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Benefits of Carbon Neutrality in a Rapidly Changing Business Environment

Frost & Sullivan
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Authors:
Frost & Sullivan
Jonathan Robinson, Principal Consultant
Ross Bruton, Senior Industry Analyst
Dr. Maximilian Wernicke, Consultant
Olivia Price-Walker, Principal Consultant

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Foreword

IDENTIFYING AND UNDERSTANDING the potential future pathways, development scenarios and their impacts is in the core of all strategic planning. It is of paramount importance to identify key megatrends and change drivers, their dynamics and impacts, and reflect the current state of the operations and goals to these future scenarios.

At Sitra, we believe that economic growth can be achieved through promoting business that solves global environmental and well-being challenges. Climate change and global warming are among the most severe challenges facing humanity, and greenhouse gas emissions need to be reduced – in ways that are economically sensible. Finland can be a forerunner in this field and take a role larger than its respective size. Finnish businesses can prosper by offering solutions to the global climate challenges, and gain access to a large and rapidly growing market.

From this standpoint Sitra, the Finnish Innovation Fund, has as a part of its focus area Carbon-neutral Industry wanted to picture the future outlook for clean and low-carbon solutions with Finnish industrial companies. A key question to address in this work has been to analyse how companies can turn low-carbon solutions and ecologically sustainable operations into a long-term strategic competitive advantage, and what is the size of the global potential. This report seeks to address both these questions through analysing the drivers of change in the global markets, the drivers of success and new business models in low-carbon solutions, and the size of the global markets until 2050.

In the analysis conducted by Frost&Sullivan, the key global megatrends from the perspective of low-carbon business were identified, and their impacts were analysed from the perspective of six important sectors to the Finnish economy: transport, energy, buildings, industry, water and waste, with bio-economy as a cross-cutting category.

This analysis portrays a picture about the size of the clean solutions markets globally, and hopefully serves as an inspiration to Finland and Finnish businesses in their quest for future sources of growth.

We wish to thank the authors and the whole project team, especially Specialist Janne Peljo from Sitra for guiding the work.

Helsinki, 23 September 2015

Mari Pantsar
Director
Resource-wise and carbon-neutral society

Tiina Kähö
Senior Lead
Carbon-neutral industry

Executive Summary

IN 2015 the global population will put 40bn tonnes of carbon emissions into the atmosphere. Greenhouse gas emissions are projected to roughly double in the next 50 years, with emissions growth driven primarily by carbon intensive industries in developing countries. Air pollution causes over 7 million premature deaths every year and climate change is causing ever more extreme weather conditions. In order to prevent further climate change, the global economy must radically evolve to one that is not primarily dependent on fossil fuels and better utilises alternative resources. This creates a significant business opportunity; the total cleantech market for the trends investigated in the report is expected to account for almost US$ 3 trillion per year by 2050, and this excludes the US$ 5 trillion market for electric vehicles. This is up from a size of US$ 597 billion in 2014.

Megatrends

Megatrends are transformative, global forces that will define our future through far reaching impacts on business, societies, economies, cultures and personal lives. These six trends are key drivers of carbon neutrality as a source of strategic competitive advantage and offer opportunities for industry: Climate Change, Future of Energy, Smart is the New Green, Future of Mobility, Urbanisation and Future Infrastructure Development.

- **Climate Change:** In order to stem the increase in global carbon emissions, business models will need to evolve to embrace low and zero carbon technologies, improve energy efficiency and promote the circular economy to eliminate waste.
- **The Future of Energy:** The energy sector will need to decarbonise, meaning massive deployment of clean technologies, supported by cost-effective storage, and business models that drive greater energy efficiency. The renewable energy market is forecast to account for over 40% of the global energy mix by 2050, amounting to an annual market of US$ 800 billion.
- **Smart is the New Green:** The market for smart cities will reach a phenomenal value of US$ 1.6 trillion globally by 2020 and by 2026 there will be 26 smart cities, half of which will be in Asia. Green products and services will be increasingly enhanced and traditional products replaced by smart products and services to ensure low carbon growth.
- **The Future of Mobility:** More than 2 billion light duty vehicles are expected to be on the roads in 2050, an increase from 900 million today. A smarter and highly integrated transport network, powered largely by electricity and low-emission fuels is vital for curbing future emissions growth.
- **Urbanisation:** 50% of the world's population lives in urban areas. This will increase to around 70% by 2050, transforming cities into enormous economic hubs and creating the phenomenon of 'Mega Cities'. Mega Cities will account for US$ 21 trillion of global GDP (nominal) by 2020. Partnerships between city governments, solution providers (businesses), and academia will become the working model for most future city projects which are vital in ensuring that this growth is not paralleled by proportional increases in carbon emissions.
- **The Future of Infrastructure:** Global investment into infrastructure development is expected to surpass US$ 27 trillion by 2025, with Asia-Pacific (APAC) accounting for a 37% share. Green construction materials, linked to circular use of material from existing buildings, will be a crucial low carbon development.

Core Market areas

In this analysis, the most attractive global cleantech opportunities for Finnish business in 2050 were derived from five core markets: transportation, energy systems, sustainable buildings, industrial processes, and water and waste management. In addition, the opportunities brought by the bioeconomy were considered across all these sectors.

Transportation

The projected global increase in the number of cars will create major challenges in terms of pollution and congestion, unless steps are taken to decarbonise transport and to improve overall transport integration and efficiency. This can be achieved through the electrification of vehicles, autonomous driving and integrated mobility solutions, enabled by increasing connectivity and rapidly growing trends in big data and predictive analytics. Frost & Sullivan forecasts that over 150 million electric and fuel cell vehicles

will be sold annually by 2050 constituting a US$ 4.7 trillion market, supported by an extensive infrastructure network and service market. Autonomous driving has the capability to reduce urban traffic congestion and enables Mobility-as-a-Service for everybody, anytime, anywhere. Annual revenues of advance driver assistance systems that enable automated driving will amount up to US$ 3.6 trillion by 2050. New integrated mobility services such as car, ride, bike and park sharing will further generate about US$ 176 billion in annual revenues by the same year.

This future vision will require significant changes in the transportation sector. The new business models envisaged will blur the lines between automotive manufacturers, electricity providers and ICT network companies; the latest indication of this is the acquisition of Nokia's *Here* mapping service for € 2.8 billion by Audi, Daimler and BMW. For eMobility, new opportunities of value creation and sources of competitive advantage are emerging in vehicle charging services, in leasing and sharing models and the overall integration of eMobility into home energy management systems and smart cities. Automated driving holds equal potential for both traditional original equipment manufacturers (OEMs) and potential new entrants who could control mobility integration. Mobility integration services will show particularly high value in multi-modal commuting. Integrated mobility will require market participants to conceptualise business models whereby all available traffic information and travel options are aggregated and analysed, and easy-to-use solutions provided to travellers. Realising such business models requires building strong collaborations and relationships between industries that previously did not extensively interact with one another.

Finland has already made significant strides in the development of real-time traffic data in order to allow for accurate management of road networks and communication with motorists. The country plans to develop its intelligent road traffic systems to create the most advanced and efficient transport system in the world by 2020. This could then be leveraged as a best in class example to win projects in other cities, both for product solutions and also for associated consultancy services.

Energy Systems

The energy market is changing fundamentally, with a shift from centralised to decentralised generation already underway in many geographic markets. The renewable energy market is forecast to account for over 40% of the global energy mix by 2050, amounting to an annual market of US$ 800 billion. Decentralised generation will lead the creation of a prosumer market, built on the foundations of battery energy storage and residential and commercial solar PV. The prosumer market is forecast to be worth US$ 120 billion by 2050, up from US$ 24 billion in 2014. This increase in value also masks the fact that technology costs for battery technologies are forecast to halve within a decade and fall further by 2050. The biofuel market in the transport sector is further expected to represent a significant market in the energy space, forecast to be worth US$ 757 billion by 2050. By 2050, biofuels have the potential to account for 27% of total transport fuels. This is an excellent opportunity for Finland – the bio-fuel sector is expected to represent the largest and fastest growing sector in the country's cleantech industry to 2020. Connected to this are further opportunities for the export of bio-based products for a range of different sectors.

This energy evolution is already changing the energy sector. Business models in the sector will be underpinned by consistently strong investment in decentralised generation and enabling smart grid technologies. Utility companies will be challenged by independent companies and will have to innovate to survive. Fundamental to this will be a stronger, more collaborative approach with customers as partners in power generation and an increased focus on energy service offerings to offset revenue losses from traditional conventional generation business models.

In the biofuel market, biotechnological innovation around increasing crop yield, efficient crop management and feedstock delivery are key to achieving market scalability. Future business models will include highly integrated value-chains from the perspective of both feedstock providers as well as manufacturers. Creation of new revenue streams through the development of associated product lines across the value chain in biochemical, bioplastics and biomaterials is further expected to represent a core requirement for scalability.

Sustainable Buildings

In 2015 cities used 75% of the world's energy and are responsible for 80% of energy-related carbon emissions. Within the next 20 years, 60% of the world's buildings will be built and rebuilt in urban areas. This creates a massive opportunity to reduce carbon emissions. New sustainable building materials and constructional know-how can improve energy efficiency by 60% to 90% compared to conventional buildings, but only if the new buildings are constructed using biomaterials and integrate the latest energy efficiency products and solutions. Annual revenues of green building materials will grow from less than US$ 150 billion in 2014 to over US$ 500 billion in 2050. Smart technology will create an opportunity to manage buildings far more efficiently than they do today using inter-connected sensors and data analytics. Home and buildings energy management systems in conjunction with X-as-a-Service (XaaS; 'anything-as-a-service') business models and energy harvesting solutions will reduce energy-related carbon emissions. By 2050 they are expected to reach annual market sizes of nearly US$ 100 billion and over US$ 50 billion respectively.

Finland has a competitive advantage in this field, thanks to the major strides in building energy efficiency over the past decade, necessitated by high energy costs. National government's targets to move toward zero or net positive energy buildings will provide further competencies that can be exploited internationally.

Industrial Processes

Widespread integration of wireless sensor networks feeding into cloud-based, big-data analytics platforms and machine-to-machine (M2M) communication interfaces will allow for new levels of control and automation in factory operations and management of global factory networks. Heightened levels of centralised remote management and automation, combined with the growth of 3D printing technologies will provide vastly increased flexibility in manufacturing processes, allowing for significant increased efficiencies in production and supply chain, reduced faults and maintenance costs, and highly customisable on-demand manufacturing to meet changing market needs. The smart factory and 3D printing markets are expected to reach annual market sizes of US$ 397 billion and US$ 207 billion respectively by 2050. The growth of smart factory technology and the development of best practice in technology integration is an immediate growing opportunity for Finland in key hi-tech manufacturing markets (e.g. USA, Germany, Japan, Singapore etc.).

Future business models will take into account demand for high degrees of manufacturing flexibility and product customisation, driving companies to integrate new smart technologies in manufacturing and supply chain processes. This, combined with closed-loop manufacturing processes and product designs flexible enough to allow high efficiencies in disassembly and re-manufacture, will become a strong competitive advantage. 3D printing will allow for instantaneous on-demand manufacturing of products by printing technology integrated into cloud based systems and analytics platforms that allow for adaptable designs based on required, or predicted, needs. Crowdsourcing R&D and product design will become an integral part of future business models, as manufacturers or retailers turn to online platforms to accept designs and ideas from innovators around the world.

Water and Waste Management

The integration of smart municipal waste technologies will represent a cornerstone of the overarching circular economy paradigm in cities striving for a zero waste future. These new smart technologies in waste recovery, sorting and processing will be essential to the management of a global production of 2.8 billion tonnes of municipal waste by 2050. The integration of smart water technologies in monitoring, remote management and automation of water grids will further assist in significantly reducing water losses amounting to a significantly high global average of approximately 30% of total water distribution in cities. The total market size for smart municipal solid waste, smart water markets and smart packaging markets are forecast to amount to US$ 32 billion, US$ 102 billion and US$ 178 billion respectively by 2050. This market growth forecast is dependent on companies integrating circular recovery waste management solutions into their businesses. This needs to happen across the entire value chain and can offer significant direct commercial benefits to companies if they are implemented effectively. Efficient resource recovery systems can also give rise to highly profitable second generation products.

Finland is already one of the most innovative countries globally in the waste management sector. Use of solid recoverable fuel (SRF) technologies that extract recyclable waste, remove organic waste and process the remaining waste into burnable fuel are already in operation. Expertise in the treatment of hazardous waste will become commercially important when the boom for lithium-ion batteries related to transport and energy starts.

Esipuhe

KAIKEN STRATEGISEN SUUNNITTELUN tai ylipäänsä tulevaisuuden toiminnan suunnittelun ytimessä on keskeisenä komponenttina tulevaisuuden erilaisten kehityssuuntien hahmottaminen ja niiden vaikutusten arviointi. Olennaista on keskeisten megatrendien ja muutosajureiden tunnistaminen, niiden dynamiikan ymmärtäminen ja vaikutusten arviointi, sekä oman toiminnan nykytilan ja tavoitteiden peilaaminen erilaisiin skenaarioihin toimintaympäristön muutoksista tulevaisuudessa.

Me Sitrassa uskomme, että talous saadaan kasvuun edistämällä liiketoimintaa, joka ratkoo maailman ekologisia ja hyvinvointiin liittyviä ongelmia. Ilmastonmuutos ja siihen liittyvä ilmaston lämpeneminen ovat yksi vakavimmista koko ihmiskuntaa uhkaavista haasteista, ja ilmastonmuutoksen hillitsemiseksi kasvihuonekaasupäästöjä on rajoitettava – taloudellisesti järkevällä tavalla. Tässä Suomi voi olla edelläkävijä ja kokoaan suuremmassa roolissa, ja suomalaiset yritykset voivat menestyä tarjoamalla ratkaisuja maailman ilmastohaasteisiin ja päästä käsiksi suureen ja nopeasti kasvavaan markkinaan.

Tätä taustaa vasten Sitra on osana Hiilineutraali teollisuus -avainaluetta pyrkinyt hahmottamaan tulevaisuuden näkymiä puhtaiden ja vähäpäästöisten ratkaisujen näkökulmasta yhteistyössä suomalaisten teollisuusyritysten kanssa. Keskeisenä kysymyksenä on tarkasteltu sitä, miten yritykset voivat tehdä vähähiilisistä ratkaisuista ja ekologisesti kestävästä liiketoiminnasta pitkän aikavälin strategisen kilpailuedun lähteen, ja minkä kokoisesta mahdollisuudesta on globaalisti kyse. Tämä raportti pyrkii vastaamaan näihin molempiin kysymyksiin, analysoiden globaalien markkinoiden muutosajureita, vähähiilisten ratkaisujen menestyksen kulmakiviä ja uusia liiketoimintamalleja, sekä puhtaiden ratkaisujen markkinoiden kokoa vuoteen 2050 saakka.

Yhteistyössä konsulttiyhtiö Frost&Sullivanin kanssa tehdyssä analyysissä olemme tunnistaneet vähähiilisen liiketoiminnan kannalta keskeiset globaalit megatrendit ja analysoineet niiden vaikutuksia kuuden Suomen kannalta tärkeän sektorin näkökulmasta (energia, vesi ja jätehuolto, liikenne, rakentaminen ja teollisuus sekä biotalous poikkileikkaavana kategoriana).

Analyysi piirtää kuvaa siitä, minkä kokoinen puhtaiden ratkaisujen markkina maailmalla on kehittymässä, ja siten toivottavasti toimii hyvänä innoituksen lähteenä Suomelle ja suomalaisille yrityksille, kun pohditaan tulevaisuuden kasvun lähteitä.

Kiitämme projektiryhmää ja erityisesti merkittävän panoksen työtä ohjatessaan antanutta Sitran asiantuntija Janne Peljoa.

Helsingissä 23.9.2015

Mari Pantsar
johtaja
Resurssiviisas ja hiilineutraali yhteiskunta

Tiina Kähö
avainalueen vetäjä
Hiilineutraali teollisuus

Tiivistelmä

VUONNA 2015 maailman väestö päästää ilmakehään yhteensä 40 miljardia tonnia hiilidioksidia. Kasvihuonekaasupäästöjen on arvioitu suunnilleen kaksinkertaistuvan seuraavien 50 vuoden kuluessa, ja kasvun moottorina toimivat ensisijaisesti kehittyvien maiden hiili-intensiiviset teollisuudenalat. Ilmansaasteet aiheuttavat yli seitsemän miljoonaa ennenaikaista kuolemaa joka vuosi ja ilmastonmuutoksesta johtuvat sään ääri-ilmiöt pahenevat entisestään. Jotta ilmastonmuutoksen eteneminen voitaisiin estää, maailmantalouden tulisi kehittyä radikaalisti suuntaan, jossa ensisijainen riippuvuutemme fossiilisista polttoaineista vähenisi ja vaihtoehtoisia energialähteitä ja resursseja hyödynnettäisiin paremmin. Tämä luo merkittäviä liiketoimintamahdollisuuksia. Raportissa tutkittujen trendien osalta cleantech-markkinoiden arvon odotetaan vuoteen 2050 mennessä nousevan yhteensä lähes 3 biljoonaan dollariin vuodessa, eivätkä lukuun edes sisälly 5 biljoonan dollarin sähköautomarkkinat. Vuonna 2014 kyseisten markkinoiden arvo oli 597 miljardia dollaria.

Megatrendit

Megatrendit ovat maailmanlaajuisia voimia, jotka muuttavat maailmaa ja määrittelevät tulevaisuutemme suuntaa kauaskantoisten liiketoimintaa, yhteiskuntaa, taloutta, kulttuuria sekä kunkin omaa elämää koskettavien vaikutusten kautta. Seuraavat kuusi trendiä ovat hiilineutraaliuden tärkeimpiä ajureita, sillä ne tarjoavat strategista kilpailuetua sekä mahdollisuuksia teollisuudelle: Ilmastonmuutos, Tulevaisuuden energia, Älykkäät vihreät ratkaisut, Tulevaisuuden liikkuminen, Kaupungistuminen ja Tulevaisuuden infrastruktuurien kehittyminen.

- **Ilmastonmuutos**: Jotta hiilidioksidipäästöjen maailmanlaajuinen kasvu voidaan pysäyttää, liiketoimintamallien on kehityttävä siten, että ne tukevat vähähiilisten ja hiilivapaiden teknologioiden käyttöä, parantavat energiatehokkuutta ja edistävät kiertotaloutta jätteiden eliminoimiseksi.
- **Tulevaisuuden energia**: Energiasektorin tulee vähentää hiilidioksidipäästöjään. Käytännössä tämä tarkoittaa puhtaiden teknologioiden laajamittaista käyttöönottoa, jota tuetaan kustannustehokkaan varastoinnin ja energiatehokkuuden parantamiseen tähtäävien liiketoimintamallien avulla. Vuoteen 2050 mennessä uusiutuvan energian markkinoiden on ennustettu kattavan yli 40 prosenttia maailman energiantarjonnasta ja yltävän markkinakooltaan 800 miljardiin dollariin vuodessa.
- **Älykkäät vihreät ratkaisut**: Markkinat älykkäiden kaupunkien luomiseksi nousevat ilmiömäiseen 1,6 biljoonaan dollariin vuoteen 2020 mennessä. Vuoteen 2026 mennessä on muodostunut jo 26 älykästä suurkaupunkia, näistä puolet Aasiassa. Vihreiden tuotteiden ja palveluiden käyttöä tehostetaan kasvavassa määrin. Älytuotteet ja palvelut korvaavat perinteisiä tuotteita, jotta pystytään saavuttamaan vähähiilistä kasvua.
- **Tulevaisuuden liikkuminen**: Vuoteen 2050 mennessä liikenteessä olevien kevytajoneuvojen määrän odotetaan kasvavan nykyisestä 900 miljoonasta yli 2 miljardiin. Älykkäämpi, pitkälle integroitu ja laajalti sähkön sekä vähäpäästöisten polttoaineiden varassa toimiva liikenneverkko on täten elintärkeä, jotta hiilidioksidipäästöjen kasvu voidaan estää tulevaisuudessa.
- **Kaupungistuminen**: 50 prosenttia maailman väestöstä elää nykyisin kaupunkialueilla. Vuoteen 2050 mennessä heidän osuutensa kasvaa edelleen noin 70 prosenttiin, jolloin kaupungit muuttuvat valtaviksi talouskeskittymiksi ja syntyy niin sanottuja megakaupunkeja. Vuonna 2020 megakaupunkien osuus maailman (nimellisestä) bruttokansantuotteesta on 21 biljoonaa dollaria. Kaupunkien johdon, ratkaisuntarjoajien (yritysten) sekä yliopistomaailman välisistä kumppanuuksista tulee yleinen toimintamalli useimmissa tulevaisuuden kaupunkihankkeissa, jotka ovat välttämättömiä sen varmistamiseksi, ettei kaupunkien kasvu lisää hiilidioksidipäästöjä vastaavassa määrin.
- **Tulevaisuuden infrastruktuuri**: Maailmanlaajuisesti infrastruktuurin kehittämiseen käytettävien investointien määrän odotetaan nousevan yli 27 biljoonaan dollariin vuoteen 2025 mennessä, ja tästä Aasian ja Tyynenmeren alueen (APAC) osuus on 37 prosenttia. Vihreiden rakennusmateriaalien käyttö yhdistettynä rakennusmateriaalien kierrätykseen on tärkeä kehitysaskel matalahiilisen tulevaisuuden kannalta.

Tärkeimmät markkinasektorit

Tässä analyysissä houkuttelevimmat maailmanlaajuiset cleantechin tuomat mahdollisuudet suomalaisille yrityk-

sille vuoteen 2050 asti nousivat viideltä keskeiseltä sektorilta: liikenne, energiajärjestelmät, kestävät rakennukset, teolliset prosessit sekä vesi ja jätehuolto. Lisäksi biotalouden mahdollisuuksia tarkasteltiin poikkileikkaavasti kaikilla näillä sektoreilla.

Liikenne

Ennustettu maailmanlaajuinen autojen määrän kasvu aiheuttaa merkittäviä haasteita saasteiden ja liikenneruuhkien muodossa, ellei samalla ryhdytä toimiin liikenteen hiilidioksidipäästöjen vähentämiseksi sekä liikenteen yleisen integraation ja tehokkuuden lisäämiseksi. Tavoitteet voidaan saavuttaa ajoneuvojen sähköistämisen, itse ajavien autojen ja integroitujen mobiilisovellusten avulla, joiden käytön lisääntyvä yhdistettävyys sekä nopeasti kasvavat big dataan ja ennustavaan analytiikkaan liittyvät trendit mahdollistavat. Frost & Sullivan ennustaa, että vuonna 2050 sähkö- ja polttokennokäyttöisiä ajoneuvoja myydään vuosittain 150 miljoonaa kappaletta. Tästä muodostuu 4,7 biljoonan dollarin markkinat, joita kattavat infrastruktuuriverkostot ja palvelumarkkinat tukevat. Itse ajavien autojen avulla on mahdollista vähentää kaupunkien liikenneruuhkia, ja se mahdollistaa liikkumisen tarjoamisen palveluna (MaaS, Mobility-as-a-Service) kaikille, missä ja milloin tahansa. Kuljettajan tukijärjestelmät, jotka mahdollistavat automaattisen ajamisen ja itseohjautuvat autot, voivat vuoteen 2050 mennessä tuottaa 3,6 biljoonan dollarin vuosittaisen liikevaihdon. Uudet integroidut liikkuvuuspalvelut, kuten autojen, ajomatkojen, polkupyörien ja parkkipaikkojen jakamispalvelut, tuottavat lisäksi noin 176 miljardin dollarin liikevaihdon samaan vuoteen mennessä.

Tämän tulevaisuuden vision toteutuminen vaatii merkittäviä muutoksia liikennesektorilla. Tulevaisuuden uudet liiketoimintamallit hämärtävät rajoja autonvalmistajien, sähköntoimittajien sekä ICT-alan yritysten välillä. Viimeisimpänä viitteenä tästä nähtiin kauppa, jolla Audi, Daimler ja BMW ostivat Nokian Here-karttapalvelun 2,8 miljardilla eurolla. eMobility-palvelut tarjoavat uusia mahdollisuuksia luoda arvoa ja saavuttaa kilpailuetua muun muassa sellaisilla aloilla kuten ajoneuvojen latauspalvelut, vuokraus- ja yhteiskäytön palvelumallit sekä eMobility-palveluiden integroiminen kodin energiankäytön hallintajärjestelmiin ja älykkäisiin kaupunkeihin. Automaattisen ajamisen ratkaisut tarjoavat liiketoimintamahdollisuuksia yhtä lailla alkuperäisille laitevalmistajille (OEM) kuin uusille tulokkaille, jotka voisivat hallita liikkuvuuden integraatiota. Liikkuvuuden integraatioon liittyvien palveluiden arvo on erityisen suuri monimuotoisessa työmatkaliikenteessä. Integroidun liikkuvuuden järjestelmän luomiseksi markkinaosapuolten on luotava liiketoimintamalleja, joiden avulla kaikki käytettävissä oleva liikennetieto ja matkustusmahdollisuudet yhdistetään ja analysoidaan sekä tarjotaan matkustajille helppokäyttöisten ratkaisujen muodossa. Tällaisten liiketoimintamallien toteuttaminen vaatii vahvojen yhteistyösuhteiden ja kumppanuuksien rakentamista sellaisten alojen välille, joilla aiemmin on ollut varsin vähän vuorovaikutusta keskenään.

Suomi on jo ottanut merkittäviä askeleita reaaliaikaisen liikennetiedon kehittämisessä, jotta liikenneverkoston täsmällinen hallinta ja kommunikointi autoilijoiden kanssa olisi mahdollista. Kansallisena tavoitteena on kehittää älykkäitä tieliikennejärjestelmiä maailman edistyksellisimmän ja tehokkaimman liikennejärjestelmän luomiseksi vuoteen 2020 mennessä. Tätä voitaisiin sitten hyödyntää luokkansa parhaana esimerkkinä, jotta ratkaisuja – niin tuotesovelluksia kuin niihin liittyviä konsultointipalveluitakin – saataisiin myytyä myös muihin maihin ja kaupunkeihin.

Energiajärjestelmät

Energiamarkkinat ovat muuttumassa perusteellisesti, kun useat maailman markkinoista ovat jo siirtymässä keskitetystä energiantuotannosta hajautettuun tuotantoon. Vuoteen 2050 mennessä uusiutuvan energian markkinoiden on ennustettu kattavan yli 40 prosenttia maailman energiantarjonnasta ja olevan kooltaan 800 miljardia dollaria vuodessa. Hajautettu energiantuotanto johtaa tuottaja/kuluttaja-markkinoiden syntymiseen, jotka on rakennettu energian akkuvarastoinnin sekä asuntokohtaisten ja kaupallisten aurinkokennojen varaan. Vuoteen 2050 mennessä tuottaja/kuluttaja-markkinoiden arvon ennustetaan kasvavan 120 miljardiin dollariin, kun se vuonna 2014 oli noin 24 miljardia dollaria. Tämä markkinoiden kasvu peittää alleen myös sen, että akkuteknologian kustannusten on ennustettu puolittuvan vuosikymmenessä ja putoavan edelleen vuoteen 2050 mennessä. Liikennesektorin biopolttoaineiden markkinoiden odotetaan myös edustavan merkittävää energia-alan markkina-aluetta, jonka arvon vuonna 2050 ennustetaan olevan 757 miljardia dollaria.

Vuoteen 2050 mennessä biopolttoaineilla on mahdollista kattaa 27 prosentin osuus liikennepolttoaineiden kokonaiskäytöstä. Tämä on Suomelle erinomainen liiketoimintamahdollisuus: biopolttoainesektorin odotetaan olevan suurin ja nopeimmin kasvava cleantech-teollisuuden ala Suomessa vuoteen 2020 mennessä. Tähän liittyy lisäksi mahdollisuuksia viedä biopohjaisia tuotteita myös monille muille aloille.

Tämä energiankäytön muutos muuttaa jo nyt energiasektoria. Jatkuva vahva panostaminen hajautettuun energiantuotantoon ja älykkäiden verkkoteknologioiden mahdollistaminen tukevat tämän sektorin liiketoimintamalleja. Uudenlaiset yhtiöt haastavat perinteiset energiantuottajat, jotka joutuvat etsimään uusia innovaatiota selvitäkseen hengissä. Kehityksen oleellisia elementtejä ovat entistä vahvempi ja yhteistyökeskeisempi lähestymistapa, jossa asiakkaat nähdään energiantuotannon kumppaneina, sekä entistä suurempi energiaan liittyvän palvelutarjonnan painottaminen, jonka avulla katetaan perinteisten energiantuotannon liiketoimintamallien laskua.

Biopolttoaineiden markkinoilla satoisuuden lisäämiseen, tehokkaaseen sadonhallintaan ja raaka-ainetoimituksiin liittyvät bioteknologiset keksinnöt ovat keskeisiä tekijöitä markkinoiden skaalautuvuuden saavuttamisessa. Tulevaisuuden liiketoimintamalleihin kuuluvat sekä raaka-ainetoimittajien että -tuottajien kannalta pitkälle integroidut arvoketjut. Kehittämällä koko arvoketjun kattavia tuotelinjoja biokemian, biomuovien ja biomateriaalien alalla saadaan luotua uusia tulovirtoja, minkä odotetaan myös olevan yksi keskeisistä skaalautuvuuteen liittyvistä vaatimuksista.

Ympäristöystävälliset rakennukset

Vuonna 2015 kaupunkien osuus maailman energiankäytöstä oli 75 prosenttia, ja ne aiheuttivat 80 prosenttia energiaan liittyvistä hiilidioksidipäästöistä. Seuraavien 20 vuoden aikana 60 prosenttia maailman rakennuksista rakennetaan tai korjataan kaupunkialueilla, mikä tarjoaa huomattavia mahdollisuuksia vähentää hiilidioksidipäästöjä. Uudet ympäristöystävälliset rakennusmateriaalit ja rakennusosaaminen voivat parantaa energiatehokkuutta 60–90 prosentilla perinteisiin rakennuksiin verrattuna, mutta vain siinä tapauksessa, että uudet rakennukset rakennetaan käyttäen biomateriaaleja ja niihin integroidaan viimeisimpiä energiatehokkuusratkaisuja. Vihreiden rakennusmateriaalien markkinat kasvavat vuoden 2014 alle 150 miljardista dollarista yli 500 miljardiin vuonna 2050. Älykäs teknologia luo mahdollisuuden hallita rakennuksia huomattavasti nykyistä tehokkaammin toisiinsa liitettyjen sensoreiden ja kerätyn tiedon analytiikan avulla. Kodin ja rakennusten energianhallintajärjestelmät yhdessä palvelullistamisen (X-as-a-Service) liiketoimintamallien ja energian harvestointiratkaisuiden kanssa vähentävät energiaan liittyviä hiilidioksidipäästöjä. Vuoteen 2050 mennessä näistä ensin mainitun vuosittaisen markkinan arvon odotetaan kasvavan lähes 100 miljardiin dollariin ja jälkimmäisen yli 50 miljardiin dollariin.

Suomella on tällä alalla kilpailuetu puolellaan sen johdosta, että olemme viime vuosikymmenen kuluessa joutuneet huomattavasti kehittämään rakennusten energiatehokkuutta korkeiden energiakustannusten vuoksi. Suomen hallituksen tavoite edetä kohti nollaenergia- tai energiapositiivista rakentamista tuottaa lisäosaamista, jota voi myös hyödyntää kansainvälisesti.

Teolliset prosessit

Tietonsa pilvipohjaisiin big data -analytiikka-alustoihin ja koneiden välisiin (M2M) käyttöliittymiin syöttävien langattomien sensoriverkkojen laajamittainen integrointi mahdollistaa tehdastoimintojen valvonnan ja automatisoinnin sekä globaalien tehdasverkostojen hallinnan aivan uusilla tasoilla. Tehostettu keskitetyn etähallinnan ja automaation käyttö yhdistettynä 3D-tulostustekniikoiden kasvuun tuovat yhä suurempaa joustavuutta valmistusprosesseihin, mikä mahdollistaa tuotanto- ja toimitusketjun merkittävän tehostamisen ja pitkälle räätälöityjen tuotteiden tilausvalmistuksen markkinoiden muuttuvien tarpeiden mukaisesti sekä vähentää virheitä ja huoltokustannuksia. Vuoteen 2050 mennessä älykkään teollisuuden markkinoiden odotetaan kasvavan arvoltaan 397 miljardiin dollariin ja 3D-tulostuksen 207 miljardiin dollariin vuodessa. Älykkään tehdasteknologian kasvu ja teknologiaintegraation parhaiden käytäntöjen kehittäminen tarjoavat Suomelle välittömät kasvumahdollisuudet tärkeimmillä huipputeknologian valmistusmarkkinoilla (USA, Saksa, Japani, Singapore jne.).

Tulevaisuuden liiketoimintamalleissa otetaan huomioon korkeat tuotannon joustavuutta ja tuotteen räätälöitävyyttä koskevat vaatimukset, mikä ajaa yrityksiä soveltamaan uusia älykkäitä teknologioita valmistuksessaan ja toimitusketjunsa prosesseissa. Näistä tulee vahva kilpailuetu, etenkin kun ne yhdistetään suljetun kierron tuotantoprosesseihin sekä niin joustavaan tuotesuunnitteluun, että myös laitteiden ja rakenteiden uusiokäyttö toimii tehokkaasti. 3D-tulostus mahdollistaa tilaustuotteiden välittömän valmistuksen pilvipohjaisiin järjestelmiin ja analytiikka-alustoihin integroidun tulostustekniikan avulla, sallien muunneltavien mallien käytön vaadittujen tai ennustettujen tarpeiden mukaan. Joukkoistetusta tutkimus- ja kehitystyöstä sekä tuotesuunnittelusta tulee

olennainen osa tulevaisuuden liiketoimintamalleja, kun valmistajat ja jälleenmyyjät hyödyntävät verkkoalustoja ja ottavat vastaan kehittäjien suunnitelmia ja ideoita eri puolilta maailmaa.

Vesi ja Jätehuolto

Älykkäiden yhdyskuntajäteteknologioiden integrointi toimii läpileikkaavan kiertotalouden kulmakivenä kaupungeissa, jotka pyrkivät kohti jätteetöntä tulevaisuutta. Nämä älykkäät jätteiden talteenotto-, lajittelu- ja jalostusteknologiat ovat ratkaisevassa asemassa maailmassa vuonna 2050 tuotettavan 2,8 miljardin tonnin yhdyskuntajätemäärän käsittelyn kannalta. Älykkäiden vesiteknologioiden integrointi vesiverkostojen valvontaan, etähallintaan ja automaatioon auttaa edelleen vähentämään vesihukkaa, joka maailmanlaajuisesti yltää varsin korkeaan keskiarvoon eli noin 30 prosenttiin kokonaisvedenjakelusta kaupungeissa. Älykkäiden kiinteän yhdyskuntajätteen markkinoiden ennustetaan olevan suuruudeltaan 32 miljardia, älykkäiden vesimarkkinoiden 102 miljardia ja älykkäiden pakkausmateriaalien markkinoiden 178 miljardia dollaria vuoteen 2050 mennessä. Tämän ennustetun kasvun toteutuminen riippuu siitä, integroivatko yritykset jätehuollon kierrätys- ja talteenottoratkaisuja liiketoimintaansa. Tämän olisi myös tapahduttava läpi koko arvoketjun. Tehokkaasti toteutettuna ratkaisujen käyttö voi tarjota yrityksille merkittäviä välittömiä liiketaloudellisia etuja. Tehokkaat materiaalien talteenottojärjestelmät voivat myös luoda hyvin tuottoisia toisen sukupolven tuotteita.

Suomi on jo nyt yksi maailman innovatiivisimmista maista jätehuollon alalla. Suomessa käytetään jo kierrätyspolttoainetekniikoita (solid recoverable fuel, SRF), joilla kierrätyskelpoinen jäte otetaan talteen, orgaaninen jäte poistetaan ja jäljelle jäävä jäte muunnetaan polttokelpoiseksi kierrätyspolttoaineeksi. Ongelmajätteiden käsittelyyn liittyvästä osaamisesta tulee kaupallisesti merkittävää, kun liikenne- ja energiakäyttöön tarkoitettujen litiumioniakkujen buumi alkaa.


NAUTICA

Sitra studies 102
Benefits of Carbon Neutrality in a Rapidly Changing Business Environment
Frost & Sullivan
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Contents

1 Introduction and Methodology

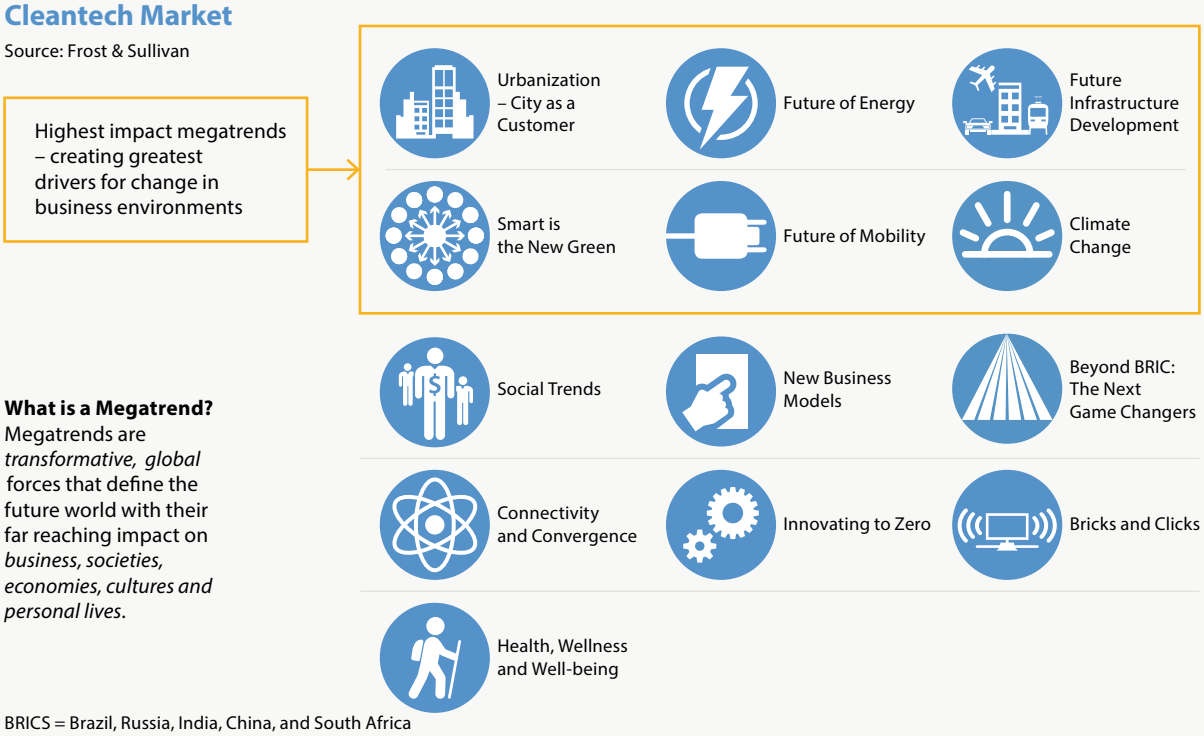
AS PART OF ITS PROGRAMME to accelerate Finland's industrial transformation toward a carbon-neutral society, Sitra commissioned this study to identify the global megatrends and subtrends that will enable the identification of global cleantech opportunities for Finnish business. The most attractive opportunities were derived from five core markets, namely transportation (eMobility, autonomous driving, and integrated mobility), energy systems (smart grids, prosumer, battery energy storage and bioenergy), sustainable buildings (energy management, biomaterials and energy harvesting), industrial processes (smart factory and 3D printing), and water and waste management (smart municipal waste and water management and smart packaging). Furthermore, the opportunities for bioeconomy were considered across all sectors.

