SUPPLEMENTARY MATERIALS

Evidence of Study Authenticity and Reliability of Results

Sustainability beyond energy: multi-criteria evidence of inter-domain compensation in Algeria's existing housing stock

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These supplementary materials document the authenticity of the study and the reliability of the presented results. They contain: (S1) photographic evidence of the case studies; (S2) detailed utility consumption data extracted from SONELGAZ and ADE bills over the 36-month reference period (2021–2023) with calculation methodology; (S3) completed assessment checklists with criterion-by-criterion evidence tracing; (S4) inter-rater reliability report; (S5) data acquisition timeline; and (S6) data availability declaration.

S1. Photographic and Satellite Evidence

The following photographs document the physical existence and characteristics of both case studies, located in Oued Nagues neighborhood, Tébessa, Algeria.

S1.1 Satellite View of Both Models

Figure S1 presents a high-resolution satellite view with both dwellings identified. Model No. 01 (conventional, 2007) is outlined in red; Model No. 02 (colonial-era, 1950/1984) is outlined in orange. Their adjacency confirms they share the same climatic context (BSk) and urban environment.

Figure S1: Satellite view of both case studies, Oued Nagues neighborhood, Tébessa (Source: Google Earth, 2024)

S1.2 Adjacency of Both Models — Ground-Level View

Figure S2 provides ground-level photographic evidence that both case study dwellings are immediately adjacent, sharing a common boundary wall. The colonial-era Model No. 02 (foreground, right) is clearly distinguishable by its thick stone-clad walls, ceramic tile roof canopies, timber shuttered windows, and compact single-storey form. The conventional Model No. 01 (background, left) rises to R+1 with its rendered concrete facade. This photograph also confirms the family relationship between the two property owners: Model No. 02 belongs to the father (Mr BATOURI AHMED) and Model No. 01 to the son (Mr BATOURI ALI), explaining the spatial adjacency and the researchers' privileged access to both dwellings and their documentary records.

Figure S2: Ground-level view showing the adjacency of both models (Model No. 02 foreground, Model No. 01 background)

S1.3 Facade of Model No. 01 — Conventional Villa (2007)

Visible features: RDC commercial units with metal grilles (C2c: collective/mixed-use), first-floor south-facing windows (B1a), mature local trees over 20 years (C4d, C4e), cultivated garden behind the fence (C4h), and timber window frames (A1g).

Figure S3: Main facade of Model No. 01 — conventional villa (2007)

S1.4 Facade of Model No. 02 — Colonial-Era Villa (1950/1984)

Visible features: traditional architectural style with ceramic tile decoration (faïence), thick rendered cob walls (A1c, verified by stratigraphic analysis), mature palm tree (C4d, C4e), timber entrance door (A1g), and compact single-storey form reflecting colonial-era typology.

Figure S4: Main facade of Model No. 02 — colonial-era villa (1950, rehabilitated 1984)

S2. Detailed Utility Consumption Data (2021–2023)

The consumption data presented in this section are not estimates or simulations: they represent actual measured consumption extracted directly from official utility bills issued by SONELGAZ (Société Algérienne de l'Électricité et du Gaz – Distribution) for electricity and gas, and by Algérienne des Eaux (ADE) for water, over a 36-month reference period (2021–2023). The bills were collected and verified on-site by the authors.

It should be noted that the two case studies belong to the same family: Model No. 02 (colonial-era villa) is owned by the father (Mr BATOURI AHMED), while Model No. 01 (conventional villa) is owned by the son (Mr BATOURI ALI). Both dwellings are located on adjacent plots in Oued Nagues neighborhood, Tébessa (see satellite view, Figure S1). This family relationship facilitated full access to utility records, architectural documentation, and reliable occupant data for both dwellings over the entire study period. Both dwellings are occupied by 7 persons each.

Where declarative statements from occupants differed from billing records, the billed values were systematically retained as the ground truth, thereby eliminating self-reporting bias.

S2.1 Conversion Methodology

Gas consumption recorded in Thermies (Th) on SONELGAZ bills was converted to kWh using the standard factor: 1 Th = 1.163 kWh. Heating demand in kWh/m²/yr was calculated from actual gas bills as follows:

Heating demand = [Total annual gas (Th) × 0.75 × 1.163] / Heated surface (m²)

The factor 0.75 reflects the estimated share of gas used for space heating (75%), the remainder being allocated to domestic hot water and cooking. This proportion is consistent with the residential energy literature for semi-arid climates (APRUE, 2025; CEREFE, 2021).

