NATIONAL TECHNICAL UNIVERSITY OF ATHENS

IS BLUE THE NEW GREEN IN THE POST-COVID ERA?

Empirical Evidence for EU-27 (2010-2019)

Call for Papers, 2021
Special Issue for Energy Policy Journal, Elsevier

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TODAY'S PRESENTATION

The problem: The ongoing pandemic of Covid-19 has put a halt to the green transformation of EU over the last two years. Nonetheless, due to the Next Generation funding scheme, there is a way for EU to leap forward towards a total and more radical transformation into a perfectly Green sustainable economy.

A SUMMARY OF CONTENTS

- The problem
- Data presentation
- Hydrogen production
- Hydrogen safe supply
- Methodology (ARDL)
- The H2PS3 model
- Result Analysis
- Conclusions
- Policy Implications
- A distant look into the future

WHAT WE'LL WORK ON

- The evolving transition from fossil fuels to green energy.
- The hydrogen, as a main fuel and as an energy carrier for electricity storage.
- The possible long term impact of a 100% energy transition to hydrogen use.

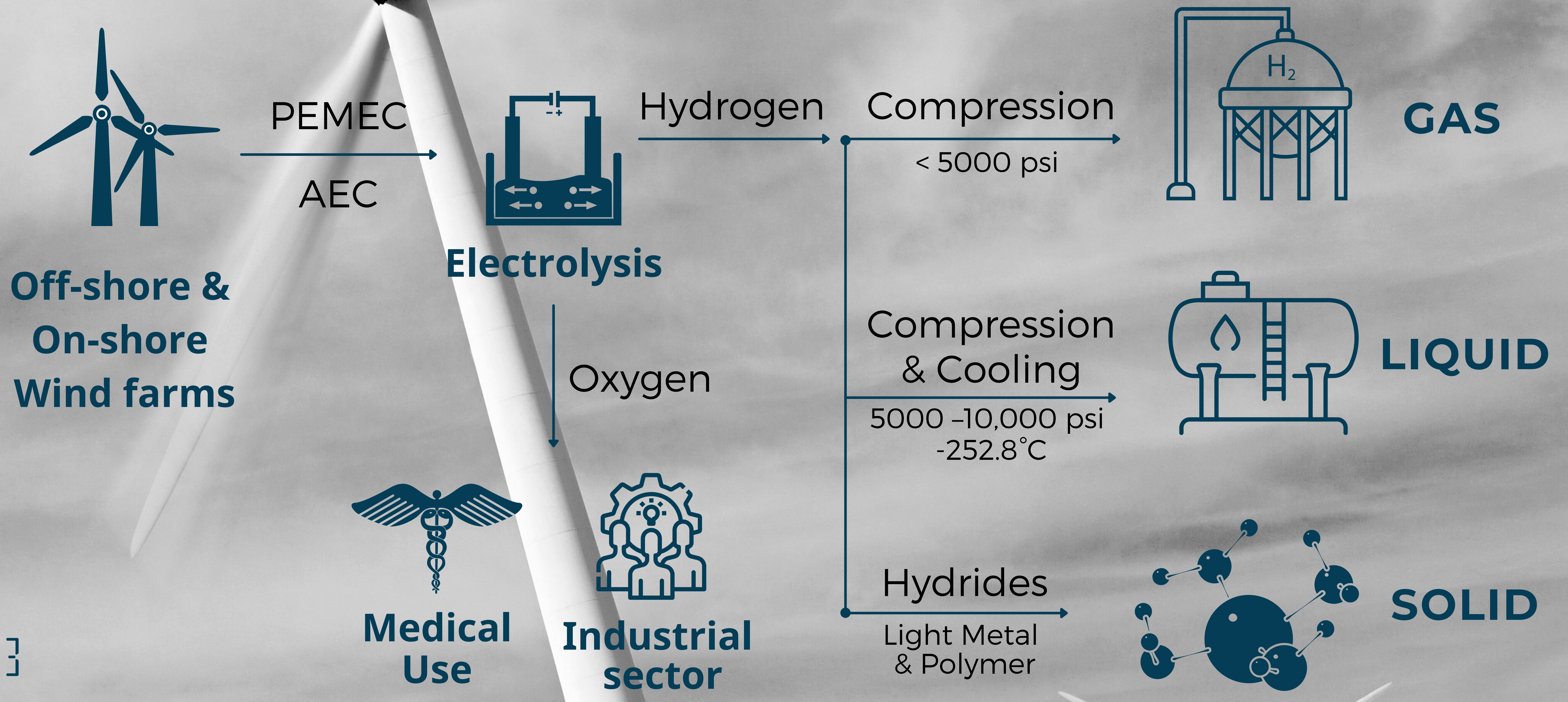
EUROSTAT
Database

EU-27
2010-2019

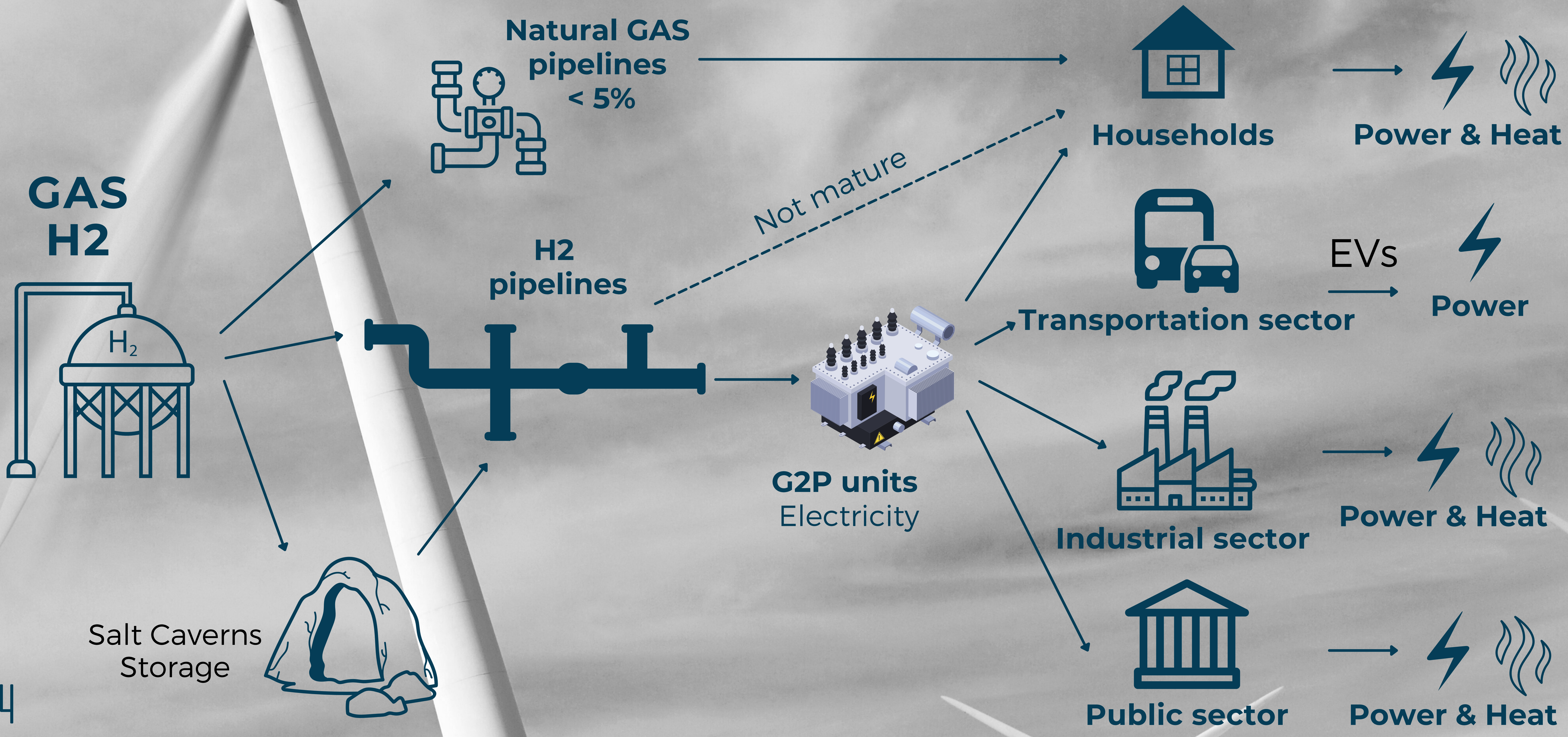
STATA
package

KEY VARIABLES
Hydro, Wind

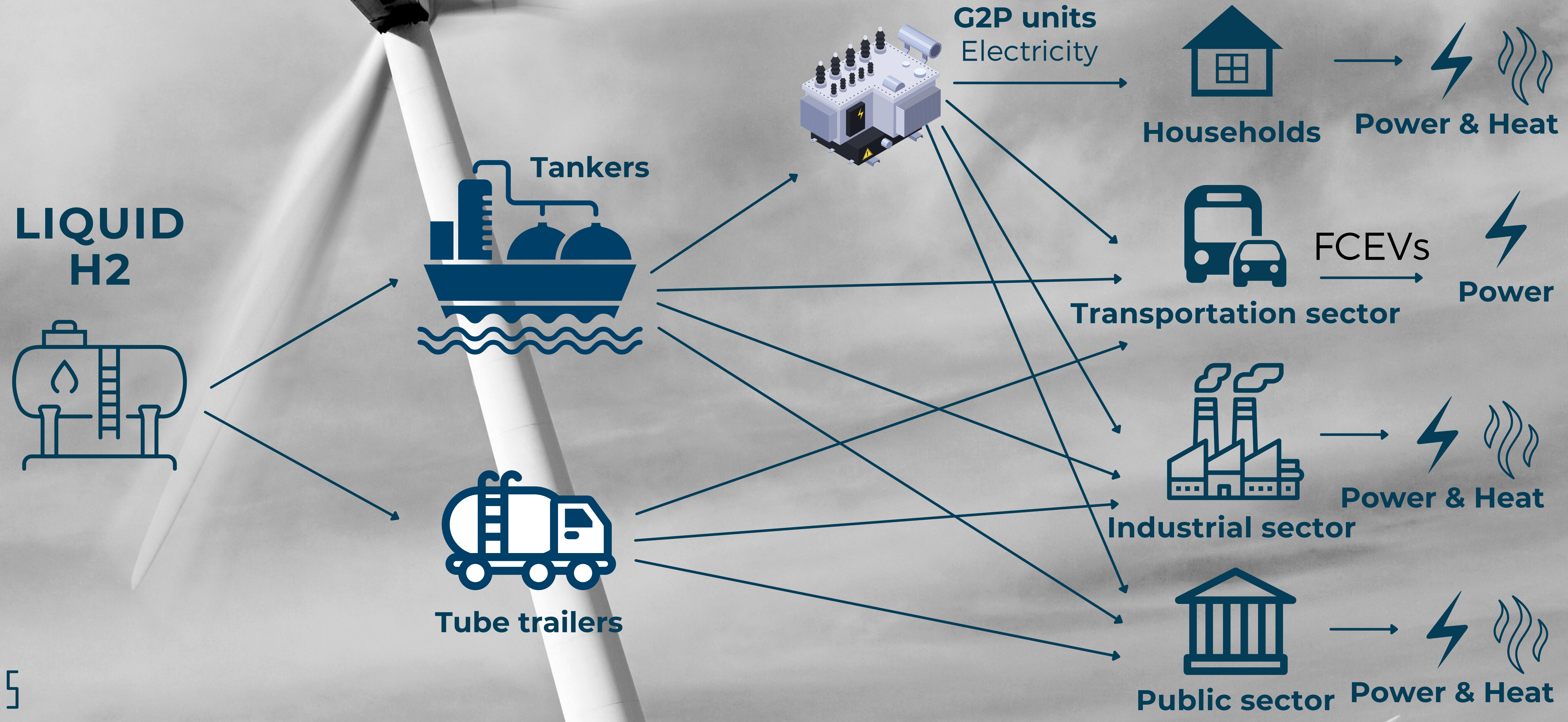
Hydrogen Production



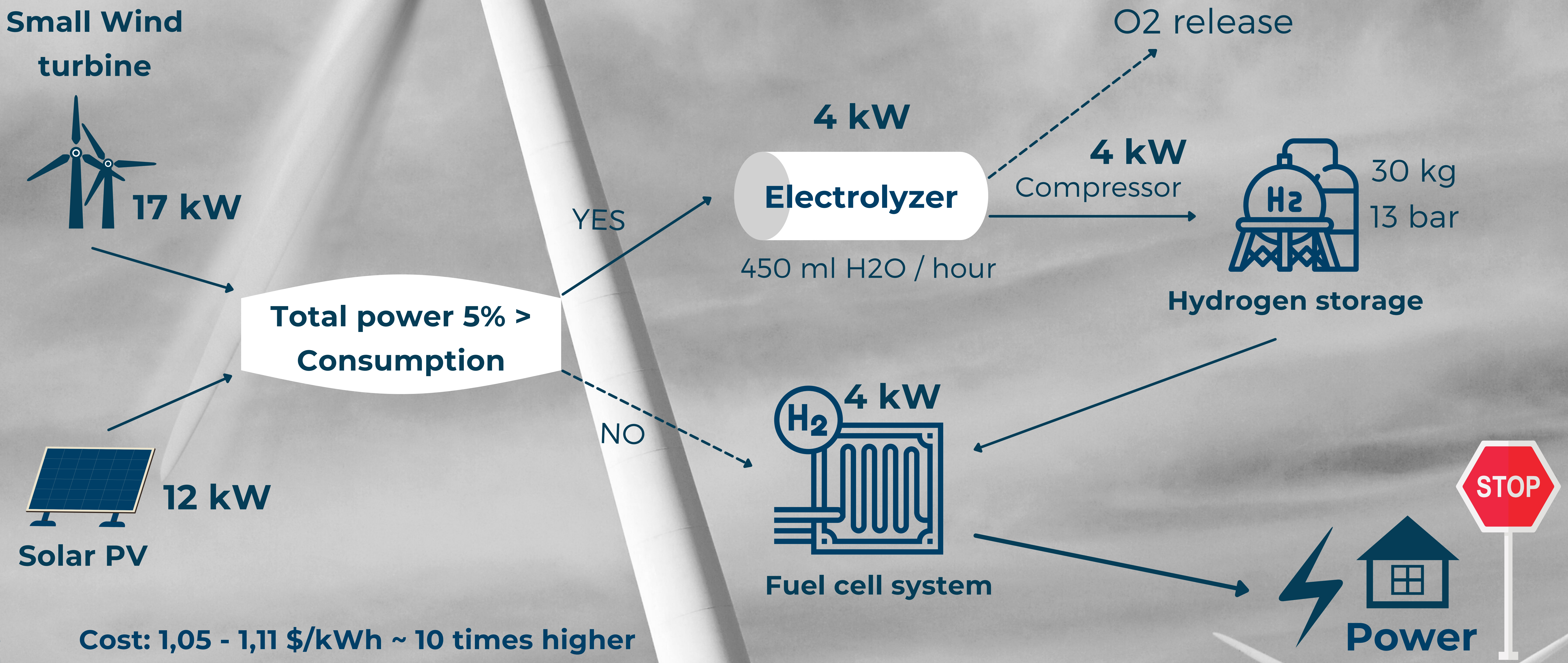
Hydrogen Safe Supply (Gaseous state)



Hydrogen Safe Supply (Liquid state)



Hydrogen Autonomous Households (x10 > $)



Cost: 1,05 - 1,11 $/kWh ~ 10 times higher than the grid electricity provider

METHODOLOGY

DYNAMIC ARDL MODEL

- The dynamic Auto-Regressive Distributed Lag (ARDL) model is gradually gaining recognition in energy and environmental economics.

