Survey of Applications for Apartment Energy Consumption Monitoring

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Tampere University, Information Technology and Communication Sciences (Pori)

Finland

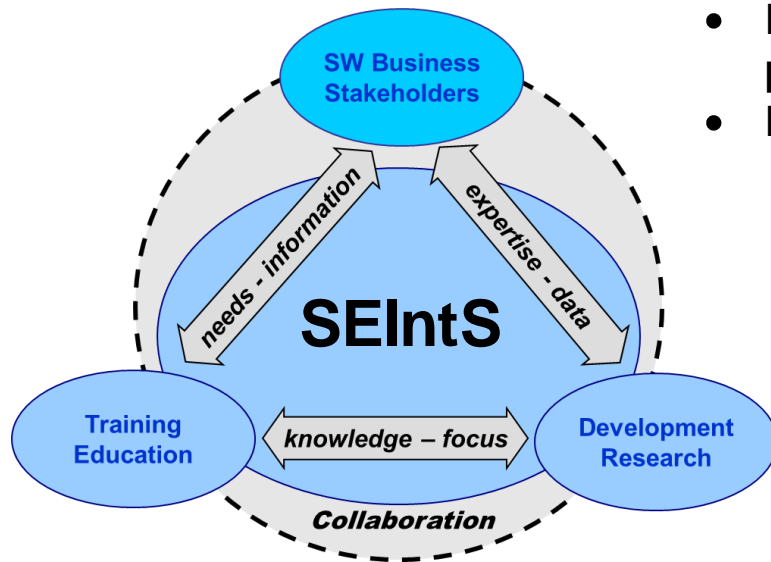# Software Engineering and Intelligent systems (SEIntS) Research Group

Professor emeritus **Hannu Jaakkola**

Assistant Professor **Sami Hyrynsalmi**

Research Manager **Jari Soini**

- Research staff: **15 persons**
- Project volume: **1 M€**

SW Business Stakeholders

needs - information

expertise - data

SEIntS

Training Education

knowledge – focus

Development Research

Collaboration

- Global software engineering
- Software business
- Software engineering management
- Software and **application architectures**
- Web services and user interface techniques
- Mobile and web applications
- **Smart systems and intelligent spaces**
- **Sensors and sensor networks**
- Embedded systems and **IoT**
- **Green ICT**

