IEA HPP Annex 42: Heat Pumps in Smart Grids

Task 1:

Market Summary

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Report compiled by:

Delta Energy & Environment

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IEA HPP Annex 42 Task 1: Market Summary

This report represents the summary of the country reports submitted under Task 1 of Annex 42. The individual country reports are available as Annexes separately. Task 1 is for each participating country to develop a market report which analyses their country-specific challenges and opportunities in using heat pumps to provide demand side flexibility. The purpose of this summary report is to compare the national markets and identify where common learnings can be shared. This report highlights questions including:

- How do different countries compare in their suitability to capture HP flexibility?
- What are the most important factors influencing how well HP flexibility can be captured?
- What are the key similarities and differences between countries?
- Where can learnings be shared across countries?

The market reports received in time for this summary were the UK, France, Germany, South Korea, the US and the Netherlands. Full reports for other markets (Denmark and Switzerland) will be included as Annexes.

Executive Summary

TABLE 1: HOW DO COUNTRIES COMPARE IN THEIR SUITABILITY TO CAPTURING HEAT PUMP FLEXIBILITY?

We compare the markets in terms of how well suited they are to capturing heat pump flexibility. The "flexibility score" is an overall score based on the assessment of five key differentiators

Market	Flexibility score	Market snap-shot
UK		**The UK will need demand side flexibility in the medium term (5-10 years), particularly to manage growing distribution grid congestion**. The HP market is expected to grow quickly in the next few years, but the **flexibility potential from HPs is restrained e.g. by the aging, poorly insulated buildings, lack of space for storage, an end-user preference for gas, and 'spiky' heat demand patterns**. The availability of flexible tariffs, and the growth of hybrids, could be key to unlocking more flexibility potential from heat pumps.
DE		Supply/demand balancing and grid congestion are recognised as a medium-term (5-10 year) challenge for which demand side flexibility will be needed. The **typical heating solution in Germany looks stronger than other markets in terms of potential flexibility** – large storage tanks and strong share of heat pumps (some of which are already remotely operated at peak times). However, e**nergy price structures do not currently encourage market growth or give benefits for end-users** from providing flexibility – this is the biggest challenge to overcome.
FR		In France, **capacity margins and grid congestion are already a challenge** to manage. The electric heating market is Europe's largest, and HPs are a significant part of this. As a result, **there is a large potentially flexible resource, and there is a lot of experience in controlling or influencing operating times of electric heating**. The main challenge in France is translating what has worked for electric heating to heat pumps, and capturing flexibility in an aging building stock.
NL		In the Netherlands, th**e need for flexibility is recognised, particularly for managing grid congestion in the medium-term**. However, similarly to the UK, the HP market is <1% of the heating market, and there are challenges of lack of space for storage. T**he flexibility potential from heat pumps is therefore quite low – hybrids could be key to unlocking flexibility** here.
KR		**South Korea faces an immediate challenge to fill a capacity margin gap** which has already resulted in black-outs. Capturing demand-side flexibility is therefore high on the political agenda. For heat pumps to contribute to this flexibility, **market challenges must be overcome (e.g. end-users' preference for gas, and unattractive electricity tariffs)**, and **the thermal storage potential in floor heating and the relatively young building stock should be tapped into**.
US		**Demand response has historically had far stronger drivers in the US than in Europe**, so the market is more advanced, leading to greater experience with "3rd party control" (even if the use of heat pumps within DR has seen only small-scale activity so far). The total HP market is huge - but **the dominance of air/air heat pumps (mostly in southern regions), and lack of storage, does create a constraint on potential flexibility**. An **emerging GSHP market in northern states and a growing DHW HP market offer greater opportunities**.
CH		**The need for flexibility is in a 2020-2030 timeframe** in Switzerland, related to managing load on the high voltage grid. **Heat pumps are a large potential flexible resource** – The Swiss HP market is the most mature of all participant countries, with HPs the technology of choice in single family homes and making up around 40% of annual heating installs. End-users with HPs are used to the HP being shut-down at peak times. The greatest challenge is capturing flexibility from the older buildings (making up about a third of the building stock).
DK		**Denmark faces more immediate supply/demand balancing challenges than the rest of Europe** because of higher penetration of wind. Heat pumps are a small resource given the dominance of district heat, but in non-district heating areas (30-40% of the country), electrification (heat pumps) is the policy direction. **There are technical & market barriers to overcome to grow the heat pump market share in non-district heat areas** – aging buildings, high temperature radiators, high price of heat pumps, lack of confidence in HP technology, and the **very high proportion of tax on electricity** in Denmark (which is not encouraging any end-user benefits to come from providing HP flexibility).

