Key concern in Europe

- EU climate and energy package
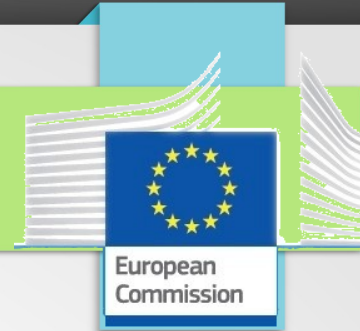   - 20-20-20 targets
        - A 20% reduction in EU greenhouse gas emissions from 1990 levels;
        - Raising the share of EU energy consumption produced from renewable resources to 20%;
        - A 20% improvement in the EU's energy efficiency.
- Europe 2020 strategy for smart, sustainable and inclusive growth.
- Key concerns for employment :
    - 20% renewable energy target could create 417 000 additional jobs
    - 20% energy efficiency improvement would create 400 000 new jobs.
- Energy Efficiency Plan 2011
- Energy Efficiency Directive

1st Generation

- FIT4Green: Federated IT for a sustainable environmental impact (2009-2012)

    – Energy-aware layer of plugins for data center automation frameworks

        - Smart allocation of VMs in DC (consolidation)
        - Smart management of resources (on/off)
        - Cooperation between Data Centers

- GAMES: Green Active Management of Energy in IT Service centres (2010-2012)

    – Improve the design and management of DC

        - Methodology
        - Energy Sensing and Monitoring Infrastructure (metrics)
        - Autonomic Runtime
            – Local runtime
            – Global runtime

2nd Generation

- All4Green: **Active collaboration in data centre ecosystem to reduce energy consumption and GHG emissions**
    - http://www.all4green-project.eu
    - 2011-2014

- CoolEmAll: **Platform for optimising the design and operation of modular configurable IT infrastructures and facilities with resource-efficient cooling**
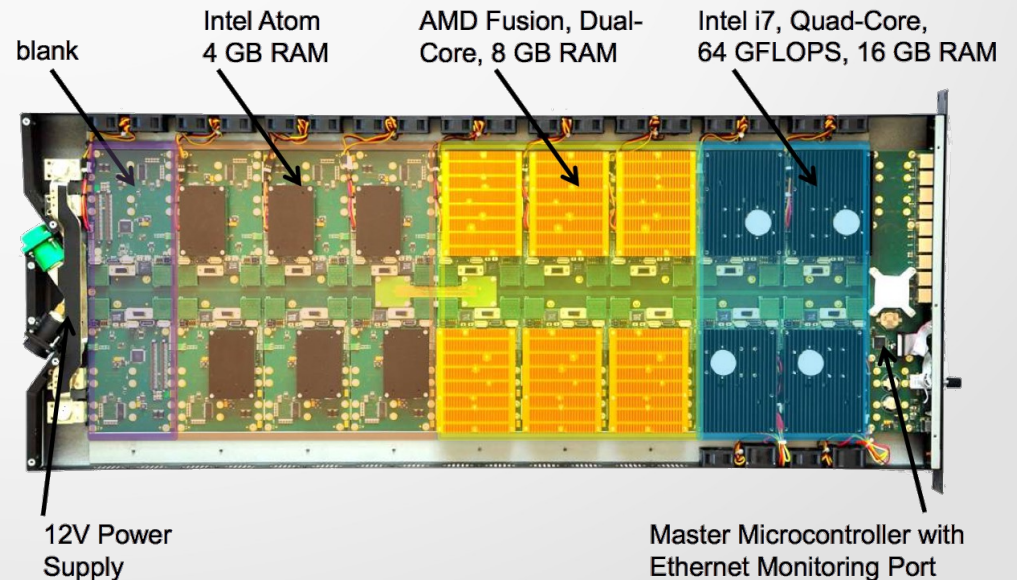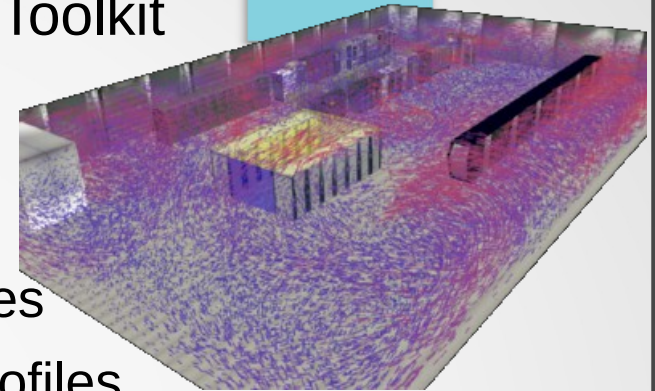   - http://www.coolemall.eu
    - 2011-2014

