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The choice of energy saving modes for an energy-intensive manufacturer under non-coordination and coordination scenarios

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ABSTRACT

Energy-intensive manufacturers have two main options for improving their energy efficiency: design and implement energy efficiency projects on their own (we call this self saving), or enter into energy performance contracts (EPCs), which mainly include shared savings and guaranteed savings. In this paper, we will discuss an energy-intensive manufacturer facing self saving and shared savings options and how this manufacturer chooses the optimal energy saving mode under non-coordination and coordination scenarios. We first formulate several mathematical models of the two types of energy-saving modes based on the assumption of exogenous unit savings (EX). We show that when the unit energy-saving benefit from shared savings is greater than the unit energy-saving benefit from self saving, the manufacturer prefers shared savings under the non-coordination scenario; otherwise, the manufacturer prefers self saving. Furthermore, we find that the bargaining power of the manufacturer is also a key factor in addition to the difference of unit energy-saving benefits under the coordination scenario. Interestingly, sometimes the bargaining power of the manufacturer has no impact on the optimal choice of energy saving modes. Finally, the basic model is extended to endogenization of unit savings (EN), and we show that the optimal choices of energy saving modes are completely different from the basic model.

1. Introduction

Energy-intensive manufacturers (hereafter referred to as manufacturers) face three “big mountains.” The first is the relatively rapid rise in energy prices. The second is increasingly stringent environmental policies. For example, the U.S.– China Joint Announcement on Climate Change (JACC) states that China intends to achieve its peak CO_2 emissions in approximately 2030. Finally, the consumer awareness of environmental protection is growing. For example, suppliers of Tesco, Walmart, IBM, and IKEA have been required to provide carbon labels [1]. These can greatly erode the profits of these manufacturers. Thus, improving energy efficiency becomes one of the most effective means by which manufacturers can address those pressures. Kim and Worrell [2] benchmarked the energy efficiency of steel production to best practice performance in five countries with over 50% of world steel production, finding that potential carbon emissions reduction due to energy efficiency improvement varies from 15% (Japan) to 40% (China, India, and the U.S.). As another example, in the cement industry, benchmarking and other studies have demonstrated the technical potential for up to 40% improvement in energy efficiency [3].

In practice, manufacturers can design, construct, and operate energy efficiency projects on their own to improve energy efficiency. This approach has some common characteristics: manufacturers depend mainly on their own strength, they provide project financing themselves, and they bear all the risk of the projects but retain all the savings. For the sake of brevity, we will call this self saving. In 2005, Pfizer Fribourg, as one of the world's largest biopharmaceutical companies, began to improve energy efficiency by self saving [4]. Large-scale manufacturers often have the potential to proceed with self saving energy efficiency projects. Such companies usually include a separate department dedicated to safety and environmental issues and hire specialists in this field. However, there are many disadvantages when some manufacturers choose self saving, such as lack of knowledge and experience during the design phase, uninformed use of energy efficiency equipment during the operational phase, etc. All the above factors may lead to a failure of project savings not making up for investment costs, which results in many potential energy efficiency projects not

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Nomenclature

EX	Exogenous unit savings
EN	Endogenization of unit savings
EXN	Exogenous unit savings and non-coordination
ENN	Endogenization of unit savings and non-coordination
EXCO	Exogenous unit savings and centralized control
ENCO	Endogenization of unit savings and centralized control
EXC	Exogenous unit savings and coordination
ENC	Endogenization of unit savings and coordination