- Thus, the novel dynamic ARDL model is a useful tool for conducting policy analysis.

- ARDL is useful for testing cointegration, long and short-run equilibrium relationships in both levels and first differences.

METHODOLOGY

DYNAMIC
ARDL MODEL

The ARDL model specification is given as follows:

$$\Phi(L,p)y_t = \sum_{i=1}^{k} \beta_i (L,q_i) x_{it} + \delta w_t + u_t$$

where

$$\Phi(L,p) = 1- \Phi_1 L - \Phi_2 L^2 -....-\Phi_p L^p$$

$$\beta(L,q) = 1- \beta_1 L - \beta_2 L^2 -.... - \beta_q L^q$$

$$\text{for } i=1,2,3,...,k \quad u_t \sim iid(0;\delta^2)$$

L is a lag operator such that $L^0 y_t = X_t$, $L^1 y_t = y_t - 1$, and w_t is a s x1 vector of deterministic variables such as the intercept term, time trends, seasonal dummies, or exogenous variables with the fixed lags. P=0,1,2...,m, q=0,1,2....,m, i=1,2....,k: namely a total of $(m+1)^{k+1}$ different ARDL models. The maximum lag order, m, is chosen by us.

METHODOLOGY

DYNAMIC ARDL MODEL

Advantages of ARDL Approach

- Since each of the underlying variables stands as a single equation, endogeneity is less of a problem in the ARDL technique because it is free of residual correlation.
- When there is a single long run relationship, the ARDL procedure can distinguish between dependent and explanatory variables.
- The **major advantage** of this approach lies in its identification of the cointegrating vectors where there are multiple cointegrating vectors.
- The Error Correction Model (ECM) can be derived from the ARDL model through a simple linear transformation, which integrates short run adjustments with long run equilibrium without losing long run information.

METHODOLOGY

DYNAMIC
ARDL MODEL

Step 1 Identification of the degree of integration using Unit Root Test

Dickey-Fuller test

$$\Delta Y_t = (\alpha-1)Y_{t-1} + u_t \quad \Delta Y_t = (\alpha-1)Y_{t-1} + \alpha_2 T + u_t$$

Ho: p=0 => a=1 (we have a unit root)
H1: p>0 => time series stationary

Step 2 Choosing the Appropriate Lag Length for the ARDL Model

Optimum lag length(k) by using proper model order selection criteria such as Schwarz Bayesian Criterion (SBC)

(*) SBCp = log(δ2) +(logn/n)P

METHODOLOGY

DYNAMIC
ARDL MODEL

Step 3

The ARDL model

$$Y_t = a_0 + \sum_{i=1}^{m} a_i Y_{t-i} + \sum_{j=0}^{n} \beta_j X_{t-j} + \varepsilon_t$$

Impulse Response Function (IRF)

$$\frac{\partial y_{i,t+s}}{\partial a_{jt}} = \psi_{ij}^{(s)}$$

(*) reaction of the ith-variable to 1 standard deviation change in innovation j

Y The H2PS3 model X

Dependent Variables

Electricity consumption by **Households**

Electricity consumption by the **Transportation sector**

Electricity consumption by the **Industrial sector**

Electricity consumption by the **Public sector**

Independent Variables

Electricity produced by **Hydrogen**

Electricity produced by **Wind**

Total greenhouse gas **emissions**

Total **environmental tax** revenues

Stock levels of **Crude oil**

GDP per capita

Data Source: Eurostat -> Data -> Database

All variables -> ln() transpose

RESULT ANALYSIS

HOUSEHOLDS

DYNAMIC
ARDL MODEL
(HYDROGEN, WIND, GDP_CAP)

(*) there are no unit roots

Variables

Dependent: Electricity consumption by **Households**

Independent: Electricity produced by Hydrogen, Electricity produced by Wind, GDP per capita

Variable	Coefficient	p-value
L1_FECH	0.985	0.000
L2_FECH	-0.195	0.066
L3_FECH	0.326	0.001
L4_FECH	-0.111	0.115
L1_Hydro	-0.078	0.082
Hydro	0.075	0.091
Wind	-0.003	0.034
GDPcap	0.269	0.019
L1_GDPcap	-0.268	0.020

FECH = Final electricity consumption by Households
(in thousand tonnes of oil equivalent)

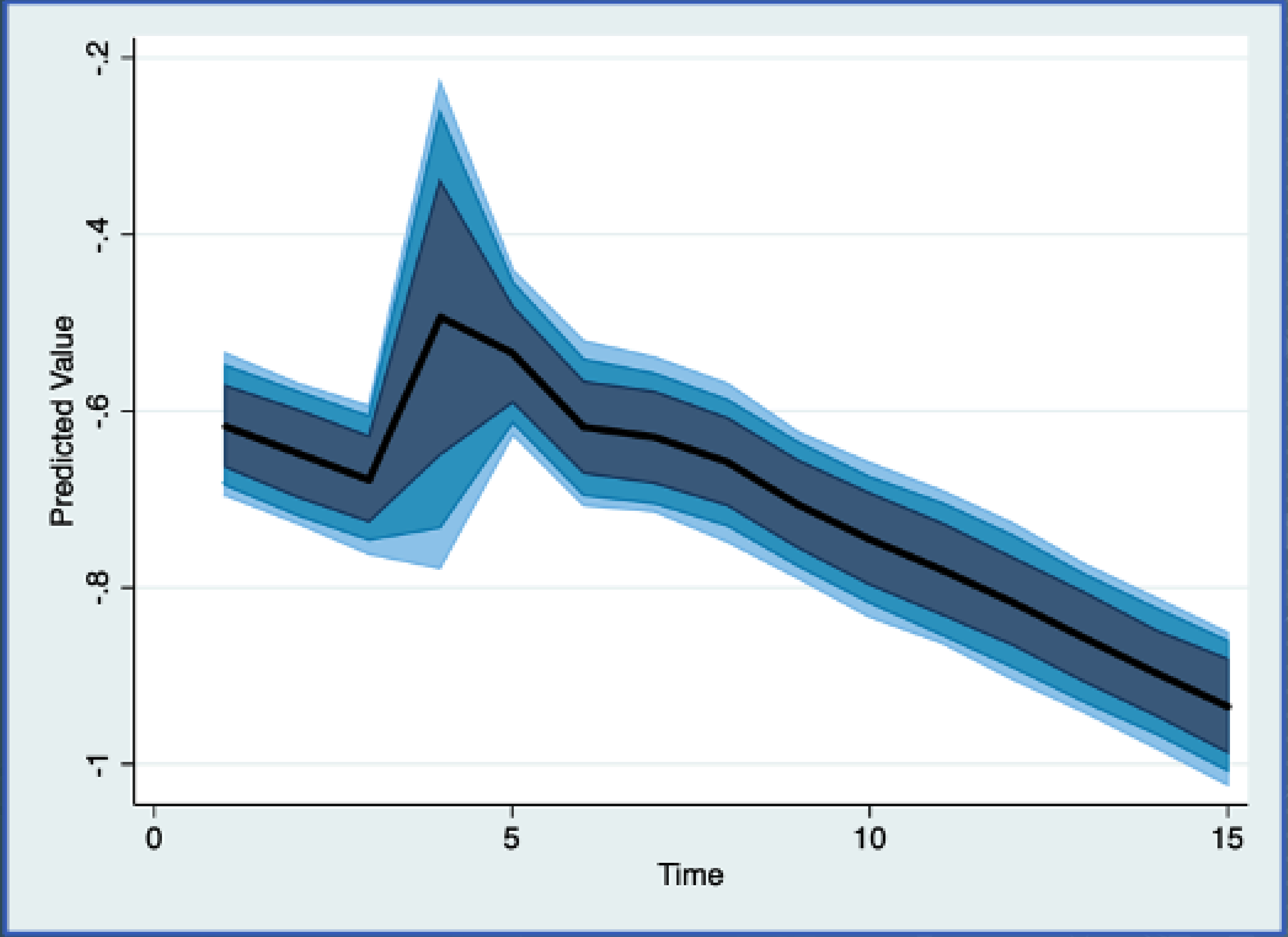
RESULT ANALYSIS

HOUSEHOLDS

DYNAMIC
ARDL MODEL
(HYDROGEN, WIND, GDP_CAP)