- ECO2Clouds: **Experimental Awareness of CO2 in Federated Cloud Sourcing**
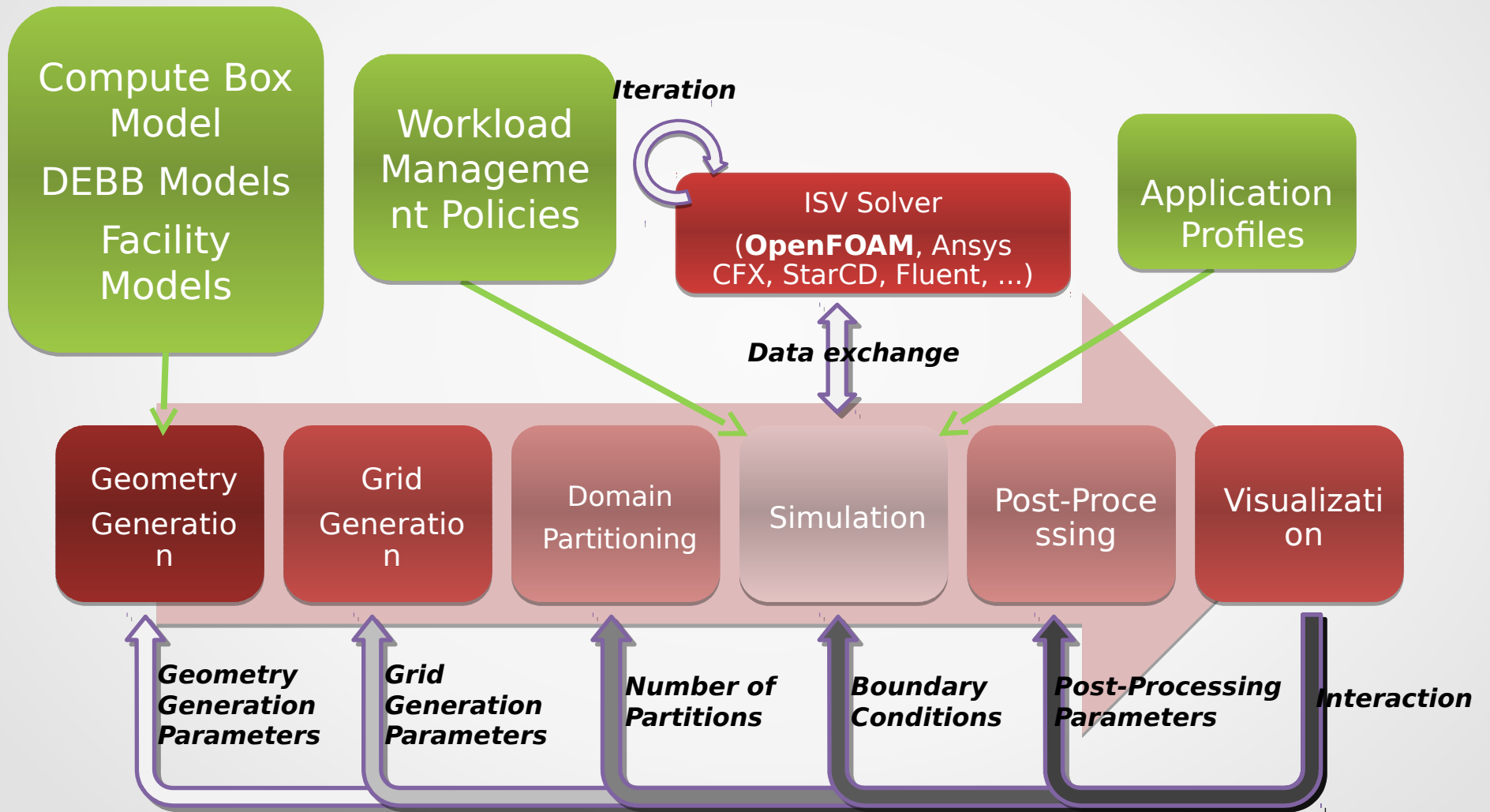   - http://www.eco2clouds.eu
    - 2012-2014

