13th IEA Heat Pump Conference
April 26-29, 2021 Jeju, Korea

Which performance indicators should we provide to policy makers to switch from gas boilers to air to water heat pumps?

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Abstract

The most commonly used performance indicator (PI) of heat pump (HP) systems is the COP. But is it a good PI? If so, does it have a minimum threshold? This article covers the potentials and constraints of different PIs for HP systems implemented in non-renovated residential buildings from an environmental, economic and social acceptability point of view, based on real case studies situated in Geneva, Switzerland. After describing the Geneva context and listing the most common PIs, we first compare a traditional gas boiler to an air to water HP system for space heating and domestic hot water of single-family building (SFB). We then follow by a similar comparison for multifamily buildings (MFB). For this particular building demand, a hybrid system is also analyzed (HP combined with gas for the peak loads) and specific PIs are included. Finally, the most pertinent PIs for air to water HP systems are identified and the minimum COP value of 2.5 is recommended to insure the reliability of the system in the 3 mentioned fields in the swiss context.

Keywords: COP; Air to water heat pump; performance indicators; residential buildings; hybrid systems.

1. Introduction

Renewable energy development is one of the main energy policy priorities nowadays. In the past, main efforts were put into renewable electricity, but the adoption of carbon emissions reduction targets as shifted the focus into renewable heat. In Switzerland, carbon emissions originate mainly from transport (32% of overall emissions), buildings (26%) and industry (22%). The country adopted the target of 20% carbon emissions reduction by 2020 compared to 1990 (40% in buildings, 15% in industry, 10% in transport,10% in other sectors) and it has currently announced a new ambitious climate policy target: 50% reduction of carbon emissions in 2030 compared to 1990 [1].

At a federal level, a variety of policy instruments (carbon tax and subsidy) were implemented to achieve carbon emissions reduction and promote renewable heat solutions. Nevertheless, they are now officially recognized as not sufficient to achieve the desired goals. Note that Switzerland's share of renewables in heat supply is about 16% (including 11% of wood-based systems, 5% of other renewables). Most of the heat (75%) is supplied by imported fossil fuels (40% heating oil, 33% natural gas, 2% coal). At the canton level, some actions were put into place. For example, in Geneva canton, the local public utility *Services Industriels de Genève (SIG)* has an energy efficiency program portfolio – *éco21* – that supports renewable heat uptake by final consumers from both single family and multifamily housing sectors [2].

The distinction between these two sectors (single-family buildings – SFB – and multifamily buildings – MFB) is important because in Switzerland, 55% of the existing building stock is composed of MFB, against 45% for SFB [3]. While MFB have the largest potential of CO_2 emissions reduction, SFB are easiest to tackle. For SFB, Geneva canton and *éco21* offer subsidies that cover about 20% of initial investment costs (including equipment and installation services). For MFB, this type of support is not suitable due to the peculiarities of Swiss housing legislation. Contrary to SFB, the majority of inhabitants of MFB are tenants. Tenants are responsible for payment of the energy bills, while it is the responsibility of the owners to invest in heating system. Investment costs cannot be transmitted to tenants via heating bills. Currently for existing buildings the investment costs of the renewable heat systems such as heat pumps are from three to five times higher compared to the conventional solutions (fossil fuel-based). The owners therefore have no incentive to opt for renewables. [1].

Technically, the replacement of fossil heat by a renewable heat solution – more precisely a HP system – is also harder to tackle in MFB than in SFB. This is reflected in the market share of HPs in the residential sector that grew from nearly zero in the 1990s to about 50% today, but only 10% corresponds to MFB (CSD, 2017). For SFB, the HP market is mature, standard hydraulic schemes guaranteeing a good system performance are used, the whole process can be handled by one professional service. For MFB this process is more complex [1,4]:

- multiple households, with diluted decision power and related problems of governance;
- buildings often located in highly dense urban areas, with limited access to renewable heat sources other than air;
- if not threated carefully, noise emissions can easily become a barrier;
- higher shares of DHW in overall heat demand and related high temperature, which can affect the HP performance;
- absence of standard hydraulic schemes and system regulation guaranteeing a good system performance;
- multiple professional services (energy concept development; noise, static and building physics assessment; planning and implementation of heating, electricity and sanitary works; administrative procedures).