Common challenges to overcome across most markets – where can learnings be shared?

Four main themes are evident across most markets, and insight into how to overcome these will be valuable for all markets. We outline the four themes, and related common research questions.

(1) Overcoming technical limitations on HP flexibility caused by building characteristics: This is a theme across most markets (in the existing building stock), particularly related to the reliance on high temperature radiators, coupled with aging and poor insulation. It means the amount of heat "stored" in the building and building fabric is limited.

- *How do different building types store heat, and how this can be tapped into to create flexibility?*
- *Is new build ultimately the only source of flexibility?*

(2) Finding ways to capture HP flexibility with limited / no storage: Limited physical space for storage tanks is a common problem in most markets –

- *What opportunities are there to capture flexibility with limited storage?*
- *What role will hybrids play?*
- *What can be learned from the use of modulation to capture flexibility from air/air heat pumps?*

(3) Developing an economic case for HP flexibility: In all markets, the economic case for flexibility (for the end-user) is difficult to make. In some markets the electricity pricing or electricity / gas price ratio does not encourage increased use of heat pumps at all. And in almost all markets, a low share of the electricity price is 'potentially flexible', so end-user savings are limited.

- *Is it possible to give any (financial or other) benefit to the end-user if they provide flexibility?*
- *How do country-specific regulatory environments and market structures influence how much benefit can be?*

(4) Understanding and influencing end-user perception: The preference for gas in the heating market (coupled with often negative perception of heat pumps) is common across nearly all markets, limiting the total potential heat pumps market size. There is also uncertainty over how end-users will react to 3rd party control of their heat pumps.

- *How can flexibility be captured while maintaining positive perception of heat pumps amongst end-users?*
- *What are the best ways to influence end-user behaviour?*

1. Comparing markets: The five differentiators influencing HP flexibility

We identify five main differentiators around which to compare participating countries - these differentiators are characteristics which influence the ability for heat pumps to provide demand side flexibility.

What is the benchmark position – where flexibility would be maximised?

TABLE 2: FIVE DIFFERENTIATORS INFLUENCING THE POTENTIAL TO CAPTURE FLEXIBILITY FROM HEAT PUMPS

We highlight in the second column the key questions/issues related to each differentiator which need to be considered when assessing each country. The third column describes what the market characteristics would be which may enable maximum flexibility from heat pumps (this is the benchmark position – and in Table 3 we then compare national markets against this benchmark).

