THE ENABLING TECHNOLOGIES OF A LOW-CARBON ECONOMY:

A Focus on Cloud Computing

Dr Peter Thomond

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Acknowledgements

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Independent, blind review

The modelling embedded within this report was subject to a blind academic review process with a panel of four anonymous expert reviewers. This process was not organised by the authors of this report but independently by the organisers of the ICT4S conference.

We'd like to thank the blind review panel for their insightful guidance and for validating our efforts. You have helped us set a new benchmark of independence for such studies. We will enjoy presenting this work at your conference in February 2013.

Disclaimer

A FOREWORD FROM GeSI

Luis Neves
Chairman
GeSI

The issue of climate change and energy scarcity is sharpening the minds of government and citizens alike to find solutions.

Current trends predict a massive population growth that will be subject to depleting energy supplies and food shortages caused by the increasing temperature of our planet. Should these trends continue, then all countries will share a burden to maintain a level of safety for their populations. We can also expect that economies will suffer and the increasing lack of resources can lead to political instability and social crisis.

The scientific community, governments and the private sector are racing to develop solutions. The progress has provided the world with some promising results. However, the question that remains unanswered is: will it be enough to make a difference?

The answer is yet to be determined as it has been hard to measure the pace of deterioration of energy supplies and the impact of climate change. Fortunately, the availability of environmental "enabling technologies"- solutions that enable dramatic reductions in energy consumption, greenhouse gas (GHG) emissions and "carbon footprints"- appears to be increasing.

One such technology that's been investigated for its "enabling potential" is cloud computing. Cloud vendors enable computing services (software, platforms, infrastructures etc.) that are traditionally provisioned on-site within organisations to be delivered across the internet, on-demand from purpose-built data centres.

This study, commissioned by the Global e-Sustainability Initiative (GeSI) and Microsoft, aims to provide stakeholders with credible data on how much GHG emissions reduction can be secured, each year, as a result of enterprises migrating to the cloud. Moreover, it seeks to do so by applying a new methodological benchmark in academic rigour and transparency.

Our deep-dive study has been completed in conjunction with a broader piece of research looking at the potential of ICT to enable the transition to a low-carbon economy entitled "SMARTer 2020: The Role of ICT in Enabling a Low-Carbon Economy". Commissioned by GeSI, the report illustrates how the ICT sector has matured since 2008 and how new technologies have emerged in key sectors of the economy ranging from transport to energy and agriculture. Critically it demonstrates how the increased use of ICT could in fact cut the projected 2020 global GHG emissions by 16.5%- by 9.1 GtCO2e- and save $1.9 trillion in gross energy and fuel savings.

Still, barriers continue to block the acceleration of mass adoption of cloud services as well as ICT solutions more broadly. With the findings of this study, we strongly encourage policy makers to embrace the enabling potential of ICT across all levels of government.

A FOREWORD FROM MICROSOFT

When we began study began in 2009, it was surprising that over 200 different internet enabled applications were emerging that could disrupt business models and drive efficiencies, ranging from rural carbon calculators and web conferencing to telematics. We decided to be pragmatic and start small. We looked at CRM, groupware and email for 11 countries- Brazil, Canada, China, Czech Republic, France, Germany, Indonesia, Poland, Portugal, Sweden and UK- and the results have been surprising.

Ray Pinto
Government Affairs Director
Microsoft

The modelling developed by the Enabling Technology research team shows that if 80% of enterprises across the countries under examination adopted cloud-based email, CRM and groupware applications while permanently shutting down their on-site servers, it would lead to an abatement of greenhouse gas (GHG) emissions totalling at least 4.5 Mt of CO_2e. This is equivalent to 1.7 million cars permanently off the road or 2% of the ICT sector's GHG footprint in these countries. It would also release $2.2 billion (USD) in energy savings.

One interesting discovery is, as we look close at the energy needs of data centres, for every tonne of energy created by vendors supplying cloud-based email, CRM and groupware, 20 tonnes is abated for the user.

The messages from the study is that we need to act faster and industry and government must come together to find sharpen policy and overcome resistance points in behaviour. The study signals a deadline of 3 years to cut through the issues otherwise the continued uncertainty to embrace cloud computing will halve absolute benefits from 4.5Mt CO_2e to 2.3Mt CO_2e.

Looking back through history we see that technologies such as file compression that lead to transmitting music and data took more than 25 years to reach full market adoption. The disruptive nature of such technologies cannot be permanently resisted but confusion and rigid behaviour can often delay their adoption. Cloud computing is dramatically changing our lives, the pace of change is in the hands of industry and policy makers.

We hope you enjoy the study and it triggers some internal as well as external debate. We've made huge efforts to provide complete transparency in our approach, thinking and data. Please question the findings and don't hesitate to engage with us or the research team.

We thank you for your time and attention.

THE ENABLING TECHNOLOGY TEAM

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Dr Peter Thomond

Pete earned his PhD in the subject of Disruptive Innovation, in 2005, from Cranfield University's School of Applied Sciences. Today, he consults, teaches and publishes to deliver innovation in the fields of environmental technology, health, high-tech and youth development. He does this as an associate to the Think Play Do Group Ltd and as a founding partner of Clever Together LLP, Qingtech Ltd and SportInspired Ltd. He is a contributing author to the International Telecommunication Union's "Toolkit on Environmental Sustainability for the ICT Sector" and outputs from the Environmental Engineering Group of the European Telecommunications' Standards Institute. To connect with Peter visit: www.linkedin.com/in/thomond.

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Microsoft

Microsoft is a multinational computer technology corporation that develops, manufactures, licenses, and supports a wide range of software products and services for computing devices. We are working to expand the possibilities for computing every day, delivering solutions and transformative technology that contribute to solving important European socio-economic challenges for governments and business alike. Microsoft is a significant long-term investor in European R&D, driving new software products and services, inspiring new ways of using efficient information technology solutions and contributing to long-term sustainable growth of our company, our partners, and Europe's economy and society. It collaborates closely with governments, NGOs, businesses and academia across Europe on ways to use technology with the aim to resolve environmental challenges such as climate change and energy efficiency, rethink business practices, and research new environmentally friendly solutions. www.microsoft.eu

Global e-Sustainability Initiative

The Global e-Sustainability Initiative (GeSI) is a strategic partnership of the Information and Communication Technology (ICT) sector and organisations committed to creating and promoting technologies and practices that foster economic, environmental and social sustainability. Formed in 2001, GeSI's vision is a sustainable world through responsible, ICT-enabled transformation. GeSI fosters global and open cooperation, informs the public of its members' voluntary actions to improve their sustainability performance, and promotes technologies that foster sustainable development. GeSI has 32 members representing leading companies and associations from the ICT sector. GeSI also partners with two UN organizations - the United Nations Environment Program (UNEP) and the International Telecommunications Union (ITU) - as well as a range of international stakeholders committed to ICT sustainability objectives. These partnerships help shape GeSI's global vision regarding the evolution of the ICT sector, and how it can best meet the challenges of sustainable development. www.gesi.org

Think Play Do Group Ltd.

The Think Play Do Group (TPDG) is a spin-out business from Imperial College London. TPDG has access to a world class network of academics and associate practitioners from the fields of innovation and entrepreneurship. TPDG provides counsel to industry leaders through multi-sector applied research programmes and consulting projects, and commercialises ideas from Imperial College's Innovation and Entrepreneurship Group. www.thinkplaydo.com

A Focus on Cloud Computing

EXECUTIVE SUMMARY

Cloud computing enables computing services (software, platforms, infrastructures) that are traditionally provisioned on-site within enterprises[1] to be delivered across the internet, on-demand from purpose built data centres. It is less a technological innovation and more a business model innovation, which is both transforming how computing services are consumed and enabling the abatement of greenhouse gas (GHG) emissions. This is because data centres are significantly more expansive and energy efficient than distributed on-site servers.

Past studies regarding the GHG abatement potential of cloud have gaps. They fail to clearly present assumptions, data and/or apply scientifically appraised methods. These gaps have fuelled scepticism, which this study seeks to overcome. Our study examines the carbon abatement potential of cloud computing in China as well as Indonesia, Canada, Brazil and 7 European countries. The study was conducted by a team at the Think Play Do Group, a spin out from Imperial College London, with support from the Global e-Sustainability Initiative (GeSI), Microsoft and co-ordination from Johns Hopkins University.

Cloud-based email, customer relationship management (CRM) and groupware applications represent the 'tip of the iceberg' in terms of cloud services. **Our scientific and open modelling demonstrates that cloud vendors have the potential to offer these three computing services with 20 times more energy efficiency**.

Our modelling shows if 80% of enterprises across the countries under examination adopted cloud-based email, CRM and groupware applications they would abate GHG emissions totalling 4.5Mt of CO_2e. This is equivalent to 1.7 million cars permanently off the road or 2% of the ICT sector's GHG footprint in these countries.

The results of our modelling broadly confirm previous commercial research, that a shift to cloud computing can have a significant impact. However, our open model can now be scrutinised, challenged and improved within the academic and commercial sectors to enhance future modelling, explore other scenarios and create a focus for action to realise the reduction in GHG emissions. Moreover, **the inclusion of enterprise size within our model revealed that over 60% of savings were accounted for by small and micro size firms.** From the perspective of GHG emission reduction, this highlights that smaller enterprises have more to gain from a switch to cloud computing given their relatively inefficient use of on-site servers.

Overall results show that the relative net emission reductions vary greatly for each country. Analyses revealed that this was due to a mixture of the GHG intensity of electricity and the variation in the current adoption of the three technology types analysed for each country. For example France has a low GHG energy intensity thus the reduction in GHG emissions is also low.

We make a unique contribution in warning that the full extent of cloud's GHG abatement potential has three key dependencies (i) enterprises must permanently switch off their old on-site servers; (ii) data are unclear regarding current levels of cloud adoption and numbers of on-site servers being utilised around the world; and (iii) there are commercial behaviours and policy based trends that may slow down the rate at which enterprises switch to cloud services.

Given a lack of a counterpoint, we assume owners of redundant on-site servers will choose to dispose of their old kit.

We hope our research encourages vendors and policy makers to work together to tackle challenges and gaps in data. Indeed, we contribute a first of its kind sensitivity analysis to highlight the possibility of a large variability in GHG reductions caused by the key variable of market penetration.

We recognise that prime responsibility for driving the market adoption of technologies that can abate GHG emissions, such as cloud computing, naturally lies with the ICT industry. To achieve the GHG abatement potential of cloud our three primary recommendations to vendors are:

1. They must present a clearer economic case for cloud.
2. They must avoid one-size-fits-all marketing massages.
3. They must recognise and respond to the challenge of the behaviour change they are requesting of internal IT teams.

We recognise that policy makers can play an enabling role, too, and must avoid unintentionally creating barriers. Of our seven policy-based recommendations, the most critical is probably the need for policy makers to genuinely embrace the potential of the ICT sector. By viewing the ICT sector as part of the low-carbon solution, not just part of the problem, policy makers will find a powerful ally in the realisation of their environmental goals. Positive examples of how policy makers have begun to embrace the ICT sector are seen in Germany and Sweden.

1 For the purpose of this report, we use the term *enterprise* to refer to all private, public and non-governmental organisations.

Contents

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BACKGROUND: THE NEED FOR THIS REPORT AND HOW TO USE IT

In 2008, the Global e-Sustainability Initiative (GeSI) helped deliver a seminal report for the ICT sector – *SMART 2020*. It made the case that the ICT sector has a dual opportunity:

(i) to reduce its own environmental impact, and
(ii) to enable environmental improvements in other sectors through the application of ICT.

In December 2012, GeSI released the much awaited SMARTer 2020 report[2]. It offered an updated analysis of the ICT landscape and its extraordinary potential for improving energy efficiency and reducing GHG emissions globally.

SMARTer 2020 illustrates how the ICT sector has matured since 2008 and how new technologies have emerged as key components of the ICT landscape. Critically it demonstrates how the increased use of ICT could in fact cut the projected 2020 global GHG emissions by 16.5% (Figure 1) and save $1.9 trillion (US) in gross energy and fuel savings.

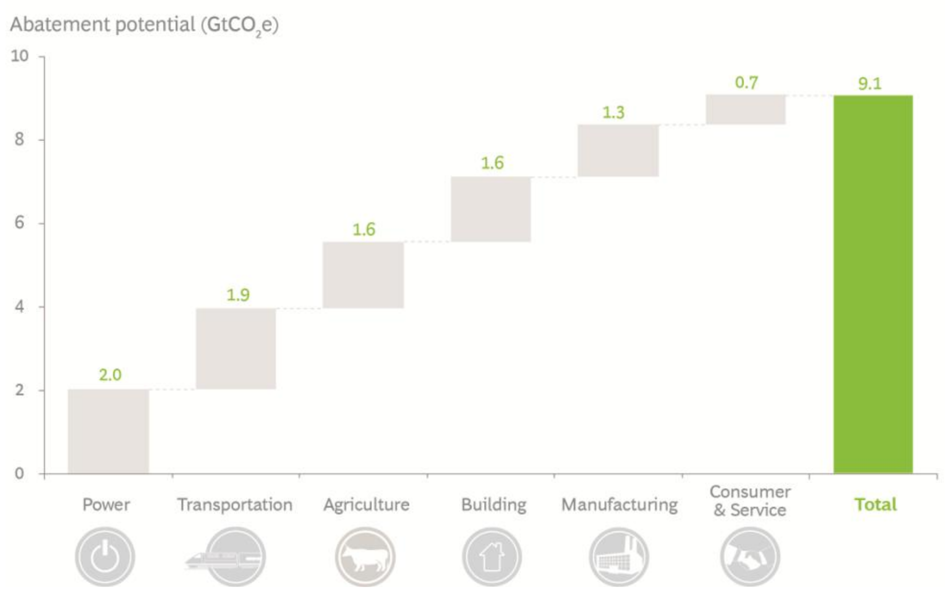


Figure 1: Summary of estimated abatement potential by sector in $GtCO_2e$ (SMARTer 2020)

Cloud Computing (cloud) is an example of a technology that has emerged and reached mainstream use in some markets during this period. Whilst pioneering efforts have been made to assess the potential of cloud to enable GHG abatement, we assert these fall short in terms of openness of methods and assumptions or in detail or both.[3]

Moreover, throughout this period industry, government and non-governmental organisations have forged methods, tools and draft standards to further guide the process of estimating the GHG abatement potential of technology. For example:

- in 2009, the OECD began developing a framework to analyse ICT and its environmental impact (the aim was to comprehensively model environmental effects of ICT production, use and their application across industry sectors),
- in 2010, GeSI and its partners developed an '*enablement methodology*' – a pragmatic approach to assess the GHG abatement potential of new ICT-based systems;
- the International Telecommunications Union in 2012 presented a toolkit on environmental sustainability for the ICT sector;
- organisations and groups such as ETSI, IEC, the GHG Protocol and consortia such as PAIA and iNEMI are working on associated initiatives; and
- academia has continued to produce new modelling techniques that can be applied to offer yet more scientific rigour to estimates of GHG abatement potential.

Despite the growing array of tools and approaches individuals and organisations face multiple challenges when implementing them in practice. There is often a lack of formal metrics, availability of real-time data, expertise to complete measurements, simple guides to the research process and agreed standards[4]

Moreover, we observe that contributions and conversations regarding calculating GHG abatement recognise market adoption as key to GHG abatement. Yet only lip service gets paid to the dynamics of technology diffusion and the influence of policy-making; knowledge from these domains remains largely absent or under-utilised in almost all GHG abatement methods.

These factors created the need for this report. To refine and enhance leading methods and apply them to validate the claims made by vendors of technologies with GHG abatement potential.

The Enabling Technology 2020 Project, also known as IT to ET, is a multi-national research project primarily sponsored by Microsoft and co-ordinated by Johns Hopkins University (JHU). It seeks to better understand if and how information technologies (IT) will become the enabling technologies (ET) of economic growth in health and the low-carbon economy.

This report, co-sponsored by GeSI and Microsoft, extends the work undertaken in the IT to ET project to date, and responds to the challenge of offering a more thorough and open investigation of the GHG abatement potential of Cloud Computing - a key enabling technology.

This report is presented in two parts:

2 GeSI (2012). SMARTer 2020: The Role of ICT in Driving a Sustainable Future. The Global e-Sustainability Initiative.

3 Indeed, this is a common challenge and criticism with presentations of GHG abatement assessment according to Unhelkar, B. (2011). Green IT Strategies and Applications: Using Environmental Intelligence (Advanced & Emerging Communications Technologies). CRC Press

4 Ibid and in spite of the ISO 14001 standard.

Part 1: key findings and recommendations

Objective: to summarise our research approach and the insights generated in a digestible simple format.

Part 1 offers a useful overview for individuals, ICT vendors, academics, NGOs and policy makers interested in cloud computing and/or the potential that technology has to enable GHG abatement. Along with the results and recommendations, it provides a 'health warning' about the reliability of some data sources.

Part 2: methods, assumptions, data – how we generated our findings and recommendations

Objective: to detail the methods and data sources employed in our research, in order to reassure readers that the conclusions drawn are academically rigorous, whilst also being industrially useful.

Part 2 offers a detailed overview, useful for individuals interested in GHG calculation methods, replicating and extending our approach or keen to feel assured that our results are valid and reliable.

By presenting this level of detail, we overcome the criticisms often levied at prior work in this space and present.

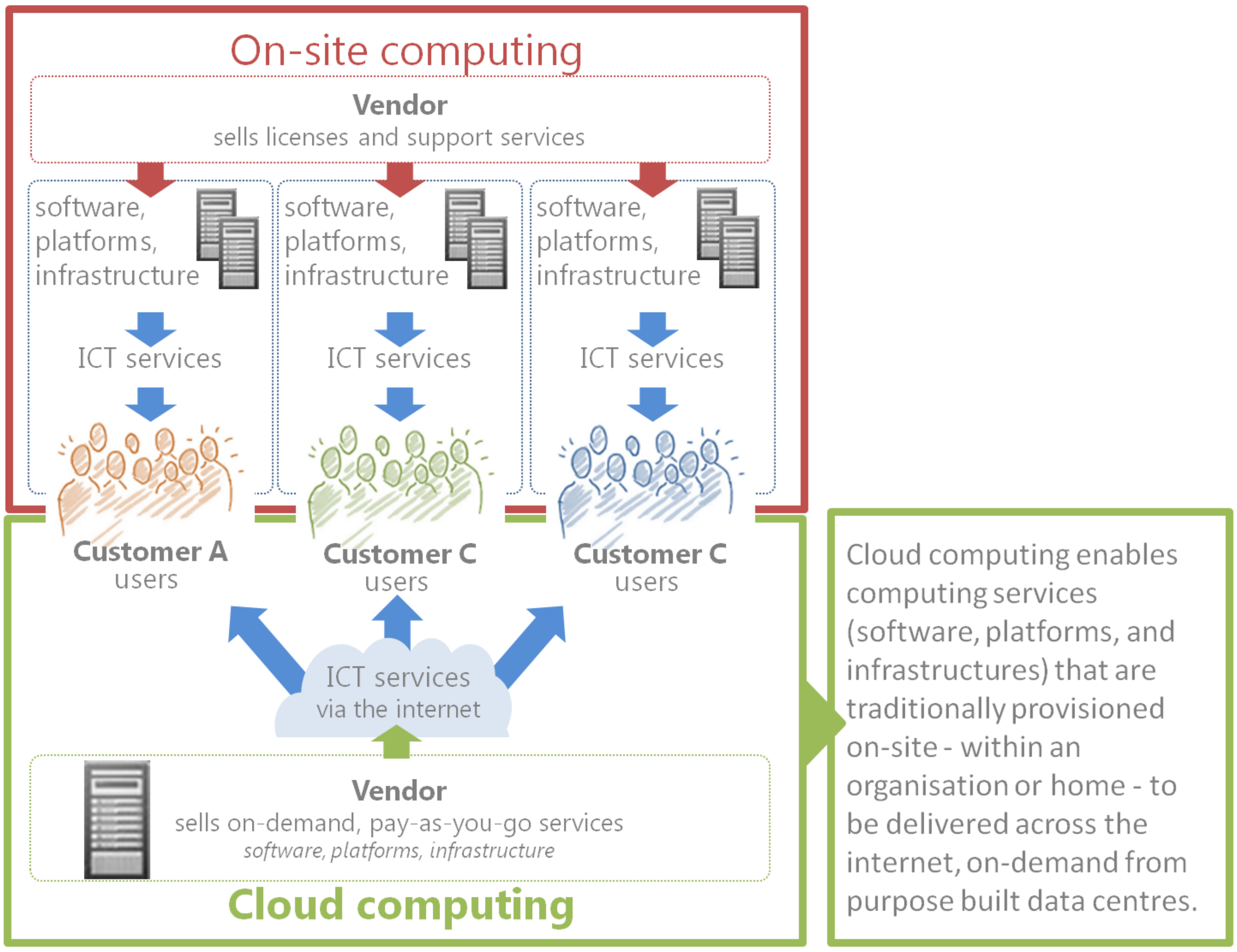
Moreover, we present a process that can be applied by expert teams to understand other enabling technologies.

The Enabling Technologies of a Low-Carbon Economy: A Focus on Cloud Computing

Part 1:

key findings and recommendations

1. What is cloud computing and why examine its GHG emissions?



Past examinations of enterprise cloud computing[5] **have presented** how a shift from on-site to cloud offers the prospect of greenhouse gas (GHG) abatement through reduced energy consumption. The primary enabler of such reductions is the provision of computing resources in large centralised data centres which can be considerably more efficient, compared to individual or small groups of servers typical of computing provided by IT teams within enterprises[6].

However, past studies do not clearly present:

- scientifically appraised analysis methods,
- how and why energy and GHG reductions are likely to vary by country,
- market penetration assumptions.

These issues create limits to their usefulness for decision-making and future model development. Hence there is a need for an open, scientific analysis – a need that this study will satisfy.

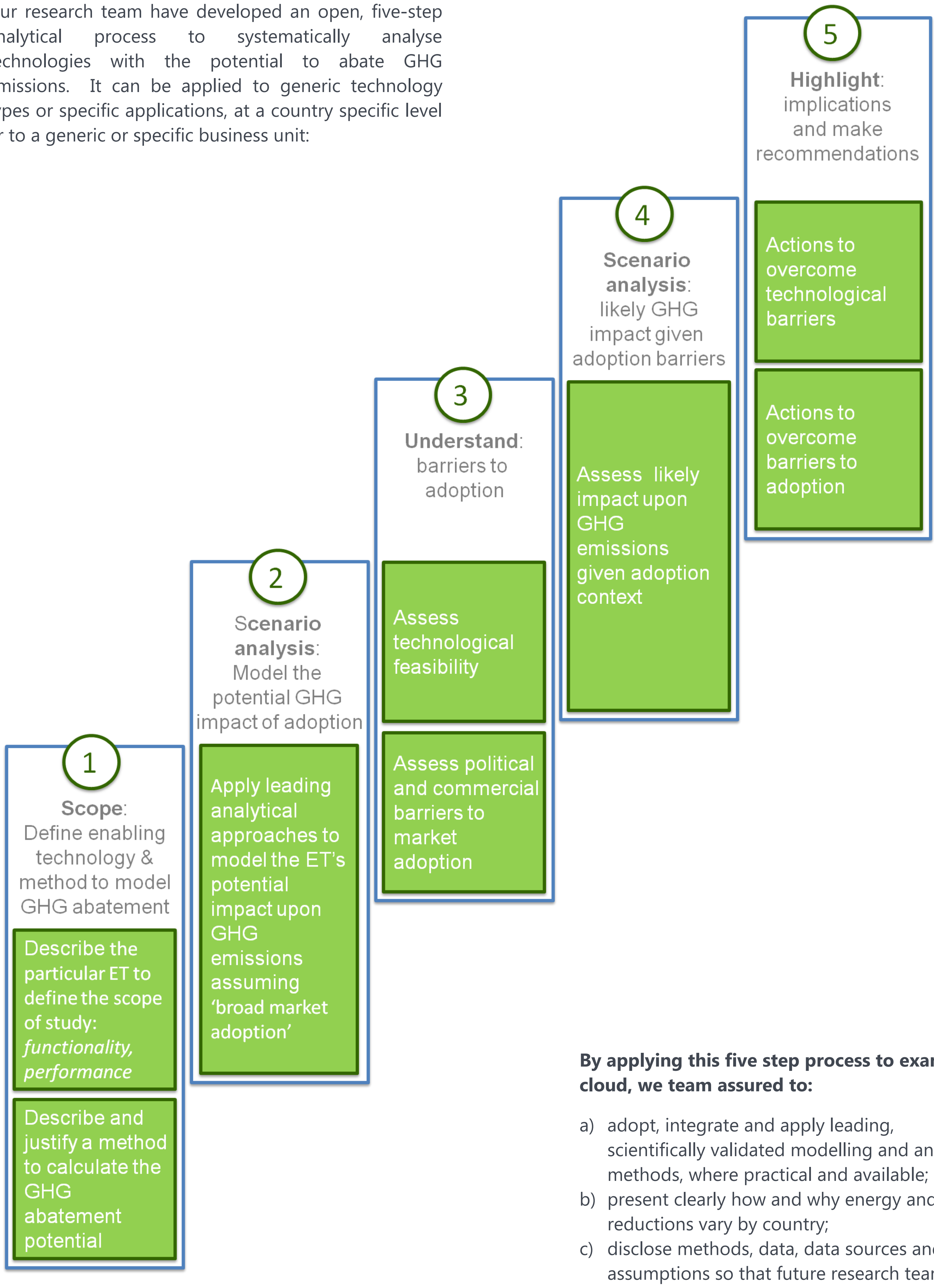
5 See for example:

- Accenture (2011) Cloud Computing and Sustainability: The Environmental Benefits of Moving to the Cloud. Accenture & WSP;
- Carbon Disclosure Project (2011). Cloud Computing – The IT Solution for the 21st Century. Carbon Disclosure Project & Verdantix, London, UK.

6 For the purpose of this report, we use the term *enterprise* to refer to all private, public and non-governmental organisations.

2. How can we examine the GHG abatement potential of cloud?

Our research team have developed an open, five-step analytical process to systematically analyse technologies with the potential to abate GHG emissions. It can be applied to generic technology types or specific applications, at a country specific level or to a generic or specific business unit:



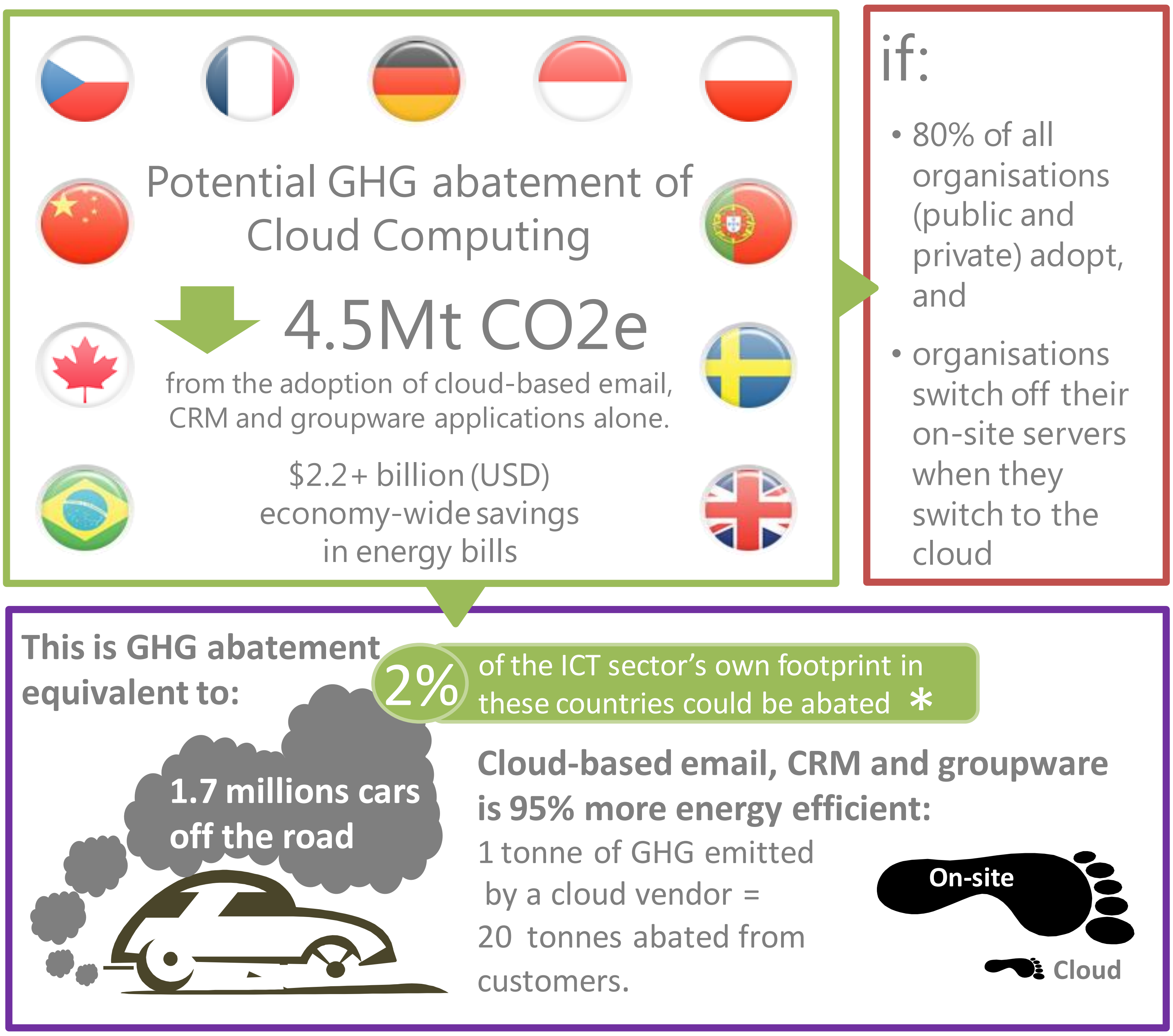
By applying this five step process to examine cloud, we team assured to:

a) adopt, integrate and apply leading, scientifically validated modelling and analysis methods, where practical and available;
b) present clearly how and why energy and GHG reductions vary by country;
c) disclose methods, data, data sources and assumptions so that future research teams can sharpen our findings, our modelling or both.

Consequently, the results presented are not only open and clear but academically robust and industrially relevant.

3. The GHG abatement potential of cloud

We find cloud computing has the potential to enable significant GHG abatement, even when constrained to an analysis of just three cloud-based applications – email, CRM and Groupware. The primary enabling effect of cloud is that the on-site servers made redundant by cloud services can be switched off[7]:



* to present conservative calculations, we employed a conservative estimate of the ICT' sector's share of global GHG emissions - 4% - if we adopt 2.8% for the sector's footprint, as suggested in the SMARTER 2020 report**, the average abatement of these thee cloud applications would increase 2.8% of the ICT sector's own footprint.

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7 This report refers to GHGs in CO2e - carbon dioxide equivalent. This enables us to discuss GHG emissions collectively and ensures all GHGs are accounted for in our analysis. For example, one ton of the GHG methane would be equivalent to 21 tons CO2. Using CO2e rather than focusing upon CO2 alone ensures we consider all emissions sources.

** GeSI (2012). SMARTer 2020: The Role of ICT in Driving a Sustainable Future. The Global e-Sustainability Initiative.

We find:

- the GHG abatement potential of cloud varies between countries because:
  - (i) the carbon intensity of the energy supplies vary, and
  - (ii) the economic mix of firms is different – some countries have a larger contingent of small sized firms for example.
- Micro and small firms account for most of the abatement potential (60%);
- energy consumption and the levels of market adoption the primary drivers of the GHG abatement potential;
- high levels of confidence regarding cloud's efficiency at the business level compared to on-site computing;
- a lack of reliable data for national variables means there is some uncertainty regarding the overall abatement estimates in each country.

Two key actions in our technical scope ensure we do not over estimate the impact of cloud:

1. **We limited our analysis to just three common applications: Email, Customer Relationship Management (CRM)** and **Groupware**: While these clearly represent a sub-set of all applications that businesses and individuals use, they are readily available as cloud based services. Moreover, they likely represent the first wave of potential applications that can shift towards cloud computing in the future.
2. **We limited attention to *business computing***: This accounts for a majority but not all of computing usage.

Country	Annual GHG emissions (t CO_2e)		
	emissions reduced – switching off on-site servers	emissions increase – to build and run replacement cloud services	Net emissions reduced
Brazil	188,376	9,240	179,136
Canada	94,647	7,985	86,662
China	1,982,625	124,777	1,857,848
Czech Rep	111,877	4,435	107,442
France	99,387	5,454	93,933
Germany	1,056,538	49,147	1,007,391
Indonesia	178,005	6,800	171,205
Poland	283,470	11,020	272,450
Portugal	81,029	2,305	78,724
Sweden	6,732	557	6,175
UK	709,012	36,006	673,006
Total from all 11 countries	***4,791,699***	***257,726***	***4,533,973***

60% of GHG abatement potential resides with micro and small sized firms.

'Embedded carbon' is not significant – it represents less than 5% of the GHG abatement potential

Most influential variables in modelling are: extent of cloud adoption and numbers of on-site servers

Carbon intensity of energy supply is significantly more influential than Power usage effectiveness (PUE)

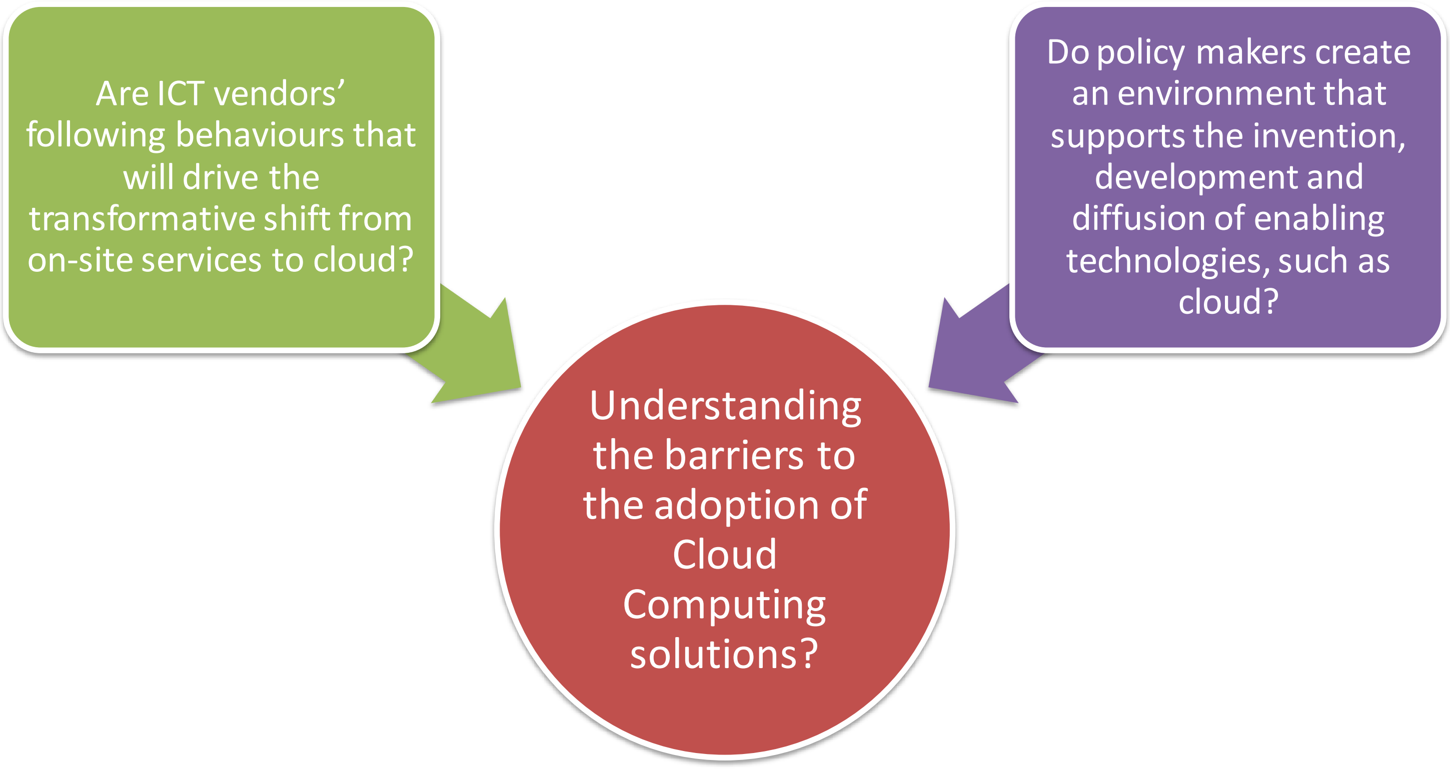
Warning! Not all data 100% reliable:

Cloud is 95% more efficient. But the current market penetration of cloud and the present number of servers being used on-site is unknown.

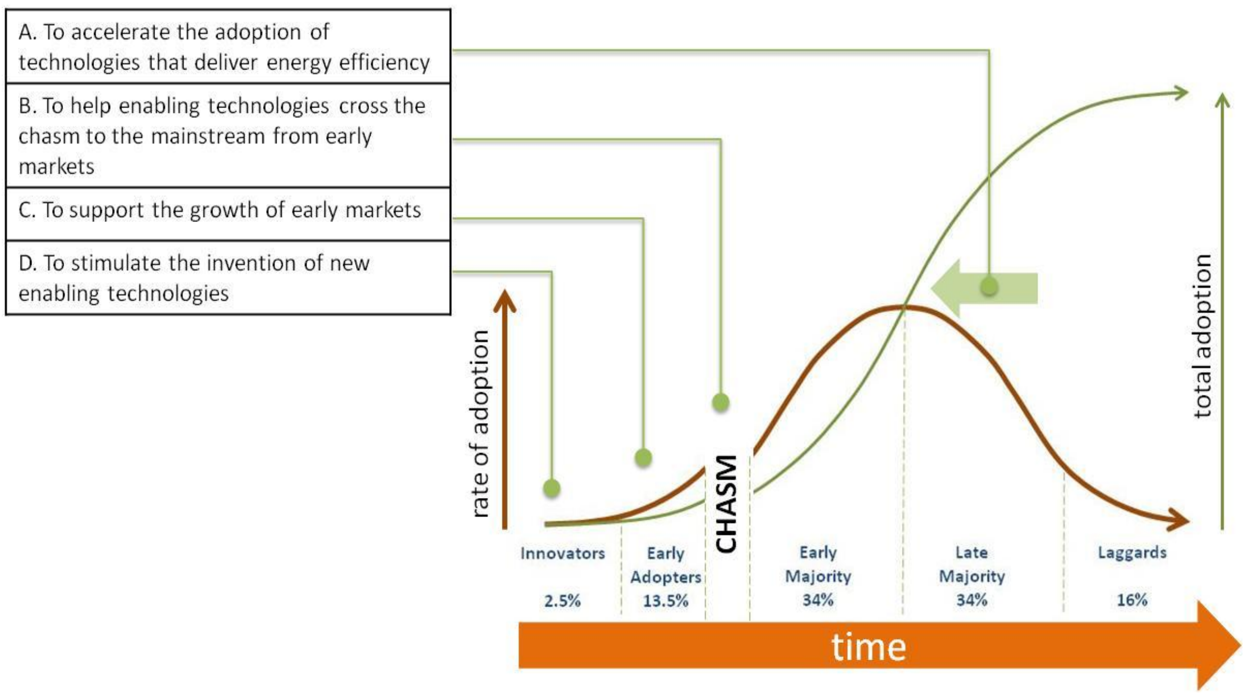
Sensitivity analysis reveals the potential GHG abatement may vary by ±35% = 3Mt to 6Mt CO2e.

