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Fundamental Economic Analysis of Ground Source Heat Pump Markets in North America

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Abstract

Ground source heat pump (GSHP) sales peaked in North America in 2008-2009, ending a ten-year trend which saw markets grow at annual rates often over 50 %. This was observed in Canada and in the United States. Over the past decade, there were a number of financial assistance programs available in both countries, for residential as well as commercial and institutional applications. While there is evidence that programs had an obvious positive impact on markets, there are many other more fundamental factors which may explain the current GSHP market dynamic. But there is very little analytical work based on economic theory and principles done specifically on GSHP markets. This paper analyses the performance of the North American residential GSHP markets within the framework of a traditional theoretical economic model and discusses the relevance of financial assistance programs as a mean to push the markets forward.

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1. Introduction

Subsidy programs are meant to increase the penetration rate of a technology, over and above the natural or systemic growth, that is, the growth taking place thanks to market forces. Financial assistance programs help new entrants make an economic choice that they would not have normally chosen. The programs help utilities and governments reach some energy efficiency targets. They are also an integral part of the objectives pursued by market transformation. They help educate the customers by making them more curious about technologies. They also contribute to develop new standards and raise the bar of older ones. In short, they contribute to enlarge the market in the long run. This is the theoretical foundation.

In practice however, there are many adverse effects caused by subsidy programs. One is the arrival of fly-by-nights – found throughout the entire supply chain – who will attempt to capture the subsidy for themselves rather than let it flow through to the end-user. Another undesirable effect is the presence of free-riders, who may sometimes represent an important proportion of those benefitting from the subsidy. Free riders are essentially those customers who would have acquired a GSHP system regardless of the availability of a financial assistance program but who nevertheless benefit from it when it is available. The buying decisions of these customers are not influenced by the financial assistance programs and must therefore be discounted when analyzing the program impacts. Jensen [1] estimated that in Canada, free-riders may have accounted for as much as 40 % of the residential retrofit GSHP market in recent years.

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Gibbs [2] concludes that "rebates can support market transformation when they reduce perceived risks to market players, capture the attention of otherwise apathetic or uniformed consumers, and temporarily reduce prices until markets naturally trend the prices downward." This is a key point as in the long run, the prices must follow a downward trend only through market operators – not by subsidies. Gibbs rightfully adds that "...rebates also have the potential for inhibiting market transformation. They interfere with natural market signals that influence product supply decisions. They thwart long-term sales when they convince consumers to try a product that they do not like." So, overall the main problem is the fact that the subsidies create disequilibrium in the entire supply and demand chain for a given product. We will address this later in this paper.

In the GSHP industry, subsidies have been offered regularly since the 1980s in North America. According to the successive programs – deployed over 25 years – they were meant to address the high first cost of the technology particularly for lower income customers. As rightfully observed by Woods [3] "The point of view that by removing barriers we can correct the market, if only we internalize externalities, is a consequence of the one, efficient equilibrium viewpoint from introductory economics." Essentially Woods argued that there are multiple equilibria in the market and attempts to remove market barriers based on the assumption of a single equilibrium is too simplistic. This argument may explain why successive attempts to remove market barriers in the GSHP industry have failed over the years. This is a very good example of why further economic research on barrier removal in the GSHP industry is necessary.

In addition, subsidy programs aimed at achieving market transformation must be designed and deployed under very specific market conditions. Duke [4] offers some interesting guidance in this regard. "[...] the costs resulting from poor program design, inefficient implementation or simply choosing the "wrong" technologies could easily outweigh cost reduction benefits. It is critical, therefore, to select technologies that are characterized by: 1) excellent prospects for long-term market penetration once subsidies end; 2) the potential for relatively fast cost reductions as indicated by a favourable progress ratio and relatively low cumulative production to date; 3) elastic market demand; and 4) public access to high-quality data about all of the above." When contrasting with the North American GSHP markets, none of these conditions is met.

As stated earlier, depending on the market structure present at the time the subsidy is available, chances are that the price of the equipment will not go down and the entire subsidy will be captured by the suppliers, not the customers. In short, prices will be either stable or go up, lower income customers who were targeted by the program will likely stay out of the market and only free-riders will "benefit" from the subsidy. Of course this is the extreme outcome. The reality is somewhere in the middle of 0 and 100 % free ridership.

