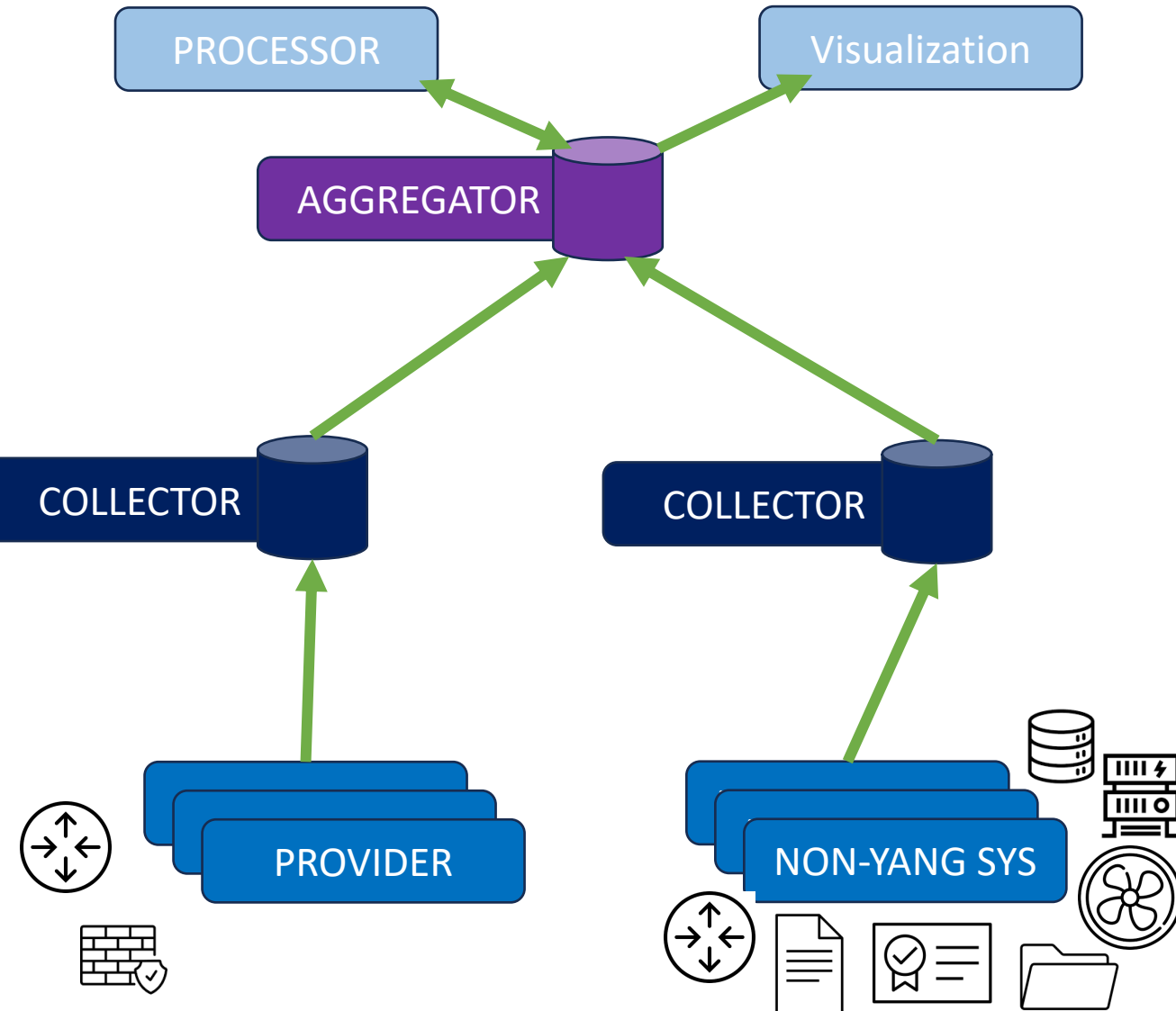
Circularity

- materials, R's, packaging, transport, etc...=> YANG or any other language defining semantic is required

Sustainability Insights Framework

Optimization

What to Optimize?

- Reduce CO2eq emissions
- Reduce e-Waste
- Reduce embedded carbon
- Accuracy of the measurements
- Simulated vs Real metrics
- Cross Domain (Ex: Traffic Path Optimization based on energy constraints)

Metrics space (contd.)

Flows	Relate carbon footprint to flows and service instances
	Function of volume and duration
	Additional considerations for packet replication, loss, etc.
	Carbon flow statistics, enable carbon-based accounting
	Examples: Energy consumption / carbon footprint over duration of flow
Paths	Assess carbon intensity of paths and route alternatives
	Energy-/ Carbon-/ Pollution-Aware Networking
	Examples: Path energy/carbon ratings (function of carbon ratings of hops)
Network-at-large	Totality of the picture aggregated across network-at-large
	Consider also HVAC, hidden / non-instrumented devices
	Examples: Total energy consumption (MWh), Network energy efficiency (MWh/PB)

Individual Metrics Controversies

- Do traffic-level metrics even matter
  - Non-linearity of energy consumption
  - Idle power very close to power at max capacity
  - Traffic volume is subject to many tradeoffs – e.g. efficient encoding may incur cost in compute
  - *Verdict is out, non-linearity may not change, more research is needed that is enabled by such metrics*
- Holistic metrics vs discount factors
  - Energy consumption – CO_2 equivalents – greenhouse gas equivalents
  - Formulas and discount factors may introduce inaccuracies; how far do we go
  - *Need to clearly document & maintain separately assumptions and conversion factors vs base metrics*
- Relating sustainability cost to utility being derived as measures of efficiency
  - E.g. power consumption relative to traffic volume
  - *Input needs to be put in relationship with utility that is being derived*
    - *Volume of traffic (e.g. W/GB)is a flawed measure of utility, but better alternatives are lacking*
  - *Any one metric can paint a distorted picture and can be gamed*
  - *It's the holistic picture that counts*

Selected Open Issues

- Data and metrics, specifically beyond device-level
  - Consistently applied and broadly supported
- Energy consumed ≠ greenhouse gas emissions
  - Which conversion factors are needed & how are they precisely defined
  - Energy mix, deployment factors, embedded carbon tax, CO2/GG equivalents
- Dealing with imprecision and uncertainty
  - Specify ranges vs absolute values in some cases (e.g. power consumption of links)
- Measuring of utility delivered for efficiency measures
  - Can we do better than traffic volume
- Virtualization – do we need virtual energy metrics
- Compliance and certification
  - Including incentive structure for accurate instrumentation
- Instrumentation of legacy equipment

+ on a practical level in IETF/IRTF, landing spots are not always clear

Backup

Context

- Reducing greenhouse gas emissions to address climate change is one of mankind's "grand challenges"
- This challenge also extends to network technology
  - How to reduce environmental impact of networks?
  - How to make them more sustainable & what can we do at IETF?
- →E-Impact Program sponsored by the IAB
  - Following several earlier activities:
    E-Impact workshop, side meetings at IETF 115-117
  - Several Internet Drafts have begun to appear, loosely coordinated here
  - Landing spots for those drafts are not always clear
    e.g. https://datatracker.ietf.org/doc/html/draft-cx-green-metrics-02:
    opsawg? ippm? somewhere else?