The aim of this work is to study performance indicators and their importance in the transition from fossil heat to renewable heat, more precisely Gas to HP heat. In order to do so, economic, environmental and social indicators are defined. Their values are then presented for different heat solutions (a gas boiler, HP system and HP+Gas system) and for both SFB and MFB. The indicators importance is discussed, solutions to improve economic, environmental and social barriers are presented. The positive and/or negative impact of these solutions on the remaining fields is also discussed. Finally minimum system performance value for the Swiss context is proposed, for both SFB and MFB.

Nomenclature

CHF	Swiss francs (0.91 €; 1.01 US$)
COP	Coefficient of performance
DHW	Domestic hot water
HP	Heat-pump
MFB	Multi-family building
PI	Performance indicator
SFB	Single family building
SIG	Industrial Services of Geneva

2. Methodology

We perform the analysis for three types of buildings: single-family, average and large multifamily. The reasoning for the respective distinction is based on two major motives:

- Contrary to the case of SFB, integration of HP heating systems in MFB is currently still more complicated than in SFB;
- The average-size MFBs do not have access to liberalized electricity market and therefore face relatively high electricity tariffs nowadays, compared to large MFBs.

2.1. Economic PI

To evaluate the performance of various heating solutions from economic perspective, we studied the available estimates of initial investment, operation and maintenance costs per unit of installed thermal capacity (CHF/kW, Fig. 1) [1]. These estimates are based on data from heating supply contracting projects provided by

Swiss ESCOs (24 air-to-water heat pumps), combined with heating modeling tools developed by Services Industriels de Genève (SIG).[1] We adjusted the available estimates, based on the available field data.

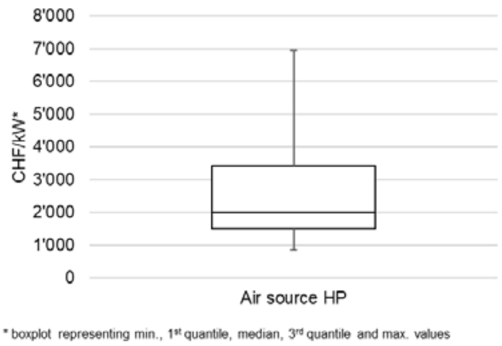

Fig. 1. Initial investment costs of heap pumps per unit of installed thermal capacity.

We calculate the levelized heating costs for an assumed lifetime of 20 years, based on the current average natural gas and electricity tariffs; and the average values of current initial investment costs, as well as average maintenance costs (Table 1). We performed the calculations with the carbon tax rate of 96 CHF/ tCO_2, and the current subsidy level of 70 and 28 CHF/tCO_2 for SFB and MFB respectively. We assumed a natural gas boiler efficiency of 85%. An annual air to water HP system performance (here on called COP) of 2.5, 3 and 3.5 for SFB [5], 2, 2.5 and 3 for MFB (for sensitivity analysis purposes).

For the HP + Gas system, we assumed the HP system would cover 80% of the heat demand and Gas the remaining 20%.

Table 1 Assumptions used in calculations of levelized heating costs of natural gas and heat-pump solutions

Item	Single-family building		Average multifamily building		Large multifamily building	
	Natural gas	Air-Water HP	Natural gas	Air-Water HP	Natural gas	Air-Water HP
Heat demand [kWh/year]	26’400		226’667		500’000	
Heated surface [m^2]	198		1700		3750	
Initial investment [CHF/kW]	600	2200	600	2200	600	2200
Maintenance [CHF/kW/year]	55	25	27	27	28	28
Energy tariff incl. carbon tax [CHF/kWh]	0.090	0.212	0.080	0.205	0.075	0.160

2.2. Social PI

In Switzerland (62%), even more so in Geneva (84%), most inhabitants of residentials buildings are not owners but tenants [6]. These buildings are heated by a centralized heating system that then distributes both SH and DHW to the apartments. The owner is obliged to provide a functioning heating system, and the tenants pay charges that cover the costs of energy consumption, maintenance and CO_2 tax.

In this context: i) owners have no financial benefit when investing in a renewable solution (higher investment costs and no benefits from the reduction of energy consumption); ii) tenants have no interest in investing in a property that they don’t own, even though they could eventually benefit from a reduction of energy consumption and CO_2 tax.

[1] Swiss ESCO datasets and SIG modelling tools are not publicly available.

Given this paradigm, the solution studied in this work is to define the tenant charges as being equivalent to the fossil system's, with a maximum increase of 10% if the fossil system is replaced by a HP solution. This way, the tenant has at maximum a rise of 10% of its charges while the owner can pay back his investments.

