D5.5 TREND Final WP5 Report, including roadmap towards energy-efficient networks

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Abstract: The main objective of the *WP5 – Dissemination and outreach* is to increase the visibility and impact of the TREND NoE research community at both European and global levels. The dissemination activities follow several directions: *Dissemination of the scientific and technical results of WP1, WP2, WP3 and WP4; technology transfer to the industry; standardization activities; training activities to support and strengthen the dissemination objective; and coordination with other research projects at EU level on concertation and cluster activities and global level. This deliverable includes the reporting of the main WP5 activities during the Y3 period from 1 September 2012 to 30 November 2013.*

Keyword list: *dissemination, publications, seminars, workshops, standardization, training, thirdt yearly report*

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1. Executive Summary

This document compiles a detailed description of the activities and main achievements of the TREND WP5 on dissemination and outreach during the third year period.

The structure of the document is as follow: Section 3 is devoted to the TREND NoE website with a description of the main changes implemented during the third year. Section 4 includes a detailed description of the achievements on organization of conferences, teaching and training, standardization, external relations and editorial activities. Sections 5 and 6 summarize the status of theWP5 deliverables and milestones. Finally, two appendices include the Y3 publications and the TREND Roadmap towards energy-efficient networks.

2. Introduction

The main objective of WP5 is to increase the visibility and impact of the TREND NoE research community at both European and global levels. This main objective can be achieved by working into the following directions:

- *Dissemination of the scientific and technical results* of WP1, WP2, WP3 and WP4, and of the Integrated Research Actions (IRAs) and Joint Experimental Activities (JEAs) planned therein. The main instruments are the scientific publications at top conferences and journals, promotion and organization of workshops, conferences, events with the industry and special issues in journals (which will be coordinated by WP5, and possibly implemented within other WPs). Each WP will have specific dissemination activities, and WP5 will integrate all of them by using the TREND website as the main vehicle for dissemination.
- *Technology transfer to the industry* by establishing synergies with the industrial and academic communities.
- *Standardization activities* by liaison and contribution in relevant bodies.
- *Training activities* to support and strengthen the dissemination objective.
- *Coordination with other research projects* at EU level on concertation and cluster activities and global level.

During the third year period covered in this document, the WP5 goal has been to consolidate the main dissemination activities that have been active during the lifetime of the NoE. The following sections describe the last year achievements.

3. Project website

During the last year of the NoE, the website (www.fp7-trend.eu) has been a flagship of the project for both the TREND researchers and the green networking research community in general. The website constitutes a key tool where to share our results and highlight them within and outside the TREND NoE. The website was improved during the previous years and the routine maintenance has been continued during the third year. There are no new sections created during the last year.

4. WP5 Dissemination Activities Plan

This section is structured based on the proposed tasks in the first WP5 deliverable D5.1 Detailed WP5 Dissemination Activity Plan. These tasks are the following:

- Task 5.1: Organization of conferences [M01-M36]
- Task 5.2: Teaching and training [M09-M36]
- Task 5.3: Standardization activities [M06-M36]
- Task 5.4: External relations [M03-M36]
- Task 5.5: Editorial activities [M03-M36]

The following subsections describe the main actions implemented during this third reporting period and the main achievements and results along the third year of the NoE.

4.1 Task 5.1 - Organization of Conferences

TREND supported and promoted many events and conferences in the area of Green ICT. Four levels of conference support were provided by TREND:

- Advertised Events: These are events that TREND considers interesting for the partners, and hence are advertised on the website.
- Supported Events: These are conferences and events that the NoE has supported with active participation by either contributing a large number of papers or/and by organizing a workshop in conjunction with the event, etc. Organizers may use the NoE logo upon authorization by the Project Office.
- TREND co-organized Events: These are workshops/events co-organized by TREND. The organizer must have the NoE logo on their website and provide the Project Office with a report on the event, highlighting the TREND contribution
- TREND Events: These are stand alone events organized by TREND

During the third year the TREND NoE has continued the reinforcement of the links with the leading networking conferences that cover the topic of green networking. The main achievements on this task are below classified by type of events described above:

- Supported events:
  - **Bell Labs Open Days 2013**
    Nozay, France, 18/06/2013 - 20/06/2013
    Conference organization: Alberto Conte (A-LBLF)
    Bell Labs Open Days is the annual event organized by Bell Labs (France), open to internal and external (selected) visitors such as MNOs. Presentation on "Smart Frame Filling for 4G and beyond".

  - **SONET Workshop in conjunction with IEEE WCNC 2013**
    Shanghai, CHINA, 07/04/2013 - 07/04/2013
    Conference organization: Afef Feki (A-LBLF)
    Co-organization of the SONET workshop in conjunction with IEEE WCNC 2013

- **IEEE International Conference on Communications (ICC 2013) workshop on Telecommunications: From Research to Standards**
  Budapest, Hungary, 09/06/2013 - 09/06/2013
  Conference organization: Yabin Ye (HWDU)
  TPC member of IEEE International Conference on Communications (ICC 2013) workshop on Telecommunications: From Research to Standards

- **ECOC 2012**
  Amsterdam, The Netherlands, 14/09/2012 - 19/09/2012
  Conference organization: Bart Lannoo (iMinds)
  Symposium on "Energy Consumption of the Internet"
  This symposium analysed the relationship between the Internet and its energy requirements with an outlook to future developments.

- **2013 IEEE Online Conference on Green Communications (OnlineGreenComm)**
  Conference organization:
  Michela Meo General Co-chair
  Marco Ajmone Marsan Steering Committee Member
  Filip Idzikowski (TUB) Publicity Co-Chair
  Albert Banchs, Andrea Bianco, Roberto Bruschi, Stefano Buzzi, Luca Chiaraviglio, Antonio Cianfrani, Alberto Conte, Ruben Cuevas, Franco Davoli, Filip Idzikowski, Ramin Khalili, George Koutitas, Michela Meo, Mario Pickavet, TPC Members
  The conference was an online event in the period 29/10/2013 - 31/10/2013

- **18th IEEE International Workshop on Computer-Aided Modeling Analysis and Design of Communication Links and Networks (CAMAD 2013)**
  Berlin, Germany, 25/09/2013 - 27/09/2013
  Conference organization: Ahmad Rostami and Adam Wolisz (TUB)

- **IEEE PES ISGT 2012 - The third IEEE PES Innovative Smart Grid Technologies**
  Berlin, Germany, 14/10/2012 - 17/10/2012
  Conference organization: Adam Wolisz (TUB)
  Session chair: Control in Smart Homes

- **25th International Teletraffic Congress (ITC 25) - "Teletraffic in the Cloud"**
  Shanghai, China, 10/09/2013 - 12/09/2012
  Conference organization: Franco Davoli (CNIT)
  Panel Discussion at ITC 25
  Organizers: Raffaele Bolla, Franco Davoli
  Moderator: Franco Davoli
  The panel topic was "Energy efficiency, network performance and users' Quality of Experience in a scalable Future”

- **PIMRC 2013 conference**
  London, 08/09/2013 - 12/09/2013

Conference organization: Stefano Buzzi (CNIT)
Session chair

- **IEEE GLOBECOM 2012**
  Anaheim, CA, USA, 03/12/2012 - 07/11/2012
  Conference organization: Stefano Bregni (CNIT)
  IEEE GLOBECOM 2012
  Anaheim, CA, USA

- **IEEE ENERGYCON 2012**
  Florence, Italy, 09/09/2012 - 12/09/2012
  Conference organization: Stefano Bregni (CNIT)

- Co-organized events:

  - **Future Internet Cluster Meeting "Green and Energy-efficient Networking" Workshop**
    Brussels, 22/10/2013 - 22/10/2013
    Conference organization: Marco.Ajmone Marsan
    TREND jointly organized with ECONET and GreenTouch a workshop on green networking within the EC concertation meeting (Future Internet Cluster meeting).

  - **24th TIWDC 2013 (Tyrrhenian International Workshop 2013 on Digital Communications: Green ICT)**
    Genova, 24/09/2013 - 24/09/2013
    TREND session organized by Marco Ajmone Marsan
    General Co-Chair Franco Davoli
    Program Co-Chair: Raffaele Bolla
    Vice Program Chair: Roberto Bruschi
    Stefano Buzzi TPC Member

  - **Future Internet Assembly (FIA) in Dublin, Ireland on 8,9,10 May**
    Dublin, 07/05/2013 - 12/05/2013
    Conference organization: Marco.Ajmone Marsan
    Joint organization with GreenTouch of the panel "Green ICT: What would be the cost of doing nothing?"