Research Context

- **Prototype development**
- Software orientation
- Utilization of **off-the-shelf devices**
  - smartphones and tablets
  - Arduino, Raspberry Pi, Beagle Bone, Intel Galileo, etc.
  - Sensors (heat, humidity, pressure, movement, position, etc.)
- Communication technologies (Ethernet, WiFi, ZigBEE, LoRa, etc.)
- Cloud-based services and data analysis
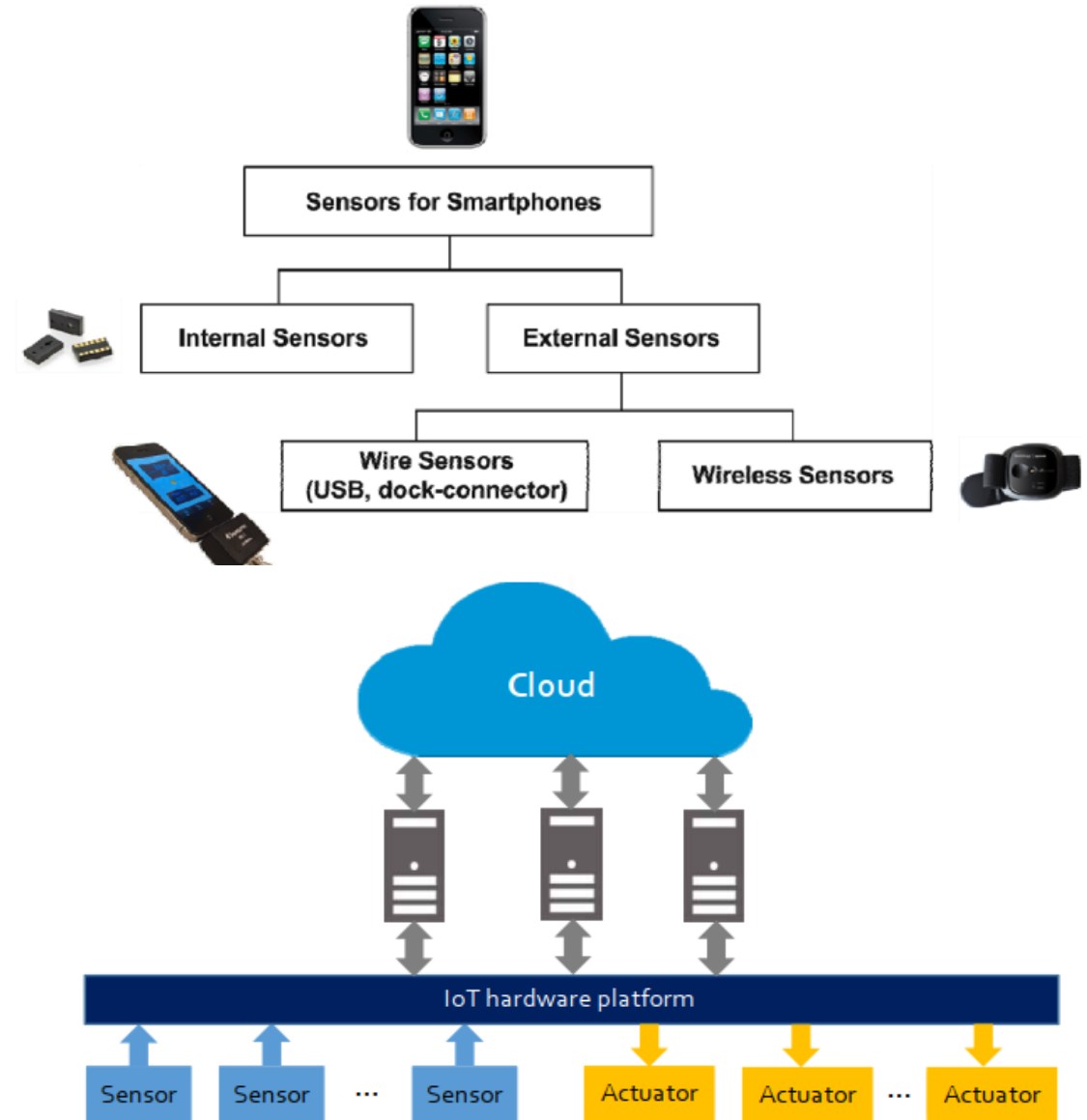- Growdsourcing based data

Sensors in a smartphone

How Many Sensors are in a Smartphone?

- Light
- Proximity
- 2 cameras
- 3 microphones (ultrasound)
- Touch
- Position
  - GPS
  - WiFi (fingerprint)
  - Cellular (tri-lateration)
  - NFC, Bluetooth (beacons)
- Accelerometer
- Magnetometer
- Gyroscope
- Pressure
- Temperature
- Humidity

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Distance, Light, Image analysis, Communication, …

