Digital Value Chains for Cabon Emission Credits

Ichiro Satoh

1 Introduction

The reduction of greenhouse gases (GHGs), including carbon dioxide (CO_2), has become one of the most serious issues in the world today to build a sustainable world. Digital economy have several contributions to the reduction of GHG emissions. Among them, *Carbon credits* is one of the most important and effect approach to reducing the amount of GHG emissions, where carbon credits are generated by the reduction of CO_2 emissions in sponsoring projects, which increase CO_2 absorption, such as renewable-energy, energy-efficiency, and reforestation projects. Although carbon credits themselves do not reduce the amount of CO_2 emissions around the world, they are important incentives for GHG reduction projects.

Many companies have also sold products with the amount of carbon credits equivalent to the amount of GHGs emitted due to the use or disposal of products so that the credits have been used to offset GHGs emissions. There are a variety of products on the market with carbon credits, e.g., automobiles, disposable diapers, and toys. For example, from September 2007, Lufthansa began offering its customers the opportunity of offsetting carbon emissions through voluntarily donating carbon credits to mitigate the amount of CO_2 emitted due to the actual average fuel consumption per passenger.

However, carbon offsetting poses several problems that result from carbon credit trading. Carbon credits are usually acquired through *carbon credit trading* between countries or companies, or in markets via professional traders, called carbon traders or agencies. Furthermore, existing trading schemes are performed through e-commerce, but they are too complicated for non-professional traders, individuals, or small and medium-sized enterprises, to participate in. In fact, the minimal unit of existing credit trading is usually more than one hundred or one thousand tonnes of

National Institute of Informatics
2-1-2 Hitotsubashi, Chiyoda-ku, Tokyo 101-8430, Japan
e-mail: ichiro@nii.ac.jp

CO_2 emissions, whereas the amount of GHGs emitted due to the use or disposal of consumables is less than one kilogram.

To solve problems in existing carbon trading, this paper aims at proposing a new scheme for trading carbon credits as a new digital economic system for reducing carbon emissions on the earth by using infrastructure and RFID tags (or barcodes). It enables a small amount of carbon credits attached to products to be transferred to endconsumers who buy these products and carbon credits to be easily traded. The key idea behind our proposed approach is to use RFID tags (and barcodes) as certificates for the rights to claim carbon credits, because RFID tags are widely used in the management of supply chains. Another idea is to use the return of RFID tags as an authentication mechanism. We designed a digital architecture for managing RFID-enabled carbon credit offsetting and trading. The architecture was constructed and evaluated with real carbon credits in a real supply-chain system.

2 Background

Before describing our approach, this section briefly outlines carbon credits and their associated problems. Carbon credits are tradable certificates, also called *carbon emission credits* or *carbon offset credits*, that represent a certain volume of absorbed or reduced emissions by different people or organizations that have reduced excessive amount of GHGs in the atmosphere in the short- or long-term. For example, developed countries or companies financially or technically support projects that aim to reduce GHG emissions in developing countries. They can, in turn, offset their emissions by credits generated from the projects. These projects might involve installing renewable energy technologies, implementing energy efficiency measures, or removing CO_2 from the atmosphere through carbon sequestration.

There are other tradable emission rights, called *carbon emission caps* (or *carbon (emission) allowances*), that are limits. A government authority first sets limits on the amount of CO_2 that companies are allowed to emit. If a company emits an amount of CO_2 due to its activities below its limit, it can sell the excess capacity, which is the difference between the limit and the amount of CO_2 that really has emitted, as caps to companies whose emissions are over their limits. If a company emits an amount of CO_2 beyond its limit, it must pay a penalty or buy caps from someone to comply with its caps. Carbon emission caps are traded between companies or in markets.

Our approach supports both carbon emission credits and intends to treat carbon emission credits in a unified manner so that it can assign carbon emission credits into products and claim the credits in a unified approach. Therefore, in the following sections, we simply describe both carbon emission credits and carbon emission caps as carbon credits to avoid any misunderstanding between them.

3 Problem Statements

This paper describes a digital economic system for trading carbon emission credits, which have several properties that other economic values do not have.

Difficulty in carbon credit trading:

Carbon credits can usually be traded through electronic commerce systems, but existing systems are quite different from digital enterprise. They are closed and complicated so that only professional traders, called *carbon providers* or *carbon agencies*, buy or sell carbon credits on behalf of their clients. Therefore, it almost impossible for end-users, small companies, or NPOs/NGOs to sell or buy carbon credits.