2. Economic Classification of GSHPs

The notion of income elasticity of demand is useful to understand consumer behaviour and GSHP markets. A positive income elasticity of between 0 and 1 reflects a "normal good", that is, a good which quantity demanded goes up with income. On the other hand negative income price elasticity would normally indicate the presence of an "inferior good" essentially a good that becomes less desirable or for which the derived utility declines as income increases. Finally, if the quantity demanded for a good does not change with an increase or decrease in income, the good is considered to be "sticky". [5]

If the income elasticity of demand is between 0 and 1, the quantity demanded will increase proportionally less as income increases. A perfect elasticity of 1 means the quantity demanded will increase in the same proportion as the increase in income. Both these cases are characteristics of normal goods. Finally, if the quantity demanded increases proportionally more as income increases – an income elasticity of demand greater than 1, ceteris paribus, we are in presence of a luxury good.

It has often been said that GSHP are expensive, high end products and therefore luxury goods. In two filings before energy boards in 2013 [6] and in 2016 [7], the author found statistical evidence of this situation. In the retrofit market in Canada, and using home sizes as a proxy for wealth, the author showed that as home size increased, there was an increasingly higher penetration rate for GSHP up to home size of 250 m^2, at which level the relative penetration of GSHP was lower.

A number of factors could explain this situation. First, although the sample sizes used were quite large (780 in one study and 12,577 in the other), the period under the analytical study were characterized by the presence of financial assistance programs providing subsidies up to 40 % of the GSHP system costs. The findings of the two studies tend to indicate that subsidies have disrupted the market equilibrium for GSHP systems for mid range home sizes by increasing the quantity demanded through an artificial price effect. In short, subsidies have lured into the market customers who would normally not have bought such a system, just as theory tells us.

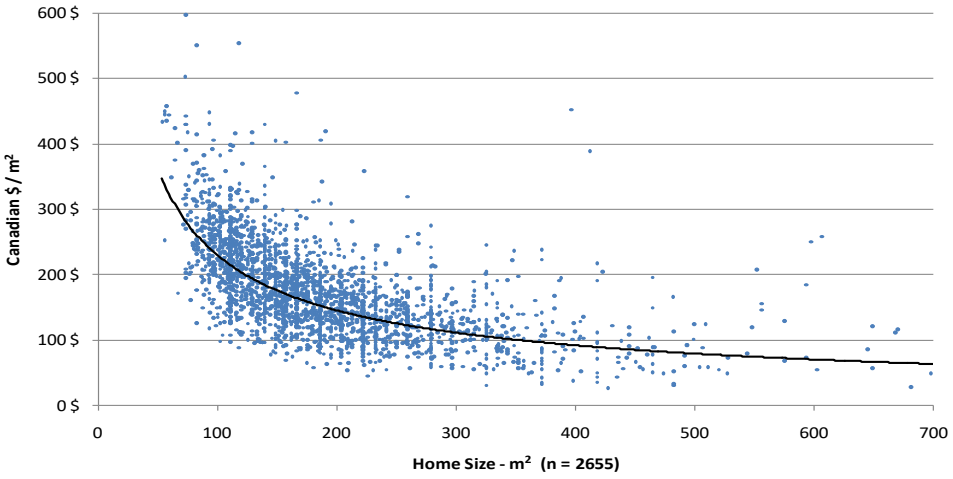


Fig. 1. GSHP System Average Cost per m^2 – Vertical Systems

We found that as homes are getting smaller they face a higher average cost calculated on a per m^2 basis as illustrated in Figure 1. This is further evidence that the economics of GSHP are not favourable for smaller homes as home owners may never recover the initial cost of their "investment". This situation reduces the potential market size for GSHP to larger than average homes.

Figure 1 shows that past a certain point, the marginal cost of GSHP systems (calculated on a capacity basis) declines significantly and home owners in the retrofit market may decide not to request the subsidies because the relative hassle of going through the program's paperwork and technical data filing may outweigh the benefits of the subsidy. The installation companies may also decide to cut on their own additional costs of managing the program's requirements by offering a rebate to the home owners who will not ask for the subsidy. In a sense, this phenomenon may not be a bad thing as it would contribute to reduce the number of free-riders. Further analysis

would be required to shed more lights on this question. However, there are sufficient statistical evidences to suggest that the income elasticity of demand for GSHP is greater than 1, which would confirm GSHPs, given the current state of the technology, can be categorized as luxury goods.