2.3. Environmental PI

In the case of HP systems, induced CO_2 emissions are calculated on the basis of a recent study concerning the carbon content of the Swiss electricity consumption mix [7], which uses hourly available data concerning the production of the various European countries, per type of production, as well as hourly data on imports/exports between the countries.

In a follow-up paper, the same authors analyze the induced CO_2 emissions of HP systems, for covering the heat demand of a sample of 6 different multifamily buildings [8]. Therefore, the authors combine the hourly dynamic of: i) the electricity used by the HPs; ii) the CO_2 content of the Swiss electricity mix. As a result, they derive the hourly CO_2 content of the electricity used by HP systems. For air-source HPs, the annual average of this mix finally amounts to 150 g CO/kWh$_{el}$ (lower CO_2 mix), or 303 g CO_2/kWh$_{el}$ (upper CO_2 mix).

The discrepancy between latter 2 values arises from a specific controversy concerning the carbon content of electricity generation from blast furnace gas units in Germany, which represent only a small share of the generation capacity of the total market, but play an important role in compensating for capacity shortages at the European level in the winter period.

In the case of gas boilers, emissions are related to natural gas consumption, by way of a constant emission factor of 228 g CO_2/kWh$_{th}$ given by the Swiss Coordination Conference of Building Services [9].

3. Results and Discussion

3.1. Economic

The costs of heating supply for the SFB are presented in Fig. 2. These values result from the hypothesis described in section 2.1 and are shown for the 2 studied technological solutions and 3 different system performances.

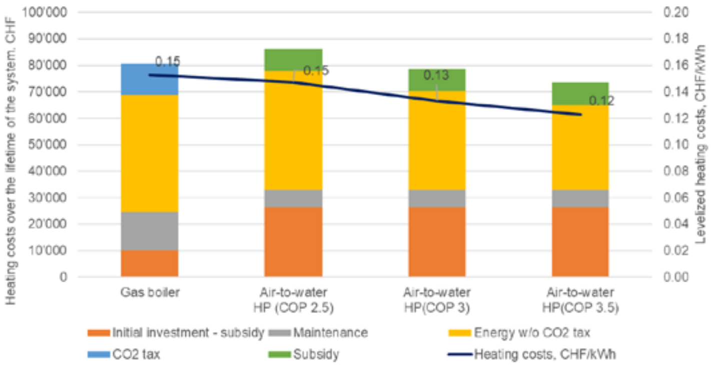

Fig. 2. Heating costs by technological solution and system performance for a single-family house (heat demand 25 MWh/year, 200 m^2 of heated surface), with CO_2 tax rate 96 CHF/t CO_2, w/o a subsidy; the assumed tariffs are 0.09 CHF/kWh for natural gas, 0.2118 CHF/kWh for electricity used for heat pumps.

The results are very positive for the air-to-water HP compared to gas boiler in the SFH. Of all solutions, Gas is the more expensive over the lifetime. It is probably explained by the well-known technology and standardized air-to-water HP systems available in the market for heating powers under 30 kW. There is no need for further engineering costs and material adaptation when installing these HP solutions.

We can consider that the subsidy granted in Geneva covers the risks of a hypothetical gap performance, which is not ideal if we aim for better performances.

From an economic point of view, this subsidy (about 20% of the initial investment) is no longer useful to cover the lifetime costs but still essential to reduce the initial investment.

The costs of heating supply for both average and large MFB are presented in Fig. 3 and Fig. 4 respectively. These values result from the hypothesis described in section 2.1 and are shown for the 3 studied technological solutions and 3 different system performances.

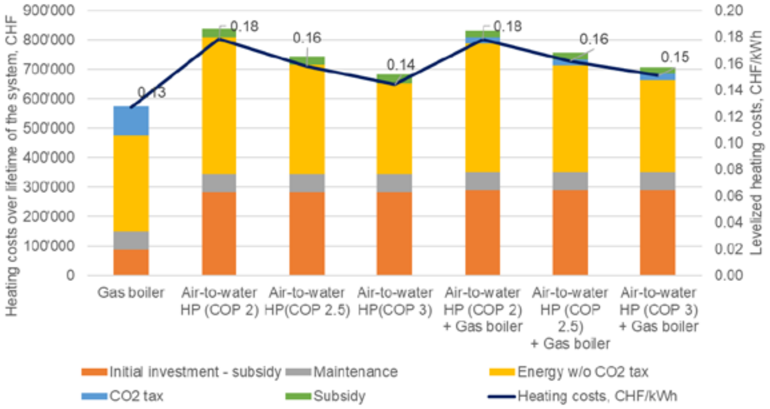

Fig. 3. Heating costs by technological solution and system performance for an average multifamily building (heat demand 225 MWh/year, 1700 m² of heated surface), with CO2 tax rate 96 CHF/t CO2, w/o a subsidy; the assumed tariffs are 0.08 CHF/kWh for natural gas, 0.205 CHF/kWh for electricity used for heat pumps.

