REPORT
PUBLIC

CS 37: Single Family House Renovation Arheilgen / Darmstadt

RENOVATION APPROACH DOCUMENT

outPHit
Deep retrofits made faster, cheaper and more reliable

Deliverable D5.2

Last updated 14. March 2024 by Jan Steiger, Berthold Kaufmann

Contact

Jan Steiger
Passive House Institute
+49 (0) 6151 82699-0| jan.steiger@passiv.de

OUTPHIT – DEEP RETROFITS MADE FASTER, CHEAPER AND MORE RELIABLE
outPHit pairs such approaches with the rigour of Passive House principles to make deep retrofits cost-effective, faster and more reliable. On the basis of case studies across Europe and in collaboration with a wide variety of stakeholders, outPHit is addressing barriers to the uptake of high quality deep retrofits while facilitating the development of high performance renovation systems,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957175. The presented contents are the author's sole responsibility and do not necessarily reflect the views of the European Union. Neither the CINEA nor the European Commission are responsible for any use that may be made of the information contained therein.

CS37_SFH RENOVATION ARHEILGEND, DARMSTADT

Renovation Approach Description

TABLE OF CONTENTS

1. Executive Summary

The private building owner family who moved into the single family house in Darmstadt Arheilgen has set himself the goal of a climate-neutral building. For this reason, they intended a deep retrofit according to the EnerPHit standard. An experienced Passive House Architect was assigned to evaluate the existing building in 2023 and elaborated suggestions how to renovate the building with EnerPHit principles. In the end EnerPHit standard could be reached according to PHPP energy balance and EnerPHit component criteria.

The original building was built in the 1920ies and had not been insulated at all. This lead to very poor indoor temperatures and humidity during wintertime. The renovation provided a very well insulated envelope with very few thermal bridge effects and an airtight layer. A ventilation system with heat recovery now provides fresh but tempered air during all the winter and a multi-split air-to-air-heat-pump system is used for space heating. An additional air-to-water heat pump for domestic hot water preparation is installed separately.

Site plan, Source: Google Maps

2. Description of the existing building

The building is typical of the multi-story residential buildings of the 1950s and 1960s in Germany. Masonry walls and reinforced concrete floors form the supporting structure. The buildings have gable roofs with cold stores. The staircases are slightly set back. The original windows have been replaced in the meantime by plastic windows and partly by wooden windows with 2-pane thermal insulation glazing.

Back side with Wintergarden before renovation, Source: PHI

2.1. Building data

Year of construction:	1920
Treated Floor Area:	137 m²
Number of floors:	2
Number of apartments:	1
Building typology (residential / other):	residential
Main construction type (e.g. massive)	massive

2.2. Owner data

Name:	Private Building Owner
City:	Darmstadt Arheilgen
Type (private / housing association):	private

2.3. Location description

Arheilgen is a part of Darmstadt in the North of the City, in the South of the State of Hesse. Due to its location in Central Europe, it is in the cool temperate climate zone. The town can neither be clearly assigned to the continental climate nor to the maritime climate. For Darmstadt, Mannheim presents a representative climate