3. Intrinsic Value of GSHP Systems

Market disruptions are rarely good for an industry. In particular, market disruptions artificially created by subsidies build false expectations as the industry stakeholders become addictive to them and adjust their business practices accordingly. Subsidies will temporarily create an artificial market for GSHP with the hope that demand will go up, prices down and then a market transformation would occur. But things are rarely that simple. Market transformation requires more than subsidies. It requires a conjuncture of research and development, innovation, adequate supply, favourable regulatory environment etc.

Subsidies are put in place for a variety of reasons by government and utilities. In North America, stakeholders have long argued that as the market expands, demand will go up and unit price will go down, hence, increasing the market share for GSHP in the heating and cooling market. Unfortunately, this argument is not sustained by statistical evidence.

Table 1 shows the unit price for vertical GSHP systems in four Canadian provinces from 2007 to 2014. In all markets, we see clearly that there is no significant price difference from one year to the other. We also note that the price per m^2 is comparable from one market to the other in spite of the fact that subsidy programs varied from $4375 to more than $11,000. It is stunning to see the prices are fairly comparable even in markets where the financial assistance was significantly higher. This would confirm that the end user did not benefit from the full subsidy, large portion of which was likely captured by others in the supply chain and therefore neutralizing their impact in the market.

Table 1: Home Sizes and GSHP Prices per m2 – Vertical Systems

	British Columbia (n = 107)		Manitoba (n = 233)		Ontario (n = 961)		Québec (n = 905)	
	m^2	$ / m^2	m^2	$ / m^2	m^2	$ / m^2	m^2	$ / m^2
2007	-	-	-	-	-	-	174	148 $
2008	191	186 $	142	160 $	184	176 $	186	162 $
2009	225	147 $	153	170 $	196	172 $	190	174 $
2010	236	132 $	155	164 $	198	168 $	187	173 $
2011	210	139 $	162	156 $	175	169 $	223	151 $
2012	192	154 $	172	162 $	204	169 $	211	156 $
2013	-	-	-	-	-	-	198	165 $
2014	-	-	-	-	-	-	182	190 $
AVRG	**213**	**152 $**	**152**	**164 $**	**190**	**171 $**	**196**	**164 $**

Overall, it could be argued that the subsidy programs did not have any impact on the high first cost of GSHP – the number one market expansion barrier identified since the 1980s. To have an impact, the programs should lead to a price reduction to a point where mass adoption becomes economically feasible. But which cost component of a GSHP system can be compressed exactly? The hard market reality is illustrated in Table 2.

Table 2: Typical GSHP System Cost Breakdown

	Water to Air (2 tons)	Water to Air (3 tons)
Drilling and Rig Mobilisation Charge, Loop, Fluid	$8 350,00	$12 090,00
Heat Pump + Electric Resistence 10 kW	$5 675,00	$6 350,00
Circulation Pump (s) + Equipment	$425,00	$460,00
Duct Work, Plubming	$1 400,00	$1 175,00
Thermostat(s) + Other Components	$1 175,00	$990,00
Engineering / Labour	$2 480,00	$2 480,00
TOTAL	$19 505,00	$23 545,00
Profit (22 %)	$4 291,10	$5 179,90
Total Project Cost	$23 796,10	$28 724,90

No matter how we look at it, the current price structure of GSHP systems shows very little if any compressible cost. Arguably, we could achieve marginal gains on such cost factors as drilling, heat pump or labour or even by

cutting on profits. While all these are feasible, they are not sustainable and certainly not sufficient to move an industry towards market transformation.

We could also argue that the subsidy programs were not in place long enough. It is also often said that other renewable technologies such as solar PV and wind successfully achieve market penetration and therefore, GSHPs are next in line. But this idea is not yet supported by technological developments or by market forces.

The solar and wind industry have successfully achieved market transformation through a mix of R&D, innovation and mass production. But this doesn't mean the recipe applies to GSHP systrems. To achieve significant market breakthrough, a major innovation would need to materialize. An example of such innovation would be the commercialization of ultra efficient CO_2 GSHPs. Under current market and technology condition, high first cost will not be addressed by subsidies and mass production. The only way out of this conundrum is via targeted R&D. Direct expansion GSHP with CO_2 are a good example of where R&D may yield interesting results in terms of costs reduction and efficiency improvement – exactly as it happened in other industries. [8] [9]

This said, the combination of solar PV with GSHP could potentially compete with a combination of gas furnaces and heat pump / cooling units. Unfortunately, in Canada and in the United States, the design and installation standard ANSI/CSA448 makes this combination difficult as the GSHP component of the hybrid system shall provide between 70 % and 95 % of the building's annual heating energy requirements. [10] Such a requirement is cost prohibitive and adds to the high first costs of GSHP systems.