Sensors for Smartphones

Internal Sensors — External Sensors

Wire Sensors (USB, dock-connector) — Wireless Sensors

Cloud

IoT hardware platform

Sensor | Sensor | … | Sensor | Actuator | Actuator | … | Actuator

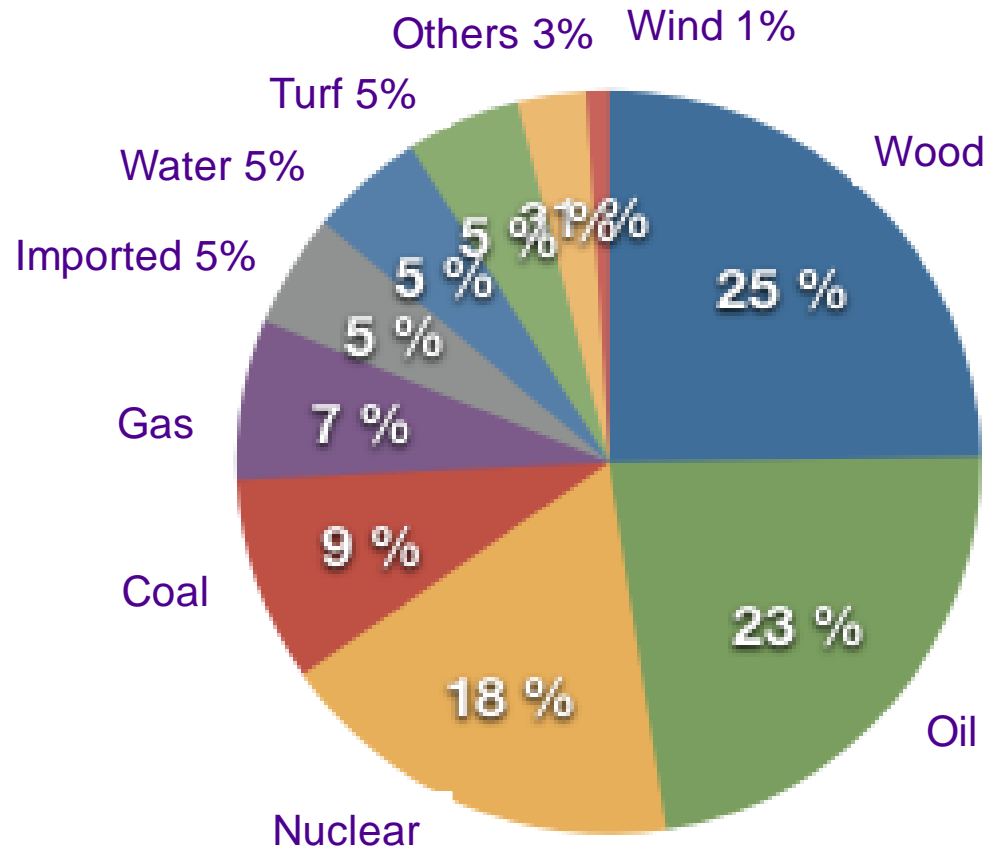# Related Research - Prototypes

- People and Object Detection (Image Contents Analysis)
  - Automatic metadata creation

- Cross Platform Programmig and API Design

- Road Condition Analysis and visualization
  - Smartphone (accelerometer, gyroscope, GPS) data collection, cloud

- Approach (Image) Data Collection (Bus, Garbage Truck)
  - Autonomous Rasberry Pi based system
  - Customer Complaint Verification