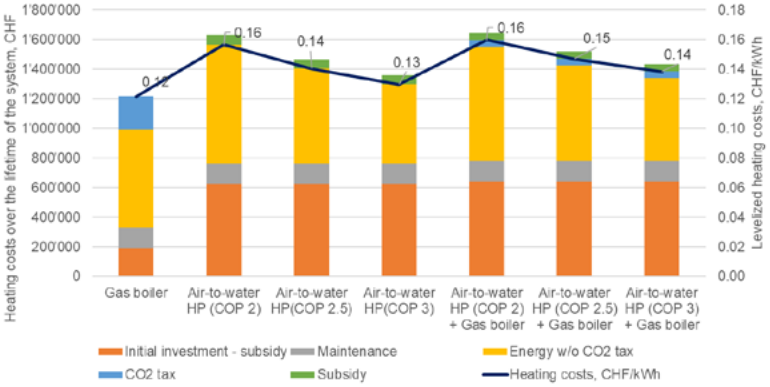

Fig. 4. Heating costs by technological solution and system performance for a large multifamily building (heat demand 500 MWh/year, 3750 m² of heated surface), with CO_2 tax rate 96 CHF/t CO_2, w/o a subsidy; the assumed tariffs are 0.075 CHF/kWh for natural gas, 0.16 CHF/kWh for electricity used for heat pumps.

For an average building, the heating costs over the lifetime of the gas system are 575 kCHF, of the HP system it's between 655 and 810 kCHF and of the HP+Gas system between 685 and 810 kCHF, depending on system performance. For a large MFB these values are: Gas 1'215; HP between 1'300 and 1'565; HP+Gas between 1'385 and 1'595 kCHF.

As seen by the figures, the big discrepancy between the Gas boiler and HP systems is mainly due to the current level of initial investment: HP heating solutions have a 3 times higher initial investment costs than the gas boiler solution. The gap between these solutions is shortened by the CO_2 tax, subsidy and increase of system performance: for example, in the average MFB, a HP system with a COP of 3 is only 80 kCH more expensive than a gas boiler solution, whereas a COP of 2 system would be 230 kCHF.

From all heating solutions, the gas boiler is the cheapest, both in terms of initial investment as well as levelized costs. This is true for both building sizes and despite of the system performance and CO_2 tax. With this discrepancy, current CO_2 tax and subsidies are not enough to make HP heating solutions economically attractive.

When comparing both figures, large MFB have lower levelized costs than average MFB. This is explained by a liberalized market price to electricity consumers above 100 MWh/yr in Switzerland (0.16 CHF/kWh instead of 0.21 CHF/kWh). This electricity tariff for bigger consumers leads to a HP solution that is more attractive for large MFB than average MFB.

3.2. Social

The costs of heating supply for SFB are presented in Figure 5, including the tenants charge and owner investments. These values result from the hypothesis described in sections 2.1 and 2.2.

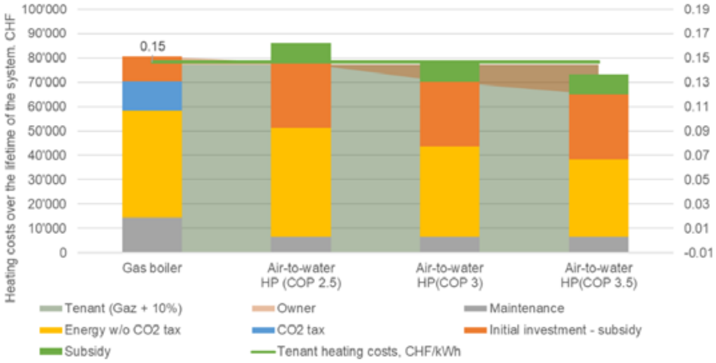

Fig. 5. Heating costs by technological solution and system performance for a single-family house (heat demand 25 MWh/year, 200 m^2 of heated surface), with CO_2 tax rate 96 CHF/t CO_2, w/o a subsidy; the assumed tenant charges are the equivalent to the gas boiler system (energy consumption, maintenance and CO_2 tax), with a maximum increase of 10%.