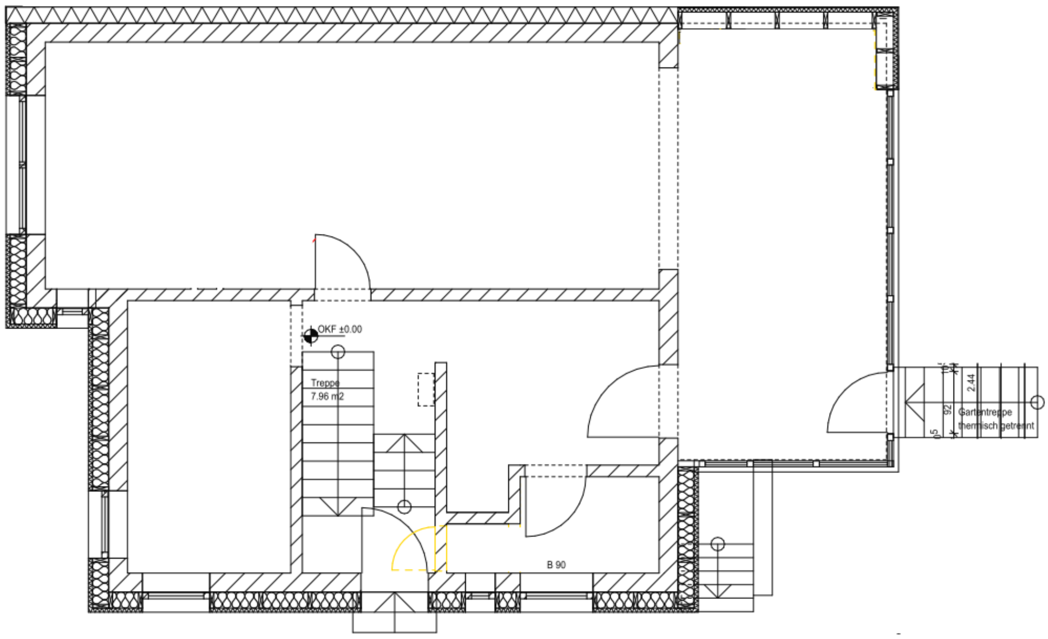
2.4. Original situation

The building fabric consists of 30cm of masonry walls and reinforced concrete ceilings as well as an almost uninsulated gable roof and a massive basement. The façade has a brick wall surface that had not been renewed once so far and neither had the pitched roof attic and basement ceiling been notably insulated. Only the original windows had been replaced during the 70s by PVC windows in the quality available during that time.

The building in original state was not at all comfortable to live in during winter times. The family living there already for about 10 years before they decided to renovate, reported that they hardly succeeded to get comfortable indoor temperatures during winter from early September to late April. So the 'suffering experience' for them was hard – and so much more surprising was their first winter (2023 / 2024) with the building shell thermally insulated so well and ventilation system with heat recovery running to provide warm supply air.

This subjective experience explains and shows the technical knowledge, that apart from the very high energy consumption and energy consumption costs of such buildings, the indoor living comfort is a striking argument to go for better buildings.

2.5. Plans and pictures of the existing building



Ground Floor, Source: A-Z Architekturbüro Zielke

2.6. Envelope of the existing building

External walls

Material:	Brick wall
Thickness:	28 [cm]
Surface (Render / Brick / Cladding):	Brick wall
U-Value:	1,70 [W/(m²K)]

Floor slab / Basement ceiling

Material:	Concrete
Thickness:	25 [cm]
Surface (Render / Brick / Cladding):	Concrete
U-Value:	1,24 [W/(m²K)]

Roof / Top floor ceiling

Material:	Concrete
Thickness:	25 [cm]
Surface (Render / Brick / Cladding):	OSB Board
U-Value:	0,64 [W/(m²K)]

Windows

Material:	PVC
Thickness:	8 [cm]
Material (Wood / Plastic / Aluminium):	Plastic
U-Value (Uw, installed):	2,45 [W/(m²K)]

2.7. Technical equipment of the existing building

Ventilation

Ventilation concept:	window ventilation only

Heating, Cooling and DHW

Heating:	central gas heating
Cooling:	No shutters for the windows, no active cooling
Domestic hot water:	central gas heating

2.8. Energy efficiency of the existing building

Passive House Planning Package (PHPP)

PHPP calculation:	PHPP_10.5
Space heating demand:	302 [kWh/(m²a)]
Heating Load:	136 [W/m²]
Overheating frequency:	0 %
Cooling demand:	0 [kWh/(m²a)]
Cooling Load:	0 [W/m²]
Primary Energy Demand:	409 [kWh/(m²a)] including household applications
PER Demand:	612 [kWh/(m²a)]

Final Energy demand

Final energy demand gas:	342 [kWh/(m²a)]
Final energy demand electricity:	18 [kWh/(m²a)] for auxiliary + household electricity
Final energy demand other:	0 [kWh/(m²a)]

Available consumption before renovation

Annual energy consumption gas:	not available
Annual energy consumption electricity:	not available
Annual energy consumption other:	not available

Available energy costs before renovation

Annual energy costs gas:	not available
Annual energy costs electricity:	not available



