Selvityksiä infra-alatyöryhmälle (28.1.2020)

Mikko Hongisto &
Tapio Rauma, VTT

Esityksen sisältö:

- Tarve ja taustaa: VTT:ssä tehty monialaista työtä aihepiirissä
- Muutamia toteutettuja hankkeita infra-työryhmän aihepiirissä (päätelaitteet, **verkot**, datakeskukset)
  - Pohjautuen kartoittavaan VTT:n tutkijapalaveriin 14.1.2020:
    - Mika Lasanen, Jukka Mäkelä, Hanna Pihkola, Olli Apilo ja Mikko Hongisto
    - ->Toivottu VTT:n julkaisuesimerkkejä, aiempia hankkeita ja kontaktihenkilöitä

  Kysymyksenasettelu yleiskeskusteluista:

    - ”Energiankulutuksesta ei ole kunnollista mittaustietoa olemassa - Ei siis oikein tiedetä, mitä kulutusta pitäisi pienentää ja kuinka paljon?”
- Alustavia jatkoajatuksia
- Kysymykset / keskustelua aiheista

Green-ICT & VTT ..long history..

- E.g: Green-ICT roadmap (2010): “ICT for Environmental Sustainability”
  - available: http://www.vtt.fi/inf/pdf/tiedotteet/2010/T2532.pdf

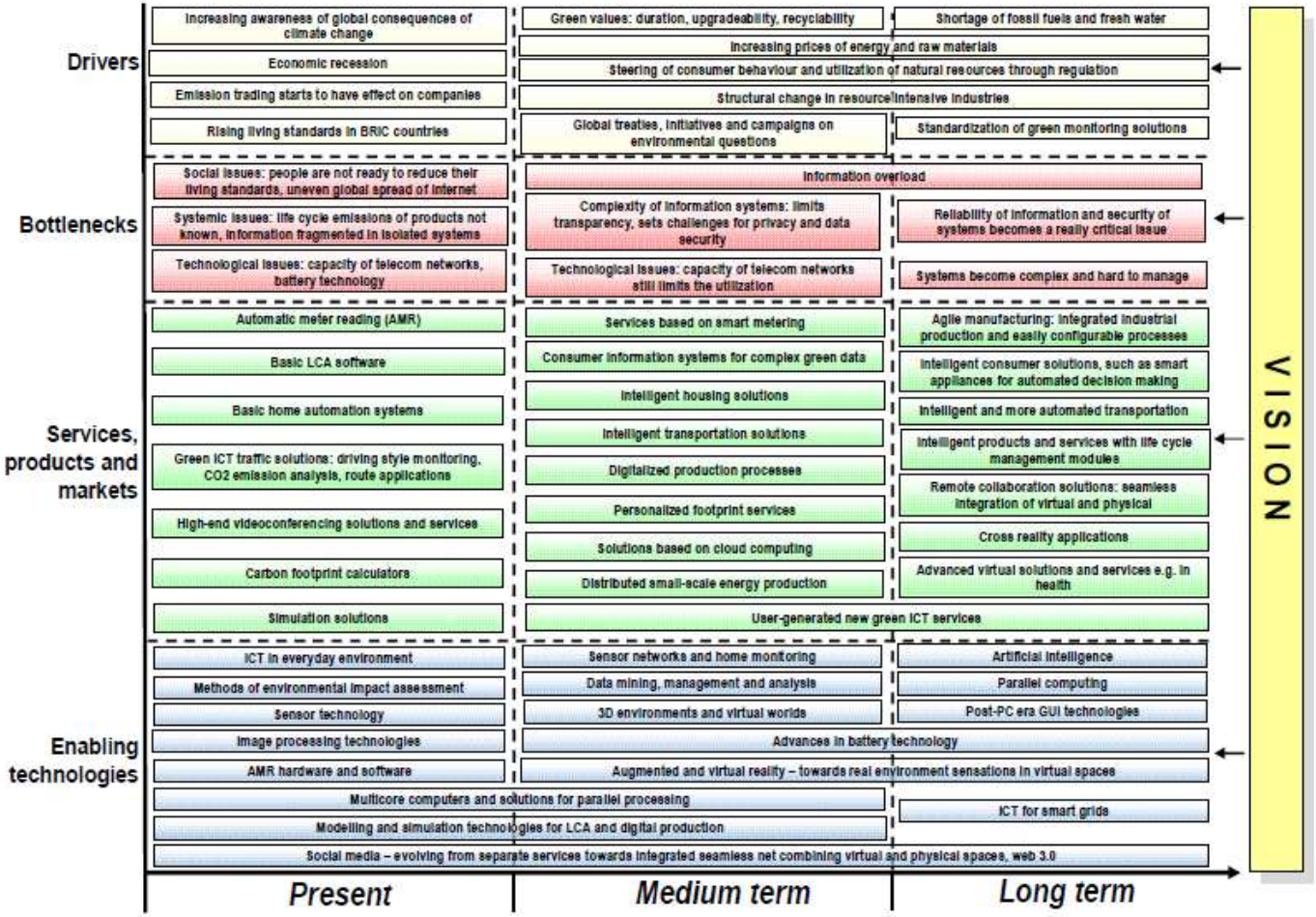
Recognized themes for further work:

1) environmentally sustainable consumption,
2) smart energy and buildings,
3) lifecycle efficient production and
4) optimised and adaptive networks.

Summary presentation: http://www.vtt.fi/files/events/Green_VTT_esitykset_071010/9_Hongisto_Green_ICT.pdf

->kaikilla osa-alueilla on VTT:ssä tehty t&k-toimia.. tutkimusportaali hakuja varten: https://cris.vtt.fi/

->esim. tukiasemien aurinkosähkösovelluksiin liittyvää työtä käynnisteltiin 2015 alkaen.



" A Roadmap "ICT for Environmental Sustainability" available at http://www.vtt.fi/inf/pdf/tiedotteet/2010/T253

Zero energy telecommunication systems

HW-SW improvements

Device technology

Purpose to create such technology that consumes less energy than current ones.
Keywords: low-power electronics, better efficiency, energy-optimized radio and SW.

System level enhancements

More adaptive demand-response control in telecommunications.
Turning resources off when possible, using resources more effectively.

Communication systems in infrastructures

Optional power sources

Dramatically longer autonomous/battery time with optional energy sources and energy harvesting methods integrated to the battery. Keywords: fuel cells, wind, solar, vibration, temperature change.

Ecodesign for zero energy telecommunication systems

Manage wireless communication systems in a sustainable way.
Optimize network planning and building, operation & maintenance, materials, replacement.

Source: Tapio Rauma

Back-up power solutions are needed (in various power levels) also to safeguard TELECOM & ICT-systems broadly – opportunities for Finnish technology companies?

Categorized power levels vs. development ideas..

Data-centers 0,1-X0 MW… even multi-MW scale, TV-sites 10-100kW..
-heat recovery systems -> district heating&cooling integration ("biofueled" smart & fast reserve generators)