Model parameters

p_e	Energy price
r_0	Unit initial energy level
a	Potential market capacity
T_s	Agreed contract term
r_i^{EX}	Unit savings under EX scenario
k_i	Marginal cost of unit savings under EX scenario
p_i	Retail price under EX scenario
c	Unit production cost expect unit energy cost
λ	Revenue fraction of the manufacturer under EXC scenario
δ	Sensitivity parameter of the demand to the retail price
α	Investment cost coefficient ratio of the ESCO to the manufacturer
D	Demand of the manufacturer
k	Investment cost factor of the manufacturer under EN scenario
p	Retail price under EN scenario
$\prod_{m,b}^{EX}$	Profit of the manufacturer under EX scenario
$\prod_{m,s}^{EXN}$	Profit of the manufacturer under EXN scenario
$\prod_{ESCO}^{EXN}$	Profit of the ESCO under EXN scenario
$\prod^{EXCO}$	Channel profit under EXCO scenario
$\prod_{m,s}^{EXN}$	Profit of the manufacturer under EXC scenario
$\prod_{ESCO}^{EXC}$	Profit of the ESCO under EXC scenario
$\prod_{m,b}^{EN}$	Profit of the manufacturer under EN scenario
$\prod_{m,s}^{ENN}$	Profit of the manufacturer under ENN scenario
$\prod_{ESCO}^{ENN}$	Profit of the ESCO under ENN scenario
$\prod^{ENCO}$	Channel profit under ENCO scenario
$\prod_{m,s}^{ENC}$	Profit of the manufacturer under ENC scenario
$\prod_{ESCO}^{ENC}$	Profit of the ESCO under ENC scenario

Decision variables

q_i	Production quantity under EXN scenario
θ	Fraction of unit savings under EXN scenario
q^{EXCO}	Channel production quantity under EXCO scenario
r_b^{EN}	Unit savings under EN scenario
r_s^{ENN}	Unit savings under ENN scenario
φ	Fraction of unit savings under ENN scenario
r^{ENCO}	Unit savings under ENCO scenario
r_s^{ENC}	Unit savings under ENC scenario
φ_s^{ENC}	Fraction of unit savings of the manufacturer under ENC scenario
γ_s^{ENC}	Fraction of the investment cost of the manufacturer under ENC scenario

Superscripts

*	Optimal value

Subscripts

m	Manufacturer
ESCO	Energy service company
e	Energy
i	Set of energy saving modes
b	Self saving
s	Shared savings

being implemented.

To make up for deficiencies when manufacturers choose self saving, manufacturers can outsource their energy services to energy service companies (ESCOs). Typically, the main form of energy services provided by ESCOs is energy performance contracting (EPC). The EPC is a new market mechanism where a manufacturer outsources energy services to an ESCO, which pays for the investment costs of energy efficiency projects by reducing energy costs and provides the manufacturer with comprehensive energy services from energy audits, investments in equipment, equipment selection, and all aspects of operation and maintenance. According to a survey of 65 foundries in France, Italy, Germany, and seven other countries, approximately 25% of responding enterprises prefer EPC to self saving [5]. There are two general types of performance contracts used in the ESCO industry – shared savings and guaranteed savings [6]. In a shared savings contract, the ESCO provides the financing, and the client assumes no financial obligation other than paying a given share of the materialized savings to the ESCO over a prescribed period of time (we call this an agreed contract term). After the agreed contract term, the customer retains all the savings. Alternatively, in a guaranteed savings contract, projects are often financed by third-party financial entities; the customer repays the loan to the creditor, and the ESCO guarantees a level of savings sufficient to cover the annual debt obligation, thus limiting the customer's performance risk. The shared savings approach is more suitable in developing countries, where energy efficiency projects lack a reliable and commercially viable means of financing, and energy-intensive customers always pursue short-term economic benefits and are reluctant to invest in energy efficiency projects. In China, shared savings is widely used, as government support for this approach is an important impetus in addition to the above-mentioned reasons. For example, both the tax cut policy released in 2010 and the financial incentives policy released in 2011 clearly require the use of shared savings; there are no similar policies to support guaranteed savings in China [7]. Therefore, we only consider shared savings in this paper.

Comparing self saving with shared savings, an ESCO always has an advantage with regard to the specialty of improving energy efficiency. For example, the ESCO always has more advanced energy-saving technologies than the manufacturer for long-term research. To obtain more unit savings, the manufacturer may consider outsourcing energy service to the ESCO. However, the more effective the technology is, the more expensive it is [8,9]. It is an important factor that the manufacturer chooses the optimal energy saving mode between the two types of energy saving modes. Furthermore, when the manufacturer chooses shared savings, if the energy-saving supply chain with the manufacturer and the energy service company is not coordinated, they make decentralized decisions. In a decentralized system, channel performance could be even worse because of the differing and usually conflicting