Households - **Hydrogen** Shock (4th year)

Electricity consumption by Households



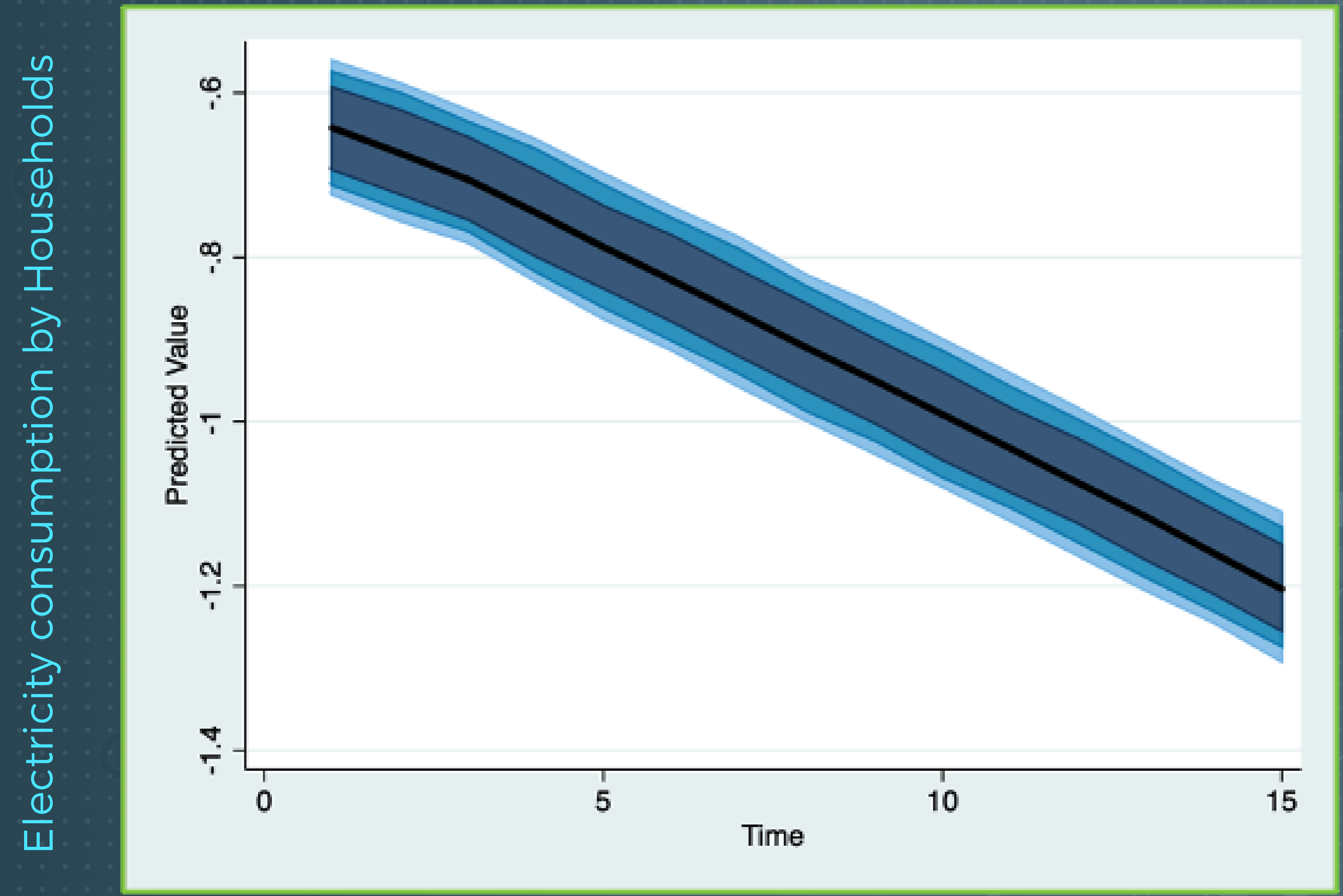
A positive shock (+1 standard deviation) in the production of electricity from hydrogen, causes a gradual reduction in electricity consumption by households, which may be due to the increase in the price of electricity per kWh, because of the installation cost of the hydrogen production units.

RESULT ANALYSIS

HOUSEHOLDS

DYNAMIC
ARDL MODEL
(HYDROGEN, WIND, GDP_CAP)

Households - **Wind** Shock (4th year)



A positive shock (+1 standard deviation) in the production of electricity from wind power, causes a gradual reduction in electricity consumption by households, which may be due to the increase in the price of electricity per kWh, because of the installation cost of the new wind generators.

RESULT ANALYSIS

TRANSPORTATION SECTOR

DYNAMIC ARDL MODEL

(HYDROGEN, WIND, GG_TOTAL)

(*) there are no unit roots

Variables

Dependent: Electricity consumption by the **Transportation sector**

Independent: Electricity produced by Hydrogen, Electricity produced by Wind, Total greenhouse gas emissions

Variable	Coefficient	p-value
L1_FECTr	0.687	0.000
L2_FECTr	0.008	0.933
L3_FECTr	0.044	0.859
L4_FECTr	0.246	0.295
Hydro	0.018	0.094
Wind	0.033	0.005
GG_Total	-1.048	0.031
L1_GG_Total	1.020	0.036

FECTr = Final electricity consumption by the Transportation sector (in thousand tonnes of oil equivalent)