4. Understanding barriers to adoption

If the estimated 4.5Mt of CO_2e abatement potential depends upon 80% of enterprises adopting of cloud-based email, CRM and groupware, then we must understand its barriers to market adoption.



Are business leaders and policy makers doing enough to create an enabling environment for technologies such as Cloud to flourish?



To answer this question, we turned to knowledge regarding technology diffusion and innovation. We assume there are no major technical barriers to the adoption of readily available cloud-based email, CRM and groupware services. We focused therefore on impact of commercial behaviour and public policy.

Do commercial behaviours create barriers?

To understand if commercial behaviours are creating barriers to the spread and adoption of cloud computing services, we surveyed industry and trade associations across Europe, the Americas and Asia. Forty-one respondents met the qualifying criteria and answered all 45 questions focused upon how the transformative shift from on-site to cloud computing may be supported by vendor capability and the market context. They represented 12 associations (two thirds from Europe), purporting to collectively understand and represent the views over 2,000 enterprises

We identified four positive insights for cloud vendors:

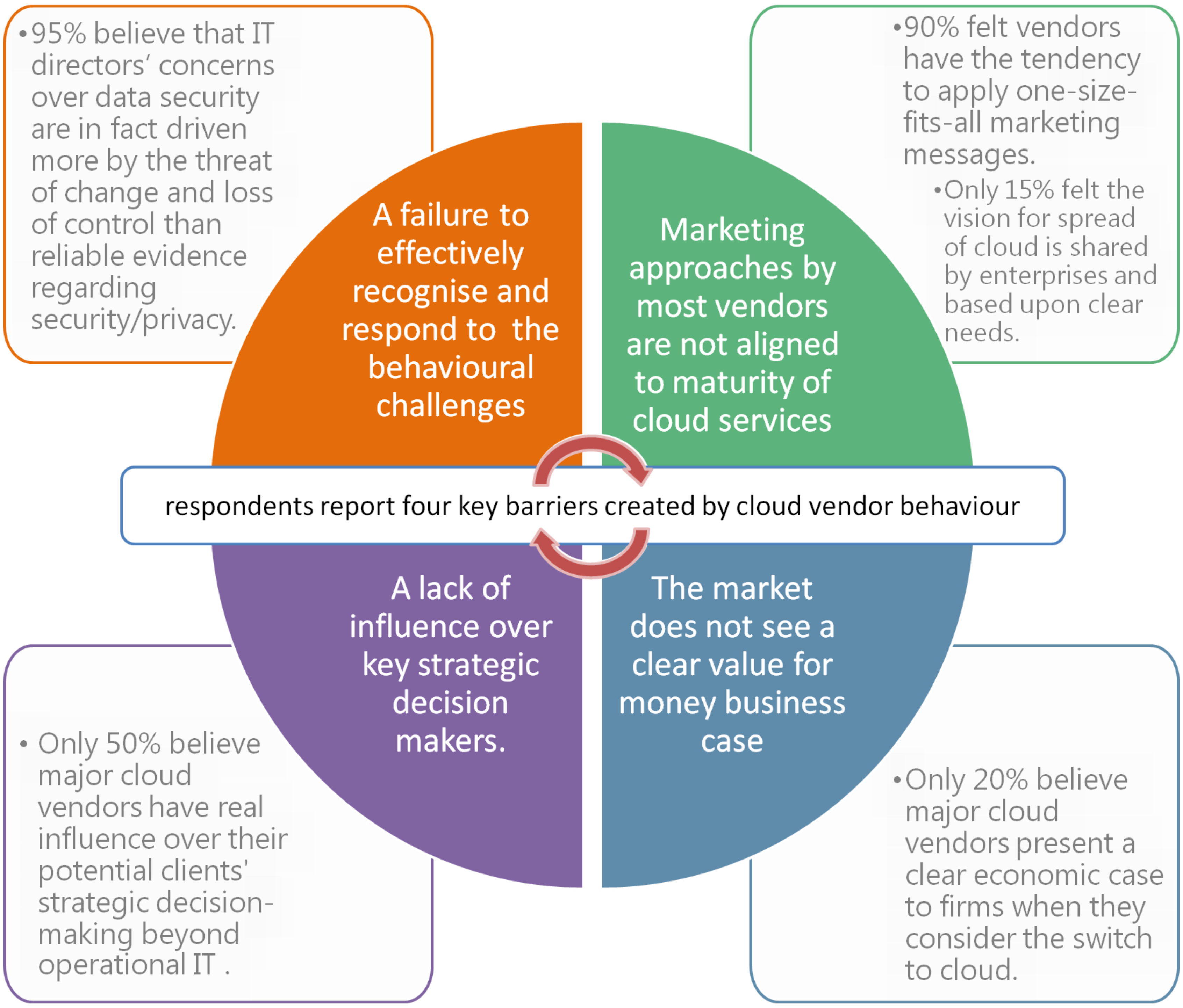
(i) 98% of respondents believe major cloud vendors have the access, the technology and the brand to deliver market transformation;

(ii) 90% of respondents believe cloud vendors have clear and strong opportunities to grow their businesses;

(iii) 75% believe workforces are likely to find cloud-based email, CRM and groupware alternatives more convenient than their current on-site solutions.

(iv) it is dynamic market, 80% of respondents believe cloud solutions are just as likely to come from smaller enterprises as they are large.

However, analysis of respondents' feedback also revealed four themes as high potential barriers:



Do public policies create barriers?

We evaluated 13 policies through two lenses:

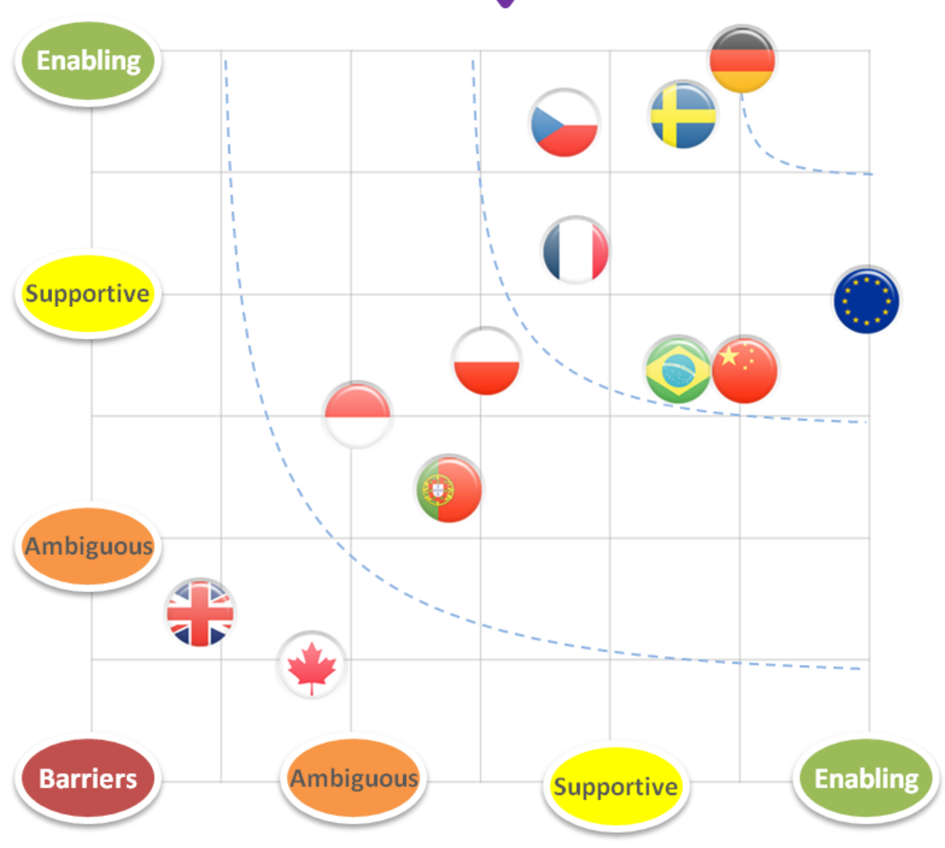
(i) How was the policy was designed?
(ii) What is the likely impact of the specific instruments employed within the policy?

The aim was not to develop a critique of specific or current policy agendas but to develop insight into common pitfalls or good practices surrounding the design and implementation of public policy. In doing so we hoped to identify how these might create barriers or enablers to the diffusion of enabling technologies, such as cloud services.

Region	Policy Focus Chosen
Brazil	National Climate Change Plan
Canada	ecoENERGY Efficency Programme
China	the 12th Five Year Plan
Czech Republic	National RDI Policy
EU	(i) ETS & (ii) EEEF
France	Grenelle de l'environnement
Germany	National EEA Plan
Indonesia	National ECM Plan
Poland	Energy Policy of Poland
Portugal	National EEA Plan
Sweden	Integrated CC&E Policy
UK	CRC Energy Efficiency Scheme

- **All policies acknowledged the importance of technology.**
- Only 2 policies directly create an enabling context for the ICT sector to leverage technologies with the potential to abate GHG emissions.
- 6 of 13 are broadly supportive but still create uncertainties.
- 5 of 13 create ambiguities and even create direct barriers for the ICT sector.

Design Evaluation
is the policy clear about what it intends to achieve and its targets, justified in its focus, integrated into the broader policy landscape and clear on the instruments being used?



Likely impact of policy instruments
what is the likely impact of the instruments employed by the policy (regulatory, economic, behavioural and/or government leadership) upon the ICT sectors' invention and exploitation of enabling technologies such as cloud?

Policies appear not to:

- directly embrace the enabling potential of the ICT sector (only 3 of the 13 policies analysed do so);
- demonstrate an understanding of the technology invention and diffusion cycle (only 1 in 13 does this adequately);
- present clear intent and targets (only 4 in 13 manage this);
- justify goals and integrate into broader policy context (2 of 13);
- embrace the full range of policy instruments available (2 of the relevant 11).
- embrace the power of 'government leadership' as a policy instrument - this includes services provision, service procurement and demonstrator projects (only 2 of the relevant 11 policies do so).

We observe thee problematic policy instruments:

1. **league tables** - fail to account for ICT's GHG abatement potential = unnecessary reputation damage;
2. **subsidy & tax instruments** - distorting effects that fail to include ICT solutions = send wrong message.
3. **emissions trading** – failing to limit the allowances is slowing market stimulation

5. Impact of barriers

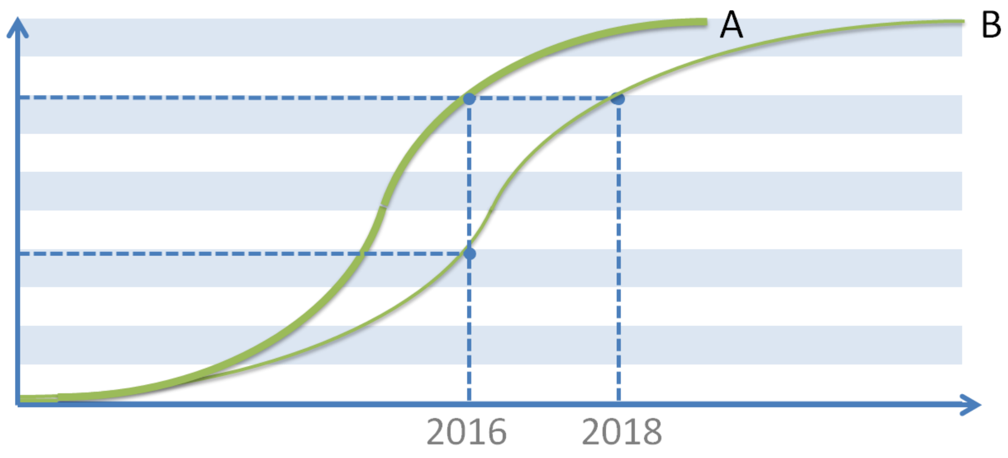
The extent to which cloud-based email, CRM and Groupware services will achieve broad penetration (i.e., 80% market adoption[8]) across all market sectors remains unclear:

- the commercial behaviour observed by our survey respondents presents an uncertain context regarding the ICT sector's capability to drive widespread adoption, and
- commercial uncertainty is compounded by and may in part also result from the uncertain policy environment that cloud vendors appear to face.

In a more certain environment we predict it could be possible to drive 80% market adoption by 2016. However, given the presence of such uncertainties, we predict cautious corporate investment and less dynamic customer markets. Indeed, we assert the market adoption is likely to be slowed during this same timeframe, easily compromising GHG abatement by as much as 50%:

Line A presents a scenario with no major commercial or policy-based barriers, where cloud-based email, CRM and groupware achieve 80% market adoption by 2016.

Line B illustrates that a mere 2 year delay in achieving the same level of adoption would reduce the impact in 2016 by half.



8 80% was elected as 'wide spread adoption' based upon Rogers, E. M. (2003) Diffusion of innovations (5th ed.). NY:Free Press, New York, USA.

6. Recommendations

Prime responsibility for driving the market adoption of technologies that can abate GHG emissions, such as cloud computing, naturally lies with the ICT industry. To accelerate these outcomes, we offer six recommendations to vendors:

Recommendations for vendors
(inferred from our industry survey)

1) Employ smarter approaches to **present a clear economic case** for cloud.

2) Support the economic case of cloud-services with **clear impartial evidence of its GHG abatement credentials**.

3) **Acknowledge that adopting cloud services may require clients to change deeply engrained behaviours** (especially IT directors and their teams).

4) **Respond to the challenge of behaviour change** with evidence and tools to make it easy for customers to switch to cloud, leaving them incentivised to stay not coerced or worried about covert lock-in.

5) **Avoid one-size-fits all marketing approaches**; instead approach specific market niches with communications that address the unique unmet needs and the 'pain points' which each niche feels.

6) **Embrace the principles of disruptive innovation.** By avoiding a premature rush to mainstream markets, vendors can grow to mainstream market penetration through niche marketing.

Likewise, we see how policy makers can play an enabling role in the shift towards a low/zero carbon economy; in the short term they must avoid unintentionally creating barriers. We therefore make four recommendations to policy makers directly from our policy analysis:

Recommendations for policy makers

(inferred from our policy analysis)

1) Embrace the ICT sector's enabling potential, with policies that show a clear role for enabling technologies, such as cloud, as part of the solution. This will not only send a clear motivating signal to industry but demonstrate policy aims are deliverable.

2) Embrace an understanding of the "technology adoption lifecycle" into policy design and tools. By doing so policy makers will see value and methods for stepping back and facilitating market places, not attempting to coordinate and step in (using tools such as government procurement and information-sharing to show leadership and to stimulate, instead of a reliance on regulation).

3) Be clearer with policy design - the "WHAT", "WHY", "HOW" and "FIT".
The uncertainty currently felt by consumers could be reduced and the confidence of vendors increased if policy makers developed clearer policy documents. They can do this by

i. laying out their intentions and aims within clear timeframes,

ii. offering clear justification for their chosen intentions and aims,

iii. ensuring environmental policy is better integrated into broader policy frameworks (e.g., economic development), and

iv. depending less on singular policy instruments by employing a more holistic use of policy tools (i.e., a spread of all four types - economic, regulation, behavioural and government leadership).

4) Be careful when using policy instruments that appear to be troublesome. This will reduce uncertainty when they are considered fit for purpose.

i. League tables: disclosure of GHG emissions is not a bad thing, if it is used to express real environmental impact not as a tool to inadvertently penalise firms for helping others to abate GHG emissions.

ii. Distorting economic tools: policy-makers should be aware that a lack of targeted support for ICT in tax breaks or subsidies, in favour of less impactful abatement solutions, could send the wrong signal to vendors and markets alike.

iii. Government leadership: if governments show more leadership and "walk the talk", through a strategic use of public procurement, service provision, pilot/demonstration projects & partnerships, they could increase confidence in enabling technologies.

iv. Carbon/emissions trading: oversupply of allowances is likely to be slowing the invention and adoption of energy efficiency technologies.

The interface between our industry and policy analyses has helped us to infer the need for four additional recommendations for policy makers:

Recommendations for policy makers

(inferred by comparing our industry survey and policy analysis)

1) Move to harmonize privacy and data protection rules.
Our research revealed most privacy and data protection issues raised by industry are driven more from a fear of change than a legitimate logical argument regarding weaknesses in cloud services or regulation. This said, government action to support the harmonizing of privacy and data protection rules could help to instil more confidence in the transition to technologies such as cloud.

2) Continue to free government data.
The spread of enabling technologies will be easier as it becomes easier for industry and consumers to understand why we need environmental policy and why we need technologies that can enable GHG abatement. Governments around the world have made great steps to free their data; they should continue this trend and get creative with how they can support data mining to reveal power insights and smart solutions.

3) Cut red tape where its constraining small to medium sized enterprises.
It is likely that the developer community will be a significant engine of growth in cloud and other ICT-based enabling technologies. The growth of the developer community could in turn enable more GHG abatement. Hence, a move to cut constraining “red tape” could enable new and smaller developers to thrive.

4) Remove barriers to funding to help get ideas from labs to the market faster.
Given the developer community is likely to be an engine of growth, faster, simpler access to finding could help accelerate the emergence and growth of high impact developers.

The Enabling Technologies Of A Low-Carbon Economy: A Focus on Cloud Computing

Part 2:

methods, assumptions, data
– how we generated our findings
and recommendations

1. CONTEXT

Pioneering studies by commercial and non-governmental groups[9] have presented how a shift from on-site to cloud computing offers the prospect of reduced energy consumption and, therefore, the abatement of GHG emissions. Whilst these studies have made a valuable start in quantifying the GHG abatement potential of cloud computing applications (calculating a 50%-90% abatement of emissions) they leave questions unanswered because:

- they do not fully consider how energy and GHG reductions are likely to vary by country,
- they do not present scientifically appraised analysis methods, and
- they do not fully disclose all assumptions, such as market penetration rates.

These issues not only limit their usefulness for decision-making and future model development but have created the need for an open, rigorous, scientific analysis.

The aim of our study and approach

Our research[10] has addressed the gaps of previous studies in three ways – (i) we have conducted country specific analyses, (ii) we openly present the methodology, data used and assumptions and (iii) we consider the prevalence of technical, commercial and policy based barriers to adoption to ascertain a more realistic view on GHG abatement.

This part of the report attempts to offer a full overview of our methodological approach, assumptions and data sets in order to create the fullest possible disclosure and transparency.

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9 See for example:
- Accenture (2011). Cloud Computing and Sustainability: The Environmental Benefits of Moving to the Cloud. Accenture & WSP;
- Carbon Disclosure Project (2011). Cloud Computing – The IT Solution for the 21st Century. Carbon Disclosure Project & Verdantix, London, UK.

10 The core modelling component of our work has been validated and accepted for publication by the peer reviewed ICT4S 2013 conference: William, D., Thomond, P., and Mackenzie, I. "The Greenhouse Gas Abatement Potential of Enterprise Cloud Computing" ICT4S 2013: Proceedings of the First International Conference on Information and Communication Technologies for Sustainability, ETH Zurich, February 14-16, 2013. Edited by Lorenz M. Hilty, Bernard Aebischer, Göran Andersson and Wolfgang Lohmann. DOI: http://dx.doi.org/10.3929/ethz-a-007337628

2. Scope:
Methodological and Technical

The GeSI 'enablement methodology'[11] employs a life cycle assessment (LCA) approach[12] to guide the assessment of changes to an existing system resulting from the adoption of an alternative ICT solution. The design and scope of our methodology centres upon GeSI's 'enablement method' and extends it in four ways (Figure 2). This created a methodology that leverages the strengths of a 'process-sum' LCA and overcomes its weaknesses using economic input-output modelling (Appendix 1 presents a brief explanation of these terms). As such, our method can be used to predict the potential energy and GHG impact of any new information and communications technology, at scale, in three steps (these will be described in the following pages):

1. **State a clear goal** - be clear about the objectives of the analysis.
2. **Limit the assessment** - by
   (a) defining a business as usual (BAU) baseline, and
   (b) identifying those parts of the overall life-cycle which would significantly impact GHG emissions.
3. **Rigorously assess** - analyse the significant processes that would be changed and the impact upon GHG emissions through the replacement of the BAU technology with an alternative and carefully interpret the results.

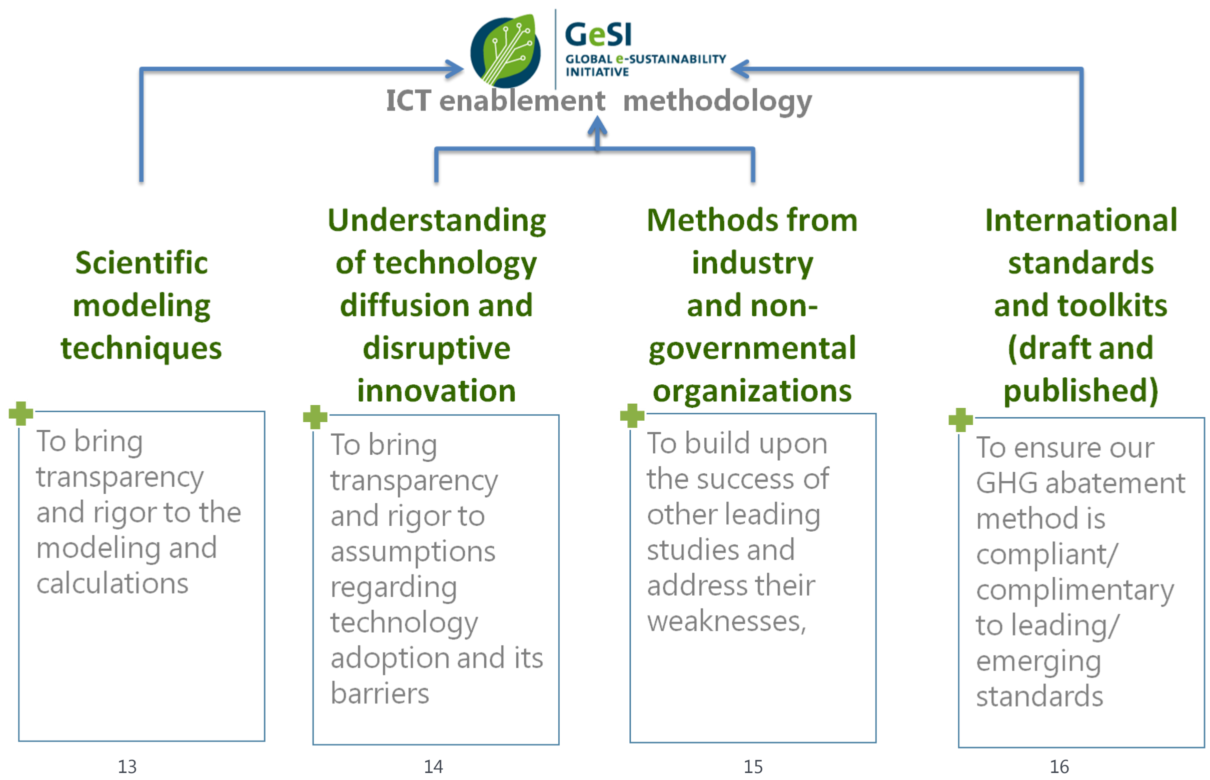


Figure 2: our method extends best practice in four ways

11 GeSI (2010) Evaluating the carbon-reducing impacts of ICT - An assessment methodology. Global e-Sustainability Initiative.

12 See for example Guinée, J.B.; Gorrée, M.; Heijungs, R.; Huppes, G.; Kleijn, R.; Koning, A. de; Oers, L. van; Wegener Sleeswijk, A.; Suh, S.; Udo de Haes, H.A.; Bruijn, H. de; Duin, R. van; Huijbregts, M.A.J. (2002). Handbook on life cycle assessment. Operational guide to the ISO standards. I: LCA in perspective. IIa: Guide. IIb: Operational annex. III: Scientific background. Kluwer Academic Publishers,

13 See in particular:

- Berl, A., Gelenbe, E., Di Girolamo, M., Giuliani, G., De Meer, H., Dang, M. Q. and Pentikousis, K. (2011) Energy-Efficient Cloud Computing. The Computer Journal, 53:7 September 1, 1045-1051.
- Baliga, J., Ayre, R. W. A., Hinton, K. and Tucker, R. S. (2011) Green Cloud Computing: Balancing Energy in Processing, Storage, and Transport. Proceedings of the IEEE, 99:1, 149-167.
- Kumar, K. and Yung-Hsiang, L. (2011). Cloud Computing for Mobile Users: Can Offloading Computation Save Energy? Computer, 43, 4, 51-56.
- Williams, D. R. and Tang, Y. (2012) Methodology To Model the Energy and Greenhouse Gas Emissions of Electronic Software Distributions. Environmental Science & Technology, 46, 2, 1087-1095.

14 See in particular:

- Rogers, E. M. (2003). Diffusion of innovations (5th ed.). NY:Free Press, New York, USA.
- Christensen, C.M. The Innovator's Dilemma: when new technologies cause great firms to fail, Harvard Business School Press, Boston, Massachusetts. 1997
- Christensen, C.M. (1997). The Innovator's Dilemma: Harvard Business School Press, Boston, Massachusetts.
- Foster, R. N. (1985) "Timing Technological Transitions", Technol. Soc. 7, 127–141, 2003
- Thomond, P. & Lettice, F. (2007) Allocating Resources to Disruptive Innovation Projects: Challenging Mental Models and Overcoming Management Resistance, Int. Journal of Technology Management.

15 See in particular:

- Carbon Disclosure Project. Cloud Computing (2011). The IT Solution for the 21st Century. Carbon Disclosure Project & Verdantix, London, UK,
- Accenture (2011). Cloud Computing and Sustainability: The Environmental Benefits of Moving to the Cloud. Accenture & WSP.

16 See in particular:

- GHG Protocol (2012) GHG Protocol Product Life Cycle Accounting and Reporting Standard ICT Sector Guidance (source: http://www.ghgprotocol.org/feature/ghg-protocol-product-life-cycle-accounting-and-reporting-standard-ict-sector-guidance). Accessed July, 2012.
- ITU (2012) Toolkit on Environmental Sustainability for the ICT Sector (source: http://www.itu.int/ITU-T/climatechange/ess/index.html). Accessed October 2012 (indeed, the ITU have used included earlier outputs from the Enabling Technology project within the content of this toolkit)
- ETSI (2011) http://portal.etsi.org/portal/server.pt/community/CLOUD/310. Draft documents accessed October, 2011.

Research goal and scope of analysis

The goal of this research is to understand the GHG abatement potential of enterprise cloud computing. We set out to produce conservative, reliable estimates of the impact of cloud computing; this meant creating a tight scope. Our chosen scope follows prior pioneering industry and NGO work[17], which is important in two respects:

A shift to cloud computing can enable:	The technical scope selected to examine the GHG impact of cloud based email, CRM and groupware: PRIMARY	SECONDARY
⊖ a direct decrease in emissions	**In scope:** GHG emissions saved by switching off on-site servers **Out of scope:** dematerialisation (e.g. no more CDs for software)	**Out of scope** (e.g. additional applications)
⊕ a direct increase in emissions	**In scope:** GHG emissions associated with the full life cycle (build, use, disposal) of replacement cloud infrastructure	No secondary direct ICT emissions
⊕ an indirect increase "rebound effects"	**Out of scope:** the potential that cloud may increase demand for computing	**Out of Scope:** the potential that enterprises redeploy redundant on-site servers for new capacity

Figure 3: A summary our analytical scope

- **Firstly, we focus our analysis on three readily available cloud-based applications**: email, customer relationship management (CRM) and groupware. While these are clearly a sub-set of all applications that businesses and individuals use, they are readily available as cloud based services and believed to represent a likely first phase in a shift towards cloud computing.
- **Secondly, we focus attention on business computing** which accounts for a majority of computing usage but not all of it, and provides richer data sets.

By limiting the scope of our analysis to three enterprise-level cloud-based applications, we sought to minimise possibility of over-estimating the impact of cloud.

We further limited our scope to modelling the impact of a scenario where the three applications were broadly adopted (i.e., they achieve 80% market penetration) in 11 countries: Canada, China, Brazil, the Czech Republic, France, Germany, Indonesia, Poland, Portugal, Sweden and the UK. These countries were selected as together they represent a broad mix of economies and for their variance in the GHG intensity of their country-level energy supply. Baseline country data was collected for the year 2007 or 2009 (where 2007 was not available). More recent data for all countries and variables was not available at the time the analysis was carried out.

Moreover, we embraced the GeSI 2010 "enablement methodology" to (a) focus us upon the main drivers of GHG emissions and (b) ensure transparency about what was in and out of the scope of our study. Figure 3 illustrates a summary of our scoping choices and Appendix 2 outlines these choices in more detail, including consideration of secondary enabling effects and rebound effects. In sum, we recognise that cloud and traditional on-site networked data services follow a logical three stage data process involving:

- a server (within a data centre),
- network transmission, and
- end user devices (e.g. laptops, mobile devices).

As previous research has found the data centre stage of a digital process accounts for the bulk of the energy demand compared to the network or user device stage, we focused our attentions here[18]. We also assumed the populations and demands for end use devices will remain relatively unchanged by a shift to the three cloud based services. Whilst the importance of the communications networks will be enhanced under a cloud computing scenario, preliminary estimates indicate that energy consumption within the network for the purposes in our scope would not materially impact overall energy consumption because of the small data sizes involved[19]. So these shifts too were placed out outside our remit.

Hence, as cloud computing offers servers that are utilised more efficiently than standard on-site servers[20], we limit our assessment to the impact of on-site servers being switched off in favour of cloud bases services.

[17] See for example
- Carbon Disclosure Project (2011). Cloud Computing – The IT Solution for the 21st Century. Carbon Disclosure Project & Verdantix, London, UK.
- Accenture (2011). Cloud Computing and Sustainability: The Environmental Benefits of Moving to the Cloud. Accenture & WSP

[18] Williams, D. R. and Tang, Y. (2012) Methodology To Model the Energy and Greenhouse Gas Emissions of Electronic Software Distributions. Environmental Science & Technology, 46, 2, 1087-1095.

[19] Baliga, J., Ayre, R. W. A., Hinton, K. and Tucker, R. S. (2011) Green Cloud Computing: Balancing Energy in Processing, Storage, and Transport. Proceedings of the IEEE, 99, 1, 149-167.

20 For example:
Berl, A., Gelenbe, E., Di Girolamo, M., Giuliani, G., De Meer, H., Dang, M. Q. and Pentikousis, K. (2010) Energy-Efficient Cloud Computing. The Computer Journal, 53, 7, 1045-1051.
Baliga, J., Ayre, R. W. A., Hinton, K. and Tucker, R. S. Green Cloud Computing: Balancing Energy in Processing, Storage, and Transport. Proceedings of the IEEE, 99, 1 (2011), 149-167.
Kumar, K. and Yung-Hsiang, L. Cloud Computing for Mobile Users: Can Offloading Computation Save Energy? Computer, 43, 4 (2011), 51-56.

Further to this, our analysis focused on the energy usage involved in running servers. The embedded carbon content of the servers, the associated server maintenance and the energy implications of end-of-life decommissioning were all deemed to have small impacts relative to direct energy consumption. Nevertheless, the embedded energy content of servers included in (new) cloud facilities was estimated through a life cycle approach.

Assessing energy consumption and GHG emissions

In sum, our approach was to calculate the annual emissions of on-site computing and compare it to the energy required to operate the equivalent services in a cloud computing scenario for a specific county assuming an adoption rate of 80%. This 'high' penetration rate was selected to highlight a 'best case scenario'[21], one that is likely to take some years to achieve. A sensitivity analysis of this rate was included to highlight the impact of a lower adoption rate. The current (baseline) adoption of cloud computing was also factored into the calculations so as to exclude impact already created by early adopters.

To make the inclusion of enterprise size tractable, we simplified the profile of enterprises in each country into a split between three sizes of small, medium and large (s, m, l), drawing the boundaries from national statistics offices[22]. Each size was attributed a different on-site server utilisation, a different assumed level of existing adoption of each of the three services under examination and, therefore, different targets to achieve the desired 80% cloud adoption rate.

Only enterprises where most people actively use internet connected computers during their normal work routine were included in the analysis.

A Microsoft Excel based model using the developed methodology was created in order to analyse the energy and related GHG emission impact of a move to cloud computing from on-site computing, at a use case level and then the level of a country. It took the following factors into account:

- the efficiency of on-site computing varies by the size of computing resource used,
- the size of computing resource used varies by the size of enterprises;
- the mix of enterprise sizes that use computing varies by country; and
- the carbon intensity of energy provision varies by country (where coal fired power stations are significant for example, compared to others where renewable energy plays a larger role).

Our modelling[23] therefore takes into account the profile of enterprise sizes across the countries being analysed and the national energy mix of each nation. Hence it provides more accurate country specific estimates.

Hence, to estimate the impact of a transition to cloud-based email, CRM and groupware upon GHG emissions, our projections were based on the following basic steps:

1. To calculate the current annual emissions of on-site computing to deliver these email, CRM and groupware services, and to compare it to the full life cycle assessment of energy and materials required to build, operate and dispose of the equivalent services in a cloud computing scenario.
2. To include a market penetration estimate to represent widespread adoption of cloud (we chose 80% to represent wide-spread adoption[24]).
3. To run the model against the specific enterprise demographics within 11 countries, which represent a broad mix of nations (Brazil, Canada, China, the Czech Republic, France, Germany, Indonesia, Poland, Portugal, Sweden and the UK).
4. To combine these estimates and calculate a conservative estimate for the abatement potential of cloud computing within each country.

21 Rogers, E. M. (2003) Diffusion of innovations (5th ed.). NY:Free Press, New York, USA..

22 See specifically,

- Statistics Canada. Employment by Enterprise Size 2007. Satistics Canada, Ottawa, http://www40.statcan.ca/l01/cst01/labr75h-eng.htm, 2007.
- US Census Bureau. Employment size by Employer and Nonemployer Firms 2007. US Census Bureau, Washington, http://www.census.gov/econ/smallbus.html 2007.
- LABORSTA. Employment General Level Switzerland: International Labour Office., http://laborsta.ilo.org, 2007.
- Eurostat. Persons employed using computers connected to the Internet in their normal work routine at least once a week. Eurostat, Luxembourg, http://appsso.eurostat.ec.europa.eu, 2010.
- Statistics Canada. Canadian Internet Use Survey. Statistics Canada, Ottawa, http://www.statcan.gc.ca/daily-quotidien/100510/dq100510a-eng.htm, 2009.

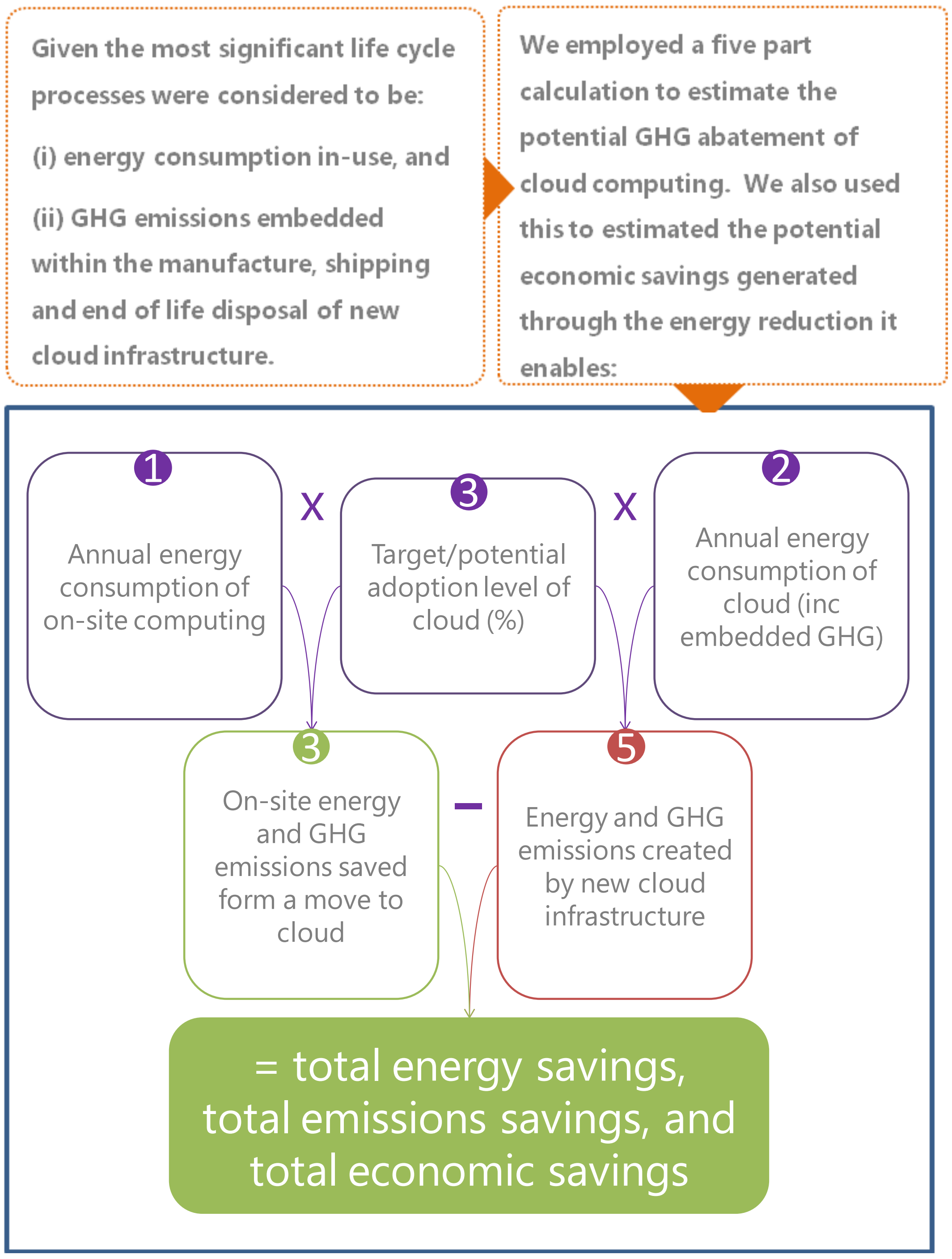
23 The core modelling component of our work has been validated and accepted for publication by the peer reviewed ICT4S 2013 conference: William, D., Thomond, P., and Mackenzie, I. (2013) "The Greenhouse Gas Abatement Potential of Enterprise Cloud Computing" ICT4S 2013: Proceedings of the First International Conference on Information and Communication Technologies for Sustainability, ETH Zurich, February 14-16, 2013. Edited by Lorenz M. Hilty, Bernard Aebischer, Göran Andersson and Wolfgang Lohmann. DOI: http://dx.doi.org/10.3929/ethz-a-007337628

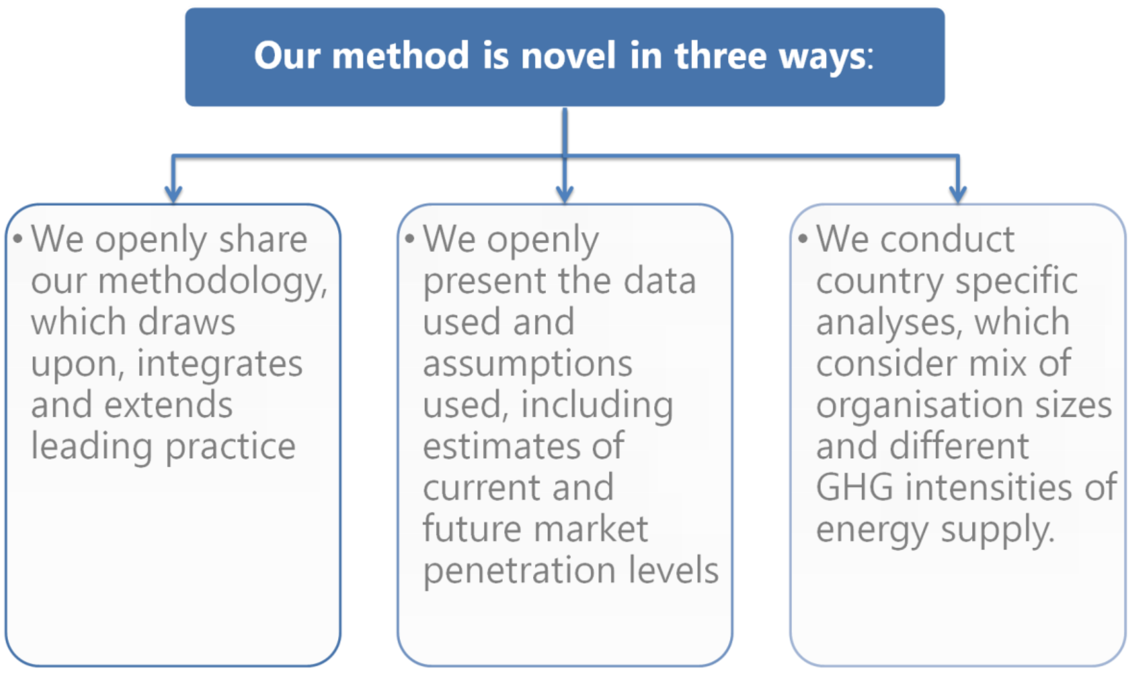
24 As suggested in Rogers, E. M. (2003) Diffusion of innovations (5th ed.). NY:Free Press, New York, USA..