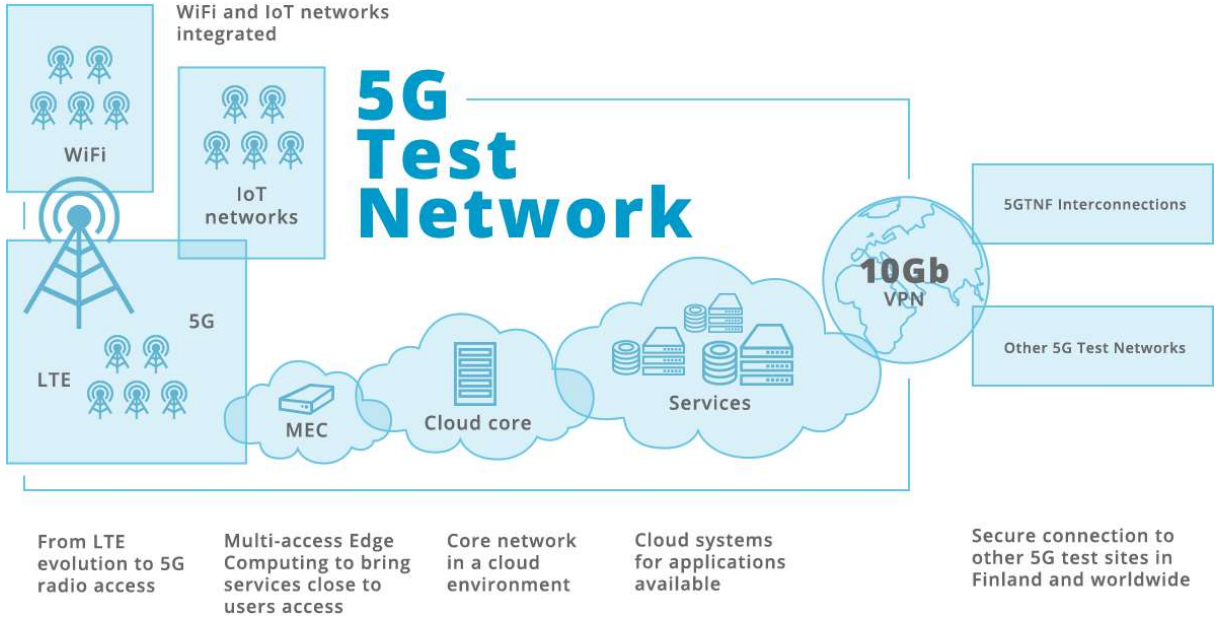
Radio basestation-sites, when several operators & technologies (1-15kW)
-hybrid & UPS-solutions (solar, biofuel/methanol/hydrogen fuel-cells, wind, semi-off-grid smart soluti
-heat recovery in apartment buildings, "plus-energy"-cases

RBS-micro/piko/femto-cells (+emerging 5G) (0,03-<1kW…)
-option for the future: development of self-sufficient & energy autonomous units?
-integration to internal systems inside office buildings

Portable devices, computers & tablets (10-30W..<100W):
-solar chargers & integrated PV-solutions, solar charging points

Smartphones, routers, wearables & sensors (0,1W-3W..<10W)
-integrated PV+battery solutions

5G test network



- Live test network for research, development and education in Oulu
- Co-operation between VTT, University of Oulu and industry partners (including e.g. Nokia and Mediatek) https://5gtn.fi/

- Fully configurable LTE-A Pro base stations with operator-grade evolved packet core
- Real-time monitoring of both performance and power consumption (Zencom –demo development)
- 5G-devices are currently partly powered by means of VTT's hybrid solar power system

Mobiiliverkon sähkönkulutusarvio:

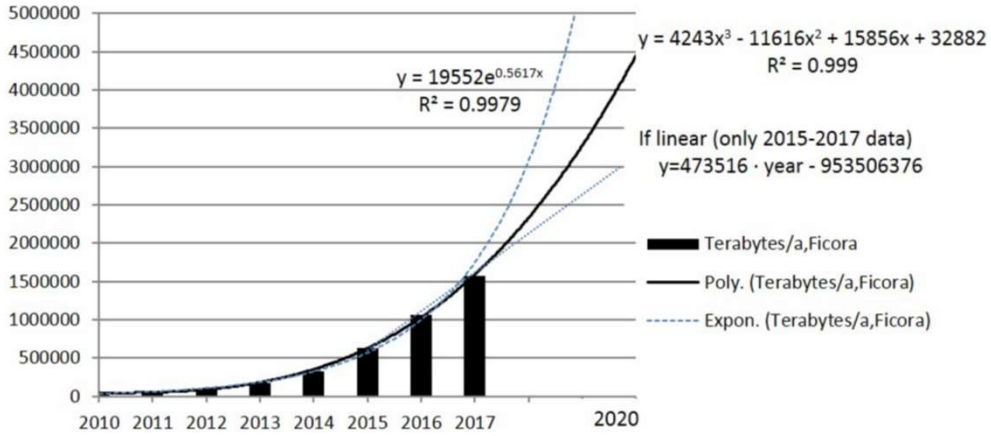
Päivitettiin 2017 tasolle julkaisussa:

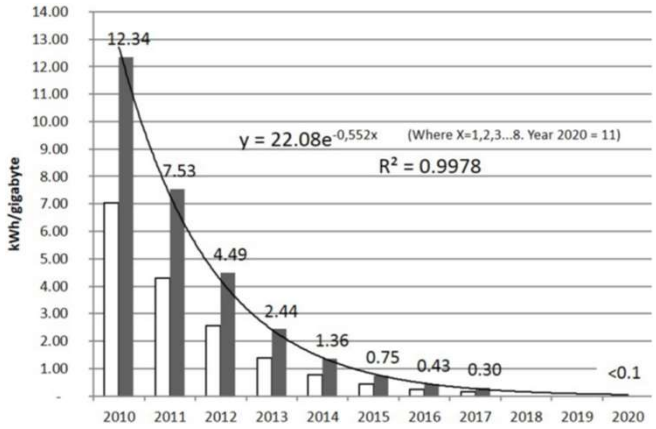
- H. Pihkola, M. Hongisto, O. Apilo and M. Lasanen, Evaluating the Energy Consumption of Mobile Data Transfer—From Technology Development to Consumer Behaviour and Life Cycle Thinking, *Sustainability* **2018**, *10*(7), 2494;
  - **https://doi.org/10.3390/su10072494**
- Artikkelin taustalla oli Viestintävirastolle 2015 tehty esiselvitys: O. Apilo, M. Hongisto, M. Lasanen, “Esiselvitys matkaviestinverkkojen tukiasemien sähkön käytöstä ja energiatehokkuudesta”, saatavilla mm:
  - **https://www.vtt.fi/inf/julkaisut/muut/2015/VTT-CR-03348-15.pdf**

  ->Selvitykseen koottiin tietoja energiatehokkuutta parantavista ratkaisuista komponentti-, laite-, solu- ja verkkotasolla sekä arvioitiin alustavasti niiden sovellusaluetta, vaikuttavuutta ja teknologian valmiusastetta.

Trends in the general level:

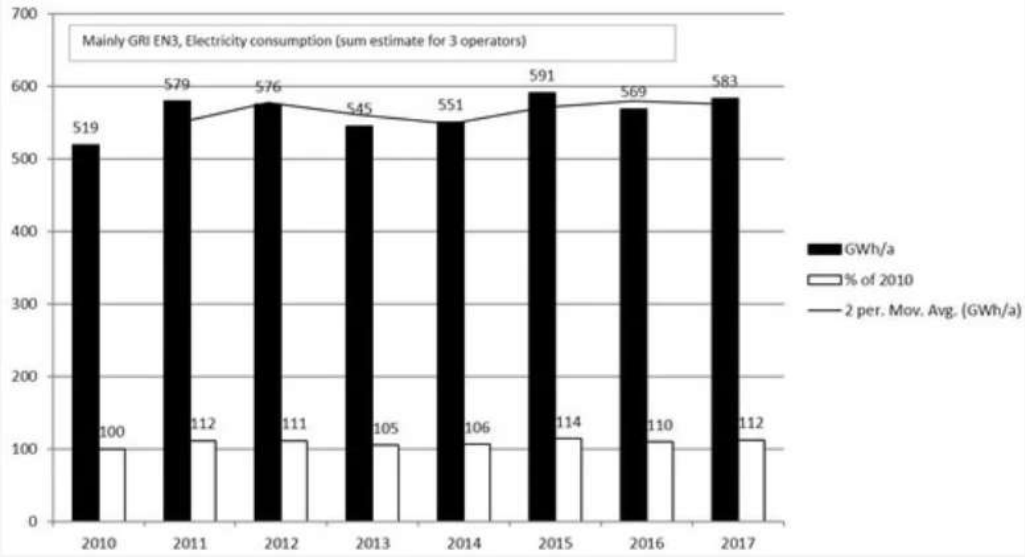
-Data usage is increasing while kWh/gigabyte is decreasing..