RESULT ANALYSIS

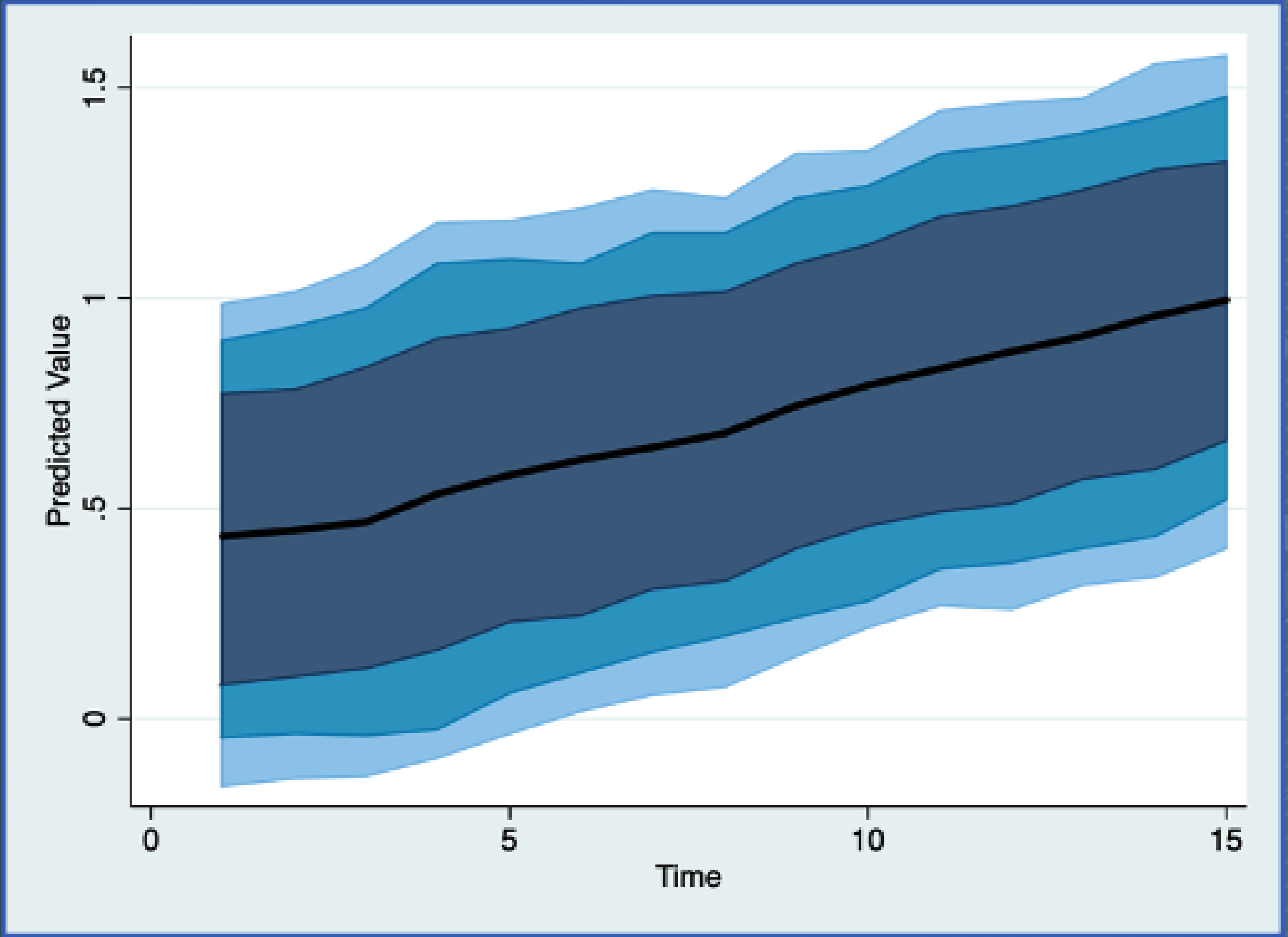
TRANSPORTATION SECTOR

DYNAMIC ARDL MODEL

(HYDROGEN, WIND, GG_TOTAL)

Transportation sector - **Hydrogen** Shock (4th year)

Electricity consumption by the Transportation sector



A positive shock (+1 standard deviation) in the production of electricity from hydrogen, causes a gradual increase in electricity consumption by the Transportation sector, which may be due to the decrease in the price per km of travel, because of the installation of FCEVs (+hydrides).

RESULT ANALYSIS

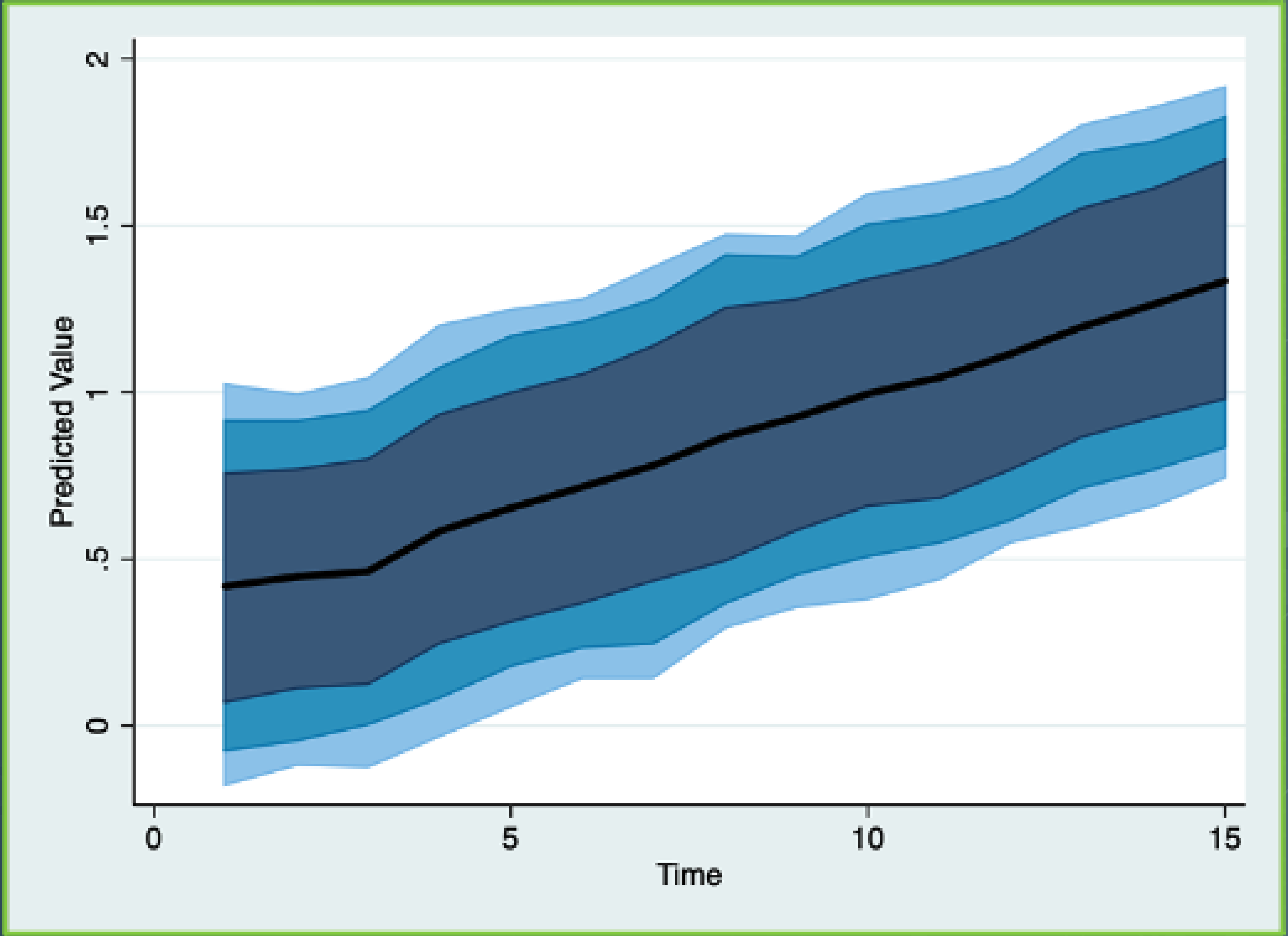
TRANSPORTATION SECTOR

DYNAMIC ARDL MODEL

(HYDROGEN, WIND, GG_TOTAL)

Transportation sector - **Wind** Shock (4th year)

Electricity consumption by the Transportation sector



A positive shock (+1 standard deviation) in the production of electricity from wind power, causes a gradual increase in electricity consumption by the Transportation sector, which may be due to the decrease in the price per km of travel, because of the installation of EVs.

RESULT ANALYSIS

INDUSTRIAL SECTOR

DYNAMIC ARDL MODEL

(HYDROGEN, WIND, TOET, STLCO)

(*) there are no unit roots

Variables

Dependent: Electricity consumption by the **Industrial sector**

Independent: Electricity produced by Hydrogen, Electricity produced by Wind, Total environmental tax revenues, Stock levels of Crude oil

Variable	Coefficient	p-value
L1_FECInd	1.001	0.000
L2_FECInd	-0.074	0.295
L3_FECind	0.065	0.182
L1_Hydro	-0.041	0.427
L2_Hydro	0.015	0.704
L3_Hydro	-0.090	0.005
Hydro	0.116	0.021
Wind	-0.002	0.098
ToET	0.008	0.065
StLCO	0.003	0.069

FECInd = Final electricity consumption by the Industrial sector (in thousand tonnes of oil equivalent)