Differentiator	Questions on specific market characteristics	Benchmark position: What characteristics would maximise flexibility?
1. Drivers for HP in smart grid / flexibility	▶ What is the flexibility needed for? e.g. managing distribution grid congestion; supply/demand balancing; energy security; ensuring capacity margins are met… ▶ Immediacy of this driver (e.g. critical today? in 5yrs? in 10yrs?)	▶ The country faces an immediate challenge to which flexibility offers a solution (therefore policy & industry driven to stronger action)
2. Potential size of flexible HP resource	▶ how many HPs installed? – today / projections for future ▶ what type of HP system with what heat distribution system? ▶ Use of storage?	▶ Large HP market / high growth ▶ hydronic HP & underfloor heating ▶ commonly use storage
3. Building characteristics – impact on flexibility	▶ age/thermal properties/insulation level ▶ building size (and/or SFH/MFH)	▶ new buildings, well insulated ▶ lots of space (i.e. for storage)
4. Energy prices / structures / tariffs – impact on flexibility	▶ energy prices / price ratios (do they encourage HPs?) ▶ tariffs – do HP tariffs exist? Is there experience with flexible tariffs?	▶ low elec price, high gas/other fuel prices encourage HP market growth ▶ flexible tariffs an enabler for HP flexibility
5. End-users – impact on flexibility	▶ use of heating system / heat demand profiles ▶ experience of how end-users respond to 3rd party control? ▶ building ownership – what proportion owned	▶ constant heat need (not bursts of heat) ▶ high level of experience to know how best to engage customers ▶ low proportion private rented properties (less control over choice of system, less incentive for savings)

Comparing markets against the benchmark – how well do they do?

TABLE 3: MARKET COMPARISON

For each market, we use the country reports as a resource to develop a 'score' against the benchmark position for each of the five differentiators shown in Table 2. Characteristics as in the benchmark position would receive a "green" score, and the other scores are measured relative to this.

Differentiator	UK	DE	FR	NL	KR	US	CH	DK
1. Drivers for HP in smart grid / flexibility								
2. Potential size of flexible HP resource								
3. Building characteristics – impact on flexibility								
4. Energy prices / structures / tariffs – impact on flexibility								
5. End-users – impact on flexibility								
Overall score								

Characteristics are positive for enabling capturing of flexibility from heat pumps (equivalent to the "benchmark" scenario in Table 2)

Characteristics are negative for enabling capturing of flexibility from heat pumps (at the opposite end of the spectrum from the "benchmark" scenario in Table 2)

2. To what extent are themes shared across markets?

Every market has its own unique characteristics, but there are also many common themes shared between some or all of the participant countries. Some of these common themes have a positive influence on potential flexibility, and some a negative influence. We summarize these below..

How do the drivers for flexibility compare across markets?

There are two groups of drivers driving a need for demand side flexibility across partner countries:

- **Managing distribution grid congestion** is the primary reason for demand side flexibility being needed in the UK and the Netherlands. In France and Germany, it is also an issue. In these cases heat pump operating times need to be shifted to avoid peak times.
- **Balancing supply/demand and ensuring security of supply** is the key issue driving the need for demand side flexibility in South Korea (where blackouts have already been a problem) and the US (with issues expected to grow in Germany). In these cases, heat pump operation needs to be shifted to match generation patterns.

For some countries, the requirements for flexibility are in response to an immediate challenge – not a future challenge (e.g. in South Korea, France and the US), which means there is already strong political (and in some cases energy industry) engagement in capturing this flexibility.

What factors influence the potential size of the flexible resource from heat pumps?

There are some themes applying across groups of markets which are positive for the potential amount of flexibility which could be captured from heat pumps:

- **Emerging markets for hydronic heat pumps** usually installed with storage tanks – in the US, a GSHP market is growing in northern states (although a small proportion of the total US market, it is significantly larger than many European HP markets). The UK heat pump market is the market in Europe expected to see the fastest growth over the next 5 years.
- **Emergence of hybrids**, with an electric heat pump combined with a gas boiler – potentially create limitless flexibility as the system can switch from electricity to gas with no impact on the end-user. The UK and the Netherlands in particular are expected to be buoyant in hybrids.
- **Advancements in smart-ready heat pumps**, or Home Energy Management systems integrated with HPs, which can accept dynamic signals from utilities and adjust HP operating patterns automatically – this enables heat pump flexibility to be captured.
- **Use of underfloor heating** – this is only widespread in new build in most markets, but maximises storage within the heat distribution system.

But there are negative characteristics, some of which are common across countries, which are a restraint on the size of the HP flexible resource.

