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Activities and considerations related to wireless power transfer (WPT) for audio, video and multimedia systems and equipment

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Activities and considerations related to wireless power transfer (WPT) for audio, video and multimedia systems and equipment

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ACTIVITIES AND CONSIDERATIONS RELATED TO WIRELESS POWER TRANSFER (WPT) FOR AUDIO, VIDEO AND MULTIMEDIA SYSTEMS AND EQUIPMENT

FOREWORD

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 62869, which is a technical report, has been prepared by IEC technical committee 100: Audio, video and multimedia systems and equipment.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
100/2134/DTR	100/2166/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

IEC TC 100 established a Stage 0 project on wireless power transfer (WPT) to develop a technical report on WPT technical standardization in relation to audio, video and multimedia systems and equipment. A survey was developed to investigate the global positioning of the technology and its uptake. Twelve National Committees provided responses. Four National Committees (China, Japan, Korea, USA) provided responses to all questions. The key research undertaken and information gathered from the survey responses included: a) terms and definitions used for WPT by IEC TC 100 members; b) regulations, national laws, public policies and industry practices related to WPT; c) status of activities and discussions in various organizations relating to regulatory activities, standards projects, and market research; d) potential topics to be addressed in IEC TC 100 TR: and e) potential role for IEC TC 100 in the domain of WPT technical standards development.

This Technical Report combines survey results with Stage 0 project expert group contributions and extensive public information to develop and present a holistic understanding of WPT and, in so doing, respond to the Stage 0 TR objectives. This understanding is developed through a progression of four interrelated topics.

- Clause 4 considers the overall WPT market, including use cases, public benefit, academic research activities, and an overview of WPT products and services.
- Clause 5 discusses leading commercial WPT technical approaches and briefly surveys additional WPT technologies by reviewing a system reference model. The system reference model can be understood at a very high level as consisting of the lowest layer of a power handling layer, where upper layers implement signalling and systems interfaces.
- Clause 6 presents the major elements of the applicable international and regional regulatory frameworks, one of whose key outputs is product categorization. Product categorization, in turn, is closely related to the topic of spectrum. Key regulatory drivers for WPT products and services as well as technical standards development include RF emissions, RF exposure and compliance.
- Clause 7 reviews global industrial consortium and standards development organization (SDO) activities, and critically discusses WPT technical standard development challenges and opportunities.

With market, technology, regulatory and standards development foundations established, the TR concludes in Clauses 8-10 with observations and recommendations about the potential for future WPT technical standards development within the scope of IEC TC 100.

ACTIVITIES AND CONSIDERATIONS RELATED TO WIRELESS POWER TRANSFER (WPT) FOR AUDIO, VIDEO AND MULTIMEDIA SYSTEMS AND EQUIPMENT

1 Scope

This technical report addresses activities and considerations related to wireless power transfer for audio, video and multimedia systems and equipment. It combines public information, contributions by experts and completed IEC TC 100 WPT survey responses and reviews global market conditions. The TR describes a range of WPT technical approaches with the aid of a system reference model, outlines the impacts on WPT of applicable regulation and surveys standards development organization (SDO) and private industry consortium-led activities in support of WPT technical standards development. The TR concludes with observations and recommendations for potential future technical standards development activities that lie within scope of IEC TC 100.

2 Executive summary

2.1 Market

A variety of metrics indicate that the commercial market is in its early phases. Annual revenue projections range from a current level of a few hundred millions to some billions of dollars (US) by the 2016-2018 timeframe. Geographic coverage spans major markets in Asia, Europe and North America, and is expected to mirror the larger CE market. Market participants range from small, focused start-ups to the largest integrated global CE market leaders. Currently, market share, or market "excitement" may be characterized as being split amongst a few small companies, each with a proprietary solution, and a broader range of companies who have coalesced around private industry consortia, each of which is seeking to promote a particular technical approach.

2.2 Technology

Commercial application of WPT technology has its origins in the pioneering work of Nikola Tesla in the early 1900s and is already well-established in several industrial and specialized application areas, such as power supply to "people mover" systems in airports, material handling systems in manufacturing and warehousing, and "mission critical" control systems that isolate power supply from environmental disruption. Within the scope of IEC TC 100, a system reference model consists of one or more WPT "sources" and one or more WPT "sinks" that interact through a "coil subsystem." This reference model captures commonalities and differences across the wide range of approaches already in the market, those expected to come to market in the near term and long-term prospective market entrants. The WPT technology environment today consists of multiple, largely non-interoperable approaches.

2.3 Regulation

The development of the WPT market is subject to applicable regulations. These serve the purpose of protecting people and services in the areas of safety, efficient use of spectrum, harmful interference and electromagnetic compatibility and immunity. WPT regulatory categorization sets the overall framework. Designs are subject to different regulations depending at least on WPT spectrum selection and signalling method. Categorization, in turn, drives RF exposure limits and highlights the importance of methods for demonstration of compliance. Currently, individual markets and regions have similar, but not uniform approaches. Policy development opportunities and challenges relate primarily to global harmonization as a means to promote technology innovation and market development.

2.4 Standards development

WPT technical standards development is an asynchronous global undertaking. Active programmes are underway at the international body level, the regional coordination level, the regional and national SDO level as well as within numerous global and regional private industrial consortia. While private industrial consortia typically focus on a single technical approach, the typical SDO WPT technical standards development programme allows parallel development of multiple technologies. Indeed, a multiplicity of WPT technical approaches are on parallel paths towards either de facto or formally approved WPT technical standards. In terms of productization in the medium term, it appears that multiple protocol support may substitute for true interoperability between competing technologies and standards.

2.5 IEC TC 100 WPT technical standards development

In terms of revenue, the largest market for WPT in the foreseeable future lies in the CE market, including audio, visual and multimedia systems and equipment. The WPT technology environment currently consists of multiple, non-interoperable technology approaches. This condition is perhaps not surprising given the range of identified use cases and power requirements (< 1W – 100W) relating to equipment within the scope of IEC TC 100. Thus, technical standards development within IEC TC 100 may be built around the concept of a framework of WPT standards. In such a concept, individual technical approaches enjoy the benefit of a globally harmonized standard. Technology selection proceeds through market-based mechanisms.

3 Terms and definitions

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
capacitive coupling
method for wireless power transfer by means of capacitance between insulated electrodes

Note 1 to entry: Capacitive coupling is also referred to as "electric field coupling".

3.1.2
electromagnetic induction
class of methods used for wireless power transfer whose central principles are Faraday’s Law and Lenz’s Law

3.1.3
magnetic resonance
subset of electromagnetic induction methods utilizing non-radiative, near-field or mid-field resonance coupling between two electromagnetic resonators where the coupling coefficient between primary or source coil and secondary or receiving coil is low (k much less than 1)

Note 1 to entry: Magnetic resonance is also referred to as "loosely-coupled magnetic resonance", "highly resonant magnetic induction" and "magnetic resonant coupling".

3.1.4
tightly-coupled
subset of electromagnetic induction methods utilizing close physical proximity and optimal alignment between power providing and power receiving coils, where the coupling coefficient between primary or source coil and secondary or receiving coil is close to the achievable maximum (k very close to 1)

3.1.5
wireless power transfer
method of non-contact energy delivery over time from one or more sources to one or more receiving units

3.2 Abbreviations

For the purposes of this document, the following abbreviations apply.

A4WP	Alliance for Wireless Power
ACK/NACK	acknowledge/negative acknowledge
ANSI	American National Standards Institute
API	application programming interface
APT	Asia Pacific Telecommunity
ARIB	Association of Radio Industries and Businesses
AWG	APT Wireless Group
CATR	China Academy of Telecommunications Research
BWF	Broadband Wireless Forum
CCSA	China Communications Standards Association
CE	consumer electronics
CE4A	Consumer Electronics for Automotive
CEA	Consumer Electronics Association
CEC	California Energy Commission
CENELEC	European Committee for Electrotechnical Standardization
CPT	contactless power transfer
CS	control and signaling
DE	Digital Europe
DG	Drafting Group
DTBC	device to be charged
EC	European Commission
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EPA	Environmental Protection Agency (USA)
EPS	external power supply
ETSI	European Telecommunications Standards Institute
EU	European Union
EV	electric vehicle
FCC	Federal Communications Commission
GSMA	GSM Association
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEC	International Electrotechnical Commission
ISM	industrial, scientific and medical
ISO	International Standards Organization
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication Sector
ITU-T	ITU Telecommunication Sector
JEITA	Japan Electronics and Information Technology Industries Association
JSAE	Society of Automotive Engineers of Japan

KATS	Korea Agency for Technology and Standards
KCC	Korea Communications Commission
KDB	Knowledge Database (USA FCC)
KETI	Korea Electronics Technology Institute
KWPF	Korea Wireless Power Forum
METI	Ministry of Economy, Trade and Industry, Japan
MFAN	Magnetic Field Area Network Forum, Korea
MHLW	Ministry of Health, Labour and Welfare, Japan
MIC	Ministry of Internal Affairs and Communications, Japan
MKE	Ministry of Knowledge Economy, Korea
MLIT	Ministry of Land, Infrastructure, Transport and Tourism, Japan
MOU	memorandum of understanding
MRM	Electronic Manufacturers Recycling Management Company
NA	not applicable
NFC	near-field communication
NWIP	new work item proposal
OEM	original equipment manufacturer
PBA	permit but ask
PCG	Project Coordination Group
PID	proportional integral differential
PMA	power matters alliance
PT	power transfer
RMS	root mean square
RoHS	restriction of hazardous substances
SAR	specific absorption rate
SDO	standards development organization
SIG	special interest group
SoC	system on chip
TA	technical area
TCAM	Telecommunications Conformity Assessment and Market Surveillance Committee
TIA	Telecommunications Industry Association
TMC	Telecomms Metrology Center
TR	technical report
TTA	Telecommunications Technology Association
UL	Underwriters' Laboratories
USA	United States of America
WCS	wirless charging system
WEEE	Waste Electrical and Electronic Equipment Directive
WG	working group
WPC	Wireless Power Consortium
WPT	wireless power transfer
YRP	Yokosuka Resarch Park

4 Market

4.1 Use cases

4.1.1 General

A broad range of WPT applications or use cases are unified under the vision of ubiquitous power. The breadth of applications is quantified in terms of device characteristic power requirement. These range from the < 1 W (e.g., cellular telephone headset), to < 10 W (e.g., feature phone or smartphone), to < 20 W (e.g., tablet or notebook) to < 50 W (laptop), and so on, up to kW levels (e.g., electric vehicles). As it relates to battery-powered, mobile, handheld CE devices for audio, video and multimedia equipment, ubiquitous power simply means that increases in device functionality and a resulting need for greater power are growing faster than advances in power storage capacity. The result is that devices require more frequent recharging. Ubiquitous power means that users can reliably recharge anywhere, anytime without the constant burden of carrying and deploying battery charging accessories and equipment.

The vision of anywhere, anytime recharging depends upon WPT integration in the physical environment. A multiplicity of independent market analysis firms, private industrial consortia, SDOs and related task groups and academic studies have surveyed or analysed user battery charging requirements and behaviour. Such endeavours, in combination with net utility analyses, resulted in categorization of WPT use cases into those described below in subclauses 4.1.1 to 4.1.6.

A common requirement across use cases is that WPT not disrupt normal device performance and not negatively impact the nominal functionality of the infrastructure where it is installed (e.g., a table with integrated WPT still functions well as a table, a car operates as a normal car, etc.)