This leads us to employ a five-part approach to estimating abatement. In doing so, we hope our research output makes two novel contributions:

- Firstly, we aim to highlight the value of a move to cloud computing in a more tangible, scientific manner through the application of our model to create country specific estimates of energy and GHG reductions.
- Secondly, we describe our model methodology in detail and explore the sensitivity of our results to changes in key variables where scientifically derived data are not available.

These bespoke and scientific results are aimed at informing decision makers from ICT vendors, users and governments alike. Moreover, by presenting our open methodology in this way we hope to encourage other researchers to enhance our work and embrace open approaches to such studies.





3. Data and results

Data for each model variable was collected from a variety of sources. Where reliable data could not be found or was commercially sensitive, estimates were generated through a series of five multi-business, expert workshops with senior personnel from the ICT sector. Although a consensus was reached around all such estimated parameters, the most conservative ranges were used. Full model data is not presented here due to size constraints; this is freely available from the authors.

The average session capacity of an on-site server was estimated at a conservative 250 sessions per server for each service. It was recognised that this value was a low estimate but reflected the probable wide range of technical support and knowledge across an entire range of company types and sizes. For cloud servers an estimate of 1000 sessions per server was used. This value was agreed to be at the middle to low end of size estimates especially for email services.

Data for the employed population of a country, percentage of workers in small, medium or large enterprises, and the average number of employees per enterprise by size (s, m, l) for each country were sourced from leading national and international suppliers of such data[25]. We note for China, Brazil and Indonesia data could not always be sourced and was inferred from a mix of averages.

The percentage of workers using the internet was estimated and inferred from a variety of sources[26]. This variable did not differentiate between internet access for an on-site service or other work and personal related internet access; however, this was the best data available.

Consistent adoption rates to demonstrate the current on-site to cloud ratio could not be sourced; this was estimated for each service by aggregating the estimates collected in a series of four expert workshops and 10 interviews.

The average power consumption of a server and associated networking and storage add on metrics were determined using methods and data from Williams and Tang[27]. A PUE of 1.3, 1.8 and 2.1 was used for small, medium and large enterprises and conservative PUE of 2.0 was used for cloud services. **These PUE values were employed to ensure our estimation remained conservative and in absence of publicly available and validated data**. For small and medium size enterprises a mid-range server type was assumed by the model. For large enterprises and all cloud services a volume server type was assumed. The embedded carbon of each server was difficult to source, so we used values from Bottner[28]. The emissions factors used in this research were sourced from World Resources Institute[29].

How these data sources were employed within the five part modelling process and the actual numbers used are openly presented in Appendix 3. We do this to engage the research community in our pursuit for ever more reliable data sources. The last table in this appendix highlights that the major weakness in the conclusions of our modelling resides in our need for more robust data regarding three factors (a) the numbers of people using internet-enabled PCs at work, (b) the precise number of on-site servers across the countries under consideration and (c) the current market penetration of cloud services.

Finally, the energy reduction calculations were used to estimate economic/cash savings that could be released as a result of enterprises using less energy; these are presented in Appendix 4.

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25 We used the following sources:
- Statistics Canada. Employment by Enterprise Size 2007. Satistics Canada, Ottawa, http://www40.statcan.ca/l01/cst01/labr75h-eng.htm, 2007.
- US Census Bureau. Employment size by Employer and Nonemployer Firms 2007. US Census Bureau, Washington, http://www.census.gov/econ/smallbus.html 2007.
- LABORSTA. Employment General Level Switzerland: International Labour Office., http://laborsta.ilo.org, 2007.
- Eurostat. Enterprises by size class - overview of SMEs in EU., Eurostat, Luxembourg, http://epp.eurostat.ec.europa.eu 2008.
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26 Specifically:
- [Eurostat. Persons employed using computers connected to the Internet in their normal work routine at least once a week. Eurostat, Luxembourg, http://appsso.eurostat.ec.europa.eu, 2010.
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- JakartaGlobe. Internet Users in Indonesia to Triple by 2015: Report. JakartaGlobe, Jakarta, Indonesia, http://www.thejakartaglobe.com/business/internet-users-in-indonesia-to-triple-by-2015-report/394066, 2010.

27 Williams, D. R. and Tang, Y. (2012) Methodology To Model the Energy and Greenhouse Gas Emissions of Electronic Software Distributions. Environmental Science & Technology, 46, 2, 1087-1095.

28 Bottner, H. (2012) Product Carbon Footprint Project at Fujitsu Technology Solutions. Fujitsu Corporate Quality, Fujitsu Europe.

29 World Resources Institute. Carbon Intensity of Electricity Production in 2007. . World Resources Institute, Washington, USA, http://cait.wri.org, 2007.

4. What are the potential carbon savings?

If 80% of all enterprises across the 11 countries studied switched off their on-site servers to adopt cloud-based email, CRM and groupware, we predict 4.5 million tonnes of CO_2e emissions could be abated. This is equivalent to:

- approximately 2% reduction in the ICT sector's associated GHG emissions;
- 1.7 million cars permanently off the roads.

On average, the associated emissions of providing email, CRM and groupware services would be reduced by 95%. This means for every one tonne of CO2e produced by cloud vendors 20t of CO2e from client-side emissions are abated.

We also found:

- energy mix is more influential than PUE in emissions abatement;
- market penetration rates are the biggest single influencer of abatement potential;
- the dramatic reduction in server numbers is a key driver of GHG abatement through energy reduction.

Table 1 summarises the country-level results of (i) the on-site emissions reduced by switching off servers, (ii) the GHG emissions created in building and operating an alternative cloud infrastructure and (iii) the associated net GHG emission reductions (Figure 4 presents these emission reductions in ranked order). In all cases, our modelling indicates significant emission reductions.

Country	Annual emissions (t CO_2e)		
	On-site emissions reduced	Cloud emissions increase	Net emissions reduced
Brazil	188,376	9,240	179,136
Canada	94,647	7,985	86,662
China	1,982,625	124,777	1,857,848
Czech Rep	111,877	4,435	107,442
France	99,387	5,454	93,933
Germany	1,056,538	49,147	1,007,391
Indonesia	178,005	6,800	171,205
Poland	283,470	11,020	272,450
Portugal	81,029	2,305	78,724
Sweden	6,732	557	6,175
UK	709,012	36,006	673,006
Total for all 11 countries	4,791,699	257,726	4,533,973

Table 1: The abatement potential of cloud-based email, CRM and Groupware with an 80% cloud adoption rate.

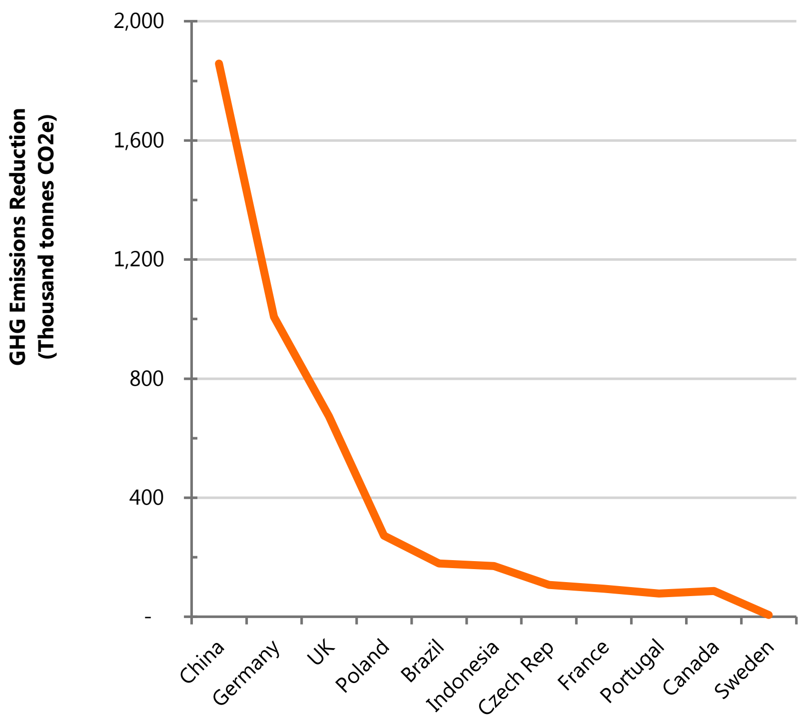


Figure 4: The net emission reductions ranked high to low

There were two primary areas where we faced a lack of reliable data when estimating GHG abatement potential across all 11 countries:

- precise data on the current market penetration of Cloud Computing services; and
- the precise number of on-site servers presently being used to deliver these services in each country.

Table 2 presents our assumed proportion of the enterprise market that has yet to adopt the three cloud services[30] and the average proportion of GHG emissions we calculate as attributable to three types of enterprise – small, medium and large.

Enterprise Size	Average Proportion of GHG emission reductions	Assumed penetration of cloud services	Average proportion of employed population
Micro & Small	68%	40%	45%
Medium	18%	66%	18%
Large	14%	90%	37%

Table 2: The average proportion of emission reductions, the assumed use of cloud services of all countries and the average proportion of employment by enterprise size.

Our model helps to highlight that on average the majority of reductions (68%) are likely to be realised by smaller enterprises. This was despite the fact that we assumed a much larger proportion of small enterprises (60%) have already adopted cloud services.

30 Given a significant lack of validated data regarding existing penetration rates, our assumptions were derived through expert workshops and interviews.

We found that on average a move to cloud reduced server numbers by 92%:

- the majority of on-site servers removed are from small and medium sized enterprises;
- most servers added to provide cloud services are for large enterprises (Figure 5).

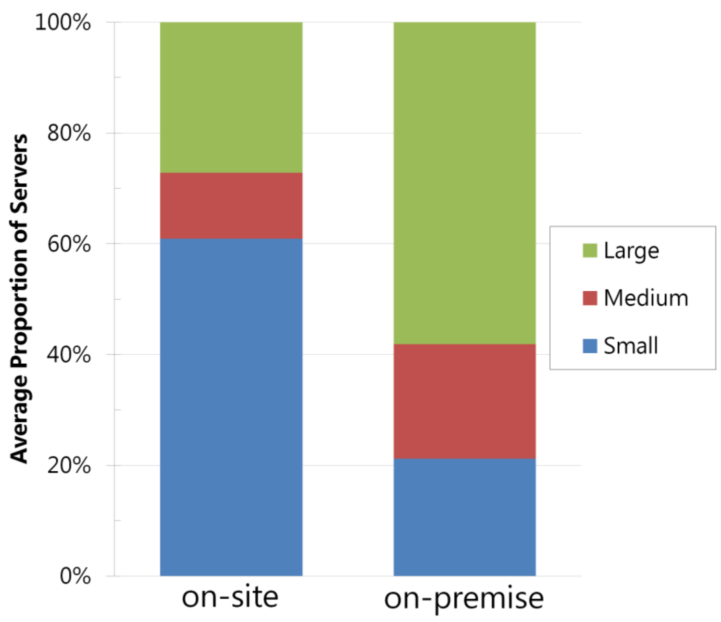


Figure 5: How the population of servers will change with the shift from on-site to cloud computing

This shift in the population of servers highlights both the higher assumed adoption of cloud computing and the higher proportion of employed populations in small enterprises.

We completed a sensitivity analysis regarding cloud adoption levels in relations to on-site servers. This was in response to a lack of scientifically derived data regarding this key input. It reveals the 4.5Mt CO_2e estimate might range by up to ±35%. For example:

- a ±20% variation in each services' ratio of on-site servers to existing penetration levels of cloud creates a ±31% shift the abatement potential;
- we predict our estimates could vary between 3.1 and 5.9 Mt CO2e (Figure 6).

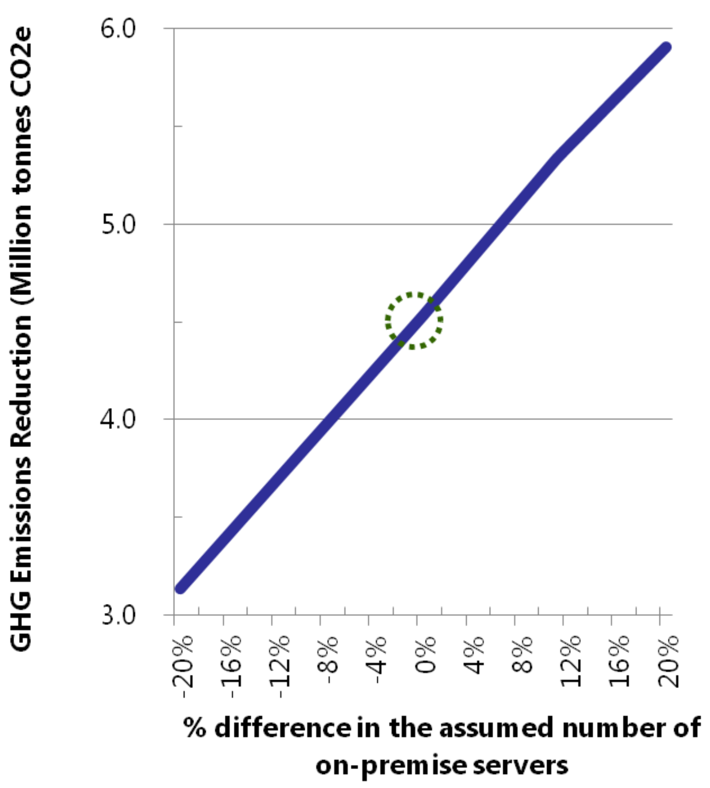


Figure 6: A collated ±20% sensitivity analysis of the on-site to cloud ratio for each service against potential emission reductions

5. What are the potential economic savings?

By calculating the average cost of energy within the 11 countries under examination, we calculated the cash savings that could be released into each national economy if 80% of enterprises switched off their on-site servers used for email, CRM and groupware and adopted cloud-based alternatives. We estimate $2,200 million (USD) of economy-wide savings in energy bills could be released (Table 3). Appendix 4 outlines these calculations and the data sources in detail.

Country/ Region	Cost of Electricity for On-site computing	Cost of Electricity for Cloud computing	Cost Savings
France	$ 174,540,280	$ 4,960,905	$ 169,579,375
Germany	$ 480,771,677	$ 15,292,769	$ 465,478,908
Sweden	$ 61,815,433	$ 1,749,285	$ 60,066,148
UK	$ 291,099,666	$ 11,157,052	$ 279,942,614
Czech Rep	$ 26,200,384	$ 910,139	$ 25,290,245
Poland	$ 85,001,537	$ 2,517,434	$ 82,484,103
Portugal	$ 43,933,430	$ 1,012,518	$ 42,920,912
Canada	$ 34,097,952	$ 2,308,027	$ 31,789,925
China	$ 152,691,943	$ 10,008,090	$ 142,683,853
Brazil	$ 377,503,857	$ 12,414,468	$ 365,089,388
Indonesia	$ 15,433,857	$ 571,552	$ 14,862,304

Table 3: The likely economic savings made possible from reduced energy consumption if 80% of enterprises adopt cloud-based email, CRM and groupware

6. Understanding the barriers to adoption

In this section, we make transparent how we analysed technology, commercial and policy environments to identify opportunities and threats. Our aim is to make clear (a) how we have arrived at our conclusions and recommendations and (b) help others to follow and extend upon our approach.

Technology barriers

We observe that the speed, availability and security of networks that supply cloud computing in some countries may serve to inhibit adoption (e.g., in Indonesia mobile and wide area Wi-Fi are being adopted where little wired infrastructure exists). However, we conclude there are, in general, few technological barriers facing the wide-spread adoption of cloud-based email, CRM and groupware services.

Barriers created by commercial behaviour

To understand if commercial behaviour is creating barriers to the spread and adoption of cloud computing services, we completed a three step process:

1) derived an understanding of the typical 'path' through which vendors drive market transformation, by applying theory and frameworks from two fields:
   - disruptive innovation, and
   - technology diffusion

2) formulated a survey instrument that could help explore if cloud vendors are following the 'path to market transformation'

3) deployed the survey to explore the performance of cloud vendors by asking leaders of ICT industry associations and business associations for their expert insight and observations.

Step 1: the typical path to market transformation:

We mapped out the typical steps on the path to market transformation using an academically derived understanding of technology diffusion, disruptive innovation and the barriers to both[31] (see diagram in Appendix 5). This helped us to understand eight important aspects to driving transformative technology diffusion.

Step 2: develop survey instrument:

As described in the previous sections, we assumed the majority of micro, small and medium sized enterprises have adopted cloud-based email, CRM and groupware services. Conversely, the bigger diffusion challenge is assumed to be large enterprises, where we assumed few have adopted these same cloud-based services. These assumptions, combined with the mapping exercise in Step 1, led us to develop a survey instrument mostly focused upon the behaviour of major cloud vendors and how they are attempting to attract large enterprise customer. The survey had 45 questions in eight-parts (See Appendix 6 for full details):

Step 3: deploy survey

Our survey was conducted in three stages from November 2011 to October 2012.

In total, 23 associations (ICT industry associations, business associations for SMEs and associations representing a range of sectors and mostly larger enterprises) were invited to nominate up to 4 people each to anonymously complete all 45 questions.

Each respondent had to state if they met two qualifying criteria:

(i) expertise within the ICT sector, and
(ii) an understanding of what their membership are telling them with respect to ICT trends and the emergence of cloud computing.

A total of 41 respondents answered all the questions who met both qualifying criteria; they represented 12 industry associations.

The respondents were asked to answer the questions in consideration of the major cloud vendors in their region (and the major IT firms they know are about to step into this space).

The respondents were told that our expert industry interviews and workshops had led us to make three assumptions about the current market penetration of cloud-based email, CRM and Groupware: (i) they have become mainstream technologies for micro and small enterprises; (ii) they have entered the mainstream market for medium sized enterprises; (iii) only early adopters have embraced these technologies within large enterprises.

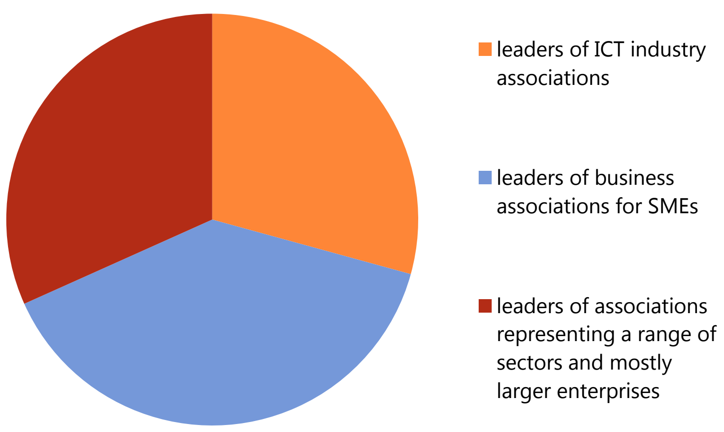
31 In particular:
- Rogers, E. M. (2003). Diffusion of innovations (5th ed.). NY:Free Press, New York, USA., 2003.
- Christensen, C.M. (1997). The Innovator's Dilemma: when new technologies cause great firms to fail, Harvard Business School Press, Boston, Massachusetts.
- Christensen, C.M. (2003) The Innovator's Solution: Harvard Business School Press, Boston, Massachusetts.
- Foster, R. N. (1985) "Timing Technological Transitions", Technol. Soc. 7, 127–141,
- Thomond, P. & Lettice, F. (2007) Allocating Resources to Disruptive Innovation Projects: Challenging Mental Models and Overcoming Management Resistance, International Journal of Technology Management.

Chi-squared statistical tests reveal no significant differences in the responses from the different types of business association.

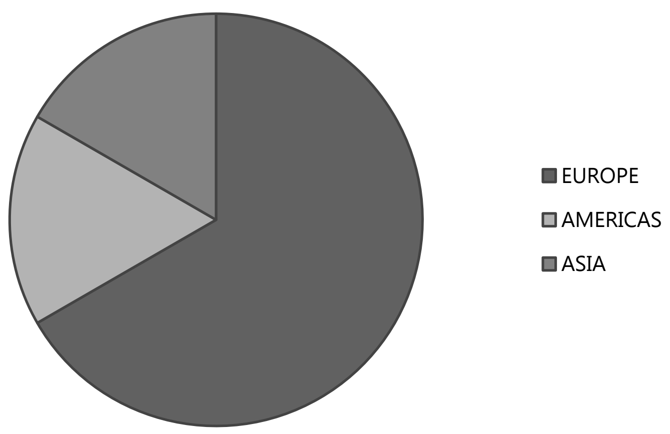
The dominance of European business associations (8 of the 12) prevents the application of tests to investigate whether or not there are key differences of opinion between the regions - therefore our data my represent a more Euro-centric view.

The associations purport to collectively represent over 2,000 businesses (including geographical business units of global enterprises).

Survey respondents: roles:



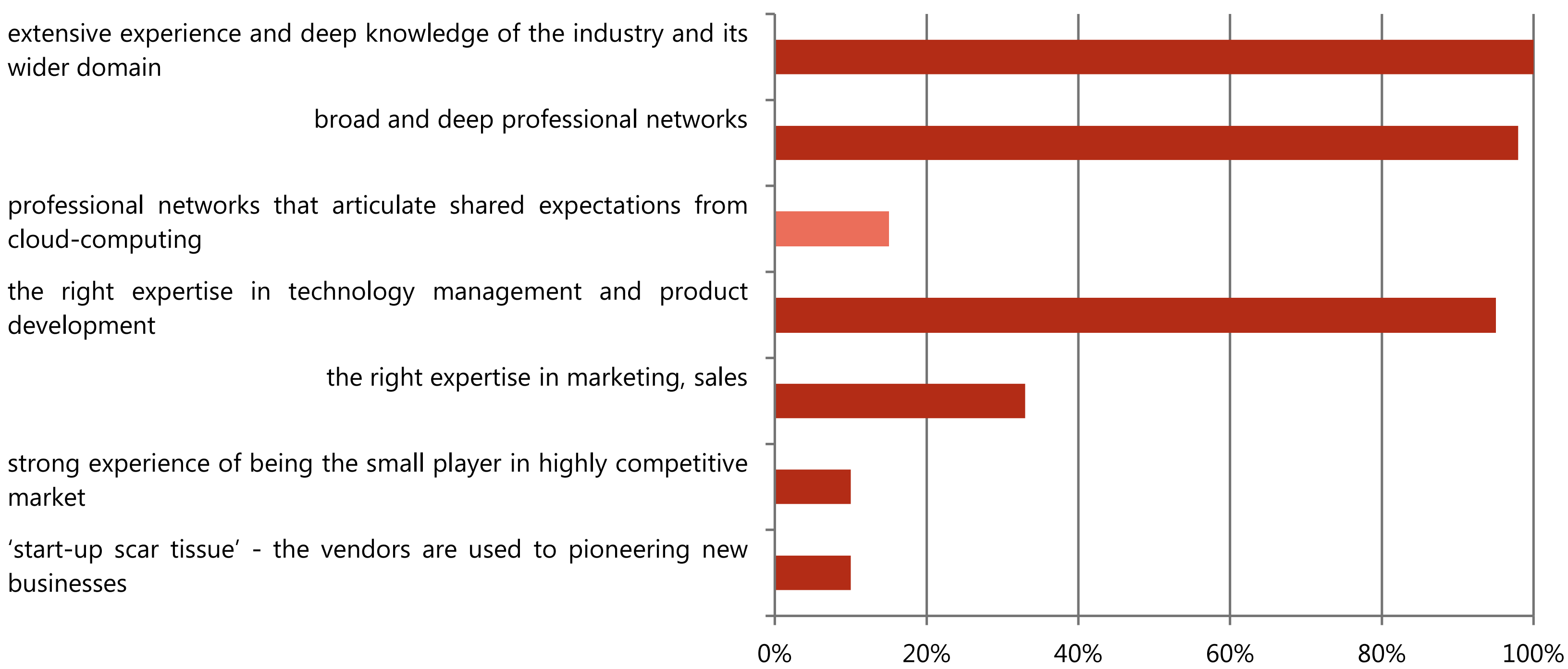
Survey respondents: geography of each business association:



Survey findings and conclusions

Do cloud vendors appear to have the right teams in place to pioneer the market transformation to on-site computing across micro, small, medium and large sized enterprises?

The desirable assets of an 'ideal team' and the percentage of respondents who believe vendors have them:

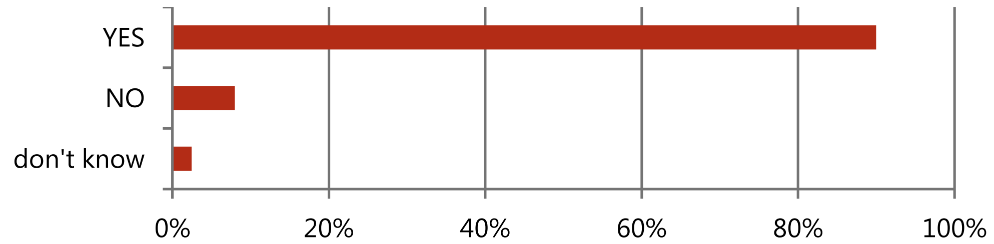


Insight: leaders of major cloud vendors might be creating unintended barriers to growth by following methods that were once successful elsewhere.

Major cloud vendors are credited with deep and extensive knowledge of the ICT sector. Yet, business associations report vendors' marketing and sales skills may be ineffective - they say the old approaches to software and hardware are being applied and they are not working as well as they once did. Business associations report that vendors appear to be led by people who once led large dominant IT firms or the old tech paradigm; therefore, they lack the entrepreneurial experience to manoeuvre a pioneering venture. This might explain why business associations believe the extensive professional networks of cloud vendors do not yet share the same vision and expectations for cloud computing.

Are there clear customer niches which cloud vendors could target as strong 'foothold markets' from which they can build widespread adoption? (large enterprises focus)

The percentage of respondents who believe vendors have clear customer niches:

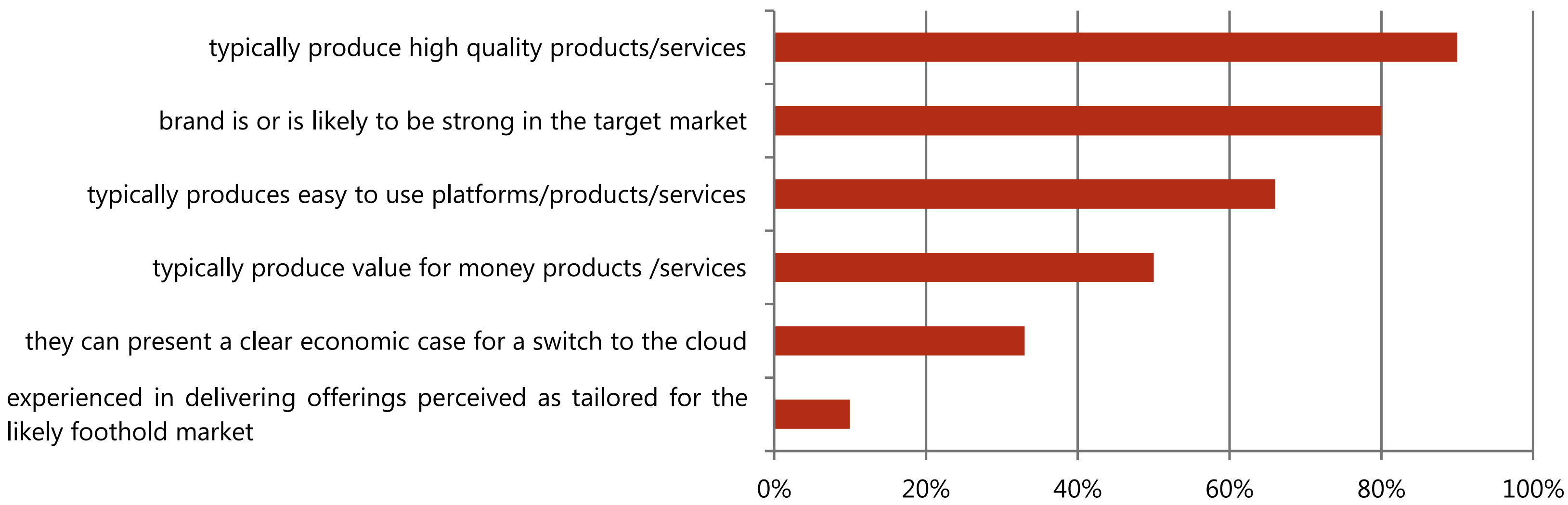


Insight: the market place is ripe for the continued emergence of cloud across large enterprises.

90% of our respondents across the three types of business associations and geographies all believe that cloud vendors have clear opportunities to build their businesses.

Can cloud vendors promote value to customers that might make up their foothold market(s)? (large enterprises focus)

The desirable assets for promoting value and the percentage of respondents who believe vendors have them:



Insight: major cloud vendors are well respected but if they want to build strong-foothold markets of large-sized enterprises they must avoid a one-size fits all approach and build a stronger economic case.

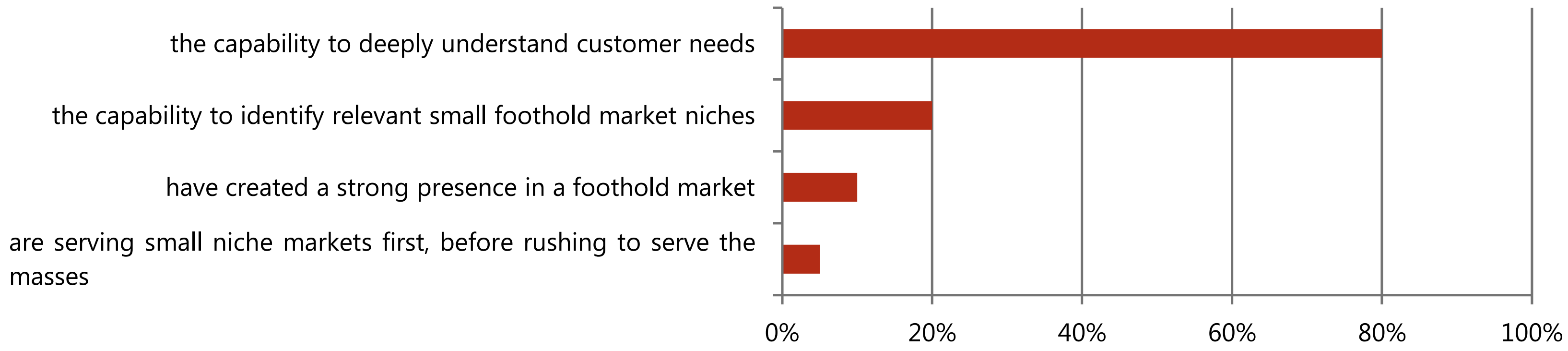
Leaders of business associations report that major vendors of cloud-services are generally well respected amongst early adopters and those that might follow. Yet, this is being undermined by two perceptions:

1) they are likely to offer one-size fits all solutions, rather than customised platforms to suit specific needs; and

2) they are unlikely to offer a clear value-for-money business case in marketing materials.

Are cloud vendors establishing strong 'foothold markets' of cloud users? (large enterprises focus)

The desirable assets for establishing strong 'foothold markets' and the percentage of respondents who believe vendors have them:

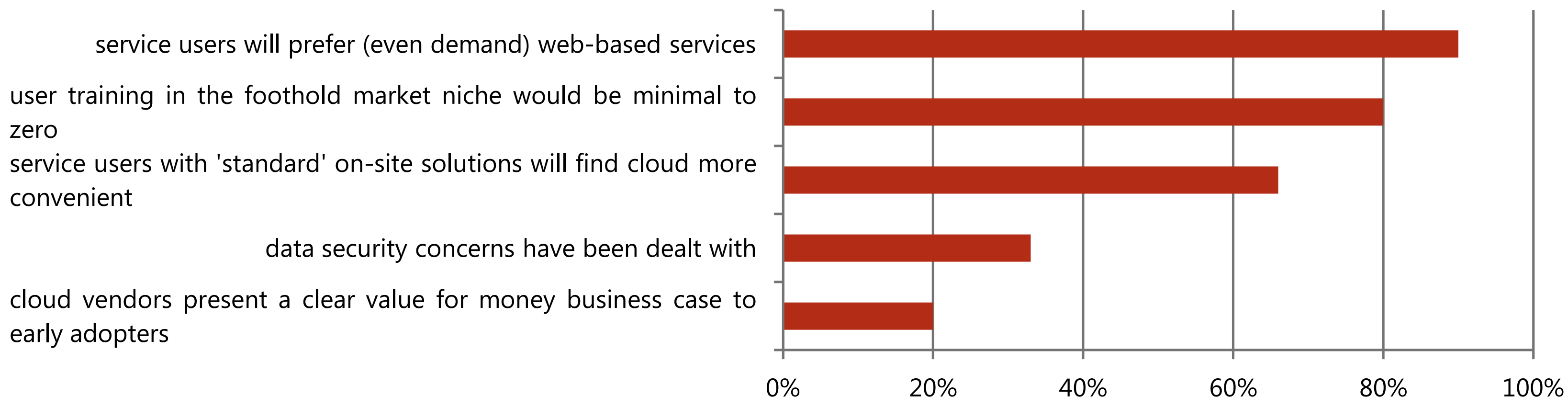


Insight: cloud vendors may be rushing to the 'big prize' of mass market penetration and risk stalling growth.

Our respondents state that vendors seem more interested in rushing to the larger revenues of the mainstream market - the markets many of them are used to serving - and in doing so, they are overlooking the needs of early smaller markets, those likely to be the foundation of their long-term growth. Four in five of our respondents believe major cloud vendors have the capability to understand market needs if they desire. Yet only one in five believe they can identify clear foothold markets of customers with a compelling reason to adopt cloud computing.

Are cloud vendors making it easy for early adopters to switch to the new way of doing things? (large enterprises focus)

The desirable assets for making it easy for early adopters to switch and the percentage of respondents who believe vendors have them:

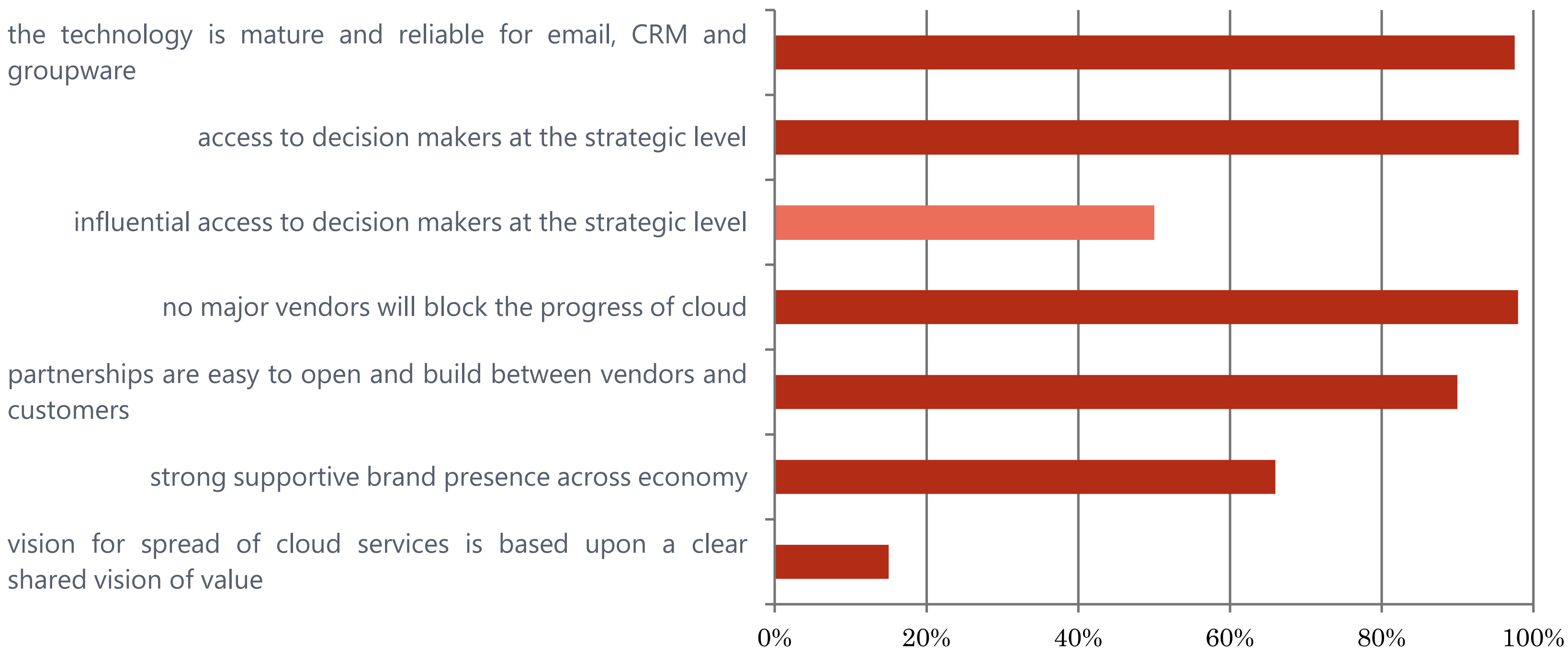


Insight: the economic case for cloud computing at the point of purchase is not clear enough to accelerate early market adoption.