- (Image Based) Passanger Counter
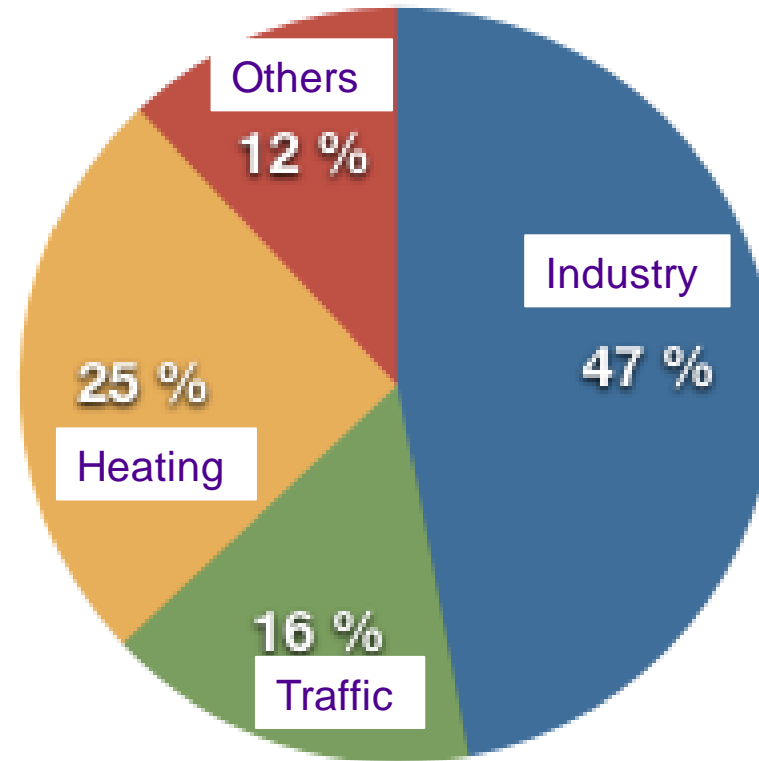 - Free to ride bus