The research was structured in two phases. In Phase I, Frost & Sullivan evaluated the importance and impact of megatrends on both the business environment and the development of the selected sectors. Megatrends expected to show the largest impact on the global cleantech industry were identified and analysed.

In Phase II, the industry and market impacts of megatrends were analysed to identify and assess opportunities for business represented by the deployment of low carbon solutions (i.e. clean technology) in the selected sectors globally. High impact cleantech sub-trends, resulting from the megatrends analysed, were identified and prioritised in terms of their expected global commercial opportunity and relative impact on carbon emission reduction. This was done through direct engagement with key industry stakeholders, workshops

Figure 1: Prioritisation and Selection of Megatrends based on Expected Impact on Cleantech Market

Source: Frost & Sullivan



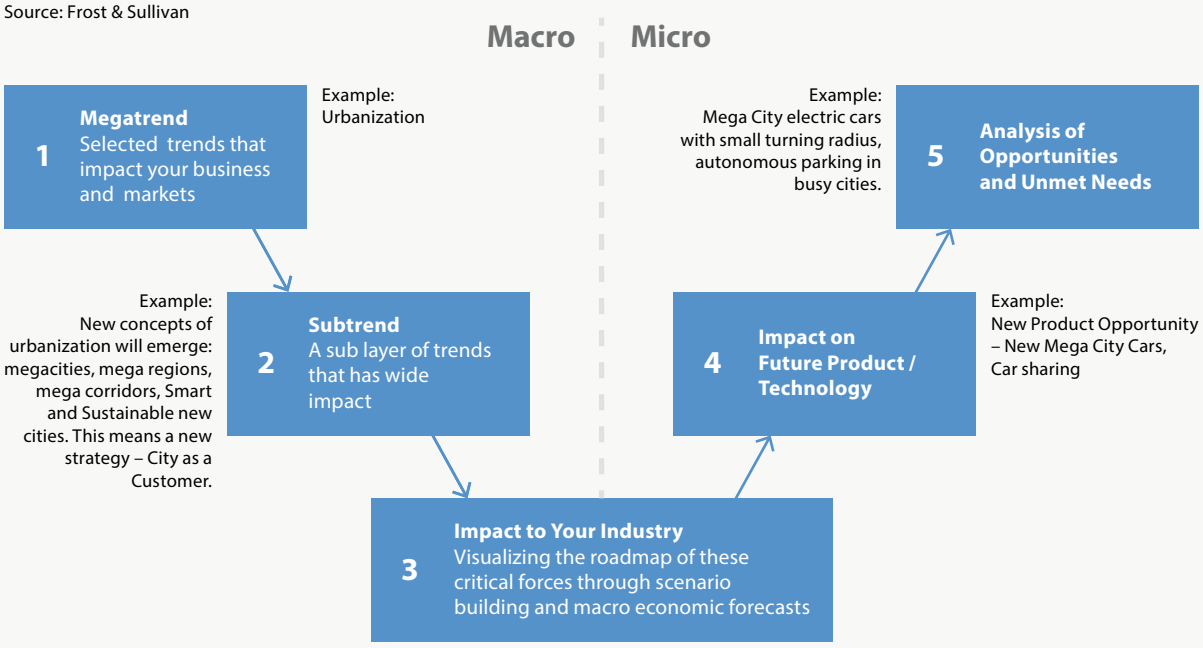
BRICS = Brazil, Russia, India, China, and South Africa

held with market participants, and supporting research and in-house expertise held within Frost & Sullivan's global network.

Following identification of the key subtrends, a far reaching assessment of the commercial opportunity represented by these trends was forecast over the 2014 to 2050 period. Analysis of the market impact of these trends was conducted within each of the selected sectors, key winning product categories were identified, and future business models were assessed, providing an understanding of key considerations for business into the future. Finally, an understanding of the relative opportunity for Finland represented by these trends was provided.

Figure 2: Opportunity Analysis based on Resulting Subtrends

Source: Frost & Sullivan



Example: People in future cities will want "personal mobility" not necessarily cars to commute to work. This will lead to need for integrated mobility combining all forms of transport including cars and new business models like car sharing (e.g Zipcar)

2 Megatrends

2.1 Introduction to Megatrends

Megatrends are transformative, global forces that define the future world with far reaching impact on business, societies, economies, cultures and personal lives to 2050. The implications of these megatrends are high impact – they have the power to change a large city or a nation and they have the power to affect the life of a single individual. They can affect revenues, costs and profitability for businesses as well as affect commuting trends, social networking, and the availability of natural resources.

Challenges and monumental questions are arising across virtually every industry. In the energy sector, will we satisfy the growing energy requirements of a highly connected and power-hungry global population increasingly concentrated in urban environments and entirely dependent on vulnerable power grids? In the transport sector, will we empower our increasingly urbanised global population with multi-modal (person and freight) transport solutions that will be affordable for all our citizens? And across all industries, how will we successfully ensure a sustainable planet for future generations?

To build a sustainable future, initiatives to reduce carbon emissions are no longer a simple strategic option, they are a global imperative. This critical need creates a significant opportunity for businesses to meet the demand for efficient and sustainable products and services. But how can businesses innovate to meet this growing challenge, with new business models, products and services that make sense for corporations and even serve as a strategic competitive advantage?

A thorough analysis of these megatrends and their implications is a vital component of any company's future strategy, development and innovation process. Effective megatrend planning supports long term sustainable growth and will provide the building blocks necessary to

Figure 3: Global Megatrends

Source: Frost & Sullivan

BRICS = Brazil, Russia, India, China, and South Africa

succeed and grow in a business environment shaped by the pressure to pursue a zero carbon future.

To build a sustainable future, initiatives to reduce carbon impact are no longer a simple strategic option, they are a global imperative. This creates a significant opportunity for businesses to meet the demand for efficient and sustainable products and services.

2.1.1 Top 6 Trends Shaping Key Sectors and Businesses

The best way to unlock the potential in creating a carbon-neutral future is to start at the top: the global megatrends that are defining the future challenges and opportunities for society as a whole (see Figure 3).

Starting from these 12 megatrends and asking simple questions about businesses' biggest challenges in terms of demographics, technology, lifestyle expectations and basic needs, we can quickly see huge opportunities for carbon-neutral innovation and new business models – a critical demand for sustainable products and services. To understand the drivers for change businesses can react to, this study will take a deeper look at the 6 megatrends that rise to the surface in terms of the carbon-neutral opportunity. These 6 prioritised megatrends are: Climate Change, Future of Energy, Future of Mobility, Future of Infrastructure, Smart is the New Green and Urbanisation.

The following sections will introduce and discuss the most dynamic elements of these 6 key megatrends, their impact on our future world and the consequent global opportunity for sustainable innovation.

2.2 Megatrend One: Climate Change

KEY ISSUES: resource nexus, smart water systems and waste for value, circular economy, resource wisdom, internalised carbon cost/price, emission reduction

Climate change is a long-term shift in the planet's average temperatures and resultant weather patterns. There is a growing body of evidence that the warming is due to the accelerating quantities of greenhouse gases in the atmosphere. This megatrend represents the core driver for zero carbon initiatives which are driven by governments and cities through regulation, by companies through innovation and by consumers through increasing awareness and changing behavioural patterns.

Carbon dioxide (CO_2) has a 'forcing' effect in that it increases the effect of global warming. The increase in concentration is mainly caused by emissions from human activity. The amount of CO_2 in the atmosphere has increased dramatically – by circa 35% – since the Industrial Revolution. As the need for energy drives the use of fossil fuels alongside other carbon intensive activities the amount of CO_2 will continue to rise. CO_2 lasts for about 100 years or more – some of the CO_2 in the atmosphere was emitted before World War I.

Zero or low-carbon initiatives are driven by governments and cities through regulation, by companies through innovation and by consumers through increasing awareness and changing behavioural patterns.

In 2015 the global population will put 40bn tonnes of carbon emissions into the atmosphere. Air pollution causes over 7 million premature deaths every year and all over the world countries are experiencing extreme weather conditions. Greenhouse gas emissions are projected to

roughly double in the next 50 years, with emissions growth driven primarily by carbon intensive industries (such as transportation and industrial processes) in developing countries. Such growth may lead to global average surface temperature increases of 3°C to 6°C by the end of the century.

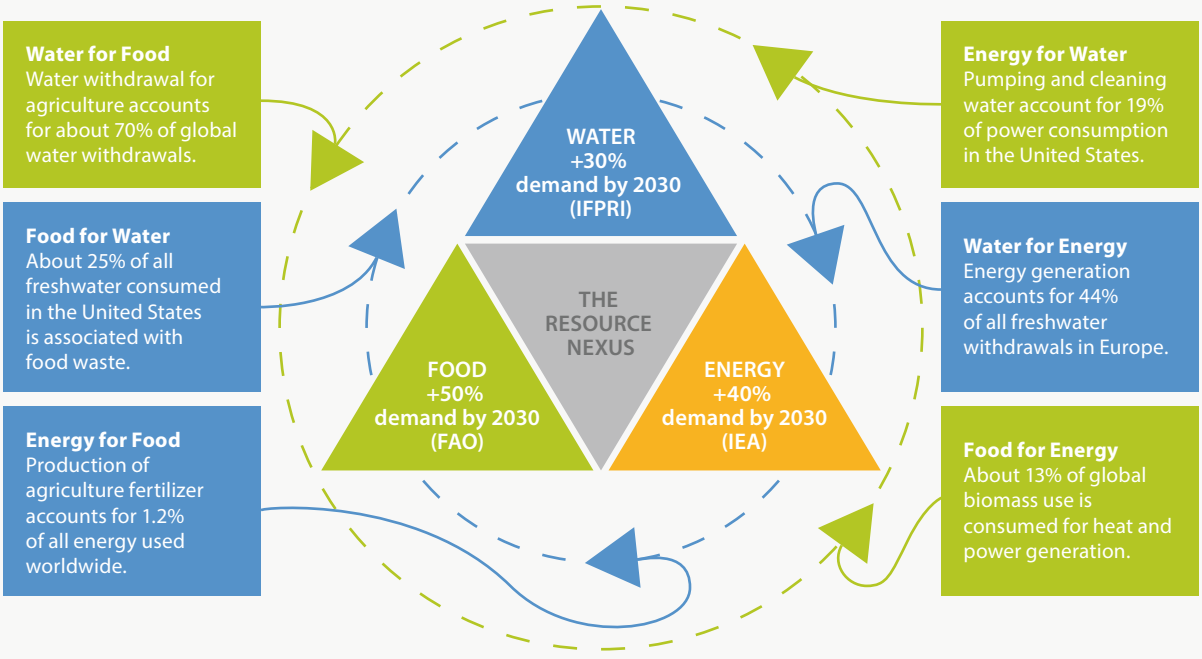
The sustainability of natural or semi-natural resources is inextricably linked to climate change. Discovery of new technologies and energy sources has altered the global energy landscape, making key resources such as water, food, and minerals more accessible – such as water desalination which could address 5% of the global water shortage by 2020. A key sub trend is the resource nexus which means that an abiotic component that is consumed to sustain human life and to produce goods and services such as water, food, and energy are intricately connected, and that actions in one component usually have an impact on one or both of the others. For example, the availability of water resources is projected to fall short by 35% in 2025 because of the increase in population growth, whilst energy generation accounts for 44% of all freshwater withdrawals in Europe. New products and services such as smart water systems and waste for value (monetising waste water) are emerging to enable sustainability to be achieved but also offer huge opportunities for businesses that are able to enter the new markets.

Circular economy embraces new business models to address resource challenges.

Circular economy, for example, embraces new business models seeking to address resource challenges and offers huge returns at the same time. Circular economy refers to an industrial economy that, contrary to a traditional linear economy, seeks to maintain and add to the value of used products and materials through reclaiming them for further use either as products or raw-material. The circular economy will promote efficient use of resources and less waste, provide greener production, and support resource optimization, with an opportunity in excess of US$ 1 trillion for the global economy. Resource scarcity drives governments and businesses to embrace the circular economy, which helps them transform from a linear model (make-use-dispose) to a circular resource management model, supported by digitalization and service-based new business models.

Figure 4: Resource Nexus

Source: Frost & Sullivan



***BMW** sells its remanufactured parts, which provides 50% cost savings to customers compared to new ones but with the same quality specifications.*

Efforts to address climate change should be directed towards both energy alternatives and the reduction of emissions in key sectors. Research, development and deployment of technology should be focused on cost-effective climate change mitigation measures and breakthroughs needed to deliver affordable (and revenue generating for businesses), lower carbon energy solutions that can be adopted globally and at scale. There are proven technologies available today that can be applied to lower or reduce the growth of global emissions. Natural gas, energy efficiency, and nuclear technologies can be implemented immediately to help reduce emissions while innovative research continues. There are also more nascent opportunities that show considerable growth potential and whilst representing new revenue streams for businesses, also vastly reduce carbon emissions. Later in this paper these solutions such as the electrification of vehicles and building energy management, will be explored in detail.

Efforts to address climate change should be directed towards both energy alternatives and the reduction of emissions in key sectors.

2.3 Megatrend Two: The Future of Energy

KEY ISSUES: smart grid, smart services, distributed generation, demand management

Powering the global economic growth, urbanisation and expanding populations in a sustainable manner is one of the biggest challenges and opportunities of the world today. Urbanisation will lead to cities consuming over 3/4 of energy globally by 2020. Combined with an increasing desire for energy security at a country level, this has triggered a global dash to find the energy sources and business models for the future such as ongoing growth in the market for renewable energy. The future of energy is expected to witness a shift in regional and fuel balance, addressing the global energy demand with new technologies such as smart grids and sustainable energy sources.

Powering the global economic growth, urbanisation and expanding populations in a sustainable manner is one of the biggest challenges and opportunities of the world today.

Gas has become a game changer for the world's energy demands and has increased the outlook for production across a wide variety of industries from railroads, shipping, local economies, and farming. In the US for example, shale gas will increase from 23% in 2010 to 46% in 2035 in the total gas production supply. Driven by its ability to provide low carbon energy at high efficiency, nuclear power will continue to present significant opportunities for players that can successfully address the dominant issues of safety and security and will account for 12% of the global energy mix in 2020. Renewable energy is expected to continue to show strong growth in investment and account for approximately 40 to 65% of total global electricity generation by 2050.

However, the global energy future will not be entirely dominated by fuel choices. Rising energy costs and an increasing focus on environmental performance has triggered innovations to manage energy efficiently through technologies such as smart grids. This has increased the world's capacity in handling energy challenges as energy through smart grids offers more control and visibility to integrate distributed generation (solar panels, wind turbines, waste-to-energy etc.) and manage demand more effectively, which results in cleaner, reliable and smarter energy.

Renewable energy is expected to continue to show strong growth in investment and account for approximately 40 to 65% of total global electricity generation by 2050.

To encourage and ensure progress, the European Union (EU) is currently considering a 40% energy efficiency target for Europe by 2030. With smarter energy services, smart buildings and homes will become a mainstream reality in 2 to 3 years, driven by the convergence of green and smart technology and the deployment of service-based business models based on energy savings.

The creation of smart buildings with energy management systems has also paved the way for brand new approaches to saving energy such as the vehicle to home system that can supply electricity from a car battery to a residence. The power is controlled through data communication processes between the vehicle, an electric vehicle (EV) charging port and a home energy management (HEM) system. With the technology now fully available, this type of new solution for home energy management will represent a huge growth opportunity for businesses throughout the value chain.

2.4 Megatrend Three: Smart is the New Green

KEY ISSUES: Smart cities, integrated infra systems, technology & ecosystems convergence, smart industry, resource wisdom

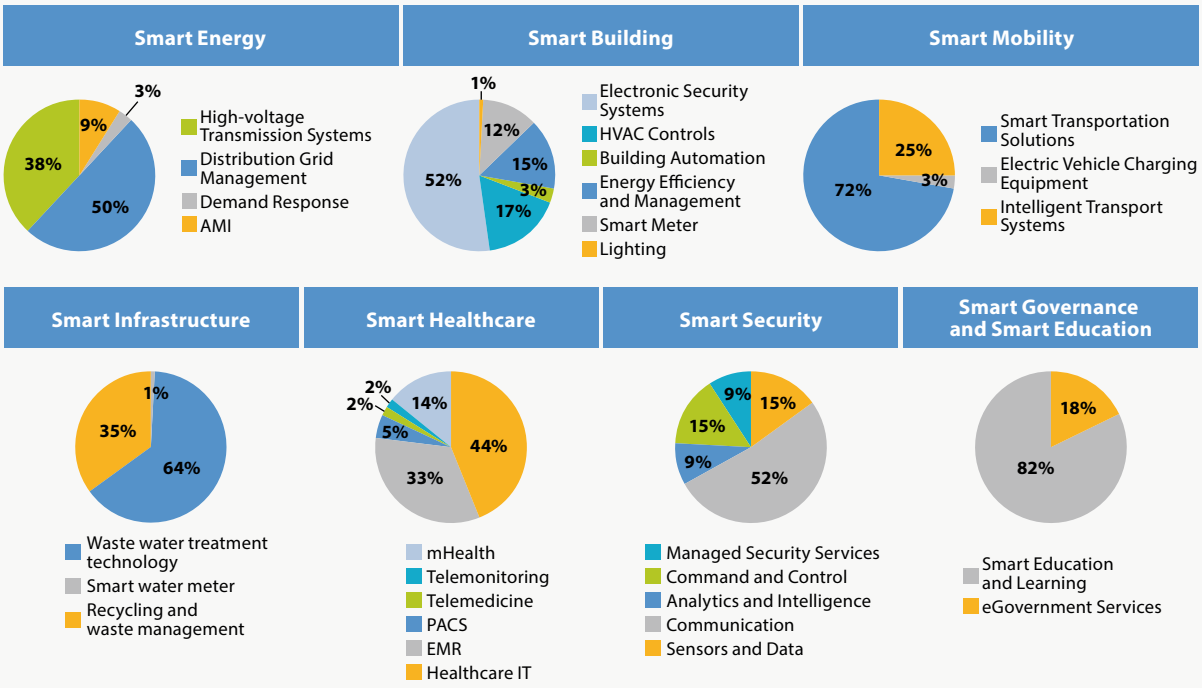
Green products and services will be increasingly enhanced and traditional products replaced by smart products and services, with intelligent sensing technology and internet connectivity driving better optimisation. Enabled by the internet of things (IoT), machine to machine (M2M) communication and over 80 billion connected devices globally, 'smart' will be the key driver of efficiency and sustainability across a vast array of applications.

Market for smart cities will reach a phenomenal value of US$ 1.6 trillion globally by 2020.

This is leading to the growth in development of smart cities using the latest intelligent and green initiatives to reduce energy and resource consumption and improve efficiencies in all facets of human life. Smart cities in the future will be measured on the level of intelligence and integration of infrastructure that connects the healthcare, energy, building, transportation, and governance sectors. There will be 26 smart cities globally by 2025 and Helsinki is projected to be one of them. The market for smart cities will reach a phenomenal value of US$ 1.6 trillion globally by 2020, with sectors such as Transportation and Energy driving revenue growth in this space.

Figure 5: Smart City Market: Detailed Breakdown by Segment, Global, 2020

Source: Frost & Sullivan



The pace of smart city market development will depend on how quickly companies can converge and tap into each other's industry value chains. Businesses can assume 4 main roles in the ecosystem: integrators (the end-to-end service provider); network operators (the connectivity providers); product vendors (hardware and asset providers); and managed service providers (service – management/operation). Increase in technology and ecosystem convergence, collaboration, and partnerships between stakeholders from different industries such as energy and infrastructure, IT, telecoms, food, water and government will expedite delivery of integrated services.

Smart technology is also at the heart of the emerging concept of Industry 4.0 – based on integration of virtual and physical production systems. Huge opportunities will exist for sustainable and efficient manufacturing by 2020 and beyond. Cyber-physical production will merge big data, artificial intelligence, and other advanced technologies to create the fourth industrial revolution. Industries of the future will witness humans and robots working hand-in-hand through sensorised human-machine interfaces without the need of safety barriers, providing for greater flexibility and efficiency in factories.

2.5 Megatrend Four: The Future of Mobility

KEY ISSUES: vehicle sharing, mobility solutions, multimodal mobility, autonomous vehicles, connectivity solutions, integrated services, electrification of mobility

Trends like connectivity and urbanisation will have a profound impact on personal and freight mobility and on the car/truck and transportation models of the future which will lead to new mobility business models. In mobility, new and upcoming services such as car-sharing and multi-modal mobility are already available in an effort to tackle the urbanisation challenges of congestion, accidents, stress for travellers and pollution. Companies that look at cities as customers and position themselves as partners and solution providers to cities will benefit from new business and investment opportunities. Concepts like bike and car sharing, integrated door-to-door transport solutions, inter-modality, smart phone-based urban mobility solutions and automotive app store based connectivity applications will become a common site on our roads of the future, and even parking spaces. By 2020, it is expected that nearly 1 million parking spaces will deliver real-time parking information with the help of sensors.

The role of technology will increase in delivering smart mobility services, as we see more intelligent transport networks, integrated fare structures moving towards personal credit cards and even mobile phones, to make the future of connected living as seamless as possible. Future intelligent platforms will connect the car to numerous functions and devices at home and the office. In the longer term autonomous vehicles or pods will serve our cities, such as the Personal Rapid Transit (PRT) systems seen in Heathrow Airport (London).

The Amritsar PRT *system in India will become the first commercially developed PRT scheme in the world, charging passengers to travel to the Golden Temple, which has been chosen so as to avoid polluting modes of transport, and due to its lightweight, cost effective construction in an area with little space for alternative modes of transport; this could prove to be a viable sustainable future mobility solution in several cities globally.*

The world economy and all global businesses are highly dependent on shipping, which meets approximately 85% of the global demand for transport. The International Maritime Organization (IMO) estimates that world shipping is responsible for about 3% of global CO_2 emissions. Of the total emissions from the transportation sector, shipping accounts for 10%, road traffic 73% and air traffic 12%. Emissions from the transportation sector will double by 2050 and from shipping they could approximately triple. The capacity of the world fleet is expected to grow during the next ten years. IHS Fairplay estimates that the total fleet will increase by approximately 50% between now and 2020, based on annual economic growth of 3%. Climate consciousness, regulation and customer demand are creating significant opportunity for innovations to reduce the carbon foot print of shipping.

2.6 Megatrend Five: Urbanisation

KEY ISSUES: partnerships, convergence between different parties, services, solutions, smart cities

For the first time in history, 50% of the world's population lives in urban areas. This will increase to around 70% by 2050. This mass migration to urban areas is transforming cities into enormous economic hubs creating the phenomenon of 'Mega Cities'. Beyond 2020, more than 35 cities globally will grow to become Mega Cities by 2025 with Asia contributing nearly 18 Mega Cities. China

alone will account for 72% of the Mega Cities in Asia. China will have one of the largest urban populaces with over 200 cities with populations of more than one million. An estimated 921 million people or 65% of China's population is expected to live in cities. These Mega Cities are expected to contribute nearly US$ 6.2 trillion to China's GDP in 2025.

Mega Cities will account for US$ 21 trillion of global GDP (nominal) by 2020. Meanwhile, developing economies will contribute around 65% to 70% of global growth in the next 10 years and the 40 largest urban Mega Regions will account for 66% of global economic activity and about 85% of global technological and scientific innovation.

Eventually cities, rather than countries, will be targeted as hubs of investment with each city becoming a unique customer with untapped opportunities in key industries such as mobility. Partnerships between city governments, solution providers (businesses), and academia will become the working model for most future city projects. Convergence between industries, players, technology and products is inevitable as the world itself converges into urban clusters.

For the first time in history, 50% of the world's population lives in urban areas, and this share will grow up to 70% by 2050.

2.7 Megatrend Six: The Future of Infrastructure

KEY ISSUES: clusters along main corridors, urban development, 5G networks, cross continental infra, multimodal logistics

The global investment in infrastructure development is expected to cross US$ 27 trillion by 2025, with Asia-Pacific (APAC) accounting for 37% share and with expected investments of US$ 11 trillion from 2010 to 2025.

Developing transportation corridors (e.g., Trans-Siberian Railway and high-speed rail corridors in the United States) will lead to mushrooming of economic and

Figure 6: Global Mega Cities, 2025

Source: United Nations, Department of Economic and Social Affairs, Population Division (2012); World Urbanization Prospects: The 2011 Revision; Frost & Sullivan

Note: A Mega City has a population of at least 8 million and a GDP of US$ 250 billion.

technology clusters along these corridors. Turkey plans to build a 6-runway Mega Airport near Istanbul, which is expected to be the largest airport worldwide, at an estimated cost of over US$ 9 billion. China plans to build a new canal through Nicaragua, at an estimated cost of US$ 41 billion, which will compete with the US-built Panama Canal for ocean-going traffic between the Atlantic and the Pacific Oceans.

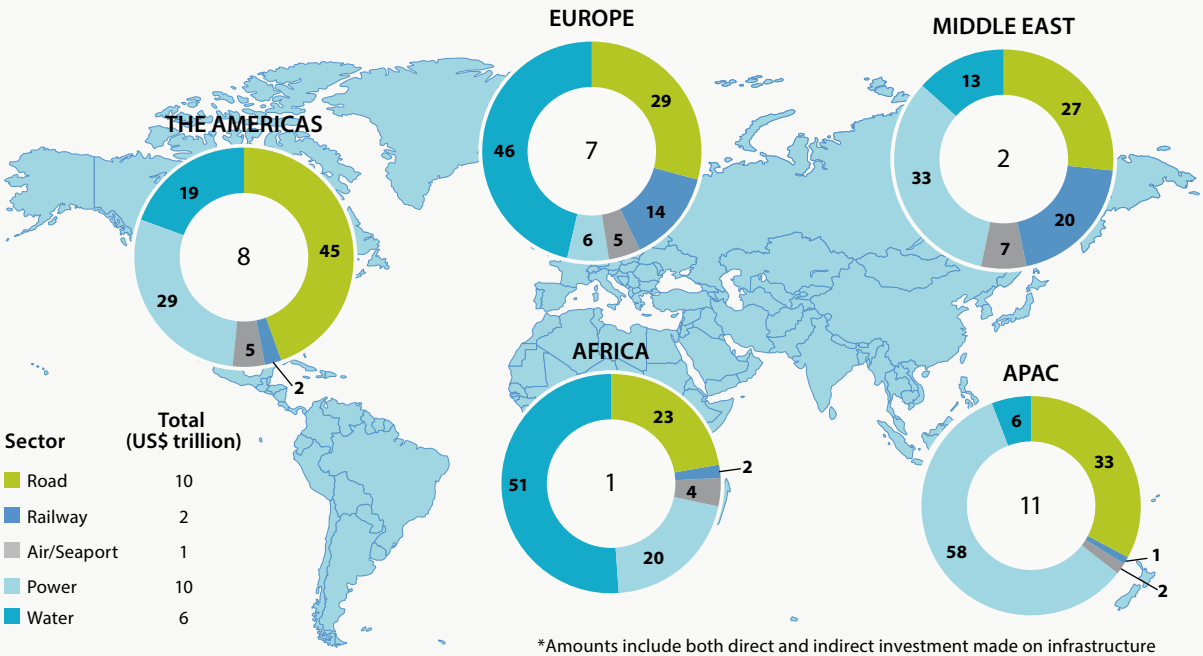
The global investment in infrastructure development is expected to cross US$ 27 trillion by 2025.

In the near future, high speed rail will connect not only cities and countries but also continents. In about 15 to 20 years from now, one could travel seamlessly from London to Beijing using the global high speed rail network. In the period 2010–2020, globally over US$ 600 billion will be spent on high speed rail projects with over 70,000 km of high speed rail track in use. High speed rail will augment growth in multi-modal freight logistics offering what is essentially a more sustainable alternative to road transportation and a faster delivery time than the typical air-road mix. This would be additionally driven by global urban logistics spending which is expected to set itself to reach US$ 6 trillion by 2020, accounting for 46% of the total logistics spend. Road freight transport will also dominate – logistics will account for over 35% of urban traffic in 2020.

The development of 5G is another game-changer in infrastructure. 5G will increase wireless capacity by 1,000 times. It will be the enabler of connected solutions such as autonomous vehicles and will offer an average of 90% energy saving on a typical consumer service such as video downloads, Internet-enabled telephone calls or remote computer updates.

Figure 7: Cumulative Infrastructure Investment, Global, 2010–2025

Source: ADBI; Eurostat; Deloitte; Frost & Sullivan



Note: Values in the center of the pie charts are expressed in US$ trillion and the pie charts show the percentage shares.

*Amounts include both direct and indirect investment made on infrastructure development projects worldwide (road, railway, air/seaport, power, and water infrastructure) at either the start-up phase or at a later stage when the project is mature.

2.8 What This Means for Business and Our Carbon-Neutral Future

These 6 megatrends will define our global societies in the future and drive the narrative regarding carbon neutrality. That means defining both the opportunities for future advancement, and also the challenges they will present.

In analysing these trends the implications are clear – urbanisation is clearly creating a need for sustainable cities where water stress and sanitation need solving; smart technology will create an opportunity for our growing cities to operate far more efficiently than they do today using inter-connected sensors and data analytics; the future of mobility will see eMobility redefine personal transportation; and the future of energy is bringing innovations such as smart grids and demand response to tackle our need to use energy more efficiently.

The successful businesses will be those that can directly address the challenges posed by these megatrends, and capitalise on the opportunity that the demand for efficient and sustainable products and services represent.

2.8.1 The Areas That Are Poised for Growth

By assessing the megatrends, resultant subtrends and the industry level consequences, it is possible to identify the high growth opportunities where businesses can take advantage of new products and services critical to the acceleration of carbon neutrality.

The opportunity and impact is greatest where:

- Existing systems or industries can be made more efficient (such as in the growth in smart grids; or in manufacturing where the emergence of Industry 4.0 will drive efficiency and sustainability)
- Vital processes can be made sustainable (such as energy, water, waste recovery and natural resource usage, including innovations such as wastewater treatment, environmental food processing and eco-friendly construction materials)
- 'Value for many' can be achieved through new business models (such as car sharing that prioritises access over ownership; or XaaS – anything as a service – models that are increasingly appearing in sectors such as public transport and energy management)

With convergence inevitably accelerating, the future opportunities will be greatest for the companies that can bring together total solutions to address these multiple needs in a coherent, integrated manner. The following chapters will address in detail the scope and scale of some of the major opportunities there are in key sectors in the future.

2.8.2 Key Considerations for Business

From the in-depth analysis conducted into key high-growth subtrends in the cleantech industry, key strategic considerations for business in leveraging these trends to achieve future growth were identified. These are summarised below.

Smart Grids, Prosumers in energy market, and Distributed Storage

- Pre-2025, the prosumer market is expected to be driven primarily through residential and commercial incentive programmes. Value-added services and software will represent a greater degree of supplier discrimination in these markets.
- Utilities or energy service companies (ESCOs) are expected to represent the primary customer in the sale of components and services post 2025, as they would own and/or maintain the equipment and lease the solar PV panel out to the customer.
- For battery storage for residential and commercial customers, the distribution system operator (DSO) or distribution network operator (DNO) is likely to maintain ownership and maintenance of systems in the long term. Consumers will lease the systems and benefit from financial incentives.
- Similar to the prosumer market, incentive based models and consumer ownership are expected to drive the battery storage market in the short term.

Biofuels

- Corporate partnerships between technology companies and multinational organisations are expected to represent the most direct route to scaling technological innovation to levels necessary for commercialisation in the future.
- Future business models will include highly integrated value-chains from the perspective of both feedstock providers as well as manufacturers.
- Biotechnological innovation in the development of high yield crops, refinement of efficient crop management practices, and the delivery of a fully integrated feedstock solution, will allow for scalability and a more price competitive product for the market.
- Creation of new revenue streams through the development of associated product lines across the value chain in biochemical, bioplastics and biomaterials is further expected to represent a core requirement for scalability.

Smart Municipal Solid Waste (MSW) and Water

- Circular recovery of waste and value shows a direct commercial benefit through the development of alternative revenue streams in waste management (e.g. waste-to-energy, biogas) and the remanufacture of discarded product components.
- Efficient resource recovery must be integrated across the entire value chain in order to maintain the inherent value of product components throughout its lifecycle and decrease the costs of collection, sorting and remanufacturing.
- Business models that focus on profitability beyond the point of sale, through the development of added products and services to be used to enhance the total value of the base product throughout its lifespan.

Smart Factory

- Manufacturing flexibility and customisation is expected to grow rapidly in the future. This will require remote monitoring and control at every level of operation through wide-spread integration of cyber-physical information and communication technology (ICT) systems and IT software.
- Development of modular components with a high degree of flexibility in their design to allow for high efficiencies in disassembly and remanufacture will become a strong competitive advantage.
- Outsourced R&D is expected to gain significant weight in the future, as manufacturers turn to online platforms to accept designs and ideas from innovators around the world.
- Pre-2025 the 3D printing market will be driven by the industrial sector, through prototyping and niche component manufacture, as well as, the commercial sector through contracted manufacturing in local 3D printing warehouses.
- In the long term (post-2025) 3D printing will provide the potential for an explosion of micro-manufacturers, developing and retailing products from homes or offices.

Smart Packaging

- Potential for significant savings in the monitoring and tracking of package contents in logistics and storage.
- Future smart packaging markets are expected to be targeted at high-margin, multi-faceted packaging products that provide significant benefits in more than one area, maximizing the value to the customer.
- Two-way information flow with customers will ensure the correct use of product and grant greater control over product quality at end-use.
- Recyclability and longevity of smart packaging technology will further represent a key factor in achieving growing market acceptance.

Energy Harvesting

- Open-source business models will foster technological interoperability and drive the integration of energy harvesting technologies into multiple products.
- Energy harvesting substitutes disposable batteries and enables a wide range of energy self-sufficient applications even at locations without electric power supply.

eMobility

- Vehicle sharing and vehicle ownership with the battery leased will be the two major business models that will facilitate the transition to electric vehicles.
- Automotive manufacturers will consequently evolve into mobility providers. First movers and early adopters of this business model trend will have the opportunity to create market entry barriers through brand establishment and infrastructure investments, e.g. in charging networks and information systems.
- Light-weight vehicles will increasingly run on electricity from batteries and fuel cells, while low-carbon biofuels will offer sufficient energy density for diesel engines in heavy long-range road haulage.

Autonomous Driving

- Autonomous driving will revolutionise the commercial transport sector as driverless trucks or busses can be operated 24/7 as rest periods will become unnecessary.
- Autonomous driving will be a key enabler for vehicle-sharing and personal driving on demand through automated delivery services.
- Autonomous driving will bring up liability issues and debates on ethical principles amongst passengers, traffic operators, manufacturers and insurance companies.

Integrated Mobility

- Intermodal door-to-door travel solutions require the integration of many different means of transportation such as walking, cycling, public transportation or car-pooling. This will require cooperation amongst public transportation, parking providers, car rental agencies, and ride and car sharing communities.
- Automobile manufacturers, railway operators or travel management software developers will establish themselves as mobility integrators, due to cross-border synergy effects and economies of scale.
- There is room for disruptive start-up companies in the market but owing to hefty investment requirements and through eventual mergers and acquisitions, corporate enterprises are anticipated to dominate the market in the long-run.

Energy Management Systems and Services

- The roll-out of commercial building and home energy management systems will require large-scale installations in existing and new buildings in the next 15 years but service-centred business models are the key revenue generators in the energy management market.
- The so-called ambient assisted living market is already growing in the Netherlands, UK and Germany and features great growth potential in all ageing societies.
- The aging and decreasing population in Europe, Japan, China and North America provides the opportunity to combine home energy management systems and ambient intelligence with services that empower the elderly and disabled to live independent lives in their own home.

Green Building Materials

- Governmental regulations will mandate demolition planning within the construction licensing procedure. Thus, the future of construction lies in modular solutions with long-lasting and easily reclaimable structures and materials.
- Architects and construction engineers will assess how buildings can sensibly be repaired or deconstructed into parts and how to utilise the remaining service life of those parts in new applications.

3 Transport

KEY INSIGHTS

Increasing connectivity and urbanisation will have a profound impact on personal and freight mobility and on the cars, trucks and public transportation systems of the future which will lead to new mobility business models. Intermodal connectivity will be predominately bringing in electric vehicles as a key mode of transportation.

Seamless travelling in the 21th century means that consumers rather use available means of transport instead of owning them. Integrated travel management applications and subscription based business models will revolutionise the way we travel over the next 35 years.

eMobility is expected to save up to 40% of the carbon emissions of conventional petrol cars over their full life cycle. Over 100 million hybrid and all-electric vehicles as well as around 50 million fuel cell vehicles will be sold annually by 2050, constituting a US$ 4.7 trillion market.

Autonomous driving has the capability to reduce urban traffic congestion and enables Mobility-as-a-Service (MaaS) for everybody, anytime, anywhere. Annual revenues of advance driver assistance systems that enable automated driving will amount up to US$ 3.6 trillion.

New integrated mobility services such as car, ride, bike and park sharing will generate about US$ 176 billion in annual revenues.

THE TRANSPORT SECTOR ACCOUNTS for more than 20% of global energy-related carbon emissions and according to the International Energy Agency, more than 2 billion light duty vehicles (not counting two- and three-wheelers) are expected to be on the roads in 2050, an increase from the approximately 900 million today.[i] This makes decarbonising transport a key priority; eMobility is expected to save up to 40% of the carbon emissions of conventional petrol cars over their full life cycle. Frost & Sullivan expects innovative and diverse mobility solutions to exist cohesively catering to a wide range of consumers' mobility needs and providing eco-friendly, cost-effective and time-saving travel options for commuters. The two key solutions are greener transport through the electrification of vehicles and smarter transport through self-drive vehicles and intermodal, door-to-door transport solutions. It is assumed that worldwide about 82% of all cars and trucks on the road will operate without fossil fuels by 2050. The majority of these will be equipped with advanced driver assistance systems that enable autonomous driving and represent a US$ 3.6 billion market in 2050. Autonomous driving has the capability to reduce urban traffic congestion by up to 30% that is estimated to cost 2% of the gross world product in lost productivity. Key growth markets in integrated mobility are bike and car sharing, shared parking and car-pooling that will skyrocket from US$ 3 billion to US$ 176 billion within the next 35 years. This represents a paradigm shift to car-usership-based models as opposed to an outright purchase. Worldwide car-sharing memberships are predicted to grow from less than 4 million today to 26 million by 2020 and one car-sharing vehicle has the potential to remove up to 17 privately owned cars from the road.

More than 2 billion light duty vehicles are expected to be on the roads in 2050.

The following section provides an overview of the key industry shaking low-carbon trends expected to drive the evolution of the transport over the following decades. The sub-trends selected for analysis based on these criteria are eMobility, autonomous driving and integrated mobility.

3.1 eMobility

3.1.1 Overview

The future of mobility is electrified. The advantages of electric vehicles (EV) over vehicles with internal

i IEA 2015: 98

combustion engines (ICE) are their high energy efficiency and the price-performance ratio of electric engines. The development of lithium-sulphur battery technologies with much higher energy and power density will further increase the competitiveness of EVs. They may be designed specifically around new electric drivetrains such as in-wheel electric hub motors, which eliminate the need for transmissions and gearboxes, further improving both driving and environmental performance.[ii]

The future of mobility is electrified.