Only 20% of our respondents believe major cloud vendors present a clear economic case to firms seriously considering the switch to cloud. This undermines the ease with which early adopters in the 'large enterprise' category can switch to cloud services. Moreover, two in three respondents state that data security and privacy concerns are still a major barrier, too.

Are cloud vendors overcoming the market and technical factors that might cause barriers in taking cloud from foothold market niches to mainstream widespread adoption? (large enterprises focus)

The desirable assets for overcoming market and technical barriers to widespread adoption and the percentage of respondents who believe vendors have them:

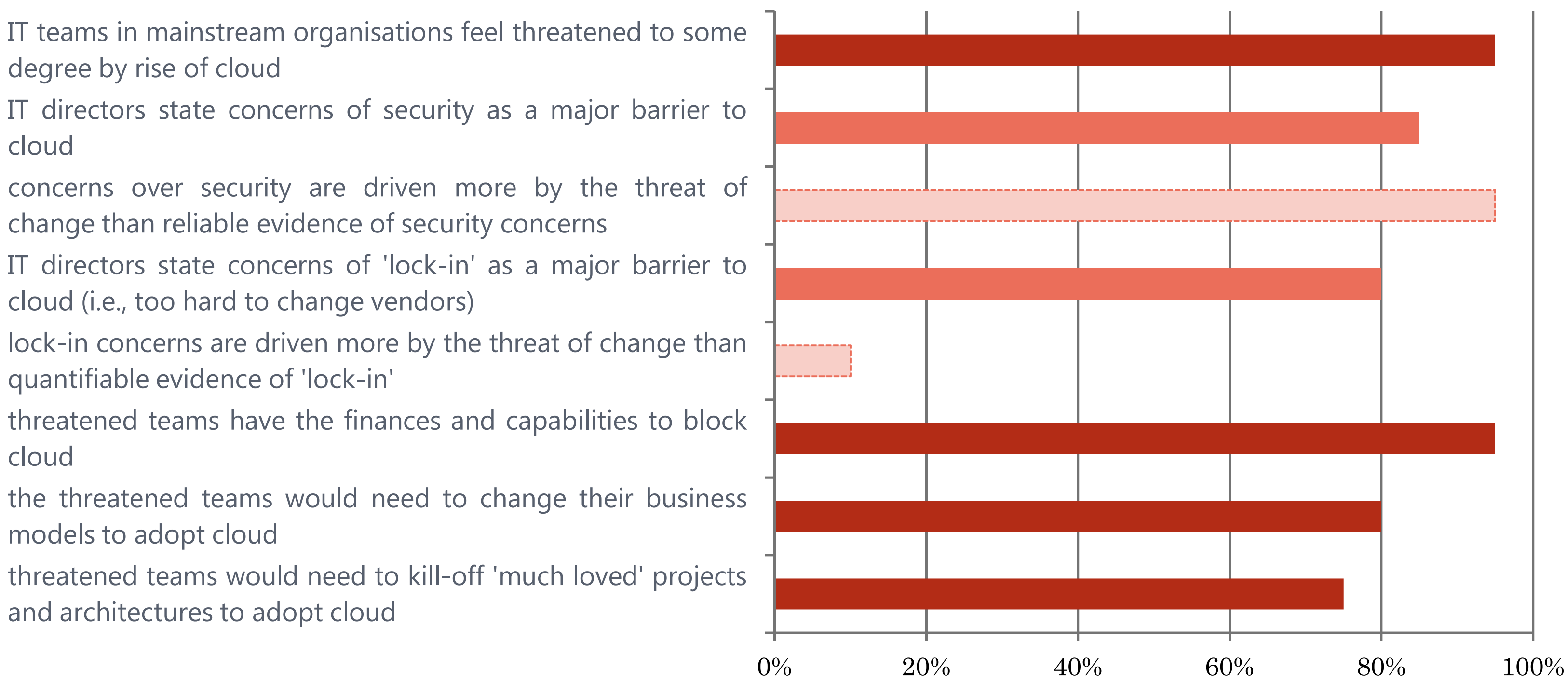


Insight: the vision for the spread of cloud may not founded on a generally accepted unmet business need.

It would seem that major cloud vendors have the access, the technology and the brand to deliver market transformation. However, business associations question whether they really have the ear of the decision makers. Only 50% of respondents believe major cloud vendors have any real influence over their potential clients' strategic decision-making. Moreover, 85% of respondents believe the vision for the spread of cloud is not shared by large enterprises - few could articulate a common and significant unmet business need.

Do cloud vendors understand how internal IT teams within mainstream enterprises feel about the shift to cloud and how they might retaliate if they feel threatened? (large enterprises focus)

The percentage of respondents who believe the following contexts exist within mainstream enterprises:

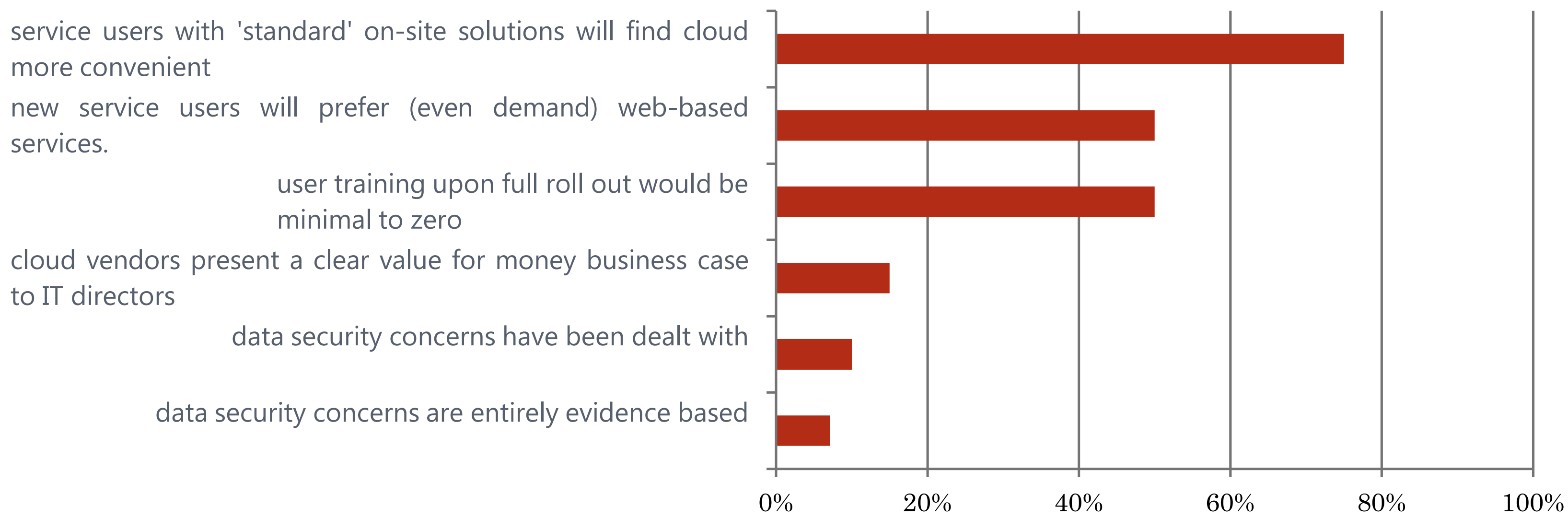


Insight: major cloud vendors may be failing to deal with the behavioural issues regarding the switch to cloud computing - this is likely to further stall market growth.

Our respondents cite a host of internal challenges that most IT directors have to overcome in order to switch to cloud services. For example, changing their internal business model, ending 'much loved' internal projects and architectures, and ensuring external vendors do not lock them into inflexible relationships. More interestingly, however, is the fact that 95% of respondents believe IT teams in large firms feel somewhat threatened by the emergence of cloud computing. For example, only 5% of our respondents felt that concerns over data security are completely justified; the rest believe that such concerns are in fact driven more by the threat of change and loss of control than reliable evidence regarding security concerns. These data point to a much deeper behavioural issue in the decision-making process to switch to cloud computing, which our respondents suggest is being overlooked by most vendors.

Do cloud vendors make it easy for all customers to switch to their new way of doing things? (focus on all enterprises)

The desirable assets for easy customer switching and the percentage of respondents who believe vendors have them:



Insight: the rate of market growth for cloud-based email, CRM and groupware may stall, putting broad penetration in the short term at risk because of ingrained commercial behaviour.

Three quarters of our respondents believe users are likely to find cloud-based email, CRM and groupware alternatives more convenient than their current on-site solutions. Yet, they cite three critical issues that are likely to create significant barriers to further market penetration:

1) data security concerns are widespread - vendors must act to demonstrate that their service levels regarding security are not just good enough but better than on-site alternatives;

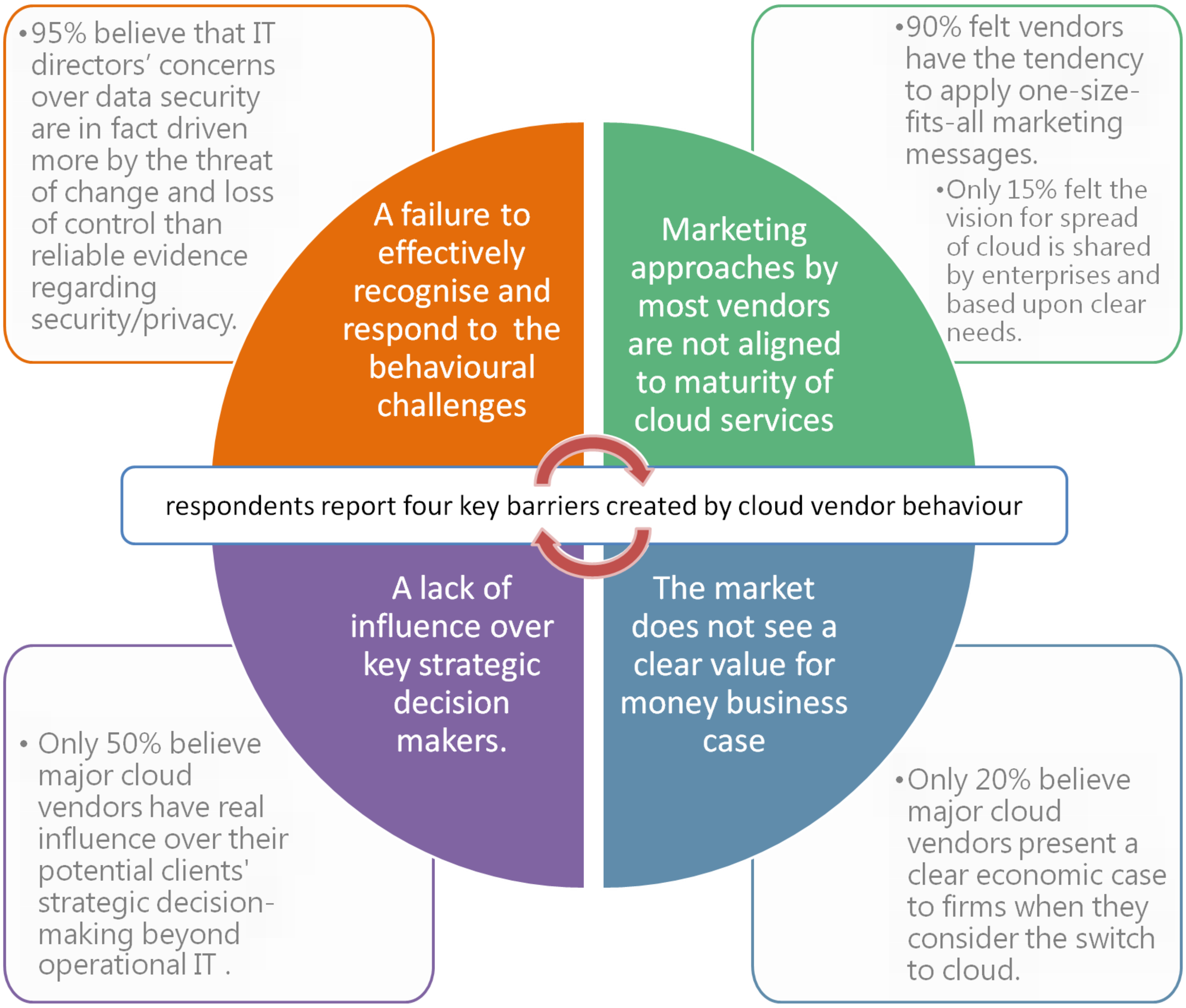
2) the behavioural challenge of change - 95% of our respondents believe security concerns are driven more by the challenge of behaviour change rather than evidence of poorer security provision, it is clear therefore, that vendors need to address threats both real and perceived;

3) the market does not see a clear consistent value for money business case for cloud - there appears to be a failure of vendors to present a clear economic case for cloud; this, surely, must be an easy fix for major vendors (worse still, this lack of clarity appears to be compounding concerns about security).

Two key insights emerged from additional qualitative feedback:

1. *Cloud computing promises to remain an exciting dynamic market.* 80% of respondents noted their observation that successful cloud solutions are equally likely to emerge from start-up, small, medium and large enterprises. Whilst the latter are more likely to bring infrastructure as a service to market by nature of their existing assets, the developer community, which is not the bastion of large enterprise, is an engine of creatively, growth and new solutions.
2. *Vendors lack simple impartial ways to demonstrate their environmental credentials*. 75% of respondents felt the economic case of cloud-services could be support with clear impartial evidence of its GHG abatement credentials, yet they report trustworthy, simple methods, data, and impartiality remain elusive.

In sum, whilst our survey instrument revealed a number of positive insights for cloud vendors, it also revealed **four themes that represent barriers to the widespread diffusion of cloud services, each created by commercial behaviour:**



Barriers created by public policy

Technologies such as cloud computing and others have the potential to enable significant carbon abatement. To maximise this potential, it is desirable to have a policy environment where these technologies can flourish.

Our aim was to enhance understanding of the barriers and opportunities public policies present to the ICT sector as the driver of technologies that can enable GHG abatement. In doing so, we sought to reveal patterns that can help deepen understanding about the impact of policy, which meant we did not seek to

- deliver a country-level analysis;
- critiques of specific, current policies; nor
- present an analysis embedded within a sympathetic understanding of the compromises imposed upon policy makers in the harsh realities of the policy design and negotiation process.

Our approach had to be specific enough to deliver useful insight, yet broad enough to able the evaluation of the many different forms of policies and the many different policy instruments employed by ministries across the world. We took six steps to complete this task:

Step 1: select a relevant policy for each country:

Ideally, we would have analysed the full policy landscape of each jurisdiction within scope. However, given the enormity of such a task and the resources at hand, we focused upon 13 policies selected by a panel of leaders from the ICT industry.

Step 2: create a framework to evaluate the design of each policy:

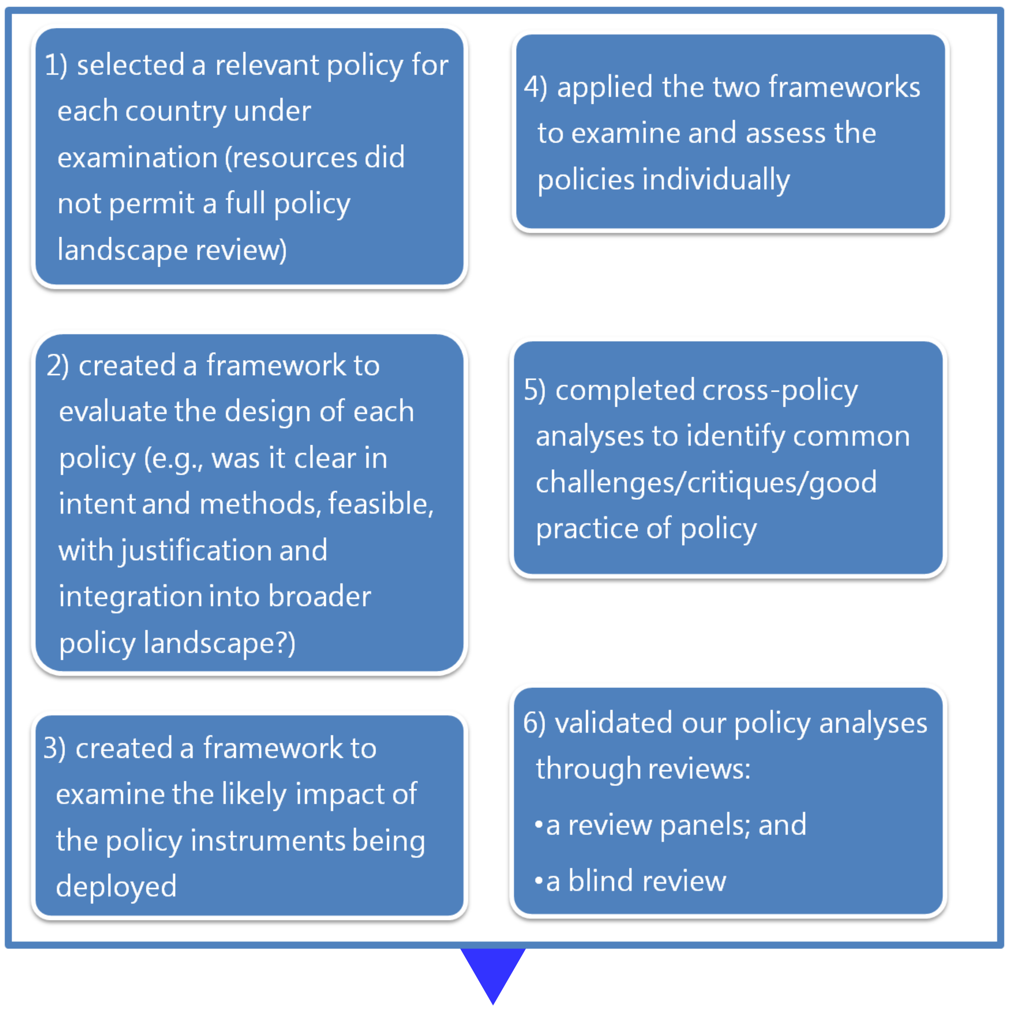
Our analysis of influential policy assessment work[32] revealed that it is useful to consider the design of a policy using four criteria:

I. The "**What**"
– is the policy clear about what it intends to achieve and its targets?

II. The "**Why**"
– does the policy provide a clear justification of its focus?

III. The "**How**"
– is it clear which instruments are being used and how?

IV. The "**Fit**"
– is the policy integrated into the broader policy landscape?



Region	Policy Chosen
Brazil	National Climate Change Plan
Canada	ecoENERGY Efficency Programme
China	the 12th Five Year Plan
Czech Republic	National RDI Policy
EU	(i) ETS & (ii) EEEF
France	Grenelle de l'environnement
Germany	National EEA Plan
Indonesia	National ECM Plan
Poland	Energy Policy of Poland
Portugal	National EEA Plan
Sweden	Integrated CC&E Policy
UK	CRC Energy Efficiency Scheme

32 Core publications used include:
- Hill, M. (1997). Implementation theory: yesterday's issue? Policy and Politics. 25(4): 375-385
- Jordan, A. (1999). The implementation of EU environmental policy: a policy problem without a political solution? Environment and Planning C: Government and Policy. 17:69-90
- May, P.J. (1992). Policy learning and failure. Journal of Public Policy. 12(04), 331-354
- Mickwitz, Per (2002). "Effectiveness Evaluation of Environmental Policy: the Role of Intervention Theories". 5th Conference of European Evaluation Society in Seville, 10 – 12 October 2002. Revised draft available at: http://www.finnishevaluationsociety.net/tiedoston_katsominen.php?dok_id=135, Accessed: 03 November 2011.
- Vedung, E. (2000) Public Policy and Program Evaluation, New Brunswick, N.J.: Transaction Publishers

A method based upon grounded theory[33] and 'blind review' was used to apply these criteria to generate a validated assessment of each policy:

- we assembled two policy analysis teams;
- each policy was analysed by two different people with prior policy analysis experience, but who did not have contact with each other;
- they were asked to assess each policy using the four criteria to produce evidence that shows how the policy was either:
  - completely and directly enabling of the ICT sector (e.g., through targeted subsidies);
  - indirectly supportive of enabling technologies (ETs) and the ICT sector (e.g., through taxes that incentivise energy efficiency indiscriminately);
  - ambiguous in its support of ETs and the ICT sector;
  - creating barriers for ETs and the ICT sector; or
  - completely disabling of ETs and the ICT sector.

Our grounded approach with blind review helped to (a) identify features of policy design that are likely to enable or inhibit the ICT sector and (b) validate such conclusions.

The insights of each independent researcher were aggregated by a third researcher (the lead author of this report) and presented for interrogation and refinement in three face to face review panels and a 'blind' review panel.

Step 3: create a framework to examine the likely impact of the policy instruments being deployed:

Our high-level review of the 13 policies revealed all government interventions employ policy instruments that fall into four broad types (see Table 4):

(i) regulatory,
(ii) economic,
(iii) behavioural and
(iv) government leadership,

Table 4: There are four types of policy instrument

Instrument types	Explanation. • ***examples of instrument in use***
Regulatory instruments	Seek to incentivise behaviour change using binding legal frameworks that set clear rules, objectives, targets, measures and benchmarks, within clearly defined timelines, to create specific shifts in target markets. Otherwise stated, "Regulatory instruments are legal, enforceable, 'command and control' type instruments aimed at reaching desired, prescribed environmental quality targets or performance standards by regulating the behaviour of individuals and/or firms".[34]. For example: • *binding targets within defined timelines (e.g., emissions limits, reduction targets, efficiency measurements, etc.)* • *standards (e.g. vehicle emissions standards, etc.)* • *permits and licensing* • *• accreditation systems*
Economic instruments	The use of fiscal and financial mechanisms to create positive and negative incentives, which result in specific shifts in target markets. For example:[35] • *market creation (e.g. emissions trading schemes)* • *fiscal instruments and charge systems (e.g. taxes, fines, subsidies, tax credits, etc.)* • *financial instruments (e.g., soft loans, revolving funds, grants, etc.)* • *liability instruments (e.g. environmental damage, health or property damage to consumers)* • *performance bonds (redeemable on satisfactory completion of a task, e.g., when a mining company has undertaken rehabilitation of the land)* • *property rights (e.g. quotas)*

33 See for example:
- Glaser, B. and Strauss, A. (1967). The discovery of grounded theory strategies of qualitative research, Wiedenfield and Nicholson, London.
- Strauss, A.L. and Corbin, J.M. (1990). Basics of Qualitative Research: Grounded Theory Procedures and Techniques, Sage Beverley Hills.

34 Seik, F. T. (1996) "Urban environmental policy: The use of regulatory and economic instruments in Singapore", Habitat International 20 (1): 5-22.
35 Australian Public Service Commission (2009). "Smarter Policy: choosing policy instruments and working with others to influence behaviour". Contemporary Government Challenges. Canberra: Australian Government., see page 10. Available: http://www.apsc.gov.au/publications09/smarterpolicy.pdf. Accessed: 06 November 2011.

Behavioural instruments	These incentivise behaviour changes that result in specific shifts in target markets through the explicit use of data transparency and knowledge-sharing. Such educational and information-based instruments can be broad or specific and can involve varying degrees of governmental effort. They include the following major categories:[36] • *education and training (e.g. media, targeted information campaigns and knowledge transfer)* • *corporate reporting requirements (e.g., full cost accounting, carbon emissions reporting)* • *community right to know laws - laws compelling disclosure of something (e.g., pollution and chemical hazards or executive remuneration)* • *public information registers (such as those for registered builders or health practitioners)* • *product certification and labelling* • *awards schemes*
Government leadership instruments	These instruments are employed when governments seek to create confidence in new technologies or practices through their procurement and service provision activities to encourage specific shifts in target markets (i.e., government behaviour is aligned with desired policy outcomes, and governments lead by example by being early adopters). For example:[37] • *public procurement (including choices, price preferences and clear government purchasing guidelines)* • *service provision* • *training government officials to effectively execute policy objectives within government departments* • *pilot/demonstration projects* • *public-private sector partnerships to increase confidence in innovation*

36 ibid, page 8-9.
37 These examples are build from a synthesis of:
- Marron, D. (2003). "Greener Public Purchasing as an Environmental Policy Instrument". OECD Journal on Budgeting 3(4), pp. 71-105. Available: http://www.oecd.org/dataoecd/2/14/43494535.pdf. Accessed: 6 November 2011 (see page 72);
- Makinson, S. (2006). "Public Finance Mechanisms to Increase Investment in Energy Efficiency". Basel Agency for Sustainable Energy. Available: http://www.sefalliance.org/fileadmin/media/base/downloads/pfm_EE.pdf. Accessed: 6 November 2011 (see page 9); and
- Vedung, E. (2000) Public Policy and Program Evaluation, New Brunswick, N.J.: Transaction Publishers

Traditionally, when evaluating the effectiveness of a policy instrument, researchers use two key classic perspectives and complete their analyses by employing two archetypal techniques[38]:

1. The value assessment perspective:

   This perspective is created when exploring if there is a match between what actually happens in the real world as a result of the policy intervention and what was expected to happen.

   Understanding value is classically achieved when the process of evaluation concerns itself with *goal attainment*. Firstly, evaluators define the objectives of a policy. They then outline the effects of the policy. Finally, evaluators perform a comparison of the two to determine whether or not the policy intervention reached its intended objectives, i.e., does the policy intervention attain its own preset goals?

2. The effects perspective:

   This perspective is created when exploring if changes in the world have actually transpired in any way as a result of the policy intervention.

   Understanding effects is classically achieved when the process of evaluation concerns itself with a scientific comparison of two equivalent, randomly created groups – an experimental group and a control group – both before and after the policy intervention. Should any differences between the groups be observed in the post intervention measurements, these differences ought to be attributed to the intervention, since all other factors are equal within two equivalent, randomly selected groups except the policy intervention itself.

However, today's analysts of policy interventions recognise the process is more complex and dynamic. Indeed, public interventions can and should be evaluated against many other value criteria than preordained intervention goals or an assessment of causal outcomes. Hence, policy evaluators can use at least six different types of value criteria in their analyses:[39]

38 Vedung, E. (2000) Public Policy and Program Evaluation, New Brunswick, N.J.: Transaction Publishers.
39 Derived from a synthesis of Vedung, E. (2000) ibid and Mickwitz, P. (2002). "Effectiveness Evaluation of Environmental Policy: the Role of Intervention Theories". 5th Conference of European Evaluation Society in Seville, 10 – 12 October 2002.

1. Post- or pre-implementation evaluations:

Evaluations of effectiveness can focus on the results of government interventions, either after policies have been delivered (ex post policy evaluations), or analyses of the likely impact/influence before policies have been launched or before they have completed their life cycle (ex ante policy evaluations).

Both are necessary and useful; however by logical extension the predictive power of ex ante policy evaluations is perhaps more useful to policy stakeholders such as industry, as it is *they* who directly or indirectly feel the impact of policy making.

2. Procedure-oriented evaluations:

Evaluations can check the procedural qualities according to which policy interventions are supposed to be handled by ministries and agencies, for example, legality, equity, representativeness, transparency, participation, publicity etc.

3. Unintended affects and effects:

The evaluation of effectiveness can and should go beyond the effects as related to the policy objectives and concern itself with the "unintended affects within as well as outside the target area of the policy"[40] and the resulting unintended side effects.

4. Policy impact from a stakeholder perspective:

It is now also common practice to evaluate policies with respect to stakeholder considerations; for example, the wishes and expectations of the public, industry, NGOs and others. This underpins a transition from evaluation as an academic exercise toward evaluation as a participative, deliberative and dialogue-based process, which is grounded in the process of representative democracy.

5. Utilisation of policy analyses:

It is also possible to evaluate policies against the ability of policy makers and their peers to utilise policy analyses. Utilisation of policy analyses is classically achieved when the process of evaluation concerns itself with observing whether goal attainment evaluations, effects evaluations and others have been actually utilised instrumentally by relevant decision-makers, i.e., used by policy makers to take new actions and to make better policy.

6. Economic evaluation:

Those seeking to understand effectiveness through an economic lens will attempt to build models to evaluate (a) how policies impact regional/national/sectoral *productivity*, and (b) whether policies are *efficient*, in terms of cost-effectiveness and costs versus benefits, both potential and actual.

Our primary policy analytical focus:

Given the scope of our task (to assess whether policies within our geographic focus are effective at minimising the barriers to the creation and adoption of technologies that will enable carbon abatement, with specific consideration to Cloud Computing) it did not make sense to evaluate policies using each of the above value criteria.

Instead, we felt it was possible to add a great deal of value by evaluating policy effectiveness with a smaller scope of ex ante analysis of policy impact from the industry stakeholder perspective.

Otherwise put, we wanted to know the ways in which instruments can support or block the ICT sector's invention and diffusion of enabling technologies. Specifically, we set out to evaluate how each policy instrument can help block or enable one or more of the ICT sector's four key objectives:

a) to accelerate the adoption of their technologies (specifically those that deliver energy efficiency);
b) to enable technologies to cross the chasm from early niche to mainstream markets;
c) to support the growth of early markets;
d) to stimulate the invention of new enabling technologies.

These four objectives were determined by logical extension of the fact that the ICT sector is concerned with selling its goods and inventing goods that will create competitive advantage. Much consideration has been given to the development and diffusion of technologies by scholars of technology adoption life cycles and innovation[41]

This work informs us that within a population of customers, some niches are more likely to adopt new practices and technologies than others. There will be some who want more information than others, and some with more levels dissatisfaction regarding the status quo than others.

40 Mickwitz, Per (2002: 72). "Effectiveness Evaluation of Environmental Policy: the Role of Intervention Theories". 5th Conference of European Evaluation Society in Seville, 10 – 12 October 2002. Revised draft available at: http://www.finnishevaluationsociety.net/tiedoston_katsominen.php?dok_id=135, Accessed: 03 November 2011.

41 For example, Rogers, E. M. (2003). Diffusion of innovations (5th ed.). New York, NY: Free Pres and Moore G A (1991). Crossing the chasm, Capstone

Hence, when confronted with the opportunity to switch to a new product, service or process, markets self-regulate along an axis of risk-aversion based upon their perception of cost versus value. This work also informs us that adoption from early niches to mainstream markets rarely follows the smooth trajectory presented in Figure 7. Indeed, a failure to adopt niche marketing approaches creates a chasm of diminished demand before the mainstream market is interested.[42]

Consequently, we assume cloud computing services will emerge following a similar adoption life cycle, where the rate of adoption can be modelled using a normal distribution curve, in which markets divide themselves into five subgroups, each with very different characteristics.

Given this backdrop, our research team completed two tasks:

(i) categorised all the instruments employed by each policy into the four types, and

(ii) appraised each instrument according to how they are likely to enable or block the four key objectives of vendors of enabling technologies.

The same dual research team and review process was employed as in the evaluation of policy design. Consequently, each policy was evaluated through the lens presented by the Table 5 and once again again, evidence was collected to assess how the policy instruments individually and then, collectively, were likely to:

- completely directly enable the ICT sector;
- be indirectly supportive of enabling technologies (ETs) and the ICT sector;
- create ambiguities for ETs and the ICT sector;
- create barriers for ETs and the ICT sector; or
- completely disable ETs and the ICT sector.

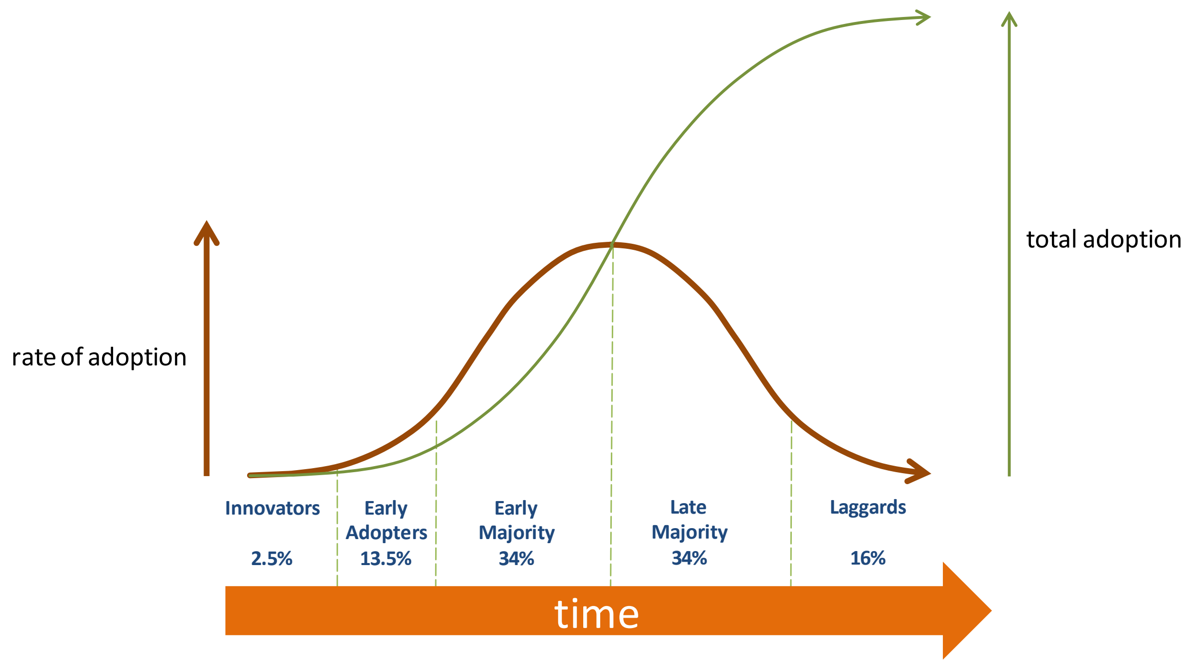


Figure 7: A standardised adoption life cycle

Ways in which instruments can support vendors		Types of Policy Instrument: Regulatory	Economic	Behavioural	Government Leadership
	A. Does it accelerate the adoption of technologies that deliver energy efficiency?				
	B. Does it help enable technologies to cross the chasm from early niche to mainstream markets?				
	C. Does it support the growth of early markets				
	D. Does it stimulate the invention of new enabling technologies				

Table 5: The four types of policy instrument mapped to the technology adoption life cycle

NB: our grounded approach with blind review once again helped to (a) identify features of policy instruments that are likely to enable or inhibit the ICT sector and (b) validate such conclusions.

42 See for example Moore G A (1991). Crossing the chasm, Capstone

Step 4: apply the two frameworks to examine and assess the policies individually:

On the surface, our early evaluations of each policy showed positive signs - most policies appeared to create an enabling environment for vendors of cloud and other enabling technologies. However, our two-pronged analytical approach – evaluating how the policies were designed for implementation and the likely impact of the policy instruments employed – revealed few policies were entirely enabling (Appendix 7 presents example summaries of the policy analyses produced for each jurisdiction examined):

Brazil's National Climate Change Plan appears to contain:

- weaknesses in intent/targets and implementation plans; and
- instruments lacking support for invention or stimulation of early markets, that are skewed to specific sectors, missing the value of ICT.

Canada's ecoENERGY Efficiency Programme appears to contain:

- major weaknesses in intent/targets, implementation plans and broader integration; and
- regulatory instruments that are likely to cause market distortions and other instruments that fail to embrace potential of ICT

China's the 12th Five Year Plan appears to contain:

- little to no implementation plan, though it is strong in terms of intent and targets; and
- some strong incentives for the ICT sector, even though a failure to demonstrate an understanding of technology diffusion undermines the effectiveness of such instruments.

Czech Republic's National RDI Policy appears to contain:

- a structurally and procedurally strong policy design, even if the implementation plans could be enhanced; and
- new regulations that centralises power with the RDI council that may cause a disconnect with stakeholders needs and opportunities

The EU's ETS & EEEF are:

- both excellently designed, let down by details in implementation and execution (in particular managing a price for carbon); and
- built with strong instruments that should, in theory, create an environment that will stimulate the ICT sector if implemented well.

France's Grenelle de l'environnement appears to:

- be generally strong, though weak in implementation plan and justification of focus; and.
- contain instruments that will (a) force firms to publish their emissions balance sheets and (b) support specific energy saving methods, which are likely to create disincentives for the ICT sector.

Germany's National EEA Plan appears to be:

- structurally and procedurally strong; and
- built using strong policy instruments, although German policy makers must be mindful that the ecotax might over penalise the ICT sector.

Indonesia's National ECM Plan appears to contain:

- a clear intent that is let down by most other policy design aspects - falling short when justifying its focus, integrating into other policies and presenting a clear plan, and
- policy instruments that (a) overlook opportunities to stimulate invention and early market growth of ICT, and (b) create market distortion skewed away from the ICT sector

The 'Energy Policy of Poland' appears to be

- only justified in reference to EU commitments, hence, lacking local customisation and presenting weaknesses in implementation plans; and
- weak in terms of instruments as a focus on built environment distorts attention away from potential of ICT sector.

Portugal's National Energy Efficiency Action Plan appears to:

- lack of political will to own EU requirements, hence its major weaknesses in justification of programmes; and

- offer no instruments to support early market growth (indeed, its certification and education programmes are likely to cause market distortions to non-ICT sector).

Sweden's Integrated CC&E Policy appears to be:

- structurally and procedurally strong, although it could enhance implementation plans; and
- equipped with enabling instruments, although changes to economic instruments (e.g., CO_2 tax relief) may reduce incentives for the ICT sector.