Source: "Evaluating the Energy Consumption of Mobile Data Transfer—From Technology Development to Consumer Behaviour and Life Cycle Thinking" Sustainability 2018, 10(7), 2494; https://doi.org/10.3390/su10072494

Operators' overall electricity consumption (2010-2017 only, status 2019?)



- An estimate of the overall electricity consumption of all operators in Finland was around 0.6 TWh/a in 2017.
- This corresponds to 0.7% of the total annual electricity consumption in Finland in 2017 (85.5 TWh/a).

Compiled and partly estimated by M.Hongisto based on corporate environmental reports

5G-DEMO-seminar 2019:

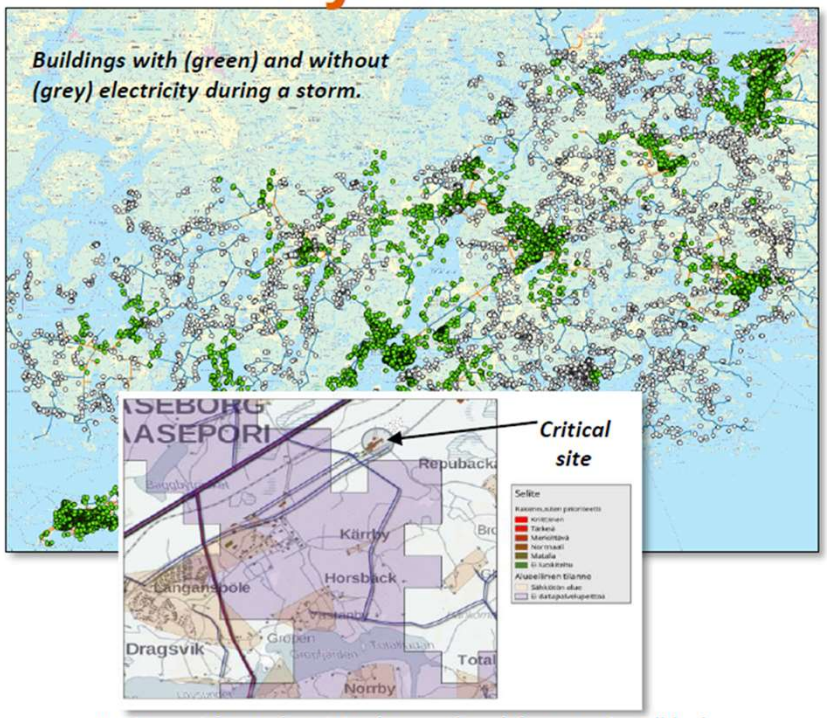
- "Solar-UPS" installed to VTT's 5G-laboratory in Oulu
- Designed to be modular and capable to supply both 48VDC and 230VAC system- and radiomodules (Indoor-pico, Macro, Nb-IoT etc.).
- Remotely controllable bi-directional inverter-charger power supply unit with almost real-time system-boundary metering & control with LiFePO4 battery modules
- Operated almost 1 year and has safeguarded RBS-devices also against power outages (UPS-functionality).