3.1.2 Key Trends in Products and Services

Conventional ICEs burning refined fossil fuels (diesel or gasoline) are expected to gradually lose market share over the long-term. Full hybrids combining ICEs are currently gaining share, but will be superseded by plug-in electric vehicles (PHEV)[iii] after 2030. ICEs burning alternative fuels such as biodiesel, biogas, compressed natural gas (CNG) or liquefied petroleum gas (LPG) will initially gain a considerable share in the automotive market along with electric powertrains. Original equipment manufacturers such as Honda and Toyota launched their first mass-produced fuel-cell vehicles (FCV) in autumn 2014. Nevertheless, there is a major advantage of EVs over FCVs: Fuel cells require hydrogen to operate and currently the most viable method to produce hydrogen is by using natural gas. The process to extract hydrogen from natural gas releases significant amounts of greenhouse gases and does not have a positive business case. There are a few efforts to extract hydrogen from biogas or water, but these methods are still either too expensive for commercialisation or under development.

Table 1 provides a breakdown of some of the key winning product categories resulting from eMobility growth globally.

3.1.3 Quantification and Forecast

If the current increase of personal mobility continues, the number of passenger and commercial vehicles is expected to reach more than 2 billion vehicles by 2050.[iv] Increasing urbanisation, the development of mega cities, generation Y

Table 1: eMobility: Products and Services – Winners & Trends, 2014–2050
Source: Frost & Sullivan

Winners	Trends
Pure electric vehicles	EVs will outrank ICE vehicles in the long-term, as public policies boost sales in order to meet climate targets
Plug-in hybrid vehicles	By 2025, most of the full hybrids will be converted to PHEVs, especially in triad markets.
Fuel cell vehicles	Fuel cells in vehicles create electricity by using oxygen from the air and compressed hydrogen.
Advanced biofuels	Biofuels, produced from renewable raw materials, offers an easy way to lower carbon emissions and increase the proportion of renewable energy used in transport.
Lithium sulphur batteries	Lithium sulphur is likely to be adopted as the next battery chemistry; however, there will be advancements in Li-ion technology.
EV charging stations	Owing to the insufficient cruising range of EVs of about 100 to max. 500 km rapid charging facilities are particularly important on highways and major transit routes to urban areas. However, the average range of EVs will be sufficient for the daily journeys of most drivers and thus most drivers would charge their car mainly at their place of residence.
Hydrogen stations	Like gasoline and diesel vehicles FCVs have to stop for short tank stops. FCVs provide an average driving range of 400 to 600 km between hydrogen refuelling.

ii BBC 2013

iii Note: The electric vehicle segment in Frost & Sullivan market forecast includes battery electric vehicles, plug-in hybrid vehicles and extended range electric vehicles.

iv BBC 2013

and intermodal connectivity mean EVs will be vital to meet national and international carbon emission targets. If the global carbon emission levels are to come down below the target of 15g/km by 2050, a more than 50% penetration of EVs[v] is required, along with a 30% contribution from FCVs.

Frost & Sullivan assumes that by 2025, most of the full hybrids will be converted to PHEVs. By 2030, sales of EVs are projected to reach 24 million and hydrogen powertrains are projected to reach almost 6 million. Together with the United States, Japan and South Korea, Northern and Western Europe are expected to be the key markets. Between 2030 and 2040, sales of conventional diesel and gasoline powertrains are expected to decline as EVs and FCVs become more competitive in terms of driving range and price. It is projected that approximately 100 million EVs and over 50 million FCVs will be sold annually by 2050.

The worldwide market for hybrids, EVs, including plug-in hybrids and fuel cell vehicles, was valued at US$ 200 billion in 2015, and is expected to reach more than US$ 5 trillion by 2050. Overall revenues for vehicles with these transmission types will grow at a CAGR of approximately 11.3% between 2015 and 2050. Frost & Sullivan projects that full hybrid vehicle revenues will peak between 2030 and 2040 as the market moves to pure electric and fuel cell vehicles.

Approximately 100 million electric vehicles and over 50 million fuel cell vehicles will be sold annually by 2050.

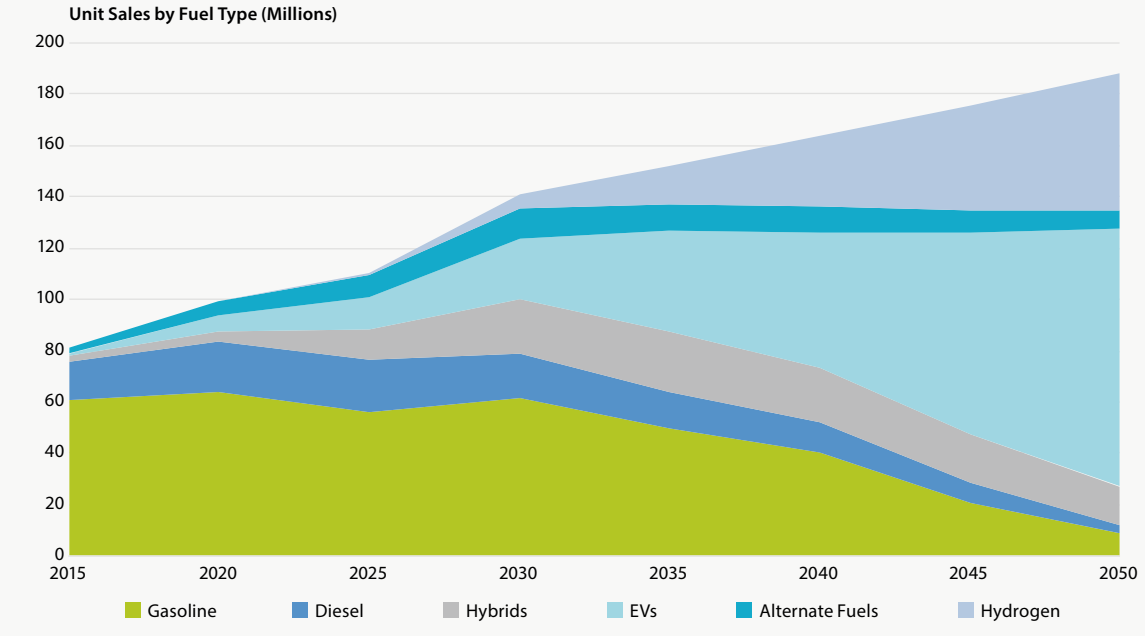
3.1.4 New Business Models

In order to offset the revenue loss from the traditional car and truck selling automotive manufacturers will focus on downstream activities that reduce customer's cost and risks. New opportunities of value creation and sources of competitive advantage are emerging in vehicle charging services, in leasing and sharing models and the overall integration of eMobility into home energy management systems and smart cities. Realising such business models requires building strong collaborations and relationships between industries that previously did not interact with each other.

Several barriers need to be overcome to ensure the commercial success of eMobility. These are the up-front costs of EVs (mainly driven by the price for high-performance batteries), the limited cruising range and the charging of EVs. The new business models envisaged

Figure 8: Powertrain Trend to 2050: Global market share by powertrain technology (Global), 2015–2050

Source: Frost & Sullivan



v Frost & Sullivan includes PHEVs in the EV segment

The worldwide market for hybrids, electric vehicles, including plug-in hybrids and fuel cell vehicles, is expected to reach more than US$ 5 trillion by 2050.

will blur the lines between automotive manufacturers, electricity providers and information and communication technology network companies that provide advanced route planning taking traffic information, the state-of-charge, typical driving habits, charging stations on the way and electricity prices into account. Frost & Sullivan has identified three business models that will shape the eMobility market in the next decades: vehicle-and-battery-ownership, vehicle-ownership and battery-usership, and vehicle-sharing.

3.1.4.1 Vehicle-and-Battery-Ownership

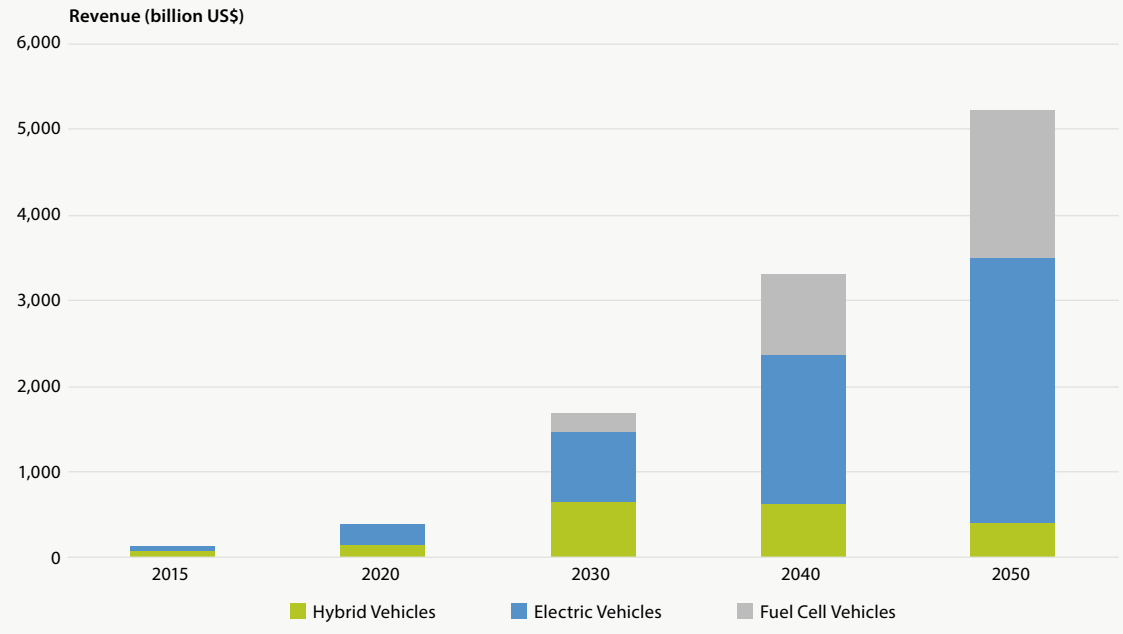
The vehicle-and-battery-ownership model is the most common in the EV industry today. As electricity has a significant cost advantage over fossil fuels, instalments for EVs including batteries may eventually be bundled with electricity bills. Therefore, the fuel savings of EVs can be used to offset the battery costs making ownership more attractive to customers.[vi] A key part of this business model is a comprehensive EV charging infrastructure. Many vehicles will be charged at home, but rapid recharge systems are particularly important on highways and major transit routes approximately at a distance of between 40km to 60km with a higher density in urban areas. This will likely bring together automotive manufacturers, petrol station operators and electricity providers. For the ease of use, all charging stations ought to be listed in detail in the vehicles' navigation system with real-time information on reachability, availability and technical specifications.

3.1.4.2 Vehicle-Ownership and Battery-Usership

Many manufacturers such as Renault allow customers to buy a car of their ZE[vii] range and lease the battery. The vehicle-ownership and battery-usership model takes away the high up-front cost of battery purchase, a severe market development barrier and provides a significant future revenue stream. Battery leasing rates can be bundled with monthly electricity bills. By this means, original equipment manufacturers (OEMs) of EVs have the potential to achieve

Figure 9: Hybrid; Fuel Cell and Electric Vehicle Market: Revenue Forecast Global, 2014–2050

Source: Frost & Sullivan



vi IEA 2011: 24

vii ZE stands for zero emissions

cost parity with with internal combustion engines (IEC). Another advantage of the Vehicle-Ownership and battery-usership model is that it enables battery swapping during longer journeys.

3.1.4.3 Vehicle Sharing

The third business model, vehicle-sharing, is based on the paradigm shift towards car-usership-based models, as opposed to an outright purchase.

> ***Car2Go*** *subscribers for example can already either collect and return a vehicle at a fixed station or search for free vehicles in their immediate vicinity using location-based applications.*

This business model features new revenue streams and cost structures that differ notably from conventional private transport: EV users can pay a subscription fee covering all ancillary costs such as insurance, maintenance, refuelling and parking while the car sharing provider bears all up-and-downstream risks. EV sharing networks will often be public-private partnerships; in many cases these will have non-for-profit business models so as to support the market breakthrough of eMobility.

3.2 Autonomous Driving

3.2.1 Overview

Autonomous automobiles are no longer science fiction; several global megatrends significantly accelerate the market for driver-free mobility. The rising urban population is creating demand for hub-and-spoke logistics and greater connectivity. The convergence of connectivity networks and leveraging big data are resulting in the development of smart and connected cities, road networks and passenger as well as freight vehicles. Governmental regulations regarding freight traffic-induced carbon emissions, road safety and truck driver hours could be met by autonomous vehicles, particularly as in highly-developed countries fewer people are entering the industry creating skills shortages. High fuel costs and price volatility are forcing fleet operators to optimize total cost of ownership (TCO) and operational efficiency. Autonomous driving is enabled by advanced driver assistance systems (ADAS), e.g. lane keeping assistance or autonomous emergency braking. Automated vehicles can be categorised into three levels of technological development: semi-automated vehicles, highly automated vehicles, fully automated vehicles.

Autonomous automobiles are no longer science fiction; several global megatrends significantly accelerate the market for driver-free mobility.

3.2.2 Key Trends in Products and Services

A semi-automated vehicle features driver assistance functions that take some control of the vehicle under specific circumstances and at the driver's discretion. These systems include electric power steering (EPS), electric braking systems (EBS) and electric parking brake as well as electronic throttle control and keyless entry. In highly automated vehicles, the driver can choose to control the vehicle and override a specific set of commands. Examples for these kinds of systems are intersection assist, redundancy back-up for connectivity and self-driving capabilities under driver supervision. A fully automated vehicle is capable of driving itself in all traffic conditions, without the physical presence of a human driver. These vehicles require multiple redundancies of critical systems to ensure sustained control of the vehicle, such as steering, braking, throttling and powertrain as well as artificial intelligence. Fully automated vehicles need to be fitted with wireless (V2x) communication modules that can also be used to share information with other vehicles (V2V) and infrastructure (V2I) and is essential for smart and connected cities. Fully automated vehicles coordinate their motion with respect to the driving environment and other vehicles in order to optimise safety, road utilisation, driver productivity and energy savings.

Autonomous vehicles can avoid congestion by proactively avoiding traffic hotspots and also be synchronised with traffic signals to improve efficiency and minimise delays. The average vehicle size will decrease resulting from trip-and-passenger-specific autonomous vehicle deployment. This form of enhanced driving has the capability to reduce fuel-wasting and air-polluting traffic congestion by up to 30% in major cities. Congestion is estimated to cost 2% of the gross world product in lost productivity – an equivalent to US$ 1.5 trillion. Likewise, 7 million deaths are caused per year by air pollution in urban areas. The risk of accidents is also likely to be much lower due to elimination of human error which causes 97% of all road accidents. Worldwide there are 66 million traffic collisions, resulting in 1.25 million deaths per year. In nearly collision-free environments, cars can be constructed out of lighter materials to make them more energy efficient.

Table 2 provides a breakdown of some of the key winning product categories resulting from autonomous driving growth globally.

Table 2: Autonomous Driving: Products and Services – Winners & Trends, 2014–2050
Source: Frost & Sullivan

Winners	Trends
Steering automation **Braking automation**	Autonomous steering and braking systems are optional in vehicles featuring assistive systems only. However, they are a prerequisite for all forms of automated driving.
Adaptive headlamp control	Adaptive headlamp controls are only necessary in highly-automated vehicles. An interim market growth can be expected until fully automated vehicles gain momentum.
Radar	As of today already medium-class vehicles are optionally equipped with radar sensors to enable adaptive cruise control. Also vehicles in the long-term future will not get along without them.
Ultrasonic sensors	Ultrasonic sensors are widely applied in today's assistive parking systems. As they are a prerequisite for all forms of automated driving, solid market growth can be expected within the next 35 years.
Forward-looking, rear-vision and surround-view cameras	Cameras are still optional equipment today but will definitely play an important role in the technical infrastructure of all types of automated vehicles.
Night vision	Night vision is not a requirement for assisted or semi-automated driving. Hence this solution will not grow significantly till highly and fully automated driving will be established.
Light Detection and Ranging (LIDAR)	Highly and fully autonomous vehicles will use this laser sensing technology for obstacle detection and avoidance to navigate safely through environments. Hence this solution will not grow significantly before 2025.
Map-supported advanced driver assistance systems	Maps can enhance the vehicle's environmental sensing capabilities. Highly and fully autonomous vehicles will use map-supported ADAS to navigate the vehicle owing to current traffic conditions and passenger's needs or preferences.
Automated parking	Today parking assist systems that automatically steer the vehicle into the parking lot while the only driver applies the breaks are substituting proximity sensors. But, 10 years from now, fully automated parking will be an established technology.

Enhanced driving has the capability to reduce fuel-wasting and air-polluting traffic congestion by up to 30% in major cities.

3.2.3 Quantification and Forecast

Within the forecasting period technical advancements in autonomous driving assistance systems will enable a continuous automation of road traffic.[viii] Semi-automated vehicles are already present in the luxury and upper-middle class segment, with systems such as active parking or brake assistance. In 2015 there are approximately 1.5 million semi-automated cars on the road; Frost & Sullivan projects this to increase to a 6.2 million manufactured per year in 2025, of which 50% will be highly automated and 10% fully automated, as autonomous enabling technologies reach maturity and scalability. Automated trucks are forecast to enter the mass market as early as 2025, when global production will reach an estimated 8,000 units increasing to 182,000 units by 2035. Fully automated vehicles including trucks will only start to be present in the market post-2040. Massive public and private infrastructure investment is needed to achieve this and only few metropolitan areas around the globe will meet the extensive requirements for a complete automation of road traffic by 2050.

viii Frost & Sullivan's projections for the ADAS market embrace the following systems: Blind Spot Detection (BSD), Lane Keeping Assist (LKA), Adaptive Cruise Control (ACC), Night Vision (NV), Park Assist (PA), Forward Collision Warning (FCW) and Autonomous Emergency Braking (AEB).

6.2 million semi-automated cars will be manufactured in 2025.

3.2.4 New Business Models

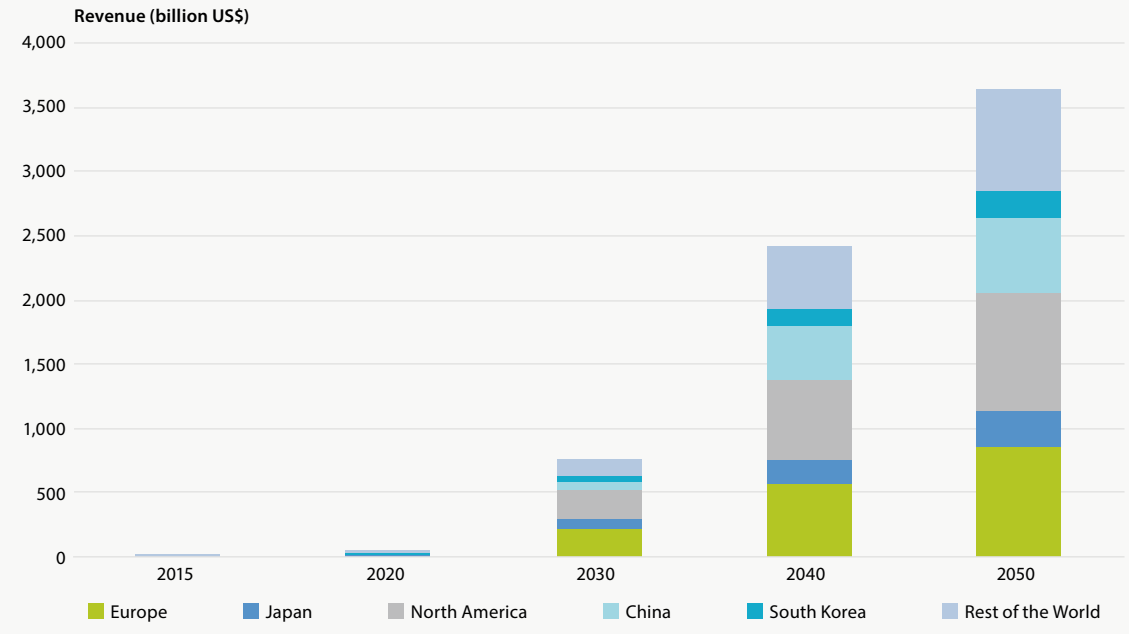
A whole new range of service-centric business models will evolve to leverage autonomous driving. Automated driving holds equal potential for both traditional original equipment manufacturers (OEMS) and potential new entrants who could control the mobility integration, especially with multi-modal commuting. Collaborative business models of public transportation and traffic information providers with automobile manufacturers and mobility integrators will shape the future of the autonomous driving market.

The established business-to-business model of leasing vehicles or entire fleets enhances the efficiency of vehicle utilisation. Vehicles will no longer be leased per individual, but per organisation or community respectively executing car-pooling. The most traditional car-usership-based business-to-consumer model is car-sharing. Today drivers either collect and return a vehicle at a fixed station or search for free vehicles in their immediate vicinity using location based applications. This business model has a tremendous growth potential thanks to automated driving; an automated delivery service can move the vehicle from one point to another. This will facilitate personal driving on demand, even for people with limited mobility options, such as the elderly and the cognitively- or physically-impaired. An automated delivery service would also mean for fewer cars per household. As a result, automakers are eager to increase this kind of downstream activities to offset decreasing demand personal vehicles.

The market can be split into non-road legal vehicles, vehicles driving on dedicated lanes and others sharing public streets with non-automated vehicles. While restricted environments are likely to be proving grounds for innovative models and applications, the general trend will be to move towards unrestricted, open environments. The key impact is likely to be on how OEMs deploy their vehicles onto roads to enable commutes to use automated vehicles.

Figure 10: Advanced Driver Assistance Systems, Revenue Forecast, Global, 2014–2050

Source: Frost & Sullivan



3.3 Integrated Mobility

3.3.1 Overview

By 2050, two-thirds of the world will live in urban areas. The future of mobility is to create a green, integrated and interoperable transport infrastructure, to give consumers instant access to necessary real-time information, flexible and customer controlled travel, safety, and payment methods, amongst other related options. The expansion of an infrastructure substituting individual car traffic will set the stage for integrated mobility. Besides bike, car and ride sharing networks, this includes dynamic parking, improved bus rapid transit, underground, suburban and intercity trains. Integrated door-to-door transport solutions, intermodal transport and urban mobility solutions coordinated by smartphone application will become commonplace in a carbon-free economy.

3.3.2 Key Trends in Products and Services

Future travellers will increasingly use a combination of various modes of transportation that will yield a wide range of linked mobility services. To make the most out of existing and future modes of transport, road operators, traffic management providers and data aggregators need to provide actionable items as data to different involved businesses in order to offer consumers up to date information for better travel and planning.

*The Israeli start-up **Moovit** is a real-time traffic information service provider which has already gained over 20 million users, aiming to provide road users with timely, relevant, accurate and up-to-date information related to their journeys. This includes information about the physical characteristics of the road network, traffic circulation plans, traffic regulations, recommended driving routes and real-time traffic data including estimated travel times.*

Future travellers will increasingly use a combination of various modes of transportation that will yield a wide range of linked mobility services.

One step further than just planning a journey is to book, pay, and potentially expense the service if you are travelling in the course of business. A range of providers from several sectors including rail and public transport, car companies, service providers and technology providers see this as a lucrative opportunity and are heavily investing into business model development. Moovel, a Daimler subsidiary, offers such a travel management solution and

Figure 11: Automated Driving Market Applications

Source: Frost & Sullivan

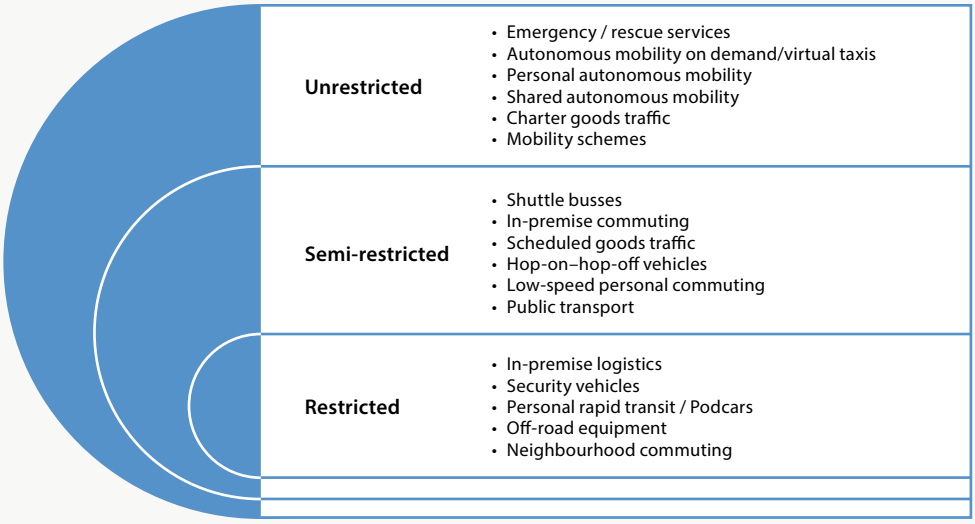
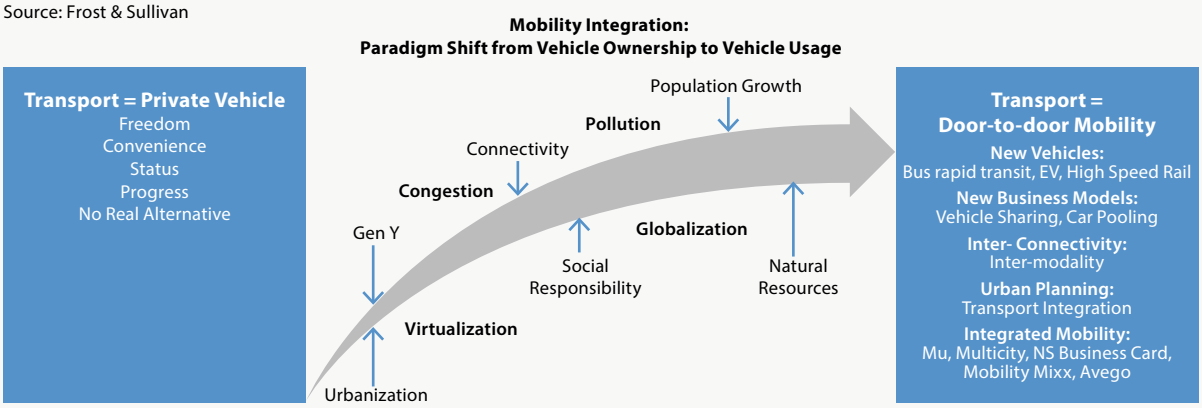


Figure 12: The Evolution of Integrated Mobility

Source: Frost & Sullivan



is already available in Germany and is planning to expand internationally. According to estimations by Transport Systems Catapult, travel management solutions will generate approximately US$ 470 billion in 2025.[ix]

Personal rapid transit offers opportunities to reduce emissions, but they also have limitations; these transit systems are effective in moving masses of travellers from fixed point to fixed point. But they do not solve the first and last mile problem. Users may live too far away from transit points to walk, have a physical disability or face extreme weather conditions.

For this issue car sharing is the best solution. The most sophisticated form today is a self-service, on demand, pay-as-you-use usage model, which allows cars to be rented by the hour, based on a membership model. From 3.3 million in 2013, Frost & Sullivan forecasts the car sharing membership to grow exponentially globally to 26 million by 2020, even in markets which have traditionally been car ownership driven such as Italy. Over 40% of Zipcar's members, one of the world's largest car sharing clubs, have given up ownership of their personal vehicles. Recent surveys indicate that one car-sharing vehicle has the potential to remove up to 17 privately owned cars from the road. Car sharing will be complemented by dynamic parking solutions at rail stations and transportation hubs which have the potential to reduce congestion by 30% that originates from searching for parking spaces in urban areas.[x]

Similarly to the car sharing, bike sharing networks are usually based on an annual subscription with a self-service, on demand and pay-as-you-use usage model. A recent report by Roland Berger found that already 533 cities around the world are operating bike sharing facilities. It is asserted that the more wide-spread use of e-bikes will attract new customers and will open up cities whose topography up to now has characterised them as difficult markets.[xi]

Autonomous mobility-on-demand (A-MoD) networks utilising lightweight electronic vehicles (LEV) will accelerate market growth of integrated mobility, eMobility and automated driving. In contrast to car and bike sharing, an A-MoD system will not face redistribution problems as it can deliver a vehicle directly to the user's location. Once the user is dropped off, the shared LEV will drive on its own to pick-up another user or to park itself for recharging.

Table 3 provides a breakdown of some of the key winning product categories resulting from integrated mobility growth globally.

3.3.3 Quantification and Forecast

The great variety of market segments is inherent for integrated mobility. Most of them such as travel management services or public transportation are well established sectors. As a result, their revenue performance cannot serve as an indicator for the integrated mobility market. Currently mushrooming market segments in the emerging era of integrated mobility are car sharing, ride sharing, bike sharing and shared parking. In 2014 bike sharing generates the highest turnover on the market but it is projected that car and ride sharing revenues will exceed those of bike sharing after 2020. Ride sharing and shared parking will have a strong growth period between 2030 and 2040 when the automated driving market and A-MoD will gain momentum.

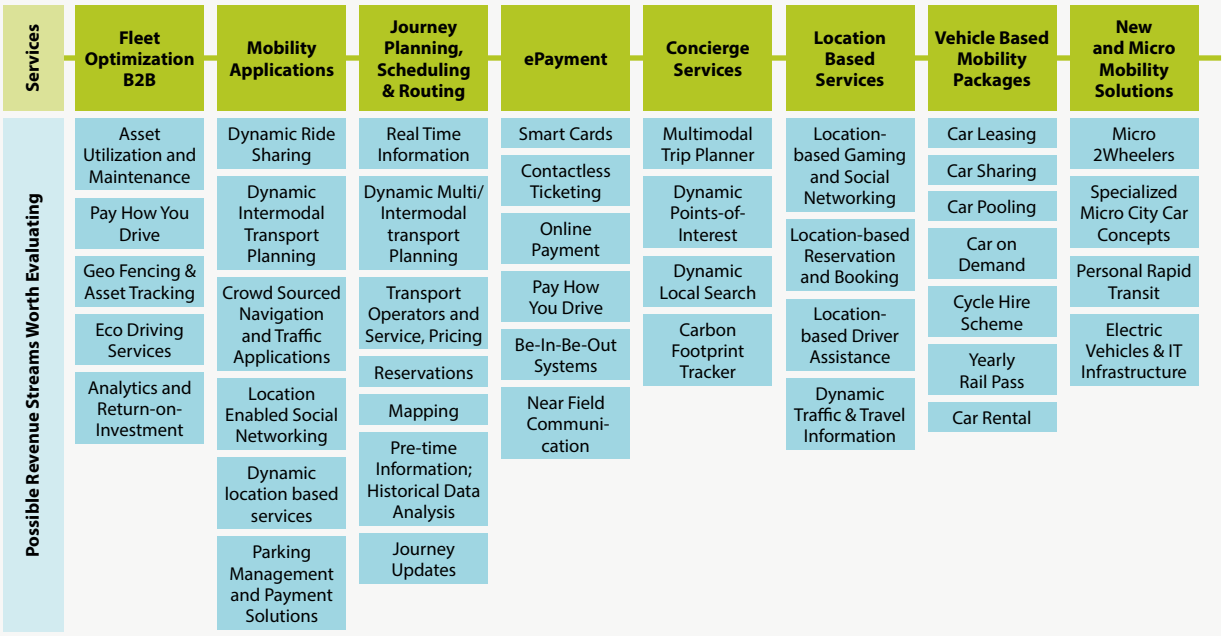
ix Transport Systems Catapult 2015

x Roland Berger 2014:10

xi Roland Berger 2014:10

Figure 13: Integrated Mobility: Products and Services

Source: Frost & Sullivan



3.3.4 New Business Models

Increasing connectivity and the big data trend are the catalysts for a surge of integrated mobility. How we move through cities and between networks of cities is revolutionised thanks to ubiquitous computing that allows integrated travel solutions. Market participants will have to conceptualise business models aggregating every available traffic information and travel options and offering easy-to-use solutions to travellers.

Seamless travel integrating different modes under a single entity will become a new reality in urban mobility models and the ownership of a car will not necessarily be an integral part of these models. According to Frost & Sullivan analysis there are three emerging business models within mobility integration: mobility integrators, aggregators and players.

3.3.4.1 Mobility Integrator

A mobility integrator is an entity which enables the existence of mobility programmes through its current offering or partnerships with third parties. It can work as a stand-alone entity or function as a programme manager along with other mobility participants to provide various modes of transport and payment options to consumers. It need not necessarily own any of the products nor offer all the modes available. National and city level transport operators are generally expected to be prime candidates capable of mobility integration. The Netherland's NS rail operator has associated with fleet companies and is looking to expand further. Major car manufacturers like BMW and Daimler are also transforming themselves into integrated mobility providers. Daimler expects to make US$ 138 million through its mobility services arm in 2014 and is targeting US$ 1 billion in sales by 2020.

3.3.4.2 Mobility Aggregator

A mobility aggregator is an entity which offers a selection of mobility services as a core business, either as stand-alone provider or through partnerships with other stakeholders to expand its mobility offering under a single packaged solution. Fleet companies like ALD, Alphabet, and LeasePlan are projected to emerge as mobility aggregators. Carsharing companies like Zipcar, Stadtmobil or Greenwheels are expected to follow the lead and partner with fleet companies to further grow and strengthen integrated mobility links.

3.3.4.3 Mobility Players

Mobility players are organisations that provide limited mobility products and services based around their core

Table 3: Integrated Mobility: Products and Services – Winners & Trends, 2014–2050

Source: Frost & Sullivan

Winners	Trends
Car-sharing (including micro car and scooter-sharing)	The boundaries between car sharing and car rental services are more and more fluid. Indeed, Avis snapped up Zipcar for a US$ 500 million in 2013 to leverage its fleet, which is relatively underutilised in the weekends. However, one of the key drivers for its purchase of Zipcar was to develop a virtual car rental model for the car rental industry, which still has brick-and-mortar stores and fixed parking to facilitate rentals.
Bike-sharing	Bike sharing is a self-service, on demand, pay-as-you-use usage model, based on a membership model, which allows renting bicycles by the minute. Bike-sharing improves the first and last mile connectivity. Thanks to e-bikes or pedelecs, travellers might bridge even greater distances on average.
Autonomous eMobility-on-demand (A-eMoD)	A-eMoD is an integrated and green mobility service combining eMobility and autonomous driving. Users can combine shared-autonomous vehicles for short distances with public transport and finish their journey by bike or foot.
Corporate car-sharing	Corporate car sharing involves placing a dedicated fleet of vehicles at a company's premises for shared use amongst its employees. There were 1,930 corporate car sharing vehicles identified across 10 European countries in 2013, but this market is expected to exceed 100,000 cars in Europe alone before the end of this decade.
Integrated travel management applications	Intermodal travelling is organised and booked through a mobile application featuring advanced transit technology and offering concierge services. Smart ticketing and payment modes will reduce the need for carrying multiple cards and paper tickets. The focus will be on consumer 'pay as you go' and e-ticketing using mobile phone and smart applications to transfer and check booking data.
On-demand busses	Busses will be dynamically routing pick-ups and drop-offs based on user demand. These systems improve operational efficiency and reduce carbon emissions by eliminating unnecessary stops.[xii]
Real-time ride-sharing	Real-time ride-sharing is a type of carpooling that utilises GPS navigation, smartphones and social networking in order to arrange instant one-time shared rides. Thus, the degree of vehicle capacity utilisation can be enhanced.
Pay as you drive (PAYD) insurance	PAYD is a type of vehicle insurance whereby the costs are dependent upon type of vehicle used, measured against time, distance, behaviour and place. Especially, the trend towards car-usership business models boosts this form of vehicle insurance. It not only takes the high number of drivers per vehicle into account but also their different usage-frequencies.
Dynamic parking **Parking Management Systems**	Dynamic parking systems support drivers' search for vacant parking spaces. The objective is to reduce search time in order to reduce road congestion and related carbon emissions. People may share their private parking lots when not in use.

product and leverage their existing core business to expand into related new mobility offerings. Mobility players may buy fleets of purpose-built vehicles from car manufacturers and provide them to subscribers, delinking drivers from the automotive market. In answer to these changing market conditions, OEMs like BMW, Daimler and Volkswagen are currently enlarging their scope of business into integrated mobility with customised solutions in order to become mobility players.

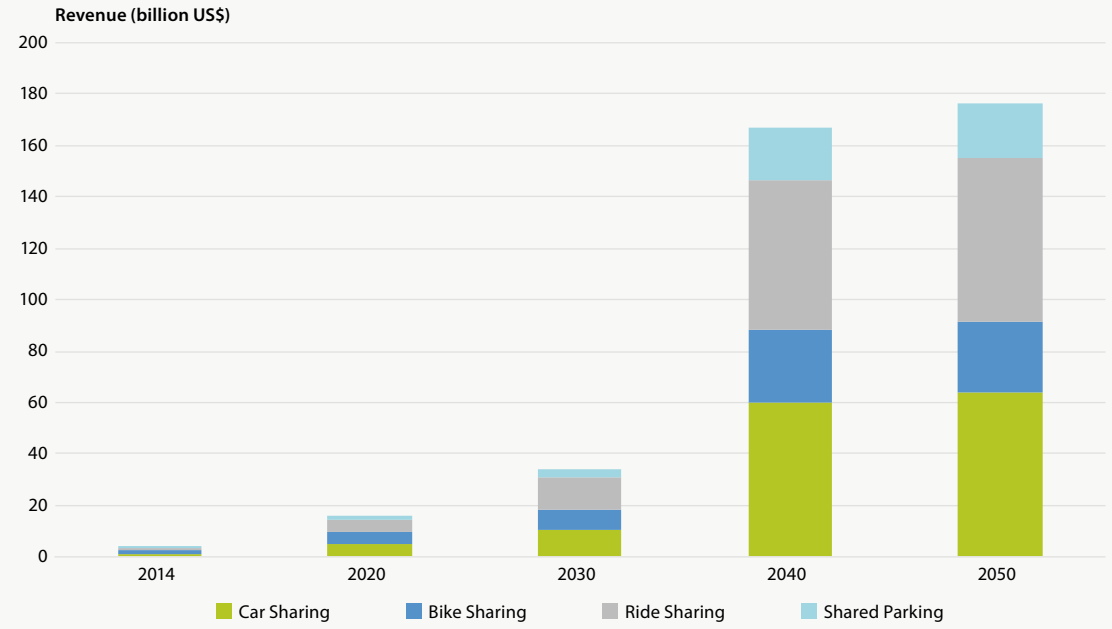
3.3.4.4 Peer-to-peer mobility

A special case is the evolving peer-to-peer (P2P) mobility business model, where personal vehicles and parking lots are lent to others through commercial platforms or through communities of trust, such as family and friends. Alternatively, rides can be shared by means of P2P networks.

xii BBC 2013

Figure 14: Integrated Mobility Market: Revenue Forecast Global, 2014–2050

Source: Frost & Sullivan



***Djump** is a profit-oriented French/Belgian mobile transport app allowing drivers to register, passengers to request a ride and drivers to answer the call. At a time when cities are under an increasing environmental and economic strain, initiatives like Djump also provide a low-cost solution to reducing urban congestion and carbon emissions.*[xiii]

Investment into integrated mobility is expected to represent a US$ 176 billion market by 2050 enabling growth in automated mobility, which is anticipated to become an enormous US$ 3.6 trillion market by the same year.