Existing Brick Wall Facade, Source: PHI

PHPP verification sheet before retrofit

EnerPHit-Nachweis

10.5 DE

Objekt:	Energetische Sanierung EFH Arheilgen als EH 70 EE
Straße:	Lönstraße 5
PLZ/Ort:	64291 Darmstadt
Provinz/Land:	Hessen DE-Deutschland
Objekt-Typ:	1-Freistehendes Einfamilienhaus
Klimadatensatz:	DE1012a-Mannheim, höhenkorrigiert
Klimazone:	3: Kühl-gemäßigt; Standorthöhe: 125 m
Bauherrschaft:	
Straße:	
PLZ/Ort:	
Provinz/Land:	
Architektur:	Zielke
Straße:	Maria Sevenich Weg
PLZ/Ort:	64289 Darmstadt
Provinz/Land:	Hessen DE-Deutschland
Haustechnik:	
Straße:	
PLZ/Ort:	
Provinz/Land:	
Energieberatung:	Energie Planer Team / Dipl.-Ing. Enikö Sariri-Baffia
Straße:	Ringstraße 26
PLZ/Ort:	64342 Seeheim-Jugenheim
Provinz/Land:	Hessen DE-Deutschland
Zertifizierung:	Passivhaus Institut
Straße:	Rheinstraße 44/46
PLZ/Ort:	64283 Darmstadt
Provinz/Land:	Hessen DE-Deutschland

Baujahr:	2024	Innentemperatur Winter [°C]:	17,0	Innentemp. Sommer [°C]:	28,0
Anzahl WE:	1	Interne Wärmequellen (IWQ) Winter [W/m²]:	2,5	IWQ Sommer [W/m²]:	2,5
Personenzahl:	2,8	spez. Kapazität [Wh/K pro m² EBF]:	180	Mechanische Kühlung:	

Gebäudekennwerte mit Bezug auf Energiebezugsfläche und Jahr — 4 Fehlermeldung(en) im Blatt 'Kontrolle'

			Wert		Kriterien	alternative Kriterien	Erfüllt?[2]
	Energiebezugsfläche	m²	136,9				
Heizen	Heizwärmebedarf	kWh/(m²a)	269	≤	-	-	-
	Heizlast	W/m²	113	≤	-	-	
Kühlen	Kühl- + Entfeuchtungsbedarf	kWh/(m²a)	-	≤	-		-
	Übertemperaturhäufigkeit (> 28 °C)	%	0	≤			
	Häufigkeit überhöhter Feuchte (> 12 g/kg)	%	0	≤	20		ja
Luftdichtheit	Drucktest-Luftwechsel n_{50}	1/h	1,0	≤	1,0		ja
Feuchteschutz	kleinster Temperaturfaktor $f_{Rsi=0.25\,m^2K/W}$	-	0,70	≥	0,56	0,38	ja
Behaglichkeit	Alle Anforderungen erfüllt?	-					nein
	U-Wert	W/(m²K)		≤	1,02		
	U-Wert	W/(m²K)		≤	1,21		
	U-Wert	W/(m²K)		≤	1,32		
	U-Wert	W/(m²K)		≤	0,55		
Nicht erneuerbare Primärenergie (PE)	PE-Bedarf	kWh/(m²a)	377	≤	-		-
Erneuerbare Primärenergie (PER)	PER-Bedarf	kWh/(m²a)	558	≤	505	520	nein
	Erzeugung erneuerb. Energie (Bezug auf überbaute Fläche)	kWh/(m²a)	0	≥	-	20	

PHPP results of the existing building [PHPP 10.5] / Source: PHI

3. Renovation approach description

The building envelope of this small building was renovated by intention using on-site small scale insulation parts. The main reason to do so was the small scale dimensions of all wall and roof areas: no part of the building was similar to any other. So the wooden beams which build-up the cavity for the cellulose fiber filling were provided individually on top of the old rafters and all along on the outside walls. On top of the new beams a 6 cm wooden fiber board was installed to close the cavity. All windows were then installed on these beams, which formed a 'perfect' installation frame so that the windows could be moved out into the insulation layer, see the photographs below. Nevertheless the conception and the construction system is straight forward routine, not at least to provide a good airtight shell without

Heating and hot water are supplied by an externally installed heat pump multi-split-heat-pump-device.

