A Proposal of the FP7 project

"Electronics Enabling Efficient Energy Usage (E4U)"

to the ICT Work Programme 2011 – 2012

www.e4efficiency.eu

Challenge 6: ICT for Low-Carbon Economy

The main goal of the FP7 project "Electronics Enabling Efficient Energy Usage (E4U)" was to foster world-leadership in ICT enabled energy efficiency in the EU through the creation of a strategic research roadmap for power electronics in alignment with the national, EU, and international policy framework. Power electronics is the technology associated with the efficient conversion, control and conditioning of electric energy from the source to the load. It is a cross-functional technology covering the very high Giga Watt (GW) power (e.g. in energy transmission lines) down to the very low milliWatt (mW) power needed to operate a mobile phone. Many market segments such as domestic and office appliances, heating, ventilation and air conditioning, lighting, computers and communication, factory automation and drives, traction, automotive and renewable energy can potentially benefit from the application of power electronics technology.

Given their considerable share in total electricity consumption and the large savings potential, the following four areas were chosen as the main focus of the E4U project:

- Buildings & Lighting;
- Power Supplies (with focus on ICT applications);
- Smart Electricity Grids (including vehicle to grid);
- Industrial Manufacturing (focus on industrial drives).

The estimated electrical energy savings potential that can be achieved by introducing power electronics into systems in the above presented areas only is enormous: more than 25% of the current EU-25 electricity consumption.

During the course of the project, the technology gaps and challenges in these areas were identified and based on these results several topics where further substantial research effort is needed are identified. By achieving substantial technology advancements in the following areas, the potential of power electronics in improving energy efficiency and the reduction of CO_2 emissions can be fully exploited.

Objective 6.1: Green ICT

Target outcome:

- **MicroEnergy Technology**
  MilliWatt and microWatt highly efficient power electronics is a key enabling technology for fully autonomous wireless sensor networks (WSNs) that have large application potential in applications such as industrial process monitoring and control, environment monitoring, healthcare applications, home automation, traffic control etc. It is critical that these WSNs not only have sensing and autonomous configuring ability but also have actuation and control capability to execute the commands they receive based on feeding the sensed data to an intelligent system (e.g. energy efficiency savings, activation of alarm systems, etc). These sensor nodes are powered by energy harvested from the environment and the efficient energy usage is a must to ensure autonomous operation. Research on the key technology gaps - ultra-low standby power semiconductors, integrated low-leakage micro-energy storage components (e.g. high density integrated solid state capacitors, thin film batteries), advanced materials for energy harvesting suitable for CMOS technology integration, and integrated magnetics and capacitors on silicon for power supplies on chip is mandatory to enable fully energy autonomous, miniaturised power supplies.

- **Ultra-High Efficiency Power Supplies for Data Centres and Telecom**
  Data centres and servers and telecom industry are in imminent and urgent need of improving energy efficiency on system level, given that more than 50% of their total energy consumption is wasted. In order to improve the efficiency of the whole energy chain, low loss high temperature power semiconductors (such as wide band gap), new (DC) fault-tolerant distributed architectures, and system integration of (digital) control, communication and power electronics need to receive considerable research attention. High-frequency and high-temperature passives and highly configurable power modules are necessary for achieving high power density and modularity.

- **Ultra-Low Standby Power Consumption**
  New devices and system architectures in power supplies are necessary for considerable reduction of standby power consumption. The key technology gaps are in ultra low power consumption IC technologies, integration of control, power semiconductors and passives (power supply on chip technology) and new topologies and architectures. The main barriers in realising the full power supply on chip is in integration of passives, hence this is where further research is needed.

- **High efficiency power distribution architectures**
  There is a need to integrate power distribution architecture technology with an ICT backbone to feed energy-intelligent algorithms so that energy-optimised power distribution choices can be made based on ICT data from the system. This pertains to nature and spread of the load(s) Vs available energy sources, optimised voltage setting for the application, optimised system switching frequency, etc. For example for data centre applications the system can operate more efficiently at a lower clock speed and at a lower system level voltage at times when date transfer demand on the system is predicted &/or measured to be low. This applies all the way from the smart grid down to optimising on-chip DC/DC power conversion architecture choices. Of course the additional power demand resultant for embedding this additional intelligence and dynamic control needs to be examined to determine viability for each application.

Expected impact:

- Wide-spread presence of autonomous wireless sensor networks for the benefit of industrial, residential, medical and military applications.

- 30-50% reduction in energy consumption for data centres and telecom radio base stations
- 80-90% stand-by energy consumption reduction and giving the European industry a leading edge in manufacturing low energy consumption electrical devices
- Better holistic understanding and capability of how to dynamically optimise power distribution and minimise energy losses. Smart power supplies and power distribution architectures that dynamically optimise energy efficiency based on ICT data (real time + predictions).