Building blocks towards energy self-sufficient / sustained 5G
Hongisto M., Rantala S. J., Mäkelä J., Lasanen M., Huusko J., Savela M., Penjala J.
(VTT Technical Research Centre of Finland)

Preliminary results: RBS devices (pico+ system- and radio-modules) were connected 19.6.2019: During 4 months trial period solar share achieved 23% of the connected consumption
-Annual production of wall mounted 2,2 kWp PV-setup is expected to reach 1,75MWh yield/a (137kWh/wall m2,a) corresponding almost 800h/a annual peak power time.
-With smaller load (e.g.continuous 0,4 kW) 50% solar share would be achievable taking all operative situations into account.

Interdepency of telecom/electricity networks

- Electricity distribution and communications networks are two core infrastructure networks.
- It is highly important to ensure that those networks stay operational in all situations, or at least the recovery of the networks is as fast as possible.
- VTT developed a tool to evaluate different technological solutions in interdependent energy and telecommunication networks and to simulate impacts of disturbance events in various scenarios.
- Realistic energy distribution and telecommunication infrastructure models with geographical information.
- The recent study focused on a comprehensive modelling of telecommunication base stations with batteries and energy networks in a hybrid situation, where the networks are hit consequently by a severe storm and a cyber-attack.



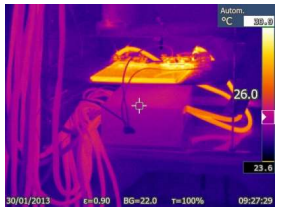
Regions without electricity (orange) and data services (lilac) in a situation awareness view.

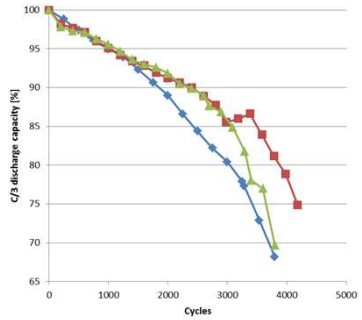
Seppo Horsmanheimo & al.

Electricity storage technologies research

1. **Technologies for electrochemical electricity storage**
   - Battery performance and lifetime testing, test methodology
   - Impact of environmental conditions
   - Technology follow-up reviews
2. **Design tools**
   - Electrical modelling
   - Heat transfer and thermal modelling
   - Battery safety
   - Lifecycle management, estimates, diagnostics
   - Techno-economic evaluations
3. **Energy storage systems and applications**
   - Instrumented battery research module
   - Concepts of thermal management
   - Battery management systems
   - Application requirements vs system design