Street façade during the renovation of the building, Source: PHI

3.1. EnerPHit standard approach

EnerPHit standard target (class):	plus
Climate Zone	cool-temperate
EnerPHit verification method:	component quality method

3.2. Design / Consultancy teams

Name:	Passive House Institute
City:	Darmstadt
Type (private / housing association)	private

3.3. Design / Construction periods

Design period:	04.2023 – 09.2023
Construction period:	10.2023 – 06.2024

3.4. Plans and pictures of the renovation

Stud wall façade with wood fiber boards before cellulose filling. Windows to be installed later into these wooden beam frames. Source: PHI

3.5. Envelope of the renovated building

External walls

Material:	Stud wall with cellulose filling and wood fibre board
Thickness:	24 [cm] / 6 [cm]
Surface (Render / Brick / Cladding):	Wood lamellas
U-Value:	0,14 [W/(m²K)]

Floor slab / Basement ceiling

Material:	EPS
Thickness:	12 [cm]
Surface (Render / Brick / Cladding):	EPS
U-Value:	0,21 [W/(m²K)]

Roof or top floor ceiling

Material:	Mineral fibre / Cellulose filling / wood fibro board
Thickness:	12 [cm] / 24 [cm] / 6 [cm]
Surface (Render / Brick / Cladding):	OSB planking
U-Value:	0,11 [W/(m²K)]

Windows

Material:	PVC
Frame Thickness:	10 [cm]
Material (Wood / Plastic / Aluminium):	Plastic
U-Value (Uw, installed):	0,89 [W/(m²K)]

3.6. Technical equipment of the renovated building

Ventilation

Ventilation concept (central / decentral)	central
Ventilation heat recovery efficiency	91 %
Ventilation specific efficiency	0,24 [Wh/m³]
Ventilation standard air flow rate	140 [m³/h]

Heating, Cooling and DHW

Heating:	1 air-water heat pump
Cooling:	Active cooling with split unit
Domestic hot water:	1 air-water heat pump

3.7. Summer comfort

Night ventilation won´t be possible because of noise. However, due to the small windows and trees nearby the cooling demand is low. Still, external shading will be installed and the active cooling concept enables the building owner to set summer temperatures he desires.

3.8. Energy efficiency of the renovated building

Passive House Planning Package (PHPP)

PHPP calculation:	PHPP_10.5
Space heating demand:	41 [kWh/(m²a)]
Heating Load:	21 [W/m²]
Overheating frequency:	%
Cooling demand:	1 [kWh/(m²a)]
Cooling Load:	7 [W/m²]
Primary Energy Demand:	67 [kWh/(m²a)] including household applications
PER Demand:	63 [kWh/(m²a)]
Airtightness n_{50} target:	1,0 1/h (maximum assumed for design purposes)

Final Energy demand

Final energy demand gas:	0 [kWh/(m²a)]
Final energy demand electricity:	50 [kWh/(m²a)] for heating + auxiliary + household

Heat pump and split unit during the installation, Source: PHI

CS37_SFH RENOVATION ARHEILGEND, DARMSTADT

Renovation Approach Description

PHPP verification sheet after retrofit

EnerPHit-Nachweis

10.5 DE PHPP

Objekt:	Energetische Sanierung EFH Arheilgen als EH 70 EE
Straße:	Lönstraße 5
PLZ/Ort:	64291 Darmstadt
Provinz/Land:	Hessen, DE-Deutschland
Objekt-Typ:	1-Freistehendes Einfamilienhaus
Klimadatensatz:	DE1012a-Mannheim, höhenkorrigiert
Klimazone:	3: Kühl-gemäßigt; Standorthöhe: 125 m
Bauherrschaft:	
Straße:	
PLZ/Ort:	
Provinz/Land:	

Architektur:	Zielke	**Haustechnik:**	
Straße:	Maria Sevenich Weg	Straße:	
PLZ/Ort:	64289 Darmstadt	PLZ/Ort:	
Provinz/Land:	Hessen, DE-Deutschland	Provinz/Land:	
Energieberatung:	Energie Planer Team / Dipl.-Ing. Enikö Sariri-Baffia	**Zertifizierung:**	Passivhaus Institut
Straße:	Ringstraße 26	Straße:	Rheinstraße 44/46
PLZ/Ort:	64342 Seeheim-Jugenheim	PLZ/Ort:	64283 Darmstadt
Provinz/Land:	Hessen, DE-Deutschland	Provinz/Land:	Hessen, DE-Deutschland