P2P mobility is the prime example of personal transport merging with public transport and utilising wasted travel capacity.

Investment into integrated mobility is expected to represent a US$ 176 billion market by 2050 enabling growth in automated mobility, which is anticipated to become an enormous US$ 3.6 trillion market by the same year.

xiii Mullie 2014

4 Energy Systems

KEY INSIGHTS

The renewable energy market is expected to account for over 40% of the global energy mix by 2050, amounting to an annual market of US$ 800 billion

The prosumer market will drive growth in distributed power and battery energy storage, preceded by widespread integration of enabling smart grid infrastructure

The biofuels market will become a major player in the liquid fuels space accounting for over 20% of liquid fuel consumption by 2050

The smart grid and biofuels market will represent the largest markets of the trends analysed amounting to annual markets of US$ 398 billion and US$ 757 billion respectively by 2050

Over the next 35 years the nature of the energy market will change fundamentally. Annual investment in the sector is expected to grow to US$ 455 billion by 2030 and reach US$ 800 billion by 2050.

OVER THE NEXT 35 YEARS the nature of the energy market will change fundamentally. Renewable energy is expected to continue to show strong growth in investment and account for approximately 40 to 65% of total global electricity generation by 2050.[xiv] Annual investment in the sector is expected to grow from US$ 214 billion dollars in 2013, to US$ 455 billion by 2030 and reach US$ 800 billion by 2050.[xv] The historically centralised nature of the electricity generation sector will fragment significantly through the incorporation of disruptive technologies in distributed power, electricity storage and demand side management. A continuing decline in costs of solar photovoltaic (PV) modules and innovations in new value-add technologies in ICT and electricity storage will increase the bankability of distributed energy projects and promote increased government support for rollout programmes. Residential and commercial solar PV is expected to account for 50% of total installed solar PV generation capacity by 2050, and 8% of total electricity generation, and this growth will be supported by the availability of cost-effective distributed storage technology.[xvi] The availability of smart infrastructure and ICT systems and services for smart grids will form the foundation for growth in distributed generation and demand response (DR) systems.

The following section provides an overview of the key industry low-carbon trends expected to drive the evolution of the energy market over the following decades. Subtrends selected for analysis based on these criteria are: Smart Grids, Prosumers, Energy Storage and Bioenergy.

Table 4 provides a summary overview of core future trends in the renewable energy market.

4.1 Smart Grids

4.1.1 Overview

The future evolution of the energy system to a more distributed model is largely dependent on the rollout of enabling smart grid infrastructure to allow for efficient integration and management of the grid without compromising electricity supply security. The smart grid market is expected to show rapid growth, reaching a market size of US$ 400 billion by 2050, accounting for 23% of the global smart city market.

Development of smart grid infrastructure will drive market opportunities in distributed 3rd generation wind and solar power, smart metering, increased integration of renewables with HVDC lines, grid feed-in by prosumer markets, virtual power plants and consumers, and on a whole, increase efficiencies in generation, transmission and distribution reducing emissions.

xiv International Energy Agency, "2DS" scenario, 2014

xv International Energy Agency, 2013

xvi International Energy Agency, Technology Road Map: Solar Photovoltaic Energy, 2014

Table 4: Global Installed Capacity & Investment Trends, 2010–2050

Source: World Energy Outlook, Frost & Sullivan

Low Carbon Generation	Trends	Investment Requirements 2010–2050 (US$ trillions) [xvii]
Photovoltaic (PV) Solar Power	Capacity is expected to rise from 98 GW in 2012 to 930 GW in 2040. To 2025, the market is expected to continue to shift away from Europe; however, this will be offset by booming markets such as China, the United States, and Japan.	**2.95** (total solar)
Concentrated Solar Power (CSP)	Capacity is due to rise from 2.6 GW in 2012 to 102 GW in 2040. To 2025, attention will shift to the United States as well as to the Middle East, North Africa, and China. New applications in thermal and electrochemical storage will further assist future growth.	
Hydropower	Global capacity will rise from 1,1 GW in 2012 to 1,8 GW in 2040. To 2025, the market will increasingly be driven by China (72% of new capacity in 2013); however, other key markets include Turkey, Brazil, Vietnam, India, and Russia.	**1.95**
Wind Power	Global wind capacity will grow from 279 GW in 2012 to 1321 GW in 2040. To 2025, the market will enter a more mature phase with weaknesses in Europe and the United States only partly offset by strong growth in China. Lower growth is expected for offshore wind than previously anticipated, as political support in Europe has declined. Small-scale wind turbines will open up new applications such as telecoms and general electrification.	**2.72**
Bioenergy and Waste	Global bioenergy and waste capacity is due to rise from 97 GW in 2012 to 289 GW in 2040. To 2025, growth is expected to shift away from Europe towards North America, China, and parts of Southeast Asia. More coal plants are being converted to biomass or co-firing operations with biomass as a way of meeting emission reduction targets.	**0.5**
Geothermal Power	Geothermal power capacity will grow from 12 GW in 2012 to 56 GW in 2040. Technology is currently operational in 25 countries but toward 2025 capacity expansion will largely be driven by Southeast Asia, Australasia, North America, Turkey, Iceland, and Kenya. Future commercialisation of enhanced geothermal systems (EGS) will stimulate future adoption, as will future price declines of organic Rankine cycle (ORC) turbines due to large-scale production.	**0.72**
Nuclear Power	Global nuclear power installed capacity will increase from 396 GW in 2012 to 624 GW in 2040. Key high growth markets to 2050 include China, India, South Korea, Russia and Saudi Arabia	**1.01**
Marine Power	Encompassing tidal and wave power, substantial deployment of marine power will only occur beyond 2025. Global capacity is set to rise from 0.5 GW in 2012 to 25 GW in 2040. South Korea and the United Kingdom are market leaders, with the European Commission releasing a new action plan in 2014 to accelerate the penetration of marine energy in Europe.	–

xvii World Energy Council, Jazz Scenario, 2013

The smart grid market is expected to show rapid growth, reaching a market size of US$ 400 billion by 2050.

4.1.2 Key Trends in Products and Services

4.1.2.1 Smart Metering

Smart Metering is an integral component of any smart grid strategy. Smart metering supports bidirectional information flow from an enabled meter at the customer premises back to the utility. The smart meter has the capability of operating as the primary communication gateway for smart grid-equipped electronic home appliances as well as value-added software services. Core revenue components of the smart meter solution include installation, communication systems/networks, meter data management, and programme management.

4.1.2.2 Demand Response

Demand response consists of tools and incentive plans offered by the utility to reduce and manage power consumption during peak power periods. Core revenue components of the smart meter solution include Power curtailment revenue, Home area network and management, and Smart home appliances.

4.1.2.3 Distribution Grid Management

Distribution grid management covers distribution automation, substation automation and integration, and field equipment. Utilities are considering strategies to implement distribution automation to mitigate and reduce power interruptions as part of their smart grid strategy. Core revenue components of the distribution grid management solution include distribution automation, substation automation and integration, and field equipment.

4.1.2.4 High-voltage Transmission

Besides automation, the market also expects to see investment in high-voltage transmission technology to address grid inadequacies in order to allow higher degrees of renewable energy integration. Key components and revenue streams for high-voltage smart transmission include high-voltage direct current lines (HVDC), ultra-high-voltage direct current lines (UHVDC), and flexible alternating.

Table 5 provides a breakdown of some of the key winning product categories resulting from smart-grid growth globally.

4.1.3 Quantification and Forecast

In 2014, the global smart grid market showed revenues of US$ 79 billion, 50% of which was accounted for by smart distribution grid management (DGM). This market share is expected to increase further to 2020, driven by initiatives to mitigate and reduce power interruptions, improve overall power management, and improve use of existing resources. This is because of continued high investment in renewable energy generation at both the utility and non-utility scale. Beyond 2020, smart DGM will continue to be driven by the need for grid flexibility to meet power fluctuations and supply-demand balances associated with EV battery charging. New renewable high voltage direct current (HVDC) lines and smart technology (e.g. FACT) will show its highest growth between 2020 and 2030, where by 2030 it will account for 49% of total smart grid market revenues. This growth will be due to a 160% increase in utility scale wind power and a massive 234% increase in solar PV power.[xviii] Growth in this market is expected to then slow to 2050 due to infrastructure saturation in key renewable energy markets. Demand response technologies (excluding distributed PV and storage),– only 3% of the market in 2014 – will show sustained growth to 2050, driven primarily through global peak demand growth in core markets, along with government mandated efficiency targets. This market is forecast to account for 6.5% and 15% by 2030 and 2050 respectively. Smart metering is forecast to show sustained, albeit relatively conservative, growth of 3% CAGR for 2014 to 2030, and 2% CAGR for 2030 to 2050, as many countries are opting for gradual rather than aggressive rollout programs. The key growth markets for the next 15 years to 2030 are France, Japan, Netherlands and the UK.

The development of the smart grid will establish end-users as active participants in electricity production.

4.1.4 Future Business Models

The four future business models discussed in this chapter assume consistently strong investment in decentralised generation to be enabled by smart grid technologies. Utility companies will be challenged by independent

xviii International Energy Agency, Hi-ren scenario, 2014

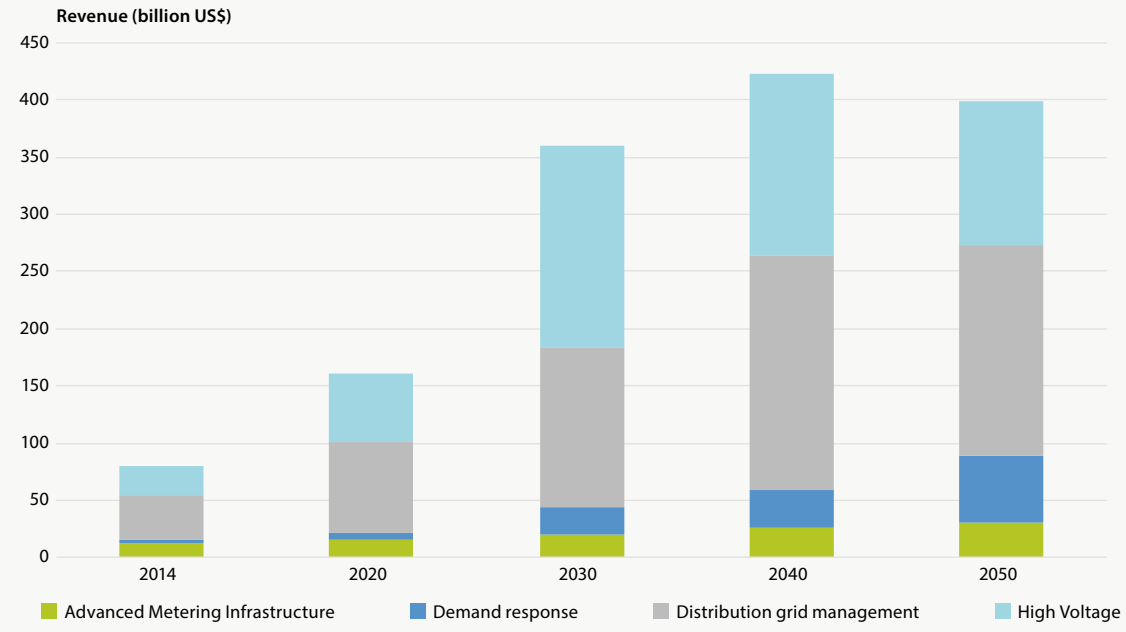
Table 5: Smart Grid: Products & Services – Winners & Trends, 2014–2050

Source: Frost & Sullivan

Winners	Trends
Smart Metering	Smart metering and home automation (lighting, thermostat, water heating, electricity consumption / feed-in), and the efficiencies these systems represent to the grid operator, is expected to represent the primary initial driver for smart grid development
Demand Response Services	Value added services for both the distributed system operator (DSO) and consumer will increase attractiveness of smart solutions. These will include: Big data & Predictive analytics; software apps for energy monitoring, control and usage; Energy management systems for meter control and billing. These systems will significantly strengthen the business case for demand response programmes and promote technology uptake by end-users.
HVDC for Renewables and FACT Devices	The market expects to see significant investment in high-voltage transmission technology including HVDC to address inadequacies for renewable energy integration, as many renewable energy projects are remote and far from load centres. This results in losses incurred by long-distance transmission. Furthermore, FACT devices such as static VAR compensators (SVC) and series capacitors can improve voltage stability as well as allow power flow on existing lines.
Grid monitoring systems and phasor measurement units (PMU)	With the expected growth in volatile renewable and decentralised power, significant upgrades in grid responsiveness will be required in order to maintain grid reliability and health. New monitoring systems, such as PMUs, will address issues such as transmission congestion, voltage degradation, and managed and unmanaged outages. These will provide data feedback on a real-time basis and alert grid operators about specific contingencies.
Wide-area monitoring systems, wide-area adaptive protection, control and automation (WAAPCA) **Network stability analysis, automatic recovery systems**	As renewable energy integration continues to increase, a greater and more responsive degree of control will be needed in order to maintain required stability levels. This will be met through grid automation, report and remote management through the integration of these technologies.

Figure 15: Forecast Revenue Growth of the Smart Grid Market, 2014–2050

Source: Frost & Sullivan



companies and will have to innovate to survive; fundamental to this will be a stronger, more collaborative approach with customers as partners in power generation and an increased focus on energy service offerings to offset the revenue loss from the traditional conventional generation business model.

The development of the smart grid will establish end-users as active participants in electricity production, fundamentally changing the traditional electricity value chain. Utilities and grid operators are expected to begin to adopt new forms of business models in order to secure their revenue streams, but there are also opportunities for independent operators. The following represents future business models that are expected to be adopted by utilities, network operators, and energy service companies (ESCOs) in the smart evolution of electricity grids.

4.1.4.1 Sophisticated Virtual Power Plants

This model typically involves a large energy utility that acts as a sophisticated virtual power plant by aggregating micro-generation units owned by residential and commercial customers. Virtual power plants can be built around any micro-generation technology (e.g., solar PV, small wind, CHP), however beyond 2015, we see solar PV dominating globally. RWE's micro-CHP pilot projects in Germany utilise the virtual power plant business model with electricity generation connected to the grid over a smart meter.

4.1.4.2 Pureplay Aggregator

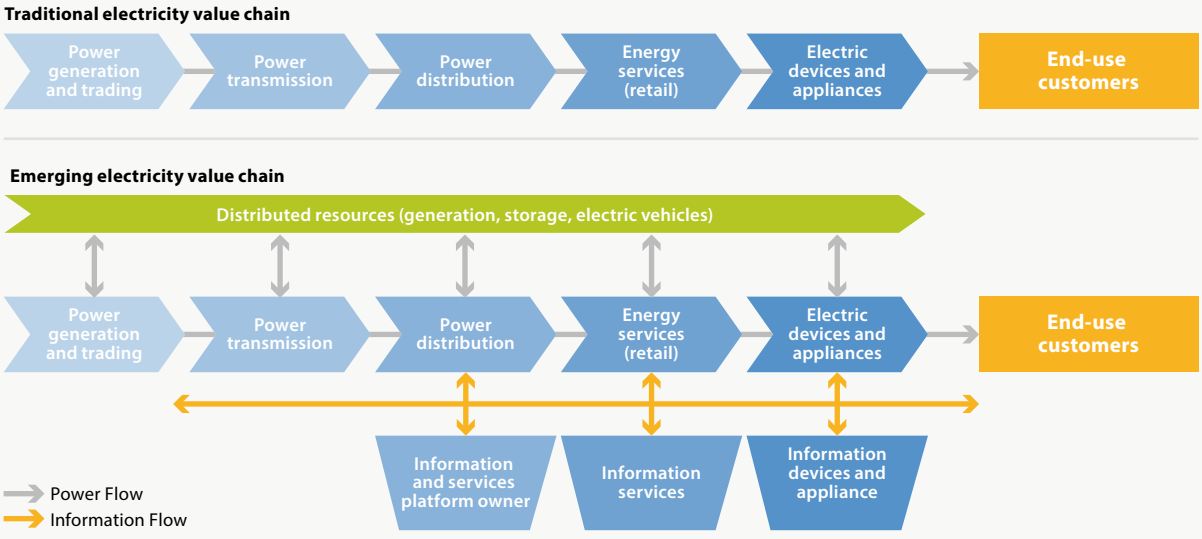
This model involves a utility or independent company that aggregates flexible micro-generation units owned by residential and commercial customers. The home aggregator's function resembles that of an energy service company (ESCO), which evaluates the profitability of an energy-saving initiative, makes installations, and helps with financing. A good example is Smartest Energy in the United Kingdom. The aggregator model has been well-tested in industrial and commercial markets; it is similar to the virtual power plant but simpler and less dependent on a sophisticated smart grid. This model is most suitable for applications in small commercial premises and community CHP and renewable energy projects.

4.1.4.3 Technology Seller/Installer

In this model, the utility or network operator sells and/or installs micro-generation units to its residential and commercial customers. For a pureplay technology seller, the key goal of this business model is to make profitable sales of equipment to domestic customers. These units are sold by the utility and may be owned by the customer or the utility through a build-own-operate (BOO) model. The

Figure 16: Emerging electricity supply chain through smart grid development, 2014

Source: IBM Institute for Business Value



model exploits the network of target customers to whom utility companies typically have access. The utility may also act as an ESCO that evaluates the profitability of an energy-saving initiative, makes installations, and helps with financing. In some cases, utility companies have seen the benefit of taking equity stakes in equipment participants, whereby the utilities become key channels to market.

4.1.4.4 Hybrid Model (Technology Installer and Aggregator)

In this model the utility or network operator plays the combined role of technology installer and aggregator. The company installs micro-generation units for its residential customers for a one-time installation fee. The customers pay for the heat/electricity, with excess electricity sold back to the grid. These units may be owned and maintained directly by the utility, or they can be owned by the customer but maintained by the utility. The end customers can apply for energy-efficiency certificates or benefit from feed-in-tariffs or low energy costs (e.g., LichtBlick, E.on, Eneco, Edison).

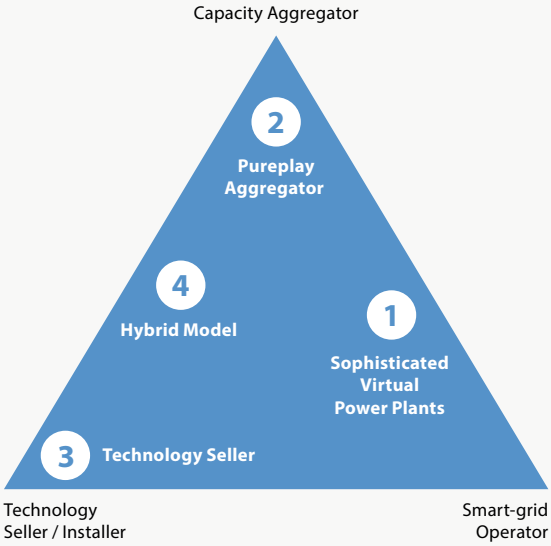
***E.on Benelux** which has partnered with Sungevity, a residential solar service company, to sell co-branded panels to customers in the Netherlands is a good example of this emerging model. In this partnership, the utility will install solar panels on residential roofs in exchange for lower bills – effectively leasing the space from the owner. The customers would initially be on a 15-year lease, paying a certain amount per year, and will eventually own the equipment. The Netherlands is a good pilot market for this concept as the cost of electricity is high making renewable energy an attractive option for residential customers. The utility shares the benefits of self-generation with the prosumer while further locking them into a long-term relationship.*

The hybrid-model allows utilities or aggregators to maintain control of electricity generation into the future, while simultaneously acquiring a high degree of transparency and control of regional load profiles through smart meters. Because of this, the hybrid model is expected to represent the more attractive business model for utilities and grid aggregators in the future.

The total size of the prosumer market is expected to reach US$ 120 in 2050.

Figure 17:
Smart grid business models, 2014

Source: Frost & Sullivan



4.2 Rise of the Prosumer

4.2.1 Overview

The growth of distributed renewable generation, supported by incentives and legislation, is creating the business case for the prosumer model, moving beyond simply grid independence toward active participation in both electricity generation and demand-supply balancing. For the purposes of the research, the commercial opportunity reported for the prosumer market includes residential and non-residential PV systems along with residential and commercial storage systems. The total size of the prosumer market is expected to increase from US$ 24 billion in 2014, to US$ 72 billion in 2030, and reach US$ 120 billion in 2050.

Currently, policy incentives and subsidies are the main drivers in key niche markets such as Germany and California. In order for the market to mature to a point whereby end-users can become commercial suppliers of electricity, the technology need to be commercially viable beyond government support programs. This point

of commerciality is largely dependent on specific market conditions within the distribution zone and country in which the prosumer is located; and will inevitably come down to a measure of the levelised cost of generation of the system vs. the presiding electricity tariff offered by the distribution system operator (DSO).

Commercial customers will principally drive growth to 2030, after which point the residential market will become more important; grid parity for the market will begin to be reached from 2022 and accelerate to 2038, with the majority of residential prosumers reaching parity post-2030. However this will vary by state and country, with some utilities becoming much more vulnerable to the rise of the prosumer much earlier. Key countries expected to strong early growth in the prosumer market are the USA, Germany, Japan, South Korea and Italy.

4.2.2 Key Trends in Products and Services

A key component of the prosumer model is storage. Electricity storage is a trend that will be analysed independently in the following chapter; however, it is worth mentioning at this stage that the rollout of distributed power in the future will be largely coupled with distributed storage (particularly residential and non-residential PV) as a total hardware solution for consumer-to-prosumer conversion. Energy storage will be essential in lowering the total levelised cost of electricity (LCOE) for distributed generation. Concurrent technology development within both these industries will drive the prosumer value proposition into the future. Smart metering is also a fundamental component of the prosumer market and future development relies on its integration into the distribution grid.

Table 6 provides a breakdown of some of the key winning product categories resulting from prosumer market growth globally.

A key component of the prosumer model is storage.

4.2.3 Quantification and Forecast

By 2050, the market for residential and commercial systems are expected to grow from an annual revenue of US$ 22 billion in 2014, to US$ 42 billion in 2030, and reach US$ 77 billion by 2050. The highest growth period is between 2030 and 2040, largely driven by the adoption of residential and commercial battery storage systems and government policy intervention. Market growth is then forecast to slow from 2040 to 2050 as saturation is reached in key markets. The market for residential and commercial battery storage systems is forecast to grow rapidly from 2020, to reach annual revenue of US$ 30 billion by 2030. As with residential and non-residential PV systems, the market will slow post 2040 due to market saturation. Total size of the prosumer market is expected to reach US$ 120 billion by 2050, up from US$ 24 billion in 2014.

Table 6: Rise of the Prosumer: Products & Services – Winners & Trends, 2014–2050
Source: Frost & Sullivan

Winners	Trends
Distributed 3rd Generation Organic Solar Cells	Third generation solar cells are less expensive, flexible, lightweight and efficient. New generation cells include dye sensitised cells, organic polymer cells, nanocrystal solar cells, hybrid solar cells and photo electrochemical (PEC) cells.
Distributed 4th Generation Wind Power	Improved efficiency through i.e. direct drive generators, direct current output, aeroelastic blades. Program management software employing preventive and predictive maintenance functionalities that help operators to adjust each wind turbine for maximum output. Simulation programs in designing and developing wind turbines, such as FOCUS and FLEX, further enhancing performance.
Residential and Commercial Battery Storage	* Discussed in following section
Solution providers and services	* See “Demand Response Services” in Table 5

Figure 19 provides a breakdown of the key first movers for the prosumer market, based upon the current development of the market.

4.2.4 Future Business Models

The rise of the prosumer market will lead to significantly increased collaboration between the consumer, ESCOs, aggregators, retailers and the distribution system operator (DSO) in order to develop efficient and mutually beneficial platforms for the trade and dissemination of electricity to the grid. ESCOs and virtual power plants (VPPs) will need to diversify their product offerings to allow for increased value added services in electricity trade, information services, predictive analytics and financing to prosumers in order to maximize value for all parties. DSO's will further need to evolve from their single axis of control through the development of required infrastructure and connectivity to ensure efficient electricity trade while maintaining grid stability and work in close collaboration with ESCOs and aggregators as the market expands.

The following chapter provides an analysis of findings by the Technical University of Madrid's (UPM) as part of the paper: "Business Models in the Smart Grid: Challenges, Opportunities and Proposals for Prosumer Profitability".

The future prosumer model is expected to encapsulate the following value propositions to consumers (Figure 20).

Energy service companies (ESCOs) will be integral in the development of prosumer business models, as they are able to offer four out of seven of the above value propositions, namely: money saving, pragmatist users, environmentally conscious, and energy stalwarts.

4.2.4.1 ESCO prosumer-oriented business model

The prosumer-oriented business model places the prosumer on the same level as the ESCO; both utilise the smart grid marketplace for value generation. Value for the prosumer is lower electricity tariffs, or revenues provided for the management and rescheduling of energy intensive operations depending on the requirements of the ESCO, and through it, the distribution system operator (DSO). Within the model, ESCOs will be responsible for the communication of energy-related information and predictive analytics, along with other value added services, to the prosumer in order to allow it to properly leverage the value of the service. ESCOs will further be responsible for the aggregation of energy produced from end-users for sale to the marketplace.

Figure 18: Forecast Revenue Growth of the Prosumer Market, 2014–2050

Source: Frost & Sullivan

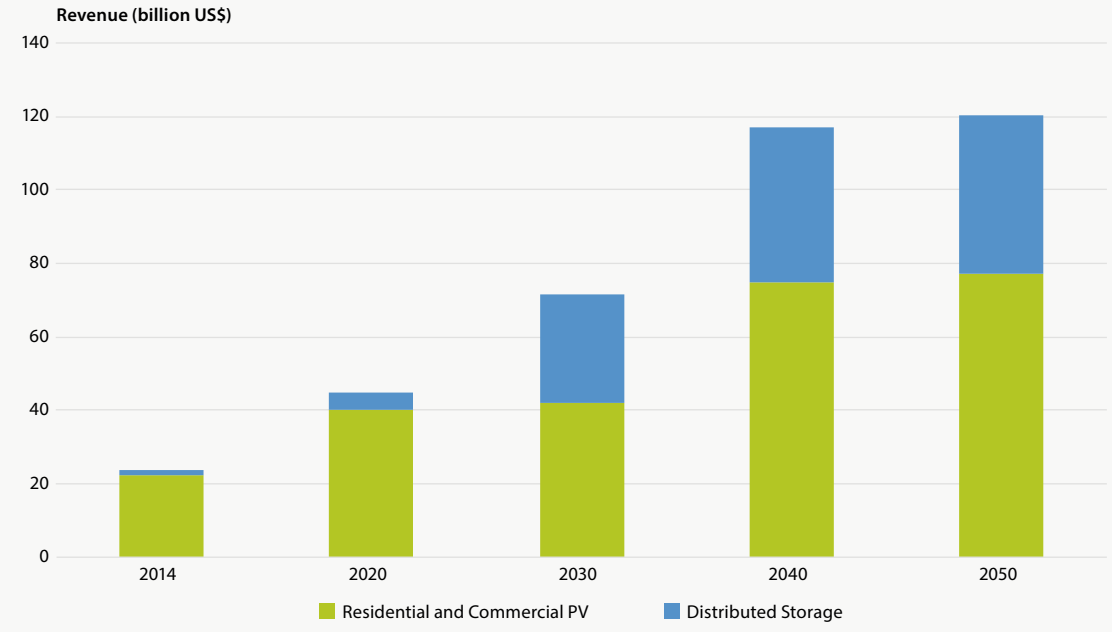


Figure 19: Future high growth prosumer markets, 2014

Source: Frost & Sullivan

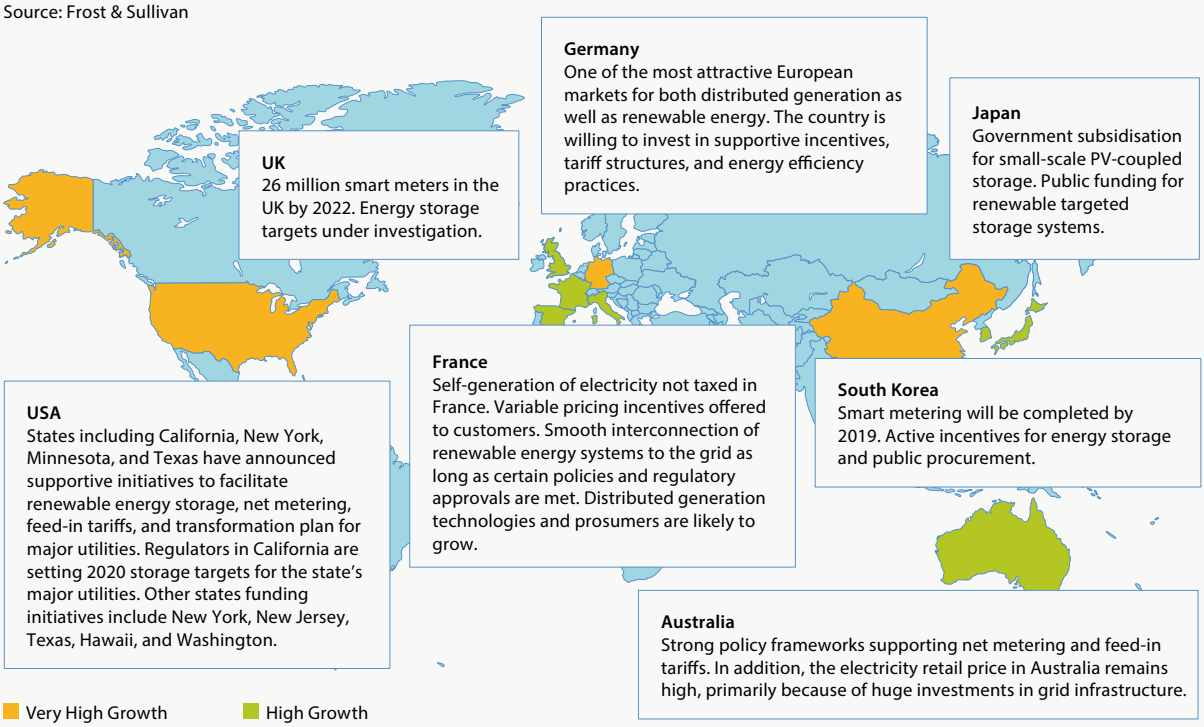


Figure 20: Key Prosumer Value Propositions, 2014

Source: Martínez-Núñez et al., Frost & Sullivan analysis, 2014

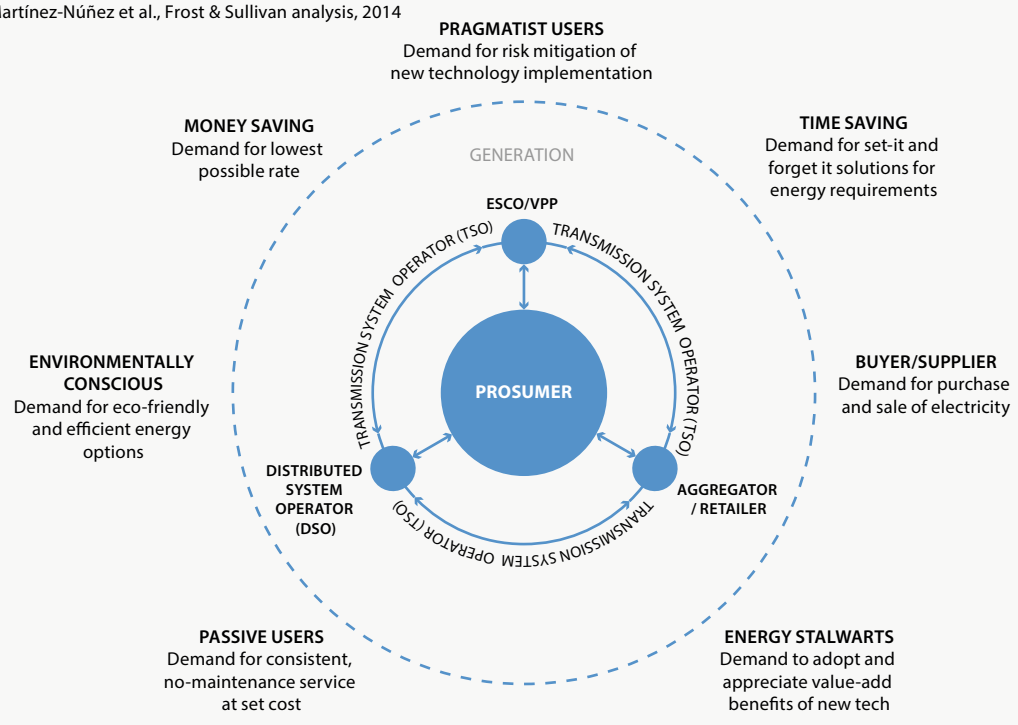


Table 7: ESCO prosumer-oriented business model characteristics, 2014

Source: Martínez-Núñez, Martínez, Pérez-Aguiar, Rodríguez-Molina, Frost & Sullivan analysis, 2014

Value Proposition	Prosumer Interface
• Improved energy efficiency • Reduced energy costs • Energy performance contraction	• Improved energy efficiency • Reduced energy costs • Energy performance contraction
Infrastructure	**Revenue Model**
• Smart grid data management • Grid monitoring	• Energy savings energy efficiency enhancements • Charge for performance / service level offered

4.2.4.2 VPP prosumer-oriented business model

The virtual power plant (VPP) prosumer-orientated business model allows for the commercial sale of electricity from aggregated prosumer generation (independently or together with privately owned distributed energy resources (DER)) to the marketplace. The VPP will operate a large number of micro-generators, responsive loads and storage units on behalf of the prosumer. The business model expresses the buyer/supplier and environmentally conscious value propositions of the prosumer business case. VPPs are likely to cooperate with the ESCO, if not being operated by the ESCO itself, in order to increase its market position and ensure profitable sale of electricity to the market based on competitive conditions. Prosumer value is delivered in the form of revenues from electricity sale via the VPP, in cooperation with the ESCO, to the marketplace.

Table 8: VPP prosumer-oriented business model characteristics, 2014

Source: Martínez-Núñez, Martínez, Pérez-Aguiar, Rodríguez-Molina, Frost & Sullivan analysis, 2014

Value Proposition	Prosumer Interface
• Flexibility of energy generation • Providing a prosumer with market access	• Advanced systems for energy management
Infrastructure	**Revenue Model**
• Distributed generation systems • Electricity storage devices	• Electricity sale • Energy consumption / production / storage based on real-time energy pricing

4.2.4.3 Aggregator/retailer prosumer-oriented business model

Aggregators are responsible for purchasing electricity from prosumers and the metering and billing of their consumer base. Within this model, the aggregator provides information and facilitation services between consumer/prosumer and the market, providing end-users the knowledge, and flexibility, to efficiently respond to changing prices and bids offered by the energy market.

Table 9: Aggregator/retailer prosumer-oriented business model characteristics

Source: Martínez-Núñez, Martínez, Pérez-Aguiar, Rodríguez-Molina, Frost & Sullivan analysis, 2014

Value Proposition	Prosumer Interface
• Operate and optimize energy consumption made by prosumers • Demand response • Flexible electricity tariffs according to momentary market conditions	• Prosumers community • Prosumer relationship management • Automatic energy price information
Infrastructure	**Revenue Model**
• Advanced metering infrastructure • Automatic metering services (AMS)	• Real-time and critical peak pricing (RTP) • Time of use pricing (ToU)

4.2.4.4 DSO prosumer-oriented business model

With the development of a fully integrated smart grid, the responsibilities of the DSO will need to evolve beyond its single axis of control, as the importance of the prosumers contribution to the health of the distribution grid increases. The business model will involve the development of the required infrastructure and connectivity in the grid to enable an open marketplace for the generation and trade of electricity from prosumers, while ensuring grid stability and security of supply. Core revenue drivers will include: revenues accrued from electricity sale, connection services and associated information services and T&D fees.

Table 10: DSO prosumer-oriented business model characteristics

Source: Martínez-Núñez, Martínez, Pérez-Aguiar, Rodríguez-Molina, Frost & Sullivan analysis, 2014

Value Proposition	Prosumer Interface
• Security of supply and quality of service • Choice of energy source • System flexibility services • Market facilitation	• Active demand program • Real-time media- or web-based communications • In-home displays
Infrastructure	**Revenue Model**
• Grid connection • Smart metering systems • Local network services)	• Energy selling • Static pricing rovision of connection services • Transmission / distribution fees

4.3 Battery Energy Storage

4.3.1 Overview

Growth in distributed battery storage will be primarily dependent on growth in decentralised renewable power, smart grid development and peak demand growth in key markets. The market will further be driven by the growth in the electric vehicle and hybrid-electric vehicle markets, through the need for storage units in households and charging stations, as well as associated cost reductions in battery technologies due to the expanding production capacities in response to market demand.

Battery technology is by no means the only growing technology in distributed energy storage (DES). Other growing technologies, such as compressed air energy storage, flywheels and super-capacitors, all offer promising storage applications to the market. However, due to the rapid development of associated battery markets for electric vehicles (electric vehicles (EV), hybrid electric vehicles), consumer electronics and wearable products (e.g. mobile phones, wrist-wear, head-wear), and the resulting substantial growth in technological development, manufacturing capacity, and cost reductions, battery technology currently shows one of the most promising options for future commercialisation. The following chapter will therefore focus on battery storage as the key trend in DES development.

Distributed battery storage revenues are forecast to be US$ 7 billion by 2020, with the fastest growing segment being that of residential and commercial battery systems, amounting to US$ 1.4 billion and US$ 3.6 billion respectively. By 2030, the market is expected to surpass US$ 50 billion to reach US$ 90 billion by 2050. Key demand markets are expected to exist in regions with: a high future growth of renewable energy and distributed power, low grid inertia due to a highly centralised generation infrastructure (e.g. microgrids, island grids), extensive, aging T&D infrastructure, a low level of electricity supply security, or high levels of investments into grid modernisation (i.e. smart grids). Government support and subsidies, which are expected to continue until at least 2020 will be crucial to initial development and wider market acceptance.

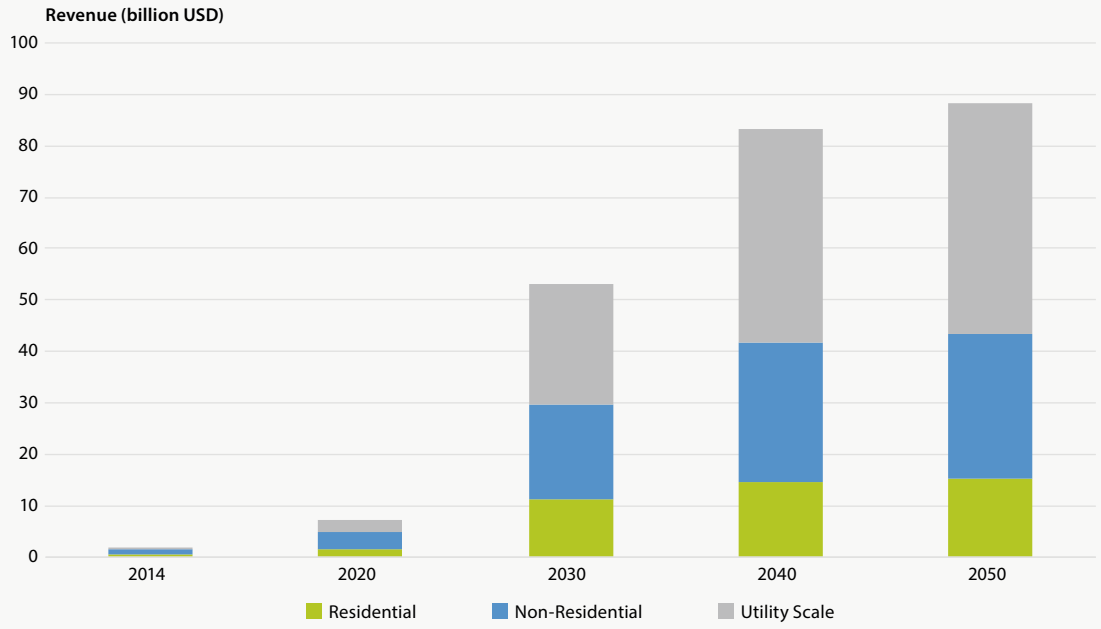
Distributed battery storage revenues are forecast to reach US$ 90 billion by 2050, with the fastest growing segment being that of residential and commercial battery systems.