  - **TREND/GreenTouch Joint Workshop on Green and Energy Efficient Networking**
    Turin, 19/04/2013 - 19/04/2013
    Conference organization: Marco.Ajmone Marsan

- **FUNEMS 2013 Conference**
  Lisbon, 03/07/2013 - 05/07/2013
  Conference organization: Stefano Buzzi (CNIT)
  Organization of a Workshop on Future Wired and Wireless Networks: Green,

Heterogeneous and Cloud-powered

- TREND events:
  - **Final TREND Workshop, Brussels 24 October 2013**
    Meeting details and presentations at: http://www.fp7-trend.eu/content/calendar-events/noe-events/final-trend-workshop-brussels-24-october-2013-presentations
  - **Phd School, Turin 1-5 July 2013**
    Meeting details and presentations at: http://www.fp7-trend.eu/TREND-Phd-School
  - **Plenary meeting, Catania 6-8 February 2013**
    Meeting details and presentations at: http://www.fp7-trend.eu/content/calendar-events/noe-events/plenary-meeting-catania-6-8-february-2013
  - **TREND & Friends Workshop, Volos, 3 October 2012**
    Meeting details and presentations at: http://www.fp7-trend.eu/content/calendar-events/noe-events/trend-friends-workshop-volos-3-october-2012-presentations
  - **Plenary meeting, Volos 1-5 October 2012**
    Meeting details and presentations at: http://www.fp7-trend.eu/content/calendar-events/noe-events/plenary-meeting-volos-1-5-october-2012

4.2 Task 5.2 - Teaching and training

The training activity is focused on contributions to teaching "Energy-Aware and Energy-Efficient Networking" topics within the regular courses of academic institution participating in the project and invited talks in key venue and institutions. The main objective is to pave the way toward a greater integration among different post-graduate school systems across Europe, and enhance curricula with topics focusing on energy-aware networking.

The teaching material produced for these courses is collected, reviewed by selected partners, and made available through the project website to the whole consortium in the section Teaching Material that is also publicly open.

During the third year, the TREND NoE has reinforced this activity. The main achievements on this task are the following, classified by type of teaching activity:

- PhD/MSc Courses/Seminars:
  - **TREND PhD School**

    The TREND PhD School took place on July 1-5, 2013 at Politecnico di Torino, and comprised lectures of industrial and academic experts in the field. Lectures were supported by a set of slides and a written text, to help PhD students in their learning experience.
    The PhD School lectures were structured as follows.

    1. An energy primer
       - Generation (fossil/renewable)

- Transport and distribution
- Metrics (LCA)

2. The big picture
    - The ICT worldwide footprint
    - Estimation of overall possible energy savings
3. The operator needs
    - Metro/core networks
    - Wired access
    - Wireless access
4. The manufacturers approach
    - Metro/core networks
    - Wired access
    - Wireless access
5. Some research proposals
    - Metro/core networks
    - Wired access
    - Wireless access
    - Applications
    - Data center networks
    - Networking based on renewable energy
6. Participants' experiences

The course details and the teaching material are available online on the TREND web site.
The course was an official PhD course of the Doctoral School of Politecnico di Torino and offered standard PhD credits after a final exam was passed.
Around 25 students from many different institutions attended the course. The majority came from institutions that did not participate in TREND, proving the effectiveness of this dissemination event.
The PhD course will be followed by *a second edition in the summer of 2014*.

- **MSc Course on "Green ICT" at the International Hellenic University in Thessaloniki, Greece, taught by Michela Meo (PoliTO) and George Koutitas (UTH)**
  The Green ICT is an official course module which includes basic TREND concepts such as energy efficiency in telecommunication networks (wired and wireless) and Green data centers. More precisely, there was a 12 hour lecture by Prof. Michela Meo (PoliTO) in the area of Energy Efficiency in Wireless and Wired Networks. In addition, there was a 9 hour lecture by Dr. George Koutitas

(IHU) in the scientific field of Green Data Centers. The module is theoretical and incorporates one assignment and written exams at the end of the term. The course, at its third edition, is titled "Green ICT" and covers most of the main issues related to this topic, from economical motivation to the design of energy efficient technologies, to solutions and open problems in wireless and wired technologies. More info can be found at:
(http://www.tech.ihu.edu.gr/index.php/en/courses/mastersmscs/msc-in-information-and-communication-technology-ict-systems.html).
Location: International Hellenic University in Thessaloniki, Greece
Date: 01/05/2013-31/05/2013 and 6/06/2013 - 8/06/2013

- **MSc Seminar on Electronic Advanced System on "Energy Efficiency in the Future Networks" by Julio Montalvo and Felipe Jiménez (TID)**
  Location: University Carlos III of Madrid – Leganes, Madrid, Spain
  Date: 09/05/2012 (not reported in previous report by mistake)

- **MSc Seminar on Electronic Advanced System on "Energy Efficiency in the Future Networks" by Julio Montalvo and Felipe Jiménez (TID)**
  Location: University Carlos III of Madrid – Leganes, Madrid, Spain
  Date: 22/05/2013

- **Lecture Seminar: " How to Influence the Major Trends in Mobile Communication?" At UC Berkeley by Adam Wolisz (TUB)**
  Location: Berkeley, California
  Date: 22/03/2013

- **Lecture Seminar: "Exploiting Context Awareness for Communication Efficiency Improvement" At SwarmLab Seminar at UC Berkeley by Adam Wolisz (TUB)**
  Location: Berkeley, California
  Date: 14/03/2013

- **Seminar: "Green Networking" At TUB by Fatemeh Ganji and Lukasz Budzisz (TUB)**
  Location: Berlin
  Date: 11/04/2013-06/09/2013
  The seminar has discussed a huge variety of topics in the area of wireless green networking.

- **Seminar: "Energy Efficient Networking" At ISTI-CNR by Franco Davoli (CNIT))**
  Location: Pisa, Italy
  Date: 28/06/2013

- **Seminar: "Energy-efficient resource allocation strategies in downlink coordinated OFDMA networks" by Stefano Buzzi (CNIT) at University of Parma**
  Location: Parma, Italy
  Date: 25/09/2013

- Invited/Keynote/Tutorial/Panel Talks:

  - **TREND session on Green Communications organized by Marco Ajmone (PoLITO)**
    Location: 24th Tyrrhenian International Workshop on Digital Communications
    Date: 24/09/2013

  - **Keynote Lecture: "Test Driving the Energy Efficiency of a Wireless Netowork" by Marco Ajmone (PoLITO)**
    Location: HotMesh 2013, Getafe, Madrid, Spain
    Date: 04/06/2013

  - **Talk: "Successful Cases and Key Remaining Research Challenges" by Marco Ajmone (PoLITO) in the Panel Collaborative Programs in Green Communications at IEEE ICC**
    Location: Budapest
    Date: 12/06/2013

  - **Panel discussion: "Enablers and Roadblocks for Green Networking" organized by Marco Ajmone (PoLITO) at the 22nd ITC Specialist Seminar on Energy Efficient and Green Networking (SSEEGN)**
    Location: Christchurch, New Zealand
    Date: 20/11/2013 – 22/11/2013
    http://www.itcspecialistseminar22.com/panel-discussion/

  - **Talk: "Network Sharing: An Energy-Efficient Option For European Mobile Network Operators"" by Marco Ajmone (PoLITO) in the Semana de la Ciencia**
    Location: Madrid
    Date: 12/11/2013

  - **Talk: "Zero Energy Cellular Systems" by Marco Ajmone (PoLITO) in Green Touch Meeting**
    Location: Paris
    Date: 04/11/2013 – 06/11/2013

  - **Talk: "Network Sharing and its Energy Benefits: a Study of European Mobile Network Operators" by Marco Ajmone (PoLITO) in Green Touch Meeting**
    Location: Paris
    Date: 04/11/2013 – 06/11/2013

  - **Tutorial: "From energy efficient networking to sustainable networking" by Michela Meo (PoLITO) at Softcom**
    Location: Split
    Date: 11/09/2012

Abstract:
Energy efficient networking has become an hot topic in the last few years. In this tutorial, I first motivated the interest and importance of this topic by presenting some data about energy consumption of network devices. Data allow identifying the network segments that are the most energy hungry. The main approaches proposed in the literature for reducing network energy consumption were then presented with particular attention to wireless networks. Finally, we shifted our attention from energy efficient networking to the new challenging topic of sustainable networking.