4.1.2 Vehicle

As distinct from electric vehicle (EV) charging, automotive CE-type WPT refers to the ability to charge occupants' CE devices during operation of the automobile. Such capabilities may be implemented either on a retro-fit or embedded basis. Target vehicles include personal cars, SUVs, minivans, trucks, vans, buses, trams and shared cars.

4.1.3 Commercial, institutional, retail

Commercial, institutional, and retail may take a form comparable to that of the stereotypical café occupant who utilizes complimentary local area network connectivity. Concretely, a cloud-based service operating in conjunction with a CE device-based discovery mechanism to learn of charging locations could lead the user to a café table or kiosk with embedded WPT capability. Additional examples include WPT-enabled hotel rooms, restaurant table tops and shopping mall kiosks. In these environments, the CE device owner chooses from what is made available by those managing those environments.

4.1.4 Residential

For the typical user, the home or private residence usually represents the primary charging location. This use case requires a variety of WPT sources for the home offering consumers a choice of appearance and cost. Examples may include WPT embedded in bedside stands, entry hall WPT-enabled dishes or bowls, and more purely functional WPT-enabled chargers for the study or garage. A key element in this use case is that the individual consumer controls his or her own WPT sources or "infrastructure" and the selection appropriate to their WPT device(s).

4.1.5 Professional office

For the typical professional or office worker, the office environment both drives demand for and offers the opportunity to meet the need for frequent CE battery recharging. WPT sources such as desktop pads or other desktop accessories are suitable. This use case is mainly characterized by the opportunity for embedded WPT capability in the individual office furniture including desks, conference tables, break-room counters, and so on. In such an environment the property manager or owner controls the WPT selection and the CE owner is a subscriber or user of that capability.

4.1.6 Transportation and public spaces

Transportation and public space use cases include those scenarios where WPT is made available even while in transit, such as during a bus, railway or plane ride, or otherwise while waiting for transportation, such as in an airport lounge, train station or other waiting area. Sponsored wired charging kiosks are one of the most crowded areas in airport lounges.

4.1.7 Beyond mobile CE

The CE market consists of more than simply battery-powered, mobile handheld devices. A WPT feature offers the opportunity to develop new form factors and configurations for televisions, displays, multimedia equipment and related devices, including tuners, equalizers and media storage devices. Wirelessly powered flat panel TVs and large displays, for example, may be more easily and flexibly positioned on the wall.

Although well beyond the scope of IEC TC 100, it is noted that WPT is under consideration for non-CE devices, such as medical devices. Concretely, as societies around the world experience aging populations, long-term health management increasingly utilizes patient monitoring of chronic conditions. Whether in the hospital or home setting, for hygienic and ergonomic reasons, these devices are ideally completely sealed, lightweight and portable. WPT addresses the challenge of recharging such devices. A further extension beyond CE devices includes wirelessly powered home and office appliances. By using wirelessly powered consumer appliances such as refrigerators, washing machines, air conditioners, cleaners and so on, flexibility of usage of home and office space is expanded.

Another area of interest is in the charging of electric vehicles (EV). Although adapted to much higher power levels (kW), candidate technologies for EV WPT are similar to those considered for mobile CE. Real-time wireless power transfer to running cars on the road has been proposed and prototyped. IEC TC 69 addresses EV WPT.

More “exotic” applications range from WPT between integrated circuits in complex, miniature machines, to human implantable medical and prosthetic devices, to microwave beam-formed WPT from orbiting power satellites.

4.2 Public benefit, including reduction in e-waste

The public benefit of WPT may be understood in part in the broader context of government and industry efforts to reduce e-waste from batteries and external power supplies.

In the USA, the EPA estimates that there were approximately 2.3 million metric tons of electronic waste generated in 2009, the last year for which EPA has made an estimate (see http://www.epa.gov/osw/conserve/materials/ecycling/manage.htm). Of this amount only a small fraction is related to power supplies and batteries – probably less than 1 % as batteries themselves are less than 0,1 % by weight according to California Integrated Waste Management studies. Estimates of impacts of primary (single-use) batteries are available at www.RecycleBattery.org (NEMA 2011 Battery Recycle Brief).

In the USA, there are in excess of 20 different state laws relating directly to electronics recycling programmes. These are summarized at http://www.ecycleclearinghouse.org/. There is a national rechargeable battery programme operated by the Rechargeable Battery

Recycling Corporation. Information about that programme is available at http://www.call2recycle.org/. Estimates on overall impact presently are not available. However, there are general e-waste reduction efforts underway within industry. The Consumer Electronics Association announced the eCycling Leadership Initiative in April, 2011 which aims to responsibly recycle a billion pounds annually by 2016 (see http://www.ecyclingleadershipinitiative.com/). This goal represents a more than three-fold increase in recycling by the consumer electronics industry over 2010 levels. Additional e-waste recycling programmes developed and run by industry and independent manufacturers include the following: MRM (http://mrmrecycling.com/); TIA (http://www.ecyclingcentral.com/).

In Japan, Korea, China and Europe, similar industry and government coordination is evident. According to the Battery Association of Japan estimates, used dry batteries, (including used lithium primary batteries) reached 49 000 tons in recent years. Discarded batteries are typically separated for recycling or otherwise disposed of as non-combustible waste. With the enactment of the Law for the Promotion of Effective Utilization of Resources, manufacturers producing or using small rechargeable batteries have become obliged to collect and recycle them. The Wastes Disposal and Public Cleaning Law mandates that business organizations take responsibility for the proper processing of waste produced in the course of their business activities. The law requires that the waste discharge organizations should properly process used industrial storage batteries. Resource conservation is linked with waste management laws in Korea, China and in Europe.

Standardization of electromechanical interfaces and specification of electromagnetic compatibility and safety for external power supplies is a longstanding feature in key markets including China, Europe, Japan, Korea, and the United States. In 2009, noting the environmental impact of obsolete external power supplies (numbering in the hundreds of million units per year globally), identifying as inefficient the use of resources in manufacturing redundant incompatible products, and recognizing the inconvenience to users of managing multiple incompatible wired battery chargers, the European Commission initiated a process in consultation with industry (e.g., GSMA, DE) to converge on a common wired external power supply for data-enabled mobile devices. Such efforts were soon mirrored in other regions. The end result from a technical standards development process was the cooperation between CENELEC and IEC to produce IEC 62684, *Interoperability specifications of common external power supply (EPS) for use with data-enabled mobile telephones.*

Complementary to the above-named global and regional common EPS programs, the introduction of standardized WPT may offer a similar public benefit, including a reduction in e-waste, by potentially reducing the number of external power supplies required per user. A common WPT charging mechanism may create an opportunity for manufacturers to reduce or eliminate the chargers which must be supplied with devices and that charge the devices via wired interfaces. One WPT charger may be able to simultaneously charge multiple devices that have WPT receivers, theoretically lowering the number of wireless power supplies to devices below a 1:1 ratio.

However, wireless charging devices may also simply introduce another type of power supply, which may be in addition to a conventional wired charging supply, rather than a complete replacement. This may be particularly true prior to broad deployments of wireless charging locations throughout consumer, corporate, and public infrastructure. This will almost certainly be true if a common standardized WPT interface is not developed, resulting in multiple proprietary and incompatible WPT systems.

Even with broad deployments of wireless charging locations, it remains to be seen whether the ratio of wireless power supplies to devices remains below a 1:1 ratio.

A number of potential secondary effects may eventually emerge should WPT systems be standardized and widely deployed. Some of these may be beneficial with regard to e-waste reduction, and some may be counter to the public benefit. It cannot be determined at this time how positive and negative secondary benefits may offset.

4.3 Overview of products and services

4.3.1 Overview

The following overview is a navigational aid that identifies key "themes" or trends contained in the list of WPT products and services shown in the next clause. The key themes of market segmentation, market size, geographic extent, market participation and market share point to the WPT market being an early phase segment within the overall CE market.

4.3.2 Market segmentation

In broadest terms, the consumer WPT market is segmented between WPT solutions delivered as accessories and those WPT solutions that are "designed-in" and sold as an embedded capability. Particularly in the mobile CE space this bifurcation is not without precedent. The evolution from accessory to embedded feature depends critically on the availability of cost-effective, easy to integrate components. Such an evolution may follow a progression, over successive CE product cycles, from the use of multi-chip to single-chip to eventual embedded SoC WPT solutions.

4.3.3 Market size

Traditional metrics such as unit volumes, total revenue and profit margins remain largely private commercial information. From various public sources and conference presentations, the market size is estimated to be a few millions of units per year with total revenue significantly less than $1 billion. For perspective, in 2012 it is anticipated that 1,7 billion mobile phones will be sold. Including notebook computers, personal media players, digital cameras and camcorders, tablets, TVs, home and PC peripherals, etc., the figure rises to nearly 5 billion units.

4.3.4 Geographic extent

Although not large by revenue, the WPT market is global. Products are manufactured and consumed in key mobile CE markets, following mainly the mobile phone market.

4.3.5 Market participation

Market participation is broad and broadening as measured by the WPT manufacturing supply chain. Key elements in the supply chain include core technology providers, analog component suppliers (e.g., inductive coils), digital and mixed-signal component suppliers, device OEMs, wireless operators and retailers. Supply chains are active within specialized "vertical" application areas including those for automotive, home and office furniture, CE devices, and so on. In nearly every category one finds well-established global leaders and dedicated start-ups and small companies engaged with one another and the market either cooperatively or in competition or both. This is a feature of a healthy, early stage market.

4.3.6 Current market technologies

A measure of WPT technology adoption by industry offers one alternative in the absence of traditional financial and market share metrics. The Wireless Power Consortium specification uses electromagnetic induction of the type commonly referred to as "tightly coupled" and has been adopted by a range CE manufacturers and power product manufacturers in their initial forays into WPT-enabled device development.

Wireless charging of mobile handsets has attracted manufacturers who offer consumer products as accessories, including charging "sleeves", charging pads and battery covers. A convenient method for assessing the depth, breadth and consumer response to such products is to consult a consumer electronics provider's website with the search term "wireless charger".

A range of WPT products within the mobile CE space (e.g., phone “sleeves” and “battery packs”) and niche applications (e.g., game console chargers) have launched and in some cases faded from view (informally measured by ease, or lack thereof, of purchase either online or through major “brick and mortar” retailers). A catalogue of available WPT products and services surely reflects “survivor bias.” This TR did not attempt to catalogue each and every attempted WPT commercial product or service.

4.3.7 Global industry engagement

Globally, there are more than 150 companies active in WPT technology research, including technical standards development, product development and related services. This includes companies with announced or anticipated WPT products and services as indicated by IEC TC 100 WPT Survey responses, public membership lists of WPT private industry consortia, publicly available lists of SDO WPT project participants, the general public press and key trade shows where wireless charging of consumer electronics is demonstrated and discussed. These include:

- Consumer Electronics Show
- Consumer Electronics Unlimited (IFA)
- Combined Exhibition of Advanced Technologies (CEATEC)
- International Wireless Power Summit (2009-2012)
- Korea Wireless Power Forum Conference (2012)
- Mobile World Congress
- Wireless Power World (2012)

The collection spans the WPT value chain, horizontally and vertically, and includes global consumer brands and leading manufacturers as well as new venture companies.

4.3.8 By underlying technology

Today, the most widely adopted WPT solutions for mobile CE devices utilize tightly-coupled electromagnetic induction (see Clause 5.2). The Wireless Power Consortium has developed and maintains a specification for tightly-coupled electromagnetic induction. Independently and in parallel, several individual private companies have developed and launched their own separate implementations of tightly-coupled electromagnetic induction solutions. Such products are also available in the market today.