With the replacement of a gas system by a HP system, and tenant charges equal to the Gas solution +10%, the owner can, in all performances, pay back his investment and the HP system performance becomes crucial to the owner: the better the performance, the more he will be able to benefit from his initial investment.

One could argue that, with current subsidy and a CO_2 tax payed by the tenant, the 10% increase in tenant charges is not needed because the owner can still payback his investment with an average system performance.

Note that, in SFB if the tenant is planning to live in the same house in the very long term, he may assume some (or all) of the investment for a HP system. This unusual situation may occur when there is a good relationship between the owner and the tenant in place, for example when the house is owned by a family member.

The costs of heating supply for both an average and large multifamily building are presented in Fig. 6 and Fig. 7 respectively, including the tenants charge and owner investments. These values result from the hypothesis described in sections 2.1 and 2.2.

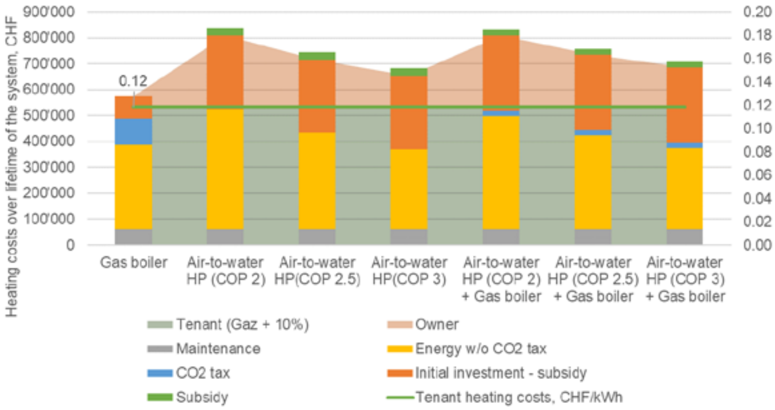

Fig. 6. Heating costs by technological solution and system performance for an average multifamily building (heat demand 225 MWh/year, 1700 m² of heated surface), with CO2 tax rate 96 CHF/t CO2, w/o a subsidy; the assumed tenant charges are the equivalent to the gas boiler system (energy consumption, maintenance and CO_2 tax), with a maximum increase of 10%.

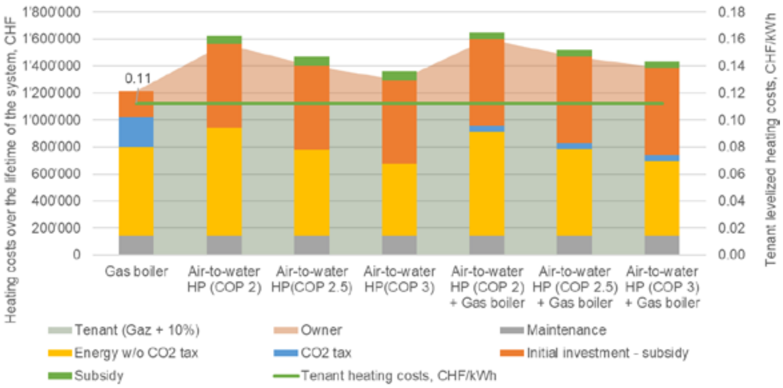

Fig. 7. Heating costs by technological solution and system performance for a large multifamily building (heat demand 500 MWh/year, 3750 m2 of heated surface), with CO2 tax rate 96 CHF/t CO2, w/o a subsidy; the assumed tenant charges are the equivalent to the gas boiler system (energy consumption, maintenance and CO_2 tax), with a maximum increase of 10%.

As seen in the figures, the tenant charges remain acceptable – 0.12 CHF/kWh for average and 0.11 CHF/kWh for large MFB. The 10% increase leading to a small increase of 0.01 CHF/kWh in the levelized costs of the Gas system.

With the replacement of a gas system by a HP system, and tenant charges equal to the Gas solution +10%, the owner can pay back part but not all of his initial investment. In this case, the HP system performance becomes crucial to the owner: the better the performance, the more he will be able to payback his initial investment.