- **Talk: "Towards Zero grid Electricity Networking: Powering BSs with Renewable Energy Sources" by Michela Meo (PoLITO)in the GreenTouch Plenary Meeting**
  Location: Shanghai
  Date: 13/05/2013

- **Seminar: "From energy efficient networking to sustainable networking" at the COST 804 Training School on Energy Efficiency in Large Scale Distributed Systems by Michela Meo (PoLITO)**
  Location: Italy
  Date: 11/04/2013
  http://cost804school.deis.unical.it/

- **Lecture: "LTE and Energy Efficiency " at INRIA/INSA by Alberto Conte (A-LBLF)**
  Location: Lyon
  Date: 17/01/2013

- **Talk "Silent Base Station - A comparative study on the signaling power consumption" by Alberto Conte (A-LBLF) at GreenTouch Plenary Meeting**
  Location: Shanghai
  Date: 16/05/2013

- **Tutorial : "Future of Communications Systems and Networks" by Jorge Lopez Vizcaino (HWDU) at IEEE Latincom**
  Location: Chile
  Date: 24/11/2013

- **Tutorial : "Future of Communications Systems and Networks" by Jorge Lopez Vizcaino (HWDU) at IEEE Latincom**
  Location: Chile
  Date: 24/11/2013

- **Talk : "Power consumption evaluation of next-generation optical access technologies". Collaboration TID and iMinds by Sofie Lambert (iMinds)**
  Location: Turin, Italy
  Date: 19/04/2013

- **Talk : “Telefonica Group on Energy Efficiency” by Julio Montalvo (TID)**
  Location: Reykjavík, Iceland
  Date: 22/05/2012 (this is reported in the third year because it was not reported in the second one by mistake)

- **Invited Talk : "TREND towards more energy-efficient optical networks” by Esther Lerouzic (Orange)**
  Location: Brest, France
  Date: 16/04/2013-19/04/2013

- **Talk : "Measuring the energy cost of networking intensive applications: P2P and OSN" by Roberto Gonzalez (UC3M) at TREND/GreenTouch Joint Workshop on Green and Energy Efficient Networking**
  Location: Torino
  Date: 19/04/2013

- **Poster : “TREND Poster” at Future Internet Assembly by Ruben Cuevas (UC3M)**
  Location: Dublin
  Date: 08/05/2013- 10/05/2013

- **Talk : "ICT footprint study” by Mario Pickavet (iMinds)at OnlineGreencom 2013**
  Location: Torino
  Date: 29/10/2013

- **Poster : “ICT footprint study” by Ward Vanheddeghem (iMinds) at PhD Symposim at University of Ghent**
  Location: Ghent, Belgium
  Date: 06/12/2013

- **Invited Talk: " How to Influence the Major Trends in Mobile Communication" by Adam Wolisz (TUB) at Telekom Innovation Laboratories (T-Labs)**
  Location: Silicon Valley Innovation Center (SVIC), Mountain View, California
  Date: 27/02/2013

- **Keynote: " How to Influence the Major Trends in Mobile Communication " by Adam Wolisz (TUB) at International Workshop on Wireless Access Flexibility - WiFlex 2013**
  Location: Kaliningrad, Russia
  Date: 06/09/2013-06/09/2013

- **Invited Talk: " Are there better Ways to handle the Mobile Traffic Growth?" by Adam Wolisz (TUB) at DFG Sonderforschungsbereich MAKI**
  Location: Darmstadt, Germany
  Date: 15/11/2013

- **Talk: "Green WLANs: Power Saving Potential of Adaptive AP Density Control in Enterprise WLANs" by Fatemeh Ganji (TUB) at Workshop CfC Fachgruppentreffen ITG 5.2.4 in Berlin (T-Labs) "Green IT in wireless access networks"**
  Location: Berlin, Germany
  Date: 29/11/2013

- **Panel discussion: Enablers and Roadblocks for Green Networking by Franco Davoli (CNIT) at 22nd ITC Specialists Seminar on Energy Efficient and Green Networking (SSEEGN 2013), in conjunction with the Australasian Telecommunication Networks and Applications Conference (ATNAC 2013)**
  Date: 21/11/2013

- **Keynote: " Green Networking and Network Programmability: a Paradigm for the Future Internet?" by Franco Davoli (CNIT) at 22nd ITC Specialists Seminar on Energy Efficient and Green Networking (SSEEGN 2013), in conjunction with the Australasian Telecommunication Networks and Applications Conference (ATNAC 2013)**
  Date: 20/11/2013

- **Talk: "Energy-efficient resource allocation strategies in downlink coordinated OFDMA networks," at University of Parma by Stefano Buzzi**
  Location: Parma, Italy
  Date: 25/09/2013

4.3 Task 5.3 - Standardization activities

Individual TREND partners are very active at different levels in relevant standardization bodies. Besides that, the TREND NoE has continued during the third year the initiative of establishing contacts with representatives of standardization bodies active in green networking.
Apart from the individual standardization activities, there is a joint collaboration between the TREND operators Orange and Telefonica (in conjunction with other operators) in the field of photonic switching technologies to reduce energy consumption of optical core and metro networks in the ITU-T Study Group 15.
The main achievements on this task during the last third year are the following:

- PoLITO participation in the ETSI Workshop on Environmental Impact Assessment and Energy Efficiency (Athens, October 2013). http://www.etsi.org/news-events/events/668-2013-eeworkshop.
- A-LBLF participates in 3GPP standardization group, and is active on the theme related to "improvement of energy efficiency of telecommunication networks". ALBLF provides support as internal consulting to ALU representatives at 3GPP and other standardization fora.
- A-LBLF participates in the ETSI EE (Energy-Efficiency) standardization group, and is active on the theme related to "improvement of energy efficiency of telecommunication networks". The following is a list of actions of ALBLF:

  - Contribution to document ETSI TS102706 V1.3.1 "Environmental Engineering (EE); Principles for Mobile Network level energy efficiency"
  - Contribution to document ETSI ES202706 V1.4.1 (draft) : "Environmental Engineering (EE); Principles for Mobile Network level energy efficiency"
  - Contribution to document ETSI ES203228 V0.0.1 (early draft) : "Environmental Engineering (EE); Principles for Mobile Network level energy efficiency"
- TID has assisted to IETF meetings 85 (Atlanta, 4-9 Nov 2012), presenting a new version of the framework for the GMPLS based control of Flexigrid DWDM networks (http://tools.ietf.org/html/draft-ogrcetal-ccamp-flexi-grid-fwk-01).
- TID has assisted to IETF meeting 86 (Orlando 10-15 March 2013) and attended to the joint ITU-T SG15 and IETF CCAMP session on Flexible networks.
- TID is promoting Elastic Optical Networks within TREND IRA3.2 as a key enabler block for overall energy savings within the Core network, being an active actor in the standardization activities on the field.
- TID has attended the 4Q 2012 meeting in the Broadband Forum (BBF), where the SD-295 document was finished including an appendix on the energy efficiency analysis of Network Located Residential Gateways (NLRG), which is based on the work performed by TID in WP1 and WP3.
  The SD-295 was successfully accepted as an internal document of the BBF and this work will continue in the Working Text 317
- Ramin Khalili (EPFL) gave a talk during IETF 88 meeting in Vancouver. He presented the findings about performance issues with the version of MPTCP congestion control that was originally proposed. Two internet drafts were prepared in the context of the IETF mptcp working group.
- Orange, Telefónica and other operators started standardization activity to promote this kind of technologies within ITU-T Study Group 15 through several contributions (T09-SG15-C152711/2011, T09-SG15-C-2322/en 08/2012). Discussions are ongoing on “Some considerations for modelling Sub-lambda photonic switched networks (SLPSN)” document T13-SG15-C-0015. This activity around the potential of sub-lambda photonic switching network gave place to several mobility actions with the objective of evaluating the performance of industrial equipment based on subwavelength photonic switching, that was available in TID labs

4.4 Task 5.4 – External relations

TREND external relations are built in several directions. One of them is within the 7th FP of the EC where there are several projects in the area of green networking (EARTH, GREENET, ECONET, C2POWER…). The TREND NoE has established strong links with these projects by inviting key researchers from them to the TREND plenary meeting and workshops. Several presentation of TREND NoE took place in the meeting of other projects.

Other example of external relations are based in the Collaborative Institutions that have been actively joining the TREND consortium, the links with the Industry and with other research projects at national and international levels.

Some examples of TREND collaboration with other FP7 projects are:

- **FP7 NoE EINS**: Within the FP7 EINS project (Network of Excellence in Internet Science), there is one work package dealing with energy efficiency, i.e. “WP8: Internet for Sustainability”, investigating, from a multi-disciplinary angle, how the Future Internet could help to relieve the main problems affecting sustainability at planetary scale, including Greenhouse gas emissions, energy production, sustainable lifestyles, and the related problem of climate change. Within this work package, attention is also paid to research activities on ICT and Internet energy reduction. More specifically, the TREND study on the estimation of the worldwide electricity consumption of ICT was partially performed in the framework of EINS.