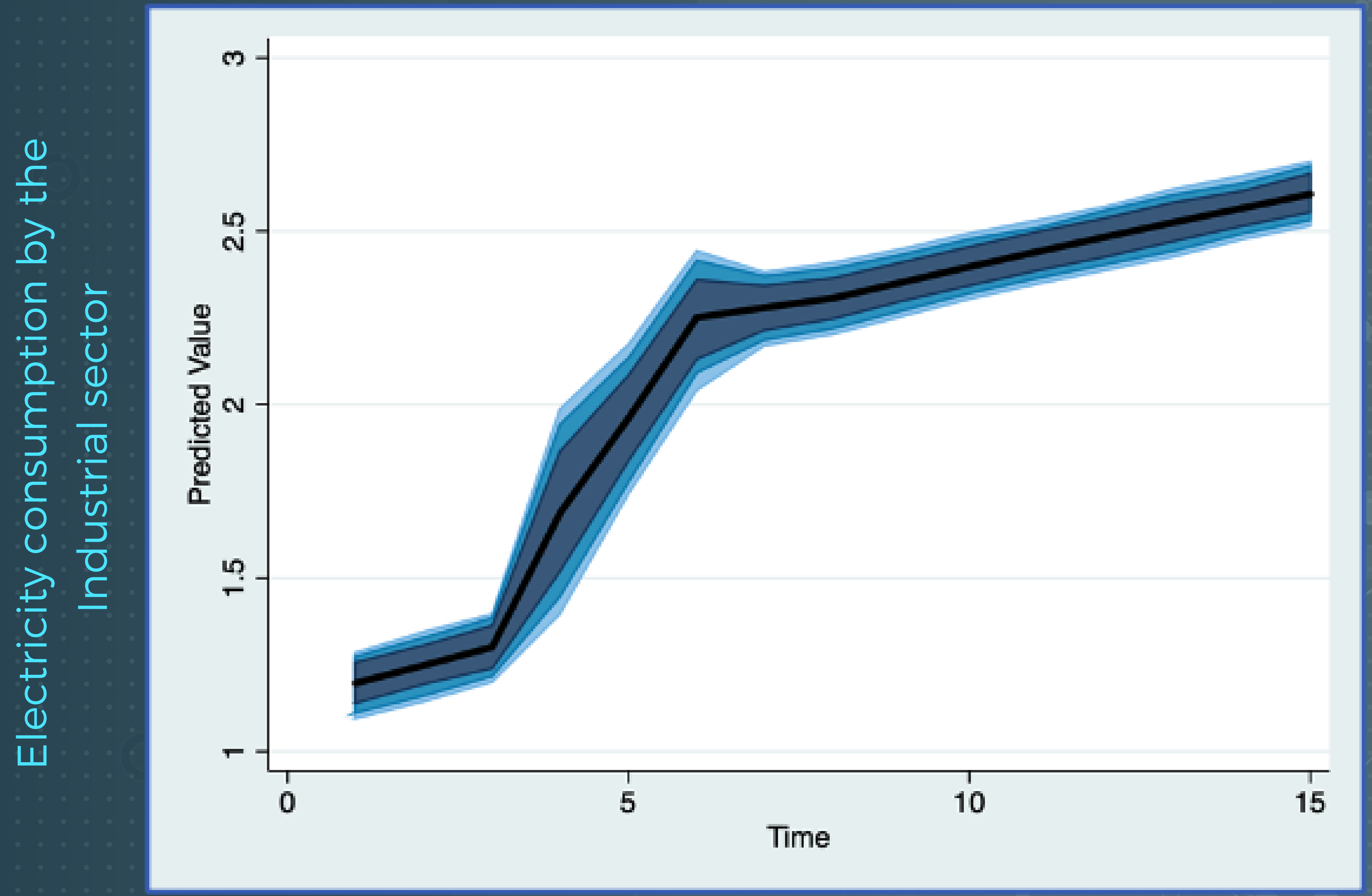
RESULT ANALYSIS

INDUSTRIAL SECTOR

DYNAMIC ARDL MODEL

(HYDROGEN, WIND, TOET, STLCO)

Industrial sector - **Hydrogen** Shock (4th year)



A positive shock (+1 standard deviation) in the production of electricity from hydrogen, causes a gradual increase in electricity consumption by the Industrial sector, which may be due to the decrease in the price of electricity per kWh, because of the installation of new G2P units and the economies of scale.

RESULT ANALYSIS

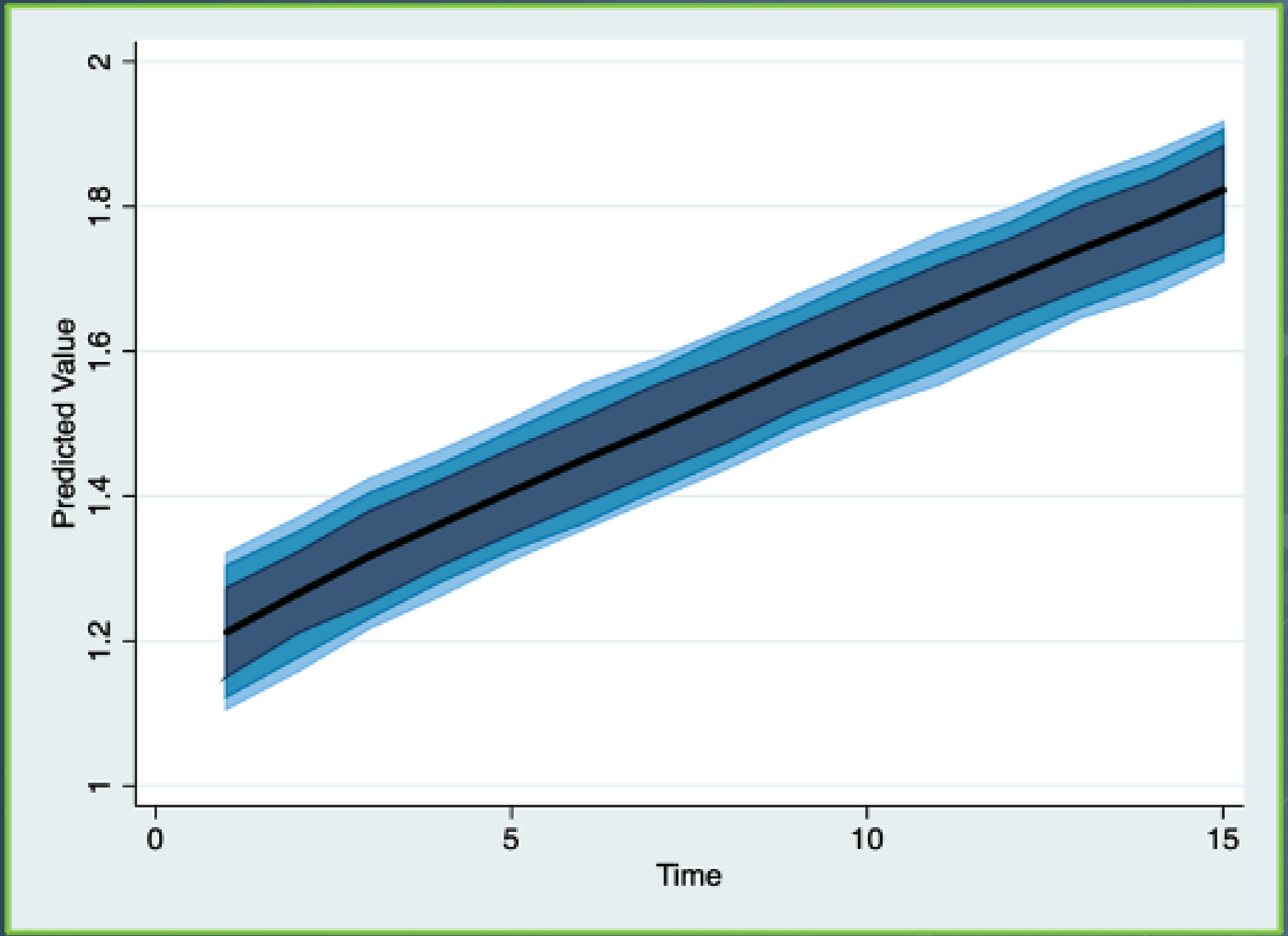
INDUSTRIAL SECTOR

DYNAMIC ARDL MODEL

(HYDROGEN, WIND, TOET, STLCO)

Industrial sector - **Wind** Shock (4th year)

Electricity consumption by the Industrial sector



A positive shock (+1 standard deviation) in the production of electricity from wind power, causes a gradual increase in electricity consumption by the Industrial sector, which may be due to the decrease in the price of electricity per kWh, because of the available energy stocks (H_2) and the economies of scale.