See also: VTT's Battery laboratory pages:
https://www.vttresearch.com/batteries



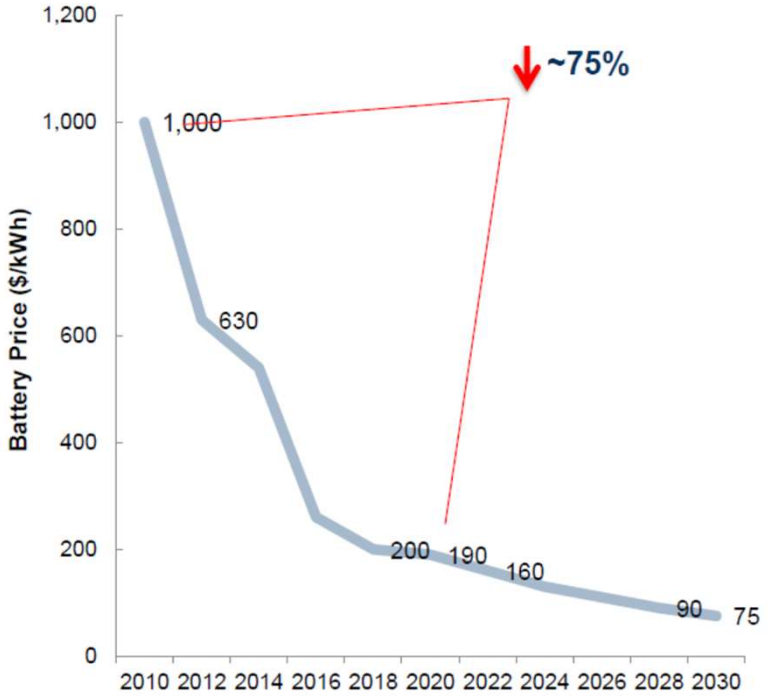


$$\frac{€}{Lifetime}$$

Battery storage cost is decreasing

- Li-ion battery prices have declined by about 75% since 2010
- Prices are expected to drop further although with slower rate
- Eventually, below $100/kWh

Q: Is it possible to find synergies in office buildings' uninterruptible power supply systems, RBS-batteries, EV-DC-charging and PV-hybrids' BESS?



Source: Frost & Sullivan, 2019

Other studies:

- Base station power consumption measurements:

  S. Boumard *et al.*, "Comparison of Spectral and Energy Efficiency Metrics Using Measurements in a LTE-Advanced Network," in *Proc. TMA Conference 2018*.

- Energy efficiency analysis and simulations: Case massive MIMO with digital beamforming

  O. Apilo *et al.*, "Cell splitting for energy-efficient massive MIMO," in *Proc. IEEE VTC Fall 2017*.
  O. Apilo *et al.*, "Unequal power amplifier dimensioning for adaptive massive MIMO base stations," in *Proc. IEEE VTC Spring*, 2016.

- Carbon handprints – positive impacts:

  H. Kasurinen, S. Vatanen, K. Grönman et al, "Carbon Handprint: Potential Climate Benefits of a Novel Liquid-Cooled Base Station with Waste Heat Reuse," Energies 2019, 12(23), 4452; https://doi.org/10.3390/en12234452

VTT participated EU's SmartNet –project: (Horsmanheimo S. & Koponen P. 2018-19)

- See http://smartnet-project.eu/publications/#tab-id-3
- Pilot –C Spain incleded telecom related materials:
  - http://smartnet-project.eu/wp-content/uploads/2018/10/10.Pardo_.pdf

SmartNet

Spanish pilot

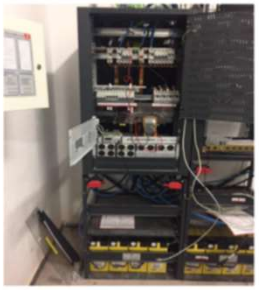
DER Owner side. Demand Response Technology over VF Base Stations

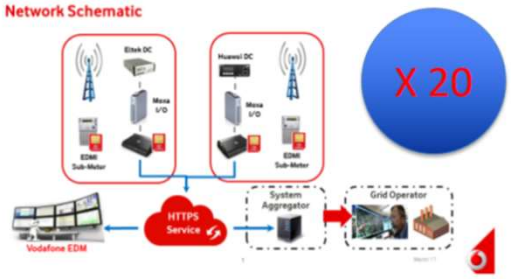
Pilot flexible aggregation capacity: around 100 kW

SmartNet

Pilot C - Physical Layer

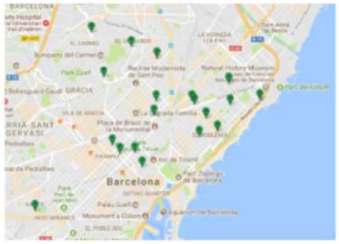
Vodafone BTS transformation into DER plants.