- **FP7 IP STRONGEST**: Some of the studies related to core networks were in collaboration with the FP7 STRONGEST IP project (Scalable, Tunable and Resilient Optical Networks Guaranteeing Extremely-high Speed Transport, grant agreement 247674, 01/2010 – 12/2012). STRONGEST’s main goal is to design and demonstrate an evolutionary ultra-high capacity multilayer transport network, based on optimized integration of optical and packet nodes, and equipped with a multi-domain, multi-technology control plane, overcoming the problems of current networks that still provide limited scalability, are not cost-effective and do not properly guarantee end-to-end quality of service.
    - The work on representative power values, which ultimately resulted in the powerlib online database, contained in its initial stages substantial input and feedback from STRONGEST partners. These findings were updated and fine-tuned within TREND using more operator specific input.
    - The survey on the power saving potential in the core was a joint work with the University of Essex, a partner of STRONGEST [W. Van Heddeghem, M. C. Parker, S. Lambert, W. Vereecken, B. Lannoo, D. Colle, M. Pickavet and P. Demeester, "Using an Analytical Power Model to Survey Power Saving Approaches in Backbone Networks", NOC, Vilanova (Spain), June 2012].
    - Similarly, a study on energy-efficient upgrade paths for edge routers was also in collaboration with this same partner. [M. C. Parker, R. Martin, S. D. Walker, W. Van Heddeghem, B. Lannoo, "Energy-Efficient Master-Slave Edge-Router Upgrade Paths in Active Remote Nodes of Next-Generation Optical Access", ACP 2012, Guangzhou (China), November 2012]

  An overview of the relevant work on energy efficiency in the STRONGEST project was presented at the TREND workshops in Ghent (February 2012) and Volos (October 2012).

- **FP7 IP OASE**: Some of the input related to optical access networks was originating from the FP7 OASE project (Optical Access Seamless Evolution), grant agreement 249025, 01/2010-02/2013):
    - Several power consumption values used in the study on power consumption evaluation of NGPON2 technologies are originating from public data from the OASE project.
    - iMinds, as OASE partner, had several discussions on the used values with the two vendors participating in OASE, i.e. Ericsson and ADVA.

  An overview of the relevant work on energy efficiency in the OASE project was presented at the TREND workshop in Volos (October 2012).

- **FP7 DISCUS** project (DIStributed Core for unlimited bandwidth supply for all Users and Services grant agreement 318137), (11/2012-10/2015). The DISCUS project defines an overall network architecture where high performance services are flexibly deployed through innovative optical elements and transmission technologies, ensuring infrastructure scalability. The project was presented by Telefónica I+D in Volos plenary meeting, as Trend relevant issues like energy efficient network architectures, resiliency mechanisms or transmission techniques were also analyzed by specific DISCUS working groups. Several papers have been produced in collaboration with DISCUS.

- **FP7 Idealist** project (Industry-Driven Elastic and Adaptive Lambda Infrastructure for Service and Transport Networks under grant agreement 317999) (11/2012-10/2015). The Idealist project analyses optical transmission technologies, network and node architectures and control plane mechanisms for Elastic Optical Networks (EONs). The project is led by TREND partner Telefónica I+D and there has been frequent interaction with the groups involved in data plane technologies and power efficient transmission techniques. This has produced, as an outcome, several papers within WP3 IRA3.2 related to innovative protection mechanisms for optical networks, increasing its energy efficiency as well as its capacity and flexibility. A book chapter on Green networking and communications was also elaborated as a result from Trend-Idealist cooperation. . Several papers have been produced in collaboration with Idealist.

- **FP7 CHRON** project (Cognitive Heterogeneous Reconfigurable Optical Network under grant agreement 258644) (07/2010-06/2013). The CHRON project proposes a network architecture that acts, learns and optimizes its performance, taking into account its high degree of heterogeneity with respect to QoS, transmission and switching techniques. As defined in the project, energy consumption is one of the key concepts that the cognitive decision system will take into account. Among other potential advantages, cognition and continuous monitoring may enable the design of energy efficient networks through remote power management. In fact, the cognitive process in the network can take into account power usage and availability of non-fossil or renewable energy sources when deciding how to handle new traffic demands according to the current network status provided by the monitoring system, and to set devices to stand-by state when appropriate. HWDU being a partner of TREND and CHRON projects, has established a close cooperation between both projects with the aim at finding strategies to improve the energy efficiency of the network. In fact, the carried research on energy-aware routing and resource allocation algorithms for Wavelength Division Multiplexing (WDM) networks and EONs, and the studies on energy-efficient protection schemes have been of great value to define the final architecture of the cognitive network system envisioned by CHRON. As a result from this cooperation, twelve TREND-CHRON joint publications have been achieved and two more papers currently under review.

TREND has established a close relationship with the French Laboratory of Excellence **Comin-labs** (2011-2020). CominLabs is an Excellence Center (Laboratoire d'Excellence from the Investissements d'Avenir program of the French government). CominLabs gathers ten research labs from Bretagne and Nantes in the area of telecommunications, Internet, and over-the-top services. Esther Le Rouzic (Orange) has presented TREND to the Energy focus group of the French Laboratory of Excellence CominLabs on the 20/10/2011. 30 researchers from Brittany (ENSSAT, Télécom Bretagne, INSA Rennes, mines Nantes, INRIA) participated in this meeting

TREND has also established a close relationship with the GreenTouch initiative across several iterations: Participation in GreenTouch Plenary meetings Shanghai in May 2013 and Paris in November 2013); joint organization of several workshops: TREND/GreenTouch workshop at INFOCOM 2013 (Turin, April 2013), FIA in Dublin (May 2013) and FI Cluster meeting (Brussels, October 2013); PoLITO, A-LBLF and HWDU has an active participation in the GreenTouch BCG2 project and several plenary meetings. More specifically, the following TREND work was presented and discussed in a GreenTouch meeting:

- Worldwide electricity consumption of ICT (presented at the Stuttgart meeting in Nov. 2012).
- Power consumption evaluation of NG-PON2 technologies (presented at the Shanghai meeting in May 2013, and the Paris meeting in Nov. 2013).
- Creation and use of reference power consumption values for core network equipment, both with information from STRONGEST, TREND and Greentouch. (for exemple, in the GreenTouch **Greenmeter report** the values in Table 9 are partly based on input from TREND partners: http://www.greentouch.org/uploads/documents/GreenTouch_Green_Meter_Research_Study_26_June_2013.pdf.

TREND has created synergies with industry, especially for the estimation of the worldwide electricity consumption on ICT, organizing several discussions with TREND consortium and external industrial partners. Some examples of these close relations during the last year are:

- TREND had direct contacts with Deutsche Telekom and British Telecom in the field of energy efficiency networking.
- A set of dynamic traffic matrices was added to the SNDlib online database that is managed by Zuse Institut Berlin (ZIB) with support of atesio GmbH. The set contains numerous traffic matrices originating from traffic measurements in core networks. More details about this data can be found in the TREND deliverable D1.3. These traces can be accessed through: http://sndlib.zib.de/dynamicmatrices.overview.action.
- A set of measurements of weekly activity in base stations of an Italian MNO (Mobile Network Operator) was collected, as a result of the cooperation of Politecnico di Torino with the MNO, and made available to the TREND partners for the realistic estimation of energy saving in mobile access networks.
- At ECOC 2012 (Sep. 19, 2012, Amsterdam, The Netherlands) iMinds organized a symposium on “Energy Consumption of the Internet” in collaboration with the European Photonics Industry Consortium (EPIC). This symposium, supported by TREND, analyzed the relationship between the Internet and its energy requirements now and in the coming decade. Renowned speakers from both energy and ICT background presented their view on this matter. There was a lot of industry involvement in this symposium, with speakers from the International Energy Agency (IEA), Orange Labs, Alcatel-Lucent and Ericsson.
- The powerlib (http://powerlib.intec.ugent.be/) online database was presented at the International Energy Agency (IEA) 'Network Standby' workshop in Paris (September 2013). The presentation raised substantial interest and feedback, and was particularly useful as almost all collaborators of the workshop did not have any links with the TREND project. The study on the worldwide electricity consumption of ICT was also a valuable input to the IEA workshop and the upcoming IEA publication on 'Network Standby'.
- Filip Idzikowski (TUB) visited ZIB on 9 and 25 September 2012. The current activities of ZIB and TUB on green networking were presented and discussed with the focus on

network and power modeling. A proposal for collaboration was made, what resulted in an application of ZIB to become a Collaborating Institution.