4.3.2 Quantification and Forecast

Battery storage is forecast to grow from a market of US$ 2 billion in 2014 to US$ 7 billion in 2020, primarily driven by a significant uptake of storage systems by the non-residential sector, as well as strong growth in the utility sector. The highest growth rates come in the period 2020 to 2030, where market conditions including technological development and price will be suitable to support broad-based market acceptance of battery storage technologies. By 2030, utility-scale storage will amount to approximately US$ 24 billion accounting for 45% of total market revenues. Following its “boom” period between 2020 and 2030, utility scale storage will continue to show strong, yet slower, growth to 2040. This will be driven primarily by

Figure 21: Forecast Revenue Growth of the Battery Energy Storage Market, 2014–2050

Source: Frost & Sullivan



continued healthy annual growth rates in utility scale wind and solar capacity over this period of 2.5% and 4% respectively.[xix] [xx] Residential and non-residential storage are expected to represent the majority of the battery storage market to 2030, due to rapid growth in distributed electricity generation, driven primarily by the commercial sector. These markets are expected to account for annual revenue of US$ 11 billion by 2030. Growth following 2030 is expected to slow, but will be maintained through distributed solar-battery systems achieving price parity in new markets. By 2050, these markets are expected to account for US$ 43 billion.

Figure 22 shows the markets which are expected to be the first-movers in the development of high growth storage markets. Figure 22 provides also a breakdown of supporting government policy for the integration of storage technology.

4.3.3 Key Trends in Products and Services

As the costs for distributed storage decrease, the technology will represent a growing opportunity to increase the bankability of renewable energy projects. This should assist in driving the total levelised cost of renewable energy to grid parity levels, significantly reducing the importance of government subsidy programs for renewables.

Integration of battery systems, in the long term, is expected to offset the need for traditional reserve generation capacity technologies, such as diesel gensets, open cycle gas turbines (OCGTs) / combined cycle gas turbines (CCGTs), and power plant flexing, all of which have high costs in terms of finance and emissions. Distributed energy storage (DES) will represent a greater degree of value, through its ability to provide rapid response renewable energy smoothing and ancillary services, such as frequency regulation and power quality management, ensuring the health and stability of the grid.

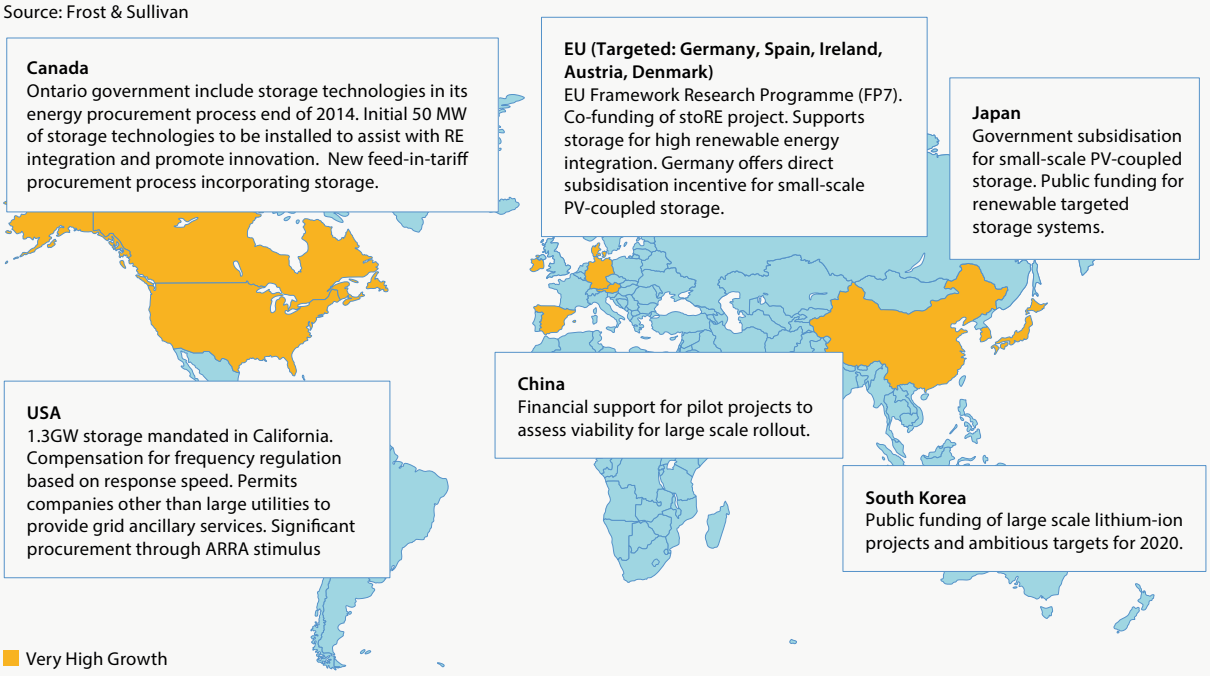
Battery technology is expected to represent the core technology for storage integration in the residential and commercial markets. Growth of residential and commercial DES will be largely predicated on the level of penetration of enabling smart-grid infrastructure in the market. Core markets will therefore be Germany, France, UK, Japan, China, South Korea, USA, Canada, Australia, Spain, Italy and Finland, where wide spread integration of smart meters and smart infrastructure is present or planned. Once technology costs have reach market acceptance levels, residential/commercial storage will

xix Global Wind Energy Outlook, Global Wind Energy Council, 2014

xx International Energy Agency, 2014

Figure 22: Future high growth for battery storage markets, 2014

Source: Frost & Sullivan



enhance the competitiveness of the commercial prosumer model against utility generation, decreasing price barriers to broad based market acceptance.

Table 11 provides a breakdown of some of the key winning product categories resulting from battery storage growth globally.

4.3.4 Future Business Models

In the long term, the DSO, ESCO, aggregator or even utility, is likely to maintain ownership and maintenance of distributed residential and commercial battery storage systems in the long term. Much the same as the prosumer market discussed, value added benefits will be provided to consumers in the form of energy savings, revenues from electricity trade, or information and analytics. Consumers will therefore lease the systems and benefit from financial incentives (e.g. electricity cost savings, sale of electricity). In the short term (pre-2020), however, incentive based models for private ownership in the residential and commercial sector are expected to drive the market.

4.3.4.1 End-user Ownership

The business model entails complete ownership of the storage system by the end-user, and will leave the end-user responsible for the maintenance and operation of the system. The significant upfront costs and operational risk taken on by the end-user is expected to limit the adoption of the business model to early adopters; many of whom already have installed distributed generation (i.e. PV systems) that they wish to couple with storage to gain a greater degree of grid independence.

4.3.4.2 Utility Ownership

Utility ownership of these battery systems would be seen as an extension of its current infrastructure, to be used to supply reserve power to load centres during periods of high demand. Utilities would purchase electricity for battery charging during low demand periods, in order to allow for available power during peak demand times. Furthermore, for home meters, utilities could have the option to rollout storage systems in their network and provide consumers the opportunity to lease the system. Consumers would then be responsible for the operation of the system.

4.3.4.3 DNO/DSO Ownership Model

The development of battery systems owned and operated by either the distribution network operator (DNO), the distribution system operator (DSO), or a cooperative between the two.

Table 11: Energy Storage: Products & Services – Winners & Trends, 2014–2050

Source: Frost & Sullivan

Winners	Trends
Battery cell manufacturers (e.g. Lithium-ion batteries, Sodium-based Batteries, Advanced Lead-acid Batteries, Nickel Based Batteries, Zinc-Bromide (ZnBr) Flow Batteries, Vanadium Redox Flow Batteries)	New advances in battery technology and rapid scaling of production capacity due to growth in associated markets of electric vehicles and consumer electronics will drive exponential growth in battery technology and distributed storage post 2020
Power Electronics and Control Systems	Power electronics and control systems for battery storage systems will subsequently show strong growth
Distributed PV and Wind	Distributed renewable energy development coupled with distributed storage is expected to become standard industry practice in the long term, due to the advantages afforded to the return on investment (ROI) of the wind or solar farm
Residential and commercial PV	Battery storage coupled with PV for residential and commercial application is an essential component to the development of a sustainable behind-the-meter PV market unsupported by government subsidies. The sustainable growth of this market and that of small scale battery storage are, therefore, very much co-dependent
Demand response solutions and services	*See "Demand Response Services " in Table 5

The DNO/DSO model assumes the full financing, development, ownership and operation of the storage system by the DNO, with two options available depending on the level of inclusion of a third-party contractor for market engagement and trade. The first option is where the DNO maintains full control and operation of the system, with full control over future profitability, flexibility in terms of scaling, or potentially even relocation of the total system if necessary. However, the DNO may lack the necessary experience and capabilities to effectively optimise the value of the asset in the marketplace. Furthermore, regulations prohibiting network operators from electricity trade (such as in the EU) would largely limit the acceptance of this model. The second option is a DNO contracted model, where the DNO finances, maintains and operates the system, however, long term capacity contracts would be signed with a third party for the trade of electricity to the market. The DNO would therefore be remunerated through fixed annual payments, or potentially a percentage pass-through of the value of traded electricity. This model will limit, or potentially remove altogether, the risk of monetising value streams from the system, outside of its core functions of supply security and ancillary services.

4.3.4.4 Third Party Ownership Model

The DNO may contract the development of the system altogether. In this model, the DNO would tender for the development of the system with technical and operational requirements that meet the security needs of the DNO, and would provide the third party with a long term capacity contract in the form of fixed annual payments. All financing, development, maintenance and operational costs would be the responsibility of the third-party; who would further be able to accrue additional revenues through the trade of additional services with the marketplace. The advantage to the DNO is the decreased investment risk due to the lack of fixed upfront costs and variable maintenance costs; however, the DNO will have no direct control over the operation of the facility, which adds a significant degree of performance risk to the project as a whole.

4.3.4.5 Storage Incentives Model

The DNO ensures that time-of-use tariffs are such that they incentivise the development of storage systems to decrease peak demand where needed. The specifications and technologies of the systems implemented are entirely out of the control of the DNO, and there is a high risk the delivery of capacity will not be sufficient to meet the security needs of the DNO when required. This has the potential to lead to an over-incentivised market in order to ensure that the capacity required is available. Within the model, the DNO holds no operational control in distributed storage in its system outside of its ability to manipulate incentives through varying daily and monthly load profiles.[xxi]

xxi UK Power Networks, 2014

4.4 Bioenergy

4.4.1 Overview

By 2050, biofuels have the potential to account for 27% of total transport fuels, in particular that of diesel, kerosene and jet fuel. This would require 100 million hectares of biofuel feedstock in 2050. To reach this potential, biofuel technology will be required to significantly increase its conversion efficiencies and sustainability properties and show a substantial decrease in production costs.[xxii] Policy incentives in the future are expected to become more consolidated and targeted toward advanced biofuels showing higher efficiencies and life-cycle GHG performance, as national and regional emission regulations become more stringent. Total annual revenue of the market is expected to reach US$ 757 billion by 2050 with advanced biodiesel occupying the largest share.

Currently, without government support, biofuel is generally not commercially viable; however, continued innovation in the industry is enhancing the economic viability of the technology.

- **Biofuels** produced from forest residues, straw and other lignocellulosic biomass waste (known as 2nd generation biofuels) are expected to make significant advances between 2015 and 2020. The technologies required to produce these biofuels were nearly approaching commercial viability, but this has been delayed by the recent drop in fossil fuel prices. The technologies for 3rd generation biofuels made from algae, are not expected to become commercially viable before 2020.
- **Integrated waste management** will improve existing waste management systems in order to accommodate significant increasing amounts of bioenergy generation from waste.
- **Biogas** production has increased considerably in the developing world, where initiatives are being implemented to capture methane generated from rotting waste (e.g. municipal, agricultural) or wood based materials (e.g. wood chips). This biomethane is subsequently used for the production of electricity and heat.
- Technologies for **fuel pellets** will improve so as to include a wider range of waste feedstock, apart from waste and wood based biomass. For example, a promising fuel pellet technology is the use of food waste or municipal solid waste as pellet feedstocks.
- **Biomethane** produced from microbes digesting CO_2 biogas technologies will eventually power vehicles. Researchers are also experimenting with microbes that will convert carbon dioxide to biomethane.

By 2050, biofuels have the potential to account for 27% of total transport fuels, in particular that of diesel, kerosene and jet fuel. Total annual revenue of the market is expected to reach US$ 757 billion by 2050 with advanced biodiesel occupying the largest share.

The creation of bioeconomies, based on value-add bioenergy, biofuels and bio-products, while leveraging countries' core competitive advantages in raw materials, industry and innovation, will enhance the competitiveness of bioenergy globally, as well as, contribute significantly to economic growth and job creation.

4.4.2 Key Trends in Products and Services

4.4.2.1 Biowaste-to-Energy

The global waste to energy (WTE) plant market (for all waste including agricultural waste) is forecast to be worth US$ 42 billion by 2020. Highest demand growth comes from regions with high population density but limited area, such as Europe, the Middle East, and South Asia. This is due to the diversion of waste from landfilling to incineration for energy recovery. In the long term, incineration is expected to be restrained by the growth of circular economies and waste recovery solutions. Currently, APAC is the global market leader with 1,480 installed plants, the highest mass volume of incinerated municipal solid waste (MSW), and highest estimated market revenue.

4.4.2.2 Ethanol

High crude oil prices, concern over environmental safety and the desire to reduce emissions have been the key historic growth drivers for Ethanol, supported by government policies (blend mandates). This is expected to remain the case for the foreseeable future. Automotive ethanol (conventional) remains at the moment the dominant biofuel used in transport globally, although the use of biodiesel has increased rapidly in recent years. In 2013, 85,572 million litres (ML) of automotive ethanol was consumed globally, which generated manufacturer revenues of US$ 60 billion. The overall market is mature, but is expected to show strong growth with the future

xxii International Energy Agency, Biofuels and Transport Technology Roadmap, 2014

commercialisation of advanced ethanols (e.g. cellulosic ethanol) showing a CAGR of 5.6% to 2030. Following 2030, as the market again matures and advanced biodiesel adoption increases, growth will slow to 2.7% CAGR to 2050.

Bioeconomies, based on value-add bioenergy, biofuels and bio-products, will enhance the competitiveness of bioenergy globally, as well as, contribute significantly to economic growth and job creation.

4.4.2.3 Biodiesel

Biodiesel has gained popularity in recent years, and government mandates have resulted in rapid expansion in production capacities globally. The biodiesel industry can be considered to be in its growth stage, generating manufacturer revenues of US$ 35 billion in 2013. Europe remains the primary consumer and producer of biodiesel, although the market has reached maturity. Asia-Pacific is the fastest-growing market to 2020, with consumption growth of 21%, followed by Latin America with 15% and North America with 13% per annum. Biodiesel is expected to show growth beyond that of ethanol to 2050, driven through the commercialisation of advanced biofuels and the growth in adoption of the fuel in the commercial transport sector. Biodiesel will show a 9.4% CAGR from 2014 to 2030, then slow as market maturity is reached, showing a CAGR of 7% for 2030 to 2050.

Table 12 provides a breakdown of some of the key winning product categories resulting from bioenergy growth globally.

4.4.3 Quantification and Forecast

Frost & Sullivan forecasts that biofuel market revenues will increase from US$ 99 billion in 2014 to almost US$ 260 billion by 2030, following which the market is expected to show substantial growth to 2050, reaching US$ 757 billion. In 2050, it is expected that bio-jet fuel and advanced biodiesel, the large majority of which will be used for commercial transport, will account for 57% of the total market. Biomethane, cellulosic ethanol and small percentage of cane ethanol is expected to account for the remaining 43%. The future rapid growth in electric vehicles is expected to represent more of a threat to the conventional fossil fuel than biofuels, as the biofuels market is expected to be based on government legislation and targets, as well as the availability of dedicated feedstock. Furthermore, even considering the potential for biofuels to reach price parity with fossil fuels toward 2030, 63% of total consumption of biofuels in 2050 is expected to be from the road freight transport, aviation and shipping, with only 37% expected to be consumed by passenger transport – the key growth market for electric vehicles.

Figures 24 and 25 provide a breakdown of key biofuel markets by consumption shares by 2020, for the global market.

Biofuel market revenues will increase to almost US$ 260 billion by 2030, and show substantial growth to 2050, reaching US$ 757 billion.

4.4.4 Future Business Models

Biotechnological innovation in the development of high yield crops, refinement of efficient crop management practices, and the delivery of a fully integrated feedstock solution, will allow for scalability and a more price competitive product for the market. Corporate partnership between technology companies and multinational organisations are expected to represent the most direct route to scaling technological innovation to levels necessary for commercialisation in the future. Future business models will include highly integrated value-chains from the perspective of both feedstock providers as well as manufacturers. Creation of new revenue streams through the development of associated product lines across the value chain in biochemical, bioplastics and biomaterials is further expected to represent a core requirement for scalability.

The current market is largely driven through mandated biofuel blends as part of national or regional low-carbon initiatives. In order to achieve scalability and reach a point of price-parity with fossil-fuels, a significant amount of collaboration will be required under the bio-product umbrella.[xxiii]

The industry is rapidly approaching what has been dubbed the "blend wall", which represents the market ceiling for first generation ethanol (e.g. corn ethanol) that can be supported by existing transportation infrastructure. This point is E10 (i.e. 10% ethanol blend) in Europe and E15 in the US. In order to grow the market beyond this point,

xxiii Clean Tech Group, 2014

Table 12: Bioenergy Products & Services – Winners & Trends, 2014–2050

Source: Frost & Sullivan

Winners	Trends
Cellulosic ethanol	Produced from agricultural residues or dedicated cellulosic crops (e.g. forestry waste). Lower greenhouse gas emissions and a higher sustainability rating than first-generation ethanol. Multiple pathways for the conversion of non-food feedstock (e.g., municipal waste, wood, sugarcane bagasse) Expected to reach price competitiveness with fossil fuels by 2020
Second Generation Biodiesel (Jatropha)	Potential source of advanced biodiesel because it is inedible and can survive harsh environments Tolerate dry, rocky soil unsuitable for agriculture, therefore, could be grown as a cash crop without denting food production However, the feedstock shows low yields and requires substantial upfront investment in production, and as such is currently not bankable without subsidy support
Third Generation Biodiesel (Algae)	Algae biodiesel yields estimated to range from 10 to 100 times more fuel per unit area compared with first-generation biodiesel crops Technology is still not-bankable, but US manufacturers estimate it could reach competitive price levels with oil products by 2020 with government tax incentives for production
Fluidised Bed (CFB, BFB) WTE	WTE fluidised bed technology is still in its nascent stage, and although consistent growth is expected, it will only account for approximately 3% of the market by 2020
Biogas (Biomethane)	Biogas is expected to show increased growth in the transport sector from 2017 and represent 6% of the total biofuels market by 2050
Biomass for heat and electricity	Biomass use in heat and electricity (e.g. wood and pulp) will further show increased growth in the short to medium term to meet mandated emission reductions, however, in the long term these markets will be restrained by zero emission technologies

Note: CFB = Circulating fluidised bed; BFB = Bubbling fluidised bed; WTE = Waste to energy.

greater advancements in higher yield second and third generation biofuels will be required in order to compete with fossil-fuels.

Restrictions in demand, exacerbated by rapidly increasing vehicle fuel efficiencies, have created a fiercely competitive industry, the size of which is almost entirely dictated by government policy mandate. Business models of the future will therefore hinge on competitive advantages in feedstock availability, supply chain, and technology innovation.

4.4.4.1 Feedstock Business Models

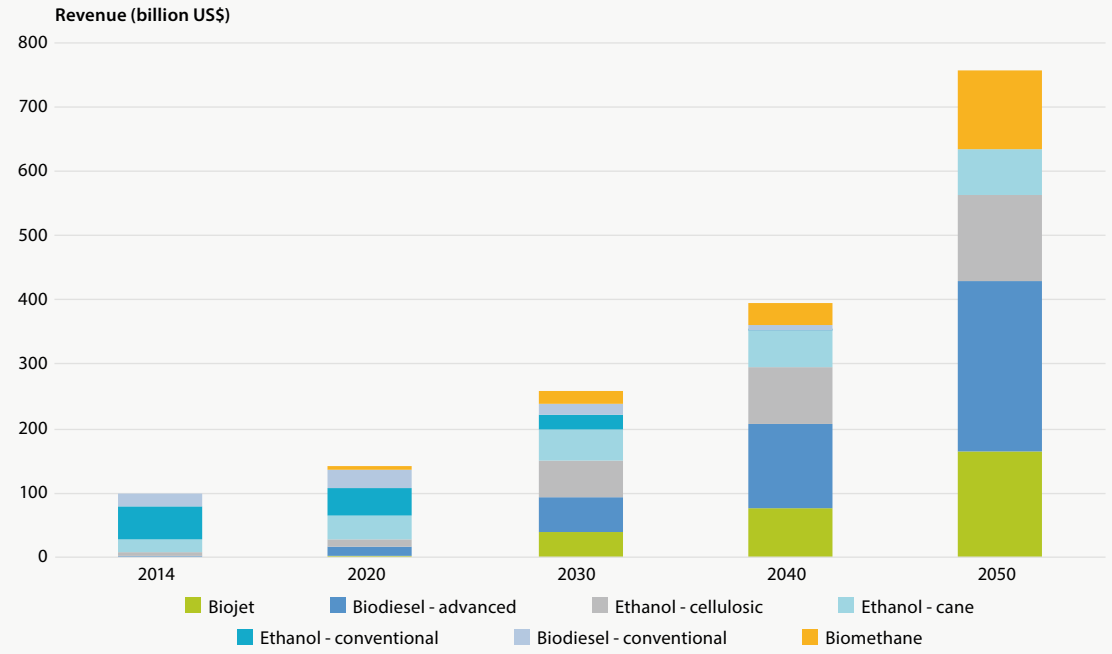
Biotechnological innovation in the development of high yield crops, the refinement of efficient crop management practices, and the delivery of a fully integrated feedstock solution, will allow for scalability and a more price competitive product for the market. A further challenge faced by the industry in the future is the development of sufficient biofuel crops that are able to avoid the fuel or food debate. Companies of the future will negotiate this challenge through new innovations in the development of non-food based feed stocks, such as renewable non-food oil crops, artificial sugars and advanced micro-algae strains.

4.4.4.2 Corporate Partnership

Investments into dedicated feedstock markets has been limited since 2009, due to global financial constraints and an aversion to unconventional, capital-intensive projects with lengthy payback periods. Investment in the biofuels and biochemical sector itself has remained strong, but has typically been into existing portfolio companies in order to demonstrate technologies at commercial scale. Corporate partnership between technology companies and multinational organisations are expected to represent the most direct route to scaling technological innovation to levels necessary for future commercialisation. Currently, these organisations largely exist in the oil and gas, transportation and waste and recycling industries due to their close synergies in operations, business models and customer value propositions.

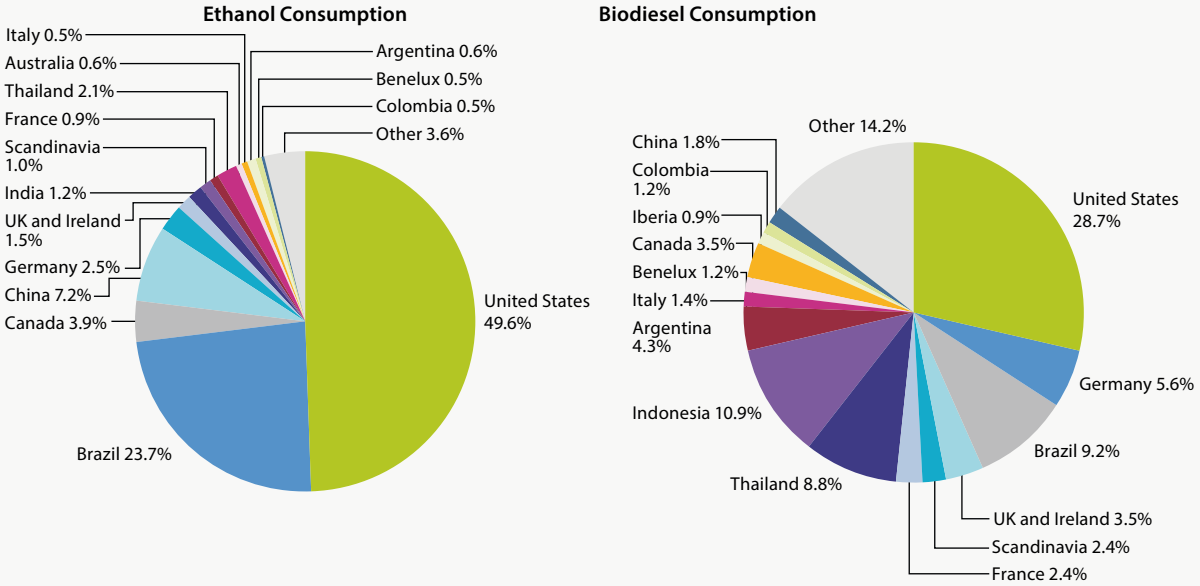
Figure 23: Forecast Revenue Growth of the Biofuels Market, 2014–2050

Source: Frost & Sullivan



Figures 24 and 25: Global Consumption of Biofuels, 2020

Source: Frost & Sullivan



4.4.4.3 Product Line Diversification

From a supply side perspective, a more scalable and efficient feedstock supply, along with the required capital and distribution network for scalability of technical innovation will assist in the commercialisation of the product. However, in order to achieve scalability for cost reductions sufficient to reach competitive levels with fossil fuels, integration and optimisation of the value chain, along with demand side considerations in identifying margin pools across all value chain segments, must be considered.

Future business models will include highly integrated value chains. Feedstock suppliers are expected to offer value added services in processing and storage, while manufacturers are expected to become more active in the distribution of product, and even in feedstock production and processing itself. The creation of new revenue streams through the development of associated product lines across the value chain in biochemical, bioplastics and biomaterials is further expected to represent a core component in the scalability of biofuel projects and generation of required margins. Biofuel exclusive companies are not expected to be common place in the future market, as companies will continue to leverage associated markets to achieve greater margins. Biochemicals and materials, furthermore, do not suffer from commodity-based pricing like biofuels, and therefore have the potential to show greater price premiums. Product diversification further allows for flexibility in optimising high margin products while consolidating low margin products; potentially through technology licencing, partnership, or outsourcing.

5 Sustainable Buildings

KEY INSIGHTS

Smart technology will create an opportunity to manage buildings far more efficiently than done today using inter-connected sensors and data analytics.

In order to reduce the carbon footprint of construction new buildings will increasingly consist of biomaterials. These possess a better ecological balance than conventional building materials and will generate over US$ 500 billion in 2050 in annual revenues globally.

Energy management systems in conjunction with X-as-a-Service business models and energy harvesting solutions will reduce energy-related carbon emissions. By 2050 they are expected to reach annual market sizes of nearly US$ 100 billion and over US$ 50 billion respectively.

In 2015 cities use between 67 to 75% of the world's energy and are responsible for 80% of energy-related carbon impact. Within the next 20 years, 60% of the world's buildings will be built and rebuilt in urban areas. Buildings are responsible for nearly 40% of both the total energy consumption and the carbon dioxide emissions in Europe[xxiv]; new sustainable buildings materials and constructional know-how improve energy efficiency by 60% to 90% compared to conventional buildings.[xxv] The production of building materials themselves is a significant source of carbon emissions. These facts create two major exciting market opportunities. First, smart energy management can reduce overall energy consumption and emissions; the equipment of new and existing buildings with energy management systems offers huge potential, with the largest revenue potential from energy management services. Service-centred business models such as energy performance contracting and light-as-a-service are projected to generate more than US$ 90 billion in annual revenues as of 2030. Second, carbon emissions can be avoided with the use of biomaterials in the construction of new buildings and in the refurbishment of existing buildings. Annual revenues of green building materials will grow from less than US$ 150 billion in 2014 to over US$ 500 billion in 2050. Renovation of existing buildings in Europe and new building construction in emerging nations will aid growth of both, sustainable construction materials and energy management systems and services.

Within the next 20 years, 60% of the world's buildings will be built and rebuilt in urban areas.

The following section provides an overview of the key industry shaking low-carbon trends expected to drive the evolution of the sustainable buildings over the following decades. Subtrends selected for analysis based on these criteria are energy management systems and services, carbon-free construction materials and energy harvesting.

Annual revenues of green building materials will grow to over US$ 500 billion in 2050.

5.1 Energy Management

5.1.1 Overview

Green and smart are converging to deliver a new generation of solutions for both homes and commercial buildings. Smart buildings are energy efficient and feature an advanced automated infrastructure that controls and manages aspects such as lighting, temperature, water and energy consumption, independently or with minimal human intervention. The global building energy management market can be segmented into building and home energy management systems and energy management services.

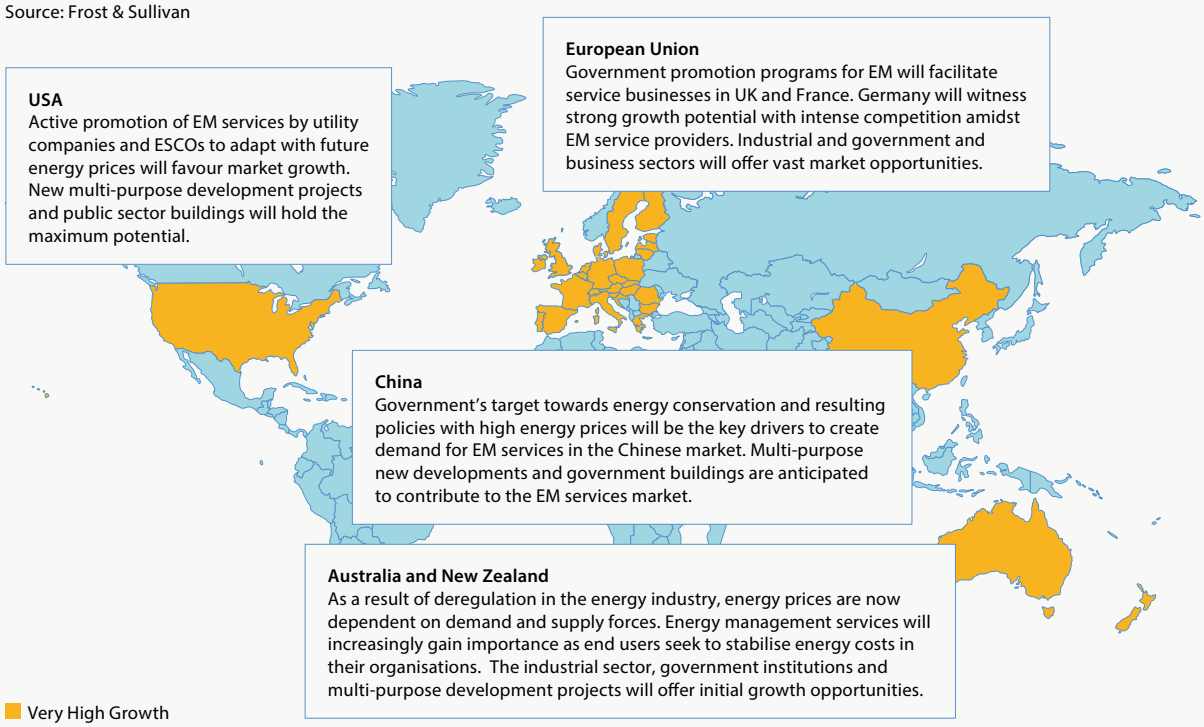
Building energy management systems (BEMS) and home energy management systems (HEMS) are computer-based systems that help to manage, control and monitor technical services (e.g. lighting, heating, ventilation, air-conditioning) and the energy consumption of devices

xxiv European Union 2010: 13.

xxv Moore et al. 2013: 3.

Figure 26: Global Energy Management Services Hotspots 2015

Source: Frost & Sullivan



used by the building. These solutions utilize data from traditional control and automation systems, smart meters and advanced sensors. In the commercial building sector the burden of performance of a firm's energy use is frequently placed on energy services companies[xxvi] (ESCOs) that provide energy efficiency related energy management services (EMS).

Increasing energy prices, a favourable regulatory environment for energy efficient buildings and the growth in global commercial construction are key drivers for the building energy management market. Cloud-based services with a strong focus on data interpretation will be key enablers for a new generation of intelligent buildings. Data interpretation rather than data analytics is now a key priority for commercial users. This is largely due to advancements in software and data analytics focused on providing easily interpretable and actionable data. Reduced energy consumption and timely failure detection are achieved by complete building automation, control, and integration which result in energy cost savings, shorter down times with fewer effects on productivity and lower maintenance costs. The business model will be dependent on the convergence of services- and solutions-based industries.

The European Union will be a key market for energy management systems and services, as it has mandated targets for reduction in greenhouse gas emissions for the building sector.

xxvi also: energy savings companies

The European Union will be a key market for energy management systems and services, as it has mandated targets for an 88% to 91% reduction in greenhouse gas emissions for the building sector by 2050 compared to the 1990 levels.[xxvii] The EU's Energy Performance of Buildings Directive (EPBD) mandates that by 2019 all new buildings occupied and owned by public authorities are nearly zero-energy buildings (nZEB) and by end of 2021 all new buildings are nZEB. This poses major challenges as most of the heating, ventilation and air-conditioning (HVAC) equipment installed in European buildings are at least 20 years old and the majority of existing buildings do not feature energy management systems. In order to turn these ageing buildings to nZEB, major refurbishment is needed. The current renovation rate of around 1% of the existing useful floor area each year needs to be increased to 2.5% per year.[xxviii] The EPBD will be a significant driver of growth post-2020.

5.1.2 Key Trends in Products and Services

Table 13 provides a breakdown of some of the key winning product categories resulting from energy management solutions growth globally.

5.1.3 Quantification and Forecast

The period between 2010 and 2015 has seen huge levels of technology innovation in the energy and environment industry, with smart technology re-defining the landscape. The next 35 years will be the era of service business model innovation, as suppliers compete to maximise the real benefits for customers through strategic partnerships and/or acquisitions. Market participants from diversified backgrounds such as hardware manufacturers, software solution suppliers, building automation providers, technical consulting companies, Facility management (FM) companies and traditional ESCOs will merge in order to offer attractive services to building owners. This gives the building owners an option to choose the best service offer according to their requirements. FM companies see the opportunity to lead.

Energy services and performance contracting will be major factors in strong market growth with revenues increasing from US$ 45 billion in 2014 to reach approximately US$ 90 billion in 2050. This is largely due to the focus on energy costs, environmental regulations and guidelines and the lack of in-house expertise of building owners in energy management. The diffusion

Table 13: Energy Management: Products & Services – Winners & Trends, 2014–2050
Source: Frost & Sullivan

Winners	Trends
Cloud-based smart energy management solutions and services	Building automation including automated thermostats, lighting, heating, ventilation and air conditioning enables energy savings. Two-way networks for electricity and heating will enable local energy production, storage and implementation of plus energy houses.
Smart Metering	The expansion of smart meters will be a prerequisite for fully functional smart grids and smart cities. A significant increase of efficiency can be achieved thanks to demand monitoring and improved end-user electricity management.
Lighting-as-a-service **HVAC-as-a-service**	Customer-centric service business models e.g. energy saving contract and performance contracting will drive growth and potentially lead to a significant change in the leaders of the energy management system (EMS) industry over time.
LEDs **Luminaire manufacturing**	LED Lighting has evolved to reach high luminous efficacy. Price erosion of LED lighting by more than 30% in the last 5 years is pulling forward its payback time. In addition, the enhanced controllability and energy efficiency fuels the diffusion of LED light sources.
Remote access and control thermostats	Remote access and control thermostats unit shipments will grow at a rate of 35% between 2012 and 2017. Global air conditioning thermostat shipments will see an increase of 50% in the next 5 years. Climate change will have the greatest impact on HVAC and water supply. Global warming will necessitate greater need for HVAC in cities thereby increasing the demand for control valves and balancing valves in HVAC.
District Heating	District heating may substitute high-emission decentral gas heating especially in larger cities. It can accommodate thermal energy from a variety of sources such as biomass and waste heat from power stations or incinerators.

Note: HVAC = Heating, Ventilation and Air-conditioning; EMS = Energy Management Systems.

xxvii European Commission 2011: 6.

xxviii Ecofys 2015: 1

of decentralised power generation, e.g. due to rooftop photovoltaics, is expected to create rising demand for energy management hardware and software within the next 15 years. Home energy management system (HEMS) growth in Europe has been slow within the last five years because of the recession and poor residential construction, but acceleration is expected post-2020. The building energy management system (BEMS) offerings are already at an early adopter stage and market will reach maturity by 2030. After the roll-out phase HEMS and BEMS revenues will be lower and mainly generated by replacements and energy management services.

5.1.4 New Business Models

Smart technology will be applied to manage buildings far more efficiently in the future than at present using interconnected sensors and data analytics. The emergence of the aforementioned business models accrues of building owners' and residents' likeliness to outsource energy management tasks to specialised contractors due increasing complexity and cost.

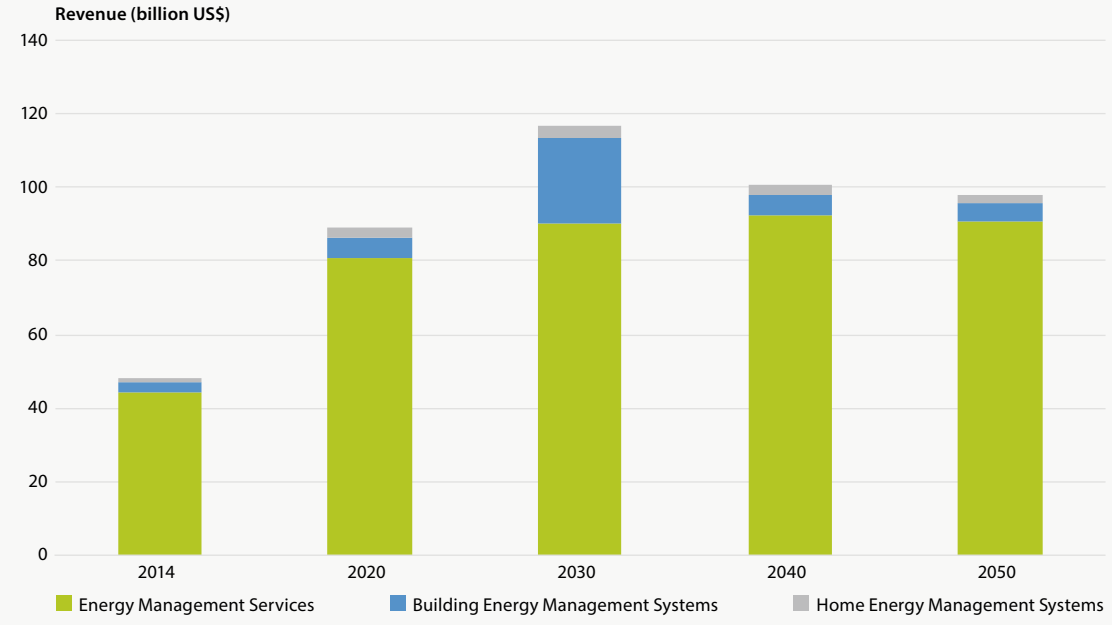
Competition in energy management will continue to intensify as facility management (FM) and utility companies compete with energy service companies and building automation vendors to offer a turnkey service business. Technology supporting real-time, uninterrupted and future-proof service business models for critical infrastructure will be new opportunities for energy management market participants. Three business models were identified that will sharpen the Energy Management market as of now and in the long-term future: Energy Performance Contracting, Cloud services and X-as-a-Service.