Alternative WPT technologies are in various stages of development and progress towards the market (see Clause 5.2). It is generally understood (i.e., as articulated by market analysts) that the market has not yet concluded its “technology selection” process.

4.3.9 By product and use case

4.3.9.1 General

Subclause 4.1 introduced in the abstract a range of WPT use cases. The extensive mapping of WPT products and services to these use cases demonstrates the depth, breadth and scope of activity in this young technology sector.

WPT products divide into a “source” of power and a corresponding power “sink”. WPT power sources include charging pads in a wide range of form factors and embedded configurations that incorporate power amplifier and inductive coil components. WPT power receivers include accessory sleeves that fit over an existing device, receiver structures and circuits embedded in an optional battery pack or external case, and those integrated into the device main power management circuitry.

While the majority of product announcements to date feature mobile phone WPT, it is generally understood that any battery-powered, hand-held CE device is a candidate for WPT.

Under the existing regulatory framework, WPT products have been brought to or planned for market release under a combination of ISM regulations and industry guidelines. For example, the Wireless Power Consortium tightly-coupled approach specifies use of 105 kHz to 205 kHz with maximum power output specified in the range to 5 W. The 6,78 MHz band, owing to its global availability for ISM use and other unique regulatory features, has been identified as an attractive candidate in particular for magnetic resonant approaches specified by the Alliance for Wireless Power (A4WP) and under investigation as a leading candidate in Korea by Korea Wireless Power Forum (KWPF) and in Japan by Broadband Wireless Forum (BWF). USA authorization to operate as ISM equipment depends on whether and how signaling between the power source and load are implemented, as well as ensuring that the "local RF energy use" requirement is satisfied, among others. See also 6.2. In Japan, although the 6,78 MHz frequency band is not officially treated as the ISM band, it can be used for ISM purposes.

4.3.9.2 Automotive

Automotive WPT source products are aimed long-term at offering integrated automobile and vehicle-based CE charging. Figure 1 shows a representative sample of such products. WPT components, including power circuits and coils, are subject to environmental robustness, EMC and long-term availability requirements designed to match the lengthy automotive industry product cycles.

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Figure 1 – Automotive CE WPT products and concepts

4.3.9.3 Commercial, institutional, retail

Commercial, institutional and retail use cases require specifically designed furniture with embedded charging capability. See also Figure 3 below.

4.3.9.4 Residential

The goal for home and residential use cases is aesthetic yet functional designs of the CE devices themselves as well as the WPT sources. Figure 2 shows representative samples that were either contributed as part of IEC TC 100 Survey responses or obtained from online shopping sites.

IEC 1660/13

Figure 2 – CE WPT products and concepts

4.3.9.5 Professional Office

At least two types of configurations are envisioned for WPT in the professional and corporate office setting: WPT desktop accessories; and WPT embedded in office and furniture systems. Figure 3 illustrates the range of furniture types under consideration for WPT applications.

IEC 1661/13

Figure 3 – Professional office WPT products and concepts

4.3.9.6 Transportation and public spaces

Rugged, multi-user, embedded solutions are key additional requirements in the transportation and public spaces. Figure 4 depicts the physical environments in which WPT applications could be delivered to consumers “on the move.”

IEC 1662/13

Figure 4 – Embedded WPT concepts for public spaces

4.4 Research activities

4.4.1 Academic research

A global combination of leading university research laboratories, private laboratories and university-industry conferences provide a strong foundation for WPT academic research. Table 1 lists a sample of entities and laboratories actively engaged in WPT research.

Table 1 – Academic-type research

Venue	Geography	Details
IEEE MTT-S International Microwave Workshop Series (IMWS) on Innovative Wireless Power Transmission (IMWS-IWPT) www.ieeexplore.ieee.org/	Global	2011 and 2012 were held in Kyoto, Japan. An academic-industry technology conference dedicated to WPT. Papers can be obtained via IEEE Xplore.
IEEE International Wireless Symposium www.ieee.org/	China	2013 meeting to be held in Beijing, China
IEEE Wireless Power Transfer Conference	EU	2013, Perugia, Italy.
University of Tokyo, Hori-Fujimoto Laboratory	Japan	WPT based on electromagnetic resonance coupling.
University of Tokyo, Asami and Kawahara Laboratory	Japan	WPT based on electromagnetic resonance coupling.
University of Tokyo, Shinoda Laboratory	Japan	General WPT research and applications.
Kyoto University	Japan	General WPT research.
Ryukoku University	Japan	WPT circuit analysis and design.
Electronics and Telecommunications Research Institute (ETRI) www.etri.re.kr/eng	Korea	Research and development consortium with broad technical agenda, including WPT.
Korea Electrotechnology Research Institute (KERI) www.keri.re.kr/english/	Korea	Research and development consortium with broad technical agenda, including WPT.
Korea Electronics Technology Institute (KETI) www.keti.re.kr/e-keti/	Korea	Research and development consortium with broad technical agenda, including WPT.
Korea Advanced Institute of Science and Technology (KAIST)	Korea	Online electric vehicles
KonKuk University	Korea	Analog chip designs for power amplifiers, regulators, etc.

Venue	Geography	Details
Hanyang University	Korea	WPT source – receiver coupling research.
University of Auckland	New Zealand	Research and development across wide range of WPT applications in CE and EV.
MIT Soljacic Laboratory	USA	Results with non-radiative, mid-range, resonant coupling WPT were widely reported and reproduced.
UC Berkeley	USA	WPT physics and circuit design
Stanford University	USA	WPT in transportation, CE and medical equipment applications

4.4.2 Market research and analysis

Market research and analysis is typically the province of private commercial market research firms and private industry consortia. A representative global sample of such entities is listed in Table 2. Typical work product of these organizations includes market research reports and projections, but may also include technology surveys, and even the development of technical specifications intended for commercial applications and ecosystem development. The table below contains a representative and by no means complete list of such entities and activities that are presently and actively engaged in WPT market research and analysis.

For market research including industry, regulators and legislators, it is not unusual for private industry consortia to serve as a venue for government-industry consultations. Examples include the interaction between Japan MIC and industry via the Broadband Wireless Forum Wireless Power Transmission Working Group, discussions between the European Commission and industry via Digital Europe during drafting of Common EPS MOUs and more recent activities relating to regulatory categorization for WPT, and in Korea between the MKE and MFAN, and between KCC and KWPF.

In addition to private industry consortia, SDOs provide a venue for government-industry consultation. In the USA, the CEA has coordinated industry-government exchanges with the FCC and Congress. In China, the CCSA is a primary venue for industry-government consultations regarding WPT.

Many of the endeavors listed above have produced draft or final reports referenced in the Bibliography.

Table 2 – Market planning and analysis[1]

Venue	Geography	Details
GBI Research www.gbiresearch.com	Global	Private market research and forecasting agency with issued WPT report(s).
IDTechEx www.idtechex.com	Global	Private market research and forecasting agency with issued WPT report(s).
IMS Research www.imresearch.com	Global	Private market research and forecasting agency with issued WPT report(s).
iSuppli www.isuppli.com	Global	Private market research and forecasting agency with issued WPT report(s).
Navagant Research	Global	Private market research and forecasting agency with issued WPT report(s).

1 The references to private market research and forecasting agencies and private industry consortiums in Table 2 and throughout this technical report are given for the convenience of users of this document and do not constitute an endorsement by IEC of these entities.

Venue	Geography	Details
www.pikeresearch.com		
Strategy Analytics www.strategyanalytics.com	Global	Private market research and forecasting agency with issued WPT report(s).
Alliance for Wireless Power www.a4wp.org	Global	Private industry consortium focused on non-radiative, magnetic resonance WPT and ecosystem.
Consumer Electronics for Automotive (CE4A) www.ce4a.org	Global	Private industry consortium with a broad agenda relating to automotive issues and which has issued a set of WPT requirements.
NFC Forum www.nfcforum.org	Global	Private industry consortium considering WPT.
Power Matters Alliance www.powermatters.org	Global	Private industry consortium focused on WPT.
Wireless Power Consortium www.wirelesspowerconsortium.org	Global	Private industry consortium focused on “tightly-coupled” WPT and ecosystem.
Digital Europe www.digitaleurope.org	EU	Private industry consortium with broad CE interest including WPT.
Broadband Wireless Forum	Japan	Private industry consortium with broad CE and communications interests including WPT.
Japan Automobile Research Inst. www.jari.or.jp	Japan	Private industry consortium with broad automotive interests including WPT.
Society of Automotive Engineers of Japan (JSAE) www.jsae.or.jp	Japan	Private industry consortium with broad automotive interests including WPT.
Yokosuka Research Park (YRP) www.yrp.co.jp	Japan	Government-industry collaboration environment, including WPT via BWF (see above).
Korea Wireless Power Transfer Forum (KWPF)	Korea	Private industry consortium focused on broad range of WPT consumer, technical and regulatory matters.
Magnetic Field Area Network Forum (MFAN) http://www.mfan.or.kr/	Korea	Private industry consortium focused on broad range of WPT consumer, technical and regulatory matters.
Consumer Electronics Association www.ce.org	USA	Private industry group with broad agenda, including WPT.
Electric Power Research Institute (EPRI) www.epri.com	USA	Industry consortium with broad programme relating to electric power, including WPT.

5 Technology

5.1 System reference model

This clause provides an overview of the major elements of the system reference model and emphasizes that which is common to and identifies points of departure between WPT system and subsystem designs. While not exhaustive in detail, this clause permits an appreciation of the richness of technology choice present in these early phases of the WPT industry.

WPT technology encompasses a range of approaches in the service of a broad range of CE use cases. To organize a discussion of common elements and key differences in WPT technological approaches and CE use cases, the high-level system reference model shown in Figure 5 below depicts a functional decomposition of a typical WPT system. The functional elements shown are a superset or superposition of reference models identified by individual consortia (e.g., WPC, A4WP) or individual SDOs (e.g., BWF, CEA, ISO/IEC JTC1 SC6) and as provided in the responses to the IEC TC 100 WPT Survey.

The main goal of the functional decomposition shown below in Figure 5 is to identify the major common elements present in WPT systems when viewed as a whole. More detailed models are required when, for example, taking the perspective solely of the WPT source or solely of the WPT device to be charged, or of a particular WPT core technology.

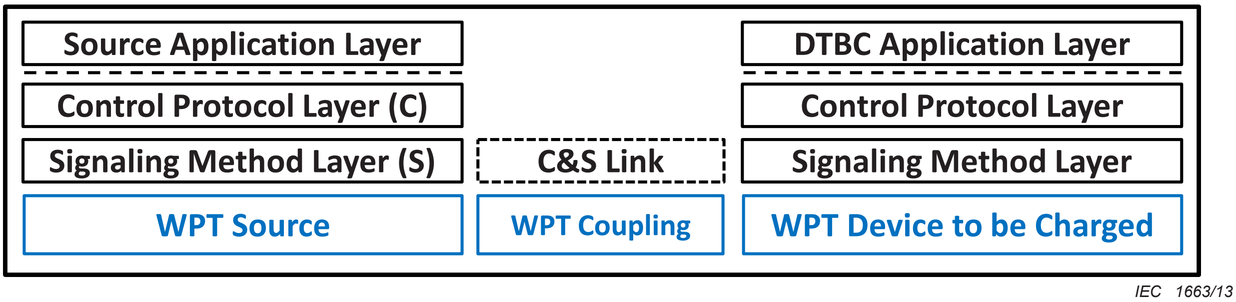

Figure 5 – WPT system reference model for single source single device

The Source application layer and DTBC application layer, or simply, application layer, shown above represent the functionality required to integrate a WPT system as a subsystem within a larger hardware and software architecture such as within the WPT source (e.g., charging pad) or a portable CE device such as a cellular phone. The respective application layers may use a combination of software APIs and hardware to support user interface(s) associated with WP. APIs, hardware details and user interface details are beyond the scope of WPT technical standards development. The dashed line shown in black below the respective application layers in the system reference model emphasizes this boundary. Above the line lies the domain of system integration and consumer operations. Below the lines lies the domain of WPT-specific elements.