- Simulation, Visualization and Decision Support Toolkit

- Complete workflow to evaluate DC + blueprints

  - Different platform
    - Simulation: CFD/Runtime
    - Real platform execution

  - Different evaluation tools
    - Metrics and Benchmarks

  - Different granularity levels
    - **D**ata Center **E**fficiency **B**uilding **B**lock

  - Different scenarii
    - System policies
    - Application profiles
    - Scheduling policies
    - Placement of servers in a room

blank   Intel Atom 4 GB RAM   AMD Fusion, Dual-Core, 8 GB RAM   Intel i7, Quad-Core, 64 GFLOPS, 16 GB RAM

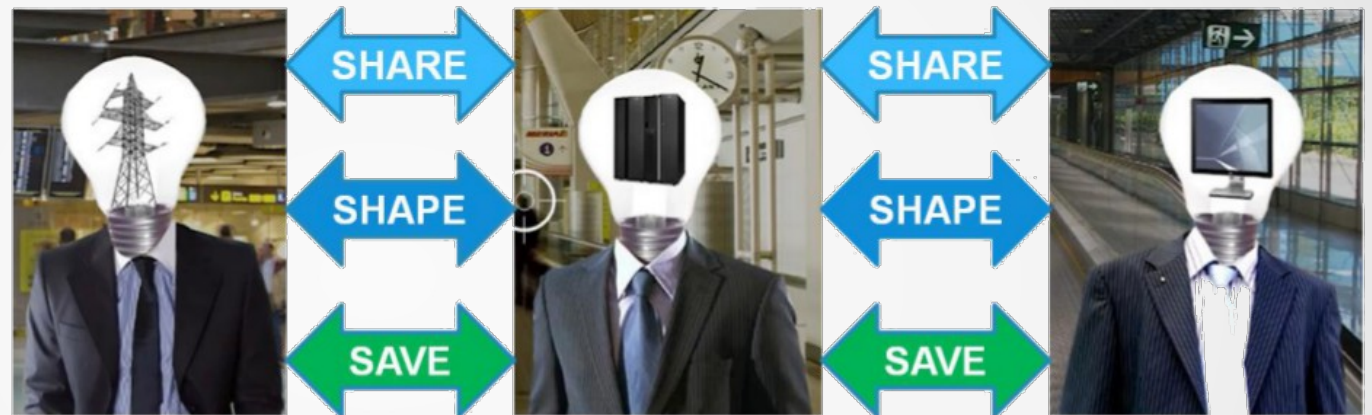12V Power Supply   Master Microcontroller with Ethernet Monitoring Port

All4green : GreenSDA & GreenSLA

- **Active collaboration in data centre ecosystem to reduce energy consumption and GHG emissions**