5.1.4.1 Energy Performance Contracting

Energy Performance Contracting (EPC) is where the service provider offers guaranteed savings on energy usage optimisation for a particular contract period and then shared savings thereafter. EPC includes the design and implementation of energy savings projects, energy supply of energy and risk management. EPC is forecast to expand to the residential sector due to the new construction of passive housing complexes. The concept of EPC will co-exist with the technological advancements but definition of contracts will vary. As a result, building management systems suppliers will develop service capabilities or partner with FM companies or ESCOs to participate in the most dynamic part of the market. Suppliers such as Siemens and Schneider Electric are currently increasing

Figure 27:
Energy Management Systems and Services Market: Revenue Forecast, Global, 2014–2050

Source: Frost & Sullivan



the focus on their service offerings, as they acknowledge the importance of service-led business models for energy management.

5.1.4.2 Cloud Services

Cloud Services enable real time building automation solutions for proactive fault detection and predictive diagnostics. Open standards or protocols will bring together a range of different vendors. Cloud services will enable dynamic energy management, building data analytics, and 'Internet of Buildings'. EMS participants will need to either gain internal competencies or partner to exploit these upcoming Information and Communication Technology (ICT) advancements in their new service business models.

5.1.4.3 X-as-a-Service

A good specific example of X-as-a-Service (XaaS) business models in the energy management market is Light-as-a-Service (LaaS) which is offering lighting management via cloud services. Scheduling, emergency lighting, automatic back-up, and maintenance are its key features. LaaS essentially corresponds to leasing-type models and pay-as-you-use services and will grow significantly from 2015 onwards due to the desire by the customer to minimise upfront capital expenditure, whilst the supplier gains a guaranteed future revenue stream. The key is for the lighting performance contractor to achieve significant energy reduction in energy use over an agreed period of time and assures that the generated savings will be sufficient to remunerate his efforts. By this means customers' costs and risks of adopting new lighting technologies are significantly reduced. Conventional lighting equipment companies such as Philips, Osram and General Electric are particularly affected by the decline in demand as the replacement of light sources has traditionally been their strong revenue generator.

5.2 Building Biomaterials

5.2.1 Overview

The building materials market is extremely diverse and constitutes a sizable chunk of the industrial base of developed countries. It includes a large range of suppliers, from cement manufacturers to specialty glass, wood and steel manufacturers, as well as providing a large market for insulation materials, paint and flooring manufacturers and a host of other related industries. Globally, non-green materials used in construction are responsible for 35% of carbon-dioxide emissions and 40% of energy use. Whether a material is rated green or not depends on factors such as its local availability, recyclability and durability. Recyclability is particularly important, as re-using material reduces landfill and demand for virgin materials. State-of-the-art construction materials will also slow down the transfer of heat through a building's skin, reducing the need for heating or cooling. Green options are available for almost all construction materials including paints, concrete, flooring, insulation and glass.

Green options are available for almost all construction materials including paints, concrete, flooring, insulation and glass.

The concrete industry is the largest user of natural resources in the world. Portland cement, a key ingredient, accounts for roughly 5% of all carbon dioxide emissions generated by human activities worldwide. Driven by stricter regulations, green cement and concrete is therefore one of the largest segments in the overall biomaterials market, valued at US$ 133 billion in 2014.

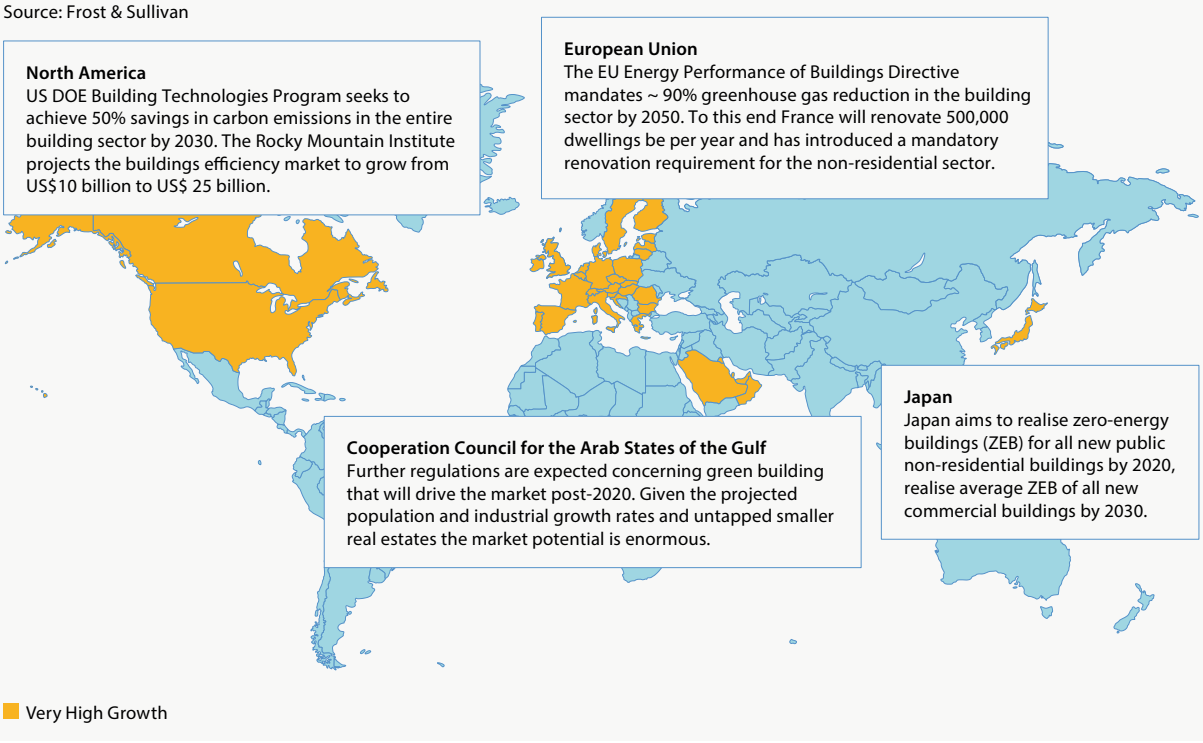
Insulation materials are a major source of transport related carbon emissions, mainly because of limited local availability. Aside from a material's origin there are other factors that determine a material's sustainable credentials, such as embodied energy, carbon, operational performance and post-life recyclability. In contrast to conventional form of insulation (e.g. fibreglass or mineral wool) organic materials (e.g. cellulose or cotton) require very little energy and provoke no carbon emissions to manufacture. They are almost always non-toxic making them safe to handle and easier to install and to recycle. Organic building materials are projected to show a modest growth post-2020.

Green floor coverings are those made from materials such as cork, wool carpet, bamboo, linoleum, ceramic tile, and hardwood. They are highly recyclable and are safer for people and the environment since they contain fewer chemicals than traditional floorings.

Smart glass for the construction industry refers to a glass used in buildings that switches from clear to dark in response to a certain stimulus. This stimulus can be sunlight, electricity, or temperature. Crucially smart windows save energy by saving costs in lighting, air-conditioning, and heating.

Figure 28: Global Green Building Materials Hotspots 2015

Source: Frost & Sullivan



Green cement and concrete is one of the largest segments in the overall biomaterials market.

5.2.2 Key Trends in Products and Services

Table 14 provides a breakdown of some of the key winning product categories resulting from building biomaterials growth globally.

5.2.3 Quantification and Forecast

The market for green construction material was valued US$ 149 billion in 2014 and is forecast to increase to US$ 521 billion by 2050. Europe accounted for 50% of the market in 2014, driven by EU policies on energy efficiency and building design, and is forecast to remain the largest market to 2050. The most important market in Europe is thermal insulation, while in the US, green floorings is the largest and fastest growing market, followed by green concrete.

5.2.4 New Business Models

There is no dramatic change in the business model for biomaterials; it will more be about the building industry integrating materials into its existing practices. Nevertheless, the increased application of bio-based building materials will lead to an enlarged value chain and thus to more circular business models.

The market for green construction materials is forecast to increase to US$ 521 billion by 2050.

Bio-based construction materials have a long history and have never been completely out of use, e.g. timber and bamboo for framing, boarding and roofing and reeds and straw for roofing and flooring. If biomaterials are used in novel applications or in novel combinations they will not disrupt the construction industry bringing up revolutionary business models. Nevertheless, as biomaterials can normally be reused or recycled into a variety of construction and non-construction

Table 14: Biomaterials: Products & Services – Winners & Trends, 2014–2050

Source: Frost & Sullivan

Winners	Trends
Green Paints	Paints from all natural ingredients are the safest green paints available. In the future paints will have a VOC content of less than 50 g/l. These paints use water as a carrier instead of petroleum-based solvents. Reflective paints result in enhanced thermal indoor comfort, longer endurance and superior exterior protection.
Mineral Concrete Admixtures	Products like fly ash and sewage sludge incineration ash can be utilised globally as a partial replacement for cement. Alternatives include stone dust, e.g. from the crushing of aggregate and concrete slurry e.g. from the washing of mixers and other equipment.
Cellulose Fibre Insulation	Loose fibres and fibre pellets out of cellulose are made out of recycled newspapers and thus feature a better ecobalance than fibreglass and rock wool that are the most common insulation materials in Europe at present.
Wood and Cork based Insulation	Wood and cork based rigid-boards are available in various thicknesses and can be used as well internally as externally. Wood and cork based spray-foam insulation is sprayed into spaces to make it airtight. Both are often used to insulate existing buildings in Europe as they offer ease of installation in comparison to other forms of insulation.
Green Hard Floors	Reclaimed hardwood flooring is the greenest wood flooring. It comes from old barns and buildings, which means it has been recycled. Bamboo is already a popular option many APAC countries and offers all the benefits of hardwood flooring. It is a naturally sustainable material and grows quickly in the wild.
Green Soft Floors	80% of world's cork is harvested in Portugal and Spain and accordingly is a common building material in the Mediterranean region. Rubber is a low odour, simple-to-install type of green flooring, which has been extensively used in Australia and parts of Europe. Another eco-friendly soft flooring option is linoleum made from natural flax seed oil. It is slowly gaining popularity in Asia as a sustainable flooring option that could replace vinyl. Wool carpeting is similar to conventional carpeting, but does not require chemicals or fossil resources.
Smart Glass	Electrochromic windows that shade automatically have been part of high-tech home demos for years in US, Japan and some EU countries, but now the installation of active smart glasses is augmenting in the commercial sector. Established passive smart glasses that do not involve an electrical interface will fade out correspondingly.

Note: VOC = Volatile organic compound

components: Dismantled wool and cork based insulation are reprocessed into insulation or into fibres for the textile and packaging industry. At the ultimate stage of the material's life cycle they may be utilised for renewable energy generation through anaerobic digestion.

5.3 Energy Harvesting

5.3.1 Overview

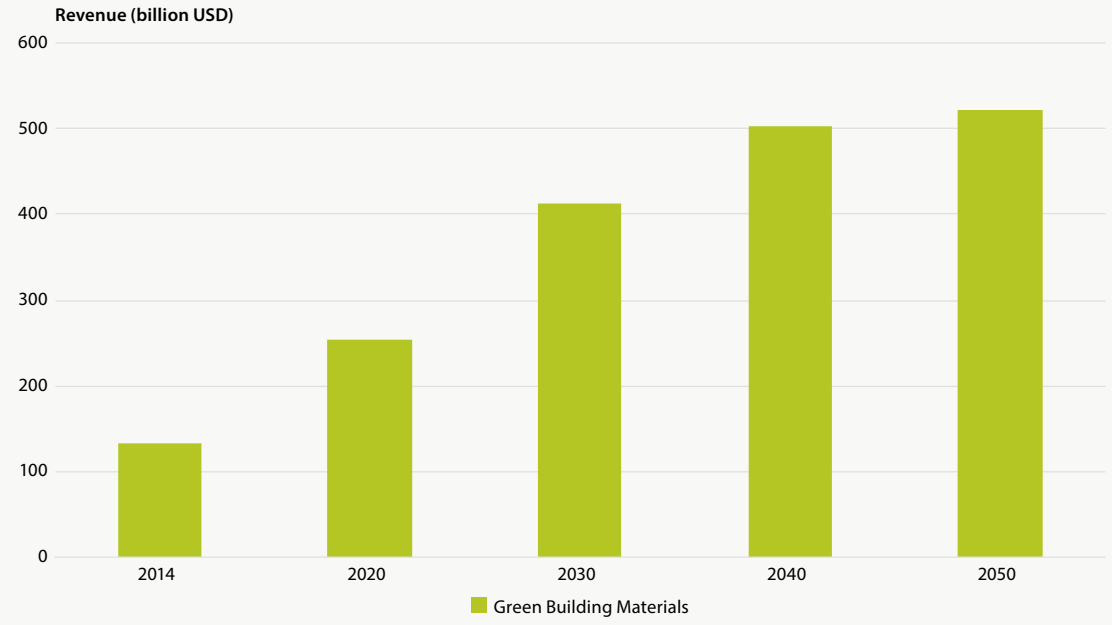
Energy harvesting (EH) is transforming ambient energy into electrical energy.[xxix] Sources of energy include ambient general lighting, captured by photovoltaic cells; vibration or pressure, captured by piezoelectric elements; or temperature differentials, captured by thermoelectric generators. Radio Frequencies (RF) are another promising source and is already being used in a number of ultra-low-power, battery-free applications such as radio-frequency identification (RFID) tags, contactless smart cards and wireless sensor networks. Also human motions such as biomechanical and kinetic energy are used to harvest energy and convert it into electricity. Energy can even be harvested from biological sources such as blood sugar and body heat.

Energy harvesting is not a disruptive technology; bicycle dynamos or self-winding wrist watches are examples of well-established applications. Nevertheless, energy harvesting is now spreading to a wider set of application areas. Particularly, wireless sensors that collect data and automate specific processes enable energy self-sufficient networks. By powering a network with EH generators instead of batteries or grid connection eases installation and maintenance. Energy harvesting can prolong the usage of battery powered devices and in case of lower power requirements, serves as the sole source of power. A

xxix also: power harvesting; energy scavenging

Figure 29: Green Building Materials Market: Revenue Forecast Global, 2014–2050

Source: Frost & Sullivan



positive side-effect of capturing otherwise lost energy as a source of power is the reduction of conventional energy consumption and associated carbon emissions.

The energy harvesting market is currently in a growth phase, helped by a focus on renewable and clean and green energy. Several products have been commercialised, and off-the-shelf EH devices are already available. The cost of energy storage techniques for EH, such as thin film batteries and super capacitors is decreasing at present. This is further accelerating the adoption of EH techniques and devices. However, wide scale adoption will be slow-growing until 2035 as the battery market is well established and consumer awareness is low for EH. Wide-scale adoption is expected first in industrial processes and building technologies.

The industrial environment includes oil and gas and manufacturing where wired infrastructure can be expensive. EH technology can be employed in these applications to power the wireless sensors and ensure long-term and autonomous monitoring systems.

The energy-efficient wireless and battery-free nature of energy harvesting networks eases the installation of building automation systems in both, new and refurbished buildings. There is considerable potential for wireless sensors that are easy to install and can power themselves from various ambient sources in order to reduce the downtime and increase production efficiency.

Automobiles will become another major application market for energy harvesting since electricity consumption has grown significantly and will further increase due to a growing number of assistance systems and their appendant sensors and actors. This increase in the energy consumption demands for the secondary alternator or larger batteries, which further increases the vehicle weight. In addition, waste heat is a favourable possibility to power several electric components or to charge the battery. The same applies to rail vehicles, water- and aircrafts.

eHealth will increasingly establish the home as a third point of care besides ambulant and stationary care. At present most body-worn electronics, implantable medical devices and wearable health tracking devices depend on lithium-ion batteries. Energy harvesting technology promises to eliminate the need for bulky disposable batteries and the risk of battery related defects.

For utilities transmission line maintenance and monitoring devices, power supply remains a challenge. In addition, use of battery increases the total cost of deployment and the additional cost for year on year maintenance and replacement. Energy harvesting technologies have key potential for enabling the use

Figure 30: Energy Harvesting Application Markets

Source: Frost & Sullivan

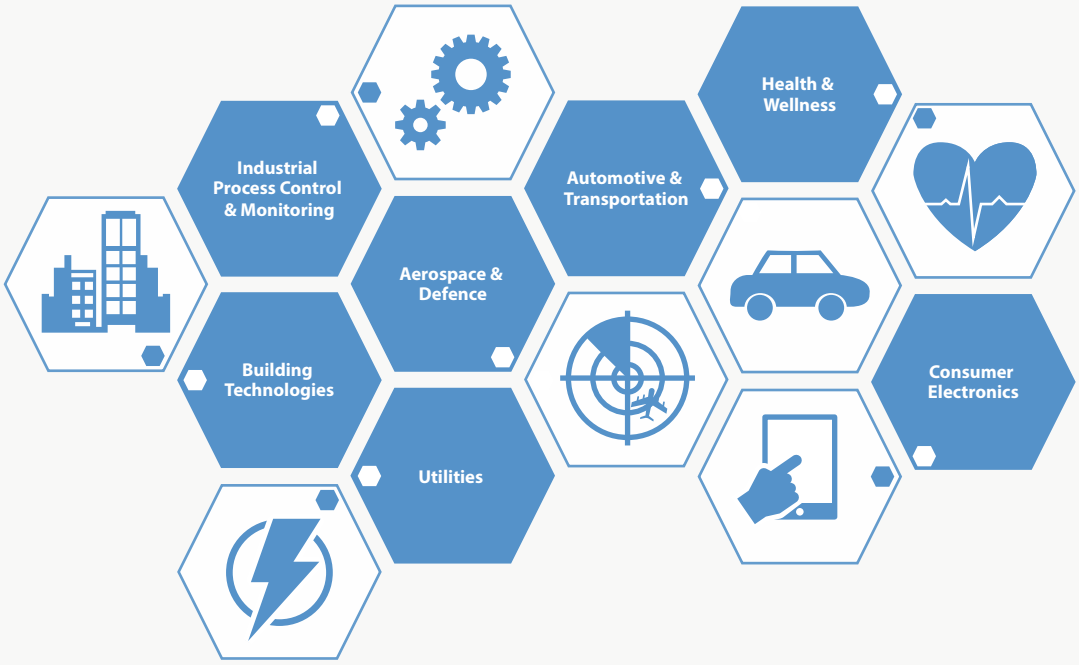
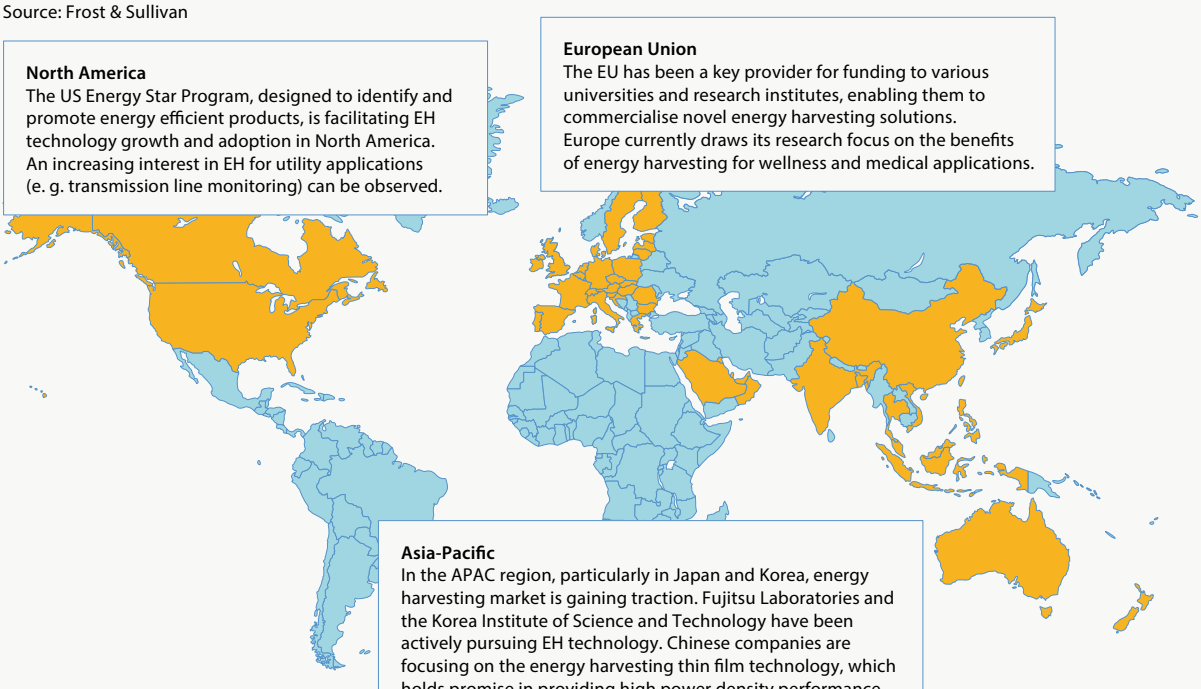


Figure 31: Global Energy Harvesting Hotspots 2015

Source: Frost & Sullivan



of wireless sensor networks to monitor key areas of electric power, such as transmission lines and substation equipment. A current transformer can be used to convert the magnetic field to electric current that can be utilised for powering devices.

Rechargeable batteries are commonly used in consumer electronic products; better energy efficiency through energy harvesting technologies can reduce the need for charging. Possible energy sources are thermal energy of microprocessors, ambient radio frequencies or kinetic energy.

5.3.2 Key Trends in Products and Services

Table 15 provides a breakdown of some of the key winning product categories resulting from energy harvesting growth globally.

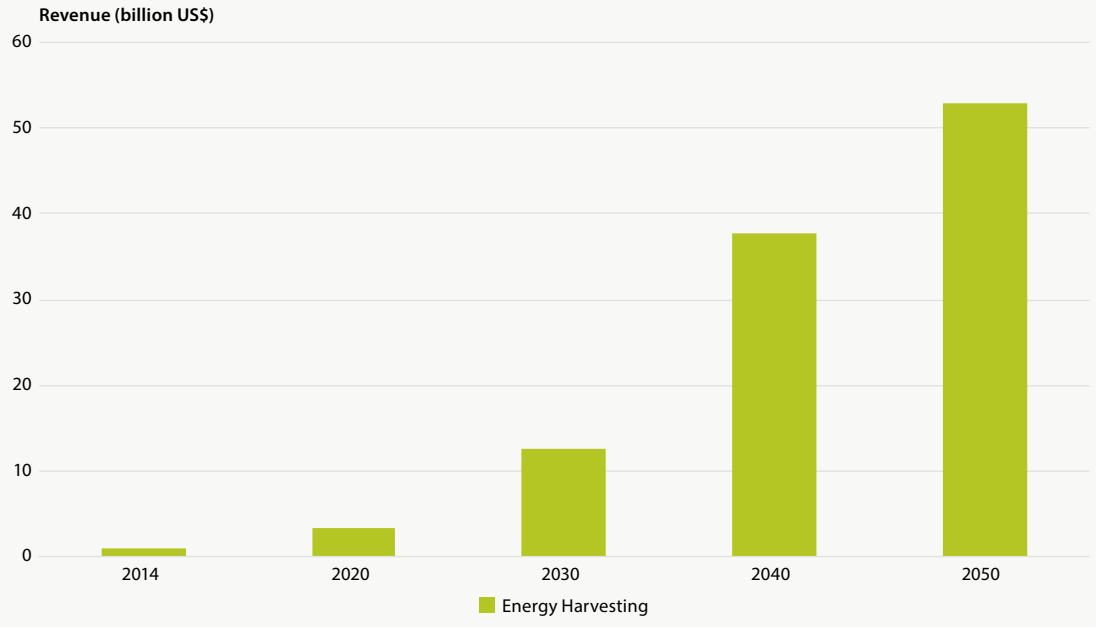
Table 15: Energy Harvesting: Products & Services – Winners & Trends, 2014–2050

Source: Frost & Sullivan

Winners	Trends
EH-powered wearables and implants	Wearables and implants will be powered through human energy sources including body heat, breathing, blood pressure and all types of motion.
EH-powered devices	Low power electronics such as mobile phones, meters, switches, sensors etc. will be powered by ambient energy sources such as motion, light, vibration etc.
EH-powered wireless sensor networks (WSN)	EH will facilitate wide-scale adoption of WSNs as it lowers total cost of ownership and eases installation and maintenance in areas difficult to access.
Waste energy recovery	Utilising waste energy recovery such as regenerative braking systems or indoor solar collectors will further reduce the energy consumption and reduce the total cost of operation of buildings, vehicles, factories etc.
Rechargeable batteries	The market break-through of energy harvesting solutions will provoke a decline of the disposable battery replacement market. Manufacturers will presumably focus on rechargeable batteries and innovative charging gadgets.

Figure 32: Energy Harvesting Market: Revenue Forecast Global, 2014–2050[xxx]

Source: Frost & Sullivan



xxx Energy harvesting market size includes revenue generated from sales of PV, piezoelectric, electromagnetic, and thermoelectric harvesters used in devices such as wristwatches, bicycle dynamo, wireless mesh networks, mobile phones and other consumer devices.

5.3.3 Quantification and Forecast

The global energy harvesting market revenue was US$ 1 billion in 2014. Europe is the fastest growing market, followed by North America and APAC. The energy harvesting market is projected to grow by more than US$ 8 billion in terms of revenue within the next ten years which can largely be attributed to its steady technological advancement. Between 2020 and 2030 thermoelectric technologies are expected to attain 10 to 15% of the total market. Human-powered EH applications are expected to be commercially available after 2025. Decreasing average sales prices of maturing EH solutions will be initially compensated by higher unit sales but will ultimately provoke a decline of overall revenues after 2045.

5.3.4 New Business Models

Energy harvesting solutions will be present in many everyday objects that require electricity. The amount of electric devices has already risen significantly during the last decades but is still far from an all-time high. This offers tremendous growth opportunities for energy harvesting solutions provided that original equipment manufacturers can agree on common interface standards.

There is no one-size-fits-all energy harvesting solution available in the market; and these solutions are tuned to the requirement of the actual end user application and energy sources available.

***EnOcean** is a pioneer in the field of indoor EH solutions for applications in buildings. The company is the mastermind of the EH wireless EnOcean technology that offers a complete maintenance-free wireless sensor solution for the building automation systems and smart homes. It is also a founding promoter of the EnOcean Alliance, an association of more than 200 original equipment manufacturers established 2008, which aims to accomplish interoperability of EnOcean wireless technology. As of today, EnOcean-enabled EH solutions were installed in more than 250,000 buildings worldwide.*

For other application markets new solutions need to be commercialised that can be integrated easily into existing products, e.g. pacemakers or scooters. To that end, open-source business models have proven to create the best possible conditions.

6 Industrial Processes

KEY INSIGHTS

Ubiquitous integration of wireless sensor networks feeding into cloud-based, big-data analytics platforms and machine-to-machine (M2M) communication interfaces will allow for new levels of control and automation in factory operations and management of global factory networks.

Heightened levels of centralised remote management and automation, combined with the growth of 3D printing technologies will provide vastly increased flexibility in manufacturing processes, allowing for significant increased efficiencies in production and supply chain, reduced faults and maintenance costs, and highly customisable on-demand manufacturing to meet changing market needs.

The smart factory and 3D printing markets are expected to reach annual market sizes of US$ 397 billion and US$ 207 billion respectively by 2050.

THROUGH THE INTEGRATION of new IT infrastructure and services, the automation and centralised remote management of factories across multiple levels of their production processes, as well as across an organisations global network of factories will enable factories of the future to gain new levels of efficiencies in material use, energy consumption, production processes and supply chain management. This highly networked and responsive production capacity will further allow for a greater degree of flexibility in response to regional or global demand profiles, maximising logistic efficiencies while providing a higher value of service and product quality to consumers. The total market size for smart factories and 3D printing is expected to grow rapidly over the 2014 to 2050 period, reaching annual market sizes of US$ 397 billion and US$ 207 billion respectively by 2050.

The following section provides an overview of the key industry low-carbon trends expected to drive the evolution of the industrial processes over the following decades. Sub-trends selected for analysis based on these criteria are: smart factories and 3D printing.

6.1 Smart Factory

6.1.1 Overview

Smart factories will achieve significantly higher levels of efficiencies through the convergence of technologies in advanced software systems, automation and advanced ICT enabled infrastructure design. Smart IT hardware, software, services and communications in the manufacturing sector is expected to represent a US$ 397 billion market by 2050. Convergence of technologies in smart factories will be focused on increasing production efficiency by reducing cost and achieving the desired quality product with minimal wastage through monitoring of the supply chain in real-time. Assets are required to be continually monitored for performance; early fault detection can help organisations plan output and maintenance more effectively. Technologies already being used to improve the capabilities of production systems, such as sensors, ultrafast lasers, augmented reality, three-dimensional (3D) printers, and machine vision systems, will show strong growth through the development of highly connected, integrated and automated smart manufacturing facilities and networks. At present, large investments are being made to implement smart factories in Europe, with Asia and North America involved in similar transformations.

Smart factories will achieve significantly higher levels of efficiencies through the convergence of technologies in advanced software systems, automation and advanced ICT enabled infrastructure design.

Figure 33 shows the direction process manufacturers are taking to usher in the new era of productivity and efficiency. Data sourced from various points is stored in the cloud through which a business analytics engine is able to provide clients with strategy-aiding intelligence and insight.

6.1.2 Key Trends in Products and Services

Through the integration of data streams collected from wireless sensor networks with the IoT, integrated management of the operation of an organisation's entire manufacturing fleet and supply chain is possible. This allows a significant degree of control across every process work stream of plant operation and distribution providing far greater levels of production efficiency. Furthermore, IoT allows the communication of selected enriched data with the manufacturers consumer base allowing for a greater degree of customer service (e.g. order tracking, delivery lead times, stock availability, etc.). Enterprise-wide traceability enables parts to be tracked back to vendors. Data-driven sensor awareness gives real-time visibility to avoid downtimes and perform preventive maintenance. Efficient resource utility helps reduce wastage and automation is maximising supply chain efficiency.

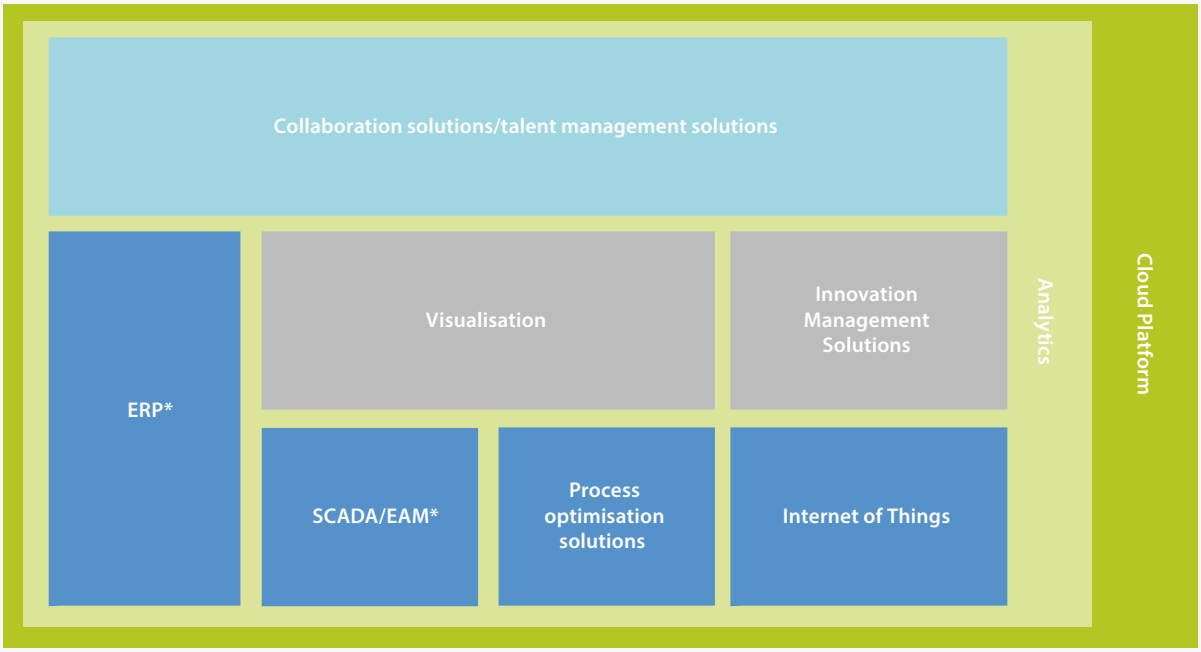
Table 16 provides a breakdown of some of the key winning product categories resulting from smart factory growth globally.

6.1.3 Quantification and Forecast

The total value of smart manufacturing hardware, software and services is expected to grow from a market of US$ 26 billion in 2014 to US$ 397 billion by 2050, increasing its share in total ICT spend 7 to 35% over the period. The most significant growth is expected in IT software and service solutions (e.g. data collection and analytics) growing at a CAGR of 9% to give a total market of US$ 303 billion by 2050. Sustained growth is further expected in IT hardware (e.g. WSNs), largely linked to growth in distributed manufacturing and increases in connectivity of developing nations. The IT hardware sector is expected to show a CAGR of 5.6%

Figure 33: Value Propositions of Smart Factories, 2014

Source: Frost & Sullivan



Note: *ERP = Enterprise Resource Planning; SCADA = Supervisory Control and Data Acquisition; EAM = Enterprise Asset Management

Figure 34: Technologies Enabling Smart Factory by 2030

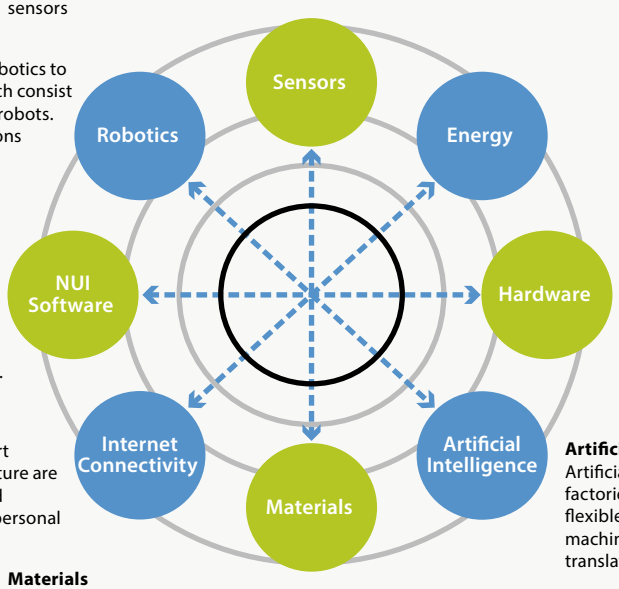
Source: Frost & Sullivan

Sensors
Sensors and actuators with wireless communication provide a digital nervous system to the world and enhance machine monitoring. Sensors that will be used in the factories of the future include ambient light sensors, acceleration/vibration sensors, electric and magnetic sensors, proximity and position sensors, leak or level detection sensors, force sensors, load sensors, torque sensors, strain sensors, pressure sensors, flow sensors, chemical/gas sensors

Robotics
Factories of future will use swarm robotics to coordinate multirobot systems, which consist of large numbers of simple physical robots. The factories will also use exoskeletons among others.

NUI* Software
The different types of software agents used in the smart factories are immersive 3D projections, Machine vision, telepresence, holography, haptics, speech recognition, gesture recognition, augmented reality, and multi-touch .

Internet Connectivity
The different ways in which the smart factories will be connected in the future are semantic Web, linked data, near field communication, cloud computing, personal area network, 3G, 4G, and 5G.



Energy
Factories of Future will produce more and address the increasing demand for goods and scarcity of resources. Smart factories will be capable of monitoring consumption of energy and use renewable and other sources of energy. Factories of future will have smart meters, fuel cells, ultra capacitors, bio-enhanced fuels, multi segmented smart grids, superconducting interties, nano-structure battery cathodes, photo-voltaic, solar thermal, artificial photosynthesis, nanogenerators, thorium reactors, wave reactors, and many more.

Hardware
Electronic devices that will be used in smart factories would be fabric embedded screens, retinal screens, pico projectors, electronic papers and boards, tabs and pads, and 3D devices.

Artificial Intelligence
Artificial intelligence will be used in smart factories for making customized products, flexible operation of coordinated machines/systems, and machine translation.

Materials
The different type of materials that would be used in smart factories include cermets, memristors (memory resistors whose resistance can be manipulat ed), self-healing materials, meta materials, bio materials, molecular assemblers, carbon nanotubes, nanowires, and programmable materials.

Note:
NUI = Natural User Interface

amounting to a total market size of US$ 66 billion in 2050. Communications, while initially largely linked to growth in IT hardware, is expected to show a faster growth from 2025, as communication systems become more software based and less dependent on heavy investments into infrastructure. The smart factory communications sector is expected to show a CAGR of 8%, achieving a market size of US$ 29 billion by 2050.

Total value of smart manufacturing hardware, software and services is expected to grow to US$ 397 billion by 2050.

6.1.4 Future Business Models

Future business models will take into account demand for high degrees of manufacturing flexibility and product customisation, expected to drive companies to integrate new smart technologies in manufacturing and supply chain processes. This, combined with closed-loop manufacturing processes and product designs flexible enough to allow high efficiencies in disassembly and re-manufacture, will become strong competitive advantages. The value that can be delivered by smart factory platforms will largely depend on the level of integration of independent computational software by overarching cyber physical systems.