In common to the Source and device to be charged (DTBC), the WPT-specific elements are divided horizontally into three layers. At the lowest layer is the physical layer over which the actual power transfer takes place wirelessly. This is ***the*** WPT layer. This is indicated in blue in Figure 5. Key elements in the WPT layer are a WPT source, a device or set of devices to be (simultaneously) charged and a means of WPT “coupling” by which is meant the physical medium through which power transfer takes place. One of the key differentiators between WPT technologies is the choice of coupling medium, e.g., magnetic vs. electrical. Such choices in turn impact Source and DTBC designs.

The procedures preceding actual wireless transfer of power from the source(s) to the DTBC(s), the management of on-going wireless transfer of power, and the orderly termination of wireless transfer of power require coordination between Source-side and DTBC-side control (C) and signalling (S).

- “Control” means information exchanged locally between Source and DTBC in the form of real-time or near real-time signalling to effect WPT detection, identification, authorization, real-time power level management, foreign object detection, overall system efficiency, and performance and safety, among many other possible functions. The Control layer describes message sequences as a protocol including timer requirements for ACK/NACK implemented as a state machine. The Control layer is alternatively named the Logical, or Management Protocol layer.
- “Signalling” means the formatting, addressing and related preparation for transmission (and the reverse in case of receiving) of Control messages over the CS physical layer. The Signalling layer typically describes message packet structure, byte encoding scheme, and possibly including some form of error correction or redundancy. The Signalling layer is alternatively named the data link layer.

A key point of differentiation between WPT technologies is the choice of CS physical layer. Some implementations may utilize a form of amplitude or load modulation of the wireless power transfer frequency itself, referred to as "in-band signalling." In this case the CS layer is identical with the WPT coupling layer. Alternative implementations use a completely separate physical layer and radio communications protocols. Discussion in the open literature includes a range of easily recognizable, widely deployed, short-range, low-power radio communications techniques. These are referred to as "out-of-band signalling."

A key design choice for the Control and Signalling layer is uni-directional or bi-directional exchange. In the case of uni-directional, the choice is reverse-link only, such as from DTBC(s) to Source(s), or forward-link only, such as from Source(s) to DTBC(s). Peer-to-peer signalling between DTBCs has been contemplated and prototyped. Peer-to-peer signalling between Sources is in principle possible, though less often discussed in the open literature.

A key design choice is whether the WPT Source system supports simultaneous charging of multiple devices. Such a choice has implications for the WPT layer, the Control and Signalling layers, in particular, for the Source.

Further, it is logically possible to consider a DTBC to interact with multiple Sources simultaneously, but this is less often discussed in the open literature.

Finally, given the range of WPT use cases, it may be necessary to consider the case in which power transfer is achieved either simultaneously or sequentially in time between multiple sources and multiple DTBC(s) utilizing different core technologies. To illustrate, a multi-protocol WPT source could support distinct power transfer physical layers.

5.2 The wireless power transfer layer

5.2.1 General

A variety of WPT physical layer technologies have been developed and applied as prototypes or as shipping products towards a wide range of CE and non-CE use cases. A critical difference in technical approaches is the choice of coupling method. The growing list of choices includes electromagnetic induction, magnetic resonance, electric field coupling, microwave radio transmission and microwave energy harvesting. Additional differentiating features include available power levels (mW to kW) for practical CE applications and industrial design constraints such as the requirement for precise (mm-scale) or more flexible (cm-scale) physical alignment between Source(s) and DTBC(s). Coupling medium choice drives unique requirements for electrical and magnetic circuit designs in the Source and DTBC.

5.2.2 Electromagnetic induction

An alternating electric current flowing through a coil (Source) generates a magnetic field that acts on a receiver coil (Sink (DTBC in Figure 5)) to produce a current within it, and thus electric power is transferred between the Source and DTBC coils. Figure 6 depicts electromagnetic induction in the case of a source and sink coil in close physical proximity. Magnetic coupling between the two coils must be tight in order to achieve high transfer efficiency. Because the electric power transfer distance is short, typically measured in the mm range, the WPT by the electromagnetic induction is often called noncontact power transfer, or tightly-coupled WPT.

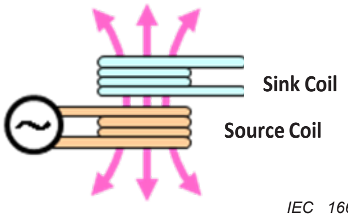

Figure 6 – Electromagnetic induction

This technology has been used as a noncontact electric power transfer technology, i.e., without the electric contact terminals. Some manufacturers have sold proprietary products that use this technology in cordless phones, electric toothbrushes and electric shavers. In 2010, the Wireless Power Consortium (WPC) developed a specification for an electromagnetic induction type wireless charging that delivers in principle up to 5 W. In 2011, cellular phones, smart phones, and charging pads using this standard began to appear in Japan and United States consumer markets. Although it is a general term, “electromagnetic induction” as discussed above is often referred to as “tightly-coupled” WPT.

5.2.3 Magnetic resonance

Magnetic resonance is a special case of electromagnetic induction where resonant coils are used such that higher efficiencies can be supported for a given coupling factor (k) in configurations designed for low (much less than 1,0) coupling factor. The magnetic resonance method utilizes a Source consisting of a coil and series capacitor as a resonator, with a corresponding sink (DTBC in Figure 5) element consisting also of a coil and series capacitor as a tuned resonator. Electric power is transferred through the electromagnetic resonance between the Source and DTBC coils. By matching the resonance frequency of the Source coil and the DTBC coil in a high *Q* factor regime, electric power is transferred over a long distance (mm to m) even where magnetic coupling (k) between two coils is low. Figure 7 depicts magnetic resonance in the case of a source and sink coil in local physical proximity. The magnetic resonance approach is referred to interchangeably as magnetic resonant coupling, highly resonant magnetic induction, or loosely-coupled WPT.

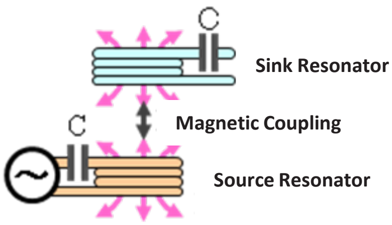

Figure 7 – Magnetic resonance

Resonant technology enables electric power transfer over a medium distance that is longer than tightly-coupled electromagnetic induction, but is shorter than the microwave power transfer. Developments are under way for a broad range of potential applications. In China, Japan, Korea and the USA systems have been developed and are demonstrated in both laboratory and commercial prototypes that span broad power and distance ranges. For example, wireless power transfer has been commercially prototyped in the range of 1 W to 50 W or more for portable, hand-held CE applications, 50 W to 100 W or more for home appliances such as multimedia equipment. Systems have been demonstrated in which charger to device separation distance is in the range of millimetres to centimetres to multiple meters (i.e., room-sized). Systems have also been demonstrated for single and simultaneous multiple device charging with tolerance for horizontal, vertical and angular displacement between charger and device(s) preserved. “Magnetic resonance” as discussed above is often referred to as “l-coupled” WPT.

5.2.4 Capacitive coupling

Capacitive coupling is the transfer of power through an electrostatic capacitance between two insulated electrodes. An electric field is created by charging the electrodes with a high potential, high frequency alternating current power supply. Although the electric power transfer distance is short, similar to the electromagnetic induction, this method has the feature that positional degree of freedom in the direction of the electrode is higher than with electromagnetic induction.

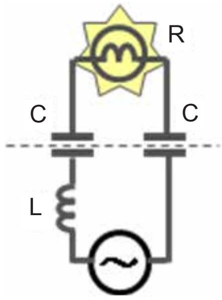

Figure 8 – Electric field inductive coupling

This technology is used in the use case similar to that of electromagnetic induction, as is depicted as a lumped equivalent circuit in Figure 8. Japan has commercialized a wireless charger set for a leading tablet device that adopts such power transfer. A multi-device charger has also been demonstrated.

5.2.5 Microwave power transfer

Electric power transfer leveraging radio waves can be made directional, allowing longer distance power beaming, using shorter wavelengths of electromagnetic radiation, typically in the microwave range. This method has the feature that the electric power can be transferred over long distances up to multiple kilometers. This is the most general wireless power transfer method, and the history of the research is arguably the longest. A lumped representation is shown in Figure 9 below.

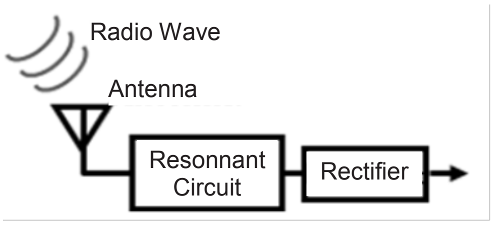

Figure 9 – Microwave power transfer

This technology has been mainly researched for long distance electric power transfer based on the concept of space-based solar power or for wireless charge to electric vehicles. A system that transfers electric power to many mobile devices simultaneously in a room-sized environment is a subject of ongoing research.

5.2.6 Microwave energy harvesting

Energy harvesting is the process by which energy is derived from external sources (e.g., solar power, electromagnetic, thermal, wind, and kinetic), captured, and stored for small, wireless autonomous devices. Microwave energy harvesting derives electric power using the same principle as the receiver of the microwave power transfer.

6 Regulation

6.1 Spectrum

Survey responses from IEC member countries confirm that under existing regulatory framework there is no definitive WPT frequency band allocation.

While there exists no explicit spectrum allocation for WPT on any regional or global basis, regulator-industry informal consultations are underway in nearly all major markets. In most countries are using, recommending or considering using 105 kHz - 250 kHz (typically associated with tightly-coupled WPT) or ISM frequencies such as 6,78 or 13,56 MHz (typically associated with magnetic resonance WPT). Japan and Korea have a voluntary power limit for WPT of 50W maximum associated with these bands. Note that such limits are due to industry guidelines rather than explicit regulations. Table 3 below lists the frequencies and power limits by country based on IEC Survey response data.

Table 3 – Operating frequencies and power limits

Country	Band	Power Limit
Korea	• 80 kHz to100 kHz • 130 kHz to150 kHz • 325 kHz to 405 kHz • 1,6 MHz to1,8 MHz • 6,78 MHz;13,56 MHz (ISM)	50 W maximum
Japan	• 10 kHz to 10M Hz • 13,56 MHz (ISM) • 27,12 MHz (ISM) • 40,68 MHz (ISM)	50 W maximum per BWF Guidelines
China	• 105 kHz to 205 kHz for tightly-coupled • recommends ISM band 6,8 MHz for highly resonant	NA
United States	• <500 kHz • 6,78 MHz • 13,56MHz	NA

Korea noted that 80 kHz to 100 kHz, 130 kHz to 150 kHz, 325 kHz to 405 kHz, 1,6 MHz to 1,8 MHz, and 6,78 MHz, and 13,56 MHz (ISM) were proposed by industry as an additional spectrum for WPT and this additional spectrum is discussed in the KWPF. In addition, Korea is developing an in-band wireless communication protocol for WPT. With this technology, WPT can share the same frequency band for exchanging both power and control and signalling data.