- Add link between

  - Utilities
  - DC Operators
  - Users

- Green SLAs, Information related to Renewable energy

- Two ways real-time informations : Emissions, Energy, needs

- Adapts Data Center load to real production, helps using renewable energy by providing more depth to decisions

- Use local energy when available reduces transport overhead

- Smart strategies in Data Centers reduces peak load for utilities

ECO$_2$Clouds

- **Experimental Awareness of CO2 in Federated Cloud Sourcing**

- Raise awareness on eco-metrics at all levels to improve :

  - Application development

  - Application and services deployment

- Eco-metrics
  - Energy, CO$_2$ (real-time mix from electricity provider) : Colect, and expose them
  - Several layers : Infrastructure, VMs, applications, services (based on actual measurements)

- Optimization and deployment models
  - Requirement at the level of infrastructure to support Eco-metrics
  - Upgrade of cloud semantics/runtime is needed

- Evaluate impact of decisions on eco-metrics + new smart decisions systems

  - Demonstration platform : BonFIRE

  - Data analysis in clinical domain

  - Eels case study

  - e-business with services

ECO₂Clouds

Measure

ECO₂Clouds develops key metrics to express energy consumption and CO₂ footprint of Cloud Facilities and Cloud Applications for quantification of their environmental impact.

Test on FIRE

Validate the effectiveness of optimization and adaptation processes through application in FIRE Facilities

Validate effectiveness

BonFIRE

Create

Create optimization and deployment models to generate configurations which reduce the environmental

Propose and design innovative application deployment strategies for sustainable federated Cloud sourcing with support for adaptation mechanisms to running applications.