Curtailment principle : integrate the remote battery test functionality to pilot the radio equipment switch to back up batteries on demand

Scenario: 20 Radio Base stations equipped with
- 48V controller SW: 2 brands – Eltek and Huawei
- SNMP connection
- Mobile Link 4G modem+ Moxa gateway
- 4x12 V 100amph VRLA Batteries
- 1 smart meter with 1mn slot readings



VTT:n selvitys LVM:lle

- M. Federley, M. Myllysilta, Esiselvitys: TV-sisältöjen monikanavaisen jakelun energiankulutuksen arviointi (2015)
- https://cris.vtt.fi/en/publications/esiselvitys-tv-sisältöjen-monikanavaisen-jakelun-energiankulutuks

Videon rooli korostuu:

- M. Forsell, M. Uitto: Podcast: ”4K- JA HD-VIDEOIDEN KATSOMINEN ÄLYLAITTEILLA ON TUHLAUSTA” https://hyvansaanaikana.fi/hiiligrilli-jakso-3-vihrean-verkon-metsastajat/
- Towards Energy-Efficient Adaptive Mpeg-Dash Streaming Using Hevc, In Proc. IEEE ICMEW 2018.

Muuta:

- Älykäs sähkökuormienohjaus:
  - Mm. Smart Otaniemi innovaatioekosysteemissä rakennustason energiajärjestelmien joustavuus tutkittavana (M. Hongisto, S. Horsmanheimo, jne. useita työpaketteja käynnissä kts. https://smartotaniemi.fi/)
  - Smart-S-market, Oulu (Klaus Känsälä)
  - Älypistorasiaprojekti_FLEX4GRID, ohjaus_appi (Taumberger)
    - VTT on ollut mukana useissa kulutusjoustoon ja erilaisten kuormien ohjauksiin liittyvissä hankkeissa (Pekka Koponen, Jussi Ikäheimo..).
- Hiilijalanjälkipalvelu ja palautejärjestelmä
  - a road map for data production: “Towards certified carbon footprints of products - a road map for data production” (M. Hongisto et. al. 2009)

    https://www.vtt.fi/inf/julkaisut/muut/2009/VATT_143_2.pdf

    https://cris.vtt.fi/en/publications/the-climate-bonus-demonstrating-the-climate-feedback-service

Lopuksi:

- Julkisen, läpinäkyvän ja vertailukelpoisen sähkön käyttöä koskevan tiedon puute on ollut pitkään ongelmana (”tiedonkeruustrategia tarvittaisiin?”).
  - Muutamat operaattorit ovat myös julkaisseet tällä alueella;
    - Vodafone, Orange, Telia+Ericsson ja Elisa
- Tarvetta täsmennyksille ja tietojen päivityksille on, esimerkiksi:
    - Tietoliikenneverkon energia-analyysi (kattaen aurinkoenergian mahdollisuudet empiiriseen dataan pohjautuen)
    - 5G-testiverkon mahdollisuudet: end-to-end datankulutusta voitaisiin monitoroida testiverkkoympäristössä, tunnistaa pullonkaulat ja riippuvuuksia.
    - Voidaan tehdä elinkaariarviointia (LCA) mittauksiin perustuen ja kuluttajien tarpeista lähtien
  - -> Teemme mielellämme tarkempia suunnitelmia keskusteluiden taustaksi ja työryhmän tarpeiden lähtökohdista.

Keskustelua aiheista ja mahdollisista jatkotoimista:

- Miten tarvittavan ajantasaisen ja riittävän seikkaperäisen ja kattavan tietoaineiston keräys organisoitaisiin?
- **Ilmastotietoiset kuluttajat** saattaisivat kaivata ”vihreäksi tai vihreämmäksi sertifioituja liittymiä ja tietoliikennepalveluita”?
  - Mikä olisi vaadittava (vertailukelpoinen/läpinäkyvä) tietopohja?
  - Minkälaisia kriteereitä olisi mahdollista määritellä telecom-sektorille ja mobiiliverkkoihin sopivalle sertifiointijärjestelmälle?
  - Olisiko mahdollista määritellä, mitä olisivat ”vihreät bitit” tai voidaanko ICT/Telecom infralle (ja palveluille) määritellä kuluttajien ymmärrettävissä olevia muita merkintäjärjestelmiä?
- Muuta?