Large trading units:

The minimal units of existing trading carbon emission credits, including caps, are more than one hundred or one thousand tonnes of CO_2 . However, the amount of CO_2 an average person emits throughout his/her life for one year is less than one tonne. Each endconsumer product should have less than one kilogram of carbon credits to offset CO_2 emissions in the use or disposal of the product. However, there are currently no approaches to trading small amount of carbon credits, e.g., one gram or one kilogram.

Non-voluntary carbon offsetting products:

As existing schemes for carbon offsetting products any mechanisms to transfer the carbon credits linked to the products to endconsumers. Instead, dealers or manufacturers, who assign the credits to products, offset the credits on behalf of the purchasers (buyers) of the products. Although the purchaser pay extra corresponding to the credits, they have no chance of owning the credits and they do not know whether the credits have been properly offset by the dealers or manufacturers.

4 Carbon Emission Trading Approach

This paper proposes a new digital enterprise approach for enabling a small amount of carbon credits to be attached to each item and to be transferred to consumers who buy it. Our approach introduces RFID tags (or barcodes) as carbon credits for the rights to claim credits in carbon offsetting, because RFID tags (or barcodes) are used in supply chains. In fact, our approach can use the RFID tags that have already been attached to items for supply chain management. The approach was designed as a complement to existing supply management systems. It therefore has nothing to do with the commerce of items themselves. It also leave the transfer of carbon credit between companies with existing carbon trading systems, because commerce for carbon credits must be processed by certificated organizations. Instead, the approach is responsible for attaching carbon credits to RFID tags and claims for carbon credits. The approach should support emission

credits in a unified manner. It also should not distinguish between items for end-consumer and others, because non-end-consumers may buy items for end-consumers. Some readers may think that our approach is trivial. However, simplicity and clarity are essential to prompt most people and organizations to participate or commit to activities to reduce GHG emission by carbon offsetting.

Our approach satisfies the following main requirements: 1) The approach needs to encourage industries and homes to reduce GHG emissions. It also needs to be compliant with regulations on carbon offsetting. 2) Simplicity must be a key concern in minimizing operation costs, because it tends to be in inverse proportion to cost. This is needed for people and organizations to understand what is required of them. 3) Any commerce scheme provides the potential to advantage some participants at the expense of others. The approach enables organizations or people that reduce more GHG emissions to be rewarded with greater advantages. 4) The values of carbon credits, particular emission credits tend be varied. The amounts, expiration dates, and sources of all carbon credits, which may be attached to items, need to be accessible. 5) When consumers purchase items with carbon credits, they should easily be able to own the credits without any complicated operations to authenticate them. 6) Item commerce in the real world is often done in warehouses and stores, where networks and electronic devices may not be available. Our approach itself should be available offline as much as possible.

5 Digital Architecture for Carbon Offsetting and Trading

Our approach introduces RFID tags (or barcodes) as carbon credits for the rights of emitters to claim credits in carbon offsetting and trading, because RFID tags (or barcodes) are used in supply chains. In fact, our approach can use the RFID tags that have already been attached to items to manage supply chains. The approach was designed to complement existing supply management systems. It therefore has nothing to do with the trading of the items themselves. It also leaves the transfer of carbon credits between companies to existing carbon trading systems, because carbon trading must be processed by certificated organizations. Instead, the approach is responsible for attaching carbon credits to RFID tags and claims for carbon credits. The approach should support emission credits in a single manner. It should also not distinguish between items for endconsumers and others, because non-endconsumers may buy items for endconsumers.

5.1 RFID tags as certificates to claim carbon credits

The basic idea behind our approach is to use RFID tags themselves, rather than their identifiers, as certificates for carbon credits. If the people or organizations that claim the credits with only the identifiers, we need a complicated authenticate them. It is difficult to replicate or counterfeit RFID tags whose identifiers are the same, because their identifiers are unique and embedded into them on the level of semiconductors.

To claim carbon credits dominated by RFID tags, we need to return these RFID tags to the stakeholders that assigned carbon credits to the tags. This is because there is at most one RFID tag whose identifier is the same. RFID tags can be used as certificates for carbon credits. For example, when sellers want to attach carbon offsetting credits to items, they place RFID tags on them that represent the credits for the items. Our approach couples carbon credits with RFID tags themselves, instead of the identifiers of the RFID tags. Therefore, purchasers, who buy the items, tear the RFID tags from them and return the tags to the sellers (or the stakeholders of the credits). When the sellers receive the RFID tags from the purchasers, they transfer the credits to any accounts for payments that the purchasers specify.