Baujahr:	2024	Innentemperatur Winter [°C]:	20,0	Innentemp. Sommer [°C]:	25,0
Anzahl WE:	1	Interne Wärmequellen (IWQ) Winter [W/m²]:	2,5	IWQ Sommer [W/m²]:	2,5
Personenzahl:	2,8	spez. Kapazität [Wh/K pro m² EBF]:	180	Mechanische Kühlung:	X

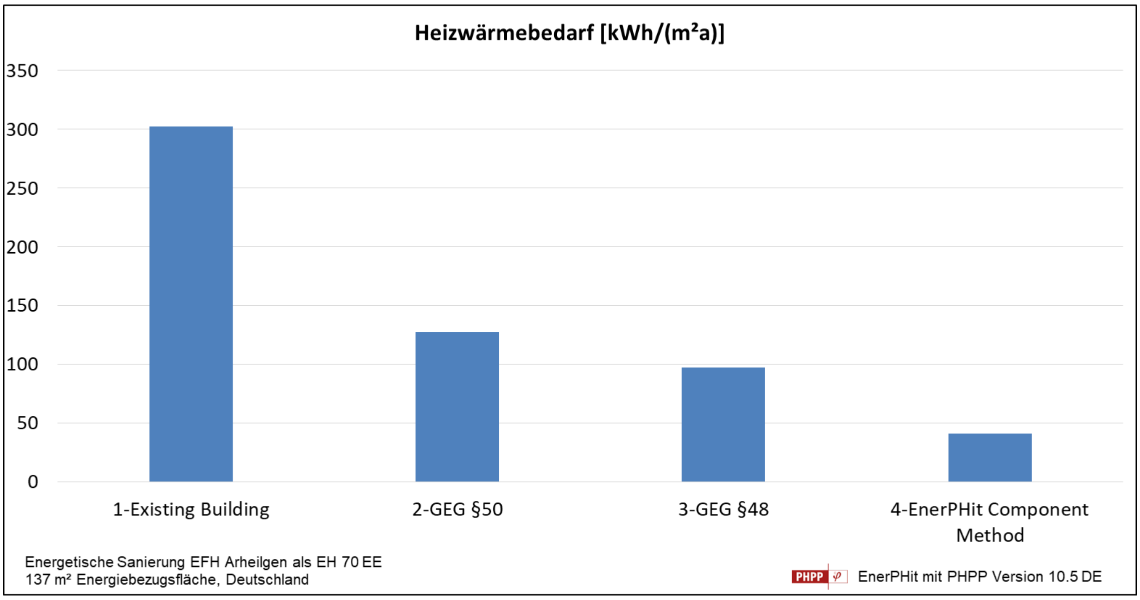
Gebäudekennwerte mit Bezug auf Energiebezugsfläche und Jahr — 2 Fehlermeldung(en) im Blatt 'Kontrolle'

		Einheit	Wert		Kriterien	alternative Kriterien	Erfüllt?[2]
	Energiebezugsfläche	m²	136,9				
Heizen	Heizwärmebedarf	kWh/(m²a)	41	≤	-	-	-
	Heizlast	W/m²	21	≤	-	-	
Kühlen	Kühl- + Entfeuchtungsbedarf	kWh/(m²a)	0	≤	-		-
	Übertemperaturhäufigkeit (> 25 °C)	%	-	≤	-		-
	Häufigkeit überhöhter Feuchte (> 12 g/kg)	%	0	≤	10		ja
Luftdichtheit	Drucktest-Luftwechsel n_{50}	1/h	1,0	≤	1,0		ja
Feuchteschutz	kleinster Temperaturfaktor $f_{Rsi=0.25\ m^2K/W}$	-	0,70	≥	0,48	0,33	ja
Behaglichkeit	Alle Anforderungen erfüllt?	-					ja
	U-Wert	W/(m²K)		≤	1,02		
	U-Wert	W/(m²K)		≤	1,21		
	U-Wert	W/(m²K)		≤	1,32		
	U-Wert	W/(m²K)		≤	0,55		
Nicht erneuerbare Primärenergie (PE)	PE-Bedarf	kWh/(m²a)	89	≤	-		-
Erneuerbare Primärenergie (PER)	PER-Bedarf	kWh/(m²a)	62	≤	71	62	ja
	Erzeugung erneuerb. Energie (Bezug auf überbaute Fläche)	kWh/(m²a)	113	≥	60	48	