Finally, there is a fundamental difference between GSHP systems and solar PV. Solar PV "is a technology, not a fuel. As such, efficiency increases and prices fall as time goes on." [11] Not quite the case for GSHPs. Although the efficiency of the heat pump itself can be increased, as was the case in recent years, the operation of a GSHP system is dependent on the electricity required to make the system work and deliver its full efficiency. From a market perspective, this is a remarkable difference and it explains why solar PV prices declined dramatically over time and why GSHP prices have remained stable. And for economists the difference is even more fundamental. "Heat pumps require electricity to run their motors, but heat output is up to five times more than electrical energy input. Thus while the heat technically comes from the earth, it is more accurate to think of groundwater heat pumps as a very efficient way to use electricity for heating." [12] When performing economic analysis this detail is important as economic agents may react differently if they are faced with an electricity production technology meant to generate revenues versus a durable good meant to provide heating and cooling.

4. Proposed Theoretical Market Analytical Framework

Figure 2 below show the theoretical quantity of GSHP systems sold over time in a given market. It is assumed that the quantity demanded over time follows a positive natural market trend reflective of marketing, increased awareness, and overall increase in consumer net disposable income. This natural market trend is represented by the dotted line.

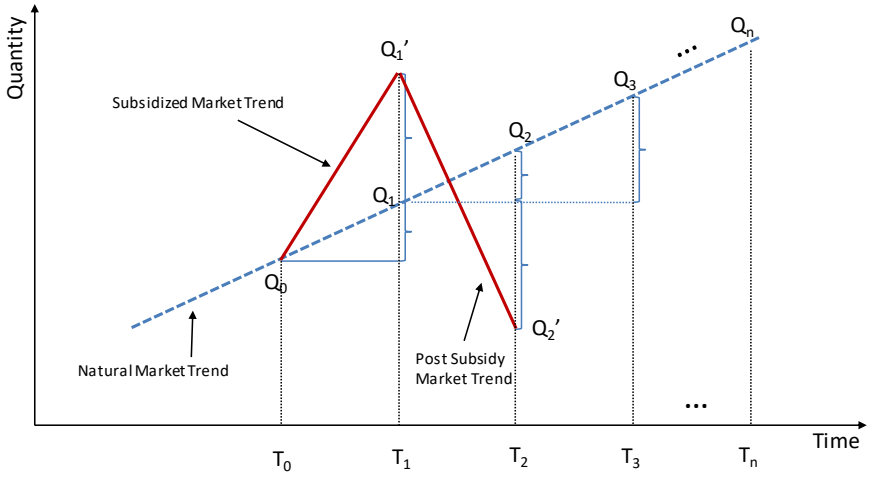


Fig. 2. GSHP Systems Demand Over Time

When financial assistance programs are in place – moving from time T_0 to T_1 – part of the total quantity demanded in T_1 is composed of free-riders, that is, customers who would have normally install a system without subsidy but who will nevertheless receive it. In Figure 3, free-riders are represented by the quantity Q_1-Q_0. Therefore, the real impact of the financial assistance program is equal to Q_1'-Q_1 and not Q_1'-Q_0. When the subsidy program is removed – moving from time T_1 to T_2 – the quantity demanded goes down below what it would have been under its natural market trend but also potentially below the quantity demanded at time T_0. Why is that?

When the market equilibrium is disrupted by the subsidy program, a number of things happen. Customers who would have never bought a GSHP system are lured to the market because of the skewed price effect. Furthermore, in the presence of a temporary subsidy, many customers may decide to advance their decision to acquire a GSHP system. As rightfully observed by Woods [3] "...every time we tweak the market or its governance structure (operating rules and regulations) we need to think about long-term effects." This is particularly true when market intervention fail to achieve market transformation. The damages made to the industry might be more significant than if no actions were taken in the first place.

So if we accept the hypotheses discussed above, this means that part of quantity that would have been bought at time T_2 and time T_3 are now bought at time T_1. This phenomenon should also be accounted for when estimating the impact of the subsidy program on the market growth and it should be discounted accordingly. It also means that the number of free-riders in the market at time T_1 is much larger than the quantity Q_1-Q_0 to which we need to add fractions of Q_2-Q_1 and Q_3-Q_2.