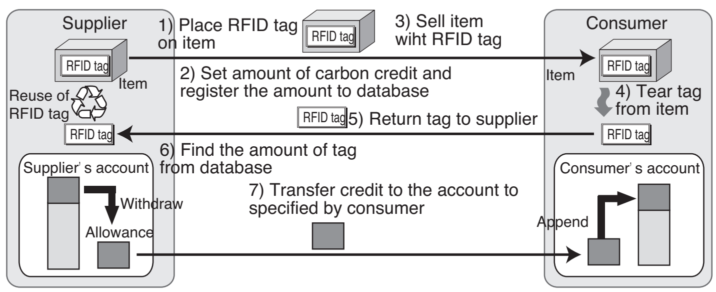

Fig. 1 RFID-based attachment of carbon credits to items

Figure 1 explains our approach to attach carbon credits to items with RFID tags, which involves seven steps

1) A seller places an RFID tag on an item (or a volume of items) if the item has no tag.
2) It sets a certain amount of carbon credits for offsets for a item and registers the amount and the identifier of the tag in a database.
3) It sells the item with the RFID tag to a purchaser.
4) The purchaser tears the tag from the item that it has bought.
5) It only returns the tag with information about the account that the credit should be paid to, to the seller.
6) The seller receives the tag and then finds the amount of carbon credits coupled to the tag in the database.
7) It transfers the amount to the account specified by the purchaser and removes information on the identifier from the database so that the tag can be reused.

5.2 *Carbon credit trading with RFID tags*

When a purchaser has torn an RFID tag from an item, which might have been attached to an item that he/she purchased, our approach permits the purchaser to resell the tag to others (Figure 2). Instead, the new holder of the tag can claim the carbon credits attached to the tag from the stakeholder of these credits or resell them to someone else. Note that trading RFID tags corresponds to trading carbon credits.

To offset GHG emissions according to the Kyoto protocol, we must donate certified carbon credits to the government via a complicated electronic commerce system. Our approach provides two approaches to carbon offsetting. The first is to simply donate RFID tags coupled to certified carbon credits to the government. For example, people can simply throw RFID (unsigned) tags into mailboxes to contribute to reducing GHG emissions in their home countries. The government then gathers the posted tags. The second is to explicitly specify the certificated cancellation account of the government as the account that the credit should be paid into.

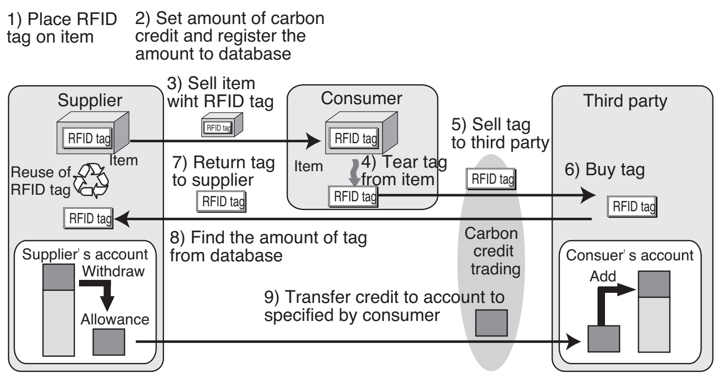

Fig. 2 RFID-enabled trading of carbon credit

6 Implementation

Our approach has been designed so that it can be used in supply chains, where each supply chain consist of sellers, retailers, distributors, transporters, storage facilities, and customers who are involved in moving an item or service from upstream to downstream. Our approach assumes that sellers at steps in a supply chain will sell their items to customers, including raw materials and components, with RFID tags coupled to carbon credits.

- Our approach requires each RFID tag to have its own unique read-only identifier. Most RFID tags used in supply chain management already have such identifiers. For example, we can directly use RFID tags that have been standardized by EPCglobal, because their identifiers, called Electronic Item Code (EPC), consist

of the identifiers of the dealers, sellers, manufacturers, or other agents, and the identifiers of the individual items themselves.
- Anyone can access information about the credits attached to the items, because the credits are transferred to purchasers who return the tags themselves to the sellers. The sellers should provide information about the credits, e.g., their amounts, expiration dates, and sources.
- To support carbon offsets, the amount of credits attached to a item need to be equivalent to the total or partial amount of CO_2 emissions resulting from the use or disposal of the items. Nevertheless, the approach itself is intended to leave the amount of credits attached to an item at the stakeholder's discretion, because the credits can be an incentive to sell the item.