All in all, to promote the replacement of a gas system by a HP system, the best system performance should be achieved and one or more of the following policy instruments could be used:

- increase in the CO2 tax, to increase the levelized heating costs of natural gas solution. In this case, it is important that the carbon tax is paid by the owner, and not the tenants who pay energy bills and have no voice in the choice of the heating systems. In addition, in the context of uncertain future energy prices, it is questionable whether building owners make their choice of a heating systems based on levelized costs only. In fact, operational costs including the carbon tax are paid on an annual basis. Investment costs are paid upfront from own savings or a loan and are recovered during the years of heating system operation. Alternatively, a contracting mechanism should be introduced to resolve landlord-tenant dilemma and mitigate potential negative effects of long payback time on owner decisions.

- an increase of subsidies, to reduce the levelized costs of heat pump solutions. However, it is important to consider increased public expenditure or potential distributional effects related to increased financing of the energy programs, as well as the risks of increased investment costs due to induced market distortions.
- legal obligations put on building owners with regard to the maximum level of emissions or energy consumption (e.g., max. tCO2/m2/year, max. kWh/m2/year). This policy measure can put a significant burden on building owners, and should be carefully thought to avoid unnecessary market distortions. Namely, it is important not to subscribe a concrete technology into the legal obligations, to incentivize innovation and market competition on different levels (e.g., between technological solutions, contractors).

In practice, a combination of different policy instruments, constantly adapting according to the market developments, may be more efficient. The proposed policy measures require adjustments in current legislation.

3.3. Environmental

The CO_2 emissions of the studied solutions, for a SFB, are presented in Fig. 8. Note that this figure displays the upper CO_2 mix of 300g/kWh$_{el}$ described in section 2.3 - the least favorable scenario for HP systems. The CO_2 emissions for both upper and lower CO_2 mixes are shown in Table 2.

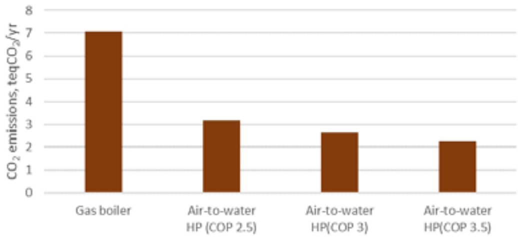

Fig. 8. CO_2 emissions (300 g CO_2/kWhel; 228 g CO_2/kWh$_{th}$) by technological solution and system performance for a single-family building.

Table 2 SFB CO2 emissions of all studied solutions for both upper (300g/kWhel) and lower (150g/kWhel) CO2 mixes in teqCO2/yr.

	upper CO_2 mix (300g/kWh$_{el}$)	**lower CO_2 mix (150g/kWh$_{el}$)**
	SFB, teqCO_2/yr	**SFB, teqCO_2/yr**
Gas boiler	7.1	7.1
Air-to-water HP (COP 2.5)	3.2	1.6
Air-to-water HP (COP 3)	2.6	1.3
Air-to-water HP (COP 3.5)	2.3	1.1

As seen by the figure, a HP system reduces CO_2 emissions by a factor of 3 in SFH, by a factor of 5 if we consider the lower CO_2 mix of 150g/kWh$_{el}$. In addition, more and more individual houses combine heat pumps with photovoltaic solar panels, which tends to lower CO2 emissions due to the grid electricity consumption.

The improvement in HP system performances can lead up to 30% savings. Note that, since the CO_2 emissions of these systems are already quite low, these savings are also low in absolute values (from 0.9 to 0.2 teqCO_2/yr.).

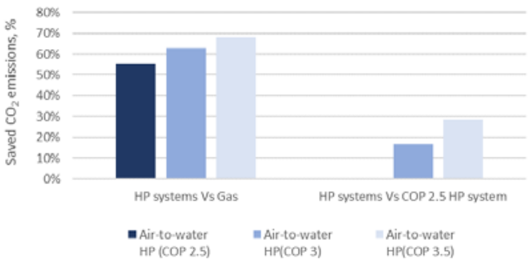

Fig. 9. Saved CO_2 emissions (300 g CO_2/kWh_{el}; 228 g CO_2/kWh_{th}) for a single-family building when comparing: i) HP solution to Gas solution; ii) HP system performance to lowest COP of 2.5.