Consider that the demand for GSHP systems is affected by a variety of market conditions under the following hypotheses: 1) New construction in residential sector and commercial sector; 2) Retrofit / fuel substitution in residential and commercial sector; 3) Replacement of existing GSHP – lets suppose 100 % in the residential market, and; 4) Rational expectations – again 100 % in the residential market.

We can add that part of the natural market trend represents the replacement of existing and aging GSHP systems and are not adding new units. It is estimated that in Canada, during the 2007-2012 period, up to 8 % of all installations in the residential sectors were heat pump replacements on existing GSHP systems. [13]

Figure 3 below is another representation of the model sketched in Figure 2. As just mentioned, considering the replacement of existing units, the true market penetration for GSHP is lower than what is showed in Figure 3 and cumulative estimates of GSHP systems installed should be discounted accordingly. Also, the basic quantities that would have normally been demanded in years 7 to 11 go down because free-riders come from this future consumer pool of customers and from customers in years 12 to 19. This hypothesis is confirmed by Jensen [1] as he concluded that: "The financial incentives were unable to sustain the adoption of GSHP beyond the incentive period and neither were the incentives able to persuade homeowners served by natural gas or central heating (furnaces) with electricity to convert in meaningful proportions. Instead the incentive likely accelerated future adoptions while incentive were available, leading to a drop after these households had been removed from the

market."

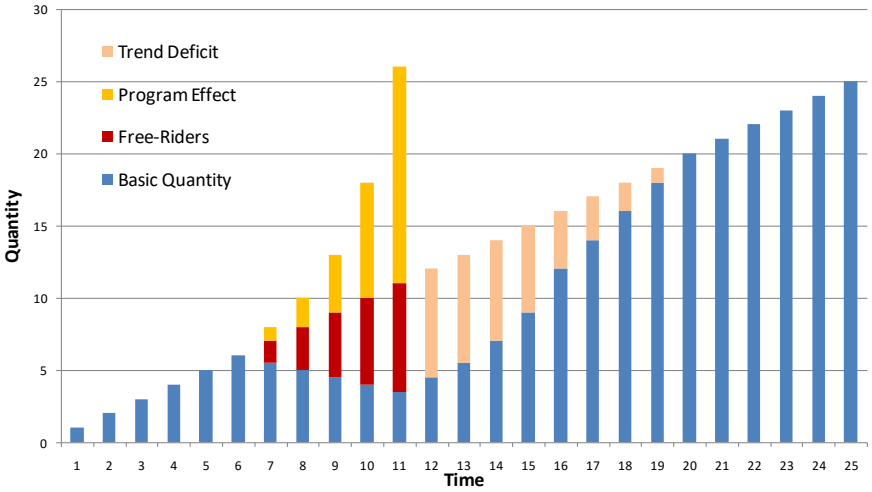


Fig. 3. GSHP Market Trends Under Different Market Scenarios

In our model, lets suppose that new construction is unaffected by programs since they only apply to the retrofit market. In addition to free-riders identified for the retrofit / fuel substitution sector, we also need to account for free-riders in the replacement of existing GSHP systems. This will contribute to the increase in the quantity demanded in the short term but also contribute to the trend deficit in the recovery period post program. This means that when the program ends, there is a "trend deficit" which will take many years to recover, hence, reducing future demand for an extended period of time.

Another factor which holds the quantity demanded to go back to its natural trend is consumer rational expectations. Over the past two decades, subsidy programs for GSHP and for energy efficiency in general have come and go a number of times – at least 3 cycles in Canada in the period 1990-2016. So, when a program ends, consumers are not reacting immediately and some will hold on their decision to purchase a GSHP system on the basis that they may expect that another subsidy program will be put in place in the near future. In an environment where subsidy programs come and go, rational expectations will amplify the business cycles and reduce demand while consumers hope for the implementation of new subsidy or financial assistance programs.

This point is well made in a report prepared for the EU SAVE EHEAT PROJETC. [14] "Rumors on subsidies, changes in subsidies or diffuse announcements on the subsidies often cause large interruptions in the market introduction of heat pumps. A frightening example of this was displayed in Sweden in 1998. [...] The consequences were devastating." Ever since the federal ecoENERGY Retrofit – Homes Program came to an end in Canada in 2012, not a single month has gone by when the author of this paper hasn't heard industry stakeholders circulate rumours of an "imminent" new program. If the Swedish experience is valid, rumours spread by the industry itself may well have contributed to the depressed markets in Canada up to this very day.