Some readers may worry that returning RFID tags to their stakeholders is more costly than returning the identifiers of tags via a network. There are two flows that are opposite to each other between sellers and purchasers at each stage in real supply chains; the flows of items and the flows of receipts or containers for the items. Our approach can directly use the latter flow to return tags from purchasers to sellers. Therefore, our cost and extra CO_2 emissions are small. Actually, returnable containers or boxes, which deliver parts or components from sellers and then return them to sellers, are widely used in real supply chains. Our approach can introduce carbon credits as incentives to return such returnable materials to their stakeholders.

To store carbon credits in a certified manner, many companies entrust certified agents to store and transfer their carbon credit accounts just like they entrust their money to banks. Our system assumes that sellers (and purchasers) have such agents. However, existing agents for carbon credit accounts are not concerned with carbon credits that are RFID tag-based. To solve this problem we introduced a new organization, called carbon credit RFID tag agents (simply called RFID agents), which is not included in existing schemes for carbon offsetting and trading. It is responsible for managing RFID tags and carbon credits coupled with the tags. Figure 3 is a minimal set in our system between a seller and a buyer.[1] Each subsystem has four kinds of facilities.

- Each seller has at least one carbon credit account entrusted to agents for carbon credit accounts. It has RFID tag reader systems to read the identifiers of RFID tags. If a seller consigns one or more RFID agents to manage RFID tags for carbon credits, they need a database to maintain which RFID agent will manage each of the RFID tags.
- Each purchaser may have at least one carbon credit account entrusted to agents for carbon credit accounts. It buys items that RFID tags have attached to them for carbon credits from sellers or traders. It needs RFID tag reader systems, when it intends to access information about carbon credits.
- Agents for carbon credit accounts, simply called *account agents*, may be existing certified carbon providers. They have two databases. The first maintains car-

[1] The proposed approach presented in this paper is described by supports gray rectangular parts in the figure.

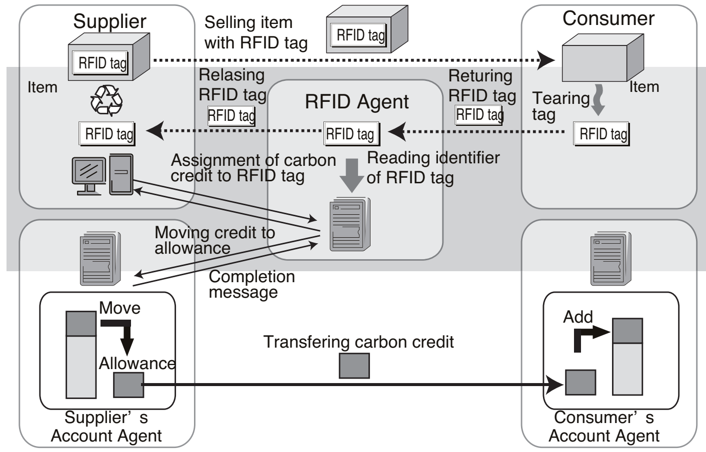

Fig. 3 System architecture

bon credit accounts and the second maintains information about assigned credits. They can only be connected to certain RFID agents and other account agents through authenticated and encrypted communications.

- An RFID agent has a database to couple the identifiers of RFID tags and information about carbon credits. The agent may lease RFID tags, which may already have been assigned a certain amount of credits to sellers.

In the following explanation, we have assumed that RFID tags have been provided to sellers by RFID agents and the identifiers of RFID tags contain the identifiers of agents in addition to the unique identifiers of items. The system in Figure 3 is self-contained but it may cascade from upstream to downstream along a supply chain.

7 Social Experiment

The experiment was an early case study on the proposed approach, but was carried out on a supply chain for beverages it was evaluated at several steps in the supply chain, including beverage companies (e.g., Pokka and Fujiya), a supermarket (Kitasuna branch of Ito-yokadou) [2], and a carbon credit agency (Mitsubishi UFJ Lease). It was carried out for two weeks from 9 am to 10 pm and more than five thousand goods were sold with carbon offset credits in this experiment.[3] We experiment was divided into two phases. The first was between the beverage factories and the retailer (supermarket) and the second was between the retailer and endconsumers. We provided items with certificates of real carbon credits, called Japan Verified Emission

[2] The supermarket is one of the biggest in Tokyo area.