The CO_2 emissions of the studied solutions, for both an average and large MFB, are presented in Fig. 10. Note that this figure displays the upper CO_2 mix of 300g/kWh_{el} described in section 2.3 - the least favorable scenario for HP system. The CO_2 emissions for both upper and lower CO_2 mixes are shown in Table 3.

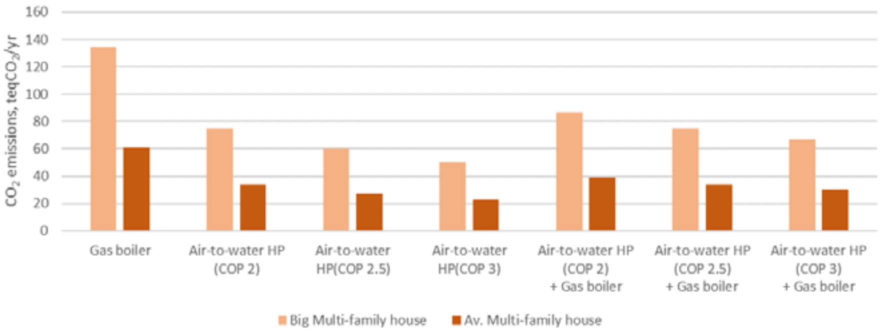

Fig. 10. CO_2 emissions (300 g CO_2/kWhel; 228 g CO_2/kWh_{th}) by technological solution and system performance for both average and large multifamily building.

Table 3 CO_2 emissions of both MFBs and all studied solutions, for both upper (300g/kWh_{el}) and lower (150g/kWh_{el}) CO_2 mixes.

	Upper CO_2 mix (300g/kWh_{el})		Lower CO_2 mix (150g/kWh_{el})	
	Large MFB [teqCO_2/yr.]	Average MFB [teqCO_2/yr.]	Large MFB [teqCO_2/yr.]	Average MFB [teqCO_2/yr.]
Gas boiler	134	61	134	61
Air-to-water HP (COP 2)	75	34	38	17
Air-to-water HP (COP 2.5)	60	27	30	14
Air-to-water HP (COP 3)	50	23	25	11
Air-to-water HP (COP 2) + Gas boiler	87	39	57	26
Air-to-water HP (COP 2.5) + Gas boiler	75	34	51	23
Air-to-water HP (COP 3) + Gas boiler	67	30	47	21

The solution with highest CO_2 emissions is the Gas system, followed by the HP + Gas system and lastly the HP system. The HP systems (both HP and HP+Gas) have around half of the CO_2 emissions of the gas system, around a quarter if we consider the lower CO_2 mix.

The CO_2 emissions of the HP+Gas system with COP of 3 are approximately the same as the HP system with a COP of 2.

Fig. 11 shows, in percentage and for the upper CO_2 mix of 300g/kWh$_{el}$, the saved CO_2 emissions when comparing: i) HP and HP+Gas solutions to Gas solution; ii) HP and HP+Gas performances to the lowest performance (COP of 2); iii) HP solution to HP+Gas solution. These values are valid for both average and large MFB.

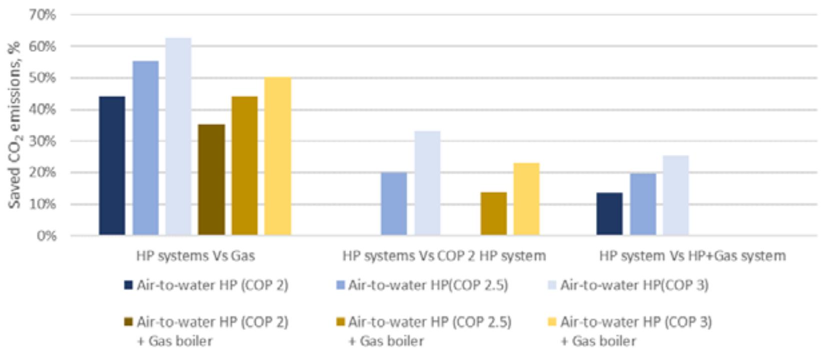

Fig. 11. Saved CO_2 emissions (300 g CO_2/kWhel; 228 g CO_2/kWh$_{th}$) for both average and large multifamily building when comparing: i) HP and HP+Gas solutions to Gas solution; ii) HP system performance to lowest COP of 2; iii) HP solution to HP+Gas solution.

As seen in the figure, when a Gas system is replaced by a HP+gas system around 45% of CO_2 emissions are saved, and if replaced by a HP system, the savings are around 55% (depending on the system performance). For the lower CO_2 mix, these values would be around 60% and 75 % respectively.