Overall, the theoretical model presented above shows that the market is not going back to its long term equilibrium as fast as it moved away from it before the market was disrupted by subsidies. But how does it compare to recent GSHP sales in North America? In fact, the market behaviour appears to respond relatively well to the theoretical model. But the market patterns provide even more insights than initially thought.

In Canada, over the period 2007 to 2015 there were a variety of financial assistance programs in place either federally or provincially. For the most part, these programs provided up to 40 % of GSHP system costs. Despite the fact that tax credits and subsidies are still in place in some provinces, the overall demand is going down since 2010. For Canada, the bulk of subsidy programs were proposed in the period 2007-2012. In fact, the market for GSHPs started falling in 2010 after reaching an all time record in 2009 and after five solid consecutive years of growth. In the early 1990s, there was a major financial assistance program deployed in Ontario, Canada's largest province. We can clearly see the growth pattern consequent to the program followed by years of low market sales in Figure 4.

In the United States, there is a 30 % tax credit in place since 2009. As we can see in Figure 5, the program had the effect of stabilizing the demand for a few years but it eventually followed the same path downward starting in 2012-2013. However, in this later case, another phenomenon can be observed. Although there has been a federal tax credit representing 30 % of a GSHP system cost in place since 1999 the markets have been declining ever since despite the federal tax credit often incremented by additional financial assistance programs from utilities and states and local governments.

There are two possible explanations to this. Either the markets reached saturation and then declined despite the tax credit or there was another factor at play. After thorough analysis of the Canadian in US market over the recent years, Jensen [1] concluded that "[…] GSHP is a stranded technology. Even when generous incentives are available, it is unable to gain momentum against natural gas and conventional heating systems. In both Canada and the US, the incentives failed to maintain adoption rates throughout the incentive period, let alone afterwards. Once the pool of households most likely to benefit from (or already considering) adopting GSHP dried up installations plummeted. While the design of incentive can be improved, expectations for the long-run potential of GSHP for realizing sizeable gains within the residential heating market in North America should be tempered."