- **Dominance of air/air heat pump** (in the US and Korea), which do not have storage. Though experience from the US shows that some flexibility can be captured here, it is far more limited than where there are hydronic systems with storage tanks.
- **Dominance of – and preference for - gas in the heating market** – in particular in the Netherlands, the UK and Korea, it is difficulty for HPs to gain market share because of the availability of low cost gas. A smaller HP market means less flexibility.
- **Reliance on high temperature radiators** – in the existing building market (which is the lion's share of the building stock), high temperature radiators are still common place in all markets which use hydronic heating. They do not provide the greatest flexibility. The exception is Korea, where there is a preference for high temperature underfloor heating – it is unclear the extent to which this could be turned into a positive storage resource.

How do the building characteristics and their impact on HP flexibility vary across countries?

In some countries, the building characteristics are very positive for promoting flexibility:

- **New, well insulated buildings** are better for heat pumps (in Korea, most of the existing buildings have been built since 1990).
- **Homes with space available for storage** are key to maximising flexibility. France and Germany in particular tend to have dwellings with large floor areas and space in e.g. cellars and basements for storage tanks.

But building characteristics are also working against flexibility in many cases:

- **Aging and poorly insulated buildings** which do not store heat limit flexibility. This is a particular issue in the UK where more than half of existing buildings were built before 1960. In other markets (e.g. France, Germany, US), a large share of relatively old or high demand houses is also a limiting factor on flexibility.
- **Limited physical space for storage** (to enable flexibility) is a particular issue in the UK and the Netherlands, where homes are amongst the smallest by area in Europe. In Korea, the majority of dwellings are apartments rather than detached homes, which again creates space limitations.

There is still a knowledge gap common across all countries:

- ? There is a lack of information on **how much thermal mass is stored in different building types**, and how this can be tapped into to create flexibility.

How do energy prices and structures influence flexibility?

Energy prices and structures are arguably the most important element in defining how much benefit could come to a customer from providing flexibility. Some characteristics across markets are positive in this regard:

- **Availability of flexible tariffs as a control or influence method for demand response** – in France, 'whole day' flexible tariffs are available (e.g. a scheme run by EDF where red days = electricity is expensive, amber days = electricity is medium price, green days = electricity is cheap, designed to encourage end-users to avoid consuming electricity on certain days, and thus provide flexibility to the system), and in the US there is experience of small-scale roll-out of several flexible tariff types.
- **A high share of the electricity price is 'potentially flexible'** – the UK appears to have the best electricity price structure to maximise potential end-user savings on energy bills should flexible tariffs become available (the wholesale part – and thus the "flexible" part of the electricity price makes up the majority of the total price).

But there are significant barriers common across most markets:

- **The electricity pricing or electricity / gas price ratio does not encourage increased use of heat pumps.** In the UK, the Netherlands and Germany electricity prices are at least 3 times the price of gas – so heat pumps struggle to compete. The outlook is particularly bleak at the moment in Germany. A 'cumulative' electricity price structure in Korea means that users are charged more per kWh if they consume more electricity.
- **A low share of the electricity price is 'potentially flexible'**, meaning even with flexible tariffs, only small savings from the total end-user bill would be made - <50% of the electricity price is potentially flexible in Germany and the Netherlands.

How do the characteristics of the end-users influence the potential flexibility?

End-users are a critical link in accessing flexibility. Some common characteristics across markets is encouraging for flexibility:

- **High proportion owner occupier properties** (e.g. in the UK and US) mean end-users have control over the choice of heating system.
- **End-users are used to the concept of 3rd party control** of their heating system (e.g. pockets of experience in the US and France, as well as demo projects elsewhere).

But there are some challenges related to the end-user

- **An end user preference for operating the heating system in bursts of heat** rather than at a constant level is a particular challenge for capturing flexibility in the UK.
- **High proportion of rented properties** where end-users have no choice (particularly in Korea)

Further questions are raised which warrant further investigation:

- **How will end-users react to 3rd party control?** – can we learn from experience in e.g. France, the US?
- **Is it possible to give any (financial or other) benefit to the end-user if they provide flexibility?** This is being investigated in various demonstration projects, and the outcomes will be critical in influencing how much flexibility can be captured.