Japan provided further details on frequency allocation considerations. At such frequency bands as the Wireless Power Consortium specification (105 kHz to 205 kHz), it is possible to be regarded as “high frequency-based equipment”, so long as the signal is not modified (which WPC specification does via amplitude modulation for signalling), does not interfere to other systems and meets the requirements of “radio-exposure protection guidelines.” In such cases, if the power does not exceed 50 W, unlicensed operation is permitted. High power WPT devices, such as electric vehicles, may be regarded as “high frequency-based equipment” with site restriction. Guidelines are applied on interference and radio-exposure protection. Avoidance of interference to other systems would probably be required in the case of unlicensed operation in any WPT spectrum allocation. In the case of EVs, candidate operating frequencies range from 20 kHz to 1 MHz. As such bands are typically occupied by existing systems, such as reference radio signals, amateur radio, AM broadcasting, etc., the spectrum allocation situation is a challenging one.

In Japan, WPT systems using in-band communication, such as Wireless Power Consortium specification-compliant products, are categorized as “radio communication equipment” and more strict restrictions are applied. It is also possible to apply the category “inductive radio communication equipment” if the electromagnetic field strength (measured in volts per meter) is 15 μV/m at a distance from source of $\lambda/2\pi$ meters, where λ is a wavelength measured in meters. A device can be considered as “high frequency-based equipment without license” if the power is 50 W or less.

6.2 RF emissions

The matter of WPT RF emissions is principally an exercise in categorization and application of existing regulations. Survey respondents commonly identified three regulations or standards that govern EMC including intentional emissions, radiated emissions and conducted emissions:

- EU: EN 55011
- International: CISPR 11
- USA: FCC Part 15 and Part 18

In the USA, at the October 2012 Telecommunications Certification Body workshop, the Laboratory Division of the Office of Engineering and Technology at the FCC discussed wireless charging for consumer devices. The FCC reiterated its earlier position that a KDB inquiry should be submitted for guidance for wireless charger applications and that wireless chargers remain on the permit but ask (PBA) list. The presentation included information regarding authorization and RF exposure. With regards to authorization, for example, the primary operating frequency can be used for both charging and load management. Part 18 authorization for the charger and device to be charged considers whether load and power management are integral to the charging operation and frequency, that only information related to power management and control may be communicated, that RF energy is locally generated and used, and that other communications be authorized separately under Part 15. The RF exposure discussion included information regarding single device and multiple device charging configurations, considerations for evaluation and additional discussion of portable devices and mobile devices. (References to the public, freely available presentation and related KDB published in 2010 are listed in the Bibliography.)

In Japan, wireless charging of consumer devices, under applicable existing regulation is limited to 50 W output.

Respondents commonly listed IEC 61000-6-1 as an international standard applicable to WPT regarding EMC immunity. The complete name for the IEC specifications is listed in the Bibliography.

6.3 Safety

6.3.1 General

WPT safety considerations for consumer applications includes RF exposure, heating (separate from SAR) and electrical safety.

6.3.2 RF exposure

Survey respondents noted that WPT is subject at least to the following broadly recognized human safety regulations and standards for EMF and RF.

- International: ICNIRP 1998, ICNIRP 2010

- International: IEC/EN 62311, IEC/EN 62233
- USA: CFR 47, Parts 1 and 2

China referenced their EMF standard, noted that it is stricter than the ICNIRP requirement and that EMF is already identified as the main public concern as WPT products are launched on the market. The Chinese regulations for EMF are GB8702-88 basic restrictions and GB 9175-88 maximum permitted exposure, whose requirements are listed in Table 4 and Table 5, respectively, below.

Table 4 – GB8702-88 (China) basic restrictions

Exposure characteristics	Frequency range	Whole body (W/kg)
Occupational exposure	100 kHz to10 MHz	0,1
General public exposure	100 kHz to10 MHz	0,02

Table 5 – GB 9175-88 (China) maximum permitted exposure

Wave length	Unit	Maximum permitted exposure	
		Class 1	Class 2
Long, moderate, short wave（100 kHz to 30 MHz）	V/m	<10	<25
Ultra short wave （30 MHz to 300 MHz）	V/m	<5	<12
Microwave （>300 MHz）	$\mu W/cm^2$	<10	<40
Mixed wave of different bands	V/m	Main band field strength; if each band field strength is scattered, then the composite field strength shall be determined by weight.	

The Broadband Wireless Forum (BWF) Guidelines recommends compliance in the Japan domestic market with the Japan Telecommunication Technology Council’s Radio-exposure Protection Guidelines (see Figure 10 below) and ICNIRP Guidelines for international markets. The relationship between these national and international guidelines is shown graphically in Figure 10.

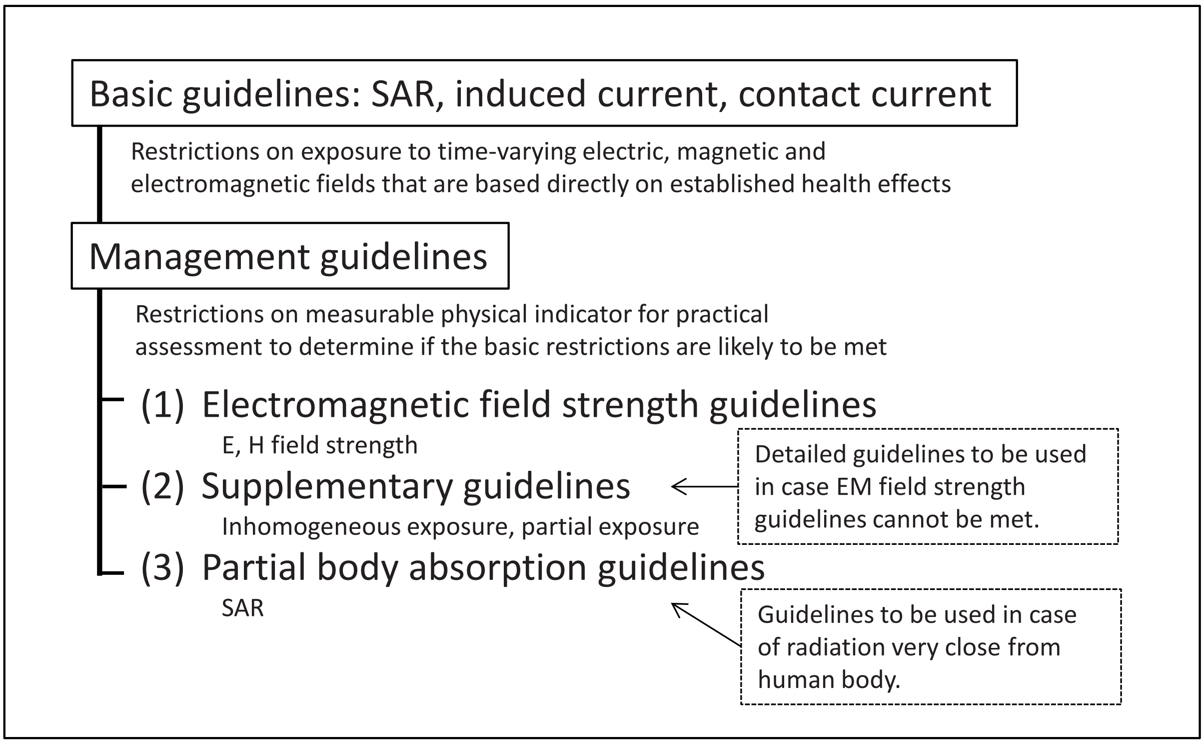

Figure 10 – Radio-exposure protection guidelines details (Japan)

SAR is a key measurement in human RF exposure. Presently, there is no international standard for the near field SAR measurement method below 30 MHz applicable to WPT. However, numerical modeling methods have been described in the academic literature for determining SAR that may be applied to WPT. Field strength measurement methods for WPT systems have yet to be developed. In Japan, the BWF is discussing concrete assessment and measurement methods with regard to RF exposure guidelines listed in applicable ICNIRIP, Japanese RF exposure guidelines, and IEEE publications.

6.3.3 Heating

Heating, apart from SAR, is the subject of regulation in Japan based on IEC 60335-1. The requirements include identification of reception side and that power should not be transferred without identification of reception side. There are temperature rise limits of 35 K (for metal), 45 K (for porcelain or vitreous material) and 60 K (for molded material, rubber or wood). Additionally a detailed measurement method and evaluation method for temperature rise are described in the Japan BWF Guidelines.

6.3.4 Electrical safety

The United States referenced the use of UL/CAS 60950, EN 60950, and IEC 60950 for electrical safety of WPT devices.

6.4 Compliance

6.4.1 Identified regulations and standards

Table 6 below presents on an informative basis a partial list of regulations and standards which are or may be applicable to WPT based on IEC WPT Survey responses. Which regulation or standard applies ultimately depends on the individual design and operating characteristics of WPT such as maximum WPT source output power, implementation method for signalling (in-band vs. out-of-band) and signalling configuration (uni-directional; bi-directional).

Table 6 – Identified regulations and standards

Country	Laws/regulations	Guidelines or Standards
Korea	Korea Communications Commission (KCC) Notice 2011-31; The rule of radio equipment Korea Communications Commission (KCC) Notice 2011-5; Korea EMC requirements Radio Research Agency (RRA) Radio Wave Act	PG709 under TTA is considering the development of a protocol relating to management systems between devices and infrastructure.
China	People's Republic of China Ministry of Industry and Information Technology, the 16th Order (2010): People's Republic of China Regulations on the Radio Frequency Allocation. People's Republic of China State Council, the People's Republic of China Central Military Commission, the 128th Order (1993). People's Republic of China Regulations on Radio. People's Republic of China State Council, People's Republic of China the Central Military Commission, No. 579 Order (2010). People's Republic of China Radio Control Requirements. People's Republic of China Ministry of Environment Protection, the 18th Order (1997): Electromagnetic Radiation Management of Environmental Protection. People's Republic of China State Council No. 390 Order (2003): People's Republic of China Certification and Accreditation Regulations. EMF Health Standard GB 9175-88 Hygienic Standard for Environmental Electromagnetic Wave. EMF Environmental Protection Standard GB 8702-88 Electromagnetic Radiation Protection Provisions. People's Republic of China State Council, No. 291 Order (2000) People's Republic of China Telecommunication Ordinance.	
Japan	Article 45, Item 3 of Regulations for Enforcement of the Radio Law Article 44, Paragraph 1, Item 2 (1) of Regulations for Enforcement of the Radio Law	BWF Guidelines for the Use of Wireless Power Transmission Technologies BWF TR-01 1.0
United States	Federal Communications Commission (FCC) Part 15 and Part 18 Code of Federal Regulations (CFR) 47 , telecommunications, parts 1,2,15, and 18 Potential energy efficiency with CEC and DOE	CEA-2042.5, Tightly-Coupled Wireless Power Transfer System Requirements CEA-2042.4, Loosely-Coupled Wireless Power Transfer System Requirements

In addition to the list of frequency, exposure and safety regulations, and guidelines/standards listed above, the following regulations are relevant to WPT:

- EU: WEEE and RoHS
- Japan: Law for the Promotion of Effective Utilization of Resource; Waste Disposal and Public Cleaning Law
- USA: California RoHS.