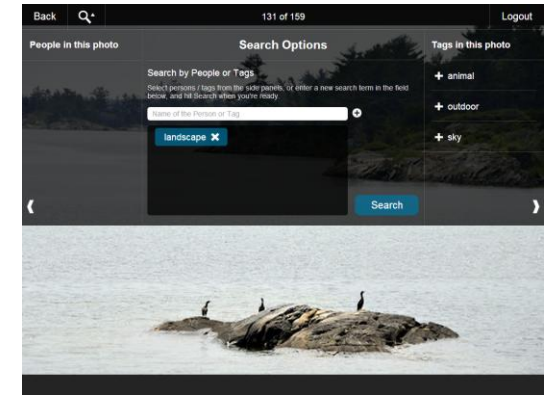
Energy Source Profile (2018) - Finland
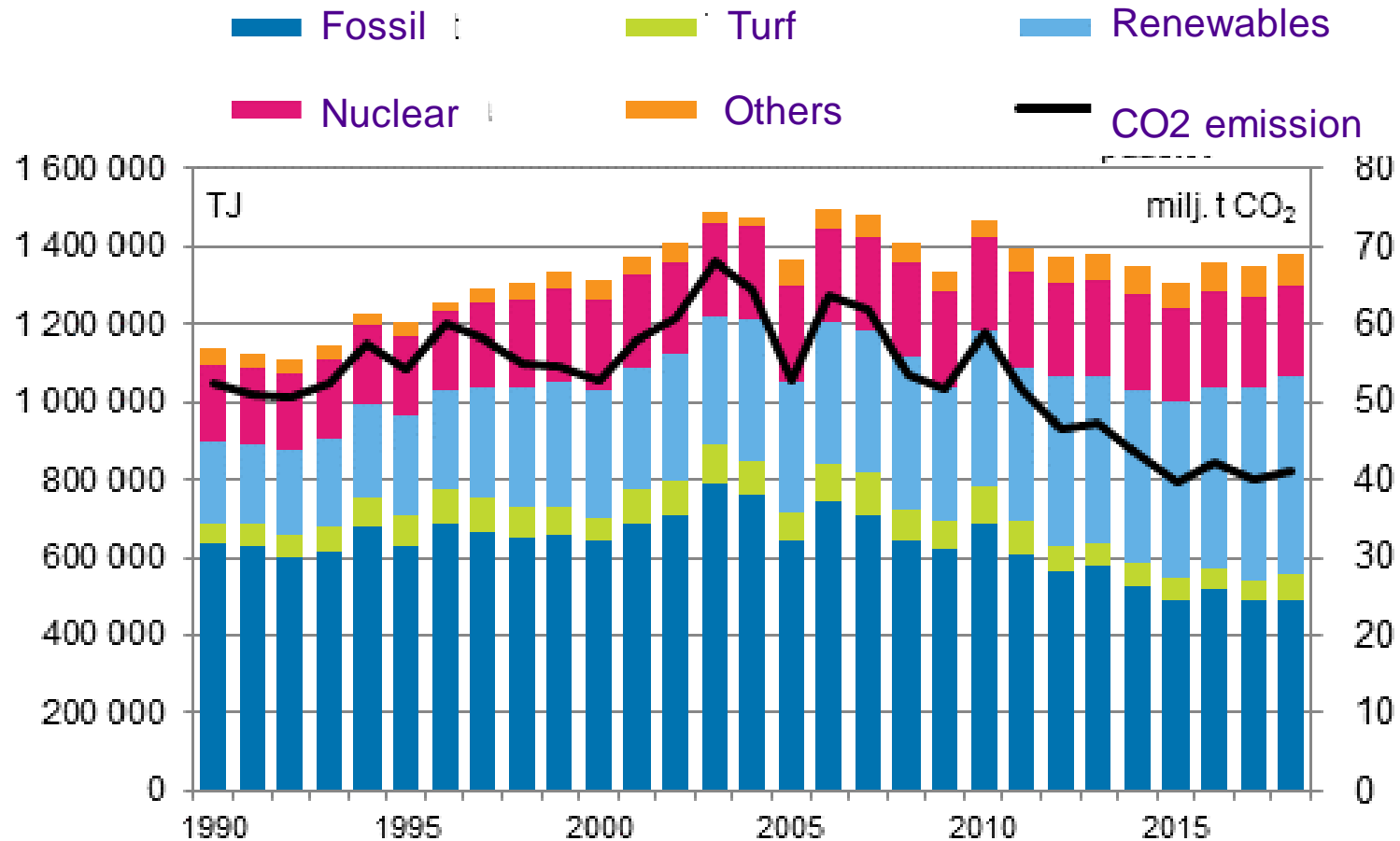