Strategies for Energy Efficient and CO2 Aware Cloud Applications

The (ideal) big picture
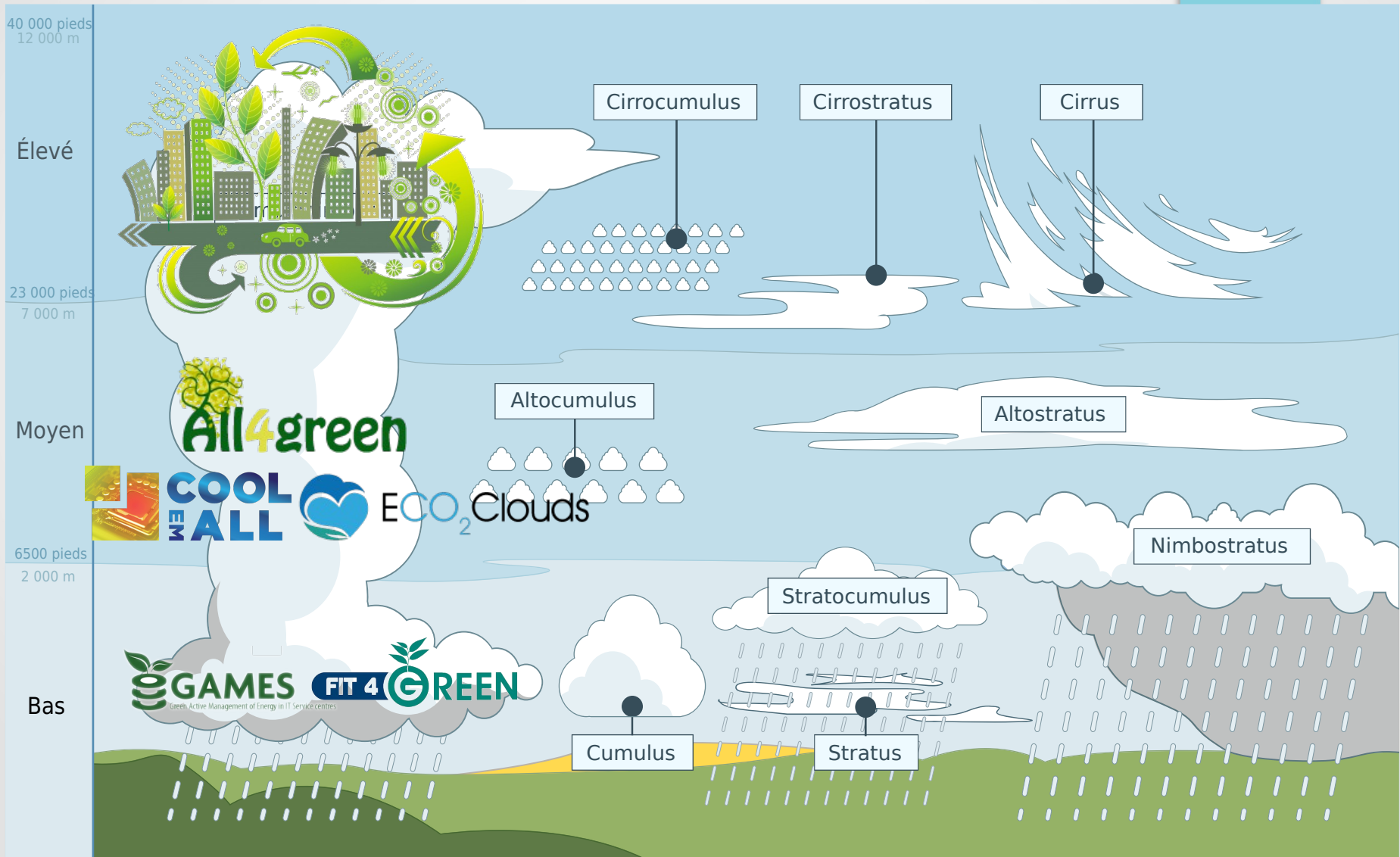
The big picture

- Common elements
  - Evaluation
    - Benchmarks
    - Metrics
    - Usecases
  - Raising awareness
    - Users
    - DC Operators/Planers
    - Utilities
  - Discussions started but
    - lack of common standards/metrics/test infrastructure
      - Hardware platform / Data Sets / Simulation tools

Energy sources: Energy sources (1d)

		last	min	avg	max
Total power	[avg]	61.2 KMW	50.74 KMW	56.86 KMW	61.2 KMW
Co2 producted per kWh	[avg]	81 g/kWh	52 g/kWh	74.76 g/kWh	90 g/kWh
Coal power	[avg]	3.53 KMW	1.96 KMW	3.17 KMW	3.81 KMW
Nuclear power	[avg]	43.71 KMW	40.21 KMW	42.31 KMW	43.71 KMW
Other power	[avg]	2.72 KMW	1.57 KMW	2.2 KMW	3.69 KMW
Wind power	[avg]	1.04 KMW	1.04 KMW	2 KMW	2.71 KMW
Oil power	[avg]	0 MW	0 MW	0 MW	0 MW
Hydraulic power	[avg]	8.89 KMW	4.45 KMW	6.23 KMW	9.04 KMW
Gaz power	[avg]	1.31 KMW	186 MW	931.34 MW	1.43 KMW

EuroEcoDC

$€ CO_2

W&J

ISO IEC
CENELEC
cen   SAC
ANSI

Data centerspecific Smart Cities projects

Data centerspecific Smart Cities projects

- 6 projects
  - DOLFIN : Data Centres Optimization for Energy-Efficient and EnvironmentalLy Friendly Internet
  - GENiC : Globally optimized ENergy efficient data Centres
  - GEYSER : Green networked Data Centres as Energy Prosumers in smart city environments
  - GreenDataNet :Designing and validating a new, system-level optimisation solution allowing urban data centres to radically improve their energy and environmental performance
  - RENEWIT : Advanced concepts and tools for renewable energy supply of IT Data Centres
  - DC4Cities : Environmentally sustainable data centres for Smart Cities