- Filip Idzikowski (TUB) visited EICT GmbH on 22 January 2013. TREND WP4 activities and related activities within the DESI project were discussed with FUB, INRIA and CNIT-UniRoma1 in a conf call.
- TUB worked with Atesio GmbH and Zuse Institut Berlin (ZIB) on the paper published in the Elsevier Journal on Optical Switching and Networking. Idzikowski et al., Dynamic routing at different layers in IP-over-WDM networks – Maximizing energy savings, July 2011.
- F. Ganji and L. Budzisz (TUB) participated in the Workshop CfC Fachgruppentreffen ITG 5.2.4 "Green IT in wireless access networks" and F. Ganji gave a talk on the strategy for power saving in dense WLANs developed in WP2, titled "Green WLANs: Power Saving Potential of Adaptive AP Density Control in Enterprise WLANs".
- Telekom Innovation Laboratories, Silicon Valley IC,Mountain View,California:
  Adam Wolisz (TUB) gave an invited talk: How to Influence the Major Trends in Mobile Communication (27.02.2013).
- Filip Idzikowski and Lukasz Budzisz (TUB) participated in the meeting with Telecom Italia at TUB on 29.07.2013 to discuss the topics and scope of potential collaboration.
- George Koutitas and Leandros Tassiulas (UTH) worked with AirCom (UK) and published one paper: G. Koutitas, A. Karousos, L. Tassiulas, 'Deployment Strategies and Energy fficiency of Cellular Networks', IEEE Transactions on Wireless Communications, vol. 7, no.11, pp. 2252-2563, 2012.

TREND partners have collaborated towards the submission of new research proposals. More precisely there were two strong collaborations over the three years. These are:

- **Marie Curie (ITN)-DARE Proposal:** In 2012 UTH, IHU, PoliTO, IMDEA, EPFL, UC3M, ALBLF, TUB together with external partners (both academia and industry) such as Univ. Southampton, Toshiba Research Europe, Univ. Gent, Secure Meters Limited, Iquadrat Informatica S.L., Sistemas Avazandos de Technologia and ITU (International Telecommunication Union) submitted the proposal DARE (Demand Response in Smart Data and Power Networks). The proposal aims to couple power networks and data networks under the umbrella of demand response.
- **COST Action-Sustainable Networking Proposal**: In 2012 WP2 TREND partners collaborated and submitted a COST proposal entitled as Sustainable Networking. The scope of the proposal is to increase networking in Europe in this direction and investigate future paths of Energy Efficient Networking.

4.5 Task 5.4 – Editorial activities

TREND partners play important roles in the editorial boards of the most prestigious journals and magazines, and in the technical program and steering committees of the best conferences covering green networking topics. These editorial activities can significantly contribute to improve the visibility of TREND in the international technical community. On a regular basis, the TREND project published key contributions in the top international journals and conferences in the field. Appendix 2 includes a full list of the third year TREND publications.

One of the main achievements in the editorial task is the final publication of the **Special Issue on Energy-Efficient Networking of the IEEE Internet Computing Magazine officially published in February 2013.**

During the third year another TREND special issue was launched on **Elsevier Computer Communications**. The expected publication date is for first quarter of 2014.

During the third year, other main achievements in the editorial task are the followings:

PoLITO

- **22nd ITC Specialist Seminar on Energy Efficient and Green Networking (SSEEGN 2013)**
  Christchurch, New Zealand, 20/11/2013 - 22/11/2013
  Michela Meo, Marco Ajmone Marsan (TPC member)
- **SustainIT 2013 - The Third IFIP Conference on Sustainable Internet and ICT for Sustainability - SustainIT 2013**
  Palermo, Italy, 30/10/2013 - 31/10/2013
  Michela Meo (TPC member)
- **2013 IEEE Online Conference on Green Communications (OnlineGreenComm) online, 29/10/2013 - 31/10/2013**
  Michela Meo (General Co-chair)
- **2013 IEEE Online Conference on Green Communications (OnlineGreenComm) online, 29/10/2013 - 31/10/2013**
  Marco Ajmone (SC member)
- **24th TIWDC 2013 (Tyrrhenian International Workshop 2013 on Digital Communications: Green ICT)**
  Genova, 24/09/2013 - 24/09/2013
  Michela Meo (TPC member)
- **24th TIWDC 2013 (Tyrrhenian International Workshop 2013 on Digital Communications: Green ICT)**
  Genova, 24/09/2013 - 24/09/2013
  Marco Ajmone (TPC member)
- **IEEE Globecom 2012**
  Orlando, Florida, 03/12/2012 - 07/12/2012
  Luca Chiaraviglio (TPC Member - Symposium on Selected Areas in

Communications - Track on Green Communication Systems and Networks**)**

- **The Second IFIP Conference on Sustainable Internet and ICT for Sustainability, (SustainIT)**
  Pisa, Italy, 04/10/2012 - 05/10/2012
  Michela Meo (TPC member)
- **2012 IEEE Online Conference on Green Communications**
  online, 25/09/2012 - 28/09/2012
  Marco Ajmone (General Co-Chair)
  Michela Meo (TPC Member)

HWDU

- IEEE Global **Communications** Conference (GLOBECOM 2013)
  ATLANTA, USA, 09/12/2013 - 13/12/2013
  Yabin Ye (TPC member)
- **IEEE** International Conference on Communications (ICC 2013) workshop on Telecommunications: From Research to Standards
  Budapest, Hungary, 09/06/2013 - 09/06/2013
  Yabin Ye (TPC member)
- **IEEE Globecom 2012 -** Optical Networks and Systems Symposium
  Orlando, Florida, 03/12/2012 - 07/12/2012

Yabin Ye (TPC member)

Orange

- **ONDM 2013**
  Brest France, 16/04/2013 - 19/04/2013
  (Esther Le Rouzic is TPC member of ONDM 2013)
- **OFC/NFOEC 2013**
  Anaheim California USA, 18/03/2013 - 22/03/2013
  (Esther Le Rouzic and Philippe Chanclou are TPC members)
- **European Conference on Optical Communications ECOC 2012**
  Amsterdam, The Netherlands, 15/09/2012 - 20/09/2012
  Philippe Chanclou (TPC member)
- **Photonics in Switching 2012**
  Ajaccio, France, 11/09/2012 - 14/09/2012
  Esther Lerouzic (General chair)

TUB

- **2nd International Conference on Connected Vehicles and Expo (ICCVE 2013)**
  Las Vegas, USA, 02/12/2013 - 02/12/2013

Filip Idzikowski (TPC member)

- **Australian Telecommunication Networks & Applications Conference - ATNAC 2013**
  Christchurch, New Zealand, 20/11/2013 - 22/11/2013
  Adam Wolisz (TPC member)
- **SustainIT 2013 - The Third IFIP Conference on Sustainable Internet and ICT for Sustainability - SustainIT 2013**
  Palermo, Italy, 30/10/2013 - 31/10/2013
  Adam Wolisz (TPC member)
- **2013 IEEE Online Conference on Green Communications (OnlineGreenComm)**
  online, 29/10/2013 - 31/10/2013
  Filip Idzikowski (TPC member)
- **Informatik 2013**
  Koblenz, Germany, 16/09/2013 - 20/09/2013
  Adam Wolisz (TPC member)
- **9th International Symposium on Algorithms and Experiments for Sensor Systems, Wireless Networks and Distributed Robotics - ALGOSENSORS 2013**
  Sophia Antipolis, France , 05/09/2013 - 06/09/2013
  Adam Wolisz (TPC member)
- **19th EUNICE Workshop on Advances in Communication Networking**
  Chemnitz, Germany, 28/08/2013 - 30/08/2013
  Adam Wolisz (TPC member)
- **First International Black Sea Conference on Communications and Networking (BlackSeaCom 2013)**
  Batumi, Georgia, 03/07/2013 - 05/07/2013
  Adam Wolisz (TPC member)
- **2nd International Conference on Smart Grids and Green IT Systems (SMARTGREENS 2013)**
  Aachen, Germany, 09/05/2013 - 10/05/2013
  Filip Idzikowski (TPC member)
- **19th European Wireless Conference (EW 2013)**
  Guildford, United Kingdom, 16/04/2013 - 18/04/2013
  Adam Wolisz (TPC member)
- **12th ACM/IEEE Conference on Information Processing in Sensor Networks (IPSN)**
  Philadelphia, USA, 08/04/2013 - 11/04/2013
  Adam Wolisz (TPC member)
- **ACM MSWIM - 15th ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems**
  Paphos, Cyprus Island, 21/10/2012 - 25/10/2012
  Adam Wolisz (TPC member)