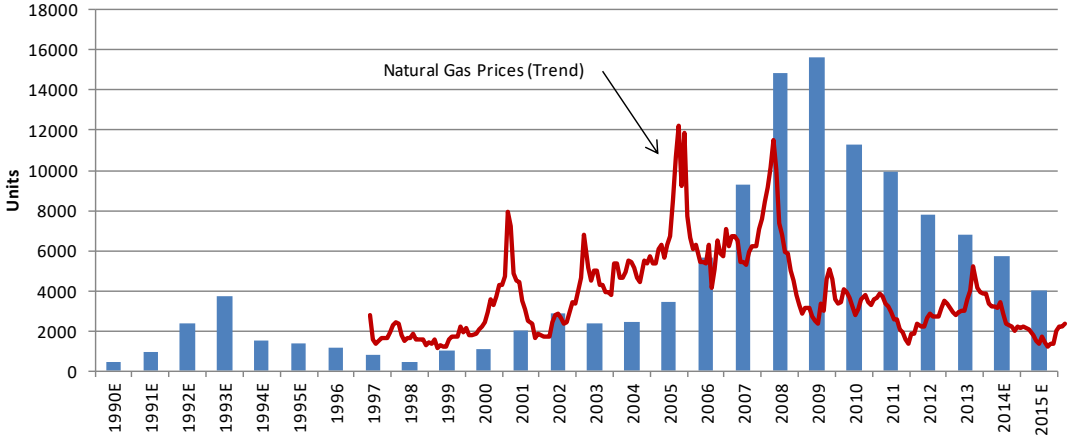


Fig. 4. Canadian GSHP Units Installed vs Natural Gas Price Trend

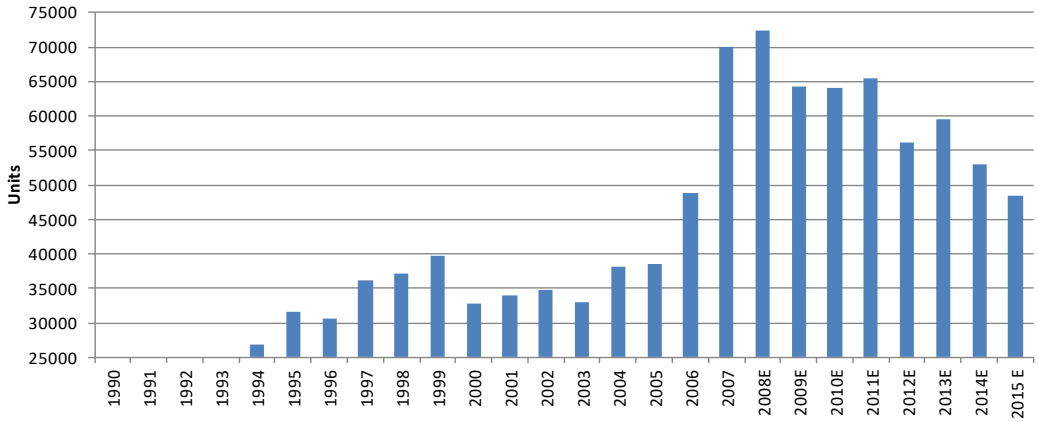


Fig. 5. GSHP Units Installed in the United States – All Markets

Jensen [1] raises an interesting point regarding the capacity of GSHPs to compete with natural gas. To be fair, and before concluding whether our model is echoed by the recent market behaviour in Canada and in the United States, it is useful to have a quick look at the oil and natural gas prices trends in North America. In the past GSHP cycles, many people have argued that high prices of oil were the perfect scenario for the emergence of GSHPs. From a theoretical point of view, this argument is somewhat skewed as it links the market for GSHP for heating and cooling (electricity using technology) to the price of an alternative fuel (oil) for competing technologies rather than find the market indicators that would be favourable to GSHPs on their own intrinsic value.

In any case, the GSHP markets did not follow this relationship in recent years. It appears that the fate of GSHP is now more intimately linked to the price of natural gas rather than oil. Figure 6 shows that from 1997 to 2009, the prices of oil and natural gas were rising and falling in sync. This pattern was clearly broken in 2009 when prices of oil went up from a low of $38 a barrel to an average of $100 up to 2014 when they dramatically dropped to a recent historic low of $30.

The interesting phenomenon was the decoupling of oil and natural gas prices over this period. Today as the price of natural gas continues to evolve according to its own supply and demand reality rather than following the movements in the price of oil. In late 2015 and early 2016, the price of natural gas was as low as it was 20 years ago. The intensity of drilling and hydraulic fracking for the sole purpose of finding natural gas created a commodity market of its own for this fuel. Shale gas is indeed abundant in North America.

In Canada, the United States and in Mexico, the total technically recoverable wet shale gas is 49,288 billion m^3. As a comparison, the total for the 43 other countries reported in EIA analysis is 165,257 billion m^3. This means that North America has about 23 % of the World's shale gas reserves at its disposal. [15] Assuming that the main competitor for GSHPs is natural gas, with such stratospheric numbers, it is conceivable that the current low natural gas price environment is here to stay for many years to come and the GSHP market will continue face the consequent challenges.