3. Summary tables for each country

3.1. South Korea

Differentiator	South Korea characteristics
1. Drivers for HP in smart grid / flexibility	▶ Maintaining capacity margins / balancing supply & demand ▶ An immediate challenge (black-outs already a problem).
2. Potential size of flexible HP resource	▶ HP account for 10% of HVAC market, and are mainly in the commercial sector. ▶ HPs are mainly air/air, primarily for cooling, though growth of reversible HP for heating also expected ▶ It is a challenge for HPs to compete with gas (which is available in 72% of all buildings; >90% in cities), and with low cost electric heating mat (low efficiency but 10% of cost of a HP). ▶ High temperature (50-60 degrees C) underfloor heating is the norm, & culture of supplying this from gas boilers, not HPs.
3. Building characteristics – impact on flexibility	▶ Majority of existing buildings built since 1980s – relatively newer than in Europe, relatively well insulated
4. Energy prices / structures / tariffs – impact on flexibility	▶ Low price differential v gas and electricity (elec only 25% higher than gas) – should technically be good for HP, but die to very low energy prices in general, there is a low incentive to switch fuel for running cost savings. ▶ Cumulative electricity tariffs where user is charged more per kWh if they consume more – discouraging for heat pumps. ▶ No flexible tariffs but some day/night tariffs.
5. End-users – impact on flexibility	▶ constant heat need – but culture of using gas boiler for heating, not HP (HP air/air for cooling) ▶ little experience of 3rd party control ▶ ~50% of total building stock is rented properties, and >50% MFH / multiplex – end-user has no choice on heating system.

3.2. USA

Differentiator	US characteristics
1. Drivers for HP in smart grid / flexibility	▶ Security of supply is the biggest issue, leading to relatively long history of demand response in the US ▶ An immediate challenge
2. Potential size of flexible HP resource	▶ Large HP market with high growth rate – but most HP are air/air. ▶ There is already some experience of capturing limited flexibility from air/air heat pumps. ▶ Small proportion of (hydronic) GSHP offer greater flexibility potential (this market mainly in northern areas and comparable in size to the largest European HP markets). ▶ Storage not common as air/air dominates, but included with the GSHP. Also a small emerging market for DHW HPs with integrated storage.
3. Building characteristics – impact on flexibility	▶ Aging building stock, with high energy demand ▶ Large buildings ▶ Not easy for capturing flexibility from HP.
4. Energy prices / structures / tariffs – impact on flexibility	▶ Gas price a third of the price of electricity ▶ Several flexible tariffs available in some regions, and though take-up is low, there is significantly more experience than Europe.
5. End-users – impact on flexibility	▶ Demand response more widespread in US so customers more used to “concept” – though questions around their response to DR with the heat pump. ▶ High proportion owned properties

3.3. UK

Differentiator	UK characteristics
1. Drivers for HP in smart grid / flexibility	▶ Reducing distribution grid congestion (particularly winter peak and daily peaks, driven by the expected HP market growth) ▶ An issue within the next 5-10years (post 10 yrs, supply/demand issue become a greater driver)
2. Potential size of flexible HP resource	▶ 20k HP/yr, projected to at least triple to 2020. But strong competition from gas boilers (HPs account for just 1% of annual heating market which is 1.5 million per year) ▶ Predominantly hydronic HP (A/W) & radiators (usually high temperature, up to 80 degrees C) ▶ Storage tanks installed with HPs, but heating market dominated by (and trend increasingly towards) combi gas boilers with no storage.