There are also labelling regulations to consider:

- EU: CE mark;
- USA: FCC Part 2, Part18.

6.4.2 Measurement methods

WPT regulatory compliance and WPT minimum performance are driving requirements for new measurement methods. These include:

- Power transfer efficiency
- Operating frequency and permitted error
- Field strength
- Current when touch, and inductive current in human body
- Harmonic spurious
- Heating
- SAR limit compliance

This TR notes activity including consultation with governments and regulators on some or all of these topics as follows: China, CCSA TC9; Japan, BWF; Korea, TTA and KWPF; USA, CEA; and in the EU, TCAM, ETSI ERM and CENELEC. Industrial consortia have concluded work or announced programmes on these topics, including the A4WP, CE4A ,WPC and NFC forum.. These consultations may drive new technical standards and rule-making.

6.5 Impact of regulation

Typical WPT regulator-industry consultations take place within the framework of existing regulations and focus on whether or how to apply or extend present regulation (e.g., efficiency) or to fill in gaps (e.g., SAR compliance methods).

In the USA, the CEC in 2011 considered WPT in the context of amendments to appliance efficiency regulations and in September 2012 clarified the conditions under which WPT systems would be defined as battery charger systems and therefore subject to the amended regulations.

Similarly, the USA DOE, in its March 2012 Notice of Proposed Rule for battery chargers and external power supplies proposed essentially not to regulate wireless charging products explaining that premature regulation of the nascent technology could adversely impact development. As new WPT products and services and new use cases enter the market, new regulatory discussions may occur.

It is conceivable that WPT products and services entering the market in new and unexpected configurations may trigger new regulations.

7 Technical standards development

7.1 General

WPT technical standards development is a global undertaking. Nearly every major region hosts ongoing consultation between industry and government, in reference both to regulatory and legislative issues. Major international, regional and national SDOs are actively engaged, supplemented by regional and international coordination activities. International SDOs are engaged on WTP technical standards development. Working in parallel, but also in coordination with SDOs, regulators and legislators, is a growing set of established and new industry-led consortia, ranging between those focused on specific WPT technology approaches, to those seeking to represent the needs and technical requirements of one or more vertical market segments.

The purpose of this clause is to list and review the status and publicly known plans of major private industry consortia and SDOs. Such an understanding promotes a critical discussion of the challenges and opportunities for WPT technical standards development.

7.2 Global survey industrial consortia

7.2.1 General

A table-driven approach is convenient due to the number of consortia engaged in WPT technical standards development. The columns of the table when read from left to right indicate the major steps from inception to publication. Organizations are listed in alphabetical order.

7.2.2 A4WP – Alliance for Wireless Power

Table 7 below summarizes A4WP scope, status, deliverables and timelines.

Table 7 – Alliance for Wireless Power (A4WP)

Name	Scope and status	Deliverables and timelines
A4WP	Focus on non-radiative near- and mid-range magnetic resonant coupling (highly resonant coupling) (loosely-coupled WPT).	Established 2012 Baseline Technical Specification completed 2012. Typical complement of Working Groups (Technical; Regulatory; Certification and Testing; Marketing).

7.2.3 CE4A – Consumer Electronics for Automotive

Table 8 below summarizes CE4A scope, status, deliverables and timelines.

Table 8 – Consumer Electronics for Automotive (CE4A)

Name	Scope and status	Deliverables and timelines
CE4A	Association of German automobile manufacturers with a broad agenda that includes WPT.	CE4A has published and maintains a WPT requirements as internal documents and regularly liaises with SDOs. CE4A has hosted an annual (or thereabouts) WPT workshop

7.2.4 DE – Digital Europe

Table 9 below summarizes DE scope, status, deliverables and timelines.

Table 9 – Digital Europe (DE)

Name	Scope and status	Deliverables and timelines
DE	Association of CE and IT manufacturers with EU focus, with broad agenda that includes WPT.	Participated in the 2011-2012 EC/TCAM consultations with industry regarding WPT and that resulted in an ETSI Internal Report.

7.2.5 KWPF – Korea Wireless Power Forum

Table 10 below summarizes KWPF scope, status, deliverables and timelines.

Table 10 – Korea Wireless Power Forum (KWPF)

Name	Scope and status	Deliverables and timelines
KWPF	Association of Korea-based manufacturers, universities and government-sponsored laboratories with an interest on spectrum and regulatory matters related to WPT.	Established in November 2011. Aggregated industry inputs and liaised with TTA prior to create TTA PG709. Venue for government-industry consultations primarily with KCC on allocation of spectrum, revision of radio laws and promotion of WPT industry as well.

7.2.6 MFAN – Magnetic Field Area Network Forum

Table 11 below summarizes MFAN scope, status, deliverables and timelines.

Table 11 – Magnetic Field Area Network Forum (MFAN)

Name	Scope and status	Deliverables and timelines
MFAN	Association of Korea-based manufacturers with an interest in resonant-based WPT technology and standardization.	Aggregated industry inputs and liaised with TTA prior to creation of TTA PG709. Venue for government – industry consultations primarily with MKE.

7.2.7 NFC Forum

Table 12 below summarizes NFC scope, status, deliverables and timelines.

Table 12 – NFC Forum

Name	Scope and status	Deliverables and timelines
NFC	Near-field communications Technical Committee, TWG NFC Device, Wireless Charging Task Force	Wireless Charging Task Force formed in 2012 to draft a NFC-WPC requirements document. Drafts in circulation for review and contribution. Targeting completion late Q3 CY 2012.

7.2.8 PMA – Power Matters Alliance

Table 13 below summarizes PMA scope, status, deliverables and timelines.

Table 13 – Power Matters Alliance (PMA)

Name	Scope and status	Deliverables and timelines
PMA	Industry consortium pursuing a vision of Power 2.0 that combines smart power management, promotion of efficient energy practices and creating a WPT ecosystem.	Typical complement of working groups (Technical; Regulatory; Certification and Testing; Marketing).

7.2.9 WPC – Wireless Power Consortium

Table 14 below summarizes WPC scope, status, deliverables and timelines.

Table 14 – Wireless Power Consortium (WPC)

Name	Scope and status	Deliverables and timelines
WPC	Focus on tightly-coupled inductive coupling solutions across a range of power levels. Website lists more than 120 members and 80 certified products including accessories, chargers and devices (e.g., mobile phones from leading OEMs).	Interface specifications completed and available. New work Items include higher power ranges and "spatial freedom." See Bibliography.

7.3 Global survey governmental and standards development organizations

7.3.1 General

WPT technical standards development takes place within a regulatory and implementation context. In some regions the progression is more or less strictly sequential; in other regions greater degrees of overlap may occur. Figure 11 illustrates the sequential, but often overlapping relationship between regulatory, technical standards development and commercial implementation.

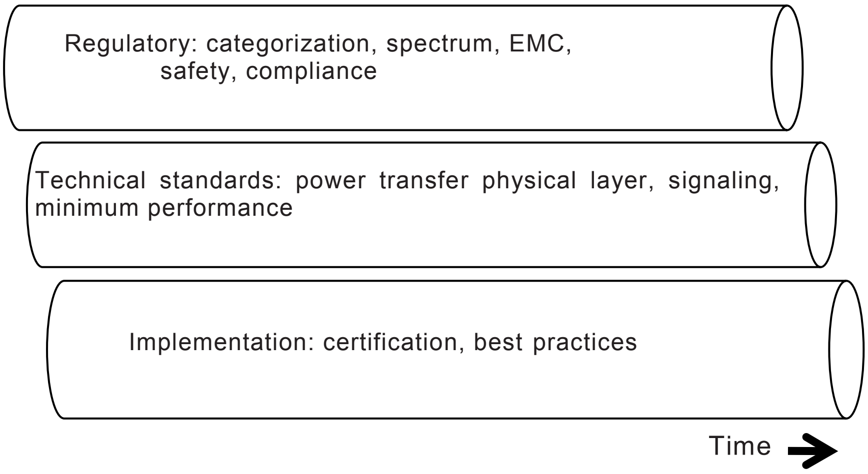

Figure 11 – Regulatory, technical standards and implementation pipelines

A table-driven approach is convenient due to the number of SDOs and related SDO coordination groups engaged in WPT technical standards development.

For a high-level understanding of progress for each group, where applicable, this TR utilizes the four "classic" phases of technical standards development. It is recognized that not all SDOs proceed identically in such fashion, but the key stages are almost certainly passed through during development of WPT technical standards.

- Phase 0. An initial analysis conducted by an SDO to consider whether and how to pursue WPT standardization. Alternatively, this type of Phase 0 study may be used to identify or respond to regulator input. An organizational hierarchy may be established, including drafting committees and work groups.
- Phase 1. An initial analysis performed by a drafting committee to develop user requirements, use cases, and systems requirements. The analysis takes the form of a deliverable document that may or may not be formally published.
- Phase 2. A drafting committee defines a system reference model with key functional blocks and interfaces, and high-level information flows between functional elements. Interfaces are selected for standardization.
- Phase 3. A drafting committee identifies in precise detail for each interface the information messages, including formats down to the bit-level, and protocols at all layers, including physical layers. In the case of WPT, power handling physical and related layers may be different from those used for the control and management protocols.

Organizations are listed in alphabetical order.

7.3.2 APT – Asia Pacific Telecommunity

Table 15 below summarizes APT scope, status, deliverables and timelines.

Table 15 – Asia Pacific Telecommunity (APT)

Name	Type	Working group	Scope and status	Deliverables and timelines
APT	GOV	AWG WG WPT TG	APT Wireless Group (AWG), Working Group on Technology Aspects (WG Tech) Wireless Power Transfer (WPT) Task Group (TG) Overall: Phase 0.	Approved April, 2012 Launches September, 2012, where work plan will be decided

7.3.3 ARIB – Association of Radio Industries and Businesses

Table 16 below summarizes ARIB scope, status, deliverables and timelines.

Table 16 – Association of Radio Industries and Businesses (ARIB)

Name	Type	Working group	Scope and status	Deliverables and timelines
ARIB	SDO		By agreement, BWF WPT WG has responsibility to draft WPT technology standards using ARIB drafting protocols. ARIB will review and standardize the draft standards developed by BWF.	See BWF (below)

7.3.4 BWF – Broadband Wireless Forum

In Japan, government and industry consultation has produced a comprehensive approach whereby BWF WPT WG will take responsibility for drafting WPT technical standards utilizing ARIB drafting protocols. ARIB will then review and subject such draft WPT technical standards to the ARIB approval process. The scope of Japan WPT technical standards development includes a multiplicity of technologies including resonant and non-resonant approaches, and also includes a wide range of use cases ranging from low-power CE-type WPT to high-power EV WPT. BWF WPT technical standards development may benefit from and contribute to potential future WPT work within the scope of IEC TC 100.

The relationship between key Japan stakeholders in WPT technical standards development is illustrated graphically in Figure 12 below.