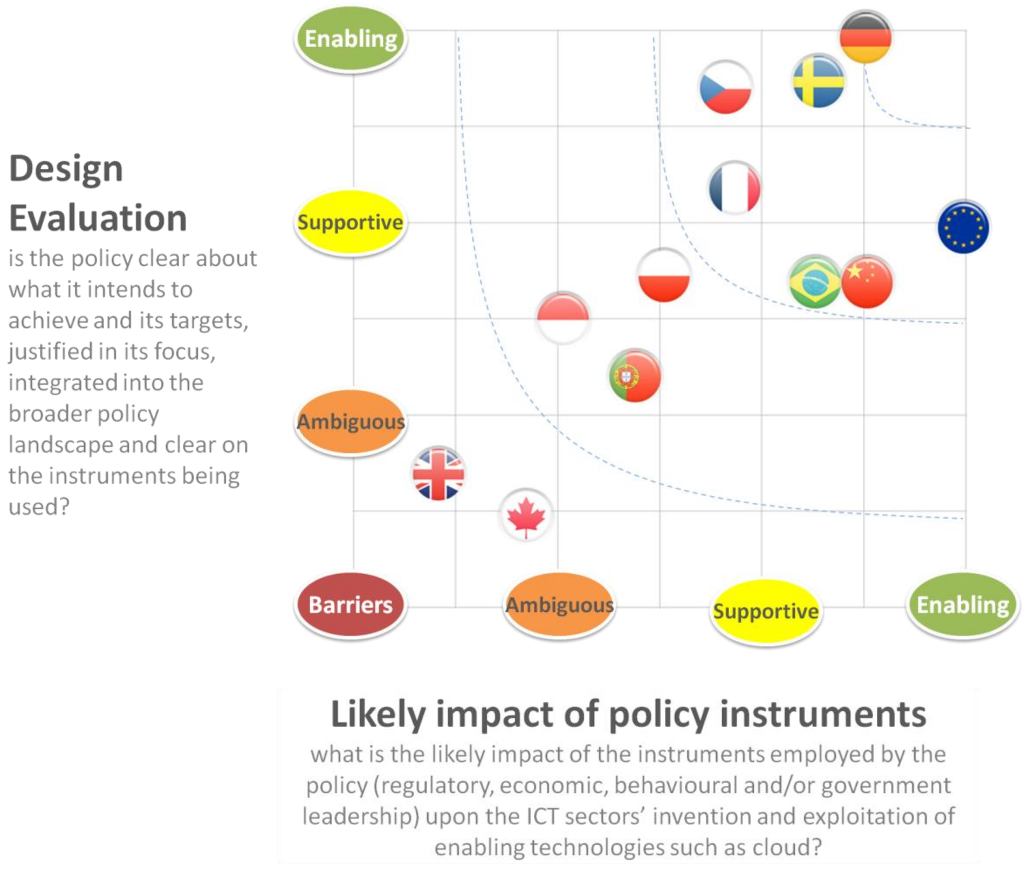


Figure 8: How the policies for each country compared in terms of design and likely impact of the instruments employed

The UK's CRC Energy Efficiency Scheme appears to:

- offer clear intent and targets, although weaknesses are present in all other areas of design; and
- proposes instruments which will penalise vendors of technologies that enable carbon abatement, through taxation and reputation damage in league tables.

Step 5: complete cross-policy analyses to identify common challenges/critiques/good practice:

Cross policy analyses were completed at three levels:

1. simply ranking policies by comparing policy design and likely impact of instruments;
2. a search for striking and common examples of good practice in policy design and the use of policy instruments;
3. a search for common challenges and striking examples of inadequate practice in policy design and the use of policy instruments.

We observed that all policies acknowledge the importance of technology. Figure 8 illustrates how the policies compare to each other, when plotting their aggregated evaluations onto a chart that contrasts design evaluation with the likely impact of instruments. It shows only 2 policies directly create an enabling context for the ICT sector (GER and SWE) to leverage technologies with the potential to abate GHG emissions. Six of 13 are broadly supportive but still create uncertainties. And 5 of 13 create ambiguities, direct barriers for the ICT sector.

We observed a number of examples of good practice policy design, which may support or build the ICT sector's confidence in the respective countries:

Intent and Targets:

- clear statement of intent and quantified targets, including sub-targets linked to the enabling technologies (SWE, GER)

Justification of Focus:

- recognition that enabling technologies have the potential to reduce overall emissions, while increasing their own (GER)
- acknowledgement of ICT solutions to reduce emissions (CHI, SWE, GER)

Implementation:

- clear structure (CZE, EU, GER, POR, SWE)
- stakeholder consultation in decision-making process (EU, FRA, GER, SWE, UK)
- clearly and effectively delineated roles and responsibilities (CZE, SWE, FRA)

Likewise, we observed good practice use of policy instruments that may support ICT sector's objectives in inventing and spreading the use of enabling technologies (Table 6):

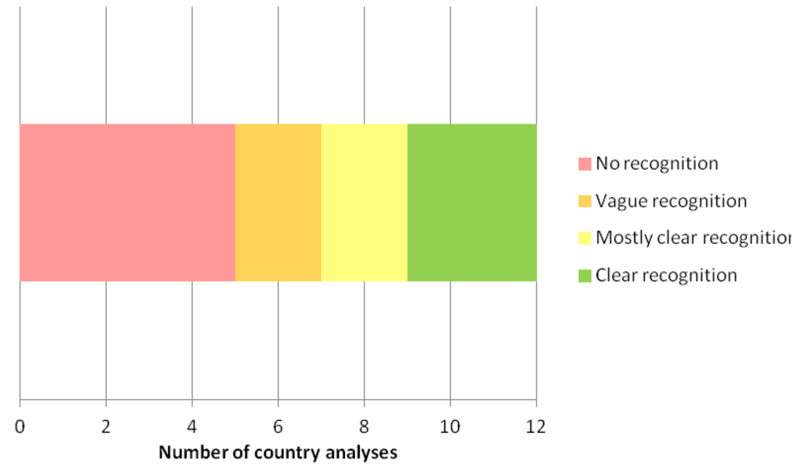
Table 6: Good practice use of policy instruments that may support ICT sector

Policy Instrument	Jurisdiction
Regulatory	
Existence of legally binding targets	CAN, CHN, CZE, DEU, EU, FRA, UK, POL, POR, SWE
'Cap' on emissions in cap and trade schemes	UK, EU
Penalties to enforce compliance	EU, UK, POR
Energy-efficiency standards for buildings	FRA
Economic	
Funding energy efficiency projects	CAN, CHN, CZE, DEU, SWE
Funding integrated concepts for ICT-based energy systems	DEU
CO2 allowances trading	EU, GBR
Mandatory purchase of CO2 allowances	GBR
Taxes	DEU, SWE, CHI
Behavioural	
Publication of CO2 emissions tables	UK, FRA
Voluntary eco-labelling in the ICT sector	DEU, FRA, POR
Awareness campaigns and expanding of education/training	DEU, IDN, POR, SWE, CHN, CZE
Government leadership	
Use of public procurement to support/stimulate energy efficiency	BRA, DEU, POR, SWE, FRA

Our cross policy analysis also helped to identify six negative trends for the ICT sector:

Trend 1: A failure to directly embrace the enabling potential of the ICT sector.

Only 3 of the 13 policies analysed appear to directly embrace the enabling potential of ICT:



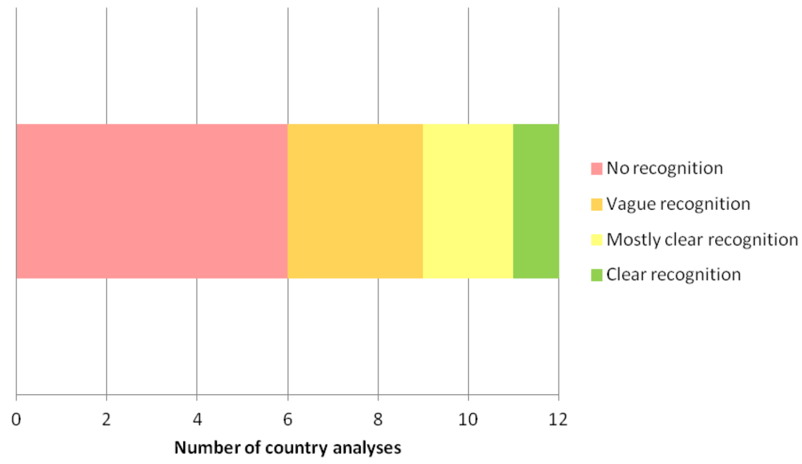
The majority of policies analysed did not appear to create either a particularly strong enabling environment, or a strong disabling environment for the ICT sector. Five out of the 12 country analyses made no mention at all of ICT in regards to energy efficiency; this represents a general trend to overlook the role of ICT in delivering energy and emissions savings. This lack of recognition of the carbon abatement potential of the sector has resulted in two indirect barriers:

- policies promote alternative solutions through eco-labelling, standards for other products, or subsidies, causing market distortion; or
- energy taxes or league tables could potentially penalise the ICT sector for increasing its carbon footprint without recognising the carbon abated from other sectors.

For example, the CRC Energy Efficiency Scheme (UK) set intentions to publish and track the emissions of large companies, thus encouraging enterprises to re-think their energy management strategies. This will potentially increase the demand for energy efficiency technologies in the UK. The scheme, however, does not differentiate enabling industries from non-enabling industries (i.e., enabling industries must also participate in the scheme). Therefore while enabling technologies such as cloud could satisfy the growing demand for energy efficient services, the Cloud vendors will simultaneously increase their own footprint and potentially suffer reputational and economic costs.

Trend 2: A failure to demonstrate an understanding of the technology invention and diffusion cycle.

Only 1 of the 13 policies studied (GER) demonstrates an understanding of the technology invention and diffusion cycle:



In most of the policies analysed, policy instruments support specific stages of the 'technology diffusion cycle' by default rather than design. Policies use the term innovation in an ambiguous manner, rather than referring to specific outcomes they would like to achieve across the stages of technology invention and diffusion. Only 1 of the 12 country policies presents a clear understanding of the technology diffusion cycle - Germany's National Energy Efficiency Action Plan. Its funding initiatives clearly set out to stimulate all stages of the technology diffusion cycle. Consequently, funding and support in the remaining 11 countries may not be directed where it is intended or most needed.

For example, in Portugal's National Energy Efficiency Action Plan, there is a focus upon standards and awareness campaigns that support technologies to 'cross the chasm' and spread. The failure to embrace a more complete view of the diffusion cycle misses the opportunity to support invention or early market development, (e.g., through R&D or funding pilot projects).

Trend 3: A failure to present 'the what' - clear intent and targets.

Despite the fact that most of the policies analysed demonstrate a clear statement of intent and high-level targets, only 4 of the 13 policies present any quantifiable sub-targets. Moreover, most policies are let down by a lack of action plans, missing the opportunity to clarify the role of ICT in the delivery of targets.

For example, while France's Grenelle de l'environnement has a clear overall target, it does not contain references to ICT solutions in its sub-divisions, except smart-metering in new buildings. This misses the opportunity to express how ICT has a role to play across most other areas, too.

Trend 4: A failure to explain 'the why' and 'the fit' - justifying goals and integrating into broader policy contexts.

Only 2 of the 13 policies appear to achieve the task of justifying their goals *and* demonstrating how they fit into the broader policy context.

Five of the policies analysed do not provide an adequate justification for the focus of their entire strategy. Some ignored entire sectors without explanation. Further, few policies offered evidence to support the selection of specific policy instruments employed to achieve the policy targets. This is important because poorly justified policies can result in policy failure in the implementation stage. This represents 'implementation failure' not because policies are not, in fact, implemented, but because they were not designed to adequately address the problem[43] [44]. This highlights important questions in the policy-making process in regards to enabling technologies, namely: are they considering all the options, and does the policy provide a sufficient response to the problem?

Likewise, policies do not appear to be properly integrated into their overall energy/environmental policy framework or other frameworks of ICT policies. This lack of integration is likely to result in policies that contradict each other, 'implementation failure' and missed targets.

For example, Poland's Energy Policy was predated by two years by a five-year EC-funded operational programme called 'Innovative Economy'. The €9 billion programme aims to boost use of ICT through infrastructural improvements, funding for R&D, and capital for early-markets and entrepreneurs. This programme could provide opportunities for state support in the diffusion of enabling ICT. However, the energy policy did not reference the programme at all—in terms of technology procurement or potential synergies. Moreover, the energy policy detailed further investment in R&D rather than supporting the diffusion of 'innovations' yielded by the operational programme. Likewise, 'Innovative Economy' did not acknowledge the enabling potential of ICT or emphasise innovation in energy efficiency. This lack of integration, which is common across all policies, misses the opportunity to link the inter-related causes of economic development and sustainable energy use.

Trend 5: A failure to demonstrate 'the how' – not embracing the full range of policy instruments available or offering clear implementation blueprints.

It would seem most policies are designed using precedence, rather than a logical overview of the possible tools available to achieve desired goals.

Only two of the relevant 11 policies utilise all four types of policy instruments. As a result, most policies seem somewhat unbalanced, relying too heavily on regulatory or economic tools, which may result in a lack of incentives for private investment, or otherwise create unnecessary market distortions. It is our contention

[43] Hill, M. (1997). Implementation theory: yesterday's issue? Policy and Politics. 25(4): 375-385.
[44] Jordan, A. (1999). The implementation of EU environmental policy: a policy problem without a political solution? Environment and Planning C: Government and Policy. 17:69-90.

that myopic choice of instruments results in unintended outcomes.

For Example, the French Grenelle de l'environnement uses a number of economic instruments that directly support alternative methods of energy efficiency, e.g., solar panels, tax refunds for house renovation. This creates market distortion for enabling industries because it creates a market for the adoption of other technologies rather than enabling technologies produced by the ICT sector.

The lack of overall delivery blue print within the framework of programmes in Canada leaves analysts lacking confidence in their reliability or validity.

Likewise, unclear plans for achieving targets through instruments and/or accountability (see CHI, BRA, POL, IDN, CAN, EU, UK) could create the perception that these countries lack political will.

Trend 6: The failure to embrace the power of 'government leadership' as a policy instrument.

Service provision, service procurement and demonstrator projects are all examples of government leadership that are broadly overlooked by the policy makers who wrote the documents studied by our research team (only 2 of the relevant 11 policies use such tools).

The final observation in our cross policy analyses reveals thee potentially problematic policy instruments.

1. Caution must be taken with league tables:

League tables designed to share the environmental performance of industries and/or business are not in themselves a bad idea. Open data on performance has been shown to be an effective behavioural tool in a number of contexts, take education for example.

In the case of vendors with enabling technologies such as cloud, a 'cut-and-dry' number detailing emissions could suggest poor performance badly despite facilitating significant reductions in emissions elsewhere. Simple rankings fail to tell the whole story, particularly the emissions avoided as a result of enabling technologies.

Hence, failing to account for the ICT sectors GHG abatement potential is likely to create unnecessary reputation damage when applying league tables as a policy instrument. British and French policy makers are driving the use of such approaches; they ought to do so with serious consideration of unintended consequences.

2. Great inclusiveness with subsidy and tax instruments should be considered:

Certain instruments are capable of creating market distortion by promoting the purchase of alternative energy-efficient technologies. Economic instruments such as tax refunds and subsidies, regulatory instruments such as building and product standards, and behavioural instruments including eco-labels all ultimately support particular products. If such support is offered to a 'cherry-picked' list of energy-efficient items, rather than a list generated through systematic appraisal (which could explain why ICT is regularly overlooked in such schemes), policy makers might promote less effective technology solutions. Such distorting effects that fail to include ICT solutions will send the wrong message both to vendors and customers.

3. Emissions trading must be enhanced:

It is now widely accepted that failing to limit the allowances in emissions trading schemes or to better manage the 'cost of carbon' is slowing market stimulation.

As previously mentioned, our grounded approach with blind review process has helped to:
(a) identify features of policy design and policy instruments that are likely to enable or inhibit the ICT sector and
(b) validate such conclusions.

7. The impact of barriers to adoption

Our analysis reveals that the extent to which cloud computing will achieve broad penetration remains unclear. It would seem that we face potential barriers created by both commercial behaviour and an uncertain policy environment:

Commercial barriers

Leaders of industry and trade associations highlight four vendor behaviours that may create uncertainties regarding the spread of cloud services:

- failure to present a clear economic case for cloud;
- failure to effectively recognise and respond to the need for clients' behaviour change;
- a failure to align marketing approaches with the maturity of cloud services (vendors are seduced by the prize of mass market penetration);
- a lack of influence over strategic client-side decision-making.

Policy-based barriers

Public policy can play an important enabling role in the decoupling of growth from GHG emissions. Nine of the 13 policies analysed were deemed to be supportive at a high-level but create unintentional market uncertainties, either through their design or application of specific instruments, or both.

The implication of barriers

Commercial behaviour and policy frameworks are creating an environment of uncertainty. Uncertainty usually results in cautious corporate investment and slow markets.

We can use technology adoption lifecycle modelling to understand the potential detrimental impact of such barriers; Figure 9 presents two scenarios:

- **Scenario 1** - Line A presents a scenario where there are no major commercial or policy-based barriers.
  In this scenario, we might predict that cloud-based email, CRM and groupware achieve 80% market adoption across all sectors by 2016.
- **Scenario 2** - Line B presents a scenario where there are commercial or policy-based barriers.
  In this scenario, a mere 2 year delay in achieving the same 80% level of adoption would reduce the 2016 GHG abatement potential by half.

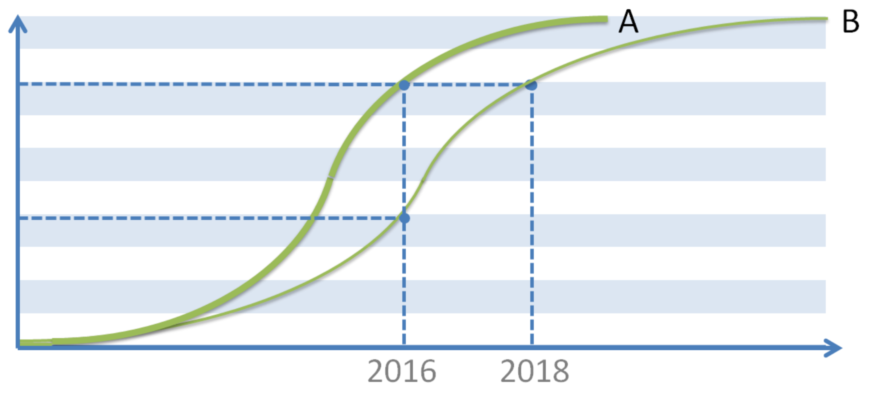


Figure 9: modeling the impact of delayed diffusion

It is, of course, possible to model additional scenarios, or to consider the different applications in different countries. Likewise, we could labour upon different shaped adoption curves to understand a range of possible outcomes. Nevertheless, a powerful point still stands from our simplistic presentation - small delays in the market adoption of enabling technologies can create large reductions in their GHG abatement potential.

8. Recommendations: opportunities to realise the potential of cloud

Vendors

If vendors embraced new ways of working, then the pace of adoption may not slow:

Prime responsibility for driving the market adoption of technologies that can abate GHG emissions, such as cloud computing, naturally lies with the ICT industry. To accelerate these outcomes, we suggest major vendors need to complete six actions:

1. Employ smarter approaches to **present a clear economic case** for cloud.
2. Support the economic case of cloud-services with **clear impartial evidence of its GHG abatement credentials**.
3. **Acknowledge that adopting cloud services may require clients to change deeply ingrained behaviours** (especially IT directors and their teams).
4. Respond to the challenge of behaviour change with evidence and tools to **make it easy for customers to switch to cloud**, leaving them incentivised to stay not coerced or worried about covert lock-in.
5. **Avoid one-size-fits all marketing approaches**; instead approach specific market niches with communications that address the unique unmet needs and the 'pain points' which each niche feels.
6. Embrace the principles of disruptive innovation. By avoiding a premature rush to mainstream markets, vendors can **grow to mainstream market penetration through niche marketing**.

Given the range of vendors and markets, these recommendations will not be expanded upon in this report. Instead we turn to how the business environment is influences by policy makers.

Policy Makers

If policy makers were to avoid common traps and embrace some new ways of working then the pace of adoption may not slow:

For policy makers to play an enabling role and avoid unintentionally creating barriers, we suggest they must:

1. **Embrace the ICT sector's enabling potential**.

We encourage environmental policy makers to embrace the ICT sector for its potential to deliver a low carbon economy. If policies that show a clear role for enabling technologies, such as cloud, they will not only send a clear motivating signal to industry but demonstrate policy aims are deliverable.

We highlight good practice in Germany, where policy makers clearly understand the opportunity afforded by embracing the ICT sector. The Federal Ministry of Economics and Technology (2012) states "further development of the energy industry will be impossible without fully drawing on the potential of digital intelligence and networking"[45]. This view is also supported by the funding of ICT-based energy systems through the National Energy Efficiency Action Plan. The integration of ICT and energy efficiency policies will accelerate the invention, development and spread of ICT-based energy efficiency solutions, which will support considerable energy savings and CO2 emissions reduction. Likewise, the expansion of the ICT industry will drive economic growth as well social benefits through job creation.

2. **Embrace an understanding of the technology "adoption lifecycle" into policy tools**.

If a critical component of future energy or environmental policy is to accelerate the diffusion of enabling technologies, then this ought to be based on a clear understanding of how technologies are invented, developed, and adopted. This understanding can be generated by studying the technology adoption life cycle process.

Once again, we highlight good practice employed by German policymakers with The E-Energy Technology Competition. This provides direct funding for enabling industries throughout the invention to adoption lifecycle. The competition directly acknowledges the linkages between energy efficiency and ICT, recognising enabling technologies, aiming to integrate chosen solutions and helping each to demonstrating their business case.

3. **Be clearer with the "WHAT", "WHY", "HOW" and "FIT"**

Being clear with the 'what' means policies make their purpose and goals clearer, both through statements of intent and quantifiable targets. These should be further supported by smaller sub-targets or clear action plans that lay out more specific policy goals.

This clarity should specify the enabling role of the ICT sector, either by explicitly creating policy instruments

45 Federal Ministry of Economics and Technology 'E-Energy' http://www.efficiency-from-germany.info/EIE/Navigation/EN/Technologies/e-energy,did=357404.html?view=renderPrint

targeting that sector, or by setting clear plans of action that clarify the role of enabling technologies.

We highlight good practice in the Czech Republic's National Research, Development, and Innovation Policy (NRDIP). It does a good job of clearly stating its main objective, which is to stimulate technology and industry innovation, then to describe seven further sub objectives that support the policy's goals (see Appendix 7 for further information).

Being clear about the 'why' means policy targets, priorities and instruments should be justified to explain (a) why policy makers have made their choices and (b) why other options were not pursued. Ideally we would like to see policy makers answer questions such as:

- What rationale was used to choose these targets, priorities, and instruments?
    - How did they derive the possible and desired GHG reductions?
    - What are the commitments made under international agreements or directives?
- Why does the policy target these sectors vs. others (e.g. the scope)?
- How will these policy instruments achieve the policy's main intent and target?
- Do (and then how) will the policy goals serve the greater policy problem?

Essentially, we are advocating a shift to transparent, real, evidence-based policy making rather than evidence-lite policy or policy-based evidence choosing (a process most governments are embracing). Due consideration to the possible solutions and decision-making process ought to be made clear, rather than a reliance upon precedent to define targets/priorities/instruments.

An important part of this is process is policy learning: "Rather, as with trial-and-error learning, learning can simply entail judgments about whether a given course of action or a given policy tool is still preferred relative to the alternatives currently being promoted. Copying or mimicking policy entails adoption of policy ideas without such understanding."[46]

We highlight good practice observed in Sweden's Integrated Climate Change and Energy Policy 2009. It clearly justifies targets in relation to international commitments, existing instruments and current progress against a 1990 benchmark. For instance, referencing EC and GEF funding mechanisms and how the policy mirrors or extends existing legislation. In doing so the policy acknowledges how it will fulfil the requirements of the Energy Services Directive, among others.

Being clear with the 'how' means policy makers ought to demonstrate they are utilising a balanced range of appropriate policy instruments. In doing so, policy makers are more likely to create a supportive environment for enabling technologies and better responses to a mixture of market inefficiencies.

We find policies that rely too heavily on one or two types of instrument (such as forms of regulatory or economic tools, which is usually the case), are less likely to create adequate incentives for private investment, or otherwise create market distortion. Hence, policy makers should seek to build policies that profile each instrument type. For instance, government leadership instruments, such as public procurement to support energy efficiency and carbon reduction are often undervalued.

We highlight good practice observed once again in Sweden. Its integrated Climate and Energy Policy is commendable for its broad range of policy tools, which encompass all four categories in our typology. Its dynamic profile of instruments creates a comprehensive framework of incentives and disincentives - such as government-led "green municipality" models, information campaigns, standards and regulations, and emissions taxes – helps to push both industry and society towards energy efficiency.

Being clear about the 'fit' means that all laws, programmes, institutions, and economic measures must be enacted with explicit consideration to pre-existing or concurrent legislation. And that this must be made explicit:

We propose this can be achieved in one of two ways:

- integration across policy issues - by incorporating relevant departments and sectors in the policy itself; or
- integration between policies by presenting the inter-relationships between the policy and other existing laws, commitments and programmes.

Integration is often thought of in terms of where the policy fits into the policy landscape. It can also be considered in terms of procedure, specifically inclusion of relevant stakeholders. Help to integrate experts, policy makers, and interest groups is useful, as all

46 May, P.J. (1992). Policy learning and failure. Journal of Public Policy. 12(04), 331-354

aspects of the policy landscape can be considered and represented in the decision-making.

We highlight good practice observed in the Czech Republic's National Research, Development, and Innovation Policy (NRDIP). It contains the Czech Republic's Programme of Support of Environmental Technologies. The programme's objective is to coordinate the development of environmental technologies in line with the EU's ETAP or Eco-Innovation for a Sustainable Future. In doing so, it also considers links with the National Reform Programme (which considered the exploitation of natural resources and reduction of energy intensity), the State Environmental Policy (which considers the energy industry, waste management, environmental degradation), and National Innovation Policy, (which is a precursor to the NRDIP policy) among others. Minor consideration is also given to policies in the framework such as the Energy Policy.

By being clearer with 'fit' the NRDIP makes the Czech Republic's wider goals of simultaneous economic and sustainable growth seem more achievable, believable and certain.

4. **Be careful when using policy instruments that appear to be troublesome**, This will reduce uncertainty when they are considered fit for purpose:

   a) ***League tables:***

   We note disclosure of GHG emissions is not a bad thing, if it is used to express the real environmental impact of companies. This might include also capturing emissions created by the products and services consumed by firms. Such actions might prevent the increase in GHG emissions experienced by enabling industries from having a negative reputational effect on these firms.

   League tables that create an aggregate social benefit through the overall reduction in CO2 emissions could be achieved by:

   - creating an indicator for enabling industries that shows the positive effect their production has on the entire country;
   - distinguishing in league tables between industries that also offer an enabling potential, or by
   - creating separate league tables for each industry.

Through these improvements, investors and customers are more likely to identify ICT vendors as a 'green' investment, when it is appropriate to do so.

To date, there is no example of good practice in this space. League tables have be considered by two countries (France and the UK), and there is, so far, no differentiation between enabling and other industries. This is likely to have a negative effect on the reputation of these companies.

b) Distorting economic tools:

Any and all policy instruments designed to promote the spread of energy-efficient products must take into account the potentially market-distorting effects. Policy-makers should be aware that a lack of targeted support for ICT, in favour of less impactful abatement solutions, could send the wrong signal to vendors and markets alike and inhibit the spread of enabling technologies.

While some policies do have market distortions that are positive for the ICT sector (e.g., compulsory energy meters for new homes in France), policy makers have to take into account that this represents a direct cost to alternative energy-saving solutions.

We highlight good practice observed by the EU EEE-F. It is a good example, as the fund provides support for projects based upon their outcomes in terms of energy efficiency. Instead of choosing specific products ('picking a winner'), they support projects that increase energy efficiency by at least 20%.

c) ***Government leadership broadly:***

This subject has been mentioned elsewhere in this report. In short, confidence in innovations can be further increased through a strategic use of public procurement, service provision, pilot/demonstration projects & partnerships. Government ought to see itself as a facilitator of markets for enabling technologies such as cloud.

d) Carbon/emissions trading:

It is now commonplace discussion in the press that the invention and adoption of energy efficiency technologies is being slowed by the oversupply of allowances in emissions trading schemes and a lack of carbon price management. Hence, suggestions will not be made here other than to say steps must be taken to (a) limit or reduce allowances and (b) create stronger incentives through stronger carbon prices.

By comparing the findings generated in our industry survey and policy analyses, it is possible to suggest four further recommendations for policy makers:

1. **Move to harmonize privacy and data protection rules.**
   Our research revealed most privacy and data protection issues raised by industry, with respect to cloud, are driven more from a fear of change than a legitimate logical argument regarding weaknesses in cloud services or regulation (indeed over 80% of respondents believed so). This said government action that is seen to support the harmonizing of privacy and data protection rules could help to instil more industry confidence in the transition to technologies such as cloud.
2. **Continue to free government data**.
   The spread of enabling technologies will be easier as it becomes easier for industry and consumers to understand why we need environmental policy and why we need technologies that can enable GHG abatement. Governments around the world have made great steps to free their data; they should continue this trend and continue to get creative with how they can support data mining to reveal needs and smart solutions.
3. **Cut red tape where it may constrain small to medium sized enterprises.**
   80% of our respondents highlighted that the developer community is likely to be a significant engine of growth in cloud and other ICT-based enabling technologies. The growth of the developer community, therefore, could in turn enable more GHG abatement. Hence, a move to cut constraining "red tape" could enable new and smaller developers to thrive.
4. **Help get ideas from labs to the market faster by removing barriers to funding.**
   Given the developer community is likely to be an engine of growth, faster, simpler access to finding could help accelerate the emergence and growth of high impact developers. Policy makers ought to consider how such steps could be taken.

9. Conclusion and limitations

This paper reports upon a methodology and a model developed to rigorously and transparently calculate the energy consumption reduction and subsequent GHG emissions reduction that might arise from a move from on-site computing to cloud computing. The approach extends previous work by including country level differences such as a mix of enterprise sizes and different GHG intensities of the energy supply. Two key aspects of this modelling were to differentiate between small, medium and large enterprises at the level of each country and to consider current and future market penetration levels.

The model was run for multiple countries assuming a cloud market penetration rate of 80%. Results show there is significant potential for GHG emission reductions in each country. Indeed 4.5 million tonnes of CO_2e could be reduced from the countries in scope through a move to cloud-based email, CRM and groupware services. For all countries in scope this represents, on average, 1.7% of the ICT sector's carbon footprint (using a conservative assumption that the ICT sector accounts for 4% of GHG emissions).

The results of this modelling broadly confirms previous commercial research that a shift to cloud computing can have a significant impact. However, the open model presented here can now be scrutinised, challenged and improved within the academic and commercial sectors to enhance modelling, explore other scenarios and create focus for further action.

The inclusion of enterprise size within the model revealed that over 60% of savings were accounted for by small and micro size firms. From the perspective of GHG emission reduction, this highlights that smaller enterprises have more to gain from a switch to cloud computing given their relatively inefficient use of on-site servers. By contrast, large firms utilise their on-site servers to better efficiency levels, hence, the attraction of shifting to the cloud is somewhat reduced from a GHG perspective.

Overall results show that the relative net emission reductions vary greatly for each country. Analyses revealed that this was due to a mixture of the GHG intensity of electricity and the variation in the current adoption of the three technology types analysed for each country. For example France has a low GHG energy intensity thus the reduction in GHG emissions is also low.

Unlike previous studies the sensitivity analysis performed highlights the possibility of a large variability in GHG reductions. The key variable to consider is the market penetration of cloud services. The 80% penetration used in the model accounted for 62% of the total possible GHG abatement. Sensitivity analysis revealed a non-linear rate of abatement. We show that a market penetration of 51% or more provided the largest increase in the rate of GHG abatement. In fact, if penetration only reaches 51% our model calculates that a mere 12% of the total GHG abatement can be achieved compared to the 80% adoption level.

Our modelling confirmed our prior belief about the relative importance of direct energy consumption compared to embedded carbon (i.e. the carbon generated in making servers in the first place). For cloud servers the impact of embedded carbon was included. Overall this accounted for 5% of the created GHG emissions related to cloud computing. The amortisation period used (5 years) was considered to be a conservative estimate and therefore this level may be lower. This reinforces the idea direct energy consumption in the key driver of GHG reductions.

It is clear that the critical parameter in our model is the extent to which on-site computing is replaced by cloud computing. In general terms, the extent of adoption of any new technology is typically driven by some combination of the technical feasibility (does it work, is it available), underlying economics (perceived benefits, costs and risks), behavioural aspects of the market (for example the amount of change that users are required to undergo) and public policy may also play a role:

- A main technological barrier could be the speed, availability and security of networks that supply cloud computing. This could cause a reduced uptake in certain countries. Mobile and wide area Wi-Fi are being adopted where little wired infrastructure exists, such as in Indonesia, these may serve to inhibit adoption of some cloud services.
- Our analyses of the behaviours and capabilities of cloud vendors suggest the sector may not be making the economics of cloud solutions clear to their market places. If true, a lack of clarity regarding benefits, costs and risks can cause a market place to hesitate. Likewise, it would seem the reluctance of incumbent IT directors to sanction 'outsourcing' of their computer resources on the basis of risk, may perhaps have as much to do with behaviour change as it does real challenges to data protection. Such conditions will only compound the challenges caused by a lack of transparency with the business case.
- Public policy may impact both on the economics and on people's willingness to change. For example, government regulations with respect to data privacy may unwittingly deter adoption (this subject must be examined in future studies). Likewise, policies that institute incentives to major IT companies to reduce their overall GHG emissions footprint fail to adequately take into account their potential to enable GHG abatement elsewhere and deter their enabling potential[47]. Similarly, unclear or ambiguous policy can create mixed signals to vendors and

47 Policy frameworks such as the progressive CRC Energy Efficiency Scheme in the UK consider the ICT sector as a consumer of energy; this risks the opportunity to embrace the ICT sector as an enabler of energy reduction too.

consumers alike, once again slowing down market adoption.

The importance of understanding technology adoption, and topics such as those discussed above, is enhanced by the model and approach described in this paper. By simply highlighting potential barriers to adoption and being able to estimate the impact of failed adoption on energy and GHG reductions we have provided a novel contribution to policy debate.

We identified six potential limitations of the modelling work presented in this study, which when overcome would greatly enhance results and applicability.

i. Our analysis has highlighted that the primary driver of the emission reductions is the net reduction of server devices being used. Results have indicated a 1:20 ratio for cloud to on-site servers which factors in the capacity of cloud servers and the multi-tenancy aspect of cloud servers. Yet, realised savings rely upon on-site servers being turned off and not being utilised for other purposes such as backup. It is likely that some on-site servers will continue to be used for other purposes, dependent upon age and capabilities. Hence, the estimates put forward in this paper may be an over estimate, though the conservative nature of our method will counter-balance these claims.

ii. The analysis covers the shifting of three services; email, CRM and groupware applications. As such this work underestimates the full potential of a shift to cloud computing. Further research is needed to understand the propensity to switch for other computing applications. We speculate that there might be a spectrum of such services from high propensity (e.g. the three applications included in the model) to low propensity (e.g. applications where security or latency concerns are paramount) suited for different business types. Indeed for large data sizes cloud computing may be less energy efficient than traditional computing.

iii. Although our model considers user devices to remain unchanged for both types of computing scenarios, the availability of cheaper, cloud-based computing services could stimulate growth in the use of computing in the long term. This might drive an off-setting increase in carbon emissions. Any such conclusion must await an assessment as to whether the expansion of computing has a net positive or net negative impact on energy consumption and GHG emissions.

iv. As stated in the method, where some parameters could not be directly or scientifically sourced, a series of expert workshops were conducted. This naturally leaves potential weaknesses in estimates. We expose all data all key in our appendices and would relish the opportunity to engage further with industry or academia to strengthen our numbers, conclusions and insights.

v. This study has examined the impact of shifting on-site computing to off-site cloud computing. However, a third scenario of a 'private cloud' has not been examined. This type of cloud scenario places the efficient servers and know-how into the hands of the enterprise to create their own on-site private cloud. This method may become more prominent to address security and legal concerns. Although more efficient than traditional service servers, on-site cloud servers may not be as efficient as off-site servers because of the lack of service volume and data centre specialisms.

vi. We have assumed cloud infrastructure is located in the same country as the on-site services it replaces. We can manipulate this variable in future modelling to generate additional insights, yet believe it would be best to do so based upon an analysis of likely cloud vendor locations.

vii. The "catch 22" of using a method like ours, which embraces primary and secondary data is[48]:

   a. secondary data relates less to the exact characteristics of specific products, whereas

   b. primary data from specific contexts limits technological comparisons and considerations of technology scale.

We've made efforts to overcome these challenges, through manual and extremely time consuming analyses. However, with access to common databases regarding server performance, data centre performance, user numbers, usage patterns and market penetration statistics, we would be able to enhance our conclusions. Perhaps in the future steps can be taken to incorporate internal power measurement into devices, and this data could be shared to a central database, anonymously, for researchers to support industry and policy makers alike.

viii. Finally, we have primarily focused on the reduction of GHG emissions caused by power generation. This underestimates the supply risks and resulting geopolitical and ecological problems caused by the demand for rare metals. And this demand is growing as hardware churn rates increase alongside the miniaturization and integration of technologies. For the ICT sector to be truly 'green' society must learn to embrace a hardware lifecycle that embraces a cradle to cradle service life.

48 Intellect (2012) "Evaluating the carbon impact of ICT or The answer to life, the universe and everything Accessed December 2012 at:: http://www.intellectuk.org/publications/intellect-reports/8597"

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APPENDICES

Appendix 1: How we employ life cycle assessment

ISO 14044 (Environmental management, life cycle assessment - requirements and guidelines) states a life cycle assessment (LCA) is the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle. ISO cites life cycle stages to be raw material acquisition, production, use, end-of-life treatment, recycling and final disposal. Similarly, the US EPA defines major life cycle stages as: manufacturing (including raw materials extraction, intermediate materials manufacturing, finished products manufacturing), finished product transportation, product use, and end-of-life (collection, reuse, remanufacturing, recycling, final disposal). Our project adopted a hybrid approach, as endorsed by GeSI: (1) material acquisition, (2) production, (3) distribution, (4) use and (5) disposal. It is possible to consider 'distribution' as spanning multiple stages of life cycle of some products, we keep it for the sake of simplicity in the pre-use phase:

Understanding LCA like this made us cognisant of the following opportunities and challenges created by adopting an LCA approach:

1. The traditional approach to an LCA, known as bottom-up or 'process-sum' (PS), has strengths and weaknesses;
    - they help generate rich local case studies of GHG emissions, with deep consideration of the components and processes used to create the technology, and the impact of the technology in a specific context of use through to its disposal at the end of its life cycle;
    - yet, PS LCAs are so context specific it is not useful to compare the results of different LCAs even if they assess the same technology, nor are such case studies useful when considering technologies at scale.
2. An economic input-output (EIO) LCA has strengths and weaknesses;
    - they use secondary data from economic and industrial analyses and population data from national statistics offices as a proxy to generate broad estimates of environmental impact of technologies at scale;
    - yet, they lack the specificity of primary to generate deep understanding or insight at a more local scale.
3. It is also possible to create a hybrid LCA approach - PS-EIO;
    - this is the method we employed, to emphasises macro data as much as process-sum data, as this enabled us to keep the richness of aggregated local data, yet move beyond local case studies to predict the impact of our enabling technology at scale.
4. It is possible to further enhance hybrid PS-EIO LCAs by integrating knowledge of technology adoption cycles within the 'use' phase of an LCA. Specifically, models can be enhanced by recognising that customers' perception of cost vs. value will lead them to self-regulate along an axis of risk aversion - adopting the use of a new product or service at different times and for different reasons (Figure 10). Five key factors are said to bare the most influence[49]:
    - Advantage - to what extent does a new service/technology offer advantage relative to current solution?
    - Compatibility - to what extent is the new service/technology compatible with current ways of working?
    - Complexity - to what extent is adoption of a new service/technology a complex decision and adoption process?
    - Trialability - to what extent can potential adopters trial new service/technology solutions?
    - Observability - to what extent can potential adopters see the experiences of existing adopters?