Within systems with HPs, the improvement in system performance can lead up to 33% savings in HP systems and up to 23% in HP+Gas systems. Note that, since the CO_2 emissions of these systems are already quite low, these savings are also low in absolute values (for a large MFB, 25 teqCO_2/yr. for a HP system, 20 teqCO_2/yr. for a HP+Gas system).

When comparing HP+Gas system to HP systems, the latter saves 14 to 25% of CO2 emissions (12 to 17 teqCO_2/yr. for a large MFB).

3.4. Overall

According to previous results, in SFB in Switzerland the replacement of gas boilers by HP systems is both environmentally, economically and socially reliable for the lowest studied system performance of 2.5. Economically, the subsidy (which helps with the high initial investment) and the absence of CO_2 tax helps the owner payback is investment in the lifetime of the equipment; the better the performance of the system, the more he will be able to save in energy costs. Environmentally, the replacement of gas by HP is positive but the increase from a COP of 2.5 to 3.5 is less impactful. Nevertheless, the benefits from better performances in peak electricity consumption should not be forgotten. Socially, with current subsidy and a CO_2 tax payed by the tenant, the 10% increase in tenant charges is not needed. Lastly, the aim of having better system performances and less CO_2 emissions is pursued, not for environmental or social reasons but because it is economically beneficial.

Regarding MFB in Switzerland, the replacement of gas boilers by HP systems is only economically and socially reliable for system performances above 2.5, particularly for average MFB. Economically, in order to payback the investment, the highest performance should be achieved and other tools should be applied (increase in subsidy and/or increase of CO_2 tax and/or obligation to have a share of renewable heat/limited CO_2 emissions). Socially, an increase of the CO_2 tax should be avoided because it would mean higher tenant charges (unless the CO_2 tax would be partially or entirely payed by the building owner), increase of subsidy and/or obligation to have a share of renewable heat and/or contracting solution could be implemented. Environmentally, similar to SFH, the replacement of gas by HP is positive but the increase from a COP of 2 to 3 is less impactful. Nevertheless, the benefits from better performances in peak electricity consumption should not be forgotten.

In other words, in MFB, system performance is critical for Social and Economic reliability but not for Environmental.

The difference between SFB and MFB results could be explained by the fact that available air-to-water HP on the market are optimized in terms of regulation for SFB. Due to lack of high-power HPs in the market, scaling up small HPs for MFB implies a more complex regulation to control all the low power HPs which in turn increases the risks of system underperformance. Standardized hydraulic schemes guaranteeing the HP system performance do not exist yet for MFB. Optimal regulation is not yet defined (production during day time – higher air temperatures – would lead to better performances and avoid running the system at nighttime when noise levels are limited).

Lastly, if policy measures are implemented (CO2 tax, subsidies, renewable heat share/limited CO2 emissions obligation), feedback mechanisms about those policies should be implemented in order to guarantee that those measures are achieving their goal.

4. Conclusion

This article covers a comparative analysis of the potentials and constraints of different performance indicators for HP systems implemented in non-renovated residential buildings from an environmental, economic and social acceptability point of view, for both single-family and multifamily buildings in, Switzerland.

In SFB, the replacement of gas boilers by HP systems is both environmentally, economically and socially reliable for the lowest studied system performance of 2.5.

Regarding MFB in Switzerland, the replacement of gas boilers by HP systems is only economically and socially reliable for system performances above 2.5, especially for average MFB. Economically, in order to payback the investment, the highest performance should be achieved and other tools should be applied (increase in subsidy and/or increase of CO_2 tax and/or obligation to have a share of renewable heat/limited CO_2 emissions). Socially, an increase of the CO_2 tax should be avoided because it would mean higher tenant charges (unless the CO_2 tax would be partially or entirely payed by the building owner), increase of subsidy and/or obligation to have a share of renewable heat and/or contracting solution could be implemented. Environmentally, similar to SFH, the replacement of gas by HP is positive but the increase from a COP of 2 to 3 is less impactful. Nevertheless, the benefits from better performances in peak electricity consumption should not be forgotten.

In conclusion, system performance is critical for Social and Economic reliability but not for Environmental and, for Switzerland, a system performance above 2.5 is highly recommended.

Acknowledgements

The authors would like to thank SIG program éco21 for financing this study and providing the data used in this study.

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