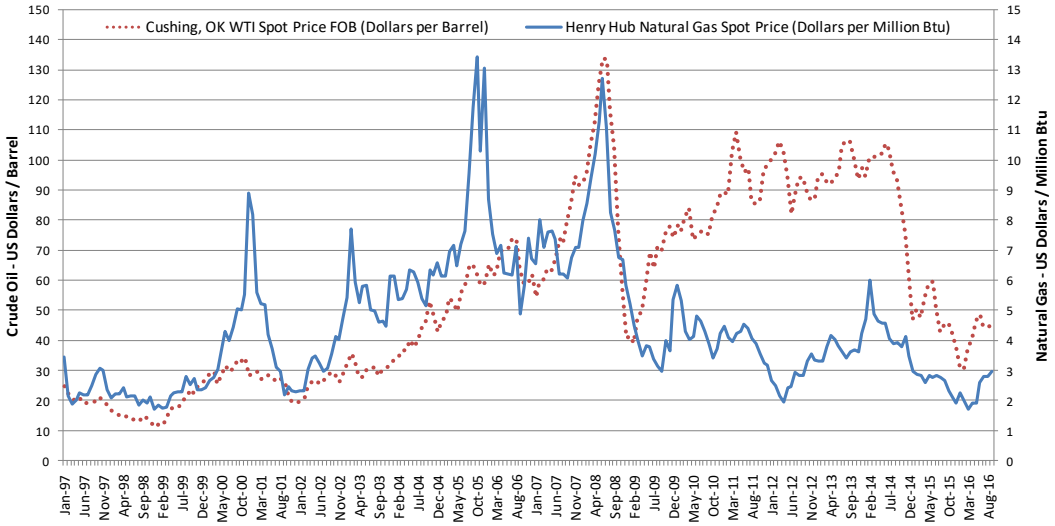


Fig. 6. Crude Oil and Natural Gas Prices 1997-2016

As stated earlier, consumers need heating and cooling. To obtain this service, they have a choice among a variety of equipment. Some are running with fossil fuels (gas furnaces, wood stoves, etc.) others with electricity (ASHP, GSHP, electric furnaces, etc.). As discussed above, recent financial programs have failed to deliver a reasonable positive outcome for GSHP market growth. To justify new program, some are raising the need to de-carbonize the markets and hence subsidize the installation of GSHP on a large scale to meet GHG emission reductions.

Unfortunately, this argument doesn't hold the test of empirical research. Recent studies have showed that the "environmental benefit is eliminated as the ground source heat pump systems emit more CO2 than the alternative common ones." [16] While this conclusion was reached for a study of residential GSHP in Cyprus, it nevertheless reflects the reality of many regional and local energy markets in North America. This is a call for prudence in the design and deployment of the next generation of financial assistance programs should governments and utilities decide to take this road, one more time.

5. Conclusion

The theoretical model developed in this paper appears to hold up to market reality. But there is definitely a need for more economic studies of the GSHP markets. Recently, extensive databases have been made available to researchers in Canada and in the United States. Few studies backed with extensive statistical evidence have been published but so far they all point in the same direction: the old business model for GSHP in North America doesn't work given the current state of the technology.

When a business model is proven wrong, this is a call for an extensive debate about market failure. But lets be clear. Market failure doesn't mean that any individual or group failed. It just means that the current technology, given current market conditions, cannot, on its own or with the help of financial assistance programs break the main market barrier: high and so far permanent first cost.

A quick scan of the literature on the ground source heat pump industry of the past 20 years shows that social scientists have been almost totally eclipsed from the debate. Maybe because the market is too small so no-one is paying special attention to what is being written and reported. Indeed, it seems that some basic market assumptions have been formulated many years ago and then taken for granted – leaving the field without satisfactory market and economic analysis. With the result that the same incomplete studies and analyses kept being quoted over and over again with the adverse effect or stakeholders having a continued and near permanent distorted picture of the real market reality.

While fundamental research in the engineering field will eventually lead to the development of ultra efficient GSHPs using new types of boreholes, new refrigerants or new compressors which will all finally contribute to significantly bring the price of GSHPs low enough to compete in the market place, there is a whole field of economic market analysis that needs to be cultivated and harvested. Nurturing new ideas, debating them in public, supporting them with factual information is essential for an industry to grow in a sustainable manner.

This paper is a small step into this direction. This field of research is near pristine. But with the databases now available to researchers in economic, business and other social sciences, much knowledge and understanding of market and consumer behaviour could be developed for the GSHP industry with the goal of helping governments and utilities design and implement better programs.

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Figure 1: Created by the author with data from the CGC Database of Residential GSHP Systems.
Figure 2: Model and figure developed and created by the author.
Figure 3: Model and figure developed and created by the author.
Figure 4 &Figure 5:
Created by the author with data collected from various sources over the period 2005 to 2016. Sources include publications by the CGC, federal and provincial government sources (press releases, research documents, public hearings filing, etc.) manufacturers production data, mergers and acquisitions documentations, the U.S. Energy Information Administration, industry annual and quarterly reports, government reports, industry association statistics, research papers, presentations at conferences, companies' press releases, etc. The methodology used to translate financial figures into units was developed by the author and considers factors such as exchange rates, manufacturer's products price increases and other economic variables.
Figure 6: U.S. Energy Information Administration. Henry Hub Natural Gas Sport Prices:
http://www.eia.gov/dnav/ng/hist/rngwhhdm.htm
U.S. Energy Information Administration. Cushing, OK WTI Spot Price FOB
http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RWTC&f=D

Table 1: Created by the author with data from the CGC Database of Residential GSHP Systems
Table 2: Created by the author with data form GSHP systems installers.