49 Rogers, E. M. (2003). Diffusion of innovations (5th ed.). NY:Free Press, New York, USA.

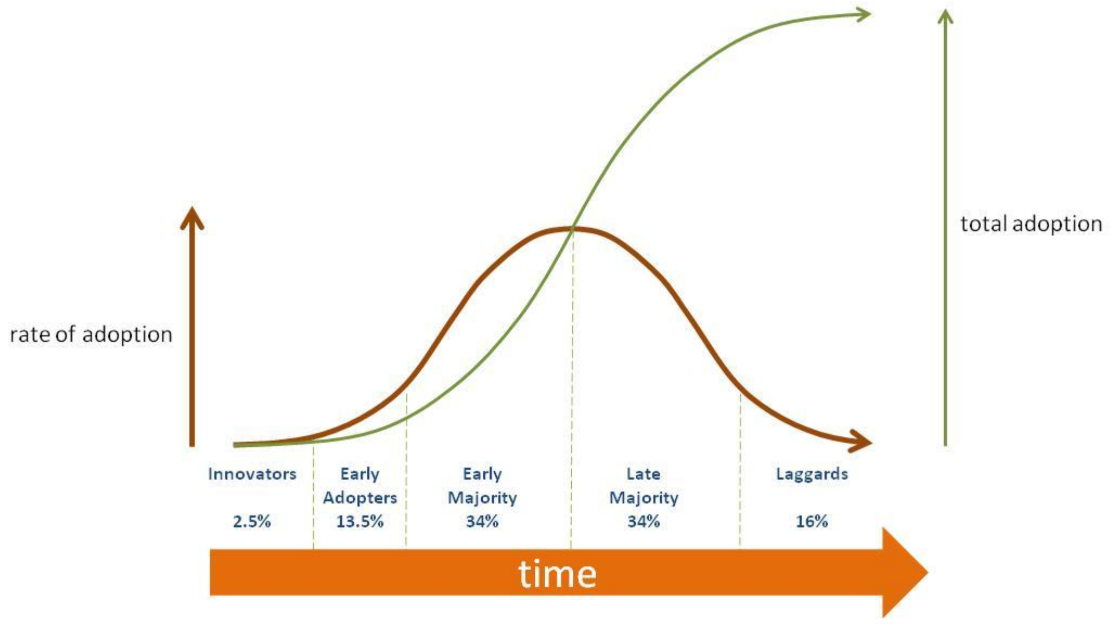


Figure 10: Technology adoption cycle:
different niches of customers will adopt the same technology at
different times but for different reasons

By integrating a technology adoption life cycle perspective into hybrid LCAs, it is possible to better understand how actions by both industry and policy makers are likely to impact technology adoption and therefore the GHG emissions and abatement potential of any chosen technology. In doing so we can suggest how vendors' marketing and sales approaches may be tuned to drive technology adoption, or not; equally, we may suggest how policy frameworks may create incentives or disincentives for consumer or industry behaviour.

APPENDIX 2: ANALYTICAL SCOPE - FURTHER DETAILS

The table below presents our basic assumptions regarding Cloud Computing versus the business as usual 'on-site' solutions:

System	Description	Components
New ICT "Cloud Computing"	*Virtual distribution and use of computing services, via dedicated data cntres.*	*(1) servers (2) network services (3) server cooling systems (4) data centre buildings*
Business as usual "On-site Computing"	*Computing services provisioned within an enterprise or home, via on-site servers.*	*(1) servers (2) network services (3) server cooling systems (4) on-site centre where servers are stored*
	Physical distribution of data (e.g. Software on CDs).	*(5) data on CDs (e.g. Software) (6) distribution of software CDs*

The following three tables summarise the factors that will create or reduce carbon emissions in a switch from on-site to cloud computing; it also highlights which are excluded by our analysis and why, and links each to the core components of the enabling technology under examination.

	Category's as defined by GeSI	Effect ID	Identified effects	Exclude?	Rationale if excluded	Method for Calculation	System components assessed
[+] Direct emissions from Cloud Computing	Material Acquisition, production, distribution and disposal	D1	Harvesting raw materials, converting the materials into components and infrastructure for Cloud Computing, distributing the components and decommissioning at the end of their useful life.			WSP analysis in Accenture report states 203kg CO2e/server.	(1) servers (2) network services (3) server cooling systems (4) data centre buildings
	Use	D2	Carbon emissions created by the energy produced to power the Cloud Computing infrastructure			Accenture formula, excluding Hardware embedded carbon	(1) servers (2) network services (3) server cooling systems (4) data centre buildings
[-] Primary carbon abatement enabled by Cloud Computing	Reduced energy consumption via enhanced efficiency or reduced operations	PE1	on-site servers and related infrastructure permanently switched off - made redundant by shifting 'first wave' of computing applications to the cloud.			Accenture formula, calculated for three firm sizes and excluding Hardware embedded carbon.	(1) servers
	Reduced or eliminated materials	PE2	Reduced production of CDs, DVDs and packaging, replaced by 'first wave' of data (e.g. Software) made digitally accessible on the Cloud	Yes	*This will be modelled in later analyses*	Estimate on carbon emissions of CD/DVD production and packaging.	(5) software on CDs
	Reduced or eliminated travel/shipment as vehicles are used less frequently to move people or distribute goods	PE3	Reduced transportation of CDs and DVDs containing 'first wave' of data (e.g. Software) made digitally accessible on the Cloud	Yes	*This will be modelled in later analyses*		(6) distribution of software CDs

	Category's as defined by GeSI	Effect ID	Identified effects	Exclude?	Rationale if excluded	Method for Calculation	System components assessed
[-] Secondary carbon abatement enabled by Cloud Computing	Reduced use of goods or vehicles as a result of increased scale of adoption and learning effects	SE1	on-site servers and related infrastructure permanently switch off - made redundant by shifting 'future wave' of applications to the cloud	Yes	We are limiting our analysis to three applications that are likely to be moved to the cloud during the 'first wave'		(1) servers
		SE2	Less people travel to work because cloud applications mean they access information they need wherever they are	Yes	*This could be modelled in later analyses*	Find the average transport footprint per head of population and assume a % reduction in this for all office workers	
		SE3	Reduced production of CDs, DVDs and packaging, replaced by 'future waves' of digitally accessible data (e.g. Software, film)	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.		(5) software on CDs
	Eliminated production of goods or vehicles (Including reduction in the number of manufacturing facilities)	SE4	Reduced production of servers	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.		(1) servers
		SE5	Reduced manufacturing facilities for CD/DVD media and packaging	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.		
		SE6	Reduced production of distribution vehicles	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.		
	Reduced use of infrastructure as a result of increased scale of adoption and learning effects (such as buildings or roads)	SE7	Reduced use of server room cooling systems to reflect fewer running servers	Yes	This has been included in our analysis in the form of Data Centre Power Usage Effectiveness		(3) server cooling systems
		SE8	Reduced use of road infrastructure	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.		
	Eliminated development of infrastructure	SE9	Reduced production of server infrastructure	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.		(4) on-site centre where servers are stored
[-] Primary rebound effects of Cloud Computing	Increased energy consumption	PR1	Increased energy consumption as cash savings are used to open existing cloud applications to new users.	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.		(1) servers (2) network services (3) server cooling systems (4) data centre buildings
		PR2	Increased energy consumption as cash savings are reallocated to provide new Cloud applications	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.		(1) servers (2) network services (3) server cooling systems (4) data centre buildings

		PR3	Increased energy consumption as cash savings are reallocated to increase other carbon emitting processes such as manufacturing	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.	(1) servers (2) network services (3) server cooling systems (4) on-site centre where servers are stored
		PR4	Increased energy consumption as reduced cost barriers to Cloud-based applications increases SME demand	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.	(1) servers (2) network services (3) server cooling systems (4) data centre buildings
	Increased travel or shipment		n/a			
	Increased materials		n/a			
[-] Secondary rebound effects of Cloud Computing	Increased use of goods/vehicles	SR1	Increased use of cell phones and personal computers and other devices connecting to the Cloud, as more people access their information virtually, in more places and in more ways.	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.	
	Increased production of goods/vehicles	SR2	Increased production of cell phones and personal computers (and other devices) tat can connect to the cloud as more people want to access their information in more places.	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.	
	Increased use of infrastructure	SR3	Switched off servers seen as spare IT capacity - savings subsequently diminished as servers are switched on to provide access to new applications.	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.	
		SR4	Increased energy consumption from phone and comms networks as more people access information in more places	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.	(1) servers (2) network services (3) server cooling systems (4) data centre buildings
		SR5	Increased energy use at home as people spend more time teleworking	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.	
	Increased development of infrastructure	SR6	More comms infrastructure is developed as more people need to access information remotely	Yes	a) We could not find a precedent/model to describe this impact b) We did not have the resource to model this impact.	

APPENDIX 3: GHG ABATEMENT - THE DATA AND HOW THEY WERE USED

This appendix summarises the key steps of the developed method and the results of the subsequent modelling to calculate the energy and carbon impact of enterprise cloud computing (see Appendix 4 for financial calculations). The basic logic involved in this process encompassed:

a) Calculating the energy consumption and related CO_2e emissions created by on-site servers and server infrastructure used by enterprises to provide their employees with email, CRM and groupware services.

b) Calculating the energy consumption and related CO_2e emissions that would be created by a cloud computing infrastructure capable of replacing these on-site services.

c) Determining the impact upon both computing types if cloud computing achieved 80% market penetration for these three services, assuming that the on-site servers are decommissioned.

d) Evaluating the sensitivity of the emissions reduced when the market adoption rate and enterprise cloud adoption rates changed.

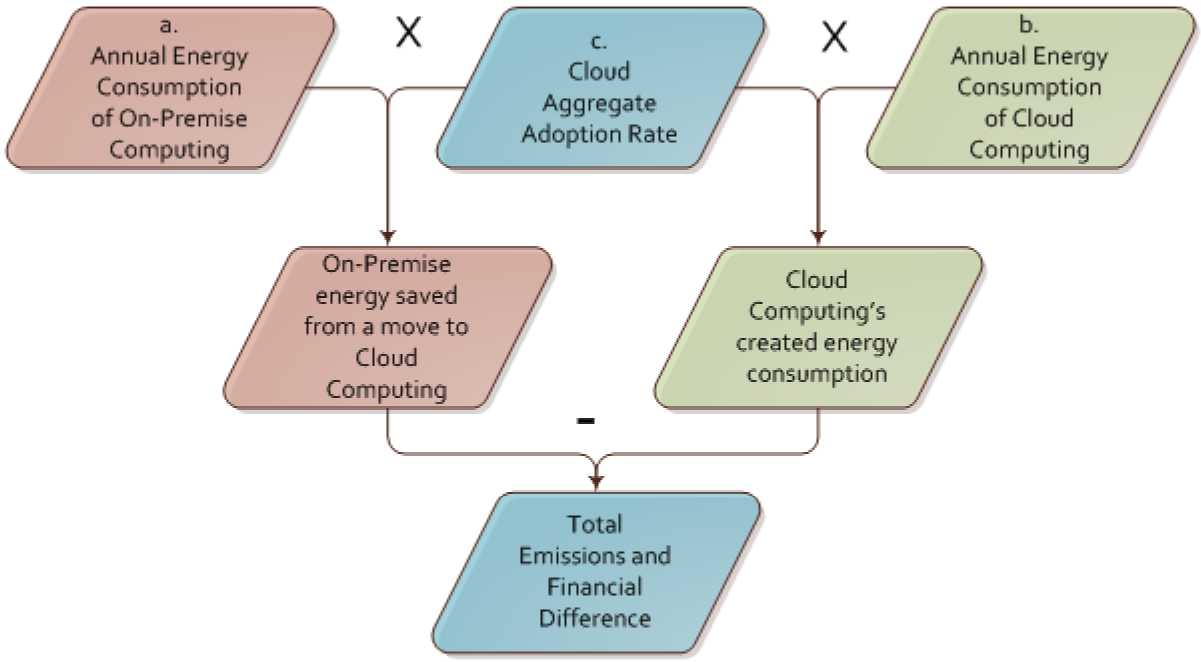


Figure 11 – The basic logic steps involved to calculate the impact of cloud computing. The alphabetic headings relate to the following sections.

Let us first recap our research scope. The services of email, CRM and groupware were analysed using the developed methodology. These products were chosen as they exist in both traditional and cloud forms and require the use of a server in both situations. However, cloud computing encompasses many different types of computing such as processing, storage, software and operating system services. Each type of cloud service was generically analysed in order to avoid a particular software or service provider.

The logical model of a cloud data service can be viewed as using a server, network and end user device. The focus for the modelling activity was the shift of servers from on to off-site. Therefore network and end user device energy consumption was not included.

In order to represent a diversified set of countries the following were selected for analysis based upon their different stages of growth in the cloud market; Canada, China, Brazil, The Czech Republic, France, Germany, Indonesia, Poland, Portugal, Sweden and the UK. For each country all data collected was for the year 2007 or 2009. More current data for all countries and variables was not available.

For each country the model was run for a small, medium and large enterprise demographic. This approach was utilised to account for the variances between different sizes of enterprises in terms of on-site server utilisation, the adoption of each application and the adoption of cloud services.

a) How we made our 'on-site' calculations:

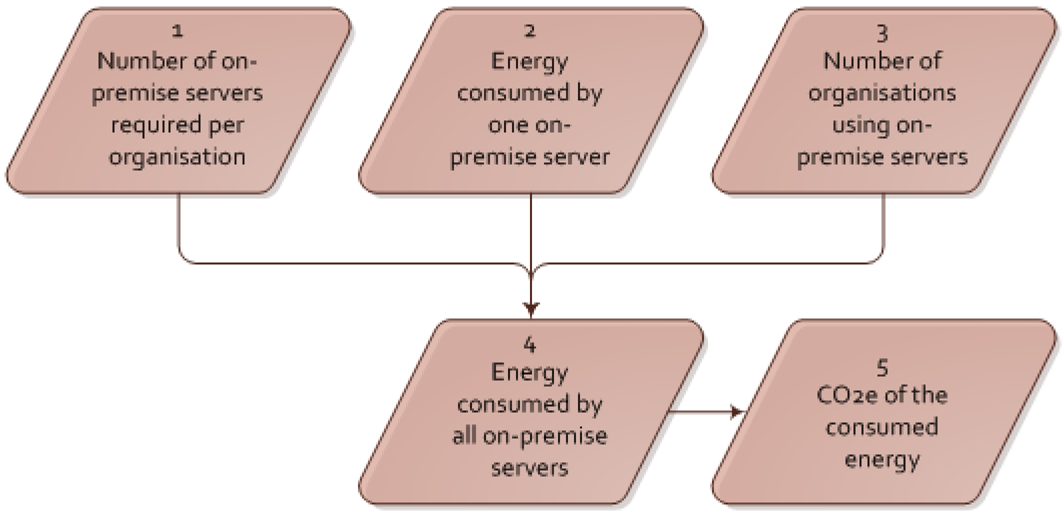


Figure 12 – The basic steps taken to calculate on-site emissions. The headings relate to the following sections.

1. How many on-site servers are required to provide email, CRM and groupware to an enterprise?

The number of on-site servers required to provide services in any enterprise depends on the number of people it employs. Because of the large variability of enterprise size (from one-person operations to enterprises with thousands of employees), it was necessary to consider different enterprise size categories and their unique requirements (Table 7). For European countries Eurostat was used as a data source which considers large enterprises to be any firm with more than 250 employees, with an average of 500[50]. Data for Brazil, Indonesia, and China could not be located. Therefore, Brazil and Indonesia were assumed to have a similar enterprise size to European countries due to their similar small to medium size and population similarities. For China an estimate was made based upon the size of all countries in scope including data from the USA[51] because of similarities in size. For Canada 'Statistics Canada' was utilised as a data source[52].

Table 7 - Enterprise types and average number of employees per enterprise

Country / Region	Average number of employees in each Small Enterprise	Average number of employees in each Medium Enterprise	Average number of employees in each Large Enterprise
European Countries, Brazil & Indonesia	25	150	500
Canada	50	300	750
China	25	250	1000

Within an enterprise, only some employees will have access to certain applications. For instance, each person may have an email address, but only client facing employees are likely to have access to a CRM system. This proportion is likely to differ based on the size and type of the enterprise. Based on the average enterprise sizes (above), we estimated the average user numbers for each service in each enterprise size (

50 Eurostat (2008) Enterprises by size class - overview of SMEs in EU. http://epp.eurostat.ec.europa.eu
51 US Census Bureau (2007) Employment size by Employer and Non employer Firms 2007. http://www.census.gov/econ/smallbus.html
52 Statistics Canada (2007) Employment by Enterprise Size 2007. http://www40.statcan.ca/l01/cst01/labr75h-eng.htm

Table 8).

Table 8 - Average number of users per enterprise for each application

	Country / Region and Enterprise Size	Average number of email users	Average number of CRM users	Average number of groupware users
small	European Countries, Brazil & Indonesia	25	12.5	25
	Canada	50	25	50
	China	25	12.5	25
medium	European Countries, Brazil & Indonesia	150	60	150
	Canada	250	120	300
	China	250	100	250
large	European Countries, Brazil & Indonesia	500	125	500
	Canada	750	187.5	750
	China	1000	250	1000

When estimating server numbers, it was necessary to consider the characteristics of the server being deployed. Servers can be categorised into volume, mid-range and high-end types[53]. Email, CRM and groupware are not demanding applications and therefore we assumed that volume and mid-range servers provisioned these services. Our expert panel suggested that small and medium sized enterprises would typically use mid-range servers, while large enterprises and data centres would utilise volume servers. In order to estimate the average number of on-site servers required to provide its employees with email, CRM and groupware services our expert panel suggested the numbers presented in Table 9.

53 Gartner (2011) Quarterly Statistics: Servers, Worldwide, 4Q10 Update' - 24 February 2011, ID:G00210594.

Table 9 - Average number of servers for each service by country and enterprise[54]

	Country / Region and Enterprise Size	Average number of servers to provide email	Average number of servers to provide CRM	Average number of servers to provide groupware
small	European Countries, Brazil & Indonesia	1	1	1
	Canada	1	1	1
	China	1	1	1
medium	European Countries, Brazil & Indonesia	1	1	1
	Canada	2	1	2
	China	2	1	2
large	European Countries, Brazil & Indonesia	3	1	3
	Canada	4	1	4
	China	5	2	5

2. **How much energy would be consumed annually by on-site servers and server infrastructure used to supply email, CRM and groupware services to an enterprise?**

To calculate the annual energy consumption of a server we used data (Table 10) and methods from recent research by Williams and Tang[55] looking at the average power consumption of popular volume and mid-range servers.

Table 10 – The average power consumption of volume and mid-range servers

Server Type	Average Power Consumption (kW)
Volume Server	0.198
Mid-Range Server	0.593

In addition to the server's power consumption, we also considered the additional data centre infrastructure required for servers to operate. This falls into three categories:

- Storage (approximately 15% of power consumption)[56];
- Networking (approximately 15% of power consumption)[57]; and
- Power Usage Effectiveness, incorporating remaining auxiliaries such as power supply and cooling (a multiplier of 1.3, 1.8 and 2.1 in small, medium and large enterprises respectively)[58].

54 The 10% scale-up for large enterprises has been included to account for backup servers operating in the background, ready to take over if main servers fail.
55 Williams, D.R., and Tang, Y. (2012) Methodology To Model the Energy and Greenhouse Gas Emissions of Electronic Software Distributions. Environmental Science & Technology, 46, 2, 1087-1095.
56 ibid.
57 ibid.

We calculated the average power consumption and annual energy consumption per server (Table 11) in each enterprise size. We assumed small and medium enterprises used Mid-Range servers and large enterprises used Volume servers.

Table 11 – The average power consumption of each server type and its related server infrastructure

	Average Power Consumption per server (kW)	Annual Energy Consumption per server (kWh)
Small Enterprise	1.02	8,931
Medium Enterprise	1.41	12,366
Large Enterprise	0.55	4,817

Consequently, the total annual energy consumption (kWh) of on-site servers and associated infrastructure supplying on email, CRM and groupware to an enterprise was calculated (Table 12).

Table 12 – The annual energy Consumption of servers and server infrastructure providing email, CRM and groupware to an enterprise

	Country / Region and Enterprise Size	Annual Energy Consumption of servers and server infrastructure (kWh)
small	European Countries, Brazil & Indonesia	26,793
	Canada	26,793
	China	26,793
medium	European Countries, Brazil & Indonesia	37,098
	Canada	61,830
	China	61,830
large	European Countries, Brazil & Indonesia	33,720
	Canada	43,354
	China	57,805

3. **How many enterprises use on-site servers to supply their employees with email, CRM and groupware in each country?**

To calculate the number of enterprises using on-site servers for the services in scope we first determined the number of enterprises where internet use was common. For Europe, we base this calculation on data that revealed the percentage of employed persons using computers connected to the Internet in their normal work routine[59]. For Canada an estimate was made from an internet usage survey[60]. For China, Brazil and Indonesia primary data could

58 Federal Ministry for Environment (2010). Nature Conservation and Nuclear Safety (2010) report: Material Existence of the data centres in Germany. http://www.umweltdaten.de/publikationen/fpdf-l/4037.pdf
59 Eurostat (2010) Persons employed using computers connected to the Internet in their normal work routine at least once a week. http://appsso.eurostat.ec.europa.eu/
60 Statistics Canada (2009) Canadian Internet Use Survey.http://www.statcan.gc.ca/daily-quotidien/100510/dq100510a-eng.htm

not be sourced and was inferred from a mix of averages[61,62,63,64,65]. In order to calculate the number of potential work internet users in each country we multiplied the percentage of enterprises where internet use was common with the total employed population of the country[66,67]. To portion this to small, medium and large enterprises, we multiplied the number of work internet users by the breakdown of employment by enterprise size[68] (Table 13).

Table 13 – The calculated number of people with regular internet access at work

Country / Region and Enterprise Size	Number of people with regular access to internet connected computers by Enterprise Size	Number of people with regular access to internet connected computers in Country
France Small	5,028,164	11,248,688
France Medium	1,777,293	
France Large	4,443,232	
Germany Small	7,620,220	18,704,177
Germany Medium	3,669,688	
Germany Large	7,414,268	
Sweden Small	1,178,974	2,596,860
Sweden Medium	475,225	
Sweden Large	942,660	
UK Small	5,436,913	13,976,640
UK Medium	2,124,449	
UK Large	6,415,278	
Czech Rep. Small	746,569	1,575,040
Czech Rep. Medium	316,583	
Czech Rep. Large	511,888	
Poland Small	2,479,558	5,029,530
Poland Medium	945,552	
Poland Large	1,604,420	
Portugal Small	998,786	1,550,910
Portugal Medium	255,900	

61 China Internet Network Information Center (2007) Statistical Survey Report on The Internet Development in China. http://www.cnnic.net.cn/.
62 DePaul CDM University (2008) Network Society of Brazil. http://facweb.cs.depaul.edu/yele/Course/BrazilDecember08/society.html.
63 Designative (2012) Internet in Brazil: 33% of Brazilians have Internet access at home. http://designative.info/2012/05/17/internet-in-brazil-33-of-brazilians-have-internet-access-at-home/.
64 Coolfounders (2009) A Broader Look at Indonesian Startups and Internet Business Prospects. http://coolfounders.com/indonesia-now-a-broader-look-at-indonesian-startups-and-internet-business-prospects/.
65 JakartaGlobe (2010) Internet Users in Indonesia to Triple by 2015: Report. http://www.thejakartaglobe.com/business/internet-users-in-indonesia-to-triple-by-2015-report/394066..
66 LABOURSTA (2010) Employment General Level, 2007, Switzerland: International Labour Office. http://laborsta.ilo.org.
67 World Resources Institute (2007) Climate Analysis Indicators Toolkit V8, 2007. Population in 2007. http://cait.wri.org/cait.
68 Eurostat (2010) Structural Business Statistics - Employment breakdown by enterprise size class, non-financial business economy, 2007. http://epp.eurostat.ec.europa.eu.

Portugal Large	296,224	
Canada Small	2,805,220	7,083,888
Canada Medium	1,069,667	
Canada Large	3,209,001	
China Small	6,755,873	27,023,490
China Medium	6,755,873	
China Large	13,511,745	
Brazil Small	10,741,800	21,788,640
Brazil Medium	4,096,264	
Brazil Large	6,950,576	
Indonesia Small	985,310	1,998,600
Indonesia Medium	375,737	
Indonesia Large	637,553	

From the number of work internet users we then determined the number of small, medium and large enterprises for each country that have active internet users (

Table **14**) using the previously found data of number of employees per enterprise (Table 7).

Table 14 - Number of enterprises using internet by size type

Country / Region and Enterprise Size	Number of Small Enterprises	Number of Medium Enterprises	Number of Large Enterprises
France	201,127	11,849	8,886
Germany	304,809	24,465	14,829
Sweden	47,159	3,168	1,885
UK	217,477	14,163	12,831
Czech Republic	29,863	2,111	1,024
Poland	99,182	6,304	3,209
Portugal	39,951	1,706	592
Canada	56,104	3,566	4,279
China	270,235	27,023	13,512
Brazil	429,672	27,308	13,901
Indonesia	4,381	2,505	1,275

In order to determine the number of enterprises using on-site servers and server infrastructure for email, CRM and groupware, we required data on the following:

- How many of enterprises have adopted the use of email, CRM and/or groupware?
- What percentage of these enterprises has already adopted Cloud or web-based versions of these applications?

Due to a lack of publicly available market data, we based our estimates (Table 15) to these data requirements from data drawn from a cross-industry panel of ICT leaders.

Table 15 – The scale of service use and current cloud adoption

	Micro/small Enterprise	Medium Enterprise	Large Enterprise
Enterprises using email	100%	100%	100%
Email using enterprises supplied by cloud	50%	33%	10%
Enterprises using CRM	50%	75%	100%
CRM using enterprises supplied by cloud	80%	50%	10%
Enterprises using groupware	50%	90%	100%
Groupware using enterprises supplied by cloud	50%	20%	10%

We estimated the number of enterprises that use on-site servers to supply their employees with email, CRM and groupware across the EU (Table 16) by multiplying together the number of enterprises by the percentage using on-site servers and multiplying this by the number of enterprises with active internet users.

Table 16 – Numbers of enterprises using on-site services by country and enterprise size

Country / Region and Enterprise Size	Number of enterprises using on-site Email	Number of enterprises using on-site CRM	Number of enterprises using on-site Groupware
France Small	100,563	20,113	50,282
France Medium	7,939	4,443	8,531
France Large	7,998	7,998	7,998
Germany Small	152,404	30,481	76,202
Germany Medium	16,391	9,174	17,615
Germany Large	13,346	13,346	13,346
Sweden Small	23,579	4,716	11,790
Sweden Medium	2,123	1,188	2,281
Sweden Large	1,697	1,697	1,697
UK Small	108,738	21,748	54,369

UK Medium	9,489	5,311	10,197
UK Large	11,547	11,547	11,547
Czech Rep. Small	14,931	2,986	7,466
Czech Rep. Medium	1,414	791	1,520
Czech Rep. Large	921	921	921
Poland Small	49,591	9,918	24,796
Poland Medium	4,223	2,364	4,539
Poland Large	2,888	2,888	2,888
Portugal Small	19,976	3,995	9,988
Portugal Medium	1,143	640	1,228
Portugal Large	533	533	533
Canada Small	28,052	5,610	14,026
Canada Medium	2,389	1,337	2,567
Canada Large	3,851	3,851	3,851
China Small	135,117	27,023	67,559
China Medium	18,106	10,134	19,457
China Large	12,161	12,161	12,161
Brazil Small	214,836	42,967	107,418
Brazil Medium	18,297	10,241	19,662
Brazil Large	12,511	12,511	12,511
Indonesia Small	19,706	3,941	9,853
Indonesia Medium	1,678	939	1,804
Indonesia Large	1,148	1,148	1,148

4. **How much energy is consumed annually by on-site servers and server infrastructure to provide email, CRM and groupware in each country?**

To calculate the total energy consumption of on-site servers we first calculated the total number of servers used in each size or enterprise and the annual energy consumption per server (Table 17). Total number of servers was achieved by multiplying together the relevant number of enterprises by the relevant number of servers per enterprise (see previous sections).

Table 17 - The total number of servers by country and enterprise size and related annual energy consumption per server

Country / Region and Enterprise Size	Total Number of Servers Used	Annual Energy Consumption per server (kWh)
France Small	170,958	8,931
France Medium	20,913	12,366
France Large	55,985	4,817
Germany Small	259,087	8,931
Germany Medium	43,180	12,366
Germany Large	93,420	4,817
Sweden Small	40,085	8,931
Sweden Medium	5,592	12,366
Sweden Large	11,878	4,817
UK Small	184,855	8,931
UK Medium	24,998	12,366
UK Large	80,832	4,817
Czech Rep. Small	25,383	8,931
Czech Rep. Medium	3,725	12,366
Czech Rep. Large	6,450	4,817
Poland Small	84,305	8,931
Poland Medium	11,126	12,366
Poland Large	20,216	4,817
Portugal Small	33,959	8,931
Portugal Medium	3,011	12,366
Portugal Large	3,732	4,817
Canada Small	47,689	8,931
Canada Medium	11,249	12,366
Canada Large	34,657	4,817
China Small	229,700	8,931
China Medium	85,259	12,366
China Large	145,927	4,817
Brazil Small	365,221	8,931
Brazil Medium	48,199	12,366

Brazil Large	87,577	4,817
Indonesia Small	33,501	8,931
Indonesia Medium	4,421	12,366
Indonesia Large	8,033	4,817

In determining the number of servers required we calculated the total annual energy consumption of servers and server infrastructure by country and enterprise size (Table 18). This was achieved by multiplying together the total number of servers by the server energy consumption (see previous sections).

Table 18 - Annual energy consumption of all servers by country and enterprise size

Country / Region and Enterprise Size	Annual Energy Consumption (GWh)	Total Annual Energy Consumption (GWh)
France Small	1,527	
France Medium	259	2,055
France Large	270	
Germany Small	2,314	
Germany Medium	534	3,298
Germany Large	450	
Sweden Small	358	
Sweden Medium	69	484
Sweden Large	57	
UK Small	1,651	
UK Medium	309	2,349
UK Large	389	
Czech Rep. Small	227	
Czech Rep. Medium	46	304
Czech Rep. Large	31	
Poland Small	753	
Poland Medium	138	988
Poland Large	97	
Portugal Small	303	
Portugal Medium	37	358
Portugal Large	18	

Canada Small	426	
Canada Medium	139	732
Canada Large	167	
China Small	2,051	
China Medium	1,054	3,809
China Large	703	
Brazil Small	3,262	
Brazil Medium	596	4,280
Brazil Large	422	
Indonesia Small	299	
Indonesia Medium	55	393
Indonesia Large	39	

5. **What are the total CO_2e emissions created to supply the energy consumed by the servers and server infrastructure providing email, CRM and groupware across the EU?**

We used carbon intensity of electricity production[69] data to calculate the total CO_2e emissions created to supply the energy consumed by the servers and server infrastructure providing email, CRM and groupware in each country (Table 19).

Table 19 – The carbon intensity electricity generation figures and subsequently calculated server carbon emissions.

Country / Region	Carbon Intensity of Electricity Generation (kg CO_2e/kWh	Carbon Emissions of Producing Energy for on-site servers and server infrastructure (t CO_2e)
France	0.0793	158,387
Germany	0.5197	1,663,788
Sweden	0.0228	10,764
UK	0.4882	1,106,257
Czech Rep	0.6061	180,117
Poland	0.4744	458,755
Portugal	0.3837	136,077
Canada	0.2019	147,783
China	0.8080	3,077,420
Brazil	0.0728	311,438
Indonesia	0.7497	294,291

69 World Resources Institute (2007) Carbon Intensity of Electricity Production in 2007. http://cait.wri.org/.

In summary, we estimated the total CO_2e emitted to supply the energy consumed by the servers and server infrastructure providing on-site email, CRM and groupware for all countries in scope at 7.7Mt.

b) How we made our 'Cloud computing' calculations:

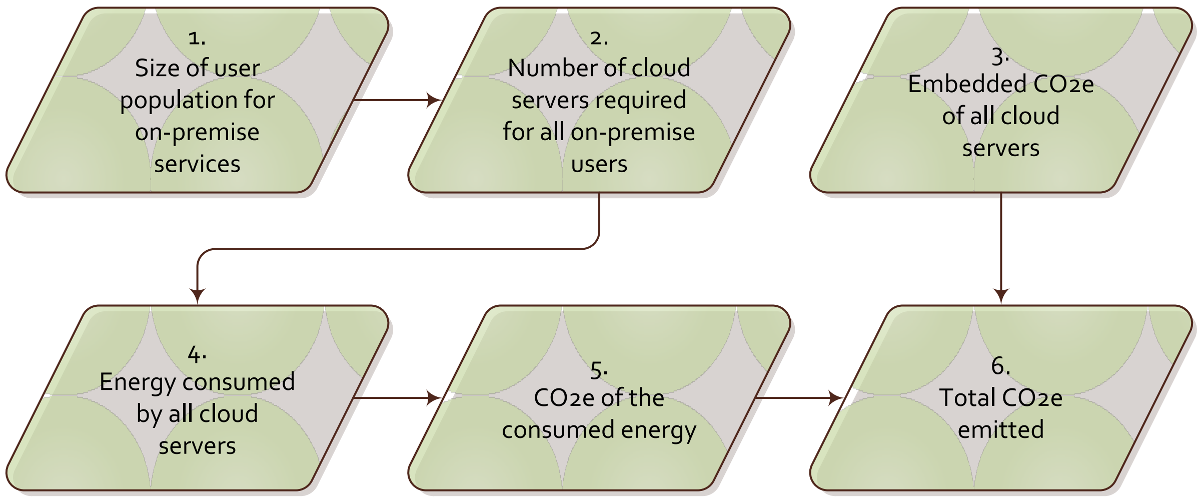


Figure 13 - The basic steps taken to calculate cloud emissions. The headings relate to the following sections.

1. **What is the size of the user population that currently uses email, CRM and groupware provisioned by on-site solutions in each country?**

We estimated the user population for on-site email, CRM and groupware (

Table **20**) by multiplying the number of enterprises that use each on-site service on by the average users per enterprise (see previous sections).

Table 20 - The user population for on-site services

Country / Region and Enterprise Size	Total number of on-site Email Users	Total number of on-site CRM Users	Total number of on-site Groupware Users	Total (Org Size)	Total On-site service Users (Country)
France Small	2,514,082	251,408	1,257,041	4,022,531	
France Medium	1,190,786	266,594	1,279,651	2,737,031	15,757,106
France Large	3,998,909	999,727	3,998,909	8,997,544	
Germany Small	3,810,110	381,011	1,905,055	6,096,176	
Germany Medium	2,458,691	550,453	2,642,176	5,651,320	26,761,390
Germany Large	6,672,842	1,668,210	6,672,842	15,013,894	
Sweden Small	589,487	58,949	294,744	943,180	
Sweden Medium	318,401	71,284	342,162	731,847	3,583,914
Sweden Large	848,394	212,099	848,394	1,908,887	
UK Small	2,718,456	271,846	1,359,228	4,349,530	20,612,120
UK Medium	1,423,381	318,667	1,529,603	3,271,652	

UK Large	5,773,750	1,443,437	5,773,750	12,990,937	
Czech Rep. Small	373,284	37,328	186,642	597,255	
Czech Rep. Medium	212,111	47,487	227,940	487,538	2,121,366
Czech Rep. Large	460,699	115,175	460,699	1,036,573	
Poland Small	1,239,779	123,978	619,890	1,983,647	
Poland Medium	633,520	141,833	680,797	1,456,150	6,688,747
Poland Large	1,443,978	360,995	1,443,978	3,248,951	
Portugal Small	499,393	49,939	249,697	799,029	
Portugal Medium	171,453	38,385	184,248	394,086	1,792,968
Portugal Large	266,601	66,650	266,601	599,853	
Canada Small	1,402,610	140,261	701,305	2,244,176	
Canada Medium	716,677	160,450	770,160	1,647,287	10,389,691
Canada Large	2,888,101	722,025	2,888,101	6,498,228	
China Small	3,377,936	337,794	1,688,968	5,404,698	
China Medium	4,526,435	1,013,381	4,864,228	10,404,044	43,170,025
China Large	12,160,571	3,040,143	12,160,571	27,361,284	
Brazil Small	5,370,900	537,090	2,685,450	8,593,440	
Brazil Medium	2,744,497	614,440	2,949,310	6,308,247	28,976,603
Brazil Large	6,255,519	1,563,880	6,255,519	14,074,917	
Indonesia Small	492,655	49,265	246,327	788,248	
Indonesia Medium	251,744	56,361	270,530	578,635	2,657,928
Indonesia Large	573,798	143,450	573,798	1,291,046	

We note that this method accounted for people more than once, as users may have access to all three applications at the same time. It is also conceivable that these applications are used simultaneously – for example a user may be sending an email to a contact from the CRM system, attaching a file stored on the enterprise's groupware server. As a result, the totals for each country above are higher than the population of each country.

2. **How many servers would be needed to provide Cloud-based email, CRM and groupware services to the user population that currently uses on-site solutions?**

From a server allocation perspective, Cloud computing is not commonly provisioned on an enterprise by enterprise basis. Our panel of industry experts revealed that estimating the necessary size of a Cloud computing infrastructure is a calculation of user sessions per server. With this knowledge a consensus was reached of one server for every 1000 user sessions for the services of email, CRM and groupware. This value was agreed to be at the middle to low end of size estimates especially for email services. Based on this ratio, we calculated the number of servers needed to provide Cloud-based email, CRM and groupware services to the population that currently uses on-site solutions (Table 21).

Table 21 - Number of cloud servers required to replace current on-site infrastructure by country

Country/Region	Number of cloud servers needed to replace on-site infrastructure
France	15,757
Germany	26,761
Sweden	3,584
UK	20,612
Czech Rep	2,121
Poland	6,689
Portugal	1,793
Canada	10,390
China	43,170
Brazil	28,977
Indonesia	2,658

3. **How much embedded CO_2e would be apportioned to create a cloud-based infrastructure that can provide email, CRM and groupware services to each country's population of current on-site computing users?**

We estimated the carbon emissions necessary to manufacture, assemble and ship ('embedded carbon') the new cloud servers to the location of the data centre. This was included as we assumed the cloud-based infrastructure was formed of new servers. This information can be sourced from various manufacturers, but the most transparent and reliable data we found was from a recent Fujitsu study, assessing their Primergy TX300 Volume Server and calculating a figure of 558kg per server[70].

We calculated the CO_2e emissions of creating the Cloud-based infrastructure for the three services to the population that currently uses on-site solutions (

70 Bottner, H. (2010) Product Carbon Footprint Project at Fujitsu Technology Solutions. Fujitsu Corporate Quality

Table **22**). This was completed by multiplying the number of servers by the embedded carbon figures. An annualised embedded carbon figure was determined by dividing the total embedded carbon of a country by the useful lifetime of the server. Our panel of industry expert interviews came to the consensus that the useful life of an average volume server was approximately 5 years.