- **ACM MOBIWAC 2012 - The 10th ACM International Symposium on Mobility Management and Wireless Access**
  Paphos, Cyprus Island, 21/10/2012 - 22/10/2012
  Adam Wolisz (TPC member)
- **The Second IFIP Conference on Sustainable Internet and ICT for Sustainability, (SustainIT)**
  Pisa, Italy, 04/10/2012 - 05/10/2012
  Adam Wolisz (TPC member)
- **2012 IEEE Online Conference on Green Communications**
  online, 25/09/2012 - 28/09/2012
  Filip Idzikowski (TPC member)
- **IEEE PIMRC 2012**
  Sydney, 09/09/2012 - 12/09/2012
  Adam Wolisz (TPC member)

UC3M

- **The 33rd International Conference on Distributed Computing Systems - icdcs 2013**
  Philadelphia (USA), 08/07/2013 - 11/07/2013
  Carmen Guerrero (TPC Member)
- **The 33rd International Conference on Distributed Computing Systems - icdcs 2013**
  Philadelphia (USA), 08/07/2013 - 11/07/2013
  Ruben Cuevas (TPC Member)
- **The 12nd IFIP Networking Conference - NETWORKING 2013**
  Brookling, NY (USA), 22/05/2013 - 24/05/2013
  Carmen Guerrero (TPC Member)
- **The 12nd IFIP Networking Conference - NETWORKING 2013**
  Brookling, NY (USA), 22/05/2013 - 24/05/2013
  Ruben Cuevas (TPC Member)
- **The 5th International Conference on Communication Systems and Networks - COMSNETS 2013**
  Bangalore, India , 07/01/2013 - 10/01/2013
  Carmen Guerrero (TPC Member)
- **The 8th International Conference on emerging Networking EXperiments and Technologies - CoNEXT 2012**
  Nice (France), 10/12/2012 - 13/11/2013
  Carmen Guerrero (TPC Member)

iMinds

- **SustainIT 2013 - The Third IFIP Conference on Sustainable Internet and ICT for Sustainability - SustainIT 2013**
  Palermo, Italy, 30/10/2013 - 31/10/2013

Bart Lannoo (TPC member)

- **IEEE OnlineGreenComm**
  Online, 29/10/2013 - 31/10/2013
  Mario Pickavet (TPC member)
- **39th European Conference and Exhibition on Optical Communication (ECOC2013)**
  London, UK, 22/09/2013 - 26/09/2013
  Mario Pickavet (TPC member)
- **ONDM 2013**
  Brest France, 16/04/2013 - 19/04/2013
  Mario Pickavet (TPC member)
- **The Second IFIP Conference on Sustainable Internet and ICT for Sustainability, (SustainIT)**
  Pisa, Italy, 04/10/2012 - 05/10/2012
  Bart Lannoo (TPC member)
- **The Second IFIP Conference on Sustainable Internet and ICT for Sustainability, (SustainIT)**
  Pisa, Italy, 04/10/2012 - 05/10/2012
  Mario Pickavet (TPC member)
- **4th International Workshop on Reliable Networks Design and Modeling (RNDM) RNDM 2012**
  St. Petersburg, Russia, 03/10/2012 - 05/10/2012
  Mario Pickavet (TPC member and Co-chair)
- **ECOC 2012**
  Amsterdam, The Netherlands, 14/09/2012 - 19/09/2012
  Mario Pickavet (TPC member)

CNIT

- **IEEE Global Communications Conference (GLOBECOM 2013)**
  ATLANTA, USA, 09/12/2013 - 13/12/2013
  Luca Chiaraviglio (TPC member)
- **IEEE GreenComm Online**
  online, 29/10/2013 - 31/10/2013
  Luca Chiaraviglio (TPC member)
- **Softcom 2013**
  Split, Croatia, 18/09/2013 - 20/09/2013
  Luca Chiaraviglio (TPC member)
- **IEEE ICC 2013**
  Budapest, Hungary, 09/06/2013 - 13/06/2013
  Luca Chiaraviglio (TPC member)
- **Workshop on Flexible Optical Networks (FON) - Colocated with Globecom 2012**

Anaheim, CA, USA, 03/12/2012 - 03/12/2012
Massimo Tornatore (TPC member)

- **IEEE GLOBECOM 2012**
  Anaheim, CA, USA, 03/12/2012 - 07/11/2012
  Stefano Bregni2 (Technical Program Vice-Chair)
- **CloudNet**
  Paris, 28/11/2012 - 30/11/2012
  Massimo Tornatore (TPC member)
- **CloudNet**
  Paris, 28/11/2012 - 30/11/2012
  Antonio Cianfrani (TPC member)
- **4th International Workshop on Reliable Networks Design and Modeling (RNDM) RNDM 2012**
  St. Petersburg, Russia, 03/10/2012 - 05/10/2012
  Massimo Tornatore (TPC member)
- **2012 IEEE Online Conference on Green Communications**
  online, 25/09/2012 - 28/09/2012
  Stefano Buzzi (TPC member)
- **2012 IEEE Online Conference on Green Communications**
  online, 25/09/2012 - 28/09/2012
  Antonio Cianfrani (TPC member)
- **2012 IEEE Online Conference on Green Communications**
  online, 25/09/2012 - 28/09/2012
  Carla Panarello (TPC member)
- **Photonics in Switching 2012**
  Ajaccio, France, 11/09/2012 - 14/09/2012
  Achille Pattavina (TPC member)
- **IEEE ENERGYCON 2012**
  Florence, Italy, 09/09/2012 - 12/09/2012
  Stefano Bregni (TPC Vice-Chair)

EPFL

- **31st International Symposium on Computer Performance, Modeling, Measurements and Evaluation 2013**
  Vienna, Austria, 24/09/2013 - 26/09/2013
  Jean-Yves.Le Boudec (TCP member)
- **ACM e-Energy 2013 - The fourth International Conference on Future Energy Systems**
  Berkeley, CA, 22/05/2013 - 24/05/2013
  Jean-Yves.Le Boudec (TCP member)
- **2nd International Conference on Smart Grids and Green IT Systems (SMARTGREENS 2013)**

Aachen, Germany, 09/05/2013 - 10/05/2013
Jean-Yves.Le Boudec (TCP member)

- **IEEE SmartGridComm 2012 WISG workshop**
  Tainan City, Taiwan, 05/11/2012 - 05/11/2012
  Jean-Yves.Le Boudec (TCP member)

5. List of WP5 deliverables

Deliverable Nº	Deliverable Title	Leader	Estimated indicative person-months	Nature	Dissemination Level	Delivery date
D5.1	Detailed WP5 dissemination activities plan	UC3M	5	R	PU	M3
D5.2	First yearly WP5 report and updated activity plan	UC3M	10.00	R	PU	M12
D5.3	Second yearly WP5 report and updated activity plan	UC3M	10.00	R	PU	M24
D5.4	White Paper on "TREND Research Challenges on Energy-Efficient Future Internet	UC3M	5.00	R	PU	M36
D5.5	Final WP5 Report	UC3M	12.00	R	PU	M39

6. List of WP5 milestones

Deliverable Nº	Milestone name	Leader	Delivery date	Comments
MS1	Kickoff meeting; consolidation of the first set of IRAs and JEAs to be activated	PoliTO	M1	Status: closed, done. Kickoff meeting organized in October (M2).
MS5	Project technical meeting; with presentation of action plans for all WPs.	PoliTO	M6	Status: closed, done. 2nd project meeting on March 2011 hosted by FT in Paris.
MS8	First-year plenary meeting; technical presentations by all WPs; plans for Y2; definition of SJRPs- JEAs	PoliTO	M12 (1)	Status: closed, done. 3rd project meeting on September 2011 hosted by UC3M in Madrid. (1) M13
MS11	Project technical meeting, with presentations of completed JSRP results	PoliTO	M18	Status: closed, done. 4th project meeting on Feb 2012 hosted by IBBT in Gent..
MS12	Submission of proposal for feature topic on Green Communications to the IEEE Communications Magazine (2)	UC3M	M20 (3) (4)	Status: closed, done. (2) IEEE Internet Computing Magazine (3) M8 (4) Final publication by Feb 2013
MS13	TREND Industrial Workshop, broadly targeted at Industry	UC3M	M21 (5)	Status: closed, done. (5) Co-located with e-Energy 2012
MS14	Second-year plenary meeting; technical presentations by all WPs; plans for the next year	PoliTO	M24 (6)	Status: closed, done (6) 5th Plenary Meeting in Sept 2012 hosted by UTH in Volos, Greece
MS16	TREND Winter School, coordinated with all FP7 Projects active on energy-efficiency networking	UC3M	M35 (7)	Status: closed, done. (7) TREND Summer PhD School, Turin 1-5 July 2013
MS17	Project technical meeting, with presentations of IRA and JEA results	PoliTO	M30 (8)	Status: closed, done. (8) 6th Plenary Meeting in Catania, 6-8 February2013
MS19	Organization of the TREND Scientific Workshop	UC3M	M35 (9)	Status: closed, done. (9) The TREN/Green Touch Joint Workshop on Green and Energy Efficient Networking, turin 19 April 2013
MS20	Final meeting with presentation of major project achievements and coordination of final reporting	PoliTO	M37 (10)	Status: closed, done (10) TREND Final Workshop in Brussles 24 October 2013