3. Building characteristics – impact on flexibility	▶ Most buildings pre-1960, poor insulation, low thermal mass ▶ Average home size smaller in UK than rest of Europe ▶ Off-gas & rural homes have space (land area and storage tanks), but increasing trend for replacing with combi boilers, removing storage
4. Energy prices / structures / tariffs – impact on flexibility	▶ Elec prices >3 x price of gas, so HP only compete against oil. ▶ Limited availability of non-flat tariffs (day/night available in limited regions). ▶ An "expectation" that flexible tariffs will come but not in short term & timetable not clear
5. End-users – impact on flexibility	▶ Heating systems used for "bursts" of heat, not constant – not good for flexibility (but also a result of the building types) ▶ Little experience of 3rd party control of HPs – CLNR project only. Some experience with electric storage heating in limited regions ▶ High proportion owned properties & social housing

3.4. France

Differentiator	France characteristics
1. Drivers for HP in smart grid / flexibility	▶ Managing increased net demand variability due to uptake of renewables and strong, decrease/shift winter peak demand ▶ An immediate challenge in some regions.
2. Potential size of flexible HP resource	▶ Biggest European HP market in terms of annual installs - currently approx. 315k HPs installed (2012), and strong growth expected, with HPs >10% of annual heating installs. ▶ Large hydronic HP market, with radiators & underfloor heating. Air/air also common (un south). ▶ Smaller storage tanks than in e.g. Germany, and less use of buffers (greater dominance of inverter-driven modulating HP).
3. Building characteristics – impact on flexibility	▶ 52% of single-family homes are pre-1975 (32% before 1949). > rather old building stock ▶ Large new build market of approximately 300,000-350,000 dwellings per year (~50% single family) – HPs expected to be primary new build technology, should be positive for flexibility.
4. Energy prices / structures / tariffs – impact on flexibility	▶ Overall relatively low energy prices, electricity compares favourably to gas (ratio of less than 2, even without considering the gas boiler efficiency). ▶ Taxes only account for approximately 33% of the total costs, -> there's room for savings on both energy costs (33% of price) and network charges (last 33%). ▶ No intra-day flexible tariffs, but day/night exists, as well as "whole day" flexible tariff (3 different day tariffs, with a predefined number of days in each tariff band)
5. End-users – impact on flexibility	▶ Information not available on end-user useage patterns ▶ Experience with "simple" flexible tariffs positive ▶ ~60% owner-occupiers

3.5. Germany

Differentiator	Germany characteristics
1. Drivers for HP in smart grid / flexibility	▶ Balancing supply and demand, and reducing the need for grid upgrade investments. ▶ A challenge in the medium term (5-10 years)
2. Potential size of flexible HP resource	▶ Approximately 450,000 space heating HPs installed at the end of 2011 (>5.3GWth and approx. 1.7GWel). Annual HP installs near 10% of heating installs (relatively high share relative to Europe). ▶ Relatively high share of underfloor heating ▶ Incentive to install a buffer storage capacity of at least 30l/kW – and the use of buffer storage tanks is more common in Germany than in e.g. UK or France.
3. Building characteristics – impact on flexibility	▶ Half of the buildings have been built before 1969 - insulation levels in most of the old building stock very low and demand is high. Less than 5% of the building stock is reaching the ENEV2009 building regulations (80-90kWh/(m²*a). ▶ Single and double-family buildings (with more physical space for HPs and storage than multi-family homes) account for almost half of the total dwellings in Germany. ▶ New build market of 113,300 residential building completions, half of which single family homes – with HPs taking around 30% share (Delta-ee figures).
4. Energy prices / structures / tariffs – impact on flexibility	▶ Strong increase in natural gas and heating oil prices has supported HP growth in the past, but this trend has been reversed since 2008, with the ratio between electricity and gas having reached >4 in 2013 – outlook for HP proposition not so positive. ▶ HP tariffs are available in many areas, which are cheaper than the standard tariff. The tariff enables the utility to shut down the HP for up to 3 times a day for a max. of 2 hours (each time) via ripple control. ▶ Flexible tariffs are required by law, but there's a lack of infrastructure (smart meters) to implement them. Smart meter rollout currently held up by doubts about their economic efficiency -> flexible tariffs several years away.
5. End-users – impact on flexibility	▶ Relatively constant heat needed. ▶ High proportion of owner occupiers