Objective 6.2 and 6.3: ICT for EE in mobility and ICT for smart grids

Target outcome:

- **Intelligent power interface between plug-in electric vehicles (EVs) and grid**
  The move to a more electric mobility will require that the electrical grids can supply the energy for these additional distributed loads. On the other hand the distributed energy storage capacity of these EVs can help to support large-scale renewable energy sources and stabilise the grid. Power electronics together with information and communication technologies is the key to providing the efficient bidirectional flow of energy and information between the electric car and the grid.

  For the vehicle-to-grid technology to exploit its full potential, further research and development in the following key areas is needed: battery technology, new smart and efficient power electronics battery chargers enabling bidirectional energy flow, seamless monitoring systems and communication protocols. Ultra-fast and efficient contactless charging should also be further explored.

- **ICT for the Fully Electric Vehicle**
  Energy consumption of auxiliary systems in EVs such as heating, airconditioning, lighting, on-board entertainment etc is important for vehicle driving range. Further research on self-powered (or low consumption) sensors, high power devices based on SiC and GaN, high efficiency LED drivers and advanced control systems as well as technologies for standardisation and automated production of automotive power electronics building blocks in these systems is needed to reduce total energy consumption of auxiliary system.

- **Super-grid and micro-grids (distributed power generation)**
  The future electrical energy system involves both Super-grid (the bulk power grid) and Micro-grids (distributed energy sources). Realisation of a European Super Grid based on low-loss, long distance power transmission integrating wind energy resources from northern Europe and solar energy resources from southern Europe (and Sahara region in Africa) needs the following technology developments:
  - High power semiconductors enabling high voltage (10kV), high currents and high temperature based on Si devices or wide band gap devices (SiC, GaN) for ultra-high voltages AC and DC grids (up to 800 kV)
  - High power DC/DC converters for MV DC grids
  - Multi-level power conversion topologies
  - Standard high-power power electronics building blocks
  - Bi-directional flow of power and information
  - Power quality in micro grids
  - Control of micro and super grids (island mode and normal grid mode)

Expected impact:

- Stable grids with increased share of renewable energy sources
- Reduction of CO_2 emissions by living in a more electric world
- Reduction of total energy consumption and the consumption of oil and gas
- Worldwide leadership of European e-mobility automotive industry

- Worldwide leadership of European high-power semiconductors and systems industry

Objective 6.x: ICT for Energy Efficient Buildings (PPP)

Target outcome:

- **High efficiency LED/OLED drivers**
  LED lights are increasingly finding new applications in liquid crystal display (LCD) backlighting, automobiles, traffic lights, and general-purpose lighting, because of their superior life time, low maintenance requirements, and improved luminance. Considerable energy savings can be achieved by replacing fluorescent sources with high luminous efficacy inorganic and organic LED luminaries fitted with intelligent power electronics drivers. Research in the domain of topologies, power semiconductors and adaptive control that enable high efficiency of drivers (>90%) combined with the integration and manufacturing technologies to keep the cost down is required. The life time of these drivers has to match the life time of LED light sources so reliability is an additional challenge.

- **Efficient Heating, Ventilating and Air-conditioning (HVAC) systems**
  Replacing all the motors and pumps in the HVAC electric systems by higher-efficiency ones, and using power electronics variable speed control can significantly improve the efficiency of the whole system. Further research in the field of intelligence and control in VSDs can achieve additional savings (e.g. by automatically optimising the magnetisation of the motor when the motor is operating at part load). Further power electronics enabled energy efficiency improvements can be achieved through intelligent building energy management (BEM) as an integrated network of sensors, control and actuators. Intelligent building energy management will require real time control of the loads. To reduce the installation and maintenance costs of the BEM system, wireless self-powered sensors will be required. Technologies for low cost, miniaturized, robust, maintenance-free small volume wireless sensor networks (WSNs) with the autonomous energy management and actuation and control capability (to execute the energy efficiency commands from the smart BMS resultant from the sensor readings) as the fundamental enabler need to be developed. A system level understanding of the application trade-offs to optimise the design is also critical. WSN design (hardware, software, drivers, RF protocol) needs to be kept as simple and low power as possible to enable self-powering through energy harvesting. However at a system level increased power is demanded to ensure capability to intelligently network with the smart BEM as well as execute actuation and control decisions.

Expected impact:

- Enabling energy positive buildings
- Energy savings, improved energy efficiency and reduced CO_2 emissions.
- World leadership of European lighting and HVAC industries
- Better system integration understanding (& resolution) of the challenges that need to be overcome for successful retrofitting of energy efficient heating and lighting systems.
- Compelling business justification for installation/retrofit of WSNs.