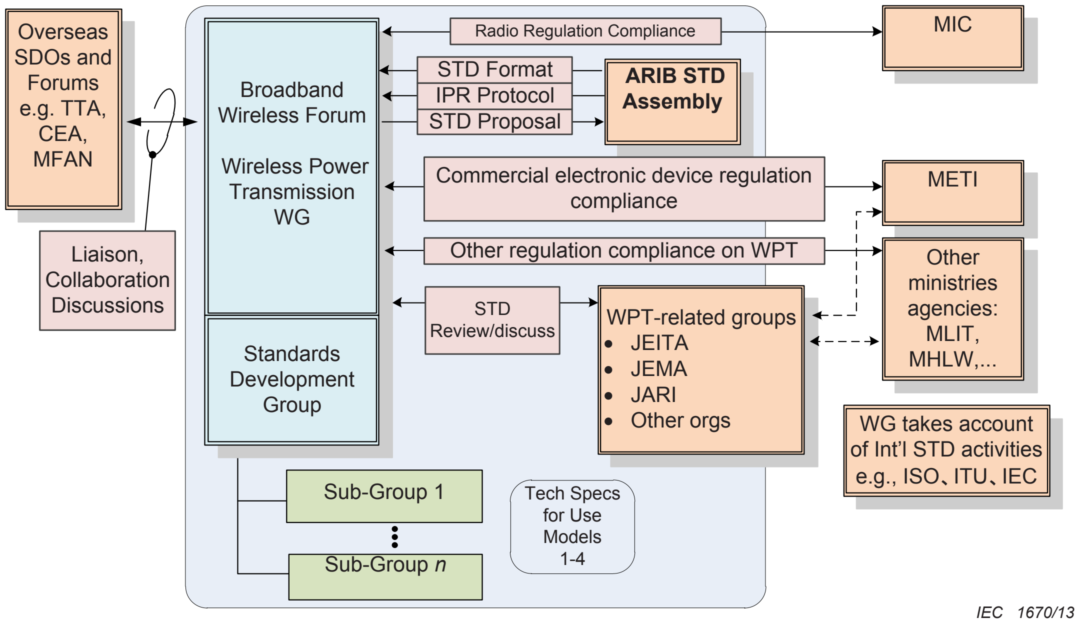

Figure 12 – Relationship between key Japan WPT technical standards stakeholders

The relationship between key Japan stakeholders in WPT technical standards development is illustrated in tabular form and includes additional details in Table 17 below.

Table 17 – Broadband Wireless Forum (BWF)

Name	Type	Working group	Scope and status	Deliverables and timelines
BWF		WPT WG	Overall responsibility to draft WPT technology standards using ARIB drafting protocols. Overall: Phase 0 and Phase 1.	Use cases Requirements WPT technical standards
		SDG	Standards Development Group reporting to WPT WG. Common requirements	Requirements, nomenclature, system definition and conformity, product grouping, spectrum, RF-safety, EMI, product safety, environmental, WG definition
		SG1	Compatibility standards, magnetic resonance or inductive: D < 10 cm; PW < 50 W, for cellular phones and portable devices	Work plan, schedule and spectrum study on-going
		SG2	Compatibility standards, magnetic resonance or inductive: D: 10 cm to 1 m range; PW < 50 W, for cellular phones and portable devices, tablet PC, note-PC, CE (low power) appliances	See above
		SG3	Compatibility standards, magnetic resonance or inductive: D: 0 cm to 1 m range; PW > 50 W, for big screen TV, CE appliance (high power), electric tools, industrial machines	See above
		SG4	Compatibility standards, magnetic resonance or inductive: D: <30 cm; PW > 1 kW, for electric ad plug-in hybrid electric vehicles	See above
		SG5	Compatibility standards, microwave power transmission (GHz) for applications similar to SG2 and SG4.	See above
		SG6	Compatibility standard, electric field coupling WPT: D < 10cm, PC < 50W, for applications similar to SG1	See above

7.3.5 CCSA – China Communications Standards Association

At present, CCSA activities are focused on WPT EMC and safety issues as listed in Table 18 below. Such work may transfer to other working committees within CCSA for follow-on technical standards development.

Table 18 – China Communications Standards Association (CCSA)

Name	Type	Working group	Scope and status	Deliverables and timelines
CCSA	SDO	TC9	Electromagnetic environment and protection	Research report, “Research of the near field wireless power supply technology”, 2012.
		TC9 WG 1	EMC	Phase 0 type study report, 2012. WPT EMC Test Spec – draft stage
		TC 9 WG 3	Electromagnetic radiation and safety	WPT SAR requirements and test specification – draft stage

7.3.6 CEA – Consumer Electronics Association

Table 19 below summarizes CEA scope, status, deliverables and timelines.

Table 19 – Consumer Electronics Association (CEA)

Name	Type	Working group	Scope and status	Deliverables and timelines
CEA	ANSI SDO	R6, Portable Handheld and In-Vehicle Electronics Committee	WPT Task Group 1	Phase 0 type report completed 2010.
		R6.3, Wireless Power Subcommittee	WPT drafting groups parent committee	
		R6.3, WG 1	Wireless power nomenclature	2042.1 (2011) 2042.1-A (2012)
		R6.3, WG 2	Wireless power safety and emissions	White paper published. See Bibliography.
		R6.3, WG 3	Wireless power transfer efficiency and standby power	Phase 1 and 2 type work draft mode. Phase 3 in progress. Open completion date
		R6.3, WG 4	Highly resonant wireless power transfer Overall: Phase 2 or Phase 3	Phase 1 and 2 type work draft mode. Phase 3 in progress. Open completion date
		R6.3, WG 5	Tightly-coupled wireless power transfer Overall: Phase 2 or Phase 3	Phase 1 and 2 type work draft mode. Phase 3 in progress. Open completion date

7.3.7 CJK – China, Japan and Korea Standards Coordination

The CJK coordination group consists of SDO members CCSA, ARIB and TTA, respectively. A summary is listed in Table 20 below. At their June 2012 meeting CJK approved the creation of a WPT special interest group (SIG). Terms of reference call for the group to develop two TRs. The first is targeted for completion by end of 2012, covering nomenclature, use cases, market assessment, and technology review and standards development issues. The second is targeted for completion by mid-2013. As listed in this TR, it is evident that SDOs in China, Japan and Korea have an interest in WPT, in which case CJK may provide a venue for coordination and collaboration. Finally, CJK interacts with APT which, in turn, interacts with ITU-R.

Table 20 – China, Japan and Korea Standards Coordination (CJK)

Name	Type	Working group	Scope and status	Deliverables and tmelines
CJK		Regional SDO Coordination Group	WPT SIG established	Phase 0 type TR #1 by end-2012 Phase 0 type TR #2 by mid-2013

7.3.8 ETSI – European Telecommunications Standards Institute

Table 21 below summarizes ETSI activities. Activities have focused on WPT regulatory categorization and EMC topics, and were originated through consultation between EC, TCAM, DE and ETSI.

Table 21 – European Telecommunications Standards Institute (ETSI)

Name	Type	Working group	Scope and status	Deliverables and Timelines
ETSI	SDO	ERM	Electromagnetic compatibility and radio spectrum matters	Phase 0 type internal report completed 2012. See Bibliography.

7.3.9 GSC – Global Standards Collaboration

To underscore the increasing visibility and importance of WPT technical standards, a resolution was passed at the GSC-16 plenary which recognized that key issues pertaining to WPT, such as market opportunity, technical standards harmonization and regulation, benefit from a global approach. The GSC resolved to facilitate standards collaboration, to encourage cooperation and to consider spectrum and safety issues in conjunction with WTP technical standards development. GSC scope, status, deliverables and timelines are listed below in Table 22.

Table 22 – Global Standards Collaboration (GSC)

Name	Type	Working group	Scope and status	Deliverables and timelines
GSC		Global SDO coordination venue	Wireless charging system HIS (high interest subject) was established. 1) to facilitate a strong and effective standards collaboration on WCS in terms of protocol, regulatory and interoperability aspects; 2) to encourage participating standards organizations (PSOs) and others to cooperate in order to develop harmonized, globally-compatible, WCS-related standards; and 3) to consider both frequency issues and safety issues for WCS standardization.	Work plan and schedule TBD Ongoing industry standards activity for evolving WPT technologies

7.3.10 IEC TC 100

Table 23 below summarizes IEC TC 100 scope, status, deliverables and timelines.

Table 23 – IEC TC 100

Name	Type	Working group	Scope and status	Deliverables and timelines
IEC	SDO	TC 100	WPT Stage 0 project	Conduct WPT survey, 2012 Publish TR 2013
		TC 100	100/1961/NP new work item, management protocol of WPT for multi-devices	Approved August 2012 Allocated project # 62827/Ed.1 Work plan TBD
		TC 100	100/2069/NP New Work Item, Wireless Power Transfer – multiple sources control management	In ballot until January 2013

7.3.11 ISO/IEC JTC 1

Table 24 below summarizes ISO/IEC JTC 1 scope, status, deliverables and timelines.

Table 24 – ISO/IEC JTC 1

Name	Type	Working group	Scope and status	Deliverables and timelines
ISO/IEC	SDO	JTC1 SC6, SC 17, SC 25, SC27, SC31	Incubator Group convened to research the information and communication technology (ICT) issues which are related to wireless power transfer (WPT), such as wireless communication support, interoperability with NFC, convergence with RFID, WPT security Overall: Phase 0	High-level work plan listed in ISO/IEC JTC1 N 11018 dated 19-March-2012.
		SC6	N10934 new work item, PHY and MAC Layer Protocol of In-band Control for Wireless Power Transfer	Draft specification of PHY and MAC Layer Protocol of in-band control for wireless power transfer submitted with ballot. Progress to date – TBD.

7.3.12 ITU-R

Table 25 below summarizes ITU-R scope, status, deliverables and timelines.

Table 25 – ITU-R

Name	Type	Working group(s)	Scope and status	Deliverables and timelines
ITU-R	SDO	SG1 WP 1A	Question ITU-R 210-2/1	Report or recommendation by 2014

7.3.13 TTA – Telecommunications Technology Association

In Korea, TTA, following extended government (KCC, MKE) and industry (MFAN, KWPF) consultation has overall responsibility for WPT technical standards development. The scope of WPT technical standards development includes a broad range of core technologies (resonant and non-resonant) to be applied across a wide range of use cases from low-power CE WPT to high-power EV WPT. Consequently, some, but not all of the TTA WPT technical standards development may benefit from and contribute to potential future WPT work within the scope of IEC TC 100. TTA scope, status, deliverables and timeline are shown in Table 26 below.

Table 26 – Telecommunications Technologies Association (TTA)

Name	Type	Working group	Scope and status	Deliverables and timelines
TTA	SDO	PCG	Wireless Power Transmission Project Coordination Group Coordinates activities between: Radio Committee. TC3 PG 309 IT Applications Committee. TC4 PG 422 Mobile Committee. TC7 PG 709 Overall: Phase 0 – Phase 2.	
		TC3 PG 309	Human protection including EMI/EMC during WPT	
		TC4 PG 422	High-power WPT, e.g., EV	
		TC7 PG 709	Wireless charging applications WG 1 Service and Structure WG 2 Interface WG 3 Evaluation	Survey of users/service TR 2011 Use case analysis TR 2011 Requirements TR 2011 Efficiency – pending (See Bibliography)

7.3.14 UL – Underwriters Laboratories

Table 27 below summarizes UL scope, status, deliverables and timelines.

Table 27 – Underwriters Laboratories (UL)

Name	Type	Working group	Scope and status	Deliverables and timelines
UL		Standards Technical Panel (STP)	More of a safety standard, but its development had characteristics of an SDO process.	UL 2738

8 Review of WPT opportunities and challenges

8.1 General

This TR approached the question of WPT along four major axes: market, technology, regulation and technical standards development. The discussion below identifies challenges and opportunities in several of these areas. Clause 9 discusses the potential for work within the scope of IEC TC 100 that may address these challenges and potentially extend these opportunities.