Table 22 - Embedded carbon of servers needed to create cloud infrastructure

Country/Region	Embedded Carbon of Cloud Infrastructure (t CO_2e)	Annualised Embedded Carbon of servers needed to create Cloud infrastructure (t CO_2e/year)
France	8,792	1,758
Germany	14,933	2,987
Sweden	2,000	400
UK	11,502	2,300
Czech Rep	1,184	237
Poland	3,732	746
Portugal	1,000	200
Canada	5,797	1,159
China	24,089	4,818
Brazil	16,169	3,234
Indonesia	1,483	297

4. **How much energy would be consumed annually by a cloud-based infrastructure that can provide email, CRM and groupware services equivalent to the current on-site computing user population in each country?**

For cloud servers we calculated all service energy consumption based upon the use of volume servers. Our industry experts described that most data centres, including Cloud data centres consist entirely of Volume servers. We also included the following add-on factors for energy consumption:

- Storage (15% of power consumption)[71];
- Networking (15% of power consumption)[72];
- Power Usage Effectiveness, incorporating remaining auxiliaries such as power supply and cooling (a multiplier of 2.0 in a Cloud data centre context)[73]; and
- Additional use of internet infrastructure (approximately 3%)[74].

We calculated the power consumption of a cloud computing server and its associated infrastructure at 0.54kW, equating to an annual energy consumption of 4725kWh per year. Using this we calculated the annual energy consumption of a cloud-based infrastructure for the three services to the population that currently uses on-site solutions (

71 Williams, D.R., and Tang, Y. (2012) Methodology To Model the Energy and Greenhouse Gas Emissions of Electronic Software Distributions. Environmental Science & Technology, 46, 2, 1087-1095.
72 ibid.
73 Federal Ministry for Environment (2010). Nature Conservation and Nuclear Safety (2010) report: Material Existence of the data centres in Germany. http://www.umweltdaten.de/publikationen/fpdf-l/4037.pdf
74 Williams, D.R., and Tang, Y. (2012) Methodology To Model the Energy and Greenhouse Gas Emissions of Electronic Software Distributions. Environmental Science & Technology, 46, 2, 1087-1095.

Table **23**).

Table 23 - Annual energy consumption of servers and server infrastructure

Country/Region	Annual energy consumption of servers and server infrastructure (kWh)
France	74,457,535
Germany	126,456,414
Sweden	16,935,176
UK	97,399,080
Czech Rep	10,024,157
Poland	31,606,540
Portugal	8,472,368
Canada	49,094,723
China	203,992,641
Brazil	136,924,030
Indonesia	12,559,589

5. **How much CO_2e would be emitted annually to supply the energy consumed by a Cloud-based infrastructure that can provide email, CRM and groupware services to the on-site computing user population of each country?**

We calculated the CO_2e that would be emitted annually to supply the energy consumed by a cloud-based infrastructure that can provide email, CRM and groupware services to the population that currently uses on-site solutions (Table 24). This was achieved using the electricity carbon intensity figures (from Section 5 in Part A).

Table 24 – The annual energy related carbon emissions of a cloud infrastructure

Country/Region	Annual carbon emissions of energy needed to operate Cloud Infrastructure (t CO_2e)
France	5,904
Germany	65,719
Sweden	386
UK	47,550
Czech Rep	6,076
Poland	14,994
Portugal	3,251
Canada	9,912
China	164,826
Brazil	9,964
Indonesia	9,416

6. **What would the total annual CO_2e emissions attributable a cloud-based infrastructure that can provide email, CRM and groupware services to the population that currently uses on-site solutions where the embedded carbon and energy consumption carbon are combined?**

We calculated the total annual CO_2e emissions attributable a cloud-based infrastructure that can provide email, CRM and groupware services to the on-site user population of each country. This was achieved by adding the annualised embedded carbon of servers with the annual emissions attributed to operation of the necessary Cloud infrastructure (Table 25).

Table 25 – The annual energy and embedded carbon emissions of a cloud infrastructure

Country/Region	Annual carbon emissions of Cloud Infrastructure (t CO_2e)
France	7,663
Germany	68,706
Sweden	786
UK	49,851
Czech Rep	6,312
Poland	15,741
Portugal	3,451
Canada	11,072
China	169,644
Brazil	13,198
Indonesia	9,712

In summary, we estimate the total CO_2e emissions created annually to supply and operate a Cloud computing infrastructure needed to supply the population of on-site computing users with email, CRM and groupware would be 0.36Mt for the all countries in scope.

c) What would the impact of an 80% market penetration rate be upon carbon emissions?

In order calculate a market penetration rate of 80% the current cloud to on-site ratio (I.e. current cloud penetration rate) was considered for each service. Sections a) and b) calculated the total energy consumption and related emissions of on-site and cloud computing assuming a 100% market share of each. In reality cloud computing has already penetrated the computing market at different rates for each service and as such a mixture already exists. This meant that if a service had already reached an 80% cloud penetration rate then no further adoption would occur in the model calculations (i.e. zero reduction). We found that for example, penetration of cloud computing for email services in large companies is currently estimated at 10%, requiring a further 70% penetration (which equated to 78% of the on-site computing population). By contrast, penetration of Cloud computing for CRM in small enterprises is already estimated to be 80%, so our model assumes no further adoption of Cloud for this application in small enterprises.

For each service and enterprise size, we calculated the percentage of current on-site users that would need to be moved to cloud in order to achieve an 80% market penetration. We subsequently aggregated the percentages for all services, as under a cloud computing scenario all applications would be delivered by a single infrastructure. Using this method, we calculated an aggregate adoption rate for each size of enterprise:

- For small enterprises, 56%
- For medium enterprises, 71%; and
- For large enterprises, 78%

We calculated the percentage of on-site emissions which would be reduced, and the percentage of cloud computing emissions that would be created using the aggregated adoption rates (Table 26). Subtracting the latter from the former allowed us to estimate the total carbon emissions reduction enabled by a move to cloud computing for the provision of email, CRM and groupware according to an 80% cloud penetration rate in each country.

In summary, the emissions reductions enabled would equate to 4.5Mt for all countries in scope.

Table 26 – The reduced emissions of on-site computing, the created of cloud computing and the total reduced emissions created.

Country/Region	Carbon emissions saved by switching off on-site infrastructure (t CO_2e/year)	Carbon emissions of a Cloud Infrastructure necessary to enable the needed shift.	Total Emissions Reductions if target penetration of Cloud computing is achieved (tCO_2e)
France	99,387	5,454	93,933
Germany	1,056,538	49,147	1,007,391
Sweden	6,732	557	6,175
UK	709,012	36,006	673,006
Czech Rep	111,877	4,435	107,442
Poland	283,470	11,020	272,450
Portugal	81,029	2,305	78,724
Canada	94,647	7,985	86,662
China	1,982,625	124,777	1,857,848
Brazil	188,376	9,240	179,136
Indonesia	178,005	6,800	171,205

d) What is the effect of changing the market adoption rate and the cloud adoption rate on the amount of CO_2e reduced?

To understand the effect of different market adoption rates on the total emissions reduction a sensitivity analysis was run. The analysis revealed that for a 100% market penetration rate a total of 7.3 million tonnes of CO_2e could be abated. However market penetration and emission reductions was found not be linear. This meant that the 80% rate set in this research accounted for 62% of the total possible reductions by moving to cloud computing. For market penetration rates of 51% or more provided the largest reduction rate increases. Below a 51% penetration rate only 12% of total GHG reduction potential could be reached. This information is especially important when the discussed barriers to adoption are taken into account. The large increase in reduction rate at 50% penetration comes from the first inclusions of the small enterprise sizes.

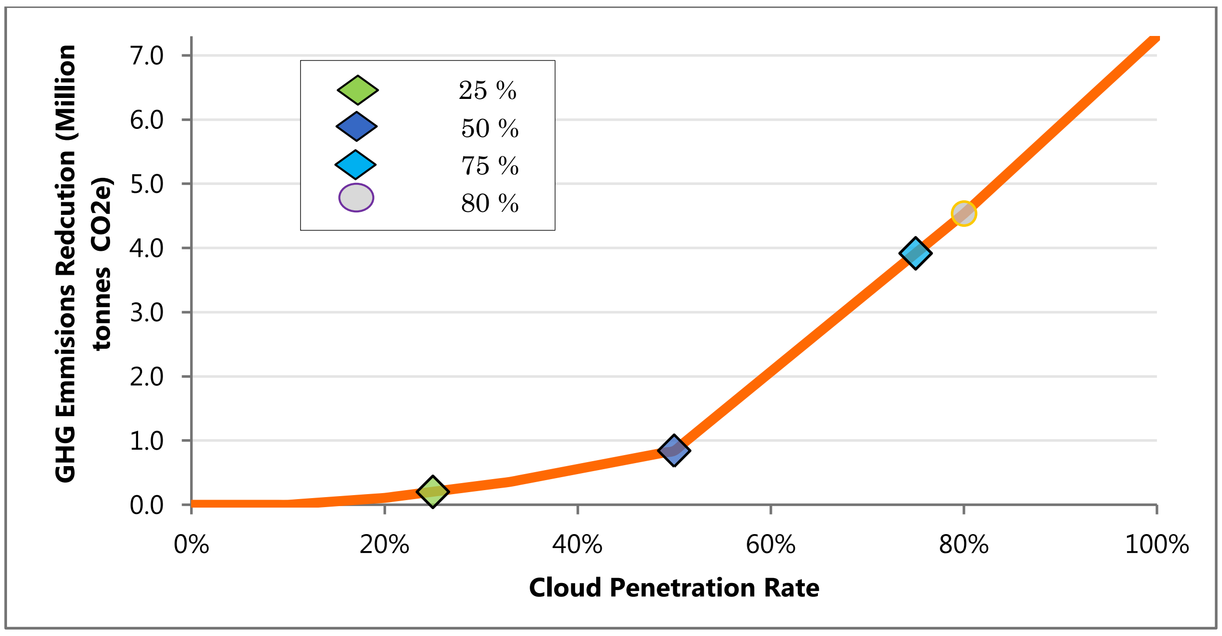


Figure 14 - A sensitivity analysis of the market penetration rate (0%-100%) against the potential total emissions reductions. 25%, 50% and 75% rates are highlighted. Results in this paper used an 80% penetration rate.

A further sensitivity analysis was performed on the cloud adoption figures that had been estimated through a series of workshops and expert interviews. The analysis shows that a ±20% change in the on-site to cloud ratio causes a linear ±31% change in GHG emission reductions. The analysis performed a ±20% difference on each service's on-site to cloud ratio estimated value (not exceeding 100%). This range was chosen according to the array of answers received in the data collection process. The variations were performed relatively to each service and each enterprise size for each country with results being collated for ease of presentation.

Although conservative cloud adoption estimates were used, this sensitivity analysis can be used as a range of potential reduction of GHG emission. Therefore at an 80% market penetration rate the reduction potential of cloud computing for all countries in scope is between 3.1 and 5.9 million tonnes of CO_2e.

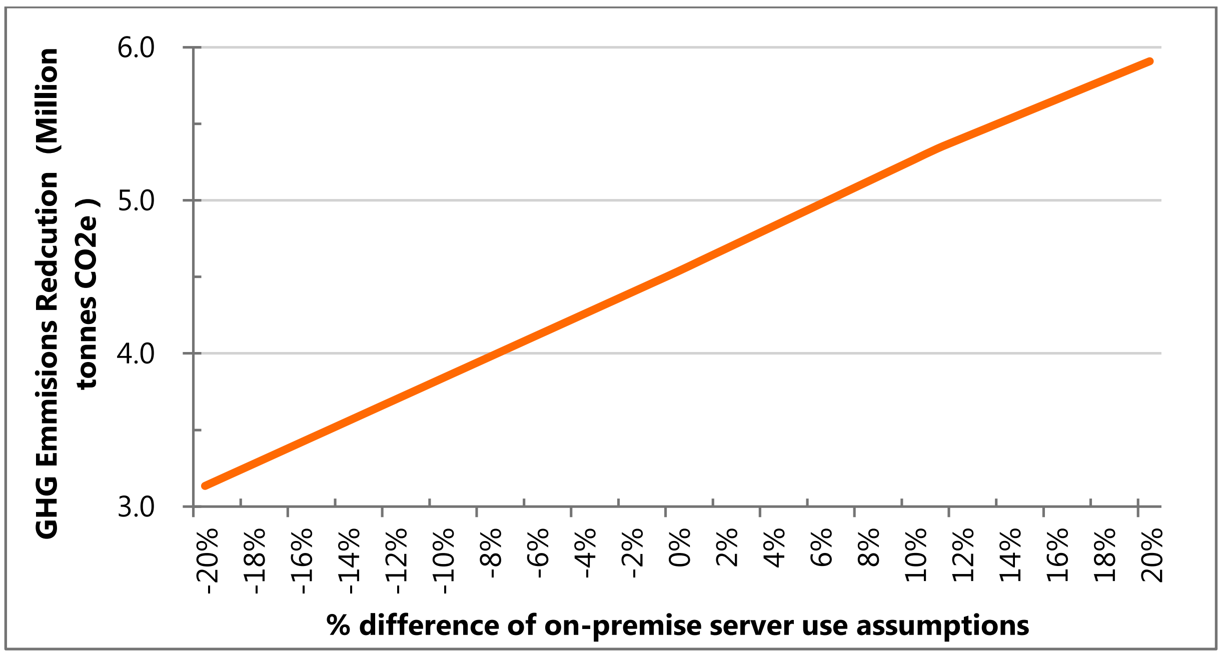


Figure 15 - A collated ±20% sensitivity analysis of the on-site to cloud ratio for each service against potential emission reductions.

Finally, whilst we are confident that our modelling approach is robust, we concede weaknesses in data may comprise the reliability of the conclusions. To mitigate this risk, we have consistently used conservative figures and lowered estimates, and for complete transparency, we highlight our areas of concern regarding key data items in the table below:

Data Item	Data Quality	Examples of data source
National populations	Strong > All data from same reliable source > All data for 2007 baseline	Climate Analysis Indicators Toolkit V8, 2007. Population in 2007. Washington: World Resources Institute. Available from: http://cait.wri.org/cait.php?page=compind [Accessed 29 Sept 2011]
Employed population	Strong > All data from same reliable source > All data for 2007 baseline	LABOURSTA, 2010, Employment General Level, 2007, Switzerland: International Labour Office. Available from: http://laborsta.ilo.org [Accessed 29 Sept 2011]. EU27 Stats have been calculated from Eurostat, 2010. Labour Force Survey. Luxembourg: Eurostat. Available from: http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=tsiem010&plugin=1 [Accessed 6 May 2011] and Eurostat, 2011. Population on 1 January by five years age groups and sex. Luxembourg: Eurostat. Available from: [Accessed 29 Sept 2011]
Carbon intensity of electricity	Strong > All data from same reliable source > All data for 2007 baseline	Climate Analysis Indicators Toolkit V8, 2007. Carbon Intensity of Electricity Production in 2007. Washington: World Resources Institute. Available from: http://cait.wri.org/cait.php?page=compind [Accessed 29 Sept 2011]
Carbon emissions of energy	Strong > All data from same reliable source > All data for 2007 baseline	Climate Analysis Indicators Toolkit V8, 2007. National GHG Emissions from Energy in 2007. Washington: World Resources Institute. Available from: http://cait.wri.org/cait.php?page=compind [Accessed 29 Sept 2011]
Average enterprise size and employment by enterprise size	Strong > Data from reliable sources > All data for 2007 baseline	EU estimate based on data from: Eurostat, 2008. Enterprises by size class - overview of SMEs in EU. Luxembourg: Eurostat. Available from: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-08-031/EN/KS-SF-08-031-EN.PDF [Accessed 10 December 2010] Canada estimate calculated from: Statistics Canada, 2011. Employment by Enterprise Size 2007.Statistics Canada: Ottawa. Available from: http://www40.statcan.ca/l01/cst01/labr75h-eng.htm [Accessed 29 Sept 2011] US Census Bureau, 2007. Employment size by Employer and Nonemployer Firms 2007. Available from: http://www.census.gov/econ/smallbus.html [Accessed 6 Oct 2011]
Internet usage at work	Weak > European and Canadian data from reliable source Issues: > Chinese, Indonesia data is not robust and the base years are inconsistent	Eurostat, 2010. Persons employed using computers connected to the Internet in their normal work routine at least once a week. Luxembourg: Eurostat. Available from: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_pi_b1n2&lang=en [Accessed 6 May 2011]
Cost of electricity	Good > All data from same reliable source > US data from 2007 baseline Issues: >Canada data for 2006, not 2007 baseline	Energy Information Administration, 2010. Electricity Prices for Industry. Available at: http://www.eia.gov/emeu/international/elecprii.html [Accessed 3 October 2011] Eurostat, 2007. Gas and Electricity Market Statistic.Luxembourg: Eurostat. Available from: http://www.energy.eu/publications/KSGB07001ENC_002.pdf [Accessed 16 Sep 2011] Domestic data based on a consumption of 3500kWh/year and 2007 prices, including all taxes. Industrial data based on a consumption of 2000MWh/year and 2007 prices, including all taxes, but excluding VAT. Peterson Institute for International Economics, 2007. China Energy: A Guide for the Perplexed. Available at: http://www.iie.com/publications/papers/rosen0507.pdf [Accessed 3 Oct 2011] More reliable data may be available from Electricity Information 2008 - IEA/OECD Publishing for £74: http://www.oecdbookshop.org/oecd/display.asp?CID=&LANG=EN&SF1=DI&ST1=5KZSV8PT80WF

Servers per enterprise	Good (potentially weak)	Estimate based on expert interviews.
Application adoption	Good (potentially weak)	Estimates based on expert interviews.
Server and network power and footprint infrastructure data	Good > All data from same reliable sources > Some expert assumptions	Williams, D.R., and Tang, Y., (2011). A Methodology to Model the Environmental Impacts of Electronic Software Distributions (to be published). Bottner, H., 2010. Product Carbon Footprint Project at Fujitsu Technology Solutions. Fujitsu Corporate Quality. Federal Ministry for Environment, Nature Conservation and Nuclear Safetly, 2010. Material Existence of the data centers in Germany. Dessau-Roßlau: Umwelt Bundes Amt. Available from: http://www.umweltdaten.de/publikationen/fpdf-l/4037.pdf [Accessed 6 January 2011]
Cloud computing adoption broadly	Potentially weak to Good	Estimates based on expert interviews.

APPENDIX 4: ECONOMIC SAVINGS – THE DATA AND HOW THEY WERE USED

This appendix explores the potential cost savings enabled by cloud computing at an economy-wide level, seeking to understand how cloud could contribute to the productivity of European economies. Our analysis consists of four parts:

a) Exploring the costs associated with the provision of enterprise computing needed to deliver email, CRM and groupware.

b) Calculating the cost of providing email, CRM and groupware via on-site computing.

c) Calculating the cost of providing email, CRM and groupware via cloud computing.

d) Calculating the savings enabled in the economy if 80% of users moved from on-site to cloud computing.

Each of these areas is described in the following sections.

a) Exploring the costs associated with provision of enterprise computing

We considered four areas of cost associated with the provision of enterprise computing. These allowed a comparison to be drawn between the costs of providing computing via on-site servers to the costs of providing computing via the Cloud. The four areas include:

- **Hardware and infrastructure:** The annualised cost of purchasing the servers and necessary supporting infrastructure to provide email, CRM and groupware.
- **Software:** The licensing cost of server operating system and applications needed to provide email, CRM and groupware.
- **Staffing:** The cost of personnel needed to configure, maintain and administer the hardware and software for providing email, CRM and groupware.
- **Energy:** The energy cost of running the necessary hardware and infrastructure to provide email, CRM and groupware.

Cloud computing enables notable economies of scale across all of the above areas. Given the vast array of hardware, software and staffing options available, significant further research is required to model the costs in these areas. As a result, this analysis only considered the energy cost savings enabled by a shift to cloud computing.

For completeness, we conservatively assumed that the costs of hardware, infrastructure, software and staffing were equal in both computing scenarios. We also assumed that we could isolate the efficiency gains in energy consumption as the worst case savings that can be made by various economies.

The following table demonstrates the foundational logic of these assumptions.

Table 27 – The assumed effect on the move to a cloud computing scenario

Cost Area	Assumed Effect on Cost of Shift to Cloud
Hardware & Infrastructure	Major reduction as a result of significantly increased server utilisation, requiring fewer servers to provide for the same number of people.
Software	Minor reduction as a result of large scale purchasing power.
Staffing	Minor reduction as a result of efficiencies in maintaining and administering hardware, infrastructure and software.
Energy	Major reduction – Modelled further below.

To calculate the energy cost reductions enabled by a shift to cloud computing, we explored the costs of providing on-site computing and cloud computing.

b) Calculating the cost of providing email, CRM and groupware via 'on-site' computing:

In order to calculate the energy cost reductions of a move to cloud computing we utilised the calculations of energy consumption for on-site and cloud computing that are presented in Appendix 3.

The annual energy consumption of on-site computing that provides email, CRM and groupware, divided by enterprise size was first calculated and is presented in Table 28.

Table 28 - Annual energy consumption of on-site computing by country and enterprise size

Country/ Region	Energy Consumption in Small Enterprises (kWh)	Energy Consumption in Medium Enterprises (kWh)	Energy Consumption in Large Enterprises (kWh)
France	1,526,814,036	258,606,475	269,683,132
Germany	2,313,898,351	533,961,107	450,010,991
Sweden	357,998,444	69,148,070	57,215,010
UK	1,650,931,789	309,119,785	389,376,988
Czech Rep	226,697,473	46,064,682	31,069,178
Poland	752,923,880	137,583,289	97,380,702
Portugal	303,283,800	37,234,967	17,979,383
Canada	425,905,870	139,108,519	166,946,729
China	2,051,437,048	1,054,308,687	702,941,960
Brazil	3,261,773,442	596,030,397	421,867,067
Indonesia	299,191,707	54,671,900	38,696,473

To calculate an annual total energy cost, we multiplied the annual energy consumption by the average cost rate for electricity (table 21). Statistics on energy prices were derived primarily from the Energy Information Administration[75] and converted into USD for ease of comparison (Table 20). It was noted that around the world a notable difference between the prices paid for electricity by smaller consumes and industrial users was realised. For the purpose of this calculation we assumed that both small and medium sized enterprises paid the higher 'domestic' tariff as the consumption of 7,000MWh/year required for an 'industrial' tariff was beyond all but the largest corporations.

75 Energy Information Administration (2010) Electricity Prices for Industry. http://www.eia.gov/emeu/international/elecprii.html.

Table 29 - Domestic and industrial electricity tariffs by country and enterprise size

Country/ Region	Domestic Tariff for Electricity (USD/kWh)	Industrial Tariff for Electricity (USD/kWh)
France	$ 0.16	$ 0.06
Germany	$ 0.26	$ 0.11
Sweden	$ 0.23	$ 0.09
UK	$ 0.22	$ 0.13
Czech Rep	$ 0.15	$ 0.12
Poland	$ 0.15	$ 0.08
Portugal	$ 0.21	$ 0.12
Canada	$ 0.08	$ 0.06
China	$ 0.06	$ 0.07
India	$ 0.05	$ 0.10
Indonesia	$ 0.07	$ 0.07

Table 30 – Total cost of energy for on-site computing by country and enterprise size

Country/ Region	Cost of electricity for on-site computing in Small Enterprises	Cost of electricity for on-site computing in Medium Enterprises	Cost of electricity for on-site computing in Large Enterprises	Total Cost of Electricity in Country
France	$ 238,182,990	$ 40,342,610	$ 15,102,255	**$ 293,627,855**
Germany	$ 608,555,266	$ 140,431,771	$ 49,051,198	**$ 798,038,235**
Sweden	$ 82,837,260	$ 16,000,172	$ 4,873,861	**$ 103,711,293**
UK	$ 361,554,062	$ 67,697,233	$ 50,619,008	**$ 479,870,303**
Czech Rep	$ 33,097,831	$ 6,725,444	$ 3,572,955	**$ 43,396,230**
Poland	$ 113,691,506	$ 20,775,077	$ 7,985,218	**$ 142,451,800**
Portugal	$ 64,902,733	$ 7,968,283	$ 2,229,443	**$ 75,100,460**
Canada	$ 33,220,658	$ 10,850,464	$ 9,849,857	**$ 53,920,979**
China	$ 123,086,223	$ 63,258,521	$ 49,205,937	**$ 235,550,681**
Brazil	$ 492,027,244	$ 89,909,124	$ 46,951,365	**$ 628,887,734**
Indonesia	$ 19,447,461	$ 3,553,674	$ 2,515,271	**$ 25,516,405**

c) Calculating the cost of providing email, CRM and groupware via Cloud computing

In order to calculate the energy cost reductions of a move to cloud computing we utilised the calculations of energy consumption for on-site and cloud computing that are presented in Appendix 3.

The annual energy consumption of cloud computing that could provide email, CRM and groupware, was first calculated and is presented in Table 22. Note that no enterprise sizing was calculated as cloud computing combines all services together thus creating large efficiencies.

Table 31 - Annual energy consumption of cloud infrastructure that could replace current on-site usage

Country/Region	Energy Consumption of Cloud computing Infrastructure (kWh)
France	74,457,535
Germany	126,456,414
Sweden	16,935,176
UK	97,399,080
Czech Rep	10,024,157
Poland	31,606,540
Portugal	8,472,368
Canada	49,094,723
China	203,992,641
Brazil	136,924,030
Indonesia	12,559,589

We calculated the annual cost of energy for cloud computing using an energy price rate for 'industrial' tariffs. This was decided as cloud data centres are commonly large industrial size with high overall electricity consumption.

Table 32 - Annual energy cost of running cloud Infrastructure that could replace current on-site usage

Country/Region	Annual Energy Cost (USD)
France	$ 7,363,738
Germany	$ 22,332,413
Sweden	$ 2,599,844
UK	$ 15,867,002
Czech Rep	$ 1,311,684
Poland	$ 3,713,274
Portugal	$ 1,557,981
Canada	$ 3,245,969
China	$ 13,532,470
Brazil	$ 18,023,945
Indonesia	$ 816,373

d) Calculating energy cost reductions according to an 80% cloud computing market penetration rate.

The energy cost reductions of an 80% cloud computing market penetration rate were calculated. This was achieved by multiplying the total energy costs of both computing types by the aggregated adoption rates calculated in section c of Appendix 3 were utilised. For reference, the percentage of on-site users that would need to move to cloud computing to achieve 80% penetration is:

- For small enterprises, 56%

- For medium enterprises, 71%; and
- For large enterprises, 78%

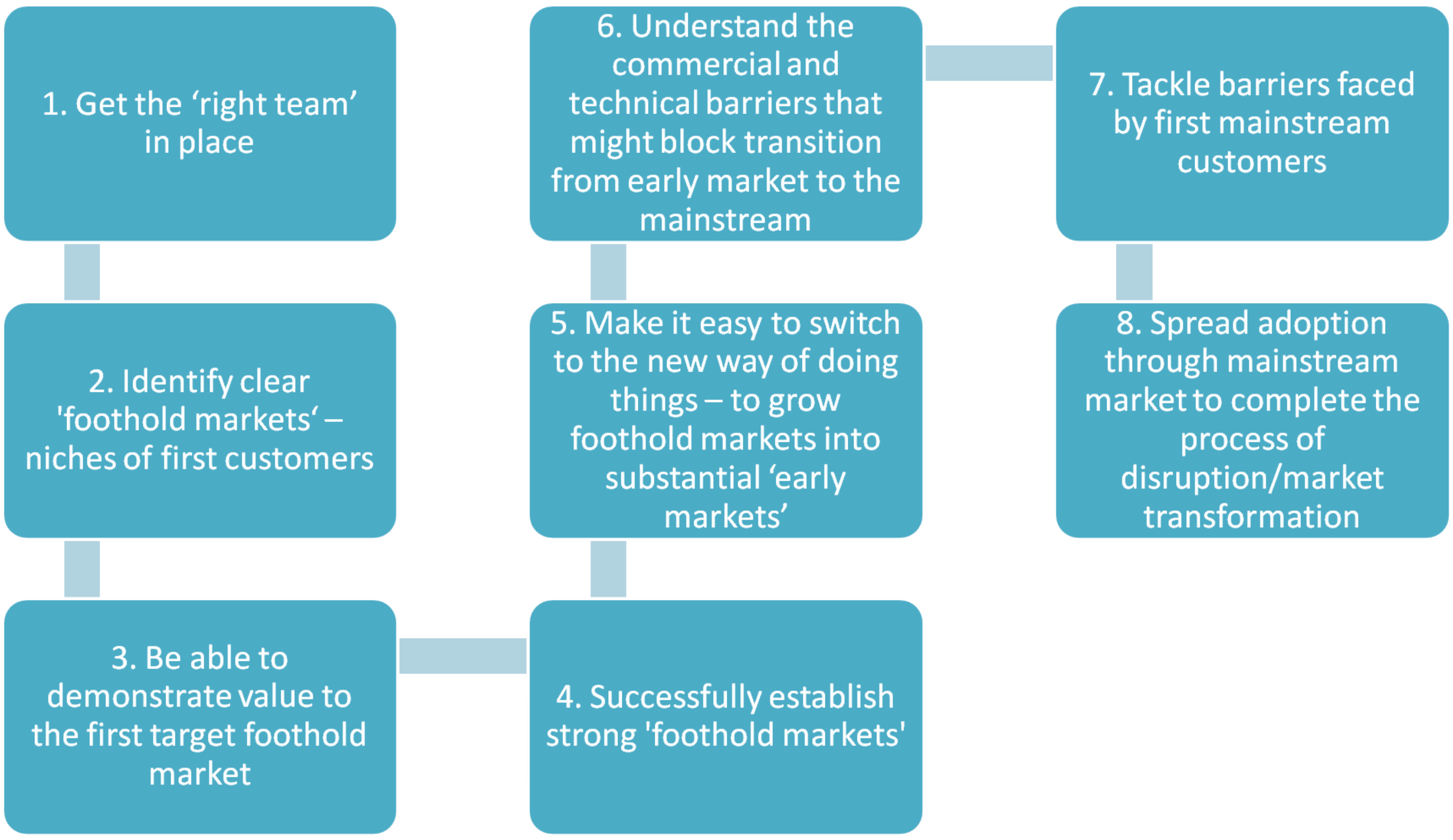
In summary, the economy-wide cost savings enabled by region are estimated to be $1.7 Billion USD for all countries in scope.

Table 33 - The reduced costs of on-site computing, the created costs of cloud computing and the total reduced costs created.

Country/ Region	Cost of Electricity for On-site computing	Cost of Electricity for Cloud computing	Cost Savings
France	$ 174,540,280	$ 4,960,905	$ 169,579,375
Germany	$ 480,771,677	$ 15,292,769	$ 465,478,908
Sweden	$ 61,815,433	$ 1,749,285	$ 60,066,148
UK	$ 291,099,666	$ 11,157,052	$ 279,942,614
Czech Rep	$ 26,200,384	$ 910,139	$ 25,290,245
Poland	$ 85,001,537	$ 2,517,434	$ 82,484,103
Portugal	$ 43,933,430	$ 1,012,518	$ 42,920,912
Canada	$ 34,097,952	$ 2,308,027	$ 31,789,925
China	$ 152,691,943	$ 10,008,090	$ 142,683,853
Brazil	$ 377,503,857	$ 12,414,468	$ 365,089,388
Indonesia	$ 15,433,857	$ 571,552	$ 14,862,304

APPENDIX 5: THE PATH TO MARKET TRANSFORMATION

The figure below illustrates the 'typical' path to market transformation inferred from the writings of Christensen, Moore, Foster, and Rogers.[76]



76 See for example:

- Christensen, C.M. (1997) The Innovator's Dilemma: when new technologies cause great firms to fail, Harvard Business School Press, Boston, Massachusetts. 1997.
- Foster, R. N. (1985) "Timing Technological Transitions", Technol. Soc. 7, 127–141, 2003.
- Moore G A (1991). Crossing the chasm, Capstone.
- Rogers, E. M. (2003). Diffusion of innovations (5th ed.). NY:Free Press, New York, USA.

Appendix 6: The industry survey tool

The table below illustrates the survey tool deployed by our research team, through both web and telephone interviews. The questions were derived from our understanding of the 'typical' path to market transformation as illustrated in Appendix 5.

Survey respondents - roles

leaders of ICT industry associations
leaders of business associations for SMEs
leaders of associations representing a range of sectors and mostly larger enterprises

Survey respondents - geography of each business association

EUROPE
AMERICAS
ASIA

Do cloud vendors appear to have the right team in place to pioneer the market transformation to on-site computing across micro, small, medium and large sized enterprises?

'start-up scar tissue' - the vendors are used to pioneering new businesses
strong experience of being the small player in highly competitive market
the right expertise in marketing, sales
the right expertise in technology management and product development
professional networks that articulate shared expectations from cloud-computing
broad and deep professional networks
extensive experience and deep knowledge of the industry and its wider domain

Large enterprises focus:
Are there clear customer niches which cloud vendors could target as strong 'foothold markets' from which they can build widespread adoption?

don't know
NO
YES

large enterprises focus:
Can cloud vendors promote value to customers that might make up their foothold market(s)?

experienced in delivering offerings perceived as tailored for the likely foothold market
they can present a clear economic case for a switch to the cloud
typically produce value for money products /services
typically produces easy to use platforms/products/services
brand is or is likely to be strong in the target market
typically produce high quality products/services

Large enterprises focus:
Are cloud vendors establishing strong 'foothold markets' of cloud users?

are serving small niche markets first, before rushing to serve the masses
have created a strong presence in a foothold market
the capability to identify relevant small foothold market niches
the capability to deeply understand customer needs

Large enterprises focus:
Are cloud vendors making it easy for early adopters to switch to the new way of doing things?

cloud vendors present a clear value for money business case to early adopters
data security concerns have been dealt with
service users with 'standard' on-site solutions will find cloud more convenient
user training in the foothold market niche would be minimal to zero

service users will prefer (even demand) web-based services

Large enterprises focus:

Are cloud vendors overcoming the market and technical factors that might cause barriers in taking cloud from foothold market niches to mainstream widespread adoption?

vision for spread of cloud services is based upon a clear shared vision of value

strong supportive brand presence across economy

partnerships are easy to open and build between vendors and customers

no major vendors will block the progress of cloud

influential access to decision makers at the strategic level

access to decision makers at the strategic level

the technology is mature and reliable for email, CRM and groupware

Large enterprises focus:

Do cloud vendors understand how internal IT teams with in mainstream enterprises feel about the shift to cloud and how they might retaliate if they feel threatened?

threatened teams would need to kill-off 'much loved' projects and architectures to adopt cloud

the threatened teams would need to change their business models to adopt cloud

threatened teams have the finances and capabilities to block cloud

lock-in concerns are driven more by the threat of change than quantifiable evidence of 'lock-in'

IT directors state concerns of 'lock-in' as a major barrier to cloud (i.e., too hard to change vendors)

concerns over security are driven more by the threat of change than reliable evidence of security concerns

IT directors state concerns of security as a major barrier to cloud

IT teams in mainstream enterprises feel threatened to some degree by rise of cloud

Focus on ALL enterprises:

Do cloud vendors make it easy for all customers to switch to their new way of doing things?

data security concerns are entirely evidence based

data security concerns have been dealt with

cloud vendors present a clear value for money business case to IT directors

user training upon full roll out would be minimal to zero

new service users will prefer (even demand) web-based services.

service users with 'standard' on-site solutions will find cloud more convenient

APPENDIX 7: HIGHLIGHTS FROM OUR POLICY ANALYSES

This appendix presents some of the policy analyses as completed by our team, for more complete details, please contact the lead author.