APPENDIX 1. Y3 TREND PUBLICATIONS

An updated version of this list can be found in the Publications Section of the TREND website: http://www.fp7-trend.eu/content/publications

Journals

1 J. Lopez Vizcaino (HWDU), Y. Ye (HWDU), V. Lopez (TID), F. Jimenez (TID), F. Musumeci (CNIT), M. Tornatore (CNIT), A. Pattavina (CNIT), P. Krummrich (TU Dortmund), Protection in Optical Transport Networks with fixed and flexible grid: Cost and Energy Efficiency Evaluation, Optical Switching and Networking, Vol. Vol. 11-Part A, No. Optical network architecture and applications, pp. 55-71, January 2014. (WP3)

2 M. Gattulli (POLIMI), M. Tornatore (POLIMI), R. Fiandra (FW), A. Pattavina (POLIMI), Low-Emissions Routing for Cloud Computing in IP-over-WDM Networks with Data Centers, Journal of Selected Areas in Communications, Vol. 31, No. 1, pp. 23-38, January 2014. (WP3)

3 L. Chiaraviglio (CNIT), R. Bruschi (CNIT), A. Cianfrani (CNIT), O. Jaramillo Ortiz (CNIT), G. Koutitas (UTH), The TREND Meter: Monitoring the Energy Consumption of Networked Devices, International Journal of Business Data Communications and Networking (IJBDCN), IGI Global, special issue on "Green Networking and Computing,", Vol. 9, No. 2, pp. 27-44, December 2013. (WP4)

4 M. Ajmone Marsan (PoliTO), L. Chiaraviglio (CNIT), D. Ciullo (INRIA), M. Meo (PoliTO), On the Effectiveness of Single and Multiple Base Station Sleep Modes in Cellular Networks, Computer Networks, Vol. 57, No. 17, pp. 3276-3290 , December 2013. (WP2)

5 A. Ahmad (PoliTO), A. Bianco (PoliTO), E. Bonetto (PoliTO), L. Chiaraviglio (CNIT), F. Idzikowski (TUB), Energy-Aware Design of Multilayer Core Networks, IEEE/OSA Journal of Optical Communications and Networking, Vol. 5, No. 10, pp. A127-A143, October 2013. (WP3)

6 R. Khalili (EPFL), N. Gast (EPFL), M. Popovic (EPFL), J. Le Boudec (EPFL), MPTCP Is Not Pareto-Optimal: Performance Issues and a Possible Solution, IEEE/ACM TRANSACTIONS ON NETWORKING, Vol. 21, No. 5, pp. 1651 - 1665, October 2013. (WP2)

7 L. Chiaraviglio (CNIT), D. Ciullo (Eurecom), M. Mellia (PoliTO), M. Meo (PoliTO), Modeling Sleep Mode Gains in Energy-Aware Networks, Computer Networks, Vol. 57, No. 15, pp. 3051–3066, October 2013. (WP3)

8 L. Chiaraviglio (INRIA), A. Cianfrani (CNIT), E. Le Rouzic (Orange), M. Polverini (CNIT), Sleep Modes Effectiveness in Backbone Networks with Limited Configurations, Computer Networks, Vol. 57, No. 15, pp. 2931–2948, October 2013. (WP3)

9 G. Koutitas (UTH), L. Tassiulas (UTH), Periodic Flexible Demand: Optimization and Phase Management in the Smart Grid, IEEE Transactions Smart Grids, Vol. 4, No. 3, pp. 1305 - 1313, September 2013. (WP2)

10 A. Zappone (TUD), G. Alfano (PoliTO), S. Buzzi (CNIT), M. Meo (PoliTO), Distributed energy-aware resource allocation in multi-antenna multi-carrier interference networks with statistical CSI, EURASIP Journal on Wireless Communications and Networking, Vol. 2013, August 2013. (WP2)

11 S. Buzzi (CNIT), A. Zappone (TUD), Potential games for energy-efficient resource allocation in multipoint-to-multipoint CDMA wireless data networks, Physical Communication, Vol. 7, pp. 1 - 13, June 2013. (WP1 WP2)

12 C. S. Chen (A-LBLF), An Energy-Aware Protocol for Self-Organizing Heterogeneous LTE Systems, IEEE Journal on Selected Areas in Communications (JSAC), Vol. 31, No. 5, pp. 937 - 946, May 2013. (WP2 WP5)

13 E. Bonetto (PoliTO), L. Chiaraviglio (PoliTO), F. Idzikowski (TUB), E. Le Rouzic (Orange), Algorithms for the Multi-Period Power-Aware Logical Topology Design with Reconfiguration Costs, IEEE/OSA Journal of Optical Communications and Networking, Vol. 5, No. 5, pp. 394-410, May 2013. (WP3)

14 A. Zappone (TUD), Z. Chong (TUD), E. Jorswieck (TUD), S. Buzzi (CNIT), Energy-aware competitive power control in relay-assisted interference wireless networks, IEEE Transactions on Wireless Communications, Vol. 12, pp. 1860 - 1861, USA, April 2013. (WP2)

15 R. Cuevas (UC3M), N. Laoutari (Telefonica Research), X. Yang (Telefonica Research), G. Siganos (Telefonica Research), P. Rodriguez (Telefonica Research), BitTorrent Locality and Transit Traffic Reduction: when, why and at what cost?, IEEE Transactions on Parallel and Distributed Systems, April 2013. (WP1 WP4 WP5)

16 A. Lombardo (CNIT), C. Panarello (CNIT), G. Schembra (CNIT), EE-ARQ: a Green ARQ-Based Algorithm for the Transmission of Video Streams on Noise Wireless Channels, Network Protocols and Algorithms, Vol. 5, No. 1, March 2013. (WP2)

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APPENDIX 2. TREND ROADMAP TOWARDS ENERGY-EFFICIENT NETWORKS

The objective of this roadmap is to provide the TREND research challenges and big picture on energy-efficient future networks, capable of sustaining traffic growth with reduced energy consumption.
The TREND research challenges have been structured according to the following main research areas, whose main objectives, achievements and potential impact in terms of energy savings are described in the corresponding TREND deliverables.

Estimation of power consumption in ICT and collection of data
TREND has conducted several studies that show the evolution of the worldwide electricity use of communication networks, PCs and data centers. When starting our studies we rapidly faced incoherence in the values found in the literature about core networks equipment power consumption. The TREND community joined their effort to a consolidated power consumption model that could be used by the research community. This work gave birth to a more general library on telecommunication equipments power consumption data – **`powerlib`**- At **`powerlib.intec.ugent.be`** we host an online database of ICT network energy consumption data. By providing a single source, we hope to facilitate power consumption data collection and referencing.

In the future, frequent estimates of the worldwide electricity use by ICT will be essential to provide timely feedback if indeed ICT electricity consumption remains relatively small, or instead continues to grow at an unsustainable rate.

Energy-aware access networks
The access sector is the most energy demanding part of telecommunication networks, because of the very large number of end-user equipment. In addition, the demand for high data rates and large traffic volumes, which continue experiencing an exponential growth, drive telecommunication operators to deploy ever more access nodes in their networks. This has a direct effect on the forecasted energy consumption of the access network, which is expected to soon become a relevant issue for the operators' OPEX and for the cost of services for end users. In this context, the TREND objective is to coordinate the efforts of partners in the area of energy-efficient access and home networks, and develop solutions and techniques which can reduce the overall energy footprint of the sector. To achieve this target, TREND has focused on four research challenges:

- *'Redesign the home equipment for energy-efficient communications'* that investigates energy-efficient techniques for home network equipment, such as femtocells and WiFi access points, to provide energy proportionality with actual utilization. In addition, the concept of energy management of home appliances, within the smart grid environment, is introduced and explored in terms of scheduling algorithms and control schemes for the demand response problem.
- *'Network access architecture and management"* that optimizes power usage one step away from the end user by investigating techniques and protocol design for achieving energy efficiency at the access network, specializing in fixed and wireless access.
- *'Organize the flying bits: saving energy on wireless access'* that investigates energy saving techniques by changing the way that the mobile devices access the wireless medium.

- *'Green protocols for handling wireless access from the network view'* that investigates energy management and radio planning techniques responsible for energy savings in cellular systems (Base Stations, WiFi access points, Femtocells.