8.2 Market

8.2.1 Interoperability

As experienced by the consumer, interoperability means that with respect to some kind of readily recognizable touchstone (e.g., logo or form factor) the consumer’s reasonable expectations are met that products should work properly together even if purchased separately. One can presume that such a typical consumer does not know or care to know about underlying regulatory, technology and standards issues. A vivid illustration can be given by considering the international traveller who, thanks to global cellular roaming, may continue normal use of his or her smartphone. Such a user will have the same need for convenient recharging as when at home.

8.2.2 Use cases

There is a broad range of WPT use cases that differ by required power levels, form factor, mobility, orientation and accessibility, among many other factors. A given WPT technology may be optimal in different use case categories. A given category may be subject to unique regulatory requirements (e.g., WPT for mobile CE in the home, in a vehicle, in a hospital room).

8.3 Technology and technical standards development

8.3.1 Competing WPT technologies

The market-based competition amongst WPT technologies extends into the technical standards development process in the form of multiple, parallel subcommittees. This may be an appropriate response as standards development organizations typically do not engage in technology selection. On the other hand, standards development may be accomplished more slowly in part due to the need for increased coordination and accommodation.

8.3.2 Parallel efforts

WPT technical standardization has been taken up by major telecommunications, mobile telecommunications and CE standards development organizations. Many of these bodies are focused on similar low-power and medium-power mobile CE WPT use cases. Duplication of effort is an early and critical challenge. Another challenge is that in order to meet the full range of identified WPT use cases, even in the category of CE and multimedia equipment WPT, it is not clear whether individually or collectively the current set of SDOs includes all of the stakeholders necessary to fully harmonize standards development for a global market.

8.3.3 Interoperability and multi-protocol support

Another consequence of parallel WPT technologies for standards development is increased complexity in achieving interoperability, if such can be obtained at all. The most obvious challenge to interoperability occurs at the WPT layer itself owing to incompatible operating frequencies. The physical layer chosen for control and signalling adds another challenge to interoperability. There is potential for interoperability at the control layer (at which the management messages and protocol reside) and at the WPT-application layer interface. (See Figure 4.)

9 Role for IEC TC 100

9.1 General

The following areas are recommended as suitable for discussion with the potential that they represent work areas within scope of IEC TC 100.

9.2 Market

9.2.1 Increase awareness and impact

Regulators, legislators, the business and trade press, the general press and consumers may benefit from IEC TC 100 participation in WPT technical standards development and related topics. Whether originating deliverables or working in conjunction with other leading SDOs and industry consortia, the IEC can lend its authoritative, inherently international voice to build common ground upon which many of the challenges facing the WPT market can be productively addressed.

9.2.2 Nomenclature harmonization

A specific area where there is a clear need for coordination and harmonization is in WPT nomenclature. Multiple, independent efforts have produced draft or published normative text. It is recommended that IEC TC 100 consider a global harmonization activity.

9.3 Technology

9.3.1 Technology taxonomy, use case and use case category harmonization

Subclause 5.1 concluded that use cases for CE and multimedia devices and equipment are very large in number. The survey in Clause 7 demonstrates that multiple, parallel efforts have produced draft use case and requirements types of analyses and documents; more are planned. Further, given the richness of CE and multimedia equipment related use cases, it seems natural to discuss use case “categories”. Today, such notions are ad hoc and may benefit from a systematic harmonization effort.

9.3.2 WPT classification

Given the diversity of CE and multimedia equipment form factors it seems reasonable that once WPT-enabled, such devices may generate a new product category of WPT-type “battery charger.” Surely there will not be a one-size-fits-all approach. It is recommended that IEC TC 100 be in a position to consider some kinds of electrical, mechanical or other performance-related metrics that can be used to segment especially the WPT-type charger product category. Areas include stand-by power consumption and efficiency, as a supplement to those already included in various regional “green” efforts.

9.4 Regulation

9.4.1 General

A recurring element in the IEC TC 100 WPT Survey responses was the suggestion that IEC TC 100 consider activities in support of open WPT regulatory questions. These were often stated as a prerequisite for effective organization and execution of any IEC TC 100 WPT technical standardization programme. Survey responses considered that IEC TC 100 has an authoritative, global voice that may assist regulators in their WPT agendas.

9.4.2 Product categorization

A critical first step in determining applicable regulation is product categorization. Regulators and industry are faced with a range of interrelated questions. Are WPT chargers and devices ISM equipment? Are they communications equipment? What kind of external power supplies do WPT chargers represent? Which regulatory framework should apply to WPT chargers and devices? Do existing efficiency standards form a barrier to WPT? Are changes required in recognition of the lower efficiencies obtained with WPT compared to wired approaches? IEC TC 100 either individually or in concert with other IEC TCs may provide valuable leadership towards global harmonization of key regulatory matters.

9.4.3 Spectrum

Many of the questions facing WPT industry and regulators depend upon the WPT operating frequency. Currently, products exist on the market in the <500 kHz range and others are targeting the ISM bands, 6,78 MHz and 13,56 MHz.. In each case there are unique issues. The opportunity exists for a globally harmonized discussion and conclusions.

9.4.4 RF emissions (EMI/EMC), RF exposure and regulatory engineering

Product categorization combined with spectrum allocation sets up questions regarding applicable regulations for EMI/EMC, for RF exposure (SAR) and methods for the demonstration of compliance. Are the current Rules and regulations sufficient? Are new categories or exceptions required? As the products themselves are new, are new regulatory engineering approaches required? There are, for example, proposals in circulation in various regions for a simulation-based approach to the demonstration of WPT compliance. There may be other valid approaches as well. The opportunity exists for a globally harmonized discussion and conclusions. IEC TC 100 either individually or in concert with other IEC TCs may provide valuable leadership towards global harmonization of key regulatory matters.

9.5 Technical standards development

9.5.1 Framework of WPT standards

Whether originated within IEC or derived cooperatively with other SDOs and private industry consortia, technical standards development appears to be within scope of IEC TC 100, and it is recommended that IEC TC 100 consider undertaking such development.

Given the state of maturity of the WPT market, it may be possible that the market will require multiple standards corresponding to each of the major core technology approaches. It is desirable that for a given WPT core technology choice there exist a single globally harmonized technical standard. Thus, IEC TC 100 may consider a concept of a framework of WPT standards and undertake such broad definition and coordination.

Solely for the purposes of illustration and understanding, a framework of WPT standards might take the following form. There might be one set of specifications that define aspects common to all WPT systems and provide obvious points of departure for individual technology choices. Example specifications may include those for nomenclature, for use case categorization, for a common WPT system reference model, for technology categorization, and for management and related “software-only” features, among others. There might then be an additional set of specifications each of which defines technology-specific aspects. Technology specificity might be defined firstly in terms of the subset of use cases targeted, the technology category occupied, and so on. Secondly, the technology-specific elements, most likely those pertaining to the WPT layer and signalling layer themselves, might be further defined.

A framework of WPT standards could feature a single base IEC standard number to which parts are added. The parts could correspond to individual documents that address WPT common elements or WPT technology-specific elements. The parts approach has the benefit of being extensible and adaptable as new technologies and new applications are submitted for standardization.

9.5.2 Interoperability

A common theme in the WPT Survey responses to recommendations for IEC TC 100 activity was interoperability. In the simplest case, WPT interoperability means a single power transmitting element interacting with a single power receiving element based on a common core technology to achieve power transfer. Generically, the core technology consists of a management protocol layer and a power transfer physical layer. Referring to Figure 5, the management protocol corresponds to the Control Protocol Layer and Signalling Method Layer, collectively. The power transfer physical layer corresponds to Figure 5 lowest layer (WPT Source, WPT Coupling, and WPT Device to Be Charged). An extension of this simple model is the case of a single common core technology and single power transmitting element, but multiple, simultaneous power receiving elements. A further generalization of the single common core technology scenario is that of a multiplicity of power transmitting elements interacting simultaneously with a multiplicity of power receiving elements to deliver WPT.

It is recommended that IEC TC 100 develop an understanding of the meaning of interoperability in the complex WPT market. To illustrate by analogy with mains-based charging, in many countries there are standardized physical interfaces (outlets and plugs) for domestic mains-powered devices and home appliances. The combination of outlet and plug type provides what consumers commonly experience as electrical interoperability. Mains-powered large home appliances such as refrigerators, washers and dryers, require a different class of outlets and plugs. The former and latter pairs are not interoperable. One physically cannot “plug in” a 120 V plug into a 220 V outlet.

WPT interoperability may benefit from a similar understanding as appropriately adapted for the wireless domain. There exist a multiplicity of WPT technologies no single one of which has been identified as optimal for the full range (mW – kW) of power levels and CE use cases. In the theoretically most general case, whether simultaneously or sequentially in space or time, multiple power transmitting devices may interact with a multiplicity of power receiving devices each of which utilizes a different WPT core technology (e.g., tightly-coupled or loosely-coupled). In such a case interoperability is more narrowly defined as possibly a common management protocol. That is, at the level of WPT session and power control, there may exist an opportunity to define technology agnostic protocols. However, there are important considerations of signalling latency, system availability and stability, and implementation complexity to be borne in mind.

At the power transfer physical layer itself, (i.e., Figure 5 lowest “WPT” layer) the power transmitting and power receiving elements could support simply one or more of the available core technologies in parallel, i.e., a multi-mode, multi-protocol configuration.

A challenge for any WPT technical standards development organization including IEC TC 100 will be to define work programs that balance the extent of available design choices with the need to create timely, high quality, globally harmonized specifications that can be implemented in a commercially feasible manner as consumer products.

9.5.3 Minimum performance testing and certification

Although not strictly within the scope of IEC TC 100, closely following the concept of a framework of WPT standards is the need for corresponding minimum performance standards and certification procedures. Whether such corresponds one-to-one per core technology or whether there exists sufficient commonality to create a globally harmonized minimum performance standard and certification procedures could have enormous benefit. Such benefit would be not only to the industrial base, but also to regulators who may optionally choose to include such specifications and procedures in the regulatory framework.

A challenge for the WPT industry will be to define minimum performance, certification and testing procedures that balance the extent of available design choices with the need to create timely, high quality, globally harmonized specifications that can be implemented in a commercially feasible manner as consumer products.

It is recommended that IEC TC 100 support the WPT industry through the development of WPT technical standards that respond to the requirements of commercially feasible minimum performance testing and certification protocols and procedures.

10 Summary and conclusions

The WPT market is in its early phases.

An addressable market exists as measured by the range of identified use cases and products offered for commercial sale to consumers, the numbers and types of market participants, among many other metrics.

The existing regulatory framework appears generally open to some of the earliest WPT product introductions. Regulators are addressing basic questions regarding efficient use of spectrum, human RF exposure, EMI and EMC in consultation with industry and academia. The full range of WPT use cases is not yet fully addressed and regulatory uncertainty remains a near-term feature of the WPT market.

Technology choices abound each with unique advantages in select applications spaces and use cases. There is no single WPT technology or approach that addresses the full range of identified use cases uniformly better than all other WPT technologies.

For WPT technical standardization, it is evident that the market currently supports the full range of strategies. These range from the de facto approach, whereby a consortium or individual company organizes to promote a select technology (including the development of technical specifications), to the creation of a global brand, to the traditional, formal consultative approach that engages regulators, legislators, industry and SDOs in a coordinated effort.

As there are many WPT use cases that include audio, visual and multimedia systems and equipment, it is recommended that WPT work be within scope of IEC TC 100.

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