Key:

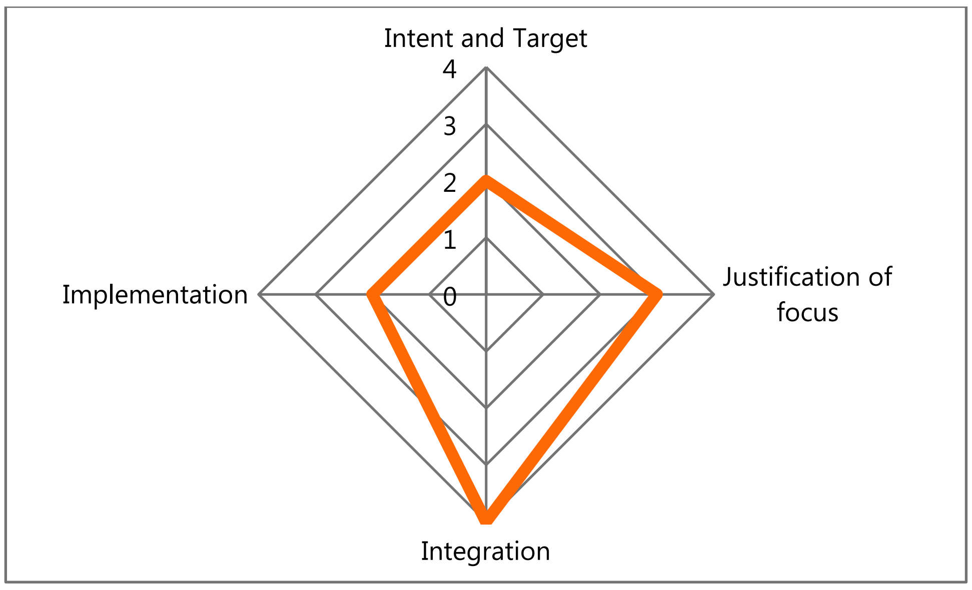
Creates barrier	Ambiguous	Supportive	Enabling

Brazil: National Climate Change Plan 2009

I) Instruments

	Invention	Early Market	Cross Chasm	Spread
Economic			Energy Efficiency Law Article 5 XIII: Incentives and support for the maintenance and promotion of low GHG emitting practices, activities and technologies	
Behavioural			Strengthening of the Climate Network—bringing together numerous research centres across the country	
Government leadership			Reduction of non-technical losses in electricity grid;	Monitoring deforestation using high-precision satellite technology

II) Policy design



Intent and Target	Justification of focus
• 10% reduction in electricity consumption • Quantifies expected emissions reductions from each instrument, but does not state a clear target for GHG emissions reductions • Narrow focus, only considers emissions from deforestation and sources of renewable energy	• targets for increasing the percentage of renewables in the energy matrix is proceeded by charts of the sources of energy supply, and considers the capacity of each industry to expand • the plan to increase renewable electricity through the construction of new plants fails to take into account widespread domestic and global dissent; as with the Belo Monte dam • Quantified expected emissions reductions and energy savings

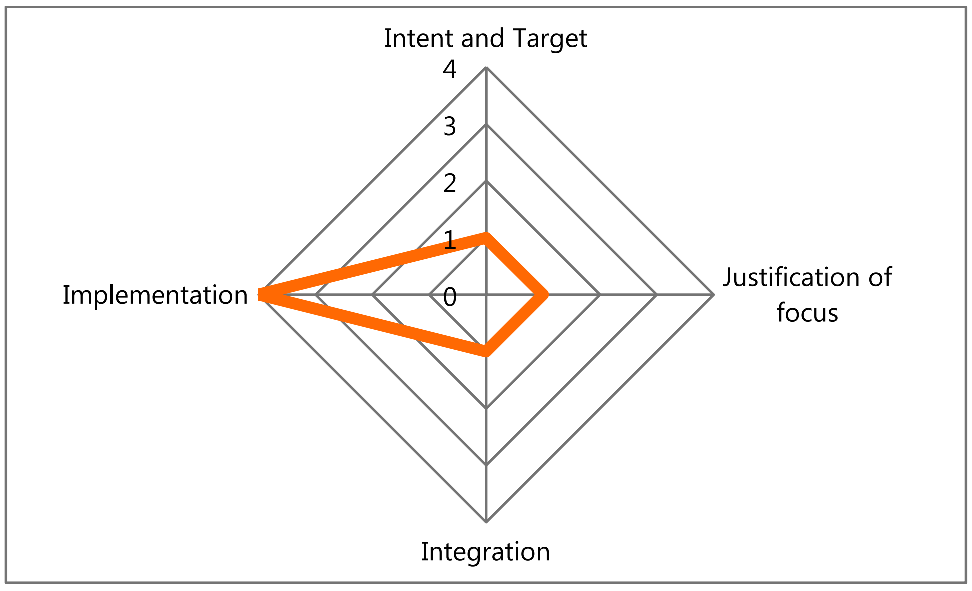
	from each action
Integration	Implementation
• Referenced relevant Decrees, existing Energy Plans, and Policies in formulation that effect each instrument	• No note of the enabling technologies or leap-frog technology • Does not consider role of energy demand reduction • Implementation clear for LULUCF and renewable energy agenda, but the road map for energy efficiency is less clear • No effective policy barriers as intervention very low • Interest in FDI through CDM creates opportunities for foreign ICT providers • Focus on renewable energy regeneration rather than energy efficiency

Canada: ecoENERGY Efficiency Programme (2011)

I) Instruments

	Invention	Early Market	Cross Chasm	Spread
Regulatory			Market Distortion through specificity, e.g. Retrofit, Technology Initiative. Increases opportunity cost for ICT solutions	
	Overall emission reduction given by the Copenhagen Accord (17% reduction in GHG emissions). However, this target is not internationally binding like the Kyoto targets.			
Economic	Financial support through ecoENERGY Innovation Initiative Fund, helping research, development and demonstration projects. Does not state the ICT sector			
Behavioural			Voluntary standards/ information-sharing/ workshops programmes for energy efficiency in Industry (eEfI)	

II) Policy design



Intent and Target	Justification of focus
• "broad framework of programmes", so no overarching structure • No continuity (e.g. cancellation of eE Retrofit Home) • Lack of precise goals for the initiative, except support for the Copenhagen Accord • No effective policy barriers as intervention very low	• No justification of the areas of investment • High specificity within programs, without a justification • No note of the ICT sector or any enabling industry within the programmes
Integration	**Implementation**
• Multi-jurisdiction of policy area creates overlap and duplication in policy area	• Implementation clear as programmes organised by the Natural Resources Canada's Office of Energy Efficiency, who also implement

China: the 12th Five Year Plan of Social and Economic Development (2011-2016)

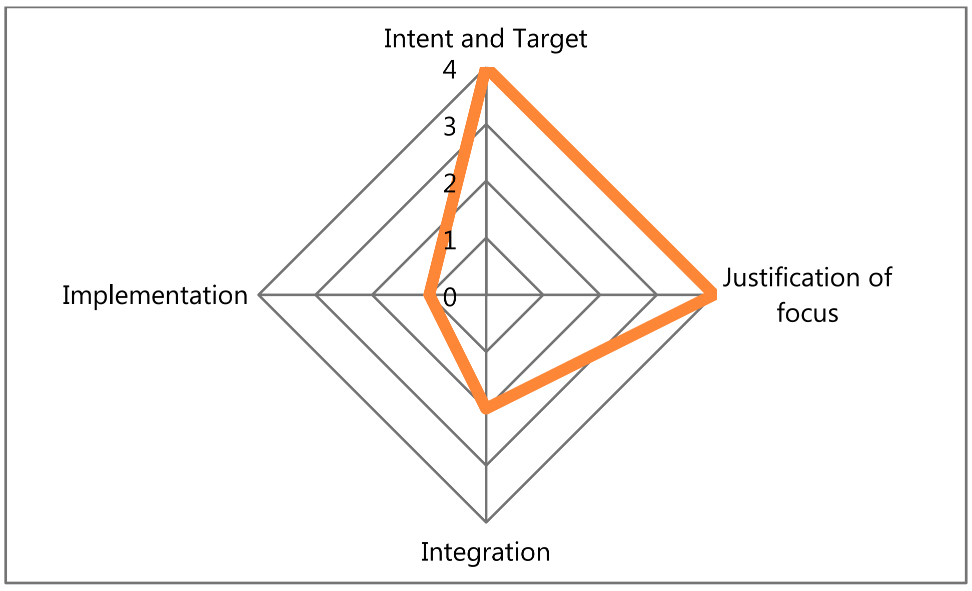
I) Instruments

<table>
<tr><th></th><th>Invention</th><th>Early Market</th><th>Cross Chasm</th><th>Spread</th></tr>
<tr><td rowspan="3">Regulatory</td><td></td><td></td><td></td><td>Develop GHG Emission Calculation tool for Chinese Power Plants (coal based) and effective monitoring system[77]</td></tr>
<tr><td colspan="4">Establish sound laws, regulations and standards to speed up access to the telecommunications network; and improve laws on networks an information security</td></tr>
<tr><td colspan="4">Formulate an overall national strategy for combating climate change and strengthen research and observation to influence our analysis of climate change using enabling and ICT technologies</td></tr>
</table>

77 Greenhouse Gas Protocol (2012). Launch GHG Calculation Tool for Chinese Power Plants http://www.ghgprotocol.org/feature/launch-ghg-calculation-tool-chinese-power-plants.

Economic	Set up special funds for the development of new strategic industries and industry investment, expand the size of governmental start-up investment in rising industries, and guide social capital to be invested in innovative start-ups (7.5 billion yuan – considering more)- includes ICT and enabling industries
	Reform of resource of tax system specifically oil, gas, and coal/electricity and carbon taxes(like EU's ETS). Move industry dependence from fossil fuels to renewable sources with prime focus of developing new strategic industries
	Discount Scheme for energy efficient products such as clean energy vehicles – focuses more on the energy efficiency of the engine rather than including SMART technology – also only approves certain vehicles and thus distorts the market
Behavioural	Popularize energy saving technologies and use of technology in energy efficiency such as ICT and smart metering– does not explain how or which technologies
Government leadership	Government leading a number of infrastructure energy efficiency and sector building projects including for instance new-generation information infrastructure, development of high tech industries – research and development programmes; broadband programme, smart metering to increase electricity efficiency[78]
	ECO-City Project: "The plan's purpose is to encourage cities to find new strategies for economic growth and improving people's quality of life." [79] – direct integration of ICT enabling technologies.

II) Policy design



Intent and Target	Justification of focus
• Policy has strong vision with clear intent and a significant number of over-arching and sector specific targets	• Justifies all programmes as related to both economic and societal strengths and weaknesses and fully integrated to policy aims.
Integration	Implementation
• 12th FYP is the main policy document with other 12th FYPs that are sector or programme specific that sit underneath – unclear how this fits with regional plans.	• No clear road map-there are not many instruments (only statements of intent) and no plan with priority targets or specific dates to reach targets - making it difficult to judge if programmes will "enable" enabling industries or create unintentional barriers. Moreover, policy is multi-jurisdictional creating overlaps and duplications among ministries.

78 EU SME Centre ibid.
79 UNESCAP 'China's low-carbon city project' Low Carbon Green Growth Roadmap for Asia and the Pacific: Case Study. http://www.unescap.org/esd/environment/lcgg/documents/roadmap/case_study_fact_sheets/Case%20Studies/CS-China-low-carbon-city-project.pdf.

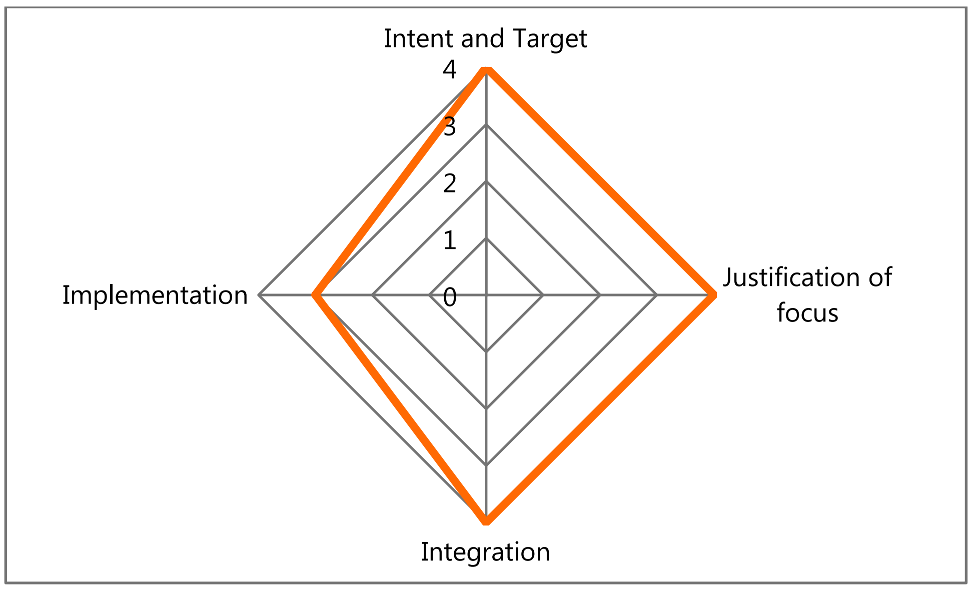
Czech Republic: National Research, Development and Innovation (RDI) Policy

I) Instruments

	Invention	Early Market	Cross Chasm	Spread
Regulatory	RDI Project Management: Power shift to RDI council and centralisation causes-"loss of 'strategic intelligence' about needs and opportunities" (disconnect of stakeholders)[80]			
Economic	Project based competition for funding or targeted support for projects that tackle national priorities and have more success at getting to market, with aim of attaining 60:40 ratio on competitive funding and institutional funding			
		Tax relief for enterprises that purchase research from Czech universities and institutions – including enabling technologies		
	Vouchers for joint ventures between private enterprises and research institutions with specific aim at ICT and energy efficiency projects			
Behavioural		Information system (web portal) give journalists/businesses access RDI information		
	Creation of Competence centres development of long-term collaboration between the public and private sectors on research, development and innovations			
Government leadership		Introduce flexible organisational structures of public research organisations to promote research/industry collaboration and research commercialisation		
		GESHER/MOST: International partnerships, collaboration between Czech companies and Israel –aim to conduct ICT and clean/sustainable technologies		
	Programme ALFA: supporting projects to stimulate Public Private Partnerships including "support of enabling technologies applicable in multiple industries"[81]			
	Project Beta: public procurement in research, experimental development and innovation for the needs of public administration bodies. Objectives include knowledge transfer and improvement of information management system			
	Project Omega: strengthen R&D activities in applied social sciences			

80 Ibid.
81 Taftie the European Network of Agencies, 2012. Technology Agency of Czech Republic. http://www.taftie.org/content/technology.

II) Policy design



Intent and Target	Justification of focus
• Well organised with 7 clear objectives and further description of intent as well as instruments	• Provides clear justification for policy objectives as well as areas for applied research using business case and sector research
Integration	Implementation
• The NRDIP further explores the goals of the National Innovation Policy, Energy Policy, and the Technology and Communication policy, fitting well into the policy landscape	• High political willingness to further CR through innovation activities • Performance based Funding System and Evaluation methodology hinders new tech development in practice • Power shift to RDI council and centralisation causes-"loss of 'strategic intelligence'- implementing irrelevant projects even if successful

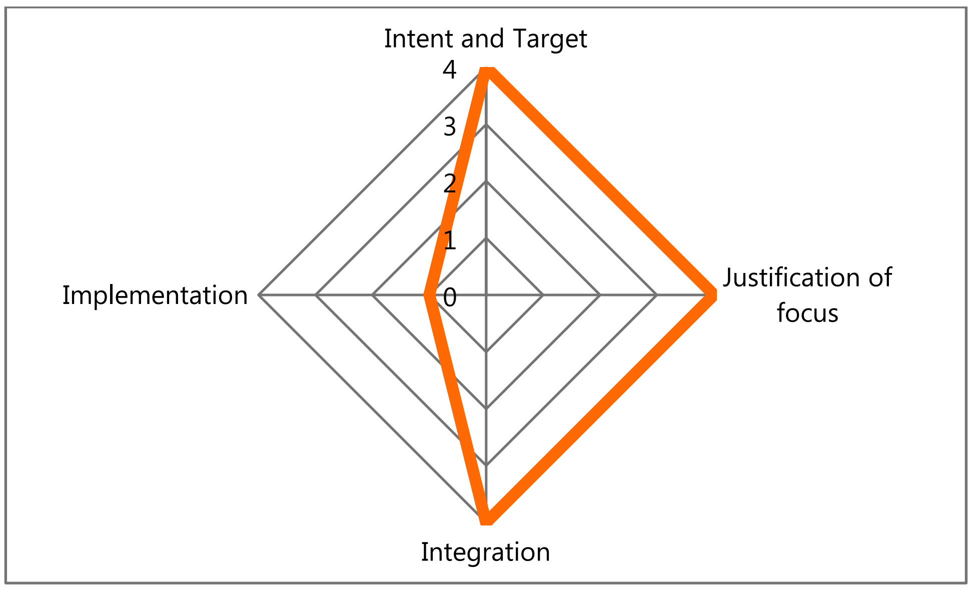
European Union: EU Emission Trading Scheme and the European Energy Efficiency Fund

I) Instruments

<table>
<tr><th></th><th>Invention</th><th>Early Market</th><th>Cross Chasm</th><th>Spread</th></tr>
<tr><td>Regulatory</td><td colspan="4">Creates a price for carbon emissions, incentivising industries within the scheme to invest into the reduction of carbon emissions, which could be investments done on any time of the innovation cycle.</td></tr>
<tr><td rowspan="2">Economic</td><td></td><td colspan="2">Financing help through the EEE-F. This market financing mechanism is built in order for municipal or local governments to invest in small scale renewable energy and energy efficiency projects.</td><td></td></tr>
<tr><td colspan="2">EEE-F Technical Assistance grants, which support beneficiaries in developing their projects by providing up to 90% of total cost</td><td></td><td></td></tr>
</table>

Behavioural				

II) Policy design



Intent and Target	Justification of focus
• The policies are the 'cornerstone' to reach the EU 2020 goals, and are supposed to adopt and strengthen the Kyoto Protocol. • ICT technology stated as an energy-saving solution in EEE-F	• As they are market-based solutions, they create no distortions within the energy efficiency market • Instrument choice of cap and trade are economically sound and the first attempt to put into practice on such a big level.
Integration	**Implementation**
• The structure of the policy is built up to allow for the addition of new sectors (e.g. aviation) or other countries (Australia)	• There is a clear roadmap on how the roles are divided between the Commission and the member states • The fact that the countries are responsible for the allocation of the allowances has lead to an over-allocation of allowances, rendering the policy ineffective • Free allowances (i.e., 'grandfathering') create indirect subsidy of production[82] – giving rise to high lobbying activity • Penalties ineffective as they are not used because of the oversaturated allowances market

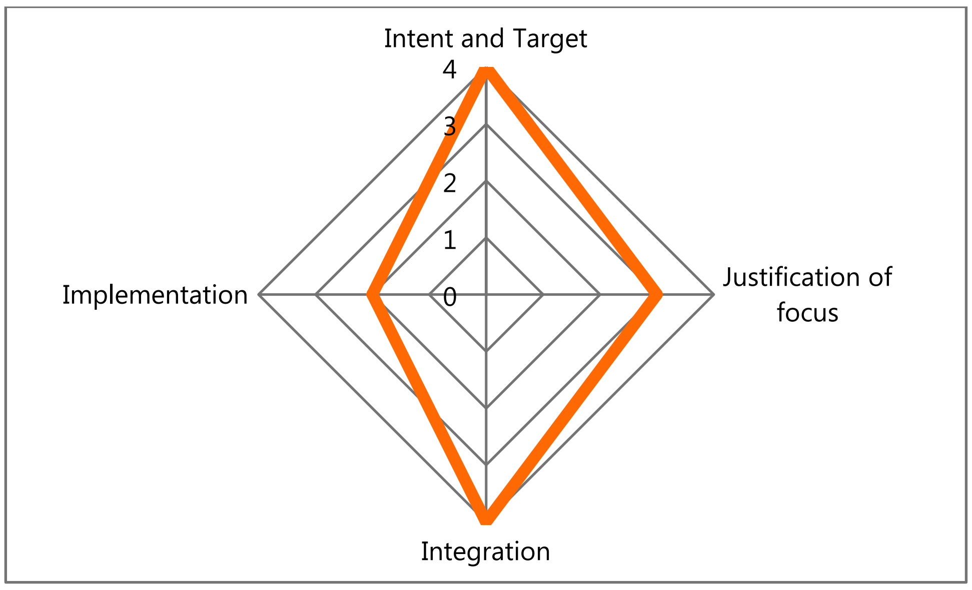
82 Hentrich, S., Matschoss, P. and Michaelis, P. (2009). Synthesis Article: Emission trading and competitiveness: lessons from Germany. Climate Policy 9.

France: Grenelle de l’environnement

I) Instruments

<table>
<tr><th></th><th>Invention</th><th>Early Market</th><th>Cross Chasm</th><th>Spread</th></tr>
<tr><td rowspan="2">Regulatory</td><td></td><td colspan="3">Publication of emissions balance sheet for firms> 500 employees. Risk of blaming enablers that are high energy users, while at the same time creating incentives for high-energy producers to buy service of enabling industries</td></tr>
<tr><td></td><td></td><td colspan="2">Smart-metering compulsory for new buildings</td></tr>
<tr><td>Economic</td><td></td><td colspan="3">Market distortion through direct support of alternative energy saving methods (e.g. financing help for solar panels, tax refunds for house renovation)</td></tr>
<tr><td>Behavioural</td><td></td><td></td><td colspan="2">Support for eco-labels for electrical appliances, including computers</td></tr>
<tr><td>Government leadership</td><td></td><td></td><td></td><td></td></tr>
</table>

II) Policy design



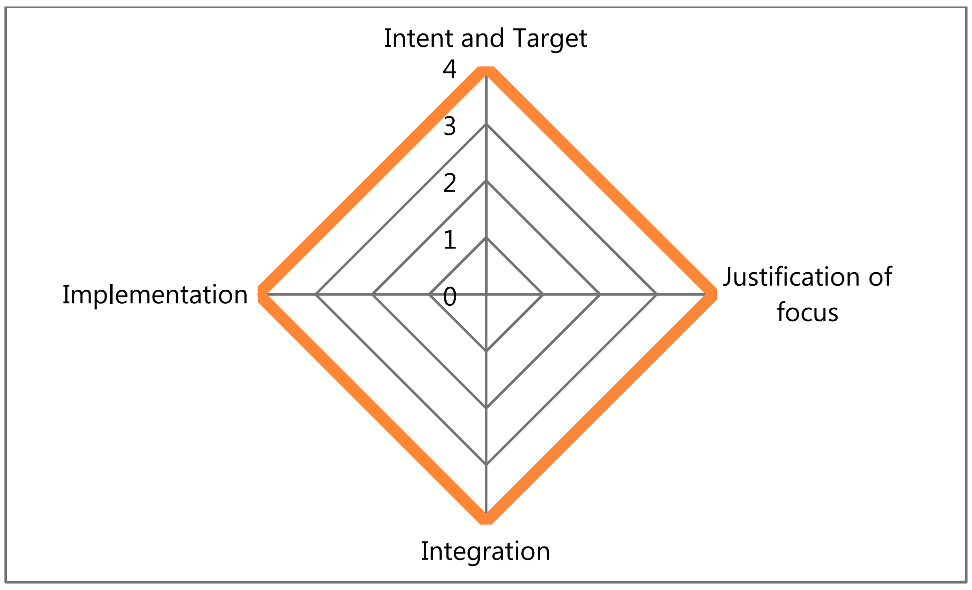
Intent and Target	Justification of focus
• Clear policy goals, higher than EU 2020 goals: overall goal is to reduce GHG emissions by an average of 3% per year, and so divide the emissions by four until 2050 • Shows area of priority for the French government	• The policy has a clear justification of focus with an analysis about energy usage and production • There are however policies that are 'picking a winner' (e.g. solar panels) within the energy-saving market without a justification • Policy founded by round-table discussions between important actors (government, NGOs, employer and employee associations), creates a shared owning of the policy and explains direction of it
Integration	Implementation
• As an overarching environmental policy, Grenelle encompasses all areas of environmental policy. • Grenelle puts into legislature a lot of European legislatives, including the 2020 goals or the taking out of the market of incandescent lightbulbs	• Generally, there is a clear roadmap on how policies will be put into practice • Localities with over 50000 inhabitants have to come up with a balance sheet of their GHG emissions and a summary of the intended policies to reduce the emissions, giving flexibility to the different areas • Ambiguity about the outcome of the balance sheets produced by firms. The law says that they will be published, but does not state standards or how whether any consequences will be drawn from these.

Germany: National Energy Efficiency Action Plan

I) Instruments

	Invention	Early Market	Cross Chasm	Spread
Regulatory			Energy efficiency requirements for buildings: cause market distortion through promotion of alternative solutions	
Economic	Funding allocated for: R&D and Demonstration of new technologies, technology commercialisation, integrated concepts for ICT-based energy systems ('E-Energy technological competition')			
Economic			Ecotax: includes electricity tax, which will penalise the ICT-sector for its growing footprint, despite the fact that it is enabling	
Behavioural			Voluntary eco-labelling: may stimulate the development of technologies enabled to produce energy efficient products, including ICT	
Behavioural	Awareness campaigns and expanding of education/training		Awareness campaigns & expanding of education/training: can result in high energy savings through mass behavioural change and stimulate the conception of innovative solutions	
Government leadership			Public procurement, energy managers appointment in municipalities, and other initiatives likely to accelerate the adoption of energy efficiency technologies	

II) Policy design



Intent and Target	Justification of focus
• National energy consumption target set to 9% p.a. over a nine-year period:2008-2016	• The policy justifies its focus by quantifying chosen measures in terms of energy savings potential • The policy recognises the ICT sector as an enabling industry
Integration	**Implementation**
• Integration of energy efficiency and ICT policies	• The 1st phase of implementation successfully completed, greatly exceeding the indicative targets

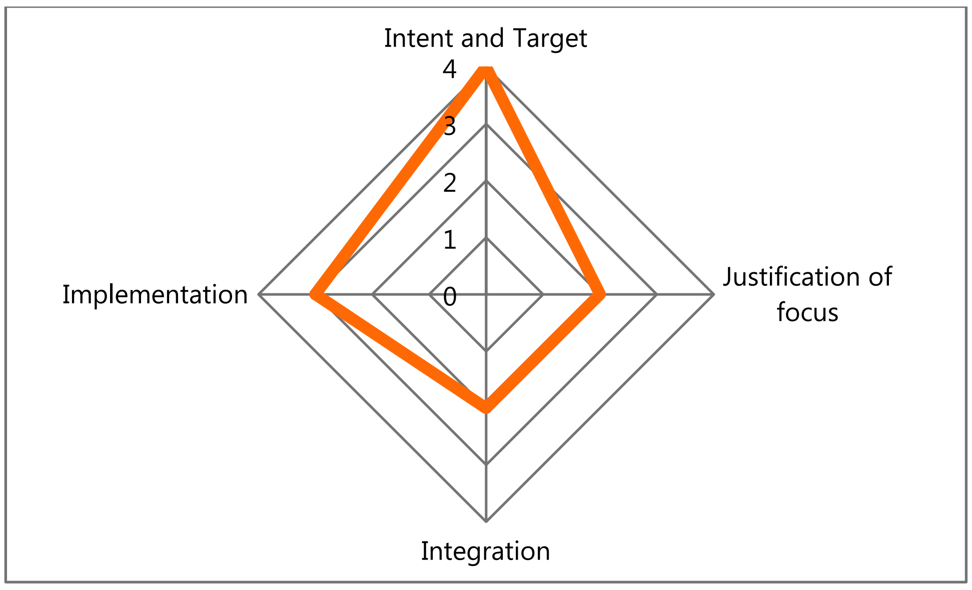
Indonesia: National Energy Conservation Master Plan (RIKEN)

I) Instruments

<table>
<tr><th></th><th>Invention</th><th>Early Market</th><th>Cross Chasm</th><th>Spread</th></tr>
<tr><td>Regulatory</td><td></td><td></td><td></td><td>Mandatory energy conservation of government office buildings/mandatory energy managers training; causes market distortion through support of alternatives</td></tr>
<tr><td rowspan="3">Behavioural</td><td rowspan="3"></td><td rowspan="3"></td><td colspan="2">The Energy Conservation Clearinghouse: platform for data and information exchange on energy efficiency; promotes non ICT solutions</td></tr>
<tr><td colspan="2">Energy benchmark and best practice guide for the commercial and industrial sectors; promotes non ICT solutions</td></tr>
<tr><td colspan="2">'National Energy Efficiency Movement': awareness campaign on efficient energy use; appears to focus on non ICT solutions</td></tr>
</table>

Government leadership			Creation of state-owned Energy Service Companies (ESCOs): ESCOs although focusing on non ICT solutions, they may also promote the use of 'smart' techs in the future, under their commitment to 'maintain forefront expertise in the field'
			Public-Private Partnership Program on Energy Conservation: a government-funded energy audit program for industries/commercial buildings; focus on non ICT solutions

II) Policy design



Intent and Target	Justification of focus
• National goal is to decrease energy intensity by an average of 1 % per year until 2025	• The policy does not recognise the ICT sector as an enabling sector; the focus non ICT solutions is not justified
Integration	**Implementation**
• It has not been integrated with the general policy framework; it is aimed at promoting energy efficiency, 'competing' with energy prices subsidies that render investments in energy-efficiency activities unattractive[83]	• The programmes are coordinated by the Ministry of Energy and Mineral Resources, but the regional governments are responsible for the implementation, allowing adaptation to local needs

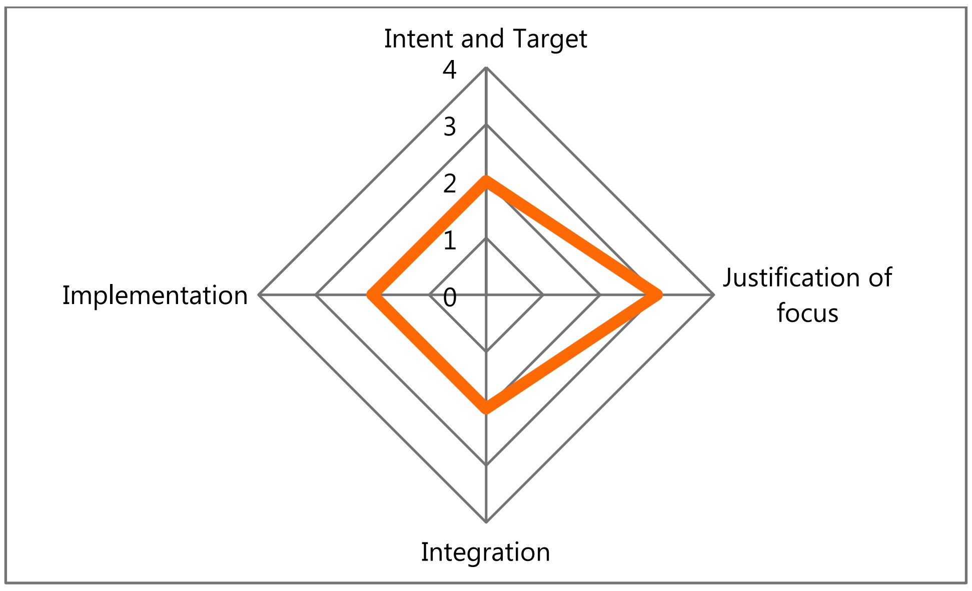
83 USAID, (2007). Indonesia Country Report. From Ideas to Actions: Clean Energy Solutions for Asia to address Climate Change' Bangkok: USAID.

Poland: Energy Policy of Poland Until 2030

I) Instruments

	Invention	Early Market	Cross Chasm	Spread
Regulatory			Minimum standards for power-consuming products create a demand for energy-efficient products, which will stimulate the spread of existing and niche technology.	
Regulatory			Mandatory energy-performance certificates for new buildings: creates market distortion by promoting alternative solutions by including HVAC, lighting, and insulation but not ICT	
Economic	Energy market—will increase competitiveness of electricity prices, but they're already cheap			
Economic	Tax exemptions for renewable energy creates market distortion that promotes preference for emissions reductions rather than energy savings			
Behavioural				Education and awareness for energy efficiency will spur spread of existing technologies from the demand-side
Government leadership			Make public sector a model of energy efficiency	

II) Policy design



Intent and Target	Justification of focus
• Clear statement of goals and targets, in line with EC Directives • Fuel security is emphasized over energy efficiency	• Reasoning is only offered in reference to EU commitments and post-Communist development • Evidence and support provided for choice to focus on high energy industries and energy production – justification for targets within these sectors
Integration	**Implementation**
• Acknowledges the policy is only one component of the National Development Strategy 2007-2015, but does not mention other parts or how they intertwine • Mentions support of R&D, but does not link to Operational Programme: Innovative Economy to promote ICT solutions	• The fuel security section of the policy is organised with clear targets, specific research goals, and focused instruments. Energy efficiency, however, was much more vague, with a few targeted instruments contributing to unclear objectives. • No mention of ICT or enabling technology • Energy efficiency mainly considered for role of energy demand reduction • No effective policy barriers as intervention very low

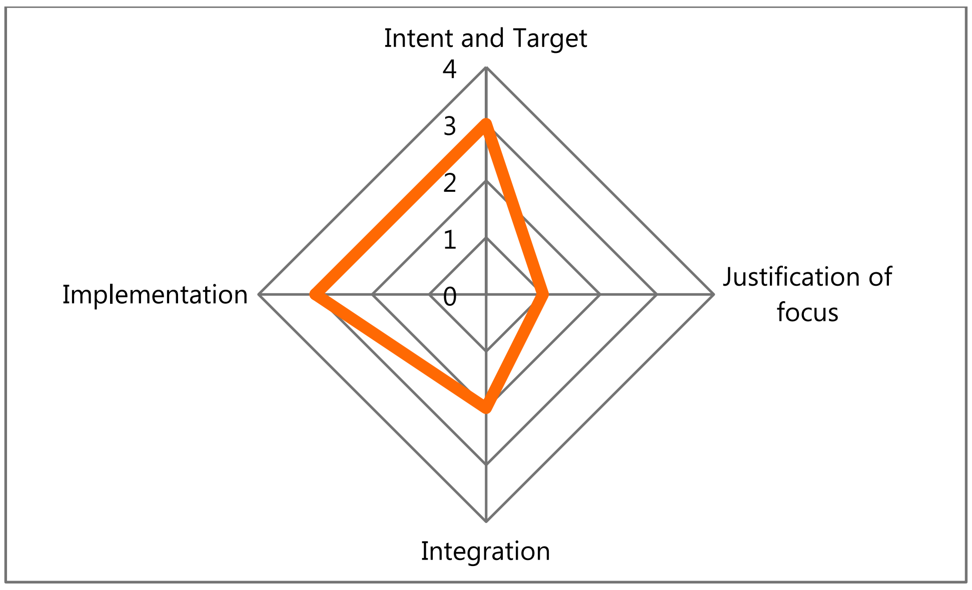
Portugal: National Energy Efficiency Action Plan (2008 – 2015)

I) Instruments

	Invention	Early Market	Cross Chasm	Spread
Regulatory	Mandatory energy audits, carbon targets, and measures for "high energy producing industries:" incentivises industries to increase demand for enabling industries			
Regulatory			National Energy Certificate Programme: creates market distortion because it does specify SMART monitoring as a measure of compliance (buildings)	
Economic			Fast fiscal depreciation system for acquisition of high-efficiency equipment such as computers	
Economic			Carbon targets with fines for non-compliance for high energy producing industries (non ICT)	
Behavioural			Educational programmes aimed at increasing energy awareness – distorted to non-ICT solutions	
Behavioural			Energy Star programme for appliances, including computers	
Behavioural			Low energy producers/carbon emitters in the high producing industries such as mining, agriculture, and manufacturing can join the SGCE (a certification scheme) – incentive offers market for enabling industries	

	Invention	Early Market	Cross Chasm	Spread
Government leadership			Regulations on public procurement to include environmentally friendly products such as ICT equipment	

II) Policy design



Intent and Target	Justification of focus
• 12 specific programmes with relevant targets as part of Portugal's ENE 2020 Strategy	• Does not justify use of these particular programmes to reduce energy consumption
Integration	**Implementation**
• While it does sit inside Portugal's ENE 2020 strategy there is not much detail how these programmes fit with other initiatives	• There are no direct barriers to ICT even though the energy efficiency plan is limited in scope and depth. • Lack of political will to go beyond EU requirements

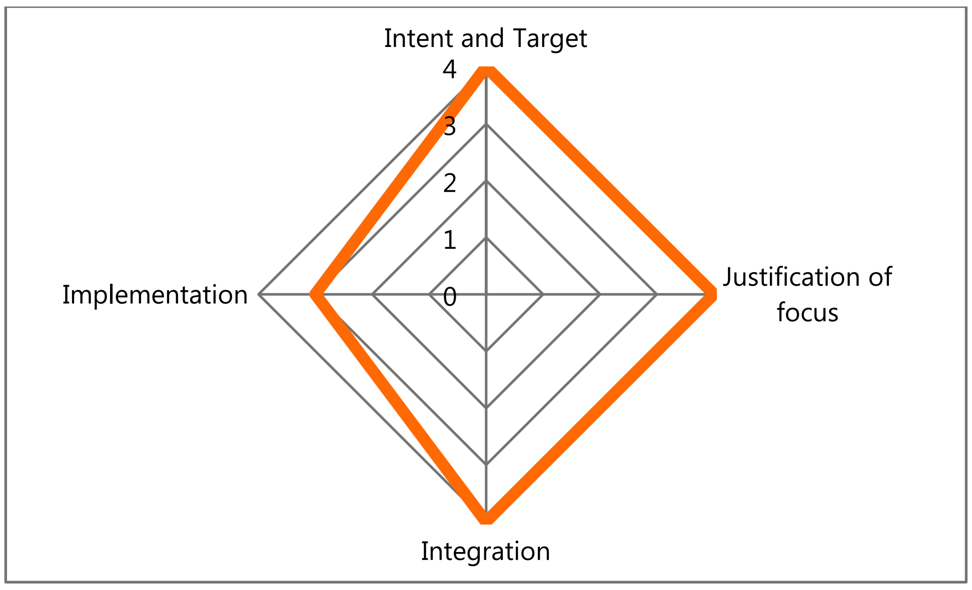
Sweden: Integrated Climate Change and Energy Policy 2009

I) Instruments

<table>
<tr><th></th><th>Invention</th><th>Early Market</th><th>Cross Chasm</th><th>Spread</th></tr>
<tr><td>Regulatory</td><td></td><td></td><td colspan="2">Requirement for individual water and electricity meters for new and refurbished buildings will stimulate production and sale of smart meter</td></tr>
<tr><td rowspan="2">Economic</td><td colspan="2"></td><td colspan="2">Decreasing the amount of CO2 tax relief for non EU-ETS industries from 30% to 60% of the general tax rate

Increase in the general CO2 tax</td></tr>
<tr><td colspan="4">'Investment in technology procurement and the introduction of energy-efficient technology on the market will be strengthened'</td></tr>
<tr><td>Behavioural</td><td></td><td></td><td colspan="2">Investment on 'reducing information and knowledge gaps' to raise awareness of potential savings in money and energy by improving energy efficiency in houses and enterprises</td></tr>
<tr><td>Government leadership</td><td></td><td></td><td></td><td>Using ICT to 'green' government</td></tr>
</table>

II) Policy design



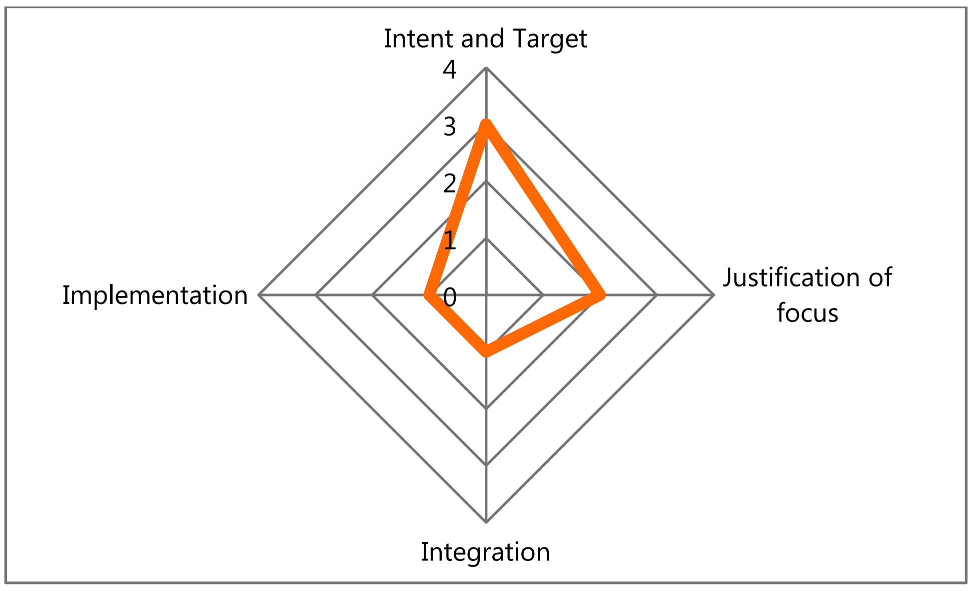
Intent and Target	Justification of focus
• Clear policy goals and strong, quantified targets	• Describes targets in relation to international commitments, existing instruments, and current progress against 1990 benchmark
Integration	Implementation
• Acknowledges parallel directives • Describes how implementation can successfully accomplish goals of two EC Directives	• Clearly delineated responsibilities and set funding targets • Acknowledges potential of ICT as an enabling technology

The United Kingdom: Carbon Reduction Commitment Energy Efficiency Scheme

I) Instruments

	Invention	Early Market	Cross Chasm	Spread
Regulatory			The 'cap' aspect of the 'cap-and-trade' scheme. This measure will cause a financial burden to the enabling industries by penalising an increase in emissions	
Economic			CO2 emissions allowances trading under the 'cap-and-trade' scheme. If the enabling industries will increase their own carbon footprints to enable reductions elsewhere; they may end up purchasing additional allowances at a higher price in the secondary market	
Behavioural			Publication of the 'CRC Performance League Table'. This instrument is likely to be an additional burden for the enabling industries; the lower League Table position can damage their reputation	

II) Policy design



Intent and Target	Justification of focus
• National carbon reduction targets set to 34% by 2020 and to 80% by 2050; CRC is contributing by targeting enterprises accounting for 10% of all UK's emissions	• The policy does not justify the employment of 'penalising' CO2 measures, over other alternatives (e.g. emissions data use to create a 'best practices' exchange platform) • It doesn't acknowledge the ICT sector as an enabling industry
Integration	**Implementation**
• The scheme has not been integrated with the national ICT strategy; unintentionally results in penalising the ICT industry, while the latter aims at its development and expansion	• The policy has been repeatedly characterised by the participating enterprises as complex and difficult to implement

Contact

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