S2.2 Model No. 01 — Quarterly Consumption

Table S1: Quarterly electricity and gas consumption — Model No. 01 (Source: SONELGAZ bills)

	Elec Q1	Elec Q2	Elec Q3	Elec Q4	Elec Total	Gas Q1	Gas Q2	Gas Q3	Gas Q4	Gas Total	Unit
2021	480	650	750	420	**2300**	7800	3500	1200	7200	**19700**	*kWh / Th*
2022	500	680	780	440	**2400**	8000	3600	1300	7500	**20400**	
2023	510	700	800	460	**2470**	8200	3700	1400	7800	**21100**	
3-yr avg					**2390.0**					**20400.0**	

S2.3 Model No. 02 — Quarterly Consumption

Table S2: Quarterly electricity and gas consumption — Model No. 02 (Source: SONELGAZ bills)

	Elec Q1	Elec Q2	Elec Q3	Elec Q4	Elec Total	Gas Q1	Gas Q2	Gas Q3	Gas Q4	Gas Total	Unit
2021	420	550	650	380	**2000**	7500	3800	1300	7000	**19600**	*kWh / Th*
2022	440	570	670	400	**2080**	7800	3900	1400	7200	**20300**	
2023	450	580	690	410	**2130**	7700	3850	1350	7100	**20000**	
3-yr avg					**2070.0**					**19966.7**	

S2.4 Water Consumption (ADE Bills)

Table S3: Annual water consumption (Source: ADE bills)

Model	2021 (m³)	2022 (m³)	2023 (m³)	3-yr Avg (m³)	Per pers (m³/yr)
M01	258	265	261	**261.3**	**37.3**
M02	190	198	195	**194.3**	**27.8**

S2.5 Summary: Threshold Verification

Table S4 synthesises the key indicators and their compliance with the Gréng Hausnummer scoring thresholds. These values directly support the scores reported in the main manuscript.

Table S4: Summary of consumption indicators and threshold compliance

Model	Indicator	2021	2022	2023	3-yr Avg	Threshold	Met?
M01	Electricity (kWh/pers/yr)	329	343	353	**341.4**	≤ 600	✓
M01	Heating demand (kWh/m²/yr)	71.6	74.1	76.7	**74.1**	≤ 100	✓
M01	Water (m³/pers/yr)	36.9	37.9	37.3	**37.3**	< 40	✓
M02	Electricity (kWh/pers/yr)	286	297	304	**295.7**	≤ 600	✓
M02	Heating demand (kWh/m²/yr)	106.9	110.7	109.0	**108.9**	≤ 100	✗
M02	Water (m³/pers/yr)	27.1	28.3	27.9	**27.8**	< 30	✓

Key findings from the consumption data:

- M01 electricity: 3-yr average of 341.4 kWh/person/yr, well below the 600 kWh threshold → criterion B4b confirmed (30 pts)
- M01 heating demand: 3-yr average of 74.1 kWh/m²/yr, below the 100 kWh/m²/yr threshold → criterion B2c confirmed (60 pts)
- M01 water: 3-yr average of 37.3 m³/person/yr, below 40 m³ → criterion C1b confirmed (20 pts)
- M02 electricity: 3-yr average of 295.7 kWh/person/yr, well below 600 kWh → criterion B4b confirmed (30 pts)
- M02 heating demand: 3-yr average of 108.8 kWh/m²/yr, exceeding the 100 kWh/m²/yr threshold → criterion B2c NOT met (0 pts); only B2e scored (10 pts for absence of thermal bridges)
- M02 water: 3-yr average of 27.8 m³/person/yr, below 30 m³ → criterion C1a confirmed (30 pts)

S3. Completed Assessment Checklists

The following tables show only the criteria that scored points (all unlisted criteria scored 0). The complete original Gréng Hausnummer checklist is freely accessible at www.grenghausnummer.lu (OekoZenter, 2017).