DOLFIN	4.3M€	2.7M€	Oct 2013	Sep 2016	9
GENiC	5.4M€	3.2M€	Oct 2013	Sep 2016	7
Geyser	5M€	3M€	Nov 2013	Oct 2016	10
GreenDataNet	4.3M€	2.9M€	Sep 2013	Aug 2016	7
Renewit	3.6M€	2.5M€	Oct 2013	Sep 2016	7
DC4Cities	4.9M€	3.5M€	Sep 2013	Feb 2016	10

- Objective FP7-ICT-2013.6.2:
  - Data Centres in an energy-efficient and environmentally friendly Internet
  - 20 M€ allocated, 18 spent
- Expected impacts
  - 80 % renewable energy
  - Quantifiable improvement using classical metric (PUE,CUE,WUE)
  - New market opportunities

DOLFIN

- **D**ata Centres **O**ptimization for Energy-Efficient and Environmenta**L**y **F**riendly **I**nter**N**et

- Key Idea : demand/response and energy stabilisation

- Data Center management system

  - Parametric energy consumption optimisation mechanisms (eCOM) and related optimization policies

  - Data Center SLA renegotiation process with multi-objectives : ICT and energy

  - Elastic SLAs taking into account dynamism of renewable energies (standardization)

- Expected experimental results

  - Management software to manage IT, power and cooling systems

  - Direct water-based cooling system of servers for heat reuse

GENiC

- **G**lobally optimized **EN**ergy efficient data **C**entres - GENiC
- Improve coordination and optimization of sensing and cooling, and scheduling
  - Multi-level approach : CPU, rack, DC level
  - Multi-level approach also for cooling : Adapt cooling effort to specific heat-points
    - Optimize chiller, air fans and server fans as a system
- Integration of renewable energy sources (RES)
  - Interoperability of generation, storage and heat recovery
  - Give feedback on installation and maintenance cost versus payback
- Complete system so integration between control systems
  - Computing, cooling, generation, energy storage, and waste heat recovery
- Integrated management and control platform for DC wide optimisation of energy consumption
  - The platform will include open interfaces, common data formats, control and optimisation functions and decision support
- Metrics : energy consumption, PUE, CUE, uptime.

GEYSER

- Network of Data Centers
  - Consuming Power (DC) and Cooling
  - Producing Computing, Heat
- Integration in the surroudings : smart city
  - Flexible supply/demand load and energy managment
  - Geographical renewable energy supply-aware load balancing
- Synergetic IT infrastructure (computing, storage), cooling and power with fine grained monitoring and control
  - Computing, storage, cooling, power
- Key concept
  - Fluid (power, heat) flows are to be integrated along with smart cities
- Metrics
  - PUE below 1,20 and CUE and ERE improvement by 30% in average
  - Simulation-based lab trial
  - Real life one year validation in three operational data centres, partially powered by renewable energy

GreenDataNet

- Remote Smart Energy Management Tool (like DCIM)
  - Manage multiple Data Centers
  - Control the interaction between IT hardware, software and renewable energy sources.
- Green Data Center Network
  - Optimization of IT, power, cooling and storage
- For cooling, heat reuse and free cooling
  - Three levels : servers and racks, individual data centers, and networks of data centers
  - Integration of local photovoltaic energy
  - Storage based on used Li-ion car batteries
- Improvement of existing Data Centers
  - Addition of renewable energy, electricity storage
  - Improve P.U.E. from 1.8, 2.0 down to 1.3
- Metrics
  - PUE and new metrics for standardisation bodies like CEN/CENELEC/ETSI
- Demo on three sites, one of them with photovoltaic panels and integrated in a experimental smart-grid