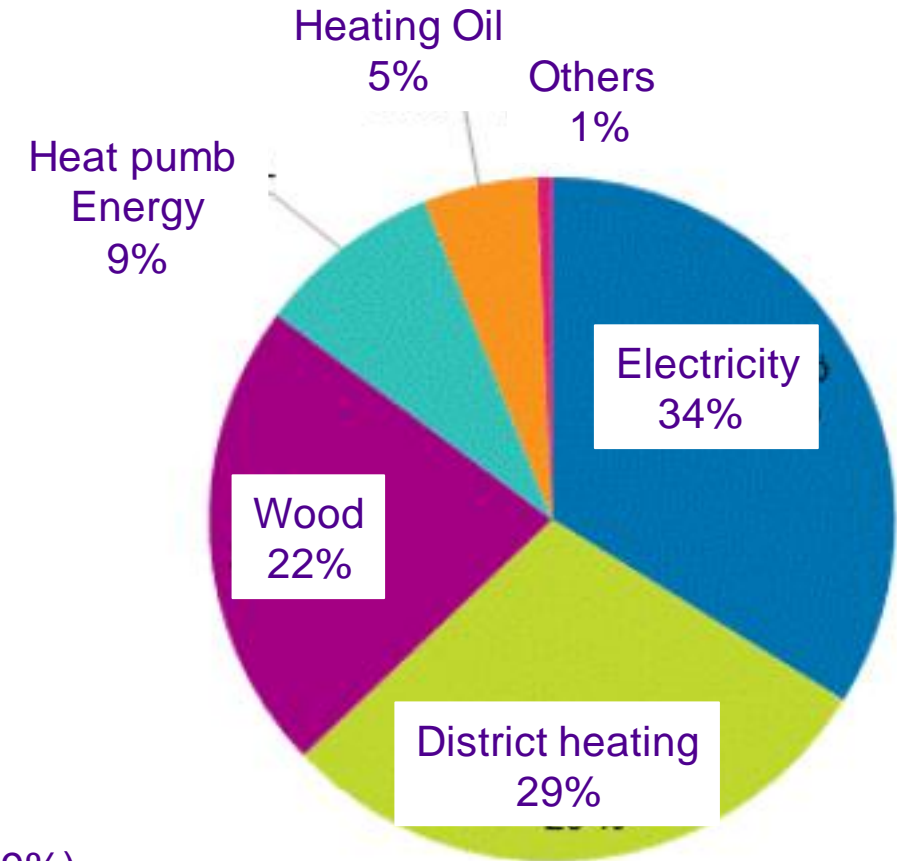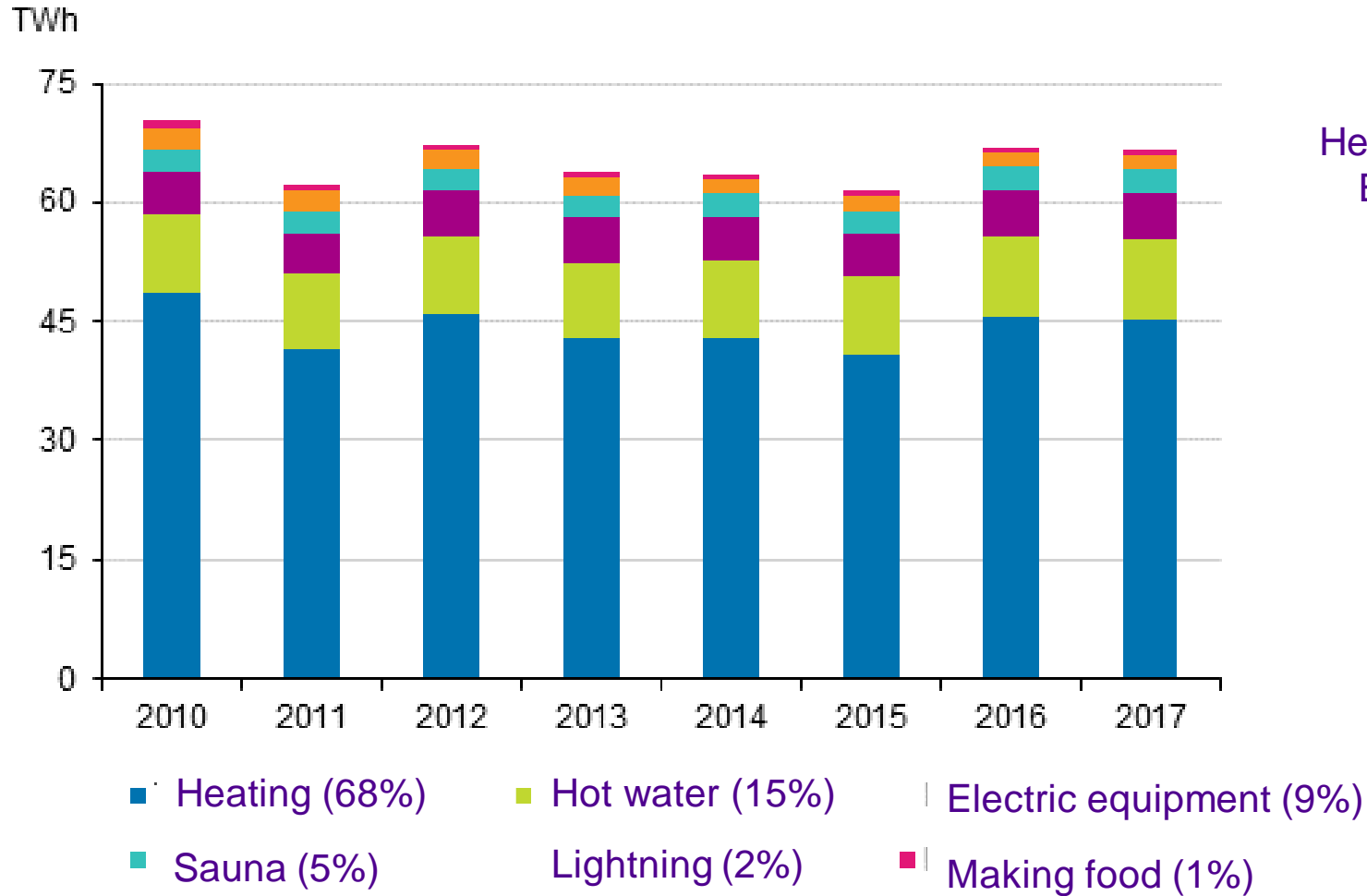# Energy Source Profile (2015) - Finland