The integration of IoT, big data and crowdsourcing into the manufacturing process will place significant pressure on enhancing the responsiveness and adaptability of manufacturing production lines, along with their associated supply chains. Demand for high degrees of customisation, with substantially shortened lead times, from increasing volatile markets is expected to grow rapidly in the future. New approaches in the management of material supply chains for delivery to high-tech, multi-model manufacturing platforms, allowing for the simultaneous production of a vast range of product lines and models, at scales necessary to maintain cost competitiveness, will be a core need in the future

Table 16: Smart Factory: Products & Services – Winners & Trends, 201–2050

Source: Frost & Sullivan

Winners	Trends
Wireless Sensor Networks (WSN)	Sensors that can be placed at various locations within equipment, process lines, or plants and send real time data about the performance of the equipment will assist greatly in addressing this challenge through the provision of a greater degree of accuracy, monitoring and control. Intelligent factories will create synergies between energy efficiency, safety, security, and comfort, which will turn factories into networked, intelligent, sensitive, and adaptable entities. Advanced sensor fusion technology is expected to create new market opportunities for intelligent factories, as a result of more efficiently integrating data from diverse sensors. A controller with an embedded sensor fusion algorithm will make sensors work better in mobile applications. Using this, smart factories can utilize the already available sensors in the factories to achieve an intelligent system with low power and latency.
Augmented Reality (AR) (cloud computing, big data, sensors)	Sensor-based AR will be able to collect data from factories with the help of various sensors and replicate them as augments. This feature will help to track changes in factories, maintain a record of all events occurring in the factories, and track accidents and identify root causes To create an engaging experience for consumers, AR will engage end users in interactive shopping anywhere in the world with the help of mobile devices. AR supported by big data will empower cognitive AR to analyse the user data to track product locations, content delivery, and preferences. Cloud-based rendering has the ability to provide significant data for AR applications, enhancing tracking capabilities and improving accuracy of image recognition for AR.
M2M Communication	Machine-to-machine communication, also referred to as industrial Internet, will play a major part in improvement of manufacturing processes and enhancing productivity. This includes greater control over resources and more efficient logistics. Systems such as human machine interface (HMI) will be required to ensure high productivity by enabling efficient communication between robots and humans.
Predictive Analytics	Predictive analytics system is programmed with certain amount of intelligence, which further allows assets to evaluate their own condition, track the fault, and diagnose the root cause of the problem. The goal is to develop a smart computational agent with self-aware capabilities and advanced analytics to perform predictive modelling functionalities
Cloud Computing	To broaden horizons across organizational boundaries, cloud computing is being used. This represents a large network of systems connected in networks (public and private) to achieve scalable infrastructure for enabling applications such as storage of data and files. With the arrival of this technology, the total cost of content storage, computation, and application hosting and delivery is concentrated significantly.
Big Data Analytics	Big data in smart factories allows for the aggregation of massive amounts of sensor data with other select data sources from the cloud via IoT, in order to derive rapid insights via a big data analytic engine allowing the optimisation of workflows, processes and solutions. Cloud computing is driving the adoption of big data analytics through significant decreased costs in storage. The use of big data analytics in uncovering patterns, unveiling correlations, and extracting information from a large amount of different data types, will play an integral role in product design of the future. The global growing demand for highly customisable products targeted at the needs of specific consumers will be met through big data predictive analytics and flexible, distributed manufacturing capacity (e.g. 3D printing).

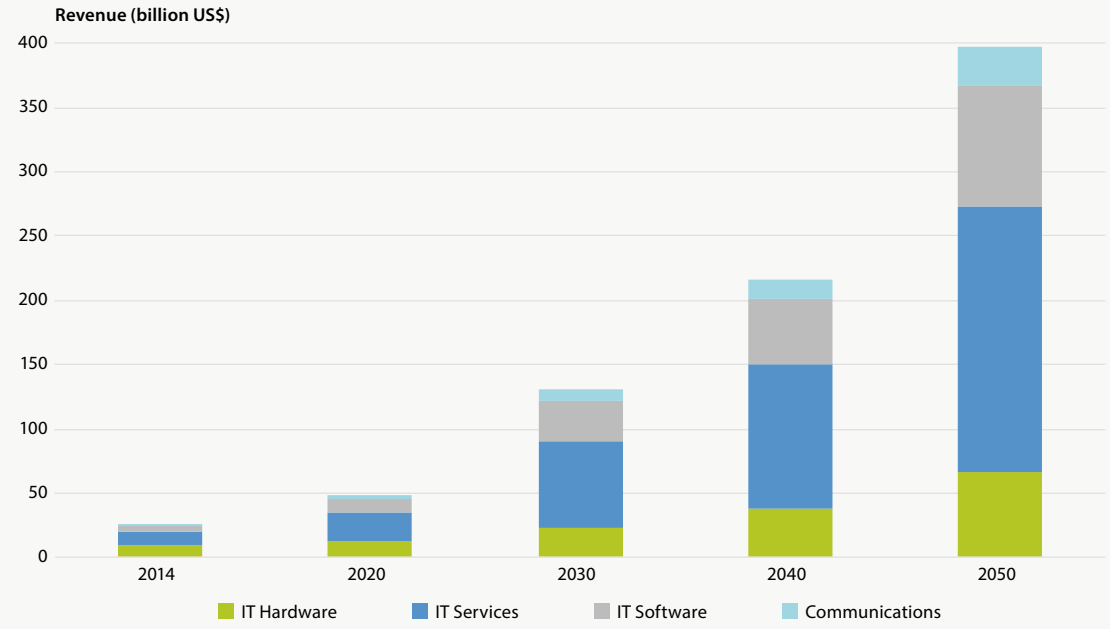
marketplace. New technologies in both manufacturing processes and ICT, along with a greater diversity and flexibility in supply chains, will be required to meet the ad-hoc supply requirements of customer-specific products.

Sustainability in product use, driven by an increasingly circular economy, is expected to be a core consideration in the manufacturing process in the future. Product design and manufacture will increasingly focus on the

Sustainability in product use, driven by an increasingly circular economy, will drive product design and manufacturing towards modularity and flexibility.

Figure 35: Forecast Revenue Growth of the Smart Factor Market, 2014–2050

Source: Frost & Sullivan



development of modular components with a high degree of flexibility in their design to allow for high efficiencies in disassembly and re-use in the manufacture of second and third generation products. Investments into new automated technologies for material recovery and processing into re-usable components (e.g. photonic processing), along with innovation into new end-use application markets for traditionally discarded materials, is expected to grow rapidly. The flexibility required in the above business model will require a significant amount of control and monitoring at every level of operation, in order for the system to meet performance levels required by its cost model to achieve necessary margins. While retrofit of these systems in existing manufacturing processes is likely, real benefits will be seen in the development of greenfield smart production lines, where the level of control and monitoring will by systemic throughout the operational design of the facility.[xxxi]

6.2 3D Printing

6.2.1 Overview

The 3D printing market has the potential to revolutionise the manufacturing value-chain through a "democratisation" of the downstream manufacturing process. The flexibility provided following broad-based market acceptance of the technology in the residential and commercial sector will allow for widespread customisation of products targeted toward a specific end-user and need. Integration of the technology with cloud-computing, big-data, M2M communication, and predictive analytics, will further allow for automated evolution of product design and development based on changing end-user needs or targeted design and development of components to meet specific critical functions (e.g. component replacement following fault detection). The market is expected to represent an annual revenue size of US$ 7 billion by 2020, and US$ 207 billion by 2050.

6.2.2 Key Trends in Products and Services

3D printing has a growing market capability in aerospace, automotive, healthcare and consumer product and is expected to see wider usage in biomedical applications, customised manufacturing, production of aircraft parts and more efficient, large-scale prototyping of parts in the auto industry.

Using 3D printing technology, companies would be able to prototype or manufacture various parts and products at a much faster rate when compared to the conventional processes. Companies would be able to significantly

xxvix European Factories of the Future Research Association (EFFRA), 2013

reduce the lead time and wastage in terms of materials, and their environmental footprint. The technology also has the potential to significantly reduce inventory, logistics and freight transport costs which is seen to be a major factor in driving greater use in manufacturing companies. 3D printing applications are expected to impact the following industries significantly: automotive, aerospace, reverse engineering, consumer electronics, fashion and lifestyle, healthcare and nanotechnology.

6.2.2.1 Consumer and Commercial

The lack of standard procedures for manufacturing various commercial products has limited adoption of 3D printing technology in commercial products and other domestic appliance manufacturing; wide scale adoption in this sector is expected post 2020.

6.2.2.2 Medical

The healthcare industry and medical/dental industry are some of the fastest growing adopters for 3D printing technology. The major reason for this has been the technical advantages of this technology that enables the manufacturing of self-healing organs and biofilm-free implants. The ability to manufacture required medical components within remote areas, such as developing countries, will provide a level of accessibility to health care products never before imagined. The wide scale adoption of this technology in the medical industry will grow from 2018.

The 3D printing market has the potential to revolutionise the manufacturing value chain and will grow to a market of US$ 207 billion by 2050.

6.2.2.3 Manufacturing Industries

Advantages include reduced process time, increased efficiency, lower material waste and increase in the mass production of parts. 3D printing will further enable the development of distributed manufacturing capacity, both residential and commercial. Customisation and manufacturing of product by end-users themselves will open up new markets for the development of proprietary product designs by a global prosumer base. In the long term, this has the potential to weaken the R&D-manufacturer link in key industries, as well as decrease the need for centralised manufacturing capacity in key product segments. Increase in the adoption rate of this technology in the manufacturing industry is expected to continue to show strong growth to 2020, following which broad-based market acceptance in the residential and commercial sectors is expected to grow.

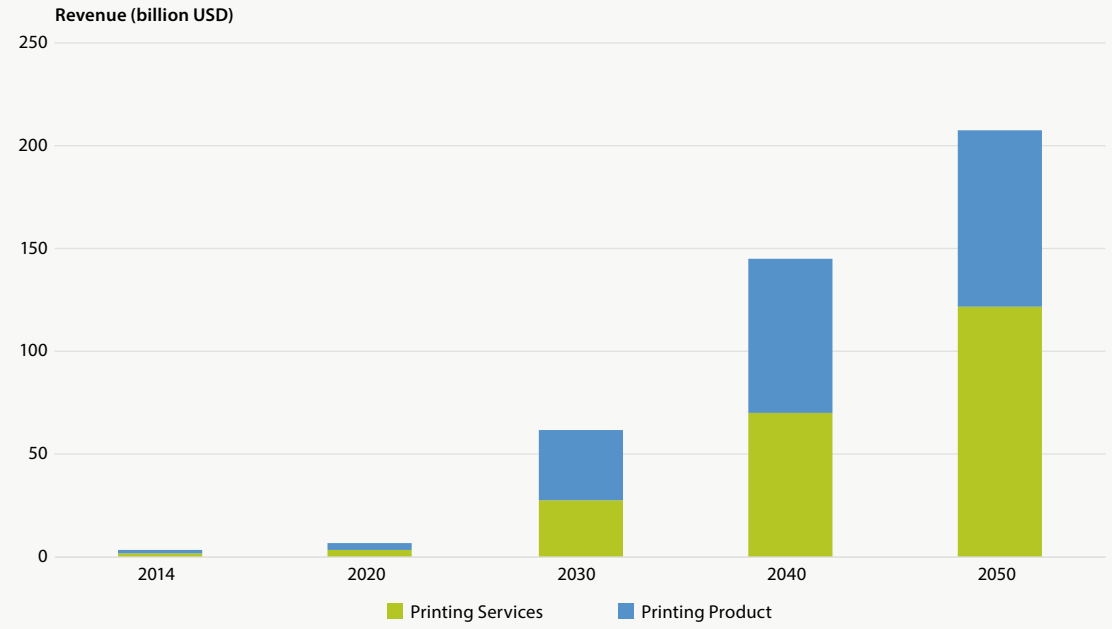
Table 17 provides a breakdown of some of the key winning product categories resulting from 3D printing growth globally.

Table 17: 3D Printing: Products & Services – Winners & Trends, 2014–2050
Source: Frost & Sullivan

Winners	Trends
3D Software developers	The software platforms used in the 3D printing process helps the developers in developing the prototype of the parts that are to be manufactured. It also aids in carrying out tests and validating the prototypes in the real-time system.
3D Scanning	Scanners are used for creating real-time models that are then integrated in computer-aided models (CAD). This is used for modification and re-manufacturing processes by the manufacturers.
3D Printer OEM	3D printers carry out various tasks such as assembly and fabrication of the products that are manufactured using the 3D printing process. The 3D printers are used by the service providers on a large scale for producing products or parts for original equipment manufacturers (OEM).
Material Supplier	Material suppliers supply the materials that are required for the 3D printing process. Materials that are usually supplied are for the layered object manufacturing and fuel deposition modelling techniques.
Service Providers	Service providers fabricate the 3D design image of a particular product or part that is to be manufactured by the OEMs into a physical model.

Figure 36: Forecast Revenue Growth of the 3D Printing Market, 2014–2050

Source: Frost & Sullivan



6.2.3 Quantification and Forecast

The total size of the market for 3D printing product and services is currently estimated at US$ 3 billion and is expected to grow to US$ 7 billion by 2020. The United States is currently the largest market, accounting for close to 40% of the total, but this will erode as other markets develop their capabilities. Following 2020, strong growth is forecast as technology acceptance is widely achieved in the commercial and residential sectors, with annual revenues of US$ 145 billion by 2040 and US$ 207 billion by 2050. Printing services (e.g. 3D design development and trade) are expected to account for almost 60% of the market by 2050.

Currently, 95% of the market exists in industrial 3D printing, and due to the high upfront costs of systems capable of developing complex products, this will remain the situation until at least 2025, with growth focused on large scale applications in prototyping and niche component manufacture. Distributed manufacturing growth is likely to be driven by the commercial sector, where printing systems will be employed for rapid manufacture and delivery of product to customers. The residential printing market is only expected to begin to show significant market penetration post-2025, and show significant growth post 2030. As commercial and domestic printing begins to grow significantly post-2025, consumer goods will be the major growth market for the technology as the capabilities and cost of the technology provides the opportunity for niche, flexible manufacturing in close proximity to demand markets.

6.2.4 Future Business Models

3D printing will hold in it the ability to substantially enhance flexibility in manufacturing through the development of rapidly customisable, distributed manufacturing potential at an industrial, commercial and residential level. New business models will allow for instantaneous on-demand manufacturing of products by printing technology integrated into cloud based systems and analytics platforms that allow for adaptable designs based on required, or predicted, needs. Crowdsourcing R&D and product design will become an integral part of future business models, as manufacturers or retailers turn to online platforms to accept designs and ideas from innovators around the world.

While the consumer's needs have always driven value creation in product development, the 3D printer model will position the consumer as an active participant in the

creation of value for the product he or she is purchasing. This allows product manufacturers a significant degree of flexibility in production without concerns relating to the scalability and commercialization of a new customized product model.

3D printing distribution channels are likely to run parallel with to-scale production channels, initially servicing niche, highly customizable product groups, previously seen as uneconomical by manufacturers. Channels could be represented through home printing, wholesale printing, or online printing retailers, where products are ordered online, printed at a local printing warehouse, and delivered to the customer's door.

3D printing will further provide the potential for an explosion of micro-manufacturers, developing and retailing products from homes or offices. The production-to-order model will require minimum stock holding and logistics. This significantly limits the required upfront investment for SMEs to achieve a scalable business, and allows the immediate trading of goods in the market. Some key expected business models of the future are the following:

6.2.4.1 In-house 3D Printing

In this type of a business model, the manufacturer has in-house capability as well as the infrastructure to manufacture components using 3D printing technology. Various automotive and industrial equipment OEMs such as GE, Ford, and General Motors are involved in manufacturing their products using their own 3D printers obtained from key 3D printer manufacturers.

6.2.4.2 Contract Manufacturing Model

This model relates to a manufacturer that contracts with a firm to manufacture components using 3D manufacturing. 3D printing contracting creates an opportunity for original equipment manufacturers (OEMs) to ensure product quality, reliability and cost for key components at all of its facilities globally, regardless how remote, reducing risks relating to supply and price uncertainty. This model is further expected to be used extensively in product prototyping, allowing for rapid development of prototypes and dramatically reduced cost. Rapid PSI, Thogus, Mcor Technologies are examples of companies providing this service.

6.2.4.3 3D Printing as a Service

This is an online business model in which the orders are received online, printed at 3D printing warehouses, and the finished products are mailed to customers. This is usually adopted for commercial and household products that customers would like to have using the 3D printing service.

6.2.4.4 Retail 3D Printing

Portable 3D printers available in the retail market can be used to manufacture products at home. The interest for 3D printers to create the commercial products is garnering a lot of interest among customers around the globe. Companies such as Cubify and other startups have developed easy to operate 3D printers, which are also easy to use for the general public.

7 Water and Waste Management

KEY INSIGHTS

The integration of smart municipal waste technologies will represent a cornerstone of the overarching circular economy paradigm in cities striving for a zero waste future.

These new smart technologies in waste recovery, sorting and processing will be essential to the management of a global production of 2.8 billion tonnes of municipal waste by 2050.

The integration of smart water technologies in monitoring, remote management and automation of water grids will further assist in significantly reducing water losses amounting to a significantly high global average of approximately 30% of total water distribution in cities.

The total market size for smart municipal solid waste (MSW) and smart water markets is expected to amount to US$ 32 billion and US$ 102 billion respectively by 2050.

WITH A RAPIDLY URBANISING WORLD and a total population forecast to increase from 7.2 to 9.6 billion by 2050, of which approximately 65% is expected to be located in urban centres, the need for smarter circular systems for waste recovery and processing will be critical in managing a projected municipal waste generation of 2.8 billion tonnes. Increasing global consumption will place further strain on scarce resources, and rapidly urbanising centres in often remote, developing countries will continue to create significant logistical challenges in product supply chains. Water infrastructure development will further continue to struggle to keep pace with urbanisation, leading to significant strain on existing infrastructure and rises in non-revenue water (NRW) resulting from leakage, theft, or non-payment. The cities of Guayaquil, Sofia and Delhi are examples of cities showing over 50% annual water loss, with the global average for major cities amounting to approximately 30% loss per year due to leakage and theft. Through the rapid integration of ICT infrastructure within urban centres, water and waste management will progressively become automated and remotely responsive, allowing for more efficient, less labour intensive operations and a greater degree of communication with consumers. Through this, the market for smart municipal waste management, water and packaging is expected to reach US$ 310 billion by 2050.

The following section provides an overview of the key low-carbon trends expected to drive the evolution of the water and waste management over the following decades. Sub-trends selected for analysis based on these criteria are: Smart Municipal Waste and Water Management, and Smart Packaging.

With a rapidly urbanising world and a growing total population the need for smarter circular systems for waste recovery and processing will be critical in managing the generated municipal waste.

7.1 Smart Municipal Waste and Water Management

7.1.1 Overview

Municipal solid waste (MSW) is expected to increase from 1.8 billion tonnes to 2.8 billion tonnes from 2014 to 2050.[xxxii] Furthermore, global urban population is expected to increase from 3.8 billion in 2014 to 6.3 billion by 2050.[xxxiii] This significant increase in urban congestion, running parallel with sustained GDP per capita growth in highly populated developing countries (e.g. China, India, Brazil), and the resulting substantial increase in municipal solid waste of a billion tons by 2050 is expected to drive new innovations into more efficient waste management systems globally. The smart waste management market, considering smart collection and processing, is expected to grow from US$ 0.4 billion in 2014, to an annual market of US$ 30 billion by 2050.

Smart collection and recycling systems will be integral to the development of a circular economy, whereby cities

xxxii Environmental Management Centre (EMC), 2014

xxxiii IMF World Bank, 2014

achieve zero waste targets through the development of fully integrated closed cycle processes, incorporating product manufacture, use, collection, processing and remanufacture. Smart recycling is the answer to solving problems related to quality and quantity of collected waste, efficiency of overall processes, as well as the downstream material value offered to final customers. The smart water grid market accounted for approximately US$ 9 billion in 2014 and is estimated to reach a market size of US$ 102 billion by 2050. Smart technologies and solutions are related to all aspects of waste management; where Information Communication Technology (ICT) can be applied as hardware, software or used as a total solution. Moreover, smart recycling systems are increasing the overall efficiency of the waste management process and as a result, they are having a positive impact on the specific cost of internal treatment (measured in US$ per ton), thus, improving the bottom line of operations. Smart recycling provides a collaborative platform for data exchange and promotes greater cooperation between all players in the sector.

The smart waste management market, considering smart collection and processing, is expected to grow to an annual market of US$ 30 billion by 2050.

Energy expenditure for water utilities can exceed 65% of their annual budget, and average leakage levels amount to 25 to 30% per year globally. The use of smart water systems will enable water utilities to move towards more sustainable energy use by reducing unnecessary waste of non-revenue water (NRW) resulting from leakage, as well as, avoid bursts and extensive repair work through remote management of pressure reduction valves (PRVs) in order to optimise pressure throughout the grid. Smart water technologies will help water utilities optimise internal budgets, present better value for customers and reduce their carbon footprints. By using grid sensor networks to remain constantly updated about field conditions, water utilities will be able to solve issues before they become major problems. Furthermore, engagement with customers will be streamlined through the use of smart analytics and control that will track historic data for addressing queries and increase accuracy of results.

7.1.2 Key Trends in Products and Services

The following represent core technology trends in water and waste management of the future.

7.1.2.1 Smart Waste Recycling Logistics Infrastructure (SWRLI)

SWRLI is aimed at optimising operations in time management, fuel efficiency, and overall asset management. It plays a crucial role in effectively collecting and transporting waste and has a significant influence in the downstream processing costs and efficiency of waste collection as a whole. The system is an integrated software and hardware solution, generally outsourced to specialist IT companies or internally applied to support company performance and integration. Logistic solutions are the intelligent frameworks that tailor together the best combination of a collection system, comprising the best container and appropriate truck type (rail or road), plan the route, and provide a summary of the material estimated for recovery. All the elements of the waste collection and management system influence the final cost, quality of material, and timing of the delivery. Smart Waste Recycling Logistics Infrastructure (SWRI) consists of coupled software and hardware, which includes cellular communication, radio frequency mesh, and sensor based sorting units. Smart track solutions can include the use of electric or hybrid automobiles. One of the most innovative solutions since 2011 has been provided by Volvo AB – an FE hybrid named Volvo FE Refuse.

7.1.2.2 Smart Container Solution

Since 2010, there has been increasing interest in smart container solutions, as it is easy to operate and is applied in urban areas. Access to the container itself is restricted and each user is authorised to operate the container with an electronic key that is linked to the container recognition software. Data about the user, type of waste disposed, amount of waste, time of input, level of filling, and status of the bin is wirelessly transmitted to the information centre. The collected data is analysed and sent to waste tracks, and therefore, every day is planned with an optimal schedule route to avoid any unnecessary cost. The smart container system is beneficial for route planning, decreasing fuel consumption, lowering service cost, personalisation, and eliminating the possibility of unauthorised access.

7.1.2.3 Odour-free Smart Automated Vacuum Collection Systems (SAVCS)

The problem of odour from biological waste material in urban areas is of the focus of the smart automated vacuum collection system (SAVCS). A waste container collects waste and segregates it into four categories of recyclables—organic waste and three recyclables fractions. Four inlets are easily accessible for all users and after placing the waste, it is then sucked under vacuum at 70km/h to the logistic station where it is collected in sealed vessels, ready for transport to the waste recycling and disposal facility. The SAVCS system is fully sealed and automated and the odours and air emissions are cleaned by filters. The system is beneficial especially for warm climates, as rising temperature is a key catalyst in increasing the odour nuisance of biological wastes. The system is equipped for recycling grades and its reliability is beneficial for special treatment materials such as nursery or hospital waste. One key shortcoming of this solution is that it requires costly underground works, which can be very difficult to apply in cities with an already cluttered underground utility infrastructure. The vacuum system is a good option for private investors in places such as hotels, spas, and airports around the globe. A good example of this is the effective vacuum system installed in 2012 in the New Delhi International Airport, which is able to collect 7.3 kilotons of kitchen and organic waste annually with a maximum uptake of 20 ton per day.

In the historic downtown of Reus *(Spain), over 35 kilotons of MSW waste is collected via SAVCS in four categories, such as organic, recyclables (packaging and paper), and others. The system has been successfully installed in the city centre and has already translated into aesthetic benefits for the old city.*

7.1.2.4 Sensor-based Sorting

The system is based on simple optical reflection (near infrared radiation, visible spectrum) or X-ray scan with a software recognition program. The waste material is placed on conveyor belts, where it undergoes Near Infrared Spectroscopy (NIR), VIS or X-ray scan to detect its shape, texture and material absorption. The camera in the system then captures an image for the software to recognise objects and ascertain the material that needs to be positively or negatively separated (by air streams), and then the final downstream product is obtained.

The process is highly efficient (recovers about 95 to 98%) and includes full recognition of plastic specific material (all types of plastic), which was the most common problem in the use of human labour. Sensors can be applied to very specific types of high value material, as they recognise not only the density (type of plastic material) and texture absorption (colour), but also detect specific types of unwanted materials in the waste stream. Optical sorting is a well-recognised solution for refuse derived fuel (RDF) producers, on whom strict requirements are placed by incineration units (e.g. waste to energy plants, cement plants) with regards to calorific values, chlorine content, heavy metal levels, and proportion of metal and inert material mass.

Smart Waste Recycling Processing Infrastructure (SWRPI), is a solution incorporating sensor based sorting, customised waste segment sorting, and a material recovery unit which are based on a concept that combines optical sensor recognition, software, and robotics. The system supports the recognition of high value material quality and recovery, and maximises performance efficiency with minimal generation of low economic value by-products. The system further ensures the highest quality of secondary material possible.

7.1.2.5 Smart Water

Smart Water Infrastructure includes smart meters, pumps, pressure reduction valves, pipes, data loggers, transmitters and communications infrastructure. Network sensors collect data on flow and pressure to track for

data anomalies that can set off localised or centralized alerts prompting action before incidents occur, such as bursting pipes, or to identify leakage points. Non-revenue water levels of 25% are unsustainable for water utilities and reducing this figure is central to future operations. This level of central oversight and control allows utilities to optimise the pressure in the water grid according to changing conditions through the use of Smart pumps and PRVs. This further allows more controlled and gradual adjustments of pressure levels, as pressure adjusted in one action can cause bursts. Sensors can further collect data on water quality to detect safety and corrosion levels. This is important for sensitive sites such as hospitals and schools and provides prior notice about corrosion and leakage. Lastly, endpoint meters, through the collection of data on flow rates and its communication back to the utility for analysis, allow for accurate and equitable billing, maximising chargeable water.

ICT, software and analytics refers to all software related programmes installed in water utilities that enable a smart water grid and data analysis. These include hydraulic modelling, grid monitoring and data analysis. Grid monitoring and hydraulic models help analytically assess the grid in real time and, using predictive analytics, assess the future health of the grid. Automation and control services utilise more established software abilities such as supervisory control and data acquisition (SCADA), and geographical information systems (GIS) and billing. This is an established market that exists outside of smart water specific software. The solutions provide two-way communication allowing remote upgrades to infrastructure, optimising the system and reserving technicians for priority events.

Table 18 provides a breakdown of some of the key winning product categories resulting from smart municipal waste and smart water growth globally.

Table 18:
Smart Municipal Water and Waste Management: Products & Services – Winners & Trends, 2014–2050
Source: Frost & Sullivan

Winners	Trends
Smart Waste Recycling Logistics Infrastructure (SWRLI)	The SWRI segment is currently in nascent phase and is expected to be the fastest growing market over the next decade, as a result of its ability to maximise process efficiency and enhance the renewability of waste resources.
Smart Container Solution	The smart container solution is expected to show significant interest in urban areas over the next ten years, due to the relative ease in implementation into urban structures
Odour-free Smart Automated Vacuum Collection Systems (SAVCS)	Due to the requirements of costly underground works in already congested subterranean infrastructure under major cities, it is likely that the solution is expected to show niche growth, focusing on new greenfield urban developments or the retrofit of smaller, less congested, cities or city blocks.
Sensor-based Sorting and Smart Waste Recycling Processing Infrastructure (SWRPI)	While currently still very niche, the technology is expected to show increased adoption in the near term, with sustained growth expected from 2020 to 2030. From 2030, the smart processing market is expected to show rapid growth, representing over 70% of the market by 2040.
Smart Water Grid Monitoring Technology (Ultrasonic measurement, electromagnetic measurement)	Ultrasonic sound waves are sent through the pipe and upon return, provide velocity, which is converted into a volumetric measurement. Electromagnetic flow meters determine velocity, and in turn, volume, by measuring electromagnetic properties in the water.
Smart water pumps and pressure reduction valves	Through sensors and data transmission, utilities can instantly measure and gradually reduce or increase pressure according to the demands of the water grid through smart pressure reduction valves. Smart pumps operate in a similar way to valves and remotely control pressure and flow in the water grid. A single pump or multiple pumps can be used to optimise efficiencies.
Smart water software	Hydraulic modelling, grid monitoring, prediction analysis, asset management, queries and remote upgrades, cyber security, AMR/AMI metering, event prioritisation, bespoke reports, remote pressure control, Distributed Control System, Human Machine Interface, SCADA.

Note: AMR = Automated Meter Reading; AMI = Advanced Metering Infrastructure

7.1.3 Quantification and Forecast

The following forecasts take into account technologies utilised in smart processing and smart collection of MSW, including RFID tagging, smart waste recycling logistics software, and advanced material recovery facilities utilising sensor-based sorting. Forecasts have been segmented into smart processing and smart collection.

Total annual investment in the waste management sector is estimated to reach US$ 310 billion in 2050, with an average annual investment of US$ 143 billion over the 2011 to 2050 period.[xxxiv] The MSW management market represents approximately 20% of the total waste market. The smart MSW waste management market (including collection and processing) is in its infancy, with annual market revenue estimated at US$ 370 million. Strong growth is forecast to 2020 (albeit off a low base) reaching an annual market revenue of US$ 830 million. From 2020 to 2040, the market is expected to show exceptional growth driven largely through developed economies pre-2030, and by developing markets (e.g. China, Mexico, Brazil, India) post-2030 due to high urban populations and strong growth in GDP per capita. By 2050, the market is expected to account for US$ 32 billion in annual revenue.

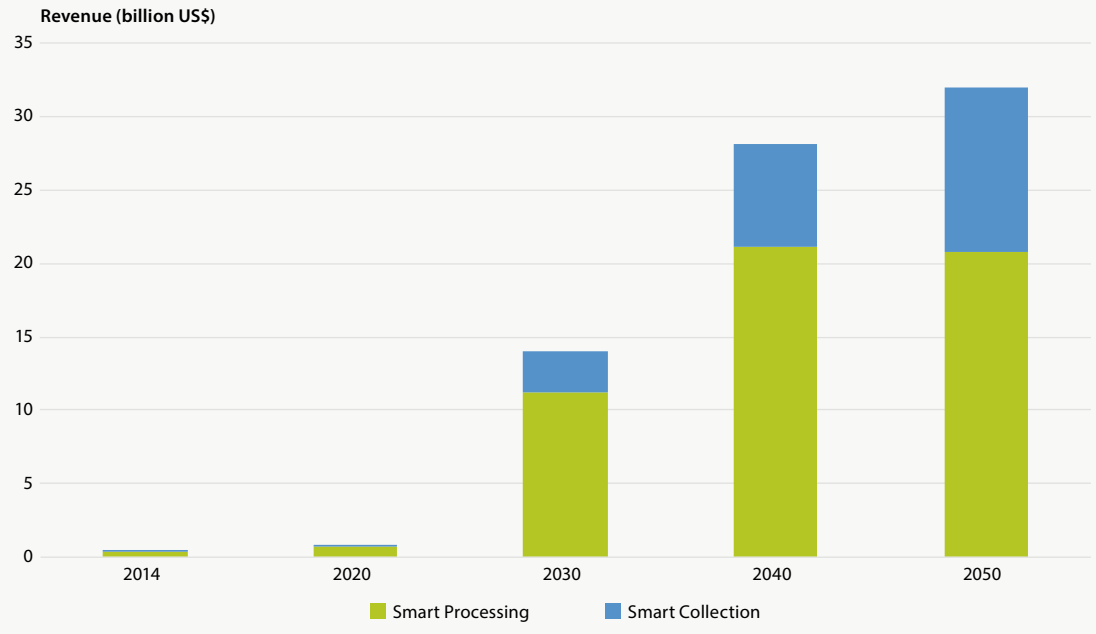
Total annual investment in the waste management sector is estimated to reach US$ 310 billion in 2050.

Figure 38 represents key growth markets for the smart MSW management market based on waste per capita vs. GDP per capita. GDP was chosen as filtering criteria as it represents a global measuring unit for standard of living. Areas showing a high standard of living and waste production per capita is are expected to be core markets for expansion of smart municipal waste solutions.

The total smart water market is expected to amount to US$ 102 billion by 2050, 66% of which will be accounted for by software of services and 34%, or US$ 35 billion, by smart infrastructure. ICT software and analytics will show the strongest growth for the 2014 to 2050 period, reflecting a CAGR of 8%. This market is expected to be driven primarily by North America and Europe over the period, however, the PAC, Africa and South America will play a strong demand drivers post 2030. Smart infrastructure is expected to show rapid growth to 2030, following which core global

Figure 37:
Forecast Revenue Growth of the Smart Municipal Waste Management Market, 2014–2050

Source: Frost & Sullivan



xxxiv UNEP, 2013

Figure 38: Key Growth Markets for Smart MSW Management based on Waste per Capita vs. Gross Income per Capita, 2011

Source: UNEP

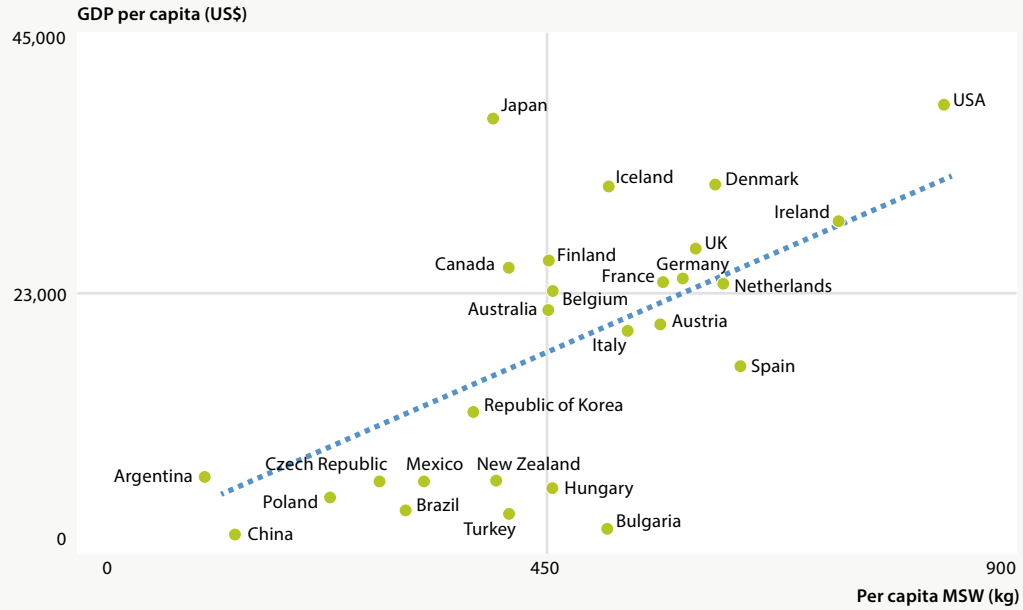
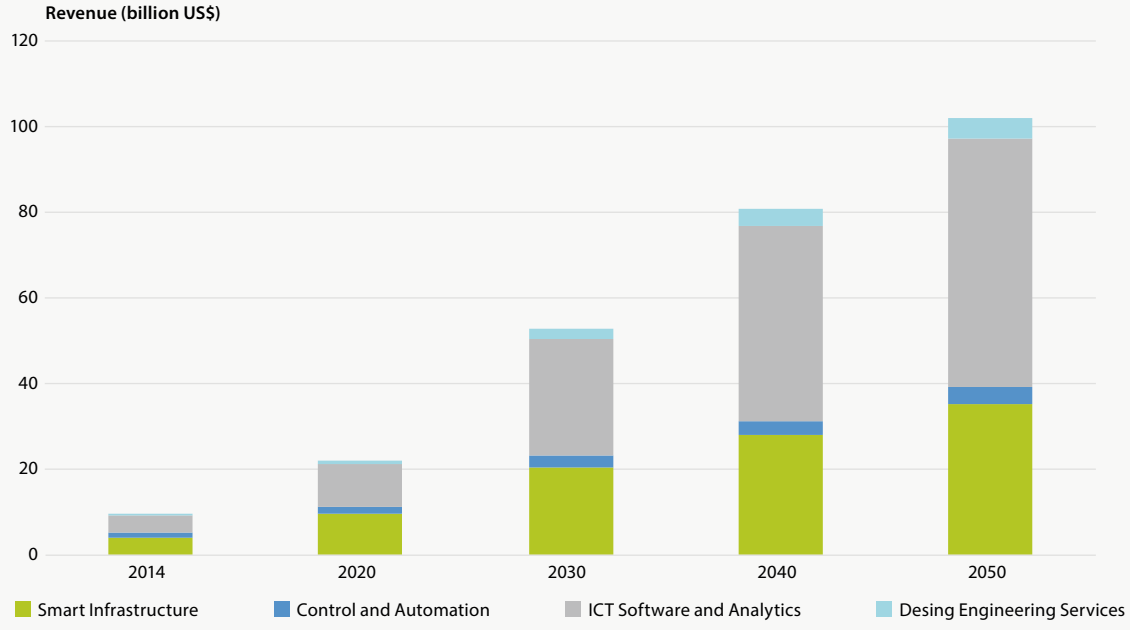


Figure 39: Forecast Revenue Growth of the Smart Water Market, 2014–2050

Source: Frost & Sullivan



markets are expected to reach saturation. Growth over this period is expected to be driven by North America and Europe to 2020, following by increasing demand from the PAC, South America and Africa to 2030. Following 2030, growth in smart infrastructure is expected to drop from its double digit CAGR of 10.5% for the 2014 to 2030 period, to 3% to 2040. Control and automation software (e.g. SCADA and GIS) is an established market, and growth is therefore expected to be largely driven through expansion of smart grid infrastructure. Total growth for the segment is expected to amount to a CAGR of 3% for the 2014 to 2050 period, achieving a market size of US$ 4 billion.

Total smart water market is expected to amount to US$ 102 billion by 2050.

7.1.4 Future Business Models

Future integration of circular recovery waste management solutions into company business models will show direct commercial benefits through the development of alternative revenue streams in waste management (e.g. waste-to-energy, biogas) and the reprocessing of discarded product components into second and third generation products. Efficient resource recovery systems will need to be integrated across the entire value chain of a product in order to maintain the inherent value of product components throughout their lifecycle and decrease the costs of collection, sorting and reprocessing into new second generation products. Business models that focus on profitability beyond the point of sale will emerge, through the development of added products and services to be used to enhance the total value of the base product throughout its lifespan.

Circular recovery waste management represents an opportunity for direct commercial benefit to companies through the development of alternative revenue streams in waste management (e.g. waste-to-energy, biogas) as well as the reprocessing of discarded product components into second and third generation products. The development of an efficient resource recovery system will need to be integrated across the entire value chain of product design, development, recycling, collection and processing in order to yield maximum benefits. The core goal of which will be to maintain the inherent value of product components throughout its lifecycle and, as far as possible, decrease the costs of collection, sorting and reprocessing into new second generation products. Successful strategies in circular waste management for companies should take into consideration the reprocessing of waste or by-product produced across each step of the value chain, and not only end-of-life products.

***Caterpillar**, through the remanufacture of product through Cat Reman, focuses on the development of effective products that allow for efficient reprocessing into second, third and even fourth generation products. This generates efficiencies that results in cost savings on materials – the most significant contributor to operating costs (approx. 65%) – rather than simple efficiencies to reduce overheads. In order to ensure quality of remanufactured product, products need to be recovered before usage leads to breakage, or before wear and tear becomes too extensive. In order to maintain the condition of components in the field, the company is making use of digital technology to monitor the status of components remotely in order to create a more effective and profitable reverse cycle. Remanufactured product is sold to customers at reduced prices, providing the company a key competitive advantage in the market. Payment is accompanied by a deposit on the product providing a financial incentive to return these products and maintain efficiencies in the circular model.*

Extending the total lifespan of products is a further consideration in the efficient facilitation of a fully circular system. The development of business models that focus on profitability beyond the point of sale will continue, through the development of upgradable products allowing for added products and services to be used to enhance the total value of the base product throughout its lifespan. The concept of product life extension, however, needs to offer a direct commercial benefit to manufacturers in order to be a sustainable model. This requires the design of products that show significant longevity and provide customers with a platform flexible enough to cross-sell value adding plug-and-play products, or provide replacements or upgrades in a cost efficient manner. The extension of the product lifecycle further decreases the risk of brand switching and deepens the consumer's relationship with the supplier.