[3] We have left the results of user evaluation to a future paper, because here we have aimed at presenting our basic ideas and implementation rather than user evaluations.

Reduction (J-VER), where J-VER credits were generated from thinning forest and were traded on the domestic market and managed by the Forestry Agency.[4]

7.1 Carbon credits attached to factory items

The beverage factories filled cans with beverages and packed twenty or thirty cans into returnable containers or cardboard boxes.[5] They adhered RFID-tags onto these returnable containers and placed attachable RFID-tags onto the cardboard boxes. They shipped such containers or boxes to retailers. Each RFID tag represented a specified amount of J-VER carbon credits. The supermarket bought the containers or cardboard boxes with the RFID tags attached. It tore the tags from the cardboard boxes and returned them to the factories so that it could claim the credits to be transferred to it. It returned the returnable containers to the factories without tearing the RFID tags. The return rate of RFID tags attached to containers was about 80 %. We knew that carbon credits coupled to the tags were an incentive for the containers to be returned to the factories (Figure 4). There were no extra operations to return RFID tags that had been adhered to the returnable containers, because the tags were returned with the containers to the factory. Retailers disposed of the cardboard boxes instead of returning them. Nevertheless, since they returned the acceptance notification documents of items or additional order documents to the factories, the RFID tags attached to the cardboard boxes could be sent with such documents to the factories.

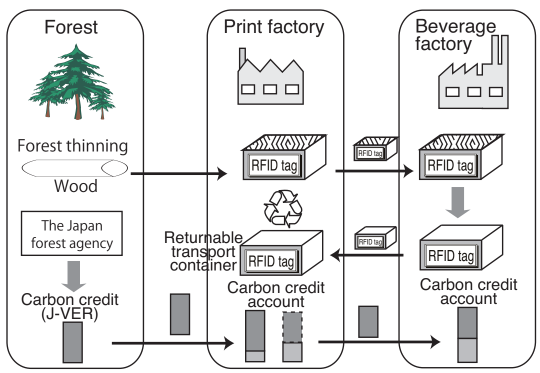

Fig. 4 Experiment in supply chain

[4] We initially acquired 6 tonnes of J-VER carbon emission credits in the experimental and divided them into small amounts, e.g., 300, 500, or 700 g, and assigned them to goods.

[5] The cans, called *CartoCans*, were made almost entirely of paper processed from wood chips obtained from thinning forests.

7.2 Carbon credits attached to final products

The supermarket opened the returnable containers or cardboard boxes containing the cans. It attached a barcode seal on the cans and sold them to endconsumers, where each barcode seal displayed small amount of J-VER carbon credits, because the price of each RFID tag was relatively more expensive than the price of a can.[6] Each barcode was formatted in a 2D barcode, called QR code, and consisted of its own identifier, the weights of carbon emission credits assigned to it, and the address of the management server. Figure 5 shows beverage cans with barcodes in a showcase at the supermarket.

Endconsumers bought cans and collected barcode seals as their carbon credits. We supported two cases to reclaim credits in the proposed approach.

- The first was for endconsumers to return barcode seals to the supermarket to reclaim credits. Cashiers could distinguish between original or imitation seals, because they received the seals themselves. Therefore, even when someone read the barcodes attached to the cans, the endconsumers who bought the cans could reclaim the credits.
- The second was for endconsumers to read barcodes by using their own scanners, e.g., cellular phones with cameras, and they then sent the information to the server specified in the barcode. As some might peel off the barcode attached on the cans in stores and illegally reclaim carbon credits. The barcodes were concealed by covering them with other seals.[7]

We used the former in our approach. Few endconsumers participated in the latter, because most endconsumers wanted to immediately reclaim their credits. The former also enabled consumers to access information about carbon credits by reading the barcodes with cellular phones before they bought the items attached with the barcodes. The experiment assumed that retailers bought barcode seals that had already been assigned to small amounts of carbon emission credits, like postage stamps. This is because small retailers might not have any terminals.

In the experiment, we provided the supermarket with barcode seals that had 300, 500, and 700 g weights of carbon credits. The supermarket sold 5320 cans, which consisted of twenty-one kinds that barcode seals had attached according to their environment load. The sales volumes of cans with carbon credits in two weeks was three times more than usual at the supermarket. Thirty-five percent of barcodes were returned to the supermarket by customers who claimed the credits. The experiment enabled consumers to offset their CO_2 emissions by using the carbon credits they reclaimed from the barcodes.