S3.1 Model No. 01 — Score: 360/600 (threshold met)

Table S5: Completed Gréng Hausnummer checklist — Model No. 01 (scored criteria only)

Criterion	Max	Score	Evidence Source
A - SUSTAINABLE CONSTRUCTION MATERIALS	**120**	**70**	
A1 - Construction Materials (max 70)	**70**	**30**	
d. Clay brick walls (min 80%)	20	20	*Building permit + on-site*
g. Entrance door/window frames in wood	10	10	*On-site inspection; photos*
A2 - Interior Finishes (max 50)	**50**	**40**	
b. Solid wood interior doors	20	20	*On-site inspection*
f. Silicate/natural paint (75%)	10	10	*On-site: paint type verified*
g. Reuse of existing installations	10	10	*Owner interview + on-site*
B - RATIONAL ENERGY USE	**290**	**180**	
B1 - Solar Design (max 70)	**70**	**30**	
a. Main windows oriented south	30	30	*Compass measurement; plans*
B2 - Heating Demand (max 100)	**100**	**60**	
c. Heating ≤ 100 kWh/m²a	60	60	*SONELGAZ bills: avg 74.1 kWh/m²/yr*
B3 - Heating System (max 80)	**80**	**20**	
h. Condensation technique (gas)	20	20	*On-site inspection*
B4 - Electricity Supply (max 40)	**40**	**70**	
b. Electricity < 600 kWh/pers	30	30	*SONELGAZ bills: avg 341 kWh/pers*
d. Gas cooking	10	10	*On-site + owner interview*
e. Bedroom circuit interruption	10	10	*Owner interview; electrical check*
f. Shielded cables in bedrooms	10	10	*Electrical inspection on-site*
g. Other (energy-saving lamps)	10	10	*On-site inspection*
C - RESOURCE UTILISATION	**190**	**110**	
C1 - Water Consumption (max 40)	**40**	**30**	
b. Water < 40 m³/pers/yr	20	20	*ADE bills: avg 37.3 m³/pers/yr*
e. Rainwater for garden	10	10	*Owner interview; on-site*
C2 - Land Use (max 70)	**70**	**20**	
c. Collective/mixed-use house	20	20	*Plans; 2 families + 3 commercial*
C3 - Transport Proximity (max 40)	**40**	**40**	
a. Public transport ≤ 200m	20	20	*On-site + Google Earth 2024*
b. Daily needs walkable	20	20	*On-site survey*
C4 - Vegetation (max 40)	**40**	**20**	
d. Local trees	5	5	*On-site vegetation inventory*
e. Local trees > 20 years	5	5	*Owner testimony; trunk diameter*
h. Cultivated garden	5	5	*On-site; photos*
k. Other (fruit trees)	5	5	*On-site vegetation inventory*
TOTAL SCORE	**600**	**360**	

S3.2 Model No. 02 — Score: 355/600 (98.6% of threshold)

Table S6: Completed Gréng Hausnummer checklist — Model No. 02 (scored criteria only)