PHPP results of the renovated building [PHPP 10.5] / Source: PHI

3.9. Predicted (calculated) energy savings

Savings In space heating demand: 260 [kWh/(m²a)]

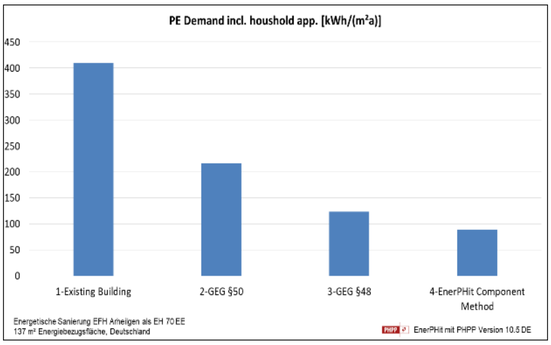


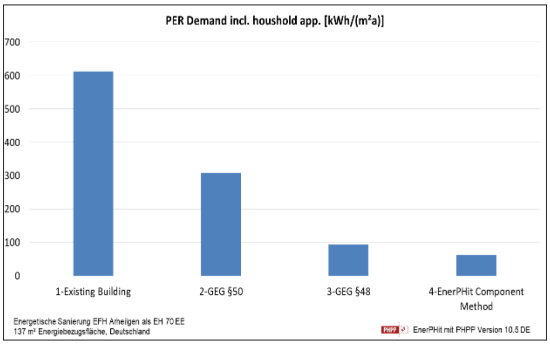
Heating demand before and after the renovation [PHPP 10.5] / Source: PHI

The two minimum requirement standards for Germany, fulfilling a minimum PE-demand approach according to GEG §50 or fulfilling a minimum component quality approach according to GEG §48 have also been modelled. Clearly visible is the considerable higher heating demand reduction enabled by the EnerPHit standard.

Savings Primary Energy Demand: 319 [kWh/(m²a)]

Savings PER Demand: 549 [kWh/(m²a)]





Primary Energy PE Demand and Primary Energy Renewable PER Demand of the building before and after the renovation [PHPP 10.5] The PER demand simulates a future energy supply environment (for example 2050), when most of the energy generation will be renewable and considerable storage losses will have to be expected, especially for seasonal energy storages, that will be required for heating / Source: PHI

Savings of Final energy demand gas:	342 [kWh/(m²a)]
Savings of Final energy demand electricity:	0 [kWh/(m²a)] Household appliances not updated
Additional final energy demand electricity:	34 [kWh/(m²a)] Heat pumps for Heating and DHW


Old brick wall with stud wall system / Source: PHI

3.10. RES strategy

The building will receive solar PV elements on the south roof after finalization. A PV yield of even 85 kWh/(m²a) could be possible, if most of the roof area would be covered with PV panels.


Old and renovated roof situation / Source: PHI

4. Project challenges and opportunities

The family decided to live in the building during the whole renovation process as they did not want to spend extra money for living elsewhere – and because they wanted to be present during all work to be able to supervise. Apart from that, they wanted to contribute a quite large part of construction work to reduce construction cost. These to intentions are not common as living in a building under renovation-construction-process is challenging with many respects. But this project shows that families can go such way and save much money like that.

The only very important precondition is, that there is a good support by an experienced architect, who will help to organize the process and coordinate all the commissioned crafts-companies. Another important task for the architect is a thoroughgoing quality control and supervision during all the process, so that mistakes are spotted early and avoided or repaired.

5. Current project status

Currently (Summer 2024) the renovation works are almost complete. Still missing is the external shading, which should be delivered in autumn. The owner family feel very comfortable in the renovated building and is highly satisfied with the EnerPHit renovation

6. Lessons learnt and guidelines for replication

Very important for the successful process is the planning phase before the renovation starts on site to be aware of the many complicated connections that arise from such a retrofit. Due to budget constraints the building owner supported the renovation works with DIY measures, that demonstrated that good results similar to the quality of trades persons can be achieved.

7. Pre-Monitoring description (if applicable)

A simplified monitoring has been installed in the building before start of the renovation works. The results show increased indoor comfort level and air condition, but an evaluation will only make sense after the first completed heating period.

Completed street façade of the building / Source: PHI