Lastly, the use of bio and renewable materials in production is expected to continue to grow in market acceptance globally. Over the short term this will be driven primarily through government policies for GHG emission mitigation and green agendas. However, as bioenergy grows in significance, and the need for the diversification of product portfolios in order to drive down production

costs grows, bioproducts will become increasingly price competitive with traditional manufacturing materials.

Increased consumer spending is expected to drive the packaging market to double to US$ 1 trillion soon after 2020.

7.2 Smart Packaging

7.2.1 Overview

The total packaging market is estimated at close to US$ 500 billion by 2015 for consumer products. Sustained growth in global population, expected to reach 9.6 billion by 2050, and a rapidly rising middle-class in developing nations is expected to drive global household consumption from US$ 65 trillion in 2014 to US$ 173 trillion by 2050 – a CAGR of 3% over the period.[xxxv] Increased consumer spending is expected to drive the packaging market to double to US$ 1 trillion soon after 2020.[xxxvi] The Brazil, Russia, India and China (BRIC) countries currently account for approximately 30% of total packaging demand and represent the industry's core future growth markets. In order to ensure quality of product and safety and security in its distribution and use, particularly considering the complexity and high risk nature of supply chains to remote developing nations, smart packaging has become a highly funded field of research. Currently, more than a third of market value of the packaging industry results in the cost of wastage due to theft, damage, loss, expiry, error, and slow delivery of goods. Effective supply chain practices are, therefore, essential to prevent wastage. Supply chain operations account for the majority of the cost of packaged goods, roughly 75% of the total price of the product. The adoption of smart technology to allow for careful tracking of the movement of goods, thereby reducing wastage along the supply chain, is expected to gain widespread market acceptance. The total market for smart packaging technology is expected to increase from US$ 19 billion in 2014, to US$ 178 billion by 2050.

The total market for smart packaging technology is expected to increase to US$ 178 billion by 2050.

Smart packaging is generally separated into active and intelligent packaging. Active packaging involves the use of a system that can maintain the shelf life of a product or extend it, for example, packaging that contains odour, moisture and oxygen scavengers. Intelligent packaging includes technologies which can process and transmit information to the consumer, for example, sensors on packages can record the temperature or pH on the product through the supply chain, and RFID and NFC technology can monitor the location and orientation of the package and its contents as well as communicate information to the end-user and operators along the supply chain.

7.2.2 Key Trends in Products and Services

7.2.2.1 Food and beverages

Food and beverages is expected to represent the largest market for smart packaging to 2020. Fresh-cut produce continues to be one of the fastest growing segments of food retailing and while conventional film packaging is suitable for lettuce and prepared salads, it cannot cope with the high respiration rates of pre-cut vegetables and fruit, leading to early product deterioration. Smart packaging provides customers with better choices for fresh foods. Smart packaging for food encompasses breathable polymer films, self-heating packages for soup and coffee, thermochromic labelling for temperature monitoring and oxygen and moisture scavenging films for wrapping food and beverages. There is significant research into smart packaging for the food and beverages industry, and many innovations have been developed to the commercial scale. These include antimicrobial packaging, freshness indicators for food, oxygen scavengers, carbon dioxide scavengers, ethanol emitters, preservative releasers, moisture absorbers, temperature control packaging, breathable materials, gas volatiles indicators and more.

7.2.2.2 Electronics

Smart packaging advances are related to the developments in electronics technology, materials and processes that have the potential to create packages that can carry digital, machine-readable data. These developments concern, in particular, new materials (such as printed polymers) and tagging applications (such as RFID and EAS systems) which are described as "intelligent", "smart" or "active" packaging.

7.2.2.3 Healthcare and Pharmaceuticals

Pharmaceuticals will be the fastest growing active and intelligent packaging market through 2017 to 2020, with opportunities driven by the health care needs of the aging

xxxv IMF World Bank, 2014

xxvi World Packaging organisation, 2012

US population, an increased prevalence of chronic diseases, and the expanding presence of high value, temperature-sensitive biotechnology drugs in the product mix. Smart packaging concepts that improve case of use could include 'dial-a-dose' smart caps and closures that allow the safe dispensing of exact controlled quantities of product, e.g. pharmaceuticals, cleaning materials, and other potentially hazardous materials. Future programmed skin patches using smart gels that rely on changes in skin properties to trigger drug delivery could replace conventional pill-taking medication. There are many products available in the industry (Med-ic, Timestrip, Dial Vial, Remindcap) but they currently do not represent significant commercial successes. However, broad-based market acceptance of these technologies is expected from 2017, following which rapid growth can be expected.

7.2.2.4 Personal care

Penetration of smart packaging in cosmetics is not as high as the food industry. Most potential is seen with products that can reflect the degree of UV exposure, moisture conditions and factors such as skin type sensors and are expected commercially by 2020.

Smart packaging has been revolutionized with RFID and electronics technology. The increasing use of RFID's for electronics in apparel tracking, consumer goods, transportation and supply chain management assists in reducing wastage and costs. Rather than the sensors by themselves, the industry is looking for sensor solutions or modules providing all hardware and software requirements. Advances in making the sensors affordable and cost-effective will boost adoption of technology. Further technological advancement, greater production scales and the intensification of competition is expected to assist in driving down prices to these levels.

Table 19 provides a breakdown of some of the key winning product categories resulting from smart packaging growth globally.

7.2.3 Quantification and Forecast

The total market for smart packaging technology for the above applications is expected to increase from 2014 levels of US$ 19 billion to US$ 34 billion in 2020. Following 2020, the market is expected to enter a dramatic growth phase, driven by broad based market acceptance and substantial increases in global household consumer spend. By 2030, the market is forecast to be US$ 83 billion, and US$ 133 billion by 2040. Market growth is expected to slow from 2040 to 2050, as smart technology reaches a mature stage in the packaging industry and growth closer reflects growth in demand for total packaged products. By 2050, the market is forecast to be US$ 178 billion. The largest markets are expected to be monitoring technology, RFID software and hardware, and NFC and IoT, accounting for 25%, 23%, and 21% respectively.

Table 19: Smart Packaging: Products & Services – Winners & Trends, 2014–2050
Source: Frost & Sullivan

Winners	Trends
Freshness monitors	Freshness monitors assess the quality of packaging contents (e.g. freshness of food), or potential compromises in packaging through information indicators, such as colour indicators.
Colour changing indicators	Provide information to the consumer as to the nature of packaging contents (e.g. food freshness) through colour change indicators.
Oxygen scavengers	Maintain food freshness through limiting food metabolism, oxidative rancidity, and growth of aerobic microorganisms.
RFID software and hardware	Radiofrequency identification (RFID) identifies and tracks tags attached to packaging material. The RFID packaging market represents an estimated market size of approximately US$ 5 billion in 2014 and is expected to show strong growth to 2020.
Intelligent blister packs for intelligent pharmaceutical products	Intelligent blister packs, along with the incorporation of RFID tracking technology, will allow for the monitoring of environmental and physical conditions in transport of pharmaceuticals, as well as allow for tracking of dosages taken by the patient throughout the prescription period. This will further allow for communication of information to the patient to ensure proper and safe drug use.
Near Field Communication (NFC) hardware and software	NFC software will allow for the multimedia communication of product information to the consumer through package integrated NFC tags linked with smart devices (e.g. phones, tablets).

Figure 40: Forecast Revenue Growth of the Smart Packaging Market, 2014–2050

Source: Frost & Sullivan

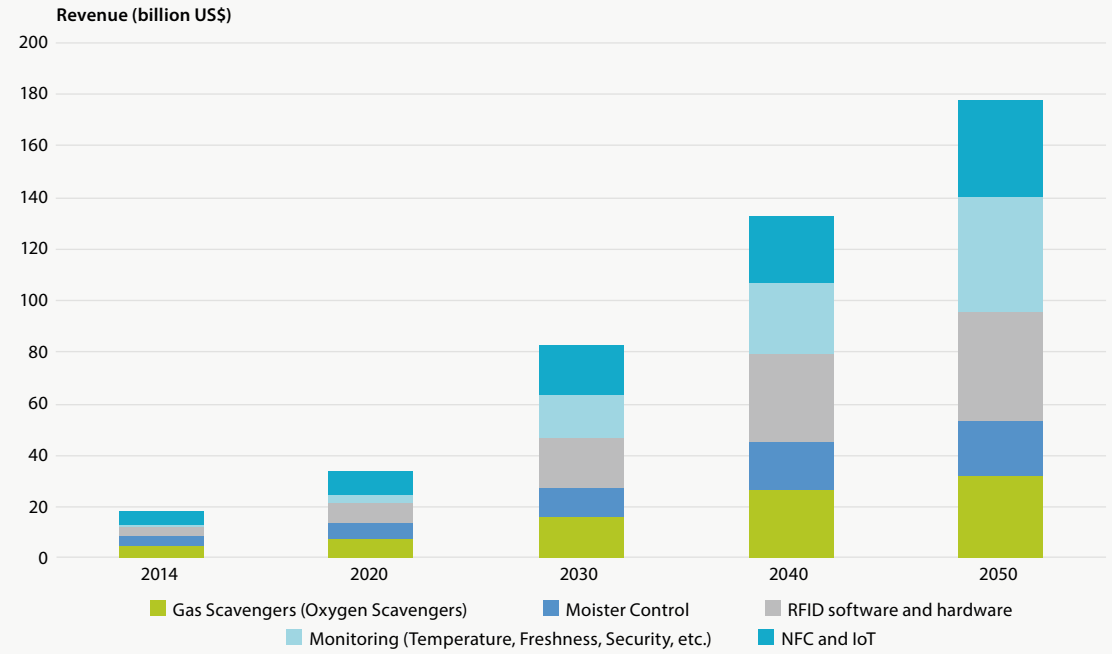
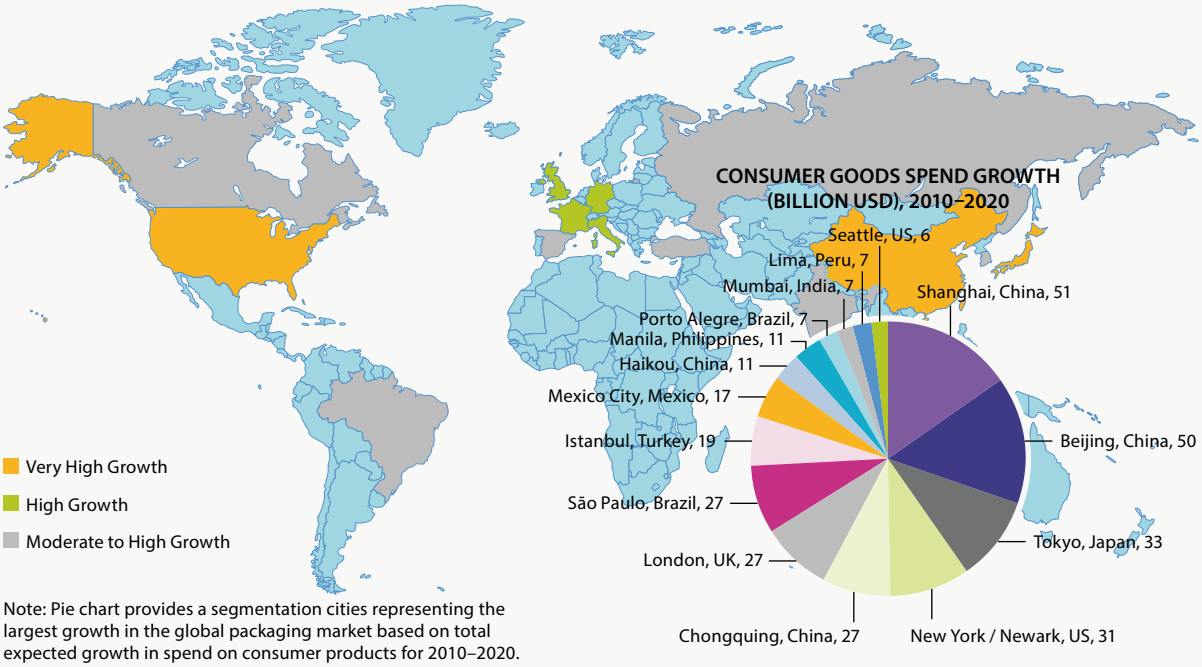


Figure 41 represents key growth markets for the smart packaging market.

Figure 41: Key Growth Markets for Smart Packaging based on Key Packaging Markets, 2010–2020

Source: McKinsey & Company, Frost & Sullivan



Note: Pie chart provides a segmentation cities representing the largest growth in the global packaging market based on total expected growth in spend on consumer products for 2010–2020.

7.2.4 Future Business Models

Packaging business models incorporating smart packaging solutions will show significant savings through the monitoring and tracking of package contents throughout product logistics and storage, as well as the prevention of product spoilage. In the future, greater investments will be made into two-way information flow with customers in order to promote the correct use of product, thereby granting a greater degree of control over product quality at end-use, provide product specific information (e.g. freshness, nutrient contents, company information), or interact with the customer via marketing campaigns. Increasing use of bio-based materials and the recyclability of packaging as a whole will further be key considerations.

Smart packaging has the potential to represent significant savings to manufacturers and distributors through the monitoring and tracking of package contents throughout product logistics and storage.

Smart packaging has the potential to represent significant savings to manufacturers and distributors through the monitoring and tracking of package contents throughout product logistics and storage. The technology further allows for two-way information flow between manufacturers/distributors and customers ensuring the correct use of product, and thereby granting a greater degree of control over product quality at end-use. The greater degree of connectivity with the consumer via NFC further allows for relationship building with consumers and opens a wide range of opportunities for value added promotions and marketing initiatives. Smart packaging technology, therefore, represents direct commercial benefits to companies in terms of cost saving, quality control, and increased sales volumes.

*In 2014, **Nestlé** provided digital barcodes for its products, providing smart phone users the ability to access nutritional information as well as additional information on the sustainability of its production. The company has further integrated augmented reality into some of its products allowing users to interact with fabricated digital objects, providing an immersive brand experience to consumers.*

Future smart packaging markets are expected to be targeted at high-margin, multi-faceted packaging products that provide significant benefits in more than one area, maximizing the value to the customer. Packaging technologies will need to be effective across multiple packaging segments, allowing for flexible supply-chain logistics and cost saving for the client. Furthermore, the recyclability and longevity of the technology will further represent a key factor in achieving growing market acceptance.

8 Opportunities for Finland

8.1 Importance of Clean Technology to Finland's Economic Recovery

With the onset of the global economic recession of 2009, Finland faced a dramatic reduction in global demand of two of its core exports, paper products and electronics. The slowing of these core demand markets, coupled with rigid labour policy resulted in a significant decrease in the net productivity and cost competitiveness of Finnish exports. Over the 2008 to 2013 period the Gross-Value-Add (GVA) of manufacturing decreased by approximately 30%, largely contributed by the contraction of the electronics sector and a 25% contraction of the forestry industries' (woodworking and paper) GVA.

However, following a tough period after 2009, metal manufacturing returned to positive growth in 2014. Outside of 2012, the chemical industry showed sustained growth throughout the recession period and professional, scientific, technical, administration and support-service activities have further continued to grow.

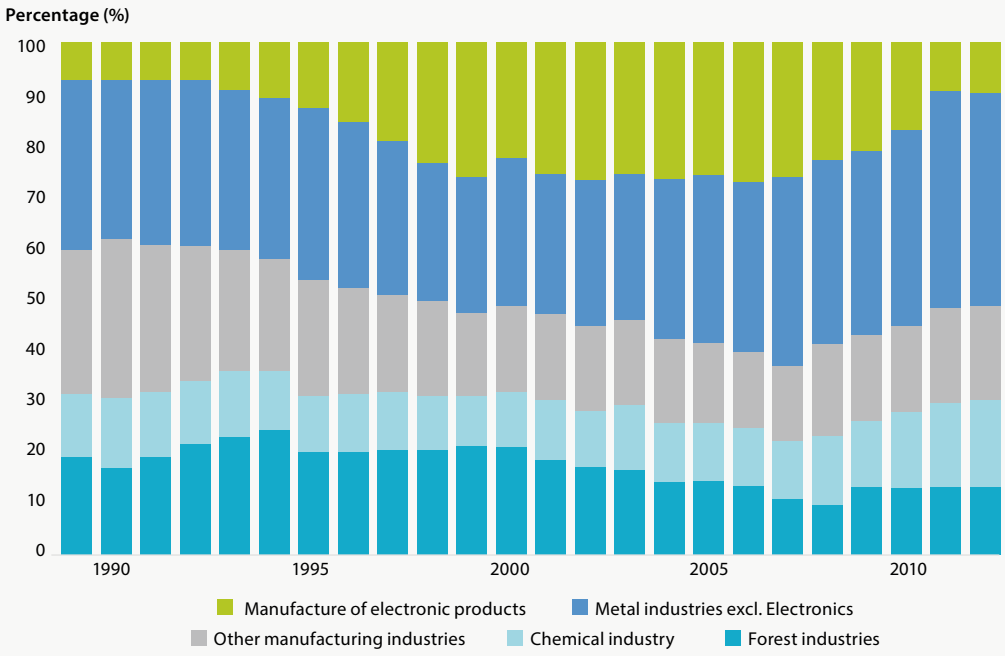
Over the 2008 to 2013 period the Gross-Value-Add (GVA) of manufacturing decreased by approximately 30%.

Finland's global export market share of products declined by 32%, from 0.7% in 2008 to 0.4% in 2013, the largest decline in the EU-28 and mainly due to a decline in export of high tech products (handsets).

In response to rising supply side costs, an off-shore drain in production capacity has occurred in Finland throughout the economy in the past ten years. Foreign direct investment by Finnish companies into production capacity abroad increased rapidly from 2000–2013, reflected clearly by the significant decline in the export of goods over this period and an incline in imported products with net exports turning negative by 2011. Over the same

Figure 42: Gross Value Added in Basic Prices, Current Prices, 1990 – 2013

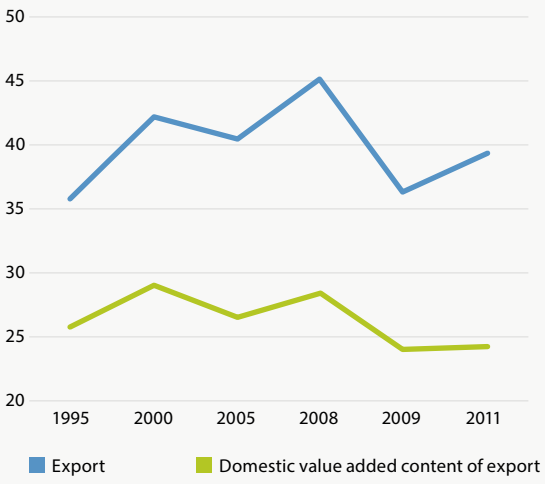
Source: Statistics Finland, European Commission



period, however, this increase in global FDI significantly enhanced Finland's export of services over the period, doubling between 2000 and 2008. Therefore, despite the loss of manufacturing revenues, companies still created and recorded the bulk of value added revenue in Finland. Due to this, up to 2008, loss of manufacturing capacity had a largely limited impact on total domestic value add in Finland.[xxxvii]

Figure 43: Domestic Value-added Content of Export (%)

Source: AMECO, OECD, European Commission

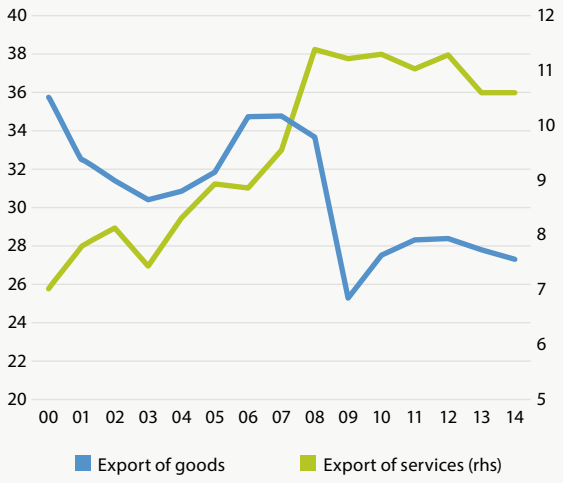


The bioeconomy and the cleantech sector have been highlighted by the Finnish government as key vehicles to promote renewed export growth through the development of a sustainable, export-competitive industry.

Considering the above, the development of innovative, high value-add products as part of lifetime service solutions, through cooperation between large industry, government and new entrepreneurial ventures, is expected to represent a key advantage in targeting new markets for growth. The bioeconomy and the clean technology sector have been highlighted by the Finnish government as key vehicles to promote renewed export growth through the development of a sustainable, export-competitive industry.

Figure 44: Export of Goods and Services, Finland (% of GDP), 2000 –2014

Source: European Commission



8.2 Finland's International Competitiveness in the Cleantech Market

With the decline of the country's paper and electronics industry, the Finnish government has highlighted bioeconomy and clean technology as key vehicles to move the Finnish economy out of stagnation and toward sustained growth to 2025. The total turnover of the Finnish cleantech industry in 2012 amounted to US$ 28 billion, up 15% from the previous year. Key revenue contributors

xxxvii European Commission, 2015

included resource efficiency of industrial processes (energy, material and water use) as well as bioenergy and bio-based products.[xxxviii] It is estimated by the International Energy Agency that in order to limit global warming to a 2˚C increase by 2050, an annual investment of US$ 1 trillion is required globally in cleantech. Excluding the automotive vehicle market (i.e. EV and automated transport), which in itself is expected to account for over US$ 5 trillion per year by 2050, and utility scale renewable power, the total cleantech market for the trends investigated is expected to account for almost US$ 3 trillion per year by 2050. This is up from a size of US$ 459 billion in 2014. Due to inherent strengths in Finland's industrial operational efficiencies and technology innovation, availability of natural resources, sustainability benefits stemming from very cold temperatures throughout much of the year, a small population size, significantly developed and stable infrastructure (ICT, electricity, transport, water, waste etc.), high levels of education and innovation, a collaborate culture between public and private sector, and leading global technology providers, the country is extremely well positioned to target this enormous future market.

The total cleantech market, including automotive vehicle market, is expected to account for US$ 8 trillion per year by 2050.

Table 20: Opportunity Targeting, 2014–2050

Source: Frost & Sullivan

Winners	Current Finland Strength	Market Size 2030	Market Size 2050	Key Product Categories	Key Growth Countries
Smart Grids				Automated Metering Infrastructure (AMI), Demand Response Services, High Voltage Direct Current (HVDC) for Renewables and FACT Devices, Grid monitoring systems and phasor measurement units (PMU), Wide-area monitoring systems, wide-area adaptive protection, control and automation (WAAPCA), Network stability analysis, automatic recovery systems	USA, UK, Germany, Italy, Spain, China, Japan, Canada, Australia, South Korea
Biofuels				Cellulosic ethanol, Second Generation Biodiesel (Jatropha), Third Generation Biodiesel (Algae), Fluidised Bed (CFB, BFB) WTE	USA, Germany, Brazil, China, UK & Ireland, Thailand, Indonesia, Argentina, France
Smart Waste Management Infrastructure				Smart Waste Recycling Logistics Infrastructure (SWRLI), Smart Container Solution, Odour-free Smart Automated Vacuum Collection Systems (SAVCS), Sensor-based Sorting and Smart Waste Recycling Processing Infrastructure (SWRPI), A customised waste segment sorting and material recovery unit	USA, Denmark, Ireland, Iceland, Japan, UK, Germany, Netherlands, France, Finland
Smart Factory				Wireless Sensor Networks (WSN), Augmented Reality (AR) (cloud computing, big data, sensors), M2M Communication, Predictive Analytics, Cloud Computing, Big Data Analytics	China, Germany, USA, Singapore, Korea, France, Japan, Netherlands, Switzerland
Battery Storage				Wireless Sensor Networks (WSN), Augmented Reality (AR) (cloud computing, big data, sensors), M2M Communication, Predictive Analytics, Cloud Computing, Big Data Analytics	USA, Germany, China, Japan, Spain, South Korea, Ireland
Prosumer Markets				Distributed 3rd Generation Organic Solar Cells, Distributed 4th Generation Wind Power, Residential and Commercial Battery Storage	USA, Germany, China, Japan, Italy, France, Spain, UK, Australia

xxxviii Finland Energy and Climate Roadmap 2050

Smart Packaging				Freshness monitors, Colour changing indicators, Oxygen scavengers, RFID software and hardware, Intelligent blister packs for intelligent pharmaceutical products, Near Field Communication (NFC) hardware and software	USA, China, Germany, France, UK, Italy, Russia, India, Turkey, Spain, Canada, Argentina, Korea
3D Printing				3D Software developers, 3D Scanning, 3D Printer OEM, Material Supplier, Service Providers	USA, Japan, Germany, China, UK, Italy, France
eMobility				Pure electric vehicles, Plug-in hybrid vehicles, Fuel cell vehicles, Advanced biofuels, Lithium sulphur batteries	EU (Top 4: Norway, Netherlands, France, Germany) US, Canada, Japan, China, South Korea
Autonomous Driving				Steering automation, Braking automation, Adaptive headlamp control, Radar, Ultrasonic sensors, Forward-looking, rear-vision and surround-view cameras, Night vision, Light Detection and Ranging (LIDAR), Map-supported advanced driver assistance systems, Automated parking	Japan, Germany, South Korea, China, US, Canada
Integrated Mobility				Car-sharing (including micro car and scooter-sharing), Bike-sharing, Autonomous eMobility-on-demand (A-eMoD), Corporate car-sharing, Integrated travel management applications, On-demand busses, Real-time ride-sharing, Pay as you drive (PAYD) insurance, Dynamic parking, Parking Management Systems, Shared parking	UK, China, Japan, Spain, France, South Korea
Building Energy Management Systems and Energy Service				Cloud-based smart energy management solutions, AMI/AMR static meters, Lighting-as-a-service, HVAC-as-a-service, LEDs, Luminaire manufacturing, Remote access and control thermostats	US, UK, France, Italy, Denmark, Sweden, Germany, China, Australia
Green Building Materials				Natural Paints, Zero or low VOC Paints, Reflective Paints, Mineral Concrete Admixtures, Cellulose Fibre loose-fill Insulation, Blanket Insulation, Wood and Cork based rigid-foam Insulation, Wood and Cork based spray-foam Insulation, Bamboo Flooring, Cork Flooring, Wool/Plastic Carpeting, Rubber Flooring, Reclaimed Hardwood Flooring, Linoleum Flooring, Electrochromic Glass	Gulf countries, South Africa, Canada, US, Japan, Indonesia, Vietnam, Singapore, Australia, Philippines, Germany, France
Energy Harvesting				Thermoelectric, Piezoelectric, Photovoltaic (PV), Electromagnetic/Magnetic Induction, Electrostatic, Electroactive Polymers, Nanogenerators, EH-powered wearables and implants, EH-powered devices, EH-powered wireless sensor networks (WSN)	US, Japan, South Korea, Germany, Switzerland

In order to facilitate the effective growth in the market, it is imperative that both commercial and administrative obstacles to commercialisation of new technologies and processes be removed, and economically sustainable support be provided to the industry in the creation of new competencies and operating models. Furthermore, collaborative promotion and marketing of the industry globally by the public and private sector will assist in growing the global Finnish cleantech brand and thereby its export competitiveness. While the small size of the country's domestic market is an opportunity in the sense that it facilitates a large degree of collaboration in private and public-private initiatives, it further increases risk in commercialisation of new products due to the necessity of these products to be as competitive as international exports. In order to assist with this, the Council of State has committed the state and municipalities to the procurement of cleantech solutions in waste management,

transportation, energy production, public food services and energy efficient buildings. Further to this, government has committed to the creation of incentives, pioneering municipalities, information services, and financial supports in subsidies and taxes to support cleantech growth. The sixteen Toward Carbon Neutrality (HINKU) municipalities in Finland have made commitments to reduce GHG emissions by 80% by 2030 through the support and procurement of cleantech. The EU-wide Town Leaders' Initiative aims to reduce emissions of the six largest towns in Finland by 20 to 30% by 2020, three of which aim to be carbon-neutral by 2050.

The collaborative promotion and marketing of the industry globally, and by the public and private sector together, will assist in growing the global Finnish cleantech brand and thereby enhance its export competitiveness.

Due to a high consumption of energy resulting from strong industrial activity, high standards of living, a cold climate, a high need for public lighting, and long travel distances, there has been an ever-present need for continuous innovation in energy efficient technologies and practices. This has resulted in Finland representing one of the world leaders in energy efficiency, particularly in industrial processes. This has been a necessity in order to allow the large industrial component of the economy in pulp and paper, metal manufacturing and mining to compete internationally. The growth of smart factory technology and the development of best practices in technology integration (i.e. wireless sensor networks (WSNs)) and management software for connection of plant operations with the cloud, IoT and big data analytics is an immediate growing opportunity for Finland in key hi-tech manufacturing markets (e.g. USA, Germany, Japan, Singapore etc.). The total size of the smart factory market is expected to grow to US$ 49 billion in 2020 and represent a massive US$ 397 billion per year market by 2050.

Finland's forestry, paper, metal and chemical industries represent approximately one third of total export revenues, and directly employ over 75,000 individuals. Industrial optimisation and efficiency has therefore been a necessity in order to allow industry to compete internationally and show sustained growth. The Efficient Energy Use Programme (EEUP), collaboration between eight industrial players and five universities, provides financing and support of R&D into energy efficiency processes and technologies beyond the country's current core competencies in power electronics, process automation, and information and communication technologies. Global opportunities under the smart factory umbrella, including wireless sensor networks (WSN), M2M communication, augmented reality and the integration into cloud computing, big data and predictive analytics are therefore expected to represent a significant opportunity for product and service export to key hi-tech manufacturing markets (e.g. USA, Germany, Japan, Singapore etc.).

Due to a high consumption of energy resulting from strong industrial activity, high standards of living, a cold climate, a high need for public lighting, and long travel distances, there has been an ever-present need for continuous innovation in energy efficient technologies and practices in Finland. This has resulted representing one of the world leaders in energy efficiency, particularly in industrial processes.

The abundance of forestry resources further represents a natural advantage in the cleantech market through the production and export of bio-based products, and has been a key contributor to the low carbon ambitions of the domestic market, accounting for approximately 20% of the country's electricity and heat production in 2014, contributing substantially to the country's 2020 renewable targets of 38%. Significant focus has been placed on the development of wood-based biofuels targeted for the transport sector, along with the development of biomaterials and chemicals as associate products. The biofuel sector is expected to represent the largest and fastest growing sector in the country's cleantech industry to 2020. By 2020, the global biofuel market is expected to account for US$ 142 billion, and reach US$ 757 billion by 2050. Cellulosic ethanol is expected to account for 17% of the market, or US$ 131 billion. Biogas further

represents a niche growth industry within the country. In Finland, biogas from municipal and agricultural waste, traditionally used primarily in the markets for heating and electricity production, is expected to increasingly focus its future growth ambitions on the transport sector. The total potential agricultural biomass suitable for energy use following bio-gasification in Finland is estimated to amount to 11 to 21 TWh.[xxxix]

The abundance of forestry resources represents a natural advantage in the Finnish cleantech market through the production and export of bio-based products. The biofuel sector is expected to represent the largest and fastest growing sector in the country's cleantech industry to 2020. Biogas further represents a niche growth industry within the country.

Finland's vast forestry resources and world leading efficiencies in the forestry industry positions the country perfectly as a leading feedstock provider for wood-based biofuels, a leading producer of cellulosic ethanols, and a leading supply of technologies and management services for feedstock management in global dedicated biofuel plantations. Cost efficiencies achieved by the country due to an uninterrupted supply of price-stable wood biomass feedstock will provide the country with strong export price advantages in the global market. Biomass refining is therefore a natural step for the forestry industry in the production of biofuels, high-value biochemicals and alternative biomaterial products (e.g. lignin derivatives and bioplastics, biocoal etc.). The potential for this market, however, will be affected greatly by the price of emission allowances, future governing criteria for the sustainability of bioenergy production, and its future carbon-neutral status acceptance in emission trading.[xl]

In 2012, bioenergy consumption accounted for one fourth of total energy consumption (92TWh) in Finland. The overwhelming majority of this was produced from forestry waste and side streams (e.g. black lye, bark, sawdust, forest chips).[xli] Finland has the capability to double the production of forest chips from current levels to 44TWh annually for 2030–2040, if the industry were to be scaled to highest sustainable felling levels. Of this, approximately 19TWh would be available for biofuel production annually from 2030, and 33TWh from 2050.[xlii] The development of a strong biomaterial industry also represents strong future export potential. The total global market for green building materials is expected to show continued growth in adoption to 2050, increasing from current levels of US$ 149 billion to US$ 521 billion.

Biomass refining is a natural step for the forestry industry in the production of biofuels, high-value biochemicals and alternative biomaterial products.

Within the waste management sector, Finland further represents one of the most innovative countries globally. Government estimates that greenhouse gases from the sector will decrease by 0.6 million tonnes of CO_2 equ. by 2050, amounting to a 85% decrease from 1990 levels.[xliii] The industry shows a strong mix of large industry players and new start-ups piloting novel technologies for industrial, municipal and hazardous waste. Large scale applications of solid recoverable fuel (SRF) technologies that extract recyclable waste (e.g. glass, metal, and wood), removes organic waste, and processes the remaining waste (e.g. paper and cardboard) into burnable fuel are already in operation. Sensor-based sorting, along with integration of ICT systems for wireless control and automation of traditional solid waste management facilities is further in use. Experience in hazardous waste management will further allow the country to benefit from the expected boom in the lithium-ion market for battery storage in both transport and stationary applications. Finally, the country's additional experience in CHP and waste-to-energy technology closes the loop for the future development and integration of a fully circular economy. Smart municipal waste solutions in collection and processing is currently a very niche market, but is expected to show strong growth in investment from 2020 to 2050, amounting to a US$ 32 billion market. Many European countries, namely Germany, France, Denmark, Netherlands, UK, Ireland and Iceland are expected to be first adopters of these technologies due to high standards of living and per capita waste production, making it an attractive export market for Finland.

xxxix Ministry of Employment and the Economy, Government of Finland, 2014
xl Team Finland, 2014
xli Ministry of Employment and the Economy, Government of Finland, 2014
xlii Ministry of Employment and the Economy, Government of Finland, 2014
xliii Ministry of Employment and the Economy, Government of Finland, 2014

Within the waste management sector, Finland further represents one of the most innovative countries globally.

Finland has made significant strides in increasing the efficiencies of their buildings over the past ten years. For the period of 2005–2013, Helsinki's population increased by eight percent, with a contrasting decrease in electricity usage by 1%. With the implementation of tighter energy efficiency standards for buildings in 2012 and government targets specifying that by 2020 all new buildings must be nearly zero energy buildings, greater investment is expected into the design, construction and management of more efficient building stock. The development of "zero energy" pilot projects, such as BioGTS and FinZEB, will assist greatly in showcasing the practical potential of Finnish solutions for efficient building markets globally, and provide a strong marketing platform for exportable products and services.[xliv] With the market in energy management systems and services expected to account for US$ 98 billion by 2050, accompanied by an associated market in energy harvesting in buildings of US$ 54 billion, leveraging Finland's inherent expertise in energy efficient buildings will represent a strong export opportunity.

Finland has made significant strides in increasing the efficiencies of their buildings over the past ten years.

Finland is one the few countries in the world which has largely completed the rollout of smart meters. This widespread integration of smart metering infrastructure sets a firm foundation for the development of associated products and services as part of the smart city value proposition. With the country's expansive ICT infrastructure and resulting high connectivity, it has the potential to be a first mover in the development of fully integrated smart systems. Finland has made significant ground in three aspects of a smart city, namely smart water, efficient buildings and intelligent traffic control. The development and showcasing of holistic, city-wide, smart grid systems, through the collaboration of government and industry participants, will provide a proven business case to the global market for the use of Finnish product and services in smart grid developments. The total size of this market globally is expected to amount to US$ 398 billion by 2050 with the USA, UK, Germany, Italy, Spain, China, Japan, Canada, Australia and South Korea representing the first movers.

Finland is one the few countries in the world which has largely completed the rollout of smart meters.

Promoted through the Finnish Transport Agency's road traffic management centre, the country has made significant strides in the development of real-time traffic data in order to allow for accurate management of road networks and communication with motorists. Finland plans to develop its intelligent road traffic systems to create one of the most advanced and efficient transport system in the world by 2020. The development of the industry will provide real-time data-collection and communication with motorists in an attempt to relieve congestion, increase transport efficiencies, and decrease the ecological impact of the transport sector. The development of these systems, along with smart grid and ICT systems, will lay the groundwork for the inception of electric and autonomous vehicles in the country. The Ministry of Transport and Communications issued a report in 2013 whereby it outlined its key objectives for the sector, one of which is that all passenger car traffic should be near zero emission by 2050. This will represent new markets for economic and employment growth in the country, new innovation in exportable technologies and services, and a more efficient logistics infrastructure increasing the competitiveness of Finnish exported products.[xlv] The development of one of the first city-wide proof of concept for automated transport through the growth, interconnection and management of integrated mobility infrastructure will position Finland as a front runner in the supply of products and services to some of the largest international markets globally. Investment into integrated mobility is expected to represent a US$ 176 billion market by 2050, enabling growth in automated mobility, which Frost & Sullivan anticipates to become an enormous US$ 3.6 trillion market by the same year. The obvious inclusion of EV infrastructure as part of the integrated mobility solution will further position the country to take advantage of one of the largest future markets in the world, measuring an expected US$ 5 trillion by 2050.[xlvi]

xliv Team Finland, 2014

xlv Team Finland, 2014

xlvi Note: The automated vehicle market takes into account the EV market. Market sizes must, therefore, not be considered as independent but rather one and the same.

Future pilot projects, incorporating efficient smart grid management of prosumer markets, sustainable building technologies and practices, city applications of smart waste management, and smart transport, will provide the ability to market Finnish products and services as integrated components of the holistic smart city offering. The ability to provide an end-to-end solution for smart city implementation by domestic technology and service providers will represent a strong sales proposition for Finnish companies globally, and position Finland as the benchmark for smart city implementation.

Finland plans to develop its intelligent road traffic systems to create the most advanced and efficient transport system in the world by 2020.

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Climate change and global warming are among the most severe challenges facing humanity. Greenhouse gas emissions need to be reduced in ways that are economically viable. In order to prevent further climate change, the global economy must radically evolve to one that is not primarily dependent on fossil fuels and better utilises alternative resources. This creates a significant business opportunity.

This study identifies the key global megatrends from the perspective of low-carbon business, and analyses their impacts from the viewpoint of six important sectors to the Finnish economy: buildings, energy, industry, transport, water and waste, with bio-economy as a cross-cutting category.

Finland can be a forerunner in this field and take a role larger than its respective size. Finnish businesses can prosper by offering solutions to the global climate challenges, and gain access to a large and rapidly growing market.

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The Finnish Innovation Fund Sitra is a future-oriented organisation that is building a successful Finland for tomorrow's world. Sitra anticipates social change, tries out new operating models in practice and accelerates business activities aimed at generating sustainable well-being.

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