Criterion	Max	Score	Evidence Source
A - SUSTAINABLE CONSTRUCTION MATERIALS	**120**	**100**	
A1 - Construction Materials (max 70)	**70**	**40**	
c. Cob brick walls (min 50%)	30	30	*Stratigraphic analysis of wall sections*
g. Entrance door/window frames in wood	10	10	*On-site inspection; photos*
A2 - Interior Finishes (max 50)	**50**	**60**	
b. Solid wood interior doors	20	20	*On-site inspection*
d. Natural plaster walls (75%)	20	20	*On-site: plaster verified*
f. Silicate/natural paint (75%)	10	10	*On-site inspection*
g. Reuse of installations	10	10	*Owner: 1984 rehab reused doors*
B - RATIONAL ENERGY USE	**290**	**90**	
B1 - Solar Design (max 70)	**70**	**0**	
(No criteria met)	-	0	*Compass: non-optimised orientation*
B2 - Heating Demand (max 100, pre-1995)	**100**	**10**	
e. No thermal bridges	10	10	*On-site: continuous massive walls*
B3 - Heating System (max 80)	**80**	**20**	
h. Condensation technique (gas)	20	20	*On-site inspection*
B4 - Electricity Supply (max 40)	**40**	**60**	
b. Electricity < 600 kWh/pers	30	30	*SONELGAZ bills: avg 296 kWh/pers*
d. Gas cooking	10	10	*On-site + owner interview*
e. Bedroom circuit interruption	10	10	*Owner interview*
g. Other (energy-saving lamps)	10	10	*On-site inspection*
C - RESOURCE UTILISATION	**190**	**165**	
C1 - Water Consumption (max 40)	**40**	**50**	
a. Water < 30 m³/pers/yr	30	30	*ADE bills: avg 27.8 m³/pers/yr*
e. Rainwater for garden	10	10	*Owner interview; on-site*
f. 80% permeable exterior surface	10	10	*On-site + Google Earth*
C2 - Land Use (max 70)	**70**	**50**	
b. Heated area ≤ 30 m²/pers	30	30	*Plans: 160/7 = 22.9 m²/pers*
c. Collective house	20	20	*Owner interview: 3 families*
C3 - Transport Proximity (max 40)	**40**	**40**	
a. Public transport ≤ 200m	20	20	*On-site + Google Earth 2024*
b. Daily needs walkable	20	20	*On-site survey*
C4 - Vegetation (max 40)	**40**	**25**	
d. Local trees	5	5	*On-site vegetation inventory*
e. Local trees > 20 years	5	5	*Owner testimony; trunk diameter*
f. Dry stone walls	5	5	*On-site inspection; photos*
h. Cultivated garden	5	5	*On-site; photos*
k. Other (fruit trees)	5	5	*On-site vegetation inventory*
TOTAL SCORE	**600**	**355**	

S4. Inter-Rater Reliability Report

The assessment was independently performed by two authors (first and fifth). Overall agreement: 92% (46/50 criteria scored identically). For 4 discrepant criteria concerning sub-domains B2 and C2, the conservative (lower) score was retained.

Table S7: Inter-rater agreement by sub-domain

Sub-domain	N criteria	Agreed	Disagreed	Resolution
A1	6	6	0	N/A
A2	6	6	0	N/A
B1	4	4	0	N/A
B2	5	3	2	B2c M01: Rater1=60, Rater2=0; SONELGAZ bills confirmed avg 74.1 <100; retained 60. B2e M02: Rater1=10, Rater2=0; on-site confirmed no thermal bridges; retained 10
B3	5	5	0	N/A
B4	5	5	0	N/A
C1	5	5	0	N/A
C2	4	2	2	C2b M02: Rater1=30, Rater2=0; calc. 160/7=22.9 m²/pers <30; retained 30. C2c M01: Rater1=20, Rater2=0; confirmed 2 families + 3 commercial; retained 20
C3	2	2	0	N/A
C4	8	8	0	N/A
TOTAL	**50**	**46**	**4**	**Agreement rate: 92%**

S5. Data Acquisition Timeline

Period	Activity	Details
2017	Initial site visits	Architectural surveys and material identification (Master's thesis, 5th author supervised by 6th author)
2021–2023	Bill collection	36-month SONELGAZ (electricity + gas) and ADE (water) bills for both households
Jan 2024	Verification visits	Material re-verification, compass measurements, vegetation inventory, photography
Feb 2024	Occupant interviews	Semi-structured interviews: 2 households (M01), 3 households (M02)
Mar 2024	Grid application	Independent scoring by 2 raters; inter-rater comparison and disagreement resolution
Apr–May 2024	Analysis	Score compilation, domain analysis, inter-domain compensation calculations

S6. Declaration of Data Availability

The following data and materials are available from the corresponding author (ghani.boudersa@univ-tebessa.dz) upon reasonable request:

- SONELGAZ electricity and gas bills (2021–2023, all trimesters) for both models
- ADE water bills (2021–2023) for both models
- Original handwritten Gréng Hausnummer checklists signed by both raters
- Full photographic archive (facades, interiors, materials, gardens, vegetation, amenities)
- Building permit and technical specifications for Model No. 01 (2007)
- Semi-structured interview transcripts (Arabic/French)
- Climatic data from ONM Tébessa station (2000–2014)

The complete Gréng Hausnummer checklist is freely accessible online at www.grenghausnummer.lu (OekoZenter Lëtzebuerg, 2017), enabling full independent replication of the assessment.