RESULT ANALYSIS

PUBLIC SECTOR
DYNAMIC
ARDL MODEL
(HYDROGEN, WIND, GG_TOTAL GDP_CAP)

(*) there are no unit roots

Variables

Dependent: Electricity consumption by the **Public sector**

Independent: Electricity produced by Hydrogen, Electricity produced by Wind, Total greenhouse gas emissions, GDP per capita

Variable	Coefficient	p-value
L1_FEnCE_Gov	0.993	0.000
L1_Hydro	0.131	0.018
L2_Hydro	-0.038	0.372
L3_Hydro	0.090	0.010
Hydro	-0.183	0.001
Wind	0.042	0.031
GG_Total	0.261	0.000
GDPcap	0.370	0.005
L1_Wind	-0.048	0.038
L2_Wind	0.001	0.950
L3_Wind	0.005	0.652
L1_GG_Total	-0.258	0.000
L1_GDPcap	-0.368	0.006

FEnCE_Gov = Final electricity consumption by the Public sector (in thousand tonnes of oil equivalent)

RESULT ANALYSIS

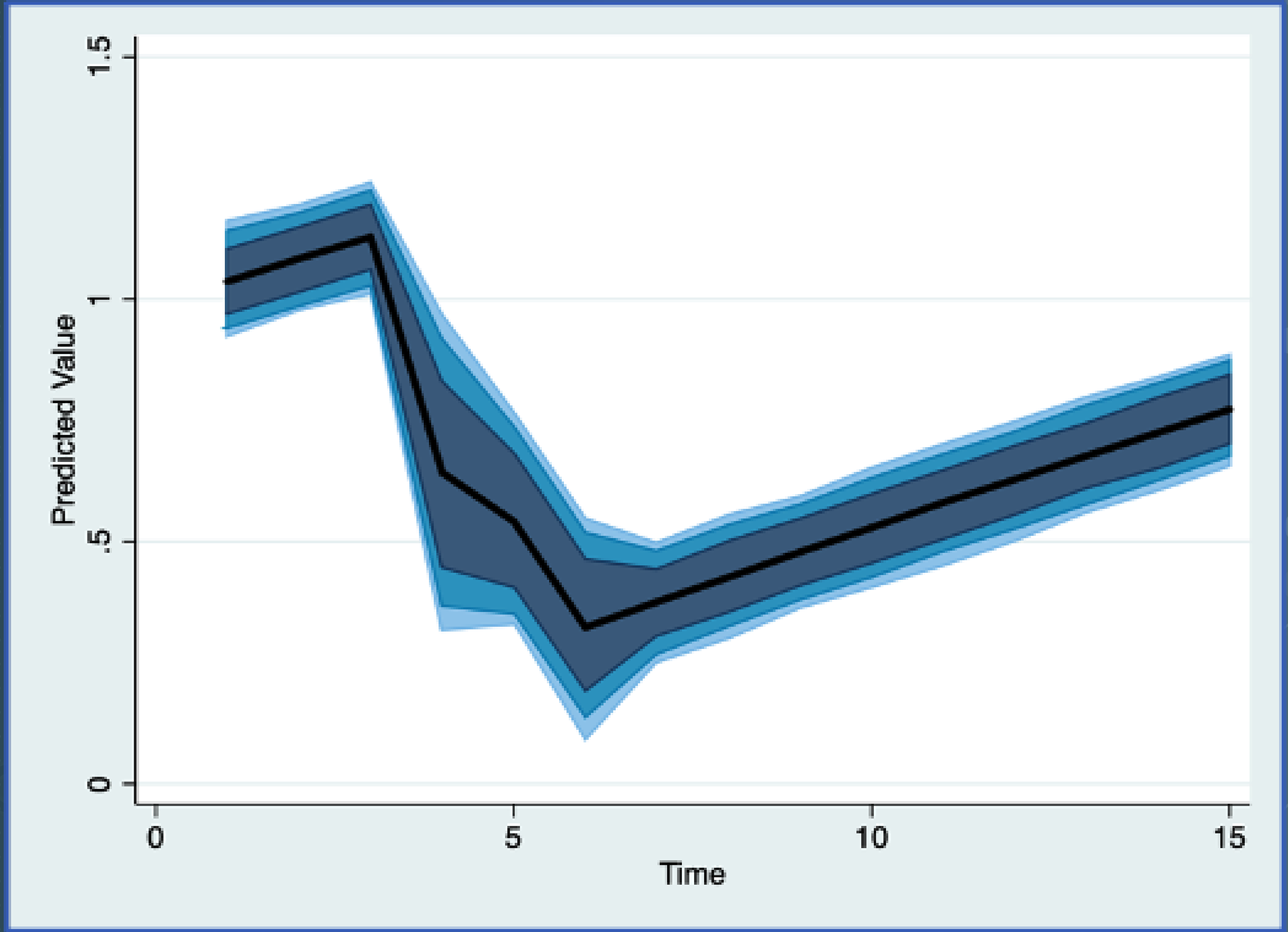
PUBLIC SECTOR

DYNAMIC
ARDL MODEL

(HYDROGEN, WIND, GG_TOTAL GDP_CAP)

Public sector - **Hydrogen** Shock (4th year)

Electricity consumption by the Public setor



A positive shock (+1 standard deviation) in the production of electricity from hydrogen, causes a gradual increase in electricity consumption by the Public sector, which may be due to the decrease in the price of electricity per kWh, because of the ability to quickly depreciate fixed assets.