RENEWIT

- Advanced concepts and tools for **RENEW**able energy supply of **IT** Data Centres
- Web-based interface for simulation tool
  - Provide feedback with key metrics : carbon footprint
  - Uses meta-models from advanced dynamic simulation models
    - Management of the IT load following "green" objectives
    - Low-energy air-conditioning systems
    - Solar cooling
    - Interaction with district heating and cooling networks, re-use of heat
    - Optimal use of heat and cold storage, and integration in smart grids
    - Energy sources
    - Connection with city-wide smart-grid
  - Metrics from standardisation and industries bodies, other european projects
- Public
  - Planners, managers, investors, owners and designers of Dcs
- Evaluating the environmental performances of different technical solutions integrating RES taking into account climate
- Validation in collaboration with 8 Data Centers (4 in Northern and 4 in Southern Europe)

Dc4Cities

- DC4CITIES : Environmentally sustainable data centres for Smart Cities

- Two roles for smart cities
  - Key component to provide the smart in *smart-cities*
  - Energy black hole
- Dc4Cities
  - For old and new Data Centers
  - New metrics, benchmarks and measurement technologies, toward new standards
  - Energy-aware SLAs
  - Match load with localy produced renewable energy
- Create a set of action to adapt to external energy constrints
  - Connected to local Smart Grids and Micro Grids
  - Holistic scheduling policies

Renewable research

	Holistic Management	Multiple Data Centers	Middleware	Other
Dolfin	x		x	SLAs
Genic	x		x	Open Software Platform
Geyser	x	x	x	Direct Current
GreenDataNet	x	x	x	Batteries
Renewit				Models
DC4cities	x	x	x	External interactions

- Similar projects
  - Lot of produced code/models/metrics
- European commission is energy-aware
  - Synchronization benchmarks are scheduled

Scheduling ~50% Renewables

Scheduling ~90% Renewables
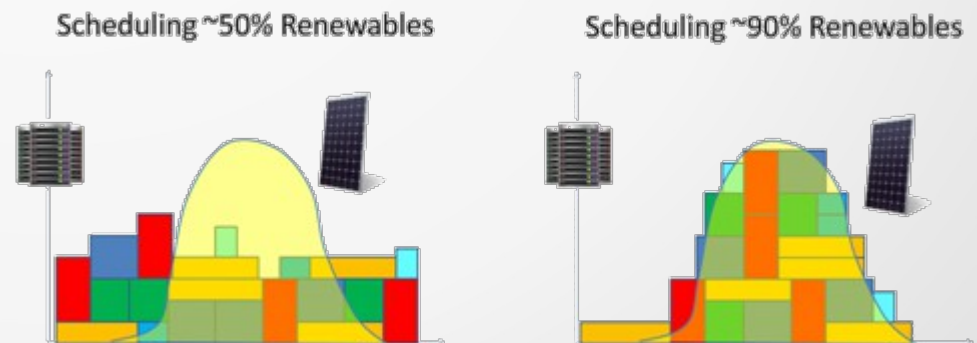
European Agenda

Horizon2020

- Euro R&I funding programme (2014-2020)

- Strong focus on societal challenges

- EU policy objectives (climate, environment, energy, transport etc) cannot be achieved without innovation

    - Proposed funding

Secure, clean and efficient energy	5 782 M€
Smart, green and integrated transport	6 802 M€
Climate action, resource efficiency and raw materials	3 160 M€

H2020 : ICT in Societal Challenges

- Secure, clean and efficient energy

  – Smart cities; Energy efficient buildings; smart electricity grids; smart metering;

- Smart, green and integrated transport

  – Smart transport equipment, infrastructures and services; innovative transport management systems; safety aspects