Energy Consumtion Profile (2014) - Finland

Energy Consumtion in 2014

- Others — 12 %
- Industry — 47 %
- Heating — 25 %
- Traffic — 16 %

Energy Consumption Profile Households (2017) - Finland

TWh

Stacked bar chart 2010–2017:
- Heating (68%)
- Hot water (15%)
- Electric equipment (9%)
- Sauna (5%)
- Lightning (2%)
- Making food (1%)

Pie chart:
- Electricity 34%
- District heating 29%
- Wood 22%
- Heat pumb Energy 9%
- Heating Oil 5%
- Others 1%

Our paper

- Motivation
  - Project KIEMI (Less is More: Towards Energy Minimum of Properties)
  - Cost-effective, open and modular **proof-of-concept development**

- Purpose:
  - to gain overall knowledge of the current state of research in the area of energy consumprion monitoring and living / working comfort

- Goal:
  - To improve energy-efficiency and achieve better **living and working comfort**

- **RQ: What are the main research subjects of energy consumption monitoring?**
  - Feasibility study, method Systematic Literature Research (SLR)

Findings from related studies

- Availability of the visual feedback reduces energy and water consumption
  - Increasing energy-saving awareness and proper knowledge changes behavior
- Promotion of energy saving activities and guiding their proper usage improves energy-saving behavior
- Warmth is the most important factor indicating comfort in living and working space
  - Comfort practices are in large extent correlate to temperature related actions
  - Willingness to change behavior is motivated by money savings
- In-home displays giving data of energy consumption encourages consumers to energy-efficiency
  - Energy consumption reduced by 7%
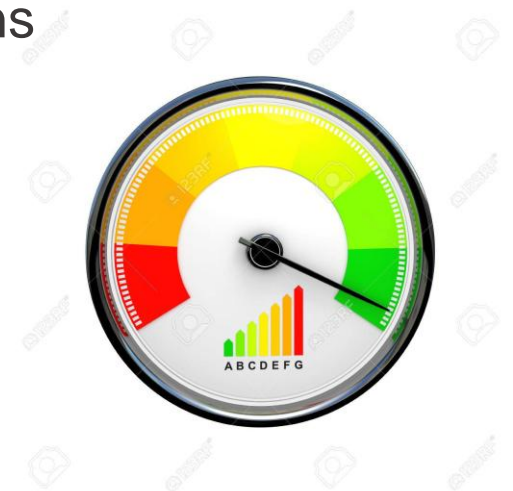
Systematic Literature Review (SLR) by Kitchenham

- Search terms:
  - "**Energy consumption**"
  - "Temperature comfort"
  - "Learning temperature comfort"
  - "Apartment temperature comfort"
  - "Smart home communication"
  - "Real-time energy consumption monitoring,"
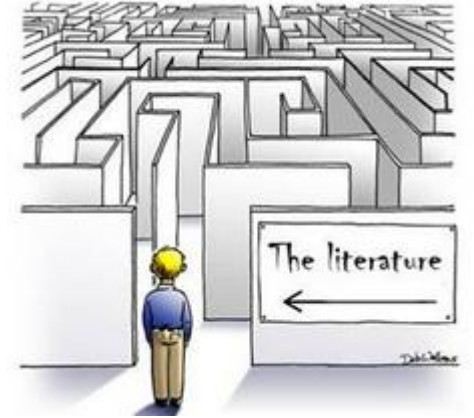 - "Energy apartment sensor"

- Sources:
  - IEEEXplore
  - Google scholar
- Result:
  - About fifty papers in total
- Classified in four categories
  - Comfort
 - Retrofitting
  - Network APIs
 - IoT

Systematic Literature Review

Paper analysis - Classifified

- Comfort
  - Living environment comfort, such as thermal comfort and humidity.
  - Papers often referred to previous studies

- Retrofitting
  - Research on applications or solutions installed in existing buildings

- Network APIs - Interoperability
  - Study of remote control or management of devices over network interfaces.

- IoT
  - Studies which do not fit in any of the other categories but are nevertheless related to our focus area.
  - All paper discuss the collection, storage and processing of data
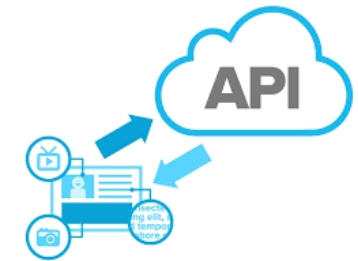
Findings (1)