3.6. The Netherlands

Differentiator	Netherlands characteristics
1. Drivers for HP in smart grid / flexibility	▶ Managing distribution grid congestion ▶ An issue within the next 5-10years

2. Potential size of flexible HP resource	▶ Currently 78,000 HPs installed (in total) in NL, <15,000/year compared with 400,000 boilers/year. ▶ Mainly hydronic HP - 79% water/water, 15% a/w and 6% hybrids, heat distribution systems mainly radiators and underfloor heating. ▶ All HPs [except hybrids] have a DHW storage tank installed – but standard boilers in NL do not have storage.
3. Building characteristics – impact on flexibility	▶ no information available – Delta-ee assumes similar characteristics to the UK
4. Energy prices / structures / tariffs – impact on flexibility	▶ A low share (approximately a third) of the electricity cost is potentially "flexible". ▶ Energy prices levels are in favour of gas, but gas prices have risen much more than electricity prices over last 10 years. ▶ Day/night tariffs are available but low value to customers – do not encourage change in consumption.
5. End-users – impact on flexibility	▶ Mainly constant temperature ▶ Approx. half of the buildings are owner-occupied

3.7. Switzerland

Differentiator	Netherlands characteristics
1. Drivers for HP in smart grid / flexibility	▶ Primary driver is the increasing renewable generation (avoiding/delaying high voltage grid upgrade – expected to be 6bn Swiss francs by 2020). ▶ Not an immediate challenge - 2030 is the key policy milestone
2. Potential size of flexible HP resource	▶ HP big market share compared to other countries. >200k HP installed in total, 20k/yr (out of a domestic heating market of ~50k/yr). ▶ Dominantly hydronic HP, mix of UFH and radiators, storage tanks common
3. Building characteristics – impact on flexibility	▶ 36% SFHs built pre-1960, and almost half of all dwellings pre 1960 - slightly lower share of old buildings than in DE, FR, significantly lower share of old buildings than UK.
4. Energy prices / structures / tariffs – impact on flexibility	▶ Gas/electricity price ratio more positive for heat pumps than in UK, NL etc, and the incumbent technology is oil rather than gas, so economic proposition for heat pumps is strong.
5. End-users – impact on flexibility	▶ End-users more used to HP, and HP tariffs with regular shut-down periods widespread. ▶ Still some perception challenges, but Switzerland is further ahead than much of Europe

3.8. Denmark

Differentiator	Netherlands characteristics
1. Drivers for HP in smart grid / flexibility	▶ Increasing renewable generation ▶ Immediate challenge
2. Potential size of flexible HP resource	▶ Small HP market – but policy aim for HP to be primary heating technology in non-district heat areas. ▶ Predominantly hydronic HP (air/water & GSHP), usually high temperature radiators. Growing market for air/air HP (more in summerhouses than for year-round heating)
3. Building characteristics – impact on flexibility	▶ The buildings which are the target for HP tend to be the more rural, older and more poorly insulated buildings (those away from district heating areas). This is a challenge for flexibility. ▶ But less challenging buildings than e.g. UK.
4. Energy prices / structures / tariffs – impact on flexibility	▶ HP a good proposition against oil, may be ok proposition against gas. ▶ Biggest challenge in Denmark is the very high tax on electricity meaning the potentially flexible part of the price is small.
5. End-users – impact on flexibility	▶ Relatively constant heat needed ▶ HP still a new technology so end-user perception still a challenge ▶ More demonstration projects than anywhere else in Europe testing the use of HP for demand side flexibility

4. Glossary

CH – Switzerland

DE – Germany

DK – Denmark FR – France

HP – heat pump

KR – South Korea

MFH – Multi-family home (apartments / flats)

NL – Netherlands

SFH – Single Family Home

UFH – underfloor heating

UK – United Kingdom

US – United States of America