RESULT ANALYSIS

PUBLIC SECTOR

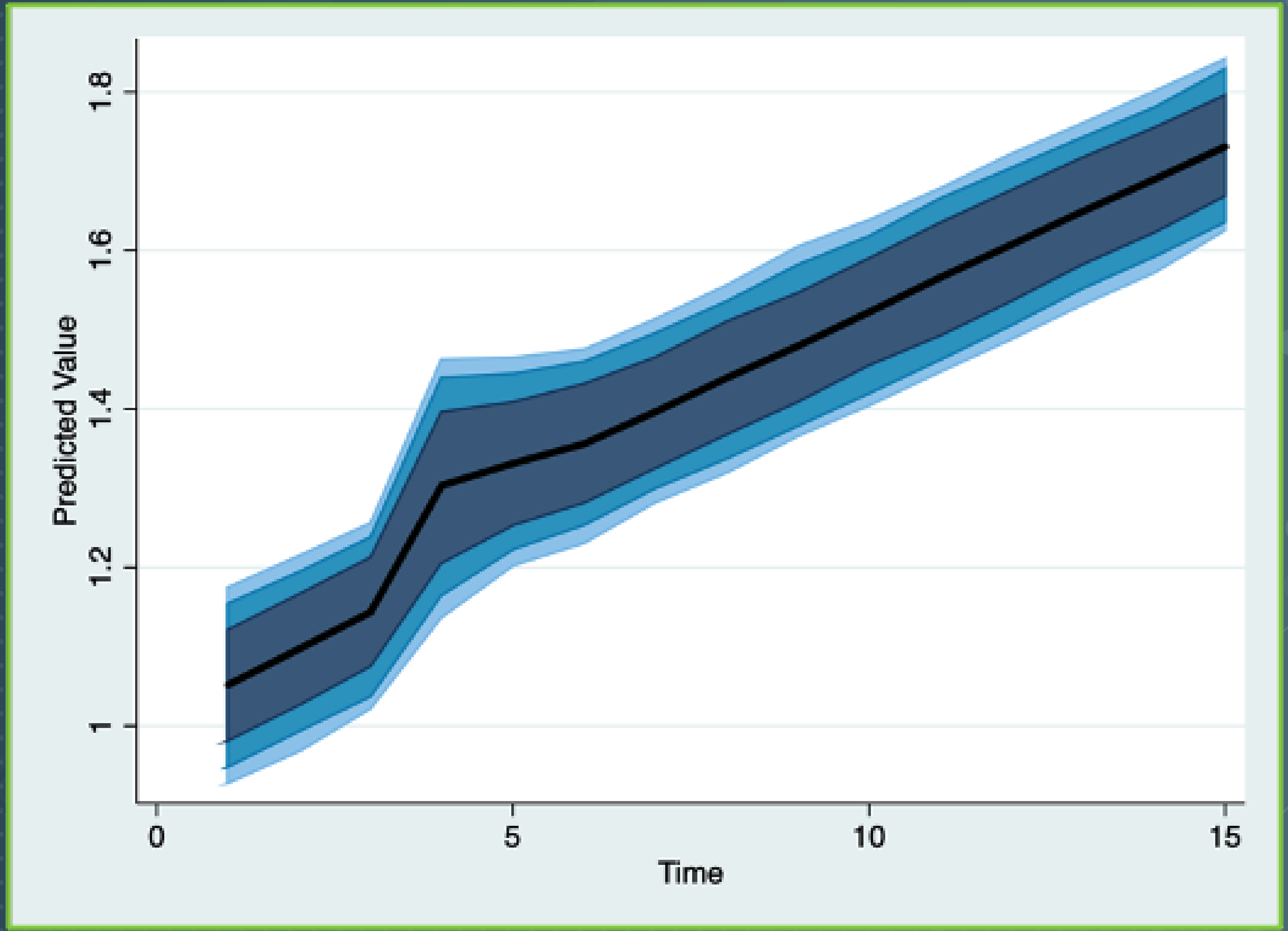
DYNAMIC

ARDL MODEL

(HYDROGEN, WIND, GG_TOTAL GDP_CAP)

Public sector - **Wind** Shock (4th year)

Electricity consumption by the Public setor



A positive shock (+1 standard deviation) in the production of electricity from wind power, causes a gradual increase in electricity consumption by the Public sector, which may be due to the decrease in the price of electricity per kWh, because of the ability to quickly depreciate fixed assets.

Conclusions

- A higher grid price per kWh would result in a reduction of electricity consumption by Households.
- An increased production of electricity by wind power & hydrogen, would cause an increase in electricity consumption by the Transportation sector, due to the decrease in the price per km of travel, because of the installation of new EVs and FCEVs (+hydrides).
- An increased production of electricity from wind power & hydrogen, will increase the electricity consumption by the Industrial sector due to the installation of more efficient G2P units, the available energy stocks of H2 and the economies of scale.
- An increase in the production of electricity from wind power & hydrogen, will cause an increase in electricity consumption by the Public sector, due to the ability to quickly depreciate fixed assets.

FIRST GROUP

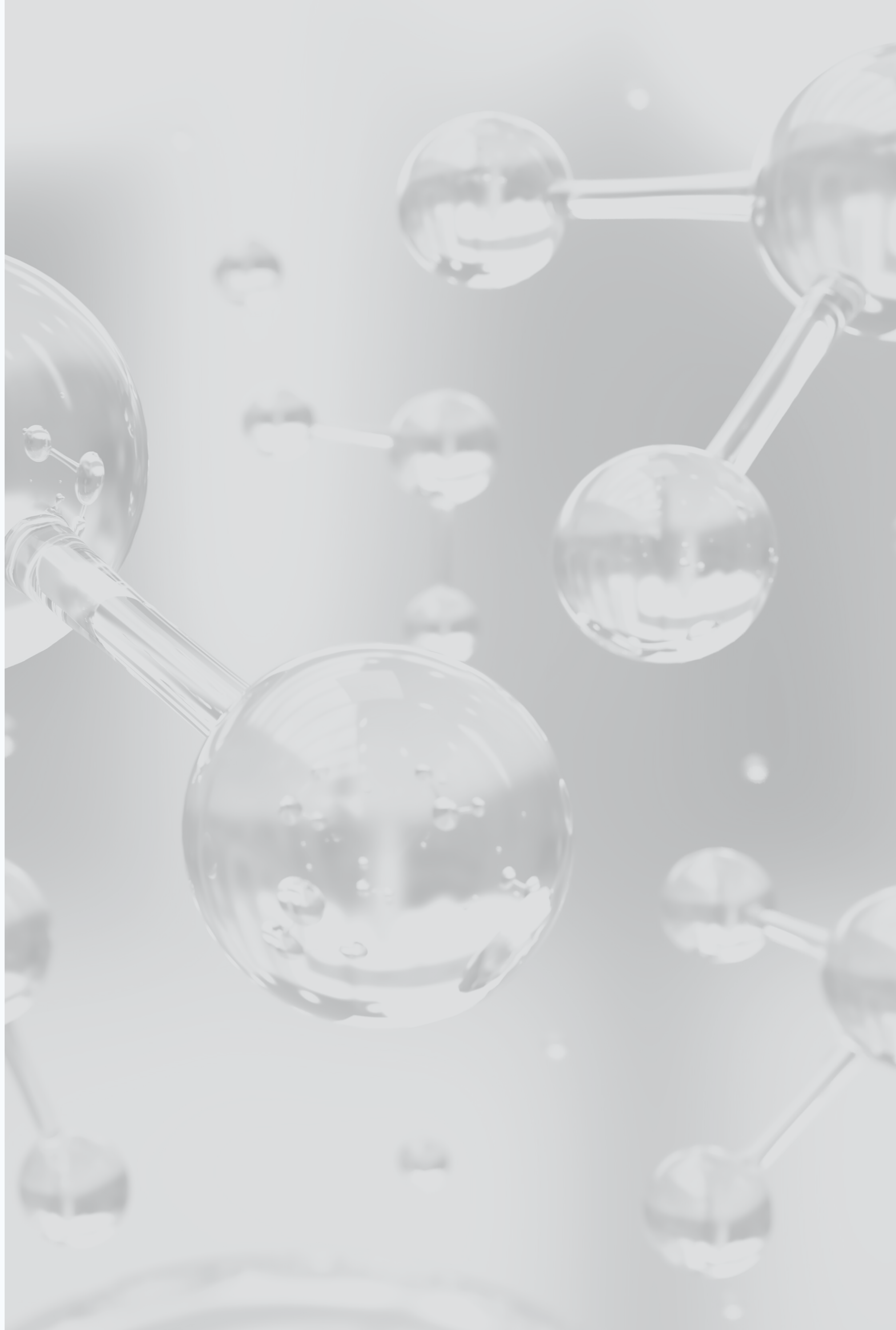
In EU-27 **Households** if we increase the production of electricity from renewable sources, electricity consumption will be gradually reduced.

SECOND GROUP

In EU-27 **Transportation sector**, **Industrial sector** & **Public sector** if we increase the production of electricity from renewable sources, electricity consumption will gradually increase.

Policy Implications

- State aid policies for households on the rising price of electricity for the mild absorption of the new green installation costs.
- Need for immediate expansion of the hydrogen supply network for the transport sector.
- Further research in the field of safe mobile hydrogen storage.
- New G2P energy units at the regional level of each EU-27 country and extensive H2 pipelines network.



A DISTANT LOOK INTO THE FUTURE

2030

GREEN ENERGY TURNS BLUE

Energy **sustainability** is a key policy priority. Hydrogen is a sustainable **energy carrier** for electricity producers (especially offshore **wind farms**).

2050

COMMERCIAL+ SECTORS TURN BLUE

Households (B2C)
Transportation sector (B2C & B2B)
Industrial sector (B2B)
Public sector (B2G)

2100

THE ENERGY FUTURE IS BLUE

Water supply is a key priority for **humankind**. Hydrogen is a sustainable energy solution on **planets** with environmental conditions similar to those of **earth**.

Thank you

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