The results obtained within TREND show that it is possible to achieve large savings (of the order of 20-40%) already with the network of today. Moreover, the proposed solutions put the basis for the design of sustainable future networks.

The main message that can be achieved through the TREND research is that the future network should become dynamically adaptive to the traffic demand and user capacity need, by exploiting and involving a wide set of possible resources, that includes nodes with their various sleep modes, heterogeneous devices, different kinds of energy, and possibly also resources from other networks.

Energy-aware backbone networks

The traffic volume in metro and core networks is forecasted to grow at very high rates for the 10 or 15 coming years. This implies that the energy consumption of this network sector will become problematic if business keeps growing as usual. Energy-efficiency in core and metro networks is thus mandatory for the sustainability of the future Internet. In this context, the research challenges of the TREND community were:

- *More energy-efficient network architectures* were addressed. Several new, energy-efficient architectures were proposed, taking advantage of optical techniques in core transport networks, exploiting for example optical bypass to save transit in IP routers, as well as photonic switching and optical aggregation to reduce the amount of optical to electrical domain conversions. Some other new energy-efficient architectures take advantage of energy-efficient electronic techniques, such as coherent detection to improve spectral efficiency in the transmission domain, or dynamic voltage and frequency scaling, to reduce chips power consumption. In addition, a full rethinking of the content distribution architecture, taking advantage of in-network caching was proposed, to reduce the amount of traffic in the network and reduce its overall energy consumption. Design guidelines were also proposed for both core networks and data centers. Energy-awareness was discussed against its impact on performance in core networks, and energy-optimal file distribution was proposed. In data centers, the energy awareness in the optimization of virtual machines placement was demonstrated, while global optimization across multiple data centers was proposed, taking into account renewable energy sources.
- *Energy-efficient ways of operating the networks* were proposed, exploiting sleep modes, adaptive routing mechanisms, and rate adaptation to make the network power consumption more proportional to its traffic load, and benefit from daily traffic patterns. Smart energy-efficient protection schemes were also proposed, with a trade-off between power consumption and Quality of Service. Cooperation of Internet service providers and content providers was discussed, to even more reduce the energy consumption of the network.

The TREND results in energy-aware backbone networks could lead from limited energy consumption (≈ 20% in the case of protection schemes) reductions to significant ones (≈80% in the case of content distribution). These estimations are purely indicative, since their relative impact on the global picture depends on the consumption of the segment they address and the considered network scenario.

Improving power efficiency is certainly under the responsibility of equipment vendors, but incentives are to be initiated from operators with requests and specifications. Improved power efficiency requires new technologies or new network architectures. It is then an operator decision to upgrade its network or change its architecture. Cost savings generated by energy consumption reduction are already a relevant incentive for network operators. Regulations also play an important role as an incentive for vendors and operators to meet certain standards. As an example, due to the free-market, the publication of the power consumption values could be a positive trigger for vendors to make their equipment more energy-efficient. Regulation though may also have a negative impact on the total network power consumption, for instance when it leads to the deployment of multiple infrastructures to avoid the dominant position of an operator.

Core networks are especially critical segments, where it is hardly possible to trade QoS for energy saving. As a result, the impact of any proposed solution should be evaluated with respect to its possible impact on failure rates of network devices, on network resilience and on possible service disruption due to energy-efficient mechanisms.

Taking a global view on energy-efficient optical networks is a complex task. While we pointed out the current solutions and open issues, which have been partially addressed within TREND, simulation or detailed modeling of the network as a whole (including core and access networks, as well as customer premises network equipment and data centers) remains an open issue for further investigations. The different energy saving schemes proposed by the TREND researchers could lead to the (estimated) energy consumption reductions summarized. These numbers are provided only as indications, since their relative impact on the global energy consumption picture depends on the combination of approaches in different network segments, on the consumption of the segment they address, and on the considered network scenario. We can however realistically claim that a large majority of the energy consumed by networks today can be saved by a clever combination of the proposed schemes, say 60 to 80%.

However, in spite of these very interesting predictions, on which most researchers in the field agree, and of the associated substantial monetary savings in operational expenditures due to the reduction of the operators' energy bills, the adoption of energy-efficient networking approaches is slow in operational networks.

Several aspects should be considered on the side of standardization bodies and regulation agencies to accelerate the uptake of energy-efficient networking approaches:

- Definition of standards for energy-efficient network operation (this is already in progress, with several groups working in this area, for example at ETSI and ITU; the publication of preliminary versions of these standards should happen rapidly, so that both manufacturers and operators can have clear indications about the paths to follow)
- Introduction of regulation to require manufacturers to publish reliable, complete, and standardized energy consumption data for their products (the fact that comparable data are presented to fully characterize the equipment energy consumption can be an important incentive for manufacturers to invest in energy-efficient options, which will give them a relevant competitive advantage, and for network operators, which can reliably estimate the monetary savings due to the reduction of their energy bill consequent to the adoption of the new equipment)

- Definition of an “energy star” scheme for network equipment and for networks (a simple ranking of the energy performance of networks and equipment can be very effective in orienting the preferences of customers sensitive to the energy and environmental issues)
- Introduction of incentives and regulations to reward energy-efficient network operators (several European countries already offer incentives for the replacement of older technologies with new, more energy efficient ones; they are considered an interesting support for technology replacement by operators; new approaches for the identification of the energy advantages of network management schemes should be introduced, in addition to those linked to new equipment)

From the point of view of researchers both in industry and academia, several topics in energy-efficient networking are interesting to tackle in the next few years:

- Definition of new energy-efficient architectures, which allow resource provisioning on demand (some work in this direction is in progress, for example with the BCG2 GreenTouch project proposal of separating the resources for coverage and signaling, from the data plane resources)
- Development of equipment with better energy efficiency and switch on/off capabilities (this issue is on the agenda of most manufacturers, but an increased interest for the energy performance features of the equipment on the side of network operators could better motivate manufacturers and stimulate this area of research)
- Definition of resource management algorithms with positive effects on energy efficiency and minor sacrifices in QoS (much work has been done in this field, but much remains to be done, especially as regards the interaction of traffic flows with realistic characteristics – e.g. TCP connections – with network controls for energy efficiency; the key objective in these efforts is the improvement of proportionality between traffic and energy within equipment, and within networks, even with non-proportional equipment)
- Careful computation of the overall energy saving resulting from the adoption of energy efficiency approaches in different sections of the network (accounting not only for the relative impact due to the different contribution to energy efficiency of the various network components, but also of the interplay among the adopted energy efficiency approaches)
- Identification of network contexts which can benefit from the exploitation of renewable energy sources for the network operation (some work in this area has recently started, but much effort is still necessary both from a theoretical and from and experimentation point of view, having in mind the utilization of renewables both in areas of new networking deployments, where the access to the power grid is typically problematic, and in areas where networks have been in operation for over a century and the power grid is ubiquitous and reliable)

TREND Roadmap towards Energy-Efficient Networks

	TREND Research Challenges	TREND Energy Savings
Redesign the Home Equipment for EE Communications'	• Prototype 3G WiFi femtocell with sleep modes • Femtocell management schemes • Smart grid algorithms for energy savings at home appliances	• ≈ 70% according to user activity in the house • ≈ 20% • ≈ 20%
Network Access Architecture and Management	• NGPON network power consumption analysis • Residential gateway virtualization for energy savings • Multipath TCP energy savings and offloading • Energy Consumption in File/Content Distribution Processes	• ≈ 10% • The energy that is saved is equal to the difference in energy consumption when a user is served by LTE base station and when he is served by WiFi base station • < 71%.
Organize the Flying Bits: Saving Energy on Wireless Access	• Resource allocation MIMO • Resource allocation in relay assisted networks • Resource allocation in OFDM networks • Energy-Efficient QoS-constrained ARQ protocols	• < 20% • < 20% • < 20% • < 10%
Green Protocols for Handling Wireless Access from the Network View	• Energy efficient network planning • Base station and access point switch on/off schemes • Integration with renewable energy sources • MNO cooperation	• ≈ 60% (prefer small cells) • < 40% and extra 25% if offloading to femtocell layer is used • < 40%
Energy-efficient core networks architecture and design	• Optical bypass to save transit IP routers • Improved spectra efficiency and Elastical Optical Networking • Optical aggregation with Sub-wavelength Photonic Switching • Energy-efficient Content Distributional • Energy awareness in optical core networks • Energy-optimal File distribution • Energy-efficient Data Centers network devices • Virtualization and self-organizing algorithm	• < 50% • < 18% • < 75% • < 71% • 10%-30% • < 50% • < 60% • < 40%
Energy-efficient core networks operation	• Dynamic usage of sleep modes • Adaptive routing at IP and WDM layers • Energy-efficient protection schemes	• < 15% • < 45% • < 21%