- Deep analysis covered appr. 50 relevant papers
- Comfort
  - The most important factors are thermal comfort and humidity
  - Microclimate conditions and user preferences
  - Standards and metrics
  - Integrated method for personal thermal comfort optimization – users feedback, IoT and AI
  - A variety of IoT solutions (multiple sensors) – knowledge based control (HVAC, air-conditioning
- Retrofitting
  - IoT based sensor systems used to evaluate the comfort level
  - Cost-optimal renovation plans and control systems
  - Existing systems, e.g., HVAC systems, can be developed further to save energy
  - Automatic detection of energy consumption of devices (ElectiSense)
  - Gamification in energy saving (based on the collected data)
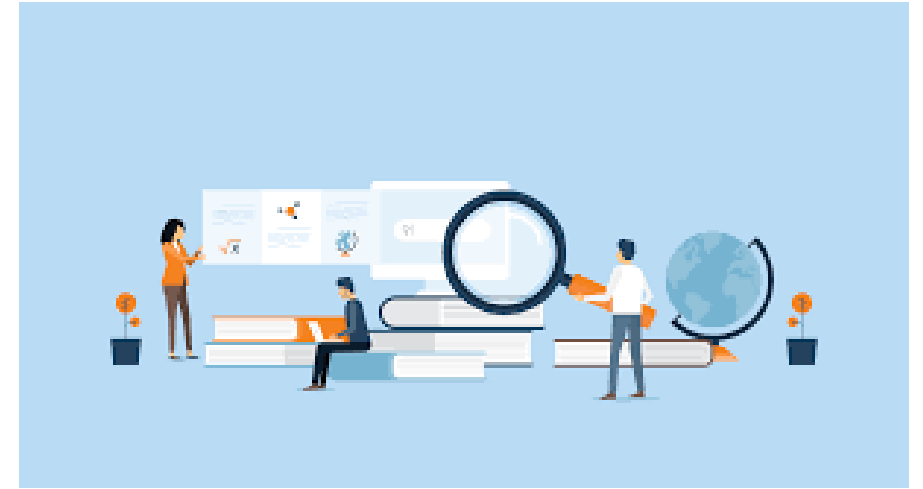
Findings (2)

- Network API
  - Applications of programmable interfaces – interoperability
  - RESTful API commonly used
  - Several examples of implemented web user interfaces and mobile phone interfaces

- IoT
  - Widest category in the study
  - Describes intelligent sensor applications: smart home management, cloud centric IoT systems, wireless smart comfort sensing,
  - Microcontroller (Arduino etc.) based sensor nodes and gateways

Numerous application and system examples of monitoring energy consumption

Summary and the next step(s)

- Comfort = temperature + humidity; additional aspects are worth of studying
    - Measurements from a human point of view
- The SLR provided a good state-of-the-art view to the research combining comfort and energy saving in in-house environment
- General finding: Energy saving is widely focused on research implementations of various kinds.
- The survey revealed the most recent trends in research and practical applications of energy saving.
- The study supports our approach focus – software, interoperability, cheap off-the-shelf devices
- What next? Project - prototype solutions in collaboration with our partners
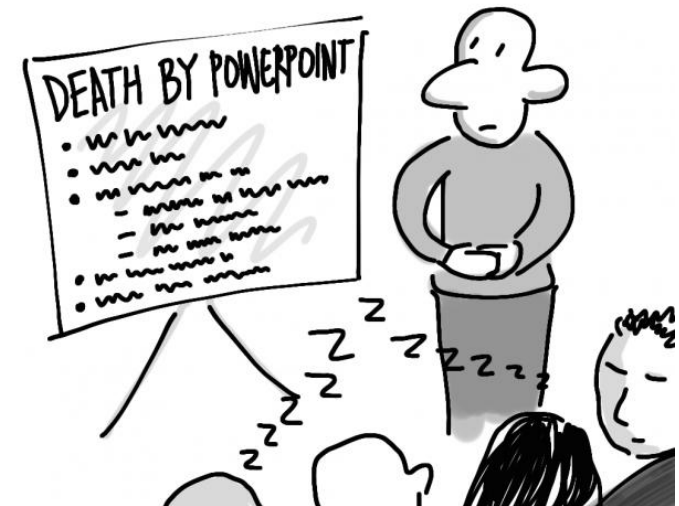
More information

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