- Climate action, resource efficiency and raw materials

  – ICT for increased resource efficiency; earth observation and monitoring
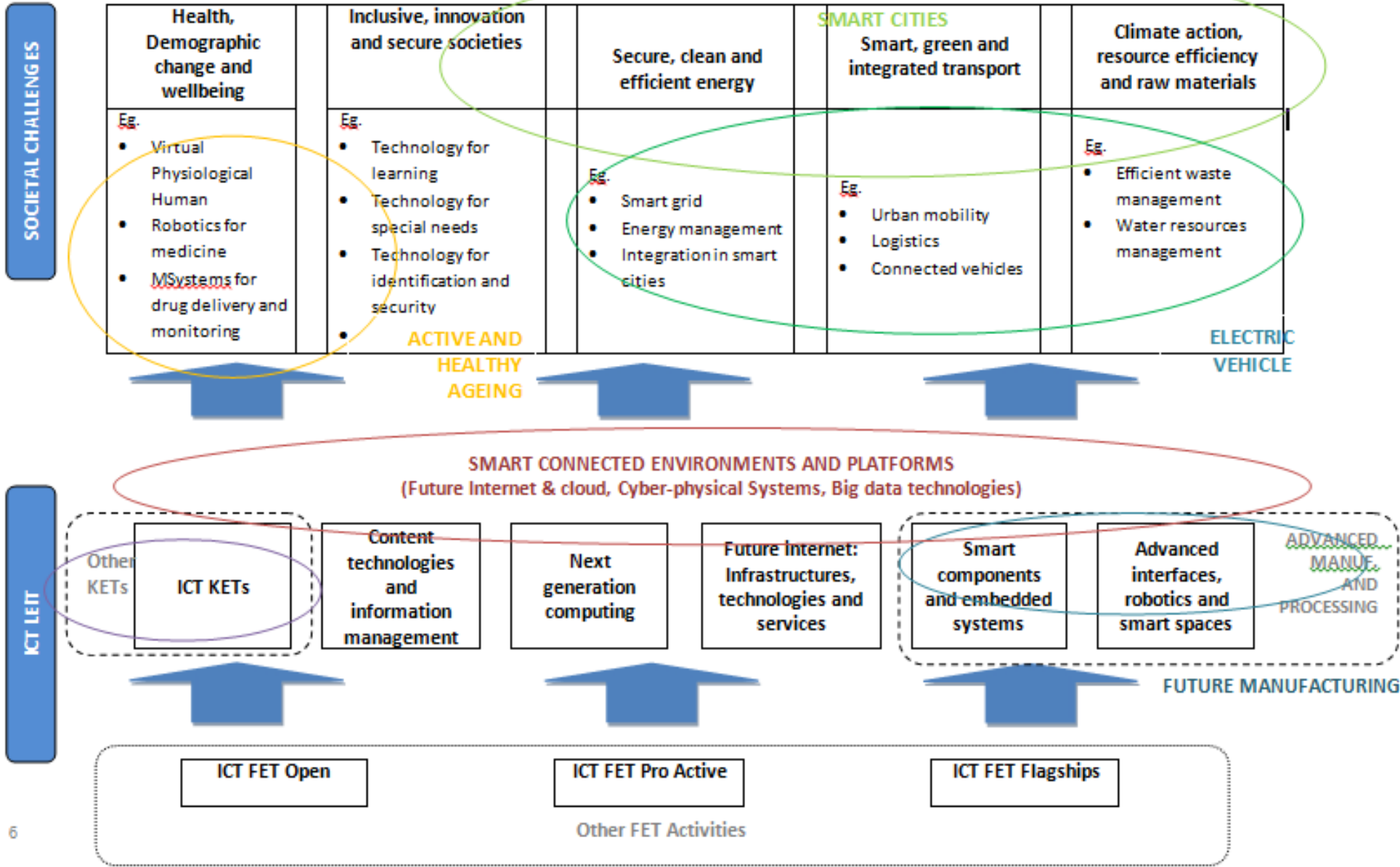
H2020 : ICT in Societal Challenges

- Digital Agenda For Europe

  - Pillar V : Research and innovation

    - Action 120: Key Transformative Action: Establishment of the European Cloud Partnership to harness public buying power to accelerate the development of the market for cloud computing

    - Action 121: Follow up of the European Cloud Computing Strategy

    - Action 122: Launch pilot action to explore the efficiency gains from moving public services into the Cloud

    - Action 132: Invest in High Performance Computing

      - Public-Private Partnership