[6] A can costs less than one dollar and an RFID tag seal costs more than a dime.

[7] The seals that concealed the barcodes used special adhesive. They could not be attached to the barcode after they had been torn.

7.3 Lessons learned

There were many lessons learned from the experiment. Most problems in the experiment were not technical. For example, many consumers asked us about the notion of carbon offsets and credits so that we spent a lot of time to dealing with their questions. The current implementation was not built for performance, but we measured the cost of attaching the carbon credits to an RFID tag after the tag's identifier had been read, which was 460 ms. The cost of claiming carbon credits was 390 ms. The costs tended to increase according to the number of simultaneous requests. Nevertheless, our system was designed to handle attachment and claim requests through batch processing. The number of attachment and claim requests was also bound to the number of RFID tags or barcodes.

Fig. 5 Beverage with Barcode for carbon credits

8 Related Work

Several researchers have explored computing technology to make a contribution to the environment. For example, Persuasive Appliances [6] was an interface system to provide feedback on energy consumption to users. PowerAgent [1] was a game running on mobile phones to influence everyday activities and minimize the use of electricity in the domestic settings. UbiGreen [3] was an interactive system running on mobile phones and gave users feedback about sensed and self-reported transportation behaviors to reduce CO_2 emissions from the transportation sector.

There have been several projects that have used sensing systems to manage warehouses and logistics to reduce CO_2 emissions. Ilic et al. [4] proposed a system for controlling the temperature of perishable goods to reduce GHG emissions. Dada, et al. [2] proposed a system for accurately quantifying GHG emissions to calculate carbon footprints and communicate the results to consumers through sensing systems. The system also planned to use EPCglobal RFID tags to trace carbon footprint emissions at higher stages of the supply chain. However, as long as our knowledge, there has been no work that supports carbon credits by RFID technology.

9 Conclusion

The approach proposed in this paper can be proposed to solve serious problems with existing carbon credits, offsetting, and trading. The key idea underlying our approach is to introduce RFID tags (or barcodes) as physical certificates for the rights to claim carbon credits, including carbon emission credits. When purchasers buy items with credits for carbon offsets, they can claim the credits by returning the RFID tags (or barcodes) coupled with the credits to stakeholders, e.g., sellers or agencies, without the need for any complicated authentication. The approach can treat carbon credit trading as the trading of RFID tags. The approach was constructed to complement existing systems of supply chain management. It can be simply and intuitively provided in real supply chains. Our early experiment proved the feasibility and effectiveness of our approach. We believe the approach will be a powerful digital economy for carbon credits to reduce the emission of greenhouse gases on the earth.

References

1. M. Bang, A. Gustafsson, and C. Katzeff: Promoting new patterns in household energy consumption with pervasive learning games, Proceedings of 2nd international conference on Persuasive technology, pp.55-63, 2007.
2. A. Dada, T. Staake and E. Fleisch: The Potential of UbiComp Technologies to Determine the Carbon Footprints of Products, Proceedings of Pervasive Computing 2008 Workshop on Pervasive Persuasive Technology and Environmental Sustainability, pp.50-53, 2008.
3. J.Froehlich, T. Dillahunt, P. Klasnja, J. Mankoff, S. Consolvo, B. Harrison, and J. A. Landay: UbiGreen: investigating a mobile tool for tracking and supporting green transportation habits, Proceedings of the 27th international conference on Human factors in computing systems (CHI'2009), pp.1043-1052, ACM, 2009.
4. A. Ilic, T. Staake, and E. Fleisch: Using Sensor Information to Reduce the Carbon Footprint of Perishable Goods IEEE Pervasive Computing, vol.8, no.1, pp.22-29, 2009.
5. IPCC fourth assessment report: Climate change 2007. Technical report, IPCC, http://www.ipcc.ch/, 2007.
6. T. McCalley, F. Kaiser, C. Midden, M. Keser, and M. Teunissen: Persuasive Appliances: Goal Priming and Behavioral Response to Product-Integrated Energy Feedback, Proceedings of Persuasive Technology, LNCS, Vol.3962, pp.45-49, 2006.
7. Nicohlas Stern: The Economics of Climate Change: The Stern Review, Cambridge University Press, 2007.